Chapter Two: Methodology

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SUMMARY

A number of technical and logistical challenges had to be overcome during this project and these required a methodology, employed in an innovative way and not usually encountered on standard archaeological excavations of burials. More specifically, the scope of the project required a methodology that accommodated the timely but careful and detailed recovery and analysis of a large number of human remains and artefacts under close media scrutiny, while maintaining the dignity of the deceased at all times. Unlike traditional archaeology, where the goal is largely scientific, this was a humanitarian project in which the sole focus was on the recovery and identification of individuals with living families. Thus, the highly sensitive nature of the work brought accountability and integrity into sharp focus, similar to modern forensic practice. It was therefore imperative that crime scene protocols were followed to ensure the continuity and chain of custody of all recovered artefacts and human remains and prevent contamination of the human remains by operatives. However, unlike forensic operations, there was no medico-legal intent to the work.

TEAM STRUCTURE AND COMPOUND LAYOUT

The project team comprised around 30 specialists and consultants consisting of a core group from Oxford Archaeology, including a senior project manager, archaeologists, osteoarchaeologists, surveyors, a liaison officer, a graphics officer and a finds manager. They were joined by a scene of crime officer (SoCO) from Gwent and Glamorgan Police, freelance forensic archaeologists and anthropologists, a freelance archaeologist from *Le Centre National de la Recherche Scientifique* (CNRS), a mortuary manager from Glasgow and Clyde NHS, a forensic radiologist from Basingstoke and North Hampshire Foundation Trust, a freelance forensic photographer, and a freelance senior forensic adviser. Consultancy was provided by a forensic pathologist, forensic odontologist and consultant forensic radiologists. Between them, the team had considerable experience in the excavation and post-excavation analysis of human remains, ancient and modern. Different members had worked on mass graves in Bosnia, Guatemala, and Iraq, and had attended mass fatality incidents, including the Indian Ocean tsunami in 2004 and the 2005 London bombings.

The range of expertise among the team was a significant factor in finalising and executing the methodology that was employed on the operation, including setting up the compound. The compound was designed to meet a number of requirements, including allowing the excavation and post-excavation processes to take place at the same time, facilitating the timely completion of the works and chain of custody, continuity and control (see below), and satisfying the client's wishes to keep the human remains and artefacts within the vicinity of the recovery site until their re-burial. In particular, it was crucial that the compound set-up allowed for a truly integrated approach, whereby the mortuary team could easily attend the graveside to inform their interpretations of skeletal changes or artefact details observed post-recovery, and the field team could visit the mortuary to inform the excavation methodology.

The compound was located in a field adjacent to the graves on an area of hard standing, set up specifically for the project, including the installation of services (water, electricity and telephone network) (Figs 2.1-2.3). It consisted of two main areas comprising the recovery site and the temporary mortuary complex which were fully monitored by a security guard and CCTV cameras, and surrounded by a perimeter fence (Fig. 2.4). The recovery site was accessed along a temporary road with a gated entrance, where changing rooms, toilets and a survey processing suite were located. From here, graves were excavated in parallel by two teams of seven individuals under cover (Fig. 2.5) in order to screen the graves from public view and protect them from the elements, in particular, rain and strong sunlight. The teams included one grave supervisor and one surveyor each, who were accompanied by an explosive ordnance disposal (EOD) engineer. All field operations were overseen by a senior field archaeologist, who also managed logistics.

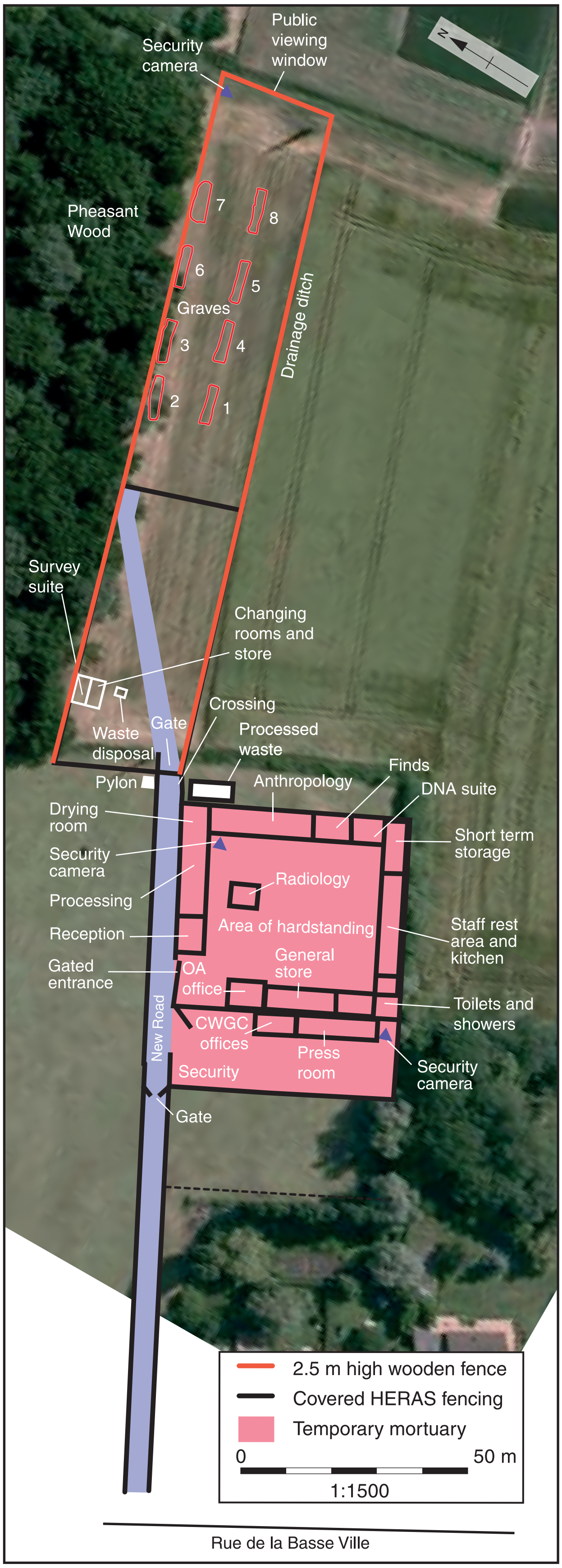

Fig. 2.1 *Compound layout and grave locations*

The temporary mortuary was designed with reference to protocols that have been employed in the context of medico-legal and/or humanitarian work following atrocity crimes (Anderson *et al.* 2008). This was required to provide a suitable facility that would accommodate all examinations of the human remains and associated artefacts and store them short term, in addition to providing offices, staff welfare facilities, a tool store and a visitor and media suite. The facility was overseen by a mortuary manager and was primarily organised to manage the workflow, maintain continuity and chain of custody and quality control (see below), prevent contamination of DNA samples, manage press and visitors, provide security, and protect the highly confidential nature of the operation. Areas of the mortuary included a booking-in and processing facility, radiography and photography suites, anthropology and finds laboratories, a DNA sample processing suite and a store.

CHAIN OF CUSTODY, CONTINUITY AND QUALITY CONTROL

Maintaining the integrity of all identification evidence recovered from the graves was of paramount importance and yet it was necessary to take samples from the bodies to be sent away for DNA analysis and remove artefacts from bodies for detailed examination and conservation. Therefore, a strict system of chain of custody, continuity and quality control was employed in order that all samples and artefacts could, at any point in the process, be traced back to the individuals they related to. This system was based on those employed to serve a judicial function and involved standards and protocols that are consistent with the confident association of human remains and other materials (Donnelly *et al.* 2008). Context and other information were rigorously recorded and then checked and signed off by relevant section managers. Chain of custody was maintained for all artefacts, bodies and DNA samples. Chain of custody refers to the process of signing for items every time they were moved from one stage of an

Fig. 2.2 *The temporary mortuary (reception entrance on very left of image)*

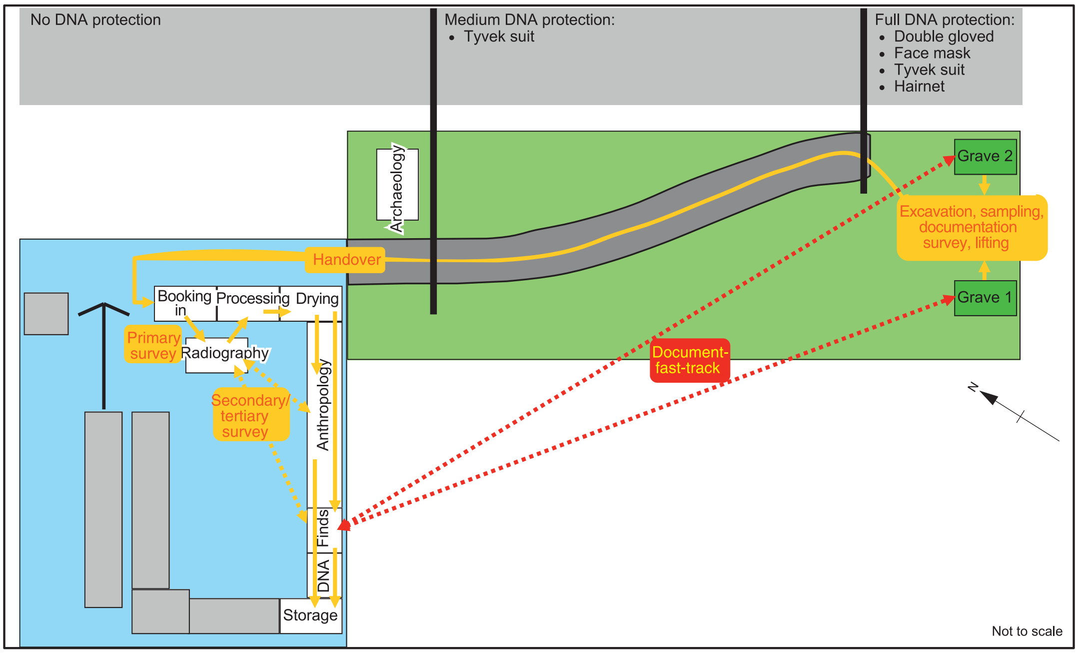

Fig. 2.3 *Diagram of compound layout showing workflow and DNA zones (image by Roland Wessling)*

Fig. 2.4 *Perimeter fence around excavation with viewing window for the public (arrowed)*

Fig. 2.5 *Graves three, four, five and six under cover of marquee; graves seven and eight in foreground, excavated and backfilled*

Fig. 2.6 *Signing a body over at the graveside to the mortuary manager*


a
b
c
d
e
f

Fig. 2.7 (left and above) DNA sampling methodology: a) Completing a sample form, b) Labelling a sterile pot, c) Sterilizing tweezers, d) Extracting a molar tooth seconds after it has been exposed, e) Placing the molar in the labelled sterile pot, f) Sealing the sterile pot, g) DNA sample in tamper-proof evidence bag, h) Surveying location of tooth that was sampled, i) DNA samples were taken from site in cool boxes to the temporary mortuary.

operation to another (Fig. 2.6), or from one operator to another, and was managed by the SoCO.

Compound integrity and continuity were maintained by operating a system of personnel entry control in which all staff were required to sign in and out with the time and date at the beginning and end of each working day. Visitors to the compound were also required to sign in and out and were only permitted to enter the compound if they had been authorised by the Oxford Archaeology or CWGC project managers. Continuity between site and mortuary operations was achieved by the role of the project's forensic photographer (see photography methodology below) and by locating the mortuary adjacent to the recovery site. Regular communication between the site and mortuary was facilitated by the use of hand-held radios and regular visits from mortuary staff to site and site staff to the mortuary. In addition, staff briefings between the project manager with the entire team and meetings between the project manager and section managers were held on a frequent basis. A computer and telephone network was also set up between the site and the mortuary, thereby allowing information to flow freely between sections.

More detailed procedures for DNA, fieldwork, mortuary operations, data storage and data security are described below. Quality assurance for anthropological recording is also relevant here and is described under 'Forensic Anthropology', later in this chapter.

DNA specific procedures

Procedures for taking and handling DNA samples were designed by the DNA project monitor and LGC Forensics in consultation with Oxford Archaeology. A pilot study was conducted at the beginning of the fieldwork operation to determine optimum teeth and bone samples for DNA extraction and analysis. Long bones, bones from the hands, feet, and thorax, different teeth, and preserved soft tissue (hair, brain and ligaments) were tested at LGC Forensics. Based on the results of these tests a methodology was devised and implemented. The methodology is detailed in a standard operating procedures document prepared by LGC Forensics (Appendix One).

The methodology is summarised in the following steps (Fig. 2.7):

i. Samples were taken from bodies as soon as they were exposed, as was practical (i.e. after recording and photography), in order to minimise exposure to contamination. This meant that the majority of samples were taken at the graveside, although a few (brains) were taken in the temporary mortuary.

ii. Samples were removed using sterile tweezers and placed into sterile pots, then clear plastic bags.

iii. All samples were labelled with the sample number, site code and body number.

iv. A sample form was completed for each sample.

v. Samples were placed into cool boxes and transported by the SoCO to the temporary mortuary where they were logged and either refrigerated at 4ºC (dry samples, such as teeth and small bones) or frozen at 20ºC (wet samples, such as waterlogged bones and soft tissues).

The SoCO was also responsible for collecting samples from the graveside, the storage of all samples, signing samples over to a courier for transportation to LGC Forensics, London and assisting with the collection and storage of samples for an elimination database. Collecting samples for the elimination database was the overall responsibility of the CWGC project manager.

Integrity of DNA samples was maintained by a bar coding system. Bar codes were issued by the SoCO for each sample and were secured to the sample container, evidence log, sample recording form, body location form, tamper proof evidence bag, anthropology recording form and the boxes that contained the bodies. Every time samples were handed over to be shipped by courier for analysis in London, bar codes were scanned with a bar code reader into a spreadsheet which was sent electronically to LGC Forensics. Upon receipt, samples were checked into LGC Forensics by scanning the bar codes on the samples and cross-referencing them with the spreadsheet.

Contamination of DNA was controlled by defining strict zones in which appropriate personal protective equipment (PPE) had to be worn at all times (Fig. 2.8). Three zones were defined (Fig. 2.2):

i. Full DNA protection zone: In this zone, which covered the tented area over the graves, staff were required to wear face masks, hair nets, overshoes or dedicated site boots, gloves and Tyvek suits.

ii. Medium DNA protection zone: Staff were required to wear Tyvek suits in this zone which covered the area between the site cabin and the entrance to the tented area over the graves.

iii. No DNA protection zone: All DNA sampling that was controlled for contamination was undertaken at the graves and therefore PPE was not required in the rest of the compound.

Further measures included keeping equipment used for taking samples clean and sterile, regularly replacing PPE and clearly defining and observing clean and dirty areas, all undertaken when new features/cases were started and/or at the start of a new working day, as appropriate (Donnelly *et al.* 2008).

Field procedures

The following procedures were carried out to maintain evidence integrity and continuity:

i. Only authorised persons could enter the graves.

ii. Graves were covered by tents at all times to prevent disturbance by adverse weather and/or animals and to shield the site from public view.

Fig. 2.8 PPE worn in the 'full DNA protection' zone

Fig. 2.9 SoCO (left) and grave supervisor at the graveside managing the site evidence log

iii. The compound was handed over to security every night.

iv. At the beginning of each working day, the site was inspected by the senior archaeologist and grave supervisors for any disturbance.

v. At the end of each day all recovered evidence was signed over to the custody of the mortuary manager. Evidence was kept under lock and key in the mortuary in controlled environmental conditions.

vi. A site evidence log, which recorded every body, body part and other evidence recovered, was maintained by the grave supervisors and SoCO (Fig. 2.9). As each piece of evidence was discovered they gave out numbers, from a running sequence, suffixed by 'B' for a body[1], 'BP' for body part, and 'A' for an artefact from the log. Body numbers were written in indelible ink onto a label which was placed next to the body/body part while it was being excavated (for example, see Fig. 3.21). As each body was discovered, its number was written on a wipe board at the grave-side and kept there until the body had been recovered. Next to this was recorded the archaeologist's name and whether or not DNA samples had been taken. As they were discovered, artefacts found in association with the body were given numbers, which were recorded on the board next to the body number (Fig. 2.17).

vii. A strict protocol for making associations between artefacts and bodies was maintained at all times. Associations were first made by the archaeologist excavating the remains, who checked them with their grave supervisor. They were then checked again on survey with the surveyors, and also by the photographer before capturing the associations graphically. The final check was made by the finds manager when examining artefacts in the laboratory with reference to the *in situ* photographs. All associations between artefacts and bodies were recorded in the evidence log and on the body forms. (Associations are described in more detail under 'Stratigraphic hand excavation'.)

viii. Evidence that could not be associated was given an artefact or body part number, and relevant forms (for example, a body part form) were completed.

ix. Prior to packing bodies, labels on containers were checked to ensure that the evidence number corresponded with the evidence number on the label with the remains. Bodies and artefacts were labelled and packaged as described below (under 'Forensic Anthropology' and 'Artefacts').

x. Retention and safekeeping of all human remains, artefacts, evidence logs, completed recording forms, exposed film, videotapes and other forms of evidence was the responsibility of the grave supervisors and SoCO until they were handed over to the mortuary.

xi. When bodies and associated evidence were handed over to the mortuary, all associated forms and other records were checked by the SoCO and the mortuary manager.

Mortuary procedures

Evidence integrity and continuity were controlled in the following ways (and detailed by Donnelly *et al.* 2008, 159-168):

i. The same numbering system employed in the field was employed in the mortuary.

ii. Artefacts and human remains were cleaned, dried, packaged and stored as described below and with reference to Donnelly *et al.* (2008, 160-163) on exhibits from bodies, and clothing from bodies.

iii. Examined human remains were kept separate from those that were to be examined.

iv. The procedures relating to photography (see below) and anthropology (see below on packaging and storage) are relevant here.

Data storage and data security

The paperwork associated with each case, comprising the body and associated artefacts, was kept with each case at all times until they were booked into short-term storage. Paperwork relating to completed cases was then scanned and archived. This often involved a two-stage approach in which site recording forms for each case were initially scanned so that the anthropologists had easy access to these records when undertaking their analyses. Once complete, anthropology recording forms were scanned and added to these.

The evidence log was entered into a bespoke database (see below) to facilitate management of numbers during the operation. All other recording form data were not required in a digital format until later and were therefore not entered at this stage to save time. This was undertaken in Oxford after the completion of site operations.

All other procedures relating to data storage and security were undertaken with reference to the guidelines described by Donnelly *et al.* (2008, 175-179).

[1] As a result of employing this numbering system the terms 'body' and 'bodies' have been employed for consistency throughout this report, even though they primarily comprised skeletons.

Documentation

Methods employed to ensure complete and accurate documentation included the following:

i. Forms and logs: A series of forms and logs were used by both field and mortuary teams. These were adapted specifically for the project from the Inforce Foundation recording forms and logs (Cox *et al.* 2008).

ii. Field and mortuary diaries/notebooks: Separate diaries and notebooks were kept by the project manager, senior field archaeologist, grave supervisors, mortuary manager and lead anthropologist, who recorded any data not captured on a log or form, as well as the chronological progress of their respective aspects of the operation. Progress on all aspects of the operation was synthesised in illustrated client weekly reports prepared by the project manager.

iii. Photography: A photographic record was maintained as described below (see 'Photographic Record'), and was closely linked to any written recording.

iv. Surveying: Optical surveying was employed to record the relationship between bodies, artefacts and features.

v. Radiographs: All digital radiographs were recorded onto CD-ROM in both DICOM and JPEG formats.

All forms and logs were scanned on a daily basis to a secure server and onto a back-up hard drive, which were kept secure at all times on site. A further back-up hard drive was kept in a secure location off site by the CWGC project manager.

Database

A stand-alone database, called 'The Fromelles Database', was designed to capture all data in such a way that the data could subsequently be imported into the documented system employed by the DAT and the JIB for the identification process.

The database was also required to:

i. Generate consistent, standardised case reports for each body and their associated finds.

ii. To be searchable and relational in order that results could be statistically analysed for the present report.

iii. To serve as a centralised electronic repository for all information pertaining to the archaeology for the Australian and British Governments and the CWGC.

It was designed using PostgreSQL 8.3 with two front ends. One front end was web based, with php5 on the server and html and JavaScript on the client side. This front end was primarily used for data entry and was designed so that multiple users could enter data at the same time. Certain restrictions were employed in the design in order to maximise accuracy and consistency in data entry.

The second front end was OpenOffice 3.2 Base, and was used for complex data queries, analysis and reporting. This set-up was easily replicated off-line on a single laptop for use externally by the DAT, without making confidential and sensitive data available to the world wide web.

The database was built and used from the outset of the fieldwork. However, most data (in particular, anthropological and archaeological) were entered after the fieldwork phase from paper records. Completing paper records, followed by data entry, was found to be more practical at all stages of the project (fieldwork and post-excavation analyses). Database formats could also be modified to accommodate knowledge gained from the evidence during the operation.

EXCAVATION AND RECORDING

The graves were located and numbered, one through to eight, by employing the data reported by GUARD from its 2008 evaluation. Graves were machine and hand excavated, two at a time, starting with graves one and two, followed by three and six and then four and five. Graves seven and eight did not contain any human remains or artefacts and were fully excavated by machine under archaeological supervision.

Water removal

The requirement to manage water levels was a key factor in the excavation of the graves, which were located at the bottom of a slope on poorly draining clay soils. Two methods were primarily employed: excavating sumps adjacent to the graves from which water was removed using diesel pumps; and the excavation of drainage ditches, connected to sumps, around the graves and which relied on the force of gravity to drain the water away (Cheetham *et al.* 2008, 230-1). Groundwater still present in the graves was removed by means of small sumps and pumps within the graves themselves (Fig. 2.10). All pumps were fitted with sludge filters and automatic activation devices to prevent water build-up overnight.

Perimeter drainage ditches were initially dug around the tents to allow rainwater running off the sides to drain away from the graves. However, this proved to be inadequate, and particularly heavy rain in May and June entered the graves (though did not disturb or damage any bodies or artefacts). Advice was sought from a specialist in the local clay to address this problem, resulting in a slightly revised water management strategy. This involved

Fig. 2.10 Water management: a 'French drain' (main image) and pumps with sumps (inset) were among the strategies employed

erecting the marquee so that all of its sides rested over a perimeter drainage ditch (rather than adjacent to it). The ditch was filled with gravel, followed by plastic sheeting and then two types of pipe (a 'French drain') (Fig. 2.10).

Waste removal

All non-contaminated waste was disposed of in accordance with the local authority's environmental guidelines.

Contaminated waste, such as discarded PPE or used materials from the temporary mortuary, was stored in secure containers on site and disposed of by a specialist waste disposal company.

All machine excavation was undertaken using a 360° mechanical excavator equipped with various sizes of toothless ditching bucket (Figs 2.11 and 2.12). This removed the turf, topsoil and the upper horizons of the graves (including the steel meshes that had been placed over GUARD's evaluation trenches in 2007) in spits under the close control of an archaeologist and an EOD engineer who thoroughly monitored each layer for ordnance and archaeological artefacts and/or features (Fig. 2.13). There was no archaeological reason to preserve the sides of the graves and therefore these were also removed by machine to facilitate access to the bodies.

Machining continued to approximately 0.22-0.3m above the anticipated level of the bodies. Overburden was stripped up to approximately 5m beyond the limit of the area of each grave to ensure that no additional burial features were present and to provide a working area around each grave, including a slip way (or in the case of Grave Five, steps) for entering and exiting. Working areas were dug down to a level of approximately 0.1m below the top of each grave, so that the graves were pedestalled (Fig. 2.14). Pedestalling protected the

Fig. 2.11 Machine excavation under the close supervision (from left to right) of the EOD engineer, the project's senior forensic adviser, and senior archaeologist

Fig. 2.12 Machine excavation of Grave Four

Fig. 2.13 Metal detecting for artefacts (left) and checking for unexploded ordnance (right)

Fig. 2.14 Graves three (bottom) and four (top) pedestalled and ready for excavation; grave four covered with a non-permeable membrane to protect the remains overnight

graves from ground water, facilitated safe access and provided a surface from which to work.

Spoil arising during excavation was stored adjacent to the graves and placed upon plastic sheeting to protect the underlying topsoil. Spoil heaps were sheeted to avoid saturation of the soils prior to backfilling. Excavated material was stored in separate heaps, depending upon the soil type, and backfilling was in reverse order of excavation with appropriate compaction of each layer.

Stratigraphic hand excavation

Once the graves had been pedestalled all subsequent excavation was by hand in a controlled, systematic manner within a defined three dimensional space using appropriate tools, including trowels, leaf trowels, brushes, and small sculptors' tools, such as wooden spatulae. Graves were worked on two at a time, by two teams, each comprising five osteoarchaeologists, one grave superviser and one surveyor. Stratigraphic excavation and recording was undertaken in accordance with the standards set out by the Institute for Archaeologists (McKinley and Roberts 1993) and published guidelines on the excavation of mass graves (Adams and Byrd 2008; Cheetham *et al.* 2008).

In accordance with stratigraphic principles excavation started with the uppermost bodies in the sondages excavated by GUARD and progressed outwards to uncover all bodies in the uppermost layers. When all bodies from the uppermost layers had been recorded and recovered, excavation continued with the second layer of bodies, starting again with those in the GUARD sondage. Once all human remains and artefacts had been recovered, each grave was excavated below its base by hand and by machine to confirm beyond doubt that all bodies had been identified and lifted (Fig 2.21).

In accordance with French law, the first bodies to be exposed were witnessed and signed off by the local gendarmes. The sequence of procedures recommended for mass graves (Cheetham *et al.* 2008) and presented in the project brief (CWGC 2008, 32) were then followed. For clarity, these are re-produced here:

i. Removal of topsoil and overburden.

ii. Excavation, cleaning and identification – context, artefacts, or human remains

iii. Recording I – recording numbers issued.

iv. Photography and drawn record – logs must be completed. (Note: when fragile and rapidly degradable materials are recovered in association with human remains [for example, paper, photographs, corroding metals] they must be photographed and recorded immediately and first aid conservation applied as they may be crucial to identification; any delay in doing so could prevent an identification).

v. Recording II – logs, forms, planning, survey commences.

vi. Excavation – observing stratigraphic sequences.

vii. Recording III – as appropriate adding additional numbers, photography, planning, survey etc.

viii. Recovery and removal – under strict chain of custody control, this is to be followed by re-evaluation of the context.

ix. Sampling and sieving – further numbers issued as appropriate, forms and logs completed.

x. Excavation and cleaning – to reveal and identify further artefacts, human remains or context.

xi. Recording IV – completion of all forms, logs, illustrations, plans, etc. pertaining to the feature. Cross-referencing, checking records and packaging materials to be sent for analysis.

xii. Repeat ii. to ix. as many times as is appropriate depending upon the complexity and depth of the grave (modified from Cheetham *et al*. 2008).

To maximise the recovery of small bones and artefacts the soil was fingertip searched and searched with hand held metal detectors (Fig. 2.15). Soil samples were also taken from the neck, shoulder and chest regions and were surveyed in the radiography suite for artefacts and bones (Figs 2.24 and 2.25). Sieving bulk soil samples, to maximise retrieval, was precluded by the heavy, sticky nature of the clay, although small amounts were sieved in the mortuary (see below).

By special permission from the Australian and British governments, additional soil samples and

Fig. 2.15 Fingertip searching the soil

Fig. 2.16 Selection of working views showing excavation in progress

Fig. 2.17 The work undertaken on each body was recorded on wipe boards at the sides of each grave

Fig. 2.19 Photographic recording within the graves

Fig. 2.18 Completing paper records

small fabric samples were collected from graves three and four for an ongoing study on aspects of the burial environment by a muti-dicsiplinary team of scientists from the University of York. This work, which had no direct relevance to the aims of the operation, was part of a wider project on new applications, including micromorphological and chemical analyses in the study of archaeological burials (Usai *et al.* 2014). The inclusion of samples from Pheasant Wood in the study will make a very significant contribution to current knowledge of these very complex environments, and this will be hugely beneficial to future investigations of mass graves and burials in general.

Once the bodies had been partially exposed they were scanned with a metal detector to check for metal objects and unexploded ordnance. Bodies were then fully exposed as much as possible using appropriate tools to allow anatomical associations and their positions to be observed and recorded (Figs 2.16).

Each context was recorded on a *pro forma* noting variables such as body position, orientation, associated arterfacts, whether skeletal, saponified, or partially skeletonised, whether fracturing had occurred during excavation, among other factors (Fig. 2.18). This was accompanied by annotated hand drawn sketches of bodies to demonstrate the archaeologists' interpretation of the remains, bodies and artefacts, and their relationships. Skeletons and artefacts were also recorded *in situ* by digital photography, as described in the relevant section below (Fig. 2.19). Digital photography of bodies with reference survey points for digital rectification was trialled but not employed. This method was too time consuming and it did not capture information any better than other techniques already employed.

A strict system for making associations between artefacts and bodies was employed (see above). To be associated, items had to be physically close to a discrete body (touching or obviously related to other items in evidence on a body) and/or in a position that made sense in terms of where that item would be worn on the uniform, or would be positioned on the body. Decisions were made allowing for the movement of items caused by the opening of jackets in order to search an individual, or movement of clothing caused by the transportation of the body to the grave. These factors were considered extensively by the archaeologists in the graves. Any ambiguities were discussed with the grave supervisor and, if necessary, with the finds manager before a final allocation was made. On a small number of occasions allocations were described as 'possibly associated' for some individuals, and items were logged as such.

Associations were further verified by survey, which recorded the locations of all bodies and artefacts in 3D. Any anomalies in the positioning of artefacts that had been associated with individuals were noted when these data were plotted and checked against the field notes, with the field team and the forensic photographer (who had photographed the artefacts and associations in the grave). Only when all parties were satisfied that the anomaly had been clarified was the association confirmed.

If it was decided at any stage in this process that an artefact was not associated with the body to which it was first allocated, the survey data and field notes were reviewed along with information provided by the artefacts specialist. The possibility of that artefact being associated with nearby bodies was considered.

The recovery of bodies and artefacts varied depending on their state of preservation, material (for example, metal, paper, textiles, leather, etc.) and the condition in which they were found. For example, it was beneficial to leave some bodies and artefacts exposed until the distribution and relationship between them and others could be determined. On the other hand, some required immediate recovery to prevent accelerated degradation following their exposure.

Bodies and artefacts were removed stratigraphically employing traditional archaeological methods, as described by McKinley and Roberts (1993), Cheetham *et al.* (2008), and Wright *et al.* (2005), wherever practicable. These methods aimed to maximise the recovery of information and maintain integrity of the remains. For example, soil surrounding heavily fragmented bones was collected and fingertip searched to maximise the retrieval of bone.

Bodies and artefacts were carefully placed into containers and signed over to the SoCO for transferral to the temporary mortuary.

Survey

Survey employed a combination of Total Station Theodolite (TST) utilising Reflectorless Electronic Distance Measurement (REDM) and, where appropriate, hand-measured elements and Global Positioning System (GPS). The survey equipment used was a Leica TCRP 1205 TST and Leica 1230 GPS (Fig. 2.20).

GPS survey was conducted by using differential corrections from a base station network via GPRS. This provides a real-time positional location of between 10mm + 1ppm and 50mm + 2ppm and a post-processed accuracy of between 1mm +1 ppm to 30mm + 2ppm on the positional (XY) plane, and no more than double this on the height (Z) plane. The TST used for this survey provided an angle measurement accuracy of 5″ and a distance accuracy of 2mm + 2ppm with a prism and 3mm + 2ppm in reflectorless mode.

The area of each grave was initially set out utilising survey information provided by GUARD. A network of control stations was laid out encompassing the area. These were set out with a TST using rigorous metric observation to establish a closed-loop traverse. At least three measurements were recorded in both faces between stations to provide latency when working out residual errors and a traverse kit, with the prism positioned on a tribrach and tripod, was used to ensure accuracy. The residual error was 8mm in the horizontal plane and 6mm in the vertical plane for the initial traverse. The position and accuracy of the control network was checked and assessed regularly throughout the course of the project.

Each control station was marked with a stable Permanent Ground Marker (PGM). Day-to-day surveying was conducted on a local grid established from these control points. The control network was orientated to the Lambert I co-ordinate system at an early stage by observing GPS readings on each point within the control network. This information was used at the end of the project to locate the data captured on the local grid to a real-world coordinate system.

Two methodologies and software programmes were adapted and employed, including Crossbones, developed in-house (Simmonds *et al.* 2008; see http://oadigital.net/software/xbones for the detailed methodology and a link to the software), and Bodies3D (Wright 2012), designed specifically for three-dimensional recording and rotational representation of bodies as stick figures in mass graves. (The Bodies3D package can be downloaded via http://osteoware.si.edu/forum/osteoware-communityannouncements/bodies3d-richard-wright-0.) The spatial location of remains were recorded to produce a stylised figure of the body in the form of polygons (Crossbones) and stick figures (Bodies3D). Designed for surveying groups of skeletons, point locations were captured in 3D using a TST on main articulations in accordance with Oxford Archaeology's standard survey operating procedure. Where disarticulated bodies or other remains of bodies, such as broken limbs, that did not fit into this category were identified, additional points were taken and incorporated into the recording system. Once these data had been downloaded, the position of the body within the

Fig. 2.20 (above) Surveying of the graves

Fig. 2.21 (right) Once all skeletons had been recovered, each grave was excavated by hand and machine to confirm that there were no more present

Fig. 2.22 (below) Holding bay for bodies and artefacts in the temporary mortuary reception; bodies and artefacts were stored here by grave number to await radiography and then processing

context of the site could be visualised quickly and easily viewed in 3D to inform the progress of the project and formulate and adjust strategies.

Crossbones and Bodies3D require all human remains survey to follow a set schema with the ends of each major element of the skeleton assigned a particular point ID. For complete bodies, a total of up to 32 point IDs were recorded for Crossbones, while 13 ID points were used for Bodies3D. For incomplete bodies the same principle applied. For example, when only a tibia and fibula were present these were numbered in such a way to indicate whether they belonged to the right or left side of the body. Cases like this were rare because the majority of human remains comprised complete bodies.

It was necessary to have two points at each articulation (for example. the patella), because these levels do not represent the patella itself, but rather the distal end of the femur and proximal end of the tibia and fibula. The Crossbones software package could then be employed to process the data and relied on these end points to create the representation.

The spatial position of artefacts, DNA sampled bones, grave cuts and the limit of excavation were also recorded. Artefacts and DNA sampled bones were recorded as point locations and tagged with evidence numbers during the data capture process. Grave cuts and the limit of excavation were recorded as polygons.

Data were downloaded, checked and backed up securely at the end of each day's survey, following Oxford Archaeology's standard survey operating procedures.

TEMPORARY MORTUARY SPECIFIC METHODOLOGIES

Mortuary set-up and management

Upon their arrival at the temporary mortuary, cases comprising bodies and their associated artefacts were signed over to the mortuary manager by the SoCO in the temporary mortuary reception area. They were then booked in and assigned a place in a holding bay to await radiography (Fig. 2.22).

The temporary mortuary was managed full time by an anatomical pathology technologist (or mortuary manager) with considerable experience in temporary mortuary design and management. The

Fig. 2.23 The radiography suite

space was divided into 'clean' and 'dirty' areas and a walkway for staff demarcated to organise workflow, minimise unnecessary movement and manual handling of human remains and artefacts and help maintain respect for the dead at all times.

Comprehensive project-specific Standard Operating Procedures (SOPs) were prepared by the mortuary manager and read and acknowledged in writing by all staff. These were kept available and easily accessible in the areas where the procedures were carried out. These related to processing, the reception of human remains and artefacts, and sampling brain matter for DNA analysis.

Exemplary general housekeeping standards were maintained, with cleaning and decontamination being carried out on a daily basis. Disposal of clinical waste, both solid and liquid, were carried out with strict adherence to local regulations.

Forensic pathology

There was no medico-legal intent to this project and extensive soft tissue that may inform on the cause of death was not encountered. One site visit was made by the project's forensic pathologist, who has extensive experience in the forensic investigation of mass fatalities. Otherwise, it was not necessary to employ the pathologist's services to meet the aims of this project.

Forensic radiography

The forensic radiography suite, comprising a digital radiography facility with ancillary equipment (radiation protection devices, barriers, warning signs, x-ray table and positioning and monitoring equipment), was set up in an isolated cabin with a stable 13A power supply adjacent to the reception area of the mortuary (Fig. 2.23). This location accommodated the work flow, but also provided radiation protection by establishing a 3m exclusion zone around the perimeter.

A forensic radiographer was employed full time to undertake examinations of all human remains and artefacts and worked closely with two part-time radiography consultants who provided service design and quality assurance. A scribe was also available part time to assist with documentation during the examinations.

Radiation protection was managed by a radiation specialist in accordance with UK and European law and recommendations. The specialist undertook facility planning, site surveys, personnel monitoring, devised a radiation protection plan and local radiation rules. A French government-appointed radiation protection adviser also contributed to radiation protection management, as required by French law.

Radiography involved three levels of examination:

i. Routine primary survey: This refers to the examination of each case prior to cleaning. Each case comprised the body and associated soil samples and artefacts, all in one container. Every container was radiographed to confirm contents, identify any material that could be hazardous to staff (for example, ballistics), identify items that required immediate attention (for example, fragile artefacts, or artefacts that had identifying features) and locate small bones, teeth and artefacts that might otherwise have been missed during the cleaning and macroscopic analysis (for example, Figs 2.24-2.26 and 2.37).

Fig. 2.24 Soil samples being radiographed

ii. Routine secondary survey: This involved systematic examination of the dentition and was undertaken in parallel with the anthropological analysis of the bodies. Antero-posterior and lateral images of all dentitions were made. These images were used to supplement the macroscopic analysis of the human remains, in particular to identify any pathological conditions, dental treatments or interventions.

iii. Elective tertiary survey: This refers to lateral and anterior/posterior projections of specific bones that were taken at the request of the anthropologists to explore skeletal structures and/or skeletal pathology and trauma that had potential to assist with identification.

All examinations were recorded on a bespoke form by employing the standards recognised by the International Association of Forensic Radiographers (IAFR 2007), as described by Anderson *et al.* (2008) and Viner (2008). This included, for the primary survey, detailed lists of what images were taken and the associated findings (for example, ballistics, preserved brain tissue), which were important for reference during cleaning and anthropological and finds analyses.

Original radiographic images were recorded onto CD-ROM in DICOM and JPEG formats, using a

Fig. 2.25 Radiography of a soil sample showing how objects could be found. Inset: a) the eye of a hook, b) rising sun badge, c) 'Australia' shoulder title

Fig. 2.26 Soldier's boot straight after recovery from Grave One and on a radiograph (inset), which showed that the foot bones were still present inside; this information was helpful when processing the boot

Fig. 2.27 General working views of processing

separate CD for each case. These were stored, untouched, in a secure location, but duplicate copies were made available during the examination of all bodies.

Images were primarily examined by the anthropologists or, for finds, the finds specialist, all of whom had prior experience of reading radiographs. When required, a registered radiologist was consulted.

Processing – non-osseous tissues and cleaning

All of the bodies were skeletonised with some limited preservation of non-osseous tissues. Non-osseous tissues included hair, nails, brain matter, cartilage and spinal cord. There is always the potential for human burials to include non-human animal bone, but ultimately all bone was found to be human.

Non-osseous tissues were air dried, packaged and stored with their associated bodies. This is with the exception of brain matter and spinal cord tissue, which were individually packaged, labelled and frozen at a temperature of -20ºC short term until their re-burial with their respective bodies.

Samples of hair and brain were initially collected in the mortuary for DNA analysis by following the project specific SOP. However, this practice was discontinued when LGC Forensics confirmed that they did not contain useful DNA.

All bones and artefacts were cleaned as soon as possible, following their recovery, so that soil and other sediments didn't adhere to them during drying. This was undertaken with reference to recognised standards (Roberts and McKinley 1993; Barker *et al.* 2008a and b), using soft bristled toothbrushes, dental and sculpting tools and sieves in warm water. This also involved wet sieving small soil samples using a 2mm mesh. All waste water arising from cleaning was collected and sent away for safe disposal. Once cleaned, remains were transferred to the designated, temperature controlled drying area, from where they were signed over to the anthropologists when dry (Fig. 2.27).

Forensic anthropology

Anthropological analysis was carried out in accordance with standard published guidelines (Barker *et al.* 2008a and b; Brickley and McKinley 2004; Buikstra and Ubelaker 1994). All work was undertaken by up to six experienced anthropologists, in a bespoke laboratory adjacent to the drying area (Figs. 2.28 and 2.29).

Aims and objectives

The principal aim of the anthropological analysis was to, as far as possible, contribute to the determination of a presumptive or positive identification of each individual.

Primary objectives were:

i. To record and analyse all bodies, and all contextual and associated evidence for the purposes of determining the cause of death and reconstructing the activities associated with the mode of interment at Pheasant Wood.
ii. To determine and ensure the discrete nature of the bodies.
iii. To ensure that collated data could be imported into a suitable database for use in the identification process and analysis of the collected data.

Methodology

For each body, the following procedures were performed as appropriate in the following order:

i. Removal, recording, packaging and storage of all non-osseous tissue (see above).
ii. Laying out each body and completing an inventory of what had survived.
iii. Consulting all records created thus far, including photographs, recording forms, survey data and primary radiographs.
iv. When present, sorting disassociated and commingled body parts or bone elements and re-associating these with a discrete body, wherever possible.
v. Assessment of completeness, condition and taphonomic alteration.
vi. Reconstruction of skeletal remains (where necessary and useful).
vii. Assessment of biological profile (ancestry, biological sex, age at death and living stature).
viii. Assessment of individuating characteristics (skeletal constitution, handedness, facial attributes, dentition, skeletal pathology and trauma, dentition).
ix. Assessment of peri-mortem trauma.
x. Secondary routine dental radiographs (see above).
xi. Tertiary radiographs (see above).
xii. Routine and detailed photography (see below).
xiii. Further DNA sampling (if required).
xiv. Packaging, labelling and storing.

These procedures are described in more detail in the following sections (with the exception of sampling, radiography and non-osseous remains, which are described above, and photography, which is described below).

Fig. 2.28 Anthropology laboratory (note the overhead cameras)

Fig. 2.29 Working view of anthropological analysis

Inventory

The bodies were laid out in correct anatomical position on a purpose-built work-bench with a lipped edge and padded wipe-clean cover designed to protect the bones. A complete inventory of all the bones present was made. Any bones or fragments that did not belong to the individual under examination were classified as 'commingled'. 'Commingled' refers to mixed or disassociated skeletonised body parts, individual bones or fragments of bones that have lost their anatomical relationship to a discrete individual. These were removed and, where possible, re-associated with their skeletons (see below). Any bones or bone fragments that could be re-associated were reconciled and included in the inventory.

The presence, absence and completeness of the skeletons were recorded by means of a written, photographic and radiographic record with reference to the body regions shown in Figure 2.30. The written record involved scoring presence/absence in an inventory table accompanied by descriptive and explanatory notes. Overhead digital photographs using Nikon D40 digital SLR cameras permanently positioned above each anthropology work station were employed to form the photographic record (see Fig. 2.28), and the primary radiography surveys formed the radiographic

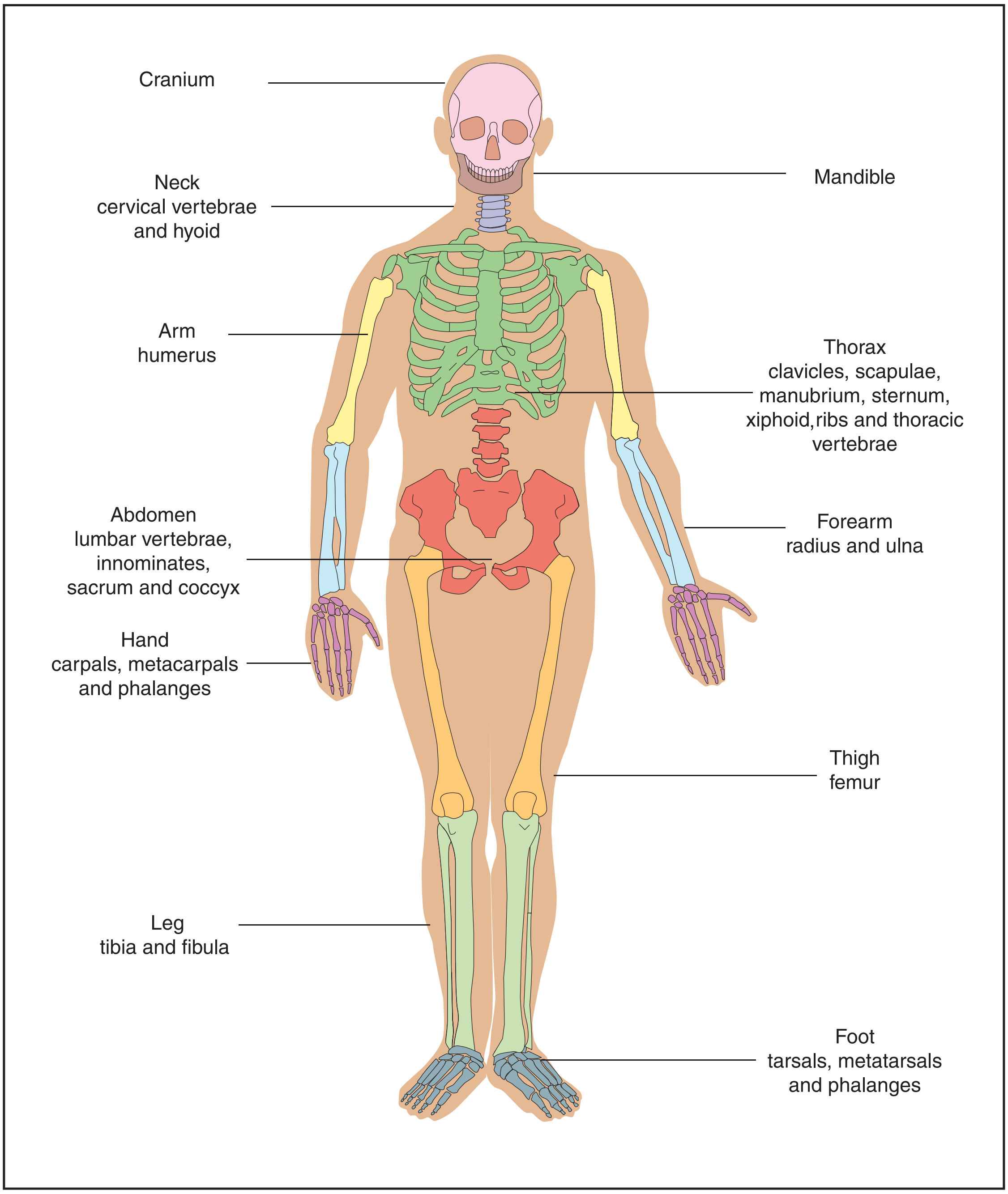

Fig. 2.30 Body regions scored for presence and absence

record. In addition, a series of overhead photographs were taken using a colour-coded arrow system to denote the presence and location of fusing epiphyses (blue), pathological conditions and ante-mortem trauma (orange), peri-mortem trauma (red) and reconciled body parts (green) (Fig. 2.45).

Dentitions were inventoried by employing the system devised by the FDI World Dental Federation (the 'FDI system') by radiography (secondary survey) and detailed digital photographic images.

Commingled human remains

Commingled human remains are often encountered in complex burial environments, such as mass graves, and therefore their occurrence at Pheasant Wood was not surprising. Bodies that are buried together as the result of a catastrophe may be commingled if the burial is hurried and/or unplanned, and the bodies are not coffined, but also as a result of peri-mortem trauma and/or the movement of bones as a result of decomposition, water percolation, disturbance by animals and other such taphonomic processes (Brooks and Brooks 1997; Haglund *et al.* 1988; Lyman 1994; Nawrocki *et al.* 1997; Olsen and Shipman 1988; Rodriguez 1997). Another taphonomic process specific to Pheasant Wood was the excavation undertaken during GUARD's evaluation. Where sondages had been sited, bones had moved as a result of the excavation activities (such as soil removal and the temporary recovery of remains), the introduction of rainwater during the excavation (Donlon pers. comm.) and, following backfilling, the percolation of water through the loose soils.

When identified, either during excavation or anthropological analysis, commingled human remains were assigned an evidence number which was prefixed by 'BP' for body part. They included single or multiple bones/fragments recovered from a single context and were re-associated with bodies in the laboratory by employing established methods (Adams and Byrd 2008; L'Abbé 2005, Wright 2003; White 1991). These included:

i. Assessment of biological profile, in particular sex and age.

ii. Visual pair matching of homologous bone elements, taking into consideration robusticity, morphology, size and anatomical reference points (while allowing for asymmetry).

iii. Metric pair matching: similarities in bone dimensions of homologous pairs. (Consideration of skeletal asymmetry precludes this approach as a primary technique.)

iv. Congruence of articulation of adjacent bones.

v. Physical fit of fragmented bone (particularly useful in cases of peri-mortem trauma).

Fig. 2.31 Example of survey plans being used to help resolve commingling

vi. Process of elimination: determining the potential candidates for re-association, using all other criteria, presence or absence of disease processes and the three-dimensional (survey) record.

vii. Context, for example, exploring the closed system of a particular grave rather than the entire assemblage (Fig. 2.31).

viii. Taphonomic patterning. This is often useful as an inclusion rather than an exclusion technique, for example, metal staining on adjacent bone elements due to contact with a metal artefact. However, variability within the same burial context may produce dissimilar patterning on associated bone material.

Where a re-association could be established, the human remains were incorporated into the routine analysis of the body that they belonged to, or as an addendum if the analysis had already been completed. The evidence log and anthropology recording forms were updated accordingly as required.

Re-associations of all commingled human remains are rarely achieved in mass grave contexts (Barker *et al.* 2008a). For the present operation all re-association possibilities were explored up to the point at which the methods ceased to provide meaningful information.

Body parts that could not be reconciled with bodies were treated as disassociated. These were inventoried by grave number and photographed. Where appropriate, details pertaining to biological profile, individuating criteria, condition and completeness and peri-mortem trauma were noted. The remains were packaged, labelled and stored under their evidence (BP) and grave numbers. Only two body parts were found that could not be associated with a grave or bodies. These were packaged, labelled and stored under their evidence numbers and the category of 'unknown grave'.

Completeness, condition and taphonomic change

The completeness of all discrete sets of human remains was scored at three levels (Table 2.1; Fig. 2.30):

i. Presence/absence of bones/portions of bones in the inventory (for example, proximal, middle and distal portions of long-bones).

ii. Percentage of skeleton present overall.

iii. Presence/absence the different body regions shown in Figure 2.30.

Condition was assessed visually and was scored with reference to the degree and extent of bone erosion and bone fragmentation after Behrensmeyer (1978) and McKinley (2004, 16). Scores were supplemented by written descriptions.

Erosion was scored according to the proportion of the skeleton that was affected as <25%, >25%-50%, >50%-75% or >75%. It was also scored according to whether it involved the cortical bone (compact dense bone) or the cancellous bone (spongy bone), or both, and whether it involved multiple body regions in no particular pattern (diffuse), or small discrete areas of the skeleton (focal).

Fragmentation was scored according to the proportion of each body affected and the amount of each body region affected, both as a percentage (<25%, >25%-50%, >50%-75% or >75%). Each body was classified according to whether they were fragmented as a result of post-mortem events (occurring between death and recovery), peri-mortem trauma (occurring around the time of death), both, or unknown (not possible to say).

Post-mortem fragmentation and peri-mortem fractures were distinguished from one another with reference to context, associated colour change, fracture outline, fracture texture, fracture angle, evidence of scavenging, and erosion or weathering (Barker *et al.* 2008a, 314; Loe and Cox 2005; Villa and Mahieu 1991, and see below).

Evidence on the bone(s) for plant rootlet and mycorrhizae activity, animal scavenging or predation, metal staining, other staining, adherent fabric, lime deposits and plastic deformation were recorded as present or absent. When present, the changes were recorded as either localised (and the body region involved stated), or diffuse (if several body regions were involved).

The predominant colour of skeletons was also recorded as sandy, light brown, mid brown, dark brown or dark greyish brown. These categories were assigned by one individual using descriptions and overhead colour photographs for consistency. This was undertaken to assist in the interpretation of burial context and compare patterns in the differential preservation of remains between grave locations, in particular to explore similarities and

Table 2.1: Completeness scores employed

	Inventory: individual bones and bone regions	*% of skeleton present*	*Body region: corresponding to those in Figure 2.30*
Score	Present (P)	> 95% (complete)	Complete
	Incomplete (I)	>75% – <95% (slight loss)	Part
	Fragment (F)	>50% – <75% (moderate loss)	Absent
	Absent (A)	>25% – <50% (considerable loss)	

differences between graves closer or further away from Pheasant Wood.

Bone was classified as either green/wet (a large proportion of the organic content is retained) or dry/crumbly (some organic content is retained). Mineralised (complete loss of organic content) is another classification, but this was not encountered at Pheasant Wood.

Non-osseous human tissue was recorded to the levels of presence or absence and tissue type (see above).

Hair was recorded according to type (straight, wavy, curly or frizzy), texture (fine, thick or coarse), length (short <5cm, medium ≥5cm, long ≥10cm), cranial coverage (complete or unknown), and colour (auburn, light, dark or very dark), as appropriate. To control for inter and intra-observer error, two observers agreed and scored all cases and a third observer quality assured a sample of cases.

Hair was recorded in this way to assist with grouping bodies for consideration in relation to the profile of a missing soldier for the JIB. For example, complete cranial hair coverage would indicate an individual without male pattern baldness. In contrast, incomplete cranial coverage may be due to baldness or may be due to taphonomic processes which have resulted in differential hair loss post-mortem. Further, the presence of certain hair types and textures may indicate the broad ancestral group of an individual, though microscopic examination by an expert would have been sought to confirm any such findings.

Reconstruction of human skeletal remains

Fragmented skeletal remains were temporarily reconstructed to assist with analysis, for example to explore the timing of fragmentation, sequencing of peri-mortem injuries, assess ancestry and analyse commingled remains.

Masking tape was routinely used to reconstruct bone because, unlike other reconstruction materials, it lacks radiodensity and therefore does not obscure features such as fracture patterns, pathological lesions, dentition and dental work on radiographs. Furthermore, it was easy to apply and remove and time efficient to use.

Assessment of biological profiles

The first step in obtaining information from the skeletons to assist with identification was to establish the biological profile of each individual. A biological profile records an individual's ancestry, sex, age at death and stature, which are the basic parameters employed to assess individuating characteristics.

Ancestry

Ancestry is defined here as '...the biogeographic population to which a particular individual belongs, by virtue of their genetic heritage' (Barker *et al.* 2008a, 322). Ancestry estimations were based on visual and osteometric assessments, as described by Bass (1995), Buikstra and Ubelaker (1994), Byers (2005), Gill (1986; 2001) and Walensky (1965).

Visual assessment of skull morphology was undertaken with reference to the craniofacial characteristics listed by Buikstra and Ubelaker (1994) and in consultation with an unpublished manuscript from the Department of Environment and Conservation of New South Wales (2005). The latter specifically deals with differences between Australian Aboriginals and non-Aboriginals. Observations relating to the degree of anterior curvature of the femur (Gill 2001; Walansky 1965) is another visual method for assessing ancestry and was also employed.

Ancestry was not assessed using skull or femur morphology when these elements exhibited plastic deformation, pathology, were considered to be too fragmentary or, for skulls, limited (<50%) landmarks survived. However, if skulls with limited landmarks had traits that were consistent with a single ancestral group, this was noted on the recording form and in the case reports.

Only a very broad classification of ancestry may be achieved using these visual methods. Broad classifications include, Aboriginal, non-Aboriginal, White (or Caucasoid), Black, Polynesian, American Indian or East Asian. Although these oversimplify the relationship between biological expression and genetic affinity (no distinct skeletal characteristics correspond perfectly to a specific ancestral group), this was a useful method for broadly classifying individuals and identifying those whose features varied in relation to the rest of the group.

Broad geographic classifications (for example, European, east Mediterranean, (Aboriginal) Australian), were also achieved by employing measurements of the cranium and applying these to CRANID (Wright 2008), a formula and associated software program based on a large world sample. The CRANID package (downloadable here: http://osteoware.si.edu/forum/osteoware-community announcements/cranid-richard-wright-0) allows the user to perform linear discriminant analysis (LDA) and a nearest neighbour discriminant analysis (NNDA) with 29 measurements on an individual cranium. The cranium is classified after automated comparison, using multivariate size and shape, with 74 samples that include 3,163 crania from around the world (Wright 2008).

The potential of CRANID for the assessment of ancestry was maximised because the author of this method was part of the team (senior forensic advisor) and was available to perform more penetrating analytical routines than those available in the freely distributable package. This expertise was employed when non-caucasoid ancestry was concluded from morphological assessment, but not all 29 measurements were available, or where non-caucasoid ancestry on a complete cranium was inferred and supplementary conclusions sought.

There are limited peer reviewed methods for assessing the ancestry of non-adult skeletons (those less than 18 years of age). However, it is recognised that relevant observations can be made by anthropologists with extensive experience of working internationally with human remains from diverse ancestral groups (Barker *et al.* 2008a, 324).

Biological sex

Biological sex was not assumed and was estimated by employing features of the cranium, mandible and pelvis (Buikstra and Ubelaker 1994; White 1991). The degree of sexual dimorphism in human skeletal remains is important to document for any population under study because the methods employed to estimate stature and some techniques for determining age at death are different for males and females. Thus, sex estimation serves to indicate the relative degrees of accuracy with which stature and age are estimated.

Each feature was scored separately as either:

1. Male (within the expected male range of expression)
2. Probable male (within the outer limits of the expected male range of expression)
3. Ambiguous (falls between the expected male and female ranges of expression)
4. Female (within the expected female range of expression)
5. Probable female (within the outer limits of the expected female range of expression)
6. Not examined (the landmark is not present or preserved, or it is not adult)

An overall sex estimation was recorded for each individual based on the most frequent score. This took into account the overall appearance of each skeleton, employing the principle that males tend to have larger areas of muscle marking than females, who are more gracile and less robust (but taking into account the cultural norms of the population that will influence this).

Greater weight was placed on features of the pelvis when assigning a sex, because these are more reliable and more sexually dimorphic from an earlier age than those of the skull (Mays and Cox 2000). Male and female features of the skull are highly dependent upon when puberty occurs and its duration, both of which can vary between individuals (Mays and Cox 2000). Genetics, cultural practices, diet, disease, and other such factors also influence the development of features, each to a greater or lesser degree. Thus, it is not uncommon for young male skulls to exhibit gracile features and the skulls of post-menopausal women to exhibit masculine features (Cox and Mays 2000). Further, an individual exhibiting female skull characteristics and male pelvic characteristics is not unusual (Walker 1995).

Post-cranial measurements, including the maximum diameters of the femoral and humeral heads and the height of the glenoid fossa, were employed as secondary indicators to estimate biological sex (Barker *et al.* 2008a, 335-342; Buikstra and Ubelaker 1994; Stewart 1979).

Biological age

Three-dimensional photographic and diagrammatic exemplars, casts and printed reference material were available for the duration of the anthropological analysis for the estimation of biological age at death. For adolescents and young adults this was primarily based on the stage of eruption and development of permanent teeth (AlQahtani 2009; Scheuer and Black 2000; Smith 1991), and epiphyseal fusion (Scheuer and Black 2000). Young to mature adult ages were estimated using late fusing ephiphyses, such as the medial clavicle (ibid.) and, for those that had reached full skeletal maturity, degeneration and remodelling (i.e. when all epiphyses have fused). Degeneration and remodelling relates to the metamorphosis of the pubic symphysis (Brooks and Suchey 1990; Todd 1921a, b, c) and the auricular surface of the ilium (Osborne *et al.* 2004; Lovejoy *et al.* 1985). Observations of rib end morphology after İşcan and Loth (1986) were also employed, but because they have large margins of error, broader age classifications were taken into account (Loth 1995).

For each skeleton, the age range suggested by each of these methods was recorded and considered alongside all others to arrive at an overall age estimation. Overall age estimations were recorded by giving the outer age limits (for example, 17-30 years) and likely age limits (for example 20-28 years), the former referring to the youngest and oldest ages suggested by all indicators, and the latter referring to the range of years where all indicators were in concordance. Broader age categories were assigned to individuals who had reached full skeletal maturity because age estimation is more difficult and much less accurate than it is for growing adolescents and young adults. For the purposes of analysis, likely age limits were employed to assign individuals to one of the age categories given in Table 2.2.

Several methods were not employed to estimate the ages of the individuals because they are considered unreliable or were beyond the scope of the project. This applied to observations relating to cranial suture closure and ossified cartilages on account of their widely acknowledged inaccuracy

Table 2.2: Age categories employed

Age category	*Age range*
Adolescent	13-17 years
Young adult	18-25 years
Prime adult	26-35 years
Mature adult	36-45 years
Older adult	>45 years

(Garvin 2008; Cox 2000). Microscopic methods, for example bone histomorphology and root dentine translucency (see Cox 2000 and Whittaker 2000), were not employed because they are expensive and time consuming and, as with macroscopic methods, carry their own set of biases and weaknesses. Further, root dentine translucency was not very applicable to the present assemblage because it is more accurate when employed on individuals over 40 years who have sufficient soft tissue preservation (Cunha *et al.* 2009). The present assemblage largely comprised individuals below 40 years who had insufficiently preserved soft tissues.

Living stature

Statures were estimated by employing the maximum lengths of long limb bones and applying these to regression equations. Maximum lengths were taken using an osteometric board in accordance with the descriptions in Buikstra and Ubelaker (1994) and Bass (1995). It is standard practice to employ measurements taken from the left side, but where this was not possible (because the element was incomplete), measurements from the right side were employed instead (and this was indicated on the recording form). Reconstructed bones were used if the union between the broken portions was close. Stature estimation was not attempted for bodies with bones that were too eroded and/or heavily fragmented.

Stature calculations employed the regression equations developed for males of Caucasoid, Negroid or mixed ancestry by Trotter (1970). They were recorded in centimetres (to the nearest mm) and converted into feet and inches using the conversion tables in Bennett (1993, 98-99). Preference was given to the equations that employ measurements taken from the lower limb, because they are considered to be more accurate (Trotter 1970). Calculations involving the maximum length of the tibia were not employed because it is currently not understood how this bone was measured when the formulae were originally devised (Barker *et al.* 2008b, 386). Simmonds and Haglund (2005) determined that Trotter's formulae (1970) are more useful for adults born prior to 1960; thus these, over others (for example Ousley 1995), were more appropriate to the present assemblage.

Each individual's stature was classified as either short, unremarkable, or tall relative to their peers with reference to the ranges summarised in Table 2.3. These broad classifications employ the mean standard deviation of the heights of the Australian and British soldiers that were recorded at enlistment and assumes they represent a statistically stable sample (n=1258) of the population under investigation (R Wright 2009 pers. comm).

It was not possible to determine the statures of some of the skeletons using the above methods because their long bones were too fragmentary. However, visual comparison using anatomical landmarks, with exemplars of estimated height was undertaken to assign them to the broad classifications given in Table 2.3 to highlight individuals who were particularly short or tall. Although there are methods for estimating stature using fragmented bones, these were not employed because they give estimates with large margins of error, which were therefore not useful. In addition, methods that have been devised for other bones, including metatarsals (Byers *et al.* 1989), metacarpals (Musgrave and Harneja 1978; Meadows and Jantz 1992), and the calcaneus and talus (Holland 1995) were not employed because margins of error are high and population specific formulae, limited.

Table 2.3: Stature categories

Gross stature category	*Metric (cm)*	*Imperial (feet and inches)*
Short	<163.8	<5' 4 1/2"
Unremarkable	>163.8 - <176.1	>5' 4 ½" - <5' 9 1/4"
Tall	>176.1	>5' 9 1/4"

Assessment of individuating characteristics

Skeletons were assessed for indicators of personal identity with reference to skeletal constitution, handedness, facial attributes, dental status, pathology and trauma.

Skeletal constitution and handedness

Skeletal constitution refers to the overall build of a skeleton, more specifically whether it is particularly robust, gracile, or neither. Handedness is the dominance or preferential employment of one hand or upper limb in skilled tasks over the other.

The assessment of these attributes is based on the principle that bone has the ability to increase or decrease its mass depending on the degree of the functional pressure (Wolff 1892). Further, bone loss or an increase in bone mass due to the extent and duration of repetitive stress and mechanical loading may suggest repetitive activity through the use of particular muscle groups (Klepinger 2006).

Skeletal constitution was assessed by taking into account measurements of bones from the upper and lower limbs and the pectoral girdle, and musculoskeletal stress markers (MSMs). MSMs are non-pathological bone modifications that occur at the sites of muscle, tendon or ligament attachment (Hawkey and Merbs 1995). These were scored for sites on the upper limb, pectoral girdle, lower limbs and pelvic girdle as 'none', 'slight', 'pronounced' or 'unobservable' with reference to the system devised by Hawkey and Merbs (1995).

The skeletal constitution of each individual was classified as:

i. Gracile – slender build.
ii. Unremarkable.
iii. Robust – sturdy and muscular.
iv. Undertermined – insufficient traits for assessment due to the fragmentation or loss of bone.

Handedness was assessed by employing the following criteria, as recommended by Byers (2005) and Cox *et al.* (2008):

i. Glenoid bevelling: visual assessment of the amount of excess bone surrounding the glenoid cavity of the scapula.
ii. Posterior deflection: visual assessment of the degree of backward angulation from the infra-spinuous plane.
iii. The combined total length of the humerus, radius and ulna.
iv. The width of the distal end of the humerus.
v. The comparative size of the right and left humeri with reference to the development of the deltoid tuberosity (assessed visually).
vi. The maximum length of the clavicle.

MSM scores for paired upper limb and pectoral girdle bones that could be measured were also taken into consideration.

Dominant arms were identified based on the side that had the largest combined length of the humerus, radius and ulna (>5mm for each bone, to account for fluctuating asymmetry), greatest amount of glenoid bevelling, posterior deflection and deltoid tuberosity development, the shortest clavicle and the more pronounced MSMs. Handedness was not determined if observations were ambiguous, there was no significant difference between bone lengths, and/or a contradiction existed between the above criteria and the MSMs.

For each individual, handedness was recorded as:

i. Possible preferential employment of the right/left upper limb.
ii. Undetermined – data inconclusive.
iii. Not examined – the full compliment of paired traits was not available for examination.

Assessment of skeletal constitution and handedness for the individuals from Pheasant Wood must be viewed with caution because opinion is currently divided on the reliability of methods employed to determine these (Cashmore 2009a, 2009b; Danforth and Thompson 2008; Klepinger 2006; Byers 2005). Cultural trends, for example pressures to conform to right handedness in the early 20th century in Australia and the UK (Steele 2000), will have influenced patterns in hand dominance to an unknown degree. In addition, variation in activity type and level at the time prior to death and at the time of death (for example, civilian sedentary occupation in contrast to that of an infantry soldier) may influence limb asymmetry signatures (ibid.) Further, it has been observed that MSMs are significantly correlated with age and sex, complicating the role that activity has in their manifestation (Weiss 2004).

Facial attributes

Research into craniofacial anatomy and forensic casework has shown that a correlation exists between the underlying hard tissue structures of the skull and soft tissue facial attributes (for example, Wilkinson and Neave 2003; Solla and İşcan 2001; Jayaprakash *et al.* 2001; Kolesnikov *et al.* 2001). Thus, recorded facial attributes may provide individuating information that may in turn contribute to identification, when compared with photographs of known individuals.

Ante-mortem photographs exist for some of the Fromelles Missing, but their potential to assist with identification is limited by the fact that faces are often obscured by hats and by the angle from which the photo was taken; in addition, the resolution of the photos is often poor and individuals are not always showing their teeth (which would reveal the presence or absence of dental work and the positioning and bite of teeth). However, the photographs do give an overall impression of face shape and whether or not features (nose, jaw and brow) were distinctive or not.

A methodology for recording facial attributes that accommodated the unique circumstances of the Fromelles project (namely, that all remains were to be re-buried prior to their identification) is not known to exist within the published forensic literature. A simple qualitative methodology was therefore developed for recording gross features with reference to forensic studies and forensic case histories (for example Ghosh and Sinha 2001; Fenton *et al.* 2008; Jayaprakash *et al.* 2001; Porter and Doran 2000; Ghosh and Sinha 2005). This involved recording the shape of the lower jaw, the presence or absence of craniofacial asymmetry and the facial profile. These features could then be compared with photographs by employing the principles of exclusion or failure to exclude (Barayabar 2008). The technique was not intended for use as a primary identification method, but was employed as an aid.

Lower jaw shape was assessed with reference to gonial eversion, chin shape and the jaw line (Table 2.4). Cranio-facial asymmetry was assessed with reference to standard anatomical landmarks. Çaglaroglu *et al.* (2008, 270) define facial symmetry as the 'similarity and equality in shape, volume and appearance of the right and left sides of the face with respect to the median saggital plane' (the mid-line). Craniofacial asymmetries may be congenital or genetic in origin (for example, a cleft palate) or

Table 2.4: Assessment of the shape of the lower jaw

Attribute	*Description*
Gonial eversion (see Fig. 2.32)	Bilateral flaring of the jaw at the junction between the ramus and body (gonial angle)
Chin shape	Square, pointed
Jaw line	Heavy or narrow

Anatomical landmarks of the Skull	Corresponding soft tissue features
Nasion - Subspinale	Nose
Nasion - prosthion	Nose and upper jaw
Nasion - menton	Face from brow to chin
Subspinale - prosthion	The upper jaw
Subspinale - menton	Upper jaw to chin
Prosthion - menton	Lower jaw

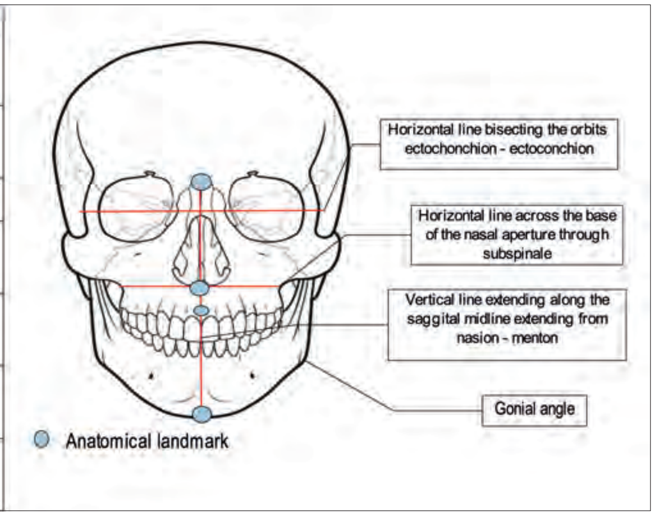

Fig. 2.32 Anatomical landmarks employed in the assessment of craniofacial asymmetry

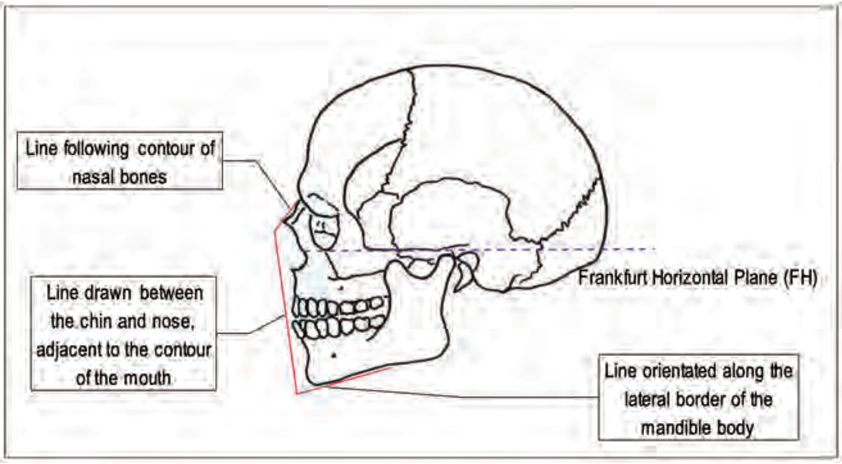

Fig. 2.33 Anatomical landmarks employed in the assessment of facial profile (Fig. adapted from Inforce recording form – Cox et al. *2008)*

environmental (for example, asymmetric chewing habits, trauma or unilateral tooth extraction and resorption of the surrounding bone tissue) (Sarver *et al.* 2000). It is accepted that skeletal asymmetry negatively affects the symmetry of the soft tissues of the face (ibid.). Thus, recorded or visible asymmetry in the regions of the face may be consistent with lateral deviations between anatomical landmarks that extend along the median sagittal plane (Figs 2.32 and 2.33).

Facial profiles were assessed by examining the relative relationship or prominence of the hard tissue structures of the chin, mouth, nose, upper teeth and lower teeth (for example, a prominent chin would project anteriorly relative to the mouth and nose).

In addition to the above, other qualitative observations were recorded as free text entries. For example, the younger individuals whose skulls possessed juvenile characteristics were noted because they may have had a youthful 'boyish' appearance in life. All assessments were made by a single observer, using anterior and left lateral photographs of the skull in the Frankfurt Horizontal (FH) plane.[2]

Photographs of each skull were annotated following the schemas in Figures 2.32 and 2.33. Those gross attributes isolated as visible were recorded as present. Gross attributes were recorded as absent when there was a paucity of traits or a reliable assessment could not be made

2 FH is the anthropological standard approximating the natural position of the head in life, introduced into anthropological use in 1884 (Pancherz and Gökbuget 1996). FH corresponds to a line extending horizontally from the inferior margin of the orbit to porion, the anatomical landmark denoting the most lateral point of the roof of the external auditory meatus.

due to fragmentation, loss of bone tissue or plastic deformation.

360º video of skulls

All complete, or reconstructed skulls were recorded in the FH plane by 360º digital video for photographic superimposition. Photographic superimposition is an established forensic identification technique (for example Bilge *et al.* 2003) where images of a presumed deceased individual are superimposed over an image of the unidentified skull, to establish points of affinity or concordance, the existence of which can contribute to the identification or exclusion of an individual. At the time of analysis it was not clear the extent to which there would be photographs of the Missing of a good enough quality, for photographic superimposition. Therefore, the aim of the 360º video was to capture relevant and useable images that could be digitally reworked for orientation to facilitate any future photographic superimposition or at least comparison with photographs.

In usual circumstances the skull is available until identified, thus photographs of the skull can be orientated to correspond with the ante-mortem photograph(s) of the presumed deceased. This option was not available for the remains from Pheasant Wood, which were re-buried before identifications were made. The 360º video recording of suitable skulls was in direct response to this. Forensic identification was performed using this method (Ghosh and Sinha, 2005), and was therefore considered a viable option for the present project. In addition, quality assurance was sought from a relevant expert on the efficacy of the video imagery for identification through photographic superimposition. The method was pronounced suitable (Adams pers. comm. 2009). The set up for this method is described in more detail below (see 'photographic record')

Dentition (dental health and dental work)

A complete dental record, comprising radiographs, photographs and a written record was created for the Pheasant Wood individuals for future work and

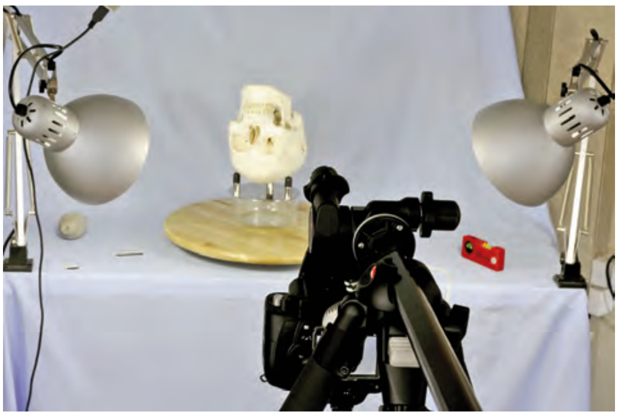

Fig. 2.34 Set up employed to capture 360º videos of skulls (plastic reference skeleton shown here)

identifications in the unlikely event that comparative records become available. Records were quality assured during a site visit by Dr Cath Adams, Forensic Odontologist, who considered them to be effective and relevant for any future odontological identification, should this become an option.

In the absence of comparative records some aspects of the dentition may still be useful for determining a presumptive identification. In particular, this includes the presence of prosthetics, other dental work, type of 'bite' (Hillson 2005, 283), tooth loss, decaying teeth, dental crowding or rotated teeth. All of these can influence facial appearance and, where photographs of individuals smiling, with open lips, survive, or where military enlistment records have recorded dental status (for example denture wearer), they can contribute to the identification process. For the Missing, some of the enlistment records state whether individuals were initially turned away because of bad teeth, and whether they had dental work, in particular gold fillings (see Chapter One).

Dentitions were recorded by employing the FDI system with reference to the codes set out in Barker *et al.* (2008b, 412) and by stating location and timing (ante/peri/post-mortem, where applicable) for the following:

1. Ante-mortem tooth loss and timing, recorded as one of the following:
   - Recent loss (9-<12 months)
   - Progressive loss (≥12 months and ≤12 months) – for multiple tooth loss not indicative of a single extraction/loss event
   - Long term ≥12 months
   - Undetermined

ii. Modification (for example, discolouration, erosion, attrition patterns).

iii. Malformation (for example, malocclusion).

iv. Pathology (for example, caries, abscesses).

v. Trauma (for example, fractures/chips, deliberate avulsion).

vi. Anomalies (for example retained deciduous, or milk, teeth or congenital absence of teeth).

vii. Dental work (for example restorations, prosthesis and type of material used).

viii. Bite (for example under-bite and open bite).

Digital radiographs were used to confirm the presence or absence of diseases, such as apical granulomas, and infection; the presence of dental work, in particular those not macroscopically visible such as root canal work, or features masked by post-mortem concretions such as calcium carbonate.

Evidence for ante-mortem pathology and trauma

Evidence for disease or trauma during life was identified, described and interpreted (as far as possible). Radiography (tertiary survey) was made available in a number of cases where it was considered helpful for diagnosis. All skeletal lesions were recorded, but levels of analysis were weighted towards those lesions that have the greatest potential to address the aims of the analysis. Thus, more attention was afforded to lesions associated with conditions that may contribute to the identification of an individual (for example, a healed fracture of the femur).

Lesions were examined to determine whether they were ante-mortem or peri-mortem. Peri-mortem lesions were identified and described separately. The precise location of lesions was described with reference to anatomical landmarks and using directional terminology (medial/proximal/distal/anterior/posterior). Descriptive terminology (for example, localised, diffuse, blastic, lytic) was employed to record the appearance of a lesion (Ortner 2003). Healing was recorded by noting the presence of lamellar (healed) and/or woven (active remodelling) bone. The distribution of the lesion was also recorded (i.e. whether it was diffuse, localised, involved several bones or was specific to a bone), as well as its relationship to any other pathology or trauma. Lesions were assigned to one of the following broad classifications:

i. Congenital and developmental.
ii. Joint disease.
iii. Infection (specific and non-specific).
iv. Metabolic and endocrine.
v. Neoplastic.
vi. Surgical intervention.
vii. Ante-mortem trauma.
viii. Miscellaneous, idiopathic conditions.

Differential diagnoses were noted, explored and the preferred diagnosis recorded (with justifications) with reference to standard texts (Aufderheide and Rodriguez-Martin 1998; Ortner 2003; Resnick and Niwayama 1995) Desk-based research was carried out prior to the field operation to explore potential diseases and disorders that the individuals at Pheasant Wood, from different geographical and ancestral groups, may have been exposed to or had a predisposition towards (for example, thalassemia, a condition that is seen among individuals of Mediterranean genetic heritage). This research was used as a reference aid throughout the analysis.

Ante-mortem trauma may make a particular contribution to personal identification, where medical records exist (such as those at the time of enlistment), or photographs and/or anecdotal evidence that document visible deformities (for example, shortening of a limb, a limp, amputations) that may relate to trauma.

Ante-mortem trauma can be the result of an acute insult, repeated stress or an underlying pathological condition. Radiography may provide additional information by confirming the presence or absence of a suspected fracture, indicate the stage of healing, and presence of secondary infection, among other factors.

The macroscopic examination of ante-mortem trauma involved recording the anatomical location (the bone, right or the left side) position (anterior, posterior) and size (with measurements in millimetres) of the lesion in relation to anatomical landmarks. Lesions were described using unambiguous terminology (for example, Barker *et al.* 2008b, 398, tables 8-10; Ortner, 2003). Terminology was descriptive rather than diagnostic, and importance was given to classifying trauma according to the predominant characteristics of the lesion, and not the mechanism or causal force (for example projectile injury) (Galloway 1999; Lovell 1997). Interpretations that attempt to explain the circumstances in which injuries occurred were avoided (Galloway 1999), the goal being to identify the forces that may have been applied and not the specific causes they may or may not be consistent with. Any preferred interpretations of lesions were justified using published literature (for example, Galloway 1999) and descriptions were supported by annotated diagrams, photographs and radiographs, where appropriate.

The healing of fractures was recorded with reference to angulation, overlap, shortening and secondary complications (for example, infection) (Lovell 1997; Ortner 2003) or possible relationships with other disease processes and/or trauma.

Where possible, ante-mortem trauma was classified as either:

i. Pathological (arising from a disease or disorder, for example osteoporosis).
ii. Traumatic (a fracture, amputation, or dislocation).

An additional consideration was the timing of the lesion(s). More than one individual may have fractures involving the same bones. However, the timing of the traumatic events may help to discriminate one individual from another. Multiple factors influence the rate of fracture healing (for example, age, nutritional status) and advanced healing is more difficult to determine than recent trauma, though radiographs can assist in this regard. As a result, only two broad time categories, longstanding $\geq$ 12 months and recent $\leq$12 months, were employed.

An attempt was made to assess the potential value of a condition in the context of identification, by considering the impact that they are likely to have had on an individual's life. They were scored with reference to the following classifications:

i. Symptomatic – symptoms or signs of the disease process or trauma may have been visible or known of during life.

ii. Asymptomatic – symptoms or signs of the disease process or trauma are unlikely to have been visible or known of during life.

iii. Undetermined.

Peri-mortem trauma

Peri-mortem trauma refers to an insult to the body around the time of death. It was given special consideration because of its potential to assist in understanding the mechanism (for example, projectile) and cause (for example, gunshot) of death, information which may contribute to knowledge of the circumstances of the battle and the subsequent interment of the bodies. In particular, this information has the potential to match bodies to the names of the Missing where their cause of death has been recorded on army records. This has recently been demonstrated in a separate piece of research that identified agreement between eye witness accounts of injuries sustained during the battle and peri-mortem trauma observed on the skeletal remains (Loe *et al.* 2014; and see Chapter Four).

The identification of peri-mortem trauma rests on the principle that bone that has an intact organic matrix ('green bone') will respond differently to bone which has partial organic matrix ('dry bone') (Loe 2009; Raul *et al.* 2008). Typical characteristics of green bone fractures include fracture margins that are sharp and smooth, radiating fracture lines, and fracture lines that are straight. Irregular fracture margins (or splintering), fragments that tend to stay attached to one another (or hinging), peeling or lifting of fracture margins, bending, margins that are usually discoloured, or the same colour as the surrounding bone and trabeculae that are stained from the haematoma, may also indicate peri-mortem trauma (Berryman and Haun 1996; Brothwell 1981; Kanze and Grossschmidt 2005). In addition, Knüsel and Outram (2006, 255) describe 'spalling', or the removal of chips of cortical bone in association with a peri-mortem parry fracture.

Additional criteria for identifying green bone fractures refer to taphonomic signatures on surrounding bone surfaces (Barker *et al.* 2008a, b; Raul *et al.* 2008) and, for long bones, fracture margin texture, fracture angle (created by the fracture surface and the cortical surface) and fracture outline (in relation to the longitudinal axis) (Knüsel and Outram 2006; Villa and Mahieu 1991). Secondary indicators include, for example, evidence of insect infestation, such as larval pupae cases, whose presence can only be the result of fractures occurring during the peri-mortem or early post-mortem periods (Galloway 1999). Dry bone fractures may be distinguished from green bone fractures because they result in smaller and more regular fragments, margins that are rough, and uneven and (often) discontinuous fracture lines (Kanze and Grosschmidt 2005; Sauer 1998).

Lesions were described by following the steps detailed for ante-mortem trauma (for example location of a lesion and orientation and type of fractures), with the emphasis on descriptive rather than diagnostic criteria. Where possible, lesions were classified according to causal force (Table 2.5) as either blast, projectile, blunt and/or sharp, with reference to accepted criteria (Gurdjian *et al.* 1950; Galloway 1999; Kimmerle and Baraybar 2008; Loe 2009). A single individual may have sustained a number of injuries, classified to one or more of these categories.

Where possible, lesions were attributed to wounding mechanism (firearms/explosive munitions/blade) by reconstructing shattered bones to identify primary wound characteristics. This was combined with examining their overall distribution and pattern and any associated ballistics (shrapnel balls and projectiles from firearms) and radiographic evidence (radiodensities visible on radiographs consistent with ballistics). This took into account context information, such as the *in-situ* position of individuals and their physical relationships with ballistics, as recorded by survey, photography and written record. Analysis benefitted from primary radiography surveys of remains and grave soil samples taken immediately following recovery. These allowed wounds and/or ballistic artefacts that were inside bones to be identified and treated accordingly before any washing or other processes were performed that would disturb them.

Skeletal injuries caused by explosive munitions are complex and may result from the blast waves (primary injuries), projectiles (secondary injuries), blast winds (tertiary injuries) and thermal effects (quarternary injuries) and ballistic effects (NATO 2004; Stewart 2006; Amber *et al.* 2008; Hare *et al.* 2007; Hull *et al.* 1994; see Table 2.6).

Table 2.5: Trauma classifications according to causal force

Causal force	*Description*
Projectile	Injuries due to any object that is propelled but is not self-propelled, including those from small arms, explosive artillery or objects from an unidentified source
Blunt force	Injuries sustained from contact with a broad instrument or surface
Sharp-force trauma	Penetrating injuries (complete or incomplete) caused by a sharp edged instrument
Blast-force trauma	Injuries sustained due to the effects of explosive artillery
Causal force unknown	Injuries with characteristic peri-mortem trauma signatures, but the mechanism that caused the injuries cannot be determined

Table 2.6: Summary of the mechanisms and effects of blast trauma

(based on Ritenour and Baskin, 2008; Stewart 2006; Túregano-Fuentes et al. *2008; Jankovic* et al. *1998; Hull* et al. *1994; Mellor, 1992; Hare* et al. *2007; Allaire and Manhein 2008; Mangworthy* et al. *2004; Champion* et al. *2003; Nato 2004; Wanek and Mayberry 2004, Weil* et al. *2008; Kosashvili* et al. *2009; Delorme 1915)*

Injury classification	*Explosive effect*	*Injury mechanism*	*Type of injury sustained*	*Causal force*
Primary	Blast wave	Short phase high pressure blast wave from explosion impacts with air filled cavities and solid structures	- Traumatic amputation - Decapitation - Multiple skeletal fractures - Blast lung, ruptures and perforations in air filled cavities	- Shearing forces from the wave cause massive disruption/ comminution of the soft and hard tissues - Joint disruption, amputations or avulsions rarely occur - Amplification of blast wave in enclosed spaces
Secondary	Projectiles	Penetrating injuries from shrapnel, bomb fragments and flying debris	- Projectile defects and associated radiating and concentric fractures - Penetrating defects - Embedded fragments	- Projectiles are propelled by the explosive device and other debris is accelerated by the blast wave and blast wind
Tertiary	Blast wind	Longer phase negative pressure, victim and objects displaced by blast wind	- Acceleration and deceleration injuries - Blunt force compression, depressed and crushing injuries - Penetrating injuries: partial or complete - Traumatic amputation: partial or complete - Multiple skeletal fractures	- The blast wind displaces object and/or a victim, and object and victim impact - Can cause complete traumatic amputations in those with primary injuries
Quaternary	Thermal effects	Burns	All other injuries, e.g. burns and exacerbation of existing conditions	- Fire and heat

Criteria for interpreting skeletal lesions arising from explosive munitions is primarily detailed in the clinical literature (for example, Ritenour and Baskin 2008; Stewart 2006; Túregano-Fuentes *et al.* 2008; Jankovic *et al.* 1998; Hull *et al.* 1994; Mellor 1992; Hare *et al.* 2007; Allaire and Manhein 2008; Mangworthy *et al.* 2004; Champion *et al.* 2003; Nato 2004; Wanek and Mayberry 2004; Weil *et al.* 2008; Kosashvili *et al.* 2009; Delorme 1915). There are virtually no anthropology texts on this subject, Kimmerle and Baraybar's (2008) publication, which primarily relates to conflict in former Yugoslavia, and Christensen *et al.*'s (2012) paper on lesions observed in pig bone, being exceptions (the latter text was not available at the time of the Fromelles operation). Therefore, for the present operation, specific criteria for identifying blast related trauma sustained on the Fromelles battlefield were developed by employing clinical descriptions, reviewing the types of weapons that were used during the First World War, considering historical accounts and testimonies and by considering the repeated occurrence of certain peri-mortem signatures, observed on the skeletons, such as partial and complete traumatic amputations.

In the human skeleton, explosions may result in multiple, extensive, comminuted fractures, an absence of fractures associated with a point of impact (in the case of blast wave injuries), decapitation, amputation, penetrating wounds, embedded fragments of bone and/or metal and/or debris, blunt force injuries, acceleration and de-acceleration injuries and burns (references from Table 2.6). Fractures associated with compression, shearing and bending forces; random fracture patterns and particularly severe fracturing in long bones are typical of the effects of the blast wave (Christensen 2012, 7). Transverse and oblique fracture patterns in the head, neck and rib shafts, and butterfly fractures in rib bodies can also occur (Christensen 2012, 7). A single explosion can cause multiple injuries and can affect a number of individuals at the same time (Leibovici *et al.* 1996). Further, the location of the victim to the explosion and whether it occurs in an enclosed, partially enclosed or open space will also affect individual injury patterns (Leibovici *et al.* 1996). The latter is particularly significant to primary blast injuries, the blast wave being amplified in enclosed or partially enclosed spaces, such as those that would be experienced in a direct hit in the trenches.

Unlike explosive munitions, skeletal trauma caused by projectile injuries (including projectiles from explosive munitions and fire arms), sharp or bladed instruments and contact with a blunt object or instrument, are well documented in the forensic anthropological literature (for example Byers 2005; Berryman and Symes 1998). Projectiles were identified by the presence of stellate fractures, or fractures associated with a point of impact, as have been described in relation to the cranium (Berryman and Symes 1998; Smith *et al.* 1987). They include entrance and exit wounds, which have bevelled margins and which refer to the direction of the projectile, radiating fractures and concentric heaving fractures (Berryman and Symes 1998; Smith *et al.* 1987). Post-cranial lesions involve considerable communition and bone loss and are therefore harder to identify, although nicks and depressions from metal fragments, bevelling and butterfly fractures are sometimes present (Heulke and Darling 1964). Lesions caused by shrapnel or fragmented shell casings were distinguished from those caused by firearms with reference to criteria given by Kimmerle and Baraybar (2008, 101, 111) and Owsley *et al.* (1995) and which primarily relate to their size, shape and number.

Sharp-force lesions include cut/incision, stab or cleft/notch wounds which fully or partially penetrate bone, skip or glance off bone, or slice, chop or scrape bone, depending on the angle and impact of the instrument (Byers 2005). Blunt force trauma may result in focal or penetrating injuries that have discrete patterns, which sometimes bear characteristic hallmarks of a particular type of weapon (e.g. a pole axe), or appear as areas of crushing with few distinctive features (Berryman and Haun 1996; Boylston 2000; Galloway 1999; Ortner 2003). During the Battle of Fromelles, blunt force injuries may have arisen as a result of hand-to-hand combat, falls or explosive munitions.

Packaging human remains

Human remains were packed for temporary storage to await re-burial in accordance with IfA guidelines (McKinley and Roberts 1993). Upon completion of analysis, each skeleton was wrapped in acid free tissue and packed into crush resistant cardboard boxes, one individual per box, with suitable cushioning. Each box was labelled with the body number, grave number and site code. Labels, carrying the same information, were placed inside the boxes, two per box.

Data analysis

All anthropological data were entered onto the Fromelles Database (see above) and were employed to generate summaries for each individual, to be compiled into case reports along with archaeological and finds data. Anthropology data were also analysed at the assemblage level in order to characterise its preservation, demographic profile, physical attributes and health status, with particular reference to the potential of the evidence to assist in the identification of the bodies.

Unlike most standard archaeological reports, a catalogue (or equivalent) detailing each individual has not been included here. This lies outside the aims of the project which concern living peoples' relatives and not anonymous archaeological cases. This also applies to the artefacts (see below).

The prevalence of different variables was explored by calculating the number of individuals with a particular change out of the number that could be observed (crude prevalence rate, or CPR). The true prevalence rate (TPR) was explored by calculating the number of body regions or bones affected out of the total number observed.

By using the statistical packages XLStat and PAST, patterns were analysed using the Chi-square analysis of probabilities, Pearson's phi coefficient, Fisher's exact test and standardised residual testing (as appropriate). Each test explored the null hypothesis that there was no spatial patterning in the properties of graves and bodies being analysed. The details of the statistical analyses are presented in appendices two and three.

Quality assurance

On-site quality assurance and control for inter-observer error were maintained by the lead anthropologist who checked the written conclusions of each analysis against the physical remains. In instances of differing opinion, relevant literature and exemplars were consulted to arrive at a unified opinion. When differences of opinion could not be resolved, both opinions and any differential diagnoses were detailed on the recording form and illustrated with photographs. Quality assurance was also achieved through regular reviews of recording by the project manager and the anthropology team. Records were also checked from time to time by the FMB's archaeological and anthropological scientific advisor to ensure impartial external quality checks.

The post-excavation phase provided a further opportunity to quality assure records. Any inconsistencies were checked against other relevant records (such as photographs, radiographs and field records). All changes made during the data analysis and reporting stage were checked by the lead anthropologist and entered into the case record as updated information. In addition, mechanisms employed in the DAT process (see Chapter Seven) allowed for identifying, correcting and preventing the propogation of any transcription errors made during data entry (this also applies to archaeological and artefacual data, not just the anthropological data).

ARTEFACTS

A wide range of artefacts was encountered in varying states of preservation and included metals, textile, paper/cardboard, rubber, leather and wood. Items associated with military issue uniform, equipment and ammunition formed the

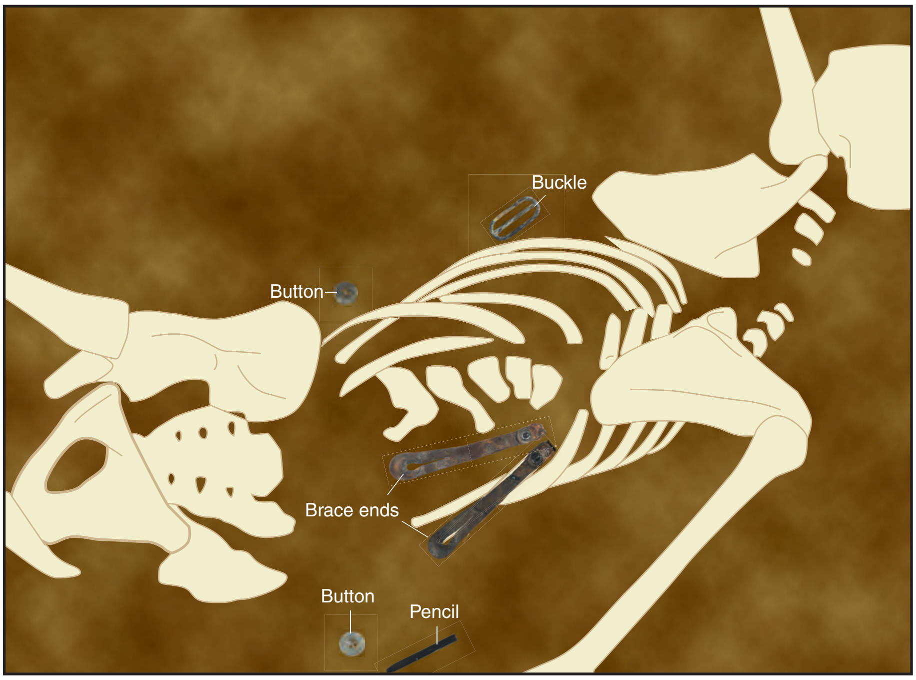

Fig. 2.35 Artefacts (Commonealth buttons, leather brace ends, indelible pencil and Australian jacket belt buckle) in situ

largest part of the assemblage, but personal effects were also recovered.
The entire finds process, including excavation, recovery, processing, analysis and secure storage was co-ordinated from the designated laboratory in the temporary mortuary complex by one full time finds manager, with two part time assistants.

Aims and objectives

The principal aim of the finds process was to, as far as possible, contribute to the determination of a presumptive or positive identification of each individual. Primary objectives were:

i. To pay particular attention to finds that were associated with individuals.

ii. To fully record all artefacts and their associations.

iii. To maintain the association of artefacts with each other and with bodies by observing continuity and a strict chain of custody.

iv. To provide short-term conservation and storage for all artefacts.

Methodology

All finds work was undertaken with reference to the IfA's standards and guidance for the collection, documentation, conservation and research of archaeological materials (IfA 2008e). Prior to the commencement of the fieldwork, desk-based research on the range and type of finds to be expected was undertaken and primarily focused on information on military issue uniforms, equipment and ammunition, identified by internet and library searches and by consulting international First World War specialists. All staff were fully briefed on the types of items that were expected to be found, including their likely locations on skeletons. This information was illustrated on laminated posters, used as reference aids at the graveside.

Excavation

Methods relating to the excavation of finds involved fingertip searching, metal detecting and sampling the soil (see detailed description above) to maximise recovery. When found, artefacts were left in situ until the entire body (or bodies) they were associated with had been revealed (Figs 2.35 and 2.36). Exceptions to this only occurred when the material of the artefact was particularly fragile and suscep-

Fig. 2.36 A pipe being recovered

tible to deterioration when exposed. In most cases this was restricted to paper and card.

Each artefact was assigned an evidence number, with the suffix 'A' for artefact, to allow the rapid identification of artefact numbers. Artefacts were photographed (see below) and their 3D position was recorded by survey. For the latter, locations were recorded with the artefact number and a one word description, such as 'button' or 'buckle'. The vast majority of finds were recorded individually with the exception of groups of finds that would have formed one item that could not be identified to a specific army or group, for example press studs and buckles, which together were part of webbing, and rows of plain under-shirt buttons. In these cases, finds were assigned a single artefact number and surveyed as such.

Following excavation and recording, artefacts were collected and sealed in individual bags labelled with the site code, grave number, body number, artefact number, excavator's initials and the time and date.

Radiography and processing

All artefacts were kept with the bodies with which they were found and were signed over to the mortuary, from where they were transferred to the radiography suite for primary radiography survey. Radiographs were not routinely examined by the finds manager at this stage except when the radiographer did not recognise an item, the item was fragile, or when the item carried highly significant identification information. In addition, radiographs of heavily corroded items were examined for information about features and marks that were not obvious macroscopically; because the aim was to recover evidence to assist with identification this was a rapid means avoiding unnecessary cleaning of corroded items that bore no useful features or marks (Fig. 2.37). In all of these cases, and where necessary, items were removed from their bags and signed over to the finds laboratory for priority attention.

Following radiography, artefacts were signed over to the processing area, where they were sorted and cleaned using soft bristled toothbrushes and dental and sculpting tools. Fabric was carefully examined again for patches, labels, attached insignia and other artefacts that may have been folded inside it, or contained within pockets.

Once clean, the finds and their associated bodies were either laid out on trays with clear labels and placed on racking to air-dry in a controlled room temperature of about 16ºC (metals, plastics, large fragments of clothing), or resealed in plastic bags (leather and glass).

Recording and interpretation

When a body was signed over to an anthropologist, the assemblage of artefacts associated with them

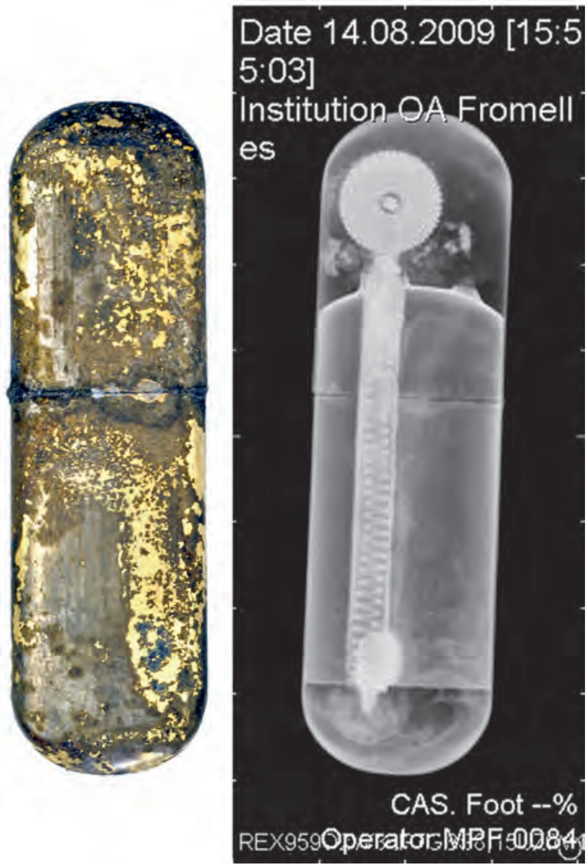

Fig. 2.37 Corroded brass lighter (left) and radiograph of the lighter (right); the radiograph shows that it bore no useful features or marks for identification

was signed over to the finds laboratory. Occasionally, artefactual evidence (for example, shrapnel from inside the skull) was recovered from the skeletons during anthropological analysis and was immediately transferred to the finds laboratory for recording and identification.

All artefact assemblages were booked into the finds laboratory upon arrival and their numbers written on the wipe board on the wall in order to maintain a record of the status and location of each. The material was laid out on the workbench (Fig. 2.38) and the association between artefacts and bodies, as recorded on site, was checked. Each item was then identified, recorded and researched as an individual entity without consideration of the rest of the assemblage to which it belonged. Artefacts were researched by consulting catalogues (such as full catalogues of army insignia; Cox 1999), relevant literature, the internet (including the extensive online visual database of The Australian War Memorial Catalogue and that of the Imperial War Museum), a local finds expert, Martial Delebarre, and by reference to the collection of First World War finds in (the original) Fromelles Museum (Fig. 2.39).

A three-staged approach was employed to conclusively identify each artefact as follows:

i. Classification: what is it?

ii. Identification: what does it tell us about the individual with whom it was found?

iii. Association: what does its association with the other artefacts with which it was found tell us?

Consideration was given to whether the item was likely to have been associated with a soldier of either army exclusively, or whether it could have been associated with both, whether it identified a regiment or battalion, or whether it was marked with a name or initials. When the assemblage was examined as a whole (see below), a decision was made on whether each artefact had potential (or was needed) to answer questions not answered by the other artefacts in the same assemblage.

A system was devised by which each item or group of related items was given an identification significance score (ID score) from one to five to reflect the level of exclusivity of identification it provided. This system minimised bias in interpretation and ensured that each artefact was assessed

Fig. 2.38 (left) Artefacts laid out with labelled finds bags for checking, identification, recording and research

Fig. 2.39 (below) Fromelles museum, Fromelles town hall (Fromelles Weppes Terre de Mémoire)

equally and that the full potential of each item for identification was realised. Scores were defined as follows:

1. Generic items that do not contribute to the identification of an individual. Examples included, but were not limited to, plain metal buttons, zinc and brass eyelets from German and British ground sheets, under-shirt buttons, gas masks, ammunition, elements of webbing and other equipment (such as trenching tools and water bottles) issued across the forces, and unidentifiable fragments of metal and other materials. All these items could have been worn or carried by both the British and Australian armies and were not specific to any army's uniform or issued equipment set.
2. Items that provide some information about an individual, but not are not indicative of which army the individual fought for. For example, a Catholic prayer book may suggest the religion of the individual, or a laced fragment of breeches could be from the trousers of a member of the AIF or a sergeant or officer of the British Army, but not from a British infantry soldier.
3. Items that identify individuals to a specific army. Examples include a British general service button or an Australian jacket belt buckle (Fig. 2.40).

Fig. 2.40 Australian jacket belt buckle being recovered

Fig. 2.41 Part of shoulder nember denoting battalion

4. Items that provide more information than the above mentioned, including closer identification within the Australian or British armies. For example, a badge or an item of insignia indicating individual rank or a battalion, regiment or sub-unit (Fig. 2.41).
5. Items that suggest personal identification because they bear a name or initials, or other information likely to indicate a name.

Where necessary, further cleaning was undertaken to assist identification. In some cases, after radiography, artefacts were cleaned very thoroughly to remove all loose rust and adherent fabric. Sometimes the cleaning involved an element of destruction. This is not typical of the way artefacts are treated on most traditional archaeology projects where identification is not a priority.

Each item or artefact group was recorded individually in a spreadsheet. This captured the following information: context number, the GUARD body number/SF number (if applicable), the associated body number, the date it was recorded, the grave number it was found in, its material (wood/metal/etc.), count, type of item, description, identifying features, description of identification provided, ID score (see above), type of short-term conservation undertaken and photo card and frame numbers in the primary digital archive. Artefacts were also recorded onto the relevant individual artefact assemblage spreadsheet, created for each body number.

Following the identification of each item, they were examined at the body assemblage level in order to create a summary and overview of the artefacts found with each individual. Analysis of artefacts at the assemblage level was a key stage in the analytical process, because this provided a more complete picture than any single find, no matter how low or high their individual ID scores, although in some cases (for example, a British general service button found with an Australian jacket belt buckle (AJBB)) the identification information was conflicting.

Conclusions about evidence provided by each assemblage were reached by subjective decision making in consultation with the excavation record, in particular the location of the artefacts on the body, taking into consideration the evidential value of individual items. For example, when present in the same assemblage, the AJBB was considered to provide more secure identification information than a British general service button because it was integral to the Australian jacket and not easily moved from person to person. Historical accounts record how easily buttons, such as the British general service button, were swapped and replaced between uniforms (Knyvett 1918, 162-63). Similarly, eyelets from the lower part of trousers could be from an Australian or British officer, but may be considered Australian when in association with an AJBB or a rising sun badge. These and

Fig. 2.42 Photography set-up in the finds laboratory

other interpretations were reached by research into individual items and by consulting specialists in the relevant military museums, as appropriate.

During the process of logging, all field notes, survey data and radiographs were consulted to establish the location of each artefact on the body. The location of an artefact could be critical in its identification and in establishing its potential as evidence of identification of the buried individual. In particular, this was very important in respect of the portability of items (see Chapter Five), which was not factored into the ID significance scoring system, but was considered separately. Thus, for example, some items with high ID scores were considered less significant if they were found in locations (for example, a pocket) that suggested they may have belonged to someone other than the individual they were found with.

Each artefact was photographed in the designated photography area, on a professional photographic background using a high resolution SLR camera and either a standard zoom lens or macro lens (Fig. 2.42). Three photographic lights and a reflector were available for use. One standard record photograph was taken of each artefact with a scale and artefact number, but if additional shots of details or the reverse of items were deemed useful, these were also taken. Photographs of particularly interesting items were also taken without a scale or number with an awareness of future publication or exhibition requirements.

Packaging and short-term conservation

Artefacts were packed in accordance with UKIC guidelines (1983; 1985). They were placed inside individual bags with 'write on' panels where the site code, grave number, artefact number, body number, the material and description were written in black permanent waterproof ink. Two boxes, one with silica gel ('dry') and one plastic ('wet') one were then assigned to each assemblage and the artefacts were divided between these as follows. Bags containing metals, bone, ivory and plastics (including cellulose/vegetable ivory) were perforated and placed inside the dry boxes, while non-perforated bags containing textiles (including all recovered uniform fabric), wood, paper and all other items made of organic materials were placed in the plastic boxes

Fig. 2.43 Skeletons in short term storage

('Stewart boxes') to retain moisture. Boxes were labelled with waterproof ink on white sticky labels. One Tyvek label bearing the same information as the bags was also placed inside all packaging. Silica gel was regularly monitored and changed when it reached saturation point. Dry boxes were stored at a constant temperature (16ºC) and wet boxes were refrigerated or frozen at a constant temperature to a maximum of *c* -5ºC to minimise further deterioration and bacterial growth.

In the case of composite items, that is, items that were partly made of materials that required dry storage and partly of materials that required wet storage, the part that was most useful for identification was given conservation priority and the relevant storage conditions applied. For example, in the case of a buckle attached to fabric (Fig. 2.40), the buckle was given priority because it provided more information on identity and thus, the entire item was stored in dry conditions.

Additional treatments

Subsequent to the field operation, artefacts were designated for re-burial, museum deposition or for return to families and relatives by the FMB. Subsequently, all artefacts that were retained were sent by Oxford Archaeology for cleaning and/or additional conservation for long-term storage. This work was undertaken between October 2010 and March 2011 under a separate contract.

SHORT-TERM STORAGE

All human remains and artefacts were stored in the short term in a secure store with temperature control until their re-burial in 2010 (Figs 2.43 and 2.44). This was managed by the mortuary manager, to whom all remains were signed over upon completion of analyses. At this stage, all finds (with the exception of those that required freezing or refrigeration) were re-united with bodies (but kept in separate boxes). Each case (body plus finds) was assigned to a bay. Cases were organised by grave number, then by body number. The store was kept at a constant temperature of 16ºC.

Fig. 2.44 Artefacts in short term storage

PHOTOGRAPHIC RECORD *by Tim Loveless*

Photography was used in two main ways at Pheasant Wood. Primarily, photographs were taken to complement the archive; all human remains and artefacts were photographed as were all methodologies and equipment used in the project both in the field and the mortuary. As important, due to the use of digital photography, photographs were actually used 'live' during the process to assist in the flow of information and facilitate analysis. Thus, an anthropologist could view the remains they were analysing *in situ* in the grave, reducing the number of visits to site whilst grave supervisors were able to refer back to a previous day's work or check on an artefact's status from the site office.

Basic workflow

The photographic record began at the recovery site prior to any excavation or preparation work. This was followed by photographs of all bodies and most artefacts *in situ* in the graves and continued into the laboratory where each case was recorded as it was analysed. It concluded with the restoration of the field as it was ploughed, harrowed and re-planted. All finds were also photographed in the laboratory and this aspect is covered above. As the field and mortuary phases were run simultaneously, it was necessary for the photographer to move back and forth, but for simplicity's sake it will be assumed that this was a linear process.

Equipment

Equipment included three Nikon D90s and four (later increased to five) Nikon D40s, all of which are digital SLRs provided with 18-115mm VR lenses with suitable filters. There were also tripods, lighting equipment and Nikon's Camera Pro software as well as sets of photographic scales and magnetic numbers.

The field

Each phase of the excavation was photographed. The field was recorded before work began and as fencing, equipment and temporary structures were assembled. When work was about to begin, the first scoop of the excavator was captured on camera (Fig. 1.4) and each step of the way was photographed. One of the D90s was used throughout the excavations for both 'evidence' and 'working' shots. The images were downloaded every evening and filed under a date and memory card description. Once downloaded, these were available to be viewed on any of the computer terminals connected to the internal network. All images were backed up onto external hard drives regularly. Each day a freshly formatted memory card was used and a new photographic log sheet begun. Every image was thus recorded on paper with date, frame number and a brief description of the subject matter. The memory card and frame numbers were then included in the archaeologists' field notes.

Each body (and associated artefacts) was photographed *in situ* as an overall view and the first frame included scales, the body number and a north arrow. The photograph showed the body's position and condition and the relationship to its neighbours. In mass graves, it is sometimes difficult to differentiate one body from another. A simple technique to aid visual comprehension is to use the scales as markers of the anatomical extremities. It is clearly also extremely important that the bodies are sufficiently cleaned and defined. In wet, heavy clay this can be troublesome but nonetheless crucial.

Subsequent photographs were taken of anatomical details considered significant, such as obvious trauma. Artefacts that could be associated with the body were numbered separately and included in the detail photographs to give a visual indication of how the association had been made by showing their relationship to clear anatomical markers. As the work progressed and the sheer scale of the number of artefacts found became clear, it was decided that anonymous articles such as plain plastic buttons would not be photographed but that anything that might possibly help identification, either personal or national, must receive priority attention. These included personal items such as pipes and cigarette holders, military badges and AJBBs.

At the end of each day an overall photograph of the whole grave was taken from the end of the trench. This provided an excellent record of each day's progress and as each grave was completed and backfilled, a folder was created so that it was simple to view the continuity of the work.

At various stages photographs were taken of specific groups of bodies and black and white prints made. These were used to assist the grave supervisors as an extra safety measure when keeping track of the numbering system and to act as an aide memoire. All these prints were destroyed at the end of the project.

It is important to stress that the individual archaeologist and certainly the grave supervisor will have a far clearer understanding of the narrative that they are unearthing than the photographer who constantly comes and goes throughout the day. It is incumbent on the photographer to respond to their timescale and directions. It is, however, the photographer's responsibility to ensure that the photographic record is clear and intelligible. At Pheasant Wood there were also two graves working simultaneously and as one of the few team members to work regularly in both, the photographer has a role to play in both quality control, that is, ensuring a consistent level of cleaning and in maintaining a corporate approach to the numbering systems.

The mortuary

Other than the use of digital photography and the instant feedback this was able to give to the site supervisors, the actual photographic methods used in the field were fairly conventional. However, in the mortuary at Pheasant Wood it was possible to be rather more innovative.

Each anthropological analysis table was provided with its own computer. When an anthropologist began a case, it would be accompanied by the field notes which, amongst other information, recorded the memory card and frame number of the in situ site photographs. It was then an easy matter to call up the images on the computer screen. Although the field and laboratory were adjacent, DNA considerations meant that it was necessary to don full protective gear of boots, suit, gloves, hairnet and mask when visiting the grave site. This and the sheer numbers involved made it impracticable for the anthropologists to make frequent visits to site and so the ability to view the in situ photograph by their table was very definitely the next best thing.

It is always important to get a good record photograph of the skeleton laid out on the analysis table and at Pheasant Wood it was decided early on to avoid the clumsy and inevitably unsatisfactory method of clambering up step ladders to achieve this. Instead each table had its own Nikon D40 suspended above it. These were firmly fixed to the ceiling with Manfrotto clamps and centred above each table (see Fig 2.28). The positions of clamps and table legs were marked with tape in case they needed to be moved. The cameras were attached to the relevant computer by USB cable and thus were operated from the computer key board using Nikon Camera Pro software. Each camera was set to automatic light metering mode with some slight exposure compensation so that they would respond to any changes in the ambient light. They were then left in place for the duration of the work.

The advantages of this system were manifold. The actual image quality was consistent and consistently good. The anthropologists were able to operate the system themselves without having to wait for the photographer who was also thus saved considerable time. As the images came straight down into the computer, it was possible to direct them immediately into the correct case folder and so save more time and involve less paperwork. Finally, a new system using different coloured arrows was developed (Fig. 2.45). These differentiated between ante- and peri-mortem trauma, and other criteria, another great visual aid.

At the same time a separate table was set up within the mortuary to take more detailed pictures. The second D90 was used here with a couple of simple daylight lamps, a blue back-cloth and a tripod with cross arm. This was operated by the photographer but always under the direction of the anthropologists. Any details that they wished illus-

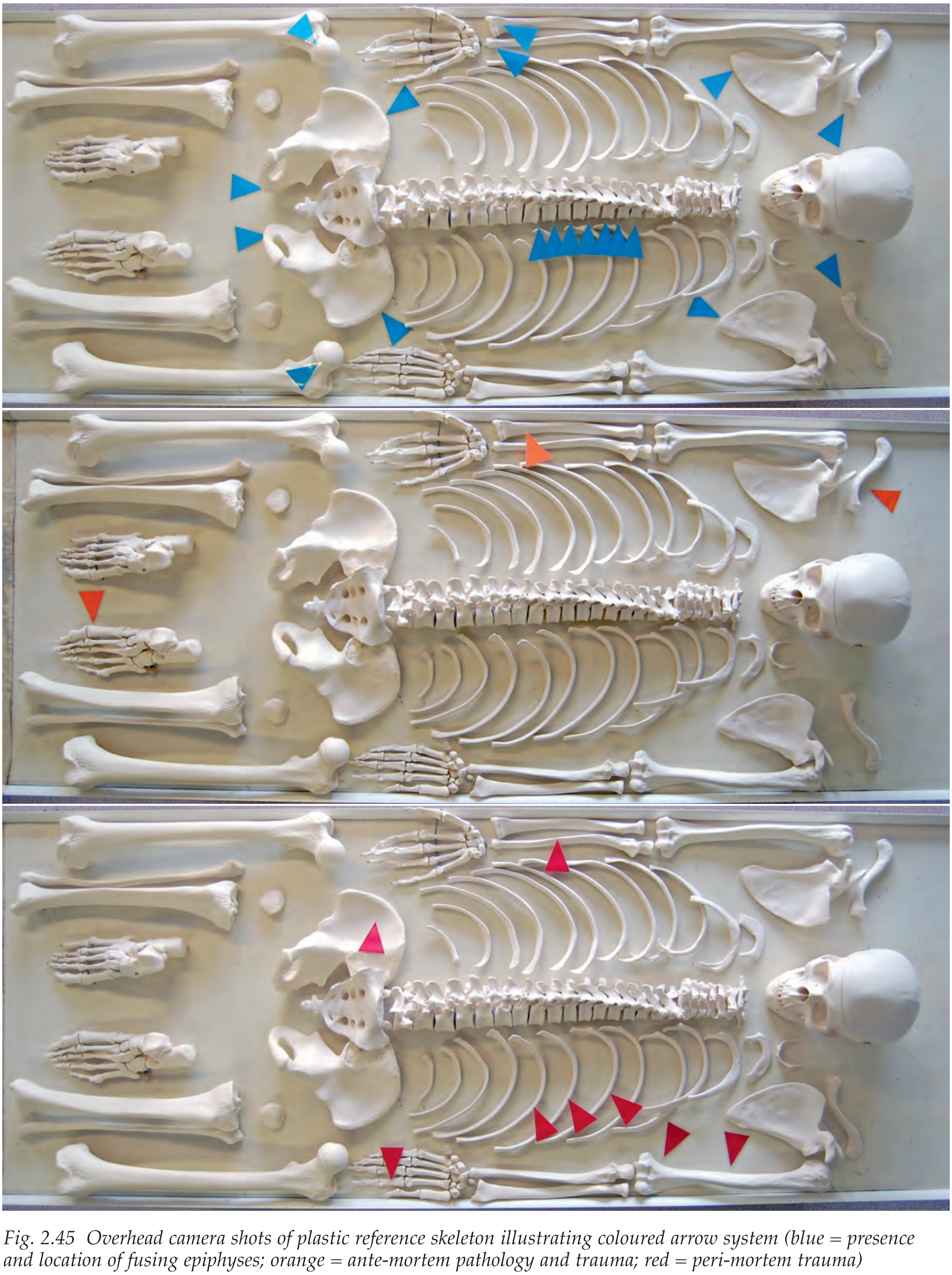

Fig. 2.45 Overhead camera shots of plastic reference skeleton illustrating coloured arrow system (blue = presence and location of fusing epiphyses; orange = ante-mortem pathology and trauma; red = peri-mortem trauma)

trated were taken here and using the same software, the photographs were sent directly to the relevant case folder. Furthermore, as the D90 has a 'live view' mode, it was possible for the anthropologists to view the image on a computer screen before it was taken and to make compositional suggestions. As there was a strict policy of not deleting any image, this again saved time and repetition.

It was decided that a 360º video of each skull (state of preservation permitting) should be made. As all the bodies would be re-buried before the identification process had been completed it was important to retrieve as much information as possible, and furthermore this might be a useful tool for later photo-superimposition techniques as the video could be frozen at any point and compared to original photographs where they might exist. The skull was placed onto a stand which in turn was placed on a revolving, circular board. The stand was an inverted tripod with rubber footings and it was found that whatever shape or size, it held every skull securely. The camera, turned to video mode, was fixed upside down on the camera tripod and the video started (Fig. 2.34). By pulling on a piece of string taped to the underside of the board, the photographer was able to rotate the skull smoothly and a one minute film clip was made. One hundred and fifty skulls out of the total of two hundred and fifty were filmed in this way.

Once the skull had been correctly positioned, it became simple, again by using the 'live view' mode, to turn it to any angle required by the anthropologists for the more usual still images and this became standard practice.

Working shots

An important part of the photographic record is to demonstrate the methodologies used throughout the process. At Pheasant Wood this was particularly so because the media were denied access to the project, yet had a great interest in it. It was therefore necessary to provide regular images of the work for inclusion on the CWGC website and the Australian and British government websites, as required. This was complicated by the sensitive nature of the project and the consequent decision by the FMB and the CWGC that no image could be released into the public domain during the operation if it showed any human remains. In effect, two parallel archives were produced, one showing the full scope of the project and including team members working with human remains and the other carefully angled to show methods but to exclude any potentially distressing elements. Although this approach did to some extent limit the photographic potential, a full archive of 'working shots' was produced.

Communications and archiving

As has been noted, the photographer's role, uniquely, involved working in both graves and in the mortuary every day. Moving from laboratory to site required putting on the full PPE which had consequently to be removed when returning to the laboratory. This took time and made communications vital. Hand-held radios were used at all times but it was also crucial that the site supervisors and anthropologists should regularly update the photographer on their predicted requirements and estimated progress. In this way very little time was lost while team members waited for a photograph and no important evidence went unphotographed.

Every camera was set to record raw files as well as JPEGs. These were downloaded every day and saved into the appropriate folder. Each camera was given its own number so that, for example, all site photographs could be found under the 'Camera Seven' folder which was further sub-divided into memory card and date files. A written log was kept and all memory card and frame numbers were also entered into the main evidence log database. The total archive was backed up onto two external hard drives, at least one of which was kept off site.

HEALTH AND SAFETY

General

Mass grave and military archaeology presents a specific and complex range of hazards. The highest risk posed by the present project was the potential for unexploded ordnance and chemicals associated with warfare. Of potentially lower significance, but important nevertheless, was the risk associated with exposure to potentially fleshed remains, both in terms of psychological stress and biological hazards. Lime was also potentially present in the graves, although reduced by association with water to an innocuous calcium carbonate.

Prior to the commencement of fieldwork a detailed health and safety plan was prepared by the site health and safety officer with the assistance of the Oxford Archaeology Group health and safety advisor. This was supported by detailed risk assessments for all areas of activity associated with the project.

Specific hazards

In response to the specific hazards presented by the exhumation of modern human remains (remains that are less than 100 years old), Oxford Archaeology undertook the following:

i. Provision of full PPE for all staff likely to work in direct contact with human remains, including but not limited to Tyvek overalls, plastic gloves, safety boots, goggles, and face masks.

ii. For those working in proximity to earth-moving plant, PPE included high visibility vests, ear defenders and hard hats.

iii. A unit was provided with shower facilities.

iv. All disposable waste was removed from site in securely sealed bags and disposed of at appropriate registered facilities.

v. Tests undertaken by a reputable laboratory determined that the ground water from the graves did not present a biohazard and contained no contaminants that were a risk to health. There was therefore no need to dispose of ground water via storage tanks or bowsers to registered disposal facilities.

vi. All 'grey water' (i.e. that generated by processing) was disposed of at a registered disposal facility.

vii. Radiography was only carried out by qualified operatives, and within a three metre exclusion zone, clearly demarcated with HERAS fencing.

viii. The temporary mortuary facility was managed by a fully qualified technician operating to recognised standards of health and safety.

ix. Access to the compound was strictly controlled and all visitors were escorted at all times.

x. Access to the inner cordoned area of the graves was limited to those with a specific reason to be present. Twenty-four hour security and CCTV cameras were provided.

Hand excavations

A combination of shoring and stepping/battering was used, as appropriate, to provide a safe working environment. The extent to which the sides of graves one and two could be adequately battered was limited by the amount of space available (reflecting their very close proximity to the treeline and/or each other and the tent). However, the erection of the marquee over graves three to five, coupled with advice from a specialist in the local clay, provided the opportunity to improve this by battering the sides at a greater angle and covering them with more secure shoring consisting of plastic and wood. The graves were also prepared with better walkways.

Careful assessment of the edges of each grave was undertaken on a daily basis by the health and safety officer, and appropriate action taken.

Post-traumatic stress disorder

Oxford Archaeology's team consisted of a combination of highly experienced forensic specialists, and some osteo-archaeologists with limited experience of 20th-century mass graves. All less experienced members of the team were thoroughly briefed in advance of the fieldwork stage of the project, and given the opportunity to opt out at any stage should they feel that they could not cope with the psychological demands of forensic archaeology/anthropology. Only one osteoarchaeologist chose to opt out during the course of the fieldwork on psychological grounds.

The psychological welfare of every member of the project team was regularly assessed by the project manager and the health and safety officer, who sought advice from a specialist psychologist on techniques designed to recognise the symptoms of PTSD (Cox *et al.* 2008, 119). During the excavation the team was visited and briefed by a psychologist, who was available for private consultation.

Regular de-briefings were given by the project manager regarding the progress of the exhumation and anthropological recording elements of the project. This helped to fully engage the team in the project and placed the discoveries into their historical and sociological context.

The team was rotated as necessary, with excavators and anthropologists given regular short or longer-term breaks, as appropriate.

Staff welfare

Staff accommodation was carefully chosen for the duration of the project to provide a comfortable home environment, away from the site but within easy driving distance. Accommodation such as this was very important, considering the challenging nature of the work, both physical and emotional. Staff were also encouraged to take breaks, either visits to the UK or holidaying, at least once during the project.

Unexploded ordnance (UXO)

There was high potential for ammunition (live rounds, hand grenades and shells) to be encountered during excavation and therefore an unexploded ordnance risk assessment of the site and a site specific UXO safety plan were prepared by NATO-qualified EOD engineers with specific knowledge of battlefield clearance and archaeological and exhumation operations.

On-site support was provided by an EOD engineer, who monitored all mechanical excavation for UXO, established muster points and drills for safe evacuation (if required), provided advice and the risk assessment of all suspicious objects found during mechanical and hand excavation, removed and arranged for the collection, under local procedures, of any item of UXO (when safe), rendered safe or disposed of UXO items that were unsafe to move, and delivered training to all staff. Training covered the following topics:

i. Recognition of the dangers posed by the most commonly encountered First World War munitions.

ii. Safety procedures to be followed while conducting investigations, including the use of mechanical excavators.

iii. Reporting, recording and immediate action procedures to be followed when a suspicious item or an item of UXO is encountered.

iv. Site arrangements for short-term storage, isolation and disposal of UXO.

v. Emergency muster points, evacuation distances and safe routes.

vi. Emergency procedures should an explosive event occur.

vii. Post-incident return to normal work procedures.

MONITORING

Throughout the operation full cooperation was extended to the CWGC/FMB monitors, Professor Margaret Cox, who oversaw the archaeology and anthropology with initial contributions from Dr Denise Donlon, and Dr Peter Jones, who oversaw DNA procedures. All monitors were provided with records and given unrestricted access, as required.

THE MEDIA, PUBLIC AND OFFICIALS

The high profile nature of the operation attracted a number of different interest groups, including relatives, battlefield tour groups, the international media, and officials. A communications officer was employed for the duration of the operation to assist the project manager, with the CWGC project manager, with enquiries and visits.

All visits were strictly managed in respect of the sensitivities involved and in order to protect the integrity of the DNA and archaeology. Authorised visitors were accompanied at all times by a project representative and, with a few important exceptions, access was restricted to the visitors/media room and the area just inside the second gate leading to the excavation area. Exceptions were extended to visiting officials and the media on an organised press day on 14th August 2009. These controlled visits involved access to the mortuary and graveside in full PPE.

Information panels were erected on the outside of the perimeter fence, where a viewing window was constructed (see Fig. 2.4). Information leaflets, in French and English, were made available from the security lodge at the entrance to the site. Panels and leaflets were produced by the CWGC. Talks were delivered to groups in the media centre and the village hall by project and section managers.

THE ARCHIVE

The archive was created in accordance with IfA guidelines (IfA 2008d), as far as was appropriate to achieving the aims and objectives of the project. It includes all records kept during the field operation; the case reports, created for the identification process; the unpublished client report (restricted); and the Fromelles database. These have been deposited with the Australian Army, Canberra, Australia. Artefacts, depending upon their nature and condition, have either been returned to families, sent to Canberra, the museum in Fromelles, or have been reburied with the soldiers. A record of the whereabouts of each artefact is held by the Australian Army.