Chapter Four:
Results Part Two – Anthropology

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SUMMARY

The skeletal remains of the soldiers recovered at Pheasant Wood were, overall, in an excellent condition, allowing a high level of biological and personal identification information to be obtained and recorded in the confidential case reports. This includes records of condition, ancestry, sex, age, individuating characteristics, dental status, ante-mortem trauma and pathology and peri-mortem trauma, with justifications and methodologies used, for each of the 250 individuals. In this chapter the results are presented at the assemblage level with particular focus on exploring the data for identification evidence. In respect of the sensitivities involved a catalogue (or equivalent) giving details of individuals is not provided here. In addition, it is important to point out that this chapter was written prior to the Identification Commission taking place and therefore before the archaeology (including the anthropology), DNA and historical data sets were collated by the DAT. Thus, the observations presented here are irrespective of the results of the Identification Board, but are considered in a later chapter (Chapter Seven).

ACTUAL NUMBER OF INDIVIDUALS

The assemblage comprised a total of 250 relatively complete skeletons and 183 disassociated body parts. The latter included complex body parts, comprising substantial portions of limbs (for example, an arm); individual bones and bone fragments. Of these, 38 could be re-associated with one of the 250 bodies by employing gross sorting techniques and by considering spatial relationships and the physical fit of corresponding bone fragments. A further 145 body parts could not be associated with any of the 250 bodies and comprised bone fragments and small bones.

There was no evidence to indicate that any of the body parts which could not be associated with bodies belonged to additional individuals; it is very likely that they were all from the 250 bodies. Therefore, the number of individuals present was 250.

COMMINGLED HUMAN REMAINS RE-ASSOCIATION EXERCISE

The largest number of body parts was recovered from Grave One (38 body parts; 20.8%), followed by Grave Two (34 body parts; 18.6%) (Table 4.1). For graves one to five, chi-squared tests for independence (p=0.7, Appendix Three) found no significant difference between the number of the disassociated body parts and the grave.

All re-associations were achieved within the closed system of each grave (e.g. Grave Five body parts were reconciled with bodies from Grave Five, Grave One body parts with Grave One bodies). No body part from one grave was re-associated with a body from a different grave. All re-associations were relatively straightforward, the successful candidate for reconciliation often lying in close proximity to the recovered body part. The application of the 3D survey record proved to be particularly useful in this respect.

The most complex case for re-association related to 2919B and 2932BP. Body part 2932BP comprised the majority of the bones of the right upper limb and was definitively reconciled with 2919B based on physical fit of adjacent peri-mortem fracture margins (Figs 3.9 and 4.1). Both the body part and the body were recovered from Grave Five, but were located *c* 5m apart, at opposite ends of the grave. Evidence suggests that these were the primary burial locations of these elements (there was no evidence that they had been moved from a primary location as a result of factors such as water or root activity). Body part 2932BP was recovered from within the GUARD sondage from 2008, but had remained *in situ* until the time of recovery (2009). While separation of the adjacent segments of the

Table 4.1: Body parts by grave

Grave number	*Number of body parts reconciled*	*% of body parts*	*Number of disassociated body parts*	*% of body parts*
1	12	6.6	38	20.8
2	7	3.8	34	18.6
3	9	4.9	27	14.8
4	5	2.7	20	10.9
5	4	2.2	23	12.6
6	1	0.5	1	0.5
Unknown	n/a	n/a	2	1
Total	38	20.7	145	79.2

Fig. 4.1 Re-associating 2932BP with 2919B: (top) 2919B in situ with missing right arm; (bottom) laid out in the mortuary with missing right arm (left) and laid out in the mortuary with right arm re-associated (right)

limb can be attributed to the antecedent peri-mortem trauma, the physical distance between them in the grave cannot be explained by post depositional processes, such as decomposition of soft tissues. It is therefore more likely that the separation of adjacent limb segments occurred at the grave-side, immediately prior to their interment in 1916.

Explanations for the disassociation of all other body parts were also sought. Some were a consequence of the excavation of GUARD's evaluation trenches (Pollard *et al.* 2008), though were restricted to bodies that had been located within the sondages. Some of these were re-associated with bodies by employing gross sorting methods with reference to images annotated by Pollard *et al.* (2008). Other disassociations were as a consequence of peri-mortem trauma, which had disrupted the anatomical integrity of hard and soft tissues and resulted in partial and complete limb amputations. Soft tissue attachment and/or fragments of clothing, although disrupted, may have ensured that body parts were not separated from bodies prior to interment, but subsequent decomposition meant that this physical relationship was lost and not always apparent at the time of recovery. Alternatively, or in addition, the German burial party may have collected body parts lying in association with, but no longer anatomically attached to bodies, and buried them together. All the body parts in this category were re-associated with individuals during anthropological analysis, based on robust resolution of commingling methods.

The disassociation of other body parts, specifically teeth, bone fragments (especially comminuted fragments arising from peri-mortem trauma) and the small bones of the hands and feet, is likely to have been caused by post-depositional migration. This is a common occurrence in burial deposits (Littleton 2000; Ubelaker 1997), the size and weight of the bones (intrinsic properties) making them vulnerable to extrinsic forces (for example, the hydrological regime) that, acting as a vehicle, can move them from their original location and deposit them elsewhere (Marshall 1989), often to deeper levels. At Fromelles, water ingress from precipitation and the action of roots, especially in the graves that lay adjacent to Pheasant Wood, are the most likely factors that caused the migration of bone. This would explain why the majority of disassociated body parts were recovered from those graves closest to Pheasant Wood. This category of disassociated body part could not be re-associated with discrete skeletons because they lacked the distinctive morphologies and/or features that are employed by standard re-association techniques.

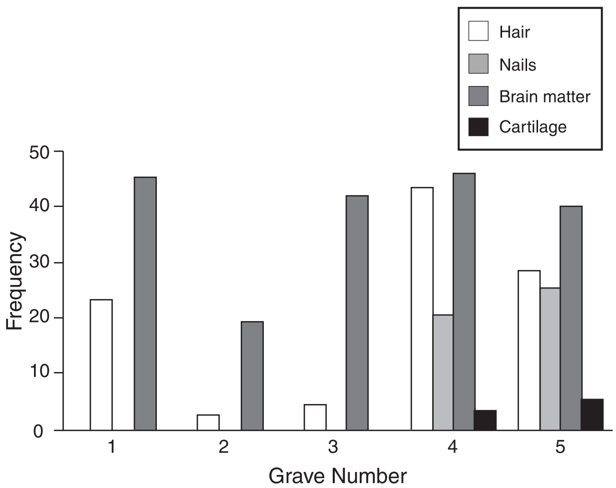

Fig. 4.2 Frequency of non-osseous tissue types, graves one to five

COMPLETENESS, CONDITION AND TAPHONOMIC CHANGES

Although all the individuals were skeletonised, 80% (n=200) had some preserved non-osseous tissue, including brain matter and keratinous tissue types consisting of body and head hair, finger and toe nails and cartilage (Fig 4.2). The individuals with these tissues were from graves one to five; no preserved non-osseous tissue was encountered in Grave Six.

Completeness

Overall, the preservation of the skeletons was excellent (Tables 4.2-4.4; Fig. 4.3). A total of 211 (84.4%) were virtually complete (>95% of the skeleton present), 34 (13.6%) were between 75% and 95% complete and 2% were between 50% and 75% complete.

The most incomplete body regions were the head (97 recorded as 'part'), thorax (66 recorded as 'part') and abdomen (62 recorded as 'part') (Fig. 4.3), primarily as a result of peri-mortem trauma leading to bone loss in these regions. In contrast, most bone tissue loss in the extremities (limbs) was primarily due to taphonomy, or more specifically exposure to recharge hydrological regimes where there are cycles of water saturation followed by a period of drying out, causing the bone to crack and subsequently fragment and disintegrate.

Condition

The condition of the skeletons was also excellent overall. Three quarters (69.2%; Table 4.2) had

Table 4.2: Completeness and condition of the skeletal remains (n=250)

Completeness	*Number of skeletons*	*%*
>95% (complete)	211	84.4
>75 - <95% (slight loss)	34	13.6
>50 - <75% (moderate loss)	5	2
Erosion		
<25 (none/minimal)	173	69.2
>25% - <50% (slight)	47	18.8
>50% - <75% (moderate)	23	9.2
>75% (considerable)	7	2.8
Fragmentation		
<25 (none/minimal)	159	63.6
>25% - <50% (slight)	49	19.6
>50% - <75% (moderate)	33	13.2
>75% (considerable)	9	3.6

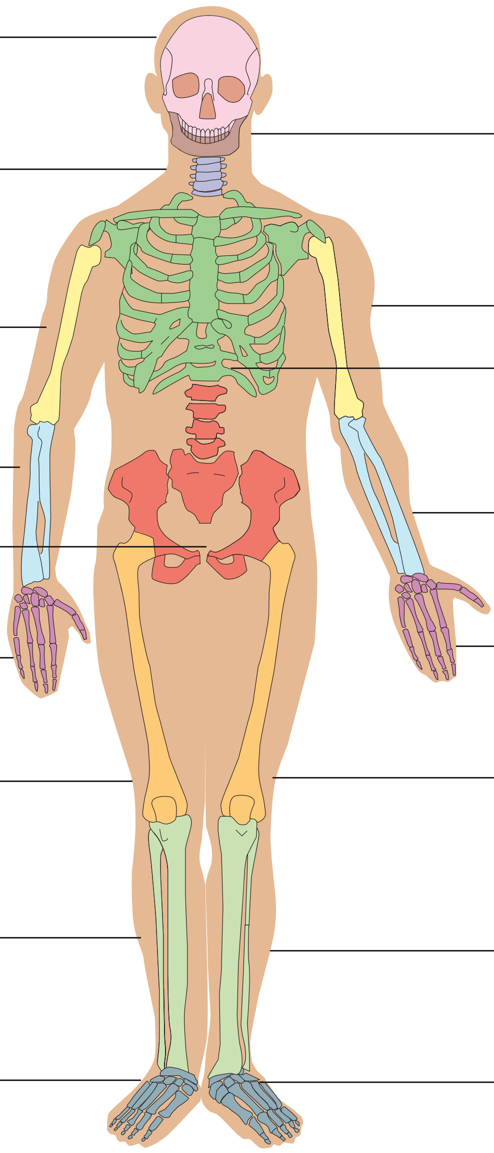

Fig. 4.3 Number of complete, part and absent body regions (n=250)

Table 4.3: Completeness and condition of skeletons by grave (graves one to three)

Completeness & condition	*Category*	*Grave One*		*Grave Two*		*Grave Three*	
		Number	*%*	*Number*	*%*	*Number*	*%*
Completeness	>95%	50	100	27	53	44	85
	>75% - <95%	0	/	22	43	7	13
	>50% - <75%	0	/	2	4	1	2
Fragmentation	<25%	44	88	3	6	25	48
	>25% - <50%	4	8	20	39	19	36.5
	>50% - <75%	2	4	23	45	7	13.5
	>75%	0	/	5	10	1	2
Erosion	<25%	47	94	9	17.6	23	44
	>25% - <50%	1	2	22	43	24	47
	>50% - <75%	2	4	15	29.4	5	9
	>75%	0	/	5	10	0	/

Table 4.4: Completeness and condition of skeletons by grave (graves four to six)

Completeness & condition	*Category*	*Grave One Number*	*%*	*Grave Two Number*	*%*	*Grave Three Number*	*%*
Completeness	>95%	50	100	40	91	0	/
	>75% - <95%	0	/	4	9	1	33
	>50% - <75%	0	/	0	/	2	66
Fragmentation	<25%	47	94	40	91	0	/
	>25% - <50%	2	4	3	7	1	33
	>50% - <75%	0	/	1	2	0	/
	>75%	1	2	0	/	2	66
Erosion	<25%	50	100	44	100	0	/
	>25% - <50%	0	/	0	/	0	/
	>50% - <75%	0	/	0	/	1	33
	>75%	0	/	0	/	2	66

minimal or no erosion on their bones and almost 64% had bones that were minimally fragmented or not fragmented at all (Table 4.2).

Erosion

A total of 77 skeletons (30.8%; 77/250) had bones that were slightly, moderately or considerably eroded (Table 4.2). Of these, 46 had erosion on the cancellous bone (59.7%; 46/77) (for example, see Fig. 4.4), one on the cortical bone (1.3%; 1/77), and 30 on both types of bone (39%; 30/77).

For all 77 skeletons the erosion was diffuse, that is, it was present on multiple skeletal regions. Skeletons with no or minimal erosion (n=173) only had small discrete areas that were affected. For example, 0747B, Grave Two, presented focal erosion on the right lower limb. This was attributed to the position of the individual in the grave, where the right lower limb was lying up against the side of the grave cut. Concentrated water ingress would have occurred at the junction between the looser grave fill and adjacent, untouched soft geology, causing chemical weathering. In addition, abrasion from the looser grave fill between the adjacent vertical strata would have caused mechanical weathering. Thus, knowledge of the location of an individual in a grave and localised context is essential to the interpretation of preservation seen here.

Fig. 4.4 Erosion (arrowed) involving the cancellous bone of the proximal tibias of 1223B

Body 2793B, Grave Three, in particular was noted for its unusual pattern of erosion. The ends of the long bones of the lower limbs – areas that have proportionally more cancellous bone than trabecular bone (cancellous rich areas) – were eroded, as well as dry and friable, but these changes were not observed on other cancellous-rich areas of the same skeleton, namely the bones of the thorax (ribs and vertebrae) and ends of the long bones of the upper limbs. This pattern of differential preservation may be attributed to variation in micro-environments within the grave, or variation in the type and thickness of clothing worn on different parts of the body, which inhibited or promoted particular taphonomic processes (Galloway *et al.* 1989). It may also reflect, to some extent, intrinsic differences between the individuals buried.

Fragmentation

A total of 91 (36.4%; 91/250) of the individuals were considerably, moderately or slightly fragmented, and 159 (63.6 %; 159/250) were minimally fragmented or (more or less) not fragmented at all (Table 4.2).

Analysis of fragmentation by body region showed that 35.2% (1494/4235) of all available body regions (complete and part body regions) were affected (Table 4.5; Fig. 4.5). Of these, 43.2% (646/1494) were post-mortem, 40% (599/1494) were peri-mortem and 9.37% (140/1494) were both peri-mortem and post-mortem in origin. A further 7.29% (109/1494) were of unknown timing.

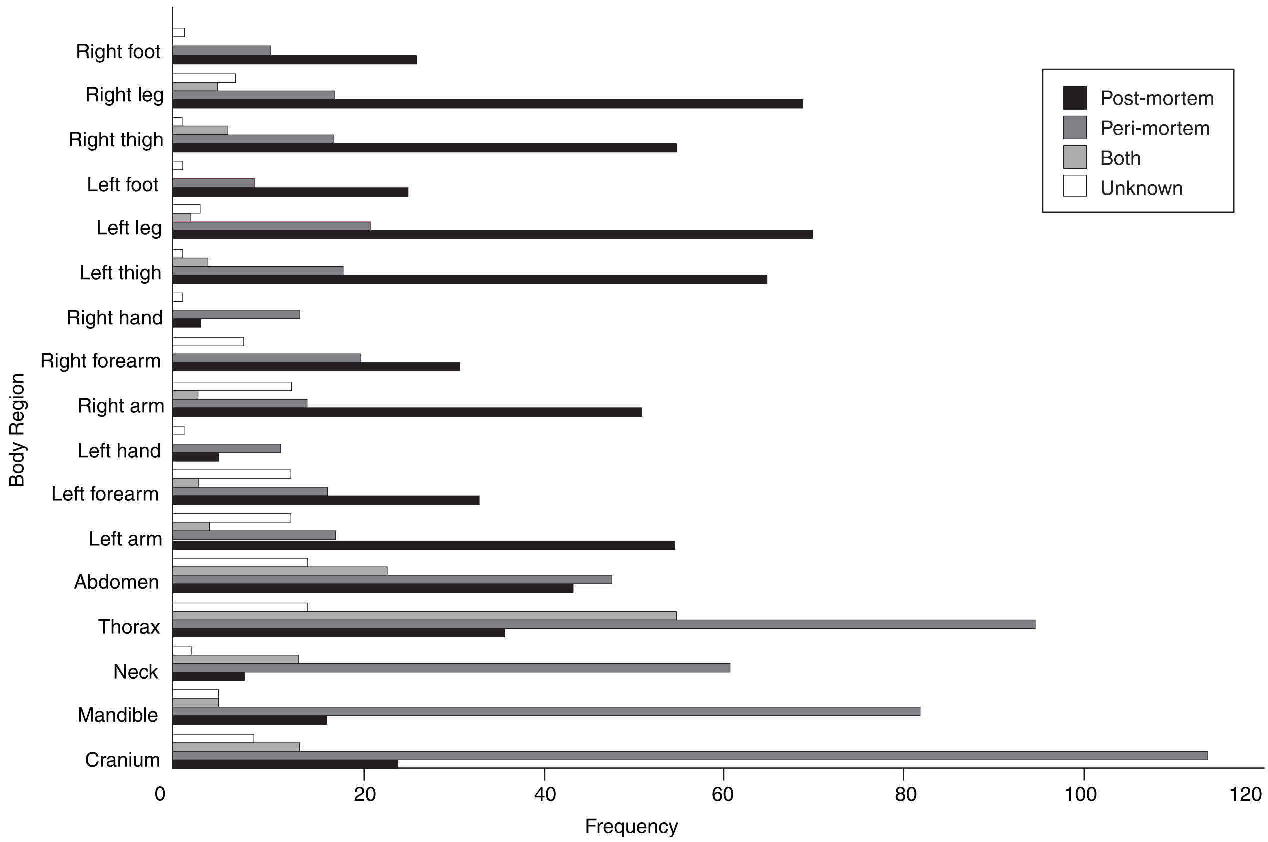

Fig. 4.5 Frequency of fragmentation for different body regions

Table 4.5: Frequency of fragmentation by body region

Region	*Post-mortem fragmentation*	*Peri-mortem fragmentation*	*Both*	*Timing of fragmentation unknown*	*Total*
Cranium	25	115	14	9	163
Mandible	17	83	5	5	110
Neck	8	62	14	2	86
Thorax	37	96	56	15	204
Abdomen	44	49	24	15	132
Left arm	56	18	4	13	91
Left forearm	34	17	3	13	67
Left hand	5	12	0	1	18
Right arm	52	15	3	13	83
Right forearm	32	21	0	8	61
Right hand	3	14	0	1	18
Left thigh	66	19	4	1	90
Left leg	88	22	2	3	115
Left foot	26	9	0	1	36
Right thigh	56	18	6	1	81
Right leg	70	18	5	7	100
Right foot	27	11	0	1	39
Total	646	599	140	109	1494

Total number of expected body regions (17 expected body regions x 250 skeletons) = 4250
Actual number of body regions = 4235
Number of fragmented body regions = 1494
Number of complete body regions = 2741

In general, fragmentation due to peri-mortem trauma most frequently involved the cranium, mandible, neck, and thorax and post-mortem fragmentation most frequently involved the limbs (Fig. 4.5). The presence or absence of fragmentation with respect to timing is affected by body region size, thus the larger the region the more likely it is to display both peri-mortem and post-mortem fragmentation. For example, the thorax is the largest body region and has the highest frequency of fragmentation of any single body region (13.6%; 204/1494). As a consequence, only body regions that are comparable in size/area (namely the upper and lower limbs and the hands and feet) could undergo statistical analysis.

Chi-squared analysis of fragmentation and timing for upper and lower limbs regions (Appendix Three) showed no significant difference (p=0.2035) between the frequency of affected regions and whether breaks were peri-mortem, post mortem, or both. However, chi-squared analysis of fragmentation and timing for the hands and feet (Appendix Three) showed a highly statistically significant difference ($p<0.0001$), but the effect was moderate (contingency coefficient 0.423). The adjusted residuals showed that the hands had a tendency towards low post-mortem fragmentation, but high peri-mortem fragmentation, whereas the feet showed high post-mortem fragmentation and low peri-mortem fragmentation.

Taphonomic changes

None of the remains showed any evidence of animal scavenging or predation. Insect pupae cases were recovered (see Chapter Three) and, given the depth of the burials and the impermeable grave fill, probably refer to infestation of the corpses around the time of interment during soft tissue decomposition in the early post-mortem stages. They are unlikely to have influenced taphonomic signatures on the skeletonised remains.

Root activity and fungal activity

Evidence of root activity was observed on the skeletons in the form of rootlets which had colonised the bone predominantly in the cancellous rich areas, such as at the ends of the long bones. It was observed that root ingress often followed trabecular pathways to populate the interior of the bone, causing fracture and fragmentation. The presence of root activity is often seen in conjunction with fungal activity (Sagara *et al.* 2008). However, this was not observed on any of the remains from Pheasant Wood. The physical evidence for fungal colonisation is mycorrhizal etching, often observed in skeletal remains from archaeological contexts. Plant roots act as hosts to the mycelia of these micro-organisms (Sagara *et al.* 2008) whose respiratory carbon dioxide reacts with soil moisture creating a solution of carbonic acid (H2CO3), which locally dissolves the calcium component in the bone resulting in the etching on the bone surface. Bodies in graves two, three and six had a higher frequency of root activity compared with bodies from graves one, four and five (see below). This is not surprising given the greater proximity of graves two, three and six to Pheasant Wood.

Bone texture

Two principal types of bone texture prevailed across the assemblage, including green/wet, and dry and crumbly. The former accounted for 56.8% (n=142) of all skeletal remains and the latter, 43.2% (n=108). An important caveat to the use of the classification 'green/wet' is that while this indicates the persistence of an organic matrix (collagen) in the bone, the texture was not consistent with that of fresh (more recent) green bone, where the collagen is much more abundant. This meant that the properties of post-mortem fractures (in particular, the appearance and texture of fracture margins) seen at Pheasant Wood generally did not mimic those caused as a result of peri-mortem injury. Thus, peri-mortem fracture signatures and post-mortem fracture signatures were usually distinguishable from one another.

Plastic deformation

Plastic deformation, or bending of bone, was identified by the loss of usual bone morphology, which may or may not have been associated with fractures. Forty-two skeletons (16.8%) exhibited plastic deformation, which primarily involved the cranium and the ribs. These areas are particularly susceptible to deformation in burial environments because the cavities or voids that are created when these hard tissue structures are skeletonised are prone to deformation as a result of slow loading pressure acting on them from the mass of the grave fill. This phenomenon was observed in all graves to a greater or lesser degree, with the exception of Grave Six.

Adherent remnants of fabric or textile

Small remnants of fabric or textile adhering to bone were observed in 15.6% (n=39) of the individuals across all graves. As would be expected, the distribution of fabric (on the extremities [limbs], thorax and abdomen) was consistent with the clothing that had been worn, such as uniform tunics and trousers, but had otherwise substantially degraded. The different preservation signatures of clothing between graves assists in the interpretation of the similarities and differences in the prevailing burial environments.

Metal staining

Metal staining was observed on 18.8% (n=47) of the individuals across all graves. This was present as corrosive residues or as green, black or rust

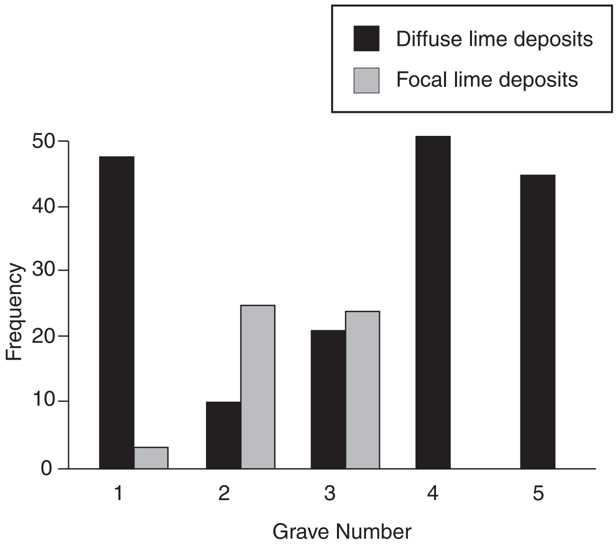

Fig. 4.6 Frequency of diffuse and focal lime deposits, graves one to five

coloured staining. The majority were green stains and the result of contact (and often survival) of copper or copper alloy items. Rust was the result of contact with ferrous (iron) based objects. Iron staining and corrosive residue was often found in conjunction with an oxidized iron object that could not be identified macroscopically and on occasions could be identified radiologically as a reduced, but identifiable, iron core (Janaway 2008).

Staining due to iron panning was also present at Pheasant Wood and was the result of naturally occurring ironstone in the soil. Staining from iron panning does not leave a corrosive residue and was recorded as a separate property.

Deposits of lime

Lime deposits were observed on the bone surfaces of 87.6% (n=219) of individuals across all graves and was diffuse (involved multiple bones) or focal (involved small discrete areas of the skeleton) (Fig. 4.6). The lime consisted of a deposit on a bone surface (Fig. 4.7) or, on occasions, as a concreted mass that held adjacent bones together and preserved positional details, such as the relaxed pose of the hand (Fig. 4.8). These concretions were of assistance in interpreting the timing of fragmentation, in particular peri-mortem injuries, because the extent of tissue disruption and fracture margins were preserved in the concreted mass (Fig. 4.9). In a moisture super-saturated state the concretions could not be easily removed from the bone. However, after cleaning and drying the mass would often slough off, or was easy to remove using wooden tools. The implications of these observations are that, as long as a grave is waterlogged, concreted masses of lime will persist *in situ* and thus preserve the anatomy or position of body regions or bone fragmentation.

It is possible that lime cycling occurred throughout the graves during the post-depositional interval with lime periodically dissolving into solution due to the presence of water and precipitating lime down to lower levels of the graves. However, in graves one to five, analysis of the

Fig. 4.7 Lime deposits (white patches) on bone surfaces (1825B)

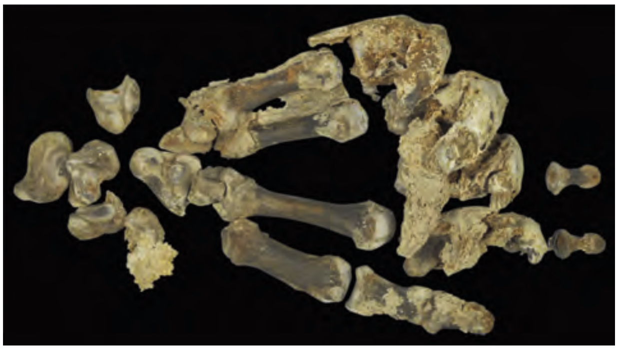

Fig. 4.8 Concretions of lime holding the bones of a hand together (1832B)

Fig. 4.9 Tissue disruption and fracture margins preserved by lime concretion (2108B)

Table 4.6: Chi-squared analysis of preservation and taphonomic changes, graves one to five

Property	*Probability by Monte Carlo chi-square*	*Pearson's Phi association coefficient*	*Interpretation of Pearson's Phi*	*Meaning based on significance of individual cells in table*
Bone texture - wet/green & dry/crumbly	<0.0001	0.984	Very high association	Graves 1,4 & 5 tend to wet/green bone Graves 2 & 3 tend to dry & crumbly bone
Non-osseous preservation - presence & absence	<0.0001	0.582	Moderate association	Graves 1,4 & 5 tend to non-osseous preservation. Grave 2 tends not to preserve.
Metal staining - presence & absence	<0.0001	0.474	Moderate association	Grave 2 tends to metal staining, Grave 1 tends to no metal staining.
Lime deposits - presence & absence	< 0.0001	0.468	Moderate association	Graves 1,4 & 5 tend to lime deposits. Grave 2 tends to absence.
Adherent fabric - presence & absence	0.0005	0.297	Slight association	Grave 2 tends to high adhering fabric, Grave 1 tends to low.
Root Activity - presence & absence	0.0014	0.267	Slight association	Grave 2 tends to high root activity, Grave 4 tends to low
Bone plastic deformation - presence & absence	0.0560	na	na	na

frequency of individuals with lime deposits on bone in the upper versus the lower layers shows no statistically significant difference ($p=0.68$) (Appendix Three). A statistically significant difference ($p<0.0001$) was observed in the distribution of focal and diffuse lime deposits in graves one to five (Appendix Three). Skeletons from the graves that were closer to the wood (graves two, three and six) tended to have focal lime deposits, while skeletons from graves further away (graves one, four and five) tended to have diffuse lime deposits (Fig. 4.6). Environmental stability over time would have influenced these characteristics, preferentially promoting or inhibiting the persistence of lime in one of the patterns observed.

Statistical analysis of preservation and taphonomic changes by grave

Statistical tests (Appendices Two and Three) were performed to explore similarities and differences in preservation and taphonomic changes between graves. For the purposes of the present analysis, each of the categories for completeness, fragmentation and erosion were collapsed into two groups:

i. Completeness: those over and those under 95% complete.

ii. Fragmentation: those over or under 25% fragmented.

iii. Erosion: those over or under 25% eroded.

Results (Tables 4.6-4.7; Fig. 4.10; Appendices Two and Three) essentially show a statistically significant correlation between skeletons from graves that lie near the wood (graves two, three and six) and high frequencies of metal staining, adherent fabric, and root activity and low frequencies of wet/green bone. These skeletons also tended to have erosion and fragmentation scores of >25% and completeness scores of <95%. Skeletons from graves further away from the wood, on slightly higher and drier ground (graves one, four and five) had significantly higher frequencies of green/wet bone textures, preserved non-osseous tissue and low frequencies of metal staining, root activity and adherent remnant fabric. This group was also characterised by erosion and fragmentation scores of <25% and completeness scores of >95%.

The bodies at Pheasant Wood were buried in two distinct layers, with soil placed in between the upper and lower layers (see Chapter Three). Further statistical testing (Fisher's exact test) in graves one to five, showed that a significant difference existed between the number of individuals with erosion in the upper and lower layers of graves one ($p=0.01$) and five ($p=0$). Specifically, individuals in the upper layers of these graves showed a greater tendency toward erosion, but all other graves showed no significant difference ($p>0.05$). It is suggested that the individuals in the lower levels of graves one and five were more protected than those that were in the upper levels, which were more exposed to the effects of chemical weathering from water influx.

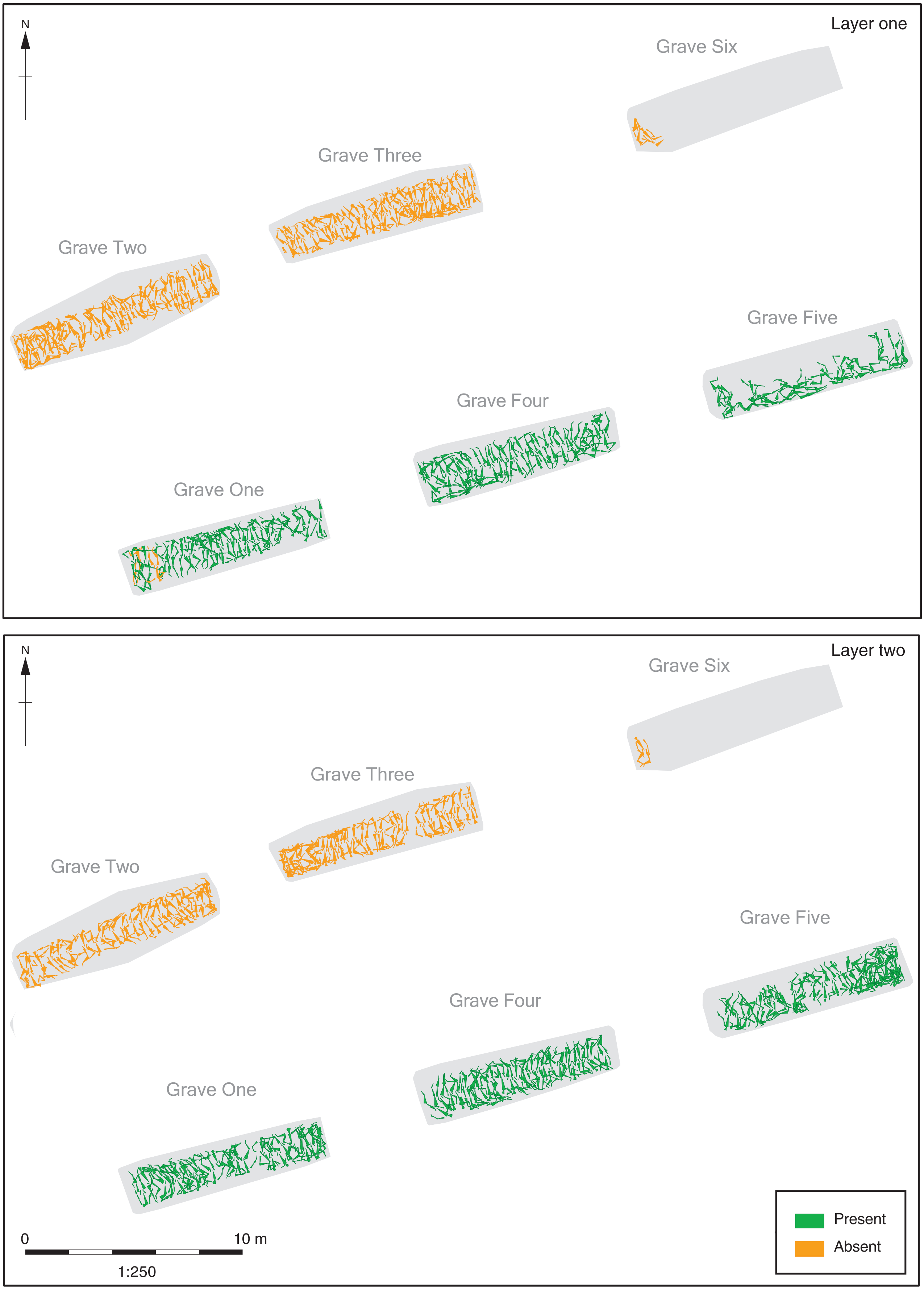

Fig. 4.10 Distribution of green bone presence/absence

Table 4.7: Chi-squared analysis of preservation and taphonomic changes: graves near edge of wood (two, three and six); graves away from edge of wood (one, four and five)

Property	*Probability by Monte Carlo chi-square*	*Pearson's Phi association coefficient*	*Interpretation of Pearson's Phi*	*Meaning based on significance of individual cells in table*
Bone texture - wet/green & dry/crumbly	<0.0001	0.984	Very high association	Near wood tends to dry & crumbly bone. Away from wood tends to wet/green.
Erosion <25% & >25%	<0.0001	0.736	Strong association	Near wood tends to >25% erosion. Away from wood tends to <25% erosion.
Fragmentation <25% & >25%	<0.0001	0.663	Strong association	Near wood tends to >25% fragment ation. Away from tends to <25% fragmentation.
Non-osseous preservation - presence & absence	<0.0001	0.466	Moderate association	Near wood tends not to preserve non-osseous. Away from wood tends to preserve.
Completeness - >95% & <95%	<0.0001	0.412	Moderate association	Near wood tends to <95% complete ness. Away from wood tends to >95% completeness.
Lime deposits - presence & absence	<0.0001	0.414	Moderate association	Near wood tends to absence of lime. Away from wood tends to presence.
Metal staining - presence & absence	<0.0001	0.354	Slight association	Near wood tends to metal staining. Away from wood tends to no metal staining.
Adherent fabric - presence & absence	<0.0001	0.300	Slight association	Near wood tends to adherent fabric. Away from wood tends to no adherent fabric.
Root Activity - presence & absence	0.0003	0.254	Slight association	Near wood tends to high root activity. Away from wood tends to low.
Bone plastic deformation - presence & absence	0.0083	0.169	Negligible association	Near wood tends to no deformation. Away from wood tends to no deformation.

ASSESSMENT OF BIOLOGICAL PROFILES

Ancestry

Broad assessment of ancestry was possible for 223 individuals (89.2%; 223/250) by employing morphological and/or metrical assessment of features of the cranio-facial skeleton. Of these, the majority (99.5%; 222/223) were classified as Caucasoid. One individual (2721B, true prevalence rate (TPR): 0.5%; 1/223) was considered to possess mixed ancestry, most likely Aboriginal Australian with possible European ancestry. Ancestry could not be reliably determined for the remaining 27 (10.8%; 27/250) individuals.

The assessment of ancestry using combined craniometric (CRANID) and morphological techniques was possible for 97 individuals. However, conclusive results were only possible for 93 of these. Ancestry was determined for 130 individuals based on morphology alone. Morphological traits denoting Caucasoid ancestry were found to be universally consistent across the assemblage. Of the 27 individuals where ancestry could not be determined, 23 had a paucity of available traits to enable a reliable assessment (loss of bone tissue due to peri-mortem trauma and taphonomic changes), and four complete skulls (1404B, 1832B, 3194B, 3310B) exhibited mixed morphological traits that were not consistent with an ancestral affinity or particular admixture. CRANID results were available for these individuals and were supplied as supplementary notes in their individual case summaries.

Of the 97 individuals with CRANID results, 53 (55%; 53/97) were best represented in the nearest neighbour analysis, compared with 44 (45%; 44/97) that were not. Of the latter group, six results (0389B, 0677B, 1585B, 1832B, 3215B, 3272B) highlighted an error in one of the measurements, which may be attributable to observer error and/or the result of skeletal anomalies, such as ante-mortem tooth loss (for example individual 1832B). The remainder of the poorly represented group may be distinct from the comparative sample population (possibly because factors, such as maternal and long term health, had impacted on their growth and maturation and therefore expression of features) and therefore large confidence intervals (two to three standard deviations from the mean) were assigned. However, the results obtained for linear discriminate analysis (LDA) and nearest neighbour discriminate analysis (NNDA) in all 97 crania were consistent across the group, whereby the ancestral affiliation of 96% (93/97) of the individuals was assigned to European and east Mediterranean geographical origins. These results are consistent with those obtained from morphological traits and together indicate that the majority of individuals exhibited Caucasoid cranial architecture.

Estimation of biological sex

Although the context of the skeletons negated any direct requirement to assess their sex, features were nevertheless scored because the extent to which male and female traits vary in their expression provides useful background information for other assessments, such as of ancestry, age, disease and facial attributes. Sexually dimorphic features of the skull and pelvis, in addition to metrical assessment, could be assessed for all individuals, and all were considered to be of male expression overall. However, it was noted that the group tended to have an androgynous looking sciatic notch compared with other male traits seen in other regions of the pelvic girdle. This phenomenon has been observed in other skeletal populations (Walker 2005), as well as among individuals from different ancestral groups (C Barker pers. comm.).

In addition to the sciatic notch, a number of young adults and adolescents, who were probably pubescent or recently post-pubescent when they died, had skulls that possessed ambiguous traits, while the rest of their skeletons (for example, diameters of femoral and humeral heads and features of fused pelves) were consistent with the male sex. Sexually dimorphic features of the skull are often female in appearance in males around the age of puberty (Cox 2000). When young males with gracile/feminine skulls were encountered, this information was recorded as a facial attribute, because these individuals may have had noticeably boyish or youthful features in life.

Estimation of biological age at death

Biological age at death could be estimated for all skeletons. Over half (n=138) were estimated to have been young adults (18-25 years) when they died, while just six were estimated to have been adolescents (13-17 years) (Figs 4.11-12). Of the remaining individuals, 81 (32%; 81/250) were prime adults (26–35 years) and 25 (10%; 25/250) were mature adults (36-45 years).

There were more young adults than any other age category in all graves (Fig. 4.12). However, the proportion of subadults (individuals less than 18 years) to other age categories was greatest in Grave Two.

The age range for all skeletons was 14-50 years based on likely age limits, or 14-57 years based on outer age limits. There are currently no accepted methods that allow skeletal age to be estimated more accurately than in bands of less than five years for sub-adults and 10 years for adults, but

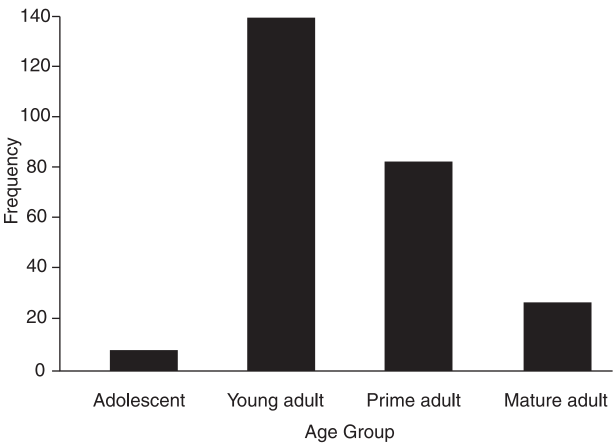

Fig. 4.11 Frequency of age groups in the total assemblage (n=250)

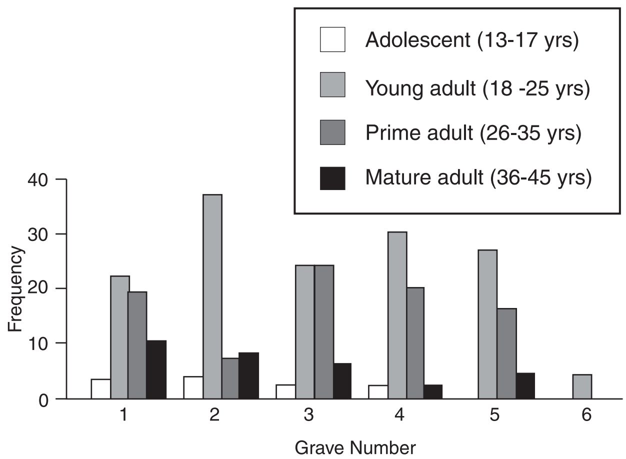

Fig. 4.12 Frequency of individuals by age categories, grave one to six (n=250)

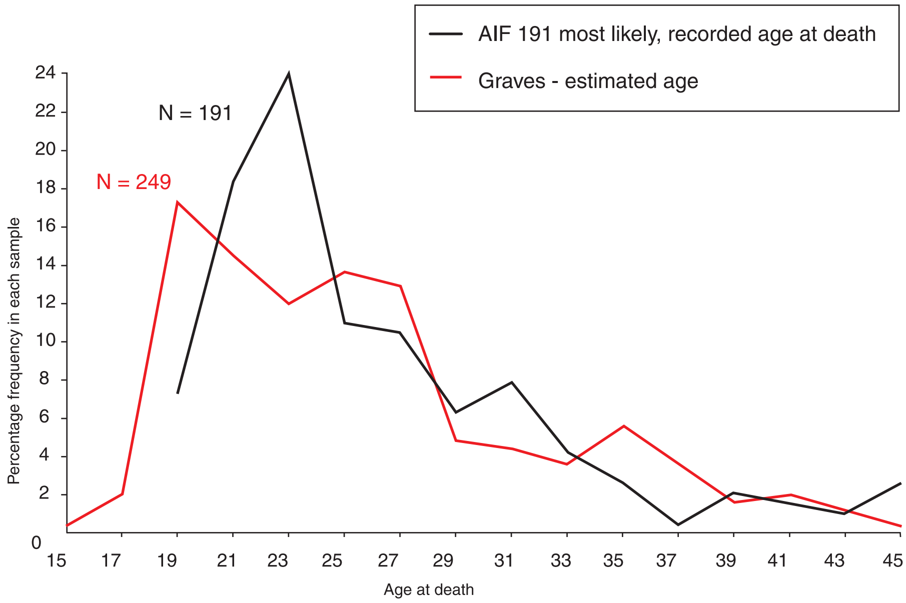

Fig. 4.13 Age: osteological data and AIF records compared

both ranges indicate that individuals under and over the age of enlistment or conscription were likely to be among the buried soldiers at Pheasant Wood. In addition, considering the ages of individuals from graves one to five (Tables 4.8 and 4.9), the number of possible under-age soldiers is greater than the number who were possibly over age (three Grave Six individuals are not included here because they were all young adults). Of the individuals who were potentially under-age, two (0104B, 0314B) were assigned a maximum age at death of less than 18 years.

Table 4.8: Frequency of under- and over-age individuals

Age range	*Number of underage*	*Number of overage*
Likely limits 14-50 years	25	2
Minimum – maximum limits 14-57 years	47	7

Table 4.9: Frequency of younger and older individuals in graves one to five (three young adults from Grave Six not included)

Grave number	*Younger adolescents & young adults*	*Older prime & mature adults*
1	23	27
2	38	13
3	24	28
4	30	20
5	26	18
Total	141	106

The distribution of estimated age at death was compared with the distribution of age at death as documented in AIF enlistment records, to determine whether the methods and results are an accurate reflection of the population under investigation. Percentage age frequencies, which employed the mid-point of the likely age limits assigned to each skeleton (n=249; one was excluded because of insufficient indicators surviving with which to estimate likely minimum and maximum age limits) were compared with percentage age frequencies from AIF records (n=191) (Fig. 4.13). AIF records were utilised in this exercise (rather than any British data) because they comprise the largest proportion of the Missing. Accounting for inconsistencies between reported AIF ages for those who were under or over the age on enlistment (see Chapter One), the goodness of fit between the two sample groups was found to be consistent. This result

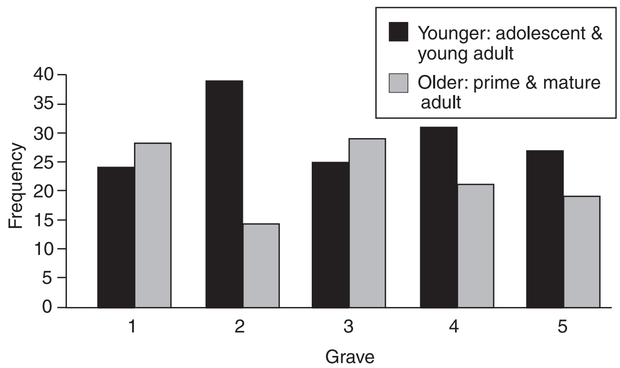

Fig. 4.14 Distribution of younger and older individuals in graves one to five (n=247)

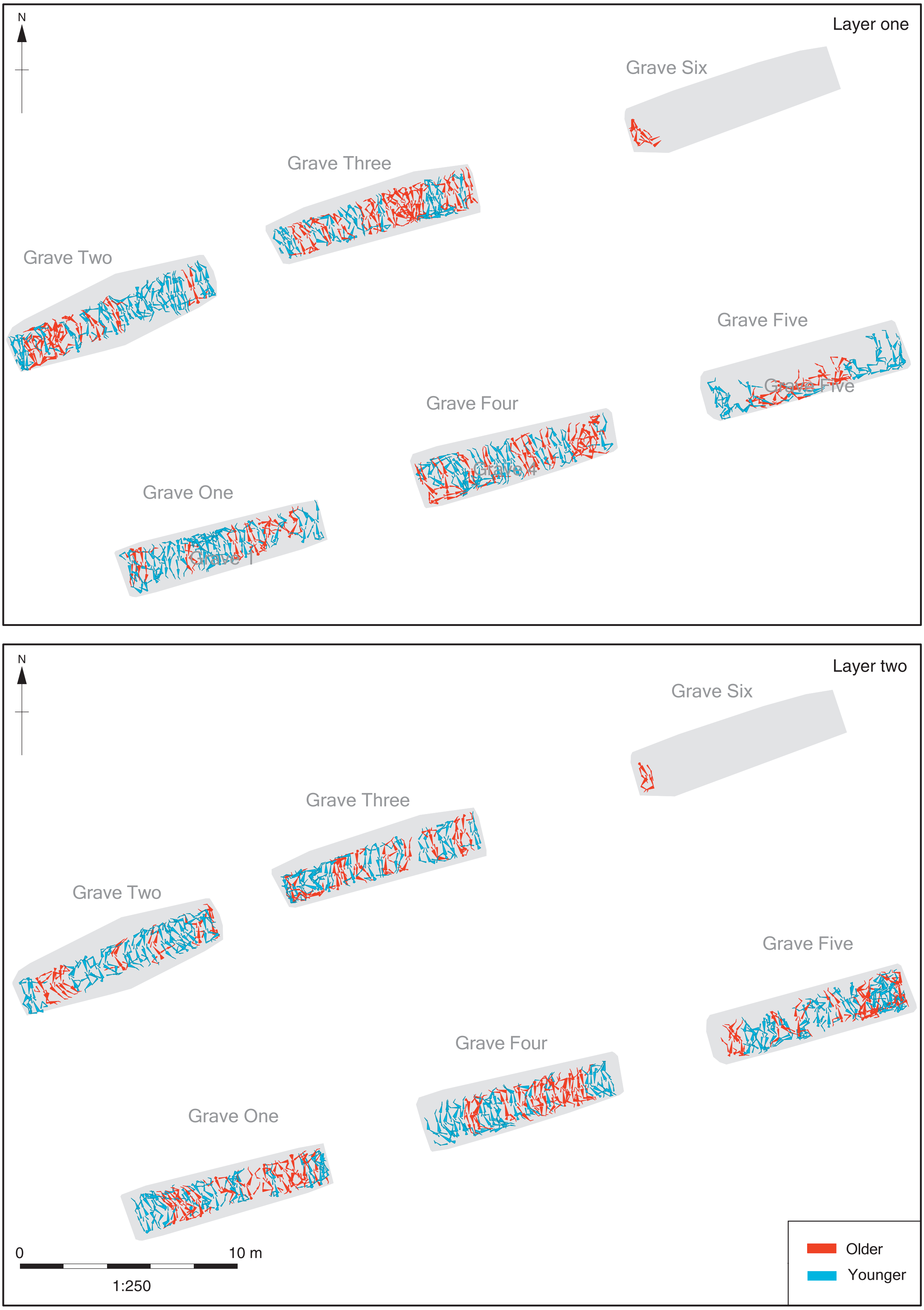

Fig. 4.15 Distribution of older/younger individuals

confirms that the methods and results presented in this report are appropriate to the group under investigation.

The age at death profiles of individuals from graves one to five were also explored to examine the possibility of deliberate sorting according to rank by those burying the dead (see Chapter One). In theory, if sorting by rank had occurred this might be reflected in the age distribution of the individuals within or between graves one to five (Grave Six was not included in the analysis due to the small number of individuals (three) interred). Based on AIF enlistment data (n=565), 6% (32/565) of the Missing were officers, whose mean and median ages (28 ± 6 years and 27 years respectively) were greater than those of other ranks (25 ± 5 years, 23.5 years respectively) (R Wright pers. comm.). In order to explore this assumption two age categories were created from the anthropology data by combining the adolescent and young adults into one group, the 'younger age group', and the prime and mature adults into another group, the 'older age group'. While there are problems with attempting to differentiate skeletons of such similar ages, the degree of association between age category and grave number and any deviation from the expected results were statistically tested. The results showed that Grave Two deviated from the expected with a statistically significant high number of young individuals (or low number of older individuals) (p=0.019) in comparison with graves one, three, four and five, having a probability of approximately 1 in 200 chances (Appendix Three).

The spatial distribution of ages, in plan and in 3D, was also explored to identify any clusters of age groups within each grave (Figs 4.14 and 4.15). No significant pattern or clustering of younger or older individuals were observed.

Stature

A total of 237 (95%) individuals had relevant bones available for metric stature estimation. Further, it was possible to assign 99% (n=248) to a broad stature classification (including 11 individuals for whom metrical assessment was not possible), based on visual assessment. It was not possible to estimate the stature, metric or visual, of a further two individuals (0.8%).

Mean statures ranged from 1.6–1.84m (5'3''–5'11½'') with an average of 1.72±5. Based on these results, none of the buried soldiers falls below the minimum height recorded for the Missing (1.58m; 5'2''), nor the height restrictions that were in place in 1916 (see Chapter One).

Percentage frequencies of estimated statures for the buried soldiers (n=237) were compared with AIF enlistment statures (n=191) (Fig. 4.16) to explore the accuracy of the methods employed for the population under study. As with age at death, AIF records were utilised in this exercise (rather than any British data) because they comprise the largest proportion of the Missing. Results showed a good match between the two datasets, thereby confirming the suitability of the osteological methods.

Of those assigned to broad stature classifications, 6% (14/248) were recorded as short (<1.63m or 5'4½''), 21% (51/248) as tall (>1.76m or 5'9¼''), and 74% (183/248) were recorded as of unremarkable or average height (>1.63-<1.76m or 5'4½-5'9¼''). Broad stature classifications were a means of highlighting individuals within the group who did not present average physical attributes.

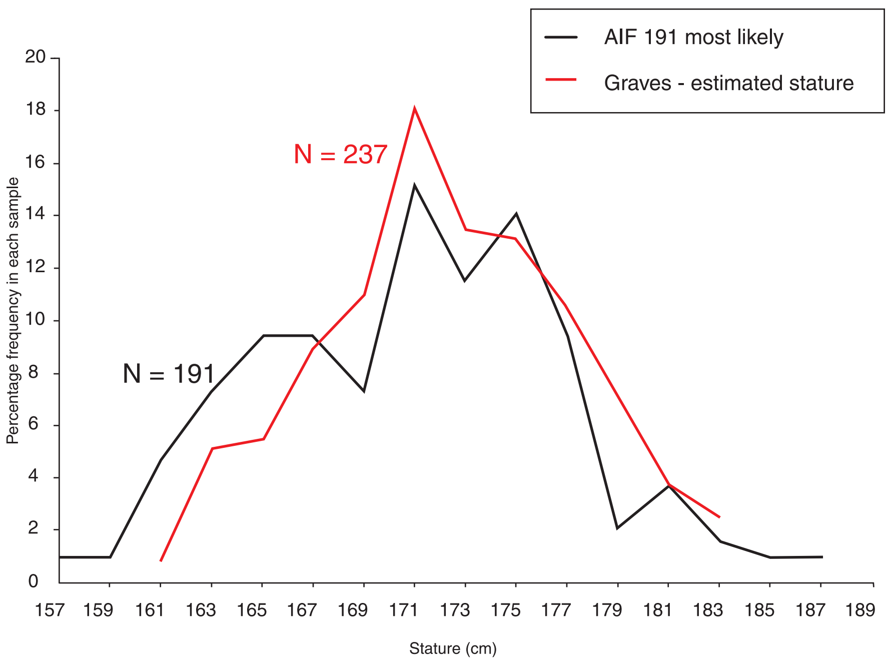

Fig. 4.16 Stature: comparison of osteological data and AIF records

ASSESSMENT OF INDIVIDUATING CHARACTERISTICS

Skeletal constitution and handedness

An assessment of skeletal constitution was made for 244 individuals (98%), where each individual was assigned to an overall category of gracile, unremarkable or robust. The majority of individuals (62%; 152/244) were scored as unremarkable or average, while 21% (51/244) were scored as robust, and 17% (41/244) were scored as gracile. Assessments were not made on individuals with pathological conditions (for example 'bone formers', see below), or where the remains were too fragmentary to provide a comprehensive understanding of skeletal physique. Observations relating to MSMs and metrical data are reported in the confidential case reports on an individual basis, but have not been analysed at the assemblage level.

Handedness, or possible preferential employment of an upper limb or hand, was determined for 41% (102/250) of all individuals. In 54% (135/250) sufficient assessment criteria were available, but noticeable asymmetry between left and right sides could not be determined or was inconclusive. No assessment could be made for the remaining 5% (13/250) due to the absence of bones or extreme fragmentation of the relevant skeletal areas.

Fig. 4.17 Anterior view of facial attributes with midline deviations (0674B)

Where osteological indicators of handedness suggested preferential employment of a particular upper limb or hand, 93% (95/102) showed a possible right side bias and 7% a possible left side bias (TPR 3%; 7/237). However, in 56% (135/237) of cases, where multiple traits for assessment of handedness were available, no clear preference for left or right upper limb/hand employment was observed.

Facial attributes and 360 degree video of the skull

A total of 223 individuals were assessed for gross facial attributes, although not all presented unique characteristics or facial architecture. Unique features were nevertheless seen and noted. Examples are individuals who had large nasal bones, projecting chins, prognathic jaws or, more unusual, gross facial asymmetry (for example, 0674B; Fig. 4.17). Although of limited value in the identification process (because only a few good quality photographs exist for comparison), all of these would have been noticeable during life and therefore had the potential to assist. A total of 154 individuals were recorded using 360 degree video.

The dentitions

Preservation

The overall preservation of teeth and corresponding alveolar tissue at Pheasant Wood was excellent. As a result, a comprehensive picture of oral and dental health and availability of dental treatments was achieved.

Out of a possible 8000 teeth and alveoli (32x250) that could have survived, 5766 (72%) and 7627 (95%) respectively were available for examination

Table 4.10: The status of all teeth (number of possible teeth=8000)

Inventory Category	*Number*	*Percentage*
Tooth lost post-mortem	144	1.8
DNA sample	256	3.2
No data	205	2.56
Tooth present in socket	5127	64
Tooth present, no socket	168	2.1
Tooth lost ante-mortem	1709	21.36
Tooth present in socket but impacted	24	0.4
Root only	108	1.35
Tooth congenitally absent	114	1.43
Tooth erupting	52	0.65
Tooth congenitally absent (not confirmed by radiography)	62	0.78
Tooth not erupted	31	0.39
Total	8000	100

Table 4.11: Prevalence of dental disease (note that 242 individuals had one or more lesions)

	Enamel hypoplsia		*Caries*		*AMTL*		*Peri-apcial cavities*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
No. of individuals	54	21.6	205	82	228	91.2	71	28.4
No. of Teeth	334	5.8	885	15.3	1709	22.4	121	1.6
Total no. of teeth:	5766							
Total no. of alveoli:	7627							

(Table 4.10). Of these, the status of 97% (7795/8000) could be recorded to some degree, while the status of 205 could not be accounted for.

Dental and oral health (pathology)

A total of 97% (242/250) of individuals had active or healed lesions at the time of death, visible on the teeth and/or surrounding alveolar bone tissue (Table 4.11). Lesions included enamel hypoplasia, dental caries, ante-mortem tooth loss (AMTL) and peri-apical cavities.

Enamel hypoplasia

Enamel hypoplasia (EH) refers to horizontal linear bands or pits, or a combination of both, on the tooth crown (for example, see Fig. 4.18). These defects refer to episodes of disruption to the formation of the enamel matrix (Hillson 1996) and are believed to be a consequence of systemic disturbances at the time of the tooth's development in childhood (Skinner and Goodman 1992; Bhat and Nelson 1989). They were identified on the present skeletons macroscopically, using a dental probe (when appropriate), and were scored on a presence/absence basis for each tooth that was examined.

Systemic disturbances may arise due to one or a combination of factors: malnutrition, a disease process, genetic factors and/or psychological stress during growth, and maturation (Pindborg 1992) being among the possibilities. The cause of EH cannot be diagnosed based on its presence alone, but on occasions it can be inferred (Lewis 2007). In addition, at a population level, the prevalence rates of EH can provide an insight into living conditions and nutrition during childhood (ibid.). On the one hand it has been suggested that prevalence rates indicate chronic low socio-economic conditions and disadvantaged individuals, when considered at a population level. On the other hand, the condition indicates an improvement in circumstances and/or high resistance to disease processes, when considered at an individual level (Palubeckaite *et al.* 2006). A number of developing teeth can be affected by the condition, but changes are usually most apparent on the anterior teeth (incisors and canines), due to their increased hypoplastic vulnerability in comparison with the teeth of the posterior dentition (Littleton and Townsend 2005). The timing of episodes of disruption can be inferred by taking into consideration the developmental stage of the tooth and the location of the defects on the crown(s) (ibid. 2005).

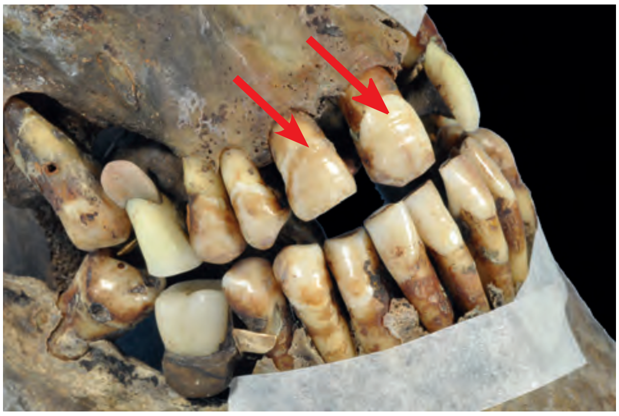

Fig. 4.18 LEH on upper (arrowed) and lower teeth (2044B)

A total of 54 individuals (21.6%; 54/250), or 334 teeth (6%; 334/5766), had EH defects. The majority of defects were linear and were located in the anterior (incisor – canine) dentition. Where timing could be inferred, the peak age of occurrence was in young childhood (>1.5–4.5 years), possibly as a consequence of physiological stresses associated with weaning or childhood illnesses, such as measles and rubella. A limited number of individuals (for example, 2446B) presented EH at various stages throughout childhood (1.5–12 years), which may indicate chronic or episodic physiological stress throughout childhood.

Caries

Caries, or dental decay, is the destruction of the hard enamel surface of the tooth leading to the formation of cavities (Hillson 1996). It is evidence of an infectious process, which is usually progressive unless dental treatment is sought or the tooth is extracted. If left untreated, caries can progress into the softer dentine and pulp cavity of the root leading to gross destruction of the tooth, and subsequent loss. Thus, pain, inflammation, tooth loss and infection in the surrounding bone tissue may occur as a consequence. Caries is caused by the action of bacterial acids arising from the bacteria that live in plaque and feed off sugars and starch from remnant food particles in the mouth (Hillson 1996). Thus,

Fig. 4.19 Example of gross caries (arrowed)

good oral hygiene habits are necessary to remove plaque and retard bacterial activity. Carious lesions occur fairly rapidly (Palubeckaite *et al.* 2006), so presence or absence is a good indicator not only of diet, but also of oral hygiene habits.

All available teeth from the graves were examined macroscopically for caries and presence/absence was scored. Some lesions were determined or confirmed through the examination of dental radiographs. The severity of lesions was scored as either small to moderate (majority of crown present) or gross (majority of the crown destroyed) (for example, Fig. 4.19).

A total of 205 (82%; 205/250) individuals had active carious lesions involving one or more of their teeth. The TPR was 15 % (885/5766), which equates to an average of 3.5 active caries per soldier. The frequency of small to moderate lesions was 85% (753/885). Gross lesions accounted for 15% (132/885) of all lesions.

Extremely significant statistical differences ($p<0.0001$; Appendix Three) were observed between caries frequency and tooth location. Maxillary and posterior teeth (premolar-molar) of the upper and lower dentition were more frequently affected than the teeth of the mandible or anterior dentition (see Appendix Three contingency table). In addition, the second permanent molar (FDI 7) was the most frequently affected tooth, accounting for 21% (185/885) of all caries. These patterns are consistent with those observed in modern populations (Ferro *et al.* 2009), and are influenced by crown shape in combination with diet and oral hygiene habits (Ferro *et al.* 2009).

Ante-mortem tooth loss (AMTL)

Ante-mortem tooth loss (AMTL) during life may be the result of periodontal disease, trauma and/or tooth extraction. Smoking (Axelsson *et al.* 1998; Albandar *et al.* 2000), poor oral hygiene, high sugar diets and calculus deposits (Palubeckaite *et al.* 2006) promote periodontal disease and infection which can undermine the bone and soft tissues that anchor the tooth in its socket and lead to tooth loss. Extractions are the elective removal of a tooth, and are often encountered when a tooth is too diseased to be restored through dental treatment, access to treatment is unavailable or a tooth is impacted. Traumatic tooth loss may result from a blow to the area of the mouth, whereby a tooth is avulsed from its socket. Whichever the manner a tooth is lost, the healing response of bone and soft tissues is the same and involves the closure of the open socket. On dry bone AMTL is identified as the partial or complete closure of a socket (resorption) at the site of a tooth.

At Pheasant Wood, AMTL was identified macroscopically and was backed up by radiography when required. Broad timings of AMTL were estimated, based on the degree of resorption, whereby a fully resorped socket was scored as long-term loss (≥12 months), active resorption of a socket and progressive loss was scored as recent loss (≤12 months) and a combination of resorption stages in a single dentition was scored as progressive loss (≥12 months and ≤12 months). The last indicates that not all teeth were lost or extracted in a single event (Fig. 4.20).

A total of 228 individuals (91%; 228/250) had lost teeth during life. For 50% of individuals (124/250) the loss was long term, while 36% (91/250) of individuals exhibited progressive tooth loss, and only 5% (13/250) of individuals exhibited recent tooth loss. These differences in AMTL and timing were found to be statistically significant ($p<0.0001$; Appendix Three).

The TPR for AMTL was 22% (1709/7627) of all teeth. There was an extremely significant statistical difference ($p<0.0001$; Appendix Three) in the frequency of AMTL between the upper and lower dentitions compared with anterior and posterior (upper and lower) dentitions. The majority of AMTL was located in the upper dental arcade, which

Fig. 4.20 Progressive ante-mortem tooth loss in the mandible (2719B)

accounts for 57%, (975/1709) of the total number of teeth lost and the posterior dentition (upper and lower), which accounts for 85% (1450/1709) of all teeth lost during life. The first molar (FDI 6) was the most frequently absent tooth (upper and lower) and accounted for 32% (549/1709) of all AMTL. In some cases, unilateral resorption following AMTL had altered the facial skeleton resulting in asymmetry of the bones. This observation could be useful for identification in the few cases where good photographs of faces survived.

A statistically significant difference in the frequency of AMTL and age (adolescent, young adult, prime adult and mature adult) was found, but this was only slight (p=0; Appendix Three). The adolescent category deviates from the expected values, there being a significantly smaller proportion of individuals in this age category with AMTL. The adult categories showed similar frequencies in all age groups (Appendix Three).

Peri-apical cavities

Peri-apical cavities are openings, pits or chambers in the alveolar bone (maxilla and mandible) located at the apex of the tooth root. They may be present as an abscess (a pus-filled sac due to infection), a granuloma (an opening that contains granulation tissue due to localised inflammation or healing) or a cyst (a fluid-filled sac that may be associated with inflammation) (Dias and Tayles 1997). It is often not possible to distinguish between these different types of lesion on dry bone, therefore they are categorised here under the generic heading, 'peri-apical cavities'.

Granulomas and cysts are often asymptomatic, but they can also represent an acute period of inflammation. An abscess may be an acute or chronic condition which may lead to osteomyelitis (infection in the bone) and is associated with pain, swelling, fever, halitosis and inflammation. A discharging abscess may extrude pus through the bone creating an aperture (sinus) in the alveolar tissue. However, once an abscess has drained, pain may subside as this stage is associated with the necrosis of the tooth nerve (Dias and Tayles 1997). Thus, evidence on the bone may be associated with earlier symptoms rather than symptoms at the time of death. All observations at Pheasant Wood were based on the macroscopic and x-ray examination of the dentition and associated bone tissue.

A total of 28% (71/250) of individuals had one or more peri-apical cavities. At the level of individual teeth the true prevalence of lesions was 1.6% (121/7627). Lesions were found in association with dental work, caries, AMTL and an impacted and a congenitally absent tooth. There was a difference between the frequency of peri-apical cavities between the maxilla and mandible, with the majority of the lesions being present (58%, 70/121) in the former. However, when explored statistically this difference was found to be only slightly significant (p=0.05; Appendix Three). There was no significant difference (p=0.057) in lesion frequency between the anterior and posterior teeth (Appendix Three).

Dental anomalies

Dental anomalies are non-pathological traits in which inheritance, environmental influences, habitual activities, or a combination of these factors, may influence their manifestation. One of these, agenesis (congenital absence of one or more permanent teeth), was observed on 21% (53/250) of individuals and involved a total of 114 (1.5%; 114/7627) teeth. Individuals with unconfirmed dental agenesis (all third molars) are not included here. The majority of cases of confirmed dental agenesis (19%; 48/250) involved the absence of one or more of the third molars, which is consistent with prevalence rates observed in modern populations (Londhe *et al.* 2008). Six individuals had hypodontia (Table 4.12), which is the congenital absence of between one and six teeth, excluding the third molars (Arte 2001). Of these, five were of particular significance for identification because the hypodontia involved teeth located within the visible dental arcade (anterior) and reflected unique patterns in human variation, as illustrated by their relatively low prevalence within the assemblage (2.4%; 6/250) and in modern populations (1.6%-9% in the permanent dentition; Londhe *et al.* 2008). These had the potential to be particularly helpful where photographs of smiling individuals were available.

The majority of dentitions (64%; 161/250) had anomalous traits which, in addition to agenesis, included ante-mortem fractures to the crowns, crowding, rotation of teeth (including winging, or rotation of the incisors), diastemae (a gap between two teeth), impacted teeth, supernumerary teeth, dental drift (the migration of a tooth from its normal position), accessory tubercles (non-pathological

Table 4.12: Individuals with hypodontia (excluding FDI 8)

Evidence number	*Pattern of hypodontia*
0268B	Bilateral hypodontia of the upper (maxilla) lateral incisors (FDI 2)
1212B	Bilateral hypodontia of the upper (maxilla) lateral incisors (FDI 2)
2792B	Bilateral hypodontia of the upper (maxilla) lateral incisors (FDI 2)
2118B	Bilateral hypodontia of the upper (maxilla) canines (FDI 3)
0437B	Unilateral hypodontia of the upper (maxilla) right canine (FDI 3)
2516B	Bilateral hypodontia of the lower (mandible) second molars (FDI 7)

Fig. 4.21 Marked protrusion of the upper anterior teeth (3095B)

Fig. 4.22 Open bite and distinctive gold denture and onlay work (2341B)

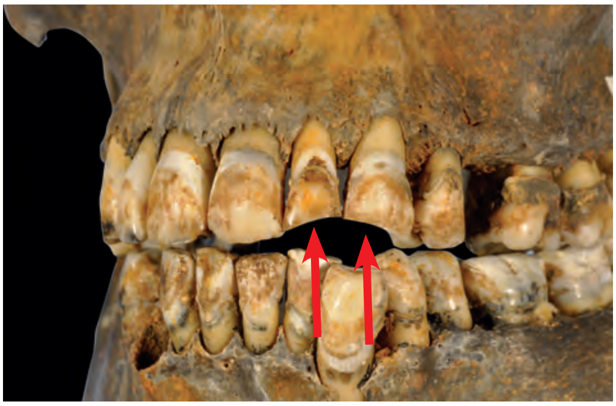

Fig. 4.23 Attrition patterns (arrowed) associated with habitual pipe smoking (1390B)

bony prominence), unusual tooth morphology, tori (a non-pathological growth of bone in the jaw), unusual bite, and distinctive attrition patterns. Analysing the frequency of each of these anomalies at the assemblage level is not of particular relevance here. Nevertheless, they may provide individuating criteria, thus all such features were recorded in individual case reports.

The absence of comparative dental records means that many of the anomalies were of limited significance for identification. However, some were sufficiently distinct to be of potential value when considered alongside other areas of the ante-mortem record (such as photographs). For example, individual 3095B (Fig. 4.21) had marked protrusion of the upper teeth, and individual 2341B (Fig. 4.22) had an open bite (no occlusion between the anterior teeth), as well as distinctive gold dental work. In addition, lifestyle or habits were inferred from some characteristics, including attrition patterns associated with habitual pipe smoking which were observed in six individuals (for example, Fig. 4.23).

Dental work

Five categories of dental work were observed across the assemblage and include, dentures, restorations (fillings), crowns, root canal work and bridge work (Table 4.13; Fig. 4.24). A total of 137 individuals (54%; 137/250) had some form of dental work, with

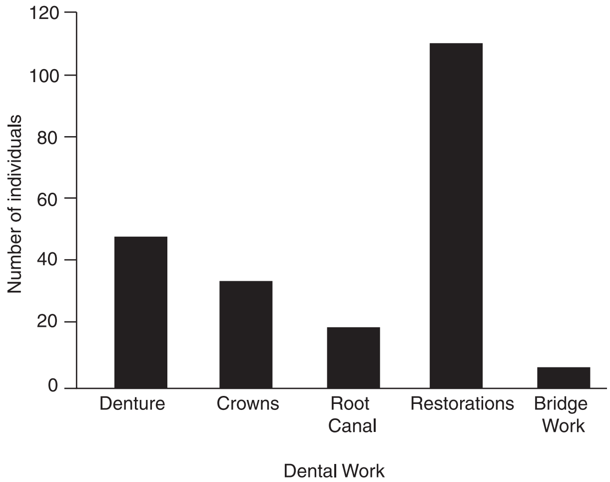

Fig. 4.24 The frequency of different types of dental work seen at Pheasant Wood (n=137)

Table 4.13: Prevalence of dental treatments.

	All dental treatments		Teeth with dental work		AMTL replaced with denture		Restorations/ *fillings		Dentures		Crowns		Root canal		Bridge work	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
No. of individuals	137	54.8	/	/	/	/	109	43.6	46	18.4	32	12.8	17	6.8	4	1.6
No. of Teeth	1459	19	1038	18	421	24.6	535	9.3	421	5.5	63	1	/		12**	0.16**

* Prevalence calculated from total number of AMTL (n=1709);

** Prevalence calculated from total teeth present and total AMTL (n=7475)

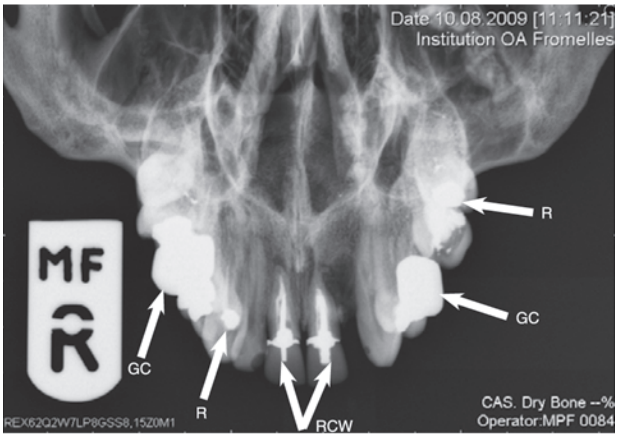

Fig. 4.25 Gold crowns (arrowed GC), root canal work (arrowed RCW) and restorations (arrowed R) (2159B)

48 of these individuals (19%; 48/250) having had more than one type (for example, 2159B had crowns, root canal work and restorations; see Fig. 4.25). Most dental treatments were restorations (43.6% 109/250), followed by dentures (18%; 46/250), crowns (12.8%, 32/250), root canal work (6.8; 17/250) and, finally bridge work (1.2%, 4/250).

A total of 1038 individual teeth (TPR 18%, 1038/5766) had dental work. In addition, a total of 421 teeth lost ante-mortem had been replaced with a denture (TPR 5.5%; 421/7651). This accounts for 25% (421/1709) of the total number of dental treatments. The total number of teeth presenting some form of dental intervention, through either the replacement of an extracted or lost tooth with a denture, or dental treatment to preserve the tooth *in situ* is 1459 (19%; 1459/7651).

Dental restorations

Dental restorations or fillings are materials added to a tooth to restore function and integrity following the loss of structure, often as a result of caries (decay) or fracture. The materials used in the fillings observed at Pheasant Wood were amalgam (metal alloy of mercury and other metals, such as silver, zinc, tin and copper), gold, white coloured fillings that are probably silicates (Adams pers. comm. 2009) and other metals and/or alloys (Table 4.15). All metals were highly radiodense and visible on radiographs. White fillings were often not visible on radiographs, indicating that the materials that had been used were not particularly radiodense or showed a similar radiodensity signal to that of tooth enamel. Thus, identification of these materials was generally restricted to macroscopic examination.

Many amalgam fillings tended to be rather crude (for example, Fig. 4.26) with occlusal surfaces that were not sculpted and biting surfaces that were probably created at the time of treatment by the individual biting down on the crown to create a negative of the occluding dentition. In addition, alloys were susceptible to taphonomic alteration, as was evidenced by pitting on the surface of fillings, as well as the leaching of liquid mercury from some fillings due to the component parts separating out into their pure metal states. The degree of pitting was proportional to the amount of mercury, whereby the greater the amount of mercury, the more porous the amalgam filling (Adams pers. comm. 2009). This would have had consequences for the integrity of the filling in the living individual, as well as for its survival during the post-depositional interval. In contrast, gold fillings showed a greater degree of sophistication in their fabrication and had sculpted occlusal surfaces. Delicate gold inlay work on many of the visible anterior teeth had seamless margins between the fillings and the enamel (for example, Fig. 4.27).

The majority of individuals (44%; 48/109) with restorations had amalgam fillings, closely followed by mixed fillings (38.5%; 42/109) (for example, Fig. 4.28). Five individuals (5%; 5/109) had gold

Fig. 4.26 Crude amalgam fillings (arrowed) (0288B)

Fig. 4.27 Sophisticated gold onlay work on upper anterior teeth (1834B)

Fig. 4.28 Amalgam (arrowed AF), gold (arrowed GF) and white restorations (arrowed WF) and gold crowns (arrowed GC) (2159B)

fillings, five (5%; 5/109) had white filings, seven (6%; 7/109) had unidentified metal fillings, which may or may not have been amalgam, and two (2%; 2/109) had fillings made of an unidentified material (classified as 'other').

At the level of individual teeth, 535 had restorations (9%; 535/5766). The greatest proportion of restored teeth (70%) were filled with amalgam (Table 4.15). There was an extremely significant difference ($p<0.0001$; Appendix Three) between the number of teeth filled and their location in the dental arcade. The greatest proportion of fillings (72%; 385/535) were present in the mandibular teeth and in the posterior teeth (72%; 384/535) of the upper and lower dental arcades. The most frequently filled tooth was the second molar (FDI 7) (23%; 130/585). There were differences in dominant filling materials used between the anterior and posterior teeth. A fairly even distribution of material types, with gold predominating (34%), was observed in the anterior teeth. In contrast, 85.5% of the posterior fillings comprised amalgam, with gold and white fillings, accounting for only 5% of all restorations involving the posterior teeth.

Dentures (prostheses)

A denture is a removable prosthetic device designed to replace missing teeth. It is supported and anchored in place using the soft and hard tissues of the mouth. A denture may be partial (if some natural teeth remain in the dental arcade) or complete (where all teeth in an arcade have been lost or extracted).

The majority of dentures at Pheasant Wood (78.2%; 36/46) were made of a vulcanized rubber hard palate with a gum shield of vulcanized rubber and/or gutta percha (for example, Figs 4.29, 4.30, 4.31 and 4.32). Modern materials such as acrylics were not available during the period under investigation. Often the gum line at the attachment of the

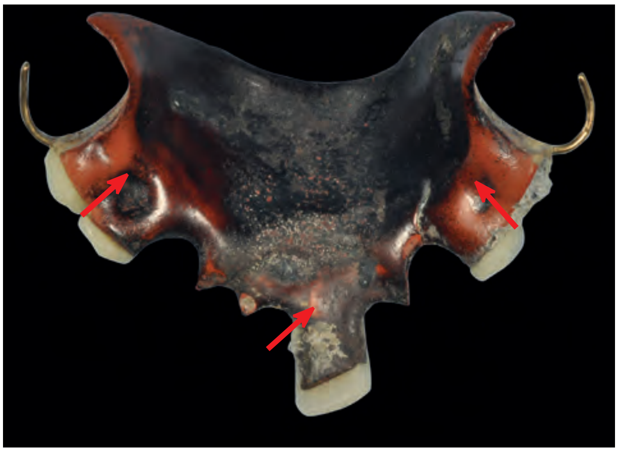

Fig. 4.29 Vulcanised rubber hard palate denture with gutta percha (arrowed) (3095B)

Table 4.14: Frequency of crown and material type in the anterior and posterior dentition (frequencies calculated from total number of filled teeth in anterior or posterior dentition and total number of crowns)

Crown Material	Gold		White		Bonded		Metal		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%
Anterior dentition (n=23)	6	26	8	34.8	8	34.8	0	0	1	4.4
Posterior dentition (n=40)	36	90	0	0	1	2.5	3	7.5	0	0
Total No. Crowns (n=63)	42	66.7	8	12.7	9	14.3	3	4.7	1	1.6

Table 4.15: Frequency of restorations and type of material in the anterior and posterior dentition (frequencies calculated from total number of filled teeth in anterior or posterior dentition and total number of fillings)

Restoration material	Gold		White		Metal		Mixed		Amalgam		Other	
	n	%	n	%	n	%	n	%	n	%	n	%
Anterior dentition (n=150)	51	34	33	22	7	4.7	12	8	45	30	2	1.3
Posterior dentition (n=385)	10	2.6	10	2.6	24	6.2	4	1	329	85.5	8	2
Total number of fillings (n=535)	61	11.4	43	8	31	5.8	16	3	374	70	10	1.8

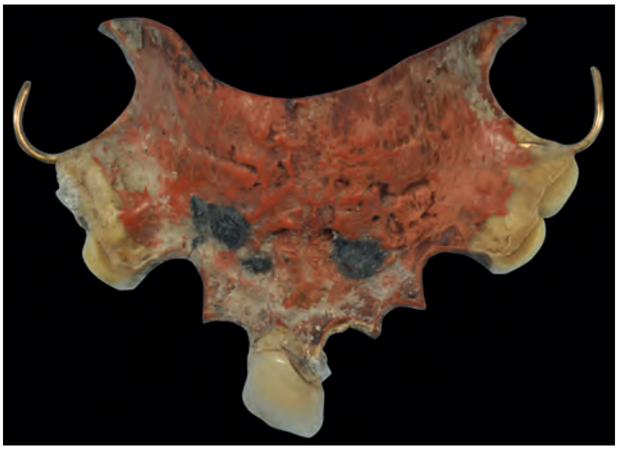

Fig. 4.30 Vulcanised rubber hard palate denture showing rugae on palatal contact surface (metal clasps for attachment to natural teeth also visible) (3095B)

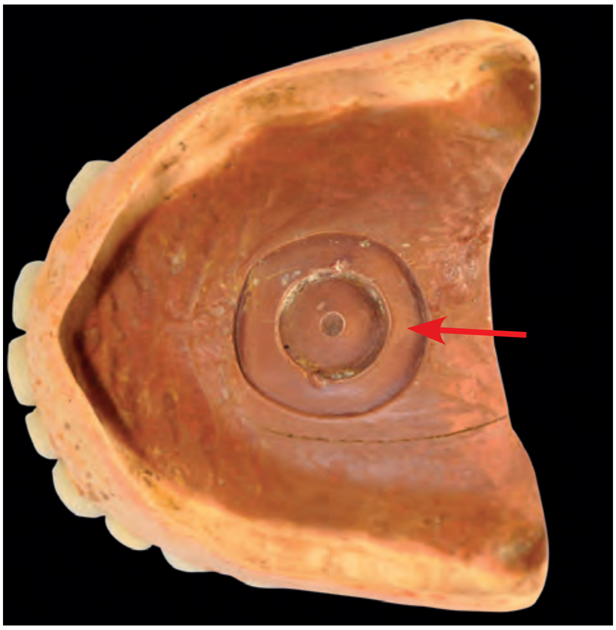

Fig. 4.31 Palatal relief (arrowed) (0269B)

Fig. 4.32 Occlusal surface of denture with metal pins holding anterior tooth in place (arrowed); posterior prosthetic teeth are embedded in the vulcanised rubber

posterior teeth was pink in colour, in contrast to the pinkish-brown colouration of the remainder of the denture. This feature is cosmetic, the visible gum-line areas designed to be sympathetic to natural gum tissue.

The individual teeth of the denture were ceramic (probably porcelain). Anterior teeth were attached by a metal pin and posterior teeth were embedded within the vulcanized rubber gum shield. Anatomical and non-anatomical occlusal (biting) surfaces were observed on the prosthetic crowns of the posterior teeth. Anatomical surfaces had been sculpted to recreate the cusps and crenulations observed on natural teeth, while non-anatomical surfaces had been created as a negative scoring or relief pattern to act as a functional grinding surface. To anchor partial dentures in place, metal ring clasps were added or the gum shield was sculpted at the border between the palate and natural teeth. Both designs relied on fixing the denture to the remaining natural teeth.

A small proportion of individuals (19.6%; 9/46), had a denture tooth made of non-precious metal (possibly copper alloy), indicated by the fact that the metal was tarnished. These may have had a shiny appearance ante-mortem and were presumably for cosmetic rather than functional reasons. A number of partial dentures presented rugae patterns (elevated ridges of soft tissue found on the hard palate behind the front teeth) on the palatal surface, which were presumably created from dental impressions taken from the mouth of the individual. Rugae patterns are as individualistic as fingerprints, no two individuals having the same pattern (Adams pers comm. 2009). Unfortunately, this information was not useful for identifying the Fromelles soldiers, for whom records of their rugae patterns no longer exist.

The bespoke dentures of one of the individuals, 0666B, were of exceptional sophistication and quality and were highly individualistic. They consisted of an upper partial denture, which was made of gold and exhibited the complex rugae pattern of the individual, and lower partial dentures with a gum shield which was made of a mixture of

Fig. 4.33 Gold denture showing owner's rugae pattern (0666B)

Table 4.16: Frequency of restorations and type of material type in the anterior and posterior dentition

Evidence number	*Denture type*	*Markings and impressions*
0129B	Partial upper and lower	Number on upper prosthesis, possibly 63. Number or letter on lower prosthesis, possibly 9
0192B	Partial upper	Manufacturer in relief: M or W overlaying SS
0269B	Complete upper	Circular-shaped palatal relief
0448B	Partial upper	Bilateral inscribed ridges and negative impression of the wearer's name
0740B	Complete upper	A '2' with an unidentifiable number or letter next to it
0762B	Complete upper	Rounded triangular indentation on upper surface
1733B	Complete upper	Heart-shaped palatal relief
2395B	Partial upper	Heart-shaped palatal relief
2508B	Partial upper	Manufacturer in relief: M or W overlaying SS
2560B	Partial upper and lower	A heart-shaped palatal relief & manufacturer in relief: M or W overlying SS
3157B	Complete upper	Stamp at centre of denture palate (superior surface); appears to be the letter 'R' with a heart shape overlying it
3246B	Complete upper	Palatal relief and manufacturers' marks: 'Ralph Potis/b.Perth'

gold (anterior) and vulcanized rubber (posterior). Ceramic crowns, graded to give the teeth a natural and realistic appearance, were attached to the gold palate (see Fig. 4.33) of the upper denture. It is likely that the visible dentition would have presented as a complete set of natural, neat teeth.

Of the individuals recovered with dentures, the majority, 59% (27/46), had a partial upper prosthetic, 19.5% (9/46) had a complete upper prosthetic, 15% (7/46) had a partial upper and partial lower prosthetic, 4% (2/46) had a partial lower prosthetic and 2% (1/46) had a complete upper and partial lower prosthetic.

The majority of dentures (78%; 36/46) replaced teeth that had been lost from the upper dental arcade. Dentures replacing teeth from upper and lower arcades were observed in 17% (8/46) of all cases and dentures replacing tooth loss in the lower dental arcade accounted for 4% (12/46) of all cases. The absence of dentures associated with other individuals with substantial AMTL does not preclude the fact that they had worn them in life. Dentures may have been removed prior to the battle, or the individual may have chosen to wear them occasionally. Thus, the number of individuals with dentures at Pheasant Wood may represent a minimum number of denture wearers within the assemblage.

Denture teeth replace 421 of the 1709 teeth lost ante-mortem. There was a significant difference ($p<0.0001$; Appendix Three) between the number of denture teeth replacing AMTL in the maxilla and mandible, with 88% of all denture replacements involving the upper arcade. However, there was no significant difference ($p=1$; Appendix Three) between the number of replacement teeth for AMTL between the anterior and posterior teeth when the complete dental arcade is considered. If the frequency of replacement teeth against the number of AMTL (that is, available locations) for upper anterior and posterior teeth versus lower anterior and posterior teeth was considered, a more complete pattern was observed. There was no significant difference ($p=0.13$; Appendix Three) between the frequency of replacement anterior teeth in the upper or lower dentition. However, there was a significant difference ($p<0.0001$; Appendix Three) between the frequency of replacement posterior teeth in the upper and lower dentition. Here, 29% (215/734) of all upper posterior AMTL are replaced with a denture, in contrast to only 6% (46/719) of lower posterior AMTL.

Dentures not only provide individuating criteria, but are also of artefactual value; for example, such things as manufacturers' marks could be indicative of where they were fitted. Twelve of the dentures had some form of marking or relief and some shared the same characteristics or markings. Five dentures had a palatal relief in the form of an impressed area at the centre of the denture at the site of contact between it and the natural hard palate, its purpose being to make the denture more comfortable to the wearer. Palatal reliefs are no longer used in modern dentistry as it can cause soft tissue changes and localised neoplasms (Adams pers. comm. 2009). The remaining seven dentures had inscribed or relief lettering/numbering, likely to be identifiers of the denture makers or the individual for whom they were made. This is with the exception of one which was the surname of the wearer (Table 4.16, Fig. 7.2).

Crowns

A crown is a fixed prosthetic cap that sits on top of the existing natural tooth and root. It may be combined with other dental work, such as bridges and root canal fillings, or be an isolated dental treatment designed to reinstate functional integrity to a lost or damaged natural crown.

The types of crown materials encountered at Pheasant Wood were gold, white (probably porcelain), bonded (a mix materials of materials bonded together, the lingual surface being metal or metal

Fig. 4.34 Evidence of sculpting of the occlusal surface of a gold crown (1973B)

alloy and the labial/buccal surface is ceramic), metal and other (material could not be identified). Metal crowns were probably manufactured using the lost wax casting procedure (Adams pers. comm. 2009), and there was evidence of sculpting of the occlusal surface of gold crowns (for example, 1973B; Fig. 4.34) to create a functional and sympathetic biting surface.

Of the 32 individuals with crowns, the majority (62.5%: 20/32) had one or more gold crowns, 18.75% (6/32) had a mixture of crowns of different materials, 6.25% (2/32) had white crowns, 9.4% (3/32) had bonded crowns, and 3.1% (1/32) had a metal crown.

At the level of individual teeth, 63 teeth were crowned (1%; 63/5766). There was a significant difference ($p<0.0001$; Appendix Three) between numbers of crowns in the maxillary versus the mandibular dentition and the anterior upper teeth in contrast to the lower anterior teeth, and a significant difference ($p=<0.0001$; Appendix Three) in the frequency of posterior upper crowns to lower crowns. Of all crowns present, 81% (51/63) were in the upper (maxillary) dentition. In addition, if anterior crown frequency only is considered, 91% (21/23) involved upper teeth. The overall trend is of a concentration of crowns in the maxilla, especially in the visible front teeth.

Of the 24% (14/63) of crowns in the lower (mandible) dental arcade, all were of gold. The majority of crowns in the upper dental arcade were also gold (58%; 28/48), followed by bonded crowns (19%, 9/48), white crowns (15%, 7/48), metal crowns (6%; 3/48) and other materials (2%; 1/48) (Fig. 4.35). Different frequencies of crown material used were observed in the anterior (visible teeth) versus the posterior dentition (Table 4.14), with 90% (36/40) of all posterior crowns in gold and 72% (16/22) of all anterior crowns white or bonded (both crown types would have been visible as white teeth). Considering the dual variables of crown material and location, gold crowns in the posterior teeth (upper and lower) represented the largest group and accounted for 57% (36/63) of all crowns.

Root canal work

Root canal treatment (endodontics) is a procedure that requires the removal of the diseased pulp chamber of the root (nerve and other tissue) and the filling and sealing of the cavity. The procedure is performed when the tooth cannot be restored by less invasive means, usually because decay (caries) and destruction of the tooth crown has reached the nerve and led to infection of the pulp chamber, sometimes with involvement of surrounding alveolar (bone) and soft tissue.

Root canal work in the early 20th century would have involved drilling the affected tooth, using a foot operated hand drill, and it is likely that anaesthesia was not available during treatment. (Adams pers. comm. 2009). Halliday *et al.* (1977) state that ether was available to early 20th-century Australian dentists, many of whom saw its use as something of an eccentricity and little more than a passing phase. Root canals were filled using a range of materials at this time (Halliday *et al.* 1977), and three material

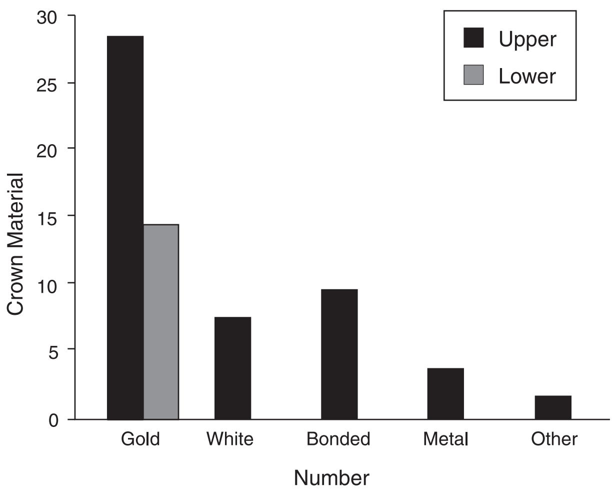

Fig. 4.35 Frequency of crown types seen in upper and lower dental arcades

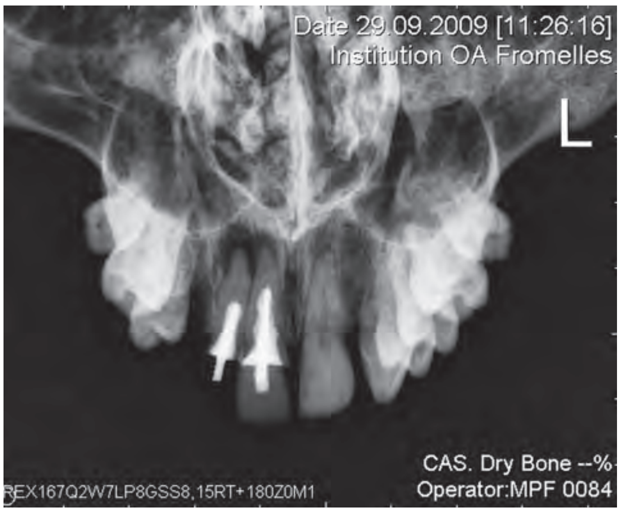

Fig. 4.36 Example of a root canal work; metal posts fixed in the root cavity of two maxillary teeth (3168B)

types were identified at Pheasant Wood, including endomethazone, silver pins/metal posts and gutta-percha. All were visible radiographically and presented as areas of radiodensity which contrasted with the surrounding tissues in the root canal.

Endomethazone is a steroid-based paste which acts as a preservative and was injected into the root canal where it subsequently solidifies. This treatment is no longer used in modern dentistry due to the potential for adverse side-effects, whereby the steroid paste leaches into surrounding healthy bone and soft tissue, causing destruction, numbness (if it affects nerve tissue) and subsequent internal resorption of the tooth. Treatments using silver pins involved feeding the pins into the drilled root cavity. Where a prosthetic crown needed to be anchored to the root canal work, more substantial metal posts (probably silver) were fixed in the root cavity and the crown screwed into place at the cemento/enamel junction (CEJ, the junction between the root and the crown) (for example, Fig. 4.36). Small tubes of gutta-percha, an early latex-type material, were passed into a drilled cavity until it was filled. Perished remnants of this material were macroscopically observed in at least one individual where the crown had been lost post-mortem.

Through the assessment of routine dental radiographs, root canal work was observed in one or more teeth of 17 individuals(7%; 17/250). This type of treatment was observed in association with a prosthetic crown in the majority of cases (88%; 15/17). One individual (2510B) had treatment in association with a filling; in another individual (2538B) the crown was absent post-mortem and it was not possible to establish whether the crown was natural or prosthetic due to taphonomic over-printing (post-depositional modification) at the CEJ. Root canal treatment was recorded in the individual post-mortem analysis records, but not in the database to the level of individual tooth.

Bridge-work

A dental bridge is a fixed, prosthetic device that replaces one or more absent teeth. The partial denture is comprised of supporting crowns and replacement teeth that are joined rigidly together. The denture fills the space of the missing tooth or teeth and the crowns, which are cemented to natural teeth, anchor and support the bridge and maintain its fixed position in the mouth.

Four individuals had bridge-work (1.6%; 4/250). Three individuals had one replacement tooth, including 1973B and 1524B who had gold bridge work involving the lower anterior teeth, and 1266B who had bonded bridge-work to replace one upper tooth. Body 2117B had more extensive bilateral, bonded (white and gold) upper bridge-work, replacing four absent teeth (Fig. 4.37). All individuals had additional dental treatments within their upper and lower dental arcades.

At the level of individual teeth a total of only 12 teeth (bridge and crown) (0.16%; 12/7475) had been replaced or used in bridge-work. This represents a minimal proportion of the total teeth available for analysis and was thus the least common of all dental treatments observed within the assemblage.

Fig. 4.37 White and gold upper bridge work (2117B)

Type of dental work and age

To test whether an association existed between types of dental work and age, multiple chi-squared analyses were carried out ($p=0.05$; Appendix Three). The tests explored the association between the frequency of individuals in adolescent, young adult, prime adult and mature adult age categories and the presence of dental work, dentures, fillings and crowns. The results ($p=0.45$, $p=0.11$, $p=0.68$ and $p=0.54$ respectively) indicate no statistically significant difference in any of the categories observed, suggesting perhaps surprisingly that the frequency of dental treatments was not associated with age.

Comparison of frequency of dental work and the different graves

It was proposed in the early stages of the analysis that the presence of dental work was a reflection of civilian social status and may indicate rank. The premise for this assertion is that officers, as opposed to other ranks, were more likely to belong to the upper and middle classes, and thus had access to more superior dental treatments (for example, root canal work) in civilian life.

To test this assertion and explore the possibility of sorting of the soldiers (officers from other ranks) at the time of interment, the relationship between the frequency of individuals with particular dental treatments (dentures, amalgam and mixed fillings, crowns, fillings and root canal work) and grave number (one to five) was tested; in an effort to establish whether the frequency of individuals with particular dental treatments was associated with a particular grave (for example, all individuals with dentures in one grave). None of the results showed any statistically significant difference (all results: $p>0.05$ Appendix Three), suggesting that particular dental treatments are not associated with individuals in a particular grave.

To determine whether the overall dental treatment profiles were similar in each of the graves (one to five), combinations of dental treatments (denture and other dental work, dentures only, other dental work no dentures, amalgam and metal fillings, fillings of all types, gold crowns and mixed crown types) were examined against grave number. Only those individuals with dental work were considered here. Six of the seven variables that were tested showed no statistically significant difference (all results: p>0.05; Appendix Three). A weak significant difference (p=0.3; Appendix Three) was found in the number of individuals with fillings, with individuals in Grave One having a low presence in comparison to graves two, three, four and five.

A visual assessment of the spatial distribution of individuals with dental work was also undertaken to identify clusters in their respective graves. The spatial distribution, viewed in plan and rotated three dimensionally, to view the two distinct layers, showed no significant pattern or clustering. The individuals in Grave Six, and the properties of bridge and root canal work, were not tested due to their small numbers.

Ante-mortem pathology and trauma

Introduction

Pathology here refers to evidence on bone that indicates a deviation from a normal or healthy condition. Skeletal pathology may reflect diseases occurring in the soft tissues, but the absence of these visceral structures limits diagnoses; a range of disease processes can show the same response on bone requiring the assignation of differential diagnoses (Ortner 2003). Involvement of bone tissue in trauma is usually more diagnostic, often being the result of physical damage due to violence or accident, and is evidenced as a healed or healing fracture or dislocation.

Disease processes may be systemic (affecting multiple areas of the body or organs) or localised (isolated lesion) and chronic (long-lasting or recurrent) or acute (rapid onset and/or short in duration – these being far less likely to evoke a skeletal response and leave any skeletal signatures). An assessment of these assists with diagnosis and inferences regarding possible long and short-term effects on an individual's life in terms of physical deformities, disabilities and symptoms. An obvious caveat here is that all enlistees or recruits had to pass an army medical examination declaring them fit for active service. The relaxing of enlistment standards in 1916 (Australian War Memorial 2010) may have had some influence on the disease patterns observed at Pheasant Wood, but it is assumed that all soldiers were sufficiently healthy and able bodied for fighting on the battlefield.

For all 250 individuals the presence/absence of pathology and/or trauma has been recorded in the confidential case reports. Differential diagnoses and observations regarding the impact that different conditions may have had on their lives (see Chapter Two) are also included. For the purposes of this report, pathology and trauma have been analysed at the assemblage level with an emphasis on conditions that may be useful for individual identification.

The assemblage

A total of 229 skeletons (91.6%; 229/250) had pathological conditions (Tables 4.17-18), broadly classified according to their most likely diagnosis as infection, metabolic disorders, congenital and developmental conditions, joint disease, circulatory disorders, neoplastic disease, trauma and miscellaneous conditions (Fig. 4.38). This includes individuals who had evidence of more than one disease process (for example, joint disease and infection), and conditions that were secondary to another disease (for example, joint disease at the site of a previous fracture). In 27 individuals (11%; 27/250) the symptomatic implications (such as pain, physiological or physical compromise) of a condition, which may have been apparent during life, was inferred. However, this does not mean that the remainder with pathology did not experience symptoms. Rather, they could not be inferred from the changes observed. Further, there is not always a correlation between the observed severity of a skeletal response and the presence or severity of pain suffered. For example, despite its spectacular appearance, the prolific fusion of the spine seen in diffuse idiopathic skeletal hyperostosis (DISH), may be relatively painless (see Rogers and Waldron 1995, 47).

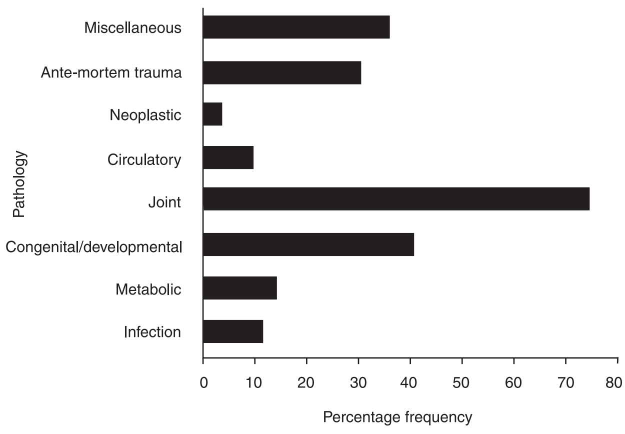

Fig. 4.38 Percentage frequency of the different pathological conditions observed in the assemblage (n=250)

Infection

Infection manifests on bone as an inflammatory response and it may involve the marrow cavity (osteomyelitis); the cortical bone (osteitis), or the outer fibrous soft tissue sheath, called the periosteum, that covers the bone surface (periostitis).

Table 4.17: Age at death and prevalence of ante-mortem pathology and trauma

Age	*All ante-mortem pathology & trauma*		*Infection*		*Metabolic*		*Congenital & developmental*		*Joint*		*Circulatory*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Adolescent (n=6)	4	66	1	16.7	0	0	2	33	/	/	/	/
Young adult (n=138)	125	91	21	15.2	23	15.2	54	39	104	75	13	9.4
Prime adult (n=81)	76	94	3	3.7	10	4	35	43	58	72	7	8.6
Mature adult (n=25)	24	96	2	8.7	3	3.7	9	36	23	92	3	12

Table 4.18: True prevalence rate (TPR) of ante-mortem pathology and trauma (TPR is the number of occurrences per body region out of the number of representations)

	Number of representations	*Infection*		*Metabolic*		*Congenital & developmental*		*Joint*		*Circulatory*	
	n	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Number of individuals	250	27	10.8	34	13.6	100	40	185	74	23	9.2
Cranium & mandible	250	13	5.2	25	10	7	2.8	5	2	/	/
Neck	250	/	/	/	/	16	6.4	11	4.4	/	/
Thorax	250	2	0.8	1	0.4	35	14	167	66.8	4	1.6
Abdomen	250	1	0.4	/	/	75	30	106	42.4	2	0.8
left arm	250	1	0.4	3	1.2	1	0.4	11	4.4	/	/
Left forearm	249	/	/	/	/	/	/	13	5.2	3	1.2
Left hand	246	/	/	1	0.4	3	1.2	13	5.3	/	/
Right arm	250	/	/	2	0.8	1	0.4	13	5.2	2	0.8
Right forearm	249	/	/	/	/	/	/	12	4.8	/	/
Right hand	247	1	0.4	/	/	3	1.2	14	5.7	1	0.4
Left thigh	250	2	0.8	2	0.8	4	1.6	22	8.8	2	0.8
Left leg	250	4	1.6	7	2.8	2	0.8	9	3.6	3	1.4
Left foot	248	2	0.8	/	/	5	2	15	6	7	2.8
Right thigh	250	2	0.8	2	0.8	4	1.6	25	10	/	/
Right leg	250	3	1.2	8	3.2	1	0.4	14	5.6	2	0.8
Right foot	246	2	0.81	/	/	4	1.6	20	8.1	6	2.4
Total	3985	33		51		161		470		32	

These changes may be due to a specific pathogen, such as tuberculosis or syphilis, or where the pattern of change is non-diagnostic and the pathogen is unknown, non-specific infection. Thus, the presentation, morphology and location(s) of inflammation on the skeleton are key in determining a likely diagnosis, for which good preservation and completeness are important factors. The aetiology (cause) of infection is multi-factorial (for example, via an open wound, ingestion or respiration) and pathogen spread may occur via the bloodstream, with bacterial transfer from the site of the primary lesion to secondary locations (metastasis).

In dry bone, osteomyelitis may present as a combination of changes, including proliferative new bone formation, cloaca (abscess drain) and involucrum (new bone that covers necrotic [dead] bone tissue [sequestrum]). Because it is often longstanding, osteomyelitis usually relates to an infection that was initiated during childhood. The bacterium most commonly responsible for osteomyelitis is *Staphylococcus aureus* (Ortner and Putschar 1985).

Of all the lesions considered in this section, periostitis is the most common one to be encountered in dry bone. This surface inflammation may be identified as fine pitting, longitudinal striations, swelling and/or plaque-like new bone formation on the original bone surface. Surface inflammation may also involve the skull but, owing to a difference in anatomy, the term periostitis does not apply here. These changes may occur as a result of infection, or may accompany other conditions of a metabolic, neoplastic or traumatic nature (Resnick and Niwayama 1995). The level of non-specific infection in a population is generally regarded as an indicator of its adaptation or maladaptation to environmental stress, such as malnutrition or poor sanitation (Roberts and Manchester 1995).

A total of 25 individuals (10%; 25/250) had evidence of infection on their bones, which involved 0.9% (36/3985) of all skeletal regions. Of

Neoplastic		Ante-mortem trauma		Miscellaneous	
n	%	n	%	n	%
/	/	/	/	2	33
4	2.8	38	28	48	35
1	1.2	27	33	32	40
1	4	10	40	6	24

Neoplastic		Ante-mortem trauma		Misc.	
n	%	n	%	n	%
6	2.4	75	30	88	35.2
5	2	5	2	10	4
/	/	/	/	5	3
/	/	21	8.4	2	0.8
/	/	8	3.2	30	12
/	/	3	1.2	8	3.2
/	/	8	3.2	6	2.4
/	/	5	2	3	1.2
/	/	1	0.4	5	3
/	/	4	1.6	3	1.2
/	/	11	4.5	4	4.5
1	0.4	4	1.6	1	0.4
/	/	8	3.2	10	4
/	/	3	1.2	13	5.2
/	/	2	0.8	12	4.8
/	/	7	2.8	10	4
/	/	5	2	18	7.3
6		95		140	

these, 24 had non-specific skull inflammation, periostitis and/or osteomyelitis and one had possible specific infection.

Non-specific skull inflammation

Thirteen individuals (5.2%; 12/250) had non-specific skull inflammation. In four of the soldiers (0036B, 0184B, 0570B and 3237B), the lesions were attributed to sinusitis, identified as new bone in the paranasal sinuses. Sinusitis occurs when infection spreads from the nasal cavity or the dentition into the mucous membranes of the paranasal sinuses (Sundman and Kjellstrom 2013). Upper respiratory tract infections resulting from environmental pollutants and/or general poor living conditions (Merret and Pfeiffer 2000); specific infectious disease such as tuberculosis and leprosy and congenital abnormalities (Lewis 2002, 21) are among the factors associated with this condition. Infection spreading from dental disease is another factor, because the apexes of the maxillary tooth roots and the sinuses are only separated by a membrane, thereby allowing infection to spread. Secondary sinusitis as a result of dental disease is the preferred diagnosis for the individuals discussed here, because they all had poor dental health, in particular caries and/or ante-mortem tooth loss.

Seven individuals (0570B, 0416B, 0438B, 0762B, 0975B, 1062B and 2147B) had inflammatory lesions that were localised to the maxilla and/or mandible, indicative of inflamed gums ('gingivitis'). In at least one the individuals (0762B), it is likely that the inflammation was a consequence of wearing a prosthesis long term. Dental disease may explain the lesions observed on the other individuals, who all had caries and/or ante-mortem tooth loss.

Two individuals (0370B and 0636B) with skull inflammation had lesions that involved the ectocranial vault (outer surface of the vault), which may have been the result of localised inflammation caused by minor scalp irritation, or anaemia (see below). Many factors of trench life, such as head lice, and poor living conditions may have contributed to the development of localised lesions such as these, or exacerbated existing conditions such as psoriasis. A further individual (0192B) had non-specific inflammation on the zygomatic bones (cheek bones) and temporal bones, adjacent to the external auditory meatus. This was in addition to non-specific inflammation on the endo-cranial surface (inside surface) of the occipital bone. The cause is unknown.

Periostitis

Periostitis was observed on 10 individuals (4%; 10/250; Table 4.19) and involved the bones of the foot (four individuals), thigh or leg (four individuals), arm (one individual) and thorax (one individual). The periostitis observed on the thorax of 2721B involved the superior surface of the first right rib and was associated with a small circular depression, possibly a cyst, approximately 7mm in diameter and 2mm in depth. The lesion possibly relates to minor muscle trauma, because it was located in the region of the attachment site for *subclavius*, a small triangular muscle between the first rib and clavicle.

Other periosteal lesions were relatively isolated, being limited to one body region. Isolated lesions are consistent with localised conditions, such as minor trauma. This is particularly so where they involve the tibia, which is more prone to knocks and scrapes because of its proximity to the surface of the skin. Periostitis as a result of trench foot, resulting from prolonged exposure of the feet to cold, damp and unsanitary conditions, is another possibility for the four individuals with foot lesions.

Only two individuals (2811B and 0268B) had more than one body region affected with periostitis. The involvement of multiple body regions may be indicative of systemic conditions, although the patterns in neither of the present cases were exclusive to a particular disease. Body 0268B also had osteomyelitis and is discussed further below.

Table 4.19: Individuals with periostitis

Body number	*Body region, bone*
0288B	Right foot, fifth metatarsal
0034B	Left thigh, anterior shaft of femur
0129B	Right foot, third and fourth metatarsals
0268B	Left arm, humerus; left thigh, femur, left and right legs, tibias
0570B	Left foot, navicular and calaneus
0925B	Left foot, all tarsals and metatarsals
1591B	Right thigh, femoral shaft
2507B	Right leg, distal tibia and fibula
2721B	Thorax, right first rib
2811B	Right and left legs, anterior tibias (midshaft)

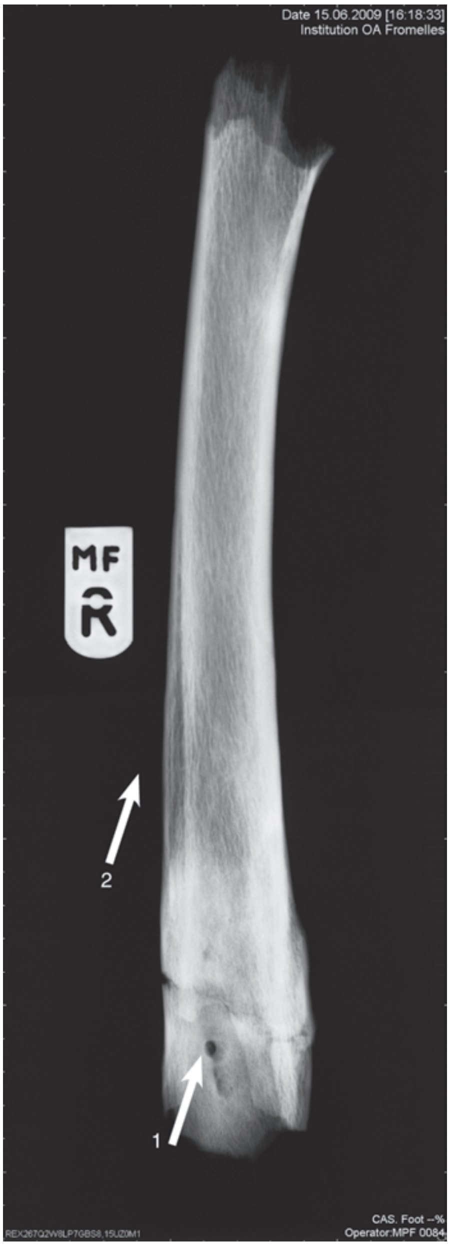

Fig. 4.39 Radiograph showing cloaca (arrowed number 1) and involucrum (arrow number 2) (0268B)

Osteomyelitis

Only one individual, 0268B, an adolescent (13-17 years), had confirmed osteomyelitis which involved the right distal shaft of the femur, the right patella and various tarsal bones from the right foot. In addition, active and healing periostitis was observed on the anterior shafts of the tibiae (diffuse), left femur (mid and distal shaft) and left humerus (distal shaft). Radiography was particularly useful here, because it confirmed the presence of a circumscribed cloaca and involucrum (Fig. 4.39) on the femur. There was no evidence of a healed, or healing, fracture, but the possibility is not discounted (post-mortem damage to the region may have obliterated this evidence). The suggested site of origin of the infection is the distal metaphysis of the femur. The lesions on this individual may be useful for identification because, considering the subadult/young age of the soldier, the chronic nature of the infection and marrow involvement, growth retardation and shortening of the femur may have occurred as a result, and may have affected the gait or caused a limp during life. In addition, the individual may have suffered from fever, pain and/or swelling in the affected regions. The preferred diagnosis here is non-specific systemic infection.

No other confirmed cases of osteomyelitis were identified, but two individuals (1859B and 2720B) had possible osteomyelitic lesions (and have been included in the calculated prevalence rates presented here). In individual 1859B, sub-circular apertures were visible macroscopically and a large lytic lesion radiographically on the cuboid bone of the left foot. This was in addition to a sub-circular aperture (7mm in diameter) adjacent to the demi-face of the left auricular surface of the pelvis. In 2720B a lytic defect was present on the proximal phalanx of their right fifth finger. In both individuals the apertures/lytic defects may have been abscesses (cloacae) and/or cysts.

Possible specific infection

Body 0764B (young adult 18-25 years) had spinal and extra-spinal lesions, that would indicate a chronic, systemic condition. Spinal lesions included lytic defects on the anterior bodies of the fourth to the eleventh thoracic vertebrae (Figs 4.40 and 4.41) and increased porosity on the lumbar vertebrae. Extra-spinal lesions included lytic defects on the inferior surface of the acromial process of the scapula and periostitis on the left and right distal tibiae, the left distal fibula, the shafts of the right tibia and femur, and the right and left femoral necks. The acetabulae of the pelvis had a more spongy appearance than usual, possibly increased sclerosis due to an increase in the number and volume of trabeculae (Capasso 1999).

The vertebral lesions, which were well organised, could be developmental anomalies, and the extra-spinal lesions could be part of a different disease

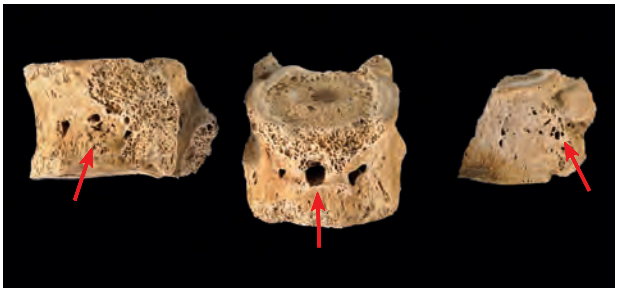

Fig. 4.40 Vertebral bodies with lytic lesions (arrowed) (0764B)

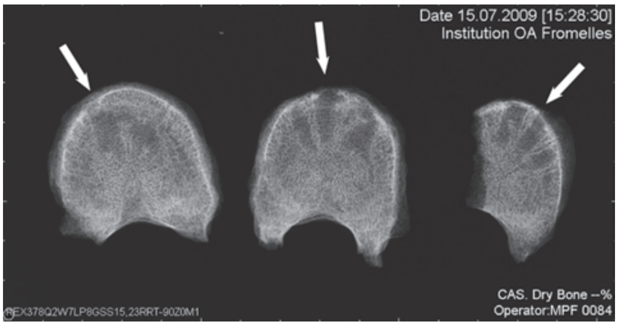

Fig. 4.41 Radiological appearance of vertebral bodies (lytic lesions are arrowed) (0764B)

process, possibly non-specific infection (but not included in the calculated prevalence rates presented in the previous sub-categories considered in this section). Alternatively, the vertebral lesions may represent non-pathological modifications caused by taphonomic processes. However, neither of these possible diagnoses are supported by the fact that the appearance of the lytic defects was more pathological than biological.

Pathological lytic defects involving the anterior vertebral bodies are seen in brucellosis and tuberculosis. These infections can be contracted from cattle and primarily involve the lower spine, but can also involve extra-spinal locations (Ortner 2003; Samra et. al. 1982). However, in the present case the vertebral bodies did not show any of the scalloping, angular deformity or collapse that are seen in tuberculoid spines. Further, the changes did not match the large circumscribed lesions, or have any of the reactive bone (periosteal and endosteal reactions), seen in vertebral brucellosis (Capasso 1999; Ortner 2003). This case therefore remains undiagnosed.

Metabolic disorders

Metabolic disorders are the result of an excess or deficiency in dietary requirements or hormone disturbances (endocrine disorders). These disorders manifest in the skeleton as an increase or decrease in bone turn over, which may be a biological artefact of conditions experienced earlier in life (for example, rickets) or they may represent active disorders at the time of death (for example, osteomalacia).

At Pheasant Wood, a total of 34 individuals (14%; 34/250) presented bone changes consistent with metabolic disorders. They involved 1% (51/4235) of all skeletal regions. The majority of bone changes (10%; 25/250) were porosities on the orbital roof (cribra orbitalia) and the outer table of the cranial vault (porotic hyperostosis). These lesions have traditionally been attributed to iron deficiency anaemia in which marrow expansion causes diploic hyperplasia (thickening) and resorption of the outer table, which exposes the underlying trabeculae (porosity) (Mays 2012). Iron deficiency anaemia may be inherited or acquired (Mensforth *et al.* 1978). It may arise as a result of a number of factors, including a lack of iron in the diet, the inability to absorb the iron in the diet (for example, a lack of vitamin C makes it harder to absorb iron), parasitic infestation in the gut, malaria, and lead poisoning (for example, Stuart-Macadam 1991). A depleted iron status may be associated with infection, whereby iron is withheld from invading micro-organisms to prevent microbial growth (Weinberg 1992). Thus, it is considered to be a defence mechanism against increased pathogen loads (ibid.). However, more recently, Walker *et al.* (2009) have indicated that iron deficiency may not cause bone marrow hyperplasia and suggest that the lesion could relate to a deficiency in vitamin B12 and/or folic acid (megaloblastic anaemia) instead. In addition, unless expansion of the diploic space can be demonstrated, porosity of the orbital roofs may occur in a variety of other conditions, such as rickets or scurvy, which may also lead to thickening of the cranial bones, although not through marrow hyperplasia (Mays 2012, 293). Regardless of aetiology, cribra orbitalia and porotic hyperostosis are often employed as one of a suite of skeletal indicators (enamel hypoplapsia and periostitis among them) of non-specific health stress, to evaluate the overall burden of disease in archaeological populations (for example, Steckel *et al.* 2009). Cribra orbitalia develops in sub-adults and may heal over the lifetime of an individual (Stuart-Macadam 1991). The low prevalence rates observed at Pheasant Wood may be because the majority of individuals were adults, or because dietary deficiency (or infection) was minimal during childhood.

Bilateral Harris' lines were observed on the radiographs of 2.8% (7/250) of all individuals. Harris lines present as multiple transverse lines of radiodensity on the long bones (tibiae and femora). Similar to enamel hypoplasia (EH) on the teeth, their presence and location is believed to be an indicator of growth arrest as a response to childhood physiological stress. The prevalence rates, at Pheasant Wood, for EH (21.6%) and Harris' lines (2.8%) differ and may reflect differences in the stability of teeth and the long bones, and/or a different aetiology (McHenry and Schulz 1976). According to Aufderheide and Rodríguez-Martín (1998, 422), Harris' lines can be associated with single, periodic or chronic episodes of physiological stress, due to metabolic or endocrine disturbances. Furthermore, their location can indicate the timing of these episodes. Where distal portions of the bones are affected the period of physiological stress may have occurred during infancy or puberty (ibid. 1998). Body 3238B (prime adult; 26-35 years) had multiple Harris' lines (a minimum of seven), which may suggest sustained physiological stress during childhood.

Cribra orbitalia, porotic hyperostosis and Harris' lines are of limited value in the context of identification. However, other metabolic conditions were observed on three individuals, which have greater potential. The first was a young adult (18-25 years), 0675B, who exhibited unilateral bowing of the proximal shaft of the left humerus (upper arm), with associated flattening. The radiograph showed osteopenia (loss of bone mineral density), but the underlying cause is unknown. Differential diagnoses include osteoporosis, osteomalacia (vitamin D deficiency), hyperparathyriodism and neoplastic disease. Another individual, 0267B, a mature adult (36-45 years), also exhibited a bowing deformity with associated flattening of both humerii. The radiological appearance of these bones showed that they were demineralised with areas of increased density. Changes were also visible on the adjacent ulna (forearm) and micro-fractures were present in the area of the pubic ramii of the pelvis. This suite of changes may be the result of a metabolic imbalance, possibly osteomalacia or a developmental anomaly. In addition, one or more pathological conditions may have been present here. Symptoms associated with vitamin D deficiency can include muscle weakness and cramps, fatigue and immunocompromise. While the diagnoses for these two cases are unconfirmed, the affected limbs in both individuals may have presented as visible deformities and/or some level of disability during life.

Individual 2896B, of prime adult age (26-35 years), presented bone changes that involved multiple areas of the skeleton (skull, ribs, vertebrae, long bones). Radiological investigation identified little differentiation between the outer cortical and inner trabecular bone and a loss of medullary cavity space, changes which were also visible macroscopically in those long bones that had fragmented post-mortem. A second opinion from an experienced radiologist was sought (P Hacking pers. comm.), in an effort to determine the disease process and impact that this may have had on the living individual. It was concluded that, although non-specific in nature, this individual exhibited bone changes (increase in trabecular bone quantity) consistent with chronic anaemia. Chronic anaemia causes fatigue and leads to the development of numerous, more minor, ailments due to an immuno-crompromised state. This individual also presented other changes (for example small epiphyses in relation to long bone shafts), which may be part of the same disease process and/or another pathological condition.

Congenital and developmental conditions

Congenital and developmental conditions occur during growth and development *in utero* and during childhood. Many of these conditions are abnormalities observed in the spinal column (for example, spina bifida occulta) (Barnes 1994). Symptoms may manifest in later life, but in most cases these changes have no or only a minor effect on the individual, who is usually unaware of their presence.

A total of 40% of individuals (100/250) presented congenital or developmental defects corresponding to defects in 161 different regions (4%; 161/4235). The majority (78%; 126/161) were mid-line defects involving the spine (cervical, thoracic and lumbosacral) and associated structures (for example, occipitalisation which involves the cranium) and ribs.

Mid-line defects involving the spine included congenital caudal and cranial shifting, hemi-vertebrae, Klippel-Feil Il syndrome (block vertebrae), neural arch defects, lumbarisation and sacralisation (partial and complete), supernumerary and absent vertebrae. Midline defects involving the ribs included supernumerary and absent ribs. Midline defects involving the spine are congenital in origin and are a consequence of foetal stress during early intrauterine life (first trimester), often originating from maternal stress such as dietary deficiency in the mother (Tobias and Cooper 2004).

Compared with more ancient archaeological populations (for example, see Roberts and Cox 2005), the frequency of mid-line defects was very high at Pheasant Wood. A high prevalence of lower spine and sacral defects has also been observed among other First World War soldiers besides Pheasant Wood (Cox pers. comm. 2009), as well as modern Guatemalan Mayan populations (Barker pers. comm. 2010).

While the presence of midline defects may be unknown in the individual (supernumerary ribs can cause problems depending on the location), foetal programming in conjunction with environmental factors at critical stages in early development increase the risk of developing other chronic diseases (for example, diabetes) and may affect bone mass and growth (Tobias and Cooper 2004). It is not possible to determine the pathological sequelae, if any, from the affected individual's skeleton. However, the presence of these defects at Pheasant Wood may have contributed to some of the other pathological conditions observed (on both bones and teeth), and may have had a detrimental effect on adult stature, preventing individuals from reaching their full height potential. In addition, where maternal dietary deficiency has played a role in the manifestation of defects, the factors that influenced this (for example, socio-economic status and environmental conditions) may persist into infancy and childhood, which may cause growth disruption, for instance in the form of EH and Harris' lines (see above). Considering the relatively low prevalence of EH and Harris' lines among the Pheasant Wood individuals, it would seem that this may not have been the case and perhaps suggests that they were sufficiently robust to withstand physiological stresses, or that detrimental living conditions did not prevail.

One of the spinal defects that was observed was of particular relevance to identification because it is likely to have caused visible changes in the face and neck and restricted the range of movement in these regions of the body. The changes were observed on individual 0674B, a prime adult (26-35 years), who presented complete occipitalisation of the atlas. This condition involves the incorporation and assimilation of the first cervical vertebra with the occipital at the base of the cranium (Barnes 1994). Occipitalisation can be partial or complete and there may be associated changes in other cervical (neck) vertebrae (ibid.). In 0671B the incorporation of the atlas into the occipital affected the midline positioning of the head, which appeared to be twisted to one side. The biological response to this condition is a compensatory muscular involvement, which brings the head back into the midline, and was visible on the skeleton as scoliosis (lateral bending) in the cervical vertebrae and torsion in the bones of the lower face (mandible). The resultant visible effects of this condition would have been asymmetry in the lower face and a torticolis (muscles of the neck pull to one side) of the neck, with the latter involving lack of usual articulation, probable stiffness and unusual posture of the head and neck. It may have caused ataxia, or weakness, of the lower legs, numbness or pain in the extremities, or a dull ache in the upper neck and occipital region (Black and Scheuer 1996, 189). Other bony changes (scoliosis and degenerative joint changes) in the thoracic, lumbo-sacral spine and pelvis were also apparent. These were probably secondary and may have caused stiffness or pain in the spine and joints of the hips. Another prime adult individual (2919B) had partial occipitalisation of the atlas, but unlike 0674B this did not appear to have affected other areas of the skeleton. Thus, the condition probably had no, or little, impact on the life of this individual.

Congenital/developmental defects observed in the limbs included bowing (which may also have a metabolic aetiology) and examples of bilateral coalition and bifurcations of carpal and tarsal bones in the hands and feet. Bowing of the lower limb bones affected three individuals, 1528B, 1871B and 1828B. In 1528B, the changes were observed as marked anterior bowing of the femurs; in 1871B, as marked lateral bowing of the femurs; and in 1828B, as slight bowing of the tibias. The changes in all may refer to childhood rickets (vitamin D deficiency), in which it is typical for the poorly mineralised weight bearing bones of the skeleton to bow when a child starts walking (Brickley and Ives 2008). Rickets may cause stunted growth and it is perhaps relevant to note that the stature calculated for 1871B (5′3″; 1.62m) was short compared with the rest of the Pheasant Wood group. The stature of the other two individuals was considered to be tall (1828B) and unremarkable (1528B). However, bowed long bones may also have a non-specific developmental cause. Considering that none of the individuals considered here showed any other changes on their bones consistent with childhood rickets, this is the preferred diagnosis (hence their inclusion in this section).

The coalitions and bifurcations observed in various bones of the hands and feet may be entirely genetic in origin, or they may be the result of environmental factors leading to the non-union of ossification centres during growth and development (Stevenson and Hall 2006). Of particular relevance for identification is the fact that, while they may be asymptomatic, they may also cause limited foot movement (rigid flat foot and impaired inversion), equinovarus angulation, pain (especially in association with periods of activity), difficulty walking on uneven ground and/or heel valgus (Stevenson and Hall 2006). At Pheasant Wood, three individuals had bilateral (0378B and 2798B) or unilateral (1266B) coalitions involving the calcaneus and navicular bones of the foot. In 0378B osteoarthritis was associated with the condition increasing the likelihood that the individual had felt pain or discomfort in both of his feet. None of the cases (in as far as it was possible to tell) appeared to have suffered outwardly visible deformities in life as a result of the coalitions.

Two individuals had unilateral (1833B) or bilateral (3194B) bifurcated tarsal bones in their feet. In both cases the medial cuneiform was involved. The changes may have been asymptomatic or have caused pain or discomfort in the mid-foot area.

Lastly, three individuals had unilateral (1116B and 2940B) or bilateral (2794B) coalition of the lunate and triquetral bones of the hand. Although previously considered to be asymptomatic, it is now recognised that the condition may cause pain (Marburger and Burgess 1995). Impaired function is another clinical feature of wrist bone coalitions, although this is rare and, unlike the Pheasant Wood cases, only really applies to the involvement of multiple bones (Stevenson and Hall 2006).

Joint disease

Several different types of joint disease were observed, including osteoarthritis, osteophytosis, Schmorl's nodes, erosive arthropathy and degenerative changes which were secondary to trauma. A total of 185 (74%; 185/250) individuals, or 470 (12%; 470/4235) body regions had one or more of these. The most frequently affected was the spine (cervical, thoracic and lumbo-sacral), which accounted for 60% of all affected body regions (284/470).

The appearance or extent of these different joint diseases does not necessarily correlate with symptoms; while some individuals may have experienced pain or discomfort, many would not have.

Osteoarthritis

Osteoarthritis (OA) affects the synovial joints and is the most common joint disease observed in both modern and archaeological populations (Rogers and Waldron 1995). On dry bone it is diagnosed by the presence of eburnation (polishing due to loss of cartilage and bone-to-bone contact) and/or a combination of at least two of either, porosity, new bone (osteophytosis) around and/or on the joint, and alteration of the contours of the joint (Rogers and Waldron 1995). Genetic and systemic predisposition, obesity, age, sex, disruption to the mechanics of a joint following trauma and mechanical stress are among the factors that may cause OA (Rogers and Waldron 1995). In addition, the advancement of age increasingly becomes a predisposing factor in this disease.

In modern 20th-century populations some patterns of joint involvement have been found to have distinct epidemiological features (Waldron 1994). For example, OA of the knee and hand are positively associated with obesity and/or hypertension (Dieppe 1994). Research has identified a correlation between OA and activity, including hip (femur/acetabulum) OA and farming (Croft *et al.* 1992) and patterns of hand and wrist OA and textile working (Hadler *et al.* 1978). In addition, OA involving the lateral part of the elbow may be directly associated with activity because of the biomechanics in this part of the joint (Ortner 1968). However, the relationship between the disease and activity is a very complex one in which many factors come into play (Jurmain 1999). For example, mechanical stress from an early age may actually reduce susceptibility in later life (Bridges 1993; Knüsel 1993), and rather than being a predisposing factor in the disease, activity may be more influential in determining which joints are affected (Rogers and Waldron 1995). Joint stiffness, pain, swelling in the area of the affected joint and limited joint mobility are among the symptoms associated with the disease.

The prevalence of OA was low at Pheasant Wood, involving just 25 individuals (10%; 21/250). The joints of the hips, hands, feet and elbow were affected by the disease, which was primarily observed among older individuals. In total, 6.5% (9/138) of all young adults, 14.8% (12/81) of all prime adults and 16% (4/25) of all mature adults were affected. These results are not surprising, given the predominantly young age of the individuals. None of the affected individuals presented a pattern of skeletal involvement that could be attributed to a specific cause, although in eight of the individuals (0486B, 1119B, 1388B, 1390B, 2044B, 2525B, 3165B), the changes were secondary to ante-mortem trauma (see below).

Osteophytosis

Osteophytosis was most common in the spine, but also involved the mandible (TMJ) and joints of the hands, feet, elbows, hips, knees and sacroiliac joint of the pelvis. Ostephytosis is positively associated with increasing age and can occur on its own as a result of generalised 'wear and tear', or in association with other changes as part of a disease process (for example, OA). On its own, osteophytosis is of limited value in assisting with identification and is therefore not considered further here.

Schmorl's nodes

Schmorl's nodes are caused by intervertebral disc herniation into the vertebral body. They are identified on bone as depressions, either on the superior or inferior surface (or both) of the vertebral bodies. A total of 61.6% (154/250) of all individuals from all age groups had Schmorl's nodes. The majority of lesions occurred in the thoracic vertebrae, followed by the lumbar spine.

Modern clinical studies on cadavers and living subjects show that prevalence rates in adult males and females vary from 4%–48%, and that prevalence increases with the advancement of age (Gali *et al.* 2009; Sonne-Holm *et al.* 2007; Williams *et al.* 2007). Although associated with degenerative disease, Schmorl's nodes have been linked to activity and trauma, especially in adolescence, or metabolic disorders (Jurmain 1999). Clinically, Schmorl's nodes usually present no symptoms and are so common that they are regarded as normal variation by some (Dieppe 1987).

Schmorl's nodes were observed in young and old individuals at Pheasant Wood. The lifestyle of the infantry soldier, which would have involved sustained carrying and walking with heavy military issue packs (60lbs), may have contributed to the high prevalence rates (61.6%) observed here.

Erosive arthropathy

Two individuals, 3211B (prime adult 25-35) and 1212B (mature adult 36-45) had erosive lesions involving the bones of their hands, differentially diagnosed as gout or joint cysts. Gout can be a familial disease and is associated with excessive alcohol intake, obesity, high blood pressure and kidney problems (Roberts and Cox 2003). Symptoms primarily include sudden acute pain in the affected joint, swelling, inflammation and itchy, flaky skin.

Secondary joint disease

Eight individuals (0266B, 0486B, 1119B, 1388B, 1390B, 2044B, 2525B, 3165B and 3168B) had secondary joint changes as a result of ante-mortem fractures and subluxation (dislocation) in an associated bone or bones. In seven individuals, the secondary changes were consistent with OA (see above), but in individual 0266B, they were in the form of inflammation (increased porosity) in the acetabulum, associated with the partial subluxation of the left hip joint (recorded under ante-mortem trauma below). The radiological appearance of this joint showed no evidence for osteomyelitis that may indicate septic arthritis. The inflammation may have caused discomfort and pain in the hip, the mechanical properties of which had been altered by the dislocation. In life, these changes may have manifested as either a slight limp, stiffness in movement or an altered gait.

Circulatory disorders

Circulatory disorders are the result of a loss or reduction in blood supply to the bone and may result in necrosis of the affected region and subsequent dysfunction. Bone changes consistent with circulatory disorders were observed in 9.2% (23/250) of all individuals and affected 0.8% (32/4235) of all body regions. They include possible Scheuermann's disease, Osgood-Schlatter disease, osteochondritis dissecans and psuedo osteochondritis dissecans. All individuals with circulatory disorders were adults, and in all the bone changes were long-standing and consistent with occurrence earlier in their lives.

Scheuermann's disease affects the spine of the growing individual, particularly males, and is characterised by erosion on the anterior surfaces of the vertebral bodies and loss of vertebral body height leading to kyphosis (anterior/posterior curvature of the spine) (Scheuermann 1921; Aufderheide and Rodríguez-Martín 1998, 87). The onset of the disease is usually between 12 and 18 years. Trauma, genetics and defects in the underlying growth plate in the cartilage have all been implicated in its aetiology (Alexander 1977; Aufderheide and Rodríguez-Martín 1998). No confirmed cases of Scheuermann's were identified at Pheasant Wood because diagnosis rests on measuring wedging of the vertebrae (Scoles *et al.* 1991; Sørenson 1964), which was not possible here. However, suspected cases include five individuals (22%; 5/23), who had a combination of kyphosis, wedging of vertebrae reflective of anterior loss of body height and eroded vertebral bodies in the antero-lateral aspect.

Osgood-Schlatter disease is common among adolescent males who participate in sports. It arises when repetitive strain on the patellar ligament from the powerful pull of the quadriceps muscles causes avulsion of part of the developing tibial tuberosity (DiGangi *et al.* 2010; Gholve *et al.* 2007; Ortner 2003; Resnick 1995). Whether the avulsed fragment fuses with the tibial metaphysis or epiphysis, or remains detached as a separate ossicle (either may occur), there is thickening of the bone and soft tissue swelling, which, in a living individual, may be visible as a bulge below the knee cap (Aufderheide and Rodriguez-Martin 1998; DiGangi *et al.* 2010; Gholve *et al.* 2007; Ortner 2003; Resnick 1995). The condition can be unilateral or bilateral and it is associated with chronic tenderness in the region. Osgood-Schlatter disease was observed on one individual (1684B, prime adult 26-35 years) from Pheasant Wood, who had bilateral involvement.

Osteochondritis dissecans refers to focal necrosis on the convex joint surface of diarthrodial joints. It is caused when a small segment of subchondral bone and articular cartilage detach, leading to avascular necrosis of this bone fragment. It is often associated with younger individuals and is probably traumatic in origin, although a familial history has been identified and detailed in clinical cases (Resnick *et al.* 1995a, 2611). Evidence of long-term healing in older adults is a rounded pit on the articular surface, and on occasions ossification of the formerly detached fragment is also observed. Pseudo-osteochondritis dissecans occurs on the concave surface of a joint. However, opinion varies as to whether this is true osteochondritis (Aufderheide and Rodríguez-Martín 1998, 81-82). Complications associated with this condition include clicking of the joint, localised pain, swelling and limited motion, although it may also be entirely asymptomatic (Resnick *et al.* 1995a, 2611). Osteochondritis dissecans, including pseudo-osteochondritis dissecans, involved 20 (87%; 20/23) of the individuals with circulatory disease from Pheasant Wood and was observed on the knee, elbow, foot and shoulder joints, which are all relatively common locations (ibid.)

Neoplastic disease

Neoplastic disease is an abnormal mass of tissue resulting from cell proliferation and new growth exceeding that of the surrounding normal tissues (Aufderheide and Rodríguez-Martín 1998). Neoplasms can be benign (not harmful), pre-malignant (without treatment they may become malignant) or malignant (harmful to health).

Neoplasms were identified on six individuals (2.4%; 6/250) and on five of them the changes were consistent with benign button osteomas on the cranium. These are small, circular, circumscribed ivory-like growths that usually measure no more than 20mm in diameter and are composed of lamellar bone (Ortner 2003). They usually occur on the frontal and parietal bones of the skull and although their aetiology is unknown, developmental conditions, trauma and infection have all been suggested (Eshed *et al.* 2002). The benign nature of this condition means that it is of limited significance for identification. It does not usually have any outwardly visible signs or symptoms and therefore knowledge of its existence in living individuals is unlikely. Further, while it may be recorded on an ante-mortem radiograph, none exist for the Pheasant Wood individuals.

Besides button osteomas, radiographs of 1834B (young adult 18-25 years) identified an ellipse-shaped fibrous cortical defect with lobulated borders and sclerotic bone on the left distal femur, although no macroscopic changes, such as a periosteal reaction, were observed (Fig. 4.42). These changes are consistent with a benign neoplasm, the preferred diagnosis being a non-ossifying fibroma. References in the clinical literature (Kumar *et al.* 1991; Marks and Bauer 1989), show that the age and sex of the individual, and the location of the neoplasm, are consistent with this diagnosis. In modern populations non-ossifying fibromas, often discovered accidentally on radiographs, are common and affect up to 40% of children (Wheeless 2010). They tend to be asymptomatic, although individuals with these benign tumours are more

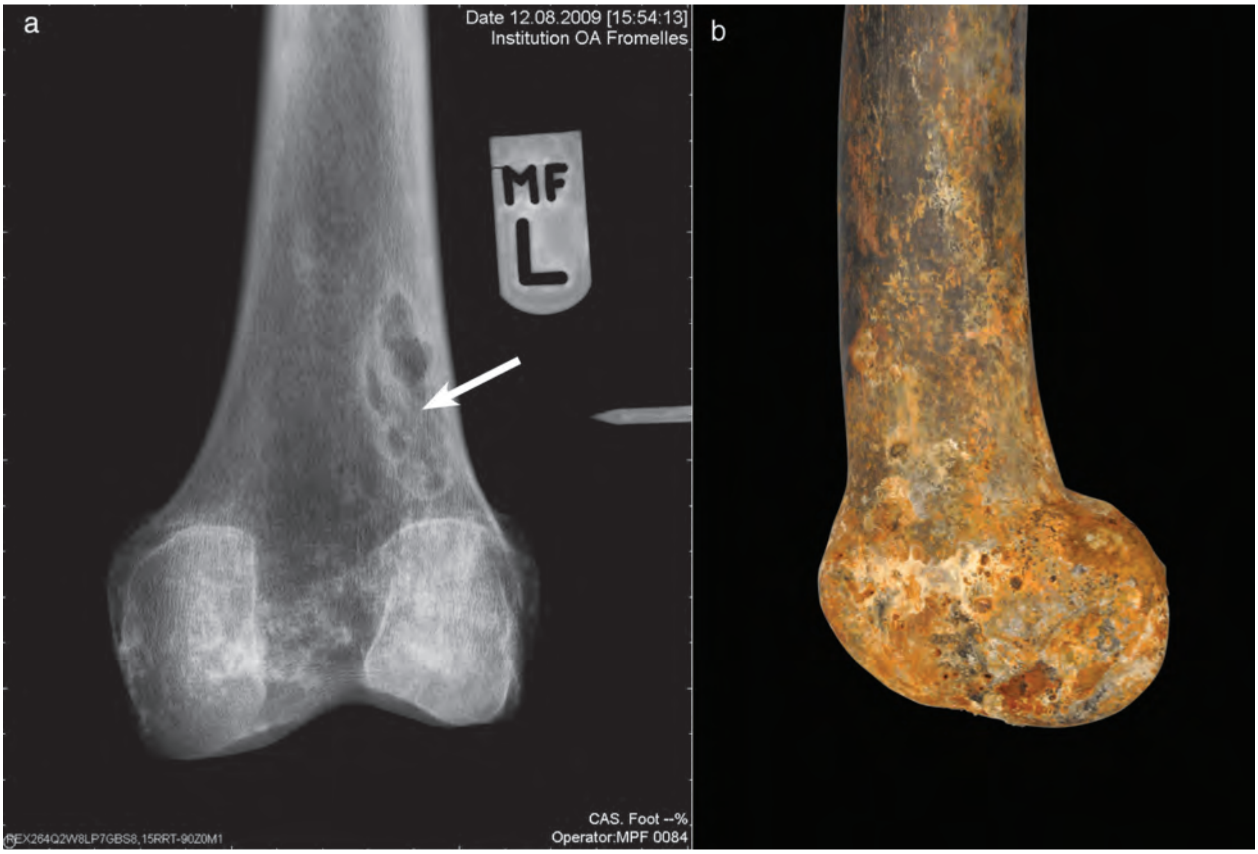

Fig. 4.42 a) Radiograph showing fibrous cortical defect on left distal femur (1834B); b) macroscopic appearance of left distal femur with a marked absence of pathological change (1834B)

prone to pathological fractures. No fractures were observed on the remains of 1834B, who was probably unaware of the neoplasm's presence.

Ante-mortem trauma

Trauma is an insult to the bone and / or surrounding tissues that disrupts the continuity of the tissue and results in fractures or dislocations (subluxations). Fractures and dislocations may be partial or complete and may be the result of an underlying pathology (pathological fractures), repeated stress or acute injury (Roberts and Manchester 1995). At Pheasant Wood, evidence of healed / healing trauma included that which involved just the bone, the bone and surrounding soft tissues, or just the soft tissues.

Fractures may be identified on bone by the presence of a healed or healing callus, a swelling or thickened area, resulting in discontinuity of the alignment of the bone. Diagnosis often relies on radiographs, which may show the fracture margins, even in healed fractures, as areas of differential bone density. Trauma involving the soft tissues may lead to myositis ossificans traumatica, a condition in which soft tissues may ossify and present as a bony mass (hence the survival of this condition into the archaeological record). Myositis ossificans traumatica may include the soft tissue structures of the periosteum, the muscle and its fascial sheaths, or the tendinous attachment of muscle to bone (Shipley 1940). It is observed on dry bone as isolated or attached lamellar bone fragments that have smooth, remodelled borders and are often spiculated in appearance (Fig. 4.43; Ortner 2003). Another type of soft tissue trauma is calcification of an undissolved haematoma, called a sub-periosteal ossified haematoma. Ossified haematomas may occur in cases of healed scurvy (Van Der Merwe *et al*. 2010), although they are more commonly encountered archaeologically as a result of trauma (Ortner 2003). Sub-periosteal haematomas are a natural stage in the healing process of deep tissue or bone injury, but they may fail to resorb and subsequently ossify when excessive stress is placed on the periosteum at the site of the injury.

Fig. 4.43 Myositis ossificans traumatica (white arrow); the red arrow points to peri-mortem trauma (1212B)

A total of 30% (75/250) of all individuals had evidence of ante-mortem trauma which involved 2.2% (95/4235) of all body regions. All regions were involved except for the neck (cervical vertebrae). A total of 83% (79/95) of all affected body regions involved trauma to the bone, 4% (4/95) involved bone and soft tissue (ossification), and 13% (12/95) were attributed to soft tissue injury only.

The greatest number of fractures were observed in the thorax (ribs and vertebral column), which accounted for 23% (22/95) of all observed trauma. This prevalence may be artificially high because it includes 10 individuals (four young adults, four prime adults and two mature adults) who showed involvement of the spine, of which not all are necessarily trauma related. Of these, one (2662B) had changes involving the sacrum that were consistent with a compression injury associated with a lateral compression fracture of the pelvis (Type B Young Burgess classification; Crawford Adams 1983). The remaining individuals displayed wedging of their vertebral bodies (thoracic and lumbar) to varying degrees, but this evidence was not conclusive enough to confirm a trauma related diagnosis. Although a vertebra may become wedge-shaped as a result of a fracture, it may also be related to other pathological conditions, such as those of a metabolic and developmental nature, that are not traumatic in origin. Depending on the extent of wedging, they may even be considered normal age related change (I Watt pers. comm. 2010). This means that the diagnosis of vertebral fractures often rests on the detection of a fracture line radiologically. However, this may or may not always be visible if the trauma is well healed and remodelled. No fracture lines were seen in the present examples, and therefore the diagnoses are very tentative and should be viewed with caution. However, whether the wedge-shaped vertebrae were or were not trauma related, this information is still useful for the identification process. The skeletal changes may have been associated with symptoms or effects (for example, pain, abnormal posture, impaired mobility) which may have been recorded at enlistment or afterwards if treatment had been required.

Cranial trauma included healed depressed fractures on the vault and fractures involving the nasal bones (broken nose). There was no evidence of any ante-mortem trauma to the mandible. Of the extremities, the right hand was the most frequently affected body region (4.5%; 11/247), with all cases being healed fractures, including one (2114B), which was a healed traumatic amputation. This trend probably reflects dominant hand use and its involvement in accidents, sport (such as boxing) and/or interpersonal violence. By comparison, four left hands had healed fractures and one left hand had an ossified haematoma.

Traumatic involvement (that is, any type of trauma) of the lower limbs (excluding feet) had a marginally higher prevalence rate (2%; 20/998), than that of the upper limbs (excluding hands) (1.6%; 16/998). Of the upper limbs, the bones of the forearm (radius and ulna) were more frequently affected than those of the upper arm (humerus). Defence injuries and accidental falls are often the cause of forearm fractures (Crawford Adams 1983) and probably account for many of these injuries seen among the Pheasant Wood individuals.

Of the lower limbs, fractures involving the bones of the lower leg (tibia and fibula) were more frequent than those of the thigh (femur). This corresponds to patterns observed in modern populations among whom fractures of the femur are relatively rare due to the density of the bone and the increased protection afforded by the surrounding soft tissues (Galloway 1999). Two individuals at Pheasant Wood presented complete healed fractures of the femur (0.8%; 2/250). Individual 0034B (young adult 18-25 years) had a well healed ante-mortem fracture to the neck of the right femur, which was visible macroscopically and on a radiograph. The status of healing was consistent with a fracture that had been sustained in childhood or early adolescence. No associated pathological changes were observed.

Individual 1683B (young adult; 18-25 years) exhibited a complete healed fracture of the left femoral shaft. The macroscopic appearance of the fracture was of a large, well healed, remodelled bony mass at the approximate midshaft, with overlapping fracture margins (Fig. 4.44), lateral displacement (to the extent that approximately a third of the fracture ends were not in apposition) and probable slight angulation of the distal end (unconfirmed owing to post-mortem fragmentation of the bone). Radiological investigation confirmed the fracture to be oblique in nature. All evidence, macroscopic and radiological, was consistent with the fracture being long-standing. Given this point, and considering the young age at death of the individual, it is likely that the fracture had occurred in childhood or adolescence. The overlap of the fracture margins suggests shortening of the left limb and the individual may have presented with a limp or uneven gait. Fractures of the femoral shaft are prone to overlap in the absence of applied traction due to the strong forces exerted in the region by the surrounding muscles. This may suggest that appropriate care at the time of the injury was unavailable.

The majority of the traumatic injuries observed were well healed, their status and appearance consistent with long-standing injuries. Many may have been asymptomatic, and/or forgotten about. Their usefulness for identification relies on suitable references in ante-mortem records. Nevertheless, a minimum of five individuals (1066B, 1688B, 1975B, 2340B, 2522B) had bone changes that were consistent with more recent trauma, probably occurring within two years prior to their deaths. These injuries are perhaps more likely to appear in enlistment/recruitment records, being more readily remembered or even visible. Alternatively, they may represent accidents happening whilst on active

Fig. 4.44 Radiograph (a) and macroscopic appearance (b) of healed fracture of the left femur shaft (1683B); right unfractured femur is also shown in the radiograph along with miscellaneous bone fragments from the same body

service. Which are usually recorded in available records where treatment was provided.

Individual 1975B (prime adult, 25-35 years) had a range of injuries involving the bones of his right side (thorax, abdomen). Some of these showed evidence for continued remodelling, and they may refer to a single incident (such as a fall) or multiple traumatic insults. Individual 2522B (prime adult, 25-35 years) presented misaligned, overlapping fractures involving the proximal third of the right tibia and fibula. Both bones were undergoing active remodelling at the time of death. The involvement of both bones would suggest that a substantial force had caused the injury (Galloway 1999). Furthermore, the overlapping fracture margins may have caused shortening of the right limb and the development of a limp or uneven gait. Individual 1066B had healing fractures involving the right hand and ribs, and 2340B and 1688B had healing fractures involving the ribs.

Of the examples of soft tissue trauma one is worth considering in detail here, because the lesions may have been caused by neoplastic disease instead. Body 1667B (young adult 18-25 years), had a raised area of cortical bone on the right tibia (leg), the radiographic appearance of which showed an area of increased density that was not reactive in nature (Fig. 4.45). The suggested differential diagnoses are an osteoid osteoma (neoplasm) or a calcified subperiosteal haematoma (trauma). Osteoid osteomas are small benign tumours of uncalcified bone matrix that consist mainly of collagen and are the result of an over proliferation of osteoblasts (Aufderheide and Rodríguez-Martín 1998, 376). They consist of a hard shell of thickened

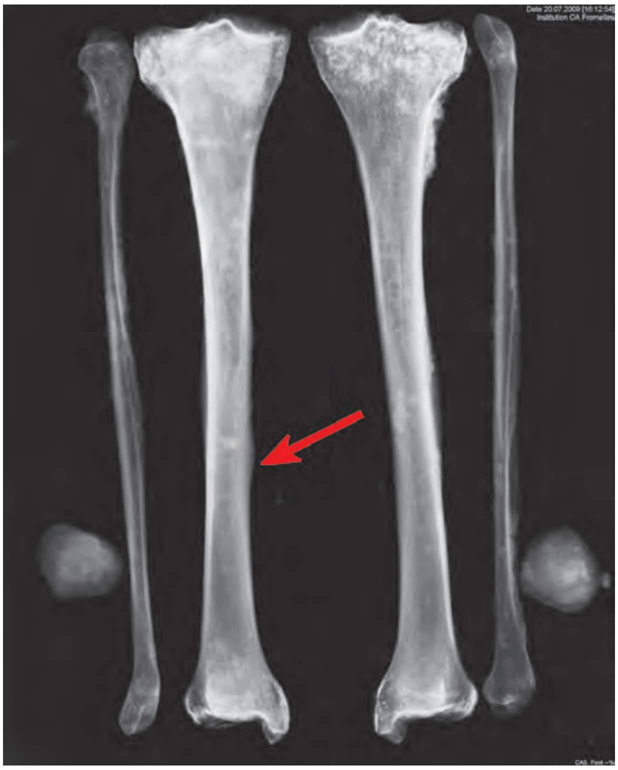

Fig. 4.45 Radiograph showing right and left lower limb bones (1667B); the right tibia has an area of increased density (arrowed)

bone that surrounds a centre of growing cells, identified radiographically as a centrally located round or oval radiolucent area surrounded by a zone of uniform bone sclerosis (Resnick 1995b, 3632). Macroscopically, calcified haematomas are characterised by localised, well-demarcated lesions of bone apposition (Van Der Merwe *et al.* 2010, 230) and when viewed on a radiograph lack the central sclerosis, seen in osteoid osteomas. In the present skeleton, the lack of bony reaction around the lesion, its location and the individual's age are all consistent with an osteoid osteoma (Ortner 2003; Resnick et al. 1995b, 3632). However, although the radiological appearance showed an area of sclerosis, there was no central radiolucent area, suggesting that a calcified haematoma is a more likely diagnosis. There were no visible signs of fracture (for example, a fracture line or mal-union) and therefore the injury may have involved the soft tissues only.

Miscellaneous conditions

A total of 35.2% (88/250) of all individuals and 3.3% (140/4235) of all body regions had miscellaneous conditions that do not easily fit into any of the above categories. Some are pathological but their aetiology is not fully understood (idiopathic) or their aetiology is attributed to more than one disease type, and some are anomalous or non-pathological in origin.

Hyperostosis frontalis interna

Hyperostosis frontalis interna is characterised by benign nodular overgrowth of bone on the inner table of the frontal bone. This condition is typically asymptomatic and is most commonly associated with post-menopausal females (Aufderheide and Rodríguez-Martín 1998, 419). It is of unknown aetiology, but in the clinical literature hormonal stimulation is implied in current hypotheses (She and Szakacs 2004). Individual 0271B (mature adult 36-45 years) displayed discrete nodular manifestations of lamellar bone on the endocranial surface of his frontal bone. The changes were clustered near the frontal crest and may represent the early development of hyperostosis frontalis interna. Considering the absence of ante-mortem radiographs and the asymptomatic nature of this disease, it is unlikely that the individual was aware of this condition.

Spondylolisis

Spondylolisis is a unilateral or bilateral defect in the pars interarticularis of a vertebra. The great majority of cases occur in the fifth lumbar vertebra, but other vertebrae can be involved. Its occurrence may be due to an underlying congenital weakness. However, the aetiology is likely to be traumatic, more specifically the result of repeated micro-trauma creating a stress fracture in the region (Merbs 1996). Individuals with bilateral defects can progress to spondylolisthesis, the gradual slippage of adjacent vertebral bodies due to their acquired instability. Lower back pain and sciatica may result from the condition(s), although usually symptoms are minor, or do not occur at all (Gunzburg and Szpalski 2006; Merbs 1996).

A total of 7% of individuals (17/250) had spondylolysis, with the majority (94%; 16/17) showing bilateral defects. All cases were restricted to the lower lumbar spine and only two (0.8%; 2/250) individuals showed bone changes consistent with early on-set spondylolisthesis.

Possible slipped femoral capital epiphysis (Developmental Dysplasia)

Slipped femoral capital epiphysis (SFCE) occurs when there is a stress fracture on the metaphyseal side of the growth plate and the neck of the femur leading to medial posterior and downward displacement of the femoral head and potential aseptic necrosis (Ortner 2003, 347). Obesity, trauma, hormonal influences, the adolescent growth spurt and inheritance all play a part in the manifestation of the disease, which most commonly occurs in boys between the ages of about 10 and 17 years (it occurs earlier in girls) (Resnick 1995a, 2646-2647). Failure of endochondral growth and attrition in the fracture area result in a shortened and thickened femoral neck, and degenerative joint disease is common (Ortner 2003, 347).

At Pheasant Wood two individuals (0.8%; 2/250) exhibited femoral head changes that may have been the result of SFCE. Individual 1360B, a young adult (18-25 years), had a left femoral head that was mushroom-shaped and was positioned lower than the greater trochanter. The femoral neck was widened, flattened and shortened; the acetabulum was shallow and elongated and the femoral head lacked the usual fovea capitis depression. Similarly, individual 1875B, also a young adult (18-25 years), had a mushroom-shaped right femoral head, a shortened femoral neck and loss of definition of the fovea capitis. Peri-mortem trauma involving the acetabulum precluded observation of the rest of this joint (Fig. 4.46). Mushroom-shaped femoral heads are not characteristic of SFCE, but are characteristic of Legg-Calvé-Perthes disease (LCPD), or idiopathic osteonecrosis of the proximal epiphysis of the femur (head) (Aufderheide and Rodríguez-Martín 1998, 84) which shares similar skeletal changes with SFCE. The condition arises when there is obstruction to the blood supply of subchondral cortical bone while the cartilagenous tissue continues to grow, which may be the result of trauma (ibid., 84). Re-vascularisation eventually occurs, but the interruption in the normal growth sequence can cause morphological changes to the proximal femur (ibid. 1998, 84). Characteristically, the head of the femur is mushroom shaped and secondary degenerative changes develop in the affected hip joint which may be flattened and widened (Ortner 2003; Herrerín and Garralda

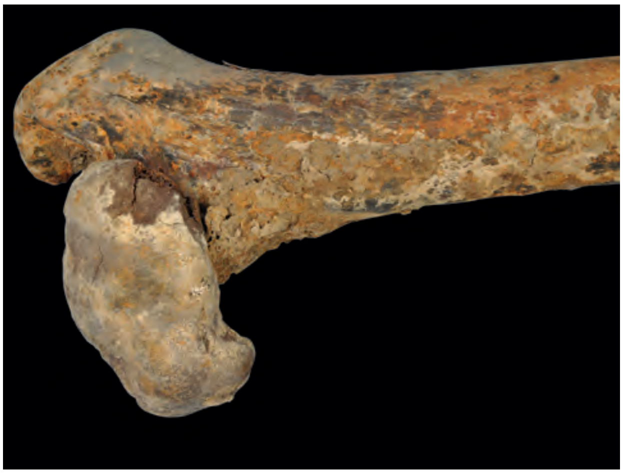

Fig. 4.46 Left femur with mushroom-shaped head (1875B)

2012). LCPD usually occurs between the ages of 3-12 years, it is more common among males than females and approximately 90% of all those affected show unilateral involvement (ibid., 84). Legg-Calvé-Perthes disease is very rare in modern populations, having a prevalence rate of only 0.023% (Gaughan *et al.* 2002). This perhaps suggests that SCFE is a more likely cause for the lesions observed on 1360B and 1875B. The fact that both individauls had shortened femoral necks is another factor that supports this interpretation, because the length of the neck is not usually altered in LCPD (Herrerín and Garralda 2012). Developmental dysplasia of the hip is another possibility, because a shallow, triangular-shaped acetabulum without dislocation and a mushroom-shaped femoral head and shortened neck are all consistent with this condition (Mitchell and Redfern 2008). Whatever the diagnosis, the conditions are likely to have been symptomatic in the living individuals and would have caused pain or discomfort and an altered gait.

Os acromiale

In this condition, the acromion process of the scapula (shoulder blade) remains separate from the spine of the scapula, instead of fusing to it at between approximately 18 and 20 years (Scheuer and Black 2000). A genetic component in the aetiology of this condition has been suggested, although it is generally regarded as a non-specific failure of union of the epiphysis (Sammarco 2000). In the archaeological literature the change is linked to repetitive activity involving the shoulder from a young age (Roberts and Manchester 1995). There is conflicting opinion as to whether it is associated with pain or is a precursor to other pathological conditions, such as impingement or tearing of the rotator cuff (Sammarco 2000). At Pheasant Wood, a total of 3.6% (9/250) of individuals had the condition, which is at the lower end of the range cited for modern populations, among whom the frequency varies between 1 and 15% (Sammarco 2000). Of the cases observed at Pheasant Wood, 33% were bilateral, 44% were observed on the right side only and 23% were observed on the left side only.

Other pathological changes/abnormalities

A range of minor bony changes, for example ankylosis (fusion of adjacent bones), idiopathic exostoses (localised and diffuse bone growth) and morphological anomalies, were also observed. As it is very likely that these were asymptomatic and the affected individuals were unaware of their presence in life, they will not be given further consideration here.

Peri-mortem trauma

Introduction

Peri-mortem trauma, an insult to the body around the time of death, may involve the soft tissues only, or the soft tissues and underlying skeleton. The skeletonised nature of the assemblage excavated at Pheasant Wood meant that only those injuries that had affected bone were available for examination, the details of which (including observations regarding the mechanism of death) are recorded in the confidential case reports for each soldier. An epidemiological approach is detailed here and includes consideration of ballistics evidence (see below for definition). Similarities and/or differences in wound location and type, and ballistics, across the assemblage and between the graves is also explored.

While the assessment of wounds and injury patterns can contribute to our understanding of the mechanism of death (defined here as the causal force, for example projectile or blast), the particular injury that caused death in the theatre of battle is difficult to determine in the absence of the soft tissues. In the context of an active battle, with sustained barrages of explosive artillery and small-arms fire, it is likely that many of the soldiers will also have sustained injuries and assaults to the skeleton post-mortem, or whilst lying on the ground (see later discussion). Wound signatures immediately after death will be the same as those that caused death, as the intrinsic properties of bone do not alter in the immediate post-mortem period. Fracture pattern characteristics can assist in the sequencing of multiple injuries (Moraitis *et al.* 2009; Finnegan 2008; Galloway 1999), and evidence to this effect was noted at the time of analysis and in case reports. This, however, is not within the scope of the aims and objectives and will not be detailed here.

A conservative and objective approach has been employed in the assessment of peri-mortem trauma at Pheasant Wood. Thus, the mechanism of death may fall into one category or span multiple categories (projectile, blunt force, sharp force, and blast force) or cannot be determined (causal force unknown). Patterns of injuries were determined through the frequency of wounds to particular body regions, and by calculating prevalence of multi-trauma (multiple injuries on an individual affecting more than one body region) across the assemblage and in the different graves. The results were presented in a separate article (Loe *et al.* 2014), and the following is taken from this.

Overall findings

Skeletal injuries caused by firearms, explosive munitions and/or bladed weapons were observed on 231 individuals (92.40%; 231/250). Evidence for peri-mortem trauma was not observed on 19 individuals (7.6%; 19/250). Wounds sustained to the thorax, head, neck and abdomen were common, while the extremities were the least frequently affected regions (Fig. 4.47). The head and thorax had significantly higher frequencies ($p<0.0001$) of wounds compared with the right and left lower limbs (Table 4.20; Appendix Three). A total of 201 individuals with peri-mortem trauma had lesions that could be attributed to one or more causal force categories, based on individual wound characteristics and/or overall patterning of lesions on the skeleton. The most frequent category was projectile (60.16%; 151/ 251), followed by blast (31.08%; 78/251), then blunt force (8.37%; 21/251) (Table 4.21). Sharp-force trauma was observed on one individual only (0.40%; 1/251). For a further 30 individuals it was not possible to determine a causal force because lesions showed no distinctive wounding characteristics and/or lacked information owing to bone loss as a result of the trauma. The values presented here, therefore, should be regarded as an absolute minimum.

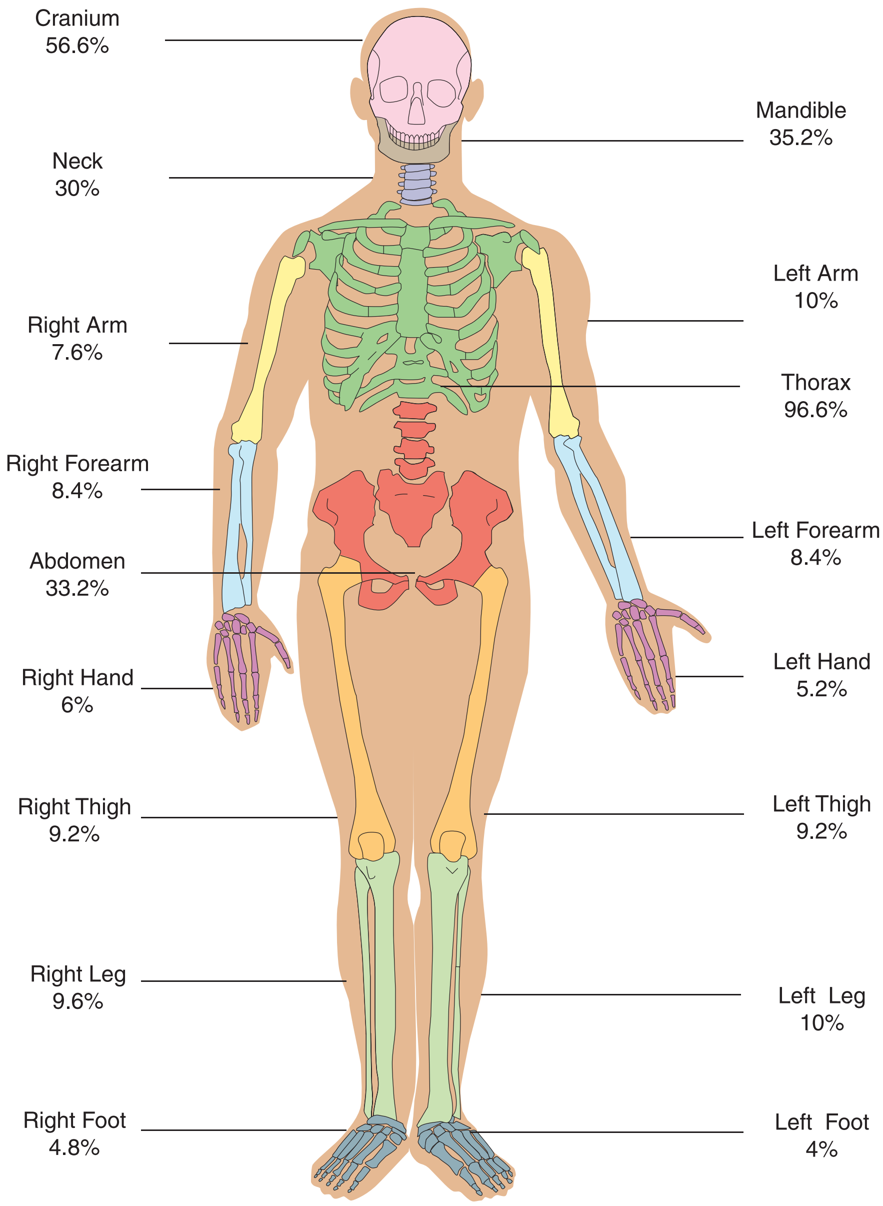

Fig. 4.47 True prevalence rates of peri-mortem injuries observed

Table 4.20: Anatomical distribution of peri-mortem trauma by body region, graves one to five

Body region	Grave One		Grave Two		Grave Three		Grave Four		Grave Five		Grave Six	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Head	24	25.5	47	24.1	33	26.6	19	23	16	18.8	0	/
Neck	5	5.3	43	22.1	11	8.9	7	8.3	8	9.4	0	/
Thorax	30	32	47	24.1	31	25	24	28.6	23	27	0	/
Abdomen	10	10.6	25	12.8	12	9.7	11	13	7	8.2	0	/
L upper limb	3	3.2	8	4.1	9	7.25	5	5.9	8	9.4	0	/
R upper limb	4	4.2	6	3	9	7.25	6	7	9	10.6	0	/
L lower limb	9	9.6	7	3.6	10	8	7	8.3	10	11.8	1	100
R lower limb	9	9.6	12	6.2	9	7.25	5	5.9	4	4.7	0	/
Total	94	100	195	100	124	100	84	100	85	100	1	100
Total no. skeletons	50		51		52		50		44		3	

n = number of body regions with peri-mortem trauma; % = relative percentages calculated on total number of injuries

Table 4.21: Pheasant Wood frequency of peri-mortem trauma by causal force (n=201 soldiers with peri-mortem wounds classified to causal force)

Type	*Number of individuals*	*%*
Blast	78	31.08
Projectile	151	60.16
Blunt	21	8.37
Sharp	1	0.40
Total number of individuals with lesion(s) attributed to one or more causal forces	251	

Table 4.22: Pheasant Wood true prevalence of peri-mortem trauma by causal force and body region

	Blast	*Firearms*	*All projectile (inc. 8 with firearms)*	*Blunt*	*Sharp*
Head	62/250 (24.8%)	2/250 (0.8%)	57/250 (22.8%)	9/250 (3.6%)	0
Neck	48/250 (19.2%)	1/250 (0.4%)	15/250 (6.0%)	0	0
Thorax	67/250 (26.8%)	4/250 (1.6%)	60/250(24.0%)	9/250 (3.6%)	1/250 (0.4%)
Abdomen	37/250 (14.8%)	1/250 (0.4%)	23/250 (9.2%)	2/250 (0.8%)	0
Left upper limb	13/250 (5.2%)	0	12/250 (4.8%)	0	0
Right upper limb	12/250 (4.8%)	2/250 (0.8%)	18/250 (7.2%)	1/250 (0.4%)	0
Left lower limb	11/250 (4.4%)	2/250 (0.8%)	20/250 (8.0%)	0	0
Right lower limb	12/250 (4.8%)	1/250 (0.4%)			

A total of 251 blast, projectile, sharp- and/or blunt-force wounds were seen among the 201 individuals with wounds that could be classified. This gives an average of 1.25 (251/201) classified wounds per soldier. This number increases to 1.69 per soldier if a further 89 lesions that could not be classified to causal force, are included. More than a third of individuals (39.39%; 91/231) with peri-mortem trauma had multiple-traumatic lesions, meaning that they showed evidence for injury due to more than one type of force. However, this value includes 37 individuals who had lesions that were only possibly caused by another or other causal force, but the evidence was inconclusive. Thus, if these individuals are discounted the number with trauma due to more than one type of force is reduced to 54 (23%; 54/231). Individuals with more than one injured body region irrespective of the number of causal insults ('multi-trauma' in Appendix Three) totalled 140 (56%; 140/250).

It is difficult to say how these numbers translate into the actual number of injuries, or even trauma events, sustained by the soldiers. Lesions on skeletons that clearly referred to more than one wound were difficult to isolate from one another because extensive comminution and bone loss often blurred distinction between them, and primary impact sites were often not seen. In addition, blast-force trauma was often diagnosed based on a combination of lesions and their patterning (for example, the presence of multiple injuries involving one side of the body. Thus, 340 (251 classified in addition to 89 unclassified) should be regarded as a minimum estimate of the total number of wounds sustained.

Wounding mechanisms (explosive munitions, firearms and/or assault with a blade or blunt instrument) are explored in the following sections by discussing the different categories of trauma observed, with examples of each.

Blast trauma

Blast trauma was observed on 78 individuals(39%; 78/201), making it the second most frequent type of trauma. This refers to skeletons that showed the patterns described in Chapter Two ('Methods'), with the exception of those that solely had projectile and/or blunt-force injuries because these may have been caused by other mechanisms. In 28 individuals, blast was the only trauma observed, while in 50 it was accompanied by projectile, blunt, sharp and/or peri-mortem trauma that could not be classified. All body regions were affected, but the most frequently involved were the thorax (86%; 67/78), followed by the head (79%; 62/78) and neck (62%; 48/78) (Table 4.22). In the majority of cases (55%; 43/78), all of these three body regions were involved together.

Injuries were essentially characterised by extensive trauma, seen as mass comminution of elements, amputation, loss of bone tissue and fracture margins that were sheared, complete and multidirectional. The pattern of trauma of the cranial vault and thorax, shown in Fig. 4.48 (0821B) is typical of the blast trauma seen in the assemblage. Here, multidirectional, complete, shear fractures through dense bone and joint surfaces (in the present case, the petrous portion of the temporal bone and the glenoid fossa of the scapula), some with 'twig peel' margins, were observed. Tearing and cracking were also observed on thinner bones (in this case, the blade of the scapula), in addition to burst and shear fractures in the vertebral column.

Burial position was consistent with the extent of disruption caused by the blast force. For example, the position of one individual (3147B) suggested that he had been wrapped in a groundsheet in a ball. Upon examination the individual was found to have comminuted, multidirectional trauma involving multiple regions of the skeleton. The changes were accompanied by embedded metal fragments and were consistent with blast trauma. This example, however, was an extreme case and, with the exception of some loss of integrity of one or two limbs due to partial or complete amputation, almost all skeletons were lying with their upper and lower limbs extended and bones in correct anatomical position.

Traumatic limb amputation, defined here as partial or complete removal of portions of limbs, was observed in at least 15 individuals, or 19.23% of those with blast trauma (15/78), and involved 19 upper and lower limbs. Upper limbs were involved more frequently (10/15 individuals; 10/19 limbs), such as the case of one individual (2203B) who had lost bone at the site of peri-mortem fractures involving his right humerus, radius and ulna. When the individual was excavated, his right upper limb was found in an anatomically in-correct position, consistent with part of it having been amputated around the time of death. The left mid-thigh and the leg of same individual had also been amputated and was also lying in an anatomically incorrect position. The individual had also sustained massive comminution trauma to his head, thorax, and right and left hands. There were multiple projectile injuries to his right femur and tibia that were not consistent with gunshot injuries, and they were accompanied by a large amount of probable fragmented weaponry. These patterns are consistent with massive high energy trauma, as would be caused by explosive munitions. This was the only individual found who was still wearing his webbing and live rounds, these items having been removed from all other soldiers by the Germans for their own use. They had probably not been

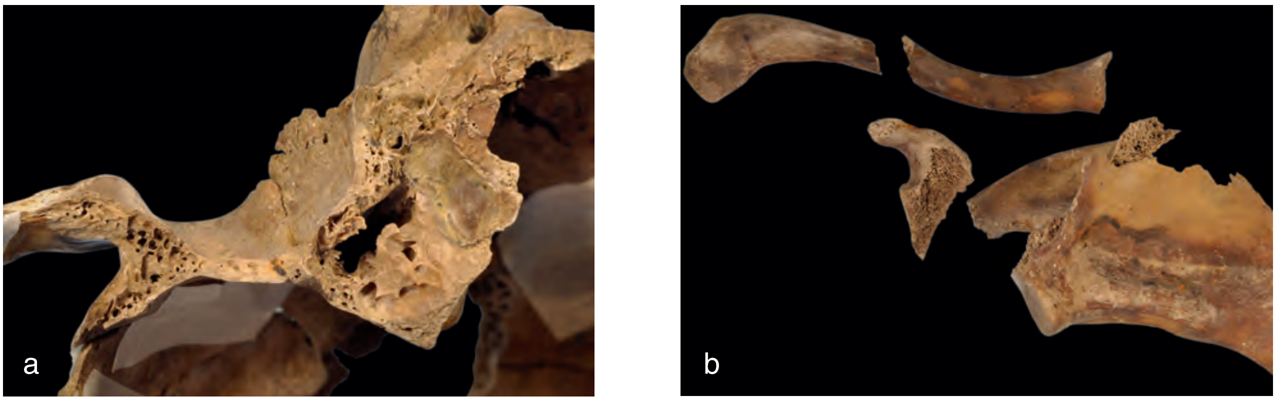

Fig. 4.48 Detail of blast trauma lesions sustained to the cranial vault (a) and thorax (b) of 0821B, showing complete shear fractures to the petrous bone and glenoid of the scapula.

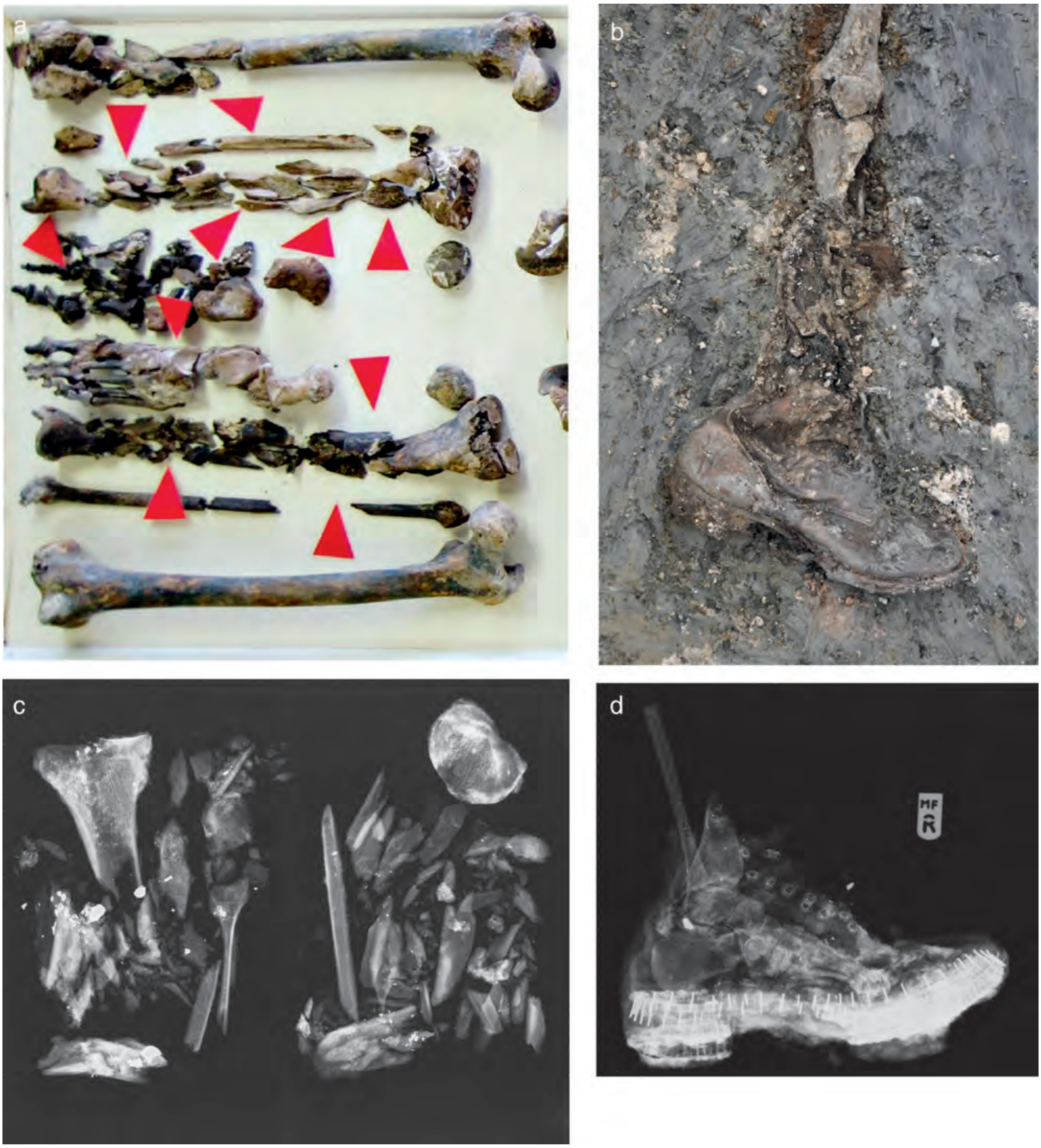

Fig. 4.49 3089B: Bilateral partial limb amputation observed as mass comminution of right and left tibiae and fibulae, and right femur and foot bones; a) laboratory, b) in situ, c) radiographic image, d) radiographic image

removed from this individual because the trauma was so extensive and consequently the task of doing so more than usually unpleasant.

Lower extremity amputations accounted for nine of all affected limbs, involving seven individuals. In two individuals (13.33%; 2/15), more than one limb was involved. For example, the mass comminution of right and left tibiae and fibulae, and right femur and foot bones shown in Fig. 4.49 (3089B) is consistent with bilateral partial amputation. The same individual had sustained projectile injuries to his cranium from shrapnel balls. Radiography revealed regular, dense, opacities, indicating the presence of shrapnel, lending further support to an interpretation of blast-force trauma (Fig. 4.49). In addition, the burial party had not removed the boots of this individual, a task for which they were ordered to carry out, owing to a shortage of leather. In this case, the massive trauma to the lower limbs had probably made it too difficult and unpleasant to remove the boots (which were very fragmentary, presumably because of the blast).

In most cases amputated body parts had not become entirely separated from bodies because soft tissues, although disrupted, had maintained some association between them at the time of burial. However, there were one or two exceptions. For example, an amputated foot had been buried in the same grave (Grave Three) some 5m away from the rest of one individual (2795B), whose tibia and fibula displayed severe comminutive fracturing and bone loss. These were reunited based on the traumatic lesions and morphology and other methods employed to resolve commingling (see Chapter Two). A similar distance also separated the right upper limb from another individual (2919B); both were from the same grave, and the two were reunited based on the physical fit between adjacent peri-mortem fracture margins. Given the physical distance between these body parts and the individuals to whom they belonged, it is highly unlikely that the disassociations had occurred as a result of post-depositional processes (for example, decomposition and water ingress into graves). The heavy clay in which the soldiers had been buried prohibited the migration of all but the smallest bones and teeth, and even then they did not move far. In the present examples, it is most likely that body parts were separated from their bodies around the time of burial (and see discussion under 'commingled remains re-association exercise', this chapter). In both examples, the exact surveyed locations of the remains, combined with details of their positions in the graves, were essential for interpretation.

There was generally no evidence for decapitation because all individuals were found with skulls (crania and mandibles) in correct anatomical association with post-cranial elements. This is with the exception of one individual (3147B) whose severely fragmented and incomplete cranium was not in correct anatomical position in the grave due to massive peri-mortem disruption and bone loss.

Projectile trauma

The vast majority of wounds (44%; 151/339) observed among the Pheasant Wood soldiers were attributed to projectile trauma, as determined by their appearance and, on occasion, further confirmed by associated ballistics. Ballistics are any object that has been propelled or accelerated by artillery or firearms, for example shell casing fragments shrapnel balls, bullet fragments from a firearm and flying debris. Associated ballistics refers to artefactual evidence (for example, shrapnel balls found on, in or with the skeletons) or evidence observed radiographically in association with peri-mortem trauma. Ballistics were also recovered as isolated artefacts from the graves and are also considered here. It is assumed these were introduced into the graves at the time of burial, with disassociation occurring as a result of the interment or migration within the deposit over time (as a result of the same post-depositional processes that influenced the migration of small bones and bone fragments, but particularly soft tissue decay releasing the ballistics from their original context).

Ballistics (physical artefacts and/or radiodensities on radiographs in association with peri-mortem trauma) were associated with a total of 90 individuals, or 39% (90/231) of those with peri-mortem trauma. The majority of the associated ballistics were shrapnel (52% 47/90) (this refers to lead shrapnel balls and metal fragments identified as belonging to shell casings) and 11% (10/90) were a combination of shrapnel and projectile (the use of the term projectile here is generic and refers to metal fragments, the source of which could not be identified due to corrosion or fragmentation). A further 29% (26/90) were projectile only and 8% (8/90) were bullets from firearms. A total of 22 isolated ballistics artefacts were recovered from the graves, and all were identified as shrapnel in nature.

Projectile wound characteristics included circular defects, with minimal or no associated fractures, attributable to shrapnel balls; circular and irregular defects with associated radiating and concentric fractures, bone loss and comminution of bone tissue; and bevelling. In addition, single or multiple partial penetration wounds were observed, often associated with embedded small metal fragments (ferrous), probably from shell case fragmentation. For example, a single penetrating shrapnel wound was observed on the left second metacarpal (dorsal aspect) of one individual (0975B; Fig. 4.50a), who had also sustained massive trauma to his head, neck and thorax and consistent with blast trauma. The wound, a circular defect with laminated margins, was associated with complete, irregular, longitudinal and spiral fractures. Radiographic analysis of the soil recovered with the remains of the individual identified probable tiny shrapnel fragments in the form of numerous irregular radio-opacities, adding further support to this interpretation. A similar wounding pattern, also as a result of blast trauma, was seen on another individual's fourth metatarsal (2108B), but in this case a very degraded ferrous fragment was also embedded in the bone (Fig. 4.50b).

It is highly likely that the identified ballistics evidence, seen in 90 individuals, under-represents the true amount that was present. Numerous corroded ferrous objects were found that were between approximately 5mm and 10mm in size and were frequently seen in the grave soil surrounding the skeletons and embedded in bones (for example Fig. 4.50c and d, showing a shrapnel ball and ferrous metal object embedded in bone), and were probably a consequence of shell or grenade fragmentation and thus consistent with Kimmerle and Baraybar's (2008; 101, 111) criteria described under 'peri-mortem trauma' in Chapter Two. They were not related to the soldiers' uniforms or personal items because of their shape, size and lack of distinct core when viewed radiographically. They

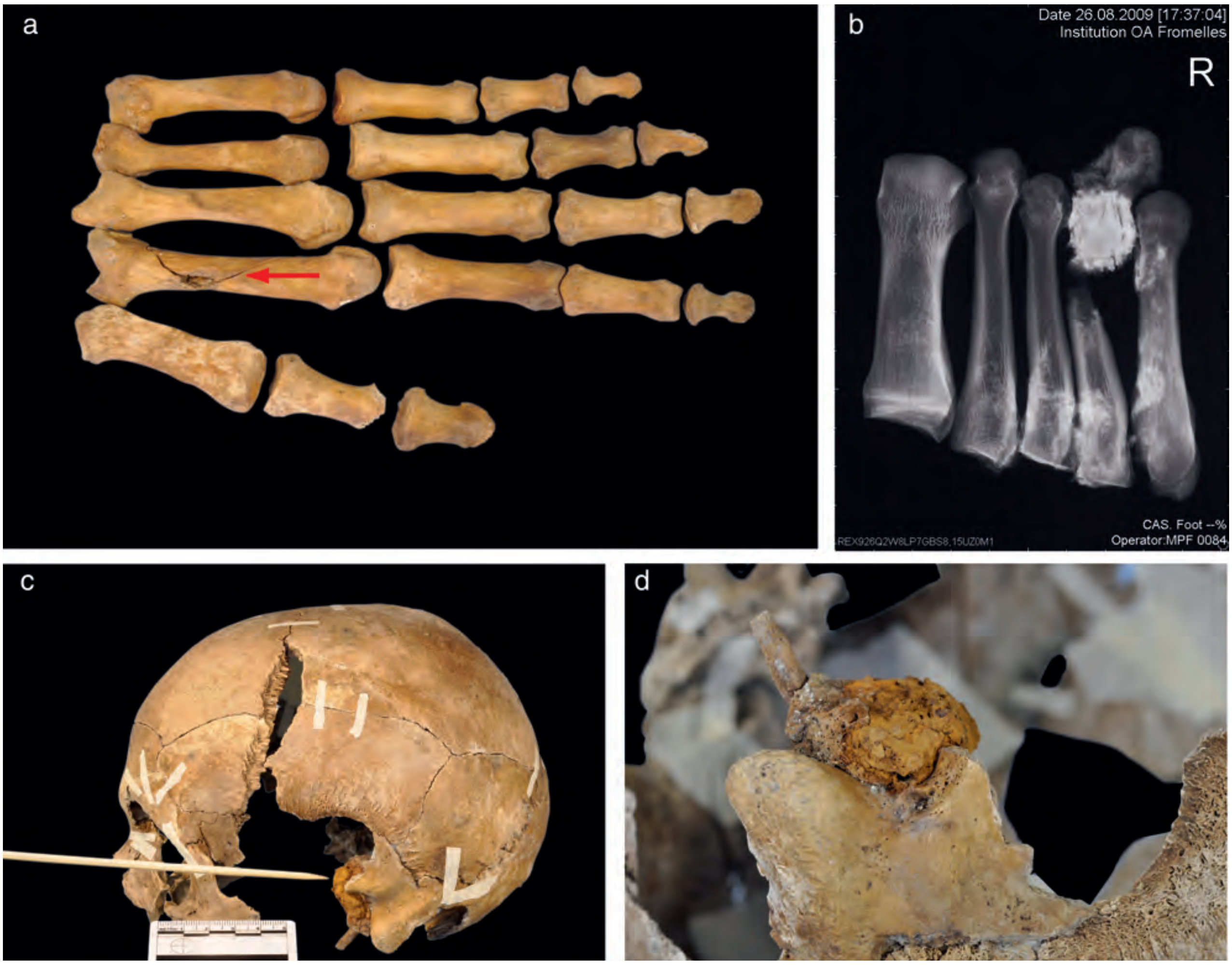

Fig. 4.50 a) Single penetrating shrapnel wound on the left second metacarpal (dorsal aspect); b) very degraded ferrous fragment embedded in 2108B's fourth metatarsal; c) 0647B, cranium with shrapnel ball and ferrous metal object embedded in bone (detail shown in (d))

were also not natural inclusions because they were not encountered in the two graves that contained no human remains. Unfortunately, they often disintegrated during pre-treatment procedures and usually did not stand out from human bone on a radiograph, being of a similar density (Viner pers. comm. 2009). Their absorption signals had also been masked by the heavy Flanders clay (Farmer pers. comm.). This was in contrast to the denser, less corroded projectiles from firearms and lead shrapnel balls, which were well defined on radiographs and probably represent all the available ballistics evidence of these types.

Projectile wounds were identified on all body regions, the thorax (40%; 60/151) and the head (38%; 57/151) being the most frequently involved. A total of eight individuals with distinct and characteristic projectile wounds were recovered with ballistics from firearms, giving a minimum prevalence of 5% (8/150) or 2% (8/339) for firearm injuries. These involved, most frequently, the thorax (50%; 4/8) and right upper limbs, left lower limbs and the head (all 25%; 2/8) (Table 4.22). Included are two soldiers (2203B and 0610B) who also exhibited blast trauma with associated multiple traumatic amputations. An additional three individuals were recovered with firearm projectiles, but had no characteristic projectile injuries, only blast injuries. A further individual (3213B) was found with a bullet in his rib cage and a butterfly fracture involving the proximal left femur shaft. No other trauma was observed, and it is possible that the bullet and this wound were not related. Butterfly fractures may occur post-mortem (Ubelaker and Adams 1994), but in the present example, the colour of the fracture margins was consistent with it having occurred peri-mortem around the time of the battle. These cases illustrate how difficult it is to determine the actual mechanism of death on a battlefield, when it is not possible to sequence injuries. Additional assaults to the body after death (while lying on the battlefield) are likely, and projectiles from firearms may also be a post-mortem artefact introduced into the grave at the time of burial.

Among the examples attributed to likely firearm injury is one individual (2928B) who was found with a contorted lead bullet in his jaw (Fig. 4.51a).

His right lateral incisor crown had been sheared off at the junction with the root and his right central incisor lost its crown at the root junction, with the fracture line extremely jagged in appearance. The remaining root had been forced upwards, so that it projected through the front of the maxilla. There was a radiating fracture from the broken socket, up to the lower margin of the nasal aperture. The left central incisor had a small amount of the crown remaining, but it was 'split' and jagged in appearance. A complete fracture was also observed through the middle portion of the mandibular body, the right side of which had sheared off, and the cervical region of the vertebral column had numerous shear and radiating fractures with massive bone loss. In addition, a bullet was recovered from the region of the individual's thorax and was probably associated with extensive comminuted and shear fractures and significant loss of bone tissue in the lumbar and sacral vertebral regions. The same individual had a probable sub-oval projectile entrance wound, 16.5mm by 32.8mm, on his left parietal, just superior to the asterion. Small hinged fragments of bone and slight internal bevelling were present on the margin of the aperture and there were no radiating fractures. No exit wound was present, but a radiograph showed a poorly defined radio-dense area inside the cranium, probably a deformed metal projectile. In this case, it was not possible to say whether the projectile was small firearms or explosive munitions related.

The radiographic survey of a different individual (3091B) identified a bullet that was embedded in brain tissue preserved in his cranial vault (Fig. 4.51b), but had no associated entrance wound. The only lesion in this body region was a circular defect on the right maxilla (Fig. 4.51c), but it could not have been the entrance site for the bullet because its margins displayed bone remodelling indicating that it had occurred prior to the battle (the defect also did not continue beyond the maxilla, as one would expect if it had been related to an injury due to the bullet). The defect was not associated with any dental pathology, and its diagnosis remains uncertain. The same individual had projectile trauma involving thoracic vertebrae, which exhibited anterior body fractures and a fractured lamina. It is possible that the projectile that caused damage to the thoracic vertebrae lost the majority of its energy on impact and then travelled up through the vertebral column to the brain where it was recovered and without further hard tissue damage.

Post-cranial examples include an individual (1872B) who had butterfly fracture involving his

Fig. 4.51 a) Jaw of 2928B: a contorted lead bullet was recovered from the area of tooth loss; b) radiograph of 3091B showing a bullet embedded in the cranial vault; c) circular defect on the right maxilla of 3091B; d) butterfly fracture involving the distal right radius, without involvement of other bones (1872B)

distal right radius, without involvement of other bones (Fig. 4.51d). The wounding pattern suggests a projectile that had travelled in a latero-posterior to medio-anterior direction. No other trauma was observed on the individual. When the individual was excavated a bullet was found lying between his right humerus and ribs suggesting that the trauma could have been due to firearms.

Shrapnel (including shrapnel balls and fragments from metal shell casings) were found with 47 individuals, linking them with explosive munitions. An additional 22 shrapnel artefacts were recovered from the graves, but were not directly associated with individuals. Some of the individuals with associated shrapnel had injuries that displayed characteristics of projectile injury. For example, the primary radiographic survey of one cranium (2799B) identified a shrapnel ball lying inside in the posterior part of the cranium. There was extensive fracturing of the facial skeleton and a *c* 13mm exit wound on the posterior right and left parietal bones. A small fragment of bone could be re-fitted onto the supero-lateral aspect of the bevelled margin of the exit wound demonstrating that the shrapnel ball had not penetrated the cranium and exited, but only fractured the outer table. No entrance wound was found, but bone loss in the facial region suggests that this was the probable location. The same individual had suffered extensive fracturing involving the limbs and torso and probable traumatic amputation of the left lower limb bones, all indicative of blast force trauma. Similarly, another individual (3089B) had two spherical apertures in the right parietal and frontal bones, which were associated with two shrapnel balls recovered from the cranial vault. This individual had also suffered comminuted fractures involving right and left lower limb bones. Dense

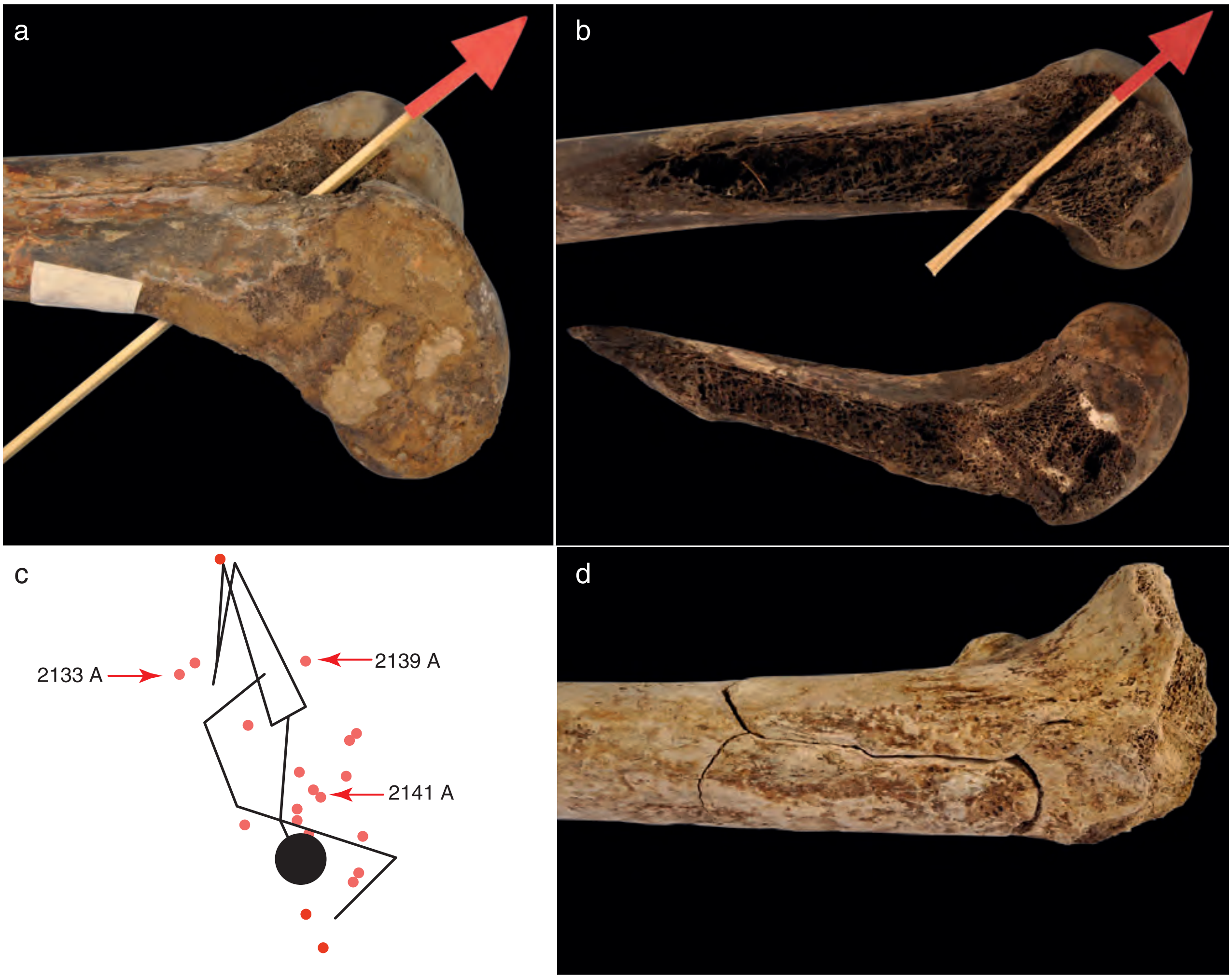

Fig. 4.52 a and b) Shrapnel ball injury to the left femur of 2811B. The arrow shows the path that the shrapnel ball had taken through the bone; c) surveyed in situ position of 2131B (represented as a stick figure) and some of the associated shrapnel balls (arrowed and numbered 2133A, 2139A and 2141A; the other red dots refer to other artefacts that were found with the soldier); d) a fracture consistent with being peri-mortem in origin was observed on the left proximal third of the femur. The physical artefacts and the peri-mortem trauma on the left femur are consistent with blast type trauma (Ambika Flavel, pers. comm.).

opacities were visible on the radiograph of these bones indicating the presence of shrapnel. Lastly, a shrapnel ball was recovered from near the distal left femur of the individual described above with the displaced cranial fragments. The left femur had been fractured longitudinally by the shrapnel ball, the path it took through the bone being clearly visible (Fig. 4.52a and b).

In other cases, shrapnel was associated with individuals who did not have characteristic projectile wounds. For example, multiple shrapnel balls were found in the regions of the abdomen and thighs of an individual who had complete linear, curved, longitudinal and transverse peri-mortem fractures of their left femur shaft (Fig. 4.52c and d). There was no focal defect or bone loss but the burial context strongly suggests that the wound had been caused by shrapnel from explosives.

Overall, penetrating shrapnel ball injuries, particularly those involving the cranium, were relatively straightforward to distinguish from other projectile injuries because the appearance of the wound was consistent with their size and shape. Comminution and radiating and concentric fractures were usually lacking in association with shrapnel balls, consistent with their low velocity and the lack of straight flight trajectory that characterizes high velocity firearm projectiles (Covey 2002, 1225). However, in some cases, the velocity was sufficient for the shrapnel ball to enter, fully penetrate tissues and exit, as was demonstrated by the 'through and through' shrapnel ball injury observed on one cranium (2810B, Fig. 4.53a) that had travelled from the individual's left to right. The entrance and exit wounds display radiating fractures and incomplete concentric fracture lines. Remarkably, the shrapnel ball was found *in situ* on the exterior surface of the right side of the cranium and had presumably been held in place during transfer of the body to the grave by soft tissue. A small fragment of bone adhered to the ball, which could be physically refitted to the external bevel of the exit wound.

Blunt force trauma

A total of 21 individuals had one or more wounds that were attributed to blunt force trauma, both direct and indirect. These most commonly involved the head and the thorax (both 42.86%; 9/21), but also the abdominal region (two cases, both involving the pelvis) and, in one case, the upper limb (Table 4.22).

None of the direct examples had characteristics that could be attributed to particular weapons or objects, because in most cases the trauma had caused extensive bone loss, thereby limiting observation. Examples include one individual (0370B), with extensive blast trauma involving his head, neck, thorax and right humerus. The fractures involving his ribs did not display the shear horizontal pattern that is consistent with a primary blast force, but splintering of bone indicating a slow loading, heavy force, consistent with blunt force trauma. Given the blast trauma on this example, the rib lesions may have arisen as the result of impact from objects or the individual being picked up and thrown in the blast wind.

Another individual (2930B) had sustained an irregularly shaped blunt force defect on the middle portion of his posterior right parietal. The defect had radiating stellate complete and incomplete fractures and margins that were depressed with no observable bevelling. These characteristics are all consistent with impact by a heavy load of relatively low velocity. Lastly, the right ulna of another individual (1683B) had an incomplete H-shaped fracture on the posterior surface of the bone. This could have been caused by falling on the elbow, the impact to the distal end of the bone causing fracturing in the middle. However, a shrapnel ball was found in the grave next to the individual's forearm, offering circumstantial evidence to suggest that the trauma was due to impact from the shrapnel ball, which had failed to penetrate the bone.

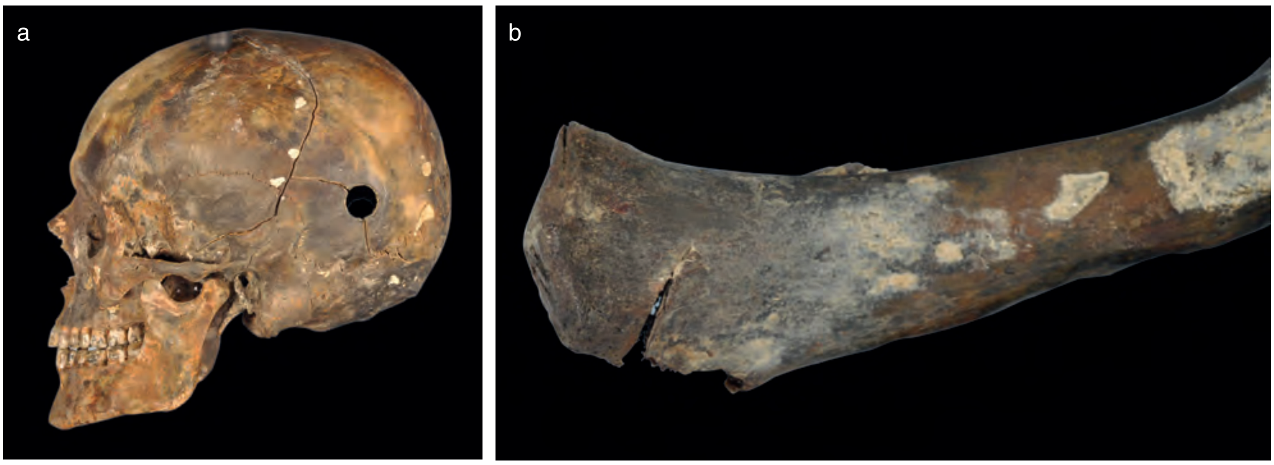

Fig. 4.53 a) 'Through and through' shrapnel ball injury observed on the skull of 2810B; b) linear incision involving the ninth rib of 2930B

Indirect blunt force trauma included a T-shaped acetabular fracture of the right innominate bone with corresponding fractures involving the femoral head, seen in one individual. This pattern is usually produced when the force from a blow to the foot, knee or greater trochanter is transmitted by the femoral head, which can be driven up into the acetabulum (Galloway 1999, 168).

Sharp-force trauma

Only one individual (2930B) had a single lesion that was consistent with sharp force trauma. This involved the ninth right rib, which had an incomplete, linear incision, 11mm in length, running supero-medially to infero-medially on the neck at the mid-point between the head and the tubercle. The incision was sharp, linear and had one flaked margin (Fig. 4.53b), all consistent with a blade injury. In addition, the eighth thoracic vertebra had a complete longitudinal, irregular and linear fracture that involved the right transverse process and ran superior to inferior. This is probably a blunt-force traumatic injury that had occurred during the same perimortem event as the blade injury of the rib, perhaps caused by the hilt of the bladed weapon. The characteristics of both lesions suggest a posterior to anterior trajectory. The same individual had also sustained a partial traumatic amputation of the left elbow and blunt-force trauma of the head (see above). The sharp-force injury suggests hand-to-hand combat, while the amputation and possibly also the blunt injury suggest blast-force trauma.

Statistical comparison of peri-mortem trauma between graves

Similarities or differences between grave number and the frequency of individuals or body regions with combat injuries may indicate groups of soldiers who were exposed to particular battlefield circumstances. To explore these possibilities, various statistical analyses were carried out on the individuals in graves one to five (Table 4.24; Appendix Three). Grave Six was excluded from the analysis due to the small number of soldiers in this grave.

The initial test determined that there was no statistically significant difference ($p>0.05$) between the number of individuals with peri-mortem trauma and graves one to five, each grave having a similar number of soldiers with peri-mortem trauma (Appendix Three). However, differences in number of soldiers with multi-trauma (injuries to more than one body region; body regions correspond to the collapsed categories in Table 4.24) in each grave, compared with those with only one injured body region or no injuries, were significant ($p>0.0001$; Appendix Three). Additional testing showed that Grave Two tended to have to a high number of individuals with multiple-trauma and, to a lesser extent, graves one, while five tended to have a low number of individuals with multiple-trauma (Appendix Three).

Multiple chi-squared analyses were carried out to test whether particular frequencies of injuries in individual body regions differed between the graves (Table 4.24). The results showed that significant differences (all results: $p<0.0001$; Appendix Three) exist between the graves for injuries in the regions of the head, neck, thorax and abdomen. However, there were no statistically significant differences between the graves and the frequency of peri-mortem trauma to the extremities (left upper limb ($p=0.35$), right upper limb ($p=0.41$), left lower limb ($p=0.26$) and right lower limb ($p=0.76$); Appendix Three). Additional testing indicated that Grave Two showed a greater tendency for combat injuries to the head, neck, thorax and abdomen in comparison with the other graves, and these differences were most marked in the regions of the neck and abdomen.

Irrespective of gross figures, the apparent pattern of anatomical distribution of injuries in all graves one to five was the same, with injuries in the head, thorax and abdomen predominating over injuries to the limbs. Thus, there is consistency across all graves.

The ballistics evidence was examined to determine whether there is any association between the frequency of individuals with associated ballistic artefacts and grave number (Appendix Three). The results showed a statistically significant difference ($p<0.0002$), with Grave One showing a low tendency for associated ballistics and Grave Four showing a high tendency for associated ballistics.

Table 4.23: Frequency of peri-mortem injuries in collapsed categories (chi-squared analysis) and percentage frequencies of combat injuries

Body regions	*Collapsed categories*	*Peri-mortem trauma n*	*%*
Cranium			
Mandible	Head	139	55.6
/	Neck	74	29.6
/	Thorax	155	62
/	Abdomen	65	26
Left arm			
Left forearm			
Left hand	Left upper limb	33	13.2
Right arm			
Right forearm			
Right hand	Right upper limb	34	13.6
Right thigh			
Right leg			
Right foot	Left lower limb	44	17.6
Left thigh			
Left leg			
Left foot	Right lower limb	39	15.6

n= frequency of individuals; % peri-mortem trauma for each body region based on 250 individuals; relative frequencies for body regions based on number of affected body regions as a percentage of all affected body regions

Table 4.24: Results of chi-squared analysis comparing the frequency of combat injuries in different body regions in graves one to five

Body region	*Probability value*	*Significance*	*Significance of individual cells*
Head	<0.001	Highly significant difference	Grave 2 tends to high frequencies of injuries
Neck	<0.001	Highly significant difference	Grave 2 tends to high frequencies of injuries
Thorax	<0.001	Highly significant difference	Grave 2 tends to high frequencies of injuries
Abdomen	<0.001	Highly significant difference	Grave 2 tends to high frequencies of injuries
R upper limb	>0.05	No significant difference	No difference between the graves
L upper limb	>0.05	No significant difference	No difference between the graves
R upper limb	>0.05	No significant difference	No difference between the graves
L lower limb	>0.05	No significant difference	No difference between the graves

Additional testing of all ballistics (including isolated ballistics artefacts recovered from within the graves) and grave number shows a highly significant difference ($p<0.05$). The greatest differences in the number of ballistic artefacts was between graves one and two. Grave One only had seven ballistic artefacts in contrast to Grave Two, which had 33.

DISCUSSION

Completeness, condition and taphonomic changes

Overall, the majority of the remains were excellently preserved and this had a very positive impact upon the analysis. Complete biological profiles could be determined in most cases, and prevalence rates for ante-mortem pathology and trauma, peri-mortem trauma and the dentition could be calculated.

The skeletonised remains recovered at Pheasant Wood represent the end stage of a sequence of decay that human corpses undergo (Payne 1965), the rate of which is influenced by numerous variables, both extrinsic (for example, soil conditions and tree root activity) and intrinsic (for example the age and body mass of the deceased). While the emphasis here is upon the effects of the burial environment on bone tissue, it is important to remember that when they were interred in 1916 the Pheasant Wood soldiers were fleshed corpses, wearing clothing, and in some cases were wrapped in groundsheets, all of which may have retarded decay, because bodies were not in intimate contact with the soil (Galloway *et al.* 1989). In addition, not only are fine clays, such as those at Pheasant Wood, associated with retarded rates of cadaver breakdown (Hopkins *et al.* 2000), but the significant peri-mortem injuries sustained by many of the individuals will have had an impact on the rate of early decay sequence stages by altering the soil chemistry and biology (Carter and Tibbet 2008).

A burial deposit represents a particular environment in terms of its physical, biological and chemical properties (Fitzpatrick 2008). Further, soil is a dynamic medium that undergoes environmental shifts throughout the period of burial. However, there were certain common findings for all graves. Crucial shared factors for consideration are the position of the graves at the base of a slope and the hydrological regime. In particular, the latter refers to water run-off and water from precipitation which had penetrated the looser fills of all graves, leading to water-logging or frequent standing water because drainage into the surrounding untouched geology was hindered by its impermeability. An environment such as this would be classified as a recharge environment and as such it would not exhibit the total water-logging that promotes anaerobic conditions (devoid of little oxygen) which inhibit the biological activity of mesofauna and microbes, such as bacteria and fungi (Clark 1967). Recharge environments are particularly deleterious, being aerobic and anaerobic, because the forces accelerating and facilitating decay in each are at play. Although the preservation of non-osseous human material was markedly different between those graves located closer and further away from the wood, its survival into the archaeological record is evidence of sustained, but not necessarily continuous periods of anaerobic soil conditions in all graves.

Hair, nails and woollen textiles (uniform fragments) are all keratinaceous proteins (Wilson 2008; Janaway 2008) and although brain matter is mainly water (78%), its second largest component is protein (12%) (McIlwain and Bachelard 1985). The persistence of these proteins in the graves suggests that the bacterial enzymes which break them down through a process called proteolysis (ibid.) were absent, had minimal presence, or other factors retarded their action. In some contexts this inactivity may be explained by a lack of seasonal fluctuation or sustained high temperatures, which accelerate bacterial activity, but this is unlikely for Pheasant Wood, considering the depth of the interments and their location in a temperate climate. Janaway (2008) and Dent *et al.* (2004) state that cyclic or periodic water-logging may retard the short-term decomposition of these types of organic materials, but not over archaeological time-scales, such as those at Pheasant Wood. In this respect, then, the findings at Pheasant Wood suggest otherwise.

The neutral to slightly alkaline pH of the burial soils (Pollard *et al.* 2008) seems to have had little adverse effect on the taphonomic signatures of the graves. Both metals (Janaway 2008) and bone (Rodriguez 1997) are better preserved in these types of soil, and the overall completeness of the bodies and numerous metallic artefacts recovered support these conclusions.

While available evidence demonstrates that the graves had been subjected to long periods of anaerobic conditions, comparative analysis showed significant differences in preservation between the graves located closer and further away from the wood, with greater degradation occurring in those situated closest to the wood. The most marked effects were observed in Grave Two. In general, the graves closest to the wood are characterised by greater degradation of the bone tissue, loss of bone integrity and collagen.

Piepenbrink (1986) states that once remains are skeletonised the biological action of soil bacteria becomes the principle decay mechanism. The protein-mineral bonds of the organic collagen matrix are broken down by bacterial enzymes (collagenases) into their amino acids and chemical weathering through the action of leaching due to water removes this substrate from the bone tissue. The inorganic matrix is also susceptible to decalcification and leaching in the presence of water (Dent *et al.* 2004). Eventually the structure of the bone material is weakened, leaving it vulnerable to destruction by physical agents such as the mass of the grave fill. The proximity of the wood is key to the interpretation here. Root ingress into these graves, as evidenced by their predominance in and on these remains, had removed standing water, promoting periodic aerobic conditions and exposing the remains to biological decay agents.

As previously stated, some plant roots behave as hosts to fungal mycorrhizal activity, and its apparent absence in the presence of root activity at Pheasant Wood is a curious phenomenon. In addition, Wilson (2008) suggests that the preliminary phase to the biological breakdown of hair is through fungal keratinolysis (the action of enzymes that break down keratin), but, although hair was less frequent in graves two and three, than graves one, four and five, it was present nonetheless. Considering other distinguishing properties of the graves located closer to the wood, there was a tendency towards metal staining and thus low-level corrosion is highly significant. All these observations perhaps demonstrate that periodic aerobic conditions, typical of a recharge regime, did occur in these graves, but they were of relatively short duration, fungi never having sufficient time to fruit and colonise the deposits. This ensured that vulnerable ferrous metal objects persisted in the artefactual record.

In conclusion, taphonomic changes are not linear events, but a complex mix of multiple factors, individually and collectively exerting a positive or detrimental affect upon the preservation of organic and inorganic materials. At Pheasant Wood the preservation signatures of the graves indicated sustained water-logged conditions, with periodic drier periods of short duration in those graves closer to the wood. The consequential factors associated with these events has led to the greater preservation of remains further away from the wood and has had a detrimental affect on those situated closer to the wood, with bodies in Grave Two being the least well preserved. This result was also reflected in other areas of the analysis, with fewer complete biological profiles obtained from those individuals from graves closer to the wood.

Demographic profile and individuating characteristics

The demographic profile of the assemblage is consistent with the expected collective identity of the Missing from Pheasant Wood namely that of an all-male group of approximate fighting age. The similarity of many of the individual biological profiles, that is, Caucasoid, young adult male of an average height and build, imposes limits on the usefulness of this information for individual identification. However, a number of individuals were more distinctive, such as those who were relatively short or tall, and/or had indicators suggesting they were very young or of mature adult age. The greater the number of unique characteristics the smaller the number of probable individuals the human remains may represent. In addition, individual biological profiles provide evidence that may be employed as exclusion criteria, imposing limits on who a set of remains may represent.

As expected, the majority of individuals from Pheasant Wood were considered to be of Caucasoid ancestry, and a minimum of one individual was of mixed European and Aboriginal ancestry. The limited occurrence of non-Caucasoid individuals therefore increases the potential for identifying the individual of mixed ancestry, should comparative and reliable ante-mortem records be available. However, it should not be forgotten that ancestry could not be assessed for 27 skeletons and, therefore, it is possible that other individuals with non-Caucasoid features were present among this group. It also has to be considered that currently available methodologies may not detect all possible variation in respect of ancestry.

A recent study by Butterfield and Jørkov (2010) found the craniometric statistical programme CRANID, which was used on the Pheasant Wood assemblage, more favourable for isolating individuals of European ancestry than an alternative craniometric programme called FORDISC. However, nearest neighbour assessment analysis, carried out on measurements from 45% of the crania from Pheasant Wood performed poorly with respect to the comparative sample population. It is unlikely that this was solely due to observer error, because other measurements (LDA and NNDA) gave consistent results which were compatible with those obtained by morphological assessment. Rather, a pathological explanation may be more relevant, because a high proportion of individuals had pathological conditions or biological artefacts of maternal and development stress in the axial skeleton. While these conditions were unlikely to have been apparent in the living individual, they may have affected growth in the bones of the skull (Lodge 1975), which in turn may have influenced some of the craniometric results.

All individuals possessed biologically male traits, with the exception of some whose skull features showed less expression because puberty was ongoing, or had only recently been completed prior to death. Interestingly, the sciatic notch, which is regularly employed by anthropologists to estimate sex of skeletons (Buikstra and Ubelaker 1994), was not dimorphic in this group. This feature has also been found to be an unreliable sex indicator in other population groups (Đurić *et al.* 2005; İşcan 2005), while some consider it to reflect the relative youthfulness of the individuals in an assemblage (Walker 1995). The work at Pheasant Wood (and prior research) indicates that the sciatic notch should not be used as a stand-alone sexing trait in any investigation.

Before discussing the results of age estimation, it is worth reiterating that the methods used are subjective in application and hence outcome, and do not provide a defined age at death, but instead an age range outside of which one in twenty will fall (Cox 2000). There are of course many benefits of applying these methods, as they provide overall population and sample trends and provide reasonably reliable broad ranges. This can be very useful for providing exclusion type data when seeking to identify individuals for whom recorded ages at death exist (Thompson and Black 2007). Using anthropological methods, the majority of individuals were accommodated in the 18-45 years of age range, in keeping with the enlistment/conscription standards of the time. In addition, probable or possible under-age and over-age individuals were identified (more so the former), but could not be confirmed because of limitations associated with biological ageing techniques. More specifically, in order to accommodate human variability, it was necessary to employ age ranges which, in most cases, fell either side of the minimum and maximum recruitment ages. None of the adults was assigned a minimum age that was over the enlistment/conscription standards (see Chapter One), and therefore it can only be said that over-age individuals were possibly present at Pheasant Wood. More can be said for the adolescents (13-17 year olds), because in these individuals, age estimation is considered to be more accurate, being based on developmental changes (epiphyseal union) which are more predictable than the degenerative changes, employed to age adults (Cox 2000; Scheuer and Black 2000). Two individuals out of six in the 13-17 year age category had maximum ages that were below the age of enlistment/conscription. Thus, a minimum of two under-age soldiers were present at Pheasant Wood.

The comparison between known age at death of the Missing and estimated age at death of the buried soldiers shows that both correspond at the assemblage level, despite the fact that over-age individuals are present among the latter, but were not represented in the enlistment records for obvious reasons (see Chapter One). However, the identification process (Chapter Seven) demonstrates that the estimated ages of the buried soldiers are not particularly accurate at an individual level. For example, the recorded age at death of some soldiers, who have been indisputably identified, fall outside the quite considerable age ranges as indicated by the anthropology. If it is assumed that all was equal at the time of enlistment/conscription (that is, similar numbers of under- and over-age individuals), the over-age group is perhaps likely to be over-represented in the buried sample, because methods produce larger age ranges to cater for human variation. However, even at a level of 95% confidence (age methods), the under-age group still out numbers the over-age group. This difference in numbers is likely to reflect the circumstances of the time, when under-age individuals joined the army in greater numbers than those who were over-age.

The existence of under- and over-age individuals within the assemblage reflects known historical soldier recruitment trends and has implications for individual identification. Age at recruitment in military records will not always accurately reflect the chronological age of the individual. Access to primary records, such as birth certificates, may resolve inconsistencies between recorded and estimated data, where an identification can be realised using other evidence, such as DNA matches.

Comparative and spatial analyses of the remains in graves one to five do not indicate preferential sorting or the separation of older aged individuals. From this it may be concluded that either age at death cannot be used as an indicator of rank, or that sorting based on rank did not occur. While the latter is most likely to be true, and is supported by the historical evidence (Barton 2007), there are imposed limitations for the use of age as an indicator of rank. The available information from the Australian Imperial Forces (AIF) is incomplete, giving rise to the possibility that certain ranks may be excluded. The average and the median ages are relatively close and there is a large overlap between the minimum and maximum ages of regular soldiers and officers. In addition, the post-mortem imposed categories and those derived from the AIF data are not directly comparable, limiting the possibility to discriminate officers from regular soldiers based on age criteria alone.

Grave Two was the only grave to show a possible anomalous demographic profile when compared with those of graves one, three, four and five. It appeared to have a high proportion of younger individuals and a low proportion of older individuals. This could be a consequence of an age bias within a particular battalion, whose soldiers tended to be brought together to the interment site. Alternatively, the pattern may simply be chance.

Stature as a primary identification technique is known to be limited (Baraybar and Kimmerle 2002). Differences often exist between recorded stature, such as those on soldiers' records (medical examinations at the time of enlistment or conscription), reported stature (anecdotal evidence and testimony from relatives), and reconstructed stature (osteological analysis) (Baraybar 2008). Within the context of this investigation, how or if recorded statures were measured is not known. The stature on a soldier's record may be accurate (where measurements were taken) or reflect the perceptions of the examining officer or the recruit (where the stature is estimated by eye or is the product of self-assessment). In addition, it is not known whether the methods employed varied at different medical examination stations, perhaps some having access to measuring equipment, others relying on self assessment. Nevertheless, the comparison between recorded stature for the entire sample and osteological estimated stature indicates that the methods employed were accurate and appropriate to the assemblage on a population level. However, inconsistencies at the level of the individual may exist as a consequence of individual variation. Gross stature estimations have allowed short and tall individuals to be confined to smaller groups, the short stature group being more discriminating due to the small number of individuals it represents.

While the assessment of skeletal constitution cannot provide primary identification data, it does have a limited potential for use as an exclusion or failure to exclude criterion, especially if used in conjunction with other characteristics such as stature (for example, photographs showing a soldier to be relatively tall and thin or short and stocky). The results show that approximately proportional groups of gracile and robust individuals, both of whom were smaller in number than those who were unremarkable or average, were present within the assemblage. Thus, there are a limited number of individuals with physical attributes that may have been noteworthy. Comparative data may exist as photographs of the deceased and as anecdotal testimony, though the latter may carry its own inherent bias, due to modern day and past cultural perceptions of physique. In addition, the recorded chest measurements in the AIF individual medical examinations may provide a framework for comparison. Osteological correlates to capture data such as chest size do not exist. However, further work to determine the range in variation of chest measurements may isolate individuals at opposing ends of the physical scale to determine those who were particularly slender or gracile and those who may have been distinct in terms of their robusticity and increased musculature. Given that recorded chest measurements appear to be to the nearest half inch, and usually include two (one taken after inhaling and one taken after exhaling) measurements, it seems likely that this is a recorded measurement rather than a visual assessment.

The results obtained from the assessment of handedness indicate that some individuals were sufficiently unilateral in the use of their upper limb to express functional upper limb asymmetry, the minority expressing left side dominance. However, the osteological assessment of handedness suffers from similar inherent difficulties in assessment and differential opinions as other skeletal criteria used to indicate functional use (Cashmore 2009a, 2009b; Danforth and Thompson 2008; Klepinger 2006; Byers 2005). As a consequence, discretion needs to be applied if the results are to be used in the identification process. Moreover, the individuals of the era under investigation exhibited cultural variability; the dominant use of the left hand was discouraged in early 20th-century Britain and Australia (Steele 2000). While the TPR of 3% for left hand dominance at Pheasant Wood is comparable to data published for individuals born around the turn of the twentieth century (Steele 2000),[1] the large number of individuals whose side dominance is inconclusive may have influenced this result. Further, consideration of handedness for writing and the use of the arm in physical tasks needs to be considered, as the two are not necessarily the same.

The efficacy of the results of the assessment of gross facial attributes and 360º video imagery are not within the scope of this report. Both datasets are intended for use in secondary identification techniques, such as comparison with ante-mortem photographs and photographic superimposition. Nevertheless, some individuals do exhibit individuating characteristics, which may provide useful exclusion criteria where relevant comparative data are available. Furthermore, capturing this type of data allows for the application of additional identification techniques, traditionally only available for use on remains that have not been reburied.

[1] Left hand dominance in an Australian and New Zealand sample increased from 2% in the 1880s to 13% in 1967. Of 800 patients studied in a London dental clinic in the mid-1970s, left hand dominance was observed in 2.9% of adults in the 55-64 year age range in contrast to 10.8% of adolescents and adults in the 15-24 year age range (Steele 2000).

The dentitions

Comparative datasets (size, sex, age, characteristics of the assemblage, and methodology) for the period are not available in the published literature, and therefore the assessment here represents a unique and stand alone review of the dental and oral health of the Pheasant Wood soldiers. This is interpreted within the historical context and with reference to what was known about trench life in the First World War and dental techniques at the turn of the 20th century.

The active and healed lesions observed among the dentitions suggest that chronic poor dental health and oral hygiene characterised the soldiers at Pheasant Wood. It is known that recruitment standards for dental fitness were relaxed by 1916 (Australian War Memorial 2010) in an effort to increase numbers of soldiers, and some of the soldiers at Pheasant Wood may represent cohorts that enlisted as a result of this policy change. Nevertheless, dental treatment to restore or extract carious teeth was available at the time. The work observed may represent dental treatments provided by civilian practitioners and the military. Provision for treatment was available on the boats that brought AIF troops to Europe from Australia (Halliday *et al.* 1977). In addition, soldiers stationed or passing through Egypt sought out local dental treatments in Cairo (ibid.). The dentition of the assemblage and/or an individual soldier may, therefore, represent a combination of treatments from these varying sources.

The prevalence of enamel hypoplasia (EH) among the Pheasant Wood soldiers was low at both the individual and population level, which may suggest that, as a group, they were sufficiently well nourished or robust during childhood to withstand periods of physiological stress. At the population level EH may not be a particularly useful indicator here of childhood circumstances because many serving AIF soldiers were born in Britain and emigrated to Australia as adults, or with their families during childhood. Thus, the soldiers at Pheasant Wood represent individuals who grew up in Australia and Britain, regardless of the flag under which they fought. At the level of the individual, most EH is associated with early childhood and may be a consequence of the usual array of childhood ailments and weaning stress. The presence of EH may be more telling in those individuals that exhibit signs of more long-term physiological stress, extending into older childhood. However, the requirement of a certain level of fitness in recruits would suggest that individuals with systemic chronic ailments may not have been fit for service and are thus not represented among the individuals at Pheasant Wood.

Caries prevalence was high at the individual level, but moderate at a population level, with the latter sharing similar prevalence rates to 19th-century USA soldiers (Sledzik and Sandberg 2002). Caries can develop in a relatively short space of time (weeks), thus its presence to a greater or lesser extent in the overwhelming majority of soldiers may indicate the short-term consequences of poor oral and dental hygiene at the Front. As previously stated, the military establishment was aware of the need for good dental health in the serving soldier. Provision for dental treatment was made through military dentists and a toothbrush was standard issue in the field soldiers' kit (British and AIF; see Chapter Five). The practicalities associated with using a toothbrush while living in the trenches can only be assumed. Reports and diary entries at the time state that trench life was difficult (Baker 1996-2009), plus basic oral hygiene was perhaps forgotten, ignored or viewed as something of a luxury or eccentricity when a number of more pressing factors would have occupied the minds and thoughts of the soldiers in daily life.

The diet of the troops is also relevant here. Rations included cariogenic foodstuffs such as sugar, as well as tobacco, which promotes periodontal disease (Axelsson et al 1998). Thus, the high numbers of individuals with caries at Pheasant Wood is likely to be the combined result of lack of dental hygiene, a diet high in sugars and daily habits. Despite remedial measures to improve the dental and oral well-being of troops serving overseas, the everyday difficulties of trench life and a diet rich in cariogenic foodstuffs promoted poor oral and dental health and hygiene. The time of enlistment of many of the AIF soldiers also coincides with the relaxing of enlistment standards. All these factors have likely contributed to the results observed at Pheasant Wood.

A further consideration, which is not covered in this report, is whether there are observable differences between those soldiers that had been serving overseas the longest. As stated, caries propagation is a fairly rapid event, and therefore those with the greatest frequency or the most aggressive (gross) caries may have served in other locations prior to their arrival at Fromelles. A more detailed study coupled with known evidence of prior or long-term overseas postings would be necessary to determine any significant differences or patterns.

Age at death and ante-mortem tooth loss (AMTL) results indicate that AMTL is a progressive disease, with adolescent individuals having a significantly smaller number of teeth lost during life. Furthermore, the aetiology of AMTL in most cases was likely the result of caries, leading to elective extractions or eventual tooth loss. Even if some AMTL is considered to be the result of a traumatic insult, the pattern of most frequently affected teeth mimics that of caries, with the maxillary dentition and posterior (upper and lower) dentition appearing to be more vulnerable to periodontal disease and subsequent loss.

The majority of the peri-apical cavities were found in association with dental treatments, AMTL, caries and an impacted tooth, which would suggest that the lesions are most likely to be abscesses and the result of infection. Where dental treatment or AMTL was associated, it may indicate a pre-treatment condition, unsuccessful treatment or extraction, not all the diseased tissue was removed, or perhaps that the treatment was inappropriate. Alternatively, it may indicate that poor oral hygiene habits persisted even after dental treatments, with new lesions thriving at the site of past insults. Periapical cavities in association with an individual with a congenitally absent tooth is less likely to be due to infection and may have been a granuloma or cyst, at the site of the absent tooth bud.

Numerous dental anomalies were present in the dentitions and perhaps have more relevance here as individuating criteria than the population based data described above. At an individual level they provide insight into personal habits, such as pipe smoking or teeth grinding, or may indicate familial relationships where the phenotypic expression is the result of a genotype. The different types described in this chapter are detailed in the individual confidential case reports and radiographic and photographic records.

The range and scale of dentistry observed among the Pheasant Wood individuals was perhaps one of the most compelling aspects of the anthropological analysis. The selection of certain dental materials over others, and the preference for replacement teeth in the visible dentition suggests that the usual vanities observed in all societies were present among the disparate individuals killed and buried at Pheasant Wood, with soldiers preferring to present neat and complete teeth where possible.

A minority of the teeth lost during life had been replaced with a denture. However, there appears to be a distinction in which teeth were replaced, with respect to the location in the dental arcade. The lower posterior teeth were the least frequently replaced by dentures, probably owing to the fact that they were notoriously uncomfortable to the wearer (Adams pers. comm. 2009) and the architecture of the lower mouth presents a more difficult terrain in which to secure the denture. Nevertheless, lower dentures may have been used when eating, to help chew and grind food. In contrast, AMTL in the visible (anterior) dentition was frequently replaced with a denture allowing the wearer to present himself as someone with a complete set of teeth.

The dentures of some of the soldiers carried the same markings, relief patterns or anchoring devices such as ring clasps. It is reasonable to assume that these similarities relate to the dental laboratory or technician that made them. With this artefactual evidence it is possible that the identification of one individual may assist in the identification of others, to some degree. The sophistication of the dentures was variable nevertheless, and partial dentures and the presence of rugae patterns on the palate are all consistent with individualised dental treatments and repeat visits to the same dentist or dental clinic.

In addition, partial dentures that accommodate natural teeth indicate that many dentists did not subscribe to the complete extraction of all teeth and replacement with a full denture. It has been reported that the unnecessary and complete extraction of all teeth was not uncommon in British recruits examined at other sites in the region (M Cox pers. comm. 2009), where many had what appeared to be 'off the shelf', rather than bespoke dentures. However, at Pheasant Wood, no individual was edentulous (without natural teeth), the number of complete mandibular or maxillary dentures was minimal and, going by the presence of various other dental treatments across the assemblage, a difference in attitudes, perceptions and availability of treatments between Britain and Australia may have prevailed. The answer to this question is not within the scope of this report, due to the apparent lack of British soldiers in the assemblage (based on the artefactual evidence detailed in Chapter Five and as subsequently confirmed by the soldiers identified by name or army – see Chapter Seven). Future work, and investigation into the historical differences and/or similarities of dentistry between Britain and Australia, may provide useful artefactual or supporting evidence in future cases of unidentified remains recovered on the Western Front.

The most frequent material used for fillings was amalgam, a material that is likely to have been the cheapest and, according to Adams (pers. comm. 2009) is the easiest to work. While fillings of other materials were present, perhaps the difference in frequency reflects the differences in availability of dental materials and treatments between elective civilian and military dentistry, with the latter perhaps using the cheaper, readily available and easy to work amalgam. In addition, amalgam fillings were generally cruder in their fabrication, in contrast to many of the gold fillings that were sculpted and sympathetic to the occluding dentition. In the later 19th century in Britain, sophisticated gold fillings were being created and applied by gold and silversmiths (Gow 2007); the high degree of sophistication and level of skill observed in the gold fillings, crowns and bridge work at Pheasant Wood would suggest this tradition was also apparent in Australia and persisted into the early 20th century. The overall impression is of a distinction between sophisticated, aesthetically pleasing white and gold crowns, bridge, and bonded dental work in contrast to the cruder more functional amalgam fillings and perhaps functional dentures. No doubt cost would have played a role in deciding who had which treatments.

There was no evidence, based on the assessment of dental work, that soldiers were sorted at the time of interment. The slight significant difference observed in the increased number of individuals with fillings in graves four and five cannot be explained, but may be the result of individuals within a particular battalion having more access to dental treatments provided by the military, or it may simply reflect chance. In addition, age does not seem to be a discriminating factor in the scope of dental treatments, but further analysis may show a difference in the frequency of long and short- term dental health profiles between the older and younger soldiers.

It was proposed in the early stages of the analysis that the presence of dental work was a reflection of civilian social status and may indicate rank. The premise for this assertion is that officers, as opposed to other ranks, were more likely to belong to the upper and middle classes, and thus had access to more superior dental treatments (for example, root canal work) in civilian life. Considering the sophisticated dental work in isolation, the relatively high frequency of these types of treatments would suggest that dental work does not reflect civilian social status and/or rank of officers. Assuming that the expected ratio of officers to those of other rank is reflected in the assemblage, the number of soldiers with sophisticated bespoke dental work is less than the number of soldiers presumed to be officers.

At the onset of the war in 1914, commissioned officers were of the upper classes in Britain. However, the social composition of officers changed throughout the war (Kenez 1972) and by 1916, due to the large numbers of officers killed, the promotion of junior officers and soldiers who were not of the regular army (recruits of middle or working class backgrounds) was commonplace. An additional consideration here is the army with which the individuals served because the artefactual data show that the majority were members of the AIF. Differential access to dental treatments in Australia and Britain, regardless of socio-economic standing, may have influenced the patterns seen among the Pheasant Wood individuals. Thus, rather than the presence of dental work at Pheasant Wood being an indicator of rank or social status, it may reflect the national flag under which a soldier served.

Some of the unique dental work configurations and dental anomalies observed at Pheasant Wood provide individuating criteria suitable for identification or exclusion, when compared to anecdotal testimony such as the wearing of a denture, gold tooth (both are mentioned in service records) or a pipe smoker, or where comparative ante-mortem photographs are available. Anomalies such as hypodontia are significant in that they are relatively unique and useful where ante-mortem records such as appropriate 'smiling' photographs are available. Their phenotypic expression may also have a familial genetic component (Arte 2001) with living family members, or other individuals within the assemblage exhibiting similar traits.

Ante-mortem pathology and trauma

The analysis of the Pheasant Wood skeletons for ante-mortem trauma and pathology focussed on information that would help to identify individuals and therefore certain analyses, typically included in most standard osteology reports, are not relevant. However, some general observations about the health status of the soldiers are worth considering here.

Overall, the disease profile of the assemblage reflects a relatively healthy group at the time of death, with low prevalence rates for many of the disease categories. This is consistent with our expectations from this particular type of catastrophic death assemblage; the soldiers did not die as a result of acute or chronic disease, but from combat wounds sustained on the battlefield. In addition, they were active and relatively able bodied at the time of death and declared medically fit to serve as soldiers.

Although the characteristics of this assemblage make it unsuitable for direct comparison with early 20th-century mortality rates and attritional death assemblages (for example, cemetery populations), available mortality data and profiles provide some insight into what types of disease had the biggest impact on the living population at that time. In early 20th-century Australia, circulatory, respiratory and infectious diseases were the greatest contributors to mortality and thus health (AIHW 2006). Many of these disease processes relate specifically to the soft tissues and are of little relevance here. However, infectious diseases, such as syphilis and tuberculosis, accounted for approximately 13% of deaths in Australia in 1907 (ibid.), and post industrialised Britain saw an increased impact on health and mortality due to infectious disease, especially in urban centres (Roberts and Cox 2003). Therefore, the relatively low frequencies of non-specific, non-systemic infection at Pheasant Wood would perhaps indicate a fairly robust group, not overly susceptible to disease, with well developed immune systems. Any impact on health due to life in the trenches is unlikely to be particularly advanced in these soldiers, as they had spent relatively little time on the Western Front prior to their deaths (Cobb 2007). Nevertheless, pre-existing conditions may have been exacerbated in this environment, for example the soldier with osteomyelitis.

Joint disease and ante-mortem trauma are two of the largest contributors to the pathological profile (excluding miscellaneous conditions which represent different and unknown disease processes). Frequencies of joint disease are consistent with a pattern of degenerative change associated with the advancement of age. For example, osteoarthritis (OA) was more frequent among older individuals. The high prevalence rates of ante-mortem trauma probably reflects the unisex nature of the assemblage (all male) and circumstances of the early twentieth century. The higher frequency of right hand fractures in comparison to other limb regions is consistent with right side dominance of the upper limb, due to handedness, or the use of tools that did not facilitate the practice of left-handedness.

Low frequencies of individuals with metabolic diseases, such as anaemia and an absence of such conditions as rickets, would suggest that dietary deficiencies during childhood were not particularly prevalent. However, these low prevalence rates for childhood related disease and/or physiological stress contrast with the high frequency of congenital defects as a result of foetal (*in utero*) or maternal stress. This dichotomy may be a reflection of the robusticity of the individual rather than their diet and socio-economic status during childhood. Additionally, it may reflect the level of maternal knowledge or education at that time with regard to healthy foetal development. Further, this dichotomy may help explain the low frequencies of adult related disease processes not associated with age related change (joint) and occupation, lifestyle or accident (ante-mortem trauma).

Infant and child mortality rates in early 20th-century Australia were high, with children (0-4 years) accounting for a quarter of all deaths. Further, congenital abnormalities were the sixth leading cause of death (AIHW 2006). Therefore, foetal and childhood survival, despite these negative health influences, would imply 'survival of the fittest' (Lewis 2007). This is turn may reflect a decreased susceptibility to disease processes in the adult individual. Growth retardation due to physiological stress during childhood can also indicate early health or nutritional trends. However, the stature of those killed at Fromelles is also consistent with that of Australian males (>17 years) in the second decade of the 20th century (Loesch *et al.* 2000) and confirms the findings from the pathological data. A caveat to this is of course that some of the individuals will represent growth, maturation and circumstances in early 20th-century Britain. However, in the absence of additional information no distinction can be made between these individuals.

In the absence of comparative ante-mortem records such as radiographs, the identification process must rely on other forms of evidence, such as service records, photographs and other anecdotal testimony, to provide an individual picture of health and trauma of the Missing. A consequence of these circumstances is that many of the pathological conditions observed during the analysis of the soldiers are of little use in identification. Often the most significant contribution to potential identification is ante-mortem trauma and the development of visible physical attributes as a consequence of an underlying condition. There were a number of individuals who presented unique physical attributes that would have had an impact on their lives (for example 1683B and 0674B). Additionally, there are a number of individuals who shared similar attributes (for example healed fractures of the forearm), but represented a significantly smaller number of potential possibilities and may provide valuable exclusion or failure to exclude type criteria.

A number of individuals (0266B, 0268B, 0674B, 1360B, 1683B, 1875B, 2522B, 2896B) presented evidence on their bones that suggested that their injuries or disease would have been debilitating. It is perhaps quite remarkable that they were declared fit for service, and this may reflect the policy of 1916, and the relaxing of recruitment standards, or a condition arising following recruitment. An obvious consequence is, of course, the probable lack of inclusion in any army medical records of the injury or disease and/or its history.

The Pheasant Wood assemblage presents a unique opportunity to assess the health and disease status of early 20th-century males (14-50 years), the majority of whom may have spent a considerable part of their lives in Australia. While congenital abnormalities may indicate overall health conditions were poor, the survival of the individual to adulthood and inferred immune robusticity provides an explanation for the low prevalence of many disease processes observed on the skeletons.

Peri-mortem trauma

The overwhelming majority of soldiers from the Pheasant Wood graves had injuries that had affected the hard tissue skeleton. The type and range of injuries were both highly complex and extensive. They include wounds that have been classified as sharp, blast, blunt and projectile force traumas, the majority being attributed to projectile followed by blast. There is considerable overlap between these categories because the wounding characteristics of small arms, explosive munitions and hand-to-hand combat with knives, bayonets and other such devices are not mutually exclusive. All may result in associated fracture lines, depending on velocity, angle of the impact, and the morphology of the bone being impacted. Further, an impact site may not always be present, or may not always survive owing to bone loss as a result of the trauma. In particular, the effects of explosive munitions are highly complex because they can cause a combination of blunt, sharp and projectile injuries. Many soldiers will have experienced more than one type of trauma mechanism and the multiplicity of injuries will have obscured wound characteristics further.

By considering the different categories, blast, projectile, sharp and blunt, overall patterns suggest that the majority of wounding mechanisms were due to explosive munitions, followed by firearms and then bladed assault. However, these determinations do not rest solely on the morphological analysis of the skeletal remains, but on the full integration of archaeological context information, survey, radiography and artefactual evidence. For example, the anatomical integrity of bones in the graves, their physical relationship with ballistics, background evidence from soil in the form of ferrous objects and the different media employed to capture these (survey, documentation, sketches and photography) have been pivotal in the interpretation of wound patterning.

Explosive munitions casualties were characterised by multiple injuries, projectile and/or blunt trauma, comminuted fractures, shearing of bone, amputation, an absence of exit wounds and degraded ferrous objects found in bone and in the soil from the graves. Most of the recorded blunt-force trauma was seen among these individuals, which was often extensive and lacked characteristic hallmarks of weapons/objects. The overall impression is that these patterns refer to secondary traumas sustained as a result of individuals being picked up by the blast and thrown down. In contrast, injuries attributed to firearms tended to be isolated projectile injuries, were often associated with a bullet, and often had exit wounds.

The single example of sharp force trauma is physical evidence of the fact that bladed instruments were used in the battle and probably reflect hand-to-hand combat in the German trenches. The low frequency is consistent with the fact that projectile weapons were favoured over bladed weapons (in particular, bayonets) on the Western Front and caused fewer injuries seen at dressing stations (Macpherson *et al.* 1922). That said, many sharp-force traumas will have perforated soft tissues sparing bone entirely. Similarly, blast trauma can cause tearing and hemorrhagic lesions (catastrophic bleeds) in various internal organs without visible external injury, depending on the range of pressure from and proximity to the blast (Knight 1996; Owen-Smith 1981); the air-filled cavities of the lungs are particularly vulnerable to the explosive effects of the blast wave pressure (blast lung) and the resulting injuries are often fatal. It is perhaps not surprising, therefore, that 19 individuals from Pheasant Wood showed no osteological evidence for skeletal peri-mortem trauma.

Although not directly comparable, the osteological findings are consistent with the forensic literature on explosive trauma to fleshed bodies, specifically secondary injuries are more common than primary blast injuries (Knight 1996; Leibovici *et al.* 1996). However, as Christensen *et al.*'s (2012) study of pig skeletons found, lesions attributed to primary blast trauma were also high at Pheasant Wood. This trend is associated with explosions in confined spaces, such as First World War trenches. The relevance of this to Fromelles is supported by the high rate of limb amputation seen among the Pheasant Wood individuals, which is also seen among victims exposed to blast trauma in enclosed spaces (Owen-Smith 1981).

Several observations made during the present study contribute further detail to present knowledge and understanding of the effects of explosive munitions on the human skeleton. For example, shearing of dense bone and joint surfaces was frequent, particularly on scapular glenoid fossae which almost always had multi-fragment fractures (Browner *et al.* 2003, 1631). This may reflect massive contraction of the shoulder muscles, which can drive the humeral head into the glenoid fossa, as seen in cases of convulsive seizure (Galloway 1999, 118). Alternatively, it may have resulted from forces from the blast wave pulling the soft tissues and corresponding bones beyond their normal limits. Fractures of the femoral head and tripartite acetabular fractures were also common and refer to falls, including those in which the femur is driven into the acetabulum (Galloway 1999). Further detailed analysis of these patterns was precluded by the fact that the primary aim of all analysis was to record details that would assist with identification and allow a timely re-burial. However, the overall impression is that these patterns refer to tertiary traumatic injuries sustained as a result of individuals being picked up by the blast and thrown down again, in effect acceleration and deceleration injuries.

A total of eight projectile injuries were attributed to firearms, these having characteristic wounds and associated bullets. This figure undoubtedly underestimates the true number of firearms injuries because few definitive lesions could be identified and some ballistics found in the graves could not be associated with individuals and/or be identified. The frequency of blunt trauma was also low and many lesions could often only be attributed to a blunt or projectile force. These often included cranial lesions that showed a brittle response, consistent with a rapid loading force, as has been described for cranial gunshot trauma (Berryman and Symes 1995). However, they were frequently accompanied by large areas of bone loss that prevented other observations, such as concentric fracturing (Hart 2005). Other such criteria for distinguishing gunshot from blunt force trauma of the cranium are described in the published literature (for example, Berryman and Haun 1996; Hart 2005 and Berryman and Symes 1995), but the extent to which these can be used to distinguish other projectile trauma, such as that from shrapnel (which is slower loading than gunshot) is unclear and therefore caution has been applied here.

Despite the fact that the true extent and range of wounding mechanisms is not reflected osteologically, the calculated rank order prevalence observed (explosive munitions, followed by firearms, then bladed assault) would seem to be an accurate reflection. This is supported by the fact that shrapnel and ferrous objects, presumed to be remnants of shell fragmentation from explosive munitions, were encountered much more frequently than projectiles from small arms during the examinations. Further, it is consistent with what is known historically about the heavy shelling that took place during the battle (for example, Cobb 2007) and, more generally, is reflected in injury types seen at dressing stations on the Western Front (Macpherson *et al.* 1922). According to Delaporte (1996), approximately 75% of trauma sustained on the Western Front was due to shells.

Anatomical distributions of wounds may perhaps be usefully explored by considering general patterns observed on the Western Front. According to Macpherson *et al.* (1922), shell fragment wounding of the thorax and abdomen was more common in stationary trench warfare, whereas bullet wounds to these regions were more common among soldiers going over the top to attack. Bullet wounds of the lower extremities, which are otherwise protected in the trenches, were also characteristic of open battlefield warfare, and blast injuries involving lower limbs were consistent with shells exploding on or near the ground (Macpherson *et al.* 1922). Added to this are the references to 'grazing fire' from firearms during the Battle of Fromelles (Lindsay 2008, 100), suggesting a high frequency of lower extremity bullet wounds. In addition, many of the Australian soldiers at Pheasant Wood had not been issued with steel helmets (Cobb 2007, 110) and were therefore vulnerable to significant head trauma. Finally, although not directly referring to the Western Front, Snow *et al.* (2008, 19) state that in conventional warfare the chest and head are more likely targets at closer ranges, suggesting that, in a First World War context, these regions are more likely to be affected among individuals engaged in trench combat, than in open battlefield warfare. If these observations are applied to the osteological evidence gathered from the Pheasant Wood soldiers, then it would seem that both trench and open warfare are reflected in this KIA (Killed in Action) group, perhaps the former more so; lower extremity trauma was less frequent than that involving the upper body and more blast trauma was seen. In addition, the allied soldiers reached and were recovered from the behind the German front line within their trenches. Unfortunately, those soldiers that fell on the open battlefield are less likely to have been recovered and subsequently buried at Pheasant Wood.

The anatomical distribution of wounds observed on the Pheasant Wood soldiers' remains (regardless of wounding mechanism) are in stark contrast to those seen among WIA (Wounded in Action) groups, such as those recorded by Butler (1940, 48) and discussed by Cobb (2007, 110) based on dressing station casualty lists. These suggest that 60-70% of injuries, most of which were small penetrating projectile injuries, were sustained by the extremities, with a much lesser proportion sustained by the head, neck, thorax and abdomen (2-19%). More generally, a similar distribution is also reflected for WIA groups in Delorme's War Surgery (1915) accounts, and also by NATO (2004), primarily on Second World War and Korean War injuries. Among the Pheasant Wood soldiers, while the most common type of injury – penetrating projectile – was the same, this KIA group showed the opposite pattern of body region involvement (few injuries to the extremities with most involving the head, neck, thorax and abdomen). This pattern is also reflected in the eye-witness accounts relating to KIA soldiers from the same battle, which indicate that the head, torso and abdomen were the most frequently involved (Loe *et al.* 2014).

These differences may be influenced by the biases inherent in the different datasets. For example, eye-witness data are entirely dependent on the memories of those who were on the battlefield (testimonies were taken months, even years after the battle), where confusion and extreme distress prevailed. Further, osteological data is biased because of the inability to distinguish wounds that were sustained by fighting soldiers from those that afflicted bodies lying on the battlefield while the battle ensued. Difficulties in identifying lesions osteologically by number, causal force and mechanism are also relevant here.

These points considered, perhaps the most influential factor relates to the nature of the groups – KIA and WIA – that are being compared. For WIA groups, injuries were not always fatal (at least not immediately) and many died from complications, such as septicemia, rather than the wounds themselves (Delorme 1915). Unfortunately, there are limited KIA data available to explore this further. Snow *et al.* (2008) present military casualty figures relating to 25 conflicts spanning Second World War to US marine casualties in Iraq in 2003, and show that in these settings the number of WIA consistently outweighs the number of KIA. However, the types of wounds and their anatomical locations are not discussed. Of more relevance is Champion *et al.* (2003), who give KIA data for several armed conflicts, the World Wars and Gulf Wars among them. They attribute penetrating head and thorax injuries to 51% of those killed in action, which is similar to the osteological findings presented here for Pheasant Wood. More generally, and also in keeping with the Pheasant Wood data, they observe that small projectile penetrating injuries, from fragments from explosive munitions, rather than bullets from military small arms, are the most common type of injury of most conventional modern-era battles (Champion *et al.* 2003).

These observations contribute to interpretations of epidemiological trends in combat trauma over time. Today, combat injuries reflect a pattern in which the extremities are vulnerable but, unlike those encountered at Pheasant Wood, penetrating injuries to the head and/or torso are limited because they are better protected by body armor (Belmont *et al.* 2010; Dougherty *et al.* 2009). Since the First World War, the character of warfare has seen a shift from a focus on military to military combat to one where civilian groups (without body armour) are targeted, particularly by explosive munitions (Gosselin 2005). Thus, patterns observed on the Pheasant Wood soldiers are more comparable with those of civilian groups and therefore have a modern forensic application where war crimes and human rights violations are suspected.

Although patterns of trauma observed among the buried soldiers and recorded in eye witness accounts for the Missing show correspondence at the population level, their use at the level of individual identification is likely to be limited and at best provide exclusion data only. Shell shock and the reliability of recall have already been mentioned as factors that will have caused conflicting reports between comrades. It is also worth re-iterating that a soldier may have sustained wounds post-mortem on the battlefield, that may contradict the testimonial evidence and which he acquired while already dead.

While there was no difference between the number of soldiers with peri-mortem injuries in any of the graves, differences were apparent in the number of individuals with multi-trauma and the frequency of injuries in particular body regions. In particular, Grave Two had a high proportion of individuals with multi-trauma in comparison to low frequencies in Graves one and five. All other graves showed an expected pattern. There are three possible explanations that may account for this difference, including observer error, the ages of the buried soldiers, and localised battle circumstances.

Observer error may account for some or all of the differences, with the over diagnosis of peri-mortem injuries in Grave Two and/or under diagnosis in graves one and five. Peri-mortem trauma is notoriously difficult to identify on the skeleton and the patterns observed may reflect this. With respect to over interpretation, Grave Two skeletons had undergone a substantial amount of taphonomic change, and this could have biased observations. However, this is unlikely because individuals in Grave Three had similar patterns of preservation, but they did not share the same trauma patterns observed in Grave Two. Further, the loss of substantial collagen in those remains closer to the wood means that post-mortem fractures that occur in the later depositional sequence do not mimic those of peri-mortem trauma. As a result, distinctions in the characteristics of peri- and post-mortem fractures should be fairly clear-cut.

With respect to under-diagnosis of peri-mortem trauma, it is possible that this has occurred in the analysis of graves one and five, which were further away from the wood. Here, fracture patterns were more difficult to interpret because the bones had retained their collagen, making the distinction between those occurring peri-mortem from those occurring post-mortem less clear cut. Thus, diagnoses may have been more cautious. However, this explanation is not supported by the fact that different patterns of multi-trauma were observed in graves three and four, where bones shared the same preservational status (that is, retained collagen). This explanation therefore seems unlikely.

Another possible explanation concerns the demographic profiles of graves one to five, which show a difference with respect to age, more specifically, Grave Two stands out for comprising a much younger group compared to all other graves. Thus, these individuals, because of their youth, may have been less experienced and this may have made them more vulnerable to the weapons of war and hence the patterns observed on their bones.

Perhaps a more plausible explanation is that the different patterns of multi-trauma are the result of localised battle circumstances. Perhaps a particular group of soldiers were the victims of targeted artillery bombardment or grenade attack. Or, the greater numbers of injuries in Grave Two soldiers were the result of an explosive insult in an enclosed space, such as the concrete constructed German trenches, where amplification of the blast wave resulted in an increase in the number of injuries. If the results reflect these circumstances, it is possible to infer the body removal and interment strategy, with those individuals killed near to one another being collected then buried together. The differences observed in Grave Two may also represent a combination of all explanations discussed here.