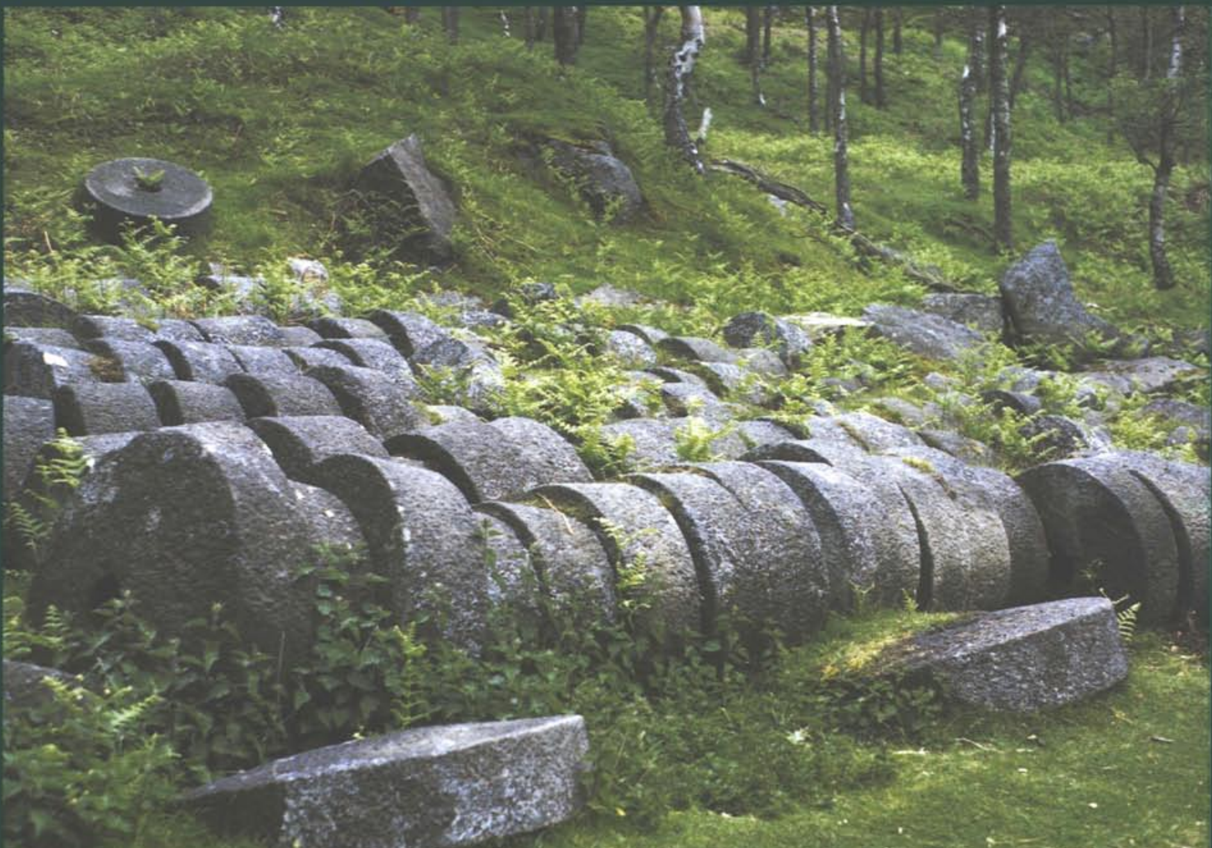
THE ARCHAEOLOGY OF STONE

A report for English Heritage

D P S Peacock



ENGLISH HERITAGE

THE ARCHAEOLOGY OF STONE

A report for English Heritage

THE ARCHAEOLOGY OF STONE

A report for English Heritage

D P S Peacock

with contributions by
Jennifer Mincham and Susan Wright

ENGLISH HERITAGE

1998

Contents

Figures

Tables

Preface

This report has its origins in the English Heritage publication *Exploring our past* (English Heritage 1991a). This seminal document, which sought to present strategies for the archaeology of England, identified stone as a problem area: 'The sources, manufacture and distribution of stone artifacts remain poorly understood, whether these are the cutting tools of prehistory, such as axes and knives, or grinding implements such as hones and querns' (op cit, 42). The same document states that 'A programme of commissioned assessments will identify basic recording standards, guidelines for processing, shortcomings in regional and local sequences and potential themes for future study' (op cit, 51). The current review was conceived as one such assessment and a specification drawn up in accordance with the revised version of *The management of archaeological projects* (MAP2, English Heritage 1991b). Flint artefacts were seen as a special case and the brief was restricted to stone materials other than flint. Within this area, the object was to examine retention and processing policies, to evaluate the needs of stone identification and provenancing, and to examine ways of recording technological traces of stone working or of use.

All of the objectives have been achieved in some measure, but as the project progressed the problem became more complex. Firstly, contact with practitioners, demonstrated that a major area of concern was not with axes, hones, or querns, but with building materials, where sheer quantities often overwhelmed even the most smoothly run operations. The problem of building stones cannot stand in isolation: consideration of loose masonry would be ludicrous if standing buildings were ignored. Thus, although excavated stone remains the focal point of the report, discussion is expanded to place such material in a wider context.

A second point to emerge was that the writing of guidelines is premature. It is easy to suggest that everything in sight should be recorded in case it one day proves useful, but such propositions are unlikely to evoke a favourable response in an environment of competitive tendering and developer funding. Any changes to current practices need to be demonstrably useful, leading to a substantially better understanding of the past. The recommendations thus point to areas where more research and evaluation are needed. When some of this work has been done it may be possible to revise practices to take account of new possibilities, but until then there is a grave danger of collecting redundant information.

The information presented in this report resulted from a combination of library work, site visits, and interviews with practitioners, principally those working in units. A large sample of units was visited, and an attempt was made to cover England from south to north and from east to west. The object was to solicit a wide spectrum of views and to see what problems arose in geologically contrasting environments. Of course, it was impossible to visit all units, but large and small were included in the sample. A questionnaire was prepared as an *aide memoire,* but more often than not it was abandoned as discussion progressed in more fruitful directions. In this way ideas were incorporated in the project as new lines of enquiry opened up. The list of visits includes: Birmingham, Cambridge, Canterbury, Carlisle, the Central Excavation Unit (now CAS), Chester, Exeter, Hereford, Humberside, Lancaster, Lincoln, London, Newcastle, Northampton, Oxford, Sheffield, Suffolk, Trent and Peak, Wessex, Winchester, and York.

I have attempted to weave what I learned into a seamless whole, and if ideas are recognised I hope it will be taken as an acknowledgement of the help I received rather than as plagiarism. I am particularly grateful to the Carlisle Unit, the Northampton Unit, Wessex Archaeology and the York Archaeological Trust for permission to reproduce internal documents as examples of good practice.

This report differs in many respects from the reviews of Roman and medieval pottery previously commissioned by English Heritage (Fulford and Huddleston 1991; Mellor 1994). The problem of stone is rather different. Pottery studies have a long history and as a more developed subject, it has attracted a wide spectrum of specialist students, usually operating on a regional basis. For this study it was necessary to draw a national picture, at the same time, attempting to suggest ways towards uniformity of data gathering and presentation, which was itself a necessary step towards more refined synthesis.

Stone is not studied with the same intensity that pottery is and is often the work of unspecialised finds staff. Stone 'specialists' are, more often than not, geologists whose aim is solely to identify material rather than to present a rounded picture. This report had to start from a different base and hence its objectives were conceived differently. Firstly, in stone studies there is a need to proselytise, to attempt to 'sell' the subject by drawing attention to the wealth of information in stone finds. Secondly, there are many facets to stone study that are often seen as discrete entities and it was necessary to draw together the disparate strands within what is becoming an increasingly fragmented interest area. Thus in contrast with ceramic studies, there seemed little point in attempting overviews of the needs of each region; neither did it seem appropriate to analyse the reactions of unit staff to every question posed. All too often stone had an 'unjustifiably low' priority in the unit's work, as one informant frankly admitted.

Acknowledgements

One aspect of the project was an investigation of identification facilities among which comparative collections are of primary importance. The Museum of Natural History, London, the Sedgewick Museum, Cambridge, the Building Research Establishment, Garston, the British Geological Survey, Keyworth, and the Oxford University Natural History Museum were all equally helpful in discussing access to their resource and in showing their collections to me.

In addition many individuals have helped shape this document, some of whom work in the above institutions, and I should like to convey personal thanks to the following: Mr J Adams, Dr P Addyman, Mr J Allan, Ms L Allen, Mr J Ashbee, Mr P Bennett, Dr I Betts, Ms P Bradley, Mr H Buckley, Mr S Buteaux, Dr R Butlin, Mr R Carr, Mr P Carrington, Ms D Cotton, Mr C Cumberpatch, Mr B Dix, Dr R Donahue, Ms J Evans, Mr J Fidler, Dr I Freestone, Dr G Gaunt, Mr S Goddard, Dr K Green, Dr C Heron, Mr D Hinton, Mr P Hinton, Dr R Ixer, Dr M Jones, Mr B Kerr, Mr D Knight, Mr A Lawson, Dr G Lott, Ms J Mann, Mr M McCarthy, Ms L McFadyen, Ms L Mepham, Dr A Middleton, Dr R K Morris, Dr R Newman, Mr C O'Brien, Mr P Ottaway, Mr N Oxley, Mr D Parsons, Professor M Pollard, Ms M Price, Ms H Rees, Dr A Roberts, Dr F Roe, Mr M Rouillard, Ms R Seager-Smith, Mr R Shoesmith, Mr K Sidiki, Mr R Stone, Mr H Swain,Ms J Sommerfield, Dr D Stocker, Dr D Sutherland, Dr R Syme, Mr T Tatton-Brown, Dr A Vince, Mr K Wade, Mr S Webster, Mr B Whitwell, Dr D F Williams, and Dr O Williams-Thorpe, Mr E Wilson, Ms S Winterbottom, and Dr T Yates.

I also had fruitful discussions with Professors A Alvarez and I Roder of the Departamento de Geología of the Universidad Autónoma de Barcelona, Professor L Lazzarini of the Dipartimento di Storia dell'Architettura, Venice, and Mr R Grande of the Dipartimento de Geologia, Università de Modena.

For assistance in preparing this document I am particularly grateful to Jenny Mincham, Pauline Salter, and Sue Wright. A special word of thanks goes to Dave Batchelor of English Heritage, for his keen interest and help throughout the project.

This work was completed and submitted to English Heritage in September 1995. A few minor amendments and additions have been made since, but essentially the text records the state of the art in the mid 1990s.

D P S Peacock
Southampton

1 Introduction

In most human societies, stone is an important commodity impinging on several spheres of social and economic activity. It is salutary to note that in Britain today (a culture apparently dominated by synthetic materials such as plastics and metal), each of us uses about 350 tonnes or 20 lorry-loads in a lifetime. Of course, much of this is destined for major projects such as road building or urban expansion and in the past consumption would have been markedly less, but in the absence of the modern range of synthetics its role in society would have been proportionately greater. It was used for construction, for making tools and other artefacts, and as a medium for display or conveying information.

The most obvious use of stone is as the basic material of construction, and in England stone building predominates in areas where durable rock outcrops naturally. There are three major zones: firstly, the south-western peninsula to the west of Exeter, secondly, a belt running diagonally across England from Dorset to the Yorkshire Wolds, and thirdly, a northern zone comprising the Pennines from Derbyshire to Northumbria and incorporating the Lake District. In addition, there are lesser areas, of which the most important is the Greensand country lying on the northern edge of the Weald of Sussex and Kent (cf Brunskill 1970, 173). Within each of these zones stone is the preferred material and was extensively used for both walling and roofing. Quarries, often with a purely local distribution, are to be found every few miles, as stone is heavy and long-distance transport would be avoided wherever possible.

Flint, which is in many ways a rather special stone, is a poor building material, as it is difficult to shape and the irregular nodules require considerable skill if they are to be utilised effectively. In the chalklands of southern England, however, it is the predominant local material. The use of flint in building follows the line of chalk beds from the Downlands of central southern England north-eastwards into East Anglia and eastwards into the North and South Downs of Sussex, Surrey, and Kent.

Most vernacular architecture would be made of whatever was locally available to reduce the cost and inconvenience of transportation, but more important buildings, which sought to make a social statement or had a particular function, might require special materials from afar, selected for their appearance or resilience. This is especially true of locations that lack good stone resources. London, for example, could have been made of flint and of Greensand rocks from relatively local sources, but because of its importance stone was imported from, for example, Devon, Portland, Purbeck, and from the Jurassic outcrop to the north and west.

Buildings constructed for the conspicuous display of wealth and power might require even more exotic materials for cladding walls, for columns or for flooring. Local materials might be incapable of creating the right effect. Thus the Roman palace of Fishbourne used large quantities of the polishable 'marble' from Purbeck, but a considerable amount of true marble was imported from the Pyrenees and from Italy. In the late Roman period both London and Colchester were adorned with exotic marbles derived largely from the central and eastern Mediterranean. During the medieval period the need for decorative stones, for example in the great cathedrals, was met largely from local British sources, and it was not until the Neoclassical period that the demand for Mediterranean stone was regenerated. At the same time, burgeoning demand may have initiated the search for more local sources, for during the eighteenth and nineteenth centuries and a wide range of decorative stones was exploited in Britain, Ireland, Belgium, France and further afield. It is an over-simplification to claim that the more important a building the further materials will be transported (because the norms are relative and change from period to period), but there is more than a grain of truth such a thought.

Stone was also important in making artefacts and broadly these fall into four categories: containers, sculpture, information panels, and tools. The most obvious example of a container is the sarcophagus or tomb. There is a number of parameters that might determine the type of rock selected. If it is to be interred, appearance might be of little importance and the rock might be chosen because it could be hewn easily and would be resistant to breakage during the process of burial. Alternatively, the rock might have special properties, like the *lithos sarcophagos* of Assos in Turkey, which was thought to dissolve flesh with particular speed. If, however, the tomb was to be seen, the stonemason might demand exotic materials, such as the white marble used in the Roman Mediterranean or the alabaster favoured in England from the medieval and, particularly, from the Elizabethan period onwards. Other containers include fonts, baths, and fountain bases designed to hold water. They were made to be seen and hence appearance would be a main parameter.

Sculpture, whether of a figure, a cross, or some other decorative form, is always made to be seen and hence appearance is of utmost importance. The softer stones, however, are easier to work than harder ones; for example it is much easier to make a figure in soapstone or alabaster than it is to work Carrara marble or granite. On the other hand, softer materials do not weather well and so ease of working has to be set against durability, which in turn depends upon the site that the artefact will occupy when finished. Another factor determining choice might be the absence of flaws, which are unsightly and weaken the artefact.

The same rules apply to information panels, which include grave markers, monumental inscriptions, and milestones. In the case of the humble milestone, appearance is less important than durability, for it must, by its nature, stand outside. Because of this, stones were sometimes moved considerable distances, but usually the best local material was employed providing it could be inscribed (see eg Sedgley 1975). In the case of grave slabs or monumental inscriptions the stone might be selected because of its propensity to form flat surfaces that would take fine lettering. A well-bedded or foliated stone might be preferable, but again durability might be important if the inscription was to be subject to the elements.

In Britain, stone tools rank among the more important artefacts and function might determine the selection of rock type. Flint was favoured for cutting and scraping because of it could be formed into sharp edges through the simple operation of knapping. Flint can also be polished to make refined cutting implements, such as polished stone axes, but the stone is inordinately hard and during the Neolithic and Bronze Age a range of softer igneous and metamorphic materials was exploited: these rocks were hard enough to perform their task but easier to fashion. In some cases the rock selected was not always the best available and other factors may have played a part. We know that these non-flint axes were distributed the length and breadth of the country (eg Clough and Cummins 1979, 1988; Bradley and Edmonds 1993). Doubtless flint would have been distributed in a similar way but unfortunately one flint looks much like another even under the microscope and the distribution of flint has yet to be evaluated. It is possible to characterise different sources on the basis of their trace element composition, but there has been no sustained programme of chemical analysis on these artefacts (cf Sieveking *et al* 1970, 1972).

In the later prehistoric and early historic periods querns and millstones were commonly used. Here the main property sought would have been the ability to resist wear and retain a rough surface that would continue to cut the grain. A vesicular lava is ideal, but alternatively rock with coarser and finer facies would serve. If the rock develops a polish during wear it can be almost useless, as it develops the 'ball-bearing effect': the grain is rolled and pelleted rather than cut to form flour. Naturally, hardness is also important, for a hard rock will leave less grit in the flour and will wear out less quickly. Again, the choice of milling rock will be a balance, but in this case between rather different parameters. The quern is often regarded as a somewhat humble tool, and yet it is directly concerned with human subsistence. It is hardly surprising that recent research is showing that mills and querns were the object of trade and that they were sometimes transported over hundreds or even thousands of miles.

A similar comment applies to whetstones, or hones, which appear in the Bronze Age and which become increasingly common with the development of iron. Early iron knives were of such poor quality that they required constant sharpening and a whetstone would be an essential part of an iron users personal equipment. To retain its whetting properties a stone needs to be fine-grained preferably with harder grains set in a softer matrix so that it will not polish. Typical examples are the sandy limestones used in Roman Britain and the Scandinavian quartz-mica-schist of the early medieval period. Some whetstones were specially made and clearly emanated from specific quarries, most of which have yet to be located, but others were produced by selecting suitable pebbles from river beds. In the latter case natural processes within the river would have produced elongate objects with a smooth surface ideal for sharpening metal. It is clear that quarried whetstones were widely traded, but it is also possible that pebbles would be exchanged in a similar manner and it may well be that selected river beds were quarried for pebble whetstones. However, whetstones are the Cinderella of artefact studies and we have almost everything to learn about them.

Another major type of tool is the stone mortarium, which appears in the Iron Age. It is developed in Roman times and reappears in the medieval and Post-medieval periods, where it is particularly important. It may have had many tasks in the kitchen and at times may have been used instead of a quern for converting grain to flour. Used with a pestle, however, it is essentially an instrument for crushing rather than cutting and grinding. The ideal rock is hard and even-grained and it does not matter if it develops a polish. A variety of stone types has been used to make mortars, including Carrara and Purbeck marble (which could not conceivably be used for making querns, granite), and dolerite. Once again, the specialised requirements lead us to anticipate wide regional and inter-regional trade.

The most important types of stone tool are mentioned above, but there are others less frequently encountered. For example, lamps hollowed out of chalk were found in the Grimes Graves flint mines. Other stones, sometimes associated with ceramic production, were used for polishing, and touchstones, used in the medieval period to assay the amount of gold in an alloy, are also encountered. The list is by no means comprehensive.

Stone, often raw and unworked, has another function which is of considerable archaeological importance: use as ships' ballast. Before the mid nineteenth century, when water ballasting was introduced, all empty ships had to be trimmed by adding heavy material to their holds. Gravels were popular (hence the popular builder's reference to gravel as ballast), but in the absence of alternatives beach pebbles or lumps of local rock might have served. When taking on a payload, the ship would need to off-load its ballast. Thus, even unworked stone can, in some circumstances, be of significance. The dumping of ballast indicates the arrival of an empty ship and the taking on of a payload.

It should be clear from this brief introductory review that stone ranks among the more important archaeological materials. The potential of stone to assist in understanding economic and social issues is obvious. It is perhaps a little less clear why it is necessary to make this point at all, but in British archaeology stone has been sadly neglected, and this *lacuna* in our knowledge has occasioned the present report.

In the above paragraphs two themes recur. One is the way in which materials relate to function and the other is the way in which function relates to trade and exchange. There are no better illustrations of these precepts than those furnished by stone and this is one of the themes to be pursued in the following pages.

2 Stone in British archaeology: an historical perspective

Stone is a common archaeological material and its study is bound up with the development of archaeology itself, a subject which it would be futile to re-iterate here. The development of stone studies as a distinct archaeological specialism is pertinent, however, and can be summarised relatively easily and briefly. The following review is not intended to be exhaustive, but to draw attention to selected highlights so that a worker, unfamiliar with the field, can gain an *entrée* to the subject. There are basically two types of contribution to the study: general works of a synthetic nature and reports on stones found in excavations. These two categories will be dealt with separately.

2.1 General

The earliest evidence of interest in ancient stone derives from the medieval period. Asser, the ninth century biographer of Alfred the Great observes Alfred's 'restoration of cities and towns... of golden and silver buildings... of the royal villas on stones removed from their old site, and finely built by the king in more fitting places'. This is clearly, as Greenhalgh (1989, 129) claims, a reference to the dismantling of Roman constructions. In the Middle Ages fine marbles and stones were imported from Rome itself, the most notable example being the Cosmatesque pavement brought by Richard de Ware from Rome in the thirteenth century, adorning Westminster Abbey (Foster 1991). A similar explanation might account for the antique marble found to the west of the cathedral of Old Sarum (Hope, Hawley, and Montgomerie 1914).

It is not always clear whether material was obtained locally or from Classical lands. Thus, the crypt at Hexham, built in the late seventh century, largely from Roman stone, could have been derived from establishments on Hadrian's Wall with perhaps additions from Rome itself as William of Malmesbury states that masons from Rome advised St Wilfrid in his building work (Greenhalgh 1989, 130). Antiquities were not studied for their own sake, but were seen as a way of making the past serve the present. Rather more difficult to understand are the small fragments of antique green porphyry, originally quarried in southern Greece and found on Monastic and other sites in Scotland and Ireland and at Jarrow in Northumberland (Peacock forthcoming; Lynn 1984). These seem to have been specially selected from Roman sites, perhaps for some liturgical reason.

The study of archaeological stone for academic reasons had to await another era. Shotton (1963, 482) claimed that credit for the first recognition of a stone artefact and the use of petrology in attributing it to a source, goes to William Dugdale who in 1656 published the *Antiquities of Warwickshire*. His account of Oldbury near Nuneaton has the following observation: 'On the north part of the Fort, have been found, by plowing, divers Flint stones, about four inches and a half in length, curiously wrought by grinding, or some such way, into the form here exprest [ie illustrated in his account]: the one end shaped much like the edge of a Pole-Axe, which makes me conjecture that, considering that there is no flint in all this part of the Countrie, nor within xi miles from hence, they being at first so made by the native Britans, and put into a hole, board through the side of a staff, were made use of for weapons, inasmuch as they had not then attained to the knowledge of working iron or brass to such uses.'

It is not surprising that this precocious attempt at what equates to modern artefact analysis was not repeated and the study of archaeological stone had to await the development of geology itself. During the crucial years of its growth in the early nineteenth century, a number of practitioners of the new science applied their knowledge of rocks to stone monuments and it is hardly surprising that Stonehenge should be the focus of attention.

One of the first contributions was that of Buckland, who as early as 1823 suggested that the larger stones were of sarsen, blocks of which could be found littering Salisbury Plain, a view later confirmed by Conybeare, Prestwick, Phillips, and Ramsey (Thomas 1923). The bluestones proved to be more problematical. In 1833, Conybeare identified them as greenstone and suggested a source in Ireland. In 1858, Ramsey and later in 1865, Moore, ascribed them to the general region of Wales or Shropshire. They were first correctly described by Maskelyne in 1878, who had access to the relatively new technique of examination in thin section under the petrological microscope, first employed by Dr H C Sorby in 1850. It was however H H Thomas (1923) who first attributed the bluestones to the Prescelly Mountains in Wales on the basis of thin-section study. It is hard to overstate the importance of his work, because for the first time it made clear to the archaeological world the value of the petrological method in attributing stone artefacts to their source. Others had been interested in this approach, but Thomas' work was a key factor in the formation, in 1936, of a truly pioneer organisation, the Sub-Committee of the South-Western Group of Museums and Art Galleries on the Petrological Identification of Stone Axes (Grimes 1979). In 1945, this initiative was developed as the Implement Petrology Group of the Natural Sciences panel set up by the Council for British Archaeology. The group has remained in existence for half a century until the CBA re-organised its committee structure in 1995. From these beginnings, petrology was to become an established and increasingly important feature of the archaeological landscape. Stonehenge has continued to be a focus of scientific attention as exemplified by the recent papers of Thorpe *et al* (1991) and Williams-Thorpe and Thorpe (1992), which seek to explain the distribution of the bluestones in terms of natural agencies.

Stone artefacts other than Stonehenge or prehistoric axes have fared less well. The importance of querns was made apparent by Curwen (1937, 1941) and later by Crawford (1953), but the study of English querns lay dormant for almost 30 years until revitalised by Hayes, Hemmingway, and Spratt (1980) in the north and by King (1986) and Peacock (1987) in the south, all of whom introduced a petrological dimension. Lava mills, characteristic of the Mediterranean have been studied petrographically by Peacock (1980a) and geochemically by Williams-Thorpe (1988), and Williams-Thorpe and Thorpe (1993a). A few lava mills from Britain are included in these studies.

Whetstones are a very common type of artefact found on most excavations. Despite their prevalence, however, there have been relatively few synthetic studies apart from Ellis' (1969) analysis of medieval hones, in which, among other things, he demonstrated the importance of Scandinavia as a source. Crosby and Mitchell (1987) developed the problem of provenancing medieval quartz-mica-schist and purple phyllite stones using a range of methods supplementing petrography with potassium-argon dating and natural remnant magnetism. The state of the art in whetstone studies has been conveniently summarised by Moore (1978, 1983).

The study of building stones is an important facet of archaeology as they comprise one of the more common materials encountered in excavations. Building stones are an archaeological problem, but as the material is usually unprepossessing they are all too often dealt summary justice.

At the turn of the century a number of museums felt it desirable to acquire collections of building stones, largely to show architects and builders what was available. The best known are the Tolley collection in the Natural History Museum, the Sedgewick Museum collection in Cambridge, and that at the Building Research Establishment collected almost single-handed by R J Shaffer during the 1920s (Shaffer 1932). Only the Cambridge collection has a published catalogue (Watson 1911, 1916), but the commentary, largely aimed at geologists and architects, has a few telling archaeological insights. There is a number of other general works on building stones, such as the books by Howe (1910), Hull (1872), O'Neill (1965), and Shore (1957), all of which have a bearing on archaeology, although that is not their prime purpose. The *Natural stone directory* compiled and produced annually by the journal *Stone Industries* is not without archaeological relevance. It lists the main working quarries, some of which have a respectable ancestry, but more to the point is the glossary of terms and the list of stones no longer available because the quarries have closed down.

In archaeology, it is one man, himself not an archaeologist, who related the geology of building stones to the artefacts in which they were employed. Alec Clifton-Taylor's (1962) remarkable book *The pattern of English building* sought to link quarry materials to the rich diversity of English buildings. His researches took him throughout the country to humble quarries, vernacular buildings, and great houses or cathedrals, everywhere discussing monuments in terms of the materials of which they were made. His work has immense implications for archaeology that have hardly begun to be realised. There has been nothing like it before or since, apart from his contributions to certain of Pevsner's *Buildings of England* volumes. There are, however, works that address the same theme on a more local scale of which Arkell's (1947) *Oxford stone* is the most celebrated example.

Clifton-Taylor's later work, with A S Ireson, published in 1983, *English stone building* is of a different genre concentrating more on the methods and techniques of the stone mason, but once again it contains useful insights for the archaeologist, although it is, to some extent, superseded by the technical detail in the stone-working treatises by Bessac (1986) and Rockwell (1993).

The principles of studying architectural stones were established in the 19th century when the works of Sharpe (1848, 1871 4) defined the parameters for dating mouldings, a study which has subsequently been developed by Bond (1905) and now Morris (1978, 1979, 1996). Of crucial importance is the guide to the recording architectural stones published by the Council for British Archaeology (1987). For the first time it established norms for detailed documentation.

Purely archaeological (as opposed to architectural) papers on building stones are not particularly prevalent. Williams' (1971a, b) work on Roman building stones has been amplified by Blagg (1976, 1990). In a somewhat later period Jope's (1964) pioneering work on the Saxon industry in southern and midland England has now been augmented by a number of other studies such as that of Tatton-Brown (1980) on Quarr stone in south-east England and Gee (1981) on the use of Magnesian Limestone in South Yorkshire. Some good examples of more recent work are to be found in the proceedings of the 1988 Loughborough stone conference edited by Parsons (1990). The following year Blair and Ramsey (1991) published a useful volume on English medieval industries, which contains perceptive reviews of work on stone (Parsons), alabaster (Ramsey), and Purbeck Marble (Blair).

The study of decorative stones has followed a different course, centred naturally on the Mediterranean. In 1828, Faustino Corsi published the first account of the antique marbles (in the broadest sense of the word) found in Rome, and, as a result, Italian terms such as *porfido verde* or *verde antico* are still in common use. His publication was, in effect, a catalogue of his collection of samples taken from the monuments of Rome, which had acquired a degree of renown and which was visited as a curiosity in its own right. Other collections were made by, for example, Stefano Karolyi in 1842 and by a Belgian, Emile de Meester de Ravenstein in the later nineteenth century (Balty 1992; Braemar 1992). Today, four of these collection survive: one remained in Rome, another found its way to Milan, a third is housed in the Musées royaux d'art et d'histoire in Brussels, and the fourth was acquired by the Natural History Museum of the University of Oxford. A table made up of small fragments of these rocks is housed in the Natural History Museum, London. These collections are the key to understanding Corsi's work and comprise a valuable resource in the identification of antique marbles.

An important event in the study of Mediterranean marbles was the formation, in 1965, of the Committee for the Study of Marble and Similar Stones in Antiquity, which was largely the brain-child of J B Ward-Perkins. It did much to foster collaboration between workers on an international scale, but unfortunately lapsed somewhat after Ward-Perkins' death (Mona 1988). In 1988 it re-emerged as the Association for the Study of Marble and Other Stones in Antiquity (ASMOSIA), which has a wide and burgeoning international membership and which holds biennial conferences. Perhaps the most significant new feature of the organisation is that its members comprise archaeological scientists as well as archaeologists and art historians, and it has achieved a degree of integration between disciplines that is seldom seen in other aspects of archaeological science. The proceedings of ASMOSIA conferences furnish an overview of current research in this field (Herz and Waelkens 1988; Waelkens, Herz, and Moens 1992; Mariatis, Herz, and Basiakos 1995).

At first sight, it might appear that Classical marble has comparatively little relevance for British archaeology, but it is surprising how much there is. Small quantities are found on Roman villas in southern England, but substantial assemblages have been recovered from London, Lincoln, and, in particular, Colchester (see Prichard 1986; Peacock and Williams 1992, forthcoming). As mentioned above, antique marbles are also found in medieval contexts, sometimes in appreciable quantities.

Quarries are another facet of the study of stone that has yet to receive the treatment due. Ironically, Neolithic quarries seem to be better documented than later ones. Recent excavations at Grimes Graves have thrown new light on flint procurement (Mercer 1981) and Langdale is now the most thoroughly investigated of the non-flint 'factory' sites (Bradley and Edmonds 1993). In the Iron Age there is a paucity of information, but attention should be drawn to quern quarries such as Lodsworth (Peacock 1987) or Wharncliffe Edge in the Pennines (Wright 1988). Evidence for the Roman period is only a little better and there is not much to add to the discussion by Blagg (1990, 40 47).

The best introduction to medieval quarries remains that of Knoop and Jones (1939) and general discussion of the archaeology by Parsons (1991). The most important quarry excavations are concentrated in the medieval period (eg Cadman 1990; Moorhouse 1990).

Unfortunately, the methodology for studying quarries has yet to be evaluated. Conventional excavations may be of value if the quarry has been backed-filled or reused in some way, but they seem to be a very hard and rather expensive way of obtaining a small increase in knowledge about rock procurement. Similarly the norms for survey and geophysical investigation need more thought, because the problems are quite different to those normally encountered by the archaeologist. Techniques designed for seeking anomalies up to 1m under the topsoil are not necessarily appropriate for looking at shafts or filled cavities perhaps tens of metres deep. Nevertheless, the issue is worth addressing, for quarries are a crucial element in stone study and as Ericson (1984) claimed they are the most important component of lithic production and distribution systems.

The ethnography of quarrying has been little studied, but Benfield's (1990) *Purbeck shop* is a unique account of quarrying by a practitioner of the trade. It is a charming and chatty book, which contains a number of rather incidental technical insights.

2.2 Excavation reports as a source of evidence on stone

No review of the literature on stone would be complete without mention of excavated finds, usually published in appendices to excavation reports. In order to evaluate this material a survey was made of recent literature with the particular objective of assessing the current standards and the practices employed in reporting stone materials from excavations.

A sample of 296 excavation reports was examined. The following national journals were searched from current issues back to 1970: *Proceedings of the Prehistoric Society, Archaeologia, Archaeological Journal, Britannia, Medieval Archaeology,* and *Post-medieval Archaeology.* In addition two local journals were searched for the same period, one produced in the south and one in the north: *Wiltshire Archaeological Magazine* and *Yorkshire Archaeological Journal.* It was hoped that this would produce a sample deliberately biassed towards some of the more important excavations of the 'Rescue' era and its aftermath. Major excavations that might warrant a monograph of their own were avoided, as were minor ones that might be published in the local journals (with the two exceptions mentioned). In each case a specially prepared pro-forma was completed to ensure consistent reporting.

It is difficult to divide the reports by period as many concern several phases of occupation, but a count based on the major period discussed suggest the following proportions: prehistoric 91 (31%), Roman 82 (28%), medieval and Post-medieval 122 (41%). Thus apart from a slight excess of post-Roman reports, the periods are broadly in balance and chronological interests more or less evenly represented.

Of the 296 reports, 291 (98%) mentioned stone to some extent and in 146 (49%) of cases it was of sufficient importance to warrant a special report. In 31 cases (10%), all but three of them concerned with the historic period, the report considered only worked stone, but in the remainder all foreign stone, whether worked or not, was recorded. This encouraging figure, however, is seriously offset by the dearth of statements indicating on-site discard and retention policy. This was evident in only 14 (5%) of reports and of these 12 merely indicated that not all stone had been kept.

In 108 (36%) of cases an attempt was made to quantify stone materials, usually by counting; only rarely were other techniques such as weighing employed. However, 62% of these were concerned with prehistoric material.

104 (36%) of reports were concerned with portable artefacts, 29 (10%) with imported building materials and the remainder with building in relation to site geology. Of the artefact reports 61 (58%) considered working technology, but 47 (77%) of these were concerned with prehistoric material.

The questionnaire also sought to investigate the use of identification services for determining material origins. In the majority of cases, the archaeologist identified his own material, but in 10 (3%) of cases a geologist or environmental scientist was involved. In almost all cases where the archaeologist did his own identification the determination was based on visual criteria and usually to the level of rock type (eg sandstone or granite) although in some cases the rock was assigned to its formation and the petrological microscope used to check the assignation.

In no case was there any indication of where the material was stored, so any further work on these collections would involve tracking them down.

The literature survey seems to have been a useful exercise. The high percentage of excavations that produced stone and the large number of special sections devoted to stone indicate its importance in British archaeology. The large number of reports considering all foreign stone, not just the worked material, suggests that it is being taken seriously by archaeologists. The usefulness of these reports is greatly reduced, however, by the lack of clear indications of whether the report was based on a sample or on the entire assemblage recovered.

For a similar reason the quantified data is less useful than it should be. This area clearly needs some careful thought and perhaps experiment, as counting is not necessarily the best method of quantification. It also needs to be more widely adopted to fully encompass the historic as well as the prehistoric period.

Portable artefacts such as whetstones, querns, or axes seem to dominate stone reports, but the biggest single category comprises imported building stones and local construction materials. There is a clear need for more attention to be given to working techniques.

Perhaps the most disturbing aspect of the survey is the paucity of specialist geological input. In some cases the archaeologist seems to have a good knowledge of regional rocks and their uses, but in many instances the determinations are at a very basic level and would need re-doing if they were to be used in the analysis of, for example, trade.

Doubtless a rather different, and perhaps a slightly more optimistic, picture would have emerged if the larger monographs had been examined, but the objective of the survey was to examine the normal and average rather than the exceptional.

3 The principles of stone study

It is perhaps obvious to state that a stone artefact is comprised of a naturally occurring material that has been modified by human intervention, but it is worth remembering that the same observation applies to pottery. Until the last few decades, when the serious study of fabric began, pottery was perceived almost exclusively in terms of its form and decoration. In other words it was the human intervention, rather than the natural material, that attracted most attention. Stone, on the other hand, is exactly the opposite. It is so self-evidently a part of nature that the material is often the most prominent property. A stone artefact is, in effect, the end result of a series assessments, decisions, and production processes, which we should be attempting to read from archaeological material. The object of this section is to draw attention to the steps involved in the production, use, and decay of stone objects and to discuss the evidence that might be apparent in the archaeological record.

Table 3.1 summarises the main parameters, but it will not stand alone. The following paragraphs, numbered in a corresponding manner, are intended to fill out the detail and explain the underlying concepts. The production of a stone artefact can be seen as a series of stages, each of which requires either decisions for their execution, or, in the case of use and decay, result in alterations through human and natural agencies. Both decisions and alterations can be seen as 'interventions' – human or natural – on the original geological material. Such interventions are determined by, or result in, a number of phenomena that can be observed archaeologically or geologically. The third and fourth stages, quarrying and production, require the physical application of technology, which may be deducible from the surface textures of the stone.

3.1 Sources of raw material

One of the most fundamental determinants that will decide what type of artefact can be made and what method will be adopted is the range of materials available. In most cases the material will come from a quarry, but there are many advantages in using *spolia* second-hand pieces taken from pre-existing buildings. Whatever the source, rocks have properties that determine their suitability and workability. The principal ones are texture, which includes grain size and porosity, hardness, colour, bedding, foliation, and jointing. Most of these properties are self evident. It should be noted that bedding refers to laminations resulting from sedimentary processes, foliation is the orientation of grains resulting from metamorphism, while jointing is the fracture pattern imposed by stress in the earth's crust.

3.2 Assessment

Assessment of the material by the stoneworker – the second determinant – leaves little or no direct archaeological trace. Here there are three paramount parameters: suitability, availability, and workability. A stone may be suitable for the intended purpose, but unavailable in sufficient quantity; or it may be available and suitable, but too hard to work easily and economically. For example, granite is ideal for a statute that is to stand out doors, but the colour may be wrong and hence unsuitable for the particular purpose; or it may be too hard for the mason to dress economically with the tools at his disposal. Hence it may be available, but unsuitable and insufficiently workable. Suitability, availability, and workability are quite distinct, but very real and important factors in making a choice.

There are many underlying properties that bear on each of these parameters. Suitability will be decided in the first instance by the shape and size of the blocks, which in turn relates to the bedding and jointing systems in the quarry. Colour and texture are also important if the stone is used for display, while texture and hardness may be significant, if a tool such as a quern or a whetstone is to be manufactured.

Availability will depend on the location of the quarry or other source and on the system of transportation. A distant source will only be usable if there is a means of getting its produce to the site where it will be used. Another parameter will be the size of the quarry, which may be determined by the geological extent of the bed. A cathedral cannot be made out of the stone from a small pit in a limited geological formation. Similarly, there must be a sufficient labour force to operate the quarry, which may preclude the exploitation of otherwise suitable rocks located on mountain tops or in deserts, for example.

Workability is a very real constraint on the stonemason and hardness is only one, somewhat obvious, factor. The condition of the stone is also important, for example a crumbling, decaying material may be of limited value. The mason will also assess the reaction of the stone to tools and the presence of bedding or foliation may be an asset or a drawback. Another important property might be the ability of the stone to take a polish.

3.3 Decision

The details listed above will combine to form a judgement in the mind of the mason and he will either accept or reject the stone. If rejected, the process must begin again with a new material. If accepted quarrying may commence.

Evidence of the quarrying process may well be obliterated from a finished stone artefact, but on

Table 3.1 A framework for the study of stone

stage	*intervention human / natural*	*related parameters*	*technology*
3.1 Raw material: quarry / spolia	none: geological processes	texture hardness colour bedding jointing foliation	
3.2 Assessment	suitability	size of blocks shape of blocks hardness colour texture	
	availability	location of quarry size of quarry transport labour limits of bed	
	workability	condition hardness bedding/foliation reaction to tools polishability	
3.3 Decision	acceptance	quarrying	wedge, pick marks etc
	rejection	search for alternative	
3.4 Process	planning	measurement marking out	marker, level, rule square, compass
	method	percussion abrasion	wedge, hammer, axe, chisel drill, saw, file
	finish	abrasion/polish	sand, grease
	assembly	*structure:* roof ashlar rubble *tools:* querns mills *sculpture:* elements	
3.5 Use	*wear in buildings*: floors doors	dishing, scuffing	
	chimneys	sooting, burning	
	wear in tools: querns mortars whetstones cutting tools	residues wear shape wear striations breakage patterns	
3.6 Decay	natural / human agencies	weathering breakage biological colonisation	

undressed faces there is always the possibility of wedge marks, and of quarry trimming (to reduce weight) with the quarryman's pick, the point, or the chisel. In exceptional circumstances engraved or painted quarry marks may be preserved.

3.4 Process

Once a material has been accepted, the stoneworker will begin to make the artefact – an activity for which Rockwell (1993, 89) has coined the term 'process': the pattern of methods used to organise and create a finished product. Rockwell recognises three types of process: 'The first is the sequence of carrying out a specific piece of work such as a table top, floor tile, capital or statue. The second is the process by which design and stoneworking are put together to make an object or group of objects. The third is the sequence of an entire project. In the last case a statue could be a whole project if it is conceived as an independent object, but one which includes quarrying and transport as part of the process. Projects also include the whole process of a large stone building from design to completed product. The first and second categories of process are part of the overall project.' Thus, 'process' links the design and aesthetics of an artefact to technology of achieving those ends and creates a seamless whole from what are too often seen as discrete activities.

This thinking underlies the somewhat simplified and modified scheme presented in Table 3.1, where process is subdivided into four stages, all of which leave substantial archaeological traces. The first step is planning. The block may be trimmed to a suitable shape and the concept marked out. The tools will be a marker, level, rule, square, and compass, and archaeological evidence of their use may be preserved on incomplete artefacts or on unutilised surfaces as incised or painted lines or as the holes left by compass points.

The second step, termed 'method', is visible archaeologically and involves shaping the stone to its near completed state. There are only two ways of doing this: percussion or abrasion. The instruments of percussion include the pick, the axe, the hammer, the point, the chisel, and the wedge, all of which recur in multifarious forms as Bessac (1986) has demonstrated. Implements of abrasion are more limited and include the drill, the saw, and the file or rasp. All of these will leave characteristic archaeological traces, which can be read by the archaeologist acquainted with the methods.

The tools mentioned above can be used to finish an artefact, or to bring it to a near finished state, when a final step is needed to complete the work. It is worth separating 'finishing', a distinct facet of process, because it may obscure traces of the earlier operations and may thus be all that is seen. The most obvious example of finishing is a polish achieved by the use of a sequence of increasingly finer abrasive sands. Alternative finished surfaces include rustication, vermiculation, rock facing, frostwork, and herringbone finish, as illustrated by Clifton-Taylor and Ireson (1983, 113 9).

The final step in creating an artefact is assembly. Many artefacts must be assembled from their component parts before they are complete. Thus, in the Classical world a sculpture may have comprised several parts, perhaps a body of porphyry, and faces and limbs of white marble (eg Lazzarini 1992). Artistic ambition is not the only motive for making an artefact of several components, however: even a quern or mill made of two stones, needs to be assembled so that the surfaces will grind together properly.

The most common example of a composite artefact is a building, which can comprise many finished stones and involved several specialist masons (although experienced masons can often work effectively in every branch of the stone trade). Masons who dress individual stones are often called 'banker masons', derived from the French word *banc,* meaning a bench, which is where they work, while those that assemble a building, perhaps modifying the stones to fit, are called 'fixer' masons (Clifton-Taylor and Ireson 1983, 74 5). The latter may impose their own marks on stone, usually in the form of holes for lewis irons or other lifting gear. In addition they will create the appearance of the building by the type of bond employed. The exception to this process is the contribution of tilers who will usually be responsible for dressing tiles and fixing them to the roof.

3.5 Use

During use, wear will occur. In the case of a building, floors and steps will be smoothed and dished, fires will cause reddening and sooting, and door jambs will inevitably be scuffed.

Artefacts will also wear and develop striations and polish. The study of microwear on flint and obsidian artefacts is a developing field (eg Donahue 1994), but there is a need to expand this approach to a wider range of materials, such as polishing stones or axes, for example. Even querns and whetstones develop characteristic shapes and striations that indicate how they were used. Other types of artefact may not show signs of use, such as sculpture, information panels, and containers, used only for burial or decoration.

Use-wear studies show considerable potential in the analysis of function, for they may indicate for how long and for what purpose a stone was used. The need now is for the techniques developed so effectively for flint and obsidian to be applied more widely. Such approaches might also be linked to residue analysis. The cavities of a quern could, under the right circumstances, contain phytoliths or other vegetable matter, indicating what grain was processed. Whetstones may still have traces of materials in the interstices between the grains.

During use, an outdoor artefact may weather and deteriorate. Weathering will impose its own pattern on a stone surface and knowledge of weathering should indicate the period of exposure. The weathering of stone is of course an important field of study in its own right, but one that has been developed within the context of conservation as opposed to archaeology.

Another facet of weathering is the development surface growths, particularly of lichen, a symbiotic association of fungi and algae. These also have considerable archaeological potential as they gradually expand from a central point and certain species grow very slowly so that the maximum size of a patch of lichen should relate to its age. This method was developed by Beschel during the 1950s for dating glacial moraine in the Alps, using gravestones in Alpine churchyards as his chronological yardstick. Although his work was subsequently discredited for a variety of reasons the underlying chronological assumptions seem valid, although local photic, temperature, and precipitation regimes will restrict their application to limited areas.

It is possible that both weathering and lichen growth may prove to be of little archaeological value, but as they affect the surface of a stone, which may contain so much information, they are worth considering. (See also Section 6.4)

3.6. Discard and decay

During use an artefact may become worn, broken, or weathered so that it is of no further use. It may be discarded and left on the surface to weather and decay, or become buried, or be reused in some other form. Whatever, the process the original surface and perhaps the internal structure of the material may be changed. This may obliterate the traces of manufacture and use or at least superimpose another set of indicators. Once again, this is unknown territory, for there have been few studies of breakage patterns or of changes due to burial.

Reuse has also been studied infrequently. An honourable exception is the work of Stocker and Everson (1990), who analysed the reuse of stone in Lincolnshire between the tenth and twentieth centuries. They identified three categories of reuse. The first they term *causal,* where the original function of the stone is disregarded in its new use. The second, *functional,* consists of pieces reused for the purpose for which they were originally cut (eg doorways as doorways, windows as windows). The final category, *iconic,* comprises pieces specially selected for reuse in an iconic context, for example effigies taken from monastic sites and reused in later churches. These categories seem to have universal application and form a useful framework for considering the final stage in the life of an artefact.

The object of this section has been to provide a framework within which stone can be studied. Many of the individual steps might seem self evident, but taken together the picture is anything but simple. A stone artefact, whether it is whetstone or a palace, is the result of a complex interaction between the mind and hands of humans and nature. Some of the cognitive steps might be deduced from a knowledge of geological determinants such as colour and texture compared with the intended function, but much of the other information may be written on the surface of the stone. Our problem is to read a rather subtle and often obscure language.

4 Ballast

Much of this report concerns worked stone, but any stone, worked or not, that is foreign to a site is of interest since it demonstrates interaction with outside communities. In this respect coastal sites are particularly significant since boulders or rough stone could have arrived as ballast, which might in turn indicate the direction and force of commercial currents.

Before the mid nineteenth century, when water ballasting was introduced, a ship's cargo would have to be carefully balanced to achieve stability. Empty ships, or those with light loads, would need to take on heavier material. McGrail (1989) has discussed 'stowage factors', which relate the density of a substance to its volume, when packed for carriage. Metal and liquids, such as beer or wine in casks, are effective in balancing a ship, while textiles are less so, but stone, sand, and gravel are high on the list of desirable ballasting.

Obviously, a saleable item would be better than a dead load, but this was not always possible and some ballasts were designed to be dumped when the payload was taken on board. Equally, if part of the load was sold, it might be necessary to take on a compensating trimming ballast. When ballast was chosen for its weight rather than for its value, locally available heavy material would be selected on the assumption that it would be dumped as soon as a heavy payload could be found. Dumped ballast indicates a change in payload and hence it is a powerful indication of commercial activity.

Stone was particularly desirable as ballast because in some circumstances it could be sold. In Newcastle, between 1508 and 1511, it could be dumped for a mere 4d a cargo and did not attract customs dues (Fraser 1987). Contemporary chamberlains' accounts indicate that stones were brought in ships coming from Whitby, Hull, Cromer, and Brightlingsea as well as foreign ports such as Abbeville, Boulogne, Cleves, Dieppe, Fécamp, Harfleur, St Valèry-en-Caux, and Le Tréport.

Another clear indication of the importance of stone is furnished by La Rochelle, once an important port on the Atlantic seaboard of France. Many of the buildings are made of granite that is clearly imported to the town. Conventional archaeological wisdom might suggest that the nearest sources would be exploited, notably those in the Massif Central to the east or the Vendée immediately to the north. Much of the granite, however, came from Canada in the eighteenth century, when La Rochelle was a major port for trade with the new French possessions in North America and the West Indies (R Hodges personal communication).

Buckland and Sadler (1990) have recently published a timely paper drawing attention to the archaeological potential of ballast. Hitherto, the field has been either ignored or insufficiently researched. For example, in a seminal and often quoted paper, Fulford (1978) compared the trade of late Roman Britain evidenced by pottery with the customs records for medieval Southampton and Bristol. The latter suggested a predominance of perishable goods. 'There are about 130 items which can be broken down into eleven classes: alcoholic beverages, such as wine, cider and beer; fish; skins such as leather hides and furs; wool; wood; manufactured hardwares; cloth; minerals and metals; agricultural produce; spices; stone. Of these only stone, minerals, and manufactured goods might survive in the archaeological record in the normal way.'

He concludes that the archaeological evidence probably represents less than 1% of the original volume of trade. This discussion, however, in common with most others ignores the potential of ballast as an indicator of trade. Ships carrying skins, wool, wood, or cloth would need ballast just as much as empty ones.

Keith and Simmons (1985, 416) adopt a pessimistic stance, perhaps over-stressing the problems rather than the potential of ballast studies:

> Stone ballast is the most thoroughly ignored object category of shipwreck archaeology, and for good reason. Beyond the fact that certain stones are traceable to their original deposits, and that no comparative collections representative of specific regions have been compiled, the potential difficulties involved in deriving geographical origin from a ship's ballast warrant the following caveats.
>
> 1 Determining the origin of stones depends on the investigator's ability to discern geographical signatures from the suites of rocks forming the sample.
>
> 2 If the stones represent loading episodes in diferent regions, the investigator must be able to discern different geographical signatures from the combination of suites.
>
> 3 If the suite of stones occurring in the ballast represents a heterogeneous mixture resulting from random human collection, mixture, and redistribution, rather than collection from one or more naturally-occurring deposits specific to a particular region, no clear geographical signature will emerge.

In some parts of the world these constraints are very real, but in Britain, where geological studies have been vigorously pursued for nearly two centuries there is an adequate geological database and the potential outweighs the problems.

It is certainly true, however, that there have been few archaeological studies on ballast and most of these are cited by Buckland and Sadler (1990). In the Mediterranean there is a dearth of studies and Gifford's (1982) analysis of ballast from the Yassi Ada wreck is a precocious and exceptional example.

One of the main problems must be to distinguish payload from ballast designed to be dumped, although this may be a somewhat academic distinction as anything that can be sold is better than something that will have to be discarded. The problem is well illustrated in the walls and other buildings of medieval Southampton, which are dominated by stone from Caen, Purbeck, and Quarr on the Isle of Wight. It is reasonable to suggest that material was specially quarried on the island and indeed in 1400 the mayor and bailiffs were 'licensed to take stone free from the Isle of Wight for the defence of the town' (O'Neill 1951, 249). The more distant material could have arrived either as ballast or as a payload, and at present it is difficult to decide which explanation is the more probable. Careful studies of the size of blocks and degree of water rounding might throw light on the matter. On the other hand, the flint pebbles and Breton material from Saxon Southampton are almost certainly ballast (Peacock 1980b).

Renn (1960) concluded that the granite, quartz, and greenish slate found in the rubble plinth of Wareham castle were probably ballast from ships using Poole harbour, but Waterman (1970) was more cautious about the nature of the imported stones used in south-eastern Ireland during the medieval period. These latter largely of a Jurassic limestone from Dundry Hill on the outskirts of Bristol and in Ireland its use is concentrated around ports such as Kinsale, Cork, Waterford, and Dublin. As Bristol was a major port it is reasonable to suggest that this arrived as ballast or at least as a low-grade payload, but the distinction is clearly a fine one.

A rather different problem is presented by the frequent occurrence of Scandinavian metamorphic and igneous rocks found at King's Lynn. Clarke and Carter (1977, 440) mention, in passing, that they might have arrived as ballast or equally could have been picked up on the fields of East Anglia, where such materials are found as glacial erratics. It is unfortunate that no petrological comparison was made, for it is doubtful if natural and human transportation mechanisms would result in exactly the same assemblages of rocks. In the case of an important port such as King's Lynn, the correct identification of ballast might have been particularly telling.

Buckland and Sadler (1990, 118) draw attention to interesting evidence for trade with Iceland, which included contemporary comment from Leyland that the streets of Hull were paved with Icelandic cobbles brought in as ballast. The counterpart of this movement of material might be the flints found off the south coast of Iceland.

They also suggest that querns and millstones would have comprised a near ideal ballast, which would have the advantage of saleability at the port of destination. This seems entirely probable and it is tempting to accept their interpretation of the single, unfinished Millstone Grit top-stone from the Roman Blackfriars boat as trimming ballast taken on after discharge of part of the cargo. Here, however, caution must be exercised, for the distinction between trimming ballast and ships equipment is a fine one.

One of the most remarkable manifestations of the importance of ballast comes from work on the banks of the river Tyne (Ellison *et al* 1993; Goodrick, Williams, and O'Brien 1994). An extensive deposit of sand in the Sandgate area of Newcastle seems to be the result of ballast dumping (an essential pre-requisite before taking on a heavy load such as coal). Even more telling is a remarkable complex of fourteenth-century limekilns, which seem to have used limestone ballast as raw material. Analysis of stones from the excavations suggests that they derive either from Carboniferous boulders, which occur on the coast of Northumberland, or from the chalk, the nearest sources of which are chalk outcrops to the south in Yorkshire. The material could also derive from East Anglia, Kent, or even northern France. Here it is interesting to compare this material with the list of stone-bearing ships in the chamberlains' accounts.

One problem in characterising ballast is that for many centuries shingle was the favoured material (Adams 1985, 282). Fairly typical is the ballast found in the Sea Venture, lost off Bermuda in 1609. It comprised flint shingle of a type that occurs around much of the southern English coast from East Anglia to Cornwall. As Adams remarks, the choice was unfortunate for another reason: an adverse affect on the health of the ship's company. A letter written by William Capps in 1623 highlights the hazard of putrid ballast mixed with organic matter accumulating in the hold during the voyage (Adams 1985, 284): 'The first cause is for want of cleanliness, for betwixt the decks there can hardlie a man fetch his breath by reason there arises such a ffunke in the night that it causes putrifaction of the bloud and breedeth a disease much like the plague.'

It must be possible to characterise flint shingles and if this were done it might to much to enhance our understanding of the commercial patterns of the ships trade of the ships that used this material.

It would be wrong to give the impression that ballast necessarily always comprises geological materials. Of other heavy materials that were used, brick was particularly favoured. Here a good example is the bricks of the *Classis Britannica,* the fleet of Roman Britain. Petrological study suggested two varieties of brick, one made in Britain the other around Boulogne (Peacock 1977). Up to one third of the bricks from Roman Boulogne seem to have originated in Britain, but the French fabric is very rare in England. This suggests that during the first two centuries AD, when the bricks were stamped, the *Classis Britannica* had very little spare capacity on the journey from the Continent, but ships may have been fairly empty on the return leg. In other words the fleet was concerned with importation of the necessities of Roman life rather than exporting locally made products.

It is hoped that this brief review has served to demonstrate the importance of ballast in the debate about sea-borne trade. Boulders and irregular lumps of stone, sand, and shingle, which many archaeologists might consider a rather insignificant category of find, have a special significance all their own. There is now an urgent need for this fertile area of enquiry to be more thoroughly researched.

5 Material

The proper evaluation of an archaeological stone requires an understanding of the properties of the rock concerned, as these are fundamental to interpretation. A knowledge of properties can be a value in two fields of enquiry: they can lead to characterisation that is of crucial importance in the study of trade and exchange, and they determine the way a rock will be manipulated and the purposes for which it can be employed. Combined with cognitive processes of the stone worker they contribute to style.

5.1 Characterisation

Characterisation of a stone artefact involves searching for properties that will serve to differentiate similar materials from different sources. This is obviously a first step in determining origins, which in turn, is fundamental to understanding trade and exchange. Many rocks can be distinguished on visual criteria alone, as they may have distinctive fossils or textures that are found only in one formation or outcrop. For example, the exceptionally pure oolitic limestone from Ketton can be readily recognised, as can Purbeck marble, which contains the characteristic fossil *Viviparus*. In some cases, however, the eye is insufficiently powerful and the search for discriminant criteria must be continued under the microscope. Alternatively, it may be considered preferable to examine the geochemistry of the rock, in the hope that two similar materials will be distinguished by varying spectra of trace and minor elements. Other methods, if trace-element chemistry does not furnish clear differentiation, include isotope analyses of carbon and oxygen, which may be used to distinguish white marbles, and organic chemistry, which might be employed to distinguish shales. On the whole, the process should be one of increasing sophistication. There is no point in using a mass spectrometer if a thin section will answer the question and there is no point in using sophisticated (and expensive) science at all, if visual examination is decisive.

One of the questions in characterisation and of determining origins must be the level of identification regarded as satisfactory. A rock can be identified as, for example, limestone, granite, or sandstone, which is of little use in the assessment of trade. A 'Jurassic limestone' or 'Keuper sandstone' is an improvement, but specification of the formation, as in the 'Devonian Quartz Conglomerate of the Forest of Dean' is even better. The ideal, however, must be the more precise identification of source as in 'Inferior Oolite from the Barnack quarries' or an 'epidotized tuff from the Great Langdale axe factory'. Such determinations might be possible for most rock types, using the methods of modern science and investing much time and effort in the detailed field study of potential geological sources.

The discovery of the Lodsworth quern quarries is a good example of what can be done starting with the broad geological determination. In many early reports querns from Wessex were simply described as 'Greensand', for which there are many possible sources on the fringes of the Wessex Chalklands or around the Weald of Sussex and Kent. The Greensand used for quern-making, however, seems to have unusual features, in particular an abundance of fossil worm burrows and extensive silicification. Study of transects through various parts of the outcrop failed to locate exact parallels, suggesting that the rock was indeed unusual, but eventually it seemed that the nearest match was in the Lower Greensand area of West Sussex. Ultimately, by combining geological and archaeological fieldwork with thin-section petrography and documentary research, it was possible to refine the diagnosis to one particular Greensand quarry where field survey revealed quern roughouts (Peacock 1987).

However attractive this process of deduction may seem, it is worth bearing in mind that this determination demanded a lot of field time and is not the sort of thing that can be done in the context of an excavation report unless there are very special circumstances.

Lodsworth was a special study and the frequency with which Greensand querns were encountered made it a worthwhile investment of time and resources. It is more difficult to offer guidelines on the level of rock determination that should be achieved generally in excavation reports. Clearly rock type alone is nadequate, and an attempt should be made to define at least the geological system, or perhaps formation. Beyond this, precision must depend upon such factors as the availability of detailed geological expertise, the importance of the find to the interpretation of the site, and the overall distribution of the type of artefact being studied.

Thus, to identify a millstone from a southern English site as Millstone Grit, is a useful attribution indicating that the stone was imported from the basal beds of the Upper Carboniferous of the Pennines. On the other hand, this identification would be less informative if the find is from a Yorkshire site where Millstone Grit is ubiquitous. Here, it might be desirable to suggest potential quarry sites such as Wharncliffe Edge, Hathersage, or others. Equally, such a determination might involve an unacceptable amount of primary research. There are no hard and fast rules, except to recommend that the most precise determination of origin should be sought within the constraints of time, money, and available expertise. The task of refining the database to permit greater precision is one for research institutions rather than field units.

Today an impressive array of scientific methods is available for rock characterisation, but despite this the basic tool remains simple visual comparison of an unknown rock with potential source materials. In order to do this effectively a comparative collection is essential and usually the quality of identifications relates directly to the extent and relevance of the reference collection. Some workers claim to 'know' certain rocks, that is to carry information about colour and texture in their heads. There is little doubt that this can lead to accurate identifications when a rock is very distinctive or when a worker has wide experience of a region or of a rock type. But there are dangers. For example, in a recent study of grey granitic rocks in the Mediterranean area, comparative chips from the major quarries were taken to archaeological sites and placed on artefacts made of grey granitic materials. There was good correlation between visual determinations made in this way and those confirmed by chemical analysis, but it is alarming to note that no fewer than six previous determinations, made by reputable workers without access to comparanda, had to be corrected (Peacock *et al* 1994). The lesson seems clear: colour and texture are complex attributes which are difficult to retain in the head and great caution is needed.

In view of the importance of comparative collections an attempt was made to locate the principal collections in England and to evaluate their suitability for archaeological purposes. The following notes summarise the outcome of this survey.

5.1.1 University geology departments

These invariably have a rock collection. Often they have good teaching coverage of the region, but beyond this the collections may be biassed by the research interests of the department. In general, access is not easy because of shortage of curatorial staff and they are best used by members of the departments concerned.

5.1.2 The Sedgewick Museum, Cambridge

This is a fine collection of British and foreign building stones amassed at the turn of the century. It is the only collection to have published catalogues (Watson 1911, 1916). Unfortunately, there have been minimal additions to the collection since then, but a few entries have been added to the Museum's copy of the catalogues. Today the collection is housed in glass cases ranged around the walls of what has become a common room. Most specimens have been cut and polished where appropriate.

5.1.3 Building Research Establishment, Watford

An extensive collection of building stones largely collected by R J Schaffer in the 1920s and 1930s with few additions since. Many specimens have been cut and polished and there is an extensive series of thin-sections. Access is by an old accessions register, which has been indexed, but the system is slow and difficult to use. Certain BRE publications have good rock descriptions and colour plates illustrating some of the more commonly used materials:

E Leary T*he building limestones of the British Isles* (1983)
E Leary *The building sandstones of the British Isles* (1986)
D Hart *The building magnesian limestones of the British Isles* (1988)
D Hart *The building slates of the British Isles* (1991)

5.1.4 English Heritage

A small, but useful, collection of the more common building stones is housed in the Architectural Conservation section in 23 Savile Row, London (c 350 samples from 150 localities). The catalogue is a draft folio which records find spot, colour, and case location.

5.1.5 British Geological Survey, Keyworth

A collection of about 80,000 stones collected in the course of the survey's work. There is also a considerable collection of overseas material with worldwide coverage. The British collection is now a computer database, which is available for public consultation. Specimens can be borrowed through the post, as can thin sections, the availability of which is indicated by an E number in the Geological Survey sheet memoirs.

5.1.6 The Natural History Museum

The Tolley collection comprises about 40,000 building stones and marbles from Britain and the Continent. The collection is arranged by rock type and the marbles by colour, which makes it particularly useful for archaeology. The collection has not been updated in recent years and access is via an old card catalogue. The collection is housed in a well lit room and study conditions are reasonably good.

5.1.7 Southampton University, Department of Archaeology

This is a collection of about 2500 samples from 450 localities, built up specially for archaeological purposes, with the assistance of English Heritage. Thus, all the material is archaeologically relevant and includes, for example, mill and whetstone rocks as well as building materials. The collection is accessed by a database on a computer which accompanies the collection. Some thin sections are available but the collection is being expanded. Coverage is excellent for southern and midland England, but falls off northwards. Study conditions are good.

5.1.8 University Museum of Natural History, Oxford

The museum has a building stone collection, but its most remarkable asset is a 'Corsi' collection of antique marbles from monuments in Rome. This is an invaluable resource in the identification of marbles imported into Britain. The collection is well curated and easy to use.

5.1.9 Private collections

A number of workers have small private collections to assist in their work.

5.2 Comments

Many of the collections seen in this survey are old and beginning to suffer from neglect over many decades. Physical access and the lack of computer databases is a serious drawback in most cases. The Geological Survey collection (5.1.5) is clearly a major resource, but much of the material is irrelevant to archaeology and finding a match could be a time-consuming and frustrating activity. To be effective a collection should be oriented towards archaeology, concentrating on samples from ancient quarry sites and from artefacts and buildings.

The collections described above will be of interest to those engaged in geological identification of rocks for the archaeologist, but this is the second phase of a process that begins in the field; it is almost inevitable that the finds staff of a unit, who may or may not have geological experience, will comprise the first point of inquiry. They will be responsible for the selection or discard of material in the field or at a later stage in the processing laboratory. To some, this may seem to be less than ideal, but it is an inescapable fact of archaeological life that the basic sorting upon which the interpretation of a stone assemblage rests has to be done by archaeologists rather than by geologists. The aim of this work must be to distinguish naturally occurring site materials from those brought to the site, and where possible, to identify local sources. More exotic material, brought in from outside the region, will then be referred to the specialist.

Many units have their own small comparative collections, which is admirable. This precept should be emulated so that local comparanda become a standard part of the equipment of a finds department. A local collection can be built up relatively quickly and easily without excessive expenditure of time, effort, or money. The more important local quarries can be found from the Geological Survey sheet Memoirs, from the lists in Clifton-Taylor (1962) or from the *Natural Stone Directory.* Examination of local parish churches and vernacular buildings can also provide useful pointers.

It will be argued by some that the classification of stone is work for the geologist, not the archaeologist, and in the ideal world this should be the case. The current structure and funding of British archaeology, however, precludes such a luxury. Not every unit can have a full-time geologist, and specialists, who are few and far between, are unlikely to be available to participate in field projects. Field archaeologists, almost by definition however, have an eye for detail and can be relied on to study stone materials intelligently. The danger is usually one of over-classification, but this is a lesser problem as it is something that can be corrected by the geological specialist at a later stage. There is, however, a widely felt need for basic training in rock recognition and in the criteria that should be used in discrimination and classification. Short courses or the services of a travelling advisor would do much to speed up the process and to disseminate basic knowledge about rocks. In the meantime it is worth drawing attention to the excellent guide for Northamptonshire materials published by Hudson and Sutherland (1990).

Scientific methods offer more precise ways of characterising lithic materials, supplementing rather than substituting for the basic approach discussed above. It would be inappropriate to attempt an excursus on lithic archaeological science, but it is perhaps pertinent to draw attention to the principal methods and their scope in this field, focusing on recent work.

The most fundamental method for studying rocks, and also one of the oldest, is examination in thin section under the petrological microscope. Petrography continues to be the second line of approach and it can be used in a routine way to confirm visual identifications or to seek distinguishing criteria in materials from different sources, which appear to be visually identical. The technique is well known to archaeologists and need not be reiterated here (see for example Kempe and Harvey 1983 for discussion of the method). In Britain, the most celebrated use of thin-section petrography has been in the classification of stone axes (Clough and Cummins 1979, 1988; Cummins 1983). In general, it is most effective in characterising coarse-grained rocks, particularly those of igneous or metamorphic origin. It usually less effective on fine-grained materials, particularly limestones, silts, and clays, unless they contain microfossils. The method is destructive and great damage has been done to fine museum specimens, sometimes, as in the case of jadeite axes, for a minimal increase in knowledge. Modern methods of using a core drill and capping the hole with a disc of the original surface are more acceptable, but still leave a blemish.

An alternative approach, which can also be destructive, is to study the geochemistry of the rock on the assumption that different outcrops of the same material are unlikely to have identical distributions of trace and minor elements. There are several ways of doing this, of which the most popular has been X-ray fluorescence analysis (XRF), largely because this instrument is readily available in university geology departments. For example, it has been widely used on, granite columns, and millstones, and on the bluestones of Stonehenge (Peacock *et al* 1994; Williams-Thorpe and Thorpe 1992, 1993b; Williams-Thorpe 1988). In each case it successfully distinguished materials and facilitated comparison with potential source outcrops.

Peacock *et al* (1994) also used a rather less destructive approach, which proved very effective on coarse-grained granitic rocks. Using a microprobe, it was possible to focus on individual biotite and amphibole crystals, which proved to have trace element compositions diagnostic of origin. In other words the rock could be characterised by removing a few minute grains of material, and the approach was, to all intents and purposes, non-destructive.

Chemical analysis has been comparatively little used on sedimentary rocks, but Holmes *et al* (1994) have effectively used neutron activation analysis to distinguish some of the fine-grained limestones used in medieval France. It appears that the signature for a single quarry face is usually homogenous and consistent regardless of variation in petrography and there are well defined differences between quarries. There is clearly great potential for the further application of this approach and as limestones are particularly common in Britain, it could make a marked contribution to the study of English rocks.

White marbles occur in relatively small quantities on British sites and their attribution to source is a problem. For example, fragments of white marble casing, which once enclosed the great monument at Richborough have been ascribed to the Carrara quarries (Bushe-Fox 1926, 36). This may well be correct, but one white marble can look much like another and there is a need for claims such as this to be independently substantiated. In the Mediterranean they have long been recognised as a problem area, with good reason, for marbles are often composed of nearly pure calcium carbonate. Isotopic analysis has been developed as an effective means of discrimination. ^{13}C and ^{18}O seem to characterise most of the principal outcrops (Herz 1988, 1992). There is a measure of overlap, however: the marbles of Proconnesus, Thasos, Paros, Carrara, and Docimium can have much the same compositions so that confusion is not difficult (cf Herz 1987). It seems preferable to adopt a multi-method approach, combining the findings of isotopic analysis with microscopic and chemical approaches, as advocated by Moens *et al* (1988).

A relatively recent development that deserves further attention, is cathodoluminescence. It seems to be an inexpensive and effective contribution to the fingerprinting marbles and perhaps other rocks made principally of calcium carbonate (Barbin *et al* 1992). The marble is bombarded with an electron beam and the resulting luminescence depends on impurities hosted in the crystal or on lattice defects. In carbonates the principal activator of luminescence is manganese (orange luminescence) while the main quencher is iron. It seems a useful addition to the growing spectrum of techniques.

Organic chemistry has been but little applied to archaeological artefacts, but jet, oil shale, and similar materials contain an appreciable content of organics derived ultimately from fossil terrestrial plants and aquatic organisms. Most of the work so far has been directed towards differentiating jet and shale, which has been successfully achieved (Pollard *et al* 1981; Hunter 1991; Hunter et al 1993). More recently Allason-Jones and Jones (1994) have begun a programme of analysis on Roman material from Hadrian's Wall, using reflectance microscopy, which effectively discriminates jet, channel coal, detrital coal, and shales. These approaches offer great potential for furthering our understanding of materials traditionally classed as 'Whitby jet' or 'Kimmeridge shale'.

Williams-Thorpe and Thorpe (1993b) advocate the use of magnetic susceptibility for distinguishing igneous rocks with a high tenor of iron minerals. This is a measure of the content and state of the iron minerals, which seems to vary systematically between rock types and even in some instances between outcrops. Williams-Thorpe *et al* (1996) have used this method to suggest the parts of the quarry field in which Mons Claudianus columns in Rome originated and Peacock (1995, forthcoming) has determined the origins of granitic columns in Central Europe using the same method. The strength of this approach is that it is quick, simple to apply, and non-destructive. It could have application to the igneous rocks found in British archaeology, but has yet to be employed.

This very brief review, focusing on certain recent and significant developments in the field of stone analysis suggests that the archaeological armoury is now equipped with some very sophisticated and powerful techniques that can be used to back up visual determinations or to form the basis of projects in their own right. Two things are now needed. The first is the systematic application of these methods to generate a body of archaeological information that can feed into syntheses of trade and exchange in a more meaningful way. The second is the development of a range of non-destructive methods so that scientific methods are not restricted in their application. As the archaeological world becomes more conservation conscious, it seems increasingly unlikely that it will be possible to take samples of museum artefacts or standing monuments in the way to which we have so readily become accustomed.

5.3 Style

Style is a real, if complex, attribute. It depends in the first instance upon design, which is the result of cognitive processes: of the training, experience, and tradition of the worker. It depends on technology: the tools available and how they are employed, which will also reflect the background of the worker, while a further major influence will be the material itself. Thus, two workers making similar artefacts from the same material will not produce the same style, but a single worker may produce two styles from two materials, because the material itself may dictate different approaches. In other words the method of producing a piece of sculpture from granite will differ from that used on marble. Hardness, texture, and the presence or absence of foliation or bedding may interact and dictate the tools to be used and their mode of employment.

The concept of style is, however, of more general application, which some examples will serve to illustrate. A shepherd's cottage on the edge of the Black Mountains in Herefordshire serves the same purpose as a shepherd's cottage on the Pennines in Yorkshire, but they look totally different. The contrasting vernacular styles is in part a result of diverging traditions of architecture, but materials also play a very important role. The flaggy Old Red Sandstone rubble of Herefordshire is a very different building material to the ubiquitous Millstone Grit of Yorkshire, which occurs as massive beds and from which large blocks of freestone can be obtained with relatively little difficulty. The difference in materials plays a considerable part in accounting for contrasts in the visual and technical appearance of the end product.

The concept of style is not limited to works of art or to buildings; it also helps in understanding more mundane artefacts. A millstone made of silicified 'burr-stone' from La Ferté-sous-Jouarre to the east of Paris, is quite different from a 'Peak-stone' millstone grit. They serve the same purpose, but are constructed in a different way. The French stone is much harder and more durable, but is only obtainable as small pieces, which have to be held together with cement and bound with an iron band around the circumference, whereas the Peak stone is monolithic. This is a fairly obvious case, but there are more subtle differences between lava mills from Mayen in Germany (the so called Niedermendig or Andernach mills), Peak stones, and mills of other origins. The physical properties of the rocks limit the size and thickness of the mills that can be made in each locality, and contribute to differences in style.

Stone axes also vary in typology. The situation is again complex, but broadly speaking the more slender ones are of finer-grained materials than the thicker ones. Thus, in general we would expect an axe of the fine Great Langdale tuff to be thinner than one of the coarse uralitised (pyroxene minerals replaced by fibrous amphiboles) gabbro that comprises group I. No doubt finer materials would be worked by flaking while perhaps coarser ones would be better suited to pecking and the two technologies could give rise to shape variation (Coope 1979). The issue is not a simple one, for as Chappell (1987) has shown there are other factors at work, such as function and breakage with subsequent reworking. Once more, however, it seems that rock type at least contributes to style.

Mention of stone axes raises another point, for knowledge of material can help in matters other than an appreciation of style. Bradley *et al* (1992) applied rock mechanics to axes and quarry material. They found that uniaxial tensile strength bore little relationship to the siting of quarries at Great Langdale: equally good material at more accessible locations was not exploited to the same extent as some of the higher quarries. Similarly study of axe materials as a whole suggested that materials were not selected for their tensile strength. It seems that other factors, perhaps of a social nature, may have been a major determinant.

It is perhaps in the study of buildings that the relationship between material and style has been most thoroughly discussed. Clifton-Taylor (1962) explored the relationship between geology and the nature of English buildings showing the way in which their character reflects the materials of which they were made. It might be possible, however, to use this approach in a rather different way. Knowledge of the properties of a rock might lead to an appreciation of its potential – the way in which it *could* be used most easily and efficiently. It might thus be possible to predict how and why the appearance of a Roman villa in the Cotswolds *might* be expected to differ from one in East Anglia, or how we would imagine the medieval walls of a town in the Carboniferous country of the north to differ from those using the contrasting materials of the Tertiary south. Alternatively how was the design of medieval houses or abbeys modified because of the available building materials? Once the role of geology has been assessed, the remaining variations might be of a cognitive nature, and this approach affords a way of tackling some of the more intractable questions.

Of course it is always important to compare like with like: a cow-shed and a house will be different because they have contrasting functions and a yeoman's house will be different from an estate owner's house because they are the products of distinct social environments. As a basic minimum it seems essential to subdivide vernacular buildings into domestic, agricultural, and industrial (Brunskill 1970, 20), while in a higher plane, perhaps involving architect design, it is possible to recognise 'polite' and formal buildings, the latter intended to make an important social statement.

In general, within any one period, the more important the building, the greater will be the proportion of ashlar and the further the builder will go to seek the most satisfactory materials. It should thus be possible to gauge the importance of a building from the range of materials employed and the distance from which they were obtained combined with an assessment of the degree to which they were worked. This simplistic concept must always be used in context. A medieval house must be compared with other medieval houses in the same region and there is little point in comparing a rubble built Cotswold cottage with one in the north country built of Millstone Grit ashlar, because ashlar is easier to produce in the latter case.

The same concept applies to portable artefacts: the more exotic the rock the greater their value is likely to have been. No doubt within Iron Age Wessex, a Lodsworth quern would have had a relatively low value, but in Northamptonshire it would have been a treasured item of considerably more value that querns made of the totally unsuitable local limestone.

The relationship between material and what we are calling style is very much unexplored ground and so it is difficult to pursue these arguments further. It is, however, a fruitful area for future thought.

6 Stone surfaces

In the previous section it was argued that the proper understanding of a stone artefact demands careful consideration of the properties of materials, including colour, texture, bedding, jointing, and foliation, and it was suggested that other parameters, such as rock mechanics, might also be relevant, although they lead to a different type of information. Another attribute common to all stone artefacts, and quite distinct from the factors discussed above, is the stone surface. This is extremely important as it may contain traces of quarrying, working techniques, use, and post-use weathering and decay. In short, the entire history of human intervention may be recorded on the surface. Without doubt, one of the greatest challenges facing the student of ancient stone is that of learning to read the somewhat ephemeral palimpsest of this activity. It is a difficult task and one that has barely begun to be tackled. In this section we can do no more than draw attention to the potential of this field of study and to suggest some of the things that need investigation. The object is to expand on the skeleton outline in Section 2, to which reference should be made.

6.1 Quarrying and preliminary processes

It is rare to find traces of the original quarrying operations on stones, but the possibility exists and care should be taken to examine unutilised surfaces. Quarry marks, used to tally output in the quarry itself, may be incised or painted, but they are unlikely to be preserved outside the quarry. The marks of the hammer, pick, or point used to reduce the weight of the raw stone and dress it roughly to shape before transportation, are more probable, but here there are difficulties as the tools of the quarryman are basically the same as those of the mason. Even under the most favourable circumstances, it may be difficult to distinguish quarry dressing from subsequent working.

Perhaps the most diagnostic tool is the wedge, for it is par excellence a quarryman's tool, although even this can, on occasion, be used by the mason to split blocks. Wedge marks are comparatively common in hard rock quarries, but less so in soft rocks, where splitting along natural fractures and dressing with a hammer was the rule. Thus, only a handful of wedge holes are known from the whole of Roman Britain, even though wedging must have been commonly practised (Blagg 1976, 154).

Wedge holes are very difficult to date and chronological schemes for their evolution, such as that proposed by Röder (1967) for Roman Egypt are not now generally accepted. All that can be said is that nineteenth-century and modern wedge holes are usually small (*c* 20 30mm across) while ancient ones seem to be larger (*c* 100 150mm). This said, it is worth noting that very rarely, large wedge holes can be seen in nineteenth-century quarries such as those on Haytor, Dartmoor. The significance of wedge size is not clear, but it may be that in the days before explosives, massive rock splitting needed larger holes to accommodate substantial wedges or perhaps a series of smaller ones backed by metal plates or 'feathers'.

Similarly, marking-out lines are unlikely to be preserved except under exceptional circumstances, since by their very nature they will be superimposed by later working.

6.2 Tool marks

The dressing of a stone will leave rather distinctive traces on the surface and even when the final process is one of smoothing or polishing some evidence of the original steps may remain. Tool marks on stone surfaces, however, remain an enigmatic a difficult area of enquiry. The most thorough study to date is that of Blagg (1976) who was able to study some of the tools involved from marks on Romano-British artefacts, but the ubiquitous medieval marks remain an area of uncertain significance. As Stocker (1993) claims 'a feeling has developed that marks left on stones by tools used to cut it might be useful in analysing the building from which it has come. Although some progress has been made with studies of Roman tooling... little real progress has been made with studies of its medieval equivalent. For example, we do not yet even have an agreed terminology for tooling marks, and much of the analysis available in print is impressionistic in the extreme.' He goes on to suggest that tooling marks will never be of great value in close dating, if only because the tools used have changed little since the Roman period. He draws attention to the 'striated' finish of the twelfth century, which often runs diagonally to the bed of the stone, but even these will have a cruder finish on their beds and joints, which may be indistinguishable from later medieval, Roman, or modern work. The striated finish was superseded by the 'claw' finish towards the end of the twelfth century although the former can still be found in the late medieval period (Stocker, 1993).

The main hindrance in the study of tool marks is that it is the domain of archaeologists who are not stonemasons, and the latter are generally practical workers who do not write books. In recent years the situation has changed radically and there is now a substantial body of written information about the craft of stoneworking. One of the earliest contributions is that of Clifton-Taylor who joined forces with AS Ireson, a practising Stamford stonemason, but their book, although useful, lacks the detail required by archaeologists (Clifton-Taylor and Ireson 1983). More recently

Peter Rockwell (1993), a practising sculptor, has produced a useful practical guide aimed partly at archaeologists, but pride of place must go to a French stonemason, Jean Claude Bessac (1986, 1988). His works furnish a guide to the multifarious instruments of the mason and he illustrates the effect they can produce on a stone surface, thus facilitating archaeological recognition. His text includes notes on where the tools were used in antiquity. With these guides, there are new possibilities for opening up the study of tooling.

There is a great need for more research to determine the significance and possible interpretation of tooling marks. It is easy enough to suggest that archaeologists should record them, but we do not yet know whether this information is worth collecting or not. Recording costs time and money and in the modern environment of competitive tendering and developer funding, an appeal for recording just in case its might one day be relevant, is likely to fall on deaf ears. On the other hand as buildings erode, the surface is likely to be the first thing to be lost.

It is clear that the interpretation of tool marks will never be a simple matter. There is no doubt that variation will depend on the complex interaction of a number of parameters. Clearly, the choice of a tool and the way in which it is used will depend on the type of stone, the training and tradition of the stonemason, and which face of a stone is being worked. Obviously, keying for plaster or mortar will demand a different style of tooling from a finished surface that is to be seen. Furthermore, the function of the stone must be taken into account: there may be an advantage in leaving a doorstep rough and a window frame smooth. Similarly a whetstone may require a fair degree of smoothing if it is to function properly, in contrast to a millstone, which may need roughening. Tooling may have chronological significance, but by its very nature the complexities mentioned by Stocker are hardly surprising.

Despite these problems, the variables can be reduced to manageable proportions by comparing similar rocks used for similar purposes and by restricting consideration to one face. An attempt was made to test the potential of tool-mark study by considering a number of cases. This is not a substitute for a proper research programme, but merely a feasibility study to test possibilities.

6.2.1 Belsay Castle, Northumberland

This castle, owned by English Heritage, is particularly suitable for study of tooling as it is made from Lower Carboniferous sandstone obtained from the local quarries, which now form the garden. The structure itself is multiperiod and comprises a fifteenth-century tower house, with additions in the seventeenth, eighteenth, and nineteenth centuries (Johnson 1984). These are shown in Figure 6.1. Tool marks abound both in the quarries and on the structure itself, and because of the nature of the rock a large number are well preserved. Some examples are shown in Figure 6.2.

Fig 6.1 Belsay Castle, Northumberland, showing the fifteenth-century tower on the right, the sixteenth-century building (with columns), and the nineteenth century addition (behind the seat); the fragment on the far left is a remnant of the eighteenth-century wing

In sixteenth century the outer faces of the stones have a rather coarse tooling running at a slight angle to the sides of the stones. The seventeenth-century stones are fine, well finished ashlar with traces of fine tooling running more or less vertically. The eighteenth-century tooling is less well defined and contains a mixture of rather coarse markings, although not as prominent as those of fifteenth-century date. The nineteenth-century tooling is quite distinctive and comprises horizontal chisel marks. There is a clear chronological sequence and the only real confusion might arise with eighteenth-century work. It only applies, however, to the outer faces, and inner faces have much coarser marks, which are more difficult to interpret. Similar coarse keying marks can be seen in the nearby nineteenth-century house designed by Dobson, but the outer faces again show a distinctive patterning, quite different from those seen in the castle.

Behind the castle is a building said to be of eighteenth-century date. Certain bulging, and obviously older, parts of the north wall, however, have tooling patterns that match those in the fifteenth-century tower, while the west end is clearly nineteenth century, or was retooled in the nineteenth century. It appears to be a complex structure, which was rebuilt in several periods, although it seems that most of the existing stonework is eighteenth century. This somewhat brief and unsystematic study is encouraging for it suggests that tooling marks, used with care, could be a powerful aid in building analysis.

6.2.2 Devon, Dorset, and Somerset churches

by Jennifer Mincham and Susan Wright

The aims of this survey were to collect a more comprehensive sample of tool marks in order to assess

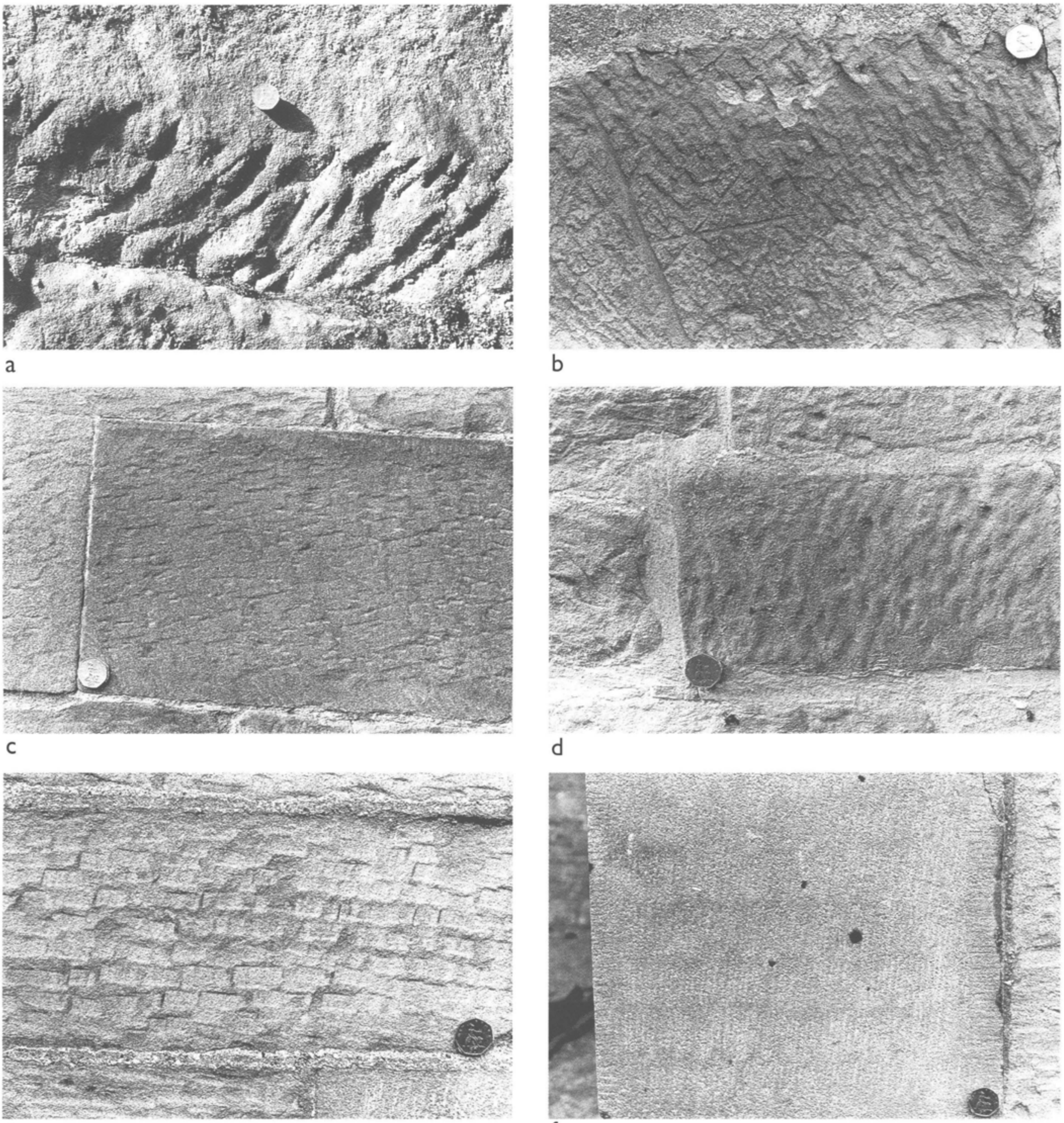


Fig 6.2 Belsay Castle, Northumberlan, stone textures:
***a** Quarryman's pick marks in the quarry garden;*
***b** fifteenth-century outer surface;*
***c** sixteenth-century outer surface;*
***d** eighteenth-century outer surface;*
***e** nineteenth-century outer surface;*
***f** nineteenth-century quoin*

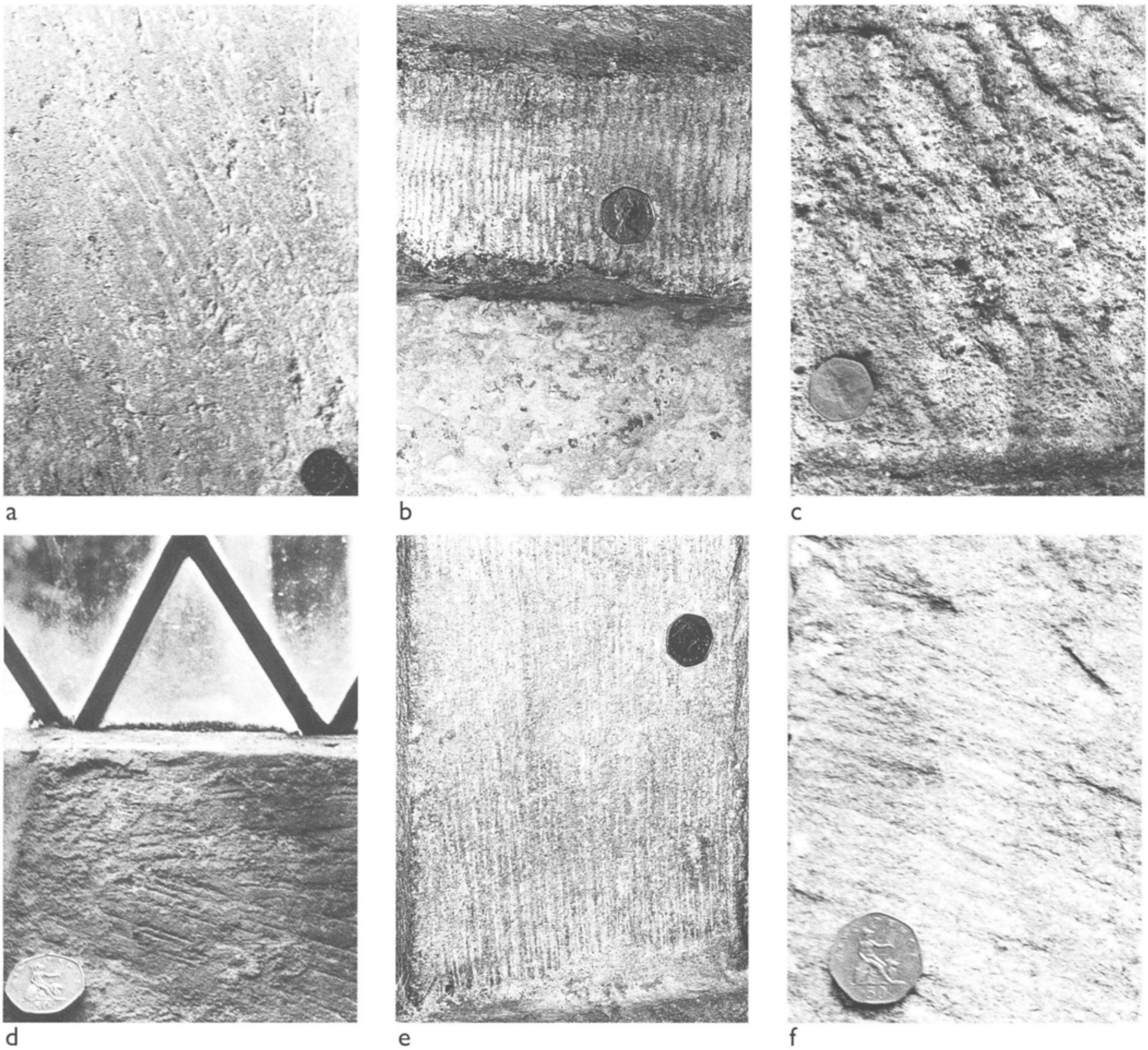
their archaeological significance, particularly for dating. The marks were recorded by black and white photography and by making a 'squeeze' in the manner described in Section 7.2.4. Some typical examples of the marks studied are illustrated in Figures 6.3 and 6.4.

Small, multiperiod parish churches were chosen, with well documented building and alteration histories. Three areas were chosen, south-east Dorset – well documented by Royal Commission on Historical Monuments (1970) – south Somerset, and south-east Dartmoor, because each contained different types of local building stone. In south-east Dorset the survey was confined to Purbeck limestone, in Somerset to Ham stone, and on Dartmoor to granite. In each case, as wide a time span as possible of was studied, from the eleventh to the twentieth century, although it was not possible to record tool marks from each century in every church. All of the churches had been restored to some extent in the mid to late nineteenth century, making it difficult to be certain of some of the earlier dates. Most of the tool marks recorded, therefore, had to be taken from dateable internal features: window frames, window surrounds, doorjambs, piscinas, squints, pillars, walls, rood stairs, and porches. An average of 30 examples per area was recorded.

Dorset

St Peter's, Church Knowle

The building of this church commenced in the early thirteenth century, the west tower being added in the fourteenth century and the north aisle in the nineteenth century. Examples from all of these periods were studied (eg Figs 6.3a and 6.3b).



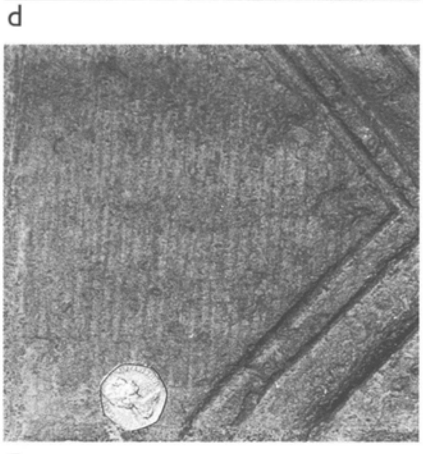


Fig 6.3 Tool marks on Dorset churches:
a *Church Knowle – fifteenth-century window surround, showing narrow, widely spaced tool marks;*
b *Church Knowle – thirteenth-century piscina, showing vertical pattern;*
c *Kimmeridge – fifteenth-century butress, showing broad, deep tool marks;*
d *St Martin's, Wareham – fourteenth-century window frame with coarse, criss-cross pattern;*
e *St Martin's, Wareham – eighteenth-century pillar with linear pattern;*
f *Winfrith Newburgh – seventeenth-century exterior*

St Nicholas', Kimmeridge
This church is of twelfth-century origin, with additions in the fifteenth century (Fig 6.3c). Extensive rebuilding took place in the nineteenth century. Examples of tool marks were obtained from the twelfth and fifteenth centuries and also from an eighteenth-century cheese press, excavated locally and displayed in the porch.

St Martin's, Wareham
This church was established in the eleventh century and has been altered extensively through its history. Examples from the eleventh, thirteenth, fourteenth, fifteenth, seventeenth, and eighteenth centuries were studied (Figs 6.3d and 6.3e).

St Mary's, Wareham
St Mary's church incorporates St Edward's Chapel, which can be dated to *c*1100. The main body of the church was constructed in stages, however, during the fourteenth, sixteenth, and nineteenth centuries. In 1841–2 a new nave was built to replace the earlier pre-conquest nave.

St Christopher's, Winfrith Newburgh
This church was much restored in the nineteenth century. The exterior south wall contains, twelfth-, fifteenth-, and seventeenth-century examples of tool marks (Fig 6.3f)

St Nicholas', Worth Matravers
The main body of the church was built *c* 1100 and contains examples of Norman architecture. Rebuilding took place in the thirteenth and mid fourteenth centuries, and the church was restored between 1869 and 1872. Examples of the twelfth, fourteenth, and eighteenth centuries were studied (Fig 6.3g)

Somerset

St Mary's, Barrington
This is essentially a thirteenth-century church with later fifteenth century, Perpendicular, and nineteenth-century additions. Tool marks were recorded from the thirteenth, fourteenth, and nineteenth centuries. Barrington stands apart from the other Somerset churches in that some of the tool marks in the church do seem to be of a particularly fine and well executed nature. Two reasons were considered for this: the Ham stone used was of a particularly fine composition, capable of being finely worked; and Barrington employed excellent craftsmen.

St Mary Major, Ilchester
The church is thirteenth century with alterations in the Perpendicular period and an aisle added in the late nineteenth century. Examples of all these periods were examined. The church has some reused stones from the Roman period, which imposed limitations (Fig 6.4a).

St Mary's, Isle Abbotts
According to Pevsner (1958, 206), this church was completed by *c* 1300. Small alterations were made in the fourteenth century and major alterations in the early sixteenth century (Fig 6.4b). Unfortunately the Perpendicular west tower was taken down and rebuilt in the nineteenth century and although this contained a selection of tool marks it was felt that they could not be used as their dates were uncertain.

St Peter's, South Petherton
This church is essentially late thirteenth century, with additions in the mid fourteenth century. Tool marks were recorded here from both of these periods. Interesting tool marks were noticed on the low pedestals supporting the nave pillars, but these could not be dated and were therefore not included.

St Mary's, Stoke Sub Hamdon
This church is of Norman origin and produced the earliest examples in Somerset. Additions were made in the thirteenth and fourteenth centuries and the church was restored in 1862. Examples of tool marks of the twelfth, thirteenth, and fourteenth centuries were studied, but two examples may possibly represent nineteenth-century restoration (Figs 6.4c and 6.3d). According to Pevsner the Norman chancel arch has been much renewed. Squeezes of the twelfth- and fourteenth-century marks revealed tool marks remarkably similar to those of a squeeze of nineteenth-century tool marks from Ilchester. It is felt these may be part of the restoration. Another interesting feature of this church is that the work of what may be a single mason can be seen in two separate places at the base of the north tower.

St Bartholomew's, Yeovilton
The church is basically late thirteenth and early fourteenth century, with a Perpendicular west tower of 1486. The church fell into disrepair until 1988, when it was taken over as the Anglican Church for the Royal Navy Air Station, Yeovilton, and dedicated for use in 1993 after much restoration. Tool marks of the fourteenth and fifteenth centuries were studied.

Dartmoor, Devon

The Church of St Peter, St Paul, and St Thomas, Bovey Tracey
The church is fifteenth century with a fourteenth-century tower. It was restored in 1857 8 and the north aisle added. With one exception, all the examples recorded were exterior as the interior walls had been plastered (Fig 6.4e).

St Michael's, Ilsington
The church is dated to the late thirteenth and early fourteenth centuries (Fig 6.4f), with additions and rebuilding in the fifteenth and early sixteenth centuries. Restoration took place in 1884. Examples of the thirteenth, fourteenth, and sixteenth centuries were studied.

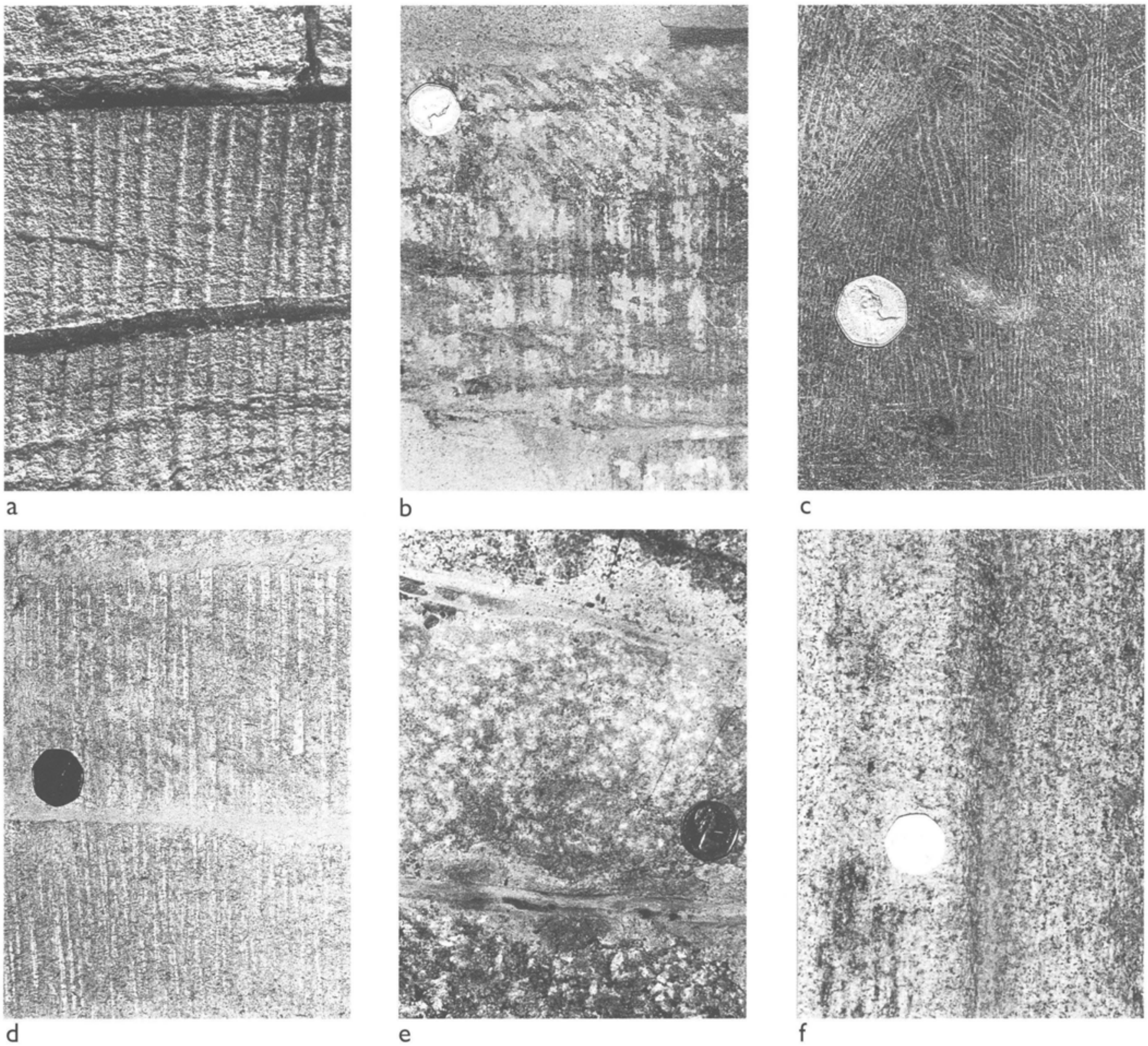


Fig 6.4 Tool marks on Somerset and Devon churches:
a *Ilchester – nineteenth-century exterior, showing regular, vertical tool marks (block 120mm thick);*
b *Isle Abbotts – sixteenth-century window surround, showing criss-cross pattern;*
c *Stoke Sub Hamdon – thirteenth-century piscina, showing extremely fine criss-cross pattern;*
d *Stoke Sub Hamdon – twelfth-century interior chancel wall, showing regular, vertical tool marks, possibly representing nineteenth-century restoration;*
e *Bovey Tracey, Dartmoor – fifteenth-century door surround, showing pecking technique;*
f *Ilsington, Dartmoor – fourteenth-century pillar, showing continuous, vertical linear striations*

St John the Baptist, Lustleigh
Lustleigh is originally an early thirteenth-century church. Additions were made in the fourteenth, fifteenth, and sixteenth centuries. Squeezes of toolmarks were obtained of all these dates, also of 6th 7th century commemorative stone and from the twentieth century.

St Winifred's, Manaton
St Winifred's was built in various stages during the fifteenth century and restored after storm damage in 1779. Further restoration was carried out in 1865, 1923, and 1925. Tool marks were limited here, owing to restoration and internal plastered walls and were only obtained for fifteenth- and sixteenth-century periods.

St Pancras, Widecombe in the Moor
This is essentially a fourteenth-century church, enlarged in the late fifteenth and early sixteenth centuries. Tool marks were recorded from all three periods. A sample was also taken from the finely worked modern pulpit.

As the techniques of working granite appear to be so different from those of working limestone, it was decided to keep granite as a separate category.

Limestone

Exterior walls

Many of the churches had fallen into disrepair by the eighteenth century and were extensively restored during the nineteenth century. It was therefore necessary to be careful when assuming a date for a particular wall. The Victorian restorers were heavily influenced by the ideas of both the Oxford Movement and of Pugin (1841, 45) who wrote 'the rubble wall of antiquity ... [impresses] the mind with feelings of reverend awe'. In consequence many of the restored exterior walls are of rubble and this had to be considered when locating and recording original exterior walls. At Winfrith Newburgh the south wall of the church has been well documented by the RCHME and it was possible to record work of the twelfth, fifteenth, and seventeenth centuries.

Seven examples of walls were recorded, ranging from the twelfth to the nineteenth centuries. In general these show a gradual progression from the twelfth to the seventeenth century from fairly coarse oblique tool marks to finer examples by the seventeenth century. In the twelfth century the tool marks are irregular, coarse, uneven, and generally at an oblique angle. In the fifteenth century the appearance is more regular and slightly finer, continuing at the same oblique angle. The seventeenth century is a continuation of this and becoming finer. Other patterns have also been noted, for example a pattern of short vertical linears arranged in rows on a twelfth-century tower at Worth (hereafter known as vertical row pattern). In addition irregular tool marks with short, deep, broad grooves made at an acute angle were noticed on a fifteenth-century wall at Winfrith Newburgh. A nineteenth-century buttress block at Ilchester shows a complete change in tooling technique, of regular, vertical, and evenly spaced, fairly broad linears.

Internal structures

These include walls, pillars, squints, and interior walls of porches. Examples were obtained from the eleventh century through to the eighteenth century. They appear to reveal specific trends through time. It was only possible to obtain one eleventh-century sample that could be positively dated, from St Martin's in Wareham. This shows fairly regular, oblique, medium-sized tool marks. In the twelfth century there is evidence of finer and more regular marks set at an acute angle. In general the tool marks of the Norman period appear to be finely worked. In the thirteenth century, however, they become even finer. The predominant trend in the thirteenth century is for a criss-crossing arrangement of tool marks. This can vary in depth and breadth, resulting in worked stone of very fine smooth appearance to stone faces with a much coarser aspect.

In the fourteenth century the tool marks become fairly regular and at an acute angle, whereas in the fifteenth century they become broader and coarser and continue this trend into the sixteenth century, from which the most harsh rugged examples are found.

Windows, including frames, ledges, and surrounds

Window dressings, in general, have much finer workmanship than other structural church stone work. The thirteenth century, however, continues to reflect the criss-cross tool pattern seen in the structural stone. In the fourteenth century the criss-cross tooling pattern continues but it is much coarser. This tooling technique was not found in the fifteenth century, but it does reappear in the sixteenth century in a similar style to that of the fourteenth century. A small number of examples from the thirteenth and fourteenth centuries also revealed evidence of vertical row pattern. The tool marks in the fifteenth century appear to be less dense and overall a more uniform appearance is achieved. A nineteenth-century example from Church Knowle shows an equally spaced and regular repeated pattern of acute tool marks. This accords with other nineteenth-century examples. Four window ledges were recorded and were found to present coarser tool marks than other types of window dressings, and showed definite differences between the centuries. Two of these were thirteenth century and were both regular and acute; the fourteenth-century sample was much coarser and at an oblique angle. The fifteenth century was slightly finer and at an acute angle. Both of these represented tool marks that were almost horizontal.

Doorjambs and arches

Several examples were recorded, dating from the twelfth to the nineteenth centuries. In the twelfth century the tool marks appear very regular and evenly spaced. The south doorjamb at Worth Matravers shows evidence of the vertical row pattern contained within a chevron ornament. An extended version of this linear pattern is found in the thirteenth century in a very finely worked doorjamb at Barrington.

The linear row pattern continues at Worth Matravers in the fourteenth century in a far coarser and shorter form. This coarser method is also illustrated at St Mary's, Wareham in a sample showing acute, irregularly spaced and fairly deep tool marks. A sixteenth-century example at Ilchester is indicative of the finer tool work found in this period as opposed to the fourteenth and fifteenth centuries. This same vertical pattern is seen in a more regular form in one of the few examples that was found for the eighteenth century, when church building and renovation appears to have been in decline.

By the peak of nineteenth-century restoration, stonemasons appear to be producing accurate copies of twelfth-century tooling, as seen in the nineteenth-century sample taken from the twelfth-century St Edward's Chapel in St Mary's, Wareham. The style and size of this tooling was identical to the twelfth-century doorjamb recorded at Worth Matravers.

Overall, it was noted that throughout the periods sampled a linear pattern of tool marks prevailed.

Piscinas
Piscinas seem to be limited to the earlier periods covered by this report, and were chosen for sampling because they could be positively dated. Of the examples studied four different patterns of tool marks emerged. A twelfth-century example from St Mary's, Wareham revealed coarse, broad and irregular tool marks. The thirteenth-century examples from St Peter's, South Petherton and St Mary's, Stoke Sub Hamdon are indicative of the fine criss-cross tooling seen throughout this period. The vertical row pattern was recorded on the front of a thirteenth-century piscina at Church Knowle. The fine extended linear pattern found on the doorjamb at Barrington was found repeated on a piscina in the same church. The fourteenth-century piscinas reflect the coarser criss-cross tooling found in other categories of that period.

Tools
In the course of this survey it was felt that it would be beneficial to consult an experienced stonemason about the data collected. It was revealed that Ham stone is softer than Purbeck stone and will take a much finer dressing. Therefore, it is possible that the use of Ham stone by an experienced stonemason may account for the superior quality of workmanship seen at Barrington in Somerset. During these discussions it was felt that limestone could have been initially dressed using a punch tool and exterior surfaces may show evidence of this style of working. For interior work, however, it is conceivable that the stone would receive further dressing. It would appear that claw tools – a chisel with small teeth of varying sizes – may have been used to achieve fine decorative finishes from the twelfth century through to the nineteenth century. To achieve an even smoother surface it is possible that a mallet headed chisel might have been used; a feasible example of this is the fifteenth-century window surround at Church Knowle, Dorset (Fig 6.3a). The same types of tools were used throughout the periods covered by this survey and the observed differences appear to be accounted for by the manner of tool use.

General characteristics
Twelfth century
In the twelfth century the work is of a fine uniform quality, the exterior work being coarser than the interior. There is evidence of vertical row pattern in both interior and exterior surfaces. The example obtained from the doorjamb at Worth Matravers shows that, at this time, very fine, controlled, regular work was being produced.

Thirteenth century
The work of the thirteenth century is noticeably finer. The most predominant pattern is the criss-cross tool mark. This is found on both structural areas and in fine dressings. The vertical row pattern continues in both coarser and extremely fine forms.

Fourteenth century
In the fourteenth century the tool marks become more coarse. Structural examples appear less regular. In fine dressings the criss-cross system continues, but the tooling is broader and deeper, thereby producing a less smooth effect. The vertical row pattern is still seen in much the same form.

Fifteenth and sixteenth centuries
The marked differences between the structural and finely dressed work continue in this period. The structural stone is worked in a much broader and deeper fashion. This creates an irregular and uneven effect. On fine dressings the tool marks are narrow and widely spaced, resulting in a smooth appearance.

Seventeenth and eighteenth centuries
Due to the neglect and decay of parish churches during this period, few examples were seen. The eighteenth century, however, does seem to reveal the emergence of the emphatic linear systems that are predominant in the nineteenth century.

Nineteenth century
The tool marks of the nineteenth century are distinctive, and recognizable as of this period. They appear regular, equally spaced, frequently vertical, and give a generally uniform appearance. In some instances it is apparent that in the Victorian restoration of churches, masons have been at pains to reproduce twelfth-century tool marks.

Granite

The stone churches of Dartmoor are, in general, of a later date than those of Dorset and Somerset. Consequently there are no examples from the eleventh and twelfth centuries, and only a few from the t hirteenth century. Pevsner suggests that stone parish churches were probably widespread in the twelfth century, but that much of this evidence has been obscured by later enlargements and rebuilding. The most common remains of the thirteenth century are towers, and typically work of the early thirteenth century is not well represented in Devon. Most of the examples studied therefore date from the fourteenth century onwards. It was not viable to record tool marks from any piscinas or from many of the widow dressings observed as frequently these were not of granite but of a stone type that was possibly more easily worked.

Exterior walls
Tool marks on exterior walls are chiefly characterised by a pecking technique. The examples reveal this

method from the fourteenth through to the nineteenth centuries. However, those for the later date are somewhat finer in appearance.

Internal structures
These include walls, pillars, and steps. Internal structures generally reveal a continuous, vertical linear style of tool marks. These vary from being fairly fine and dense on the fifteenth-century pillars at Widecombe to broader and coarser on the tower arch at Ilsington and a riser of the sixteenth-century step at Lustleigh. Again, in Dartmoor the walls present a coarser appearance and the decorative structures, a finer aspect.

Windows
In many cases the fine window dressings were of a sedimentary stone and not of granite. The examples that were studied, however, showed similar continuous, vertical linear tool mark to those that have been found on other internal structures and dressings. A twentieth-century window frame recorded at Lustleigh, has been more finely worked and presents a much smoother appearance. This is repeated with even finer techniques on a modern pulpit at Widecombe.

Doorjambs and arches
The doorjambs clearly show the two tooling techniques that are used on granite; pecking and the vertical linear style. Both of these methods can be seen to be used in a decorative manner. The pecking technique is seen used on the south door arch at St Peter, St Paul, and St Thomas church at Bovey Tracey. All the blocks on the supporting arch had been treated this way, presumably to add decoration or to give a patterned effect. The continuous, vertical linear method is used on a finely decorated outer door way at Ilsington. A sample from a fourteenth-century interior doorjamb at Widecombe presents a fine and smoothly worked example of the vertical linear method comparable to those of the twentieth century.

Tools
As with limestone, granite would probably have been initially dressed with a punch tool. This produces a pecking style similar to that seen on the fifteenth-century door surround at Bovey Tracey, Dartmoor (Fig 6.4e). To achieve a finer dressing the punched stone surface may then be further worked with a fine axe. This tool is a toothed implement in which the teeth are arranged in rows like a brush. The use of this tool could produce the continuous, vertical linear pattern, seen on the fourteenth-century pillar at Ilsington, Dartmoor (Fig 6.4f).

General characteristics
From the examples studied it would appear that the much harder composition of granite restricted the variety of tooling methods used. Only two definite types of working were observed: pecking and a continuous, vertical linear method. Both of these styles persisted through the periods covered and varying degrees of coarseness or fineness were encountered in all centuries. This appeared to be dependent on what type of decorative or structural feature was being dressed. It was impossible to identify any chronological development within these two methods. The only distinction noted appeared in the nineteenth- and twentieth-century examples, which consistently revealed a much finer and shallower degree of working.

Conclusion
The work suggested that tool marks have considerable potential in stone dating. Overall, the chronological characteristics noted in the working of both Ham stone and Purbeck stone were similar, but it appeared that the Ham stone was more receptive to very fine tooling. It was noted that there was no real correlation between the tool marks recorded on the Carboniferous sandstone at Belsay Castle, and those on the Ham and Purbeck Limestone of this survey. Only in one seventeenth-century instance, could a similarity be found. This would suggest that tool marks may also reflect regional preferences and fashions.

From the results of this survey it was felt that granite was less likely to yield significant results, perhaps due to the hard texture of the stone permitting the use of a more limited range of tools. A more extensive survey may reveal more positive evidence.

The recording of worked stone by the squeeze technique (described below in Section 7.2.4) has proved successful. It is a cheap and accessible method, which can be carried out easily in the field by relatively inexperienced persons.

6.3. Masons' marks

Stone surfaces, particularly those of the medieval period, sometimes bear marks attributed to the mason, but as Coldstream (1991, 44) has pointed out, their purpose is uncertain. It is possible that they may have been used to identify the work of individual mason's when calculating pay. The most extensive study is that of Rziha (1883) who made an extensive study of marks in Germany and what is now the Czech Republic. He began by analysing the symbolism of various geometrical shapes and then tried to relate the marks to complex combinations of these. The result seems unconvincing by modern standards as, in practice, the marks are often scratched irregularly and the supposed underlying geometry so complex that almost any pattern could be fitted on it with a little adjustment.

More recently Jennifer Alexander (1996) has made a detailed study of the marks to be seen in Lincoln cathedral distinguishing banker mason's marks, assembly marks, and quarry marks. Clearly systematic recording such as this will help clarify this somewhat enigmatic characteristic of medieval stone work.

6.4 Use-wear

In buildings, tool marks are often the latest trace of human intervention on a stone surface although some features, such as doorjambs or steps may show evidence of wear. Such wear patterns may be used to suggest, on a comparative basis, which parts of the building were most frequented or for how long. Portable artefacts, however, were designed to be used and almost inevitably show wear traces.

Use-wear analysis is now a well established field of enquiry and it is usual to examine microwear on fine-grained materials such as flint or obsidian. Since these materials lie beyond the scope of this report it might be assumed that such studies have little relevance here (see Donahue 1994 for a review of recent research). It is true that the techniques for the microscopic examination of striation and polish and the classification of different types of wear will perhaps only apply to stone axes and polishing stones. Nevertheless, use-wear is another field awaiting exploration, although new techniques may need to be developed.

Querns and millstones offer considerable potential. There are several matters that need addressing that could be useful in site interpretation. Study of the rate of wear of different milling rocks would help assess the likely life of a stone before discard. Assessment of the pattern of wear might also be useful. Some querns tend to wear asymmetrically, suggesting that they were operated with a to and fro rather than a rotary motion. This might imply that work was shared between two people.

The most important facet of usage, however, might be an attempt to asses the type of grain that was being ground. It is quite possible that organic traces might be preserved in the interstices between mineral grains, or with the vesicles of lava mills. Such traces might be amenable to the organic methods developed by Heron *et al* (1994), or it is possible that phytoliths and other siliceous matter might be retained. This needs to be investigated, preferably beginning with well preserved material from waterlogged environments.

A similar study might be applied to stone mortaria of the Roman and medieval periods and the more porous the material the greater the chance of residue being trapped.

Whetstones might also be susceptible to wear analysis. Some become dished and others were worn more evenly, presumably because they were used in contrasting ways, perhaps while sharpening different types of instrument. Presumably, a whetstone used to sharpen a kitchen knife will differ in size and shape from one used to whet a sickle or scythe. Once again material traces might repay the searching. In most cases they should be iron traces, but more exotic materials might be encountered. Heron *et al* (1994, 266) record the presence of birch bark tar on a stone artefact from a 4th-millennium BC site at Ergolding in southern Bavaria. The stone could have been used to clean other tools (C Heron personal communication).

Organic analysis also has considerable potential in studying the means of fixing stone tools to hafts of wood or antler as Evans and Heron (1993) and Heron *et al* (1991) have suggested. There is a considerable field of application waiting to be exploited.

6.5 Weathering

The weathering and decay of stone surfaces has received little attention from a strictly archaeological, as opposed to conservation, point of view, but it is clearly time for dependent and hence possibly chronological interest. Stone surfaces are often difficult to date because they lie outside the normal scientific orbit of radiocarbon, optical, and thermoluminescence dating methods, and so it is worth considering other approaches even if they have low precision.

Unfortunately, rock weathering is not a simple phenomenon, but it has long been recognised that there are five fundamental variables (see Jenny 1941; Carroll 1970, 15): climate, parent rock, biological activity, topography, and time. All of these apply to building stones, although for topography we should perhaps substitute aspect and surface relief. Each of these parameters is, in itself, complex. Thus, the effect of climate will depend on a multitude of factors of which temperature change and humidity are perhaps the most important.

Water itself is a complex agent. It may freeze and thaw, it can transmit chemicals into a rock, or it may leach them out in solution, and it can promote biological activity. Its action depends on the properties of the rock itself, particularly porosity.

Biological activity will depend on the chemical environment furnished by the surface chemistry of the rock, by the moisture content of the rock and its surface, and by temperature and latitude or available sunlight. Finally, surface aspect and relief are also more or less infinitely variable. Mineral weathering is also a complex field in its own right. The reaction of an individual grain depends on its size, shape, and degree of perfection as well as the access available for weathering agents (Ollier 1984).

Obviously to try to isolate time as a single variable will be extremely difficult, but not impossible. Certain assumptions have to be made, namely that the climatic regime will have changed but little through time, and comparisons have to be made between rocks of the same composition and similar aspect. When this has been done the remaining phenomena, such as chemical or biochemical change, microgeomorphology of the surface, and the development of plant growth may all be, to some extent, time dependent.

All of these approaches have been used in the dating of rock surfaces, but in each case the study is in the experimental stage and full archaeological development lies in the future. Surface dating methods have been most thoroughly explored by archaeologists concerned with rock art, for without them even crude assessments of date are at best speculative (Bednarik 1992a).

Wall paintings with a carbon content can be subjected to accelerator mass spectrometer (AMS) radiocarbon dating. An alternative approach is to study surface patinas and coatings. Rock varnish, which develops in tropical and arid regions, can be subjected to cation-ratio dating. Dorn (1983) claimed that in rock varnish the ratio of mobile elements such as sodium and potassium to stable elements such as titanium decreases with time. Unfortunately, the method is not applicable in British archaeology and is not without its critics as Bednarik's (1992a) review makes clear. Other surface patinas include layers of carbonate or oxalate, which are susceptible to stratigraphic analysis or to radiocarbon dating, but again have little applicability in British archaeology apart from cave sites. There is also the problem that surface deposits accrete after the stone surface has been worked and the time lapse might be considerable. More recently Dorn (1997) has retracted his conclusions based on a quarter century of work.

Bednarik (1992b) has suggested an alternative approach to the dating of petroglyphs, which might be applicable to rock surfaces in general. Cernohouz and Solc (1966a, 1966b) suggest that wanes might be used for dating sandstone and basalt, claiming that this method 'has produced useful geological and archaeological results'. Wanes are the blunted edges that form as sharp rock edges weather and the degree of rounding will be time dependent. Bednarik has corrected the formula devised by Cernohouz and Solc and applied the same concept on a microscopic level, examining the rounding of sharp edges of quartz and felspar grains in granite. He applied the method to the dating of rock art at Besov Nos in Karelia, obtaining results that apparently accord with other archaeological estimates. Before the technique can be accepted, however, more information on the method of measuring micro-wane retreat and its precision is required. The question of objective calibration also needs to be addressed.

These methods are very much in the experimental stage, and by their nature it is doubtful if great precision will ever be attained, but in a field where any estimate is better than none at all, they are certainly worth pursuing. In British archaeology they are of potential interest in dating petroglyphs, cup and ball markings, and perhaps standing stone or other megalithic artefacts. It is doubtful if they will be of much value in the study of buildings, although future research might dispel this pessimism.

Rock surfaces also attract biological activity. Microbiological action may account for the formation of rock varnish (Dorn 1983), but in Britain botanical colonisation is usually the most obvious consequence of weathering. Lichens are in evidence on most old rock surfaces and these are a group of plants with considerable archaeological potential. Lichens are not a single plant, but the symbiotic growth of an alga and a fungus. They often grow very slowly, expanding from a central point, and some species may live for many hundreds or even thousands of years. They are resistant to desiccation, which might kill other plants, and can withstand extremes of temperature. Some species are affected by pollution, but otherwise they seem to be among the more hardy members of the plant kingdom.

Since they grow by expanding from a central point measurement of the diameter of thalli should be an indication of age. The science of 'lichenometry' was devised 40 years ago by Beschel (1950) who used it to date Alpine moraine by measuring the growth rates of *Aspicilla* and *Rhizocarpon* revealed by dated gravestones in Alpine churchyards. His work was subsequently the subject of serious criticism, but lichenometry has emerged as an established means of dating rock surfaces. Archaeological applications have been few, but Follmann (1961) attempted to date the standing stones of Easter Island by this method and obtained dates that accord broadly with archaeological expectation. More recently Joubert *et al* (1983) have studied it potential in southern African rock art. Despite the pessimism of workers such as Bednarik (1992a, 146), lichens would seem to have the best potential for dating British rock surfaces and for this reason some initial feasibility studies were undertaken by Jenny Mincham and Susan Wright. The method used was as outlined by Lock, Andrews, and Webber (1979).

A study of gravestones with inscribed dates was made. Three types of stone were selected: Purbeck limestone, Ham stone, and Dartmoor granite, as it was hoped that this would furnish a range of lichen species and facilitate study of their reaction to different stone types and local conditions. Nine graveyards were sampled: Wareham, Studland, and Winfrith Newburgh in Dorset; Martock, Stoke Sub Hamdon, and Norton Sub Hamdon in Somerset; Islington and Widecombe in the Moor; and Bovey Tracey on Dartmoor. In both Dorset and Somerset, 20 gravestones were sampled in each churchyard; in Dartmoor, however, the survey had to be limited to ten gravestones in each churchyard due to the scarcity of older granite gravestones. As wide a time span as possible was recorded in each churchyard, commonly ranging from the early eighteenth century to the present day.

Identification of lichen species is not always simple, but we were greatly aided by Dr Chris Jackson of the Biology Department of Southampton University. Different lichen species grow on various substrates and in a variety of localised conditions. They are affected by aspect, abrasion by wind and water, sunlight, and temperature. To take account of at least some of these factors, Dorset churchyards were chosen for their proximity to the coast. Those of Somerset contrast because they are inland and Dartmoor was selected to examine occurrences at higher altitude and on a granite substrate. Other parameters need to be examined, but this lay beyond the scope of this preliminary test.

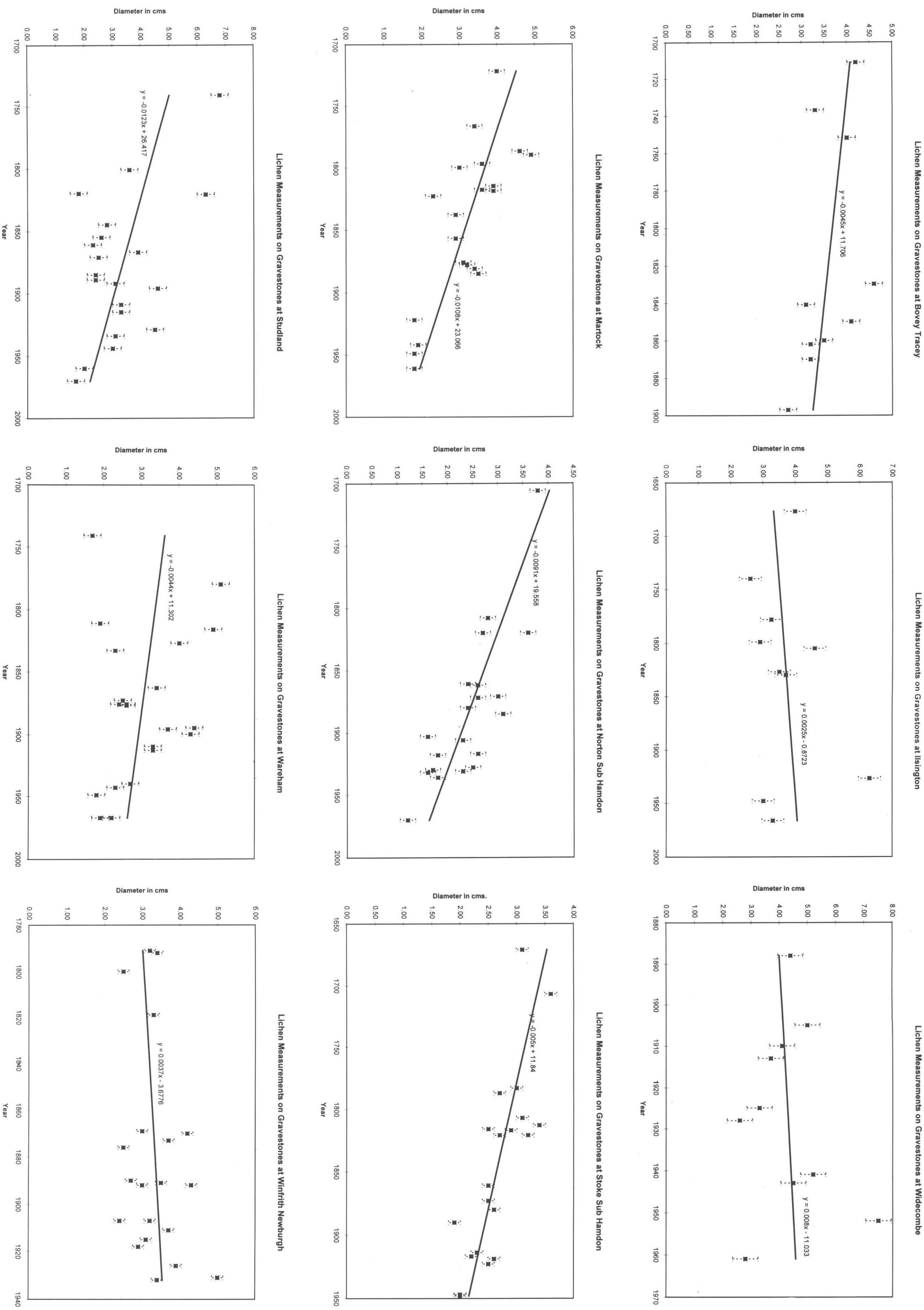


Fig 6.5 Regression curves for lichen measurements:
***a** Bovey Tracey; **b** Ilsington; **c** Widecombe; **d** Martock; **e** Norton Sub Hamdon; **f** Stoke Sub Hamdon; **g** Studland; **h** Wareham; **i** Winfrith Newburgh*

Each churchyard was visited and the most commonly occurring lichen was selected. Each was photographed and a sample taken for analysis and identification in the laboratory. At this point similar lichens were initially identified by hand lens.

The lichen selected for measurement in Dorset and Somerset was *Caloplaca saxicola,* which has a yellow-orange crustose thallus, with yellow to orange or rust-red flat disc-like fruits in the centre. On Dartmoor, *Parmelia glabratula fuliginosa* was selected. This has a foliose olive black thallus with rather infrequent fruits.

On each gravestone five lichens of the specified type and of the largest and most similar size were selected for measurement across their widest diameter. An average for the five measurement, was then calculated. The aspect of each gravestone was noted and its position relative to the church and whether it stood in sunlight or shade. It was also noted where the lichens occurred on the gravestone. Where possible samples were taken from approximately the same level on each gravestone, as growth can be affected by low lying mists and by dogs urinating against them.

The majority of the problems encountered were directly related to the gravestones. There were restrictions on the time span that could be recorded mainly because of weathering. Dates had become obliterated and, in some cases, exfoliation of early limestone graves had occurred, particularly those made of the Ham stone. Many early graves had been lifted and placed against church walls or reused as flag-stones in paths. Some other early graves had been left untended and were obliterated by ivy growth. There was also often evidence that gravestones had been cleaned.

A further problem was that many graves contain more than one body and therefore there were several dates recorded on the headstone. In these cases it was felt that the earliest date need not correlate with the growth of the lichen as cleaning may have been carried out when subsequent inscriptions were added.

Lichen growth is affected by the polishing of the substrate and also by the presence of lead used in lettering on the headstone. Additional problems were encountered with the oldest gravestones as here the lichens had often appeared to grow into one large mass and individual limits could not be clearly discerned. On a practical level headstones did not always contain the five specimens required to produce an average measurement.

The data collected from the survey was subjected to regression analysis. The results are shown in Figure 6.5 It would be premature to discuss these preliminary results in great detail as there are many factors that should be reconsidered if the experiments were to be repeated. The positive correlations achieved, however, are most encouraging and suggest that lichenometry is worth pursuing as a means of dating stone surfaces.

6.6 Moulding analysis

The dating methods mentioned above are at best speculative and in need of further critical evaluation. The most satisfactory method of dating medieval stone is from the form of mouldings, used in, for example, window surrounds. The subject has a long history, commencing with the work of Sharpe (1848), but in recent years it has been refined and developed by Richard K Morris (eg 1978, 1979, and 1996, whence further references will be found). Nowhere outside England is the study so rewarding and mouldings are a crucial key in unravelling ecclesiastical architecture, particularly those of the 'golden age' of mouldings in the thirteenth and fourteenth centuries. The method is a classic of comparative archaeological dating, involving working from mouldings with a date established by written evidence to the unknown. At its best, the method is very accurate, permitting dating to within a few years. Insensitive restoration, however, can distort or obliterate the evidence, and there is a need to record existing masonry as accurately as possible.

6.7 Conclusion

This discussion has been about potentials and possibilities, but it should be clear that the surface of a stone may have a wealth of information and indeed, in favourable circumstances, the whole story of human intervention can be recorded therein. This is clearly an area that needs to be researched with some urgency for the stone surface is the most vulnerable part of a stone. The effect of weathering is shown dramatically in Figure 6.6, which shows an all too common sight: the flaking of a stone surface. In such cases potentially valuable information is being lost. If, after further evaluation, the information on a stone surface is deemed worthy of collection, steps must be taken to ensure that a full record is made immediately after excavation or before cleaning and conservation.

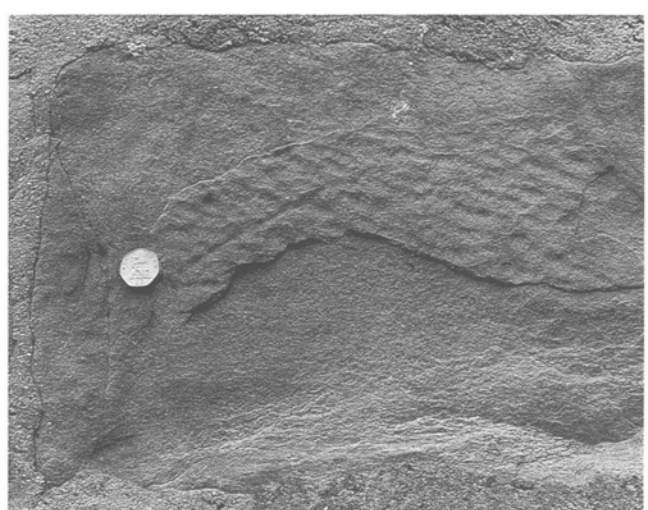


Fig 6.6 Belsay Castle, Northumberland: loss of archaeological information through surface flaking

7 Aims and methods

7.1 Aims and strategies

Any study of stone must be undertaken with a clear understanding of objectives. The aim may be quite simply to make an accurate record that will contribute to broader studies at a later date. Thus, the find of a single whetstone in an excavation does not merit an excursus on that type of artefact, although the discovery of a hoard, or evidence that they were being made on site, might be good reason for doing this. An example is be the discovery of the collection of whetstones, which were apparently being sold in the forum at Wroxeter when it was destroyed *c* AD 160 (Atkinson 1942, 129; Cantrill 1931). Even if the objectives are less ambitious, however, and the brief is to make a record, it is necessary to understand how and in what ways the evidence may be used. Otherwise redundant information may be included at the expense of more critical attributes.

Broadly, stone studies are concerned with portable artefacts, architectural fragments and standing buildings. In each case the aims and objectives differ, although there is a measure of overlap.

Artefacts may have a bearing on site function and the way in which artefacts were used could be important. It might be particularly pertinent to know more of the use wear and other aspects discussed above (in Chapter 6). Artefacts were often objects of trade and hence identification, or at least unambiguous description, of the material is important. Finally, unworn faces may bear traces of production technology.

To be useful, a report will need to address each of these facets and a basic minimum is a drawing of the shape, identification of the material, and mention of any surface markings. It is of course customary to record this information and there is little new in this suggestion.

Quantitative information, however, is also important and can have a bearing on the interpretation of the site. Most archaeologists record the quantities, by number, of worked stones, but unworked stone, foreign to the site, can also be important.

Architectural stone or loose masonry, is of another genre and will be studied with different objectives in mind. Rock type is important, and once again may indicate trade; and surface markings may tell something of production technology. Usually, loose masonry is too large and heavy to be treated alongside the portable artefacts, nor should it be. It is part of the site and indeed may be the site: the prime object in studying architectural stone must be to assess the appearance of the building from which they came. This point was made clear in the Council for British Archaeology booklet *Recording worked stones* (1987) and has subsequently been re-enforced by Stocker (1993). Loose masonry requires a different approach from that normally employed for small finds, because it is usually anything but small, and the aims of the study are quite different.

This field clearly overlaps with the examination of masonry *in situ,* but in a standing monument the objectives change again. The problem may be less of reconstruction and more of understanding what is preserved. Again, the sources of materials are important, as is stoneworking technology, for the same reasons as above. But superimposed on these is another objective: the analysis of the building in terms of chronology and building technology.

Because of these differences in aims, it is best that archaeological stone be treated in this tripartite manner. There is certainly an overlap in the methods deemed appropriate in each case, but the nature of the record and its contribution to archaeological understanding will differ.

Examinations of this type may be part of a broader research strategy designed to assess problems on a wider canvas. Thus, identification of materials might be used in an assessment of trade in querns or building stones of a particular type. Examination of surface tooling could help in establishing a chronological sequence or it might lead to the identification of schools of masons or even an individual mason, all of which goes far beyond a single site. Such studies must lie beyond the scope of a single project and are, in general, inappropriate to reports whose brief rests on a single site.

On the other hand, the site itself can be the focus for an effective research project with broad objectives. For example, Allan (1991) attempted to assess the sources of building stones used in Exeter Cathedral and was able to use archaeology to expand on the sparse medieval accounts.

Work at York provides an excellent example of what can be achieved by examining stone supply to a single town. Gaunt and Buckland (forthcoming) have recently completed a perceptive synthesis of the stone used in Roman York, all of which had to be imported since there is no available stone in the immediate environs of the town. Naturally, relatively local sources predominate, but some stone came from farther away, such as the 'Forest marble' from Oxfordshire.

Some sites in York have been the subject of even more detailed analysis involving the retrieval by sieving, identification, and quantification of both large and small fragments of stone. This novel diachronic approach has proved most fruitful, for the appearance of certain stone types can be used together with pottery as a chronological indicator. It is also possible to recognise the stone types and the stone forms associated with different building phases so that reused material can be identified in standing monuments (P Addyman and P Ottaway personal communication). The two facets of stone work in York, the broader geographical assessment of sources, and the diachronic approach are exemplary and demonstrate the way in which a properly designed research strategy can place stone at the centre of archaeological debate. This initiative now needs to be expanded and developed; such projects could be emulated elsewhere with great profit. The results from Winchester, discussed below, reinforce this claim.

7.2 Methods

7.2.1 Processing systems

The methods of stone study are well established. Portable artefacts are processed by the finds departments of units, usually in an exemplary manner. Architectural stone can produce problems, but guidelines have been produced by the Council for British Archaeology (1987), and recently updated by Stocker (1993). There seems little point in reiterating this material or in trying to suggest a uniform finds system for units to adopt. Stone is only one aspect of finds work and its importance may vary greatly from one excavation to another or even from one unit to another. It seems best to concentrate on points that require more attention. Therefore, what follows concentrates on problem areas identified during visits to units and in the publications referred to above.

The degree of detail that can and should be included in the record is a matter of debate and will obviously depend on the brief of the project. Here the concept of data levels advocated and formalised by Morris and Mepham (1994) is relevant. It provides a structure for finds work that relates the level of data recording to the objectives of the project. Six data levels are defined and it is expected that all site evaluation or assessment work will reach data level 3, while major excavations will be expected to implement data levels 3–5, and data level 6, as appropriate to the deposits recovered and the questions being asked. The following summary is taken from their report:

> The creation of the *Data levels guidelines* formalises the kinds of processing and analysis which Wessex Archaeology has been conducting for the past ten years. It provides a structure for finds work. It is to be used as part of the finds assessment and report preparation procedures. Figure 1 presents a flow diagram indicating how these procedures are conducted and how the Data Levels develop. Copies of the recording forms mentioned are included at the end of this document.
>
> **Data Level 1**
>
> *Record presence; do not collect.* This level can be used in field scanning only if experienced personnel are participating. It is a level of recording which could be used to enhance information about an area which has been well-documented archaeologically. Data Level 1 could comprise, for example, part of a rapid field scan to identify areas of potential for more detailed survey in an environmental assessment or evaluation. Information could be sketch-plotted and recorded on field or hectare sheets. In excavation or evaluation by excavation it is unlikely to be used except, for example, in the excavation of dumps of ceramic building materials from building demolition, or for modern finds in topsoil. Such occurrences must be noted on context records.
>
> **Data Level 2**
>
> This is the basic finds records: for bulk finds, this is the *Context Finds Record;* for objects, this includes the mandatory fields of the Object Record (see *WA Guideline No 3)*. This level is the minimum requirement in order to provide quantified data about each material type by context or by collection unit. For excavated artefacts, preparation of the *Finds Index by Category,* which lists and quantifies each material type by context and summarises the information, is necessary. This can be done by entering all the Context Finds and Object Records onto a computer database, or can be calculated manually. Include all material recovered from samples selected for artefact analysis, and artefacts recovered from environmental samples if required.
>
> **Data Level 3**
>
> This is the assessment level. The artefactual evidence collected during fieldwalking, or any stage of evaluation and excavation, is scanned, and the potential and suggested methodology for further analysis assessed. The assessment stage can be implemented at two levels. The general dating and quantification information from Data Level 3 can be used to assist in the preparation of client reports, and provide information for SMR work. Spot-date for general chronological range of the material and scan to assess the nature and quality of the material, using the *Spot-dating and Scanning* form, or those specifically targeted for particular materials such as the *Ceramic Building Material and Stone Scanning* form. The scan may include an assessment as to whether the material is representative of primary deposition or mainly redeposited material, activity areas, or evidence for a building. Give the reasons for date range, such as specific types of pottery or metalwork. At this stage, no further analysis is proposed.
>
> Data Level 3 may also be used in the preparation of detailed research designs for post-excavation work, a process which is formalised as the 'assessment of potential for analysis' in the *Management of archaeological projects* (English Heritage 1991). In addition to the scanning procedure outlined above, the assessment should also include a statement of the archaeological

potential of the material, and an outline of the proposed analysis. Determine whether a selection of the material type is necessary or if the full collection is to be analysed. Prepare a series of questions to be asked of the material type, and the analytical methods to be implemented. An indication of the range and quantity of material to be illustrated should also be given.

Data Level 4

This is the first analytical stage, and is the level of analysis employed for standard assemblages where no specialised research is to be undertaken (eg, for pottery, this is basic fabric and form analysis; for ceramic building materials, recording of the general diagnostic pieces; for lithic material, the recording of metrical and technological data). For selected material types and certain deposits, this stage of work is enough to provide a great deal of information from a limited amount of work. This is the level of analysis traditionally achieved in most excavation reports.

Data Level 5

This is the second analytical stage, and includes the more detailed research which may be undertaken on selected material types if the nature of the assemblage (and the project budget) allows it. It is generally only undertaken on large assemblages, ie, those where the return of information justifies a more labour-intensive approach than *Data Level 4*. It might include, for example, the detailed recording of an assemblage of decorated floor tiles, in order to investigate production groups; or an in-depth spatial analysis of pottery sherds individually recorded within an occupation deposit.

Data Level 6

This consists of *scientific and other detailed research,* as well as *regional analyses* with support sought from outside bodies such as the period societies, universities, English Heritage and the Ancient Monuments Laboratory, the British Museum, the Oxford Research Laboratory for the History of Art and Archaeology, the British Academy (Research Grants and Fund for Applied Science in Archaeology), and the Science and Engineering Research Council. Encourage specialists interested in particular research topics which may need a body of data for the application and testing of techniques.

The specific recommendations on stone recording made by Morris and Mepham are shown in the following tables:

Table 7.1 Stone building materials

general information:

- includes stone roof and floor tiles, tesserae, dressed stone for walls and columns, other architectural fragments, sepulchral stone, eg grave markers, sculpture
- useful for indicating structures
- can be used as indicators of the relative status of building, eg stone used instead of organic materials
- can provide indication of stone sources exploited
- may be reused in later structures

data level	*type of data recorded*	*information recovered*
1	Record presence; do not collect	Presence/absence; presence of demolished structures
2	Collect, wash, and quantify on **Context Finds Records**; record groups of *tesserae*, complex architectural fragments (mouldings, decoration) and inscribed stones on **Object Records**; create **Finds Index by Category**	Indicates a quantified presence for comparison with other material types recorded to same Data Level; some indication of types present
3	Scan for an indication of the range of types present; record data including lithology if known on **Ceramic Building Material and Stone Scanning** forms; assess integrity and value of the collection; propose appropriate methodology for any further analysis (Data Levels 4 6); discard policy; undiagnostic building material, retaining samples for geological reference collection	Quantified lithological data; limited information concerning stone sources exploited; limited information concerning nature of structures; very limited chronological information, indication of status
4	Submit samples to specialist for identification/confirmation of types, if necessary; sort into types (roof tile, floor tile, ashlars, mouldings etc), quantify data by detailed lithology and phase; *illustration:* limited selection of unusual architectural fragments: all inscribed *stones*; all masons' marks	Indicates use of local and non-local stone for quantified measure of trade and aspects of production; demonstrates changes in resource/trading patterns through time; detailed information concerning the nature and construction of buildings; may be correlated with documentary evidence to give

Table 7.1 ***continued***

		information concerning building phases; limited chronological information
5	Conduct more detailed research into large and/or specialised assemblages/items; examine in more detail the types of architectural mouldings – record full dimensions and draw profiles; record details of decoration, masons' marks etc; submit pieces of sculpture to specialist for discussion of chronology and art historical aspects	More detailed information concerning building construction; more detailed chronological information based on stone-working technology; evidence for the trading of finished stonework,or the movement of skilled craftsmen
6	Petrological analysis, as needed	Likely or precise sources

Table 7.2 Stone objects

general information:
- includes mortars, querns/millstones, grinding stones/rubbers, hones/whetstones, spindlewhorls, weights, basins, slingstones, counters, pestles, and any other portable objects, but not worked flint, chert, quartzite and sarsen tools, and the waste material from their manufacture
- for the earlier prehistoric period stone assemblages, the range should be considered as part of the lithic collection (see below), and viewed as a whole whether chipped/flaked/ground and whether flint/chert/quartzite/sarsen/non-local
- useful for indicating activities and trading relationships
- generally not particularly useful as chronological indicators

data level	*type of data recorded*	*information recovered*
1	Record presence; do not collect	Presence/absence only
2	Collect, wash, and quantify on **Context Finds Records**; record all objects on **Object Records**; create **Finds Index by Category**	Quantity of material for comparison with other sites or materials; will provide some idea of range of types present
3	Scan to indicate range of types present; and potential date range; assess value of collection; propose appropriate methodology for any further analysis; *illustration;* very unusual objects for client reports	Range of general activities by broad period/phase; limited chronological information
4	Record all aspects of objects: dimensions, details of decoration, evidence of use etc; submit samples to specialist for identification of stone type; prepare catalogue; illustration: all grave-goods; representative samples of objects, except for common items, to illustrate range present	Indicates use of local/non-local stone sourcesfor quantified measure of trade and aspects of production; demonstrates changes in resource/trading patterns through time; determination of on-site activities
5	Inappropriate for this material	
6	Petrological analysis, as needed	Likely or precise sources

Table 7.3 Lithic material

general information:
- includes flint, chert, quartzite, sarsen, and other rocks which have been chipped, ground or flaked to produce tools, and the products from the creation of these tools (debitage)
- includes burnt worked flint, but not burnt unworked flint
- has the advantage of being virtually indestructible and can be relied on to survive as evidence of human activity against almost all odds
- reductive nature of technology of flint and similar rocks means that successive stages in the procurement, manufacture, use, and discard of lithic material may, if they were originally discrete, be inferred from the surviving debris; such information can be particularly informative for the spatial organisation of prehistoric settlement and broader landscapes
- sourcing of flints and cherts can indicate direction(s) and extent of range and/or contacts even at the crude level of chalk/gravel/beach pebble

Table 7.3 ***continued***

- changes in technology and in finished implement morphology over time provide some indication of date and cultural affinities
- is a particularly common find from surface artefact collection, where its distribution may be used in the highlighting of areas of potential archaeological significance

data level	*type of data recorded*	*information recovered*
1	Record presence; do not collect	Presence/absence only
2	Collect, wash, mark, and quantify on **Context Finds Records**; create **Finds Index by Category**	Indicates a quantified presence for comparison with other material types and similar collection units or sites recorded to same Data Level
3	Rapid count to determine number of cores, flakes, implements and other debitage; basic classification of implements; propose appropriate methodology for any further analysis (Data Levels 4-6); *illustration:* unusual objects only for client reports	To identify/isolate the utilised component; overall nature of the assemblage; give an indication of the chronological range; the distribution of components can be plotted to allow intra-/inter-site comparisons
4	Record metrical and technological data for flakes and blades; record cores and retouched pieces by typological form; plot spatial distribution of various components *illustration:* minimal selection to enhance discussion	More detailed indication of technology used, and raw materials exploited; definition of zones of activity, their extent and intensity; indication of site function
5	Conduct more detailed analysis of specific groups of material, eg, from closed groups relating to short phases of deposition, preferably with datable associations; record metrical and technological attributes of various components at a more detailed level; attempt refitting exercises; *illustration:* as for Data Level 4	Definition of technological change through time
6	Usewear and residue analysis (organic residues; radiocarbon dated)	Functions of tools, and thus a clearer picture of activities carried out on site; more accurate dating

Table 7.4 Burnt flint

general information
- does not include burnt worked flint (see Lithic material, below)
- a common find on many sites, especially chalk and gravel sites
- intrinsically undatable, but frequently associated with prehistoric artefacts
- intensity of burning can be used to differentiate between crop burning versus truly pyrotechnical activities or the recognition of a registered level of 'background noise' versus intensity of firing activities may also be differentiated
- the possibility of using any differentiation in the average size of pieces of burnt flint to identify different types of pyrotechnical activities or repeated versus single activities has yet to be fully explored
- generally not a good chronological indicator unless subjected to thermoluminescent dating methods

data level	*type of data recorded*	*information recovered*
1	Record presence; do not collect	Presence/absence; indicates activity, but undated; presence of concentrations
2	Collect, can wash, check for presence of any worked pieces (transfer to *Lithic Material*); quantify on **Context Finds Records;** create **Finds Index by Category**; *discard policy:* retain 1% sample from each major stratified context, feature or phasing group	Quantity of material overall; relative differences between areas, features or phases; intensity of pyrotechnical activities

Table 7.4 ***continued***

3	Highlight concentrations within distribution; scan material for any distinctive groups from features or phases	Definition of activity areas, but undated; some indication of activity, eg, pyre construction
4	Conduct spatial analysis to determine more detailed variations in distribution; correlate burnt flint distribution with other artefacts	Can provide some chronological indication for burnt flint; more detailed definition of activity areas; differences between activities can be indicated using 'mean fragment size' data
5	Inappropriate for this material	
6	Encourage researchers to find out more about burnt flint using pyrotechnical analyses; fatty acid traces from cremations	May help to identify the uses of burnt flint and the activities it represents

As a more detailed example of the procedures that can (and should) be adopted at Level 4 and above it is useful to reproduce the scheme for the processing, identification, and publication of stone from West Cotton, kindly supplied by Mr Brian Dix:

West Cotton

There are 453 objects of stone from West Cotton, comprising mainly millstones/quernstones (255), hones/sharpeners (82), and miscellaneous objects (dressed stone fragments, roof tiles, and gaming boards).

On site procedure
Each find was allocated its own unique small find number, in addition the location was recorded by context and three-dimensional coordinate. All information was recorded in a 'special finds register' and each find was individually packaged and boxed by material and object type.

Post excavation procedure
Initially all finds were washed and, where applicable, marked. A basic catalogue was compiled. All information was recorded on proforma objects record sheets. Each find was described, measured, sketched together with full reference to context, group, and structural group numbers. In addition a summary of this information is held on a computer database system to permit rapid sorting on a range of parameters.

Millstones and quernstones
There were 255 recorded finds of millstone and quern fragments with a total weight of 428kg.

All large fragments or smaller pieces with diagnostic features were recorded individually, while quantities of other small pieces from within and around the watermills were grouped as a single find recorded by context and 5m grid square. These finds were sub-divided in post-excavation by geological type and sub-type. The recorded finds represent at least 392 individual fragments ranging in size from substantial parts of single stones to pieces measuring 50mm or less and recognizable only by their distinctive geological types.

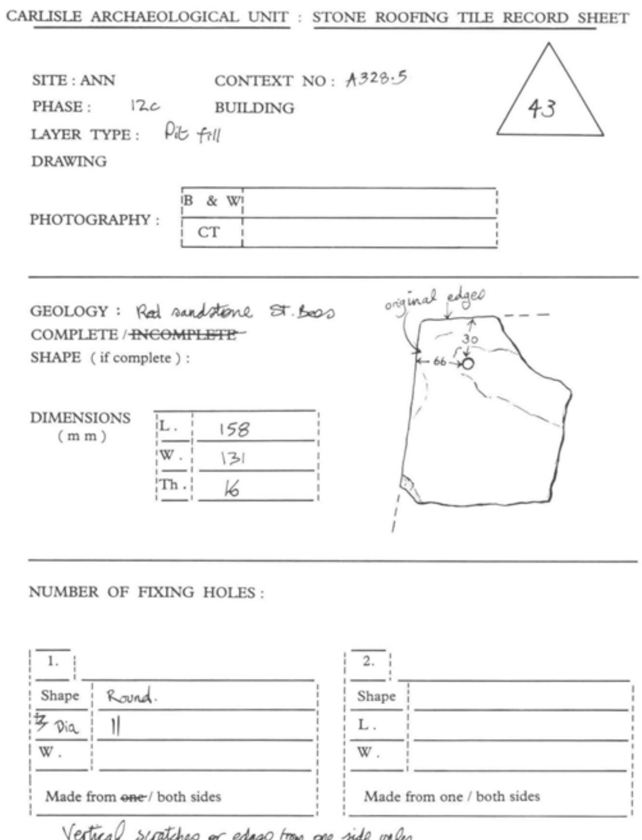
For the purposes of analysis and discussion the assemblage was divided into three groups: sandstone millstones, lava millstones, and querns. Geological identifications were provided by Dr Diana Sutherland, Leicester University, who examined a representative sample of the total assemblage. No petrological analysis was undertaken.

To classify the large quantity of millstone grit a stone type series was defined. Three relative types were defined: fine, medium, coarse-grained stones. Each type was then sub-divided into three forms by the variations in mineral inclusions, with this largely dictated by the proportion of feldspar to quartz. This system provided nine possible sub-divisions of the millstone grits. In practice only six groups were present due to the close relationship between the presence of feldspar inclusions and the overall coarseness of the grain.

A database catalogue was compiled to retain all information for each recorded piece and allow the manipulation of data. This included not only all stratigraphic details but weight, stone type, and pertinent comments (eg upper stone, lower stone, socket, grooved etc).

Hones/sharpeners
Eighty-two stones for sharpening ferrous metal knives and tools. Two types are represented: hones (64) and sharpeners (19), utilised irregular pebbles or stone fragments recognised by the presence of smoothed surfaces or knife point sharpening grooves.

The finds were sub-divided by stone type and tables were compiled, grouping the hones and sharpeners by period to determine any chronological or temporal differences. Information recorded included: stratigraphic details, dimensions, and features worthy of note. Analysis comprised comparison of features and dimensions by period and stone type. A type series of cross-section types was compiled to see if


CARLISLE ARCHAEOLOGICAL UNIT : STONE ROOFING TILE RECORD SHEET

SITE : ANN CONTEXT NO : A328.5

PHASE : 12c BUILDING

LAYER TYPE : Pit fill

DRAWING

43

PHOTOGRAPHY : B & W | CT

GEOLOGY : Red sandstone St. Bees

COMPLETE / ~~INCOMPLETE~~

SHAPE (if complete) :

original edges

30

66

DIMENSIONS (mm)	
L.	158
W.	131
Th.	16

NUMBER OF FIXING HOLES :

1.	
Shape	Round.
~~L.~~ Dia.	11
W.	

Made from ~~one~~ / both sides

2.	
Shape	
L.	
W.	

Made from one / both sides

Vertical scratches or edges from one side only

Fig 7.1 A system for recording stone roofing tiles (courtesy of Carlisle Archaeological Unit)

there is any comparison with the shape of the hone, stone type, and wear, and the cleavage plane was noted.

Publication

The illustrations for publication have been chosen to provide a representative sample of the full range of types recovered and also to illustrate pieces of intrinsic merit. The discussion of the finds is followed by a catalogue of illustrated items, which contains brief descriptions and dimensions.

There are many ways of recording stone artefacts and each unit has its own system. Figure 7.1 shows one specialised version: the method used by the Carlisle Crahaeological Unit for recording stone roofing tiles.

It has already been stressed that, by the nature of the excavation process, the initial selection of stone materials is likely to be in the hands of archaeologists rather than geologists. Stone retention policy varies from one unit to another and often from one excavation to another, sometimes with good reason. In other cases it seems more at the whim of the field supervisor. Unless there are good reasons otherwise, all stone foreign to a site, whether worked or not, should be retrieved and retained for at least the first stage of processing. The first problem is to identify what is foreign and what is not, but it is usually possible to obtain basic geological information about a site during the pre-excavation planning phase or from test pits. The sorting of this material requires access to a reference collection and the object will be to distinguish rocks local to the region from more exotic materials, the latter to be the subject of specialist investigation. On the geological side, the scheme devised by Dr Gaunt and the York Archaeological Trust is reproduced as Tables 7.5 and 7.6.

7.2.2 Quantification

After identification the fragments can be quantified. Unfortunately, the various methods of quantification of stone have yet to be evaluated, but in the interim it seems advisable to record number and weight. Through the courtesy of Mr K Qualman and Ms Helen Rees we undertook a quantification experiment on Roman material from the Brooks site, Winchester. The excavator had divided the finds into four chronological phases and the rocks were classed into 60 types. A total of 2473 fragments weighing 536, 678gm was available. The average weight of a fragment was 217 gm.

The results of this quantification are presented in Figure 7.2 The number and the weight data are in broad agreement and only rarely would the choice of one rather than the other lead to a significantly different archaeological interpretation. In some cases, however, the weight data give a higher percentage than the number data, in others the situation is reversed. The controlling parameter is the friability of the rock, some materials tending to break down more readily than others.

If quantification studies are to advance beyond this basic level, a system needs to be developed whereby properties of individual rocks are compensated. Such considerations lie beyond the scope of this report, but for the moment it is reassuring that the number and weight spectra are broadly similar in most cases.

There are few published metrical studies, but it is worth citing some examples to emphasise their importance and potential. Figure 7.3 shows the way in which Lodsworth querns peak in the first century AD. It was derived by laboriously weighing both worked and unworked fragments of Lodsworth rock found in Professor Collis' excavations at Owslebury. The results were then grouped into the broad chronological phases determined by the excavator, which produced a consistent and revealing pattern, with possibly little disturbance from rubbish survival.

Another telling metrical study is Allan's (1984) work on the remarkable collection of medieval and post-medieval slates from Exeter, which derived from quarries in south Devon. The results of this meticulous investigation are shown in Figure 7.4. It seems that before *c* 1300 slates show much more variety of form than those of later date, with more large, thick slate, although the number of complete examples from earlier context is quite small. The products of the late medieval period are more standardised, but as the scatter diagrams show, there is no clear sign of the employment of a graded series of uniform sizes. Early post-medieval examples are similar, but on average marginally thinner.

Table 7.5 Geological recording form

SITE NAME:	CONTEXT:	SAMPLE NUMBER:	SAMPLE TYPE:

ROCK TYPE:	%	**SIZE RANGE:**			MAX SIZE: ca	**SHAPE:**	**STATE:**
		Small < 2 ca	Medium 2 - 6 ca	Large >6 ca			
100 Magnesian limestone (Persian)		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
102 Oolitic limestone (Jurassic)		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
104 Limestone, other (Excl Carb boulders)		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
105 Chalk		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
108 Tufa		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
110 Millstone Grit -type (sandstone)		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
112 Elland Flags - type (sandstone)		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
114 Sherwood sandstone (Triassic)		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
116 Sandstone, other		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
118 Pebbles/cobbles/ boulders/ including Carboniferous Limestone		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
120		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O
122		R O C	R O C	R O C		Ro Sr Sa Aa	F B R O

Notes:

Codes: **SIZE RANGE:** R = Rare O = Occasional C = Common

SHAPE: Ro = Rounded Sr = Sub-rounded Sa = sub-angular Aa = Angular

STATE: (if ARCHAEOLOGICALLY altered) F = Flattened B = Burnt R = Roof slab O = Other (specify in Notes)

Action: Photograph ..../ Keep all / Keep just .... for reference / Discard all

Table 7.6 On-site geological recording form

ON-SITE GEOLOGICAL RECORDING FORM - NOTES FOR THE USE OF

Equipment: 10% HC1 to test for calcium carbonate, steel knife, copper coin, for hardness tests, geological hammers, hand lens and/or magnifying glass or sheet

Main rock types

Elland Flag type: will scratch the steel knife, will NOT fizz with HC1 (ie non-calcareous), a fairly fine-grained sandstone. Other similar sandstones you might confuse this with are thin-bedded sandstones from other parts of the Carboniferous or Jurassic - these WILL fizz with acid though, and should go in 'Sandstone, other'.

Millstone grit type: will scratch steel knife. A medium to coarse-grained sandstone with occasional small pebbles.

Sherwood sandstone: covers the Triassic Bunter and Keuper sandstones. A fairly soft, incohesive, usually red, fairly fine grained, non-calcareous sandstone.

Sandstone, other: this will include sandstones from the Yoredale Series for example, or ones that cannot be identified. Also included here are the Jurassic calcareous, fossiliferous oolitic sandstones – they will fizz somewhat in acid, but are not to be confused with the Oolitic Jurassic limestone below.

Oolitic Jurassic Limestone: it fizzes strongly with acid. Oolites that do not fizz strongly are probably the Dolomitic or Magnesian Permian limestones.

Magnesian (Permian) limestone: this will only fizz slightly in acid because the rock has been dolomitized (altered) and consists mostly of magnesium carbonate rather than calcium carbonate. It may be oolitic or microcellular (fine honey-comb) or smooth. Magnesian limestone from the lower levels contains fossil shell moulds and is therefore more calcareous and may fizz more than expected.

Carboniferous limestone: a hard, very variable limestone. It will usually occur as pebbles from the boulder clay on archaeological sites in York, therefore it should be included under 'Pebbles/cobbles/boulders'. Often has a bituminous (burnt) smell.

Flint is a siliceous (silica) stone from within the Cretaceous *chalk.* Chert is similar but formed in Carboniferous *limestone.* It is usually dark colour.

Ironstone nodules composed of siderite (which usually fizzes a little in HC1) or haematite (which does not fizz) may come from the Lower Jurassic or from the Carboniferous coal measures. They may have fissures of calcite.

Notes for filling in the forms:

Column:

% Fill in the approximate percentage for each of the rock types present.

size range: Indicate by circling, R, O or C for each of the three size ranges whether the rocks are rare (ie one or two), occasional (ie several) or common (forming a large proportion).

max size: Give the maximum dimensions of the largest stones in cms. The sizes are based on the Soil Survey Classifications

shape: This is to give an indication of the angularity of the stones and may suggest whether they have been weathered or are fairly fresh building stones.

state: If the stone has obvious indications of working eg flattened building stone or holes in for roof slabs or if it has been burnt or in any other way altered indicate this and make an additional note in the space below if necessary.

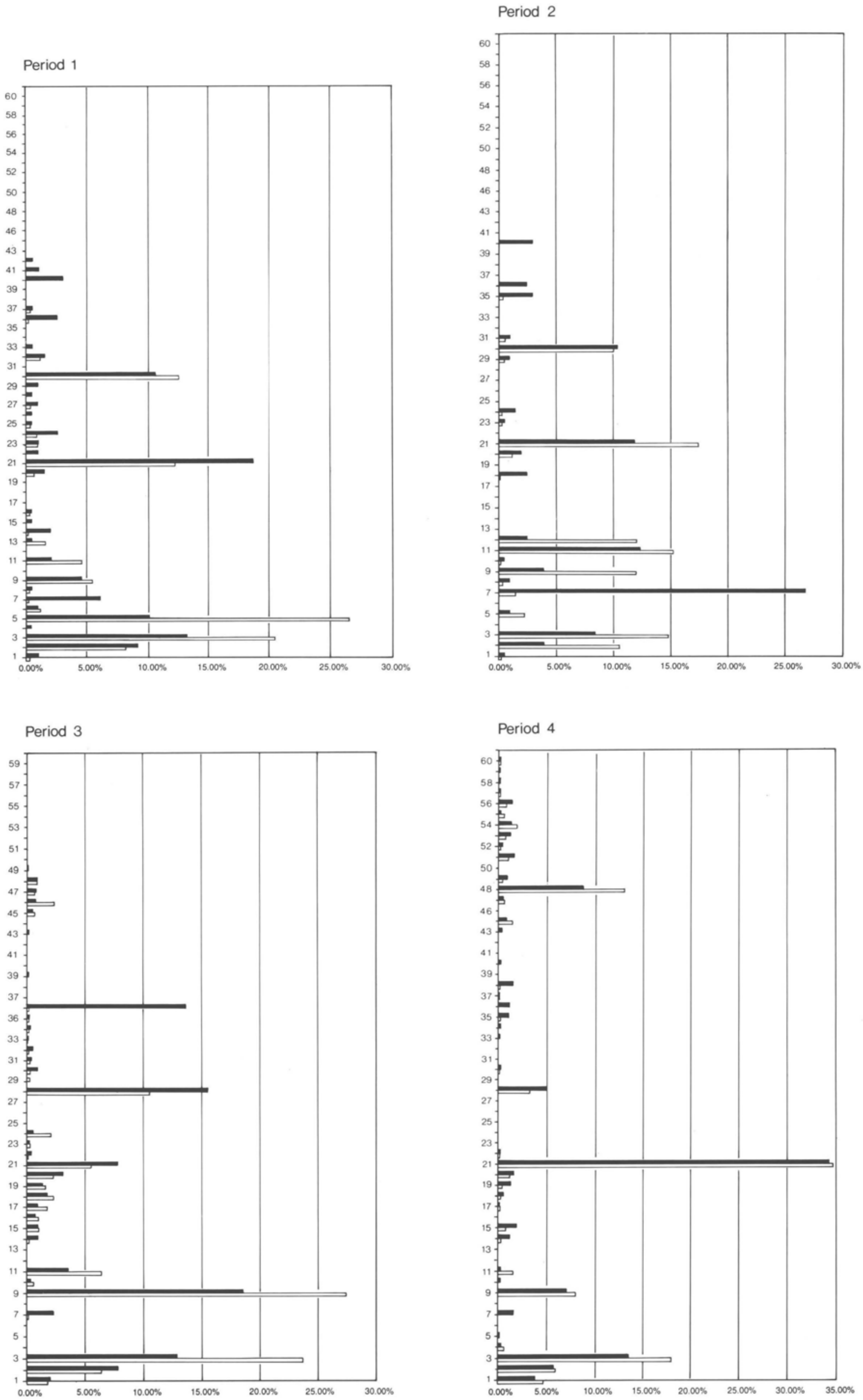


Fig 7.2 The Brooks site, Winchester: quantification of stone (types 1 60) from four Roman phases; solid line = count data, white line = weight data

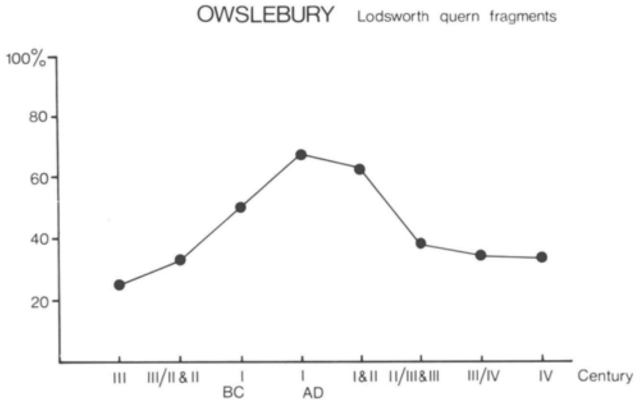


Fig 7.3 The chronological distribution, by weight, of fragments of Lodsworth rock at Owslebury (from Peacock 1987)

The slates, despite their quantity were not discarded and have since been effectively used in reconstructions in the Exeter museum.

Winchester has produced a large collection of whetstones stratified in contexts dating between the tenth and eighteenth centuries. It was possible to quantify by number and thus to analyse the chronological distribution of the principal rocks used: sandy limestones, sandstones, and Norwegian ragstone and phyllite. The results are shown in Figure 7.5 Such analysis is only worthwhile if artefacts occur in sufficient quantity (Ellis and Moore 1990).

Analysis of the 54 quern fragments from Winchester shows the predominance of lava, particularly in the eleventh century and the way in which mortars become increasingly important from thirteenth century onwards (Biddle and Smith 1990).

In a similar manner, on the basis of numerical quantification, Biddle (1990) was able to chart the changing fashions in building stone used in the ecclesiastical establishments of Winchester. In the Old Minster, dating between AD 648 and c 1100, Bath stone predominated, with Quarr, from the Isle of Wight a poor second. In Norman and later periods, Quarr gains ascendency over Bath with increasing contributions from the Dorset coast and Caen, which appears for the first time. In Wolvesley Palace, after c 1100, between a quarter and nearly half of the stone is from Quarr, about a quarter from Caen, and 15% or more from the Isle of Purbeck. At the same time, exotic stones such as Sussex marble, Tournai marble, and travertine appear.

An alternative method of quantification is shown in Figure 7.6, pie diagrams which show the chronological variation in quern lithology at Odell, Bedfordshire (courtesy of Mr Brian Dix).

There are, however, problems with the quantification of large fragments of stone such as moulding. Weight can be difficult to measure and number or perhaps length might be all that can be reasonably expected. As stone is usually bulky, it is impossible to retain it all

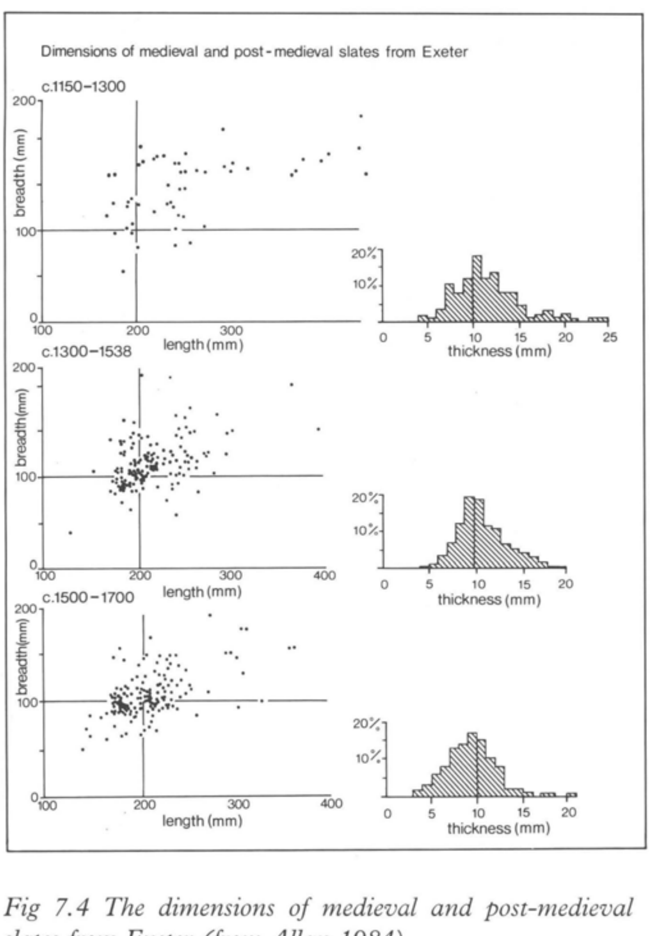


Fig 7.4 The dimensions of medieval and post-medieval slates from Exeter (from Allan 1984)

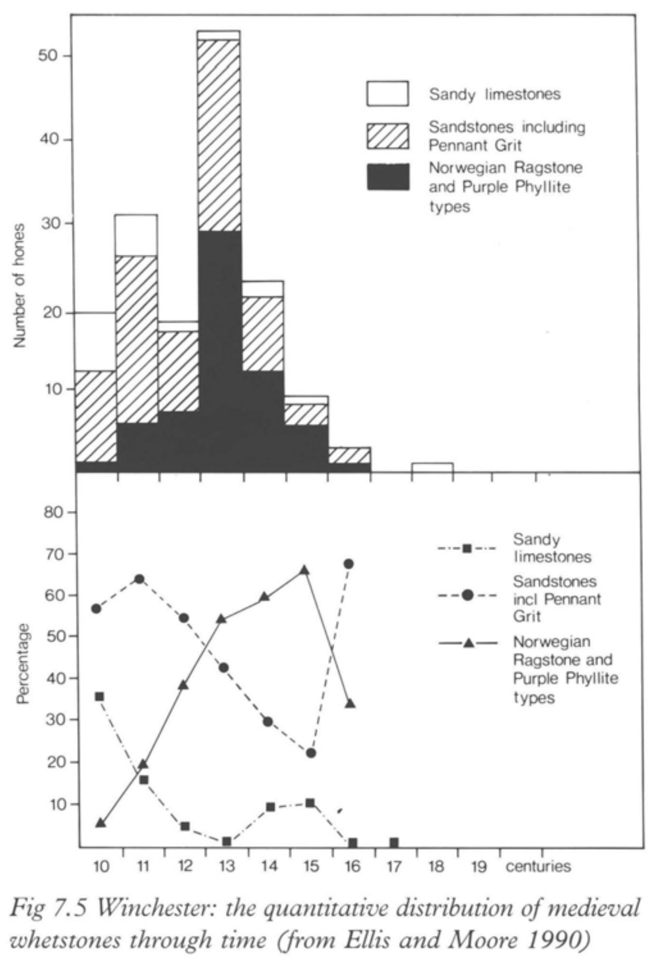


Fig 7.5 Winchester: the quantitative distribution of medieval whetstones through time (from Ellis and Moore 1990)

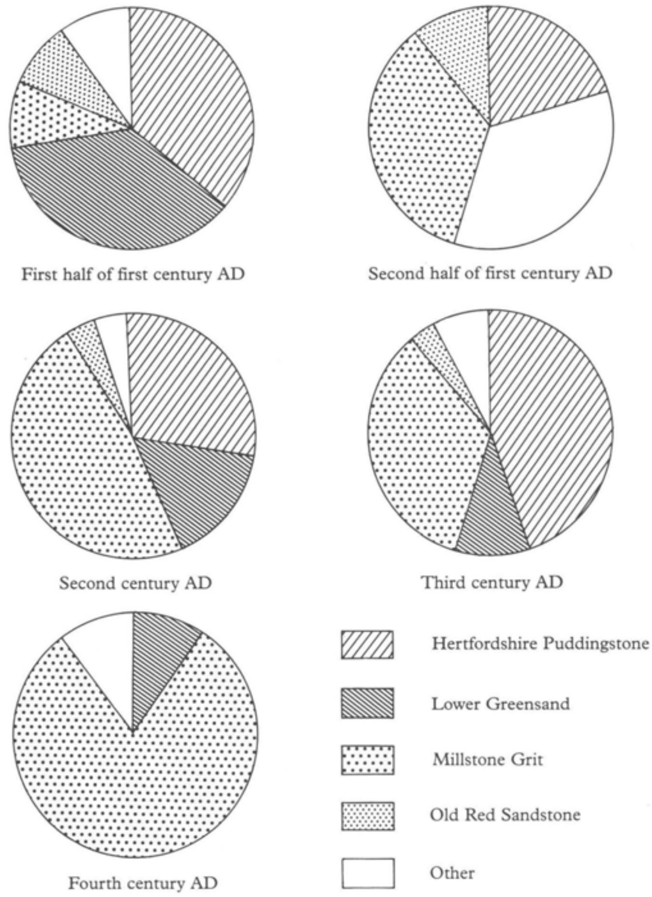


Fig 7.6 The use of pie diagrams in the quantitative analysis of querns from Odell, Bedfordshire (courtesy Mr B Dix)

and after quantification, the unworked regional material can be discarded.

7.2.3 Loose masonry

Loose masonry is well catered for in the works mentioned above, to which reference should be made. Table 7.7 shows the scheme for recording mouldings adopted by the City of Lincoln Archaeology Unit, based on the accepted norms.

A few comments on the Council for British Archaeology guidelines seem pertinent, however. The main problem is that they tend to underestimate the importance of material identification. Thus, paragraph 4.1 suggests that uncut stone might be suitable for petrological investigation. No such provision is made for worked stone and 'material' is reduced, albeit unintentionally, to a side issue.

Quantification is not addressed, but if the guidelines are followed and a detailed record made of each architectural fragment, quantification by number is implicit.

In sections 6.6 – 6.10 various suggestions are made for marking loose masonry. All of these have been tried by the units, but all have been found wanting. Large stones usually have to be stored outside and with time and weather all forms of mark deteriorate. There are only two satisfactory alternatives: one is to carve the mark on an unworked surface, the other is to make an accurate drawing from which the stone can be identified.

7.2.4 Recording tooling

Another problem is the suggestion (Council for British Archaeology 1987, Appendix II, 4) that tooling can be recorded photographically or by wax rubbing. Photography is quick and effective, but depends on lighting and may be difficult in a standing building. Many units have tried rubbings but find them unsatisfactory except for fine markings. Coarser tooling is not well represented, as rubbing merely picks up the high points at the expense of detail in the hollows. Stone surfaces, however, contain a lot of information and deserve more sympathetic treatment.

A much better way is to take squeezes in the manner adopted by epigraphers for recording inscriptions. A sheet of squeeze paper is lain on the surface and pushed, with a wet brush, into the contours of the stone surface. When dry it is removed and the contact surface can be photographed under ideal studio conditions. If the negative is then printed in reverse a facsimile of the original is produced.

This method seems to be one of the best available, but epigraphers use a special starch-free paper made only to bulk order by the Papeterie de l'Arche. This is difficult to obtain and so experiments were made with other materials, for unless the paper and brushes are readily available, the method is unlikely to be widely adopted. The aims of this exercise were to experiment with various types of media, in order to see which combination produced the best record of the textures left by stonemason's tools on stone.

The stones used comprised three tool-marked pieces of loose masonry from the marble quarries at Quarr in Purbeck and two quern stones of Iron Age date from the Lodsworth quarries. Several types of paper were used: toilet paper, Kleenex Mansize Tissues, kitchen roll, blotting paper of both poor and high quality, packing paper, and sugar paper. Four brushes were tested: a stencil brush, a shoe brush, a suede brush, and a 'Chubby' glue brush.

The stones were cleaned using the shoe brush. They were then liberally wetted with tap water; the easiest way found to do this was with the shoe brush. Some of the papers were wetted before application, but the toilet paper, tissues, and the kitchen roll were laid dry onto the stone and tap water poured over them. The other papers were immersed in a bowl of tap water and then placed on the stone. All the types of paper were worked into the tool marks with a brush to remove the air. The papers were left on the stones for varying time spans: 10 minutes, 15 minutes, one hour, and 48 hours.

Toilet Paper: six layers were used. The surface was found to crease and crumple. The paper also tended to disintegrate when worked with the brush. The tool mark impressions recorded were generally poor.

Table 7.7 An Architectural moulding recording form

ARCHITECTURAL MOULDING RECORDING SHEET							
CITY OF LINCOLN ARCHAEOLOGY UNIT					Mus. Acc. No (EH Atcham No)	Sitecode	Context
SF No.	Period	Early Date	Late Date	Length	Height	Width	Diameter
Object name		General form		Precise form		Stone type	
Burning	Re-use	Masons' mark	Mortar	Plaster	Limewash	Paint	Tooling record made?
Recorder			1:1 Drawing?		Date		
Description							
Tooling description							
Notes							
Photograph				Drawing			

Tissues: eight layers were used. The surface again was found to crease and crumple. The best results were achieved when the paper was removed still wet, as the layers tended to separate when left to dry on the stone. Generally, however, the impressions were poor.

Kitchen roll: It was felt that there might be problems with this paper as the surface is stippled. The paper was found to ruckle badly, and it was difficult to work into the tool marks. Again the impressions achieved were poor.

Poor quality blotting paper: The paper was liable to tear, therefore two layers were found to be necessary. It was difficult to work into the stone and tended to distort on the outer surface when worked with the brush. The final impressions, however, were better than the previous three types of paper.

Wrapping paper: A layer of two sheets was used. It was found not to take up the water well, and additional water had to be used when stippling with the brush. The impression achieved was poorly defined.

Sugar paper: A single layer was used. It was found to absorb water very poorly and did not work into the stones well. A poorly defined impression was achieved.

Good quality blotting paper: A single layer of paper was used. This did have a tendency to tear if the tool marks were particularly deep. There was no evidence, however, of the distortion found with the poor quality blotting paper. It was easily worked into the stone and it was found that the air bubbles could be gently worked to the edge of the paper. One small drawback with the higher quality blotting paper is that it contains water marks, which make it a little difficult to work into the stone at those points. A good impression of the tool marks was achieved with this paper, especially in combination with the stencil brush.

Brushes: The stencil brush was found to be the best brush for stippling the paper onto the stone and working out the air bubbles. The shoe brush was found to be ideal for wetting and cleaning the stone. It was not suitable for stippling, however, as the size of the brush obscured the view of the area being worked. The suede brush, was useful for cleaning the stones, but tended to tear and ruck up the paper when used for stippling. The 'Chubby' brush was felt to be too soft and did not possess the flat surface of the stencil brush.

The best results were achieved by using good quality blotting paper in combination with the stencil brush. It is recommended that this should be left on as long as possible to dry, but a one hour minimum will give an acceptable result. There appeared to be no significant shrinkage using this method.

7.2.5 Storage and disposal

The storage of large fragments is a problem that faces many units, in particular those that have excavated a medieval ecclesiastical site. Large fragments may not be accepted by museums whose store rooms are full. The option of burial on site, suggested by the Council for British Aarchaeology (1987, paragraph 9.2), may not be feasible if the site is to be destroyed. In many such cases they are left weathering outside the unit's premises awaiting an uncertain future. Wherever possible, reburial is recommended, but even here there are problems. We do not know the effect on a stone of taking it from one soil environment, in which it has achieved equilibrium, and placing in what may be an altogether different environment. Clearly controlled experiments are needed.

Alternatively, unwanted stone might be of use in building conservation, although it is doubtful if it will be of the right size, shape, and quantity, and the presence of salts acquired from ground-waters may adversely affect its utility. Some might be used in conservation training in centres such as the English Heritage teaching unit at West Dean College near Chichester, but there is the cost of transportation to consider.

There is no simple solution to the problem. If reburial is not possible, there seems little alternative to outdoor storage in most cases. If this is to be the case, it is a good idea to take latex or fibreglass moulds of the more important pieces. Exeter Museum has a collection of architectural moulds made in this way (seen courtesy of J Allan).

7.2.6 Stone in standing buildings

The recording of standing buildings is a specialised field that goes far beyond the scope of this report as it involves consideration of bonding, mortar, and materials other than stone (see Wood 1994). Stone-by-stone surveys, however, whether done manually or photogrammetrically, provide a window of opportunity to obtain new information about stone. For example, they may yield quantitative information about the types of stone used and the probable quarry sites, or they may be a unique occasion when tooling and other surface phenomena can be studied in detail. Parsons and Brooke (1994) sum up some of the academic advantages admirably '... a further refinement can be built into the manual stone by stone survey: the geological 'fingerprinting' of the stones that make up the walling and the features in it. This can make an enormous contribution to the understanding of the fabric and its development as well as allowing conclusions to be drawn about socio-economic conditions in the building industry at the various periods represented in the fabric'.

Figure 7.7 is an example of what can be achieved. All too often, however, material is insufficiently

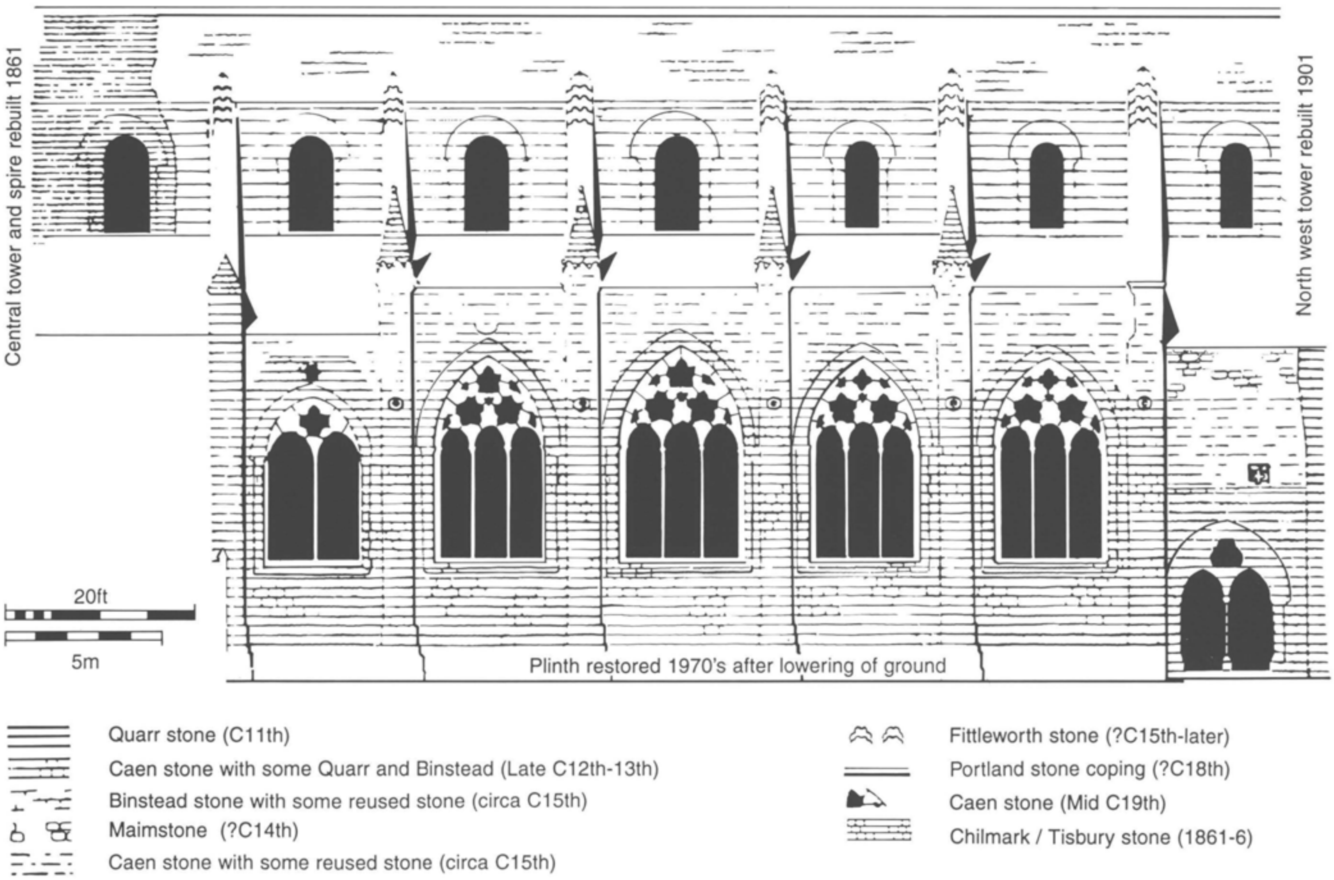


Fig 7.7 The distribution of lithic types in the north aisle and nave clearstory of Chichester Cathedral (J A Bowen, courtesy of the Dean and Chapter of Chichester)

considered in building recording. For example it is hardly mentioned in the Royal Commission on Historic Monuments specification for recording historic buildings. Only at the highest level of recording (Level 4) is it suggested that the written account include 'A note of the significance of the building locally, regionally, or nationally, in terms of its origin, purpose, form, construction, design, materials, or status.' This is patently inadequate.

Often surveys of this type are undertaken in advance of conservation, which may clean surfaces or replace original stones and there is thus some urgency in creating the fullest possible record of the materials used.

Another reason why a study of the stones of standing buildings is important is disaster management (Brodie 1994). If the building is to be rebuilt there will be a sudden demand for materials to match the original structure and it would be as well to know in advance where suitable replacement rocks can be found and what effect their extraction would have on ancient quarry sites. It is clearly desirable to initiate an audit of the stones used in archaeological monuments. A medieval building made of locally available rubble presents little problem, as the ancient tradition of using what was readily available can be perpetuated, but ashlar and decorative stones are another matter.

The main problems in initiating such an audit are, firstly, the large number of sites to consider and, secondly, the variability within materials, which can make it difficult to assign a stone to a source without detailed investigation of the quarries themselves. The problem could be more effectively tackled the other way round, by beginning with the quarry and then identifying the sites on which the stone was used. Comparanda from the quarry site itself would permit precise identification.

7.2.7 Distributional studies

Study of distributions is an important way of examining stone and knowledge of the wider picture may be essential to the correct interpretation of an excavated find. It can involve extensive field, museum, and library work, however, and is generally not appropriate to a developer-funded excavation. For this reason, broad-based synthetic studies have usually been the province of university- or museum-based academic archaeology. This is unfortunate as the topics covered depend on the whims and fashions of academe or of the Research Councils and it has resulted in an uneven knowledge of stone artefacts. This is presumably why the authors of Exploring our past claimed that the sources, manufacture, and distribution of stone artefacts remain poorly understood. There is a need for new broad-based studies to be commissioned if this aspect of the study is to advance.

Fig 7.8 The distribution of Group I axes from Cornwall (from Cummins 1983)

The problems and potential can be illustrated with some examples. In 1974 Cummins published the first major attempt to study the overall distribution of stone axes in England and Wales (Cummins 1974), which was long overdue as by then thin sectioning had been routinely applied for nearly 40 years. Even so, he was confronted with an uneven spread of data, a problem resolved by attempting to construct contoured relative frequency distribution maps for the major groups. In some cases, such as with Group VIII, the axes showed a frequency fall-off from a central concentration at the source, as might the predicted. In other cases anomalous concentrations were disclosed away from the source, suggesting to Cummins that there were bulk exports from the quarries that were later redistributed. Thus, there appears to be a curious concentration of Cornish Group I axes in Essex (Fig 7.8) and a similar wealth of Group VI axes from Langdale in Yorkshire.

As Bradley and Edmonds (1993, 47) point out, however, the distribution maps that underpin this theory are not entirely satisfactory. They neglect absolute quantities, with a result that some of the highest proportions of non-local objects come from areas with very few finds. They suggest that it would have been more helpful to include flint axes and advocate Chappell's (1987) gravity model, which seeks to predict the spread of products of different stone sources in relationship to their attractiveness to a consumer, measured by the proportion of different types in the country as a whole. Much more could be said on this subject but the lesson is clear: the interpretation of distributions is by no means easy and partial consideration of the evidence is fraught with danger.

Patchy coverage is a problem that hinders the study of exchange for another type of portable artefact as well: the quern, which becomes important on sites dating from the latter part of the Iron Age onwards. Peacock (1987) published a distribution map showing the wide dispersal of products of the Lodsworth quarries (Fig 7.9). It is remarkable that such heavy artefacts were transported over 150km from the source both during the Iron Age and during the subsequent Roman period.

It is difficult, however, to make further deductions about the nature of the exchange and the value of Lodsworth querns because of a lack of knowledge of other sources. We need to know with what sources Lodsworth was competing and we need an assessment of the efficiency of the rocks involved in the task of grinding corn.

At present, studies have been concerned with more basic matters, such as dating and petrological definition. Ingle (1989) and King (1986) have attempted this for much of eastern England, while Hayes, Hemmingway, and Spratt (1980) and Wright (1988) have undertaken similar work in the North. Before the study can proceed we need more information about the Midlands and the west of England, which must include an assessment of a major source about which virtually nothing is known: the Quartz-conglomerate of the Forest of Dean. We also need quantitative data and the development of a yardstick for objectively judging the efficiency of milling rocks.

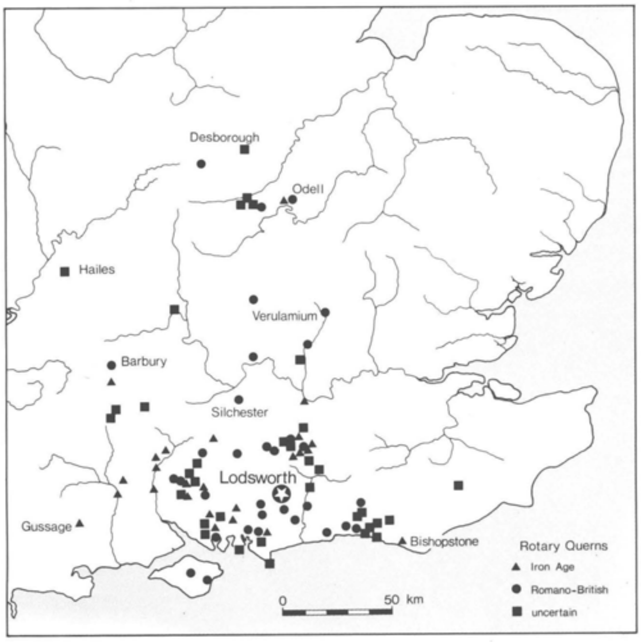


Fig 7.9 Distribution of Iron Age and Roman Lodsworth querns (from Peacock 1987)

The study has a long way to go and in the Roman period the picture is complicated by the importation of lava querns from Mayen in Germany. These become a major factor in Saxon and later medieval times. There has been no distributional study of medieval querns or of the mortars that seem to take their place increasingly from the thirteenth century onwards.

Medieval whetstones have, however, been studied from the point of view of their petrology and distribution (Ellis 1969; Moore 1983), but the work badly needs updating with the inclusion of more precise quantitative data (Fig 7.10). In contrast, Roman whetstones have been largely neglected although it seems that they were distributed widely from their quarries.

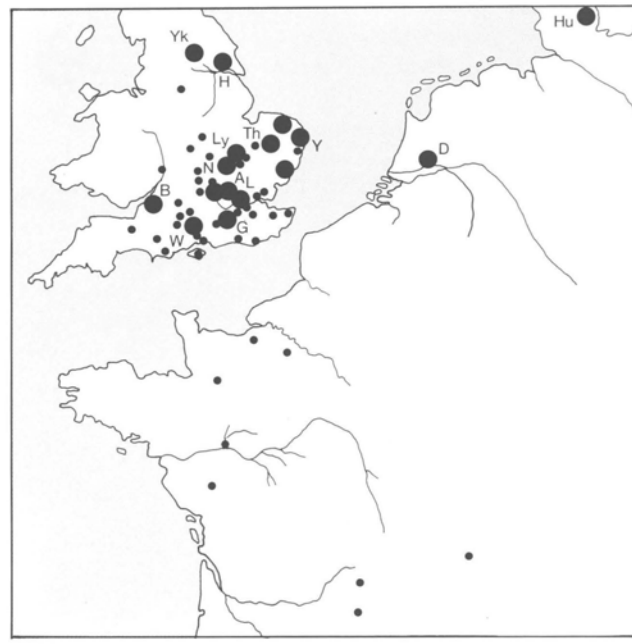


Fig 7.10 The distribution of medieval schist whetstones (from Moore 1983). The small dots are sites mentioned by Dunning, the larger have been scientifically accredited: A=Aylesbury, B=Bristol, D=Dorestad, G=Guildford, H=Hull, Hu=Haithabu, Ip=Ipswich, L=London, Ly=Lyveden, NEP=North Elmham Park, Ox=Oxford, Th=Thetford, W=Winchester, Y=Yarmouth, Yk=York

The ubiquitous pebble whetstones need to be taken seriously, as they too may have been centrally produced. Peacock (1971) drew attention to the frequent occurrence of whetstones in sandy glauconitic limestone. Various sources have been claimed for these, including the Hythe beds of Kent, the Jurassic to the west of Leicester, and the Stony Stratford Towcester area of Northamptonshire. Such is the state of research that we do not even know whether we are dealing with a single quarry misidentified by geologists seeking the

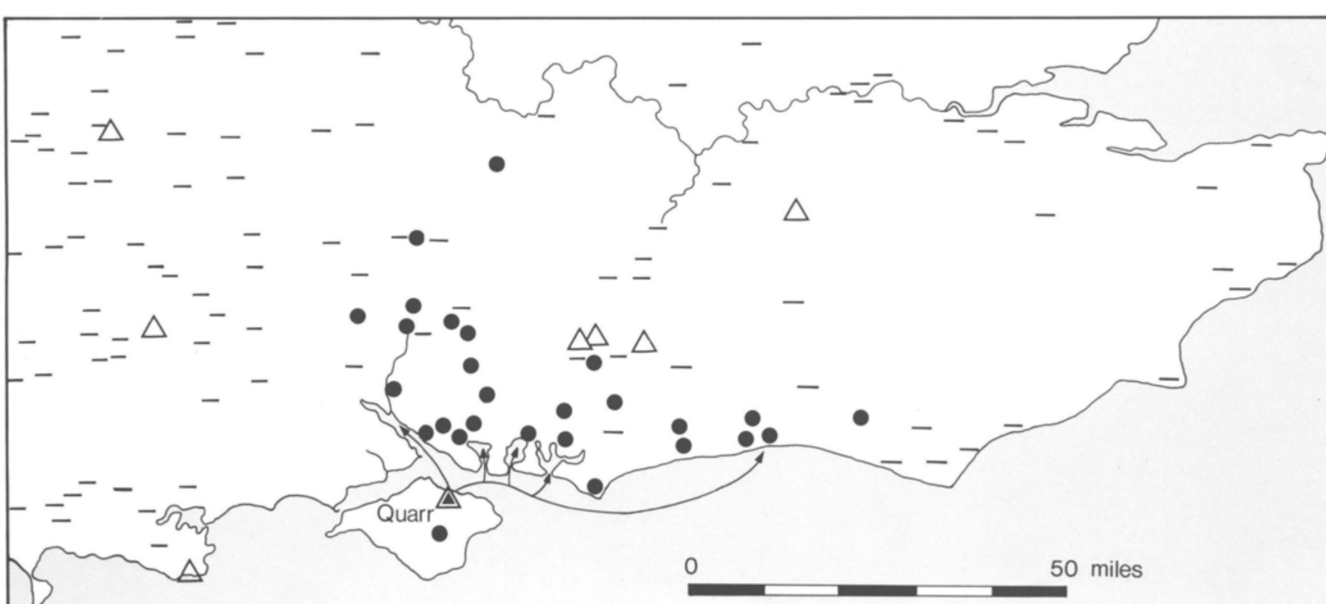


Fig 7.11 The distribution of Quarr stone in southern England (from Jope 1964)

'nearest possible source' for the material they were studying, or whether a preferred rock type was sought in a variety of places.

Distributional studies on building stones were long ago pioneered by Jope (1964) and it is salutary to note that some 30 years later his efforts remain as a model of what can be achieved.

Just one example is presented: the distribution of Quarr stone in Saxon buildings (Fig 7.11). The lack of quantitative data is compensated to some extent by the inclusion of negative evidence and we are left with the impression of a real distribution rather than one artificially created by the archaeologists knowledge and experience. Unfortunately, few rock types have been examined in this way, and the next step, an attempt to gather quantitative data, has not been taken.

Analyses permitting an investigation of the relationships between quarries are almost entirely wanting. Distributional studies of this type need to be linked to a more detailed appreciation of the properties of stones so that reasons for choice or for long-distance transport can be evaluated.

8 Recommendations

It should be clear that the establishment of firm guidelines for the study of stone lies in the future as there are many areas of uncertainty that require more detailed elucidation. It is nevertheless possible to suggest certain areas that need immediate attention. For convenience and clarity the recommendations have been listed under the headings of policy, research, training, and conferences, although it will be obvious that there is considerable overlap and interplay between them.

8.1 Policy

8.1.1 A more integrated approach is needed to the study of stone. For example, the study of mouldings, tooling marks, use wear, and petrology are too often seen as discrete entities. In reality they interrelate and should be considered together in archaeological reports. This is a matter for the attention of report writers and editors.

8.1.2 Those concerned with architectural stone and standing buildings should reconsider the status of 'material' in current recording frameworks. This relates to research Recommendation 8.2.1.

8.1.3 English Heritage should consider making an appointment in the field of archaeological geology. The appointee would have training in both geology and archaeology and would advise units on procedures. He or she should be located near to a good comparative collection and would also undertake identification work for projects without access to geological expertise. The person would be responsible for advising on research needs, monitoring standards, and coordinating across regions.

8.1.4 Stone reports are generally of a high standard, but more attention should be given to providing quantified data, by number, and, where feasible, by weight. The is a matter for the attention of excavating units.

8.2 Research

8.2.1 A pilot study should be launched to test the feasibility of a 'stone audit' to link buildings, remains of buildings, and quarries. The work would involve the following steps:

- detailed survey of the quarry earthworks as well as the immediate environs, which might hold traces of transportation processes
- detailed geological mapping of the outcrop, using a portable core drill if required; this would permit assessment of stone reserves and stone varieties and would point to areas that might be exploited with minimum damage to the ancient quarry site
- systematic examination of guardianship and other sites for use of the stone; this would include material from excavated sites now housed in museums

The object of this work would be to record the main stone building materials used in the test region. This should be of value in conservation and disaster management. In addition, data will be available on where appropriate materials might be found and to assess the impact of modern extraction on old quarry sites so that destruction will be minimised.

8.2.2 Stone surfaces are of crucial importance and they are also the most vulnerable part of the stone. There is a need to evaluate the significance of tooling marks for chronological and other studies. This should be done by examining historically dated buildings or multi-period buildings with good historical evidence for the construction sequence. Care must be taken to compare like with like, ie keying with keying, finished surfaces with finished surfaces, even to the level of windows with windows, etc.

This study is seen as fundamental to the practice of stone recording and should also have an impact on conservation policy.

8.2.3 More research is needed into artefacts such as whetstones, querns, and millstones. There are several aspects to this work.

- Use-wear needs to be examined and this could profitably be linked to a scientific programme of residue analysis.
- Methods for assessing the efficiency of such artefacts need to be devised.
- Distributional studies on Iron Age and Roman querns need to be undertaken to complete the national picture. Roman whetstones need examining from the point of view of trade and exchange, while medieval ones need reassessing.

8.2.4 More research is needed into ballast, combining historical and archaeological evidence. Methods for characterising shingle ballast need to be considered.

8.2.5 Weathering processes need to be examined from an archaeological perspective. Such a programme should be perceived as a collaborative venture between the archaeologist, the buildings conservator, and the geomorphologist. Lichenometry should be further explored as a means of dating stone surfaces.

8.2.6 The detailed study of stone use in individual towns needs to be pursued. The 'stones project' initiative of the York Archaeological Trust should be developed and brought to a conclusion. Consideration should be given to expanding this approach to other towns. These should, in the first instance, be chosen because they lack good stone of their own; all material will thus be imported to the site. Winchester is one possibility and this town has the benefit of an extensive body of information collected over many years, some of which has been synthesised (Biddle 1990).

8.3 Training

8.3.1 Since the unit is inevitably responsible for the preliminary sorting and selection of excavated stone, training in rock recognition should be given to unit finds staff. Short courses of a regional nature would seem to be needed, but a geological advisor should be available to follow up the training and give on-site advice (see Recommendation 8.1.3).

8.3.2 Loose architectural stone presents a major problem to many units. There is a need for more specialists in this field. Much could be achieved through short training courses or by seconding established specialists to work in units with problems in this direction.

8.4 Conferences

Conferences are of two types. Firstly, there are those that seek to resolve matters by debate among practitioners, while a second type seeks to inform by disseminating specialist knowledge.

8.4.1 The illustration of non-flint stone artefacts needs to systematised. It is recommended that a conference of archaeological illustrators be convened to address this issue.

8.4.2 The organisation ASMOSIA hold biennial conferences on stone, but there is a need for similar conferences from a specifically British perspective. These could be usefully centred around artefact types such as querns or sculpture, or around common and decorative building materials. The object would be for specialists to disseminate the findings of their research to a wider audience.

8.4.3 The developments in modern scientific characterisation need to be more widely appreciated and a training conference attempting to present these to the non-specialist might do much to increase their application.

Bibliography

Adams, J, 1985 Sea venture: a second interim report – part 1, *Int Journ Naut Archaeol Underwater Explor,* **14**, 275–99

Alexander, J S, 1996 Masons' marks and stone bonding, in Tatton-Brown and Munby 1996, 219–36

Allan, J P, 1984 The stone, in *Medieval and Post-medieval finds from Exeter,* 1971 1980 (J P Allan), Exeter Archaeological Report, **3**

—, 1991 A note on the building stones of the Cathedral, in *Medieval art and archaeology at Exeter Cathedral* (J P Allan), 10–18

Allason-Jones, L, and Jones, D M, 1994 Jet and other materials in Roman artefact studies, *Archaeol Aeliana,* **22**, 265–72

Arkell, W J, 1947 *Oxford stone,* London

Atkinson, D, 1942 *Report on the excavations at Wroxeter (the Roman city of Viroconium) in the County of Salop, 1923–1927,* Oxford

Balty, J-C, 1992 Une collection de marbres antiques, *Les Dossiers d'Archeologie,* **173**, 68–71

Barbin, V, Ramseyer, K, Decrouez, D, Burns, S J, Chamay, J, and Maier, J L, 1992 Cathodoluminescence of white marbles: an overview, *Archaeometry,* **34**, 175–84

Bednarik, R G, 1992a Developments in rock art dating, *Acta Archaeol,* **63**, 141–55

—, 1992b A new method to date petroglyphs, *Archaeometry,* **34**, 297–91

Benfield, E, 1990 *Purbeck shop, a stoneworker's story of stone,* Southampton

Beschel, R, 1950 Flechten als Altersmasstab rezenter Moränen, *Zeits Gletscherk und Glazialgeologie,* **1**, 152–61

Bessac, J-C, 1986 *L'outillage traditionnel du tailleur de pierre de l'Antiquité à nos jours,* Paris

—, 1988 Problems of identification and interpretation of tool marks on ancient marbles and decorative stones, in Herz and Waelkens 1988, 41–54

Biddle, M, 1990 *Object and economy in medieval Winchester,* Oxford

Biddle, M and Smith, D, 1990 The querns, in Biddle 1990, 881–9

Blagg, T F C, 1976 Tools and techniques of the Roman stonemason in Britain, *Britannia,* **7**, 152–72

—, 1990 Building stone in Roman Britain, in Parsons 1990, 33–50

Blair, J, and Ramsey, N (eds), 1991 *English medieval industries,* London

Bond, F, 1905 *Gothic architecture in England,* London

Braemer, F, 1992 Pierres de décoration, *Les Dossiers d'Archeologie,* **173**, 70

Bradley, R, and Edmonds, M, 1993 *Interpreting the axe trade,* Cambridge

Bradley, R, Meredith, P, Smith, J, and Edmonds, M, 1992 Rock physics and the neolithic axe trade in Great Britain, *Archaeometry,* **34**, 223–33

Brodie, A, 1994 Emergency recording: RCHME'S rapid response methodology, in Wood 1994, 111–28

Brunskill, R W, 1970 *A handbook of vernacular architecture,* London

Buckland, P C, and Sadler, J, 1990 Ballast and building stone: a discussion, in Parsons 1990, 114–25

Bushe-Fox, J P, 1926 *First report on the excavation of the Roman fort at Richborough, Kent* Rep Res Comm Soc Ant, London no **6**

Cadman, G, 1990 Recent excavations on Saxon and medieval quarries in Raunds, Northamptonshire, in Parsons 1990, 187–206

Cantrill, T C, 1931 Geological report on Uriconium, *Archaeol Cambrensis,* **86**, 87–98

Carroll, D, 1970 *Rock weathering,* New York

Cernohouz, J, and Solc, I, 1966 Use of weathered sandstone wanes and weathered basaltic crust in absolute chronology, *Nature,* **212**, 806–7

Chappell, S, 1987 *Stone axe morphology and distribution in Neolithic Britain,* BAR, **177**, Oxford

Clarke, H, and Carter, A, 1977 *Excavations in King's Lynn 1963 1970,* Society for Medieval Archaeology Monograph Series, 7

Clifton-Taylor, A 1962 *The pattern of English building,* London

Clifton-Taylor, A, and Ireson A S, 1983 *English stone building,* London

Clough, T, and Cummins, W (eds), 1979 *Stone axe studies,* Council for British Archaeology Research Report, **23**

—, 1988 *Stone axe studies 2,* Council for British Archaeology Research Report, **67**

Coldstream, N, 1991 *Medieval craftsmen: masons and sculptors,* London

Coope, G R, 1979 The influence of geology on the manufacture of Neolithic and Bronze Age stone implements in the British Isles, in Clough and Cummins 1979, 98–101

Council for British Archaeology, 1987 *Recording worked stones: a practical guide,* Practical Handbooks in Archaeology, **1**, London

Crawford, O G S, 1953 Querns and quern quarries, in *Archaeology in the field* (O G S Crawford), 98–106, London

Crosby, D D B, and Mitchell, J G, 1987 A survey of British metamorphic hones stones of the 9th to 15th centuries AD in the light of Potassium-Argon natural remnant magnetization studies, *J Archaeol Sci,* 14, 483–506

Cummins, W A, 1974 The Neolithic stone axe trade in Britain, *Antiquity,* **48,** 201–5

—, 1983 Petrology of stones axes and tools, in Kempe and Harvey 1983, 171–226

Curwen, E C, 1937 Querns, *Antiquity,* **11**, 133–51

—, 1941 More about querns, *Antiquity,* **15**, 15–32

Donahue, R E, 1994 The current state of lithic microwear research, in *Stories in stone* (eds N Ashton and A David), 156–68, London

Dorn, R I, 1983 Cation-ratio dating: a new rock varnish age determination technique, *Quaternary Research,* **20**, 49–73

Dorn, R I, 1997 Previously identified uncertainties in C-14 dating of petroglyphs, *J Natur Pictographic Soc*, **8**, 6–7

Ellis, S E, 1969 The petrology and provenance of Anglo-Saxon and English medieval honestones, with notes on some other hones, *Bull Brit Mus Natural History,* **2**, 135–87

Ellis, S E, and Moore, D, 1990 The hones, in Biddle 1990, 279–87

Ellison, M, McCombie, G, MacElvaney, M, Newman, A, O'Brien, C, Tavener, N, and Williams, A, 1993 Excavations at Newcastle quayside: waterfront development at Swirle, *Archaeol Aeliana,* **21**, 151–234

English Heritage, 1991a *Exploring our past: strategies for the archaeology of England,* London

—, 1991b *Management of archaeological projects* (2 edn), London

Ericson, J E, 1984 Towards the analysis of lithic production systems, in *Prehistoric quarries and lithic production* (J E Ericson and B A Purdy), 1–10, Cambridge

Evans, K, and Heron, C, 1993 Glue, disinfectant and chewing gum: natural products chemistry in archaeology, *Chemistry and Industry,* 21 June, 446 9

Follmann, G, 1961 Lichenometrische Altersbestimmungen an verchristlichen Steinsetzungen der polynesischen Osterinsel, *Naturwissenschaften,* **48,** 627–8

Foster, R, 1991 *Patterns of thought,* London

Fraser, C M, 1987 *The accounts of the chamberlains of Newcastle-upon-Tyne, 1508 1511,* Society of Antiquaries of Newcastle-upon-Tyne, Record Series, **3**

Fulford, M, 1978 The interpretation of Britain's late Roman trade: the scope of medieval historical and archaeological analogy, in *Roman shipping and trade: Britain and the Rhine Provinces* (eds J du Plat Taylor and H Cleere), CBA Res Rep, **24**, 59–69

Fulford, M G, and Huddleston, K, 1991 *The current state of Romano-British pottery studies,* English Heritage Occasional Paper, **1**

Gaunt, G D, and Buckland, P C, forthcoming Building materials in Roman York, in *Industry in Roman Yorkshire* (ed J Price)

Gee, E A, 1981 Stone from the medieval limestone quarries of South Yorkshire, in *Collectanea Historica* (ed A Detsicas), 247–55, Kent Archaeol Soc

Gifford, J A, 1982 Description of the ballast stones, in *Yassi Ada,* vol I (G Bass and F van Doorninck Jr), 321, Texas

Goodrick, G, Williams, A, and O'Brien, C, 1994 Excavations at Newcastle quayside: the evolution of Sandgate, *Archaeol Aeliana,* **22**, 219–33

Greenhalgh, M, 1989 *The survival of Roman antiquities in the Middle Ages,* London

Grimes, W F, 1979 The history of implement petrology in Britain, in Clough and Cummins 1979, 1–4

Hayes, R H, Hemmingway, J E and Spratt, D A, 1980 The distribution and lithology of bee-hive querns in north-east Yorkshire, *J Archaeol Sci,* **7**, 297 324

Heron, C, Evershed, R P, Chapman, B, and Pollard, A M, 1991 Glue, disinfectant, and chewing gum in prehistory, in *Archaeological sciences, Bradford, 1989 Proceedings of a conference on the application of scientific techniques to archaeology* (eds P Budd, B Chapman, C Jackson, R C Janaway, and B S Ottaway), 325–31, Oxford

Heron, C, Nemcek, N, Bonfield, K M, Dixon, D, and Ottaway, B S, 1994 The chemistry of Neolithic beeswax, *Naturwissenschaften,* **81**, 266–9

Herz, N, 1987 Carbon and oxygen isotope ratios: a data base for classical Greek and Roman marble, *Archaeometry,* **29**, 35–45

—, 1988 Oxygen and carbon isotopic data base for classical marble, in Herz and Waelkens 1988, 305–14

—, 1992 Provenance determination of Neolithic to Classical Mediterranean marbles by stable isotopes, *Archaeometry,* **34**, 185–94

Herz, N, and Waelkens, M, 1988 *Classical marble: geochemistry, technology, trade,* Dordrecht

Holmes, L L, Harbottle, G, and Blanc, A, 1994 Compositional characterization of French limestone: a new tool for the art historian, *Archaeometry,* **36**, 25–39

Hope, St J, Hawley, W H, and Montgomerie, D H, 1914 Report on the excavation at Old Sarum in 1913, *Proc Soc Antiq London,* 2 ser, **26**, 100–17

Howe, J A, 1910 *The geology of building stones,* London

Hudson, J D, and Sutherland, D S, 1990 The geological description and identification of building stones: examples from Northamptonshire, in Parsons 1990, 16–32

Hull, E, 1872 *Building and ornamental stones,* London

Hunter, F J, 1991 *An investigation of methods of identifying archaeological jet-like artifacts,* Central Excavation Unit Report, London

Hunter, F J, McDonnell, J G, Pollard, A M, Morris, C R, and Rowlands C C, 1993 The scientific identification of archaeological jet-like artefacts *Archaeometry,* **35**, 69–89

Ingle, C, 1989 *Characterisation and distribution of beehive querns in Eastern England,* unpubl PhD thesis, Univ Southampton

Jenny, H, 1941 *Factors in soil formation,* New York

Johnson, S, 1984 *Belsay,* English Heritage, London

Jope, E M, 1964 The Saxon building stone industry in southern and Midland England, *Medieval Archaeol,* **8**, 91–118

Joubert, J J, Kriel, W C, and Wessels, D C J, 1983 Lichenometry: its potential application to archaeology in southern Africa, *South African Archaeol Soc Newsletter,* **6**, n p

Keith, D H, and Simmons III, J J, 1985 Analysis of hull remains, ballast, and artifact distribution of a 16th-century shipwreck, Molasses Reef, British West Indies, *J Field Archaeol,* **12**, 411–24

Kempe, D R C, and Harvey, A P (eds), 1983 *The petrology of archaeological artefacts,* Oxford

King, D, 1986 Petrology, dating, and distribution of querns and millstones: the results of research in Bedfordshire, Buckinghamshire, Hertfordhire, and Middlesex, *Bull Inst Archaeol London Univ,* **23**, 65–126

Knoop, D, and Jones, G P, 1939 The English Medieval quarry *Econ Hist Rev,* **9**, 17–37

Lazzarini, L, 1992 Des pierres pour l'éternité, *Les dossiers d'archéologie,* **173**, 58–67

Lock, W W, Andrews, J T, and Webber, P J, 1979 *A manual for lichenometry,* British geomorphological research group technical Bulletin, **26**, London

Lynn, C J, 1984 Some fragments of exotic porphyry found in Ireland, *J Irish Archaeol,* **2**, 19–32

Maniatis, Y, Herz, N, and Basiakos, Y, 1995 *The study of marble and other stones used in antiquity,* London

McGrail, S, 1989 The shipment of traded goods and of ballast in antiquity, *Oxford J Archaeol,* **8**, 353–8

Mellor, M, 1994 *Medieval ceramic studies in England,* London

Mercer, R, 1981 *Grimes Graves, Norfolk excavations 1971–72,* London

Moens, L, Roos, P, De Rudder, J, De Paepe, P, Van Hende, J, and Waelkens, M, 1988 A multi-method approach to the identification of white marbles used in antique artifacts, in Herz and Waelkens 1988, 243–50

Mona, D, 1988 J B Ward-Perkins and the marble committee, in Herz and Waelkens 1988, 3–6

Moore, D T, 1978 The petrography and archaeology of English honestones, *J Archaeol Sci,* **5**, 61–73

—, 1983 Petrological aspects of some sharpening stones, touchstones, and milling stones, in Kempe and Harvey 1983, 277–300

Moorehouse, S, 1990 The quarrying of stone roofing slates and rubble in West Yorkshire during the Middle Ages, in Parsons 1990, 126–46

Morris, E L, and Mepham, L N, 1994 *Data level guidelines: a structure for finds analysis (4th edition),* Wessex Archaeology Guideline, **2**

Morris, R K, 1978 The development of later Gothic mouldings in England *c* 1250 1400, *Architect Hist,* **21**, 18–57

—, 1979 The development of later Gothic mouldings in England *c* 1250 1400, *Architect Hist,* **22**, 1–48

—, 1996 Mouldings in medieval cathedrals, in Tatton-Brown and Munby 1996, 211–17

Ollier, C, 1984 *Weathering,* London

O'Neill, B H St J, 1951 Southampton town wall, in *Aspects of archaeology in Britain and beyond* (ed W F Grimes), 243–57, London

O'Neill, H, 1965 *Stone for building,* London

Parsons, D (ed), 1990 *Stone quarrying and building in England, AD 43–1525,* Chichester

—, 1991 Stone, in Blair and Ramsey 1991, 1–28

Parsons, D, and Brooke, C J, 1994 Recording churches and cathedrals, in Wood 1994, 129–54

Peacock, D P S, 1971 The whetstones, in *Excavations at Fishbourne vol II: the finds* (B W Cunliffe) Rep Res Comm Soc Antiq London, **27**, 153–5

—, 1977 Bricks and tiles of the Classis Britannica: petrology and origin, *Britannia,* **8**, 235–48

—, 1980a The Roman millstone trade: a petrological sketch, *World Archaeol,* **12**, 43–53

—, 1980b The stones, in *Excavations at Melbourne Street, Southampton, 1971 1976* (ed P Holdsworth), CBA Res Rep, **23**, 75

—, 1987 Iron Age and Roman quern production at Lodsworth, West Sussex, *Antiq J,* **47**, 61–85

—, 1995 The *Passio sanctorum quattuor coronatorum:* a petrological approach, *Antiquity,* **69**, 362–8

—, forthcoming Charlemagne's black stones

Peacock, D P S, and Williams, D F, 1992 *Imported Roman marble from Lincoln,* Ancient Monuments Lab Rep, **36/92**

—, forthcoming The Roman marbles of Colchester

Peacock, D P S, Williams-Thorpe, O, Thorpe, R S, and Tindle, A G, 1994 Mons Claudianus and the problem of the *'granito del foro'*: a geological and geochemical approach, *Antiquity,* **68**, 209–30

Pevsner, N, 1958 *The buildings of England South and West Somerset,* Harmondsworth

Pollard, A M, Bussell, G D, and Baird, D C, 1981 The analytical investigation of early Bronze Age jet and jet-like material from the Devizes Museum, *Archaeometry,* **23**, 139–67

Pritchard, F A, 1986 Ornamental stonework from Roman London, *Britannia,* **17**, 169–89

Pugin, A W N, 1841 *The true principles of pointed or Christian architecture,* London

Renn, D F, 1960 The keep of Wareham castle, *Medieval Archaeol,* **4**, 56–68

Rockwell, P, 1993 *The art of stoneworking: a reference guide,* Cambridge

Röder, J, 1965 Zur Steinbruchgeschichte des Rosengranits von Assuan, *Archäologischer Anzeiger,* 467–552

Royal Commission on the Historical Monuments of England, 1970 *County of Dorset volume 2, South-east,* London

—, 1991 *Recording historic buildings: a descriptive specification,* London

Rziha, F, 1883 *Studien über Steinmetz-Zeichen,* Vienna

Sedgley, J P, 1975 *The Roman milestones of Britain,* BAR, **18**, Oxford

Shaffer, R J, 1932 *The weathering of natural building stones,* Building Research Establishment, Special Rep, **18**, Garston

Sharpe, E, 1848 *Architectural parallels,* London

—, 1871–4 *The mouldings of the six periods of British architecture from the Conquest to the Reformation,* London

Shore, B C G, 1957 *Stones of Britain,* London

Shotton, F W, 1963 Petrological examination, in *Science in Archaeology* (eds D Brothwell and E Higgs), 482–8, London

Sieveking, G de G, Craddock, P T, Hughes, M J, Bush, P, and Ferguson, J, 1970 Characterisation of prehistoric flint mine products, *Nature,* **228**, 251–4

Sieveking, G de G, Bush, P, Ferguson, J, Craddock, P T, Hughes, M J, and Cowell, M R, 1972 Prehistoric flint mines and their identification as sources of raw material, *Archaeometry,* **23**, 13–22

Stocker, D, 1993 Recording worked stone, in *Advances in monastic archaeology* (eds R Gilchrist and H Mytum), BAR, **227**, 19–27

Stocker, D, and Evison, P, 1990 Rubbish recycled: a study of the reuse of stone in Lincolnshire, in Parsons 1990, 83 –101

Tatton-Brown, T W T, 1980 The use of Quarr stone in London and east Kent, *Medieval Archaeol,* **24**, 213–15

Tatton-Brown, T, and Munby, J, 1996 *The archaeology of cathedrals,* Oxford

Thomas, H H, 1923 The sources of the stones of Stonehenge, *Antiq J,* **3**, 239–60

Thorpe, R S, Williams-Thorpe, O, Jenkins, D G, and Watson, J S, 1991 The geological sources and transport of the bluestones of Stonehenge Wiltshire, UK, *Proc Prehist Soc,* **57**, 103–57

Waelkens, M, Herz, N, and Moens, L, 1992 *Ancient stones: quarrying, trade, and provenance,* Leuven

Waterman, D M, 1970 Somersetshire and other foreign building stone in Medieval Ireland, *c* 1175 1400, *Ulster J Archaeol, 33*, 63–75

Watson, J, 1911 *British and foreign building stones,* Cambridge

—, 1916 *British and foreign marbles and other ornamental stones,* Cambridge

Williams, J H, 1971a Roman building materials in South-east England, *Britannia,* **2**, 166–95

—, 1971b Roman building materials in the South-west, *Trans Bristol and Gloucestershire Archaeol Soc,* **90**, 95–119

Williams-Thorpe, O, 1988 Provenancing and archaeology of Roman millstones from the Mediterranean area, *J Archaeol Sci,* **15**, 253–305

Williams-Thorpe, O, and Thorpe, R S, 1992 Geochemistry, sources, and transport of the Stonehenge bluestones, *Proc Brit Acad,* 77, 133–61

—, 1993a Geochemistry and trade of eastern Mediterranean millstones from the Neolithic to Roman periods, *J Archaeol Sci,* **20**, 263–320

—, 1993b Magnetic susceptibility used in the non-destructive provenancing of Roman granite columns, *Archaeometry,* **35**, 185–95

Williams-Thorpe, O, Tindle, A G, and Jones, M C, 1996 Chapter 9, Characterisation studies: magnetic susceptibility, in *Survey and excavation at Mons Claudianus, 1987–1993, volume I: topography and quarries* (D P S Peacock and V A Maxfield), Cairo

Wood, J, (ed), 1994 *Buildings archaeology: applications in practice,* Oxford

Wright, M E, 1988 Beehive quern manufacture in the south-east Pennines *Scott Archaeol Rev,* **5**, 59–65

Additional picture credits for e-book (PDF)
Fig 7.5 is reproduced from Ellis, S E & Moore, D T 1990 'Stone Objects: Petrography & Provenance' in Biddle, M (ed) *Artefacts from Medieval Winchester: Part II Object and Economy in Medieval Winchester*, figure 62, 282, by permission of Oxford University Press

Fig 7.7 has been reproduced by permission of The Dean and Chapter of Chichester www.chichestercathedral.org.uk

Fig 7.8 is reproduced from Cummins, W A 1983 'Petrology of stones axes and tools' in Kemp, D R C & Harvey, A P (ed) *The Petrology of Archaeological Artefacts*, figure 6.2, 193, by permission of Oxford University Press

Fig 7.10 is reproduced from Moore, D T 1983 'Petrological aspects of some sharpening stones, touchstones and milling stones' in Kemp, D R C & Harvey, A P (ed) *The Petrology of Archaeological Artefacts*, figure 9.4, 285, by permission of Oxford University Press

Fig 7.11 has been reproduced by permissions of www.maneypublishing.com/journals/med and www.ingentaconnect.com/content/maney/med

Published by English Heritage, The Engine House, Fire Fly Avenue, Swindon SN2 2EH
www.english-heritage.org.uk
English Heritage is the Government's lead body for the historic environment.

E-book (PDF) published 2012

E-book (PDF) ISBN 978 1 84802 133 4
Version 1.0

First published 1998 in paperback ISBN 1 85074 683 4

British Library Cataloguing in Publication data
A CIP catalogue record for this book is available from the British Library.

For more information about English Heritage images, contact Archives Research Services, The Engine House, Fire Fly Avenue, Swindon SN2 2EH; telephone (01793) 414600.

Edited and brought to publication by David M Jones, Publishing, English Heritage.

Design and page layout by Pauline Hull
Scanning and production of e-book (PDF) by H L Studios www.hlstudios.eu.com

Front cover
Nineteenth-century millstones from a Millstone grit quarry at Bolehill, near Sheffield.