Taphonomy Today:
a Taphonomic Analysis of Faunal Remains from Black Cat Cave (40RD299)

by
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Dedicated to my mother for her undying support.

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ABSTRACT

This comparative taphonomic analysis of faunal remains is an interdisciplinary and multipronged study of faunal remains and soil inside and outside of Black Cat Cave 40RD299. This study utilizes the methods of anthropology, geosciences, and biology though the analysis of taphonomy, soil testing, and PXRF respectively. Macroscopic analysis of the faunal remains reveals differential taphonomic color changes to the remains specific to the location of retrieval. Testing shows Black Cat Cave's soil pH was consistent, nearly neutral, and found to not be a factor in bone color differences though instrumental in the remarkable preservation of the faunal assemblage. The PXRF results indicate significantly high levels of iron found on the osseous material and soil material collection from outside the cave may play a part in the taphonomic color changes of those samples.

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LIST OF SYMBOLS AND ABBREVIATIONS

1. 40RD299 – Black Cat Cave's site number, assigned by the Tennessee Division of Archaeology
2. MTSU – Middle Tennessee State University
3. K – Thousand
4. NISP – Number of Individual Specimens
5. XRF - X-ray florescence
6. PXRF – Portable x-ray florescence
7. SOD – Standards of Data Collection for Human Skeletal Remains
8. LOD – level of detection
9. BP – Before present (1950)
10. BCE – Before the Common Era
11. CRITA – Current Research in Tennessee Archaeology Conference
12. SEAC – Southeastern Archaeology Conference
13. VA – Veteran's Administration

I. INTRODUCTION AND BACKGROUND

Black Cat Cave

Black Cat Cave (40RD299) is an archaeological site in Middle Tennessee located only a few miles from MTSU. It has been home to a speakeasy, a restaurant, fraternal initiations, and a prehistoric grave site. Remains were initially discovered in the cave in 2004, in 2014, reports of looting at Black Cat Cave prompted the excavation and relocation of artifacts to MTSU. In 2015, a customized steel gate was put in place to protect Black Cat Cave from further vandalism. Rutherford County is said to have been regional hunting and fishing grounds of several prehistoric Native American tribes. Black Cat Cave was occupied from the Early to Middle Archaic period (Peres and Keasler, 2015). Faunal (animal) remains from these prehistoric occupations were found both inside and outside the cave. These remains will be the focus of this taphonomic study.

Figure 1 Black Cat Cave today

Black Cat Cave's varied historical uses are not well documented; few records exist, and the stories have been passed down primarily through oral traditions. During the Civil War, farmers would hide equipment and livestock from Union troops in the cave (Davis 2005). Black Cat Cave was also known as Rainbow Cave during the 1920's when it was owned by the Sullivan family and operated as a speakeasy. This nickname was possibly due to the rainbow painted on the bluff or perhaps the nickname prompted the painting.

After prohibition ended, Mr. Sullivan leased it to Mrs. Neely who ran it as "Black Cat Tavern" until 1937 when the Sullivan's sold it to the VA. In 1971, Black Cat Cave became property of the city of Murfreesboro to be a park and recreation area (Tucker 2013). In the 1970s and 80s, the cave was mainly visited for fraternity initiations and parties until a mass of limestone was dumped there in the late 80s (Peres et al. 2016, 190).

Contrastingly, Black Cat Cave's prehistoric function is well documented in scholarly contexts through the work done by TDOA and MTSU which was published in the *Journal of Archaeological Science* and presented at the 2016 CRITA and SEAC conferences. Black Cat Cave is one of only 25 caves with archaeological resources dating to the Archaic period in Tennessee. Caves were locations where prehistoric people created art, worked materials, and buried the dead; cave environments create good conditions for the archaeological record to be well preserved (Peres et al. 2016, 187).

The dating to the Archaic period of 40RD299 was conducted via two radiocarbon analyses performed by Beta-Analytic and resulted in the range of 6460 – 6360 ±30 B.P. The full 2016 report details the history, archaeology, and skeletal remains but focuses on

the faunal assemblage, which comprises the majority of remains recovered. There were 9224 faunal remains recovered at the site, 8121 of which were located inside the cave, and all of those were "introduced to the cave environment by humans as opposed to representing wash-in or the result of raptor prey deposits" (Peres et al. 2016, 192).

Peres goes some length into discussing the meaning and symbolism that animals have to humans. One of the notable finds at Black Cat Cave are remains from a *Canis familiaris* (domestic dog), some of which are pictured in the following sections and which prompted initial interest in this site. As caves are ritual and liminal locations, one theory is that the dog may have been placed as a guide or gatekeeper figure due to its location at the threshold and associated worked artifacts (Peres et al. 2016, 192,197). This is further supported by the lack of signs that this dog was used as a pack animal (Peres et al. 2016, 197), typical of domestic dogs buried alongside humans (Warren 2004).

The dogs excavated from Dust Cave in northern Alabama were recovered from the same area as the human burials; two dogs were buried individually and had grave goods associated with them, and another one was buried with a teenage boy (Walker 2010, 427–445). The Archaic period dogs of Koster, Illinois (also part of the Eastern Woodlands) were also not simply hygienic disposals, but one of the earliest domesticated dogs in North America, evidenced by their intentionally placed burial positions which resembled a sleeping pet's position, head tucked in and feet underneath. Plant domestication may be the focus of the Woodland period, but dog domestication marks the beginning of the changing relationship between humans and plants and animals that began in the Archaic period (Feder 2014, 255-257).

Archaic Period in the Eastern Woodlands

Black Cat Cave and all of Middle Tennessee is part of the prehistoric culture area known as the Eastern Woodlands. The Eastern Woodlands interior encompasses roughly everything east of the Mississippi river and west of the Appalachian Mountains but includes the Smoky Mountains. The environment is generally humid with mild winters below the 40° latitude, while above that winters are generally below freezing with moderate snowfall. The Archaic period for this area is from approximately 10,000 to 3,000 years go (8051 BCE – 1051BCE) (Neusius and Gross 2013, 331-352).

Archaeologists Gordon Willey and Philip Phillips designated the term "Archaic" to signify the transitional period between hunting and gathering to more sedentary agricultural subsistence. Being a liminal period, the cultures are extremely variable and include both small nomadic groups as well as large and more sedentary groups. (Salem Press Encyclopedia 2019). The differences among groups are largely due to the adaptations made for the specific region's environment and climate (Feder 2014, 252). Staples included shellfish on the coast to marsh elder in Illinois, and of course white tail deer in most of the Southeast. Sustenance during the Archaic primarily still relied on gathering and hunting (sometimes with *Canis familiaris*) wild resources, but Archaic period peoples also began the process of domestication. (Salem Press Encyclopedia 2019).

The lithic variety of the area is rich in the Archaic period with over a dozen types of projectile points forming the record. The Dalton point ranges from the Paleo-Indian to Archaic tradition, was found at the Sloan site in Arkansas where it had traveled from far north. Other Dalton tools, particularly Dalton adzes could be the first woodworking tools

in the Eastern Woodlands. Other stone tools such as bannerstone (atlatl weights) become far more common during the Middle Archaic and non-local lithics are less prominent. Bone and copper are also found during this time (Neusius and Gross 2013, 331-352).

"Archaic peoples were adept at the use of leather, sinews, and plant fibers. Basketry was used for containers, sandals, and even shelters. Leatherwork, as well as twining and weaving, was used to make bags, hats, clothing, and sandals. Pottery was invented by Archaic peoples. In the lower Mississippi Valley, fired clay was used to make boiling "stones," while fiber-tempered vessels were manufactured in the Southeast" (Salem Press Encyclopedia 2019). The oldest ceramics of eastern North America, the Stallings ceramics, are a fiber tempered pottery which show impressive decoration accomplished by "drag and jab."

Figure 2 Stallings Ceramics (Neusius and Gross 2013, 376-391).

During the Archaic Period, mortuary practices as a whole become much more complex, including long distance trade for grave goods. Red Ocher is abundant. Shell mounds and rings become much more prominent. Stone beads, effigies, turkey-tail blades, and bannerstones are included as grave goods. (Neusius and Gross 2013, 331-352). The variation in individual grave goods may be an early indicator of social ranking (Salem Press Encyclopedia). Formal cemeteries also appear during Middle Archaic; the Sloan site being home to one of the earliest cemeteries of North America (Neusius and Gross 2013, 331-352). Taphonomic processes on the remains can reveal a great deal of information about these mortuary treatments and provide insights into the lives and deaths of prehistoric peoples.

Taphonomy

What is taphonomy? Greek for "burial laws," taphonomy used to be described as everything occurring to the body once it had been buried. This term was coined by Russian paleontologist Efremov (White and Folkens 2005). The modern and broader definition includes everything that happens to the body after death; the modern practice of taphonomy is utilized amongst several disciplines including zooarchaeology, paleoanthropology, bioarchaeology, and forensic anthropology (Christensen et al. 2014).

While the term taphonomy is credited to paleontologist Efremov in the 1930s, it is important to note that the study of processes of the body after death had already been introduced as a valuable tool by Wilder in a 1923 publication. His new field of 'necrodynamics' caught on but under the name of taphonomy (Buikstra et al. 2003). Taphonomic changes may be caused by physical agents such as weathering, biological

agents such as flora and fauna, or human modification which may be intentional or accidental. From sun bleaching to rodent gnawing to accidental breakage of bones during recovery, even mortuary practices have taphonomic effects. Taphonomic processes are abundant and can reveal much about not only an individual but a community (White 2005).

In the field of zooarchaeology, taphonomy was first used to describe the "transition of animal remains from the biosphere into the lithosphere" (Christensen et al. 2014). In more recent research, it became imperative to understand how deposits were formed at archaeological sites (Marín-Arroyo 2015). In the field of paleoanthropology, taphonomy has been used to on animal bone collections to interpret ancient hominin lifestyles (Bunn 1991). In both forensic anthropology and bioarchaeology, it is important to distinguish taphonomic damage from other processes. In bioarchaeology, it is crucial to determine whether damage was caused due to taphonomy or paleopathological processes (White and Folkens 2005). In forensic anthropology, it is important to distinguish taphonomic processes from perimortem events especially trauma (Christensen 2014).

Taphonomy has weight of its own in both fields as well. In bioarchaeology, taphonomy is most often used to study mortuary practices while in forensic anthropology, taphonomy is the key to learning the postmortem interval (time-since-death). It is worth mentioning the difference between these fields especially when both look at the taphonomic process of human remains. Forensic anthropology focuses on remains from a medicolegal aspect while bioarchaeology studies the remains of a past population to understand the culture. So, the discovery of cut marks on bone has wildly different

contexts between these two fields. While cut marks in bioarchaeology can point to cannibalism, cut marks in forensic anthropology are usually a sign of dismemberment for disposal. Of course, these are just generalizations. Context and additional evidence would confirm or deny these assumptions in specific cases.

While taphonomy includes all processes of the body after death, this study will only focus on the processes which affect skeletal remains. The *Standards for Data Collection* (Buikstra and Ubelaker 1994, referred hereafter as the SOD) divides taphonomic processes into color, shape, and surface texture. Keep in mind a singular taphonomic process may fall into more than one of these categories. Burning is an interesting taphonomic process as it may have effects in all three of these categories. Burning may cause calcination or a bluing effect on bone falling under the color category and may also cause bones to warp or fracture at given temperatures falling under the shape category. Lastly, it can cause checking or flaking of surface texture (Buikstra and Ubelaker 1994).

Natural bone has an ivory color. However, a number of taphonomic processes may affect the color of bone. Burial and burning (cremation) would likely be the most common factors resulting in discoloration followed by sun-bleaching. After so long in the ground, bones will begin to absorb minerals and dirt resulting in a tannish brown color while burning discoloration depends on the temperature of the fire. A low temperature fire results in a dark black bone while extremely hot fires result in the previously mentioned calcined or greyish blue bone (Buikstra and Ubelaker 1994). An example of color changes due to burning bone from 40RD299 as follows: Figure 3 shows three metacarpals, one from *Canis familiaris* (domestic dog) found outside of the cave at level

2 and two from *Vulpes vulpes* (red fox) found inside the cave. Note the dark appearance of the bottom most fox metacarpal. The characteristic dark color is due to low temperature burning. Another example can be seen in Figure 4.

Figure 3 Comparison of burnt to non-burned remains

Consider this case study example of taphonomic discoloration: a study was conducted on the human remains found in El Mirón Cave, Spain, "the only human Magdalenian burial found in the Iberian Peninsula in a clear, intact stratigraphic context." The combination of skeletal representation, carnivore tooth marks, diagenetic modifications, and spatial distribution of the bones led the researchers to believe this was the primary burial location and that the cranium and long bones had been removed to a secondary unknown location while the original deposit was ritually covered with red ocher. The bones were completely stained red. "Fully 81% of NISP of the anatomical human elements are partially or completely stained with ochre" (Marín-Arroyo 2015).

Specific to 40RD299, we also have a case of ocher stained faunal remains. Note the mandible of the *Procyon lotor* (racoon) in Figure 4. While it can be

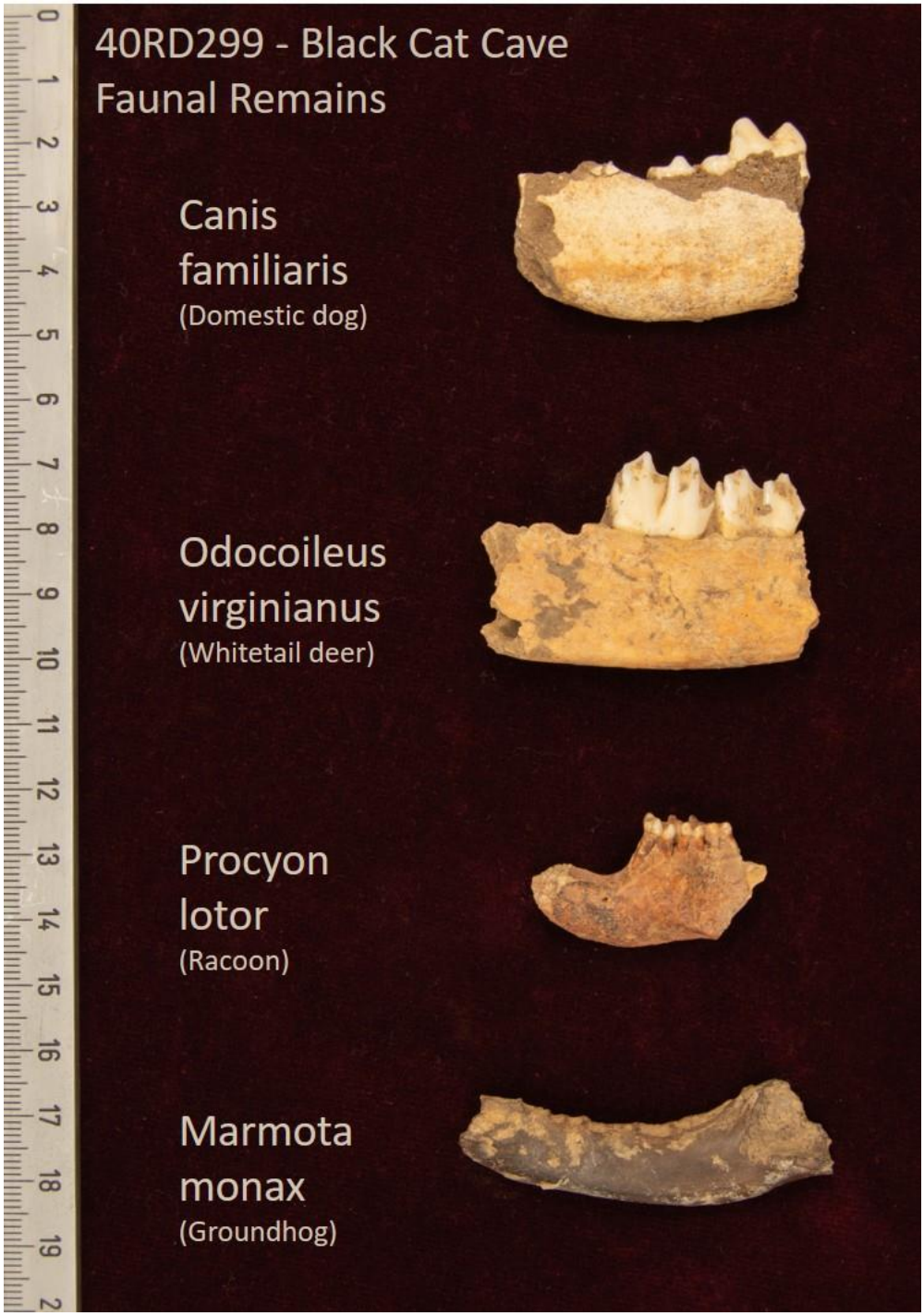


Figure 4 Evidence of shape and color changes

argued that burning of skeletal material could have occurred during everyday events such as food consumption or use as fuel, ocher usage is characteristically used in decoration, art, and ritual (Peres et al. 2016, 197).

Taphonomic shape changes are most notably seen via fractures. One of the most common is the temporal bone of the skull 'popping' due to ground pressure in the burial environment. Breakage may also result from intentional processing of the remains, such as the manufacturing of utilitarian bone tools or amulets for ancestor veneration. This is where taphonomic processes must be distinguished from trauma by evaluating the type of fracture (Buikstra and Ubelaker 1994). In regard to 40RD299, cases of fracture and fragmentation are abundant. Note in Figure 4 all four mandibles presented are fragmentary. This process whether natural due to time or accidental due to recovery or looting is all considered taphonomic damage.

Here is a separate example of taphonomic shape changes: consider again the taphonomic study conducted on the human remains found in El Mirón Cave, Spain, where only 42% of the bones recovered were intact. The remaining bones especially the ribs and vertebrae sustained post-mortem fractures due to the pressure of overlying rocks and sediment (Marín-Arroyo 2015).

Surface changes may be the most frequant taphonomic process. Many of the natural processes that happen to all bodies involve surface texture changes such as weathering and scavenger activity and plant/insect activity. It is important to note this is often where taphonomic processes must be ruled out against paleo-pathological processes on the surface of skeletal remains (Buikstra and Ubelaker 1994).

Warfare and violence can also alter skeletal elements. The human remains from Castle Rock and Sand Canyon Pueblos show a significant amount of antemortem, perimortem, and postmortem damage. There is a significant amount of skull trauma including some indicative of scalping (Figure 5) which could occur before or after death.

Figure 5 Probable scalping at Sak tat rock-shelter shrine

Cucina, Andrea, Vera Tiesler, and Joel Palka. 2015. "The Identity and Worship of Human Remains In Rock-Shelter Shrines Among The Northern Lacandons Of Mensabäk." Estudios de cultura maya. 45(0):141-169.

Weathering and carnivore damage occur on seven bodies from the sample indicating they spent a considerable amount of time on the ground surface before being buried. The most distinguishing taphonomic damage is the cutmarks sustained by three bones which cooccurred with heat alteration indicating cannibalism. Additionally, there were a total of 39 heat altered bones in which there was no evidence of intentional cremation (Kuckelman 2002).

The subfield of taphonomy is continually growing and evolving with new technologies to measure and observe these varied processes so we may better understand the story of the remains. PXRF is one of the newer technologies now being applied to taphonomic analysis methods.

Portable X-Ray Florescence (PXRF)

PXRF is portable x-ray fluorescence, a hand-held technology that can sample the elemental composition of different materials. It has been used in a wide array of applications and can be used to identify elements from atomic numbers from 9 (fluorine) to 92 (uranium) (Christensen et al. 2012, 47). PXRF has been used to identify lead in children's toys (Sanders, Stolz, and Chacon-Baker 2013) and to determine species differentiation (Nganvongpanit et al. 2015, 101). In forensic / bioarchaeological contexts, XRF has been used to determine sex via teeth and hair samples (Baranowska et al. 2004, 639), to identify osseous and dental material from other samples (Christensen et al. 2012, 50) and to sort commingled remains (Finlayson et al. 2017, 497).

Importantly, PXRF is ideal for use on skeletal remains due to its capability of non-destructive analysis (Burns and Bush 2016, 1041). Notably, PXRF can reach the same conclusions as XRF concerning bone and soil (Pessanha, Guilherme, and Carvalho 2009, 503) which are used in this experiment. While there has been debate on the efficacy of non-destructive versus destructive XRF methods, a 2017 experiment showed whole bone – the method used in this study - was preferable to the powdered bone (Finlayson et al., 497).

II. METHODS

The section will cover the specific methods used in faunal sample selection, taphonomic recording, soil sample collection and processing, and XRF.

Faunal sample selection

Suitable faunal materials for comparison were selected under the direction of Chris Lane, Anthropology GTA, Candidate for the Master of Liberal Arts, MTSU. Exhaustive efforts were made to choose the most comparable remains so that preservation capabilities of the osseous material would be as similar as possible. The remains in Table 1 were ultimately selected.

Table 1 Faunal Material Selection

*Munsell will be completed when COVID-19 conditions allow.

Species	**Common**	**Bone**	**Weight**	**Munsell***	**Fragmentary**
Canis familiaris	Dog	2nd metacarpal	1.03		no
Canis familiaris	Dog	radius	2.22		yes
Canis familiaris	Dog	humerus	4.91		yes
Canis familiaris	Dog	humerus	4.25		yes
Canis familiaris	Dog	femur	9.89		yes
Canis familiaris	Dog	mandible	9.04		yes
Canis familiaris	Dog	femur	15.46		yes
Canis familiaris	Dog	maxillary canine	1.03		yes
Canis familiaris	Dog	vertebrae	1.94		no
Castor canadensis	Beaver	vertebrae	5.68		no
Marmota monax	Groundhog	mandible	2.81		no
Marmota monax	Groundhog	mandible	6.22		yes
Odocoileus virginianus	Whitetail deer	mandible	15.82		yes
Procyon lotor	Racoon	ulna	2.91		yes
Procyon lotor	Racoon	mandible	3.6		yes
Procyon lotor	Racoon	mandible	1.52		yes
Vulpes vulpes	Red fox	metacarpal	0.71		no
Vulpes vulpes	Red fox	metacarpal	0.74		no

Taphonomic recording

The Standards for Data Recording for Human Skeletal Remains (SOD, Buikstra and Ubelaker 1994) provide standardized methods for identifying and recording information from human skeletal remains. Burned bone has its own recording form in SOD Attachment 23 (Figure 6) and is recorded using standardized color references from the Munsell Color Chart (Buikstra and Ubelaker 1994). However, we are not concerned with color changes due to cultural modification for this study, but color changes in relation to diagenesis.

All additional taphonomic damage is recorded on the SOD Attachment 24 (Figure 7), the 'Taphonomic Changes Recording Form.' Reporting on Attachment 24 should be divided into the following categories: weathering (table 2), discoloration (use Munsell), polish, cutmarks, gnawing (table 3), and other forms of cultural (human) modification (Buikstra and Ubelaker 1994).

Weathering is broken down into categories 0 – 5 on the Behrensmeyer scale shown in Table 2. A score of zero indicates no signs of wreathing are present and a score of 5 occurs when the most advanced weathering possible is observed. Scavenger activity is scored between 0 – 4 and weighted the same as the Behrensmeyer scale; a score of zero indicates little scavenger activity and a score of 5 occurs when extreme scavenger activity is observed.

Table 2. Taphonomic Weathering reporting (Behrensmeyer, 1978)

0	Bone surface shows no sign of cracking or flaking due to weathering
1	Bone shows cracking, normally parallel to the fiber structure, articular surfaces may show mosaic cracking of covering tissues as well as in the bone itself
2	Outermost concentric thin layers of bone show flaking usually associated with cracks
3	Bone surface is characterized by patches of rough, homogenously weathered compact bone, resulting in a fibrous structure, all lamellar bone is absent from these patches
4	The bone surface is coarsely fibrous and rough in texture
5	Bone is falling apart in situ

Table 3. Scavenging reporting (Haglund 1997)

0	Early scavenging of soft tissue with no body unit removal
1	Destruction of the ventral thorax accompanied by evisceration and removal of one or both upper extremities including scapulae and partial or complete clavicles
2	Lower extremities fully or partially removed
3	All skeletal elements disarticulated except for segments of the vertebral column
4	Total disarticulation with only cranium and other assorted skeletal elements or fragments recovered

There was no evidence of scavenger activity on the remains; the Behrensmeyer scale was not used. There were a few cracks due to weathering that would fall into the "1" category on the Haglund scale. There was also no evidence of cutmarks on the bones. Attachment 24 is not necessary or helpful when going beyond simply listing taphonomic processes observed on the remains like the taphonomic comparison on bone and soil conducted here.

TAPHONOMY RECORDING FORM I: BURNED BONE

Site Name/Number _____/_____ Observer _____

Feature/Burial Number _____/_____ Date _____

Burial/Skeleton Number _____/_____

Present Location of Collection _____

List bones individually or in fragment clusters. Bone should be reported as Tan, Black (including dark brown), or White (including blue-gray). If more than one color appears on a single bone, list all appropriate colors and percentage of bone(s) affected. If reporting poorly preserved or highly fragmented materials, weights may be substituted for percentages. Surface texture should be reported as L (Longitudinally Split); T (Longitudinal and Transverse Checking); or C (Curved Cracks). Indicate presence by recording appropriate initials. Similarly, report the presence of deformed (warped) bone as Y (Present) or N (Not Present). The presence of surfaces shielded through articulation or by dense soft tissues should also be recorded as Y (Present) or N (Not Present) and described in the space provided.

Bone(s)	Color % Affected	Surface Texture	Warped?	Shielded Surfaces?

CHAPTER 9: Attachment 23

Figure 6 SOD Attachment 23 Taphonomy Recording I

TAPHONOMY RECORDING FORM II:
WEATHERING, DISCOLORATION, POLISH, CUTMARKS, GNAWING, and OTHER CULTURAL MODIFICATIONS

Site Name/Number _____/_____ Observer _____

Feature/Burial Number _____/_____ Date _____

Burial/Skeleton Number _____/_____

Present Location of Collection _____

This form is to be used in recording the following modifications: discoloration due to contact with metals, polish, cutmarks, other forms of cultural modifications, and rodent/carnivore gnawing. The following should be recorded. In every example, the nature of the modification should also be described in the space allocated.

Weathering: 1) Bone identification, 2) photographs of representative samples, 3) degree of weathering (use Behrensmeyer system provided in Table 1 for coding degree of weathering).

Discoloration: 1) Bone identification, 2) location (append drawing and photograph), 3) color of discolored bone and "normal" adjacent bone (use appropriate Munsell Chart(s)).

Polish: 1) Bone identification, 2) location (append drawing and photograph).

Cutmarks: 1) Bone identification, 2) location (append drawing and photograph), 3) number of cuts, 4) average cut length, 5) range of cut lengths, 6) sketch and cast (optional but recommended) of representative cut(s).

Evidence of Rodent and Carnivore Gnawing: 1) Bone identification, 2) location (append drawing and photograph), 3) number of paired grooves or incisions. Evidence of rodent and carnivore gnawing should be recorded separately.

Other Forms of Cultural Modification Including the Creation of Artifacts: 1) Bone identification, 2) shape (append drawing and photograph).

Type of Bone Alteration	Location of Modification	# of Photographs/ # of Drawings	Additional Descriptive Information

CHAPTER 9: Attachment 24

Figure 7 SOD Attachment 24 Taphonomy Recording II

Soil Sample Collection

Varying soil composition (due to mineral content) at the very least affects the degree and variation of soil staining to bone (Dupras and Schultz, 2013:323). I expect the soil composition would be different inside and outside the cave, and would produce different soil staining on each set of remains. The soil samples were collected on 25 February 2020 after a few delays due to weather and attempted tampering with the Black Cat Cave gate. The inside sample was collected first; henceforth to be referred to as soil sample 1 or S1. Due to the previous soil admixture as a result of looting, there was no need to auger inside the cave or collect the sample from a specific depth. The sample was collected from the area between Pit 2 and Pit 3 (Figure 9). The original plan to screen on site was unfeasible due to the high water content of the sample.

Figure 8 Soil Sample 1 (S1) collection in progress

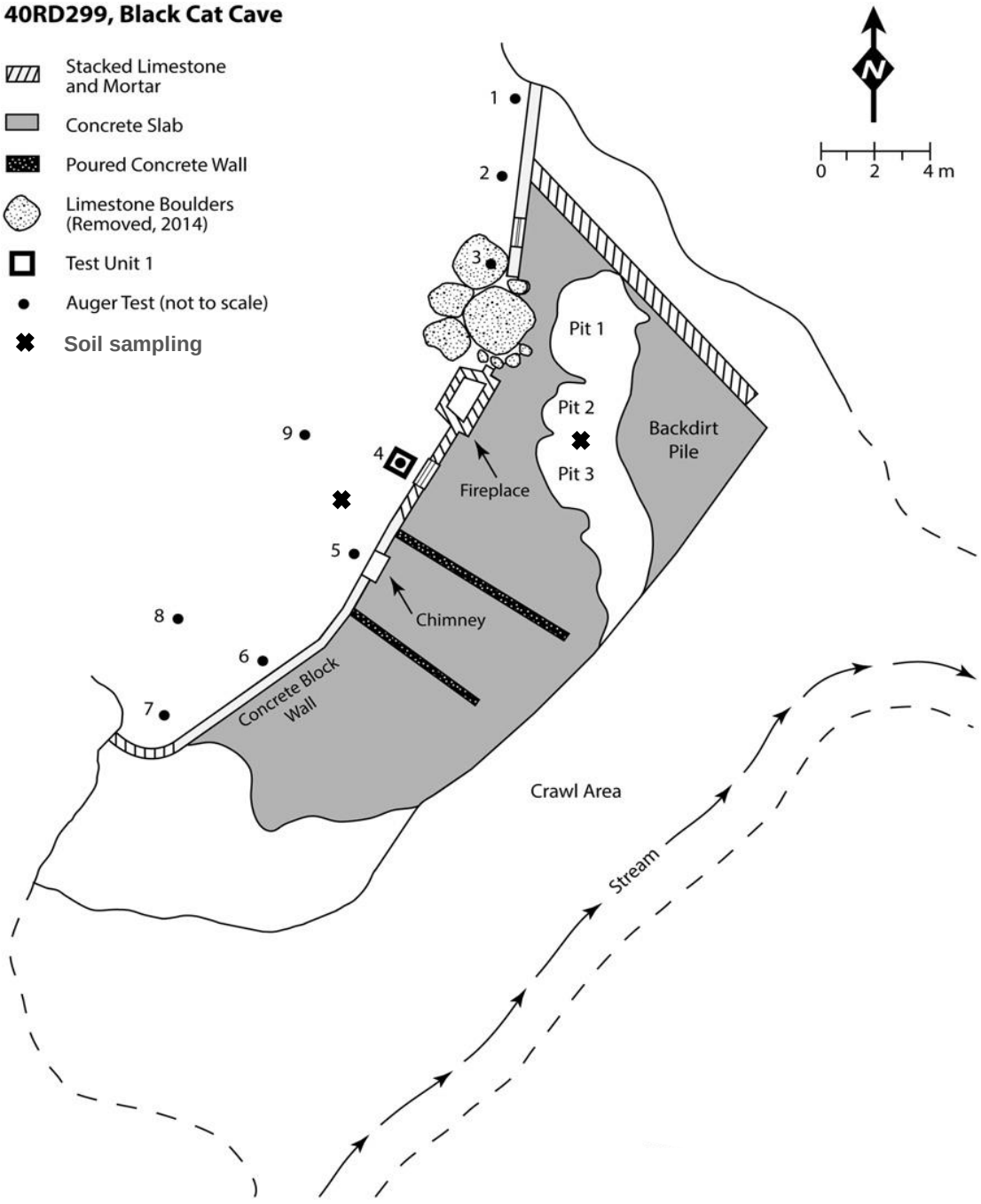


Figure 9 Plan map of Black Cat Cave (used with permission)

Peres, Tanya M,. Aaron Deter-Wolf, Joey Keasler, and Shannon Chappell Hodge. 2016. "Faunal remains from an Archaic period cave in the Southeastern United States." *Journal of Archaeological Science: Reports* (8): 187-199.

The outside sample area was determined to be most appropriate in between previous Test Unit 1 and Auger 5 (Figure 9). The area is in proximity of the *Canis familiaris* burial but should not have been previously disturbed. The canine was found in level two, 10 - 20 centimeters depth below the ground surface, ergo the soil sample was taken from level two as well. The top layer (10cm) was cleared via hand troweling. The sample was then extracted via auger to ensure no contamination from level one (Figure 11). Additional measures were maintained in order to ensure no cross-contamination of samples 1 and 2 including separate collection containers, separate screens, and separate weighing containers.

Figure 10 Soil sample 1 collection

Figure 11 Soil sample 2 collection

The soil samples were brought to MTSU and stored in the Anthropology and Public History Lab in Wiser-Patten Science Building. The samples were measured for weight and color. The Munsell color chart (Figure 13) is used to document the soil color of any archaeological project. The soil is compared to the color chips in order to find the closest match as there is usually not an exact match due to normal variance (Munsell Color 2009). The color of S1 was 10YR 2/2 very dark brown and the total weight was 2579.69g. The color of S2 was 10YR 2/1 black and the total weight was 2158.37. Initial reactions to the soil color difference is that S2 is darker because it contains more organic material i.e. leaf litter and seepage. The soil samples were then left to air dry. Once suitably dry, the samples were sieved using a 1/8" mesh sieve (Figure 12).

Figure 12 Sieving in progress

Figure 13 Munsell color chart

The samples were then weighed again. After sifting, S1's composition included 1553.85g of soil and 803.05g of inclusions of rocks. The total post sifting material amount of S1 is 2356.9g. After sifting, S2's composition included 1500.09 of soil and 629.56g of inclusions including rocks and rootlets. Note this total post-sifting material is 2129.65, a 28.72g difference from initial weighing. I surmise this is due to a combination of water evaporation and Locard's principle of exchange. S1 lost a significantly higher amount at approximately 222.79g. This is largely due to evaporation. As previously mentioned, S1 had a much higher water content, so much so that it required 4 more days of air drying than S2.

Figure 14 Soil distribution after sifting (S1 on left, S2 right)

In order to conduct more advanced soil testing, I enlisted the help of Dr. Samuel Haruna, MTSU Assistant Professor of Plant and Soil Science, who provided two analysts, Alaina Kresovic and Robert Eichas, to help with these tests. Fifty grams of each soil were taken to the Stark Agriculture Building Plant and Soil Lab for testing. The pH test was conducted on 3 Mar 2020. The test consisted of combining 10g of each soil sample with 10ml of deionized water. Each mixture was stirred for 3-5 minutes before being tested with a Bluelab combo meter for pH.

Soil textural analysis was also conducted at the SAG Plant and Soil Lab. Twenty grams of each sample was combined with 50 ml distilled water and 10 ml of 30% H_2O_2 and then placed on a sand bath at a temperature near 90 ˚C for an hour (Figure 15). This was then left overnight for full oxidization. The next day the mixtures were each combined with 20 ml of 5% Na hexametaphosphate, put into a graduated cylinder and

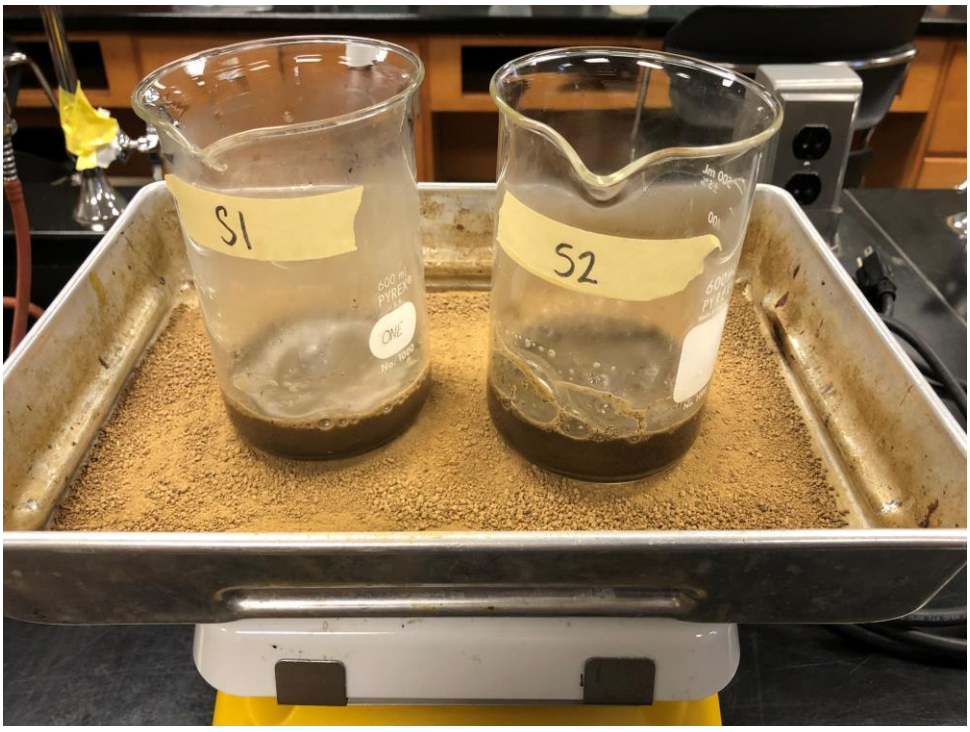


Figure 15 Soil textural analysis preparation on sand bath

brought up to 500 mL. The top 10cm and 5cm of suspension is taken off after 30 seconds and 8 hours respectively. Each is placed in an aliquot and baked in the oven at 105 ˚C for 24 hrs.

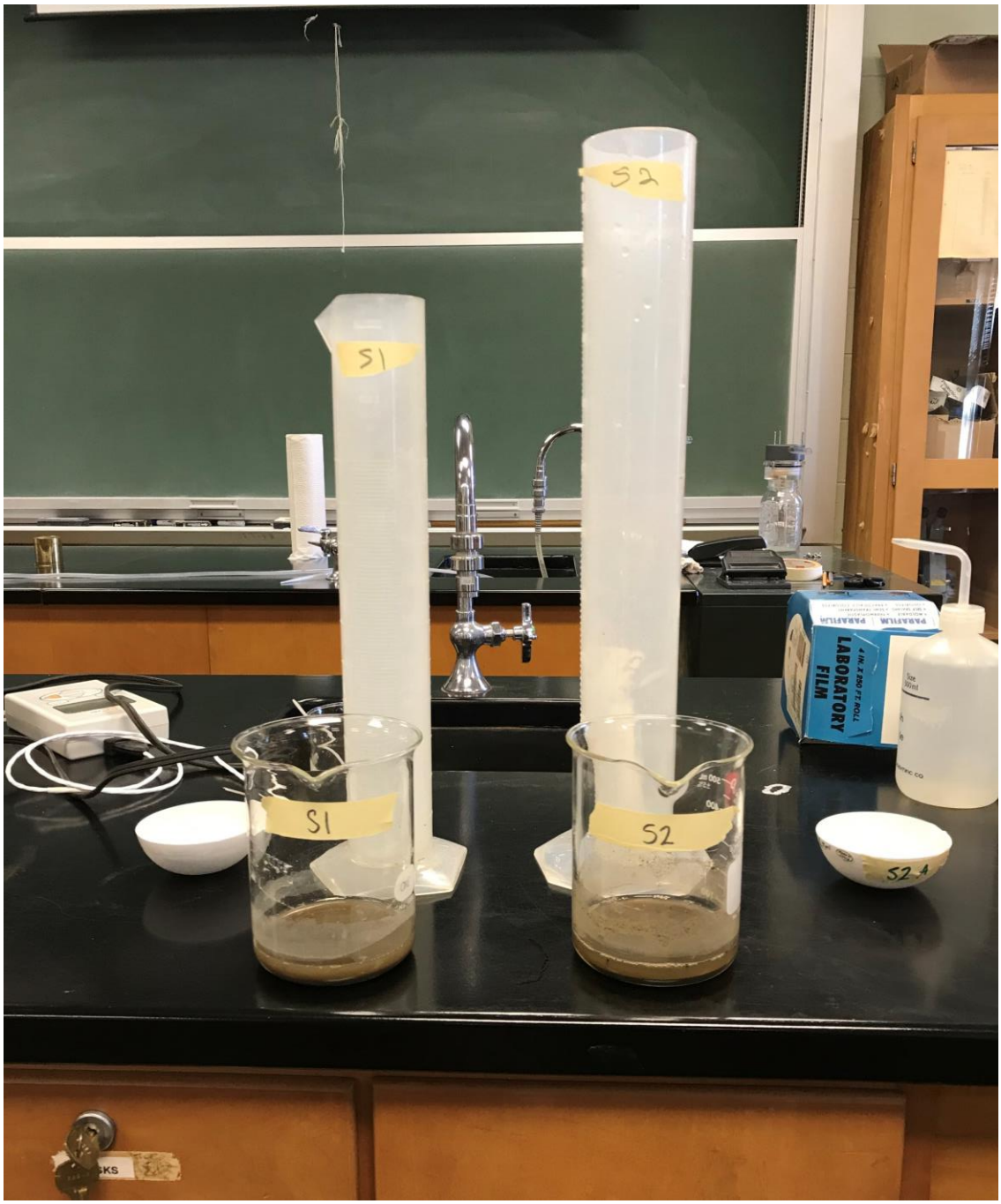


Figure 16 Setup of Beakers, cylinders, and aliquots

PXRF

PXRF was used in order to assess if the environment inside and outside of the cave is varied enough to result in different chemical composition of the soils collected as part of this research or the osseous and tooth samples previously recovered archaeologically. PXRF was conducted on Tuesday 3 Mar 2020 under the direction of Dr. Tiffany Saul with the assistance of lab assistant Summer Shipley. The PXRF is a Niton XL3t model produced by Thermo Fisher Scientific, located in the Forensic Institute for Research and Education (FIRE) lab in Wiser-Paton Science Building. It has been mounted and attached to a lead box approximately 8x6x4 inches in size in order to contain the radiation produced by the instrument (Figures 17, 18).

Figure 17 PXRF Setup Close up

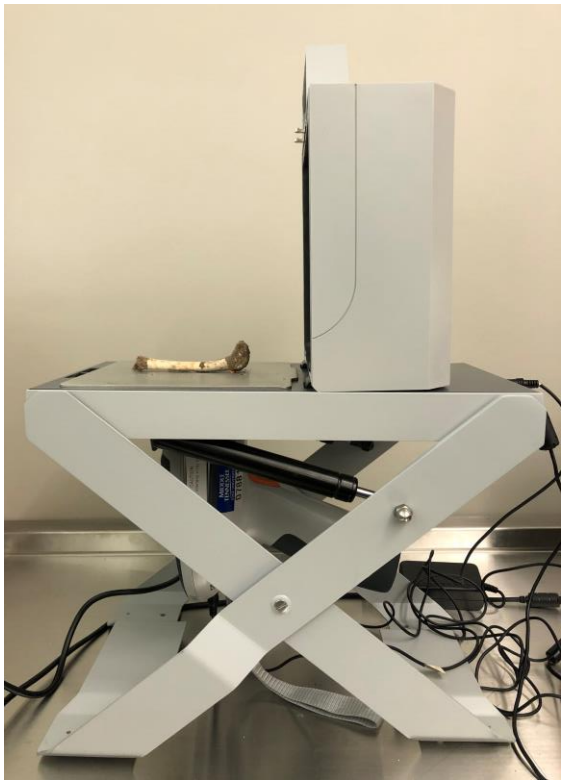


Figure 18 PXRF Setup

Adult osseous material consists of two structure types: cortical and trabecular. The solid dense bone that makes up the bone's exterior walls is cortical bone. Trabecular bone is the porous, honeycombed structure found inside bones, sandwiched between walls of cortical bone (White and Folkens 2005, 40).

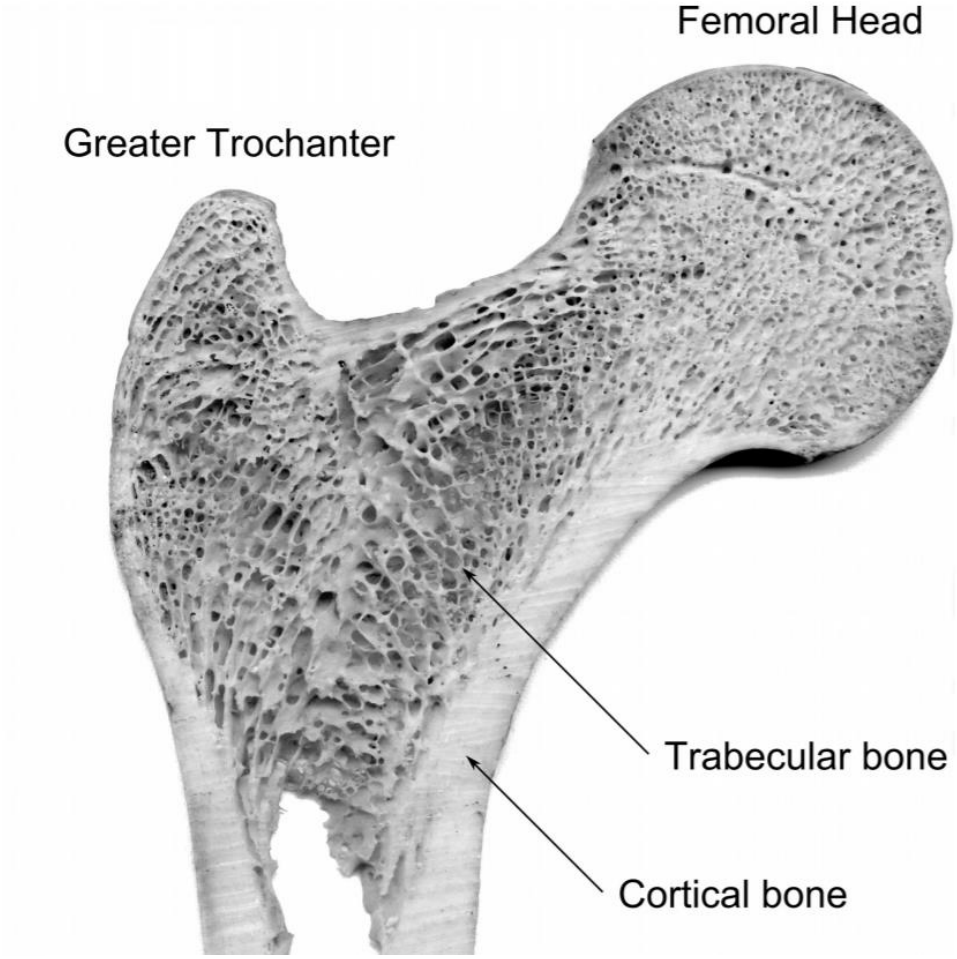


Figure 19 Labelled slice of a femur

Phillips, Andrew T. M. 2011. "Structural Optimization: Biomechanics of the Femur." Accessed at http://arxiv.org/abs/1110.1286

Cortical bone is preferable over trabecular bone for PXRF analysis due to trabecular bone's uneven surface (Burns and Bush 2016, 1042). Cortical bone was used for both osseous samples in this study. All samples were dry and at room temperature, (Nganvongpanit et al. 2015, 102). No sample preparation was required for the osseous or dental material for this test, same as the Christensen and colleagues' study (2012, 48). An intact bone's fairly flat surface was used for analysis in order to achieve the best possible results, as the Finlayson and coauthors recommends (2017, 495).

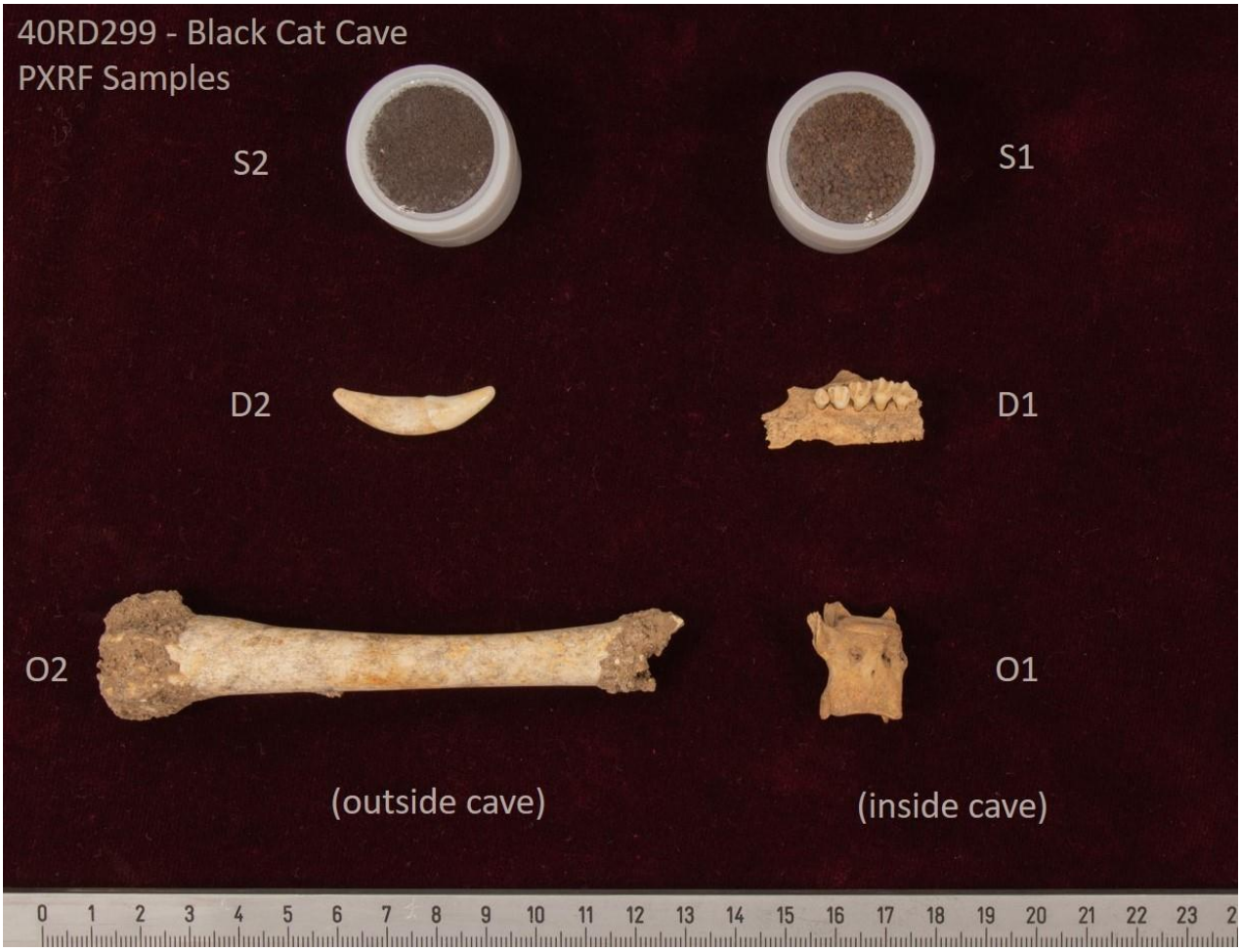


Figure 20 PXRF Samples

III. RESULTS

Taphonomic observations

The taphonomic color comparison of faunal remains found inside and outside of Black Cat Cave was productive. Initial observations exposed there was a consistent color pattern of the faunal remains found inside of the cave and a consistent color pattern of the *Canis familiaris* remains found outside the cave. This is separate from the outliers of worked bone shown in the introduction material. As an example, Figure 21 is a closeup of the two characteristic color patterns of the faunal remains at Black Cat Cave. Figure 21 is a closeup of these colors while Figure 22 shows the sample consistency.

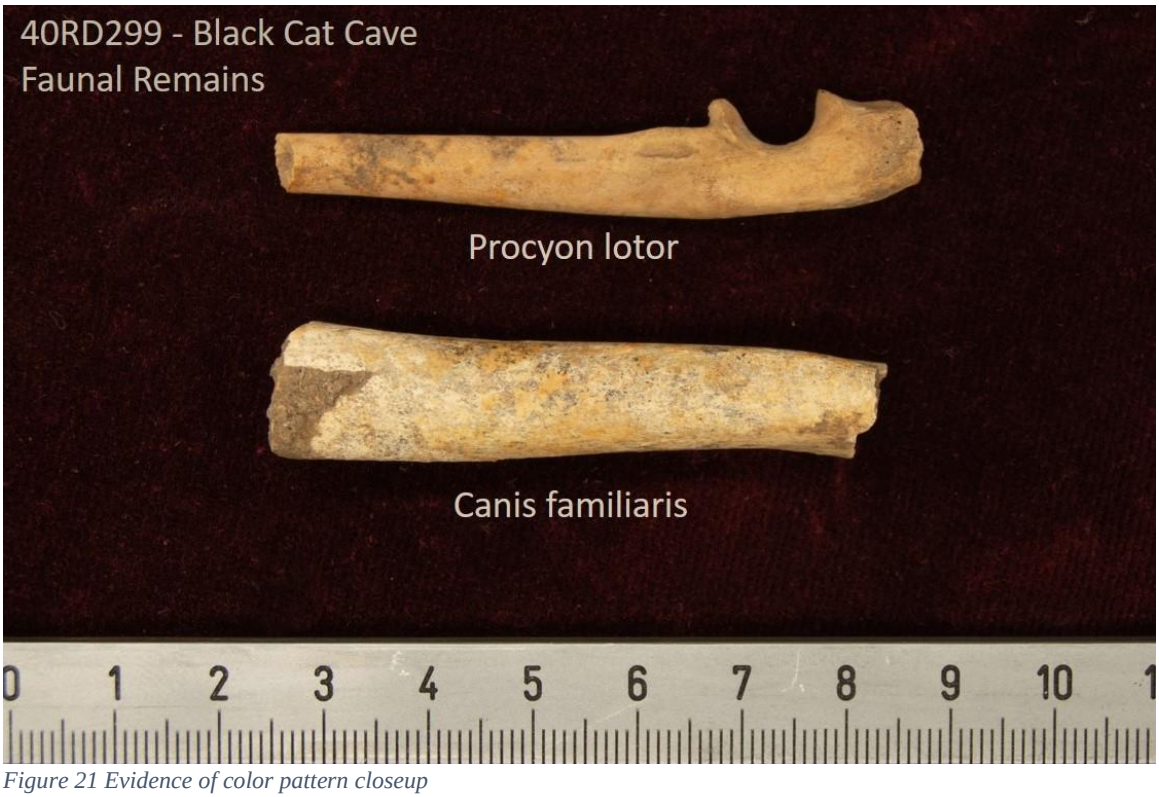


Figure 21 Evidence of color pattern closeup

Figure 22 Evidence of Color ***(left series found outside of cave, inside of cave on right)***

Bone staining due to contact with soil is common and the specific coloration of the staining is due to the soil composition (Dupras and Schultz 2013, 323). According to Millard, chemistry and pH of the soil will affect these changes to bone (1996). It stands to reason there must be a signature difference in soil compositions between inside and outside of Black Cat Cave responsible for the differential color changes to the osseous materials inside versus outside the cave. The soil composition was tested using the PXRF and the pH of the soil was tested at the MTSU Soils lab.

Soil analysis

The archaeological testing includes the previously mentioned color test as well as a texture test, performed in the field to identify the soil components. You begin by taking a golf ball sized amount of soil in your hand and wetting it. If the sample can maintain the shape of a ball without crumbling, you continue to the 'soil ribbon' test which consists of pinching out the ball as far as it can go before breaking. The length of this ribbon helps determine the soil consistency. The soil test performed on both S1 and S2 resulted in an identification of Silty Clay Loam (Figure 23) after producing a ribbon over an inch but less than two and feeling smooth in contrast to gritty (Ritchey, McGrath, and Gehring 2015, 2). The Munsell Soil Color Book also contains granularity references. S1 was determined to medium in granularity while S2 was considered fine.

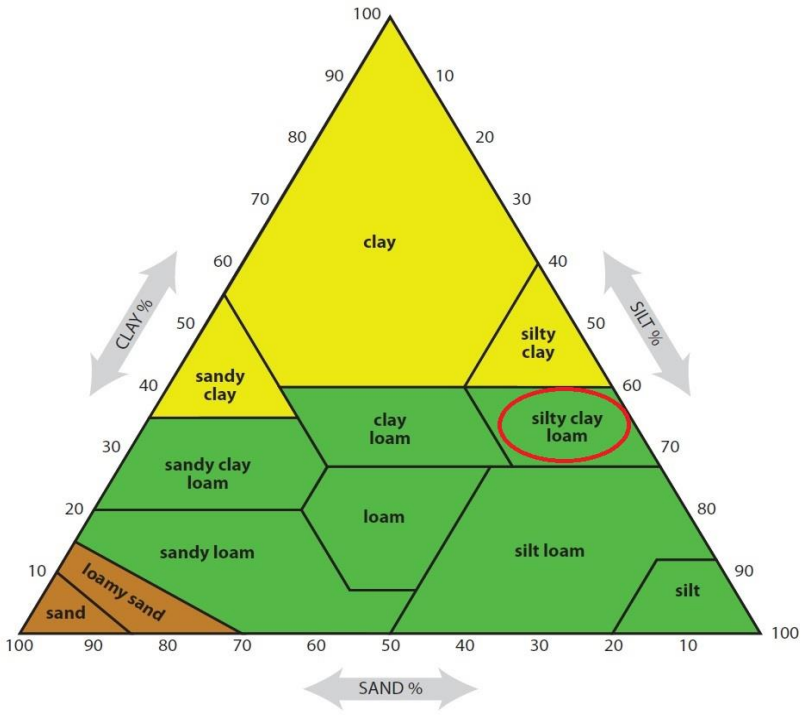


Figure 23 Soil pyramid

The second soil test available for analysis was the pH test; S1's pH was 8.7 while S2 came in at 8.4. While both are only barely alkaline and there is only three tenths of a difference in pH, this can be significant in regard to soil science (personal communication Robert Eichas 2020). "Soil pH can have a major effect on the rate of decomposition" however this study was done using only the three main pH types: acidic, neutral, and alkaline (Haslam and Tibbett 2009, 900). Additionally, archaeological bone samples are more at risk to pH damage. However, bone degradation due to pH occurs in highly acidic soil (High et al. 2015, 159). The soil's both inside and outside of the cave nearly neutral pH not only does not have an adverse impact but is in part why the remains have been well preserved.

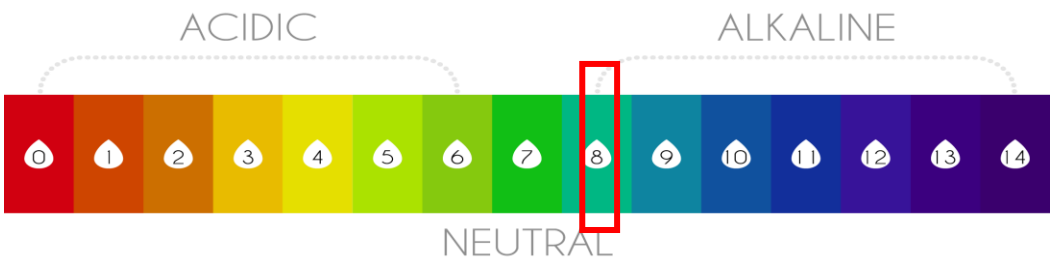


Figure 24 pH scale results

The most complex soil test conducted was the textural analysis (Appendix 1). After having entirely dried out in the oven (Figure 25), the remaining clay weight was subtracted from the clay and silt mixture weight with sand inferred.

Figure 25 Remaining clay in aliquot

Table 4 Textural Analysis Results table

Sample ID – S1	**Aliquot 1a**	**Aliquot 1b**
Weight dish + dry sample	47.1	45.3
Weight of empty dish	46.3	45
Weight of silt + clay	.8	
Weight of clay		.3
Sample ID – S2	**Aliquot 2a**	**Aliquot 2b**
Weight dish + dry sample	43.6	45.7
Weight of empty dish	43.1	45.4
Weight of silt + clay	.5	
Weight of clay		.3

Textural Analysis Calculation instructions:

> "Oven-dry mass = air-dry mass /(1.00 + [% moisture/100%]). Please note that air-dry mass is 20g (mass of soil you used for the analysis). Percent moisture is the moisture content between air-dried samples and oven-dried samples. For most soils, this can be assumed as 2%.
>
> The next step will be to calculate the percent of each particle size in the sample. This can be done as follows; % clay (or silt or sand) = (20g x mass of clay in aliquot/oven-dry mass of soil) x 100."
>
> (Dr. Haruna, personal communication, March 17, 2020).

By putting the results from Table 4 into the formula above the results were as follows., the soil sample from inside S1, was determined to be 30.6% clay, 51% silt, and 18.4% sand. Using the soil pyramid, this results in S1 being categorized as Silty Clay Loam (as previously indicated in Figure 23). This confirms the archaeological analysis previously described via ribbon test. The soil from outside, S2, was calculated to be

30.6% clay, 20.4% silt, and 49% sand which would be a Sandy Clay Loam. However, these results for S2 are inaccurate. The feel test conducted during the archaeological analysis did not result in a gritty feel that would accompany a rating of 49% sand. It was very smooth and when rubbed between the fingers left brown staining characteristic of silty clay (Singer and Munns 1999, 25).

The soil textural analysis requires many steps physically and mathematically, it is undetermined at this time where the analysis of S2 failed. One reason could be that the presumed moisture content of 2% is inaccurate for the interior sample as it was not entirely dry when beginning the textural analysis. Another complication could involve the omitted weight of the organic material destroyed during the sand bath. There was significantly more organic material in the exterior sample that possibly not accounted for.

While the exact percentages are unknown, assuming there is more sand in the outside sample would be cause to assume that S1, inside the cave, has a higher water holding capacity (Singer and Munns 1999, 127). This would appear accurate considering the extended period of time the S1 sample needed to dry.

One pretest hypothesis for the lessened color absorption of the remains found outside the cave was that the water holding capacity of that soil was higher, minimizing absorption to the same level of the interior remains. That would appear to be inaccurate, but additional testing would need to be done to confirm these assumptions. Ideally results of the soil testing and PXRF results would support each other.

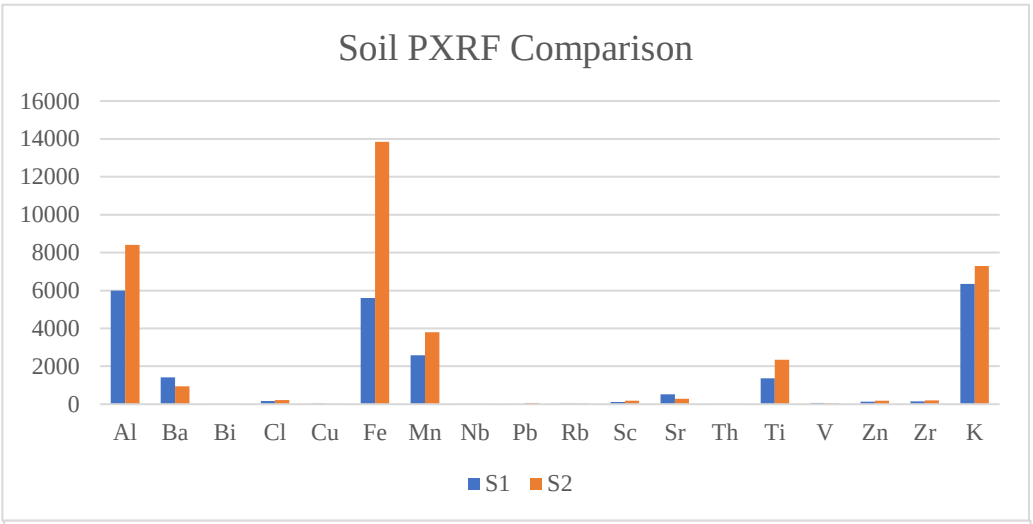
PXRF results

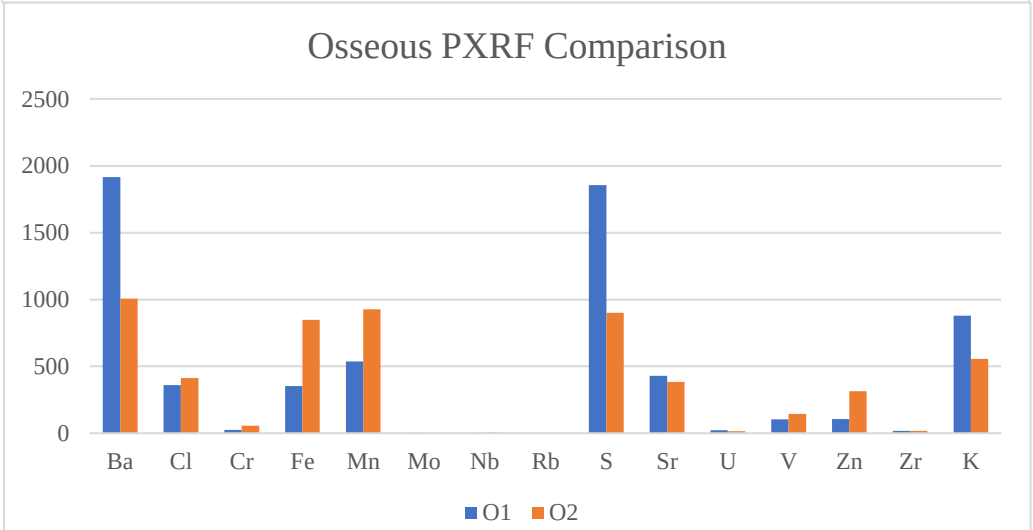
A previous study utilizing PXRF on Andean skeletal remains shows that soil does affect the elemental reading of the remains, in this specific case, concentrations of lead (Pb) (Fleming and Blom 2007, 41). In addition to soil, ground water also plays a factor in diagenesis when interpreting PXRF results (Burns and Bush 2016, 1042). Osseous material is more susceptible to taphonomic changes than dental material (Burns and Bush 2016, 1042). Christensen and coauthors suggest the iron and silicon peaks are due to soil absorption which in their study is considered "interference from surface contaminants" (2012, 49).

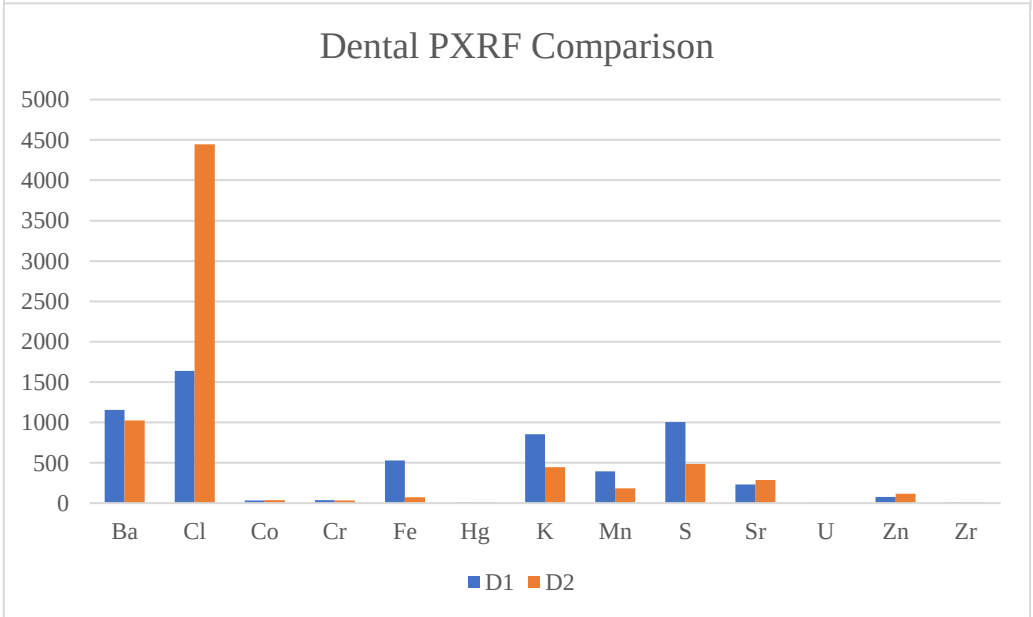
Cortical bone is a matrix of calcium phosphate (Burns and Bush 2016, 1043). "Many works are focused on correlating or calculating ratios (e.g. Sr/Ca or Ca/P) between chemical elements in order to identify pre-mortem dietary signals from the post-mortem soil "contamination" (López-Costas, Lantes-Suárez, and Cortizas 2016, 44). Due to the high levels of calcium and phosphate obscuring the rest of the elemental comparison, they were removed from this analysis. Eleven elements had levels less than the level of detection (LOD) for all six samples, so they were also removed. These elements were also removed from the charts in Table 5, as was any element not able to be mirrored in the other sample of same material.

In the Thai study referenced above, Magnesium (Mg) and Chlorine (Cl) were only found present in the dog remains (*Canis familiaris*) and not the elephants, humans, or dolphins (Nganvongpanit et al. 2016, 104). However, this did not hold true for this study. Magnesium was under the LOD for all six samples. Chlorine was present and measurable in all the samples which included both dog and racoon, as seen in the Table 5 Osseous Comparison section.

Table 5 PXRF Results







IV. CONCLUSIONS

Comparative taphonomy

The comparative taphonomic analysis was seriously hindered by a lack of adequate recording procedures conducive to comparative analysis. The current recording forms for taphonomic processes provides only a place to list observations. With additional time and resources, a comparative form could be produced that culminated in an overall taphonomic scoring system for quantifying differential taphonomic damage.

Black Cat Cave

The hypothesis of this study was that the varying environment inside and outside the cave would yield quantifiable differences in taphonomic effects on osseous material, soil structure and the elemental compositions of both. Upon analyzing the remains, the expectation was that testing on the osseous and soil samples from outside the cave would yield a higher elemental concentration which could be determined to be responsible for the level of discoloration (in this case believed to be mineral absorption).

While the chemical analysis did reveal nearly twice the iron signature in both soil and osseous materials, additional sampling would be needed to determine if in fact the level of iron trace is statistically significant between the two environments. Future testing should conduct PXRF on at least another 40 samples from inside and another 40 from the outside in order to conduct a robust statistical analysis.

The soil testing for pH revealed the neutral nature which current research suggests would not cause any adverse effects to the remains at this site. The soil testing

for texture was intended to reveal differences in water holding capacity which could affect the amount of soil and mineral absorption to the osseous material but was unfortunately corrupted and would need to be reevaluated.

The attempt to find the root cause of this characteristic difference of osseous color change through soil and PXRF testing yielded inconclusive results but revealed the need for additional advanced study of the materials and further testing and research needed to determine the full consequences of soil elemental composition on skeletal remains in the various environments of Black Cat Cave. These results will be reported to the Tennessee Division of Archaeology (Tennessee Department of Environment and Conservation, Nashville, Tennessee) for inclusion in the state site file, so that future projects may build upon this initial analysis. Furthermore, this research will inform ongoing and future analyses of the Black Cat Cave human skeletal remains, and can be extrapolated to the human bone, thus preserving it from any destructive.

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GLOSSARY

1. Aliquot – a portion of a larger whole, especially a sample taken for chemical analysis or other treatment
2. Antemortem– occurring before death
3. Bioarchaeology – the study of human skeletal remains within their archaeological and mortuary contexts
4. Calcination – bone being burned at a high temperature long enough to consume the organic component, leaving behind only the mineral component
5. Diagenesis – a change in the chemical content of the bone due to taphonomic processes
6. Faunal - animal life; as opposed to human or plant
7. Forensic Anthropology – a subfield of physical anthropology that involves skeletal remains
8. Hominid – primate of the family *Hominidae* that includes humans and their fossil ancestors and some of the great apes
9. Hominin – a primate of the family *Hominini*, which is part of the larger Hominid group
10. Magdalenian – a culture of the Upper Paleolithic and Mesolithic in western Europe dating from 17,000 to 12,000 years ago
11. Medicolegal – involving both medical and legal aspects
12. Ocher – also ocher - a natural clay earth pigment which is a mixture of ferric oxide and varying amounts of clay and sand
13. Paleoanthropology – the branch of anthropology concerned with fossil hominids

14. Paleopathology – the branch of science concerned with the pathological conditions found in ancient human and animal remains
15. Perimortem – occurring around the time of death
16. Physical Anthropology - the branch of anthropology concerned with the study of human biological and physiological characteristics and their development
17. Postmortem – occurring after death
18. PXRF – portable X-ray fluorescence; the same technique as XRF but utilizes a portable hand-held tool
19. Sand bath – piece of laboratory equipment made from a container filled with heated sand.
20. Taphonomy – the study of the processes occurring on organisms after death
21. XRF – X-ray fluorescence is an analytical technique that returns information about the elemental composition of a sample.
22. Zooarchaeology – branch of archaeology that studies faunal remains

APPENDICES

Instructions for Soil Texture Analysis, Dr. Samuel Haruna (2020)

For an accurate mechanical analysis of soil, the soil sample must be completely dispersed so that each particle settles individually rather than as part of aggregated clump. Addition of Na^+ to the soil-water suspension forces exchange of Na^+ for adsorbed flocculating cations such as Ca^{2+}. Soil particles with a diffuse layer saturated with Na^+ tend to act as individual particles in suspension and settle at rates dependent on their radii.

Prior to analysis, air-dry the soil, crush and pass through a 2-mm sieve.

1. Weigh out 20.0 g of air-dried and sieved soil sample. Place sample in a 1000 ml glass beaker.
2. Add 50 ml distilled water to the sample.
3. Add 10 ml of 30% H_2O_2 to the sample in the beaker (cut the froth produced with a stream of distilled water from a wash bottle.
4. Allow the reaction to proceed until it slows down.
5. Place the beaker on the sand bath (maintained at a temperature near 90 ^{0}C) for 1 hr. (if still bubbling, leave on the bath until no bubbles are noticed).
6. If the bubbling is intense and the sample dries before one hour, then add another 10 ml of H_2O_2 to ensure that the sample remains on the bath for approximately 1 hr.
7. Allow the reaction to go to completion (to remove excess H_2O_2, heat until no bubbles are noticed).
8. Leave the sample in the lab overnight for complete oxidation
9. Add 20 ml of 5% Na hexametaphosphate. Stir for 5 minutes.
10. Pour contents into a 500 mL graduated cylinder. Use a stream of distilled water from a wash bottle to transfer soil remaining in cup. Bring volume to 500 mL.
11. Cover top of cylinder with parafilm. Put palm of hand over top, grasp bottom of cylinder and invert several times to re-suspend soil.

12. Set on bench top, begin timing, gently remove parafilm and take a 25 mL aliquot from the upper 10 cm of suspension at 30 sec. A mark on the pipette at 10 cm from the tip serves as a good guide for depth.
13. Transfer aliquot to a weighed (record mass in Table 1) evaporating dish and put in oven at 105 ^{0}C for 24 hrs. Higher temperature than boiling is needed due to presence of solutes. Label evaporating dish “silt + clay”.
14. Take the second 25 mL aliquot after 8 hrs but from upper 5 cm of the suspension. Mark pipette 5 cm above tip.
15. Transfer aliquot to weighed, labeled (“clays”) evaporating dish and put in oven at 105 ^{0}C for 24 hrs.

    After 8 hrs, all silt greater than 0.005 mm diameter will have settled to below 5 cm. Thus, the second aliquot contains some silt (0.005 to 0.002 mm diameter) as well as clay.
16. After 24 hrs, remove evaporating dishes from oven, cool and weigh. Record the net weight of the first evaporating dish as combined silt and clay in 1/20 of the soil-water suspension. The net weight of the second is assumed to be 1/20 of the clay.

APPENDIX 2 CITY OF MURFREESBORO PARKS AND RECREATION VOLUNTEER WAIVER

CITY OF MURFREESBORO VOLUNTEER WORKER

WAIVER AND RELEASE OF LIABILITY & HOLD HARMLESS AGREEMENT

PLEASE READ CAREFULLY

In consideration for permission to participate as a volunteer in a City of Murfreesboro ("City") public service project for the **Murfreesboro Parks and Recreation Department: Volunteer Event**, I agree as follows:

1. I have considered and evaluated the risks, danger and possibility of injury resulting from my or my child/ward's participation as a volunteer performing a public service project for the City of Murfreesboro.

2. I know and understand foreseeable and unforeseeable injuries from common or unexpected sources could occur from the nature of the activity, conditions of the location and from actions of myself or my child/ward, other participants, the City, its employees or volunteers, and other persons involved in this public service project.

3. *I deliberately and knowingly assume all costs, risks of injury and/or other damages including, but not limited to, cost of my medical treatment, permanent injury or death, and my property damages resulting from my or my child/ward's participation in the public service project. I waive, release and hold harmless the City, its employees, volunteers, and agents from all legal and financial responsibility and from all costs, injuries and/or other damages which might occur while I or my child/ward is participating in the public service project.*

4. I give my permission to the City of Murfreesboro for any photos or video footage of myself or my child/ward taken during the course of this public service project to be used for educational, promotional, or any other purpose by the City of Murfreesboro.

Name (please print): Tabatha Wadford

Signature (Parent /Guardian if under 18): T Wadford

Date: 24 Feb 20

e-mail or mailing address (optional): tyw2f@mtmail.mtsu.edu

Additional Family Members

Name	Signature (Parent/Guardian if under 18)

APPENDIX 3 PHOTO STATION FOR DOCUMENTATION OF OSSEOUS MATERIALS