mJournal of Archaeological Science (1999) **26,** 1–8
Article No. jasc1998.0283, available online at http://www.idealibrary.com on IDEAL

Thermal Alteration of Buried Bone

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(*Received 21 July 1997, revised manuscript accepted 28 January 1998*)

Burned bone is a common component of archaeological deposits traditionally associated with cremations, culinary activities, waste disposal, fuel use and a by-product of naturally occurring fires. Such interpretations assume responsible agents act upon bone prior to deposition or burial. This sequential relationship between heating and burial is challenged by the suggestion that post-burial alteration of bone is not only possible, but can serve to explain the condition of burned material recovered in certain situations.

Exposure to heat following burial incorporates several additional variables. The sediment in which bone is deposited, duration of exposure to a heat source, and the interval between burial and burning affect the degree and extent of thermal alteration. Experiments have been conducted to test the hypotheses and parameters surrounding subsurface (i.e. post-burial) alteration by surface fires.

Keywords: BURNED BONE, POST-BURIAL PROCESSES.

Introduction

The recovery and analysis of burned bone provokes numerous taphonomic questions. Given the role of fire in site formation processes archaeological interpretations must consider the cultural (intentional) or natural (accidental) origins of fire (Rowlett, 1991). Recently, it has been suggested that bone may be burned following burial (e.g. De Graaff, 1961; Binford, 1984; Walters, 1988; David, 1990; Lyman, 1994; Stiner *et al*., 1995). More specifically, post-burial thermal alteration has been put forth by some as a plausible explanation for the presence of burned bone in the archaeological record (e.g. Webb & Snow, 1959; Archer, 1977; Lampert, 1981). This contradicts the assumed sequential relationship between burning and burial and introduces several additional variables that require investigation: sedimentary deposits, duration of heat exposure and the elapsed interval between burial and exposure to heat. Accurate interpretations of burned bone assemblages rely upon the ability to identify the temporal relationship between deposition and burning.

Deposition, the placement or location on a surface and burial, the covering or layering with sediments are separate contexts in the taphonomic history of artefacts (Lyman, 1994). Numerous post-depositional and post-burial agents affect and potentially alter skeletal material (see Gifford, 1981 for a review). However, it is often difficult to interpret such agents due, in part, to the absence of known signatures of certain taphonomic processes. The present study aims to discern features which characterize bone burned following deposition and burial, specifically whether bone located in deposits can be burned by a present day surface fire. The effects of intensity and duration of heating upon the degree of post-burial alteration are considered. In addition, variation attributed to the sedimentary composition of the deposit in which an element is located is addressed.

The discovery of burned material (e.g bone and sediment) prompts numerous questions regarding natural and/or cultural influences upon the formation of the deposits. Ethnographic considerations indicate that heat-affected bone may be attributable to the indirect action of humans (e.g Walters, 1988). The incorporation of discarded waste bone into the hearth area of a subsequent fire has resulted in the post-depositional burning of bone (Jones, 1980; Walters, 1988). A high frequency of burned bone was recognized in deposits located directly below the occupational level in Seton Cave which led researchers to conclude that this may result " . . . from fires lit during the occupation phase, affecting bones that had accumulated there prior to human residence . . . " (Lampert, 1981: 109). Similar conclusions were drawn in the analysis of burned faunal material from Puntutjarpa Rockshelter (Archer, 1977). Investigation of mounds and charnel structures have further confirmed the plausibility of post-depositional and post-burial alteration (Caldwell & McCann, 1941; Webb & Snow, 1959; Perino, 1971; Harn, 1980). Binford presents the possibility of transformation in open sites resulting from " . . . a fire kindled on top of a previously abandoned and scavenged bone . . . " (1984: 1960). Similarly, Lyman suggests that charred bone in

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an organically rich and charred stratum probably burned " . . . when the matrix in which they are embedded burned . . . " (1994: 392).

Numerous actualistic studies have addressed alteration of deposits resulting from surface fires (see Whyte, 1984 for review). However, such examinations are limited in number concerning the *in situ* responses of bone. De Graaff (1961) attempted to replicate the effects of a primitive hearth on sub-surface bone fragments. Skeletal fragments were excavated from below the hearth following 7 weeks of heat exposure. Bone recovered from 4–8 inches (10·16–20·32 cm) below the fire revealed considerable charring and bone located at a depth of 12 inches (30·48 cm) exhibited attributes of heat alteration. Investigations conducted by Stiner and coworkers (1995) considered the insulating potential of soil on buried bones. Bones buried to a depth of 5 cm exhibited burning to the point of carbonization (blackening), though less than half of the bone fragments buried at 10 cm displayed evidence of thermal alteration. The work of De Graaff (1961) and Stiner *et al.* (1995) demonstrate that post-burial thermal alteration is possible and further suggest that variables such as duration of heating directly influence the degree of post-burial alteration. The present study incorporates additional and systemic experimentation to investigate more accurately the variability of post-burial thermal alteration of bone.

As proposed by Lyman, investigations involving burned bone must incorporate two fundamental points: recognition of heat alteration and the determination of burning relative to deposition and burial (1994: 385). Contained within these basic concepts are numerous themes which have guided and characterized research during the last 50 years. Although early investigators considered the roles of intensity, duration and proximity to fire while establishing criteria to facilitate interpretation of cremations, they refrained from investigating specific temperature-related changes (e.g. Webb & Snow, 1945; Baby, 1954; Binford, 1963; Buikstra & Goldstein, 1973). Building upon these early works, actualistic investigations have addressed incremental temperature related changes in surface morphology, (i.e. fracturing and shrinkage), as indicators of pre-incineration condition and level of heat exposure (Thurman & Willmore, 1980; Gilchrist & Mytum, 1986; Buikstra & Swegle, 1989; Spenneman & Colley, 1989). During the last decade, research has focused upon the investigation of surface colour, macroscopic morphology and microscopic crystalline structure of bone burned in controlled settings (Shipman, Foster & Schoeninger, 1984; McCutcheon, 1992; Nicholson, 1993). Although laboratory experimentation on burned bone has generated a general scheme of traits to draw inferences about maximum heating temperature correlated to morphological change, the sole application of laboratory results to archaeological analysis of burned bone is imprecise and unreliable. The present study incorporates both actualistic and experimental approaches towards recognition of the parameters of subsurface thermal alteration.

Both experimental and actualistic investigations have incorporated colour variation as a mechanism for identifying and assessing the degree of heat alteration (Thurman & Willmore, 1980; Shipman, Foster & Schoeninger, 1984; Spenneman & Colley, 1989; McCutcheon, 1992; Nicholson, 1993). Research has indicated that bone subjected to increasingly high temperatures exhibits change in surface colour, from browns to black, to blue grey and white, with one colour usually dominating the surface (see Correia, 1997 for review). Surface colours traditionally described using Munsell Soil Color Charts (Munsell Soil Company Inc., 1954) have been associated with ranges of exposure temperatures (Thurman & Willmore, 1980; Shipman, Foster & Schoeninger, 1984; Spenneman & Colley, 1989; McCutcheon, 1992; Nicholson, 1993). Although Shipman, Foster & Schoeninger (1984) state that this method is imprecise as a sole indicator for estimating maximum heating temperature, Taylor, Hare & White (1995) found that surface colour is commonly the sole criteria used in assessing the level of thermal alteration of bone. Recently, Cole *et al.* (1996) successfully interpreted the surface colour on archaeologically recovered bone as resulting from heat exposure. This was confirmed by comparison with X-ray diffraction patterns and microscopic surface textures of experimentally burned bone. Such analyses are usually prohibited by high costs. While the assessment of surface colour may be subject to slight researcher variation, the applicability and availability of the technique warrants its use as a measure of heat exposure.

Materials and Methods

Samples of modern weathered and archaeological bone (Archaic) were utilized in this study. The modern bone sample consists of weathered white-tailed deer, *Odocoileus virginianus*, metapodial segments. Complete bones exhibiting characteristics of late stage 1 and early stage 2 weathering, as described by Beherensmeyer (1978), were collected during the autumn of 1994. Collected elements were rinsed in water to remove any residue and were thoroughly dried prior to use. Similarly sized metapodials were selected. The modern weathered bone segments were produced by longitudinally bisecting each metapodial using a stryker saw. Each half was then cut into proximal, middle and distal segments.

Archaic bone specimens were selected from a single 1 m × 1 m × 10 cm excavation unit (988 N 920 E-level 19) from a Late Middle Archaic archaeological horizon at the Hayes site (40 ML 139), a stratified midden on the Duck River in central Tennessee. The sample consists of 34 similarly sized bone fragments of white-tailed deer dated to approximately 5500 BP. These specimens demonstrate extensive cracking and

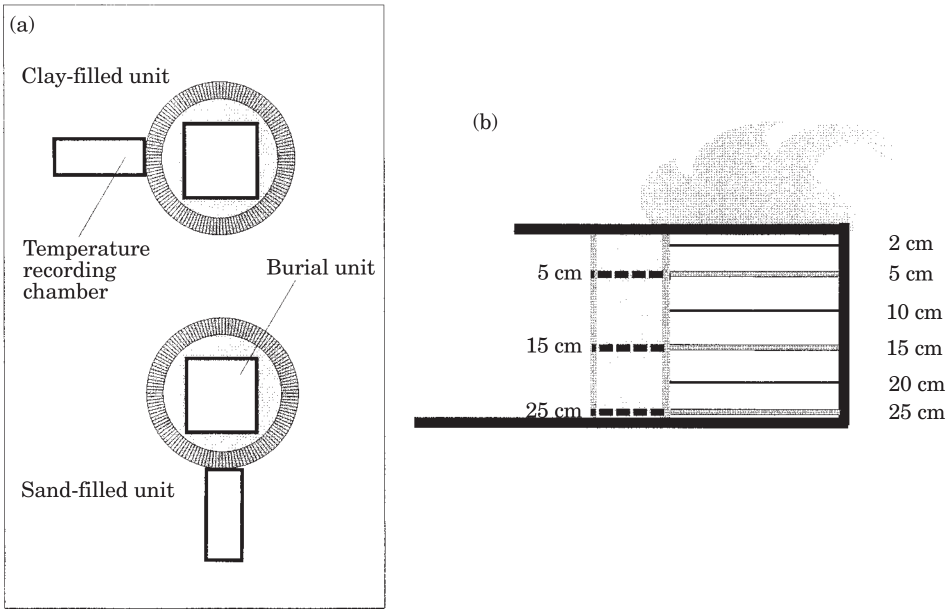

Figure 1. (a) Aerial schematic of units. (b) Profile schematic depicting subsurface burial levels (2, 5, 10, 15, 20 and 25 cm) and temperature probing chambers at 5, 15 and 25 cm below surface.

exfoliation of cortical surfaces reflecting an extended period of exposure; stage 4 (after Beherensmeyer, 1978).

Designed to replicate a prehistoric occupational campfire, this procedure is comprised of two identically prepared fire simulations (see Figure 1), each consisting of a burial unit, 25 cm × 30 cm × 30 cm, and a temperature recording chamber. The temperature chambers facilitated insertion of a pyrometer for measurement of temperatures in the subsurface levels. Each temperature chamber was separated from the burial unit by a 15 cm wide earthen bulk. Three holes were drilled through this bulk at 5, 10 and 15 cm below the original surface and fitted with ceramic insulators to permit accurate insertion of a digital pyrometer for temperature readings.

Each burial unit consisted of six incremental levels. The uppermost is located 2 cm below the surface with the remaining five located at 5, 10, 15, 20 and 25 cm below surface (see Figure 1). Two bones, one modern metapodial segment and one archaeological fragment were buried at each level in both units. Bones in adjacent levels were alternately positioned at 90 degree angles to allow even exposure to radiating heat. Modern distal segments were buried in one unit and modern proximal segments were buried in the other unit. Segments cut from the same bone were buried in adjacent levels.

To investigate potential differences in the conductive properties of varied sediments, one unit was filled with a non-local dark reddish-grey clayey-silt and one was filled with a fine grain pale yellow sand. Sediments were screened and compacted during refilling. Stone hearths, with an internal diameter of 45 cm, were built above each unit and fires were maintained for 48 h. A plentiful and local species of cedar (*Juniperous virginiana*) was utilized. Subsurface temperatures were recorded hourly (in °C) using a Thermolyne Sybron type pm 20700 digital pyrometer. Temperatures were taken by extending the probe into the centre of the subsurface matrix in proximity to the bone (directly under the fire) until a constant temperature was reached.

A total of 45 hourly readings were taken; 40 during the 48 h of fire maintenance and five readings at 12 h intervals following termination of the fire. To facilitate interpretations concerning the transfer of heat within the deposits, mean temperatures were calculated for several periods in each of the burial units. The units were excavated 7 days later and included measurement and removal of the ash layer. The appearance of the sediment in each level was evaluated using the Munsell Soil Color Chart (Munsell Soil Company Inc., 1954). Recovered bone specimens were placed in separate paper coin envelopes and labelled for unit and depth.

Bone segments were assessed for change in surface appearance; primary (dominant) and any additional (secondary) surface colours were recorded using the Munsell Soil Color Chart (Munsell Soil Company Inc., 1954). In addition, both the degree and location of morphological distortion, (i.e. fracturing and warping) was recorded. These specimens were compared to modern-weathered and Archaic bones heated in a controlled setting (i.e. known temperature), using a Skutt 240 amp electric kiln (model 227). Temperature was regulated by three controls and was monitored by inserting the probe of the pyrometer into the kiln. Specimens of modern weathered and Archaic bone

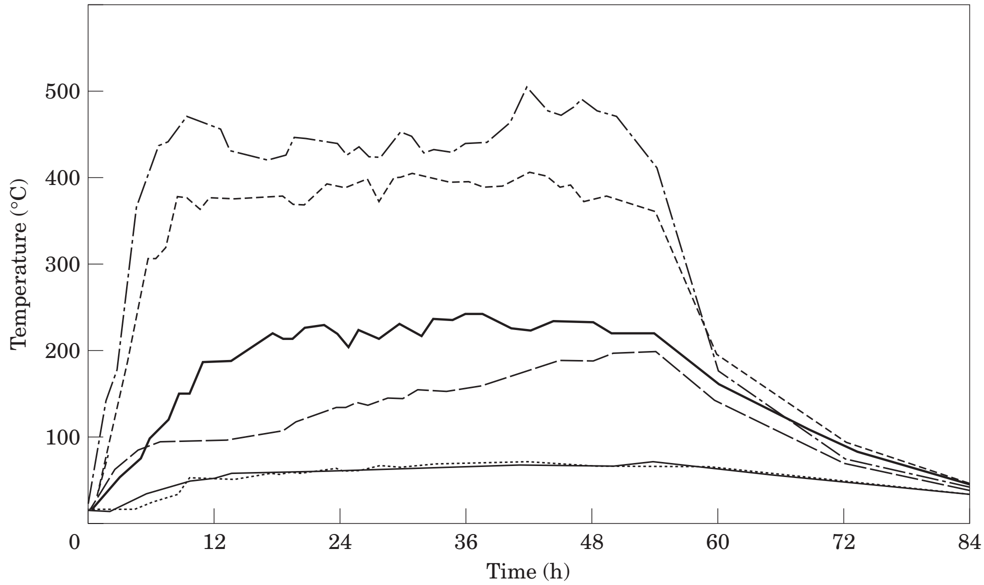

Figure 2. Subsurface temperatures. — - —, 5 cm clay; - - - 5 cm sand; ━━, 15 cm sand; — — —, 15 cm clay; ——, 25 cm clay; ·······, 25 cm clay.

were subjected to controlled heating to facilitate comparison with the burned bone and to investigate the roles of intensity and duration of heating upon skeletal elements. A segment of modern metapodial and a fragment of archaeological bone were simultaneously heated for 48 h. Pairs of bones were situated on a shelf suspended in the centre of the kiln. One pair was heated to 130°C ± 5–10°, a second pair to 240°C ± 5–10° and a third pair to 390°C ± 5–10°. These temperatures were selected as they are comparable to the average temperatures recorded during the campfires. Similarly, pairs of modern weathered and Archaic bone were heated to 190°C ± 5–10° and 300°C ± 5–10° for periods of 72 h. These two temperatures represent approximate median heating temperatures between those three mentioned above.

Results

Subsurface temperatures reflect separate trends of heating, maintenance and cool down. The subsurface radiation of heat is characterized by a period of increasing temperature during the first 10 h followed by a period of heat maintenance through approximately hour 50 culminating in an initially rapid then gradual cool down (see Figure 2 and Table 1). Maximum temperatures attained at each level are presented in Table 2. Three maximum temperatures occurred after 42 h of heating while two others were recorded at 54 h, 6 h after termination of the fire. The highest subsurface temperature was recorded in the clay deposit at a depth of 5 cm; approximately 100°C higher than the maximum temperature reached in the sand filled unit. At the 15 cm depth, the sand deposit reached a higher temperature than the clay deposit, although little variation between sedimentary deposits exists at the 25 cm depths.

Bones were evaluated based on the duration and intensity of heating. Surface colours on bone recovered from 2, 5, 10 and 15 cm depths are presented in Table 3. The appearance of bones from depths of 25, 20 and 15 cm below surface do not indicate they were exposed to heat, though minimal soil staining was apparent on these specimens at the time of recovery. Modern weathered specimens from 10 cm and above demonstrate dramatic alteration, while change in Archaic specimens is minimal. Colour is consistent across all surfaces, although the segment from the 5 cm depth in the sand filled unit appears slightly darker on the inferior surface. Modern weathered segments from depths of 5 cm and 2 cm exhibit colours which suggest they were in the final stages of combustion of the organic component (calcination).

Structural distortion is visible on several modern weathered segments. Segments buried at 2, 5 and 10 cm in the sand-filled unit demonstrate minimal distortion and longitudinal splitting, propagating from the medial margin toward the epiphyseal region. Similar longitudinal splitting with transverse fracturing in the metaphysis is visible on bone segments from the clay filled unit but only at depths of 2 and 5 cm. No macroscopic deformation attributable to heat is apparent on the Archaic bone specimens.

Approximate heating temperature, primary and secondary surface colours and length of heat exposure of samples heated in the kiln are presented in Table 4. The only apparent structural distortion is minimal longitudinal splitting of the modern segment heated for 48 h at 390°C ± 5–10°.

Table 1. Temperatures (°C) recorded in deposits

Hour	Sand unit			Clay Unit		
	5 cm	15 cm	25 cm	5 cm	15 cm	25 cm
1	28·3	15·7	14·3	90·0	23·7	13·6
2	79·0	28·0	13·3	142·7	48·8	13·3
3	128·0	50·3	15·8	172·1	62·2	17·0
4	183·0	60·5	15·1	259·0	72·6	23·3
5	249·0	69·8	17·9	367·0	81·5	29·4
6	306·0	93·0	22·7	397·0	89·0	34·5
7	306·0	106·8	25·4	437·0	93·0	38·0
8	325·0	120·0	28·8	440·0	93·0	42·0
9	381·0	151·2	33·8	454·0	93·7	46·7
10	377·0	147·8	52·5	471·0	94·4	50·3
11	360·0	182·5	50·9	469·0	95·2	50·3
12	377·0	188·2	51·6	466·0	97·0	52·5
13	374·0	187·0	51·8	460·0	96·0	54·0
14	376·0	187·7	50·5	430·0	96·8	58·5
18	378·0	221·0	58·1	419·0	105·6	60·6
19	380·0	212·0	57·5	423·0	107·1	59·8
20	369·0	212·0	61·3	445·0	116·0	60·0
21	368·0	227·0	58·2	447·0	121·5	59·3
23	394·0	230·0	63·4	442·0	130·2	60·9
24	391·0	222·0	64·5	443·0	134·3	60·8
25	388·0	203·0	61·3	427·0	134·9	61·6
26	396·0	225·0	62·1	437·0	140·1	61·7
27	399·0	218·0	64·8	425·0	137·0	62·5
28	375·0	215·0	67·8	424·0	142·0	62·8
29	400·0	223·0	66·6	441·0	145·3	63·8
30	401·0	232·0	67·3	454·0	142·0	64·0
31	407·0	217·0	67·7	449·0	152·0	64·7
32	402·0	217·0	68·8	430·0	154·4	65·5
33	401·0	238·0	70·0	434·0	153·3	66·1
34	398·0	236·0	70·4	432·0	154·6	66·2
35	394·0	236·0	71·0	430·0	157·0	66·7
36	397·0	243·0	71·3	439·0	159·6	67·6
38	390·0	244·0	71·0	442·0	161·0	68·0
40	392·0	229·0	72·0	463·0	170·0	68·1
42	408·0	224·0	73·9	506·0	176·0	68·5
44	404·0	237·0	71·6	478·0	186·6	68·7
45	390·0	236·4	69·7	472·0	188·3	69·2
46	396·0	235·0	70·9	479·0	189·7	68·7
47	374·0	234·0	70·7	495·0	189·2	68·1
48	378·0	234·0	68·9	484·0	190·5	68·6
50	380·0	220·0	66·4	474·0	198·4	68·6
54	363·0	222·0	68·6	415·0	201·0	72·1
60	193·2	164·5	67·6	179·0	139·9	65·9
72	98·2	91·5	52·5	78·4	72·5	52·5
84	52·2	49·5	38·3	47·7	45·0	38·4

Discussion

Bone located in a subsurface matrix can be affected by surface fire though results indicate the extent of alteration is influenced by the interaction of several variables including pre-incineration condition, intensity of heating, duration of exposure and the depositional sediment. Modern weathered bone segments subjected to low intensity, long duration burning exhibit minimal distortion and uniformity in colour across exposed surfaces. Similarly heated Archaic specimens exhibit muted, though uniform, surface colours and an absence of heat-related fractures. In contrast, bone subjected to high intensity, short duration burning demonstrate multiple surface colours and moderate distortion, possibly caused by dramatic fluctuations in temperature (Bennett, 1996). The bone specimens heated in the kiln display even colouring across superior surfaces, probably due to an even distribution of heat throughout the kiln.

Table 2. Temperatures (°C) attained in deposits

Depth (cm)	Sand unit	Clay unit
Maximum subsurface temperatures		
5	408·0	506·0
15	244·0	201·0
25	73·9	72·1
Hour 11 to 48 mean subsurface temperatures		
5	388·6	449·5
15	221·5	144·1
25	64·9	63·3

A discussion of the parameters surrounding subsurface thermal alteration will focus on specimens buried at 5 cm depths. The colours exhibited on

Table 3. Surface colours (after Munsell Color Company Inc., 1954) identified on specimens burned in campfires

	Specimens			
	Sand Unit		Clay Unit	
Burial levels	Modern	Archaic	Modern	Archaic
Unaltered	2.5Y 8/2,4 white, pale yellow	2.5Y 8/4 10YR 7/3 pale yellow, very pale brown	2.5Y 8/2,4 white, pale yellow	2.5Y 8/4 10YR 7/3 pale yellow, very pale brown
2 cm	5YR 6/1 grey	10YR 6/1 grey	2.5YR N5 grey	10YR 6/2 light brown, grey
5 cm	7.5YR 7/2 pinkish grey 7.5YR 5/2 brown	10YR 4/1 dark grey	5YR 5/1,2 grey/red grey	5YR 5/1,2 grey/red grey
10 cm	5YR 2/1 black	10YR 5/3 brown	7.5YR 4/4 dark brown	10YR 6/4 light yellow brown
15 cm	2.5Y 8/4 pale yellow	2.5Y 8/4 pale yellow	10YR 8/4 very pale brown	10YR 8/4 very pale brown

Table 4. Surface colours (after Munsell Color Company Inc., 1954) identified on laboratory specimens heated in kiln

Time (h)	Temperature (°C)	Specimens Modern	Archaic
	20	10YR 7, 8/3 very pale brown	2.5Y 8/4, 10YR 7/3 pale yellow, very pale brown
48	130	10YR 6/8 brown yellow	2.5Y 8/4, 10YR 7/3 pale yellow, very pale brown
48	240	10YR 3/2 very dark grey brown	10YR 5/1, 5YR 7/4 grey, pink
48	390	5YR 6, 7/1 grey, light grey	10YR 5/1, 5YR 7/4 grey, pink
72	190	10YR 8/3 very pale brown	10YR 7/3 very pale brown
72	300	7.5YR N7, 7.5YR 7/4 grey, pink	10YR 7/1, 7.5YR 7/4 grey, pink

modern weathered bone segments are commonly associated with higher temperatures than those recorded during this research (see Table 3; Thurman & Willmore, 1980; Shipman, Foster & Schoeninger, 1984; Spenneman & Colley, 1989; McCutcheon, 1992; Nicholson, 1993). This conclusion is based upon the mean calculated temperatures for each unit during the period of fire maintenance (i.e. hour 11 to hour 48) (see Table 2).

Recorded temperatures did not exceed 500°C at a depth of 5 cm. However, segments from the upper two levels (2 and 5 cm) were grey in colour. Given that the specimen recovered from a depth of 10 cm in the sand unit exhibits qualities of partial combustion of the organic component (blackened), it follows that segments from 2 and 5 cm depths represent near complete combustion of the organic component. This may help to explain the findings of De Graaff who noted that bone recovered from depths of 0 to 2 in. (0–5·08 cm) was extremely fragile, but did not appear to be dramatically altered; "the dominant coloration of the bones from this stratum was a light brown" (De Graaff, 1961: 26). Given the duration of his fire, and the fact that bone from the adjacent, lower stratum appeared "pitch black in colour . . . " (De Graaff, 1961: 26) bone in the upper stratum should demonstrate substantial heat alteration. The colours De Graaff recognized may be similar to the grey, muted colours witnessed here on the modern weathered segments from 5 cm levels.

In the research conducted by Stiner *et al*. (1995), fires used only 6 kg of hardwood and were allowed to burn unattended. No calcination of buried skeletal elements, even those situated 1 cm below surface, was noted during this shorter duration heating experiment (Stiner *et al*., 1995). In addition, Stiner *et al*. (1995) found that less than half of the bones buried at 10 cm displayed marked change. The range in degree of post-burial thermal alteration found between De Graaff (1961), Stiner *et al*. (1995) and the present study is attributable to the differential periods of heating. The apparent influence of duration of heating suggests that the correlation between temperature and macroscopic appearance may not be as strong as previously considered. This is particularly critical, as suggested by White (1992), given current interpretations of burned bone and the possibility that in certain instances signatures of heating may be misconstrued as evidence of diagenetic alteration.

The longitudinal splitting and fractures witnessed on modern weathered samples are consistent with the findings of Buikstra & Swegle (1989) who suggest fractures and warping on dry bone are limited in number and degree. There are several additional factors that may explain the limited modification seen on specimens: the degree of weathering (Archaic specimens are almost entirely devoid of heat-related fractures), the effects of radiating heat as opposed to direct exposure to fire and the support provided by the sedimentary deposits. Moderate distortion has been noted on bone buried at 0–5 cm in the presence of rapidly rising high intensity fires of short duration (Bennett, 1996).

Subsurface temperature information is necessary for assessment of the degree of alteration, but it also demonstrates variation in the thermal conductivity of sediments. The recorded temperatures indicate that the diffusion of heat occurs at different rates. In the upper level the clayey silt heated up faster than fine grain sand and the maximum temperature recorded for the clayey silt exceeded that recorded for the sand. In the middle level, the sand attained a higher temperature than the clayey silt (see Figure 2). It would appear this is attributable to variation both in the particle size, which would affect the radiation of heat through the subsurface matrix, due in part, to the amount of air in the deposit, and the conductive properties of the sediment.

Data presented here demonstrates that bone situated in a subsurface matrix can be altered initially or long after deposition, forcing a re-evaluation of the traditional assumption that bone is burned through direct exposure to flame. Although this research suggests that certain morphological qualities characterize bone burned following burial, these traits cannot be considered solely reflective of post-burial burning. Hence, thorough contextual investigations incorporating sedimentary analysis may provide a more holistic view of the *in situ* processes that affect bone thereby enabling more accurate inferences of post-depositional and post-burial processes.

Conclusions

This investigation indicates that bone can be burned in a subsurface, i.e. post-burial context. Segments of modern weathered bone situated 10 cm below the surface are burned to the point of carbonization (blackened) indicating that bone located at 5 and 2 cm depths are in the process of calcining (near complete combustion of the organic component). Bone fragments dated to approximately 5000 BP located in a subsurface deposit can be altered through the effects of a present day surface fire.

The appearance of bone burned in a subsurface context (indirect exposure) differs slightly from bone burned in a surface (direct) context. Surface colour on specimens heated through the radiating effects of a campfire exhibit continuous colour across all surfaces.

Based on these results and previous studies, it is clear that duration of heating and intensity of exposure affect the degree of burning. De Graaff (1961) recovered charred bone at depths of 8 in. (20·3 cm) following 7 weeks of exposure to a primitive campfire, while in the present study blackened bone was recovered from depths of 10 cm following 48 h of burning. Furthermore, after a shorter period of heating, Stiner *et al.* (1995) found that less than half of the bone located at a depth of 10 cm demonstrated any degree of alteration.

The data indicate that transfer of heat occurs at different rates and in varying patterns between sediments. The variability noted between units in subsurface temperatures suggests that particle size of sediments influences the radiation of heat through subsurface deposits. Although the clay filled unit heated up faster than the sand filled unit and reached a higher maximum temperature, heat radiated more evenly through the sand deposit.

Recognizing that surface colour is not traditionally accepted as a sole indicator of temperature, these conclusions are not intended as analytical guidelines. Instead, they are set forth for consideration of the potentiality of post-burial burning. The pattern of continuous surface colour, negligible fracturing and warping which characterize bone burned in a post-burial setting must be tested against assemblages recovered from such contexts to investigate the reliability and applicability of these features as tools for recognizing the temporal association between burning and burial.

Acknowledgements

There are many people who gave graciously of their time and made this research possible. Thanks to Jim Evans of The Tennessee Wildlife Resource Agency who provided a limitless supply of metapodials. Fire Investigator Mike Dalton of the Knox County Sheriff's Department eagerly contributed knowledge and time as did Rural/Metro Fire Department. James Darrow of the Ceramics Department at The University of Tennessee, Knoxville graciously availed his kilns to me. In addition the guidance and support of Walter Klippel, Murray Marks and William Bass of the Department of Anthropology at The University of Tennessee, Knoxville, enhanced the quality of this investigation. Further, the time and attention of those that reviewed the manuscript is greatly appreciated.

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