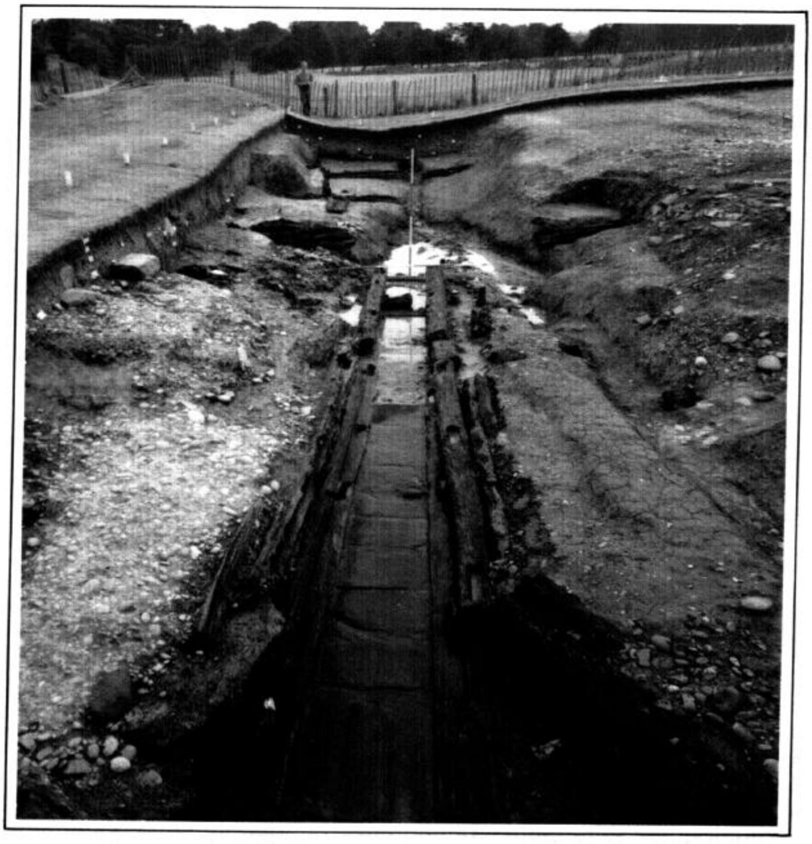
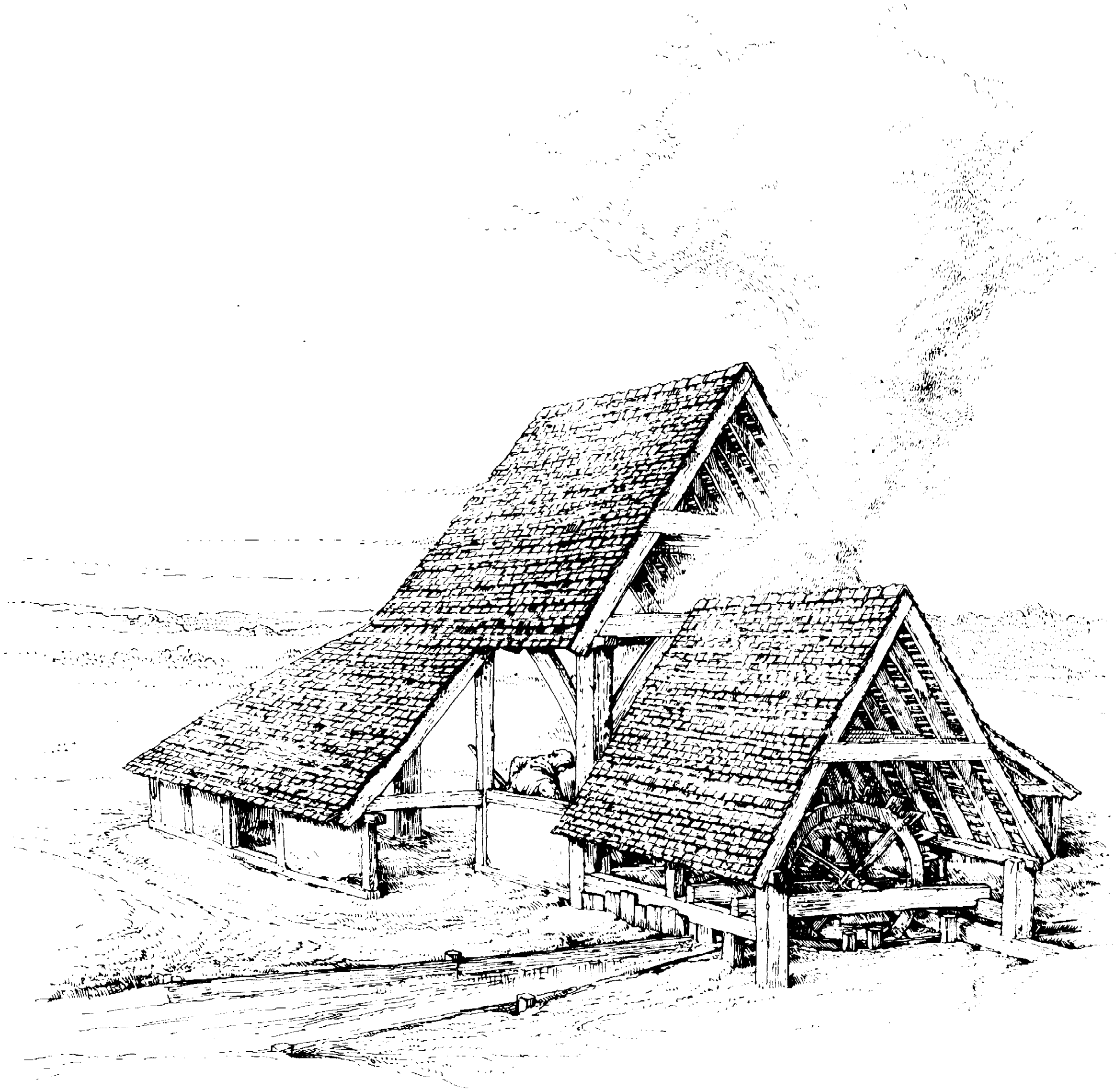
A MEDIEVAL INDUSTRIAL COMPLEX AND ITS LANDSCAPE : THE METALWORKING WATERMILLS AND WORKSHOPS OF BORDESLEY ABBEY

G G ASTILL



CBA RESEARCH REPORT 92

1993



Bordesley Abbey: reconstruction of the period 4 mill, from the south-west (D A Walsh)

A Medieval Industrial Complex and its Landscape: the Metalworking Watermills and Workshops of Bordesley Abbey

Bordesley Abbey III

By G G Astill

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1993

CBA Research Report 92

Council for British Archaeology

Published by the Council for British Archaeology
Bowes Morrell House, 111 Walmgate, York, YO1 2UA

ISBN 1 872414 43 5

British Library Cataloguing in Publication Data
A catalogue card for this book is available from the British Library

This book is published with the aid of a grant from the British Academy

Typeset by M C Bishop, Ryton, Tyne and Wear
Printed in Great Britain at Adpower, Halifax

Cover
Front *Bordesley Abbey: period 6 mill* race, *from the east*
Back *Bordesley Abbey: reconstruction of the period 3 mill, from the south-west (D A Walsh)*

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Summary

This is the third in the series of volumes reporting on work on the Cistercian abbey of Bordesley. This report describes excavations and fieldwork undertaken between 1980 and 1991 in the eastern part of the precinct of Bordesley Abbey. The aim of the programme was to excavate the monastic watermills and workshops, and to elucidate the development of that part of the valley of the River Arrow in which the monastic precinct is located.

The pre-monastic valley was occupied by natural water channels which often changed course during periods of flooding. Some of the silted channels contained Roman pottery of the first to second century AD which may indicate seasonal use of the valley, perhaps for rough pasture.

During the third quarter of the twelfth century, soon after the monastery's foundation, the valley was cleared and drained and a workshop constructed on a low platform. In the last quarter of the twelfth century (dated by dendrochronology) a triangular pond was constructed and a leat dug in which was constructed the head race, wheel pit, and tail race of a vertically-wheeled water mill. On the north side of the leat a large earthfast mill building was constructed which contained hearths.

After a short time - in the late twelfth century, according to dendrochronological dates - the mill building was destroyed by fire. A new tail race (on a new alignment) was superimposed on the first tail race. A mill building, of similar proportions to the destroyed mill, was erected on padstones and functioned for about a century.

In the early fourteenth century a new wheel trough and tail race were superimposed on the late twelfth-century structures. The mill building was retained but the hearths were replaced. The banks of the pond were raised to increase the head of water in an attempt to compensate for the decreasing gradient of the mill race. A workshop was built to the east of the mill.

In the mid-fourteenth century the wheel trough and tail race were reconstructed in a haphazard way. The building was not altered, although one hearth was enlarged. At some later time in the fourteenth century the wheel house was demolished and the west wall of the mill building replaced and the interior partitioned. The number of hearths was reduced to one and this was relocated. The building ceased to operate as a mill. A new and longer workshop, perhaps a farriery, was built either in the mid- or later fourteenth century to replace the previous workshop.

The sequence as a whole is notable because of the well-preserved timber remains of the four superimposed mill races and the survival of some machinery - trip wheel, 'cogs', and stone bearings - which allow a reconstruction of the workings of the mills. The fieldwork and subsidiary excavations also enable a reconstruction of the water supply. The preserved wood has augmented our knowledge of medieval carpentry.

The hearths in the buildings and the finds assemblage, which includes part-worked items of iron, copper alloy, and lead, as well as scrap material, indicate that these were metalworking mills in which small items were made and repaired. The water-power was used to drive trip hammers and bellows. Bordesley represents some of the earliest evidence for water-powered metalworking in Britain. The quantity, range, and character of the metal objects suggest that the smiths were making items for use in the precinct and on the granges of the monastery as well as for sale on the market. The quality and range of evidence from excavated medieval smithies generally is reviewed. Textile-working, leatherworking, and ceramic making are also attested within the general area of the Bordesley mills.

The mill site ceased to be used in the late fourteenth or early fifteenth century as a result of a combination of social, economic, and religious factors, but its abandonment was probably occasioned by the silting up of the valley downstream of the site which eventually made the mill unworkable. This part of the valley became subject to flooding, it was no longer managed, and the vegetation started to regenerate: the valley reverted to a partially wooded landscape. In the nineteenth and twentieth centuries attempts were made to improve the pasture by digging drains and planting hedges.

Résumé

C'est le troisième d'une série de volumes qui rapportent les travaux entrepris **à** l'abbaye cistercienne de Bordesley. Ce rapport décrit les fouilles et le travail sur le terrain entrepris entre 1980 et 1991 dans la partie est de l'enceinte de l'abbaye de Bordesley. Le programme avait pour objectif la fouille des moulins **à** eau et des ateliers monastiques et l'éclaircissement du développement de cette partie de la vallé de la rivière Arrow dans laquelle se trouvait l'enceinte du monastère.

La vallée prémonastique était occupée par des chenaux naturels qui changeaient souvent de cours pendant les périodes d'inondations. Certains des chenaux envasés contenaient de la céramique romaine datant du premier au deuxiéme siécle qui pourrait indiquer une utilisation saisonniére de la vallée, peut-êre pour des pâturages.

Pendant le troisiéme quart du douziéme siècle, peu aprés la fondation du monastére, la vallée fut déblayée et drainée et un atelier fut construit sur

une basse plate-forme. Au cours du dernier quart du douzième siècle (date basée sur la dendrochronologie), un réservoir de moulin triangulaire fut construit et un bief fut creusé dans lequel furent construits le bief d'amont, la fosse de la roue et le bief d'aval d'un moulin à roue verticale. Sur le côté nord du bief, un grand moulin qui contenait des foyers fut bâti à terre.

Au bout d'une brève période – à la fin du douzième siècle, selon la dendrochronologie – le moulin fut détruit par un incendie. Un nouveau bief d'aval (sur un nouvel alignement) fut superposé sur le premier bief d'aval. Un moulin de proportions similaires à celui qui avait été détruit fut érigé sur des pierres coussins et fut utilisé pendant environ un siècle.

Au debut du quatorzième siecle, une nouvelle cuve de roue et un nouveau bief d'aval furent superposés sur les structures de la fin du douzième siècle. Les bâtiments eux-mêmes furent conservés, mais les foyers furent remplacés. Les rives de l'étang furent élevées pour augmenter la hauteur d'eau et pour essayer de remédier ainsi l'inclinaison décroissante du bief du moulin. Un atelier fut construit à l'est du moulin.

Au milieu du quatorzième siècle, la cuve de la roue et le bief d'aval furent reconstruits un peu au petit bonheur. Le bâtiment ne fut pas changé quoiqu'un foyer fut agrandi. Plus tard au cours du quatorzième siècle, la cage de la roue fut démolie et le mur ouest du moulin fut remplacé et l'intérieur fut divisé. Il n'y eut plus qu'un seul âtre, qui fut installé ailleurs. Le bâtiment cessa de fonctionner comme moulin. Un nouvel atelier de plus grande longueur, peut-être une maréchalerie, fut construit soit au milieu, soit à la fin du quatorzième siècle pour remplacer l'atelier précédent.

La séquence entière est remarquable pour les restes de charpente bien préservés des quatre biefs superposés et des quelques équipements qui restent – roue à bascule, 'dents' et paliers en pierre – qui permettent une reconstruction des équipements des moulins. Le travail sur le terrain et les fouilles secondaires permettent également une reconstruction de l'alimentation en eau. Le bois préservé nous a permis d'approfondir nos connaissances quant à la grosse menuiserie médiévale.

Les foyers situés dans le bâtiments et l'assemblage des découvertes, qui comprennent des articles façonnés en partie de fer, d'alliage de cuivre et de plomb ainsi que de ferraille, indiquent que c'était des moulins pour le travail des métaux dans lesquels on fabriquait et on réparait de petits objets. L'energie hydraulique servait à entraîner des marteaux à bascule et des soufflets. Bordesley constitue une des documentations les plus anciennes de métallurgie hydraulique de la Grande Bretagne. La quantité, l'étendue et le caractère des objets en métal suggère que les forgerons fabriquaient des objets pour le cloître et pour les fermes du monastère ainsi que pour la vente sur le marché. La qualité et l'étendue de la documentation provenant de forges médiévales fouillées en général est mise en revue. La fabrication des textiles, le travail du cuir et la fabrication de la céramique sont également documentées dans la zone générale des moulins de Bordesley.

Le site du moulin cessa d'être utilise a la fin du quatorzième ou au début du quinzième siècle à cause d'un mélange de facteurs socio-économiques et religieux mais il fut probablement abandonné à cause de l'envasement de la vallée en aval du site, ce qui éventuellement rendit le moulin inutilisable. Cette partie de la vallée commença à subir des inondations, on ne la gérait plus et la végétation commença à se renouveler : la vallée retourna à l'état de paysage partiellement boisé. A diverses reprises au cours des dix-neuvième et vingtième siècles, on essaya d'améliorer les pâturages en creusant des drains et en plantant des haies.

Übersicht

Der vorliegende Band ist der dritte in der Serie über die Zisterzienser-Abtei Bordesley. Dieser Bericht beschreibt die Ausgrabungen und Feldforschungen, die zwischen 1980 und 1991 im östlichen Teil des Geländes der Abtei Bordesley unternommen wurden. Das Ziel dieses Projektes war, die zum Kloster gehörigen Wassermühlen und Werkstätten auszugraben und den Entwicklungsprozeß dieses Talabschnittes am Arrowfluß, in dem das Klostergelände liegt, aufzuhellen.

Natürliche Wasserläufe, die ihren Lauf oft während Überschwemmungen änderten, durchflossen das Ta1 vor dem Bau des Klosters. Einige dieser verlandeten Gewässer enthielten römische Keramik des ersten und zweiten Jahrhunderts AD, was vielleicht ein Hinweis auf jahreszeitlich bedingte Nutzung des Geländes (z.B. als Weiden) sein könnte.

Bald nach der Gründung der Abtei, während des 3. Viertels des zwölften Jahrhunderts, wurde das Tal gerodet und entwässert und auf einem niedrigen Aufwurf eine Werkstatt gebaut. Im letzten Viertel des zwölften Jahrhunderts (datiert anhand Dendrochronologie) wurde ein dreieckig geformter Teich angelegt und ein Wassergraben gegraben, der den oberen und unteren Triebwasserkanal und den Wasserradschacht einer Vertikalrad Wasser-Mühle enthält. An der nördlichen Seite des Wassergrabens wurde ein Pfostenbau errichtet, in dem sich Herdstellen fanden.

Nach kurzer Zeit – im spätem zwölften Jahrhundert, nach Ausweis der Dendrochronologie – war die Mühle niedergebrannt. Ein neuer unterer Triebwasserkanal wurde mit unterschiedlicher Ausrichtung über den ersten unteren Triebwasserkanal gelegt. Ein Mühlengebäude mit ähnlichen Ausmaßen wie die zerstörte Mühle wurde auf Auflagersteinen errichtet und war ungefähr ein Jahrhundert lang in Gebrauch.

Im frühen vierzehnten Jahrhundert wurden ein neuer Radtrog und ein unterer Triebwasserkanal über den am Ende des zwölften Jahrhunderts gebauten Anlagen angelegt. Das Mühlhaus wurde erhalten, aber man ersetzte die Herde. Man versuchte, den fallenden Grad des Werkkanals auszugleichen, indem man die Ufer des Teiches erhöhte, um das Wasser im oberen Kanal zu vermehren. Östlich der Mühle wurde eine Werkstatt gebaut.

In der Mitte des vierzehnten Jahrhunderts wurden der Radtrog und der untere Triebwasserkanal nachlässig umgebaut. Obwohl eine Herdstelle erweitert wurde, blieb das Gebäude unverändert. Zu einem späteren Zeitpunkt im vierzehnten Jahrhundert wurde das Mühlradhaus abgerissen, und die westliche Mauer der Mühle wurde ersetzt und der Innenraum untergeteilt. Die Zahl der Herdstellen wurde auf eine vermindert, für die ein neuer Platz gefunden wurde. Das Gebäude hörte auf, als Mühle zu funktionieren. Eine neue und größere Werkstatt, vielleicht eine Hufschmiede, wurde, entweder um die Mitte oder urn das Ende des vierzehnten Jahrhunderts gebaut, urn die letzte Werkstatt zu ersetzen.

Wegen der gut erhaltenen Bauholzüberreste der vier aufeinanderliegenden Mühlgräben und des Uberlebens einiger Maschinenteile - das Auslösungsrad, ‘der Zahn’ und die Steinlager - ist eine Rekonstruktion der Mühle im Detail möglich. Die Feldforschungen und Ausgrabungen erlauben darüberhinaus eine Rekonstruktion der Wasserversorgung. Das erhaltene Holz hat unser Wissen über die mittelalterliche Zimmerei vertief’t.

Die Herdstellen in den Gebäuden und die Funde, einschließlich der teilweise verarbeiteten Eisen-, Kupfer- und Bleifunde und des Altmaterials, weisen darauf hin, daß diese Mühle der Metallverarbeitung diente, zur Herstellung kleinerer Gegenstände und zu Reparaturen. Die Wasserkraft wurde benutzt, urn Auslösungshammer und Blasebälge anzutreiben. Bordesley ist einer der frühesten Belege für den Einsatz der Wasserkraft zur Metallverarbeitung in England. Die Menge, Auswahl und Art der Metallobjekte deutet an, daß die Schmiede Gegenstände für den Gebrauch im Kloster und in den Bauernhöfen des KIosters sowie zum Verkauf auf dem Markt machten. Auch Textil und Lederverarbeitung und Töpferei sind auch im weiteren Umkreis der Mühlen von Bordesley nachgewiesen.

Aufgrund einer Kombination von sozialen, wirtschaftlichen und religiösen Faktoren wurde die Mühle im spätem vierzehnten und frühen fünfzehnten Jahrhundert aufgegeben. Der eigentliche Anlaß zur Aufgabe war aber wohl das Verlanden des Baches unterhalb der Mühle, was ihre weitere Betreibung schließlich unmöglich machte. Dieser Talabschnitt erlitt Überschwemmungen und konnte deshalb nicht mehr bearbeitet werden. Die natürliche Vegetation begann wieder zu wachsen, das Tal wurde wieder zur teilweise bewaldeten Landschaft. Im neunzehnten und zwanzigsten Jahrhundert versuchte man, die Weiden durch das Graben von Abflußrinnen und das Pflanzen von Hecken zu verbessern.

Preface

The Bordesley Abbey Project

Bordesley Abbey (Fig 1) is one of the few monastic sites in the country which has its entire precinct surviving as a complicated set of earthworks, extending over 36ha. The site is also remarkable because of its well-preserved archaeology: the site has remained as meadow since the Dissolution and so the monastic levels have lain largely undisturbed; the site's low-lying position in the valley of the River Arrow has also ensured that organic materials survive.

A sustained programme of research at Bordesley Abbey started in 1969 under the supervision of Philip Rahtz. Work concentrated on the abbey church because the Borough of Redditch, the owners of the site, wished to display a well-preserved part of the site as a monument for the rapidly growing population of the new town. The excavations of the south transept, and of the presbytery, crossing, and choir have been published as two monographs (Rahtz and Hirst 1976; Hirst *et al* 1983); excavations of the nave continue. These demonstrate the extraordinary depth of floor levels and survival of ephemeral features, which, in combination with the remains of the standing structure, have allowed a sophisticated reconstruction of the building sequence and use of the church. The church sequence is also the most sensitive guide to the general well being of the community and its ability to attract patronage (Hirst and Wright 1989; Astill and Wright 1993).

A complete survey of the earthworks and small-scale excavations within the precinct were also undertaken and demonstrated the equally high potential of other areas of the precinct. We thus had an opportunity to investigate a medieval monastery in its entirety, and also the effects that community had on its immediate environment, at a time when monastic archaeology was dominated by the importance of establishing the plan of the claustral area. We also realised that it would be possible to excavate well-preserved examples of sites which usually do not survive well in urban or other rural areas.

The decision was taken to extend the project in order to investigate those, eastern, parts of the precinct which were thought to be the sites of the mills and industrial workshops of the monastery. The intention was, firstly, to gain new information about medieval industry, at that time an under-researched subject. Secondly, it was important to place the workshops in the context of their immediate environment by carrying out fieldwork in the surrounding areas. The general aim was to try to reconstruct the history of landuse within this section of the Arrow valley and in the process gain some perspective on the impact of the Cistercians' occupation of this river valley: we were thus concerned to characterise the three ages, or landscapes, of the Arrow valley, the pre-monastic, the monastic, and the post-monastic. This report, the third Bordesley monograph, thus discusses the monastic water-mills and workshops in the context of their immediate environment.

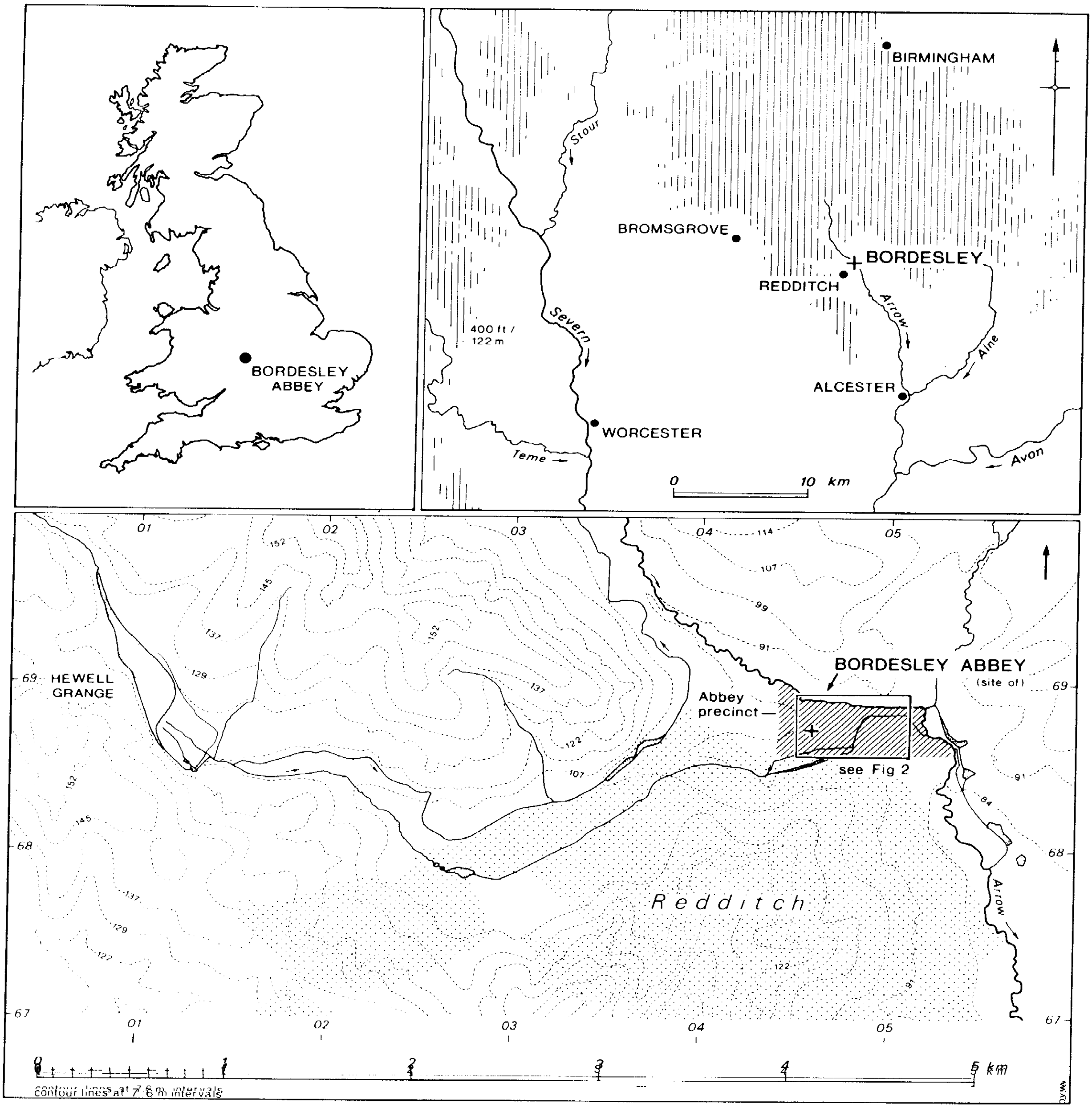

Figure 1 Location of Bordesley Abbey

Acknowledgements

The Bordesley Abbey Project has now been running for 25 years. In that time there has naturally been a great change in the circumstances - academic, political, financial, and personnel - in which this research project has operated, and consequently the project is indebted to many institutions and individuals. Despite the vicissitudes, it is a pleasure to acknowledge the constant support given by the owners of the entire monastic precinct, the Borough of Redditch. The Borough had initiated the excavations on the church in order to display the monument, but the representatives' and officers' interest in the whole precinct was such that they encouraged the project also to investigate the industrial workshops and mills, which they supported financially and with help in services and in kind. The Redditch Development Corporation also assisted with grants until its demise in 1984, as did the British Museum in 1987 and 1988. The Universities of Reading and York also supported the mill excavations; the British Academy and the Royal Archaeological Institute awarded grants for, and the University of Reading facilitated, post-excavation work. In 1990-2 the British Academy also generously awarded me a Research Readership to investigate the Bordesley estates and their landscapes; some of the results of this research are presented in part III of this monograph. It has also funded the preparation of the camera-ready copy and given a publication subvention.

The success of the long-term mill excavations was entirely dependent on the high quality of the supervisory staff and volunteers - many of whom returned again and again - who continued to work efficiently and good humouredly in spite of the unpleasant conditions. Verna Wass and Stephen Wass (who has in large part distilled his own experiences of archaeology at Bordesley in a book) provided the continuity of supervision on the mill site that was so essential. They have contributed much to the project, not only by digging and recording, but also by instructing and entertaining volunteers, and working on the excavation archive. With Steven Allen (who stayed with the project during the mill post-excavation phase) and John Bateman, I was fortunate to gain a similar continuity of supervision for the valley transect. Karen Campbell, Martin Cook, Ken Dark, Roy Harold, Mark Holmes, Richard Kemp, Colin Richards, Nick Thorpe, and Mark Whyman were also efficient supervisors.

Kathy Baker, Mary Bird, Paul Cannon, Julie Lovett, Sophia Sharif, and Liz Wild oversaw an efficient finds department with the assistance of Penny Anscombe, Paul Cuming, Gil Fewings, Julia Green, Felicity Lynch, and Ellen Walsh. Mary, Julie, Gil, Sophia, and Kate Walsh also carried out important post-excavation tasks. Iain McCaig did the site surveying and Mark Corney offered much advice when we re-surveyed the east end of the precinct.

The mill and the church excavations took place at the same time and the task of catering for both teams was accomplished magnificently by Zita Berrington, Ann Franklin, and Caroline Kennedy. Isobel Barnden, Vince Gaffney, Charlie Hollinrake, Dave Hopkins, Spencer Marlow, Dave McCardle, Ralph Seller, Dick Snodgrass, Tim Steemson, and Ed Walford ensured the smooth running of the camp site. Technical and practical help was unstintingly offered by Ian Coley and Alan Jones (Borough of Redditch); Alan also cheerfully and regularly put his expertise of operating heavy plant machinery at the service of the project and Isis Plant Hire, through Jim Brown, deputy manager, kindly made machinery available to us. Barry Mead, Jo Glogger, and Sue Werner of the Forge Mill Museum have always contributed to the smooth running of the excavation, and helped cope with the storage and conservation of finds. Chris O'Shea of Portsmouth City Museums offered valuable advice about, and undertook, the conservation of the structural timbers and other organic material, some of which is now exhibited in the new Bordesley Abbey Visitor Centre. We are also grateful to the British Museum staff who undertook the conservation of the 'book cover'. The inconvenience of living in a field was considerably reduced by the hospitality and help given by friends and neighbours of the project, especially Jo and George Fissler, Betty and Ron Passingham, and the late Stan Wright.

I am grateful to the many students from universities and schools who, in receiving training on the excavation, have participated at all levels of the work. In particular I would like to acknowledge the help of students from the Abbey High School, Redditch, the Universities of Reading, York, and Birmingham, University College London, and Rochester University, New York State.

I would also like to thank the Secretary of State, the Department of Environment and, later, English Heritage, for permission to excavate within this scheduled monument; and Graham Fairclough and Anthony Streeten, successively Inspectors in the West Midlands, for their continued support and valued advice.

The important results presented in this monograph owe much to the specialists who have contributed reports as well as those who have offered advice. In particular I would like to thank the following for the identification and comments on particular artefacts: John Allen, David Moore, John Thomas (stone); Gerry McDonnell (slags); Francis Grew, Betty Haines, and Glynis Edwards (leather); the Birmingham Assay

Office, John Cherry, Alison Goodall, Ian Goodall, and Phillipa Hardman (copper alloy and other metals); Justine Bayley, John Evans, Brian Johnson, and Raymond White (infrared spectoscropy and XRD); Bill Whitfield (soils). Christopher Dyer, Damian Goodburn, and Annie Grant kindly offered comments on particular sections; and Leo Biek has examined and offered invaluable advice on much of the metal and ceramic assemblage and has facilitated contacts with other specialists. John Hurst has been a constant source of advice, help, and encouragement.

Victoria Nailor wishes to thank Paul Booth, Victoria Buteux, Stephanie Rakhai, Keith Scott, Mike Stokes, and Alan Vince for information and advice about the pottery. Wendy Carruthers would like to acknowledge the help of James Greig, Allan Hall, A al Azm, P F Cannon, and Paul Bright in the preparation of her botanical report, and to thank Allan Hall and Lisa Moffett for permission to refer to their unpublished work. Nat Alcock discussed the reconstructions of the buildings with David Walsh.

I would also like to thank the illustrators whose work has enhanced this report: Steven Allen (structural timbers and reconstructions, diagrams), Mary Bird (stone, fired clay, glass), Lesley Collett (leather), Jane Goddard (pottery), Margaret Mathews (iron), David Walsh (wood, copper alloy, other metals, building reconstructions), and Brian Williams (plans, sections, maps).

My knowledge of watermills has been immeasurably extended by many discussions with the molinologists Robert Spain and Alan Stoyel; their practical experience, infectiously conveyed, was formative in devising reconstructions of the water supply and mill machinery; nor could these have been realised without extended debates with David Walsh and Iain McCaig. I also benefited from the exchange of ideas with David Crossley, Christian Fischer, Richard Holt, Connie Jantzen, and Christopher Salisbury.

Lastly, my greatest debt is to two generations of Bordesley directors: to Philip Rahtz, who not only introduced me to Bordesley and to water-mills, but also encouraged the work on the Bordesley mills from its inception, through its execution (including the practical assistance of photography), to completion with a scrutiny of the draft report; and to Susan Hirst and Susan Wright, co-directors of the project, who have made sure that the research programme has consistently produced important and high quality information. Susan Wright also gave extensive help with the preparation of the text at every stage and finally edited the report for publication. The report has been seen through the press by Christine Pietrowski of the CBA.

Plates 1 and 38 were provided by the Cambridge Committee for Aerial Photography and Plate 36 by the British Museum. Site photography was by Philip Rahtz (Plates 17 and 20-5) and the author. Unless otherwise stated, all photographs which include scales have half-metre divisions.

The finds and archive are deposited in the Forge Mill Museum, Redditch.

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Plate 1 Bordesley Abbey precinct, from the east. The triangular pond is at the bottom, centre (Cambridge Committee for Aerial Photography)

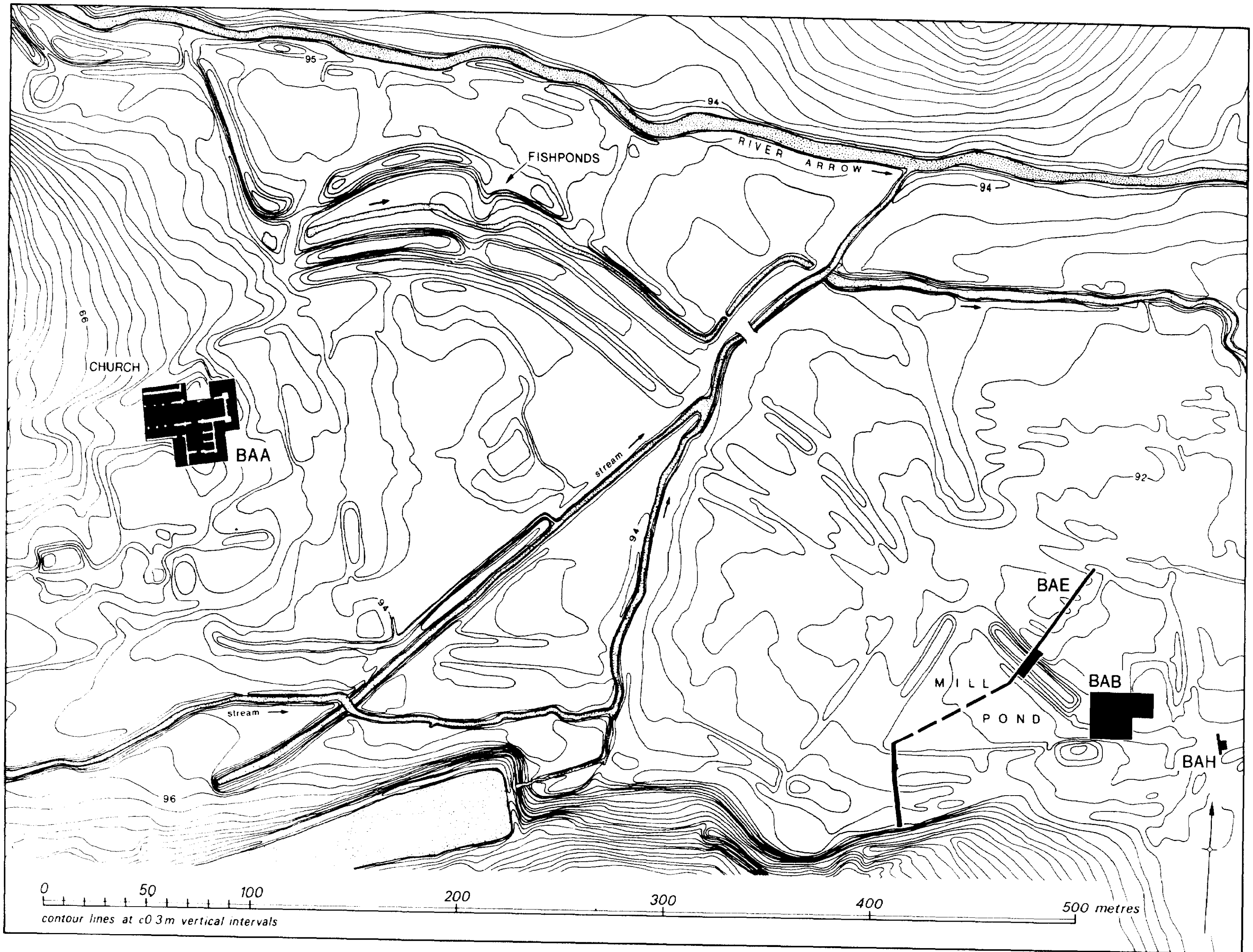


Figure 2 *Bordesley Abbey precinct, showing major excavations*

I Excavations and fieldwork 1980-1991

G G Astill

Circumstances and methods of excavation

During their earthwork survey of the Bordesley Abbey precinct in the 1970s, Aston and Munton identified a triangular mill pond some 360m east of the abbey church. They also located a ditched enclosure, immediately to the north of the mill race, which they interpreted as a possible industrial site (Aston and Munton 1976, 32; Rahtz and Hirst 1976, 119; Plate 1). Excavation within this enclosure (Bordesley Abbey site B: 'BAB') was begun in 1967 by Trevor Rowley, who excavated topsoil and post-abandonment silts or flood deposits. In 1968 Trevor Rowley and Michael Wise extended this excavation to include almost the whole of the interior of the enclosure, an area of *c* 412 m^2; over a limited area some of the latest features (of BAB period 6) were reached, but most of the time was spent in the removal of flood deposits. A trench was also cut through the eastern ditch, but wet conditions prevented the completion of the excavation. The subsequent excavations and survey have demonstrated that the 'enclosure' was in fact composed of ditches of different periods. While the eastern ditch was probably the monastic precinct boundary (S11: Fig 4), those on the west and north were post-medieval drains (S14, S23: Fig 4). Thus, contrary to first appearances, the enclosure did not mark the limit of the medieval industrial workshops.

In 1968, and again in 1969, Philip Rahtz directed work in a 10m square in the south-west corner of the larger area already opened up. This square was excavated down to an overall pebble surface (BAB period 5) and then work was suspended because The site proved to be a very difficult one which it was impossible to do justice to or supervise adequately, concurrently with that of the church' (Rahtz and Hirst 1976, 119).

In 1980 the major excavation of the presbytery, crossing, and eastern choir of the church was completed and work was resumed on the 'industrial site'. The square (square A) abandoned in 1969 was reopened and a further 10m square was opened to the west (square B). The silts in square B were removed to reveal a part of what was interpreted as a mill building. A trench, designed to section the valley in order to investigate the relative sequence and function of earthworks to the west of BAB and to determine the nature of the changing floodplain, was also started - the valley transect (BAE). In 1981 a further three 10m squares adjacent to square A were opened in order to excavate the entire building and its associated waterworks (squares C, D, and E); the total area of the new, 'BAB', excavation was therefore 500m^2 (Figs 2 and 4).

From 1982 to 1987 the sequence of mills and workshops was excavated. In 1988 the pre-mill sequence was excavated and in the following year the subsidiary excavations through the tail race downstream of the mills were carried out (BAH, BAJ: Fig 3). In 1990 the valley transect excavation (BAE) was completed, and a resurvey of the earthworks was carried out in 1991. The whole fieldwork took approximately 36 weeks over 11 seasons, with a mill-excavation team of, on average, 20 people.

This report details all the above fieldwork; the excavation by Philip Rahtz has been incorporated into the mill (BAB) sequence; those by Rowley and Wise can only be commented upon briefly and the surviving metal finds are published here as unstratified.

The mills site was excavated using a module of a 10m x 10m square in order to maintain greater spatial control for excavation and recording (Fig 5). The recording system was adapted from that used on the church (Hirst 1976). One set of context numbers was used for the whole site, prefixed by the letter allocated to that square. The arrangement of the five squares was determined by the previous excavation on the site (square A). It proved unfortunate, however, that four of the squares intersected in the middle of the building, where the stratification was most complex. This made the recording complicated because a context which straddled several squares could have up to four context numbers.

Some modifications to the church recording system were necessary to cope with the very different conditions on BAB. For example, because BAB had large negative features which remained open for, or had been progressively filled over, a considerable time, it was decided to give the fills of all negative features separate context numbers. Planning was done from a grid set 1m back from the edges of the excavation. The major sections were located at the edges of the excavation and on the intersections of the five squares (Fig 5); the latter were drawn cumulatively. Subsidiary

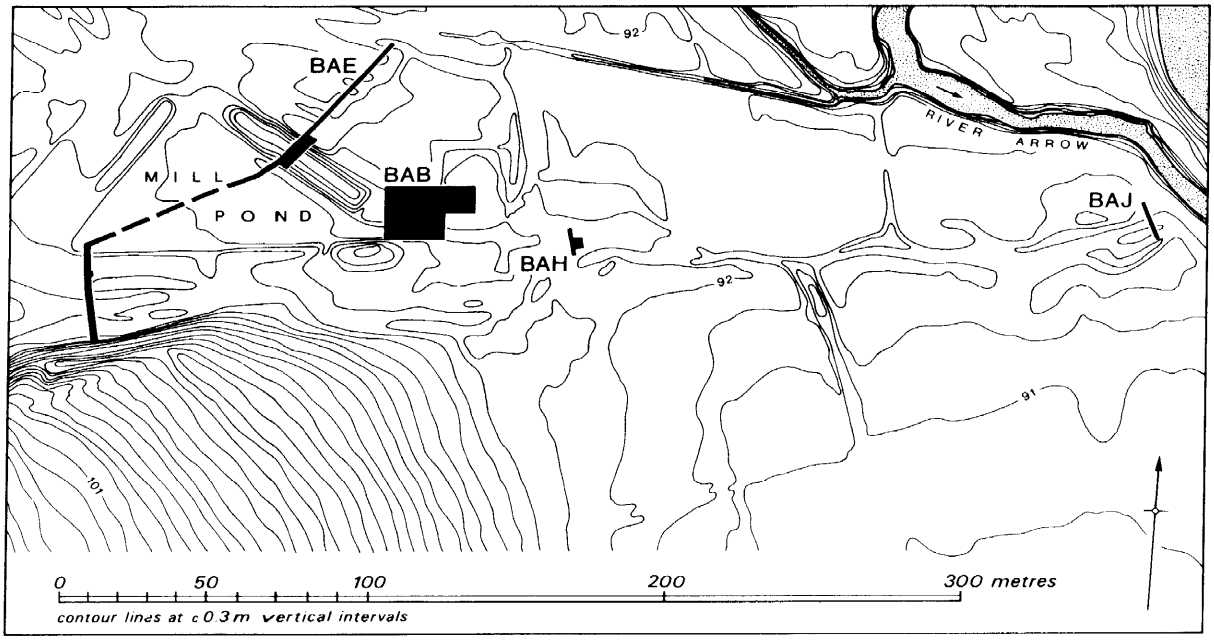


Figure 3 East part of the precinct, showing excavations reported here (BAB: mill; BAE: valley transect; BAH: tail race; BAJ: tail race)

sections were established to record the stratification of particular parts of the site, for example the hearths (S19) or the tail race (S18, S24) (Fig 5).

In view of the nature of the site, all metal finds were recorded three-dimensionally, except in cases where the objects occurred so densely that they were recorded by 1m square. (The distribution of the metalwork is discussed by V Wass in part III.) Each of the five squares was subdivided into 25 2m squares in order to record the more plentiful pottery and bone finds. The range and number of organic finds were so much more extensive than from the church that the leather (OA) and the wood (OB) were recorded separately.

All the mill features were excavated by hand. When it was realised that more archaeology existed below the building platform and the north mill pond bank, a small machine was used to excavate the clay platform and bank in spits; each resulting surface was cleaned by hand and when necessary recorded before further mechanical excavation.

Excavation in the tail race suggested that evidence of even earlier activity was masked by a thick (at least a metre) layer of clay sediment. The evidence for pre-monastic occupation could only be sampled. A machine was used to complete the major sections, which were then cleaned and drawn. Where the evidence appeared most abundant, further trenches were excavated by hand, mainly in squares A and B (Figs 5 and 6). The deposits encountered were mainly alluvial, clay with varying quantities of river gravel and pebbles, and the underlying Mercian Mudstone (Rahtz 1976, 14 'marl') was only exposed in one place (see below, Period 1 pre-monastic activity).

The conditions for excavation were extremely difficult, particularly in the waterlogged areas of the site such as the tail race or the bypass channel where it was necessary to use mechanical pumps even in the driest season. It emphasises that some sites are best dug, not all through the year or in an extended campaign, but only at certain times of the year, in this case in the summer when the water table should be at its lowest. It is a testimony to the quality and endurance of the supervisors and volunteers that such high-quality information was obtained. Excavation often had to be carried out by lying on planks suspended clear of the levels being excavated in order not to disturb the organic remains. While the excavation of the deepest parts of the site was made difficult by a high water table and shoring, that of the building was exacerbated by the dry conditions that often prevailed on the platform, especially as the floor levels rarely consisted of a continuous layer, but rather a series of thin dumps.

The fluctuating water table made the excavation of the earlier levels extremely difficult. It was, for example, only possible to see the two periods of platform in limited exposures because the fluctuating water level had effectively leached out and redeposited any distinctive inclusions which

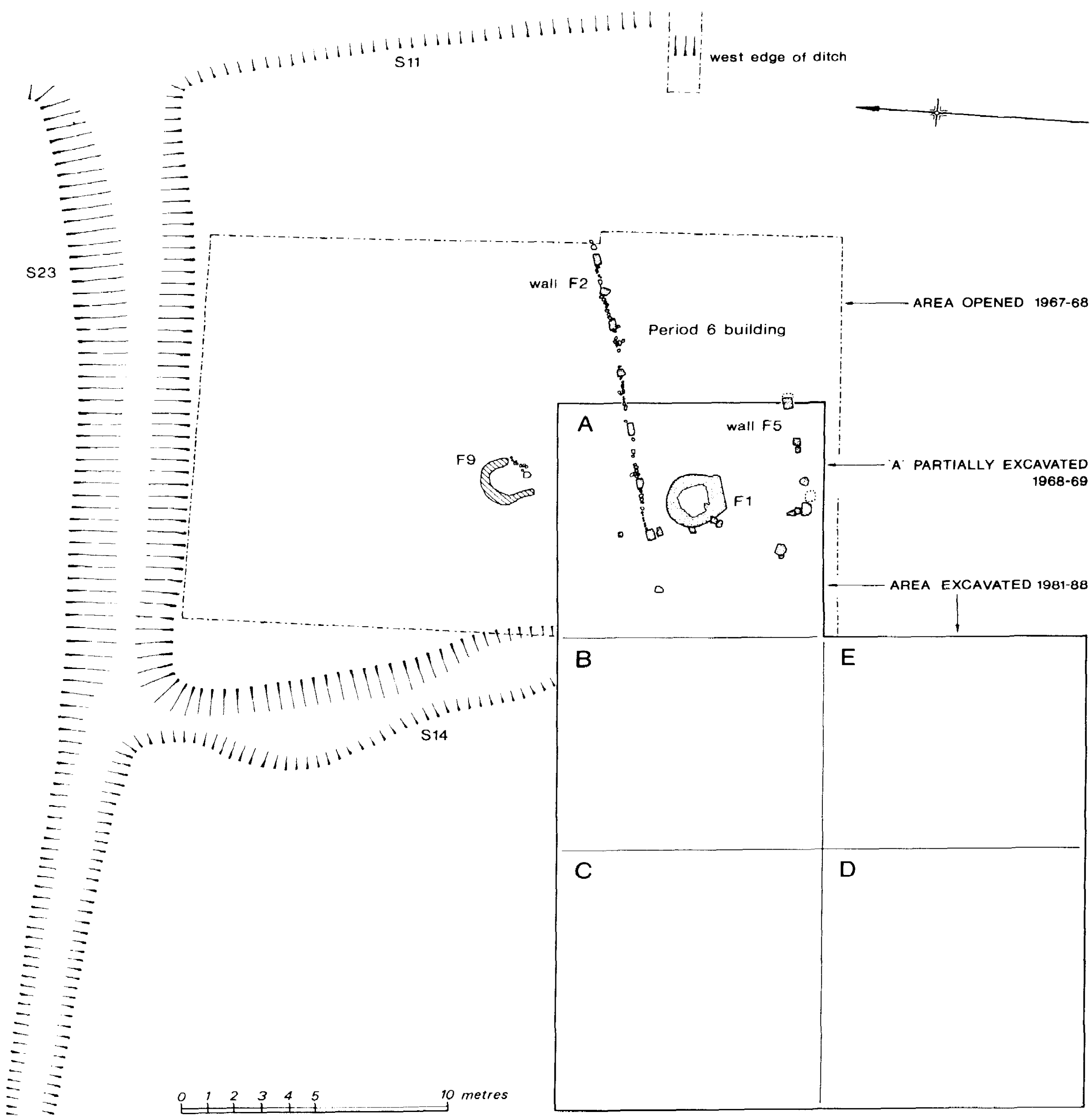


Figure 4 Mill (BAB): excavation areas

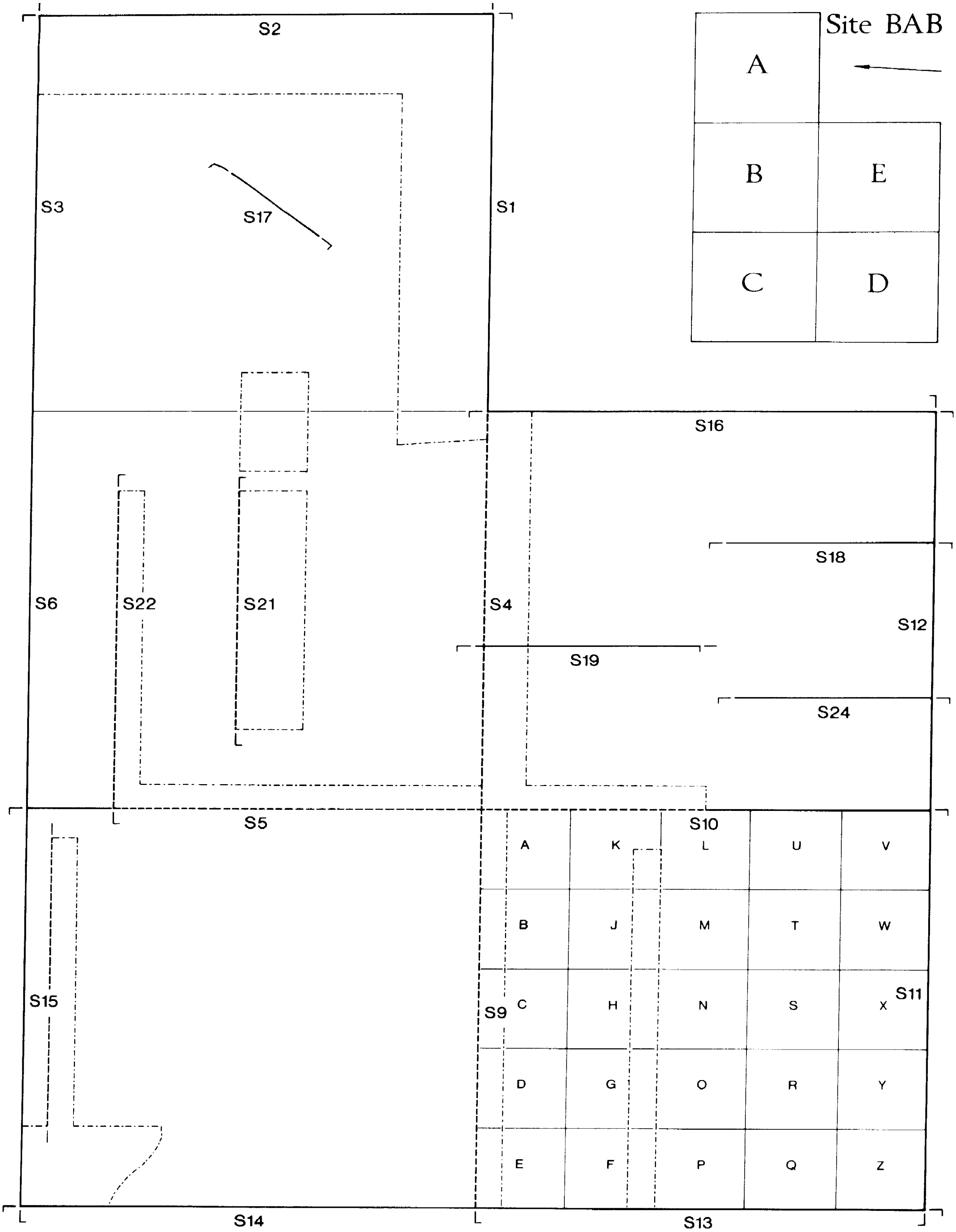


Figure 5 *Mill (BAB): area excavated 1981-8, showing recording grid and sections, and the location of trenches used to sample the pre-monastic (period 1) stratification*

could have made the layers easily distinguishable. After the 1986 season the surface of the (period 2) platform was left exposed to weather over winter; this procedure effectively demonstrated the existence of robbed postholes which otherwise would have been difficult to recognise. A similar problem existed in many parts of the site as regards the immediately pre-monastic ground surface.

The partially waterlogged levels could be misleading, especially if one part of a layer was permanently under the water table and another was not. The colour difference and texture between the two parts was sufficiently different to the archaeological eye to be classed as two separate contexts whereas to the soil scientist the discrepancy was the result of the lower part being permanently, and the upper only partially, under water.

The differences between the building and its platform, on the one hand, and the mill race, on the other, were of course also reflected in the state of preservation of the finds. Most finds, but most noticeably the metal, wood, and leather, were well preserved in the race but very fragmented in and around the building (see below, Biek, The nature and condition of the metalwork'). The relative dearth of finds from the building may reflect the poorer conditions for preservation, but it may also indicate that the building and its environs were not used for the deposition of rubbish.

The difference between the two parts of the site was further emphasised by the later use of the site. The period 7 drains effectively severed the stratigraphic connection between building and mill race. In addition, some of the building stratification in the south appears to have been lost through slumping after the (postulated) wooden revetment of the wheel pit had either rotted or been removed. The best indication of this was the way the large hearth of period 6 (E764) as found sloped down towards the wheel pit at an angle which would have made it impossible to use. These events have made it difficult to relate the building sequence to that of the mill race.

The stratigraphy, report structure, and interpretation

The chronological scheme proposed here correlates major changes to the tail race with similar changes in the building. Thus, for the monastic occupation, a period represents a grouping of all the evidence for the construction, use, and disuse of a particular mill. The first (period 3) tail race, for example, is associated with the first building on the site which had the right relationship with the tail race to be a mill. The association between building and tail race of period 3 was confirmed by the very close dendrochronological dates for the two parts of the site. Of course, the felling dates can only provide a *terminus post quem,* but the dendrochronological dates for the period 4 tail race are consistently only a dozen or so years later than those for period 3, which would suggest that the period 3 dates are reliable.

The association of building and tail race becomes more difficult in periods 5 and 6 because there is only a limited amount of independent dating. In addition, the extensive evidence for alterations in the period 5 tail race was not matched by significant changes to the period 4 building. In period 6 the renovations of the building have been grouped together in one phase of activity (phase 2) and this has included changes to the wheel house because these all seemed to be of a similar character.

To avoid repetition, the discussions of the stratigraphic sequence and the structural remains assume that the excavated structures and associated earthworks are the remains of a sequence of watermills. While it is hoped that the reader accepts this interpretation, it is worth setting out the considerations which justify the watermill interpretation. Firstly, there is the evidence of the topography as shown by the surviving earthworks and excavation. The triangular arrangement of three broad banks in a low part of the Arrow valley has suggested to many that these were created in order to store water to power a mill. The excavation at the neck of the triangle has demonstrated that a channel issued from the triangle and on the northern side a platform had been thrown up, presumably with material won from digging the channel, upon which was constructed a series of timber-framed buildings which faced the channel. The well-preserved timbers in the channel indicated that it was divided into three parts, the first and third parts of which appear to have been designed to achieve a flow of water from the triangular pond; this interpretation was also confirmed by the water-deposited sediments which filled the channel. Lastly, there was an assemblage of finds which can only have been derived from mill machinery - a wheel felloe, paddles, ‘cogs’, and stone bearings.

What follows is a summary presentation of the results of excavation (by period); the evidence recovered is expressed in more detail in the stratigraphic tables (Tables M1, M8, M10, M11). The plans (BAB, Figs 6-19) are simplified: the intention is to show the various periods of building, in construction and use; the numerous dumps of material to level up floors, for example, are not included. To avoid confusion the context numbers of the constituent parts of the timber tail races are included on separate plans; these will also be found on the detailed drawings of the tail race structures (Figs 33-7). In order not to overload the text or drawings with context numbers when several numbers refer to the same or equivalent context, one number is used (the highest, usually, E number) followed by '...'; this convention is also used on the sections (Figs 20-30). In Figure 23 sections 4 and 9 and sections 5 and 10 have been rearranged to give continuous sections through the mill building. The full list of all the constituent contexts will be found in the stratigraphic tables under the number quoted in the text.

Summary of chronology

Period 1 prehistoric to mid-twelfth century AD

Pre-monastic activity. Three phases of anastomosing channels separated by extensive sedimentation. Seasonal use of a more open valley in phases **2** and 3, from the first or second century AD.

Period 2 mid-twelfth century

Initiation of Cistercian abbey complex: ground clearance; a platform was raised on top of which an earthfast building, a ?workshop, was built.

Period 3 later twelfth century

Construction of water channels, platform, and earthfast structures of watermill. Occupation and disuse of mill caused by a fire.

Period 4 late twelfth to early fourteenth centuries

Demolition of period 3 building, wheel house, and tail race; abandonment of bypass channel. Construction of new padstone mill building and realigned wheel house and tail race.

Period 5 early fourteenth to ?mid-fourteenth centuries

Replacement of period 4 wheel trough and tail race. Later shortening of tail race and rearrangement of tail race uprights. Period 4 building retained; large hearth replaced, but small period 4 hearth continued in use, until, after a phase of working, this was also replaced.

Butt end of north mill pond bank broadened. Area to north-east and east of mill gravelled over and a ?workshop constructed.

Period 6 ?mid-fourteenth to ?late fourteenth/early fifteenth centuries

Phase 1: reconstruction of period 5 wheel trough and tail race. Period 4 building retained, large hearth further increased in size.

Phase 2: wheel house demolished and ?replaced by a structure on the south bank. West wall of mill building replaced and new partitions added. Large hearth abandoned and the small hearth relocated away from the wheel house area; ?cessation of water-powered metalworking. In either phase 1 or

2 a new, enlarged workshop, perhaps a farriery, was built to the east of the mill.

Period 7 ?late fourteenth/early fifteenth century and seventeenth to twentieth centuries

Phase 1: abandonment and demolition of period 6 mill and workshop, followed by extensive flooding.
Phase 2: filling in of leat; drainage trenches.

The mill (BAB) stratigraphic sequence

Figures 20–30 (sections); Table Ml

Period I: pre-monastic activity, prehistoric to mid-twelfth century AD

Figure 6 (plan)

This period includes all the pre-monastic activity on the site. The information is more fragmentary than for later periods because the stratification was sampled (see above, 'Circumstances and methods of excavation'). The sequence consisted of stream beds, their fillings, and more extensive deposits of sediment. The following interpretation is based on an attempt to correlate features exposed in the different trenches. The correlation took into consideration similarity of profile of the stream beds and of their fills, and relative levels and gradients. The stream bed activity was interspersed by two phases when sediment accumulated over the whole site, effectively blanketing the earlier stream beds and fills. This allowed the water courses to be grouped into three successive stages. However, in some trenches the phases of widespread sedimentation were not separable because there was no evidence of intervening stream activity: for example, the sediments started to be laid down after the first phase of streams and continued to be deposited during phases 2 and 3 (eg E997). No evidence of stream activity was recovered from square D, the north part of which appears always to have been the highest part of the site.

The basic stratigraphic sequence is outlined by phase, first, and, second, the chronological evidence is reviewed.

Phase 1

The Mercian Mudstone ('marl' in Rahtz and Hirst 1976, 14), which comprises the upper part of the underlying geology, was only exposed in one place (E992). This was overlain by pebbles, which extended over much of the site (E967...). A dish-like cut, interpreted as either a pond or stream bed, had been made in the pebbles (E991). It was partially filled with organic debris, largely leaves and twigs (E971), and then with water-deposited pebbles (E993); it was then sealed by more water-deposited pebbles (E996...) (S16, S12: Figs 27 and 28).

At some time during the cutting and filling of E991, silts accumulated in the eastern part of the site (A1171) which were then cut into by a stream (A1192) flowing from west to east (S2: Fig 21). Its course was abandoned and started to fill with gravel and silt, which continued to be deposited to form a feature like a bank or ridge (A1172). The southern side of the bank was then dissected by a water course (A1180), which started to silt up (with organic material) (A1189). This in turn was cut by another stream (Al194); gravel and silts were then deposited in this stream bed and formed a bank similar to All72 (A1181). Silt continued to form over A1189 and the north side of the ridge (A1179). The southern side of the ridge was eroded by another stream (A1195) which silted up (with organic debris: A1188; A1164; A1187). The area south of the gravel bank A1172 was covered by a layer of silt (A1173), which appears to mark the start of a phase of sedimentation which can be traced over the whole site as a continuous layer of silty clay, a blanket silt,

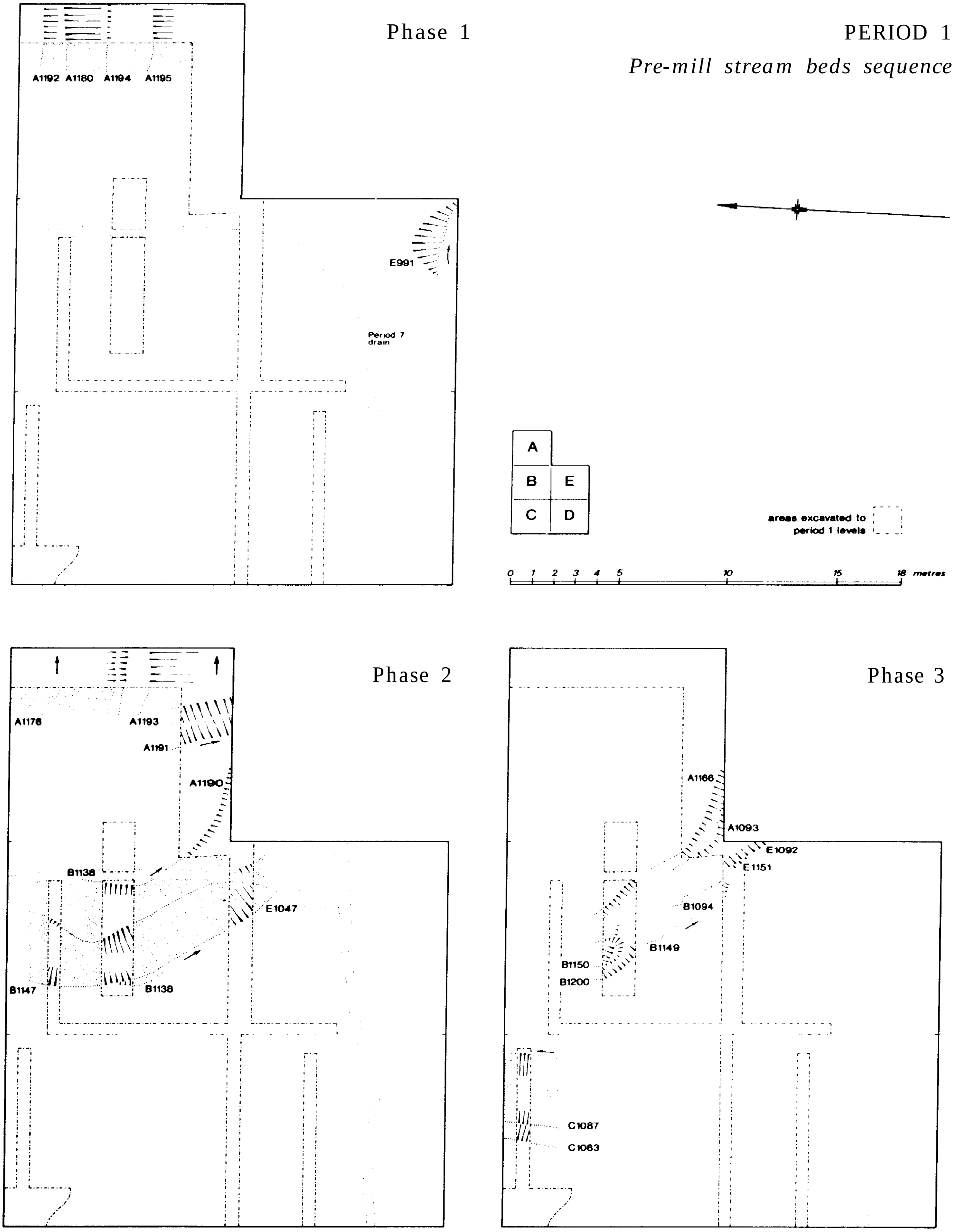


Figure 6 *Mill (BAB) period 1: pre-mill stream beds sequence*

Plaite 2 Period 1 phase 3 stream bed (E1151/A1166) with wood debris fill (E1152lA1168), from the west

which sealed all evidence of earlier activity (E1044...).

Phase 2

The second phase of water erosion and deposition was concentrated in squares A and B (S21, S22: Fig 25). A wide, curving stream bed was eroded into the blanket silt (B1138...), flowing north-west to south-east. In the eastern part organic debris accumulated on the bed (A1177), and then the whole course was filled with water-deposited pebbles (B1042...) and sealed by silts (B1041...; B1141...).

In square B a bank of water-deposited pebbles formed (B1140). which was later eroded on its east side by a stream (B1147) which also flowed through square E (E1047...). The stream bed was filled first with silts (B1142), wood fragments (B1139), and other organic material (B1145), and then by pebbles (E1046...).

At some time during this sequence a small stream eroded a channel into the first blanket silt (A1191), which in turn silted up (A1178) (Sl, S2: Figs 20 and 21). The blanket silt was also later dissected by two broader streams apparently flowing in parallel (A1176; A1193); both silted up (A1167; A1169).

The entire area was then covered by a thick (average 0.5m) layer of sediment which blanketed all the phase 2 features (E1036...).

Phase 3

During this phase of stream activity, the watercourses in squares A, B, and E re-established the north-west to south-east direction of phase 2. The first stream bed was broad and shallow (E1151...), and silts and woody material were deposited (E1152...) (Plate 2). In some parts of this old bed, there were signs of a new watercourse beginning to erode, but the cuts were not continuous (eg B1150) and it may be that two separate streams may have started to cut through the old stream bed on different alignments; the latter may be the preferred interpretation as the depth of the bed at the intersection of squares E, B, and A was substantial (E1092...). The watercourses silted up (B1136; E998...), but the larger also contained lenses of organic material (A1170).

Subsequently, a further stream (B1200) appears to have started to erode a channel into the, now old, stream bed B1150 (an equivalent channel was not located in any of the other trenches); it filled with silt that contained much organic material (B1132) (S21: Fig 25).

At some time during this final phase a stream flowed (south to north) through square C (C1083); it was filled with a silt that contained many fragments of wood (C10841 (SE: Fig 26). A more widespread deposition of silt in a layer *c* 0.40m thick (C1085) also appears to have occurred in this part of the site. A stream eroded a shallow channel into this silt (C1087) and this channel was in turn later filled with organic material in a silt matrix (C1086). While the watercourses had shifted west (into square C), it is possible that a phase of extensive sedimentation took place over much of square A, as shown in the lower levels of the sediments A82 and A1162.

Discussion

This extensive evidence for pre-monastic change and activity in this part of the Arrow valley was unsuspected prior to the 1980s excavation: none of the earthworks in the eastern part of the precinct relate to this period. It also demonstrates that the earthwork meanders of the course of the River Arrow soon after the foundation of Bordesley Abbey (Aston and Munton 1976, 30-1, 33) do not reflect the earlier character of the valley.

The complicated sequence of channels, banks, and sedimentation owes little to direct human intervention. The profile of the channels, the water-deposited character of the fills, and the prolific organic deposits of what appears to be drift wood would all point to extensive fluvial activity. It is extremely difficult to interpret conditions within the valley from such relatively small excavations. However, the evidence is consistent with a valley where water flowed in an irregular network of channels - anastomosing channels - rather than in a single course (as suggested by the earthwork evidence mentioned above). These anastomosing channels are not necessarily connected with flood conditions, but reflect the ‘normal’ condition of a valley in one particular, low-energy, stage of its development; the migration of channels and gravel banks are other, typical, features (cf Brown 1987 and 1991).

The shift in the location of the streams, whereby a new water system is created, can be a result of either a gradual migration or a more dramatic shift, or avulsion, which is often the result of flooding. Beavers may also have caused channels to shift by the construction of dams, although little evidence for animal marks on the wood debris was noted. There is a tendency for sediment to build up in the vicinity of the stream courses and thus to raise that area in relation to the rest of the valley. Such a development of relief would eventually encourage a movement of the streams to the lower parts of the valley. In the light of these characteristics which are normally associated with the development of anastomosing channels, it may be appropriate to interpret the two layers of silt which separated the three phases of stream beds as indicative of times when the channels shifted to another part of the valley. Thick layers (up to 3m) of post-glacial alluvium have been noted in the Arrow valley; they are often underlain by bedded sand and gravel, although there is considerable variation over the length of the valley (Old *et al* 1991, 52).

Although the evidence for numerous stream beds indicates a great deal of change within a relatively small area, it should be remembered that the sequence probably developed over a long time, and is thus likely to be less dynamic than it first appears. It is appropriate to consider the dating evidence. None of the pre-monastic material has been scientifically dated. The diagnostic pieces in the (residual) flint assemblage are of late Mesolithic/early Neolithic date (pers comm J Richards). The stratigraphic sequence, however, has produced a relative chronology, and some elements contained material which may provide a very general dating. Plant macrofossils, for example, are often inadequate for dating purposes, but the botanic evidence shows a change in environment from a mixed oak and lime woodland in phase 1 to a more open alder woodland in phase 3. As Carruthers notes (see below, part II, The valley environment ...‘). the phase 1 assemblage could have occurred at any time from the Atlantic onwards, but comparison with other botanic sequences from the West Midlands might hint at the Bronze Age, although no reliance can be placed on such an analogy. Shotton has drawn attention to a sequence of alluvium and gravels in the Arrow valley at Ipsley. He interpreted the uppermost alluvium as a relatively sudden deposition which was the indirect result of widespread ploughing after forest clearance, perhaps during the Bronze Age (Shotton 1978, 29).

Two sherds of Roman pottery, probably of the first or second century AD, were recovered from the fills of two stream beds (Al 190; A1191), both interpreted as phase 2 features. The sherd from the fill of A1190 was found with two worked flint flakes, which were probably residual (FL 145; FL 147). Is there a possibility that the sherds were also residual? This is less likely because neither sherd was abraded or waterworn, and because pottery of a similar date was recovered from later, phase 3, features. Eight, large and unabraded sherds (including three of Severn Valley ware) were found in the fill (B1137) of channel B1149, and a further ten sherds, including some of a carinated jar, were recovered from a later channel fill (B1132). All of this phase 3 pottery is dated to the first or second century AD.

The similarity of the pottery coming from phases 2 and 3 may indicate that the succession of phase 2 channels, the second blanket silt, and the majority of the period 3 channels took place over a relatively (in this context) short time, perhaps a maximum of 200 years. This is in contrast to the (presumably) lengthy sequence of phase 1. It also implies that, because the Roman pottery occurred in the fill of one of the latest channels, there was little riverine activity - either erosional or depositional - in this part of the valley during the late Roman and Saxon periods.

A much larger amount of Roman pottery (202 sherds) of a similar date was found in demonstrably medieval layers, often dumps of material that must have been dug from nearby, if not from within the area excavated. This is strong evidence for Roman occupation in the vicinity, but not necessarily on the valley bottom. The period 1 sherds merely demonstrate that some of the channels were used for dumping rubbish. Indeed, the watery and ill-drained character of the valley may have militated against permanent settlement. It may be more appropriate to think of settlement on the valley sides or on the higher areas nearer the eventual site of the church. Small quantities of potentially Roman material (such as tile) have been recorded from other parts of the precinct (Wright 1976b, 172; Hirst *et al* 1983, 29). Given the more open environment of phase 3, the valley may have been used seasonally, perhaps as summer pasture. A single charred oat grain from A1170 might indicate Roman cultivation in the vicinity. The few animal bones from period 1 were mainly cattle from phase 3.

While there was little sign of direct human activity before the twelfth century, there is some indirect evidence for all phases of period 1. The gradual removal of the phase 1 oak and lime woodland and its replacement by a more open, damp landscape with alder indicates a growing intensity of use. Worked pieces of wood, often in the form of offcuts or chippings, have come from phases 1 and 2 (A1179, OB 406; A1178, A1177, OB 405, OB 400, OB 404) as well as phase 3 (A1168, OB 403; A1170, OB 401), and charcoal came from a phase 2 context (B1143).

Period 2: ground clearance, platform, and pre-mill structure, mid-twelfth century

Figure 7 (plan)

To judge from the areas which had been sealed by later dumps or platforms, the ground surface immediately prior to the abbey's foundation appears to have been fairly level with no open stream beds. It did, however, need to be cleared. Two large areas of tree roots, identified as of alder (see below, part II, Carruthers, The valley environment . ..'), were found to the south, in the south of squares D and E (D1159, E1201) (S11: Fig 28; Plate 3). All these roots had been cut off at one level, as if the trees had been felled, the stumps removed and then the roots trimmed. The level at which the roots survived at El201 probably indicated the contemporary ground surface, especially as the levels preserved under later platforms matched that at E1201. The small diameters of the roots at D1159 would suggest that the rest of the trees had been cut away, probably indicating that the contemporary ground surface had been removed at the same time. This is to be expected, for part of the D1159 group was located in the bottom of the head race where alluvium had clearly been dug away. Other roots, on what was to become the south mill pond bank, were about 0.30m below the level of the contemporary ground surface established on other parts of the site. The smallness of the roots and the lower level at which they were found would imply that the ground surface in the southern parts of the site was lowered prior to the digging of the first (period 3) mill race.

The tree felling was accompanied by the burning of some of the wood, as shown by quantities of charcoal found in a small pit (E994), but some trees, especially the stumps, were dumped into a large pit found in the north-east corner of the excavation (C1077). This pit was probably dug to help drain the site, but it was soon filled with the debris from ground clearance and trimmings, perhaps from on-site woodworking (C1075...) ($15, S16: Figs 26 and 27).

A central area of at least 147m^2 was raised, between 0.55 and 0.65m, to make a platform (E1043...) by dumping alluvial clay (S4, S5, S10, S14: Figs 20, 22, 24). The clay may have been gained from the lowering of the southern parts of the site. The bounds of the platform could not be precisely defined. To the east, for example, the platform merged imperceptibly into the alluvial clays deposited during phase 3 of period 1 (A82). To the west, a thin layer of platform material had been spread over a large part of square C (C189).

There is some evidence that a building was erected on this platform. During excavation it was difficult in some places to distinguish between this, period 2, platform and the period 3 heightening, and in some cases the invisibility of the sides of holes in which the bases of posts survived meant that they could have been of either period 2 or 3. However, in the eastern edge of square C it was possible to distinguish the stratification more clearly.

The existence of a building in period 2 hinges on three postholes (C1060; C1012; D589), which were clearly cut from the top of the period 2 platform, and whose fills were sealed by the period 3 platform. The holes were between 0.60 and 1.0m in diameter and a collection of pieces of wood survived in the bottoms; these acted as pads or supports for the upright posts; one piece from D589 was part of a structural timber which had been discarded (OB 367.2: Fig 31). The posts had been dug on the western edge of the period 2 platform; they were in line and were *c* 1.8m apart.

Four groups of roughly worked timbers (B542; B545; B1101, the only one with traces of its hole; B1118) were found within the period 2 platform, on its northern edge, close to the sealed, old ground surface. These timber settings were in line, at right

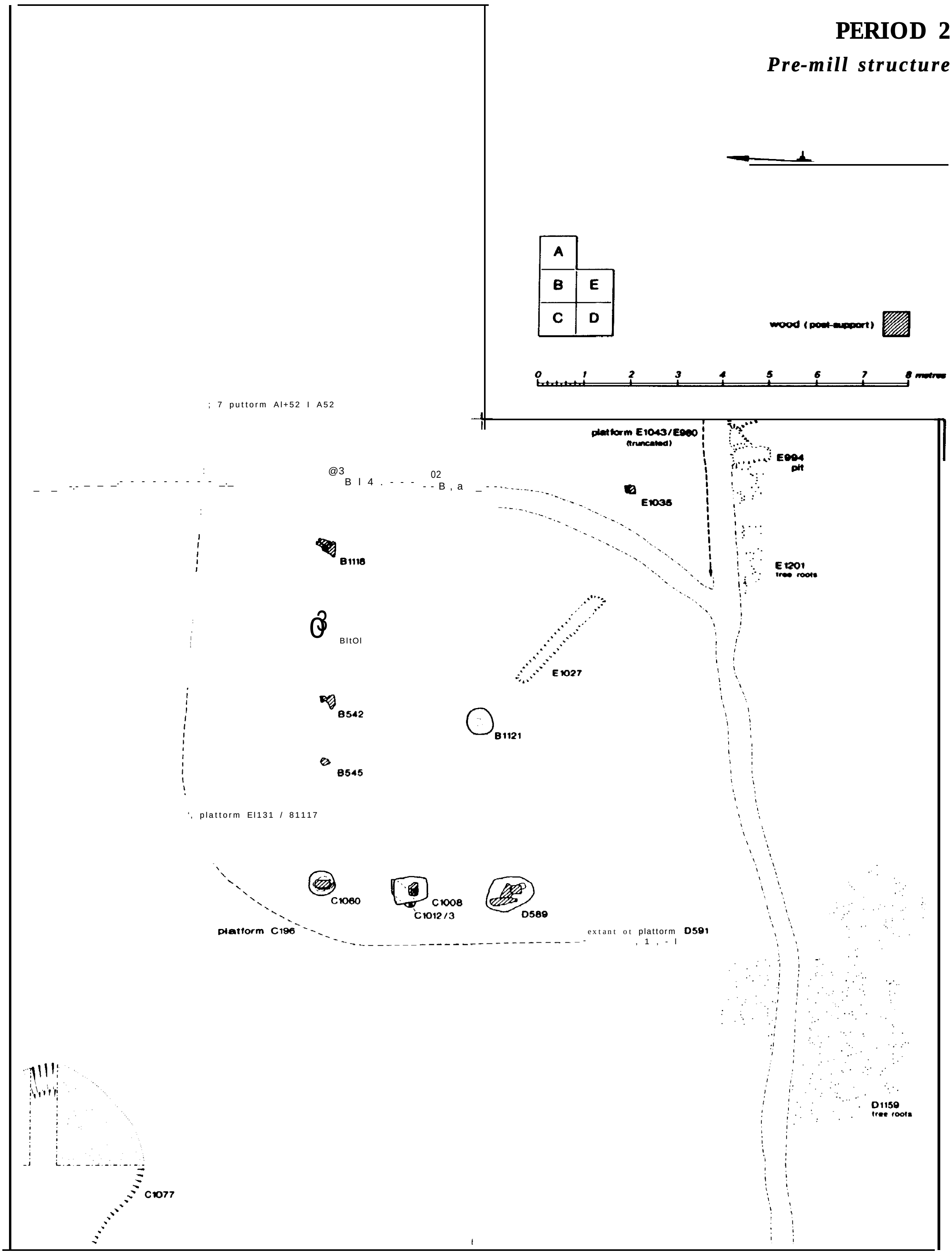


Figure 7 *Mill (BAB)* period *2: pre-mill structure*

angles to, and approximately at the same level as the timbers in the bases of the definite period 2 postholes. They were also each 1.7 to 1.8m apart. It is, therefore, likely that they represent the supports of upright posts, which, with the three postholes (C1060; C1012; D589), formed a building. The bases of three, squared timber uprights (B148; B133; E1035) (two of them in postholes: B131; B132) were found in the bottom or sides of a period 7 drain. It is thus difficult to date them, but they have been included here as the potential supports of an east end to the period 2 building because they were aligned and had a comparable spacing to the timbers to the west and north. They were not, however, supported on timber pads.

A further argument for assigning these timber pads to period 2 rather than 3 is that their spacing was completely different from that of the major uprights of the period 3 structure, and could not be made to match.

It is, therefore, probable that an earthfast building was erected on the period 2 platform. It had a minimum length of 10m and width of 6.25m. There was no obvious evidence for internal supports, although a slot-like feature was found (E1027), but, as it was not aligned on any wall, it may only mark the position of a discarded timber; a central shallow posthole was also found (B1121). The more substantial character of the timber supports in the two larger holes at the west end (C1012; D589) may argue that they supported the gable roof truss (see below, part III, Walsh, 'Reconstructions of the mill (BAB) buildings'; Fig 110). The absence of a post between B3545 and C1060 may mark the site of an entrance.

It is difficult to suggest the function of such a structure for there was very little associated stratification. However, given the evidence for clearance in period 2, it might best be interpreted as a workshop or store, that was used by the labourers and builders during the clearance operations for, and the construction of, the period 3 watermill. It was not an ephemeral structure - one of the posts was replaced (C1008) - nor a makeshift construction (see below, part III, Walsh, 'Reconstructions of the mill (BAB) buildings'; Fig 110), but equally the absence of occupation layers may argue for a relatively short period of use or one which left no domestic residues.

Another possibility is that the structure may have been the first watermill. The best evidence for this interpretation is that one of the baseplates of the period 3 tail race had structural features which were redundant, suggesting it may have been reused, but Allen does not regard this as unusual in the context of the rest of the period 3 assemblage (OB 207: p 83). There are also stronger arguments to the contrary. The building, in comparison with the period 3 structure, was not built to withstand the stresses imposed by mill machinery. Further, there were no residues associated with either corn milling or metalworking. Perhaps most significant of all, there was no sign of cuts, pre-period 3, in which to insert a wheel frame or tail race. The period 3 race structures were in the wrong position to be used with the period 2 building. There was also insufficient vertical distance between the base of the period 3 wheel pit (assuming it reflects in some way any possible period 2 wheel pit) and the top of the period 2 platform to allow a vertical water wheel of any sensible size to rotate.

The dating of this phase is difficult because of the total lack of floors or work surfaces associated with the building; consequently there is a small material assemblage for this period. The pottery is not conclusive. 86 sherds were recovered from period 2 contexts and 36 of these were residual Roman wares. The majority of the medieval pottery is from cooking pots in a red-brown sandy ware (37 sherds); this fabric group has affinities with pottery from Alcester which is dated to the twelfth and thirteenth centuries (see below, part II, Nailor, 'Pottery'). Most of the pottery was recovered from the clay used to build the platform. Because the surface of the platform remained exposed throughout period 2, and also probably during the initial, construction phase of period 3, it is possible that some of the pottery was incorporated into the platform in period 3. However, the large proportion of Roman pottery suggests that the platform material was brought on to site with some pottery - both Roman and possibly medieval - already in it. Nevertheless, the red-brown sandy fabrics in the fill of a posthole (D588), which was clearly of period 2, need not be residual, and so this pottery could be contemporary with the construction of the building.

The most reliable dating comes from a dendrochronological determination of an upright (B538/ OB 410/Q7664) of the period 3 building which had been seated in a pit which cut through the period 2 platform. The post had retained all its sapwood and was felled between the autumn of 1175 and the spring of 1176 (see below, part II, Brown, 'Dendrochronological analysis'). The large size of this timber (*c* 0.50m wide) is so unlike the (much smaller) size and character of the period 2 posts that it is improbable that it had been retained from period 2 and reused in period 3. Because it is thought that the Bordesley timbers were used green (see below, Allen, 'Woodworking techniques'), it is therefore likely that the period 2 building had a *terminus ante quem* of *c* 1176.

The dating evidence for the beginning of period 2 is more circumstantial. Nailor considers that red-brown sandy ware, found in a posthole of the building, started to be used in the third quarter of the twelfth century (see below, part II, Nailor, 'Pottery'). The clearance character of the occupation would suggest that it is appropriate to place period 2 in the early phases of the monastic occupation of the valley. Bordesley was founded in *c* 1140 and there is evidence for a massive building programme soon after, which may have been associated with the major drainage operations (Astill and Wright 1993, 130-l). It is possible then to think of period 2 as starting within the lives of the first generation of monks, say *c* 1150, which would mean that period 2 lasted for about 25 years. However, the paucity of archaeological material might argue for a shorter time. The first, period 3, mill also had a dearth of finds and it is possible that it was built, used, and abandoned in the space of about a dozen years; period 2 may have lasted for an even shorter time.

Period 3: watermill, later twelfth century

Figures 8 and 18 (plans)

The sequences for the four mills (periods 3-6) are presented in the same way, Each period accommodates the construction and occupation of a mill. In each period the stratification of the mill race has been severed from that of the associated building by the deep, post-medieval (period 7) drains- Correlating the evidence for the period 3 mill is less difficult than for the subsequent periods because the construction of the first mill should mark a pronounced change in the character of the archaeological record, especially if, as seems likely, the mill was the first major occupation of the site after ground clearance (the character of the period 2 building, and the reasons why it was not a mill, are discussed above).

The mill race

Figures 9 and 10 (plans)

The constructional sequence of the mill race will be presented first because it appears to have been the first stage of the building programme, assuming that the material for the raising of the building platform and the mill pond banks in period 3 was obtained from the excavation of the water channels (S11, S13: Figs 28 and 24). Stratigraphic evidence shows that the wheel pit was dug before the tail race trench, and it is clear that work started with the excavation of the head race, which would have made the establishment of an acceptable gradient along the channel easier and prolonged the use by the workforce of the period 2 workshop on the adjacent platform to the north.

A channel *c* 3.0m wide and 0.30m deep was excavated in the clay silts (D500) for the head race (Plate 3). The silts were probably piled up to the south and to the north to create the butt ends of the mill pond banks (D221...; D340). The sides of the banks may have had a stepped profile. The bank end D340 and the surviving timber baseplates (D319; D330) for the revetment of the south side would give a minimum height for the bank at that point of *c* 0.5m, but the great depth of derived bank material (D341) that accumulated over the bank end D340 after the site was abandoned in period 7 would confirm the earthwork evidence that the bank increased in height just to the south of the excavation edge. The original profile of the north bank of the head race was destroyed in period 7.

Shallow foundation trenches (D1158; D328) were cut at the base of the south bank in which the side revetment timber baseplates were laid (D319; D330) (Plate 4). The north side was probably the same. The alignments of the south revetments and of the surviving north bank show the head race to have been funnel-shaped in order to direct the water on to the water wheel. To the west of the revetment planks, in what was the neck of the mill pond, the south bank was revetted by a series of stakes (D502-D506) driven into the channel side, which would have had wattles woven between them.

A trench (D1088) was cut across the bottom and into the side of the head race channel midway along its length; in this trench a large baulk of timber (D227/D228) was laid. This is interpreted as a baseplate for the planked floor of the head race. To the west a baseplate (D312/D313) of a similar size was laid and this, with the morticed upright (D333), probably also supported a debris grill, an interpretation which assumes that the period 6 arrangement, which had a grill, repeated that of the previous periods. No foundation trench survived because it was probably destroyed when the baseplate was shifted in period 4. The baseplate D312/D313 was supported midway along its length by a post (D225) which had been set in the bottom of the channel (posthole D1089). A rebate on the downstream top edge of baseplate D312/D313 was probably matched by another on the badly damaged baseplate D227/D228; these would have supported planks of the head race floor (Fig 33).

Access from the bank to baseplate D313, perhaps for repairing or freeing the grill, was provided by a gap in the south side revetment (D330), in which had been laid a block of timber (D331), which is interpreted as a step (Plate 27).

To interpret the east end of the head race it is necessary to extrapolate information from the better-preserved period 4 arrangement because it appears that some period 3 timbers were reset at that time.

The eastern end of the head race was apparently marked by a large baseplate (D318/E271), set in the bed of the head race, which probably supported a sluice gate (Figs 9 and 33). It would have been placed in a foundation trench dug into the period 2 building platform (to the north) and the pre-mill ground surface (to the south) as well as the bottom of the head race. (The period 3 trench must have been at approximately the same depth as the surviving period 4 trench because it would have left some trace if it had been lower and it could not have been much higher without preventing the flow of water through the head race).

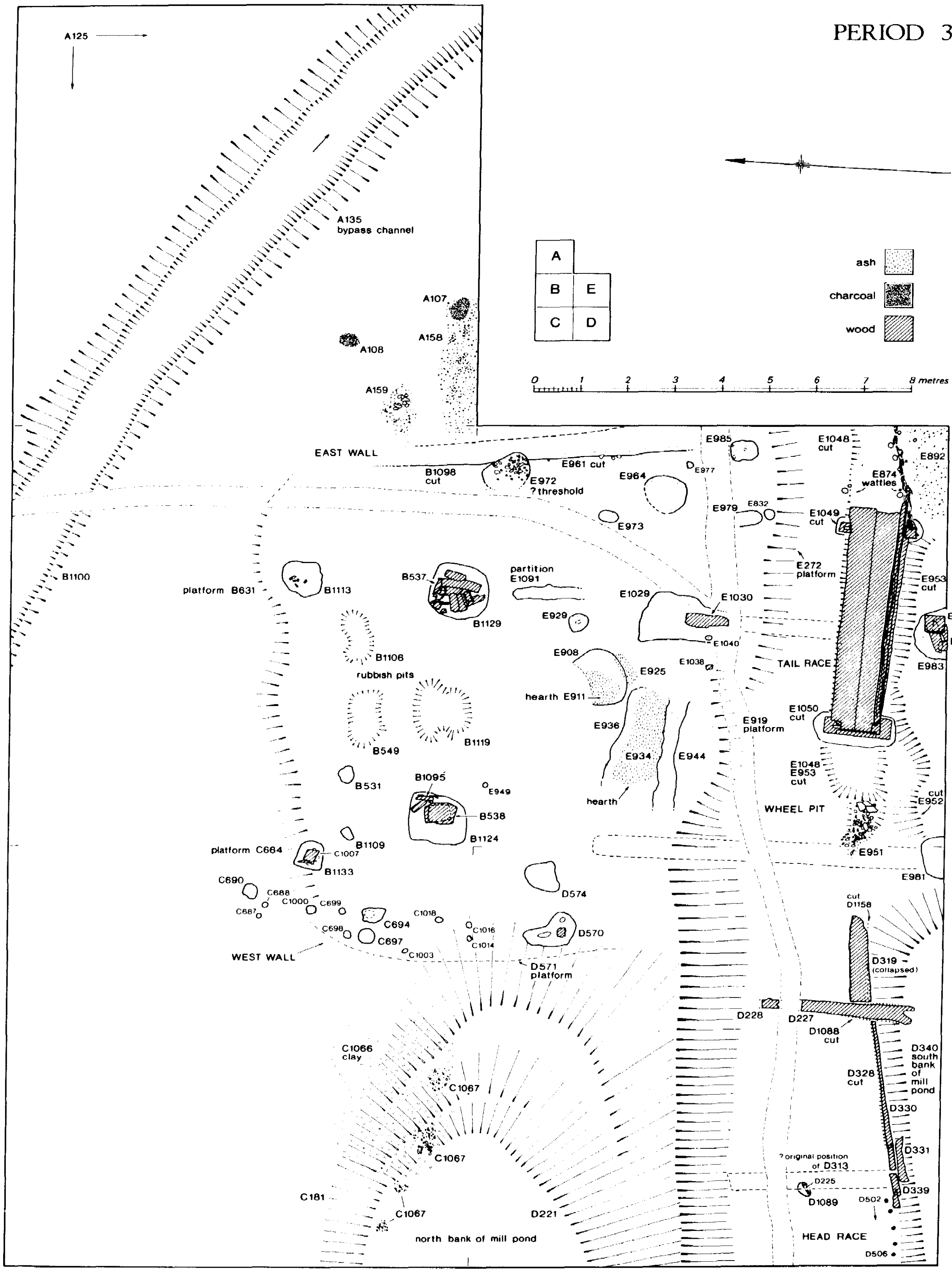


Figure 8 Mill (BAB) period 3: mill

Plate 3 The period 3 mill channel, from the east. The alder roots (D1159), trimmed in period 2, can be seen at the top (west)

The head race would thus have been founded on three, equally spaced (north–south), large baseplates which would have supported a planked floor and taken uprights to hold the revetted sides and a grill and sluice. The eastern baseplate would also have provided a – western – foundation for the wheel house (see below and Fig 9).

The channel dug for the head race was continued, first for the wheel pit and then for the tail race; the cut for the north side had mainly been destroyed by the period 4 alterations (S10: Fig 22). The base of the wheel pit (E952) contained fragments of wood and grey clay (E951), the residue from the construction of the head race structures. Both wood and clay were truncated by the channel (north E1048; south E953) dug for the tail race and this was about 0.9m lower than the head race channel. The alluvial clay sediment was entirely removed to expose the surface of the pebbles which overlay the Mercian Mudstone; the clay spoil appears to have been piled on top of the period 2 platform (see below). These excavations thus produced a shallow gradient for both head and tail races (Plate 5; about 1 in 200 and 1 in 100 respectively when commissioned) with a relatively steep drop (of about 1 in 3) in between (see below, part III, ‘Gradients’).

In the south-east corner of square E, the clay (E816) which formed the south side of the tail race channel was partially dug into to create a platform-

PERIODS 3-4

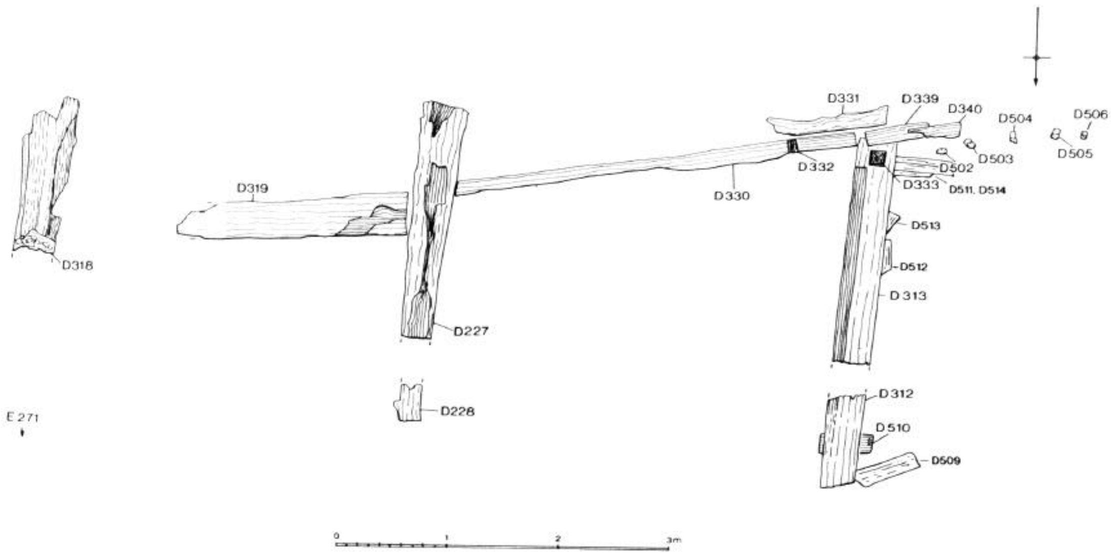


Figure 9 Mill (BAB) periods 3–4 head race

Plate 4 The period 3 mill race, from the west. The baseplates for the south side of the head race (right: D319; D330) and those for the head race floor (nearest D312/D313, repositioned in period 4; D227/D228) are in the foreground

Plate 5 The period 3 mill race, from the east, with head race at the top, wheel pit in the middle, and tail race (with north side missing) at the bottom

PERIOD 3

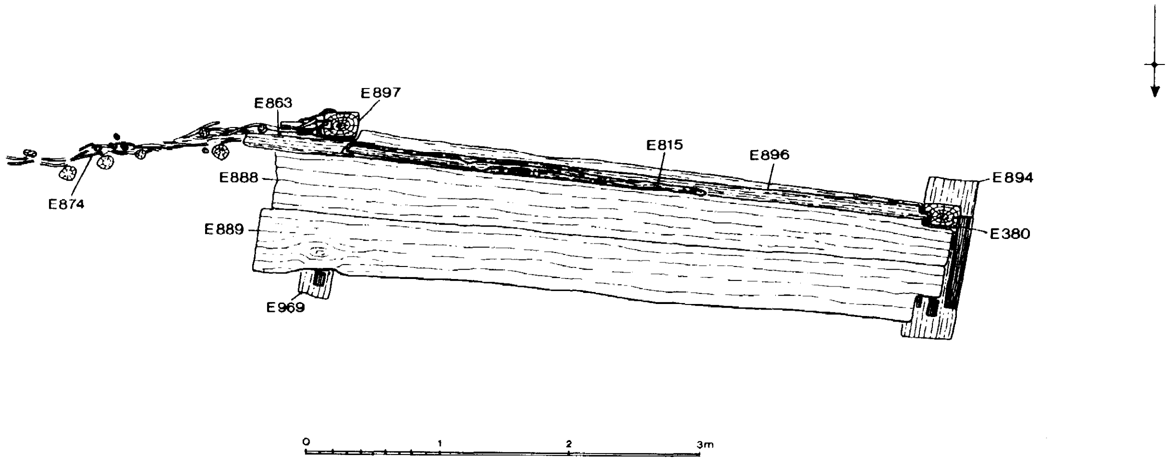


Figure 10 Mill (BAB) period 3 wheel trough and tail race

like feature the same length as the timber tail race (S12: Fig 28).

Two slots (E1050; E1049) were cut across the tail race channel and in each was placed a baseplate (E894; E969). Four uprights (only two of which, E380 and E897, survived *in situ)* were then morticed into the baseplates; two large planks (E888; E889) were then laid east-west on top of the baseplates to form the base. The south side of the tail race was constructed of three horizontally laid planks (Plate 6). The western ends of the bottom two planks (E863; E896) had tongues which were inserted into the groove in upright E894 and the eastern ends were laid (and in the case of E863, pegged) against the north face of upright E897. The top plank (E815) was badly preserved and there was no evidence of attachment. The north side of the tail race was destroyed by the period 4 alterations, but the construction is assumed to be similar to that of the south side (Figs 9 and 33).

The tail race continued east of the timber channel (on the south side) as a wattle revetment of willow (E874) (S12, S16: Figs 28 and 27; Plate 7). The fence uprights were stakes driven into the pebbles and the western rod ends of the southern fence were secured in a groove in the side of upright E897. The area behind (south of) the south fence, which had been previously dug away, was backfilled by dumps of clay (E898; E893) which contained substantial pieces of wood (E956) which were presumably the residue from the construction of the tail race. Pebbles were then laid over the reinstated area as a hardstanding (E892). The space between the sides of the tail race and the channel was also backfilled with dumps of mixed clays containing wood fragments (E898; E899; E740).

The wheel house

Two postpits (E981; E983) were dug into clay E816 to the south of the wheel pit and tail race (S11, S12: Fig 28). The eastern postpit (E983) contained the remains of a timber upright (E957) which rested on a pad of timber pieces (E987; E988; E989); the western postpit (E981) had been robbed in period 4 (E982). These two pits would have contained the southern uprights of the wheel frame and house. The configuration of the south side of the channel was arranged so that the butt end of the south mill pond bank stopped just to the west of the wheel house, which allowed easy access to the wheel house for the maintenance and repair of the machinery without the need to scramble down a bank.

Pit E1029 also contained a horizontal baulk of timber (E1030) which probably straddled the tail race and was jointed to the post E957 to the south of the tail race. A similar baulk to the west (which did not survive) would have been jointed to the post set in pit E981. This arrangement is interpreted as the foundations for the wheel frame and house.

The platform and mill building

The absence of the uprights from most of the period 2 pads and postholes would suggest that the period 2 workshop was dismantled. A robbing hole (B150) for post B148 was cut from the top of the

Plate 6 The south side and base of the period 3 tail race, from the north

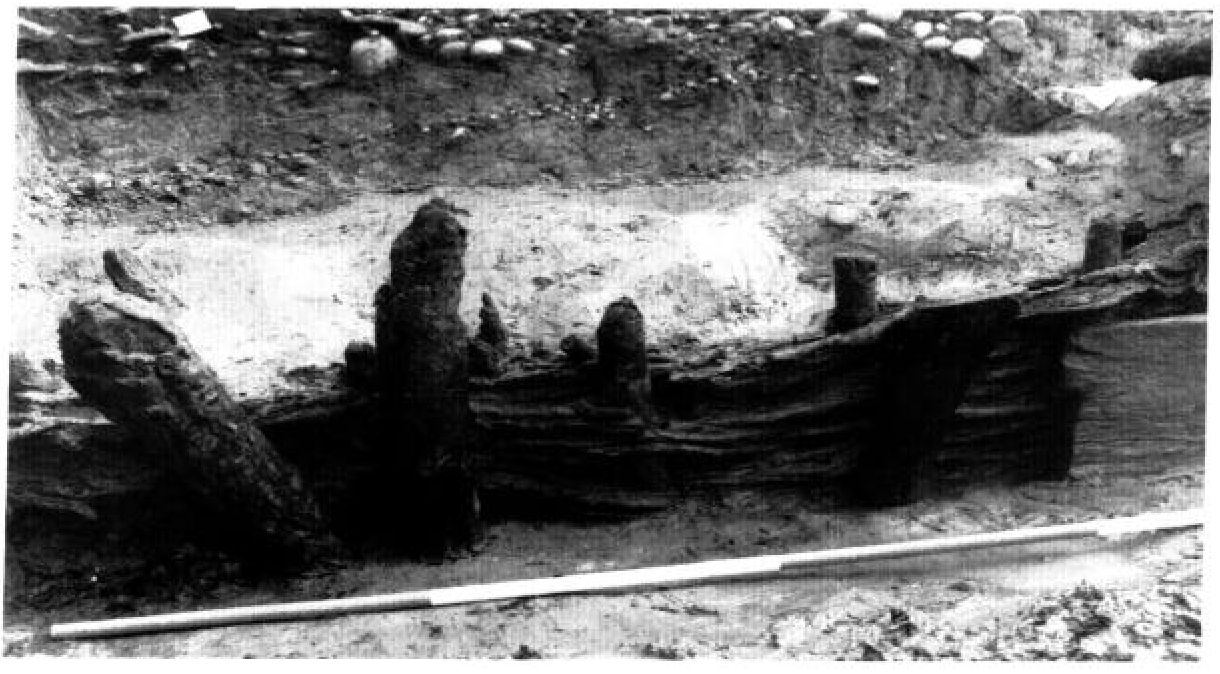


Plate 7 Wattle revetment east of period 3 timber tail race, from the north

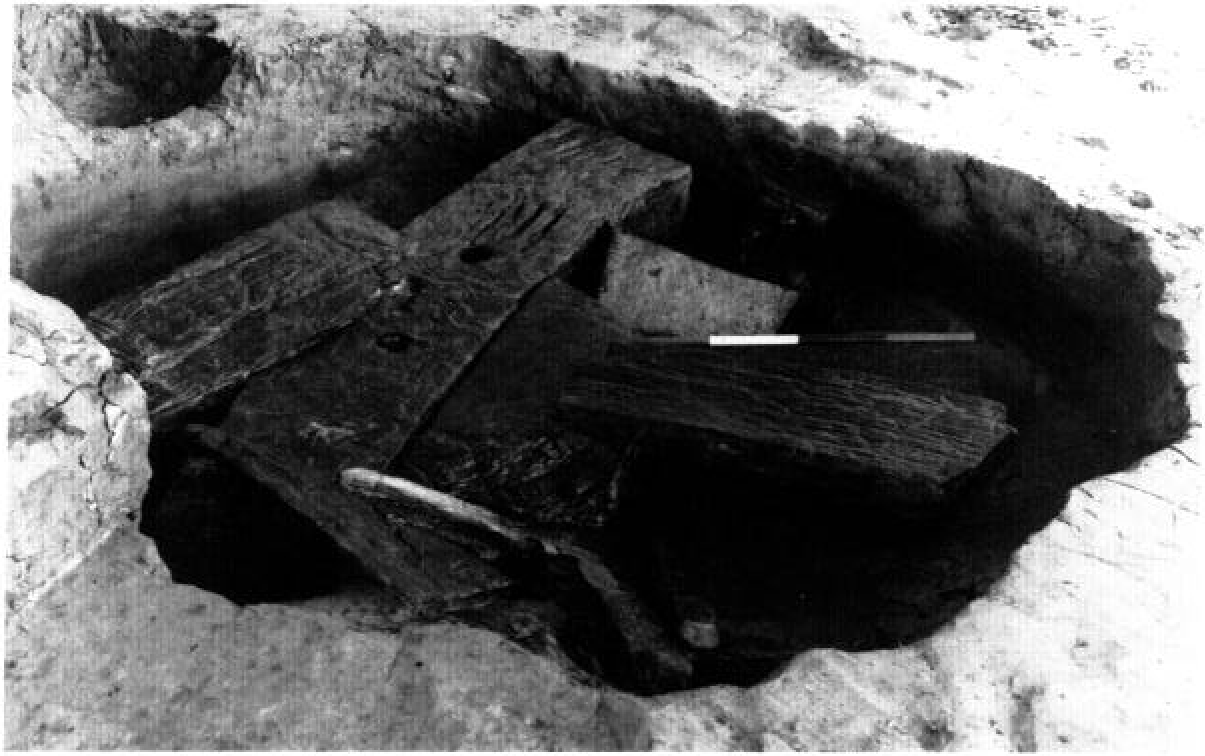


Plate 8 Period 3 mill building: postpit (B1129) with pad of reused timbers (B537), from the north. (Scale: 0.10m divisions)

period 2 platform (B1117) and indicates that demolition took place before the raising of the platform. Similar robbing holes (B540; B543; D580) for other posts of the period 2 building were found but it could not be determined whether they had been cut from the period 2 surface (B1117) or from within the period 3 platform.

The period 3 building was also started before the heightening of the platform was completed. The postpits for the major uprights were dug from the top of the period 2 platform. The bottom of the eastern pit (B1129) was lined with large pieces of timber (B537) which were designed to act as a pad to support the upright (which was removed in period 4) (S4: Fig 20; Plate 8). Two of the pieces (B537/6 and B537/9: Fig 31) were fragments of structural timbers which were probably salvaged from the period 2 building. The western pit (B1124) also contained a pad of timbers (B1095) which supported an upright, the stump of which (B538) had survived the period 4 robbing (Plate 9). The pits were then backfilled with clay (B1130; B1123) and then more clay (E919) was dumped around the uprights when the platform was heightened. This may have been an attempt to give the uprights more support as they would have had to withstand substantial vibration from the working mill machinery.

The stratification allows an alternative interpretation, that the posts were actually in use in period 2. The main argument against this is the character of the pits. All the certain period 2 timbers were much smaller, judging from the few surviving uprights and the surface area of the timber pads, and the postholes were less deep. Neither did the postpits align with any of the period 2 posts. It also seems unlikely that the two large posts would have been left standing to be incorporated into the period 3 building while the rest of the period 2 building was demolished.

The platform was raised between 0.2 and 0.40m by the addition of clay (E919...), presumably from the excavation of the tail race; it sealed the tail of the north mill pond bank (D221), demonstrating that the platform was later than the mill pond bank (S9: Fig 20); it was also packed around the two major uprights which had been set into pits dug from the top of the period 2 platform. The

Plate 9 Period 3 mill building: postpit (B1124) with a pad of timbers (B1095) supporting remains of upright (B538, felled in the autumn of 1175 or spring of 1176), from the north. (Scale: 0.10m divisions)

foundations for the rest of the building were cut from the surface of the period 3 platform.

The structure was rectangular in plan, based on the two uprights which had been erected earlier (upright B538 in pit B1124; robbed upright in pit B1129), the upright which would have been placed in the north end of pit E1029, and a western one assumed to have been destroyed in the period 4 rearrangement.

The building (Plate 10) had lean-tos to the north, east, and west. That on the north side was formed by posts (B1096 and Cl007 founded in holes B1113 and B1133). Because no evidence intermediate, posts was found, it is possible that the north lean-to was open, as was the case in later periods. The west lean-to wall was composed of posts in individual holes (C692; C687; C688; C698; C696; C697; C699; ClOOO; C694; C690; C1003; C1016; C1018; C1014; D570; D574), in contrast to the east lean-to which was apparently founded in a sleeper trench (E961/B1098). The stratification was, however, not clear and it is possible that the trench marked the later robbing of what could have been a wall based on earthfast posts similar to the west lean-to wall. Little evidence survived for the south wall of the mill building because of the later disturbances. The postholes E985 and E832 and slot E979 probably mark the south wall of the east lean-to. All these features had been cut into the clay (E919...) of the period 3 platform. The east lean-to thus extended further to the south than the west (see Fig 112).

In all periods the area between the wheel trough and the south wall of the mill building (a distance of some 3.75m in period 3) had been badly disturbed by the period 7 drain and by slumping of the platform into the water channel (see above, 'Circumstances and methods of excavation'). This slumping is interpreted as evidence for the removal of vertical boarding which would have retained the

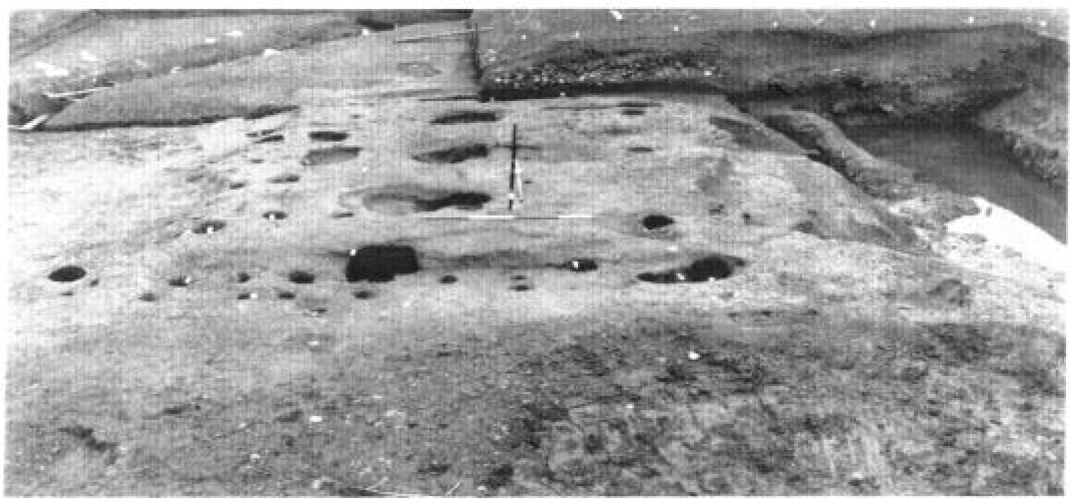


Plate 10 Period 3 mill building, from the west

platform in this area while the mills were in use. Thus, the space between the south wall and wheel trough is thought to have been occupied by a timber-lined, rectangular pit, which housed the machinery to transfer power from the water wheel into the central area of the building (see Figs 112 and 117).

Layers of ash and charcoal (E934; E911 and E925) in two hollows (E936; E908) cut into the floor in the middle of the mill building are interpreted as hearths. One hearth (E936) was adjacent to a timber slot (E944) which may have served to separate the hearth area from the machinery pit (see Fig 18).

There is also some evidence - for example, the slot (E1091) and posthole (E929) between the large uprights on the east side - to suggest that the central (and highest) part of the building was partitioned as if to separate the hearths from the east lean-to. Other postholes (E949; E929; E1038; E1040; E977; E973; B1109; B531) were found within the building which, as they do not appear to have had a structural purpose, may have supported other partitions or machinery. The position of some features appears to have been retained in later periods, as, for example, the shallow pit E964 in the east lean-to. The pebble spread E972 is interpreted as a threshold for a door in the east lean-to wall.

Evidence for the use of the building was slight. There were the hearths already mentioned, and three irregular pits (B1106; B549; B1119) which had been dug in the north lean-to; all three were filled with clay. Their purpose is not clear; they are unlikely to have been used in conjunction with the hearths because they were too far away. This also makes interpretations such as tanks for soaking cloth during fulling or for iron quenching unsatisfactory, as indeed does their irregular shape and the absence of distinctive residues in their fills. It is perhaps best to regard them as rubbish pits which had been cleaned out. Another possible interpretation for pit B1119 is that it was a major postpit because it was in line with, and almost equidistant from, the two postpits B1124 and B1129. It was, however, in a different stratigraphic relationship from the other two postpits and it was much more irregular in shape and, although it contained some wood (B526) in addition to clay, there was no sign of timber pads in the base. An intermediate post would also have been unnecessary in such a structure.

Charcoal patches (A107; A108; A158; A159) were found on the surface of the platform to the east of the mill building; they may represent the remains of what was originally a more general layer of charcoal which had been spread in the vicinity of the building. Dumps of clay with small amounts of charcoal (C1066; C1067) had also been deposited on the tail of the north mill pond bank, to the west of the mill building; these features, however, could be of either period 3 or 4.

The bypass channel

To the north-east of the mill building a large ditch (BllOO/A135) was excavated which appears to skirt the mill (S17: Fig 29; Plate 11). It was approximately 1.5m wide, 1.2m deep, and drained to the east; it had near-vertical sides which had no evidence of revetment, although it is possible that it was lined with planks which were subsequently removed. If it was not lined, one would have expected the clay sides to have eroded very quickly. The ditch may have been cleaned out because the area to the north of the ditch was spread with a thin layer of loose clay with charcoal (A125...), which may have come from the ditch. This large

Plate 11 Period 3 bypass channel, from the south-east

feature was also located beyond the excavation to the west by electrical resistivity tomography (see below, Noel and Xu, 'A pilot electrical resistivity tomography survey'). It is difficult to interpret, but this feature was probably a channel which took water from the mill pond (or its feed) and around the mill; in other words, a type of bypass channel.

The character and length of use

The period is remarkable for having much structural evidence but few archaeological deposits that could be definitely associated with occupation or use. The paucity of finds would also argue for a short phase of use. However, the range of finds and the arrangement of the mill building were similar to those found in the later periods and would thus suggest that the character of the period 3 occupation was similar to that of the subsequent periods.

During the time the mill was in use, the bank to the south of the tail race was repaired by the addition of more clay and pebbles (E740) (S18: Fig 27). Silts (E968; E970) may also have accumulated within the tail race channel, but they are more likely to have been deposited when the mill had gone out of use. This is certainly the case with the silt E864, which contained a section of the felloe of a trip wheel (E862), a crucial piece of mill machinery. These silts were sealed by what appeared to be a dump of clay (E886), perhaps derived from the south bank.

Period 3 is the best dated of all the site's periods. Six dendrochronological determinations were obtained from the structural remains (see below, part II, Brown, 'Dendrochronological analysis'). Three samples had complete sapwood: from a revetment baseplate from the south side of the head race, which was felled in the summer of 1174 (D330/OB 265/Q8319; shifted slightly in period 4); from a plank from the base of the tail race, which was felled in the summer of 1174 (E889/OB 211/Q8275); and from a post from the mill building, which was felled between the autumn of 1175 and the spring of 1176 (B538/OB 410/Q7664). In addition, the other plank of the tail race base had nearly complete sapwood; the date of the last ring was 1173, and the best estimated felling date would be 1174-5 (E888/OB 210/Q8274). The lowest side plank of the tail race had incomplete sapwood; the date of the last ring was 1165, and a best estimated felling date of 1169+9 is proposed (E863/OB 212/Q8276). The west baseplate of the head race was also sampled, but this had no sapwood; the date of the last ring was 1134; a best estimated felling date of 1166±9 or later is suggested (D313/OB 266/Q8320; repositioned in period 4).

In addition, a sample from a post of the period 4 wheel house had complete sapwood and, as the date of the last ring was 1175, it was probably felled in the winter of 1175-6. This post (E731/OB 284/Q8321) is thought to have been first used in period 3 and repositioned in period 4.

Brown believes these dates are consistent and that the main felling phase for the construction of the period 3 mill was between 1174 and 1175-6. Because the head and tail race timbers were felled in the summer of 1174 and the timbers for the building in 1175-6, this suggests the race timbers could have been stockpiled for a short time or the races could have been constructed first, and the latter is the interpretation already argued on the basis of the stratification. This argument alone could, however, generate an overly-complicated sequence. The 1175-6 date came from the post which had been placed in a pit that had been dug from the top of the period 2 platform; it was, therefore, in place when the platform was raised by the addition of more clay, which, it is suggested, came from the excavation of the mill race. If the head and tail race timbers, dated to 1174, were used immediately after felling, this would imply that the mill race channel had been dug out by that date. The spoil, therefore, would have had to be stockpiled somewhere before it was used to raise the building platform; as the clay surrounded a post which had been felled in 1175-6, it could not have been dumped in that location until during or shortly after 1175-6. Thus there is clear stratigraphic evidence to show that the mill races were constructed before the main part of the building, but it seems most likely that there was not a gap of as much as a year in the construction sequence and that the race timbers were stockpiled for a short time before being used.

While these dates are consistent, they can only provide a *terminus post quem* for the start of period 3. The dendrochronological determinations for the period 4 tail race are, however, also consistent and indicate a construction phase in the late 1180s, perhaps about 1187. Allen (see below, The mill race structures') argues that there is no evidence for later reuse of the period 4 timbers that were sampled. It seems, therefore, that the outer chronological limits of period 3 are in the later twelfth century, perhaps between 1175 and 1187, a very short range. The archaeological evidence, or lack of it, would substantiate a short period of occupation; there were neither extensive floor deposits nor a large material assemblage, for example. There is also evidence that at least part of the period 3 mill caught fire (see below, 'Period 4 ...') and this may explain why the period 3 mill was used for such a short time.

Period 4: watermill, late twelfth to early fourteenth centuries

Figures 11 and 18 (plans)

The period 3 mill building was abandoned, perhaps as the result of a fire; it was then dismantled and replaced by another building which had a similar plan, but this time was built on padstones and sleeper walls. The mill race structures were realigned and rebuilt, which also involved a reconstruction of the wheel house.

The sequence will be presented in the same order as for period 3, even though evidence for the potential cause of the rebuilding (the fire which ended period 3) will be discussed later with the building.

The mill race

Figures 9 and 12 (plans)

The head race was altered at both the west and east ends. The debris grill must have been dismantled in order for the west baseplate (D312/313) to be lifted and placed in a new foundation trench (D1090). A series of timber pieces (D509; D511-D514), including a paddle of a wheel (D510), were placed underneath the baseplate in order to make it level (Fig 9).

The baseplate (D318/E271) which connected the head race with the wheel trough, being the west baseplate of the wheel house, was repositioned. This would have entailed digging through the period 3 platform in order to extract the north end of the baseplate, and lifting the post from its pit (E981) on the south bank to which the south end of the baseplate would have been jointed. On the north side a new trench was cut through the platform (E724; D592) in order to reposition the baseplate (D318/E271). A subsidiary trench (E1032) was also dug to take the new north-west upright of the wheel house/south-west upright of the mill building (E1033), and perhaps also to support some of the mill machinery. The two trenches were backfilled with dumps of clay (E726...; E1023...; E1026...; E1034...) which contained burnt material.

On the south side, robbed postpit E981 was backfilled and the area was levelled up with a large dump of clay (E734) (S11, S12: Fig 28). A wide trench (E733/D507) was then cut into this in order to reposition the upright E731 (felled in the winter of 1175-6) and the south end of the baseplate D318/E271. The south end (D318) of the baseplate had a rebate which was probably designed to interlock with the rebate on the upright E731. Whether this was part of the period 3 arrangement or a period 4 modification, baseplate and upright were positioned so that they failed to touch. The trench was then filled with cobbles and packed with stiff grey clay (E732/D508), and silted over (E707) when the mill was working.

The baseplate D318/E271 would have had to be moved when the wheel pit and tail race were realigned: wheel pit and tail race were shifted over, to the north, by between 0.80 and 1.20m. This was achieved by cutting (E839) into the building platform after the north side of the period 3 tail race had been dismantled. The bottom of the wheel pit was levelled by dumping gravel (E435) and clay (E848), and gravel was also dumped in the tail race (E865).

The south side of the tail race channel was shifted northwards by further dumping of material. The south side of the period 3 tail race was not dismantled, but the upper parts of the wattle

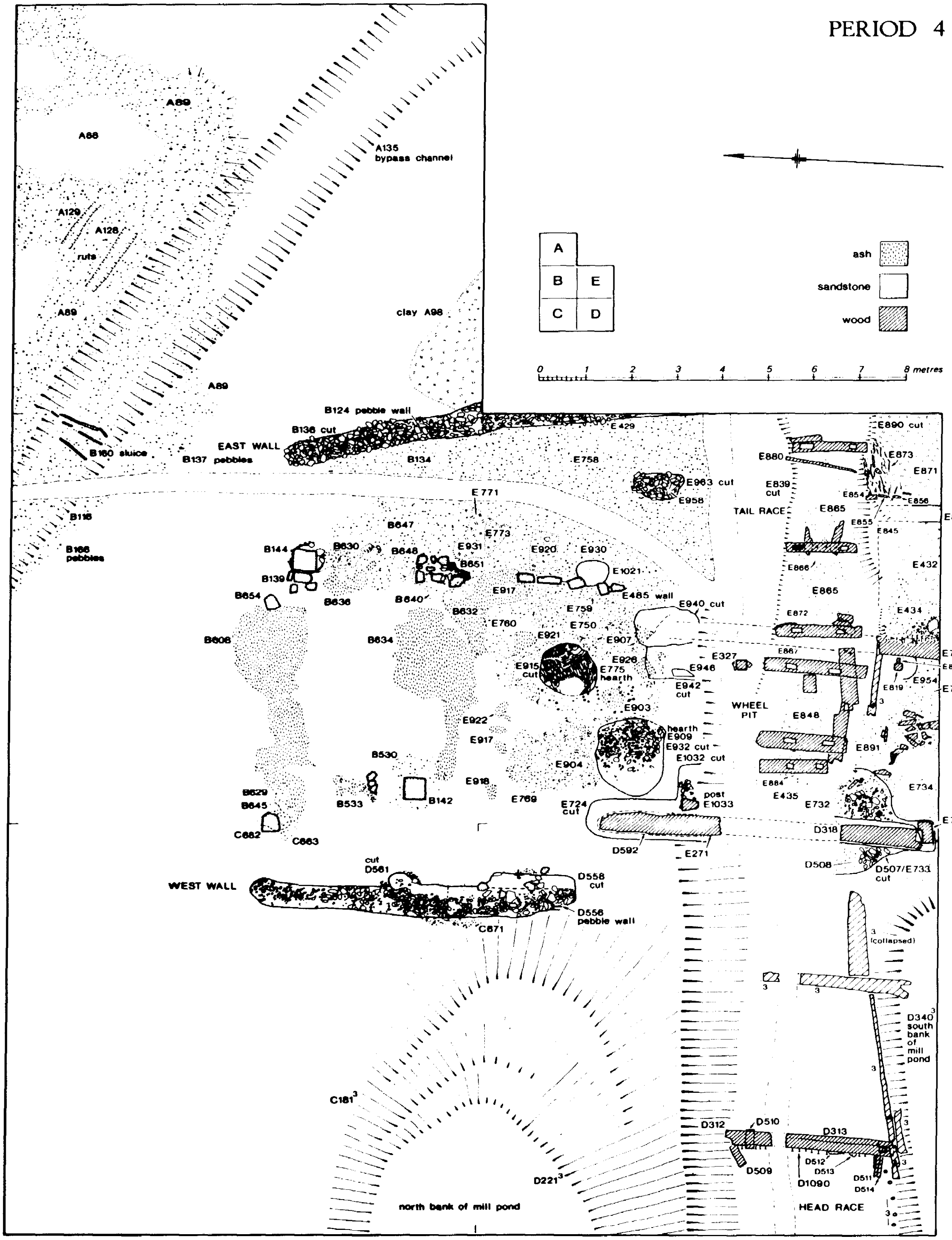


Figure 11 Mill (BAB) period 4: mill

PERIOD 4

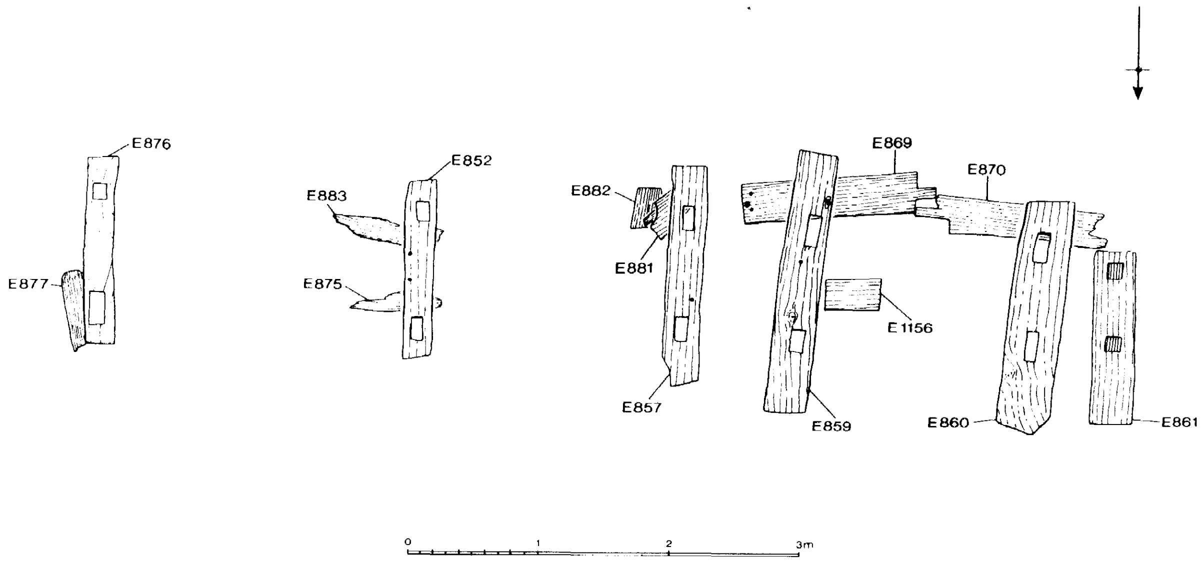


Figure 12 Mill (BAB) period 4 wheel trough and tail race

revetment were cut off (E873), thrown down, and sealed by a dump of clay (E871). Three timbers (E854-E856) were driven into the wattles to provide a support.

The most westerly baseplate (E861) of the period 4 tail race (Figs 11 and 12; Plate 12) was laid directly on the gravel E435. The next two to the east (E860; E859) were laid on clay (E848) and levelled by the addition of wedges under their south ends. The wedges (E869; E870) had been made by splitting the uprights salvaged from the dismantled north side of the period 3 tail race. The next two baseplates to the east (E857; E852), laid on gravel (E865), were also supported by pieces of timber (E881 and E882; E875 and E883) (S18, S24: Fig 27). The most easterly baseplate (E876) was set in a cut (E890) made through a clay dump (E871) and supported by a timber wedge (E877). The baseplates would have supported the bottom planks of the tail race, none of which survive but are indicated by the pegs in the upper surfaces of some baseplates (E852; E857; E859). The mortices in the baseplates would have taken the uprights which would have supported the tail race sides: none of the uprights nor the side planks survived. One upright (E327), set on a timber pad (E887; E895) to the north of baseplate E859, may have been an additional support in the wheel house. The reconstruction of the wheel trough and tail race raised the arrangement some 0.25-0.40m above the period 3 level, which in consequence reduced the gradients within the water channel.

When the plank sides had been assembled, the space between the south side of the period 3 tail race and the new (south) tail race side was filled with blue-grey clay (E845). That space between the period 3 south side of the wheel pit (E952) and the south side of the wheel trough was also filled with clay (E891). When the tail race was in use, deposits of silt and sand (E866; E867; E872; E884; E885) accumulated under the boards.

The wheel house

The south bank of the channel (E816) also underwent change, partly as a result of the repositioning of the east baseplate of the wheel house. The period 3 baseplate (E1030) was removed, as was the south post (E957) to which it was probably jointed; the postpit was backfilled (E984). The north end of the (?new) baseplate was set in a trench (E940) cut into the building platform 0.80m west of its period 3 position; with its extension to the west (E942; E946), this trench was a mirror image of the trench for the west baseplate of the wheel house. The south end of the east baseplate survived (E739) and this was bedded partly into the top of the pit fill E984 and partly into the south bank (E816); to the west it was also kept in place by two posts (E818; E819, ?reused from period 3) set in a single hole (E954). This bank was sealed by a clay and pebble surface (E738).

Some 3.3m to the east of, and parallel to, the east, wheel house baseplate (E739), a slot (E834) was cut to take another timber. In between these two timbers a small clay platform (E432) was created, perhaps from the upcast of the new trench (E839) dug for the tail race; it was capped by a

Plate 12 Period 4 mill race, from the east, showing realigned tail race

spread of pebbles (E434). The platform may have provided additional support for the wheel house.

The mill building

The period 3 mill building appears to have been demolished. Most of the period 3 postholes showed signs of having been dug into, presumably to remove the uprights, and then backfilled with a material that was distinctly dirtier than the primary fill of the posthole. The robbing fills often contained a substantial quantity of charcoal and occasional pieces of ceramic roof tile, a material that was apparently introduced in period 4. The following period 3 features which had contained timbers were apparently robbed (context numbers in brackets refer to the post-robbing fills): the partitions E1091, E929, and E944 (E941; E928; E945); the posts and slot of the south wall E985, E979, and E832 (E986; E980; E833); the slot of the east lean-to wall E961 (E962); the postholes of the north lean-to wall B1113 and B1133 (B546; C1005). The smaller posts of the west lean-to wall were removed by digging a long robbing trench (C674, filled with C675) and by digging pits for D574 and D570 (D569...; E948...). The non-structural posts E949, E977, E964, B531, and B1109 were also removed (E950; E978; E959; B532; B1105).

The major uprights of the building were also robbed. A robbing hole (B528; B535) was dug in order to remove upright B537 and some of the upcast (B522, B534) was spread over the surface. The fill appears to have settled, and the resultant depression (B525) was used as a rubbish pit (B521...) (S4: Fig 20). A robbing hole (B660, with fill B659 and B655) was dug to extract the other main

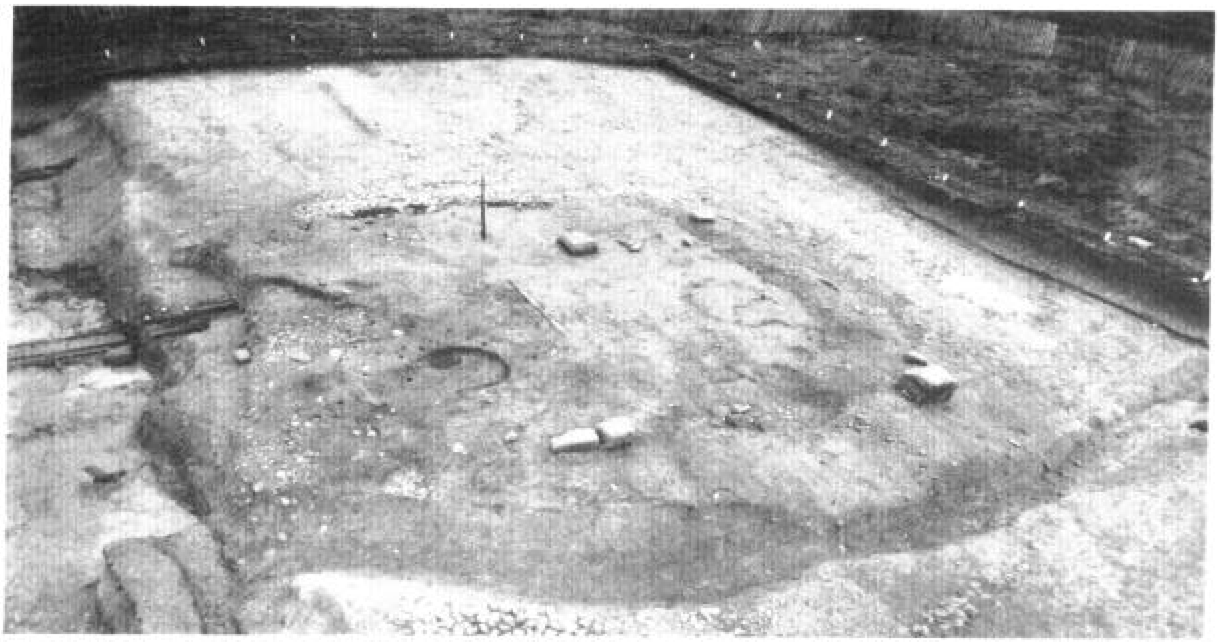


Plate 13 Period 4 mill building (hearths removed), from the south-east

upright B538, but this attempt was abandoned and the upright was cut off at ground level, leaving the stump *in situ,*

Most of the fills of the robbing holes contained burnt material, especially charcoal, which would not be regarded as unusual on a site with hearths. However, in the north-east corner of the central part of the building the platform had apparently subsided, perhaps into one of the pre-monastic (period 1) stream beds. After the demolition of the period 3 building, this corner was levelled using dumps of brushwood (B1127) and dark clay (B644), which contained large quantities of ash, charred wood, and charcoal. It also contained an unusually large number of small lead runnels which can be produced when lead sheet melts in a conflagration (see below, part II, 'Other metal'). The distinctive character of B644 would suggest that it represented the residue of material after a fire, and its location might indicate that the north-east corner of the central part of the period 3 building caught fire. Given the paucity of floor levels in the period 3 building, the collections of burnt material in the fills of other negative features might also reflect the demise of the building by fire, rather than its occupation. An alternative interpretation would be that, after a more extensive fire, the floor level of the period 3 building was cleared of material and dumped in the north-east to reinstate the platform.

Further dumps of clay (B643; B646) were added to this corner prior to the laying of a padstone. It is possible that these dumps may mark a later attempt to deal with further subsidence, as reflected in a depression (B653), of this corner after the period 4 building had been erected, and that the padstone had to be removed (and the upright of the building supported in some way), the ground made up, and then the padstone replaced.

The period 4 building plan was closely based on that of period 3, but most of the superstructure was supported on padstones and dwarf stone walls rather than being earthfast (see Fig 114; Plate 13).

The two, north, corner uprights of the central structure (B142; B648) and the north-west upright of the north lean-to (C862) were 0.70m to the north of their period 3 position. (The position of the north-east upright of the north lean-to (B144) did not change significantly from period 3 to period 4.) Some of the robbing holes were levelled with further dumps of clay (B527; B655) and then pebble hardstandings (B530; B652; B650; C676) were laid, on top of which the sandstone pads were set (B142; B144; B648; C682). Further padstones (B139; B654 ?displaced) appear to have been added to the north-east corner of the north lean-to for additional support, and a tile surround (B651) around padstone B648. If post El033 is interpreted as the south-west upright of the central area (the south-east upright of the central area was probably destroyed by the period 7 drain), then the south uprights were also moved, to the south, by the same amount, 0.70m; this would have made the central area virtually square in plan. The shift by 0.60m to the west of the east baseplate of the wheel house meant that the east side of the central area and the wheel house were no longer in line.

A trench (E965/B136) was dug for the east wall, on a slightly different alignment from its

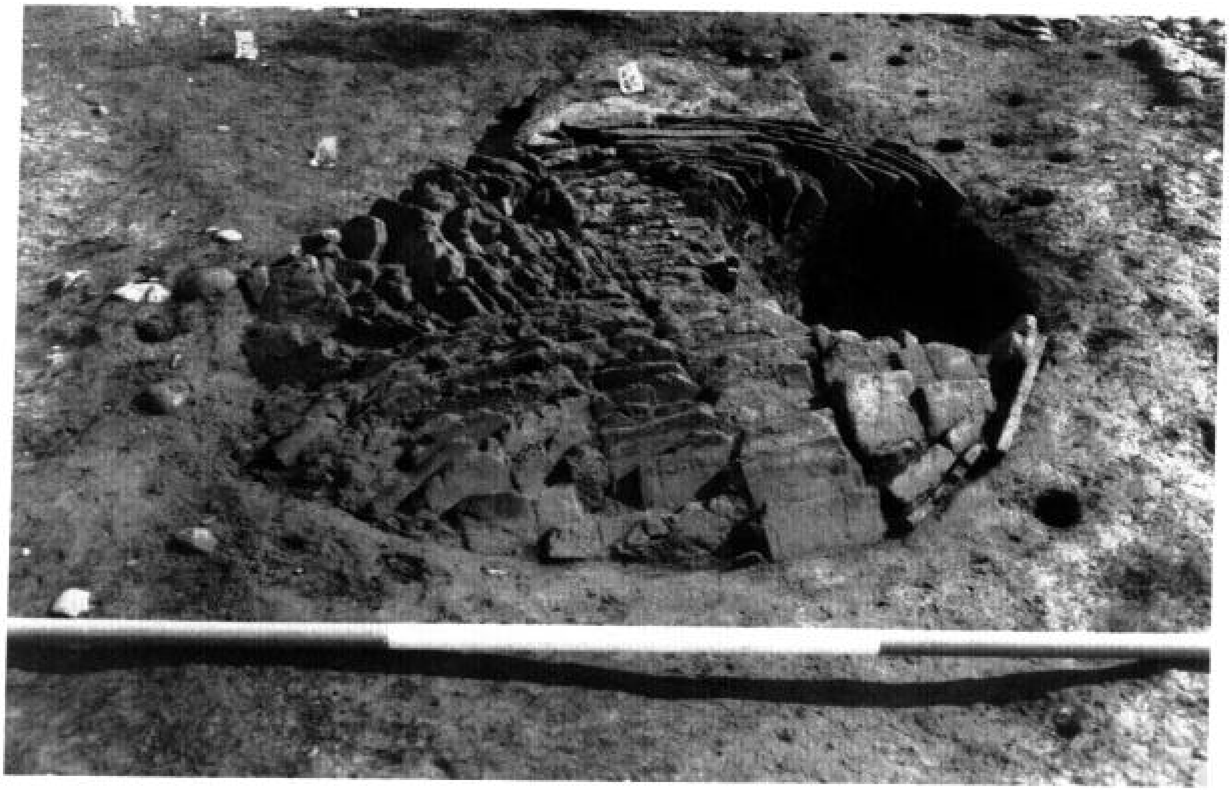


Plate 14 Period 4 pitched tile hearth (E775), from the north

predecessor, and large pebbles set in it as a foundation (E429/B124). The west wall was built in a similar way after the area had been levelled with dumps of clay and pebbles (C693; Cl00l; C680; C681; C691; C678; C679; C677; C669; C670-C673). A trench (D558...) was dug and filled with pebbles and packed with gravel (D556...; D554; D559...). On its east, internal side, the trench had been enlarged in places (eg D561), perhaps to take additional timber uprights. The period 4 modifications produced more regularity and precision in the construction of the superstructure. The repositioning of the wheel house, wheel trough, and the south expansion of the central area of the building resulted in a more integrated whole, where the wheel was brought closer to the mill building; this would probably have made the mill more efficient by, for example, reducing the length of the main wheel shaft. There would, however, still have been sufficient space between the wheel and the mill building for a lined pit for mill machinery.

The period 3 partition slot (E1091) between the east lean-to and the central area of the building was filled in (E933; E759), levelled (E484), and replaced by a wall of sandstone blocks (E485) with a post setting (E1021) for a major upright on the east side. The interior of the east lean-to was spread with clay (E490) on top of which was laid a pebble hardstanding (E930...; E758...; B647; but not found in the north-west). In some places small dumps of clay with charcoal were deposited over the pebbles (E931...; E920...; E771...; B640...). Further areas of pebbles (E773; E774) were laid at the north end of the partition wall where a doorway was probably located. An oval setting of cobbles (E958 in cut E963) in the floor of the lean-to replaced a shallow postpit (period 3) and probably supported some machinery.

While the internal arrangements of the main part of the building were largely reproduced from period 3, widespread but small-scale dumping - attempts to level the floors - separated the two horizons. Clay (E935...; E902...; E913; E906; D553; B633; B640-B642; B628; B637-B639), clay with pebbles (E916...; B630), and occasionally sand (E905) were spread over the central part of the building.

A large shallow pit (E932), lined with pebbles (E909) set in clay (E937) is interpreted as a large hearth. About a metre away another, sub-circular, hearth, 1.20m in diameter, was built: a shallow pit had been dug (E915), lined with clay (E914), and then packed with pitched ceramic roof tiles in a precise way which gave the hearth a domed surface (E775; Plate 14) (S19: Fig 30). There is little doubt that these two distinctive features were hearths

(Fig 18) because the areas between and around them were covered by a series of interleaved layers of ash (E921/E917/B632; E927; E907; E918...), clays heavily impregnated with charcoal (E926; E923), sands (E924; E772...; E760...), and 'debris' of loose clay containing decayed sandstone and tile fragments, intermixed with pockets of ash and charcoal (E922; E903; E904; E750...). A series of stakes had been driven into the area between the two hearths; the holes (E777–E799; E900; E901) were filled with ash (Fig 18). As this is the most likely location for a trip hammer, it is possible that the stakes supported equipment such as tool rails.

A sharp reduction in the number and thickness of these 'industrial' layers occurred about 2m away from the hearths. In the north part of the building, for example, the surface of the clay platform was only covered with a thin, discontinuous, skin of ash (B634; B533; B636). Ash staining (B608) straddled what should have been the line of the north lean-to wall, indicating that the north lean-to was open and that the ash had been swept out (see below, part III, Walsh, 'Reconstructions of the mill (BAB) buildings'; Frontispiece).

There was very little sign of industrial activity in the west lean-to, to judge from the lack of ash deposits on the make-up layers. The area may have been used for storage: there were possible doorways at both the north and south ends of the lean-to, but these may have been used infrequently as there was no sign of wear, or hardstandings, at the thresholds. Indeed there is very little sign of use of the external area to the north or west of the mill building; access to the mill must have been from elsewhere, perhaps from the south, beyond the excavation.

The bypass channel

There were, however, signs of a significant change in the use of the bypass channel to the east of the mill building (S17: Fig 29). The channel ceased to be cleaned out, probably when the period 3 mill went out of use, the sides eroded, and material collected in the bottom of the channel, which gave it the shallow, V-shaped profile of a ditch (A1160/B164). Water appears to have continued to flow, however, and a green silt (A157...) was deposited. A sluice (B160) was constructed by driving two stakes into the south side of the ditch and a post into the north side; these served as uprights to hold in place, across the ditch, the planks, which were found next to the uprights. A sluice would have allowed better control of the water, and the botanic evidence from the ditch suggests that it could have been used to process cloth (see below, part II, Carruthers, 'The valley environment ...').

The ditch, however, also seems to have been used for the dumping of rubbish at this time. A highly organic silt (B1149...) developed in the ditch bottom and this contained the largest and most varied finds assemblage from the site. Much of what survived may reflect domestic refuse, particularly the animal bone and pottery, but there were indications of more specialised activities such as cobbling, textileworking, and woodworking (see below, part II, 'Leather' and 'Worked wood'). The woodworking was indicated by large quantities of wood chippings and a substantial fragment of a structural timber, perhaps a wall stud (OB 496, Plate 15; Plate 16); such a deposit could have been dumped between the demolition of the period 3 mill and the construction of the period 4 mill.

The ditch was then filled with clay (B1111...; B1110; B1103), perhaps deliberately as the remains of two parallel ruts (A128; A129) from a cart had worn into the clay surface to the north of the ditch. Approximately the northern half of the ditch was covered with a gravel hardstanding in a red clay matrix (A92...); in places it had worn away (A88).

The character and length of use

The similarity of the plans of the period 3 and 4 mill buildings and the latter's almost exact superimposition, in addition to the evidence of the reuse of parts of the period 3 head and tail race structures, would argue for no, or a short, interval between the disuse of the period 3 mill and the construction of that of period 4. That the mill was used for metalworking is shown, firstly, by the hearths surrounded by layers of ash and charcoal and, secondly, by the metalwork, which included scrap and part-forged iron, copper alloy vessel and sheet fragments, and casting waste – items which clearly indicate that metalworking took place on site.

The comparatively large finds assemblage and the stratigraphic evidence for change would indicate a much longer period of use for the period 4 metalworking mill.

The main evidence for the disuse of the period 4 mill comes from the tail race, which accumulated a layer of grey silt (E840) into which wood (E880) fell, and from the east exterior, where the remains of a destruction layer (A98) were found (S16, S18, S24: Fig 27).

The major evidence for the date of the inception, and duration, of period 4 comes from the dendrochronological determinations of the period 4, and period 5, tail races (see below, part II, Brown, 'Dendrochronological analysis'). Three baseplates of the period 4 tail race were successfully analysed. A sample from E857/OB 229/Q7667 had complete sapwood and produced a felling date of 1187. The sample from E852/OB 215/Q7665 had incomplete sapwood, the date of the last ring was 1184, and the suggested felling date was 1184 + 2 or 3 years. One from E876/OB 216/Q7666 had no sapwood, and the date of the last ring was 1165; using the Belfast estimate for sapwood of 32 ± 9 years, the estimated felling date would be 1197 ± 9 or later.

Plate 25 South-east end of partially filled bypass channel with structural timber (OB 496), from the north

Brown regards these dates as consistent, and compatible with a felling date of 1187. However, he raises the possibility that E876 and E852 might be later additions or repairs, but, given the well-preserved sequence of the tail races, the absence of evidence for alterations within period 4 would argue against this.

The dendrochronological determinations from four timbers of the period 5 tail race suggest the early fourteenth century as the most likely felling date. As there is no evidence that timbers were reused in period 5, period 4 therefore seems to have a *terminus post quem* of the late 1180s, perhaps 1187, and a *terminus ante quem* of the early fourteenth century.

The pottery generally appears to be consistent with this dating, with the exception of some jugs with thumbed bases. These have not yet been recorded earlier than *c* 1215 in London, but they do occur here in period 4 deposits which are sealed by the dendrochronologically dated timbers (see below, part II, Nailor, 'Pottery'). It is worth noting, however, that the carpentry technique of pegging mortices was used in the construction of the period 4 tail race and that this appears to be in advance of when the technique was first used in London (Brigham 1992, 93). No other part of the finds assemblage is sufficiently susceptible to precise dating to be able to contribute to the discussion.

Period 4 was unusual in that various forms of ceramic were first introduced to the site then. Roof tile, for example, was not used in period 3, but appears to have been available early on in period 4, as reflected in its occurrence in the fills of the robbing holes of the period 3 postholes. (For the earliest occurrence of roof tile on the church, and the use of roof tile (and of floor tile) in the church in the first half of the thirteenth century (BAA period 2), see Hirst *et al* 1983, 38–9; Hirst and Wright 1989, 301–2.) Similarly, kiln furniture was brought on to the site for reuse during the construction of the period 4 mill and, as has been stated, jugs were also first introduced early in period 4.

The mill environs

The marked differences between the assemblages of the tail race and the bypass channel could indicate that there was another building close to the mill – perhaps a workshop for clothmaking and leather-working – but one which was demolished at the same time as the period 3 mill.

The botanic evidence indicates the valley remained open as damp grassland after the period 3 clearance. Nevertheless, some trees continued to grow – alder, elder, and hazel – and in sufficient numbers to provide a habitat for woodmice, bank voles, and red squirrels (E955/OB 204: see below, part II, Carruthers, 'The valley environment ...').

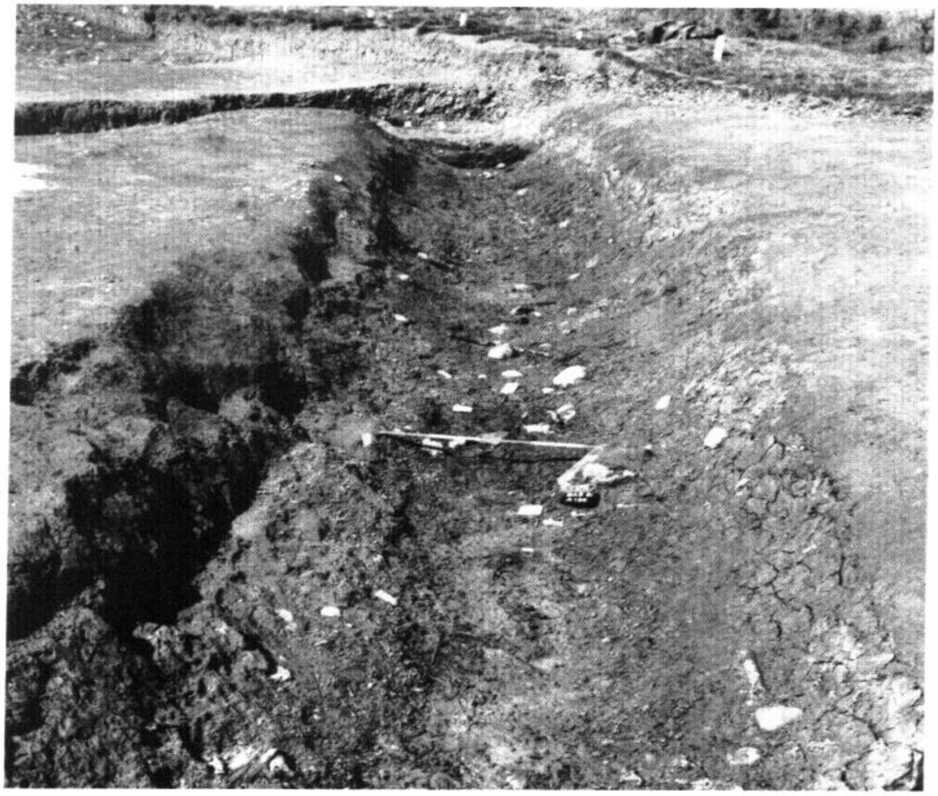


Plate 16 Bypass channel with period 4 fill, from the south-east. (Scale: 0.20m divisions)

Period 5: watermill, early fourteenth to ?mid-fourteenth century

Figures 13 and 18 (plans)

In period 5 major structural alterations were limited to the wheel trough and the tail race; the period 4 head race remained, unaltered, and occupation from period 4 to period 5 was continuous. The internal arrangement of the mill building was changed, including a replacement of the hearths. There was increased activity outside the mill building: the end of the north mill pond bank was broadened and a new building was erected to the east of the mill.

The mill race

Figure 14 (plan)

The construction of a new wheel trough must have been achieved in difficult circumstances as there is no evidence that the period 4 superstructure of the wheel house was disturbed, although an additional upright in one wheel trough baseplate (E736) might suggest the machinery pit was altered. The wheel pit was recut (E808; E813); three reused timbers (E369; E736; E737) were set directly on the period 4 silts (E840) as baseplates, which slightly raised the base of the wheel trough and again reduced the gradient. Uprights must then have been morticed into the baseplates and the base and side planks fitted: none of the uprights or planks survived. However, the top-plates that would have tied together the uprights appear to have been reused in period 6 (see below, Allen, 'The mill race structures'). The space between the side planks and the wheel pit was backfilled with clay and pebbles (E809; E814; E453).

The spacing between the mortices on each wheel trough baseplate was *c* 150mm narrower than in previous periods, suggesting that both trough and wheel were consequently narrower. The sides of the head race may have been realigned in order to achieve a better join with the (narrower) sides of the period 5 wheel trough, but no evidence survived for such a revision.

The trench (E810; E837) for the tail race structure was then excavated out of the period 4 tail race silts; the western side (E847) of the trench was cut into the period 5 wheel pit, suggesting that

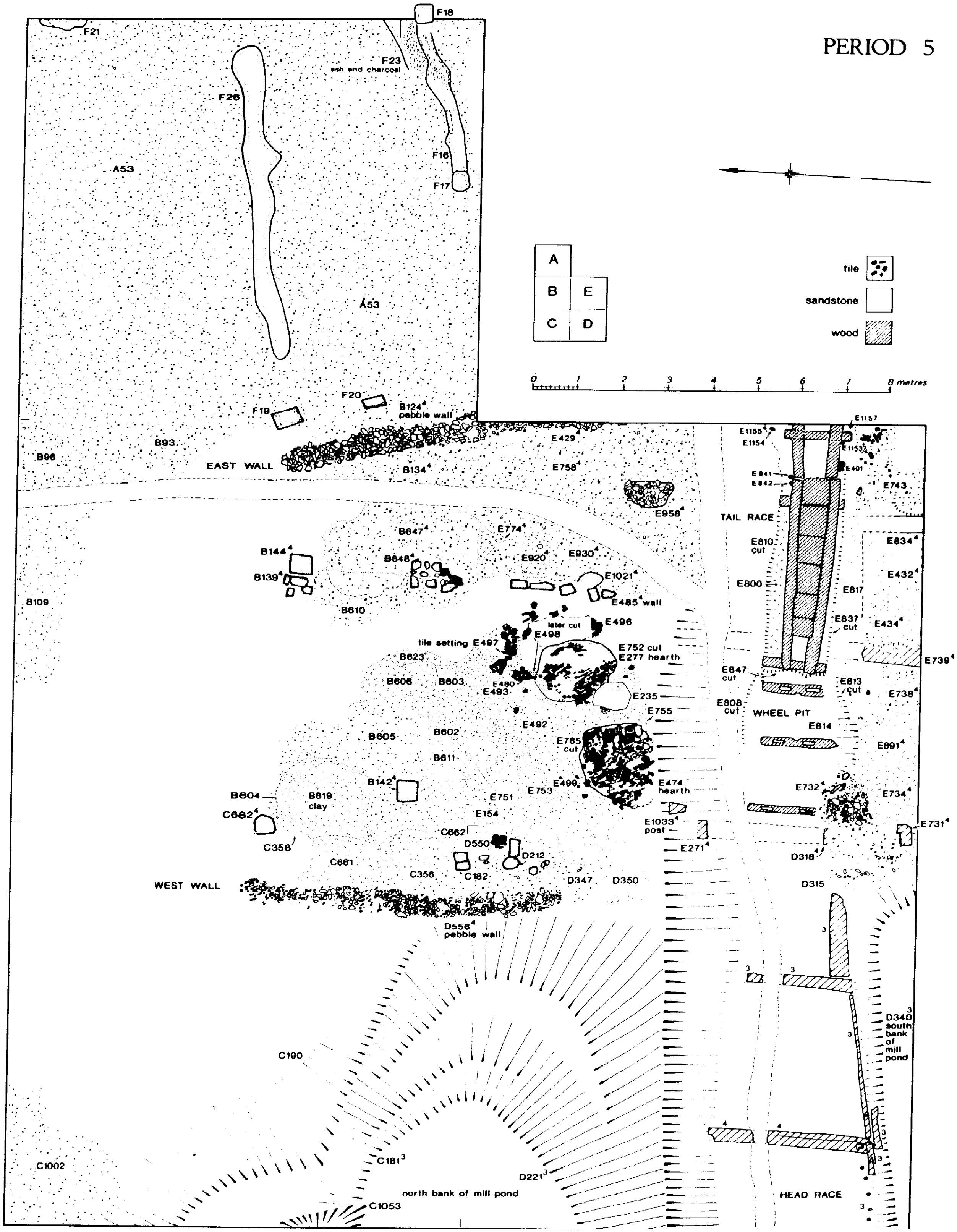


Figure 13 Mill (BAB) period 5: mill

PERIOD 5

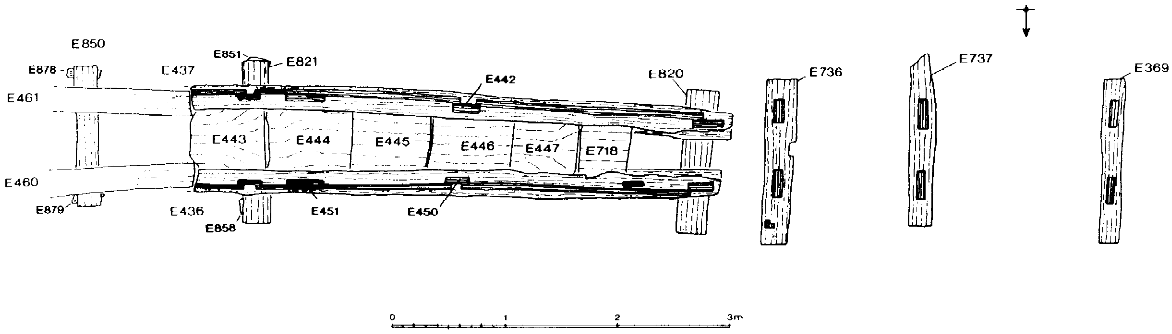


Figure 14 Mill (BAB) period 5 wheel trough and tail race

the tail race structure was positioned after the wheel trough had been assembled, as one would expect.

The base of the tail race appears to have been a prefabricated structure (see Figs 14 and 30; Plates 17 and 18): it consisted of two longitudinal baseplates (E436; E437) - into which the base boards (E443-E447; E718) had been jointed - which had been tied together with two transverse baseplates (E820; E821). The base was thus lowered into the trench, and pieces of timber (E851; E858) were used to level the structure. The tenons of two uprights (E442; E448) were the only parts of the sides to have survived. It is probable that the sides were assembled after the base had been set in the trench. The spacing of the mortices for the uprights and the raggedly sawn east end are strong evidence that originally the tail race structure extended further east, beyond the excavation. The space between trench and sides was then backfilled with clay (E800; E836). The occurrence of fine silts (E811) behind (to the north of) the north longitudinal baseplate (E436) shows that there was some seepage of water through the sides (S18: Fig 27).

The south bank of the tail race was then heightened and broadened by large dumps of clay (E817; E838); the east end was capped with a pebble hardstanding (E743) (S16: Fig 27). A relatively large number of finds, including 34 metal objects, was recovered from the body of this bank material which suggests that some of this clay either had been derived from earlier occupation layers or that the surface of the period 4 south bank had been removed and redeposited (suggested by the truncated nature of the top of dump E845; see S18: Fig 27).

After some time the tail race structure was shortened (Plates 17 and 18). The eastern section was crudely sawn away and removed. It was replaced by two longitudinal baseplates (E460; E461), joined by a transverse baseplate (E850), wedged by pieces of wood (E878; E879); the modifications were staked (E841; E842; E401; E1153-E1155; E1157) in place. In order to retain the now shortened sides, it was necessary to cut additional mortices for new uprights (E449; E451) in the two longitudinal tail race baseplates E436 and E437 to the west. The retention of the period 5 tail race sides, shown by the cutting of these new mortices, is the major reason for not assigning all the modifications to period 6, when the tail race sides were replaced.

It is difficult to explain the function or purpose of these alterations. The new baseplates (E460; E461) had no mortices or rebates to support any side boards, which suggests that the water flowed through the tail race and then debauched into a wider channel. Given the shallow gradients, the new arrangements would probably cause the ponding back of water, making the wheel work less efficiently.

The mill building

Within the building, one (E909) of the two period 4 hearths was replaced by a larger hearth (Fig 18). An ovoid pit (E765), 2.25 by 1.2m, was partially cut through the earlier hearth and filled with clay (E912) in which were laid ceramic roof tiles (E474) pitched in such a way that the working surface was made convex. Close to the new hearth, a setting of tiles (E770) had been laid. Hollows that had been worn in the period 4 floor were patched with clay (E768; E767). The clay and charcoal floor/occupation levels (E757...; E499) associated with this new

Plate 17 Period 5 mill race, from the east

hearth show that it was used in combination with the period 4, smaller, circular, tile hearth (E775) (Plate 19).

These floor/occupation levels were then cut into when a large pit (E752) was dug in order to replace the circular hearth; it was packed with roof tile (E277...; S19: Fig 25) and was surrounded by three settings of roof tiles (E480; E496; E497) which are interpreted as supports for tanks or machinery. A large flat stone (E235) was laid between the two hearths and probably served as an anvil for a trip hammer (Fig 18).

The large hearth (E474) was repaired by replacing some of the tiles with sandstone fragments (E776: Fig 18); the floor was renewed, and hollows filled, in the central part of the building (north of the hearths) with dumps of clay (E766/C662; E753/D350; E755/B603; B614; B604/B606; B610), pebbles (B605/C359..., E754; E751/D347/C356; E492...; B623...), and tiles (B622) (S4, S5, S10, S19: Figs 23 and 30), while the areas around the hearths accumulated deposits of ash and debris (E498; E493; E495). As in period 4, the floor deposits were greatest near the hearths. A setting of sandstone blocks and tiles (D212...; D550; C182) laid in the western lean-to probably supported some machinery, which might indicate a greater intensity of use of this part of the building.

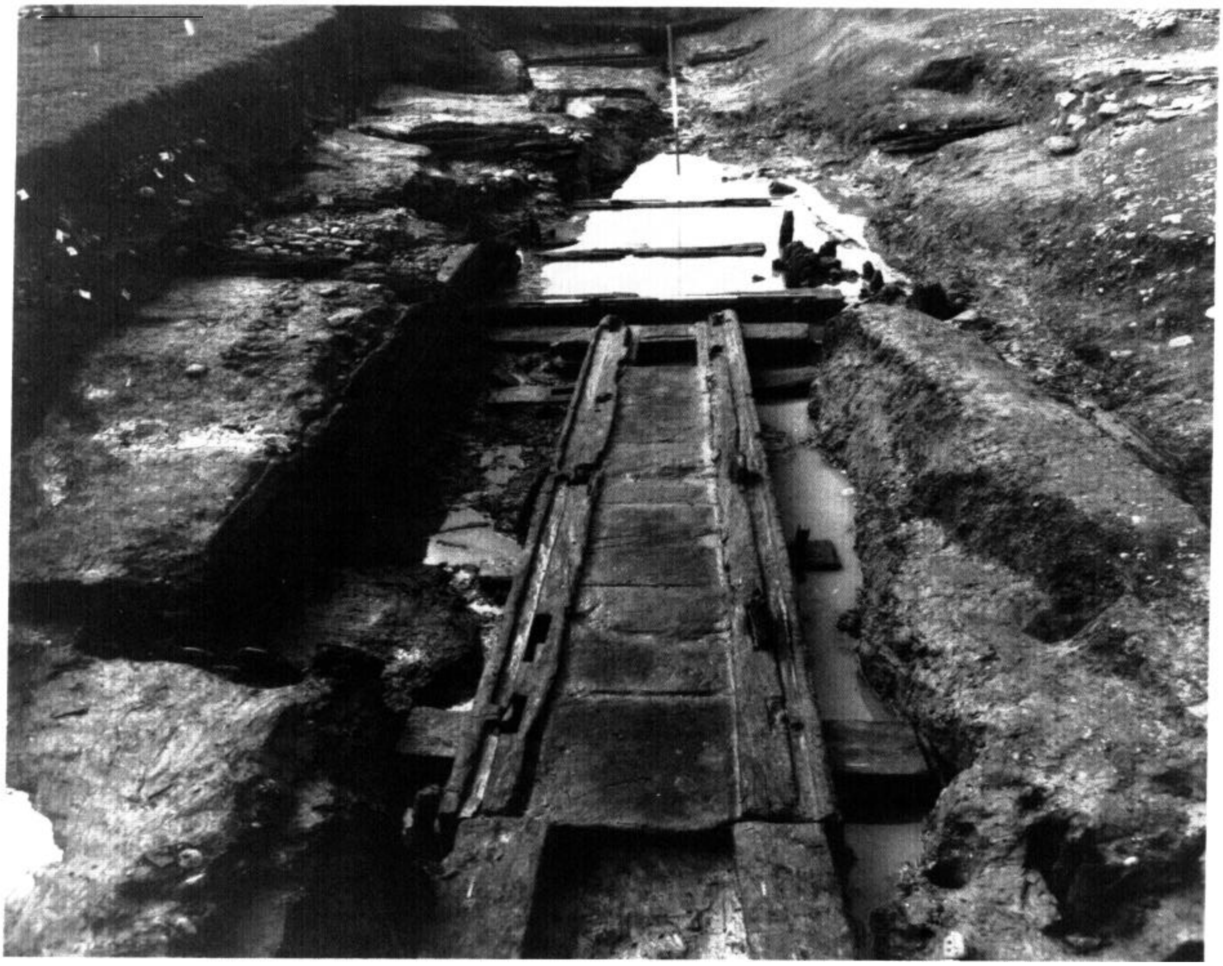


Plate 18 Period 5 tail race, from the east

The mill pond banks

To the west of the mill building, the fill of the large period 2 pit Cl077 had settled and was covered in pebbles (C1002) in preparation for the broadening of the north side of the north mill pond bank with dumps of clay (C190; C1053) (S14, S15: Figs 24 and 26). The valley transect (BAE) excavations have shown that the north and south mill pond banks were altered, apparently at the same time, to increase the capacity of the mill pond in an attempt to provide a greater head of water for the mill at a time when the gradient was decreasing. The subsidiary excavations BAH and BAJ, downstream of BAB, appear to demonstrate that extensive sedimentation took place in that part of the Arrow valley, which effectively reduced the gradient of the (long) tail race. In order to maintain the efficiency of the mill in these circumstances - where the lowering of the tail race structures would be counter-productive - the mill pond banks were raised in order to increase the head of water and a more sophisticated tail race was constructed to ensure that water got away from the wheel as quickly as possible.

The east? workshop

To the east of the mill building, a large area was covered in pebbles (B109...) for a hardstanding as a preliminary to the construction of a building. Two slots (F16; F26) were cut into the surface, the

Plate 19 The hearths in use early in period 5, from the west. The new hearth (E474) in the foreground was initially used with the period 4 hearth (E775) in the top left

southern slot (F16) also had a posthole at each end (F17; F18) which may indicate entrances. These slots can be interpreted as the remains of an earthfast building that was founded on timber sills; their irregularity suggests that the sills were later robbed, rather than rotting *in situ* (of which there were no indications). The west gable end of the building, however, appears to have been based on padstones (F19; F20). An alternative interpretation, which perhaps is more in keeping with the character of the contemporary mill building, is that the slots were originally filled with pebbles so that the building would have been supported on stone footings. The earthfast technique of construction was last used on the mill in period 3. The slots are, however, a little narrow for pebble foundations in comparison with those in the mill building. Little was found in this east building, although a small area of a floor (F23) survived, impregnated with ash and charcoal, and might suggest the structure had an industrial purpose, perhaps as a workshop; an external pit (F21) also contained ash and charcoal.

The length of use

The dating of the inception and duration of period 5 is difficult. Four of the five samples taken from the tail race timbers produced dendrochronological determinations, but sapwood had not survived on any of the timbers (see below, part II, Brown, 'Dendrochronological analysis'). The four dated samples were taken from the four (middle) base boards and the dates of the last rings were: 1233 and 1262 for the samples from the two western boards (E447/OB 259/Q7756 and E446/OB 258/Q7757), and these two were definitely from the same tree; and 1223 and 1264 for the samples from the two eastern boards (E445/OB 257/Q7755 and E444/OB 256/Q7754), these two being probably from the same tree. If the standard Belfast allowance for sapwood of 32 ± 9 years is used, the following estimated felling dates are produced: 1265, 1294, 1255, and 1296, all ± 9 or later. Brown considers that these indicate a felling date in the early part of the fourteenth century, rather than the late thirteenth century, because it is impossible to know how much heartwood had been removed.

Samples from the tail race baseplates (longitudinal E436/OB 253/Q7668 and E437/OB 254/Q7669; transverse E821/OB 2521Q7670) had too few rings to be dated, but all three came from trees which had been felled in the same year, reinforcing the idea of prefabrication of the tail race.

Although timbers of period 6 were sampled, none could be dated. It is, therefore, very difficult to suggest a date for the end of period 5. The evidence for disuse - the silt accumulation (E273) and collapsed timber (E388) in the wheel pit - was so slight that it probably occurred during the reconstruction of the period 6, phase 1, wheel trough, and cannot be used to demonstrate a hiatus in the use of the site. However, some qualitative comments can be made which may give some indication of how long the period 5 mill was used.

The amount of material recovered from period 5 contexts is remarkably small by comparison with period 4, whose date range is from the late twelfth to the early fourteenth centuries, and there is no evidence to suggest that the period 5 layers were not intact. Indeed, as has been noted above, some of the material found in period 5 contexts may well have derived from earlier deposits. For example, in comparison with period 4, period 5 produced (by number) a third of the pottery sherds and animal bone fragments, a quarter of the wood, a fifteenth of the lead, a third of the copper alloy, and a quarter of the iron objects. If the quantity of archaeological material is any guide to the intensity and length of occupation, assuming of course that methods of rubbish disposal remained the same, one could conclude that the period 5 mill was not in use for very long, but the character of the finds assemblage would indicate that the function of the mill had not changed in this period. There is, however, a notable change in the relative proportions of pottery fabrics and forms, but this cannot provide a sensitive chronological guide other than that such changes are compatible with a fourteenth-century date.

The only indication of a possible date for the end of period 5 comes from a silver halfgroat of Edward III, which is dated to 1361-9, found in a period 6 context (CO 20). Dating by coins is notoriously unreliable, but, if the evidence of this coin is to be used, all that can be said is that period 5 had finished by 1369 or later. However, comparing the relative quantities of material from period 4, probably deposited over a century, and from period 5, it would be difficult to see period 5 lasting as long as fifty years.

Period 6: *watermill, ?mid-fourteenth to Plate fourteenth/early fifteenth centuries*

Figures 15, 17, and 18 (plans)

A further, crudely executed, revision of the wheel trough and tail race occurred in period 6. This is associated with a continuation and, with the enlargement of one hearth, perhaps an expansion of the metalworking activities of the previous periods. There then followed substantial alterations to the mill building and wheel house, and these have been separated into a second phase. The old wheel house was dismantled and perhaps replaced, although it is possible that the mill ceased to function. The west wall of the mill building was rebuilt; the building was extensively partitioned for the first time and this was associated with the abandonment of the large hearth. The other hearth was rebuilt in a new position.

The ?workshop to the east of the mill was demolished and replaced by a larger padstone building which may have been a forge; this work, and the use of the areas outside the mill building, could have occurred at any time during period 6 and are thus shown on the plans of both phase 1 and phase 2 (Figs 15 and 17).

The mill race phase 1

Figure 16 (plan)

The head race and the wheel house remained, unaltered, while the sides of the wheel trough were dismantled; some of the timbers were probably reused in the new tail race (E385; E390) (Figs 16 and 37; Plate 20). Although the three period 5 baseplates of the wheel trough were not removed, they were not used to support the overlying timbers. Two large baulks (E279; E280) were laid on the silts to act as baseplates for a wheel trough. (The western ends of both were removed in period 7.) The baseplates were supported and wedged in place by timber blocks (E281; E282; E407; E455; E700) and secured by stakes driven into the wheel pit (E823-E830; E701; E702).

The evidence for sides to the wheel trough is problematic. Two mortices in the upper face of the south baseplate, one of which contained the remains of a tenon (E381), were not matched in the north baseplate which only had one central mortice (Plate 21). It is of course unnecessary to have both sides of a trough symmetrically arranged (and a further mortice may have been lost when the west end of E280 was removed in period 7), but the east end of the north side of the trough would have been

Figure 15 Mill (BAB) period 6 phase 1: mill

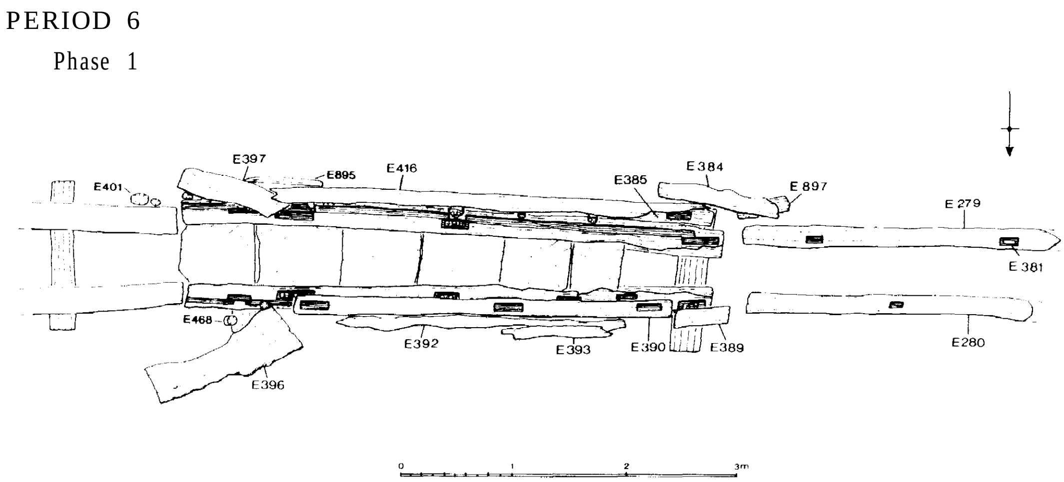


Figure I6 Mill (BAB) period 6 phase 1 wheel trough and tail race

unsupported. Although laid on edge, the baseplates were not high enough on their own to retain sufficient water to drive a wheel, and the surviving tenons would imply that there was some kind of structure above the baseplates.

There appears to have been considerable seepage of water out of the wheel trough into the wheel pit to judge from the cusped, eroded, sides of the pit and the numerous stakes driven into the area in an attempt to stabilise both sides (north side: E283; E372; E373; E375-E377; E703; E704; E708-E710; E719; south side: E378; E417-E419; E705; E712-E717); planks and boards were also thrown into this area (E379; E720-E722) (S18: Fig 27). The space between the sides of the trough and pit accumulated, or was backfilled with, silts (E433), some of which were highly organic.

The boarded sides of the period 5 tail race were removed. A trench (E735) was dug through the north bank and another (E741) through the south bank, down to the top of the period 5 baseplates. These were then filled in a rather haphazard way with horizontal timbers, some of which probably had been salvaged from the period 5 wheel trough (north side: E389; E390; E392; E393; E396; south side: E384; E385; E397; E895; E897). The timbers were held in place with stakes that had been driven into the banks and behind the period 5 baseplates (where these survived) (north side: E459; E462-E469; E801-805; E745-E748; E822). The gaps between the staked timbers and the sides of the tail race channel were then backfilled with a loose clay, which was surrounded by silts (E454; E742; E744), which presumably indicate that water seeped between the timbers (S18: Fig 27). The south bank was capped with a further layer of clay (E430).

The configuration of this new tail race was different from that in previous periods. The sides were about two-thirds the height *(c* 0.40m) of the period 5 race. The wheel trough and the tail race were no longer jointed together. Instead, the gaps between the two were blocked with timbers (E384; E389) wedged behind the baseplates. Such an arrangement must have allowed much water to escape, which no doubt contributed to the erosion of the wheel pit noted above.

Where the new channel was founded on the baseplates of the period 5 tail race, the sides remained approximately parallel; this was the arrangement for about the west two-thirds of the excavated length of the race. The sides of the east third were splayed, which produced a pond-like feature. This east section continued beyond the excavation and probably only a small part was within the excavation, but it might imply that the water no longer flowed through a defined channel from here on. If this was the case, it would have increased the likelihood of water ponding back up the tail race, causing the wheel to operate in dead water. The lower parts of the base of the tail race certainly started to collect silt (E846; E452) during this period (S16: Fig 27).

The mill race phase 2

Structural changes to the wheel house area are tentatively linked with substantial alterations which were made in the building (see below).

The timber-revetted platform on the south bank (E430, raised in period 4) was dismantled and the east half of the platform was dug away to leave a slope. At about the same time, and probably using the old platform material, the area around the

Plate 20 Period 6 mill race, from the east

uprights of the wheel house was filled in. This area had previously been kept at a lower level than its surroundings (the south head race bank immediately to the west and the platform to the east) to allow easy access to the wheel and its frame for maintenance. The clay (E360...) which filled the area covered the east sill (E739) and the stump of the west upright (E731) of the wheel house. The wheel house had thus been dismantled, and the pieces of timber not required had been used probably for backfilling the area (E370...; D224...) and roof tile presumably from the wheel house roof scattered over the surface as a hard-standing (E423; E426) or dumped (E725; E730). The effect of the dumping was to create a continous bank on the south side of the mill channel.

Padstones were then set on top of the clay in the area where the wheel house stood (E295; E297; E1202; ?displaced E299). These might be interpreted as the foundations for a building which extended south beyond the excavation were it not for the timber slot (E294) that extended north from padstone E295 and the floor levels of pebbles and clay that were laid up to the edge of the wheel pit (E290...; E298; E422). It appears as though the wheel house had been replaced on a smaller scale and on a slightly different alignment; it could be associated with the pebble wall/footing (E236) built over the large hearth in the mill building which aligns with the west end of this new structure. It is, however, doubtful that this was a structure that supported a water wheel and mill machinery (as the wheel houses of previous periods had done) because the foundations are too insubstantial and

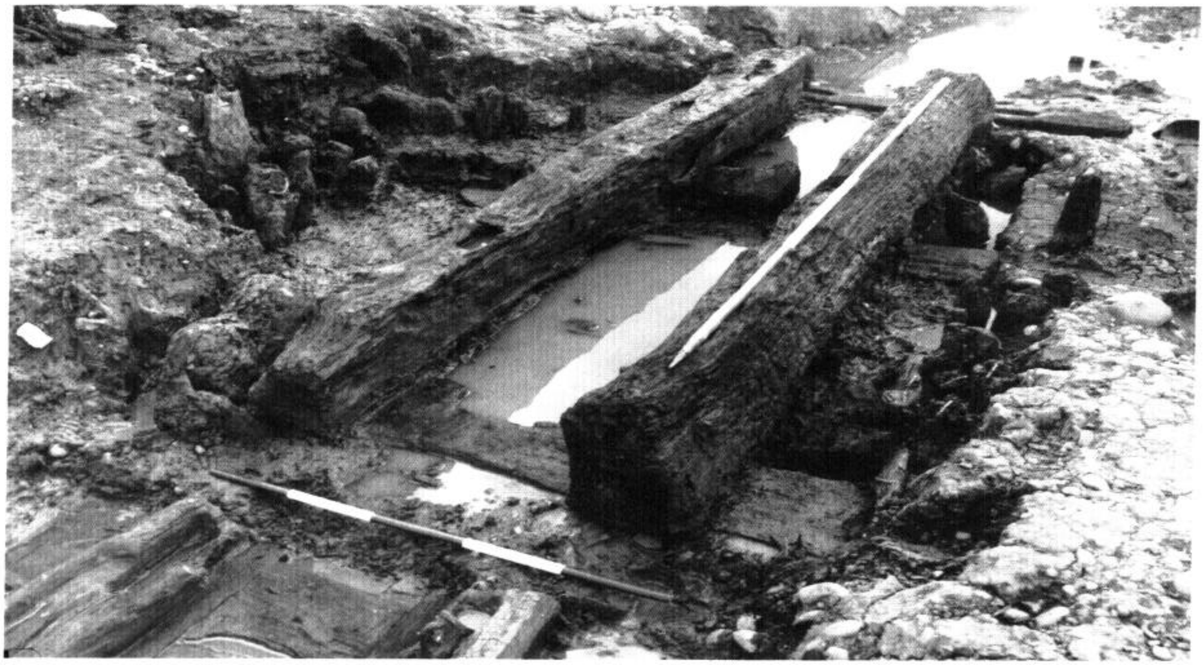


Plate 21 Period 6 wheel trough baseplates and stakes to stabilise the sides of the wheel pit, from the north-east. (Smaller scale in the foreground: 0.20m divisions)

the building is at too high a level. It is best interpreted as a structure on the south bank which may have been connected with the mill building to the north, but, as the channel was clearly still open, it is difficult to suggest a function.

The mill building phase 1

The stratification within the building is difficult to put into sequence. The larger (E474) of the two period 5 hearths was increased in size. Some large slabs of sandstone were added to the north (E763; E240; E241) and west (E245; E482; E483) of the hearth as a kerb of sandstone blocks, which were extensively burnt. Other areas were repaired with tile patches (E764). These additions created a large, rectangular hearth which showed signs of extensive use (Fig 18).

During, or shortly after, the reconstruction of this hearth, a new floor was laid, of pebbles set in clay (E486/E478; B601; B123; B111; D215; C357; C198) and of clay (E473...; B169). There then followed a phase when the rectangular hearth (E474) and the ovoid, period 5, hearth (E277) were both used, as reflected in the deposition of a layer of clay, charcoal, and hearth debris (E471).

The mill building phase 2

The phase 1 arrangement of the mill building was abandoned and parts of the building altered. The changes are sufficiently different to regard the alterations and subsequent occupation as a separate phase (Plate 22). The northern section of the west (lean-to) wall was replaced on the same alignment. A new foundation trench (C195) was dug and filled with pebbles set in clay (C354; C187). Roof tile, perhaps dislodged from the lean-to roof during renovation, was spread with pebbles (C352; E479) to fill a hollow and to make a new floor.

The central area of the building was divided into more compartments (Plate 23). The large rectangular hearth (E474) was taken out of use, partly dismantled, leaving a destruction layer (E268), and a length of pebble wall/footing (E236) built over it with a padstone (E475) set near its north end.

East of this, an east-west partition of sandstone and oolite blocks (E264-E267), as found, partially divided the mill's central space; it may have extended across the width of the building to join with pebble wall E236, but there is no sign of a break in the floor deposits here. One of the blocks (E266) had a hollow; this block may have been reused but it could have pivoted a piece of

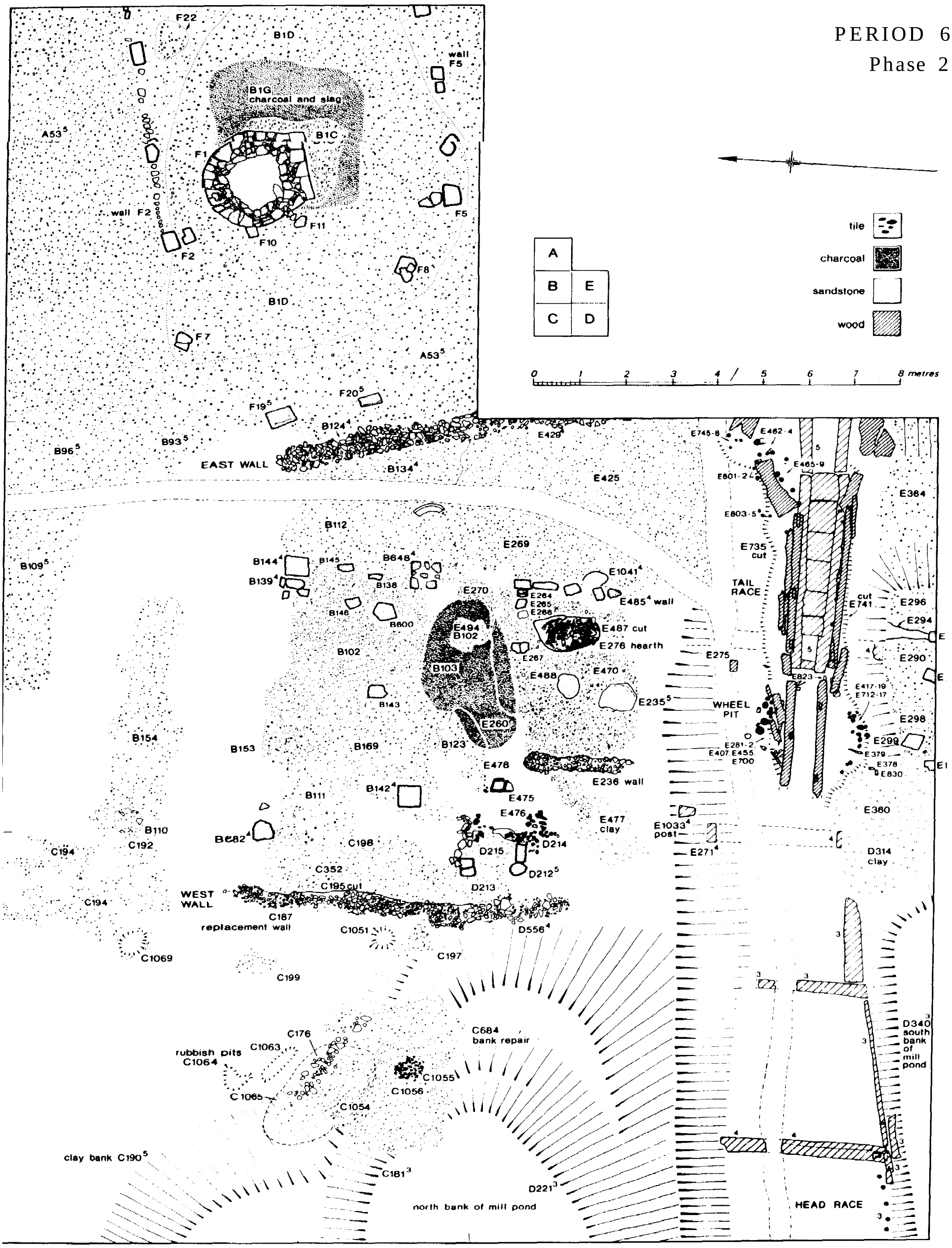


Figure 17 Mill (BAB) period 6 phase 2: mill

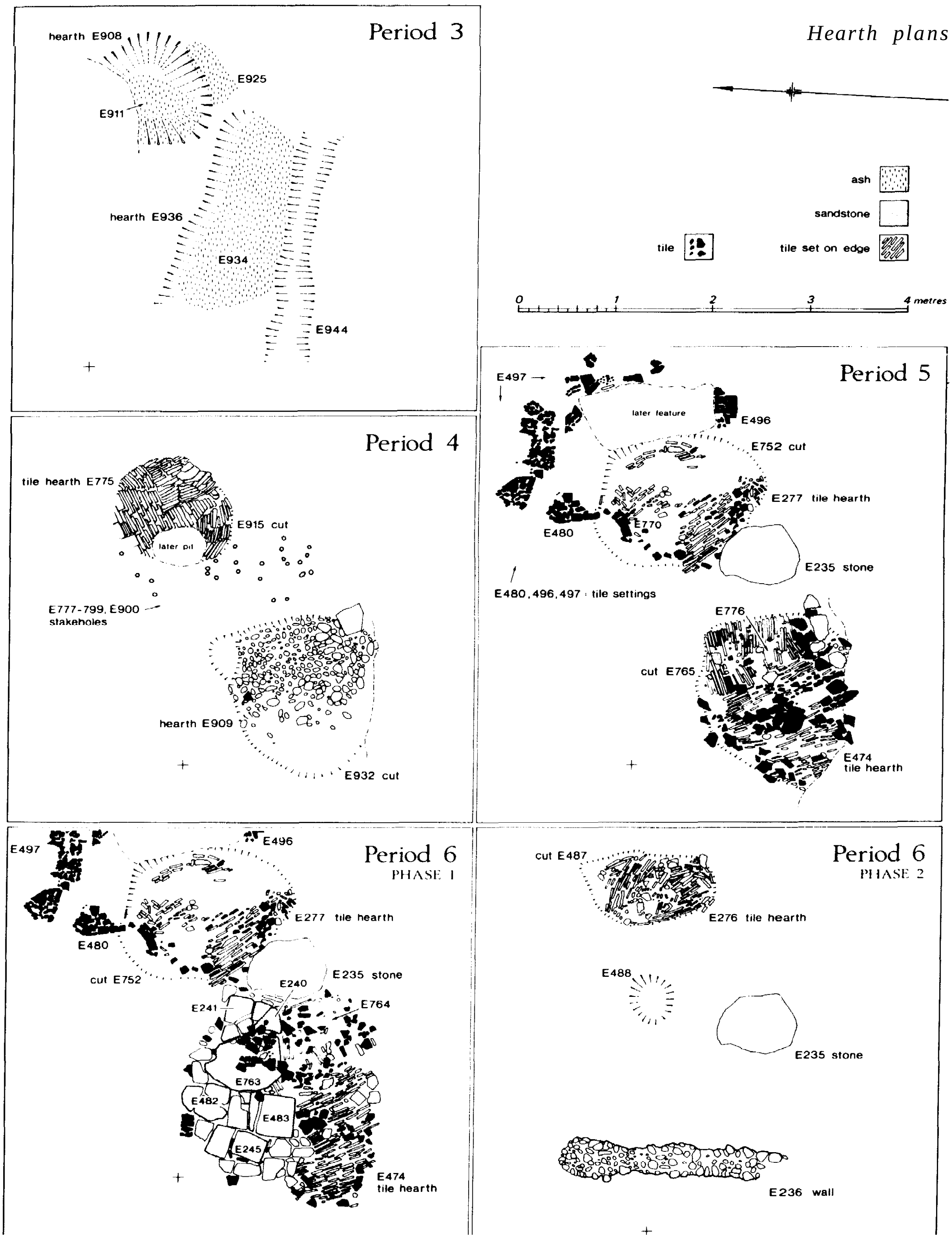


Figure 18 *Mill (BAB) periods 3-6: hearth plans*

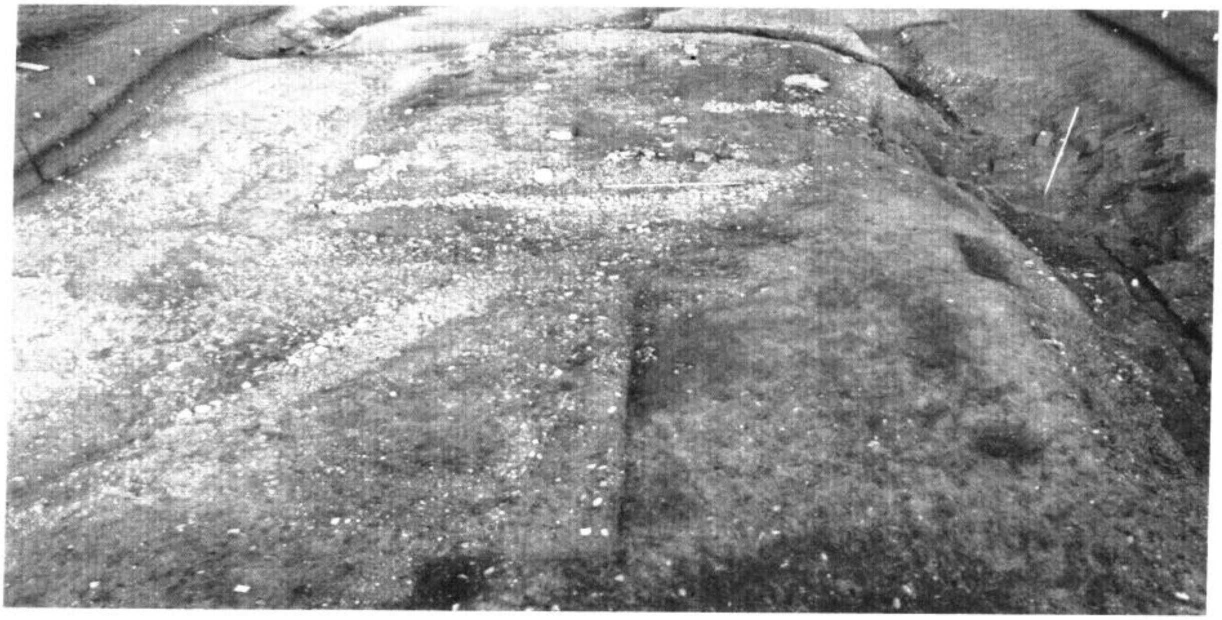


Plate 22 *Period 6 phase 2 mill building and north and west environs, from the west*

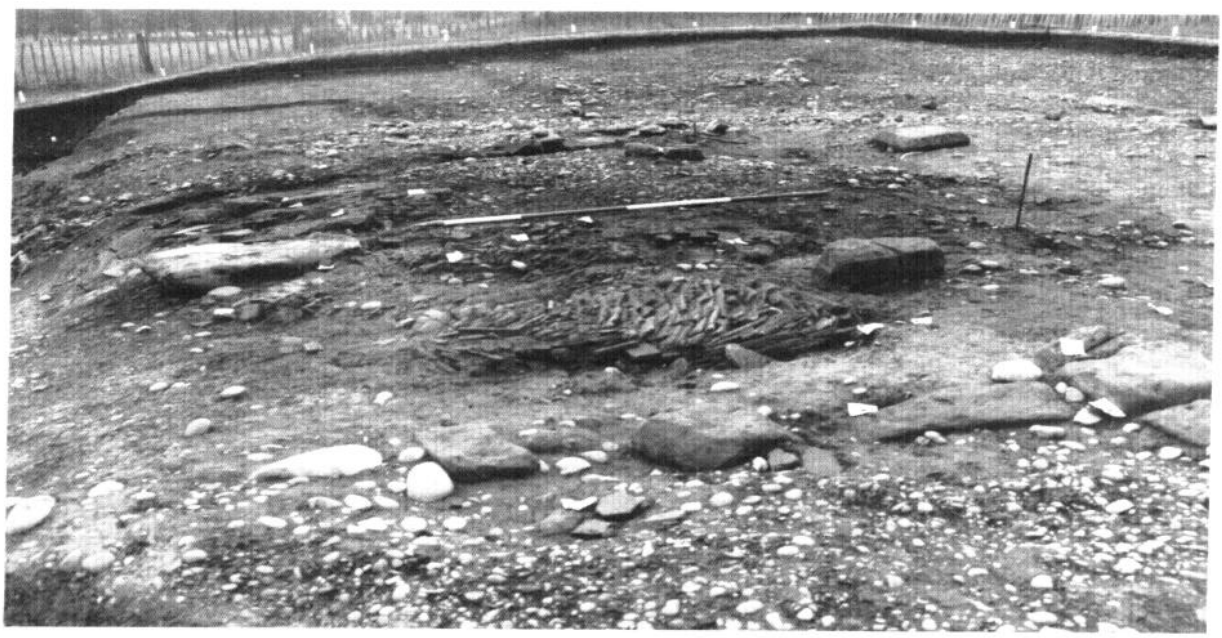


Plate 23 *South-east part of period 6 phase 2 mill building, showing new hearth (E276) and partitions (E264-E267), from the south-east*

machinery; given its position, it is unlikely that it was for a door.

A new, sub-rectangular hearth (E276) was built in the central part of the building, south of the new east-west partition, in the angle formed by this partition and the east wall (E485) of the central area. A pit (E487) was cut into the floor and into the east edge of the period 5 hearth, and was filled with pitched roof tile (E276) (Fig 18; S19: Fig 30; Plate 23). A substantial posthole (E488) was dug to the west of the hearth; it may have supported an anvil, and replaced the large stone (E235) used in period 5.

For the first time, the north half of the main building was separated from the east lean-to by a partition based on sandstone blocks (B138; B145; sandstone blocks B146 and B600 may have been displaced from the partition wall). It extended south as far as the central padstone B648, leaving a wide gap for a doorway between this (north) partition and that to the south (wall E485). A new pebble floor was then laid over the whole of the east lean-to (E425/E269/B112).

After these substantial internal rearrangements, clay floors continued to be laid in some parts of the mill (E477...; E270; B102...). In some cases these became heavily impregnated with ash, hearth debris, and charcoal (E494; E472; E470; B153); this is particularly true of the floors near the hearth (E276), but especially so it seems in the part of the building that led from the forge area to the east lean-to (E260; B103...).

The north mill pond bank, period 5 and/ or 6, and east building/forge, period 6

Some external features could only be classified as period 5 and/or 6. As most of the contexts imply an intensity of use or repair work, it was thought most appropriate to discuss them in period 6 when there was more renovation and occupation.

The north side of the north mill pond bank (C190) had clearly deteriorated. Clay and pebbles were dumped to consolidate the bank (C1065; C1055; C1054; C1056...; C197). In some cases the clay was packed with large cobbles (C684; C176). The area north-east of the bank also seems to have been popular for the dumping of rubbish in pits (C1063; C1064; C 1069; C1051). The area to the north of the mill building was consolidated with dumps of pebbles (C199; C192/C194/B154; B110).

After the period 5 ?workshop to the east of the mill building had been demolished, the immediate area was levelled by the addition of more pebbles (F22...; B1D). A new building, based on padstones with lines of cobbles in between, was erected (F5; F2). Only the west end of this building was excavated in the 1967-9 seasons, but the stripping of the topsoil from a larger area in 1967-8 by Rowley and Wise showed the building to have been at least 12m long (Fig 4).

The building appeared to be featureless except for a stone structure (F1, including an incomplete grindstone, ST 60; Plate 24) at the extreme west end which was horseshoe-shaped in plan. This structure was at least three courses high and its interior was packed with clay and tile. As the pebble floor was strewn with smithing slag and charcoal (B1C; B1G), the structure is interpreted as a possible forge. Two smaller padstones (F10; F11) adjacent to the west side of the forge structure may have supported a chimney hood, and the two outlying padstones to the west (F7; F8) may have supported a lean-to attached to the gable end of the building. The forge was clearly built as close as possible to the mill. The large amount of space available in the rest of the building to the east is puzzling, but this may have been a farriery, and most of the building could have been used for tethering horses. Another possible hearth, consisting of an incomplete ring of slag and pebbles (F9), was excavated to the north of the workshop in 1967-8 (see Fig 4).

The character and length of use

The occupation of the mill in period 6 appears to have two distinct phases.

The first phase, before the renovations in the building, seems to be similar in character to the previous periods. The internal arrangements and the character of the floor levels would point to a continuity of metalworking using two hearths with water-powered bellows and a hammer. Indeed, the increasing size of the hearths throughout the periods, culminating in phase 1 of period 6, could be evidence for this phase being the most active in terms of industrial production (Fig 18).

This has to be reconciled with the evidence from the wheel pit and tail race. The period 6 alterations to these can best be regarded as haphazard, and mark a decline in the standards of mill repair and maintenance. The superimposition of the tail races in previous periods had had the effect of progressively reducing the gradient which potentially led to a decreasing efficiency in each successive mill of the sequence. In period 5 it appears that the millwrights maximised the efficiency of the mills, firstly, by making sure that sufficient water got to the wheel to turn it by increasing the head of water through raising the pond banks, and, secondly, by producing the most sophisticated tail race structure of the sequence to make sure the water got away from the wheel as quickly as possible.

In contrast, the alterations made in period 6 appear very inefficient. The evidence seems to suggest that the new structures with their obvious weaknesses - the gaps between wheel trough and tail race, the inefficient tail race sides, the funnelling out of the tail race which probably caused ponding back - were not executed with the prime intention of effective water management. Indeed, it is difficult to see why the period 5 mill was altered. The revisions could not have improved the gradient

Plate 24 Period 6 forge (F1) with (bottom) a part of the north, padstone wall (F2). (Larger scale in the foreground: 6inch divisions)

because the period 5 tail race bottom was maintained in period 6. In view of the relatively short length of time that the period 5 mill operated, it is unlikely that the structures had to be replaced because of deterioration, especially as the most vulnerable part, the tail race base, was retained.

Two interpretations are possible. Firstly, that the mill continued to function in period 6, and that the shortcomings of the revisions had little effect on the mill's efficiency. The evidence for the use of water-power remained constant, indeed the same, from periods 5 to 6. What increased was the size of the large hearth, which could imply that increased output was thought possible.

Secondly, that the first phase of period 6 of the mill building, whose similarity of character to earlier periods has already been noted, should actually be interpreted as the last phase of period 5. In other words, the extensive metalworking occurred when the period 5 wheel trough and tail race were still in place.

In the absence of a stratigraphic link between the mill races and the mill buildings, either interpretation is possible. The correlation between race and building throughout is based on the assumption that substantial alterations in the race were accompanied by changes in the building. This approach appears to be justified in the case of periods 3 and 4. Thereafter it becomes increasingly difficult to divide the sequence into periods because of the continuity in location of the functionally important features such as the wheel house and hearths.

The justification for interpreting the race and building phase under discussion as belonging to period 6, and not period 5, is twofold. Firstly, a short period 5 was judged to be indicated by the paucity of the archaeological assemblage, in conjunction with the stratification, and because it would be difficult to fit in another phase of hearths. Secondly, the character of the second phase of period 6 suggests reduced metalworking in the mill and it is likely that this phase did not use water-power (the evidence is presented below). If this is the case, and the first phase of period 6 of the mill building were reassigned to period 5, then the alteration of the mill race in period 6 is difficult to explain because there would have been no need for any alterations if the water were not going to be exploited. There was no need to continue to maintain the mill race purely as a drainage channel for water when at least one, and possibly two, bypass channels existed (see below, part III, 'Water supply').

In phase 2, the large hearth (E474) went out of use and the second hearth (E276) was reconstructed 1.25m east of its period 5 predecessor. The large anvil stone set between the two hearths for ease of working in period 5 was probably abandoned for one that was placed nearer to the new hearth. All the activity appears to be concentrated in a restricted corner formed by the erection of a new partition.

The reconstructions of the mill machinery have had to take into account not only the surviving fragments of machinery but also the positions of the hearths and the wheel house (see below, part III, The machinery and its arrangement in the mill buildings'). Over periods 3, 4, 5, and, perhaps, the first part of 6, the variables remained remarkably constant. However, in the second phase of period 6, the arrangement is sufficiently different that it has to be asked if water could have provided a source of power. Given that all the surviving stone bearings supported horizontal axles, it would be impossible to power bellows to a hearth so far from the water wheel without a gearing arrangement which would have required vertical shafts. In addition, no wooden objects have been positively identified as gear pegs. But this would not have prevented the use of a trip hammer if the stone anvil continued in use. This is, however, over 2m from the phase 2 hearth, which would have been inconvenient. The suggested replacement anvil is 1.5m further (north) away from the wheel and, for the same reasons as the bellows, would have been difficult to service with a power hammer.

The proposal is, therefore, that in phase 2 water-power was abandoned, but a forge in the mill building continued (?with a wheel house structure) and the character of the metalworking was maintained - the range of metal finds does not change during period 6 - albeit on a reduced scale. What was the function of the east workshop/forge? Firstly, it is important to stress that an east building existed in period 5, clearly associated with the mill building, and there is very slight evidence that it was a workshop. The period 6 east building was larger and there is more evidence that it was used for smithing. The choice is between regarding the workshop as supplementing the metalworking in the mill, perhaps by being concerned with more specialised activities, such as farriery, or the east workshop/forge somehow compensated for a decline in productivity when water-power ceased to be used. A middle way is of course possible, but first building an east workshop in period 5, when the mill was probably working to capacity, and the unusual position of the forge in the large, period 6, east workshop might argue that the workshop was intended, and continued, to augment the kind of metalworking that was practised in the mill, with or without water-power.

This discussion has been extensive because of the difficulties of the site chronology. There are dendrochronological dates for neither period 6 nor period 7. A coin of 1361-9 was recovered from a floor which was laid in the first phase of period 6. Potentially, therefore, there is a *terminus post quem* of 1361 for period 6, even allowing that phase 1- could be in period 5.

The pottery assemblage for this period contains no new fabric or form introductions. The pottery from period 7 lacks the later fifteenth-century wares which have been found on the church and Nailor thinks that most of it was in use during the later fourteenth or early fifteenth century. This, therefore, seems to indicate that period 6 occurred during the second half of the fourteenth century.

Period 7: ubandonment and post-medieval use, late fourteenth /early fifteenth centuries and seventeenth to twentieth centuries

Figure 19 (plan)

This period is divided into two phases: firstly, the extensive evidence for the abandonment of the site and, secondly, post-medieval landuse and frequentation of the valley.

Phase 1: abandonment

The cessation of activity on the site is treated as a separate episode in the site sequence because of the large amount of evidence; alternatively, it could have been treated as a final phase of period 6, but this was felt to be too unwieldy.

After, and perhaps during, phase 2 of period 6, silts started to be deposited in the tail race. The stratification of the tail race shows clearly that the tail race had almost filled with sediment before the mill building was demolished (S16, S18: Fig 27). It is possible, therefore, that the sedimentation may have started, and the waterwheel ceased to work, while the mill building was in use. In such a situation the mill race would probably have become little more than a drainage channel which, because it was not being maintained, rapidly silted up.

The majority of the tail race was filled with a homogeneous red-brown silt which contained a large amount of organic material, especially small pieces of wood, branches, twigs, and leaves (E368). The silts were laminated and interleaved with lenses of different material such as silts of different colours, pebbles, and organic material (E411; E366...; E431), which presumably derived from the building or had been eroded from the banks (S16: Fig 27; Plate 25). Large timbers occurred in the upper levels of the main organic silt (E368) and when first uncovered they were thought to be part of a structure and *in situ* (E391; E406), which was not the case. Instead, they must indicate a phase of demolition of some part of the mill building or race. The main silt (E368) was also sealed by material which had come from a decaying building (E363; E730; E364; E367).

After the removal of the base planks of the head race, silts accumulated. The silts here were less

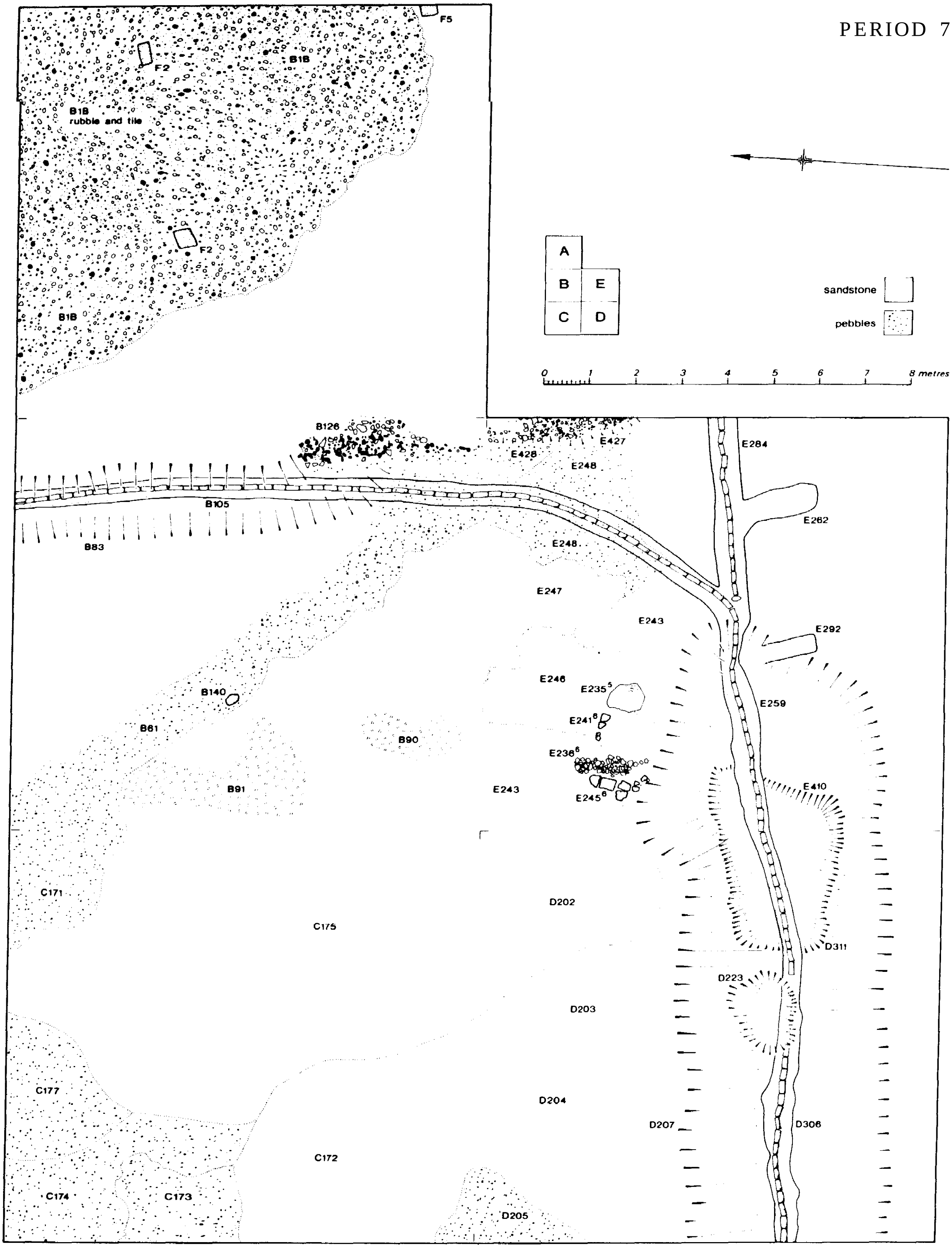


Figure 19 Mill (BAB) period 7: abandonment and post-medieval use

Plate 25 *Mill race with period 7 phase 1 silts, and the later, phase 2, drains (E259; B105), from the east*

Plate 26 Mill race with period 7 phase 2 silts, from the east

deep and much finer than the material in the tail race (D335...; D303; D307; D302). Some silt layers contained structural timbers, such as the remains of a grill (D303/1-4), and there were also dumps of pebbles (D337; D338).

Most of these primary silts were evenly deposited, evidently by water. However, the later fill materials (E364; E289...; D341; D336; D300; D301) contained more clay and had clearly derived from the banks on the side of the race, which must indicate that the mill and its surroundings had started to deteriorate (S10, S13: Figs 22 and 24).

The north mill pond bank had weathered and the material (C186; C193; C184...) had been redeposited close to the building. This was accompanied by what appear to be water-deposited silts (Cl80...; C185; C188; C191; C177; C179) to the west and north of the mill building, which may indicate increasingly wet conditions.

At this point in the sequence the mill building appears to have been demolished. There is little evidence for the actual process because most of the structure stood on padstones. However, the east wall of the central area was robbed by digging a trench (E427...) through the pebble foundations; this was subsequently covered with roof tile fragments (E428...). Indeed, the occurrence of roof tile on the floor levels and ground surface, subsequently covered in silts, gives the most widespread evidence of demolition. The distribution of metalwork in phase 1 of period 7 is notably different from the previous periods and is indicative of the demolition process (see below, Part III, Wass, 'Intra-site activities as reflected in the distribution of metalwork'). Most of the metalwork was concentrated in the area to the west of the mill building, mixed with roof tile and derived bank material (sealed by C175). The material appears to have been stockpiled here for salvaging. The east workshop was probably also demolished at this time, leaving a layer of sandstone fragments and roof tile (B1B).

The north mill pond bank weathered further (E247...; E246...; D205...; D211; C173) and some of the pebble repairs were robbed (C353, filled with c 174).

The entire site then seems to have been periodically flooded for a considerable time, to judge from the depth of sediment that sealed the site (E249...; D302...) (S3, S6: Fig 26; S1, S4, S9: Fig 20). These increasingly wet conditions in this part of the valley must be a major reason for the abandonment of the site.

There is very little dating evidence for this phase, and what there is has been discussed in relation to the dating of the end of period 6. To summarise, a coin of 1361-9 in a period 6 context is the latest coin from the site. Five medieval coins were recovered from period 7 contexts and these range in date from 1280 to 1351; they provide another salutary warning against the use of coins to date archaeological deposits, except in providing a *terminus post quem*. The pottery from this phase is thought to be no later than the early fifteenth century, which is the most reliable estimate for the date of abandonment. The botanic material shows the area reverted to grassland with wet-loving trees such as alder and willow (see below, part II, Carruthers, 'The valley environment ...').

Phase 2: post-medieval landuse and frequentation of the valley

Contexts have been assigned to this period on the basis of their stratigraphic position and because some of them contained small amounts of post-medieval pottery (seventeenth to twentieth centuries) that was considerably later than the previous phase of occupation.

The mill pond banks continued to weather and the material was redeposited in the mill race (D219; D218; D210) and on the silts (D209) (S13, S16: Pigs 24 and 27). The wheel pit and the west part of the tail race remained the deepest part of the channel and this was filled with a homogeneous deposit of pebbles, gravel, and clay (E255...; E254; E288...), as if the trench had been deliberately filled (S10: Fig 22; Plate 26). However, the date range of the clay pipes in the fill of the head race (D207) - between 1670/80 and 1840 - may suggest the head race, at least, took some time to be backfilled. The fill then silted over (E251...; E261; E252...; E250; D206).

Other evidence suggests there was a deliberate attempt to improve the quality of the land. Pebbles and clay (E248...; B61; B90; B91) had been dumped across the site apparently to make a path, perhaps in connection with the backfilling of the mill race. There was also an attempt to drain the area. A large sump (E410...) was cut in the wheel pit and this appears to have been filled in quickly (E365...). A trench (E259...; D306) was then cut through the mill race and continued (B105) around to the north, with another trench (E284) continuing the west-east line through the mill race. U-shaped ceramic 'pipes' were placed in both trenches and both backfilled (E361...; E258...; E256...; E362; E285); the main trench drained to the north, E284 to the east. Side trenches (E292; E262) were also cut in an attempt to create a herring-bone arrangement, but the attempt was abandoned. Although comprehensive, the drainage system may not have been successful as a shallow sump (B83) was dug later, and another hole (D223) was dug in the mill race, but this may have been to dispose of rubbish.

The pottery from the majority of the features is of nineteenth-century date. The attempts to improve the land represent a renewed interest in this part of the valley after a period of perhaps 400 years. A suitable occasion for these improvements might be the time when the valley was divided with hedges and ditches into smaller fields. As most of these are marked on the 1839 tithe map, this gives a *terminus ante quem*. Aston and Munton, however, do report a drainage operation in the valley in 1948 and the ceramic drains may date to that time (Aston and Munton 1976, 32). The Victorian locket (OM 65), clay pipes, and the child's school slate(s) (ST 332; ST334) are relics of the meadows' visitors.

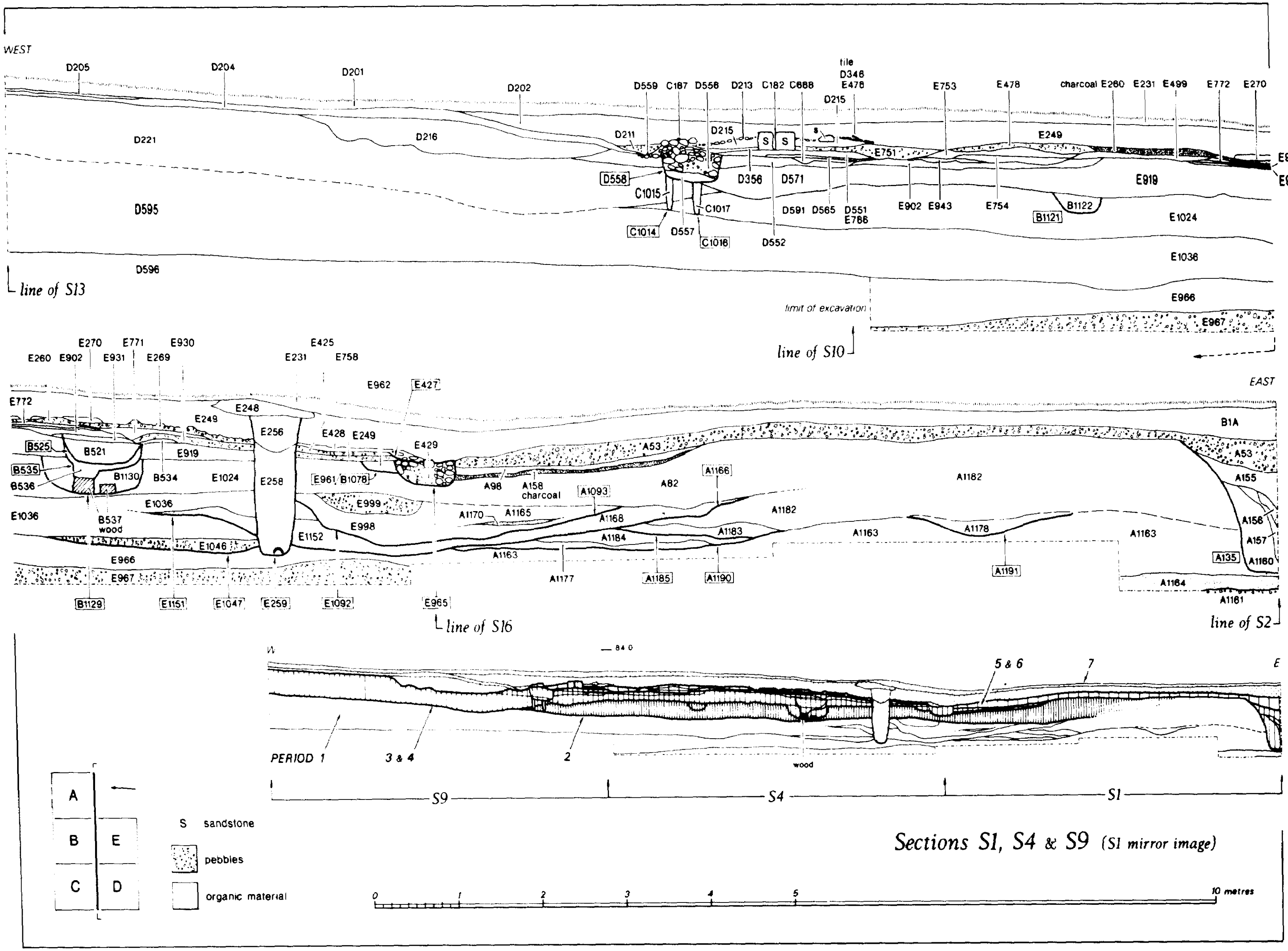


Figure 20 *Mill (BAB) sections S1, S4, and S9*

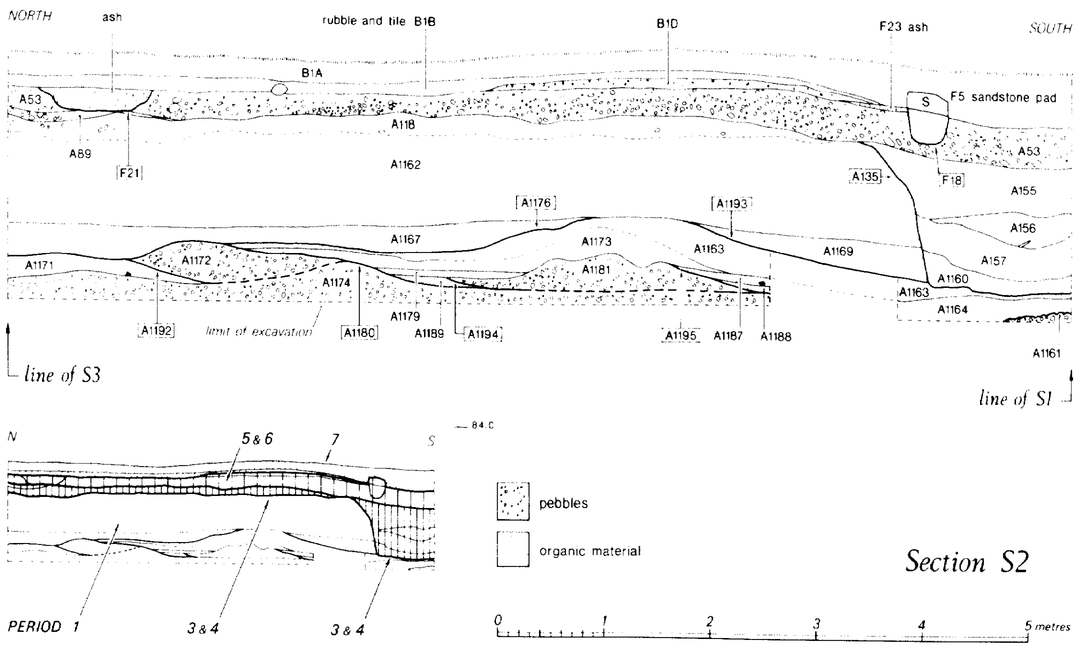


Figure 21 Mill (BAB) section S2

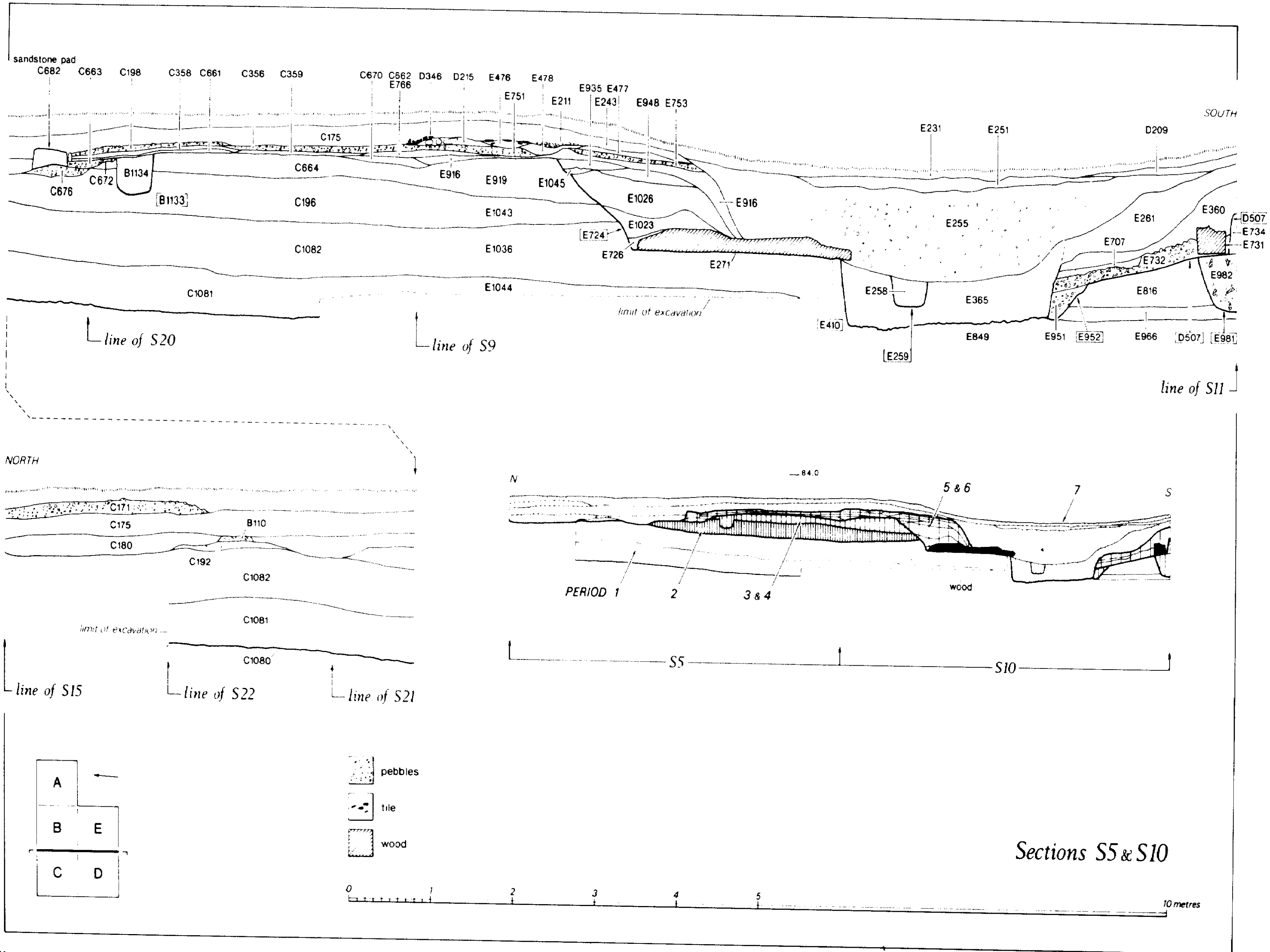


Figure 22 *Mill (BAB) sections S5 and S10*

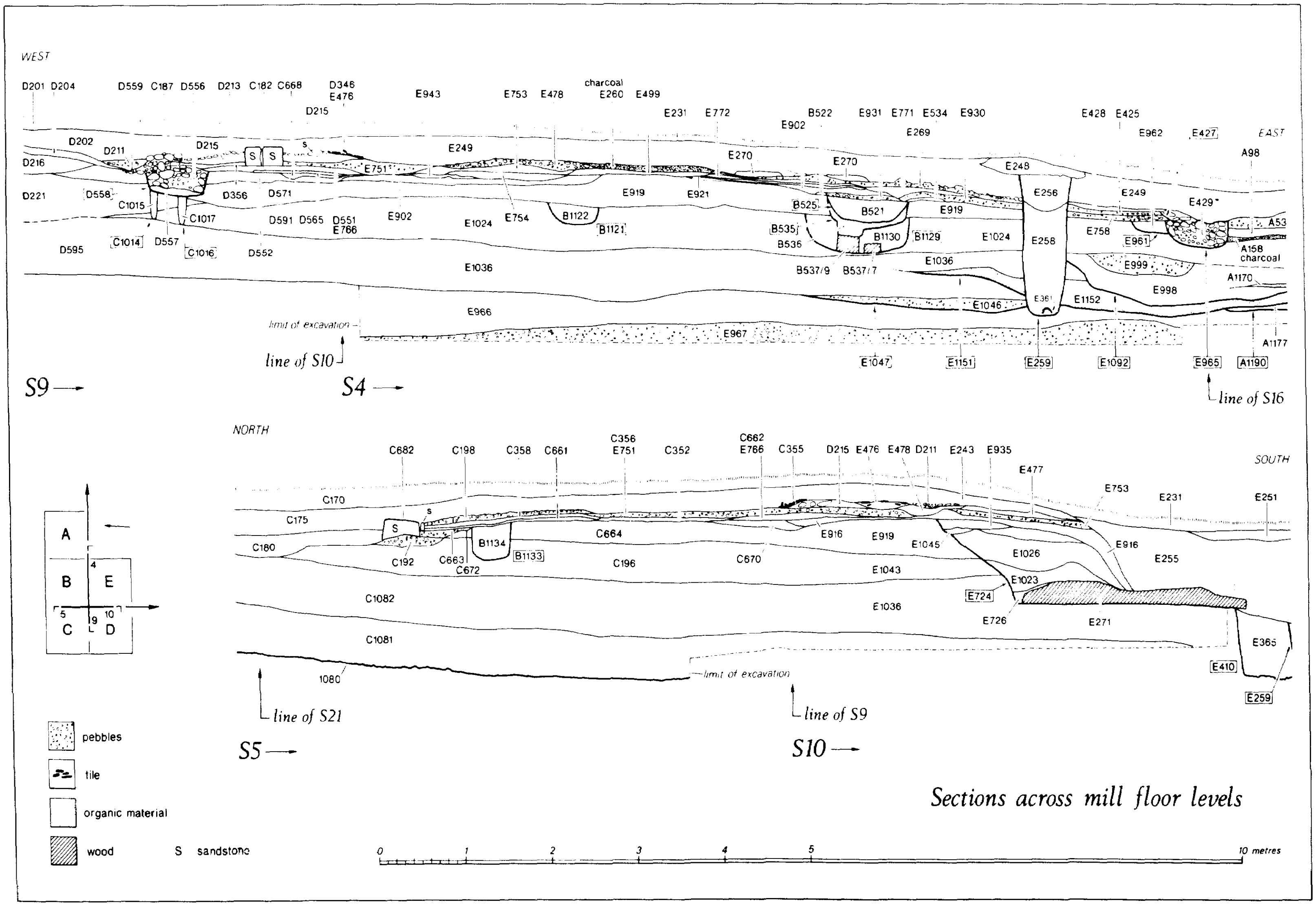


Figure 23 Mill (BAB) sections across mill floor levels, S9, S4, S5, and S10

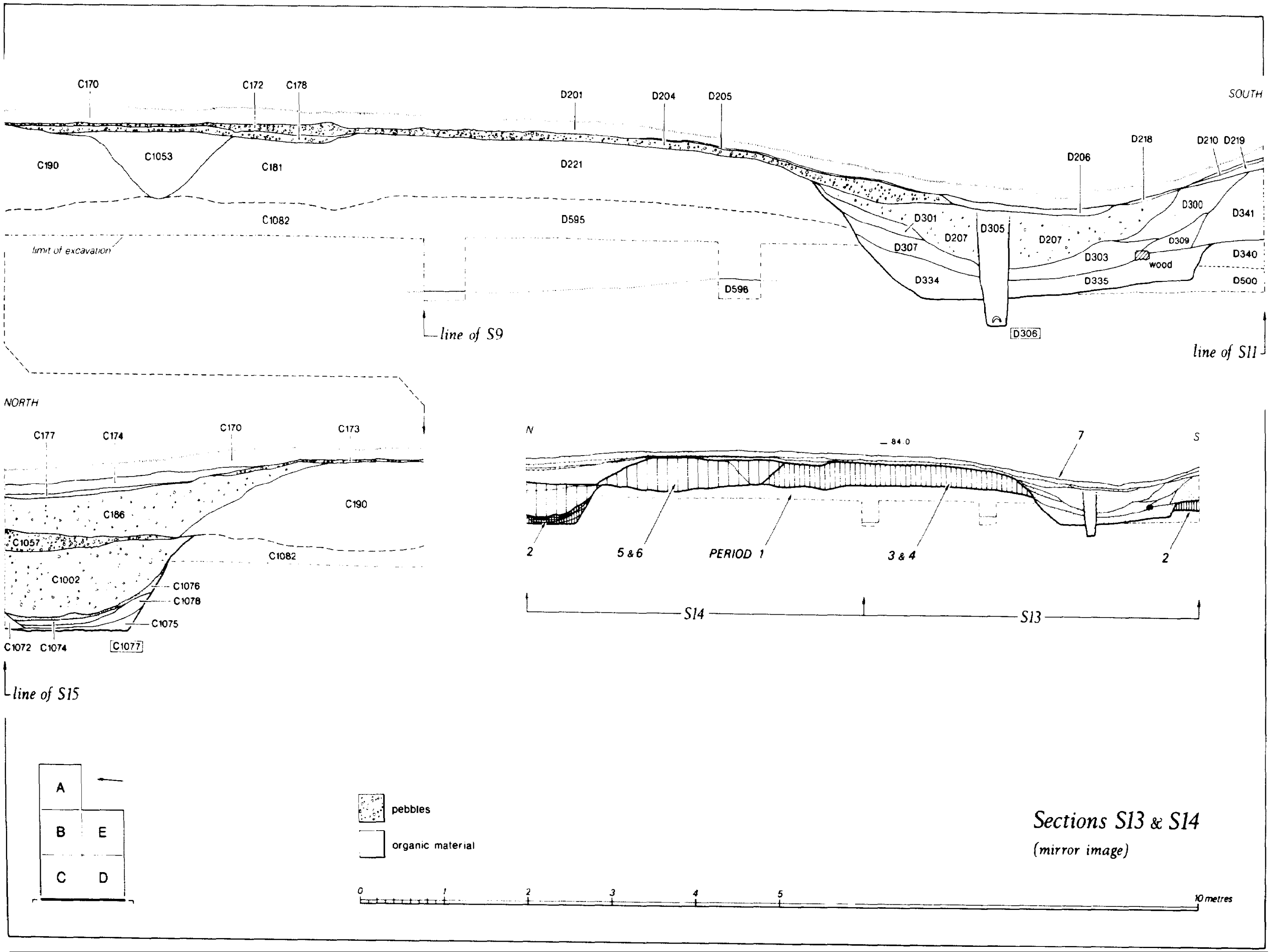


Figure 24 Mill (BAB) sections S13 and S14

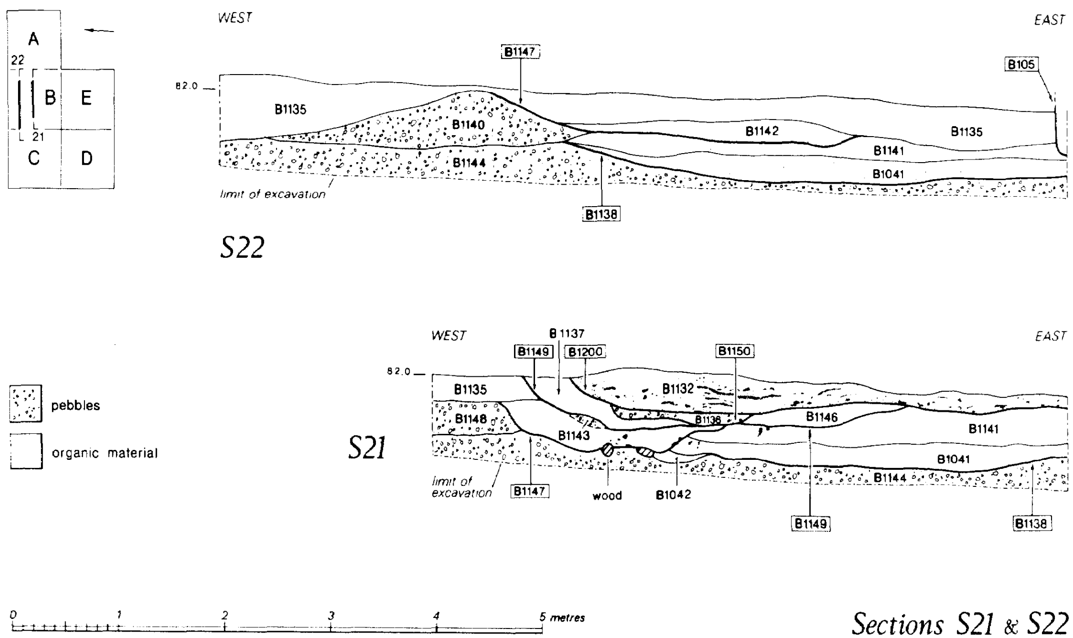


Figure 25 Mill (BAB) sections S21 and S22

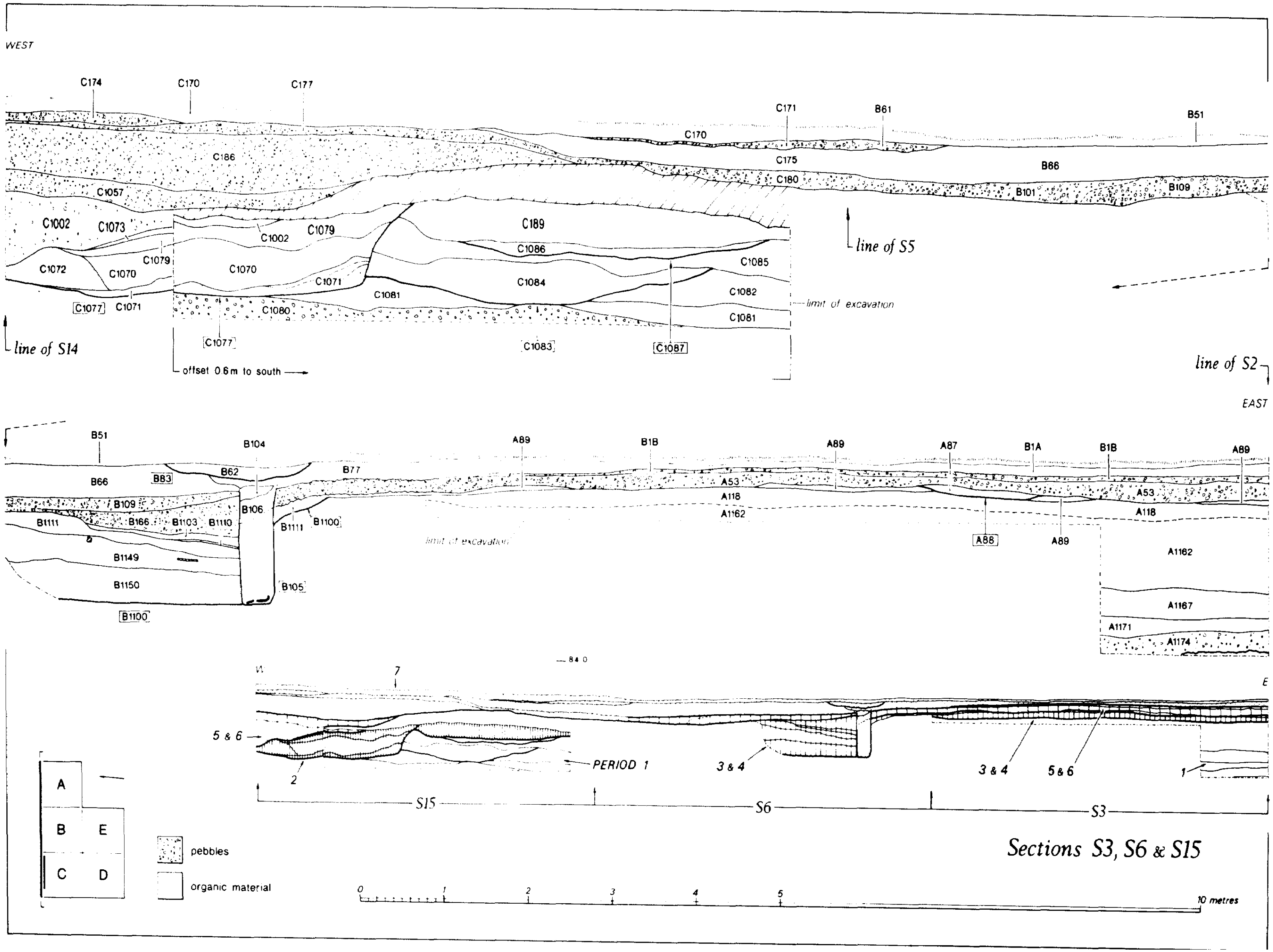


Figure 26 Mill (BAB) sections S3, S6, and S15

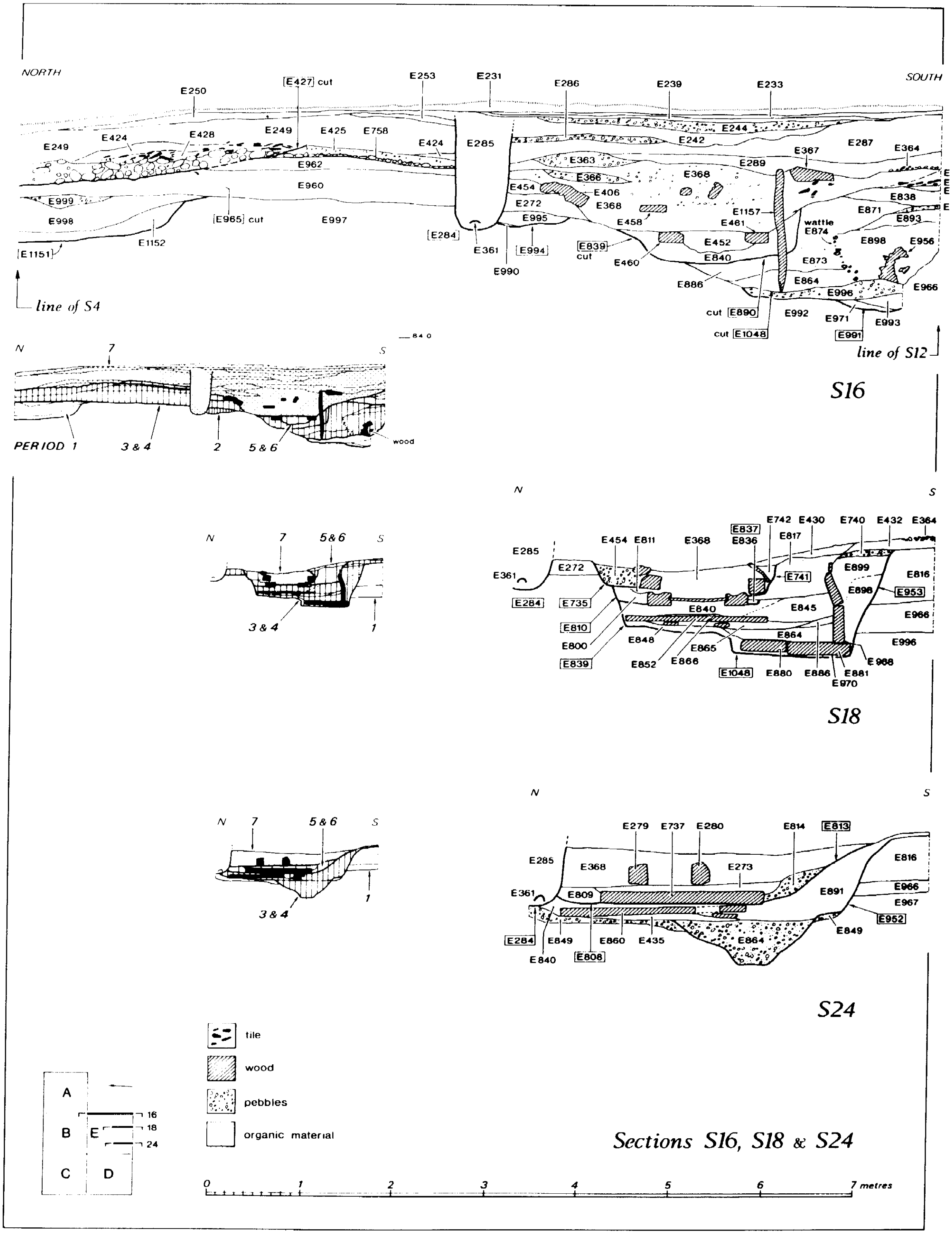


Figure 27 Mill (BAB) sections S16, S18, and S24

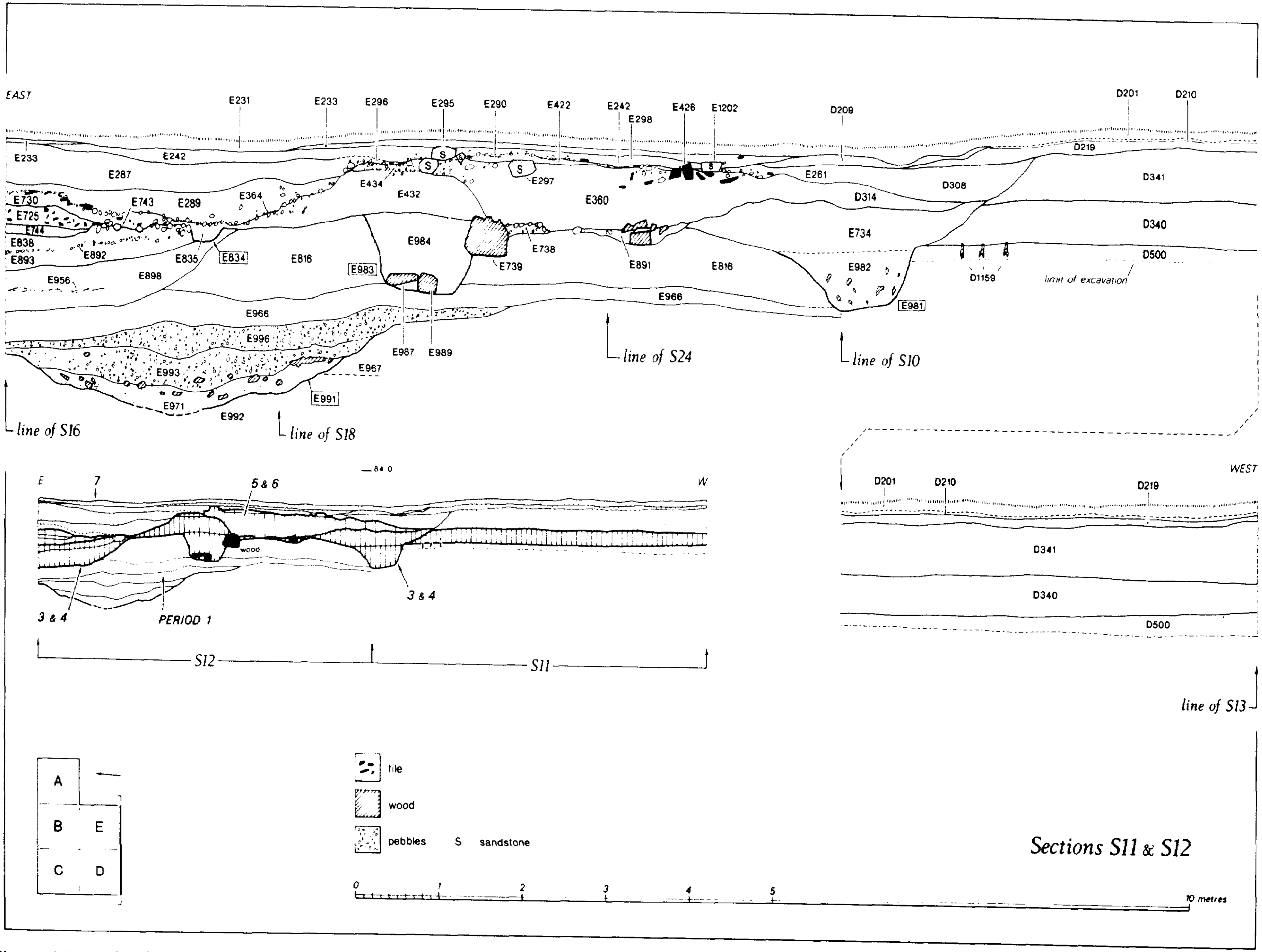


Figure 28 Mill (BAB) sections S11 and S12

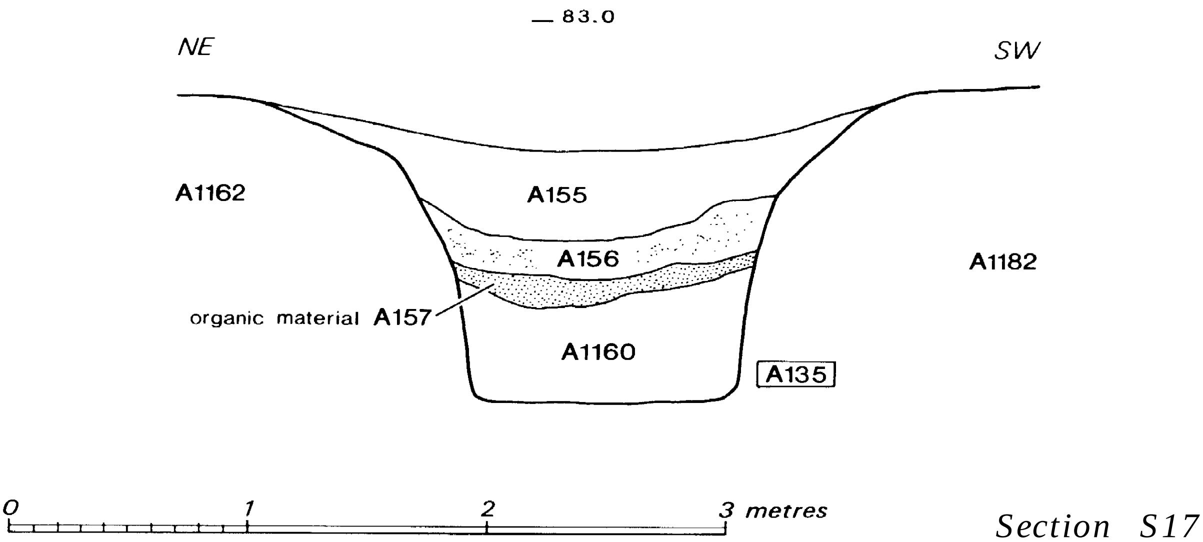


Figure 29 *Mill (BAB) section S17*

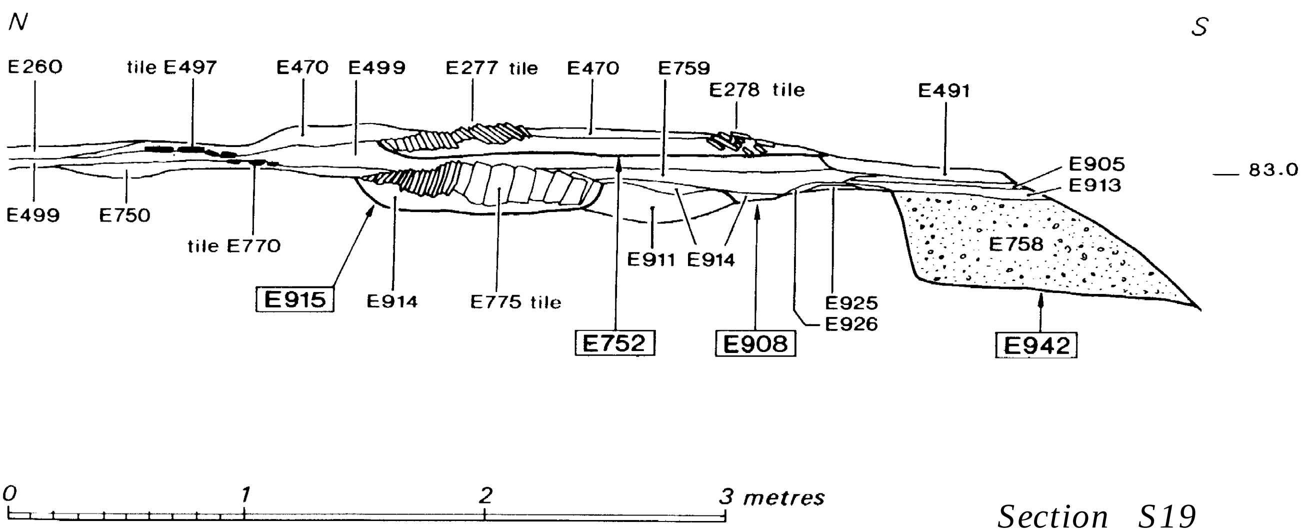


Figure 30 *Mill (BAB) section S19*

The mill (BAB) structural timber sequence by S J Allen

The reconstruction drawings (Figs 33-7) are based on the excavated evidence, The south sides of the mill races were better preserved than those on the north, the surviving parts of which generally matched those of the south sides. It was, therefore, decided to reconstruct the south and omit the north sides above baseplate level in the interest of clarity. Most of the reconstructions are based on evidence presented in the text. Where none survives, the solutions adopted are those most consistent with the carpentry of the mill races.

Wood is referred to here by OB (other botanical) number; Figures 33-7 show both context numbers and OB numbers. Technical terms are defined in the Glossary (see below, Appendix). The catalogue of structural timber is on fiche.

The period 1 wood

The period 1 stream channels (Fig 6) contained a number of roundwood fragments. The species are summarised by Carruthers (see below, part II, The valley environment ...'). Most of the wood showed clear evidence of having been deliberately cut, the roundwood finished by the delivery of a single blow at an acute angle to the axis of the stem with a metal tool blade. The cutting may be a result of woodland management such as coppicing. Alternatively, it could be the result of more extensive woodland clearance (see below, part II, Carruthers, The valley environment ...'). In some channel fills (A1170; A1177) the roundwood was associated with other fragments of oak (OB 401.6, .7; OB 400.2) which had been worked. This wood assemblage then is not derived from a completely unmanaged landscape.

The period 2 wood and pre-mill structure

The pit (C1077) dug to drain the site was quickly filled with stumps, but there was also a large quantity of oak roundwood, which may represent unwanted trimmings from the on-site preparation of timber, transported here from the felling site.

The period 2 pre-mill structure was of earthfast post construction (Fig 7). Only the bases of some of these posts survived. Each had been dressed to a rectangular cross-section from small diameter oaks, either box quartered or boxed heart. Some rested on ‘pads’ of timber. A possible wall stud fragment (OB 367.2) was discarded in a period 2 pit which

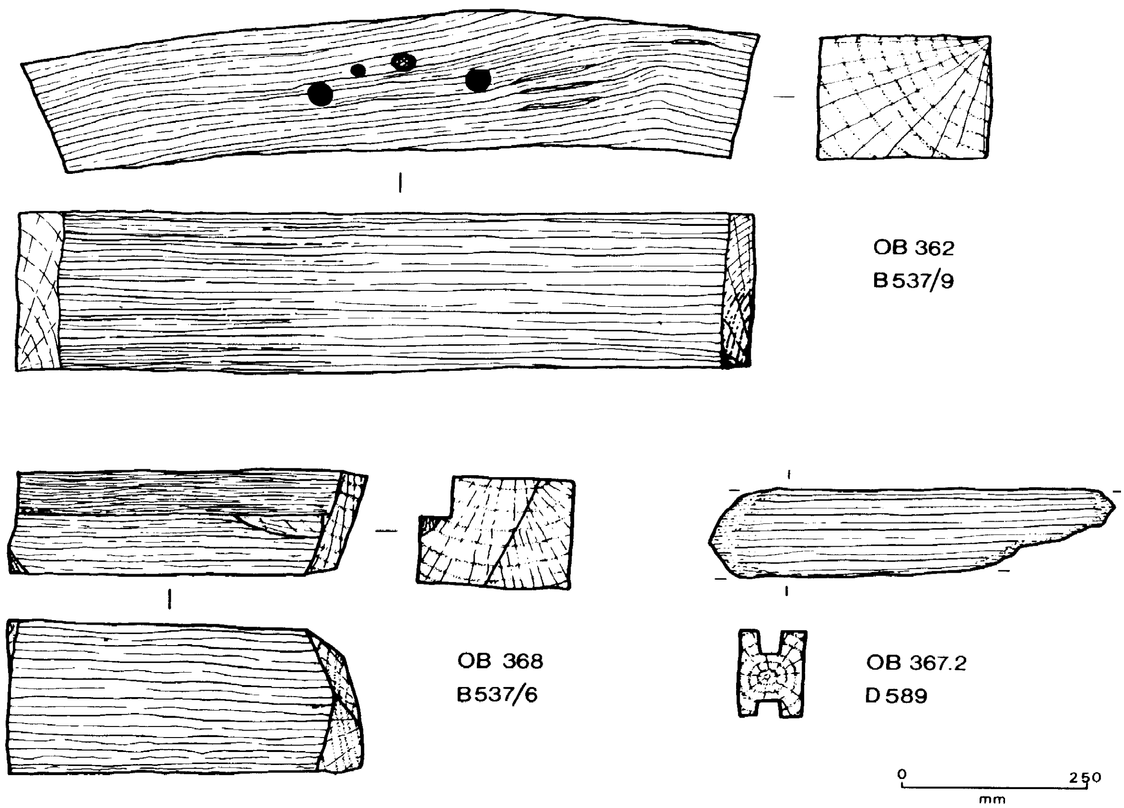


Figure 31 Mill (BAB): period 2 structural timbers (OB 362; OB 368; OB 367.2)

might indicate a wall of panelled wattle or plank and muntin construction (Fig 31). The wood was too decayed for jointing evidence or for many tool marks to survive.

The mill buildings and workshops

The period 3 mill building was also built using an earthfast post technique (Figure 8; Plates 8-10). The posts were used butt end down and dressed to sit on timber pad supports, some of which (OB 362 and OB 368: Pig 31; Plates 8 and 9) may have come from the structure of the earlier, period 2, building. The main uprights of the period 3 building (OB 410; OB 284) were of comparable size. Both were hewn from large, boxed heart oaks with basal diameters of some 0.72m and 0.8m, respectively. A crude chamfer cut at the base of OB 284 was probably a relic of its felling. One corner of each timber was left waney, with sapwood and bark present. OB 284 had a rebate in one corner, perhaps to take a wall section. The smaller posts of this building were similar in character to those of the period 2 structure.

The mill buildings of periods 4 to 6 and workshops of periods 5 to 6 were also timber-framed, but were supported on stone pads, with the exception of the period 5 east workshop which had timber sills of which no timber survived.

The period 3 mill race structure

Figures 32-4; Plates 27-30; Tables 2 and 3

The head race (Fig 33) had not survived well, probably because it remained in use (with some alterations in period 4) throughout the life of the four mills. In addition, the northern edge of the tail race seems to have been robbed and further damage caused by a drain (D306) in period 7 (Plates 4-7). The head race timbers are large, the baseplates (west to east) OB 266, OB 264, and OB 473, being lengths of boxed heart or halved oak, while the baseplate from the side of the channel, OB 265, had been box halved. All had been squared with an axe. OB 265 had been worked from both ends towards the middle. Although no toolmarks survived in the rebates, the mortices in both OB 264 and OB 266 had had their corners drilled out with a spoon bit. The lap of OB 265 had been carefully dressed. The west baseplate, OB 266, is so similar in size and carpentry to the tail race baseplate (OB 207) that it must have belonged to period 3 and was adjusted in period 4. Its rebate, like that in OB 207, should indicate the presence of a planked floor to the head race in the original arrangement. A series of stakes (OB 464-OB 468) indicates that the south mill pond bank was revetted with wattle fencing where it met the head race.

Plate 27 South-west part of head race, showing step in south bank revetment baseplate (D330/OB 265) and its relationship to the west baseplate with its rebate on its east corner (D312/D313/OB 266) and upright (O333/OB 156). (Scale: 0.10m divisions)

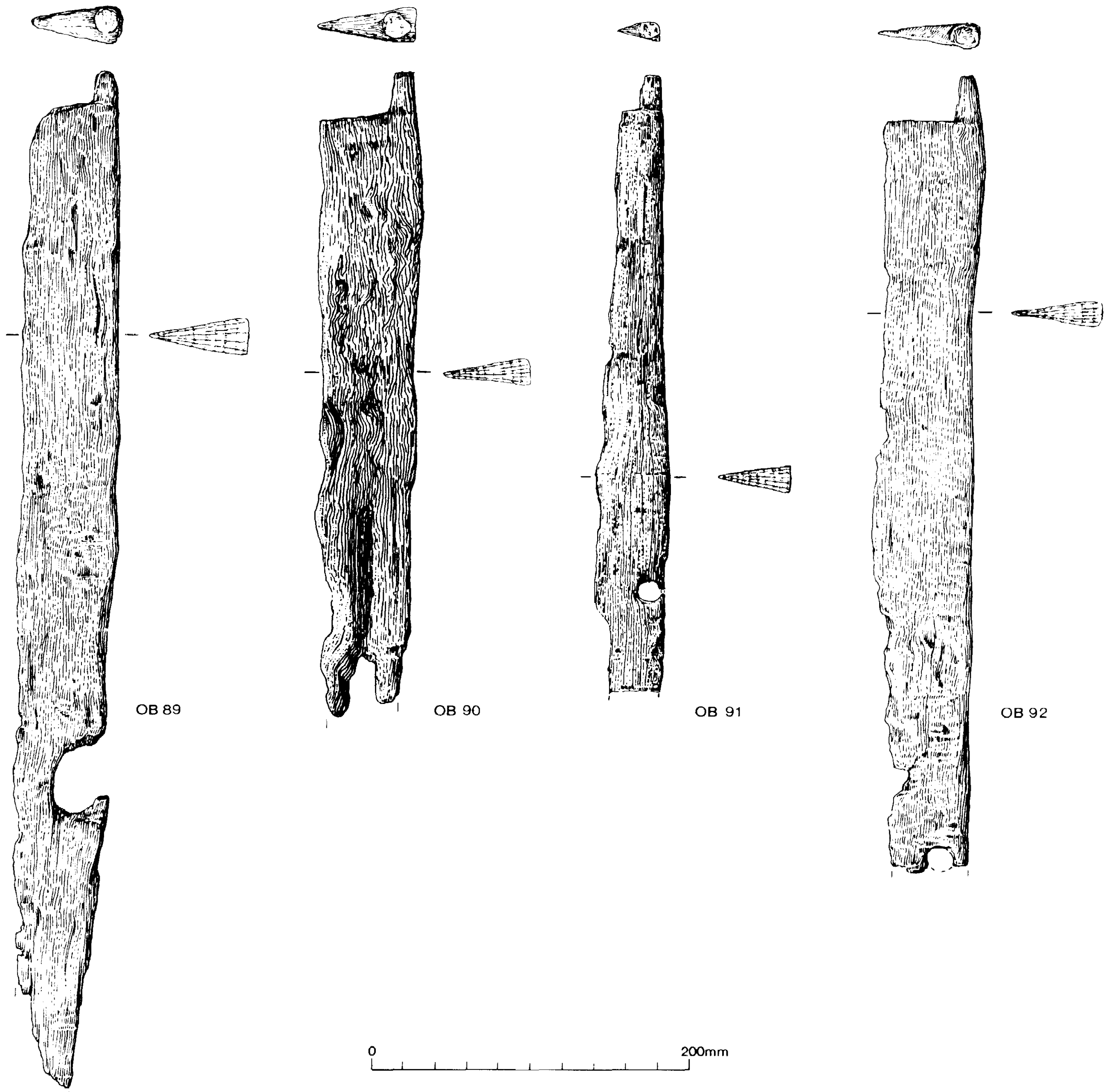


Figure 32 Mill (BAB): elements of a debris grill (OB 89-92)

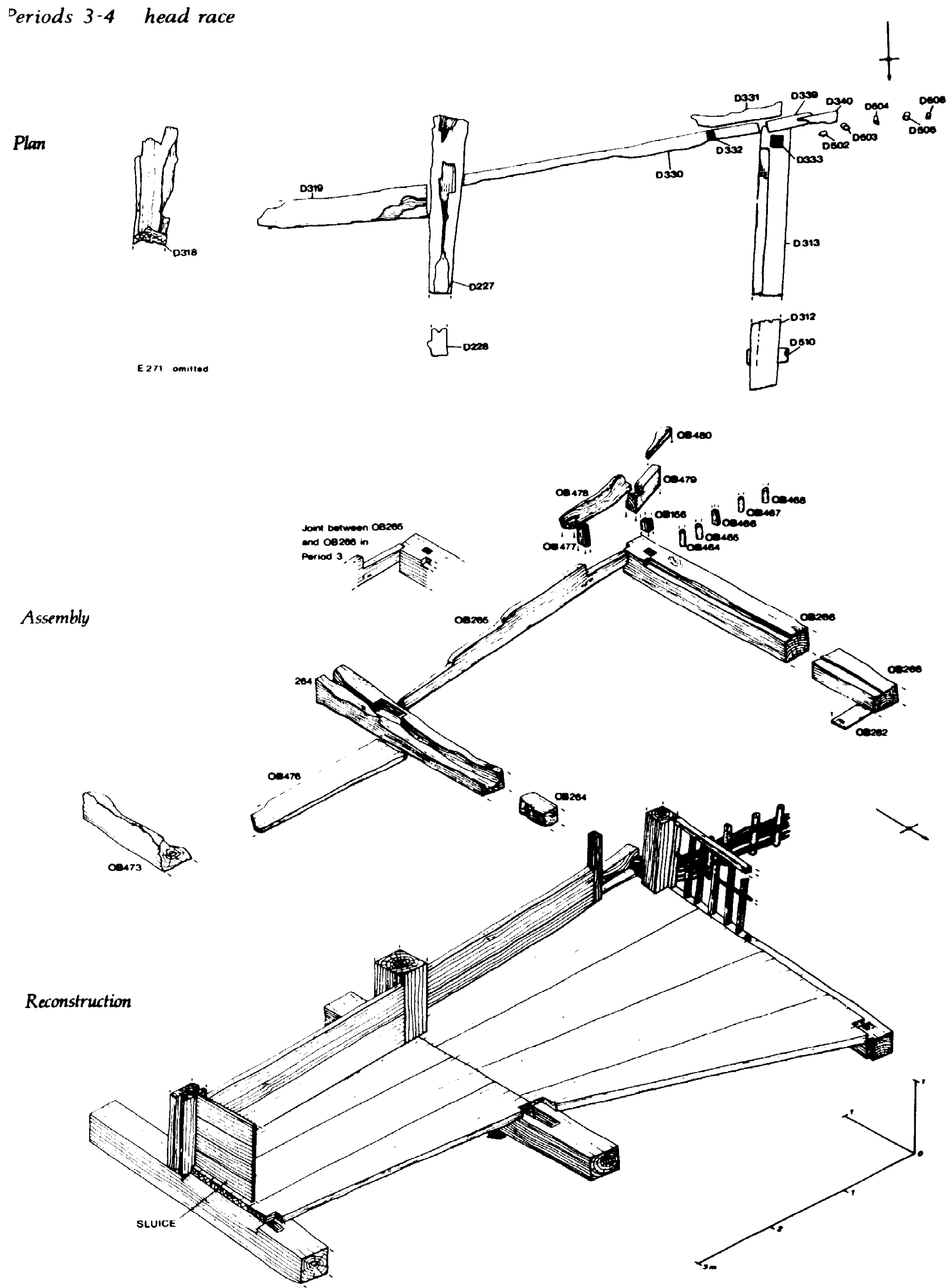


Figure 33 Mill (BAB): structure of periods 3-4 timber head race

Table 2 Mill (BAB) head races: summary of structural timbers

OB no.	Context	Description	Structural relationships	EFD	Q no.
Period 3					
264	D227/8	Baseplate of head race	Morticed to take missing uprights	No match	Q8318
Period 3, reset in period 4					
156	D333	Upright of south side revetment	Tenoned into south mortice of OB 266	None	None
266	D313/2	Baseplate of head race	Morticed to take upright OB 156. Rebate to take plank floor? End rebate to take OB 265? Rested on OB 491, OB 282, OB 493, and OB 237	1166±9 or later	Q8320
491	D509	Pad of OB 266		None	None
282	D510	Pad of OB 266	Reused paddle from water wheel	None	None
493	D512	Pad of OB 266		None	None
237	D513	Pad of OB 266	Reused stake	None	None
492	D511	Collapsed upright	?Tenoned into mortice of OB 266	None	None
494	D514	Collapsed upright	?Tenoned into mortice of OB 266	None	None
480	D340	Timber of south side revetment		None	None
479	D339	Timber of south side revetment		None	None
478	D331	Timber step of south side revetment		None	None
490	D329	Timber of south side revetment		None	None
265	D330	Baseplate of south side revetment	Butted on to end rebate of OB 266	1174	Q8319
476	D319	Baseplate of south side revetment	Collapsed	None	None
477	D332	Upright of south side revetment		None	None
473	D318 /E271	Baseplate of head race/wheel trough		None	None
464-8	D502 -D506	Stake and wattle revetment of south mill pond bank/head race		None	None

EFD: estimated felling date; Q no.: Queen's University of Belfast dendrochronological sample number.

Table 3 Mill (BAB) period 3 wheel trough and tail race: summary of structural timbers

OB no.	Context	Description	Structural relationships	EFD	Q no.
207	ES94	West baseplate of tail race/east baseplate of wheel trough	Morticed to take OB 225 and another, missing, upright. Rebates to take (west) ends of OB 210, OB 211, and (east) end of wheel trough base	None	None
224	E969	East baseplate of tail race	Morticed to receive OB 208 and another, missing, upright	None	None
225	E380	West upright of south side tail race	Tenon into south mortice of OB 207. Groove in west face to take missing timber (?from wheel trough). Groove in east face to take west ends of OB 212, OB 221, and OB 250	None	None
208	E897	East upright of south side tail race	Tenon into south mortice of OB 224. Groove in east face to take west end of OB 283	None	None
211	E889	North plank of tail race base	Lap joint at west end to OB 207. Pegged once to OB 224	1174 -1175	Q8275
210	E888	South plank of tail race base	Pegged lap joint at west end to OB 207	1174	68274
212	E863	Lower plank of south side tail race	Tongue at west end to OB 225. Pegged once to north face of OB 208	1169+9	68276
221	E896	Middle plank of south side tail race	Tongue at west end to OB 225	None	None
250	E815	Upper plank of south side tail race	Tongue at west end to OB 225	None	None
283	E874	Stake and wattle revetment of south side tail race, east end	Wattles engage groove in east face of OB 208	None	None

Period 3 wheel trough and tail race

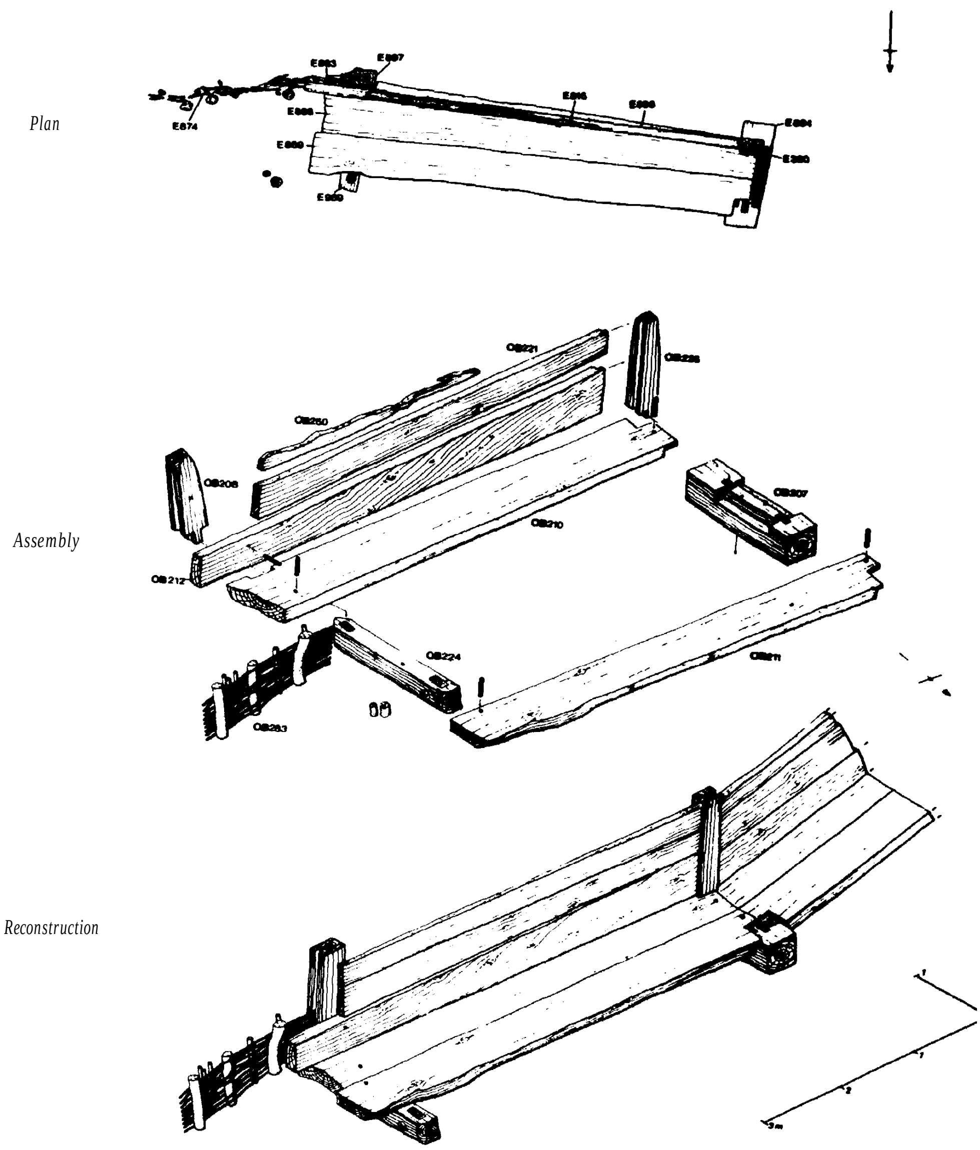


Figure 34 *Mill (BAB): structure of period* 3 *timber mill race*

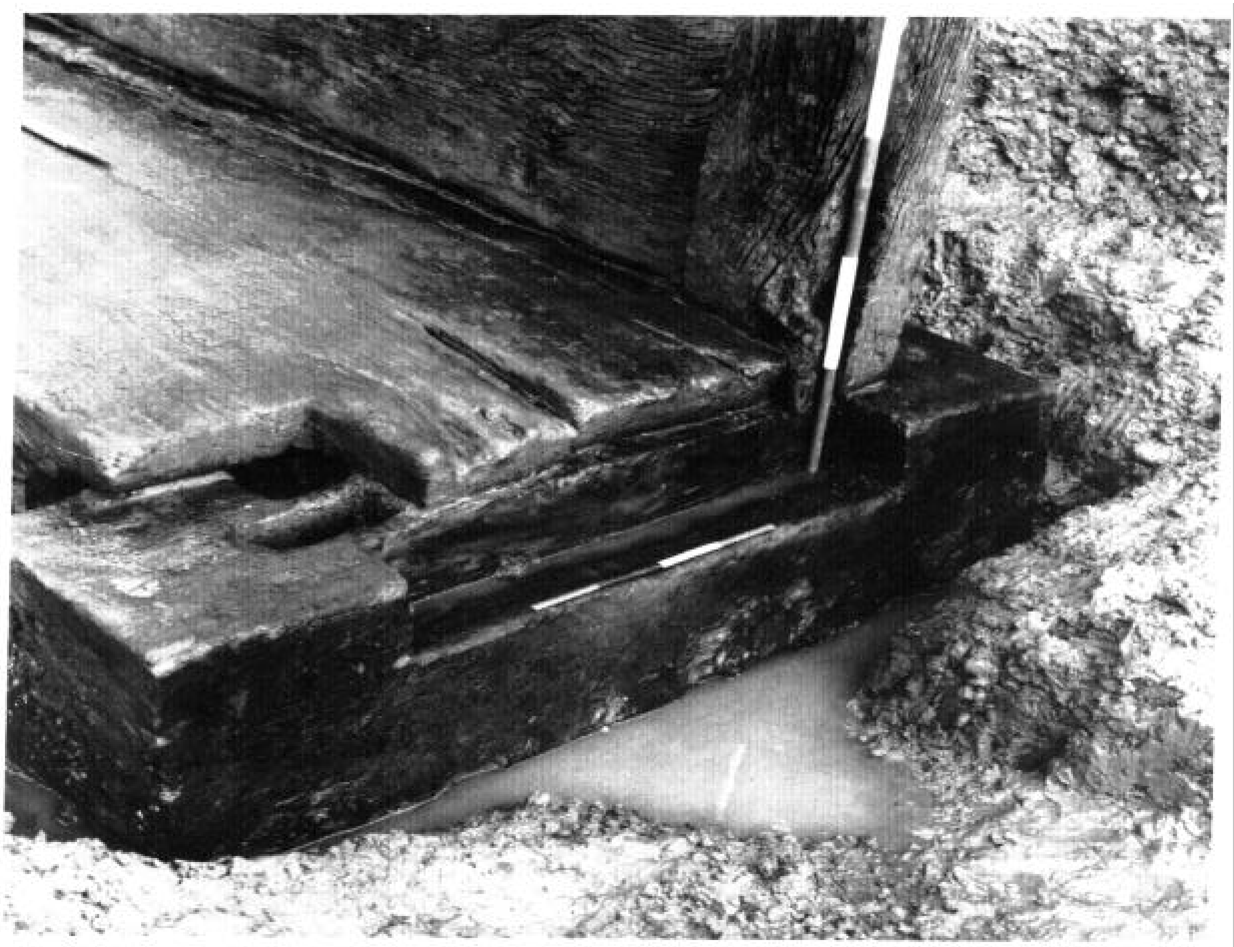


Plate 28 West end of period 3 tail race, showing the joint between the base planks (E888/OB 210; E889/ OB 211) and baseplate (E894/ OB 207), from the north-west. (Larger vertical scale: 0.20m divisions)

Fragments of the later (found in period 7) debris grill were associated with OB 266 and show that it was made of triangular-section vertical oak vanes, five of which were recovered (OB 80; OB 89-OB 92: Fig 32). These were tenoned at top and bottom into a light frame and strengthened with a pole which passed through holes at the mid-point of the grill. The frame could then have slotted into grooves in the uprights morticed into OB 266. The east baseplate, OB 473, probably had uprights to support a sluice gate.

The rebate in the west face of OB 207 (below, and Fig 34) and the west-facing grooves in the west uprights of the tail race (OB 225: Fig 34; OB 227/ 228) suggest that the wheel trough had a planked floor and sides similar to (and a westward extension of) the tail race. This would match the suggested contemporary arrangement of the head race and make OB 473 the baseplate for the west end of the wheel trough and the east end of the head race, and the most likely location for a sluice gate. No timbers or cuts survive to suggest that the wheel was founded on plates or posts set in the mill race. It is probable, therefore, that the wheel was suspended over the mill race, rotating in a continuous plank-lined trough or ‘penstock’.

Both baseplates of the tail race, OB 207 and OB 224, were hewn from boxed heart oak, the former from a tree with a minimum basal diameter of 0.6m, the latter from a smaller tree of some 0.26m. The roughly hewn, pointed end of OB 224 may be a relic of its felling. The rebates in OB 207 were cut out with an axe. The mortices in both timbers had their corners drilled out with a spoon bit auger and

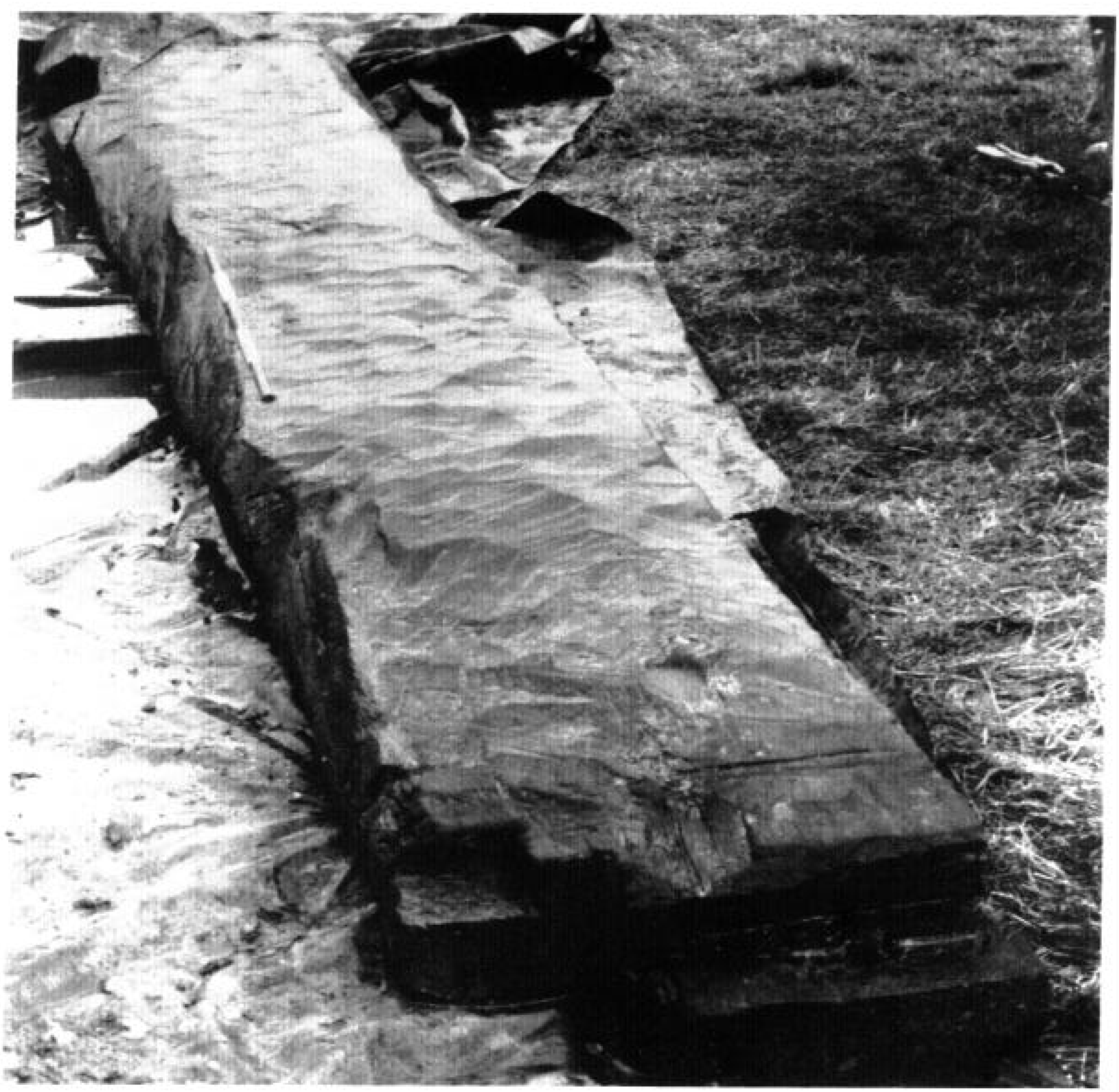


Plate 29 Underside of period 3 tail race base plank (E888/OB 210), showing hewing marks and cut-outs to take uprights and to overlap with baseplate E894/OB 207. (Scale: 0.20m divisions)

the waste removed with a large chisel or more probably a twybill. The uprights (OB 208; OB 225; Plate 30) were of very similar form, hewn from boxed heart, small diameter oaks. Tenons were hewn to shape and finished with a slight chamfer to ease fitting into their respective mortices. The inner surfaces of the grooves were abraded. However, that of the *in situ* east upright (OB 208) did have clear signs of having been hewn along its length with a narrow bladed adze. The uprights of the north side were robbed and split (OB 1991209; OB 227/228) for reuse in period 4. Both original ends of OB 227 survived, allowing the height of the period 3 tail race sides to be established at 1.32m above the upper face of the baseplates (and 1.26m above the upper surface of the planked floor). The planks (base: OB 210 and OB 211; side: OB 212) were each a split half-log, which had a minimal basal diameter approaching 0.8m and was then hewn to the required thickness. Where the base planks butted edge to edge the touching surfaces were dressed. Otherwise the edges were left waney, with sapwood not removed. The cutouts to respect the uprights were abraded, but clear

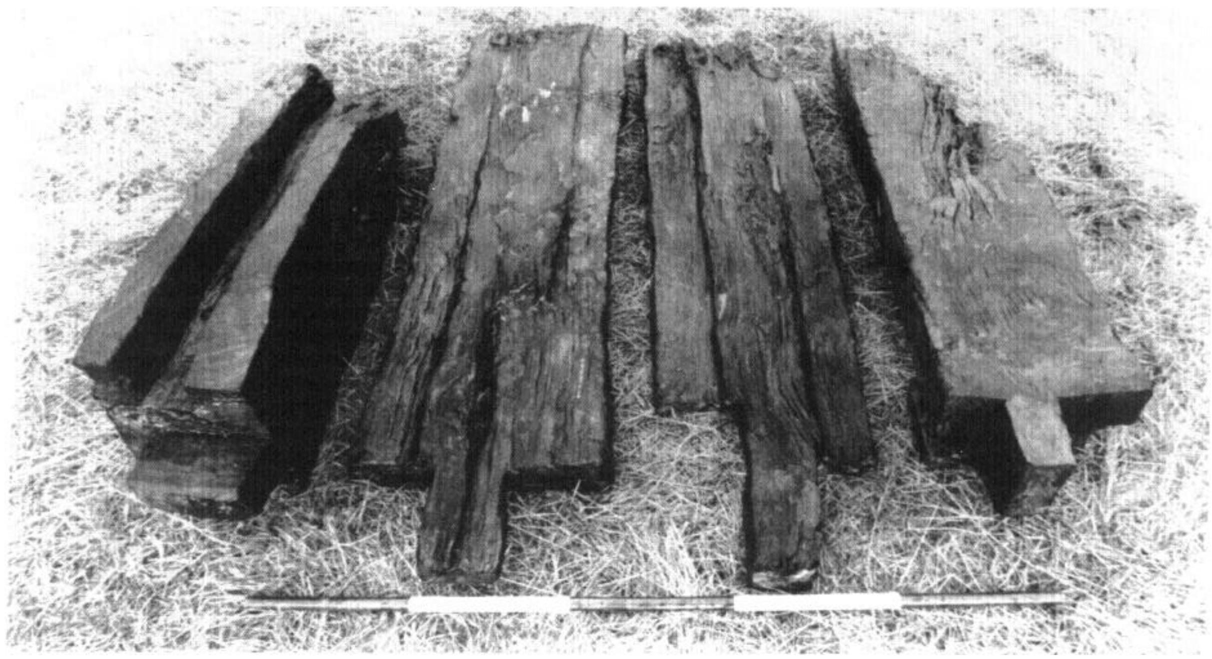


Plate 30 Three uprights of period 3 tail race. Left (E897lOB 208) shows groove to take wattle revetment. Right (E894/0% 225) is south-west upright found in situ *Centre is third upright which had been split into two and reused to support baseplates of period 4 tail race (centre left: E869lOB 227; centre right: E870lOB 228)*

hewing marks were visible where the ends of OB 210 and OB 211 were cut to lap over OB 207 (Plate 29). All the peg holes were cut with the same size auger, probably of spoon bit type. Assembly took place *in situ*, the peg hole for OB 210 to OB 224 catching the edge of the latter instead of passing into it.

A wattle revetment of willow (OB 283; Plate 7) continued the south side of the period 3 tail race to the east. When fresh this fence would have provided a robust barrier, helping to retain, and reduce water erosion on, the south bank.

The period 4 mill race structure

Figures 33 and 35; Tables 2 and 4

The period 3 mill race was partially dismantled and the mill race realigned. The head race was adjusted. A new wheel trough was inserted. The north side of the earlier tail race was removed to allow a tail race of modified construction to be superimposed on a slightly different alignment (Plates 12,27, and 30).

The period 3 west baseplate (OB 266) of the head race was lifted and repositioned (Fig 33). The rebate in its south-east corner, previously housing the side baseplate OB 265, thus became redundant. It was carefully levelled in its new position, one of the wooden fragments used below it being a paddle blade (OB 282) presumed to be from the first water wheel. The side baseplate OB 265 was slightly repositioned so that its west end butted on to the east face of OB 266, making the original rebate redundant. The planked floor of the head race may have been removed or altered in consequence. No other changes are attributable to this period.

Six major timbers (OB 215; OB 216; OB 218; OB 222; OB 223; OB 229) constitute the surviving evidence for the period 4 wheel trough and tail race (Fig 35). They were transverse baseplates, levelled in place with scrap timbers, some of which were reused, split, and hewn thinner, from the earlier tail race (OB 227; OB 228; OB 376; OB 481-OB 484; OB 209, OB 199, OB 214, OB 485; Plate 30). The westernmost baseplate, OB 222, was both smaller and the only one of the six to have blind mortices cut into its upper face. All the others had through mortices and belonged to the tail race; they were similar, boxed from oaks of c 0.4m diameter.

Although most of the surfaces of these timbers had been abraded to a greater (wheel trough) or lesser (tail race) extent, some toolmarks did survive. The timbers had been dressed to a regular

Period 4 wheel trough and tail race

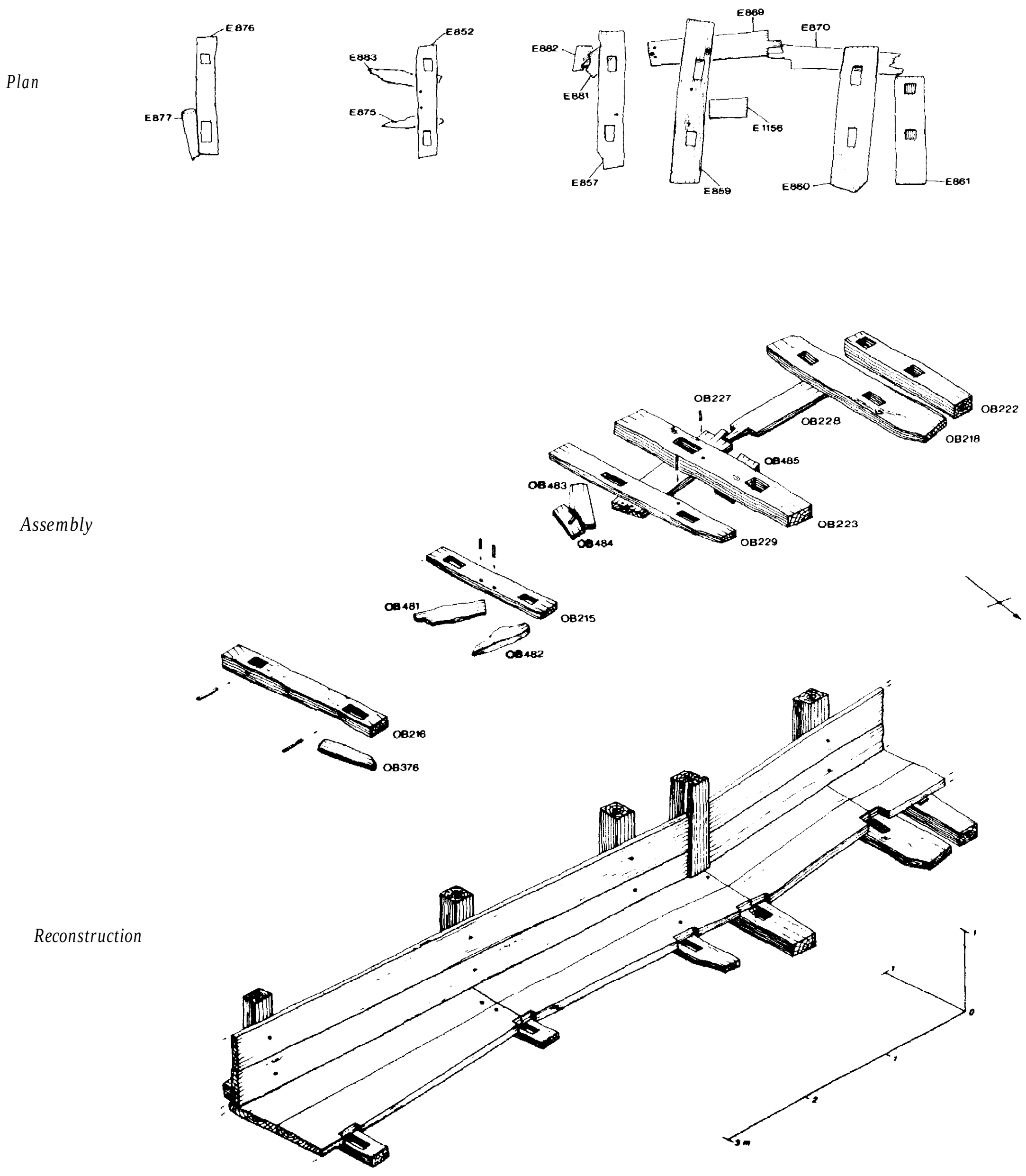


Figure 35 Mill (BAB): structure of period 4 timber mill race

Table 4 Mill (BAB) period 4 wheel trough and tail race: summary of structural timbers

OB no.	Context	Description	Structural relationships	EFD	Q no.
222	E861	?Baseplate of wheel trough	Morticed to take two missing uprights. ?Reused	None	None
218	E860	Baseplate of wheel trough	Morticed to take two missing uprights. Rests on OB 228	None	None
228	E870	Pad below OB 218	Reused, period 3, timber	None	None
223	E859	Baseplate of wheel trough	Morticed to take two missing uprights. Rests on OB 227	None	None
227	E869	Pad below OB 223	Reused, period 3, timber	None	None
229	E857	Baseplate of tail race	Morticed to take two missing uprights. Rests on OB 483, OB 484	1187	Q7667
483	E881	Pad below OB 229		None	None
484	E882	Pad below OB 229		None	None
215	E852	Baseplate of tail race	Morticed to take two missing uprights. Pegged to two missing base planks. Rests on OB 481, OB 482	1184±2 or 3	Q7665
481	E883	Pad below OB 215		None	None
482	E875	Pad below OB 215		None	None
216	E876	East baseplate of tail race	Morticed to take two missing uprights with pegged tenons. Rests on OB 376	1197±9 or later	Q7666
376	E877	Pad below OB 216		None	None
209	E819	Upright	Split and reused upright, revetment for south bank (E816)	None	None
485	El156	Pad		None	None

EFD: estimated felling date; Q no.: Queen's University of Belfast dendrochronological sample number.

shape with an axe during conversion. No distinct signatures were observed. The corners of the mortices were drilled out. Those in OB 222 had been cut with a spoon bit and emptied with a chisel or twybill. The same size of auger was used to cut the peg holes into the east-facing edge of OB 216. A smaller auger was used to cut the pair of peg holes in the upper face of the central tail race baseplate (OB 215).

The mortices would have held the tenoned lower ends of those upright posts supporting the sides of the wheel trough and the tail race. Only one pair of uprights was pegged to its baseplate, OB 216, at the east end of the tail race. Such a joint would have needed to be prepared in advance. It is possible that OB 216 was the first baseplate to be placed in the race and used to align the other uprights. Alternatively, the posts at the extreme east end of the tail race needed additional reinforcement.

The pegs in the upper faces of OB 215, OB 223, and OB 229 suggest that the bottom of the tail race was boarded or planked over. There is no direct evidence to suggest the arrangement of the side revetment planking, but, given the general similarity between the period 3 and period 5 side planking, that of the period 4 mill race should not have been dissimilar.

The period 4 bypass channel

The remains of a light structure were found *in situ* which appear to relate to the use of the bypass channel (Fig 11) after it had been partially filled. A post (OB 286) had been driven vertically into the north side of the ditch. To the south were the remains of two boards (OB 285; OB 287; OB 289; OB 292) associated with stake fragments (OB 290; OB 291; OB 293). In the south side of the ditch were two pieces (OB 284; OB 288) which might have been stakes. The boards were probably retained horizontally on edge between these two stakes to the south and against the east face of the post to the north. This structure would seem to have partitioned the ditch. It is possible that the boards were removable and not fixed or pegged in place, in which case this structure can be seen as a mechanism for controlling the flow of water along the ditch.

The period 5 mill race structure

Figures 33 and 36; Table 5

A major reconstruction of the wheel trough and tail race provides the evidence for a third phase of the mill race (Plates 17 and 18). The head race was retained from period 4 (Fig 33), with a possibility that the sides were realigned.

All three of the baseplates (OB 261-OB 263) of the wheel trough (Fig 36) were reused timbers, two of them (OB 261 and OB 263) from one longer original. All had a pair of blind mortices cut into their upper faces, the mortices having been drilled out along their centre line first. Whilst the mortices were spaced equidistantly, the plates were not. Their eccentric spacing matches that of the mortices in both OB 147 and OB 154. These were two

Period 5 wheel trough and tail race

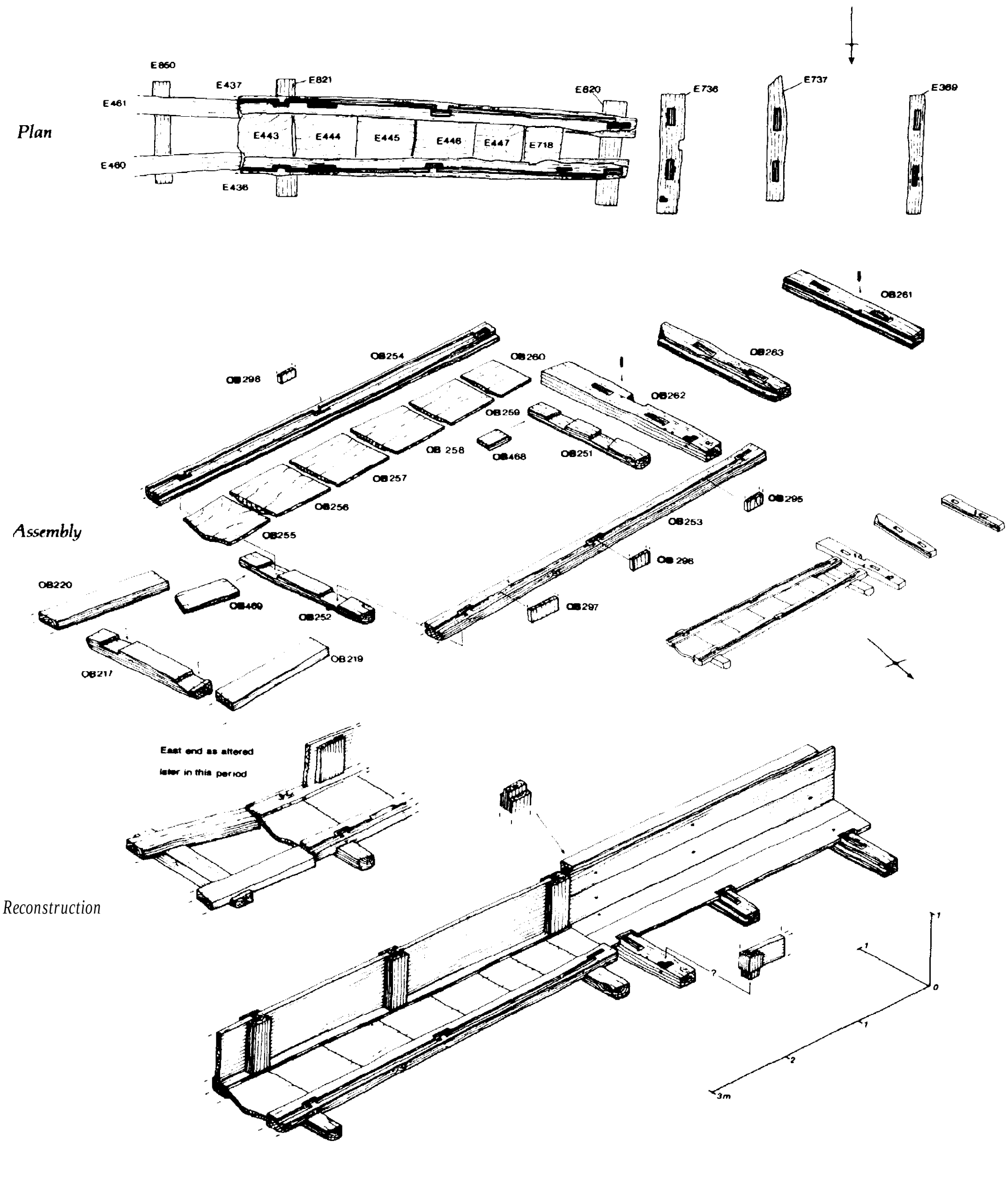


Figure 36 Mill (BAB): structure of period 5 timber mill race

Table 5 Mill (BAB) period 5 wheel trough and tail race: summary of structural timbers

OB no.	Context	Description	Structural relationships	EFD	Q no.
261	E369	West baseplate of wheel trough	Morticed to take two missing, and another, uprights. Reused twice	None	None
263	E737	Central baseplate of wheel trough	Morticed to take two missing uprights. Reused twice	None	None
262	E736	East baseplate of wheel trough	Morticed to take two/three missing uprights. Reused	None	None
251	E820	West baseplate of tail race	Grooves cut to take west ends of OB 253 and OB 254	No match	Q7674
468	E851	Pad	Beneath OB 251	None	None
469	E858	Pad	Beneath OB 252	None	None
252	E821	Easternmost baseplate of tail race	Grooved to take OB 253 and OB 254	No match	Q7670
253	E436	North longitudinal baseplate	West end in groove of OB 251. Set in a groove in OB 252. South edge grooved to take OB 255–260. Upper face with three mortices to take OB 296 (E450) and two missing uprights. Two mortices to take OB 295 (E449) and OB 297 (E451) added in modification. Shallow discontinuous groove to take missing planks	No match	Q7668
254	E437	South longitudinal baseplate	West end in groove of OB 251. Set in a groove in OB 252, North edge grooved to take OB 255–260. Upper face with three mortices to take OB 298 and two missing uprights. One mortice to take missing upright added in modification. Shallow discontinuous groove to take missing planks	No match	Q7669
255	E443	West board of tail race base	North edge chamfered into groove of OB 253; south edge chamfered into groove of OB 254	No match	Q7753
256–9	E444–7	Boards of tail race base	North edges chamfered into groove of OB 253; south edges chamfered into groove of OB 254	1296±9 or later	Q7754
				1255±9 or later	Q7555
				1265±9 or later	Q7756
				1294±9 or later	Q7757
260	E718			None	None
Tail race modification					
217	E850	Baseplate of modification	Grooved to receive OB 219 and OB 220	No match	Q7671
219	E460	North longitudinal baseplate	Set in OB 217	None	None
220	E461	South longitudinal baseplate	Set in OB 217	None	None
295–7	E449–51	Upright on north side	Tenoned into mortice of OB 253	None	None
298	E442	Upright on south side	Tenoned into mortice of OB 254	None	None

EFD: estimated felling date; Q no.: Queen's University of Belfast dendrochronological sample number.

identical plates of small (0.3m) diameter, boxed heart oaks, used in the lining of the period 6 tail race (Fig 37). The match of their mortices with those of the baseplates suggests that OB 147 and OB 154 were top-plates which sat on top of the uprights of the wheel trough. No evidence for fixings to support wheel bearings was found. The 'L'-shaped mortice in OB 262 may be related to a change in the machinery pit.

The mortices in the wheel trough baseplates were *c* 150mm closer than in the previous periods, which implies that the width of the trough, and therefore the wheel, was consequently that much narrower. The head race sides may have been realigned in order to obtain an efficient join with the wheel trough; there is, however, no evidence that such action was taken.

The two transverse baseplates (OB 251; OB 252) of the tail race (Fig 36) were split from a single, fairly knotty oak and the bark trimmed off roughly with an axe. Much of the sapwood was left on and the ends were cut square. The two longitudinal baseplates (OB 253; OB 254) were box quartered from an oak and again an axe was used to remove the bark and much of the sapwood. The western ends were cut square with an axe but the sawn east ends are not original (see below).

The boards which formed the base of the tail race (OB 255–OB 260) were offcuts of through and through sawn boards, several certainly from the same tree, with saw marks surviving on the undersides. These trees had a minimum basal diameter of 0.73m. The edges of each base board were chamfered to fit inside the grooves in the inner edges of each longitudinal plate but were not otherwise worked. Due to the scouring effect of the mill race silts, any working marks which might have survived in these long grooves have been lost.

The baseplates were competently joined together. The shallow trenches cut in the upper face of each transverse plate were the same width as that part of the longitudinal baseplate they were to receive. They were not cut directly across the axis of the plate, the northern groove on the western baseplate being especially askew. This suggests that a degree of prefabrication was present in this tail race; the longitudinal baseplates and the boards between them had been assembled before the trenches to contain the longitudinal plates were marked out and cut on the transverse baseplates (OB 251; OB 252).

The scouring of the silts had greatly abraded the upper surfaces of the longitudinal plates and the base boards, removing some 15mm of wood from the surface of the latter. The mortices and shallow grooves were originally almost certainly deeper than as found. No toolmarks survived on the upper faces of the longitudinal baseplates or in the shallow grooves for the side planking. Only where the remains of an upright had survived *in situ* were the toolmarks in that mortice preserved. The three original mortices in each plate were paired with those in the opposite plate and the groove for the side planking broken by a stop behind them. They were drilled out along their axis with spoon bit augers. The number of holes varied according to the length of the mortice but were consistently spaced some 75mm apart (measured centre to centre). The holes were then joined up and the mortice widened with a chisel or twybill: two tenons survived (OB 296; OB 298). The groove stopped behind the mortice at the west end of each longitudinal baseplate but continued right to the east ends. As with the mortices, each length of groove matched its opposite on the parallel timber, to form a pair. The spacing of these mortices suggests that the baseplates, and thus the tail race, may have been 1.4m longer than the surviving timbers.

A reconstruction of the missing sides of this tail race can be made from the surviving carpentry. The uprights would have been similar in cross-section to those of period 3, tenoned to fit the mortices and with grooves in their east and west edges to match the stopped shallow grooves in the upper face of the longitudinal plates. It is possible that the ends of these longitudinal planks were those used for the base of the tail race and the longer remaining portions used for the sides of the tail race, sitting with their lower edges in the shallow upper grooves and their ends housed in grooves in the edges of the uprights.

At some stage after its construction, the boarded tail race was truncated. Its east end was crudely sawn away and replaced by OB 217, a roughly dressed baseplate into which were trenched two longitudinal plates (OB 219; OB 220). This end was not boarded over. The sides of the tail race were reinforced and partly replaced by additional uprights to each side (north baseplate: OB 295; OB 297), worked in the same way as the earlier mortices in the longitudinal baseplates (OB 253; OB 254), but cutting into the groove for the side planking.

The period 6 mill race structure

Figures 33 and 37; Table 6

The head race from period 4 was retained without significant modification (Fig 33). A new wheel trough was constructed and alterations made to the tail race (Fig 37; Plates 20 and 21).

The two longitudinal baseplates of the wheel trough were both cut from boxed heart oak. OB 155, the south baseplate, had been roughly hewn to size. OB 159 to the north was more regular in shape. The west ends of both timbers had been removed by the cutting of a later pit (period 7, E410) and would probably have extended at least as far as the transverse baseplate, OB 261, of the wheel trough being replaced (Fig 37). The mortices had been started with axially drilled spoon bit holes. Neither baseplate was anchored to the baseplates of the previous wheel trough. Set on edge, rather than on face, these plates also provided a trough in which a wheel could rotate.

The planked sides of the period 5 tail race were completely removed. A number of stakes (north side: OB 275; OB 276; OB 487; south side: OB 271; OB 299; OB 463; OB 486; OB 488; OB 489) retained various reused timbers (OB 148–OB 152; OB 158; OB 213; OB 470; OB 471) which did not form a coherent structure, although OB 147 and OB 154 were probably taken from the period 5 wheel trough.

Woodworking techniques

Figure 38; Table 7

While few of the structures survive higher than baseplate level, it has been possible to obtain structural information, for example, from the features cut into baseplates and the surviving uprights, although the working and jointing of

Period 6 Phase I wheel trough and tail race

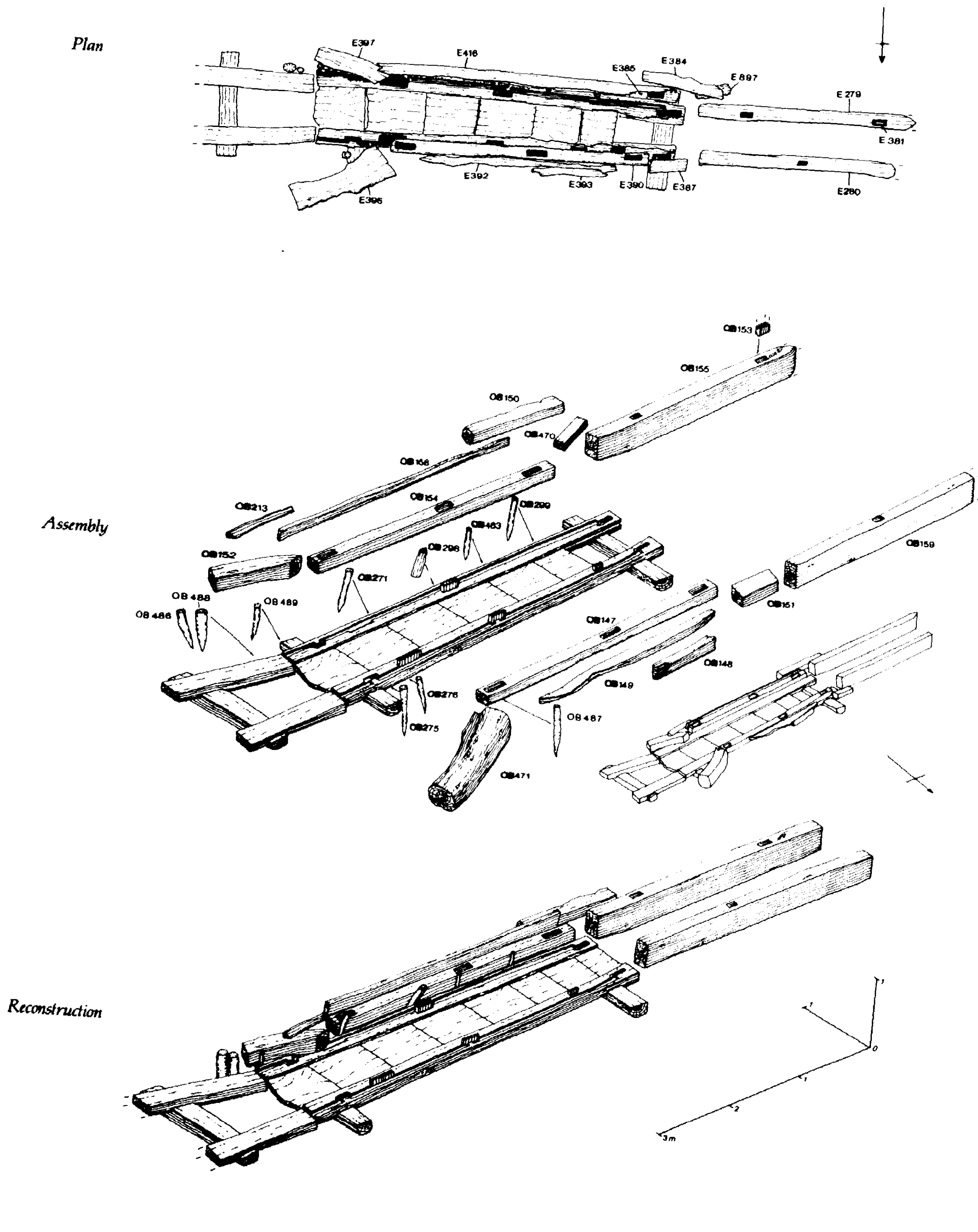


Figure 37 *Mill (BAB): structure of period* 6 *timber mill race*

Table 6 Mill (BAB) period 6 wheel trough and tail race: summary of structural timbers

OB no.	Context	Description	Structural relationships	EFD	Q no.
155	E279	South baseplate of wheel trough	Morticed to take OB 153 and another upright	No match	Q8317
159	E280	North baseplate of wheel trough	Morticed to take one missing upright	No match	Q7672
153	E381	Upright on south side wheel trough	Tenoned into a mortice of OB 155	No match	Q7673
150	E384	Timber of south side of tail race		None	None
154	E385	Timber of south side of tail race	Reused from period 5 wheel trough. Cf E390	None	None
152	E397	Timber of south side of tail race		None	None
158	E416	Timber of south side of tail race		None	None
213	E895	Timber of south side of tail race		None	None
470	E897	Timber of south side of tail race		None	None
271	E387		None	None	
299	E440		None	None	
463	E439	Stakes retaining south side		None	None
486	E401	of tail race		None	None
488	El214		None	None	
489	El215		None	None	
151	E389	Timber of north side of tail race		None	None
147	E390	Timber of north side of tail race	Reused from period 5 wheel trough. Cf E385	None	None
149	E392	Timber of north side of tail race		None	None
148	E393	Timber of north side of tail race		None	None
471	E396	Timber of north side of tail race		None	None
275	E468			None	None
276	E469	Stakes retaining north side		None	None
487	E822	of tail race		None	None

EFD: estimated felling date; Q no.: Queen's University of Belfast dendrochronological sample number.

some elements cannot be absolutely determined. It is clear from this evidence that, with important exceptions, basic woodworking practice, tools, and working methods underwent little drastic change between periods 4 and 7. However, the structure of the successive mill races became increasingly complex, with a greater use of smaller individual timbers and a consequent decline in very simple structures composed of large timbers.

It is tempting to relate this to a decreasing availability of timber, or a fall in its quality, yet the diameter of one of the trees from which the boarded base of the period 5 tail race was sawn was greater, at 0.72m (excluding sapwood), than that of the tree from which the west baseplate of the period 3 tail race was hewn (0.64m, excluding sapwood).

The sources from which the monastery obtained its timber cannot now be determined. Many of the trees used in period 3 were of a size which Rackham would describe as 'outsize' oaks, that is large trees with basal diameters of 0.75m or more (Rackham 1990, 81). The timbers produced from these trees could be transported over considerable distances between their source and the place they were used. Such practice is frequently attested in the medieval period (Rackham *et al* 1978, 121) and may be inferred at Bordesley by the redundant pegs in the mill pond drain timber OB 440 (Plate 32).

Recent work on reconstructing a late Saxon woodscape based on archaeological timber remains (Goodburn 1992, 118–23) shows that similar trees were a frequent component of woodland at this time. The Bordesley timbers lack significant knots over much of their length (4m on OB 210 and 6m on OB 440). The appearance of large knots above this height indicates that their lower branches were suppressed by other vegetation until the trees reached the woodland canopy. If this is the case then it is indicative of an environment of coppice-with-standards – a managed woodland. The tree from which OB 440 was cut started growing in AD 947 and that from which OB 439 came in AD 894 (see below, part II, Brown, 'Dendrochronological analysis'). Such dates indicate that the timbers originated in what was at least a tenth-century managed woodland.

The location of that woodland is not known; it was evidently not in the immediate vicinity of the mills (see below, part II, Carruthers, The valley environment ...'). Such a woodland might have been present on some of Bordesley's granges, especially those in the area of the Forest of Feckenham. 'Wood and material for building' from

Table 7 Mill (BAB): summary of woodworking tools used

Tool type	Purpose	Period 3	Period 4	Period 5	Period 6
Felling axe	Felling trees and cutting some timber to length	70+mm	No evidence	No evidence	No evidence
Hewing axe	Dressing timbers and cutting most joints	160, 186mm	106+mm	98, 110+mm	80+mm
Spoon bit augur	Cutting peg holes and preparing mortices	18, 30, 35, 40mm	25, 30mm	20, 30, 35, 40mm	No evidence
Chisel/twybill	Emptying and cleaning mortices	25mm	25mm	15-20, 25-30mm	No evidence
Narrow bladed adze	Cutting long grooves	>50, 63mm	No evidence	>50mm	No evidence
Pit saw	Conversion and preparation of boards	No evidence	No evidence	Present	No evidence
Woodworking tools inferred from character of wood remains					
Maul, wedges, levers	Conversion of timber and cleaving of planks and boards				

Feckenham forest formed part of the original endowment of the abbey, and Bordesley was itself busy assarting from the 1150s and throughout the thirteenth century (Wright 1976a, 18-19). It is possible, however, that the trees were bought in.

However obtained, the trees provided straight-grained timber, although occasionally some very knotty pieces were tolerated (OB 217). Most of the surviving timbers had been taken from the trunk below the height of the principal branches. Branch material was used for the wheel felloe (OB 169) and could have been used for items like pegs, wedges, roof shingles, and other small objects (see below, part II, Allen, Worked wood. Wooden objects'). Wattling could have used up any smaller branches and most of the bark reserved for tanning. Any remaining wood could have been used for fuel. Very little of the tree would have been wasted.

Medieval timbers were generally worked immediately after being felled, installed, and left to season *in situ.* The condition of the Bordesley timbers is consistent with this practice. No pre-burial degradation or insect attack was found. Bark was normally completely trimmed away but generally the sapwood was left on.

Although many of the larger timbers were of boxed heart conversion, the heart itself was usually off to one side, suggesting that a smaller timber might also be obtained from the same tree. The proliferation of radial conversion among planks and boards implies that most of the timbers which were not boxed heart had been split along the medullary rays and hewn. Only one group of timbers, the boards from the period 5 tail race, had been through and through sawn. Boards appear to have been removed when the mill races were altered, which suggests that they were a valuable commodity. It is possible, then, that sawing is under-represented in the assemblage, although the lack of sawn material among the surviving fragments suggests that this technique was rare. So far the earliest example of medieval sawing, in the late twelfth century, is in London (Milne 1992, 80). Sawing does not occur on any of the numerous period 3 timbers at Bordesley, and it is not known whether it was used to provide planking for the period 4 tail race.

The stakes had usually been cut from branch material and larger pieces of underwood, of which there would have been an abundant supply after the construction of a mill race. Some selection for straightness is evident though little actual conversion was undertaken. No preference in the type of point cut could be identified. An axe was used to cut the stake at an angle and either two, three, or more faces were hewn to form the point,

Much of the working, such as trimming and conversion, would have been carried out at the felling site. The drain in the north mill pond bank, for example, had very few associated chippings so the bulk of the working must have been done elsewhere. This practice would have had the advantage of reducing the weight of timber which had to be transported from the felling site. Redundant pegs driven into the sides of the timber are best interpreted as the attachment points for traces used in handling and hauling the timber (Plate 32). A cart or sled to raise the timber off the ground could have been of use, depending on the distance and surface over which it had to be drawn.

The presence of multitudes of hewn chippings in the mill race silts demonstrates that some working was necessary at the mill. Such work would probably include the cutting or alteration of joints and would certainly involve the reworking of timbers taken from earlier structures. The best example of the latter is probably the splitting of the north-east and north-west uprights of the period 3 tail race and their use as props for the period 4 tail race (Plate 30).

The distribution of these hewn chippings is generally confined to the tail race of each phase, although it is not possible to link these chippings directly with the timbers in the tail race: some may have been washed in from the wheel trough, the head race, the mill building, or from the mill pond; these chippings, then, may indicate the relative intensity of woodworking in the vicinity. Even allowing for any inconsistencies in the sampling of the relevant silts, this suggests that the amount of woodworking carried out at the mill site was roughly comparable in periods 3 and 4 and increased in period 5 when the prefabricated tail race was inserted. The lack of woodworking debris in period 6 is remarkable and supports the suggestion that the woodworking in this period was very limited.

The presence of a large number of hewn chippings in the period 4 fill of the bypass channel requires some explanation. The construction of the possible sluice gate would not have produced such a quantity even had the sluice been entirely worked in the ditch. It is probable, therefore, that these chippings were derived from the construction of a timber building, or the demolition and reuse of a nearby timber building and its component parts.

In qualitative terms, the period 3 mill race stands out through the apparent clumsy fitting of the tail race elements. The misfitting of joints contrasts with the care with which the individual timbers were worked. The crude finishing of the construction suggests that this mill race was finished in a hurry. This need not mean that it was any less efficient than its replacements. It did not have to be finely worked in order to function- The period 4 replacement may have been more carefully converted, carpentered, and built, despite the apparent offset towards the west end. It could have been prefabricated. The period 5 mill race was partly prefabricated; the tail race in particular is a highly competent piece of woodwork. In contrast, the period 6 mill race is very crudely executed. The few new timbers were poorly finished and there is a great reliance on low quality, reused fragments to line the sides of the tail race.

The jointing techniques used in the mill races were limited and have affinities with those used in timber bridge trestles, being primarily concerned with the problem of joining timbers set vertically on end to timbers set horizontally on face (Rigold 1975). The mortice and tenon was the usual solution adopted. Each of the tenons examined had been hewn to shape and size, often with the lower ends slightly chamfered to ease assembly. The mortices were invariably started with a drill, usually of spoon bit form, and finished with a chisel or twybill. It is noticeable that the earlier periods of the mill race (periods 3 and 4) favour a large, squarish mortice prepared by having the corners drilled out, whilst the later periods (periods 5 and 6) use a longer and narrower mortice with preparation holes drilled along the centre line (Fig 38). Since the same type of auger seems to have been

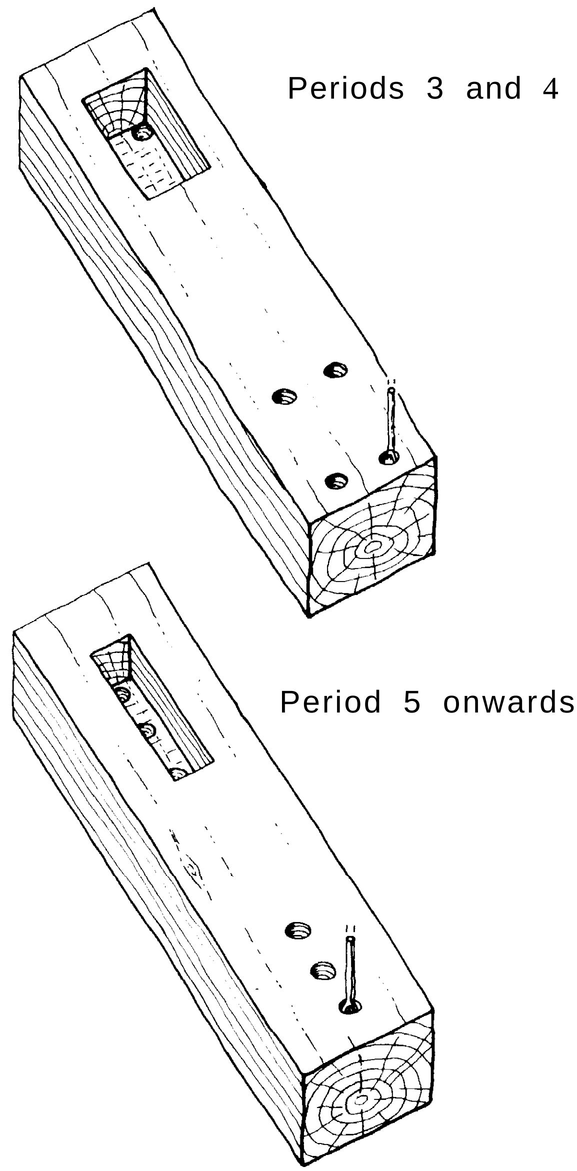


Figure 38 Mill (BAB): shape and manufacture of mortices: periods 3 and 4 compared to period 5 onwards

used in each period, the change in drilling practice must be related to this change in mortice form. This change in morticing practice is also seen in the London waterfront in the late twelfth/thirteenth century and in bridge trestles of similar date (Brigham 1992,87,94; Rigold 1975,88).

Lap joints were used to join horizontal timbers to other horizontal timbers at right angles. These were exclusively hewn. Tongue and groove joints were used to join the edges or ends of boards to either horizontal plates or uprights. The boards or planks were usually reduced in thickness by hewing. The method of cutting the grooves is more difficult to establish. In the absence of other evidence, it would seem that the narrow adze or twybill, which produced a flat, hewn base, attested in period 3, probably remained in use.

Very few of the mortice and tenon joints were secured with pegs, only the easternmost baseplate of the period 4 tail race and the period 3 drain timbers being so fixed. Nonetheless, these are early examples of a technique which is more common from the early thirteenth century (Brigham 1992, 93). Pegs (see below, part II, Allen, Worked wood. Wooden objects') were used to fix face-on-face contacts, extensively in the period 3 structures and less so in period 4.

The Bordesley carpenters' principal tool was the axe. All the hewing marks mentioned above in relation to the dressing of timbers cut across the grain at an angle which is consistent with a carpenter standing above the timber and working along a vertical face with an axe, rather than with an adze. This axe could have a long cutting edge (more than 186mm broad on OB 207), larger than an adze, but was similarly ground on one side only to give a characteristic shallow, scooping cut. The blades had a slightly curving profile. This type of axe would be present in a variety of sizes. It was used for sapwood trimming, in addition to the shaping and dressing of timbers. Lap joints and trenches might be cut with it. The evidence for sawing is limited to the cutting of boards for the period 5 tail race, which would in itself have been a major operation.

It is impossible to identify whether mortices were cut with a twybill or chisel or with both, since the marks these tools produce are so similar. A variety of augers were used, of 18mm to 40mm diameter. These are usually of spoon bit form, producing a concave base to the bottom of the hole. The shallowness of the timbers into which these holes were cut means that the full length of the auger cannot be reconstructed, but the minimum size would seem to be between 150mm and 200mm in order to cut from the edge of a timber such as OB 216 or OB 430 to their respective mortices.

Marking out lines for the cutting of joints appear to have been made with a knife and a square or other straight edge, the surviving evidence for which is a ruled knife cut defining the shoulders of the tenon on OB 208. The close fitting of some timbers, such as the lap joints between the longitudinal and transverse plates of the period 5 tail race, suggests that some form of marking out was often done but has not survived. No evidence for the use of assembly marks was found on any timbers. Few of the woodworking tools found on the site (see below, part II, Goodall, 'Iron') have left traces on the excavated wood. The axe (IR 1251) has a much shorter and more curved cutting edge than those used to dress timbers from the site. The reamers (IR 979; IR 339; IR 171) could have been used on site although they are only half the diameter of the usual drilled holes. Of the chisels, only IR 494 had a surviving blade. At 25mm broad, this matches the usual width of marks made by chisels or twybills in the Bordesley timbers. Owing to its corroded state it cannot be directly compared with the toolmarks.

In conclusion it can be said that the Bordesley mill races show consistent development within an established woodworking tradition. Basic tools such as the spoon bit auger, the hewing axe, and the chisel or twybill remained in use. The appearance of through and through sawing in period 5 coincides with the change to long, narrow mortices. This must indicate that new woodworking techniques and technology reached Bordesley in the late twelfth to thirteenth century, perhaps linked to the introduction of full timber-framing techniques. Such technology could have allowed the use of smaller or poorer quality individual timbers than could previously have been employed. Whether this development is part of a wider trend, confined to the West Midlands or even limited to the Cistercian order, cannot be established without detailed comparative evidence.

Appendix: Glossary

DOUBLE SHOULDERED COMMON TENON A tenon which retains one or more of the original edges of the timber. See TENON

BASEPLATE A timber laid horizontally on or in the ground acting as a foundation upon which other timbers are either laid or jointed.

BOARD A flat piece of wood less than or equal to 1.5inches or 37mm in thickness. Contrast PLANK, STAVE

BOX HALVED A type of conversion in which a tree is cut into two radial squared halves which are then squared so as to provide four flat faces meeting at right angles. See CONVERSION

BOX QUARTERED A type of conversion by which a tree is cut into radial squared quarters. See CONVERSION

CHIP, CHIPPING A small piece of wood debris derived from conversion or working. See OFFCUT

CONVERSION The process of cutting a felled tree or a part thereof into a usable piece of timber. Also the resulting cross-section of the wood. See BOX HALVED, BOX QUARTERED, HALVED, QUARTERED, RADIALLY FACED, TANGENTIALLY FACED, THROUGH AND THROUGH SAWN

FACE The two widest sides of a piece of timber. With reference to the mill, the Upper Face is that lying uppermost in the mill channel. The Lower Face is that set on or in the ground. Other faces are described in relation to the compass direction in which they are most closely presented or in relation to the centre of the water channel.

FACE HALVED SCARF A scarf joint in which each timber is joined by having part of one face cut away. See SCARF

HALVED A type of conversion by which a tree is cut into two radial halves. See CONVERSION

MORTICE A socket cut in a piece of wood to receive another piece of wood or part thereof. See TENON, THROUGH MORTICE

OFFCUT A large piece of debris derived from conversion or woodworking. See CHIP, CHIPPING

PLANK A flat piece of wood greater than 1.5inches or 37mm in thickness. Contrast BOARD, LATH, STAVE

PLANK AND MUNTIN A form of wall construction in which horizontal planks are laid on edge with their ends housed in grooves in vertically set posts.

QUARTERED. A type of conversion by which a tree is cut into radial quarters. See CONVERSION

RADIALLY FACED A type of conversion by which a tree is cut along the medullary rays into multiple segments. See CONVERSION

ROD A straight length of underwood usually woven between uprights to form wattle panels.

SCARF A joint between two timbers meeting end to end. See FACE HALVED SCARF

SIGNATURE MARK The faint ridges on a tool mark caused by slight irregularities in the cutting edge. They are specific to an individual tool at a particular (usually short) interval of time.

TANGENTIALLY FACED A type of conversion by which a tree is cut at right angles to the axis of the medullary rays. See CONVERSION

TENON The end of a piece of wood cut to fit into the mortice of a second timber. See DOUBLE SHOULDERED COMMON TENON, MORTICE

THROUGH AND THROUGH SAWN Method of conversion by which a log or baulk was sawn into parallel slices.

THROUGH MORTICE A mortice cut entirely through a piece of timber. See MORTICE

TIMBER Trees large enough to make beams and planks. Also the large structural members made from such trees. Contrast UNDERWOOD

UNDERWOOD. Poles, rods, and stems usually grown to specific sizes through the practice of coppicing. Contrast TIMBER

WANEY Irregular angle or face of a dressed piece of wood, part of the original outer surface of the wood immediately below the bark.

The valley transect (BAE) stratigraphic sequence

Figures 39-44 (sections and plans); Table M8

The valley transect was started in 1980 in order to investigate the relative sequence and function of earthworks within the eastern part of the precinct (Figs 2 and 48). It was designed to be the start of a systematic examination of the three landscapes - the pre-monastic, monastic, and post-monastic - of the Arrow valley. In particular, it was hoped to chart the changes in environment and earthworks during these three periods, and to define the extent to which the surface evidence was of monastic or post-monastic date.

The intention was to section the valley, from the river cliff on the south to the redirected (and present) course of the River Arrow to the north, a distance of 265m. In the event, the extremely wet ground conditions encountered in the lowest parts of the valley made it too dangerous to excavate there and so the transect was terminated at the north precinct boundary, leaving unsampled that part of the valley outside the precinct. A trench 160m long was excavated; it was arranged in several differently oriented sections in order to section major earthworks at right angles to their axis (Figs 3 and 48).

The transect was designed to be a 1m-wide trench excavated by hand. Different methods of excavation were tried in order to gain the maximum information from each particular stretch of the transect. In all cases excavation was extremely difficult. The depth and narrowness of the trench meant that shoring had to be in place all the time, and often a high water table reduced further the working space and caused sections to collapse. In 1980 a trench 7m long was excavated to what was thought to be ‘natural’ at the south end of the valley. It was anticipated the stratification would be relatively uncomplicated to the north and would change little over distance, so in 1981 a baulk of 1.5m was left unexcavated and the trench was continued to the north. However, the complications produced by such a procedure meant that in 1983 (after a year’s postponement to concentrate all effort on BAB) this baulk had to be excavated, and the trench through the south mill pond bank was dug as a continuous excavation (Figs 42-4). The lower levels were so waterlogged that it proved impossible to sample all of the pre-monastic levels. The profile of these, however, was established by the excavation of small pits and by extensive augering.

The hand excavation of the mill pond silts could not be justified and so in 1984 a machine was used to cut six, 1m-wide trenches with baulks 3m wide in between. The sections were cleaned by hand and then recorded. The profile of the lowest levels was established by augering.

The north mill pond bank was excavated by hand

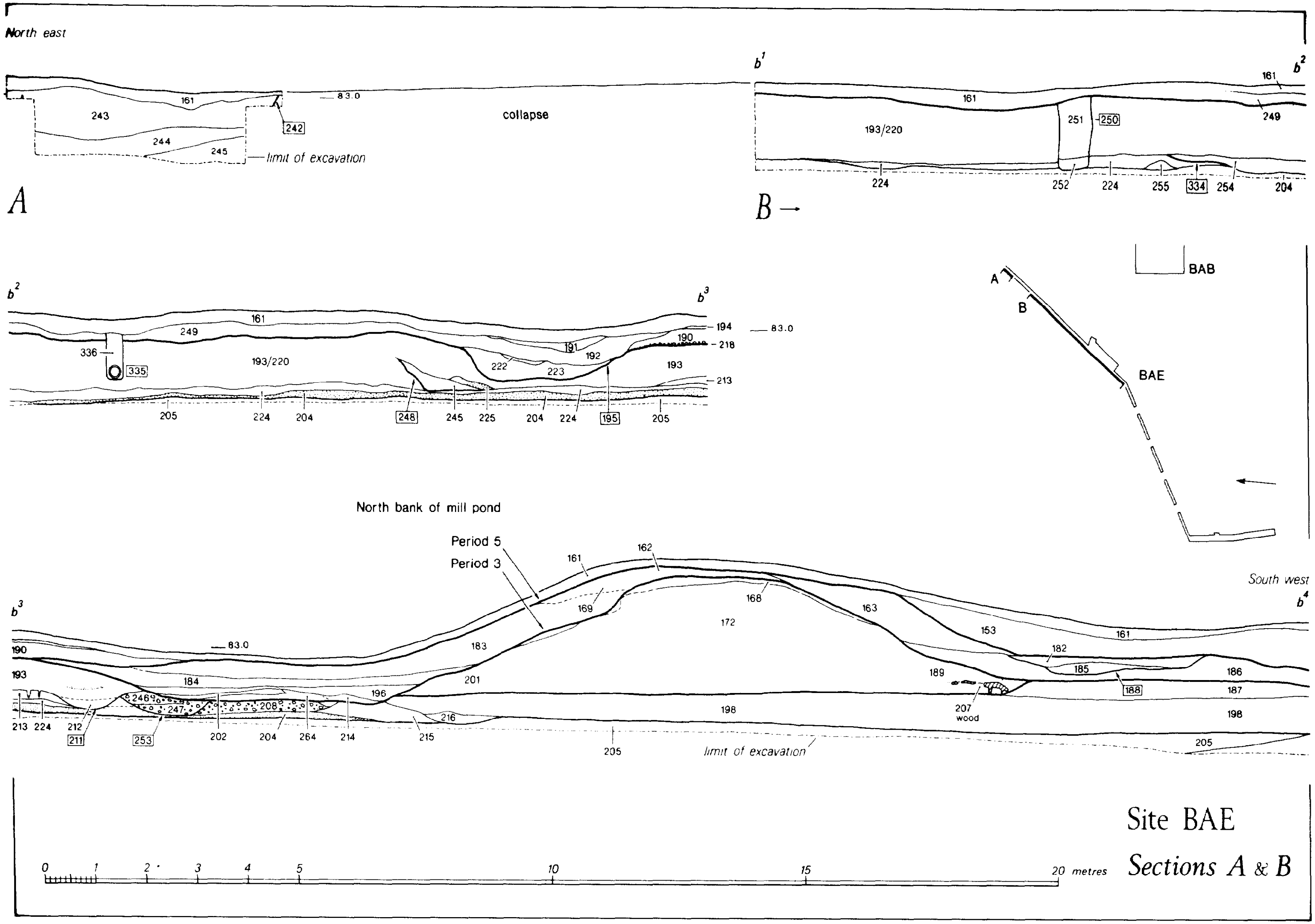


Figure 39 *Valley transect (BAE) sections A and B*

in 1985 and 1988; work in the intervening years was concentrated on BAB. The discovery of the large timber drain (under the mill pond bank) in the east section of the trench in 1988 necessitated widening the trench by a further 3m: the bank was removed mechanically and the drain and lower levels excavated by hand (Fig 40).

A further trench of 45m was dug between the north mill pond bank and the precinct ditch (Fig 39). A new procedure was adopted in order to try to reduce the amount of hand excavation in an area that appeared to have few earthworks. A 1m-wide trench was cut mechanically and the sections were drawn; features were then excavated by hand in areas to the side of the machine trench.

The sampling of the lowest of the pre-monastic levels after 1983 had shown that they were much more complex than had been realised when the transect was started in 1980. The 1980 and 1981 trenches were reopened and widened in 1990 in order to gain this information and to expose more of the structure of the mill pond bank (Figs 42 and 43). The BAB recording system was used on BAE; one series of context numbers was used, but without a letter prefix.

The following sequence is based on a correlation of contexts of a similar character and at a similar level. An attempt has been made to relate the BAE sequence to that of the mills in BAB; the dendrochronological determinations and the general character of each phase have been the main guides. However, often it has only been possible to assign particular contexts to a group of periods, for example period 5-6. The whole trench is presented as one sequence, with the exception of the channel in the extreme south, which appears to have been independent and is thus treated separately. Where a correlation has been made between layers, only the first context number is used in the text, followed by '...'. The full list of constituent contexts is given in the stratigraphic table, after the first number (Table M8).

Period 1: pre-monastic

The floor of the valley was of Mercian Mudstone which, because it was only located in the south, appears to slope down to the north (65...) (SK: Fig 42). In the central, and therefore lower, parts of the valley it was overlain by waterlain cobbles and large pebbles (340) which in turn were sealed by a further layer of water-deposited gravel and silt (122...). There was also some indication of water-formed banks of pebbles (120; 208...; 210...) similar to those found in BAB and associated with anastamosing channels: these appear to have been sufficiently extensive to have influenced the siting and shape of the mill pond.

In the north-central part of the valley (SA, SB: Fig 39) there were further deposits of sediment, some highly organic (204). Evidence for a sequence of stream channels (253; 211; 333) which cut into these gravel spreads demonstrates much stream activity. The water channels clearly occupied the full breadth of the valley (SK: Fig 42); two streams (310...; 295) cut into the Mercian Mudstone on the south side of the valley, one of which re-established itself twice (293; 288).

The location of some watercourses on the south side of the valley may be associated with a larger stretch of water which occupied the central and lowest part of the valley. Fine and laminated sediments, of sand, silt, and organic debris (121...; 140; 139; 94...), were deposited between the two gravel banks established earlier and indicate a pond. There then followed a more general phase of sedimentation (106...; 224; 33...; 193...) which effectively sealed the site of the pond and which appeared to be more extensive on the south side of the valley (SK: Fig 42); some streams eroded shallow courses through these silts (278...; 334; 155; 156). Located within the silt in the north-central part of the valley was a possible pit containing burnt and organic material (193...; 248), which might indicate human activity (SB: Fig 39).

The BAE evidence fits well with the pre-mill sequence from BAB in that it shows that there were periods of intense stream activity interspersed with phases of more widespread sedimentation. It is, however, difficult to correlate the phases between the two sites, but the extensive sedimentation shown in BAE by 193... probably reflects the second widespread blanket silt in BAB (phase 3, period 1). Only two Roman sherds were recovered from BAE so it is impossible to relate any of the stream courses with those in BAB that were open in the Roman period. There is no equivalent in BAE to BAB period 2.

Periods 3-7: the redirected south stream course

This sequence is treated separately from the rest of the transect because the stream was independent of the rest of the valley. There is, however, very little dating evidence for the sequence.

Close to the south river cliff a wide, shallow ditch (280) was cut into the underlying silts and abandoned stream courses (SK: Fig 42). This is interpreted as an artificial stream channel that is visible as an earthwork in the field to the west (see S6 on Fig 48); it is now thought to be the redirected course of the Batchley Brook. The upcast from the excavation of the channel was dumped (62...) to the north to create a kind of flood barrier between the stream and the (lower) mill pond waterways (SK: Fig 42); this bank can also be identified in the field to the west of BAE.

The stream course silted up (276...) and was recut at least twice (331; 332; cut by 281). The stream bed was then only cleared in places (282; 283), as if to remove obstructions rather than an attempt to clear the stream.

The course was then recut (329) and sub-

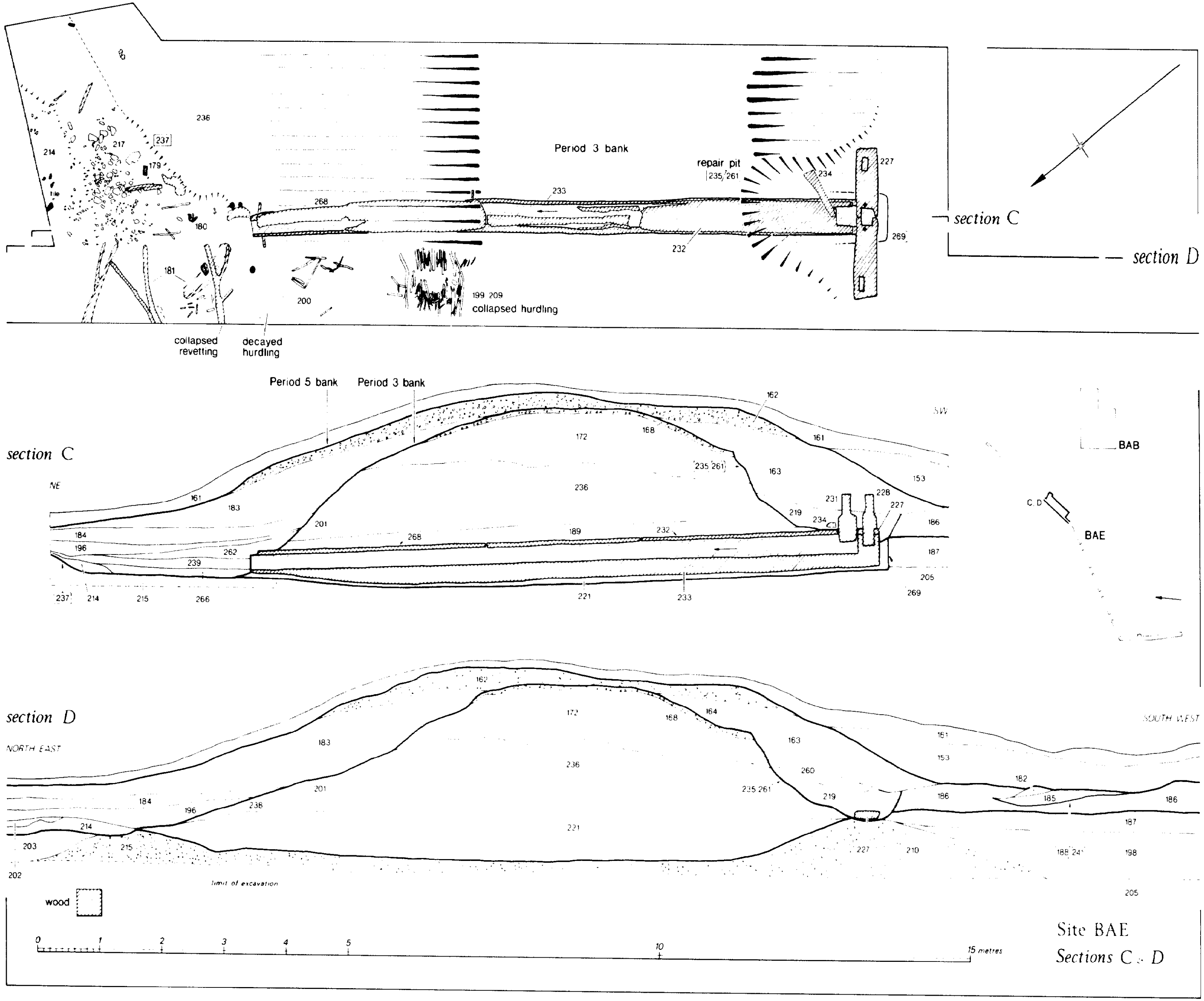


Figure 40 ***Valley transect (BAE): plan of north mill pond bank, and sections C and D***

sequently filled with silt and pebbles (26; 23...; 16; 17; 7...; 19...), followed by further water-deposited sediments (27; 24; 15; 286; 285). The small size and profile of many of these deposits suggest that the stream went through alternate phases of deposition and erosion.

It is difficult to date this feature. The first, second, and third fills of the stream course (276...; 275; 274) contained no ceramic tile fragments. This probably indicates that the stream was redirected before the introduction of tile on the BAB site in period 4 and this would be consistent with the idea that the drainage of the precinct took place early in the life of the monastery. The frequent recuttings during this time could suggest that the gradient of the new course needed some alteration. The redirection of the stream may be associated with the phase of ground clearance and drainage in period 3.

The first stream fills which contained ceramic roof tile (22) are probably then of period 4 or later, to extrapolate from BAB. The last major recut of the stream was filled with sediment that contained fourteenth-century pottery (26), and is tentatively assigned to periods 5-6. The last pebble fills, which were above the level of the flood bank on the north side of the stream and therefore indicate that the stream course had been abandoned, contained pottery of the later seventeenth or eighteenth century. The reinterpretation of the earthworks suggests that the stream was diverted when the Forge Mill was constructed, at some time in the seventeenth or eighteenth century (see below, 'A new survey and interpretation of the east part of the precinct').

Periods 3-4: ground clearance, drainage, and construction of the north precinct boundary ditch and mill pond

This phase of ground clearance and construction illustrates a flexible approach to the existing landscape where some features were exploited and retained while others were modified or removed.

Initial drainage and construction of north precinct boundary ditch

A channel (324) on the south side was cut to drain the area and the upcast of pebbles and clay (107; 108) was spread over the area immediately to the north as a temporary working surface. A small trench cut through these surfaces and covered with a timber plank (111; 110) was probably a gutter draining into the ditch 324 (SK; Fig 42). Both the gutter and the ditch went out of use quickly, to judge from their dump-like fills (109; 312). A wide ditch (242) was cut,, interpreted as the north precinct boundary ditch; it was only possible to excavate the upper part of its south edge.

Construction of the mill pond

The mill pond was sited to take advantage of the existing topography. The two water-deposited ridges, which appeared to retain an earlier (period 1) pond in the lowest parts of the valley, probably influenced the laying out of the mill pond banks; although partially truncated by earlier water action, they remained prominent (120; 215; 210) (SB, SK: Figs 39 and 42). The unusual triangular shape of the mill pond may have less to do with Cistercian ideas about water engineering than the location of these pre-monastic banks and (silted-up) pond.

The south mill pond bank was created by using the upcast from the excavation of an exterior ditch (cutting the abandoned drainage ditch 324) which was later used as an overflow channel (SK: Fig 42). There was also a need to level the interior of the pond, presumably to increase its capacity, and so some of the pre-monastic silts were removed (326). The mill pond bank was constructed only of the clay (102...) derived from the valley sediments; there was no evidence of any timber strengthening, although some stakes (297; 300; 318) were driven into the north side, which, with a layer of pebbles (96), were perhaps a precaution against water erosion. The lack of an internal structure may explain why the bank was so broad and low with a stepped profile.

The north bank was probably constructed in a similar way. An external ditch (237) was excavated to provide the bank material and subsequently acted as an overflow (SC: Fig 40). The bank building sequence was, however, more complicated. During the initial ground clearance and probably at the same time as the overflow ditch was dug, a long narrow trench (269) was excavated through the pre-monastic silts. It was dug with an even slope from south to north to house the main body of a timber drain, consisting of a hollowed-out oak tree (233) with a planked lid (232; 268) (Figs 40 and 45; Plates 31-3). Its south end, in the mill pond, was jointed to a baseplate (227) and braces (229; 230: see Fig 45) which supported a pivot post (228) that enabled the bung (later replacement = 231) to be lifted. The drain was packed around with clay (221; 270).

The drain lid was slightly above the level of the old ground surface. While the ground was prepared and the drain was being positioned, the mill pond bank was being raised to either side. Elements of wattle fences (181; 199; 200; 209) were found to the west of the drain which were used to retain the bank material and prevent it covering the drain. The gap in the bank left for the drain was then filled in by different gangs of labourers dumping material from either side, as shown by the interleaving of the clays (189...; 236; 201...; 172) above the drain. The bank was capped by a pebble hardstanding (168...) which formed a trackway along the crest of the bank for those who managed the

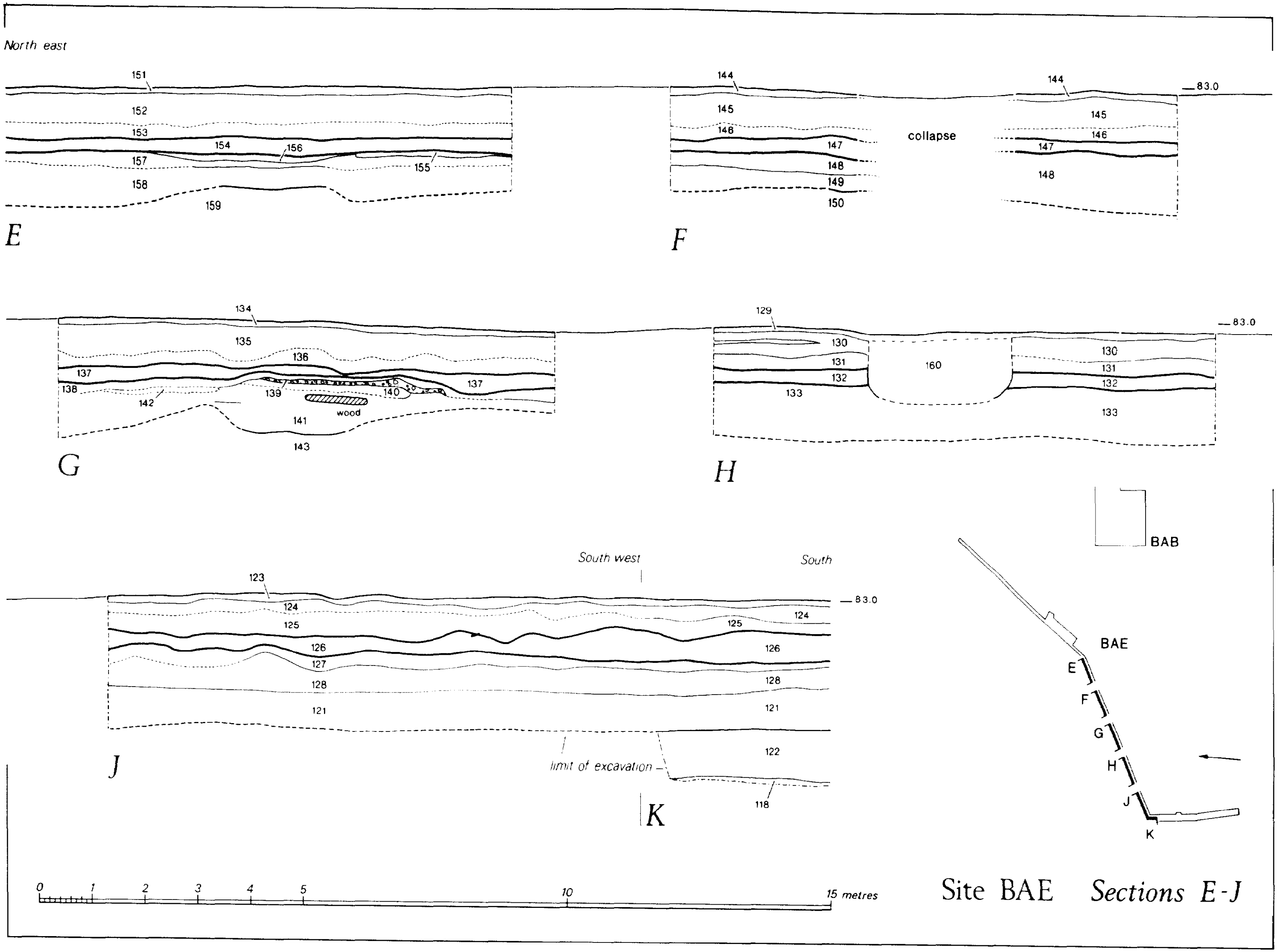


Figure 41 Valley transect (BAE) sections E-J

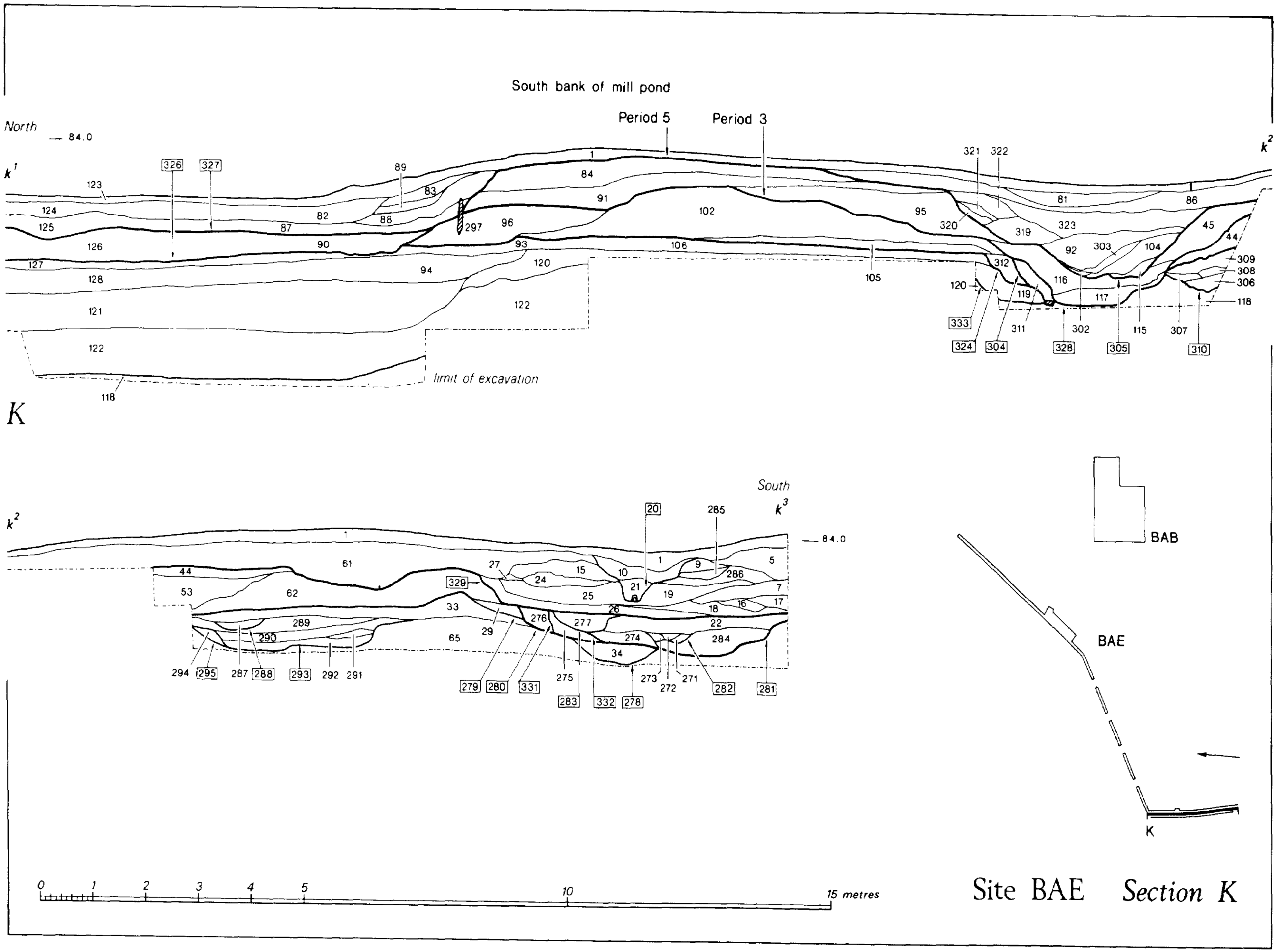


Figure 42 *Valley transect (BAE) section K*

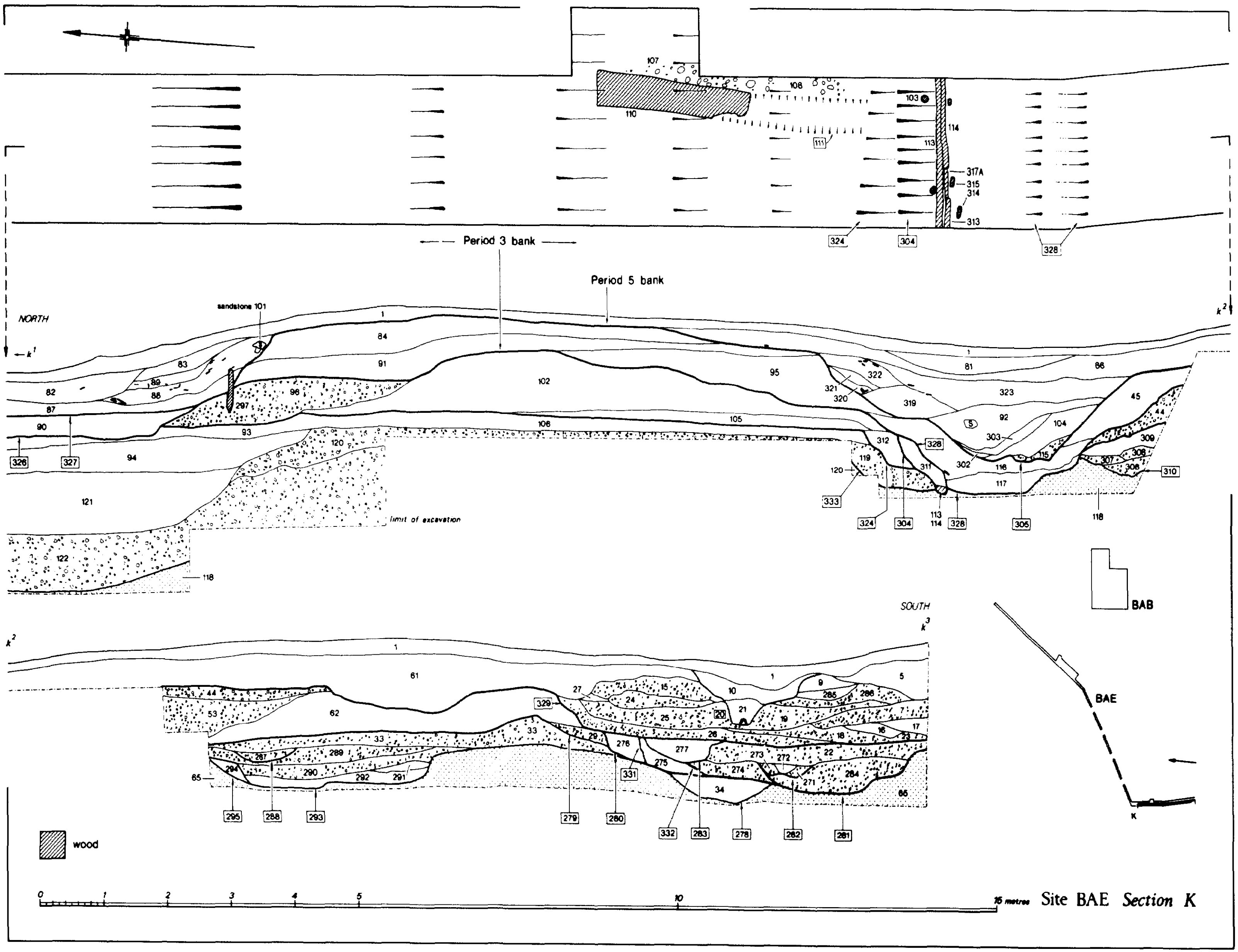


Figure 43 *Valley transect (BAE) plan of south mill pond bank, and section K*

water system; a single posthole (177) may indicate a fence.

Where the drain debouched into the overflow channel the tail of the bank was revetted with oak stakes (180; 179) which would have supported wattle fences, a guard against bank erosion (Fig 40). Another channel (195) was excavated to the north of the overflow channel which may be an additional drain for the area; the area between the two channels was covered in gravel (218) (SA: Fig 39).

The north-west corner of the mill pond was, according to the resistivity survey (see below), occupied by a stone building, from which the flow of water into the pond was controlled. This could have been either retained from periods 3 and 4 or built when the pond banks were altered in periods 5-6 (see below).

Modifications and repairs to the mill pond

The mill pond was modified and repaired during its use in periods 3 to 4. The overflow channel to the south bank needed to be repaired at least twice (SK: Fig 42). In one case the bank was cut into (304) in order to insert a revetment of small timber plates (113; 114; 313; 317), crudely scarfed together, in order to protect the channel side and bank (Fig 44); the bank was then reinstated (311). Later, further support was provided by two stakes (3 14; 315) driven into the silts that had accumulated in the bottom of the channel. This strengthening may have been carried out after the channel was recut (328); this recut in turn silted up (116).

The area between the south bank overflow and the flood bank of the redirected stream was raised (perhaps using the material gained from recutting (53) the south overflow), to create a causeway by widening the flood bank; this was capped with pebbles (44...). The bank thus appears to have been improved to act as a major routeway along the valley, demonstrated by the ruts in the pebble surface.

The head of the drain in the mill pond was also repaired. A pit (2351261) was dug into the mill pond side of the north bank in order to gain better access to replace the bung (231) of the drain (Fig 40). The pit was not reinstated, but remained open to silt up (219); it may, however, have been revetted with timber planks, one (234) of which collapsed into the silt.

The bottom of the north bank overflow channel was covered with gravel and a coarse silt (214...; 202), which were overlain by finer silts (266), deposited during the use of the drain. Later the channel was not maintained and silt (262; 239) accumulated until it blocked the outflow of the drain and filled the overflow channel (196), thus putting out of use the north drainage arrangements of the mill pond. The inside of the drain also silted up at some time, but the character of the sediments (267/233) was very different from those that blocked the drain outflow. The results of analyses of the drain fill demonstrate the fine texture of the deposit with only a small trace of fine sand, and it is suggested that the deposit, as found, was more likely to be the result of vertical seepage through/from overlying strata, over a long period, rather than of horizontal silting along the drain (Biek, Bloomfield, and Evans, 'The drain fill analyses...', see fiche). The gradient of the drain (c 1 in 35) would have ensured that the flow of water prevented silt deposition while the drain was in use; there was, of course, no means of access to clear any blockages.

During periods 3 and 4 the bottom of the mill pond became covered with sediment (90...). A channel (188...; 182...; 167) was scoured through these silts at the base of the north bank which indicates that water continued to flow through the pond when most of it had been emptied. This episode should be associated with the abandonment of the period 4 mill and the preparations for the building of the period 5 mill.

The dating of the creation of the mill pond and its first period of use is dependent on some crude indications, such as the occurrence of ceramic tile, which was introduced on BAB during period 4, and some dendrochronological determinations. Although ceramic tile can only indicate a date of period 4 or later, the absence of an otherwise ubiquitous material, nevertheless, can be an indication of a potential pre-period 4 date.

The trough of the timber drain was sampled (233/OB 440/Q7952); no sapwood was present and the date of the last ring was 1148 (see below, part II, Brown, 'Dendrochronological analysis'). Using the Belfast sapwood estimate of 32±9 years, the best estimated felling date is 1173±9 years or later. A plank of the lid of the drain also produced a sample without sapwood (232/OB 439/Q7951); the date of the last ring was 1136, giving a best estimated felling date of 1168±9 years or later.

Turning to the mill pond, one of the stakes that reinforced the north face of the south mill pond bank, and is interpreted as contemporary with the bank's construction, was sampled (300/OB 454/Q8198), but had no sapwood. The date of the last ring was 1120, the best estimated felling date is 1152±9 or later.

These estimated felling dates correspond to a phase of activity in the later twelfth century and, although there is no way of relating these determinations to those from the mill, it is probable that the construction of the drain was contemporary with the construction of the period 3 mill.

The bung of the timber drain was sampled (231/OB 438/Q7950), but had no sapwood. The date of the last ring was 1195; the best estimated felling date is 1227±9 or later. As this date is some 50 years later than those from the trough and lid, it is likely that the bung is a replacement, which is

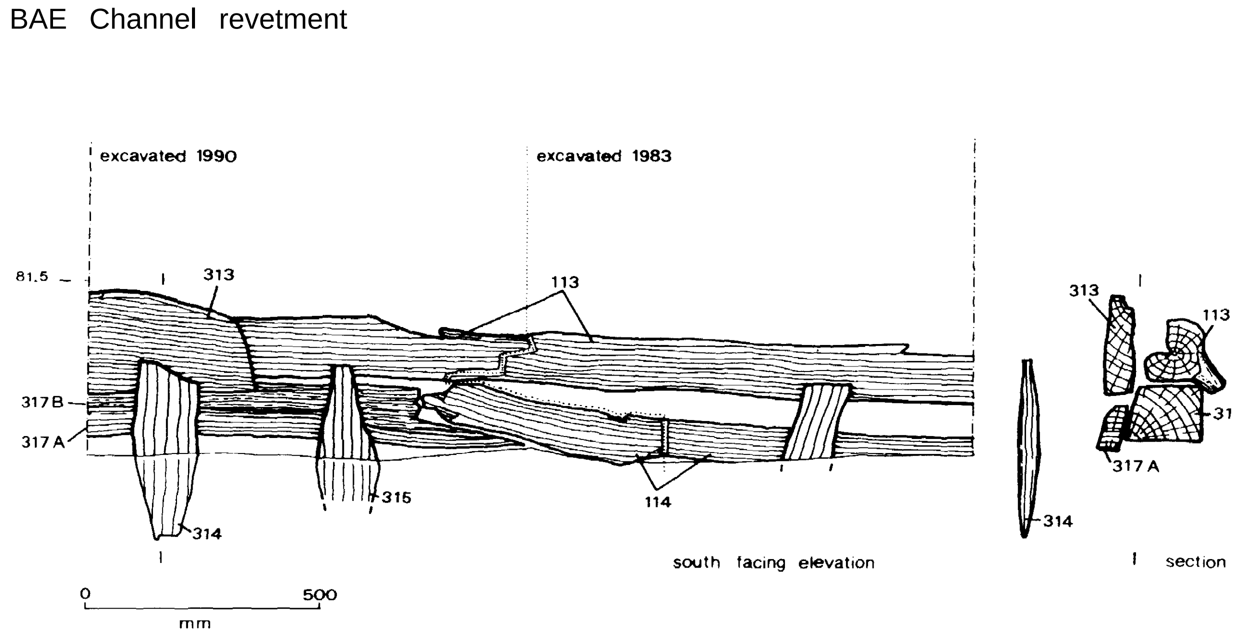


Figure 44 Valley transect (BAE): elevation of revetment in overflow channel

confirmed by the evidence for the pit cut into the bank above the drain head. The bung is, however, sealed by the period 5 enlargement of the bank which would place the bung in period 4. It also indicates that the outflow of the drain was not blocked until the mid-, or later, thirteenth century.

In summary, the dendrochronological determinations indicate the timber drain was constructed (as was the bank) in the later twelfth century and was contemporary with the construction of the period 3 mill; the surviving bung is a later replacement, contemporary with the use of the period 4 mill.

The revetment of the south overflow (Fig 44) furnished two dendrochronological determinations. One of the original timbers was sampled (317B/OB 460/Q8197), but it had no sapwood. The date of the last ring was 1150, giving a best estimated felling date of 1182±9 or later, which is consistent with the stratigraphic evidence for a post-period 3 (and pre-period 5) date. The other date came from a stake (314/OB 461/Q8195) which is interpreted as a secondary repair and on stratigraphic grounds was pre-period 5. This sample had incomplete sapwood; the date of the last ring was 1255, giving a best estimated felling date of 1266±9, placing this stake in the later part of period 4.

Periods 5-6: raising of the mill pond banks

The mill pond banks *were* enlarged in order to increase the capacity of the pond. Clay (45...) dumped on the south side of the south bank outflow widened the causeway (SK: Fig 42). Further dumps of clay (95; 91; 98) were added to the south mill pond bank, some of the dumps being temporarily retained with stakes and planks (112; 103), and partially sealed the silts in the overflow. At this time or slightly later the overflow was recut (305) to produce a narrower channel. The north face of the bank was scattered with sandstone blocks (10 1). The material for raising the bank may have derived from the excavation of some of the silts (327) that had accumulated on the south side of the pond.

The north bank was also raised by the addition of a clay capping (184) to the north overflow and then by dumps (260; 163...; 183) which blanketed the overflow and the head of the drain (SC: Fig 40). The bank was capped with a pebble and tile hardstanding (162...; 170...) and perhaps a post (171 posthole).

The stone building at the north-west corner of the mill pond (identified by resistivity survey) could have been either built when the pond banks were altered in periods 5-6 or retained from periods 3 and 4.

During the use of the *mill* pond, silt continued to accumulate in the bottom (87...) and in the south overflow (115) which went on silting through lack of maintenance (104; 302; 303; 92...).

The raising of the banks is dated to period 5 on the basis of the sequence uncovered in BAB. There, the enlargement of the end of the north mill pond bank was dated to period 5, and it is assumed that the rest of the bank, and by association the south bank too, was altered at the same time. The enlargements of the mill pond banks sealed the timbers with estimated felling dates of 1227±9 or later and 126629; the enlargements, therefore, have a *terminus post quem* from the latest dated ring of 1255.

If it is accepted that the revision of the banks took place at the same time as the construction of the period 5 mill, then the latest estimated felling dates from the period 5 tail race, of 1294±9 or later and 1296±9 or later, would suggest that the reconstruction of mill pond and mill race took place at the beginning of the fourteenth century.

As there is no evidence of further alterations to the mill pond when it was in use, the pond silts can only be dated to the time when the later mills were working, that is in periods 5 and 6.

Period 7: abandonment of the mill pond

The south overflow channel filled with slumps from the pond bank and silts (319-323), and the pond edge was masked by material that had eroded and weathered from the south bank (88; 89; 83) (SK: Fig 42). The evidence for the degradation of the north bank could not be so clearly distinguished from that for sedimentation. The filling (243-245) of the north precinct boundary ditch might also date to this period (SA: Fig 39).

The evidence for the abandonment of the mill pond was sealed by a thick layer of alluvium (9...; 82...; 190...) which probably masked most of this part of the precinct. The south river cliff also seems to have eroded and slumped into the stream channel (5...) (SK: Fig 42).

As with BAB, there is evidence of an attempt at land improvement by the digging of drains, some of which had ceramic pipes at the bottom (20...; 81...; 335), while others had gravel (250; 252; 194).

The dating of these contexts is dependent on a few sherds of pottery. The degradation of the banks and the filling in of the south overflow had occurred by the seventeenth century and probably relates to the period between the abandonment of the mill and the Dissolution, while the thick flood deposit appears to have been accumulating from at least the seventeenth century, although, to judge from BAB, this may have started earlier.

The mill pond drain by S J Allen

Figure 45; Table 9

The wooden drain found below the north mill pond bank was one of the earliest components of the watermill scheme (Plates 31-3). The body of the drain (OB 440) was hewn from a single trunk of straight-grained oak with a basal diameter of at least 0.90m. Its sides and faces were dressed to create a roughly square cross-section. An exact

Table 9 Valley transect (BAE): summary of structural timbers

OB no.	Context	Description	Structural relationships	EFD	Q no.
434	227	Baseplate of drain	Pegged to south end upper face of OB 440. Morticed to take upright OB 435 and diagonal braces OB 436 and OB 437	No match	Q7949
435	228	Upright of drain (pivot post)	Set in socket of OB 440, pegged through mortice in OB 434	None	None
436	229	West diagonal brace of drain	Pegged into mortice in OB 434	None	None
437	230	East diagonal brace of drain	Pegged into mortice in OB 434	None	None
438	231	Bung of drain	Set in hole in OB 439	1227±9 or later	Q7950
439	232	Plank of drain lid	Laid over trough in OB 440. Butts against north edge of OB 434	1168±9 or later	Q7951
440	233	Body of drain	OB 439, OB 442 laid over trough. OB 434 pegged to upper face, south end. OB 435 sits in socket in upper face, south end	1173±9 or later	Q7952
441	268	Plank of drain lid	Laid over trough in OB 440. Butts against OB 439	No match	Q7953
442	234	Plank of revetment of drain head		None	None
454	300	Stake in face of mill pond bank		1152±9 or later	Q8198
456	113	Plank lining of south channel	Laid on OB 459, OB 457	No match	Q8192
457	114	Plate of south channel lining	Scarfed to OB 460	No match	Q8193
458	313	Plank lining of south channel	Laid on OB 459, OB 460	No match	Q8194
459	317A	Plate of south channel lining	Scarfed to OB 460	None	None
460	317B	Plate of south channel lining	Scarfed to OB 459, OB 457	1182±9 or later	Q8197
461	314	Stake of repair to channel		1266±9	Q8195
462	315	Stake of repair to channel		No match	Q8196

EFD: estimated felling date; Q no.: Queen's University of Belfast dendrochronological sample number.

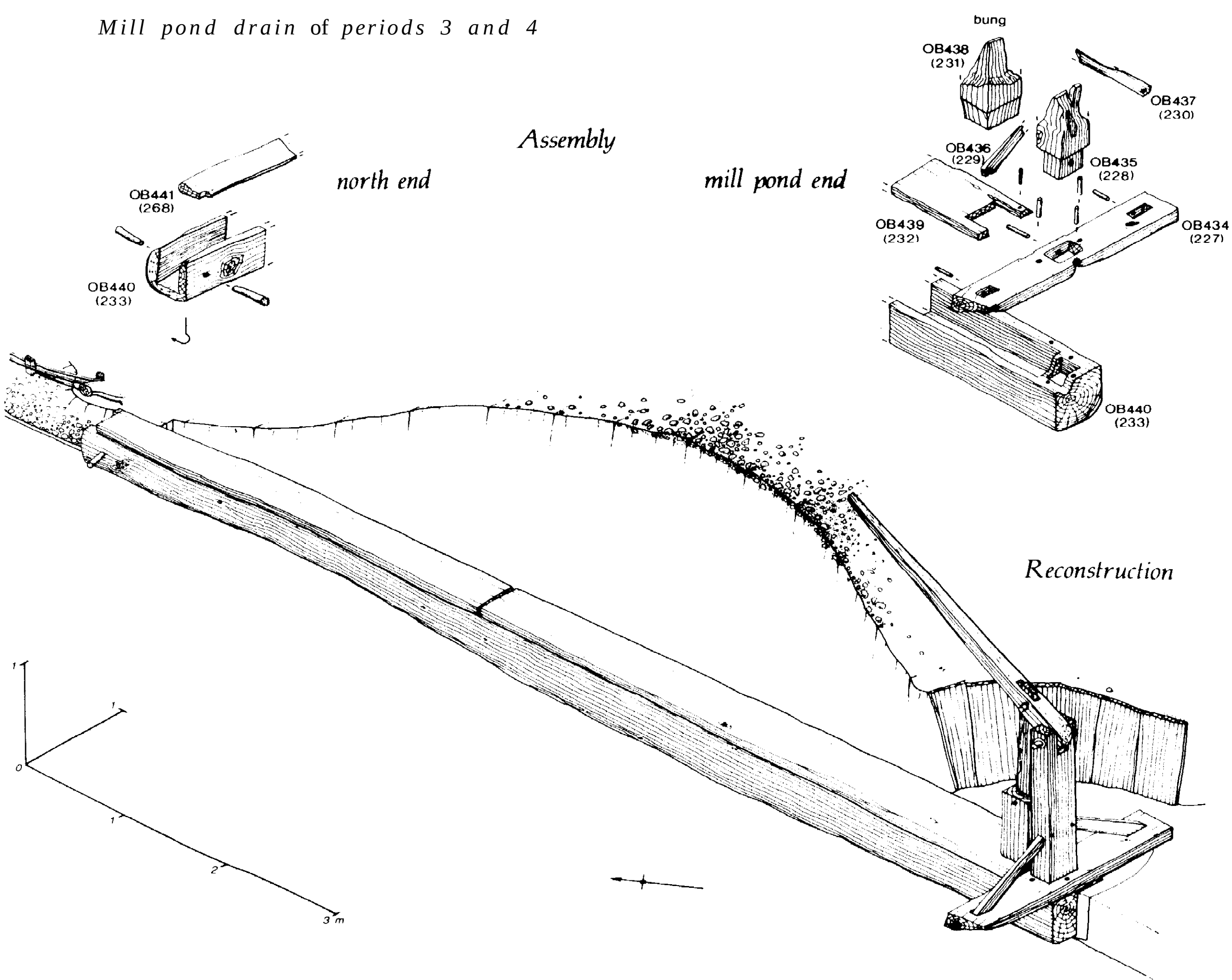


Figure 45 Valley transect (BAE): structure of periods 3 and 4 mill pond drain

squaring of the tree would not have been possible as the tree had a slight curve halfway along its length. Each face had been hewn from the ends towards the middle with axes; the ends were squared. Water scouring had removed any tool-marks from the trough interior. The corners of the socket at the south end of the trough had been drilled out with a spoon bit auger and the waste removed using a chisel or twybill. The same auger might also have been used to cut most of the peg holes required in the structure. The oak pegs set in holes in the east and west faces were presumably for the attachment of ropes for moving the timber (Plate 32). The hole in the lower face had a square mortice cut around it; its function is not known but may be related to whatever means was used to raise the timber off the ground during transportation.

Neither plank from the lid (OB 439; OB 441) was cut from the same tree as the trough or body of the drain. Each plank had been hewn to the required thickness. The single peg in plank OB 439 was the only fastening used in the drain lid and had been cut with a smaller auger, presumably to fit the thickness of the side of the trough and to hold the plank in place during assembly. The transverse baseplate OB 434 had been hewn from the heart of an oak with very wandering grain. It was pegged to the upper face of the trough. One of the splayed mortices had a spoon bit mark in a corner but no other toolmark survived. Both heavily abraded diagonal braces (OB 436; OB 437) were quartered from oak, with holes drilled through their lower ends to take the pegs which fixed them into the splayed mortices. The upper ends had rotted away, as had the adjacent part of the pivot post, OB 435. The post was of boxed heart, small diameter oak and its double shouldered common tenon had a

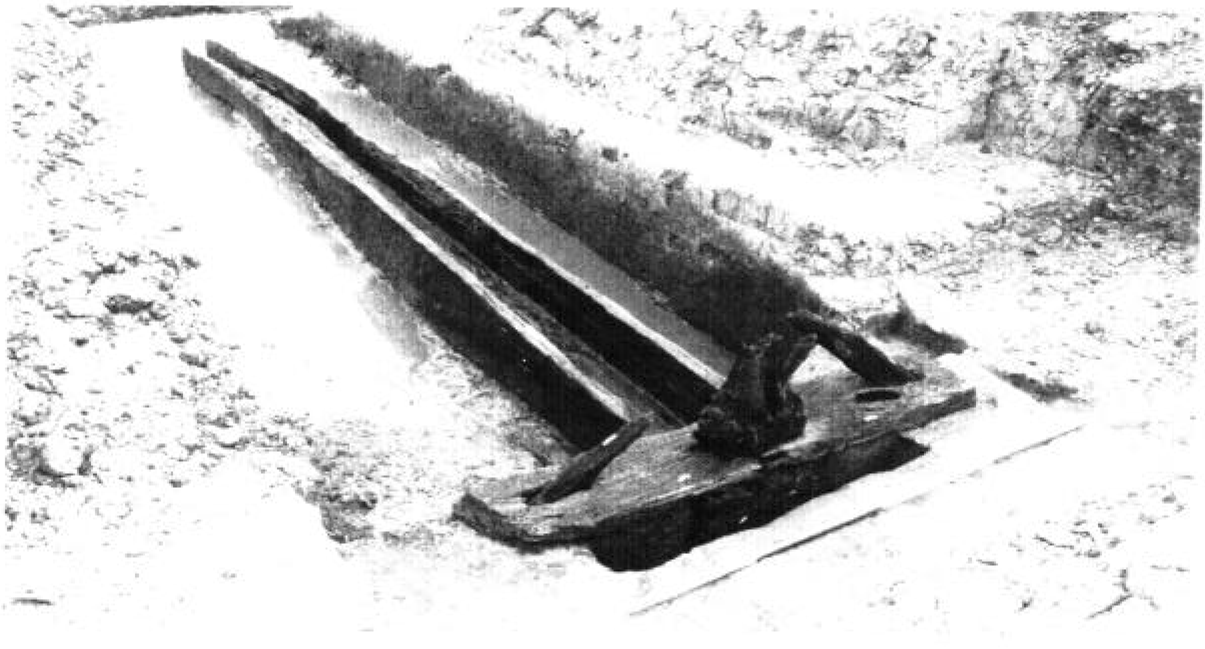


Plate 31 *Millpond drain, from the south-west, (upper) with plank lid, (lower) with lid removed*

Plate 32 Mill pond drain, from the north, showing the three pegs

drilled hole through it to house the peg fixing it to transverse baseplate OB 434. The boxed heart bung, OB 438, had a hewn taper to its base but no other features; this bung was a replacement of the original (see above),

The fixed post OB 435 is interpreted as acting as a pivot to a hinged lever passing over the mill pond bank. When the lever was raised, the bung (OB 438) would be lifted out of the hole in the plank allowing water from the mill pond to enter the drain, pass under the mill pond bank, and flow away. The pit (235/261) in the face of the mill pond bank may have been protected from scouring by a lining of boards or planks set vertically on end, one of which (OB 442) survived. The stakes driven into the north side of the north mill pond bank, but lack of any internal structure, are discussed in the stratigraphic sequence, as is the revetted channel side of the south mill pond bank.

Subsidiary excavations through the tail race (BAH and BAJ) by S Wass

In 1989 two small excavations (BAH and BAJ: Fig 3) were mounted to the east of BAB to investigate the character and gradient of the tail race, which is visible on the present ground surface as an earthwork which stretches from BAR to the modern course of the River Arrow, a distance of 260m.

Tail race (BAH)

Figure 46 (plan and section); Table Ml0

A 1m-wide, 10m-long trench was cut by machine across the earthwork ditch 40m east of BAB (Figs 3 and 46). The trench was cut to a depth of 2.5m to the bottom of the channel. The sections were cleaned and drawn and then an area 3m by 4m immediately to the east was excavated by machine to the top of the first channel and then the channel was excavated by hand (Fig 46).

Plate 33 *Mill pond drain, from the north, showing pivot arrangement with (right) tapered bung partially lifted out of its hole in the drain lid*

The cut (15) for the first channel was *c* 1.3m below the present ground surface. It had been dug through a layer of red-brown silty clay (6), but the top of the channel was not associated with a visible surface. The channel was steep-sided with a flat bottom and was similar in profile to the bypass channel (A135) excavated in square A of BAB. Channel 15 had cut through the underlying layer of grey alluvium (13) and the channel bottom was located on what appeared to be the top of a pebble layer (16) similar to that encountered in BAB and BAE.

The channel bottom was covered by silts (22; 18) which contained much organic debris and wood fragments. These were sealed by two layers of red clay (20; 21) which probably derived from the erosion of the channel sides. A further black organic silt (19) with twigs and wood fragments had accumulated above, which in turn was sealed by another collapse (17) from the channel sides. This was sealed by a thick organic silt (11) which not only contained worked and unworked wood fragments but also animal bone and leather; this was partially sealed by clay (12) eroded from channel sides. Then the channel appears to have been filled in with dumps of pebbles, gravel, and sand (10).

The layer of alluvium (6) through which channel 15 had been cut continued to form and indeed partially sealed the top of the (filled in) channel. At least a further 0.5m of sediment was deposited before the channel was re-established. This chan-

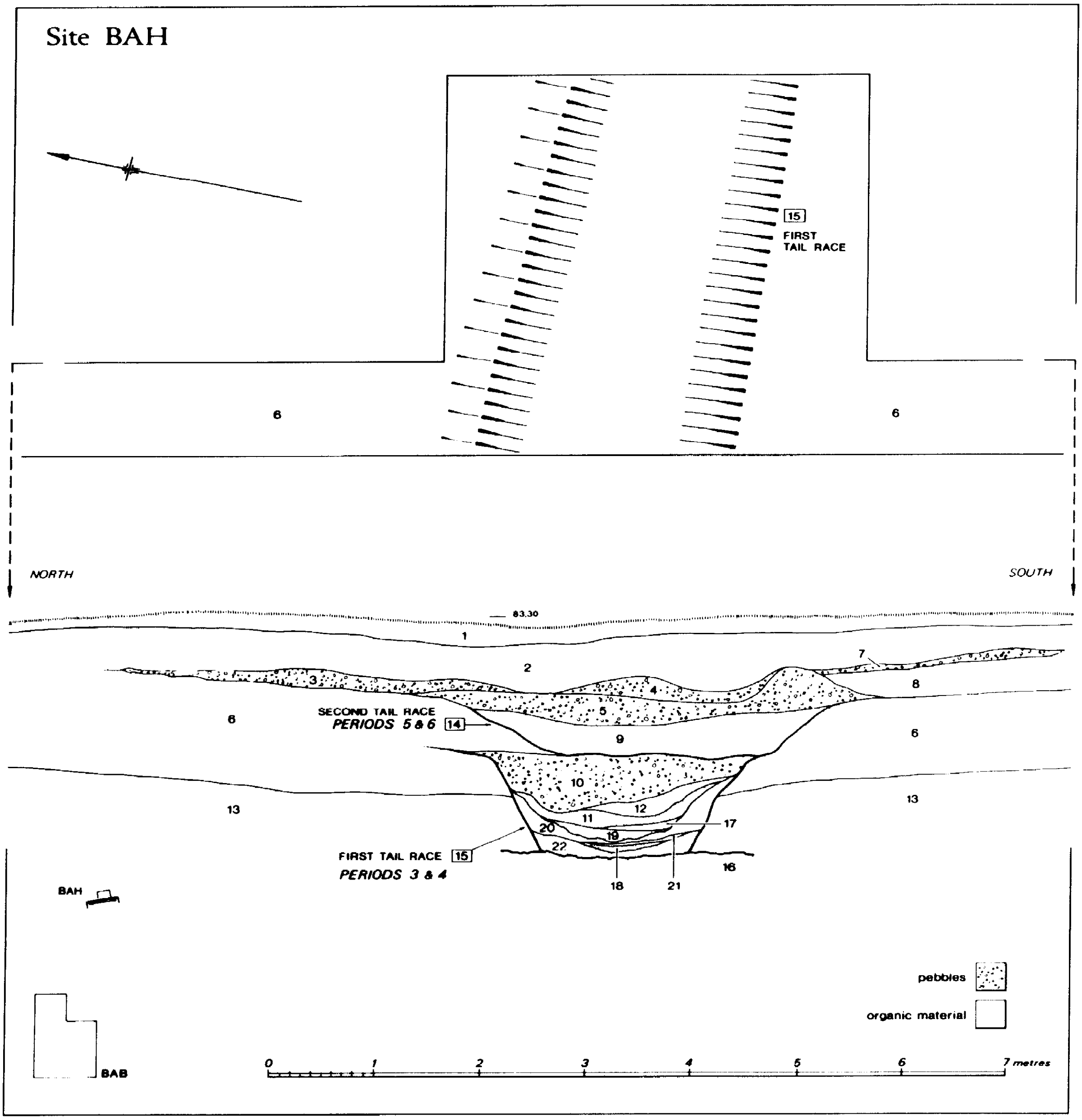


Figure 46 Tail race (BAH): plan and section

nel (14) had less steep sides and was less deep than the first channel; it had been cut through the sediment and its bottom was formed by the pebble fill of the first channel. The channel was filled with a series of laminated, loose sandy, orange to brown, silts (9), similar to those encountered in the period 6 tail race in BAB (E368). These were sealed by an uneven layer of pebbles in a sandy loam (5) which banked up on the south side, as if the pebbles had been eroded by water. Further layers of pebbles in loam (3; 4; 7) were deposited across the top of the channel, with further silting (8) to the south. The whole area then appears to have been flooded, to judge from the silts (2); away from the channel, these were continuous with the silt layer 6.

It is impossible to provide a direct correlation with the excavated sequence from BAB, but some tentative associations can be made. Firstly, the earthwork evidence points to these channels being the tail races of the medieval mills. The first channel is assumed to belong to the first, period 3, mill, a conclusion that is to some extent supported by the similarity in profile of this channel and the period 3 bypass channel (A135) in square A of BAB.

Some of the lowest silts (21; 17) produced small quantities of pottery which are thought to be thirteenth century (see below, part II, Nailor, ‘Pottery’). The thick organic silt 11 produced a wider range of pottery, which is more characteristic of period 4 (or later). No other pottery was recovered from the later silts of either channel. If silt 11 is correctly attributed to period 4, the second channel must, therefore, belong to the period 5 or 6 mills and, as the base of the tail race in BAB remained unaltered between periods 5 and 6, the second channel is more likely to have been cut in period 5. The similarity in the character of silts between the period 6 tail race in BAB (E368) and those in BAH might reinforce this interpretation. It is assumed that the second channel would not have been cut after period 6, when the mill had been abandoned.

If this chronology is accepted, the BAH sequence provides a remarkable record of the sedimentation of the valley during the monastic period. The accumulation of 0.5m+ of silt between periods 4 and 5 testifies to a dramatic change in the profile and gradient in this east part of the valley. It also provides an explanation for the, at first sight curious, superimposition of tail races at the water mill: it was an attempt to maintain sufficient gradient for the mills to work in the face of a rising water level downstream (see below, part III, ‘Gradients’).

Tail race (BAJ)

Figure 47 (section); Table Ml1

A machine trench, 1m wide and 13.5m long, was cut across an earthwork ditch which had been interpreted as the tail race of the mills. The excavation was located as close as possible to the present course of the River Arrow, some 220m east of BAH (Figs 3 and 46). The sections were cleaned and drawn, but further work was not possible because the trench sides collapsed.

The lowest layer encountered was of large pebbles (10), as in BAB, BAE, and BAH. The layers immediately above provided further evidence for pre-monastic anastomosing channels in the valley. To the north a layer of loosely packed pebbles in silt (9) is interpreted as a water-deposited bank, similar to those recorded from BAB in period 1. It was sealed by water-deposited grey silts (5; 16), which in turn were eroded by a stream channel (20) in the south, which then silted up (15; 14).

A 7m-wide channel (19) was then excavated through the silts down to the pebbles; its north side had a shallow, stepped profile whereas its south side was steeper and indeed was revetted by wooden stakes (17). The upcast from the channel was piled on the south side to form a low bank (12; 11). However, it is possible that the stakes and the upcast may be the result of recutting the channel.

The channel filled with gravel (8), followed by an organic silt (7), and grey silts (6), which rendered it inoperable. A channel was re-established, but in a narrower form; a new course (18) was cut into the north half of the old channel. This in turn filled with an organic silt (4) and then a grey silt (3).

The entire area was then sealed by a thick, 1m+, flood deposit (2). The level nature of the bottom of this layer, apparently flattening underlying contexts, suggests that its deposition was preceded by a phase of water erosion which truncated the contemporary ground surface. If this interpretation is correct, the original depth of the second channel cannot be established.

This trench provided valuable confirmatory evidence to that from BAB and BAH It should be noted that no dating evidence exists for the BAJ sequence. However, the evidence for extensive water activity above the pebble layer confirms the pre-monastic character of the valley established in BAE and BAB.

It is assumed that the first channel represents the tail race of the early monastic mills, which, by analogy with BAH, would imply periods 3 and 4. It follows that the recut channel would correlate with the suggested period 5 channel in BAH. However, the critical evidence for increased sedimentation in this part of the valley between periods 4 and 5 has been lost as a result of an erosion phase, of period 7, which destroyed the level from which the second channel (18) was cut.

Finally, it is salutary to compare the results of this small excavation with the surface evidence. The extant earthwork evidence reflects the pre-monastic stream channel in the south of BAJ and the tail race of periods 5 and 6 in the north. It does not, however, indicate the position or size of the major channel which was the tail race in periods 3 and 4.

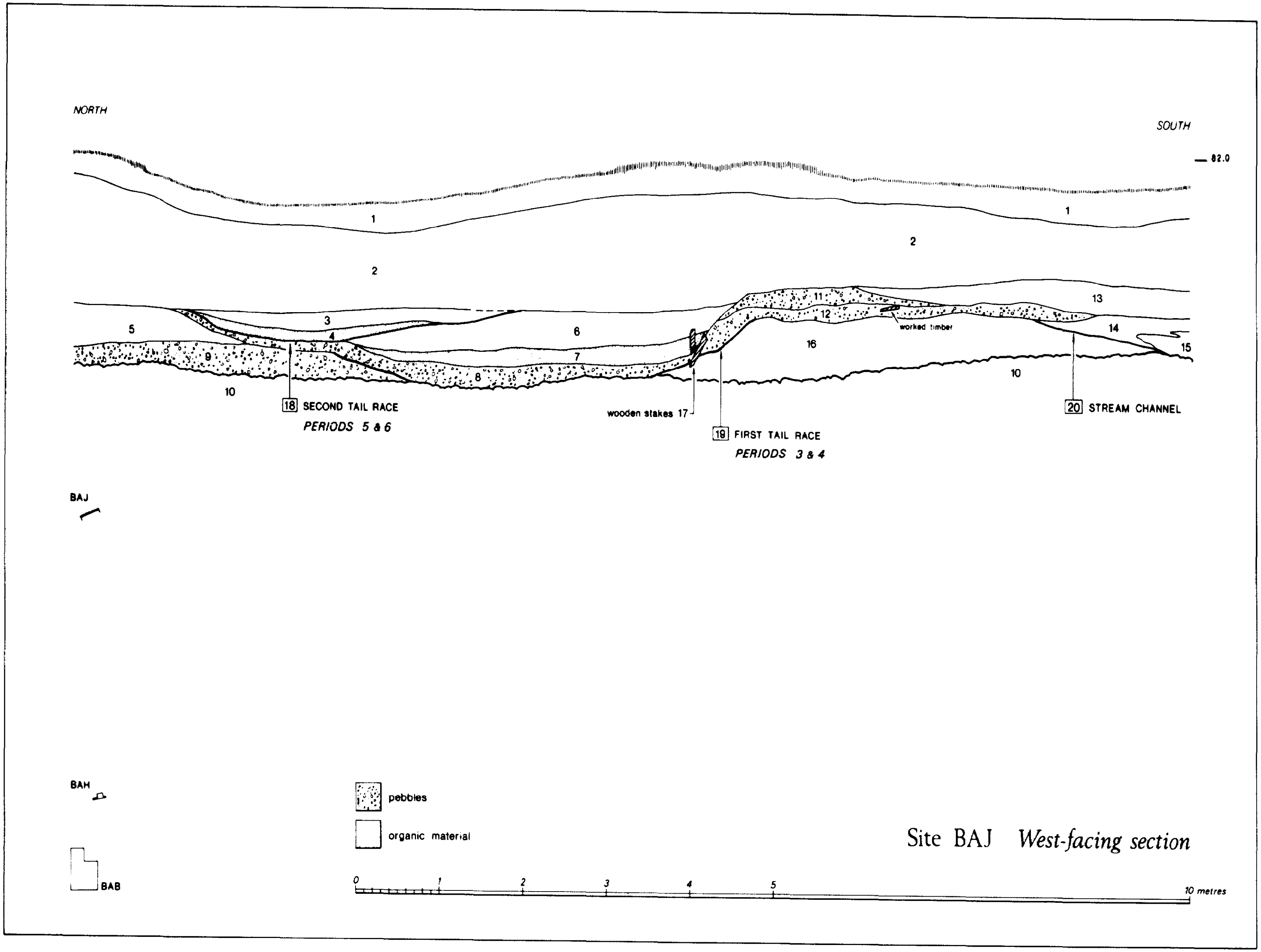


Figure 47 *Tail race (BAJ): west-facing section*

The medieval and post-medieval landscape of the east part of the precinct: a new survey and interpretation

Figures 48. and 49

The earthwork survey, and the interpretative developmental scheme, by Aston and Munton (1976) has hitherto formed the basis of all discussions about the Bordesley Abbey precinct. This remarkable piece of fieldwork was carried out before any excavation had taken place within the valley, and the interpretations were, therefore, based on surface observations. The subsequent excavation campaign in the east of the precinct was accompanied by a magnetic susceptibility survey (readings taken on a 1m grid) carried out in the east third of the precinct, and a pilot resistivity survey (on a 1m grid) was done in the area of the north-west corner of the mill pond; two pilot traverses using electrical resistivity tomography were also carried out (see below). The aim was to improve the understanding of the water system in this part of the valley.

The results from this variety of techniques offered some new interpretations, which, it was thought, could be explored by resurveying the area surrounding the triangular mill pond. This was carried out, with the assistance of Mark Corney, under the supervision of Stephen Wass in 1991 (Fig 48). The following discussion was also aided by information from the Redditch tithe map of 1839 and aerial photographs taken in 1962-4. Features identified as medieval are discussed in the interpretation of the water supply (see below, part III).

In the past, post-Dissolution activity has been underestimated. The excavations have recovered elements of an extensive post-medieval drainage system. Those drains which were established by sectioning as of post-medieval date could also be seen to be earthworks which were characteristically smaller, of a regular pattern, and sharper than the demonstrably medieval earthworks. It is, therefore, possible to interpret all earthworks of this form as post-medieval drains, and to remove them from the plan in order to see the potentially medieval features more clearly. This process removes some features that were previously thought to be medieval, such as a potential moat around the industrial area, which can now be shown to be composed of two post-medieval drains (north and west arms, S14 and S23) and a part of the monastic boundary ditch (S11) (see Fig 48). The putative irrigation system to the west of the triangular mill pond also appears to be part of the post-medieval drainage operations (cf Aston and Munton 1976,31).

The aerial photographs show some drains continue into the field to the north of the pond, a field which Aston and Munton (1976, 32) record as having been drained in 1948. The excavations, however, show that some of the drains were earlier, of the late eighteenth or nineteenth century, and therefore part of a different system, which is also true of the field boundaries. The 1839 tithe map shows a set of boundaries which occupy or follow for the most part the medieval earthworks. This is in contrast to the post-1839 (hawthorn) hedges which ignore the medieval earthworks and are on a different alignment from some of the drains. There were thus at least two post-Dissolution schemes to improve the land, one of which is partly recorded in the 1839 tithe map.

The BAE excavations have also redated some elements of the water system from the medieval to the post-medieval period. In the south end of BAE, hard against the south side of the valley, a medieval watercourse was sectioned which is interpreted as the Red Ditch alias the Batchley Brook. This present watercourse now makes a sharp change of direction in the middle of the precinct to join the outflow from the eighteenth-century Forge Mill and then, further north, the River Arrow. The BAE results would suggest (contrary to Aston and Munton 1976, 29, 35) that the brook was redirected in the post-medieval period, most probably at the time the Forge Mill and its waterworks were built. The evidence from BAE (BAE26) shows that the brook had gone out of use there by the late seventeenth or early eighteenth century.

The BAE excavations also showed that the triangular mill pond could not have been supplied with water from the south but must have been fed from the north-west corner of the pond. The implication is, therefore, that the feeder channel took water from the fish ponds in the middle of the precinct. This medieval arrangement was destroyed when the Forge Mill outflow was dug and the Batchley Brook redirected: these works cut through, and thus foreshortened, the fish ponds.

The survey was undertaken in July 1991, after the grass had been cut, using an EDM to record the major earthworks and intersections and tapes for the minor features. The area to the south appeared to have been heavily disturbed as the result of the laying of a large sewage pipe in 1965. The extreme north and east areas had also been confused by hedges and associated ditches. A comparison between the aerial photographs taken in 1962-4 and the present ground surface showed that some features clearly visible in 1962-4 had since become obscured.

The post-medieval landscape

The ditches which had been sectioned by the excavations and were clearly of post-medieval date were S8, S12, S18, S13, and S14 (visible as two different ditches on the surface, but, when excavated, proved to be continuous) (see Fig 48). The similarity of size and character of other ditches to those excavated would suggest that the following

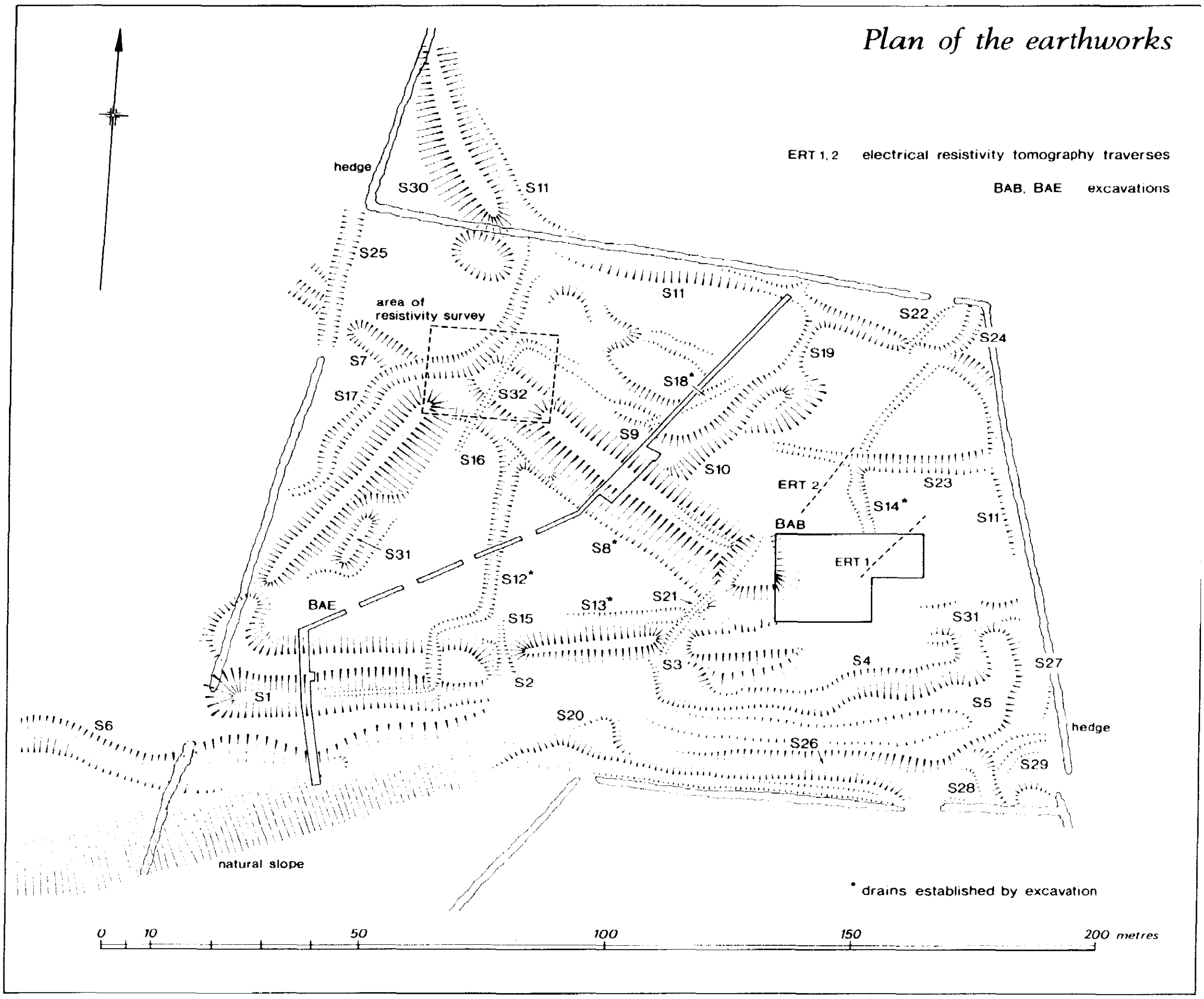


Figure 48 The eastern precinct as resurveyed in 1991: plan of the earthworks

were also post-medieval drains: S15; S16; S17; S19; S23; S24; S28; and S29; some of the smaller sections of ditch may have joined to give a more coherent drainage system. It is also possible that some of the ditches may have been associated with hedges: for example, a fragment of bank (S20) and the sections of ditch S21 and bank S22 align with a trench cut through the north mill pond bank and all continue the boundary on the south side of the valley which is recorded on the 1839 tithe map. S25 is also probably the remains of a ditch associated with a section of hawthorn hedge that was removed.

The medieval landscape

The BAB and BAE excavations have demonstrated that elements of the medieval landscape (for example, the north bypass channel) have been completely obscured, and that, while other, apparently contemporary, medieval earthworks survive, a total reconstruction of the monastic arrangements is impossible without further intensive prospection and excavation. The same would of course apply to the pre-monastic (period 1) landscape.

Most of the precinct was defined by a boundary bank and ditch; the exception was the area dominated by the triangular mill pond, and Aston and Munton (1976, 32) suggested that the precinct bank was incorporated into the (higher) north mill pond bank. Excavation failed to provide evidence for this view, but at the north end of BAE the edge of a substantial ditch was encountered (BAE242). This ditch was also seen to continue as an earthwork (S11) east of and mirroring the substantial portion of surviving bank to the north (S30), skirting the north edge of the area, and then turning (in the north-east corner) to the south (mirrored and obscured by the east hedge and ditch) to empty into the mill tail race (sectioned in 1967-8) (Fig 4). This ditch seems to be the remains of the precinct boundary; this interpretation, however, does not explain why there is no evidence of a bank along its course.

The south of the area was bounded by a slightly sinuous watercourse (S6 and S26 and excavated in BAE) which can also be traced to the west, although in some places the ditch has been filled in. As the stream bed is sited on the side of the valley, above the lowest levels in the valley, it is interpreted as the redirected course of the Red Ditch alias the Batchley Brook, which had been created early in the life of the monastery probably at the same time as, or even before, the redirection of the River Arrow. There are also possible traces of a much degraded flood bank immediately to the north of the watercourse; in the area to the west the bank is much better preserved. The course of the brook to the east of the mill pond is difficult to trace: there is no clear evidence for its continuation to the east; it may have been destroyed by the later drainage operations, but another possibility is that the brook was diverted north to join the mill tail race, perhaps opposite the outflow of the precinct boundary (at S27). The effect of this would have been to provide a continuous boundary around the east part of the precinct.

The BAE excavations have demonstrated that the surviving banks of the triangular mill pond are of period 5, although they appear to be an enlarged form of the first, period 3, banks. The pond was sited in the lowest part of the valley, and its shape may have been determined by pre-existing stream courses and banks. The banks were created from material excavated from ditches and from the levelling of the area which became the bottom of the mill pond. The north bank was constructed in sections or lengths, illustrated by the interleaving of dumps of bank material; wattle fences were used to revet the dumps. One division between two different sections occurred above the wooden drain. A similar explanation may account for the slight difference of alignment between the three sections of the south mill pond bank; here the divisions between the lengths coincided with the positions of the sluices (S2 and S3).

Both the north and south banks were associated for some of their length with external ditches which were probably dug to provide bank material. In the case of the south ditch (S1), it may have been used as an overflow channel. The north ditch (S9) was only present for the west half of the bank; it terminated in a butt end to the east and this arrangement may reflect the original layout or that the east section of the ditch was filled in (see below, part III, The water supply'). There is no clear evidence for an external ditch to the west bank, but the bank itself has an unusual shape. At its north end the west bank has a similar width to the other banks, but there is a pronounced constriction midway along that reduced by half the breadth of the south length of the bank. At the point of the constriction, there is a mound inside the mill pond (S31). This is an unusual position for an island, but there is a possibility that an enlargement of the west bank (if it was similar to the other two banks, enlarged in period 5) was not completed and that the mound represents the initial dumps intended to widen the south section of the bank.

There is no evidence for breaks in the north or west mill pond banks which would have housed sluices. The two breaks in the south bank clearly preceded the post-medieval drains located there and both were probably the site of a sluice. One (S2) would have been an outflow into the ditch S1, while the other (S3) was connected to a ditch (S4) which skirted the east end of the pond and debouched into the tail race. This is interpreted as a bypass channel for the mill. The bank immediately to the south (S5) is probably the upcast (with a depression in the centre) from the excavation of the bypass channel and acted both as a flood bank and an additional marker of the precinct boundary. Such earthworks connected with water control can only be associated with the period 5 enlargement of the south bank. There is, however, a possibility that there was a similar arrangement in periods 3 and 4 and this is discussed elsewhere (see below, part III, ‘The water supply’).

The channel that brought water to the mill pond via its north-west comer is indistinct because of later drainage ditches and the large break in the pond banks at this point which in the past has been interpreted as a post-medieval slighting (Aston and Munton 1976, 32). However, the new survey has shown that the west end of the north bank ends in a broad, flat platform which occupies much of this gap and on which a building may have been located (S32). This interpretation was confirmed by resistivity survey (see below). The function or date of such a structure must remain unknown, but the lack of suitable water channels makes it unlikely that another mill was located here.

The relationship between the feed channel (S7) and the external ditch of the north bank (S9) has been lost through later activity, but it is possible that there was some bypass arrangement (controlled from within the stone building at S32) by which water could be prevented from entering the mill pond and diverted into this external ditch. The present earthworks suggest the water would have drained from S9 into the precinct boundary ditch via another, ?partly disturbed, ditch (S10).

The channel which issues from the apex (east corner) of the triangular mill pond has been confirmed by excavation as the mill race, which continues east as a sinuous tail race (S31) for about 280m until it reaches the present course of the River Arrow.

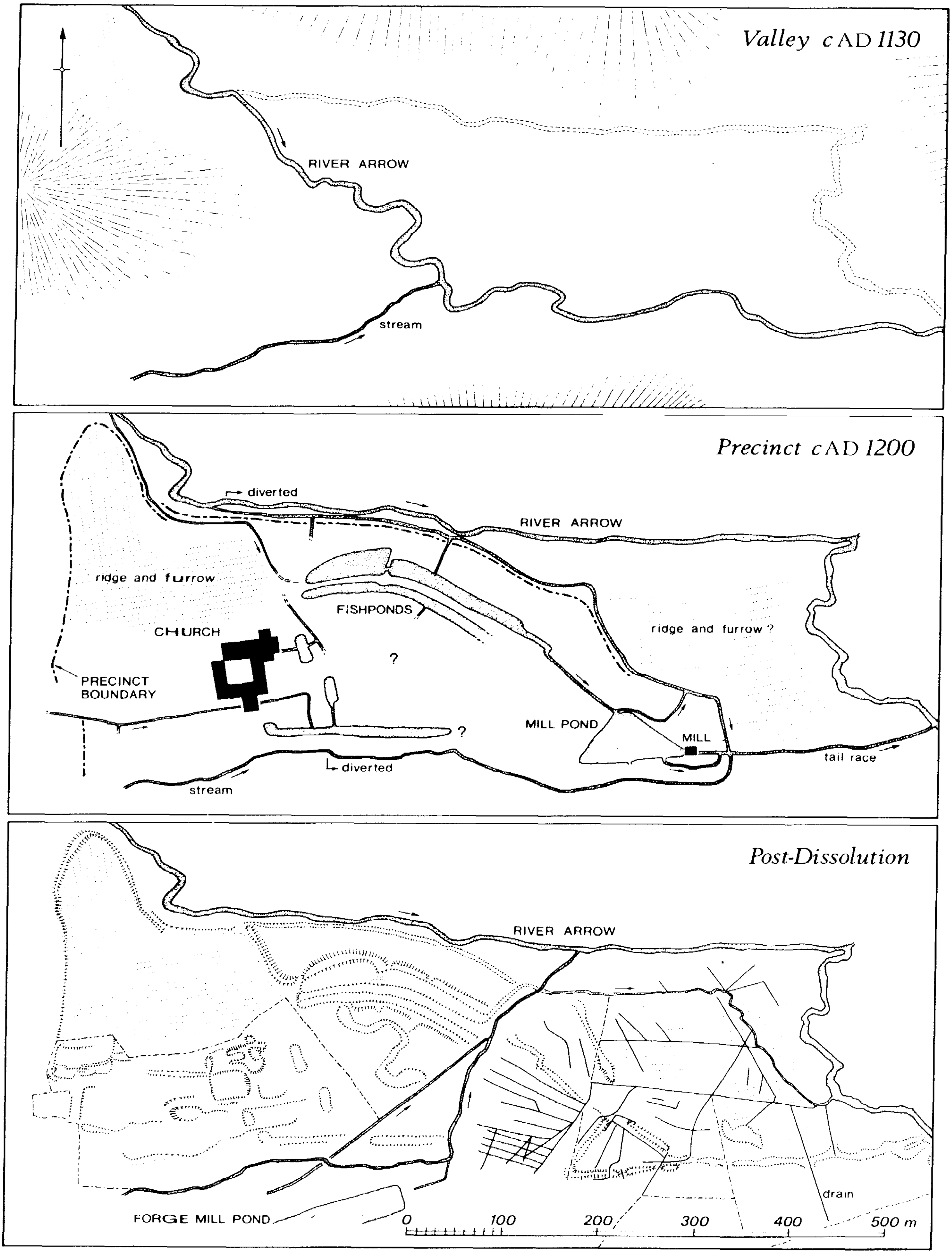


Figure 49 The development of the Bordesley Abbey precinct: a reinterpretation

The combined fieldwork and excavation have significantly increased information about the east part of the precinct. While this is not the place to reconsider the interpretations of the whole precinct, the results in the east end do significantly revise Aston and Munton's 1976 developmental sequence. Firstly, the earliest monastic occupation can consistently be dated to the last quarter of the twelfth century, and it can be shown that that occupation is a water-powered metalworking complex. It therefore follows that within 40 years the whole precinct had been laid out and an efficent water control system introduced (Fig 49), that is considerably earlier than was previously thought. This does not discount the possibility of an earlier and smaller precinct which preceded the diversion of the River Arrow, but it does suggest that, if such a stage existed, it was of short duration, probably less than 30 years.

The stratigraphic and environmental evidence for the failure of the water system in the east part of the precinct in the later fourteenth century, coupled with the failure of the magnetic susceptibility survey to locate any later medieval replacements to the industrial workshops, strongly argue that the east part of the valley was abandoned and that the precinct contracted: it may thus be possible to reverse Aston and Munton's scheme and to suggest that the precinct initially was a large area which subsequently contracted (Fig 49).

Resistivity survey by C Gaffney and C Heron

A pilot resistivity survey of an area of 520m^2 (Fig 50) was conducted at 1m intervals using a Bradphys MKIV meter in the twin probe configuration over two days in January 1984. The area was located at the north-west corner of the triangular mill pond at the point where there is a gap in the banks and a large level platform (Fig 48); this has been interpreted as a post-medieval slighting of the mill pond (Aston and Munton 1976,32).

A large area of high resistance approximately coinciding with the platform was located. The main area was rectangular of c 10 x 8m with a north-westerly extension (*c* 4 x 6m). The clarity of shape and the high resistance values (of c 87 ohms) would indicate the presence of a stone structure that was built against the west end of the north bank. The bank itself produced slightly lower resistance values than the structure, as did a feature in the south-west quarter of the survey area, which is probably the north end of the west mill pond bank.

A feature of similar resistance values occurred in the north-west corner of the survey area. While this appears to be an area of coherent high resistance which might be interpreted as another stone structure, the 1962-4 aerial photographs show this feature to be the end of a bank associated with the feeder channel for the mill pond.

Three linear areas of low resistance located between the feeder channel bank and the proposed stone structure are interpreted as ditches and can be identified from the aerial photographs as post-medieval drains.

The survey has thus indicated that the gap in the mill pond banks was in all probability occupied by a stone structure of presumably medieval date. The absence of leats and the unsuitability of the gradients mean that it would not have been another mill, but probably contained machinery to control and channel the water supply intended either for the mill pond or the bypass channel.

A pilot electrical resistivity tomography (ERT) survey by M Noel and B Xu

A small survey was undertaken in July 1991 to try to locate the course of a steep-sided ditch (S14 on Fig 48), part of which had been excavated and interpreted as a bypass channel (A156) for the period 3 mill.

The limited time available only allowed two traverses, each 20m long, to be recorded (Fig 48). One traverse (ERT1) was located across the backfilled excavation area square A (BAB) in order to cross the excavated section of the channel at 90°. The other traverse (ERT2) was parallel to ERT1 and located 20m to the west.

The survey employed an array of 20 electrodes spaced at 1m intervals which were multiplaced (switched) to an ABEM SAS300B resistance meter. The multiplacer was used to collect all possible independent measurements of apparent resistivity along the array (170 readings) and these data used to form a vertical geophysical image by back projection (see Noel and Xu 1991 for procedure) (Fig 51).

In section ERT1 a zone of low electrical resistivity was detected at a depth of 1.5m near the centre of the image which corresponded with the position of the bypass channel. Two other low resistivity features to the right of the first and at similar depths suggest other infilled channels (which were beyond the excavated area, to the north-east, and do not show on the surface).

Section ERT2 detected only one low resistivity zone at a depth of c 1m. It is similar in profile to the channel located in ERT1, and it is likely that it is a continuation of this feature. The other two channels located in ERT1 must have diverged (to the north-east) from the bypass channel at some point between ERT1 and ERT2.

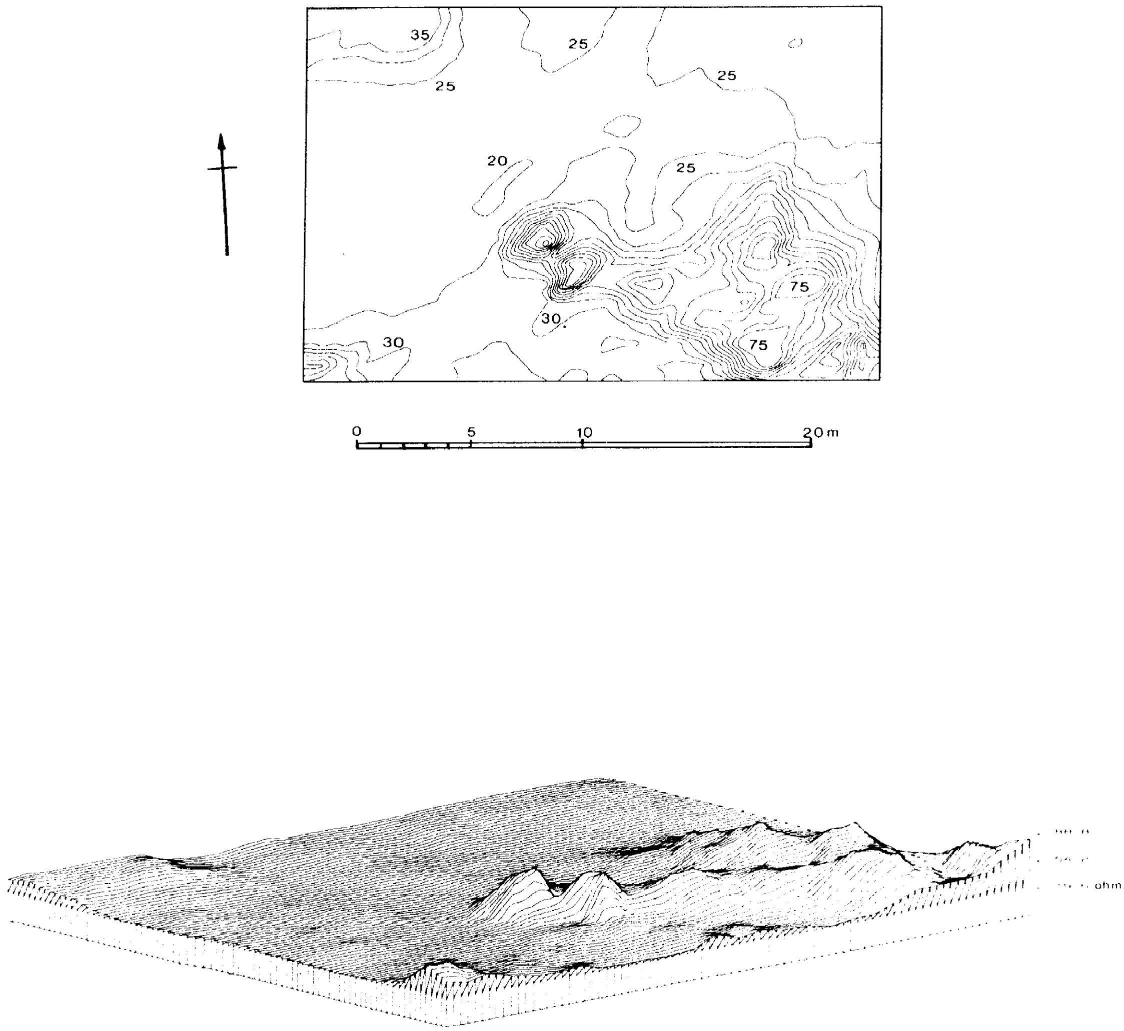
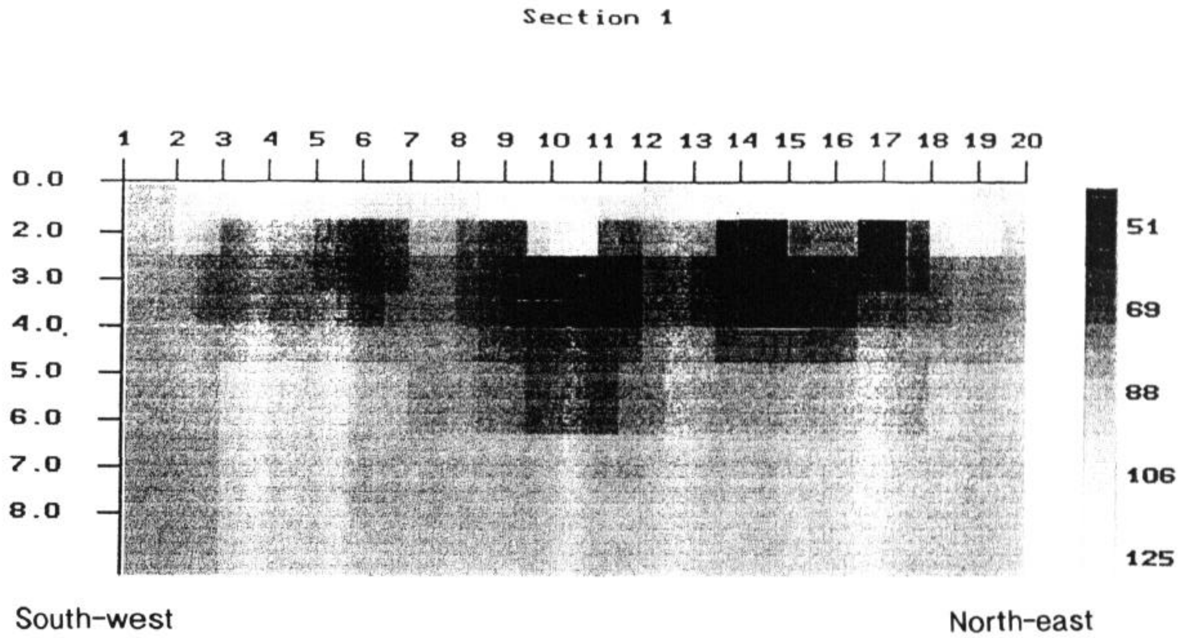


Figure 50 Resistivity survey of the north-west corner of the mill pond (see Fig 48): (upper) contour plot of resistance data (minimum value is 20 ohms and the increment is 5 ohms); (lower) rotated X-Y view of resistance data



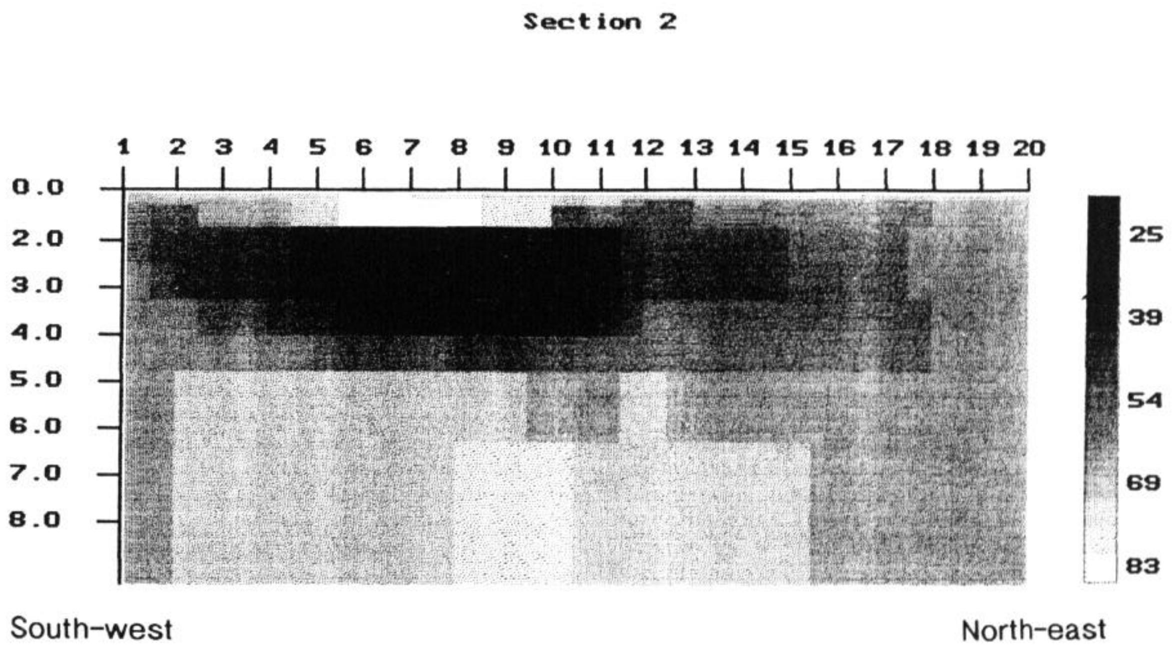


Figure 51 Electrical resistivity tomography survey of the bypass channel of the period 3 mill (horizontal axis gives the sequence number of electrodes (1m spacing); vertical axis gives depth in m; Section 1 = ERT1 on Fig 48)

II The finds

Introduction by G G Astill

An extensive coverage of the finds is justified because of the nature of the site: medieval mills rarely survive in such a good state of preservation. The detailed description of the wooden mill machinery, for example, is necessary because such artefacts are seldom recovered from other mills; the large Bordesley assemblage will assist the identification of mill sites from chance finds, as indeed it has already. Similarly, the attention given to the metalwork is designed to present the range, character, and volume of material coming from a metalworking site. In the past, industrial sites have often been published without an indication of quantities of material and associated residues, which can lead to the use of false criteria by which industrial sites are identified and characterised - the emphasis can be on particularly diagnostic, but rare, finds while the, perhaps larger, quantities of less prepossessing and less obviously diagnostic material are ignored, and in the process the true nature of industrial activity becomes obscured.

Finds are grouped by material and where possible, and appropriate, each group is treated as follows. Finds of one material are summarised by function and period in a table. An introduction summarises the distribution of the group and comments on the assemblage generally and its affinities. Each catalogue (and its associated illustrations) is arranged according to function, and within a functional group artefacts are ordered according to the site chronology (and not in numerical object order), In the case of finds from period 7, the phases are noted to distinguish between medieval and post-medieval material. The catalogue is followed by any scientific analyses. Where only selected items are described and illustrated in the printed text, a full catalogue is produced in microfiche (eg kiln furniture). In some cases, summaries only are presented and the detailed catalogues in their entirety form part of either the microfiche (eg clay pipe) or the (unpublished) archive (eg baked clay).

In all catalogue entries for material from the mill (BAB), the site code is omitted; only the context number is given. All measurements are maxima and in mm unless otherwise stated. (1: length; w: width; h: height; th: thickness; d: depth; dia: diameter; '+': incomplete dimension; u/s: unstratified; per: period.)

The various classes of material are considered together in part III, in the sections on the working of the mills, on metalworking, and on other industries.

Stone (ST) by G G Astill and S M Wright

Table 12

Thirty-six pieces of worked stone were recovered from the mill (BAB) which are summarised according to period and function in Table 12. Geological identifications are by John Allen, David Moore, and John Thomas.

Table 12 Mill (BAB) stone: summary of worked stone, by period and by function

Function	Period 3	4	5	6	7	U/S	Total
Bearings	-	1	2	1	3	-	7
Grindstones	-	1	1	2	2	1	7
Hones	1	4	-	1	3	1	10
Weights	-	-	3	-	1	-	4
Miscellaneous†	-	1	-	3	4	-	8
Total	1	7	6	7	13	2	36

† Including roofing stone, architectural fragments, discs, and school slates.

Stone bearings

Figures 52 and 53; Plates 34 and 35

Seven stone bearings were found, of a sufficiently large size and with sufficiently distinctive wear patterns to be interpreted as the main bearings for the water wheel. The identification is based on the presence on most stones of two separate areas of characteristic wear. The first occurs on the upper horizontal surfaces where grooves had been worn by, it is thought, iron spindles ('journals') fitted into the shaft of the water wheel. The faceted character of the wear indicates the considerable lateral movement of which the journals were capable, a movement produced by the vibrations caused by the dual actions of water hitting the wheel and the interlocking of the machinery, the two actions combining perhaps to produce a shift of the bearings in their seatings. In two cases (ST 352; ST 353) the wear is so asymmetrical that the journals may also have moved upwards, in the opposite direction to the rotation of the wheel, as well as laterally. The size of the grooves suggests a consistent minimum for the diameter of the journals between 30 and 35mm, while most bearings supported a length of journal between 60 and 62mm (the lengths were proportionally less for the smaller bearings: ST 352; ST 354). The over-deepened wear at the end of the grooves (away from the shaft) would suggest that some of the journals were, or had worn to become, uneven in shape and had expanded or bulbous ends (ST 352-ST 354; ST 359; ST 500).

The other distinctive, and related, type of wear occurs on those vertical faces where the shaft came into contact with the bearings. The concentric polishing and wear shows that the iron journals were let into (presumably wood) shafts that had iron parts, and it is these parts which were responsible for the wear on the bearings. The extent of the wear on the bearings indicates that the shafts had at their ends iron hoops fitted to the outer circumferences, but also some iron between the journals and the hoops. The undulating character of the wear also indicates the uneven nature of the ironwork on the shaft, due to either manufacture or wear or a combination of the two. The wear would suggest a minimum shaft diameter of 170-236mm.

The variation in the circumferential wear on the vertical faces of the bearings shows, like that on their upper surfaces, that the position of the journal on the stone shifted several times and/or the alignment of the shaft changed.

All the bearings were of large pebbles, and were mostly quartz or quartzite. They are of a similar character to the pebbles found in the modem bed of the River Arrow, and the medieval river, or one of its abandoned channels, is the most likely source of the bearings. Pebbles with a flat surface - for a potential base - seem to have been preferred (eg ST 352-ST 354; ST 359; ST 500). In one case the top surface had been pecked to provide a seating for the journal (ST 500).

Three of the bearings were fractured in the same place, that is in the bearing groove, which was the thinnest and weakest point of the bearings (ST 359; ST 500; ST 506). The worn grooves on the upper surfaces (and the associated wear on the vertical faces) show that the bearings were 'open'; nor is there any evidence of conical or tapering grooves which are typical of bearings for vertical spindles: therefore, the bearings could only have supported horizontal shafts (Graham 1986, 123-4; Fischer 1984, 7).

It is difficult to see how the bearings were seated in a wheel frame, although the bases of the bearings show some signs of polishing which has presumably been produced by vibration. There is no evidence that the stones were chipped in order to fit into a recess in the wheel frame (cf Graham 1986, 118). As they had a flat base, it is possible that the stone bearings were packed around with, or bedded in, clay.

The best collection of comparable bearings comes from the excavation of a corn mill with two wheels at Abbotsbury Abbey, where nineteen stones were recovered. While this mill was clearly functioning in the fourteenth century, it continued into the sixteenth century and beyond, and there is no clear dating for the stones. Thirteen of the bearings were for horizontal shafts and they shared some of the characteristics of the Bordesley stones: the patterns of wear on both upper and vertical surfaces, the position of the fractures, and the initial pecking of the stone to provide a seating for the journal. The diameters of the journals, however, were larger, ranging from 30 to 50mm, but this difference may be a result of the different type and size of wheel - the Abbotsbury wheels were thought to be overshot and about a metre larger in diameter - or of different function (Graham 1986, 123-4). A corn mill cannot function without vertical and horizontal shafts, whereas an industrial mill can function with horizontal shafts only (see below, part III, 'The machinery and its arrangement in the mill building'). Similar stone bearings, using local stone, have been identified from Colliford tin mill and from Newbury (Austin *et al* 1989, 176-7; Ford 1979, 78-82).

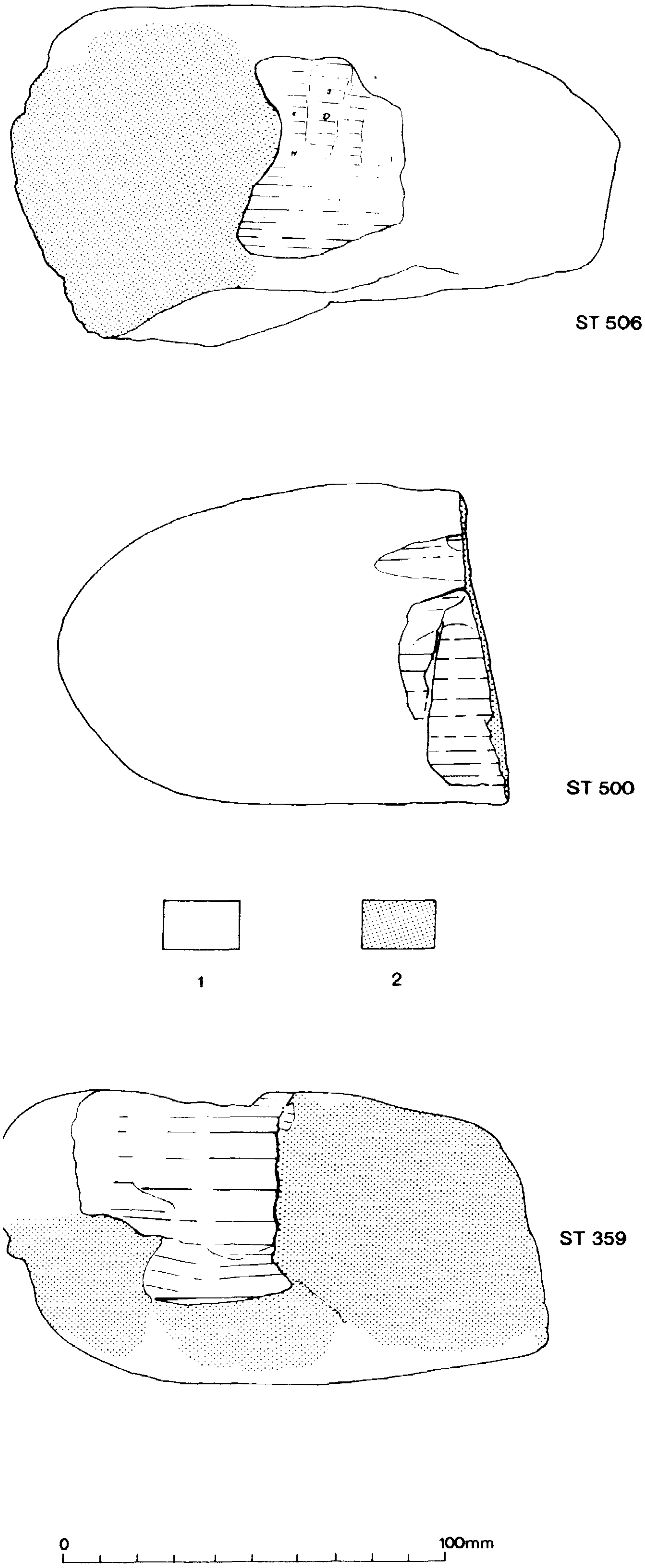
Holt's survey of the documentary evidence for medieval mill machinery notes the frequent use of metal bearings, but, as he says, this information comes from accounts which record financial outlays and the use of local stone for bearings may not have been recorded as the material was free (Holt 1988, 123-8). Stone bearings were used in Roman Britain (Spain 1985, fig 12). It should also remind us that metal bearings may not have entered the archaeological record because the metal of a worn bearing could have been reused (cf Tamworth: Rahtz and Meeson 1992, 86-7).

Six of the stone bearings came from contexts reflecting disuse such as the tail race silts, and the other had been reused and incorporated into a wall. Stone has continued to be used for mill bearings and in his *Surveying* of 1546 Fitzherbert recommends the use of both 'boulder stones' and brass for bearings (fol 56).

ST 506 Approximately two-thirds of large bearing, for a horizontal shaft? The worn groove on the upper surface shows four polished facets produced by a shifting of the journal (minimum length 62). A broad, concave, polished area on the vertical face (next to the shaft) has at least four differently aligned patterns of wear. There is a pronounced lip to the outer edge of the polished area (cf ST 363) which would give a minimum shaft diameter of 236. Lump of veined quarts. Pig 52; Plate 34. 156 1, 162 w, 113 h. (E435, per 4)

ST 500 Approximately half of a bearing for a horizontal shaft. The upper surface had been pecked to make an initial bedding for a journal. Two areas of polished wear have resulted from the changed position of the journal (minimum length 60) with some over-deepened wear at the back of the groove (cf ST 352-ST 364; ST 359). No wear on vertical face. Pebble, metaquartzite. Pig 52; Plate 34. 1211, 98 w, 75 h. (E800, per 5)

ST 359 Part, about two-thirds, of a bearing for a horizontal shaft. Two opposite sides, both fairly flat, have broad polished arcs (which show three different sets of wear lines and suggest a minimum diameter of 170 for the axle shaft) indicating it had been turned around for use from the other side. The groove in the upper surface, worn by the journal minimum diameter 35 and length 62), has at least two facets which are finely corrugated and may have been produced by grit trapped between



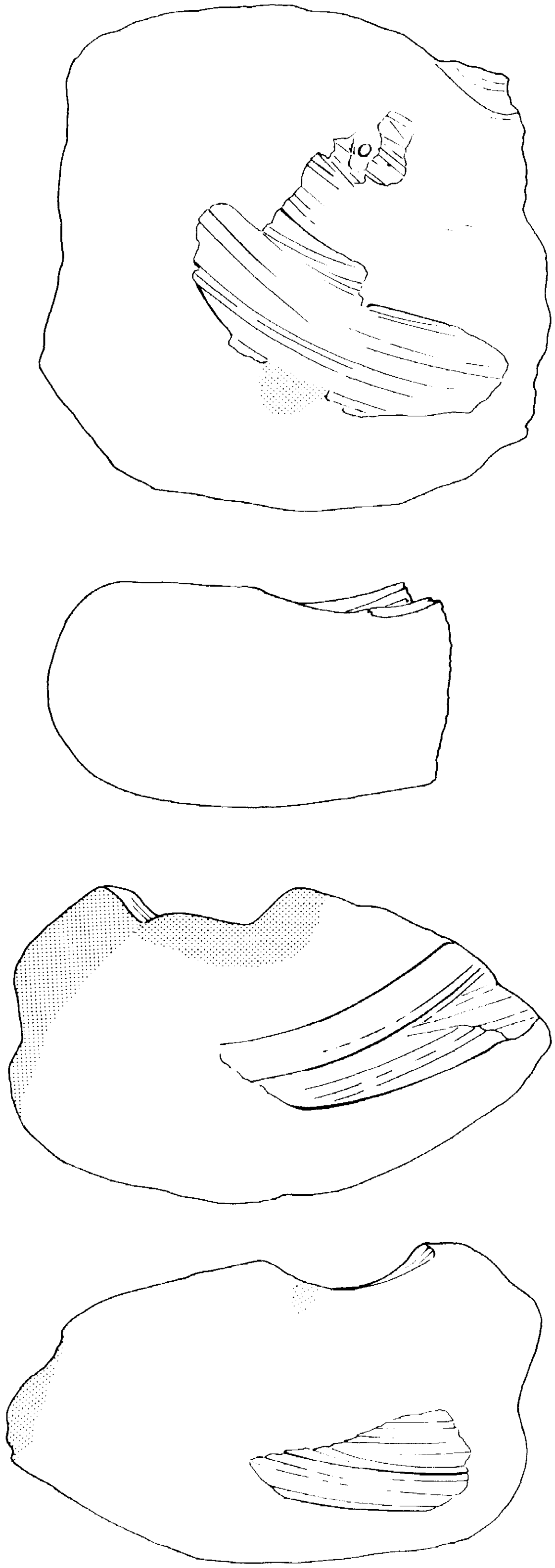
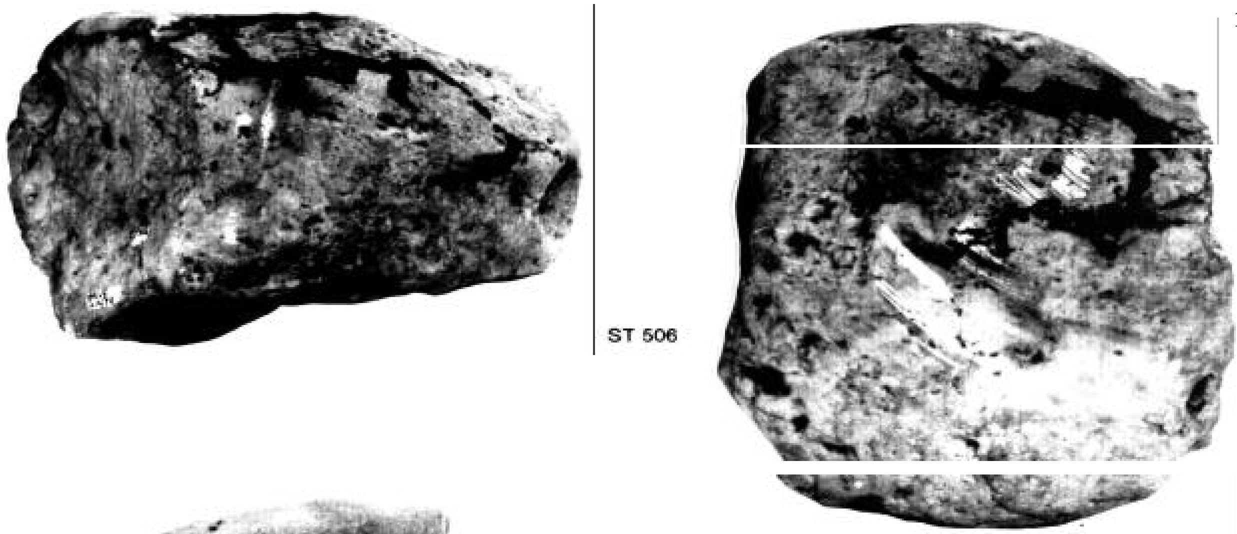
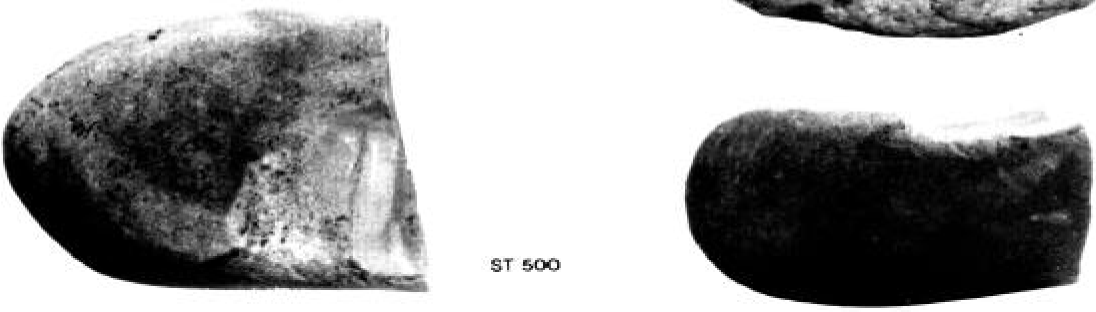


Figure 52 *Stone 1 (a): bearings. Key for stone bearings: 1: pecking; 2: fractures* ▲

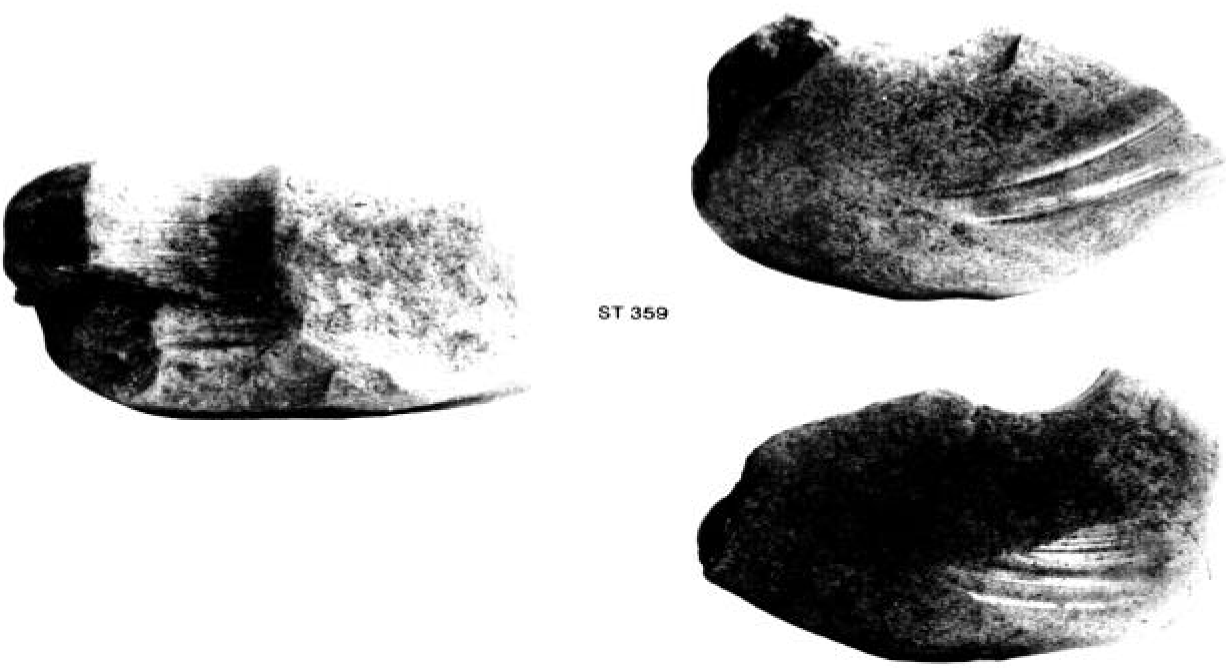
Plate 34 *Stone 1 (b): bearings* ▶



ST 506



ST 500



ST 359

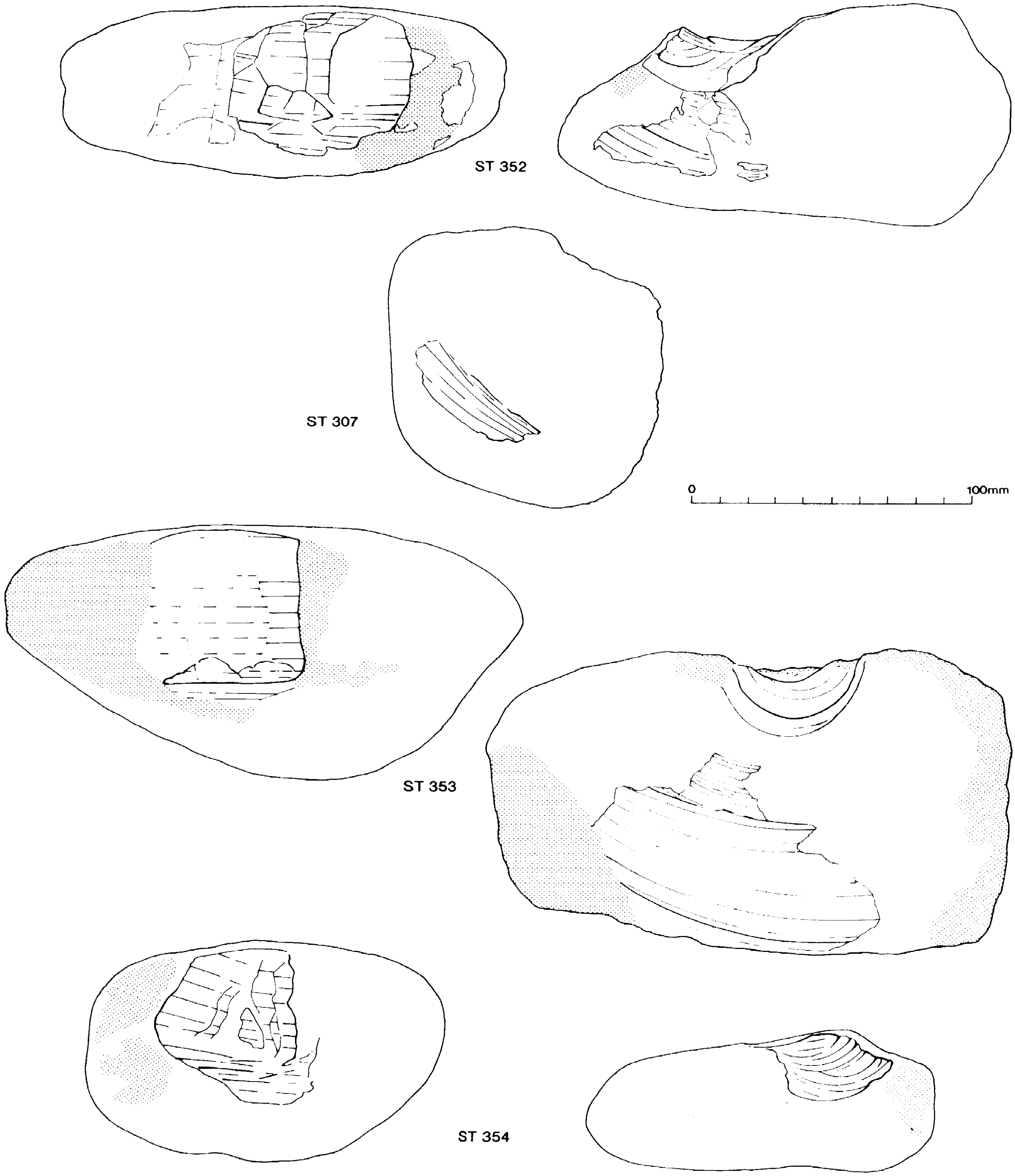
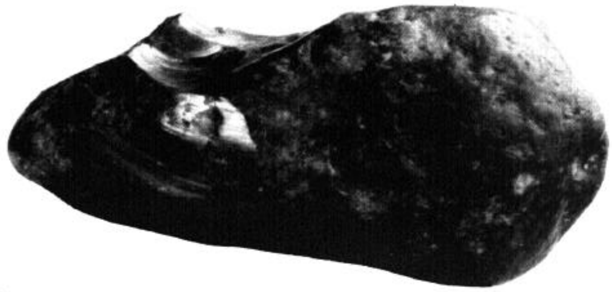


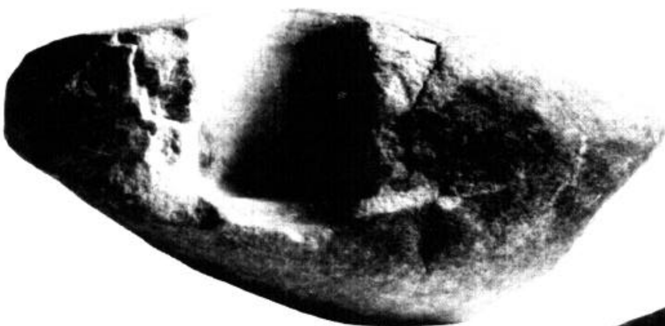
Figure 53 *Stone 2 (a): bearings* ▲

Plate 35 *Stone 2 (b): bearings* ▶

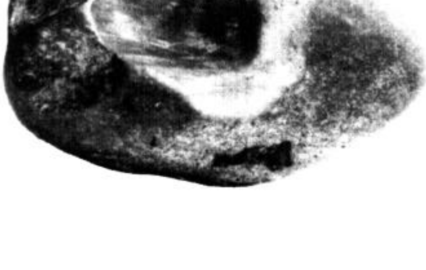


ST 352

ST 307



ST 353



ST 354

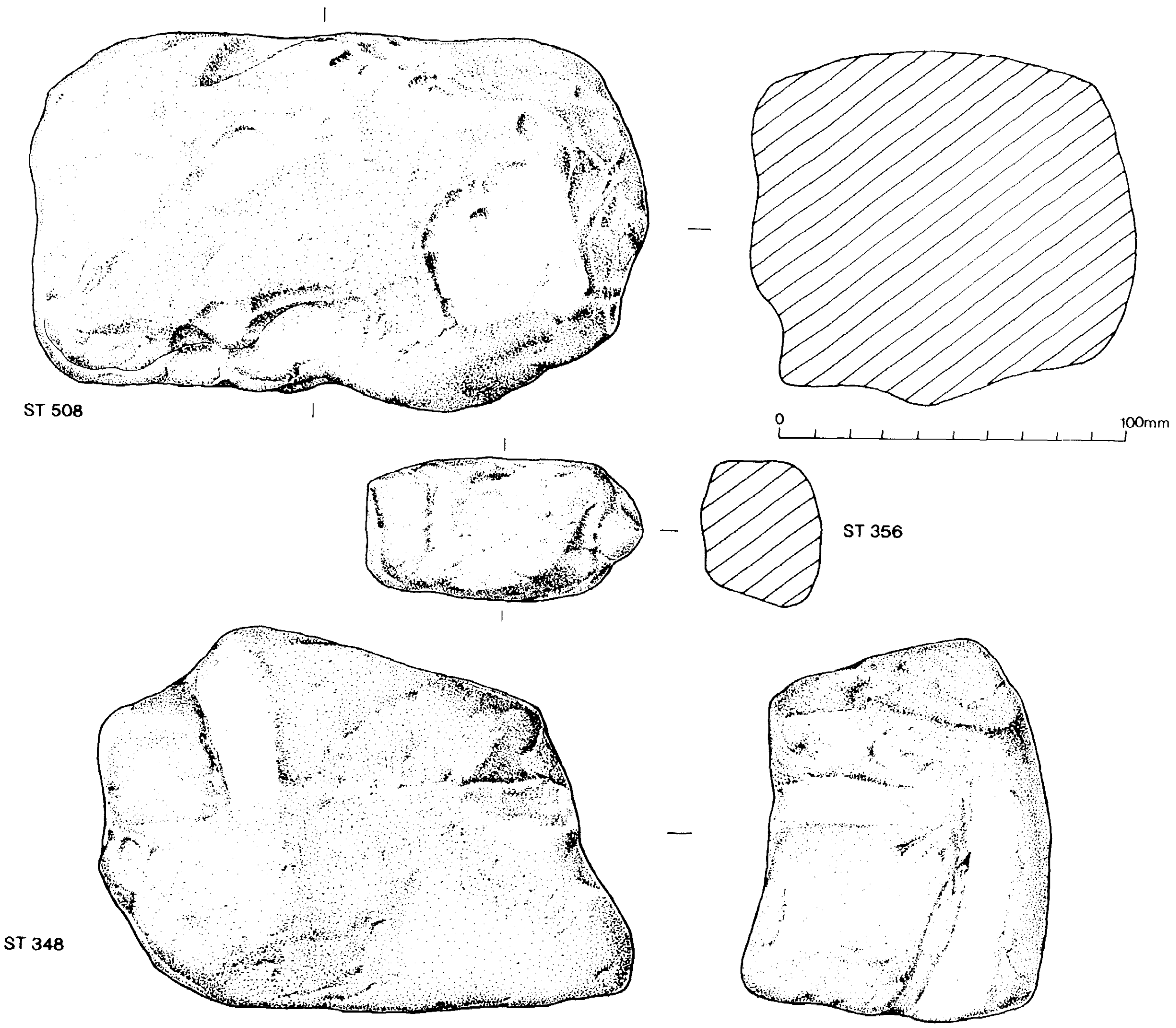


Figure 54 *Stone 3: grinding and sharpening stones*

journal and stone; the back of the groove had deeper areas of wear (cf ST 352-ST 364; ST 500). The stone must have sat on the face which is largely broken off. Pebble, feldspathic quartzite, ?from the Welsh border. Fig 52; Plate 34. 159 1, 86 w, 110 h. (E453, per 5)

ST 352 Near complete bearing for a horizontal shaft. The upper horizontal surface has a worn groove which has at least eleven adjoining and highly polished facets which reflect the numerous different locations, and the size, of the journal" The minimum journal diameter is 30, and the length of journal seated in the bearing 45. The adjacent vertical face (ie next to the shaft) has small polished arcs of at least two different circumferential wear patterns. Sarsen; from the south of England. Fig 53; Plate 35. 170 1,78 w, 95 h. (E236, per 6)

ST 307 Part of bearing, with a concave, highly polished arc (max 17 w) comprising two differently oriented circumferential wear marks, one (inner) slighter and one (outer) broader and more pronounced. Seating for journal does not survive. Quartzite pebble. Fig 53; Plate 35. 101 1, 114+ w, 77 h. (E261, per 7, phase 1)

ST 353 Near complete bearing, for a horizontal shaft. The upper surface has a worn groove with two polished facets and two more deeply worn areas at the end of the groove which may indicate the journal had a bulbous end: the journal would have been at least 35 in diameter and 62 long. The vertical face next to the shaft has a broad, worn and highly polished area which is made up of three different arcs. This polished area has a lip at its outer edge, which could indicate the shaft's circumference and would give a diameter of 230. One end of the upper horizontal face is broken. Pebble, tuff, medium grained quartzite. Fig 53; Plate 35. 194 1,105 w, 122 h. (E368, per 7, phase 1)

ST 354 Near complete bearing for a horizontal shaft. The pattern of wear in the groove on the upper surface demonstrates a skewing of the journal (*c* 32 diameter and at least 50 long). The two deeper areas of wear at the end of the groove indicate that the journal was bulbousended. The vertical face near the shaft has some slight signs of circumferential wear. One end of the upper horizontal face is broken. Pebble, metaquartzite. Fig 53; Plate 35. 138 1, 93 w, 54 h. (E368, per 7, phase 1)

Smoothing, polishing stones, and grindstones

Figures 54 and 55

The metalworking implications of the following are discussed in that section (part III). The majority (four) are sandstones, and the (four) largest pieces were incorporated into hardstandings or structures.

ST 508 Rectangular, roughly square-section, red sandstone block, nearly complete, with a variety of wear areas on all faces, viz smooth concave roughly circular (57 dia, 11 d), linear and arc-like (38 1, 9 max d), and one V-shaped- section point sharpening groove (67 1). A grinding and sharpening stone; the larger circular depressions are perhaps the result of smoothing ends. Micaceous New Red Sandstone, cf ST 356, probably Carboniferous from the Forest of Dean. Fig 54. *c* 180 1, 100 w, 110 th. (E809, per 5)

ST 356 Approximately rectangular-section fragment of a red sandstone sharpening/grinding stone, much worn/eroded, both ends probably broken. V-section sharpening groove (2 d) across one wide face and running over and across adjacent narrow face; a second shorter and shallower V-section groove at approximately right angles to first; traces of one or two other possible grooves visible. Micaceous New Red Sandstone, probably Carboniferous, perhaps from the Forest of Dean. Fig 54. 79+ 1, 46 w, 33 th. (E425, per 6)

ST 348 Roughly rectangular-section, red sandstone block with three large and one smaller grooves on two sides; the large grooves are U-shaped and almost flat-bottomed in section. The other faces of this block have dressing/tooling marks suggesting this block is a reused ashlar or other architectural fragment. The grooves may have been used to remove scale after working pieces of iron. Slight blackening. Micaceous New Bed Sandstone, cf ST 356, probably Carboniferous, perhaps from the Forest of Dean. Fig 54. 150 1, 122 w, 86 th. (D304, per 7)

ST 509 Large fragment with smooth, worn, slightly concave, upper surface; one unbroken, fairly smooth, edge survives; smooth wear on upper surface extends a few mm down over this edge. Cf ST 524, but upper surface not so worn or concave: ?smoothing/polishing stone. Quartzite, ?quite local, resembles Lower Palaeozoic in south midlands, eg Lickey quartzite (south of Birmingham). Fig 55.340 1,231 w, 111 th. (E364, per 7)

ST 524 Large fragment of a natural rounded boulder with worn, distinctly concave, upper surface. Two small roughly circular small holes in the upper surface and one in the broken edge (10 dia, 6 d). ?Saddle-type quern in an industrial context it may be a sinking dish which is used to beat iron and copper alloy into a curved shape in the preliminary stages of making, for example, bowls or pieces of armour. A boulder, medium-grained quartzitic sandstone, ?Carboniferous provenance. Fig 55. 280 1, 210 w, 160 th. (B651, per 4)

ST 61 One grindstone fragment, from outer edge with no trace of a central socket. Highly polished and very worn outer edge with rust-coloured staining; in places this edge has broken off. A finishing or polishing stone. Published Rahtz and Hirst 1976, 163 and fig 29.3. Coarse-grained quartzitic sandstone, ?Carboniferous. *c* 640 dia, 33-43 th on edge, 73 th nearer centre. (BAB 69 U/S)

ST 60 Incomplete grindstone (three joining pieces) for sharpening; one surface has little sign of tooling, the other has coarse, wide chisel marks and a finer diagonal tooling. The outer edge has been worn smooth and is asymmetrically convex, which may mean it has been used more on one side than the other; in one place it has broken off. The roughly square socket is off-centre; of the three sides present, one has a vertical face, another is slightly battered, and the third side has a mom pronounced batter with coarse dressing marks (the battering allowed the use of wedges to secure the stone to the shaft). The grindstone seems to have fractured along the stress lines radiating from all four comers of the socket, which may have been a result of eccentric wear (assuming that the socket was originally in the centre of the stone). The size, weight, and the large socket might imply that this stone was turned mechanically. The stones had been incorporated into the forge in the period 6 workshop. Published Rahtz and Hirst 1976. 163 and fig 29.1. Carboniferous, Millstone Grit, ?Pennines. Fig 55. 560 dia, 145 th; socket 150 1, 140 w. (BAB 69 F1, per 6)

Hones

Figure 56

These are discussed in the metalworking section (part III). The majority (five) were of imported Norwegian Ragstone from Eidsborg, while the others were of sandstone, and one silt or mudstone. The sandstone hones showed signs of extensive transverse honing and were thus used for coarse sharpening, while the imported hones were used for finer work.

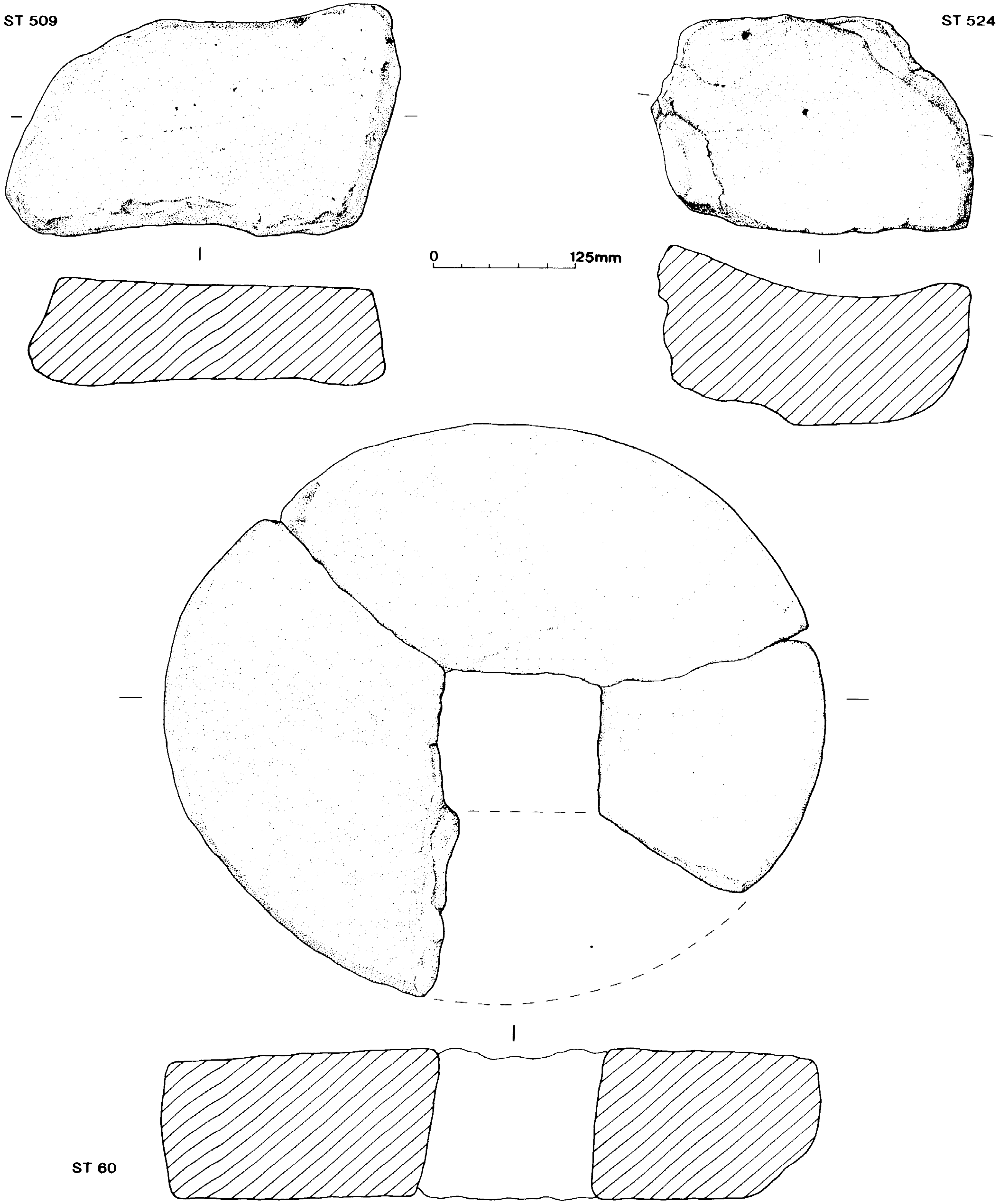


Figure 55 *Stone 4: smoothing/polishing stone, ?sinking dish, and grindstone*

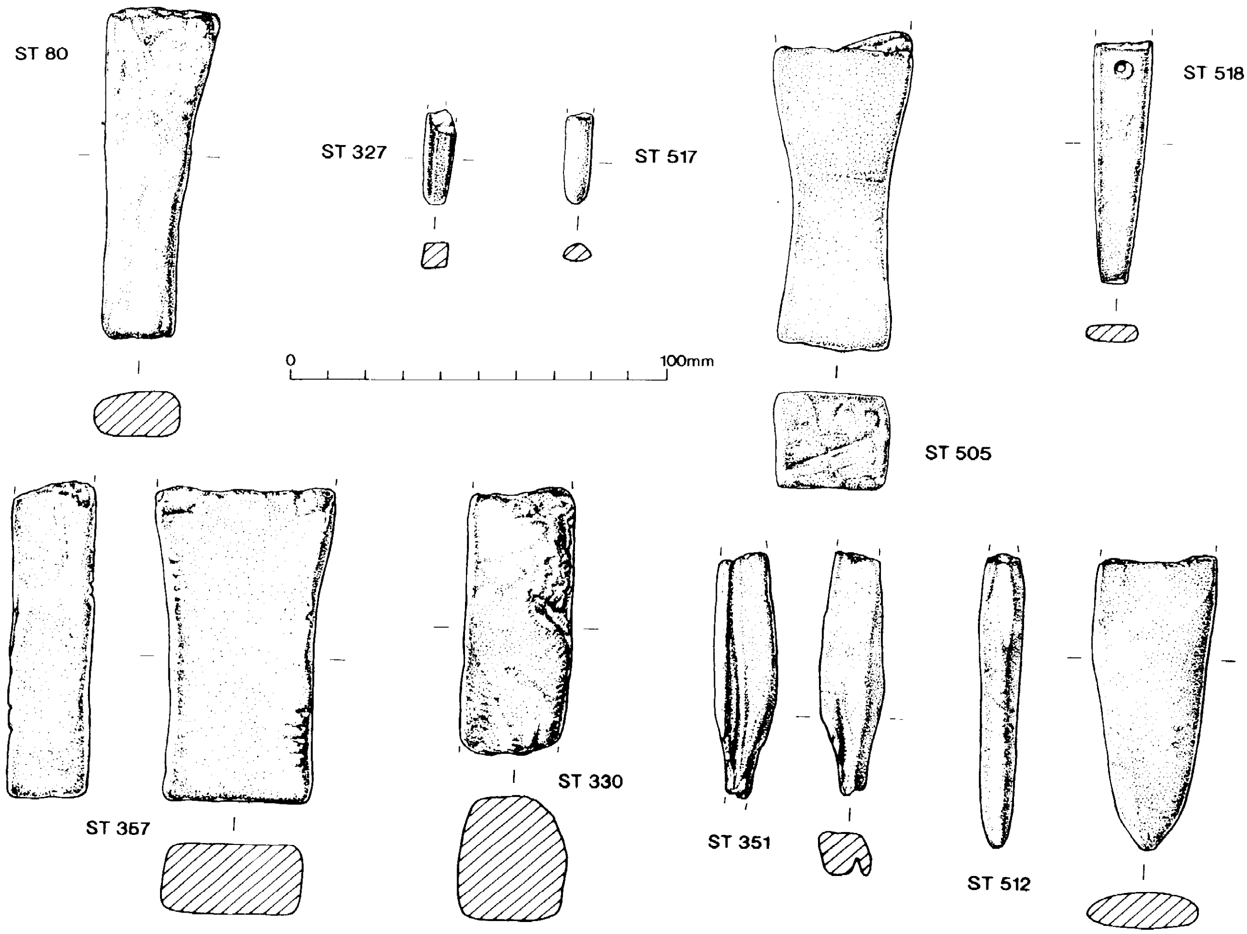


Figure 56 Stone 5: hones

ST 80 Tapering 'waisted' rectangular-section hone, probably complete. Worn on all four faces from transverse honing. Norwegian Ragstone. Fig 56. 100 1, 31 w, 14 th. (BAB 68 U/S)

ST 327 Small rectangular-section hone fragment, tapering towards broken end. Worn smooth on all four faces; complete end has three facets, all smooth. Slight iron/iron corrosion traces on one wide face. Finely banded mudstone or siltstone, probably Palaeozoic from Welsh borders or Wales. Fig 56. 29 1, 9 w, 8 th. (A118, per 3)

ST 517 Small tapering semicircular-section hone fragment, broad end broken, tapering end complete. Worn smooth on all faces. Norwegian Ragstone. Fig 56. 28 1, 8 w, 5 th. (E959, per 4)

ST 505 Roughly square-section hone, one end broken. Worn smooth and pronounced transverse honing on all four faces; some slightly irregular V-section sharpening grooves on complete end. Very fine-grained micaceous sandstone. Fig 56. 97 1, 38 w, 35 th. (E840, per 4)

ST 518 Thin tapering rectangular-section hone fragment, broad end broken, tapering end complete. Pierced for suspension at broad end, pierced at an angle to the object so hole eccentric. Worn smooth on all four faces. Norwegian Bagstone. Fig 56. 74 1, 15 w, 6 th. (B647, per 4)

ST 521 Incomplete hone fragment with two smooth, but incomplete, faces at right angles to each other, both ends broken. Norwegian Ragstone. 41 1, 22 w, 6 th. (B644, per 4)

ST 351 Rectangular-section hone fragment, both ends broken. Worn smooth on all four faces; pronounced taper towards one broken end caused by transverse honing on the two opposing narrow faces; both wide faces and one narrow face have V-section sharpening grooves. Norwegian Bagstone. Fig 56. 75 1, 17 w, 13 th. (E425, per 6)

ST 357 Rectangular-section hone fragment, both ends broken. Worn smooth on all four faces; two opposed narrow faces 'waisted' by transverse honing; also small areas of transverse honing and sharpening grooves on the edges. Very fine micaceous sandstone. Fig 56. 96 1, 48 w, 23 th. (E368, per 7, phase 1)

ST 330 Rectangular-section hone fragment, faces and both ends damaged. Worn smooth on all four faces; some slight transverse honing on two wide faces; short V-section sharpening groove

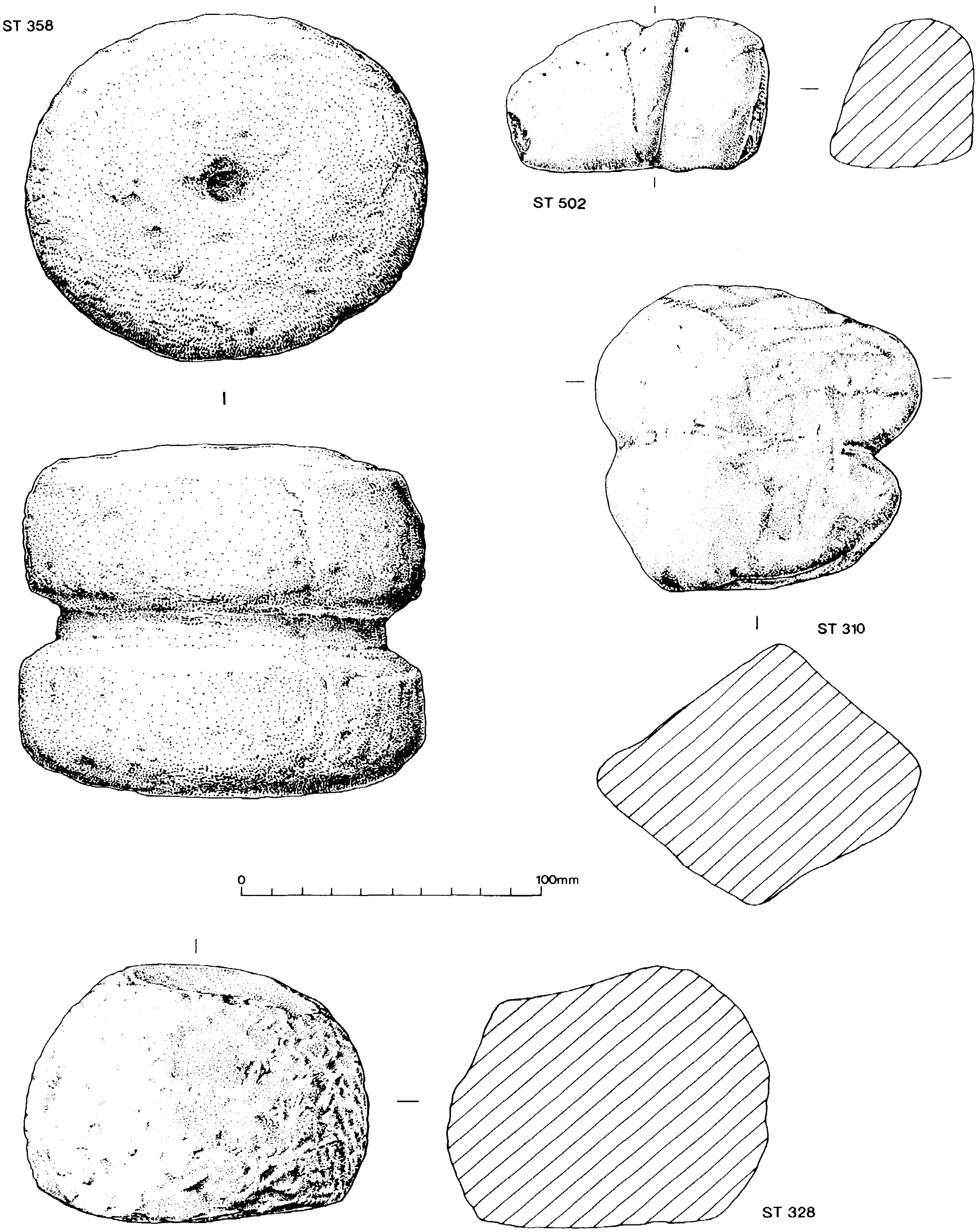


Figure 57 *Stone 6: ?machinery/weight and weights*

across one comer of complete end and on to narrow face. Medium to coarse sandstone, possibly Coal Measures Sandstone, more likely to be Millstone Grit. Fig 56. 81 1,38 w, 30 th. (C175 per 7, phase 1)

ST 512 Thin, tapering rectangular-section hone, broad end broken, complete end tapers to point. Worn smooth on all four faces; some slight transverse honing across narrow faces. Fine sandstone. Fig 56,90 1.32 w, 12 th. (E368, per 7, phase 1)

?Machinery/weight

Figure 57

ST 358 Cylinder with two flattish ends and a wide U-shaped groove around the middle. A circular tapering hole centrally placed in one flat end (25 dia, 12 d) is probably original while the groove is ?secondary. The cylinder has the appearance of a small column shaft and the diameter matches those found in the church (Hirst et al 1983, 279). It was probably used in the mill as a weight with a rope tied round the groove, but its shape makes it suitable for rolling and might suggest a piece of machinery. Inferior Oolite, either from north Cotswolds or south Lincolnshire. Fig 57. 134 1, 134 dia. (E800, per 5)

Weights

Figure 57

ST 502 Small much weathered/worn roughly triangular-section stone, possibly complete. V-section groove running around the stone, in three sections; worn as the result of the stone's use as a weight. One face also has some parallel slight V-section ?sharpening grooves, 31 1, indicating original or secondary use as sharpening stone. Micaceous New Red Sandstone, probably Carboniferous, from Forest of Dean. Cf ST 310, ST 348, ST 349, ST 511. Fig 57.88 1,60 w. (E814, per 5)

ST 310 Small block of roughly rectangular-section red sandstone, with roughly flat faces, much weathered but apparently complete. Pronounced V-section groove running around the stone cuts into the stone (cf ST 502). One end is blackened from burning. ?Counterweight. Micaceous New Red Sandstone, probably Carboniferous, from Forest of Dean: cf ST 348, ST 349, ST 502, ST 511. Fig 57. 115 1,81 w, 84 th. (A53, per 5)

ST 328 Stone, roughly pecked into a sphere with two flat ends, both of which are naturally smooth. Small deposits on the broad end appear under a low-power binocular microscope to consist of abundant small quartz grains and sand. ?Used for pounding or a weight. Fine to medium quartzite, resembling Cambrian quartzites of the south and west midlands, as found for example in the Lickey Hills. Fig 57. 114 dia, 97 h. (B106, per 7, phase 2)

Miscellaneous

Figure 58

ST 507 Roughly rectangular block, with one comer cut away. One of the broad flat faces has deep lines cut into it, three parallel roughly equally spaced grooves across the width of the face (two V-shaped section, one broader, U-shaped) and one groove (V-shaped section) at right angles along the length of the face. Grooves cut for bedding the stone or are they blade/point sharpening grooves? Stone is extensively burnt and crumbly; burning does not seem to reach right across the middle of the grooved face. XRD showed this to be a poorly crystalline hematite. Fig 58.280 1,210 w, 140 th. (E482, per 6)

ST 321 Just over half of fragment with flat base' and two convex 'sides' which narrow towards a slightly domed 'top' (mostly broken away); sides and top taper to pointed end. The smooth faces are natural and show no sign of wear, although the chip off one end might be the result of use. ?A maul, Medium grained sandstone. Fig 58. 165 1, 107 w, 21 th. (B101, per 7, phase 1)

Roofing stone

Figure 58

ST 511 Small roofing stone, nearly complete; a bored, tapering fixing hole below apex; a second hole close to edge of a long side; one surface has spalled along the bedding planes (not drawn). Chamfered edges. Micaceous New Red Sandstone, probably Carboniferous, from Forest of Dean. Fig 58. 165 1, 107 w, 21 th. (E483, per 6)

Architectural fragments

Not illustrated

ST 510 A circular or semi-circular base moulding (dia 860) with two rolls. Outer roll is ovoid in profile and may have been keeled. The inner roll is more circular in profile. A plug of lead had been inserted into the stone, presumably when it was reused. The profile may be of later thirteenth-century date (pers comm D Walsh). (B112, per 6)

ST 349 Small fragment of roll moulding. Micaceous New Bed Sandstone.75 1,49 w, 45 th. (E285, per 7, phase 2)

Disc

Figure 58

ST 515 Approximately circular disc, roughly fashioned from a pebble with one flat face and one domed face. Pebble, quartzite from Bunter Pebble beds. Cf FC 2, FC 3, FC 4, FC 33. Fig 58.79 dia, 18 th. (B628, per 4)

School slate(s)

Not illustrated

ST 332 Small fragment of a ?modern slate with a finished edge and highly polished surfaces on one of which there are four incised parallel lines. Slightly thinner than ST 334 (below). Purple slate. 35 1,37 w, 3 th. (D201, per 7, phase 2)

ST 334 Small fragment of a ?modern slate with highly polished surfaces on one of which there are two incised parallel lines. Slightly thicker than ST 332, ?perhaps from centre of slate of which ST 332 is edge fragment. Purple slate. 46 1, 33 w, 4.5 th. (E231, per 7, phase 2)

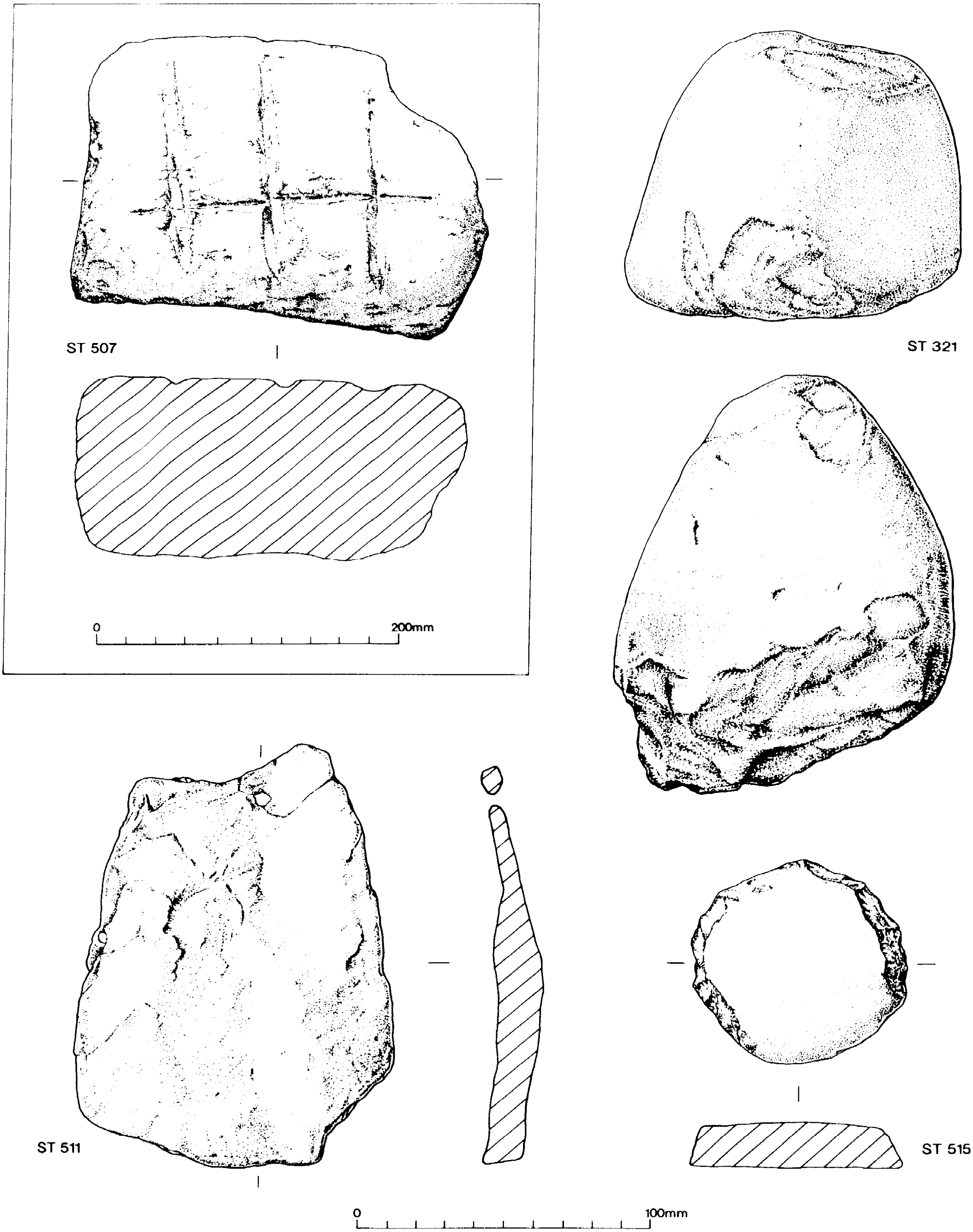


Figure 58 *stone 7: miscellaneous, roofing stone, and disc*

Flint (FL) by G G Astill

Not illustrated

Fifty-two worked flints were recovered from the mill (BAB). All were residual in their contexts (Roman to post-medieval) but, like those from other excavations in the precinct (Wright 1976b, 139-40; Watts and Rahtz 1983, 129), are regarded as evidence for prehistoric frequentation of the valley. The entire Bordesley assemblage will be discussed in a later volume.

Fuels by G G Astill

Not illustrated

Coal

Table M13

The distribution of the small amount of coal (0.805kg) recovered from the mill (BAB) is similar to that of the metalworking residues (slag) in that most of the pieces had been incorporated into hardstandings and walls, and none came from the mills' floor levels. None, however, was found in the tail race silts, nor in the silts of the period 3 bypass channel (nor indeed any period 3 context). The coal found in the period 7 silts may have derived from period 6 levels. The evidence from the ironworking residues suggests that coal was a major fuel used in metalworking. The full catalogue is in the archive.

Charcoal (classified as OB)

Table Ml4

0.514kg of charcoal pieces was recovered from the mill (BAB). The small amount of charcoal, with its limited distribution that avoids tail race silts and, in the main, contexts directly associated with the mills, might suggest that charcoal was not used to any great extent as a fuel. It should be remembered, however, that charcoal is recorded as a constituent of some period 4, 5, and 6 floors in the mills, and that charcoal is a preferred fuel for fire welding (see below, part III, Sim, 'Experience and experiment . . .'). The full catalogue is in the archive.

Baked clay (BC) by G G Astill

Not illustrated

Forty-three pieces (65Og) of baked clay, interpreted as daub, were recovered from the mill (BAB): none of the pieces had vegetable impressions. The majority of pieces (34; 56Og) came from period 4 contexts which can be associated with the renovation of the site after the destruction of the period 3 structure, and probably before the use of the period 4 mill. Although little has survived, the daub in these contexts might suggest that it was used as a building material in the period 3 structure(s). The full catalogue is in the archive.

Fired clay (FC) by G G Astill and S M Wright

Kiln furniture

Figures 59 and 60; Tables 15 and 16

Eighty-four pieces (three from BAE) of fired clay have been identified as kiln furniture. The distribution of the BAB material by form and period and by type of context is summarised in Tables 15 and 16. None of the pieces was found in a context where the material could have been used for its original purpose. As the greatest number of pieces was found in association with the hearths of roof tile, the furniture could have been brought on to the site with the roof tile. The bulk of the material occurred in contexts of periods 4 and 5; a small amount may also have come in in period 6, but it is possible that this had been retained and reused from the previous period. Of the 34 fragments from period 4, seven were found in the construction phase of the period 4 mill and 21 pieces came from the hearths: this implies that the kiln furniture was brought on to site early in period 4.

While there is no evidence in any period for a working kiln in the immediate vicinity of the mills, the material would not have travelled a great distance. The neutron activation analysis (NAA) results show that the kiln furniture clays were local, as indeed were those used to make roof tile, although the two types of clay were not identical (see below, Hughes, 'Ceramic roof tiles and fittings ... Neutron activation analysis ...'). It is likely that the kiln(s) themselves were located in the precinct.

Much of the material is of a type that has been recognised from excavated medieval kilns, all of which have been interpreted as tile kilns (Eames 1961; Drury and Pratt 1975; Smallwood 1978; Mayes and Scott 1984; Eames 1988). The elements, or voussoirs, of kiln arches appear to have had a consistent shape – either a rectangle with chamfered corners or, sometimes, semi-circular. BAB produced examples of the rectangular chamfered type and possibly the semi-circular type. The voussoirs from some kiln sites had been stabbed, and in some cases the clay bonding had survived, as with the BAB voussoirs (Smallwood 1978, 51-2; Eames 1988, 130-5; Mayes and Scott 1984, 168). The other distinctive elements from BAB were the rectangular tiles which had two or more corners cut out and this type was also found at Danbury; when the tiles were laid the spaces between may have acted as vents (Drury and Pratt 1975, 123-6, 143). The comparable kiln sites illustrate the way roof and floor tiles were used to construct the floor and sides of kilns. It is, however, impossible to gain any idea of what the 81 kiln pieces from BAB might imply in terms of intensity of activity because none of the published kiln excavation reports quantify the kiln parts and furniture recovered.

There is clear evidence that the BAB kiln fragments had been used. Patches of glaze occurred on

Table 15 Mill (BAB) and valley transect (BAE): summary of kiln furniture, by period and by form

Form	Period 4	5	6	7	Total
Voussoirs	3	3	2	2	10
'Voussoir' type	6	5	2	8	21
Square 'tiles'	–	2	-	–	2
Rectangular 'tiles'	–	3	3	1	7
Kiln floor	20	2	1	–	23
Roof tile type?	1	-	–	1	2
Miscellaneous	4	5	2	8	19
Total	34	20	10	20	84

many pieces: in some cases it had dripped from to-be-fired items in the kiln (FC 143; FC 168; FC 193); in other instances the glaze was caused by clay coming into contact with fuel ash, as occurred on the ?kiln floor tiles (FC 186). The most interesting evidence is the microscopic bright turquoise blue flecks observed on some of the 'floor tiles' and the square and rectangular structural tiles/bricks (FC 144; FC 146; FC 193; FC 194; FC 162; FC 183). This may be evidence for the application of a copper-based glaze, the constituents of which had become attached to the kiln parts (see below, Biek, The bright turquoise flecks'). The rectangular 'tiles'/'bricks' not only had patches of glaze on them but also tile-shaped discolourations where tiles had been set (on edge) for firing (FC 193), as well as the blue flecks; this is strong evidence that all the 'tiles'/'bricks' found on BAB were once used in the construction or loading of a kiln.

The manufacture of the 'tiles'/'bricks' was standard, with one sanded and one smooth surface. Technical comments are by Leo Biek. The full catalogue is on fiche; only the illustrated pieces are described individually here.

Table 16 Mill (BAB) and valley transect (BAE): summary of kiln furniture, by period and by type of context

Type of context	Period 4	5	6	7	Total
Structures†	–	1	1	-	2
Hearths	21	12	1	–	34
Dumps	7	–	5	6	18
Tail race/ditch silts	6	7	3	5	21
Flood deposits	-	-	-	9	9
Total	34	20	10	20	84

† Hardstandings or walls.

Voussoirs

Figure 59

These tiles (seven large and three small fragments) were mainly grey to grey-red right through and appear to form a distinct group comprising two types: rectangular with chamfered corners and semi-circular.

FC 143 Incomplete tile, tapering in thickness with one chamfered comer at the thinner end (the other is missing). Buff-orange margins with a pale grey core. The smooth surface has a drip of a mixed apple-green-brown glaze near the chamfered corner. An area appearing pink to orange under and along the edge of the bubbly glaze is due to iron oxides in the fired tile and suggests that the glaze did not form on it but dripped from another source which was hotter at that time. NM = cluster 17. Fig 59.200+ 1, 170+ w, 35-40 th. (E939, per 4)

FC 49 Complete tile, tapering in thickness, with two chamfered comers at thinner end, with applied (bonding) clay (2-3 th) on both sanded and smooth faces. NAA = cluster 3. Fig 59. 146 1, 158 w, 32-42 th. (E474, per 5)

FC 141 Comer (slightly rounded) fragment with chamfer, similar to FC 49; probably tapered. Drip of clear glaze on the only surviving edge and applied clay layer on smooth surface. Fig 59. 103+ 1,65+ w, 32 th. (B113, per 7, phase 1)

FC 174 Incomplete, ?semi-circular tile; traces of applied clay on both surfaces. Fig 59. 145+ 1, 100+ w, 45-50 th. (E814, per 5)

'Voussoir' type

Figure 59

These are often too fragmented to be classified as voussoirs, but they are sufficiently similar in fabric and appearance to FC 143 and others of the above group to regard them as possible voussoirs.

FC 189 Very thick ?voussoir. Apparently tapering but at one point there is a sudden reduction in thickness (occurring on both faces). No edges or applied clay are present. Mottled orange-buff-grey colour. Fig 59. 110+ 1, 80+ w, 42-62 th. (A156, per 4)

Square structural 'tiles'

Figure 59

These tiles have bevelled edges and are red to grey and of a similar fabric to the voussoirs.

FC 145 Near complete tile. A patch of pan-like staining on the tile may be due to pedo-factors (cf FC 161 and FC 146). Fig 59. 115 1, 115 w, 38 th. (E755, per 5)

Rectangular structural 'tiles'/'Pbricks'

Figure 59

There are two types, the first with cut-out cor-

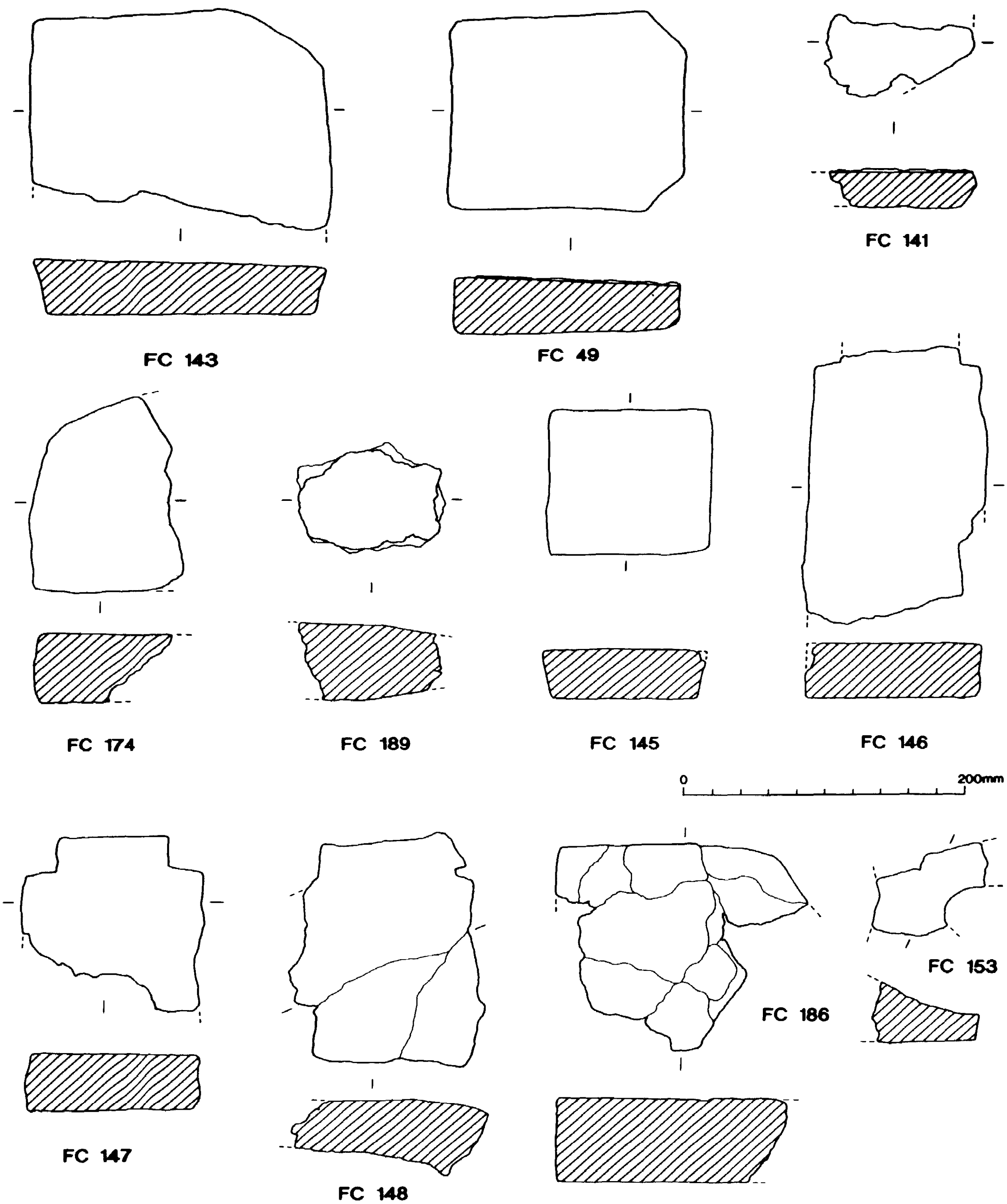


Figure 59 Fired clay 1: kiln furniture

ners. Two of the three tiles below are buff to orange, the third (FC 148) is an overtired tile and is dark grey. A knife has been used to cut out the corners leaving a roughly square space; when laid side by side and end to end these spaces may have served as vents.

FC 146 Fragment, one end with cut-out corners. There is a pederived 'manganese oxide' deposit over some of the tile. Turquoise flecks were also seen. NAA = cluster 3. Fig 59. 223+ 1, 120+ w, 40 th. (E755, per 5)

FC 147 Half of tile with cut-out comers; traces of applied clay (for bonding and of a lighter colour) on the edges of the tile. NAA = cluster 14. Fig 59. 132+ 1, 120+ w, 42 th. (E755, per 5)

FC 148 Incomplete, distorted and overfired tile (in three pieces) with four cut-out comers, one of which has some extra clay adhering to it (of the same type) which appears to be a mistake and may have occurred during firing. NAA = cluster 3. Fig 59. 160+ 1, 116+ w, 40-53 th. (E755, per 5)

The second type (three examples; not illustrated) is without cut-out corners but with indications that the 'tiles'/'bricks' supported tiles during firing.

?Kiln floor

Figure 59

FC 186 Thick tile fragment (in nine pieces) ?part of the kiln floor. One edge has a chamfered corner. Buff-brown with traces of a calcareous layer, possibly a limewash caused by contact with ash. Fig 59. 180+ 1, 160+ w, 70 th. (E474, per 5).

Roof tile type?, probably used in a kiln

Figure 59

FC 153 Fragment (in two pieces), tapering in thickness, with three edges, one of which formed part of a hole. Buff-brown. Roof tile fabric 1. Fig 59. 75+ 1, 72+ w, 14-19 th. (E368, per 7, phase 1)

Miscellaneous rectangular or square 'tile'/'brick' or fragments of general floor tile type, probably used in a kiln

Figure 60

These tiles could be classified as floor tiles or of floor tile type but differ in terms of both size and form from most recovered from BAB. Most are buff on the exterior and have a red-orange core.

FC 157 Large fragment (in two pieces) with one complete edge. The sanded surface is 'manganese oxide' stained and shows turquoise-blue flecks, and the core of the tile is black, red, and ash coloured. Fig 60. 253+ 1, 165+ w, 40 th. (E755. per 5)

FC 162 Large fragment with two comers; buff margins with a red-orange core. Both surfaces have manganese oxide deposits and occasional white patches which are presumably due to water-deposited calcium salts. Turquoise-blue flecks are also present. Fig 60. 300 1, 130+ w, 40 th. (E755, per 5)

The bright turquoise flecks by L Biek

One fragment of kiln furniture (FC 144) was subjected to X-ray diffraction analysis. It was thought that the blue substance might be Egyptian Blue, formed during the firing inside the kiln in its original position. The hypothetical mode of formation involved copper filings or powdered compounds being blown on to a surface containing calcareous material.

The white material on which it was found was shown to be calcite, but apart from quartz and feldspar no other crystalline phases could be detected in either white or blue material. As the quantity was inevitably small, the latter could have failed to reach detection level; alternatively it might be amorphous. In view of the circumstances under which it occurs, this record of it was thought important enough to warrant publication although the direct relevance to site activities must be tenuous.

?Oven material

Figure 60

Seven rectangular fragments of 'tiles'/'bricks' with holes are interpreted as oven material (five fragments from BAE and two from BAB, all with hole(s), plus three similar fragments from BAB but without holes). These, however, may be parts of kilns; thick tiles with cylindrical holes have been recovered from Chilvers Coton, but the holes are smaller (Mayes and Scott 1984, 62, 170 fig 118). (Cf Rahtz and Hirst 1976, 172; Hirst *et al* 1983, 137-8.) The full catalogue is on fiche; only the illustrated pieces are described individually here.

FC 72 Oven brick fragment; orange throughout with three original edges including two comers with four square holes in top surface (20-5 d; sides of square at top 15-16). Fig 60. 135+ 1, 190 w, 53 th. (BAE95, per 5-6)

FC 73 Oven brick fragment; orange throughout with three original edges including two corners and a complete, knife-trimmed, width; four circular holes in top surface (40-5 d; 17-19 dia at top). Fig 60. 150+ 1, 195 w, 54 th. (BAE95, per 5-6)

FC 75 Oven brick fragment; orange margins with grey core and a comer with one hole (31 d, 19 dia at top) and a groove running parallel to one side, both in the top surface. Fig 60. 130+ 1, 120+ w, 55 th. (BAE87, per 5-6)

Discs

Figure 60

All roughly circular, fashioned from roof tile. None is large enough to be a lid for the pottery found on site. Cf ST 515.

FC 2 Roof tile fabric 4. One original edge of the tile survives. 75

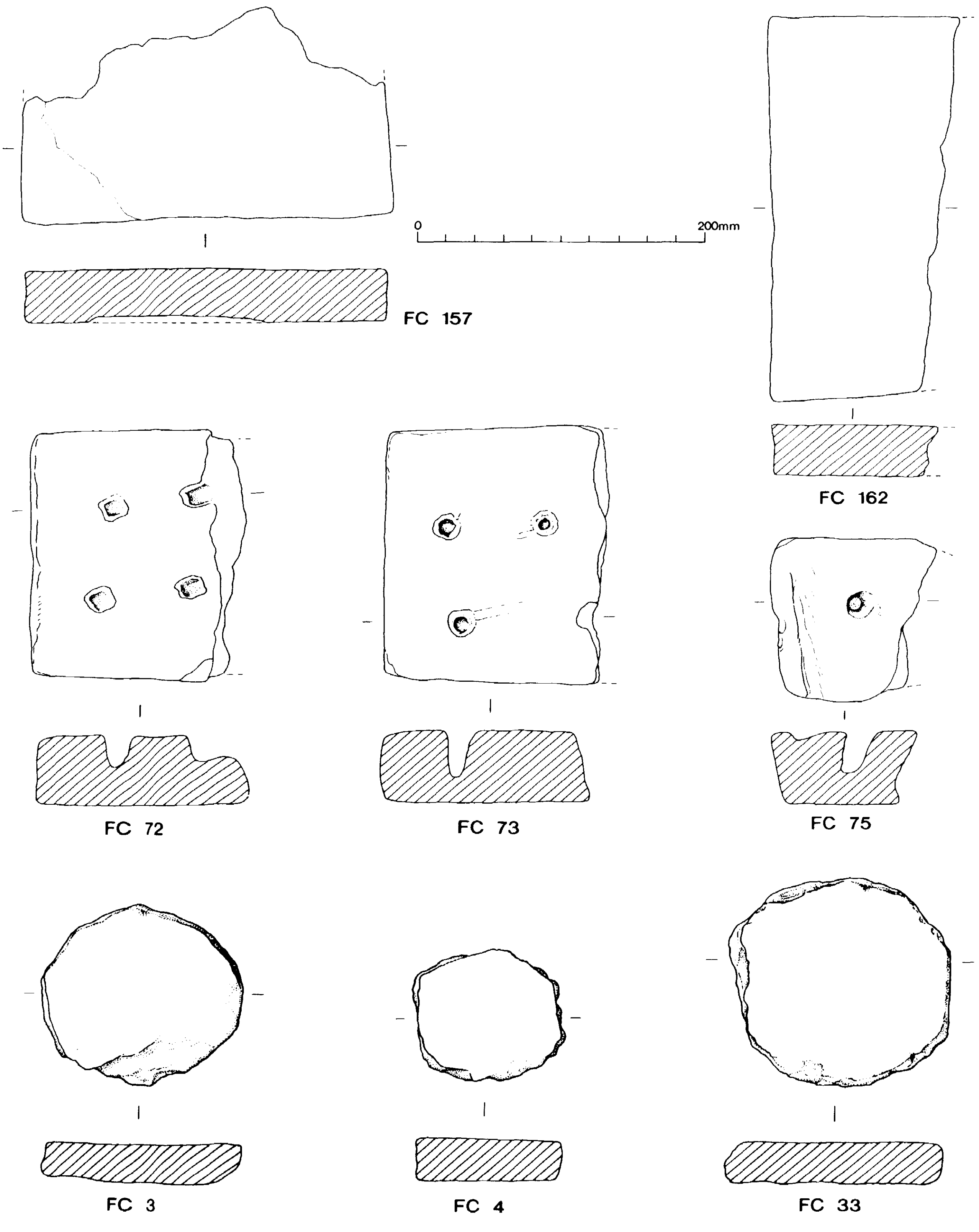


Figure 60 *Fired* clay *2: probable kiln furniture, ?oven material, and ceramic discs*

dia, 13 th. (BAB 68 U/S)

FC 3 Roof tile fabric 1. Fig 60. 65 dia, 15 th. (BAB 70 F8, per 6)

FC 4 Roof tile fabric 2. Fig 60. 48 dia, 15 th. (BAB 70 F8, per 6)

FC 33 Roof tile fabric 4. One original edge of the tile survives. Fig 60. 87 dia, 16 th. (E261, per 7, phase 2)

Clay tobacco pipes (CP) by P Cannon

Not illustrated

Forty-two clay pipe fragments were recovered from BAB (38) and BAE (4). The fragments have a wide date range from *c* 1630 to *c* 1900. Most are stem or bowl fragments with no real distinguishing features but there are a number of makers' marks and some distinctive regional types. The majority of the pipe fragments came from the period 7 post-abandonment silts and dumps, the most (23) from the last fills of the head race-and tail race. Judging from the date range of the pipes from the head race (D207), between 1670/80 and 1840, the leat took some time to be completely filled. Most of the material must come from occasional dumping, and from those involved in agricultural work (hedging and ditching) and in casual frequentation of the meadows. The full catalogue is on fiche.

Ceramic roof tiles and fittings

by G G Astill and S M Wright

An illustrated type series of clay roof tile forms, largely based on excavated material from the south transept of the church and the boundary bank, was published in Rahtz and Hirst (1976, 175-80). Tile fragments are extremely plentiful in all but the earliest periods at Bordesley (see Hirst *et al* 1983, 38-9). However, prior to the beginning of the mill (BAB) excavation, ceramic roof tile and furniture had not been comprehensively and systematically quantified and classified by fabric and form. As with the pottery and animal bone, roof tile was recovered by context within 2m squares to allow some spatial control. Detailed recording of tile from BAB was carried out from 1981 onwards; a stratified assemblage of 2235 fragments, weighing 290.877kg, from periods 4 to 7 inclusive, was obtained. As a consequence of this analysis of the BAB data the recording sheets have been modified. The roof tile recovered from the valley transect (BAE) (periods 4 to 7: 4533 fragments, 403.836 kg) was very fragmentary in comparison with that from BAB, and this sample is considered briefly.

Fabric and form type series

The clay roof tile was divided visually into fabrics; nine fabrics were identified. All fragments were classified by fabric, counted, and weighed. Fragments with a recognisable form were classified according to whether the fragment had a peg hole(s), or a nib, or peg hole(s) and nib, or was from a ridge tile, a crest or possibly finial, or from a hip or valley tile (that is a curved tapering tile: see Streeten 1985, 95-7 for a discussion of tile forms and their manufacture). No certain ceramic finials or other roof furniture were identified. Those fragments possessing other features (eg a complete measurement, the presence of glaze or animal prints) were also recorded individually, including details of any nibs and peg holes (type, size, and distances between nibs and holes).

The following descriptions are based on the guidelines in Peacock 1977. However, fabrics 1 and 4 appeared to have highly fired versions which were given different fabric numbers (2 and 5 respectively) because the unusual hardness may have been an important and intentionally produced characteristic.

Fabric 1

Soft to fairly hard with smooth fracture, surfaces range from dark red to grey, but orange is by far the most common colour; sometimes the core is grey. Common to abundant, well sorted, sub-rounded and rounded quartz up to 1mm. Sparse red-brown inclusions 0.5-1mm.

Fabric 2

Very hard with hackly fracture, dark grey to purple throughout. Inclusions as fabric 1. Apparently a highly or overfired version of fabric 1.

Fabric 3

Hard with smooth fracture, orange surfaces, often with grey core. Sparse to moderate, well sorted, sub-rounded to rounded quartz to 0.5mm. Sparse, hard, angular white inclusions to 0.5mm.

Fabric 4

Soft with fairly smooth fracture, orange throughout. Abundant, well sorted, sub-rounded quartz, 0.5-1mm; common, soft, dark orange to brown sub-rounded clay pellets up to 2.5mm. Sparse, hard, dull brown inclusions 0.5-1mm.

Fabric 5

Very hard with hackly fracture, dark grey to purple throughout. Inclusions as fabric 4. Apparently a highly or overfired version of fabric 4.

Fabric 6

Soft with smooth fracture, orange surfaces, often with grey core. Abundant, well sorted and sub-rounded quartz 0.5-1mm. Moderate, ill sorted and angular quartz 2-3mm; moderate, soft, dark orange to brown sub-rounded clay pellets 1-2mm.

Fabric 7

Soft with hackly fracture, orange throughout, but often with lighter and smoother orange surfaces (sometimes giving the impression of a slip). Sparse to moderate, well sorted and sub-rounded quartz 0.1-0.5mm. Sparse dull red to brown sub-rounded inclusions 0.5-1mm.

Fabric 8

Soft to fairly hard with smooth fracture and dark orange surfaces and grey to brown core. Moderate, well sorted, sub-rounded quartz 0.5-1mm. Dark brown to black streaks in core, but most often just below the surface.

Fabric 9

Hard with smooth fracture with dark orange to brown surfaces and grey core. Moderate, well sorted, angular quartz 1-2mm with dark grey smudges which appear to be vegetable tempering.

Samples of the nine fabrics were thin-sectioned and petrologically examined (see below, Freestone).

Table 17 Mill (BAB): ceramic roof tiles and fittings: fabrics 1 to 9 for periods 4, 5, 6, and 7, by number of fragments

Period	Fabric 1	2	3	4	5	6	7	8	9	Total
4	270	49	63	112	20	16	13	9	11	563
5	259	39	31	252	7	2	21	15	6	632
6	129	61	68	146	6	6	29	14	7	466
7	211	37	14	237	10	9	39	8	9	574
Total	869	186	176	747	43	33	102	46	33	2235

While there was no well-defined fabric which cross-cut the nine fabric groups, no great variation in inclusion grain size, shape, or composition distinguished any of these nine fabrics. The differences appear to be due to variation in firing conditions and to the overall abundance of the inclusions. However, the characteristics common to the groups were sufficient to suggest the fabrics came from similar clay sources.

The neutron activation analysis of the nine fabrics (see below, Hughes) has demonstrated that all came from local clay sources and that the nine could be arranged into three chemical composition groups: (1) fabrics 1 and 4; (2) fabrics 2, 3, and 4; and (3) fabrics 5, 6, 7, 8, and 9. After considering each of the nine fabrics in turn (see below), in order to make larger samples, the chemical composition groups were used as a basis for grouping the nine fabrics. Because fabric 4 was represented in two of the chemical groups, this fabric was treated on its own; thus the groupings used were as follows: fabric 1; fabric 4; fabrics 2 and 3; fabrics 5, 6, 7, 8, and 9 (see below).

That two samples of one visually identified fabric should be placed in two of the chemical composition groups emphasises the limitations of visual classification. This is particularly true of two of the roof tile fabrics, 4 and 5. Fabric 4 could only be identified with certainty if the clay pellets were darker than, and offered a contrast to, the clay matrix. Similarly, fabric 5 could often only be distinguished from fabric 2 if the tile fractures contained clay pellets.

The mill (BAB) assemblage

Figure 61; Tables 17-19

The chronological framework and sequence is discussed in detail in the stratigraphic sequence and is summarised in relation to the pottery. A very small quantity of ceramic tile, mostly 'unfeatured', was recovered from periods 1 to 3 (1: 10 frags, 0.883kg; 2: 27 frags, 2.015kg; 3: 68 frags, 6.977kg). It is possible that some of this 'unfeatured' material (which occurs in the range of fabrics, with the exception of fabrics 6 and 9) may be Roman, although none has been positively identified as such. However, a fragment of R box flue tile was recovered from the 1965-6 excavations to the south-west of the church (Wright 1976b, 172). Tile from period 1 (the pre-monastic valley) contexts must be intrusive or Roman. The material from period 2 (mid-twelfth century: monastic ground clearance etc) and period 3 (later twelfth century: first watermill) comes (with a single exception) from contexts where there was a probability of contamination from later features: tail race silts and dumps, or features which had later tile hearths immediately above, or from posthole fills that were subsequently dug into to rob the posts, or from contexts whose surfaces were exposed for a considerable time, into periods 4 and 5.

It was felt that there was no unequivocal occurrence of ceramic tile earlier than period 4 and so this small quantity from periods 1 to 3 has been omitted from the analysis.

The stratified assemblage from periods 4 to 7

Table 18 Mill (BAB): ceramic roof tiles and fittings: fabrics 1 to 9 for periods 4, 5, 6, and 7, by weight(g) of fragments

Period	Fabric 1	2	3	4	5	6	7	8	9	Total
4	33435	5142	9571	13448	1823	2358	2241	1320	1297	70635
5	26749	5207	5110	39523	920	1218	2029	1274	1255	83285
6	26612	10819	5860	19341	645	794	4521	2505	1202	72299
7	22426	8312	1696	23222	978	752	5342	684	1246	64658
Total	109222	29480	22237	95534	4366	5122	14133	5783	5000	290877

Table 19 Mill (BAB): ceramic roof tiles and fittings: fabric groups for periods 4, 5, 6, and 7, by number and by weight (g) of fragments

Period	Fabric by no.					Fabric by wt (g)				
	1	4	2 and 3	5 to 9	Total	1	4	2 and 3	5 to 9	Total
4	270	112	112	69	563	33435	13448	14713	9039	70635
5	259	252	70	51	632	26749	39523	10317	6696	83285
6	129	146	129	62	466	26612	19341	16679	9667	72299
7	211	237	51	75	574	22426	23222	10008	9002	64658
Total	869	747	362	257	2235	109222	95534	51717	34404	290877

inclusive comprises 2235 fragments, weighing 290.877kg, and the total sample size for each of the periods is broadly comparable. However, a large proportion of the fragments are 'featureless', as indicated by the figures for tile classified as 'featured' (period 4: 79 frags, 15.173kg; 5: 79 frags, 14.157kg; 6: 147 frags, 39.438kg; 7: 141 frags, 24.132kg; total 446 frags, 92.900kg). There is thus roughly twice as much featured tile in periods 6 and 7 as in periods 4 and 5, and this difference is reflected in the statistics for particular characteristics and must be taken into account. There are very few complete or near-complete tiles. Tile fragments classified as peg tile with a peg hole or as nibbed tile may in fact have been part of peg and nib tiles. Identification of tile as ridge or hip/valley was problematic. Furthermore, the sample size is greatly reduced when one considers characteristics such as nib and peg type or measurements such as width (comparable problems are discussed by Streeten as part of his analyses of tile from Bayham and Battle Abbeys: Streeten 1983 and 1985).

Two factors make the BAB tile assemblage different from those usually recovered from monastic, or indeed other medieval, sites. Firstly, the timescale involved at BAB is relatively short: periods 4, 5, and 6 cover the late twelfth to ?late fourteenth/early fifteenth centuries, period 7 the abandonment of the mill in the late fourteenth/early fifteenth century and some very limited post-medieval activity. Secondly, it is also significant that, once the period 4 building had been constructed, the structure of the mill building remained virtually unaltered during the subsequent periods; there was thus no major constructional occasion during which the roof would have had to have been changed or replaced. The stratigraphic sequence does, however, show modifications to the mill building. In period 6 the foundations of the wall of the west lean-to were rebuilt which could have involved the dismantling of the lean-to structure and its roof, although it is possible, as has been suggested elsewhere, that such remedial work could be done in stages without disturbing the superstructure (Wrathmell 1989, 254-5).

Periods 5 and 6 may also have provided occasions for the introduction of large quantities of roof tile on to the site, for a workshop was built in each period. These were excavated (in the late 1960s) before the mill excavation and unfortunately the roof tile was not systematically collected.

The implication from the stratigraphic sequence is that much of the tile from BAB, from periods 4, 5, 6, and 7, may have been brought on to site during the construction of the period 4 building. Some support for this comes from the analysis of the tile, which shows that the complete range of fabrics and forms was present in period 4 (below). Subsequently, some repairs would inevitably have been necessary and new 'stock' may have been introduced to meet the demands both of repair work and of the construction of the tile hearths (see below). On the other hand, old tile may have been extensively reused.

The BAB assemblage is also an unusual one in that some of the material was not simply waste or demolition debris from buildings. A significant proportion was (either in its primary or secondary use) from the hearths (hearth contexts: period 4: 46 frags or 8%, 13.733kg or 19% wt; 5: 48 frags 8%, 5.940kg 7% wt; 6: 127 frags 27%, 35.647kg 49% wt), and, because the tiles used in the hearths were more complete, the vast majority of these fragments are 'featured'. The proportion of 'featured' tile derived from hearths is most marked in period 6 ('featured' from hearth contexts: 109 frags, 30.173kg, or 74%, 77% wt of 'featured'). The character of this hearth material does not, however, appear to differ significantly from the rest of the assemblage (see below); whether this represents new tile brought on to site or the reuse of old tile is impossible to say.

Analysis and discussion

The total sample size for each period (that is periods 4 to 7) is broadly comparable. All of the nine fabrics identified visually occur in all of the periods (Fig 61; Tables 17 and 18). Throughout, the clearly dominant fabrics are 1 and 4, with 2 and 3 occurring slightly more frequently than 5, 6, 7, 8, or 9. The fabric groups (1; 4; 2/3; 5-9) show a similar pattern (Fig 61; Table 19). The relative proportions of the individual fabrics and of the fabric groups may indicate some variation between periods but are not generally suggestive of any consistent

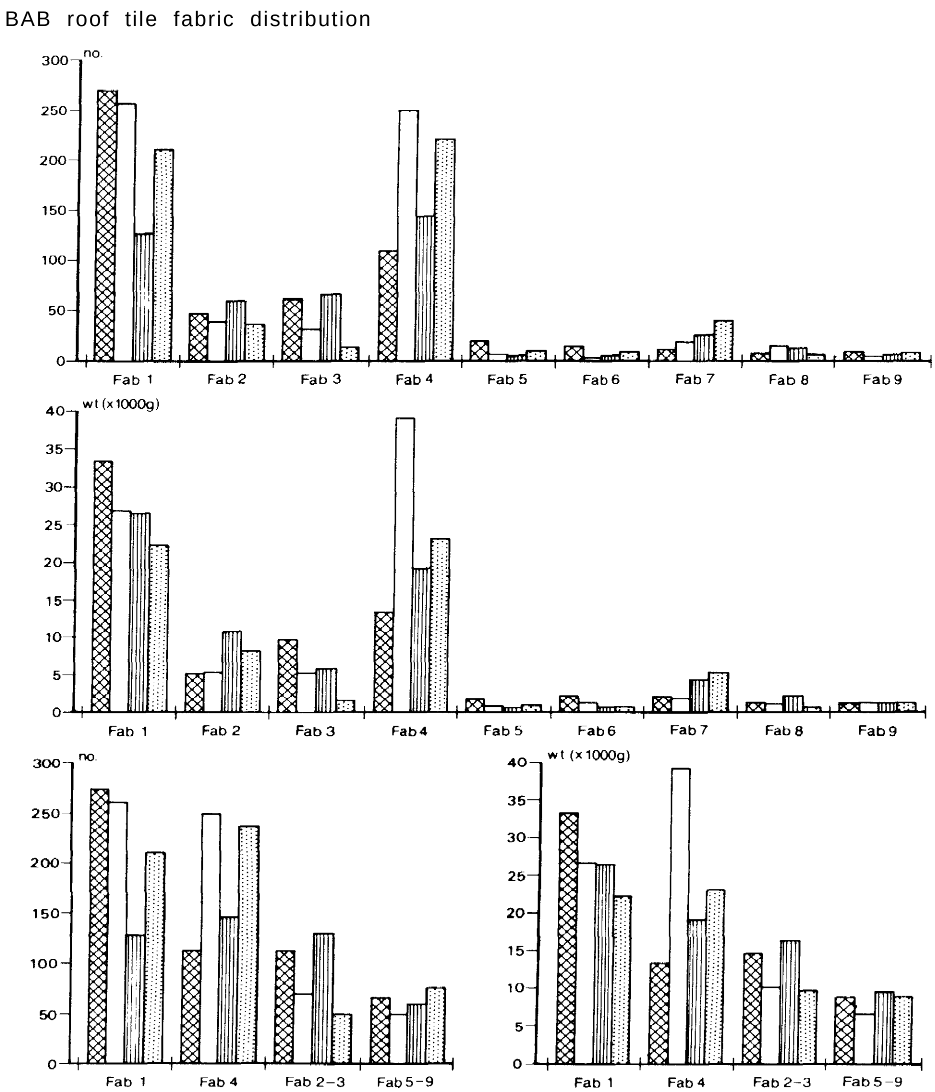


Figure 61 Mill (BAB): ceramic roof tiles and fittings: fabrics and fabric groups by period, by number of fragments and by weight (g)

broad trends (although a minor fabric, 7, appears to increase over time). Interpretation of statistics for the fabric groups is complicated by fabric 4, which has to be considered separately from 1 and 2/3, although its addition either to 1 or to 2/3 would have a very considerable effect.

Harder-fired fabrics (2 and 5) are a relatively small proportion of the total for all periods, but possibly a growing proportion from period 6 (period 4: 69 frags or 12%, 6.965kg or 10% wt; 5: 46 frags 7%, 6.127kg 7% wt; 6: 67 frags 14%, 11.464kg 16% wt; 7: 47 frags 8%, 9.290kg 14% wt).

Although very broadly similar, the relative proportions of the fabrics and fabric groups do differ between the total BAB assemblage and the smaller (20% by no., 32% wt) sample of featured tile, both overall (eg fabric group 5-9 12% of the total but 17% by no., 15% wt, of featured tile) and, more markedly, within periods. Thus conclusions regarding fabric based on a sample of only featured tile could and would differ significantly from those based on the total assemblage.

The fabrics in the hearth material show a broadly similar pattern to that of the overall assemblage.

The complete range both of fabrics (l-9) and of forms (nib, peg, peg and nib, hip/valley, ridge, crest/?finial) is already present in period 4 (date range late twelfth to early fourteenth centuries).

Nibbed tiles and peg hole tiles occur in all nine fabrics, peg and nib tiles in fabrics 1, 2, 3, 4, 7, and 9. Thus nib, peg, and peg and nib tiles occur in all of the four fabric groups and in all of the periods. Although the sample is large, because of the fragmentary nature of the tile and the consequent problems of classification, it is difficult to identify any patterns or chronological development. Tile fragments with a peg hole are commoner overall (52% by no., 47% wt) than those with a nib (29% by no., 24% wt) or a peg hole and nib (7% by no., 15% wt), although the proportion of nib/nib and peg fragments would seem to be increasing.

The thickness of nib, peg, and peg and nib tiles ranges between 10.0 and 30.0mm, with an overall average of 14.7mm and a slight suggestion that these tiles may be getting thinner over time (average (total no. 426): period 4: 15.1; 5: 14.5; 6: 15.0; 7: 14.3). There was no obvious correlation between fabric group and a particular tile thickness. The few complete breadth and length measurements give a range of 101 to 185mm wide and 186 to 230mm long, but incomplete tiles measure as much as 215+mm wide and 278+mm long. (The single near-complete tile measured 101mm wide by 207mm long.)

Peg and nibbed types generally have one sanded and one smooth surface, and nibs are usually formed on the smoother side of the tile; thus the sanded surface of these tiles would be exposed when in position on a roof.

Nibs occur in a variety of shapes and sizes and are classified according to a detailed typology (in archive). Both hand-made and knife-trimmed nibs are present in period 4. Entirely hand-made and finger-smoothed nibs overall outnumber knife-trimmed products (the extent of knife-trimming varies) (by no.: period 4: knife 8, hand 12; 5: 18, 14; 6: 17, 49 (of which hearths = 6, 32); 7: 25, 34; total periods 4-7: 68,109). There are examples of hand-made nibs in all the fabrics except 5 (and only one example in fabric 6) and examples of knife-trimmed nibs in all the fabrics except 5 and 6. (Fabrics 5-9 are quantitatively the minor fabrics.) The commonest nib types were type 3 (no. = 44), hand-made and pulled up from the edge of the tile, with a finger streak at the base of the nib, and type 9 (no. = 44), knife-trimmed, faceted nib type (similar to that illustrated in Rahtz and Hirst 1976, 175 fig 34, roof tile type 3C). Type 3 nibs occurred in all the fabrics except 5 and type 9 nibs in all the fabrics except 5 and 6.

Both hand-made and knife-trimmed nib types occur as small (<50mm) and large (≥50-99mm) nibs throughout. However, the majority of nibs are small (total no.: small 144, large 38; period 6 hearths only: small 32, large 5), regardless of nib-trim type (with one exception where there are equal numbers of small and large nibs, viz. nib type 2, but a total sample of only eight). Small nibs occur in all fabrics except 5, and large nibs in all fabrics except 5, 6, and 9.

On very few tiles is the position of the nib certain. On peg and nib tiles the nib may be central with a peg hole to one side or with two peg holes, one to either side. Holes and nibs are placed close together. On nib only tiles, the nib may be central or positioned to the right (viewed from beneath); there are no examples of tiles with two nibs. Thus the five nibbed tiles with complete breadths from period 6 hearths comprise a nib tile (120mm wide) with the nib on the right-hand side (viewed from beneath), three peg and nib tiles (132 to 179mm wide) with a central nib where the distance between nib and peg hole ranges from 25 to 40mm, and a peg and nib tile (165mm wide) with a central nib and a peg hole to both left and right of the nib (nib to hole distance 23 and 25mm, overall distance between holes 85 mm). The peg holes on these few near-complete examples of (central) nib and peg tiles (no. = 4) include small round, small square, large square, straight, and tapering hole types.

Peg tiles with two peg holes occur in all four periods. The distance between the holes varies between 20mm (periods 6 and 7) and 130mm (period 4), the average is 74mm (no. in sample 9). Holes are round, or less commonly square (by no.: period 4: 41 round, 7 square; 5: 39, 10; 6: 63, 23 (of which hearths = 32, 18); 7: 55, 21). Large round holes (≥10mm) are commoner than small round holes overall, but whereas large round holes clearly predominate in periods 4-5 the position is reversed in periods 6-7 (by no.: period 4: small round 13, large round 31; 5: 6, 40; 6: 35, 41 (of which hearths = 17, 25); 7: 36, 24). In the case of square peg holes, small holes (<10mm) predominate over large (≥10mm) throughout (by no.: period 4: 3 small square, 1 large square; 5: 3, 0; 6: 9, 1 (of which hearths = 6, 1); 7: 13, 3).

Peg holes (round and square, small and large) are sometimes tapering (by no.: small round: 54 straight, 25 tapering; large round: 108, 11; small square: 11, 28; large square, 17, 5) (by no.: period 4: 36 straight, 12 tapering; 5: 41, 8; 6: 62, 24 (of which hearths = 39, 11); 7: 51, 25). There is no obvious correlation between hole types and fabrics.

There is a small quantity of both (1) ridge tile and crests or possibly finials (3% by no., 5% wt) and (2) possible hip or valley tile (that is curved tapering tiles) (9% by no. and wt). These are in the same broad fabric groups as the flat roof tile (ridge and crest/finial: fabrics 1, 2, 3, 5, 7, fabric groups 1, 2/3, 5-9, but not group 4; hip/valley: fabrics 1-9 except 5, fabric groups 1, 4, 2/3, 5-9). Both categories occur in all four periods. The sample size is small and the material fragmentary. However, glaze would seem to occur on proportionally more fragments in these two categories (by no. 5 and 3) than on flat roof tile fragments (by no. 6); the glaze colour varies, from dark yellowish green to light and dark yellowish brown on the ridge and crest/finial pieces, and from dark green to dark greenish brown on the possible hip/valley fragments.

The spatial distribution of the tile is generally similar to that of the pottery and the metal finds,

Table 20 Valley transect (BAE): ceramic roof tiles and fittings: fabrics 1 to 9 for periods 4, 5, 5-6, and 7, by number of fragments

Period	Fabric 1	2	3	4	5	6	7	8	9	Total
4	255	19	93	62	2	14	13	3	0	461
5	1007	87	62	443	7	11	43	126	2	1788
5 to 6	699	80	51	445	15	5	41	112	1	1449
7	294	45	297	141	3	11	12	32	0	835
Total	2255	231	503	1091	27	41	109	273	3	4533

with the exception of the concentrations within the buildings which reflect the location of the hearths. In periods 4, 5, and 6 there is a low scatter within (excluding the hearths) and around the building with a greater number of pieces in the tail races. In period 7 a larger proportion of the tile is distributed in an area to the north-west of the building, and over the tail of the north mill pond bank: the changed emphasis in distribution is also true of the metalwork and is assumed to reflect the process of demolition; unlike the metalwork, however, some tile continued in period 7 to be dumped in the tail race.

The valley transect (BAE) assemblage

Figure 62; Tables 20-2

The stratified assemblage from periods 4, 5, 5-6, and 7 inclusive comprises 4533 fragments, weighing 403.836kg (period 1 included two - intrusive or possibly Roman - fragments). The total sample size for each period varies considerably. All of the nine fabrics identified visually occur in all of the periods, with the exception of fabric 9 which is rare from BAE (absent from periods 4 and 7, total no. frags 3) (Fig 62; Tables 20 and 21). The clearly dominant fabric is 1, followed by fabric 4, with fabrics 2, 3, and 8 occurring slightly more frequently than 5, 6, and 7. The fabric groups (1; 4; 2/3; 5-9) show a similar pattern (Fig 62; Table 22), although the addition of fabric 4 to either 1 or 2/3 would have a considerable effect. As with BAB, the relative proportions of the individual fabrics and of the fabric groups may indicate some variation between periods but are not suggestive of any consistent broad trends. Harder-fired fabrics (2 and 5) are a small proportion of the total for all periods, and somewhat smaller even than for BAB (period 4: 21 frags or 5%, 1.426kg or 2% wt; 5: 94 frags or 5%, 10.650kg or 9% wt; 5-6: 95 frags or 7%, 17.291kg or 10% wt; 7: 48 frags or 6%, 3.398kg or 10% wt). To sum up, in terms of fabric, the BAE sample presents a very similar pattern overall to that from BAB.

Although the total sample size is large, the material was markedly more fragmentary than that from BAB. So very few featured tile fragments were recorded that no analysis has been made of forms and other characteristics. While the RAE roof tile has a similar overall pattern to BAB, the circumstances of its deposition appear to have been different. Unlike BAB, there is no evidence that the tile from BAE was primarily derived from structures. Most of the tile in the prolific period 5 occurred in contexts interpreted as dumps and used to raise the south mill pond bank and causeway (contexts 91 and 95). The tiles were incorporated into the clay dumps, but were mostly used as a capping, probably to limit water erosion of the bank sides. The tiles were, therefore, apparently brought on to site as hard core; that they might have derived from a kiln site was suggested by the high number of fragments that were distorted. It is also noticeable that the contexts which contained a high number of tiles in period 5-6 were deposits that had been eroded from the south mill pond bank and were, therefore, ultimately from the same contexts as those from period 5 (contexts 88 and 92).

Table 21 Valley transect (BAE): ceramic roof tiles and fittings: fabrics 1 to 9 for periods 4, 5, 5-6, and 7, by weight (g) of fragments

Period	Fabric 1	2	3	4	5	6	7	8	9	Total
4	47033	1122	7020	7036	304	2946	2192	250	0	67903
5 to 6	65524	10075	4050	27474	575	1540	6635	7505	70	123448
5 to 6	98207	14516	4777	43622	2775	795	7157	5443	120	177412
7	10493	3183	13269	6160	215	222	965	566	0	35073
Total	221257	28896	29116	84292	3869	5503	16949	13764	190	403836

Table 22 Valley transect (BAE): ceramic roof tiles and fittings: fabric groups for periods 4, 5, 5-6, and 7, by number and by weight (g) of fragments

Period	Fabric by no.					Fabric by wt (g)				
	1	4	2 and 3	5 to 9	Total	1	4	2 and 3	5 to 9	Total
4	255	62	112	32	461	47033	7036	8142	5692	67903
5	1007	443	149	189	1788	65524	27474	14125	16325	123448
5 to 6	699	445	131	174	1449	98207	43622	19293	16290	177412
7	294	141	342	58	835	10493	6160	16452	1968	35073
Total	2255	1091	734	453	4533	221257	84292	58012	40275	403836

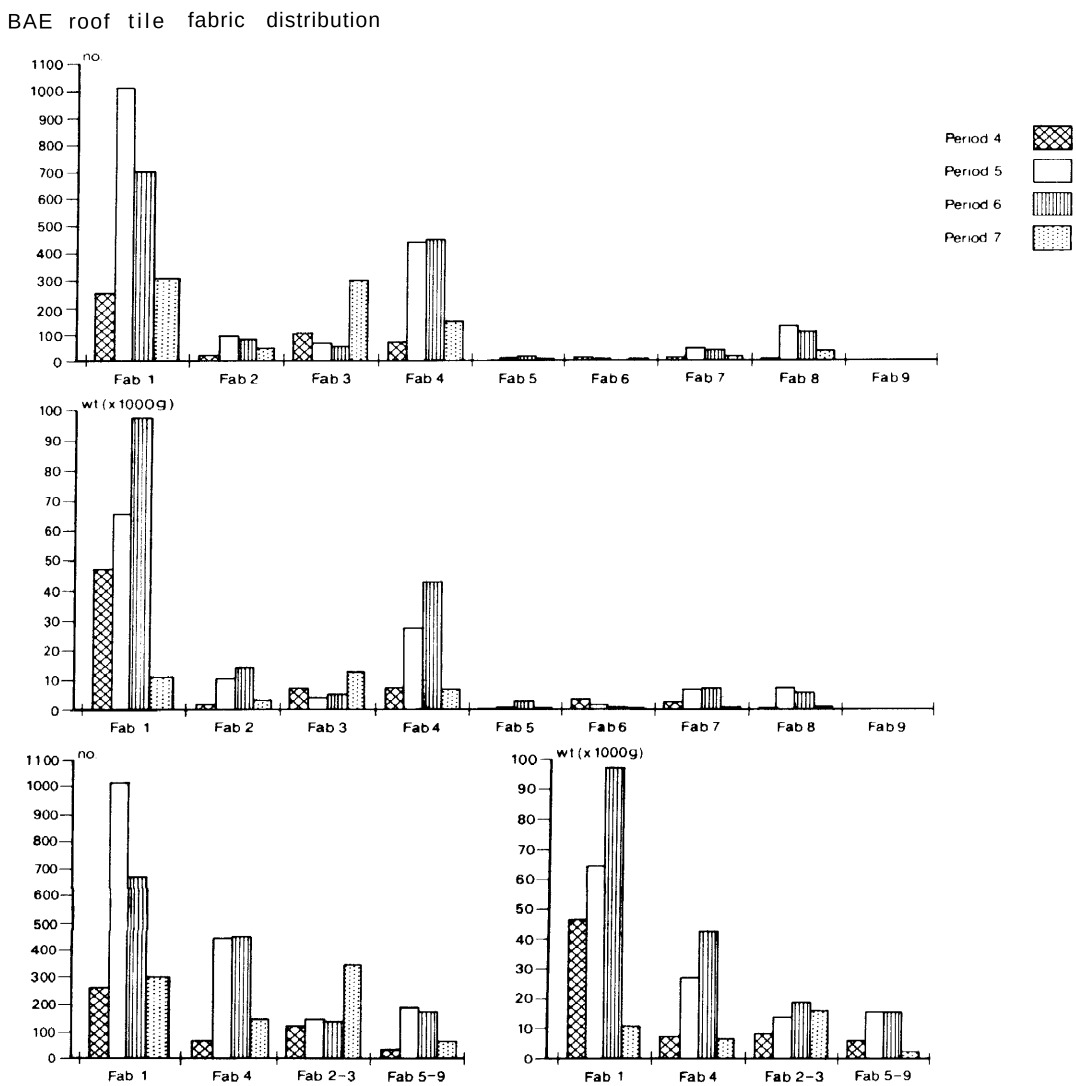


Figure 62 Valley transect (BAE): ceramic roof tiles and fittings: fabrics and fabric groups by period, by number of fragments and by weight (g)

Conclusion

Tiles with nibs and/or peg holes are thirteenth-century types, as are ridge tiles and crests/finials, and probably hip or valley tiles. The variation is considerable and differences in size and manufacturing traits have been analysed in order to try to establish predominant characteristics and chronological change. This is severely limited by the scarcity of complete or near-complete tiles and even complete widths or lengths. There are dominant types, as regards both fabrics and forms and in terms of specific characteristics or manufacturing techniques (for example, hand-making of nibs). But chronological development is difficult to identify, except for the suggestion that tiles may be getting thinner and peg holes smaller. The mill timescale may be too short to see much change and old tiles may have been extensively reused. This thirteenth- and fourteenth-century sample should, however, prove extremely useful in comparison with recent data from the church excavation which cover a broader date range.

Ceramic roof tile appears to have been first used on site early on in period 4 (that is from the late twelfth century), and to have been in common use in the thirteenth century, which is consistent with the evidence from the church (see above, part I, 'The mill (BAD) stratigraphic sequence . . . Period 4 . ..'). The large and sudden appearance of tile on both sites, BAB and BAE, would suggest an influx of the material, as if access to, or the creation of, production sites was achieved in the years around 1200. That all forms of tile were found in the period 4 levels would point to a basic change in roofing materials rather than the use of particular tiles in association with another, more established, covering, for example, the use of ridge tiles with stone slates, as seems to be the case elsewhere (Keene 1990b, 320). The adoption of ceramic tile then appears to occur at an earlier time than in some towns, for example in Coventry or Winchester where clay tiles were first found in the mid-thirteenth century, but were not widely used until a century later (Wright 1982, 101; Keene 1990b, 320); this also seems to be the pattern for southern and eastern England (Drury 1981, 131). On other monastic sites, however, such as Battle Abbey, ceramic tile was present before *c* 1100 and was in widespread use by the early thirteenth century (Streeten 1985, 100).

Hare has shown that the adoption of ceramic tile was often dependent on a region's access to other, more established, roofing materials such as stone slates or wooden shingles: where the supply of the latter was assured, the use of ceramic tile remained limited (Hare 1991, 91). However, the wholesale adoption of ceramic tile at Bordesley apparently occurred in advance of other types of site in the region and would suggest that the trend was related to developments within the monastery rather than the region. By *c* 1200 the huge initial outlay of labour and materials to build the church and the claustral complex and to remodel the valley had come to an end, and there was both an opportunity and the labour to exploit other local resources such as the clays for tiles.

Hare has also demonstrated from a survey of the documentary evidence for Wessex that clay tiles were rarely carted more than 16km (10 miles) from the production centres, except in those cases where seigneurial households had their own kilns in which circumstances the products would, if necessary, be transported over greater distances (1991, 97). The NAA has shown that most of the clays used for roof tiles at Bordesley were local and would thus not involve carting the tiles over great distances. There is some - documentary - suggestion of a tilery in the vicinity in the late thirteenth century (see below, part III, 'Other industries within the precinct . . . Ceramic manufacture'). In combination with the occurrence of distorted examples, the evidence of the early occurrence of kiln furniture (at the inception of period 4) would argue for production either within the precinct or in the near vicinity much earlier, *c* 1200. The fact that clay tiles appear to be first used in towns about fifty years later may suggest that the tiles used at Bordesley in *c* 1200 were produced for the community's sole use and perhaps would also explain the sudden and widespread use of the roofing material rather than the gradual process of adoption which appears to have happened in some towns.

Petrological examination of roof tile

by I Freestone

A qualitative examination was made of 36 thin-sections of roof tile with at least two examples from each of the nine visually-identified fabrics: fabric 1, six; fabric 2, six; fabric 3, four; fabric 4, four; fabric 5, two; fabric 6, two; fabric 7, three; fabric 8, four; fabric 9, five.

The main inclusions are abundant variably sorted quartz sand and rounded pellets of clay-rich material, often darker than the matrix and hence presumably richer in iron oxides. These are highly variable and originate in at least two ways. Firstly, as a result of soil formation processes before the clay was dug to make the tile and, secondly, they were pellets of clay which failed to disaggregate during preparation. A combination of these two processes is the most likely explanation for the clay inclusions.

The variations in inclusion grain size, shape, and composition are as great within each fabric as the overall variation. The differences between fabrics appear to be due to variation in firing conditions and to a lesser extent the overall abundance of the inclusions. For example, fabric 3 does tend to have the finer and less abundant inclusions.

These tiles were probably made from a similar

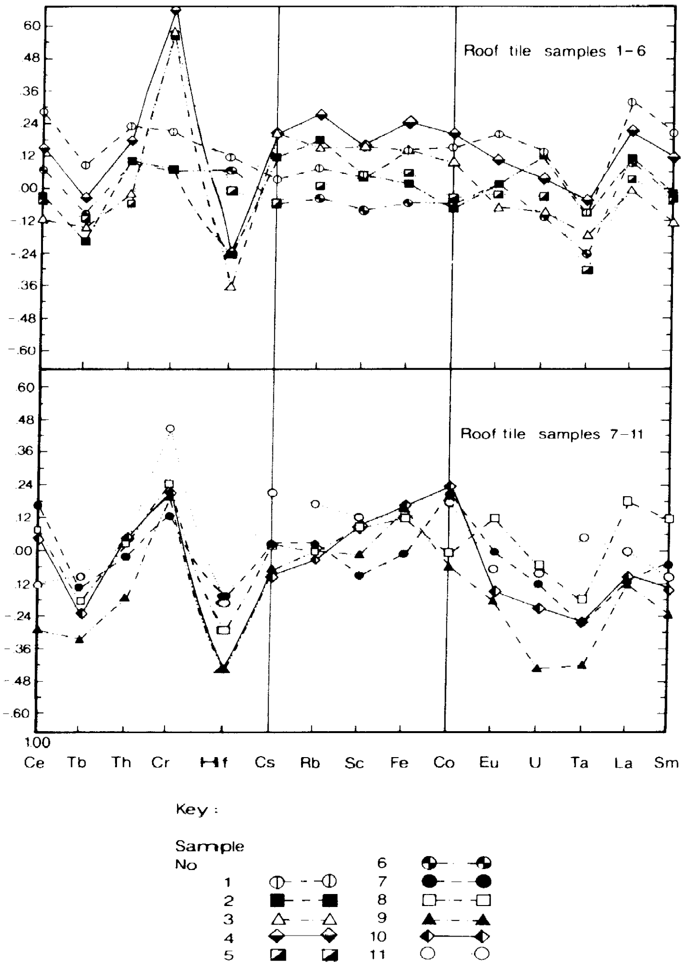


Figure 63 Mill (BAB) neutron activation analysis (NAA) of ceramic roof tile: mountain plots for roof tile samples l-6, and 7-11, showing the concentrations of fifteen elements as a connected line on a logarithmic vertical scale. Samples with similar chemical compositions produce parallel plots (cf 1, 2, and 6). Constants (different for each element) were subtracted from each log-transformed element before plotting to bring all the elements to a common scale

clay source. However, the fabrics are sufficiently heterogeneous to make it difficult to prove on the basis of petrography.

Neutron activation analysis of mill (BAB) roof tile by M J Hughes

Figures 63-5; Tables 23-6

A large project of neutron activation analysis (NAA)- has been completed on the decorated floor tiles excavated from the church (BAA) and the gateway chapel of St Stephen (BAG); samples of kiln furniture from BAB and of the valley clays were also analysed. This showed that many of the archaeologically defined 'production groups' of floor tiles were made locally, although with changes in chemical composition over time (Stopford 1990, 47-152; Leese *et al* 1989; Stopford *et al* 1991). The analytical evidence suggests that this local area was confined to the valley (rather than embracing, for example, the west midlands region). Another important result of the research was to demonstrate that the kiln furniture was of a local clay composition (see above, 'Fired clay. Kiln furniture'). The far more numerous roof tiles have not been previously analysed.

A group of eleven roof tiles was selected to include all of the nine visually identified fabrics (Table 23) (see above, 'Fabric and form type series', for definition of these fabrics). The aim of the analysis was to establish the relationship between the decorated floor tiles, the kiln furniture, the valley clays, and these roof tiles.

Samples from each of the tiles were taken and analysed according to the standard procedure of the British Museum Department of Scientific Research, which had previously been applied to the Bordesley floor tiles (Leese *et al* 1986; Hughes *et al* 1991). Twenty-three elements were measured in each tile and the results are given in Table 24.

Although cluster analysis and principal components analysis were used to interpret the large floor tile data set, in the case of the roof tiles it was more appropriate to use the simpler visual comparison method of mountain plots, where a line connects the concentrations of a selection of elements on a vertical logarithmic scale. Samples with similar chemical compositions produce parallel plots. As the number of roof tiles analysed is so small, these tiles can only be classified into broad chemical composition groups. The mountain plots for fifteen elements (the same as used for the floor tile) are shown in Figure 63. Representative mountain plots for some groups of floor tiles, the valley clays, and the kiln furniture are given in Figures 64 and 65 (from Stopford *et al* 1991, fig 3).

The mountain plot for each roof tile sample was then visually compared with those from the production groups (PGs), kiln furniture, and valley clays from the previous research programme to look for matches.

Comparison of results from Bordesley roof tile, floor tile, kiln furniture, and valley clays

Figure 63 shows that the roof tiles fall into a number of chemical composition groups. Samples 7-11 have a reasonably consistent composition although sample 9 differs from the rest in several elements. Although samples l-6 look similar to 7-11, samples 1, 2, and 6 seem to form a second group characterised by a different pattern for the elements Ce to Hf, and samples 3, 4, and 5 form a third group characterised by its higher concentrations of Cr.

When the individual and group plots were compared with those of the earlier programme, certain matches could be made and these are reported in the final column of Table 23.

Roof tile samples 7, 8, 9, 10, and 11 seem to be like BAA floor tiles of PG2 (Fig 64), which has a *terminus post quem* of 1260-80 (Stopford *et al* 1991, 351). Analysis has shown that PG2 was one of the main locally produced groups of tiles at Bordesley. These tiles also represent five visually identified fabrics (Table 23: fabrics 5, 6, 7, 8, and 9).

The roof tiles of the second composition group (samples 1, 2, and 6) are similar to both floor tiles of PG1 (Fig 64) and to some of the valley clays. PG1 comes later in the church sequence with a *terminus post quem* of 1330, and analytically it is also thought to be a local production (Stopford *et al* 1991, 352). The similarity of the three roof tiles (samples 1, 2, and 6) to the local valley clay composition also confirms their local manufacture. In the earlier study of the floor tiles, the clays as a composition group fell on the edge of the composition range of the locally made floor tiles (Stopford *et* al 1991, fig 2). Roof tile samples 1 and 2 are both fabric 1 and sample 6 is of fabric 4, so again the composition crosses the fabric boundaries.

Tiles of the third composition group (samples 3, 4, and 5) are like floor tiles of PG12 (Fig 64), which are also thought to be a local product. Sample 4 is closest of the three to PG12 while the two others seem to be diluted versions of the same, that is, with larger proportions of a diluting non-plastic such as sand. Samples 3, 4, and 5 represent fabrics 2, 3, and 4 and again the composition profile crosses the fabric boundaries. Thus fabric 4 falls into both the second (sample 6) and third (sample 5) chemical composition groups. The floor tiles of PG12 fall chronologically between PG2 and PG1, in the second half of the thirteenth century, and analytically they are part of the locally made major group at Bordesley (Stopford *et al* 1991,351).

The petrological report on samples of the nine fabrics concludes that all the fabrics probably represented the same basic clay and differences were due to variations in firing conditions and to a lesser extent the overall abundance of inclusions (see above, Freestone). The NAA results support this conclusion by showing that, although the composition subgroups are present in the roof tiles, there is a general chemical similarity between the subgroups which crosses the fabric boundaries and that the production groups which they match are all thought to be locally made. The chemical sub-groups also cut across the fabric boundaries.

Do the roof tiles bear any relationship in composition to the kiln furniture? Ten examples of the kiln furniture were analysed (Tables 25 and 26) and the results indicate an indirect link to the roof tiles: the kiln furniture also falls within the general spread

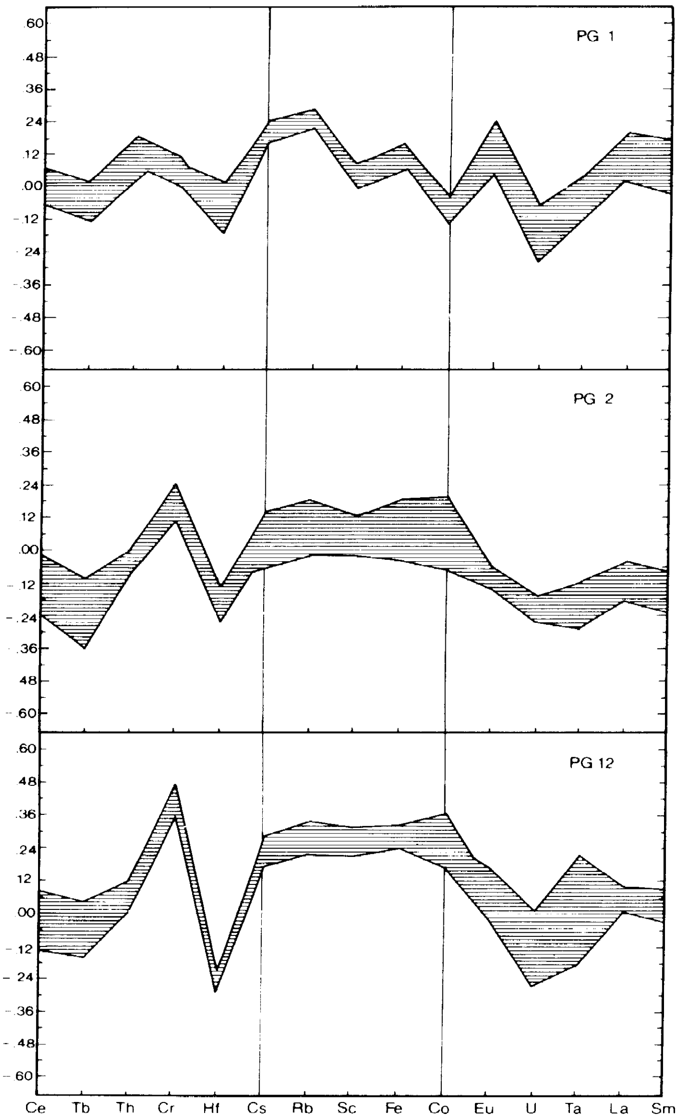


Figure 64 Neutron activation analysis (NAA) of Bordesley Abbey ceramics and *clay samples: mountain plots for floor tile production groups 1, 2, and 12, for comparison with the roof tile mountain plots of Figure 63 (where there are the same elements and scale). The shaded areas show the envelopes of the compositions, that is the boundaries of the major composition spreads for the samples of the group*

of composition of the local floor tiles at Bordesley. Seven of the ten examples of kiln furniture do form a narrow composition group, suggesting a common origin for their manufacture (Fig 65). They fall into cluster 3 (Table 25), which contains floor tiles of PG4 and PG13. Tiles of PG4 are from the second half of the thirteenth century and considered to be locally made, while PG13 are hand-made tiles which seem extremely likely *per se to* have been

Table 23 Mill (BAB): neutron activation analysis (NAA) of roof tile: summary of samples analysed and chemical composition matches with floor tile production groups (PG)

Sample	BM no.	Fabric	Form	Context and period	NAA similar to
1	37844Q	1	Peg and nib	E764, per 6	PG1/valley clays
2	37845Z	1	Hip/valley	B522, per 4	PG1/valley clays
3	37846X	2	Peg and nib	E276, per 6	PG12
4	37847Y	3	Unfeatured	E452, per 6	PG12
5	37848T	4	Nib	E276, per 6	PG12
6	37849R	4	Hip/valley	E429, per 4	PG1/valley clays
7	37850U	5	Unfeatured	E452, per 6	PG2
8	37851S	6	Peg	E452, per 6	PG2
9	37852Q	7	Nib	E275, per 6	PG2
10	37853Z	8	Unfeatured	D214, per 6	PG2
11	37854X	9	Peg	E425, per 6	PG2

Table 24 Mill (BAB): neutron activation analysis of roof tile: chemical compositions

Sample	Ce	Tb	Th	Cr	Hf	Cs	Rb	Sc	Fe%	Co	Eu	U	Ta	La	Sm	As	Ba	Ca%	K%	Lu	Na%	Sb	Yb
1	88.5	0.95	13.9	123	7.52	10.3	145	14	4.22	19.1	1.49	2.6	0.93	41.2	7.41	8.6	453		3.52	0.549	0.378	1.39	2.91
2	65.1	0.71	12.2	107	5.2	11.2	161	14.1	3.73	15.2	1.24	2	0.8	33.6	5.92	8.1	443	3	4.33	0.397	0.227	1.49	2.26
3	59.3	0.75	10.8	177	4.63	12.2	156	15.7	4.22	18.1	1.14	2	0.86	29.7	5.31	6.9	410		4.05	0.389	0.261	1.2	2.22
4	77.8	0.84	13.2	193	5.29	12.2	176	15.8	4.67	20.1	1.35	2.3	0.97	36.7	6.78	8.7	406		4.35	0.453	0.242	1.51	2.65
5	63.9	0.77	10.4	175	6.6	9.48	135	14	3.89	15.8	1.19	2.2	0.75	30.9	5.79	15.4	671		3.65	0.411	0.274	1.39	2.59
6	71.6	0.79	12.1	106	7.15	9.42	129	12.4	3.47	15.5	1.23	2.5	0.93	33	5.83	11.8	502		3.59	0.4	0.189	1.31	2.52
7	78.2	0.76	10.8	114	5.68	10.3	138	12.3	3.64	20.3	1.22	2	0.79	27	5.81	6.7	461		3.08	0.434	0.253	1.16	2.42
8	71.8	0.72	11.3	127	4.98	10.2	134	14.6	4.14	16.3	1.38	2.1	0.86	36	6.79	8.6	393		3.55	0.373	0.236	1.05	2.22
9	49.7	0.63	9.26	121	4.32	9.32	135	13.3	4.28	15.6	1.02	1.5	0.67	26.7	4.8	13.3	419		3.41	0.337	0.257	1.39	2.03
10	70	0.69	11.6	123	4.34	9.19	131	14.9	4.36	20.9	1.06	1.8	0.79	27.6	5.32	13.9	648		3.22	0.416	0.283	1.27	2.16
11	59.1	0.79	11.3	156	5.55	12.4	159	15.2	4.15	19.7	1.15	2.1	1.08	30	5.51	23.1	551		3.14	0.455	0.368	1.13	2.27

All results in parts per million, except Na, K, Fe, and Ca which are in percent.

Table 25 Mill (BAB): neutron activation analysis of kiln furniture: summary of samples analysed and cluster results

BM no,	FC no.	Context and period	Cluster no.†
29314T	FC 149	E255, per 7	3
29315R	FC 49	E474, per 5	3
29316P	FC 148	E755, per 5	3
29317Y	FC 146	E775, per 4	3
29318W	FC 193	D214, per 6	3
29319U	FC 143	E939, per 4	17
29320X	FC 142	E755, per 4	3
29321V	FC 140	B114, per 6	1
29322T	FC 151	C180, per 7	3
29323R	FC 147	E755, per 4	14

† Cluster no. as in table 1, Stopford *et al* 1991, 357.

Table 26 Mill (BAB): neutron activation analysis of kiln furniture: chemical compositions

BM no.	Ce	Tb	Tb	Cr	Hf	Cs	Rb	Sc	Fe%	Co	Eu	U	Ta	La	Sm	As	Ba	Ca%	K%	Lu	Na%	Sb	Yb
29314T	60.1	0.7	10.8	118	4.96	10.7	150	13.8	3.93	16.3	1.15	1.8	0.79	27.2	4.66	11.1	474	1.1	3.52	0.361	0.295	0.97	2.17
29315R	58.2	0.72	10.9	113	4.73	10.5	139	13.3	3.77	14.8	1.09	1.9	0.76	28.5	5.53	7.2	483		3.9	0.351	0.203	1.02	2.21
29316P	66.9	0.76	12.7	154	5.39	11.4	166	17.9	5.03	20.6	1.44	1.8	0.93	32.9	5.63	10.7	438	2.3	3.85	0.386	0.293	1.24	2.49
29317Y	66.9	0.78	11.4	133	5	9.73	138	15.2	4.47	20.5	1.28	2	0.96	30.5	5.31	11.2	448		3.82	0.387	0.261	1.11	2.32
29318W	63.1	0.74	11.7	121	5.21	11.2	149	14.6	4.15	15.7	1.17	1.9	0.86	29.3	4.8	6.8	369		3.94	0.384	0.228	1.14	2.33
29319U	66.3	0.77	10.1	109	5.77	10.2	154	14.2	3.87	16	1.26	3.1	0.76	29.7	5.96	13.6	608		3.55	0.424	0.295	1.02	2.29
29320X	60.7	0.78	11.8	124	5.11	12.1	151	15.1	4.22	16.8	1.28	2	0.83	30	4.99	19.1	500		4.14	0.399	0.333	1.15	2.24
29321V	53.7	0.7	9.76	119	4.77	9.66	130	12.5	3.54	13.9	1.1	1.7	0.64	25.2	5.14	8.4	328		2.94	0.337	0.276	1	1.92
29322T	61.3	0.73	10.9	119	5.14	10.9	132	14.3	4.2	17.8	1.25	2.3	0.83	28.7	4.86	9	496	1	3.63	0.352	0.301	0.96	2.19
29323R	60.3	0.82	10.7	121	5.16	10.7	145	14.2	4.02	22.8	1.24	2	0.72	27.2	5.82	9.5	376		3.55	0.378	0.297	1.24	2.16

All results in parts per million, except Na, K. Fe, and Ca which are in percent.

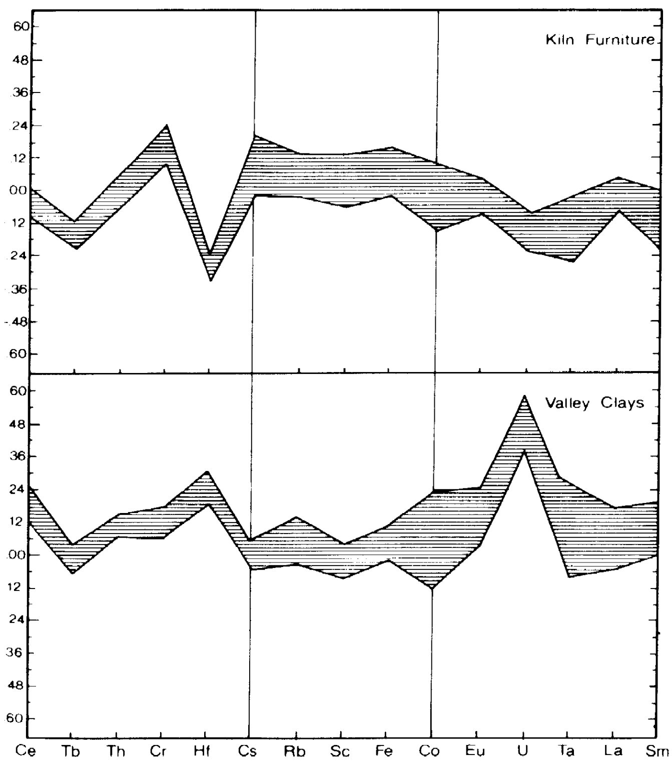


Figure 65 Neutron activation analysis (NAA) of Bordesley Abbey ceramics and clay samples: mountain plots for mill (BAB) kiln furniture and valley clay samples, for comparison with the roof tile mountain plots of Figure 63 (where there are the same elements and scale). The shaded areas show the envelopes of the compositions, that is the boundaries of the major composition spreads for the samples of the group

made on or near the site (Stopford *et al* 1991, 353). Another item of kiln furniture (FC 140) is similar to PG1 floor tiles (and therefore to roof tiles 1, 2, and 6), while another (FC 147) is similar to PG2, that is to roof tiles 7, 8, 9, 10, and 11. The remaining piece of kiln furniture (FC 143) falls into cluster 17 which consists mainly of local clays.

Most of the analysed pieces of kiln furniture are similar to PG4 and PG13 which do not match any of the roof tiles and, of the remaining three, two match with different groups of roof tiles, while a third matches with local clays. The variety of compositions for the kiln furniture do, however, in all cases appear to represent local production.

Conclusion

All eleven roof tile samples subjected to NAA have chemical compositions which link them to local production at Bordesley Abbey. They fall into three composition groups which cross the visual fabric boundaries, and the groups link up with the composition of either established PGs or some of the locally dug clays. They are not directly related to the composition of the kiln furniture, which however also has a local composition. The report on the roof tile shows that all nine fabrics (the visual differences being mainly associated with firing conditions and to a lesser extent the abundance of inclusions) occurred in period 4, that is during the late twelfth to early fourteenth centuries (see above). Samples 7, 8, 9, 10, and 11 (fabrics 5, 6, 7, 8, and 9) are associated with floor tile PG2 which has a *terminus post quem* of 1260-80, while samples 1, 2, and 6 (fabrics 1 and 4) were similar to floor tile PG1 which has a *terminus post quem* of 1330. Samples 3, 4, and 5 (fabrics 2, 3, and 4) were similar (especially sample 4, fabric 3) to PG12, associated with the second half of the thirteenth century. A tentative conclusion, therefore, would be that a variety of local clay sources were exploited for the production of roof tiles from early on in BAB period 4, but were also later used selectively, and at different times, for the manufacture of decorated floor tiles.

Pottery by V Nailor

The report is in four sections: an introduction and summary of the fabric type series; individual discussion and period dating for the mill (BAB), the valley transect (BAE), and the tail race (BAH), followed by a general conclusion; a fabric and form type series for the total assemblage from BAB, BAE, and BAH, including a catalogue of the illustrated pottery (Figs 66-70); and an appendix (on fiche) which provides correlation with the previously published Bordesley pottery type series. Tables 27-33 show fabrics by period, and forms in each fabric grouping (unstratified pot is excluded).

The pottery from BAB dates from the late first to the nineteenth or early twentieth centuries AD, that from BAE from the Roman period to the late nineteenth century, and that from BAH mostly from the medieval period but with some Roman. A total of 3796 stratified sherds weighing 66.899kg were recovered from BAB, 120 sherds weighing 2.340kg were found in BAE, and there were 17 sherds weighing 0.247kg from BAH. The BAB pottery was excavated by context in 2m squares in an attempt to obtain more precise spatial information about pottery distributions. The BAB periods relate to a series of mills and industrial features with their associated phases of construction, use, and disuse; the site chronology was based on a series of dendrochronological dates.

This pottery constitutes the first substantial assemblage excavated within the Bordesley Abbey precinct: the quantity and nature of the material justified consideration of this assemblage in its own right and independently of the very much more limited amounts of pottery from excavations elsewhere in the precinct. All three sites (BAB, BAE, BAH) produced a similar range of pottery and there was a marked contrast with the (provisional) pottery type series previously published which was based on (sparse) material recovered from the church and also from minor excavations within the precinct (Rahtz and Hirst 1976, 186-90; Hirst *et al* 1983, 169-71). Although there were basically the same wares from the mill and the church, both the ware proportions and the date range for the material differed. For example, BAB produced more earlier-dating fabrics and less of the later medieval to early post-medieval/fifteenth to sixteenth century wares which occur in the church excavations. The BAB assemblage also included a high proportion of red-brown sandy, cooking-vessel fabrics, whereas this would not appear to be so on the church where fifteenth- and sixteenth-century, and indeed earlier (viz Stamford), fine wares do occur.

Summary of fabric type series

A total of 65 fabrics were identified which can be divided into Roman, medieval, and post-medieval fabrics. The fifteen Roman fabrics were mainly greywares, some of which were organic tempered, as well as Severn valley ware, and a small number of grey or black sandy fabrics. The 37 medieval fabrics divide into a small number of major fabrics and a larger number of minor fabrics, often represented by relatively few sherds. Major fabrics in the medieval assemblage include: red-brown sandy cooking vessel fabrics; orange sandy, light-bodied sandy glazed, and sandy glazed which are all mainly jug fabrics; coarse orange sandy fabrics in a range of vessel types; and very hard sandy fabrics in jugs and related forms. The minor fabrics include examples of Stamford ware, coarse tempered fabrics, a brown sandy fabric, and a hard grey sandy one. The thirteen post-medieval fabrics given general common names are predominantly nineteenth century or later in date.

There were a small number of medieval sherds which were not assigned independent fabric codes. A review of these small, often abraded, sherds has indicated in one or two examples that they are possibly from known sources. In particular, there is a single shelly sherd (see below, dull white gritted fabrics, F23), which may be from the Oxford region (Brill/Oxford; see McCarthy and Brooks 1988, eg 172-4, 280-5, 292, and references cited therein), and there is a body sherd (see below, very hard sandy fabrics, F12), with white slip, which may indicate the source of production as Deritend, Birmingham (Birmingham Museum and Art Gallery collections; Sherlock 1955).

Fabric groups

Roman	
Greyware	F1, 2, 3, 4, 5, 18, 19, 43, 44, 45
Sever-n valley ware	F10
Grey-black sandy	F6, 31, 46, 47
Medieval	
Stamford	F13
Red-brown sandy	F20, 24, 25, 26, 30, 35, 40
Brown sandy	F33
Hard, grey sandy	F38
Hard, fine sandy	F36, 41, 49
Orange sandy	F8, 9, 17
Light-bodied sandy, glazed	F14, 15, 16, 50, 51
Sandy, glazed	F21, 22, 32, 37, 42
Sandy, miscellaneous	F39, 48, 52
Very hard, sandy	F12, 28, 34
Coarse tempered grey-brown	F11, 27, 29
Coarse orange sandy	F7
Dull white gritted	F23
(Crucible fabrics from 1967-8)	
Post-medieval	
Transfer-printed	F100
Stoneware, late	F101

Slipware	F102
Black-glazed	F103
Miscellaneous 'whiteware'	F104
Yellow ware, late	F105
Tin-glazed	F106
'Feather-edged' (cobalt blue, dipped edge)	F107
Miscellaneous, late	F108
Cistercian type	F109
Orange, self-coloured glaze	F110 (BAE only)
Mottled/streaked glaze	F111 (BAE only)
Midland Purple type	F112

The mill (BAB) assemblage

Tables 27-9

The series of dendrochronological dates which relate to the sequence of mills built on the site provide a framework for the dating of the pottery. However, it must be remembered that this chronological framework should emphasise a period of time which reflects the construction and the use and disuse of each mill rather than simply a *terminus post quem*. The BAB periodisation is as follows.

Period 1: pre-monastic activity, prehistoric to mid-twelfth century AD

Period 2: monastic ground clearance, platform, and pre-mill structure, mid-twelfth century

Period 3: first water-mill, later twelfth century (felling dates 1174 and 1175-6)

Period 4: watermill, late twelfth to early fourteenth centuries (felling date of tail race timbers 1187)

Period 5: water-mill, early fourteenth to ?mid-fourteenth century (likely felling date of tail race timbers early fourteenth century)

Period 6: watermill, ?mid-fourteenth to ?late fourteenth/early fifteenth centuries

Period 7: abandonment of mill, late fourteenth/early fifteenth centuries; filling in of leat, drainage trenches, seventeenth to twentieth centuries

The pottery when seen within this chronological framework raises problems, on the one hand, of residuality and, on the other, of intrusive material. Archaeological conditions were extremely wet and muddy, particularly in the tail race area and, indeed, in the lower levels on all sites.

Period 1: pre-monastic

There was very little pottery from this period, reflecting the nature of the deposits which comprised three stages of stream activity: three phases of streams, interspersed with two periods of blanket silts, that begin some time after the last glaciation. The most common wares were Roman: greywares, some of which are organic tempered, Severn valley ware, and grey/black sandy including a virtually complete carinated jar (Fig 66 no. 1). A small quantity of Roman pottery comes from phase 2 of the stream beds, but most comes from the succeeding phase 3. Any medieval (or later) material in phase 3 is certainly intrusive and it may be that any ceramic at all before phase 3 should be regarded as intrusive; however, there are Roman sherds in phase 2 contexts where contamination is extremely unlikely (A1178, B1142) and so some of phase 2 activity did possibly take place in the Roman period. The carinated jar occurred in phase 3 and was *in situ* (rather than intrusive); it has been suggested by Paul Booth (Warwickshire Museums, pers comm) as probably dating to the late first century AD and may be a local product: the organic tempered greyware may also have a local source.

Throughout the site periods there are significant quantities of Roman pottery, most of which dates to either the first or second centuries AD (pers comm Paul Booth). This concentration may reflect Roman occupation of the site. It occurs in period 1 in stream beds and could have originated upstream, but it is unabraded and so could reflect dumping in stream beds originating from nearby occupation.

On this basis, the (few) medieval and post-medieval sherds recorded from period 1 contexts are all intrusive and due to the difficult archaeological conditions. These intrusive sherds comprised red-brown sandy cooking vessels (8 sherds), orange sandy fabrics (3 sherds), light-bodied sandy glazed fabrics (1 sherd), and black-glaze (post-medieval) (3 sherds). (No pottery was found at the level of the top of the phase 3 ground surface which stratigraphically would correspond to the late Saxon ground surface.)

Period 2: ?mid-twelfth century

Roman pottery is present in this site period, but its relative proportion has declined (36 sherds: 42% no./34% wt) and it is residual.

The medieval material is dominated by red-brown sandy fabrics (37 sherds: 43% no./59% wt) occurring as wide-bodied, straight-sided cooking pots with sagging bases and fairly upright sloping rims (Fig 66 no. 2), or as unidentified vessels, probably for cooking. There is a very small quantity (6 sherds: 7% no./3% wt) of coarse tempered (F27, F29) cooking vessels, including pots and bowls (Fig 69 no. 49); these occur in contexts where it is possible that sherds could have been incorporated subsequently in period 3, but the fabrics and forms would not seem out of place in period 2. It is suggested, therefore, that both red-brown sandy and coarse tempered fabrics are found in relatively small amounts prior to the last quarter of the twelfth century, and probably occur from sometime in the third quarter of the twelfth century.

However, there is in addition in period 2 a very small amount of orange sandy fabric (6 sherds: 7% no./3% wt) (F9, F17) and hard, fine sandy fabric (1 sherd) (F41) from contexts where again it is possible, and in some instances probable (including the F41 sherd), that sherds could have been incorporated subsequently in period 3 or later. Both these fabric groups would seem more likely to be later in date than period 2. However, the sherds are body sherds: the orange sandy fabric type at least could have originated earlier, although in later periods its typical form was the jug. Only one sherd is definitely from a jug (the F41 sherd) and that is a small fragment, with partly abraded surface, whose general appearance suggests it could possibly be twelfth century. It remains uncertain then whether this pottery can be firmly attributed to this date.

Period 3: later twelfth century

In period 3 the dominance of red-brown sandy fabrics continues (72 sherds: 63% no./75% wt), along with residual Roman wares (21 sherds: 18% no./12% wt); the latter would have been produced by the process of excavation of the mill race and the construction of the mill platform and mill pond banks. Forms in red-brown sandy fabrics are dominated by wide-mouthed, straight-sided cooking pots with sagging bases and long-necked, fairly upright sloping rims (Fig 66 nos 3-5). There are three sherds (3% no./8% wt) of coarse tempered cooking vessels.

The small quantity of sherds from light-bodied, thumbed-based jugs is intrusive from period 4. All these sherds occur in contexts which either continued to be exposed in period 4 (B631, 11 sherds, join with nos 38 and 39 Fig 68) or belong to the final stages of period 3, even possibly to early period 4 (B1107, 1 sherd joins with no. 39 Fig 68). The three sandy glazed sherds (F32, from A158V) may also be intrusive from period 4.

Period 4: late twelfth to early fourteenth centuries

The three dendrochronological dates from the period 4 tail race timbers centre on 1187. As such they provide a *terminus post quem* for the construction of the period 4 mill race, with no indication of its period of use, or when, or for how long, it was disused. The period 5 tail race timbers are dated dendrochronologically to the early fourteenth century. The period 4 pottery, therefore, has a broad date range of the thirteenth century.

The importance of red-brown sandy fabrics continues during this period, with this group being represented by the largest number of sherds (277 sherds: 32% no./38% wt). Occurring as cooking vessels, the pots are typically wide-mouthed, straight-sided with sagging bases and long-necked, thickened, sloping rims (Fig 66 no. 13). A variety of rims occur in this group (Fig 66 nos 6-15). There are some coarse tempered fabrics (58 sherds: 7% no./8% wt) with both cooking pots and bowls represented (Fig 69 nos 50-52).

This site period, however, is characterised (a) by a large increase in the total number of sherds (see Table 27; period 4 assemblage 867 sherds, 23% no./33% wt of total assemblage, and second only in size to period 7 assemblage, 2054 sherds, 54% no./46% wt of total assemblage), (b) by an increase in the range of fabrics and forms represented, (c) by the introduction and appearance in considerable quantity of light-bodied sandy glazed fabrics (typically a jug fabric) (237 sherds: 27% no./18% wt), and (d) by the occurrence of a number of part profiles or largely complete vessels (Figs 67 nos 25 and 27, 68 nos 38-40, 69 no. 42). This is exemplified by the three part profiles of jugs with thumbed bases in light-bodied sandy glazed fabrics (Fig 68 nos 38-40). The vessels have wide bodies, squat necks, sagging thumbed bases, simple out-turned rims, and either combed or rouletted designs on the pot body. Another part profile of a jug in a sandy glazed fabric has an almost frilled, thumbed base with a complex applied and incised design (Fig 69 no. 42). This fabric group (apparently characteristically a jug fabric) was represented in period 3 (3 sherds, F32) but was probably intrusive there, whereas in period 4 there were 57 sherds (7% no./5% wt). 76% no./85% wt of the light-bodied sandy glazed fabric group, and 58% no./71% wt of sandy glazed fabrics, occur in period 4.

There is, therefore, a distinct concentration of the light-bodied jug fabrics in period 4 (and also to a less extent of the sandy glazed, probable jug, fabrics); their deposition appears in some respects specific (see below). It should be remembered that the occurrence of this group in particular may not represent the length of use of these fabrics on the site, merely their disposal.

Other new types in this period include a brown sandy fabric (46 sherds: 5% no./11% wt), occurring as large globular cooking pots (Fig 67 no. 23) and as a virtually complete wide-mouthed bowl (Fig 67 no. 25), and hard grey sandy ware (60 sherds: 7% no./13% wt). Nearly all of the hard grey sandy ware is concentrated in this site period (per 4 92% no./99% wt), represented by a mostly complete large globular cooking pot (Fig 67 no. 27). A small number of relatively unusual forms occur in a hard, fine sandy fabric (Fig 67 nos 28-9); this fabric (per 4, 7 sherds) was previously recorded from period 2 where it was very likely intrusive.

There is a small amount of pottery which is probably either intrusive in period 4 (1 sherd, F108) or relates to the very end of this site period. This includes a few examples of very hard sandy fabrics W28, F34, 4 sherds), whereas most of this

Table 27 Mill (BAB): pottery distribution, by period and by fabric/fabric group, by number of fragments and by weight (g)

	Fabric	Period 1		2		3		4		5		6		7		Total	
		no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt
Roman	Greyware F1–5, F18–19, F43–45	11	365	20	236	16	126	44	601	9	215	9	99	58	773	167	2415
	Severn valley F10	3	27	14	224	5	34	4	36	2	11	4	21	13	69	45	422
	Grey-black sandy F6, F31, F46, F47	10	458	2	10	–	–	–	–	–	12	–	–	–	–	14	480
Medieval	Stamford F13	–	–	–	–	–	–	5	29	–	–	–	–	–	20	6	49
	Red-brown sandy F20, F24–26, F30, F35, F40	8	125	37	821	72	1037	277	8307	221	2186	209	5373	412	8864	1236	26713
	Brown sandy F33	–	–	–	–	–	–	46	2325	26	342	–	–	2	18	74	2685
	Hard grey sandy F38	–	–	–	–	–	–	60	2929	–	–	1	9	4	28	65	2966
	Hard fine sandy F36, F41	–	–	1	10	–	–	7	262	3	13	2	16	12	287	25	588
	Orange sandy F8, F9, F17	3	13	6	39	4	12	46	366	27	335	59	848	400	6892	545	8305
	Light-bodied sandy glazed F14–16	1	10	–	–	12	50	237	3983	3	68	6	165	54	404	313	4680
	Sandy glazed F21–22, F32, F37, F42	–	–	–	–	3	20	57	1199	5	37	7	178	27	263	99	1697
	Sandy, miscellaneous F39, F48, F52	–	–	–	–	–	–	16	179	1	8	4	185	27	296	48	668
	Very hard sandy F12, F28, F34	–	–	–	–	–	–	4	26	2	139	13	89	109	2044	128	2298
	Coarse tempered grey-brown F11, F27, F29	1	9	6	42	3	107	58	1659	6	80	4	47	17	305	95	2249
	Coarse orange sandy F7	–	–	–	–	–	–	4	38	1	8	6	300	40	1083	51	1429
	Dull white gritted F23	–	–	–	–	–	–	1	10	–	–	–	–	2	10	3	20
Post-medieval	Transfer-printed F100	–	–	–	–	–	–	–	–	1	2	–	–	202	790	203	792
	Stoneware, late F101	–	–	–	–	–	–	–	–	–	–	–	–	21	287	21	287
	Slipware F102	–	–	–	–	–	–	–	–	–	–	–	–	9	308	9	308
	Black-glazed F103	3	21	–	–	–	–	–	–	–	–	–	–	148	3740	151	3761
	Miscellaneous 'whiteware' F104	–	–	–	–	–	–	–	–	–	–	–	–	271	2101	271	2101
	Yellow ware, late F105	–	–	–	–	–	–	–	–	–	–	–	–	70	1308	70	1308
	Tin-glazed F106	–	–	–	–	–	–	–	–	–	–	–	–	13	24	13	24
	'Feather-edged' F107	–	–	–	–	–	–	–	–	–	–	–	–	39	182	39	182
	Miscellaneous, late F108	–	–	–	–	–	–	1	5	3	20	–	–	99	422	103	447
	Midland Purple type	–	–	–	–	–	–	–	–	–	–	–	–	2	25	2	25
Total		40	1028	86	1382	115	1386	867	21954	312	3476	324	7330	2052	30343	3796	66899
% of total assemblage (no. sherds)		1		2		3		23		8		9		54			
% of total assemblage (wt sherds)			2		2		2		33		5		11		45		

fabric type comes from period 7 (see below, period 5).

The spatial distribution of the BAB pottery in this period is of interest. The relative proportions of the broad form categories overall (crudely measured in number of sherds) were: cooking pot 343 sherds 45%, jug 286 sherds 38%, other forms 11 sherds 1% unspecified 124 sherds 16%. With a reasonably large assemblage from this period, plotting of sherd density (by number) according to the 2m grid (see Fig 5) shows three clear concentrations and these were confirmed, and characterised, by plotting sherds (by number) according to broad form categories.

Thus, the bypass channel contained a large concentration of cooking pots, with a scatter of these vessels between the bypass channel and the mill building to the west. In sharp contrast, jugs are concentrated overwhelmingly in the area of the mill building in square B (2m squares J, M, N)/east part of mill building; this includes the three jugs with thumbed bases in light-bodied sandy glazed fabrics (Fig 68 nos 38-40). A third, smaller, concentration is apparent at the junction of squares C and D (2m squares W and B) in the centre of the mill building, this time of cooking pots together with a very small amount of jugs. The disposal patterns of these two broad vessel categories then differ; the cooking pots were probably part of deliberate dumping in the bypass channel.

If we separate out the bypass channel pottery, we find that virtually every medieval fabric is represented, even if by only a single sherd, reflecting the increased range of fabrics in period 4. However, cooking pots dominate overwhelmingly: thus, in addition to cooking pots, the pottery identified to form comprised a bowl (Fig 67 no. 25), a part-profile of a jug (Fig 69 no. 42), and one further jug sherd.

The date range of this pottery deserves careful consideration. The largely complete or part-profile vessels might be considered to have more affinities with the thirteenth rather than the late twelfth century. Although the red-brown sandy vessels continue to echo the rather baggy shapes of periods 1-3, the light-bodied sandy glazed jugs with thumbed bases present a problem. Discussion of this vessel type with Alan Vince (pers comm) indicates that current thinking is that in London jugs with thumbed bases date no earlier than *c* 1215. However, the light-bodied sandy glazed fabrics occur early in period 4, coming from contexts associated with the construction phase of the period 4 mill: both from the area of the mill building (this applies to, for example, the three illustrated jugs with thumbed bases (Fig 68 nos 38-40) from the mill building) and the tail race area (one sherd of F16, form 7 bowl with internal green copper glaze, from E865 below the tail race timbers). The felling date for the period 4 tail race timbers analysed is 1187.

Period 5: early fourteenth to ?mid-fourteenth century

There is evidence of change both in fabrics and forms in period 5. Quantitatively red-brown sandy cooking vessels continue to dominate (221 sherds: 71% no./63% wt). Examination of the red-brown sandy rims shows forms similar to those in periods 2-4, as well as new forms represented by a small number with shortened, simple, ever-ted rims (Fig 66 nos 16-17); the continued presence of certain forms may be evidence that a proportion of this fabric group is residual in period 5.

The brown sandy fabric introduced in period 4 and represented by cooking pots or jars and wide-mouthed howls also continues (26 sherds: 8% no./10% wt). Change is also evident in other fabric forms. In the orange sandy fabrics (27 sherds: 9% no./10% wt) there is an example of a small bottle or jug base (Fig 67 no. 32). Thus orange sandy jugs apparently continue but in small numbers.

However, in marked contrast to period 4 (see above, especially the disposal pattern) where light-bodied sandy glazed fabrics were dominant, very little is present in this period (3 sherds); the group is again characterised by jug forms (with simple decoration of combing or rouletting). Measured by number and weight, the fall-off in this fabric group is dramatic. The proportion of sandy glazed fabrics, again characterised by jugs, also declines (5 sherds). Hence the change in this period of the relative proportions of the broad form categories crudely measured in number of sherds (not vessels), viz cooking pots 111 sherds 45%, jugs 25 sherds 10%, unspecified (not glazed and more likely cooking or storage, jars rather than bowls) 104 sherds 43%, other forms 4 sherds 2%.

A very hard sandy fabric (2 sherds) in a jug form (Fig 69 no. 47) may be relatively early for such a high-fired fabric. The greatest concentration of this fabric is in period 7; the four sherds in period 4 may be intrusive or these may relate to the later part of the date range for period 4, that is to the late thirteenth or early fourteenth century.

Period 6: ?mid-fourteenth to ?late fourteenth/early fifteenth centuries

Dating of the period is difficult, with a suggested general fourteenth-century date. A single coin from a period 6 floor is dated to 1361-9.

The pottery illustrates both potential problems of residuality and evidence of change in fabric groups. There is a small amount of residual Roman pottery (13 sherds: 4% no./2% wt), a feature which may substantiate the suggestion that, although red-brown sandy fabrics are - still - the largest group (209 sherds: 65% no./73% wt), they are to some - possibly large - extent residual (cf period 5).

Light-bodied sandy glazed fabrics (typically jugs) remain at a very low level (6 sherds), contrasting with orange sandy jug fabrics which have increased

Table 28 Mill (BAB): pottery distribution, by form and by fabric/fabric group, by number of fragments and by weight (g)

	Fabric	Forms Cooking pot		Bowl		Jug		Bottle		Pot - general		Hollow-ware		Flatware		Total	
		no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt
Roman	Greyware F1-5, F18-19, F43-45	-	-	-	-	-	-	-	-	167	2415	-	-	-	-	167	2415
	Severn valley F10	-	-	-	-	-	-	-	-	45	422	-	-	-	-	45	422
	Grey-black sandy F6, F31, F46, F47	-	-	-	-	-	-	-	-	14	480	-	-	-	-	14	480
Medieval	Stamford F13	-	-	-	-	1	20	-	-	5	29	-	-	-	-	6	49
	Red-brown sandy F20, F24-26, F30, F35, F40	1007	22708	-	-	-	-	-	-	229	4005	-	-	-	-	1236	26713
	Brown sandy F33	44	1147	30	1538	-	-	-	-	-	-	-	-	-	-	74	2685
	Hard grey sandy F38	59	2925	-	-	-	-	-	-	6	41	-	-	-	-	65	2966
	Hard fine sandy F36, F41	18	469	-	-	-	-	-	-	7	119	-	-	-	-	25	588
	Orange sandy F8, F9, F17	11	156	2	5	372	6748	2	132	158	1264	-	-	-	-	545	8305
	Light-bodied sandy glazed F14- 16	-	-	3	80	309	4560	1	40	-	-	-	-	-	-	313	4680
	Sandy glazed F21-22, F32, F37, F42	-	-	-	-	95	1642	-	-	4	55	-	-	-	-	99	1697
	Sandy, miscellaneous F39, F48, F52	6	95	1	8	16	275	-	-	25	290	-	-	-	-	48	668
	Very hard sandy F12, F28, F34	-	-	-	-	123	2246	-	-	5	52	-	-	-	-	128	2298
	Coarse tempered grey-brown F11, F27, F29	68	1565	27	684	-	-	-	-	-	-	-	-	-	-	95	2249
	Coarse orange sandy F7	9	128	16	712	4	154	-	-	22	435	-	-	-	-	51	1429
	Dull white gritted F23	-	-	-	-	-	-	-	-	3	20	-	-	-	-	3	20
Post-medieval	Transfer-printed F100	-	-	-	-	-	-	-	-	-	-	79	439	124	353	203	792
	Stoneware, late F101	-	-	-	-	-	-	-	-	-	-	21	287	-	-	21	287
	Slipware F102	-	-	-	-	-	-	-	-	-	-		-	9	308	9	308
	Black-glazed F103	-	-	-	-	-	-	-	-	-	-	151	3761	-	-	151	3761
	Miscellaneous 'whiteware' F104	-	-	-	-	-	-	-	-	-	-	151	1633	120	468	271	2101
	Yellow ware, late F105	-	-	-	-	-	-	-	-	13	223	57	1085	-	-	70	1308
	Tin-glazed F106	-	-	-	-	-	-	-	-	-	-	13	24	-	-	13	24
	'Feather-edged F107	-	-	-	-	-	-	-	-	-	-	-	-	39	182	39	182
	Miscellaneous, late F108	-	-	-	-	-	-	-	-	-	-	52	207	51	240	103	447
	Midland Purple type	-	-	-	-	-	-	-	-	-	-	2	25	-	-	2	25
Total		1222	29193	79	3027	920	15645	3	172	703	9850	526	7461	343	1551	3796	66899
% of total assemblage (no. sherds)		32		2		24		<1		19		14		9			
% of total assemblage (wt sherds)			44		5		23		<1		15		11		2		

numerically significantly (59 sherds: 18% no./12% wt) (Fig 67 no. 33). Also in period 6 very hard sandy jug fabrics occur in small amounts (13 sherds: 4% no./1% wt). The relative proportions of the broad form categories crudely measured in number of sherds (not vessels) might suggest an increase in period 6 over period 5 of jug forms: cooking pots 115 sherds 46%, jugs 83 sherds 34%, unspecified (cf period 5) 43 sherds 17%, bowls 7 sherds 3%. A light-bodied sandy glazed bowl (Fig 68 no. 41) occurs in this period and is a slightly unusual form (?partly date-related), although howls in light-firing fabrics are known from, for example, Tamworth (Nailor with Wright 1992, 112).

Period 7: late fourteenth/early fifteenth centuries and seventeenth to twentieth centuries

This period includes the abandonment of the mill and its masking by flood deposits, filling in the tail races, mainly within the lifetime of the abbey, and the cutting of late post-medieval drains and related features, together with frequentation of the valley. Five coins came from abandonment contexts (phase 1 period 7); these are of late thirteenth- to mid-fourteenth-century date and the latest coin is 1344-51. Period 7 has, therefore, a *terminus post quem* of 1361, provided by the single coin from period 6.

Pottery from this Period falls into three groups: a small amount of residual Roman, and large amounts of both medieval and post-medieval pottery. The period can be divided into the two broad phases, first abandonment and second post-medieval, and the approximate proportions of the three pottery groups are shown in Table 29.

The medieval pottery comprises three main groups: red-brown sandy fabrics (37% no./44% wt of the total of medieval sherds in period 7), orange sandy and coarse orange sandy fabrics (40% no./ 38% wt), and very hard, sandy sherds (10% no./wt). These represent the later site fabrics, although the red-brown fabrics may be residual as many of the rims betray no change from those in the preceding site phases and red-brown fabrics are the dominant medieval fabric group, occurring from period 2.

The orange sandy forms are dominated by jugs (Fig 68 nos 36-7), while the coarse orange sandy examples are in a wider range of forms including wide-mouthed bowls (Fig 69 no. 55), cooking pots with heavily ever-ted rims (Fig 69 no. 53), and pipkins (Fig 69 no. 54). Jugs are the most common form in the very hard, sandy fabrics. They are similar to the orange sandy jugs having simple rims, wide, squat bodies, no decoration except for neck cordons, and limited use of glaze. Other fabrics include hard, fine sandy sherds occurring as lid-seated jars (Fig 67 no. 30)

Table 29 Mill (BAB): period 7 pottery, by phase and by date-range (based on number of fragments)

	Abandonment %	Post-medieval %
Roman	59	41
Medieval	84	16
Postmedieval (Fl00-109, F112)	3	97

Dating the pottery is difficult. In contrast to the church, there is no site evidence for early post-medieval, that is later fifteenth/early sixteenth century, wares, with the exception of one sherd of Cistercian type from the later phase. This almost certainly indicates the abandonment of the mill by the late medieval period. The presence of very hard, sandy jugs, which have some similarities to Midland Purple ware fabrics but not the full range of forms, may suggest a later fourteenth-century date, extending into the fifteenth century, for this material. Two sherds of Midland Purple type occurred in the abandonment phase; these two sherds are not diagnostic but would suggest a date in the fifteenth century. The abandonment phase did include a small quantity of - intrusive - late post-medieval pottery.

The late post-medieval pottery in domestic forms includes late stoneware, black glaze, transfer-printed, and other decorated wares. With the possible exception of some of the black-glazed sherds (*c* seventeenth to nineteenth century), the material dates to either the nineteenth or even the early twentieth centuries. A tin-glazed vessel (seventeenth to eighteenth century, probably first half of the eighteenth century) and a slipware dish (second half of the seventeenth to first half of the eighteenth century) attest to a smaller amount of earlier pottery mixed in with the later dump.

The valley transect (BAE) assemblage

Tables 30 and 31

The pottery from the valley transect is similar to that from the mill; there were 120 sherds of pottery from BAE, weighing 2.340kg.

Medieval

With the exception of two Roman sherds, the medieval pottery from the transect had generally more jugs and later fabrics than the mill assemblage. This dominance is partly a reflection of the occurrence of two jug part profiles, one in an orange sandy fabric (Fig 70 no. 58) and the lower part of a jug in a light-bodied sandy glazed fabric (over-fired ?F16). The former vessel may date to the later thirteenth or more likely fourteenth century (from context 95, assigned to period 5-6), the latter jug possibly to the later thirteenth or fourteenth centuries (from context 90, period 3-4). There are

Table 30 Valley transect (BAE): pottery distribution, by period and by fabric/fabric group, by number of fragments and by weight(g)

	Fabric	Period 1		2		3 to 4		5 to 6		7		Total	
		no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt
Roman	Greyware F2	-	-	-	-	-	-	1	8	-	-	1	8
	Severn valley F10	-	-	-	-	-	-	-	-	1	5	1	5
Medieval	Red-brown sandy F20, F25, F26, F30, F35, F40	2	13	-	-	3	30	25	398	9	149	39	590
	Hard fine sandy F36, F41, F49	-	-	-	-	1	10	4	78	-	-	5	88
	Orange sandy F8, F9, F17	-	-	-	-	-	-	20	471	2	44	22	515
	Light-bodied sandy glazed F14, F16, F50, F51	-	-	-	-	26	902	8	65	-	-	34	967
	Coarse orange sandy F7	-	-	-	-	-	-	-	-	1	3	1	3
Post-medieval	Transfer-printed F100	-	-	-	-	-	-	-	-	1	1	1	1
	Stoneware, late F101	-	-	-	-	-	-	-	-	3	60	3	60
	Slipware F102	-	-	-	-	-	-	-	-	1	12	1	12
	Black-glazed F103	-	-	-	-	-	-	1	49	1	3	2	52
	Miscellaneous 'whiteware F104	-	-	-	-	-	-	-	-	2	2	2	2
	Yellow ware, late F105	-	-	-	-	-	-	-	-	3	9	3	9
	Miscellaneous, late F108	-	-	-	-	-	-	-	-	3	8	3	8
	Orange, self-coloured glaze F110	-	-	-	-	-	-	-	-	1	19	1	19
	Mottled/streaked glaze F111	-	-	-	-	-	-	-	-	1	1	1	1
Total		2	13	-	-	30	942	59	1069	29	316	120	2340

also some red-brown sandy fabrics, which occur on the mill site from the later twelfth century (see above): the sherds in period 1 came from a context whose surface was exposed at the start of period 2, when the material started to appear in BAB; these fabrics also occurred in periods 3-4 and 5-6. Of interest were two cooking vessels with holes pierced in their side walls (contexts 115 and 88, period 5-6) (Fig 70 nos 56-7) (see below, 'Conclusion', for a possible interpretation of these vessels).

Post-medieval

The BAE assemblage lacked any definite early post-medieval wares; it is additional evidence for the absence of activity in this part of the valley at that time.

The small amount of post-medieval pottery was similar to material recovered from BAB. With the exception of a few sherds dating to the late seventeenth or first half of the eighteenth centuries, the pottery is nineteenth-century or later in date. (The single sherd of F103 from 84, period 5-6, is intrusive.)

The tail race (BAH) assemblage

Tables 32 and 33

There were seventeen sherds of pottery from BAH, weighing 0.247kg and, with one exception (Roman), all were medieval and probably dated primarily to the thirteenth century. Fabrics were comparable with those from BAB, with examples of both orange sandy fabrics and light-bodied sandy glazed represented.

The three pottery-bearing contexts were fills of one ditch, which is interpreted as the tail race for the period 3, and probably the period 4, mill. Trying to connect the stratification of BAB with BAH (because there is no internal dating other than pot from BAH), all that can be said is that all three contexts are period 3-4. The contexts were all silt levels. The earliest was 21, followed by 17

Table 31 Valley transect (BAE): pottery distribution, by form and by fabric/fabric group, by number of fragments and by weight(g)

	Fabric	Forms Cooking pot		Jug		Pot - general		Hollow-ware		Flatware		Total	
		no.	wt	no.	wt	no.	wt	no.	wt	no.	wt	no.	wt
Roman	Greyware F2	-	-	-	-	1	8	-	-	-	-	1	8
	Severn valley FlO	-	-	-	-	1	5	-	-	-	-	1	5
Medieval	Red-brown sandy F20, F25, F26, F30, F35, F40	21	301	1	68	17	221	-	-	-	-	39	590
	Hard fine sandy F36, F41, F49	-	-	2	51	3	37	-	-	-	-	5	88
	Orange sandy F8, F9, F17	1	59	16	388	5	68	-	-	-	-	22	515
	Light-bodied sandy glazed F14, F16. F50, F51	3	4	31	963			-	-	-	-	34	967
	Coarse orange sandy F7	-	-	-	-	1	3	-	-	-	-	1	3
Post-medieval	Transfer-printed F100	-	-	-	-	1	1	-	-	-	-	1	1
	Stoneware, late F101	-	-	-	-	1	15	2	45	-	-	3	60
	slipware F102	-	-	-	-			1	12	-	-	1	12
	Black-glazed F103	-	-	-	-			2	52	-	-	2	52
	Miscellaneous 'whiteware' F104	-	-	-	-	2	2	-	-	-	-	2	2
	Yellow ware, late F106	-	-	-	-	2	6	1	3	-	-	3	9
	Miscellaneous, late F108	-	-	-	-	2	4	-	-	1	4	3	8
	Orange, self-coloured glaze F110	-	-	-	-			1	19	-	-	1	19
	Mottled/streaked glaze F111	-	-	-	-			1	1	-	-	1	1
Total		25	364	50	1470	36	370	8	132	1	4	120	2340

and then 11; 11 contained most of the pottery (12 sherds) and a much wider range, including light-bodied sandy fabrics; 11 and 17 both contained hard grey sandy fabrics. The pottery would suggest that the uppermost silt (11) and probably the intermediate silt (17) are period 4.

Conclusion

BAB produced evidence for a broad pottery sequence, the main characteristics of which are as follows: (largely residual) Roman pottery, dominated by greyware, some of which is organic tempered; red-brown sandy fabrics, usually in baggy cooking pot forms, were the earliest medieval pottery from the site; and a slightly later introduction of glazed tablewares, primarily in jug forms, occurred in three broad types, that is orange sandy fabrics, light-bodied sandy glazed fabrics, and a smaller amount of sandy glazed fabrics. In the later periods there is evidence of change in both forms and fabrics, with an increase in harder fired, often oxidised fabrics; cooking pots becoming more globular in form, the jugs had more defined squat, wide-bodied shapes, and the variety of forms increased to include more bowls, as well as new forms such as pipkins and bottles or small jugs. With the exception of a few probable eighteenth-century sherds, all the post-medieval material dates to the nineteenth or early twentieth centuries.

Overall the range of forms is typical of a domestic assemblage. Perhaps if industrial use occurred, standard forms may have been used, although no visible residue or unusual wear was found to substantiate this. However, two crucible rim sherds were found in the area opened in 1967-8 north and east of BAB (Fig 70 nos 59-60). Two vessels from the valley transect were unusual in having holes pierced in the sides of the vessels (Fig 70 nos 56-7). Roman pots with similar holes have been recovered from Pompeii and have been interpreted as containers for growing grafted trees and shrubs; modern Pompeians still use similar vessels for the

Table 32 Tail race (BAH): pottery distribution, by context and by fabric/fabric group, by number of fragments and by weight (g)

	Fabric	Period 3-4 Context 21		Context 17		Context 11		Total	
		no.	wt	no.	wt	no.	wt	no.	wt
Roman	Greyware F1	-	-	-	-	1	7	1	7
Medieval	Red-brown sandy F20	1	18	-	14	1	5	3	37
	Orange sandy F8, F9	1	7	-	21	3	59	5	87
	Hard grey sandy F38	-	-	-	22	1	10	2	32
	Hard fine sandy F36	-	-	-	-	1	13	1	13
	Light-bodied sandy glazed F16	-	-	-	-	3	49	3	49
	Sandy glazed F22	-	-	-	-	1	5	1	5
	Coarse orange sandy F7	-	-	-	-	1	17	1	17
Total		2	25	3	57	12	165	17	247

Table 33 Tail race (BAH): pottery distribution, by form and by fabric/fabric group, by number of fragments and by weight (g)

	Fabric	Forms Cooking pot		Jug		Pot - general		Total	
		no.	wt	no.	wt	no.	wt	no.	wt
Roman	Greyware F1	-	-	-	-	1	7	1	7
Medieval	Red-brown sandy F20	3	37	-	-	-	-	3	37
	Hard grey sandy F38	2	32	-	-	-	-	2	32
	Hard fine sandy F36	1	13	-	-	-	-	1	13
	Orange sandy F8, F9	1	6	3	74	1	7	5	87
	Light-bodied sandy glazed F16	-	-	3	49	-	-	3	49
	Sandy glazed F22	-	-	1	5	-	-	1	5
	Coarse orange sandy F7	-	-	-	-	1	17	1	17
Total		7	88	7	128	3	31	17	247

same purpose (Jashemski 1979, 239-40).

The proportions of cooking pots and jugs appear to be remarkably constant throughout, with the exception of the apparent decline in jugs in period 5. The tail race seems to have been used as a general dumping area, except in period 4, when the bypass channel was used to dump, in particular, cooking pots, and jugs were disposed of differently, in different locations.

It is likely that the pottery from the site is from a number of sources. While it is possible that the red-brown sandy, cooking vessel fabrics are of local origin, the glazed jug fabrics must be seen as coming from a variety of locations. This may also be true of a number of fabrics which occur as only a few or even as single vessels. Sourcing these fabrics remains problematic. Examination and discussion of potential origins at sites such as Alcester (pers comm Stephanie Bakhai), Chilvers Coton (pers comm Keith Scott), and of regional comparison at centres such as Worcester (pers comm Victoria Buteux) and Coventry (pers comm Mike Stokes) has highlighted some similarities, particularly with the jugs, but no evidence for direct attribution to a distinct source emerged.

There are no similarities with such well-known types and centres as Brill or Oxford (with the exception of a single shelly fabric sherd), and only an isolated sherd possibly from Deritend in the Birmingham area. More locally, there is documentary evidence for potters at Inkberrow in the later thirteenth century but no products are known (Hurst 1990). The most likely ‘non-local’ sources are Alcester, Chilvers Coton, and Coventry, but the evidence is inconclusive.

The illustrated fabric and form type series

Figures 66-70

The division into fabrics was based on the criteria of colour, inclusion type(s), hardness, and fracture. The fabrics were described by reference to Peacock (1977) and the Lincoln fabricing system (Gilmour 1988, 59-63). Each fabric category was checked with the aid of a x 20 binocular microscope, and white inclusions were tested for reaction to acid. Details of each vessel were recorded on individual context summary sheets. Information on each vessel included vessel form (where known), glaze, decoration, and individual features of rims, bases, and handles. Illustrated sherds are separately numbered in Figures 66-70.

The terms ‘fabric’ and ‘ware’ are both used here (Gilmour 1988, 59-63). A ‘ware’ is a broad category which includes a number of fabrics and a range of vessel forms; it may cover a single production centre or a more broadly based tradition, such as Sever-n valley ware, or Yellow ware. A fabric is a grouping based upon a collection of sherds, which are visually distinct from other sherds; it usually relates to an associated collection of forms, for example cooking pots, or jugs. To a certain extent a fabric is an artificial division, but it does provide a method of attempting to classify pottery from a number of sources.

Numbers 1 to 55 inclusive of the illustrated pottery are from the mill and for these the context is given, but the site code and 2m square are omitted (thus, B1132).

Roman

Figure 66 no. 1

226 sherds of Roman pottery weighing 3.3kg were recovered from BAB and occurred in significant quantities throughout the stratification. Most date to either the first or second centuries AD. Much was residual, but in period 1 (phase 3) a largely complete carinated jar was found (Fig 66 no. 1). Fifteen fabrics were identified, falling into three groups: Severn valley ware; a probable local greyware, some of which is organic tempered; and a small number of grey or black sandy fabrics which include the carinated jar. The concentration of organic tempered greyware (rather than a more mixed group, and a larger proportion of Severn valley ware) has been suggested by Paul Booth (pers comm) as a possible indication of a local source for this organic tempered greyware. The carinated jar probably dates to the late first century AD and may also be a local product; it is a devolved ‘Belgic’ beaker type which occurs in the Avon valley at sites such as Tiddington, Wasperton, and, further south, Beckford (pers comm Paul Booth).

With the exception of the carinated jar, most of the forms are either cooking or storage vessels with out-turned or hooked rims. Little decoration is evident, only simple cordons or burnishing on the rim and/or upper pot body.

1 Carinated jar with a simple outturned rim, mid-body carination, and a flat, grooved base. The upper body is burnished, with dark grey surfaces, grey margins, and a red-brown core. (B1132, per 1, fabric 31)

Medieval

Stamford ware

Not illustrated

There were only six sherds of Stamford ware, F13, which were identified by Howard Leach (pers comm); they included five unglazed sherds in fabric A (Kilmurry 1980, 8-9), and a green-glazed jug or pitcher base in fabric B (Kilmurry 1980,8-9).

Red-brown sandy fabrics

Figures 66 nos 2-22, 70 nos 56-7

This is the dominant fabric category (BAB, BAE, BAH) - and the dominant medieval fabric group - and as such probably represents a local product, especially as it is essentially a cooking vessel group. Although the pottery betrays some visual similarities in fabric to the Alcester kiln waste, it is at present felt unlikely that it is from this source (pers comm Stephanie Rakhai). In terms of rim forms and shapes, the closest parallels for this pottery in the Alcester kilns material are with the cooking vessels.

The Alcester kiln material (derived from waster pits; no kiln has yet been found) is dated to the twelfth to thirteenth century on the evidence of tripod pitchers (pers comm Stephanie Rakhai). The similarity of forms could suggest the Bordesley pottery might be from Alcester, but such forms may reflect a very broad trend and the Bordesley material could equally be from a different and/or more local source.

Seven fabrics were identified: F20, F24, F25, F26, F30, F35, and F40. Together they form a cohesive group in both general fabric character and vessel type. As such, they are considered as a ware, rather than simply a fabric category.

Fabric

Fairly hard with a hackly, laminar fracture, the fabric has oxidised red-brown or brown surfaces and outer margins, often sooted to a dark brown or dark grey colour on the vessel exterior. The core is grey or grey-brown. The main inclusion is common, well-sorted sub-rounded/sub-angular quartz in a range 0.3-0.6mm. There are sparse, dull red-brown inclusions in a range 0.1-1.5+mm, and organic material in the poorly sorted fabrics (eg fabric 25).

Fabric 30 is a general ‘ragbag’ of a sandy fabric, belonging to the ware group. Fabrics 20 and 25 are closely related: Fabric 20 has relatively more, sparse, sub-angular quartz in a range 0.4-0.8mm, while Fabric 25 has relatively more, sparse, soft, pale grey, platy inclusions (no reaction with acid; ?clay) in a range 0.4-1.5+mm. Fabric 26 may also fit into this group.

The other fabrics in this group are much more distinct, and may be from other sources. Fabric 24 has a very distinctive background of finer quartz sand (0.1-0.3mm), while Fabric 35 also has smaller grain size, but slightly larger (0.3-0.5mm) than Fabric 24. Fabric 40 is a minor fabric, and is harder fired, better made, firing a paler grey colour. These last three fabrics may be distinct from the F20/F25/F30 group, but this is the closest grouping.

Forms

Vessels in this ware are exclusively baggy-shaped cooking pots with fairly straight sides, sagging bases, and upright sloping rims (Fig 66 nos 2-15, 18-19, 21-2). There is limited evidence for some rim change although residuality (see above) confuses the picture. Rims may become everted, with a less pronounced vessel neck (Fig 66 nos 16-17). Some of the fabrics have examples of different rims. Fabric 24 includes an internally recessed cooking pot rim (Fig 66 no. 10) and from period 7 a thickened rounded example (Fig 66 no. 20). In Fabric 30 from period 1 there is a simple bowl rim which may be Roman or medieval in date, but in either case should be considered on the basis of the stratification as intrusive (see above).

2 Cooking pot rim with pale grey, grey, and red-brown surfaces and a pale grey core. (A82, per 2, fabric 25)

3 Cooking pot rim with a grey surface, red-brown margins, and a grey core. (A159, per 3, fabric 20)

4 Cooking pot rim with a sooted grey-brown surface, red-brown margins, and a grey core. (A118, per 3, fabric 25)

5 Cooking pot rim with a brown sooted surface and a grey core. (A159, per 3, fabric 30)

6 Cooking pot rim with brown surfaces, red-brown margins, and a pale grey core. (B523, per 4, fabric 20)

7 Cooking pot rim with red-brown surfaces and margins, and a grey core. (B626, per 4, fabric 20)

8 Cooking pot with a brown sooted exterior, red-brown interior and margins, and a grey core. (A156, per 4, fabric 20)

9 Cooking pot/jar rim with orange surfaces and margins and a pale grey core. The rim type is unusual for this ware. (D569, per 4, fabric 20)

10 cooking pot rim with dark grey surfaces and core. (E771, per 4, fabric 24)

11 Cooking pot/jar rim with orange surfaces and grey core. (C693, per 4, fabric 26)

12 Cooking pot rim with orange surfaces and a grey core. (B523, per 4, fabric 25)

13 Cooking pot with a grey-brown sooted exterior, grey interior, red-brown margins, and a pale grey core. (E871, per 4, E817, per 5, E830, per 6, fabric 26)

14 Cooking pot rim with sooted grey surfaces and a red-brown core. (E435, per 4, fabric 30)

15 Cooking pot rim with dark grey surfaces and margins, and a red-brown core. (D576. per 4, fabric 30)

16 Cooking pot with a brown sooted exterior, red-brown interior and margins, and a grey core. (E838, per 5, fabric 20)

17 Cooking pot with a pulled lip, sooted brown exterior, orange surface and margins and a grey core. (C359, per 5, fabric 25)

18 Cooking pot with sooted brown exterior, red-brown interior and margins, and a grey core. (E454, per 6, fabric 26)

19 Cooking pot rim with a grey surface, red-brown margins, and a grey core. (E364, per 7, fabric 20)

20 Cooking pot rim in a grey-brown fabric with a sooted exterior. (C178, per 7, fabric 24)

21 Cooking pot rim with a d-orange exterior, dark grey

interior surface, and a pale grey core. (B94, B101, per 7, fabric 25)

22 cooking pot with a sooted grey-brown exterior surface, red-brown margins, and a grey core, (E364, per 7, fabric 25)

56 Base with two holes in body wall. (BAE88, per 5-6, fabric 20)

57 Base with two holes in body wall. (BAE115, per 5-6, fabric 26)

Brown sandy fabric

Figure 67 nos 23-6

Represented by a single fabric, F33, a small number of relatively complete cooking pots and bowls were found.

Fabric
Fairly hard with a finely irregular fracture, the fabric is oxidised with brown surfaces and margins and a grey core. The main inclusion is common, well-sorted sub-rounded/sub-angular quartz in a range 0.2-0.4mm, and occasionally larger grains up to 1.0mm in size. There is sparse, dull red-brown, sub-rounded/rounded (?iron/grog) in a range 0.1-0.4mm and grey laminar, possibly organic, matter, 0.6-3.0mm in size (most 1.0+mm).

Glaze
Thin, soft, yellow-green glaze.

Forms
Cooking pots or jars and wide-mouthed bowls are the only vessels in this fabric. The pots are large, globular shapes with thickened, sloping rims (Fig 67 nos 23-4), with some use of applied and thumbed vertical strip decoration. The bowls are wide-mouthed with sagging, trimmed bases and neat, thickened, sloping rims (Fig 67 no. 28).

23 Cooking pot with red-brown surfaces and a pale grey core. There is a thin white slip, with evidence of an eroded glaze. Decoration is vertical applied and thumbed strips. (B1103, A156, per 4, fabric 33)

24 Cooking pot with sooted dark grey exterior, brown interior, red-brown margins, and a grey core. (E871, per 4, fabric 33)

25 Bowl with brown surfaces, red-brown margins, and a pale grey core. Sooted externally. (A156, per 4, fabric 33)

26 Cooking pot with orange surfaces and core, sooted externally. (A53, per 5, fabric 33)

Hard, grey sandy fabric

Figure 67 no. 27

A single fabric, F38, represented by very few vessels.

Fabric
Hard with a finely uneven fracture, firing grey with grey surfaces and margins and a red-brown core. The main inclusion is common, well-sorted sub-rounded/sub-angular quartz in a range 0.1-0.3mm, and occasional grains up to 0.6mm. There are also sparse, rounded dull red (?iron) inclusions, 0.1+mm, mostly 0.1-0.4mm, and dull cream/pale grey laminar inclusions, 3.0-4.0+mm in size (no reaction with acid).

Forms
The only form is that of a globular-shaped cooking pot with a neat angular rim and sagging base (Fig 67 no. 27).

27 Cooking pot with sooted grey exterior, brown interior, and a grey core. (A156, per 4, fabric 38)

Hard, fine sandy fabric

Figure 67 nos 28-30

Three fabrics were identified, F36, F41, and F49, all of which are distinct.

Hard, with sparse, large quartz, F36

Fabric
Fairly hard with a slightly uneven fracture, the fabric is oxidised with red-brown surfaces and margins and a grey core. The main inclusion is sparse, poorly-sorted rounded or sub-rounded quartz in a range from 0.4-50+mm. There are also sparse, grey laminar inclusions, 0.2-4.0+mm, possibly organic, and sparse, red-brown, rounded, probably iron, inclusions, 0.2-4.0mm in size.

Glaze
Dull, yellow-green glaze.

Forms
Forms are unusual in this fabric and include a pipkin rim (Fig 67 no. 29) and an uncertain vessel type with an applied foot or handle (Fig 67 no. 28).

Fabric 41 is a fairly hard fabric, with a finely irregular fracture, with red surfaces, orange margins, and grey core; it is a very fine fabric with sparse quartz, 0.2-0.4mm in size. It occurs as either body sherds (including jug-type) or, a single example, a lid-seated jar (Fig 67 no. 30).

Fabric 49 is a fairly hard fabric, with a finely irregular fracture, with orange core, outer margin and surface, dark grey inner margin and surface; it is a fine micaceous fabric with sparse sub-rounded/sub-angular quartz grains, 0.1-0.3mm in size. Fabric 49 occurs only from the valley transect.

28 Uncertain form with an applied handle/foot with slash decoration. The outer surface is sooted, with red-brown surfaces and margins and a grey core. (A157, per 4, fabric 36)

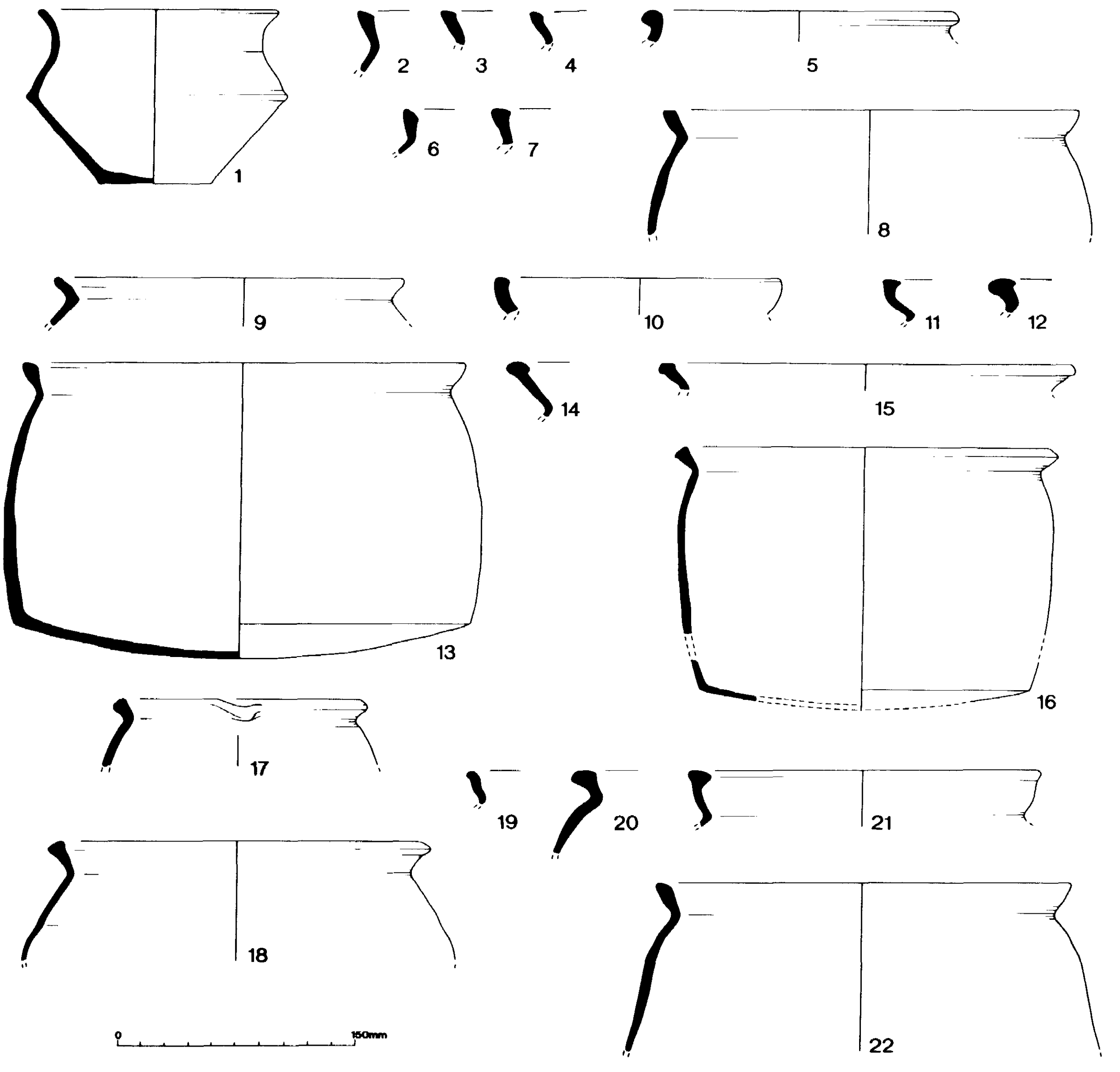


Figure 66 Pottery 1: nos 1-22

29 Pipkin with an angular rim and pulled, hooked handle. There is a dull, ?burnt green-brown glaze on the exterior, with red-brown interior surfaces and margins, and a grey core. (A156, per 4, fabric 36)

30 Jar with an internally recessed rim, horizontal combed lines on the shoulder, and a thin glossy mottled green glaze. Surfaces are pale brown with a grey core. (C179, E185, per 7, fabric 41)

Orange sandy fabrics

Figures 67 nos 31-4, 68 nos 35-7, 70 no. 58

Three fabrics were identified, F8, F9, and F17, all of which may have separate origins. These fabrics were not paralleled at Alcester. There is some similarity between these orange sandy fabrics (especially F9) and orange sandy material from Coventry, but not really in decoration or form (Coventry: Wright 1982, 121-4, types 5 and 7 and references to Kirby Corner, Canley, wasters; Redknap 1985,69-74, 'Cannon Park').

Orange sandy, F9

Fabric
Fairly hard with a finely irregular fracture, firing orange with pale pink or orange-pink surfaces, and an orange core. The main inclusion is moderate to common, well-sorted sub-rounded/sub-angular quartz mostly in a range 0.2-0.4mm, but ranging up to 0.8mm. There are also sparse, sub-rounded/rounded dull red (?iron/grog) inclusions in a range 0.2-0.5mm and cream, sub-angular inclusions (no reaction with acid) 0.1-1.0+mm in size.

Glaze
Examples include the use of a white slip beneath the glaze. Glaze colour ranges from an orange self-coloured glaze to a soft yellow-green to a copper-rich mottled green.

Forms
Examples of cooking vessels and jugs occur in the ware, with a few later bottles. Information on the forms is limited, although there is an example of a jug with body rilling and a thickened rim from the valley transect (Fig 70 no. 58). Limited jug decoration consists of either incised horizontal lines or neck cordons. Other vessels include cooking vessel body sherds and a jar rim (Fig 67 no. 34).

Micaceous, fine orange sandy, F17

Fabric
Fairly hard with a fine irregular fracture, firing orange with orange or orange-brown surfaces and margins and an orange core. Occasionally there is a dull red exterior surface. Noticeably micaceous, the main inclusion is common, well-sorted sub-rounded/sub-angular quartz in a range 0.1-0.3mm, with sparse, larger grains in a range 0.4-0.6mm. There are also sparse, sub-rounded/rounded red-brown (?iron/grog) inclusions in a range 0.1-0.3mm, some 1.0+mm, and sparse, sub-rounded off-white/cream inclusions (no reaction with acid) of variable size, 0.1-2.0+mm.

Glaze
Thin, glossy, copper-rich green or mottled green glaze.

Forms
The most common form in this fabric is a jug (Figs 67 no. 33, 68 nos 36-7) with occasional examples of other vessels such as small bottles (Fig 67 no. 32). The jugs are wide-bodied, squat shapes with short necks, simple out-turned rims, and fairly thick strap handles. Decoration is confined to neck cordons and bands of combed horizontal or wavy lines. There are examples of small rod handles, being possibly from small jugs or bottles.

Hard, pink-orange sandy, F8

Fabric
Hard to very hard with a fairly smooth fracture, firing a pink-orange, with pale orange or orange-pink surfaces, very pale orange, cream or orange-pink outer margins, and either a pale grey or cream/pink core. The main inclusion is moderate, well-sorted sub-rounded/sub-angular quartz in a range 0.3-0.5mm. There are also sparse rounded dull red (?iron/grog) inclusions, 0.3-1.8+mm in size, and dull white/cream rounded inclusions (no reaction with acid), 0.2-0.6mm in size.

Glaze
Possible iron glaze which is thin, patchy and strongly spotted with brown iron staining. The colour ranges from yellow-brown to a dark olive green.

Forms
Jugs are the only vessel in this fabric (Fig 68 no. 35). They are wide-bodied, probably squat forms, with short necks, simple rims, and occasional slash decoration on the strap handles. Vessels have neck cordons.

31 Jug rim and strap handle stub in an orange fabric, with traces of white slip beneath an eroded orange glaze. (B626, per 4. fabric 9)

32 Small jug or bottle in an orange fabric and eroded basal edge. (C474, per 5, fabric 17)

33 Jug with strap handle and simple out-turned rim in an orange fabric. (C684, per 6, fabric 17)

34 Jar in an orange fabric. (E289, per 7, fabric 9)

35 Jug with a slashed strap handle and simple rim. Pink-orange surfaces and a pale grey core. There is a thin, brown-green glaze with brown iron spotting on the main body. (B104, per 7, fabric 8)

36 Jug with a simple rim and strap handle in an orange fabric with a red external surface. There is a thin, glossy, orange-

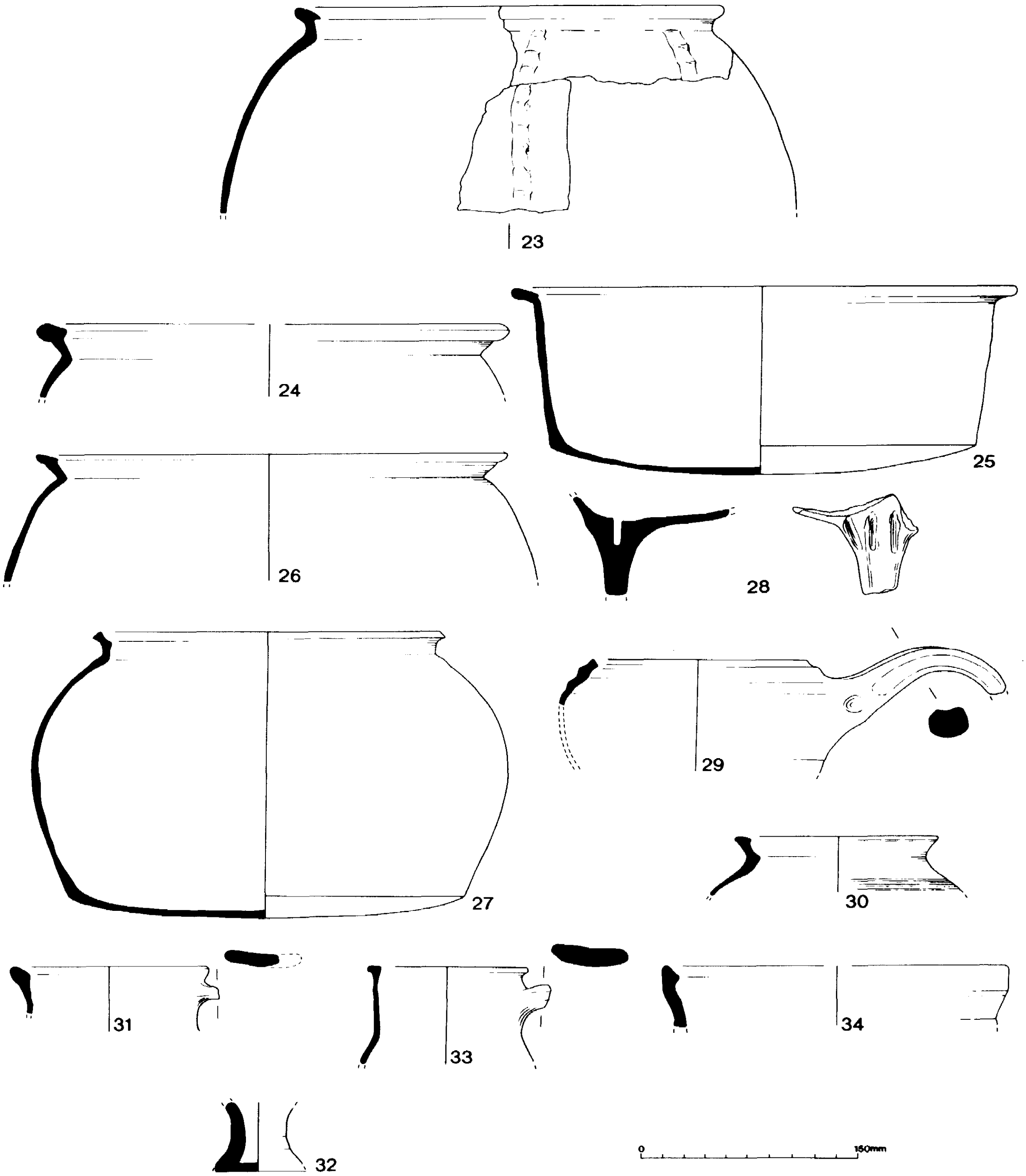


Figure 67 Pottery 2: nos 23-34

brown mottled green glaze from the shoulder to mid-body. (B101, per 7, fabric ?17)

37 Jug with a simple rim and strap handle in an orange fabric. Slip and green glaze on neck. (B101, per 7, fabric 17)

58 Jug with an inturned rim, strap handle, and ribbed body. The fabric is orange with a white slip and an eroded, copper-rich green glaze. The handle is thumbed, with centrally incised marks, and there are bands of incised lines on the pot body. (BAE95, per 5-6, fabric 9)

Light-bodied sandy glazed fabrics

Figure 68 nos 38-41

Five fabrics were identified, F14, F15, F16, F50, and F51, and of these fabric 16 was dominant, with only a few jug sherds in the other fabrics. Jugs were the main form in fabric 16.

The source(s) of these light-bodied sandy glazed fabrics has not been established. One might have expected that some of this material should have originated from Chilvers Coton (Nuneaton) (see Mayes and Scott 1984), but none has so far been firmly attributed to this source. Nuneaton products do occur at both Alcester and Warwick (pers comm Stephanie Rakhai). Fabric 14 has been suggested as broadly similar to material found in Worcester, but the source is unknown (pers comm Victoria Buteux).

Light-bodied sandy, glazed, F16

Fabric
Hard with an uneven fracture, the fabric is oxidised, firing in a range from pale cream to off-white, with cream, off-white or pale grey surfaces and margins, and a pale grey core. The main inclusion is common, well-sorted sub-rounded/sub-angular quartz in a range 0.2-0.4mm. There are also sparse, dull crumbly brown (?iron) inclusions, 0.1-1.0+mm in size.

Glaze
The glaze is thin, patchy, dull and usually yellow-green, occurring from the neck to the lower body.

Forms
Jugs dominate (Fig 68 nos 38-40) and are wide-bodied with short necks, simple out-turned rims, strap handles, and sagging thumbed bases. Decoration is in simple designs using either square toothed rouletting or combing in horizontal bands or as zones of end combing. There are a few bowls in this fabric (Fig 68 no. 41).

The other four fabrics, F14, F15, F50, and F51, occur as a small number of jug body or bowl body sherds. These fabrics are hard with a colour range similar to that of F16, that is off-white and cream to pale pink and pale grey.

Fabrics 14 and 15 have a smaller quartz grain size than F16, with iron-coated quartz. Fabric 14 is hard, with a slightly irregular fracture, with common, well-sorted sub-rounded/sub-angular quartz, mostly 0.1-0.2mm but occasionally 0.5+mm. There are also sparse, pink, iron-concretions of fine quartz (iron-coated quartz). Fabric 15 is very similar to and merges with fabric 14 (F15 was isolated during processing of the pottery).

Fabric 50 is a hard, sandy fabric, with a finely irregular fracture and the smaller quartz grain size characteristic of F14 and F15, but without the iron-coated quartz of F14 and F15. The main inclusion is common, well-sorted sub-rounded/sub-angular quartz, mostly 0.1-0.3mm and a few 0.5-0.6+mm; there are also sparse, rounded, dull crumbly brown (?iron) inclusions.

Fabric 51 is similar to F15 but the quartz is sparse in comparison.

38 Jug with a thumbed base, a simple rim, cream/pale grey surfaces, and a pale grey core. Soft, thin green glaze from neck to lower body. Bands of combed incised horizontal lines decorate the pot from neck to lower body. (B165, per 1, B631, per 3, B608, B626, B644, B646, per 4, B101, per 7, fabric 16)

39 Wide-bodied jug with a sagging thumbed base and strap handle with incised line decoration. It has cream and pale grey surfaces and a pale grey core. There is a thin, dark grey glaze from the neck to lower body. Bands of combed incised horizontal lines alternate with zones of end combing (five prongs) on the pot body. (B631, B1107, per 3, B608, B643, B644, B646, B652, per 4, B101, per 7, fabric 16)

40 Wide-bodied jug with a sagging thumbed base, simple out-turned rim, ream surfaces, and a pale grey core. Soft, thin yellow-green glaze from nick to lower body. Diagonal intersecting bands of square toothed rouletting on the main pot body are enclosed by zones of horizontal rouletting on the shoulder an lower vessel body. (B608, B626, B643, B644, B646, per 4, B101, per 7, fabric 16)

41 Bowl rim thickened and internally recessed with a cream surface, off-white margins, and a grey core. (E360, per 6, fabric 16)

Sandy glazed fabrics

Figure 69 nos 42-4

Five fabrics were identified, F21, F22, F32, F37, and F42, representing single or only a few jug sherds in each fabric from a number of sources.

Micaceous sandy glazed, F21, is hard, with a finely irregular fracture, oxidised, orange or pale brown, with a background of very fine quartz and some visible grains (probably sub-rounded/sub-angular), in a range 0.2-0.4mm. The jug fragments have a yellow-green glaze.

Red sandy glazed, F22, is hard, with a finely irregular fracture, oxidised, red or red-orange, with common fine rounded quartz in a range 0.1-0.3mm and sparse sub-angular white inclusions (no reaction with acid), in a range 0.1-4.0mm. The jug sherds have body rilling and a thin mottled green glaze.

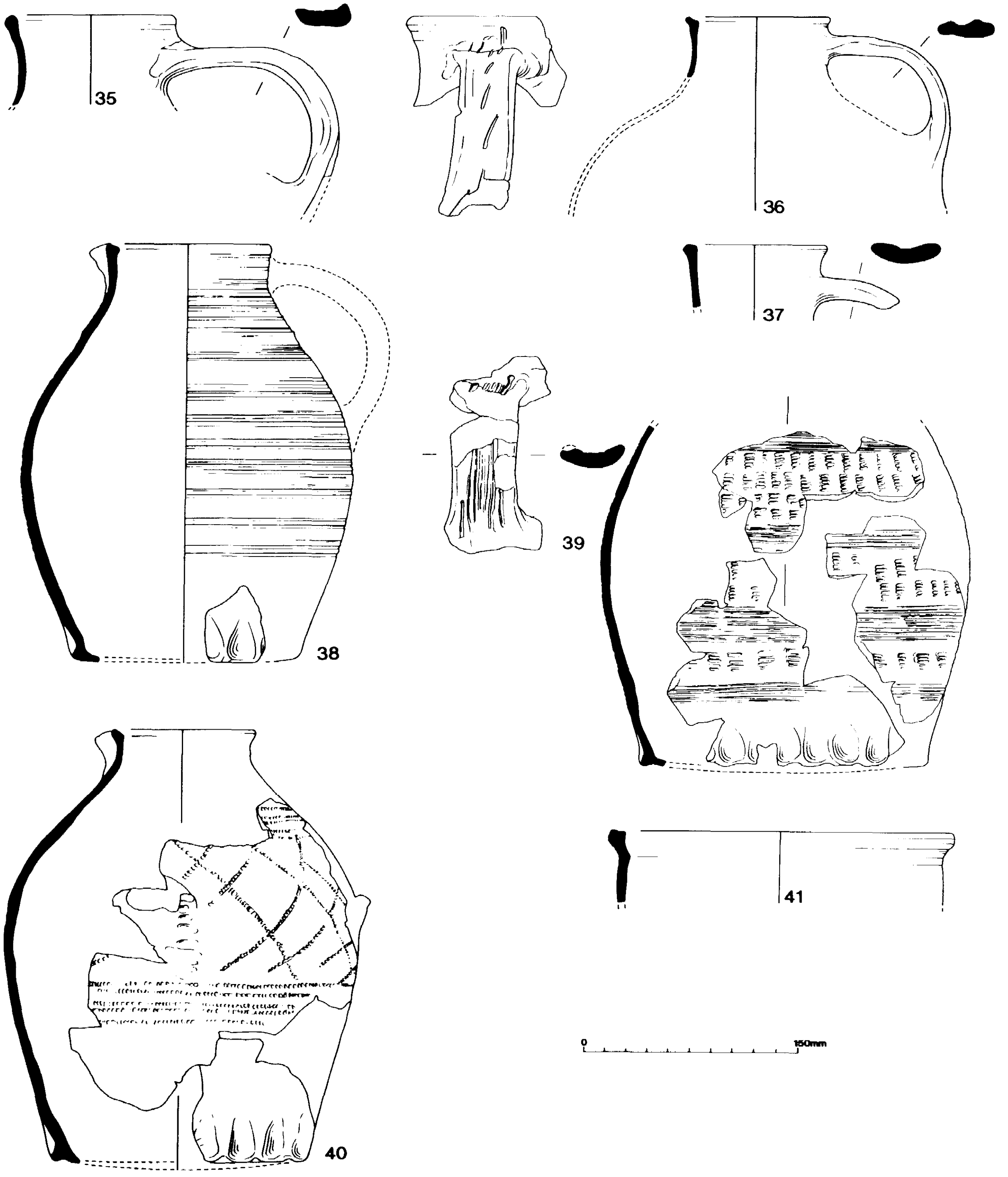


Figure 68 Pottery 3: nos 35–41

Sandy glazed, F32, is hard, with a finely irregular fracture, with a grey core, orange interior, and a thick glossy dark green exterior glaze. The main inclusion is common, well-sorted sub-rounded/sub-angular quartz, mostly in a range 0.1-0.3mm, but some 0.8-1.0mm. The fabric is represented by a single highly decorated jug with 'frilled' base (Fig 69 no. 42).

Sandy glazed, F37, is hard, with an uneven fracture, red-brown surfaces, and grey core, with common, moderately sorted sub-rounded/sub-angular quartz, mostly 0.4-0.6mm in size, but with a range of 0.4-1.0mm. F37 is distinguished by its larger sized quartz grains from F32. The fabric is represented by jug body sherds and a decorated strap handle (Fig 69 no. 43).

Sandy glazed, F42, is fairly hard, with an uneven fracture, buff surfaces and a grey core, with moderate sub-rounded/sub-angular quartz, mostly 0.4-0.6mm in size, but with a range of 0.3-0.8mm. A yellow-green glaze is found on a small number of (probably jug) body sherds and a single inturned rim (Fig 69 no. 44). Forms in this fabric are fragmentary and so evidence of jug forms is less conclusive than in other instances.

42 Tall, wide-bodied jug with a 'frilled' sagging base, orange interior, and grey core. There is a dark green, thick, glossy glaze from the base to the upper body. A complex applied and incised design occurs over the main pot body. (A158, per 3, A156, per 4, fabric 32)

43 Jug handle with a red-orange surface and grey core. There is a little sparse, thin, glossy brown-green glaze. There is a central incised line and notching on each handle edge. (B608, per 4, fabric 37)

44 Jug rim, with buff surfaces, a pale grey core, and spots of a yellow-green glaze. (8836, per 5, fabric 42)

Sandy, miscellaneous fabrics

Figure 69 nos 45-6

There are a small number of fabrics represented by only one or two vessels. Fabrics in this category include F39, F48, and F52 which were distinguished from the rest of the fabrics by colour, or the size of the quartz grains, or their frequency.

Fabric 39 is a reduced, coarse sandy fabric with quartz grain size larger than most of the sandy fabrics from the site. Hard, with an uneven fracture, firing grey, with brown outer margins and a dark grey core. The main inclusion is common, moderately sorted sub-angular/sub-rounded quartz, in a range 0.3-1.5+mm, most of which fall into 0.6-0.8mm.

Fabrics 48 and 52 are both fine, oxidised fabrics. Fabric 48 is a fine, buff sandy fabric, represented by a single vessel, in a distinct form, a long-neck cooking pot (Fig 69 no. 46). Hard, with a finely irregular fracture, with buff-orange surfaces and outer margins, and a grey core. The main inclusion is sparse, moderately sorted sub-rounded/rounded quartz, mostly 0.4-0.6mm but up to 1.0+mm.

Fabric 52 is fine, orange sandy, occurring as a cooking pot (Fig 69 no. 45). Hard, with an uneven fracture, with pale orange surfaces and an orange core. The main inclusion is sparse, moderately sorted sub-rounded/sub-angular quartz, mostly 0.1-0.3mm, but up to 0.8-1.0+mm. The surface of the vessel is noticeably micaceous.

45 Cooking pot with orange surfaces and core. (A156, per 4, fabric 52)

46 Cooking pot with possible pulled rod handle stub and a sooted exterior. Pale yellow-brown surfaces and margins, and a dark grey core. (E448, per 5, E452, per 6, fabric 48)

Very hard, sandy fabrics

Figure 69 nos 47-8

Three fabrics were identified, F12, F28, and F34, all three of which are highly fired and occur primarily as jugs. F12 shows affinities with Midland Purple type (F112) in its fabric, but does not have the full range of forms, and shows some similarities with Malvern Chase ware. A late medieval date for this group seems probable. One small body sherd (period 7 abandonment), in a very fine sandy fabric classed as F12, with orange exterior margin and surface, grey interior margin and surface, and yellow-brown glaze, was distinguished from the rest of this group by the presence of white slip; a red fabric with white slip, identified as possibly Deritend (Birmingham) ware, has been found at Alcester.

Very hard, fine sandy, F12

Fabric
Very hard with a smooth fracture, the fabric has reduced grey or grey-brown surfaces and a red-brown core. The main inclusion is moderate, well-sorted sub-rounded/sub-angular quartz in a range 0.2-0.4mm, most being 0.2mm or less, but occasionally up to 0.6mm. There are sparse rounded, dull red (?iron) and dull white/cream rounded inclusions (no reaction with acid) in a range from 0.1 to 2-3+mm.

Glaze
The glaze is thick, treacly, being either dark brown or olive green in colour. The glaze occurs on the shoulder and main vessel body.

Forms
The only form is a wide-bodied, squat jug with short necks, simple rims and strap handles, some of which have slash decoration (Fig 69 nos 47-8). There is often a neck cordon.

Both fabrics 28 and 34 occur in similar shapes. Fabric 28 is sandier than both fabrics 12 and 34, with generally reduced surfaces. Fabric 12 also has

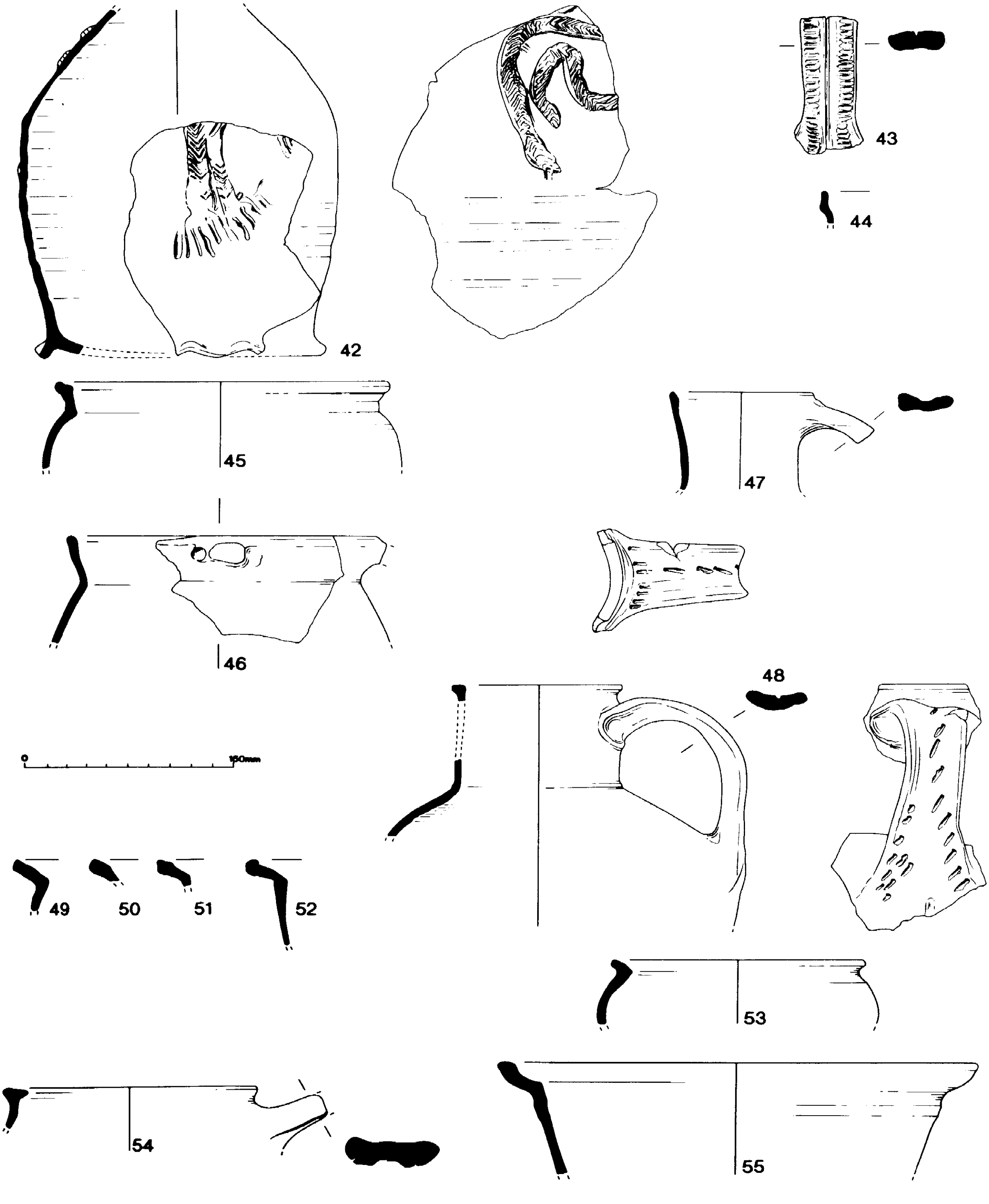


Figure 69 *Pottery 4: nos 42–55*

reduced surfaces. Fabric 34 is similar to F12, although slightly more sandy, but is an oxidised fabric, firing either pink or pale orange, with a pale grey core. Fabric 34 may be closely related to F12, but there was insufficient material to assign it definitely to F12; it may have links with F8.

47 Jug with simple strap handle, grey surfaces, and a red-brown core. Them is a streak of thick, treacly brown glaze on the neck. (C359, per 5, D202, per 7, fabric 12)

48 Jug with simple out-turned rim, strap handle with slash decoration and a cordon at the junction of the neck/shoulder. The surfaces are grey with a red-brown core and a thick brown-purple and dark green glossy glaze on the upper body. (E425, per 6, B66, E247, B101, per 7, fabric 12)

Coarse tempered, grey-brown fabrics

Figure 69 nos 49-52

Three fabrics were identified, F11, F27, and F29, of which the most common was F11, occurring as either cooking pots or bowls. The fabrics probably come from distinct sources. Fabric 11 is not identified as Malvern ware, although it does have some similarities with Malvern ware, a little of which has been found at Alcester.

Coarse tempered, F11

Fabric
Hard with a hackly, laminar fracture, the fabric has oxidised brown surfaces and margins and a dark grey core. The main inclusion is poorly-sorted sub-rounded, but often sub-angular, quartz with a background of well-sorted grains in a range 0.4-0.8mm and moderate poorly-sorted sub-angular grains in a wide range from 2.0-3.0+mm. There are a number of other inclusions, 2.0-3.0+mm, which may be from (unidentified) sedimentary rock fragments.

Forms
Wide-mouthed, baggy-shaped cooking vessels are the only forms in this fabric. There are examples of both bowls (Fig 69 nos 49, 51-2) and cooking pots (Fig 69 no. 50). Bases are sagging with occasional applied and thumbed decoration on the vessel body.

Coarse tempered, F27 and F29

There were very few cooking vessel body sherds in these two fabrics. Fabric 27 is a hard, reduced, quartz-tempered fabric, with brown to grey-brown surfaces and dark grey core, with moderate to common sub-rounded/rounded grains in a range 0.6-0.8mm. Fabric 29 is a fairly hard fabric with an uneven fracture, reduced with dark grey core and surfaces and red-brown margins, with sparse to moderate sub-angular/angular, possibly granitic, inclusions in a range 0.2-3.0mm (most 1.5-3.0mm).

49 Probable flanged bowl rim with finger grooves on upper sooted surface. Brown surfaces and a pale grey core. (C189, per 2, fabric 27)

50 Cooking pot rim with sooted grey exterior, brown interior, and grey core. (D585, per 4, fabric 11)

51 Probable bowl rim, sooted grey surfaces and core. (B650, per 4, fabric 11)

52 Bowl rim with brown surfaces, grey core, externally sooted. (A156, per 4, fabric 11)

Coarse orange sandy fabric

Figure 69 nos 53-5

A single fabric, F7, distinguished by being both very sandy and a 'very dirty' sandy fabric, and by the range of forms which seemed distinct from those in the orange sandy group.

Fabric
Hard with an uneven fabric, firing an oxidised red, or orange, with dark red-orange surfaces and an orange core. The main inclusion is common to abundant, moderately sorted sub-rounded/sub-angular quartz in a range 0.2-0.8mm, most within 0.4-0.6mm. There are also occasional, quartz sandstone fragments (ie clusters of sub-rounded./sub-angular quartz), 1.0+mm, and sparse to moderate sub-rounded/sub-angular, dull crumbly red-brown inclusions (?iron) in a range 0.3-5.0+mm.

Glaze
A small number of vessels have an internal 'swill' of thick, glossy green-brown, orange-edged glaze with spotted brown iron staining.

Forms
A number of vessel types occur in this fabric of which the most common are kitchen rather than tablewares. These include cooking pots (Fig 69 no. 53), pipkins (Fig 69 no. 54), and wide-mouthed bowls (Fig 69 no. 55). There are a few jugs, with examples of slash decoration on the strap handles and poorly applied, square tooth rouletting over the pot body.

53 Cooking pot in a red-orange fabric with a swill of orange-brown glaze on the vessel interior. (E255, per 7, fabric 7)

54 Pipkin with a thickened rim, a wide thumbed and incised pulled handle, pale brown surfaces, and an orange core. Sooted externally. (E368, per 7, fabric 7)

55 Wide-mouthed bowl with a wide, internally recessed rim in an orange fabric and a swill of brown-green glaze on the interior. Sooted externally. (D207, E368, per 7, fabric 7)

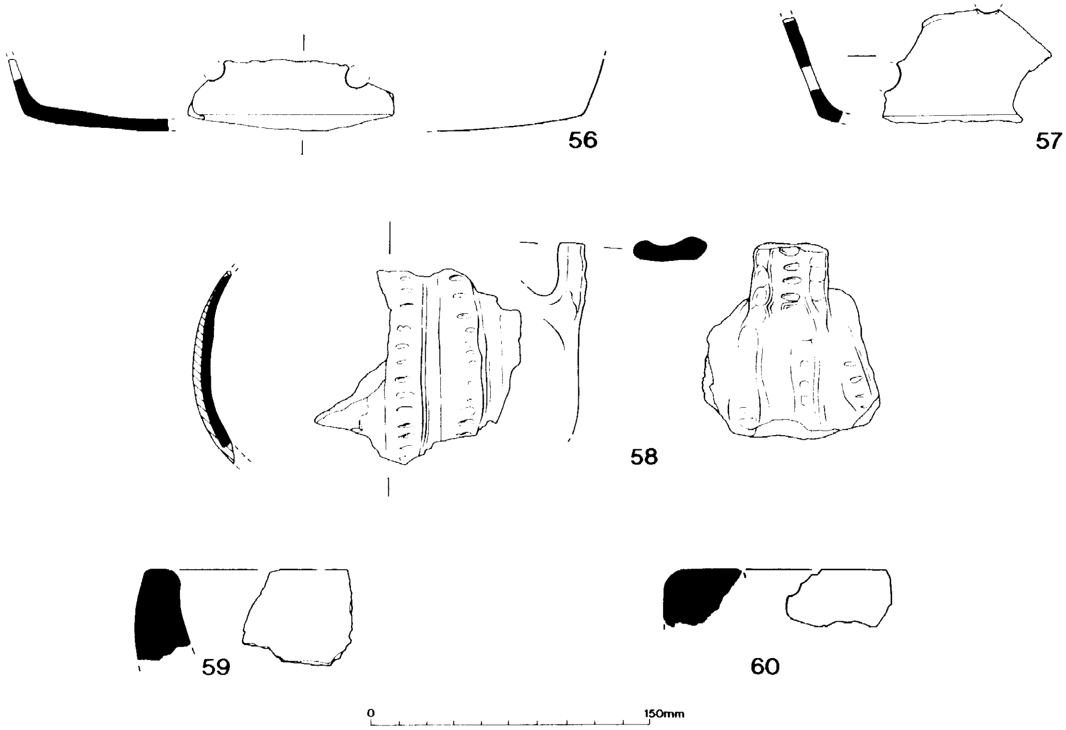


Figure 70 *Pottery 5: nos 56-60*

Dull white gritted fabrics

Not illustrated

There were three sherds in a fabric, F23, which contained abundant, rounded, dull white inclusions and some voids, in a range 0.3-1.0+mm. The fabric is fairly hard with an uneven fracture, with pale brown surfaces and pale grey core. Two of the three sherds did not react when tested with acid; the third is shelly ware.

Crucibles from area opened in 1967-8 to north and east of BAB

Figure 70 nos 59-60

Crucible fabric: Wright 1976b, 190, fabric type 'Q1 ... rough dark grey or reddish-orange, darker grey core, micaceous'.

59 Crucible rim (missing sherd.

60 Crucible rim (missing sherd).

Post-medieval

Not illustrated

A total of 882 sherds of post-medieval pottery (including two sherds of Midland Purple type and one of Cistercian type) weighing 9.235kg were recovered from the mill and seventeen sherds weighing 0.164kg from the valley transect. Of the thirteen broadly defined wares, eleven occur from the mill and two are exclusive to the valley transect (see above). There are examples of both hollow-ware and flatware forms. Many of the sherds were small and difficult to categorise; thus, for example, miscellaneous 'whiteware' (F104) may include some sherds from transfer-printed vessels (F100).

Glass by G G Astill

Window glass (GLW)

Figure 71

GLW 76 Complete quarry of pale blue glass with all edges grozed. Slightly twisted. Fig 71. 57 1, 20 w, 2 th. (B113, per 7, phase 1)

GLW 77 Piece of pale blue glass with one curving, grozed edge. Fig 71. 42 1, 11 w, 2 th. (B109, per 5)

GLW 78 Piece colourless, frosted glass. 40 l, 21 w, 2 th. (B77, per 7, phase 1 - intrusive)

GLW 79 Piece colourless glass. 19 1, 17 w, 2 th. (D311, per 7, phase 2)

Glass vessels (GLV)

Not illustrated

Eight pieces of bottle glass were recovered from BAE; none was found from BAB. All the pieces came from period 7 contexts and appear to be recent. The details are in the archive.

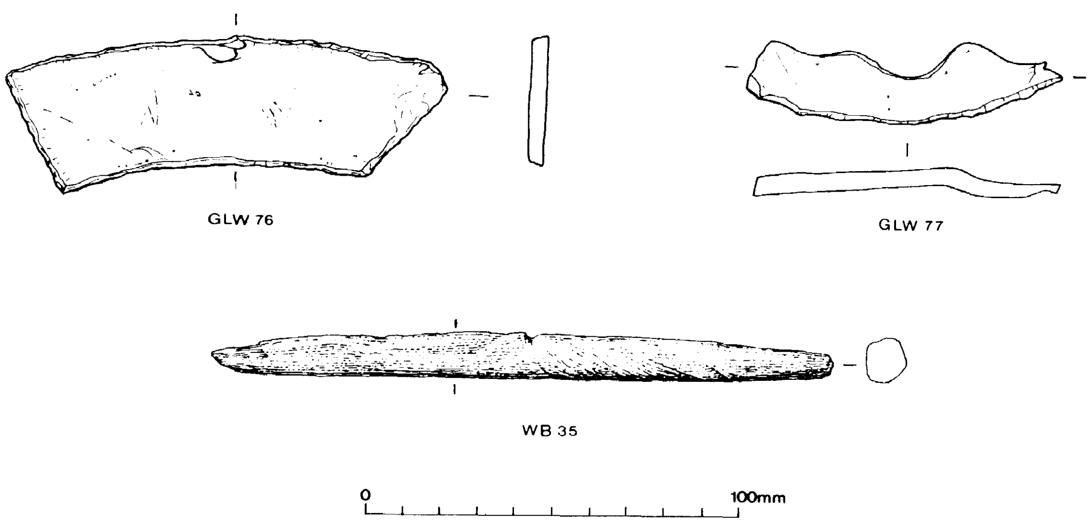


Figure 71 Window glass and worked bone

Iron (IR) by I H Goodall
armour by I Eaves

Figures 72-80; Tables 34-6

A total of 2632 recognisable iron objects were recovered from BAB; Table 34 provides a summary.

Bar iron, scrap iron, and part-forged iron

Bar iron and scrap iron, the blacksmith's raw material, were both recovered from BAB. The bar iron, not found in substantial quantities, varies in section and includes square- and rectangular-sectioned bar fragments, circular-sectioned rods, thin rectangular strips, and fragments of sheet iron (see Fig 72, IR 275.1, IR 513, IR 975, IR 990, and IR 172). None of the pieces of bar iron is particularly long, and they must all be unused, offcut lengths. IR 975 shows particular evidence of this in its straight-cut, V-sectioned end, created by chisel-cuts from two sides. The bar iron is generally quite slight in size, and lacks some of the substantial pieces of bar iron, as well as the slender lengths of wire, present among that from the monastic forge at Waltham Abbey, Essex (I H Goodall 1973, 170, fig 11 nos 1-6).

A substantial number of broken objects, some of them quite small fragments, were found on BAB, and much of this could have been scrap iron available for the blacksmith to heat and hammer together, and re-forge. The items catalogued below as scrap iron are mostly small, indeterminate fragments; identifiable yet also incomplete iron objects are described in classified groups below, although many of these could also be scrap. A quantity of scrap iron, as well as bar iron and incomplete forgings, is also known from the Civil War forge at Sandal Castle, West Yorkshire (I H Goodall 1983, 240, fig 4 nos. 1-15).

A number of bars and strips (including Fig 72, IR 967, IR 987, and IR 1124) show evidence of having been drawn down in a hearth, a process which increased the length and reduced the cross-section of iron, and which was a stage in forging an object. All this part-forged iron is fairly slender, the bars being suitable for making objects such as tenter hooks or timber nails, for each of which there is evidence of manufacture on site. Just how many of the complete or near-complete objects, among them knives, some lock furniture, and a small number of arrowheads, were made on the site is, however, unclear.

IR 112 Iron bar. 57 1, 7 w, 3 th. (E269, per 6)

IR 436 Iron bar. 60 1, 6 w. (C179, per 7, phase 1)

IR 275.1 Iron bar. Fig 72. 54+ 1, 31 w, 2 th. (C174, per 7, phase 1)

IR 309 Iron bar. 96 1, 5 w. (C175, per 7, phase 1)

IR 1106.1 Iron rod. 57, 54, and 21 1, 3 w. (E452, per 6)

IR 513 Iron rod. Fig 72. 182 1, 22 dia. (E470, per 6)

IR 293 Iron rod. 45 1, 12 dia. (C175, per 7, phase 1)

IR 234 Iron rod. 90 1, 6 dia. (C175, per 7, phase 1)

IR 975 Iron strip. Fig 72. 60 1, 23 w, 10 th. (E840, per 4)

IR 891 Iron strip. 75 1, 7 w. (E723, per 5)

IR 532 Iron strip. 25 1, 7 w, 2 th. (E470, per 6)

IR 196 Iron strip. 25 1, 13 w. (B66, per 7, phase 1)

IR 991 Iron strip. 46 1, 13 w, 1 th. (E452, per 6)

IR 990 Iron strip. Fig 72. 58 1, 11 w, 2 th. (E452, per 6)

Table 34 Mill (BAB): summary of iron objects, by period and by function

Function	Period								
	1	2	3	4	5	6	7	U/S	Total
Bar iron, scrap iron, and part-forged iron	-	-	1	12	5	12	22	-	52
Tools	1	-	1	7	2	2	11	-	24
Knives	-	-	-	3	1	4	7	1	16
Building ironwork	-	-	1	6	5	1	6	-	19
Timber nails	-	-	41	698	136	1108	309	-	2292
Studs	-	-	2	5	3	1	6	-	17
Tenter hooks	-	-	-	30	7	29	4	-	70
Lock furniture	-	-	-	3	1	3	6	-	13
Domestic ironwork	-	-	-	6	-	9	7	-	22
Horse furniture	-	-	7	18	20	2	20	-	67
Buckles	-	-	-	3		1	1	-	5
Arrowheads, caltrop	-	-	-	3	2	3	4	-	12
Armour	-	-	-	-	-	-	23	-	23
Total	1	-	53	794	182	1175	426	1	2632

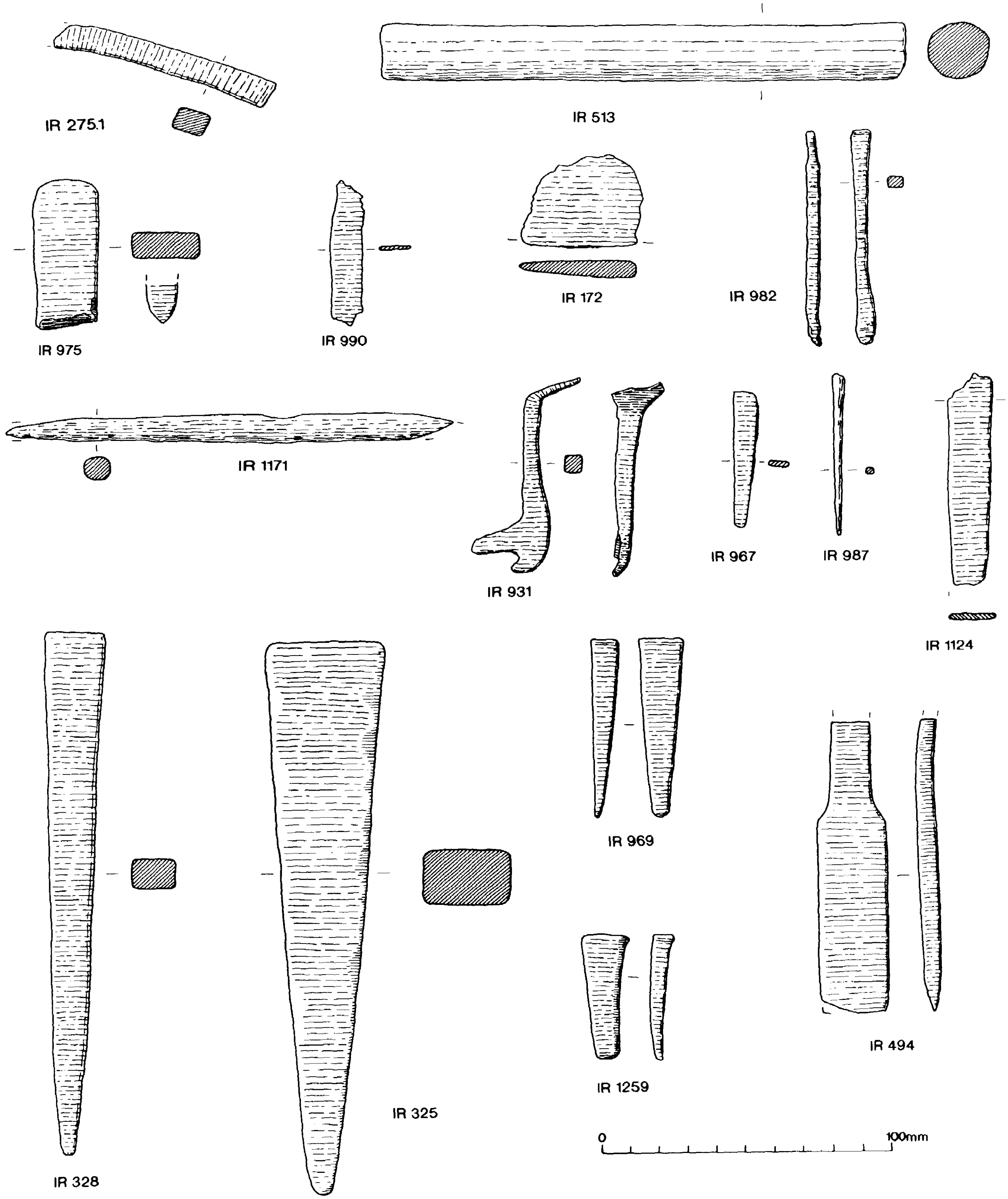


Figure 72 *Iron 1: bar iron, scrap iron, part-forged iron, and tools*

IR 374 Iron strip. 33 1, 9 w, 2 th. (C177, per 7, phase 1)

IR 312 Iron strip. 40 1, 13 w. (D202, per 7, phase 1)

IR 1240 Iron sheet. 50 1, 25 w, and 30 1, 50 w. (B644, per 4)

IR 994 Iron sheet. 15 1, 14 w. (E865, per 4)

IR 986 Iron sheet. 39 1, 36 w. (E867, per 4)

IR 962 Iron sheet. 58 1, 55 w. (E867, per 4)

IR 918 Iron sheet. 20 1, 15 w. (E492, per 5)

IR 909 Iron sheet. 32 1, 27 w. (E452, per 6)

IR 924 Iron sheet. 50 1, 23 w. (E452, per 6)

IR 172 Iron sheet. Fig. 72. 40 1, 36 w, 2-7 th. (A50, per 7, phase 2)

IR 301 Iron sheet. 43 1, 32 w. (C175, per 7, phase 1)

IR 263 Iron sheet. 25 1, 25 w. (C175, per 7, phase 1)

IR 259 Iron sheet. 25 1, 18 w, 28 1, 21 w and 41 1, 29 w. (C175, per 7, phase 1)

IR 195 Iron sheet. 48 1, 29 w. (B62, per 7, phase 2)

IR 978 Iron scrap. 40+ 1, 21 w. (E844, per 4)

IR 210 Iron scrap. 87 1, 25 w, 8 th. (A89, per 4)

IR 982 Iron scrap. Fig 72. 84 1, 5-8 w, 4 th. (E867, per 4)

IR 976 Iron scrap. 47 1, 11 w, 5 th. (E884, per 4)

IR 1171 Iron scrap. Fig 72. 154 1, 9 dia. (B605, per 5)

IR 931 Iron scrap. Fig 72. 76 1, 8-26 w, 6-8 th. (E817, per 5)

IR 1128 Iron scrap. 117 1, 18 w. (E723, per 5)

IR 516 Iron scrap. 33 1, 25 w. (E470, per 6)

IR 315 Iron scrap. 27 1, 22 w. (D204, per 7, phase 1)

IR 396 Iron scrap. 41 1, 20 w. (C179, per 7, phase 1)

IR 848 Iran scrap. 37 1, 12 w, 7 th. (E368, per 7, phase 1)

IR 896 Iron scrap. 113 1, 24 w. (E368, per 7, phase 1)

IR 189 Iron scrap. 108 1, 33 w, 22 th. (B52, per 7, phase 1)

IR 421 Iron scrap. 38 1, 18 w (C180, per 7, phase 1)

IR 850 Iron scrap. 52 1, 14 w, 5 th. (E368, per 7, phase 1)

IR 1220 Part-forged iron. 105 1, 9 w, 9 th. (E 951, 3)

IR 967 Part-forged iron. Fig 72. 54 1, 4-8 w, 2 th. (E867, per 4)

IR 987 Part-forged iron. Fig 72. 63 1, 2 dia. (E452, per 6)

IR 1106.2 Part-forged iron. 74 1, 4 w, 4 th. (E452, per 6)

IR 367 Part-forged iron. 92 1, 10 w, 10 th. (E251, per 7, phase 2)

IR 897 Part-forged iron. 72 1, 11 w, 9 th, tapering. (E368, per 7, phase 1)

IR 957 Part-forged iron. 119 1, 9 w, 7 th. (E840, per 4)

IR 992 Part-forged iron. 36 1, 9 w. (E866, per 4)

IR 1124 Part-forged iron. Fig 72. 82+ 1, 11-16 w, 3 th. (E269, per 6)

Tools

The tools of a number of different crafts, namely metalworking, woodworking, textileworking and leather-working, were found, as well as some tools for digging or cultivating soil. Despite the nature of the site, with iron, copper alloy and lead all being worked, metalworking tools are few in number and comprise just two chisels, IR 969 and IR 1259, and two punches, IR 328 and IR 325. The chisels are both slight, their size and burred heads suggesting that they cut non-ferrous metal, whereas the punches are more substantial, their plain heads indicating that they punched holes in hot iron.

The woodworking tools include two axes, IR 1251 and IR 327, the former the more slender and suited to dressing timber, the latter more substantial and recognisable as a general-purpose tool (I H Goodall 1981, 51, 53, fig 51 nos 2-4). The claw hammer, IR 932, capable of driving in and extracting nails, is unusual among medieval hammers in having a socket to support the haft. Lugs and side straps were more usual, serving, like the socket, to strengthen a weak point which was created when leverage was applied to the hammer head. The chisel, IR 494, with its asymmetrically-set cutting edge, could have cut mortices or dressed timber. The three reamers, IR 979, IR 339, and IR 171.1, were used to clean out holes drilled in wood.

The tenter hooks (see below) could have been intended for textileworking, but there is more certainty about IR 971, a harbick. Harbicks, or shear-board hooks, are double-ended hooks of iron or copper alloy with in-turned points which were used for securing cloth to a cropping board during the shearing of the nap of woollen cloth. IR 971 has lost its pointed tip, but has a simply-shaped central fingerhold reminiscent of that on other harbicks (I H Goodall and Keene 1990, 239-40, fig 51, pl XV).

Leather-working is represented by seven awls and a needle. The awls, IR 1217 to IR 454, which were used to pierce leather, are all straight and either square or lozenge-shaped in section. Most taper evenly, sometimes almost imperceptibly, towards each end, although IR 454 is unusual in having a specially-formed tang for its handle. The needle, IR 956, lacks its eye.

The various tools for digging are all incomplete. The pick arm, IR 188, may be broken across the start of the eye of the haft, or across a weld. If longer, it may have resembled the single-ended pick from Lydford Castle, Devon (I H Goodall 1980c, 165, fig 18 no. 2). The spade-irons are both from rectangular-mouthed spades, which became

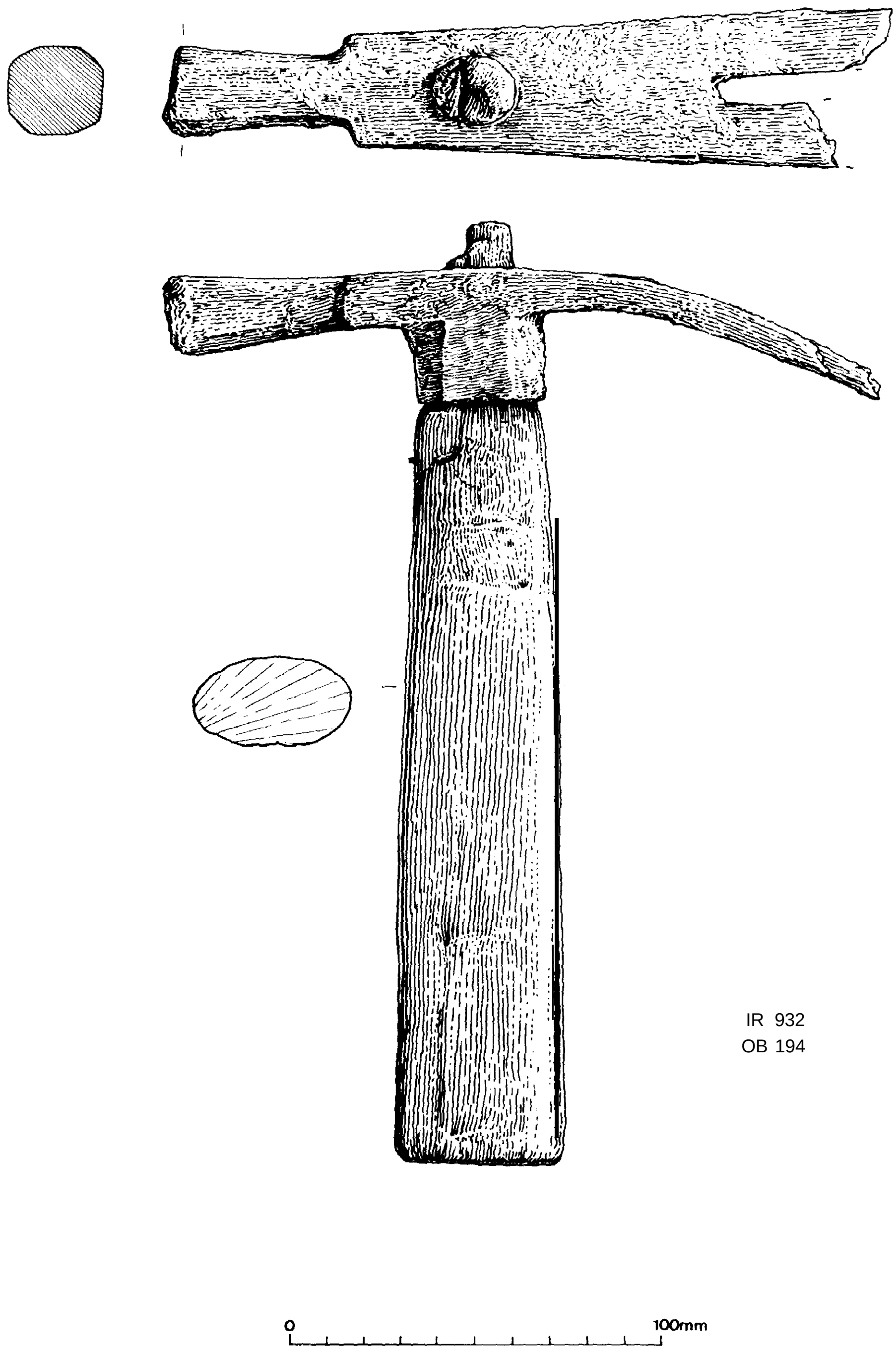


Figure 73 Iron 2: tool

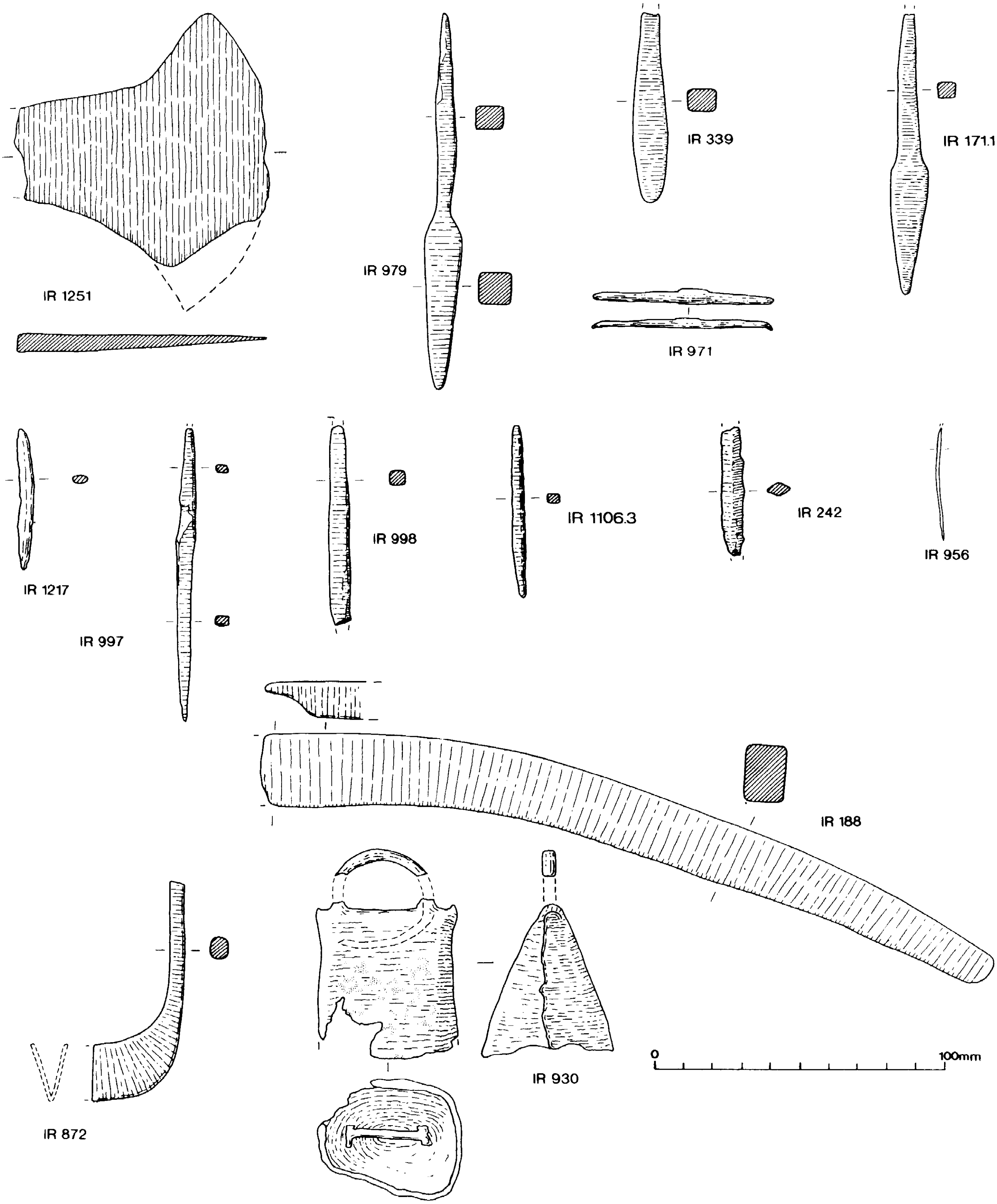


Figure 74 *Iron 3: tools*

more common in the later medieval period, superseding triangular- and round-mouthed spades (Goodall 1980a, 66-7, F6-17, figs 44-5; Hassall 1970). Each retains part of the grooved mouth which received the wooden blade of the spade, and a side strap which on IR 872 ends in a terminal. The bell, IR 930, is probably a cow or sheep bell. A high proportion (eleven; 45%) of these tools came from period 7 levels, but the majority were from phase 1 contexts which relate to the abandonment of the period 6 mill.

IR 328 Punch, rectangular-sectioned stem. Fig 72. 204 1, 22 w, 12-19 th. (B106, per 7, phase 2)

IR 325 Bunch, rectangular-sectioned stem. Fig 72. 214 1, 41 w, 21 th. (D207, per 7, phase 2)

IR 969 Chisel, burred head, rectangular-sectioned stem. Fig 72. 70+ 1, 6-16 w, 10 th. (E840, per 4)

IR 1259 Chisel, burred head, broken rectangular-sectioned stem. Fig 72. 50+ 1, 8-16 w, 7 th. (E723, per 5)

IR 494 Chisel with asymmetrically-set cutting edge. Tang broken. Fig 72. 112+ 1, 24 w, 7 th. (E289, per 7, phase 1)

IR 932 Claw hammer with gently-curved claw, socket for wooden (holly) handle (OB 194.1) and expanding octagonal-sectioned butt. Fig 73. 204 1, 46 w, 26 th. (E864, per 3)

IR 1251 Axe blade. Fig 74. 90+ 1, 92 w, 8+ th. (C670, per 4)

IR 327 Axe with lugged socket and broken blade. 95+ 1, 50 w, 25 th. (B106, per 7, phase 2)

IR 979 Reamer. Fig 74. 146 1, 12 w, 11 th. (E840, per 4)

IR 339 Reamer, tang broken. Fig 74. 74+ 1, 11 w, 8 th. (E247, per 7, phase 1)

IR 171.1 Reamer. Fig 74. 110+ 1. 11 w, 8 th. (A50, per 7, phase 2)

IR 971 Harbick with centred, shaped finger-hold. End hooks lost. Fig 74. 64 1, 7 dia. (E840, per 4)

IR 1217 Awl. Fig 74. Intrusive. 55 1, 5 w, 4 th. (E849, per 1)

IR 1062.1 Awl. 40+ 1, 5 w, 4 th. (E840, per 4)

IR 997 Awl, tang broken. Fig 74. 114+ 1, 5 w, 4 th. (E865, per 4)

IR 998 Awl, blade and tang broken. Fig 74. 77+ 1, 3 w, 3 th. (E865, per 4)

IR 1106.3 Awl. Fig 74. 68 1, 4 w, 3 th. (E452, per 6)

IR 242 Awl, blade and tang broken. Fig 74. 50+ 1, 8 w, 4 th. (B62, per 7, phase 2)

IR 454 Awl. 1231, 10 w. 6 th. (C 185, per 7, phase 1)

IR 956 Needle, eye lost. Fig 74. 44+ 1, 3 dia. (E452, per 6)

IR 188 Pick arm, possibly broken across eye of haft. Fig 74. 268+ 1, 28 w, 14 th. (B52, per 7, phase 1)

IR 872 Spade-iron. Side strap with clasping terminal. Start of grooved rectangular mouth. Fig 74. 90 1, 20 w, 4 th. (B610, per 5)

IR 400 Spade-iron. Base of side strap and start of grooved rectangular mouth. 70+ 1, 34 w, 4 th. (C179, per 7, phase 1)

IR 930 Bell with damaged sheet-iron body and broken clapper loop. Copper-base plating. Fig 74. 80+ 1, 50 w. (E368, per 7, phase 1)

Knives

The knives comprise a number of whittle-tang knives and some blade fragments; there are no scale-tang knives. The whittle-tang knives have been grouped according to blade shape: IR 953 has an angled back, but most, IR 981 to IR 1222, have tapering blades, the commonest shape among medieval knives. IR 984 is too incomplete to classify. IR 1308 is exceptional among the knives in retaining a fine quality bone handle whose end is carved in the form of a king's head. Knife handles, particularly on whittle-tang knives, were usually quite simply shaped (see Cowgill *et al* 1987, 25-6, for some knives from London) and this knife is unusual. IR 878, which has a bolster set between blade and tang, is probably of seventeenth-century date. Knife blade fragment IR 475 is like IR 953, but the others are too fragmentary to classify. The majority of the period 7 knives are from phase 1 contexts, associated with the abandonment of the period 6 mill.

IR 953 Knife, whittle-tang broken. Fig 75. 104+ 1, 24 w, 3 th. (E452, per 6)

IR 981 Knife, blade and whittle-tang broken. Fig 75. 60+ 1, 10+ w, 2+ th. (E435, per 4)

IR 960 Knife with whittle-tang. Blade broken. Fig 75. 134+ 1, 20+ w, 5 th. (C665, per4)

IR 1308 Knife with whittle-tang set in bone (sheep metacarpal or radius) handle with end carved in form of a king's head. Fig 75. WB 33. 270 1, 21 w, 4 th. (E800, per 5)

IR 801 Knife, blade and whittle-tang broken. Fig 75. 134+ 1, 20 w, 4 th. (E425, per 6)

IR 268 Knife, blade and whittle-tang broken. 98 1, 17 w. (C174, per 7, phase 1)

IR 854 Knife, blade and whittle-tang broken. Fig 75. 126+ 1, 14 w, 3 th. (E368, per 7)

IR 1222 Knife, blade tip lost. Fig 75. 128+ 1, 13 w, 6 th. (E364, per 7, phase 1)

IR 984 Knife, blade and whittle tang broken. Fig 75, 42+ 1, 11 w, 2 th. (E867, per 4)

IR 878 Knife with solid, circular-sectioned bolster. Blade and whittle-tang broken. 60 1. (E261, per 7, phase 2)

IR 56 Knife blade fragment. 80 1, 20 w. (BAB 69 U/S)

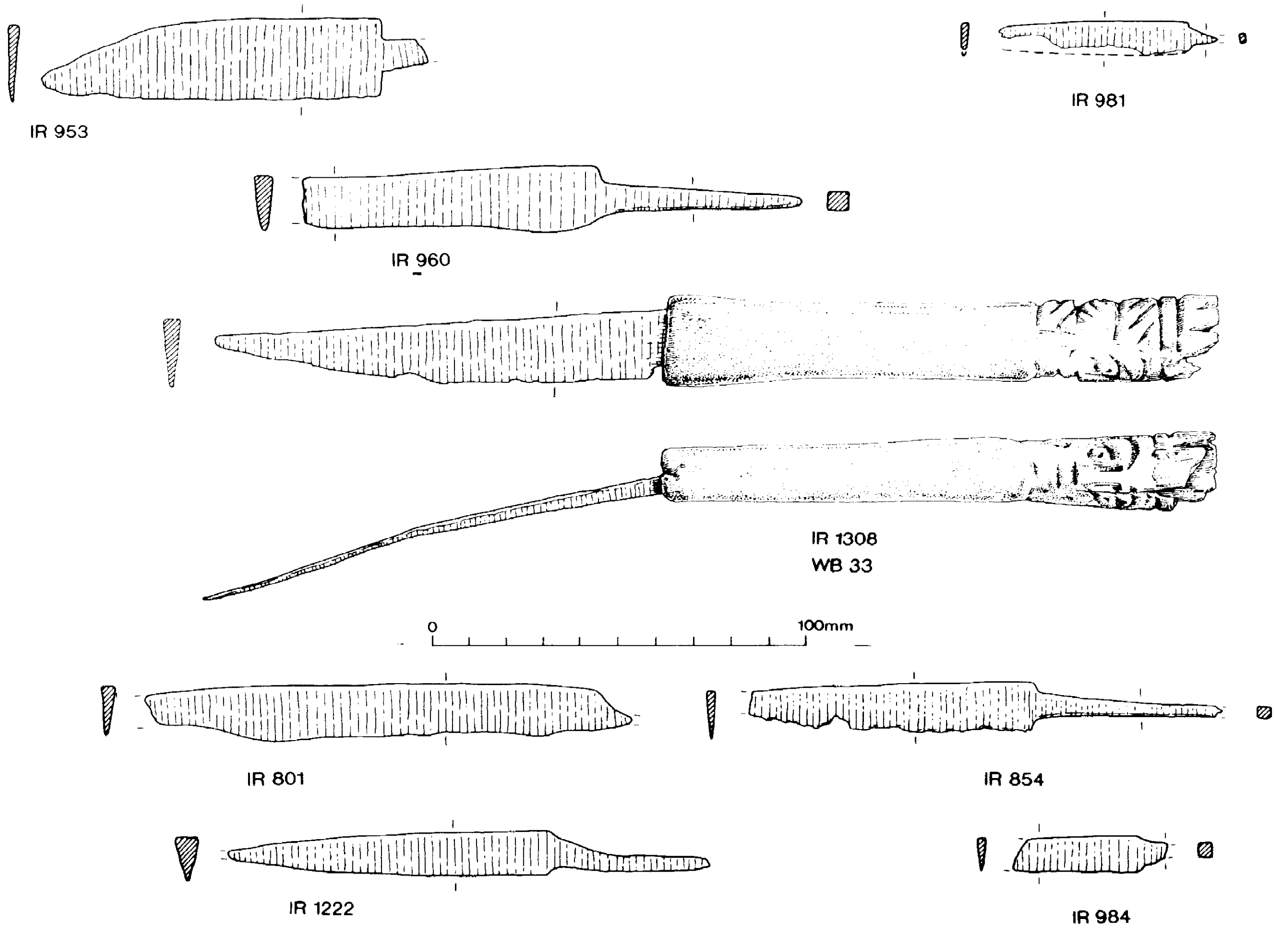


Figure 75 Iron 4: knives

IR 954 Knife blade fragment. 60 1, 23 w. (E452, per 6)

IR 993 Knife blade tip. 37 1, 10 w. (E452, per 6)

IR 267 Knife blade fragment. 40 1, 12 w. (C171, per 7, phase 2)

IR 367 Knife blade fragment. 106 1, 22 w. (C176, per 7, phase 1)

IR 476 Knife blade fragment. 54 1, 16 w. (E289, per 7, phase 1)

Building ironwork

Items of ironwork associated with the structure of buildings or their fittings include staples, hinge pivots, a series of strap fragments, and two roves. Most are incomplete. The hinge pivots, IR 190 and IR 323, are both small and may be from shutters or furniture rather than doors. Both have tapering shanks, which indicate that they were set in wood rather than masonry. The strap fragments, IR 1260 to IR 442, with the exception of a terminal (IR 300) and an end-looped support eye (IR 326) are all parallel-sided and vary in length from 30 to 84mm, and in width from 20 to 31mm. IR 1001 and IR 1192 are roves which formed part of clench bolts used in doors, shutters, and hatches. IR 1001 is the more elaborately shaped, and it recalls the more angular and substantial roves on the well cover from Lydford Castle, Devon (Geddes 1980, 165, fig 17).

IR 995 U-shaped staple. Fig 76. 53 1, 25 w, 5 th. (E865, per 4)

IR 996 U-shaped staple, broken. Fig 76. 60 1, 31 w, 8 th. (E865, per 4)

IR 190 Hinge pivot. Fig 76. 48 1, 21 w, 6 th. (A53, per 5)

IR 323 Hinge pivot, shank broken. Fig 76. 53+ 1, 26 w, 7 th. (E234, per 7, phase 2)

IR 1260 Strap fragment. (D221, per 3)

IR 958 Strap fragment. 28+ 1, 26 w. (E840, per 4)

IR 1271 Strap fragment. 50+ 1, 27 w. (B656, per 4)

IR 977 Strap fragment. 38+ 1, 30 w. (E884, per 4)

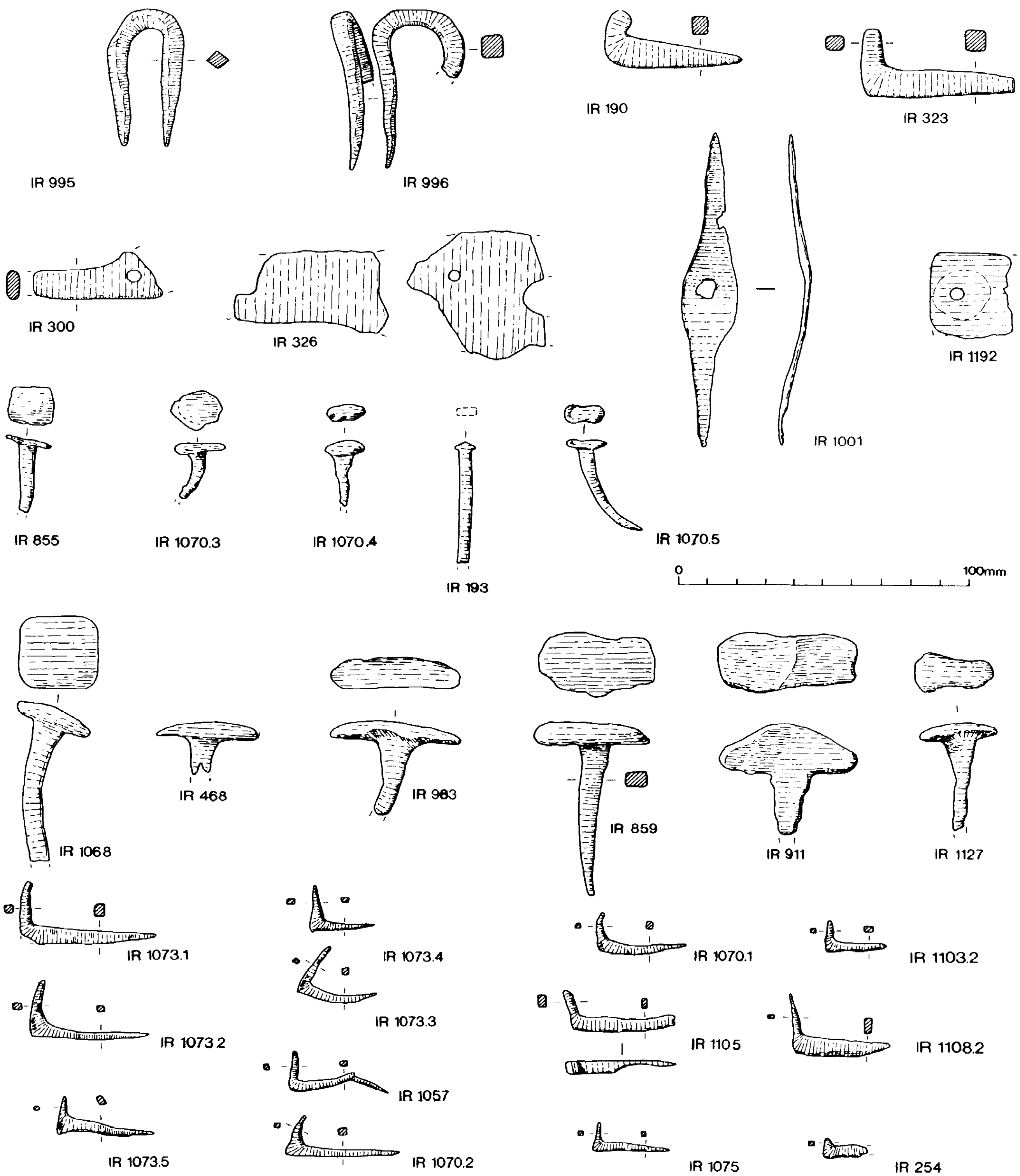


Figure 76 Iron 5: building ironwork, timber nails, studs, and tenter hooks

Table 35 Mill (BAB): summary of iron timber nails, by type and by period

Period	Type 1	Type 2	Type 3	Type 4	Type 5	Shanks	Part-forged
3	17,71%	1, 4%	2, 8%	–	4,17%	17	
4	165, 51%	6, 2%	9,2.7%	1, 0.3%	142 44%	346	29
5	40, 60%	5,7%	6, 9%	–	16,24%	69	–
6	271, 47%	16, 3%	9, 1%	–	280, 49%	491	41
7	74,68%	14,14%	7, 6%	3, 3%	11,9%	200	–
Total	567, 51.5%	42,4%	33,3%	4, 0.5%	453,41%	1123	70

%: % of number of nails with recognisable heads per period.
Total number of nails: 2292.
Total number of nails with recognisable heads: 1099.

IR 1175 Strap fragment. 36+ 1,22 w, 2 th. (B612, per 5)

IR 961 Strap fragment. 51+ 1,31 w. (E817, per 5)

IR 1180 Strap fragment. 84+ 1,25 w. (D350, per 5)

IR 1109.2 Strap fragment. 58+ 1,25 w. (E452, per 6)

IR 429 Strap fragment. 56+ 1,28 w. (C180, per 7, phase 1)

IR 275.2 Strap fragment. 57+ 1,29 w. (C174, per 7, phase 1)

IR 442 Strap fragment. 74+ 1,28 w. (E247, per 7, phase 1)

IR 300 Strap fragment with broken terminal. Fig 76. 46+ 1, 18 w, 5 th. (C175, per 7, phase 1)

IR 326 End loop and strap fragment expanding to terminal. Fig 76.48+ 1,50 w; 52 1,31 w. (B106, per 7, phase 2)

IR 1001 Rove. Fig 76. 122 1,20 w, 4 th. (E840, per 4)

IR 1192 Rove. Fig 76.28+ 1,34+ w. (B602, per 5)

Timber nails

Five types of timber nails were recognised, Type 1 with a flat square or sub-rectangular head, Type 2 with a flat circular head, Type 3 with a long flat rectangular head, Type 4 with a long rectangular head raised across the centre, and Type 5 with a flat figure-eight-shaped head. Types l-3 are utilitarian in form, Types 4 and 5 more decorative. A total of 1099 nails with identifiable heads were found, as well as many nail shank fragments, and it is clear from the quantity and from some incomplete forgings that nails were being manufactured on the site. Incomplete forgings take the form of tapering shanks with either clean or burred chisel-cut ends. Such shanks, which were ready to have their heads formed in nail-heading tools, were found in a number of period 4 and period 6 contexts, in particular E840 (IR 1060 and IR 1062.3), E867 (IR 1073) and E452 (IR 1103.1, IR 1105, and IR 1108.1). Similar incompletely-forged nails can be recognised on another two smithy sites, Chingley Forge and Chingley Furnace in Kent (I H Goodall 1975b, 85-7, fig 45, Types 1, 2). A number of part-worked bars with roughly-tapered shanks and thickened heads from which the head would be formed were found. The chronological distribution of timber nails is shown in Table 35.

Type 1 IR 855. Fig 76. 30+ 1. (E368, per 7, phase 1)

Type 2 IR 1070.3. Fig 76.22+ 1. (E865, per 4)

Type 3 IR 1070.4. Fig 76.26+ 1. (E865, per 4)

Type 4 IR 193. Fig 76.48+ 1. (B62, per 7, phase 2)

Type 5 IR 1070.5. Fig 76.42 1. (E865, per 4)

Studs

Five head shapes can be recognised among the studs. Type 1 has a square or sub-rectangular head, Type 2 a long rectangular head with either a flat or shaped top, Type 3 is as Type 2 but with a raised head, and Type 4 has a figure-eight-shaped head. The chronological distribution of studs is shown in Table 36.

Table 36 Mill (BAB): summary of iron studs, by type and by period

Period	Type 1	Type 2	Type 3	Type 4
3	1	1	–	–
4	1	4	–	–
5	–	1	1	1
6	–	1	–	–
7	3	2	1	–

IR 1068 Stud, Type 1. Fig 76.52+ 1, head 30 x 30. (E864, per 3)

IR 1265 Stud, Type 1.37+ 1, head 29 x ?. (B658, per 4)

IR 468 Stud, Type 1. 20+ 1, head 32 x ?. Fig 76. (E289, per 7, phase 1)

IR495 Stud, Type 1.43+ 1, head 34 x 40. (D309, per 7, phase 1)

IR 170 Stud, Type 1.70+ 1, head 25 x ?. (A50, per 7, phase 2)

IR 1206 Stud, Type 2. 76+ 1, head 23 x 34+. (E898, per 3)

IR 1016 Stud, Type 2.18+ 1, head 29 x 12. (E865, per 4)

IR 983 Stud, Type 2. Fig 76. 34+ 1, head 44 x 10. (E867, per 4)

IR 1066 Stud, Type 2.50+1., head 26 x 7. (E845, per 4)

IR 1061 Stud, Type 2.64+ 1, head 27 x 8. (E840, per 4)

IR 859 Stud, Type 2. Fig 76. 68 1, head 40 x 24+. (E817, per 5)

IR 1160 Stud, Type 2.49 1, head 32 x ?. (B169, per 6)

IR 171.2 Stud, Type 2.38+ 1, head 28 x 16. (A50, per 7, phase 2)

IR 173 Stud, Type 2.49 + 1, head 28 x 14. (A50, per 7, phase 2)

IR 911 Stud, Type 3. Fig 76. 41 + 1, head 50 x 24. (E453, per 5)

IR 548 Stud, Type 3.25 + 1, head 25 x ?. (E364, per 7, phase 1)

IR 1127 Stud, Type 4. Fig 76.41 + 1, head 27 x 14. (E123, per 5)

Tenter hooks

Tenter hooks are small slender hooks whose original use, as their name implies, was to hold woollen cloth taut on tenters as it was dried and stretched after passing through the process of scouring and fulling. Tenter hooks were also used to support tapestries and wall hangings. Expenses for preparing York Palace for a visit by Charles I in November 1641 included expenditure on '100 tenter hooks for the king's chamber to hang up his clothes' (Butler 1988, 31, 43 footnote 331), and they may also have been used as tile pins to support roof tiles. The intended function of the tenter hooks from Bordesley Abbey is uncertain, but there is evidence that they were manufactured on the site since IR 1105 (Fig 76, E452, per 6) is an incompletely forged example. The range of heights of complete hooks (7 to 25mm) and lengths of complete shanks (19 to 46mm) is slightly less than that of other groups of tenter hooks from Winchester (I H Goodall 1990a, 234-9, fig 50) and Nonsuch Palace (I H Goodall forthcoming.). The number of tenter hooks from Bordesley Abbey was: period 4: 30; period 5: 7; period 6: 29; period 7: 4.

IR 1073.1 Tenter hook. Fig 76.46 x 24+. (E867, per 4)

IR 1073.2 Tenter hook. Fig 76.42 x 22. (E867, per 4)

IR 1073.5 Tenter hook. Fig 76. 33 x 14. (E86TI7, per 4)

IR 1073.4 Tenter hook. Fig 76.22 x 18. (E867, per 4)

IR 1073.3 Tenter hook. Fig 76.27 x 20. (E867, per 4)

IR 1057 Tenterhook. Fig 76. 36 x 16. (E836, per 5)

IR 1070.2 Tenter hook. Fig 76.39 x 15. (E865, per 5)

IR 1070.1 Tenter hook .Fig 76.30 x 15. (E865, per 5)

IR 1105 Incompletely forged tenter hook. Fig 76.36 x 15. (E152, per 6)

IR 1075 Tenter hook. Fig 76. 27 x 10. (E425,per 6)

IR 1103.2 Tenter hook. Fig 76. 20 x 13. (E452,per 6)

IR 1108.2 Tenter hook. Fig 76.33 x 25. (E452,per 6)

IR 254 Tenter hook. Fig 76. 15+ x 7. (C175, per 7)

Lock furniture

The lock furniture includes padlock bolts, hasps, a lock, and some keys, much of it fragmentary. The padlock bolts are either U-shaped (IR 935, IR 873, IR 1122) or T-shaped (IR 378, IR 277), both types from barrel padlocks, the latter specifically from barrel padlocks with shackles. IR 342 is the hasp from an embossed padlock: near-complete examples include those from Goltho, Lincolnshire (I H Goodall 1975a, 84, fig 39 no. 65) and North Elmham Park, Norfolk (I H Goodall 1980b, 509, fig 265 no. 10). The lock, IR 506, was probably fitted to a door or piece of furniture. The mechanism, attached to a flat lockplate, is similar to and worked according to the same principles as a lock from Winchester (I H Goodall 1990b, 1017, figs 319, 320). The stapled hasp, IR 968, was used in conjunction with locks such as IR 506, its rear staple entering the lock and being secured by the toothed sliding belt. Keys IR 462, IR 452, and IR 255 are merely bow or bit fragments. The figure-eight hasps IR 191 and IR 329, the latter on the end of a chain, were used in conjunction with padlocks and staples to secure doors, gates, hatches or furniture.

IR 935 Padlock bolt. U-shaped, both arms broken. Spring arm retains traces of copper-base brazing from lost decorative scrolls and from closing plate (cf padlock bolt from Weoley Castle, west midlands: Oswald 1962-3, 129, fig 51 no. 2). Fig 77. 54+ 1, 24 w, 4 th. (E865, per 4)

IR 873 Padlock bolt. U-shaped fragment. Non-ferrous coating. 24 1, 19 w. (B611, per 5)

IR 1122 Padlock bolt. U-shaped fragment. Non-ferrous coating. 30 1, 31 w. (E269, per 6)

IR 378 Padlock bolt. T-shaped with three spines, one perhaps retaining a single-leaf spring. Fig 77. 65 1, 32 dia. (D211, per 7, phase 1)

IR 277 Padlock bolt. T-shaped with two broken spines (C175, per 7, phase 1)

IR 342 Hasp from embossed padlock, both arms broken. Fig 77. 46 1,44 w, 7 th. (E246, per 7, phase 1)

IR 506 Lock. Fiat lockplate with comer fixing holes, keyhole retaining bit from key, and hole for entry of staple of stapled hasp. Attached mechanism comprises toothed bolt with stop for S-shaped spring tumbler on top edge. Fig 77. 66 1, 77+ w. (E470, per 6)

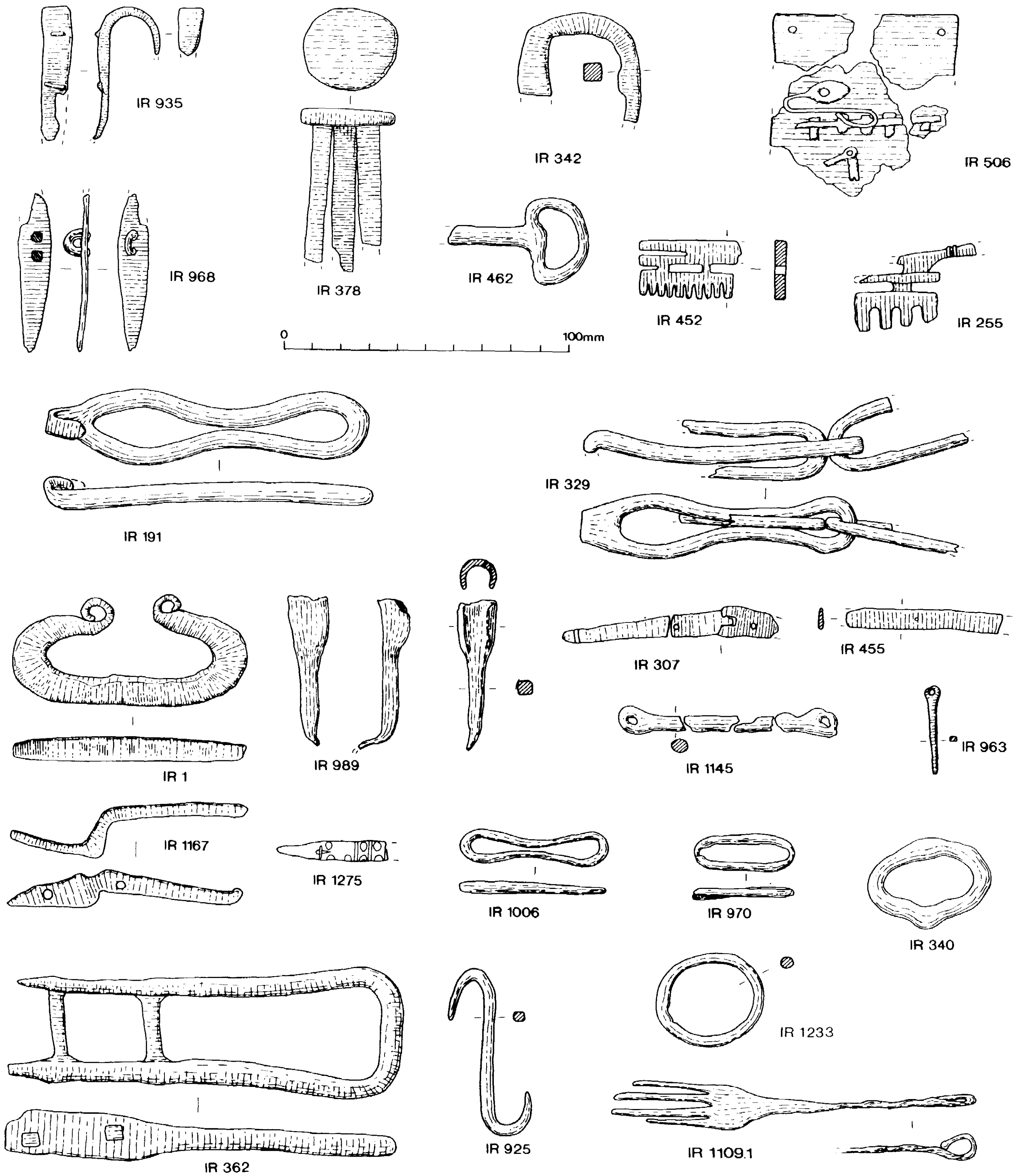


Figure 77 Iron 6: lock furniture and domestic ironwork

IR 968 Stapled hasp with chamfered front and shaped finger-hold at base. Top lost; staple to rear. Fig 77. 64 1, 12 w. (E867, per 4)

IR 462 Key, D-shaped bow, broken solid stem. Fig 77. 60+ 1. (B101, per 7, phase 1)

IR 452 Key bit and stem fragment. Fig 77. 36+ 1, 22 w, 4 th. (El85, per 7, phase 1

IR 255 Key bit and stem fragment. Fig 77. 48+ 1, 30 w. (C175, per 7, phase 1)

IR 191 Figure-eight hasp, gently curved in side view. Looped finger-hold. Fig 77. 114 1, 30 w. (B530, per 4)

IR 329 Figure-eight hasp with attached staples or links. Fig 77. Hasp 99 1, 26 w. (E260, per 6)

Domestic ironwork

Domestic ironwork includes objects associated with lighting, furnishings, and other aspects of daily life. The strike-a-light, IR 1, used in conjunction with a flint to create sparks and ignite tinder, and the socketed candleholder, IR 989, are both related to lighting. IR 307, a pinned hinge, may be from a cupboard or other piece of furniture, while the lengths of binding strip may be from boxes or caskets. IR 1193 to IR 455 are just plain parallel-sided strips, while IR 963 to IR 1275 are shaped, the latter also with decorative grooves, and have traces of a non-ferrous coating. The two U-shaped brackets, IR 362 and IR 363, could have been fixed to bucket staves in order to support a handle. The chain links IR 1006, IR 964-5 and IR 970, and the swivel ring, IR 340, may be domestic, from a kitchen fire, or from a door or gate, or may he from a harness.

IR 1 Strike-a-light. Fig 77. 43 x 82. (A58, per 4)

IR 989 Socketed candleholder with cranked stem. Socket damaged. Fig 77.60 1,14 w. (E452, per 6)

IR 307 Pinned hinge with non-ferrous coating on straps. Fig 77. 38 1,9 w. (C175 per 6)

IR 1193 Strip fragment. 30 1, 13 w. (E865 per 4)

IR 929 Strip fragment. 87 1,12 w. (E452 per 6)

IR 999 Strip fragments. 50 and 39 1,15 and 18 w. (E452, per 6)

IR 455 Strip fragment. Non-ferrous coating. Fig 77. 56 1, 8 w. (C185, per 7, phase 1)

IR 963 Strip fragment with perforated terminal. Non-ferrous coating. Fig 77.36 1,2 w. (E867, per 4)

IR 1145 Strip with perforated terminals. Non-ferrous coating. Fig 77. 78 1,5 dia. (B112, per 6)

IR 1167 Strip fragment, shaped. Non-ferrous coating. Fig 77.86 1, 14 w, 4 th. (C198, per 6)

IR 1275 Strip fragment, shaped and decorated. Non-ferrous coating. Fig 77. 38 1,8 w. (D300, per 7, phase 2)

IR 362, 363 Handle brackets with squared ends and double-riveted terminals. Fig 77. 140 1, 52 w, 18 th. (E247, per 7)

IR 1006 Chain link, figure-eight-shaped. Fig 77. 52 1, 14 w, 5 th. (E865, per 4)

IR 964, 965 Chain link, figure-eight-shaped, 88 1. (E867, per 4)

IR 970 Chain link, oval. Fig 77. 36 1, 14 w, 3 th. (E840, per 4)

IR 340 Swivel ring. Fig 77.44 1, 32 w. (E260, per 6)

IR 925 S-shaped hook. Fig 77. 68 1, 4 dia. (E452, per 6)

IR 276 Collar. Part of circular collar 44 dia, 10 w. (Cl75 per 7, phase 1)

IR 1233 Ring. Fig 77.38 dia, 4 th. (C188, per 7, phase 1)

IR 1109.1 Fork-like object with four tines and hooked terminal with ring. Fig 77. 130 1, 18 w. (E452, per 6)

IR 491 Cast-iron vessel, incomplete. Base dia 159. (D311, per 7, phase 2)

IR 1307 ?Book cover. See OB 143 for details. Fig 99; Plate 37. (E368, per 7, phase 1)

Horse furniture

Bridle bits, horseshoes, and their nails, and parts of two spurs make up the horse furniture. The bits, IR 928/890 and IR 215, are all curb bits. IR 928/890 has been broken into two pieces and the mouth-piece deliberately bent back against one of the cheekpieces. The mouthpiece is unusual in being rigid rather than composed of individual links and its U-shaped port with central melon bead indicates that the bit had a very severe action. IR 215, an almost complete curb bit, has a complicated mouthpiece and cheekpieces with asymmetrical side rings. The lower part of the bit is forged into a single U-shape, the cross bar between the cheek-pieces having swivel loops to which the reins were attached by rings. IR 246 is the mouthpiece link from a bridle bit.

The horseshoes are of two types, six having countersunk nailholes and three nailholes of the succeeding rectangular shape. Three of the former type of horseshoe, IR 955, IR 1017, and IR 985, have arms whose web is below 19mm in width, a dimension consistent with horseshoes of late eleventh to thirteenth-century date. The other three, IR 988, IR 926, and IR 324, have webs 20mm or more wide, a dimension found on thirteenth- and fourteenth-century horseshoes (Clarke 1986; I H Goodall 1990c, 1054-67). In all cases the dates of the contexts of the Bordesley Abbey horseshoes agree with the typological dates. Horseshoes such as IR 349, IR 219, and IR 370, with rectangular nailholes, were introduced in the fourteenth century and continued, with modifications, until the present day. Those from Bordesley Abbey have the wider web characteristic of the type. IR 370 is

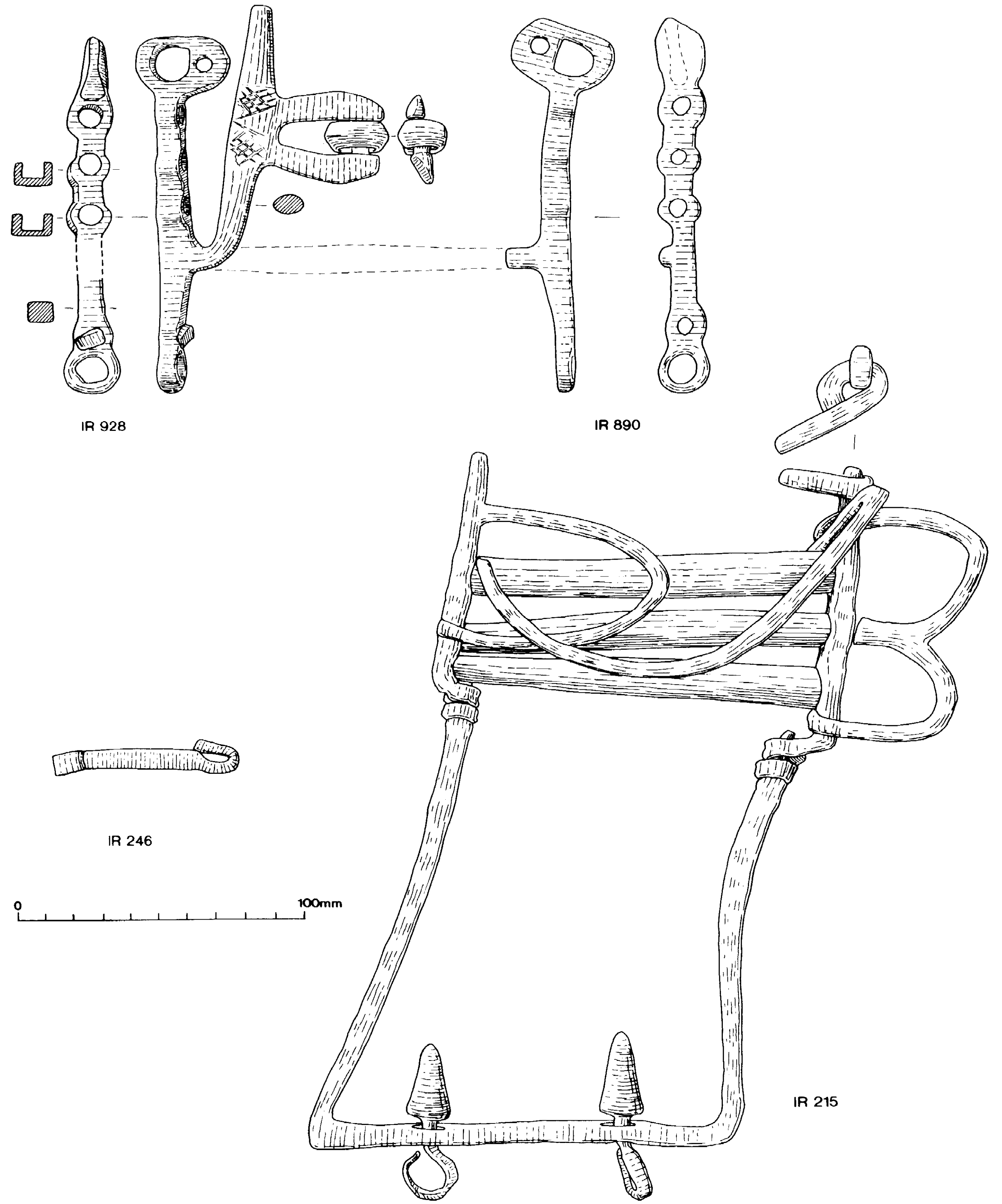


Figure 78 Iron 7: horse furniture

complete and may have been forged on the industrial site. IR 1242, IR 240, and IR 292 are unclassifiable horseshoe tips.

Five types of horseshoe nail were recognised, Type A with a semicircular or squared head no thicker in side view than the shank, Type B with a trapezoidal head often with well-defined ears, Type C with a shouldered head with near-straight or sloping sides expanding in side view, Type D as Type C but narrowing in side view, and Type E with a shank expanding from the sides to a flat top. Types A and B were used in conjunction with countersunk nailholes in horseshoes, Types C–E with rectangular nailholes. Apart from a few residual nails of Type A, most of the nails are in contexts of approximate date. Most are incomplete, a few worn, indicating that they were either the by-product of farriery or were scrap. A few incomplete nails, in particular some of Type B from E840 (IR 1062.2) and E867 (IR 1073), might have been made on the industrial site. The chronological distribution of horseshoe nails is shown in Table 37.

Table 37 Mill (BAB): summary of iron horseshoe nails, by type and by period

Period	Type A	Type B	TypeC	TypeD	TypeE
3	5	–	–	–	–
4	2	14	–	–	–
5	1	12	1	3	1
6	–	–	–	–	–
7	2	1	3	–	4

No prick spur or rowel spur was found intact, but IR 453 may be the terminal from a spur, and IR 410 is an eight-pointed rowel.

IR 928 Curb bit. Shaped cheekpiece and distorted mouthpiece with lattice decoration on central mount with loose ring. Joins IR 890. Fig 78. 138 l, 90 w. (E814, per 5)

IR 890 Curb bit. Incomplete shaped cheekpiece. Joins IR 928. Fig 78. 140 l. (E723, per 5)

IR 246 Mouthpiece link. Fig 78. 66 l, 7 w. (C175, per 7, phase 1)

IR 215 Curb bit. Fig 78. 290 l, 185 w. (C175, per 7, phase 1)

IR 955 Horseshoe with countersunk nailholes, complete. Fig 79. 107 l, 105 w. (E864, per 3)

IR 1017 Horseshoe arm with three countersunk nailholes and calkin. 100+ l. 18 w. (E864, per 3)

IR 985 Horseshoe arm fragment with two countersunk nailholes. 65+ l, 18 w. (E867, per 4)

IR 988 Horseshoe arm with three countersunk nailholes and iron toe. Fig 79. 90 l, 20 w. (E452, per 6)

IR 926 Horseshoe arm with three countersunk nailholes and calkin. Fig 79. 104 l, 26 w. (E452, per 6)

IR 324 Horseshoe arm with three countersunk nailholes and calkin. Fig 79. 92 l, 17 w. (D211, per 7, phase 1)

IR 349 Horseshoe arm tip with one rectangular nailhole. 100+ l, 25 w. (E247, per 7, phase 1)

IR 219 Horseshoe arm fragment with rectangular nailhole. 90+ l, 30 w. (C175, per 7, phase 1)

IR 370 Horseshoe with rectangular nailholes and calkin. Complete. Fig 79. 130 l, 30 w. (E257, per 7, phase 2)

IR 1242 Horseshoe arm tip. 53+ l, 30 w. (D565, per 4)

IR 240 Horseshoe arm tip. 55+ l. (C175, per 7, phase 1)

IR 292 Horseshoe arm tip. 64+ l. (C175, per 7, phase 1)

IR 582 Horseshoe with rectangular nailholes. Complete. 108 l, 100 w, 30 w. (BAE82 per 5–6)

IR 427 Horseshoe nail, Type A. Fig 79. 22+ l. (C180, per 7, phase 1)

IR 1062.2 Horseshoe nail, Type B. Fig 79. 40 l. (E840, per 4)

IR 417 Horseshoe nail, Type C. Fig 79. 23+ l. (C185, per 7, phase 1)

IR 1030 Horseshoe nail, Type D. Fig 79. 23+ l. (E814, per 5)

IR 1019 Horseshoe nail, Type E. Fig 79. 20+ l. (B628, per 4)

IR 463 Spur terminal (?). Fig 79. 30 l, 12 w, 5 th. (Cl85, per 7, phase 1)

IR 410 Eight-point round with non-ferrous coating. Fig 79. 54 dia. (C177, per 7, phase 1)

Buckles

IR 936 Circular buckle frame. Fig 79. 17 dia. 2 th. (E866, per 4)

IR 1007 Circular buckle, frame broken, pin with decorative bar. Non-ferrous coating. Fig 79. 24 dia. (B365, per 4)

IR 283 D-shaped buckle frame with non-ferrous coating. Fig. 79. 56 l. 36 w. (Cl75 per 7, phase 1)

IR 1282 Buckle pin. 40 l. (E941, per 4)

IR 1100 Buckle pin. Fig 79. 57 l. (E462, per 6)

Arrowheads and caltrop

The arrowheads, all of them socketed, are of three types, those with barbs (IR 941 to IR 512) and with a leaf-shaped blade (IR 273) being suitable for hunting or military use, the bullet-like ones (IR 845, IR 232) for target practice. The barbed arrowheads include a particularly fine example, IR 923. The caltrop, IR 533, was thrown down to ensnare horses' feet.

IR 941 Arrowhead. Fig 80. 42 l, 12 w. (E865, per 4)

IR 966 Arrowhead, socket broken. Fig 80. 50+ l, 10 w. (E867, per 4)

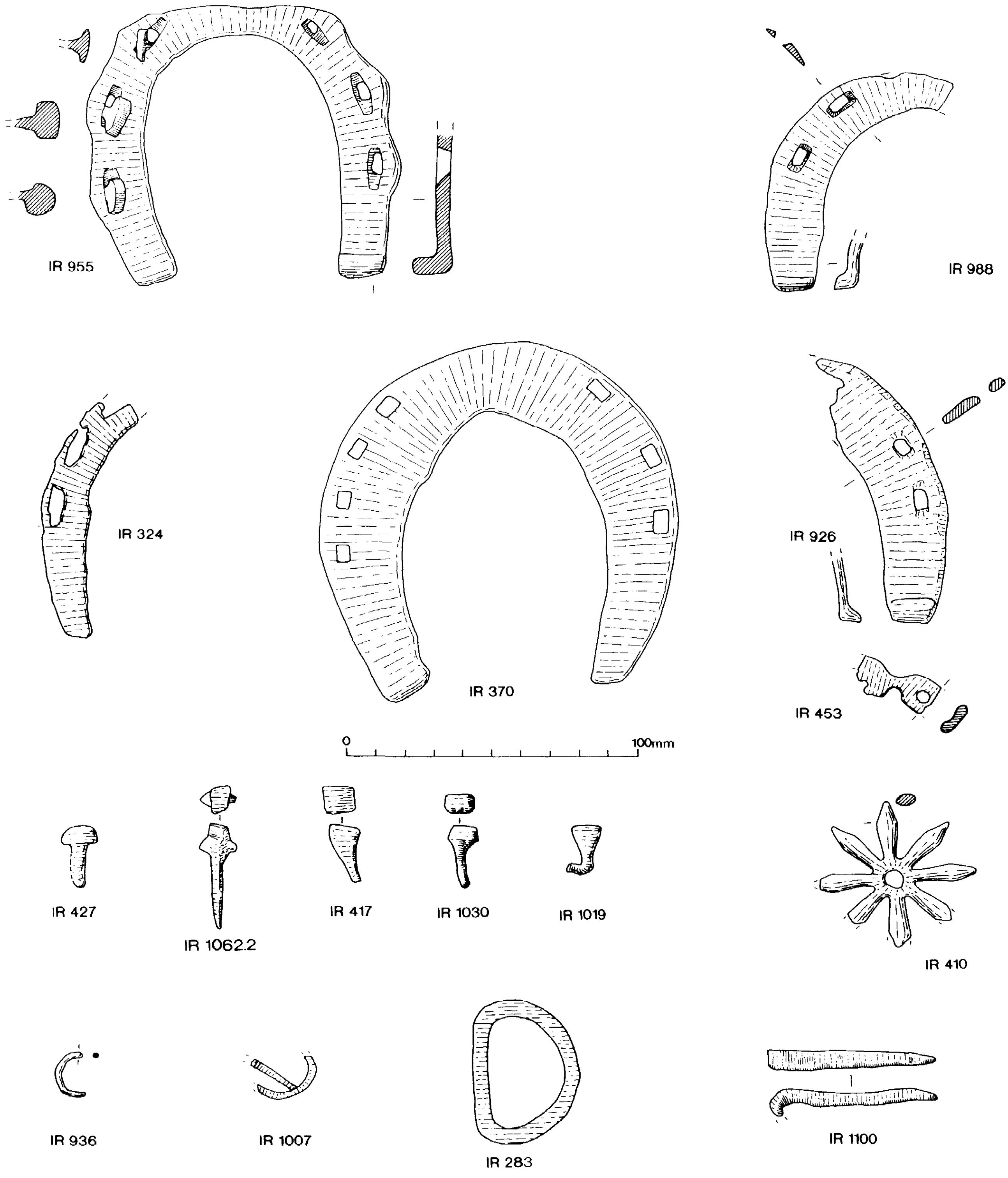


Figure 79 Iron 8: horse furniture and buckles

IR 959 Arrowhead, socket tip broken. Fig 80. 56 1, 10 w. (E840, per 4)

IR 923 Arrowhead with pin hole in socket. Fig 80. 54 l, 18 w. (E452, per 6)

IR 1157 Arrowhead, blade and socket tips lost. 57 1. (B169, per 6)

IR 512 Arrowhead, blade broken. 55 1. (E246, per 7, phase 1)

IR 273 Arrowhead, socket broken. Fig 80. 42+ 1, 16 w. (C174, per 7, phase 1)

IR 845 Arrowhead. Fig 80. 31+ 1. (E477, per 5)

IR 1107 Arrowhead. Fig 80. 33+ 1. (E452, per 6)

IR 341 Arrowhead. 24 1, 10 dia. (D211, per 7, phase 1)

IR 232 Arrowhead. Fig 80. 60 1, 14 w. (C175, per 7, phase 1)

IR 533 Caltrop, arms broken. Fig 80. 40 1. (E470, per 5)

Armour by I Eaves

Twenty-three fragments of iron sheet were recovered from period 7 phase 1 contexts; from their thickness and general character it is likely that these finds represent fragments of armour. All the pieces came from similar locations and they also have so much in common that they can be treated as a coherent group.

Most of the plates show evidence of rivets with large, domed heads, 10-12mm in diameter, and slender shanks. The rivets are set reasonably close to one another (21-30mm apart) in straight lines. Most have traces of a non-ferrous metal coating, probably tin. In general the rivets appear to be confined to the edges of the plates, although IR 411 is an exception to this rule and in this instance there is no evidence of overlapping plates. Small indications of fabric can be discerned on many of the fragments. These are found on the same side of the plate as the rivet heads. It is difficult to determine the size of the plates from which the fragments derived, but some pieces have one or two original edges with rounded corners (IR 413; IR 458) and the fragment IR 411 must be close to its original size.

The armour fragments were found in the destruction level (period 7 phase 1) of the last (period 6) mill, in two areas: to the north-west of the building, scattered over the north side of the north mill pond bank (C175; C180; C185), and to the north of the building (B101). This distribution reflects that of all other metal objects in period 7. All the fragments are very similar in character, which may suggest that they derived from one piece of armour and it was brought on to site for repair or as scrap.

Armour formed of plates riveted within fabric was most commonly used in Europe from the late thirteenth to the early fifteenth centuries. Since the Bordesley plates show no noticeable curvature, it is unlikely that they derive from limb defences, but formed parts of a body defence of a type known as a 'coat of plates' (Blair 1958, 55-61; Thordeman 1939). It is unlikely that the pieces come from a brigandine (a type of armour developed from the coat of plates in the third quarter of the fourteenth century and still occasionally used as late as the early seventeenth century) since many of them are too large to have belonged to such a defence. However, some brigandines of the late fourteenth and fifteenth centuries had large plates covering the breast and the back, but the type and arrangement of the rivets on the Bordesley examples differ from those found on all but possibly the earliest versions of such defences (Eaves 1989, 81-154).

The Bordesley fragments are best interpreted as the remains of a coat of plates, a type of armour which was used from the late thirteenth to the early fifteenth centuries and was most popular from the middle to second half of the fourteenth century. Coats of plates are of great rarity and these pieces provide important evidence for their use in England.

IR 211 Two plate fragments, one with an ?original edge and three rivets (26 and 30 apart) with traces of non-ferrous metal coating. Fig 80. 63+ 1, 46+ w; 50+ 1, 36+ w. (B101, per 7, phase 1)

IR 245 One plate fragment with one rivet with traces of a non-ferrous coating. 34+ 1, 12+ w. (C175, per 7, phase 1)

IR 411 Rectangular plate with ?three original edges and two rivets (25 apart) with traces of a non-ferrous metal coating. A stereo-X-radiograph pair produced by Glynis Edwards (English Heritage) showed the domed shape of the rivet heads, with the precise locations of their non-ferrous plating residues, as well as the faint and discrete remnants of fabric weave outlined in terms of mineralised skins among islands of plating residues. Fig 80. 73+ 1, 61 w, 2 th. (C185, per 7, phase 1)

IR 413 Four plate fragments. Fig 80. Two (joining) with ?two original edges and rounded comers, 43+ 1, 38+ w; 31 1, 21 w, 1 th; two other fragments with ?one original edge and one rivet (with traces of a non-ferrous metal coating), 52 1, 42 w; 52 1, 32 w, 2 th. (C185, per 7, phase 1)

IR 430 Plate fragment with three rivets (21, 25 apart) with non-ferrous metal coating. Fig 80. 46 1, 33 w. (B101, per 7, phase 1)

IR 431 Five plate fragments; one with two rivets (with traces of a non-ferrous metal coating, 25 apart), 40 1, 30 w; three fragments with one rivet, 55 1, 30 w; 39 1, 30 w; 32 1, 22 w. (B101, per 7, phase 1)

IR 444 Five plate fragments; one with ?two original edges and two rivets (with non-ferrous metal coating, 25 apart), 38 1, 35 w; one fragment with one rivet, 36 1, 34 w. (C180, per 7, phase 1)

IR 447 Plate fragment with one rivet (with traces of non-ferrous metal coating). 35 1, 32 w. (C180, per 7, phase 1)

IR 458 Plate fragment with ?two original edges and a rounded comer with two rivets (with non-ferrous metal coating, 30 apart). Fig 80. 64 1, 52 w. (C185, per 7, phase 1)

IR 463 Two plate fragments, one with a rivet with non-ferrous metal coating, 35 1, 30 w. (B101, per 7, phase 1)

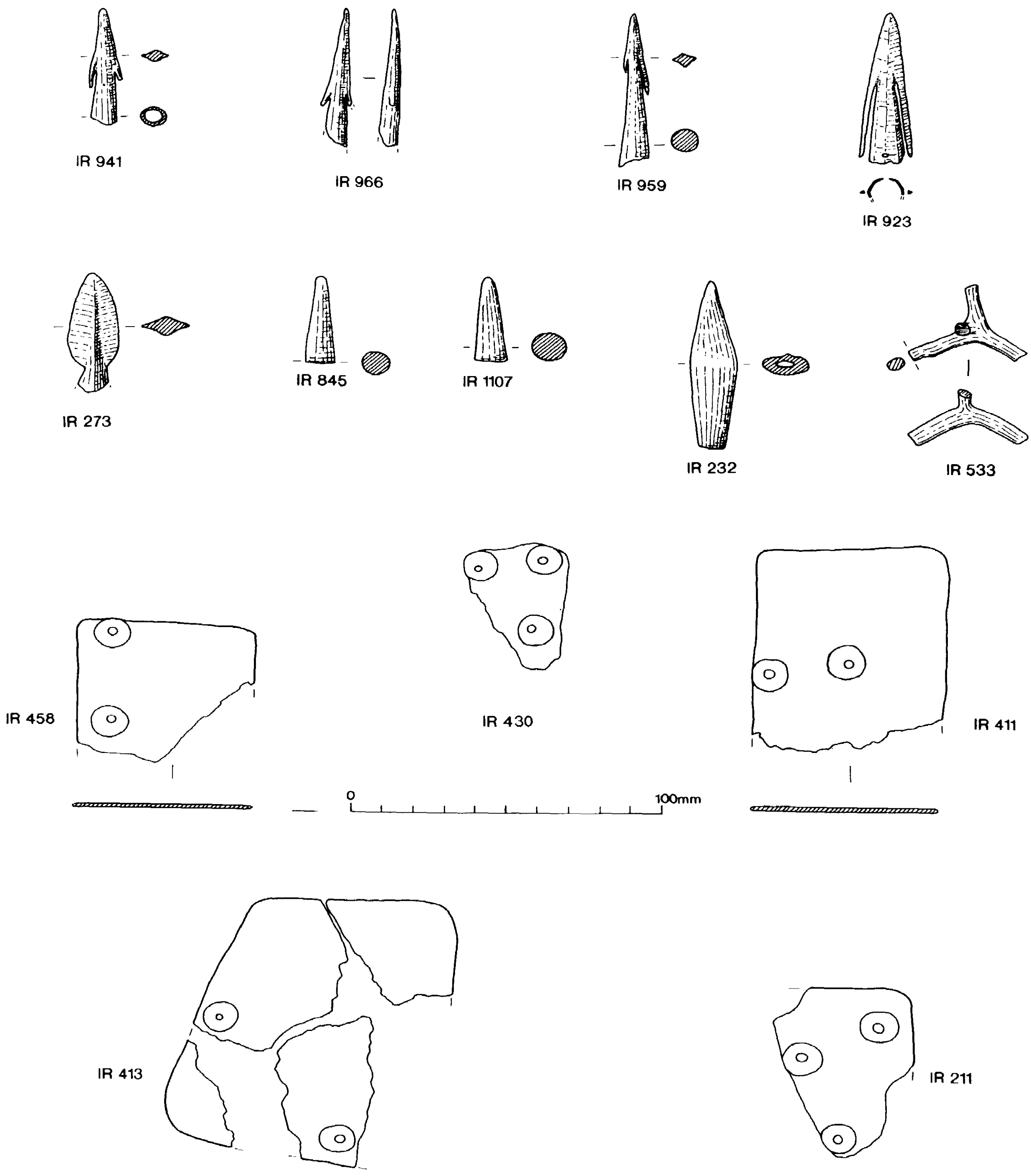


Figure 80 Iron 9: arrowheads, caltrop, and armour

Metallographic examination of iron knives and other objects

by I Ridge

Figures 81–4; Table 38

Fourteen medieval knives and one example from each of the main tool types from BAB – a punch, a reamer, an awl, an axe, a hammer, a chisel – and a tenter hook and two nails were examined after they had been X-radiographed.

Samples were obtained using similar methods to those described by Tylecote (1990b, 145–7) and Wilthew (1987, 63). Most of the blades, the axe, and the hammer were sawn across but the other tools, the nails, and the tenter hook were sectioned longitudinally; also, where the object was well preserved and complete, V-shaped pieces were removed instead from the edge, and where possible from the back, to provide composite but complete sections. These were mounted in polyester resin and then polished by wet grinding followed by diamond polishing and then etching in nital (2% nitric acid in methanol). They were first examined using a low-power binocular microscope and photographed. Structural details were then added using a metallurgical microscope (at magnifications of x 100 and x 400). Hardness was measured using a Vickers pyramid microhardness tester (50g or 100g load). In some cases corrosion had left the object with a very loose structure which made sectioning and testing for hardness difficult and may explain some apparently anomalous readings (eg IR 801).

Some comparable Roman nails, similarly tested by Blackwell (Blackwell and Biek 1985, 343–5), gave results underlining the need to consider the different amounts of work which went into making different types of nail head, as shown also by the present figures which are otherwise equivalent despite the gap of 1000 years. The essential importance of heat treatment for knives is fully discussed in Tylecote 1990b. Table 38 summarizes the main features of the knives and other objects. There is a description of each sample and schematic drawings (Figs 82-4) which show where the samples were taken and the structure and hardness(es) of the objects.

Table 38 Mill (BAB): summary of metallographic examination of iron objects

IR no.	Period	structure				Hardness		Comments†
		A	B	C	D	Edge (max)	Back/sides (min)	
Knives								
981	4		•			517	412	Cf 2809
984	4		?•			800	139	Cf 2761
1308	5	•				308	185	Cf 2729
801	6	•				548	199	Cf 2727
953	6		•			490	135	Cf 2735
954	6		?•			129	165	Cf 2817
993	6		•			762	188	
268	7					286	564	?A mistake
357	7					452	452	Cf 2710
475	7	•				589	337	Cf 2680
854	7				•	292	483	?A mistake. Cf 2812
878	7	•				517	317	Cf 2729
1222	7		•			434	105	Cf 2735
56	U/S				•	667	147	
Tools								
328 punch	7	•				739	266	
494 chisel	7	•				455	194	
932 hammer	3				•	501	162	
1251 axe	4		•			721	196	
979 reamer	4				•	191	152	
1106.3 awl	6				•	328	208	
833 tenterhook	6				•	290	180	
1105A nail	6				•	310	170	
1105B nail	6				•	158	130	

Structure: A: steel core; B: steel edge; C: piled steel; D: iron core.
† Comparison with the Winchester knives in Tylecote 1990b, 147–55.

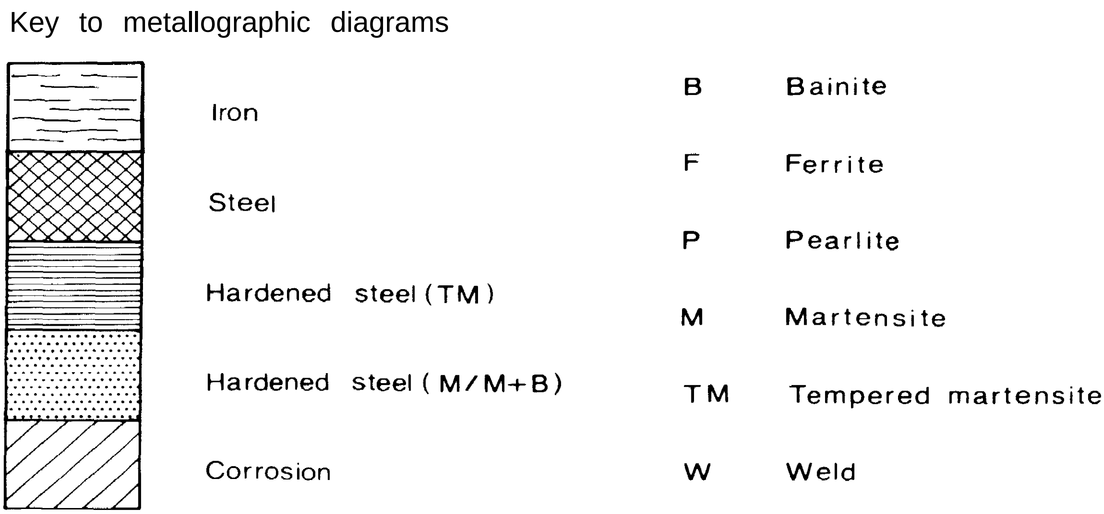


Figure 81 Key to metallographic schematic sections. B: bainite; F: ferrite; M: martensite; P: pearlite; TM: tempered martensite; W: weld

Knives

IR 981 Fig 82. (E435, per 4)
Whittle-tang knife with tapering blade. The blade appears to have been steel-cored (piled), wrapped around with more steel (martensite) with a well-tempered steel strip scarf-welded as an edge (tempered martensite). A good quality knife.

IR 984 Fig 82. (E867, per 4)
Whittle-tang knife. The back of the blade was made of piled ferrite with a ?butt-welded steel (martensite) edge. The blade's brittle character would suggest it had been over-quenched. Although it is badly corroded, the knife is of an adequate quality.

IR 1308 Fig 82. (E800, per 5)
Whittle-tang knife with a tapering blade set in a bone handle. It had a pearlite edge wrapped around with ferrite. Back not sampled. Weld visible. An adequate knife.

IR 801 Fig 82. (E425, per 6)
Whittle-tang knife. A blade with a ferrite core wrapped around with a low carbon steel (pearlite) to which a piled steel (tempered martensite) edge had been welded. Corroded, but a good quality knife.

IR 953 Fig 82. (E452, per 6)
Whittle-tang knife. The main body of the blade is of piled ferrite with a scarf-welded steel (martensite) cutting edge. There appears to be pearlite in the region of the weld, A good quality blade.

IR 954 Fig 82. (E452, per 6)
Knife blade fragment, consisting of homogeneous, piled, wrought iron with common slag inclusions. Has the blade lost its edge?

IR 993 Fig 82. (E452, per 6)
Tip of knife blade, with a back of piled ferrite which had been folded, on to which had been scarf-welded a steel (martensite) edge. At the junction of the weld light bands of arsenic oxide are visible. There is a heat-affected zone of tempered martensite between the weld and the back, which may suggest that the knife was over-quenched. A knife of good quality.

IR 268 Fig 82. (C174, per 7, phase 1)
Whittle-tang knife with a piled and folded homogeneous steel (pearlite) blade which appears to have a harder area (tempered martensite) welded to the back. Does this indicate a mistake made by the smith? Badly corroded, but of good quality.

IR 357 (C175 per 7, phase 1)
Blade fragment of piled, homogeneous steel (tempered martensite) with no sign of an edge, although the metal is badly corroded. A good quality knife.

IR 475 Fig 82. (E289, per 7, phase 1)
Blade fragment. A steel core (tempered martensite) apparently wrapped around with a softer steel (pearlite). The blade is too badly corroded to see any welds, but is of a good quality.

IR 854 Fig 82. (E368, per 7, phase 2)
Whittle-tang knife, consisting of an iron core wrapped around with steel (pearlite). The back has an area of steel (martensite) welded on to it which seems to be unnecessary, ?a mistake.

IR 878 Fig 82. (E261, per 7, phase 2)
Whittle-tang knife. The blade has a steel core (tempered martensite) wrapped around with a softer steel (pearlite). Corroded, but of fair quality.

IR 1222 Fig 82. (E364, per 7, phase 1)
Whittle-tang knife with a tapering blade. It has a wrought iron back (ferrite) on to which had been butt-welded a steel (ternpered martensite) cutting edge. Between the weld and the iron back there is a heat affected zone of ferrite and pearlite. A knife of good quality.

IR 56 Fig 82. (BAB 69 U/S)
Knife blade consisting of a piled iron core (with slag inclusions) with a layer of steel (tempered martensite) around it. Badly corroded, but of good quality.

Tools

IR 328 Fig 83. (B106, per 7, phase 2)
Bunch. A layered structure with a core made of a wrought iron

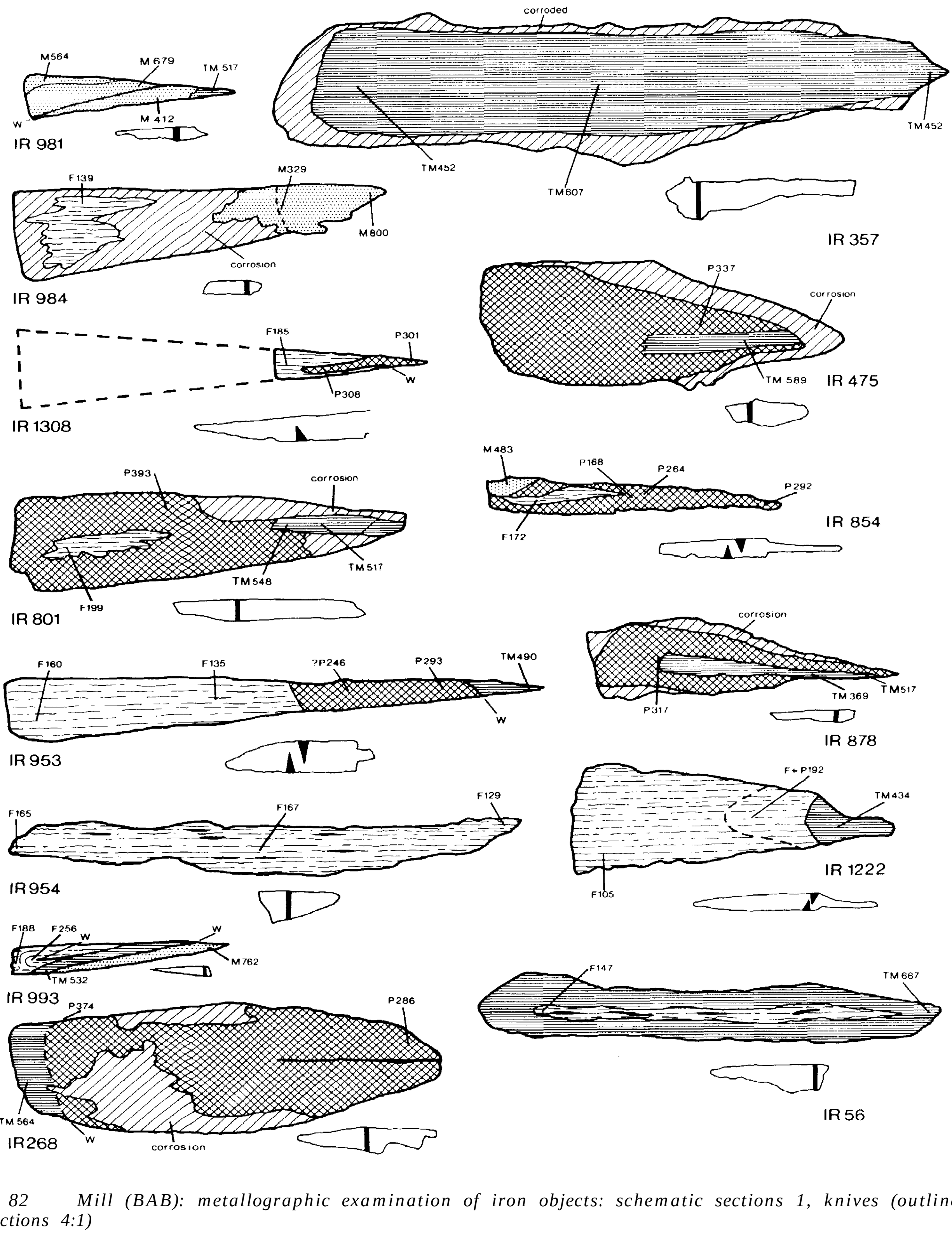


Figure 82 Mill (BAB): metallographic examination of iron objects: schematic sections 1, knives (outlines 1:4; sections 4:1)

rod to which had been wrapped around some steel (martensite) which appears to converge towards the tip of the tool (the tip is corroded). Iron was welded to the outer edges of the martensite.

IR 494 Fig 83. (E289, per 7, phase 1)
Chisel with asymmetrically-set cutting edge. The blade has a layered structure with a wrought iron core to which had been welded on one side a layer of wrought iron (ferrite) and to the other a strip of harder steel (martensite). A further layer of ferrite was welded to the martensite. Although the tip of the cutting edge has corroded, a hardened edge was created by welding two strips, or folding over one layer of martensite and butt-welding it to the iron core. This would also have entailed welding the strip between the other layers of martensite and ferrite.

IR 932 Fig 83. (E864, per 3)
Claw hammer, consisting of a soft wrought iron core surrounded by, and welded to, a thick layer of martensite. There was clear evidence of a heat affected zone of pearlite.

IR 1261 Fig 83. (C670, per 4)
Axe blade consisting of a ferrite back to which had been scarf-welded a steel edge of martensite and bainite. A high quality tool.

IR 979 Fig 83. (E840, per 4)
Reamer. The tool appears to consist of work-hardened ferrite.

IR 1106.3 Fig 84. (E452, per 6)
Awl. Both ends were sampled. The entire awl seems to have been made of a homogeneous ferrite.

Tenter hook and nails

IR 833 Fig 84. (E452, per 6)
Tenter hook - all of the same material - a ferrite which has ?voids in between layers which suggests that the metal was hammered and folded or piled. At the elbow of the tenter hook there is some increase in hardness and this is consistent with work (strain) hardening.

IR 1105A Fig 84. (E452, per 6)
Type 1 nail (square headed) of hard, layered, ferrite suggesting it had been piled or hammered and folded; has a work-hardened head.

IR 1105B Fig 84. (E452, per 6)
Type 5 nail (figure-of-eight head) of ferrite with a similar structure to IR 1105B. but not so hard.

Conclusion

The majority of the knives had a combination of iron and steel to produce an efficient cutting edge, most had been reheated and quenched to produce a harder steel edge. In terms of the way the iron and steel were combined, the most common method was by attaching a steel edge, either by butt- or scarf-welding. As BAB has a relatively short chronology between the late twelfth and late fourteenth/early fifteenth centuries, it is difficult to see any chronological significance in the types of knife, but the frequency of the steel-edged knives is consistent with the results from other sites. Knives made of piled homogenised steel or with an iron core start to be manufactured from the fourteenth century, which may explain why these types are not so common from BAB (Tylecote 1990b, 143).

Most of the knives are of fair or good quality and demonstrate a high degree of manufacturing competence. However, there are knives which are not of such a high standard - for example, the two mistakes (IR 854; IR 268), and two which were probably over-quenched (IR 984; IR 993).

The tools which needed a sharp cutting edge appear to be of a very high quality and were made using as, or more, sophisticated methods of manufacture as or than are used for the knives, especially the axe, chisel, punch, and hammer. Those tools which did not need a sharp edge - the awl and reamer - were made from plain wrought iron.

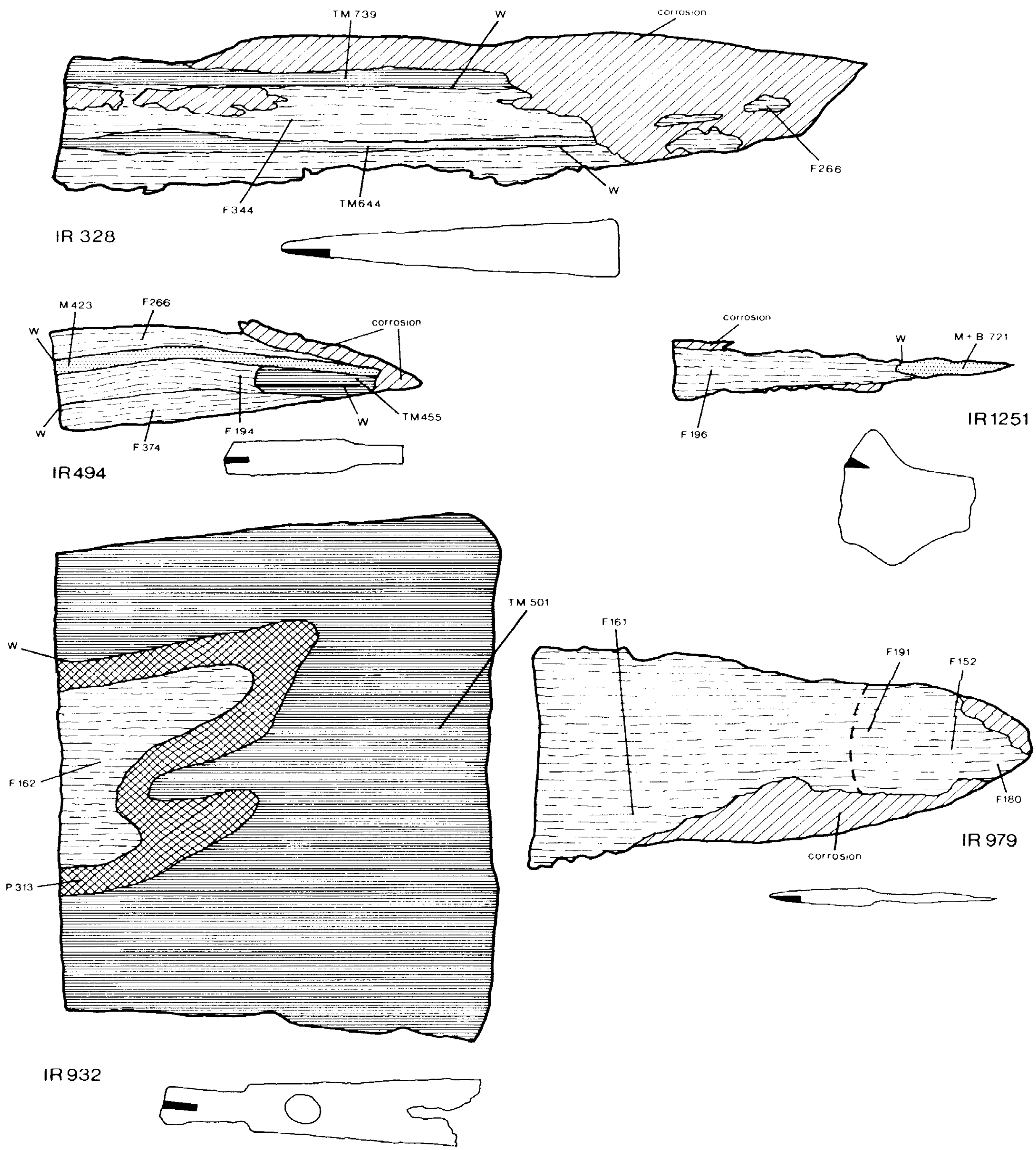


Figure 83 Mill (BAB): metallographic examination of iron objects: schematic sections 2, tools (outlines 1:4; sections 4:1)

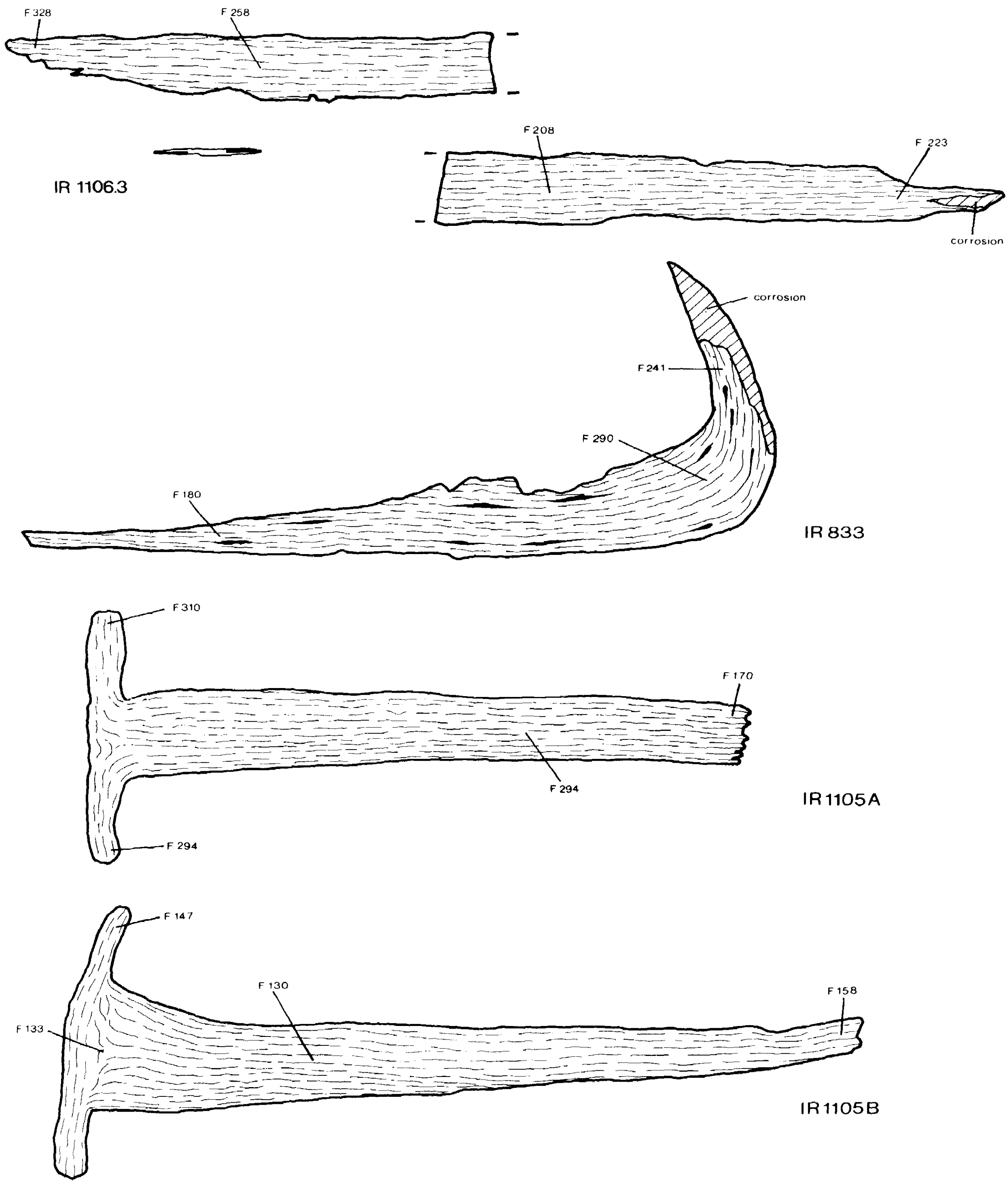


Figure 84 Mill (BAB): metallographic examination of iron objects: schematic sections 3, tool, tenter hook, and nails (outlines 1:4; sections 4:1)

Copper alloy (CA) by G G Astill

Figures 85-9; Table 39

In total 96 pieces of copper alloy were recovered from BAB and one piece from BAE. Table 39 provides a summary.

Table 39 Mill (BAB): summary of copper alloy, by period and by function

Function	Period								
	1	2	3	4	6	6	7	U/S	Total
Vessels	-	-	-	2	1	4	7	3	17
Sheet fragments	-	-	-	2	-	4	4	-	10
Casting waste	-	-	-	3	-	-	-	-	3
Sword/knife parts	-	-	-	-	-	1	3	1	5
Horse furniture	-	-	-	-	-	1	1	-	2
Bindings	-	-	-	2	-	3	1	-	6
Strap fittings	-	-	-	1	-	4	2	-	7
Book/belt fittings	-	-	-	1	-	4	1	-	6
Buckles	-	-	-	5	1	2	5	-	13
Brooches	-	-	-	1	-	1	1	-	3
Pins etc	-	-	1	3	3	10	2	-	19
Unidentified	-	-	-	2	2	1	-	-	5
Total	-	-	1	22	7	35	27	4	96
No. in wet silts	-	-	1	18	7	29	5	-	60

The majority of the material in periods 4 to 6 was recovered from the tail race silts and was therefore deposited during the use and disuse of the mills. By contrast, most of the period 7 material was recovered from the layers associated with the abandonment of the last mill. The distribution of the copper alloy by period is similar to that of the ironwork, that is very small quantities in periods 1 to 3, with sizeable quantities in periods 4, 6, and 7; and small amounts in period 5. Very few of the finds could be dated independently, although it is clear that there are no obvious post-medieval types in the assemblage.

The most common material was in the form of vessel or sheet fragments, some of which had evidence of previous repairs; these pieces were probably brought to the site as scrap. Within the other categories there is a substantial proportion of broken or cut up pieces which might also be interpreted as scrap: Goodall has noted a similar pattern in the ironwork. There are also some pieces which were partly finished. Indeed, the only part of the assemblage which might have been brought to the mills in the course of use is the pins, which are often complete. The implication then is that this assemblage is different from those normally associated with occupation sites: it was not formed as a result of accidental loss and disposal of items of dress or household items associated with the habitation of a building; rather the high proportion of scrap and pieces damaged or discarded in manufacture indicates metalworking on site.

All finds from waterlogged deposits, and some others, were examined by low power microscopy with special reference to surface condition and type of alloy. Those objects analysed by energy-dispersive X-ray examination linked to a scanning electron microscope (SEM with EDAX) are marked by '†'. Tentative identifications of alloy type, prefixed by '?', are mostly based on visual comparisons between analysed and other pieces with 'clean' metal areas. Specialist comments by A Goodall, I H Goodall, and L Biek.

Vessels

Most of this material consists of vessel fragments which may have been brought on to site as scrap for reuse.

CA 42 Thick cast vessel fragment with raised line on inner face. ?Leaded tin-rich alloy. 32+ 1, 21+ w, 5 th. (BAB 68 D S2 U/S)

CA 265 Vessel fragment with possible casting line and carination and one punched hole at either end. Piece has been cut off just below carination. ?A rim repair (cf CA 22 in Watts and Rahtz 1983, 177 and fig. 68, but with no hole). Fig 85. 102 1, 25+ w, 1.5 th. (E743, per 6)

CA 280 Vessel (sheet) fragment or offcut. ?Low-tin alloy. 73+ 1, 12+ w, 0.4 th. (E840, per 4)

CA 129 Fragment cut from a sheet vessel rim with one rectangular hole pierced from upper surface and one circular hole pierced from lower surface. Piece reused as a repair. Fig 85. 75 1, 18+ w, 2 th. (E289, per 7, phase 1)

CA 130 Two vessel (sheet) fragments. Black 'tarry'-looking deposit on exterior surfaces (but see below, Biek, 'The nature and condition of the metalwork'). 35+ 1, 29 w, 1.2 th; 32+ 1, 16+ w, 1.9 th. (E365, per 7, phase 2)

CA 131 Vessel (sheet) fragment; possibly a rim (cf Platt and Coleman-Smith 1975, Vol 2, 262 no. 1803). 41+ 1, 16+ w, 0.8 th. (E422, per 6)

CA 133 Vessel (sheet) fragment, curving with a second piece pleated over the ?rim; possibly a repair or for strengthening. ?Leaded tin-rich alloy. Fig 85. 128+ 1, 19+ w, 1.5-3.2 th, *c* 250+ dia. (E472, per 6)

CA 136 Fragment, cut from a sheet vessel rim. Rim edge folded over, and bent into a U-shape with two holes pierced from outer surface, as if piece had been wrapped round an object and secured by two nails. ?A cover for a shaft bearing. Zinc-rich alloy?. Fig 85. 144+ 1,43+ w, 1 th. (E368, per 7, phase 1)

CA 146 Vessel (sheet) fragment; folded over along one edge. Random scatter of 'curly green' fibre fragments present (cf Biek 1985, Ml, E13-14, and illustrated in Biek 1969, pl 31). Their presence, often associated with copper alloy vessels and resulting from impregnation (and 'preservation') of fibres by copper corrosion products, is taken to imply the erstwhile occurrence of textile, since unravelled and broken up by conditions of burial. 59+ 1, 31+ w, 0.6 th, 440+ dia. (E454, per 6)

CA 290 Vessel (sheet) rim in two pieces, plus fragments. Rim ever-ted, but not folded, three knicks have been cut out of one rim fragment; two holes below the rim, pierced from the interior by a flat blade. Low-tin alloy?. Fig 86. 0.8 th, *c* 14+ dia. (E246, per 7, phase 1)

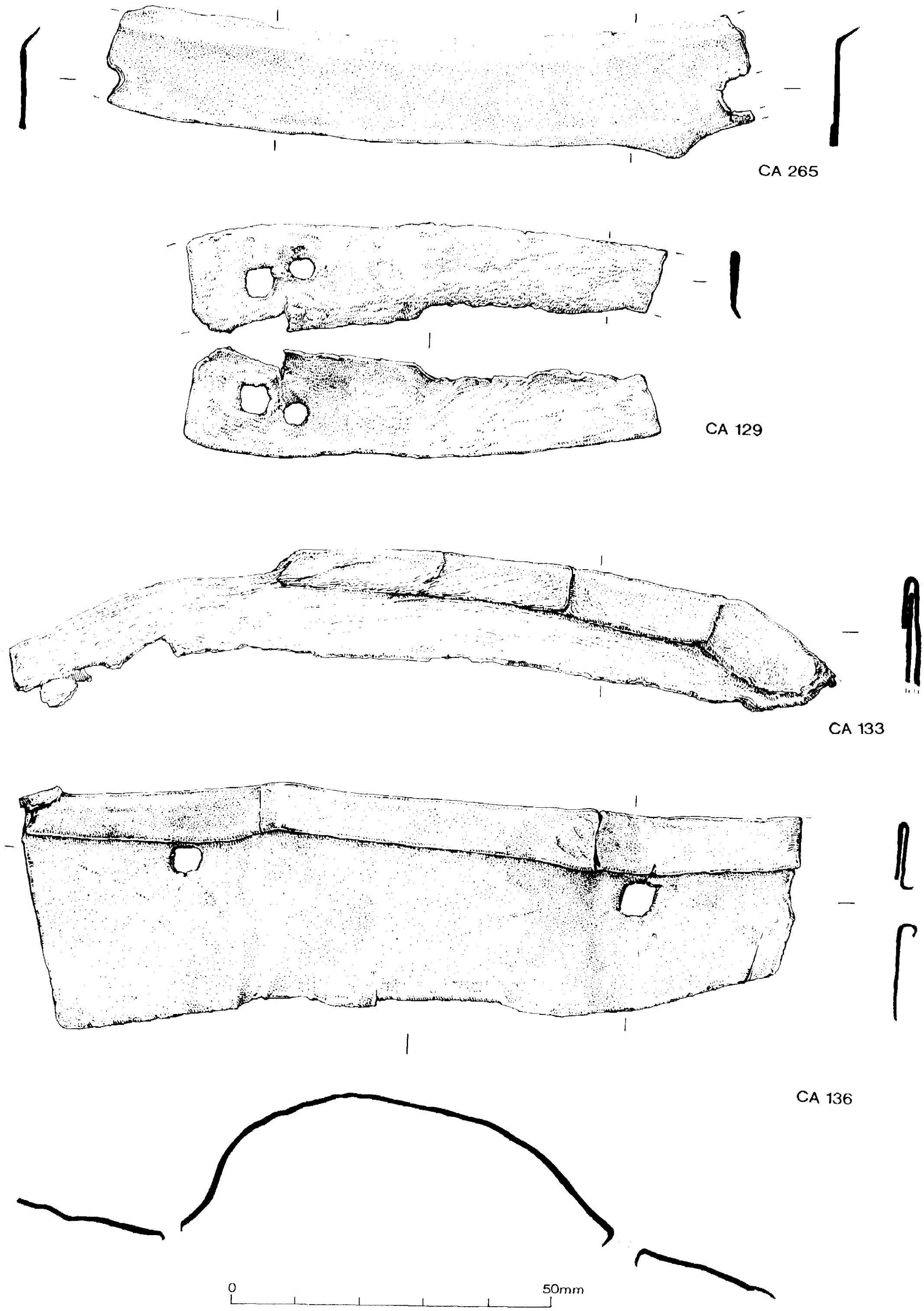


Figure 85 Copper alloy 1: vessels

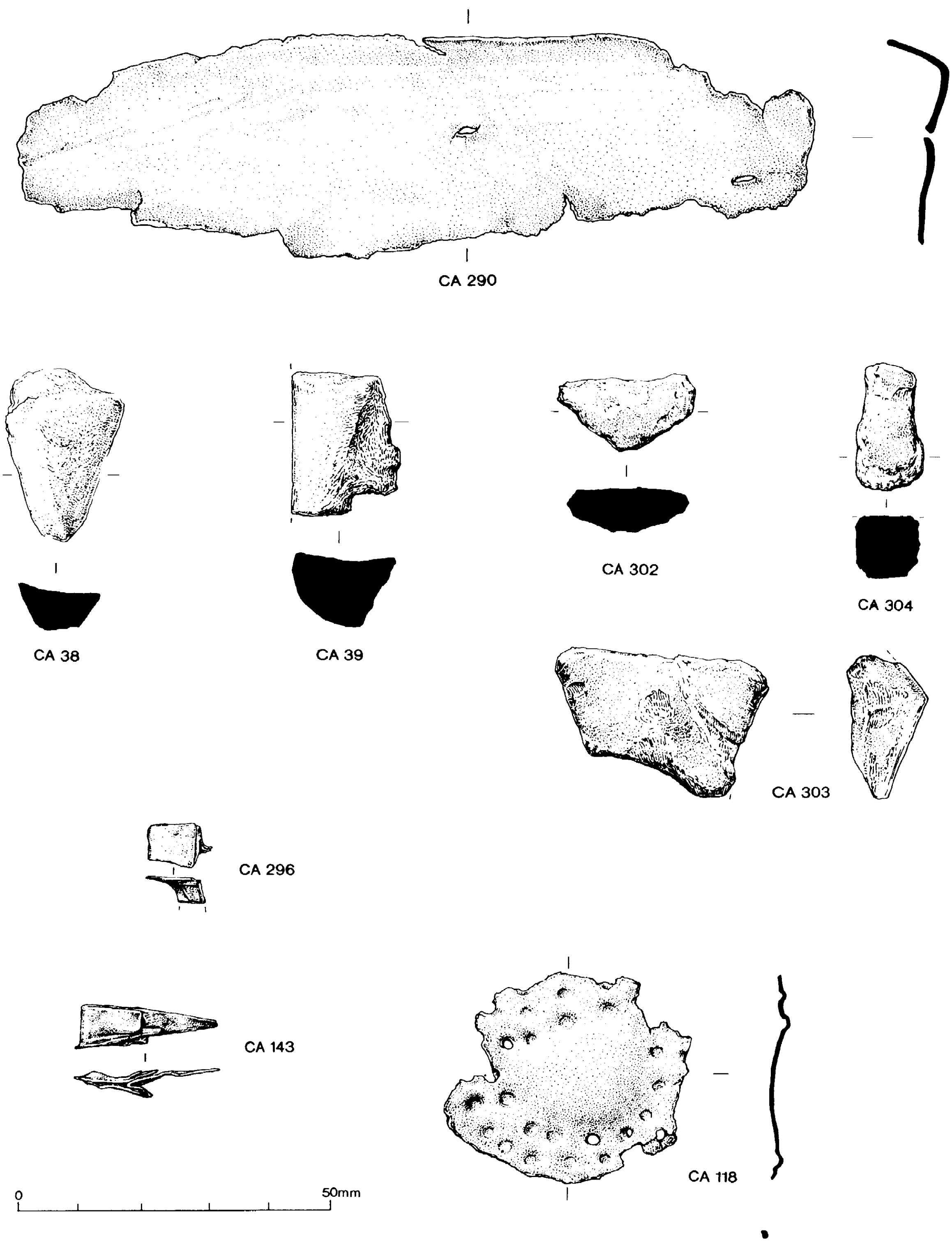


Figure 86 *Copper alloy 2: vessels and sheet fragment*

Valley transect (BAE)

CA 190 Fragment of sheet vessel with two edges cut by shears, ?scrap. ?Zinc-rich alloy. 56 1, 34 w, 2 th. (BAE116, per 3-4)

CA 38 Skillet foot fragment with a patchy black coating (see below, Biek, 'The nature and condition of the metalwork'). Fig 86.31+ 1, 18+ w, 9 th. (BAB 68 DS2 U/S)

CA 39 Skillet foot fragment. Black coating as CA 38. Fig 86. 27+ 1, 17+ w, 13 th, *c* 300+ dia. (BAB 68 DS2 U/S)

CA 302 Skillet foot. Black coating as CA 38. Fig 86. 22+ 1, 12 w, 7 th. (B101, per 7, phase 1)

CA 303 Skillet foot. Black coating as CA 38. Fig 86. 26+ 1, 36 w, 14 th. (D211, per 7, phase 1)

CA 304 Skillet foot. Black coating as CA 38. Fig 86. 22+ 1, 17+ w, 18 th. (C185, per 7, phase 1)

CA 296 A rivet for repairing a vessel. Tin-rich alloy†. Fig 86. 10+ 1, 8 w. 0.5 th. (E865, per 4)

CA 143 A rivet for repairing a vessel. Fig 86. 24+ 1, 8 w, 1 th. (E453, per 5)

Sheet fragments

Most of this material consists of fragments which may have been brought on to site as scrap for reuse.

CA 292 Sheet fragment with obliquely cut edges, ?scrap; ?heterogeneous alloy with some areas having a higher zinc component, ?indicative of on-site working. 26+ 1, ll+ w, 0.5 th. (E865, per 4)

CA 296 Sheet fragment punched, as CA 118. 22+ 1, 10+ w, 0.5 th. (E865, per 4)

CA 294 Sheet fragment. ?Zinc-rich alloy. 26+ 1, 18+ w, 0.5 th. (E464, per 6)

CA 132 Sheet fragment. 25+ 1, l0+ w, 0.6 th. (E425, per 6)

CA 118 Sheet fragment with depressions punched (from the same side) in double circular, concentric pattern, each punch mark is domed in the centre. Possibly a try-out piece?, cf CA 295 (cf CA 11, Watts and Rahtz 1983, 175, fig 69, for a similar but more obvious decorative fitting). Fig 86. 42+ 1, 39+ w, 1 th. (E246, per 7, phase 1)

CA 123 Sheet fragment. 39+ 1, 32+ w, 3 th. (D207, per 7, phase 2)

CA 124 Sheet fragment. 40+ 1, 24+ w, 2 th. (D207, per 7, phase 2)

CA 300 Sheet fragment. 19+ 1, 8+ w, 1 th. (D216, per 7, phase 1)

CA 269 Offcut; edges cut by shears. Zinc-rich alloy†'. 24+ 1, 4+ w, 0.6 th. (E452, per 6)

CA 276 Offcut; edges cut by shears. Tin-rich alloy†. 38+ 1, 3+ w, 1 th. (E452, per 6)

Casting waste

CA 285 Casting waste. Bronze with some zinc†, in places surface overlaid by ?spilt lead. 52+ 1, 25+ w, ll+ th. (E867, per 4)

CA 286 Casting waste. Bronze with some lead and zinc†. 35+ 1, 30+ w, 4 th. (E865, per 4)

CA 287 Casting waste. Bronze with some lead and zinc†, less pronounced than CA 286. 36+ 1, 21+ w, 1 th. (E865, per 4)

Sword and knife parts

CA 37 Cast wheel pommel of a sword. Decorated with the arms of the De Clare family on one face and a dragon on the other. Traces of solder inside for attachment of tang; cast in one piece, but cracked; ?a leaded tin-rich alloy with a speckled white surface; vestigial ?tin coating or more corrosion resistant delta-phase of medium-high tin bronze (cf Meeks 1986). Published in Rahtz and Hirst 1976, 203 and fig 38.3. (Similar to Type VIII in LMMC 1975, 22, dated to the fourteenth century, and Oakeshott type I (1960, 224-5)). Fig 87. 52 outer dia, 29 inner dia, 47 w, 31 th. (BAB 67 L1 - topsoil)

CA 40 Cast wheel pommel casing fragment, with a corner of the rectangular hole for the sword tang, apparently not used. Alloy and condition as CA 37, though ?tin coating visible on inner and outer surfaces. Similar to Oakeshott type J, dated c 1250-1400 (1960, 224-5). Fig 87. 47 outer dia, 23 inner dia, l–2+ th. (BAB 68 DS2 U/S)

CA 41 Cast wheel pommel casing fragment, apparently not used. Alloy and condition as CA 40. Fig 87. 50 outer dia, 2 th. (BAB 69 F12, per 7, phase 1)

CA 116 Cast wheel pommel casing fragment, with a corner of the rectangular hole for the tang, apparently not used. Alloy and condition as CA 40. Fig 87. 50 outer dia, 27 inner dia, 2 th. (C175, per 7, phase 1)

CA 139 End plate from a knife handle; trapezoidal plate with irregular central oval hole (cf Cowgill *et al* 1987, 25; Biddle 1990c, 860-l). ?Zinc-rich alloy. Fig 87. 19.5 1, 9.2-11 w, 0.5 th. (E454, per 6)

Horse furniture

CA 120 Strap distributor, consisting of a convex circular plate with three rectangular holes into each of which was inserted a strap terminal which has a rivet for fixing the strap. Fig 87. Circular plate 4 th, 37 dia. (E261, per 7, phase 2)

CA 127 Part of a cheek piece from a bridle bit. Decorated with a panel of lattice near broken ends and five double lined chevrons on the main body. Traces of ?tin coating on both sides. Fig 87. 73+ 1, ll-16+ w, 7 th. (D220, per 6)

Bindings and strips

CA 283 Binding strip, probably incomplete, curved in section, with rivet. ?Zinc-rich alloy. Fig 88. 7+ 1, 4 w, 0.6 th. (E867, per 4)

CA 272 Binding fragment; strip with one long edge folded over and the other scalloped with incised line decoration and six holes, punched from both sides, cf CA 140 (cf Hinton 1990b, no. 4316, 1121-2, dated to the fifteenth century). Zinc-rich alloy?. Fig 88.25+ 1, 9 w, 0.3 th. (E867, per 4)

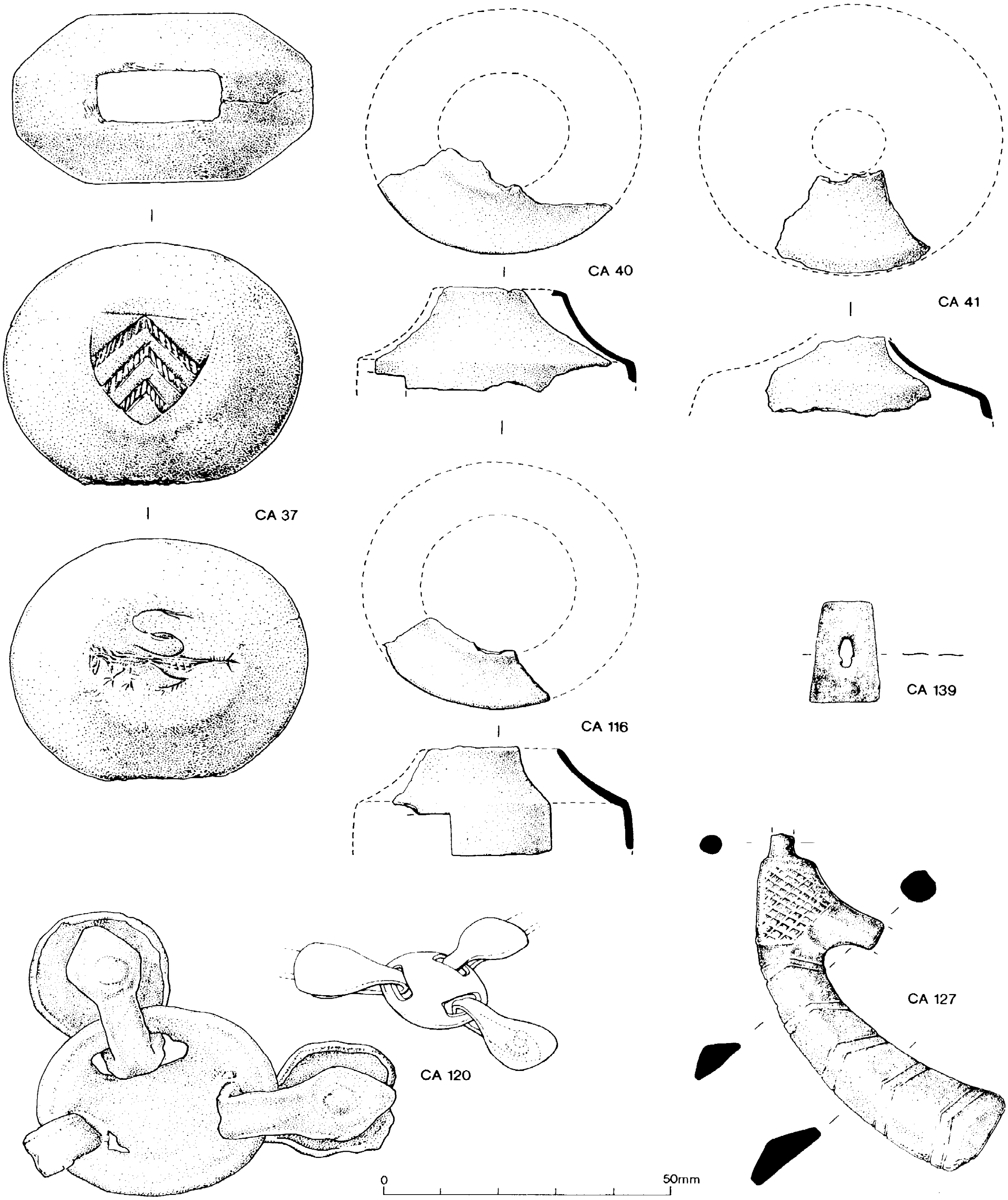


Figure 87 *Copper alloy 3: sword parts, knife part, and horse furniture*

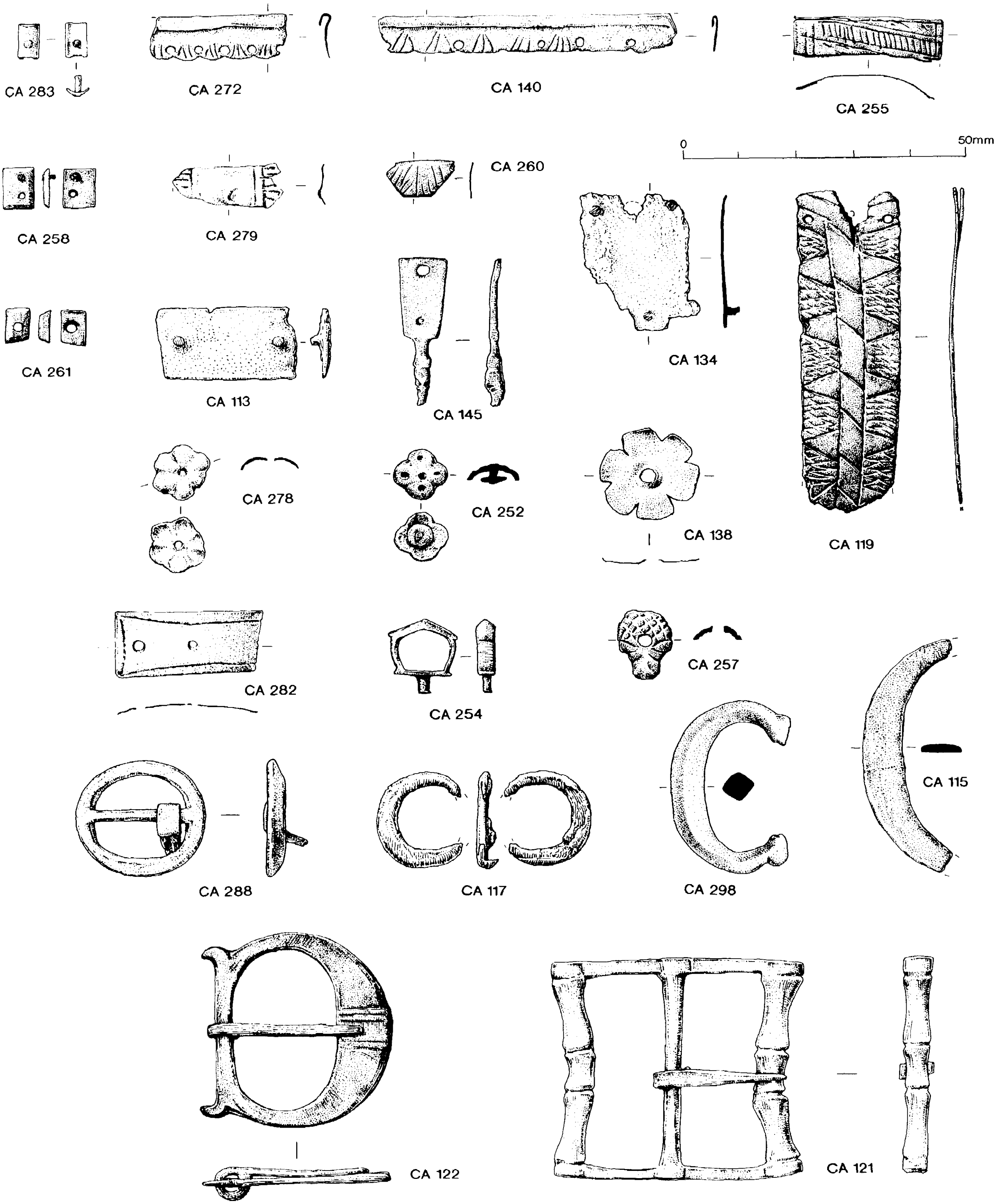


Figure 88 *Copper alloy 4: bindings, strips, strap fittings, strap ends, book or belt fittings, and buckles*

CA 140 Binding fragment; one long edge folded over on to decorated side. Other long edge scalloped with five holes, cf CA 272. Zinc-rich alloy?. Fig 88. 53+ 1, 7-w (folded width), 0.5 th. (E730, per 7, phase 1)

CA 255 Decorative strip with one end folded over and a hole punched through one layer (prior to folding). Incised linear decoration; two double lines running diagonally across the strip with vertical lines in between. Slightly curved; one edge worn away or cut off. ?Zinc-rich alloy. Fig 88. 27+ 1, 8 w, 0.2 th. (E452, per 6)

CA 260 Strip decorated with incised lines; one central line with lines at a slightly different angle either side. Appears to have been cut up: ?scrap. Fig 88. 12+ 1, 7+ w, 1 th. (E452, per 6)

CA 274 Decorative tapering sheet with a hole at one end. 22+ 1, 4-7 w, 0.5 th. (E452, per 6)

Strap ends and fittings

CA 258 Strap fitting with two holes drilled (from one side only) off to one side, one with rivet still in place. Bevelled around all four sides with scratch marks in bevelled areas. Tin-rich alloy?. Fig 88. 9 1, 6 w, 1 th. (E452, per 6)

CA 261 Strap fitting with central hole and four bevelled edges, cf CA 258 but single hole drilled from only one side. ?Zinc-rich alloy. Fig 88, 7 1, 4 w, 2 th. (E452, per 6)

CA 279 Strap end fragment, divided into three fields. Central field has a raised punched circle and is separated from each of the outer fields by two parallel and incised lines. The outer fields have vertical incised lines. No complete edges survive, ?scrap. Zinc-rich alloy?. Fig 88. 19+ 1, 9+ w, 0.2 th. (E865, per 4)

CA 145 Strap end with stylized animal head terminal. Trapezoidal plate with one complete hole at widest end and one not punched right through near the narrow end; ?a part-finished item. ?Zinc-rich alloy. Fig 88. 30 1, 6-8 w, 0.8-3.8 th. (E433, per 6)

CA 134 Strap end fragment; rectangular with at one edge one hole and two small rivets and a small rivet at the other edge. Fig 88. 29+ 1, 19+ w, 1 th. (D314, per 6)

CA 119 Strap end with three holes (one central) punched through one end for rivets. One side divided into three decorative fields; the outer fields infilled with irregular incised zigzag lines and the inner field with diagonal chasing. The back shows many striations filled with white metal residues, in many places uncorroded, such as would be left by normal techniques of keying for solder. Fig 88. 64+ 1, 18 w, 0.8 th. (E255, per 7, phase 2)

CA 113 Belt stiffener with two iron rivets, Fig 88. 25+ 1, 15 w, 0.9 th. (E258, per 7, phase 2)

Book or belt fittings

CA 278 Rosette stud; six petalled flower with central hole punched from one side (top) (cf CA 10, Watts and Rahtz 1983, 176). Zinc-rich alloy†. Fig 88. 111, 10+ w, 0.3 th. (E452, per 6)

CA 252 Rosette stud; four lobed, each lobe decorated with a central incised dot, with rivet and washer of the same material at the back (cf no. 18 in A R Goodall 1981, 68, fig 66). ?Zinc-rich alloy. Fig 88. 9 1, 9 w, 0.4 th. (E452, per 6)

CA 138 Rosette stud; six petalled flower with central hole (cf CA 10. Watts and Rahtz 1983, 176). Fig 88. 0.5 th, 18 dia. (E368, per 7, phase 1)

CA 282 Belt fitting; three sides show bevelling, the fourth is incomplete. A single incised line along the three complete edges. Two holes (unequally punched from both sides, in one case twice) for rivets. ?Zinc-rich alloy. Fig 88, 26+ 1, 18 w, 0.3 th. (E867, per 4)

CA 254 Swivel fitting, perhaps for a belt or purse. ?Tin-rich alloy. Fig 88. 14 1, 12 w, 3 th. (E452, per 6)

CA 257 ?Stud; convex with central hole punched from one side (top). Incised to produce a lattice pattern at the widest part, with three lines either side on the narrow part. Latten (see Biek, The nature and condition of the metalwork')t. Fig 88. 13+ 1, 9+ w, 0.4 th. (E452, per 6)

Buckles

CA 288 Single loop circular buckle frame with central bar. Flat backed with pin (cf LMMC 1975, Al6435 pl LXXVII no. 4). ?Leaded tin-rich alloy. Fig 88. 3 th, 23 dia. (E867, per 4)

CA 117 Circular buckle frame fragment, lacking pin bar. Fig 88. 4 th, 20 dia. (C175, per 7, phase 1)

CA 298 D-shaped buckle with pin bar missing (cf no. 3 in Wright 1982, 89 and fig 50). ?Tin-rich alloy. Fig 88. 35 1, 21 w, 6 th. (E937, per 4)

CA 115 D-shaped buckle fragment; flat backed with many scratches on upper face as preparation for the white coating, probably tin. Fig 88. 47+ 1, 8 w, 2 th. (C175 per 7, phase 11

CA 122 Lombardic 'C'-shaped cast buckle. Flat backed with two straight and parallel incised lines either side of the pin rest; pin curled around bar. Fig 88. 40 1, 32 w, 2 th. (B101, per 7, phase 1)

CA 121 Cast square belt buckle with central bar with pin, baluster decoration, rounded back (cf LMMC 1975, A2633, 277, pl LXXIX no. 5). ?Leaded alloy; areas of clean white plating metal remain visible in places which would not have been subject to wear. Fig 88. 45 1, 44 w, 5 th. (B101, per 7, phase 1)

CA 297 Buckle with an integral buckle plate; there are two rivets along the main body and a (worn) hole for the buckle pin and five holes punched from one side around the widest end, and faint incised radiating lines for decoration (cf LMMC 1975, A2685, 272 pl LXXVII no. 16). Fig 89. 64 1, 15 w, 2 th. (B650, per 4)

CA 256 Strap end buckle, ?cast; flat backed (cf LMMC 1975, pl LXXV no. 7). ?Zinc-rich alloy. Fig 89. 5 1, 12 w, 2 th. (E452, per 6)

CA 264 Buckle plate. Near rectangular sheet doubled over and punched once through both ends; buckle frame or perhaps ring would have passed through the closed end (cf Wright 1982, 90 no. 11). ?Zinc-rich alloy. Fig 89. 19 1, 9 w, 0.5 th. (E817, per 5)

CA 259 Buckle plate; rectangular plate with two rivets and a narrow extension. Decorated with two incised lines with roughly toothed outer edges. Solder residues around the free ends of the rivets suggest attachment to metal fitting. Latten†. Fig 89. 14 1, 5 w, 0.8 th. (E452, per 6)

CA 289 Buckle frame from strap end buckle (cf A R Goodall

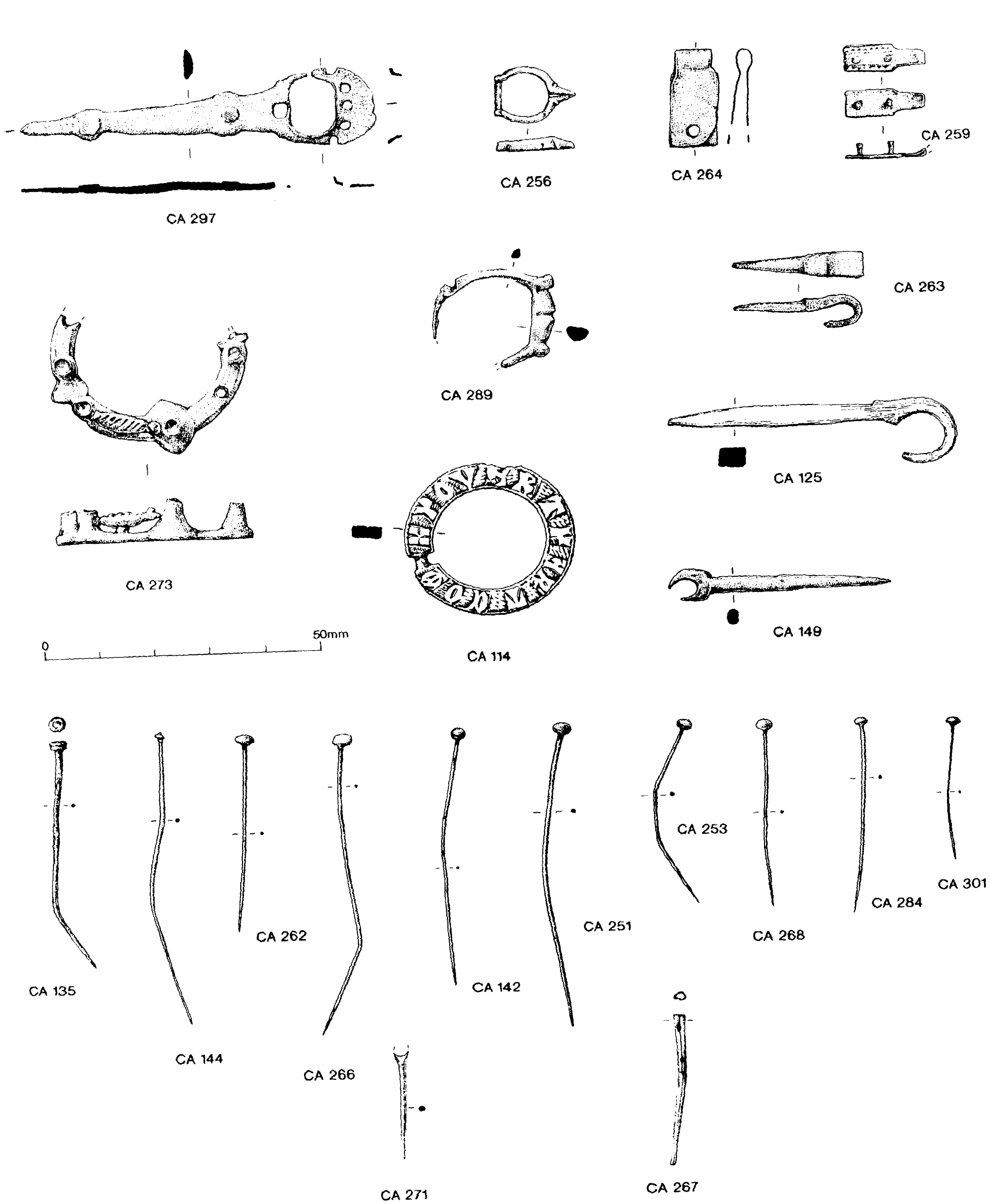


Figure 89 *Copper alloy 5: buckles, brooches, pins, needle, and lace point*

1981, 68 nos 2 and 3). ?Zinc-rich alloy. Fig 89. 24+ 1, 21+ w, 5 th. (E867, per 4)

CA 263 Buckle pin. ?Tin-rich alloy. Fig 89.23 1, 5 w, 2 th. (B762, per 4)

CA 125 Buckle pin. Fig 89. 52+ 1, 5 w, 4 th. (E247, per 7 phase 1)

Brooches

CA 273 Incomplete circular brooch with a flat back. One break along pin bar. Four ornamental bosses survive (there were probably six) with minute traces of a glass-like substance in the settings. The pin rest is located between two bosses (as probably was the pin bar). A crude bird, with diagonal hatching on its back, has been riveted into a hole in the brooch between two bosses. Two further punched holes also survive, one between two bosses: the brooch has fractured along the other hole. However, sufficient survives to suggest that the brooch originally had four birds arranged between the bosses (cf LMMC 1975, 276, A2542 pl LXXVIII no. 1). ?Zinc-rich alloy. Fig 89. 3 th, 35 dia. (E867, per 4)

CA 114 Circular cast brooch, with recessed pin bar, but no pin, with the Latin '+ POVERT PARTCOM' incised on one face. Speckle of highly reflective white metal in the deep olive corrosion product suggests that the surfaces had once been tin-plated. but could be due to preferential preservation of isolated micro-areas with greater corrosion resistance in the tin-rich alloy (cf CA 37 above. Meeks 1986). Corrosion products show large remnant dendrites confirming the b-h-was cast and cooled slowly. We are grateful to Dr P Hardman of the Department of English, Reading University, for suggesting that the second 'P' of the inscription may be a thorn and would thus read '+ POVERT(Y) TH(OU) ART COM(E)' (cf LMMC 1975, 276, C962, pl LXXVII nos 3 and 4; and one from Gloucester is probably fourteenth century, pers comm John Cherry). Fig 89. 5 w, 3 th, 31 dia. (C170, per 7, phase 2)

CA 149 Brooch pin. Appears to have been hammered from a cast rod. ?Tin-rich alloy. Fig 89. 40 1, 3-6 w, 2.5 th. (E452, per 6)

Pins, bell, needle, and lace point

Wound wire headed pins, complete; all evidently of a zinc-rich alloy

CA 250 Pin; wound wire head. 39 1, 0.8 th, 2 dia of head. (E814, per 3)

CA 135 Pin; wound wire head. Fig 89. 48 1, 1 th, 3 dia of head. (E452, per 6)

CA 144 Pin; wound wire head. Fig 89. 60 1, 1 th, 20+ dia of head. (E452, per 6)

CA 277 Pin; wound *wire* head. 46 1, 0.3 th, 3 dia of head. (E452, per 6)

Globular headed pins (all apparently with solid heads)

CA 270 Pin; globular head; complete. ?Zinc-rich alloy. 68 1, 0.2 th, 3 dia of head. (E435, per 4)

CA 262 Pin; globular head; complete. Fig 89. 40 1, 0.8 th, 4 dia of head. (E723, per 5)

CA 266 Pin; globular head; complete. Fig 89. 62 1, 0.9 th, 3 dia of head. (E836, per 6)

CA 142 Pin; globular head; complete. ?Zinc-rich alloy. Fig 89. 51 1, 1 th, 3 dia of head. (E452, per 6)

CA 251 Pin; globular head; complete. ?Zinc-rich alloy. Fig 89. 63 1, 0.9 th, 4 dia of head. (E452, per 6)

CA 263 Pin; globular head; complete. ?Zinc-rich alloy. Fig 89. 41 1, 0.7 th, 3 dia. of head. (E452, per 6)

CA 268 Pin; globular head; complete. ?Latten. Fig 89. 37 1, 0.8 th, 3 dia of head. (E452, per 6)

CA 284 Pin; globular head; complete. ?Tin-rich alloy. Fig 89. 41 1, 0.9 th, 2 dia of head. (E435, per 4)

CA 301 Pin; globular head; complete. Fig 89. 29 1, 0.2 th, 3 dia of head. (E452, per 6)

Unclassified pins

CA 275 Pin without head. 28+ 1, 1 th. (E452, per 6)

CA 137 Pin; head broken but probably globular. 16 1, 3 dia of head, 0.3 th. (E368, per 7, phase 1)

CA 141 Pin without head. 35+ 1, 1 th. (E368, per 7, phase 1)

Bell, needle and lace point

CA 299 Rumbler bell; fragmentary with the 'ball'. 0.4 th, *c* 17 dia. (C691, per 4)

CA 271 Needle with broken eye. A hammered, rolled sheet of latten†. Fig 89. 22+ 1, 3+ w, 1 th. (E723, per 5)

CA 267 Point for lace. Seamed tube with holes (cf CA 80, CA 86, and CA 97, Watts and Rahtz 1983, 179-81). Fig 89. 31 1, 2 w, 2 th (rolled). (E452, per 6)

Unidentified fragments

CA 281 Thick fragment. ?Latten. 47+ 1, 11+ w, 4 th. (E840, per 4)

CA 293 Fragment; no complete edges. 8+ 1, 5+ w, 2 th. (E732, per 4)

CA 148 Lump. 41+ 1, 23+ w, 10 th. (E817, per 5)

CA 291 Narrow fragment pointed at each end. 13+ 1, 1.5 w, 0.5 th. (E814, per 5)

CA 147 Small lump. 13+ 1, 9+ w, 6 th. (E473, per 6)

Other metal: lead and silver (OM)

by G G Astill

Figures 90 and 91; Table 40

A total of 306 pieces of lead or lead alloy (and including one silver item) were recovered from BAB. Table 40 provides a summary.

Table 40 Mill (BAB): summary of other metal (lead or lead alloy and including one silver object, per 7), by period and by function

Function	Period								
	1	2	3	4	5	6	7	U/S	Total
Objects	-	-	-	-	1	-	5	1	7
Pot repairs	-	-	-	1	-	1	-	-	2
Lead waste	-	-	2	204	9	8	12	1	236
Sheets	-	-	1	12	6	3	14	1	37
offcuts	-	-	2	7	-	8	4	-	21
Unidentified	-	-	-	-	1	-	2	-	3
Total	-	-	5	224	17	20	37	3	306

Unlike the copper alloy, the contexts in which the lead items were found were not predominantly from the tail races of the mills. There was, however, a similar period distribution with few finds from periods 1 to 3, although the dearth of material from period 5 was not so marked. The most common material was lead casting waste, in the form of runnels which indicated that the lead had been molten and had then solidified. The vast majority came from a period 4 context which consisted of burnt debris that had been dumped after, it is suggested, the period 3 mill had caught fire. The other occurrences of lead runnels, however, probably indicate that the heating of lead occurred in or near the mills.

The other common form in which lead was found was as sheets and offcuts which had probably been brought to the mills as fragments for reuse. Some had clearly come from roofs, while others had been rolled up; on other sites this has been regarded as a convenient way to keep test pieces or waste lead (Bahtz and Greenfield 1977, 79, 294, 361).

All the objects below are of lead unless otherwise stated. Those objects analysed by energy-dispersive X-ray examination linked to a scanning electron microscope (SEM with EDAX) are marked by '†'. Comments by A Goodall, I H Goodall, and (technical) L Biek.

Objects

OM 24 Double scabbard chape. At top three narrow bands in relief with semicircular leaf pattern above. On one side there is the remains of a smaller chape which belonged to another scabbard. Animal fibres, possibly sheep or goat, are present inside the larger chape (pers comm Glynis Edwards, English Heritage). Soft lead-tin alloy† with tin-enriched surface (see below, Biek, The nature and condition of the metalwork'). Fig 90. 80+ 1, 18+ w, 1.5 th. (BAB 68 DS U/S)

OM 85 Fragment with three facets on one face, broken or cut from a larger object. ?Part of a scabbard. Soft lead-tin alloy† with tin-enriched surface (as OM 24). Fig 90. 20+ 1, l0+ w, 1.5 th. (Cl85 per 7, phase 1)

OM 25 Weight, circular with tapering sides; central tapering hole. Fig 90. 7 th, 24 dia, 25 g wt. (BAB 69 B1A, per 7, phase 2)

OM 65 Silver locket with glass face and suspension ring. We are grateful to the Birmingham Assay Office for the following information. The rim has the following marks: 'D & Co' (the makers' mark) followed by an anchor, a lion passant, and the letter 'a'. The makers' mark was that of Edward Henry Durbaw and William Nelson Last who traded as Durbaw and Co, 41 Frederick Street, Birmingham. The company first registered their mark with the Assay Office in September 1897 and their last entry was 29 September 1919. The anchor (the Assay Office Mark) signifies that the object was hallmarked in Birmingham and the lion passant denotes Stirling silver (92.5% silver by weight of alloy) and the 'a' is the date letter, for 1900, the year in which the article was hallmarked, and invariably the year it was made. 25 1, 3.9 th, 20 dia. (C170, per 7, phase 2)

OM 77 Tack or stud; probably used on a pliable material such as leather. A ?soft lead-tin alloy. Fig 90. 12 1, 2 w, 2 th, 6 dia of head. (E836, per 5)

OM 86 Circular mounting; with part of the outer edge cut and peeled back on itself. Two opposed studs on the inner surface. Fig 90. 26 dia (internal), 31 dia (external). (B101, per 7, phase 1)

OM 91 Cast pendant. Rim has five projections, three on one side and two on the other. The reverse has traces of a pitch-like substance used to attach the pendant to a rigid backing. The material has not been heated to a high enough temperature for its infrared spectrum to be precisely diagnostic but was evidently derived from the destructive distillation of a softwood (R White, National Gallery Laboratory). The recessed face has a St Catherine's wheel in relief and in alternate segments of the wheel there are traces of a pinky red and yellow pigment. Results of SEM and energy-dispersive X-ray fluorescence analysis indicate that the metal is lead-rich with a tin-enriched surface (see below, Biek, 'The nature and condition of the metalwork'); the yellow material is ferruginous, ?a yellow ochre (bole'). A faint suggestion of mercury in the rod area could be due to cinnabar (English Heritage Laboratory). Fig 90. 35 dia of base, 29 dia of rim, 8 height of pendant. (B106, per 7, phase 2)

Repairs for pottery vessels

OM 194 Repair for a pot; lead either side of a sherd of green glazed pottery. Fig 90. 30 1, 30 w, 10 th. (E840, per 4)

OM 97 Repair for a pot. Roughly circular in plan and in some places two layers remain with traces of pottery in between. Fig 90.53 1, 25 w, 8 th. (E425, per 6)

Lead waste

A total of 236 fused runnels were found (see Table 40). The full catalogue is on fiche; only the illustrated pieces are described individually here.

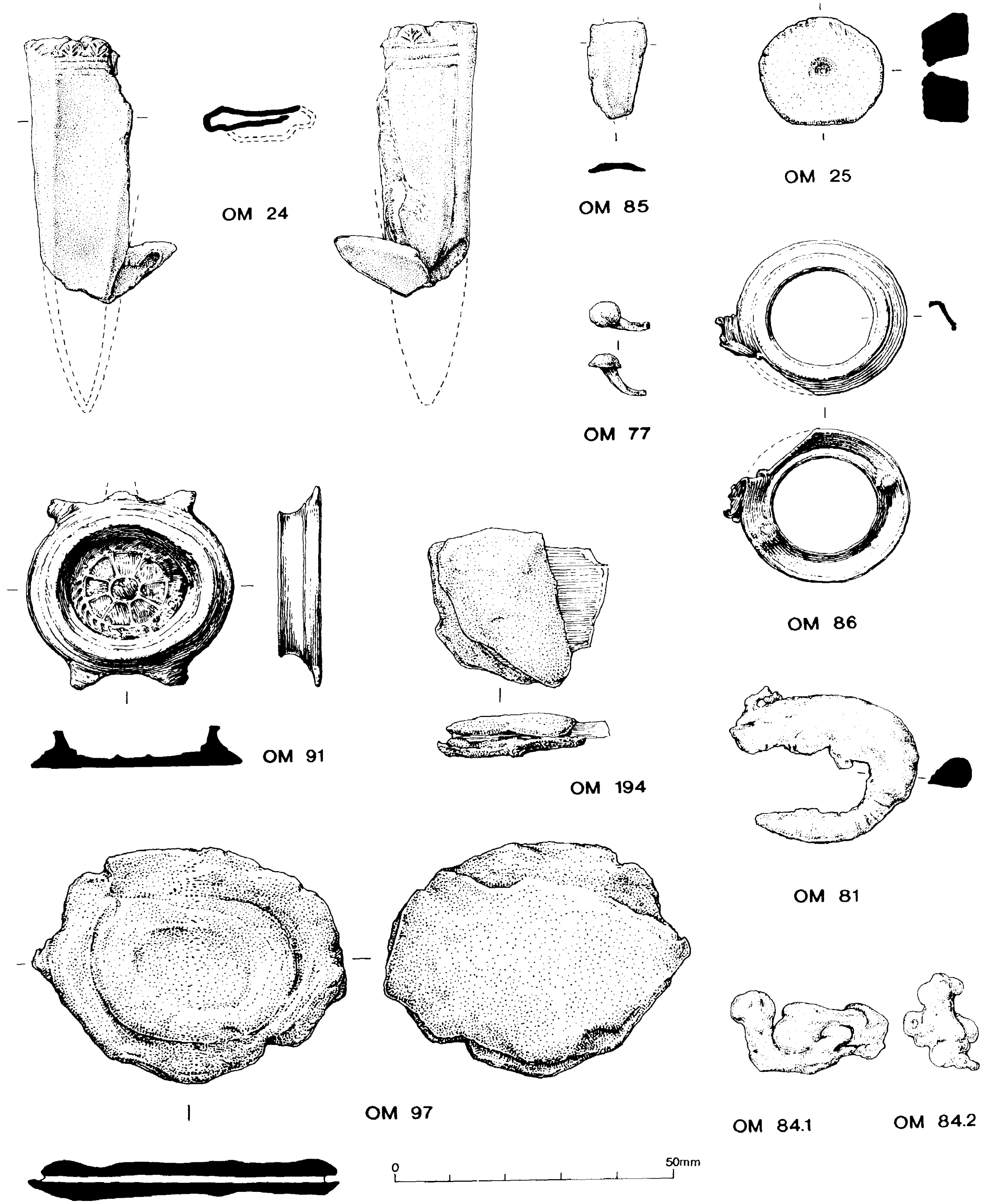


Figure 90 *Other metal 1: objects, repairs for pottery vessels, and lead waste*

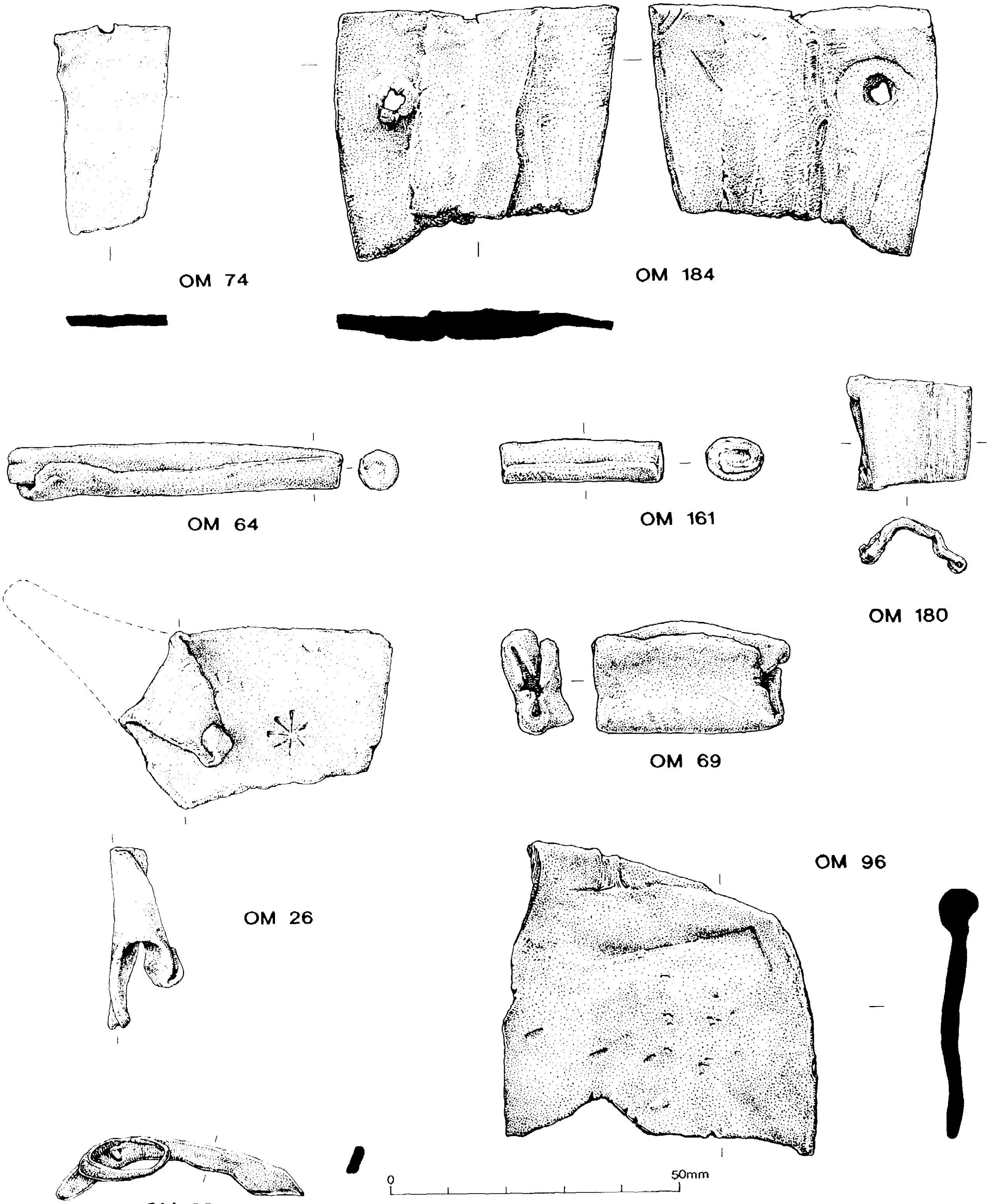


Figure 91 *Other metal 2: sheets and offcut*

OM 81 Large part-circular fused runnel or fragment. Fig 90. 69 l., 66 w, 11 th. (D207, per 7, phase 2)

OM 84.1, .2 Two fused runnels. Fig 90. (B101, per 7, phase 1)

Sheets

Most of this material (total number of pieces 37) could have been brought on site as fragments, perhaps for reuse (see Table 40). The full catalogue is on fiche; only the illustrated pieces are described individually here.

Sheets with nail holes (total number 8)

OM 74 Sheet fragment; three obliquely cut edges and the fourth has broken off along the line of a nail hole. Fig 91. 41+ 1, 21+ w, 3 th. (E243, per 7, phase 1)

OM 184 Thick sheet fragment; rectangular with three obliquely cut edges and one broken with two scored lines in one corner. Made by butting the edges of the two sheets together and sealing the joint with one strip on each side; one corner has a nail hole with the impression of a circular nail head. ?Part of a roof sheeting subsequently cut up. Fig 91. 50 1, 50 w, 6 th. (E864, per 3)

Rolled sheets (total number 5)

OM 64 Tightly rolled sheet, cf OM 161. Fig 91. 65+ 1, 11+ w, 3 th. (D207, per 7, phase 2)

OM 161 Tightly rolled sheet, cf OM 64. Fig 91. 37 1, 1 th, 9 dia. (B622, per 5)

OM 180 Rolled sheet with two cut edges. Fig 91. 25 1, 20 w, 2 th. (E884, per 4)

Sheet fragments (total number 24)

OM 26 Sheet fragment; two cut edges with impressions of stars on one side; other side has one scored line ?Try out. Fig 91. 78.9+ 1, 36+ w, 2 th. (BAE 68 DS U/S)

OM 69 Thick sheet fragment, folded. Fig 91. 34 1, 23 w, 3 th. (D300, per 7, phase 1)

OM 96 Sheet fragment; three cut edges - one rounded and curled over slightly. One edge has a wide V cut out of it and one face has a corner-shaped impression which may suggest that it had been salvaged from a container. Fig 91. 55 1, 51 w, 8 th. (E368, per 7, phase 1)

Offcuts (total number 21)

The full catalogue is on fiche; only the illustrated piece is described here.

OM 99 Offcut. Fig 91. 43 1, 7 w, 2 th. (E452, per 6)

Unidentified fragments (total number 3)

The full catalogue is on fiche.

The nature and condition of the metalwork by L Biek

Table M41

The catalogued copper alloy and lead(-based) finds were compared visually and, where useful, also microscopically. A selection of 'clean' copper-based artefacts was analysed by energy-dispersive X-ray examination linked to a scanning electron microscope (SEM+EDAX) at the Institute for Sedimentology, University of Reading. The results gave comparative values for the significant elements present, chiefly for areas of 'clean' metal surface, and are incorporated in the catalogue ('†'). Where such 'clean' metal is visible on other objects, tentative suggestions prefixed by '?' are made from visual comparison with these 'controls'. The three fragments of 'casting waste' were analysed by 'straight' X-ray fluorescence (XRF) at the School of Archaeological Sciences, University of Bradford. The generic medieval name of 'latten' has been used in the catalogue to denote alloys containing about equal quantities *(c* 5-10%?) of both tin and zinc, with or without significant amounts of lead (cf Oddy *et al* 1986, 5-6).

Three lead-based artefacts were similarly analysed by SEM+EDAX('†'), and one of them also by XRF, at Beading. The two methods are distinguished by the greater penetrating power of XRF. The importance of using both in work on such alloys, especially when corroded, is clearly shown by the present results, SEM+EDAX giving 'essentially tin' and XRF 'virtually pure lead'. In the case of this soft alloy of lead with some tin, the surface could have been enriched in tin through 'tin sweat' on cooling after manufacture, and/or the surface as found had lost lead preferentially by corrosion during burial.

A large proportion of the report on iron objects, including the whole of the note on the armour fragments, is based on X-radiographic evidence. Nevertheless, the site, and especially the waterlogged areas, produced a wealth of moderately and even well-preserved, relatively 'clean', metallic ferrous artefacts. A number of artefacts from waterlogged contexts were examined microscopically along with the copper alloy, and for the same reasons, that is to investigate further in this instance the generally well-known connection between such burial environment and the reactions of metal surfaces to it.

Although the available material and supporting data were plentiful it was not possible to mount a comprehensive professional multi-disciplinary project in depth, such as could have been developed on the kind of thorough analytical basis recently provided by Blades *et al* (forthcoming) for an assemblage which is remarkably similar in respect of copper alloy finds. The following comments are therefore restricted to reflections of previous experience on to present observations, perhaps suggestive of lines for future research.

Table M41 (based on a matrix prepared by Verna Wass) shows the relationship particularly for copper alloy. As noted many times in the last 40 years (eg Farrer *et al* 1953; Booth *et al* 1962; Biek 1963, 142ff, 188ff; 1969, 567-70; 1972, 90-2; 1976, 69-70; 1977, 338-9, 346; 1979a, 205-10; 1979b, 75-81; 1979c, 283-4; 1980, 116-17; Connolly and Biek 1971, 44-50) there is a very obvious direct connection between state of finds and burial under water; and especially between 'good' preservation of a metallic surface and waterlogged, or rather anaerobic (strictly, 'anoxic'), deposits. However, such a link is known to be spurious and only supported where bacterial activity is suppressed. Most of the work in this area has dealt with iron (Booth 1960; Booth and Mercer 1964) but it applies similarly, if not quite equally, to non-ferrous metals. In essence, some very slowly decaying organic matter would appear to be responsible and necessary to inhibit corrosion, although it is as yet not clear exactly what substances are specifically active. A general background of anti-oxidant activity is taken for granted, because the particular bacteria require an anoxic medium to be really effective, but the precise bacteristatic mechanism has yet to be demonstrated.

In this context it is important that there is in fact much evidence here of mild sulphide activity in the deposits concerned (see also fiche, Biek, Bloomfield, and Evans, The drain fill analyses'). Copper alloy objects from the waterlogged muds and silts carry slight but clear islands of earthy material caked with typical copper sulphide skins showing the usual bluish and other interference colours. These skins are not adherent or aggressive but it is equally clear that there has been very mild corrosion, over the centuries, of the underlying metal often to the extant of producing the appearance of a virtually 'electropolished' surface. Equally striking are copious micro-mounds of framboidal pyrite in somewhat thicker crusts on some copper alloy and iron objects. The latter, again, show signs of gentle etching, in 'loose' or separating skins of both vivianite and hematite; this last could only have been lifted off, or out of, burnt or forged surfaces. Oscillating or marginal conditions have left transitional states. Vivianite occurs here in some cases over a surface of magnetite such as may result in 'normal' aerobic corrosion, and has thus not been protective in the way described by Booth et al 1962. Its presence in small patches and areas seems to be linked largely with the physical nature, especially the porosity, of the substrate: under suitable conditions it is found indiscriminately on soil, wood, and pottery as well as on iron objects and bones (Biek 1963, 142ff).

The presence of siderite, ferrous carbonate ($FeCO_3$), associated as here with anoxic conditions, has been discussed both geologically (Watkins 1972) and in an archaeological context (Biek 1962, 6, 13: see Woodfield and Johnson 1991, 165, 231; Biek 1979a, 205-10); it appears to be related to slow oxidative metamorphosis of iron sulphides that had been previously formed by the activities of sulphate-reducing bacteria. The loose, powdery blackening found on some of the iron artefacts from the waterlogged silts, as well as the faint smell of 'rotten eggs' noted in some sections, are characteristic of mildly aggressive bacterial action, but Miller's report (below) labels conditions 'non-aggressive' in general.

A novel point of interest arose through the study of some skillet feet fragments. All of these (CA 38; CA 39; CA 302-4: Fig 86) carried remains of a jet black part-glossy surface layer which was seen as the result of standing in a fire. However, standard infrared spectroscopy on all, and gas-liquid chromatography on one, of the solvent extracts, carried out by John Evans at the University of East London, completely failed to detect any organic components. The analyses by Blades et al (forthcoming) and Brownsword (1991, 117) have shown that late medieval cauldrons, as a class, so far from being the expected leaded medium-tin bronzes, in fact have a peculiar composition including high arsenic and antimony levels which may be responsible for the way in which this particular alloy corrodes under these conditions.

Conversely, of course, as is clear from their 'reduced' state, organic matter of all kinds, from recognisable twiglets down to finely cornminuted 'humic' debris, would have contributed very largely to the grey colour of the tail race silts and similar deposits, both during their transport along the water course and in their final positions. (This aspect has been closely examined in what is, in effect, the same material in the fired state - that is pottery - by Gillies and Urch (1983)) Nevertheless, again, the black ferrous sulphide dispersed throughout such deposits would provide a complementary colour component of variable but significant strength. In many such cases the relative contributions of these and some other factors remain unresolved, and even in dispute despite some firm analytical evidence (Pruden and Bloomfield 1969).

The surface condition of some iron objects

by J D A Miller

Table M42

A sample of soil and two nails (IR 834 and IR 838), all from E452 (tail race silts, per 6, see Table M41), were examined. The soil, after standard incubation (Miller and Tiller 1971, 100-l), was shown to contain *c* 10^3-10^5 cells of sulphate reducing bacteria (SRB) per gram and thus to be non-aggressive to metals. The undoubted presence of sulphide would therefore be either the result of 'purely' chemical activity, or it could be residual from a period of greater concentration of SRB. It is just conceivable, however, that this situation as found, like the tenuous sulphide skins, might represent some form of equilibrium with siderite established after centuries of mildly fluctuating redox conditions. In the absence of observations on controlled systems over periods longer than half a century, no firm conclusions about any chemical or biological shifts in the tail race silts are possible.

The results of J B Johnson's analysis, by X-ray diffraction, of a 'sky-blue' deposit on nail IR 834 and a deep red deposit on nail IR 838 are given in Table M42. Both the colours were remarkably well developed. Vivianite has, of course, been suspected of having a role in the long-term survival of iron objects (Booth et al 1962). In our case it occurred on top of a bulky layer of 'rust' instead of directly overlying the metal, but it is not possible to say whether rust or vivianite was formed first: the situation is typical of a change in conditions. The hematite, in the present context, could only have been formed at a high temperature - it is very stable under all conditions of burial (Biek 1963, 133-4, 236; Blackwell and Biek 1985, 343-5) - so it would either be due to the forging or (here far less likely) the result of a conflagration, but certainly not an underground corrosion product. The presence of dominant siderite reinforces our earlier belief, from looking at other buried iron objects (eg in Field forthcoming), that it plays an important role in preservation.

Coins and jetton by N J Mayhew

CO 12, 13, and 14 were recovered from the topsoil. The rest, of the period 7 coins came from phase 1 contexts, associated with the abandonment of the period 6 mill, and were widely scattered within the same area as the metalwork: this would discount an interpretation of CO 15, 16, 17, and 18 (from over and around the mill building) as a hoard. CO 20, from a period 6 context, provides the *terminus post quem* of 1361 for the abandonment of the period 6 mill.

CO 20 Silver halfgroat, Edward III 1327-77. 21 dia, 2. 10g. Treaty period 1361-9. London mint, (B169, per 6)

CO 12 Halfpenny, Victoria 1862. (B51, per 7)

CO 13 Penny, George V 1927. (C170, per 7)

CO 14 Penny, George VI 1938. (E231, per 7)

CO 15 Silver halfpenny, Edward III 1327-77. 15 dia. 0.500g. Florin issue 1344-51. London mint. No stops visible in legend or on reverse; no marks by crown. (C175, per 7)

CO 16 Silver penny, Edward I, 1272-1307. 19 dia, 1.406g. Group IV 1297-1302. Dublin mint. Small lettering on obverse, large lettering on reverse. Pellet on bust not visible. (C175, per 7)

CO 17 Silver penny, Edward II 1307-27. 19 dia, 1.283g. Fox class XC-f. Crown not visible but late lettering and must be crown 3-5; struck c 1310. Durham mint. Bishop Bek. (C175, per 7)

CO 18 Silver penny, Edward I 1272-1307. 18 dia, 1.120g. Fox class IIIc, *c* 1280-L London mint. (B101, per 7)

CO 19 ?Lead token. 16 dia. 1.53g. (E368, per 7)

CO 21 Jetton. 20 dia, 0.41g. Obverse as Barnard pl III no. 12 reverse, but symbol, monogram appears to be left of, and not directly below +. Reverse a cross and circle design; roundel border. These jettons were counters of the Lombard bankers and financiers, working in England from the mid-thirteenth century. Roundel borders suggest a date of manufacture of *c* 1300 ± 30. (E368, per 7)

Metalworking residues by G G Astil1

Ironworking residues - slag (SL)

Tables 43-5

7.2kg of waste from ironworking was recovered from BAB (Table 43). It was examined by G McDonnell and L Biek. The vast majority was smithing slag, with some fuel ash slag present, and some 'iron debris', which had been produced in the process of working iron. There was no smelting slag. The catalogue giving identifications, numbers, and weights of slags by context and period is in the archive.

This comparatively small quantity was not found in great concentrations, but was distributed over the site (Table 44). However, it was noted that in periods 4 to 6 a high proportion had been incorporated into walls and pebble surfaces ('structures' in Table 44), while in periods 3 and 7 most was found in silts and dumps of material used to raise banks or fill holes. Only a very small amount came from floor levels, and none, interestingly, from hearths.

Most of the material was featureless, but five pieces of smithing slag were buns formed in the bottom of a hearth (SL 15, F22, per 6; SL 96, B124, per 4; SL 125, B109, per 5; SL 151, E817, per 5; SL 223, E742, per 6).

There were also four cases where smithing slag had adhered to ceramic roofing tile (SL 194 and SL 195, C359, per 4; SL 123, C185, per 7; SL 154, E725, per 6). As all the excavated hearths from periods 4 to 6 were constructed of pitched roof tile, such slag-on-tile fragments provide indirect evidence that the hearths had been used in iron working.

20% by weight of the smithing slag also provided evidence that the fuel used had been coal. While present in periods 3 and 4, most of the evidence came from periods 5, 6, and 7.

It is thought that roughly, in terms of order of magnitude, smithing slag could on the average represent 1% of metal, so that even 10kg would be equivalent to about a tonne of artefacts fashioned (eg Biek and Fells 1980, 52).

BAE slags

Only 0.17kg of slag (six pieces and all smithing slag) was recovered from the entire trench. The majority came from the turf and topsoil (four pieces, 0.l5kg), the remaining two pieces came from the second phase of the south mill pond bank and from the fill of the 'silt trap' (BAE45).

Other ironworking residues

Samples (of c 0.5kg of soil) were taken from floor levels and fills of negative features near the hearths in the periods 4 to 6 mill buildings. The period 3 floor levels did not survive sufficiently well to be sampled. The soil samples were crushed and the metalworking residues extracted using a magnet (Table 45). In general, the quantities were small (in most cases it was only possible to record the presence of hammerscale) and thus are probably more indicative of smithing than smelting.

Table 43 Mill (BAB): ironworking residues: summary of slag and iron debris quantities, by type of residue and by period

Period	Smithing slag		Fuel ash slag		Irondebris		Total	
	no.	wt (g)	no.	wt (g)	no.	wt (g)	no.	wt. (g)
3	1	65	1	15	2	15	4	95
4	8	370			2	35	10	405
5	33	2590	1	5	-	-	34	2595
6	11	650			-	-	11	650
7	40	3158	5	135	6	160	51	3453
Total	93	6833	7	155	10	210	110	7198

Table 44 Mill (BAB): ironworking residues: summary of slag and iron debris, by type of context and by period (in % of the total weight of slag for each period)

Period	structures	Tail race silts	Floors	Dumps	Silts
3	-	-	-	100%	-
4	58%	28%	14%	-	-
5	82%	-	-	18%	-
6	43%	3%	4%	50%	-
7		44%	-	39%	17%

The occurrence of these residues as evidence for ironworking is considered below (part III, 'Metalworking at Bordesley ...'). In some cases, however, a conglomeration of iron fragments can be seen to include waste from ironworking and part-forged iron objects, as for example in IR 812.

Other metalworking residues

X-radiographs of some iron conglomerations not only allowed identification of the constituent artefacts, but also revealed small radiopaque fragments of a distinctive shape which are interpreted as the debris from copper alloy working. All of the conglomerations were recovered from semi- or completely waterlogged silts of the tail races (per 4: E840 x 1, E845 x 1, E867 x 2; per 6: E452 x 11).

Three pieces of copper alloy (CA 285-CA 287) have also been identified as casting waste, of mixed copper alloy (tin bronze) and lead spillage, and one iron conglomeration (IR 977) also contained non-ferrous debris. These came from the period 4 tail race silts (E865).

X-radiographs of iron conglomerations have also revealed distinctively shaped radiopaque fragments which are interpreted as pieces of lead which had been subjected to heat. While these are probably evidence of lead working, the fragments could have resulted from a conflagration. All but one (E473, a floor) came from the silts of the tail races (per 3: E864 x 1; per 4: E840 x 1, E865 x 4, E867 x 8, E435 x 1; per 6: E452 x 7, E473 x 1).

The valley environment: the evidence of the plant remains

by W J Carruthers

Tables M46 and M47

Method

Samples of c 5 litres of sediment were taken from a range of waterlogged contexts in the period 1 stream channels, and in the mill pond and its channels, the mill races, and the bypass channel, for the recovery of environmental remains. Plant macrofossil analysis was carried out on 46 anoxic samples from 41 contexts. Subsamples of 500ml were processed by soaking them in hot water until the sediments disaggregated, and then pouring them through a stack of sieves (mesh sizes ranging from 5mm down to 250microns). The residues in each sieve were washed through with clean water and examined under a binocular microscope (x 10 to x 50) in a little water. Plant remains were removed for identification and stored in 75% alcohol.

Plant remains from an initial group of eleven samples were counted, but remains from samples examined later were scored for frequency using a scale of one to four (+ = occasional to ++++ = numerous: see Table M47) because of time limitations. It is not thought that the final interpretation of the remains was greatly hampered by this method, as quantitative analyses can be difficult to interpret with assemblages of this kind due to problems such as differential preservation, differential seed production, different methods of seed dispersal, and swamping of samples by seeds from the local vegetation. Some measure of changes in assemblages through the periods, for example changes in

Table 45 Mill (BAB): summary of hammerscale extracted from soil samples, by type of context and quantity, and by period

Period	Type of context	Type of residue	Quantity
4	B608, floor	Hammerscale	•
4	B521, pit fill	Hammerscale, ash and coke present	• •
4	E785, fill stakehole near hearth E914	Hammerscale	•
4	E750, floor around hearth E914	Hammerscale	• • •
5	E277, hearth	Hammerscale	•
5	E498, floor near E277	Hammerscale with ash, slag and charcoal	• •
5	E493, floor near E277	Hammerscale with iron flakes	•
5	E495, floor repair	None	
6	E470, floor	Hammerscale	•
6	E473, floor	Hammerscale	•
6	B103, floor	None	

Residues: •: present; • •: in small quantities; • • •: in moderate quantities.

woodland representation, was achieved by comparing the average frequency for each woodland species and the total number of woodland species for each period. Differences in preservation had to be taken into account in this analysis.

Table M46 lists the contexts sampled for plant macrofossils. Table M47 presents the data as a summarised species list by period. Where phasing is imprecise, for example period 4-5, the later of the periods is used for this table. Of the 46 samples examined, ten were too desiccated to contain any useful information; these are listed in Table M46. The identifications for each of the remaining 36 samples are given individually in the archive. The plant macrofossils will be retained by the author for two years after publication and then kept at the Forge Mill Museum and Bordesley Abbey Visitor Centre, Bedditch.

Identifications were made by comparison with modern reference material. Habitat information and nomenclature are primarily taken from Clapham *et al* (1987).

Wheat The few carbonised wheat grains recovered appeared to be of the bread-type free-threshing hexaploid form *Triticum aestivocompactum* s l), but it is possible that there were tetraploid free-threshing wheats present, as these two taxa can be difficult to separate using grain morphology. No wheat rachis fragments, which can be identified with certainty when well preserved, were recovered.

The fairly large number of waterlogged cereal caryopses that were recovered from the period 4-5 tail race sediments (BAH19 and BAH11) were generally not identified further than 'indeterminate cereals', partly because many were fragmentary and partly because time was limited. Some wheat/ rye forms were observed, however, amongst the remains.

Barley The only remains of barley recovered were some waterlogged rachis fragments which appeared to be from the six-rowed species *(Hordeum vulgare* L) but were generally poorly preserved. The identification is therefore left at *Hordeum* sp.

Oats The few carbonised oat caryopses recovered did not retain their floret bases and so could only be identified as wild or cultivated oat *(Avena* sp).

Rye One sample (E864) contained a number of waterlogged rachis fragments (chaff) of rye *(Secale cereale).*

Fuller's teasel The seeds of fuller's teasel *(Dipsacus sutivus* (L) Honckeny), a cultivated species, can be distinguished from the wild teasel *(D fullonum* L), a weed of rough ground and stream banks, by the presence of bifurcated or double ridges on at least one of the four faces of the fruit in place of the usual ridges (Hall 1991). Where single ridges were present on all four faces it was not possible to be sure which species was present, since some fruits of fuller's teasel do not possess double ridges. In addition to the fruits, some samples contained quite large numbers of receptacular bracts which are easily distinguished from wild bracts due to their termination in a short, stiff, recurved spine rather than a long, slender, ascending spine (Clapham *et al* 1987).

Weeds Levels of identification vary for some taxa according to the state of preservation of the specimen. Buttercups were only identified to species where the preservation was exceptional and the achenes possessed uneroded borders and beaks. Docks *(Rumex* sp) were taken to species level only where perianths were preserved.

Plant groups

A wide range of anoxically preserved plant remains (primarily fruits and seeds) were recovered from the samples as well as a few carbonised remains. Some of the 500ml samples contained large numbers of seeds, for example, Al57 produced over 1000 stinging nettle *(Urtica dioica)* achenes alone, whilst others contained very little organic material of any kind, such as BAE294. To some extent this will reflect the degree to which the sediment has remained waterlogged *in situ* over the years and the rate of sediment accumulation, but in other cases samples may have deteriorated in storage, as not all of the analyses were carried out immediately after excavation. Samples with + and ++ total seed frequency ratings (Table M47), therefore, should be treated with caution as some differential preservation may have affected the results, the tougher-coated woody seeds, for example, are more likely to have survived.

Sediments from flowing bodies of water such as stream channels and mill races will contain some plant remains that originated further upstream, particularly plant propagules deliberately designed to float such as alder *(Alnus glutinosa)* fruits and female catkins, but the assemblages will usually be dominated by the local vegetation type, that is aquatic and bankside plants.

In order to characterise these mixed assemblages the plant remains can be grouped according to their habitat preferences. In this way variations can be observed between the samples. It should be noted that many species will grow in a range of different habitats, for example, chickweed *(Stellaria media)* will grow as a weed of cultivation or in a variety of other disturbed and wasteground situations, particularly on nutrient-rich soils.

The main groups represented are as follows.

Woodland

The range of taxa included in the analyses for this section includes the tree and shrub species, such as lime *(Tilia cordata),* oak *(Quercus* sp), and silver birch *(Betula pendula),* and some woodland herbs such as three-nerved sandwort *(Moehringia trinervia)* and red campion *(Silene dioica).* Most of the woodland herbs and shrubs can only grow to produce seed where the canopy is open. Many will also occur in areas of scrub and hedgerows, so it is possible that in some cases where woodland is being discussed these other habitats are actually present.

Alder and some willows *(Salix* sp) are characteristic of wet soils alongside streams, alder requiring moving groundwater and not too poor soils. It is notable that, although in many samples the number of alder fruits was high, the number of woody female catkins was small, perhaps indicating that the trees were not directly overhanging the streams and ditches. The fruits Possess inbuilt corky floats and so may have been carried from some distance upstream. The presence of elder *(Sambucus nigra)* seeds is indicative of soils with a high nitrogen content.

Some of the edible species, such as sloe *(Prunus spinosa),* hazel *(Corylus avellana),* and elder were left out of the analysis because their deliberate collection for food would have confused the calculations. Several herb species which can grow in a wider range of habitats including woodland were also omitted, for example, ground ivy *(Glechoma hederacea)* and lesser marsh stitchwort *(Stellaria graminea/palustris).*

Grasslands

Grass seeds are not well preserved by waterlogging but a number of herbs recovered are characteristic of different types of grassland. Wet meadows were indicated by meadowsweet *(Filipenduta ulmaria),* ragged robin *(Lychnis flos-cuculi),* and creeping buttercup *(Ranunculus repens).* Small scabious *(Scabiosa columbaria)* and bulbous buttercup *(Ranunculus bulbosus)* are more characteristic of dry meadows.

The presence of meadow species could be due to seeds being deposited from a local hay meadow vegetation or from the disposal of waste hay or dung. Deposits of animal manure in Oslo (Griffin 1988) contained a range of grassland taxa, a high proportion of which were also found in samples from Bordesley, including ox-eye daisy *(Leucanthemum vulgare),* hawkbit *(Leontodon* sp), and self-heal *(Prunella vulgaris).* As will be discussed later, dung may have been used as part of the treatment of textiles prior to fulling. However, no specific concentrations of stems, leaves, and flower heads were observed to confirm the presence of dung.

Shorter grassland, that is pasture, was indicated by daisy *(Bellis perennis),* whilst great plantain *(Plantago major)* and silver-weed *(Potentilla anserina)* suggested areas of open, trampled ground or dung from grazing animals. Small scabious is worthy of note since it is typical of calcareous pasture whilst the local soils are on alluvial clays. The presence of sheep's sorrel *(Rumex acetosella)* and blinks *(Montia fontana* subsp *chondrosperma)* indicate acidic soils and, in the latter case, sandy soil that is damp at least part of the year. Rush seeds *(Juncus* sp) were present in a number of samples and these included both the *J effusus* group which are tufted perennials that often occur in grazed damp pastures and the *J articulatus* group which are more typical of damp hay meadows. Rushes also occur in more marshy areas and along stream banks.

Marsh and bankside plants

The stream channels and the mill pond, channels, and mill races would have all provided wet habitats for a variety of semi-aquatic plants. Several of the Polygonaceae (dock family) such as water-pepper *(Polygonum hydropiper)* grow as marginals alongside streams and ponds or in marshy ground. A variety of sedges *(Carex* spp) were present and often frequent, and bulrushes *(Schoenoplectus* sp) and spike-rush *(Eleocharis* subg *Palustres)* were recorded. These may also have grown in the same kinds of habitat at Bordesley.

Some of the Ranunculaceae (buttercup family) grow in marshy areas near streams and ditches, for example, marsh marigold *(Caltha palustris),* greater spearwort *(Ranunculus lingua),* and celery-leaved crowfoot *(R sceleratus).* Hemlock *(Conium maculatum)* will often colonise wet, disturbed soils along river banks. It is possible that this plant was first introduced into the area as a medicinal plant as it does not occur until period 4. The plant is very poisonous but Culpeper (1669) recommends various parts of it for external uses such as for inflammations and ulcers. However, the plant is common on many medieval sites and it may have simply been growing as a weed.

Aquatics

The various bodies of water in the vicinity of the mill site would have provided habitats for a range of submerged, floating, and emergent aquatic plants depending on the rate of flow and nutrient content of the water. Most of the taxa represented, such as horned pondweed *(Zannichellia palustris)* and horn-wort *(Ceratophyllum demersum),* can grow in still to slow or moderately flowing water with a medium to high nutrient status (Haslam *et al* 1982). No major differences were found between the aquatic floras of the different streams and ditches to indicate different rates of flow or nutrient content, although some taxa were only found in one area of the site, for example, flote grass *(Glyceria* sp) was only present in BAE although it occurred through several phases. This is unlikely to be of great significance but probably indicates a long established colony of this floating grass which spread from the millpond to the overflow channels.

Plants such as water plantain *(Alisma* sp) and pondweed *(Potamogeton* sp) were present in many of the streams and ditches in each of the areas. It is perhaps surprising that most of the taxa which prefer slow-flowing or still water, such as horn-wort and duckweed (Lemna sp), were found in the tail race silts rather than the mill pond. However, these seeds mainly occur in periods 6 and 7, which might reflect reduced flow through disuse. During the major periods of use of the mill the periodic release of water from the mill pond might have been sufficient to prevent the build up of aquatic vegetation of this nature, or the channels may have been deliberately kept clear.

Cereal remains and arable weeds

A few carbonised cereals and some waterlogged grains and chaff fragments were recovered from some of the samples from BAB and BAH. A carbonised oat caryopsis from a period 1, phase 3, stream bed silt (A1170) could indicate earlier activity in the area. It is not possible to say whether the oat was a wild or cultivated species, but there is no clear evidence for cultivated oats in Britain until the Roman period.

Wheat *(Triticum aestivocompactum),* barley *(Hordeum* sp), oats *(Avena* sp), and rye *(Secale cereale)* were all represented either by carbonised grain or by waterlogged rachis (chaff) fragments in samples from the periods of occupation of the site. The total number of cereal remains was not great, although one sample from a period 3 tail race silt (E864) did contain some few barley and rye rachis fragments and the period 4-5 tail race produced large numbers of waterlogged cereal caryopses (BAH19 and BAH11). It is not possible to say anything about the relative importance of the cereals from these mixed assemblages but in general bread-type wheat would have been most valued for its superior bread-making qualities, whilst barley and oats might have been more often used as fodder. The documentary records mention the receipt of wheat, barley and oats, malt and pulse from one abbey property (Wright 1976a, 20). No germinated grain was recovered to indicate malting, but if the grain had already been ground to extract the malt then it is unlikely to have been identifiable. Pulses are not often preserved by waterlogging and so would have had to have been carbonised, like the carbonised deposit of vetches at Beading Abbey (Carruthers forthcoming a), to have been recovered.

It is also not possible to say much about crop processing activities except that the presence of the mixed barley and rye rachis fragments in E864 could suggest that not all of the cereals being sent to the mill were fully processed. As no grains were present in the sample the chaff remains appear to represent crop processing waste and this may have come from separate barley and rye crops or a mixed crop. An alternative explanation is that the remains originated from unprocessed or semi-processed crops, since the light chaff is likely to float away from the grain when deposited in water and sediment out further downstream. The remains could also be derived from animal fodder or dung, as crop processing waste was a useful supplement for feeding to livestock.

A single carbonised bread-wheat type grain and a few waterlogged cereal caryopses were recovered from post-abandonment sediments, the latter being the only cereal remains from BAE.

A range of arable weed seeds was recovered from the samples and these were almost all found in the vicinity of the mill building (BAB and BAH) and from the main periods of occupation. The only evidence of arable weed seeds in samples away from the mill was a trace of corn cockle *(Agrostemma githago)* in the fill of a period 3 ditch (BAE276). Troublesome weeds such as corn cockle, corn marigold *(Chrysanthemum segetum),* and cornflower *(Centaurea cyanus)* are commonly found in medieval assemblages. Some species such as corn marigold and corn spurrey *(Spergula arvensis)* are indicative of the cultivation of acidic soils whilst others, such as corn crowfoot *(Ranunculus arvensis)* and thorow-wax *(Bupleurum rotundifolium),* are more common on calcareous soils. The former range of weed seeds was present in samples from periods 3, 4, 5, and 7 and the latter in periods 4, 5, 6, and 7. This slight difference may not be of any great significance as the remains in the samples for period 3 were fairly poorly preserved. The range of soil types does, however, suggest that cereals were being brought in from more than one source. Since the abbey owned a large number of granges which are likely to have supplied the monks with grain, this seems quite likely, It is doubtful whether cereals would have been grown on the damp, poorly drained alluvial soils of the floodplain in the vicinity of the mill, as these would have been better suited for use as grazing and hay meadows.

It is unfortunate that with these mixed assemblages it is not possible to determine which of the remaining weed taxa that can grow in a variety of habitats were also growing with the crops, as these may have revealed further information about the soil types, such as whether they were damp, dry, well-manured or poor in nutrients. The arable weed seed small nettle *(Urtica urens)* often grows on well-manured soils, although it is not restricted to an arable habitat. It was present in a period 5 tail race silt.

Differentiation between spring-sown and winter-sown cereals was also not possible due to the mixed nature of the deposits. It is likely that crops sown in both seasons were represented in all phases, since corn marigold and corn spurrey (weeds indicative of spring sowing) and corn cockle and cornflower (weeds of winter sown crops) were all present with no obvious distribution pattern.

Other possible food plants

A variety of wild fruits and nuts was present in the samples, some of which may have been growing in the vicinity of the channels and so may represent the local vegetation, but others may have been collected and entered the deposits as domestic waste or sewage. Since most were present from before the construction of the mill to after its abandonment and no large concentrations of faecal-type remains were found (large numbers of small fruit seeds such as strawberry and fig and cereal 'bran'), it is not possible to be sure of the precise origin. As most of the other woodland taxa were greatly reduced in frequency during the period of mill activity, however, it is likely that the majority of edible remains recovered were from collected fruits and nuts at this time. These include hazel, sloe, elderberry, hawthorn *(Crataegus monogyna)*, rose *(Rosa* sp), blackberry *(Rubus fruticosus)*, raspberry *(R idaeus)*, and strawberry *(Fragaria vesca)*.

The evidence for plants that may have been cultivated in orchards, herb gardens, physic gardens, and vegetable gardens at the abbey is slight in samples from the mill area. One each of bullace *(Prunus domestica* subsp *insititia)*, bullace/plum *(P domestica* subsp *insititia/domestica)*, and cherry *(P avium cerasus)* stones were recovered, but the latter two stones were from post-mill samples. It is not possible to tell from many of the seeds whether they grew as wild or cultivated plants, for example strawberry, carrot, and parsnip. However, in the case of the last two taxa the cultivated vegetables would probably not have been left to run to seed; the cultivated carrot is said not to have reached England until the fifteenth century (Banga 1976). Many of the wild plants recorded could have been used medicinally and plants such as mint *(Mentha* sp), a common streamside plant, could have been used as a culinary herb.

Two species which were probably imported as dried fruits are fig *(Ficus carica)* and grape *(Vitis vinifera)*. Fig pips were found in small quantities in periods 4-5, 5, 6, and 7 in BAB and BAH. It is possible that figs were cultivated in this country during the time of warmer climatic conditions in the early medieval period although seeds from fruit grown in England are not always fully formed (Roach 1985). The only grape pip found was from a post-mill sample in BAB (per 7 phase 1). There is documentary and archaeobotanical evidence (Carruthers forthcoming a) for the cultivation of grape vines by monastic establishments during the medieval period, but the samples from the mill area provide no clear evidence of this at Bordesley.

Plants associated with textile manufacture

There is evidence for cultivated flax *(Linum usitatissimum)*, fuller's teasel, and hemp *(Cannabis sativa)* in samples from periods 3 to 7. Flax seeds and capsule fragments were present in fairly large numbers in a period 3-6 ditch sediment in BAE (context 272) and in lesser numbers in several samples from BAB and BAE, indicating that retting was taking place.

In the cultivation of flax to produce linen, the plants may or may not be grown on to the seed setting stage. Flax has a shallow root-run so it requires damp soils, which means that it may well have been grown on the low-lying land around the mill. When fully grown the plants are uprooted and dried and then pulled through a comb-like device or 'rippled' in order to remove most of the dry leaves and seed heads (capsules). Bundles of stems are then tied up and left in water to rot or 'rett' in order to extract the stem (bast) fibres. It is the fact that a water source is needed for this stage that means that the seeds and capsule fragments of flax are often recovered from Saxon and medieval rivers and ditches. They may have been deposited as a waste product of rippling or have remained on the plant when placed in the water to rett. The rotted stems are then beaten with a 'brake' and 'scutched' with a scutching knife in order to remove the remains of the rotted stem from the fibres. The bundles of scutched fibres are pulled through a 'hackle' to comb the fibres and they can then be spun and woven into linen (Burnham 1980). From the large number of flax seeds and capsule fragments in the period 3-6 ditch in BAE it would appear that it had been used for retting. As it was said to have been a very smelly process it is likely to have been carried out away from the mill buildings.

Flax seed also produces linseed oil or can be consumed whole, so the crop may have been cultivated to serve several purposes if allowed to grow on to produce seed. It would have been necessary to grow at least some plants to this stage in order to provide seed for the next year's crop.

Fuller's teasel fruits and bracts were recovered in fairly large numbers from the period 4 bypass channel fill (A156) as well as from the tail race silts and from a number of other contexts in BAB and BAH. Fulling was a process by which woollen cloth was thickened and condensed by controlled shrinking in order to make it more weatherproof and hard-wearing (Beesley 1987). A mixture of cow dung, urine, and possibly pigments were put into some sort of container with the cloth and it was trampled in order to loosen the dirt and encourage shrinkage. A water supply was then needed for the rinsing. For the fulling, water and fuller's earth were applied to the cloth and it was beaten by feet or with heavy hammers powered by a mill in order to bring about the felting. After being washed the cloth would be stretched or 'tentered' on 'tenter hooks' and left to dry and bleach in the sun. The final process was raising the nap of the cloth by brushing it with teasels. Teasels were particularly suitable for this purpose as, when the sturdy hooks got caught in the threads, instead of pulling a thread the bracts would break off (Wild 1970).

The plant evidence and the presence of tenter hooks could suggest that the water power of the BAB mill was being harnessed for the purposes of fulling. Documentary records and wall paintings provide evidence of Roman fulling activities in Italy where it was a large scale and well-organised business (Wild 1970). The earliest references to fulling mills in England occur in the later twelfth century (Holt 1988, 153).

Although the bone assemblage was found to contain abnormally low numbers of sheep for a site of this nature (see below, Lovett), wool may have been brought in from the other properties owned by the abbey. No specific dye plants were recovered from this site, unlike the records of plants like dyer's greenweed, woad, and madder from sites such as Anglo-Scandinavian Coppergate in York (Tomlinson 1985). However, many of the wild plants which were present on the site will produce a variety of colours, for example, elderberry (violet), blackberry (purple-grey), nettle (yellow green), and bracken (lime green).

The single hemp achene that was recovered from the site was present in the period 6 overflow channel silt (BAE92). Hemp provides a coarse fibre which was often used for rope. The plant also has medicinal uses.

Disturbed ground and wasteland

Many of the plant species with a wide range of habitat types may grow on wasteground, especially the weeds of cultivation which can rapidly colonise bare soil and overcome frequent disturbance by having a short life cycle. This includes plants like chickweed, fat hen *(Chenopodium album),* and the sow-thistles *(Sonchus* spp). Several taxa, for example, fat hen, henbane *(Hyoscyamus niger),* and stinging nettles, are particularly characteristic of nutrient-rich soils, such as farmyards and rubbish tips. Nettles were particularly numerous in the period 4 bypass channel fills (A156 and A157) which might be due to accumulations of organic waste from the various activities going on in the mill area, including perhaps the rinsing of urine- and dung-soaked textiles.

Chronological changes

Observations relating to changes in the seed assemblages through the periods are in some cases hampered by the different numbers of samples having been taken from each period and by the varying states of preservation of the remains. In addition, different types of waste are likely to have been deposited in each area according to what the range of activities occuring was, so the deposits are only comparable on a very general level.

Period 1

The old stream channels in BAB were undated but are pre-monastic. Samples from the earliest deposits of this period, phase 1 (E971 and E993), contained large quantities of twig and leaf fragments but relatively few seeds. This could reflect the closed nature of the forest canopy but could also partly be due to poor conditions of preservation.

A mixed deciduous forest of lime and oak with an understorey of hazel and some birch was indicated by the plant macrofossils. The few alder fruits probably represent the vegetation on the wettest soils which would also include the sedge *(Carex* sp) and bur-reed *(Sparganium* sp) fruits. Dock *(Rumex* sp), stinging nettle *(Urtica dioica),* blackberry *(Rubus fruticosus),* and chickweed *(Stellaria media)* indicate possible areas of disturbance and soil enrichment, although the total number of seeds of this group was small.

An organic sample from sediments underlying the church contained remains from deciduous woodland plants, indicating that the forest also extended into this area (Rahtz *et al* 1983).

Two large fruiting bodies of the fungus *Daldinia concentrica* (Bolt) Ces & de Not, sometimes called cramp balls, were recovered from E971. This fungus is very common on fairly recently felled wood and bark, especially of ash, and also grows on dead branches of standing trees. It was used in the past as a folk remedy for cramp, as the name suggests, but in this context may well have been naturally occurring rather than deliberately collected.

Identifications of unworked wood from these two contexts (E971; E993) (pers comm S J Allen) were of oak, alder, field maple, ash, and willow. Ash indicates some opening up of the canopy and willows usually prefer damp soils.

This woodland composition could date from any period from the Atlantic onwards. Pollen and macrofossil analyses from other archaeological sites in the area such as Beckford, Worcestershire (Greig and Colledge 1988), and Alcester, Warwickshire (Woodwards and Greig 1986), have provided evidence of oak/lime/hazel forest remnants in largely cleared landscapes by the Early Bronze Age and ?Iron Age/Roman periods. The lime decline is asynchronous in different parts of the country, although in most cases it occurs in the Late Bronze Age and is probably associated with clearance for agriculture (Scaife 1987, 143). The evidence of a few plant macrofossils is insufficient to provide indications as to dating and it is unfortunate that suitable deposits for pollen analysis and radiocarbon dating have not yet been located at Bordesley, as this would have provided additional information of a more regional nature.

Samples from the later phase in period 1 (phase 3, El151 and A1170) contained much larger quantities of alder fruits and fewer remnants of the dry woodland taxa. The range of wood/scrub/hedgerow taxa was greatly increased including hawthorn *(Crataegus monogyna),* field maple *(Acer campestre), rose (Rosa* sp), and willow *(Salix* sp), indicating the more open nature of the site. The seeds of elderberry *(Sambucus nigra)* were particularly numerous, perhaps reflecting the high nutrient status of the alluvial soil. The diversity of woodland, hedgerow, and more open grassland taxa was also increased, including such herbs as three-nerved sandwort, meadowsweet *(Filipendula ulmaria),* and buttercups *(Ranunculus acris/bulbosus/repens).* The quantities of leaves and wood fragments in the samples was still high, as was the overall woodland/scrub component of the samples. Thus, there appears to have been a change from mixed oak woodland to alder woodland between phases 1 and 3, perhaps as a result of a raised water-table or through clearance of the larger woodland species. Small amounts of charcoal in the samples also indicate human activity and this may have resulted in the opening up of the vegetation to some extent. It is possible, but only speculation, that this activity relates to the scattered finds of Roman pottery in the area. As mentioned earlier, a single oat grain was recovered from one sample providing further evidence of human activity.

Period 2

Little archaeobotanical information can be recovered from this period as only two, poorly-preserved samples from a pit fill (C1070, pit C1077) in BAB and a ditch fill in BAB (276, period 2-3) were available for analysis. The pit fill is said to be associated with ground clearance. The few plant macrofossils in both samples were from disturbed ground species, which included elder, and from species of alder woods and damp ground. One lime fruit and a holly leaf *(Ilex aquifolium)* indicated the possible survival of some areas of mixed woodland. Since ten of the 23 taxa present were woodland/scrub/hedgerow taxa, it appears that the area was still probably fairly scrubby at this point. Twigs and leaves were still much in evidence in the sample and some charcoal was present. A couple of fragments of corn cockle *(Agrostemma githago)* seed were recovered from a BAE sample of period 2-3 (BAE276) and this might indicate faecal waste.

Periods 3 to 6

The main period of activity in the mill area occurred during this time. The number of woodland taxa was greatly reduced, particularly in periods 3 and 4. Alder, elder, and hazel continued to be represented, but in much lower numbers and birch fruits were occasionally present. Alder and birch fruits may have floated in from some distance upstream and elder and hazel could have been collected for various uses. The larger tree species, oak and lime, were no longer represented, although a single oak acorn cupule fragment was present in a period 6 sample.

It appears that the area had largely been cleared by period 3 and this was maintained until possibly some regeneration of scrub began to occur in period 6. A single seed of the woodland herb, three-nerved sandwort, was present in period 5 in addition to some willow catkin buds but by period 6 hawthorn, rose, oak, and red campion were present. Alder fruits were still low in numbers and in total the proportion of woodland/scrub remains was not great. Wood identifications from a period 6 sample included oak, alder, willow, elder, and subfamily Pomoideae (includes hawthorn, apple, and whitebeam).

An additional indication of deteriorating conditions in period 6 comes from a major addition to the list of waterside plants, the large concentration of *cyperus* sedge *(Carex pseudocyperus)* fruits in BAE303, a period 6 sediment of the overflow channel. This plant grows in eutrophic to mesotrophic water (high to middle nutrient levels) and is said to be common along slow-flowing dykes and derelict canals (Jenny *et al* 1982). Its presence in large numbers here indicates the abandonment of the management of this channel.

Grassland taxa were present throughout the periods of mill occupation and probably accounted for the majority of the macrofossils recovered. These remains probably reflect the predominant vegetation type in the vicinity of the mill buildings at this time: damp grassland which may have been grazed and/or cultivated for hay. No obvious changes in the taxa could be detected through the periods of occupation, or in comparison with the earlier grassland species. The wetland and aquatic species were similarly numerous and provided no indications of changes in water management.

Differences in woodland, grassland, and aquatic taxa across the different areas sampled are difficult to detect because of differences in the level of sampling. Of the scrubby taxa, however, alder and hazel were present through most of the periods in all three areas. These fruits could, of course, have floated in from some distance upstream.

Apart from a few stray corn cockle fragments in the earliest phase of a ditch (period 2-3, BAE276) and a waterlogged cereal caryopsis in a period 6 sediment in an overflow channel (BAE303), all the remaining cereal remains and arable weed seeds were recovered from BAB and BAH. The vast majority of cereal caryopses and arable weed seeds were found in the two upper layers of BAH (period 4-5, contexts 19 and 11), whilst a fairly large number of rye and barley rachis fragments were recovered from a BAB period 3 tail race silt (E864).

These more concentrated deposits may relate to the milling of cereals for flour during these periods or could have originated as animal fodder. The former deposit, which was rich in cereal grain fragments and small fragments of corn cockle seed, amongst other weeds, is likely to represent waste flour.

The occurrence of remains related to textile processing has been discussed. All of the teasel remains occurred in BAB and BAE. (The one seed of Fuller's teasel from period 7 could represent an escape from cultivation as the wild plant grows along stream banks and in rough pasture.) Flax was recovered from all of the areas although the main concentration was in BAE so the other remains could have been washed downstream from there. Most of the remains were from BAE272 which was difficult to assign to a period but could date between periods 3 and 6. The single hemp 'seed' from period 5-6 could indicate small scale cultivation for fibre and medicinal use, but in any case the processing of this plant does not require the operation of a mill. Thus, the evidence for textileworking corresponds to the period of occupation of the mill area.

Period 7, abandonment

The number of woodland/scrub taxa again increased in samples of this period with the addition of field maple, hedge mustard *(Alliaria petiolata),* and enchanter's nightshade *(Circaea lutetiana).* Alder increased to some extent in occurrence but the total percentage of woodland/scrub remains was still much lower than in periods 1 and 2.

As in the previous period, plants of still to slow flowing water and marsh were well represented in three samples. There were no obvious differences in the range of species to indicate changes in the management of the channels.

A similar range of grassland taxa was recorded to that found in earlier samples. One notable addition was small scabious which is primarily a plant of calcareous pasture. As the local soils are alluvial clays its occurrence in the tail race silts (E431) could be due to the presence of dung from animals grazed some distance away.

Evidence of cereal remains is low in samples of this period although a waterlogged cereal caryopsis was present in BAE and some arable weeds and a carbonised wheat grain were present in BAB. These remains could have been deposited as sewage or domestic waste. The presence of flax was commented on earlier.

The occurrence of weeds of wastegrounds might be expected to increase after the abandonment of the mill area but, although some of the late deposits contained quite high numbers of nettle achenes (eg the tail race silt E368), the general incidence of weeds of this group was not notably higher. However, the nitrophilous plant henbane was recorded for the first time in this period from BAB indicating an area that was probably rich in organic waste. It appears that, although some areas were neglected and allowed to return to damp scrub, other parts of the land were still grazed and cut for hay, as seeds from plants of these habitats were frequent.

Inter-site comparisons

It should be noted that, because of time limitations, the sample size at Bordesley was smaller than that usually taken from urban sites for the recovery of large fruit remains (ie according to sampling guidelines by Kenward *et al* 1980, no 'bulk samples' were examined). It is possible that a wider variety of 'exotic' food remains would have been recovered from some of the contexts had larger samples been examined.

In urban situations in the medieval period rivers provided a much-needed means of disposing of domestic waste, including faecal waste (Keene 1982). Plant assemblages from Norwich (Murphy 1983) and Beading Abbey (Carruthers forthcoming a) waterfronts have provided evidence of the disposal of a variety of domestic and industrial waste products. In a rural situation the problem of accumulating waste would not have been so acute, partly due to the reduced population pressure but also because organic materials would have been valued as 'night soil' or compost for the land. These factors should be taken into account when comparing the Bordesley Abbey assemblages with those from more urban situations.

Very few rural medieval sites have been examined archaeobotanically, and few have produced waterlogged plant remains. Carbonised assemblages from farmstead and village sites such as Eckweek (Carruthers forthcoming b) have provided evidence of a number of kinds of cereal and legumes, with little evidence for 'luxury' foods but quite a high occurrence of wild fruits and nuts.

The twelfth- to fourteenth-century grange farm at Dean Court Farm, owned by Abingdon Abbey, produced some rich cereal deposits which contained a variety of cereals and legumes (Moffett 1987). The seeds of grape and fennel provided some evidence of 'luxury' goods which may have been grown by the abbey.

Since these sites produced primarily carbonised remains comparisons cannot be made between them and the Bordesley assemblages. However, the moated fourteenth-century site at West Cowick, which was the site of a royal manor, produced a variety of waterlogged plant macrofossils and pollen (Hayfield and Greig 1989). The high status of the site was reflected in the presence of fig, grape, fennel, and walnut. Flax and hemp were also recorded.

Organic remains from a number of pits and ditches at Taunton Priory contained a few flax seeds, but the absence of pollen suggested that these were only casual occurrences (Greig and

Osborne 1934). In general, the assemblages consisted of mixed waste material such as burnt straw and wood so that apart from the carbonised grain deposit little could be deduced about diet.

The waterfront deposits at Beading Abbey were found to contain a variety of fruit remains, herbs, flax, hop, and hemp (Carruthers forthcoming a). Evidence for the cultivation of vines at Beading Abbey was provided by the identification of vine wood in addition to grape pips. There was an indication that flax retting had taken place in the river, since flax seeds and capsule fragments were numerous in some of the samples. It is likely that the reredorter emptied into the river close to where the samples were taken, and the high proportions of fruit remains in some of the samples indicated that much of the assemblages probably consisted of faecal waste. For this reason, and because of the differences in sample size referred to above, the samples from Bordesley are not comparable with those from Reading. Material from the reredorter at Bordesley has not yet been recovered, but it may have been used as 'night soil' since the abbey buildings were not located close to a flowing river. Therefore, it is not possible to suggest that the monks at Bordesley had any less varied a diet than the monks at Reading appeared to have. The presence of a few fig and grape seeds indicates that some 'luxury' foods were consumed at Bordesley; the latter was only recovered from a period 7 phase 1 sample.

Other sites producing teasel fruits and bracts in addition to a range of dye plant remains are the Dominican Priory site in Beverley and Anglo-Scandinavian deposits from Coppergate, York (Hall 1992). The pit fill from the Dominican Priory which contained the plant remains probably predates the foundation of the priory in the twelfth century. An adjacent property in Eastgate, Beverley, was found to contain a similar range of material (McKenna forthcoming).

Conclusion

Waterlogged samples from the mill area at Bordesley Abbey were found to contain evidence of the local environment and evidence of textile processing. The samples originated from old stream channels, the mill pond and its channels, the mill races, and the bypass channel. Prior to the establishment of the buildings on the mill site the area appears to have been wooded, with lime, oak, and hazel probably being the predominant species. There is evidence for a change to a more open, wetland vegetation at some point in this early period with alder and elder predominating.

The mill area was cleared of woodland and the surrounding area was probably managed for grazing and hay production. The mill power could have been used for fulling, since fuller's teasel is well represented in the bypass channel and tail race. These remains were mainly present in samples from periods 4 and 5. Flax retting is also indicated, but this may have occurred at any time after period 3. Hemp was only present in a period 6 overflow channel silt.

The evidence for food plants was limited. Hedgerow fruits and nuts were quite frequent and these may represent collected foods, but luxury goods like fig and grape were only present in low numbers, the former from periods 5 to 7, the latter in period 7 only, Wheat, barley, oats, and rye were present as carbonised and waterlogged remains in low numbers, although a large waterlogged deposit of grain and weeds probably representing flour, and a second large deposit of waterlogged chaff fragments representing crop processing waste were recovered from the mill area.

Appendix: Other plant remains (identifications not discussed in this report)

BAE221: *Thuidium tamariscinum* (Hedw) B, S, and G, moss primarily found in woods and hedge banks on heavy clay soils, also open grasslands; recovered from between timbers.

E955 (OB 204): 19 hazel nuts all nibbled by rodents as follows: woodmouse 4; bank vole 4; red squirrel 4; unknown 7. Rodents identified by Paul Bright of The Mammal Society, He questions whether they could have been carried underground more recently, but thinks the presence of red squirrel does suggest it might be a genuine 'life assemblage'.

Worked wood (other botanical: OB)

by S J Allen

Table 48

A total of 3293 pieces of worked wood were recovered from BAB (32371, BAE (42), and BAH (14). Table 48 is a summary by function and period. The assemblage almost exclusively either reflects industrial activities, such as milling and possibly weaving, or consists of structural remains.

Priority has been given here to artefacts which form a significant corpus and which give an insight into the operation, function, and structure of the mills and associated features. All of the machinery is presented to show the range of size and wear patterns. Pegs and wedges show little variation in wear or breakage patterns and therefore those illustrated have been chosen for their completeness. The structural timbers are discussed in the accounts of the mill structural timber sequence and the mill pond drain (Allen, above, part I), and summarised in Tables 2-6 (BAB) and Table 9 (BAE). A catalogue of the structural timbers is on fiche. Where material is repetitive, it is tabulated and quantified. All the excavated wood is fully described (by the categories in Table 48) in the archive catalogue.

Wood was recovered from the waterlogged parts of the site, namely the mill races, the period 4 fill of the bypass channel, and in the bases of (mainly period 3) postholes cut into and/or packed with clay. This skewed distribution, combined with the fact that most of the wood came from secondary contexts (mainly silt levels), limits the value of spatial analysis to discover how and where wooden artefacts were used.

The timber terminology follows Alcock *et al* 1989. All dimensions were taken before conservation. Species identification was done using Schweingruber (1982). Unless otherwise stated, all timber was of oak *(Quercus* sp). Conservation, impregnation by polyethylene glycol followed by freeze drying, was undertaken by Portsmouth City Museums under the direction of C O'Shea. Structural timbers were planned at 1:20 and elevations drawn at 1:10; most timbers were drawn after lifting at 1:10 and detailed recording was carried out at Portsmouth during conservation, as was the sampling for dendrochronological dating (noted as 'sampled' in the catalogue).

Table 48 Mill (BAB), valley transect (BAE), and tail race (BAH): summary of worked wood, by period and by function

Type of artafact	BAB period 1	2	3	4 Race	4 Bypass	5 Race	6 Race	7 Race	BAE Drain	BAE S. Bank	BAH	Sub-total	Total
structural		5	23	12	4	13	20	10	9	8		104	
Stakes		-	10	2	6	2	15	1	10	3	1	50	
Boards	1		15	13	13	19	2	5		-	7	75	229
Machinery													
'Cog' heads			11	8	4	1		1		1	1	27	
'Cog' shafts	-			8	1							9	
Other			3	1	1	2		1				8	44
Tools			1		5			2				8	
Other objects	-		2	1	3	1	1	1			1	10	18
Wedges													
For wheel			9	11		9	1	1				31	
Other			1	2	1			1				5	36
Building fittings	-			2	2							4	4
Pegs													
Carpenter's	-		10	10	6	2	1					29	
Headed pegs	-		5	8	3	5						21	
Roofing pegs	-				5							5	
Indeterminate	-	1	3	1	7		3	5			4	24	79
Chippings/offcuts	9	14	193	360	1669	421	27	179	11			2883	2883
Total	10	20	286	439	1730	475	70	207	30	12	14	3293	3293

Wooden objects

Figures 94-101

The Bordesley wooden small finds are not from a domestic assemblage: vessels, buckets, pins, combs, footwear were absent; it is a structural and industrial assemblage.

The wooden small finds from each phase form very similar groups, 'Cogs', headed and carpenter's pegs, wedges, and fragments of boards are associated in mill race contexts in periods 3 and 4 reflecting a consistent pattern of disposal. The reduction in quantities of these artefacts after the construction of the period 5 mill race implies that a slightly different disposal pattern was favoured; fewer artefacts were deposited in the mill race but the same range of artefacts was discarded, suggesting that activities in the mill building continued much as before.

The assemblage in the period 4 fill of the bypass channel is broadly similar to the contemporary assemblage in the mill race. 'Cogs', pegs, wedges, and board fragments are present in both and a common source might have been the mill building. The channel assemblage, however, also contained significant numbers and types of object which are not found in the mill race and which must derive from a different source. This includes finds interpreted as roofing materials (small pegs, shingle) and weaving apparatus ('heddle horse', winding peg, warping paddle).

It is probable, therefore, that there is a second nearby source of wooden artefacts and possibly also of building debris, that is chippings. If the identification of the weaving apparatus is correct then there may have been a building nearby, perhaps associated with textile processing and leatherworking, which was dismantled or repaired while the bypass ditch was open.

The types of wood and of artefacts represented in the Bordesley assemblage are limited: oak for most artefacts, Pomoideae for objects subject to significant wear, willow for fencing, and two examples of holly. Much has undoubtedly not survived and a large proportion of the wood used would have been in the mill building where it would have been easy to rob, remove or burn. Wood was a valuable commodity and would presumably be reused or burned as fuel where possible, rather than being discarded. The roofs, walls, and frames with their fittings and fixtures could, therefore, be dismantled and leave few traces in the archaeological record, except where pieces fell and were lost in the waterlogged areas of the site, as indeed appears to have happened to some artefacts. A full picture of the medieval assemblage is thus elusive but the surviving evidence indicates that wooden artefacts were being made from the same species, for the same purposes, in the same quantities throughout the active life of the mills.

The watermill machinery

Figures 94-7

The mill races and bypass channel yielded a number of wooden objects identified as mill machinery which has enabled a reconstruction of one waterwheel and the methods of power transmission from the wheel to the mill building.

A paddle (OB 282) from a waterwheel was found reused as a wedge below the baseplate of the period 4 head race (OB 266). It is of a form common in medieval mills in Denmark (Fischer 1984, 6) but is entirely different from those of the fourteenth-century waterwheels excavated at Chingley and Batsford (Crossley 1975, 14-16; Bedwin 1980, 194 and fig 8). The paddle blade was fastened to a large stave with pegs. The stave end was in turn inserted into the outer edge of the wheel. The paddle was braced by a pair of laths which passed through rectangular slots cut towards each end of the blade and thence through similar slots in the neighbouring paddles. Although no lath fragments were identified in the excavated assemblage, one intact stave and one fragment were found in the silts of period 5 (OB 165.3; OB 165.2) and a piece of a similar stave (OB 191.14) from the silts of period 3 (Fig 94). The latter had been broken across the lowest hole and was slightly larger. The presence of this paddle type in periods 3 and 5 implies that this design of waterwheel continued to be used in the wheel cages of these periods and presumably also in the intervening period 4. It is possible, however, that the period 3 wheel was the only one to have its (larger) paddles supported by laths.

The Danish waterwheels were held together with small wedges; many of the Bordesley wedges were either found in the same (period 5) context as the stave or were elsewhere associated with 'cogs' in periods 3, 4, and 5. These wedges are thus the best candidates for the fastenings of this type of waterwheel.

Evidence for the internal machinery of the Bordesley mills is derived from 'cogs' and their wear patterns. A 'cog' is a solid wooden peg with a cylindrical head and a narrower axial shaft projecting from it. The shaft passes into a hole in a felloe of a wheel to leave the head protruding from the rim. These 'cogs' could have been used in two ways. Firstly, as gears either to transfer through 90° power from the waterwheel or to change the rotational speed of a second shaft. A series of 'cogs' mounted in a wheel could be spaced so as to mesh with the 'cogs' mounted around the rim of a second wheel. When the main wheel is rotated, the 'cogs' force the other wheel to rotate at a speed dependent on the relative diameters of the wheels and the speed of rotation of the waterwheel. Secondly, the 'cogs', mounted in a wheel on the same shaft as the waterwheel, could have directly driven machinery such as hammers or bellows; in other words the 'cogs' were really a type of cam. The latter

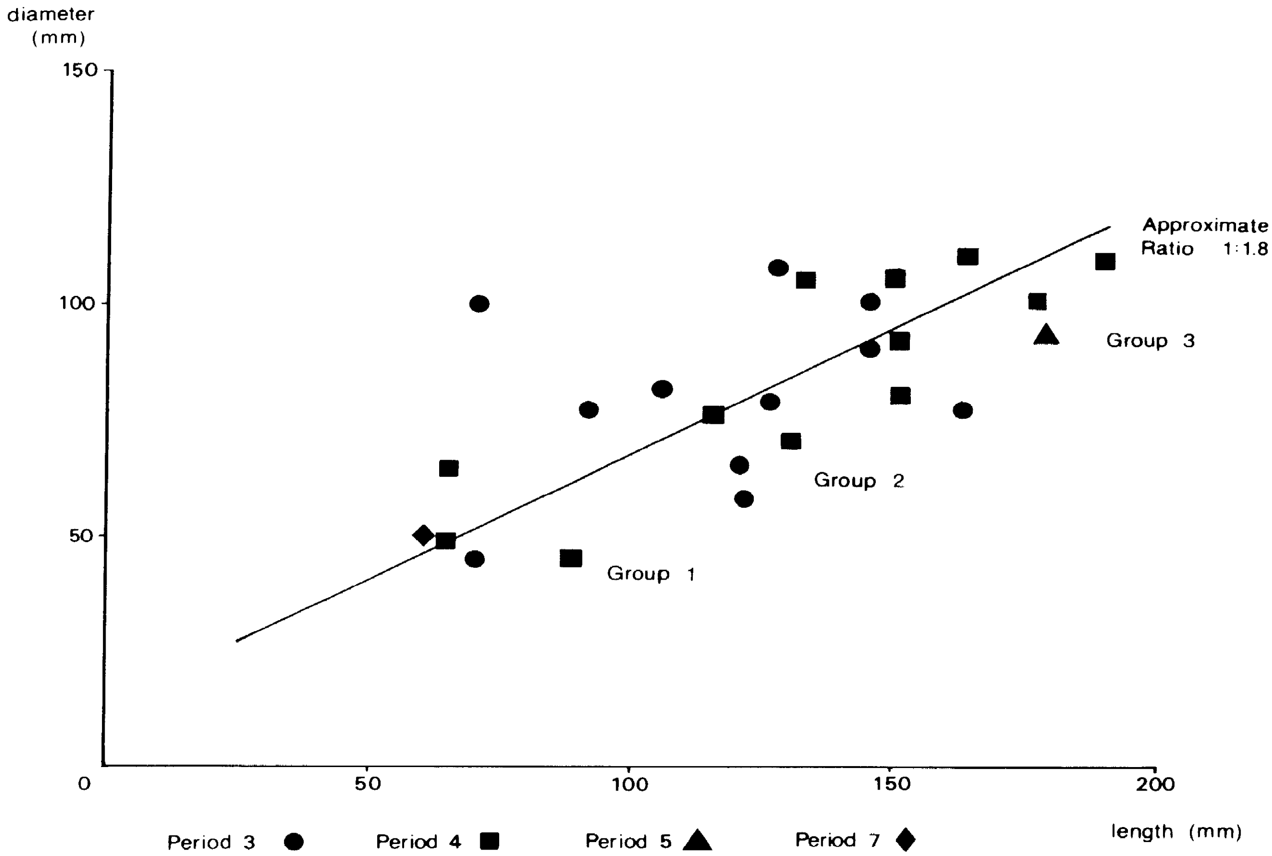


Figure 92 Mill (BAB) and valley transect (BAE): plot of cog head length against diameter

interpretation is preferred, and set out below (see part III, 'The machinery and its arrangement . . .').

A minimum of 25 individual 'cogs' was excavated from BAB, one from BAH, and another from a channel feeding the millpond (BAE): a large number are illustrated (Figs 95-7), together with part of a felloe from a cog wheel on which some of them may have been mounted. Toolmarks and, on the original end surfaces, signature marks were preserved. Every one of the excavated cogs was carved from a block of wood of Pomoideae, either round or quartered. Each was cut to length with an axe. One end of the block was then pared down to form the long, narrow shaft which might be of circular, rectangular or polygonal cross-section. The other end of the block was trimmed to form the cylindrical head. The final stages of working around the junction of the head and neck were done quite crudely, again with an axe. Although no direct evidence survives, a tool such as a drawknife could have been used in the final finishing process.

Most of the 'cogs' recovered had been broken, most frequently the shaft had snapped at or near the junction with the head. There is no difference in size between 'cogs' of any period. Of the 'cog' heads, eleven were recovered from the silts of the period 3 mill race, twelve from those of period 4, and one each from periods 5 and 7. This change in the disposal pattern may be more apparent than real since the broken shafts of 'cogs' continue to be found in the latter periods. Only three complete 'cogs' were found, all from period 3. Considered in isolation, the three complete 'cogs' would suggest an overall 'cog' length of between 258 (OB 186.1) and 329mm (OB 188.1) with a head length to shaft ratio of between 1:1.11 and 1:1.54. The other 24 'cog' heads vary quite widely in size. Clearly more than one size of 'cog' was present in the assemblage and the above proportions cannot be used to generalise.

A comparison between the length and diameter of 'cog' heads, the most frequently available dimensions, produced three groupings (Fig 92). Group 1 (five examples) had heads of between 60 and 88mm in length and 45 to 60mm diameter. Group 2 (eight examples) had heads of 77 to 130mm in length and 58 to 100mm diameter. Group 3 had the largest sample (twelve examples), with heads of 127 to

190mm in length and 77 to 120mm diameter.

Figure 92 shows that there was an approximate ratio between the diameter and the length of the head. The best fitting straight line through the plotted points gives a diameter to head ratio of 1:1.8 which may be an approximate ideal for a 'cog' although it would have been varied in practice as some deviation was required in order to work the 'cogs' on different wheels into a close meshing arrangement. The period 3 'cogs' vary slightly more in size, period 4 examples being a little more consistent.

'Cogs' of the three groups were found together in the same contexts and areas of the mill race in both periods 3 and 4. Within each period they must have been discarded at the same time and thus were presumably in contemporary use. The mounting of several widely varying sizes of cogs on the same wheel rims would not be practical since either they would tend to clash and thereby throw the wheels out of gear with potentially disastrous results for the machinery or, if they acted as cams, they would trip the hammers or bellows irregularly. The three 'cog' sizes thus suggest an arrangement of three 'cog' wheels.

Almost all of the 'cog' heads had evidence of unevenly distributed wear: a wide curved facet in one part of the 'cog' head had been caused by contact with another piece of machinery. A number of 'cogs' had as much as half of the diameter of the head worn away in this manner (OB 188.2; OB 192.2). Others had overlapping facets indicating that wear had been received from two (OB 330) or even three (OB 191.1; OB 192.2) successive directions. Worn 'cogs' from period 4 were no more worn than those from period 3. These wear patterns suggest, firstly, that the 'cogs' were firmly fixed in the wheels and would explain the breakage pattern noted above which might have occurred in use or in the changing of worn 'cogs'. Secondly, the life of a 'cog' could be prolonged by removing it from its socket and turning the head so that a new meshing surface was available. Thirdly, it suggests that either the cogs meshed at right angles to each other or that the 'cogs' tripped levers.

The Bordesley 'cogs' can be contrasted with those from the fourteenth-century mill at Batsford, East Sussex (Bedwin 1980, 199-200). Although the Batsford cogs are of similar form, they are of oak, have a different wear pattern, and are significantly smaller than those from Bordesley - however, all would fit in the Bordesley group 1 (Fig 92). The Bordesley machinery, as represented by the 'cogs', must have been much heavier and robust than that of Batsford and, by implication, more powerful, perhaps a reflection of their different functions.

The form of one 'cog' wheel can be reconstructed from the period 5 wheel felloe fragment (E862, OB 169: Fig 94). The felloe was of oak cut from branch wood; several knots indicate the former presence of side branches. The diameter of the entire wheel at its outer circumference was 1.48m and at the inner circumference 1.12m. Although the felloe had been substantially reworked, many original features survived. The broken end of the felloe had one end of a through mortice, cut from the inner to the outer surface of the wheel with a chisel. Near the broken end of the felloe a circular hole contained a piece of circular-cross-section Pomoideae cut off flush with each face of the felloe. The thinnest end of the felloe had one face cut back to form a continuous slope; it had four holes, each containing an oak peg. The pair of pegs nearest the end of the felloe were treenails and had been driven from the non-sloping face.

These features allow the original form of the wheel to be reconstructed, assuming it was symmetrical (Fig 93). The wheel was constructed using four equal-sized felloes which were joined end to end with a face halved scarf joint secured with four treenails. One spoke was morticed into each felloe and passed into the hub or shaft, a form of construction known as compass-armed (Hewitt 1985, 197). A 'cog' was placed in a large hole drilled through the face of each felloe, though it is possible, but unlikely, that some of the felloes carried more than one 'cog'.

Parts of the outer ends of two ?bellows plates (OB 137.1; OB 317) were found, the former in the mill race silts of period 7 and the second in the bypass channel fill of period 4. A hinged pair of wooden boards linked with a leather sheet are compressed by pressure on the outer end of the upper board, driving air through a valve to a hearth. A spring pole over the shaft raised the upper board once the cam has passed, via a cord passing through a hole in the outer end of the upper board. The fragments illustrated appear to be from the outer ends of these upper plates; there is no indication of the full size of the bellows plates. The relatively small size of the fragments does, however, raise the possibility that they were operated by hand rather than by machinery.

Only two wood species appear to have been used to make machinery components, oak and for the 'cogs' Pomoideae. Oak is fairly tough and was the standard tree used to provide structural timber in the medieval period. Fruit woods are not suitable for structural timber, being generally small and without substantial lengths of straight wood. Fruit wood is a close grained wood, very hard and tough, and therefore suitable for making small artefacts which will be subjected to a great deal of wear. This was the reason for their selection at Bordesley. Fruit woods continue to be selected for water-mill cogs (Fuller and Spain 1986, 147, 182).

OB 169 Part of felloe of 'cog' wheel. Curved timber with remains of through mortice at thickest broken end and one large drilled hole (65 dia) towards that end with remains of peg. Four drilled holes (25 dia) at thinner broken end with remains of treenails and remains of an edge halved scarf joint secured by the pegs. Axe marks (22+ w) on interior of mortice, cuts (58+ w) around large peg on damaged face of wheel, axe marks (58+ w) on inner circumference, split face of joint (102 w), and comer of joint. Figs 93-4. Wheel 180 w, 140 th, 1.48m dia. Mortice 58+ 1, 48 w.

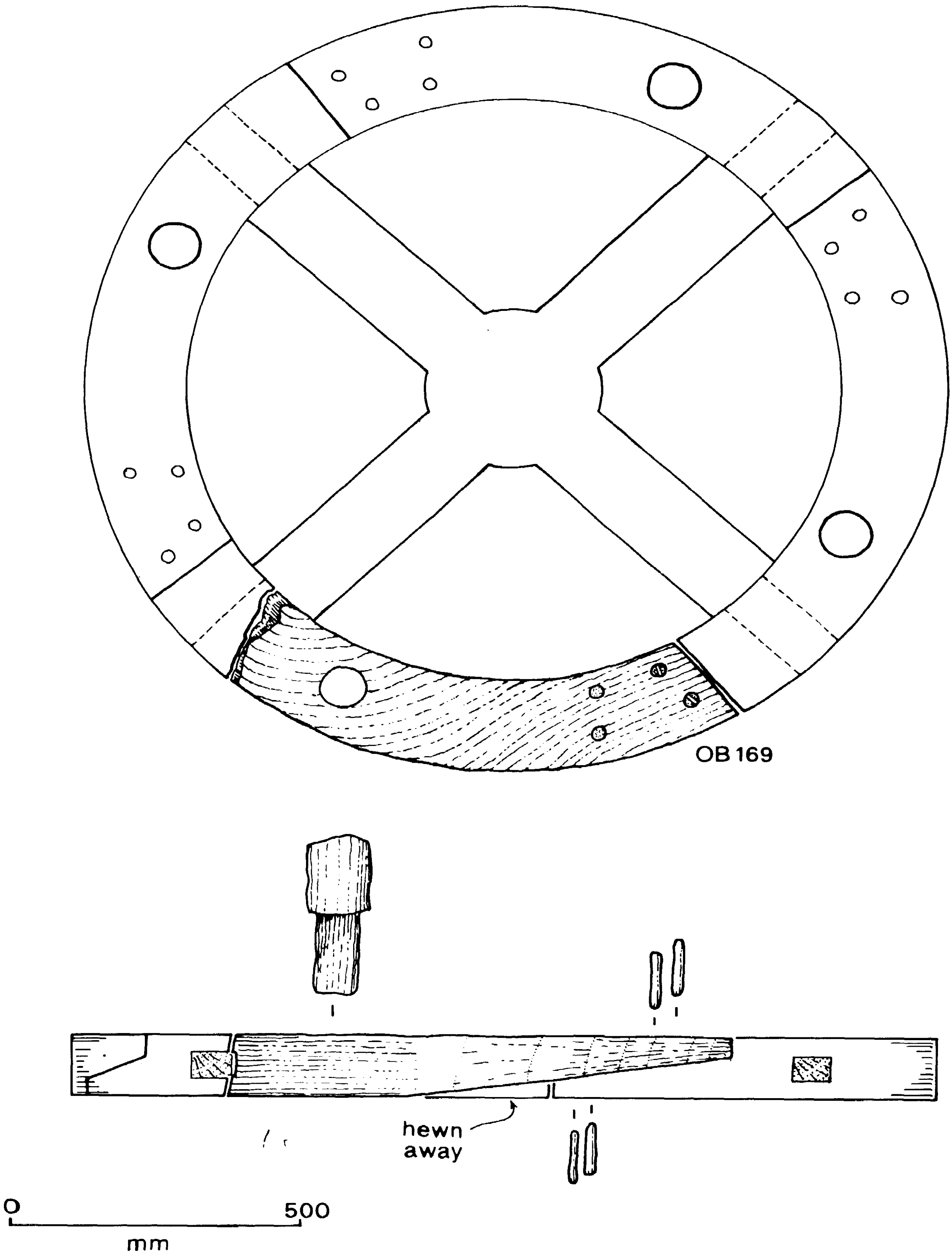


Figure 93 Mill (BAB): reconstruction of trip wheel, based on OB 169

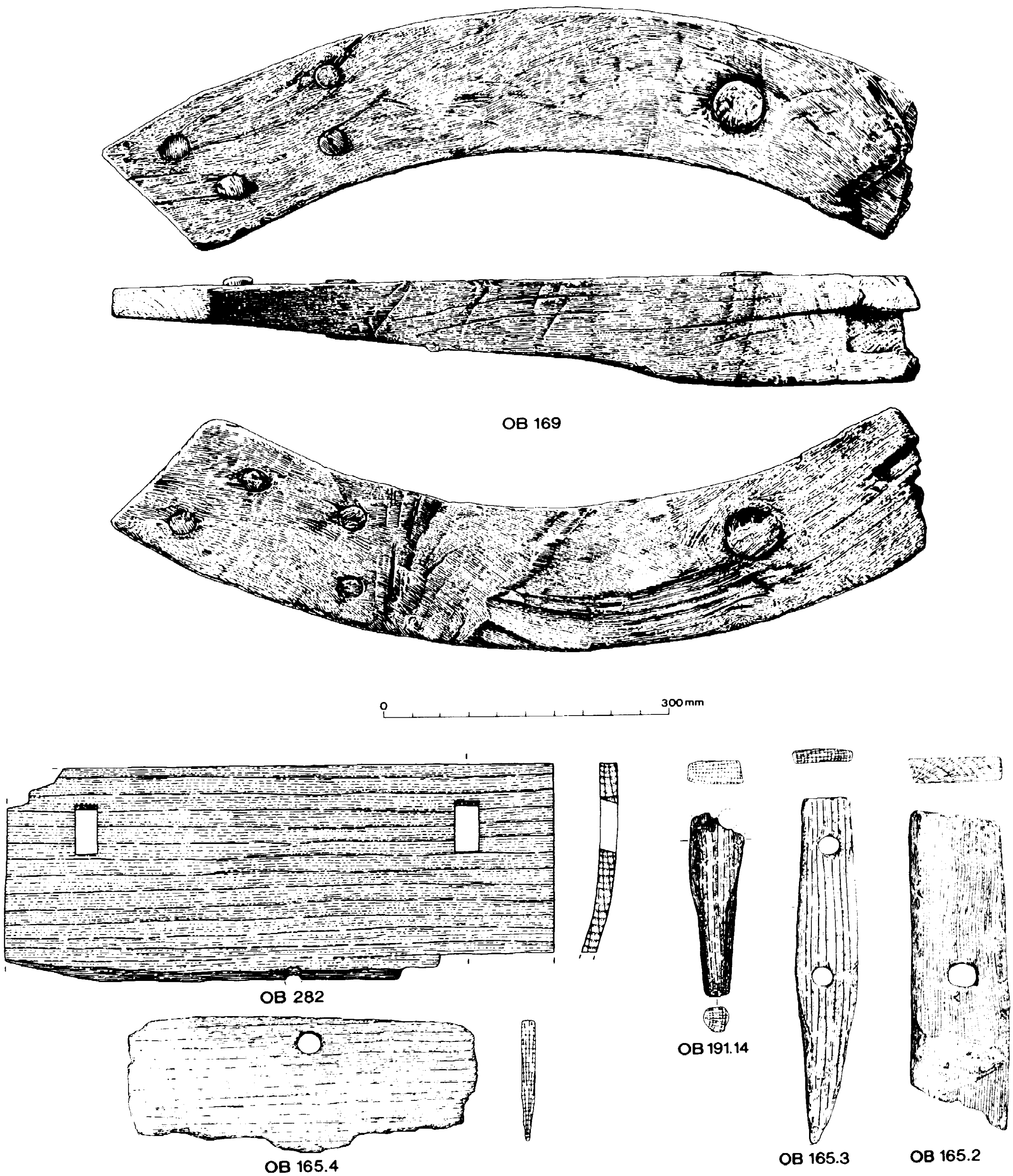


Figure 94 *Worked wood 1: machinery*

barge peg 63 dia, small treenails 25 dia. Box halved from trunk/ branch junction, treenails radially cleft. Large peg (Pomoideae). (E862, per 3)

OB 282 Paddle blade from period 3 waterwheel reused as support in period 4 head race. Board with two rectangular slots cut through the face, one towards each end. Remains of one drilled hole (25 dia) through face at broken edge of board. Fig 94. 544 1, 240+ w, 20 th. Radially faced. (D510, per 4)

OB 165.4 Possible paddle blade. Board, sub-rectangular cross-section, hole (25 dia) drilled halfway along length and offset to one edge, corners abraded. Fig 94. 340 1, 156+ w, 4-16 th. Radially cleft. (E817, per 5)

OB 191.14 Stave from paddle of waterwheel, rectangular, tapering to circular cross-section, remains of drilled hole (25 dia) at thickest, broken, end. Fig 94. 208+ 1, 26-56 w, 30 th. Radially cleft. (E864, per 3)

OB 165.3 Stave from waterwheel paddle, sub-rectangular cross-section, one end tapered to a point, intact. Two holes (20 dia) drilled along centre line, one near squared end, other halfway along length. Fig 94. 391 1, l0-63 w, 15 th. Radially cleft. (E817, per 5)

OB 165.2 Stave fragment, sub-rectangular cross-section, slight longitudinal curvature, centrally placed drilled hole (25 dia) towards broken end. Fig 94. 352+ 1, 96 w, 30 th. Radially cleft. (E817 per 5)

OB 191.3 Cylindrical ‘cog’ head, polygonal section, bottom end of head and shaft missing. Fig 95. 70+ 1, 48 dia. Box quartered (Pomoideae). (E864, per 3)

OB 191.2 Cylindrical ‘cog’ head fragment, irregular cross-section, very damaged, no remains of top end. Fig 95. 70+ 1, 50 radius. Bound (Pomoideae). (E864, per 3)

OB 182.1 Cylindrical ‘cog’, circular cross-section, shaft worked with drawknife, almost intact. Fig 95. Head 127 1, 67 dia. shaft 133 1, 52 dia. Bound (Pomoideae). (E864, per 3)

OB 186.1 Cylindrical ‘cog’, sub-circular cross-section, intact. Fig 95, Head 112 1, 80 dia, shaft 146 1, 54 dia. Round (Pomoideae). (E864, per 3)

OB 188.1 Cylindrical ‘cog’ head, circular cross-section, ends cut with axe, intact but pronounced longitudinal curvature. Fig 95. Head 140 1, 80 dia, shaft 189 1, 66 dia. Bound (Pomoideae). (E864, per 3)

OB 186.2 Cylindrical ‘cog’ head, circular cross-section, one worn facet, axe marks on top, no remains of shaft. Fig 95. 140 1, 112 dia. Bound (Pomoideae). (E864, per 3)

OB 191.1 Cylindrical ‘cog head, irregular cross-section, three worn facets, axe marks on top, bottom of head and shaft missing. Fig 95. 150 1, 96 dia. Box quartered (Pomoideae). (E864, per 3)

OB 186.3 Cylindrical ‘cog head, circular cross-section, one slightly worn facet, axe marks on bottom of head, part of damaged shaft present. Fig 95. Head 153 1, 102 dia, shaft 16+ 1, 40 square. Bound (Pomoideae). (E864, per 3)

OB 188.2 Cylindrical ‘cog’ head, sub-circular cross-section, very worn, no remains of shaft. Fig 95. 159 1, 82 dia. Bound (Pomoideae). (E864, per 3)

OB 176.4 Cylindrical ‘cog head, sub-circular cross-section, fragment only. Fig 96. 57+ 1, 52 dia. Bound (Pomoideae). (E845, per 4)

OB 176.3 Cylindrical ‘cog’ head, polygonal cross-section, part of damaged shaft present. Fig 96. Head 84 1, 50 dia. shaft 14+ 1, 40 dia. Bound (Pomoideae). (E845, per 4)

OB 176.1 Cylindrical ‘cog’ head, one worn facet, half-round cross-section, part of very damaged shaft present. Fig 96. Head 120 1, 84 dia, shaft 10+ 1. Bound (Pomoideae), part of bark present on outer edge of head. (E845, per 4)

OB 187.2 Cylindrical ‘cog’ head fragment, half-round cross-section, slightly worn, no remains of shaft. Fig 96. 124 1, 64 dia. Bound (Pomoideae). (E840, per 4)

OB 176.2 Cylindrical ‘cog’ head, worn, sub-circular cross-section, part of damaged shaft present, top of head cut with axe, shaft worked with drawknife. Fig 96. Head 156 1, 120 dia, shaft 25+ 1, 52 dia. Bound (Pomoideae). (E845, per 4)

OB 320 Cylindrical ‘cog’ head, irregular cross-section, very damaged, two worn facets, scar of shaft present. Fig 96. Head 134 1, 90 dia, shaft 48 w, 38 th. Bound (Pomoideae). (A156, per 4)

OB 319 Cylindrical ‘cog' head fragment, irregular cross-section, very damaged, shaft missing. Fig 96. Head 184 1, 80 dia. Bound (Pomoideae). (A156, per 4)

OB 192.1 Cylindrical ‘cog’ head, circular cross-section, three worn facets, shaft missing. Fig 96. 166 1, 92 dia. Bound (Pomoideae). (E871, per 4)

OB 192.2 Cylindrical ‘cog’ head, circular cross-section, very worn, part of damaged shaft present with axe marks around junction of head and shaft. Fig 96. Head 162 1, 94 dia, shaft 28+ 1, 37 dia. Bound (Pomoideae). (E871, per 4)

OB 330 Cylindrical ‘cog head, sub-circular cross-section, two worn surfaces, part of shaft present, axe marks around junction of head and shaft. Fig 97. Head 168 1, 106 dia. shaft 42+ 1, 50 square. Bound (Pomoideae). (A157, per 4)

OB 342 Cylindrical ‘cog head fragment, irregular cross-section, one worn surface, very damaged, no remains of shaft. Fig 97. Head 167 1, 96 dia. Bound (Pomoideae). (B1104, per 4)

OB 174.1 Cylindrical ‘cog’ head, one worn facet, circular cross-section, no remains of shaft. Fig 97. 80+ 1, 104 dia. Bound (Pomoideae). (E814, per 5)

OB 205.1 Cylindrical ‘cog’ head, unknown cross-section, part of shaft present. Head 120 1, 65 dia. shaft 40+ 1. (E898, per 3)

OB 230 Cylindrical ‘cog’ head, complete. Head 77 1, 91 dia, shaft 143 1, 45 w, 40 th. Bound (Pomoideae). (E956, per 3)

OB 58 Cylindrical ‘cog shaft fragment, polygonal cross-section, head missing, axe mark at lower end. Fig 97. 96+ 1, 59 dia. Bound. (Pomoideae), (A156, per 4)

OB 176.5 ‘Cog shaft, polygonal cross-section. 180+ 1, 48 dia. Bound (Pomoideae). (E845, per 4)

OB 176.6 ‘Cog’ shaft, polygonal cross-section. 248+ 1, 46 dia. Bound (Pomoideae). (E845, per 4)

OB 176.7 ‘Cog’ shaft fragment, circular cross-section. 136+ 1, 50 dia. Bound (Pomoideae). (E845, per 4)

OB 176.8 ‘Cog’ shaft fragment, circular cross-section. 274+ 1, 52 w, 43 th. Box quartered (Pomoideae). (E845, per 4)

OB 183.1 ‘Cog’ shaft fragment, polygonal cross-section, worked with axe and drawknife? 120+ 1, 55 dia. Bound (Pomoideae). (E848, per 4)

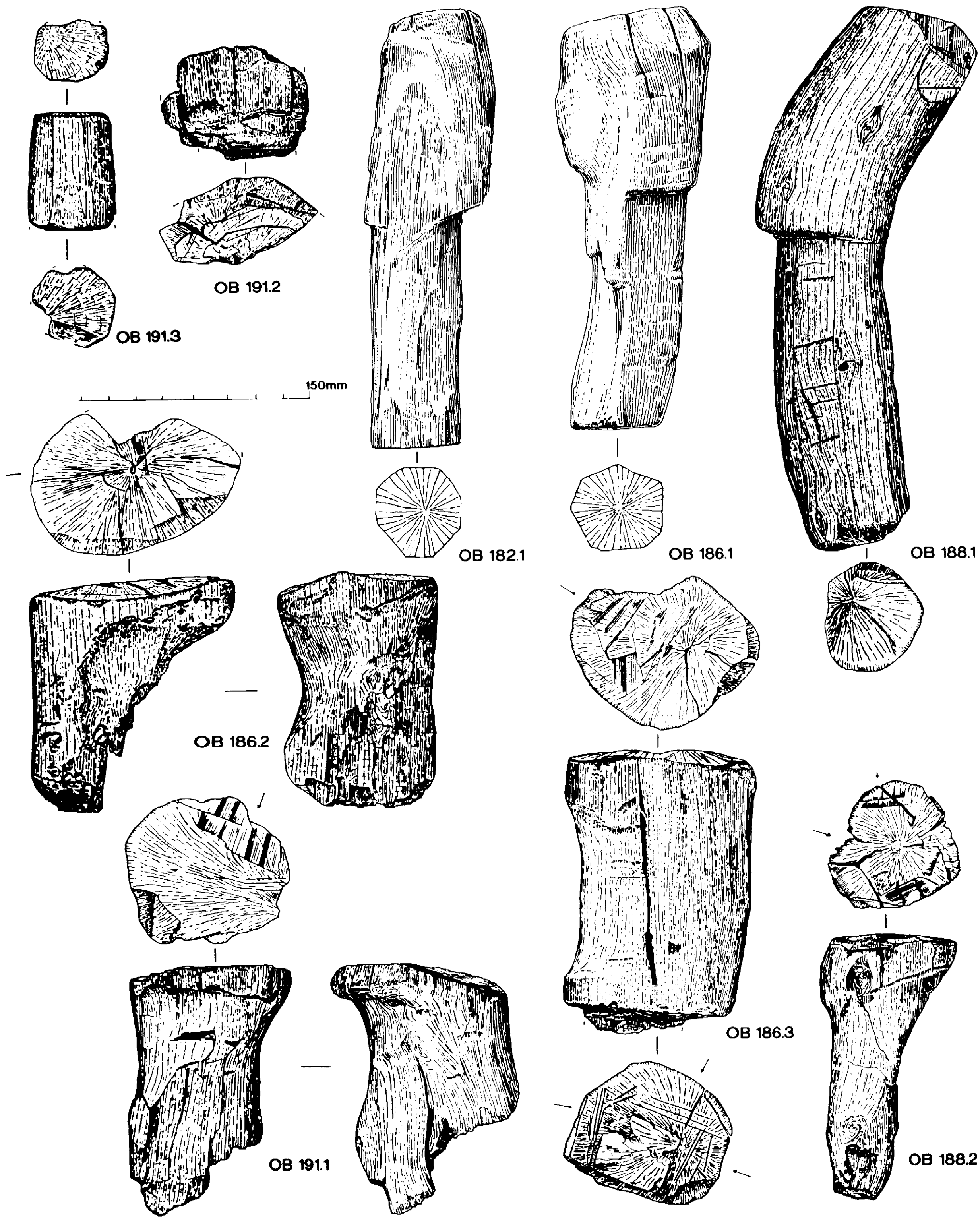


Figure 95 *Worked wood 2: machinery*

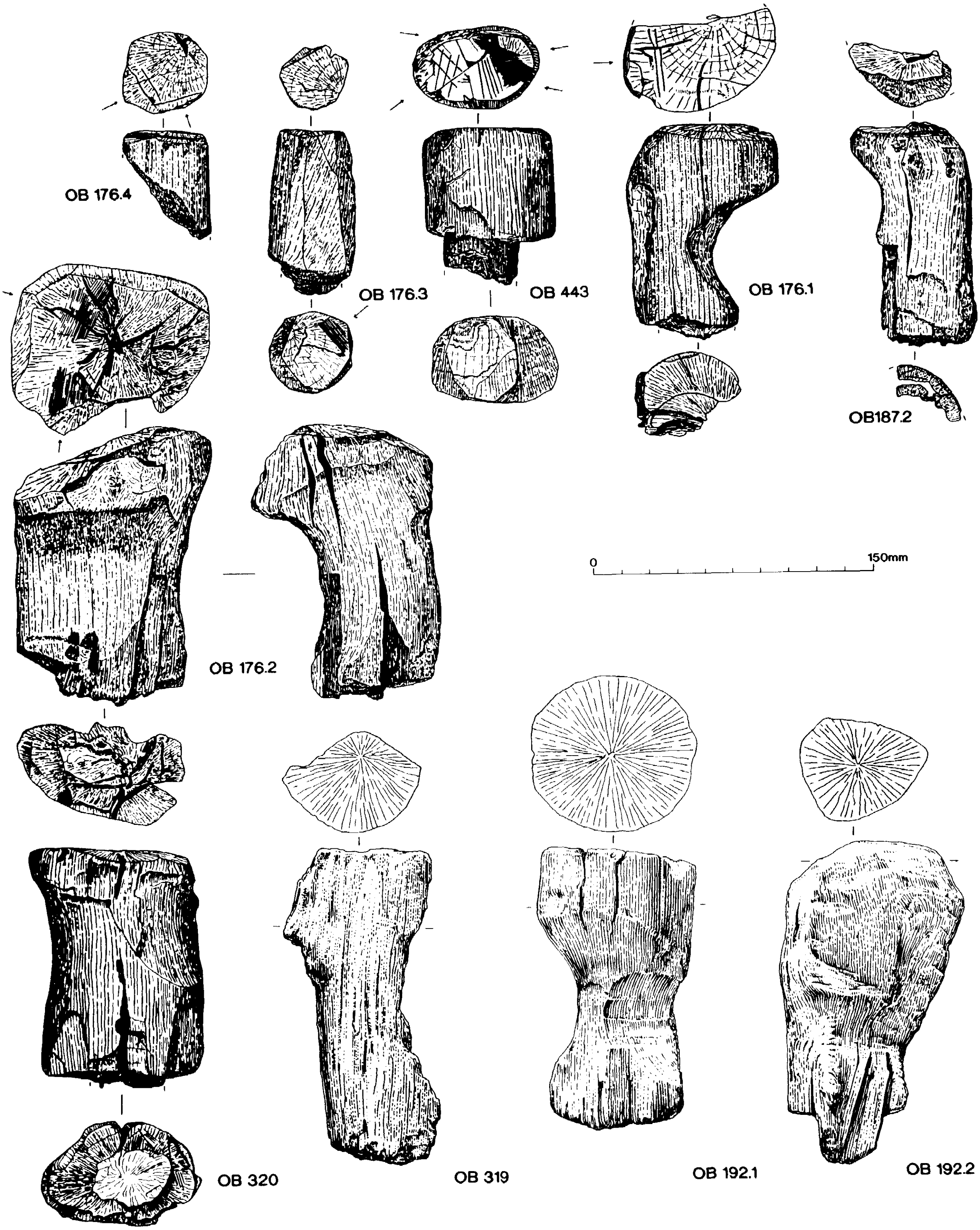


Figure 96 *Worked wood 3: machinery*

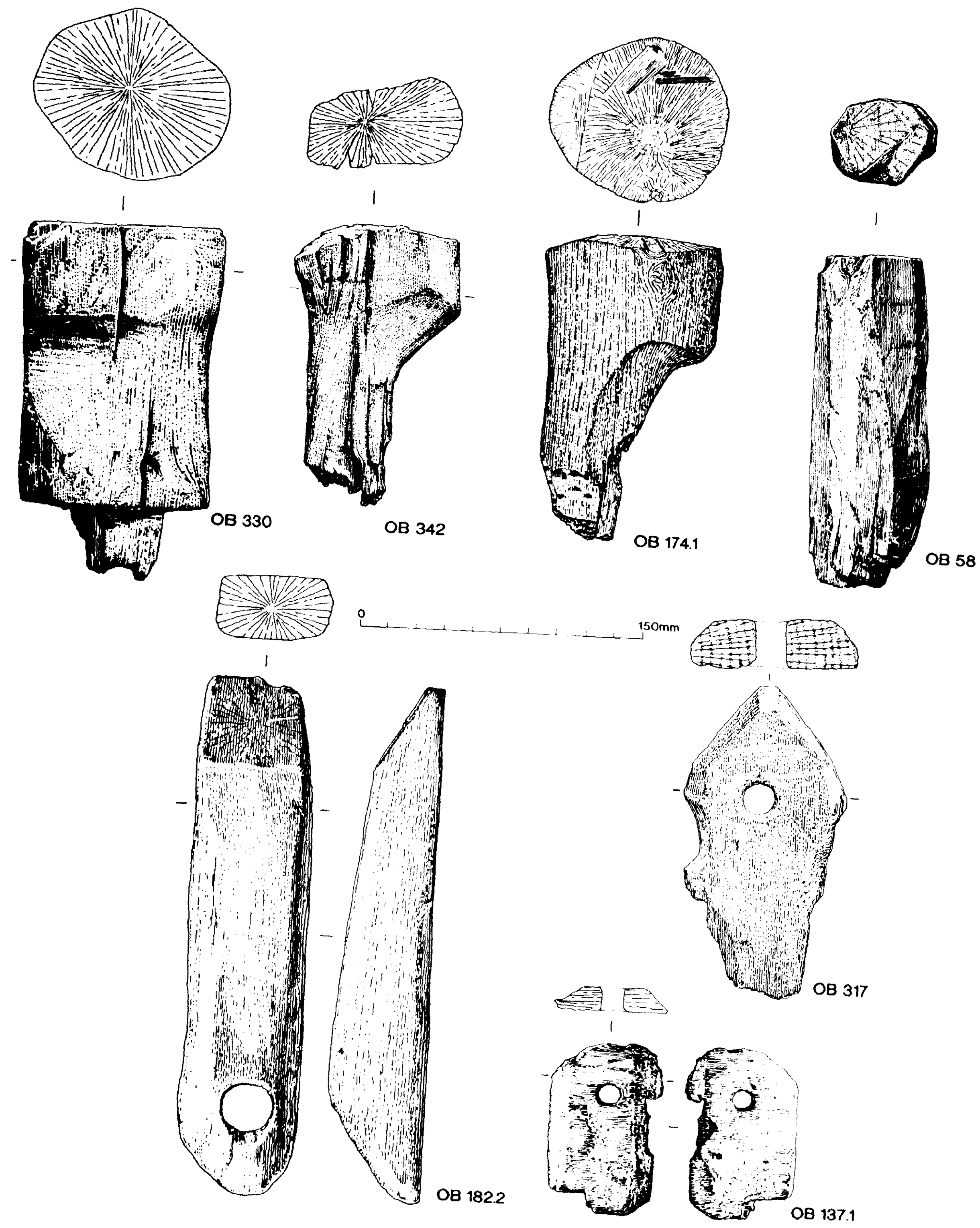


Figure 97 *Worked wood 4: machinery*

OB 187.1 'Cog' shaft fragment, polygonal cross-section. 104+ 1, 29 dia. Round (Pomoideae). (E840, per 4)

OB 190.1 'Cog' shaft fragment, irregular/square cross-section. 118+ 1, 50 square. Box quartered (Pomoideae). (E891, per 4)

OB 190.2 'Cog' shaft fragment, polygonal cross-section. 105+ 1, 45 w, 10-30 th. Tangentially faced (Pomoideae). (E891, per 4)

OR 231 Cylindrical 'cog' head, unknown cross-section, part of damaged shaft present. Head 60 1, 50 dia, shaft 130 1. (E368, per 7, phase 1)

OB 182.2 Trip lever? Block, sub-rectangular cross-section, intact, with one end cut at slight angle, other end very worn with drilled hole (25 dia). Fig 97. 304 1, 65 w, 53 th. Boxed heart, holly *(Ilex Aquifolium* L). (E864, per 3)

OB 317 Bellows plate fragment? Sub-rectangular cross-section, hole (17 dia) drilled towards intact end, intact end kite-shaped with chamfered edges, other end broken and missing but traces of a shoulder of the rest of the board. Fig 97. 186+ 1, 88 w, 31 th. Radially cleft (Pomoideae). (B1104, per 4)

OB 137.1 Bellows plate fragment? Sub-rectangular cross-section, drilled hole (10 dia) towards one end, one of long edges chamfered, both ends and other edge broken and missing. Fig 97. 98+ 1, 64+ w, 16 th. Radially cleft (Pomoideae). (E368, per 7, phase 1)

Valley transect (BAE)

OB 443 Cylindrical 'cog' head fragment, sub-circular cross-section, one damaged side, no apparent wear. Hexagonal-cross-section shaft broken away below head. Axe facets on base and top of head, slight chamfer to top of head. Fig 96. Head 68 1, 68 dia. shaft 28+ 1. 48 w. 39 th. Tangentially cleft (Pomoideae). (117, per 4)

Tail race (BAH)

OB 452.2 'Cog' head fragment, split and most of shaft missing. Head 90 1, 84 dia. shaft 25+ 1, 25 w, 20 th. Round (Pomoideae). (22, per 3-4)

Tools and weaving equipment

Figures 73, 98, and 99

Several pieces could be identified as tools or parts thereof, for example, the claw hammer handle of holly wood (OB 194.1) from the period 3 silts of the tail race, found with the iron head still in place; the handle was worn smooth which indicates that it had been in use for some time. Another handle fragment was found, possibly from an awl-like tool (OB 234); this was carved from an oak burr, the edges and surface were worn; it may have broken in use. OB 32 is part of a ?pickaxe head, its point worn.

Some finds from the period 4 fill of the bypass channel indicate weaving. OB 318 may have been used either to help control several threads being warped at the same time or perhaps to smooth cords. It is very similar to examples from medieval Bryggen, Norway (Oye 1988, 76-7, fig 111.13). A small flat stave (OB 35) from the same context appears to be a 'heddle horse', used in pairs to raise a heddle bar on a horizontal loom during the weaving process (Oye 1988, 75). OB 34, a piece of notched underwood, might be an unfinished winding pin used for winding thread rapidly during weaving (Oye 1988, 75-6). There is no evidence for holes piercing the notches on OB 34, as there are on the Bryggen examples. It is, however, possible that this artefact was a measuring rod, similar to a mid-eleventh-century example from Winchester (Biddle 1990d, 925 and fig 286). The notches are 600mm apart; however, it has no divisions marked on its single flat surface and if it is a measuring rod it can surely only have been of limited use. While acknowledging Oye's identifications to be tentative, it is possible that a horizontal loom was used in period 3 or 4.

One artefact defies classification. OB 143 (Fig 99; Plate 37) from the (period 7. phase 1) silts of the abandoned period 6 mill may be a book cover. Wooden book covers from the medieval period are known, but those which have been described, including some from Bordesley itself (Watts *et al* 1983. 201-2) tend to be much thicker and have small lacing holes cut along an edge, which are not present on this artefact. Neither do these examples have the leather panel embroidered with iron wire.

An alternative is that the object is part of a wooden box or box lid. The chamfered ends might slot into grooves in a small frame. The groove could have housed the hinge for the lid. There is no evidence which might suggest the presence of a locking mechanism whether the object is part of the side or part of the lid. No other finds from the site could be related to this board either as a book cover or as a box lid. An item in the Roach-Smith Collection in the British Museum (56 7-l 1859) is a piece of leather which has also been sewn with iron wire; it is of a similar size to the Bordesley example and also has evidence of a border; the iron stitching is, however, not so well executed. There is no indication of its function (pers comm Margaret McCord).

OB 194.1 Claw hammer handle, oval cross-section, damaged and top of shaft still in iron head (IR 932) found with handle. Fig 73. 225 1, 40 w, 26 th. Box quartered holly *(Ilex Aquifolium* L). (E864, per 3)

OB 40.4 Handle. Sub-rectangular cross-section, one end trimmed away, otherwise intact. 106 1, 44 w, 12 th. (E368, per 7, phase 1)

OB 234 Handle. Circular cross-section, tapers towards broken end from wider flat end. Axial hole (6 dia) drilled from broken end. Fig 98. 49+ 1, 18-28 dia. Cut from burr wood. (E368, per 7, phase 1)

OB 32 Pickaxe head fragment. Polygonal cross-section, part of drilled hole (dia 25) at broken end, other end sharpened, slight longitudinal curvature. Fig 98. 296+ 1, 52-5 w, 32-5 th. (A156, per 4)

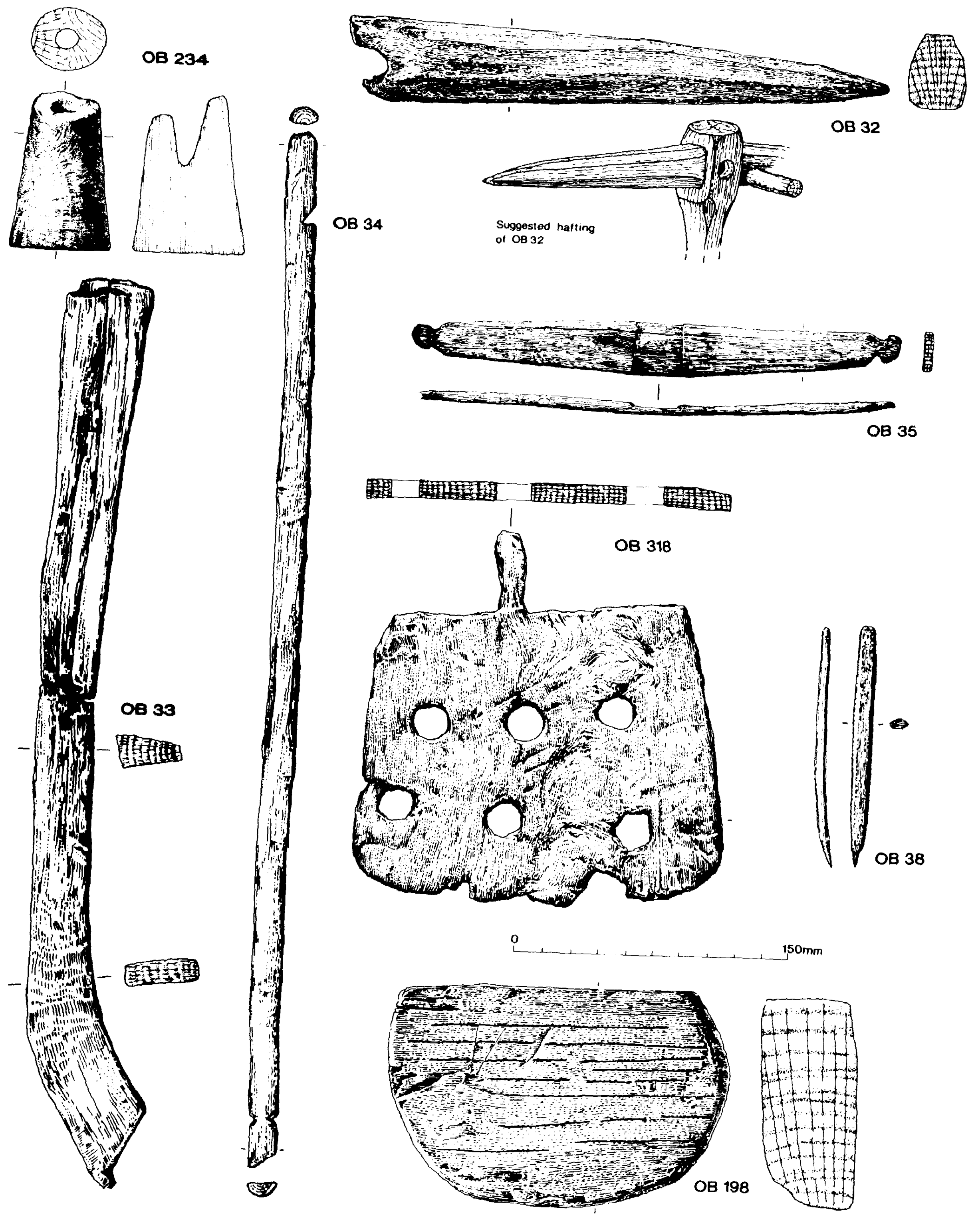


Figure 98 *Worked wood 5: tools and other objects*

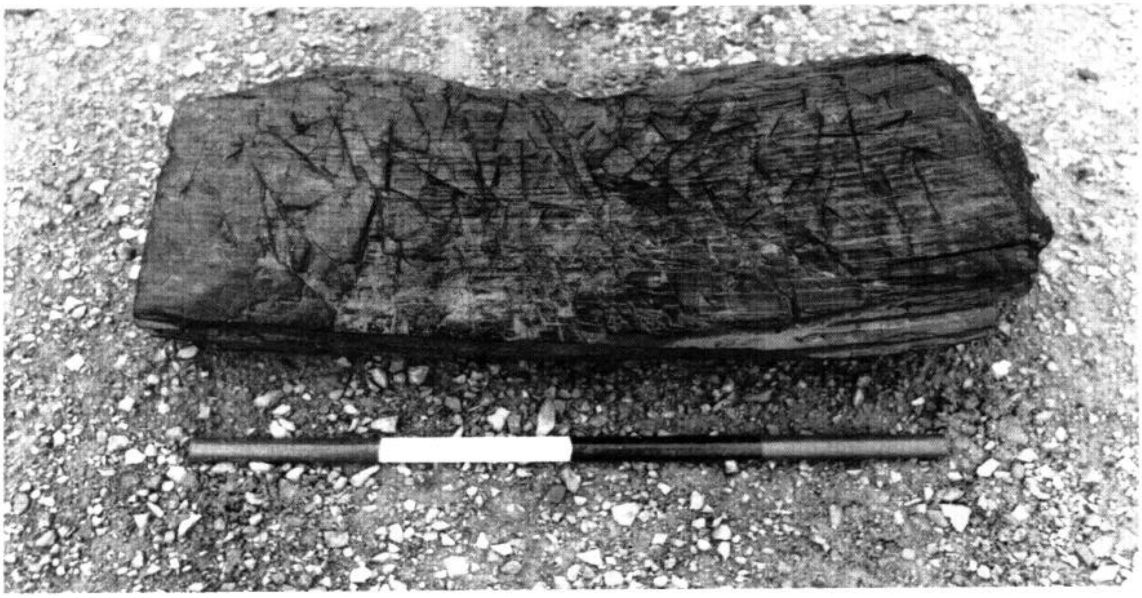


Plate 36 Cutting block (OB 93). (Scale: 0.10m divisions)

OB 33 Paddle, function unknown, sub-rectangular cross-section, one end flatter and curved. Fig 98. 565 1, 30-45 w, 12 th. (A156, per 4)

OB 34 Winding stick or measuring rod? Piece of halved underwood with bark attached, notched towards each end. Fig 98. 640 1, 20 dia. Hazel (*Corylus avellana* L). (A156, per 4)

OB 35 Heddle horse? Sub-rectangular cross-section, tapers and notched towards each end with shallow trench cut across middle of artefact, intact. Fig 98. 266 1, 10-34 w, 8 th. Radially cleft. (A156, per 4)

OB 318 Warping board. Sub-rectangular cross-section, tang projecting from top end, six drilled holes (18-20 dia) in blade. Fig 98. Blade 178 1, 158-202 w, 5-13 th, tang 50 1, 18 square. Radially cleft. (A156, per 4)

OB 38 Stylus or pen? Oval cross-section, slight longitudinal curvature, one end sharply pointed, complete. Fig 98. 148 1, 6-10 th. Species not determined. (A156, per 4)

Other objects

OB 198 Circular disc, sub-rectangular cross-section, one side missing. Fig 98. 80 dia, 48 th. Radially faced. (A1160, per 4)

OB 93 Cutting block? Rectangular cross-section with dressed faces and ends. One side may have had sapwood remaining but was very abraded. Possible groove in lower face which curved from one end to the other. Multiple vertically struck axe marks in upper and lower faces. Plate 36. 470 1, 190 w, 140 th. Axe marks up to 120 1. Box quartered. (E807, per 6)

OB 143 Board, rectangular cross-section, chamfer at each edge, groove cut part of way across upper face halfway along length. One corner of board broken. Board and insert radially faced. Groove contains rectangular cross-section insert, broken. Calf leather sheet embroidered with iron wire placed on upper surface of board, partially covering the insert and groove. Sheet fixed in place with eighteen iron nails nailed through strips of vermilion-dyed calf leather around the edges of the sheet. Some damage to reverse and one corner. Fig 99; Plate 37. Board 247-9 1, 130-l w, 8-11 th. Groove 45-7 1, 31-6 w, 9 d. Insert 38-41+ 1, 30-3 w, 7 th. Sheet *c* 231 1, 112 w. Strips 7-14 w. Also recorded as OA 161 and IR 1307. (E368, per 7, phase 1)

Tail race (BAH)

OB 450 Scoop? Hollowed semi-cylindrical block, both ends damaged. 116+ 1, 61 w, 5-15 th, 57 dia. (20, per 3-4)

Wedges

Figure 100

The 36 wedges had been cleft from oak and were usually radially faced. Most (31) were very similar in size. All of these 31 were from the wheel pit/tail race areas and nine came from period 3, eleven from period 4, and nine from period 5 (with one from each of periods 6 and 7). Almost all were associated with cogs. The similarity in size between these wedges from different periods implies that they had the same function, namely to tie the parts of the waterwheel together. The wedges would have been slotted either through holes in tenons or driven in mortices to prevent the larger tenoned components slipping out.

The remaining five wedges were probably used to fasten other joints. The missing sides of the tail races and wheel troughs, for example, may have used pegs, wedges, or indeed a mixture of both to hold them together. Only one of these wedges was

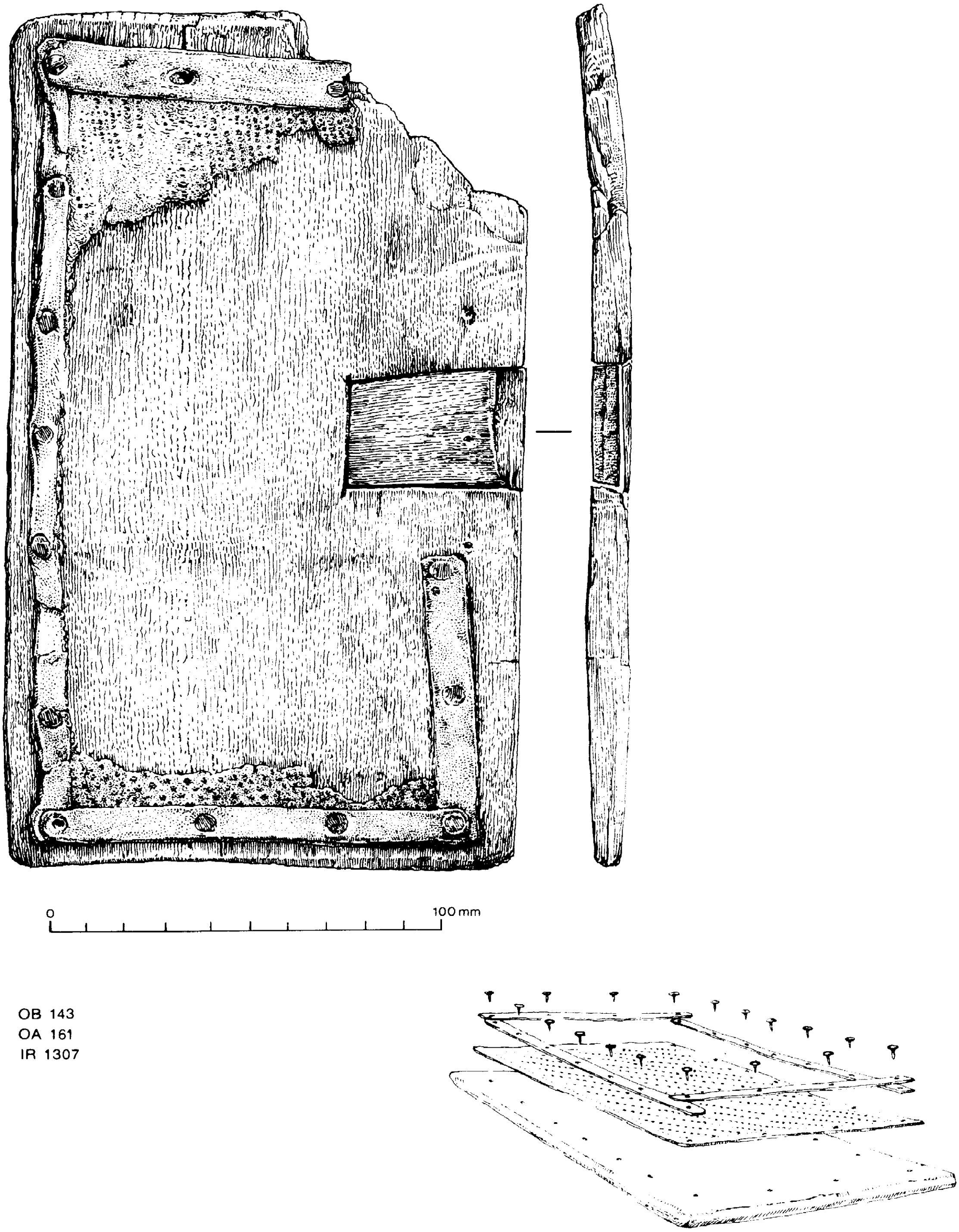


Figure 99 ***Worked wood 6: other objects: ?book cover (OB 143)***

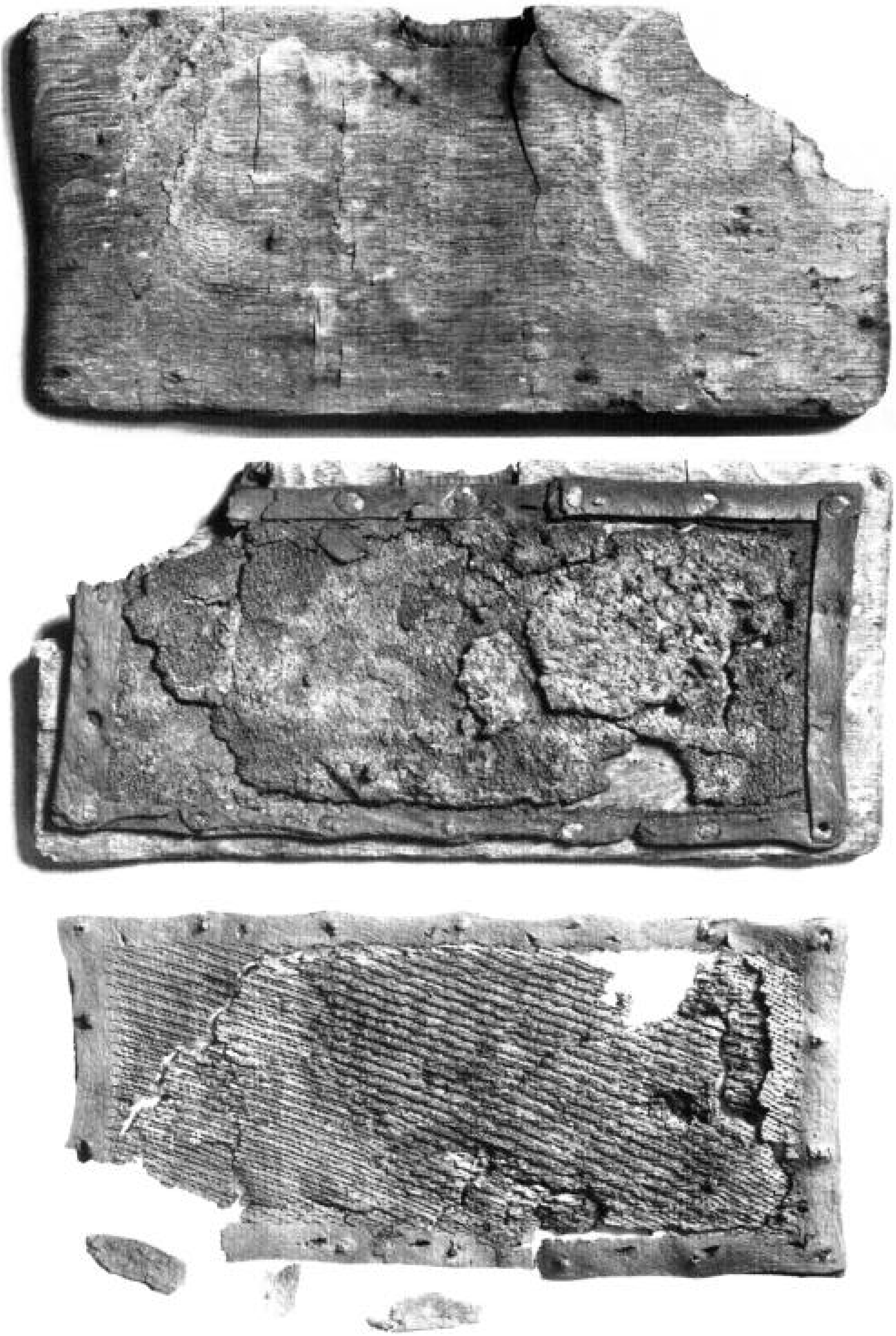


Plate 37 ?Book cover (OB 143); top: exterior surface of oak panel; centre: inner surface, showing attachment of leather sheet to oak panel; bottom: underside of leather sheet, showing areas of intact iron wire (British Museum) found outside the mill race, in the bypass channel, which suggests that their use was in fact restricted to mill race structures.

Some of the wedges which are thought to have come from the waterwheel are here presented; they are summarised in Table 48.

OB 188.10 Wedge from waterwheel. Rectangular cross-section, some axe marks, complete. Fig 100. 110 1, 30 w, 2-16 th. Quartered. (E864, per 3)

OB 176.25 Wedge. Rectangular cross-section, thinnest end chamfered, complete. Fig 100. 108 1, 44-56 w, 8-30 th. Radially cleft. (E845, per 4)

OB 176.27 Wedge from waterwheel. Rectangular cross-section, complete. Fig 100. 100 1, 28 w, 3-16 th. Radially cleft. (E845, per 4)

OB 176.28 Wedge from waterwheel. Rectangular cross-section, complete. F'ig 100. 121 1, 12-24 w, 3-20 th. Radially cleft. (E845, per 4)

OB 170.7 Wedge from waterwheel. Rectangular cross-section, axially curved, complete. Fig 100. 110 1, 18-39 w, 3-20 th. Radially cleft. (E817, per 5)

OB 170.4 Wedge. Rectangular cross-section, complete. Fig 100. 280 1, 32-66 w, 9-44 th. Radially cleft. (E817, per 5)

Building fittings

Figure 100

A small group of objects has been tentatively identified as building fittings. The shingle (OB 316) had a single hole allowing it to be fastened by a wooden peg (cf above) or iron spike over a wooden lath. Its chamfer would have been on the lower end to assist the run off of rain water. Laid in overlapping rows, its size suggests that the laths were spaced no more than 150mm apart. This example is much smaller than eleventh-century examples from Brook Street, Winchester, and late thirteenth-century shingles from Cuckoo Lane, Southampton (Keene 1990b, 320; Platt and Coleman-Smith 1975, 235). In form it is similar to the Southampton type, but better made.

An oak roof finial was recovered (OB 192.5); it was partially hollowed so it could be mounted on a rod. A large wedge (OB 176.31) was in a form and size similar to a pine toe wedge found in thirteenth-century levels at Kings Lynn, Norfolk (Carter 1977, 374 and fig 174/90). Toe wedges are used to create sprocketed eaves such as those illustrated in Brunskill (1987, 81b); they are pegged to the bottom of the outer face of a rafter and serve to lower the pitch of the roof at the eaves, to improve the run off of rain water and direct it away from the walls. Although usually associated with thatching, they have been used on slate and shingle roofs.

A small rectangular block (OB 325), with severe damage and wear around the hole, suggests that it pivoted around a peg, or more probably a metal nail, and may be a very simple latch used to secure a pair of shutters.

OB 176.31 Toeing wedge? Rectangular cross-section, drilled hole (26 dia) centrally placed towards thickest end, intact. Fig 100. 248 1, 68-87 w, 6-31 th. Radially cleft. (E845, per 4)

OB 192.5 Finial or handle fragment? Half-round cross-section, axial spoon bit drilled hole (26 dia), raised rim around exterior of object, some working marks, very damaged. Fig 100. 110+ 1, 68 dia. Quartered. (E871, per 4)

OB 316 Shingle. Rectangular cross-section, one drilled hole (16 dia) on centre line near one end, other end chamfered, intact. Fig 100. 166 1, 82 w, 7 th. Radially cleft. (A156, per 4)

OB 325 Latch? Sub-rectangular cross-section, hole (0.7 dia) drilled towards one end, one face around hole very worn, intact. Fig 100. 148 1, 55 w, 30 th. Radially cleft. (A156, per 4)

Pegs

Figure 101

All the pegs had been cleft from radially faced pieces of wood, usually oak, rarely of fruit wood (Pomoideae - five examples). A drawknife had probably been used to work the pegs to a roughly square or circular cross-section, tapering towards one end.

Two main types of pegs were identified - headed pegs and carpenter's pegs. The first have expanded, larger heads in relation to the diameter of the shaft, whilst the second do not. There is no difference in range of size between the two types. Most pegs came from the tail race silts of periods 3 (eighteen pegs) and 4 (nineteen pegs). The pegged joints in the associated structures used carpenter's pegs and those found loose in the silts were probably derived from the missing superstructure of the mill races. The small numbers recovered from the: tail race in periods 5 and 6 reflect the extremely, limited structural evidence for pegged joints in these periods. Headed pegs were found *in situ* only in the wheel felloe (OB 169) where they were used to fasten a joint which would have been under significant stress. These pegs were further locked in place by having a small wedge driven into their- ends. Headed pegs were probably used to faster: joints which would be under particular stress and therefore in this context would be associated with the machinery and the frame used to support it.

A similar range of pegs from the bypass channel (and ultimately from buildings or machinery implies that their differential use was not restricted to the tail race structures. The fill of the bypass channel also yielded a group of five short pegs of rectangular cross-section which were significantly smaller than the rest (OB 31.1-.4; OB 50). Similar pegs have been identified at the Austin Friars Leicester, Kings Lynn, and Winchester as roofing pegs (Allin 1981a, 67; Carter 1977, 369; Keene 1990c, 455); they indicate that the roof of the mill building was covered with a material which

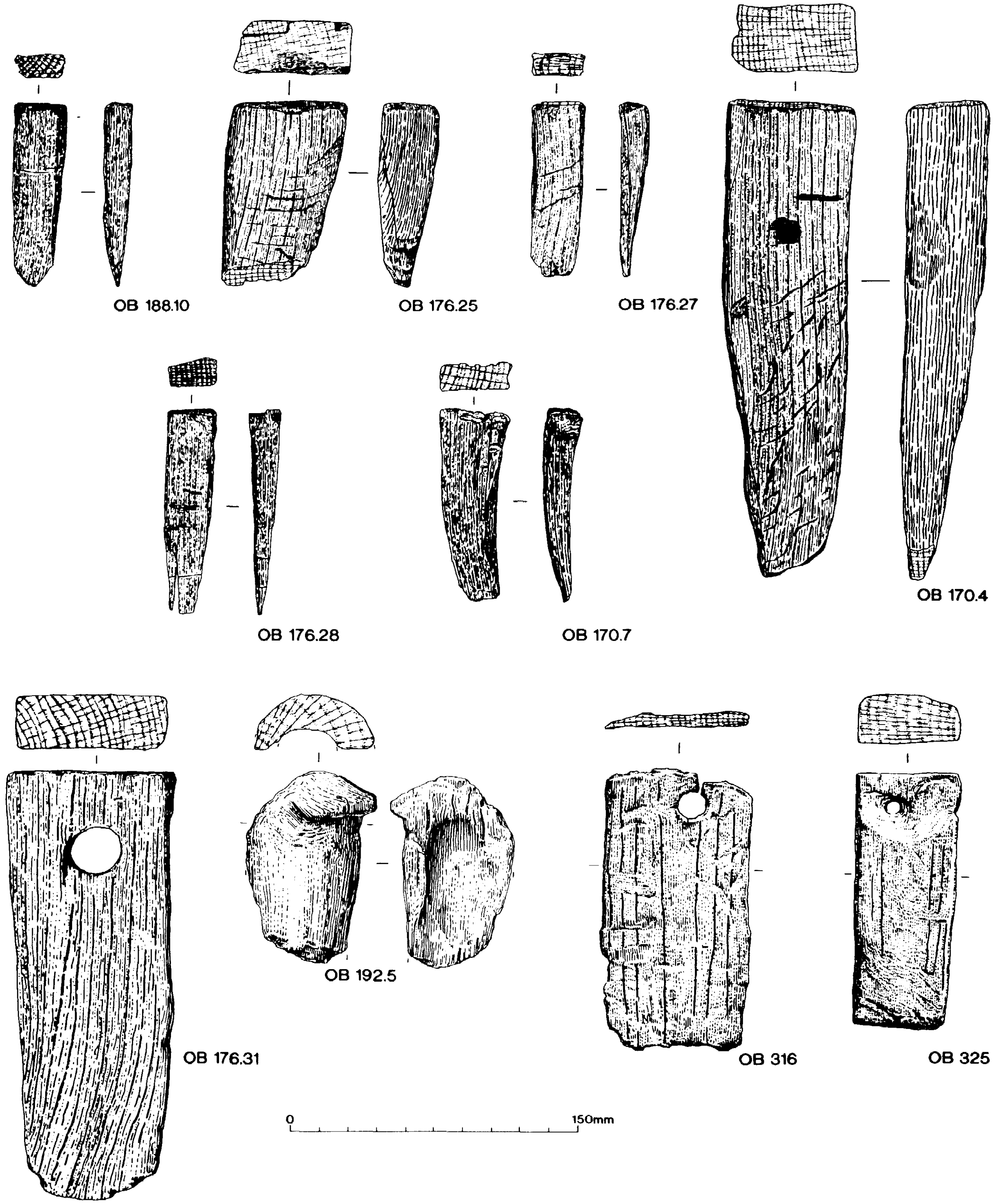


Figure 100 Worked wood 7: wedges and building fittings

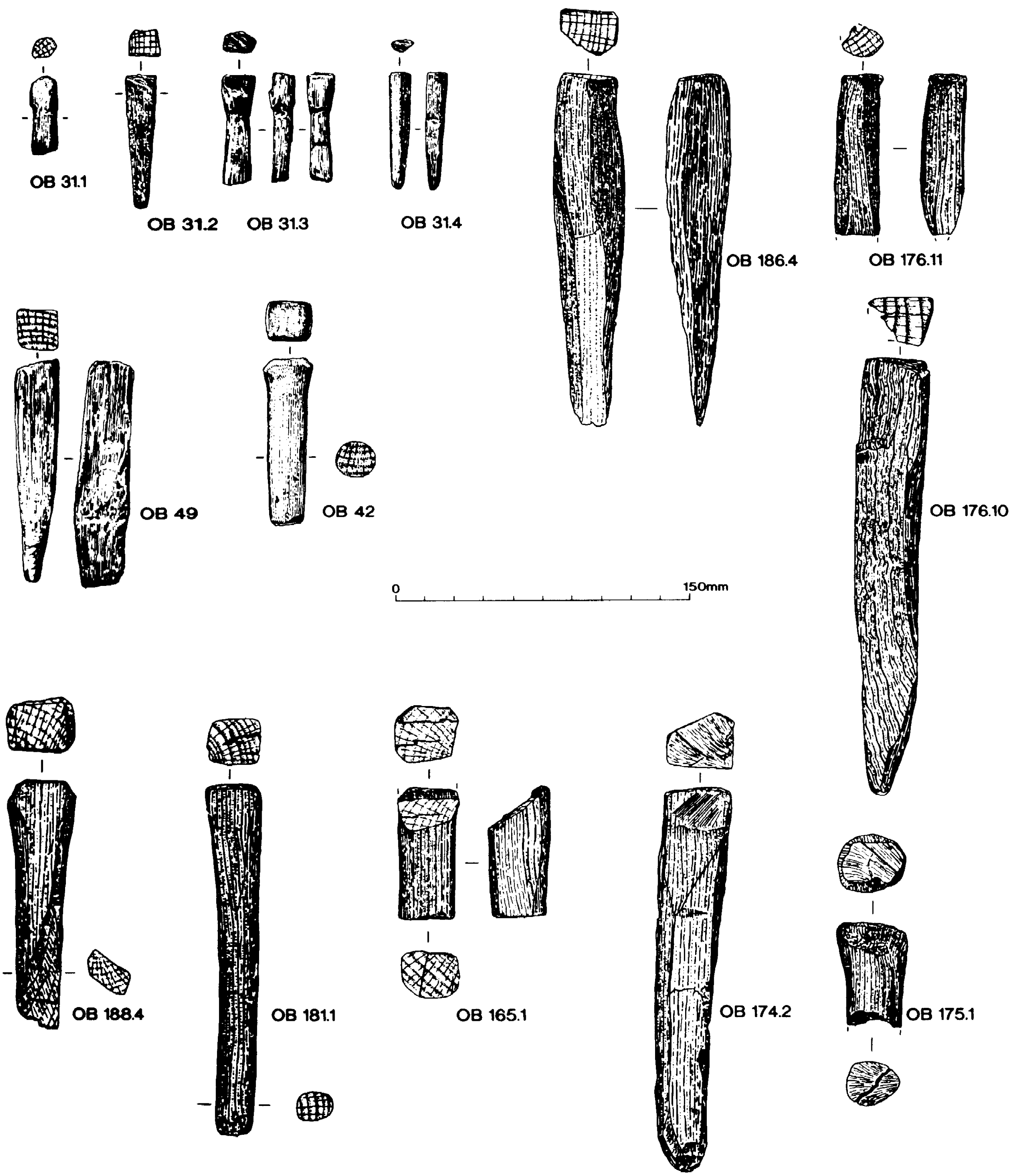


Figure 101 Worked wood 8: pegs

needed hanging on laths, either ceramic tiles, slates, or shingles. Twenty-four pegs were too damaged to be classified and have been described as indeterminate.

To summarise, therefore, three forms of peg were identified: roofing pegs, carpenter's pegs, and headed pegs, with some damaged examples which could be either carpenter's or headed pegs. A selection of the most complete of each type is presented here. All the other pegs are fully catalogued in the archive.

OB 31.1 Roofing peg, sub-circular cross-section, one half slightly thicker than other. Fig 101.44 1, 14 dia. (A156, per 4)

OB 31.2 Roofing peg, rectangular cross-section, complete. Fig 101. 78 1, 16 w, 7- 16 th. (A156, per 4)

OB 31.3 Roofing peg, irregular cross-section, one end thicker than other, other end missing. Fig 101. 62+ 1, c 15 dia. (A156, per 4)

OB 31.4 Roofing peg, irregular cross-section. Fig 101. 64 1,6-12 w, 6-11 th. (A156, per 4)

OB 176.11 Carpenter's peg, sub-circular cross-section, one end cut to a flat point with a sub-rectangular cross-section, other end burred by hammering, complete. Fig 101. 90 1, 21 dia. Radially cleft. (E845, per 4)

OB 49 Carpenter's peg, one end missing. Fig 101. 130+ 1, 22 w, l0-22 th. (A156, per 4)

OB 176.10 Carpenter's peg, sub-rectangular cross-section, complete. Fig 101. 248 1, 36 w, 12-36 th. Radially cleft. (E845, per 4)

OB 186.4 Headed peg, polygonal cross-section, end cut to form a point, complete. Fig 101. 202 1, 10-34 w, 4-32 th. Radially cleft. (E864, per 3)

OB 42 Headed peg. Square tapering to circular cross-section, one end missing. Fig 101. 92+ 1, 25 square, 20 dia. Quartered. (A156, per 4)

OB 188.4 Headed peg, square cross-section, two chamfers each cut away on opposite corner of the shaft to meet in a flattened end diagonally across the axis of the peg, complete. Fig 101. 146 1,34 w, 30 th. Box quartered. (E864, per 3)

OB 181.1 Headed peg, square tapering to circular cross-section, complete. Fig 101. 202 1,27 w, 25 th. Quartered. (E840, per 4)

OB 165.1 Headed peg, polygonal cross-section, one end cut at angle with axe. Fig 101. 78+ 1, 31 w, 30 th. Quartered. (E817, per 5)

OB 174.2 Headed peg, polygonal cross-section, complete. Fig 101. 220 1, 34 w, 32 th. Quartered (Pomoideae). (E814, per 5)

OB 175.1 Headed peg, circular cross-section, point missing. Fig 101.60+ 1, 38 dia. Quartered (Pomoideae). (E814, per 5)

Animal bone (AB) by J Lovett

A total of 1961 bones were recovered from BAB, BAE, and BAH of which only 433 were identifiable both to species and element, the remainder consisting of unrecognisable fragments and ribs. The bone from BAB is treated as one sample for discussion and total counts (by period and by species) for BAB, BAE, and BAH sites are presented in Tables M49, M55, and M58. This is the first sizeable animal bone assemblage to have been recovered from the precinct.

The mill (BAB) sample

Tables M49-M54

Bone was mostly recovered by hand excavation, but *c* 1 m^3 of Al56 (the period 4 fill of the bypass channel which contained the largest bone assemblage from the site) was wet-sieved and this did produce an equivalent range of species to the assemblage excavated by hand. The bone (like the pottery) was collected by context and within 2m squares in an attempt to gain more information about spatial distribution, but the quantities were too small and so these subdivisions have been abandoned for this analysis. Table M49 summarises the general distribution of BAB bone by period and by the five 10m squares into which the excavation was divided.

The volume and distribution of bone generally corresponds with that of the rest of the material assemblage, that is small amounts in periods 1 and 2 (pre-mill) and period 3, with an intense and relatively long phase of activity in period 4, followed by lower deposition in periods 5 and particularly 6. Least bone was recovered from those parts of the excavation dominated by the mill pond banks (areas C and D), while the greatest amounts occurred in those areas with large negative features such as the tail races in area E or the period 4 fill of the bypass channel in area A, which produced the largest bone assemblage.

Most of the fragmented and unidentifiable bone derived from floor levels where it would have been broken and trampled. In area E, for example, it was possible to compare the amount of unidentifiable bone found in negative contexts such as the tail races with that from the mill buildings: *c* 70% of the bone from building levels and features was unidentifiable compared with 35% from the tail race silts, where, once discarded, bone would have been protected. A proportion of the sample displayed the friable, slightly blackened characteristics of waterlogged bone, some with traces of vivianite (a mineral deposit laid down in waterlogged conditions).

Species represented

Table M50

The proportions of the various species for each area have been calculated following the three methods used and discussed by Grant (1977): epiphysis only; total fragments; and minimum number of individuals. No attempt has been made to differentiate between sheep and goat and throughout this report sheep is used for sheep and/ or goat.

Cattle was the dominant species throughout periods 4 to 7 with pig apparently second in importance. There seems to be a consistently low proportion of sheep which is somewhat unusual compared with other medieval rural sites. At most of these, sheep bones predominate, followed by cattle and then pigs. At the village site of Upton, Gloucestershire (Noddle and Bramwell 1969), for example, 74% of the bones were of sheep with 17% of cattle and 4% of pig. Roughly twice as many sheep as cattle bones were found at the village of Wharram Percy (Ryder 1974) with pig bones only forming 8% of the sample. There are, however, a few sites which are more comparable to Bordesley in terms of species proportion. At the village site of Walton, for example, the percentage of sheep to cattle bones was 38% to 30%, and Noddle suggested that cattle were the more important and were reared for their meat (Noddle 1976, 274, 287). The same may have been the case at the village site of Grenstein, Norfolk (Ambrose 1980). It is also interesting to note that the only other bone assemblage from a medieval mill, Chingley in the Bewl valley, also had a higher percentage of cattle than sheep, but had roughly equal proportions of sheep and pig; the sample size, however, was very small (Barker 1975).

The watery environment of the Arrow valley may have been more suited to cattle than to sheep rearing as sheep are susceptible to foot rot in damp conditions. The apparent predominance of cattle could also be seen as a response to the abbey's extensive commitment to arable cultivation and the consequent need for plough animals and manure. Another explanation is that the cattle were raised for meat. Pigs also produce meat economically and rapidly, their secondary uses being limited to refuse consumption and manure production.

Horse bones are usually found on most medieval rural sites, but generally in lower proportions than pig bones, although a fairly high number came from the rural settlement of North Elmham (Noddle 1980, 379-80). Horses are usually assumed to have been used for traction, their consumption being forbidden in the medieval period (Grant 1988, 174). Humans *may* have consumed horse meat, but the gnawed metacarpal and tibia might suggest that horse bones were fed to dogs. The scored horse tibia might suggest that horse hide was prepared and used, but none of the leather fragments from the site was recognisable as horse (see below, Astill, Grew, and Wright, 'Leather').

Birds are represented by domestic fowl and goose, as indeed they chiefly are on most medieval rural sites, such as Upton, Wharram Percy, Walton, and North Elmham. There appears to be more fowl than goose bone in the Bordesley sample; however goose is present in periods 3, 4, and 5, whereas fowl have only been identified in period 4 contexts. At. both Walton (Noddle 1976, 274) and North Elmham (Bramwell 1980, 409) fowl predominated.

Dog bones were found only in period 4 contexts and no other domestic animals, such as cat, were found, nor any wild bird. The only non-domestic species were red deer, from area A (period 4) (an antler fragment) and area E (period 6) (an articu lated radius and ulna), and frog or toad, from area E (period 6) (leg bones). The presence of frog/toad on a site by water is hardly surprising; they were also found in small numbers at Walton (Noddle 1976,274).

The lack of any other small species may be due to biases in survival and recovery, although it is notable that no small species were found in the wet-sieved samples, which may indicate that the greater number of larger bones in the sample represents the real situation. Domestic bird bone is of course quite small and fragile and the fact that this has survived and been collected also suggests that the BAB sample is representative.

The absence of fish bones from the sample is, however, very surprising considering the general importance of fish in the medieval diet and the presence of fish ponds within the Bordesley precinct. It is possible that fish bone has not survived due to its fragile nature and to the periodic cleaning out of ponds; and the detritus from fish meals may not have entered this particular archaeological record.

Representation of skeletal elements

Table M51

In the majority of cases in BAB there appears to be a preponderance of the more robust elements for all species in most periods, particularly mandibles, metapodials, and phalanges. Exceptions include the representation of cattle elements in area E, where there is a slightly higher proportion of 'weaker' parts of the body, although in period 7 the greater majority of elements were the relatively robust lower limbs.

The lack of upper parts of the skeleton (those which are associated with the best joints, such as the humerus, scapula, pelvis, and femur) may indicate that these were removed and the meat consumed and the waste dumped elsewhere. Certainly the presence of skull fragments and lower limb bones, such as the metapodials, phalanges, and calcanea, could be waste bone produced when butchering an animal, perhaps on site.

The most frequently occurring element of the pig is the mandible, which is, as previously noted, a very durable part of the body. In the case of area A, almost all originate from context 156, the period 4 fill of the bypass channel which produced the greatest amount of bone and variety of species; as noted already elsewhere, the assemblage from this channel probably represents a different type of activity from metalworking.

Several elements can be shown to have been articulated: a cattle hind leg, consisting of (unfused) femur, tibia, calcaneum, and astragalus (A156, per 4); and a cattle articulated calcaneum and astragalus (E840, per 4). The latter are often found together and this is hardly surprising given the nature of the articulation and their size. It is a little more unusual to find the femur and tibia still attached. There were no visible butchery marks on the elements although it is possible that the incomplete leg represents a discarded joint. The period 4 bypass channel fill (A156) produced a fowl humerus, scapula, and corocoid, probably representing part of a wing from a meal.

The dog bones (all A156, per 4) include a scapula and humerus, probably from the same animal, although this cannot be demonstrated conclusively because the articulating surface of the scapula was chopped away. Two other dog bones, also a humerus and a scapula, are not only of a similar size, but also share similar score marks and come from the same context. It seems likely that all these represent one animal and are further discussed below in the section on butchery practices.

Age assessment from tooth wear

The state of wear of the mandibular teeth of cattle, sheep, and pigs is given in Table M52 using Grant's method (Grant 1982, 92-4, 98-103).

There were very few jaws with teeth, let alone a complete dentition, and, although many single teeth were found, it was not possible to determine which teeth were from the same jaw; this limited the value of the sample for assessing the mortality profile of the domestic animals. However, an attempt has been made to estimate mandible wear stages for single teeth as well as from mandibles with teeth. As Grant notes, there are considerable problems in giving absolute ages to mandibles yet it is generally true that where one mandible wear stage is notably higher than another, the former will have been older at death and a mandible wear stage of 30+ is likely to indicate a mature animal; this criterion has been applied to the BAB sample (Grant 1982, 106).

86% of the area A (per 4) cattle wear stages (using lowest estimates of wear stages) are over 30; the only one for period 5 was over 30. The calculations for area E (the only other area of BAB with cattle wear stages) were similar (period 4, 100%; period 6, 83%; period 7, 71%). If the upper estimates of mandible wear stages are used, even more of the sample could be considered as from mature animals. Although a different method was used to assess the age of cattle at Walton, it is interesting to note that there 49% were thought to be between one and four years old, while only 29% were older than four years (Noddle 1976, 277).

There is some suggestion at BAB that sheep were killed, on average, at a slightly younger age than cattle; however, there was insufficient evidence for sheep mortality to discuss this in detail. This does seem to have been the case at Wharram Percy which shows that not all medieval sites kept sheep only for wool and some animals were sheared a few times and then eaten (Ryder 1974, 47).

The teeth and mandibles from pigs are from significantly younger animals than cattle, although a mandible (from area B) had a wear stage of over 40. The presence of a few older animals within a predominantly juvenile population is the typical pattern for stock bred for meat production. A small number of breeding adults are maintained, with the majority of the animals culled when the juvenile growth rate begins to tail off into maturity. This point of diminishing returns is particularly pronounced in pigs, where secondary uses for live animals, which might justify continued investment in fodder, are extremely limited. Pig mortality profiles from other medieval sites are similar: at Wharram Percy pigs were generally slaughtered at eighteen months (Ryder 1974, 47).

Age assessment from bone fusion

Ageing animal bones from archaeological excavations using the criteria of epiphyseal fusion is problematic in that certain elements of the skeleton are more useful for this purpose than others. This report has used those ages of fusion proposed by Silver (1969, 282-3), who based them on 'scrub crossbred animals. The full range of fusion ages of all the species can be seen in Table M53.

Cattle ages indicated by fusion data largely agree with those findings for mandible wear stages as the majority of bones are fused in all periods. The ages for both sheep and pig also confirm the tooth wear evidence with a larger proportion of bones being unfused.

Bone measurements

Table M54

The relatively short chronology of BAB prevents any long-term comparison of change in animal size, while informative comparison between Bordesley and other medieval rural sites was limited by the paucity of data from elsewhere. The few measurable bones from Walton indicated a somewhat smaller range of cattle (no comparison was possible for any other animal) (Noddle 1976,279).

Butchered and burnt bone

Roughly 2% of BAB hone showed signs of butchery. This included score and chop marks on such elements as the pelvis, humerus, scapula, and ribs, which would seem to imply the preparation of joints of meat. There was also some evidence of marrow extraction as the epiphyses of a few tibiae and metatarsi had been broken away (in periods 4, 5, and 6), and another metatarsal and also a radius had been longitudinally split. Cut marks were found on the bones of cattle, sheep, horse, and dog.

Chop marks on a cattle calcaneum may suggest separation of the lower leg from the rest of the limb, and perhaps not only butchery for consumption but also skinning.

A red deer radius was scored around the epiphysis which again might imply skinning as well as the consumption of the rest of the animal. The red deer antler fragment had been chopped in two places along the beam and may indicate the use of antler as a raw material.

A horse bone appears to have been split lengthwise perhaps to extract marrow. The other horse bone, a tibia, has faint but discernible traces of cuts made by a knife; these are perhaps the result of skinning the animal, in order to remove the hide, rather than an indication of butchery for consumption. The eating of horse flesh was forbidden by the Church (Grant 1988, 174) but it is possible that these two bones show that this prohibition was not always obeyed.

There are very clear butchery marks on the scapula of a dog. It appears that some of the acromion, tuber scapulae, and fossa articularis have been chopped away. The chop is at an angle slanting down towards the proximal part of the humerus and suggests that the blow was aimed so as to separate the scapula from the humerus. The scores are fairly deeply incised around the neck area, although only on the anterior face. This bone is frequently found with cut marks in animals such as cattle, pig, and sheep. Although no other examples are known to this author of butchered dogs on medieval sites in Britain, there are examples on Iron Age sites in Britain and the Continent. At Villeneuve Saint-Germain in France (Yvinec 1987, 83-9), some of the dogs were evidently eaten, and some also skinned. Commonly the scapulae were chopped into two, then the scapula and humerus were separated by knife, although in one example the proximal humerus was slightly chopped. The humerus also tends to be scored on the distal epiphysis in the same area. It is possible that the Bordesley dog bones, which are probably from a single animal, represent the remains of a meal. This may be suggested by the nature of the chop and score marks, and their location on meat-bearing joints, although it is equally possible that the animal was simply over-zealously skinned.

Burnt bone occurred in periods 3 to 7 and most was recovered from the tail race silts, particularly in period 6; very little was recovered from floor levels.

The valley transect (BAE) sample

Tables M55-7

The BAE sample is extremely small (sixteen identified bones) and, although interpretation is limited, it is interesting that there are still six species represented (the unidentified bird bone may represent a seventh). Cattle are once again the best represented species with roughly equal numbers of all others. There is nothing else of particular note in the sample.

The tail race (BAH) sample

Tables M58-61

The slightly larger BAH sample of 34 identified bones came from three contexts (11, 21, and 22) and the majority were from context 11. This sample reinforces the conclusion that cattle was the most common species at Bordesley. They represent 62% of the total (total fragment method). Similar proportions of sheep, pig, goose, and fowl were found. One element of a small mammal (unidentified) was also present.

The majority of the cattle bones were fused, suggesting, as with the BAB sample, a predominance of mature animals in the mortality profile. In contrast, the only mandible wear calculation possible suggests an immature animal.

The only evidence of butchery from BAH was a scored cattle humerus which probably facilitated the separation of the humerus from the radius, and a longitudinally chopped tibia which is likely to have enabled the extraction of marrow.

Conchsion

The analysis of the total sample (BAB, BAE, and BAH) revealed that cattle was numerically the most important species on the site, followed by pig, and then sheep. Butchery and skinning possibly took place on site, at least for cattle and sheep, and a dog seems to have been dismembered and perhaps even consumed. Both cattle and sheep leather has come from the site. No evidence for disease or deformity was discovered among the bones.

Horse, dog, deer, and domestic fowl and goose, which are present in the BAB sample, are common on other contemporary rural sites and so would suggest a fairly ordinary medieval sample of ammals used largely for food, traction, wool, and milk.

The relative proportions of species may indicate the character of animal husbandry within the precinct. To judge from the relatively large areas of the Bordesley precinct that have few earthworks, and the description of other Cistercian precincts (Coppack 1986a, 129-30), there were extensive areas of pasture. However, larger Cistercian monasteries appear to have lacked substantial agricultural buildings such as granaries and byres which may suggest that animals were brought into the precinct from elsewhere. The Beaulieu account book may support this idea, for only pigs were apparently reared in sizeable numbers within the precinct (Hockey 1975, 182-4). At Bordesley in 1278 a piggery and shearing shed were probably sited in the abbey precinct *(VCH Vol4,* 444).

A second possibility is that the bone assemblage reflects what was brought to the monastery from its granges. Most of Bordesley's granges were located in the woodland-pasture region of north Worcestershire and Warwickshire, but there is little information about what stock was reared. The heavy involvement in wool production suggests a high commitment to sheep raising which probably took place at other locations besides Bordesley's one Cotswold grange at Combe (Wright 1976a, 19).

A third possibility is that the bones and the remains of animals were bought in, perhaps from local markets. However, the occupation of the mill site from the later twelfth to the later fourteenth/ early fifteenth centuries mostly coincided with the time when the abbey was a direct producer and had the majority of its lands in hand and so would have been less dependent on markets for basic foodstuffs (Wright 1976a, 19).

Finally, it is possible that the assemblage found on the mills and workshops does *not* directly reflect what was consumed in the monastery. The mills were at a distance from the main claustral area and various selection procedures may have taken place between the cloister and the mill. It is noticeable that the bone evidence suggests that cattle were butchered and the better meat joints taken before the remainder was brought to the mill site.

Considering the mills' industrial character the bone may have been brought on site as a raw material, but the absence of residues from bone-working or associated tools would argue against this.

Leather-working, however, did take place, and some of the cut marks may have resulted from skinning. The (admittedly small) assemblages from the subsidiary excavations BAE and BAH reflect the character of the mill hone collection which again argues against an industrial origin. Some comparable assemblages are from medieval rural (usually village) settlements which do not have a particularly high status; however, the relatively high proportion of pig bones is more typical of a high-status site (Grant 1988, 152).

The bone assemblage is lacking in small animals and fish and, perhaps more importantly, exotic species that are generally associated with high-status sites. This is also true of the rest of the material assemblage, although the botanic evidence does show fig and grape (see above, Carruthers, 'The valley environment . ..'). Whether this discrepancy reflects the difference between the 'secular' and spiritual areas of a monastery, or is actually typical for Bordesley, is too early to say.

Worked bone (WB) by G G Astill

Figures 71 and 75

WB 30 One fragment of cattle-size long bone. Part of inner surface removed by a knife, with two cut marks visible. Three of the edges appear to have been cut. 69 l, 27 w, 10 th. (E366, per 7)

WB 33 Knife with bone handle. See IR 1308 for details. Fig 75. (E800, per 6)

WB 36 Needle-shaped long bone fragment, with a notch cut midway. Has a polished appearance and may be a weaving tool (cf Brown 1990, 230–2). Fig 71. 85 l, 5 dia. (E835, per 3)

Leather (other animal: OA)

by G G Astill, F Grew, and S M Wright

Figures 99, 102–4; Tables 62 and 63

A total of 296 pieces of leather were recovered from BAB; a further eighteen pieces came from BAH and one piece from BAE 34% were unidentifiable fragments.

The catalogue here is a selection of all the main categories of leather found during the excavations Most of the entries in the catalogue, and the illustrations, are concerned with leather from the period 4 channel fill A156, which represents the largest assemblage. A full catalogue, giving identifications and dimensions, forms part of the archive; the character of the complete assemblage is summarised in Table 62. All measurements arc maxima and were taken before conservation, unless otherwise stated (viz, ac = after conservation), except for thicknesses which are minima due to wear and lamination. Shoe heel, waist, and tread measurements are only given where complete; stl = stitch length.

Francis Grew provided the identifications of, and comments on, many of the pieces, in particular the shoe parts. Animal identification was by Betty Haines; in those cases where identification is not certain, because the grain layer is badly preserved, but an examination of the structure of the leather permits a probable identification, that identification is preceded by 'probably'. Identification of stitching material was by Glynis Edwards (English Heritage). The excavated leather was generally in a poor condition, but all of it has been conserved (by freeze drying) by Portsmouth City Museums.

All of the leather came from waterlogged contexts such as the tail race silts, but the largest assemblage (184 pieces) was recovered from the period 4 fill (A156) of the period 3 bypass channel in area A (A135/B1100) (Table 63). There are, however, no great differences between the leather collection obtained from the channel and that from the tail races. The rest of the associated material assemblage from the channel is, however, sufficiently different to suggest that it had been derived from a building other than the period 3 mill, perhaps a

Table 62 Mill (BAB): summary of leather, by function and by period

Period	Shoe parts	Reused shoes	Other objects†	Trimmings	Waste	Unidentified	Total
3	1	–	–	1	–	–	2
4	29	20	26	20	17	74	186
5	12	6	–	–	–	–	18
6	3	6	–	–	–	–	9
7	32	2	8	4	–	35	81
Total	77	34	34	25	17	109	296

† Includes patches, other objects, and pieces from larger objects.

Table 63 Mill (BAB): summary of leather from period 4 bypass channel fill (A156), by function and by 2m square within A156

Area	Shoe parts	Reused shoes	Other objects	Trimmings	Waste	Unidentified
A156E (NW)	1	1	–	–	–	1
A156F	10	–	–	–	7	10
A156G	6	1	–	–	2	–
A156N	–	–	–	–	1	4
A1560	4	2	–	–	1	–
A156T	2	1	–	–	–	–
A156V (SE)	6	13	26	20	6	59

workshop for clothmaking and leatherworking.

The leather assemblage is distinctive in having a high proportion of waste and offcuts (see Table 62). The majority of shoe fragments are either repair pieces or show evidence of repair; the remainder (of the shoe pieces) are the worn offcuts left after the good leather had been salvaged from the shoes. Waste pieces, either from original manufacture or from salvaging, were also common; trimmings, shaved off completed shoes, were also present. The other identifiable pieces were patches or reinforcements for objects that were larger than shoes, and sheets, probably for the repair of such items as bags. Cattlehide was the most commonly used skin and was used to make all parts of shoes, although calf was also used for some shoe parts and patches and binding strips. Goat or sheepskin was apparently preferred for making items from larger sheets and was also used for patches and binding strips. In the main this assemblage suggests leatherworking that involved cobbling and repairing leather rather than primary manufacture; the day-to-day repair of shoes and garments, sometimes with new leather, sometimes with scraps salvaged from existing articles. Although the leather-work from the Austin Friars in Leicester is similar in character (Allin 1981b), the Bordesley assemblage is not a distinctly monastic one. It is, however, probably the residue from a cobbler's workshop which serviced the monastic community and its secular employees. The Beaulieu Abbey account book indicates a clear difference in the quality of shoes made for the community and for its servants, and those made to be given as presents by the abbot, but no record was made of repairs (Hockey 1975, 208–14).

The period 4 assemblage contained shoe fragments with vertical lacing (eg OA 39.1–.3: Fig 102) which is consistent with the late twelfth- to thirteenth-century date for the context (A156). However, a fragment of a piked shoe (OA 158), conventionally dated to the later fourteenth century, was recovered from the same fill. Most of the leather from the channel fill (A156) concentrated in the south-east, and deepest, part of the channel, while there was a predominance of shoe parts in the north-west parts of the channel (see Table 63).

The fourteenth-century date for period 5 (early fourteenth to ?mid-fourteenth century) appears to be consistent with the types of shoe recovered: toggle-fastened shoes probably have a *terminus ante quem* of *c* 1330 (eg OA 81: Fig 103), while buckle-fastened shoes have a *terminus post quem* of about the same date (eg OA 53.1: Fig 103). It is noticeable that only two fragments of a piked shoe (OA 53.5, OA 158: Fig 102), a style current from the later fourteenth century, were recovered, and only one multi-piece sole was found (OA 76).

The period 7 shoe fragments demonstrate that generally soles became much narrower, a trend which has been noted in most other shoe collections; however, the period 5 shoes exhibit a range of widths, including some very broad shoes.

Shoe parts

OA 4 Repair piece from forepart of shoe, complete, tunnel stitch (irregular) on inside around edge, grain side has an impression of a repair piece and tunnel stitching (irregular), but where repaired not particularly worn, band of wear outside repair on the ball of the foot. Cattlehide. Fig 102. 148 l, 98 w, 2 th. (A156, per 4)

OA 43.1 Part of a sole of turned shoe. Sole for a left foot, probably worn on inner heel and on tread, has had repair pieces (both missing) stitched to heel and to forepart. Fig 102. 210 l, waist 60, edge/flesh seam stl 6, 4 th. Also shoe upper of same shoe, but subsequently cut up: see OA 43.2. Both pieces probably cattlehide. (A156, per 4)

OA 143.1–.2 Two parts of shoe sole, one (.1) probably forepart and waist of left foot. Waist 38, 149 l, 1 th; other (.2) repair sole, probably of same shoe. Cattlehide. Fig 102. 112 l, 45 w, tunnel stl 6, 1.5 th. (A156, per 4)

OA 155.1–.3 Forepart of sole of shoe (.1) with a fairly pointed toe, apparently with a repair sole (.2, with a lasting margin, implying the remaking of the shoe) stitched to it, and then another repair with tunnel stitching (.3). The final sole thus had three layers. All probably cattlehide. Fig 102. Original (and largest piece) 70 l, 62 w, edge/flesh seam stl 6, 4 th. (A156. per 4)

OA 157 Part of shoe sole – heel, forepart, and part of heel stiffener with binding stitch on two edges; repaired on both heel and forepart. Sole probably of cattlehide, stiffener of calf. Stitching material vegetable, probably bast. Fig 102. 200 l, 70 w, edge/flesh seam stl 5–6, 3 th, binding stl 5, tunnel stl 5–7. (A156, per 4)

OA 158 Part of toe from fairly pointed shoe, edge/flesh seams on two sides. ?From a piked shoe *c* 1360 and later. Probably

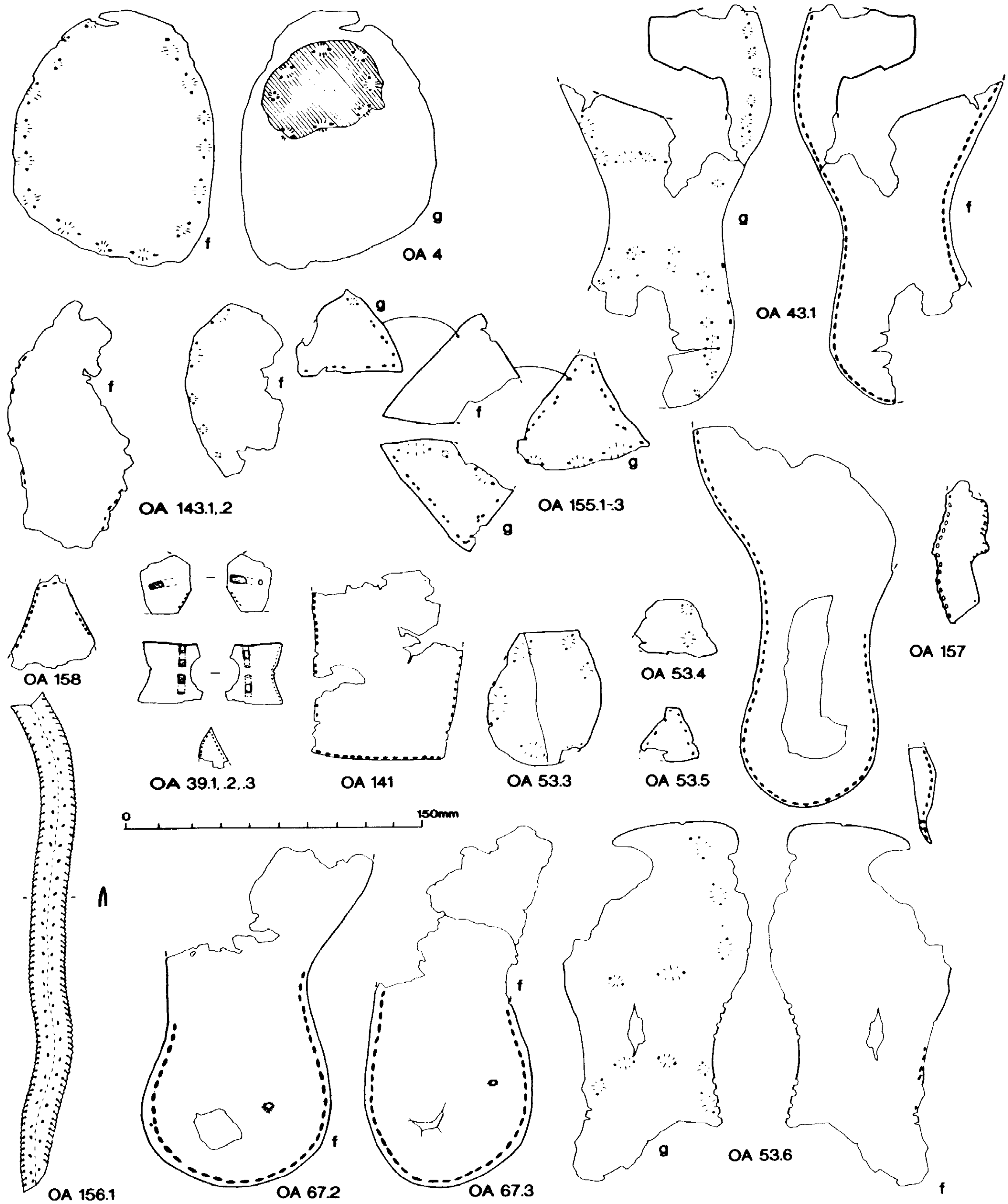


Figure 102 Leather 1: shoe parts

cattlehide. Fig 102. 57 1, 43 w, edge/flesh seam stl 3, 1.5 th. (A156, per 4)

OA 39.1-.3 Three small inserts from front of ankle shoe, two (.l, .2) with thick leather thongs passing through pairs of slits and a butt seam along one edge. The third insert (.3) is triangular and has seams on two edges. Cattlehide. Late twelfth/early thirteenth century. Fig 102. 37 1, 28 w, stl 3, 2 th; 47 1, 25 w, stl 2.5-3, 2 th; 50 1, 25 w, stl 3, 2 th (ac). (A156, per 4)

OA 141 Part of a shoe upper ?insert towards the quarters, edge/flesh butt seams on three original edges. Probably cattlehide. Fig 102. 107 1, 85 w, edge/flesh seam stl 5, 2 th. (A156, per 4)

OA 156.1 Binding strip, folded double, would have been attached to a binding seam and possibly the top binding of a shoe; two ends cut, Coat or sheep skin; stitching vegetable, probably bast. Fig 102. 290 1, 22 w, stl 5, 1 th. (A156, per 4)

OA 67.2 Heel and waist of a large shoe sole, with edge/flesh seams, no signs of repair. Secondary square nail hole made from the inside of the heel. Probably cattlehide. Fig 102. Waist 73, heel 94, 190 1 (incomplete), edge/flesh seam stl 5-6, 4 th (ac). (E817, per 5)

OA 67.3 Part of a very broad heel and waist of a shoe sole, with edge/flesh seams. A secondary square nail hole made from the inside of the heel. Probably cattlehide. Fig 102. Waist *c* 72, heel 88, 210 1 (incomplete), edge/flesh seam stl 6, 4 th. (E817, per 5)

OA 53.3-.5 Three pieces. (.3) Repair sole from heel with tunnel stitching (irregular). 80 1, 60 w, 1 th. (.4) Repair sole from forepart with tunnel stitching (irregular). 50 1, 40 w, 1 th. (5) Toe end of forepart of shoe, edge/flesh seams on two sides, apparently converging to sharp point, suggesting a piked shoe. c 1360 or later. 35 1, 30w, edge/flesh seam stl 5, 2 th. All pieces probably cattlehide. Fig 102. (E817, per 5)

OA 53.6 Part of very large shoe sole with very broad waist, edge/flesh seam along two sides, repair pieces added to heel and to forepart (tunnel stl 12). Probably cattlehide. Fig 102. Waist 68, 190 1, edge/flesh seam stl 5, 2 th. (E817, per 5)

OA 63.1 Complete turnshoe, left foot, sole and one-piece economy type upper. Sole has pointed toe with a fairly wide broad joint and moderate waist; rear of seat missing; tunnel stitching (stl 12) across joint near forepart and waist indicates repairs to forepart and heel. 240 1, tread 99 w, waist 53, edge/flesh seam stl 7, 5 th. The upper was cut in one piece with butt seam join on inside; pointed toe with fairly deep opening at instep; top of quarters and instep opening are cut straight. The upper was probably fastened with a strap and buckle. Three parallel knife slashes on the vamp may be decorative. Second quarter of fourteenth century or later. All parts probably cattlehide. Fig 103. Toe-instep opening 106, height of quarters 99, grain/flesh seam stl 7, 1.5 th. (E817, per 5)

OA 81 Piece from a toggle fastened shoe, one edge has edge/flesh seam, with a thong which passes through a slit. Shoe subsequently cut up. *c* 1270-1330. Probably cattlehide. Fig 103. 60 1, 60 w, edge/flesh seam stl 7, 4 th. (E836, per 5)

Reuse of shoe parts, ?indicative of cobbling

Soles

OA 39.36 Edge piece from a repair sole that was ripped off and then cut up (suggests reuse of repair soles). Cattlehide. Fig 103. 711, 24 w, irregular tunnel stitching, 4 th. (A156, per 4)

OA 42 A trimming off the edge of a sole, with edge/flesh seam, cut off to salvage the rest of the sole. Probably cattlehide. Fig 103. 96 1, 8 w, stl 5, 3 th. (A156, per 4)

OA 150 Part of shoe sole, repaired, subsequently cut up for reuse. Probably cattlehide. Fig 103. 85 1, 70 w, edge/flesh seam stl 6, 4 th. (A156, per 4)

Uppers

OA 39.13 Forepart of upper of small narrow shoe, fine grain flesh seam on the two roughly parallel edges; subsequently cut. Calfhide. Fig 103. 74 1, 51 w, stl 5, 2 th (ac). (A156, per 4)

OA 43.2 A shoe upper (probably from the same as 43.1) has part of lasting margin, part of one edge/flesh seam, probably from side of shoe, and has subsequently been cut up for reuse. *c* 1300. Probably cattlehide. Fig 103. Largest piece of upper 95 1, 64 w, edge/flesh seam stl 3, 4 th. (A156, per 4)

Waste from cutting out soles and repair pieces from new leather

OA 39,24-.29 Six waste pieces from cutting out shoe soles or repair soles, unworn. Cattlehide. Fig 103. Largest piece 73 1, 20 w, 3 th (ac). (A156, per 4)

OA 143.3 One thick waste piece, ?from the cutting out of soles. Cattlehide. Fig 103. 95 1, 27 w, 5 th (ac). (A156, per 4)

OA 144 Waste piece, with marking out line, ?for shoe sole. Cattlehide. Fig 103. 82 1, 22 w, 4 th. (A156, per 4)

OA 149.1-.2 Two thick waste pieces from cutting out shoe soles, one (.l) with marking out lines on two edges. Fig 103. Largest piece 81 1, 42 w, 5 th. Cattlehide. (A156, per 4)

Trimmings from completed shoes (or possible waste pieces from cutting out)

OA 145.2 Knife-cut trimming. Unidentifiable animal. Fig 103. 70 1, 35 w, 2 th. (A156, per 4)

OA 39.30-.34 Five trimmings of thinner (?calf) leather, including a disc, unworn. Probably cattlehide. Fig 103. Largest piece 70 1, 16 w, 1 th (ac). (A156, per 4)

OA 39.50 Unworn and thin trimming. Calfhide. Fig 103. 115 1, 11 w, 1 th (ac). (A156, per 4)

Patches or reinforcements

OA 39.7-.9 Three reinforcement patches (two rectangular, one sub-rectangular), seamed on all edges with very fine, neat binding stitch. Coat or hairy sheepskin. Fig 103. 90 1, 62 w, stl 3-5, 1 th; 118 1, 63 w, stl 2.5-3.5, 1 th; 60 1, 58 w, stl 3-5, 1 th (ac). (A156, per 4)

OA 39.45-.47 Three patches or reinforcements with stitching around original edges, possibly from bags or clothing. Probably cattlehide. Fig 103. Largest piece 95 1., 90 w., stl 7-8, 1 th (ac). (A156, per 4)

OA 45.2 Patch or reinforcement, of semicircular shape, unworn with grain/flesh running stitches. Calfhide. Fig 103. 84 1, 30 w, stl 4-5, 1 th (ac). (A156, per 4)

OA 47 Oval piece with two circular holes (dia 5) at centre. Probably cattlehide. Fig 103. 67 1, 40 w, 2 th. (A156, per 4)

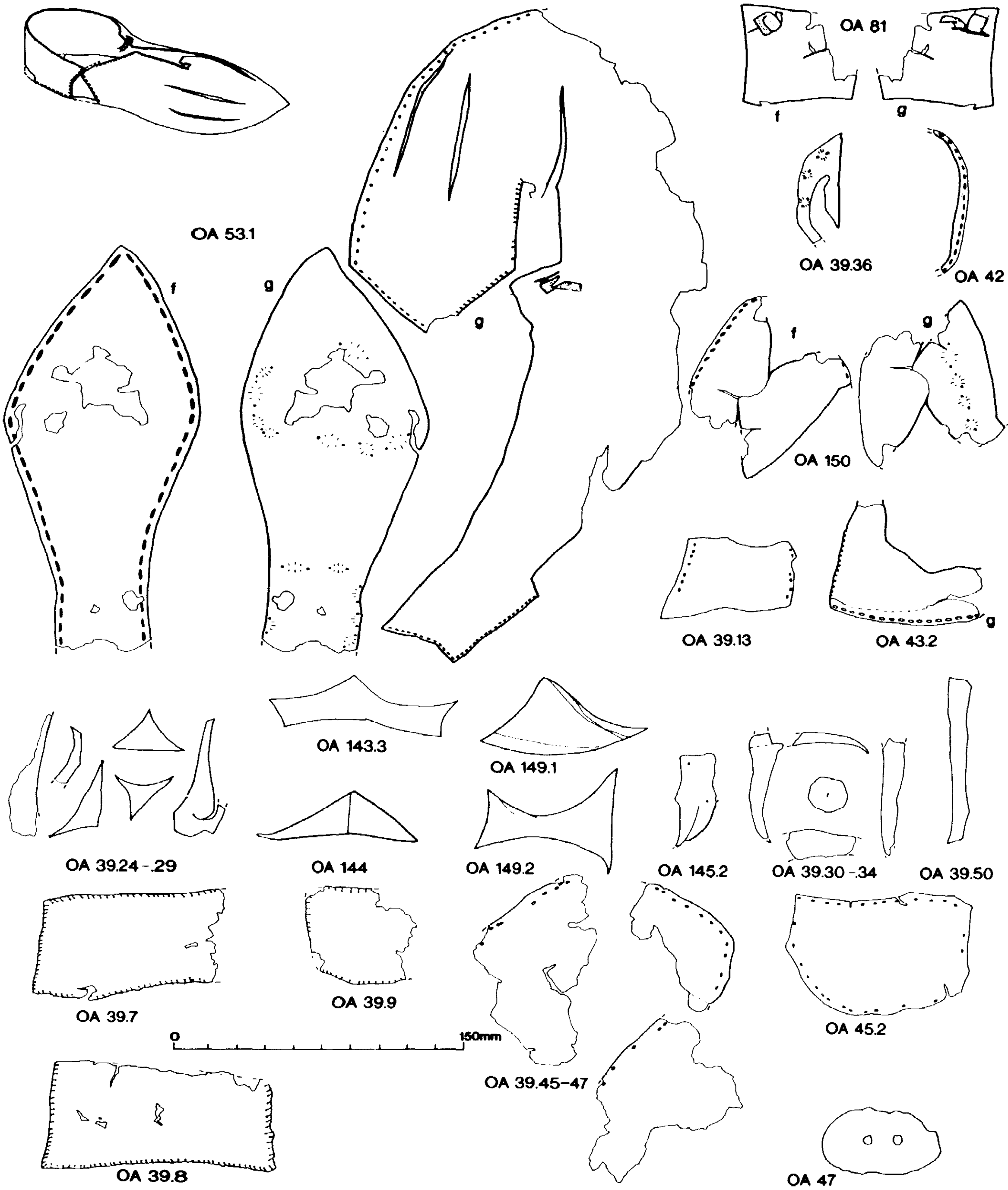


Figure 103 Leather 2: shoe parts, reuse of shoe parts, waste, trimmings, and patches or reinforcements

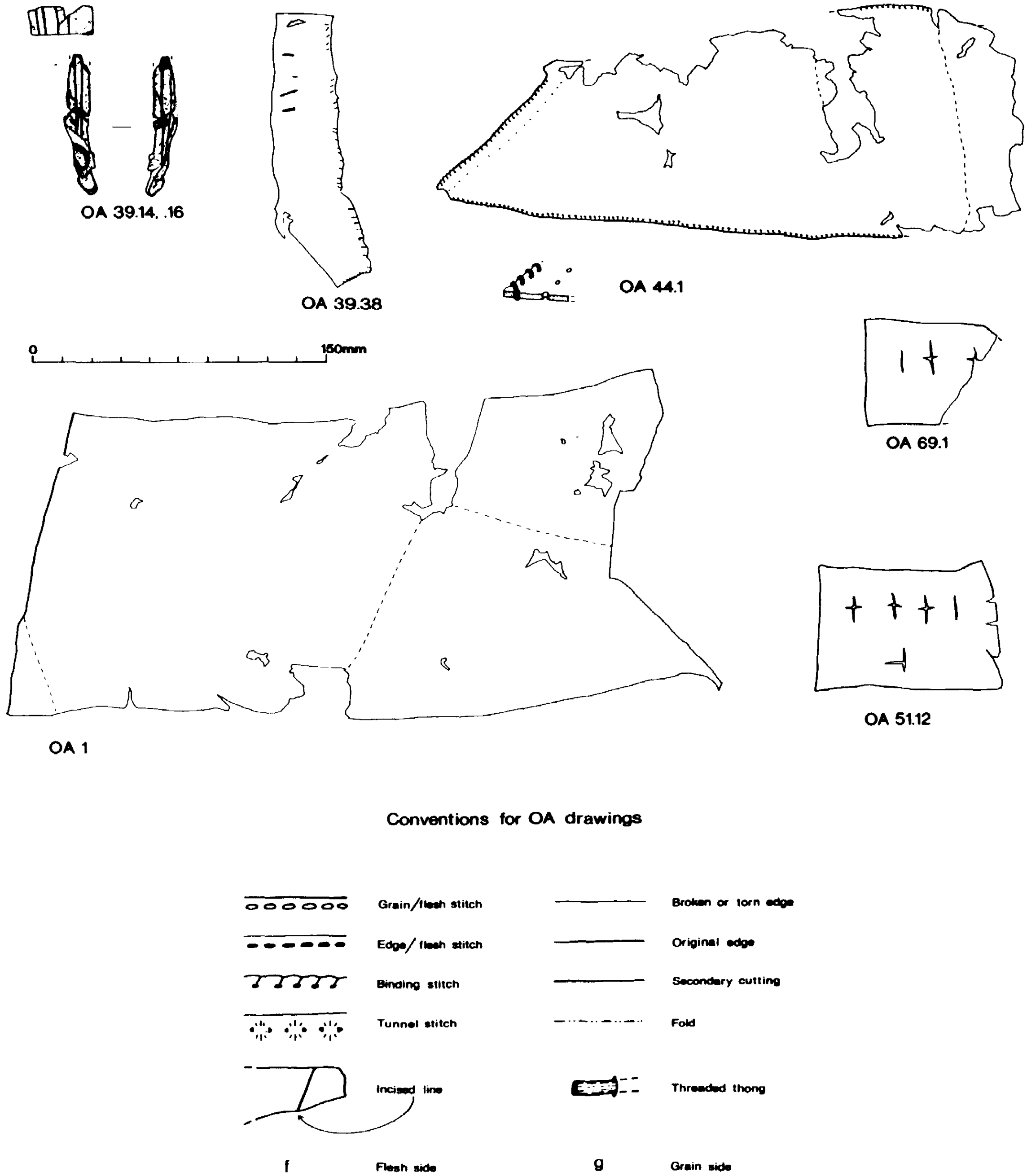


Figure 104 Leather 3: other objects, pieces from large objects, and conventions

Other objects

OA 39.14-.16 Three fragments (two joining) of one scabbard, decorated with burnished lines, probably executed freehand with a wooden tool. Probably late twelfth/thirteenth century. Cattlehide. Fig 104. 80 1, 12 w; 16 1, 32 w, (A156, per 4)

OA 38 Binding or reinforcement piece, one long edge partly unworn, suggesting it was overlapped by another piece, stitchholes probably indicate binding stitch. Four or five slits survive towards one edge which may have carried a thong for a draw string. Appears to have been ripped off and there is a secondary cut on at least one edge. Calfhide. Fig 104. 60 1, 35 w, stl 6, 1 th (ac). (A156, per 4)

OA 39 One large piece with three original edges, one having a binding seam (stl 3) on a folded back edge, another with a complete seam (stl 3) which was probably joined to another piece, and a third edge which was folded back and tacked with binding stitch at the edge (stl 5 and stitches intact). Calf or light cattlehide; stitching probably vegetable. Fig 104. 264 1, 132 w, 1 th (ac). (A156, per 4)

OA 161 ?Book cover, see OB 143 for details. Fig 99; Plate 37. (E368, per 7)

Pieces from large objects

OA 1 Roughly rectangular piece, no seams, occasional possible traces of stitchholes, heavily worn, possibly piece cut out from much larger object from inside the seams, two types of knife cutting present, straight vertical cutting and more oblique cutting done with a trimming knife, viz skiving. Coat or hairy sheepskin. Fig 104. 372 1, 182 w, 1 th. (A156, per 4)

OA 69.1 Roughly rectangular piece, three edges knife cut, other part of a seam, with two cruciform cuts and one slot (cf OA 51.12, 58.1, 70.4). Cattlehide. Fig 104. 70 1, 65 w, 2 th. (E817, per 5)

OA 51.12 Thick rectangular piece with cut edges, ?cut from larger object, has four cruciform cuts and one slot, ?for toggles, or a trial piece (cf OA 58.1, 69.1, 70.4). Cattlehide. Fig 104. 100 1, 75 w, 3 th. (E368, per 7)

Dendrochronological analysis

by D Brown

Figure 105; Table 64

Between 1989 and 1991 37 oak wood samples were analysed in the Palaeoecology Centre, Queen's University of Belfast. The results are summarised in Table 64 and Figure 105.

In this report the estimated felling date range is obtained by adding the Belfast sapwood estimate of 32±9 years to the date of the last heartwood ring (where the sapwood is incomplete).

Of the original 37 samples received, seventeen samples could not be uniquely dated because of their short tree-ring patterns. Only three of the undated samples yielded ring patterns over 100 years in length. The remaining twenty samples could be divided into three groups. Firstly, five samples had complete sapwood present which means the felling year of the tree can be given. The second group consists of five samples with a portion of the sapwood crushed or missing and in these cases a close estimate of the felling date is suggested. The remaining ten samples had no trace of sapwood and, as they could therefore have missing heartwood, any felling estimate represents a *terminus post quem*. By definition the ten samples with complete or partial sapwood are the best samples to use to show the possible construction dates of the various structures.

Initially four sub-master chronologies were constructed (Bordesley Abbey 1, 2, 3, and 4). The tree-ring patterns of the individual samples from three of these sub-masters (Bordesley Abbey 1, 2, and 4) and other individual tree-ring patterns were used to build the overall Bordesley Abbey site chronology; it includes, for example, a determination of a grave cover excavated from the eastern exterior cemetery (Q4495 and shown on Fig 105; Hirst and Wright 1989, 307). This master chronology is 405 years long, from AD 860 to AD 1264. Sub-master 3 could not be definitively dated against the Bordesley Abbey site chronology nor any other English or Irish chronologies. Although there is a suggestion that the timbers in sub-master 3 may relate to the fourteenth century, additional evidence would be necessary before a specific dating could be claimed.

Samples from the period 3 mill

These samples give a good example of the precision possible in dendrochronological analysis. Two samples from the mill building, Q7664 and Q8321 (the latter first used in period 3 and repositioned in period 4), both have complete sapwood and were felled between the autumn of AD 1175 and the spring of AD 1176. Samples from the head and tail race, Q8319 and Q8275, also have complete sapwood and were felled in the summer of AD 1174.

Table 64 Mill (BAB) and valley transect (BAE): summary of dendrochronological analysis

Sample no.	OB no. (& context)	Description	Centre present?	No. of rings measured	Date of last ring	Felling date	Period
BAB							
Q7664	410 (B538)	Post, mill building	No	266 + 15 swc	1175	aut 1175/spr 76	3
Q7665	215 (E852)	Baseplate, tail race	No	101 + 12 swi	1184+	1184 +2 or 3	4
Q7666	216 (E876)	Baseplate, tail race	No	112 nb	1165+	1197±9 or later	4
Q7667	229 (E857)	Baseplate, tail race	No	127 + 16 swc	1187	1187	4
Q7668	253 (E436)	Baseplate, tail race	No	41 + 10 swc		NM	5
Q7669	254 (E437)	Baseplate, tail race	No	59 + 12 swc		NM	5
Q7670	252 (E821)	Baseplate, tail race	No	29 + 12 swc		NM	5
Q7671	217 (E850)	Baseplate, tail race	No	46 + 13 swc		NM	4
Q7672	159 (E280)	Baseplate, wheel trough	Yes	43 nb		NM	6
Q7673	153 (E381)	Upright, wheel trough	Yes	76 b		NM	6
Q7674	251 (E820)	Baseplate, tail race	No	45 + 14 swc		NM	5
Q7753	255 (E443)	Board, tail race	No	2		NM	5
Q7754	256 (E444)	Board, tail race	No	82 nb	1264	1296±9 or later BFD	5
Q7755	257 (E445)	Board, tail race	No	52 nb	1223	1255±9 or later BFD	5
Q7756	259 (E447)	Board, tail race	Yes	83 nb	1233	1265±9 later BFD	5
Q7757	258 (E446)	Board, tail race	Yes	120 nb	1262	1294±9 or later BFD	5
Q8274	210 (E888)	Base plank, tail race	No	98 + 18 swi	1173	1174-1175 BFD	3
Q8275	211 (E889)	Base plank, tail race	No	206 + 28 swc	1174	summer 1174	3
Q8276	212 (E863)	Base plank, tail race	No	198 + 29 swi	1165	1169+9 BFD	3
Q8317	155 (E279)	Baseplate, wheel trough	No	43 nb		NM	6
Q8318	264 (D227)	Baseplate, head race	No	136 nb		NM	3
Q8319	265 (D330)	Baseplate, head race	No	175 + 34 swc	1174	summer 1174	4
Q8320	266 (D313)	Baseplate, head race	No	218 nb	1134	1166±9 or later BFD	4
Q8321	284 (E731)	Post, mill building	No	142 + 34 swc	1175	winter 1175-76	4
BAE							
Q7948	116 (204)	Fragment	No	128 nb		NM	1
Q7949	434 (227)	Baseplate, pond drain	No	71 nb		NM	3
Q7950	438 (231)	Bung, pond drain	No	71 nb	1195	1227±9 or later BFD	4
Q7951	439 (232)	Plank, pond drain	Yes	190 nb	1136	1168±9 or later BFD	3
Q7952	440 (233)	Trough, pond drain	Yes	248 nb	1148	1173±9 or later BFD	3
Q7953	441 (268)	Plank, pond drain	No	126 nb		NM	3
Q8192	456 (113)	Plank, south channel	No	37 nb		NM	4
Q8193	457 (114)	Plank, south channel	No	70 nb		NM	4
Q8194	458 (313)	Plank, south channel	No	60 + 15 swi		NM	4
Q8195	461 (314)	Stake, south channel	No	81 + 22 swi	1255	1266±9 BFD	4
Q8196	462 (315)	Stake, south channel	Yes	61 nb		NM	4
68197	460 (317B)	Plate, south channel	No	222 nb	1150	1182±9 or later BFD	4
Q8198	454 (300)	Stake, south pond bank	No	84 nb	1120	1152±9 or later BFD	3-5

swc: sapwood complete; swi: sapwood incomplete; b: sapwood/heartwood boundary present; nb: no boundary present; BFD: best estimated felling date; NM: no match against existing chronologies.

This can be determined as the growth ring had not fully formed; only the early wood vessels were present. The other samples from the period 3 mill race are not inconsistent with felling between AD 1174 and AD 1175-6. Q8274 had 116 annual growth rings, including eighteen sapwood rings. The sapwood was incomplete, but it was estimated that only a few rings were missing. The ring pattern gave a significant correlation with the Bordesley Abbey master, producing an end date of AD 1173. The best estimated felling date would be AD 1174 or 1175. Q8276, with incomplete sapwood, produced an end date of AD 1165. The best estimated felling date, using the Belfast estimate of 32±9 years added to the last heartwood ring, would be AD 1169+9. Q8320, without sapwood, had an end date of AD 1134; the best estimated felling date (using the Belfast estimate) would be AD 1166±9 years or later. Timbers in the head and tail race were felled in the summer of AD 1174 whereas the timbers used in the building were felled in AD 1175-6. It is possible that the timbers for the mill race were felled first and perhaps stored for a year or more before being used. However, only the archaeology of the structures will be able to confirm this suggestion.

Baseplates from the period 4 tail race

All three samples, Q7665, Q7666, and Q7667

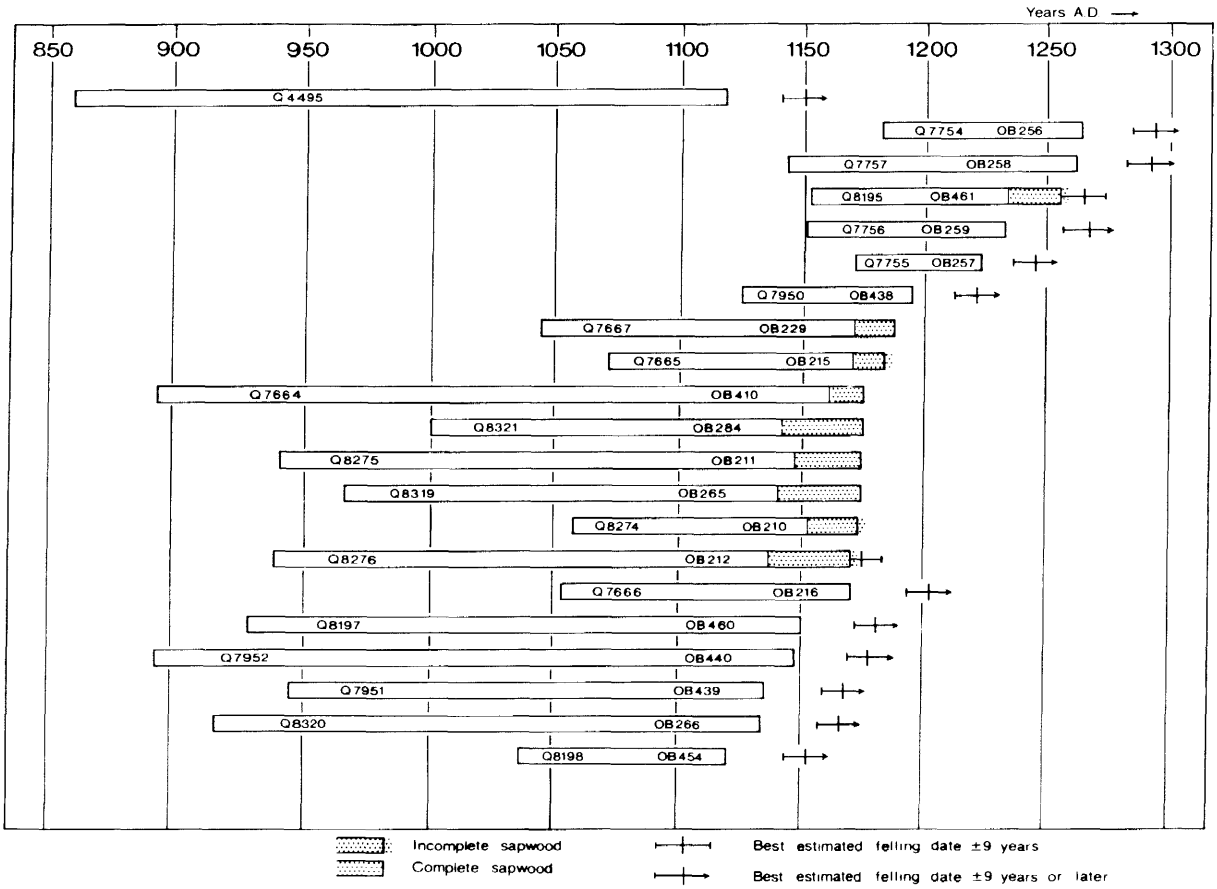


Figure 105 Bar diagram of dendrochronological dates. Q4495 is from a grave cover excavated from the church east exterior cemetery

(sub-master Bordesley Abbey 2), are compatible with a felling date of AD 1187 suggested by the complete tree-ring pattern of Q7667. Q7665 had the outer sapwood rings crushed, with the last measurable ring dated to AD 1184, and probably only a few rings unmeasurable; the best estimated felling date for this tree will be AD 1184+2 or 3 years. Q7666 had an end date of 1165 with no sapwood, which would give an estimated felling date of AD 1197±9 years or later. On the other hand, it is not impossible for samples Q7665 and Q7666 to be later additions or repairs.

Base boards from the period 5 tail race

Of the four datable samples from the base boards of the period 5 tail race, two definitely (Q7756; Q7757), and another two probably (Q7754; Q7755), came from the same tree. The nature of these two sets of determinations would suggest that the elements of the tail race were contemporary and that none of the wood was reused.

The four samples, Q7754, Q7755, Q7756, and Q7757, were used to construct a sub-master called Bordesley Abbey 4 and provided the latest dendrochronological dates for the Bordesley mills. Although none of the samples had sapwood or a heartwood/sapwood boundary, an estimated felling date for the tree can be given. Because it is impossible to tell how much heartwood had been removed in the cutting process, it is likely that this tree was cut down in the early part of the fourteenth century rather than the late thirteenth century (after AD 1296). The boards from which these samples were taken were part of the same structure as the period 5 baseplates which, although undated, were all from trees felled in the same year (see below).

Baseplates of the period 5 tail race

The three samples, Q7668, Q7669, and Q7670, were meaned into a sub-master chronology (Bordesley Abbey 3) of only 71 years. All the samples had complete sapwood and, as their final growth rings coincided with each other, the trees were felled in the same year. It is, however, impossible to give a definitive tree-ring date for the trees used in the baseplates because of the very short tree-ring patterns.

The valley transect (BAE) samples

The samples from the mill pond drain (Q7951; Q7952) have produced estimated felling dates that correspond to a phase of activity in the later twelfth century; and, although there is no way of correlating these determinations with those from the mill, it is likely that the construction of the drain was contemporary with the construction of the period 3 mill. Sample Q8195, on the other hand, with an estimated felling date of AD 1266±9 years, is the only sample with sapwood that dates to the mid-thirteenth century.

Age profile

The paucity of samples with the pith present limits an assessment of the age profile of the trees used in the mill. In the two cases where this is possible - in the period 3 mill pond drain (Q7952; Q7951) - the first rings are dated to AD 894 and AD 947 respectively. From the observations of the samples measured it can be suggested that the monks had access to large and mature trees, although smaller trees were also used in the mill structures.

III Medieval technologies: water-power and industries at Bordesley Abbey

G G Astill

The working of the Bordesley mills: the water supply, the mills, and their machinery

The following is based on the results of the BAB, BAE, BAH, and BAJ excavations, the new survey of the east end of the precinct, the geophysical work, and the 1962-4 aerial photographs (see eg Plates 1 and 38); it aims to place the Bordesley mills in the context of the immediate environment, and to discover the extent to which that landscape was altered and managed by the monastic community.

Crossley has argued that the interpretation of mill sites is often particularly difficult because the fundamental decisions and requirements, such as location and water supply, could not be achieved in the most straightforward or logical way because of the restrictions of, for example, property boundaries (Crossley 1985, 107; and also Wikander 1985). Such restrictions should not have hampered the Cistercians in the siting and working of the first Bordesley mill or its water supply because the archaeological evidence suggests that the monks were able to mould their environment for their own purposes to a remarkable extent. The identification of the medieval mill and pond earthworks of 'New' alias 'Lye' Grange, one of Bordesley Abbey's properties since the late twelfth century, some 2km to the north-west of the precinct, would suggest that the monastery controlled the upper reaches of the River Arrow for at least that distance (Aston and Munton 1976, 24-6).

The supply and control of water

Figures 106 and 107

The BAE excavation has shown that the twelfth-century, period 3, mill pond banks were raised and broadened in period 5; associated channels were also changed. It is, therefore, particularly hazardous to reconstruct the primary, period 3, water supply and control system.

In their survey and interpretation of the earthworks, Aston and Munton identified a ditch or contour canal, which lay parallel to, and south of, the south mill pond bank, as the supply channel for the mill pond (number 57, Aston and Munton 1976, 32 and fig 43; S1 on Fig 106). However, the BAE excavation sampled this feature and demonstrated that it was associated with the period 3 south mill pond bank (BAE304), and that it was recut in period 5-6 after the bank had been broadened and raised (BAE305). This channel could not have beer, used to supply water to the pond because in both periods its base was *c* 0.7m below, and the top of the sides was at approximately the same level as, the bottom of the mill pond (SK: Figs 42 and 43) The channel could have been dug initially to obtain material for the construction of the bank - an interpretation confirmed by the absence of the channel in the area of the present-day field to the west - and then used as an overflow channel.

There is no evidence for the location of breaks in the bank where sluice gates could have been sited in period 3, but it is probable that the two breaks visible in the bank and identified as of period 5 reflect the position not only of the secondary, but also the original, sluices (S2, S3 on Fig 106; Fig 107). It is, of course, possible that other primary (period 3) sluices were buried when the bank was remodelled (period 5) and these sluices were not recommissioned. In period 5 the most easterly sluice (S3) was connected to a channel (S4) which took the water around the south side of the mill and fed it into the tail race to the east of the excavated area. For most of its course this bypass channel is flanked on its south side by a bank (S5) which may just be upcast or a protection against flooding. The ground is very disturbed in this area, but the same channel may also have taken water from the sluice to the west (S2), midway along the pond bank. Alternatively, the bypass channel (S4) may have been a later feature, cut to drain water from both sluices (S2, S3) when the (east part of the) overflow channel (S1) had gone out of use.

The BAE excavation also produced evidence of a water channel (BAE280) slightly higher up the south side of the valley, hard against the river cliff its sinuous course can be traced (S6 on Fig 106) in the area of the present-day field immediately to the west of the mill pond, but all trace of it appears to have been destroyed further west by the work: associated with the Forge Mill. It is best inter preted as the bed of a stream, known locally as the Red Ditch alias the Batchley Brook, which had been redirected (presumably early in the life of the monastery) to flow along the south side of the valley (Fig 107). BAE has demonstrated that this stream could have fed the mill pond, but this is

Plate 38 *Bordesley Abbey precinct, from the east (Cambridge Committee for Aerial Photography)*

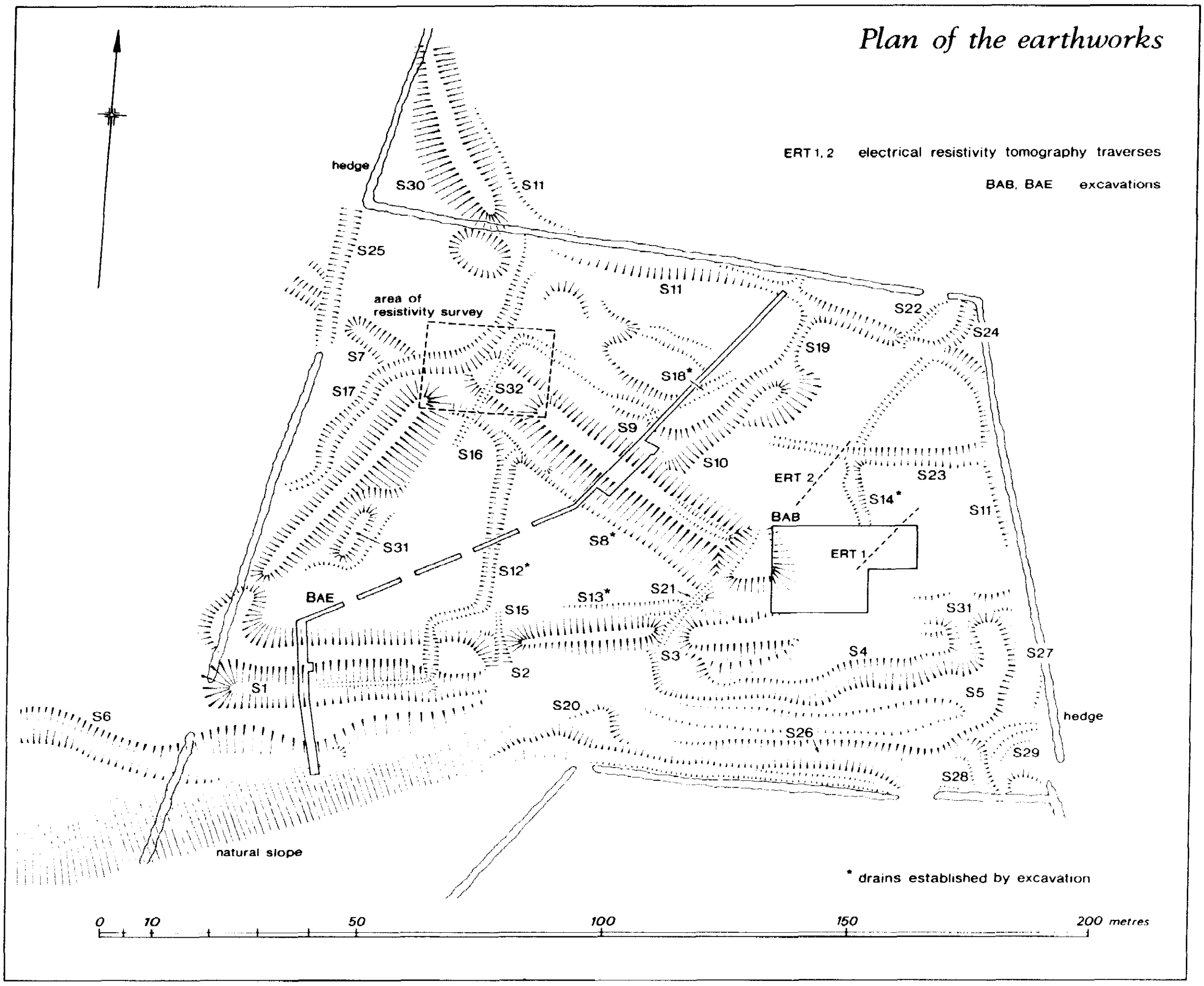


Figure 106 Eastern precinct: plan of the earthworks

unlikely for three reasons. Firstly, despite the disturbed nature of the ground, there is no evidence for the ditches or feeds that would have been necessary to connect the stream to the pond. Secondly, BAE has shown there was a metalled road (BAE44) with cart ruts between the stream and the outflow from the mill pond which appeared to act as a barrier between the two. Thirdly, in the later (period 5) arrangement, the only two breaks visible in the bank appear to be for taking water out of the pond (S2, S3, as discussed above), and water from the stream would have had to cross the channel (S1) to enter the pond.

The main source of water to feed the pond would seem rather to have come from the north-west. A ditch (S7), flanked by a bank on its north side, channelled water from the main fishponds, at least in the latest phase. This fed water into the north-west comer of the mill pond. An additional reason for thinking the main source of water came from the north-west comer is that at some time in period 4, perhaps when the pond had been drained in order to build the period 5 mill (and remodel the pond banks), a scouring channel (BAE188) was etched into the pond silts at the base of the north pond bank (cf below, 'Water levels'): the implication is that (some) water continued to flow from a feed, located in the north-west corner. A similar scouring channel (S8), in the same position, can be seen on the present ground surface and must relate to a time after the mills were abandoned; it does, however, suggest that the location of the feed did not change for the later mills and the supply channel is shown entering the north-west comer of the pond in all periods (Fig 107).

Two additional reasons for locating the main feeder at the north-west corner are, firstly, the structure which resistivity survey has located there

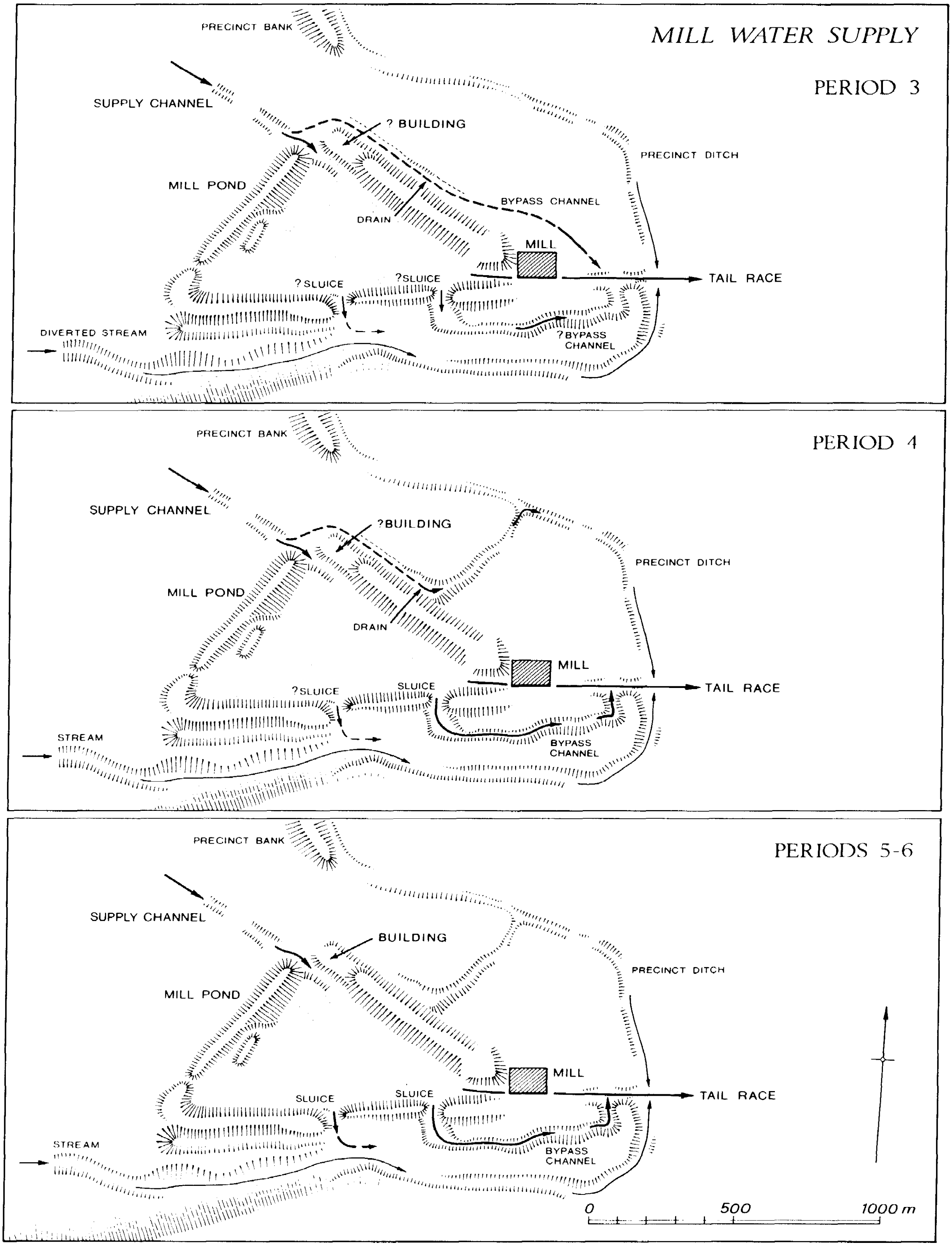


Figure 107 Mill water supply: periods 3, 4, and 5-6

and from which the course and volume of water were probably regulated, and, secondly, it has frequently been noticed that during periods of heavy rain the flood water in the valley first flows along this feeder channel.

As neither the north nor west mill pond banks have any visible breaks where sluices could have been located, the water level in the pond was probably controlled by the sluices in the south bank and by the head race of the later, periods 5 and 6, mills. However, there is evidence to suggest a different arrangement for the earlier periods 3 and 4. The steep-sided, flat-bottomed, ditch (A135/ B1100) excavated in square A of BAB is interpreted as a possible bypass channel for the first, period 3, mill (Fig 107; Plate 11). Although only a 18m length was excavated, the ditch skirted around the mill building and appeared to join, and drain into, the tail race to the east (downstream) of the mill (Fig 8). An ERT (electrical resistivity tomography) traverse demonstrated that a/this ditch existed some 20m to the north-west of square A. It is impossible to establish its precise relationship with the mill pond, but it may have had a course parallel to the north pond bank. The fact that the course, or indeed the presence, of this bypass channel could not and cannot be detected among the surviving earthworks visible on the present ground surface argues for a later, substantial, reshaping of this part of the valley. The profile of the bypass channel and the contents of its fill show that it soon went out of use before the second, period 4, mill was commissioned. Thus, either the bypass channel on the south side of the pond (S3 on Fig 106) may have been dug at this time to replace that bypass on the north or both channels were in operation in period 3 (see Fig 107).

The initial design for the mill waterworks included provision for additional drainage. The timber drain excavated under the north mill pond bank had clearly been laid on the old ground surface before the construction of that bank (Figs 40 and 45; Plates 31-3). As the pond water drained under the bank, the initial intention may have been to avoid having sluices set in the bank, and to take advantage of the natural south (down) to north slope of the valley. The size of the drain would suggest that it could only cope with limited quantities of water at any one time, and it could not have been intended as the principal means of reducing a large volume of water quickly in order to avoid damage to the mill. A wide, open, bypass channel would have met this need much more efficiently, although there is, of course, the possibility of more drains awaiting discovery under the north mill pond bank.

The drain was sophisticated in design. The gradient (*c* 1 in 35) ensured that the flow of water would have prevented silt deposition. However, there was no means of access to clear any blockages. The drain was clearly in operation from the inception of the first mill in the late 1170s, and it lasted sufficiently long to have its bung replaced in timber whose best estimated felling date is 122729 or later; it was definitely put out of use when the period 5 mill was built in the early fourteenth century and the mill pond bank raised, which sealed the drain. As the drain took water from the bottom of the pond at one of its lowest points, it was probably used to empty the pond completely, which may not have been possible using the bypass channel(s) and sluices. A similar, but smaller, structure was recovered from the outflow of a fishpond at St Catherine's Court, a grange of Bath Priory (Dennison and Iles 1988, 215-17). Underground drains are rarely found, but the medieval documentation and modern water management practice clearly show they were, and remain, of considerable use (Roberts 1988, 10-13). The periodic need to remove silts from the bottom of ponds required these to be completely emptied of water.

The drain diverted water from the pond into a wide, shallow ditch (S9 on Fig 106) which ran parallel to, and was hard against, the north side of the north bank (Fig 107). The earthworks of this ditch can be traced along the west half of the bank, but just to the east of the timber drain it had a butt end. At this point it is connected to a sinuous ditch (S10) that appears to have drained into the precinct boundary ditch to the north (S11).

The ditch (S9) that ran parallel to the north bank was (like that to the south of the south bank) probably originally dug to win material for the bank. Two interpretations of these earthworks are possible. Firstly, the north ditch was also intended to be a bypass channel that diverted the water away from the pond at the point where the feed was located (in the north-west corner of the pond), led it along the base of the north bank, and took it round the mill (in the - excavated - bypass channel) to debouch into the tail race. Evidence for the existence of such channels alongside fishponds is common on grange sites of Bordesley Abbey and elsewhere (Aston and Munton 1976, 24-5; Aston and Bond 1988, 424-5; Roberts 1988, 11). Further support for this interpretation may come from the similarity of profile between the bypass channel and the tail race excavated in BAH. For some reason, this arrangement was apparently unsatisfactory, and the east section of the channel, including that part found in square A of BAB, was allowed to fill to become a smaller ditch during period 4. There was, however, still a need for a mill pond bypass channel and to take the water from the timber drain(s), so a new ditch (S10) was dug which took the water from the blocked bypass channel to the precinct boundary ditch.

The second possibility is that the - partly excavated - bypass channel was not associated with the drainage of the mill pond, and that from the beginning, in period 3, water from the timber drain(s) was channelled via ditch S10 into the precinct boundary ditch.

To summarise, the major channels for the control of water during the life of the first, period 3, mill appear to have been located to the north of the pond and linked to the supply channel. In period 4, a new bypass channel was dug to the south of the pond, and this, in combination with the sluices in the south pond bank, became the principal means by which water was controlled in periods 5 and 6.

Water levels

Water levels within the medieval pond are extremely difficult to reconstruct from the existing information. Firstly, there are the heights of the banks: these should give the maximum capacity of the pond, but the banks would have subsided by consolidation and become degraded during and after the occupation of the mills, and so the heights should be regarded as minima, The pond was built on ground that sloped down from south to north, and thus to compensate the northern bank was made *c* 0.5m higher. There is, however, some evidence to suggest that the natural slope was reduced in the south in order to give the pond a more level bottom (BAE326). The first set of mill pond banks was constructed for the period 3 mill and remained in use until the construction of the period 5 mill when the banks were remodelled.

The maximum water level in the first pond can be determined from the height of the south bank and, if the water reached to the existing crest of that bank, its depth would have been about 1.35m. The depth of the second mill pond, in use in periods 5 and 6, was increased by raising the height of the south, and perhaps the west, mill pond banks. The north bank was not raised by a significant amount (only 0-10–0.20m), but was increased in breadth, as was the south bank, for no obvious reason. These changes would have increased the depth of the water (assuming it reached the existing crests of the banks) to about 2.05m. The potentially greater depth, and so greater head, of water was probably necessary to compensate for the decrease in gradient caused by the superimposition of the period 5 tail race on that of period 4.

The minimum level of the water in the ponds can be determined from the depth of silts. During periods 3 and 4 silts had accumulated to a depth of 0.45-0.50m. In periods 5 and 6 a further 0.30-0.40m of silts was deposited in the pond.

If the area of the mill pond is reckoned to be c $2625m^2$ during the whole period of occupation (assuming all the banks had a similar profile), the following approximate maximum and minimum capacities result.

Periods 3 and 4

maximum capacity:	35,000 hectolitres (780,000 gallons)
minimum capacity:	13,000 hectolitres (290,000 gallons)
average capacity:	24,000 hectolitres (535,000 gallons)

Periods 5 and 6

maximum capacity:	(54,000 hectolitres (1180,000 gallons) minus volume of pond occupied by silts deposited in periods 3 and 4) 41,000 hectolitres (890,000 gallons)
minimum capacity:	(24,000 hectolitres (520,000 gallons) minus volume of pond occupied by silts deposited in periods 3 and 4) 10,500 hectolitres (600,000 gallons)
average capacity:	26,000 hectolitres (745,000 gallons)

It is difficult to decide which of the figures above represents the more likely approximate capacity. Shallow water allows much greater weed growth which would be undesirable because it would tend to make the water supply for the mill less reliable. An additional indication of a shallow pond might be the scouring channel (BAE188) cut into the period 3-4 mill pond silts close to the north mill pond bank: these channels are sometimes produced near the feed of the pond when the water is shallow, but such scouring often occurs when a mill pond is drained as in this case during the construction of the period 5 mill. Such an argument would, of course, not apply to the mill pond of periods 5 and 6 when no evidence for any such scouring occurred. The relatively steep gradient of the period 3 wheel trough (Fig 108) might indicate that the mill pond water was shallow, and that it was only necessary to increase the depth of the pond to provide a greater head of water to compensate for the decreasing gradients of the wheel troughs from period 4 onwards.

The way the pond was constructed may, however, have militated against keeping the water in the pond at a low level. Where the north and south banks have been sectioned, the profiles of both phases of the banks are remarkably shallow. Indeed the period 3-4 bank profile was stepped. There was no evidence that the profile was caused by later slumping, and there were some posts which may have been intended to prevent such slippage (BAE297; 300; 318). The shallow profiles of the banks, presenting a greater surface area to the water, might have increased the amount of erosion of the banks and led to increased deposition of silt in the pond. Some attempt was made to protect further the south bank with dumps of tiles and stones (BAE84; 91; 101), but the side of the north pond bank was not protected in this way. In the face of silt deposition, it may have been increasingly necessary to keep the water at a high level in order to provide sufficient head for the mills. Relatively little evidence for aquatic plants, particularly those taxa which prefer slowly flowing water, was recovered from the mill pond sediments in any period, in contrast to the ditches and channels. A combination of water depth, regular replenishment (and therefore movement) of water, and deliberate clearance was probably responsible (see above, part II, Carruthers, 'The valley environment ...').

This evidence does not, however, indicate how the water supply was managed to power the mills; there are two possibilities. Firstly, the pond could have been used as a reservoir which, once full, could be used to drive the mill until the pond was virtually drained. Assuming the flow rate of 500m^3 per hour used to calculate the power output, the period 3-4 pond could have provided water for about six to seven hours, and the period 5-6 pond for about nine to ten hours. The second possibility is that the feed to the pond was sufficient to keep the water level steady while the mill wheel was driven.

Reconstructions of the mill races

The proposed configuration (Fig 108) is based on the structural remains that were excavated (Figs 33-7) and was consistent for all periods of mill: a funnel-shaped head race which concentrated the water into a narrow, timber-lined trough, in which turned the vertical, undershot water wheel, suspended so that there was little space between the sides of the wheel trough and the paddles; and a parallel-sided channel (or one funnelling out away from the wheel) - the tail race - which took the water away once it had turned the water wheel. The same configuration appears to be typical of Roman, medieval, and post-medieval, undershot, vertically-wheeled mills; the narrow wheel trough or 'lower penstock' is particularly characteristic (Rynne 1989, 26-9).

The head races periods 3-6

Figures 33 and 108; Plates 4 and 27

In all periods the base of the head race was probably planked. The west end of the boards may have been laid in the downstream rebate in the west baseplate (OB 266). The next baseplate to the east (OB 264) probably had a rebate on both the upstream and downstream sides in order to take both sections of floor planking (upstream and downstream of this middle baseplate).

The surviving mortice in the west baseplate (OB 266) is too insubstantial to have taken an upright of a sluice gate - it is more likely that it supported a grill, an interpretation based on grill parts found here in period 7. The baseplates had mortices to take the uprights which supported the plank sides, although the efficiency of the arrangement would have been improved if the uprights in OB 264 had not projected out into the race beyond the line of the revetment planks.

Approximately midway between the middle baseplate of the head race and the west baseplate of the tail race another baulk of timber would have stretched across the race in a similar position to that of the east head race baseplate, OB 473, in period 4. This had been firmly bedded into the building platform on the north side and into the south bank; it was only very slightly lower than the two head race baseplates to the west. This baseplate would have supported the uprights for the planked sides of the head race (which would have continued to converge in order to connect with the wheel trough: see below); it would also probably have had a rebate on both upstream and downstream edges in order to seat the planks of the bases of both the head race and the wheel trough. Whereas there was barely a gradient through the head race, there was a drop of 0.91m over the 3.2m (ie 1 in 3) between the east baseplate of the head race and the west end of the tail race base planks. This would have ensured a fast flow at the point where the water hit the wheel and so the east baseplate of the head race marks the most efficient position for the sluice gate. The sluice would probably have consisted of a series of horizontal boards which fitted into a groove in each upright.

In period 4 the west baseplate (OB 266) was repositioned, as was the east baseplate (OB 473), but the basic arrangement remained the same. The pond bank on the south side sloped down to the west of the east baseplate OB 473, at the point where the wheel house would have been located, and would have allowed reasonable access for maintenance without having to scramble down a bank (see Fig 11).

The wheel trough and trail race period 3

Figures 34 and 108; Plates 5, 6, and 30

The evidence for the later periods suggests that the baseplates located in the wheel area could not have supported the wheel, largely because they were too insubstantial, and were not jointed, to resist any lateral thrust (ie from the direction of the mill building) or vibration via the wheel shaft. The baseplates then only supported the sides of the trough in which the wheel turned. It therefore follows that the disposition of the baseplates gives no guide to the exact position or size of the wheel. In all probability these considerations were also relevant for period 3.

The height of the period 3 wheel trough can be gauged from one of the north uprights of the tail race (which survived with both its original ends: OB 227/228; Plate 30), which would also have supported the side planking of the wheel trough. the height of the trough was c 1.26m above the upper surface of the base (Fig 108).

There are two indications of the period 3 wheel trough width: firstly, the spacing of the mortices on the west baseplate of the tailrace (OB 207) and, secondly, the width of a paddle of a wheel (OB 282) that was found under the repositioned west

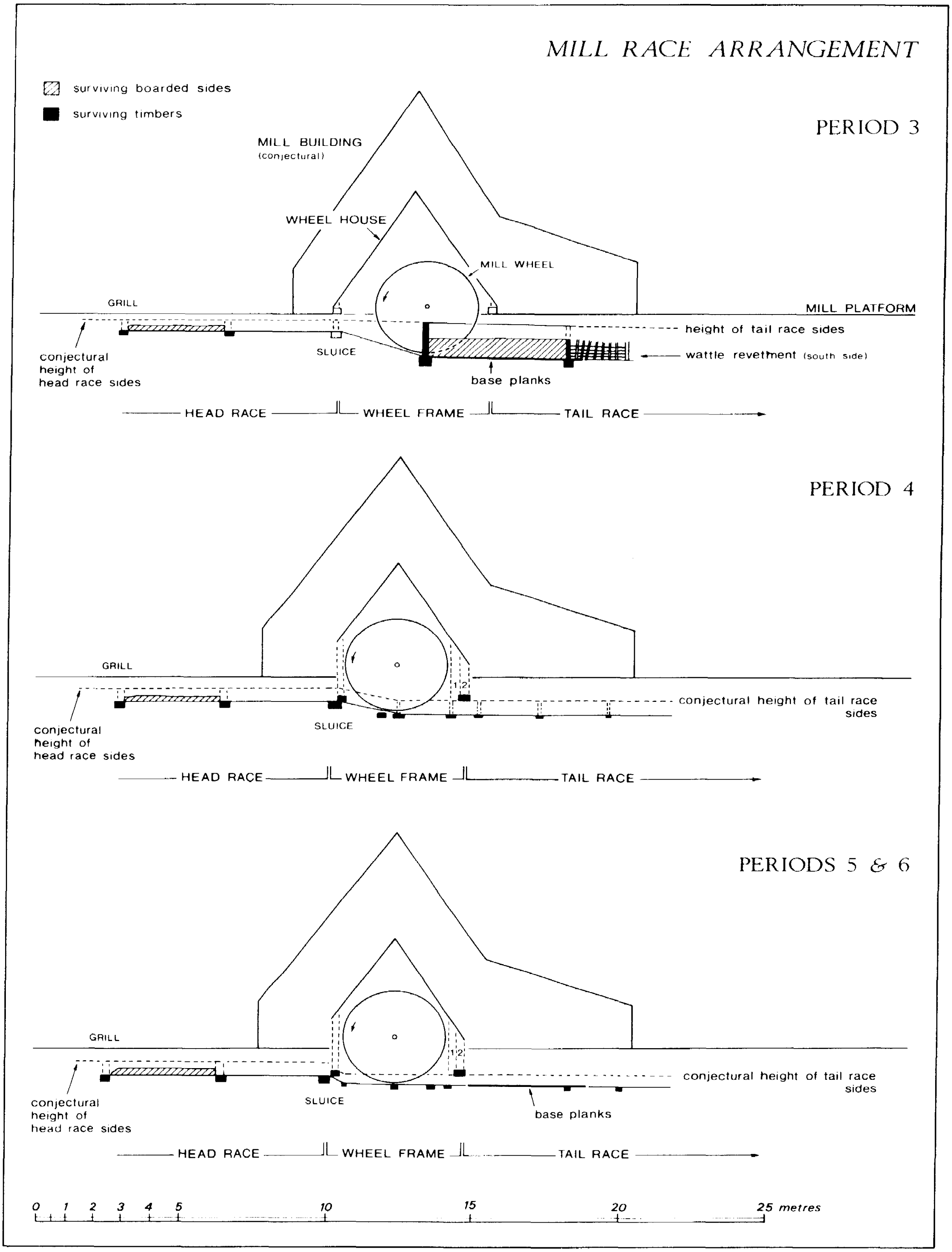


Figure 108 *Mill race arrangement: periods 3, 4, 5, and 6. 1 and 2 mark alternative positions for the east uprights of the wheel house*

baseplate of the head race. The repositioning is dated to period 4 and, therefore, the paddle is assumed to have come from the period 3 mill. The wheel trough was about 0.62m wide (based on the distance between opposing uprights, which projected slightly beyond the line of the boarded sides). The width of the paddle was 0.54m, which would have left a clearance of 40mm between the paddle and each side of the trough.

It is very difficult to estimate the size of the period 3 wheel on the basis of one incomplete paddle and one incomplete stave (OB 191.14). One peg hole survives midway along the width of the paddle and so the paddle was probably pegged to a central stave or ‘start’ by which it was attached to the (single) wheel rim or ‘felloe’ of the wheel; two rectangular holes near the outer edge of the paddle imply that the paddles were given additional strength by laths which joined the paddles. Nine complete paddles of this type have been excavated from two medieval mills in Denmark (Dallerup and Vejerslev) and there appears to be a 1:2 relationship between the depth and the width of the paddles (data obtained from excavation archives in Silkeborg Museum). If these proportions are applied to the Bordesley paddle, the depth would have been about 0.27m. In order to arrange such a paddle around a wheel, it is likely that the diameter of the wheel would be in the region of 3m.

A more reliable guide to the wheel diameter is the vertical distance between the base of the wheel trough and the floor level of the mill building, assuming that the shaft went directly from the wheel into the building without any gearing to raise the level. The levels of the period 3 mill floor varied by some 0.20m. The vertical distance, 1.42-1.62m, needs to be increased slightly to allow some space between the paddles and the trough floor and between the wheel shaft and the mill floor. If we use the 40mm space between wheel and trough side as a guide to the former, it is necessary to allow for the diameter of the wheel shaft and some clearance of the mill building floor - an absolute minimum of 0.40m - then the wheel diameter would be c 3.5m (ie 1.42 x 2 + 0.44 or 1.62 x 2 + 0.44 = 3.28 or 3.68). If it is assumed the wheel was located at the bottom of the slope of the wheel trough to gain maximum velocity, then the wheel shaft would have entered the building at floor level in the middle of the gable end and the shaft would have rotated above the west baseplate of the tail race.

The wheel appears to have been housed within a structure which was based on earthfast upright posts and on two, large, horizontal (south-north) baulks of timber. On the north side the baulks were bedded into the platform of the mill building and were aligned with the major uprights of the mill building. Both Batsford and Chingley wheel frames were deeply anchored into banks (Bedwin 1978, 191-2; Crossley 1975, 7-13). The west baulk (OB 473) also supported the base and sides of the head race/wheel trough. The east baulk (E1030) straddled the planked tail race and was c 0.025m higher. Both baulks were supported at their south ends by earthfast uprights (E981; E983/E957). Judging by the similar arrangement of the later periods, there were also major uprights on the north (mill building) side, just to the north of the wheel pit. The low level of the major horizontal timbers means that the wheel house was lower than the mill building and the structure was supported by timbers located in the wheel pit. The fact that the horizontal timbers were aligned on the major structural elements of the mill building would argue that the wheel structure was integrated with that of the mill. As with Batsford and Chingley mills, the horizontal timbers also provided for the support of machinery in a pit between the wheel trough and the mill building (Bedwin 1980, 193-4; Crossley 1975, 7-13). The wheel could have been supported on a timber that could have rested on the east horizontal baulk. However, there would have had to have been an additional cross baulk on the west side to provide such support - evidence for which may have been destroyed by later modifications.

If the wheel shaft was directly above the west baseplate of the tail race, the wheel occupied approximately the west 1.5m of the tail race, thus effectively shortening the tail race. The planked tail race was in total only 5.3m long, but was clearly designed to take the water away efficiently despite the shallow gradient (see below).

Period 4

Figures 35 and 108; Plate 12

The rebuilding of mill building and race took place only c twelve years after the construction of the period 3 mill, which probably caught fire. There were, however, some significant changes. The mill building was rebuilt on padstones, but the basic plan remained the same. The head race was realigned, but the period 3 arrangement was essentially unchanged. The wheel trough and tail race were modified.

The width of the wheel trough seems to have remained the same as for period 3, at *c* 0.60m (based on the spacing of mortices in OB 223). There is no evidence for the period 4 wheel, but the occurrence of paddles and/or staves in contexts of periods 3 and 5 would suggest that the form of the wheel remained unchanged. As the vertical distance between the base of the wheel trough and the floor level of the mill building remained about the same, it is possible that the period 4 wheel was of the same size as that of period 3. However, the size of the wheel house was reduced. The west horizontal baulk (E271/D318) (which continued to support the planks of the head race and wheel trough) was reset, but in approximately the same position as for period 3. The east horizontal baulk (E739) was shifted some 0.60m to the west, thus reducing the width of the gable end by that amount: the wheel shaft was also probably shifted westwards. It is difficult to explain this narrowing of the wheel house for the modification appears to have introduced a structural weakness in that the east end of the wheel house structure was no longer aligned with the major east uprights of the main mill building.

The tail race appears to have been of a similar character to that of period 3, but longer and with a shallower gradient.

Period 5

Figures 36 and 108; Plates 17 and 18

The building and wheel house remained the same as in period 4. The wheel trough was narrowed to c 0.45m wide, which consequently entailed a repositioning of uprights and replanking of the sides of the east section of the head race to achieve the necessary increased convergence. The baseplates of the wheel trough were laid on the silts above the period 4 baseplates, which had the effect of reducing by about half the gradient in the trough.

One worn paddle (OB 165.4) and one complete stave (OB 165.3) have come from period 5 levels. The paddle has no original edge, but is 0.34m+ wide and 0.l5m+ deep. It has one peg hole for fixing to a central stave. As the complete stave came from the same context, the two elements may have been used together which would produce a paddle depth of 0.22-0.23m. By analogy with the excavated examples from Danish mills, the general dimensions and proportions of the Bordesley paddle would suggest it was of a type that did not have strengthening laths at its outer edge. The depth to width ratio of the Danish examples of this type is between 1:1.5 and 1:1.8, which would produce a width of between 0.345m and 0.414m for the Bordesley paddle and therefore for the period 5 wheel. If this comparison is appropriate, it means that there would have been a clearance of between 52.5mm and 18mm between the wheel and each side of the trough. As the former figure is more likely, it may mean that the actual width of the paddle is close to its original width. As in previous periods, an indication of the wheel diameter can be gained from the vertical distance between the base of the wheel trough and the (period 5) floor level of the mill building. Allowing for a clearance of *c* 0.40m above the mill floor (as in period 3 above), this produces an approximate wheel diameter of 3.4m.

The tail race was of a more sophisticated construction than in previous periods, but the basic structure continued. There is no direct evidence for the height of the plank sides, but the timber is thought to have been sawn from the same trees as the base boards and the planks were thus in the region of 0.60-0.70m wide. The east horizontal baulk E739 would have continued to limit the height of the sides to *c* 0.60m.

Period 6

Figures 37 and 108; Plates 20 and 21

Phase 1

The replacement of the wheel trough and the remodelling of the tail race characterise this period: these changes appear to have produced a less efficient mill.

The period 5 wheel trough was dismantled and about 50mm of silt was deposited in the wheel pit. Two large baulks of timber (OB 155; OB 159) were laid on this silt in approximately the same position as that of the period 4 trough sides. These timbers had small mortices in their top surface, but they did not correspond, which may suggest the timbers were reused. It is difficult to see how these could have supported a planked wheel trough. There is no direct evidence that the trough had a planked or boarded base, and it is difficult to see what it could have been attached to. If planks had been placed on the top surface of these timbers, the floor would have been at approximately the same level as the boards of the east section of the tail race and so all advantage of a sudden increase in gradient just upstream of the wheel (as in previous periods) would have been lost. If these timbers are a guide to the width of the wheel, there may have been a return to the size of wheel used in periods 3 and 4.

There is a similar lack of evidence for trough sides. There are no adequate mortices to support uprights for an arrangement employed in previous periods. There were no peg holes on the inner faces to show that boards had been fixed at their base. The timbers stood to a height of 0.l6m, which, on its own, was probably inadequate to contain the amount of water required to drive the water wheel.

Similar problems exist for the tail race. The removal of the boards from the period 5 tail race and their replacement by reused timbers that were not carpentered together produced an arrangement which could not have retained water efficiently. At the point where the wheel trough joined the tail race, for example, there was a gap which was filled by timber blocks (OB 150; OB 151) that had been placed behind the main timbers of both trough and race: this would have allowed water to escape.

The makeshift tail race sides survived to a maximum of 0.30m which was barely adequate to retain the water. Another problem must have come from the way the period 5 tail race was shortened and blocks were laid to create a widening in the race; this must have slowed the flow of water and caused ponding back and thus checking of the wheel. The ponding back, in combination with the lack of adequate joins between the major mill race elements, must have caused much leakage of water into the mill channel, witnessed perhaps by the large number of stakes in the areas behind the wheel trough, driven in in an attempt apparently to stabilise the ground.

The combination of a shallow gradient, the problems of trying to reconstruct adequate sides for the wheel trough and tail race, and the inattention to leaking water make it difficult to understand how a mill could have worked in these circumstances, but work it clearly did, to judge from the evidence of continued activity in the mill building.

Phase 2

The demolition of the wheel house and its replacement by a structure which could not have supported a water wheel, in combination with a rearrangement of hearths in the building, argues for a discontinuation of milling in this phase.

Gradients

Figure 109

The information about gradients comes from three narrow excavations, that is, across the mill pond (BAE), of the tail race 48m east of the wheel (BAH), and a further section 196m to the east of BAH, 12m from where the tail race joined the modern course of the River Arrow (BAJ), as well as from BAB. The levels found in BAE, BAH, and BAJ can only be related approximately to those found in BAB (see above, part I, The valley transect (BAE) stratigraphic sequence' and 'Subsidiary excavations through the tail race'). It is easiest to calculate the gradient for the period 3 mill because we can assume that no silt had accumulated in the pond, and it is possible definitely to identify the bases of the pond, head race, and tail race.

The overall gradient between the bottom of the pond as exposed in BAE and the bottom of the tail race exposed in BAJ, separated by a distance of 340m, was approximately 1 in 150. The gradient between the pond (BAE) and the east end of the head race was c 1 in 200. There was then the sudden drop immediately upstream of the wheel - of about 1 in 3 - and thereafter the tail race was virtually horizontal. However, the gradient between the tail race in BAB and BAH was 1 in 100, which was sharply reduced to *c* 1 in 450 between BAR and BAJ.

Although there is evidence in all the excavations of increased silting after period 3, it appears that there was no great overall change in gradient in later periods, with the one critical exception of that of the wheel trough. The level of the head race appears to have remained the same, but the superimposition of the later wheel troughs and tail races meant that levels had been raised by the end of period 6 by between 0.28m (in the wheel trough) and 0.37m (at the east end of the tail race). This reduced the gradient of the trough from 1 in 3 in period 3 to 1 in 4.6 in period 4 and 1 in 5 in periods 5 and 6.

There are two major questions. Firstly, can a mill work with this range of gradients?; this is difficult to answer in the absence of one important piece of information - that is, the level of the River Arrow during the twelfth to fourteenth centuries. It is clear that the present level of the river is no guide at all because it is c l.0m above the bottom of the period 1 stream channel (20) and the periods 3-4 tail race (19) in BAJ. However, if there was a significant drop where the tail race joined the river, this could have caused a rapid flow in the water between the pond and the tail race.

Secondly, why were the later tail races superimposed, instead of the earlier ones being dug out? The silting in the lower stretches of the tail race, especially in BAJ *(c* 0.45m depth), may argue that the current was so slow that widespread deposition took place and that, if there was a drop where the tail race joined the Arrow, it was insufficient to prevent silting further back in the tail race. Indeed, the silting in the east stretches of the tail race may well explain why the wheel troughs and tail races were superimposed. The evidence of the deposition of 0.5m of silts between periods 3-4 and periods 5-6 in the tail race (BAH) clearly points to this process. The river seems to have caused widespread silting in the lower part of the valley, and the only way the monks could respond to this and keep the mills working was progressively to raise the wheel trough and tail race upstream of this silting. However, because they could not significantly alter the gradients upstream of the mill (although they did try to increase the head by raising the pond banks), the mills were consequently operating more and more inefficiently. A common practice to avoid 'dead' or 'back' water in the tail race, which was probably a problem in periods 5 and 6 because of the shallow gradients, would have been to raise the water wheel to lift the paddles out of the dead water (Cleere and Crossley 1988, 235). This solution is, however, only effective if a sufficient fall of water remains upstream of the wheel to drive it; as has been shown above, this was not the case in periods 5 or 6.

The mill (BAB) buildings

A review of building materials and fittings

The period 2 and 3 buildings were of a similar, earthfast timber, construction with most uprights resting on timber pads in pits. The possible wall frame fragment (OB 367.2) would suggest either wattle panelling or walls of plank and muntin construction for the period 2 structure. The majority (79%, but only 650g) of the BAB burnt clay was found in debris from the period 3 mill, which presumably indicates the use of daub within that

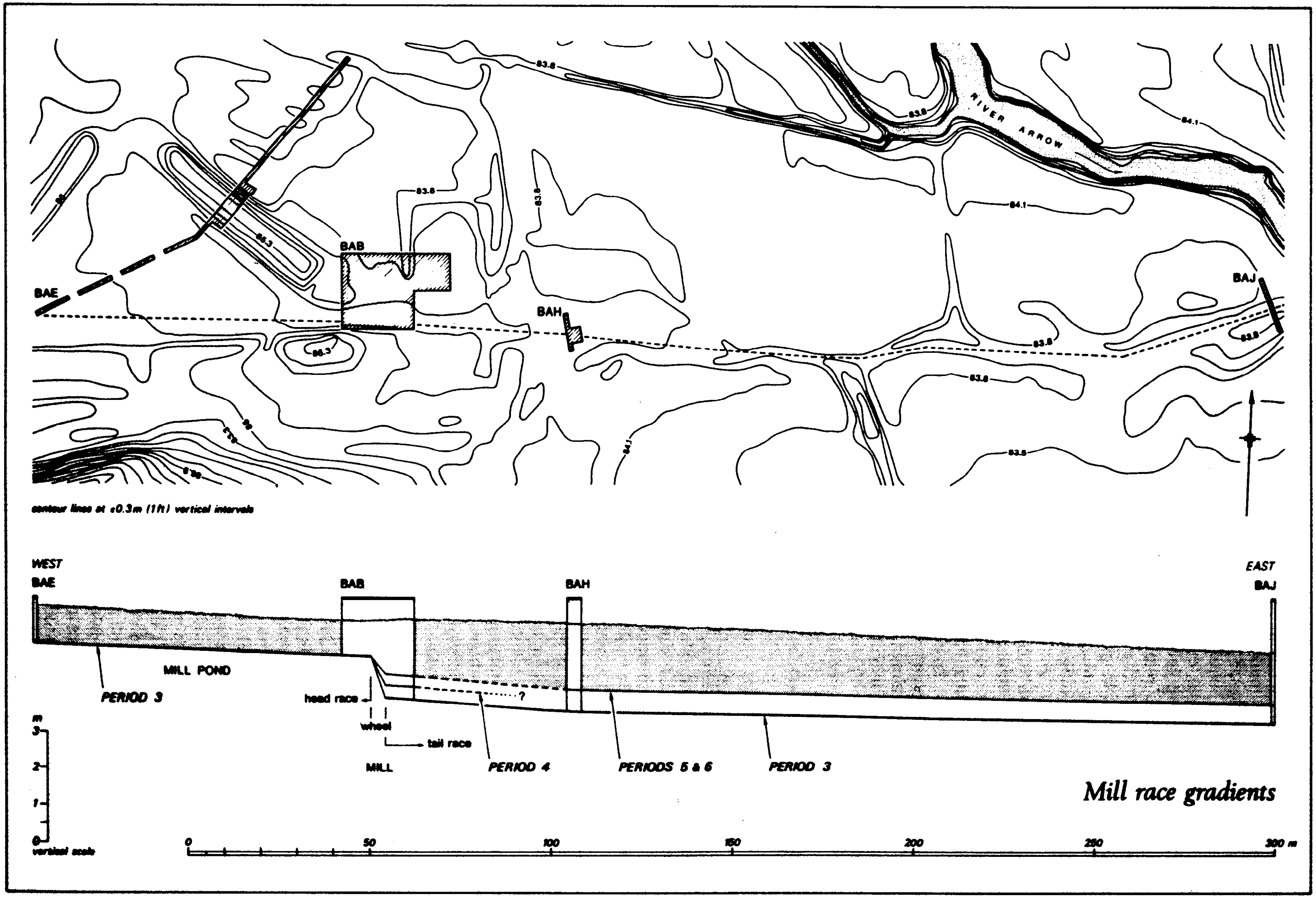


Figure 109 Reconstruction of mill race gradients: periods 3, 4, 5, and 6

structure (see above, part II, 'Baked clay'). It is likely that daub was also used in the later structures, but very little was recovered: these buildings, unlike the period 3 mill, did not catch fire and thus any daub was less likely to be preserved.

The lack of other building materials in periods 2 and 3 may be in part a result of the depleted archaeological levels, but the appearance of a greater range of materials in period 4 (and later), in combination with other changes in the character of the contemporary assemblage (eg pottery), could suggest that actually a greater variety of material became available in period 4. For the first time ceramic tiles were used for hearths and presumably roofs, and sandstones and cobbles were laid for padstones, wall foundations, and hardstandings; such a change must have been associated with the adoption of a different technique of building construction at this time (timber on stone foundations rather than earthfast), perhaps full timber-framing techniques. These materials continued to be used (or reused) in later periods.

Roofing materials

There is no evidence for the roof of the period 2 building, but it is assumed to have been of thatch. The first (period 3) mill apparently caught fire and thus lasted for a short time, perhaps as little as twelve years. There is little direct evidence for roofing, but the apparent absence of ceramic roof tile would suggest an organic roof covering such as thatch or wooden shingles, and without ceramic ridge tiles (see above, part II, 'Ceramic roof tiles and fittings'). The complexity of the roof structures, especially the relation between the gables of the central area and the lean-tos might suggest a lighter covering of wooden shingles would have been used. However, the possible toeing wedge (OB 176.31), found in a tail race dump assigned to the preparation and building phase of the period 4 mill, may have been used on a period 3 mill roof. Toeing wedges are normally associated with thatched roofs and are used to create sprocketed eaves in order to increase the run-off of rain water and to keep it, away from the walls (see above, part II, Allen, 'Worked wood ... Building fittings').

A single oak shingle (OB 316) was recovered from a period 4 context, the fill of the bypass channel (A156). A structural timber (OB 496, ?wall stud) which had clearly been part of a building was also found in the same context; this is interpreted as the remains of a building which was dismantled towards the end of period 3. The shingle may, therefore, have come from a period 3 building, but, as the fill of the bypass channel remained open during period 4, it could also be from the period 4 mill. The shingle is smaller than those found at Southampton or Winchester, dated between the eleventh and thirteenth centuries, although shingles remained in use until the early fourteenth century at Winchester, when they were replaced by stone slates and ceramic tiles (Platt and Coleman-Smith 1975,235; Keene 1990b, 320). The Bordesley shingle could have been used in conjunction with thatch in period 3 or perhaps with ceramic tiles in period 4. Shingles were often a preferred covering for roofs with a steep pitch, and one possibility is that they were used on the roof of the wheel house of either period (reconstructed as a steeply-pitched roof; Figs 112 and 114); however, no shingles were recovered from the fills of the wheel pit.

The large quantities of roof tile from periods 4 to 7 are clear evidence that the roofs of the mills of periods 4-6 were of ceramic tiles. While ridge and crest, tiles are comparatively rare elements of the assemblage, they were brought on to the site at the same time as the other tile types. There appears to have been little variation in the fabrics or tile type used during these periods. No fragments of ceramic chimney or louver were found and this may support the suggestion that some sections of the walls were open to allow the smoke from the hearths to escape (see below, Walsh, 'Reconstructions of the mill (BAB) buildings'). Some roof tiles may have been attached to the laths by iron nails or by wooden pegs, five of which were found (OB 31). However, as all the wooden pegs came from the same period 4 fill of the by-pass (ie A156) as the shingle, they may have been used with shingles on the roofs of the period 3 building(s). A potential wooden roof finial was recovered from a period 4 context (OB 192.5).

A small roofing stone had been reused in a period 6 hearth; it is of sandstone, not a common stone for roofing, but it is worn and so was probably hung. It is a reminder that the mills had a number of roofs - on the main buildings, the lean-tos, and the wheel houses, in addition to those on the workshops in periods 5 and 6 - which may have used different coverings, depending on availability. There is, however, no evidence that lead was used as the main covering material. Although lead sheets which had clearly been used on a roof were found on BAB, the pieces were of a small size and had apparently been brought on to site as scrap (see above, part II, 'Other metal'). The only other indication of the use of lead came from the debris from the fire of the period 3 mill, in which many lead droplets were found; but, as no other type of lead was found, it is assumed that a small number of lead pieces stored in the mill melted during the conflagration.

Building fittings

The majority of the fittings are of iron; however, as most of the pieces were broken, there is a possibility that they were brought on to site for repair or reuse rather than deriving from the mill buildings. The ironwork was often not sufficiently large to have been used in the structure but was appropriate to fittings or pieces of furniture: for example, the hinge pivots (IR 190; IR 323) were for fixing in wood and for shutters or furniture; the roves for clench bolts (IR 1001; IR 1192) were suitable for doors, shutters or hatches, as were the studs. An oak latch for a door (OB 325) was also found. The iron strap fragments and binding strips also probably came from boxes, as did the locks, chain links, and pinned hinge. The character of the ironwork did not change between periods 4 and 6 and this would confirm the structural evidence, that little was altered after period 4. Considering the character of the mill structures, window glass - the few pieces found included a small complete quarry (GLW 76) - is unlikely to have been used in the buildings.

Reconstructions of the mill buildings

by D A Walsh

Period 2 pre-mill structure

Figures 110 and 111

The timber pads and postholes on the platform are interpreted as the remains of a substantial earth-fast timber building. The pads and postholes define three sides of a structure of rectangular plan (Fig 7). Traces of all the uprights of the north wall can probably be identified, giving a length of *c* 10m. Three postholes of the east wall and three of the west wall remained. The position of the south wall is uncertain, but it seems probable that El035 represented the post of the south-east corner of the building, indicating that the short, east and west sides were *c* 6.25m long. Although the size and nature of the pads and postholes suggest considerable variation of size among the supports, the three postholes of the west wall were substantially larger. The spacing of the pads and postholes was remarkably regular at 1.8m and well aligned along all three walls.

In the proposed reconstructions (Figs 110 and 111), the north and south walls are low with a height of 1.5 to 2m. The precise alignments of the uprights suggest that a wall plate could be placed directly on them; moreover, such an arrangement could easily accommodate variation in support size. Alignment of the supports of the north with those of the south may have created distinct bays with tie beams running north to south between, but without the evidence of the south wall this can only be conjecture. Such ties could be placed below or above a wall plate. Another possibility would be to exclude tie beams which, with the low walls, would have limited headroom in the interior. Roof rafters could have been placed directly on the plates of the north and south walls, with close spacing of perhaps a metre. With the continuous plate, the positions of the rafters need not correspond to those of the uprights. The rafters could be held firm by collars positioned somewhat below their mid-points. Such collars could eliminate the necessity of tie beams below, creating a light and simple structure with an ample interior space appropriate to its suggested use as a workshop. The larger postholes of the west wall might indicate that their uprights were more substantial. These posts are reconstructed sufficiently high to meet the collar of the gable, a composition of three large vertical bays. The remains of the postholes from the east end were less substantial and it is difficult to say if it had a similar design. The change in the distance between postholes at the west end of the north wall may indicate an entrance, and the framing suggested for the west wall would also provide an entrance of a considerable height. Lap joints are suggested for the rafters and their collars, and the rafters are notched to the wall plate. The scale of the structural members is probably indicated most accurately by the fragments likely to have been from this work which were reused in period 3 (OB 362; OB 368: Fig 31).

Thatch would seem to be the most likely roofing. There was probably wattle infilling of the wall panels, although the timbers thought to be from this building show few seating or attachment holes. OB 368, however, has a substantial rebate on one corner, and OB 367.2 is smaller in scale but has two opposed rebates. Alternatively, plank and muntin construction could have been used.

Period 3 mill building

Figures 112 and 113; Plate 10

Period 3 represents the wholesale replacement of the period 2 structure with a building, whose function as a mill is clear, on a higher platform. The posts and pads of this building were composed of earthfast timbers as well, but in all cases the postholes were newly positioned (Fig 8). As was the case with the period 2 building, the postholes are varied in type and size, and preservation was uneven with dramatic losses on the south side. Sufficient survives, however, to indicate that this was a complex building, very different from that of period 2, with a number of distinct but interrelated and connected areas and structures.

The centre of the complex was probably a rectangular structure, *c* 4m x 5m, with massive corner uprights. B537 and B538 represent the north pair, while the south-east corner upright was placed in pit E1029; evidence for the south-west corner is lost. Lean-tos were built against the east, north, and west sides of the central structure. The west lean-to appears not to have extended the full length of the main structure's wall to the south, but is continuous with the north lean-to, which may have been open in the central portion. The east lean-to continues from the north but widens to the south. The wheel house had the same width as the central structure but had a lower roof and extended to the south to span the mill race and to support the water wheel and its associated machinery.

The central structure provided a substantial clear space as a working area, with hearths in its

Period 2 reconstruction

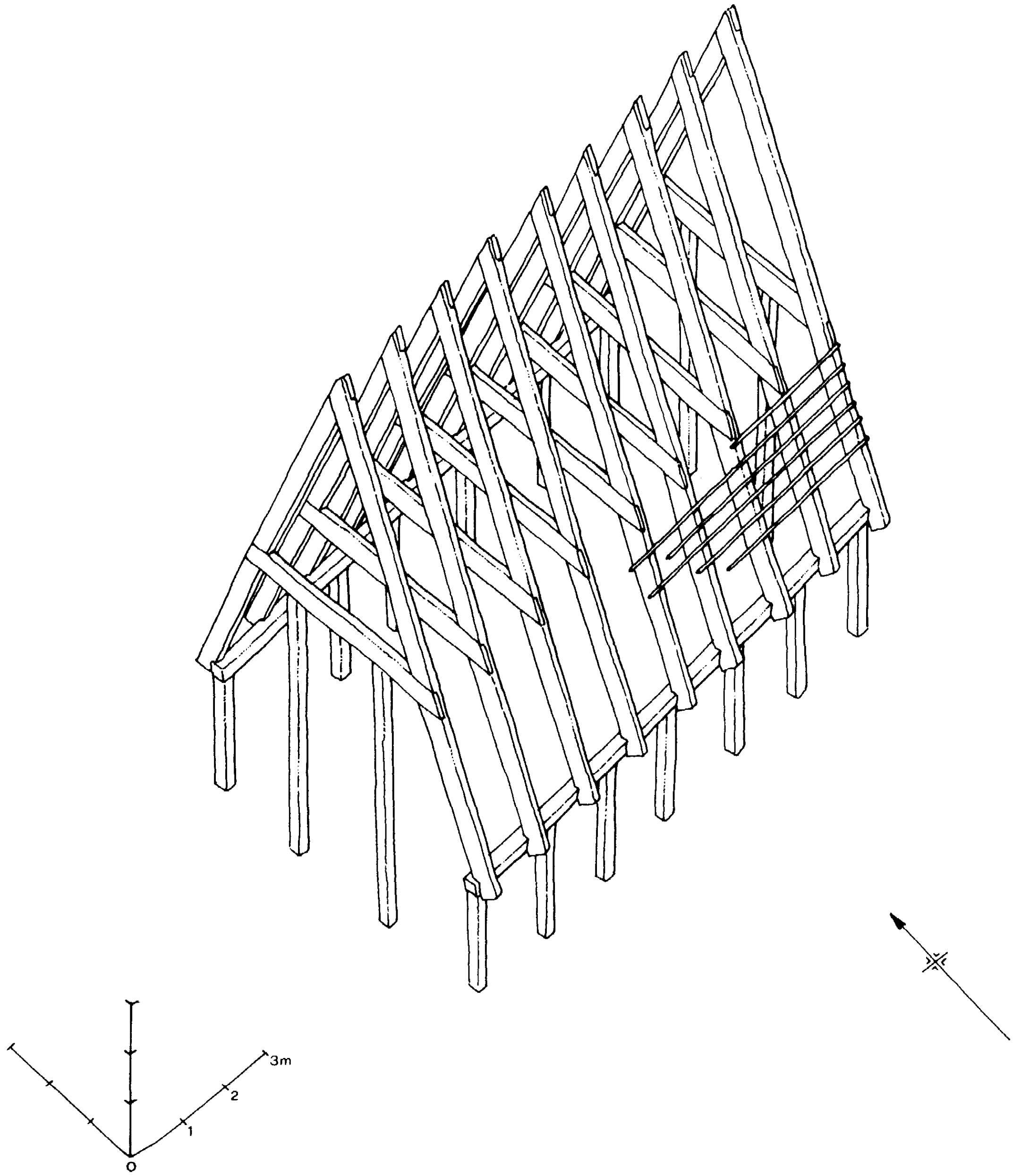


Figure 110 Mill (BAB): axonometric reconstruction of period 2 pre-mill building, from the south-west (D A Walsh)

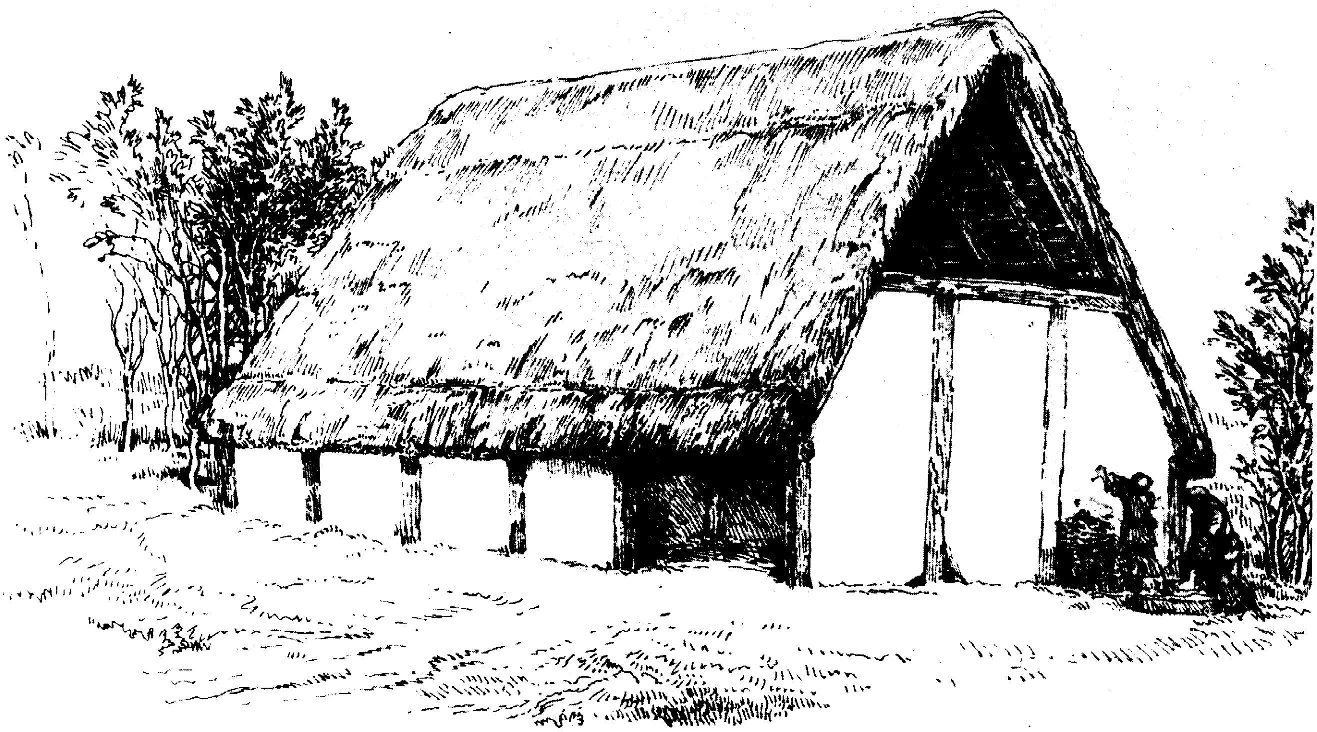


Figure 111 Mill (BAB): reconstruction of period 2 pre-mill building, from the north-west (D A Walsh)

south part. In the proposed reconstructions (Figs 112 and 113), four corner timbers support wall plates on the east and west sides and tie beams on the north and south, the frame made firm by corner braces. Six collared rafters, with gables facing north and south, are positioned on the uprights. With a steep pitch to the gables, a total height of just over 10m seems likely. This height is suggested by the distance of the outer walls to the west: if 1m or 1.5m is allowed for the height of the outer walls of the lean-tos and it is assumed that the pitch of the subsidiary roofs is the same as the main roof (and it seems likely that the line of the roof would have been continuous where possible), the large corner uprights must be *c* 4m high.

The lean-tos were of a much less substantial character than the framing of the central structure, to judge from the traces left by the outer supports. On the west, some were large, possibly squared, posts and others appeared to be unshaped. The curious pairing of supports could mean a change in wall position or may indicate a wide, plank-like wall plate (as shown in Fig 112). The upright(s) in pit D570, and its close proximity to D574, just to the east, is interpreted as the south end for the west lean-to, midway on the west wall of the central structure. D574 and a postulated upright to its east would define a south wall for the lean-to, while the south half of the west face of the main structure could have been open.

The north lean-to must have had a roof that continued the pitch and height of that of the west as the structures look to be continuous around the north-west corner, where a jack rafter is shown. The problem of the central section of the north lean-to has already been mentioned. A span of the roof over the central section without support is not impossible, particularly if there were braces at the sides (considering the size of pits B1113 and B1133). The opening would provide access to the 'back' (north) of the working area in the central structure. In the subsequent period, 4, there were no postholes, sill or sole plate, and a continuous spread of ash in the area where a north wall might

Period 3 mill reconstruction

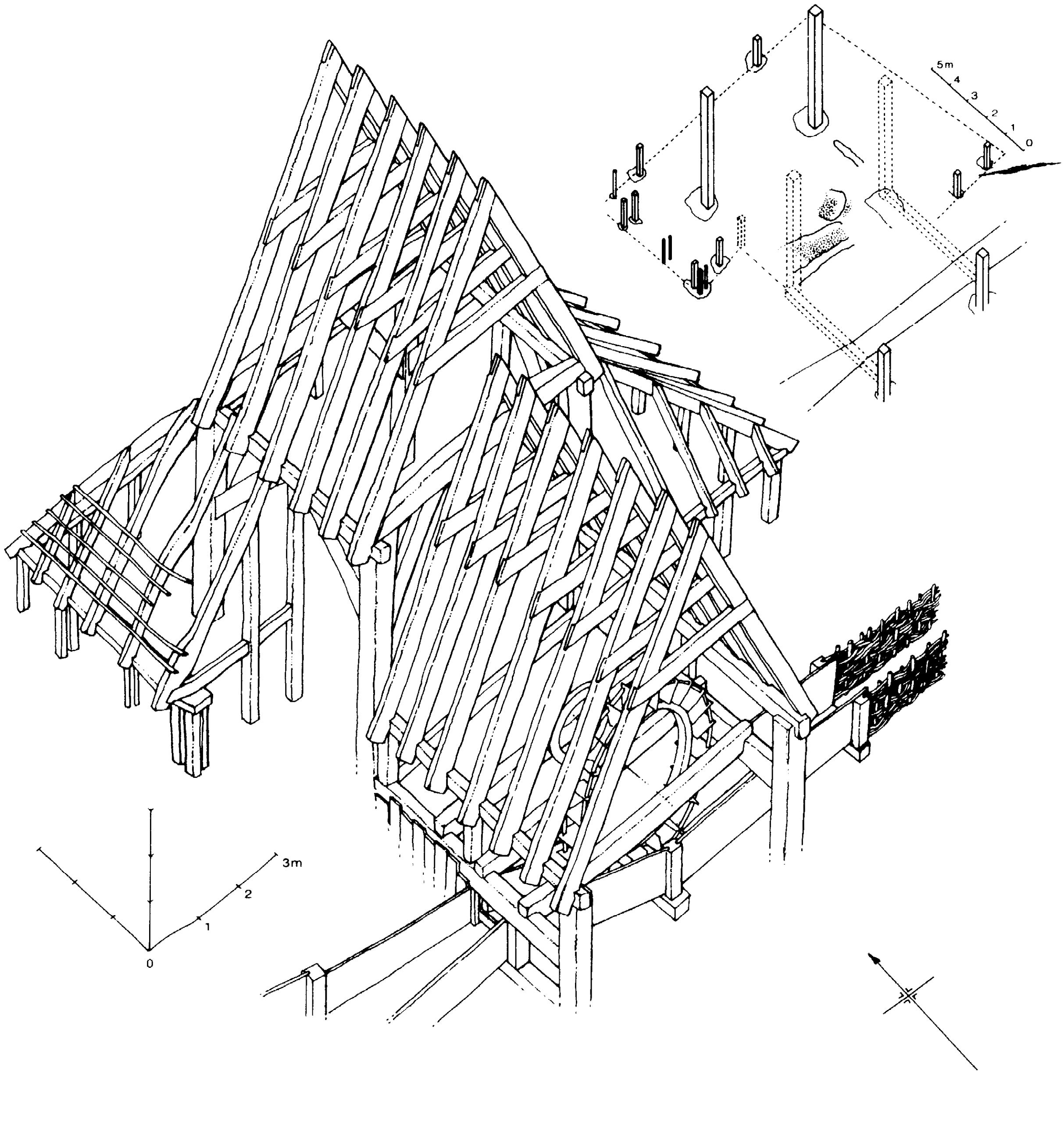


Figure 112 Mill (BAB): axonometric reconstruction of period 3 mill, from the south-west (D A Walsh)

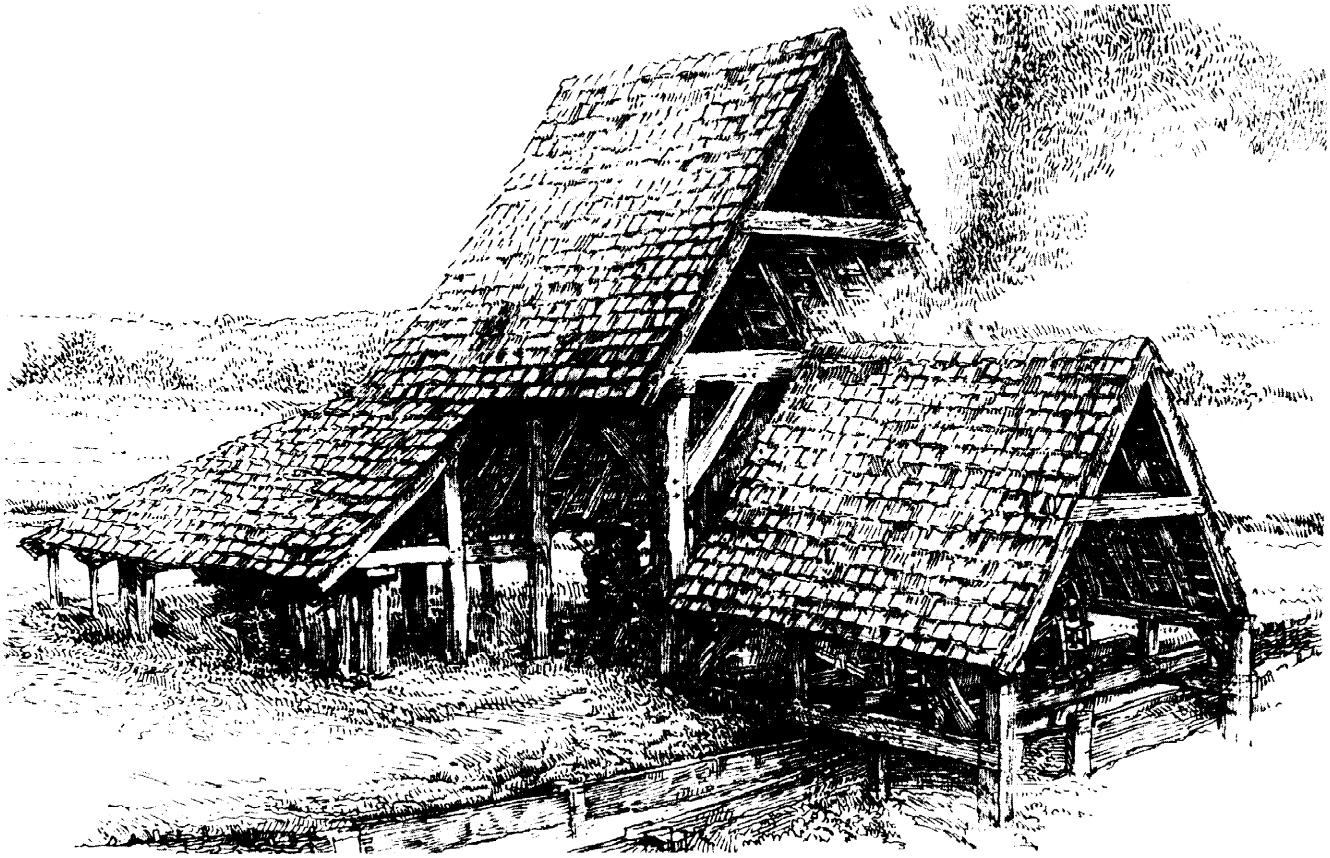


Figure 113 Mill (BAB): reconstruction of period 3 mill, from the south-west (D A Walsh)

be, strongly suggesting that at this period the space to the north of the central structure was open. As there is strong continuity of composition between periods 3 and 4, a discontinous wall or even a roofless space in period 3 is a possibility. Thus, we might imagine sections of roof only at the north-west and north-east corners of the building.

The east lean-to extends southward on a wall which is not parallel with the east side of the central structure; it thus had an irregular plan with a greater width at its south end. It must have been covered with a roof that had a changing pitch. At its north end it matched the roofs of the north and west sides, joining with the north roof at the north-east corner, where a jack rafter is shown. With the widening of the lean-to to the south the pitch becomes much lower. This irregular plan is repeated in the later mills.

The wheel house structure, which extended to the south of the central building and was closely aligned to it, rested on massive horizontal timbers which ran south from the central building to bridge the mill race. Vertical posts (in E961 and E983) near the ends of these timbers raised the support plate for the roof on what amounts to two walls. The horizontal timbers, tenoned into the uprights at the floor level of the central building, would be the ideal foundation for east to west beams which supported the shaft of the water wheel which turned within the tight space of the timber-lined trough. The west timbers which spanned the mill race may have integrated with a sluice immediately to the west of the wheel. It is proposed that a machinery pit between the wheel trough and the building was revetted with planks, also attached to these horizontal timbers. A gabled roof over the wheel and machinery seems appropriate; the minimum height of c 5m may be determined by the proposed size of the wheel. The pitch and the collared rafters duplicate the configuration of the central structure. The lack of beams makes possible an ample space for the wheel; moreover, the high collars make for easy access to the wheel for repair and maintenance.

For this period a substantial roofing for the main structure and the wheel house is suggested, with rafter spacing of no more than a metre, while that of the lean-tos may have had lighter members of less regular construction. As there is no certain evidence for ceramic tile at this period, the roofing material must have been either thatch or wooden shingles. One oak shingle was found in a period 4 context and so could be of period 3 or 4. The complicated relationship of gables and lean-tos suggests that the thinner and lighter covering of wood might have been preferred; the period 3 mill is thus shown with a shingle roof.

The gables of both the central structure and the wheel house have been left open as this would have achieved an adequate level of ventilation in the forge. It is difficult to say whether the low outer walls were open. In view of the small holes which appear to have held stakes, sections of wattle seem likely, especially as the lean-tos were probably used for storage.

It is hard to know precisely how all of the parts of the period 3 mill building worked and why it took the precise form it did. The spaciousness and particularly the height of the building that has been reconstructed may seem difficult to justify. However, the evidence of a heavy and sophisticated structure is apparent not only from the mill building but also from the mill races. As to the function of the timber form, the clear space of the central structure provides a working area for the metalworking. The vertical space appears excessive for the smiths who must have crouched over the floor-

characterised as a central vertical shaft of space with large open gables at its top, surrounded by low-walled lean-to appendages, virtual architectural hood which would create the updraughts necessary for the efficient working of the forge. The building must have worked well since there is a remarkable formal continuity with the later mill building, as the following reconstruction of period 4 will show.

Period 4 mill building

Figure 114 and Frontispiece; Plate 13

The period 3 mill was replaced by a composition which seems to be closely based on that of the destroyed structure (Fig 11). If the general arrangement shows more continuity than change, an opportunity was taken to transform certain aspects of the structure. The two extant north corner supports of the central structure (B142; B648) and the two supports of the north lean-to (C682; B144) were placed on padstones. New and different foundations are found elsewhere. The outer walls of both east and west lean-tos were based on pebble foundations, which must have supported sill beams. The size and shape of the central structure was changed. The north pair of corner uprights was moved north by nearly a metre, and the line of the north lean-to wall was also shifted north by moving C682 (the north-west support) by the same amount. If post El033 represents the position of the south-west corner support (no evidence for its south-east counterpart survived), the central structure would have become more nearly a square in plan. The reconstruction shows that this extension could have necessitated an additional, central, tie beam which divided the central area into two bays (see post setting E1021). The south end of the east lean-to could well have ended parallel with the south wall of the central structure rather than continuing south beyond the central building as happened in period 3. The arrangement of the (open) north lean-to has already been discussed.

The position of the wheel house in relation to the central structure changed, with its axis shifted to the west. The wheel house supports were modified, but there is no reason to think that the form of its superstructure differed much from that of period 3.

With the replacement of most earthfast timbers by members on pads and sills in period 4, there was probably a greater precision and regularity in the construction of the superstructure generally. The sill of the west lean-to wall implies a structure with more substantial, evenly-spaced uprights, which also suggests the walls were filled with wattle panels. A more substantial wall on a sill on the west side could mean heavier rafters than in period 3; in fact, it is a possibility that the rafters of the central roof continued down to cover the west lean-to. A closer spacing of rafters to 600-700mm seems in character with the change of support; perhaps a denser roof structure is related to the use of ceramic tiles as a covering.

There was little change in the main structure between periods 4 and 6.

The period 6 workshop

Figure 115

The sandstone pads and lines of pebbles (F2; F5) defined the walls of a large rectangular building (Figs 4 and 15). The remains of the north wall were particularly clear, running east for nearly 13m. The short sides were c 6.5m long. The pads on the north were rectangular and fairly evenly spaced at c 2m, although towards the east the stones were less regularly spaced and closer together. Some of the south pads appear to have been removed. The varying regularity of the pads, especially as there is little north to south correspondence between the stones, would at first suggest that the north and south walls consisted of a series of uprights set on the pads and fastened to wall plates. But a close look at the pad positions shows that they could have been arranged to take major crucks on every other padstone. The cruck blades would have rested directly on the padstones. The building would have at least four pairs of crucks, in which case it would have extended to just under 13m in

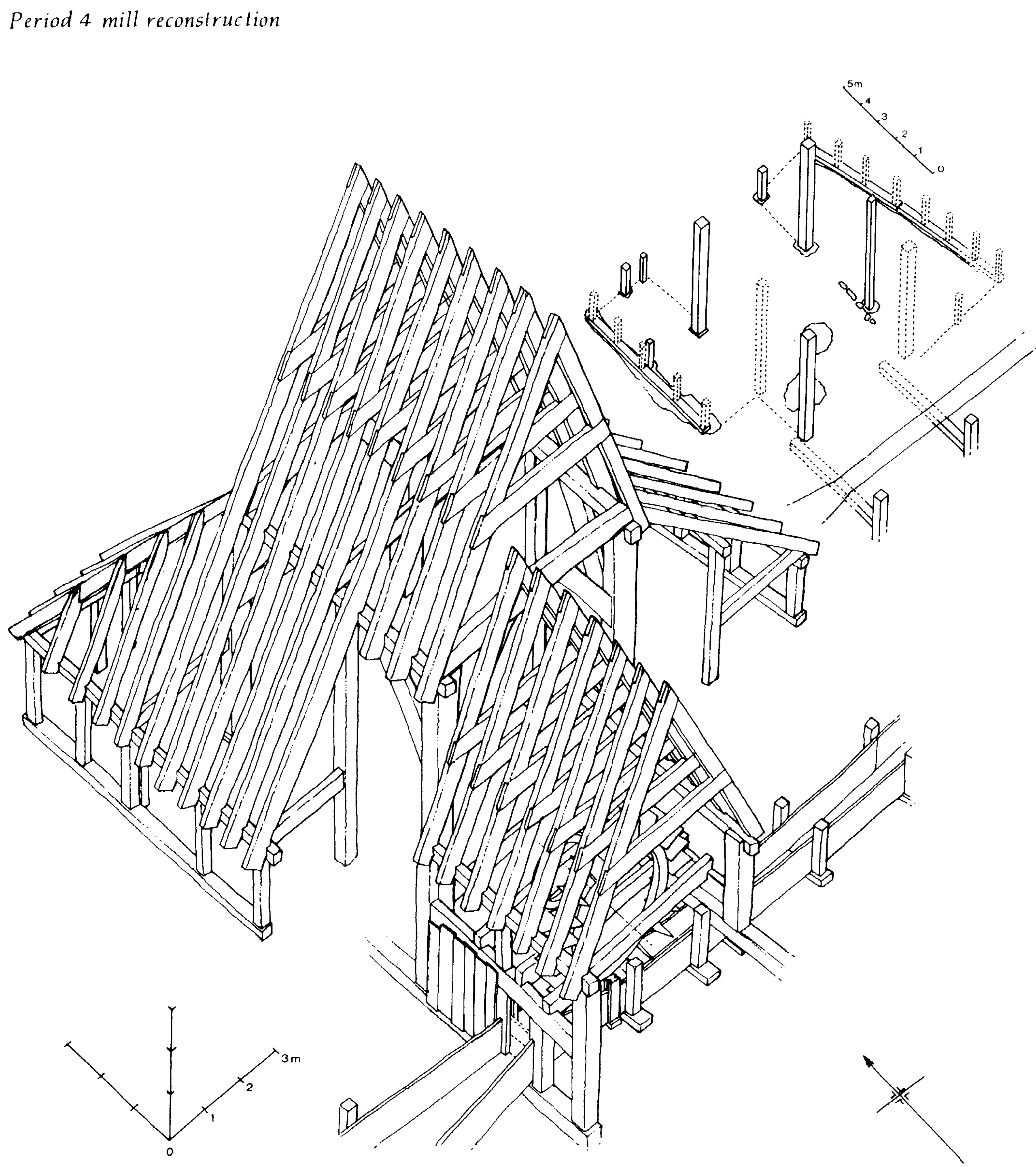


Figure 114 Mill (BAB): axonometric reconstruction of period 4 mill, from the south-west (D A Walsh)

Period 6 workshop reconstruction

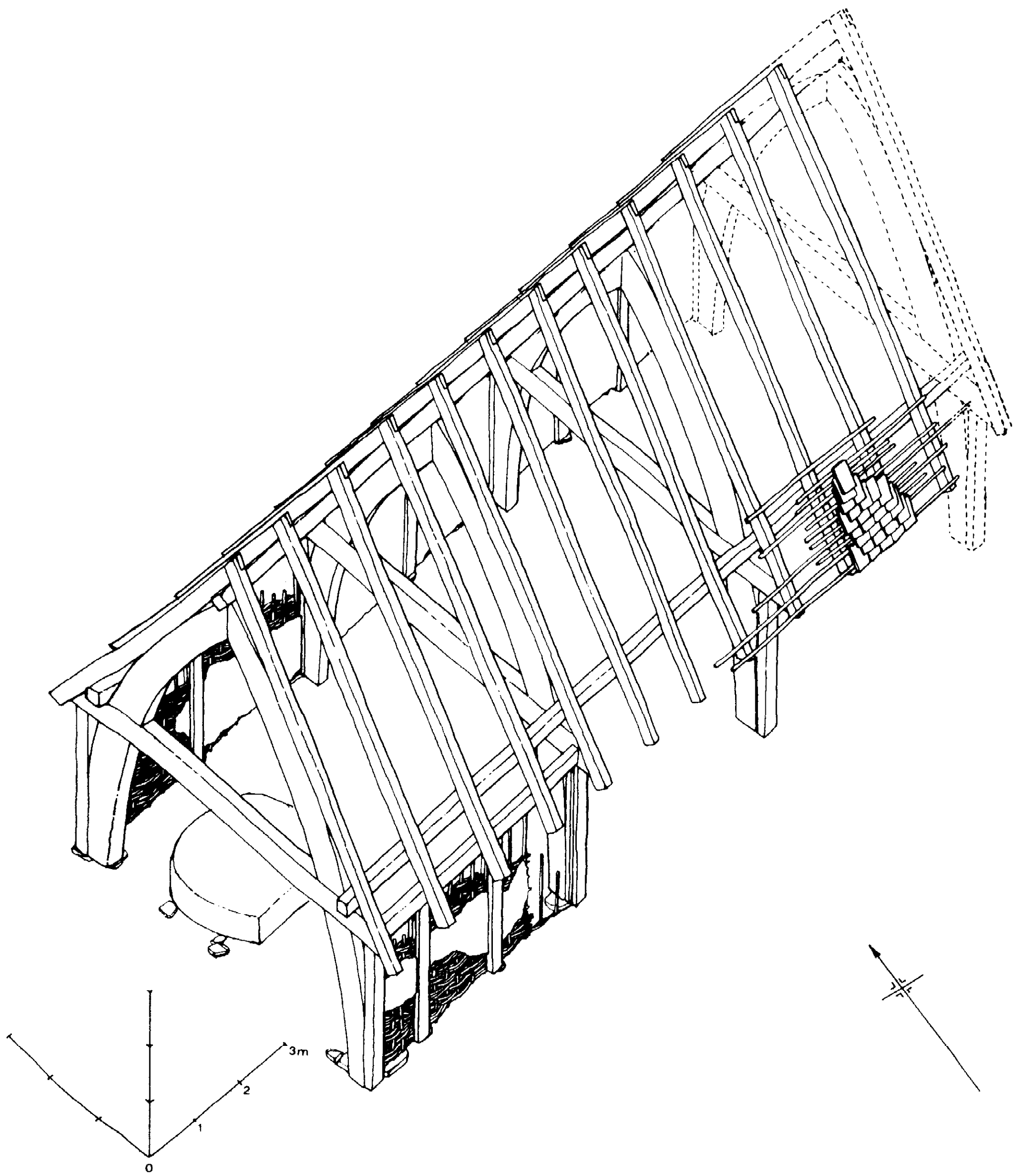


Figure 115 Mill (BAB): axonometric reconstruction of period 6 workshop, from the south-west (DA Walsh)

length, although, of course, there may have been additional bays.

The long walls would be defined by vertical timbers attached to and rising on the backs of the blades with intermediate supports set on pads between the crucks. On the north wall, all spaces between the pads have lines of pebbles which would have supported a light panelling of wattle. Some bays to the west may have been open, as may have been the gable ends. The pads F10 and F11 at the west end might indicate a wall, but could instead have supported a hood over the hearth. The pads F7 and F8 may have supported a lean-to on the west gable end; this has not been included in the reconstruction in Figure 115. The roof, of ceramic tiles, is carried on rafters; in combination with crucks they act as principals, and as a series of common rafters, three in the reconstruction, between the crucks. All rafters rest on a ridge purlin held at the apex of the joined blades. The total height of 6m to 7m is suggested by the usual proportions possible with crucks set to give a 6m breadth.

The machinery and its arrangement in the mill buildings

Figure 116

The major classes of information that enable some discussion of the workings of the mill are as follows: the water wheel fragments, the stone bearings, the wooden 'cogs', and the (wooden) trip wheel; and perhaps the wood bellows plate fragments, the grindstone, and stone weights, which could all have been used manually. Detailed descriptions and analysis will be found in the appropriate catalogues (see above, part II). The material is summarised in Table 65.

While most evidence exists for periods 3 and 4, there is not enough to discuss change through time, so it is proposed to discuss all the information together. This is felt to be justified because to a great extent the determining factors in the use of the machinery are the space available and the size of the water wheel. In all periods the size and proportions of the buildings varied very little, and there was apparently little change in the size of the wheel (see above).

Table 65 Mill (BAB) and valley transect (BAE): summary of machinery, by period and by function

Function	**Period** 3	**4**	**5**	**6**	**7**
Paddles/staves	1	1	2	-	
Stone bearings		1	2	1	3
'Cogs' - group 1	1	2	-	-	-
'Cogs' - group 2	6	3	-	-	-
'Cogs' - group 3	4	6	1	-	-
Bellows plates		1	-	-	1
Trip wheel	1	-	-	-	1
Grindstone	-			1	-
Machine weights	-	-	3	-	-

The paddle and stave, or 'start', fragments from periods 3 and 5 are interpreted as evidence that the type of water wheel remained the same in all the mills. The wheel type, consisting of a rim or felloe into which staves with paddles were inserted (with laths which connected the outer parts of the paddles present only in period 3), has not been recorded from other English medieval water-mills.

Crossley's (1985) survey of (eleven) excavated overshot water wheels shows that between the mid-fourteenth and seventeenth centuries all these wheels were vertical and had a common structure, with a compass-arm arrangement, sole boards, side boards, and bucket boards. The consistency in the remains was interpreted as evidence for a pattern of wheel construction which was common in most areas of the country (and perhaps parts of northern Europe) from at least 1500 (Crossley 1985). The Bordesley examples clearly derive from a different tradition, and it is premature to explain this variation. There are, however, two fundamental differences between the Bordesley mills and those considered by Crossley. Firstly, only the Bordesley mills are interpreted as undershot mills, and this major difference alone may well explain the variation in wheel type and also the size of machinery (see below). Secondly, the Bordesley mill sequence started at least 150 years before Crossley's medieval examples (Chingley and Batsford). While at least one phase of the Bordesley mills may have been contemporary with Chingley and Batsford, the Bordesley arrangement had changed little since its beginning and was, therefore, essentially a late twelfth-century mill. (This leaves aside the problem of potential differences in function because the purpose of Chingley and Batsford is by no means certain; see below.) There is, therefore, a possibility of an earlier medieval tradition of wheel type, perhaps associated with undershot mills, which may have continued into the fourteenth century and of which Bordesley is so far the only example. A paddle similar to those from Bordesley has recently been discovered in an abandoned channel of the River Trent near Hemington, Leicestershire. It has produced a dendrochronological date of 1090-1100 (best estimated felling date, based on 116 rings with no sapwood: pers comm C Salisbury). In the same parish, the excavation of a dam produced indirect evidence for a ?breastshot mill, including paddles which fitted a wheel with side boards. As the dam structure is dated to c 1140, that is roughly contemporary with the other paddle, it appears that different wheels (perhaps for different types of mill) were used at about the same time and at the same place (Clay and Salisbury 1990,292-3).

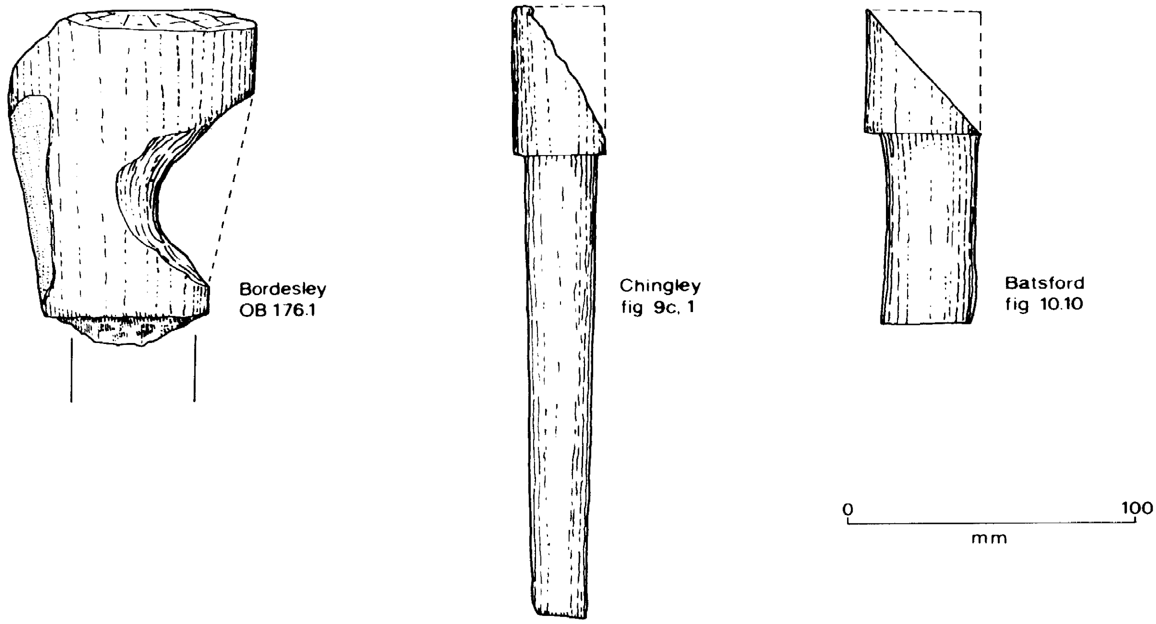


Figure 116 Cog wear patterns: comparison of finds from Bordesley with Chingley and Batsford (Crossley 1975, 16; Bedwin 1980, 200)

Any attempt to reconstruct the arrangement of the machinery has to take into account the features of the building. The character of the successive mill buildings was remarkably consistent; most impressive is the continuity of location of the major elements such as the water wheel and the hearths. The implication is that the initial arrangement was efficient and served the needs of those who worked in the mill sufficiently well that few alterations were necessary over at least two hundred years. Any reconstruction, therefore, has to acknowledge this continuity of arrangement even though it may appear inconvenient or inefficient according to modern molinological practice. For example, the distance between the water wheel and the hearths would be regarded by modern eyes as excessive (period 3 *c* 4m; period 4 *c* 3.2m), but little effort was expended to reduce the distance after period 4 (but see below). It is also likely, to judge from the way the latest levels had slumped into the area of the wheel pit, that a machinery pit, revetted with planking, existed alongside, and to the north of, the wheel pit.

A further imperative in any reconstruction would be to have the head of the trip hammer close to one or both of the hearths in order for the smiths to work efficiently. Thus the hammers could only have been worked by the depression of the helves (rather than the lifting of the heads): the hammer would, therefore, have to he operated on the downstroke and out of necessity would have to be located at the east end of the wheel. Such a location would allow bellows to be operated on the upstroke, to the west of the wheel. A further possible consideration is that most sixteenth- to eighteenth-century industrial mills had hammers that were positioned so that the hammer helve was parallel with the water wheel (Crossley 1990, 153-73).

The best evidence for mill machinery is the bearings and 'cogs'. In terms of evidence for what the mill was used for, the most useful piece is the trip wheel which clearly indicates that it was driven by water-power: less reliable are the bellows plates and the grindstone, which need not have been water-powered, and the weights which may not have been machinery. In general, however, the main thrust of the structural evidence and the material assemblage would suggest that the mills were most likely to have powered trip hammers for working metals and bellows for maintaining the temperatures of the hearths.

Allen shows that, on the basis of the size and proportions of the heads, the 'cogs' fall into three groups (Fig 92). As it is extremely unlikely that any wheel would have cogs of different sizes, these groups are evidence that at least three wheels were in use at the same time, certainly for periods 3 and 4, and probably for the other periods (the different 'cog' types were found together in the same stratigraphic contexts).

It is, however, difficult to interpret these 'cogs', if they were cogs. The size and wear patterns are unlike any gears identified from medieval mills such as Chingley or Batsford (Fig 116). The gears from such mills had been worn to a triangular section, where the greatest amount of wear occurred at the extremity of the gear where it started to mesh; the wear progressively decreased as the gears meshed fully and then parted; such gears have been interpreted as evidence for a right-angled drive (Crossley 1975, 16; Bedwin 1978, 199–200).

Such a pattern is in contrast to that of the Bordesley 'cogs', which show a pronounced cusping midway along the length of the head (Fig 116). The wear could have been produced by a sudden contact with a cam, which implies a different action from those gears found at Chingley or Batsford; the suddenness and violence of the contact is also suggested by the deep striations within the worn cusp which hardly indicate the smooth meshing of gears. It is, however, possible that cogs set in a wheel meshed at right angles with another cog wheel. But the depth of wear on some 'cogs' may have prevented an efficient meshing and it is difficult to see how such an action could have produced the type of wear on the Bordesley 'cogs', although the majority of the surviving 'cogs', because they had fractured, were probably at the end of their useful life when meshing would have been loose and destructive.

There are thus two possible interpretations of the 'cogs'. One is that they were part of (three) series of cogs set in (three) wheels which meshed at right-angles, as has been suggested at Chingley and Batsford. The three wheels might have been used in the following manner: one as the driver wheel attached to the same shaft as the water wheel, one as the trip wheel, and the third for driving bellows. However, another possibility, which is preferred because of the larger size of the Bordesley 'cogs' and their unusual wear, is that the 'cogs' functioned as cams and that they were fixed to three wheels (not in a regular series as cogs, but irregularly) which interacted with three separate trip levers (see below and Fig 117).

This kind of arrangement would probably require all the wheels to be attached to horizontal shafts. All seven stone bearings are clearly for supporting such horizontal shafts; there is no evidence for the use of a vertical shaft, and thus nothing like a lantern (so necessary for a corn mill) was involved.

Table 68 Mill (BAB): summary of features of stone bearings, by period (measurements in mm)

Period	ST no.	Shaft dia	Journal dia	Journal l	Lateral wear
4	506	236	–	62	Yes
5	359	170	35	62	Yes
5	500	–	–	60	Yes
6	352	–	30	45	Yes
7	307	164	–	–	–
7	353	230	35	62	Yes
7	354	–	32	50	Yes

The information in Table 66 is derived from the areas of wear and polishing on the stones and can give only minima for shaft diameters and journal lengths and maxima for journal diameters. There is no great variation in the size of the journals, although two of the smallest bearings, ST 352 and ST 354, had the smallest journal lengths; there was a consistency, however, in the journal diameters. The minimum diameters of the shafts, 164–236mm, were calculated from the worn and polished areas clearly visible on the sides of most bearings. The distinctive shape to the wear suggested that the shafts had an iron hoop or gudgeon ring at their end (on the outer circumference) and that some pieces of iron were applied between the journal and the hoop, either as bands to protect the edge or as wedges that had been driven into the shaft to secure the hoop. The undulating character of the wear produced by journals and shaft ends shows that the iron parts had also been worn into unusual shapes.

Given the size of most of the bearings, and the minimum sizes of the shafts, it is likely that they supported the main, water wheel, shaft. The bearings appear to have been open, or at best loosely covered, and it was expected that the weight of the shaft and whatever machinery it supported would have been sufficient to keep the journals in place. This, however, may not always have been the case. On two bearings (ST 352 and ST 353) wear patterns where the journal would have been seated show several facets to one side of the worn groove which suggest that, while it rotated, the iron journal 'climbed' the groove (in the opposite direction to the rotation of the journal). All but one of the bearings also have journal wear patterns which demonstrate considerable lateral movement, probably produced as a result of the vibration from the water-powered machinery (especially the water and cam or trip wheels) or by the bearings shifting in their seatings or by the movements of the shafts; a combination of these factors may have been responsible. One piece of copper alloy, CA 136, may be interpreted as a bearing cover. A wooden example was found at Hemington Fields (Clay and Salisbury 1990, 292–3) and such covers are shown in Figure 117.

Arrangement of machinery

Figure 117

The disposition of the machinery is first and foremost influenced by the arrangements within the buildings, the principal determinant of which was the hearths. Out of necessity the bellows had to be located close to the hearths and the same would have been true of the trip hammer. In no period (except perhaps period 5) was the location of an anvil base definitely established. In all periods of mill the concentration of hearths in the south of the building, close to the wheel house, is of critical

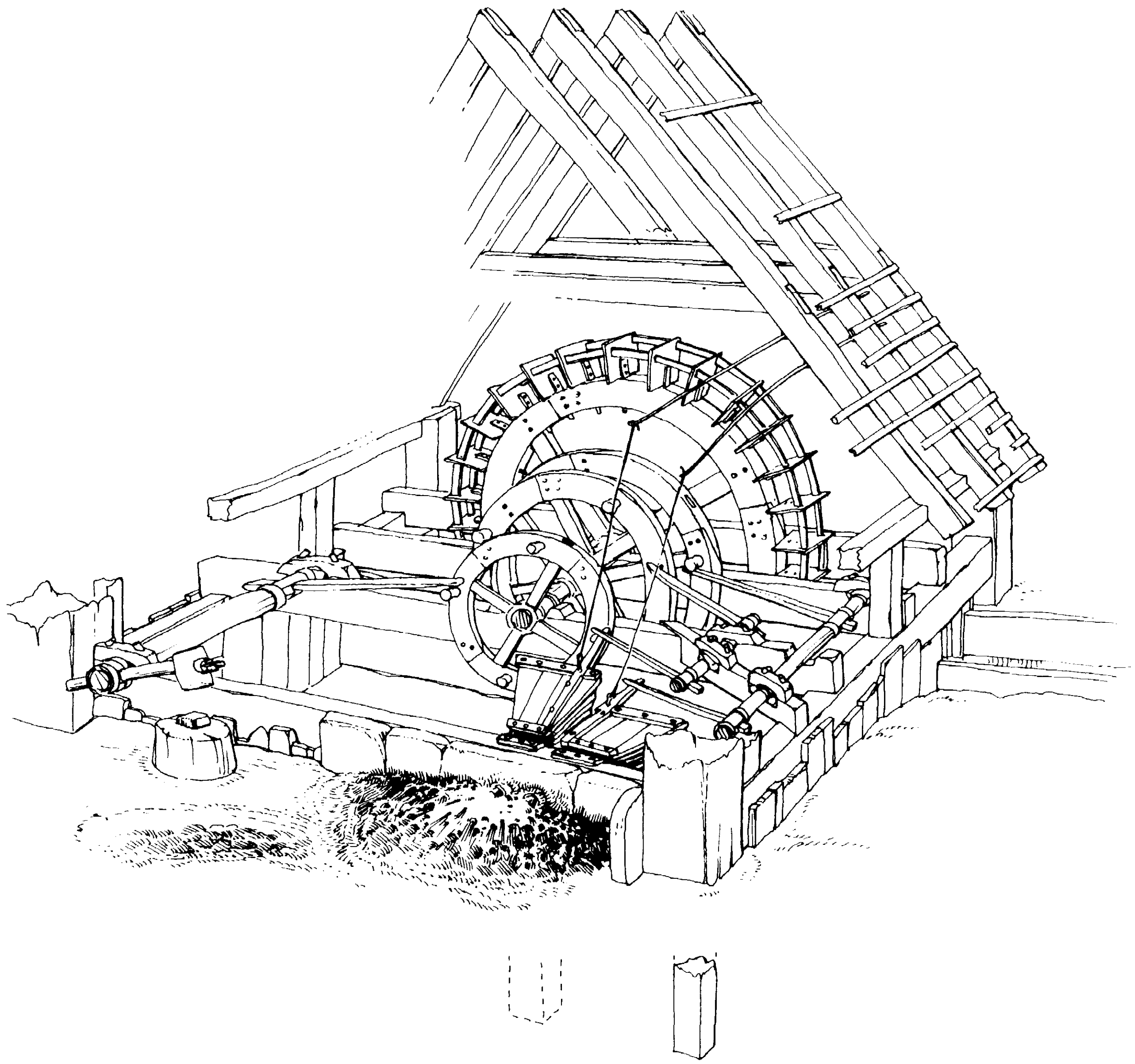


Figure 117 Mill (BAB): possible reconstruction of machinery arrangement in period 3 (D A Walsh)

importance.

On the basis of post-medieval analogies, and the absence of bearings for vertical shafts, the wheel shaft could probably pass directly into all the mill buildings without intervening gear wheels. It has been suggested above that the wheel shaft was located midway between the walls of the wheel house and that the space between wheel trough and building was taken up by a timber-lined pit in which machinery was located. The following conjectures are based on the idea that the 'cogs' were in fact cams and that they were fixed into three trip wheels.

The clustering of hearths close to the wheel house limited the amount of space for a working area and the placement of bellows or a trip hammer. Given the continuity of arrangement between periods 3 and 6 phase 1, it is only proposed to consider a possible arrangement for period 3 (cf Fig 8).

Assuming that it was normal medieval practice to have the hammer parallel with the water wheel and that it was necessary (given the location of the hearths) to trip the hammer using the helve (see above), it is only possible to place the hammer in a location where it could be conveniently used from one, the smaller, hearth. Similarly, the necessity (because of limited space) of having the trips for the bellows on the upstream side of the wheel shaft means that it was only possible to service one, the larger, hearth.

Given the distance between wheel trough and hearth, there was a premium on devising an arrangement which reduced the length of the wheel shaft. The simplest solution appears to be to have all three trip wheels located on the shaft of the water wheel. The trip wheels would be located in the machinery pit, which would have been divided into areas by transverse timber baulks into which the bearings would have been set. So as not to overload the shaft, one trip wheel is placed on the extreme north end of the shaft, oversailing one of the transverse baulks. In order to avoid any kind of gearing (for which there is no evidence), a system of trip levers is proposed. The trip wheel moves a lever which is attached at right-angles to another shaft. At the other end of the shaft is attached, in the equivalent position to the first lever, either the hammer or another lever for depressing the top plate of the bellows. It is these subsidiary shafts which effectively eliminate the need to have a wheel shaft which comes near the hearths.

Thus, although on the downstream side of the wheel shaft, the hammer is in effect only indirectly lifted by its head, and the bellows on the upstream side have their top plates depressed by the levers and lifted by spring poles. The illustrated arrangement (Fig 117) shows two pair of bellows working alternately to maintain a constant draught on the large hearth. This acknowledges that there is evidence for three trip wheels. Another possibility would have been to have two hammers and one set of bellows, but it is difficult to find a suitable place for an additional hammer.

While this proposal may appear cumbersome, it does fit all the requirements of the stratification, spatial arrangements, and the artefacts, while some cognisance has been taken of the requirements of milling practices.

Power output of the mills

It is notoriously hazardous to try to calculate any figures for power output on the basis of incomplete and variable data from excavated mills. However, it may be useful to make some crude calculations to indicate the kind of power that was generated by the Bordesley mills. Most evidence exists for the first, period 3, mill.

It has not been possible to undertake a detailed hydrological reconstruction (cf Park 1989). However, if the flow rate was 500m^3 per hour (pers comm R Spain), and the drop before the wheel was 1m (see above, 'Gradients'), this produces a maximum potential in the water of 1.3kW (1.8hp). Assuming a maximum efficiency of 35% (however Tylecote and Cherry (1970, 106) assume 50% efficiency for a hammer in a forge), then the wheel developed c 0.47kW (0.63hp), which may suggest that the wheel power was between 0.37 and 1.1kW (0.5 and 1.5hp). This amount of power is regarded by some molinologists as sufficient for powering the machinery we have suggested above (cf Gordon 1985), although 1.5kW is regarded as a typical output for an undershot wheel (Cotterell and Kamminga 1990, 57). The estimate of output for the fourteenth-century forge wheel at Chingley was 1.1kW (1.5hp) (Strange 1975, 42).

Metalworking at Bordesley and elsewhere: a review of the evidence

The following section considers the variety of evidence for metalworking from BAB. The catalogues (see above, part II) describe material potentially indicative of iron-, copper alloy, and leadworking. On their own, the small quantities of each type of find might not necessarily be regarded as sufficient evidence for metalworking, especially as it is a common assumption that the amount of metalworking material, especially waste material, found is related to the scale of metalworking (eg Biddle 1990b, 135). Taken all together, the evidence for metalworking at BAR is substantial, but it needs to be considered in the context of other medieval metalworking sites in order to appreciate the type and scale of the activities.

The major evidence for the industrial character of the Bordesley mills and workshops comes from the structures - in particular the concentration of hearths and the associated ash layers. Industrial residues, especially slags, occurred in comparatively small quantities and could be regarded as additional evidence; these are discussed below. More reliable indicators are the partly worked objects and the general scrap character of the metal assemblages, as reflected in the preponderance of broken objects and the presence of offcuts and objects which had been cut up.

Most evidence exists for ironworking but non-ferrous metalworking, mainly copper alloy but also leadworking, took place. The three activities will be discussed separately, although it is clear that it was often necessary to combine the three metals in order to produce composite items.

Ironworking

Ironworking is usually identified by the presence of slag, incomplete forgings, and metalworking tools (I H Goodall 1981, 51).

The great majority of the slag was from smithing iron; the remainder was fuel ash slag (Table 43). The comparatively small quantities did not occur in concentrations but were mainly found in dumps, walls, and hardstandings, and not in floors near the hearth/working areas (Table 44). The five examples of buns' of smithing slag, usually deriving from the bottoms of concave hearths or hollows near to the source of heat, may not be connected with activity in the mill buildings because all the hearths from periods 4 to 6 were convex and constructed from pitched roof tile and the floors were generally level and without hollows in which the slag could collect to solidify into buns.

A comparison of the quantities of iron objects and slag recovered by period shows that in the periods when many iron objects were found (Table 34) little slag was recovered. Period 4, for example, produced much metalwork, including some incomplete forgings, but only eight pieces (0.37kg) of slag whereas in period 5, which is distinguished by a general dearth of artefacts, including ironwork, there is a relatively large quantity (2.59kg) of slag. It is as if there was an interval between the production of the slag and its incorporation into (what was to become) the archaeological record.

The spatial distribution would suggest that the slag was cleared from the working areas and reused as hard core. (The largest quantity of smithing debris from the 1961-71 Winchester excavations was found in Wolvesey Palace, incorporated into a courtyard (Biddle 1990b, 137).) That slag had been produced in the hearth area is suggested by the cases where slag had adhered to roof tile fragments; all the period 4 to 6 hearths were constructed from roof tiles. The slag may have been carted some distance away from the mills; it is noticeable that the dumps on the south mill pond bank were of roof tiles with no slag and generally very little slag came from BAR. Crossley notes that in the post-medieval period the amount of slag from smithing was anyway likely to be small and could be carted away to be reused (1990, 174).

The quantity of slag produced from a smithing site is of course dependent on the initial quality of the iron brought in. It may be unnecessary to account for the small quantities of slag recovered from the excavation because it could reflect the amounts that were actually produced. Recent calculations show that smithing slag could on the average represent 1% of forged metal, so that even 10kg of slag would be equivalent to about a tonne of artefacts produced (Biek and Fells 1980, 52); but this may vary according to what was produced. The accounts for the Cistercian abbey of Beaulieu in 1269-70, for example, record that about 2 tonnes of slag was produced from working 6 tonnes of bloom ('ferri grossi') (calculated from Hockey 1975, 265-9).

The site also yielded very small amounts of hammerscale from samples from floors which were close to the hearths (Table 45). While this is useful confirmatory evidence for smithing, it is normally assumed that hammerscale remains close to where it was produced, and so the small amounts art potentially puzzling, unless it could have been removed with the slag. Small quantities, however, should be regarded as the norm, and again will vary with the typo of activity (Crossley 1990, 174). Additional material indicating on-site smithing included lumps of ironworking debris and conglomerations of iron fragments which include waste and part-forged objects. The slag also indicates that coal was frequently used as a fuel for smithing.

The iron finds give a further indication of the character of the smithing. The bar iron (28 pieces) was in short pieces, probably unused offcuts, in a variety of rectangular and circular cross-sections.

Such bars were usually drawn down to make smaller objects such as nails and tenter hooks, some of which were found in BAB in a part-forged state. The part-forged material had been worked into bars which were of square section of 4-11mm thickness, suggesting the manufacture of slightly larger items. Goodall (above, part II, 'Iron') notes that, in contrast to the forge from Waltham Abbey, thick (200mm+) bars were absent; the bar iron was similar to that from the Fountains Abbey smithy (5mm thick). However, the bar iron and part-forgings may not completely reflect the range of smithing as the two ironworking tools from the site were punches used to pierce hot iron and are of a (large) size that would have been unsuitable for use on any of the surviving bar or sheet.

The majority of the iron, however, may have been brought on to site as broken objects. While only fifteen pieces have been classified as scrap because of their small size and indeterminate character, a substantial number of the objects from BAB had been broken, some into quite small fragments, and their condition suggests they were brought on to site as scrap rather than for repair. That some objects were brought to the site for repair might be indicated by a curb bit which had been broken into two pieces and which was recovered from two different, but nearby, contexts of the same period (IR 890; IR 928).

The near-complete state of some objects, such as some of the knives, lock and horse furniture, and arrowheads might indicate they were manufactured on site. The evidence of part-forged material demonstrates that timber nails (70 examples) and tenter hook (one example) were made in the mills. The number of nails (2292) from BAB would in itself be suggestive of manufacture.

The drawing down of iron to create bars suitable for nails would have been time consuming (see below, Sim, 'Experience and experiment ...'). The metallographic analysis of the nails and tenter hook (see above, part II, Ridge) shows that the wrought iron was free of slag inclusions and the laminated structure demonstrates that the iron was piled and folded many times. It illustrates the labour-intensive process required to produce such mundane items to a serviceable standard. In such circumstances water-power could have been used to increase production and make it more efficient.

Any further assessment of the quality of the ironworking based on the analyses of the knives and tools has to be conditioned by the uncertainty of whether or not they were produced on site. Although no blanks or 'moods' were recovered from BAB, this is not conclusive as they are comparatively rare finds on similar sites. Most of the knives had been expertly heat-treated by welding a hardened steel cutting edge on to a wrought iron back. There were, however, two cases where the steel had been mistakenly applied to what became the back of the knife, and these might be taken as evidence of manufacture and discard.

The tools which needed a hard edge necessarily had a complex structure of wrought iron and hardened steel, for example the punch (IR 328) and carpenter's chisel (IR 494), which would have required considerable expertise in metalworking and heat control.

The manufacture of iron items larger than nails and tenter hooks often involved working with another material - wood or bone for handles and sometimes another metal in order to fix the object to its handle or intended place of use. Only one of the knives from BAB had a handle, of sheep bone (IR 1308). Sheep (unusually for a medieval rural site) is one of the least well-represented species in the site's fauna1 assemblage and, therefore, could not have been a common local source for knife handles. However, bone knife handles from medieval Winchester showed roughly equal proportions of cattle and sheep, and cattle bone would have been freely available at Bordesley (Hinton 1990a, 865-7; see above, part II, Lovett, 'Animal bone'). The corpus of knives from London shows that wood was by far the most common material for handles there (61:10: Cowgill *et al* 1987, 24) and may suggest that wood handles are under-represented at Winchester. While a variety of wood was used, oak was the least suitable and hard; flexible species such as box, the Pomoideae family, and holly were preferred (Cowgill *et al* 1987, 25). The few tool handles from Bordesley were of holly (eg OB 194.1) which, with other hardwoods, grew in the valley and was thus available for use (see above, part II, Carruthers, 'The valley environment ..').

During the twelfth and thirteenth centuries knife tangs were usually short and did not extend far into the handle. They were commonly fitted into handles by burning or through the use of glue or wedges (Cowgill *et al* 1987, 25). Later medieval knives often had whittle-tangs of a similar length to their handles and could be fixed by clenching the end of the tang. Another, more elaborate, method, and one which was increasingly used in the manufacture of scale-tang knives (none of which was found at BAB), was to attach an end plate to both handle and tang. These were most commonly of iron or copper alloy; the London examples were most frequently made of brass (Biddle 1990c, 860-l; Cowgill *et al* 1987,27).

A brass end plate which came from a period 6 context (CA 139) could illustrate the manufacture and/or repair of composite objects; the casing fragments of sword pommels would also support this interpretation (CA 37; CA 40; CA 41; CA 116). On occasion uncomplicated items like a copper alloy belt stiffener were attached by iron rivets (CA 113). The most elaborate composite object from the site is the ?book cover, composed of an oak board to which had been attached (by leather strips, dyed vermilion, and iron tacks) a leather sheet which had fine iron wire or thread, stitched in close diagonal lines (OB 143). The fineness of the wire, and its flexibility and strength in order for it to be threaded, must indicate considerable ironworking ability.

Some categories of iron objects were plated with a non-ferrous metal, usually tin, in order both to protect the metal from corrosion and to enhance appearance. The categories of plated iron objects from the mills are similar to those from other medieval sites - keys and padlocks, bridle bits, buckles, and furniture fittings such as straps and hinges. More unusual is the armour and the copper-alloy plated animal bell (IR 930). Plating could be achieved through dipping or by rubbing sticks of tin on to a prepared (by the addition of resin to prevent oxidation) and heated iron surface (Tylecote 1986, 112).

Some stone finds from BAB are clearly related to metalworking and iron smithing in particular. The site has yielded ten hones, all of which had had extensive use. Five were of Norwegian Ragstone, imported from the Eidsborg region, four were of Coal Measures sandstone, and another a mud&one/silt&one. Five, including all the sandstones, had evidence of transverse honing and of these most (four) had pronounced grooves as a result of sharpening points. The majority of the imported hones and the mudstone were worn smooth, but showed no sign of coarse honing. This supports the difference in use between the finer imports and the coarse sandstone hones - the former for small blades and craftsmen's tools and the latter for domestic and agricultural blades - which has been noted elsewhere (Ellis and Moore 1990, 869). The hones (and sharpening stones) were concentrated in the east lean-to of the mill buildings, which might indicate that this part of the mill was used for finishing metal items.

Two fragments of local red sandstone (ST 356; ST 508), with areas of wear and sharpening grooves, and a quartzite smoothing stone (ST 509) should also be regarded as finishing and polishing stones, along with the grindstone ST 61 which was probably turned by hand. Another grindstone (ST 60) is larger and could have been rotated mechanically; it is of a coarser sandstone and would have been used for preliminary grinding, especially of larger tools.

Two stones of less identifiable form would in the view of a blacksmith (per-s comm D Sim) have been of use in a forge: one (ST 348), with a flat surface in which had been scored a regular series of grooves, could have been used to remove scale during and after the process of working pieces of iron. The other, a boulder with a pronounced concave surface (ST 524), could be a 'sinking dish', used to beat iron or copper alloy sheet into a curved shape.

These stones further contribute to the evidence for the manufacture or repair of a wider range of iron objects than nails and tenter hooks, being grinding, polishing, and finishing stones to complete a variety of edged tools and dished items of iron, or copper alloy, sheet.

While there is evidence for leadworking within the mill (considered separately below), the metal does have a variety of uses in ironworking. It is possible, for example, that building or domestic ironwork was fixed to stone within the forge, by caulking with molten lead: evidence for this practice can be seen on the ironwork from the church (Rahtz and Hirst 1976, 193). Lead hammers are also used for delicate, low heat work on iron and thin sheets of iron are still today hammered on lead sheeting. Lead sheeting is also manipulated in order to create tanks (?OM 96) for quenching, such as those found at the Fountains Abbey smithy (Atkins 1986, 81-2).

In summary, despite the small quantities of metal residue, traditionally a guide to iron smithing, the structures themselves and the various types of find indicate on-site smithing. There is definite evidence for the manufacture of small, utilitarian objects (which nevertheless were labour-intensive to produce) in terms of the size of the iron bars, the part-forged items, and also the sheer quantity of the finished items found. A considerable proportion of the iron objects found on the site could be interpreted as scrap. Indirect evidence, most notably the sharpening and grinding stones, points to the manufacture or repair of larger items, and those were probably of a composite structure which required materials other than iron, either non-ferrous metals, bone, or wood. The iron assemblage did not alter sufficiently with time to indicate any change in what was made in the smithy.

So far the Bordesley material has been presented as if the ironworking was small-scale because it is commonly assumed that the size of the activity is directly related to the quantities of waste product or incomplete forgings found. To test if such assumptions are justified, the character of the Bordesley evidence is assessed by a comparison of the evidence and interpretations of excavations of other ironworking sites (Table 67).

A very large number of ironworking sites have been identified on the basis of the recovery of iron slag. For our purposes such sites are of limited use, firstly, because there has been much confusion regarding the identification of smelting and smithing slag and, secondly, because this discussion of ironworking requires information other than just the one waste product. We are, therefore, dependent on data from those sites which have been definitely identified as smithies. Smithies have usually been recognised from the occurrence of smithing slag, incomplete forgings, and smithing tools, often in buildings which had one or more hearths or hearth foundations; nearby postholes or pads for a chimney hood; ash layers; pits, variously interpreted as quenching hollows (boshes) or anvil foundations; and small areas of stone slabs seen as

Table 67 Summary of evidence from nine excavated medieval and post-medieval smithies

	Waltham	Chingley 1	Alsted	Goltho	Fountains	Kirkstall	Chingley 2 & 3	Sandal	Bordesley
Date (century)	**12–17th**	**14th**	**14–15th**	**14–15th**	**15th**	**15th**	**late 16–17th**	**17th**	**late 12–14/15th**
Structure									
Walls	stone	–	timber	timber	stone	stone	timber	stone	timber
External size	15.7x10.1m	–	6x6m	7.3x4.2m	6x4m	10x7m	10x9m	6.3x5.5m	6.5x5.3m
Associated workshop	2 lean-tos	–	yes	no	?	no	no	yes	yes
Floor	earth	–	earth	earth	rubble	?	timber	earth	earth
No. of hearths	3+	–	1	2	1	2	3	?1	2
Hearth type	2 p;1 w	–	1w	2 p	1 ?f	1w; 1f	3 f	?	2 f
Chimney hood	yes	–	yes	yes	no	?yes	no	no	no
Setting for bellows	?yes	–	?yes	no	no	yes	yes	no	?yes
Setting for anvil	?yes	–	stone	no	no	3 pits	1 pit	?3 pits	1 pit, 1 stone
Support/pit for bosh	3+ pits	–	?	1 pit	3 of lead	stone	no	stone	?
Residues									
Slags	large	small	yes	yes	no	yes	yes	no	small
Hammerscale	yes	no	yes	no	yes	?	yes	no	small
Ash deposits	yes	yes	yes	yes	yes	yes	yes	yes	yes
Fuel used	ch, coal	ch	coal	coal	?	?	ch	?coal	coal
Bar iron	100+	no	no	no	1	?	?	3	28
Scrap iron	no	no	no	no	4	?	many bits	many bits	16
Part-forgings	1 key	no	no	1 key	no	?	22 nails	8	80
Moods	6	1	no	no	2	?	6	no	no
Tools									
Cold sets	2	no	no	1	no	?	no	4	no
Chisels	1	no	no	no	no	?	no	1	2
punches/drifts	4	no	1	no	no	?	10	3	2
Wedges	no	no	1	no	no	?	?	no	no
Other tools	no	no	no	no	tongs	?	no	nail header	no
Hones/ grindstones	2h; 1g	no	3 hones	?	no	?	no	no	10 h; 4 g
Copper alloy									
Scrap	yes	yes	no	no	yes	?	6	no	?28+
Spillage	yes	no	no	no		?	1	no	3
Lead:									
Scrap	yes	1	no	no	yes	?	2	no	59
Spillage	yes	no	no	no	no	?	no	no	236
Melting hearth	yes	no	no	no	yes	?	no	no	no

ch: charcoal; f: floor level; grindstone or polishing stone; h: hone; p: pit; w: waist-high.
See text for references.

either supports for quenching tanks or bellows.

Seven smithies have been published with varying detail given to the quantities of finds and metal-working residues. (This excludes the late medieval smithy in the west range of buildings in the outer precinct of Tintern Abbey, which produced few structural remains or finds: Courtney 1989, 106–13.) One forge, dated to the fourteenth and fifteenth centuries, was excavated at the medieval village of Goltho (Beresford 1975, 46–7; I H Goodall 1975a, 79–90). Two were monastic forges, one in an apparently purpose-built building at Waltham Abbey which seems to have operated between the twelfth and seventeenth centuries (Huggins and Huggins 1973, 131–42; I H Goodall 1973, 168–77); the other from Fountains Abbey, where part of an aisled building in the outer court was converted to a smithy in the mid-fifteenth century (Coppack 1986b, 50–1, 62; Atkins 1986, 80–2). Alsted was a fourteenth-century smithy close to a secular manor house (Ketteringham 1976, 22–31; I H Goodall 1976, 56–61) and at Sandal Castle part of a bake-house was converted into a forge in the seventeenth century (Mayes and Butler 1983, 50–1; I H Goodall 1983, 240). Chingley is also considered as this is the only other excavated medieval metalworking water-mill: the building, however, had not survived and the artefactual evidence was largely derived from the fill of the wheel pit and tail race, but its inclusion is justified because the majority of the Bordesley mill finds were recovered from the same contexts. By way of comparison the evidence for the succeeding sixteenth- and seventeenth-century forges at Chingley is also considered, although all the Chingley mills were used for working blooms as well as smithing (Crossley 1975, 6-29; I H Goodall 1975b, 60-89; Tylecote 1975, 90-7). Other smithies have been reported in an interim form, such as the thirteenth-century forge from Godmanchester (Webster and Cherry 1975, 259-60), the fifteenth- and sixteenth-century smithy set up in part of the converted west hall of the guest quarters at Kirkstall Abbey (Wrathmell 1987, 16-18), and the thirteenth- to fifteenth-century smithy in the rural settlement of Burton Dasset (Gaimster *et al* 1989, 216-17); where appropriate, information from these sites will be used.

The presence of nine categories of non-structural information can be regarded as suitable for defining a smithy: smithing slag; hammerscale; ash layers; bar iron; scrap iron; blanks or 'moods'; incomplete forgings; metalworking tools; and associated stone artefacts. None of the excavated smithies had all nine categories of information; one had three (Chingley period 1), two had four (Goltho; Chingley 2 and 3), and one had five (Sandal), six (Fountains), and eight (Waltham) of the categories; the Bordesley mills had eight.

The overriding impression from these sites is one of the meagreness of survival. Waltham is very unusual, for example, in having 100+ pieces of bar iron, compared to the three pieces from Sandal or the one from Fountains. Similarly, no site has produced more than eight incomplete forgings (viz Sandal - except the 22 nails from Chingley 2 and 3) and six blanks. There are obvious difficulties in identifying scrap but, where it has been found, it is in small quantities. The slags are often not quantified, but were present on five sites. Much was found in the Waltham forge; the slag from Goltho was found incorporated into a yard and path, which would confirm the Bordesley evidence for the reuse of the material. Hammerscale can usually only be detected if samples are taken, which is often not specified in the reports, but where scale did occur it was usually close to the hearths (Waltham, Fountains).

Ironworking tools were found within every forge building. The most common tools were punches and cold sets, both found in half the forges, then wedges (two sites), and a hot chisel, a cold chisel, and a pair of tongs (one site). The greatest combination of tools came from Sandal - four cold sets, one cold chisel, three punches, and one ?nail-heading tool - and Waltham - two cold sets, one hot chisel, and four punches; the rest of the forges had one tool type represented by only one tool.

Waltham and Alsted were the only forges with associated stone artefacts - two hones and one grindstone (Waltham) and three hones (Alsted) - although an unspecified number of unstratified hones were recorded from the croft in which the Goltho smithy was located.

Three smithies in addition had a small amount of evidence for non-ferrous metalworking, usually in the form of copper alloy and lead offcuts (Chingley 1, Waltham, and Fountains), but at Chingley there was also a crucible fragment, at Waltham some lead melting pits and copper alloy spillage, and at Fountains some copper ore and slag.

Clearly it is hazardous to carry such a comparison much further because it is difficult to make allowances for the obvious variables - the social and economic context in which the smith is working (reflected in our sample from a village community, two monasteries of different orders, an industrial mill in an area of dispersed settlement, and a secular manor), the different ways of running a smithy and of disposing of waste, and, of course, the length of time over which a forge operated, whether continuously or sporadically. As it is likely that quantities of slag offer no real indication of the intensity or longevity of the activity, this may also be true of the size of the artefactual assemblage found within buildings identified as forges, although it is noticeable that the greatest range and quantities of material indicative of metalworking came from Waltham which operated the longest time, perhaps for almost 500 years. Given these considerations, it is understandable that none of the excavation or specialist reports attempt to characterise the activity in greater detail than as general ironworking, which would probably have included farriery.

What the comparison has shown, however, is that the obvious archaeological evidence of ironworking, discussed as criteria at the beginning, cannot be expected in great quantities; what survives from a smithy is not necessarily an accurate reflection of the full range of ironworking which may have taken place. This appears to contrast with the plentiful scrap and residues from late Saxon or Anglo-Scandinavian ironworking in York (Ottaway 1992, 471-510). After allowing for different ways of disposing of waste, it is likely that the paucity of material associated with smithing indicates a high level of reuse and recycling of materials. The (presumed) high cost (in terms of money and labour) of bringing in and working wrought iron would also greatly increase if steel was involved and would, therefore, place a high premium on saving and reusing spare material. The smith was (and is) in the unusual position that the more (s)he worked wrought iron the purer and more valuable it became (because it had been turned into better quality material) and thus offcuts became progressively more prized.

Copper alloy working

The evidence for copper alloy working consists of waste and spillage, partly worked or partly finished objects, scrap, repairs, and the broken character of many of the objects found.

Three pieces of mixed copper alloy with lead and/ or zinc spillage (CA 285; CA 236; CA 287) and the many examples of small fragments of copper alloy debris embedded in conglomerations of iron material (and inaccessible for non-destructive study) provide the main evidence for copper alloy working. Sheets composed of a heterogeneous alloy, where, for example, some areas had a higher zinc content (eg CA 292), are regarded as additional evidence. Mention should also be made of two crucible fragments, recovered during the 1967-8 excavations, which may indicate casting (see above, part II, Nailor, 'Pottery', and Fig 70, nos 59 and 60).

The site produced a few definite examples of part-finished objects, but material of this kind is more difficult to identify in copper alloy than it is in iron. There is the part-punched animal head terminal (CA 45) and the four unused fragments of casings for sword pommels which may have been miscast or broken before they could be attached to the weapons.

The scrap and offcuts - as well as the majority of the vessel fragments - are the most plentiful indication of copper alloy working. Some of the scrap had clearly been cut by shears (CA 190; CA 269; CA 276) and some fragments had been reused (CA 136). The hoarding of scrap was clearly common and the very mixed character of some alloys was probably produced by the extensive reuse of scrap (A Goodall 1981, 63; Blair and Blair 1991, 82-3).

It is clear that copper alloy vessels were repaired on site. Two repair rivets (CA 143; CA 296) were found and, amongst the fragments of sheet vessels, there were several examples of rim repairs (CA 133; CA 265) and pieces of rim that had been salvaged to make a repair (CA 129). Fragments of sheet vessels were significantly more common than those of cast vessels. It is uncertain whether this is an indication that sheet vessels were used more frequently (and therefore needed more repairs) than cast vessels - although, of course, the two types of vessel usually had different functions - or that there was a preference for sheet scrap, which may suggest a more limited technology in the workshop. I H Goodall comments that the slightness of the two metalworking chisels suggests they were used to cut non-ferrous metal.

The objects do, however, illustrate some metalworking techniques, but whether these were practised on site is impossible to say. The preference for working in sheet rather than casting copper alloy has already been mentioned, although crucibles were found. Some types of object which were usually cast can he shown to have been hammered from a bar or rolled up sheet, for example, the needle (CA 271) or brooch pin (CA 149). Holes in fittings were either drilled, sometimes from both sides, or punched; examples of mistakes for both types were found (CA 258 and CA 261; CA 145 and CA 278). Pins were made from wire; some heads were of wound wire which was not punched. Other metals were used in conjunction with copper alloy, iron rarely (CA 113 stiffener with iron rivets), but tin probably quite frequently, for coating such items as the sword pommels, horse furniture (CA 127), buckles, and brooches: the surfaces were normally scratched as a preparation for coating (eg CA 115). The surfaces of some buckle plates and strap ends show striations filled with white metal residues, apparently keying for solder (CA 119; CA 259).

The fittings and studs from BAB can be paralleled in the material which has been recovered from the church excavations (see above, part II, 'Copper alloy').

On those occasions where it has been possible to determine the alloy of an object, it seems that no alloy was used exclusively for the manufacture of a particular type of item. However, the majority of vessel and sheet fragments were composed of tin-rich alloys and the sword pommels were all of a leaded tin-rich alloy. Zinc-rich alloys were used for the pins, and commonly for bindings, straps or fittings, and book or belt fittings. 'Latten' (or gunmetal), applied here to copper alloy with *c* 10% each of tin and zinc, with or without lead, was used in book or belt fittings and buckles. This variety, and the prominence of zinc-rich alloys - brasses - is unusual compared with the (sparse) results from other medieval excavations where tin-rich alloys predominate, although the collections from London are similar (Tylecote 1990a, 131; Hey-worth 1991). Zinc was regarded as a scarce commodity which had to be imported in some form or other - either as raw materials or in an alloy - but scrap could have been used as the raw material in small-scale casting, which is what would have been involved as far as the Bordesley finds are concerned (Tylecote 1986, 39; Blair and Blair 1991, 85; A Goodall 1981, 63). Pins, however, invariably seem to be made of zinc-rich alloys (Tylecote 1990a, 131; Caple 1983, 277; Caple 1991, 250-2).

This evidence is broadly comparable with the material from other sites where copper alloy working has been identified. Generally the range and scale of the activity is very limited which, it is argued, indicates the small-scale nature of the industry (A Goodall 1981, 63). The major evidence for copper alloy working from the other smithies discussed was the presence of copper alloy scrap (most often), spillage, and crucible fragments (Chingley 1, Waltham, Fountains); this material invariably occurred in small quantities.

Leadworking

In the middle ages lead was worked primarily to produce objects of lead or lead alloy and secondly for combination with other materials, usually other metals, such as a copper alloy, to produce other alloys.

The BAB evidence for leadworking can be divided into two parts; casting waste and cutting waste. Casting waste consisted either of droplets of molten lead, which have been observed in the conglomerations of iron fragments and debris, and also the larger runnels or of drips of solidified lead. Although all such debris is usually interpreted as the byproduct of leadworking, runnels and droplets could also be produced as a result of a fire (Biek 1963, 139). That this was indeed the case here can be demonstrated by the greatest concentration of lead runnels, mixed with charcoal and burnt debris, in dumps deposited after the period 3 mill had caught fire. Such evidence must imply that, within an earthfast timber building (which could not have supported a lead roof), lead was being stockpiled. However, a different pattern of distribution of such material in later periods does indicate leadworking.

Where found on its own, cutting waste need not indicate a leadworking site because the trimming of lead would have occurred on many building sites. The variety of the waste at Bordesley was such, however, that it can be regarded as indicative of leadworking. The waste occurred in four forms: indeterminate sheet fragments; sheet fragments that had been salvaged from some roof elsewhere, usually indicated by the occurrence of nail holes but also sometimes by pieces which had sealed joints (OM 184); tightly rolled sheets, regarded as a convenient way to store test pieces of lead or scrap; and offcuts which were often twisted. Many of these pieces had obliquely cut edges and scored lines which presumably were made when the lead was first used.

Very few lead objects were found and the evidence for part-finished material or scrap is consequently limited. The double scabbard chape could have been brought in for repair (OM 24) and a scrap with similar facets (OM 85) may have been salvaged from another chape; both pieces were of a similar, lead-tin, alloy. The two pottery repairs (OM 97; OM 194), with pottery surviving between the layers of lead, were probably scrap. The objects show little variation in alloy, but the manufacture of pendant OM 91 required a sophisticated combination of materials including yellow ochre and cinnabar, for filling decorative fields, and pitch, used to attach the object to a rigid backing. The range of copper alloy objects shows that, if any of these were made on site, high proportions of lead were rarely added to the alloy (usually done to make the more expensive copper and tin go further - three examples exist: CA 121; CA 288; CA 133).

Leadworking is not well represented in other medieval smithies; at Waltham a pit had been used to melt lead, and spillage and/or waste sheet fragments were found in ten contexts (amount unspecified) (a similar leadmelting pit was found at Fountains, but this was thought to have been used to cast the roof lead into ingots in the course of the building's demolition).

Metalworking at Bordesley: summary

The structural and artefactual remains (including waste products) provide strong evidence for ironworking, with some copper alloy working and leadworking. The incontrovertible evidence is for the manufacture of small items such as nails and tenter hooks which would have benefited from water-powered assistance. The subsidiary evidence of tools and stones would suggest that a wider repertory of items was produced. If the evidence of the knives, tools, and 'book cover' is taken for on-site manufacture, then their complex structure would argue that the Bordesley smiths possessed a high level of expertise. However, the general scrap character of a high proportion of the iron assemblage may also suggest that much repairing took place. The range and character of activity would suggest a blacksmithy, with two important exceptions. Firstly, the evidence for the large production of nails which was probably done with water-power-assisted hammers and bellows. Secondly, the evidence for copper alloy working and leadworking would argue for the production of composite items (that is of several materials) which may have required expertise not usually possessed by a blacksmith. The most unusual aspect of the composite or time-consuming items present in the assemblage is the comparatively large sample of weapons and armour. The definite evidence for the production of such material at Bordesley comes from the sword pommel casings, and perhaps the arrowheads (eleven in number) and caltrop, but the damaged material which may have been brought in for repair includes the other pommel (with the Clare coat of arms), the two dagger chapes, and the coat of plates. The large-scale production of nails and the unusual emphasis on weaponry may provide indirect evidence for the production of metalwork beyond the needs of the monastic community (armour has been found at other monastic sites, for example, the Dominican friary at Boston (Moorhouse 1972, 41-2)); the forge was servicing a wider circle which may have included patrons and those who frequented local markets.

Any statement about the intensity and character of the Bordesley forge is dependent on how the other excavated smithies are interpreted. The range and quantity of evidence for metalworking at Bordesley is as great as, if not greater than, that from the other sites; and for none of these is it suggested that the activity was anything but full-time.

The organisation of the medieval smithy

Figures 118 and 119

The previous excavations of medieval smithies can also contribute to the interpretation of the Bordesley forge. Sufficient structural and spatial detail has been recovered to allow some rudimentary comments to be made about the organisation of the medieval smithy.

The range in size of the smithies is difficult to assess as many of the - small - sample were not located in a purpose-built structure. Those at Goltho, Alsted, Godmanchester, and Burton Dasset were built as smithies and were timber-framed structures resting on either stone walls or padstones. Goltho and Godmanchester are comparable (7.3 x 4.2m; 5.8 x 4.5m - all are external dimensions), while the structure at Alsted has been reconstructed so that only the hearth and working areas were under cover. The remaining forges were located within stone buildings, which had often been partitioned, and these smithies were fairly similar in size to the purpose-built examples (Sandal 6.3 x 5.5m; Fountains 4 x 6m; Kirkstall 10 x 7m). Most of the forges, then, were housed within compact buildings. The exception was the large aisled hall at Waltham which was built as a forge and was 15.7 x 10.1m. In addition, there were two lean-tos on the Waltham forge. Attached or nearby buildings, interpreted as associated workshops, occurred at four sites (Fountains, Godmanchester, Sandal, and Alsted).

Floors appear frequently to have been of earth, although rubble and timber were also used. There appears to be no correlation between the floor type and the survival of metalworking residues.

The majority of the forges had two (apparently contemporary) hearths, and often there was a marked difference in size between the two, which presumably indicates they were used for different purposes. A variety of hearths appear to have been in use throughout medieval England. It is customary to classify hearths into pit/bowl and waist-high types, with some suggestion that there was a chronological progression from the former to the latter (Tylecote 1981, 42-3). The classification has, to a certain extent, been influenced by manuscript illustrations. On most occasions the archaeological record makes it difficult to discriminate between waist-high hearths and hearths which were raised slightly above ground level. Waist-high hearths have been claimed at Waltham, Kirkstall, and Alsted, and in the cases of Waltham and Kirkstall there was an additional hearth(s) which was either of the pit or ground-level type. Above-ground hearths were made of stone slabs (Fountains, Kirkstall) or a combination of stone and brick (Waltham). It appears that Bordesley was unusual in having pitched roof tile hearths in periods 4 to 6. Pads or postholes close to the hearth have been interpreted as supports for a chimney hood (Goltho, Waltham).

Anvils have not survived well in the archaeological record. Three pits (each *c* 0.6m in diameter) in an arc close to the hearth at Kirkstall have been interpreted as the successive locations for an anvil, as have three pits at Sandal (each 0.2m square, or they may have been for roof supports), and a stone block at Alsted. But the only surviving anvil bases appear to come from water-powered post-medieval mills such as Chingley 3 and the size may not be appropriate for medieval forges whether manually- or water-powered. Chingley's consisted of a 2m length of oak trunk, *c* 1m in diameter, set vertically in a deep pit and braced with radiating timbers.

More frequently pits within the forge have been interpreted as quenching hollows, such as at Goltho. Clay-lined pits at Waltham were identified by the excavators as smelting furnaces because the pit fills contained some smelting slags. The authors acknowledged the possibility that the pits may have been used for quenching, because some of the initial fills were silty, and this is the preferred view of others (eg Tylecote 1986, 191). Stone settings on the floor have been identified as supports for quenching tanks at Sandal and Kirkstall. The most unusual evidence comes from Fountains where the bases of three rectangular lead tanks were found in situ and interpreted as the lower lining for wooden quenching tanks. The largest was 0.51 x 0.22m and the smallest 0.12 x 0.16m. Stone settings which have been regarded as a suitable support for bellows have been reported from Waltham and Kirkstall.

These are the main features which have been recovered from excavated smithies and they allow some assessment of the working area required by a smith and what was regarded as a convenient distance between the hearth (and bellows), anvil, and quenching tank, or the crucial operations of heating, beating, and tempering. An estimate of this distance has been made by describing the minimum circle to include quenching tank, anvil foundation, and bellows support, whose centre was located in the middle of the hearth: Waltham less than 1m; Sandal 1.4-1.8m; Kirkstall and Fountains 2.25m; Goltho 2.3-2.9m; Chingley (3) 2.6-3.3m. An average arrangement would have been to have *c* 2.0m between the hearth and the furthest tank, anvil, or bellows.

The Bordesley smithy arrangements

The results of this rapid survey can now be applied to the evidence from the Bordesley forges; but this comparison cannot be exact because the Bordesley smithies were water-powered. The stratigraphic sequence has shown the remarkable stability of plan of the mill buildings through the four periods,

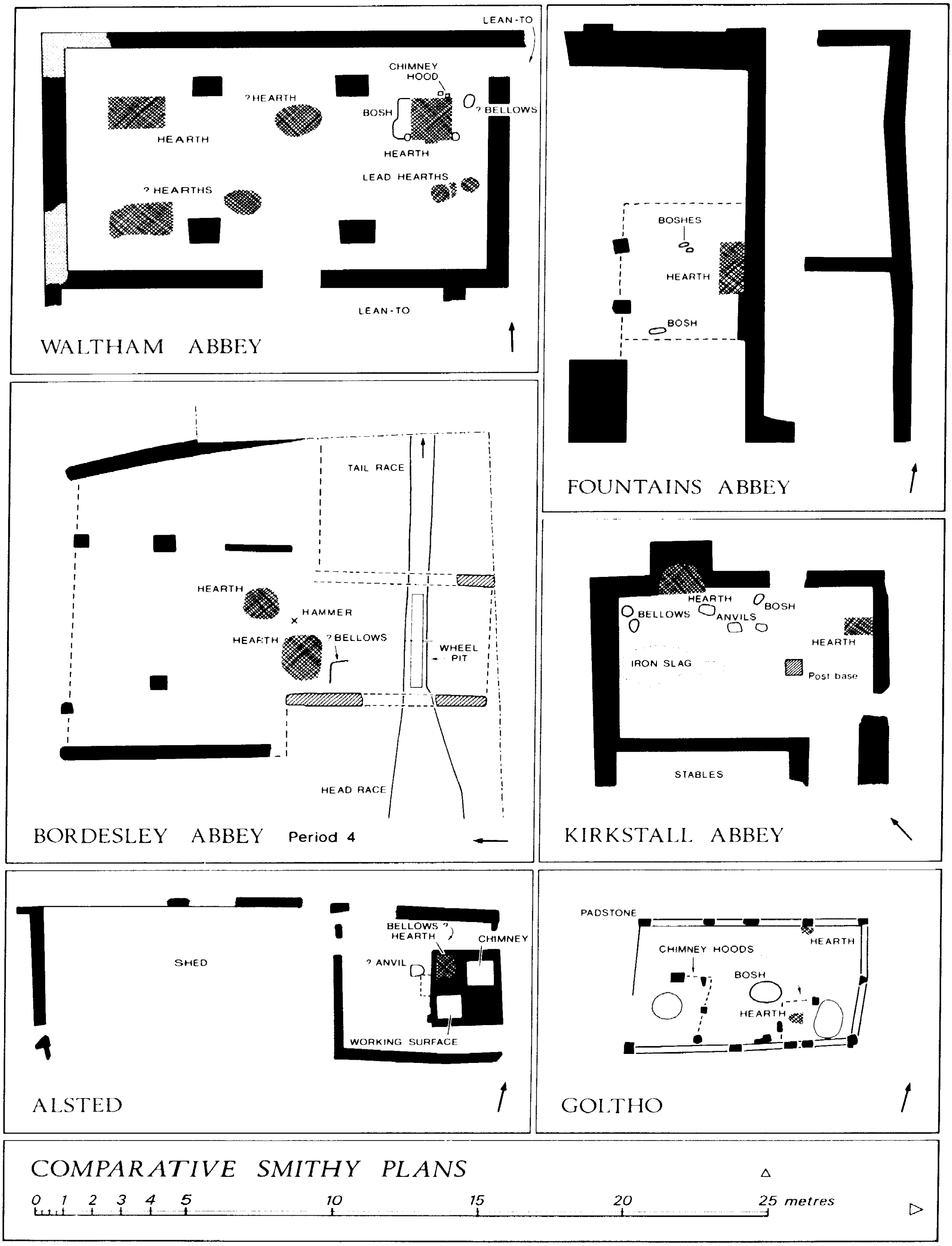


Figure 118 Comparative smithy plans: Waltham, Fountains, Bordesley (period 4), and Kirkstall Abbeys, Alsted, and Goltho

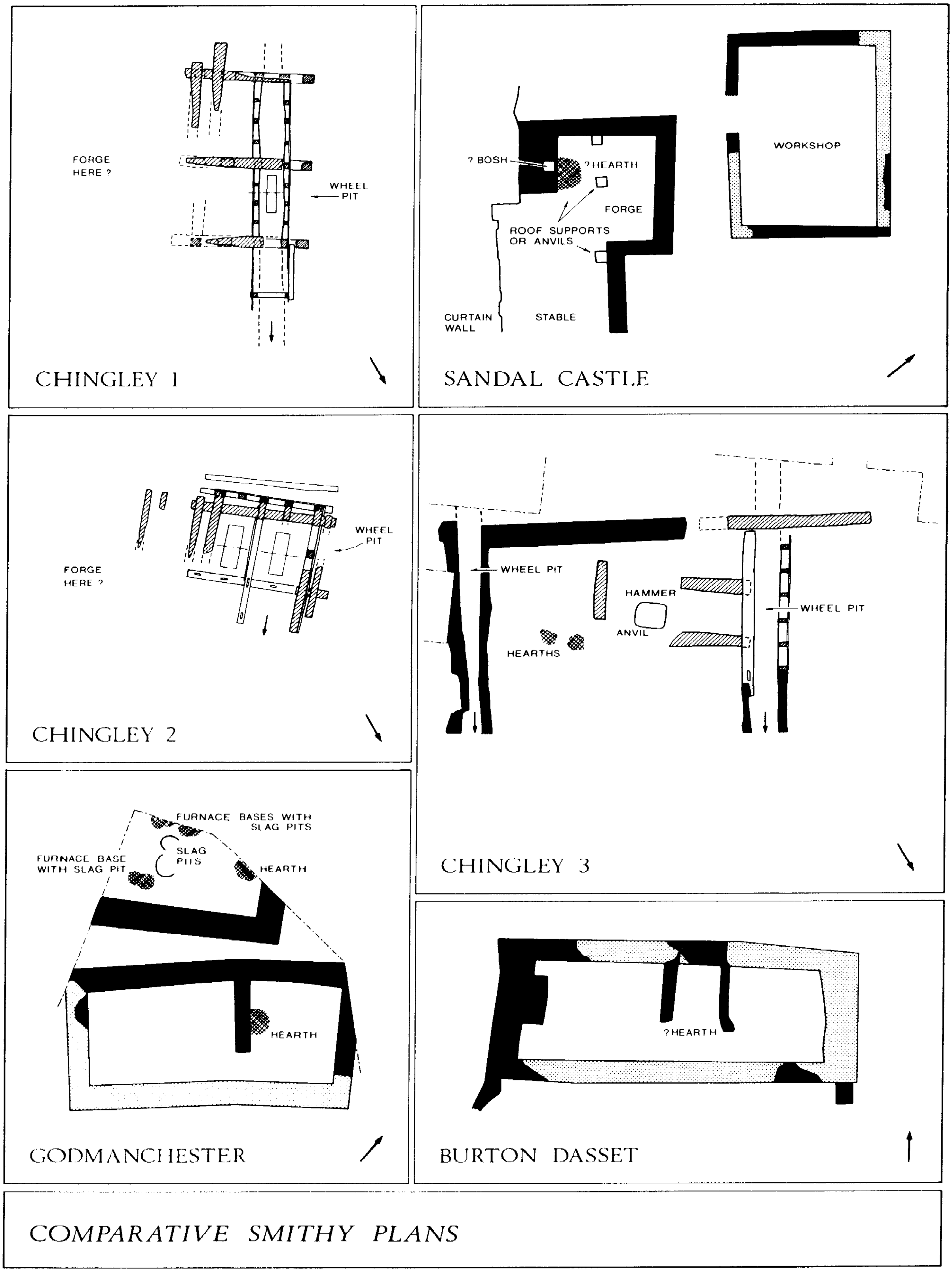


Figure 119 Comparative smithy plans: Chingley 1, 2, and 3, Sandal Castle, Godmanchester, and Burton Dasset

which to a major extent is also reflected in the continuity of location of the hearths. All the buildings consisted of a high, central part, with a wheel house attached to the south and lean-to structures to the north, east, and west sides. The central area, where the hearths and associated features were located, was, depending on period, between 6.5-6.6 x 5.3-5.8m, that is similar to the area of the Sandal forge. Any feature which cannot definitely be shown to be part of a structure has been considered.

Period 3

Figures 8 and 18

The area closest to the wheel pit was dominated by two pit-type hearths of unequal size, the largest (2.3 x 0.9m) similar to that from Goltho, and set against a wall. The two hearths were very close and this must have made using them together difficult. If the mill machinery was used to drive a hammer and bellows, it was necessary for the smith to work close to the machinery, that is to the east and north of the hearths. There were no negative features which could be interpreted as anvil bases or quenching tanks close to the hearths. There was, however, a collection of three pits to the north of the hearths, but, as the nearest was over 3.5m away, it is unlikely that they were used during smithing, It is, however, possible that these pits may have been used in fulling, but they were not large enough for soaking cloths and at too great a distance from the hearths. There is indirect environmental evidence for fulling in the form of the cultivated teazle (see below, 'Other industries within the precinct'). Indirect evidence also suggests a nearby workshop, perhaps used for clothmaking and leatherworking.

Period 4

Figures 11 and 18; Plate 14

During this period the building was rebuilt on padstones, but nevertheless retained the form of its predecessor. The period 3 small hearth was reconstructed in pitched roof tiles and the larger hearth was remade with pebbles set in a shallow pit. Both were in approximately the same position as the period 3 hearths, but *c* 1m was left between the hearths; the hammer could have been placed here and used from both hearths; the area was also covered in stakeholes- With this arrangement, the smith could work from the centre of the building and be no further than 2m from the hammer and the other hearth. However, it still only allowed one hearth to be worked by water-powered bellows.

In the south end of the east lean-to an oval setting of cobbles may have been a support for some kind of machinery; this was also present in period 5.

Period 5

Figures 13 and 18; Plate 19

The large hearth was converted into a pitched tile hearth with a sandstone curb and, initially, it was used in conjunction with the period 4 small hearth, This small hearth was then considerably enlarged, again with pitched tiles, and roof tiles which were laid around the hearth may have acted as a support or setting for tools or indeed a quenching tank. The space between the two hearths remained and in that space a large stone (0.88 x 0.66m) was laid, which may have been the foundation for an anvil. The putative machinery arrangement would have remained the same. The area over which the smith would have had to move between hearth, hammer, and settings was 2.5m. There was little change in the east lean-to, although a new timber-framed building constructed to the east of the lean-to may have been an additional workshop. In the west lean-to a further setting was built, for an unknown purpose.

Period 6

Figures 15, 17, and 18; Plate 23

In phase 1 the large hearth was surrounded by sandstone slabs which could have been supports for tanks. They were, however, heavily burnt and so could have been part of the actual hearth. The period 5 machinery arrangements would not have needed to be changed.

In phase 2 the east (smaller) hearth was abandoned and was rebuilt further east on a smaller scale. This was accompanied by the construction of a partition wall to the north partially to enclose the hearth. The large west hearth was apparently abandoned: a pebble wall was laid across the hearth and the rest of it covered with tiles. The rebuilt workshop with its waist-high hearth to the east of the mill building may have been used instead.

The abandonment of one hearth and the relocation of another would have made it extremely difficult to get either powered bellows or a trip hammer close to the hearth and it is argued that water-powered machinery was abandoned. It would also probably have made the large stone anvil base redundant, and in this period a deep hole was cut nearer the hearth, interpreted as the foundation for an anvil (0.62 x 0.53m). If the stone anvil base had gone out of use, the distance over which the smith worked would have beeen *c* 1.2m; if the stone anvil had been in use, the distance would have increased to 2.0m, so both arrangements would have been convenient for the smith.

Intra-site activities as reflected in the distribution of metalwork by V Wass

All the metalwork was plotted three-dimensionally with the exception of the large quantities that were recovered from some of the tail race silts, and these were recorded by 1m square. The following discussion is largely based on the distribution of metalwork within and around the building because there is a greater chance that that distribution reflects how the material was initially discarded, in contrast to the material in the tail race silts which is more likely to be secondary refuse. While it is possible to discuss the distribution of individual classes of ironwork, the comparatively small numbers of copper alloy and lead objects (lead, see 'Other metal' on Figs 120-4) mean their distribution can only be treated in general terms.

Period 3

Figure 120

Because this period lasted for such a short time *(c* twelve years), and because very few floor levels were identified, the metal assemblage is small and mainly concentrated in the tail race. Iron objects, especially nails, were common. There was no copper alloy and one lead offcut.

Period 4

Figure 121

This period produced the second largest collection of metalwork. Nails were the most common iron objects, and most were shanks and of types 1 and 5 (see above, part II, Goodall, 'Iron'), although the collection from the tail race was more varied with a greater number of shanks. Most classes of ironwork were present in the building and the tail race, but tenter hooks, lock furniture, domestic ironwork, and arrowheads were only found in the tail race, as were most of the metal-, wood- and leatherworking tools.

Most classes of copper alloy were represented, and most pieces (18/22) were from the tail race. The lead distribution is distorted by the large number of runnels from the north-east of the building, where the burnt debris from the period 3 mill was dumped.

The metalwork generally (ignoring the concentration of lead in the north-east of the building) was concentrated in the north part of the building and on the lines of the west and north lean-to walls. The hearths were not a focus for finds and, indeed, the objects associated with metalworking were considerably removed from the hearths - the copper alloy casting waste was in the tail race, the bar iron and lead sheet in the north-east part of the building. The lean-tos, especially the east lean-to, had very little metalwork, although it has been noted already that most of the hones came from the east lean-to.

Period 5

Figure 122

This period is remarkable for the general dearth of artefactual material. With the exception of the knives, studs, and horse furniture, which were only found in the tail race, all other classes of ironwork were found in both building and tail race. All the copper alloy and the vast majority of the lead was from the tail race. Unlike period 4, when most of the material from the tail race came from the silts, the period 5 metalwork came from the filling of the trench for the tail race structure, including dumps to make up the sides of the tail race, or dumps on the south bank of the tail race. It was thus deposited during the construction of the period 5 tail race. The implication is that the metalwork may have derived from the previous period(s) and not period 5.

The distribution within the building was no longer focused in the north of the building, but in the central area, to the north-west of the hearths. The hearths, however, had few finds.

Period 6

Figure 123

Period 6 produced the most iron and copper alloy of all periods. No tools, building ironwork, horse furniture, nor buckles were found in the building; nail types 1 and 5 were dominant, as in period 4, although there was a large number of shanks. The vast majority of the copper alloy (28/31) came from the tail race silts. The distribution within the tail race was different from previous periods. No metalwork came from the wheel pit and little was recovered from the majority of the tail race silts. Instead, there was a very large concentration in the east end of the tail race, especially between the timbers of the modified structure; it probably continued east beyond the excavation. It is difficult to account for this change. One hearth went out of use and another was relocated in phase 2, when the metalworking had probably ceased to be water-powered. But what perhaps had more influence on the distribution was the construction of the smithy in the building to the east of the mill, and so any dumping of debris from here might have been in the part of the tail race closest to that building.

There is also a change in the distribution within the building. The hearths were reduced in number and size, and relocated. The metalwork, however, continued to be deposited away from the hearths. There was a concentration to the north of the

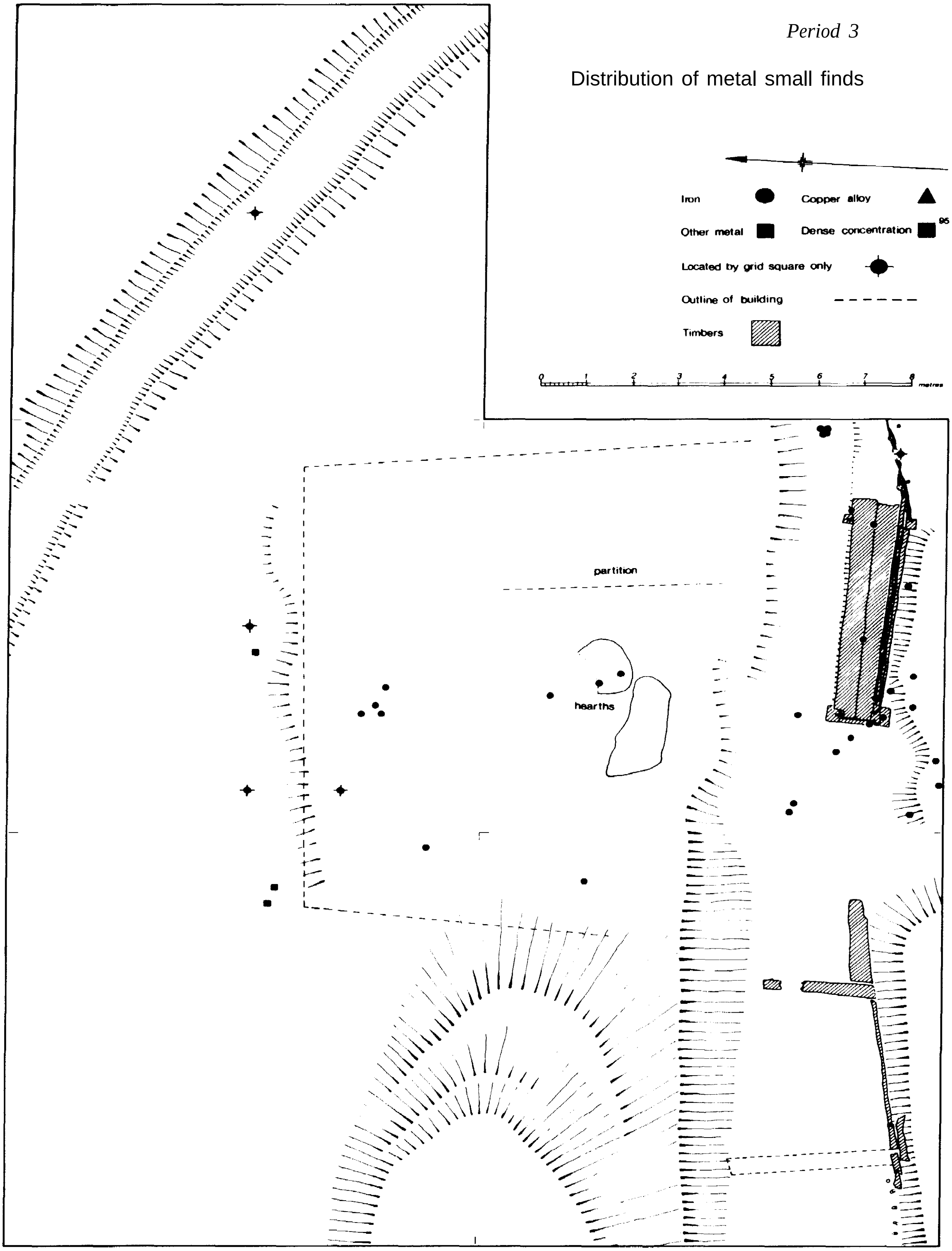


Figure 120 Mill (BAB) distribution of period 3 metal small finds

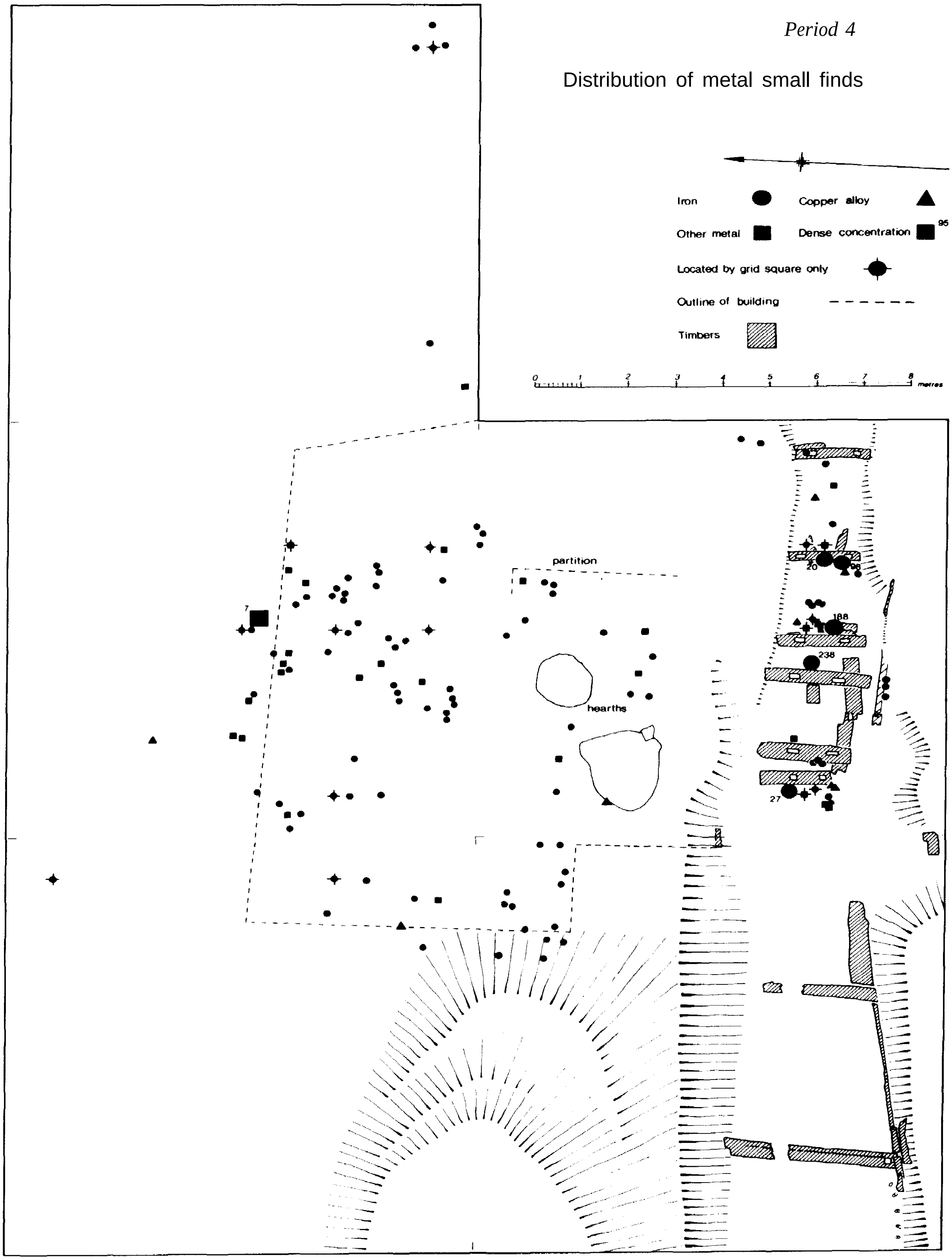


Figure 121 Mill (BAB) distribution of period 4 metal small finds

Figure 122 Mill (BAB) distribution of period 5 metal small finds

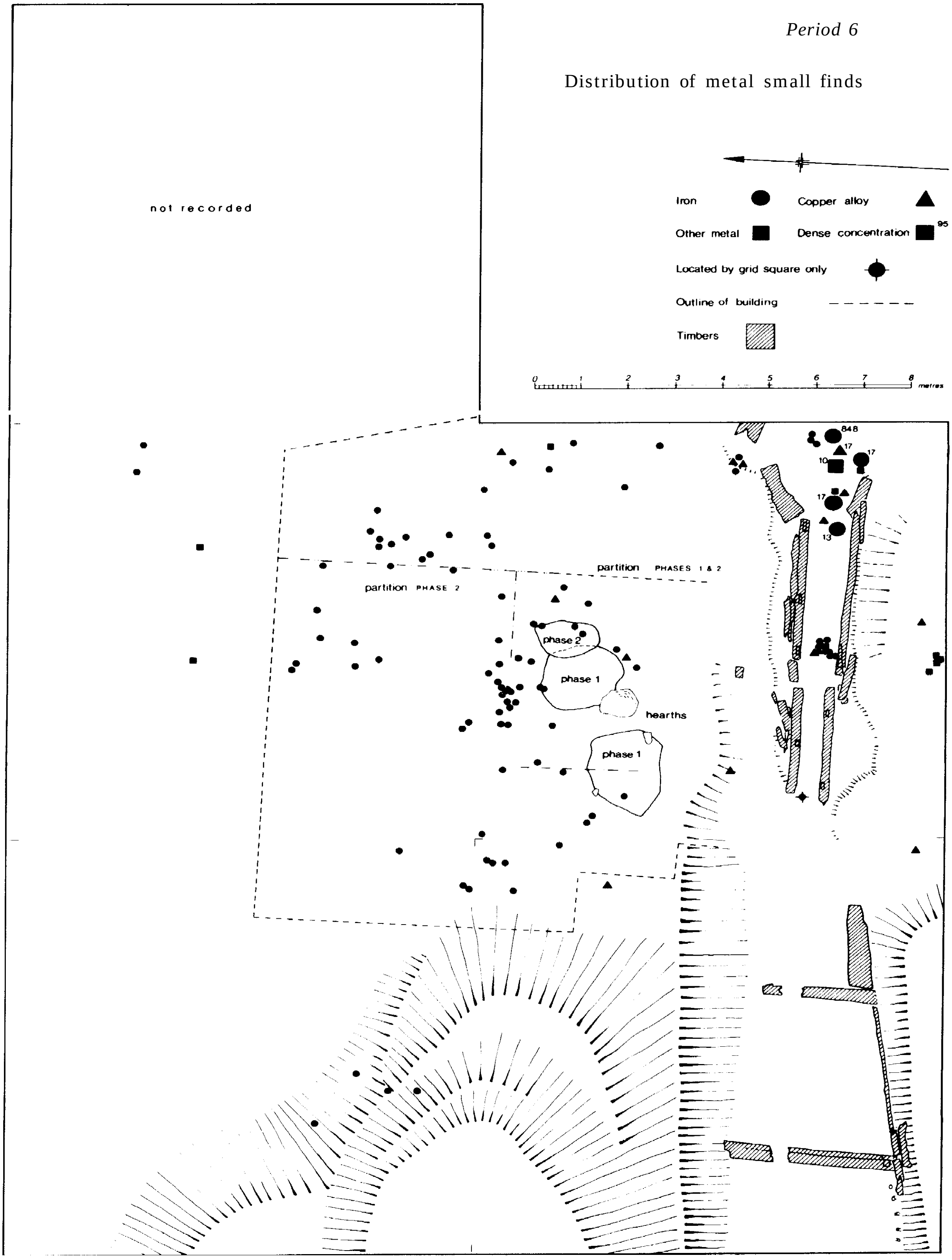


Figure 123 Mill (BAB) distribution of period 6 metal small finds

hearths, associated with a particularly ashy floor level, and in the north-east of the building, especially in the north part of the east lean-to.

For the first time metalwork is found in quantity in the south-east part of the east lean-to (and this might just be related to the increased activity taking place in the new workshop immediately to the east). Metalwork is also found in the west lean-to, apparently concentrated around the possible internal structure there. Also for the first time a small amount of ironwork was found to the west of the building, scattered on the east end of the millpond bank.

Period 7

Figure 124

Virtually all the metalwork of this period is related to the abandonment of the period 6 mill rather than the (later) haphazard accumulation of material produced by occasional frequentation of this part of the valley.

The distributions are extremely different from the preceding periods. The proportional division between tail race and building was completely changed with little coming from the tail race and the majority from the building environs. However, there was no difference in the distribution of the types of ironwork, with the exception of the studs, which were only found in the tail race, and the armour, which was found outside the building.

The eastern emphasis within the tail race continued and for the first time there was a quantity of ironwork from south of the tail race.

The distribution within the building was similar to that of period 6, but most remarkable was the thick scatter of material to the north-west and also to the north of the building. This pattern may in fact reflect two different periods of activity: that within the building representing the residue from metalworking within the period 6 mill (indicated by the largest collection of bar iron, scrap iron, and part-forged material of any period, and also knives and tools), and that without the dismantling of the building. That the exterior distribution might be associated with the demolition of the building is suggested by the nails, the most common piece of metalwork, which have a much higher proportion of shanks than at any other period: the nails may have been used and may represent the residue from salvage work (types 1 and, unusually, 2 were the most common).

Discussion

The most significant result of these distributions is the changing proportions of metalwork in and around the buildings and in the tail races. For the periods where there is a large amount of material, especially periods 4, 6, and 7, it is possible to see a definite change in the disposal of metalwork between periods 4/6 and period 7. The amount of metalwork in the tail races as a proportion of that in (and around) the building changed little between periods 4 and 6 - 17:l and 15:l - which would argue that there was little difference in disposal during these periods. The tail race:building proportion in period 7 is, however, 1:5 and demonstrates the cessation of metalworking activities and the abandonment and dismantling of the building. The variation in the types of ironwork over the whole site does not appear to be significant.

The distributions within the mill buildings are less easy to interpret, but it is clear that the metalworking areas, assumed to be close to the hearths, did not yield quantities of metalwork, let alone the types which demonstrate metalworking such as bar or scrap iron or casting waste. In some cases, for example, in period 4, the metalwork appears to reflect the distribution of waste materials such as the slags, which tended to be incorporated into walls or hardstandings. But, in general, the material was concentrated within the central part of the mill building, and it was only in period 6 that there was any appreciable amount in the lean-tos or outside. The greater spread of metalwork during this period may be a reflection of the presence of the workshop to the east of the mill.

Experience and experiment: a blacksmith's comments on the ironworking by D Sim

The following are some comments on the material from the BAB excavations, based on my experience as a professional blacksmith and experimental archaeologist.

Fuel

Coal and charcoal were both used on site, but it is not clear which fuel was used for which specific smithing activities. Coal will produce a high temperature and will reduce production time and fuel consumption. It can be used for most processes in blacksmithing, but only certain types are suitable for forge welding. Coals with high sulphur content make forge welding very difficult and charcoal is often preferred.

Quality of material

Wrought iron is refined by heating and hammering to remove as much slag as possible. This reduces the cross-sectional area and increases the length of the billet (consolidated bloom). The quality of wrought iron can be determined by the quantity and size of the slag inclusions. In poor quality iron these inclusions are large and will cause severe cracking when any attempt is made to forge the material into thin sections. Therefore if thin sections are required, as here in the

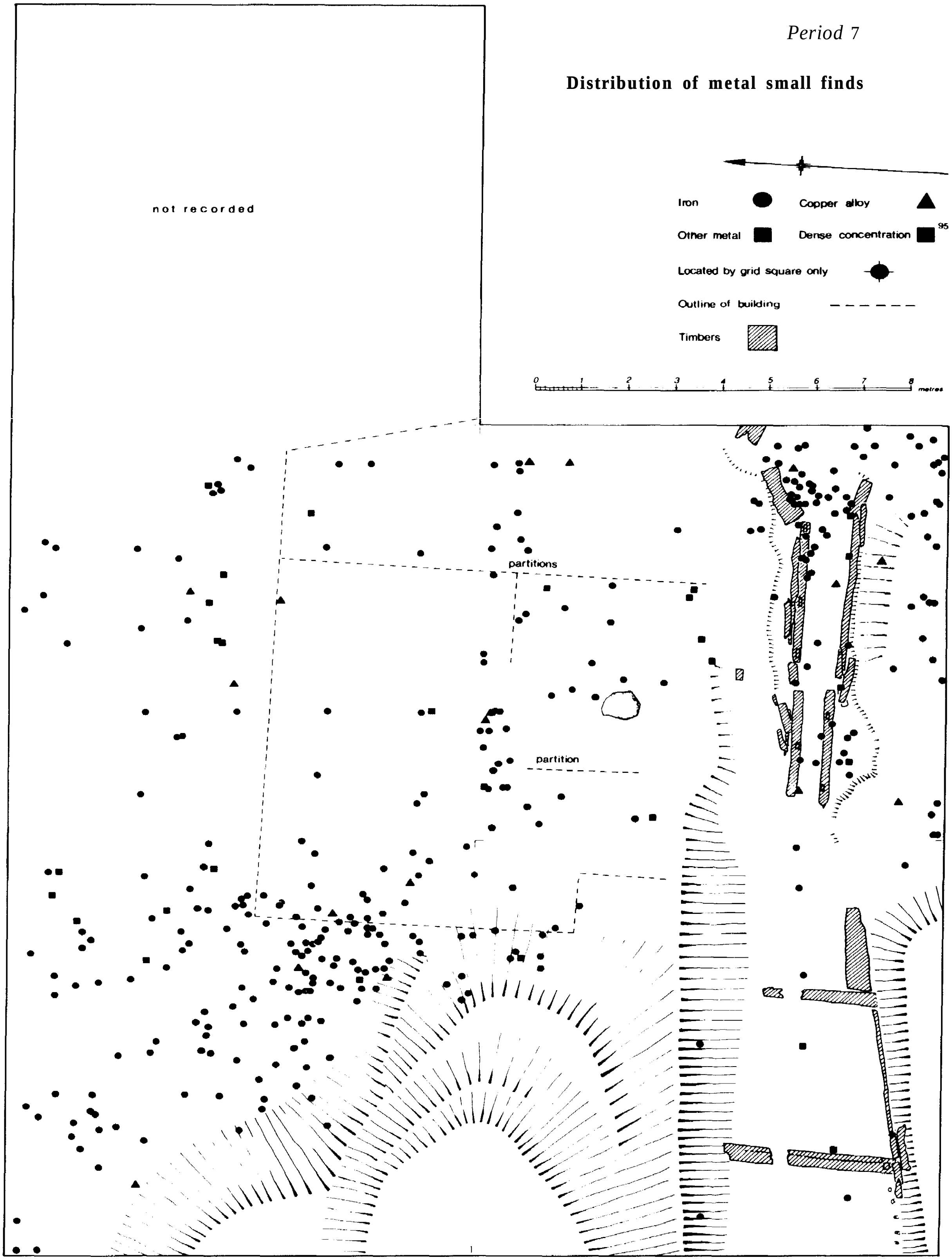


Figure 124 Mill (BAB) distribution of period 7 metal small finds

production of tenter hooks, the material can only be brought to the necessary quality by a considerable amount of refining. Experiments by the writer have shown that drawing down iron into fine wire requires high temperatures and heavy hammer blows.

Recycling of scrap

Scrap, wrought iron can be recycled by forge welding pieces together to form billets. If done correctly, all traces of the individual elements will merge into a homogeneous structure and it will be impossible to determine if the billet is made from scrap or direct from bloom iron. These billets would be drawn down into bar and re-forged into new artefacts.

Experimental work to make tenter hooks and nails

A short series of experiments was carried out to produce nails and tenter hooks of the type found at BAB. The objective was to determine the production time and the quality of material needed.

In order to make a tenter hook of 3mm square section from wrought iron, the following procedure was adopted:

(1) heat iron to welding temperature and draw end to short square point;
(2) heat to yellow heat, draw end to long square point;
(3) heat to red heat, cut required length from bar;
(4) hold forged end in tongs, heat to yellow heat, and draw end down into short square point; and
(5) heat to yellow heat, draw down to long square point, bend through 90°, quench in cold water.

The metallographic report (see above, part II, Ridge) shows the tenter hook that was analysed was made from wrought iron. It was work hardened at the bend only and this could have been achieved either by bending at room temperature or by hammering the tenter hook into, for example, a wall. The water quench at the end would not increase the hardness. It took 3.75 minutes to produce one hook. With practice this could be reduced to well under three minutes. The quality of the iron must be high enough to allow it to be drawn down to a c 3mm square section.

Small nails could be made in 2.2 minutes, but again, with an improved technique, the production could be less than two minutes.

Range of iron objects found

The range of items found would indicate that the smiths had a high enough level of expertise to allow them to deal with some of the more difficult processes of ironworking. The forge welding of steel to iron to make knife blades was a common enough process but this does not detract from the skills necessary to achieve this. The standard of heat treatment also shows a good level of competence. The variety of items found, including the armour in period 7, indicates work of a specialist nature.

Mechanisation

The trip hammer proposed for periods 3, 4, 5, and 6 (phase 1) would reduce the number of smiths required for the manufacture of finished items. It might be assumed that some material was delivered to the mill site in the form of ready-made billets; these would need to be reduced into smaller cross-sections for forging into small objects such as nails, and a trip hammer would be an ideal tool for the purpose. A trip hammer is, of course, also ideal for the recycling of scrap to make billets, for example. A precise figure for power output is unknown, but a hammer could replace more than one smith.

Until recent times, most blacksmiths worked with a striker who stood opposite the blacksmith and, when instructed, struck the iron with a sledge hammer. This arrangement allowed the smith to hold the work in one hand and a tool in the other. A trip hammer would replace several strikers and, if they worked in rotation, many smiths could share one hammer.

Workforce

Any assessment of the size of the workforce is bound to be speculative because the exact nature of the work undertaken is unknown. The use of water-power in periods 3, 4, 5, and 6 phase 1 implies a large output of iron objects. When the large hearth was in operation it is quite possible, with close cooperation, for as many as six smiths to have used it at any one time. In addition, two smiths could have worked the smaller hearth. A workforce of eight smiths is, therefore, possible in periods 4, 5, and 6 phase 1. A smaller force of four to five is more likely in period 3, and for period 6 phase 2, when there was no water-power, two or three smiths could have worked the single hearth in the mill building. A similar number could have used the hearth in the workshop.

Hearth arrangement

The proximity of the period 3 hearths would have made them dangerous and difficult to use. The large hearth could have been a communal hearth which could have been used by several smiths, all of whom would have been engaged on similar work, like nail making; or it was used for heating large cross-sections of iron such as billets that were to be forged down to bar stock.

In periods 4, 5, and 6 phase 1 the arrangement of the hearths was the same and so the work system proposed for period 3 could have continued. The increased space between the hearths in the later periods would suggest that it was important for both hearths to be worked at the same time. In all periods the smaller hearth was probably used for heating small pieces of iron and could have been used for final production work.

The burning of charcoal does not produce large amounts of smoke after lighting, but it does produce carbon monoxide. Even in a room with reasonable ventilation the effects of the gas are felt within an hour, making work impossible. A chimney over the forge hearth is usually the most efficient way of expelling fumes. The absence of evidence for chimney hoods in the mill buildings probably indicates they were unnecessary. The considerable height of the central part of the building as reconstructed (Frontispiece and Figs 112-14), with possible open gables and the probable absence of panelling in some wall sections, would have created sufficient ventilation to give reasonably comfortable working conditions, as well as providing an updraught.

Other industries within the precinct

The excavations of BAB, BAE, and BAH have produced considerable evidence for other industrial activities; it is, however, often difficult to interpret. There are, for example, metal objects associated with particular activities, but there is the strong possiblity that such items were brought on to site as scrap or for repair, rather than for use; it follows that, on its own, such material cannot be used as evidence for particular industrial activities in or near the mills. More acceptable are the cases where objects made of several materials but used in the same industrial activity have been found, often of the same period, and the following discussion is based on this criterion.

Textileworking

The mill and its environs have produced evidence for several stages of textile production and processing, most of which relates to periods 3 and 4, that is mainly during the thirteenth century.

Most data are concerned with clothmaking, which is usually assumed to have involved wool. Given this, it is worth noting that the animal bone assemblage is unusual for the low proportion of sheep represented; and the assessments of age suggest animals were killed when comparatively young, sufficient perhaps only to obtain several clips before being used for meat. These animals then were not bred for intensive wool production. The implication is that wool was brought in, also suggested by the fact that large byres have rarely been identified in the precincts of the larger Cistercian monasteries (Coppack 1986a, 129-30). Large woolhouses for storage and processing, however, have been identified, often in the outer courts; that at Fountains appears to have been used for fulling in the fourteenth century (Coppack 1986b, 56-7).

The period 4 fill of the bypass channel produced a collection of wooden artefacts identified as weaving tools: a warping board (OB 315), a heddle horse (OB 35), a winding stick (OB 341, and a bone needle (WB 35). All these implements would have been used with a horizontal loom.

There is, however, more evidence for the finishing of cloth. Especially interesting, and prominent, were the remains of the fruit and bracts of fuller's teasel, a cultivated species, which occurred in the period 4 bypass channel fill. Smaller quantities were found in later contexts in the tail races, which may suggest some plants had escaped to colonise the leat banks (see above, part II, Carruthers, 'The valley environment ...'). Teasels were specially grown for raising the nap of cloth after the material had been fulled and stretched. The fruits and bracts were the parts of the plant used in this process and such remains are regarded as a strong indication of cloth finishing. Carruthers also draws attention to the prolific remains of nettles in the bypass channel which may indicate accumulations of organic waste; she notes that cloth was often soaked in cow dung and urine in preparation for being fulled, and suggests that the channel was used for such a purpose. By period 4 the channel had ceased to be the bypass of the mill and had acquired enough silt and rubbish to have a V-shaped profile. The construction of a sluice gate in the north-west part would have enabled the ditch to be divided into sections, each with different amounts of water; this would have facilitated such operations as cloth washing and soaking.

While the botanic evidence for cloth preparation from BAB is good, the archaeological evidence is ambivalent. This is not unusual - very few medieval fulling sites have been identified and excavated and even in the sixteenth and seventeenth centuries, when fulling was the only stage in textile manufacture which required large specialised structures, the archaeological remains have been found to be very slight. Without the fulling stocks, few distinct traces survive; even the occurrence of fuller's earth is exceptional (Crossley 1990, 217-18).

The metal finds, however, need to be taken into consideration, even though they may not have been used on site. Firstly, is the evidence of the tenter hooks. Tenter hooks are usually thought to have been used for stretching cloth after it had been fulled, but as Goodall notes (above, part II, 'Iron'), the hooks were also used to hang roof tiles and tapestries. Those found at Winchester have been connected with clothworking because of their occurrence in the tenements associated with fulling and dyeing and because the hooks were found in phases before ceramic roof tiles were introduced (I H Goodall 1990a, 234-5). Most of the Bordesley examples are smaller than those from Winchester which may merely indicate that they were intended for use on smaller pieces of cloth: on the basis of the thickness of the roof tiles from BAB (above, part II, 'Ceramic roof tiles and fittings'), the tenter hooks would have been too small effectively to secure tiles.

Seventy tenter hooks were recovered from BAB, and one of these had been incompletely forged, indicating that these items were probably manufactured this site (see above 'Metalworking at Bordesley ...'). While the greatest quantity (30) occurred in period 4 contexts, the period for which there is most evidence for cloth processing, the finds did not concentrate with the rest of the cloth evidence in the bypass channel, but with the majority of the metalwork in the tail races and buildings, which may indicate a distribution resulting from manufacture rather than use.

The harbick, or sheer board hook (IR 971), was also from a period 4 context and potentially indicates a highly specialised aspect of cloth finishing. Harbicks were used in pairs to secure a cloth to a cropping board so that the nap (of the cloth) could be sheared (Goodall and Keene 1990, 239). Neither of the hooks survived on the Bordesley example and there were no traces of fibres, which may indicate that it was brought on to site as scrap.

The excavations in Brook Street, Winchester, and the Fountains Abbey woolhouse are two of the few instances where fulling has been suggested. In both cases the evidence for fulling is less plentiful than that for dyeing. The buildings in which cloth preparation took place were not characterised by quantities of residues from the processes but by large circular 'oven' structures or furnaces, which were used for heating the liquids in which to steep the cloth, and by extensive evidence for the provision of running water (Keene 1990a, 208; Coppack 1986b, 58-62). The Bordesley mill buildings did not have similar structures.

Yet it is tempting to argue that the watermills of periods 3 and 4 were used for fulling because that is the direction the Bordesley environmental and the general documentary evidence would lead. The earliest references to watermills being put to industrial use concern fulling and are close to the time when the period 3 mill was constructed: these early mills were also often in Cistercian hands. In addition, it has been argued that, given the heavy investment of building a mill, the most profitable industrial use for a watermill would be for fulling (Holt 1988, 158).

We should, therefore, reconsider the possibility that the mills were involved with fulling. Most of the evidence for cloth finishing comes from period 4 and, therefore, it is the period 3 and 4 mills that could potentially have been used for fulling. As mentioned already, the major objection to such an interpretation is the lack of the 'furnaces' recognised at Winchester and Fountains and the absence of foundations for vats or large pits for steeping. In period 3 two pits had been dug in the north half of the building, but they were not of a suitable size for soaking cloth and were an inconvenient distance from the hearth areas.

Another important consideration is whether a watermill could be put to two uses at the same time. The evidence of bar and scrap iron and part-forgings plus metalworking residues for periods 3 and 4, in combination with the hearths, is strong evidence for water-powered metalworking. Could these mills have also been used for fulling? The mechanical requirements of both metalworking and fulling were essentially the same - the provision of tilt hammers. A recent reconsideration of the evidence previously advanced for multi-purpose mills (Tann 1967) has shown it to be ambiguous. Holt argues that the vast majority of documentary references to water-mills show that mills were invariably used only for one purpose. If two sets of machinery were driven off one water wheel, which is often implied in the term multi-mill, it would have been necessary to cease both operations for repairs on either because a disconnecting device was unknown to medieval millwrights (Holt 1988, 131-2).

It is, of course, possible that two mechanisms could have been driven off the one Bordesley wheel, but a consideration of the possible machinery arrangements within the mill building has shown that there was limited space, even for one set of machinery.

Holt thinks it likely that most multiple mills were in fact two mills, one on each bank, with two wheels which existed side by side in the same leat, perhaps under a single roof. There were, therefore, two main shafts which could, if required, be put to different uses (Holt 1988, 131-2), as occurred on Bordesley's Bidford grange where corn and fulling mills operated under the same roof (in 1534, PRO E303/20/42). Such an arrangement would have been impossible at Bordesley, firstly, because the leat was too narrow for two wheels, secondly, because the area to the south of the wheel pit was too low for another mill building to use the leat, and, thirdly, there was no evidence for any building on the south side of the leat until period 6 phase 2 when the water wheel had ceased to function.

We have, therefore, to conclude that the periods 3 and 4 mills were probably not used for fulling, but this is not to deny that cloth finishing took place within the precinct, in all probability close to the watermills. Indeed, the range of materials from the fill of the bypass channel was so different from that from the mill race as to suggest that the material was derived from another building close to the mill (but not found in the excavation) - perhaps a workshop (or workshops) for weaving, cloth finishing, and leatherworking (see below) - which was demolished at the same time as the period 3 mill.

During the twelfth and thirteenth centuries the different processes in clothworking were often carried out in different locations and, although the arrangement was particularly characteristic of towns and their suburbs (Keene 1990a, 208-9), it may also have been appropriate for a monastic precinct such as Bordesley. The watery areas around the mills, for example, were suitable for the cultivation of teasels and the ditches existed for degreasing and cleaning cloth. The metal, weaving tools were produced in the mills, but the process of fulling may have taken place elsewhere, perhaps closer to the outer court, as was the case at Fountains in the fourteenth century.

Botanic remains also indicate that the valley was used for the production of other textiles. The large quantities of flax seeds and capsules from the silts of the (recut period 3-6) course of the Red Ditch alias the Batchley Brook, which flowed on the south side of the valley, probably indicates that the watercourse was used for retting. The water from this stream was not used to feed the mill pond, or indeed any other pond, and thus could have been used for retting without impeding the water supply system. The proximity of medieval fulling mills and retting pool complexes has been noted in Lancashire (Higham 1989). Both linen and linseed oil could be obtained from the plant, but it is interesting to note that stem fibres of flax, or bast, were used as a stitching material for shoes (eg OA 156.1; OA 157). Flax is a plant which requires damp conditions which may also suggest that it was grown in the valley.

Leatherworking

Evidence for leatherworking can be drawn from the ironwork and the surviving leather (see above, part II). Tools used to pierce leather - seven awls and one needle - were some of the most common tools from the site; three of the awls, the most for any period, came from period 4 contexts, the period (late twelfth and thirteenth centuries) which produced most leather.

The most prolific evidence is the leather itself. The greatest amount came from period 4 and of that 94% came from the fill of the bypass channel. The discussion of textileworking has already indicated the possibility that a workshop for cloth-making and leather-working existed close to the period 3 mill. A high proportion of the leather was offcuts or waste, most frequently from shoes, including shoe parts which had been salvaged and repair pieces. The character of the assemblage clearly points to cobbling rather than the primary manufacture of footwear. However, there is some evidence for a more diverse industry. The large sheets indicate that larger items such as bags were probably made and/or repaired. The scabbard fragments are also a reminder that many of the metal objects probably made in the mill could only be completed with the addition of leather parts, for example, the chape, the belt and strap ends, the belt fittings, the horse furniture, and the book cover'.

The vast majority of the leather used was cattle hide, but calf and goat/sheep was used for the large sheets, and the pieces appear to have been stitched with bast, which would have been available from the valley (see above). The watercourses were not, however, apparently used for tanning, for neither insect nor plant remains associated with this process were found. The prepared leather, then, appears to have been brought in (in the late twelfth and thirteenth centuries), probably from another part of the precinct. A shoemaker's workshop and tannery within the precinct is mentioned in 1396 (E315/32/135).

The animal remains are difficult to interpret in this context and need not directly relate to the leather-working. However, there is a preponderance of cattle over pig and sheep, which might suggest that cattle hides were more frequently available than those from sheep. The most common cut marks found indicated chopping on the cattle bones which, it is thought, could have been produced during skinning (wherever that took place); similar marks were found on a few red deer and horse bones.

All the evidence points to small-scale activity which was primarily geared to the repair of shoes, although the demands for leather items created by the metalworking were also probably met.

Woodworking

The evidence is discussed by Allen (see above, part I, 'The mill (BAB) structural timber sequence ... Woodworking techniques').

Ceramic manufacture

Reused waste products provide the indirect evidence for ceramic production. Such residues from ceramic making are rarely found on production sites and they may have been removed to be reused. The presence of waste fragments is, therefore, often no guide to the location of the kilns. However, the results of the neutron activation analysis (NAA) show that, while the material was not *in situ,* it had originated locally, and in all probability in the Arrow valley. Samples taken from the kiln fragments show these were clearly made from local clays, although they did not have the same composition as the samples taken from the valley (see above, part II, Hughes, 'Ceramic roof tiles and fittings ... Neutron activation analysis ...').

The major evidence is the kiln parts and furniture, discussed in the introduction to the fired clay (see above, part II, Astill and Wright, 'Fired clay'). The types of fragments are similar to those recovered from kilns which have been traditionally interpreted as tile kilns. The Bordesley evidence appears to confirm this, for the marks left on the 'bricks', which indicate the size of the material they supported, were clearly from floor tiles. Additional evidence might come from the blue specks on the surface of some pieces which might be Egyptian blue, formed, during firing in the kiln, either from copper filings or powdered compounds blown on to surfaces containing calcareous material during the process of glazing, which again suggests the production of floor (or ridge) tiles.

While some of the kiln fragments indicate floor tile manufacture, other evidence points to the production of roof tile. The NAA results again suggest a local source for the clays (see above, part II, Hughes, 'Ceramic roof tiles and fittings ... Neutron activation analysis ...'). and the occurrence of distorted and over-fired roof tiles in the dumps on the south bank of the second mill pond is further evidence for monastic manufacture. The evidence for tilemaking (both floor and roof) first appears during period 4, and suggests that this started in the late twelfth/early thirteenth century. A tilery in the vicinity of the abbey is suggested by the case recorded on the roll of forest pleas for 1280 concerning John of the Tilery (de la Teylereye) and John son of William 'le Stodhurde', arrested in 1278 for poaching but begged off (with a bribe) by brethren of Bordesley; the implication is that both were probably servants of the abbey *(VCH IV,* 444).

Agricultural activities

Evidence for agricultural activities in the vicinity of the mills is slight. The plant remains indicate that the eastern part of the precinct was mainly grassland with some hazel and alder; it was, therefore, probably used for grazing animals (perhaps indicated by the cow or sheep bell, IR 930). The damper areas, however, may have been turned over to the cultivation of flax and fuller's teasels. The two pick arms (IR 188; OB 32) and the two spade irons (IR 872; IR 406) may have been used for such agricultural purposes as well as for maintaining the complex water system.

Little survives to suggest a more intensive land-use: earthworks to the west of the mill pond were originally interpreted as an irrigation system, perhaps for a vineyard (Aston and Munton 1976, 31); they should now be regarded as part of the post-medieval drainage scheme. Documentary sources give the impression that all the available ground between monastic buildings was used as orchards and vegetable and herb gardens (Hockey 1975, 37). Such a pattern, however, was probably more typical of areas closer to the claustral complex, which in Bordesley's case would have been better drained and more suitable. The pots found in BAE and which were probably used in plant propagation (Fig 64, nos 56 and 57) were the only evidence for horticulture.

The supply of resources, the monastic economy, and the Arrow valley

The existence of metalworking mills at Bordesley, the evidence for the production of large quantities of small iron objects and for a repair service that apparently catered for a demand beyond that of the monastery necessitate some consideration of the relationship between Bordesley and its locality. The evidence is sparse, but some comments should be made about the supply of resources to the mills and about the economic circumstances in which the mills were operated, if only to act as a pointer for future work.

One of the major current problems is that some classes of artefactual data do not occur in sufficiently large quantities from all the excavations at Bordesley to allow us to disentangle trends which were common to the whole precinct from those which may only have been evident in certain parts. (This is in contrast to the stratigraphic data which indicate not only a difference in the character but also the length of occupation between excavated sites.) Animal bone and pottery, for example, do not occur in sufficiently large quantities from the abbey church or the gateway chapel (and none of the areas which would produce 'domestic' assemblages has been excavated) to indicate if the BAB assemblages reflect the relative proportions of the animals or pots either when first brought into the precinct or after being 'processed' before being sent to the mills.

It is appropriate to ask how the monastery was supplied with the resources which were used and discarded in the mills between the late twelfth and early fifteenth centuries. Two possibilities exist which are by no means mutually exclusive: firstly, from Bordesley's own estates and, secondly, from the open market.

Bordesley's estates are fragmentarily documented (Wright 1976a) but it is clear that the lands were grouped around twenty granges, all within 35km of the precinct, and that this pattern was established by the later twelfth century. Fourteen of the granges were located in the woodland-pasture region of north Warwickshire and Worcestershire; three g-ranges were in the Feldon of south Warwickshire of which the majority of the lands were based around Bidford and Binton in the valley of the River Avon. The last three granges to be founded were in the Cotswold region. The distribution potentially allowed the monastery to draw on the resources of three different regions (Fig 125). That this was indeed the case is demonstrated in the fifteenth-century accounts for Bidford, located in a cereal growing area, which record that large quantities of barley and some animals, especially pigs, were sent to the abbey (PRO SC6/1038/4-7: 1448/49, 1451/52 to 1454/55). An account of 1327 recorded that grain was also received from the grange at Childs Wickham in the Cotswold foothills (PRO SC6/859/33). The oolite for the period 1 cloisters may have been supplied from Combe grange (Wright 1976a, 19). The botanic remains from BAB include a range of weeds associated with cereal cultivation that thrive in different soils, from acidic to alkaline, which shows that grain had been brought to the precinct from a variety of locations, as for example from different granges (see above, part II, Carruthers, 'The valley environment ...').

The mechanisms by which the abbey was able to collect at its precinct some of the surplus produced by the granges probably remained constant during the twelfth to fourteenth, and perhaps part of the fifteenth, centuries. Granges do not appear to have been leased until the late fourteenth century at the earliest (Oxhill, 1395: PRO SC2/207/59); the first references to the leasing of other granges occur between the 1430s and the 1450s (eg Songar, Kington: PRO E303/20/52 and /21), while other granges remained in the community's hands until the Dissolution (Bidford, Hewell). The granges were thus able to supply the precinct with surplus products during the time the mills were working. It is, however, worth noting that some abbey precincts continued to receive products from granges even after these had been leased. The terms of the lease could specify the provision of particular goods or indeed the rent could be collected in kind (Michelmore 1981, xvi-xxx). The lease of Bordesley's grange of Sheltwood in 1529 included a condition that the lessee should collect and carry wood from the grange to Droitwich (PRO E303/20/29).

Some resources could also be supplied from within the precinct itself, while there is also the possibility, but undocumented, that exchange links existed between mother and daughter houses.

The alternative way to obtain resources was from the open market. Documentary work has revised ideas about urban marketing. In the past the extent of the urban network had been underestimated because the small towns, which can be shown to have had a varied occupational structure, were nevertheless judged to be not truly urban (Hilton 1975, 77-80). Many of these small places had an active commercial life which indicates that much buying and selling took place outside the formal system of boroughs and markets (Dyer 1992). There were, therefore, places, in addition to the boroughs, where goods could be bought and sold in any one region.

Wealthy individuals and institutions, however, ranged much more widely than the local markets to obtain commodities. High quality goods were fetched from far-flung fairs and markets, often in the larger towns (Dyer 1989a). A reconstruction of the trading patterns of Bordesley would, therefore, have to allow for exchange occurring at all levels of the urban hierarchy and in many parts of the

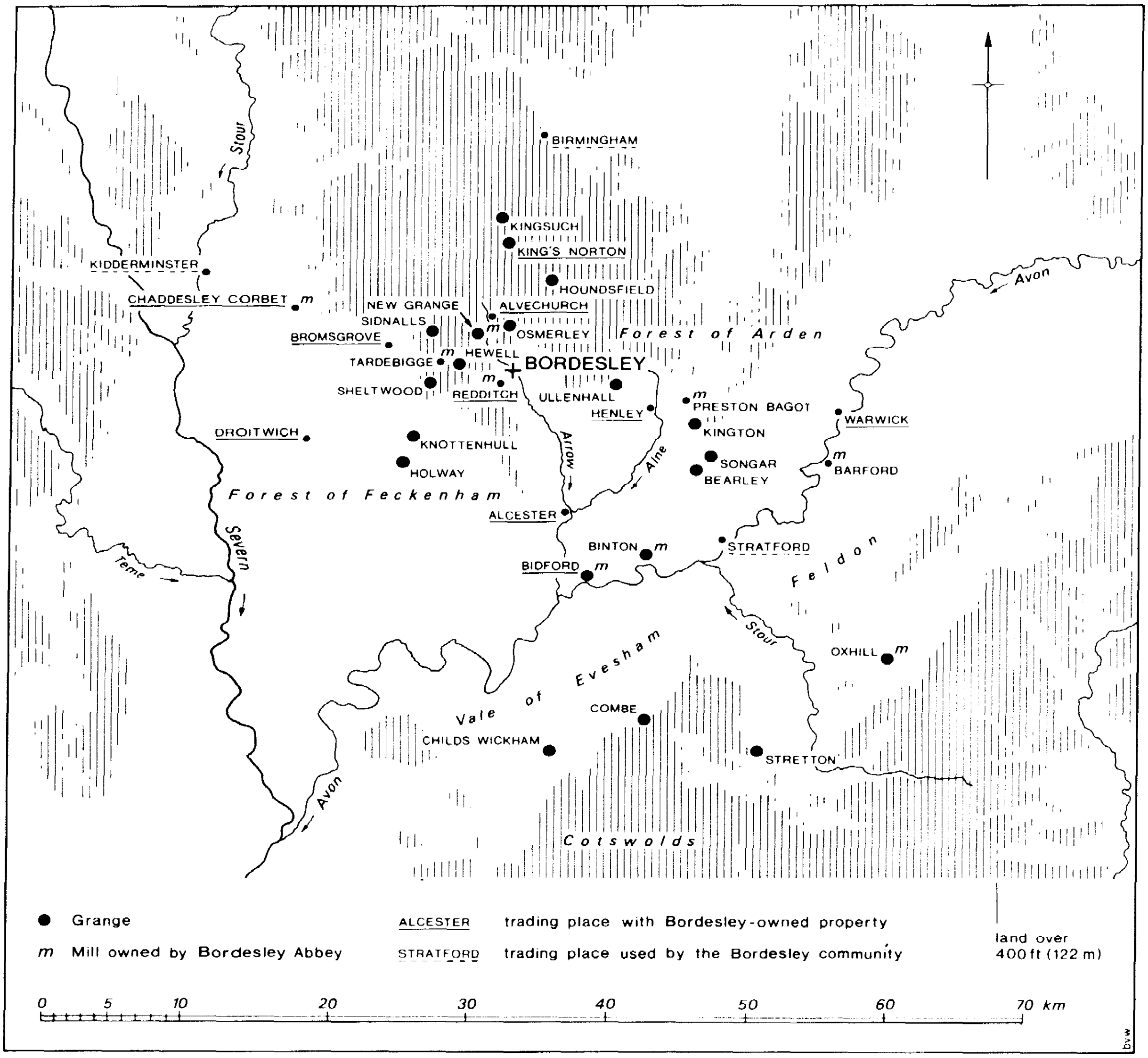


Figure 125 Granges and *mills owned, and trading places used, by Bordesley Abbey*

country; it would also have to accommodate the flow of goods from the granges. Can the archaeological and documentary evidence allow such a reconstruction? (see Fig 126).

The major parts of the finds assemblage which can give some insight are the ceramics and the stone, while some general, less precise, information comes from the botanic material.

The neutron activation analysis of the roof tile fabrics shows that all the tiles were locally made and that some were similar in chemical composition to the samples of clay taken from the precinct and were also related to the kiln furniture. There were also similarities with those decorated floor tiles thought to have been produced at Bordesley (see above, part II, Hughes, 'Ceramic tiles and fittings ... Neutron activation analysis'). This is strong evidence for a tilery within the precinct in the thirteenth century, and there is indirect, documentary evidence for a tilery in the vicinity of the abbey in 1278 *(VCH IV*, 444).

Additional support for this argument comes from the nature of and date for the appearance of the roof tile. Roof tile (and kiln furniture) is first certainly used early in period 4, that is in the late twelfth/early thirteenth century, which is consistent with the evidence from the church (Hirst *et al* 1983, 38–9; Hirst and Wright 1989, 301–2). All forms of tile were in use together in period 4 – ridges, hip/valley tiles, and flat tiles. In both

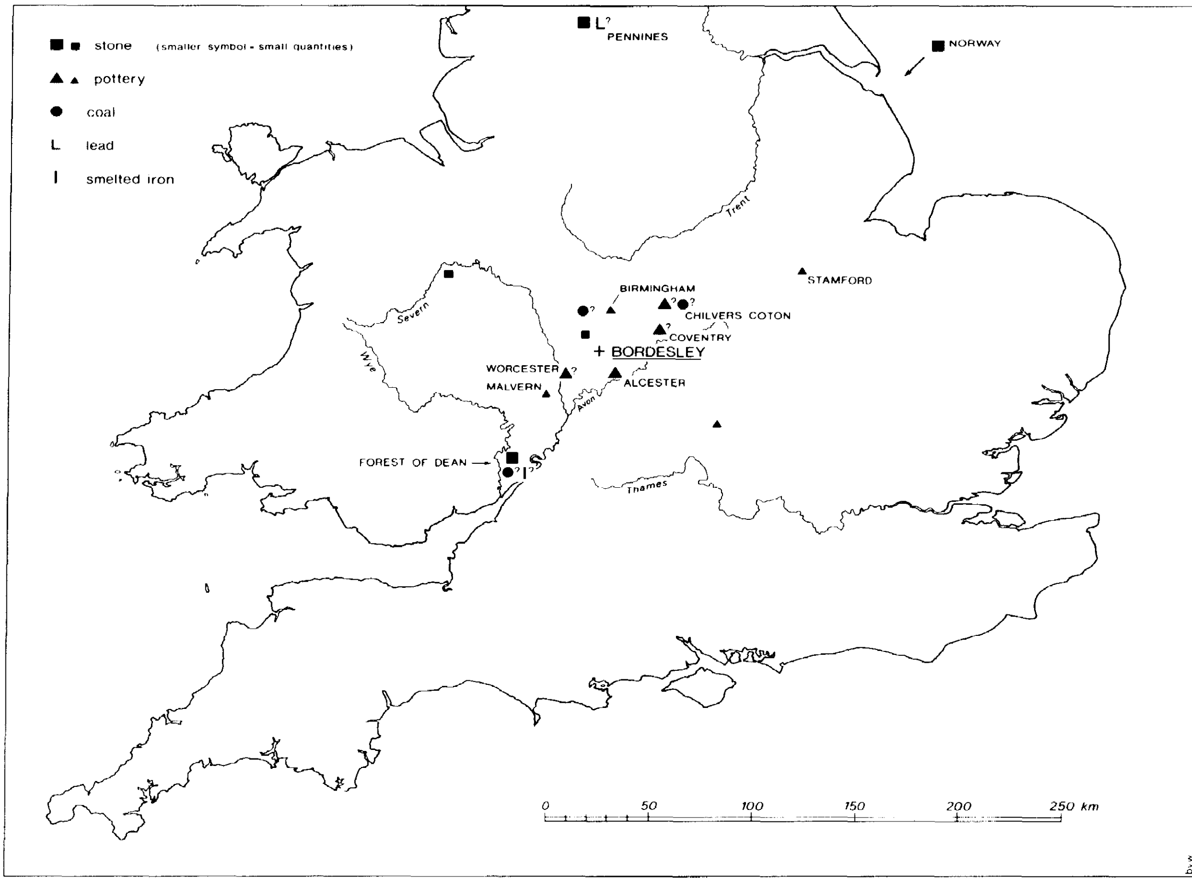


Figure 126 Resources supplied to Bordesley Abbey

respects the Bordesley assemblage seems to be earlier than those found in the neighbouring towns. There, roof tile appears to have been gradually adopted as a roof covering, often as ridge crests in combination with other more traditional materials (Keene 1990c, 320; Hurst 1992b, 156). In Coventry, for example, tiles first appear in the mid-thirteenth century but were not widely used until a century later; flat tiles were first used in Droitwich in the thirteenth to fourteenth centuries and in Worcester in the early fourteenth century (Wright 1982, 101; Hurst 1990, 247; Morris 1980, 228). Roof tile, therefore, was readily available to the monks of Bordesley some 50 years before the townspeople of Coventry and Worcester. Taken in combination with the NAA evidence, the implication is that the community started to manufacture its own tiles around the year 1200 and that they were intended for the monastery's own use. It is suggested that the occasion for the start of a tiler-y was when the initial building phase of the monastery had ended and labour became available to exploit the local clays, a development that was related to the internal dynamics of the community rather than to economic developments in the locality. A further reflection of the same process can be seen in the change from earthfast to padstone structures at the same time (period 4), which appears to be in advance of the same sequence on rural settlements (Beresford and Hurst 1971, 93; Astill 1988, 51–61). The introduction of full timber-framing techniques may also be linked with the contemporary use of pegged mortices (in the construction phase of period 4), which again appears to be in advance of when such a technique was first used in London (Brigham 1992, 93).

An equally dramatic change in the pottery assemblage occurs at the same time as the introduction of roof tile, in period 4. The range of pottery forms increased, and the introduction of jugs in a light-bodied sandy glazed ware is particularly striking. The range of pottery did not change in subsequent periods; it is as if the community was in a position in *c* 1200 to buy in types of pottery that were appearing on the market for the first time, a further reflection perhaps of the community's behavioural patterns changing with the completion of the first phase of claustral building.

The pottery assemblage is, however, different from those found in local towns, especially Worcester. Most of the cooking wares appear to have been obtained locally, perhaps from Alcester, while it is difficult to suggest a source for the sandy glazed fabrics, although Chilvers Coton is one candidate. Other regional imports were remarkably sparse, such as the small amount of Stamford pottery. Most surprising perhaps was the very small amount of material possibly from Worcester or Malvern. By contrast at Droitwich, 16km south-west of Bordesley, there was a steady increase of Malvernian wares from the thirteenth century to a point of dominance in the fifteenth (Vince 1977, 283–6; Hurst 1990a, 142–8), whereas very small quantities of these wares have been recovered from Alcester.

The emphasis on the use of local wares is, however, also evident in Worcester and Coventry (Morris 1980; Wright 1982, 46). In view of these cities' extensive documented contacts with large parts of England and beyond, the ceramic record reflects a different, more local, level of exchange, and the same conclusion might be drawn from the Bordesley assemblage.

If the pottery indicates contacts with the immediate locality and perhaps the area east of Bordesley, the stone shows a somewhat different pattern. The most common identifiable stone, used for smoothing stones, hones, and weights, was a highly micaceous New Red Sandstone which may have originated from the Forest of Dean. However, as it was also used for building stone, for example, an architectural fragment (ST 349) and a roofing stone (ST 511), it is possible that there was a nearer source.

The Millstone Grit grindstones and hone were obtained from the Pennines, while the nearby outcrop of Lickey Hills quartzite was used for a weight and smoothing stone. Most of the hones were of Norwegian Ragstone and must also have been bought on the market, as was the siltstone hone from the Welsh borders. The only stone (apart from sandstone) which could have been obtained from the Bordesley estates was the oolite column, reused as a weight, which probably came from Combe in the Cotswolds. The stone finds, then, indicate trading contacts which were much more diverse than the ceramics would suggest.

Indeed, when the potential sources for the raw materials needed in the metalworking mills are considered, it is possible that some of the stone was brought with them. It is impossible to say how much copper alloy, iron billet, and lead was brought to Bordesley in an unworked state and the metal finds suggest that some of the iron and copper alloy was salvaged from damaged artefacts.

The most prolific area of medieval lead production was the Peak in Derbyshire; that this was the source for the Bordesley lead is suggested by the occurrence of the Millstone Grit grindstones coming from the same area (Blanchard 1981, 80).

The most likely and nearest source of iron would have been the Forest of Dean, from where the New Red Sandstone artefacts probably originated. While there is extensive Roman evidence from Worcester for the smelting of iron from ore brought by boat from the Forest of Dean, as yet there is none for the medieval period (Carver 1980, 23; Allen and Fulford 1987, 278–81). This might mean that iron ore was not transported to Severn-side towns like Worcester during the medieval period but was smelted at or near its source in the Forest of Dean. Iron blooms may thus have been traded via the Severn valley towns and/or directly between the producers and those who needed iron. That the latter may be more likely in the case of Bordesley may be indicated by the small proportion of possible Worcester pottery in the Bordesley assemblage and by the presence of the potential Dean sandstones. An inquisition of 1332 records that 41s 8d was spent in purchasing iron (Bodleian Library Dodsworth MS 76 fol 94).

Another possible context in which iron blooms from the Forest of Dean could have been obtained by Bordesley is suggested by the documentation. One of the most frequently recorded forges operating in the Forest of Dean was owned by Flaxley Abbey. The abbey obtained royal grants to mine and smelt ore in the Forest with timber which had also been granted by the crown. The number of complaints made by Forest officials about the Flaxley workings suggest they must have been intrusive and extensive (Crawley-Boevey 1887, 29–31). Flaxley was a daughter house of Bordesley founded in 1151, and the filiation may have been the means by which iron was obtained by Bordesley. The Flaxley cartulary makes no mention of coal mining, but it is possible the coal that was used for iron smithing at Bordesley also came from the Forest.

An alternative, and closer, source of coal would have been either the South Staffordshire or the East Warwickshire coalfields. The coal in Warwickshire outcropped between Atherstone and Coventry and ran close to the Chilvers Coton pottery kilns (Cook 1984, 1–2; Gooder 1984, 4); the occurrence of Nuneaton-type glazed wares at Bordesley might suggest that coal was also obtained from this area.

The 1529 lease of Sheltwood grange stipulates that the lessee should carry one and a half wain-loads of sea coals (mineral coal) 'from the pits' to Droitwich (PRO E303/20/29). This tantalising reference is difficult to interpret. Sheltwood grange is in Tardebigge parish and the geological survey shows that the Staffordshire coal measures do not extend that far south (Old et al 1991, 2). The pits then are unlikely to have been on Bordesley land and the lease may refer to a carrying service unconnected with the grange. In the 1380s the Droitwich salt pans were supplied with coal from south Staffordshire and Sheltwood grange was well placed to provide transport for such journeys (information from C C Dyer's work on the Westwood Priory archives).

The same lease also details the intricate coppicing arrangements that existed on the grange lands. Although this is a late reference, most granges in the woodland pasture region had coppices which would have supplied the precinct with timber and charcoal. Sufficient was produced to be sold (Bodleian Library, Dodsworth MS 76, fol 84). The large oaks used in the (period 3) mill pond drain were taken from a managed woodland of coppice-with-standards which had been tended for 200–300 years beforehand, and may suggest that such outsize timbers were obtained from an established forest area such as Feckenham (see above, part I, Allen, 'The valley transect ... The mill pond drain').

Most of the evidence for Bordesley's economic contacts emphasises the direct connections between the monastery and resource centres. The role of the market could be interpreted as minimal. There is, however, other, documentary, evidence which illustrates the monastery's involvement with the local markets. Bordesley owned property in boroughs such as Droitwich (some salt works, PRO E303/20/55), Warwick (PRO E326/6132), Alcester (PRO E326/73), Alvechurch (Price 1971, 16), Bromsgrove (PRO E326/102), and Henley in Arden; in the case of Henley this included a stall in the market place (PRO E329/347). There was also a chartered market at Bidford.

A sub-cellarer's account of 1338 (PRO SC6/1065/4) also shows that the larger boroughs of the region were visited to purchase livestock – Kidderminster, Birmingham, and Bromsgrove – and fish was bought from Boston, a further example of the ability of wealthy institutions to purchase goods from all over England. There were also contacts between the granges and nearby towns. The Bidford accounts record that goods were bought and sold at Stratford upon Avon (PRO SC6/1038/4–7).

The identification of trading places which operated outside the network of boroughs and markets shows that the potential existed for the further involvement of Bordesley with the locality. The abbey, for example, owned two granges very close to the exchange centre of Rings Norton, and the closest settlement to the abbey's precinct, Redditch, was also involved in buying and selling. Bordesley owned a mill at another such centre, Chaddesley Corbett (Dyer 1992).

In summary, the evidence for the provision of goods to Bordesley shows that several mechanisms were involved, some of which are illustrated from archaeological material. During the life of the metalworking mills it was possible for the granges to supply some materials, in particular timber and charcoal. Raw materials were apparently obtained by direct dealings with the producers, the majority of which were not directly reflected in the archaeological record; other materials from possibly the same area, such as the Nuneaton-type pottery or the Millstone Grit, may be an oblique testimony to the connection. The ceramics illustrate a more limited exchange network which may reflect the monastery's dealings with the local trading places.

The function of the metalworking mills in Bordesley's economy

The unequivocal evidence for metalworking mills in use between the late twelfth and early fifteenth centuries needs to be considered in the context of the sparse information for the monastic economy. Historians of medieval technology have in the past stressed the importance of the use of water-power for industrial purposes and have argued that industrial mills greatly advanced the medieval economy (White 1978; Reynolds 1983). A reconsideration of the evidence, which in the main consists of isolated references to mills throughout Europe, has shown that such claims are inflated because the earliest statements could refer to orthodox cereal mills while the later reports were not as frequent as was once thought (Holt 1988, 145–51).

The most commonly documented industrial mill was used for fulling cloth and, in his recent survey, Holt argues that they were of limited economic importance for most estates. In comparison with corn mills, fulling mills were very scarce and limited to particular areas of the country and, where they did operate, the revenue was a fraction of what was produced by corn mills (Holt 1988, 152–8). It is clear, however, that in those areas where there was a plentiful water supply, such as the Cotswolds and north Worcestershire, the proliferation of fulling mills, especially when combined with a manorial monopoly of fulling, was highly profitable (Hilton 1966, 209–13).

Holt employs similar arguments to emphasise the small number of mills involved with other industrial processes such as bark crushing or metalworking. Langdon reaches a similar conclusion in his survey of mills documented on 104 manors in Gloucestershire, Warwickshire, and Worcestershire between 1086 and 1500 – *c* 1% of the total was used for industrial purposes (Langdon 1991, 435). The demand for industrial commodities was not sufficiently great to justify the investment in specialised mills: 'industrial production was limited because this was an impoverished society in which practically all of the population directed most of their efforts towards acquiring sufficient bread: corn mills alone were generally worth building because flour was the only commodity that was always, everywhere, in demand' (Holt 1988, 158). The extension of water technology, Holt argues, 'could not come about until the growing markets and emerging capitalist enterprise of the sixteenth century ushered in an era of larger scale production' (Holt 1988, 158).

Holt may well be right in thinking that larger-scale industrial production needed the stimulus of a growing market, but this occurred well before the sixteenth century. Recent studies of towns and markets show that the urban network was very extensive and active by the thirteenth century, and it had grown because most of the rural population sold their produce and regularly bought their requirements at markets, for very few families were self-sufficient (Dyer 1989b, 110–18). Given the extensive demand for specialised goods throughout most of the medieval countryside, it is surprising that there are not more documentary references to industrial mills. One possibility, suggested by the distribution of documented fulling mills, is that the marketing system had become so extensive and entrenched that it allowed those areas with copious raw materials (including water) to specialise in the production of particular commodities; and these particular areas may not be well documented.

If the Bordesley metalworking mills were built as a response to an increasing demand, it is necessary to consider these mills in the context of the Bordesley estates. Some attempt should be made to estimate the total number of mills owned by the abbey; this is, however, a perilous exercise because the most reliable guide to mill numbers and function, the grange accounts, have not survived for most of the properties. Instead, numbers have to be assembled from general, overall surveys of the estates at particular times, such as at the monastery's foundation, in the 1291 *Taxatio Ecclesiastica*, the *Valor Ecclesiasticus*, and the post-Dissolution accounts and surveys. These can be supplemented by the occasional and unsystematic reports of mills contained in charters or leases. A single reference is difficult to assess; the mill may not have stayed in the monastery's control for long, or could have been abandoned and replaced by a mill built in a different location (Holt 1988, 14–16).

Three mills are mentioned in the foundation documents, four in the 1291 *Taxatio*, and five or six in the *Valor Ecclesiasticus*. The mills at Bidford grange are recorded in all three sets of documents and the mills at Chaddesley in 1291 and 1534. Thirteenth-century charters refer several times to mills at New Grange, Barford, and Binton (PRO E315/31/2; PRO E326/8590, /8591; PRO E326/6131) and there are single grants of mills, also of the thirteenth century, at Oxhill and Preston Bagot (PRO E326/4435, /934, /2955); a fulling mill, worked by abbey servants, is recorded in Tardebigge (Hilton 1959, 280–1). A lease of 1529 of Pool Mill, just outside the precinct, also refers to the abbey corn mill (PRO E303/20/38). Three mills existed at Bidford, two at each of Chaddesley, Barford, and Binton. In all these cases, one is identified as a fulling mill.

Aston and Munton identified the potential site of a mill close to the gateway chapel, a common location for corn mills in Cistercian monasteries; they also located the mill pond of Pool Mill to the west of the precinct and the earthworks of Lye mill in New Grange (1976, 24-9). Taken together with the excavated mill sequence, there is evidence for nineteen to twenty mills between the thirteenth and fifteenth centuries; of these, five or six are referred to as fulling mills, seven as corn mills, leaving six which are unidentified. Even allowing that three of the mills were only mentioned once, there was still a substantial number of mills on Bordesley lands. In particular, the high proportion of fulling mills is important, for it shows that industrial mills were quite common on the estate. As a comparison, the account book of Beaulieu details one corn and one fulling mill in the precinct, and six of the thirteen granges had a single mill (Hockey 1975; Hockey 1976, 56–73).

A metalworking mill is mentioned neither for Bordesley nor Beaulieu, but the Beaulieu account book for 1269/70 shows that the estate only had one forge which was located in the precinct. This, therefore, had to service the entire estate and this is reflected in the quantities of raw materials bought in: 5.7 tonnes of 'ferri grossi' (presumably iron blooms), 1.8 tonnes of 'ferri operati' (iron that can be directly made into objects), 105kg of steel, with 8.7 tonnes of mineral coal and 9.8 tonnes of charcoal (figures in this and the next three paragraphs calculated from Hockey 1975, 265–9).

Approximately 6 tonnes of bloom were beaten into 4 tonnes of usable iron in one year at Beaulieu; 2 tonnes of slag was produced. The forge was one of the largest employers of labourers in the precinct. 40s was paid to an unspecified number of workmen; as the rates for famuli employed in the various departments within the precinct ranged from 4s 6d to 7s, the forge could have employed between five and eight people. All of this iron appears to have been used during the year. It is impossible to know into what the majority of this iron was fashioned because most of the iron is recorded in weights. However, the repair of carts and ploughs, requiring steel as well as iron, is recorded, as well as the manufacture of two and a half dozen knives, along with other utensils.

By far the most iron went to the stables, presumably in the form of horseshoes and hoops for cartwheels, but the works department also used large quantities. However, as would be expected, virtually every department in the monastery received some iron. In total, the largest quantities of iron objects were sent to the granges, in particular St Leonards, which received 654kg.

It is of particular interest to note that the smith sold 914kg of worked iron, which represents about 17% of the total produced in the year. This may not have been a typical year of course, but the implication of this account is that it was possible for smith(s) working in a manually-operated forge to produce not only sufficient ironwork for the needs of a monastic estate but also a sizeable proportion that could be sold on the open market.

The analysis of the metalworking carried out within the Bordesley mills concludes that a wide range of ironworking took place, including repair work, some of which required a high level of expertise such as one would expect to find in a blacksmithy. This part of the Bordesley assemblage could be regarded as the archaeological correlate of the workshop documented in the Beaulieu account book. However, two aspects of the Bordesley assemblage indicate that manufacturing processes took place which were more complicated than those normally found in a smithy: firstly, the evidence for large-scale production of small objects such as nails and tenter hooks which was probably done with water-powered hammers and bellows; secondly, both copper alloy and lead were worked in the mills to produce composite items. The most unusual of the composite or time-consuming items were the weapons. Some of these items, for example, the sword pommel with the Clare coat of arms and the armour, were probably brought for repair or scrap. These two aspects are interpreted as indirect evidence for the production of metalwork which was destined for use outside the monastic community. The forge serviced a wider circle which included potential patrons and market traders. The significance of the use of water-power was that it enabled an increased production of ironwork which could be sold on the market. The suggested size of the workforce in the Beaulieu forge (five to eight) is similar to Sim's estimate of the number of smiths who could work around the Bordesley hearths (see above). Such a workforce in a manually-operated forge was able to produce surplus ironwork for sale. It therefore follows that the production of surplus ironwork could be increased if the process was mechanised through the use of water-power, as happened at Bordesley.

The Bordesley metalworking mills were operated between the late twelfth and the early fifteenth centuries. During this time, most of the granges were directly managed and therefore required metalwork in the same way and perhaps the same quantities as the Beaulieu granges. Despite pleas of impoverishment, major building and repair programmes were carried out in the abbey church during most of the thirteenth and the first part of the fourteenth centuries; and the gateway chapel was built and refurbished during the thirteenth century (Astill and Wright 1993). These works would indicate a certain buoyancy in the monastic economy during the thirteenth and early fourteenth centuries; they would also have required a constant supply of metalwork.

This period, 'the long thirteenth century' *(c* 1180-13301, was one of great economic expansion as reflected in an increased area under cultivation and the direct management of demesnes, the rise in the population, and the rapid development of an urban network, particularly of markets which were a response to the increased need for trading in the countryside. It is in this kind of economic climate, when the surplus of cereals, wood, and wool from the Bordesley estates was in demand, that the grange mills were processing large quantities of woollen cloth and grinding cereals, much of which would have been offered for sale. It is also the time when the metalworking mills were in operation, repairing and producing large quantities of metalwork. All the available evidence for the region would suggest that Bordesley, like the other west midland institutions, was responding to the increased commercial activity by producing goods for the market in as an efficient way as possible, which in many cases entailed the use of waterpower. While the monastery was clearly responding to trends in the regional economy, it was only able to do so because Bordesley had reached a suitable stage in its development. By the 1170s the major, initial campaign to build the claustral complex, to refashion the valley, and to found daughter houses had ended, and the monastery appeared to respond to extramural trends, as reflected in the ceramic record.

In the same way, the decision to abandon the period 6 mill was taken because of a combination of local and regional factors. The archaeological sequence would suggest that production of metalwork declined in the fourteenth century (period 6) after water-power ceased to be used. The immediate reason for the abandonment of the mill machinery appears to have been that large amounts of sediment were deposited in the lower stretches of the Arrow valley, downstream of the mill. This had the effect of reducing the gradient in the valley to the extent that it became impossible for the mill to operate efficiently.

It is important to emphasise that the immediate cause of the drainage problems originated downstream of the mill. These problems were not related to the structural problems encountered in the abbey church. Here settlement and subsidence of the building are evident from the early thirteenth century, and continued into the fourteenth century, when the collapse of the north-west crossing pier was possibly due to ancient stream beds or springs in the vicinity (Hirst *et al* 1983, esp 49-50). The break-up of the tile floor and the 'mud' in the south transept in the late fourteenth/early fifteenth century has been interpreted as possibly the result of flooding (Rahtz and Hirst 1976, 70-l; Hirst *et* al 1983, 54). However, subsequent excavation in the church of areas to the west suggested that the contemporary break-up of the tile floor in the south aisle and retrochoir was probably due to waterlogging of the plastic clay 'subsoil' and could have resulted from the roof being off (Youngs *et al* 1986, 153). These events appear now to be associated with a major rebuilding programme undertaken c 1400. The large scale of this programme suggests the involvement of a patron, particularly in the case of the nave, while the new cloister may indicate a reorganization of the claustral area as a result of the reduction in the monastic population and in the size of the precinct (Astill and Wright 1993, 131).

It is difficult to explain the sedimentation in the lower precinct, but one possible cause was a deterioration of the complex drainage system within the precinct, as indicated by the flora growing in some water channels, similar to that found in abandoned canals, and the sedimentation of the mill pond. One explanation of the breakdown in the drainage system could be a lack of labour, possibly reflected in the regeneration of trees. Information about the monastic population is sparse, but it is clear that there was a dramatic decline in numbers during the fourteenth century. In 1332 there were 60 in the community, by 1381 there were fourteen monks and one lay brother, and twenty monks at the Dissolution. In the face of such a reduction in resident manpower and the rising cost of wage labour, there was little need, and still less the resources, to maintain the large precinct. A decision seems to have been taken to abandon the eastern (and lower) parts of the valley to judge from the failure of geophysical prospection techniques to identify industrial structures in those areas (Astill 1989, 283-5).

It is also necessary to consider the late medieval trends in the economy and religious sentiment. Most Cistercian houses were debilitated in the fourteenth century by a decline in the population in general and a sharp reduction in the recruitment of lay brothers in particular (Donnelly 1949, 38-70). This occurred at a time when the cost of wage labour rose and seigneurial incomes declined or failed to increase. The decline in agricultural prices encouraged most institutions to abandon the direct farming of the majority of demesnes between the later fourteenth and fifteenth centuries; however, in order to be sufficiently attractive, the leases for granges had to be at low rents for long terms. Most of the Bordesley granges appear to have been leased by the first third of the fifteenth century. In a situation of rising prices and stable or declining income, most institutions could only survive by a policy of retrenchment involving reduction in expenditure and a more efficient use of resources. And one way of reducing expenditure was to limit the number of recruits to the monastery (eg Dyer 1989b, 86-108). Entry to a monastery, however, may not have been such an attractive prospect in the later fourteenth or fifteenth centuries as it had been previously. Religious sympathies of patrons appear to have shifted from monasteries to the mendicant orders and the creation of chantries in parish churches (Knowles 1953,287; Rosenthal 1972, 127-33).

At Bordesley, then, there were strong local as well as regional pressures that limited the size of the monastic population and which hastened the abandonment of the mills.

The farming out of most of the granges would also have reduced the need for the mechanised, large-scale repair and production of metalwork. The late fourteenth and fifteenth centuries are also a time when there was a dramatic reduction in elements of the urban network: the income and the population of boroughs declined and markets became moribund. At first sight, such a decline in boroughs and markets had removed the main reason for maintaining a mechanised mill. Yet, although the institutional urban foundations were suffering, it appears that the ‘unofficial’ trading places continued to thrive (Dyer 1992, 153). However, the combination of an increasingly inefficient mill, a reduced monastic community, and a decline in demand from the (leased) granges and declining boroughs and markets was no doubt sufficient to justify the abandonment of the industrial workshops. It is perhaps significant that the tannery and shoe workshop in the precinct were leased in 1396 (PRO E315/32/135).

The dendrochronological dates for the first mill, of 1174-6, are worth considering in relation to the documentary evidence for the diversification of water-power in England. The technology required for a fulling mill is no different from that needed for a metalworking mill. The earliest references to fulling mills occur between 1154 and 1185 (Holt 1988, 153) and it is notable that most of the references concern monastic property. The earliest documentary reference, of 1349, to a hammer mill for smelting iron is from Warley, Yorkshire (Jewel1 *et* al 1981, 39-40). The archaeological evidence from Chingley, Kent, is interpreted as a water-powered bloomer-y of the fourteenth century (Crossley 1975, 14-16). However, the technology for both the fulling of cloth and metalworking clearly existed in England by the third quarter of the twelfth century. The documentary material and the archaeological evidence presented here would encourage us to think that the industrial mills were essentially a monastic introduction to this country in the later twelfth century. This is, however, to disregard the cryptic references in Domesday to those mills in Lexworthy, Somerset, which paid rent in iron blooms (Holt 1988, 149). It is perhaps sufficient evidence to suggest an alternative interpretation: that, by Domesday, the technology for all forms of industrial mill existed in England, but that the economic, social, or cultural conditions necessary for the widespread adoption of such an innovation did not exist until the later twelfth century, when the monastic foundations had the necessary resources and need for such machines. The surviving European evidence for the use of water-power also highlights the monastic contribution, and perhaps a similar developmental sequence: from the outbuildings in the plan of St Gall, sometimes interpreted as housing water-powered pilae (Horn and Born 1979, vol 2, 224-47), to the increasingly plentiful structural information from the mid-twelfth century for water-powered industrial mills such as forges (eg Bloch 1967; Benoi t 1988).

Conclusion: the medieval landscape and the identification of industries - an ongoing agenda

The fieldwork within the Arrow valley has considerably extended our knowledge of the relationship between Bordesley Abbey and its environment. The volatile pre-monastic phase provides new information about the character of smaller valleys in the west midlands. It also serves to put in perspective the achievements of the community during its first two hundred years of existence. The monastery's foundation was accompanied by a huge outlay of resources designed to change the valley in order to allow for the first time there permanent occupation, albeit of a type with specific requirements. It illustrates the breathtaking confidence that existed amongst early Cistercian communities, a belief in their capacity and ability to mould their environment to their own uses. That this took place at Bordesley while the claustral complex was under construction and when daughter houses were being founded makes it all the more impressive (Astill and Wright 1993, 130-l).

The key to environmental control of the Arrow valley was the construction and maintenance of a drainage system which had to work over 35ha. Success is illustrated by the lack of flood deposits and the creation of an open, but damp, meadowland which survived for about two centuries, just as the subsequent failure (in this part of the valley) is demonstrated by the extensive silts and regeneration of woodland which characterise the 150 years to the Dissolution and indeed later.

The abandonment of the workshops and the east part of the precinct is interpreted as the result of a combination of local and regional factors which encompass geographical, economic, social, and religious changes, many of which were beyond Bordesley's direct control. No doubt the real situation was even more complicated, but our interpretation provides a salutary warning against the use of monocausal explanations, whether, for example, climatic or economic, which in the past have been so popular in medieval archaeology.

The Bordesley mill and workshop sequence is one of the few to have been recovered from a medieval monastery. That the remains were so well preserved is unusual, but such industrial complexes were relatively common to judge from documentary accounts and surveys, although there seem to be more references to water-powered fulling than to water-powered metalworking. The essential technology required for the two processes was, however, similar and, indeed, is usually regarded as less sophisticated than that required for a vertically-wheeled corn mill.

This archaeological evidence for water-powered metalworking is important because it pre-dates the earliest documentary evidence for the activity in England by some 175 years. This in itself should not be surprising and indeed the archaeological evidence for metalworking is now similar in date to the earliest documentary evidence for water-powered fulling. However, the concordance should not be interpreted as an indication of when the industrial use of water-power was first adopted or introduced. The majority of the earliest industrial mills were owned by monasteries, including Cistercian houses (Donkin 1978, 135-8), and it is tempting, given the well-known water engineering capabilities of the Cistercians, to credit them with the introduction of the technology into this country (cf Rynne 1989). But this is to ignore the biases of the documentary record and earlier potential references to industrial mills. It is more appropriate to argue that within some monasteries both the resources and the perceived need - whether economic or social - existed in the later twelfth century for the construction of such mills. At the least, the particularly monastic contribution may well have been the efficient construction and maintenance of such mills and their systematic use. We should not ignore in this regard the extensive Cistercian involvement in iron production, in all probability water-powered, in France, Britain, and Sweden (Verna and Benoit 1991; Benoit 1988; Donkin 1978, 134; Moorhouse 1989, 50-2; Karlsson 1987), but this is largely concerned with ore extraction and smelting. The Bordesley smithing forge was on a smaller scale and it belonged to a monastery which used and sold its products; the abbey was not geographically well placed to be involved with iron production.

The Bordesley sequence also provides some of the most complete evidence for medieval vertically-wheeled mills. The combination of information about water supply, leat structures, and the associated mill buildings is unusual and is clearly of importance for medieval technology as a whole.

The sophistication and, more importantly, the continuity of mill arrangements - of the leat and the building - demonstrate that the mills worked efficiently in the twelfth century and there was little need to make alterations to the form of the mills over the subsequent 200 years. Change was, however, necessary in order to retain efficiency in the face of the increased sedimentation in the valley downstream of the mill site. The potential for change, however, was limited and when it had been exploited the mill site was abandoned. The configuration of the mill pond and its relationship to the rest of the precinct was established in the twelfth century and would have been difficult to alter subsequently without a complete replanning of the monastic complex. The only feasible action was to increase the head of water by reshaping the pond banks, which was done in the first half of the fourteenth century (period 5). The water supply system thus tended to fossilise the mill arrangement and militated against innovation. A similarly dominant influence of the original layout of a precinct has been identified at Thornholme Priory, where the numerous reconstructions and changes in function of buildings in the outer court were made according to the plan established at the priory's foundation (Coppack 1989).

Excavations have demonstrated that it is often difficult to identify the function of medieval mills and this has implications for future work. Given their numerical dominance, there is an understandable tendency to interpret most mill remains as of corn mills. In the case of Chingley and Batsford mills, the difficulty was compounded by the lack of evidence for the mill building and the few finds in the silts of the wheel pit and tail race.

The lack of finds specifically associated with fulling and the absence of ironworking debris at Batsford was sufficient for it to be interpreted as a corn mill; and indeed it was suggested that Chingley, interpreted by the excavator as a forge, might also have ground cereals (Bedwin 1978, 195). Bedwin used as supporting evidence gear pegs, found on both sites, which indicated that a right-angled drive was in use; he argued that this arrangement was only necessary in a corn mill.

An interpretation of function is dependent on the presence of residues and the kind of machinery present. The conclusions to be drawn from the Bordesley evidence and the survey of medieval smithies here are that known metalworking sites produce little in the way of diagnostic tools and often the quantities of residues such as slag are small. Indeed, industrial sites often cannot be recognised by large quantities of residues because that material had been carted away and in all probability recycled. Small amounts of diagnostic material then should be expected, which of course has implications as far as the location of such sites by geophysical prospection is concerned. The recovery of structural information, therefore, becomes crucial, which often necessitates large-scale excavation.

By the same token, corn mills have to be identified positively - that is, by having material associated with milling cereals, for example millstones and cereal remains, as at Tamworth (Rahtz and Meeson 1992, 70-9, 155) – rather than by default.

Clearly, environmental evidence can be of fundamental importance, but again the Bordesley material is instructive. It is necessary to remember that botanic material often reflects activity that took place over a wider area rather than at the specific site. The plentiful remains of the cultivated teasel in combination with tenter hooks could be regarded as strong evidence for fulling, but it has to be countered with the structural and stratigraphic information which could not be interpreted as indicating a fulling mill. Similarly, the concentrated deposits of cereal coryopses and arable weed seeds in the tail race silts in BAB and BAH could relate to the milling of cereals, but the structural and artefactual data from BAB indicate that it did not happen there, but elsewhere in the precinct, and the material was carried along the water system.

Relatively little is known about the range of machinery used in medieval mills. The great difference in size and wear between the gear pegs found at Chingley and Batsford and the Bordesley 'cogs' has been interpreted as indicating two types of movement: the gears for a right-angled drive and the 'cogs' working as cams for tripping. While most medieval and post-medieval water-powered bellows, stocks, and hammers appear to have been directly driven by cams located on or near the main wheel shaft, there may have been occasions where this was impossible. The configuration of the Bordesley mills, for example, made such a direct arrangement impossible and it was necessary to suggest an alternative, indirect, system. In some circumstances this may have involved gearing, as perhaps was the case at Chingley. That evidence could also be interpreted as a double mill. Crossley suggested that two wheels operated in tandem (1975, 10) and one could have been used to drive millstones (using gear pegs) and the other to trip a hammer.

The numerous questions posed by the Bordesley sequence serve to underline the paucity of archaeological data for the most common machine in the middle ages. Future work must be sufficiently wide-ranging to deal with some of the problems raised here.

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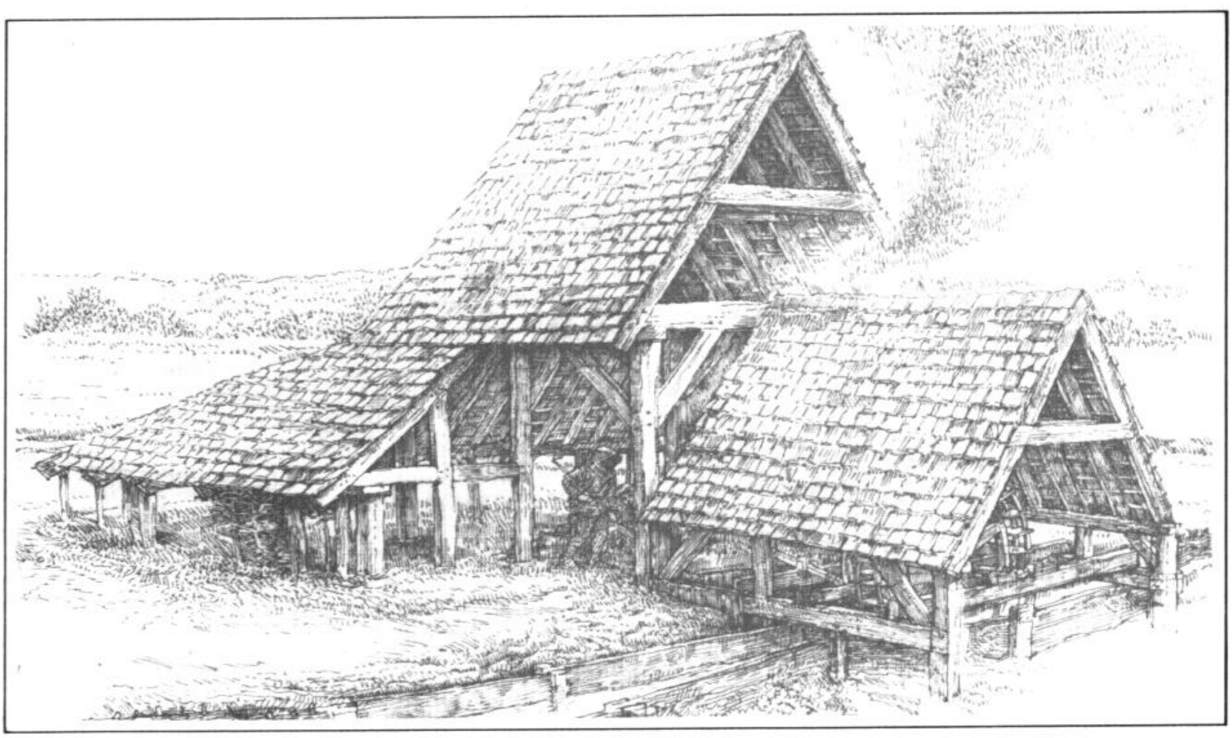
Index

A MEDIEVAL INDUSTRIAL COMPLEX AND ITS LANDSCAPE: THE METALWORKING WATERMILLS AND WORKSHOPS OF BORDESLEY ABBEY

Excavations within the valley precinct of Bordesley Abbey have recovered a sequence of four well-preserved water-mills which were in use between the late twelfth and early fifteenth centuries. The survival of much of the mill race timber structures and of mill machinery has allowed a reconstruction of the workings of the vertically-wheeled mills. Fieldwork and subsidiary excavations have increased our knowledge of water supply and control, and have also indicated the changes which took place in the valley between prehistoric and modem times. The Bordesley water-mills exclusively provided power for metalworking. The mills and associated workshops were used to manufacture and repair small items of iron, copper alloy, and lead.

This report outlines the excavated sequence and provides a detailed discussion of some of the earliest evidence for water-powered metalworking in the country; particular attention is given to the surviving structures and the mill machinery. The evidence for metalworking is also presented and discussed in the light of other excavated medieval metalworking sites. A final section considers the supply of resources to the mills and the role of the mills in the monastic economy.

A Medieval Industrial Complex and its Landscape provides much new information about medieval industry and technology and will be essential reading for those interested in mills and the medieval economy.



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