Appendix 6 – Optically stimulated luminescence (OSL) dating

by Sarah Hall

Aims of the dating

A visit was made to Areas Ex1 and Area 3 at the Eton Rowing Course during archaeological excavations in 1995, which had exposed a sequence of channel cut and levee deposits relating to a former channel of the Thames. In both areas, the channel cut into earlier sediments interpreted as early Holocene lacustrine and backswamp deposits, but dating evidence for this sequence was sparse. Although a little Neolithic pottery had been recovered from the earliest phase of the channel, it was uncertain whether this might have been redeposited. Few finds were found on the top of the levees in either area, and while the lower, waterlogged sediments of the successive phases could be clearly distinguished, there was some doubt as to whether the observed differences between the levee phases in section were genuine, or might have resulted from post-depositional processes.

OSL dating was therefore carried out, both to establish whether the uppermost sediments of the phase 1 and phase 2 channels in each area had genuinely been laid down at different times, and to provide approximate dates for these two different phases of channel in different parts of the site.

Sediment

Four sediment samples were taken: samples 968a and 968b from Area 3, and samples 968c and 968d from Area Ex1.

Sample 968a was from context 3039, the latest deposit on the levee adjacent to the first, and supposedly early Neolithic, phase of the channel. Sample 968b came from context 3163, the uppermost fill of the levee of the second phase of channel in Area 3, which built up over the fills of the first phase channel (Fig. 6.26).

Sample 968c came from context 651, the latest deposit on the levee of the first, and supposedly early Neolithic, phase of channel in Area Ex1. Sample 968d was taken from context 638, the uppermost deposit of the levee belonging to the second phase channel in Area Ex1, which overlay the fills of the first phase channel (Fig.6.3).

Dating was carried out in 1996, and the report written in January 1997.

Measurements procedures

The samples were treated with dilute hydrochloric acid to remove calcium carbonate, with hydrogen peroxide to remove any organic material and with Calgon accompanied by ultrasonic treatment to remove clays.

The material was then thoroughly rinsed in distilled water and the polymineral fine grains (4-11μm) separated. The fine grains from samples 968a, 968b and 968c would not disaggregate even after numerous washes in Calgon, so these samples were treated with fluorosilicic acid to remove all non-silicate material. This treatment results in a sample which is approximately 95% quartz. Sample 968c however contained very little quartz, and there was insufficient material left after this fluorosilicic acid treatment to carry out a viable analysis on this sample.

The luminescence signals were measured using Elsec optical dating systems. The luminescence signals from the polymineral grains of sample 968d were measured by exposure to infra-red light, which stimulates a luminescence signal only from feldspars (Spooner *et al*. 1990). The signal from the quartz fractions of samples 968a and 968b were measured using green light from an argon ion laser (Huntley et al. 1985). A similar measurement procedure was used for both stimulation wavelengths apart from different preheats. A preheat is required to remove the unstable signal, resulting from laboratory irradiation, that is not present in the natural signal.

A preheat temperature of 160° C was used for the infrared signal from sample 968d, and a preheat test was carried out to find the appropriate preheat duration. This involved irradiating aliquots with increasing beta doses from a Sr^{90}-Y^{90} source and making short shine measurements (exposing the sample to infra-red light for 1 second) after preheats of increasing duration. For each preheat temperature an additive dose curve was constructed and an equivalent dose (ED) was calculated, this being the beta dose giving rise to a luminescence signal equivalent to that of the natural signal. These EDs increase in value with preheat time until the time is sufficient to remove all charges unstable over the burial time. The results showed that a preheat of 6 hours at 160° C was required for sample 968d. A preheat of 5 minutes at 220° C was used for the

Table App 6.1: Summary of OSL dates

Lab. Ref.	Context number	Palaeodose (Gy)	a-value	Dose-rate (mGy/year)	Age BP (1950) at 68% confidence	Age range BC
968a	3039	4.25+0.29	0.038	0.87+0.06	4,900+500	3400-2400
968b	3163	2.66+0.26	0.038	0.69+0.05	3,900+500	2400-1400
968d	638	3.57+0.26	0.058	0.81+0.03	4,400+550	2950-1850

quartz signal from samples 968a and 968b (Smith *et al*, 1986).

The measurement procedure for dating involved constructing additive alpha and beta radiation growth curves. All aliquots were first normalized by the counts produced from a short shine of infrared light applied to the natural signal. The aliquots were then irradiated with increasing alpha or beta doses, preheats and measured by a 200-second exposure to the stimulation light. The growth curves produced were fitted either by a least squares linear fit or an exponential fit, and were extrapolated to give alpha and beta EDs. The alpha was used to calculate alpha particle effectiveness at creating a luminescence signal (a-value). For samples 968a and 968b the a-value was assumed to be 0.038, based on earlier calculations and as there was insufficient sample material for further tests. The samples used to construct the beta growth curves were bleached after the measurements had been taken, were redosed and used to construct a second growth curve from which the intercept correction (I) associated with a supralinear growth, recuperation or a residual hard to bleach signal could be determined. This is used to correct the ED value and calculate the palaeodose (P), which is the dose that the sediment has received since last bleached.

The annual dose rate received by the sediment during burial was calculated using portable gamma spectrometry, inductively coupled plasma mass spectrometry (ICPMS), thick source alpha counting and potassium flame photometry. The final dose rate used for the age calculation was a combination of these sets of measurements. The total gamma dose rate and the beta dose rate due to uranium and thorium was determined by on-site gamma spectroscopy, and the remaining beta dose due to potassium was determined by flame photometry. The alpha dose was determined using the results of ICPMS analysis (sample 968d) and thick source alpha counting (samples 968a and 968b).

The saturation water contents of the sediments were also measured at the time of sampling and found to be between 65% and 85% of the saturation values. As a result a value for the water content of 80+20% was used to correct the beta and alpha dose rates for absorption of energy by water.

The errors quoted in association with the age estimate take into account both systematic and random errors (at 68% confidence level) in OSL measurements, dose-rate measurements and calibrations radioactive sources and equipment. The calculations of these errors follows the method of Aitken (1976 and 1985).

Results

The measured values for the palaeodoses, a-values and dose rates are presented in Table App.6.1.

Conclusions

The three dates obtained are consistent with the statigraphy of the site. The results for 968a and 968b are further supported by the fact that 968a, which gave the older date range, is the phase 1 sample from Area 3, and stratigraphically earlier than sample 968b, from which a younger date range was obtained.

Appendix 7 – Human remains: methodology and overview

by Angela Boyle and Peter Hacking

Introduction

This report considers the probably Neolithic and late Neolithic/early Bronze Age human skeletal assemblage, which comprises four or possibly five skeletons (5587, 5856, 81318, 9941 and possibly 5127), ten deposits of disarticulated bone representing eleven individuals (692, 2999, 3839, 6900, 7004, 718, 9198 – adult and subadult, 9931, 5123 and probably 11058) and a single cremation deposit (70037). The Eton Rowing Course bones were recorded by Peter Hacking, those from the Flood Alleviation Scheme by Angela Boyle, and the report was written by Angela Boyle. Due to the wide date range and small size of the assemblage it is meaningless to consider the material as a single group. This Appendix describes the methodology used in the analysis of the human remains and provides a brief overview of the results relating to stature, metrical analysis, skeletal and dental pathology, and of discontinuous traits.

Methodology

Inhumations

Adult individuals were aged by combining a number of different methods: dental attrition (Brothwell 1981, 72), pubic symphseal ageing (Katz and Suchey 1986, 69) and auricular surface ageing (Lovejoy *et al.* 1985). Subadults were aged according to degree of epiphyseal fusion, long bone length (Workshop of European Anthropologists 1980; Brothwell 1981; Bass 1987) and dental development (Van Beek 1983). The sexing of adult individuals was based on pelvic and skull morphology and metric data (Workshop of European Anthropologists 1980). In keeping with standard practice, no attempt was made to sex subadults. Stature was calculated using the regression formulae of Trotter and Gleser (1952, 1958; reproduced in Brothwell 1981, 101). The dental notation employed was as follows:

/	post mortem loss	X	ante mortem loss
C	caries	A	abscess
NP	not present	U	unerupted
E	erupting	PE	pulp exposed
k	calculus	-	alveolus and tooth absent

Cremations

The cremated bones from each context were passed through a sieve stack of 10, 5 and 2mm mesh size. In each of the sieve groups, the bones were examined in detail and sorted into identifiable bone groups, which were defined as skull (including mandible and dentition), axial (clavicle, scapula, ribs, vertebra and pelvic elements), lower limb and upper limb. This may elucidate any deliberate bias in the skeletal elements collected for burial. Each of the samples were weighed on digital scales and details of colour and largest fragment were recorded. Where possible, the presence of individual bones within the category was noted.

Estimate of adult age was based on cranial suture closure (Meindl and Lovejoy 1985), degenerative changes to the auricular surface (Lovejoy *et al*. 1985), and pubic symphysis (Katz and Suchey 1986). Estimation of sex is based on isolated features and should therefore be viewed as tentative.

Assemblage composition

There were three adult male skeletons (5127, 81318 and 9941), one adult female (5587) and a subadult (5856) aged 5-6 years. The inhumations are summarised in Table App 7.1 and the disarticulated material in Table App 7.3. The disarticulated material comprised two adult male skulls (7004 and 3839), a single fragment of partially burnt skull (9931), skull vault of an adult (11058), an adult clavicle (692), a possibly adult metapodial (718), the right femur of a possible female (2999), midshafts of adult femur and tibia (5123), a portion of adult first metatarsal (6900), and a deposit comprising bones of an unsexed adult and a subadult (9198). In addition, a single cremation burial of a possible male adult was recovered from a central pit within a round barrow (Marsh Lane East Site 2, 70037).

Stature

Stature could be calculated for three adult skeletons: the female, 5587, measured 1.57m while the adult males, 81318 and 9941, measured 1.60m and 1.61m respectively.

Table App 7.1 Summary of the inhumations

Skeleton no.	*Site*	*Context*	*Preservation and completeness*	*Age*	*Sex*	*Stature*	*Skeletal pathology*	*Dental pathology*	*Discontinuous traits*
5127	Area 6	grave 5125, ring ditch 5361	poor, missing most of torso and extremities	30 y	M			caries	
5587	Area 6	grave 5588	virtually complete, condition good	25-30 y	F	1.57 m	parry fracture	enamel hypoplasia, calculus	spondylolysis of lv5, left os acromiale
5856	Area 6	grave 5856	condition fair, largely complete, missing metapodials	5-6 y	-	-			
9941	Area 16	ring ditch 9233	condition poor, most bone present though fragmented	40 y	M	1.61 m	grade II osteophytes of right 1st MCP joint, osteophytic lipping of ulna and coronoid		
81318	Watching Brief	river	condition fair, skull and mandible, fragmentary torso, long bones	c 21 y	M-	1.60 m		severe calculus	

Metric analysis

Disarticulated femur 2999 was platymeric. The shape of the proximal shaft of the femur is expressed as an index calculated from the antero-posterior and transverse diameters. This index, known as the meric index, is a measure of the antero-posterior flattening of the bone below the subtrochanteric portion of the shaft. An index of above 85.0 indicates eumeria; from 75.0-84.9 indicates platymeria, a flattening frequently noted in earlier populations (Hooper 2000, 169), and an index of below 74.9 is indicative of hyperplatymeria, a more extreme antero-posterior flattening. Disarticulated skull 3839 was dolicephalic, that is narrow or long headed (Bass 1987, 69).

Skeletal pathology

Trauma

Skeleton 5587 exhibited a soundly united 'parry' fracture of the distal right ulna.

Degenerative joint disease

Degenerative joint disease affected the ulna and coronoid and well as the right first metacarpophalangeal joint of skeleton 9941.

Dental pathology (Table App 7.2)

Enamel hypoplasia

Enamel hypoplasia affected the dentition of skeleton 5587. The condition is a developmental defect in the enamel of the dentition which can be related to generalised disturbances during the growth period. Although a number of workers have defined methods for estimating the timing of enamel defects (eg Schultz and McHenry 1975; Goodman *et al.* 1980) there are drawbacks and these are discussed elsewhere (Goodman and Rose 1990; Hillson 1996, 172-176). Skeleton 5587 exhibited four episodes of arrested growth between the ages of 2 and 5 years.

Table App 7.2 Summary of dental pathology (adults only)

Context	*AM loss*	*Caries*	*Abscess*
5127	5/22	1/12	A/22
5587	1/32	0/29	0/32
81318	0/22	0/22	0/22
3839	13/16	0/2	1/16
9941	3/9	0/0	0/9

Calculus

Calculus was present on the dentition of individuals 5587 and 81318, though was much more severe in the case of the latter. Calculus is mineralised dental plaque, which accumulates at the base of a living plaque deposit, and is attached to the surface of the tooth. The mineral is deposited from plaque fluid, but ultimately derives from the saliva, and the sites closest to the ducts of the salivary glands – lingual surfaces of anterior teeth and buccal surfaces of molars – show the most abundant calculus formation. It is still unclear how plaque mineralisation is initiated, although bacteria probably have an important role (Hillson 1996, 255-6).

Caries

Skeleton 45127 exhibited a single carious cavity.

Table App 7.3 Summary of disarticulated material

Context no.	*Site*	*Relationships*	*Bones present*	*Age*	*Sex*	*Cephalic index*	*Meric index*	*Dental pathology*	*Discontinuous traits*	*Comments*
692	Ex1		left clavicle, damage to both ends	adult						
718	Ex1	river channel	metapodial	adult?						
2999	Evaluation Trench 201/7	associated with scatter of struck flint	right femur	adult	F?		platymeric (75)			
3839	Area 5	river channel	skull only	45+ y	M	doliocephalic		abscess		
5123	Area 6	post-medieval ditch cutting ring ditch 5361	mid femoral and tibia shafts	adult	?					sinuous striations on abraded cortex
6900	Area 10	2 m2 within hollow	metatarsal fragment	adult						
7004	Watching Brief	palaeochannel	skull only	35+ y	M				large wormian bone	
9198	Area 16	ring ditch 9233	skull and long bone fragments (humerus, tibia), patella femoral epiphysis	adult subadult						
9931	Area 16	fill of pit 9930	skull fragment	adult	?					partly burnt
11058	Area 6	contaminated early Neolithic layer in hollow	skull vault fragment	adult	?					

Dental caries is a destruction of enamel, dentine and cement resulting from acid production by bacteria in dental plaque, ultimately leading to the formation of a cavity in the crown or root surface. Usually caries progresses slowly (chronic caries) and arrested or remineralising phases alternate with more active phases, so that a cavity may remain stable for months or years (arrested caries). Rapidly progressive destruction (rampant caries) is rare and characteristically results in the loss of most erupted tooth crowns in a child's mouth (Hillson 1996, 269).

Abscess

An abscess was noted on the dentition of skull 3839. The tooth had been lost in life presumably as a result of gross carious decay. After pulp death the inflammation passes down the root canal and leads to the build-up of pus in the jaw bone.

Discontinuous traits

Spondylolysis

The fifth lumbar vertebra of skeleton 5587 had a separate neural arch, the condition known as spondylolysis. The overall prevalence of spondyloysis in modern populations is 3-7% (Resnick and Niwayama 1981, 2253). The favoured interpretation of the defect is a stress or fatigue fracture that fails to heal (Resnick and Niwayama 1981, 2253). It may, however, also be caused by a genetic weakness (Hensinger 1989). There is no doubt that genetic influence is important and there are families in which a quarter of the members have spondylolysis, frequently associated with other congenital abnormalities of the spine such as transitional vertebrae or spina bifida (Shahriaree *et al.* 1979; Fredrickson *et al.* 1984). Clinical and experimental evidence, however, tends to support the view that these lesions are acquired as the result of trauma sustained between infancy and early adult life (Waldron 1991, 64). In his comparison of Roman and Anglo-Saxon groups with the 18th- and 19th-century assemblage from Christ Church, Spitalfields, Waldron (1991, 64) found that the condition was much less prevalent in the latter group and suggested that this may be one indication of a lifestyle that was much less arduous or physically demanding compared to earlier populations in Britain. There is no evidence for spondylolisthesis which is the term used for displacement of the affected bones.

Wormian bones

Skull 7004 and a fragment from cremation 37 had lambdoid wormian bones. They are extra bones which can occur in the suture line between two cranial bones. It has been argued that they are inherited (El-Najjar and Dawson 1977) while others have argued (Bennett 1965) that their occurrence is purely related to environmental or stress factors.

Os acromiale

Skeleton 5587 had os acromiale which is generally a rare condition (3% in modern populations). It is a failure of the epiphysis to unite to the acromion. Fusion should occur by 18-19 years of age (Stirland 2000, 120). It has often been considered an anomaly that develops as the skeleton grows and matures, with the particular epiphysis failing to unite to the main bone. Others have suggested that it might be caused by a traumatic incident (Miles 1994).

Possible anthropogenic alterations of human bones
Summarised from a dissertation by Irene O'Sullivan

Introduction

A total of 48 human bones were recovered from the Thames palaeochannel (including one virtually complete skeleton: SF 81318). When possible cut marks and scavenging marks were noticed on human bones from the palaeochannel, advice was sought from Professor Margaret Cox at Southampton University. She suggested that all of the human bones from the palaeochannel should be analysed for evidence of anthropogenic alteration, and a post-graduate student at Southampton, Irene O' Sullivan, carried out the work as a dissertation submitted as part of her MSc in Forensic Archaeology (O'Sullivan 2001). This work has not been published, and so a summary of the method and results is given below.

Of the total of 48 bones, 43 were examined. The remainder were other bones from skeleton SF 81318.

Aims of the study

The aims of the study were:

- To determine whether the alterations to the bones had occurred peri-mortem or post-mortem.
- To establish whether the alterations were caused by natural accidental damage or were caused as a result of deliberate actions, and if the latter, whether by humans or animals. A particular concern was the possible effect of fractured natural flint gravel on the bones during periods of high channel flow.
- To characterise the types of intentional alterations by humans, what processes are represented by them, and to attempt to interpret why these occurred.
- To establish whether there was a chronological pattern to the human alterations to the bones.

Methods

Control samples were made using animal bones to characterise the types of deliberate alteration created by particular actions such as cutting tendons, defleshing (including scraping the bones) and animal gnawing. A growing literature upon human alteration of bones, particularly in societies practising cannibalism, was consulted, including a range of recent experimental analyses. The control samples and previous experiments were used to design forms to record the alterations, and a pilot study was then undertaken to check the recording forms against the questions they were designed to answer. In response to this, some recording forms were altered and others added, following which the control samples and the ancient bones were all examined macroscopically and under x25 magnification to characterise the marks left on the ancient bones. Full details of the forms, and of the types of analysis undertaken, can be found in O'Sullivan (2001). SEM analysis of cut marks (notch analysis) was also undertaken, but due to problems obtaining necessary materials this study was limited to only 3 bones.

Dating

Key to the wider interpretation of the results was the dating of the altered bones. Of the total of 43 bones, 26 had directly related radiocarbon dates, and another 3 were dated by association, leaving 14 undated except by broad stratigraphic association.

Results

A total of 11 bones of the 43 examined were dated to the periods covered by this volume. Eight belonged to a skeleton from Area 6 radiocarbon dated to the late Neolithic, a skull and a clavicle came from early Neolithic contexts 3839 and 692, and a calvaria (part of another skull) was of middle Neolithic date.

Only two of these bones showed signs of deliberate alteration. The clavicle from 692 was fractured after death, but showed a tooth puncture and two tooth scores – evidence of gnawing by a carnivore. The mandible of the late Neolithic skeleton in the channel adjacent to Area 6, SF 81318, had five shallow striations on the lingual side suggesting scraping of the bone while still fresh. None of the other bones examined from this skeleton bore any other signs of deliberate modification.

Discussion

In the first case, the evidence might indicate that the individual had been exposed (excarnated) for defleshing prior to burial, and that this bone had been scavenged before finally being deposited at the edge of the early Neolithic channel. The multiple striations on the late Neolithic mandible appear to suggest that the tongue of this individual may have been cut out at or soon after death. The marks are unlikely to have been the result of a single violent blow, and suggest deliberate defleshing, though whether in preparation of the skull or in order to eat the tongue is not clear.