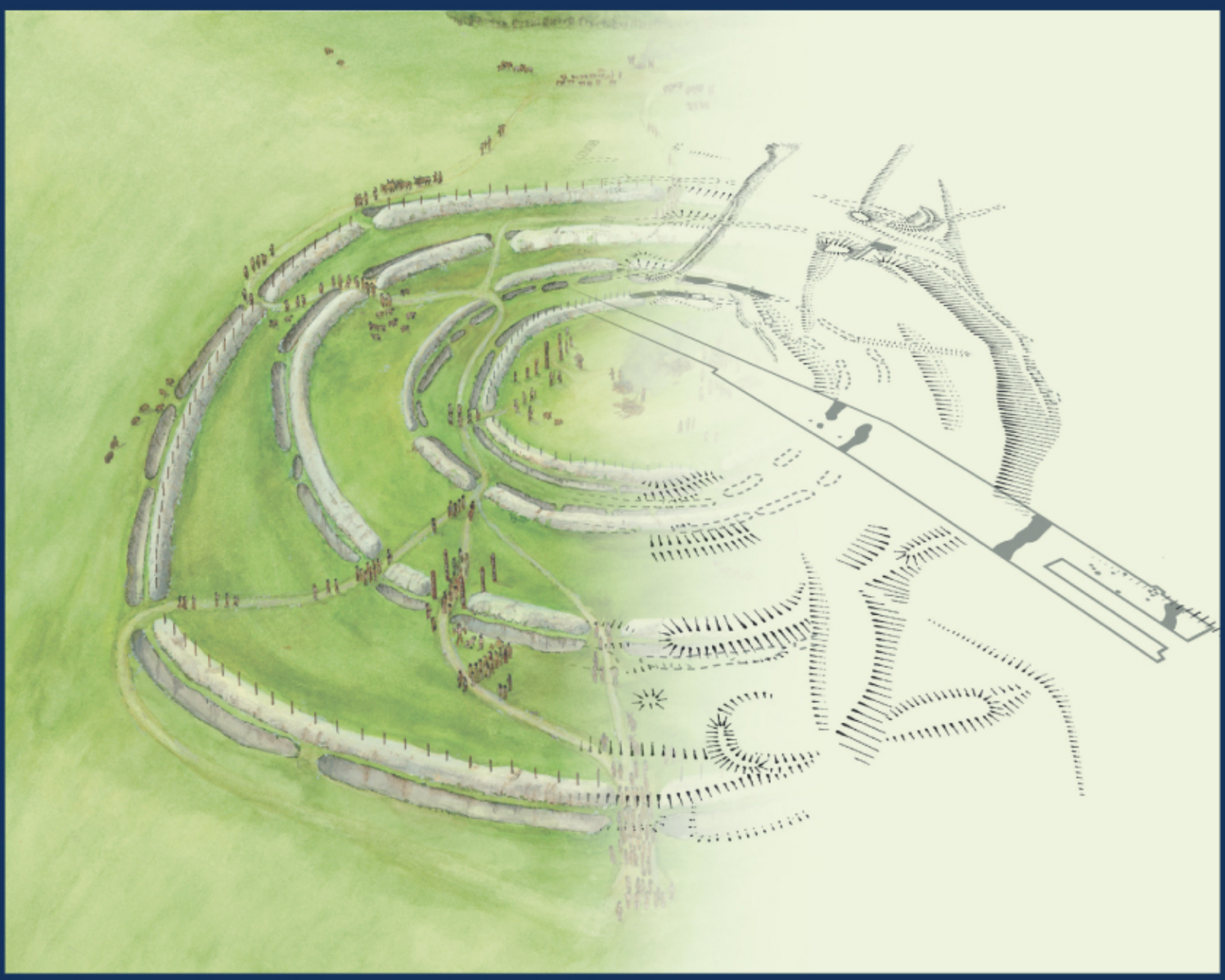
Gathering Time

Dating the Early Neolithic Enclosures of Southern Britain and Ireland



Alasdair Whittle, Frances Healy and Alex Bayliss

Volume 1

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Contents

VOLUME I

Authors' note

This book is about the dating of the early Neolithic causewayed enclosures of southern Britain and Ireland. Currently it is also, by far, the largest application of the Bayesian approach to modelling archaeological chronologies undertaken anywhere in the world. As such, we hope that this study will be of wider interest, not only for specialists in the European Neolithic, but for archaeologists everywhere so far lacking precise dating. The effort of this project could have been directed, after all, at any number of other kinds of site, period or area.

Different readers may wish to trace different paths through this volume. Chapter 1 provides an overview of the questions which the project aims to address, and sets the scene for those readers who are not devoted to the early Neolithic of Britain and Ireland. Bayesian virgins – a term which currently includes the vast majority of archaeologists inhabiting planet earth! – should read Chapter 2, which provides an introduction to the methods employed in the following chapters. Chapters 3–11 each deal with the enclosures of a southern British region and place them in the context of the regional evidence for other early Neolithic activity. Chapter 12 similarly covers Ireland, but on an island-wide basis. These regional chapters can be digested piecemeal, but we strongly urge all readers to engage with at least one of them (3, 7, or 10 may be the most digestible) before attempting to grapple with the more synthetic discussions contained in Chapters 12 and 14.

These chapters weave narratives out of the chronological threads spun from the models constructed in the course of the regional discussions. They therefore contain many complex models, which often build on the foundations laid in the site-based and regional models and represent a second level of interpretation. The implications of these narratives, both for our understanding of the early Neolithic of southern Britain and Ireland, and the ways in which we can now practise prehistory, are discussed in Chapter 15.

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The project owes its execution and completion to its co-funders, the Arts and Humanities Research Council and English Heritage. We are wholeheartedly grateful to them for the opportunity to undertake the work reported here. English Heritage also monitored the project's progress, providing a store of support and advice. Here we owe a particular debt to Jonathan Last, Head of Research Policy for Prehistory and to Andrew David, Head of Archaeological Science and Archaeological Archives, as well as to Barney Sloane and Chris Scull. Grateful thanks are also due to John Meadows, Derek Hamilton, Henrietta Granlund Marsden, Isabelle Parsons and Kate Cullen of the Scientific Dating Section. The Arts and Humanities Research Council also supported the Thames Valley project (see Chapter 13).

Radiocarbon dates were the cornerstone of the project. The AMS dates obtained in the course of the project were measured by the Oxford Radiocarbon Accelerator Unit, led by Christopher Bronk Ramsey, and by the Centrum voor IsotopenOnderzoek, Rijksuniversiteit Groningen, led by Johannes van der Plicht. A smaller number of high precision measurements were made by the Queen's University, Belfast Radiocarbon Dating Laboratory, led by Gerry McCormac. All three laboratories were immensely professional and helpful, consistently delivering results on time so that work could proceed, answering numerous questions and making extra measurements to resolve specific problems.

Equally essential was access to collections and permission to sample them. We owe an immense debt to Museum curators, among them: Janet Ambers, Gillian Varndell and Pam Young of the British Museum; Tom Cadbury of the Royal Albert Memorial Museum and Art Gallery, Exeter; Jonathan Catton of Thurrock Local History Museum; Rosamund Cleal of the Alexander Keiller Museum, Avebury; Ian Friel of Chichester District Museum; Jill Greenaway of Reading Museum Service; Paul Hyman of Wardown Park Museum, Luton; Richard Le Saux of Brighton Museum and Art Gallery; Arthur MacGregor and Alison Roberts of the Ashmolean Museum, Oxford; Jane Marley of the Royal Cornwall Museum, Truro; Emma O'Connor of Barbican House Museum, Lewes; Oxfordshire Museum Services; Paul Robinson of the Wiltshire Heritage Museum, Devizes; Sara Rodger of the Arundel Castle archives; Richard Sabin of the Natural History Museum; Peter Saunders of the Salisbury and South Wiltshire Museum; the staff of the Towner Art Gallery and Local History Museum, Eastbourne; and Peter Woodward of the Dorset County Museum, Dorchester.

The volume could not have been written without the co-authors of individual chapters, who provided a fund of specialised knowledge and advice, access to potential samples from excavations still under analysis, illustrations and their own valuable time. Numerous other colleagues generously gave support, information and advice, among them Luke Barber, Sussex Archaeological Society (formerly of Archaeology South-East); Martyn Barber, English Heritage; Alistair Barclay, Wessex Archaeology; Martin Bell, University of Reading; Robin Bendrey, University of Winchester; Anna Brindley, Rijksuniversiteit Groningen; Steve Burrow, National Museum, Cardiff; Peter Drewett, University of Sussex; Toby Driver, Royal Commission on the Ancient and Historical Monuments of Wales; Tim Gent, Exeter Archaeology; Frances Griffith, Devon County Council; Detlef Gronenborn, Römisch-Germanisches Zentralmuseum, Mainz; Chris Hayden, Oxford Archaeology; Neil Holbrook, Cotswold Archaeological Trust; Mike Ilett, University of Paris; Lars Larsson, Lund University; Ken Murphy, Cambria Archaeology; Poul Otto Nielsen, National Museum, Copenhagen; Jacqueline Nowakowski, Cornwall County Council; Joshua Pollard, University of Southampton; Miles Russell, Bournemouth University; Jean-Luc Schwenninger, Oxford University Research Laboratory for Archaeology and the History of Art; Alison Sheridan, National Museum of Scotland; Martin Smith, University of Birmingham; Julian Thomas, University of Manchester; Martin Tingle; and Lesley Zienkiewicz. Wessex Archaeology shared information about the excavation of the Kingsborough and Northborough enclosures prior to publication, and we thank Tony Lynch for permission to quote unpublished isotopic data.

Any volume which seeks to synthesise a large corpus of existing radiocarbon dates, many of which were measured many years ago, throws up innumerable queries. All the radiocarbon dating laboratories we approached for further information in this regard were unfailing helpful, and we thank for providing such details: Janet Ambers, British Museum; Gordon Cook, SUERC Radiocarbon Dating Laboratory; Henny Deenen, Rijksuniversiteit Groningen, The Netherlands; Darden Hood, Beta Analytic Inc., USA; Stephen Hoper and Michelle Thompson, Belfast Radiocarbon Laboratory; John Matthews, University of Swansea; Marie-Josée Nadeau, Christian-Albrechts Universität zu Kiel, Germany; Ingrid Olsson, University of Stockholm; Anna Pazdur, Silesian University of Technology, Poland; Fiona Petchey, Waikato Radiocarbon Laboratory, New Zealand; and Michael Sim, Rafter Radiocarbon Laboratory, New Zealand.

In Cardiff University, Ian Dennis succeeded in the daunting task of creating many of the illustrations and of preparing the heterogeneous and often intractable remainder for publication. Kirsty Harding helped to push things over the line. Dani Hofmann, Emily Stewart and Sue Virgo did

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On a final personal note, Alex would like to thank Lynne Keys for putting up with her being in Cardiff for so much of the past decade, and Alasdair would like to thank Anna and Andrew Maxwell for unstinting hospitality in London.

The archive

The paper archive consists of copies of submission forms and certificates of results for radiocarbon samples, with some accompanying correspondence. The digital archive consists of a database of both dated samples and potential samples from enclosures, with contextual, bibliographic and other information. It will be integrated with the radiocarbon dating archive and database of the Scientific Dating Section of English Heritage (National Monuments Record Centre, Kemble Drive, Swindon, SN2 2GZ).

Summary

This volume presents the results of a dating programme on the early Neolithic causewayed enclosures of southern Britain and Ireland. By incorporating hundreds of radiocarbon dates from nearly 40 southern British causewayed enclosures in Bayesian chronological models, in the largest exercise of this kind so far undertaken, it is estimated that the main period of enclosure construction lasted from the late 38th century cal BC until the mid-to-late 36th century cal BC. While some sites were in primary use for up to three centuries, many others proved to be of much shorter duration (even down to a few decades). By comparing results from enclosures with other aspects of the early Neolithic in southern Britain, creating Bayesian chronological models incorporating hundreds of radiocarbon dates from other monuments including long barrows and from settlement sites, it is shown that enclosures appeared up to 300 years after the first Neolithic things and practices were established in southern Britain, from the 41st century cal BC. The process of the spread of the Neolithic in Britain is shown to have been gradual and regionalised, taking over two centuries and beginning in south-east England. The first long barrows and related monuments are shown to precede causewayed enclosures by a century or so. Tens of radiocarbon dates from two enclosure sites in Ireland were also modelled in a Bayesian framework, and put into context by comparison with hundreds of radiocarbon dates from other aspects of the early Neolithic in the island. Although one of these enclosures presents particular difficulties of interpretation, it is argued that the early Neolithic in Ireland probably began around 3800 cal BC.

Chapter 1 introduces central questions of time and chronological resolution, arguing that many archaeologists have been resigned to imprecise timescales, which affects the kind of pasts they regularly construct. It goes on to introduce causewayed enclosures and the history of their research. Chapter 2 introduces the main concepts of Bayesian chronological modelling and describes the detailed information and rigorous interpretations which are required for its successful implementation in archaeological practice. Not only is the vital 'prior' archaeological information – knowledge of sample taphonomy, context, association and stratigraphy – discussed, but also the statistical assumptions involved in model building. We emphasise the inevitable scatter of radiocarbon dates for any given phenomenon which, unless models are constructed to counteract this, means that any given phenomenon will normally appear to have begun earlier, lasted longer and ended later than was the case in reality. The laboratory procedures necessary for accurate radiocarbon dating and an assessment of the accuracy of the existing corpus of radiocarbon dates are also discussed.

In this project, southern Britain has been divided into a series of pragmatically defined regions (Chapters 3–11). In each chapter, chronological models for the causewayed enclosures chosen for study are presented first, with consideration of the implications of the new chronologies for our understanding of each site. It is estimated that enclosures were constructed from the late 38th century cal BC until the mid-to-late 36th century cal BC. Many sites were in primary use for relatively restricted periods of time, although some remained in use for 300 years or so. The following enclosures were dated in the course of the project: Windmill Hill and Knap Hill, in north Wiltshire (Chapter 3, with consideration of Rybury); Whitesheet Hill, Maiden Castle and Robin Hood's Ball, in south Wessex (Chapter 4, with re-analysis of the extensive series of radiocarbon dates from Hambledon Hill); Whitehawk, Offham Hill, Bury Hill, The Trundle and Court Hill, in Sussex (Chapter 5, with consideration of Barkhale, Combe Hill and Halnaker Hill); Maiden Bower, Haddenham, Etton, Etton Woodgate and Northborough, in eastern England (Chapter 6, with consideration of Briar Hill and Great Wilbraham); Orsett, Kingsborough 1 and 2, and Chalk Hill, in the Greater Thames estuary (Chapter 7, with re-analysis of the existing radiocarbon dates from St Osyth); Staines, Eton Wick, Gatehampton Farm and Abingdon, in the middle and upper Thames valley (Chapter 8); Crickley Hill and Peak Camp, in the Cotswolds (Chapter 9); Hembury and Raddon Hill, and the stone-walled tor enclosures of Helman Tor and Carn Brea, in the south-west peninsula (Chapter 10, with consideration of Membury); and Hill Croft Field and Banc Du in south Wales and the Marches (Chapter 11, with dating of Beech Court Farm, which proved to be of much later date, and of Billown on the Isle of Man, an important early Neolithic settlement but probably not a causewayed enclosure in the southern British sense). Radiocarbon dates and chronological models for other early Neolithic activity in the region are then presented. Formal estimates for the appearance of Neolithic things and practices are presented in Chapters 5, 6, 9, 10 and 11, with further analysis presented in Chapter 14. Each chapter concludes with a discussion of the implications of all the chronologies in the region for understanding the first centuries of Neolithic activity there.

In Ireland (Chapter 12), chronological models are presented for the enclosures of Donegore and Magheraboy. The construction of Donegore, Co. Antrim, falls within the main *floruit* of southern British enclosure building, and its local and regional contexts are considered. Magheraboy, Co. Sligo, appears to date rather earlier, to the 40th or 39th centuries cal BC. This necessitated a wider review of the dating of the early Neolithic in Ireland as a whole.

Hundreds of radiocarbon dates have been incorporated into chronological models for a range of other monuments and activity, and it is estimated that Neolithic things and practices first appeared in the island in the late 39th or 38th centuries cal BC (two main variant models are given). There is much that is not precisely dated, including many court tombs and portal tombs; Linkardstown burials and passage tombs are seen as middle Neolithic innovations, of the second half of the fourth millennium cal BC, and are used to constrain the models for the early Neolithic. Rectangular timber houses are better dated, and were constructed and used only from the late 38th into the 37th century cal BC. Domesticated cattle aside, which are present in a later fifth millennium context at Ferriter's Cove, Co. Kerry, there is a challenging gap between the apparent early dating of Magheraboy and the onset of Neolithic things and practices in Ireland as estimated by all the other chronological models. Further discussion of Ireland in the context of southern Britain follows in Chapter 14.

A suite of isotopic data from human and animal samples from four southern British causewayed enclosures are given in Chapter 13. Comparing results with other early Neolithic contexts, probable diversity in environments and diets is emphasised.

Chapter 14 pulls together the chronological threads spun in Chapters 3–12 to construct narratives for the development of the early Neolithic in southern Britain and in Ireland. Causewayed enclosures in southern Britain are analysed first; then other early Neolithic activity, including models for the appearance of Neolithic things and practices across southern Britain. Finally, the appearance of the Neolithic in Ireland, the Isle of Man and Scotland south of the Great Glen is considered.

Many central aspects of southern British causewayed enclosures are examined from the perspective of the more precise chronologies now available. The currency, the establishment and the spread of causewayed enclosures are analysed, the individual site and regional models being brought together. The first enclosures appeared in eastern parts of the country, and the pace of construction accelerated over three to four generations to a peak in the later 37th century cal BC, apparently followed by a lull at the turn of the 36th century and then resumption of fresh building till the mid- to late 36th century cal BC. Modelling also enables more precise discussion of the effort of construction, which at some sites now can be broken down into more concentrated episodes of labour investment; of the trajectories of development of multiple circuits and multiple enclosures, which may have a tendency to last longer than simpler layouts; and of the endings and very variable durations of enclosures. Modelled estimates for rates of ditch filling and recutting are presented, and, at a selection of sites, for the intensity of deposition in enclosure ditches; more precise timescales serve to show less intensive deposition at any one time than often supposed in the literature, but nonetheless it is clear that substantial numbers of people could have been fed by the meat from even one or two cattle. A series of dated episodes of violence at enclosures, including killings, attacks by archery and burnings, are compared, with fewer signs of this behaviour in the eastern part of southern Britain.

Apart perhaps from two or three early candidates, it appears that constructions such as long barrows and long cairns began to be built in numbers probably from around 3800 cal BC. There is so far no support for claims that forms such as portal dolmens, small oval barrows or rotundae are particularly early. In each region studied in southern Britain, the appearance of causewayed enclosures can be shown to be later than the start of other early Neolithic activity. The interval varies, because the date estimates for the start of other Neolithic activity vary by region across southern Britain. The first Neolithic things and practices appear in the Greater Thames estuary in the 41st century cal BC, spreading westwards, although not necessarily from a single focus, to emerge in south Wales and the Marches by the generations around 3700 cal BC. Chronological trends in the development of pottery styles and axe production and circulation can also be modelled. South-Western pottery appears in the 38th century cal BC, later than the ubiquitous Carinated Bowl style which is present from the beginning, and Decorated pottery in the late 38th or early 37th century cal BC, either coinciding with or just after the emergence of enclosures. Axehead circulation also appears to have extended from the 38th into the 37th century cal BC. Such developments help to define an accelerating surge of innovations through the 38th century cal BC, preceding and accompanying the emergence of enclosures themselves. This section of Chapter 14 ends with a synthetic narrative of the main elements of the development of the early Neolithic in southern Britain as a whole.

Chapter 14 continues with comparison of the early Neolithic sequences in Ireland (drawing on Chapter 12), on the Isle of Man (from Chapter 11) and in Scotland (using available radiocarbon dates for the area south of the Great Glen). The modelled date estimates suggest that the start of early Neolithic activity in Ireland and Scotland fell in the late 39th or earliest 38th century cal BC, and on the Isle of Man perhaps in the 38th century cal BC. Timber halls in Scotland are identified as early features of Neolithic activity; other monument sequences are harder to trace in both countries (and there are virtually no dates for the monuments of the Isle of Man). Chapter 14 concludes with a review of the chronological development of the early Neolithic in Britain and Ireland as a whole.

Chapter 15 offers commentary on the narratives laid out in Chapter 14. Here, the discussion tracks the sequence, from the start until the latter part of the early Neolithic. The models set out in Chapter 14 for the start of early Neolithic activity are compared with other dominant interpretations in the literature, from colonisation on the one hand to indigenous acculturation on the other. A different interpretation is adopted, using wider colonisation theory, in which there was probably some, small-scale colonisation from the adjacent continent, into southern England, followed by a continuing, and accelerating spread of Neolithic things and practices, which probably

involved indigenous acculturation from early on. Patterns of settlement and change are briefly examined on the adjacent continent, in order to reinforce the probability of small-scale, filtered colonisation, combined with local change. Evidence for settlement and subsistence in the first centuries of the southern British Neolithic is then reviewed in the light of the chronological models. It is argued that there are no clear signs of either radical increases in population or marked intensification of economic practices, though much remains to be better understood, including the development of cattle herding. Monuments and material culture, however, show more signs of change. The possible social roles of constructions such as long barrows and long cairns, which began to be built in numbers probably from around 3800 cal BC, are considered, including involvement in the competitive definition of group identities. The accelerating surge of material innovations through the 38th century cal BC, preceding and accompanying the emergence of enclosures themselves, also helps to suggest dynamic social conditions, perhaps competitive.

The continental background of enclosure construction and use shows a long history, back to the sixth millennium cal BC. Causewayed enclosures in southern Britain and in Ireland can be best compared with those of the Michelsberg-Chasséen complex on the adjacent continent, said to have appeared already in the later fifth millennium but to have still been built in the earlier fourth millennium cal BC (although the imprecision of the available Continental chronologies makes the unravelling of fine-grained connections currently impossible). The establishment of enclosures in southern Britain from around 3700 cal BC speaks for (apart from the possibility of the arrival of new people) a deliberate attempt to evoke contacts and affiliation with more distant practices, and reinforces the notion of inter-group competition and emulation.

Worldviews centred in a combination of ideas, including principles of seniority, prowess and affiliation or connection, are given a specific context by the detailed history of enclosure building and use in the *floruit* of their construction in the 37th and 36th centuries cal BC. Differing characterisations of social relations are considered for this context, with special attention given to the possible role of pre-eminent ritual experts and organisers. The southern British emphasis on enclosures at this time is contrasted with other kinds of sociality elsewhere in Britain and Ireland, perhaps smaller-scale and less intense, as seen for example in the building of timber halls and houses, and various forms of barrows and cairns; there are, however, overlaps, as in the circulation of axeheads through some house sites in Ireland, and a widespread regard for forebears and other dimensions of the past.

From the later 36th into the 35th and 34th centuries cal BC, there appears to have been a complex world of innovation and continuity. While the primary use of some causewayed enclosures continued, and there may have been a few late constructions, after a *floruit* of only eight generations or so, monumental innovation passed to the building of linear cursus monuments. Long barrows and long cairns, and probably also portal dolmens, continued to be constructed and used. In the present state of evidence, with many features beyond the immediate remit of the project, it is hard to characterise this situation, but explanations could include either an increase in inter-group competition or something more subtle by way of rivalry between senior and junior clans or lineages.

The volume ends with further reflection on kinds of time, agency and memory. The much more precise timescales for some aspects of the early Neolithic in southern Britain enable emphasis to be shifted from the *longue durée* to a social history measurable at the scale of centuries, half centuries, generations and even on occasion decades. This opens up various kinds of transmission between generations to much closer interpretation, and beams a light into ‘prehistory’.

Résumé

Ce volume présente les résultats issus d'un programme de datation qui concerne les enceintes à fossés interrompus dans le sud de la Grande Bretagne et en Irlande. Des centaines de datations radiocarbones, provenant d'une quarantaine d'enceintes à fossés interrompus du sud de la Grande Bretagne, ont été intégrées dans des modèles chronologiques bayésiens – un exercice d'une très grande amplitude, jamais réalisé auparavant. Il a été démontré que la période de construction principale des enceintes s'étend de la fin du 38ième siècle jusqu'au milieu voire la fin du 36ième siècle cal BC. En outre, si la période d'utilisation principale peut atteindre jusqu'à trois siècles sur certains sites, elle s'avère être bien plus courte dans beaucoup d'autres cas (parfois à peine quelques décennies). Les résultats obtenus pour les enceintes ont été comparés à ceux issus d'autres contextes du Néolithique ancien dans le sud de la Grande Bretagne. Pour ces derniers, des modèles chronologiques bayésiens ont également été élaborés, intégrant des centaines de dates radiocarbones regroupant aussi bien des sites d'habitat que des monuments tels des tumulus allongés (*long barrows*). Ainsi, il a pu être démontré que les enceintes sont apparues jusqu'à trois cents ans après l'introduction des premiers objets et pratiques néolithiques dans le sud de la Grande Bretagne, à partir du 41ième siècle cal BC. Le processus de diffusion du Néolithique en Grande Bretagne est progressif et régional, il s'étale sur deux siècles et prend sa source dans le sud-est de l'Angleterre. Il a été mis en évidence que les premiers tumulus allongés (*long barrows*) et monuments apparentés précèdent d'environ un siècle les enceintes à fossés interrompus. Quelques dizaines de datations radiocarbones provenant de deux enceintes en Irlande ont également été modélisées dans une approche bayésienne, placées dans leur contexte et comparées avec des centaines de datations radiocarbones provenant d'autres contextes Néolithique ancien de l'île. Bien qu'une de ces enceintes soit particulièrement sujette à des problèmes d'interprétation, on peut maintenir que le Néolithique ancien en Irlande débute probablement autour de 3800 cal BC.

Le chapitre 1 introduit les principales questions ayant trait à la chronologie et à la résolution chronologique, sachant que de nombreux archéologues se sont résignés à des chronologies imprécises ce qui a une incidence sur les scenarios du passé qu'ils ont l'habitude de construire. En second plan seront présentées les enceintes à fossés interrompus et l'historique de leurs recherches. Le chapitre 2 expose les concepts principaux de la modélisation chronologique bayésienne et met l'accent sur l'information détaillée et l'interprétation rigoureuse requises pour une application réussie en archéologie. Seront discutés, non seulement les données archéologiques essentielles de départ – connaissance de la taphonomie des échantillons, du contexte, des associations et de la stratigraphie – mais également les hypothèses statistiques impliquées dans l'élaboration des modèles. En outre, l'accent est mis sur l'inévitable dispersion des datations radiocarbones pour chaque évènement donné – puisque les modèles sont élaborés pour contrebalancer ce phénomène – à savoir, chaque évènement donné semble avoir un début plus précoce, une durée plus longue et une fin plus tardive qu'il y paraîtrait dans la réalité. Les procédures techniques nécessaires à une datation radiocarbone précise seront également discutées ainsi que l'évaluation de la précision du corpus des datations radiométriques existantes.

Dans le cadre de ce projet, le sud de la Grande Bretagne a été subdivisé en une série de régions définies arbitrairement (chapitres 3 à 11). Les modèles chronologiques sont présentés au début de chaque chapitre et tiennent compte des implications apportées par les nouvelles chronologies dans la compréhension de chaque site. La durée estimée des constructions d'enceintes s'étend de la fin du 38ième siècle jusqu'au milieu voire la fin du 36ième siècle cal BC. Dans la plupart des sites, la période d'occupation principale est relativement courte même si chez certains elle atteint trois cents ans environ. Les enceintes suivantes ont été datées au cours du projet: Windmill Hill et Knap Hill dans le nord du Wiltshire (chapitre 3, en tenant compte de Rybury); Whitesheet Hill, Maiden Castle et Robin Hood's Ball, dans le sud du Wessex (chapitre 4, avec une nouvelle analyse de l'importante série de datations radiocarbones provenant de Hambledon Hill); Whitehawk, Offham Hill, Bury Hill, The Trundle et Court Hill, dans le Sussex (chapitre 5, en tenant compte de Barkhale, de Combe Hill et de Halnaker Hill); Maiden Bower, Haddenham, Etton, Etton Woodgate et Northborough, dans l'est de l'Angleterre (chapitre 6, en tenant compte de Briar Hill et de Great Wilbraham); Orsett, Kingsborough 1 et 2, et Chalk Hill, dans l'estuaire de la Tamise (chapitre 7, avec une révision des dates radiocarbones existantes du site de St Osyth); Staines, Eton Wick, Gatehampton Farm et Abingdon, dans la moyenne et haute vallée de la Tamise (chapitre 8); Crickley Hill et Peak Camp, dans les Cotswolds (chapitre 9); Hembury et Raddon Hill, ainsi que les enceintes de type tor, délimités par des murs en pierres sèches de Helman Tor et Carn Brea, dans le sud-ouest de la péninsule (chapitre 10, en tenant compte de Membury); et finalement Hill Croft Field et Banc Du dans le sud du Pays de Galles et dans les Marches (chapitre 11, la datation de Beech Court Farm, s'est révélée être beaucoup plus tardive, tout comme celle de Billown sur l'île de Man, un habitat important du Néolithique ancien mais probablement pas une enceinte à fossés interrompus à l'image de celles du sud de la

Grande Bretagne). Par la suite, sont présentés les datations radiocarbones et les modèles chronologiques élaborés pour d'autres contextes du Néolithique ancien dans la région. Des estimations globales concernant l'apparition des objets et pratiques néolithiques sont données dans les chapitres 5, 6, 9, 10 et 11, avec une analyse supplémentaire exposée dans le chapitre 14. Chaque chapitre se termine avec la discussion des implications de l'ensemble des chronologies afin d'améliorer la compréhension des premiers siècles de l'occupation néolithique dans ces régions.

Concernant l'Irlande (chapitre 12), des modèles chronologiques ont été élaborés pour les enceintes de Donegore et de Magheraboy. La construction de Donegore, dans le comté d'Antrim, coïncide avec la période principale de construction des enceintes dans le sud de la Grande Bretagne. Cependant, le contexte local et régional de ce site est discuté. Magheraboy, dans le comté de Sligo, semble être plus précoce, du 40ième ou 39ième siècle cal BC. Cette observation a nécessité une révision plus large de la datation de l'ensemble du Néolithique ancien en Irlande. Des centaines de datations provenant d'une série de différents monuments et faits, intégrées dans des modèles chronologiques, permettent de supposer que les premiers objets et pratiques néolithiques apparaissent sur l'île à la fin du 39ième ou pendant le 38ième siècle cal BC (deux variantes principales du modèle sont proposées). Beaucoup de monuments ne sont pas datés avec précision, de même qu'un grand nombre de tombes à cour et de dolmens. En revanche, la datation des cistes de type Linkardstown et des tombes à couloir, considérées comme innovations du Néolithique moyen, dans la deuxième moitié du quatrième millénaire cal BC, est l'argument principal pour délimiter les modèles développés pour le Néolithique ancien. Les maisons à poteaux et à plan rectangulaire sont datées avec plus de précision. Elles ont été construites et occupées exclusivement de la fin du 38ième jusqu'au 37ième cal BC. A l'exception du bœuf domestique, qui est attesté dans un contexte daté de la fin du cinquième millénaire à Ferriter's Cove, dans le comté de Kerry, se pose le problème du hiatus entre la date apparemment précoce de Magheraboy et celle de l'apparition des objets et pratiques néolithiques en Irlande, soutenue dans tous les autres modèles chronologiques. Une discussion plus approfondie du contexte irlandais par rapport à celui du sud de la Grande Bretagne suit dans le chapitre 14.

Le chapitre 13 présente une série de datations isotopiques obtenues sur des ossements humains et animaux prélevés dans quatre enceintes à fossés interrompus dans le sud de la Grande Bretagne. La comparaison des résultats avec d'autres contextes du Néolithique ancien, met l'accent sur une diversification probable des environnements et des diètes.

Le chapitre 14 réunit les séries individuelles présentées dans les chapitres 3 à 12 qui serviront à construire des scenarios évolutifs du Néolithique ancien dans le sud de la Grande Bretagne et en Irlande. En premier lieu seront analysées les enceintes à fossés interrompus du sud de la Grande Bretagne, ensuite l'analyse portera sur les autres contextes du Néolithique ancien y compris les modèles développés autour de l'apparition des objets et pratiques néolithiques dans tout le sud de la Grande Bretagne. Enfin sera discutée l'apparition du Néolithique en Irlande, ainsi que sur l'Ile de Man et en Ecosse, au sud du Great Glen.

De nombreux aspects déterminants, caractérisant les enceintes à fossés interrompus du sud de la Grande Bretagne, sont examinés à partir des chronologies plus précises maintenant disponibles. La fréquence, la fondation et la diffusion des enceintes à fossés interrompus sont analysées et les modèles développés pour chaque site sont individuellement rapprochés du modèle régional. Les premières enceintes émergent dans les régions à l'est du pays et le rythme des constructions s'accélère pendant trois ou quatre générations avant de culminer vers la fin du 37ième siècle cal BC. Il s'en suivra apparemment un ralentissement au tournant du 36ième siècle cal BC et une reprise de nouvelles constructions jusqu'au milieu voire la fin du 36ième siècle cal BC. La modélisation permet également d'élaborer une analyse plus fine des efforts de construction. Ceux-ci, dans quelques sites peuvent être segmentés en épisodes concentrés d'investissement en travail; en trajectoires de développement de circuits multiples et en construction d'enclos multiples. Ces constructions ont tendance à perdurer plus longtemps que des formes de construction plus simples, ou même plus longtemps que les enceintes dont les fins et les durées sont très variables. Pour un petit nombre de sites, des estimations modélisées concernant le rythme de remplissage des fossés et les recoupements sont présentés ainsi que le volume des dépôts dans les fossés des enceintes. Des chronologies plus précises ont permis de mettre en évidence l'existence de dépôts moins importants dans chaque évènement isolé par rapport à ce qui a été supposé dans la littérature. Il ressort de façon évidente que la viande d'une ou de deux vaches suffisait sans doute à nourrir un grand nombre de personnes. Dans les enceintes ont été datées des séries d'épisodes violents incluant des tueries, des attaques d'archers et des incendies. Ces comportements sont par comparaison moins fréquents dans la partie est du sud de la Grande Bretagne.

Excepté peut-être deux ou trois monuments, il semble que des constructions de type tumulus allongés (*long barrows*) et les cairns allongés (*long cairns*) ont été érigés en plus grand nombre à partir de 3800 cal BC environ. Jusqu'à présent, rien ne permet de soutenir l'hypothèse que des architectures comme les dolmens à portique et les petits tumulus ovalaires ou circulaires remontent à une date particulièrement précoce. Dans chaque région étudiée du sud de la Grande Bretagne, il peut être mis en évidence que l'apparition des enceintes à fossés interrompus succède à l'établissement des autres occupations du Néolithique ancien. Cet intervalle varie dans la mesure où les datations estimées, qui situent le début des autres contextes du Néolithique ancien, varient dans les différentes régions d'un bout à l'autre du sud de la Grande Bretagne. Les premiers objets et pratiques sont introduits dans l'estuaire de la Tamise au cours du 41ième siècle cal BC puis se

diffusent vers l'ouest – pas forcément depuis un seul centre d'origine – et émergent dans le sud du Pays de Galles et dans les Marches autour de 3700 cal BC. L'évolution chronologique des styles céramiques et de la fabrication et de la circulation des haches peut également être modélisée. La céramique du sud-ouest apparaît au 38ième siècle cal BC, plus tard que le style à bols carénés omniprésent qui est attesté dès le début du Néolithique et plus tard également que la céramique décorée de la fin du 38ième siècle ou du début du 37ième siècle cal BC, soit en même temps ou juste après l'émergence des enceintes.

De la même manière, la circulation des lames de hache semble s'étendre du 38ième siècle jusqu'au 37ième siècle cal BC. De telles trajectoires permettent de définir une montée des innovations tout au long du 38ième siècle cal BC, qui précèdent et accompagnent l'émergence des enceintes elles-mêmes. Cette partie du chapitre 14 se termine avec un scénario de synthèse des principaux éléments qui constituent le Néolithique ancien du sud de la Grande Bretagne dans sa globalité.

Le chapitre 14 se poursuit en comparant des séquences du Néolithique ancien en Irlande (en référence au chapitre 12), sur l'île de Man (chapitre 11) et en Ecosse (en utilisant les datations disponibles pour l'aire géographique au sud du Great Glen). Les estimations modélisées des datations laissent supposer un début du Néolithique en Irlande et en Ecosse qui coïncide avec la fin du 39ième ou le tout début du 38ième siècle cal BC. Sur l'île de Man, celui-ci se situe probablement au courant du 38ième siècle. En Ecosse, les édifices en bois sont identifiés comme des structures associées à une occupation néolithique précoce. Dans ces deux pays, les autres séquences de monuments sont plus difficiles à retracer (sur l'Ile de Man il n'y a pratiquement pas de datations disponibles des monuments). Le chapitre 14 se conclut par une révision globale de l'évolution chronologique du Néolithique ancien en Grande Bretagne et en Irlande.

Le chapitre 15 commente les scenarios présentés dans le chapitre 14. La discussion s'étendra ici depuis le début de la séquence jusqu'à la phase tardive du Néolithique ancien. Les modèles proposés dans le chapitre 14 pour le début de l'occupation Néolithique ancien sont comparés avec d'autres interprétations courantes de la littérature, allant de la colonisation jusqu'à l'acculturation autochtone. Notre interprétation est différente ; elle se fonde sur une théorie de colonisation plus large selon laquelle il y aurait probablement eu un mouvement de colonisation à petite échelle depuis le continent voisin vers le sud de l'Angleterre, suivi par une diffusion continue et accélérée d'objets et pratiques néolithiques ; ce qui impliquerait probablement une acculturation autochtone dès le début. Des modes d'occupation et des changements ont été inventorié de façon succincte sur le continent voisin et renforcent la probabilité d'une colonisation filtrée à petite échelle combinée avec un changement local. Les modes d'habitat et les stratégies de subsistance mis en évidence dans les premiers siècles du Néolithique du sud de la Grande Bretagne ont ensuite été réévalués à partir des modèles chronologiques élaborés. On a souligné qu'il n'existait pas d'indices manifestes dans le sens d'un accroissement significatif de la population ni même d'une intensification marquée des pratiques économiques. Cependant, beaucoup d'aspects demanderaient à être mieux compris notamment l'évolution de l'élevage bovin. On constate néanmoins que les monuments et la culture matérielle révèlent le plus de changements. On discutera du possible rôle social des constructions de type tumulus allongés (*long barrows*) ou des cairns allongés (*long cairns*) qui ont été érigés en plus grand nombre probablement à partir de 3800 cal BC environ. Il en va de même de l'implication de la compétition dans la définition de l'identité des groupes. La montée accélérée d'innovations matérielles tout au long du 38ième siècle cal BC qui précèdent et accompagnent l'émergence des enceintes elles-mêmes, contribue également à présupposer l'existence de conditions sociales dynamiques, vraisemblablement compétitives.

Les tenants de la construction et de l'utilisation des enceintes sur le continent mettent en évidence une longue histoire qui remonte au sixième millénaire cal BC. Les enceintes à fossés interrompus du sud de la Grande Bretagne et de l'Irlande sont plus comparables à celles du complexe Michelsberg-Chasséen du continent voisin dont on suppose l'apparition dès la fin du cinquième millénaire et dont les constructions se succèdent jusqu'au début du quatrième millénaire cal BC (bien que le manque de précision des chronologies continentales rende en général impossible la corrélation d'évènements ponctuels). La fondation des enceintes dans le sud de la Grande Bretagne, à partir de 3700 cal BC environ, plaide en faveur (en excluant la possibilité d'une arrivée de nouvelles populations) d'une action délibérée de maintenir des contacts et affiliations avec des pratiques ancestrales et de renforcer la compétition et l'émulation entre les groupes.

L'élaboration de l'histoire détaillée de la construction et de l'occupation des enceintes durant leur évolution florissante au cours des 37ième et 36ième siècles cal BC, permet de modeler une vision du monde basée sur une combinaison d'idées mélangeant des principes d'ancestralité, de savoir-faire et d'affiliations ou de relations qui s'insèrent dans un contexte spécifique. Dans ce contexte, les différentes caractéristiques des relations sociales sont prises en compte, une attention particulière est donnée au rôle probable d'experts et de personnages éminents dans l'organisation de rituels. Durant cette période, l'accent mis sur les enceintes dans le sud de la Grande Bretagne contraste avec d'autres aspects sociaux qui se développent ailleurs en Grande Bretagne et en Irlande, à une échelle probablement plus petite et moins importante, comme le démontrent la construction d'édifices et de maisons de poteaux ainsi que les formes variées de tumulus et de cairns. On remarque toutefois l'apparition de chevauchements dans la circulation des lames de haches dans des sites d'habitat irlandais, tout comme l'attention généralisée portée aux ancêtres et aux autres dimensions du passé.

De la fin du 36ième jusqu'aux 35ième et 34ième siècles cal BC évolue apparemment une société complexe caractérisée

par des innovations et des continuités. L'occupation principale de quelques enceintes à fossés interrompus se poursuit avec quelques nouvelles constructions tardives. L'innovation monumentale prend son essor au cours d'une période florissante d'environ huit générations seulement, avant de se tourner vers la construction de monuments rectilignes de type *cursus*. Les tumulus allongés (*long barrows*) et les cairns allongés (*long cairns*) continueront à être construits et utilisés. Dans l'état actuel de la documentation, il est encore difficile de décrire la situation, car beaucoup d'aspects dépassent la problématique initiale de notre projet. L'hypothèse qui pourrait être retenue serait l'augmentation de la compétition entre les groupes, ou bien encore, et de façon plus subtile, la rivalité entre des clans ou des lignées ancestrales et plus récentes.

Ce volume s'achève par une réflexion sur la notion de temps, d'action et de mémoire. Les cadres chronologiques beaucoup plus précis concernant certains aspects du Néolithique ancien du sud de la Grande Bretagne permettent de passer du concept de la « longue durée » à une histoire sociale mesurable à l'échelle de siècles, de demi-siècles, de générations et même parfois de décennies. Cette démarche ouvre la voie à une interprétation beaucoup plus détaillée des différents mécanismes de transmission entre générations et remet ainsi en question le terme de 'préhistoire'.

Traduit par Karoline Mazurié de Keroualin

Zusammenfassung

Der vorliegende Band legt die Ergebnisse eines Projektes zur Datierung der frühneolithischen unterbrochenen Erdwerke (*causewayed enclosures*) im südlichen Großbritannien und in Irland vor. Im bisher umfangreichsten Projekt dieser Art wurden hunderte von Radiokarbondaten aus fast 40 Erdwerken im südlichen Großbritannien in Bayes'sche chronologische Modelle integriert. Auf dieser Grundlage kann die Errichtung dieser Erdwerke im Wesentlichen auf den Zeitraum zwischen dem späten 38. Jahrhundert und Mitte bis Ende des 36. Jahrhunderts v. Chr. geschätzt werden. Während die Hauptnutzungsphase einiger Fundplätze bis zu drei Jahrhunderte währte, waren zahlreiche andere von viel kürzerer Dauer (sogar nur einige Jahrzehnte). Die anhand der Erdwerke erzielten Ergebnisse wurden mit anderen Erscheinungen des südbritischen Frühneolithikums verglichen, wobei auf der Grundlage hunderter von Radiokarbondaten aus anderen Monumenttypen, einschließlich Grabhügeln (*long barrows*) und Siedlungsplätzen, Bayes'sche Chronologiemodelle aufgebaut wurden. Dies zeigt, dass sich Erdwerke erst bis zu 300 Jahre nach dem Erscheinen der ersten neolithischen Gegenstände und Praktiken im 41. Jahrhundert v. Chr. etablieren. Es konnte auch nachgewiesen werden, dass der Ausbreitungsprozess der neolithischen Lebensweise sich langsam über mehr als zwei Jahrhunderte vollzog, in Südostengland begann und sich regional unterschiedlich abspielte. Die ersten *long barrows* und ähnliche Monumente erscheinen etwa ein Jahrhundert vor den unterbrochenen Erdwerken. Dutzende von Radiokarbondaten aus zwei irischen Erdwerken wurden ebenfalls bayesisch modelliert und durch einen Vergleich mit hunderten von Radiokarbondaten von anderen frühneolithischen Fundplätzen Irlands in ihren Regionalkontext eingefügt. Obwohl eines der beiden Erdwerke besondere Interpretationsschwierigkeiten bereitet, wird hier argumentiert, dass das irische Frühneolithikum wohl um 3800 v. Chr. begann.

Kapitel 1 widmet sich zentralen Fragen zum Konzept der Zeit und zur zeitlichen Auflösung. Viele Archäologen geben sich mit ungenauen Zeitmaßstäben zufrieden, was sich wiederum auf die Vergangenheitskonstrukte auswirkt, die gewöhnlich vorgeschlagen werden. Ferner gibt das Kapitel eine Einführung zu den *causewayed enclosures* und ihrer Forschungsgeschichte. Kapitel 2 legt die grundlegenden Konzepte der Bayes'schen Modellierung von Chronologien dar und beschreibt die präzisen Informationen und exakten Interpretationen, die für eine erfolgreiche Anwendung in der archäologischen Praxis nötig sind. Es werden nicht nur die entscheidenden ‚a priori' vorliegenden archäologischen Informationen – Vorwissen zur Taphonomie der Proben, sowie deren Kontext, Vergesellschaftung und Stratigraphie – diskutiert, sondern auch die statistischen Annahmen, die in das Modell einfließen. Besonderes Augenmerk liegt auf der unausweichlichen Streuung der C14-Daten für ein gegebenes Phänomen; werden keine Modelle erarbeitet, die dem entgegen wirken, führt dies dazu, dass das jeweilige Phänomen scheinbar früher beginnt, länger anhält und später endet, als in Wahrheit der Fall. Die Laborverfahren, die für genaue C14-Messungen notwendig sind, sowie eine Einschätzung der Genauigkeit der gegenwärtig vorliegenden Radiokarbondaten, werden ebenfalls dargelegt.

Im Zuge dieses Projektes wurde der südliche Teil Großbritanniens in pragmatisch definierte Regionen unterteilt (Kapitel 3–11). Jedes Kapitel stellt zunächst die chronologischen Modelle für diejenigen Erdwerke vor, die für die vorliegende Studie ausgewählt wurden. Dabei werden auch die Auswirkungen der neuen Chronologien auf unser Verständnis der individuellen Fundplätze berücksichtigt. Auf dieser Grundlage wird geschätzt, dass Erdwerke vom späten 38. bis zum mittleren/späten 36. Jahrhundert cal BC angelegt wurden. Die Hauptnutzungsdauer zahlreicher Fundplätze ist zeitlich relativ eng beschränkt, einige wurden jedoch bis zu drei Jahrhunderte lang genutzt. Die folgenden Erdwerke wurden im Zuge des Projektes datiert: Windmill Hill und Knap Hill im nördlichen Wiltshire (Kapitel 3, mit Bezugnahme auf Rybury); Whitesheet Hill, Maiden Castle und Robin Hood's Ball im südlichen Wessex (Kapitel 4, mit einer Neuanalyse der umfangreichen Serie an C14-Daten aus Hambledon Hill); Whitehawk, Offham Hill, Bury Hill, The Trundle und Court Hill in Sussex (Kapitel 5, mit Bezugnahme auf Barkhale, Combe Hill und Halnaker Hill); Maiden Bower, Haddenham, Etton, Etton Woodgate und Northborough in Ostengland (Kapitel 6, mit Bezugnahme auf Briar Hill und Great Wilbraham); Orsett, Kingsborough 1 und 2 und Chalk Hill im Bereich der Themsemündung (Kapitel 7, mit einer Neuanalyse der bereits vorliegenden C14-Daten aus St Osyth); Staines, Eton Wick, Gatehampton Farm und Abingdon im mittleren und oberen Tal der Themse (Kapitel 8); Crickley Hill und Peak Camp in den Cotswolds (Kapitel 9); Hembury und Raddon Hill, sowie die mit Steinmauern eingefassten Anlagen von Helman Tor und Carn Brea in der südwestlichen Halbinsel Englands (Kapitel 10; mit Bezugnahme auf Membury); sowie Hill Croft Field und Banc Du in Südwales und den Welsh Marches (Kapitel 11; mit der Datierung von Beech Court Farm, das sich als bedeutend jünger herausstellte, und von Billown auf der Insel Man, einer wichtigen frühneolithischen Siedlung, die aber wohl keine *causewayed enclosure* im Sinne der südbritischen Anlagen ist). Im Anschluss werden Radiokarbondaten und chronologische Modelle für andere frühneolithische Verhaltensweisen

der jeweiligen Region vorgestellt. Formale Schätzungen für das erstmalige Auftreten neolithischer Gegenstände und Praktiken werden in den Kapiteln 5, 6, 9, 10 und 11 entwickelt, weiterführende Analysen folgen in Kapitel 14. Den Abschluss jedes Kapitels bildet eine Diskussion der Auswirkungen aller regionalen Chronologien auf unser Verständnis der ersten Jahrhunderte, in denen neolithische Verhaltensweisen auftreten.

Für Irland (Kapitel 12) werden chronologische Modelle für die Erdwerke von Donegore und Magheraboy vorgestellt. Der Bau der Anlage von Donegore in der Grafschaft Antrim fällt in die Blütezeit der Errichtung südbritischer Anlagen und es wird auf den örtlichen und regionalen Kontext des Fundplatzes eingegangen. Magheraboy in der Grafschaft Sligo hat ältere Daten erbracht und scheint in das 40. und 39. Jahrhundert cal BC zu fallen. Dieses Ergebnis verlangte nach einer weiter gefassten Prüfung der Datierung des gesamten irischen Frühneolithikums. Hunderte von C14-Datierungen wurden in chronologische Modelle für weitere Monumenttypen und Verhaltensweisen eingearbeitet. Es wird geschätzt, dass neolithische Gegenstände und Praktiken im späten 39. oder im 38. Jahrhundert zum ersten Mal in Irland auftraten (zwei alternative Modelle werden diskutiert). Viele Aspekte können nicht genau datiert werden, was auch auf zahlreiche *court tombs* und Portalgräber zutrifft; Gräber vom Typ Linkardstown und Ganggräber werden als mittelneolithische Innovationen der zweiten Hälfte des 4. vorchristlichen Jahrtausends angesehen und werden benutzt, um die Modelle für das Frühneolithikum zeitlich näher einzugrenzen. Die rechteckigen, aus Holz erbauten Häuser lassen sich besser datieren und wurden lediglich vom 38. bis ins 37. Jahrhundert cal BC errichtet und genutzt. Abgesehen von domestizierten Rindern, die in Ferriter's Cove in der Grafschaft Kerry aus einer Fundschicht des späten 5. Jahrtausends bekannt sind, besteht eine schwer interpretierbare Lücke zwischen der offenbar frühen Datierung Magheraboys und den Schätzungen des ersten Auftretens neolithischer Gegenstände und Praktiken in Irland, die auf der Grundlage aller anderen chronologischen Modelle vorgeschlagen werden. Eine weiterführende Diskussion zu Irland im Rahmen des südlichen Großbritanniens folgt in Kapitel 14.

Isotopische Ergebnisse von menschlichen und tierischen Überresten aus vier südbritischen *causewayed enclosures* werden in Kapitel 13 vorgestellt. Der Vergleich mit anderen frühneolithischen Kontexten hebt hervor, dass sich Umweltgegebenheiten und Ernährung wohl recht vielfältig gestalteten.

Kapitel 14 führt alle in Kapiteln 3–12 gesponnenen chronologischen Fäden zusammen, um auf dieser Grundlage eine neue Interpretation der Entwicklung des Fühneolithikums in Südbritannien und Irland zu entwickeln. Zunächst werden die unterbrochenen Erdwerke aus dem südlichen Großbritannien analysiert, danach weitere frühneolithische Verhaltensweisen, unter Einbeziehung der Modelle für das Auftreten neolithischer Gegenstände und Praktiken im südlichen Großbritannien. Schließlich wird der Beginn des Neolithikums in Irland, auf der Insel Man und in Schottland südlich des Great Glen angeschnitten.

Zahlreiche zentrale Aspekte der südbritischen *causewayed enclosures* werden aus dem Blickwinkel der genaueren Chronologien, die jetzt verfügbar sind, untersucht. Die Geläufigkeit, Einführung und Ausbreitung dieser Erdwerksform werden analysiert und die Modelle für einzelne Fundplätze und Regionen zusammengeführt. Die ersten Erdwerke wurden in Ostengland errichtet und die Geschwindigkeit von Neugründungen stieg über drei bis vier Generationen kontinuierlich an, bis im späten 37. Jahrhundert cal BC ein Höhepunkt erreicht wurde. Zu Beginn des 36. Jahrhunderts erfolgte dann offensichtlich eine gewisser Rückgang der Bautätigkeit, gefolgt von weiteren Neubauten, die bis Mitte/Ende des 36. Jahrhunderts cal BC anhielten. Die neuen Modelle erlauben auch eine präzisere Diskussion zu weiteren Aspekten, wie zum Arbeitsaufwand, der mit der Errichtung dieser Anlagen verbunden war und an einigen Fundplätzen in konzentriertere Episoden intensiver Tätigkeit aufgeteilt werden kann; zu den Entwicklungsverläufen von Fundplätzen mit mehreren Grabenringen oder mehreren Erdwerken, die tendentiell länger als einfache Anlagen bestehen; sowie zu den Endpunkten und der sehr unterschiedlichen Dauer der einzelnen *causewayed enclosures*. Für ausgewählte Fundplätze werden modellierte Schätzungen zur Verfüllungsdauer und zum erneuten Ausheben der Grabenringe, sowie für die Intensität der Fundablagerung in Gräben vorgestellt. Die präziseren zeitlichen Rahmen zeigen dabei, dass die Fundablagerung zu einem beliebigen Zeitpunkt weniger intensiv war, als generell in der Literatur angenommen, aber selbst mit dem Fleisch von nur ein oder zwei Kühen konnte wohl eine beträchtliche Anzahl Personen bewirtet werden. Es folgt ein Vergleich mehrerer datierter Gewaltepisoden in Erdwerken, die Tötungen, Angriffe mit Pfeilen und Brandschatzung umfassen. Im östlichen Teil des südlichen Großbritanniens treten Anzeichen solcher Verhaltensweisen seltener auf.

Abgesehen von vielleicht zwei oder drei frühen Kandidaten scheinen Bauten wie *long barrows* und *long cairns* ab ungefähr 3800 cal BC in größerer Anzahl errichtet worden zu sein. Bisher können die Behauptungen, dass Typen wie Portaldolmen, kleine ovale Grabhügel oder Rotundae besonders alt seien, nicht bestätigt werden. In jeder der hier behandelten Regionen Südbritanniens kann nachgewiesen werden, dass das Erscheinen der *causewayed enclosures* nach dem Beginn anderer frühneolithischer Verhaltensweisen einsetzt. Die Intervalle sind dabei unterschiedlich, da auch die geschätzten Anfangsdaten für den Beginn anderer neolithischer Verhaltensweisen sich zwischen den südbritischen Regionen unterscheiden. Die ersten neolithischen Gegenstände und Praktiken erscheinen um die Mündung der Themse im 41. Jahrhundert cal BC und breiten sich dann, nicht unbedingt nur von einem Mittelpunkt ausgehend, nach Westen aus. In den Generationen um 3700 cal BC erreichen sie Südwales und die Welsh Marches. Chronologische Tendenzen in der Entwicklung keramischer Stile und der Herstellung und Verbreitung von Steinäxten können ebenfalls modelliert werden.

Südwestliche Keramikstile treten im 38. Jahrhundert cal BC auf, sind also jünger als der weit verbreitete und von Anfang an vertretene Windmill Hill-Stil (Carinated Bowl style) mit den characteristischen Knickwandschüsseln. Die sogenannte ‚verzierte Keramik' erscheint im späten 38. oder frühen 37. Jahrhundert cal BC, zeitgleich mit oder kurz nach dem ersten Auftreten der *causewayed enclosures*. Steinäxte scheinen ebenfalls vom 38. bis ins 37. Jahrhundert cal BC hinein in Umlauf gewesen zu sein. Diese Entwicklungen bündeln sich zu einer beschleunigten Innovationsrate, die durch das gesamte 38. Jahrhundert cal BC hindurch anhält und dem Auftreten der Erdwerke selbst vorangeht oder es begleitet. Dieser Teil des Kapitels 14 endet mit einer systematischen Zusammenschau der grundlegenden Elemente in der Entwicklung des Frühneolithikums im gesamten südlichen Großbritannien.

Kapitel 14 beschäftigt sich ferner mit einem Vergleich der frühneolithischen Entwicklung in Irland (auf der Grundlage von Kapitel 12), auf der Insel Man (aus Kapitel 11) und in Schottland (unter Nutzung verfügbarer Radiokarbondaten aus dem Gebiet südlich des Great Glen). Die modellierten Schätzungen zur Datierung weisen darauf hin, dass der Beginn frühneolithischer Verhaltensweisen in Irland und Schottland ins späte 39. oder an den Anfang des 38. Jahrhunderts cal BC fällt, auf der Insel Man vielleicht ins 38. Jahrhundert cal BC. Die hölzernen hallenartigen Häuser Schottlands und die irischen Häuser werden als frühe Komponenten neolithischer Verhaltensweisen definiert; die Abfolge anderer Monumenttypen ist für beide Regionen schwerer nachzuvollziehen (und für die Monumente der Insel Man gibt es fast keine C14-Daten). Kapitel 14 endet mit einer Gesamtübersicht zur chronologischen Entwicklung des Frühneolithikums in Großbritannien und Irland.

Kapitel 15 kommentiert die in Kapitel 14 dargelegten Interpretationen. Die Diskussion orientiert sich am Ablauf der Ereignisse vom Anfang bis zum späteren Abschnitt des Frühneolithikums. Die in Kapitel 14 vorgestellten Modelle zum Beginn frühneolithischer Verhaltensweisen werden mit anderen einflussreichen Interpretationen aus der Literatur verglichen, die von Kolonisation einerseits bis zur Akkulturation einheimischer Jäger- und Sammlergruppen andererseits reichen. Hier wird ein alternativer Interpretationsweg eingeschlagen, der auf einer weiter gefassten Kolonisationstheorie fußt. Nach dieser Auffassung gab es wohl, in kleinerem Umfang, eine gewisse Kolonisationsbewegung aus den benachbarten Regionen Kontinentaleuropas nach Südengland. Dem folgte eine anhaltende und sich stetig beschleunigende Verbreitung neolithischer Gegenstände und Praktiken, die wahrscheinlich von Anfang an auch die Akkulturation einheimischer Bevölkerungsgruppen umfasste. Siedlungsmuster und Veränderungsprozesse auf dem benachbarten Festland werden kurz angerissen um das Argument einer gefilterten Kolonisationsbewegung geringen Umfanges, kombiniert mit örtlichen Veränderungstendenzen, wahrscheinlicher zu machen. Im Folgenden wird Beweismaterial zur Siedlungsstruktur und Ernährungsweise in den ersten Jahrhunderten des südbritischen Neolithikums im Lichte der chronologischen Modelle neu bewertet. Es gibt weder deutliche Hinweise auf einen massiven Anstieg der Bevölkerungszahl noch eine deutliche Intensivierung wirtschaftlicher Praktiken. Vieles muss jedoch noch besser untersucht werden, vor allem auch die Entwicklung des Rinderhütens. Andererseits zeigen Monumente und materielle Kultur deutlichere Anzeichen von Veränderung. Es wird auf die möglichen sozialen Rollen eingegangen, die Anlagen wie *long barrows* oder *long cairns* beispielsweise im Zuge der Definition von Identitätsgrenzen miteinander konkurrierender Gruppen spielten; sie wurden wahrscheinlich ab ungefähr 3800 cal BC in grösserer Zahl errichtet. Das sich ständig beschleunigende Aufkommen materieller Neuerungen hielt durch das gesamte 38. Jahrhundert cal BC an, begann also vor der Errichtung der ersten Erdwerke und begleitete dann deren Entwicklung. Es weist ebenfalls auf dynamische, vielleicht auf Konkurrenzverhalten basierende gesellschaftliche Verhältnisse hin.

Der kontinentaleuropäische Hintergrund zu Bau und Nutzung von Erdwerken zeigt eine lange historische Entwicklung auf, die bis ins 6. Jahrtausend cal BC zurückreicht. Die unterbrochenen Erdwerke im südlichen Großbritannien und in Irland lassen sich am besten mit denen des Michelsberg-Chasséen Komplexes auf dem benachbarten Festland vergleichen, die angeblich bereits ab dem späteren 5. Jahrtausend auftreten, aber noch bis ins frühere 4. Jahrtausend hinein erbaut werden (allerdings macht die Ungenauigkeit der zur Verfügung stehenden Chronologien auf dem europäischen Festland eine Aufschlüsselung detaillierter Beziehungsgeflechte zum gegenwärtigen Zeitpunkt unmöglich). Die um 3700 cal BC einsetzende Errichtung von Grabenwerken im südlichen Großbritannien weist (abgesehen von der Möglichkeit einer Einwanderung neuer Bevölkerungsgruppen) auf einen gewollten Versuch hin, sich auf Kontakte und Gemeinsamkeiten mit ferneren Regionen und deren Praktiken zu berufen und unterstützt die Idee von Wettbewerb und Nachahmung zwischen sozialen Gruppen.

Weltanschauungen waren um einen zentralen Ideenkomplex gruppiert, der Prinzipien einer altersbedingten Rangstruktur, dem Beweisen von Können und Tapferkeit, sowie Zugehörigkeit und Beziehungsnetzwerke umfasste. Die detailliert nachgezeichnete historische Situation der Errichtung und Nutzung von *causewayed enclosures* während ihres Höhepunktes im 37. und der ersten Hälfte des 36. Jahrhunderts cal BC verankert diesen Ideenkomplex in einem bestimmten Kontext, für den hier verschiedene Ansätze zu potentiellen sozialen Beziehungen in Betracht gezogen werden. Ein Hauptaugenmerk liegt dabei auf der möglichen Rolle ritueller Experten und Organisatoren mit einer gesellschaftlichen Vorrangstellung. Der Schwerpunkt, der zu dieser Zeit im südlichen Britannien auf Erdwerke gelegt wird, steht alternativen Modalitäten des gesellschaftlichen Zusammenlebens gegenüber, die in anderen Regionen Großbritanniens und Irlands vorherrschten und vielleicht als kleinräumiger ausgerichtet und weniger intensiv

beschrieben werden können. Sie zeigen sich beispielsweise in der Errichtung von hölzernen hallenartigen Gebäuden und Häusern und in den verschiedenen Arten von Grab- und und Cairnkonstruktionen. Allerdings gibt es auch Übereinstimmungen, die sich etwa in der Zirkulation von Steinäxten zwischen einigen irischen Hausfundplätzen und in einer weit verbreiteten Ehrfurcht gegenüber Ahnen und anderen Aspekten der Vergangenheit andeuten.

Vom späten 36. bis ins 35. und 34. Jahrhundert cal BC scheint eine komplexe Welt aus Innovationen und Kontinuitäten bestanden zu haben. Obwohl die Erstnutzungsphase mancher unterbrochener Erdwerke anhielt und es möglicherweise einige späte Neuerrichtungen gab, verschob sich das Streben nach monumentalen Innovationen, nach einer Blütezeit von nur circa acht Generationen, hin zur Errichtung linearer Cursus-Monumente. *Long barrows*, *long cairns* und wohl auch Portaldolmen wurden weiterhin errichtet und genutzt. Bei gegenwärtiger Beweislage und mit zahlreichen noch ungeklärten Aspekten, die jenseits der Zielsetzungen dieses Projektes lagen, ist es schwer, die Situation präzise zu beschreiben. Mögliche Erklärungsansätze könnten entweder eine Intensivierung des Konkurrenzverhaltens zwischen sozialen Gruppen beinhalten, oder sich auf subtilere Prozesse, wie beispielsweise Rivalitäten zwischen Clans oder Lineages unterschiedlichen Ranges berufen.

Der vorliegende Band endet mit weiteren Überlegungen zu verschiedenen Auffassungen von Zeit, Vergangenheitsbezug und zielgerichtetem Handeln. Der jetzt viel genauere zeitliche Rahmen für einige Aspekte des Frühneolithikums im südlichen Großbritannien ermöglicht es, den Schwerpunkt unseres Interesses von der *longue durée* hin zu einer Sozialgeschichte zu verschieben, die man in Einheiten von Jahrhunderten, halben Jahrhunderten, Generationen und manchmal sogar Jahrzehnten messen kann. Auf diese Weise öffnen sich mögliche Überlieferungsprozesse zwischen den Generationen einer viel genaueren Analyse und erhellen so Teilaspekte der ‘Vorgeschichte’.

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Abbreviated list of figures

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1 Gathering time: causewayed enclosures and the early Neolithic of southern Britain and Ireland

Alasdair Whittle, Frances Healy and Alex Bayliss

> The long run is a misleading guide to current affairs. In the long run we are all dead. Economists set themselves too easy a task…if they can only tell us that when the storm is past the ocean is flat again.
>
> Maynard Keynes, *A tract on monetary reform* (1923)

1.1 Prehistorians and chronological resolution

'There is no history without dates': thus Claude Lévi-Strauss (1966, 258) towards the end of *La pensée sauvage*. To this leading anthropologist of a generation ago, it seemed self-evident that to write history required quantification of the lapse of time. In contrast, the thinking of most prehistorians has been characterised by a time that is either entirely un-quantified, or by one that is confined to a vocabulary of millennia, half-millennia or at best quarter-millennia. In this volume, we seek to challenge this fuzzy prehistory, and to show, in this provisional, first account, how a very different kind of history can emerge.

Chronology has not been entirely neglected. In continental European Neolithic studies, laborious attention has long been given to building chronologies, but often within a restrictive model of culture history (Whittle 1988a), and often with calendar dates serving only as occasional hooks on which long relative sequences are hung. In British Neolithic studies, chronology building since the advent of radiocarbon dating has tended to rely on informal estimates based on visual inspection of calibrated radiocarbon dates. In contrast, the Neolithic dendrochronologies of the Alpine foreland stand out for providing astonishing timetables, which are both detailed and reliable (Menotti 2004); a striking recent example is the dating of the life of one settlement, Arbon Bleiche 3 in northern Switzerland, to a mere 15 years, between 3384 and 3370 BC (Jacomet *et al.* 2004). But this precision is confined to the domain of settlement and the everyday at discrete locations. The detailed individual site biographies of the Alpine foreland tend to float separately from wider generalisations about the pattern of long-term change (including, for example, a gradual shift in subsistence staples, extending scales of clearance, and increases in site size and duration). It is not clear that these detailed site chronologies have yet contributed to a fundamentally different kind of prehistory.

In the different settlement record and the wide array of monuments characteristic of Britain and of north-west Europe as a whole – but largely lacking in the Alpine foreland – a recurrent perspective has emerged. This allows us to investigate the cycles of daily life, the broad outlines of social relationships and the essential elements of worldview, perhaps even including something of the experience of time, and the slow turn of cultural change, within an imprecise timeframe that necessarily floats across centuries. Given our general reliance on radiocarbon dating and its inherent imprecision, this may seem both natural and unavoidable, but this can now be challenged.

This book is about the dating of the early Neolithic causewayed enclosures of southern Britain and of Ireland. Using chronological estimates produced by Bayesian statistical analysis of hundreds of radiocarbon dates, it establishes that these ceremonial arenas, the loci for gathering, construction, intense social interaction, and deposition, began in southern Britain in the late 38th century cal BC, and flourished principally in the 37th and 36th centuries cal BC. By interpretation in a Bayesian chronological framework of more than a thousand other radiocarbon dates from other kinds of contexts, the volume also shows that causewayed enclosures were preceded, by some three to four centuries, by the first Neolithic activity in southern Britain; the initial establishment and spread of Neolithic things and practices was gradual, from the 41st century cal BC in south-east England onwards, and probably did not reach the majority of Britain and Ireland till around 3800 cal BC. The first monuments to be built, long barrows, long cairns and other related forms, were in existence by that date, and a series of other accelerating changes can begin to be detected during the course of the 38th century cal BC. Some causewayed enclosures went on to have a long history, the initial use of a few continuing into the 34th or 33rd centuries cal BC, but these have proved the exception rather than the norm; probably from

the mid- or later 36th century cal BC, a new linear kind of construction, the cursus monument, came into fashion, and in the 35th and 34th centuries cal BC there was a mixture of tradition and innovation which challenges many of our current assumptions and interpretations.

This outline, we believe, begins to offer a new view of the historical development of the early Neolithic in southern Britain, and we present too a first sketch of new possibilities for the early Neolithic in Ireland, where enclosures were far scarcer. Is this approach of interest, as we hope it will be, only for specialists in the study of the Neolithic period in Britain and Ireland, or at a pinch, in north-west Europe more broadly? Or is it of more fundamental importance, as we think it should be, for prehistorians and other archaeologists everywhere so far lacking detailed control of chronological sequence? The effort of the project could have been directed, after all, at any number of other kinds of site, period or area. So we begin by reflecting further on the interpretation and resolution of time, and this general concern with the kind of prehistory that we can now write will also run through the whole volume and form its endnote.

How then have prehistorians, say over the last 60 years, got on with time? The simple or widely provided answer would point to chronological schemes based on typologies and seriations of material culture assemblages, to dendrochronologies in the few areas blessed with the necessary conditions of organic preservation, and above all to the advent and development of radiocarbon dating, through a series of well documented revolutions: from initial establishment, to calibration, to the use of much smaller samples in accelerator mass spectrometers (Renfrew 1973a; R. Taylor 1995; Bayliss 2009). There have been stunning successes. The word 'revolution' can be over-used but there is a genuine gulf between pre-radiocarbon and post-radiocarbon prehistories. Calibration in particular enabled prehistorians to isolate the local or regional from the general, and to track processes of change over the long term. But developments of this kind, as Chapter 2 will set out in much more detail, did not radically improve the precision as opposed to the accuracy of the radiocarbon method, and dates were routinely and universally interpreted on an informal basis, by visual inspection. Using this approach, archaeologists generally incorrectly estimate the start and end dates of given phenomena, and overestimate their durations, and while long-term trends may be visible, precision is still elusive. Suppose, however, that historians were unable to separate processes and events in England in the fourteenth, fifteenth and sixteenth centuries AD. In that scenario, the decline and then re-establishment of kingship, factional struggles, the end of feudalism, the growth of the more centralised Tudor state, the Black Death, the beginnings of enclosure, religious upheaval, and innumerable shifts in foreign policy, to name but a few factors (Elton 1974), would all be inextricably mixed together.

As Chapter 2 sets out in much more detail, formal date estimates of much greater precision can now be achieved by implementing Bayesian statistics to model archaeological chronologies explicitly (Bayliss and Bronk Ramsey 2004). This approach is not new. The mathematics for its application to radiocarbon dating have been developing since the 1990s (Buck *et al.* 1991; 1992; Christen and Litton 1995; Christen *et al.* 1995; Bronk Ramsey 1995; 2009a; Nicholls and Jones 2001) and many other projects have been successfully carried out with it (Bayliss 2009). But most of these are either site-based studies, valuable in their own right but limited by lack of a corpus of sites dated to a similar resolution for comparison, or general studies of typological or phasing sequences which simply aim to provide more robust and precise chronologies for particular aspects of prehistory. One of the aims of this study, in contrast, is to demonstrate what may be possible when Bayesian techniques are applied routinely to all aspects of a particular archaeological period or problem. What sort of prehistory could emerge if all radiocarbon dates for the British Neolithic were in future measured on samples selected by the criteria employed here and modelled using the methods adopted in this study? Within British archaeology the benefits of such an approach are beginning to be appreciated, and the skills-base necessary for its routine implementation is beginning to be developed. The implications of the approach, however, have not yet reached general consciousness within the wider discipline, and so another aim of this volume is to accelerate and reinforce that process.

Another kind of catching up can be seen in the broader, more reflective interpretation of time and timescales that can be traced back to the end of the 1970s and the 1980s, and which has then accelerated from the 1990s through to the present. Gavin Lucas has usefully discussed many of the key texts in his *The archaeology of time* (2005), so this initial account can be brief and selective. From the first general reflections of Mark Leone (1978) and Michael Shanks and Christopher Tilley (1987), and the detailed treatment of anthropological perspectives by Alfred Gell (1992) and Tim Ingold (1993), to more concentrated archaeological approaches offered for example by Douglass Bailey (1993), Richard Bradley (1991; 2002), Chris Gosden (1994; Gosden and Lock 1998) and Dušan Borić (2003), increasing numbers of prehistorians and archaeologists in general have concerned themselves with the experience and flow of time, and from that with issues of the social construction of time, of memory and forgetting, and of the nature of the past in the past. There have been discussions of the philosophy of time, going back to McTaggart, Heidegger, Bergson and Merleau-Ponty (Gell 1992; Ingold 1993; Lucas 2005, chapter 1). What might seem like the abstract discussions of, for example, McTaggart's A-series (described in terms of tense) and B-series (described in terms of succession) time, or the retentions and protentions of the experience of the flow of time first perhaps fully propounded by Heidegger (building on initial reflections by Husserl), have been brought into more concrete interpretations of different aspects of the European Neolithic. There has been a surge in studies of

memory (and forgetting), and the popular notion of an abiding consciousness of ancestors, though it can probably be traced to other sources as well, fits in well here. What can be loosely called the social construction of time has also benefited from renewed anthropological attention, itself with a distinguished longer history (briefly documented also by Lucas (2005, 61–7)). The recent volume *The qualities of time* (James and Mills 2005) seeks to move beyond characterisations of a sense of time as cultural representation or norm, to better understanding of how ideas about time affect action, history and tradition.

These are therefore, in many ways, fertile interpretive times. The approaches noted underpin part of our own interpretations in this volume of the historical significance of causewayed enclosures and other sorts of early Neolithic construction and practice. But it is important to stress that these kinds of enquiry have so far been followed within a very generalised chronological framework. There has been a tendency to downplay sequence as 'mere chronology', as the order of beads on a string, in the search for history and temporality (Ingold 1993). On another tack, general dicta about the span and reach of memory have been offered, for example by Richard Bradley (2002, 8) on a claimed 200-year maximum duration for the normal transmission of unaltered oral traditions.

This is not to claim that no attention has been given, alongside these other developments, to timescales and time resolution, but this has mostly been in favour of the longer-term perspective, in varying forms. Geoff Bailey (1981; 1983; 2007) proposed 'time perspectivism', 'the belief that differing timescales bring into focus different features of behaviour, requiring different sorts of explanatory principles' (G. Bailey 1981, 103). This view draws attention to different timescales, and especially 'the relatively coarse temporal resolution and palimpsest nature of much of the archaeological record; [and] the possibility that the increased time depth and varied time resolution of observation afforded by archaeological data might allow us to perceive phenomena and processes not visible at smaller scales of observation' (G. Bailey 2007, 199). In claiming that 'different sorts of phenomena are best studied at different time scales', Bailey goes on to argue that (2007, 201–2):

> …the analysis of small-scale phenomena such as individual agency, inter-personal interactions and perception, which have become such a dominant tendency in recent archaeological interpretation, is better focused on observations of, say, present-day practices or recent historical periods rather than the deeper prehistoric past.

The 'palimpsest' nature of the formation of the archaeological record brings in the problem of chronological control, and in general a very pessimistic view of the possibility of achieving chronological precision is taken (G. Bailey 2007, 206). This volume strongly disagrees with this stance (see also J. Harding 2005), since it appears to accept that past difficulties in achieving chronological precision are fixed for all time, and cannot be countered, and appears to lump all manner of archaeologies and archaeological records crudely together. It is telling that the substantive example offered in the most recent presentation of time perspectivism is to do with long-term erosional processes in Greece, for which we would advocate, instead, interrupting the sequence at any one point, to examine change over the short-term. Without this, it is pointless to declare in advance that change is long-term only. Nonetheless, the vision of 'the intersection and interweaving of many different sorts of processes with different sorts of temporal rhythms – operating over different time spans and with different frequencies and amplitudes of variation' (G. Bailey 2007, 214) raises important challenges which must be faced over the course of this volume.

Another obvious approach favouring the long term is that inspired by the *Annales* school of history (Bintliff 1991; Knapp 1992; cf. Lucas 2005, 16–17), and especially the application of the concept of *la longue durée* found in the early work of Ferdnand Braudel (1975). As Geoff Bailey has commented (2007, 201), 'archaeologists who feel most comfortable identifying with this approach [*Annales*] are generally those who work on recent millennia with a time depth and resolution of data quite similar to historians, inclined to consign phenomena of greater time depth to Braudel's somewhat indeterminate *longue durée*'. The simple *Annales*-derived approach downplays the shorter timescales of *l'histoire événementielle* and medium-term social history but it is important to stress that the substance of Braudel's classic treatment of the sixteenth-century Mediterranean is in fact precisely at these scales. The opening rhetoric, which has swayed many prehistorians resigned to having coarse or fuzzy chronology, is about long duration and deep time, but the vast majority of the book deals with a combination of individual and social histories. Nor are the relationships between the different timescales and processes, even though there are claims to have identified them (e.g. Cobb 1991), often directly addressed.

Other important variations on this theme are to be noted. John Robb (2007) has argued for the need to get beyond a kind of 'ethnographic present' to produce accounts of change at much longer timescales (2007, 287), referring to a scale of 'spans of time up to several centuries' (2008, 57). For him, 'explaining long-term change has been a striking lacuna in recent archaeological theory' (Robb 2007, 287), with accounts trapped in a kind of ethnographic timeframe of a generation or so (Robb 2007, 291). Specifically in his study of long-term change in the Neolithic Mediterranean, he has called for fresh perspectives on 'how humans make their history on a scale beyond experience of a single lifetime' (Robb 2007, 3), and argues that 'the timescale of most interest for observing historical workings of practice is likely to be neither the span of decades nor of millennia, but on the order of a few centuries' (Robb 2007, 294); 'the pace of change is likely to be highly variable, with great stability and slow, gradual change punctuated by episodes of rapid change' (Robb 2007, 295). But overall, the Neolithic sequence is in general smoothed, though

there are 'at least three distinct moments of change', with much continuity, change happening 'in degrees without abrupt ruptures, even when the aggregate transformation over long epochs was dramatic' (Robb 2007, 320–21). In this approach to the long term, there is a chronological frame, but timing and tempo tend to be subjugated to the bigger, overall picture.

Ian Hodder's recent synthesis of the Çatalhöyük project argues, alongside other, particular themes, for a 'big picture' change over the span of the occupation of the east mound (*c.* 7400–6000 cal BC), from what he calls the 'prowess-animal spirit-hunting-feasting network', involving also notions of ancestry (Hodder 2006, 236–7, 245), to one concerned more with the individual house, domestic and specialised production, and exchange, evident in the upper levels (Hodder 2006, 251, 255–6). The big picture is made even bigger, and the sequence longer, by claiming that practices of feasting and public ceremony did not begin with settled life, but preceded it (Hodder 2006, 236), and, like Andrew Sherratt, Hodder argues that sedentism was the long-term outcome of other factors and processes (including what he calls 'material entanglement') rather than the other way round (2006, 242). What is further distinctive in this account is the view of timescale. The emphasis is on very gradual, slow change: through 'myriad small steps' (Hodder 2006, 251), a 'long-term process of slow gradual change' and 'infinitesimal moves in daily life and daily practices' (Hodder 2006, 236). The process of social and material entanglement 'happened incredibly slowly' (Hodder 2006, 240), though the details of that process have yet to be resolved.

Gavin Lucas (2008, 61) has argued that 'when it comes down to it, an event defined from a historical or sociological perspective does not really work well with archaeological phenomena', and, rather like Geoff Bailey, suggests that concepts of palimpsest, evoking the 'aggregate nature of the record' are more appropriate. In the Mediterranean field, despite much tighter timeframes (Foxhall 2000), Christopher Witmore has urged the use for landscape studies, especially those based on survey data, of ideas of 'percolating time', which the ensemble of the landscape produces, rather than the other way round (2007, 196; cf. Bender 2002). A rather similar position has been expressed by Laurent Olivier; 'the past itself is not made up of a series of successive temporalities but is basically multi-temporal at any time' (2001, 69–70).

Contrary to these varied suggestions, finally, a significant case has been made for the importance of events. Drawing on the historical thesis of William Sewell (2005) that events are transformative of structure, by creating ruptures between material resources and their associated conceptual schemas, Beck *et al.* (2007; cf. Bolender 2010) have argued that events were responsible for many major transformations in the archaeological record, citing cases in Bronze Age Denmark, the emergence of Cahokia, and elsewhere. The approach is very appealing, in that it draws attention again to the short term, but it is not without its own problems. There is the fundamental problem that Sewell (2005, 210) defines other situations which did not produce (or appear to produce) structural transformation merely as 'episodes', and the related difficulty that in the cases offered by Beck *et al.* (and indeed by Sewell) one can detect not single events but a series of developments over a period of time that might equate to Braudel's social history or medium-term *conjoncture*, to be measured in generations. Events in these terms are part of the flow of short- and medium-term process.

Prehistorians therefore have got on with time in a partial, selective and incomplete way.

Imprecise chronologies and long-term perspectives are all very well, if change is really played out over the long-term. But do we know that this is always the case? Does the imprecision of our chronologies smear short-term change over centuries of uncertainty (Baillie 1991) and make it appear, erroneously, to emerge piecemeal over extended timescales? It is possible to aggregate short-term chronologies to study the long-term, but not to utilise long-term data to look at shorter timescales. Having said this, so far there has been little attempt to exploit the detailed biographies of particular sites provided, for example, by dendrochronology, to examine the pace of change or to untangle webs of inter-related development at the temporal scale of the people and communities who experienced them. Partially this is because, working from the base up, it is so easy to drown in detail; and partially because it is so hard to amass a sufficient, and representative, corpus of well-dated sites for such an exercise to be feasible (Bayliss 2009, 142). We need, however, to move from the measurement of elapsed time, to a sense of successive events, and then to how people experienced the flow of time and saw themselves in time. Refined chronologies bring into focus the social context in which agency, change and the choices of individuals and communities occurred. Without time there is no history, and without history our view of human agency, identity, choice, and values must remain substantially incomplete.

1.2 The early Neolithic in southern Britain and Ireland: a note for the general reader on the wider context

Specialists will need no introduction to the familiar ground of the early Neolithic in Britain and Ireland. The general reader or specialists in other fields will want to be aware that in focusing on this period in these areas, from the very late fifth well into the fourth millennium cal BC, we are investigating part of a much longer and wider history. There are, at one level, and in deliberately simple terms, two principal threads. By this time hunter-gather populations had been established in Britain and adjacent parts of continental Europe since recolonisation following the last glacial maximum and in Ireland since early in the Holocene (McCartan *et al.* 2009). Neolithic farmers began to appear in south-east Europe in the seventh millennium cal BC, and had appeared in central and western continental Europe as the LBK (*Linearbandkeramik*) by the middle

of the sixth millennium cal BC (Whittle 1996). The two threads intertwine. New practices and ways of thinking were probably brought in some situations by new people, but the people already there were part of the processes of change, resisting, delaying, adopting and altering slowly or quickly, according to local and regional circumstance.

The LBK world probably encompassed a range of such actors and processes. This was focused on the timber longhouse, but already included some ditched and palisaded enclosures. By approximately the middle of the fifth millennium cal BC, that world changed. By and large timber longhouses disappeared, and a different pattern appeared of dispersed settlements or occupations, with many more enclosures, and a whole range of constructions containing remains of the dead – and over much wider areas of continental western and central Europe, taking the Neolithic way of life for example north into Scandinavia and west to Brittany and central-west France. Complicated interaction between newcomers and the people already there continued, constituting much of the action of the mid- and later fifth millennium cal BC (Whittle 1996; Whittle and Cummings 2007).

Britain and Ireland were now drawn into wider processes of change. This was the time when hunter-gather lifeways were replaced by Neolithic ones. Circumstances differed greatly on the two islands (Cooney 2000a). Ireland had a restricted wild fauna, in which wild boar was the only substantial source of meat, and, by the fifth millennium, had developed a distinctive heavy-blade lithic industry which lacked the microliths which had characterised the earlier industry. In Britain, on the other hand, the wild fauna was similar to that of adjacent parts of the continent, including red and roe deer and wild cattle as well as wild boar, and microliths continued to feature in the narrow-blade lithic industry.

New things and practices appeared in both Britain and Ireland, including an increased scale of woodland clearance, the cultivation of cereals, the keeping of domesticated animals, bowl-shaped pottery, leaf-shaped arrowheads, and ground stone[1] and flint axes, some of them moved or exchanged over considerable distances. People now built rectangular timber structures, and the very varied range of constructions dubbed 'monuments', including again barrows and cairns containing remains of the dead – and causewayed enclosures. That these enclosures were numerous in southern Britain but apparently scarce in Ireland (Fig. 1.1) is only one sign among many that the uptake of innovations which marked the unfolding of the Neolithic was probably different in detail on the two islands. They form the principal theme of this study, but in placing them more precisely in their times, the wider early Neolithic context also comes into sharper focus.

1.3 Causewayed enclosures in southern Britain and in Ireland

Causewayed enclosures (Fig. 1.2) consist of single or multiple circuits and other lengths of interrupted ditch, sometimes with surviving banks (Fig. 1.3), and range in area from over 8 ha to less than 1 ha. Their ditches, especially, contain varied and sometimes rich deposits of human bone, food remains, digging implements and artefacts. These monuments have been pivotal to any understanding of the first part of the Neolithic in southern Britain since they were recognised as a distinct class in the first half of the twentieth century (Cunnington 1909; Curwen 1930). There are now over 70 certain or probable examples and almost as many possible ones in Britain (Fig. 1.2). Their significance for thinking about the period in the twentieth and twenty-first centuries is mainly due to their large size compared with other early Neolithic earthworks, to their often rich cultural assemblages, and to the stratified sequences which they provide. In Ireland, by contrast, only two certain examples are known, and, of these, Donegore was first recognised in the early 1980s, while Magheraboy was discovered in 2001. The story in Ireland has therefore been different (Cooney 2000a; and see Chapter 12 for more detail), though the potential significance of enclosures for the nature of beginnings and early settlement and other questions has not been neglected in the recent literature (Cooney 2007a; Danaher 2007).

The history of investigation in southern Britain is summarised by Alastair Oswald *et al.* (2001, 9–34). The complexity of the sites and their contents have prompted multiple interpretations, through which common threads have run across the decades, their weave shifting with the *Zeitgeist*, as summarised by Chris Evans (1988c), Mark Edmonds (1999, 80–108), Julian Thomas (1999, 38–45) and Alastair Oswald *et al.* (2001, 120–32). The sheer quantity of the debris of living in the ditches of many – greater than in other kinds of contemporary site – has recurrently prompted identification of a settlement component. The ditch segments themselves were initially seen as pit dwellings. In discussion following a lecture to the Society of Antiquaries in 1928 on his excavations at Abingdon, Oxfordshire, E.T. Leeds 'was not prepared to say why Neolithic man lived on the silting. The four hearths in the trenches were good evidence of occupation. At Sutton Courtenay he had unearthed a Saxon dwelling with an ox skull and split bones on the floor, and concluded that primitive man was proof against such inconveniences' (Leeds 1928, 477). The inhabitants were later moved from the ditches to the interior, some sites being seen as settlement enclosures, exemplified by Mortimer Wheeler's Neolithic 'town-ditches' at Maiden Castle, in Dorset (1943, 85). Fortification and defence, originally inferred from superficial similarity to Iron Age hillforts (Cunnington 1909), returned to the fore in the 1980s with evidence for hostilities at sites such as Crickley Hill in Gloucestershire (Dixon 1988a; 1988b) and Hambledon Hill in Dorset (Mercer 1988). A role in animal herding, prompted by the abundant domestic fauna, was seen by Cecil Curwen in the multiple entrances (1954, 79), by Stuart Piggott in a kill pattern suggestive of the autumn slaughter of young cattle that could not be carried through the winter (1954, 29), and by him and by Graeme Barker and Derek Webley

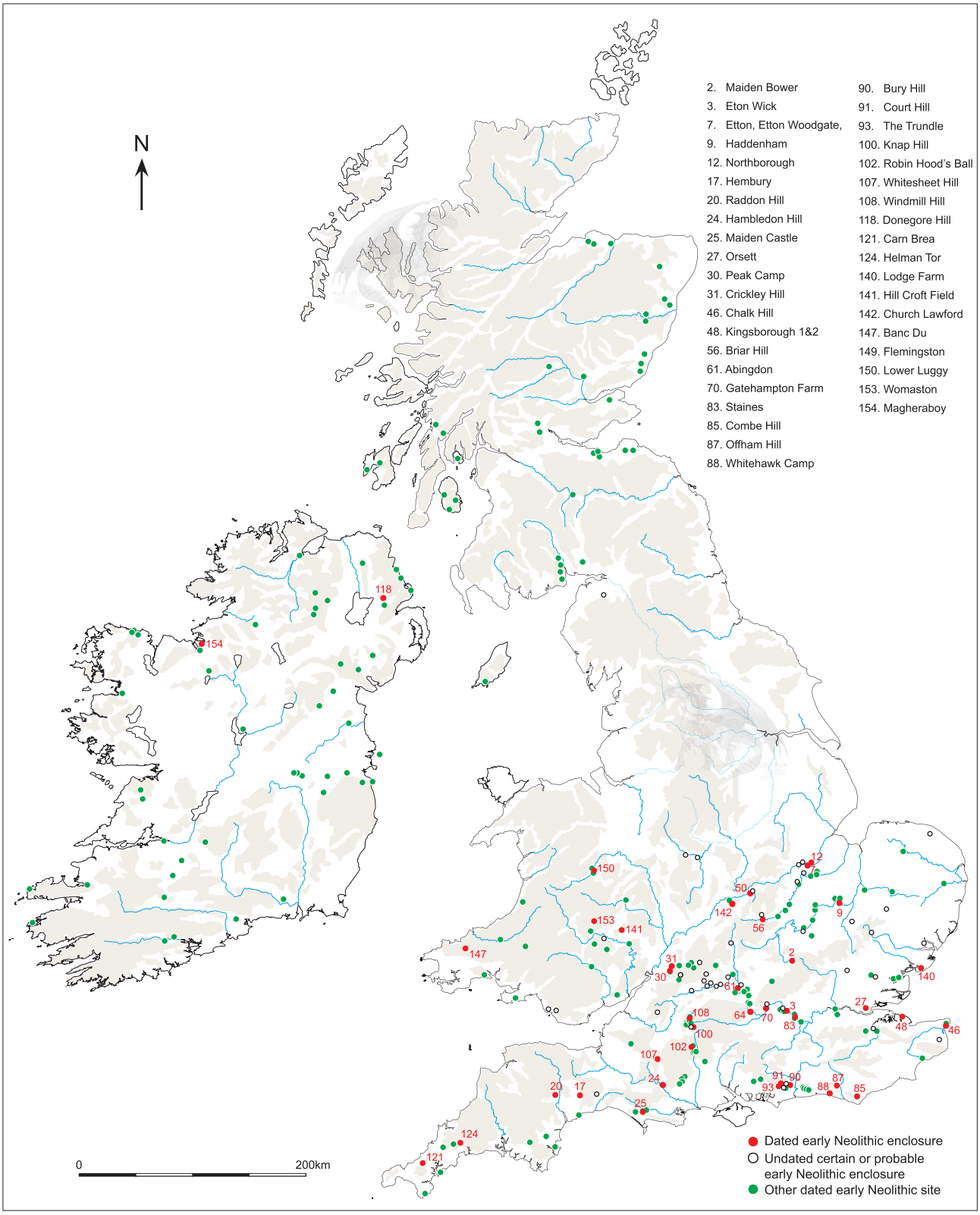

Fig. 1.1. The scope of the project. Dated early Neolithic enclosures in Britain and Ireland, mapped with undated certain or probable early Neolithic enclosures and with other dated early Neolithic sites considered in the text. The latter are confined to southern England, south and mid Wales, Ireland, and Scotland south of the Great Glen. Enclosures are numbered in the sequence of Oswald et al. *(2001, fig. 1.1 and gazetteer) with some deletions and with additions starting at 140. Dragons lurk over areas not modelled in this study.*

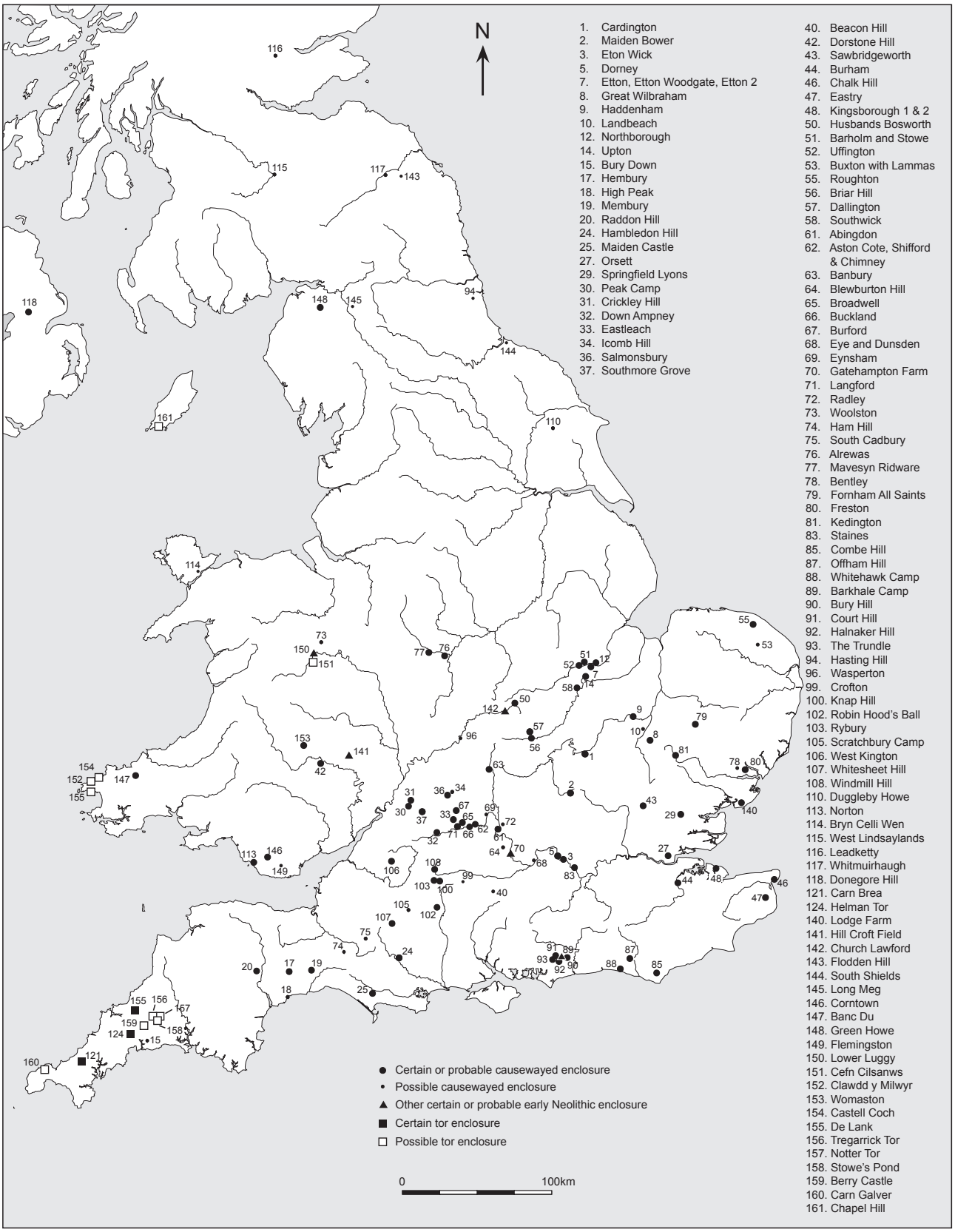

Fig. 1.2. The distribution of certain, probable and possible causewayed enclosures, tor enclosures and other early Neolithic enclosures in Britain. Sites are numbered in the sequence used by Oswald et al. *(2001, fig. 1.1 and gazetteer), with some deletions and with additions starting at 140.*

Fig. 1.3. A reconstruction of the Whitehawk causewayed enclosure in its complete state. Drawing by Ian Dennis.

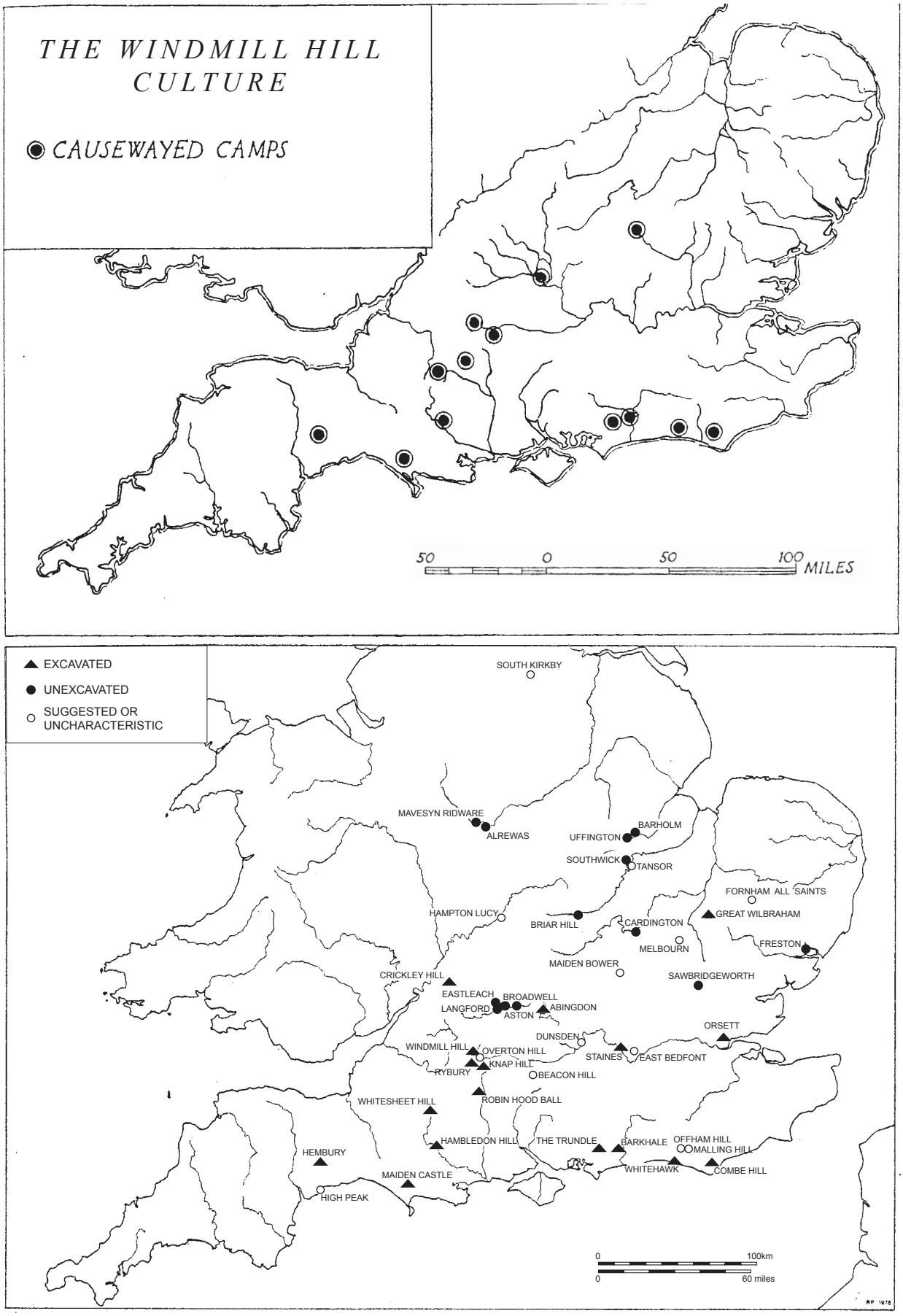

Fig. 1.4. The distribution of causewayed enclosures in the 1950s (upper) and the 1970s (lower). After Piggott (1954, fig. 1) and Palmer (1976a, fig. 1).

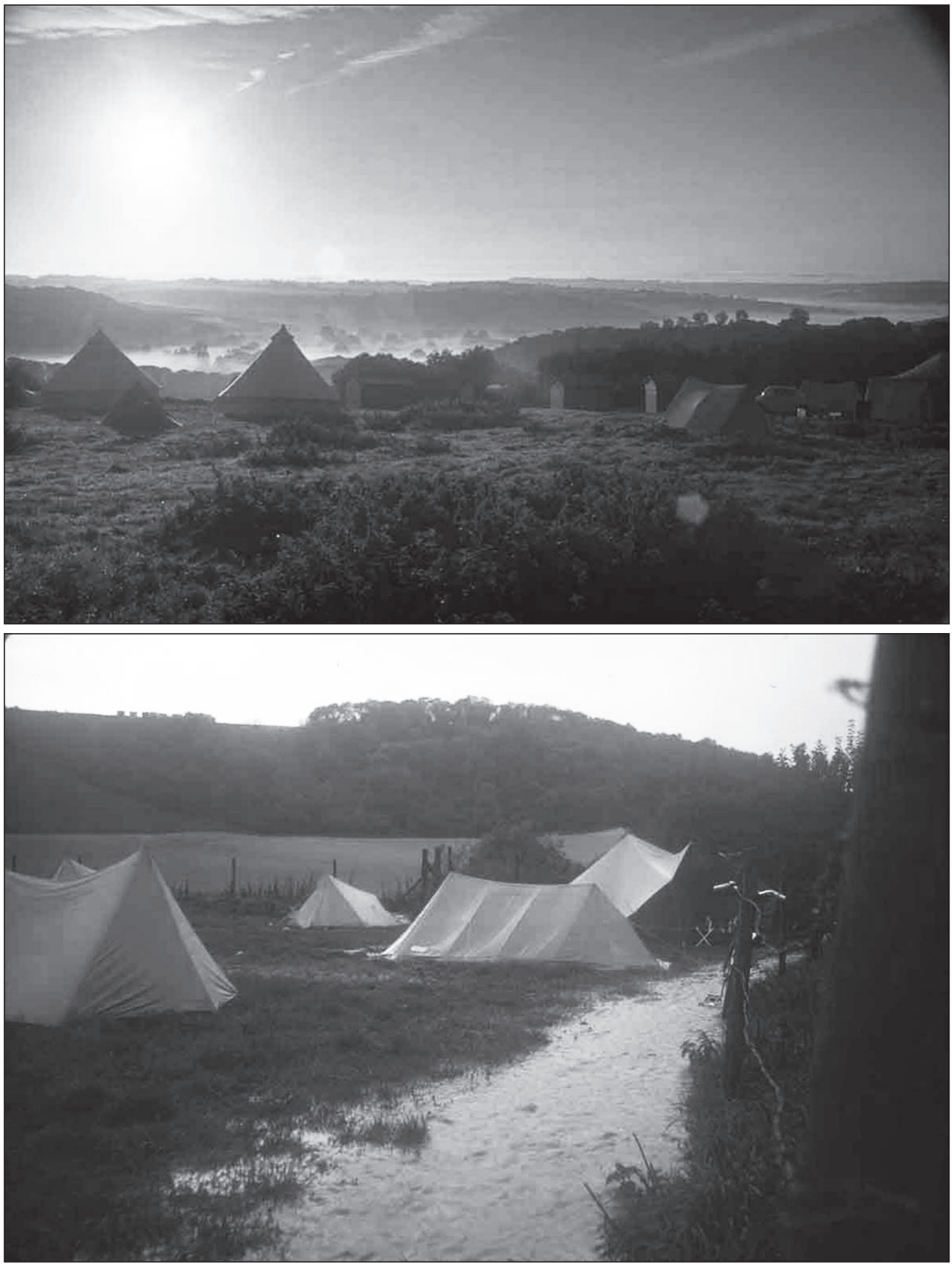

Fig. 1.5. Encampments for the excavations on Hambledon Hill, in 1974, with ground mist (upper), and below the hill in 1976, in wetter conditions (lower). Photos by Rog Palmer.

(1978, 171–3), in the proximity of potential pasture. The frequency of pottery and lithics from remote sources, sometimes of finer quality and manufacture than local products, suggested that causewayed enclosures were foci for the exchange, consumption and deposition of significant objects (I. Smith 1971, 102–5; R. Bradley 1984a; Mercer 1986; Edmonds 1993b). Isobel Smith was among the first to recognise that deposits in causewayed enclosure ditches may have had 'a special, even sacramental, significance', and that there was 'no doubt whatever that the mass of this

material was deliberately thrown or placed in the hollows' (1965a, 7, 20). The identification of pattern and intention in these deposits accelerated and intensified with an increased tendency to see structure and symbolism in the ways in which the mass of artefacts, food remains and spent fuel, as well as obviously 'special' objects, were placed in the ground (e.g. J. Thomas 1999, 62–88).

The frequent presence of human remains, generally weathered and disarticulated, showed that the sites figured in mortuary rites, including excarnation. The possibility of cannibalism (Curwen 1954, 84) gave way to that of the circulation of defleshed bones between enclosures, long barrows and other contexts (Piggott 1962, 68). This line of thought culminated in Mercer's evocation of one of the uses of the main enclosure on Hambledon Hill. 'Was this enclosure one of the "elsewheres" where human corpses were exposed, the transient flesh allowed to deteriorate and ultimately disappear; this prior to a further occasional ceremony whereby some selected bones . . . were passed along an undoubtedly complex funerary *continuum* to encapsulation within a long barrow? . . . Little would have survived of the majority of bodies so disposed in the open, subject to wind, weather and worse . . . Occasionally dogs . . . would have gained access to the site to reap their grizzly harvest' (Mercer 1988, 95). Pictures like this fed a wider perception of the incorporation of ancestors into the affairs of the living (e.g. Barrett 1994, 50–5).

Humphrey Case (1982a, 2–5) used minimum community size, inferred from resource estimates for construction, as the basis of a system in which each enclosure was the nexus of the territory of a descent group composed of up to a dozen nuclear families, each with its own farmstead, and that of the leading family actually located in the enclosure. The territory would provide most of the essential resources, such as timber, antler, potting clay, pasture and arable, some of them extracted from temporary settlements away from the farmsteads, and others would be obtained by exchange with other groups. The accompanying diagrams include a river and a track: journeys within and beyond the territory in the course of the seasonal round would entail contact within and between kin groups, several of whom might come together at particular monuments or events.

Another all-encompassing interpretation, offered by Piggott (1954, 29–30) and expanded by Isobel Smith (1965a, 19), saw the enclosures as seasonal gathering-places for scattered, largely pastoral, populations, foci for the slaughter of cattle and for skin-dressing, but also for everything that such a population might undertake when assembled rather than dispersed: building the earthworks themselves, politics, ceremony, sacrifice, exchange, feasting, match-making and rites of passage. This picture enjoys a long and vigorous life, partly because it fits so much of the evidence from the enclosures themselves, with even the occasional violent episode matching the consideration that a scattered people can be attacked on any scale only when gathered, and partly because it fits so much of the evidence from beyond the enclosures, especially an abiding impression of a contemporary society made up of small, relatively mobile units (e.g. Whittle 1997a). There are loud echoes of Isobel Smith and Stuart Piggott in the more recent evocations of Mark Edmonds (1999, 106–8, 130–2), Francis Pryor (1998, 363–71) and others, not least in the suggestion that, at Windmill Hill, in Wiltshire, practically every dimension of early Neolithic existence was represented: the users' concept of and place in nature, their dealings with the dead, their remembered or mythical pasts, the value placed on live and dead animals, the social roles of feasting and sacrifice, and negotiation of position among and between communities (Whittle *et al*. 1999, 354, 381–90).

For many, if an enclosure was a focal point for a population then there was a connotation of authority. Colin Renfrew's identification of each causewayed enclosure in Wessex as the aggregation site for an emerging chiefdom (1973b) was presaged by Cecil Curwen's 'certain number of defended camps – perhaps tribal headquarters – belonging to the Neolithic period . . . the pottery found in them sometimes exhibits differences of type between one camp and the next, suggesting that communication between them must have been limited, and that pastoral nomadism must have been confined to the tribal area – perhaps as large as an English county' (1946, 55). For others, including Mark Edmonds (1999, 99), enclosures may have been arenas in which identity and authority came into being, rather than expressions of pre-existing authority.

Whatever its sociopolitical context, an enclosure has a relation to its catchment. When it comes to placing the sites within their human and physical landscapes, Isobel Smith was the first to point out that causewayed enclosures tend to lie across the contours rather than on hilltops, most of them being designed to face in a particular direction (1971, 92). The extensive analysis of Alastair Oswald and colleagues has elaborated and expanded this observation, proposing connections between enclosures and the areas to which they are 'tilted' and with which they are intervisible (Oswald *et al.* 2001, 91–106). Such a connection between an enclosure and a lower-lying area to one side meshes with persuasive molluscan evidence that, on the Sussex and Wessex Chalk, enclosures stood in woodland, peripheral to areas regularly occupied by people and their animals (K. Thomas 1982; Evans and Rouse 1991; Bell *et al.* 2008, 450). They were, in other words, part of a round which encompassed a larger landscape; 'What often gets missed is the sense of variety and change in the encounter that people had with these places. Visited periodically, many enclosures were points along the pathways that people trod with their animals. Founded on ecotones, sites like Knap Hill and Rybury sat on the threshold that separated seasons. They were between the lands of winter and summer and, even in more lowland settings, they were often marginal to the places in which people lived for much of the time' (Edmonds 1999, 92–3). Remoteness from the scenes of everyday life has suggested that enclosures may have been the scenes of potentially dangerous rituals, such as rites of passage, conducted in liminal, peripheral locations where the norms of everyday life may not have applied (Evans *et al.* 1988).

This and other interpretations share a tendency to generalise about enclosures, as if they and their uses were formed to a single mental template. Recognition of their diversity in form, size and history has followed from the progressive accumulation of information, viewed, from the 1980s onwards, from a more open, imaginative and creative theoretical standpoint. 'There are parallels between sites and they do seem to reflect the recognition of common ideas and the playing out of familiar themes. Yet . . . it is clear that these ideas were drawn upon rather differently from one time and place to another' (Edmonds 1999, 83). The chronology of the enclosures has largely also been viewed in a generalising way. Sequence and change have long been recognised, both in the use of individual earthworks, as in the introduction of dense, midden-like, deposits of artefacts and food remains into the upper, but not the lower, fills of the inner ditch at Maiden Castle in Dorset (Sharples 1991a, 50–1, 253–4), and in the modification and expansion of earthworks, as in the replacement of two multi-causewayed circuits at Crickley Hill with a single, more continuous, circuit (Dixon 1988a). Chris Evans drew such observations into a view of causewayed enclosures as ongoing projects, construction and reworking inherent parts of their use and purpose (1988b), suggesting that the vast but finds-poor Haddenham enclosure could reflect a very short-lived impetus to the massive collective effort necessary to build it and only rare, if any, subsequent gathering there (Evans and Hodder 2006, 333–7).

This inference of a short, circumscribed history was a rare one. The timescale and use-life of enclosures have generally been left vague and long. Even for examples with reasonably substantial series of radiocarbon dates, it could, in the late 20th century AD, be said only that Windmill Hill was built in the middle of the fourth millennium cal BC following pre-enclosure activity, with continued deposition in secondary ditch fills to the end of the fourth millennium or the beginning of the third millennium cal BC (Ambers and Housley 1999, 119–20); that the Maiden Castle enclosure was built between 3900 and 3700 cal BC and the long mound built over it by *c*. 3350 cal BC (Sharples 1991a, 104–5); and that Etton, in Cambridgeshire, fell within the expected range for British causewayed enclosures and may have been one of the earlier examples, with a span of some centuries for the original use of the site (Ambers 1998). Less still could be said of the others. Even at this stage, however, Russell's proposed fifth millennium cal BC origin for some of the Sussex enclosures (2001a, 114) seemed surprising. Their overall position in the early Neolithic has correspondingly been left undefined; furthermore, because later Neolithic and early Bronze Age material often occurs in the upper fills of causewayed enclosure ditches, they were thought to have been in continuous use into the third or even the second millennium cal BC.

The much shorter history of research on enclosures in Ireland is set out in Chapter 12.

1.4 The enclosures dating project

Context

The project was conceived in the early 2000s. It grew from two main sources.

First, there had been advances in the investigation of the monuments. The publication, actual or imminent, of excavations at Maiden Castle (Sharples 1991a), Eton Wick, Berkshire (Ford 1993), Combe Hill, East Sussex (Drewett 1994), Etton (Pryor 1998), Windmill Hill (Whittle *et al.* 1999), Raddon, Devon (Gent and Quinnell 1999b), Whitesheet Hill, Wiltshire (Rawlings *et al.* 2004), Great Wilbraham, Cambridgeshire (Evans *et al.* 2006), Haddenham (Evans and Hodder 2006), Hambledon Hill (Fig. 1.5; Mercer and Healy 2008), Magheraboy, Co. Sligo (Danaher 2007) and Donegore, Co. Antrim (Mallory *et al.* forthcoming) had vastly augmented the stock of detailed information about the enclosures and their use. These involved investigations at varying scales, including of much larger areas than before, closer stratigraphic observation and the application in most cases of finer recovery techniques. All this work brought into focus the diversity in size, layout, complexity, construction methods, contained activities, intensity of re-working and intensity of deposition – the last two perhaps proxies for duration of use – and thus called for new interpretations of the phenomenon. At a national level, survey of the entire monument class (Oswald *et al.* 2001) had recorded the sites in unprecedented detail; raised the total of certain or probable examples from over 50 in the 1980s (Darvill 1987, 59) to over 70 by the end of the 1990s (Fig. 1.2); reviewed previous readings of their roles and, most importantly, identified patterns in their topographic location. Their distribution had expanded north-westwards, although the southern concentration persisted (Figs 1.1–2, 1.4); there were now outliers to the regional groups identified by Rog Palmer (1976a); and the discovery of Donegore in the 1980s and of Magheraboy in the early 2000s had extended the distribution to Ireland. These advances again called for fresh interpretations, the more so as work on enclosures in Europe, summarised by Andersen (1997, 133–309), made it ever clearer that the British sites formed part of a wider network of shared traditions and practices, as already long recognised (Whittle 1977a; 1988a).

Parallel to these developments in research on Neolithic enclosures, there had been advances in radiocarbon dating. For individual measurements there had been progressive improvements in accuracy and precision (Bayliss 1998); it had become possible to obtain AMS dates from increasingly small samples, down to a single cereal grain or a gram of bone or antler (Dennell 1987); and well-replicated tree-ring calibration was now available for the entire period of this study (Reimer *et al.* 2004). At the same time, a means of reducing the still inherent imprecision of the method, through the application of Bayesian statistical modelling (Chapter 2; Bayliss *et al.* 2007a), had been developed (Buck *et al.* 1996) and, crucially, had become widely accessible through the availability of user-friendly computer software (Bronk Ramsey 1995; Buck *et al.*

1999). This methodology makes it possible to combine scientific dating evidence, such as radiocarbon dates, with other information about the samples and their contexts, such as the relative dating between contexts provided by stratigraphy. Thus, the probability distributions of individual calibrated radiocarbon dates can be constrained and we can estimate the dates of events that occurred in the past. An introduction to Bayesian chronological modelling is provided in Chapter 2.4 (and see also Buck *et al.* 1996; Bayliss 2007; Bayliss *et al.* 2007a).

A growing corpus of applications to single prehistoric sites, such as Stonehenge (Bayliss *et al.* 1997), the Drayton cursus (Bayliss *et al.* 2003a), the timber circle at Holme next the Sea (Bayliss *et al.* 1999), the Dover boat (Bayliss *et al.* 2003b), a burnt mound at Northwold (Crowson and Bayliss 1999) and the Iron Age cemetery at Yarnton (Hey *et al.* 1998), had all demonstrated that it was possible to establish precise construction dates and durations routinely. Applications in later periods, such as those at Tintagel (Bayliss and Harry 1997) and Buttermarket, Ipswich (Scull and Bayliss 1999), had demonstrated the potential for precision at a resolution which allowed comparison with historical evidence. Above all, the dating of Hambledon Hill (Bayliss *et al.* 2008a) demonstrated the potential for revealing sequences, the intervals between events within sequences, and even something of the pace of change.

At a national level, the modelling of dates for particular kinds of artefact or monument was beginning to show that, for example, the successive metalworking phases of the middle and late Bronze Age almost all started earlier than anticipated and that the transition from one to the next was brief (Needham *et al.* 1997), or that the construction of even a few long barrows was spread over some three centuries and that the initial use of each was much shorter than previously envisaged (Whittle *et al.* 2007a). These and other modelling exercises employed not only radiocarbon dates measured as part of these studies, but others from the pool of reliable dates that was accumulating faster than ever before (Bayliss 2009, figs 1 and 2). This body of data makes comparative studies increasingly feasible.

Aims

The project set out to build on these developments in the study of causewayed enclosures and in our ability to date archaeological sites precisely, by refining the dating of the enclosures themselves. As the project was formulated, it was unclear how far the start date of the Hambledon Hill complex in *3685–3640 cal BC* and its history of modification and initial use lasting *310–370 years* (both at *95% probability*; Figs 4.14, 4.16) were typical or exceptional. The questions formulated at the start of the project, around which our sampling strategies were built, were thus the following:

- When did causewayed enclosures begin to be built in Britain and Ireland?
- Did all of them begin to be built at the same time?
- How quickly was each built?
- Was it possible to see in detail, even at a generational timescale, how their use developed and changed through time?
- To what extent was their use continuous and to what extent episodic?
- Were they all used for the same length of time?
- What would better dating of causewayed enclosures contribute to a firmer understanding of the initial development of the British and Irish Neolithic?

1.5 Beyond the enclosures

To consider the last of these questions entailed defining the chronology of the rest of the early Neolithic. Several enclosures formed part of larger monument complexes, the varying trajectories of which have been repeatedly interpreted as reflections of forces at work within the societies which built and used them (e.g. J. Thomas 1999, 163–220), but it remained unclear whether they were the 'founder monuments' of those complexes and which other elements would have been in use with them. Even where other monuments in a complex were undated or imprecisely dated, dating the enclosures would pave the way to defining their local status in the future. Instances include the roles of Windmill Hill in the Avebury area, of Robin Hood's Ball in the Stonehenge area, of Maiden Castle in the Dorchester area, of Etton in the Maxey complex and of Abingdon in the Barrow Hills complex.

In or out of larger complexes, enclosures are only a part of the wider process of the emergence of monument building and use. Approaches to monumentality in general have been at least as diverse as those to enclosures. A tradition of morphological analysis tending to typological classification, the definition of relationships, both national and European, and the establishment of sequences has had many practitioners, from Grimes (1936) and Daniel (1950), through Kinnes (1979a; 1992), to Darvill (2004a). Darvill is among the most recent of those to identify as potentially early elements of the insular Neolithic the circular stone monuments over or around which some long cairns were built (2004a, 68–71). A parallel, though younger, tradition of viewing monuments from the perspective of human experience emphasises their roles as performative arenas, as framers and guiders of movement, as distillations of accumulated memories and understandings, and as both meshed into and modifying the natural landscape (e.g. R. Bradley 1993; 1998a; 2000). The possibility of otherwise unattainable sensory effects, especially in enclosed spaces (e.g. Watson 2006), adds a further dimension to the experience of monuments.

Monuments attract attention because they are conspicuous. They occupy, however, only a small fraction of the terrain used by the early Neolithic population and they seem to have been favoured unevenly across regions, not least in the case of causewayed enclosures (Fig. 1.2). The inconspicuous traces of living, whether deliberately buried in pits, preserved in palaeosols or, most frequently, surviving only as lithic scatters, form a more evenly distributed and

preserved body of evidence, which has so far been analysed and interpreted more effectively at a local or regional level than at a national one (e.g. Holgate 1988a; Edmonds *et al.* 1999; Gardiner 1991). A tendency for early Neolithic artefacts to occur in smaller clusters than those of earlier and later periods (Edmonds 1995, 35) accords with the inference of small, mobile groups mentioned above.

Across Britain, the pattern and pace of the emergence of an insular Neolithic remained as unclear as its precise chronology. Although the probability of a pre-monumental Neolithic (perhaps little visible) has long been entertained (e.g. Case 1969, 180–1), once new beliefs and practices had been taken up, the early Neolithic has tended to be seen as a long-lasting and little changing set of lifeways in which monumental and artefactual traditions remained constant through the earlier part of the fourth millennium cal BC. During these centuries the same funerary monuments, whether earthen long barrows or stone-built chambers, were seen to have been used and elaborated by successive generations who also gathered repeatedly at causewayed enclosures, contributing to an ever-growing accumulation of cultural material in their ditches and sometimes expanding the enclosures themselves. Parallel to this, and often away from the monuments, small deposits of cultural material were placed in pits, rare rectangular houses were built, cereals were cultivated and domestic stock reared – the last two to a debatable extent (e.g. G. Jones 2000; J. Thomas 1999).

Many previous syntheses and accounts have operated within a very coarse chronology. One example is the definition of an Early Neolithic running from '*c.* 4000–34/3300 BC' (Whittle 1999, 59), though this is noted as not doing 'full justice to the regional patterns of landscape and subsistence change across the country, nor to artefact- or site-specific sequences' (Whittle 1999, 60). A more fluid and dynamic picture was painted by Edmonds, though few specific dates were suggested (1999). More recently, Richard Bradley has drawn on the emergent new dating to suggest a fairly rapid transition from earlier beliefs and practices and to stagger the emergence and cessation of different features in the 'early' insular Neolithic, pointing out that causewayed enclosures are not primary elements (2007, 27–87).

More detailed schemes have been proposed. Ian Kinnes' seriation of the grave goods from British Neolithic round barrows yielded a six-stage sequence spanning the fourth and third millennia cal BC (1979a, figs 6.1–8.1) in which 'radiocarbon dates have been used with caution…They are overall too few in number to be of real value, and further hesitation is invoked by the fact that single determinations often derive from long-lived multi-phase sites' (1979a, 49). In the twenty-first century, a many times-larger stock of radiocarbon dates took a fundamental rather than a peripheral role in detailed schemes for the Neolithic, including Alistair Barclay's for the Upper Thames catchment (2000; 2007, 332–5), Rick Peterson's for Wales (2003, 133) and Rosamund Cleal's, based primarily on the evidence from Wessex and the South-West but also on that of Britain as a whole (2004, 180–2). They differ in detail rather than in essence, so that one may serve as an example. Cleal's is made up of a low-visibility, possibly aceramic, earliest or contact Neolithic, *c.* ?4100–3850 cal BC; an early or developing Neolithic *c.* 3850–3650 cal BC, during which largely undecorated pottery, including Carinated Bowl, was made and used, long mounds began to be built and flint-mining was initiated if it was not already practised in the preceding period; and a 'high' or developed Neolithic, *c.* 3650–3350 cal BC, during which causewayed enclosures were built, other features of the 'classic' early Neolithic, including various Decorated Bowl styles, were most fully developed and, towards the end, Peterborough and Impressed Wares began to develop. A pattern seemed to be emerging, but, since all three schemes were based on evaluation (more critical in some cases than others) of available radiocarbon dates without statistical modelling, the task of quantifying the relationship of the enclosures to the rest of the 'early' Neolithic record still remained.

Precise chronology is also a prerequisite for any attempt to define the European roots of the insular Neolithic. It has long been recognised as self-evident that the ultimately south-west Asian practice of rearing domesticated animals and raising crops was introduced to Britain from the continent, as were monument-building, pottery-making and other artefactual innovations, whether independently or as a 'package'. Debate has centred on the processes by which this occurred, whether they were rapid or long-drawn-out, the areas of the continent involved in the contact and the balance between an influential incoming population and a receptive indigenous one. Here too intellectual fashion has fluctuated. There has been a long-lived tendency to seek specific source areas, following in the footsteps of Gordon Childe (1931), Jacquetta Hawkes (1934; 1935; 1938), Stuart Piggott (1955), Humphrey Case (1969) and Alasdair Whittle (1977b). For all these authors, the insular early Neolithic was eclectic in its European references so that source areas, if they existed, must have been plural.

The current major proponent of this tradition is Alison Sheridan, who sees distinct continental strands in the Neolithisation of Britain and Ireland (Pailler and Sheridan 2009; Sheridan 2003a; 2004; 2005; 2007a; 2010). These, in her view, began with an unsuccessful introduction of cattle into Ireland, probably from western France, in the second half of the fifth millennium cal BC, via an Atlantic route, represented by the animal(s) eaten at Ferriter's Cove, Co. Kerry (Sheridan 2003a; Tresset 2003). In the late fifth millennium cal BC there was, she argues, a movement of people from the Morbihan via an Atlantic and Irish Sea route along the coasts of Wales, western Scotland and northern Ireland, reflected in the construction of simple passage tombs and closed megalithic chambers and in parallels between pottery from a tomb at Achnacreebeag in Argyll and the Castellic II style of Brittany and Normandy (Sheridan 2003a). In the very early fourth millennium, a package of traditions is seen as introduced contemporaneously into southern, eastern and northern Britain from northern France: plant and animal domesticates; Carinated Bowl pottery; the construction of

long mounds, rectangular wooden buildings and perhaps enclosures; the transport and exchange of axeheads from remote sources; and the mining of flint (Sheridan 2007a; 2010; Pailler and Sheridan 2009). In the early part of the fourth millennium cal BC, contacts between Normandy and Brittany on the one hand and, the South-West peninsula and the Severn-Cotswold region on the other are seen in some simple passage tombs, the rotundae underlying some long cairns, and in the association of the Broadsands tomb, in Devon, with sherds of two Carinated Bowls (Sheridan *et al.* 2008). It is noteworthy that both the Michelsberg culture (the favoured source for Sheridan's Carinated Bowl Neolithic) and parallels between shouldered pots with concentric arc decoration from tombs in Brittany and the west of Scotland have been players on this stage at least since Childe, who in the latter case drew attention to pots from Beacharra (1931, pls IV, VII).

In the 1980s and 1990s many British prehistorians favoured a very different scenario, modelled on the better-documented transitions of Scandinavia and the Netherlands (and see Chapter 15). The indigenous Mesolithic population, often seen as having superior seafaring skills to neighbouring farming populations, was viewed as adopting, probably rather slowly, selected elements of Neolithic culture, with little influx of population and with a long survival of hunter-gatherer lifeways in the form of mobility, substantial reliance on wild plant foods and continued use of Mesolithic living sites (e.g. Zvelebil and Rowley-Conwy 1984; 1986; J. Thomas 1991, 15–17). This model was married largely to the southern English record and it has been urged that it does not fit the Irish evidence, especially in its assumption of a high level of settlement mobility and of relatively insignificant cereal cultivation (e.g. among others: Cooney 2000a; 2003; Monk 2000).

The gradualism of this model, still present in Cleal's contact Neolithic, has been challenged as much as its indigenism. By the start of the twenty-first century, Peter Rowley-Conwy could claim (2004) that it was increasingly apparent that, in Britain, Ireland and Scandinavia, Neolithic people subsisted mainly on cultivated plants and domestic animals and were fully sedentary, and that the transition to agriculture was rapid and probably traumatic. Within the narrower compass of southern Britain, Rick Schulting could propose that 'the adoption of "Neolithic" traits was for the most part an all-or-nothing affair in Britain, perhaps forming part of a sociopolitical and/or economic strategy wherein piecemeal adoption did not make sense' (2000, 33). This was prompted by an increasing perception that there might have been only a short interval between the latest use of microlithic armature in gatherer-hunter contexts and the earliest presence of Neolithic traits. Microlith manufacture and use had persisted into the very late fifth millennium cal BC not only in areas that could be seen as marginal, like March Hill on the Pennines (Spikins 2002, 43) but on the Wessex Chalk in the Fir Tree Field shaft in Dorset (Chapter 4; French *et al.* 2007, 282–5) and on the south Welsh coast at Lydstep Haven, Pembrokeshire (Leach 1918; Jacobi 1980, 175; David and Walker 2004); while an early Neolithic presence in the form of the Post and Sweet Tracks and their associated artefacts in the Somerset Levels was securely (dendrochronologically) dated to the end of the 39th century BC (Chapter 4; Coles and Coles 1986; Hillam *et al*. 1990), and occurrences elsewhere might be rather earlier, although their dating was far from watertight, mainly because of the presence of already old charcoal in radiocarbon samples (cf. Cleal 2004, 186–8).

Disjuncture at this time in Scotland, including an upsurge in contact across the Irish Sea and in interest in the remote and the exotic, seemed so great to Graeme Warren as to suggest a renegotiation and restatement of identity at a time of contact with immigrants, however few (2004). In a different reaction to the same body of evidence, Patrick Ashmore applied models derived from the analysis of present-day social networks to explain the apparent speed with which Neolithic practices spread across Scotland, proposing a fifth millennium cal BC indigenous population for at least some of whom distance and the time taken to travel it were negligible costs, leading to a high degree of connectivity between widely-spaced groups by means of relatively few long-distance journeys (2003, 43–6).

A signal change in the early fourth millennium cal BC emerged in the form of stable isotope evidence for the replacement of marine proteins by terrestrial ones in human diet, even in coastal areas (Richards and Hedges 1999; Richards *et al.* 2003; Schulting and Richards 2000; 2002a; 2002b), although there is disagreement about the speed and extent of this dietary transformation (e.g. R. Hedges 2004; Milner *et al.* 2004). Schulting (2004) related this to a social context in which cattle were becoming so important a currency as to provide compelling reason for wholesale adoption of the beliefs and practices of which cattle-keeping formed a part, a process accelerated by the impact of herding on human routines and the ecology of wild game.

The indigenism of the Scandinavian/Dutch model remains strong. It is difficult to imagine large-scale immigration in the context of the time; it is difficult to imagine how the indigenous population could have been eliminated; and it is significant that, while new finished lithic artefact forms were adopted, the traditional, indigenous flint-working technology persisted (Gardiner 1984, 17–19; Healy and Jacobi 1984; Holgate 1988a, 111, 132; Jacobi 1982, 21–2; Pitts and Jacobi 1979, 171–3) and that both late Mesolithic and early Neolithic lithics are often found in the same areas, even at the same locations, in regions as diverse and as widely separated as the East Anglian Fens (Hall and Coles 1994, 37, 41; Healy 1991, 132–5), the upper Thames catchment (Holgate 1988a, fig. 6.9), the Wear valley, Co. Durham (Young 1987, 32–6) and the Milfield Basin, Northumberland (Waddington 1999, figs 5.3, 6.3, appendix 6). In these circumstances, it is easy to see a persistence of traditional routines, including the seasonal rhythms of movement developed by previous generations (Edmonds *et al.* 1999, 74). Historical continuity may have been at least as significant as cultural disjuncture in this period (Harding and Healy 2007, 45–6).

Julian Thomas, having abandoned gradualism for the inception of the British Neolithic, although not for its subsequent development, proposed that 'the inception of the Neolithic period in Britain involved the sudden and synchronous appearance of a new cultural repertoire, including monuments, portable artefacts, and domesticated plants and animals. Not all of these have direct continental parallels, implying that the process involved inventiveness and *bricolage* on the part of the indigenous population' (2003, 73); and later that 'the only way in which we can make sense of the evidence is by assuming that the indigenous Mesolithic populations had a dynamic role in the formation of the British Neolithic . . . the introduction of the Neolithic into a new set of social and ecological conditions required that it should be reconstituted, and this reconstitution involved an interaction between Mesolithic and Neolithic communities. The sudden appearance of the Neolithic in Britain was a consequence of its having taken on a character that could be readily assimilated by local groups' (J. Thomas 2007a, 427). Thomas (2007a, 429) and others (e.g. R. Bradley 1993, 16–17; Hodder 1990; Whittle 1996, 370–1) emphasise in different ways that the material transformations must have been the manifestations of new beliefs and values, entailing altered attitudes to the natural world. Both ideological and material transformations required contact. The debate over immigrant and indigenous elements in the early British Neolithic is not between alternatives, but is a question of the degree and manner in which each contributed (Whittle 2007a, 390–4).

While uptake was clearly faster than many had previously believed, its assumed suddenness and synchroneity were impressionistic, built from the mass of accumulating radiocarbon dates, sometimes without adequate evaluation of individual measurements – despite the strictures of Waterbolk (1971) and Kinnes and Thorpe (1986) – and always without statistical modelling. The timescale of uptake, both of individual elements and in different regions, needed to be examined and its better definition could shed light on the human processes involved, the pace of change, and the relation between early conditions and the situations in which causewayed enclosures could be proposed as emerging.

1.6 This volume

Structure

The core of this monograph is formed by Chapters 3–12, each of which deals with the enclosures of a British region or, in the case of Chapter 12, the whole of Ireland, and places them in the context of the local evidence for early Neolithic activity. This exercise combines two unequal datasets. Radiocarbon dates from the enclosures are made up, in approximately equal parts, of measurements obtained in the course of this project for samples selected on the criteria described in Chapter 2 and of a range of measurements from a miscellany of sources for samples selected on widely varying criteria. The remainder of the dating falls entirely in the second category and derives from the chance of what happened to be available when the chapters were written. The resulting regional stories are thus based on foundations of variable soundness and strength and should be viewed as preliminary sketches which point the way to more focussed investigations.

The regions covered in the detailed chapters were determined by the presence of excavated and datable enclosures and are thus rather arbitrary in their boundaries and confined to southern Britain and Ireland. They do not include those parts of southern Britain which lack excavated enclosures or lacked them during the course of the project, among them Berkshire, Hampshire and Somerset. Chapter 13 reports stable isotope analysis of human and animal bone samples from some of the dated enclosures in the south of England. Chapter 14 combines the regional models to provide narratives for the date, duration and character of the enclosures and for other forms of early Neolithic activity, reviewing also a substantial sample of the Scottish evidence south of the Great Glen, and culminating in a preliminary attempt at the wider task of constructing reliable chronologies and interpretive narratives for the early Neolithic of Britain and Ireland as a whole. Chapter 15 discusses the many implications of these narratives, including the continental context.

Terminology and conventions

In the text, the repeatedly used terms 'generation' and 'lifespan' are taken respectively as 25 and 70 years (cf. Whittle *et al.* 2007a, 131–2; and see Chapter 15.13).

Following international convention (Mook 1986), radiocarbon ages are cited as 'BP', dates 'cal BC' or 'cal AD' are calibrated radiocarbon ages, and dates 'BC' or 'AD' are actual or estimated dates on the calendar scale (such as those derived from dendrochronology or input into simulation models). Dates '*cal BC*' or *'cal AD' in italics* are posterior density estimates derived from Bayesian modeling. All calibrated radiocarbon dates or posterior density estimates are followed by their identifying distribution name (often, but not necessarily, a laboratory number) and, if appropriate, the number of the figure on which the distribution is shown. On the figures, posterior density estimates are shown black and probability distributions derived from scientific dating alone are shown in outline. Further details of the terminology used in this volume can be found in Chapter 2.

Note

1 Though some ground stone axes were already used in parts of western Britain and in Ireland.

2 Towards generational time-scales: the quantitative interpretation of archaeological chronologies

Alex Bayliss, Johannes van der Plicht, Christopher Bronk Ramsey, Gerry McCormac, Frances Healy and Alasdair Whittle

The origins of this project lie in the first years of the 21st century AD. Bayesian approaches to modelling archaeological chronologies had been around for a decade or so (Naylor and Smith 1988; Buck *et al*. 1991; 1992; 1996), and were beginning to transfer into routine archaeological practice in Britain and beyond (Bronk Ramsey 1995; Buck *et al.* 1999; Bayliss and Bronk Ramsey 2004). By this time English Heritage had undertaken around 150 dating programmes using this new methodology. These site-based studies produced robust chronologies, often of much higher precision than had previously been possible (e.g. Bayliss and Harry 1997; Bayliss *et al.* 1996; 1997; 1999; Hey *et al.* 1998; Crowson and Bayliss 1999; Scull and Bayliss 1999). But, in the absence of a corpus of sites dated to a similar resolution, these applications were fundamentally lacking. Site-specific questions of sequence and tempo could be resolved, but lacking comparative evidence of a similar resolution these sites stood as isolated beacons in a wine-dark sea.

In the late 1990s, as part of an English Heritage-funded project to publish the extensive excavations which had taken place on the early Neolithic monument complex at Hambledon Hill, Dorset, during the 1970s and 1980s, a number of us were invited by the excavator, Roger Mercer, to collaborate on a major dating programme for the site (Bayliss *et al.* 2008a). This was undertaken in a Bayesian framework, with samples selected using simulation to make most effective use of the available stratigraphic information. The results of this dating programme (summarised in Chapter 4.1 and especially Fig. 4.14) – which produced a generational narrative for the development and use of the complex – perhaps gave us the first indication that a new kind of prehistory could emerge if dating of this resolution were to be available everywhere.

Consequently, a major impetus for this project was to provide an exemplar of the methodology, first, to illustrate the potential for using radiocarbon dating and Bayesian chronological modelling to produce precise chronologies routinely, and secondly, to explain and demonstrate the technical complexities which have to be addressed if such chronologies are to be constructed in practice. And, most importantly, to demonstrate what difference these chronologies make to the types of prehistory that we can write. As David Clarke (1973, 10) remarked more than a generation ago, 'the *consequences* arising from the introduction of new methodologies are of far greater significance than the new introductions themselves'.

So, this book proposes a new narrative for causewayed enclosures and the first centuries of the Neolithic in southern Britain and Ireland, but it also has a message for those devoted neither to the early Neolithic nor to *Ultima Thule*. Unlike dendrochronology, which is the preserve of the few fortunate enough to have the necessary structures and conditions of preservation, the methods set out in this chapter can be employed routinely by all archaeologists. You too can build chronological models for your site of the kind described in our regional chapters (Chapters 3–12; and see Bayliss and Whittle 2007; Bayliss 2009). You too can construct the types of narrative for your archaeology that we have set out in Chapter 14. You too can explore the kinds of prehistory that these narratives allow (see Chapter 15; Whittle *et al*. 2007a).

2.1 The radiocarbon dates

The tables in this volume provide full details of 2350 radiocarbon measurements. A total of 871 of these come from sites which were regarded as Neolithic enclosures at the start of this project (in fact 816 are from sites now regarded as Neolithic enclosures). We have obtained 427 new measurements, and reassessed 1923 existing measurements: 444 from enclosures and 1479 from other early Neolithic sites (Fig. 2.1). Of these radiocarbon dates, 1782 (76%) are incorporated in at least one of the Bayesian chronological models described in this volume.

Except for a few determinations made in the early years of radiocarbon dating before international conventions were established and which generally cannot now be recalculated (see below, section 2.6), all the radiocarbon measurements cited in this volume are conventional radiocarbon ages,

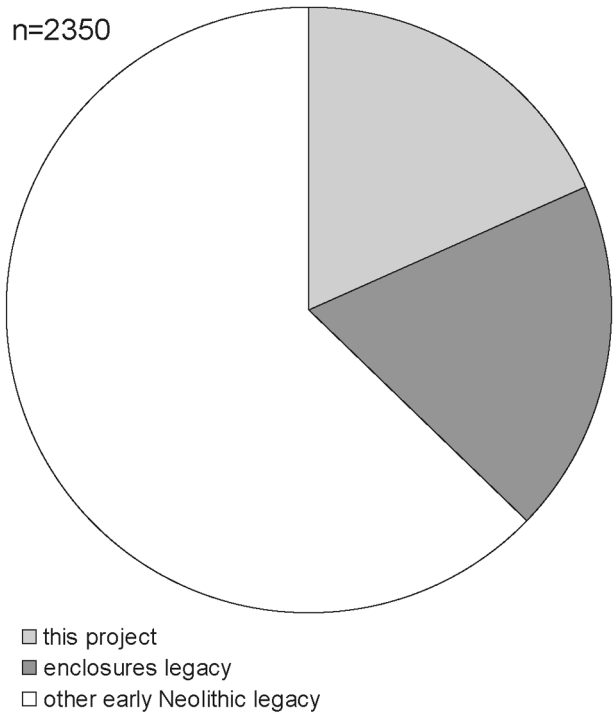

Fig. 2.1. Radiocarbon measurements discussed in this volume (n=2350).

corrected for fractionation (Stuiver and Polach 1977). Where replicate measurements have been made on the same sample, their consistency has been tested using the methods outlined by Ward and Wilson (1978), and if appropriate a weighted mean has been taken before calibration.

The calibrated date ranges provided in the tables and cited in the text have been calculated using the maximum intercept method (Stuiver and Reimer 1986) and the currently internationally agreed dataset for terrestrial samples from the northern hemisphere (Reimer *et al.* 2004). Date ranges are quoted in the form recommended by Mook (1986) with the end points rounded outwards to 10 years (or five years when error terms are less than ±25 BP). These calibrated date ranges are cited in normal type. A few marine samples have been calibrated using the currently internationally agreed dataset for the marine environment (Hughen *et al.* 2004) with local reservoir corrections as specified in the text (Stuiver and Braziunas 1993; Harkness 1983). Two samples of human bone from Ferriter's Cove, Co. Kerry (Table 12.10), which have strongly marine isotopic signatures, have been calibrated using a mixture of the terrestrial calibration curve and the marine dataset, again with an appropriate local ΔR correction (Bronk Ramsey 2001). The proportion of marine protein in each individual's diet has been estimated by linear interpolation based on the ranges of $\delta^{13}C$ values for terrestrial and marine food sources published by Mays (1998). A few measurements are regarded as inaccurate for reasons discussed in the text, and have not been calibrated.

Whilst it is hoped that readers will find these calibrations helpful, the intercept method itself is best regarded as a 'quick and simple' way of providing an indication of the calendar date of a sample. The full complexity of the calendar age is only apparent from the probability distribution of the calibrated date. These calibrations have been undertaken using the probability method (Stuiver and Reimer 1993). They are shown as black in the graphs, except where they form the 'standardised likelihoods' component of a Bayesian model (see below, section 2.3). In this case (the majority of graphs), they are shown in outline.

2.2 Scatter matters

Most prehistoric chronologies are derived from tables or graphs of simple calibrated radiocarbon dates. When faced with a graph such as Fig. 2.2, most archaeologists visually assess the area where most of the probability seems to lie, in this case interpreting the use of the enclosure perhaps as extending from *c.* 3780 cal BC to *c.* 3640 cal BC and lasting for perhaps 140 years. But in this graph the radiocarbon dates have been simulated (by a process of back-calibration[1]) from samples whose actual dates lie between 3700 and 3676 BC, and so span a period of only 25 years. Using this method of informally estimating chronology by visual inspection of calibrated radiocarbon dates, past activity will nearly always[2] be interpreted as starting earlier, ending later, and enduring for longer than was actually the case.

From this example, this may not seem to matter very much. Our point estimate for the date when the enclosure was built is 'only' 80 years wrong, and our assessment of the end date is 'only' 34 years wrong – and what is a generation or two on the scale of prehistory? But, in relation to a period of activity that actually only spanned 25 years, these estimates are between 150% and 300% wrong! Our estimate of duration is more than five times longer than it was in reality!

Consider, now, the second group of radiocarbon dates from the currency of a particular type of pottery (Fig. 2.3). Here visual inspection of the graph might suggest a date range of *c.* 3950–*c*. 3500 cal BC, a period of perhaps 450 years. Again, this is importantly misleading. In fact, these dates (simulated using the same procedure of back-calibration) actually run from 3860–3610 BC and span a period of 250 years. Once more, our date estimates are anomalously early, anomalously late, and our estimate of duration is far too long. But this time, with fewer dates spanning a longer period of activity, we are *proportionately* much less wrong.

This effect arises from the probabilistic nature of radiocarbon dating. Radiocarbon measurements themselves are estimates of the true radiocarbon content of a sample – ages therefore scatter around the true value in accordance with the, normally distributed, quoted error. This effect is often exacerbated by the process of radiocarbon calibration, when calibrated dates can also spread on to plateaux in the calibration curve adjacent to the true dates of the samples.

Unfortunately, our present understanding of the chronology of British and Irish prehistory largely derives from

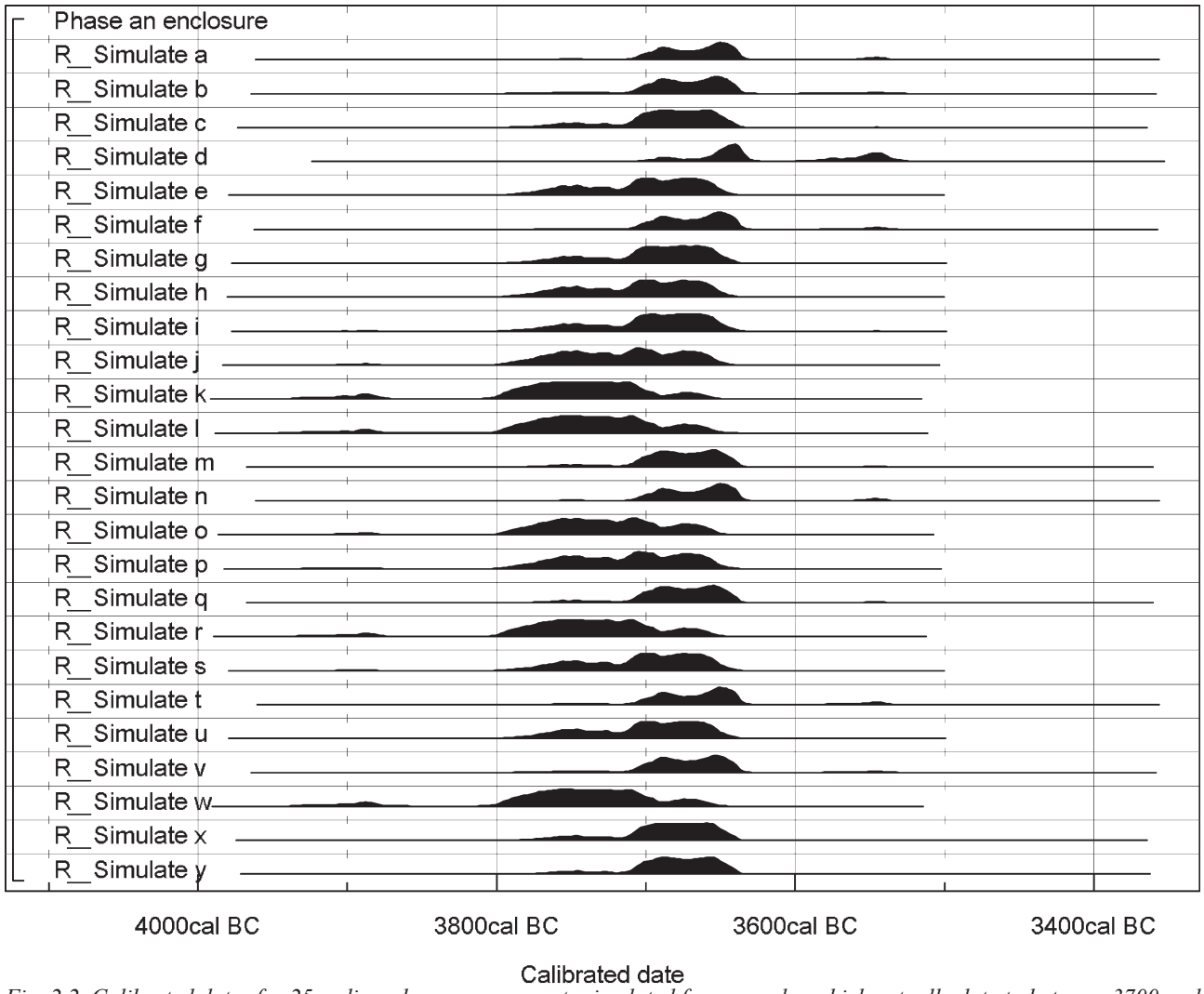

Fig. 2.2. Calibrated dates for 25 radiocarbon measurements simulated from samples which actually date to between 3700 and 3676 BC.

the informal interpretation of graphs or tables of calibrated radiocarbon dates by visual inspection. This approach demonstrably does not take into account the scatter on the radiocarbon dates, and leads to date estimates for archaeological activity that are, quite simply, wrong. As importantly, our estimates of the duration of activities in the past are also routinely too long. The consequences are a fuzzy prehistory which floats timelessly across centuries, and an impression of change playing out over similarly extended timescales.

It is this demonstrable inadequacy of informal methods which makes the utilisation of formal mathematical approaches for modelling chronology essential.

2.3 The Bayesian approach

The basic idea behind the Bayesian approach to the interpretation of data is encapsulated by Bayes' theorem (Bayes 1763; Fig. 2.4). This approach is fundamentally probabilistic and contextual. It simply means that we analyse the new data we have collected about a problem ('the standardised likelihoods') in the context of our existing experience and knowledge about that problem (our 'prior beliefs'). This enables us to arrive at a new understanding of the problem which incorporates both our existing knowledge and our new data (our 'posterior beliefs'). This is not the end of the matter, however, since today's posterior belief becomes tomorrow's prior belief, informing the collection of new data and their interpretation as the cycle repeats (Fig. 2.5). We do this by the use of formal probability theory, where all three elements of our model are expressed as probability density functions. An accessible general introduction to the principles of Bayesian statistics is provided by Lindley (1985).

In this volume we implement a Bayesian approach to modelling archaeological chronologies. This is an explicit, probabilistic method for estimating the dates when events happened in the past and for quantifying the uncertainties on these estimated dates. When constructing a Bayesian chronology, the calibrated radiocarbon dates form the 'standardised likelihoods' component of the model and archaeology provides the 'prior beliefs' (Fig. 2.4). This

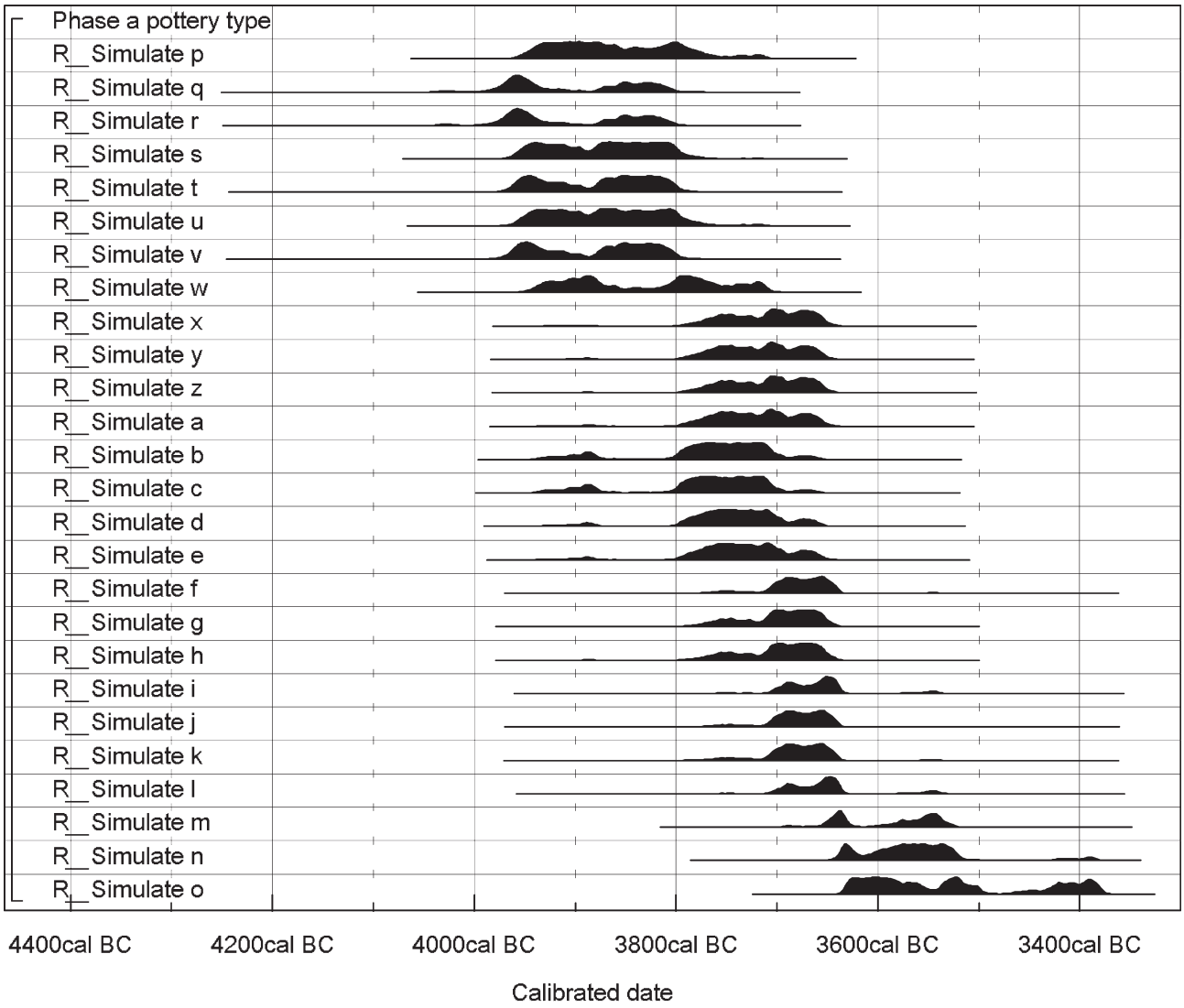

Fig. 2.3. Calibrated dates for 26 radiocarbon measurements simulated from samples which actually date to between 3860 and 3610 BC.

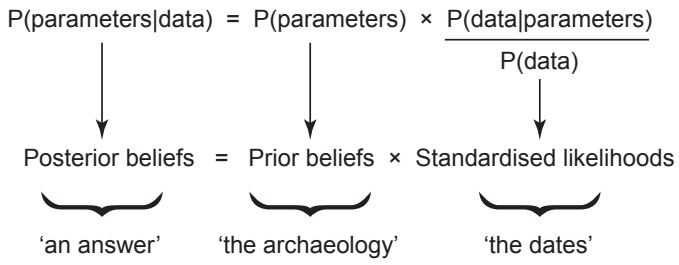

Fig. 2.4. Bayes' theorem.

means that the radiocarbon dates are reinterpreted in the light of the archaeological information, to provide posterior beliefs about the dates we are modelling. There is a conceptual shift here. Independent, scientific radiocarbon dates were once heralded as providing 'good objective chronology' (Renfrew 1973a, 109). Bayesian chronologies are different. They are contextual and interpretative. They can and will change as more radiocarbon dates are obtained and incorporated into our models, and as we choose to build our models in different ways. Sometimes, a group of radiocarbon dates may be modelled in different ways to answer different questions (compare, for example, the models for the long cairns defined in Figs 11.12–14, with the use of the same dates in the overall model for the early Neolithic in South Wales and the Marches defined in Figs 11.10–11). Indeed, the construction and comparison of alternative models (known as 'sensitivity analyses') are a fundamental part of the Bayesian process.

A general introduction to the application of the Bayesian approach to archaeological data is provided by Buck *et al.* (1996). More specific introductions to building Bayesian chronologies in archaeology are provided by Bayliss *et al.* (2007a) and Bayliss (2007). Details of the mathematical methods involved in chronological modelling can be found in a series of papers by Blaauw and Christen (2005), Bronk Ramsey (1995; 1998; 2000; 2001; 2008; 2009a; 2009b), Buck *et al.* (1991; 1992; 1994a; 1994b), Bronk Ramsey *et al.* (2001), Christen (1994), Christen and Litton (1995), Christen *et al.* (1995), and Nicholls and Jones (2001).

2.4 An introduction to Bayesian chronological modelling

All the chronological modelling in this volume has been undertaken using the program OxCal v3.10 (Bronk Ramsey 1995; 1998; 2001). As described in the documentation and references relating to this program, each model is exactly defined by the sequence of brackets and keywords down the left-hand side of the diagrams. In this application, many models contain far too many standardised likelihoods for them to be defined in single diagrams. In these cases, one diagram defines the overall structure of the model, with its components defined in one or more additional graphs. Chapters 12 and 14 in particular contain many complex models of this kind, and prehistorians with limited experience of chronological modelling are strongly recommended to engage with at least one of the regional chapters before attempting to grapple with these more synthetic discussions.

Simple or complex, all Bayesian chronological models comprise two elements: standardised likelihoods and prior beliefs (Fig. 2.4). In practice, both of these come in a variety of archaeological forms.

2.4.1 'Uninformative' prior beliefs

Prior beliefs are no more than a formal, mathematical expression of our understanding of the archaeological context of the chronological problem we are modelling. Archaeologists are very good at prior beliefs. It is extremely unusual for us to know nothing at all about a set of samples. Unfortunately, however, archaeologists often do not realise how much they actually know about their samples and have difficulty in expressing this information in a form which can be incorporated into chronological models.

At the most simple extreme, consider the sets of calibrated radiocarbon dates shown in Figs 2.2–3. We may think that we know nothing about the context of these dates. But we do. We know that they are *related*. The dates in Fig. 2.2 come from an enclosure. The dates in Fig. 2.3 are all associated with a particular type of pottery. In each case, the dates sample a period of activity that happened in the past. This may not sound like very much, but even this prior information is extremely powerful.

It allows us to quantify the scatter on calibrated radiocarbon dates, which as we saw in section 2.2 above is a real issue in using them to interpret chronology. This is done by imposing a statistical distribution on the underlying, real period of activity in the past, of which our radiocarbon dates are a sample. This is illustrated in Fig. 2.6, where we have implemented a uniform distribution on the underlying sample of dated activity for the fictitious enclosure whose dates were illustrated in Fig. 2.2. This means that we assume that the occupation of the enclosure began, continued relatively constantly, and then ended (see below, section 2.8). This approach allows the model to assess how far the variation in the calibrated radiocarbon dates arises from variation in the actual dates of the samples, and how far from the probabilistic scatter inherent in radiocarbon dating and the calibration process.

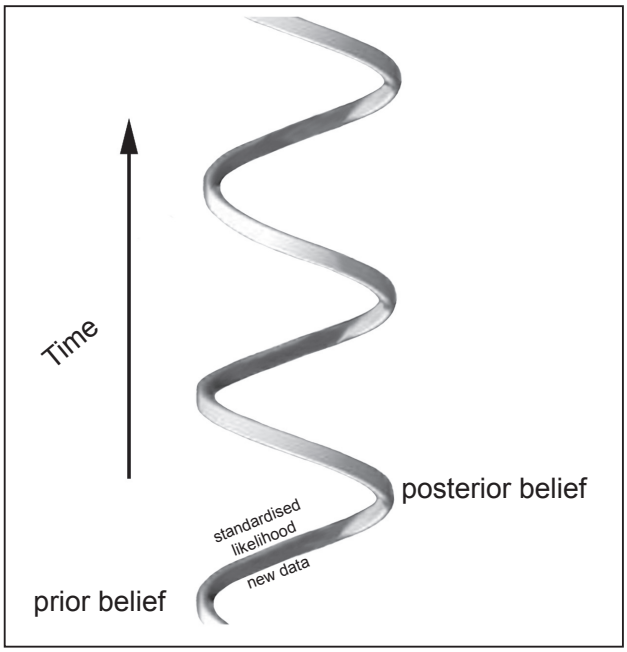

Fig. 2.5. Bayes' theorem and the hermeneutic spiral (after Hodder 1992, fig. 22). Drawing by Derek Hamilton.

In this diagram the calibrated radiocarbon dates, which form the standardised likelihoods for the Bayesian model, are shown in outline. The probability distributions in black are the posterior beliefs, or *posterior density estimates*. By convention, when these are expressed as date ranges they are given *in italics* to distinguish them clearly from simple calibrated radiocarbon dates. In this volume, all posterior density estimates have been rounded outwards to the nearest 5 years. Each calibrated radiocarbon date now has a revised probability distribution, a *posterior density estimate*. This revised probability distribution has been calculated by taking into account not only the radiocarbon content of the sampled material, but also the fact that each radiocarbon date is part of an assemblage of related dates associated with a period of past activity.

So, for example, the calibrated date for sample x is 3770–3630 cal BC (95% confidence), as a radiocarbon age of 4906±35 BP was simulated from the actual calendar date of this sample (3677 BC). This is the distribution shown in

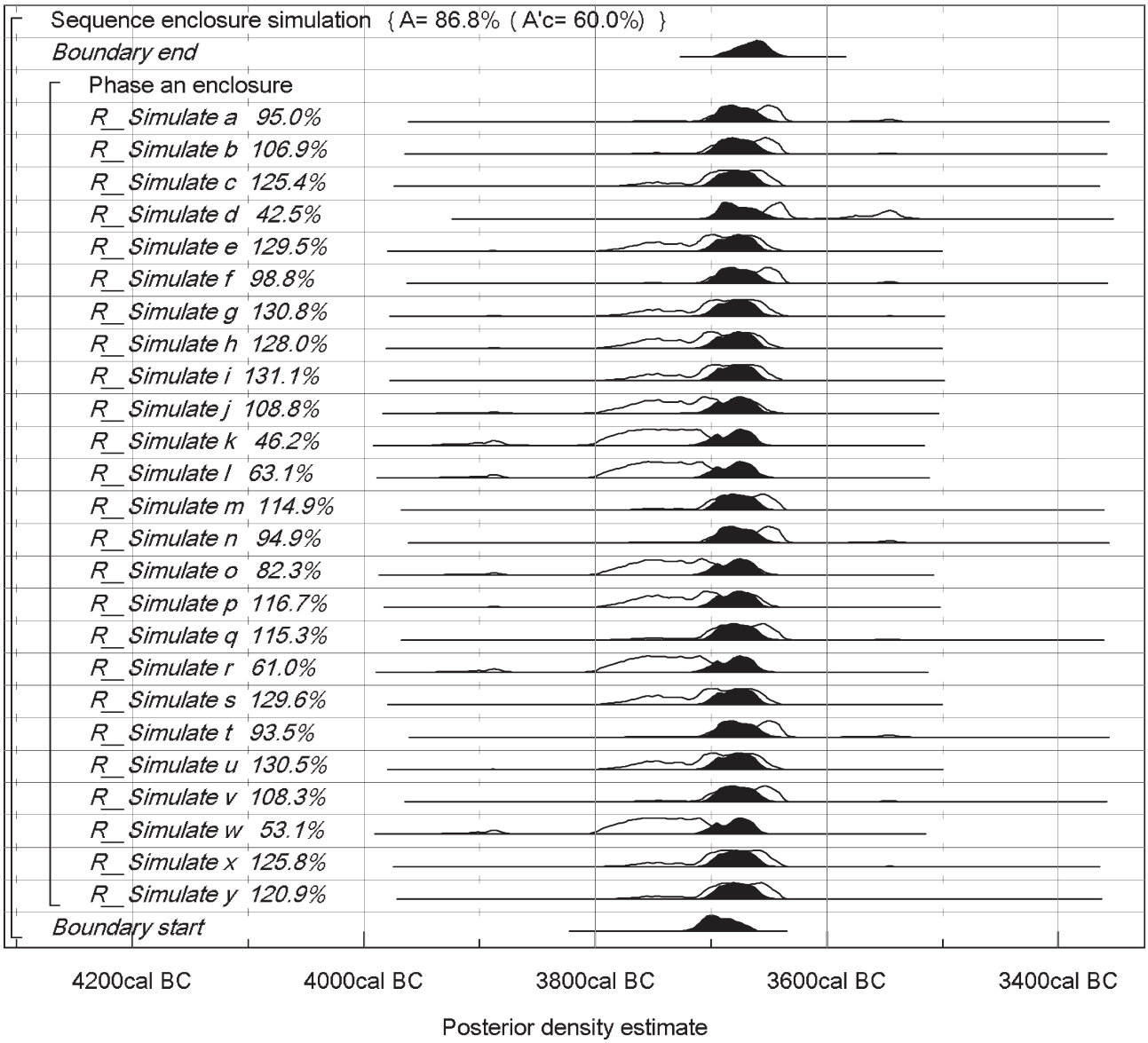

Fig. 2.6. Probability distributions of dates from a fictitious enclosure, incorporating a uniform distribution for the use of the site. The simulated dates are those shown in Fig. 2.2 (3700–3676 BC). Each distribution represents the relative probability that an event occurs at a particular time. For each radiocarbon date, two distributions have been plotted: one in outline which is the result of simple radiocarbon calibration, and a solid one based on the chronological model used. The other distributions correspond to aspects of the model. For example, the distribution 'start' is the posterior density estimate for the time when the enclosure was constructed. The large square brackets down the left-hand side of the diagram and the OxCal keywords define the overall model exactly.

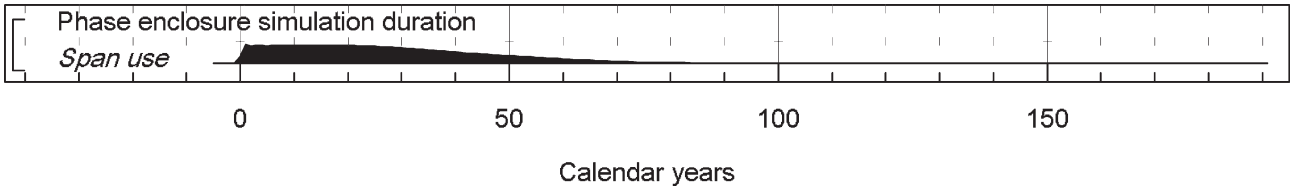

Fig. 2.7. Probability distribution of the number of years during which the fictitious enclosure was in use, derived from the model shown in Fig. 2.6.

outline in Fig. 2.6. The posterior density estimate for sample x is *3705–3655 cal BC* (*95% probability*; *x*), probably *3695–3660 cal BC* (*68% probability*). This is the probability distribution shown in black in Fig. 2.6. Note that '*x' in italics* refers to the probability distribution of the posterior density estimate, whereas 'x' in normal type refers to the radiocarbon age or the calibrated date. In this instance the known date of this sample (3677 BC) lies within the range

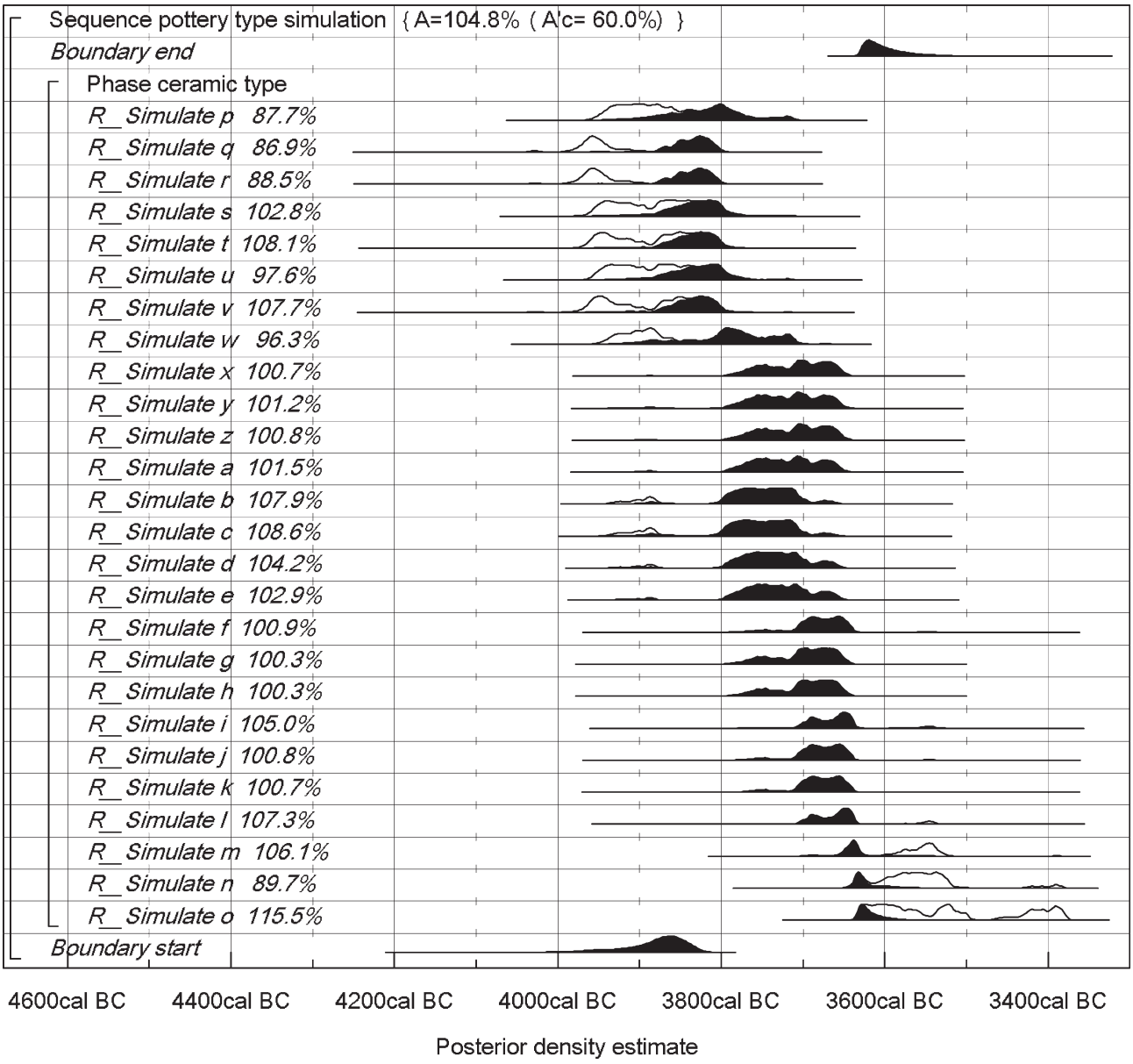

Fig. 2.8. Probability distributions of dates from a fictitious ceramic type, incorporating a uniform distribution for the currency of this pottery. The simulated dates are those shown in Fig. 2.3 (3860–3610 BC). The format is identical to that of Fig. 2.6. The large square brackets down the left-hand side of the diagram and the OxCal keywords define the overall model exactly.

of the calibrated date (at both 95% and 68% confidence), and also within the ranges of the posterior density estimate (at both *95% and 68% probability*). It is important to recognise this, probabilistic nature of both radiocarbon dating and Bayesian modelling. Our date estimates are just that – estimates, and the true dates of our samples will lie outside the 95% range once in every twenty cases, and outside the 68% range nearly once in every three. We will present formal date estimates for 38 Neolithic enclosures in this volume. Probability theory means that the true date of the construction of one or two of these enclosures will lie outside the 95% probability range of the relevant posterior density estimate, and that the true date of around a dozen enclosures will lie outside the 68% probability range of the relevant posterior density estimate.

In Fig. 2.6 not all the probability distributions shown map one-to-one with calibrated radiocarbon dates. There are additional probability distributions shown which do not. This is another difference between Bayesian chronologies and radiocarbon dating. These additional parameters estimate the dates when things happened in the past that are not directly sampled by radiocarbon dating. So, for example, the parameter '*start'* is the posterior density estimate for the date when our fictitious enclosure was established. This estimate is derived from all the radiocarbon dates in our sample, but account is also taken of the fact that it is extremely improbable that we have actually dated the first piece of datable material to be deposited on the site. We have in this case 25 radiocarbon measurements covering a period of 25 calendar years (in

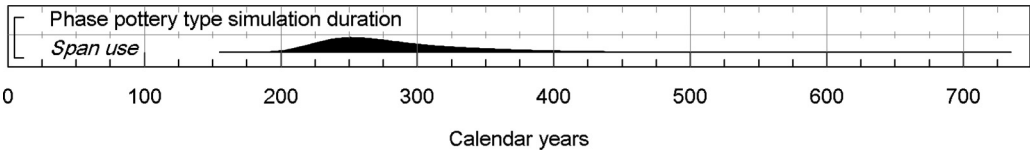

Fig. 2.9. Probability distribution of the number of years during which the fictitious ceramic type was in use, derived from the model shown in Fig. 2.8.

fact, such a high sampling density is probably rare in real archaeological applications). But there are almost certainly hundreds, if not thousands, of animal bones, charred cereal grains, fragments of charcoal and so on from our site, and so the probability that we have actually dated the first is tiny. By assessing the number of dates in our sample and the period of calendar time over which they scatter, the model can allow for this fact in estimating the date when activity on the site started.

The model shown in Fig. 2.6 does this. It estimates that our fictitious enclosure was established in *3720–3660 cal BC* (*95% probability*; Fig. 2.6: *start*), probably in *3710–3675 cal BC* (*68% probability*), and it ceased to be used in *3695–3640 cal BC* (*95% probability*; Fig. 2.6: *end*), probably in *3680–3650 cal BC* (*68% probability*). Again, in both cases the actual dates of these parameters (3700 BC and 3676 BC) fall comfortably within the posterior density estimates at both 95% and 68% probability. This example also illustrates another aspect of chronological models. By taking the difference between the probability distributions for the *start* and *end* of a period of activity, it is possible to estimate formally the duration of its *use*. This parameter is shown in Fig. 2.7. The period when the site was in use is estimated to have lasted *0–65 years* (*95% probability*; Fig. 2.7: *use*), probably *0–35 years* (*68% probability*). These estimates of duration are compatible with the actual span of the dates input into the simulation: 3700 – 3676 BC (25 years).[3]

In the example just discussed, and indeed for many of the enclosures and other sites whose dating is discussed in this volume (e.g. Windmill Hill and West Kennet, Chapter 3; Hambledon Hill and Maiden Castle, Chapter 4; Crickley Hill, Chapter 9), we are fortunate enough to have a sampling density that allows us to discuss past human activity at a scale of generations. Frequently, we are not so fortunate. Figure 2.8 shows a chronological model for the currency of the ceramic typology associated with the radiocarbon dates shown on Fig. 2.3. Again, we have imposed a uniform distribution on the underlying period of dated activity to allow for the relationships between the dated samples.

This model suggests that this pottery type began to appear in *3965–3820 cal BC* (*95% probability*; Fig. 2.8: *start*), probably in *3900–3835 cal BC* (*68% probability*). It fell out of favour and ceased to be deposited in *3635–3540 cal BC* (*95% probability*), probably in *3630–3590 cal BC* (*68% probability*). Again, the actual start and end dates (3860 BC and 3610 BC) fall comfortably within the relevant posterior density estimates for these dates suggested by the model. The actual duration (250 years) also falls within the estimates for the duration of this ceramic type provided by the model: *200–390 years* (*95% probability*; Fig. 2.9: *use*), probably *220–305 years* (*68% probability*).

In this example, we can no longer talk about generations. The resolution of our chronology is more at a scale of centuries or maximum lifetimes. This is the type of dating we have been able to achieve for many of the models that we have constructed for other elements of the early Neolithic in southern Britain and beyond to compare with our dating of enclosures (see especially Chapter 14). It is essential to recognise these different resolutions in our interpretations of these chronologies. The posterior density estimate for the start of our fictitious enclosure (Fig. 2.6: *start*) has a calendrical bandwidth of 60 years, while that for the start of our fictitious type of pottery (Fig. 2.8: *start*) has a calendrical bandwidth of 165 years. These are statements of our uncertainty about exactly when the first antler pick broke the turf to begin the construction of the enclosure or the first sherd identified as belonging to our fictitious type of pottery was deposited. Both these events in reality happened in one hour of one day in a particular year; we can just estimate the date of the construction enclosure more precisely than the date of the introduction of the pottery type.[4]

In the examples considered so far, we have had what are (for archaeology) reasonably dense sampling intervals – 25 radiocarbon dates spread over 25 calendar years in the example shown in Figs 2.2 and 2.6, and 26 radiocarbon dates spread over 250 calendar years in the example shown in Figs 2.3 and 2.8. But what happens when, for whatever reason, we have far fewer radiocarbon dates? Such a scenario is illustrated by the model shown in Fig. 2.10. In this model, we now only have seven radiocarbon dates spanning the 250-year period from 3860–3610 BC – one every 40 years or so.

This model suggests that the use of the fictitious ceramic type began in *4120–3810 cal BC* (*95% probability*; Fig. 2.10: *start*), probably in *3985–3835 cal BC* (*68% probability*), and that it ended in *3635–3385 cal BC* (*95% probability*; Fig. 2.10: *end*), probably in *3625–3510 cal BC* (*68% probability*). The posterior density estimates from this model do contain the true dates of these parameters (3860 and 3610 BC), but in both cases they lie at the inner extremes of the distributions. The long tails on posterior density estimates such as these arise because the model contains insufficient data to effectively assess, and counteract, the statistical scatter on the radiocarbon dates. This is why date estimates for parameters of this type which come from models containing many radiocarbon

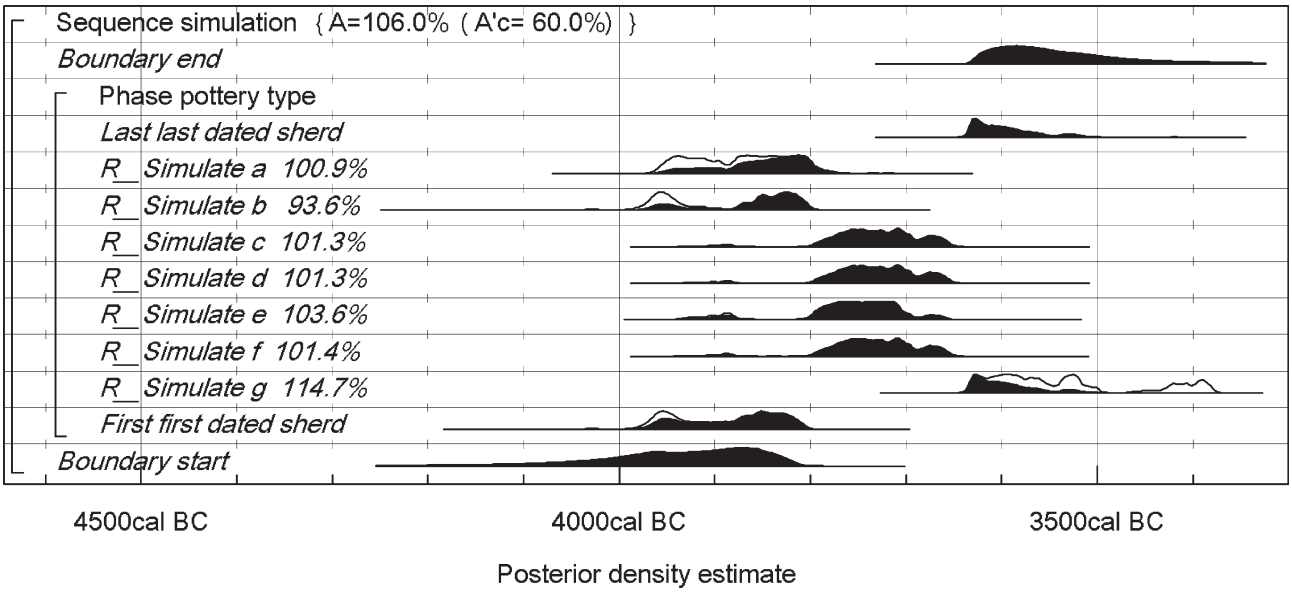

Fig. 2.10. Probability distributions of dates from a fictitious ceramic type, incorporating a uniform distribution for the currency of this pottery. Only seven dates have been simulated spanning the period 3860–3610 BC. The format is identical to that of Fig. 2.6. The large square brackets down the left-hand side of the diagram and the OxCal keywords define the overall model exactly.

dates (e.g. Fig. 9.7: *start Crickley Hill*) are routinely much more precise than those from models which contain fewer measurements (e.g. Fig. 9.18: *start Peak Camp*).

These formal, probabilistic estimates provide accurate assessments of the dates of activities in the past and provide realistic, quantitative estimates of our uncertainty on those estimates. Distributions with such long tails, however, can be archaeologically misleading, and so in such situations we have also calculated the first or last dated event in a group of measurements. These estimates are still constrained by the uniform distribution on the underlying period of activity, and so the effect of statistical scatter on the radiocarbon dates is still taken into account, but they do not attempt to estimate the dates when the site was in use, only the period spanned by the actual dated samples. In this example, the first dated sherd was deposited in *3970–3805 cal BC* (*95% probability*; Fig. 2.10: *first dated sherd*), probably *3965–3935 cal BC* (*13% probability*) or *3885–3810 cal BC* (*55% probability*). The last dated sherd was deposited in *3640–3515 cal BC* (*95% probability*; Fig. 2.10: *last dated sherd*), probably in *3635–3585 cal BC* (*68% probability*). This example is unusual because we have actually simulated dates from the first year and the last year of the period of activity in which we are interested. In reality, these parameters are usually slightly later or slightly earlier than the estimates for the start and end of activity respectively (see, for example, Fig. 9.32). This is as it should be. The first dated activity will always be slightly later than the actual date when a period of activity started, and the last dated activity will always be slightly earlier than the actual end of the activity. If, for example, we have dates from the base of a causewayed enclosure ditch, these are unlikely to date from long after its construction. In these circumstances, the first dated event in the enclosure appears to be a more realistic estimate for the date when the enclosure was constructed than a formal estimate for the start of the start of activity on the site that has an anomalously long tail of probability because we have insufficient data to address the real issue at hand.[5] In an ideal world, we would always have sufficient data to estimate the dates when a period of activity began and ended effectively, but in the absence of such data the first and last dated samples can act as a pragmatic proxy. We have used this approach, for example, in estimating the date when the outer ditch at Peak Camp, Gloucestershire, was excavated (Fig. 9.18: *build outer Peak Camp*). We must always be aware, however, that when we compare parameters such as these with formal estimates for the start of activity on a site, strictly we are not comparing like with like.

Figure 2.11 shows the estimate for the length of time the ceramic type dated by the model shown in Fig. 2.10 was current. This model estimates that this period lasted *210–650 years* (*95% probability*; Fig. 2.11: *use*), probably for *250–475 years* (*68% probability*). This distribution again has a long tail, in this case tailing towards a longer period of use. This is typical, and is particularly noticeable for sites which probably had a short duration but where the number of dates is insufficient to effectively demonstrate this (e.g. Whitesheet Hill, Chapter 4; Kingsborough 1 and 2, Chapter 7). In these cases, the distribution of the duration is usually skewed heavily towards zero.

This example also demonstrates that other calculations can be performed on the posterior density estimates output from Bayesian models. By taking the difference between the start and end of a period of activity, we can calculate the duration of the period (see above, Figs 2.7 and 2.9). But we can actually compare any two distributions and calculate

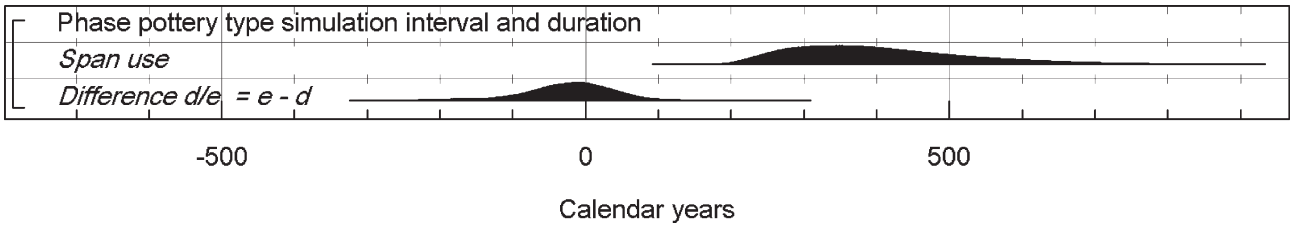

Fig. 2.11. Probability distributions of the number of years during which the fictitious ceramic type was in use and of the gap between samples d and e, derived from the model shown in Fig 2.10.

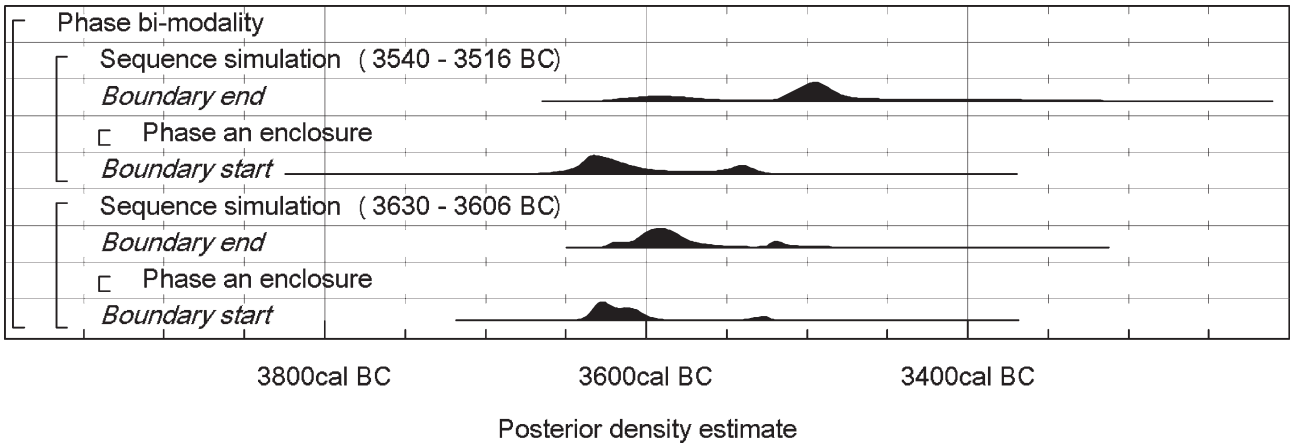

Fig. 2.12. Probability distributions of the estimated start dates of two fictitious enclosures, derived from models identical in form to Fig. 2.6 where the simulated dates span the periods 3630–3606 BC and 3540−3516 BC respectively.

the difference between them. For example, in Fig. 2.10 the probability that sample *d* was deposited before sample *e* is 37%.[6] The interval between the deposition of these two samples is shown in Fig. 2.11. The model estimates this interval to have been between *−195 years and 110 years* (*95% probability*; Fig. 2.11: *d/e*), probably between *−75 and 45 years* (*68% probability*). Because we do not know certainly which event came first, this distribution spans zero. So, this interval is positive when sample *e* is later than sample *d*, and negative when sample *d* is later than sample *e.* In this, it is unlike the durations of sites or periods where (logically) the beginning is constrained to come before the end! Distributions of this type are found, for example, in Chapter 8 where we consider the order of construction of the circuits of the Abingdon causewayed enclosure (Fig. 8.23).

So far most of the posterior density estimates discussed in this section have been conveniently unimodal. Because of wiggles in the radiocarbon calibration curve (see below, Fig. 2.17), this is by no means always the case. This is illustrated by the posterior density estimate for the *first dated sherd* in the previous example: *3970–3805 cal BC* (*95% probability*; Fig. 2.10: *first dated sherd*), probably *3965–3935 cal BC* (*13% probability*) or *3885–3810 cal BC* (*55% probability*). Here, the highest posterior density interval at 68% probability is split between two different ranges which together make up 68% probability. The significance of this effect for some of the enclosures dated in this study is shown in Fig. 2.12. This shows the *start* and *end* estimates calculated by models of the form shown in Fig. 2.6, but where the 25 simulated radiocarbon dates really span the periods 3630–3606 BC and 3540–3516 BC respectively. In both cases, the resultant posterior density estimates are strongly bimodal (Fig. 2.12), although in the earlier example the true dates fall on the earlier peak of the distribution and in the later one they fall on the later peak. In both cases the true dates of these parameters fall within the date ranges provided by the posterior density estimates at both 95% and 68% probability (although they do not necessarily fall on the higher peak of the distribution). Distributions of this type have been obtained for a number of sites in this study (the West Kennet long barrow, Chapter 3; St Osyth, Chapter 7; Abingdon, Chapter 8), and it should be remembered when interpreting these estimates that the true date of the site could fall on either peak of the distribution. In cases where the estimate of the duration, however, is short (e.g. West Kennet and St Osyth, but less certainly Abingdon), it appears that the true dates of these sites must lie either on the earlier peak of both the *start* and *end* estimates, or on the later peaks of both. We have been unable to reproduce this effect in a simulation which spans more than 25 calendar years in this period.

The type of archaeological prior information we have included in our models so far is known as ‘uninformative’ or ‘vague’ prior information. This is where we have little definite information about a problem, but where we need to include information to avoid biasing a model (see section 2.2

above; Steier and Rom 2000; Bronk Ramsey 2000; Bayliss *et al.* 2007a, 8–15). In chronological modelling these vague prior beliefs usually take the form of statistical distributions imposed on a group of related dates. In this volume, we have used a uniform distribution of the underlying activity (Buck *et al.* 1992; Nicholls and Jones 2001). This choice is discussed further in section 2.8 below.

2.4.2 *'Informative' prior beliefs*

Informative prior beliefs are the second type of archaeological information which can be incorporated into our chronological models. As the name suggests, this is where we have specific and definite information about a problem which should affect the outputs of a model substantively. It has long been recognised that 'the pattern of radiocarbon ages of samples, especially where there is stratigraphic control, is of greater significance than a single determination' (J.G.D. Clark 1994, 122), and in modelling archaeological chronologies, informative prior beliefs usually derive from the relative dating evidence provided by stratigraphic relationships between radiocarbon samples. This is the bedrock of most site-based models (Bayliss and Bronk Ramsey 2004; Bayliss 2009), and has been incorporated into most of the models for enclosures discussed in Chapters 3–12.

A simple example of this kind of prior information is provided by the Harris matrix of dated deposits from the causewayed enclosures at Chalk Hill, Ramsgate, Kent (Fig. 2.13, and see Figs 7.19–22). It is the relative sequence of deposition of the archaeological contexts in this matrix which provides the informative prior beliefs. There is a critical proviso here. Stratigraphy provides a relative sequence of *contexts*. Radiocarbon dating does not date contexts – it dates *samples.* In order to use the relative dating of contexts as informative prior information in our models, it is therefore imperative that the order of the deposition of the contexts is the same as the order in which the organisms which provide the radiocarbon samples died. This means that the samples *must* have been recently dead when deposited in the context from which they were recovered if we are to include them fully in our models.

Some key sites in our study, however, were excavated in the 1920s and 1930s and were recorded by arbitrary spit rather than by stratigraphic context. In these cases the stratigraphic sequence of samples had to be inferred by projecting the spits on to the recorded sections. Often this enabled us to assign potential samples to the basal fills, or to more finds-rich deposits on top of the primary silting, or to secondary fills. This outline sequence was then incorporated into our models. We trialled this approach on the archive of the excavations at Windmill Hill undertaken by Alexander Keiller in 1925–9, where we could compare the results from the spit-dug trenches with those from excavations undertaken in 1957–58 and 1988 (Chapter 3.1). In fact, the use of material excavated by spits proved, perhaps surprisingly, viable (see below, section 2.7.2) and so we were able to undertake dating programmes on other sites excavated in this way, most successfully at Whitehawk Camp, East Sussex (Chapter 5.1) and Hembury, Devon (Chapter 10.2).

The unravelling of the relative date of deposits on a site, whether by single context recording and Harris matrices or by the interpretation of older archives, and the identification of samples which are close in age to those deposits, is critical. This is because informative prior beliefs are just that – informative. They are very powerful and make a substantive difference to the outputs of the model. This is important in two ways. First, because it affects the outputs of the model so strongly, if the informative prior information which we include in a model is incorrect, then there is a good chance that the outputs of the model will also be incorrect.[7] Second, informative prior information is an extremely cost-effective way of obtaining precise chronologies, and can be essential for their production in parts of the radiocarbon calibration curve where wiggles and plateaux are particularly acute. Consequently, we want to include as much informative prior information in our models as possible.

The taphonomy of the dated samples is therefore of fundamental importance. How did the datable material get into the deposit in which it was found? This is, of course, never known but may be interpreted with varying degrees of certainty by the archaeologist (Fig. 2.14). Our desire to incorporate relative dating from stratigraphy into Bayesian models to produce precise chronologies re-emphasises the need to consider archaeological taphonomy in the selection of samples for radiocarbon dating. These considerations are considered in detail in sections 2.5 and 2.7.2 below.

Radiocarbon dates on short-life material which is closely associated with the deposition of the context from which it was recovered (such as the articulating bones or refitting sherds from Chalk Hill; Table 7.5) form the backbone of the chronological models presented in this volume. Such samples, crucially, provide information not only about the end of activity on a site, but also about its beginning. Many of our dated samples, however, do not meet the rigorous criteria outlined in section 2.5. These dates provide less information for our models, but they are not entirely useless. If a sample was residual in its context, or was composed of material with an in-built age-offset, then it does usually provide a *terminus post quem* (maximum age) for its context and for any stratigraphically later deposits. Strategically located, such dates can provide extremely effective constraints for parameters of interest (e.g. *GrA-29112* and *OxA-14834* for the construction of the inner ditch of the causewayed enclosure at Maiden Castle; Fig. 4.42). Overall, 511 (29%) of the 1782 radiocarbon dates included in at least one of the models presented in this volume have been incorporated as *termini post quos* (Fig. 2.15).[8] A few dates have been incorporated into the models as *termini ante quos* (minimum ages). These are rare, since the dated context must be later than the enclosure or other archaeological activity of interest and the sample must be of short-life material and closely associated with that context. Residual samples or those containing potentially

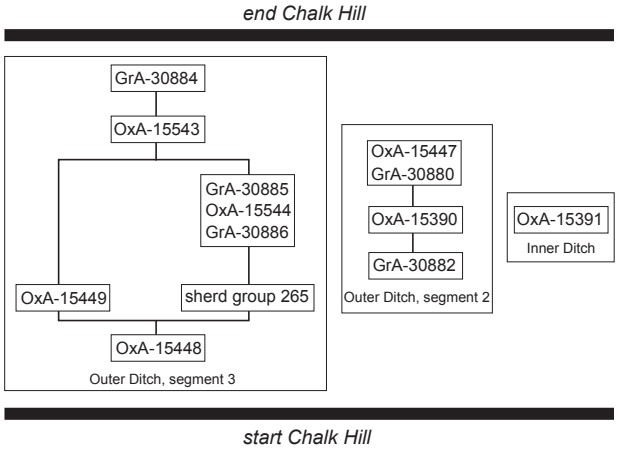

Fig. 2.13. Schematic diagram showing the prior information included in the chronological model for the enclosure at Chalk Hill, Ramsgate, Kent (Fig. 7.21).

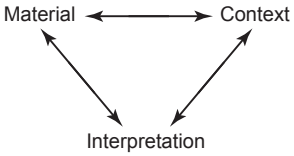

Fig. 2.14. The relationship between interpretation, an archaeological context and the material recovered from it.

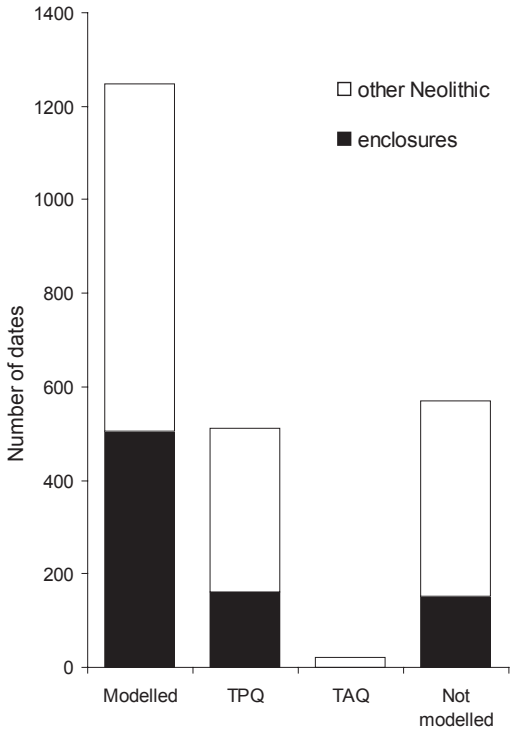

Fig. 2.15. How the corpus of radiocarbon dates considered in this volume has been modelled (n=2350).

long-lived material cannot be used as *termini ante quos* in chronological models.

Although stratigraphy is the most common type of informative prior information included in the models described in this volume, it is not the only type. On occasion we have also incorporated in our models the relative sequence and number of years between samples of wood taken from floating tree-ring sequences (e.g. Haddenham long barrow, Fig. 6.17). This very informative prior information leads to a special variety of analysis, known as Bayesian wiggle-matching (Christen and Litton 1995; Bronk Ramsey *et al.* 2001; Bayliss 2007). Also on the basis of our understanding of the formation of wood samples, occasionally we have offset radiocarbon dates by the number of missing sapwood rings on a timber (e.g. Raunds long barrow, Fig 6.27; Hillam *et al.* 1987; Bayliss and Tyers 2004).

2.4.3 Standardised likelihoods

Prior beliefs form one of the generic components of Bayesian models. The second generic component is composed of the 'standardised likelihoods' (Fig. 2.4) – the data that are interpreted in the light of our prior beliefs. In chronological modelling in archaeology, standardised likelihoods usually take the form of dates derived from scientific methods. On occasion, however, dates from documentary sources, coins or inscriptions might also be included in models (e.g. Sidell *et al.* 2007).

In this study the overwhelming majority of the standardised likelihoods are radiocarbon dates. We have considered 2350 radiocarbon dates in detail in this volume. In contrast, there are six OSL ages from the two cursus monuments at Eynesbury, Cambridgeshire (Table 6.5) and three TL ages from sherds of Ebbsfleet Ware from the disturbed site at High Rocks, Tunbridge Wells, Kent (Chapter 7.6). There are also tree-ring dates for the Sweet Track, Somerset (Chapter 14.5), and a trackway at Derrygreenagh Bog, Co. Westmeath, Ireland (Table 12.7). Of these, 1782 radiocarbon dates, the six luminescence ages from Eynesbury, and both tree-ring dates have been included in at least one of the chronological models presented here.

Dendrochronology and luminescence dating both provide dates on the calendar scale (English Heritage 1998; Duller 2008); radiocarbon dating does not. So, before our radiocarbon measurements can be incorporated as radiocarbon dates into our chronological models, they have to be calibrated on to the calendar timescale (Pearson 1987). Since the Bayesian approach is fundamentally probabilistic, we implement the probability method of radiocarbon calibration (Stuiver and Reimer 1993; Dehling and van der Plicht 1993; van der Plicht 1993). This is illustrated in Fig. 2.16. We consider the radiocarbon age in equal-sized segments called bins (e.g. covering one radiocarbon year). Each bin of probability of the radiocarbon age is converted to one or more probability values on the calendar scale by means of the calibration curve (in Fig. 2.16 the probability at 4725 BP is distributed between calendar dates in the last quarter of the 37th century cal BC, the last quarter of the 36th century cal BC and the first quarter of the 34th century cal BC). Account is taken both of the probability

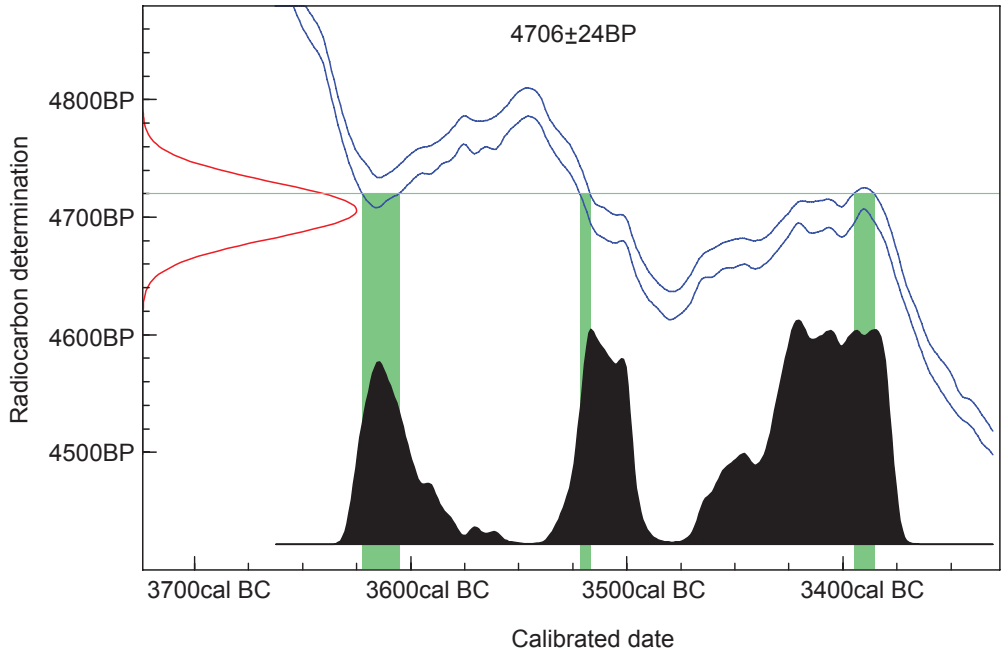

Fig. 2.16. Probability distribution of a calibrated radiocarbon date from the Greater Stonehenge Cursus (032, Table 4.13).

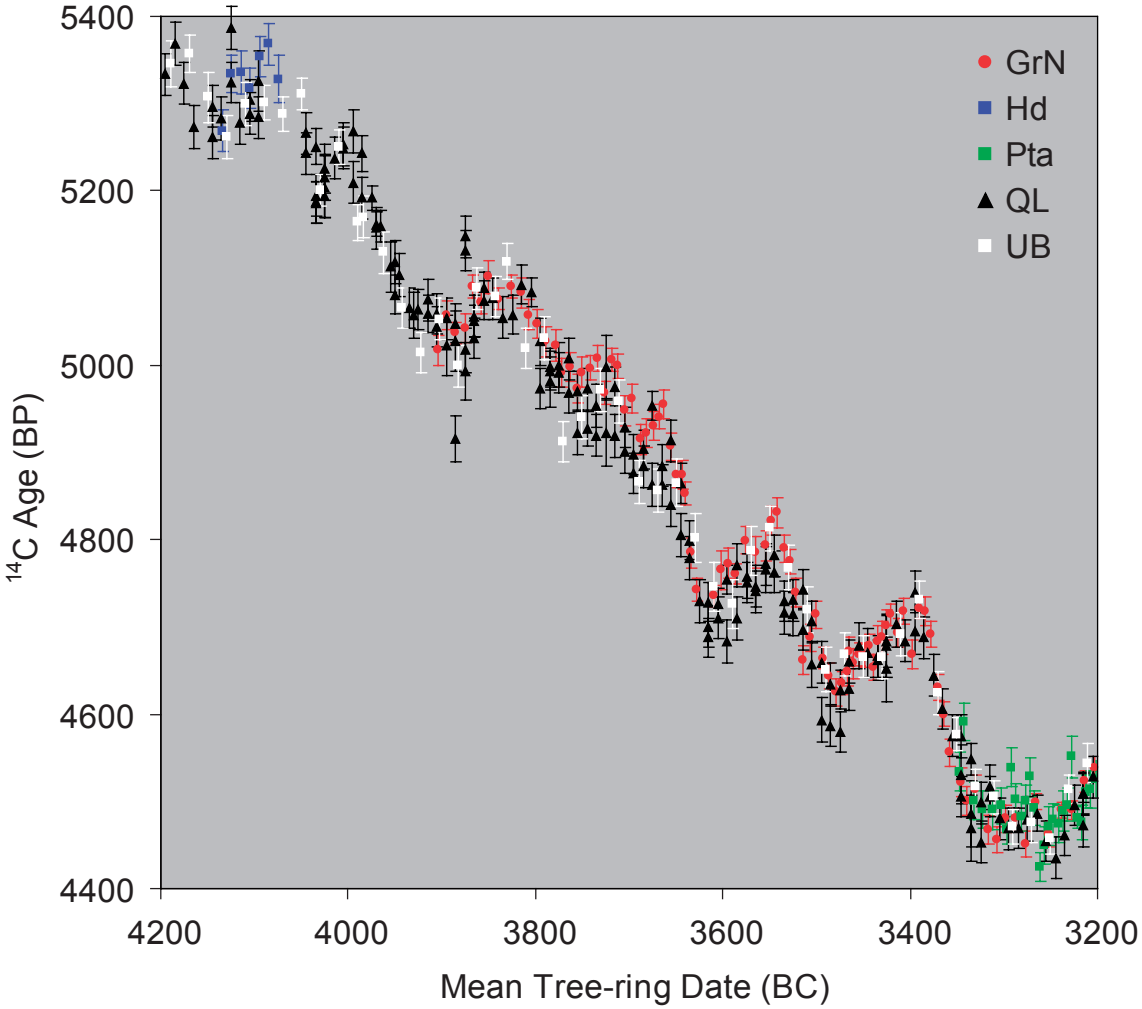

Fig. 2.17. Radiocarbon measurements included in INTCAL04 (Reimer et al. *2004) on wood dated by dendrochronology to between 4200 BC and 3200 BC (GrN – Rijksuniversiteit Groningen; Hd – Heidelberger Akademie der Wissenschaften; PtA – National Physical Research Laboratory, Pretoria; QL – University of Washington, Seattle; UB – The Queen's University, Belfast).*

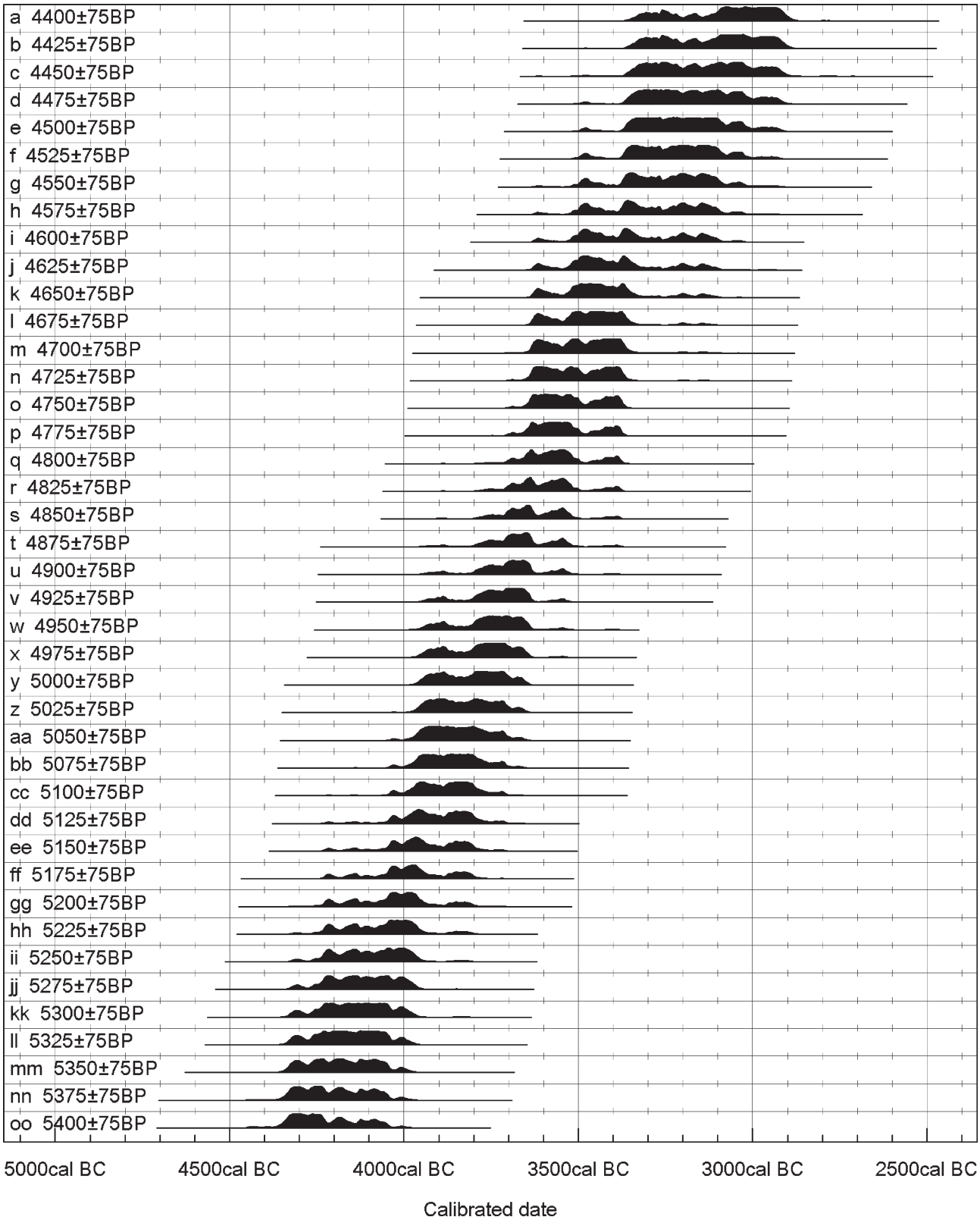

Fig. 2.18. Probability distributions of calibrated radiocarbon dates from radiocarbon ages spanning 5400–4400 BP (with measurement errors of ±75 BP).

of the radiocarbon age and the error term on the calibration curve. The sum of the probability values at each bin on the calendar scale, once all the probability in the radiocarbon age has been transferred, forms the probability distribution of the calibrated radiocarbon date. It is this probability distribution which forms a standardised likelihood for a Bayesian model.

Figure 2.16 illustrates the effect of the wiggles and

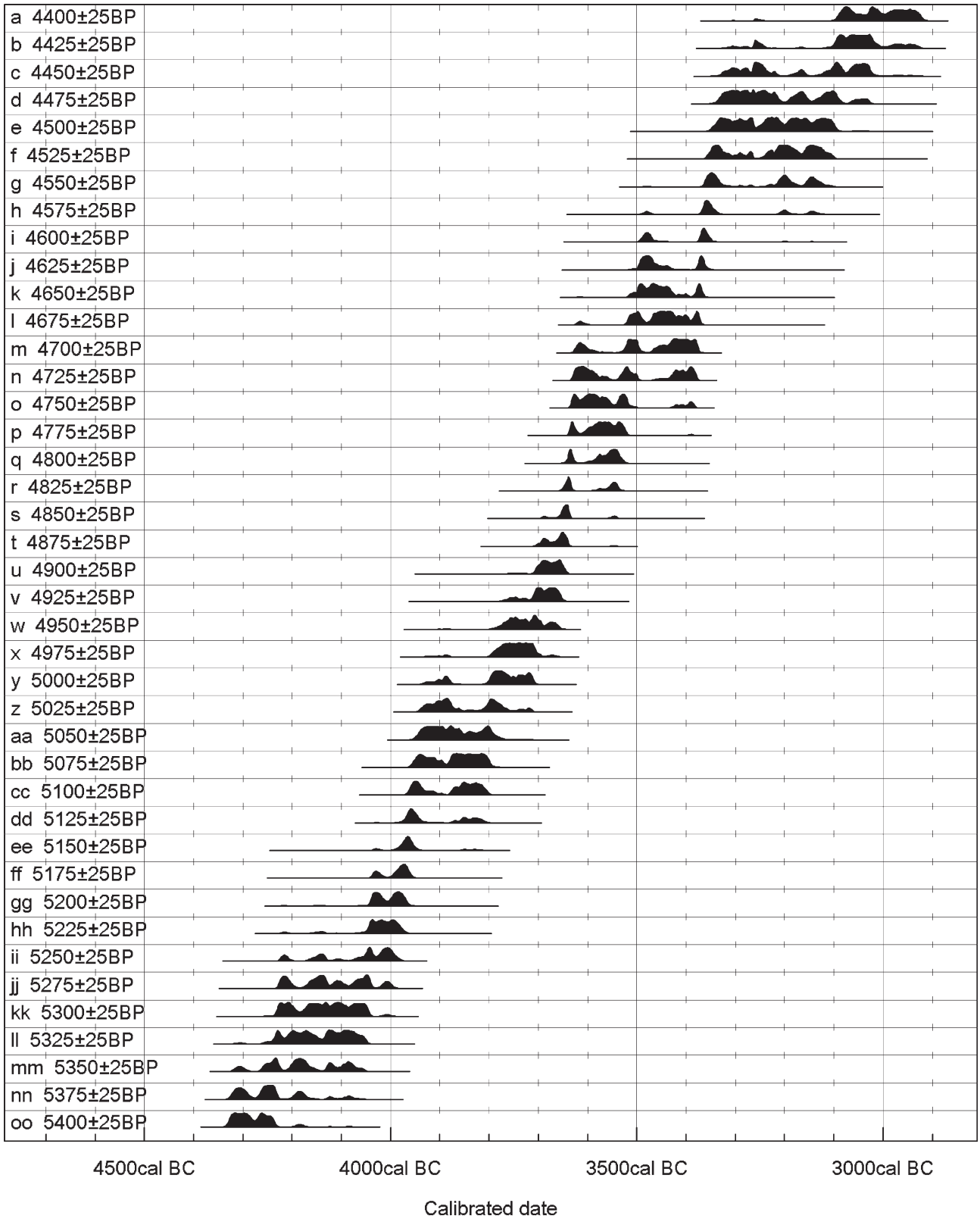

Fig. 2.19. Probability distributions of calibrated radiocarbon dates from radiocarbon ages spanning 5400–4400 BP (with measurement errors of ±25 BP).

plateaux in the radiocarbon calibration curve on the probability distributions of calibrated dates. This radiocarbon sample dates either to 3630–3585 cal BC (19% probability) or to 3530–3490 cal BC (21% probability) or to 3470–3370 cal BC (55% probability). The shape of the radiocarbon calibration curve in the relevant period is therefore a material consideration in the application of Bayesian chronological modelling.

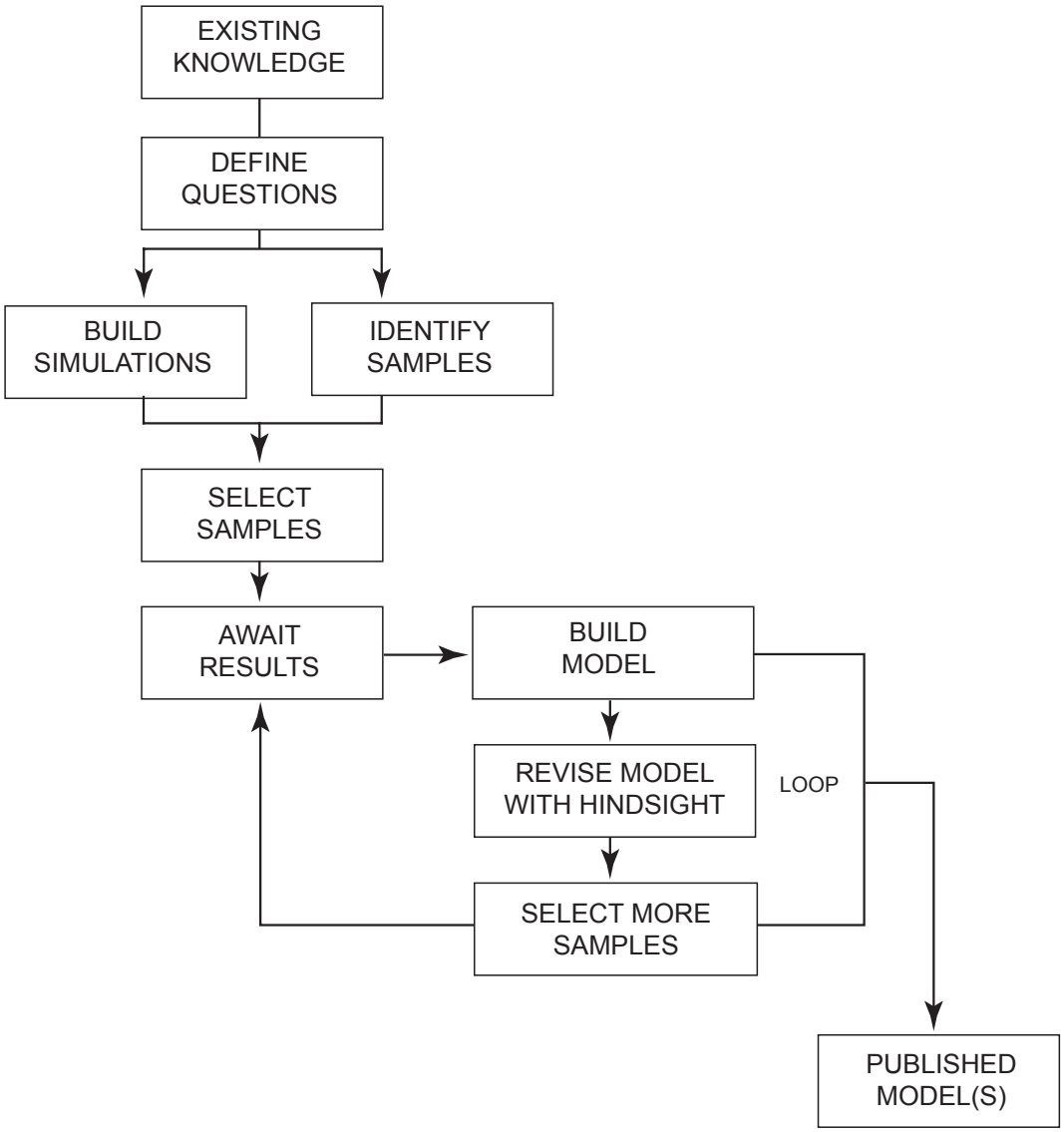

Fig. 2.20. Flow diagram showing the stages in sample selection and chronological modelling.

Fig. 2.21. Charcoal sample recovered in 1926 from Windmill Hill (inner ditch, segment 7, spit 5), as stored since the excavation in the Alexander Keiller Museum, Avebury. Photo: Amanda Grieve.

Fig. 2.22. Articulated cattle ankle from Chalk Hill, Ramsgate (outer ditch, segment 2). Photo: Canterbury Archaeological Trust.

Fig. 2.23. Distal right cattle tibia and astragalus from the inner ditch of the causewayed enclosure at Maiden Castle, possibly articulating (although the surface condition of the two bones is different). Photo: Amanda Grieve.

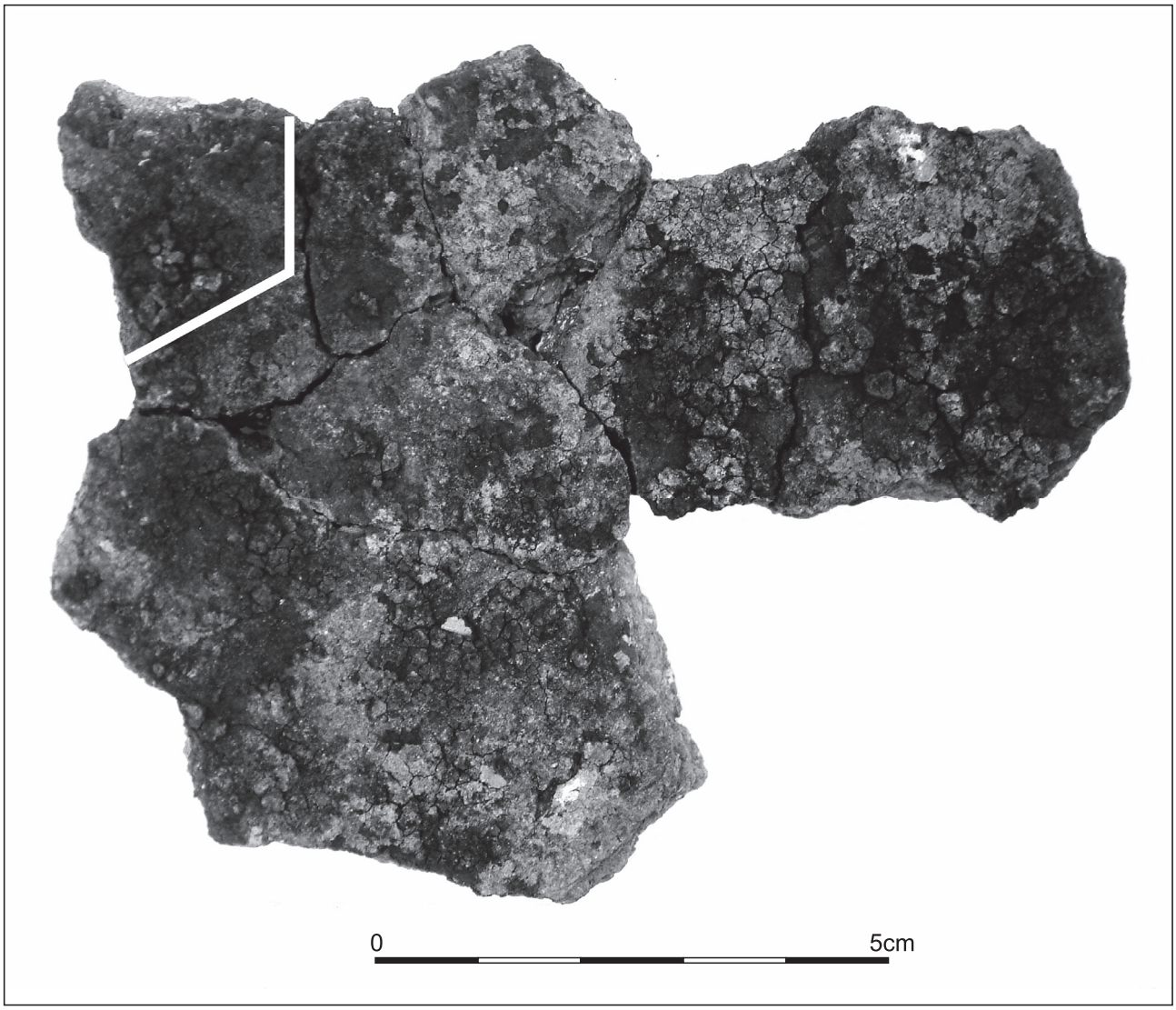

Fig. 2.24. Conjoining sherds of a Neolithic Bowl with internal carbonised residue, from the midden layers in the inner ditch of the causewayed enclosure at Maiden Castle. The red box denotes the area of residue required for AMS dating. Photo: Amanda Grieve.

The data included in the relevant section of the current internationally-agreed calibration curve (INTCAL04; Reimer *et al.* 2004) is shown in Fig. 2.17. In the fifth and fourth millennia BC, this curve is based on blocks of European oak whose calendar date is known by dendrochronology (Pilcher *et al.* 1984). Five sets of data contribute to this section of the calibration curve. Measurements on decadal tree-ring samples were made by the University of Washington, Seattle (Stuiver and Becker 1993; corrected as described by Stuiver *et al.* (1998a) and the Heidelberger Akademie der Wissenschaften (Kromer *et al.* 1986); and bi-decadal tree-ring samples were dated at the Queen's University, Belfast (Pearson *et al.* 1986). Unusually, this section of the curve also contains data with sub-decadal (1–4 calendar years) resolution from the Rijksuniversiteit Groningen (de Jong *et al.* 1986; corrected as described by de Jong *et al.* 1989) and the National Physical Research Laboratory, Pretoria (Vogel *et al.* 1993). This means that the part of the calibration curve of relevance to this study is unusually well replicated, and contains data of a resolution uncommon in the prehistoric period (but see Vogel and van der Plicht 1993). This curve was constructed by a group of laboratories who exchanged standard materials and known-age wood, minimising inter-laboratory offsets to within the range 0–20 BP (Stuiver *et al.* 1998b). For example, the difference between the Groningen and Pretoria conventional laboratories (GrN and PtA) on the same material is on average 7.1±6.4 BP (Vogel *et al.* 1993, 74).

The data-dense and well-replicated nature of the calibration curve in the fourth millennium BC means that we can have confidence that it accurately reflects the changing radiocarbon content of the atmosphere during this period. Because of the high resolution data available from the Groningen and Pretoria laboratories, there is unlikely to be significant additional structure in the shape of the curve at this time, such as has been revealed in other periods by the measurement of more closely-spaced tree-ring samples (McCormac *et al.* 2004; 2008). Since the known-age wood used for the calibration samples itself grew in north-west Europe, it is also unlikely that there is any regional or growing-season offset (Kromer *et al.* 2001) between the calibration curve and archaeological samples from Britain and Ireland.

Figure 2.17 demonstrates that the radiocarbon calibration curve in the fourth millennium BC is characterised more by wiggles than by plateaux. Tree-ring samples from *c.* 4200–*c.* 4050 BC produce a plateau of radiocarbon ages very close to 5300 BP. But thereafter, in the early centuries of the fourth millennium, there are two shallow wiggles (peaking at *c.* 3995 BC and *c.* 3830 BC) separated by steeper sections of curve. The middle centuries of the millennium are covered by two much more pronounced wiggles (each spanning almost 150 BP between *c.* 3610–*c.* 3540 BC and *c.* 3475–3395 BC respectively). Another plateau at *c.* 4500 BP runs from *c.* 3330–*c.* 3000 BC.

We have seen, in Fig. 2.16, how this non-monotonic calibration curve can result in multi-modal probability distributions for the calibrated radiocarbon dates that form the standardised likelihoods component of our chronological models. But is this the usual form of calibrated dates in this period? Figure 2.18 shows the calibrated dates for a series of radiocarbon ages (with error terms of ±75 BP) running from 5400–4400 BP. Although some peaks and troughs of probability are visible in these distributions (e.g. t), in general the wiggles in the calibration curve are not apparent from measurements at this precision. Compare Fig. 2.18 with Fig. 2.19, however, where the same radiocarbon ages have been calibrated, but on this occasion they have error terms of ±25 BP. Much more of the structure of the calibration curve is now apparent in the probability distributions of the calibrated dates. They are more multimodal, and the peaks and troughs in their distributions are more pronounced. Even an apparently severe plateau such as that covering the last centuries of the fourth millennium BC resolves into a series of wiggles and mini-plateaux at this precision.

Measurement precision is one weapon in our battle to obtain precise chronologies notwithstanding the effect of radiocarbon calibration. Except in periods when the radiocarbon content of the atmosphere is changing sharply, it is a relatively blunt tool. By considering a corpus of radiocarbon dates and the relationships between them together, however, prior beliefs in a Bayesian model can perform a similar function. The model determines which part of a standardised likelihood is most probable given the available prior information, effectively matching a sequence of radiocarbon dates to the detailed structure of the calibration curve.[9]

Standardised likelihoods are shown in the graphs in this volume in outline. Sometimes, especially when a model has little informative prior information, these distributions may be hidden behind the posterior density estimate of the same date (which is shown in black). In this case, the label for the distribution will appear *in italics*, since it is a posterior density estimate. Distributions followed by a '?' on the graphs are calibrated radiocarbon dates, which have not been included in the model for reasons discussed in the text.

2.4.4 Calculating posterior density estimates

Once the components of a Bayesian model have been assembled – the standardised likelihoods obtained and the prior beliefs explicitly defined – they can be combined using Bayes' theorem (Fig. 2.4). This is done using a Markov chain Monte Carlo (MCMC) random sampling technique. In this study all modelling has been undertaken using OxCal v3.10, which utilises a mixture of the Metropolis-Hastings algorithm and the more specific Gibbs sampler (Gelfand and Smith 1990; Gilks *et al.* 1996).

Two statistics are calculated by OxCal which aid the archaeologist in an assessment of the reliability of a model. The first of these is the individual index of agreement (A: Bronk Ramsey 1995, 429). This index provides a measure of how well any posterior density estimate agrees with the standardised likelihood from which it derives. If the posterior

density estimate is situated in a high-probability region of the likelihood, the index of agreement is high; if it falls in a low-probability region, it is low. If the index of agreement falls below 60%, then the radiocarbon result may be in some way problematic. It should be noted that this threshold has been empirically derived, and in practice provides only an indication of when a date may be inconsistent with the model employed (about 1 in 20 dates will have a low index of agreement simply on statistical grounds). The index of agreement is not a quantitative measure of how well a date 'fits' the model. For example, in Fig. 2.6, *m* has an index of agreement of 114.9%, whereas *l* has an index of agreement of 63.1%. Date *m* is no more consistent with the constraints of the model than date *l* – both dates are accurate and entirely compatible with the prior information included in the model (remember, this is a simulation which has been designed thus!). Equally date *k*, which has a poor individual index of agreement (A=46.2%), is also entirely consistent with the model employed.

This example highlights how we have utilised individual agreement indices in this study – as a trigger which prompts the re-examination of the accuracy of a particular date or set of prior information (according to the criteria set out in sections 2.5 and 2.6). Sometimes a low index of agreement merely indicates that the radiocarbon date is a statistical outlier, although a very low value may suggest that a sample is residual or intrusive (i.e. that the calendar age of the sample is different to that implied by the stratigraphic position of the context from which it was recovered), or that it may have been contaminated. Dates with low individual indices of agreement are not excluded from the analysis if detailed re-assessment suggests that they are simply statistical outliers rather than dates which are inaccurate on either archaeological or scientific grounds.

The second statistic is the overall index of agreement, which is calculated from the individual agreement indices ($A_{overall}$: Bronk Ramsey 1995, 249). This provides a more general measure of the consistency between the prior information and the standardised likelihoods. Again, the overall index of agreement has a threshold value of 60%, and models which produce values lower than this should be subject to critical re-examination. Usually, a low overall index of agreement is derived from a small number of misfits – dates on residual, intrusive or contaminated samples. These can be identified through very low individual indices of agreement and, in most cases, can be explained by detailed consideration of the archaeological evidence or laboratory procedures. The model can be modified and re-run according to our re-interpretation of these data. For example, samples which have proven residual provide *termini post quos* for their contexts and have no relationship with stratigraphically earlier samples. Samples whose radiocarbon ages appear anomalous have been excluded from the analysis. The names of these distributions are followed by a '?' in the graphs, with the relevant calibrated radiocarbon date shown in black. The reasoning behind individual decisions to exclude particular measurements is explained in the accompanying text.

A third statistic is calculated by OxCal which allows us to determine whether a model is stable. This is known as convergence. This is a measure of how quickly the MCMC sampler is able to produce a representative and stable solution to the model. Details of the measure used in OxCal (C) may be found in Bronk Ramsey (1995, 429). In practice, a model whose convergence is poor (less than 95%) is unstable and the results should not be used. None of the models reported in this study have poor convergence.

2.5 The Bayesian process

The iterative approach to radiocarbon sampling and chronological modelling which we have adopted in this study is summarised in Fig. 2.20. This methodology has been developed over the past 15 years to ensure that best value is obtained routinely for dating projects funded by English Heritage (Bayliss and Bronk Ramsey 2004). It has been refined through practice. We have now dated more than 500 sites and submitted well over 3000 radiocarbon samples using this framework for sample selection (Bayliss 2009, fig. 11).

2.5.1 Groundworks

The first step is to determine exactly what is known about the chronology of a site before any new samples are submitted for dating. To this end, we elicit the precise archaeological provenance of each of the existing radiocarbon dates from a site, establish precisely what material has been sampled and the methods used to date it, and construct stratigraphic matrices of the contexts from which the samples were recovered. In practice, this is a considerable task that requires research in both published sources and a wide range of archives. Excess material surviving from samples dated in earlier decades is retrieved from storage and retrospectively identified to age and species; stratigraphic sequences are culled from detailed readings of site publications or from unpublished excavation archives; laboratory procedures are traced from technical publications or by contacting the laboratories concerned.

This detailed information enables us to build chronological models of sites using the existing radiocarbon dates (e.g. Windmill Hill, Fig. 3.6). From it we are able to assess the accuracy of the existing radiocarbon measurements (see sections 2.6 and 2.7 below) and so determine which calibrated radiocarbon dates should be included as standardised likelihoods in our model. Crucially, we are also able to interpret the relationships between the dated samples and the contexts from which they were recovered (see section 2.5.2 below), and so define, retrospectively as it were, the prior information that can be included in our model.

The quality of the dating information available before this project began varied immensely. For some sites, such as Banc Du, Pembrokeshire (Chapter 11.3), the suggestion that they were Neolithic rested solely on the

Fig. 2.25. Shed antler with signs of charring and a very worn burr (used as a hammer?) recovered from the lowest fill of pit 2276, which was cut into the primary fills of the Maiden Castle long mound. Conventional dating would require the destruction of the entire specimen; AMS dating was undertaken on the fragment outlined in red. Photo: Amanda Grieve.

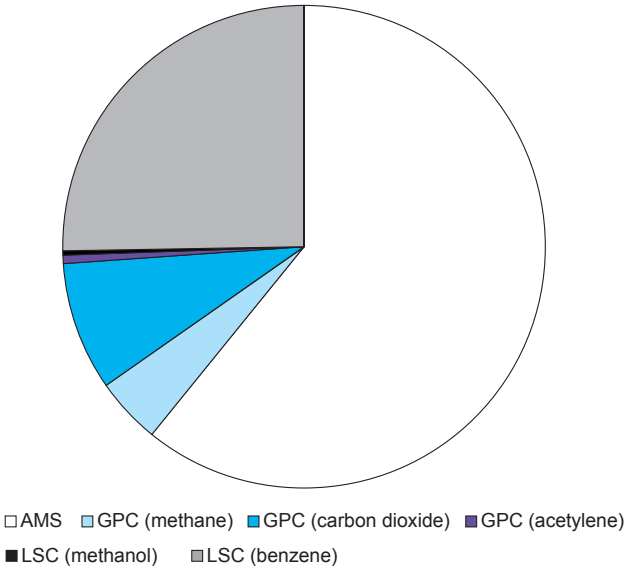

Fig. 2.26. Numbers of radiocarbon measurements considered in this volume measured using different techniques (n=2350).

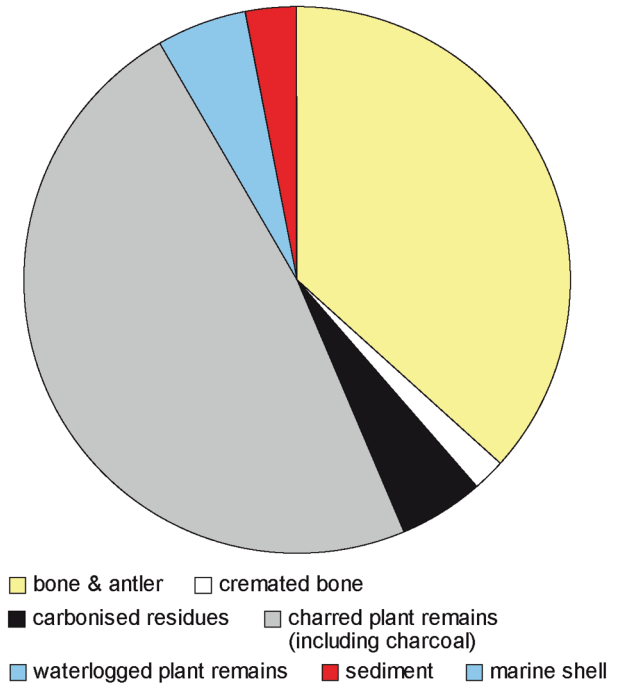

Fig. 2.27. Numbers of radiocarbon measurements considered in this volume obtained from different material types (n=2350).

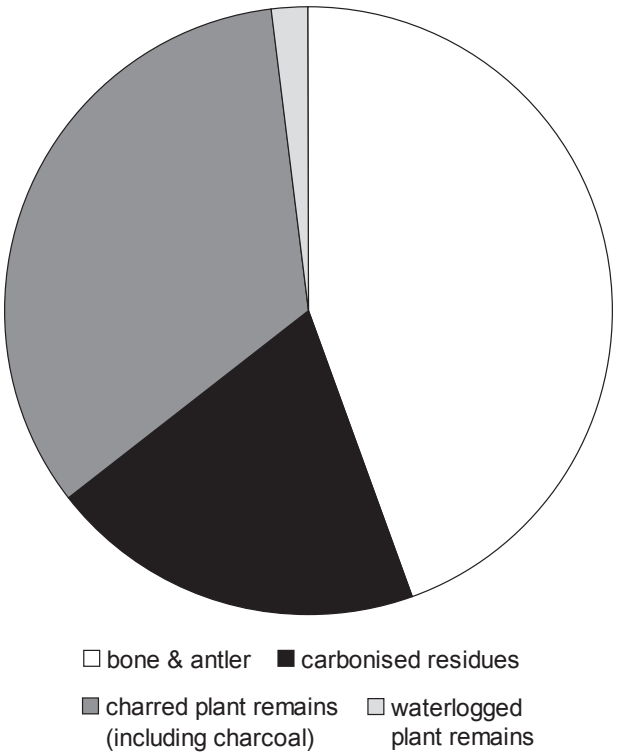

Fig. 2.28. Numbers of radiocarbon dates obtained during this study from different material types (n=427).

form of the enclosure. For others, such as Hill Croft Field, Herefordshire (Chapter 11.1), a Neolithic date was postulated on the basis of the recovery of Neolithic finds such as Bowl pottery. Some sites, such as Orsett, Essex (Chapter 7.2), although possessing the appropriate form and finds, had yielded a handful of existing radiocarbon dates, of varying reliability, which did little more than suggest that the site was used sometime within the fourth millennium cal BC. In contrast, other sites, such as Maiden Castle (Chapter 4.3), already possessed substantial suites of radiocarbon dates. In these cases, formal modelling of the existing radiocarbon dates substantially refined our understanding of the chronologies of the sites even before any additional samples were submitted for dating (see Table 4.10; or compare Figs 3.4 and 3.5).

Once we had established our interpretation of the chronology of a site based on existing information, we could consider what other questions the dating programme should be designed to address. In addition to the general project aims set out in Chapter 1.4, we also considered subsidiary, site-specific objectives that might relate to the development of a particular monument complex or series of sites in a locality. The objectives of each sampling programme are set out for each site in the regional chapters which follow (Chapters 3–12). The formulation of explicit research objectives is an essential step in the process of Bayesian chronological modelling because the aims of a project materially affect the model we construct and the samples we submit for dating (see section 2.5.3 below).

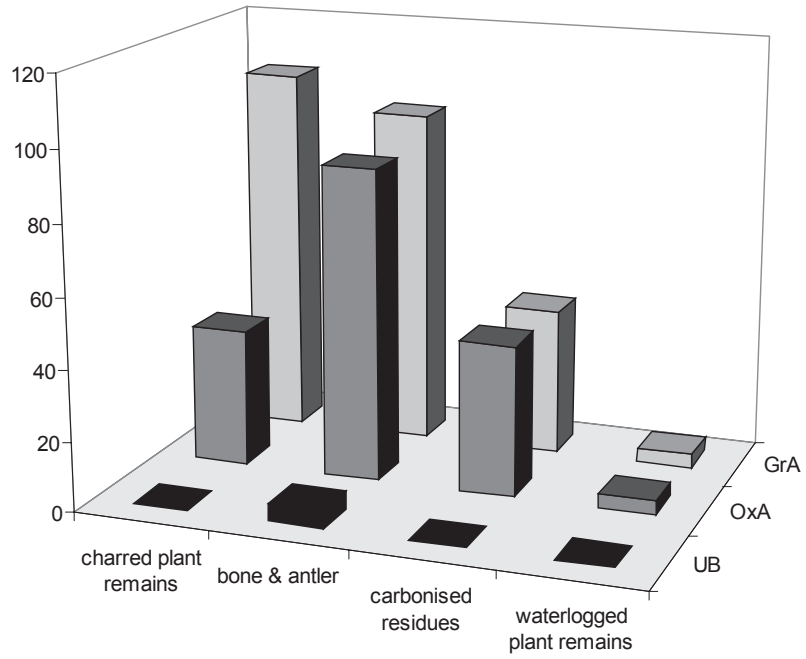

Fig. 2.29. Numbers of radiocarbon measurements made on each sample type by laboratories in the 2004–7 dating programme.

2.5.2 Identifying suitable samples

The next step in the process of construction of Bayesian chronologies is to identify a pool of samples that are suitable for dating (Fig. 2.20). This is a complex task, involving all the technical intricacies of radiocarbon dating and requiring rigorous consideration of some difficult archaeological problems.

There are three basic criteria which a sample must meet before it can be considered suitable for radiocarbon dating. First, the carbon in the sampled organism must be in equilibrium with the carbon in the atmosphere (or some other well-characterised reservoir) at the time when the organism died. By far the most common source of error of this type is the 'old-wood effect' (Bowman 1990, 51), where dates are obtained on wood or charcoal from long-lived plants. The carbon in a tree-ring dates from the year in which that tree-ring was laid down (that is why radiocarbon calibration works!), and so all samples should consist of twigs or the outer rings of the tree. Samples of heartwood from long-lived species, such as oak, or samples which have not been identified to age and species before dating can only be incorporated into models as *termini post quos* (and are thus far less effective at producing precise chronologies). All the samples submitted for dating as part of this project consisted of short-life material, although in a few cases oak charcoal which was only probably identified as sapwood was dated (see Chapter 5.1).

Other effects which can complicate the relationship between the carbon absorbed by the sampled organism in life and the contemporary atmosphere are isotopic fractionation (Bowman 1990, 20–1) and reservoir effects (Bowman 1990, 24–7). All the dates produced during the course of this study are conventional radiocarbon ages and have been corrected for isotopic fractionation using measured $\delta^{13}C$ values. Those listed in this volume were measured by conventional mass spectrometry unless otherwise specified (and see Table 2.3). It has not been possible to determine exactly how many of the other radiocarbon ages considered in this study have not been corrected for fractionation (using either measured or global average values). Based on the date when the measurements were made, however, probably under 5% of the total corpus of radiocarbon determinations are uncorrected. There are no samples from marine or freshwater reservoirs from enclosures, and only three from marine sources in the entire study (Tables 12.10 and 14.14). These ages have been calibrated as described in section 2.1, taking into account their marine origin. As there seems to have been very little if any use of marine resources during the Neolithic in southern Britain (Hedges *et al.* 2007b; M. Richards 2000; M. Richards *et al.* 2003), all radiocarbon ages on Neolithic human bone have been calibrated as fully terrestrial samples. The exceptions are the two individuals with strongly marine isotopic signatures from Ferriter's Cove discussed in section 2.1.

The second criterion which a sample must meet if it is to be considered for radiocarbon dating is that it must not be contaminated by any other carbon-containing material. This is a tall order. Almost all samples are contaminated by their burial environments, and radiocarbon laboratories go to great trouble to remove such contamination. This is the reason for the chemical pre-treatment protocols adopted by all radiocarbon laboratories since the earliest years of the method. Over time, however, some approaches have proven more reliable in practice than others. This is the reason why we have attempted to track down how each sample in our study was prepared and dated (see section 2.6 below). The major archaeologist-derived contaminants that have been encountered in this study are Polyvinyl Acetate (PVA), a consolidant which had been applied to a handful of the bone samples, glues (of unknown and probably variable composition) which had been used to reconstruct many of the groups of refitting pottery sherds with carbonised residues and some of the antlers and bones sampled, and varnish (again of unknown and probably variable composition) which covered many of the context notations which had been marked on bones and sherds in Indian ink. A few of the specimens recovered during excavations in the 1920s and 1930s had been reconstructed using plaster of Paris. Packaging was varied (Fig. 2.21).

The third basic criterion which a sample must meet before it is dated is that it must be securely associated with the archaeological activity that is of interest. The importance of this relationship between the *dated event* (e.g. the shedding of an antler) and the *target event* (e.g. the digging of a Neolithic ditch) has been highlighted repeatedly since the seminal paper on the subject by Waterbolk (1971), but routinely still far too little attention is paid to the association between the sample, the context from which it was recovered and the archaeological event that our dating targets (Dean 1978; Van Strydonck *et al.* 1999; Bayliss 2009). Bayesian modelling, because of our desire to incorporate informative prior information from stratigraphy in our models, reinforces the critical importance of the taphonomy of the dated material and the association between it and the past activity which we wish to date. As this relationship is never known, but inferred on the basis of archaeological evidence (Fig. 2.14), we have explicitly described the basis of our taphonomic interpretation of each sample in the detailed description of each model given in the regional chapters (Chapters 3–12, and Chapter 14.7 for Scotland). This may seem tedious, but it is fundamental to how we have incorporated each standardised likelihood into our models. Bayesian modelling is an explicit, statistical process and demands that we make a clear, open and unequivocal decision about how to model each and every radiocarbon date in our study.

Since it is the interpretation of the taphonomy of the dated material which so often goes awry in archaeological sample selection, it is perhaps worth outlining in some detail the grounds we have used for making this inference in this study. The following categories of samples have been submitted for dating, in roughly descending order of reliability:

1) Bones found in articulation and recorded in the ground as such (Fig. 2.22). These samples would have been still connected by soft tissue when buried and hence

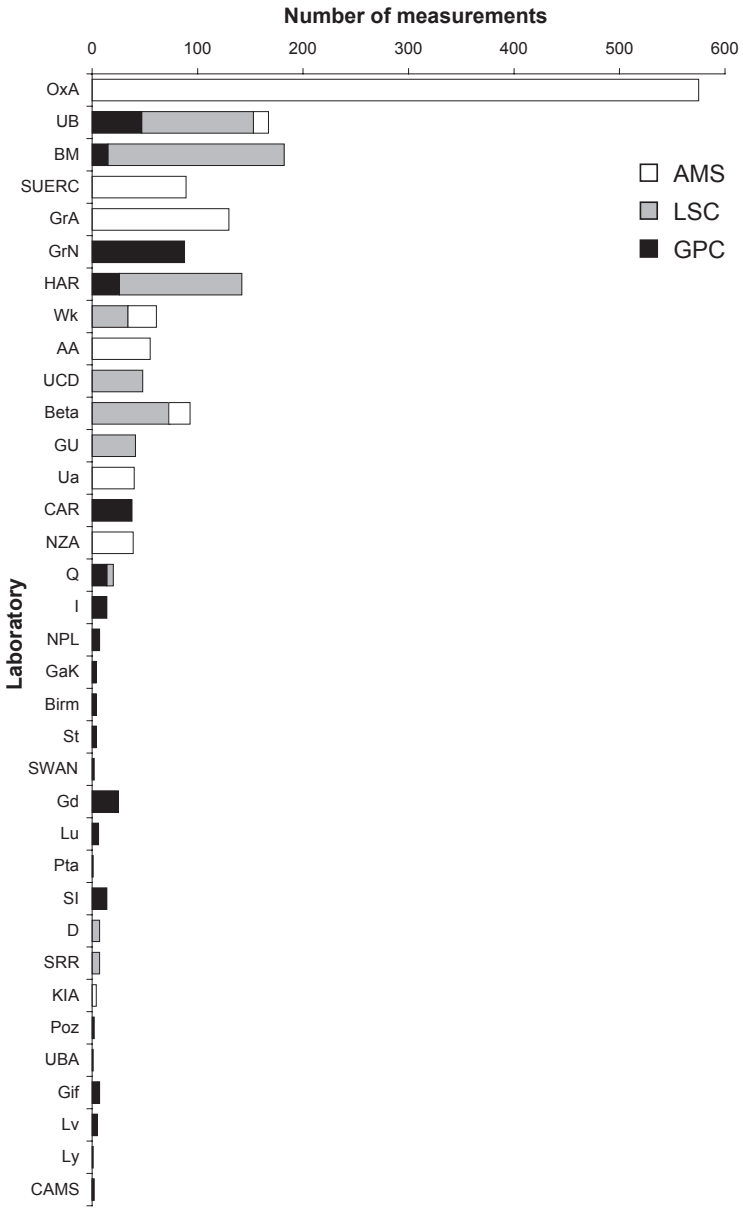

Fig. 2.30. Numbers of radiocarbon measurements by laboratory from samples included in this study but dated by previous researchers (n=1923).

from animals which were not long dead (Mant 1987, 71).

2) Articulating bones identified as such during faunal analysis (Fig. 2.23). These samples may have been articulated in the ground (but not recognised as such) or have only been slightly disturbed before burial. The presence of more than one bone from the same individual provides evidence that such samples are close in age to their contexts. The security of this inference increases as the number of articulating bones increases.
3) Bones with refitting unfused epiphyses identified during faunal analysis: see 2) above.
4) Carbonised residues adhering to the interior surface of groups of refitting pottery sherds (Fig. 2.24) or from a group of sherds thought to derive from a single vessel. As the residues are on the interior of the vessel, this material probably represents the remains of charred food (rather than sooting) and, since the sherds refit or much of a pot survives, the vessel has a good chance of being in the place where it was originally discarded (see sections 2.6 and 2.7 below for the reliability of dates on carbonised residues from pottery).
5) Antler tools discarded on the base of ditches and other negative features (Fig. 2.25): thought to be functionally related to the digging of the features. This inference is most secure when the tine is embedded in the base of the cut or striations from the picks are visible in the substrate.
6) Short-lived parts of waterlogged wood. This was

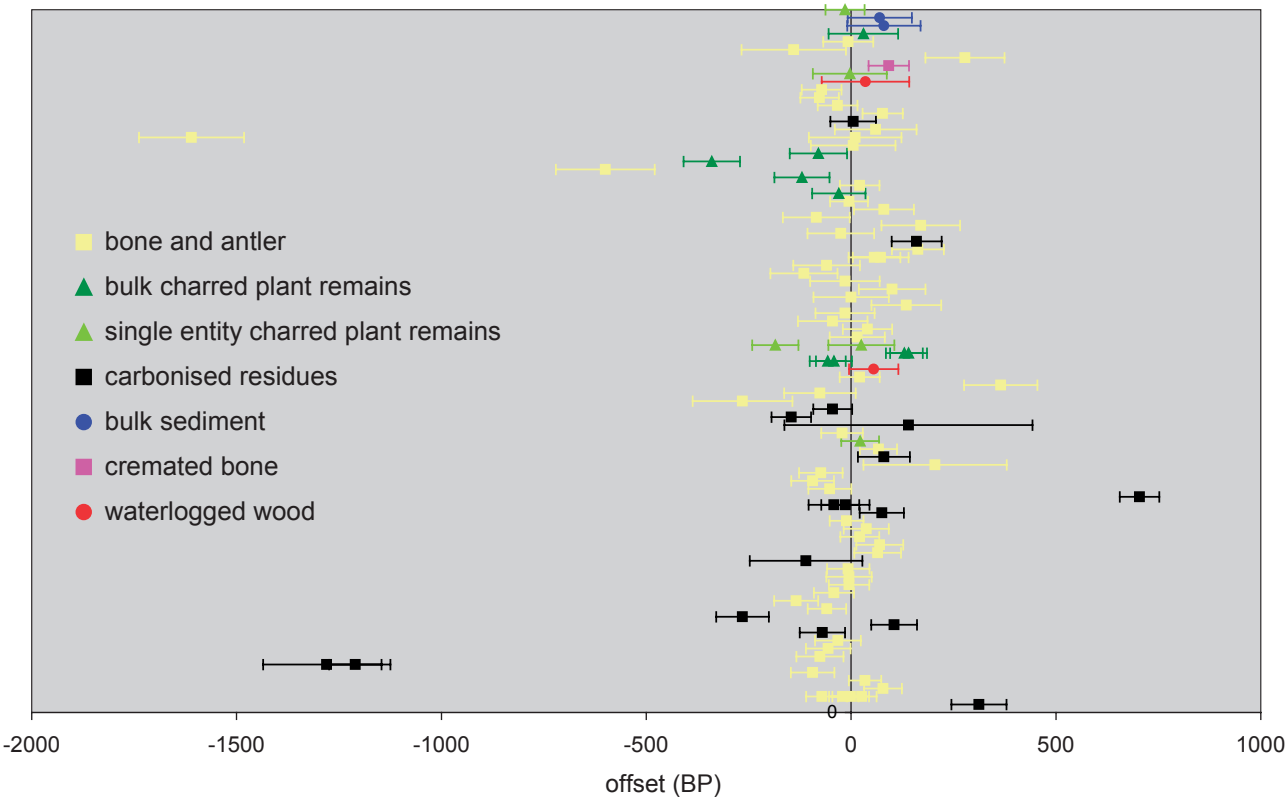

Figure 2.31. Offsets between replicate pairs of radiocarbon results on samples considered in this study (where there are more than two measurements, the first measurement listed in Table 2.4 is compared with each succeeding measurement).

probably in the original context in which it was deposited or it would not have remained waterlogged and survived.

7) Single fragments of short-lived charred plant remains functionally related to the context from which they were recovered (e.g. charcoal from a hearth or cremation pyre, or the outer sapwood rings of charred posts).
8) Paired bones (usually from different sides, e.g. left and right ulnae) thought to be from a single individual on the basis of size, morphology etc: see 3) above but less secure.
9) Groups of bones thought to have been deliberately deposited together at the same time (e.g. bundles of cattle ribs). Fresh deposition is inferred on the basis of the depositional context.
10) Single fragments of short-lived charred plant remains from coherent, often friable or ashy, dumps of charred material: inferred on the basis of their coherence and fragility to be primary disposal events.
11) Carbonised residues adhering to the interior surface of a single pottery sherd: see 4) above. The inference that the sherd is not residual is on the basis of the inherent fragility of early Neolithic pottery fabrics and the superficial nature of the residue.
12) Well-preserved disarticulated animal bones: submitted on the basis that the latest date from a group of measurements should provide a *terminus post quem* which is (hopefully) not too much earlier than the actual date of interest.

These categories cover all the new samples submitted for dating as part of this project. It is obvious that none is fool-proof (even complete articulated skeletons can be in unidentified re-cuts or mummified!), and our inferences are of descending security. Wherever there has been a choice of suitable material, we have, of course, always submitted samples from as close to the top of this list as possible. But in reality there is not always choice. As we will see in the next section, sometimes our sample choice is tactical. We may deliberately choose to submit a potentially residual sample as a *terminus post quem* for an overlying context because simulation demonstrates that it provides an effective constraint for our developing model (see, for example, TPQ 2233, Fig. 4.40).

Pre-existing dates from enclosures and other aspects of the early Neolithic of Britain and Ireland have been retrospectively assessed by these same criteria and modelled accordingly. These dates, however, raise a whole battery of other taphonomic interpretations that again range from the secure to the completely unknown. It is obvious that most of these samples were originally submitted for dating either without explicit consideration of the relationship between the dated event and the target event, or in desperation, simply because they were the only samples large enough for conventional dating (see section 2.6 below).

The most secure of these associations are dates which

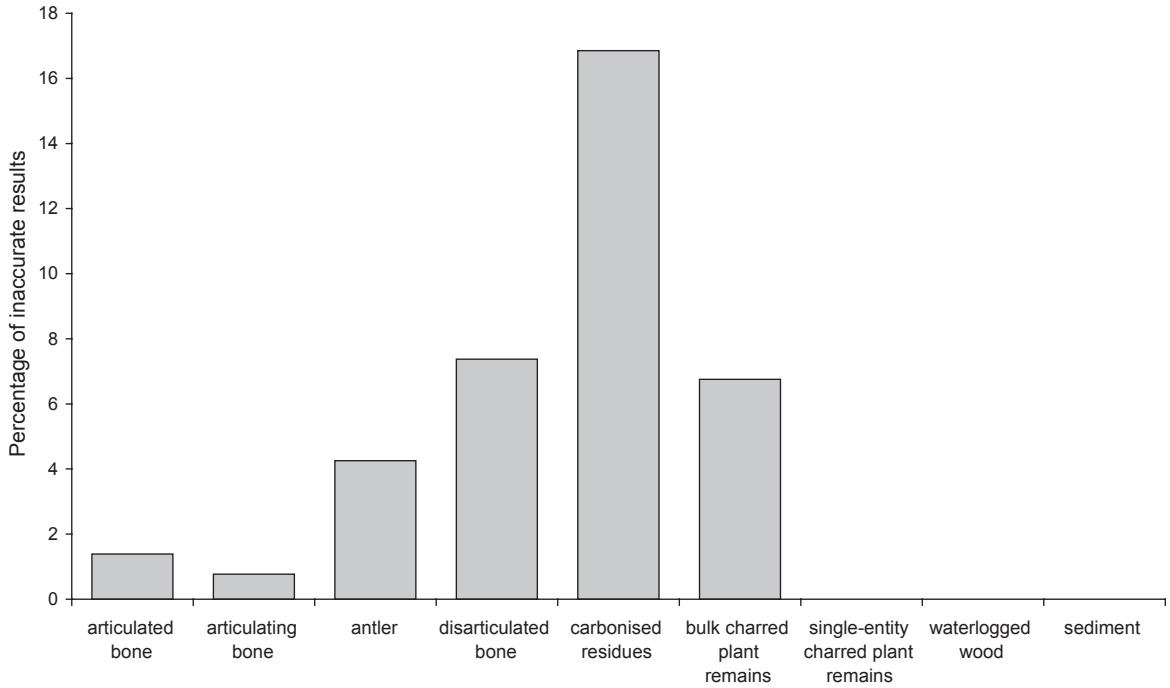

Figure 2.32. Proportions of radiocarbon measurements from Neolithic enclosures (n=816) of different material types judged to be inaccurate on archaeological grounds.

are actually on the material of interest – for example, measurements on cereal grains or bones of domesticated animals. After these come dates on cremated bone from cremations, antler tools or short-life charcoal associated with the process of extraction in flint mines, and short-life material from deposits deliberately placed in pits. In the middle of the range are single fragments of short-life plant remains derived from the postholes of timber buildings, and thus putatively derived from the period during which the structure was in use (Reynolds 1995); samples of bulk peat and other sediments from environmental sequences whose taphonomy can be complex (Walker *et al.* 2001; Lowe and Walker 2000); and disarticulated bones from burial monuments which are probably functionally related with the site, even if they do not necessarily represent primary deposition. Bottom of the pile are samples which may well be residual: disarticulated bones from the upper fills of features; charred plant material from small assemblages sieved from litres of sediment; or organic remains from mixed artefact-bearing levels in caves.

Over the past decade, in Britain, there has been considerable emphasis on the selection of short-life, *single-entity* samples for dating (Ashmore 1999a). Single-entity samples are those which derive from a single organism, such as bones from a single individual, a single cereal grain or hazelnut shell, or a single fragment of waterlogged wood. Their great advantage is that the dating of single fragments eliminates the risk of combining material of different ages in the same sample, and so obtaining a date which may be anomalously old because of the incorporation of residual or reworked material. The submission of such samples for dating on a routine basis has only become feasible since AMS became widely available to archaeologists in the early 1990s. Another advantage of single-entity sampling is that it helps us to ensure that each of the radiocarbon dates included in our model is statistically independent (avoiding potential bias in our results). So, for example, we can select each of our radiocarbon samples from a different individual in a burial assemblage. Such sampling means that we know that each radiocarbon date estimates the time of a different event in the period of past activity in which we are interested (and know which results are replicate measurements on the same person which can be combined before inclusion in the model). The major disadvantage of single-entity sampling is that it is vulnerable to tiny fragments of intrusive or residual material that may be selected for AMS dating, which would form an insignificant proportion of a larger radiometric sample (Lanting and van der Plicht 1994; Prendergast 2000).

The single-entity sampling made possible by AMS has undoubtedly been a major advance in the use of radiocarbon dating in archaeology. It is not, however, a fool-proof strategy and, on its own, it is not enough. Of the 12 categories of sample listed above which we have submitted for dating during this project, only ten are strictly single-entity samples. Carbonised residues on the interior of pottery sherds (categories 4 and 11) are interpreted by us as the remains of burnt food. These residues will, therefore, usually derive from a number of different animals and plants which provided the ingredients for the recipe, and not from a single entity. This does not make them 'bad samples', as our archaeological judgement is that most of the ingredients will have been used fresh (and even those that had been preserved by pickling or the like are unlikely to have been

more than a few seasons old before consumption). Once again, it is the taphonomic interpretation of the dated material that is central to our sample selection.

We have carried over this logic in our assessment and modelling of pre-existing dates. For example, dates on bulk samples of short-life charcoal from contexts where the charcoal may be functionally related to the deposit, such as hearths, have been incorporated into models fully, not as *termini post quos* (e.g. *Corylus*; Fig. 5.34). Conversely, just because a date is from a single entity and on short-life material does not mean that it cannot be residual, reworked, or curated and so more appropriately modelled as a *terminus post quem* (e.g. *OxA-1396–7* and *OxA-1400–2*; Fig. 4.51).

2.5.3 From samples to sampling

Having identified a pool of samples suitable for radiocarbon dating, the next step in the process of creating a Bayesian chronology is to select those which should be dated (Fig. 2.20). Here strategy meets pragmatism.

For some sites, particularly those with little existing chronology and/or little datable material, all the available suitable samples were submitted for dating. This included sites such as Orsett (Chapter 7), Banc Du and Hill Croft Field (Chapter 11), where there has been limited excavation, and sites such as Haddenham (Chapter 6), and Helman Tor and Carn Brea (Chapter 10), where the conditions of preservation were such that limited datable material remained in archive. The chronologies we have been able to construct for these sites are generally imprecise, and are probably the least archaeologically reliable of those presented for enclosures in this volume.

For other sites, the pool of suitable datable material was larger and we could choose what to date. There were two guiding principles to our sampling strategy. The first was to maximise the quantity of informative prior information that was included in our models by targeting sequences of stratigraphically-related, non-residual samples for dating. The second was to ensure that these samples were archaeologically representative: chronologically, by selecting samples from the entire vertical sequence in the ditches, and spatially, by sampling at more than one location around a circuit. Replicate samples were often submitted from deposits where the taphonomy of the dated material was more questionable (such as charred plant remains from supposedly primary disposal events). In this case, the statistical consistency of measurements from a deposit, and the good agreement in the model of these dates in relation to those from material with more secure associations from stratigraphically related contexts, might support our original taphonomic interpretation of this dated material as close in age to its context.

But how many samples should be dated? And which sequences would provide the most effective constraints for our models? These questions were answered with the aid of simulation models (Fig. 2.20). The components of a simulation model are those of any model. First the available informative prior beliefs are established, from the model of existing dates and from the stratigraphic matrix of suitable samples. After this, radiocarbon dates can be simulated from the pool of suitable datable material and the appropriate prior information incorporated into the simulation model. Errors on the measurements are estimated from those recently obtained by the selected laboratory on similar material of similar age. In this process the actual date of the site has to be fed into the model, which is done on the basis of our existing understanding of the site chronology. Multiple models can be run for different actual ages and for different sampling strategies to see which approach might be most effective. Some examples of the simulations created during the process of sample selection for the enclosures dated in this project are given in the regional chapters (e.g. Figs 3.7, 4.40 and 5.4).

Often sequential sampling strategies are the most efficient. First, the minimum number of samples which might be able to achieve the archaeological objectives are submitted for dating (assuming that the site falls on the most helpful piece of calibration curve possible). Once these results have been reported and incorporated in the model, further simulated dates are added to the existing dates in a new simulation and the cycle repeats (Fig. 2.20). In practice, it is rarely this simple. Some samples will provide dates which are not in agreement with the prior information included in the model. Sometimes, something will have gone wrong with a radiocarbon measurement in the laboratory, but almost always it is the interpretation of the taphonomy of the dated sample (and therefore its relative chronology within the dated sequence) that will be in error. These problems are identified and the site is re-modelled in an appropriate way. Ideally, we repeat this sampling cycle until adding more simulated dates does not materially improve the precision of the chronology produced by the model (e.g. Maiden Castle, Chapter 4; Abingdon, Chapter 8). Sometimes, however, we simply ran out of suitable samples (e.g. Etton, Chapter 6).

It should be noted that we have not adopted a purely statistical approach to sampling in this study. Such approaches have been suggested (Buck and Christen 1998), but in practice we find that there are so many scientific and archaeological factors affecting the accuracy of radiocarbon dates that these usually outweigh purely statistical criteria. Having said this, projects where the samples are selected around the model, rather than where the model is grafted on to an existing suite of dates, have consistently provided much more precise chronologies and been much more cost-effective (Bayliss and Bronk Ramsey 2004, 26). This approach to sample selection and sampling is time-consuming, but is essential for the production of precise and reliable archaeological chronologies.

2.5.4 Reporting the models

Finally, a model is built which incorporates all the radiocarbon dates and all the archaeological prior information that we have painstakingly identified. Our interpretation of

these data may be straightforward, in which case we simply report our preferred interpretation. Frequently, however, it is useful to provide a series of alternative models, perhaps exploring different readings of the archaeological sequence or different statistical assumptions. These sensitivity analyses provide an indication of the robustness and reliability of the preferred model. They can demonstrate how far our posterior beliefs are changed by different statistical models or archaeological interpretations, and also show which components of a model are most critical in determining those posterior beliefs.

2.6 Laboratory methods

The procedures used for the preparation and dating of samples in the laboratory are critical for accurate radiocarbon dating. In this study, although we have undertaken a substantial number of new measurements on material selected and retrieved from archives during the project, we have also included a much larger number of existing radiocarbon dates. These have been accumulated over the past 60 years by a variety of researchers for a variety of purposes. As described in the previous section, these samples were often selected using different criteria from those employed in this study. They were also prepared and measured in laboratories using a variety of techniques, not all of which are still in use.

Until the mid-1980s all radiocarbon dating was undertaken using conventional, beta-counting techniques. Samples were pre-treated to remove exogenous carbon and then combusted to produce carbon dioxide. This could then be dated by gas proportional counting (GPC).[10] The dataset considered in this volume includes radiocarbon measurements obtained by the GPC of carbon dioxide (8.4%), methane (4.6%), and acetylene (0.7%) (Fig. 2.26). Alternatively, the carbon dioxide produced by combustion could be converted to a carbon-rich liquid, usually benzene, and dated by liquid scintillation spectrometry (LSC).[11] Just over a quarter of the measurements considered in this study were made by the LSC of benzene (25.1%), with a few measurements made at Trinity College, Dublin, during the development stage of the technique being made by the LSC of methanol (0.3%) (Fig. 2.26). The major disadvantage of conventional radiocarbon dating was the very large sample size required (Fig. 2.25). This limited not only the samples that could be dated, but the types of material that could be dated. From the mid-1980s radiocarbon dating by accelerator mass spectrometry (AMS)[12] became available to archaeologists, although initially the technique was less precise and more costly than conventional dating. Because it measures the radiocarbon atoms in a sample directly, much smaller samples are required (Fig. 2.25). Samples are pre-treated, combusted to carbon dioxide and then converted to graphite before dating in the accelerator. Sometimes carbon dioxide can be introduced directly into the accelerator, omitting the graphitisation stage. The majority of measurements considered in this volume were undertaken by AMS (60.7%) (Fig. 2.26). A general introduction to the laboratory techniques of radiocarbon measurement can be found in Bayliss *et al.* (2004).

Chemical pre-treatment techniques for removing contaminants before a sample is combusted have also evolved over the past decades. These approaches are strongly linked to the types of material dated. Figure 2.27 shows the types of material which provided the measurements detailed in this volume. Samples of charred plant remains (including charcoal) (47.5%) and bone and antler (40.0%) are the most common types of material dated, with smaller numbers of samples coming from carbonised residues on ceramics (5.1%) and cremated bone (1.8%). These types of material can only be dated by AMS. Samples of waterlogged plant remains (5.3%), bulk sediment (3.0%) and marine shell (0.1%) make up the remainder of the dataset.

Since the 1950s the most common method used for the chemical pre-treatment of charred and waterlogged plant material has been the acid/alkali/acid (AAA) protocol (Mook and Waterbolk 1985), which has proved routinely effective (at least for samples of Holocene age). Approaches to dating bulk sediment are usually also based on this method, although either the acid insoluble/alkali soluble ('humic acid') fraction or the alkali/acid insoluble ('humin') fraction of the sample can be dated. Sometimes both of these fractions are combined and the 'total organic carbon' fraction is dated. More rarely, the sample is simply given an acid wash and the solid residue is dated. Shore *et al.* (1995) provide a useful overview of approaches to dating bulk sediment. Where we have been able to trace this information, details of the fraction dated for sediment samples are provided in the tables in this volume. Similarly based on the AAA protocol are approaches to dating carbonised residues on pottery. This technique has a much shorter history, but again both acid insoluble/alkali soluble and alkali/acid insoluble fractions have been shown to provide accurate dates (Hedges *et al.* 1992a).

Bone and antler have consistently proven a challenging sample type. The most reliable dates on unburnt bone are provided by the protein fraction. Although there were attempts to extract this in the 1960s (e.g. Berger *et al*. 1964; Haynes 1967), the collagen extraction protocol suggested by Longin (1971) was a major advance. This method was swiftly adopted by most radiocarbon laboratories around the world and, in its original or variant forms, is still widely used. It is generally effective in providing accurate dates for material of Holocene age in Britain and Ireland. Many other techniques have been employed for dating bone samples, however, particularly where the bone is poorly preserved, of Pleistocene age, or contaminated by consolidants (T. Brown *et al.* 1988; Law and Hedges 1989; Nelson 1991; Bronk Ramsey *et al.* 2000b; 2004a). With the exception of the flawed ultrafiltration protocol used briefly in Oxford in 2000–2 (Bronk Ramsey *et al.* 2000b), all these methods routinely produce accurate dates on the comparatively well-preserved samples of Neolithic age from Britain and Ireland considered in this study. Most inaccurate dates on bone and antler were undertaken in the 1960s when methods for reliably extracting bone protein were under development

and attempts were made to date the carbonate fraction of unburnt bone; in the 1980s on low-collagen bones when AMS laboratories were establishing the minimum level of protein preservation required for accurate dating; or more generally on burnt or carbonised bone where the protein had been sufficiently denatured for it to be irretrievably contaminated by its burial environment.

Protein does not survive in fully cremated bone, and this type of material was not datable until a new protocol for dating the structural carbonate in calcined bone using AMS was proposed by Lanting *et al.* (2001). This protocol has been widely adopted and provides accurate results (Van Strydonck *et al.* 2005; Naysmith *et al.* 2007).

2.6.1 Methods used for dating the samples submitted during this project

Of the 427 new radiocarbon measurements obtained as part of this project, five high-precision results were produced by the Queen's University Belfast Radiocarbon Dating Laboratory using LSC, 173 measurements were made by AMS at the Oxford Radiocarbon Accelerator Unit, and 249 measurements were made by AMS at the Centrum voor IsotopenOnderzoek at the Rijksuniversiteit Groningen, The Netherlands. All samples were dated between 2004 and 2007.

The profile of dated materials for the new sampling programme (Fig. 2.28) is slightly different from that of the overall dataset (Fig. 2.27). During this project higher proportions of the dated samples were bone and antler (44.5%) and carbonised residues on ceramics (20%), and a smaller proportion charred plant remains and charcoal (33.7%), than in the larger dataset. This reflects the emphasis on archaeological taphonomy for sample selection outlined in section 2.5.2 above. The five samples dated at Belfast by LSC were of bone or antler (Fig. 2.29). The different types of sample were otherwise evenly distributed between the two AMS laboratories, except for charred plant macrofossils. A disproportionate number of samples of this type were dated by the Groningen laboratory because most of the samples from Ireland, the Isle of Man and Wales had to be processed there in early 2006 because of a temporary technical problem at Oxford. This accounts for the slightly larger number of AMS results measured at Groningen.

In Belfast the bone and antler samples were processed according to methods outlined in Longin (1971) and Pearson (1984) and measured by LSC (Noakes *et al.* 1965; McCormac 1992; McCormac *et al.* 1993).

Charred and waterlogged plant remains dated at the Rijksuniversiteit Groningen were processed using the AAA protocol (Mook and Waterbolk 1985); samples of unburnt bone were prepared as described by Longin (1971); carbonised residues on pottery sherds were pre-treated by using the AAA method on the entire sherd and selecting the alkali-soluble fraction for dating (Mook and Streurman 1983). The samples were then combusted to carbon dioxide and graphitised as described by Aerts-Bijma *et al.* (1997; 2001) and dated by AMS (van der Plicht *et al.* 2000).

At the Oxford Radiocarbon Accelerator Unit samples of charred and waterlogged plant remains and carbonised residues were prepared using the methods outlined in Brock *et al.* (2010); carbonised residues (and a few samples of charred plant remains) were pre-treated using acid only as they were generally too fragile to withstand the alkali step; unburnt bones were processed using the gelatinisation and ultrafiltration protocols described by Bronk Ramsey *et al.* (2004a). Samples were combusted, graphitised and dated by Accelerator Mass Spectrometry (AMS) as described by Bronk Ramsey *et al.* (2004b). Four samples, OxA-14039–41 from Whitehawk Camp and OxA-14009 from the Trundle (Chapter 5.1 and 5.4), were dated using carbon dioxide targets (Bronk Ramsey and Hedges 1997).

For various technical reasons, a few results from both AMS laboratories were reported with reservations. GrA-30197 and GrA-30176, measurements on samples of unburnt bone from Staines (Chapter 8.1), produced anomalously enriched $\delta^{13}C$ values and had very low carbon content which raises concerns about the accuracy of these dates. Three samples processed at Oxford had low yields of carbon, and so produced small targets which gave low currents in the AMS. These results are reported as experimental measurements, distinguished by the laboratory code 'OxA-X'. The samples were carbonised residues from Maiden Castle (OxA-X-2135-46; Chapter 4.3) and Raddon (OxA-X-2165-10; Chapter 10.3), and a fragment of burnt plank from Magheraboy (OxA-X-2173-16; Chapter 12.2). These three results should also be interpreted with caution.

2.6.2 Methods used for dating other samples considered in this study

It has been much harder to trace the methods used to date the 1923 measurements considered in this study which we inherited from previous workers. These determinations come from 35 radiocarbon laboratories (Fig. 2.30) and were dated over a period of more than 50 years. This means that not only were different methods used in different laboratories, but laboratories that provided measurements over an extended period also produced results using a variety of methods. We have attempted to trace these differences as far as possible, using laboratory numbers as a guide to when measurements were produced. In this section we provide a general guide to the methods used. Detailed references to the methods appropriate for particular samples are given in Chapters 3–12 and 14 when the results are discussed. For laboratories which produced datelists regularly during the period when they were in operation, tracing the methods used to measure particular samples has been relatively simple. It has been much more difficult to trace methods for other laboratories, where statements of the methods used, usually part of laboratory datelists, were only produced in the first years of a laboratory's operation. On the whole, methods in such facilities probably remained largely unchanged in later years, although this is sometimes hard to demonstrate unequivocally.

Overall, 318 measurements in this dataset (17%) were

produced by Gas Proportional Counting in 18 different laboratories (Fig. 2.30). This reflects the popularity of GPC in the first two decades of radiocarbon dating when laboratories produced very low numbers of measurements. The methods used for dating these samples are summarised in Table 2.1. Some of the ages produced in the Smithsonian Institution (see Chapter 12) and in the early years of the miniature gas counter at Harwell (see Table 2.1, fn 1) appear to be anomalously young. This is noted in the text where appropriate.

More than 600 radiocarbon determinations in the dataset (32%) were produced by Liquid Scintillation Counting in 11 laboratories. The methods used for dating these samples are summarized in Table 2.2 (and see section 2.6.1 above for details of measurements produced at Queen's University, Belfast as part of this study). Some of the ages produced at Trinity College, Dublin, Ireland (D-), during the pioneering era of LSC appear to be anomalously young (see Chapter 12). The laboratory problem at the British Museum in 1980–4 and the thorough measures taken to address it are fully reported by Bowman *et al.* (1990).

Two laboratories, Beta Analytic, USA (Beta-), and the University of Waikato, New Zealand (Wk-), undertake both conventional dating by LSC of benzene and prepare graphite targets for AMS dating (during the period of this study both laboratories sent these targets to a variety of other AMS laboratories for measurement). In both cases, both AMS and conventional measurements are reported with the same laboratory code. Unfortunately, although the laboratories concerned always specify precisely how each measurement was made when reporting results, these details are often not published by archaeologists. Where we have been able to trace this information, it is provided, although often the measurement technique can only be inferred from the type of material dated.

Slightly under 1000 AMS measurements are included in this dataset (52%). All of these results have been produced since 1980, and the vast majority of them have been produced in the last 15 years. The Oxford Radiocarbon Accelerator Unit (OxA-) accounts for 62% of the AMS measurements considered, with the remaining 38% deriving from 11 other laboratories (Fig. 2.30). The methods used for dating these samples are summarised in Table 2.3. Results on bone and antler with laboratory numbers in the ranges OxA-9361 to OxA-11851 and OxA-11214 to OxA-11236 should be interpreted with caution as a technical issue with the bone preparation method used at Oxford for these samples led to some results on this material being anomalously old (Bronk Ramsey *et al.* 2004a).

2.7. Accuracy

The overwhelming majority of radiocarbon dates that do not provide accurate estimates for the date of archaeological interest are inaccurate because inadequate attention has been paid by archaeologists to the association between the dated material, the context from which it was recovered, and the target event that we wish to date (see section 2.5.2 above). This is illustrated by Fig. 2.15, which shows that 511 of the 1782 radiocarbon dates included in at least one of the Bayesian models in this study can only be included in the models as *termini post quos*. These samples – unidentified charcoal, charcoal from long-lived wood species, disarticulated bones or plant macrofossils that are not functionally related to the contexts from which they were recovered – represent 28.7% of the data in our models. In other words, almost one in three of the radiocarbon dates considered in this volume are anomalously old because archaeologists selected their radiocarbon samples unwisely. This is particularly disappointing as more than 80% of the radiocarbon dates concerned have been produced since the importance of the archaeological associations of radiocarbon samples was first highlighted (Waterbolk 1971).

Almost all radiocarbon laboratories worldwide have voluntarily, and at their own expense, participated in a continuing series of international inter-comparison exercises over the past 30 years. These studies cover the period during which about three quarters of the measurements included in this study were made. The results of these inter-comparisons are published (International Study Group 1982; Scott *et al.* 1990; Rozanski *et al.* 1992; Scott 2003) and the results are used by the participating laboratories to identify and resolve technical problems with their sample processing and measurement systems. Although an extremely useful means of cross-checking results between laboratories, these formal, international inter-comparisons form only part of the on-going quality assurance procedures which laboratories undertake. Commonly these include not only the measurement of internationally agreed standard materials, but also the dating of known-age tree-rings (see, for example, Bronk Ramsey *et al.* 2002).

These formal international inter-comparison studies grew out of a long-standing concern with the accuracy and reproducibility of radiocarbon measurements. Groups of radiocarbon laboratories had been exchanging and dating known-age material since the 1950s (e.g. Willis *et al.* 1960), and much effort had gone into the establishment of internationally agreed standard materials (Olsson 1970; Polach 1972; Mann 1983). As the need for the calibration of radiocarbon dates became apparent during the 1960s (Suess 1967) and as tree-ring calibration became available during the 1970s and 1980s (e.g. Ralph *et al.* 1973; Stuiver and Pearson 1986; Pearson and Stuiver 1986; Pearson *et al.* 1986), issues of accuracy and reproducibility became more pressing (R. Clark 1975; Baillie 1990). There were also now, particularly after the advent of AMS, many more laboratories producing dates. In the late 1970s, the British laboratories then in operation participated in a formal inter-comparison study (Otlet *et al.* 1980), which was followed by the formal international inter-comparison exercises which continue today.

2.7.1 Replicate measurements

One method of assessing the reproducibility of radiocarbon results is to consider groups of replicate measurements

Table 2.1. Methods used to produce measurements considered in this study which were dated by Gas Proportional Counting.

Laboratory	Laboratory code	Counting gas	Methods
Louvain-la-Neuve, Belgium	Lv-	methane	Samples were pretreated using the AAA protocol, except for bones which underwent a modified Longin protocol which included an alkali step (Gilot 1997, 7–10), and dated as described by Dossin *et al.* (1962).
Smithsonian Institution, USA	SI-	methane	Samples were pretreated using acid and alkali; no fractionation correction was applied (Stuckenrath and Mielke 1972; 1973).
Cardiff University, later Swansea University	CAR- SWAN-	methane	Samples were pretreated either using the AAA protocol or (for bones) a modified Longin protocol which included an alkali step (Dresser 1985). The results quoted were conventional radiocarbon ages.
University of Birmingham	Birm-	methane	Samples were pretreated either using the AAA protocol or (for bones) a modified Longin protocol which included an alkali step (Shotton *et al.* 1967; Williams and Johnson 1976).
Queen's University, Belfast	up to UB-2560	methane	Samples were processed and dated as described by A. Smith *et al.* (1970).
Gakashuin University, Japan	GaK-	acetylene	Samples were processed and dated as described by Kigoshi and Endo (1962; 1963).
British Museum	BM-150 and below	acetylene	Measurements made at the British Museum before 1968 (in this study BM-150 and below) were made using GPC of acetylene (Barker 1953; Barker and Mackey 1959). Samples were pretreated using the AAA protocol, except for bones where the organic fraction was extracted using acid only. Ages were not corrected for fractionation, although the reported error includes ±80 for fractionation and ±100 for the 'de Vries effect' in addition to the counting errors (Barker and Mackey 1961).
Gif sur Yvette, France	Gif-	carbon dioxide	Samples were processed and dated as described by Delibrias *et al.* (1972).
Pretoria, South Africa	Pta-	carbon dioxide	The measurement is a conventional radiocarbon age produced as described by Vogel and Waterbolk (1967), Vogel and Marais (1971) and Vogel *et al.* (1986).
Lund, Sweden	Lu-	carbon dioxide	Samples were processed and dated as described by Östlund (1957) and Håkansson (1968).
Stockholm, Sweden	St-	carbon dioxide	Conventional radiocarbon ages were produced using methods described by Östlund (1959) and Östlund and Engstrand (1963).
National Physics Laboratory, Teddington	NPL-	carbon dioxide	Samples were pretreated using acid and alkali and dated as described by Callow *et al.* (1963). These results were corrected for fractionation and the error term included an allowance of ±80 for the 'de Vries effect'.
Teledyne Isotopes, USA	I-	carbon dioxide	Samples were dated as described by Trautman and Willis (1966). The reported ages are not corrected for fractionation, although $\delta^{13}C$ values were measured (Buckley and Willis 1970). Bones were prepared using the method described by Berger *et al.* (1964) as modified by Haynes (1967).
Gliwice, Poland	Gd-	carbon dioxide	Samples were pretreated as described by Olsson (1979), combusted and purified as described by M. Pazdur *et al.* (1979), and dated as outlined in A. Pazdur *et al.* (1982).
Rijksuniversiteit Groningen, The Netherlands	GrN-	carbon dioxide	Samples were processed and dated as described by Mook and Streurman (1983).
British Museum	BM-170–214	carbon dioxide	A small number of measurements were made by GPC of carbon dioxide at the British Museum in 1968 (in this study BM-170–214) (Barker and Mackey 1968).
Godwin laboratory, Cambridge	Q-676 and below	carbon dioxide	Samples dated in the first decades of operation of the laboratory (in this study Q-676 and below) were dated as described by Switsur *et al.* (1970), Switsur and West (1973; 1975) and Switsur (1981).
AERE Harwell	Selected HAR-numbers	carbon dioxide	In the mid-1980s, 26 samples included in this study were dated by GPC of carbon dioxide using the miniature gas counter at AERE Harwell.[1] These samples were pre-treated and dated as described by Otlet and Warchal (1978), Otlet and Evans (1983), and Otlet *et al.* (1983; 1986).

[1] HAR-2041, -2369–72, -2377–8, -4438, -6037–8 and -9166–9 from Hambledon Hill, HAR-4110, -5125, -5216a–b and -5271 from Briar Hill, HAR-8903–4 from Haddenham, HAR-6477–8 from Drayton, and HAR-5246, -8083, -8544 and -941 from Rowden, Druid Stoke, Tiverton and Alfriston respectively.

Table 2.2. Methods used to produce measurements considered in this study which were dated by Liquid Scintillation Counting.

Laboratory	**Laboratory code**	**Counting liquid**	**Methods**
Trinity College, Dublin, Ireland	D-	methanol	This laboratory was operational for a short period during the late 1950s. Samples were pretreated by the AAA protocol, synthesised to methanol as described by Delaney and McAulay 1959, and dated as described by Cummins *et al.* (1960) and McAulay and Watts (1961).
University of Lyon, France	Ly-	benzene	The bone sample was prepared as described by Longin (1971) and dated by LSC of benzene (Evin *et al.* 1983).
NERC Radiocarbon Laboratory	SRR-	benzene	The measurements are conventional radiocarbon ages and were dated as described by Harkness and Wilson (1972; 1973).
Scottish Universities Research and Reactor Centre	GU-	benzene	Samples were prepared as outlined in Stenhouse and Baxter (1983) and dated as described by Noakes *et al.* (1965).
University College, Dublin, Ireland	UCD-	benzene	Samples were processed and dated as described by O'Donnell (1997) and Caulfield *et al.* (1998).
Godwin laboratory, Cambridge	Q-2634 and above	benzene	Results from this laboratory during the latter part of its period of operation (in this study Q-2634 and above) were produced as outlined in Switsur (1994).
Queen's University, Belfast	UB-3058–6315	benzene	Results between these laboratory numbers were produced as described by Pearson (1984)
British Museum	BM-	benzene	Radiocarbon determinations reported by the British Museum (BM-) after 1968 were produced as described by H. Barker *et al.* (1969a; 1969b). All ages with laboratory numbers above BM-638 are conventional radiocarbon ages, corrected for fractionation (H. Barker *et al.* 1971). Techniques were developed during the later period of the laboratory's operation and measurements with laboratory numbers above BM-2400 were dated as described by Ambers *et al.* (1987). A technical problem in this laboratory between 1980 and 1984 meant that results were systematically too young (Bowman *et al.* 1990). Many of these samples were re-dated, although others were recalculated. These are denoted with the laboratory suffix 'R' (e.g. BM-2283R, Chapter 4).
AERE Harwell	HAR-	benzene	All samples included in this study, except those listed in Table 2.1, were prepared and dated as described by Otlet (1977; 1979), Otlet and Warchal (1978) and Tamers (1965).
Beta Analytic Inc, USA	Beta-	benzene	All samples are prepared and dated as described at http://www.radiocarbon.com.
University of Waikato, New Zealand	Wk-	benzene	Details of the methods used to prepare and date these samples are provided by Hogg *et al.* (1987), Higham and Hogg (1997) and Petchey and Higham (2000).

Table 2.3. Methods used to produce measurements considered in this study which were dated by Accelerator Mass Spectrometry.

Laboratory	**Laboratory code**	**Methods**
Beta Analytic Inc, USA	Beta-	All samples are prepared and dated as described at http://www.radiocarbon.com.
University of Waikato, New Zealand	Wk-	All samples are prepared and dated as described at http://www.radiocarbondating.com.
Queen's University, Belfast	UB-6407–UB-7596 (in this study)	A small number of samples were prepared and graphitised at the Queen's University, Belfast (Mook and Waterbolk 1985; Longin 1971; Slota *et al.* 1987) and then dated at the Oxford Radiocarbon Accelerator Unit (Bronk Ramsey *et al.* 2004b). Quoted $\delta^{13}C$ values were measured by AMS.
Queen's University, Belfast	UBA-	Samples are prepared and graphitised as described by Mook and Waterbolk (1985), Longin (1971), and Slota *et al.* (1987) and dated as described at http://www.chrono.qub.ac.uk.
Scottish Universities Research and Reactor Centre	AA- (in this study)	Samples were pretreated and graphitised at the Scottish Universities Research and Reactor Centre using methods described by Stenhouse and Baxter (1983) and Slota *et al.* (1987), and measured by AMS at the NSF-Arizona AMS facility as described by Donahue *et al.* (1997).
Scottish Universities Environmental Research Centre	SUERC-	Samples were pretreated as described by Stenhouse and Baxter (1983), graphitised using methods described by Vandeputte *et al.* (1996), and dated by AMS (Xu *et al.* 2004; Freeman *et al.* 2007).
Rijksuniversiteit Groningen, The Netherlands	GrA-	Methods are described in section 2.6.1, but note additionally that cremated bone samples were pretreated as described by Lanting *et al.* (2001).
Uppsala, Sweden	Ua-	Samples were prepared as described by Wohlfarth and Possnert (2000), graphitised as described by Vogel *et al.* (1984), and dated by AMS (Possnert 1984; 1990).
Rafter Radiocarbon, New Zealand	NZA-	Samples were pretreated by the AAA method (Mook and Waterbolk 1985), except for unburnt bone which was pretreated as described by Longin (1971) and cremated bone which was prepared as described by Lanting *et al.* (2001). Samples were graphitised as described by Slota *et al.* (1987) and dated by AMS (Zondervan *et al.* 2007).
Leibniz-Labor, Christian Albrechts Universität, Kiel, Germany	KIA-	Samples were pretreated as described by Grootes *et al.* (2004) and graphitised and dated as described by Nadeau *et al.* (1997; 1998). Quoted $\delta^{13}C$ values are measured by AMS.
Posnań Radiocarbon Laboratory, Poland	Poz-	Samples were pretreated as described by Mook and Waterbolk (1985), combusted and graphitised as described by Czernik and Goslar (2001), and dated by AMS (Goslar *et al.* 2004). Quoted $\delta^{13}C$ values are measured by AMS.
Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory, USA	CAMS-	The samples were prepared and dated as described by Vogel *et al.* (1987), Southon and Roberts (2000), and Fallon *et al.* (2007).
Oxford Radiocarbon Accelerator Unit	OxA-	The first dates on archaeological material were produced by this facility in the early 1980s, and since that time results have been produced continuously, using a variety of methods and three AMS machines. The pretreatment methods for charred and waterlogged plant material, sediments, charred residues on pottery, and cremated bones are described by Brock *et al.* (2010). With the exception of the latter, which is based on the protocol of Lanting *et al.* (2001), these pretreatments are variants of the AAA protocol. Until *c.* 2006 the alkali step may have been omitted for fragile samples of charred plant remains, and until *c.* 2004 an alkali step was sometimes used on charred residues on pottery (Hedges *et al.* 1992a). A final bleaching step may have also been used for non-charred plant material (Hedges *et al.* 1989a; Wand *et al.* 1984), and additional protocols may have been adopted for samples contaminated with preservatives and the like.

It is bone pre-treatment methods that have most varied over the years. Early on bone and antler samples were prepared as described by Gillespie *et al.* (1984b; 1986). There then followed a period when the extracted protein was purified using ion exchange (Hedges and Law 1989; Law and Hedges 1989). From OxA-7000 this method was abandoned and protein was extracted as described by Bronk Ramsey *et al.* (2000a). Samples with laboratory numbers within the ranges OxA-9361 to OxA-11851 and OxA-11214 to OxA-11236 were prepared using the gelatinisation and ultrafiltration protocol described by Bronk Ramsey *et al.* (2000b). More recent samples have been prepared following the revised ultrafiltration protocol described by Bronk Ramsey *et al.* (2004a) (and see also Brock *et al.* 2007a; 2010). Further details of the pretreatment methods used for particular samples are given in the following chapters where the interpretation of these results is considered.

Following appropriate pre-treatment, samples are combusted to produce carbon dioxide (Hedges *et al.* 1992b). For samples with laboratory numbers below OxA-6293, this was placed into the carbon dioxide ion source in the AMS and dated (Gillespie *et al.* 1983; R. Hedges 1981). This gas ion source was a major focus of the laboratory's technical research during the 1980s (Bronk and Hedges 1987; 1989; 1990). Samples with laboratory numbers between OxA-6293 and OxA-11738 were dated in the second AMS machine at Oxford. This used the hybrid carbon dioxide and graphite ion source described by Bronk Ramsey and Hedges (1997). Increasingly samples were graphitised (Dee and Bronk Ramsey 2000), with only samples which yielded very little carbon being run as carbon dioxide targets. From OxA-11739 samples were dated using the current AMS machine at Oxford (Bronk Ramsey *et al.* 2004b).

made on the same material. The 88 groups of replicate measurements considered in this study are listed in Table 2.4. Thirty-eight of these replicate groups were obtained from enclosures during the course of this study, eight further groups were produced during this study by obtaining repeat measurements on samples for which determinations were already available, and 42 groups of replicates were available from previous studies (although 18 of these are from the early Neolithic complex on Hambledon Hill). The large sample size needed for conventional dating (Fig. 2.25) meant that the number of replicate measurements made on archaeological samples was severely constrained by the availability of sufficient material until the advent of AMS. Additional material was often only made available if there was perceived to be a problem with the original measurement.

Since radiocarbon ages have errors which are normally distributed, the consistency of replicate measurements can be tested using the χ^2 test (Shennan 1988, chapter 6; Ward and Wilson 1978). If all our radiocarbon ages are perfectly accurate and all the uncertainties on the measurements have been estimated perfectly, we expect the actual radiocarbon content of one in 20 radiocarbon ages to lie outside the quoted determination at two standard deviations. We therefore expect that four or five replicate groups will fail to pass a χ^2 test simply on statistical grounds. In fact 16 groups of measurements fail to pass the test (Table 2.4), which is significantly more than expected ($T'=48.2$; $T'(5\%)=12.6$; $\nu=6$). Overall, bone and antler samples and samples of carbonised residues on pottery sherds produce inconsistent results more often than expected (Table 2.5). If we consider only the 38 replicate groups produced as part of this study, again more groups of measurements are statistically inconsistent than would be expected simply on statistical grounds ($T'=29.6$; $T'(5\%)=6.0$; $\nu=2$). In this case, however, bone and antler samples produced inconsistent results only as often as expected, although carbonised residues again produce inconsistent results more often than expected (Table 2.5).

Since the bone and antler samples dated as part of this project were dated by three different methods (see section 2.6.1 above), the consistency of the replicate groups measured as part of this study is striking. Although more sophisticated techniques may be required for dating poorly preserved bone samples or those dating to the Pleistocene (Higham *et al.* 2006), it is apparent that results produced using methods outlined by Longin (1971) and by gelatinisation and ultrafiltration (Bronk Ramsey *et al.* 2004a) are reproducible for the types of sample dated as part of this study.

Of the six inconsistent replicate groups of measurements on bone and antler samples which include measurements undertaken before this study, four were undertaken specifically because there was thought to be a technical problem with the initial measurement (group 41, Sharples 1991a, 104–5; group 68, Jordan *et al.* 1994, 4; group 72, Chapter 6.4; group 82, Chapter 8.4). These replicates do not therefore represent a random sample of the radiocarbon

Table 2.4. Replicate radiocarbon measurements (a) produced during this study, (b) produced during this study on previously dated samples, and (c) existing prior to this study. T' values for groups which are significantly different (at 95% confidence) are in bold.

Site	Material	Laboratory Number	Radiocarbon Age (BP)	χ^2 test (Ward and Wilson 1978)	Replicate Group
Replicate groups obtained during the course of this study					
Windmill Hill (Table 3.2)	Carbonised residue	OxA-13732	4672±45	**T'=21.4**; T'(5%)=3.8; ν=1	1
		GrA-25391	4360±50		
Windmill Hill (Table 3.2)	Antler	UB-6186	4699±20	T'=5.2; T'(5%)=9.5; ν=4	2
		OxA-15075	4717±30		
		OxA-15076	4673±30		
		OxA-15088	4770±33		
		GrA-29706	4700±40		
Windmill Hill (Table 3.2)	Bone	OxA-13814	4807±32	T'=2.9; T'(5%)= 3.8; ν=1	3
		OxA-14967	4729±33		
Windmill Hill (Table 3.2)	Bone	GrA-25368	3558±26	**T'=4.7**; T'(5%) =3.8); ν=1	4
		OxA-13730	3524±30		
Windmill Hill (Table 3.2)	Bone	OxA-14966	4521±35	T'=3.1; T'(5%)=3.8; ν=1	5
		GrA-29711	4615±40		
Windmill Hill (Table 3.2)	Carbonised residue	OxA-13561	2770±40	**T'=391.2**; T'(5%)=6.0; ν=2	6
		GrA-25389	4050±150		
		GrA-25821	3980±50		
Windmill Hill (Table 3.2)	Bone	GrA-25367	3640±50	T'=1.8; T'(5%)=3.8; ν=1	7
		OxA-13759	3716±28		
Knap Hill (Table 3.3)	Bone	OxA-15200	4699±37	T'=1.1; T'(5%)=3.8; ν=1	8
		GrA-29809	4755±40		
Whitesheet Hill (Table 4.7)	Bone	OxA-15291	4768±33	T'=0.3; T'(5%)=3.8; ν=1)	9
		GrA-30071	4800±45		
Maiden Castle (Table 4.9)	Carbonised residue	GrA-29209	4910±45	T'=1.65; T'(5%)=3.8; ν=1	10
		OxA-14733	4980±32		
Maiden Castle (Table 4.9)	Carbonised residue	GrA-29207	4935±45	T'=3.6; T'(5%)=3.8; ν=1	11
		OxA-14734	4830±33		
Maiden Castle (Table 4.9)	Carbonised residue	GrA-29213	4605±40	**T'=17.2**; T'(5%)=3.8; ν=1	12
		OxA-14793	4870±50		
Whitehawk (Table 5.2)	Antler	GrA-26962	4715±35	T'=1.6; T'(5%)=3.8; ν=1	13
		OxA-14126	4774±31		

Whitehawk (Table 5.2)	Bone	GrA-26966	4605±40	**T'=6.2**; T'(5%)=3.8; ν=1	14
		OxA-14061	4739±36		
Whitehawk (Table 5.2)	Bone	GrA-32365	4780±35	T'=0.7; T'(5%)=3.8; ν=1	15
		OxA-16287	4822±34		
Whitehawk (Table 5.2)	Bone	GrA-32364	4785±35	T'=0.0; T'(5%)=3.8; ν=1	16
		OxA-16286	4790±35		
Whitehawk (Table 5.2)	Bone	OxA-14178	4755±32	T'=0.0; T'(5%)=3.8; ν=1	17
		GrA-27330	4760±45		
Whitehawk (Table 5.2)	Bone	GrA-26977	4785±40	T'=0.0; T'(5%)=3.8; ν=1	18
		OxA-14063	4792±33		
Whitehawk (Table 5.2)	Carbonised residue	GrA-26976	4710±45	T'=0.6; T'(5%)=3.8; ν=1	19
		OxA-14041	4820±130		
Whitehawk (Table 5.2)	Bone	OxA-14062	4785±35	T'=1.3; T'(5%)=3.8; ν=1	20
		GrA-29363	4720±45		
Whitehawk (Table 5.2)	Antler	GrA-29364	4720±45	T'=1.5; T'(5%)=3.8; ν=1	21
		OxA-14065	4650±35		
Whitehawk (Table 5.2)	Antler	GrA-26973	4410±35	T'=0.2; T'(5%)=3.8; ν=1	22
		OxA-14064	4389±32		
Offham Hill (Table 5.3)	Bone	OxA-14177	4722±32	T'=2.5; T'(5%)=3.8; ν=1	23
		GrA-37322	4685±45		
The Trundle (Table 5.5)	Bone	OxA-13935	2124±28	T'=0.1; T'(5%)=3.8; ν=1	24
		GrA-36819	2135±30		
Etton (Table 6.8)	Carbonised residue	OxA-14972	4300±36	T'=1.9; T'(5%)=3.8; ν=1	25
		GrA-29355	4225±40		
Chalk Hill (Table 7.5)	Carbonised residue	GrA-30888	4825±50	T'=0.6; T'(5%)=6.0; ν=2	26
		OxA-15509	4867±36		
		OxA-17122	4839±31		
Staines (Table 8.1)	Carbonised residue	OxA-15253	3869±27	**T'=205.4**; T'(5%)=3.8; ν=1	27
		GrA-30036	3165±40		
Abingdon (Table 8.5)	Bone	GrA-30942	4780±40	T'=1.0; T'(5%)=3.8; ν=1	28
		OxA-15393	4832±34		
Abingdon (Table 8.5)	Bone	GrA-30934	4760±40	T'=3.3; T'(5%)=3.8; ν=1	29
		OxA-15397	4854±33		

Crickley Hill (Table 9.2)	Bone	OxA-14414	4696±35	T'=1.9; T'(5%)=3.8; ν=1	30
		GrA-27820	4770±40		
Crickley Hill (Table 9.2)	Bone	GrA-27813	4830±170	T'=1.4; T'(5%)=3.8; ν=1	31
		GrA-30368	4625±40		
Crickley Hill (Table 9.2)	Carbonised residue	OxA-15704	4530±45	T'=1.6; T'(5%)= 3.8; ν=1	32
		GrA-31103	4450±45		
Crickley Hill (Table 9.2)	Bone	OxA-14416	4890±32	T'=2.2; T'(5%)=3.8; ν=1	33
		OxA-14417	4823±32		
Crickley Hill (Table 9.2)	Single-entity charred plant remains	OxA-14428	4913±34	T'=0.2; T'=(5%)=3.8; ν=1	34
		OxA-14321	4891±31		
Peak Camp (Table 9.3)	Bone	GrA-30030	4760±40	T'=0.2; T'(5%)=3.8; ν=1	35
		OxA-15284	4782±31		
Raddon (Table 10.2)	Carbonised residue	OxA-X-2165-10	4950±300	T'=0.2; T'(5%)=3.8; ν=1	36
		GrA-31191	4810±40		
Helman Tor (Table 10.3)	Carbonised residue	GrA-31319	4705±35	**T'=9.2**; T'(5%)=3.8; ν=1	37
		OxA-15631	4851±33		
Carn Brea (Table 10.4)	Carbonised residue	OxA-15632	4746±34	T'=0.9; T'(5%)=3.8; ν=1	38
		OxA-15633	4791±33		
Replicate groups obtained by this study by re-dating previously dated samples					
Knap Hill (Table 3.3)	Antler	BM-205	4710±115	**T'=4.6**; T'(5%)=3.8; ν=1	39
		GrA-29808	4975±40		
Maiden Castle (Table 4.9)	Bone	OxA-1148	4810±80	T'=0.8; T'(5%)=3.8; ν=1	40
		OxA-14832	4886±35		
Maiden Castle (Table 4.9)	Bone	GrA-29108	4915±40	**T'=16.2**; T'(5%)=3.8; ν=1	41
		OxA-1144	4550±80		
Etton (Table 6.8)	Bone	BM-2765	4830±33	T'=2.5; T'(5%)=3.8; ν=1	42
		OxA-14969	4809±36		
Etton (Table 6.8)	Waterlogged wood	BM-2890	4820±45	T'=0.8; T'(5%)= 3.8; ν=1	43
		GrA-29358	4765±40		
Donegore (Table 12.1)	Bulk charred plant remains	UB-3067	4728±40	T'=1.0; T'(5%)=6.0; ν=2	44
		GrA-31330	4770±35		
		GrA-31328	4785±45		

Donegore (Table 12.1)	Bulk charred plant remains	GrN-15962	4920±25	**T'=14.8**; T'(5%)=6.0; ν=2	45
		GrA-31321	4790±35		
		GrA-31320	4780±35		
Magheraboy (Table 12.2)	Single-entity charred plant remains	GrA-31961	5085±40	**T'=13.2**; T'(5%)=6.0; ν=2	46
		OxA-X-2173-16	5270±40		
		Beta-186488	5060±70		
Replicate groups available before this study					
Hambledon Hill (Table 4.2)	Bone	OxA-7768	4810±45	T'=0.0; T'(5%)=3.8; ν=1	47
		OxA-7769	4795±50		
Hambledon Hill (Table 4.2)	Bone	OxA-7773	4765±45	T'=0.4; T'(5%)=3.8; ν=1	48
		OxA-7774	4725±40		
Hambledon Hill (Table 4.2)	Bone	OxA-7015	4690±60	T'=0.3; T'(5%)=3.8; ν=1	49
		OxA-7016	4735±60		
Hambledon Hill (Table 4.2)	Bone	OxA-7097	4855±60	T'=0.0; T'(5%)=3.8; ν=1	50
		OxA-7098	4870±40		
Hambledon Hill (Table 4.2)	Bone	OxA-7022	4835±55	T'=2.5; T'(5%)=3.8; ν=1	51
		OxA-7023	4700±65		
Hambledon Hill (Table 4.2)	Bone	OxA-7020	4800±65	T'=0.0; T'(5%)=3.8; ν=1	52
		OxA-7021	4800±65		
Hambledon Hill (Table 4.2)	Bone	OxA-7019	4725±60	T'=1.5; T'(5%)=3.8; ν=1	53
		OxA-7058	4625±55		
Hambledon Hill (Table 4.2)	Bone	OxA-7039	4550±60	T'=0.0; T'(5%)=3.8; ν=1	54
		OxA-7040	4565±60		
Hambledon Hill (Table 4.2)	Bone	OxA-7828	4795±50	T'=2.0; T'(5%)=3.8; ν=1	55
		OxA-7829	4910±65		
Hambledon Hill (Table 4.2)	Bone	OxA-7037	4710±55	T'=0.5; T'(5%)=3.8; ν=1	56
		OxA-7038	4770±60		
Hambledon Hill (Table 4.2)	Antler	UB-4152	4792±20	T'=1.8; T'(5%)=6.0; ν=2	57
		OxA-7042	4735±60		
		OxA-7043	4720±65		
Hambledon Hill (Table 4.2)	Bone	UB-4138	4648±21	**T'=6.6**; T'(5%)=3.8; ν=1	58
		OxA-7041	4485±60		

Hambledon Hill (Table 4.2)	Carbonised residue	OxA-7926	4845±50	**T'=6.9**; T'(5%)=3.8; ν=1	59
		OxA-7844	4685±35		
Hambledon Hill (Table 4.2)	Bone	OxA-7035	4820±55	T'=0.1; T'(5%)=3.8; ν=1	60
		OxA-7036	4845±60		
Hambledon Hill (Table 4.2)	Bone	OxA-7024	4855±60	T'=3.1; T'(5%)=3.8; ν=1	61
		OxA-7025	4685±75		
Hambledon Hill (Table 4.2)	Bone	OxA-7044	4560±55	T'=1.1; T'(5%)=3.8; ν=1	62
		OxA-7045	4645±60		
Hambledon Hill (Table 4.2)	Bone	OxA-7026	4740±42	T'=3.6; T'(5%)=3.8; ν=1	63
		OxA-7059	4660±60		
Hambledon Hill (Table 4.2)	Bone	UB-4311	4710±23	T'=0.0; T'(5%)=3.8; ν=1	64
		OxA-7818	4715±40		
Maiden Castle (Table 4.9)	Bulk charred plant remains	BM-2450	5020±50	T'=0.1; T'(5%)=3.8; ν=1	65
		BM-2450A	5050±60		
Stonehenge cursus (Table 4.13)	Antler	OxA-17953	4716±34	T'=0.2; T'(5%)=3.8; ν=1	66
		OxA-17954	4695±34		
Harrow Hill (Table 5.7)	Bulk charred plant remains	BM-2071R	4900±120	T'=0.5; T'=(5%)=3.8; ν=1	67
		BM-2075R	5020±110		
Alfriston oval barrow (Table 5.7)	Bone	HAR-942	2590±90	**T'=24.6**; T'(5%)=3.8; ν=1	68
		HAR-1811	3190±80		
Briar Hill (Table 6.6)	Bulk charred plant remains	HAR-5216a	4130±150	T'=3.5; T'(5%)=3.8; ν=1	69
		HAR-5216b	4470±100		
Briar Hill (Table 6.6)	Bulk charred plant remains	HAR-2284	3460±120	T'=0.3; T'(5%)=3.8; ν=1	70
		HAR-2389	3540±90		
Raunds long barrow (Table 6.7)	Bone	OxA-5632	4825±65	T'=0.0, T'(5%)=3.8, ν=1)	71
		OxA-5633	4820±80		
Etton (Table 6.8)	Bone	OxA-1031	1440±100	**T'=174.3**; T'(5%)=6.0; ν=2	72
		OxA-1313	3040±80		
		OxA-1314	3050±80		
Etton (Table 6.8)	Antler	OxA-1311	3080±80	T'=0.4; T'(5%)=3.8; ν=1	73
		OxA-1312	3020±60		
St Osyth (Table 7.1)	Carbonised residue	OxA-13008	4745±33	T'=0.0; T'(5%)=3.8; ν=1	74
		GrA-25022	4740±45		

Coldrum (Table 7.7)	Bone	OxA-13718	5089±38	T'=2.5; T'(5%)=3.8; ν=1	75
		OxA-13735	5012±31		
Coldrum (Table 7.7)	Bone	OxA-13719	4599±38	T'=0.5; T'(5%)=3.8; ν=1	76
		OxA-13738	4632±30		
Coldrum (Table 7.7)	Bone	OxA-13720	4709±37	T'=2.7; T'(5%)=3.8; ν=1	77
		OxA-13741	4786±29		
Coldrum (Table 7.7)	Bone	OxA-13721	5000±38	T'=2.2; T'(5%)=3.8; ν=1	78
		OxA-13743	5072±30		
Horton (Table 8.3)	Waterlogged wood	BM-2797	4390±100	T'=0.1; T'(5%)=3.8; ν=1)	79
		BM-2816	4355±37		
Yarnton (Table 8.6)	Carbonised 'bread'	NZA-8679	4672±57	T'=0.0; T'(5%)=3.8; ν=1	80
		OxA-6412	4675±70		
Yarnton (Table 8.6)	Calcined bone	OxA-14479	4867±35	T'=3.5; T'(5%)=3.8; ν=1	81
		SUERC-5689	4775±35		
Berinsfield (Table 8.6)	Bone	OxA-15748	4738±35	**T'=8.1**; T'(5%)=3.8; ν=1	82
		HAR-4673	4460±90		
Peak Camp (Table 9.3)	Bone	OxA-445	4670±90	T'=1.2; T'(5%)=3.8; ν=1	83
		OxA-446	4810±90		
Ty Isaf (Table 11.4)	Bone	OxA-14249	4545±50	T'=0.0; T'(5%)=3.8; ν=1	84
		OxA-14395	4552±35		
Kishoge (Table 12.3)	Bulk charred plant remains	GrN-26771	5020±40	T'=0.2; T'(5%)=3.8; ν=1	85
		GrN-26789	4990±50		
Céide Fields (Table 12.6)	Bulk sediment	GrN-23497	4110±40	T'=0.8; T'(5%)=3.8; ν=1	86
		Gd-6693	4030±80		
Céide Fields (Table 12.6)	Bulk sediment	Gd-7147	3360±50	T'=1.0; T'(5%)=3.8; ν=1	87
		Gd-7148	3290±60		
Belderrig (Table 12.6)	Single-entity charred plant remains	UB-7591	4717±37	T'=0.1 T'(5%)=3.8; ν=1	88
		UBA-7591	4732±30		

Table 2.5. Summary of chi-squared tests for the replicate groups of measurements listed in Table 2.4. T' values for groups which are significantly different (at 95% confidence) are in bold.

	All replicates			This project only		
	Groups	**Inconsistent groups (5%)**	**T′**	**Groups**	**Inconsistent groups (5%)**	**T′**
Bone and antler	57	8	**9.3**	24	2	0.5
Calcined bone	1	0	0.6	-	-	
Carbonised residues	15	6	**36.8**	13	5	**29.1**
Waterlogged wood	2	0	0.1	-	-	
Single-entity charred plant remains	4	1	0.1	1	0	0.0
Bulk charred plant remains	7	1	1.2	-	-	
Bulk sediment	2	0	0.1	-	-	
Total	**88**	**16**	**48.2**	**38**	**7**	**29.6**

ages on bone and antler samples which we inherited from previous workers. Consequently, it is unlikely that these replicate results truly reflect the accuracy of radiocarbon dating on bone in previous studies. In practice, rather more than 5%, but probably less than 10%, of the dates on bone and antler which we have inherited from previous workers probably really lie outside the 95% probability range quoted.

In contrast, there are obviously still significant technical issues with the accurate dating of carbonised residues on pottery sherds. Six of the 15 replicate groups of measurements on this material type (40%) did not produce statistically consistent results. Figure 2.31 shows the offset between the pairs of replicates (where there are more than two measurements, each subsequent measurement is compared with the first listed from the sample in Table 2.4). It is apparent that carbonised residues can produce results which are not only statistically inconsistent, but also many hundreds of radiocarbon years different!

As we have seen in section 2.6.1, carbonised residues are subject to different pre-treatment protocols at Oxford and Groningen, and different chemical fractions are selected for dating. Nonetheless, consistent results are produced for nine of the sample groups. Where they differ, Groningen produced more recent measurements in five cases (groups 1, 12, 14, 27 and 37) and Oxford produced a more recent measurement in one (group 6). The intra-laboratory pair from Oxford (group 59) is statistically inconsistent. The intra-laboratory pair from Groningen (part of group 6) is statistically consistent, but almost certainly inaccurate (see section 2.7.2 below). Both pre-treatment methods appear to give accurate ages for some samples, and inaccurate ones for others. This may suggest that it is the composition of the dated residue that accounts for this variation. Some of the replicate measurements on carbonised residues were undertaken because the original date had poor agreement with the developing Bayesian model for a site, so again the replicate groups do not form a random sample of the results on carbonised residues considered in this study. We therefore return to the question of what proportion of radiocarbon ages on carbonised residues may be inaccurate in the next section, once we have taken our archaeological understanding of the dates of these samples into account.

Other sample types appear to present fewer technical difficulties in dating. Although the number of replicate groups is limited, they are consistent within statistical expectation for all other sample types (Table 2.5).

2.7.2 Archaeological prior information

The overall accuracy of radiocarbon dates can also be assessed by their agreement with the archaeological prior information included in the Bayesian models. For this analysis we consider the sample of radiocarbon dates from Neolithic enclosures (n=816). This sample includes 419 measurements obtained by this project, and 397 measurements obtained during previous studies. Each date has been categorised based on how it has been incorporated in the preferred model for the site. These models are explained in detail in Chapters 3–12. Our approach to constructing these chronologies, identifying inaccurate radiocarbon dates and validating the archaeological prior information included in our models, has already been introduced in this chapter.

Table 2.6 provides a summary of how each of the 816 radiocarbon dates from Neolithic enclosures has been included in the preferred model for the site from which it comes. We consider 38 measurements (4.7%) to be inaccurate, either on scientific grounds (for example, the reported dates on bone from Staines, Chapter 8.1) or on archaeological grounds (for example, GrA-25389 and GrA-25821, the statistically consistent determinations on carbonised residue from a plain Bowl at Windmill Hill (Chapter 3.1) which produced a mid-third millennium date). We do not consider these radiocarbon results to be statistical outliers, the one in 20 measurements that lie outside the 95% range, but rather to be inaccurate. They have not been included in the modelling.

Figure 2.32 shows the proportion of dates from Neolithic enclosures on different material types which we consider to be inaccurate on archaeological grounds. Again, carbonised residues prove to be the most problematic sample type, with 16.9% of measurements being judged

Table 2.6. How the radiocarbon dates from Neolithic enclosures have been incorporated in the preferred site-based models (detailed in the captions to Figs 14.2–4), by material type (n=816).

	Modelled	TPQ	Not modelled	Inaccurate
Articulated bone	61	2	9	1
Articulating bone	109	12	9	1
Antler	37	0	10	2
Disarticulated bone	59	47	16	9
Carbonised residues	55	13	21	15
Bulk charred plant remains	31	63	54	10
Single-entity charred plant remains	143	23	27	0
Waterlogged wood	9	0	5	0
Bulk sediment	1	0	0	0
Total	**505**	**160**	**151**	**38**

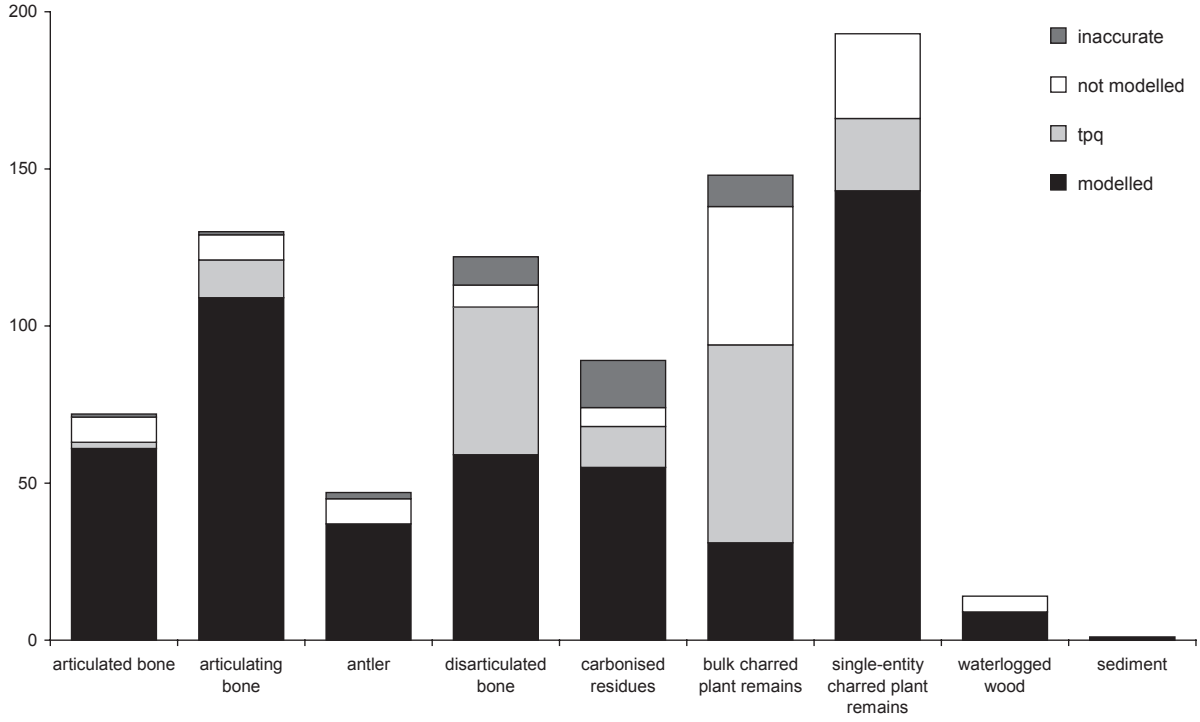

Figure 2.33. How the dates from Neolithic enclosures judged accurate on archaeological grounds (n=778) have been incorporated into the preferred site models (Chapters 3–12), by archaeological material type.

inaccurate. This may be a more reliable indication of the proportion of measurements of this material type which are currently difficult to date accurately, as it derives from the analysis of all 89 measurements from enclosures and is not biased by the preferential selection of problematic results for replication. The proportion of inaccurate measurements on bone is increased by our despairing attempts to date the poorly preserved material from Staines (Chapter 8.1), and that for bulk charred plant remains by initial difficulties with the miniature gas proportional counter at Harwell encountered at Briar Hill (Chapter 6.3).

The next stage in the analysis is to consider how the 778 dates which we have judged on archaeological grounds to be accurate are incorporated into our preferred site models. This analysis assesses the accuracy and effectiveness of different archaeological sample types in dating enclosures. It is summarised in Fig. 2.33. The most effective sample types are articulated and articulating bone groups and antlers functionally related to the contexts from which they come (in this study usually antler tools from the base of ditches). More than 80% of each of these sample types can be incorporated fully into our models. Those that cannot are usually samples such as the child burial in the outer ditch at Windmill Hill (Chapter 3.1) which must have lain in unidentified recuts (and, of course, the burrowing toad at the same site!). Carbonised residues on pottery sherds and single-entity samples of charred plant remains, which are either functionally related to the deposits from which they came or which derive from what are interpreted as primary disposal events, can be fully incorporated into models in more than 70% of cases. In both cases, the fragile

nature of the material concerned may limit opportunities for residuality. The least effective sample types are bulk samples of charred plant remains and disarticulated bone. Less than 25% of dates on bulk samples of charred plant remains can be fully incorporated into our models. Many of these are samples of unidentified charcoal which have been modelled as *termini post quos* because of the potential for the 'old-wood' effect. Just over 50% of dates on disarticulated bone have been incorporated fully in the preferred site models. Most of the others provide *termini post quos* for their contexts. This type of material is robust and can easily be residual or reworked. Because of the special conditions necessary for its preservation, which again limit the potential for residuality, waterlogged wood also seems to be an extremely effective sample type (the samples not included in our models are from later contexts at Etton). The single sediment sample included in this study is fully modelled.

Finally, we consider the effectiveness of our attempts to elicit prior information from sites dug in arbitrary spits (see section 2.4.2 above). We obtained 92 measurements from samples derived from spits at three sites, Windmill Hill (Chapter 3.1), Whitehawk Camp (Chapter 5.1) and Hembury (Chapter 10.2). Of these, 77 (83.7%) could be incorporated into our models. The remaining samples were usually later material from the upper silts, parts of which must have lain in spits which principally included earlier layers.

2.8. Further mathematics

All the modelling in this volume has been undertaken using OxCal v3.10 (Bronk Ramsey 1995; 1998; 2001), and so we have constructed our models from the available range of functions in that software. Without this type of user-friendly software and modular model construction, an application on this scale would simply not have been possible. Nonetheless, it is worth considering the merits and demerits of the types of model that have been available to us during the course of this project, and areas for future development.

First, we consider the use of the uniform distribution. The mathematics of this approach have been available for some time (Buck *et al.* 1992; Nicholls and Jones 2001), and it has proven very forgiving in routine usage (Bayliss *et al.* 2007a, figs 15–17). Archaeologically the major drawback of this approach is the need to define endings. Sometimes this is unproblematic – an LBK longhouse is constructed, used and then destroyed or abandoned – but sometimes reality is not so neat, as a site can be established slowly and decline gradually, or can be used for a period, abandoned, and then reused. Generally, however, it is possible to identify such discrete phases of use archaeologically and the uniform distribution does seem to be appropriate for most site-based studies. In this volume, perhaps only at Windmill Hill is the quantity of later fourth millennium material such that a continuing, if much reduced, presence at the enclosure can be realistically envisaged. This is unusual. Hundreds of chronological models for individual sites have been constructed in England over the past 15 years (Bayliss 2009), and it is rare for a model based on a uniform distribution to be *importantly wrong* (Bayliss *et al.* 2007a).

In Chapters 12 and 14, however, we employ a uniform distribution to model the chronology of the early Neolithic (and elements thereof) in different areas of Britain and Ireland. In this we follow the approach to spatio-temporal modelling suggested by Blackwell and Buck (2003)(and see Buck and Bard 2007). There are two difficulties here. The first is that we wish to estimate the date of the first Neolithic things and practices in each region or area, but these things and practices do not end but rather gradually transform into something else. There is no ending in reality and so we are forced to define an assemblage of Neolithic things and practices which constitute the 'early Neolithic phase' whose chronology we are modelling (see Chapters 12.3–4 and 14.4). The second issue is that we have to define the spatial areas of our analysis. In this volume this is done on an entirely pragmatic basis, regions having been defined around one or more of the enclosures that we have dated. Partially this relates to the distribution of (excavated) enclosures (Fig. 1.2), and partially to topography. There is, for example, some geographical basis for the isolation of Sussex (Chapter 5) or the South-West peninsula (Chapter 10), but very little for the separation of north Wiltshire (Chapter 3) from South Wessex (Chapter 4) or the upper Thames valley (Chapter 8) from the Cotswolds (Chapter 9).

In time, new modelling approaches may be developed to address these issues. Alternative distributions have been proposed for the underlying, real period of activity (Karlsberg 2006; Bronk Ramsey 2009a; 2009b), but in this case they will only alleviate the first issue. We will still need to define endings where archaeologically there are none (although at least the things and practices will be allowed to fade away) and we will still need to define our areas of analysis. Spatio-temporal models that do not model an underlying phase of activity, but rather model the spread of a phenomenon, can also be proposed (Buck 2004, 18–20; Karlsberg 2006; McColl 2008; Nicholls and Nunn submitted[13]). At their most basic, these postulate a centre from which the phenomenon spread and a belief that the phenomenon is more likely to spread to nearby sites than to ones further away. Neither of these beliefs may be appropriate for the spread of the Neolithic across Britain and Ireland. As we will see in Chapter 14.4, there was not necessarily a single focus for the earliest Neolithic in Britain, and if the suggestion that there was an element of long-distance migration in the spread of Neolithic things and practices to Britain and Ireland (Chapter 15.2) is valid, then the belief that there is a simple relationship between distance and the probability of change may also be erroneous. Our analysis also suggests that the pace of the spread of Neolithic things and practices across Britain and Ireland may vary substantially (Chapter 14.8). These complexities in the past call for more complex models than are currently available.

In Chapter 14 we also use the uniform distribution to model the underlying, real period during which certain types of artefact were current. This is also clearly not

ideal. Considerable attention has been given to the popularity curves of artefact types in the archaeological literature, largely in relation to seriation. Brainerd (1951, 304) suggests that seriation is effective when 'each type originates at a given time in a given place, is made gradually in increasing numbers as time goes on, then decreases in popularity until it becomes forgotten, never to reoccur in an identical form'. These uni-modal, but not necessarily normally distributed, popularity curves do appear to be frequently encountered in the occurrence of archaeological types. This has been demonstrated using known-age datasets (Deetz and Dethlefsen 1965, 203; Lyman and Harpole 2002, fig. 8), and indirectly by the number of applications of seriation and correspondence analysis which have successfully identified chronological sequences (Müller 1996, 217). In the pioneering days of Bayesian applications in archaeology, Naylor and Smith (1988, 589) suggested that a beta distribution might be suitable for modelling the production of a type rather than a uniform distribution. More recently, the gradual introduction and demise of archaeological phases have also been modelled using trapezium-shaped prior distributions (Karlsberg 2006, 72–3 and chapter 4). In due course, approaches of this sort may prove more appropriate for modelling the currency of archaeological types.

2.9 Conclusion

Bayesian statistics provide a powerful tool for explicitly modelling archaeological chronologies. The effective implementation of this approach, however, demands much of both archaeologists and radiocarbon laboratories. Archaeologists must establish and unambiguously define their prior information. They must then select their radiocarbon samples wisely. Far greater attention must be given to the critical association between the sample, the context from which it was recovered and the archaeological event that the dating programme targets (section 2.4.2). Sampling strategies must be constructed (section 2.4.3). Then, of course, the samples must be dated with accuracy and reliably estimated precision. Implementing the Bayesian process (section 2.5; Fig. 2.20) is undoubtedly challenging. But it is the means to the kind of chronologies and the kind of narratives (see Chapters 14.1 and 15.13) which we have been able to construct in this volume.

Notes

1 The process of radiocarbon calibration is when a radiocarbon age is converted to a calendar date by means of the calibration curve. Here, we have implemented the process in reverse, converting a calendar date to a radiocarbon age (using the R_Simulate function of OxCal v3.10). In both cases, the methodology takes account of the probabilistic nature of radiocarbon dating (see Fig. 2.16 and section 2.4.3).

2 Between 2006 and 2009 more than 150 archaeologists from the commercial and academic sectors in six countries were asked to estimate the dates of construction and abandonment, and duration of use, of sites from similar simulations to that shown in Figure 2.2 (see also Bayliss *et al.* 2007a, fig. 4; Bayliss 2009, fig. 7; Bayliss and O'Sullivan forthcoming, fig. 1). The vast majority of these archaeologists got the answers *importantly* wrong – 80% estimated the start date to be earlier than that input into the relevant simulation, 87% estimated the end date to be later, and 91% significantly over-estimated the duration!

3 Counting from 1 January 3700 BC to 31 December 3676 BC!

4 The ranges of these estimates do *not* tell us anything about how long it took for the enclosure to be built or for the pottery type to rise to popularity.

5 It should be noted that for many of these sites we actually have samples which seem to be directly associated with the construction event – antler picks from the base of the enclosure ditches. In these circumstances there will be a higher probability that we actually have a radiocarbon measurement which directly relates to the start of activity on the site. It should be noted that it has not been possible to associate radiocarbon dates specifically with boundary events in this study, although this refinement is now possible within OxCal v4 (Bronk Ramsey 2009a, 345).

6 This means that there is a 2 out of 5 chance that sample *d* is earlier than sample *e*, and conversely a 3 out of 5 chance that sample *e* is earlier than sample *d*. This is not much better than tossing a coin (in which case both alternatives would have a chance of 2.5 out of 5, or 1 in 2), so in this case we really do not know which sample came first.

7 Although there are checks to ensure that the prior beliefs and likelihoods input into a model are not mutually contradictory (see below, Chapter 2.4.3).

8 Only 160 (24%) of the 665 radiocarbon dates included in the enclosure models, however, have been incorporated as *termini post quos*. This reflects the corpus of new dates on samples chosen according to the criteria laid out in Chapter 2.5.

9 This means that a smaller number of radiocarbon dates with fewer stratigraphic relationships will produce more precision on steep or wiggly parts of the calibration curve than on plateaux. We do not agree with Ashmore (2004a, 130), however, that precise dating is impossible in the later fourth millennium because of the plateau – we simply need to target situations with highly informative archaeological sequences (be they stratigraphic or typological).

10 The counting gas is held under pressure and a high voltage is introduced between the central wire in the counting chamber and the counter wall. The electron produced by the decay of a radiocarbon nucleus creates an ionisation trail and an avalanche of electrons, which are measured as an electrical pulse.

11 A scintillant is dissolved in the counting liquid and produces a photon of light when an electron is emitted by the decay of a radiocarbon nucleus. These flashes of light are counted using photo-multiplier tubes.

12 In the AMS the carbon in the sample is turned into charged ions which are accelerated to high velocities by strong electro-magnetic fields and then bent by a series of strong magnets according to their mass and charge. This allows the radiocarbon ions to be separated from other ions and counted using an ionisation chamber.

13 Other formal approaches to spatio-temporal modelling have also been suggested (e.g. Davison *et al.* 2006; Dolukhanov *et al.* 2009; Steele 2010), although these do not as yet take the complex nature of calibrated radiocarbon dates fully into account.

3 The North Wiltshire Downs

Alasdair Whittle, Alex Bayliss and Frances Healy

The North Wiltshire Downs can be defined as the chalk downland bounded by the Vale of Melksham to the north-west and the Vale of Pewsey to the south, including the upper valley of the Kennet in their midst and the Marlborough Downs to the north-east (Fig. 3.1).[1] The area includes three certain causewayed enclosures: the archetypal site of Windmill Hill, on the northern edge of the area, and two much smaller ones, both with well preserved earthworks, at Rybury and Knap Hill on the southern edge, less than 4 km apart and within 8 km of the larger enclosure (Oswald *et al*. 2001, fig. 6.2).

Crofton, Great Bedwyn, to the south-east of these, is often accepted as a further example, but this is questionable on the grounds of both size and location. At over 25 ha, it is more than twice the size of the next largest causewayed enclosure (Oswald *et al*. 2001, fig. 4.23), and more than three times the size of Windmill Hill, the main Hambledon Hill enclosure and Maiden Castle, the largest unambiguous

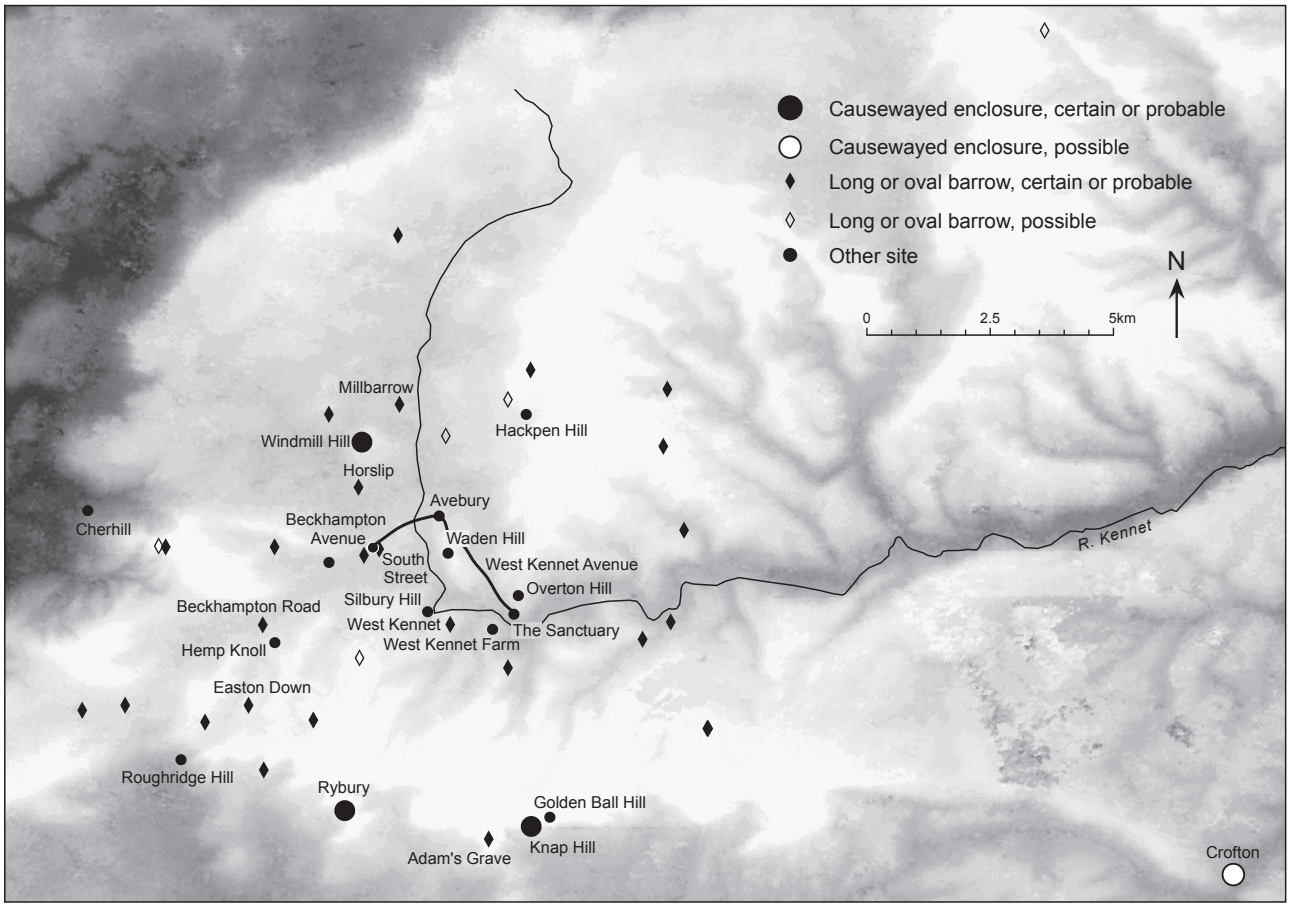

Fig. 3.1. The North Wiltshire Downs showing causewayed enclosures, long barrows and other sites mentioned in Chapter 3.

examples in Wessex. It is even more extensive than the largest enclosures of the third millennium, such as Avebury, Durrington Walls and Marden in Wiltshire, and Mount Pleasant in Dorset (Wainwright and Longworth 1971, fig. 83). Its location, straddling the valley of the river Dunn and encompassing both its slopes, with the circuit possibly open on the downstream side (Oswald *et al*. 2001, figs 4.21, 5.22), invites comparison with those of Durrington Walls and the massive Dorchester timber circle, both built on sloping sites around dry valleys (Wainwright and Longworth 1971, fig. 3; Woodward *et al*. 1993, figs 171–2). Despite its interrupted ditch, the date of this enclosure remains uncertain. The single trench cut across it (Lobb 1995) yielded fresh flint debitage of Neolithic character and a predominantly woodland molluscan fauna, both of which would be compatible with a third millennium cal BC date as well as a fourth millennium one.

Just off the chalk in the west of the area at Cherhill, another site has been mooted as a fourth millennium enclosure by, among others, Joshua Pollard (2005); it has not, however, been included in this project. Here a sinuous, irregular hollow was traced for some 50 m and contained plain Bowl pottery, struck flint, small quantities of animal bone, a fragment of human bone and much sarsen, some of these apparently placed in clusters on the base. Two pits had been dug into the base and deliberately filled, and the subsequent backfilling of the hollow seemed deliberate. A charred *Corylus* timber from the upper part of its initial fills was dated to 3660–3340 cal BC (95% confidence; Table 3.4: BM-493; H. Barker *et al*. 1971, 174; Evans and Smith 1983, 52–8, 111–12, fig. 10). As the excavators pointed out, the depositional practices echo those of causewayed enclosures, and their own interpretation of the feature as simply a linear quarry for marl and fine combe rock which might be used as daub is weakened by the continued dearth of evidence for contemporary timber structures to which it might have been applied. The extreme irregularity of the hollow, however, and the fact that it was seldom more than 0.50 m deep, argue against its having been a monument like the others considered here. It may indicate that different kinds of structures and features were built and used off the Chalk. The relatively low-lying location of Cherhill, on the edge of an historical village and masked by colluvium, means that comparable sites, if they exist, are likely to be under-recognised.

3.1 Windmill Hill, Avebury and Winterbourne Monkton, Marlborough, Wiltshire, SU 08670 71440

Location and topography

The Windmill Hill enclosure lies at 195 m OD, on a down formed by an outlying block of Middle Chalk above surrounds of Lower Chalk (Fig. 3.1). The hill slopes gently south-east towards the Kennet valley and more abruptly to the north-west towards the Lower Chalk and the Vale of Melksham beyond it. The enclosure is centred north-west of the summit of the down and tilts towards the Vale, so that, while it commands views in all directions, these are particularly extensive to the north and west, and the enclosure would itself have been visible from lower-lying ground in that direction (Whittle *et al*. 1999, 7–13; Oswald *et al*. 2001, fig. 5.24: C). The enclosure has a total area of 8.45 ha, making it one of the largest in England (Oswald *et al*. 2001, fig. 4.23). It has three circuits, defined by the inner, middle and outer ditches (Fig. 3.2). The inner ditch, the slightest of the three, has no trace of a surviving bank, and the north-west part of its circuit is concave, probably marking an entrance (I. Smith 1965a, 5; C. Evans 1988a, 139; Oswald *et al*. 2001, fig. 3.16). The middle ditch is nearly circular (Whittle *et al*. 1999, fig. 14), may have traces of a vestigial inner bank, and has a possible entrance, in the form of an exceptionally wide causeway just west of north, slightly offset from the probable entrance in the inner ditch (McOmish 1999, 14, fig. 15: B). The outer ditch is the most substantial of the three and is backed by a largely continuous bank which, in the better preserved north-eastern part of the circuit, survives to 0.70 m high and 5 m wide.

The date of the enclosure and its location in the Avebury area place it near the beginnings of an unique monument complex, whose earliest elements may have been some of the numerous local long barrows (Whittle *et al*. 1999, fig. 7), two of which lie within 1 km of the enclosure: Millbarrow (Whittle 1994) to the north-east, and the Horslip long barrow (Ashbee *et al*. 1979) to the south. Later developments included Silbury Hill (Whittle 1997b; Bayliss *et al*. 2007e), the Avebury henge and avenues (I. Smith 1965a; Gillings *et al*. 2008), the Longstones enclosure (Pollard and Reynolds 2002), and the West Kennet Farm palisade enclosures (Whittle 1997b). In the Early Bronze Age round barrows were built on the hill itself and on the slope to the south (Whittle *et al*. 1999, fig. 9).

History of investigation

Windmill Hill was one of the first causewayed enclosures to be recognised and to be excavated extensively. Its assemblages have played a seminal role in demonstrating the extent of the long- and medium-distance transport of artefacts and materials during the early Neolithic, the character of contemporary animal husbandry, and the development of early and middle Neolithic pottery styles. This section summarises information already presented by Whittle *et al*. (1999, 1–6).

The outer ditch of the enclosure was recognised by Stukeley (1743), as were 15 round barrows on and below the hill, one of which he opened. The enclosure continued to be noted and occasional barrows continued to be opened through the next 150 years. From the early twentieth century, the extensive flint scatter within which the enclosure lies attracted collectors, the most assiduous of whom was the Reverend H.G.O. Kendall, Rector of Winterborne Bassett. Kendall collected from the slopes of the hill (Kendall 1914; 1919; 1922; Holgate 1988a; Whittle

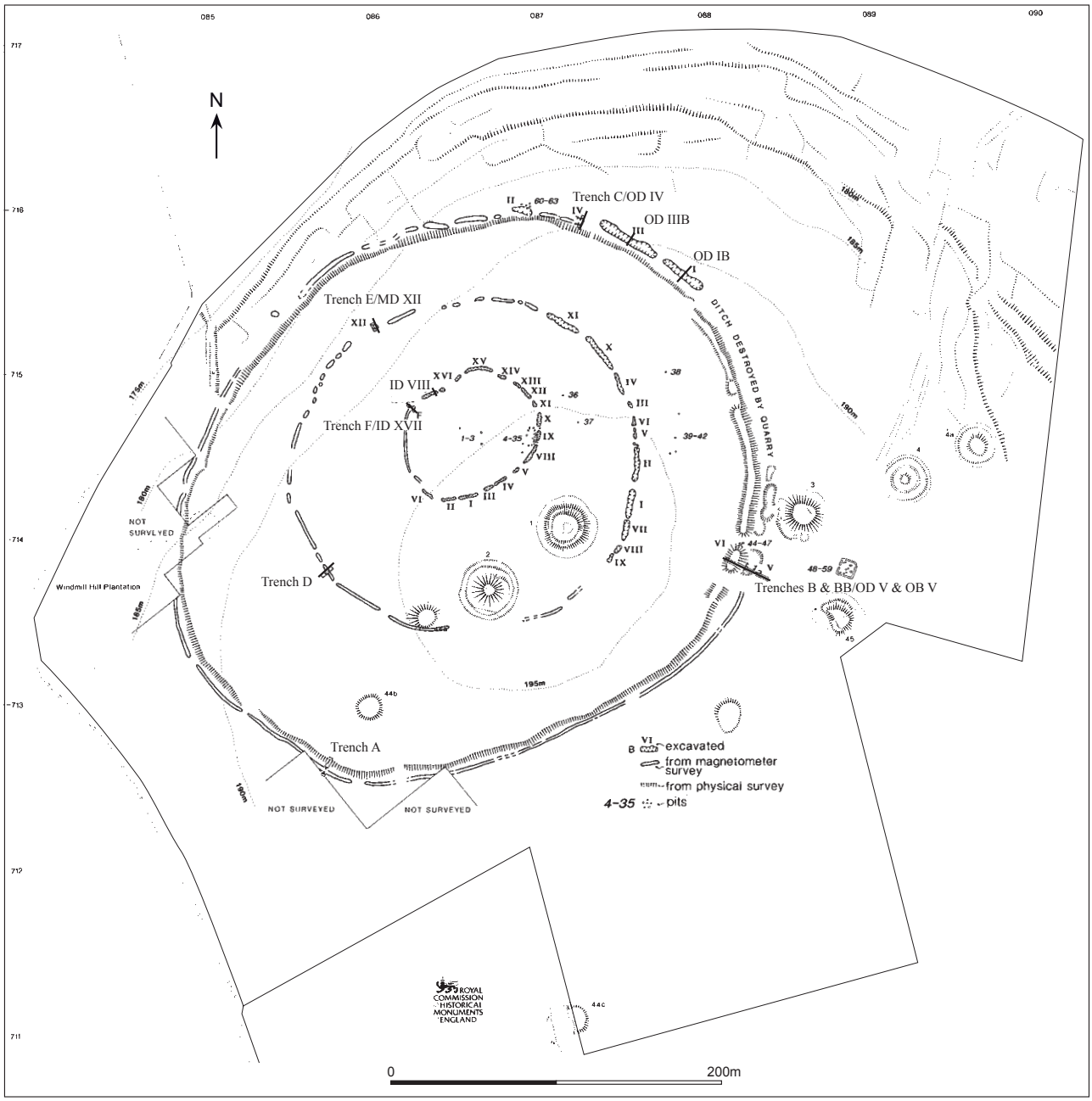

Fig. 3.2. Windmill Hill. Plan, showing the location of cuttings, the results of excavation, earthwork and geophysical survey, and the location of the sections reproduced here. After Whittle et al. *(1999, figs 14–15).*

et al. 2000) and, in 1922–3, he excavated one butt of a segment of the outer ditch (Kendall 1923). The threatened construction of a wireless station on the hill led to its purchase by Alexander Keiller and to his excavations of 1925–9, in the course of which he defined the characteristics of the monument and, for a long time, of the monument class. The scale of Keiller's excavations is noted in Table 3.1; his methods and results are described by Pollard (1999a). Cuttings were numbered consecutively within each ditch in the order in which they were excavated, so that, for example, Inner Ditch VI is next to Inner Ditch II rather than to Inner Ditch V. Most of the excavation was done by workmen and ditch fills were removed in spits, which means that the stratigraphic contexts of finds are not always clear. The locations of significant finds were, however, measured-in, and delicate or 'special' deposits were, once recognised, excavated by professional staff (Fig. 3.3). Articulated burials, both human and animal, and carefully heaped deposits of animal bone were thus exposed and recorded in their entirety. Animal bone, was, however, retained only selectively. It has not, for example, been possible to locate a complete, articulated cattle forelimb photographed in 1928 (Grigson 1999, fig. 165).

By the end of the 1920s, when Keiller's own interest shifted to Avebury, his Windmill Hill excavations had provided the body of evidence which for decades defined the material culture and subsistence base of the early Neolithic population of southern England, most clearly

Table 3.1. Windmill Hill, Wiltshire. Certain and possible pre-Iron Age features.

Element	Notes	Investigation
Inner Ditch	Ovoid, with indentation in NW. Maximum dimension 85 m, enclosing 0.52 ha. No surviving trace of bank	ID I–XVI (approx. 190 m or 75% of circuit, amounting to approx. 130 m of actual ditch) and E half of interior excavated 1925–9 by Keiller. ID XVII (approx. 1.5 m wide) excavated 1957–8 by I. Smith. Trench F (1 m wide, immediately adjacent to ID XVII) excavated 1988 by Whittle
Middle Ditch	Almost circular. Maximum dimension 220 m, enclosing 3.32 ha. Possible vestigial traces of inner bank	MD I–XI (approx. 185 m or 25% of circuit, amounting to approx. 140 m of actual ditch) excavated 1925–29 by Keiller. MD XII (approx. 1.5 m wide) excavated 1957–8 by I. Smith. Trench E (2 m wide, immediately adjacent to MD XII) excavated 1988 by Whittle. S part of circuit defined by David 1999
Outer Ditch	Ovoid. Maximum dimension 360 m, enclosing 8.45 ha. Substantial remains of inner bank in E, and less pronounced to S. Segments generally longer than those of other ditches	Segment butt adjoining OD I excavated by Kendall 1922–23. OD I–III (approx. 130 m or 9% of circuit) excavated 1925–9 by Keiller. OD IV–VI (8.5 m, OD IV and OD V including the bank, OD VI confined to the bank) excavated 1957–8 by I. Smith. Trenches A, B and C (6 m, C and B immediately adjacent to OD IV and V, A in south of circuit) excavated 1988 by Whittle
Square enclosure	Approx. 9 m x 9 m, lying between two round barrows 43 m E of the gap north of OD VI. Surrounding and in some cases cutting a pit cluster of unknown extent. Date uncertain but presence of oolitic limestone may suggest connection with local long cairns	Ditch, interior and very narrow surrounding margin completely excavated by Keiller
Discrete features	Pits virtually confined to single cluster in stripped E half of interior of inner ditch. Sporadic pits excavated elsewhere in enclosure, probably located by probing. Beaker/EBA pits immediately outside outer circuit, early and late Neolithic pits on slope to south of enclosure. Extent of pit-digging inside and outside enclosure still unknown	Pits in and to N of enclosure excavated by Keiller 1925–9. Pits to S excavated by Whittle 1993
Round barrows	Five within enclosure, more immediately outside it to E and on slope to S	Intermittent antiquarian excavations. Small cutting made by Keiller 1935 in the largest round barrow on the hill (Winterbourne Monkton 2) when a Biconical Urn containing a cremation exposed by rabbit burrowing (I. Smith 1965a, 169–70)
Fourth ditch?	Possibly reflected by the line followed by lynchets around NW, N and NE of the hill, if these do not simple follow the contours. See 3.9	Surveyed by McOmish 1988
Field system	Extending to NW, N and NE of hill	Surveyed by McOmish 1988

Fig. 3.3. Sorting finds on Windmill Hill in the 1920s; the subject is probably Veronica Keiller. Photograph Alexander Keiller Museum, Avebury.

evidenced by the weight accorded the site in Piggott's *Neolithic cultures of the British Isles* (1954). The number of artefacts of non-local stone found on and around the hill (I. Smith 1965a, 110–24; Pollard and Whittle 1999) prompted the foundation of the South-West Group of Museums and Art Galleries' Sub-Committee for the Petrological Identification of Stone Implements, of which Keiller was the first Chair (Piggott 1965, xxi–xxii).

Following Keiller's death in 1955, his widow commissioned Dr Isobel Smith to publish the results of his excavations of both Windmill Hill and Avebury. Smith also undertook small-scale excavations in all three ditches at Windmill Hill in 1957–8 in order to facilitate the interpretation of the earlier excavations. The results of Keiller's and her own investigations (I. Smith 1965a) can be summarised as follows.

There was Neolithic activity on the hill prior to the construction of the inner circuit, which cut some of a cluster of pits, and of the outer circuit, the bank of which overlay artefact scatters, pits and postholes (I. Smith 1965a, 21–8).

Stripping of half the area enclosed by the inner ditch showed that it was virtually devoid of pits outside the single cluster mentioned above. No other areas of the interior were stripped. Pits elsewhere in the enclosure were excavated in individual small trenches (I. Smith 1965a, fig. 3), and were probably identified by probing, a method which Keiller certainly employed (David 1999, 17). Outside the enclosure to the north there were four pits of Beaker or Early Bronze Age date at the outer edge of cutting Outer Ditch II. Others may have extended beyond it.

Further pits and possible postholes were encountered outside the circuits to the east, during the excavation of a square enclosure which may have been a bedding trench for posts. The very few finds from these features would be compatible with a Neolithic date and, since at least one was cut by the enclosure, they may all have predated it. Here again, pits may have extended beyond the excavated area. The date of the square enclosure itself remains uncertain (I. Smith 1965a, 30–3).

Bank structure was preserved only in the outer bank in the east of the circuit. Here, Smith's excavations in cuttings Outer Bank V and VI showed that the first stage of bank construction had been the two low parallel mounds of topsoil and weathered chalk which may have been intended as setting out lines for the bulk of the bank. Her Outer Bank V section shows a contrast between the bank in the area defined by them, which was made up of clearly bedded tips of topsoil and weathered chalk, and the inner edge of the bank beyond their limits, which was built of more jumbled, undifferentiated chalk rubble and earth (Fig. 3.14; I. Smith 1965a, fig. 4).

The fills of all three ditches were asymmetrical, arguing the former presence of internal banks even where none survived. All three were rich in artefacts and food remains, the inner ditch being richest of all; 'there is no doubt whatever

that the mass of this material was deliberately thrown or placed in the hollows' (I. Smith 1965a, 7–8). The absence of any surviving bank inside the inner and middle ditches was attributed to the practice of backfilling material from the bank over deposits placed in the ditch, which at the same time accounted for their integrity and good preservation, with the at least partial survival of the outer bank corresponding to a lower level of cultural material in the fills of the outer ditch (I. Smith 1965a, 15–17; 1966).

The plotting of individual sherds in 1957–8 showed that, in all but one of the sections then excavated, only Neolithic Bowl pottery (Windmill Hill Ware) was present in the primary and secondary fills, with Peterborough Ware, Grooved Ware (Rinyo-Clacton Ware), Beaker, Early Bronze Age and Roman pottery all occurring together in the tertiary fills (I. Smith 1965a, 14–15, figs 5–6). The exception was Outer Ditch V, where six sherds from a pot in the Ebbsfleet substyle of Peterborough Ware were found near the base of the secondary silts, separated by at least 0.65 m of accumulation from the lowest Beaker sherds (I. Smith 1965a, 11–12, fig. 4, fig. 31: P237). This fuelled an argument that the Ebbsfleet substyle developed earlier than the more elaborate varieties of Peterborough Ware (I. Smith 1966a, 474–8).

Analysis of the soil preserved beneath the outer bank and its contained pollen indicated that the soil was truncated and that the vegetation was dominated by weeds of cultivation with some cereals and with hazel outnumbering larger trees; charcoal from the 1957–8 excavations was correspondingly dominated by scrub species, with some oak and ash (Dimbleby 1965). The Mollusca from the same palaeosol, the overlying bank and the adjacent ditch were all, however, woodland species (Maitland Howard 1965). Results from samples taken nearby at a rather later date were comparable (J. Evans 1966; 1972, 242–8; Dimbleby and Evans 1974). A subsequent survey of the evidence has claimed a picture of fragmented, patchy woodland, not the complete woodland cover once suggested (M. Allen 2005; Allen and Davis 2009). Apart from the pollen, evidence for cereal crops was confined to impressions on pottery, which were predominantly of emmer wheat (Helbaek 1952). The animal bone, insofar as it had been retained, was dominated by cattle, many of them over two years old, followed by sheep and goat (Jope 1965).

There was a substantial later Neolithic and Early Bronze Age presence on the hill, seen primarily in the quantities of pottery and lithics of these periods from the tertiary fills of the ditches.

All the struck flint from the hill had been brought there, since neither the Middle Chalk on which the enclosure was built nor the Lower Chalk which surrounds it is flint-bearing (I. Smith 1965a, 85–6). This applies with equal force to the extensive flint scatter on the slopes of the hill to the south of the enclosure (Whittle *et al*. 2000).

In later papers Smith went on to develop the idea of the special nature of the enclosure. This was based on the character of deposition and the practice of deliberate backfilling (I. Smith 1966a, 471–4; 1971, 96–7). Two of her most important contributions were to point out how frequently causewayed enclosures lie across contours, and thus 'face' in certain directions (I. Smith 1971, 92), and how extensively causewayed enclosure ditches were recut. Progressive identifications have shown that the substantial collection of imported stone artefacts from Windmill Hill is part of a larger concentration focussed on the Avebury area, a concentration so great as to be visible on distribution maps compiled at a national scale (Cummins 1979, fig. 1; J. Thomas 1984, 173). Caroline Grigson, who had contributed to the 1965 monograph, continued to work on the Windmill Hill animal bone and published both methodological (Grigson 1982a) and interpretative (Grigson 1984) results. Bob Smith incorporated Windmill Hill into a synthesis of the ecology of Neolithic farming in the area, concluding that the enclosure was marginal to more intensively managed and farmed areas of land down in the Kennet valley (R. Smith 1984). Attention was also turned to the extensive flint scatter on the south slope of Windmill Hill from which Kendall and others had collected. In 1983 fieldwalking by Robin Holgate and Julian Thomas in Gibbs' Field, immediately to the south-west of the enclosure, recovered predominantly later Neolithic material (Holgate 1987; 1988a, 92, fig. 6.13).

Excavation of the enclosure itself resumed in 1988, when Alasdair Whittle cut sections across all three ditches in order to obtain fuller environmental evidence and samples suitable for radiocarbon dating, as part of wider investigations aimed at establishing a more secure local sequence and a fuller sense of environmental variation through time and across the Avebury area (Whittle *et al*. 1999). The exercise was accompanied by earthwork and geophysical survey. A particularly important component was a detailed reassessment of the records and finds from Keiller's excavations. Results included the following.

Earthwork survey showed that a slight trace of a bank, previously unobserved, may survive within the middle ditch and that an apparent double eastern entrance, formed by two breaks in the outer bank some 20 m apart, both corresponding to causeways in the ditch, is not original, since the north gap is crossed by a vestigial bank and the bank terminals on either side of the south one are sharply truncated (McOmish 1999, 14, fig. 15: A). A previously unidentified round barrow was identified to the east of the enclosure.

A magnetometer survey defined the degraded south-west part of the middle ditch for the first time, showing the circuit to have been nearly circular and permitting it to be sectioned in this area in Trench D. The definition of the south and west parts of the outer ditch was enhanced sufficiently to indicate that the segments here were, like those excavated to the north, longer than those of the other circuits. Few internal features were recognised, among them an additional round barrow between the middle and outer ditches, a scattering of possible pits, and a few weakly defined linear anomalies. The poor definition of the southern parts of the middle and outer circuits was shown to be due to cultivation in the historic period (David 1999).

More of the artefact scatter and features beneath Outer Bank V were explored, including the grave of an adult male in which the corpse had lain exposed for some time, on the evidence of displacement of some of the bones and of the presence of the skeletons of numerous frogs and toads and some small rodents, which had apparently fallen into the open grave and been unable to get out.

The outer of Smith's marking out banks was clearly visible, the inner less so. The distinction described above between the clearly bedded forward part of the bank (context 703) and a less differentiated rear part (context 702) was replicated in the 1988 excavation. Pottery from the extenuated tail of the bank (context 701, undoubtedly a product of weathering) was multiperiod, but dominated by sherds of Ebbsfleet Ware (Zienkiewicz 1999, table 155).

Also uncovered were three postholes which aligned with a row already exposed in Outer Bank V and VI (I. Smith 1965a, figs 3, 8) and others running at right-angles to them (Whittle *et al*. 1999, figs 67, 220). The small areas exposed make interpretation difficult. Both excavators suggest that the postholes, and the structure or structures of which they formed a part, may have pre-dated pits sealed by the bank because they were less readily recognised once the bank had been removed (Whittle *et al*. 1999, 78–9). This may, however, reflect the different fills of pits and postholes, and the possibility of timbering connected with the outer bank has to be considered.

Excavation of ditch sections provided the opportunity for detailed study of bone and artefact deposits like those known from photographs and descriptions of the Keiller excavations. The sequence of fills in Trench B, next to Smith's cutting OD V, replicated the sequence recorded by her, including the occurrence of Ebbsfleet Ware near the base of the secondary fills, in this case one sherd only, probably from the same pot as the sherds found by Smith, in bone group 227 on the surface of layer 210 (Whittle *et al*. 1999, fig. 77; Zienkiewicz 1999, 272, table 156, fig. 187: 522). It was only in this cutting that lower and upper secondary fills were distinguished, the latter equating to Smith's layer 2, containing Beaker and Early Bronze Age pottery. The interface of the two was marked by the cutting of small pits or scoops (Whittle *et al.* 1999, 86–7).

The palaeoenvironmental record was greatly enhanced. Soil micromorphology indicated a prolonged human presence, including possible cultivation, before the construction of the outer bank (Macphail 1999). Molluscan analysis confirmed disturbance to the soil prior to the construction of the outer bank and emphasised that the surrounding area before and during the construction and early use of the enclosure was predominantly wooded, more so than that of local long barrows. In the outer ditch, woodland species were predominant throughout the primary and lower secondary fills, but with a temporary drop in overall numbers and an increase in species diversity at the junction of the chalk rubble fills with the overlying silts. Open conditions were reflected only from the upper secondary fills onwards (Fishpool 1999). Attempts to extract countable quantities of pollen from samples from beneath the outer bank and analysis of a comparative sequence from the surface of the bank resulted in the conclusion that there had probably been differential post-depositional destruction of tree pollen (M. Walker 1999).

A major achievement of the 1999 publication was the contextualisation of a high proportion of the finds from the Keiller excavations. Reconstruction, as far as was possible, of the deposits in each segment (J. Pollard 1999a) made it possible to identify significant differences between the depositional signatures of the three ditches (Grigson 1999, fig. 185; Zienkiewicz 1999, figs 193–6; Whittle *et al*. 1999, 357–71).

In 1992–3 the lithic scatter on the south slope of the hill was investigated by geophysical survey, fieldwalking, test-pitting and excavation (Whittle *et al*. 2000). The exercise focussed on North Field, immediately east of the areas walked by Holgate and Thomas, although geophysical survey extended on to it (Whittle *et al*. 2000, fig. 1). Both fieldwalking and test-pitting returned highest densities in the north of the field, close to the enclosure, and continuation of one row of test-pits downslope showed that falling densities were genuine, and not simply an effect of colluviation. Bronze Age material tended to concentrate around the known round barrows. Investigation of 18 magnetic anomalies led to the discovery of Neolithic pits in only two. A cluster of intercutting early Neolithic pits 100 m south-east of the enclosure contained moderate quantities of artefacts and animal bone, and far more abundant charred cereals and wild plant foods, especially hazelnut shells, than those thinly scattered through the enclosure ditch fills (Fairbairn 1999a; 2000). Perhaps correspondingly, the pits in this group yielded a quern fragment and two rubbers. Two more widely spaced late Neolithic pits 200 m south of the enclosure yielded lower levels of cereal and higher levels of hazelnut shell along with far more abundant charcoal than in the earlier pits.

Previous dating

In presenting the results of the excavations of both Keiller and herself, Isobel Smith had three radiocarbon dates at her disposal (Table 3.2: BM-73–5), but her principal reference in discussing sequence and chronology was the combination of stratigraphy and finds. The radiocarbon dates, two from the ditches and one from the buried soil under the Outer Bank, were duly noted and their contexts compared (I. Smith 1965a, 11, 28); unidentified charcoal was used and the material for BM-74 was bulked from segments of the middle and outer ditches (see below). In her introduction, Smith used the uncalibrated radiocarbon determinations to suggest a date of '*c*. 3000 B.C.' (i.e. *c.* 3790–*c.* 3650 cal BC) for earlier settlement on the hill, and a date 'round the middle of the third millennium B.C.' (i.e. *c.* 3350–*c.* 3000 cal BC) for the construction of the enclosure, by then 'the type-site for the earlier Neolithic culture of southern England' (I. Smith 1965a, xxvii). Sherds said to be from the same vessel were recognised in all three circuits, and in other instances from two of the three circuits, and this