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A Preliminary Analysis of Saw Mark Degeneration in Bone Due to the Application of Hydrated Calcium Oxide

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A PRELIMINARY ANALYSIS OF SAW MARK DEGERNERATION IN BONE DUE TO THE APPLICATION OF HYDRATED CALCIUM OXIDE

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The use of calcium oxide (lime) in both agricultural and burial customs has been seen since the Iron Age. Due to this usage, the myth stating that the application of this chemical will expedite the complete destruction of human remains developed. This myth, in conjunction to historical and contemporary instances of its usage related to criminal activities has demonstrated a need to better understand the interactions of this chemical with bony tissue, particularly as it relates to saw cutmarks.

Using pig elements as proxies for human remains, this research aims to systematically examine the degenerative effects resulting from the application of calcium oxide to bone with traumatic defects, specifically as it pertains to class characteristics commonly found in saw cutmarks on bone. At the conclusion of a four week duration while utilizing two depositional contexts, the saw cutmarks on the remains did not display any significant alterations that may be attributed to the chemical application of calcium oxide.

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Introduction

As the methods and specialization of skill sets and interests in taphonomy grow within the field of forensic anthropology, the frequency of the utilization of these skills has greatly increased. Originally used within paleontological and archaeological assemblages, the concept of taphonomy has been modified over the years due to a multidisciplinary approach. It is this approach that has enabled the creation of forensic taphonomy. Forensic taphonomy as defined by Haglund and Sorg (1997b) "focuses on reconstructing events during and following death by collecting and analyzing data about depositional context, discriminating peri- and postmortem modification of the remains and estimating the postmortem interval" (p.13).

Due to the multidisciplinary and ecological knowledge base regarding the agents that may affect these events (i.e. scavenging, plant materials, water, fire, etc.), the forensic anthropologist may be able to provide information from the death assemblage to assist in "reconstructing the finer details of the cause and manner of death" (Haglund and Sorg, p.14). Additionally, due to osteological training, forensic anthropologists are often asked to provide a basic biological profile of an unidentified person and/or aid in estimating the postmortem interval.

In addition, the forensic anthropologist may be called upon to assess the possible peri- or postmortem taphonomic events that may have occurred to a decedent. These events may include the identification of different pathological conditions that an individual may have had, or the identification of peri- or postmortem trauma inflicted on an individual. It is during this examination that the distinction of human versus non-human modification can be established from not only the contextual information of a burial assemblage, but also from an ecological knowledge of agents (other than human) which may have modified a set of human remains. These details may ultimately provide legal professionals with the evidence that they need to make headway with a particular case, specifically when trauma found on a set of remains involves marks left by the application of a saw or other cutting instrument.

Often when saw marks are seen in particular locations on bone, they may be indicative of an attempt to dismember portions of the body, which primarily occur to ease transport or hinder the identification of an individual (Reichs, 1998; Symes et al., 1998; Di Nunno et al., 2006). There are times that a perpetrator already going to these extreme lengths will conceive of additional methods to hide the remains of an individual with the use of a chemical substance to further hinder investigative processes. The application of calcium oxide (hydrated lime) can be seen throughout history as one of these substances thought to speed the deterioration of human remains. This was due to the fact that the application of calcium oxide to the farming fields would deteriorate plant materials and it was believed that the same processes would occur when applied to human remains (Laudermilk, 1932; Gittings, 2007; Solla, 2007; Congram, 2008; D'Errico et al., 2011 Van Strydonk et al., 2011).

While the application of these methods can be seen primarily through use in a forensic context, the study and further investigation of sharp force trauma, specifically saw marks, can be of use to those within other sub-specializations of anthropology, namely archaeology and bioarchaeology, given that artifacts and remains found may display similar markings or chemical alterations; wherein these alterations may assist in defining subsistence or funerary practices of a given area or could be indicative of alterations based solely on the soil content where the remains are located. Should this be the case, it becomes necessary for a deeper understanding of the chemical alterations that may be produced by the application of calcium oxide on remains, both in cases of direct and indirect application as this may allow for differing interpretations of events that lead to the placement of remains in a given location.

While the dismemberment of human remains after the commission of a crime is relatively rare, it is "known to be the major postmortem activity performed by humans on the remains of others. The main objective is to prevent identification of the victim by destroying body integrity as well as criminal evidence" (Delabarde and Ludes, 2010 p. 1105). While there are current instances where dismemberment is being utilized throughout the world, it may also be seen in conjunction with the application of calcium oxide to further prevent identification of human remains (Toms et al., 2008; Delabarde and Ludes, 2010; D'Errico et al., 2011; Schotsman et al., 2012). Thus, it becomes necessary for research to systematically examine the degenerative effects resulting from the application of calcium oxide to bone with traumatic defects, specifically as it pertains to class characteristics commonly found in saw marks on bone by examining two differing environments over the course of four weeks.

The elements that will be examined over the course of the four weeks are humerii and tibiae from a common pig (*Sus Scrofa*), which will be inflicted with saw trauma to the proximal and mid-shaft regions of the bone. This will allow the research to examine elements which are the most likely to be affected, as well as the location of the initial trauma. The environments used are two types of surface depositions that have been used in previous homicides (Delabarde and Ludes, 2010; D'Errico et al., 2011; Schotsman et al., 2012).

Using these variables, this research tests the hypothesis that the application of calcium oxide will alter the class characteristics of saw marks to the point that they could not be used in the determination of a saw class. Concurrently, the null hypothesis states that the application of calcium oxide will not alter any of the class characteristics found to be present within a common saw mark.

Literature Review

Taphonomy, as defined by Efremov in 1940, refers to the "study of death assemblages or the laws of burials" (Haglund & Sorg, 1997, p. 3). Initially seen only as relevant to paleontology and archaeology, taphonomic research examined the processes in which a living organism transitions from the biosphere back to the lithosphere, especially as it pertained to the preservation of fossil assemblages (Martin, 1998; Komar and Buikstra, 2008). This definition, however, has been expanded over the years to include the examination of modern osteological assemblages, as well as being modified to include the study of the immediate post-mortem interval which has become known as forensic taphonomy (Haglund and Sorg, 1997a). While forensic taphonomy shares many of the same goals as the broader field of taphonomy, the primary goals of forensic taphonomy are to estimate time since death, identify human versus non-human agents of bone alteration/modification, and the reconstruction of perimortem circumstances and postmortem movements (Haglund and Sorg, 1997a; Komar and Buikstra, 2008).

Upon the death of an organism, and dependent on its deposition, competition for the nutrients possessed by a set of remains begins (Gill-King, 1997). The agents responding to the introduction of this food source may be those related to the processes of decomposition (i.e. different stages of beetles, flies) wherein they are effecting the changes related to the soft tissues that are present on remains. It is during the insect response to remains as a food source that we are able to see and measure discernible changes to the amount of tissue present on a set of remains, which may affect the estimations made regarding the postmortem interval (Bass, 1997; Galloway, 1997; Anderson and Cervenka, 2002).

During this same point in time there may be other agents that are responding to the introduction of a food source, primarily those considered scavengers. These scavengers may range from the large carnivores (bear), mid-level carnivores (coyotes or dogs), to small scavengers such as rodents. The effects that these animals have on a set of remains may range from soft tissue consumption and disarticulation to the removal of body portions to a completely different location (Haglund, 1997). In addition to these processes theses scavengers may proceed to puncture or gnaw on exposed bone in order to retrieve the rich source of nutrients found in the marrow (Ubelaker, 1997).

Additional alterations such as weathering may be a result of contact with soil minerals or plant roots that have resulted in the degradation of the skeletal material (Gill-King, 1997; Ubelaker, 1997; Haglund et al., 2002). Depending on the deposition of a set of remains there are a variety of possibilities in which these taphonomic changes may occur. Given the context in which the burial assemblage was discovered a set of remains may have been exposed to the processes of cultivation where both chemical and structural changes may have occurred through the application of fertilizers, pesticides, tillage and harvesting of the ground (Haglund et al., 2002). Through these processes the remains may come into contact with plant life as well. Evidence of plant interaction presents as root etching and can be seen where the roots of a plant have absorbed organic nutrients from bone. In conjunction to these possible alterations, remains may show evidence of exposure to the sun which results in the bleaching of skeletal material.

Given that a number of variables begin to effect remains upon deposition, researchers have focused on the stages and patterns that can be seen during decomposition and how this is relevant for estimating time since death (Haglund and Sorg, 2002). Depending on the stages or patterns that can be seen, a forensic anthropologist may also be able to garner additional contextual information about the remains. More specifically, the researcher may be able to distinguish instances of sharp force trauma on a set of remains from blunt force or projectile (gunshot) trauma (Komar and Buikstra, 2008).

Blunt force trauma may be defined as trauma “produced by low velocity impact from a blunt object (i.e. a beating, motor vehicle accident, concussion wave) or the low velocity impact of a body with a blunt surface (i.e. fall)” (Passalacqua and Fenton, 2012 p. 400). This type of trauma is generally presented as skeletal fractures due to a slow-load application; however the resulting fracture may be dependent on both intrinsic and extrinsic factors related to the application. Due to the tension and compression that is expressed during this trauma, the directionality of the contact may be identified. Additionally these are the most common form of injury (Passalacqua and Fenton, 2012; Symes et al., 2012).

The opposite end of the spectrum consists of trauma related to gunshot wounds. These traumatic defects are the result of both high velocity and high-load application and have previously been defined by the circular defect that is commonly present in accompaniment of beveling on the opposite side of the trauma (Burns, 2007; Berryman et al., 2012). Additionally the resulting fracturing will produce ‘starburst’ pattern due to the expansion that takes place (Burns, 2007). However, the fact that a bullet may in some cases produce an entry that is not the typical circular defect may lead to misinterpretation, and has resulted in prompting additional research into projectile trauma (Berryman et al., 2012).

Sharp force trauma identification generally includes those that were inflicted by chopping, stabbing, or slashing injuries (Reichs, 1998; Symes et al., 1998; Symes et al., 2002; Komar and Buikstra, 2008). These injuries can be classified as a slow velocity type of trauma similar to that found within blunt force trauma, however are produced with a sharp edged object (Symes et al., 2012). The presence of sharp force trauma in an archaeological assemblage may be indicative of butchering, or inter-/intra-population conflicts and may even indicate cannibalism (Graver et al., 2002; Thompson and Inglis, 2009). However, when the presence of sharp force trauma is found in modern forensic contexts it may indicate an attempt to hide criminal actions with mutilation and dismemberment of remains (Di Nunno et al., 2006). It is the systematic examination of remaining saw and knife marks present on human remains that allows for inferences about the context of a person's death (Reichs, 1998; Thompson and Inglis, 2009) and the postmortem treatment of the body. The peri- or postmortem treatment of human remains may include the use of a chemical substance, particularly calcium oxide that was applied in efforts to hinder identification and/or expedite the destruction of the remains (Laudermilk, 1932; Schotsman et al., 2012).

Saws

While saws are a tool that have been in use by humans for several millennia (Symes et al., 1998), to many people a saw is simply a tool that can be best characterized as a piece of metal which has teeth located on one edge of the blade (Blackburn, 1974; Saville et al., 2007) and "differ only in outward appearances and produce the same results" (Symes, 1998 p.390). Given the very basic definition that most people have regarding saws, up until the late 20th century many anthropologists and forensic investigators believed that saw marks could tell an investigator little and believed that "saw teeth destroy characteristics with consecutive cuts as the tool progresses in the cut" (Bonte, 1975 p. 318). However, during the mid to late 1970s the examination of key characteristics of saw marks in human bone was explored (Bonte, 1975; Andahl, 1978). Bonte's article *Tool marks in bones and cartilage* (1975) initially gave researchers a method to determine the class characteristics present within cut marks. This publication and the research that followed has shown contrary to prior belief

> "…in fact, continuous or reciprocating actions of saws enhance, rather than erase, details necessary for saw class identification. Saws' repetitive actions will commonly produce more diagnostic features than, for example, the penetration and removal of a knife associated with a single stab wound" (Symes et al., 1998).

The classification of saws is dependent on several characteristics and classified according to the material that they are designed to cut (Symes et al., 1998). While there is no universal classification system for saws, most are generally classified by their primary characteristics which include their size, shape, set, and power (Symes, 1992; Symes et al., 1996; Symes et al., 1998; Saville et al., 2007). These primary characteristics are most commonly found within the kerf, which consists of the walls and floor of the saw mark. The kerf occurs when a blade initially incises the bone creating a groove, and is used by researchers and investigators to narrow the possible range of tools that were used in cases of sharp force trauma or dismemberment.

For most saws the characteristics that determine type relate to the teeth of the saw which are generally referred to as teeth per inch (TPI) or points per inch (PPI). When examining the size of the saw it is common for the ripsaw to have a TPI of 3.5 to 7, whereas the crosscut will usually have a TPI of 5 to 12 (Symes et al., 1998). The shape will also allow for a distinction of saw type in that ripsaw teeth are “flat chiseling teeth usually found on wood saws and designed to cut along the grain of the wood” (Saville et al., 2008 p.350). Whereas the crosscut have teeth that are generally filed “at opposing angles, typically 70° and will terminate in a point and the teeth will cut material rather than chisel it” (Symes et al., 1998 p.392). The set generally refers to the way the teeth are bent on the blade, a feature designed to reduce the binding of the blade (Symes, 1996). Binding is generally seen when movement of the blade is restricted by the walls of the cut, or the blade is unable to continue moving. The directionality of the teeth in conjunction with the width of the saw determines the kerf width of the cut mark. The power component can generally be determined through an examination of the striae found on both the walls and floor of the saw mark. For saws that are mechanically powered the striae will be finer than those created by hand-held saws (Freas, 2010). Additionally, the striae produced from mechanical saws will be more uniform than those produced by handheld saws (Symes, 1996).

Kerf Mark Morphology

In making a determination regarding the primary class characteristics of a saw, specific morphological features of the saw mark assist in making a determination of saw type. The first of these is the kerf and several other features are based on it. When a blade first incises the bone it creates a groove, or what is referred to as the kerf. The groove will display the initial corner, floor corners of the kerf wall and the kerf floor (Bonte, 1975; Andahl, 1978; Symes, 1992; Symes et al, 1998, Saville et al., 2007; Freas, 2010; Symes et al., 2012). From the kerf floor corners it may be possible to extrapolate information regarding the TPI and evidence of the tooth set from the configuration of the kerf floor (Saville et al., 2007, Symes et al., 2012).

These characteristics may be easily identified when viewing a false-start, or a cut mark that fails to go completely through the bone. False starts may provide invaluable information related to the classification of a saw, in that it provides a clear view of the width of the kerf, the kerf floor, and the floor corners. This information allows for the reconstruction of the general saw class that was used by answering four primary questions. These questions include (i) the powering of the saw, (ii) the direction of the cut, (iii) the morphology of the teeth, and (iv) the shape of the teeth (Symes et al., 2012).

At the termination point of a saw mark there may be a breakaway spur or notch. The breakaway spur is a projection of bone that indicates the exit location of the blade and is a result of the pressures that are being exerted on the bone causing it to fracture at that location (Symes, 1992). The breakaway spur may provide a view of the kerf floor if the pressure being exerted on the blade was not too great. If there is a large amount of pressure, the breakaway spur may be capable of “disguising” the characteristics of the kerf floor as the blade is drifting and forcing its way out of the bone (Symes, 1992). Drifting is generally seen at the beginning or end of a saw cut made within tubular bone due to the fact that there are smaller amount of material resisting or blocking the movement of the blade (Symes, 1992).

As a saw progresses through bone, each pass of the saw will generate a small furrow which may be found within the walls of the saw mark (Savile et al., 2007). These furrows are what is referred to as the striations and are caused by the saw blade entering the bone at a slightly lower point than the previous pass of the saw blade through the bone. This characteristic becomes invaluable when trying to determine the directionality of the cut, the tooth size of the blade, and the powering of the saw (Symes, 1992, Saville et al., 2007; Symes et al., 2012). If the striae are parallel it indicates the directionality of the cut, as the kerf floor becomes the end point of the striations. Symes (1992) has shown that the size of the saw tooth may be inferred from the patterning of the striae. This research indicates that within a saw mark produced by large teeth the accompanying striae will initially be straight then becoming slightly wavy as it passes through the medullary cavity, and finally straightening back out as the cut finalizes. These striations may also assist in determining the powering of the saw. These marks may be indicative of mechanical powering if the striations appear to have a continuous uniformity with no false-starts apparent. If the striae appear to have several directionalities this could be a sign that the saw is hand powered and the changes in patterning representative starts and stops throughout the cutting process. When the striae in the bone appear to have been polished, this typically results from mechanically powered blades when the progression of the cut through bone is slower than necessary and the moving blade remains stationary for brief periods of time (Symes, 1992). Additionally when examining the directionality of the cut one can examine any exit chipping present long the initial corners of the kerf wall. This chipping is generally located on the side of the cut that is closest to the individual producing it and may help in positioning the bone during reconstruction of the cut (Symes, 1992).

Chemical Alteration

The application of caustic chemicals may expedite the processes of overall bone degeneration or assist in the partial destruction of bony material. The utilization of chemical agents on a set of human remains may be an attempt to hinder identification (Ubelaker and Sperber, 1988; Ubelaker, 1997). Within the last several years there has been an increase in research devoted to understanding chemical interactions with bone (Buckley, 2005; Solla, 2007;

Cope and Dupras, 2009; D'Errico et al., 2011; Harnett et al., 2011; Schotsmans et al., 2012). Additionally, with the increase in knowledge about chemical interactions with bone, comes the desire to test societal myths or "old wives tales" to determine whether these are true. Of these, so far the ability of *Coca-Cola* to destroy remains has been tested and rendered a myth (Hartnett et al., 2011). Due to its long standing use throughout history and the accompanying myth which implies that the use of calcium oxide will completely destroy human remains, some research has recently focused on the properties of calcium oxide, or lime.

Calcium Oxide

The effects of calcium oxide in relation to postmortem bodily alterations are poorly understood and have prompted an increase in research surrounding this concept. However, despite this lack in definite knowledge, this chemical has had a longstanding utilization within burials for various reasons (Laudermilk, 1932; Rosensaft, 1979; Jarvis, 1997; Gittings, 2007; Bianucci et al., 2008; Gilead et al., 2009; VanStrydonck, 2011), and on occasion has been used by criminals attempting to hinder the identification of a victim (Solla, 2007; Congram, 2008; D'Errico et al., 2011).

Calcium oxide is created when naturally occurring limestone is heated to temperatures above 800°C. This resulting product is known by a variety of different names, such as quicklime or burnt lime. However the addition of water to this chemical results in hydration and allows for carbonization to occur under prolonged contact with oxygen (Schotsmans et al., 2012). Due to the fact that this chemical is alkaline in nature, it is commonly used in the agricultural arena to raise the pH of soils. This increase in the alkalinity of soils assists in the breakdown of organic compounds within the soil and it has been noted that prolonged skin exposure to this chemical will result in burning of tissues (Shermin and Larkin, 2005; Poppe et al., 2012). This has resulted in the societal myth that this chemical will destroy a set of remains; however, the use of this chemical has shown to slow the progression of decomposition (Buckley, 2005; Schotsmans et al., 2012). Research conducted by Buckley (2005) and Schotsman et al. (2012) attempted to examine the effects of the application of calcium oxide on both burial and surface depositional environments. This results of this research in both depositional contexts revealed that the soft tissue portions of remains that were in contact with the calcium oxide would become desiccated wherein the portions that were not in constant contact would proceed through stages of active decomposition. This was followed by additional research by Schotsman et al. (2012) in a laboratory setting using small cubes of belly and rump pork samples exposed to calcium oxide. These samples showed rapid desiccation, having lost 50% of their moisture content within one day; however, research provided by Buckley (2005) would indicate that while small cubes of tissue will desiccate quickly, larger tissue pieces will desiccate at a slower rate due to surface area and volume ratios.

Throughout history uses of this chemical in a non-farming nature have been proposed and utilized. Some of these uses have included being used as a disinfectant and as an odor retardant in regards to the odors produced by decomposition. The most notable uses in this manner can be seen in its use within the plague pits of Europe (Bianucci et al., 2008) as these pits were used until they had reached maximum capacity. Additionally, this type of application has been seen during the modern era in some of the great atrocities that have been committed during the 20th century, primarily during the mass grave inhumations during WWI, WWII, the Spanish Civil War, and the civil war that occurred in the former country of Yugoslavia (Klug, 1989; ICTY, 2000; Marquez-Grant et al., 2012; Schotsman et al., 2012). However despite its long-standing utilization within societies, whether it pertains to agriculture or burial practices, the need to better understand the interactions this chemical has with the human body persists in the knowledge base.

Materials and Methods

In order to determine if the application of hydrated lime to saw marks in bone would cause any degradation to features (kerf and striae morphological patterns) commonly examined, several scenarios were utilized during this research. This research utilized eight specimens, each being exposed to induced trauma from a mechanical saw. Upon the introduction of the trauma, each of the specimens would be exposed to calcium oxide for varying time intervals, which spanned one to four weeks. The specimens were also separated into two groups which would be exposed to differing yet distinct environmental exposures intended to mimic disposal methods. Over the course of this research detailed notes and photographs were taken to document any macroscopic changes that were occurring. Additionally, microscopic photography was undertaken of the specimens both pre- and post chemical exposure in order to document any changes due to chemical exposure that could not be distinguished macroscopically. The specimens, number of days treated and post exposure environment are outlined in Table 1.

Table 1. Summary of specimen type and treatment exposures.

Specimen Number	Element	Number of Days Treated	Type of Environment Exposed To
SS-1	Humerus	7	Outside Disposal
SS-2	Humerus	14	Outside Disposal
SS-3	Humerus	21	Outside Disposal
SS-4	Tibia	28	Outside Disposal
SS-5	Humerus	7	Transportation
SS-6	Humerus	14	Transportation
SS-7	Tibia	21	Transportation
SS-8	Tibia	28	Transportation

Calcium Oxide

For the purposes of this research the application of hydrated lime was applied to the cut ends of humeri and tibiae from a common pig (*Sus Scrofa*). The utilization and application of hydrated lime was chosen due to the fact that there is a paucity of scientific research examining the effects of this chemical compound on hard tissues such as bone, in light of it being linked to myths that imply that it will "lead to the rapid and total destruction of human remains" (Schotsman et al., 2012 p.50).

Given the ease with which one can acquire this chemical compound, as its primary purpose is usually related to masonry, it is little wonder that this chemical is still being used with nefarious intent. However, within the last twenty years, research has been conducted regarding the events and sequences that surround soft tissue decomposition in presence of lime. Nevertheless, there is no research that focuses on the effects that this substance has on the hard tissues of the body.

Environments

For this research two different types of enclosures were used. The first environment consisted of yard waste disposal garbage bags. These bags are black in color and made of a thicker plastic than those used for household garbage. The purpose of these bags was to mimic circumstances that could be utilized in both disposal and transportation of remains. The second environment aimed to mimic conditions that would be found in a surface deposition of remains. Four small storage containers were filled with soil and accompanying flora that would be found during late fall and winter months such as leaves and pine needles.

Test Subjects

For the purposes of this research, long bones primarily humerii and tibiae, from a common pig *(Sus Scrofa)* were utilized. The utilization of pig long bones is because they are readily available, but more importantly, previous research has demonstrated pig bones to have a similar hardness rating and present the "same types of marks as human bones when cut" (Saville et al., 2007 p.352).

Sus Scrofa specimens 1-8 (SS-1-8) were all procured January 10, 2013 from a butcher in Whitefish, Montana and consist of portions of long bones remaining from daily butchering practices. All specimens had both muscular and fatty tissue and ligaments remaining on the bone and in some cases were still attached to adjoining bones. Upon procurement the bones were frozen until February 4, 2013 to preserve the bones and associated tissue and to inhibit the process of decomposition from initiating until this study began. Upon thawing, a portion of the adhering tissue was removed to allow for the bones to be examined and photographed with a microscope.

On February 8, 2013 the proximal portions of all bones were cut using a *Milwaukee* brand variable speed reciprocating saw with a *Lennox* brand 6T 4.2mm blade designed for both wood and metal cutting. After the cutting the remains were examined and photographed microscopically to examine the pre-treatment resulting from sharp force trauma. Upon completion all specimens were treated with *Western* Miracle Pressure Hydrated Type "S" Lime, a hydrated lime application.

Treatment

On February 8, 2013 all remains were treated with one-fourth cup of the hydrated lime, with the cut surface of the bones receiving the initial application to cover the surface, and placed in the bags for the specified time increment of one, two, three or four weeks. All remains were placed in the containers and treated with one-eighth cup lime within the container which was then covered with chicken wire to prevent smaller animals from coming into contact with the bones and the hazardous chemical. These microenvironments were then left outside to allow exposure with the colder temperatures that winter provides as well as any form of precipitation that occurred during the one, two, three, or four week time increments allotted for this research.

Data Collection

Data collection for this research consisted of both macro- and microscopic photography (50x), as well as a detailed recording of the cut mark characteristics found to be present on each of the specimens as detailed by Symes (1992), Reichs (1998) and Symes et al (1998). This consisted of an examination of the kerf characteristics as well as the characteristics of the striae present within the cuts marks. Kerf characteristics documented included the determination of the kerf floor configuration (whether this was flat, curved or w-shaped), which is a characteristic related to saw class. A description of this characteristic (flat, curved, w-shaped) was used during the microscopic examination and was classified according to the shape that was present within the kerf floor. Additionally, the presence or absence of a breakaway notch or spur was recorded as well as any accompanying entrance or exiting chipping of the bone.

The initial corners of the kerf wall were examined as well to determine the angle degree that the saw entered the bone.

Recording of these characteristics was completed during both the visual and microscopic examinations. The data related to the breakaway spur or notch was recorded on the basis of the presence or absence of this trait and most commonly able to be completed with the visual examination. In the cases where this trait was not obvious to the naked eye, a microscopic examination was needed to document this trait and necessary to verify the presence or absence of this trait. While examining the entrance or exit chipping of the bone related to infliction of the cut mark microscopic examination was necessary. During this examination the edges of the bone were examined to determine the presence or absence of bone chipping only; however this data may be used by researchers during later point in the examination to determine the direction of the blade progress through the bone. Scoring of the initial corners of the kerf wall was completed during the visual examination of the remains and was recorded as being greater or lesser than 90° or at 90° to the rest of the bone when the specimen was laid in anatomical position.

Characteristics related to the striae found on the kerf walls were documented. During the visual examination the cut marks were examined to determine if they present striations that are both parallel and visible to the kerf floor which may be used to determine the directionality and continuity of the cut mark, and therefore, recorded as present or absent during data collection. The presence of harmonics, or oscillations created by defects found in the blade were noted within these striations and recorded simply as present or absent indication. The presence or absence of this characteristic may provide information regarding the power source. Additionally the striations were examined to determine if the striae were uniform and smooth, as well as whether they were concave or convex; each of these characteristics being used to determine the power-source for the saw that was used to make these marks. Recording of this data was completed during the visual examinations while looking directly at the cut surface of the specimen and was recorded as being either uniform and smooth or not, and the designation of convex or concave striae on the bone. Included in the data collection protocol was a section which included any additional information, which was to be of use in the post-chemical observational recordings. Observations made within this section of the data recording generally related to the presence of polishing on the cut mark which is most commonly seen in saw marks created by power saws. However, observations made regarding the changes observed within the soft tissue were recorded within this section as well to thoroughly document all degrees of alterations that were observed on the specimens.

At the end of the designated time increment the bones were removed from their environment and cleaned initially with distilled water to remove any remaining lime. After this had taken place the remains were then cleaned to remove any of the remaining tissue that was present of the bones following the protocols described by Nawrocki (1997). This consisted of placing the remains in a metal pot, filling with water just enough to cover the bones with an additional 2 inches and 1 cup of enzyme-active borax and boiling for 30 minutes up to an hour. After boiling, the remains were reduced to a low simmer for several hours, wherein any remaining tissue was removed with wood clay instruments or brushing it off with a toothbrush.

After all specimens were dry the same methods were used to examine SS1-8 both macro- and microscopically. The same features from each saw mark were evaluated and documents for comparison to the pre-treatment condition of the specimens.

Results

The results from this research are a compilation of visual and microscopic examinations of bone specimens SS1-8. Both the visual and microscopic examinations depict the degradation of the bony tissue that occurred during the exposure to calcium oxide using the criteria listed in the previous chapter. All specimens (SS1-8) were cut using the same *Milwaukee* brand reciprocating saws-all on February 8, 2013. Additionally all specimens were cleaned of both the calcium oxide and remaining tissue using the methods listed previously.

Initial Examination of Specimen #1

The cutting and initial examination of SS-1 took place on February 8, 2013 (Figure 1) after which SS-1 was exposed to the calcium oxide and placed in the outside disposal environment. The initial visual examination of the remains noted that there was some tissue present on the bones; the tissue remaining was primarily muscular and connective tissues. Additionally, this tissue was starting to produce odors consistent with decomposition. Examination of the kerf characteristics of SS-1 showed that the floor configuration of the kerf was flat, and that there was a breakaway spur present, however there was not breakaway notch. There appeared to be no signs of false starts within the kerf or on the outer portions of the bone indicating that there had not been multiple attempts at cutting the bone. Additionally, there were no signs of exit chipping and the initial corners of the kerf wall appeared to be at 90°. The characteristics of the striations that were apparent on the bone appeared to be parallel and visible to the kerf wall floor, as well as appearing very uniform in nature. However due to the amount of tissue remaining on the bone, making a definitive assessment of the characteristics related to the striae was impossible.

Saw classification prior to treatment: During this examination the characteristics that are present related to the kerf wall would indicate that the tooth set for the weapon used to implement this cut would fall within the alternating tooth set. The flat kerf floor indicates that the saw used possessed chisel styled teeth found within the rip saw classification. The visible features that are related to the striae would indicate that the saw used was mechanically powered due to the organization of the striae being parallel to the floor. However the presence of tissue greatly reduces the appearance of these characteristics.

Post Exposure Examination of Specimen #1

On February 15, 2013 (7 days post-treatment) SS-1 was visually examined to determine if any changes had occurred. Upon visual examination it was noted that the muscular and connective tissues that were not touching the soil were showing signs of desiccation (Figure 2). However, the portion that was exposed to the soil showed little signs of tissue reduction and the fatty tissue still appeared to be moist. Additionally, the bone did not retain the odor of decomposition that had been present during placement of the remains. SS-1 was then removed from the disposal environment and cleaned of the calcium oxide using the protocols listed previously, however despite the cleaning process there are still locations within the cut mark that have minute portions of calcium oxide that are present. This substance appears to have solidified to the bone.

During the visual and microscopic examinations that were conducted, both examinations of the kerf characteristics reveal a flat floor configuration located on the small breakaway spur present on the posterior portion of the cut, as well as the initial corners of the kerf wall being at 90° (Figures 3 and 4). Also present were signs of exit chipping that were found on the lateral portion of the bone near the middle of the cut. There were two possible false starts located on the initial portion of the kerf wall. The striations that were present ran parallel to the kerf floor and could be considered to be visible to the kerf floor as well. The striations appear to be uniform with no indication of harmonics present throughout the cut. The curvature of the striations is inconclusive. Additionally the initial portion of the cut mark has an appearance of being polished.

During the post exposure examination the characteristics that were recorded did not differ from those made in the pre-exposure examination with exception of the appearance of two false starts that had been obscured by tissue previously. Due to the fact that there were no differences among the characteristics the classification of saw type would stand.

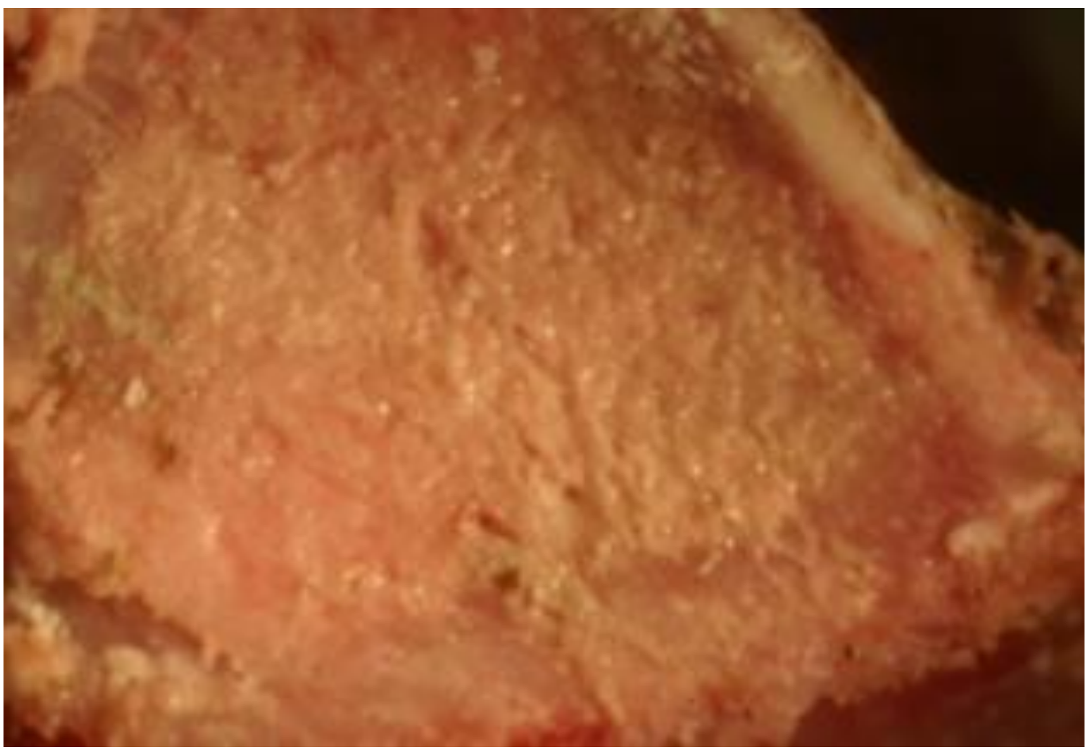

Figure 1. Initial examination of SS-1. Post cutting, prior to calcium oxide application


Figure 2. SS-1 end of calcium oxide exposure, 1 week.

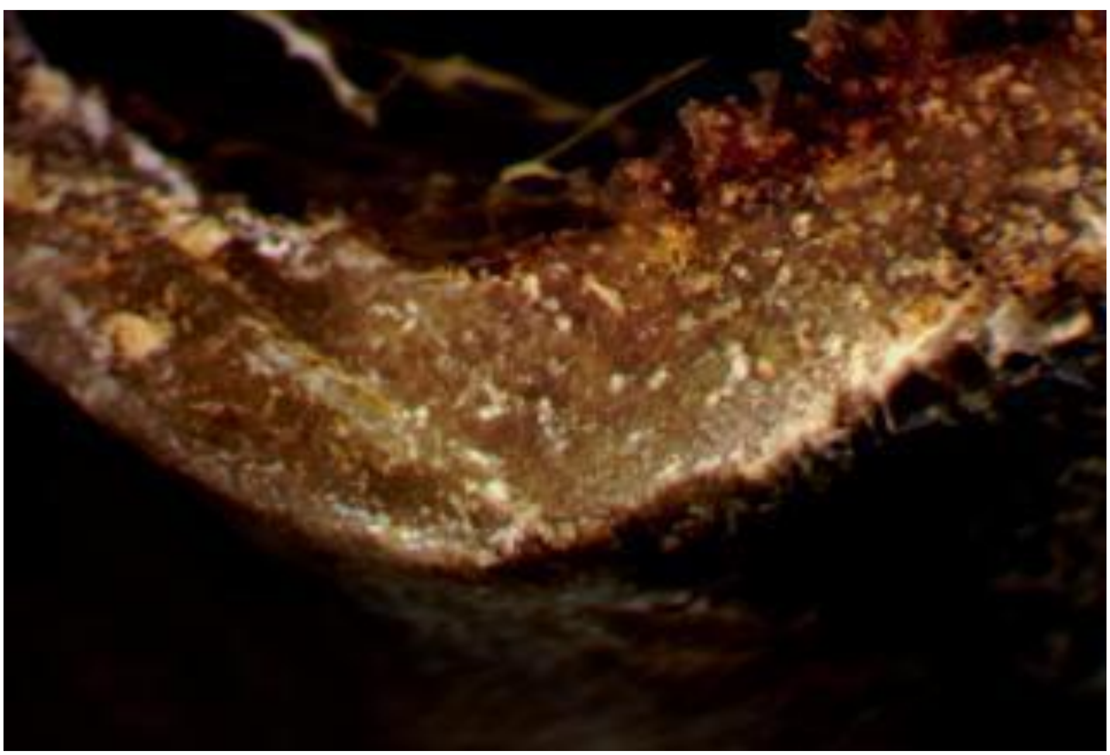
Figure 3. Post exposure examination, SS-1. Microscopic view of breakaway spur.

Figure 4. Overview of SS-1. Post Exposure.

Initial Examination of Specimen #2

The initial examinations of SS-2 were completed on February 8, 2013 and the specimen was later exposed to the calcium oxide in the surface deposition context. Upon examination of the kerf characteristics, the floor configuration appeared to be flat as it was seen from the breakaway spur. The breakaway spur present was minor in size and relatively hard to identify without the aid of the microscope when viewed in conjunction to tissue remaining. In addition to the breakaway spur there appears to be a breakaway notch that is located towards the medial side of the spur. The initial corners of the kerf wall were at 90° presenting with sharp corners in the compact bone. There does not appear to be any signs of exit chipping present, not does there appear to be any indicators of false starts in the cut marks. The striations that were present do not appear to be visible to the floor; however, they do appear to be parallel to the kerf floor. These striations appear to be very uniform in both appearance and depth, with no evidence of harmonics.

During this initial examination of SS-2 there was both muscular and connective tissue remaining on the bone (Figure 5). In addition to the remaining tissue there was marrow present within the medullary cavity. SS-2 was also starting to exude odors that are consistent with the processes of active decomposition. The amount of tissue that was present on SS-2 also prevented a definitive assessment of the curvature of the striations.

Saw type classification prior to treatment: While SS-2 presented a flat kerf floor which would be consistent with the chisel style teeth that are found within the rip saw classification as well as the alternating tooth set. The striations that were visible were indicative of the saw being mechanically powered, however due to the fact that these were not visible to the floor nor were there harmonics present this categorization cannot be definitive.

Post Exposure Examination of Specimen #2

On February 22, 2013 (14 days post treatment) SS-2 was removed from its depositional environment to be photographed and cleaned of the calcium oxide. During the exposure time SS-2 had experienced a brief amount of rain which lead to the calcium oxide becoming very chalk-like to the touch (Figure 6). The tissue that remained on SS-2 had a very dry appearance, while the underside still appeared moist. The smell of decomposition that had been present during initial placement was no longer there as well.

After cleaning the kerf and striae characteristics were then re-examined both visually and microscopically to determine if any changes had taken place on the remains. Both the microscopic and visual exams continue to place the kerf floor configuration as flat as it could be seen on the breakaway spur. While the spur remained present and small in size, the breakaway notch became more easily visible (Figure 7). There was some exit chipping that became visible after the cleaning process was complete. The initial corners of the kerf walls remained sharp and at 90°. There did not appear to be any sign of false starts being present either on the outer portion of SS-2, or within the striae. The striae appeared to be visible as they proceed to the kerf floor, as well as running parallel to the floor. The striae also appeared to be uniform as it progresses through the bone, however there did appear to be some slight harmonics present at the location of the exit chipping. Additionally, there were small remnants of calcium oxide on SS-2 that are very hard and stuck on the cut mark (Figure 8).

During the post exposure examination the characteristics that were present and recorded in the earlier examination did not differ. Additionally, given that the striations became visible to the floor in conjunction with the presence of harmonics further confirmed the categorization of the saw being mechanically powered.

Figure 5. Examination of SS-2 prior to exposure.

Figure 6. SS-2 at the end of the calcium oxide exposure.

Figure 7. Microscopic view of breakaway spur and notch.

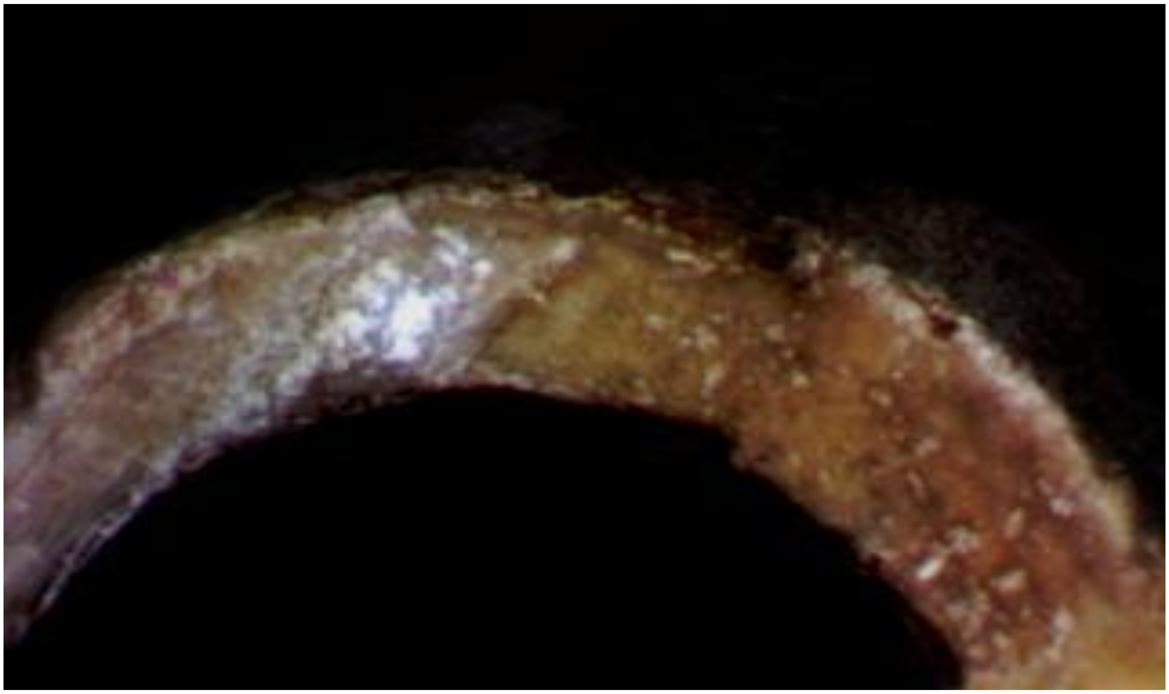

Figure 8. Striations visible and calcium oxide remnants.

Initial Examination of Specimen #3

On February 8, 2013 SS-3 was cut and examined to determine the characteristics that were present resulting from the cut. Upon this examination it was determined that the characteristics relevant to the kerf floor could not be identified due to the amount of remaining tissue on SS-3. Additionally the distinction of false starts could not be made; however, there do not appear to be any false starts or exit chipping located on the outer portion of the specimen. It does appear, though, that SS-3 has a breakaway spur present as well as initial kerf corners that measure 90°. There does appear to be an indicator of a large chip that has broken off of the bone located on the medial anterior aspect on the neck of the femur.

In examining characteristics that are relevant to the striation there are several that cannot be determined due to the presence of tissue on SS-3 (Figure 9). When examining the striations on the kerf wall, it cannot be determined whether the striations are either visible or parallel to the floor of the kerf or if there are harmonics present within the striations. While the striations are difficult to discern on SS-3, the striations that can be seen in the marrow indicate that the striations are uniform. The tissue that remains on SS-3 is primarily fatty and connective tissues, which at the time of the initial examination has started to produce odors consistent with active decomposition.

Saw type classification prior to treatment: Due to the fact that the majority of the characteristics being recorded were obscured and could not be determined with exception of the uniformity of the striations, a classification of this saw could not be made for this specimen.

Post Exposure Examination of Specimen #3

On March 1, 2013 (21 days post treatment) SS-3 was briefly examined prior to being removed from its deposition environment. During this examination it was noted that SS-3 had come into contact and was still partially covered with snow that had fallen a couple of days prior to the examination (Figure 10). The appearance of the calcium oxide had transitioned from a powder to wet and chalky. Additionally the smells associated with decomposition were absent during this cursory initial post exposure examination. Once SS-3 was cleaned it was then examined both visually and microscopically to assess the characteristics present. During this examination the floor configuration of the kerf was found to be flat, as well as a confirmation of the presence of a breakaway spur. The large chip that was seen during the pre-exposure examination does not appear to be a breakaway notch, however does fall within the characteristics of exit chipping. The initial corners of the kerf wall remained at the 90° measurement and remain sharp.

When examining the characteristics that are particular to the striae it has been found by both the visual and microscopic examinations that these characteristics cannot be distinguished. While there are areas of the cortical cone that exhibit striation marks these marks are interrupted by trabecular bone. Additionally SS-3 has become highly porous and a portion of the bone is no longer present, and was not found during the cleaning process (Figure 11) as well as the epiphyses disarticulating from the bone during cleaning.

While a determination of a flat floor was able to be distinguished for this specimen and indicative of a rip saw, a classification of the saw used could not be determined given the lack of additional identifiable characteristics.

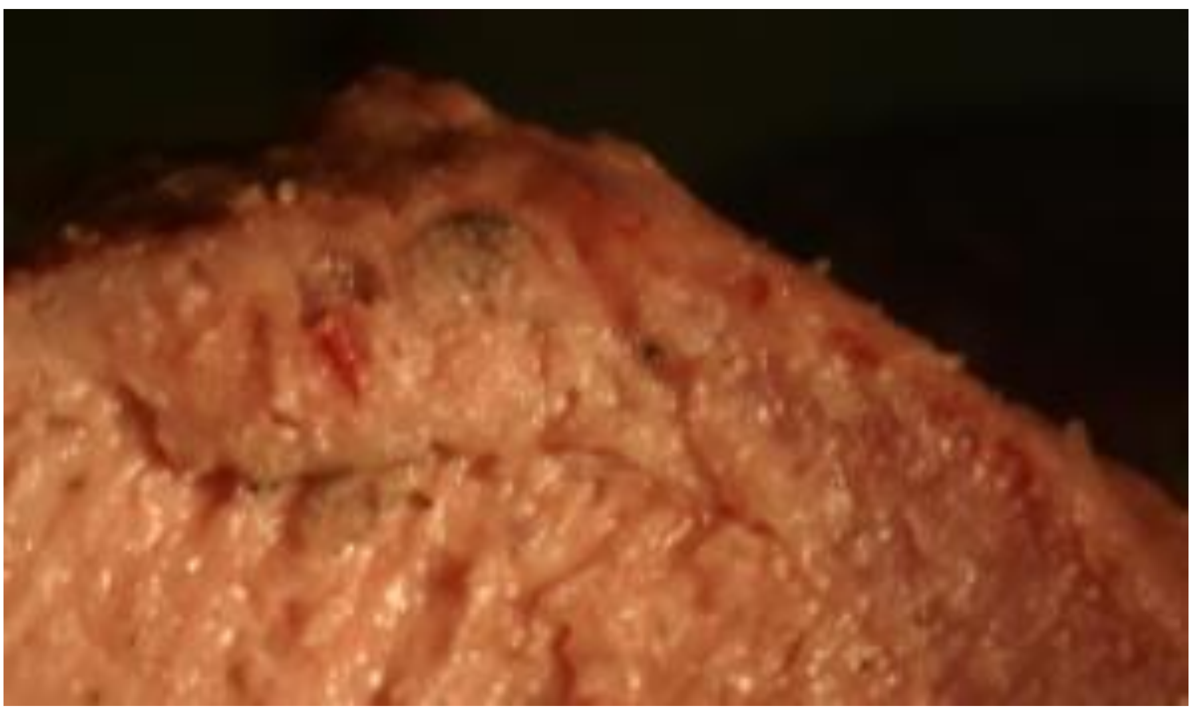

Figure 9. SS-3 post cutting.

Figure 10. SS-3 at the end of the exposure period, March 1, 2013.

Figure 11. SS-3 post cleaning, missing portion of bone.

Initial Examination of Specimen #4

Specimen #4 was cut and examined on February 8, 2013 to establish the characteristics that are present prior to any chemical exposure. During this initial examination SS-4 presented with the following tissue remnants: cartilaginous, muscular and fatty. This tissue was also exuding smells that were consistent with decomposition. The initial corners of the kerf walls appeared to be at 90° over the entire circumference of the cut mark. The cut mark also exhibited a breakaway spur that was found on the tibial crest (Figure 12). This breakaway spur also showed the configuration of the kerf floor, which was flat in nature. There did not appear to be any evidence of false starts within the cut mark or on the outer portion of the bone. In examining the characteristics that are pertinent to the striations it was found that the striations were indeed very uniform and were visible to the kerf floor. These striations were also found to be parallel to the floor as well; however, the determination of the curvature of the striae could not be determined.

Saw type classification prior to treatment: The pre exposure examination of SS-4 identified characteristics that are associated with the chisel-style tooth type found in rip saws. Additionally the characteristics related to the striations present are indicative of the saw being electrically powered as opposed to hand powered due to the uniform organization from the beginning to end point of the cut.

Post Exposure Examination of Specimen #4

On March 8, 2013 (28 days post treatment) SS-4 was subjected to a cursory visual examination to determine any changes that took place during the exposure time. After the exposure time the muscular tissue that was present on SS-4 had begun to desiccate, and the fatty tissue took on a rubbery appearance. The calcium oxide surrounding SS-4 had the appearance of chalky pebbles, resulting from moisture contact during the exposure period (Figure 13). The portion of SS-4 which had remained in contact with the soil had retained a “wetter” appearance with no signs of the tissue drying. The decomposition odors that had been present during the initial examination could no longer be detected.

After the cleaning process had been completed both a visual and microscopic examination was completed. These examinations revealed the presence of a breakaway spur, which further revealed a flat kerf floor configuration. The initial corners of the kerf walls remained at 90° and could still be considered sharp (Figure 14). There was no indication of entrance or exit chipping that could be seen on the cut mark. While there were no indicators of false starts within the kerf, there were indicators of harmonics present at the start of the cut mark. The striations in the cut mark were highly uniform and were both visible and parallel to the kerf floor. The microscopic examination revealed that there were remnants of calcium oxide within some of the initial striations (Figure 15). With exception of the presence of harmonics there were no deviations between the pre and post exposure examination. Due to the fact that harmonics were observed in the post exposure examination the classification that the cut was produced by a powered rip saw is further supported.

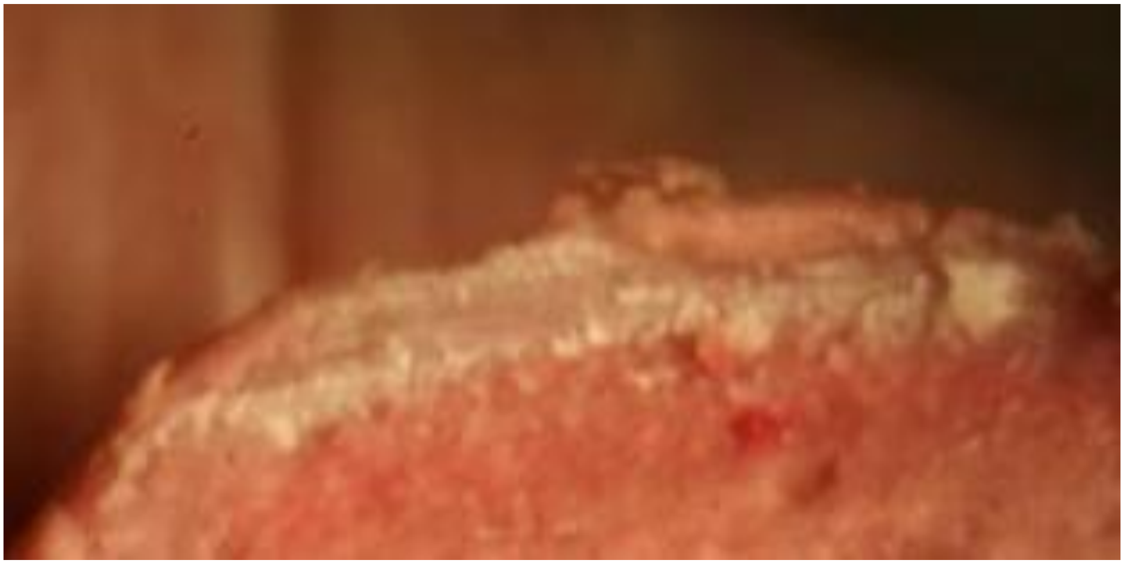
Figure 12. Initial Examination of SS-4


Figure 13. SS-4 at the end of the calcium oxide exposure. March 8, 2013.

Figure 14. SS-4 after calcium oxide exposure and cleaning process.

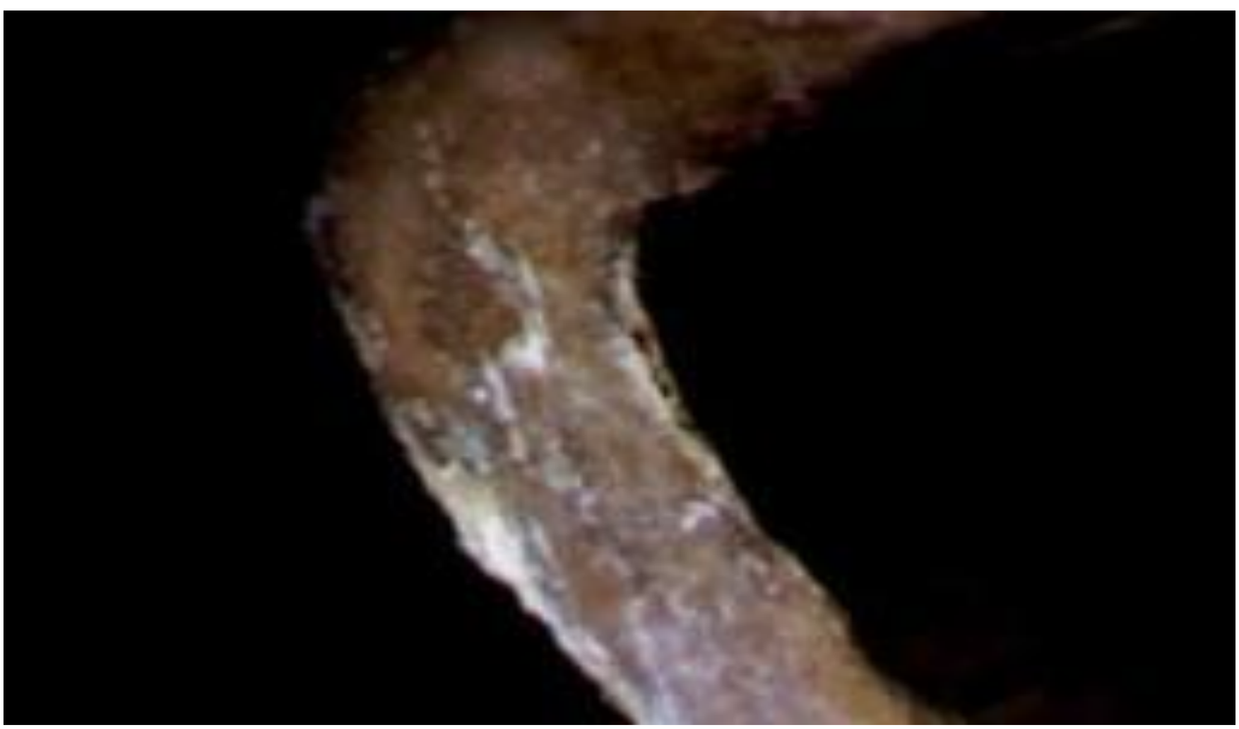

Figure 15. Residual calcium oxide within the striae of SS-4.

Initial Examination of Specimen #5

On February 8, 2013 SS-5 was cut and examined to document the resulting characteristics that were found on the bone, after which SS-5 was exposed to calcium oxide and placed in the garbage bag environment. During the initial examination there were extraneous tissues that remained on the specimen (Figure 16). The tissue that was present was beginning to produce odors that are consistent with those of decomposition. During the examinations the configuration of the kerf floor could not be established as there was no evidence of a breakaway spur or notch. The initial corners of the kerf wall appeared to have been cut at a 90° angle. This examination showed no evidence of any false starts within the kerf and no definitive indicators of exit chipping. The striations that were viewed within the cut mark appeared to be uniform. However, due to the amount of marrow that had been rubbed into the kerf wall during the cutting process it was impossible to determine if the striations were parallel or visible to the kerf floor.

Saw type classification prior to treatment: the absence of either a false start or kerf floor during the pre exposure examination due to the abundance of soft tissue meant that a classification of the saw type could not be made. This was further supported by the interference of the soft tissue while trying to make distinctions regarding the characteristics of the striae. Overall, there could be no determination made at this point.

Post Exposure Examination of Specimen #5

On February 15, 2013 (7 days post treatment) SS-5 was removed from its exposure environment and subjected to both visual and microscopic examinations. When SS-5 was removed from its environment the tissue that remained on the specimen showed no signs of desiccation. The calcium oxide that had been applied to SS-5 still remained powered and showed no sign of contact with moisture (Figure 17). During the opening of the environment the strong odor of decomposition was still present. When examining the saw mark characteristics specific to the kerf floor there could be no determination made regarding the configuration due to the large breakaway notch that was present on SS-5 (Figure 18). There was some evidence of both entrance and exit chipping present on both sides of the cut mark. SS-5 presented two false starts at the top of the cut mark, the first of which is relatively small in size when compared to the second of these false starts. In examination of the characteristics related to the striae, while the striae appear to be organized and uniform through the cut mark, and the striae run parallel to the start of the breakaway notch the contour of the cut mark is jagged at best and therefore impossible to make a determination regarding whether harmonics are present.

During the post exposure examination the presence of two false starts provided information regarding the kerf floor that was unavailable during the initial examination. These false starts provided information that would suggest that the floor was flat, and the saw belonged to the rip saw family. However, this information could not be derived from the principal cut due to the large breakaway notch present. The characteristics of the striae indicate that the saw producing this cut was electrically powered due to the visibility and uniformity of the striations.

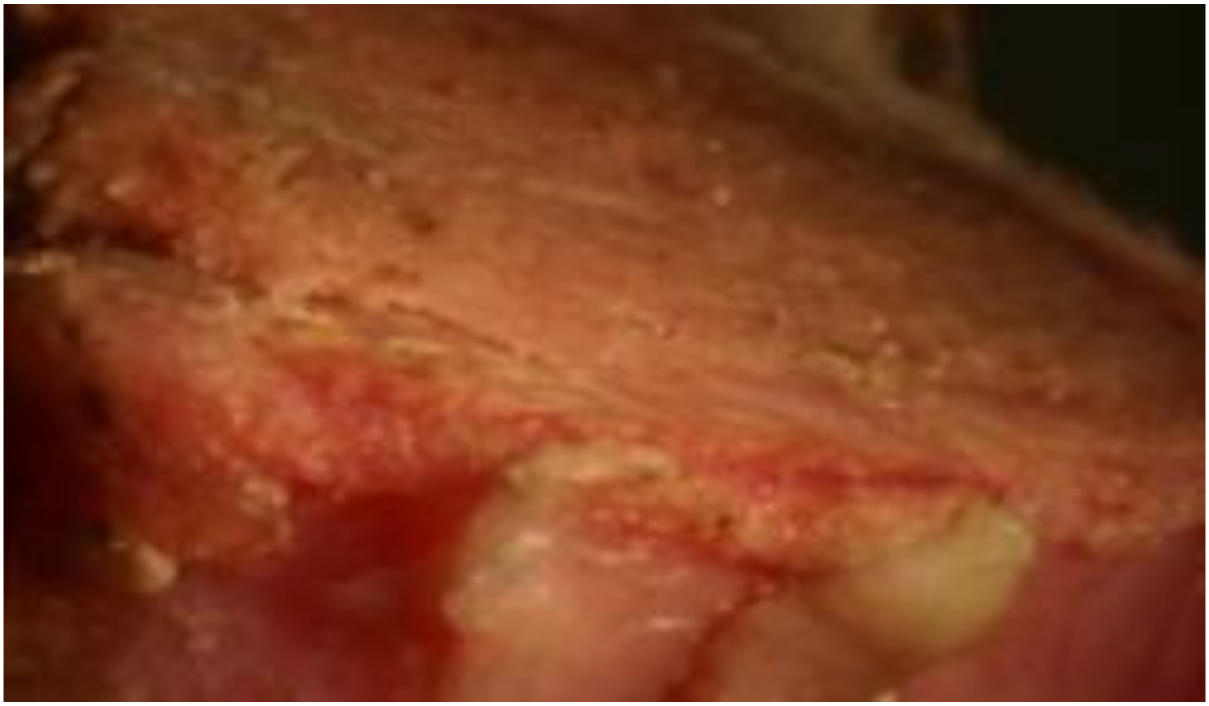
Figure 16. Extraneous tissue remaining on SS-5, prior to exposure. February 8, 2013.


Figure 17. SS-5 upon removal of deposition environment.

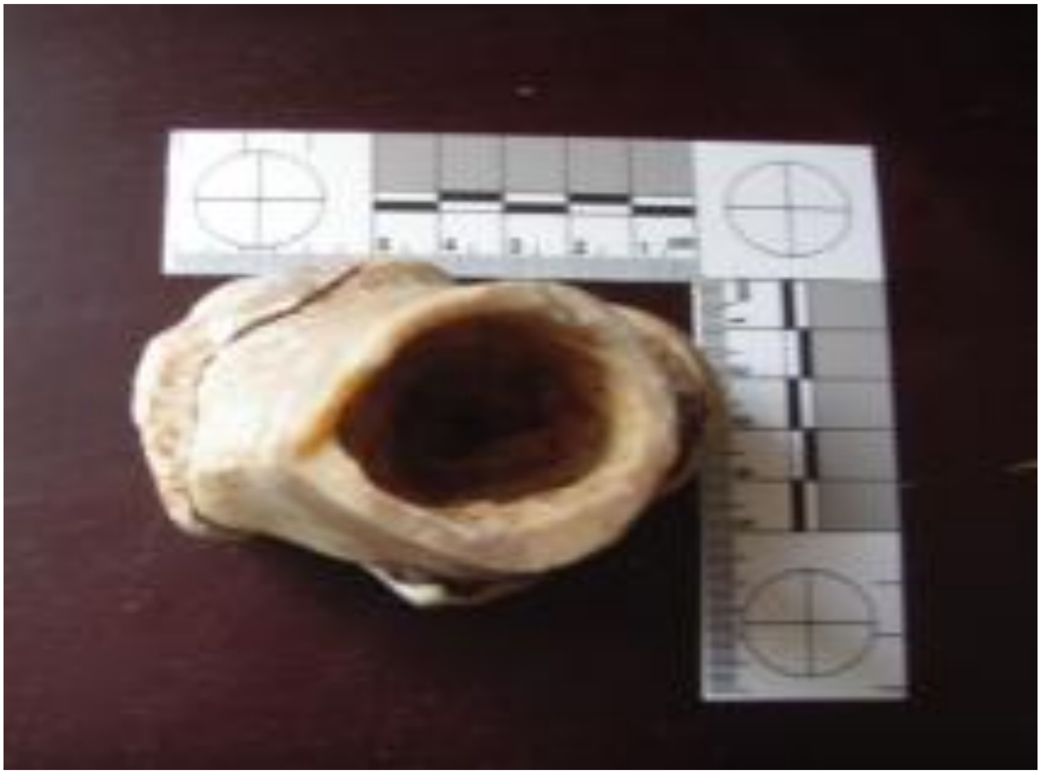

Figure 18. SS-5 displaying large breakaway notch.

Initial Examination of Specimen #6

On February 8, 2013 SS-6 was cut and those marks were examined both visually and microscopically. SS-6 presented with additional tissue that was remaining on the specimen. This tissue was primarily muscular and connective tissue as well as a large amount of bone marrow. After SS-6 was cut, specific characteristics could not be reasonably be distinguished due to the amount of tissue that was obstructing these characteristics (Figure 19). Given the presence of additional tissue present on SS-6 preventing the classification of the saw mark characteristics a classification regarding the saw type cannot be made at this time.

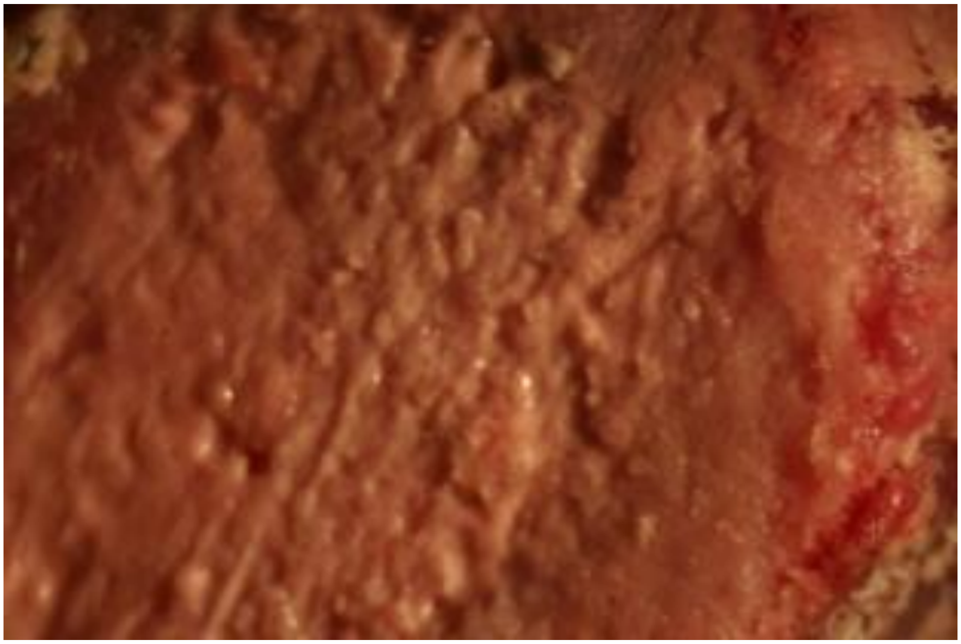

Figure 19. SS-6 after cutting, during initial examination. February 8, 2013.

Post Exposure Examination Specimen #6

On February 22, 2013 (14 days post treatment) SS-6 was removed from the deposition environment, wherein it would be cleaned according to the procedures listed previously. Upon the opening of the environment which it was contained, SS-6 appeared as moist as it did when it was originally placed. SS-6 also presented with the pungent odor of active decomposition. The calcium oxide that SS-6 was exposed to had areas exposed to moisture during the deposition timeframe, indicating that the bag may have had a hole in it (Figure 20). After SS-6 was cleaned it was examined again both visually and microscopically to determine if characteristics could be distinguished.

During these examinations the characteristics that pertain to the kerf wall indicate that there is a minor breakaway spur that can be distinguished. This breakaway spur however cannot provide details related to the floor configuration of the kerf. There does not appear to be any entrance or exit chipping on the outer portions of the cut mark, it does however contain a foramen that is within the cut mark (Figure 21). The cut mark does not contain any false starts either within the kerf wall or on the outer aspect of the bone. The initial corners of the kerf wall are primarily 90°, however there are portions on the lateral side of the cut mark that are just under the 90° mark and do not feel as sharp as the rest of the initial corners. When looking at the characteristics that are specific to the striations, the striae appear to be highly uniform in nature (Figure 22). These striae are visible and run parallel to the location of the kerf floor. Given that there are no false starts present there does not appear to be harmonics that typically accompany these marks.

Upon the post exposure examination of SS-6 there appear to be few deviations from what was noted during the pre-exposure assessment of the saw mark. While the striations would indicate that the saw was powered no other classification can be made regarding the saw responsible. However the differentiation of the initial corners of the kerf could be indicative of change induced by the calcium oxide, especially as the angle was noted as being 90° at the time of exposure.

Figure 20. SS-6 during the opening of the deposition environment. February 22, 2013.

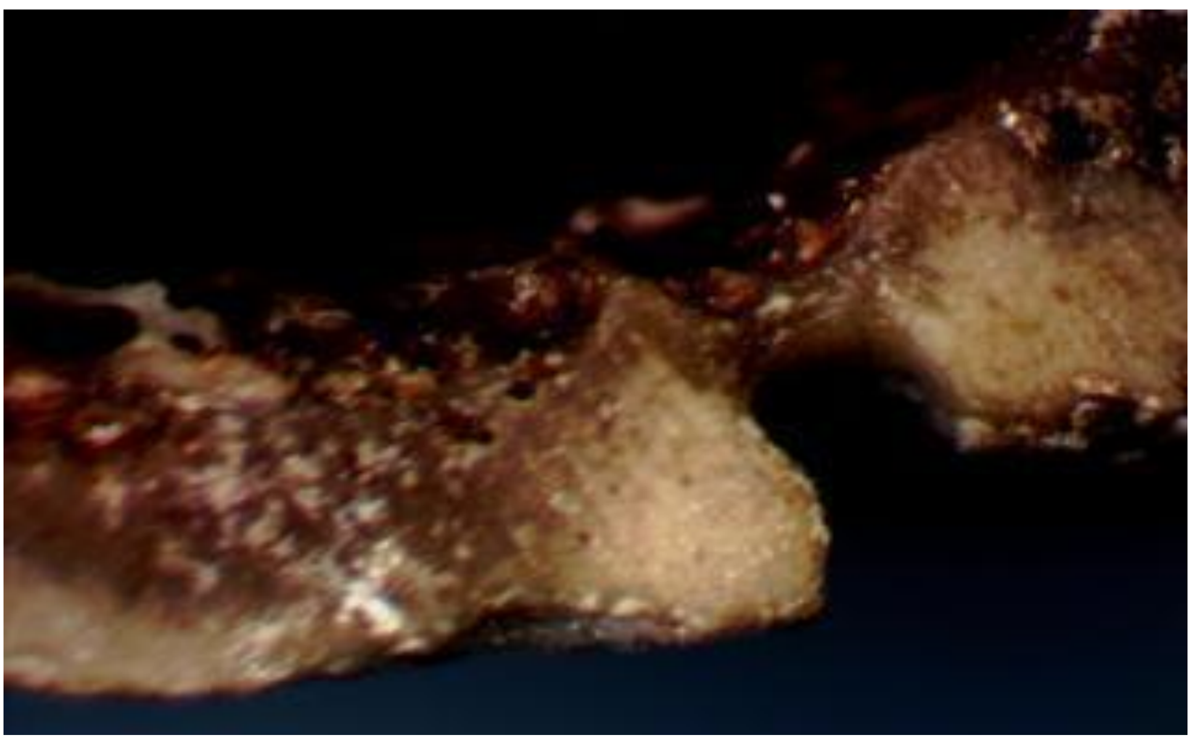

Figure 21. Microscopic view of the foramen located within the saw mark of SS-6.

Figure 22. SS-6 post exposure. Striations of left side of the specimen.

Initial Examination of Specimen #7

The initial cutting and examination of SS-7 was completed on February 8, 2013. During this examination it was noted that the specimen had soft tissue still attached, which was primarily muscular and fatty tissue with some cartilage present. The soft tissue was emanating an odor that is associated with the processes of decomposition. The cut marks present on SS-7 were examined and both a breakaway spur and notch could be seen; however it was not possible to determine the configuration of the kerf floor. The initial corners of the kerf wall were at 90° and the corners were sharp to the touch. The specimen did show characteristics consistent with at least one false start (Figure 23) while there were not indicators of entrance or exit chipping of the walls. The striations that were present were relatively uniform and ran parallel to the kerf floor, but these striations could not be seen down to the kerf floor.

Saw type classification prior to treatment: while there was no observable kerf floor within the saw mark, the type of saw used becomes indeterminate during the pre-exposure examination. However, the appearance of the striae would indicate that the saw used was mechanical in nature due to the uniformity.

Post Exposure Examination Specimen #7

On March 1, 2013 SS-7 (21 days post treatment) was removed from its depositional context were it was briefly examined prior to cleaning and further examination. During this initial cursory examination, SS-7 was still releasing odors that are consistent with decomposition. Additionally the soft tissue that had been present on SS-7 still appeared moist. The calcium oxide also appeared to have come into contact with a small amount of moisture and appeared coarse and pebble-like (Figure 24). After the specimen had been cleaned the characteristics of the kerf walls were examined. SS-7 contains a relatively prominent breakaway spur which allows for the distinction of a flat kerf floor configuration to be made. Directly adjacent to the breakaway spur is the accompanying notch that can be seen. There are no signs of entrance or exit chipping; however, there is a large notch that is consistent with a false start in the cut mark (Figure 25). The initial corners of the kerf wall are all at 90° and are sharp to the touch. The striations on the kerf wall appear to be smooth and uniform (Figure 26), and are visible to the kerf floor. These striations appear to be parallel to the kerf floor as well, while there are no signs of harmonics present within this cut mark.

Upon the post exposure examination SS-7 displayed a deviation from the original examination in that the kerf floor was able to be fully examined. During this examination the kerf floor showed that it was flat in nature, and consistent with both the alternating tooth set and chisel tooth type. The determination of this saw being mechanically powered still remains; however, the classification for this saw would be changed from indeterminate to one belonging to the mechanized rip saw family.


Figure 23. Initial cutting, false start located on left side of bone.


Figure 24. Post exposure of SS-7. March 1, 2013.

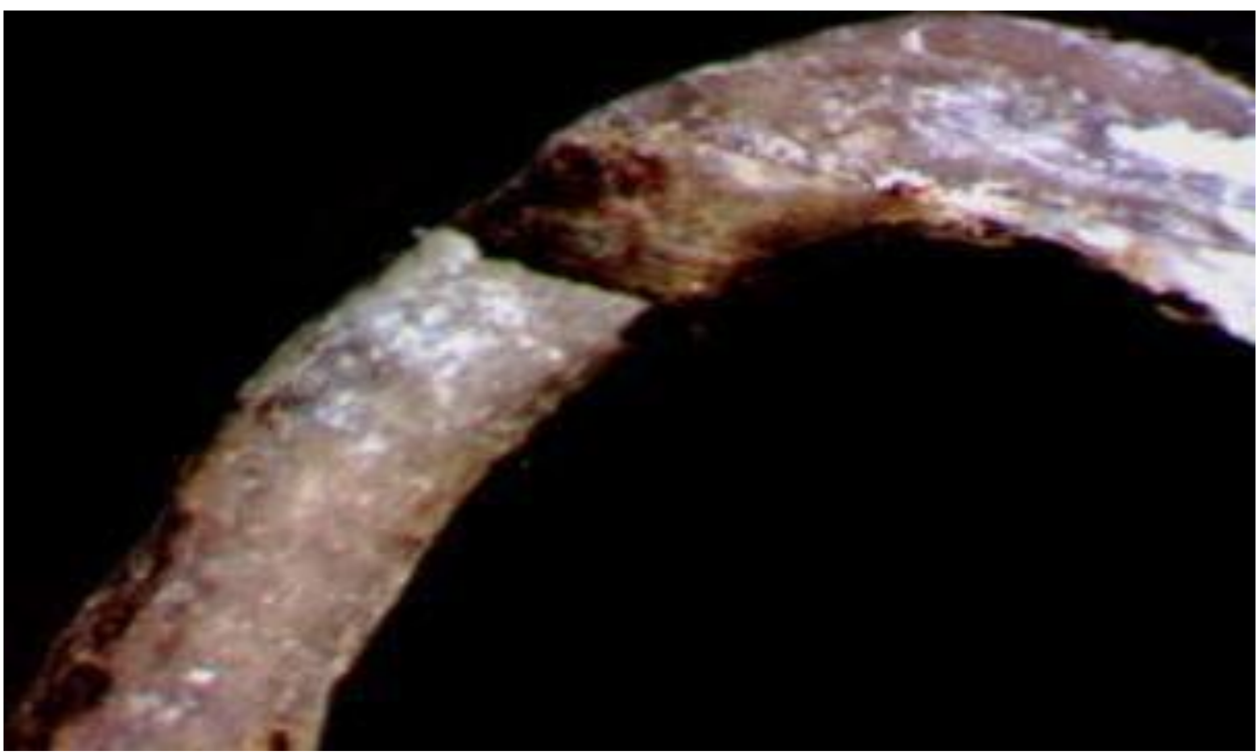
Figure 25. False start in SS-7.

Figure 26. Breakaway spur, false start, and striations on SS-7.

Initial Examination of Specimen #8

During February 8, 2013 SS-8 was subjected to the initial cutting of the bone and examination of the characteristics that could be seen as a result of that cutting. While completing this process it was noted that SS-8 had soft tissue still remaining on the bone, which primarily consisted of fatty tissue and was emanating odors that are consistent with those of decomposition. The characteristics relevant to the saw mark were examined. During this examination it was determined that there was no apparent kerf floor, nor was there a breakaway spur or notch. The initial corners of the kerf wall appear to be consistently at 90°. There does appear to be evidence of one false start located within the kerf of the cut mark. The striations appear to be uniform and smooth; although there is too much tissue and marrow covering the kerf wall to distinguish if the striations are parallel to the kerf floor (Figure 28). Saw type classification prior to treatment: due to the abundance of soft tissue and marrow obscuring both characteristics relevant to the kerf and striations it become impossible to make a classification of the saw type with any certainty.

Post Exposure Examination of Specimen #8

The afternoon of March 8, 2013 (twenty-eight days post treatment) SS-8 was removed from the depositional context that it had been exposed to. Initially when this context was opened there was a strong odor that is consistent with those of active decomposition. The calcium oxide that SS-8 had been subjected to appeared chalk-like and had the appearance of pebbles (Figure 27). Additionally the tissue that had been present on the specimen showed no obvious change in its appearance and looked as it did when it was placed. After these conditions were noted the specimen was cleaned using the aforementioned method. During the examination of the primary kerf characteristics it was found that there was a flat kerf floor configuration, as well as both a breakaway spur and notch. There was no evidence of entrance or exit chipping, nor are there indicators of false starts. The striations that are present are smooth and uniform, although there is some evidence of harmonics on the lateral aspect of the cut mark. The striations are also visible to the kerf floor and appear to be parallel to the floor (Figure 29). During this examination it became apparent that there was still calcium oxide present of the cut mark that had been resistant to the cleaning (Figure 30). Upon the cleaning of SS-8 the characteristics previously obscured have become available for examination. Due to the flat shape of the kerf floor being flat with at least one floor corner being square in shape it becomes possible to classify this saw as one with alternating tooth set and chisel style teeth most commonly found within the rip saw classification. Additionally, due to the visibility, organization, and harmonics present within the striations it becomes possible to state that this saw was mechanically powered.

Table 2 provides an overview of the pre and post exposure saw cutmark charateristics. This indicates that while there were characteristics belonging to both the kerf and striae obscured during the pre-exposure examination a classification of saw classification could still be made for all but two of the specimens. Additionally, it shows the post-exposure examination results, which resulted in an identification and clarity of many of these characteristics and therefore, a better ability to classify the saw used.

Figure 27. Conditions of the calcium oxide during retrieval of SS-8. March 8, 2013.


Figure 28. Tissue covering the striations of the kerf.

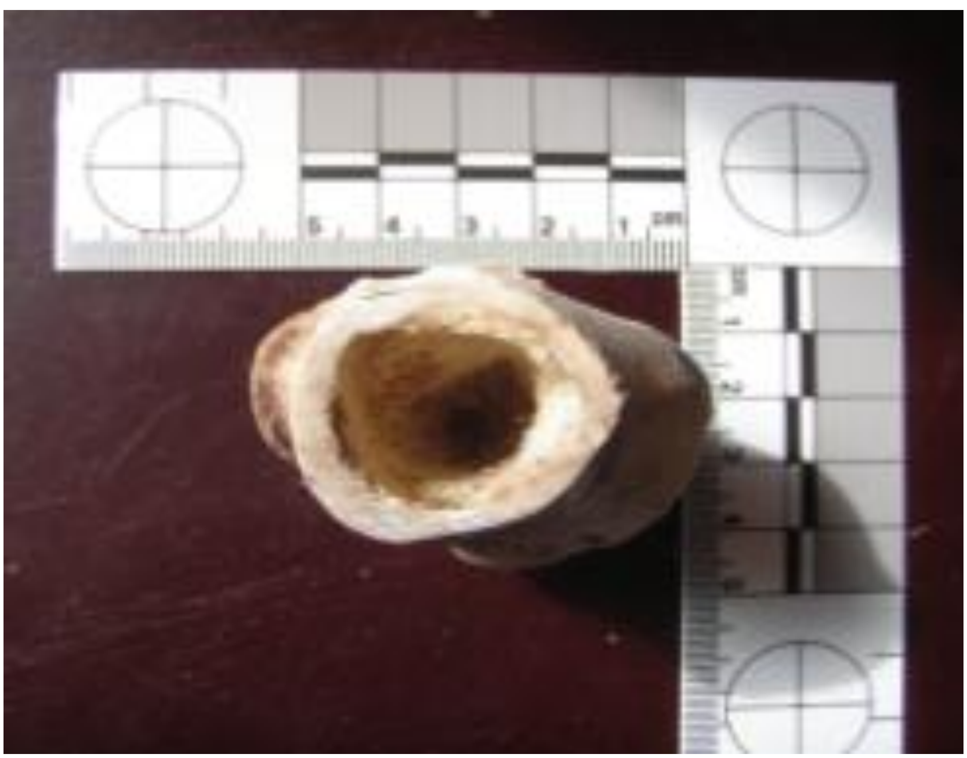
Figure 29. Striations and breakaway spur found on SS-8.


Figure 30. Residual calcium oxide found microscopically in the cut mark of SS-8.

Table 2. Presence of Key Characteristics: Pre- and Post-treatment of Specimens 1-8.

Saw Mark Feature	SS-1		SS-2		SS-3		SS-4		SS-5		SS-6		SS-7		SS-8	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Kerf Floor	Flat	Flat	Flat	Flat	N/O	Flat	Flat	Flat	N/O	N/O	N/O	N/O	N/O	Flat	N/O	Flat
Exit/Entrance Chipping	Yes	Yes	No	Yes	No	Yes	No	No	No	Yes	N/O	No	No	No	No	No
Breakaway Spur	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/O	No	N/O	Yes	Yes	Yes	N/O	Yes
Breakaway Notch	No	No	Yes	Yes	Yes	No	No	No	N/O	Yes	N/O	No	Yes	Yes	N/O	Yes
Initial Corner of Kerf Wall (degrees)	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	N/O	<90°	90°	90°	90°	90°
False Starts	No	2	No	No	No	N/O	No	No	No	2	N/O	No	1	1	1	No
Striae-Parallel	Yes	Yes	Yes	Yes	N/O	N/O	Yes	Yes	N/O	Yes	N/O	Yes	Yes	Yes	N/O	Yes
Striae-Visible	Yes	Yes	No	Yes	N/O	N/O	Yes	Yes	N/O	Yes	N/O	Yes	No	Yes	N/O	Yes
Striae-Smooth & Uniform	Yes	Yes	Yes	Yes	Yes*	N/O	Yes	Yes	Yes	Yes	N/O	Yes	Yes	Yes	Yes	Yes
Harmonics	N/O	No	No	Yes	N/O	N/O	No	Yes	N/O	N/O	N/O	No	No	No	N/O	Yes
Striae Curvature	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O

*N/O= Not Observable; see texts for reasons why this was unobservable.

Discussion

The purpose behind this research was to examine the degradation that would occur to the class characteristics of a saw mark due to the application of calcium oxide. While it has been used on to burials dating from the Iron Age (Van Strydonck et al., 2011) to the present and has been linked to a societal myth, or "old wives' tale," regarding it destructive qualities, there has been little research done regarding the effects this chemical compound has on human remains after application. This research, while preliminary, looks to bridge some of these gaps in knowledge base.

There was only a single hypothesis proposed for this research. The hypothesis states that the application of calcium oxide will degrade the class characteristics present within a saw mark to the degree where they cannot be used to make a determination of a saw class. The results provided by this research make it clear that given the parameters of this study, the application of calcium oxide will not alter characteristics used to determine saw class, therefore the hypothesis can be rejected.

In the post exposure examinations of SS1-4, which were exposed to the ground depositional environment for durations lasting from one to four weeks, there were no changes found that provide any indication that the calcium oxide was responsible for any change. The primary characteristics found within saw marks were examined and, therefore, it was possible to make the determination that a mechanically powered saw was responsible for the saw marks. These determinations were made through examination of the shape of the kerf floor present on the breakaway spurs of all four specimens (SS1-4). In looking specifically at the shape of the kerf floor and the associated walls it becomes possible to make a determination of the shape and set of the blade that was used to make the cut to the bone. Overall in specimens 1 through 4 these characteristics presented with both flat walls and a flat floor, which would indicate that the saw used would have a ripsaw style blade with an alternating tooth set. The determination of tooth shape was made due to the fact that the kerf floor when viewed from the side was flat; additionally, the corners of the kerf floor were square which would indicate a chisel style tooth found within the ripsaw categorization. The set determination was made due to the fact that the primary style of tooth set found in ripsaw style blades today are those that are alternating (Symes, 1992; Savile, 2007). In conjunction to the kerf floor, the striae would indicate that a powered saw was used due to the fluidity and uniform appearance as well as the directionality of the striae. It becomes important to note that while specimen 3 did in fact present with a kerf floor in relation to the minor breakaway spur it contained and it was possible to determine the shape of the teeth, the specimen failed to exhibit indicators of striae or other characteristics implicit with saw classification due to the preponderance of trabecular bone; therefore, making a classification of saw type impossible.

During the post exposure examinations of SS 5-8 which were exposed to the transportation environment, these speciemens were found to have no additional changes present on the specimens that would be consistent with degradation due to calcium oxide. The determination of the tooth shape was able to be distinguished in SS7 and SS8 only due to the presence of a breakaway spur. The inference of shape was made due to the fact that the kerf floor was flat, which is indicative of the ripsaw style blade. From this inference it was possible to postulate that the set of the teeth was congruent with the alternating pattern, as this is the most common style associated with ripsaw. The striations however were visible within the kerf walls of specimens 5-8. These striations all appeared to be fluid and uniform throughout the cut, which allows for the determination that the saw that created these cuts was mechanically powered. Additionally these striations also allowed for the directionality of the cuts to be determined as it would pertain to cases of suspected dismemberment.

The determination of saw characteristics needed to determine the classification of a saw generally requires the ability to answer a series of four questions derived by Symes (1992): Is it mechanic or hand powered? What is the directionality or orientation of the cut? What is the morphology of the set configuration/TPI? And finally what is the shape of the teeth? While it was determined that all of the specimens were able to answer at least three of the four questions, the examination of the initial corners of the kerf walls was undertaken as a measure of degeneration that had taken place during the period of exposure. The results of this analysis further support the negation of the initial hypothesis presented with this research. With the exception of SS-6, all specimens retained an initial corner of the kerf wall that was 90° and sharp; there were no observable differences either through visual or microscopic examination, these cuts appeared as they did when they were initially created. In regards to SS-6, this specimen showed 90 ° initial corners that were sharp, although the lateral aspects of this bone had areas where the corners appeared and felt dulled. While this could be indicative of degeneration due to the application of calcium oxide, it is impossible to attribute the change due to the fact that the initial examination was limited due to an excess of tissue remaining on the specimen.

While there was no change observable to the bony portion of the specimens, it was noted that the tissue that was present initially did appear to change, especially in the ground depositional environment. The calcium oxide on these specimens, SS 1-4, at the end of the exposure periods appeared to be hard to the touch or crusted, which could be due to the calcium oxide absorbing carbon dioxide from the open air and carbonating as described by Schotsmans et al. (2012). During this process the calcium oxide reacts with the carbon dioxide present in the atmosphere, bonding with an additional carbon dioxide, transitioning into calcium carbonate, becoming a stable compound ($CaO \rightarrow CaCO_3$). While it would be expected for there to be a 'cast' created with the tissue beneath starting to exhibit signs of decomposition, this was not the case. The calcium oxide appeared to have desiccated the tissue that was exposed to the open air, while the tissue in contact with the soil could still be considered moist. While it could be due to the time constraints that were placed on the exposure, this study shows the specimens to be exhibiting differing characteristics found when comparing cubes of tissue to whole carcass desiccation in relation to the retention of moisture (Laudermilk, 1932; Buckley, 2005; Schotsmans et al., 2012).

The second depositional environment proved to be consistent with previous research regarding burial contexts (D'Errico et al., 2011; Schotsmans et al., 2012). These specimens during their exposure intervals remained moist, while the calcium oxide could be classified as maintaining a "soft and creamy texture" (Schotsmans et al., 2012, p. 56). While it has been found that large quantities of calcium oxide will diminish the odors related to decomposition (Laudermilk, 1932; Rosensaft, 1979; Congram, 2008; Gilead et al., 2009; D'Errico et al., 2011; Schotsmans et al., 2012), the specimens in this environment displayed strong decomposition-related odors despite the excess quantity of lime that was used which may be due to the fact that the environment was sealed, leaving no areas for dispersal of the volatile odors as would be found within a soil enclosed environment.

While this research did not support the hypothesis that was presented, there could be a number of variables that were responsible for affecting this outcome. The first and most important of these is the temperatures in which this research was conducted under. While there is no previous research regarding the effects on temperature in relation to calcium oxide there are case reports (Solla, 2007) that would indicate that this could be a factor in the degree of degeneration possible of the bony tissues. It becomes a source of inquiry as the majority of the controlled research that has been conducted regarding this chemical appears to have taken place in cooler climates, such as the United Kingdom. In relation to temperature the interaction and effect of water could be an important variable concerning the effectiveness of the degenerative qualities calcium oxide. The destructive nature that water presents in relation to human remains has been and is currently being researched in depth; however, the effects of water in conjunction with calcium oxide has only briefly been examined and has been shown to have some degenerative qualities (Laudermilk, 1932). Additionally, the variable of time may be an important factor in regards to the possibility of calcium oxide altering the specimens. While within this study the maximum exposure time was four weeks, there is evidence of remnants of calcium oxide present within burials that date to the Iron Age (Van Strydonck et al., 2011). The lasting nature of this chemical could play a role in the time needed to make alterations to a hard tissue, such as bone; and furthermore, find its applicability more related to a bioarchaeological/archaeological context rather than that of a forensic context.

Conclusion

The results from this research are part of the systematic examination of the degenerative qualities of calcium oxide as it applies to the class characteristics of saw marks in bone. While preliminary, this research provides data demonstrating that there are no observable changes to bony tissues due to the application of calcium oxide. Furthermore, this study indicates that calcium oxide does not possess the qualities attributed to it via societal myths in regards to the complete destruction of human remains, which could be considered an advantage to investigators in cases where there is sharp force trauma, specifically saw marks, associated with disposal attempts.

While the results of this study failed to support the proposed hypothesis presented within, this research is able to provide data that may be applicable to the directionality of future research with regards to chemical interactions and bony tissue. With the protocols used for this research replication would be encouraged while addressing and focusing on the examination of one of the extraneous variables (time, temperature, water). Additionally, studies utilizing different depositional environments, such as cremation or burial, may provide data that further supports these findings as well as the findings related to those utilizing whole body specimens.

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