Scientific and Technical Review, Issue 1, June 1992 (Conservation Bulletin 17 supplement)

(NB: page numbers are those of the original publication)

Science and conservation for English Heritage

English Heritage is responsible for the conservation of a substantial proportion of the nation's material heritage. Through our grant-aid programmes, statutory work, advice, or in the course of caring for our own considerable holdings, we conserve, directly or indirectly, a very wide range of buildings and artefacts. From cob cottages to historic houses; from wrought iron gates to the iron corrosion stain in the soil of a Saxon grave; from medieval wallpaintings to the historic paint layers on a beam engine – English Heritage needs to find the technical expertise to preserve and interpret.

We have built up a strong scientific and technical advice service which covers the following areas:

survey and recording – geophysical prospection, research into techniques of remote sensing, radiocarbon and archaeomagnetic dating, dendrochronology; photogrammetric and manual survey of standing buildings and monuments; maintaining the archive of historic plans

environmental analysis – of ancient landscapes and ecofacts, including soils, botanical remains, and animal and human bone; of landscape design and management

technological studies – of past industries and artefacts; investigative conservation of archaeological material

Excavating a soil block in the laboratory

The laboratory's scanning electron microscope in use

conservation – of historic objects and interiors, including advice on the correct environmental conditions for objects, historic houses, and stores; the design and installation of environmental monitoring control and service systems

paintings–conservation of wallpaintinngs, other historical painted surfaces, and easel paintings; historic paint analysis

architectural conservation – including metal, stone, and a wide range of building materials; research into building materials and their behaviours; architectural conservation practice; conservation engineering practice

information support and the development of complex scientific computing systems for conservation, survey, and scientific analysis

provision of audit and advice on contracts and on the economics of building conservation.

Since the creation of Technical Services Group within English Heritage in July 1989, the core of scientific and related professional disciplines have been brought together under a single management, although they are, as yet, still separately housed in six different locations. The chart on the back page shows how the group is organised, incorporating the Ancient Monuments Laboratory, with its strong range of analytical equipment, with the other technical disciplines. As well as in-house staff, we work through a network of specialist contractors.

Publications

The Technical Services Group is extending and enlarging the range of its technical publications. An index of publications is available directly from TSG (from Ancient Monuments Laboratory, Fortress House, 23 Savile Row, London W1X 1AB) and will continue with additional titles in technical fields.

The creation of this new management structure has offered an exciting opportunity to build an integrated science and conservation service and improved our capacity to answer the wide range of science and conservation questions posed by English Heritage's work. This Scientific and Technical Review has been produced as a snapshot of some of the practical work and research in progress at this time of opportunity and challenge.

New directions

The new structure reinforces the professional expertise of English Heritage. The skills of staff now brought together in this area, working with those who are dealing directly with our own properties and with the regional teams of Conservation Group, facilitate an integrated approach to the technologies of the past. Similarly, the approach to conservation has become increasingly holistic, as the insights of a multidisciplinary team offer a greater ability to consider not only the artefact but also the building that contains it and the environment enclosed by that building. The environmental studies and scientific landscape analysis, aided by geophysical prospection, will be able to help in the understanding of the parks and gardens surrounding our own monuments, as well as the ecofacts resulting from archaeological excavation.

Geophysical surveying, Castle Acre Priory

Inevitably, the cross-fertilisation brought about by bringing complementary disciplines together brings new insights and challenges to add to traditional commitments. The stimulus of uniting the intellectual resources and practical skills of staff from different disciplines makes practicable new work, but the ratio of staff to workload remains the same. If we are to benefit from our opportunities, we must adopt a more critical approach to deciding what we can do ourselves and what we must ask others to do for us.

New targets

English Heritage has responsibilities as a national advisory body and a museum authority. Scientific and technical advice is needed to support much of its own work and the extent to which it can fulfil these demands and provide assistance beyond this needs to be assessed.

Science and Conservation Services and Works Professional Services are undertaking, with the advice of English Heritage's own Science and Conservation Advisory Panel, a thorough overhaul of the relevant research and development programmes, the aim being to target those areas where the need to have a national overview makes it important to concentrate effort. We are considering what developmental research should be done by us, what could and should be done by universities and funded by the research councils (with ourselves as field-testing partners), and what we should fund others to do for us. Projects range from, for example, guidelines in the various techniques of scientific assessment of excavated material, undertaken in-house, to a project into the decay of sandstone, undertaken by the Building Research Establishment on our behalf. *Exploring our past* clearly demonstrated the need for a more synthetic approach to regional problems in archaeology. This is reflected in the work ofinhouse staff and in the targeting of the funds available, and we hope that a greater proportion of the time of our contractors will be similarly directed. In particular, our effort will be directed towards an improved framework for better choices for science-based archaeology in both excavation and analysis. They will also maintain an advisory and assessment service and retain an overview of their regions.

In the course of the next year, we shall be looking at the range of expertise offered by the 31 contract staff currently funded in 11 different locations to see whether or not, as presently located, they offer the best regional coverage for the scarce science and conservation disciplines which they represent.

Although it is vital to retain enough practical work to form the basis for the advice we give and the research we do, our role will need to shift towards defining standards and monitoring quality for the work done on behalf of English Heritage. To this end, staff in the Science and Conservation Services and Museums Division will be carrying out a conservation audit on our own holdings to give us better information from which to construct priorities and define standards for care.

As the Framing Opinions campaign on traditional doors and windows shows, the conservation message can be brought to the wider community. We intend, through campaigns like this, and through publication, to continue to influence conservation practice by deepening the knowledge of its scientific and technical base. We have also contributed in this area, historically, through education and training, and we hope that our involvement here will grow. We will continue to offer internships to newly qualified scientists, conservators, and works professionals and to be involved with the national effort to produce and test National Vocational Qualifications. Through initiatives like the setting up at Fort Brockhurst of a practical building conservation centre, and through our recent service level agreement with the Courtauld Institute to collaborate in the practical training of wall painting students, we hope to influence conservation practice in those two very important fields.

Bone recording in the laboratory

This thumbnail sketch encapsulates many of English Heritage’s aims over the next decade in relation to building an effective science and conservation service which will meet the organisation’s own needs and underpin the advice it gives. It demonstrates the commitment that English Heritage has made to science and conservation practice as an essential part of our role in understanding, preserving, and interpreting the historic environment.

RICHARD DAVIES and KATE FOLEY

Conservation of the painted decoration at Brodsworth Hall

In April 1990, English Heritage received Brodsworth Hall, a stately home near Doncaster dating from the 1860s, as a gift from its owner, Mrs Pamela Williams. This was an important acquisition, since the historic interiors of Brodsworth have been acclaimed as a rare example of surviving mid-Victorian decorative and finishing schemes. The Hall

contains a wealth of painted marbling, *trompe l'oeil* work, stencilling, decorative wallpapers, and bronzed ironwork. Unfortunately, both the fabric of the Hall and its contents were in extremely poor condition, having suffered from years of industrial pollution, water damage, and general neglect.
This presented English Heritage with a dual challenge. The first and most immediate was to prevent any further deterioration of the building and its contents. The second was the wider task of retaining the elusive character of an aged family house while providing access to the general public.

Development of a conservation strategy

A working party of curators, architects, and inspectors was created to formulate a general strategy for the conservation and presentation of Brodsworth Hall. A wide range of conservation options was examined, and opinions were also sought from historic buildings experts outside English Heritage. The consensus of opinion was in favour of a policy of conservation as found, rather than restoration, meaning that all subsequent alterations to the house were accepted as equally important parts of the building's history.
Once a basic strategy was established, specific problems such as structural damage, leaking roofs, rising damp, and fragile carpets could be identified and dealt with. At this stage, a preliminary condition survey and study of the decorative history of the painted decoration at Brodsworth was undertaken by our painting conservation studio in conjunction with the architectural paint research unit.

Brodsworth Hall during structural renovations, May 1991

Decorative history

The identification and dating of the wide range of decorative painted finishes in the Hall formed an initial problem. Most of these decorations appeared to have been untouched for a considerable period. There had been a general assumption that little redecoration had been carried out in the house after its fitting out in the 1860s. However, it became apparent after a preliminary examination that many areas had been redecorated. Far from being 'preserved in aspic', it became obvious that large areas of the Hall, like any other home, had been gradually renovated and altered. The need for more detailed information on the decorative history of the interior became apparent. Rather than relying on purely stylistic analysis of the various decorations, we were able to base this research on two sources of evidence: the family archives, held by the Doncaster Archives department and the Yorkshire Archaeological Society record offices, and the physical evidence of the paint finishes themselves.

General view of main staircase showing marbled decoration

Historic paint research offers the opportunity to examine the buildup of painted finishes and clarify the sequence of decorations applied to the interior. Small samples of paint and substrate may be removed and examined under high magnification. More sophisticated methods of analysis maybe used to identify standard pigments and additives within the paint which provides valuable evidence for dating individual decorations. For instance, the presence of titanium in a paint would indicate that the decoration must have been applied after 1920 when that pigment became commercially available. It was hoped that by carrying out paint sampling in selected areas, in conjunction with a study of the builder's and painter's accounts, it would be possible to establish the full decorative history of the Hall.

The original building specification (Yorkshire Archaeological Society DD 168/2) proved a useful starting point for this research. It was drawn up in 1861 prior to the demolition of the old Brodsworth Hall. It provides a range of interesting information, but it is unclear how closely the specification was followed. The instruction to rehang 15 mahogany doors from the old Hall in the new building was certainly followed. Other aspects are less clear; it was also specified that the dado linings from the old Hall should be reused in the new Dining Room, Library, and Morning Room, but if these were fitted they have since been removed. This suggests that the original specification was drawn up with a view to reusing Georgian elements, but was later modified to suit contemporary Victorian taste. Further research will be required to clarify the early decoration of these rooms.

In other areas, paint research was able to show that the building specification had been closely followed. It included fairly precise instructions for the decoration of the Entrance Hall. It stipulated that the walls of the Entrance Hall, corridors, and principal staircases were to be painted 'five times in oil and finished in imitation marble'. The decoration was then to be given two coats of copal varnish. These instructions do appear to have been carried out; examination revealed that the original finish of the painted marbling had not been overpainted.

Drawing room ceiling: detail of decoration

References in the specification to the decoration of other areas in the house are rather vague. All of the walls on the ground floor were to be distempered 'according to the tint approved'. The principal bedrooms were to be papered with paper of the value of 8 shillings (40p) per piece, while the servants' rooms were decorated with paper of the value of 2 shillings (10p) per piece. No traces of early decorations appear to have survived in these rooms.

The archives also contain painters' bills for later decoration projects. These indicate that as early as 1880 extensive repairs were being carried out to areas of the painted marbling in the Entrance Hall. A bill submitted by Maple and Co in 1914 also describes extensive repainting which attempted to match the original decoration. Further sampling and analysis of these retouched areas may offer a useful comparison of marbling techniques and materials. There was obviously a desire to retain the original marbling in this area, but other areas of the Hall seem to have been completely redecorated at regular intervals.

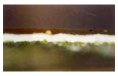
Painters' bills indicate that several major redecoration schemes were carried out in the late nineteenth and early twentieth century, which involved the washing off of distemper decorations and removal of wallpaper. Paint samples taken from the more utilitarian areas of the house, such as the kitchens and servants' quarters, confirm that these areas have undergone repeated redecoration.

Despite later redecorations and repairs, Brodsworth still retains many of its original nineteenth-century painted schemes throughout the formal ground-floor rooms and passages. From what is known at present, it would seem that the last major redecorations were carried out in the 1930s, mostly in the family bedrooms and service areas.

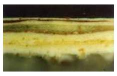
Detail of marbling on main staircase

The condition and treatment of the painted decoration

The purpose of the condition survey was to identify the main categories of deterioration, the causes of the damage, and those areas in urgent need of conservation. For practical purposes, the rooms were divided into two categories: those with elaborate painted finishes such as marbling, and other rooms that had standard painted decoration. Only the former required specialist attention, and it was from this category that a trial area was selected for conservation treatment to enable us to design a strategy for treating the remaining areas.



Paint sample in cross-section, showing original marbling and discoloured varnished layer



Paint sample in cross-section, showing repeated decorations over early stencilled border

Detail showing macro flaking of painted marbling

Causes of deterioration

The condition of the painted decoration at Brodsworth was in places extremely serious, with substantial flaking and loss in both the paint and plaster layers. Initial examination revealed that this deterioration was largely the result of disruption by salt efflorescences and cycles of salt crystallisation, rather than of problems relating to the original technique of the painted decoration. Salts are naturally available in building materials and deterioration only occurs when cycles of salt crystallisation are set in motion by the ingress of water. There are generally two sources of water: infiltration, for example through rising damp or from a leaking roof, or condensation as a result of poor environmental conditions.

Water infiltration

It was evident that there were substantial water infiltration and water disposal problems. The reasons for this are fairly complex and stem from a combination of external factors, arising outside the Hall, and internal factors or problems deriving from the physical characteristics of the Hall itself. In the first category, the two main issues appear to have been industrial pollution from local power stations and domestic coal fires, which has affected the stone fabric of the house, and the subsidence caused by the coal mining which was undertaken around and under the Hall. In the second category, there are several causes: a build up of earth at the base of the walls, an unsuccessful slate damp-proof course, and a general lack of maintenance, as well as ineffective repairs to the roof and a lack of attention to downpipes, gutters, and gulleys, have led to serious water infiltration problems.

Environmental conditions

The deterioration of the fabric has been further exacerbated by the environmental conditions of the Hall. Initial examination suggests that condensation may be a problem in some areas and that environmental modifications are therefore required to improve ventilation and control heating levels. The environmental conditions are at present under investigation by our Mechanical and Engineering section.

Problems of water infiltration are relatively straightforward to remedy. Environmental modifications are necessarily more subtle: relative humidity has a direct relationship with cycles of salt crystallisation. When the relative humidity drops, salts increasingly crystallise, and when it is raised, previously crystallised salts will re-dissolve. The relative humidity level is affected by temperature and ventilation. However, deciding a suitable level of relative humidity (and therefore the levels of heating and ventilation) is complicated by the fact that the various salt types precipitate in slightly different ways and under differing conditions. Thus, in order to arrest the damaging cycles of salt crystallisation in the long term at Brodsworth, it will be helpful to establish a profile of the salt types in conjunction with repairs to the fabric and modification of the environmental conditions.

The back staircase during conservation

Condition of the painted decoration

The condition survey revealed that up to 40% of the fine painted decoration required conservation treatment. Areas where water infiltration had occurred, for example near windows or just above ground-floor level, were consistently found to be in a very serious condition. The plaster was subject to decohesion, cracking, delamination, and loss. The paint layer also showed extensive macro-flaking, and much of the overlying varnish had darkened to a dull orange-brown, obscuring the original bright colours. Some of the marbling, particularly sun-damaged sections, were prone to craquelure, shrinkage, and ‘alligatoring’ effects. A substantial number of poor quality repairs and retouchings had also been added over the years; the materials used to repaint even included nail varnish! Finally, the overall appearance of the painted decoration was considerably worsened by the substantial amount of surface dirt which had accumulated.

Treatment of the test area

The north wall of the back staircase is decorated with pink Sienna marbling which is now dull orange-brown in appearance owing to the thick overlying layer of discoloured varnish. This area was subject to extensive macro-flaking and also had numerous poorly applied and badly discoloured retouchings, as well as a substantial amount of surface dirt and evidence of some ‘thunder fly’ insect infestation. It was identified as being in most urgent need of conservation in the preliminary condition survey and was therefore selected as a test area. The aim of the conservation treatment was to make safe rather than restore, in keeping with the overall conservation policy at Brodsworth.

Following tests, the first phase of treatment involved fixing paint flakes and surface cleaning. The technique for fixing the paint layer involved an initial injection of a wetting agent of 40:60 acetone:white spirit behind the flake. This was followed by a further injection of Plextol B500 (a standard conservation grade adhesive – ethyl acrylate and methyl methacrylate 60:40) at 15% in water. The inclusion of acetone in the wetting agent served to reduce the drying time by accelerating evaporation of the water content of the Plextol, thus creating the effect of a contact adhesive. Once injected, the flakes were readhered by positioning a pad of absorbent paper over the treated area and pressed back with a small roller. Surface cleaning of the accumulated dirt was undertaken with a mild soap. This was applied with a sponge or brush and rinsed from the surface with water. The insect infestation was largely dealt with through the fixing and cleaning procedures and did not require further treatment. The varnish layers and later retouchings were not affected by this cleaning process; this method was simply designed to remove surface dirt.

Injection of paint flakes

The second phase involved filling of losses in the paint layer, and for this a standard commercial filler was employed. This was considered necessary in order to secure the vulnerable edges of the losses and to improve the aesthetic appearance of the wall surface. In order to make these repairs, the poorly matched past retouchings were removed because of their inaccurate application over both the original paint layer and the losses. The final presentation of the marbling remains in question. It is proposed that the repairs are toned to blend with the present colour of the marbling, and a final synthetic protective varnish, such as Ketone or Paraloid, applied.

The Brodsworth policy of preserving, not restoring, is an exacting one. Technically, it would have been more straightforward to remove the discoloured varnish and fully restore the losses in the painted marbling. It is perhaps hardest to know when to limit an intervention. Conducting research to establish the exact nature of the painted decoration within the Hall, in conjunction with the development of a conservation strategy to ensure its preservation, emphasises the value of all the existing decoration and the significance of preserving it for the future; the present policy allows for later adjustment.

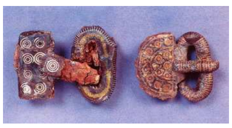
CAROLINE BABINGTON and HELEN HUGHES

Changes of approach to archaeological conservation

The excavation of burials from pagan Anglo-Saxon cemeteries presents a unique opportunity for studying metal grave goods which, rather than being discarded or lost, have been deliberately buried along with their organic components and alongside organic artefacts. In the Ancient Monuments Laboratory, the potential for the investigation of organic materials preserved by metal corrosion products had long been recognised. Techniques have been developed and refined over the years by the examination of material from many sites and the importance of the conservator in observing and recording such evidence has been recognised.

Developing techniques

The excavations at Mucking, near Thurrock, Essex, produced many artefacts from two cemeteries and many other features, and the work of archaeological conservation on the cemetery material mirrors the development and modification of techniques which have taken place generally over the last 20 years. The current preparation of the catalogue has provided the opportunity to take a retrospective look at the conservation carried out in the 1970s and also to adjust identifications and interpretations in the light of more recent experience. It also confirmed the value to the study of archaeological material of research archives: having the site records, the artefacts, and the conservation records all collected in one place, in this case at the British Museum, is a necessity when dealing with complex materials and contexts.



Inlaid iron buckles and plates from Mucking

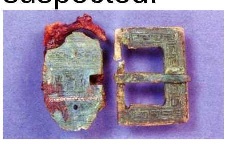
From the beginning of the conservation of this material, the excavators, Margaret and Tom Jones, showed an awareness of the potential of the artefacts, ensuring that no cleaning was carried out on site and that the organic material was presented to the laboratory with a protective coating of soil. They also showed a great interest in any information recorded by the conservator about the examination of the artefacts. Conservation was felt to be an important part of the post-excavation process and this led in the mid 1970s to the production of detailed drawings on the conservation cards as the clearest way of recording complex information.

X-radiography has always been an important technique, particularly in the examination of iron. Initially, its main importance was felt to be the identification of iron artefacts and the clarification of any obvious detail, egnon-ferrous metal inlays on objects such as buckles, of which Mucking produced several examples. It was not at first appreciated that more subtle detail could be revealed by this technique. This was demonstrated in the Mucking material by the reexamination of an iron spearhead which had a copper alloy coating on the socket. The original report stated that this was only discovered on cleaning, but closer examination of the X-radiograph revealed that the non-ferrous metal coating could be seen. X-radiographs were even shown to reveal metallurgical details: the weld lines on artefacts such as knives, where the steel cutting-edge was joined to the back, could also be seen when the original plates were closely examined.

Further X-radiography has been carried out for the preparation of the catalogue. Some of the original X-ray plates were inadequately washed and have darkened, emphasising the importance of archival quality processing. In some cases, it has been felt that details of metallurgy or shape will be clarified by further radiography. Also, stereo X-radiography has been employed to sort out the detail of some of the more complex items, eg an iron buckle and plate inlaid with silver and copper alloy.

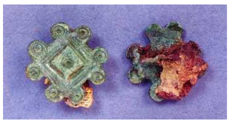
The decoration was revealed on this artefact by using a dental drill, at that time the only means of removing strongly adhering accretions from weakened objects. The surface was gently abraded until the inlay was revealed, leaving a smooth, polished surface. Unfortunately, this method did not give an accurate representation of the surviving surface and was not able to sort out fine constructional details, such as the exact form of the hinge mechanism.

The introduction of the airbrasive machine in the early 1970s for cleaning iron was an important development. The controlled removal of the corrosion products, using aluminium oxide powder through a fine nozzle at a low air pressure, enabled the cleaning of inlaid iron to be carried out with much more precision. This method was able to reveal the copper alloy coating on the spearhead, even though its presence was not originally suspected.



Copper alloy buckle and plate from Mucking

In the Ancient Monuments Laboratory in the 1970s, conservation was a more interventionist discipline than it is today. It was thought necessary to remove far more corrosion than would be done now, and it was considered important to attempt to stabilise the objects by means of washing and chemical processes followed by waxing or lacquering. Fragile, mineral-preserved organic material was consolidated with plastic resins, copper alloys were lacquered, and iron coated with wax – all of which now makes it more difficult to see details. Time has proved that the washing method for stabilising iron has not been entirely successful and the search continues for a universal safe method of preventing the decay of this most vulnerable of materials. However, the inlaid iron, which it was not considered safe to treat in this way, was stored with silica gel to maintain a low relative humidity and to prevent further corrosion. This has now been shown to be a safe method of maintaining the condition of unstable iron and is generally preferred, whenever circumstances permit.

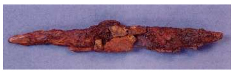


Pair of copper alloy brooches from Mucking, showing front and reverse

Mineral-preserved organics

The mineral-preserved organic material – the evidence of handles and sheaths on knives, hilts and scabbards on swords, organic components of shields, and traces of garments preserved on brooches – was always seen as an important feature of this site; textile remains were reported on from an early stage by Elisabeth Crowfoot. An important development in the identification of wood was the introduction of the Scanning Electron Microscope which enabled the species of wood to be determined, whereas the presence of iron corrosion had made it impossible to identify using traditional transmitted light microscopy. For many years, it was believed that knife handles had been made of wood, because under low magnification the preserved organic material on the tangs was seen to have a grain. An iron object from West Stow had similar material preserved on the inside, but it was looked at again when the object was identified as the rim of a drinking horn. The material was found to be horn, which can closely resemble wood under low magnification. This has led to the re-examination of many Anglo-Saxon knives, including those from Mucking, and they have been found to have handles formed of horn.

The methodology that has come to be used in the post-excavation examination of artefacts from excavations has largely been developed from the seminal work done on the objects from Mucking. Through the work of the many conservators who have been associated with the site, new standards have been set for archaeological conservation which have been adopted by the archaeological community throughout the United Kingdom and beyond. Most of all, there has been a growing realisation that the finds from excavations are capable of yielding far more information than had hitherto been realised. In this process, the conservators have seen their roles changed from simply being cleaners of objects for others to interpret to being fully-fledged members of the excavation team, contributing to the sum total of knowledge gleaned from the site.



Iron knife from Mucking, with visible leather and horn grain

GLYNIS EDWARDS and MICHAEL CORFIELD

Disaster mitigation for historic buildings

Those charged with the care and management of historic buildings live constantly with nightmare visions of catastrophe and disaster. International concern has centred on significant losses of cultural property in the flooding of Florence (1966), the Mexico City earthquake (1986), the conflagration of Lisbon's historic core (1988), and recently the bombardment of Dubrovnic (1991). Nearer to home, the fires at York Minster, Hampton Court, Uppark, St Mary at Hill, and Tomes Eastgate are no less shocking. Indeed, it can be argued that the United Kingdom has suffered more than its fair share of natural and man-made calamities – Brighton Pavilion and Uppark suffering structural distress in hurricane winds, Shropshire churches shaken by earth tremors, and Belfast and now London victims of bombing. And, despite these episodes being exceptions to the norm, we have all experienced smaller scale disasters, such as the falling chimney pots, leaking gutters, and burst pipes of home maintenance.

An incident becomes a disaster when destructive forces act on historic fabric in a significant, unforeseen, and uncontrolled way. Disasters are frequently characterised by the failure of management to take adequate precautions to avoid risky or hazardous situations and by an inability to respond appropriately to incidents before they escalate.

Uppark fire damage: disaster mitigation starts with management systems in order to minimise risks and help cope with them as incidents occur

Crisis management

English Heritage has built up a wealth of experience on disaster mitigation and crisis management based on its direct participation in and observation of limiting these catastrophes. The technical, logistical, and management lessons gained from individual cases and from the collected wisdom of national and international research and practice continue to guide the development of policies and procedures that we can share with others. Here, we summarise recent achievements in the field and briefly describe our ongoing work.

English Heritage's work in promoting conservation through grant-aid and advice has brought its interdisciplinary professional teams literally to the front line, during and in the immediate aftermath of fire disasters where insights have been gained into salvage and damage control. After the fires at Hampton Court and Totnes, our specialists were on hand to provide guidance on structural stability, fabric retrieval, first-aid conservation works, and archaeological survey and analysis. At York Minster and at St Mary at Hill, our skills in rectified photography and photogrammetry provided the conservation teams with speedy and effective records. The techniques of survey were further developed at Uppark, where our Central Archaeology Service responded rapidly to the damage and systematically collected collapsed, sodden, and charred material amongst the ruins in the now famous 3860 labelled plastic dustbins for speedy cataloguing, sorting, and sifting to aid restoration. These responses, although refined, are still reactive. We continue to develop and tune them, but we now see the protection of life and property in an holistic sense. Planning for disaster mitigation needs to be set within a strategic framework of integrated management policies and procedures aimed at minimising the risk of disasters ever occurring.

Fire safety and protection

Within Technical Services Group, long-range research on passive fire protection methods has gradually improved our knowledge of the performance of traditional construction in fire. We are making replicas of historic panelled doors and walls and are testing their behaviour in British Standard fire examinations together with various methods for upgrading their resistance. We are no longer reliant on passive techniques for fire safety, however; active systems are also now required.

In the course of the next 12 months, we hope to publish the results of our research and disseminate guidance on fire safety management based on our model system devised for Osborne House, one of the properties in our care. Osborne was the family home of Queen Victoria and the Prince Consort on the Isle of Wight. It is one of the most complicated buildings in English Heritage's care, in terms both of form and usage. Part of the building, the Household Wing, houses a nursing home managed by the Civil Service Benevolent Fund; other parts are managed by English Heritage and are open to the public. Accommodation is also provided for offices, workshops, storage, and other ancillary functions.

Fire safety was important to Osborne's designer. Thomas Cubitt devised what we now call 'compartmentation' in the original construction with brick internal walls and floors and a roof of iron and brick ‘jack arches’. In addition, the tower houses a water tank connected to fire hydrants.

In 1991, a detailed fire safety audit revealed that even in the best-run houses there will be deficiencies, notably on standards of housekeeping and maintenance. For example, large numbers of visitors in the house at peak periods caused congestion on the escape routes. There were inadequate planning for emergencies, little staff training, and no rehearsals. Fire compartments had been breached by the removal of doors and the absence of fire stopping around pipes and ductwork. The shortcomings were limited but critical, so measures to remedy the situation were put in hand within the framework of a comprehensive and coordinated fire safety strategy devised jointly by architects, services engineers, fire engineers, curators, conservators, and the house management, and in conjunction with the local fire authority.

Osborne House, Isle of Wight, where English heritage’s fire safety management plan forms the foundations of a total package of developing disaster mitigation measures

The protection of life and of the building and its contents are the key objectives of this exercise. Reasonable standards have been targeted with the minimum interference to the architectural and historic integrity of the property. This is achieved by addressing fire prevention and risk management, structural fire protection, and management policies for fire safety. For example, in some instances the standard of fire protection of some escape routes is less than the fire resistance normally required. To compensate for this, the fire load (the amount of combustible material) in the rooms in these areas is monitored and a system of automatic fire detection linked to the fire alarm has been provided. Thus, the existing standard of fire resistance of the escape routes, combined with planned emergency procedures and the early warning system, provides adequate time for occupants to escape safely. Such tradeoffs and balances are precisely engineered and tested. They are also often confirmed by surprise fire drills which are regularly executed with the public present – adding to the enjoyment of their tourist visit! By such means the standard half-hour fire resistance demanded in text books is well surpassed by total evacuations lasting only seven minutes and, on this basis, disruptive upgrading of historic fabric for fire protection has been avoided.

The fire-safety strategy encompasses staff responsibilities, manning levels, training, security, disabled egress, risk management, safety system checks, building works, special events, practice drills, and fire-safety audits. Evacuation and damage control procedures are also explicit, building once again on our experiences at Hampton Court and Uppark.

Uppark post fire: the National Trust’s temporary site stores for salvaged material awaiting treatment – lessons here for future disaster planning

Damage control systems

Our tasks for the next 12 months lie in formulating systems for damage control before, during, and after a fire or flood. With colleagues in our Museums Division of Properties in Care Group, the Science and Conservation Services Division will be preparing protocols and techniques for rescue, salvage, first-aid treatment, and care of objects damaged in disasters.

Pre-planning here is vitally important, so that salvage and damage control limit loss, deterioration, and decay of the building fabric and contents during any catastrophe and in its aftermath. The plan requires the designation of an onsite salvage warden to liaise with the fire brigade and an emergency support team to assist in rescue, protection, and emergency conservation operations.

Contents need to be ranked as to their art historical importance to provide a priority list for evacuation or local protection. Snatch squads require detailed briefing and training on dismantling, removal, and shielding in case of fire.

Plans need to be devised so that temporary storage and first-aid centres for salvaged objects can be arranged speedily for use immediately after an emergency. Here, the logistical planning is affected by conservation technology and scientific developments in cleaning, consolidation, and repair.

From our research and the experiences of our colleagues in the National Trust and Property Services Agency, we now know more about how masonry buildings dry out after dowsing during fires. Large quantities of water used during fire fighting can saturate brickwork and cause shattering during frosty weather; salts can be put into solution, migrating to cause subflorescence and exfoliation; and dormant fungi can be reactivated to cause timber decay. English Heritage and others are working on sensors to monitor the micro-environments caused by fire and flood in order to assess how to control conditions in the fabric’s best interests.

Professional skills

In the United Kingdom as a whole, an increasingly wide range of professional skills is now being focused on the special problems of disaster mitigation for historic buildings and artefacts. This is being done through such bodies as the International Council on Monuments and Sites, the Fire Protection Association (FPA), the UK Working Party on Fire Safety in Historic Buildings, the United Kingdom Institute for Conservation (UKIC), the Heritage Coordination Group, and the Regional Museum Services.

Information and guidance has been disseminated through seminars and publications, such as the FPA’s advisory leaflets and *Heritage under fire* and the East Midlands Museum Services’ *Museum and Record Office emergency manual*. Further publications are in preparation, including a UKIC response manual for conservators, a Butterworth publication on strategic planning for disaster mitigation, and an English Heritage guide to fire safety management in historic buildings.

Hampton Court immediately post fire: English Heritage’s experience of fast track salvage archaeology will be made available to a wider audience

The Science and Conservation Services Division, with its consultants, played a role in the subtle drafting of the new Building Regulations to the benefit of fire protection standards for historic buildings. We retain representation on the UK Working Party on Fire Safety in Historic Buildings and have been asked to help train fire officers to gain a better understanding of conservation issues. English Heritage’s Technical Services Group participated in UKIC’s seminar on disasters during last year’s RAI Exhibition at London’s Business Design Centre, and we are collaborating with the National Trust on the control of, or alternatives to, the infamous ‘hot work’ permits for leadburning etc in historic building repairs.

Finally, we should announce that funds have been set aside from English Heritage’s Cathedrals Grants Programme to carry out research on fire-safety strategies for cathedrals over the next three years. Many lessons have been learnt from the tragedy of York Minster’s fire, and tailor-made safety plans developed from this and other experiences should benefit these important buildings without detriment to their special interest.

In research, policy development, and crisis management, work goes on. Disaster mitigation for historic buildings is an important part of our conservation mission.

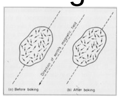
JOHN FIDLER and IAIN McCAIG

Archaeomagnetic dating

Whilst radiocarbon dating *(Conserv Bull* **15**, 11–12) is possibly the most revolutionary application of science to the study of the past, magnetism has achieved an almost equal importance owing to the breadth of its application. The use of magnetic prospecting techniques to locate and identify buried archaeological features was described in *Conservation Bulletin* **8**, 10–12. This technique measures local changes in the strength of the magnetic field brought about by past human intervention. However, it is also possible to date some of these structures by examining the magnetic fields that they create. This magnetic dating technique relies on two physical phenomena: the variation over time of the earth's magnetic field and the ability of iron oxides to record a magnetic field to which they are exposed under certain circumstances, called remanent magnetism.

The earth's magnetic field

The earth's magnetic field is not constant either in strength or direction: Magnetic North is not the same as True North, and the angle between the two is not constant. Whilst the annual change is barely perceptible, it may be as much as 10 degrees over a century, owing to the way in which this magnetic field arises.



Domain alignment in baked clay: (a) unbaked clay – the domains are magnetised in random directions, cancelling each other out, and the clay has no net magnetic field; (b) baked clay – heating has allowed the domains to realign themselves more closely with the earth's field, giving the clay a net magnetisation in its direction

At the centre of the earth, there is a region of hot, electrically conducting material, known as the core, extending outwards to about 3000km beneath the surface. Part of the core is fluid, and the flow within it acts in the same way as a dynamo generating electric currents that in turn give rise to a magnetic field. The main fluid flow produces a magnetic field with the same lines of force as if a bar magnet were located at the centre of the earth, giving rise to the North and South magnetic poles. In addition, small irregularities in the flow in the upper part of the core produce 'localised' perturbations of the earth's magnetic field as measured at the surface; these affect restricted areas a few thousand kilometres across. Both components of the magnetic field vary with time in both strength and direction, the localised component being the more transitory, lasting typically for a few hundred years. Changes in the magnetic field measured at the earth's surface are known as secular variation. The directional variations have been observed and measured at London, Paris, and Rome for about four centuries using magnetised needles, while records for other parts of the world have only been undertaken more recently. Two angles are measured: the angle between the needle and True North, referred to as declination, and the angle that the needle makes with the horizontal, referred to as inclination. In 1899, L A Bauer produced a classic paper that collated all the measurements of declination and inclination made by earlier scientists. This paper graphically illustrated the fact that measurements made even a few hundred kilometres apart are significantly different, and this has implications for the use of the phenomenon as a dating tool.

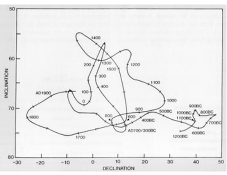
Remanent magnetism

Most clay and soil, as well as some rocks, contain a small percentage of iron oxide present as dispersed grains. Crystals of most iron oxides are 'ferrimagnetic', meaning that they have an intrinsic permanent magnetic field owing to the alignment of the atoms into magnetic domains within the crystal structure. Usually, for example in a naturally occurring clay, the directions of magnetisation of the domains are randomly distributed and the net magnetic field is extremely small; on average, each domain is balanced by another pointing in the opposite direction. However, if the temperature is raised by a few hundred degrees centigrade, the thermal agitation of the crystal lattice allows some of the domains to reverse their direction, aligning them more closely with the direction of the ambient geomagnetic field. On cooling, the domains are frozen in their new alignments and the clay obtains a net magnetisation in the direction of the earth’s field. The temperature to which the iron oxide grains must be heated depends on their size, shape, and mineral composition; typically, it is between 500 and 700 degrees centigrade. Provided that the clay is not disturbed or reheated, this thermoremanent magnetisation can remain stable for hundreds of thousands of years – effectively recording the direction of the earth’s magnetic field at the time that the clay was heated. If the clay is reheated, it will acquire a new thermoremanent magnetisation; hence the magnetic direction recorded is that for the last period of heating.

Sampling in progress at Burton Dassett, Warwickshire

Past directions of the earth’s field may also be recorded by depositional remanence. Particles of sediment containing iron oxides may have a very weak natural overall magnetisation. If these particles are suspended in still water, they will tend to rotate, so that their magnetic moments are aligned with the earth’s field. As they settle and are buried under the weight of more sediment being deposited above them, they are locked in position and thus record the direction of the earth’s magnetic field at the time that they were deposited. Cores taken from lakes can thus reveal substantial sequences of past geomagnetic field directions.

Calibration curves



Magnetic calibration curve for Britain, showing changes in the declination of magnetic north since 1200 BC

To use the recording mechanism of magnetic remanence as a dating technique, a reference curve is required that shows the direction of the earth’s magnetic field at different times in the past. Owing to the localised variations in the earth’s field, it is not possible to create a single calibration curve for the whole world: a series of curves is needed, each covering a region about 500km across. Data for the recent past are relatively easily obtained, as scientists have been measuring the changes directly. For less recent times, it is necessary to find features that have acquired a remanent field in an event that can be independently dated. Usually these are archaeological structures, such as kilns, ovens, or hearths that can be dated by documentary evidence, association with artefacts, or by their relationship to wood which has been dated using dendrochronology (*Conserv Bull*, **16**, 16–18). This information can be supplemented by cores taken from lake sediments, as organic material deposited with the sediment can be radiocarbon dated. Calibration curves covering the last two millennia have been developed for many parts of the world, including the state of Arkansas, France, China, Japan, Bulgaria, and Britain. Early work on the British chronology was carried out by Aitken at Oxford University. The Ancient Monuments Laboratory, through the work of Clark, was quick to see the potential of this new dating technique and was instrumental in further developing a calibration curve for Britain in collaboration with colleagues at Newcastle University. Work to refine and improve this curve and the method by which magnetic directions are calibrated still continues at the laboratory with the help of Durham University.

Practicalities

To date an archaeological feature using this technique, it is necessary that it should have remained undisturbed since it acquired its remanent magnetisation. Structures which are not underlain by firm soil or bedrock, or are otherwise disturbed, are not suitable, and the material, primarily clay, should be well baked so that it is not plastic when wet. Therefore, the most commonly dated structures are the remains of kilns, hearths, and furnaces. In the right circumstances, bricks and mortar from buildings may be datable. Samples are taken from the structure or feature to be dated by first fixing reference disks to it, levelling them, then marking a reference line on each using a gyro-theodolite to orientate the disk to True North. Finally the disks are removed, each attached to about 8cc of material from the structure. The samples are measured in the laboratory in a spinner magnetometer, a device that uses the magnetic field within the sample to generate an electric current that can then be measured to determine the magnetisation of the sample. The direction of magnetisation is related to the orientation line on the disk to determine the direction of the earth's field which it records. This can then be calibrated with the reference curve. Using a modification of this technique, the depositional remanence of sediments – for instance, from ancient pond, ditch, or moat deposits – can be dated, although results are generally less precise than for baked clay materials.

The accuracy of the dating obtained relies on the amount of calibration information available for the region and the period in question. Thus, the British curve is less accurate for the Dark Ages, where little complementary dating evidence is so far available. Also, for periods where the earth's field returns to a direction that it has occupied before, independent criteria must be used to choose between several possible date ranges. Precision depends on the rate at which the field direction was changing, periods of rapid change giving more precise dates. Typically, features can be dated to within 50 or 60 years, but the method is most precise in the Iron Age (*c* 600 BC–AD 50) and during the thirteenth to sixteenth centuries AD, where features can potentially be dated to within 35 years. It is important to note, therefore, that for the later middle ages at least, archaeomagnetic dating can be considerably more precise than radiocarbon dating. Also, if the appropriate fired clay features are available for sampling, archaeomagnetic dates can be obtained cheaply and the results made available within a few days if necessary.

The Archaeometry Branch maintains a programme of archaeomagnetic dating, both for provision of service dates and for research and development of the technique. Since 1990, the branch has produced 50 dates from 15 sites. Recent projects include a major sampling and dating programme for the Deansway Archaeological Project in Worcester, providing an important contribution to the chronology of the site. In addition, precise dates have been obtained from a series of domestic ironstone hearths at the deserted medieval village of Burton Dassett in Warwickshire. The most recent of these dated magnetically between 1387 and 1418, which agrees well with the documented abandonment of the site in 1397.

Although the archaeomagnetic dating facility operates at a modest scale, it provides a service scarcely available elsewhere in Britain. Apart from providing dates for projects supported by English Heritage, the branch is also involved in the continued research and development which, it is expected, will lead to the dating of structures from all archaeological periods to the same degree of precision as those quoted above. The Archaeometry Branch are therefore always pleased to hear of suitable features for dating by this method, especially where corroborative data are available for the consolidation of our calibration curve.

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