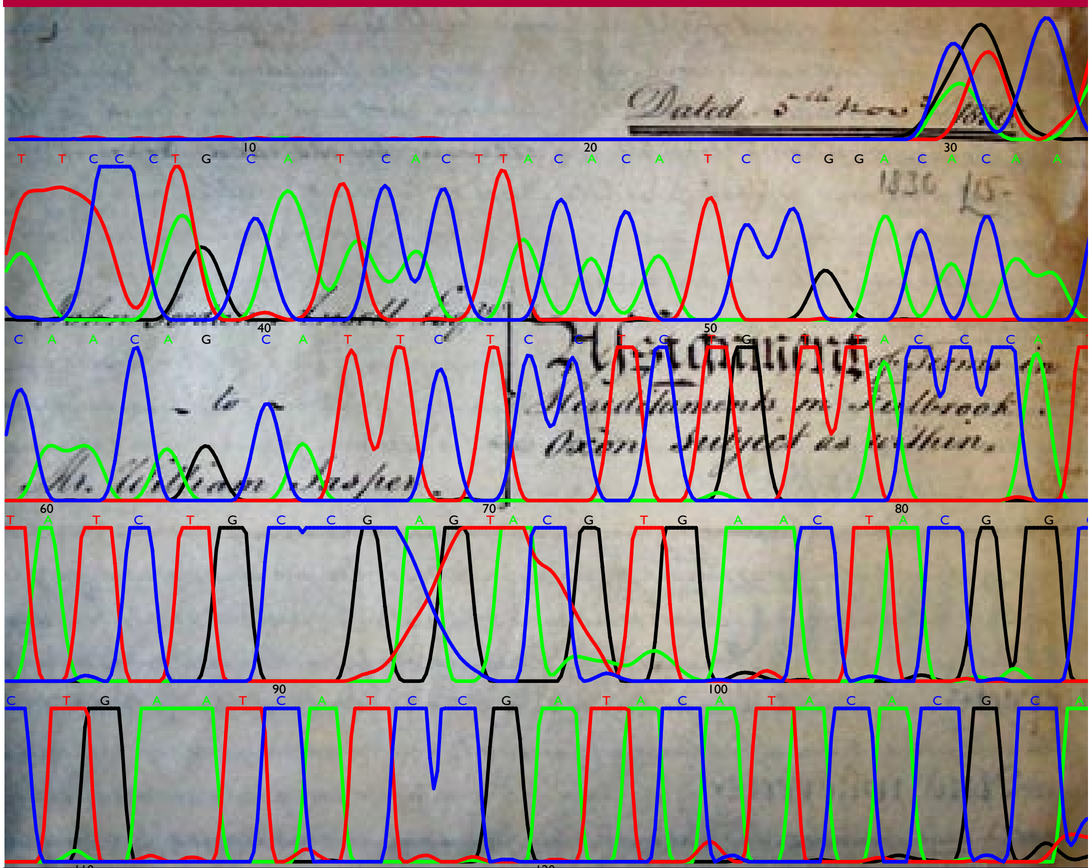
Issue 45 : Spring 2004

A BULLETIN OF THE HISTORIC ENVIRONMENT

Conservation bulletin

Issue 45 : Spring 2004

SCIENCE AND THE HISTORIC ENVIRONMENT



Typical DNA sequence results, showing four kinds of nucleotides. An unambiguous sequence will have a clear pattern of peaks without overlaps, but ancient DNA sequences are often damaged and hard to read. The underlying 19th-century legal document is one of a series of specimen parchments analysed by the University of Cambridge. Its study of ancient DNA signatures found in medieval parchments seeks to discover both the animal sources and the relatedness of the animals used.

ENGLISH HERITAGE

Science and the Historic Environment
Introduction

Martin Jones *Chairman of the Research Panel; Professor of Archaeology, University of Cambridge*
Sebastian Payne *Chief Scientist*

Developments in technology and scientific techniques have led to major advances in understanding and managing the historic environment.

Science makes a vital and often underestimated contribution to developing our understanding of the past and protecting the historic environment. This issue illustrates some aspects of this wide-ranging contribution.

New technology

Dating has been one of the more important areas of advance; it is hard now to remember how uncertain dating was only 50 years ago, before the common use of radiocarbon dating and dendrochronology. Dendrochronology recently dated the imported oak boards forming the ceiling of the nave at Peterborough Cathedral to the mid-13th century, much earlier than had been realised, and it has improved our understanding of the history of large complex buildings such as Lincoln Cathedral. Less spectacularly but just as importantly, the routine application of dendrochronology is bringing about a slow revolution in our knowledge of the history of the development of timber-framed houses, and we are now often able to date not only primary construction but also major rebuilding to the nearest year or two.

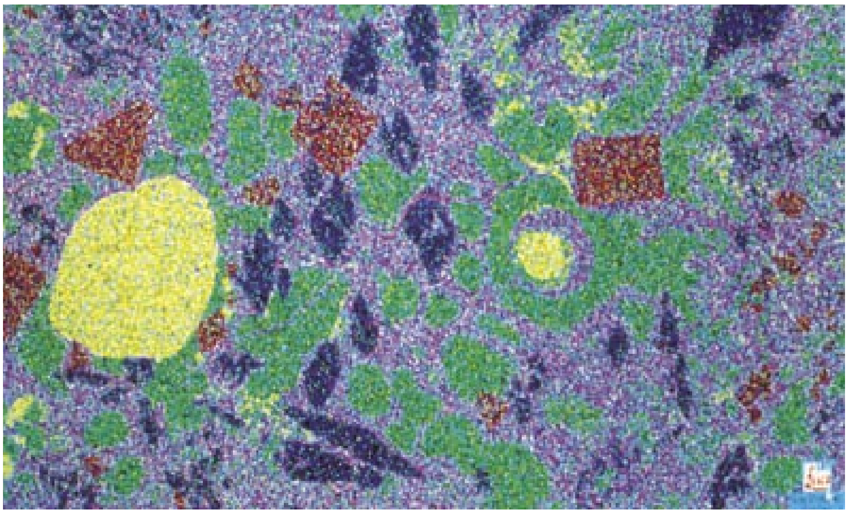
Radiocarbon dating has given us a secure dating framework for prehistory. Statistical modelling techniques applied to sequences of samples from the same site now date, often to within a few decades, events that happened several thousand years ago. A combination of radiocarbon dating and dendrochronology recently dated the construction of the timber circle (Seahenge) at Holme-next-the-Sea, Norfolk, to the spring of 2049 BC.

New techniques are telling us much more about how people lived in the past. Stable isotope analyses of samples from human teeth both answer questions about how important fish was in medieval diet, and also let us track changes in the diet of an individual within his or her life. X-radiography and densitometry of human skeletons show that osteoporosis was just as common in older women in a medieval Yorkshire village as it is today; though, interestingly, typical osteoporosis-related fractures were less common – possibly because medieval women were more physically active.

Small pieces of charred bread dated to the later fourth millennium BC – the earliest-known bread from Britain – have been recognised among charcoal fragments from Neolithic Yarnton, Oxfordshire. Stable isotope analyses of traces of fat in Neolithic pots from Windmill Hill, Wiltshire, Hambledon Hill, Dorset, and Eton Rowing Lake, Berkshire, show abundant traces of milk, revealing that secondary products were already important in Neolithic animal husbandry – though we still can't say whether the milk was from cattle, goats or sheep.

Non-destructive techniques

Another important advance has been the development of non-destructive techniques. X-ray fluorescence lets us analyse artefacts such as Roman brooches without having to drill them to remove samples, giving us a better understanding of how they were made, and of the locations of production and trade networks involved. X-radiography of the Iron Age mirror and sword from Bryher, in the Scilly Isles, has revealed details of decoration under the corrosion. Geophysical survey allows us to develop our understanding of archaeological sites without excavation – including, recently,



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False colour back-scattered electron image of a 12th-century litharge cake, a waste product of silver refining, from Guildhall Street, Thetford, Norfolk. The green areas represent a lead-copper oxide; dark blue, unreacted bone ash hearth lining; red, a tin-calcium-lead oxide; and yellow, droplets of silver metal. Similar finds are known from many Anglo-Saxon towns that had mints, showing that the silver content of the coinage was being carefully controlled (image width *c.* 1 mm).

the Neolithic henge and nine concentric pit circles at Stanton Drew, Somerset, the extensive Roman town outside the Roman fort at Richborough, Kent, and, on a larger scale still, the ancient settlements, cemeteries and trackways around Heslerton, North Yorkshire.

Scanning electron microscope

One of our most important new tools is the scanning electron microscope, which gives us much clearer pictures at high magnification than is possible with traditional microscopes. Modern scanning electron microscopes also allow us to analyse and map variations in the composition of what we see. This combination of structure and composition applied to waste products such as litharge cakes gives important new insights into manufacturing processes: tiny patches of precious metal reveal that a medieval brooch was originally silver-plated, or a Roman one mercury-gilded. Analysis of small glass threads from Silkstone, Yorkshire, a 17th-century glass-working site, confirms that lead glass was worked on the site, providing rare direct evidence of the transition to lead glass production in this country.

Understanding decay

Conservation of objects and buildings has been revolutionised by a better understanding of historic materials and how they decay – from buildings and wall paintings to buried archaeological sites. Research on historic mortars has resulted in a better understanding of their advantages in the conservation of buildings, and those mortars are being produced and used again.

Another major advance has been in realising the importance of the remains of cloth and other organic materials preserved in iron and copper corrosion. These remains have enabled the reconstruction of clothing, weapons and various personal items included with burials in the Anglo-Saxon cemeteries at Mucking, Essex, and West Heslerton, North Yorkshire. One result of this advance is that conservation has moved away from cleaning objects for display to investigation and storage in passive environments, so that more material remains for future research when techniques have improved still further.

Ecological studies

Pollen analysis and other palaeoecological studies contribute to our understanding of how people have modified the natural environment over the past 10,000 years to create the patchwork of woods, hedges, fields, settlements, ponds and rivers in the historic environment that contributes so much to our quality of life. This understanding is particularly important in managing the historic environment in the light of human impacts, such as farming, forestry and development, and possible climate change.

CfA: our advisory role

It is vital, in a world of rapid change and technological advances, that English Heritage stays at the forefront in using science to improve our understanding and management of the historic environment. We have recently set up well-equipped laboratories at the Centre for Archaeology, Fort Cumberland (CfA), where the facilities include an up-to-date scanning electron microscope with analytical capability, X-ray fluorescence and X-ray diffraction equipment, real-time X-radiography, a freeze-drier, and outstanding reference collections of seeds and animal bones. We also work closely with universities and fund a number of specialist posts; examples of this collaboration include the Neolithic dairying project with the University of Bristol, dendrochronology at the University of Sheffield, where we fund two posts, and radiocarbon dating contracts with the University of Oxford.

Our advisory role is also vital. We work increasingly closely with English Nature and the Environment Agency. For the past five years, we have funded regional science advisors in each of the nine regions, who work closely with regional teams, local authority archaeology officers and the staff at the CfA to improve the scientific contribution to understanding and managing the historic environment. □

Tree-Ring Dating at Salisbury Cathedral
Informing Repairs

Peter Marshall *Assistant Scientific Dating Coordinator, Centre for Archaeology*
Daniel Miles *Oxford Dendrochronology Laboratory*
David Heath *Chief Conservation Architect*

The identification of 750-year-old under-lead sarking boards from Salisbury Cathedral by tree-ring dating illustrates the benefit of an informed approach to the repair and conservation of the historic environment.

Establishing significance is a key requirement of conservation research, and the application of dendrochronology to provide precise dating of timbers within historic buildings is a technique extensively used by English Heritage. Tree-ring analysis can provide precise dates and, when combined with building analysis, can also provide a powerful tool for understanding the development of structures.

Ongoing work at Salisbury Cathedral exemplifies the importance of 'informed conservation' and the role that tree-ring dating can play in determining repair specifications.

Salisbury Cathedral is considered by many to be the epitome of Early English church architecture. Unlike most other cathedrals, it was built almost entirely in accordance with a single design of unparalleled coherence and elegance. The first foundation stones were laid in 1220, and the cathedral was consecrated in 1258.

Major programme of roof repairs

Since 1997, a major programme of repairs to the roofs of the Cathedral has been grant-aided by English Heritage, to renew the lead coverings and timber structures that form the roofs. The works have given unparalleled access to the roof timbers and allowed for a full investigation of them as part of the conservation programme. Such an informed approach to conservation has a long history at the cathedral. In 1668, Christopher Wren produced the first objective survey and a series of recommendations for the repairs of the roofs. Although not acted on until Francis Price was given the post of Clerk of the Works in 1737, Wren's survey led to a massive rebuilding campaign of virtually all of the roofs. The north nave triforium escaped with only minor repairs and thus its re-leading in 2000 provided a unique opportunity for dendrochronological investigation of its timbers. Unfortunately, due to the recent defrassing of the roof timbers, very little sapwood survived, as the majority of bark-edge surfaces left on the timbers by the original builders had been removed.

Described by Cecil Hewitt as being 'the most impressive lean-to roof surviving in any English cathedral,' the 200-foot-long north nave triforium roof extends for ten double bays from the west front to the central crossing. A unique feature of the roof is the survival of sarking boards measuring ½–¾″ thick and 4–6″ wide. Although a number of phases of boarding

North nave triforium showing wall plates and roof sarking boards.

Salisbury Cathedral from the south-east.

were thought to survive, most were assumed to date from Price's 18th-century repairs. As the repair proposals included the removal of those boards and their replacement with new treated softwood boards, precise dating of them was required before their removal.

Irish medieval timber

Once the roof lead had been removed, the quality of the boards quickly became apparent, and the possibility that they were medieval was raised by Dan Miles, the dendrochronologist commissioned by English Heritage. Following consultation with Michael Drury, the cathedral architect, it was agreed that no boards would be removed until the spot dating of a representative sample was complete. Analysis concluded that the oak boards were part of the original mid-13th-century construction of the north nave triforium roof and that they originated from Ireland. As well as the survival of a considerable number of boards from the original construction of this part of the cathedral, further analysis also identified material from three post-medieval repair phases. The first, dating to the early 1660s, represents repairs carried out to the roof after the Civil War, when the lead was stripped from this part of the building. Two boards with felling dates of spring 1669 probably represent minor repairs following Wren's report, and finally a series of boards dating to the spring of 1763 relate to the repairs carried out by Francis Price.

The survival of Irish under-lead sarking boards dating to the first half of the 13th century was completely unexpected and challenges ideas about the survival of such material in historic buildings. The evidence from Salisbury suggests that sarking boards may be considerably older than the roof lead they support, and it should not be assumed that because a medieval building was re-leaded in the 19th century, the original sarking boards have been replaced. At Salisbury, under-lead boards in the roof of this part of the cathedral have clearly been retained by past repair programmes. Recognition of the early boards has resulted in their being left *in situ* where possible if they were not hindering the re-leading works. This was achieved by diagonally overboarding the historic boards with new softwood boards to support the lead.

The use of tree-ring dating at Salisbury Cathedral exemplifies the key role that scientific techniques have in providing objective information for informing conservation of the historic environment. □

By defrassing, I mean the removal of the outer layer of wood from… timber elements, where they have either been worm eaten, rotted by fungus or been abraded. Usually it is undertaken as a specific element of a repair programme to a timber-framed structure… by adzing/axing… or by sand blasting… Which bits of an oak timber get defrassed? Always it is the sapwood… because oak heartwood is almost invulnerable to wodwood attack… What effect does it have on the archaeology of the building? It… removes historic surfaces that may contain tool-marks, numbering schemes and chamfer details… What effect does it have on the dendrochronology? It stops us being able to provide exact felling dates for some buildings or phases of building, or reduces the ring counts sufficiently that we cannot date buildings at all.

Extracts from a letter of 8 November 2001 by Ian Tyers, Dendrochronology Laboratory, University of Sheffield.

3D Laser Scanning
New techniques of observation

Paul Bryan *Metric Survey Team Leader and Head of the Photogrammetric Unit, York*

New developments in laser scanning now provide a high-speed, high-density observation of 3D data.

Electronic Distance Measurement equipment (EDM) and its reflectorless version (REDM) allow the user to select a range of points for measurement ('point and shoot' devices). Laser scanners offer an alternative to EDM and REDM by providing an automated, reflectorless process that collects three-dimensional (3D) data in a 'mass capture' manner. Often referred to as a 'data or point cloud', this collection of 3D observations holds no 'intelligence' on the object that has been surveyed, unlike observation using EDM or REDM with its selected measurement points. Depending on the choice of scanner, this 'data cloud' can contain an immense amount of 3D data, ranging from thousands to millions of points recorded every second. Such large volumes of data, however, require time and computing power to convert them into useable products. For projects that provide only a short time for survey, though, laser scanning is of great benefit.

Types and applications

Though this article is focused on terrestrial applications, laser scanning can be applied to any scale of survey, from a sub-millimetre analysis of an archaeological artefact to the visualisation of an entire historic landscape. Such variations require different equipment, and for larger-scale applications, aerial platforms such as fixed wing aircraft or helicopters are regularly used to transport the scanning equipment across the landscape at the desired speed and flying height for appropriate observation.

Aerial LiDAR survey

This application – commonly referred to as aerial LiDAR (Light Detection And Ranging) – produces 3D 'data clouds' which can be processed to provide a Digital Terrain Model (DTM) of the landscape. This can be used either as an output in its own right or as the basis for further 3D modelling using artificial rendering or image-draping techniques.

There are currently two types of terrestrial systems in use, based on LiDAR technology or on 'structured light' principles. The LiDAR system, similar in operation to the speed cameras used by many UK police forces, works by emitting a series of infra-red measurement beams in an array, using automated sweeps. The intensity, speed and array type all vary, depending on the device used, but they still produce a 3D 'point cloud' that is capable of supplying both surface and reflectance information from the scanned scene. The point accuracy is typically 5–25 mm and the range 5–50 m, making the LiDAR system more useful for medium- to large-scale projects.

Close-range scanners are based on 'structured light' principles and consist of a laser and charge coupled device (CCD). The CCD records the displacement of a stripe of laser light projected onto an object. The fixed geometry between laser and CCD enables simple triangulation to determine the position measurement. The point accuracy is typically 0.2–2 mm and the range 0.1–5 m, making them more appropriate for small-scale projects.

Both terrestrial and close-range laser scanners have been used to generate 3D images of the shaft and galleries in Greenwell's Pit, Grimes Graves, Norfolk.

Grimes Graves, Norfolk. Greenwell's Pit is marked by a yellow-brown area towards the bottom centre of the photograph.

Other survey techniques such as photogrammetry produce the same level of 3D information, but there is no hard and fast rule to follow when selecting a technique. The client must balance the advantages and disadvantages of each technique to match the project requirements.

Application by English Heritage

Since the first terrestrial laser scanner appeared in 1999, the English Heritage Metric Survey Team has studied its application within the historic environment sector. As well as funding a recently completed three-year research project with the Department of Geomatics at the University of Newcastle – *Laser Scanning for Heritage Applications* – our study has included trial scanning on several English Heritage projects including Ironbridge, Shropshire, Chatterley Whitfield Colliery near Stoke-on-Trent, Staffordshire, the 'Seahenge' timbers from Holme-next-the-Sea, Norfolk, and most recently, Grimes Graves, Norfolk.

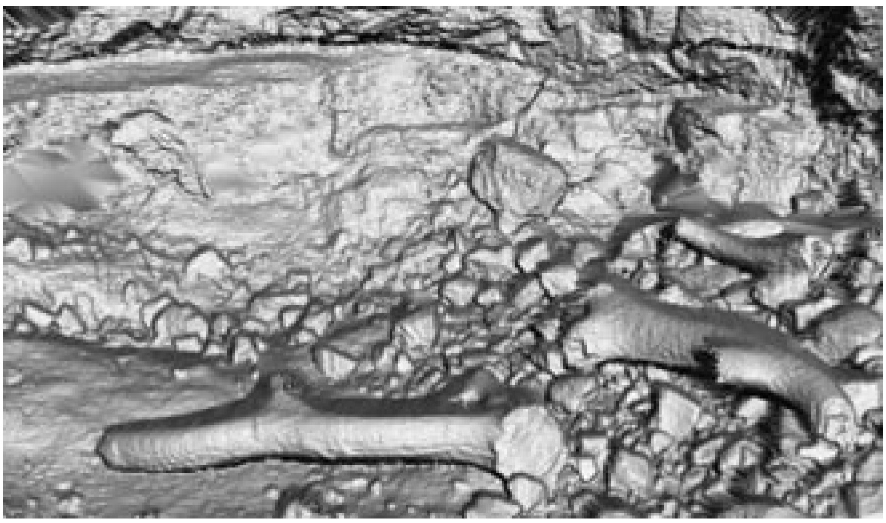
The area of heathland known as Grimes Graves lies seven miles north-west of Thetford, Norfolk, and is the earliest major industrial site in Europe. These remarkable flint mines, dug by Neolithic miners some 4000 years ago, can still be seen today. There are about 400 shafts across the 40-acre site, many of which are shallow hollows, though some have been excavated and may be descended by ladder.

To enable a detailed study of the extent and scale of the mine, a laser scan survey of the shaft and galleries in Greenwell's Pit is currently underway. The first phase of survey was completed by a consultant in 2002, using a Cyrax 2500 terrestrial scanner. This survey has already provided a substantial amount of 3D and volumetric information about the size, shape and form of the subterranean mine workings. It is currently being supplemented by additional survey using a Minolta VI-900 close-range scanner to record in finer detail the remaining archaeological evidence, including angular irregularities of the chalk surface, shallow indentations in the gallery floors and axe marks left by the Neolithic miners. As well as providing an invaluable management tool to monitor any evidence of collapses within the mine, these surveys may also produce a 3D virtual model of the site. By combining the underground scan survey with the existing DTM of the surface, produced by English Heritage's Cambridge-based Archaeological Investigation Team, it is hoped that remote access will be available, when the project ends in early 2004, for a site too fragile to be opened to all visitors.

Towards a standard specification

Recently, the School of Civil Engineering and Geosciences at Newcastle University completed an English Heritage-funded research project – *Towards a Standard Specification for Terrestrial Laser Scanning of Cultural Heritage* – to produce an addendum to Metric Survey Specifications for English Heritage outlining the requirements for the use of terrestrial laser scanning.

Although the project set out to cover all aspects of the process, including the capture, use and storage of scanned data, the addendum



has concentrated on the collection and archiving of 'point cloud' data obtained by terrestrial laser scanning. Though scanning has already been applied to some building recording projects in the last three years, and most scanners now feature some form of vector generation within their processing software, the use of the data has still to be defined in terms of standard products. The production of 3D CAD and meshed models, profiles and cross sections, and animations and visualisations are all potential outputs from scanned data, though their presentation or level of attainment has yet to be specified. For cultural heritage projects, it is worth considering the type of fabric to be surveyed, the potential for voids in the data set, the minimum feature size to be recorded and the minimum ranges available before selecting laser scanning technology.

However, where traditional vector output is required, often for accurate 'edge detection', English Heritage currently considers it more appropriate to use survey techniques such as hand survey, theodolite/REDM survey and photogrammetry, which produce detailed architectural drawings and are included in Metric Survey Specifications for English Heritage.

Future research and development

An agreement must be reached on a common data exchange format for all laser-scanned data. Aerial surveyors have welcomed the recent announcement by the American Society of Photogrammetry and Remote Sensing (ASPRS) of an industry standard for the exchange of LiDAR data between manufacturers, software developers, data providers and users. This 'LAS' format has widespread international support. Further research and development should include informed users such as English Heritage to ensure that proper tools and formats are available for cultural heritage projects. □

REFERENCE

Barber, D *et al* 2003 'Towards a Standard Specification for Terrestrial Laser Scanning of Cultural Heritage', in *New Perspectives to Save Cultural Heritage: CIPA 2003 International Symposium, 30 September–4 October 2003*, 619–24, CIPA / ICOMOS (ISBN 975-561-245-9)

The results of the terrestrial laser scanning project were presented at the CIPA XIXth International Symposium on 'New Perspectives to Save Cultural Heritage', held in Antalya, Turkey, 2003; the addendum is available on request. Further information on the survey work of English Heritage and its use of laser scanning technology may be obtained from the Metric Survey Team (paul.bryan@english-heritage.org.uk). *Metric Survey Specifications for English Heritage* (Product Code 50562, price £15) may be ordered from English Heritage Postal Sales, c/o Gillards, Trident Works, Marsh Lane, Temple Cloud, Bristol BS39 5AZ. Tel 01761 452966; Fax 01761 453408; ehsales@gillards.com.

3D LASER SCANNING	
ADVANTAGES	DISADVANTAGES
Applicable to all 2D and 3D surfaces	Some systems do not work in sun or rain
Rapid 3D data collection – near 'real-time' – requiring substantially less site time	Large, high-resolution 3D data sets require post-processing to produce a useable output
Very effective due to large volumes of data collected at a predictable precision	Difficulty in extracting the edges examples from indistinct data clouds
Ideal for all 3D modelling and visualisation purposes	Output requires manipulation to achieve acceptable recording quality
Both 3D position and surface reflectance generated which, when processed, can be viewed as an image	Does not currently generate an image comparable to those produced by other techniques
Extensive marketing from manufacturers and exposure to technology by clients, through conferences	No common data exchange format – such as DXF – currently in use to allow ease of processing by third parties
Rapidly developing survey technology	Difficult to stay up-to-date with developments
Extensive world-wide research and development currently being undertaken on both the hardware and software tools	With hardware still expensive and sophisticated software required to process data, cost is prohibitive for many projects

Science-based reports
A proposal for presentation

Helen Hughes *Head of Historic Interiors, Research and Conservation*

The presentation of science-based research is a current topic of debate among conservators. This proposal keeps the needs of the commissioning client in view.

There has been much debate among conservators about the importance of presenting scientific evidence in a clear and useful manner. At De Montfort University's conference on 9 September 2002, 'Where Conservation meets Conservation,' speakers and delegates stressed the need for improved communication between members of the conservation research team and clear presentation of scientific evidence.

In a keynote lecture at the United Kingdom Institute for Conservation 's annual general meeting on 9 July 2003, Norman Tennent of the University of Amsterdam, advised that science-based research reports should be written to be readily understood by commissioning clients. If not, he warned, it was increasingly likely that the results of scientific investigation may be ignored. Conservation scientists who use technical jargon, unexplained data, inappropriate formats and conclusions presented in unexplained spectrograms or stratigraphies help no one.

Most technical investigations are commissioned by informed professionals who expect information to be delivered in user-friendly packages, enabling them move a project forward. If they do not understand a report, it is the author who is at fault.

Research collaboration

Ian Jardin, the project manager of English Heritage's conservation of Danson House, London, stated that the success of that project was due to the willingness of the research team, historians, building analysts, curators and conservation scientists to share their results and develop ideas collectively. In the modern conservation world, despite the constraints of time and budgets, such collaboration is essential for the timely delivery of high quality research.

A proposal for reports

To ensure that scientific investigation plays its proper role in conservation, scientific and technical reports should be written in two parts.

Part I

The first part should present the brief, research findings and recommendations in a simple manner, using illustrations and summary charts. In architectural paint research reports, for example, it is useful to distil the findings into a narrative of the history of a building and its occupants, supported by a simple chart of key developments.

Part II

The second part – or appendix – should provide the supporting technical data. If clients are interested in the details that support the conclusions in Part 1, they may refer to this data.

To keep the whole team abreast of developments during the course of the research phase, the project manager should circulate a 'research update chart' by email. All team members would summarise their findings to date and add references to newly discovered data, with the understanding that this is work in progress, to be altered if new discoveries are made. This chart would encourage communication between disciplines and provide an unexpected research synergy that could result in dramatic discoveries. □

REFERENCE

Jardin, I 2002 'Architectural paint research in practice', in Hughes, H (ed) *Layers of Understanding: Setting standards for architectural paint research*. Shaftesbury, Dorset, and Massachusetts: English Heritage in association with Donhead, 27–30

Mapping Roman earthworks
Photogrammetry: Cawthorn Camps

Jane Stone *Investigator, Aerial Survey*
Michael Clowes *Senior Photogrammetrist, Metric Survey*
Ed Dennison *Archaeologist, EDAS*
Graham Lee *North York Moors National Park Archaeologist*
Pete Wilson *Senior Archaeologist, Centre for Archaeology*

Aerial photography, digital photogrammetry, ground survey and excavation have been used to improve our understanding and management of Cawthorn Camps.

The current programme of research at Cawthorn Camps is a joint venture funded by the North York Moors National Park Authority and English Heritage. The purpose of this work is to improve academic understanding, to investigate erosion and to inform the future management of the site. The project is multi-disciplinary in its approach, combining geophysical, aerial and topographic survey, and excavation.

Digital photogrammetry: the plan

To underpin the work at Cawthorn, it was essential to have a metrically accurate base map of the site. This requirement was an opportunity to record the earthworks using the latest digital photogrammetric technology and large-scale, vertical air photographs, the first time English Heritage has undertaken a photogrammetric project on earthworks at this scale and level of accuracy.

Photogrammetry is the art and science of using stereo photography to obtain accurate measurements of a subject. The latest photogrammetric equipment involves viewing three-dimensional (3D) digital images on a computer monitor using polarising glasses.

These stereo models are geo-referenced by the inclusion of accurate control data observed on site. Features of interest are drawn from the 3D models to create a metrically accurate plan. Within English Heritage, photogrammetry is most commonly used for the recording of buildings, although it has also been used to record archaeological landscapes, notably in upland areas, from air photography.

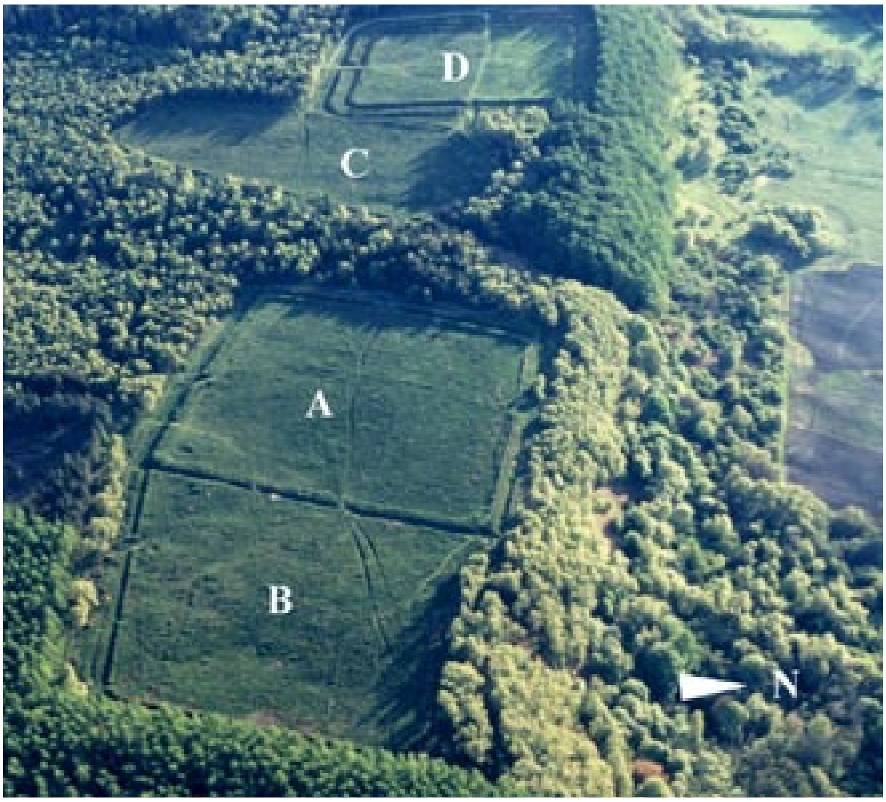
The vertical air photographs used for the mapping of Cawthorn were taken in May 2000, when vegetation on site was low. The ground control used to establish the models was observed using the Global Positioning System to an accuracy of ±12 mm. The results of the interpretation and plotting, which took 35 days, far exceeded initial expectations, with banks of as little as 10 cm in height being recorded.

The rectification of other photographs and plans with the photogrammetric plot led to further interpretation and mapping, including the precise identification of many excavation trenches and spoil heaps visible on photographs taken in 1925, as well as World War II features from photographs taken in 1945.

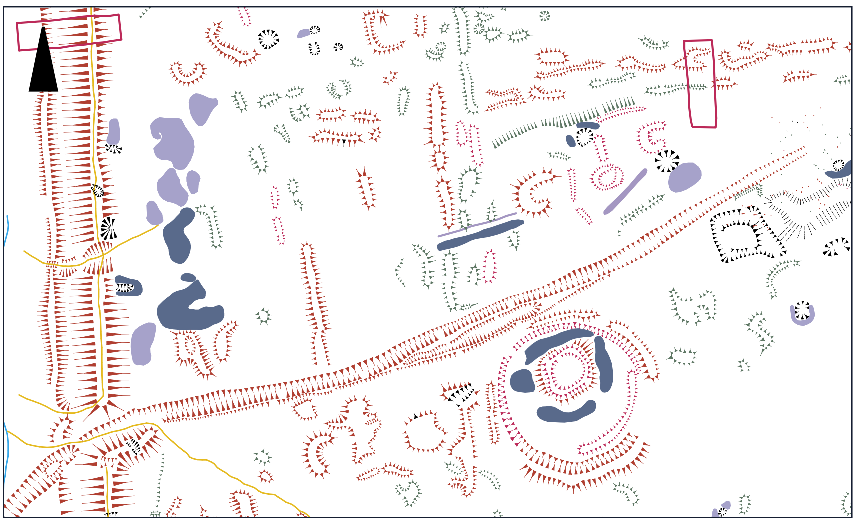
Manipulation of the data

Digital photogrammetric workstations can further manipulate the digital imagery to create other products including automatic digital elevation models (DEMs), perspective views and orthophotographs. (An orthophotograph is an

A greyscale view of Cawthorn generated from a DEM of 1 m spacing, viewed from a near vertical angle with lighting from the north-east.



Cawthorn Camps, an important scheduled earthwork site primarily of Roman date, comprises an elongated camp, C, and two forts, D and A; one enlarged by the addition of a later annexe, B.



The hachured plan of a western part of fort A is accurate to ±10 cm. The colours represent different categories of feature: for example, old excavation trenches and spoil heaps are recorded in blue. The magenta rectangles represent trenches opened in 1999–2000.

image that has had the perspective errors due to angle of view removed.)

Trials were undertaken to investigate how useful the automatic DEMs would be in identifying earthworks; the results were encouraging, with a large amount of detail visible. The software also allows the operator to change the direction and angle of the simulated sunlight to highlight the features to best advantage – a critical factor in identifying earthworks.

In summary, the work at Cawthorn has demonstrated the potential for recording earthwork sites using digital photogrammetry and has shown the level of detail that can be recorded from large-scale air photographs. The interpretative and illustrative use of some of the digital photogrammetric products has been highlighted. Moreover, the vertical photographs, together with the use of photogrammetry, provide an accurate and objective condition statement for the earthworks as at May 2000, useful as a baseline for future condition monitoring. This is an increasingly important consideration as the problem of erosion of earthwork sites grows.

Ground survey of the earthworks

A detailed topographic survey of fort A and annexe B was begun by Ed Dennison Archaeological Services Ltd (EDAS) before the aerial photogrammetric work. A 1:500-scale hachured plan was produced (with detail at plotted at a scale of 1:200).

There was a degree of overlap between the results of the two survey techniques. While the aerial photogrammetric work identified many slight features otherwise hidden by ground vegetation, the on-site survey recorded subtle nuances often seen on earthwork sites, as well as those features obscured on the aerial photographs by woodland. However, the ability accurately to overlay other data – such as old excavation trenches and spoil heaps – taken from aerial photographs is a significant advancement, and the combined results of both surveys provide a comprehensive addition to our knowledge of this complex site.

Excavation

In 1999 and 2000, ten trenches were excavated both to assess modern impacts on the site, including forestry, military training and visitor erosion, and to enhance our understanding of the earthwork complex. Both forts (A and D) were shown to have two phases of ramparts, and fort D four phases of ditch. Some of the slight earthworks in fort A and annexe B were shown to be early Roman military buildings. Their survival as earthworks is unique. The excavations also demonstrated the fragility of the remains. In one area, a feature visible in both the aerial photogrammetry and the earthwork survey was shown not to have survived below the root mat. □

For further information on the air photographic and photogrammetric work undertaken at Cawthorn, contact Jane Stone (jane.stone@english-heritage.org.uk).
A full archive report of this work is available through the NMR.
For information on the overall project, including the excavations, contact Pete Wilson (pete.wilson@english-heritage.org.uk).

Geochemistry: Richborough
Analysis of the Roman town

James Moore *Research Assistant*
Jen Heathcote *Geoarchaeologist, Centre for Archaeology*

A study at the site of the Roman town at Richborough in Kent, designed to test aspects of the technique of geochemical analysis, has established procedures for future projects and yielded intriguing results concerning the nature and location of activities within the town.

Geochemical analysis of archaeological deposits exploits the fact that human activity may modify the chemical composition of soil, creating anomalous, localised accumulations of elements such as copper, lead, zinc and phosphorus.

Soil phosphorus has a long tradition of use as an indicator of past human activity, accumulating as a consequence of social and agricultural processes (such as food preparation and the input of faeces, domestic waste or manure). In contrast, analysis of the heavy metal content of soils is a more recent development, based on the theory that its concentration may be enhanced through the incorporation of organic and inorganic materials into the soil. By analysing the relative concentrations of these metals, anomalies may be identified that signify locations where people have engaged in particular types of domestic, craft or industrial activities.

As part of a wider landscape project that included geophysical survey, aerial photograph transcription and excavation, a trial geochemical survey was carried out in 2001 at the site of Richborough Roman town in Kent. The primary aim of the geochemical work was to develop a methodological framework – from on-site sampling to laboratory analysis – that might be applied on other sites in the future. Another integral part was an assessment of the current use of geochemical survey in archaeology. This led to the conclusion that, although geochemical survey has been applied to a number of sites, there has been little attempt to characterise the nature of anomalies occurring as a consequence of particular identified activities.

Methods

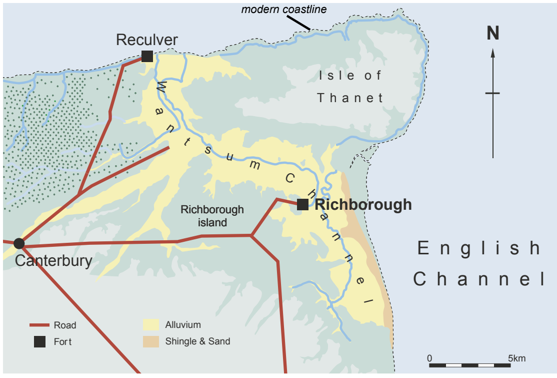
The survey covered approximately 8–9 ha, with samples typically taken at 30 m intervals, although in one complex area of the site, samples were taken every 15 m. These samples were analysed using ICP-AES, a method that quantifies the minute concentrations of chemical elements present, typically expressed as parts per million (ppm). The results were then plotted for each element so that clusters of concentrations of, for example, lead could be recognised.

Plan of Richborough showing position of elevated value (yellow, orange, red: 1, 3 & 4) and low value (blue: 2, 5, 6 & 7) chemical anomalies.

What happens where?

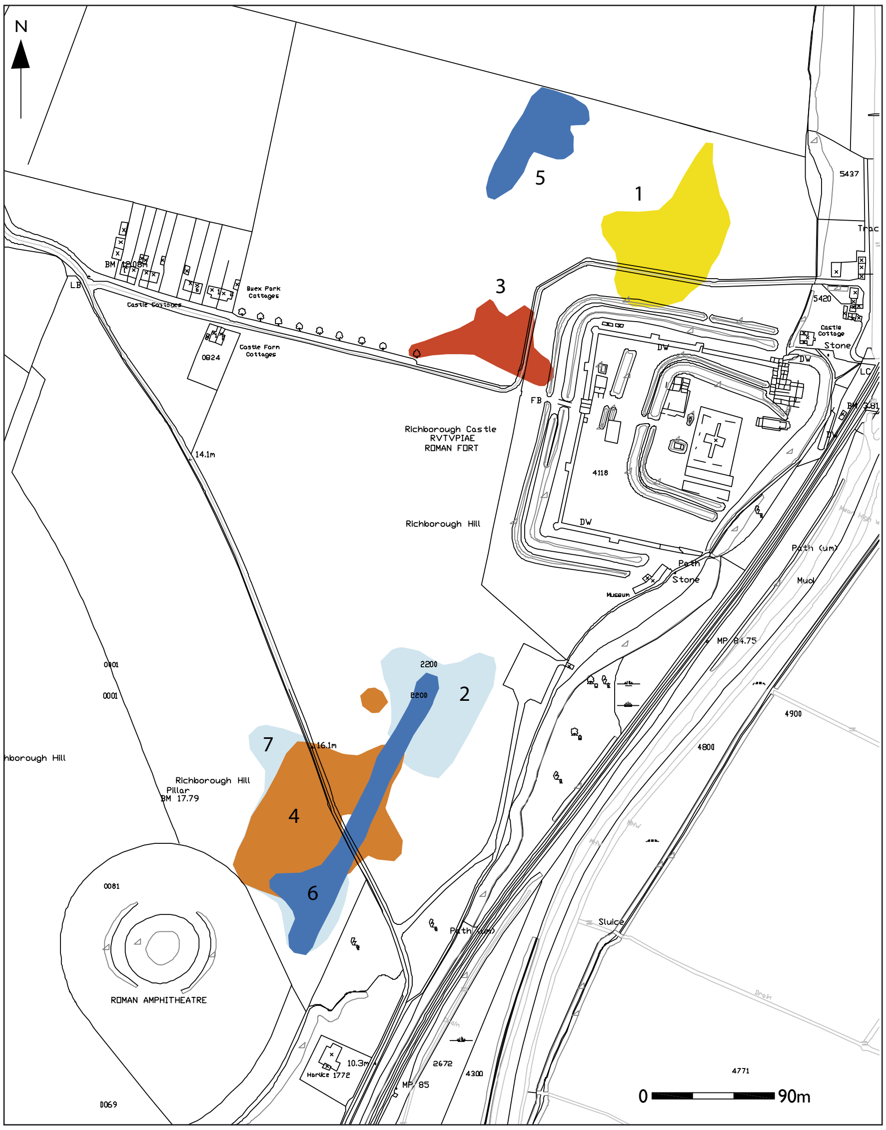
Several clusters of samples showing relatively enhanced concentrations and low concentrations of a number of elements were detected. In addition, several isolated samples showing elevated levels of individual elements were found which may relate to smaller anomalies.

Richborough, the main entry port for Roman Britain. View across the triple ditches.



Location of the site showing the Roman landscape with road connecting the fortifications at Richborough and Reculver to Canterbury.

The geophysical and 15m geochemical survey, showing zinc anomaly (red) and the thermo-remnant anomalies.



Of particular interest was an anomaly detected to the west of the 4th-century fort. This contained elevated concentrations of a number of elements (calcium, copper, lead, magnesium, manganese, phosphorus, strontium and zinc: calcium is a major component of shell, bone and mortar; strontium is commonly associated with marine-derived flora, fauna and minerals).

The area of the anomaly 3 corresponds to an area of disturbed magnetic response from the geophysical survey; amounts of Roman material (fragments of mortar, shell, bone and pottery) were noted as inclusions in the samples. All of the elements detected have been suggested by other geochemical surveys to be good indicators of everyday human activity. Specific activities or features, however, have not been linked to them, although the presence of phosphorus (and possibly of copper) suggest the presence of organic material. No clearly defined features were visible on the geophysical or aerial photograph surveys in this area. Despite this lack of visible evidence, the combination of the location of the anomaly and the geochemical signature may hint at the presence of mortared buildings, rubbish pits or possibly burials. Only tentative hypotheses can be made without further excavation.

Elsewhere, an anomaly contained highly-elevated levels of zinc correlated with strongly magnetic geophysical anomalies. As zinc was not used as a separate metal until the late medieval period, this anomaly may provide evidence for copper alloy working (such as brass, an alloy of copper and zinc). Given the scarcity of evidence for copper alloy smelting, the anomalies may represent hearths relating to the casting or wrought metalworking of brass.

Further work

The study was designed to test certain methodological aspects of geochemical survey, including sample collection, sampling intervals and data analysis. In has also produced tantalising results regarding the potential location of particular activities at the site of Richborough Roman town.

Further work is now being carried out to refine our understanding of the range of elements that can be used as indicators of particular types of activity, such as cooking, dyeing of textiles or iron-working. This research is essential if we are to recognise the full potential of geochemical analysis as an interpretative tool that allows us to examine the function of individual structures and the use of space within settlements. □

Geophysics: Richborough
Characterising the Roman remains

Paul Linford, Neil Linford, Louise Martin and Andrew Payne
Geophysics Team, Centre for Archaeology

Richborough in Kent has long been considered the principal Roman entry point into the British Isles. Recent work by English Heritage has revealed much new information about the character and extent of the Roman occupation.

Remains of the 3rd-century Saxon Shore fort at Richborough survive as an impressive reminder of Roman military engineering. To the south, a raised sub-circular mound is speculated to be the location of an amphitheatre. These sites, both in the care of English Heritage, are situated on what was once an island, dominating and protecting the now-silted-up Wantsum Channel. During 2001, the English Heritage Centre for Archaeology, in partnership with the Universities of Southampton and Cambridge, and local research groups, conducted archaeological research to improve understanding of these monuments and their setting. Before this work, limited antiquarian investigations in the mid-19th century provided sketchy clues about the supposed amphitheatre while later excavations, primarily between 1922–38, produced a wealth of information about the various phases of activity within the ditches of the Saxon Shore fort.

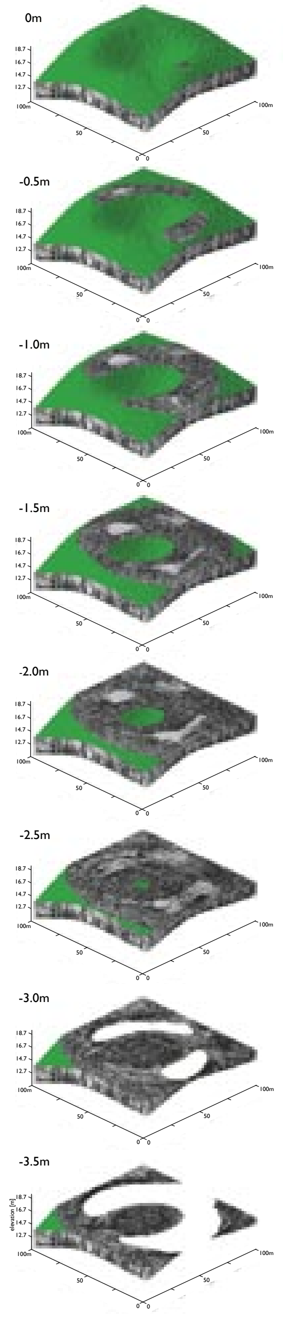
Very little was known, however, about related Roman occupation in the intervening area. Thus, as a precursor to excavation, the Geophysical Survey Team conducted extensive surveys over the land surrounding the fort as well as more intensive investigation of the site of the amphitheatre. This work complemented the existing aerial photographic record.

The Roman town

A magnetometer survey of about 21 hectares was conducted around the fort and over the amphitheatre. The magnetometer responds to changes in the magnetic properties of the soil caused by human activity in the past, and anomalies associated with Roman remains show up in white against the grey background level. The results show a dense pattern of settlement along newly discovered roadways – quieter, less inhabited areas and traces of former field systems. It is clear that the fort and amphitheatre did not exist in isolation but were surrounded by a thriving and extensive settlement. More detailed analysis of the data suggests that development of the town was irregular, not planned, and complex areas of superimposed anomalies suggest several phases of activity.

The amphitheatre site

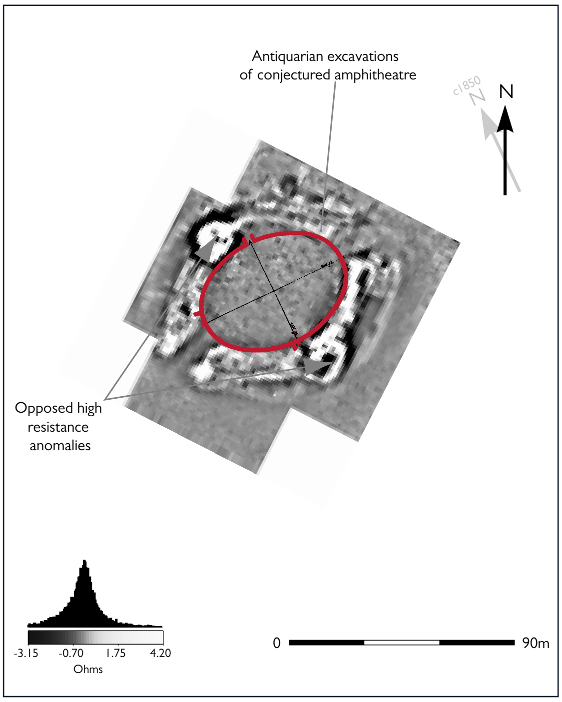
The circular field containing the remains of the conjectured amphitheatre lies at the southern end of the magnetometer survey. This survey has revealed an arc of Roman buildings surrounding the mound but little information about structures within it. An earth resistance survey was thus conducted over this area. This technique uses electric current and responds to differences in soil moisture content. The results considerably improve the interpretation of the monument and identify a number of significant near-surface anomalies. These anomalies not only appear to confirm its interpretation as an amphitheatre but also demonstrate that the antiquarian excavations by a Mr Rolfe in 1849 were indeed limited, recording only what was probably an inner wall, perhaps separating the *cavea* from the *arena*. Two entrances are clearly visible on the SW-NE alignment as breaks between the two elliptical walls. Other intriguing anomalies include two high resistance responses (showing up in white) within the walls of the amphitheatre that may represent additional, stone lined, entrances to the monument.



Antiquarian excavations (*right*: shown in red) in the area of the amphitheatre.

Visualisation of the GPR data (*left*) as 3D volumes at 0.5m increments to account for the significant variation of topography over the site.

Plot of fluxgate gradio-meter data over base OS map (*below*). The extent of known archaeology outside the fortified area, excavated between 1922 and 1938, is shown in red.



To gain further insight into the nature of the remains, an electromagnetic survey was conducted over a sample area within the amphitheatre. This method uses low frequency radio waves to detect changes in both the magnetic and electrical properties of the ground. It is comparable to the earth resistance survey but also shows evidence of recent military activity, mapping an electrical cable running into the centre of the amphitheatre.

Finally, a ground penetrating radar (GPR) survey was conducted. This equipment characterises the depth of sub-surface remains by sending a burst of high frequency electromagnetic radiation into the ground and then measuring the time taken for reflected waves to return from buried objects. At the amphitheatre site, owing to the significant topographic variation, the migrated GPR profiles were corrected for elevation and the data visualised as a three-dimensional volume to aid interpretation of anomalies. This volumetric representation demonstrates that the NW high resistance response is the highest point of the buried structure, with the SE anomaly not becoming apparent until the 1 m cut-away. This latter anomaly also appears to be associated with the elliptical wall-type response possibly coincident with the structure excavated by Rolfe. However, the two enigmatic anomalies demonstrate a similar reverberating signal to that often observed from near-surface concrete structures. It is thus possible that these represent more recent features, perhaps military emplacements from the last war.

Hence, the geophysical surveys have confirmed the interpretation of the amphitheatre and shown that it was surrounded by a large Roman town stretching North beyond the Saxon Short fort. They also reveal new detail about its structure but further investigation will be required to completely uncover the history of this intriguing monument. □

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Climate Change Scenarios
Protecting historic assets

Jenifer White *Senior Landscape Advisor*

The historic environment sector should make full use of current research on climate change in developing its longer-term adaptation strategies.

The extremities of the English summer of 2003 generated further interest in the effects of global warming. At least 300 mature trees in the historic Royal Parks of London died. According to a Royal Parks report, tree and landscape repairs for Hyde Park alone were expected to cost more than £250,000. Concerns about the future of the fruit industry were raised, and, at the start of 2004, a claim was widely covered by the media that climate change could extinguish a million of the world's species by 2050.

Possible scenarios

Climate refers to the average weather experienced in a region over a long period, typically 30 years. This average includes temperature as well as wind and rainfall patterns. Since the early 1900s, increasing climate change has been recorded. To add to our understanding of these changes, the Department for the Environment, Food and Rural Affairs (Defra) commissioned a £12 million research project to study climate change and stratospheric ozone depletion, and to produce new scenarios of possible changes in the UK climate during the 21st century. As more information becomes available, these scenarios are updated. In December 2003, Defra reported that the scenarios suggest a future of hotter, drier summers and warmer, wetter winters and indicate that:

- annual temperature averaged across the UK may rise by between 2 and 3.5°C and some areas could warmer by as much as 5°C by the 2080s
- heavy winter rainfall events that occur every two years are expected to increase in intensity by between 5 and 20 per cent
- relative sea-level around the UK could rise perhaps as much as 86 cm in southern England by the 2080s, with extreme sea-levels being experienced more frequently.[1]

Even with these scenarios, there is much uncertainty about the reliability of middle- to longer-term climate change predictions.

Sector studies

More tools are being developed to help organisations assess how they may be affected by climate change and how they could prepare for the longer term. The UK Climate Impacts Programme (UKCIP), set up by Defra in 1997, aims to coordinate assessments of possible impacts of climate change for individual sectors and UK regions. UKCIP also acts as a bridge for research and decision-making in government and business. Its sector studies so far include gardens, water demand, health, biodiversity, the marine environment and the built environment. Findings have been published for nearly every region now.

It is difficult to map the longer-term implications for the historic environment as a whole, but projects are underway to develop policies for specific conservation issues. For example, English Heritage has been working with others on coastal erosion, river flooding, de-watering of wetlands, soil erosion, flooding and rain damage, and fire damage.

One of the first reports on aspects of the historic environment is UKCIP's report[2] on gardens. Commissioned by a partnership of organisations – the Royal Horticultural Society, the National Trust, English Heritage, Anglian Water, Defra, the Forestry Commission, Nottcutts, Royal Botanic Gardens Kew – the study was carried out by Reading University in 2002. It enabled this broad partnership to review climate change issues and establish research and conservation requirements.

From this initial work, a useful forum has grown for joint research and networking with other sectors. Examples include a joint project by the Woodland Trust and the Centre for Ecology and Hydrology on 'Nature's Calendar' (www.phenology.org.uk), which enlists volunteers to record spring and autumn events to help understand the effect of climate change on our woods and wildlife. In the first two years, nearly 10,000 people each year have helped to gather records. This data provides useful phenological information (the patterns of recurring natural phenomena in relation to climate change) that can be used to conserve historic landscapes.

Other research is being carried out by this climate change forum who are planning a conference in 2005 on trees in a changing climate. Also, the National Trust will use its parks and gardens to study aspects of climate change – sea-level rise, waterlogging, drought, stormy conditions – and their implications for horticultural and garden management.

University College London's Centre for Sustainable Heritage has been commissioned by English Heritage to determine how the historic environment sector should measure the impacts of climate change. This was one of the challenges identified in *State of the Historic Environment Report* (English Heritage, 2002) and *Heritage Counts: State of the Historic Environment Report* (English Heritage, 2003). The new English Heritage *Practical Conservation* guidelines will offer advice on the impact of climate change.

Conclusion

Although climate change is uncertain, conservation management must maintain and indeed improve the stability of heritage assets and their resilience to climate change. Managers will need to understand the risk of climate change as well as the risk of taking insufficient or excessive action. Monitoring, management and maintenance are essential for longer-term adaptation strategies. □

Westbury Court, Gloucestershire, flooded by the Severn in 2001.

© The National Trust

'Climate change is the most severe problem we are facing today.'
Sir David King, the Government's Chief Science Adviser. *Science* (2004) **303**, 176-7

'Doing nothing is not an option. You may doubt some of the [climate change] predictions and their likely impacts, but I suggest that a sensible analysis of the risks does not allow us to sit back and wait.'
Peter Ewins, Chief Executive, The Met Office, January 1999

In the South East, English Heritage is funding local recording and excavation, and a series of Rapid Coastal Zone Assessments where rising sea level, crustal subsidence and changing coastal defence regimes are resulting in damage and losses of archaeology.

The EU-funded Network for Integration of Coastal Wetlands Heritage and Environmental Management will address the impact of climate change on coastal wetlands by exchanging information and developing new approaches for use by historic environment and nature conservation managers.

Useful web sites:

www.defra.gov.uk/environment/climatechange for Defra's climate change information.

www.ukcip.org.uk for UK Climate Impacts Programme's climate change scenarios, sector and region studies.

www.heritagecounts.org.uk for *The State of England's Historic Environment Report*, and a report on risks to the historic environment.

1 Defra 2003 *Global Atmosphere Research Programme: Annual Report 2002–2003* available at www.defra.gov.uk/environment/climatechange/

2 Bisley, R and Hadley, P 2002 *Gardening in the Global Greenhouse: The impacts of climate change on gardens in the UK*. Oxford: UKCIP

Dust in Historic Houses
Conservation and management

Barry Knight *Head of Conservation Research, The British Library (formerly Senior Conservation Scientist, Collection Care, English Heritage)*

Far from being a curiosity, the study of dust has led to a new understanding of how visitors view historic houses and has implications for the use of resources and the management of housekeeping. It has also led to interesting scientific discoveries in their own right.

Housekeeping is a time-consuming activity for historic house staff, especially the removal of dust. Dust detracts from the appearance of the house and its contents and can cause physical and chemical damage to objects. If left for a long time, it may become much more difficult to remove. A balance has to be struck between cleaning or causing damage and increasing staff costs. Floors may be vacuum cleaned and polished surfaces dusted daily, while more sensitive or less visible surfaces may be cleaned only once a year.

For the past three years, English Heritage, the National Trust, Historic Royal Palaces and the University of East Anglia (UEA) have been working together to examine dust in historic houses. Initially, work concentrated on developing reliable methods of measuring the rate of deposition of dust, and on assessing different sources of dust. More recently, visitors' perceptions of dust and their reactions to it have been studied, as well as the possible mechanisms whereby dust particles 'cement' themselves to surfaces. The Leverhulme Trust has generously supported this project for two years and will continue to do so for a further year.

Counting dust

There have been two approaches to studying the rate of deposition of dust in historic houses. The first has relied on measuring the decrease in reflectance of a glass microscope slide as dust is deposited on it. The measured 'loss of gloss' as the surface collects dust is a good surrogate for the way people perceive dustiness, but it does not tell us anything about the nature of the particles – their size, shape and number. We have therefore chosen the second approach: counting the number of particles collected on a sticky surface or a glass slide, and measuring the fraction of surface area they cover.

The use of sticky samplers has been pioneered by Dr Young-Hun Yoon and Professor Peter Brimblecombe at UEA, while the counting of particles on glass slides has been brought to a high degree of automation by David Howell at Hampton Court Palace. Using a video microscope with a motorised stage and advanced image analysis software, he is able to take 50 readings from a slide in less than 2 minutes, and calculate the average number of particles per square millimetre and the percentage of the surface covered.

By placing sticky samplers or glass slides in a historic house and collecting them at intervals, it is possible to build up a picture of how rapidly dust gathers at different places. Ideally, it would be useful to know how the rate varies on a daily or even an hourly basis, and, although there are technically difficulties in this, Derek Bowden at UEA is working on a real-time dust-measuring device to relate the rate of dust deposition to visitor flow and numbers.

Where does dust collect?

Our initial experiments focused on one English Heritage property, Audley End House, two National Trust properties, Knole and Osterley Park, and Hampton Court Palace. Sticky samplers (white self-adhesive Teflon labels attached sticky side up to plastic tiddlywinks) were arranged horizontally or vertically in inconspicuous locations, out of the reach of visitors. These sticky samplers measured how the build-up of dust depended on varying

The State Bed, Howard Bedroom, Audley End, East Anglia. One of the most important surviving late-18th-century beds, supplied in 1786 by the London firm of Chipchase and Lambert. Measurements of dust deposition along the visitor route will affect decisions about conserving and protecting the fragile fabrics.

distances from visitor routes (delineated by ropes and stanchions) and on the height above the floor.

Major source of dust

First of all, these studies confirmed that visitors are the major source of dust in historic houses. Measurements at Knole, which was closed during the early part of 2001 because of the outbreak of Foot and Mouth Disease, showed that the amount of dust in the Brown Gallery increased 20-fold when the house re-opened. Measurements at all the sites showed that dust decreased rapidly with distance from the visitor route. In general, the rate halved with every additional metre of distance from the route. More dust was deposited where visitors turned or were more active.

The vertical profile of dust deposition was particularly interesting. Many large dust particles were found up to 30 cm from the floor, either from visitors' shoes or kicked up from the carpets. These particles were too heavy to rise much higher, and the amount decreased with increasing height. The rate increased again between about 80 to 150 cm, roughly hip-to-head height, and consisted mostly of clothing fibres dislodged by friction. Above 150 cm, the rate decreased rapidly and was very low above 200 cm.

Decisions made at Audley End

At Audley End, we concentrated on measuring dust deposition on the State Beds in the Howard and Neville Bedrooms. In the Neville Bedroom, visitors pass in a straight line from door to door, about 1 m from the bed. Horizontal monitoring between the visitor route and the bed showed that the deposition rate decreased substantially with increasing distance from the visitors. The deposition rate at 240 cm was only one quarter of that at 120 cm. Vertical monitoring inside and outside the bed curtains found that, outside the curtains, deposition reduced continuously from ground level up to about 175 cm, after which it was more or less constant at about one tenth of its value at floor level. Inside the curtains, the deposition rate was lower and hardly affected by the height from the floor.

In the Howard Bedroom, the position of the doors means that visitors pass close to the side of the bed. As in the Neville Bedroom, the rate of dust deposition was measured vertically, inside and outside the hangings. Here, there was a very large peak in the deposition rate between 50 cm and 150 cm above the floor. The rate at 100 mm was approximately twice the rate at floor level, but above 150 cm the rate was about one third of that at floor level. Inside the curtains the rate was more or less independent of height, although there was a small peak between 100 and 175 cm.

The curator at Audley End had been contemplating extending the visitor route in the Neville Bedroom into the area at the foot of the bed. However, these studies indicate that the greater proximity of visitors and the greater number of turns they would make in moving into this space would lead to increased rates of dust deposition.

In the Howard Bedroom, the bed had formerly been protected from fingerprints by a glass screen about 180 cm high, which had been removed in the year 2000 because of safety concerns (it was hard to see in the low light levels required to preserve the hangings). The screen also made it difficult to clean the hangings, as there was no room to erect scaffolding, and it reduced the aesthetic quality of the room. In view of the dust measurements, it may be necessary to review the 2000 decision, as the screen clearly protected the bed from the large amount of dust deposited below 150 cm.

Visitors' perceptions of dust

For the past two years, we have carried out surveys at several properties to discover what visitors think about standards of care. From a management point of view, given that cleaning can damage delicate surfaces such as fragile textiles, it is counter-productive to clean more than necessary. If visitors do not notice the dust, there is no point in removing it, as long as it is causing no harm. These surveys have shown that visitors are largely conditioned by the general ambience of the house. They expect a grand house to be cleaner than a humble one, and they are prepared to accept more dust if the display policy is 'preserve as found' rather than 'restore as new'. When asked if any item needs more care, most visitors will point out the most prominent feature, whether it needs cleaning or not. Also, of course, dust is more noticeable on polished surfaces than on textured ones such as most textiles.

Similar surveys of conservators and curators revealed that while they were more aware of the possible harmful effects of dust, they were also more observant and critical than the average visitor. In a sense, therefore, they may be the wrong people to determine the optimum frequency of cleaning. This work is on-going, but we hope that it will lead to new guidelines for housekeeping schedules.

Cementation of dust

Housekeepers and others have often commented that dust becomes much harder to remove if left for a long period of time. Conservators have also observed that a hard-to-remove film may form on the surface of glass and glazed ceramics if they have not been cleaned for several years. It is not known whether these are examples of the same 'cemented dust' phenomenon. These anecdotal reports now appear to be true.

At UEA, Dr Yoon has managed to take SEM pictures that show the cement binding two fibres together, and he has shown that this material is organic. Laboratory experiments suggest that at high relative humidity (damp conditions) dust containing hygroscopic salts or sugars will adhere strongly to cotton fibres. It is possible that in nature these sugars may be of fungal or microbial origin, and may be responsible for cementation. More experiments will be needed to demonstrate conclusively whether this is the case.

In conclusion, according to Professor Brimblecombe, 'This important project will make a major scientific contribution to the management of the historic environment. More broadly, it will contribute to the general debate about air pollution.' □

The State Bed, Neville Bedroom, Audley End, East Anglia. Supplied in 1766 by the London upholsterer Paul Saunders. Measurements along the visitor route revealed the horizontal and vertical range of dust deposition, which altered plans to extend the route.

Medieval Pigments
A ground-breaking study of English medieval wall painting

Sophie Godfraind *Architectural Conservator, Building Conservation and Research Team*

Helen Howard's recently published book on medieval wall painting pigments is an important addition both to wall painting analysis and the history of art in England.

The first comprehensive study of English medieval wall painting techniques, Helen Howard's book* draws upon her research at the Courtauld Institute of Art, London, which has underpinned new perceptions and interpretations of the art of this period, both vital to the development of conservation techniques for monumental English art.

Dr Howard's systematic approach to scientific examination encompasses a vast range of analytical tools, each selected to answer specific questions against a clearly defined examination and sampling strategy. Her optimal application of the various analytical techniques has been based on an informed selection, determined by a strategy of examination, sampling and preliminary identifications using polarised light microscopy. This analytical research is complemented by a thorough investigation and dynamic interpretation of the primary and secondary sources – treatises, recipe books, antiquarian literature and more recent publications.

The evolution of wall painting technology is traced within the context of contemporary polychromed sculpture and panel painting, and wider European developments. One of the most important of her findings is that the same technologies were used on different substrates. This has important implications for the study of workshop practice. Similarly, strong parallels have been indicated between English and continental wall painting, suggesting a ready diffusion of expertise and technique across Europe.

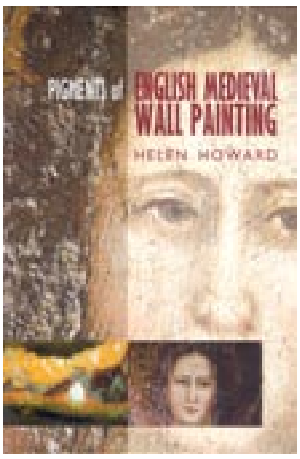
The variety and sophistication of the palette of English wall painting throughout the Romanesque and Gothic periods is fully laid out. Contrary to all previous presumptions about Romanesque technique, Dr Howard's work has revealed a technology certainly rooted in the *fresco* tradition, but lavishly combined with *secco* binders and pigments applied in complex stratigraphies. We are shown how artists of the two periods achieved very different effects with an essentially static palette, through elaborate application. Gothic artists, for example, seeking new effects of luminosity and translucency, used increasingly complex glazes and combinations of materials, supplemented with intricate relief ornamentation.

Major discoveries

Dr Howard has made a number of major discoveries. Four of the 30 pigments she has identified – kermes lake, madder lake, vivianite and salt green – were previously unknown within the English medieval wall painting palette. Three new pigment alteration phenomena have also been revealed: the lightening of red lead, the alteration of blue vivianite to a yellow form, and the transformation of verdigris to a blue copper chloride-based alteration product.

The vast amount of data brought together has created a book dense with information; it is by no means an easy read. However, the captions accompanying the numerous illustrations are so complete that they afford an easy and engaging overview of the book's contents. The quality of the plates is very high, though from time to time rather on the small side. Some plates are absolute gems (such as the 'jewels' on the helm of Sir Roger de Bois' tomb effigy at Ingham, Norfolk). Meanwhile, the clear logical structure, the excellent index, the superb list of references, and a number of extremely useful tables guarantee the book a long life as a research tool. □

* Helen Howard 2003 *Pigments of English Medieval Wall Painting* London: Archetype Publications (ISBN 1-873132-48-4)



Human Osteology at Wharram Percy

Life and death in a medieval village

Simon Mays *Human Skeletal Biologist, Centre for Archaeology*

Scientific study of human skeletal remains from the deserted village of Wharram Percy sheds new light on disease, diet and death in a rural medieval community.

The deserted medieval village at Wharram Percy, in the Yorkshire Wolds, was the subject of one of the longest-running archaeological excavations in Britain (1950–90), led by Maurice Beresford and the late John Hurst. Part of the fieldwork focused on the churchyard, and this was the first excavation of a sizeable collection of human skeletons from an English medieval rural site. The scientific work on the remains is being coordinated from the Ancient Monuments Laboratory at English Heritage's Centre for Archaeology, Portsmouth, and many workers in Britain and abroad have collaborated with English Heritage on research using the skeletons. The application of the latest scientific techniques has allowed fresh insights into medieval rural life.

Infant mortality

About 15 per cent of the skeletons were infants. This suggests that infant mortality levels may have been fairly low for an early population where figures may be as high as 40 per cent. Insight into infant feeding practices was provided by analysis of nitrogen stable isotope ratios in the bones. Breastmilk contains a high level of nitrogen-15, permitting duration of breastfeeding to be investigated. Results indicated that infants were usually breastfed until they were about 18 months old. Breastfeeding builds the infant's immune system and prevents early contact with potentially contaminated foods. It may well be that the extended breastfeeding practiced by the Wharram Percy women played a part in the fairly low levels (for that time) of infant mortality.

Growth during childhood

The children's problems began once breastfeeding ceased. By two years of age, they had started to fall behind modern children in their growth, and, by later childhood their growth was greatly retarded. A Wharram Percy 14-year-old child, for example, was only about the same height as a modern 10-year-old, and comparison with 19th-century figures shows that the medieval children were no taller than factory children in the Industrial Revolution. This suggests that childhood health and nutrition were no better than that of 19th-century slum-dwellers. Despite this problem, the average height of the adults (5'6" for men, 5'2" for women) was only a few inches shy of modern figures. This is probably due to prolongation of growth – in the past, people continued to grow well into their 20s rather than growth ceasing in the late teens as now.

Sacrum and right pelvic bone from a Wharram Percy burial. The lowest lumbar vertebra is fused to the sacrum. There is a large hole in the vertebral body leading to an abscess cavity within. Spinal abscesses are typical of tuberculosis. There is some new bone formation on the sacrum, probably as a response to pus exhuded from the abscess. Analysis of bone samples revealed DNA from tubercle bacilli, confirming the diagnosis of tuberculosis.

© Wharram Research Project

Part of the churchyard at Wharram Percy under excavation.

Osteoporosis

Approximately 40 per cent of adult burials were of individuals over 50 years old. This shows that even in this rather poor settlement, life expectancy was reasonable once adulthood had been attained. Indeed, many manifested evidence of diseases which afflict the elderly today. For example, the loss of bone density due to osteoporosis was no less than that seen nowadays. This finding is an example of how studies of ancient bones have relevance for modern medicine. It has often been held that many aspects of modern lifestyles, such as cigarette smoking and sedentary habits, exacerbate loss of bone density in osteoporosis. The finding that osteoporosis was just as severe among the non-smoking, physically active peasants at Wharram Percy as it is in modern populations leads one to question the importance of lifestyle factors in influencing the disease.

© English Heritage

A femur from a Wharram Percy burial, showing a porous deposit of new bone. This is a typical bony response to infection, although which particular disease was the cause cannot be determined. Such lesions are less frequent at Wharram Percy than among burials from medieval York.

Seafood in diet

The bone data provides evidence for trading and other links between Wharram Percy and surrounding settlements. The stable isotope analyses played a role here. Consumption of seafood can be detected using this technique, and analyses revealed that marine fish were a minor but significant source of dietary protein. Seafood may have been acquired direct from coastal settlements or via trade with inland market towns.

Disease

Regular links between Wharram Percy and larger settlements may have affected the disease experience of the community. Evidence for tuberculosis was found among the skeletons. There are two forms of tuberculosis, one acquired from animals (particularly cattle) and one transmitted human-to-human. DNA analysis of skeletons showing tuberculosis indicated that the Wharram Percy people suffered from the human type. As this type thrives in large, crowded settlements it may be that regular contact with large urban centres helped maintain the disease, even in rather thinly populated countryside.

Notwithstanding the evidence for regular contact between town and country, there were some differences in health between the Wharram Percy population and those from nearby towns. For example, despite the evidence for tuberculosis, in general, infectious disease was less often seen on the Wharram Percy bones than was the case in a coeval skeletal series from York. This is consistent with the idea that rural populations had generally fewer infectious diseases than those from crowded, insanitary urban centres.

New research

The Wharram Percy skeletal collection continues to attract researchers from around the world. A number of projects are currently being conducted, including investigation of the effects of peasant labour on health using analyses of spinal and other joint injuries, a study of diet using chemical analysis of mineralised dental plaque found on the teeth, and further studies of osteoporosis. Most of these are being carried out as collaborative work between English Heritage and other research institutions. □

Dairying in Prehistoric Britain

Milking the organic residues

M S Copley[1], R Berstan[1], S N Dudd[1,2], G Docherty[1], A Mukherjee[1], V Straker[3], S Payne[4] and R P Evershed[1]

A collaborative research project has discovered new evidence of the importance of dairying as part of animal husbandry in prehistoric Britain.

The detection of milking of domesticated animals is a question that has occupied archaeology for many years. The traditional approach rests on assessments of skeletal remains leading to the reconstruction of herd structures. An emerging alternative – indeed more direct – approach, is to exploit animal fats preserved in pottery vessels used to process dairy products. Recent research at the University of Bristol has shown that a range of chemical criteria can be used to assign the origins of these ancient fats to the most important domesticated animals: sheep/goats, cattle and pigs. Fresh milk fats have a composition characterised by the presence of short-chain fatty acids. During vessel use and burial, however, these short-chain components are lost and the composition of degraded dairy fats comes to resemble that of carcass fats. Thus all degraded animal fats are recognised by the high abundances of $C_{16:0}$ and $C_{18:0}$ fatty acids.

Detecting dairy fats

Fortunately, nature and new stable isotope technologies have come to our rescue in a collaborative research project funded through the Natural Environment Research Council's CONNECT B scheme, with English Heritage as partners. The project investigated the importance of dairying as part of animal husbandry in prehistoric Britain.

Although the $C_{18:0}$ fatty acid is abundant in both milk and carcass fats, it has different biosynthetic origins that are reflected in its stable carbon isotope values (termed $\delta^{13}C$ values), and this forms the basis for investigating the importance of dairying in prehistory. These isotope values are determined using a new generation of ratio mass spectrometer incorporating a gas chromatograph that allows on-line molecular separation and stable isotope analysis. This allows carbon isotope values to be determined from individual fatty acids. The $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids from modern ruminant adipose and dairy fats, and porcine (non-ruminant) adipose fats were determined. All the animals were raised on unimproved pastures on an organic farm so that their diets closely resembled those of domesticated animals in British prehistory.

The key to separating the milk and adipose fats rests on the difference of *c.* 2.3‰ between the $\delta^{13}C$ values of their respective $C_{18:0}$ fatty acid. This difference is principally due to the cow overcoming its mammary gland's deficiency in the $C_{18:0}$ fatty acid by transforming dietary polyunsaturated fatty acids to $C_{18:0}$ in its gut, and then exporting this to the mammary gland for milk fat production. Since the carbohydrate used to biosynthesise the adipose fat $C_{18:0}$ has a significantly different $\delta^{13}C$ value from the fatty acids in plant tissues, milk and adipose fat $C_{18:0}$ exhibit different $\delta^{13}C$ values.

Dairy fats in prehistoric pottery

The project involved the analysis of well-stratified sherds from fourteen archaeological sites spanning the entire prehistoric period in Britain* (see table). A greater proportion of the sherds was selected from the Neolithic to increase the sensitivity of the study during this key period. Upper body or rim sherds were sampled from vessels likely to have been used during cooking. Fatty acids were analysed using protocols developed over the past decade.

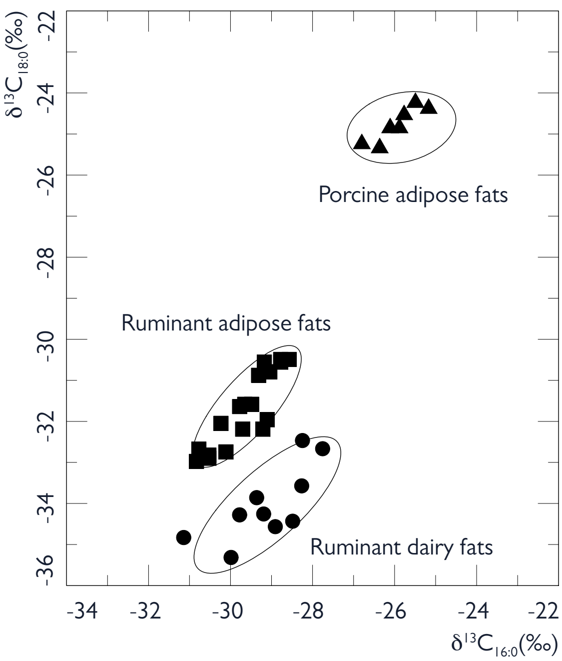
The results show clearly that dairying was evident at all sites spanning the 4,500 years of British prehistory. Not unexpectedly, there is some site-to-site variation, although generally the evidence for dairy fats was strong. At the majority of the sites, ruminant animals dominated the faunal record, and this dominance was reflected in the organic residues; ruminant dairy and adipose fats were the predominant residues detected.

The domestication of sheep and goats is believed to have occurred before that of cattle in south-west Asia by the 8th millennium BC, and the exploitation of secondary products, such as dairy products, is believed to have occurred one or two millennia later. These results demonstrate that the exploitation of animals for milk was an established practice when farming arrived in Britain in the late 5th millennium BC. □

1 Organic Geochemistry Unit, University of Bristol
2 Micromass UK Ltd
3 English Heritage South West
4 English Heritage

* Copley, M S, *et al* 2003 'Direct chemical evidence for widespread dairying in prehistoric Britain'. *Proceedings of the National Academy of Sciences* **100**, 1524–29

Plot of the $\delta^{13}C$ values of the major fatty acid components of modern reference fats. The three fields correspond to p = 0.684 confidence ellipses calculated for the $\delta^{13}C$ values known to comprise the major component of prehistoric economies in Britain.



We thank the following for permission to sample from various collections/ assistance in the sampling of the pottery vessels: Kay Ainsworth, Tim Allen, Alistair Barclay, Ros Cleal, Vicky Crosby, Peter Drewett, Caroline Grigson, Frances Healy, Helen Keeley, Andrew Lawson, Roger Mercer, Elaine Morris, Stuart Needham, Mark Norman, Jacky Nowakowski, Rachael Seager-Smith, Anna Tyacke, Alasdair Whittle and Emma Young. Tony Legge and Gill Jones are also thanked for supplying unpublished faunal data from Hambledon Hill and Eton Rowing Lake, respectively.
We also thank J Carter, A Gledhill and I Bull for assistance with mass spectrometric analyses, and NERC and English Heritage for financial support.

Summary of sites from which pottery was analysed, showing the relative importance of dairying in prehistoric Britain.

Site*	Prehistoric period*									Importance of dairying†
	Neolithic			Bronze Age			Iron Age			
	Ea	Mid	La	Ea	Mid	La	Ea	Mid	La	
Stanwick (n=65)										+++
Danebury (n=69)										+++
Maiden Castle (n=54)										++++
Yarnton CF (n=49)										++++
Potterne (n=69)										+++
Trethellan Farm (n=69)										++
Black Patch (n=59)										++
Brean Down (n=59)										+++
Yarnton FP (n=91)										++++
Runnymede Bridge (n=57)										+++
Abingdon CE (n=59)										+++
Hambledon Hill (n=72)										++
Windmill Hill (n=70)										++++
Eton Rowing Lake (n=88)										+++++

* CF = Cresswell Fields; FP = Flood plain; CE = Causewayed enclosure | Ea = Early, Mid = Middle; La = Late

† Based on relative abundance of sherds containing dairy fat residues ranging from +, low, to +++++, high.

Stone Testing for Historic Building Repair
Truro Cathedral, Cornwall

Bill Martin *Head of Building Conservation and Research Team*
with acknowledgements to **Elizabeth Laycock** *Sheffield Hallam University*

None of the accepted tests for building stone can be used to evaluate material for insertion into historic fabric. Recent research shows that testing stone under simulated climatic conditions can provide data for such evaluation.

English Heritage's repair philosophy for historic buildings is one of minimal intervention, to preserve as much of the original fabric as possible. However, the need to selectively replace severely decayed stones, to ensure structural stability, for example, is accepted as part of the conservation process. Identifying and sourcing the correct stone is of paramount importance if repairs are not to have a deleterious effect on the surrounding historic masonry.

Any stone used for this work must be petrographically compatible with the original masonry, as durable in the prevailing climatic conditions and aesthetically acceptable. Sampling and analysis of the original masonry – a process described in a forthcoming English Heritage Technical Advisory Note *Identifying and Sourcing Stone for Historic Building Repair* – provides identification and characterisation of the material to be replaced. It is too often the case, however, that the original stone is no longer available, and a nearest equivalent must be sought from current sources. Many commercially available stones have undergone standard laboratory tests – for porosity, saturation coefficient and ability to withstand soluble salt cycling – to provide guidance on suitability of use and some measure of predicted durability. While this information may be considered adequate in new buildings, it often falls short of the criteria for replacing stone in original historic masonry. Replacement decisions, therefore, are often based on an evaluation of the medium-term performance, *in situ*, of previous stone insertions, sometimes to the detriment of a proper consideration of overall compatibility.

A new suite of tests is required that enables the specifier to evaluate the likely performance of a range of potential replacement stones within the context of the original masonry, nature of construction and local climatic conditions, without waiting an unacceptably long time for external exposure trials or resorting to over-harsh accelerated weathering protocols.

Truro Cathedral

Against this background, in 2001, the Dean and Chapter of Truro Cathedral, Cornwall, supported by English Heritage's South West Region and the Building Conservation and Research Team, commissioned Sheffield Hallam University to undertake a groundbreaking programme of testing. Using an advanced climatic simulation chamber, the Sheffield tests identified the most appropriate replacement stone for use in an extensive external fabric repair programme for the cathedral. Designed by J L Pearson and completed in 1910, the exterior of the cathedral was constructed of local granite and a Bath stone, areas of which had deteriorated and required replacement. The extreme nature of the decay suggested either that some of the stone originally used – a Box Ground according to Pearson's records – was sub-standard, or that the marine climate had encouraged decay through the wind-borne deposition of soluble salts, or, perhaps, a combination of the two.

Truro Cathedral, Cornwall, west front.

© English Heritage / Bill Martin

The Box Ground was no longer available, and an appropriate substitute was needed that would be compatible with the original and offer good durability in a harsh climate.

The Testing Programme

Sheffield's climatic simulation chamber was designed to investigate the performance of materials under a wide range of climatic conditions. Used mainly to study the behaviour of masonry construction elements with realistic inner and outer wall conditions, the chamber has two parts: a 'design' side that can mimic internal conditions and a 'climatic' side that allows the creation of realistic sequences of weather elements run in a cyclical manner. Within the cycle, start and finish temperatures are specified with the rates of change of each weathering component. Precipitation, including driving rain, is simulated by pre-cooled water pulsed through jet nozzles to create rain droplets, and relative humidity is regulated by injecting temperature-controlled mist sprays into the airflow.

For the Truro stone test, the simulated weather was based on long-term climatic data obtained from the Met Office for the immediate vicinity, and it ran for 100 days on a three-day cycle. Salt was added to the water sprays to represent amounts of contamination found in damaged stones taken from the building.

While this testing system had been successfully used at Sheffield before, the protocol was not circumscribed by a national testing standard. It was decided, therefore, further to calibrate the tests by running a similar, but less sophisticated series, alongside in an accelerated freezing cabinet, using a British Standards-recognised test for brick masonry units. To further validate and compare results, blocks taken from the main chamber would be subjected to the industry standard BRE salt crystallisation test, a proxy for freeze-thaw cycling.

While most protocols measure the performance of stone cubes in isolation, the Sheffield work examined the response of stone and mortar structures. The testing involved the construction of two sets of masonry units, one in the main chamber and the other, smaller unit in the accelerator. These units were comprised of eight or nine blocks of each of the seven potential stone types, including a stone previously specified for the repairs and one believed to have been taken from the cathedral when the Chapter House was built, to serve as a proxy for the original material. Each stone type was built into the masonry units so that it was juxtaposed with every other type in order to identify any similar weathering influences; in the climatic simulator wall, each type was of a dimension suitable for use on the cathedral. The units were constructed in traditional masonry manner using a mortar of NHL 3.5 hydraulic lime and well-graded aggregate, which was allowed to cure before testing began.

A system of visual and graphic recording was developed using a range of surface decay descriptions, so that periodic regular inspection of the exposed surfaces within the simulator would provide a record of the changing conditions of the stone blocks relative to one another and a quantification of surface loss.

Results

Data was prepared after 200 cycles in the accelerator and 105 in the climatic chamber. Each stone type was assigned a value based on its performance across the range of testing and ranked in order of decreasing suitability. Mean values were taken from this data to characterise the behaviour of each stone type and to give a ranking of overall appropriateness.

While results from some of the stones varied across the tests and in some cases were contradictory, several important conclusions about the testing protocols and stone selection emerged: damage was considerably reduced in realistic conditions in comparison with accelerated tests; the salt crystallisation test produced notably different results from the frost test; and the data clearly identified a reasonable-to-good range of stone which was recommended as appropriate for use in the Truro repair programme. Interestingly, the stone originally specified was not one of them. □

Reburial of Excavated Sites
Conservation and management

John Stewart *Senior Architectural Conservator, Building Conservation Research Team*

Reburial is an increasingly common method of conserving and managing archaeological sites. The complexities of the burial environment are now subject to more rigorous scrutiny to improve knowledge and

Some types of archaeological artefacts and structural remains, if buried in certain soil conditions, suffer considerably less change than if exposed to the elements. They are protected from the large climatic fluctuations of an exposed environment, with its different levels of oxygen and types of micro-organisms, among other factors. Yet those same archaeological features can also undergo a range of transformations below ground, through the process of diagenesis. This process may weaken the material structures, rendering them more vulnerable when exposed through excavation.

Architectural remains that survive are integral to an archaeological site – and are most meaningful if left *in situ.* Past approaches to the management of excavated structures have included consolidation, maintenance and sometimes the erection of protective cover buildings. Yet these measures can be costly, and the rate of attrition of historic fabric can still be significant. Furthermore, there are limited resources to maintain, repair, monitor, protect and present excavated sites. A rational management regime needs to be based on an understanding of the vulnerability and significance of each site, and these criteria should ultimately help to determine if a site is to be left exposed or reburied.

Previous UK experience

During the past few centuries, some excavated sites in Britain have been deliberately reburied, or backfilled, either as a preservation measure or a functional requirement, say, to restore arable land. More recently, reburial has often been applied as a mitigation strategy, in accordance with *Planning Policy Guidance Note 16: Archaeology and Planning*. Reburial allows for potentially benign new uses over archaeological sites (such as car parks) or the continuation of former ones (such as agriculture).

Most reburial interventions in Britain have been based on empirical experience or subjective judgement. Few are deliberately ‘designed’ with clear conservation objectives. The Rose Theatre site, discovered in Southwark, London, in 1989, is an exception. It is also rare in being one of the few reburied sites with a monitoring regime to record water levels and chemistry in real time, allowing for an appraisal of the efficacy of the burial environment.

Professional conferences on the preservation of archaeological remains *in situ* have largely concerned sites which have been excavated and remain exposed (Ghent 1985; Mexico City 1986; Montreal 1994). The two seminal conferences, Preservation of archaeological sites *in situ* (PARIS I and II), held in London in 1996 and 2001 respectively, advanced the agenda to consider the preservation of *unexcavated* sites. Yet paradoxically, there has been little concerted appraisal of reburied sites and their environments, even though this has become a common conservation intervention in such countries as the UK.

New initiatives

In March 2003, a specialist colloquium on the reburial of archaeological sites took place in Santa Fe, New Mexico. The colloquium was an initiative of the Getty Conservation Institute, Los Angeles, California, and the US National Parks Service (Intermountain Region), organisations with a strong interest in practical research in site reburial. Cogent local examples of reburial were evident in numerous prehistoric Pueblo structures that have been partially backfilled, largely to reduce the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The Rose Theatre site, Southwark, before reburial.

progressive loss of historic fabric and the scale of required routine maintenance.

Materials for reburial

The colloquium covered the broad themes of decision making, the reburial environment, technical design, monitoring and testing, and it included the first formal presentation of recent unpublished research, some ongoing for the past ten years. One of the topics reviewed was the range of materials used for reburial. Over the past 15 years, civil engineering technology and materials have been applied. In particular, geotextiles (membranes of polypropylene, polyester or nylon) have been extensively used as archaeological horizon markers between unexcavated and backfilled soil, and as separation membranes to facilitate re-excavation. Their potential effects on reburied remains, however, are sometimes not fully understood. For example, geotextiles vary greatly and may be inappropriate for certain applications. Reports from a number of re-excavated sites describe damage caused by geotextiles adhering to architectural surfaces, through the formation of mineral precipitates on and around the fabric. Furthermore, good water transpiration through the fabric is generally required but may not always be achieved by some varieties. Non-woven, needle-punched geotextiles are the most water permeable.

Research on sands for reburial carried out by English Heritage has sought to establish criteria for the identification of affordable materials without potentially harmful impurities. Yet even the application of relatively pure sands cannot prevent transformation of the burial environment through a change of groundwater characteristics, such as pH.

Our knowledge of the properties of geotextiles, and to a lesser extent of burial materials, has evolved over recent years. However, the creation of ideal burial environments for complex sites is currently only an aspiration. Even on unexcavated sites, an understanding of the myriad of dynamic parameters, such as oxygen levels, pH, redox potential and their affects, is at its infancy. In planning a reburial, therefore, an interdisciplinary approach is essential – not only between the archaeologist and conservator, but also the geologist, soil scientist, materials scientist, civil engineer, botanist or landscape architect, according to local complexities and requirements.

The presentations of the reburial colloquium in Santa Fe will be published as a special issue of *Conservation and Management of Archaeological Sites* early in 2004 – the first dedicated publication on the subject. Publication of the experience of professionals will lead to further understanding of site conservation through reburial. □

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Chaco Canyon, New Mexico, one of several 'great houses' within this centre of Puebloan culture (9th to 12th century AD). Excavated in the late 19th and early 20th century, many structures have been backfilled by the U S National Park Service as a conservation measure.

Investigating Wall Paintings
Seeing is believing

Robert Gowing *Senior Wall Painting Conservator, Building Conservation Research Team*

Conservators have made great advances in imaging and recording painted architectural surfaces through new methods of exploiting the responsiveness of materials to different wavelengths. These non-destructive methods can inform conservation works.

Preliminary surveys are an essential step in establishing the conservation requirements for painted architectural surfaces (wall paintings, polychromy, painted panelling and other decorative elements). By combining detailed visual examination with associated documentary research, the conservator can build up a physical history of the site and its decoration, and try to characterise the factors influencing current condition and deterioration.

Despite the obvious benefits of preliminary surveys, often only a minimal amount of time and budget are spent on this part of a project. Additional pressure is placed on the conservator by ever-increasing public enthusiasm for the perceived technological advances in scientific analysis. Sampling and material analysis are now often seen as obligatory even in the preliminary stages of investigation, so that reports can contain 'scientific data' to support proposed conservation works. This rush to analysis encourages the use of invasive sampling before establishing the overview necessary for an appropriate sampling strategy, and it produces only a partial – and often misleading – impression of the painting and its condition.

Clearly it is vital to develop ever more effective and versatile non-destructive examination and recording methods to aid the preliminary survey. Significant benefits have already resulted from the use of portable magnifiers and hand-held video microscopes, and the costs of these tools have now dropped to the point where they are within the reach of even the smaller private conservation firms. However, much of this equipment is limited in one crucial way: it is restricted to visible light. Broadening the investigation to include other wavebands has enormous potential for radical improvements in non-destructive examination.

Beyond the visible

Conservators are well-versed in using visible light to study painted surfaces – specular, diffuse and raking illumination are all commonly used for examination and assessment. Yet visible light represents only a small portion of the electromagnetic spectrum. To gain insight into the physical and chemical properties of the materials used in paintings (and for that matter, of their conservation), we can use the characteristic interactions of particular materials with other wavelengths, particularly the ultraviolet (UV) and infrared (IR). Recently, digital imaging has made it much easier to record these interactions *in situ.*

The ceiling of the Heaven Room in Bolsover Castle, Derbyshire, with an allegorical painting of the early 17th century. It was suggested that the painting had been extensively over-painted: this was not clear under visible light because of the application of a modern varnish.

Ultraviolet illumination

In the early 1850s, British scientist Sir George G Stokes showed that fluorescence – the phenomenon whereby certain materials emit visible light when stimulated by incoming energy – could be readily induced by UV light (rather more energetic than the visible wavelengths), and that the degree and colour of the fluorescence was specific to the material. Many pigments, media and coatings (both organic and inorganic) display these characteristic responses. In particular, waxes, resins and re-touching materials, often difficult to discern in visible light, are extremely obvious in UV. This can instantly reveal much about the degree and extent of previous phases of restoration.

Although dedicated (and expensive) ultraviolet illumination systems are available for conservation, UV lamps can also be purchased to fit standard housings. Conservators can construct very inexpensive units, tailored to suit their own needs.

Imaging UV florescence requires some way of cutting out visible light (usually the simple expedient of waiting until nightfall), as well as yellow lens filters for the recording cameras (whether film or digital). This means that exposure times are rather long, and it is necessary to stabilise the camera: no easy feat when using scaffolding, but still perfectly achievable with forethought and care.

The same area recorded under UV illumination clearly shows that re-touching was limited to localised losses and damage (areas appearing darker), while the majority of the ceiling is original. This UV survey was able to reduce the need for sampling of the painting.

© Paine and Stewart Conservation, 2000

Near-Infrared radiation

IR THERMOGRAPHY: Heat is emitted from objects in wavelengths within the IR region. IR thermography records this, and therefore can indicate other aspects of specific physical and chemical composition. It is, of course, best known for its military applications but, as the price of equipment drops, it is becoming more common as a surveying tool. Within historic buildings, IR thermography has been used to reveal concealed alterations to the fabric (such as blocked doors and windows), as well as the effects of heating systems. As a preliminary inspection tool, it can provide clues to localised differences in condition, and can guide further investigations, including material sampling and environmental monitoring.

Early thermography sensors required complex cooling systems, making the cameras cumbersome for portable applications. Now that this has been overcome, there has been an explosion in the market, with numerous hand-held, fast-operating cameras offering ranges of sensitivity and resolution. These units still represent a significant capital outlay, but alternatively short-term rental is available from a number of specialist firms.

IR REFLECTANCE: Its longer wavelength means that IR radiation can penetrate quite deeply into the surface of the painting, being reflected back to the eye only when it meets a dense material. Charcoal being one such material, IR reflectance has had some value in revealing carbon black underdrawings for wall paintings.

Until quite recently, *in situ* IR recording was confined to photography under natural light using IR-sensitive film to record both the 'natural' emission of IR and the reflected IR component of the natural light. This methodology unfortunately has been of rather limited success with wall paintings, for a number of technical reasons.

In the 1960s, IR reflectography was developed to look at IR emissions beyond the film sensitivity range, and there are now a number of relatively portable systems that can capture defined wavebands up to the far IR (between 900 and 2500 nm). Interestingly, the charge coupled device (CCD) inside many digital cameras is now sensitive to IR in regions up to almost 1200 nm. With their factory-installed IR filters removed, these can provide a useful low-cost alternative, or perhaps a quick test to see whether more elaborate systems are likely to prove useful.

Informed conservation

Taking advantage of – even keeping abreast of – the ever-growing range of tools and equipment available requires a certain amount of determination and enthusiasm on the part of a conservator, but one is well-repaid by the improvements in ease of survey and effectiveness of results. One should not be overwhelmed by the technology, or by the apparent need to produce copious amounts of data. Undoubtedly, the skill lies in the ability to extract the information from the readings: to be able to decipher what has been observed. Establishing the conservation needs of the painting cannot be done with equipment alone, no matter how elaborate. Data is worse than useless without informed interpretation.

But neither should the use of sophisticated technology be thought of as being blinded by science; rather, it is like donning reading glasses to see the small print. Seeing clearly requires facility in both tools and thought, the classic combination of the skilled conservator. □

In visible light, the drapery behind Christ in this late 14th-century wall painting in the Chapter House, Westminster Abbey (*above*), appears undecorated. When recorded in the near-IR region, a floral brocade pattern emerged, with under-drawings, which guided later sampling.

Stone Consolidants
Inorganic treatments

John Fidler *Conservation Director*

New research on inorganic solvents offers improved techniques for masonry conservation.

The history of conserving historic building materials could be written around our attitudes towards building materials. Stone masonry, of course, takes pride of place as the most popular and revered natural construction material because of its prominence, beauty, antiquity and resilience through the ages. It is one of the most common building materials in England and the most studied: vast libraries of books and papers bear witness to its appeal and to the study of its preservation.

If you look through any Internet search engine for lists of 'conservation' and 'preservation', a host of sites will appear on studies of stone consolidants, the impregnating chemicals that strengthen the surface or sub-surface of decaying stones, and protect against moisture and pollution.

Organic consolidants in England

In England, we have a long track record of experimentation with so-called 'preservatives'. William Lethaby, for example, cited the medieval practice of using linseed oil to protect stonework, and Professor Robert Baker revived limewatering and lime shelter coats at Wells Cathedral (Fidler 2002). After the fiasco of the serious stone decay of A W N Pugin's facades at the Palace of Westminster within 30 years of building, the report of the public inquiry in 1861 included investigations of solutions such as Sylvester's treatment (1846), a water repellent based on soap and alum. Most of the consolidating materials used unsuccessfully in the second half of the 19th century included potassium or, even worse, sodium silicate ('waterglass') such as Kuhlmann's patent of 1852 and Szerelmey's of 1857.

At Westminster Abbey in the 1860s, Sir George Gilbert Scott used a solution of shellac in 'spirits of wine' (ethanol) on the interior of Westminster Abbey, squirted into the stone. Scott observed that it was not effective on the exterior in areas of driving rain, and he and subsequent surveyors used waxes on the interior instead. He also permitted a Professor Church to experiment with wall paintings and Reigate stone conservation at Westminster Abbey Chapter House by using 'baryta water', an early experiment with barium hydroxide solution.

In the 20th century, a great deal of international effort, time and money was spent on testing and failing to find successful outcomes with epoxide and polyvinyl fluoride (PVF) materials. More promise was shown by research into acrylics, alkoxysilanes and mixtures of the two materials. English Heritage's own experimental field work with the Building Research Establishment on Brethane (Martin 2002) shows the scope and limits of these organic compounds. The most widely used of the silanes is ethyl silicate, as conservators consider it safe, straightforward and controllable. These organic materials, however, all have limitations, and there has been concern about compatibility with calcareous materials such as marbles, limestones and calcareous sandstone masonry.

Inorganic consolidants

In response to the disadvantages of organic consolidants, English Heritage and the Getty Conservation Institute, Los Angeles, California, convened an international colloquium at the Society of Antiquaries, London, in December 2000. Specialists in conservation science and practice from the USA, UK, Spain and Italy discussed the use of alternative methods based on inorganic materials, potentially of benefit to decaying marbles, limestones and plasters. These include:

- limewatering (calcium hydroxide in solution): a revived yet scientifically unproven craft process
- barium hydroxide (a complicated variation

on limewatering with higher risks): successfully used on certain frescoes and plasters in Italy
- biological deposition of calcium carbonate: a new pioneering technique using a variety of pathways from calcite precipitation through bacteria, to precipitation enhancement due to proteins from seashells
- the creation of a protective layer of artificial calcium oxalate by limestone exposure to ammonium oxalate
- the part conversion of calcareous surfaces by exposure to heavily buffered tartaric acid to enable them to be chemically sensitised to silane-based consolidants, especially ethyl silicate.

The findings of the colloquium, which included 14 participants and 12 authors, have now been published by the International Institute for Conservation, in its series of *Reviews in Conservation*.

The report (Hansen 2003) reviews key literature, identifies questions and promotes discussion of a range of issues, including application techniques, performance, compatibility and retreatability. While many of these issues have been discussed in publications before, Hanson identifies significant areas for new research.

It is important to distinguish between consolidating properties (either at the stone surface or at depth) and other properties such as protective water repellency (oxalate patinas) and sacrificial coatings (lime shelter coats). Claims made by advocates for some of these systems do not appear to stand close scrutiny (Woolfit 2002), but Hanson concludes that quantitative data to evaluate the success or failure of inorganic consolidants has rarely been collected, or analysed and published. For usable conclusions, however, data should be collected on the following aspects: consolidating or strengthening value; depth of penetration; effect on appearance; compatibility with substrate; durability of treatment; effect on porosity and permeability; biological resistance; ease of application; and health and safety impacts.

All the inorganic treatments evaluated rely on reaction chemistry, that is, where material is precipitated from solution, some chemicals are dissolved and others are precipitated in their place. The chemicals tend to be environmentally friendly, water- rather than organic solvent-based. Importantly, some of the treatments assumed by practitioners to be simple folk remedies embody complex preparation and treatment methods where the application technique is as critical as the materials used or the degree of decay.

Ways have been found to remedy some effects in traditional practice. For example, in the application of lime watering (using calcium hydroxide), the amount of material in solution can be increased by increasing the use of sugars, by limiting sedimentation with ethanol or by using dispersed lime (micro-particles). Also, for statuary, a new approach is to apply the solution in a 100% carbon dioxide environment.

Hansen concludes that these methods are all developmental work in progress: 'Problems in evaluating the consolidation and protective treatments fall into two categories: the lack of knowledge of specifics in reaction chemistry and application procedures; and the lack of sufficient experimentation and testing methods necessary to quantify the required strength of consolidation, compatibility and long-term effects.'

Wells Cathedral, Somerset, where extensive consolidation with calcium hydroxide has been carried out.

Advice to the practitioner

The use of any type of masonry consolidant should be an action of last resort for conservators, and English Heritage has provided guidance on the matter (Ashurst & Ashurst 1988; Martin 1996). Some unproven remedies, cloaked by their advocates in the mantle of craft tradition, are based on complex inorganic chemistry and crystallography, about which little is understood. Importantly for the practitioner, some inorganic consolidating treatments have little effect or wear away so rapidly as to be uneconomic (Fidler 2002). There is plenty of scope for further research. □

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Howden Minster, Goole, North Humberside. Deterioration of decorative tracery in an external arcade built of magnesium limestone, which is particularly difficult to consolidate.

Damp Damage in Stone

An assessment of the columns at St John The Baptist, Pinner

Brian Ridout *Senior Architectural Conservator, Building Conservation Research Team*

Damp problems can be difficult to interpret and, if the cause is misunderstood, expensive remedial works may prove to be worthless. An inexpensive investigation using relatively simple equipment can provide a solution to a seemingly intractable problem.

The church of St John the Baptist in Pinner, West London, has been a focal point of the village for 600 years. Unlike many other churches today, it still has a sizeable congregation and supports a busy array of community functions.

The interior of the church contains six north (N) and six south (S) stone columns, which separate the nave from the aisles. Many of these columns, particularly on the south side, are damp stained, and have been substantially damaged by salts. The effect is unsightly, and there is a progressive loss of the medieval surfaces.

Damage was thought to have occurred because a concrete slab was laid between the columns during the 1960s. The long-term effect would have been to concentrate ground water evaporation through the columns, thus transporting salts from the concrete and depositing them in the surface layers of the stone. Sodium sulphate, from concrete and other building materials, can cause considerable damage in a fluctuating environment because the hydrated salt occupies a very much larger volume than the anhydrous form. The salt swings between its anhydrous and its hydrated forms as temperature fluctuations change relative humidities. The resulting changes in pressure within the pores of the stone, caused by changes in crystal size, result in crumbling and spalling.

Measuring damp

The presence of damp staining and salt damage does not necessarily indicate current water penetration. Considerable time and money can be spent on searching for a source of damp to explain a problem that occurred decades or even centuries earlier. Damp stains are like beetle holes in timber; they do not disappear when the cause has gone.

The first step in an investigation should be to ascertain whether water penetration is still occurring, but this is not as easy as it would seem. The standard approach is to apply a moisture meter to the surface, but the readings obtained would be of little value. A moisture meter does not measure moisture but the electrical properties of the material investigated, and the equivalent 'moisture content' reading given by the instrument is dependent upon the manufacturer's idea of calibration. Salts heavily influence electrical properties, so the presence of salt damage in the church columns at Pinner would preclude their investigation with a moisture meter. A small amount of salty dampness would give a very high meter reading – and might easily lead to the wrong conclusions.

English Heritage's Building Conservation Research Team therefore decided to assess moisture contents directly by measuring the environment the pillars would produce beneath a strip of black plastic sheet.

Method

Columns were numbered in pairs (eg 1N : 1S) from the W end. In order to test the method, two data loggers recording temperature (°C) and relative humidity (%RH) were taped to columns 2N and 2S at a height of 600 mm

St John the Baptist, Pinner, West London, where investigation was carried out on the source of damp to the internal stone columns.

above the floor. Each logger was covered with a strip of black plastic sheet wrapped around the column and taped top and bottom. Column 2N was selected because an area of concrete had been removed the previous year from around its base as an evaporative zone, and it was hoped that the monitoring would demonstrate whether this had aided drying.

Table 1: Average temperature (°C), humidity (%RH) and air moisture loading (g/kg dry air) produced by moisture in the columns during 12-hour monitoring periods. Air moisture loadings of 7–8 per cent would be considered to be acceptably dry in this situation.

Period	Column	%RH	°C	Air moisture
1	2N	61.4	20.8	9.5
	2S	97.8	20.9	15.2
2	2N	55.6	17.4	7.0
	1N	54.4	17.5	6.8
	1S	70.5	28.3	9.0
3	2N	56.8	17.5	7.1
	3N	50.1	17.8	6.5
	3S	85.3	17.8	11.0
4	2N	59.0	17.6	7.3
	4N	55.3	17.9	7.1
	4S	73.2	17.8	9.4
5	2N	60.3	17.3	7.3
	5N	53.7	17.5	6.8
	5S	63.3	17.6	7.8
6	2N	61.0	17.1	7.4
	6N	62.7	17.5	7.8
	6S	78.0	17.4	9.8

Table 2: Comparison of average moisture loading for each pillar, (a) after subtraction of the average moisture loading recorded at the control column 2N and (b) during the same monitoring period.

Column	N (a–b)	S (a–b)
1	-0.2	+2.0
2	0.0	+5.3
3	-0.6	+3.9
4	-0.2	+2.1
5	-0.5	+0.5
6	+0.4	+2.4

The results from this first monitoring period (Table 1) showed that column 2S was much wetter than 2N. The results also showed that the environment maintained by the moisture in the pillars did not fluctuate greatly over time, so that a shorter monitoring period would be acceptable. This meant that all of the pillars could be assessed in order to find out if there was a pattern to the moisture distribution.

Three data loggers were used for the next phase of the monitoring. One logger was attached to 2N as a control throughout the monitoring period, while the others were moved from each N/S pair to the next after an equilibration period of 12 hours. Loggers were fastened in the same manner as before.

Results from this second monitoring period are also presented in Table 1. Air moisture loadings under the polythene are calculated from temperature and humidity.

The effects of different time periods and temperatures can be removed from the analysis by subtracting each moisture loading from the control during the same time period. The results from this assessment are presented in Table 2.

Results

Table 2 shows the following:

- The damp problem still continues on the S side
- The E end is a little damper than the W
- The wettest columns are 2S and 3S.

Discussion

The pillars on the N side are the driest, and there are no indications that the evaporative zone around column 2 has influenced its moisture content.

Ground on the S side of the church slopes down from the SE. The wettest columns, however, are the second and third from the W end. Their substantially elevated moisture contents suggest a more localised fault than general ground water, and the adjacent external down pipe may provide the answer. If there were a problem with the gully or drain in this area, then it would account for the observed moisture distribution in the columns. A preliminary camera inspection proved impossible because the drain was filled with silt, thus suggesting that the diagnosis is correct. The first action must therefore be to ensure that rainwater is conducted away from the building, and this should solve the damp problem. □

Rain Damage to Masonry
Wall cappings and towers

Chris Wood *Senior Architectural Conservator, Building Conservation and Research Team*

New research is underway to provide remedies for the damage water causes to towers and ruined walls.

Work has started on two research projects commissioned by the Building Conservation and Research Team. Soft Capping is a study of the advantages and disadvantages of growing grass on the top of ruined walls. Damp Towers is an investigation of the problems caused by driving rain on solid masonry walls and possible remedies.

Both three-year projects build upon earlier experimental work carried out in the laboratory and on site. Although separate research studies, they are both concerned with the movement and control of moisture, so some experiments will be designed to be mutually beneficial. The aim is to produce Technical Advice Notes to owners, specifiers, conservators and contractors on determining the work required and offering best practice guidance in carrying it out.

Soft capping

Soft capping has been tried on a number of English Heritage sites in the last decade, mainly on very low walls. This has been done in response to the failure of 'traditional' hard caps, which were repaired in cements that caused excessive cracking, allowing water to penetrate. Also, lime mortars have been unable to withstand the harsh climate of some sites. Even where hard capping has been successful, rainwater has been directed swiftly away down the face of the wall, resulting in continual wetting and greater exposure to frost attack. The cost has been high, not only in terms of deteriorating or lost fabric but also of the finances repeatedly required to repair and maintain walls.

Tests carried out in a 2001 study at the University of Oxford revealed that a thin layer of soil (2″: 50 mm) prevented the top of the wall freezing even in the harshest of winters.* A tight mass of roots combined with a loamy/clay soil also held water, acting as a sponge in wet weather or drying out during dry, windy spells. Water run-off was greatly reduced. The current research aims to test these findings further, both in the laboratory and on English Heritage sites. In addition, investigations will be held on the practical aspects of establishing and maintaining soil and grass on wall-tops. The performance of existing and proposed 'best practice' hard caps will also be studied.

Damp towers

The Damp Towers research project – understanding and controlling the ingress of driven rain through exposed, solid wall masonry structures – is the latest in a series of investigations on sites, especially in the south-west of England where the problem is particularly acute. A tower that receives over a 100 inches of rain a year, much of it blown horizontally for several days at a time, will become saturated no matter how well it is constructed and maintained. The secret is to limit the amount of moisture that finds its way into the building, and try to ensure that it is held in the core until it dries to the outside in fairer weather. Repair methods such as repointing, rendering or grouting are well known, but determining the internal condition of the tower can be difficult without extensive opening-up and damage to important fabric. Deciding upon the appropriate repair and its extent can therefore be hazardous.

Tests of driving rain carried out in 2002 at Sheffield Hallam University covered a number of remedies. These experiments will be extended in this current research project, along with monitoring and testing the performance of towers before, during and after repair. □

* Viles, H, Groves, C, and Wood, C 2002 'Soft wall capping experiments', in Fidler, J (ed) *Stone: stone building materials, construction, and associated component systems – their decay and treatment* English Heritage Research Transactions series (Vol 2). London: James and James (Science Publishers) Ltd, 59–73

Callacombe Church, North Devon, showing the effect of driving rain constantly soaking the walls. The tower was repaired four years ago (see *Conservation Bulletin* **36**, 14–16).

Thornton Abbey, Lincolnshire. Preparing a section of low brick wall for experimental soft capping.

Regional Advisors
Archaeological science network

Peter Murphy *RSA, East of England Region*

A network of nine regional advisors has led to an increased dissemination of guidance and best practice in archaeological science, in collaboration with a range of organisations.

A network of nine posts was established by English Heritage in 1999 to provide scientific advice to its regional teams and local authority archaeology officers. Developed from former university contract posts in archaeological science and conservation, these regional advisors (RSAs) work closely with Inspectors of Ancient Monuments, regional planners and policy officers on statutory casework, site management and regional planning issues. Based in universities and regional offices, these advisors also collaborate with a range of organisations – government agencies and departments, national parks authorities, wildlife trusts, national and regional museums, and universities – to develop joint management and research projects, and to bring in new funding to archaeology. The RSAs also collaborate with and advise local authority curators, field units and consultants.

Producing good practice standards and guidance is a priority. *Archaeological Science at PPG 16 interventions: Best Practice Guidance for Curators and Commissioning Archaeologists*, written by the RSAs, was published on the English Heritage website in 2003. Working with English Heritage's Centre for Archaeology (CfA), the RSAs have produced guidance on environmental archaeology and provided the science component for regional archaeological research frameworks.

A particularly successful collaboration between the RSAs and the CfA has been the delivery of professional training in archaeological science. In the last four years, over 1000 people have attended one or more of 41 courses, and these will continue.

The RSAs also have their own areas of expertise in areas such as contaminated land, wetlands, coastal change and managed realignment, site preservation *in situ*, groundwater monitoring at wetland sites, maritime sites and managing wreck sites.

Looking ahead, new legislation and integrated approaches to land and resource management will call for archaeological science responses – for example, the EU Water Framework Directive and Catchment Flood Management Plans.

A recent external review of the RSA posts (available at www.english-heritage.org.uk/rsareview) has concluded that they have made a significant contribution to the quality of archaeological science in England since 1999. The very nature of their role draws them into the inter-agency collaboration that will form a large part of English Heritage's future work. □

The RSAs and their regions

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Towards Precise Dating
An 18th-century clergyman's legacy

Alex Bayliss *Scientific Dating Coordinator, Centre for Archaeology*

For the past decade, English Heritage has used mathematical techniques to interpret radiocarbon dates. This has led to more precise chronologies and has increased the range of questions that can be answered.

In 1763, the Reverend Thomas Bayes' 'Essay Towards Solving a Problem in the Doctrine of Chances,' published posthumously in the *Philosophical Transactions of the Royal Society of London*, introduced Bayes' Theorem (*left*). This mathematical equation allows new data to be interpreted in the light of existing knowledge ('prior beliefs') to derive new insights into a problem ('posterior beliefs').

For more than 200 years, however, Bayes' idea lay dormant, as no solution could be found for his equation. This changed in the late 1980s when advances in computing began to allow solutions using simulation.

Archaeology was quick to identify the potential of this new method, and the first software allowing the routine application of this approach for the interpretation of radiocarbon dates became available in 1993. Since that time, more than 2000 ^{14}C dates have been commissioned by English Heritage, of which about 85 per cent have been included in chronological models combining the absolute chronological information provided by the radiocarbon dates with the relative dating sequence provided by archaeological stratigraphy. This evidence allows some areas of probability to be excluded and more precise dating to be achieved.

During the past decade, this approach has increased the precision of archaeological chronologies provided by radiocarbon dating for English Heritage projects by about 35 per cent (for example, where a simple calibrated date range might span 300 years, the *posterior density estimate* spans only 200 years). The gain in precision, however, is not equally spread over all projects. It is greatest for sites with full archaeological excavation, vertical stratigraphy, and well-preserved bone or other organic material. For such sites, refined chronologies with a resolution of under a century are often now achievable.

$$\underbrace{P(parameters\ /\ data)}_{\text{Posterior belief}} = \underbrace{\frac{P(data\ /\ parameters)}{P\ (data)}}_{\text{Standardised likelihood}} \times \underbrace{P(parameters)}_{\text{Prior belief}}$$

Bayes Theorem.

The benefits

Refined chronologies have two consequences. First, they allow scientific dating to be useful in a wider range of archaeological periods. In particular, radiocarbon dating can now provide sufficient precision to be informative in proto-historic and historic periods where traditional archaeological chronologies are already comparatively refined. For example, useful applications have been undertaken in both the early medieval period and the middle Iron Age.

The second consequence is that the range of chronological questions which can be tackled with these new techniques has been extended. The question is no longer, for example, 'in which half of the fourth millennium was the Stepleton enclosure built?', but 'was it built before or after the main enclosure at Hambledon?', 'for how long was it in use?', and 'how does it relate to the construction and use of other monuments in the landscape?'. In fact, for the first time, we have a realistic chance of answering all these questions in a quantitative manner.

The 18th-century Enlightenment produced the equation, 20th-century computer science enabled the simulation of solutions and 21st-century archaeology will reap the benefit. □

Archaeology and DNA
Understanding the human past

Martin Jones *Chairman of the Research Panel; Professor of Archaeology, University of Cambridge*

Recent advances in DNA science have a considerable impact on our understanding of the human past. Projects at the University of Cambridge, the birthplace of DNA science, illustrate the range of that impact.

In the last two decades, archaeology and DNA science have interacted in a remarkably fruitful way. That interaction has brought the 'Out of Africa' model of modern human evolution to prominence, initially through the sequencing of modern samples, and subsequently by the sequencing of Neanderthal specimens. It has raised the profile of many areas of archaeological enquiry, from early diseases, to kinship patterns, to the domestication and breeding of plants and animals, and the movement of different communities around the world. The University of Cambridge is one of several centres in which such research is active. The following examples of its research illustrate the growing range of this new branch of archaeological science.

The spread of farming

There has been much debate over how much the spread of farming took new communities around the world. The clear survival of a genetic signature of the palaeolithic movements show that such a replacement was far from total, and indeed some have argued that farming spread largely as an idea rather than a community. There are however, both genetic and linguistic arguments that the physical spread of extraneous Neolithic communities was substantial. This is an issue that can be explored by comparing and contrasting human genetic patterns with patterns of domesticated plants and animals that clearly moved during the farming episode. Martin Jones' group is part of a newly funded NERC consortium, in which Cambridge institutions partner with the University of Manchester Institute of Science and Technology (MIST) and the University of Sheffield to map precisely the genetic signatures of two key Neolithic crops, emmer wheat and barley, across the European continent. This project will examine DNA from extant plants and ancient archaeological specimens, and also material from an intermediate group, including herbarium specimens and thatch fragments that might loosely be described as 'stale DNA'.

Most ancient DNA projects are now nested within extensive modern DNA studies. The cereal project above is an example of that, as is the recent work of Peter Forster and Marsha Levine on the origins and spread of horse domestication, working largely from modern mitochondrial DNA. With their detailed global analysis in place, Mim Bower is able to situate an extensive multi-period collection of excavated horses from the Cambridgeshire site at Earith Quarry in context, and two individual horses from Roman Cambridgeshire have already been linked to their European types.

Conquerors and slaves

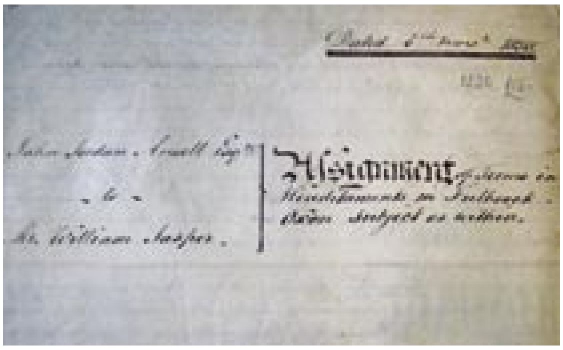
Written history is almost invariably shaped by the conquerors, but archaeogenetics bears witness to the oppressors and oppressed alike. In collaboration with Mark Jobling at Leicester, Peter Forster's Cambridge group used DNA sequences to trace the spread of African slaves into the Caribbean. A critical feature of this research was the independent tracing of male lines (through the Y chromosomes) and the female lines (through the mitochondrial DNA). The most striking result in the sample studied was that more than 95 per cent of Caribbean mitochondrial DNA is African, whereas more than 25 per cent of Caribbean Y chromosomes are European, the latter presumably derived from the slave owners. Native American DNA comprised only 1 per cent, confirming the large-scale extinction of the indigenous population. Conversely, Native American slaves have left their trace in the Polynesian Islands, where Matt Hurles managed to connect certain unusual genetic types today to the 19th-century Peruvian slave trade.

Conquerors have very often been male, a feature brought out by Peter Forster's group in the contrasts between Y and mitochondrial signatures in various parts of the world, a point graphically illustrated by the 'Genghis Khan' signature. This is a Y-chromosomal lineage that makes up only half a per cent of the world's male population, but eight per cent between the Caspian Sea and the Pacific Ocean, a modern genetic fossil of the Mongol expansion.

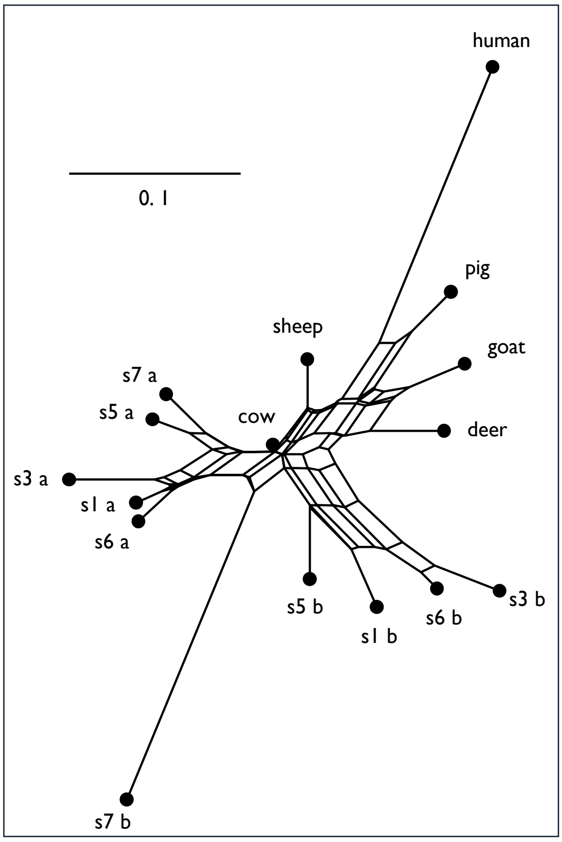
Text genetics

An unusual spin-off of the growth of genetic analyses has been the transfer of family-tracking or 'phylogenetic' programmes, designed for the study of strings of DNA, to strings of words. In Chris Howe's biochemistry lab, alongside the test tubes, molecular reagents and DNA sequences, he is using these programmes to study the 'relatedness' of slightly variant mediaeval texts. His group is also refining methods to study the ancient DNA signatures from mediaeval parchments, not just to determine the animal sources, but also the relatedness of the animals used.

Peter Forster has also extended these programs from molecules to words, to explore the contentious ancestry of certain Indo-European languages. His analysis of the Celtic family group raised alarm bells among certain historic linguists, as it broadly supported Colin Renfrew's hypothesis of linkage with the spread of early farming. However, a similar, more wide-ranging analysis of Indo-European languages, also using phylogenetic programs, has arrived at a similar conclusion.



One of the parchment specimens with which the University of Cambridge has been experimenting: a legal document, written in Oxford in 1830.



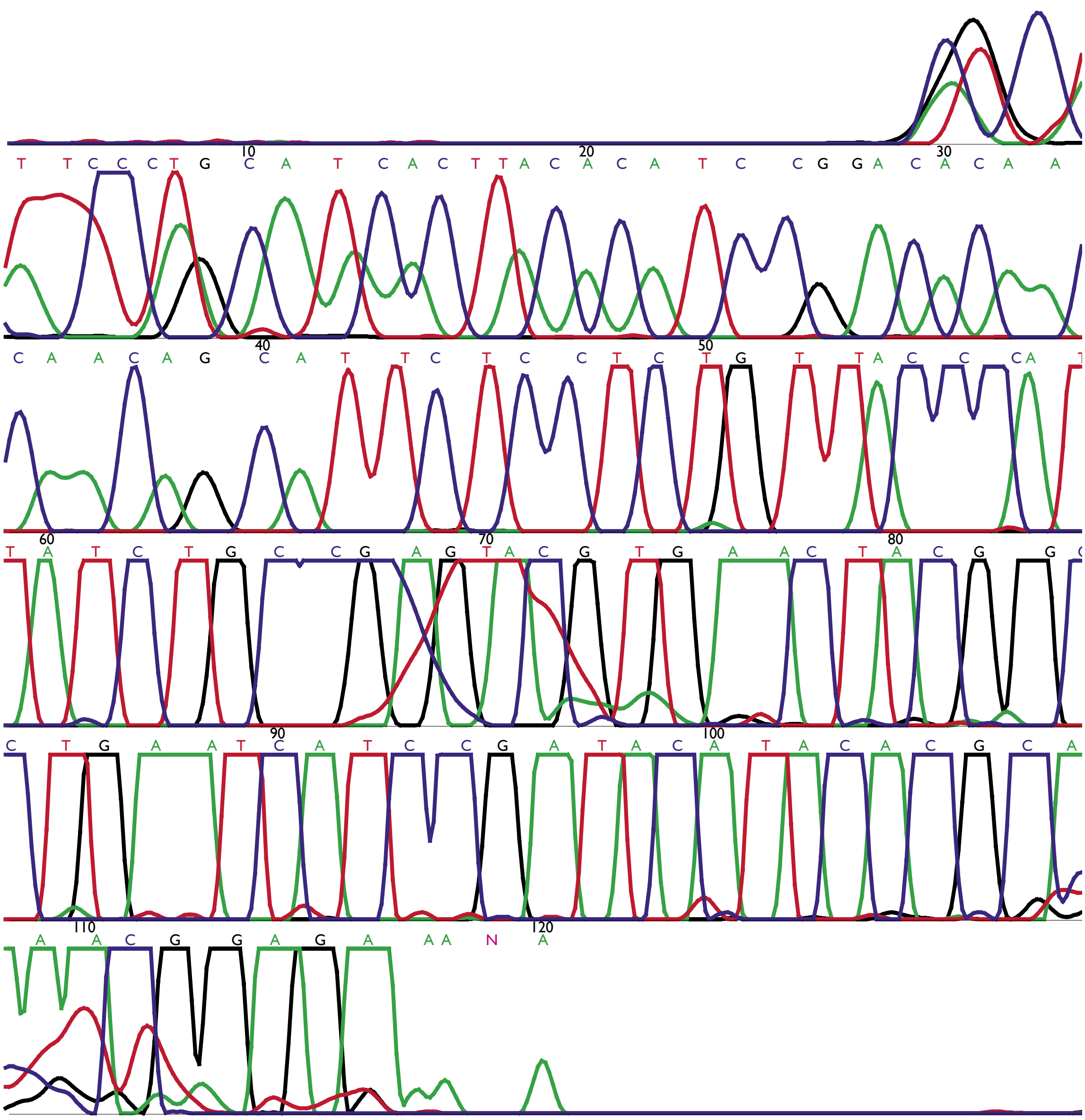
DNA sequences from parchment samples (labelled s1a, s1b, ...) compared to those from common domestic animals. Lines on the graph represent possible evolutionary relationships, with lengths proportional to the number of nucleotide differences. Parchment samples are closest to those from cow, with differences probably caused by post-mortem damage.

Genes and beyond

Much of the interface between DNA science and archaeology has exploited DNA sequences as a kind of neutral tracker, charting family relationships without getting too confused by other issues. However, DNA sequences are also a driver of our form and structure, and one of the exciting directions of the archaeology / genetics interface is an exploration of the links between DNA, active genes and the tangible world of human life and its varied forms. Robert Foley and Marta Lahr are pioneering the study of the genetic basis of human physical variation. Their Leverhulme Centre of Human Evolutionary Science, soon to move into a new, state-of-the-art building, will take forward modern and ancient DNA studies in the context of traditional human skeletal and behavioural studies.

Human health and disease

Another Cambridge anthropologist, Leslie Knapp, explores the relationship between health, disease and genetics among the wider primate group, which included humans. Her research group is studying the major histocompatibility complex (MHC) group of genes among a variety of primates. These are genes that are fundamental to our immune system, providing resistance to malaria, tuberculosis, HIV infection and even SARS. However, they not only affect our resistance to diseases, as Dr Knapp's work demonstrates that they also have a discernible effect on our social and mating behaviour. Thus, a complex series of patterns is interconnected. At one end



Typical DNA sequence results. Each coloured line represents the amount of one of the four kinds of nucleotide at a particular point in the sequence. An unambiguous sequence will have a clear pattern of peaks without overlaps, but ancient DNA sequences are often damaged and hard to read. The letters above the peaks indicate the corresponding nucleotides in the sequence.

lie those subtle, unspoken signals that attract us to one another and to the social worlds we build around that attraction. In the middle is the ecology of disease resistance that will be strengthened in the offspring that attraction generates. At the other end is the complex but tangible chemistry of sequences of DNA, which to a great extent we share with many of our animal relatives. □

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The NMR
News and events

ENGLISH HERITAGE
NATIONAL MONUMENTS RECORD

The National Monuments Record is the public archive of English Heritage. It includes over 7 million archive items (photographs, drawings, reports and digital data) relating to England's historic environment.

The following information gives details of web resources, new collections (catalogues are available in the NMR search room in Swindon) and outreach programmes.

Images of England

The number of photographs featured on the Images of England website continues to grow. There are currently over 82,000 images of England's listed buildings included, with more added regularly. The site has now been redesigned to make it quicker and easier to use. Images may now also be purchased from the site.

The Images of England project aims to create a 'point in time' photographic record of England listed buildings, both as an invaluable source for research, study or teaching – for example, history and geography at primary, secondary or higher levels of education – and also as a comprehensive record for future generations of England's listed buildings.

Images of England is a ground-breaking initiative funded jointly by English Heritage and the Heritage Lottery Fund. For more information, please visit: www.imagesofengland.org.uk or contact Alexandra Saxon: Tel 01793 414779; alexandra.saxon@english-heritage.org.uk.

ViewFinder: On-line image resource for England's history

The launch of *ViewFinder* was reported in the last issue of Conservation Bulletin. Since then, the New Opportunities Fund has enabled the NMR to continue to add photographs from its important collections to this public access website. The NMR's collection of 2,800 photographs by Eric de Maré is now available on-line.

Eric de Maré (1910–2002) was an influential architectural photographer and writer. After training as an architect, he spent many years photographing and writing about industrial subjects in Britain. His particular interest was what he termed the 'functional tradition' within architecture. The resulting collection is fascinating both for its unique perspective on England's industrial history and also for the inherent aesthetic properties of the individual images. It is therefore of interest to a wide audience.

Since July 2003, the NMR's computerised catalogue records for Eric de Maré's photographs have been enhanced and the images themselves digitised. They are now available on *ViewFinder* at www.english-heritage.org.uk/viewfinder.

Society for Photographing Relics of Old London

The Society for Photographing Relics of Old London was founded in 1875 in response to the threatened demolition of the Oxford Arms, a 17th-century coaching inn (see page 46). The NMR holds this interesting collection, which comprises two complete sets of 120

Market stalls in Ross-on-Wye, Herefordshire, clustered around the late 17th-century market hall Photographer: Eric de Maré, 1945–60.

A detailed view of a pottery kiln in Stoke-on-Trent, Staffordshire. De Maré was interested in functional industrial structures such as this one. Photographer: Eric de Maré, 1945–58.

photographic prints, dating from 1875 to 1886, of galleried inns, timber framed houses and other 'relics' of London, many of which have since been destroyed by development or enemy action in World War II. The first 24 photographs were taken by Alfred and John Bool, the remainder by Henry Dixon. The NMR also holds 79 10 inch x 12 inch glass plate negatives relating to the collection, and copy negatives of the majority of the images.

Paul Barkshire

Paul Barkshire is a London-based professional freelance photographer. The Barkshire collection provides a key context for any visual understanding of late-20th-century London. Paul Barkshire studied photography in Canada before returning to England in 1978 to photograph London's historic buildings. His intention was to record the changing London of the late 1970s. The NMR first purchased prints from him in 1982, eventually holding 5,079 negatives and acquiring the copyright in 1994. The 8 inch x 10 inch negatives are mostly black and white and produce images of a very high quality. They span the period from 1978 to 1993, providing the NMR with a modern element to its London records.

The subject matter is mainly architectural – houses, public buildings and structures, including contemporary buildings – and also public art. The choice of subject matter, however, often goes well beyond the conventional and commercial views of London: no other photographer represented in the NMR

The Oxford Arms, Warwick Lane, Holborn, London, photographed from a window of the Old Bailey, with St Paul's Cathedral in the distance. This 17th-century galleried inn was demolished in 1878. Photographers: A & J Bool, 1875.

A newspaper vendor and café tables in Leicester Square, Westminster, London. Photographer: Paul Barkshire, 27 July 1984.

has attempted to convey suburban areas, minor roads and alleyways.

Like Henri Cartier Bresson, Paul Barkshire printed the full image; there is never any editing or cropping and the caption is always clearly evident on the edge of the image. He exhibited at the Photographers Gallery in 1984 and has also exhibited in Europe. Three books feature his photography: *Paul Barkshire's Unexplored London* (1987), *Paul Barkshire's Other London* (1989) and *London Villages* (1992).

Cataloguing our Historic Plans

The NMR has recently embarked on an initiative to make the historic plans of English Heritage and its predecessor bodies, including the Ministry of Works, available to the public through a programme of cataloguing. In the first year of this project, the NMR aims to catalogue all the photograph albums and drawings of at least 20 properties managed by English Heritage that have been selected for special investment over the next three years.

The collection contains around 250,000 measured drawings and 1,500 albums and files of photographs and postcards created as a record of repairs, restoration, interpretation and works required to enable public access to sites and properties in guardianship. Dating mainly from the 20th century, though with some notable 19th-century items, the drawings include maps, plans, elevations, sections, sketches and reconstructions, from general views to highly detailed surveys of particular parts of sites. Photographic coverage is also mainly 20th-century, with a range of general and more detailed views that complements the drawings.

For further details, please contact Michael Russell: Tel 01793 414828; mike.russell@english-heritage.org.uk.

Outreach

NMR Outreach is currently trialling a local history project which aims to help communities engage with their past. The Living Story Project will create a photographic archive to capture the history, heritage and life of the Rodbourne area of Swindon (also known as Even Swindon) over the past 150 years.

The project looks back from life in Rodbourne today to the development of the community in the late 19th century, when suburban streets of terraced houses were laid out by speculative builders, as homes for workers of the Great Western Railway, on land that was part of an earlier rural farmstead.

The project brings together the local community by encouraging its members to share their memories and experiences of the area, to discover how local archive resources can help and to contribute their own material to a digital community archive. Activities by the 'street detectives' explore the architecture and historical development of individual streets linked to the stories of past inhabitants. When complete, the archive will become an important record and resource for the local community.

Supporters of the project include the NMR, STEAM – Museum of the Great Western Railway, Swindon Library Service, Wiltshire and Swindon Record Office, and partners within the local community.

Outreach programme

A varied programme of workshops, tours, lectures, weekly classes and events is designed to help participants make the best use of NMR resources for work, research or personal interest.

Short introductory tours to the NMR Centre in Swindon are available, and for those wishing to explore the resources in more detail, study days are organised on a number of different themes.

For further information about the Living Story Project or NMR Outreach, please contact Jane Golding: Tel 01793 414735; Fax 01793 414606; jane.golding@english-heritage.org.uk.

The NMR's London search room closed on 13 February and its holdings were transferred to Swindon. Please note that the Swindon search room will be closed to visitors until 3 May 2004 to allow the London material to be integrated, but a reduced service will operate for enquiries sent by post, phone or email:
NMR Enquiry & Research Services, NMRC, Kemble Drive, Swindon, SN2 2GZ; Tel 01793 414600; nmrinfo@english-heritage.org.uk

News
from English Heritage

Historic Environment: Local Management

On 31 March, English Heritage launched HELM, its £500,000 national training programme aimed at improving decisions that impact on the historic environment across all aspects of local government and government agencies. The project, which has the backing of the Office of the Deputy Prime Minister, will help local government understand the significance of the historic environment. It is targeted at decision-makers, including elected members, and officers, including planners, highways engineers and estate managers.

A range of expert guidance relating to historic buildings, archaeology and landscapes is available online from 31 March at www.helm.org.uk. The site, currently in development, contains information on local heritage management as well as technical advice and training activities. We would welcome your feedback.

HELM is part of English Heritage's wider commitment to providing the tools to enable local authorities to manage change in the historic environment and meet the challenges of the 21st century. For further information, email helm@english-heritage.org.uk.

Heritage Counts 2003

This report is an annual audit of the state of the historic environment, published in November 2003 by English Heritage on behalf of the heritage sector. It highlights the contribution England's heritage can make to the nation's quality of life.

Commenting on the report, Sir Neil Cossons, our Chairman, said:

> Heritage Counts 2003 *is a guide to the true state of what is arguably England's greatest asset. Above all, it delivers the resounding message that in our small, crowded and ancient country, the historic environment is all around us and that the vast majority, whatever their ethnic, social and cultural background, cares passionately about it. But statistics in the report show that much of our heritage is at risk – despite the evidence of its contribution to core Government policies such as social and economic regeneration, sustainability, social inclusion, tourism, education and citizenship.*

The Rt Hon Tessa Jowell MP, Secretary of State for Culture, Media and Sport, said:

> *We are the guardians of the past and the trustees of the future… As* Heritage Counts 2003 *demonstrates, millions of us choose to live, work and relax in historic buildings and landscapes. I want to involve communities more directly in how their historic assets are best safeguarded and preserved. To this end, our Designation Review, which is already well advanced, is looking at a new system of protection that would give people a greater say. I hope it will unlock in the public mind the link between citizenship and heritage. This will only strengthen the contribution the historic environment makes to our education, our economic well-being and our quality of life.'*

Heritage Counts 2003 takes the form of one summary document, one main data document and nine regional documents. The summary and data documents have been produced by English Heritage on behalf of the Historic Environment Review Steering Committee; the regional documents have been produced by English Heritage Regional Offices in collaboration with regional Historic Environment Forums. Copies may be downloaded from www.english-heritage.org.uk or obtained free of charge from Customer Services (Tel 0870 333 1181; Fax 01793 414926; customers@english-heritage.org.uk).

Regional Plans 2003–5

English Heritage has produced nine *Regional Plans* (A4 12-page documents) that explain what we will be doing in each region from 2003 to 2005. The plans also describe our national strategy and include details of our activities in each region. Practical case studies illustrate our work. Copies may be downloaded from www.english-heritage.org.uk/Around our Regions or obtained free of charge from regional offices or from Customer Services (details above).

Ecclesiastical Review

The long awaited consultation paper on the ecclesiastical exemption from listed building and scheduled monument consent controls, promised by Government in *A Force for our Future*, has now appeared. The paper follows, and forms part of the Government's wider review of heritage protection, as set out in last year's consultation document *Protecting our Historic Environment: Making the System Work Better*. The paper proposes that the ecclesiastical exemption should continue, but should operate under high-level management agreements to be reached, as appropriate, with each denomination in England. Such management agreements would be in force for a five-year period, after which they should be subject to a thorough review. It suggests that English Heritage might be appointed to the role of validator and empowered to monitor the operation of the exemption. The document can be downloaded from the DCMS website (www.dcms.gov.uk). The period for consultation lasts until 31 May 2004.

Chairman's lecture

Sir Neil Cossons gave a public lecture at the Getty Conservation Institute, Los Angeles, California, on 19 February, one of a series of lectures on international conservation issues. He reviewed current trends and views about communities, heritage and conservation, and explored future options. Recent conservation work in England – part of a wide-ranging review of protection and management of the historic environment – has demonstrated that support for it is widespread, as it is increasingly seen as a key to creating sustainable communities.

Civic heritage guidance

English Heritage has identified that almost 17 per cent of Grade I and II* listed buildings at risk of loss from neglect and decay are owned by central and local government. Reorganisation and financial constraints mean that many architecturally and historically significant local landmarks such as former town halls, swimming pools, libraries and assembly rooms are now redundant.

New guidance – *Managing Local Authority Heritage Assets* – has been published by English Heritage, and endorsed by the Office of the Deputy Prime Minister and the Department for Culture, Media and Sport, to help local authorities secure the future of these local landmarks. Aimed at key decision-makers, the guidance covers a range of landmarks from town halls, archaeological remains and listed buildings, to conservation areas, historic landscapes, cemeteries and battlefields. It encourages local authorities to know what they have, understand its condition and potential and take a positive and strategic approach to its management, including finding new uses for buildings or disposing of them to provide a sustainable future.

Managing Local Authority Heritage Assets: some guiding principles for decision-makers may be downloaded from www.english-heritage.org.uk/policy or ordered free of charge from Customer Services (details above).

Sustainability Forum

According to the Bruntland Report (1987), sustainable development 'meets the needs of the present without compromising the ability of future generations to meet their own needs.' English Heritage's original Environmental Forum, set up in 1999, aimed to formulate, implement and review our environmental policy. Since then, the Government has broadened the concept of sustainability to include economic and social as well as environmental issues.

Last year, the Executive Board agreed that English Heritage should develop a policy to cover the Government's concept of sustainability, to re-name the Forum and to ensure that its membership reflected the wider issues it will consider.

The Forum, which meets quarterly, has three main roles: to develop proposals, to monitor and report, and to promote their implementation. The aim is to embed the ideal of sustainability throughout English Heritage so that it is evaluated in terms of the cost to the organisation and the benefit to the historic environment.

For more information, please contact David Drewe (Tel 020 7973 3597).

Building crafts

The UK's historic environment is under threat because of a shortage of skilled craftspeople. As the construction industry increasingly adopts system-building methods, such as the use of prefabricated units and stick-on bricks, so the teaching of traditional building skills, as well as new methods of repair, declines within the Further Education sector across the UK. Yet according to the 2001 *English House Condition Survey*, 21 per cent of the total number of dwellings in the UK were actually built before 1919; it estimates that some 69 per cent of dwellings of all ages have at least some fault to the interior or exterior fabric. Repairing historic buildings requires familiarity with traditional building methods and techniques if the work is to be done sensitively and appropriately.

So there is work to be done, provided that we can interest people in learning traditional crafts and deliver higher standards in workmanship through appropriate training. To tackle this problem, English Heritage and the Government's Sector Skills Council for the construction sector, CITB-ConstructionSkills, have created the National Heritage Training Group (NHTG). The first task of the NHTG will be to commission region-by-region research to discover where the critical skills shortages actually are, and then to work with employers and Further Education colleges to deliver the necessary training.

CITB-ConstructionSkills has produced a careers brochure to help show young people what is entailed if they decide to follow a career in one of the traditional building crafts, the qualifications they can attain and examples of the subsequent career paths of people in the sector. If you would like a copy of *Building Conservation and Restoration*, please contact CITB-ConstructionSkills (01485 577 577) or English Heritage's Customer Services (details above).

RIBA Affiliate membership

Key resources of The Royal Institute of British Architects (RIBA) are now available to a wider range of people with an interest in the historic environment, following the launch of its new class of Affiliate membership. The RIBA provides a unique forum for a wide diversity of people and is dedicated to the betterment of the built environment. The RIBA has raised the profile of architecture with the public and is working with the Government and its agencies on promoting good design.

Affiliate membership is open to anyone with a professional or personal interest in architecture. Benefits include a free subscription to the RIBA Journal and free use of the RIBA library, Information Centre and online services. The RIBA also has a new partnership with the V&A, which will provide much greater access to its combined world-class collections of architectural drawings and archives. A new architecture gallery for the public at the V&A will also open. For more information, please contact Sandy Lopes (marketing@inst.riba.org; Tel 020 7307 3626).

Charter for planning and development

English Heritage is committed to improving the quality and delivery of advice for those involved in changing or influencing change to the historic environment. Enclosed with this issue of *Conservation Bulletin* is a copy of our new charter explaining our role in the modernised planning system and what clients can expect from English Heritage. To receive further copies, or to discuss the implications of the charter, please contact any English Heritage regional office. General enquiries about the streamlining of our advisory services for planning and development should be addressed to Anthony Streeten (anthony.streeten@english-heritage.org.uk).

Conservation Bulletin

The new format of this issue is the result of a strategic design review by Boag Associates Ltd, who consulted widely with internal and external stakeholders, and the editorial board. We are grateful for everyone's comments and advice during various stages of the review. The new design is intended to strengthen the presentation of policy, best practice and news, and this issue will be the first to appear on the English Heritage website (www.english-heritage.org.uk).

Books received

Allen, Geoffrey *et al*, *Hydraulic Lime Mortar: For stone, brick and block masonry,* 104 pp, Donhead, 2003, ISBN 1-873394-64-0, pb, £20

Bankart, George, *The Art of the Plasterer (facsimile of 1908 original with amendments)*, 368 pp, Donhead, 2002, ISBN 1-873394-51-9, hb, £65

Brown, Sarah & Strobl, Sebastian, *A Fragile Inheritance: The care of stained glass and historic glazing – a handbook for custodians*, 68 pp, Church House Publishing, 2002, ISBN 0-7151-7600-5, pb, £9.95

Collings, Janet, *Old House Care and Repair*, 208 pp, Donhead, 2002, ISBN 1-873394-61-6, hb, £25

Cunnington, Pamela, *Caring for Old Houses* (revised edition of 1984 *Care for Old Houses*), 256 pp, Marston House, 2002, ISBN 1-899296-17-4, pb, £14.95

Earl, John, *Building Conservation Philosophy (3rd edition of revised 1996 original)*, 230 pp, Donhead in association with the College of Estate Management, 2003, ISBN 1-873394-56-X, hb, £37

Jones, Gwen, Lake, Jeremy & Martins, Susanna Wade (eds), *Rural Regeneration: A sustainable future for farm buildings (Papers of the Historic Farm Buildings Group 2002 Conference)*, 47 pp, The Historic Farm Buildings Group, 2002, ISBN 0-9517503-2-1, pb, £9.50

Kilburn, Mike, *London's Theatres* (Foreword by Zoë Wanamaker CBE), 160 pp, New Holland, 2002, ISBN 1-84330-069-9, hb, £24.99

Lavédrine, Bertrand, *A Guide to the Preventive Conservation of Photograph Collections*, 312 pp, Getty Publications, 2003, ISBN 0-89236-701-6, pb, £34.50

Leonard, Mark (ed), *Personal Viewpoints: Thoughts about painting conservation*, 128 pp, Getty Publications, 2003, ISBN 0-89236-698-2, pb, £22.95

Maekawa, Shine & Elert, Kerstin, *The Use of Oxygen-Free Environments in the Control of Museum Insect Pests*, 224 pp + CD-ROM, Getty Publications, 2003, ISBN 0-89236-693-1, pb, £45

Oxley, Richard, *Survey and Repair of Traditional Buildings: A Sustainable Approach*, 224 pp, Donhead, 2003, ISBN 1-873394-50-0, hb, £39.50

Prizeman, John, *Houses of Britain: The outside view* (Foreword by HRH The Duke of Gloucester; new edition of 1975 *Your House: The outside view*), 134 pp, Quiller Press, 2003, ISBN 189916367-0, pb, pb, £14.95

Scott, David A, *Copper and Bronze in Art: Corrosion, colorants, conservation*, 520 pp, Getty Publications, 2002, ISBN 0-89236-638-9, hb, £53.50

Smith, Major Percy, *Rivington's Building Construction* (facsimile of 1904 revised edition of 1875 original), 1376 pp (3 vols), Donhead, 2004, ISBN 1-873394-66-7, hb, £99.50

Swallow, Peter, Dallas, Ross, Jackson, Sophie & Watt, David, *Measurement and Recording of Historic Buildings* (2nd edition), 224 pp, Donhead, 2004, ISBN 1-873394-62-4, hb, £35

Teutonico, Jeanne Marie & Matero, Frank (eds), *Managing Change: Sustainable approaches to the Built Environment* (4th Annual US / ICOMOS International Symposium 2001), 214 pp, Getty Publications, 2004, ISBN 0-89236-692-3, pb, £38.50

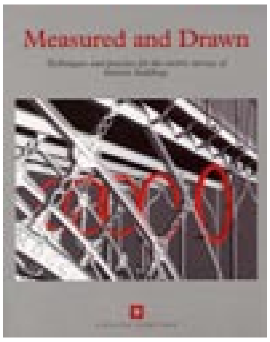
Watt, David & Colston, Belinda, *Conservation of Historic Buildings and their Contents: Addressing the conflicts*, 128 pp, Donhead, 2003, ISBN 1-873394-63-2, pb, £20

Weaver, Lawrence, *English Leadwork, Its Art and History* (facsimile of *1909* original), 288 pp, over 400 illustrations, Donhead, 2002, ISBN 1-873394-60-8, hb, £60

New Publications
from English Heritage

Measured and Drawn: Techniques and practice for the metric survey of historic buildings

by David Andrews, Bill Blake, Tom Cromwell, Richard Lea and Sarah Lunnon



The metric survey of our historic environment is a crucial part of our understanding. Mapping the historic estate means that it can be conserved, managed and enjoyed. This book gives an introduction to the metric survey techniques currently available to conservation professionals and building archaeologists. It examines control, detail and procurement, and concludes with case studies of metric survey projects undertaken on historic buildings and structures ranging from Battle Abbey courthouse to the nave ceiling at Peterborough Cathedral. *Measured and Drawn* is prepared in sequence with *The Presentation of Historic Building Survey in CAD* (English Heritage 1999) and *Metric Survey Specifications for English Heritage* (English Heritage 2000; reprint 2003) as part of a series of technical guides for heritage recording.

PRICE £15 + £2.50 P&P
ISBN 1 873592 72 8
PRODUCT CODE 50729
Paperback, 62 pages, 71 illustrations

Publications may be ordered from English Heritage Postal Sales, c/o Gillards, Trident Works, Marsh Lane, Temple Cloud, Bristol BS39 5AZ; Tel 01761 452 966; Fax 01761 453 408; ehsales@gillards.com.
Please make all cheques payable in sterling to English Heritage.
Publications may also be ordered from www.english-heritage.org.uk.

Publication Catalogues
Our main catalogue of priced and free publications *New Titles: May to December 2004* (Product Code 50902), as well as catalogues of technical conservation publications (Product Code 50777) and free publications (Product Code 50673), may be obtained free of charge from English Heritage, Customer Services Department, PO Box 569, Swindon, Wiltshire SN2 2YP; Tel 0870 333 1181; customers@english-heritage.org.uk

ISSN 0753-8674
Product Code 50821
Conservation Bulletin
Appears three times a year
Mailing List:
mailinglist @ english-heritage.org.uk
Tel 020 7973 3253
Editor:
Karen Dorn
kd@academyprojects.com
Editorial Address:
English Heritage, 23 Savile Row, London W1S 2ET
Designed by Boag Associates Ltd
Produced by JW Offset Ltd
www. english-heritage.org.uk

English Heritage is the Government's lead body for the historic environment