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Environmental factors affecting an experimental low-density mass grave
near Edmonton, Alberta, Canada

by

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ABSTRACT

The investigation of mass graves involves aspects of high political, judicial, and emotional impact. Understanding how bodies held within mass graves change between the time they are deposited and the time they are discovered (the realm of forensic taphonomy) is vital for competent collection of evidence and accurate evaluation of the scene. This thesis explores these issues by detailing experimental research undertaken to better understand the affects of environmental factors on low-density, orderly placement mass graves. Issues pertaining to how decomposition of bodies in contact differs from that of single bodies, intentional disturbance, and temperature change were examined experimentally using pigs as human analogues over a period of almost one year outside of Edmonton, Canada. There are three primary avenues in which the information obtained can be applied to the real world: estimation of elapsed time since death, planning mass grave investigations and reducing evidence loss, and evaluating post-burial disturbance or intentional vandalism.

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CHAPTER 1 – INTRODUCTION AND BACKGROUND

1.1 - Introduction

The investigation of real world mass graves involves aspects of high political, judicial, and emotional impact. The forensic examination and exhumation of such graves therefore must be done in a highly controlled and competent fashion. In order for evidence to be proficiently collected, an in-depth understanding of the conditions of the bodies held within the grave, and how these conditions have changed over time, is paramount. When such an understanding is furthered through experimental research such as is presented in this thesis, the loss of evidence and other important physical information can be reduced, and conclusions regarding elapsed time since burial can be held more strongly. The investigation of mass graves normally involves biological/forensic anthropologists whose job it is to link cultural behaviour, human biology, and forensic archaeology in order to bring a holistic perspective to mass grave exhumation and analysis (1). Such undertakings have taken place since World War II and have intensified since the mid nineteen-eighties (2-4). Investigations have been conducted in such places as Argentina, Guatemala, Somalia, Afghanistan, Iraq, Rwanda, and the former Yugoslavia.

This thesis details experimental research undertaken to further the understanding of the taphonomy of low-density, orderly placement mass graves and the bodies held within them. Issues pertaining to how decomposition of bodies in contact differs from that of single bodies, intentional disturbance, and temperature change were examined experimentally using pigs (*Sus scrofa*) as human analogues, an accepted and proven method of forensic anthropological research (5).

1.2 - Background Information

Taphonomy is defined as the study of postmortem processes which affect three things: 1) the preservation, observation, or recovery of dead organisms; 2) the reconstruction of a dead organism's biology or ecology; or 3) the reconstruction of the circumstances of an organism's death (6). As such, the appraisal of taphonomic factors (i.e. factors affecting remains between the time of death to the time of discovery) and changes can be applied to forensic investigations involving human remains, the realm of forensic anthropology. While taphonomy was originally studied by palaeontologists in order to gain an understanding of fossil formation processes over millions of years (6,7), it is now being regularly utilized in forensic investigations to decipher further the processes immediately surrounding death, the perimortem period, and those spanning a postmortem period of days, weeks, months, and - less often - years. Time and environmental factors, such as climate, temperature, and exposure period, as well as human or faunal factors, such as intentional grave vandalism or carnivore scavenging, produce patterns of morphological change in an organism's remains that can be observed and interpreted. The forensic interpretation of these changes has five main goals: 1) to estimate the time since death and/or burial; 2) to distinguish human from nonhuman agents of modification; 3) to understand selective transport of remains; 4) to identify variables resulting in differential preservation of remains; and 5) to reconstruct unknown perimortem and postmortem events, circumstances, and environments (8,9). Information derived from forensic taphonomy studies can often be applied to human remains in both forensic and archaeological contexts. Overall, the assessment of taphonomic influences on a set of remains can help in the formulation of a timeline of what has happened to these remains since the time of death of the organism at hand, why the remains are in a certain condition, and how this condition came about. The forensic applications of taphonomy are clear.

Mass graves are disturbing commonplace extra-legal measures utilized to cover-up both human rights abuses and war crimes. Burial of multiple persons in one grave may also occur in instances of man-made or environmental mass disaster (10), while human remains found in archaeological contexts are also typically buried. There is currently no consensus as to what exactly defines a mass grave (11). Such defining characteristics as minimum number of individuals (12,13) and victims sharing some common trait connected with the cause and manner of death (1) have been presented. Haglund and colleagues (3) suggest the term "mass grave" be left as a relative term and specific graves be described according to the number of bodies they contain and other physical characteristics. The experimental mass grave (hereafter referred to as EMG) detailed in this thesis will be described and defined below; however, it can be stated that a mass grave must contain multiple individuals deposited in contact with each other. Burials containing bodies in contact with one another present complex taphonomic environments affected by a multitude of factors beyond those influencing single burials (4,12,14). As such, this experimental research is designed to establish the extent of these effects in order to justify and exact anthropological and taphonomic conclusions concerning masses of bodies.

Such research as that presented below will add to the limited current knowledge surrounding how taphonomic factors affect a mass of bodies, and will increase the precision of anthropological and circumstantial evidence drawn from mass grave investigations. The current literature on this topic is limited, and the high humanitarian, moral, and emotional charge of this subject warrants solid groundwork.

1.3 – Statement of Purpose and an Explanation of the Research

This section will detail the experimental research undertaken, aims and purpose of the research, taphonomic factors for consideration, the grave layout and scenario, and key research questions. The basis for the experiment was to create an experimental low-density, orderly placement mass grave and let it stand for a period of approximately 10 months (296 days, from November 20, 2008 to September 12, 2009). Periodic checks, as well as two invasive partial exposures, were performed to assess the condition of the grave, and the bodies within, as the experiment progressed.

1.3.1 - Experimental Design

For this research pig carcasses were used as human analogues. Such a practice is an accepted standard in anthropological taphonomic studies due to similar decomposition rates and stages as well as similar internal micro-flora and hairless skin (5). A low-density mass grave, with seven pig carcasses, was created in order to observe and interpret taphonomic factors affecting the remains within. A single, outlier body was buried under the same conditions to act as a control. The experiment ran for approximately one full cycle of seasons beginning in late fall, included two partial exhumations as well as observations and photographs of the grave site at set intervals, and ended with the complete exhumation of the entire grave. The description and layout of the grave is detailed below. Temperature data of the bodies within the grave was collected using temperature probes, and climate data was obtained from a weather station near to the site of burial.

1.3.2 – The Purpose and Value of the Research

There are many rationales for the exhumation and investigation of mass graves (4), which also justify experimental research such as that presented here. It has long been appreciated that the gathering of physical evidence from mass graves can contribute to prosecution in international or domestic courts, and will create an accurate historical record (13,15). Such evidence collection and careful examination of remains will also help in establishing the identities of those interred and in returning the remains to surviving family members. Additionally, such investigations expose atrocities to world opinion and will help establish an international standard to prevent crimes of this nature from occurring in the future (4). Mass graves may occur in contexts of natural or man-made disaster (10) where the previous list of rationales may apply. As the number of individuals in mass graves varies greatly from one event to another (17), the observations and results of this experiment have validity and application. Large numbers of people have been buried in multiple and separate low-density graves, and as such, taphonomic processes affecting such graves must be understood in order for evidence to be competently collected. Haglund and Beattie (17) observed this in Somalia.

A study performed by Steadman and Haglund (18) reveals a clear increase in the number and extent of international investigations of human rights abuse involving mass graves throughout the nineties. The authors predict a further increase of such investigations in the future, as public expectations and support grow. Additionally, it was found that forensic anthropologists are increasingly assuming a leadership role in multidisciplinary human rights investigations. Clearly, a thorough and meticulous knowledge of how mass graves and the bodies held within them change from the time of burial until the time of discovery and exhumation is essential to effective evidence collection, forensic investigation, and accountability now and in the future.

The purposes and aims of this research specifically are as follows. By utilizing temperature data and physical observations, an understanding of decomposition processes and rates of a multiple burial in a warm summer continental climate will be gained. Regarding this unique grave type, it will be determined if the results can be used to establish an elapsed time since death and/or burial, and if the observations can be used to prove that the bodies went through a winter freeze and spring thaw. Such issues as establishing time since death and seasonality are of great importance in the real world when corroborating witness testimony, when establishing if a given grave is actually the correct one named in an indictment, and when connecting actual events to actual graves. If the collected data is not sound enough to make such determinations, then it may serve as a warning to others in the future.

This research will serve as a model of what to expect under similar environmental conditions, and will highlight differences between burials involving multiple individuals and those involving single victims. This information can lend itself to more competent exhumation management and planning of mass grave investigations, and can help reduce the loss of evidence. Additionally, a greater understanding of how bodies buried in contact with each other decompose, and why, will be achieved.

Half of the EMG was disturbed twice to gain access for visual observation. This created a situation similar to intentional grave disturbance and vandalism – a realistic scenario. Therefore, the final data collected reflects these impacts, and through comparisons between undisturbed and disturbed portions of the grave a greater understanding of the ultimate effects of such actions will be gained. Deliberate attempts to destroy evidence in the real world has been experienced by investigators (15, 16) and is considered a serious problem impeding the pursuit of justice.

1.3.3 - Taphonomic Factors and the Grave Scenario

Haglund (4) lists many major taphonomic factors that affect the condition of bodies within mass graves. Few of these have been thoroughly researched or documented in an experimental setting. This list serves as a basis for detailing and defining the low-density EMG and the taphonomic factors affecting it. Additions and subtractions have been made here, and the list also serves to detail the burial scenario.

Environmental and Geographical Factors

Grave Location - The EMG was located at the Ellerslie Research Station in the southwest periphery of the city of Edmonton, Alberta, Canada, at coordinates of 53°25'07.42" N 113°33'09.40" W, and an elevation of 686 meters above sea level. Geographically the area is a gently rolling morainal plain. The land is currently leased from the city by the University of Alberta, and is used primarily for agricultural research. The grave was located in an area just south of a group of trees (see Figure 1-1) creating a sun and shade interface, with primarily sun.

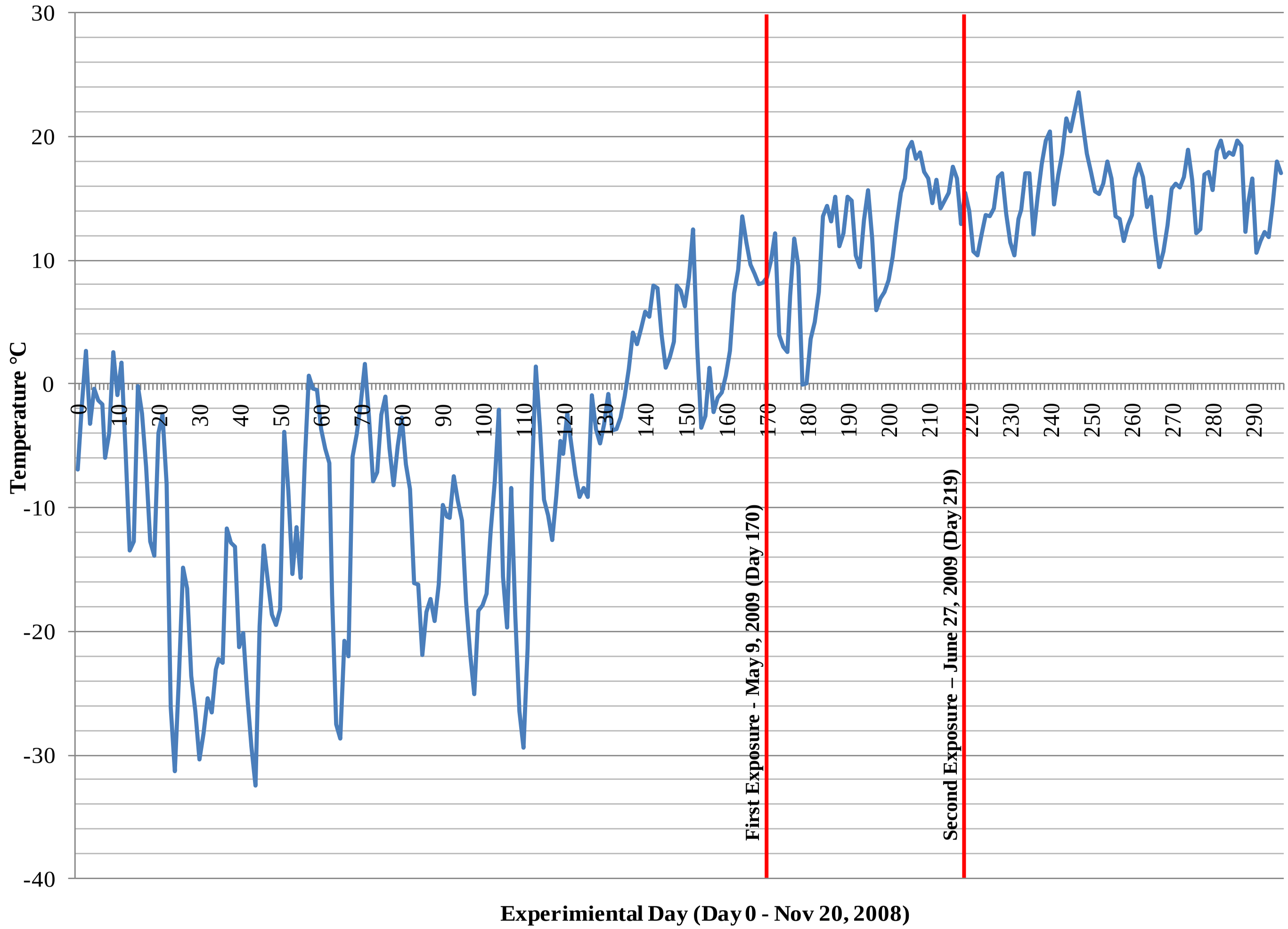
Figure 1-1 – Satellite image of the location of the EMG (yellow tack and white line). Used according to fair use criteria and expectations as defined by Google, 2009 (19).

Climate - Edmonton experiences a warm summer continental climate (20) with extreme seasonal temperatures. The average annual temperature range is approximately -11.7 °C to 17.5 °C, while average monthly temperatures are below freezing for five months of the year (21) (See Figure 1-2).

Precipitation - On average, Edmonton receives 476.9 mm of precipitation per annum, of which 365.7 mm is rain and 123.5 mm is snow (21).

Soil temperature – Utilizing a temperature probe placed on the bottom of the grave at a depth of 60 cm, and separate from the decomposing bodies, it was determined that the average soil temperature for the duration of the experiment was 6.1 °C. See Chapter 4.

Figure 1-2 - Average daily air temperature (°C) at burial site during the duration of the experiment. Data collected by Ellerslie Research Station Weather Station.



Grave Characteristics

Depth - Grave depth is known to affect the rate of decomposition; the deeper the grave, the less decomposition can be expected (22). The excavated depth of the EMG was approximately 60 cm and was effectively level. It was dug primarily with a front-end loader tractor, while hand shovels were used for the final levelling of the floor. The pig carcasses themselves rested approximately 30 cm below the surface. See Figure 1-3.

Compaction - Soil was shovelled and dumped back onto the grave with a front-end loader tractor. The surface was made flat with hand shovels. The grave was located in a remote agricultural field, and as such there was no vehicle traffic over the grave and only minimal human or animal impacts.

Inclusions - No inclusions were present other than a sparse amount of vegetation (grass, weeds, etc.) that covered the original grave fill.

Intervening Fill - The soil that was dug out of the grave was redeposited in a random and mixed manner, emulating observed real life situations (4).

Dimensions - The grave was a rectangle measuring approximately 12.0 m x 2.6 m, with 5.0 m of the floor consisting of a ramp rising to the surface at the east end. The actual 60 cm deep burial area was 7.0 m x 2.6 m. See Figure 1-3.

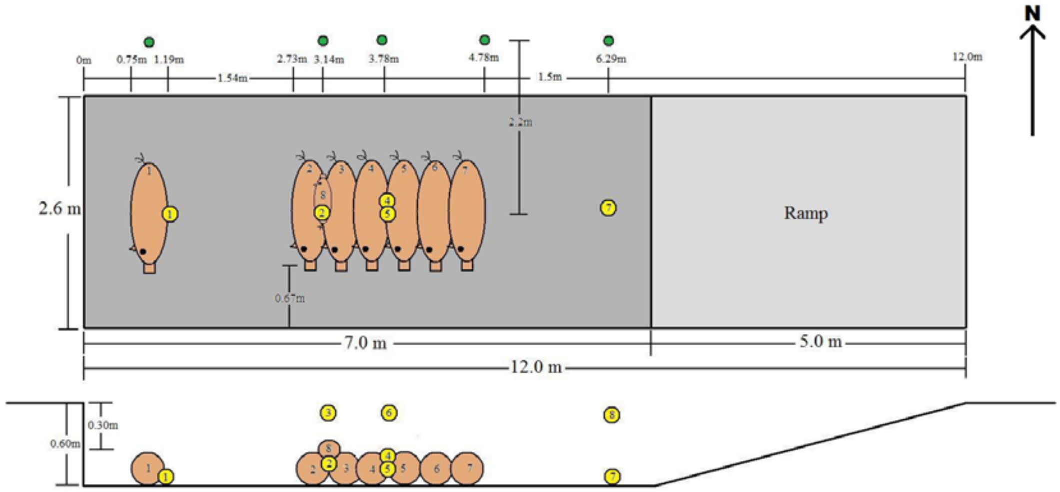


Figure 1-3 – Grave layout. This image details the dimensions of the grave, locations of pigs, and locations of temperature probes (yellow circles). Markers are also present. Pigs are identified by number, see Table 1-1 below. See Appendix B for larger figure.

<u>Temporal Factors</u>

Postmortem interval prior to burial - Eight pigs were obtained from Northern Alberta Processing Co. on November 19, 2008 at ~4:00pm. It is known that all pigs died of natural causes and had been dead for between 24 and 48 hours. No pigs were killed specifically for this experiment.

Duration of the burial - All pigs were buried on November 20, 2008 (day 0). Half of the body mass (three pigs, numbered 5, 6, and 7) were exposed on May 9, 2009 (day 170), and June 27, 2009 (day 219). The entire burial (the seven pigs in the mass and the one single pig) was exposed on September 12 (day 296) and 13 (day 297), 2009.

Season - The pigs were buried three-quarters of the way through autumn 2008 before the first snow, remained in the ground through the rest of autumn, winter, and spring, and were exhumed at the end of summer 2009. They were buried for almost a full cycle of seasons.

Body Characteristics

State of decomposition (see Table 1-1) - Of the eight pigs, five were fresh, two were in a stage of early bloat, and one was bloated. See Appendix C for details of the decomposition templates used.

Cause of death - In reality, the pigs died of natural causes on farms. In the experimental scenario each deceased pig was struck in the head with a sledgehammer to simulate death by blunt force trauma to the head. This was done as to provide an avenue to investigate the ability of recognizing such perimortem trauma in an actual mass grave exhumation, and the challenges associated with this goal.

Body habitus (see Table 1-1) - The pigs ranged from 104-188 lbs, excluding the piglet which weighed 6.5 lbs. This was an acceptable range to represent human torsos, which on average comprise two-thirds of body weight. The average size of an adult human torso is therefore ~120 lbs. Overall body mass of the east and west halves of the grave were made near equal. The west half (undisturbed) contained 401.5 lbs, and the east half (disturbed) contained 417 lbs. A total of 818.5 lbs of pig was present in the body mass, along with the 180 lb outlier.

Clothing or other wrapping - None. The pigs were deposited naked (a scenario seen in real situations (17)).

Table 1-1 - Pig data at time of burial (November 20, 2008 – Day 0)

Pig Number	Weight (lbs)	Length - Nose to Rump (cm)	Girth (cm)	State of Decomposition	Time Since Death (hrs)
1	180	133	96	W – I G – A1	24-48
2	120	119	96	W – early II G – B4	24-48
3	163	128	100	W – I G – A1 Abdominal rupture with purple protrusion	24-48
4	112	117	84	W – I G – A1	24-48
5	125	118	92	W – early II G – B4	24-48
6	188	145	124	W – II G – B4	24-48
7	104	100	82	W – I G – A1	24-48
8	6.5	59	47	W – I G – A1	24-48

W – Wilson et al. (23) G – Galloway et al. (24)

Soil Characteristics (25)

pH - The soil in which the pigs were deposited exhibits primarily a slightly acidic to neutral reaction.

Drainage - The area in which the grave was located is considered to be well to moderately well drained.

Compaction - Soil was shovelled and dumped back onto the grave with a front-end loader tractor. The surface was made flat with hand shovels. The grave was located in a remote agricultural field, and as such there was no vehicle traffic over the grave and only minimal human or animal impacts.

Coarseness and type of soil - The Ellerslie Research Station is located on a gently rolling morainal plain with a blanket of fine-textured glaciolacustrine sediments up to 16 m thick over the underlying till. The type of soil in which the grave was located is known as Eluviated Black Chernozemic soil. This is a black, fertile, topsoil occurring in cool to temperate semiarid grassland regions (26). Of concern are three horizons: Ap (0 – 30 cm), Ae (30 – 37 cm), and Bt1 (37 to 87 cm) (see Figures 1-4 and 1-5):

- Ap - 0 – 30 cm – black silt loam; weak to moderate, medium subangular blocky breaking to moderate to strong, fine granular; friable; abundant, fine random roots; many, fine random pores; no clay films; no carbonates; no coarse fragments; abrupt, wavy boundary; 23 to 34 cm thick; slightly acidic to neutral reaction.
- Ae - 30 – 37 cm; brown silt loam; weak to moderate, fine platy; friable; plentiful, fine, vertical roots; many fine random pores; no clay films; no carbonates; no coarse fragments; clear, broken boundary; 1 to 10 cm thick; slightly acidic reaction.
- Bt1 - 37 – 87 cm; brown loam; moderate, medium to coarse prismatic; firm; plentiful, fine, vertical roots; common, very fine, vertical pores; many, moderately thick, dark greyish brown clay films in many voids and on many ped surfaces; estimated 10% gravelly coarse fragments; gradual, wavy boundary; 43 to 61 cm thick; slightly acidic reaction.

It must be kept in mind that, while the pigs lied on the Bt1 horizon, the grave fill overlying them was redeposited and mixed, and thus represents a conglomerate of the above three horizons.

Figure 1-4 – Empty grave, facing northwest. Note soil horizons, particularly clay deposits of Bt1.

Figure 1-5 – Soil profile of north wall. Note soil horizons, particularly clay deposits of Bt1.

Body Assemblage Characteristics

Thickness and extent - The body assemblage contained six pigs deposited in a row and in contact with one another (see Figure 1-6). They were all facing the same direction. This is known as an orderly placement arrangement of bodies (9). Their heads were on the south side of the grave, and they were lying on their right sides with snouts facing south and legs pointing east. A piglet (pig 8) was lying on top of and in between two adult pigs (pigs 2 and 3). Its limbs were pointing in the same direction as the adults; however, its head was on the north side of the grave, it was lying on its left side, and its snout faced north. Overall the bodies covered an area of approximately 2.6 m^2. The single, outlier, control pig (pig 1) was in the same position as the adults, and was located 1.54 m west of the body mass. See Figures 1-3 and 1-6.

Position relative to the core and perimeter - Haglund (4) and Mant (12,14) address this issue in regards to graves containing a jumbled mass of many individuals and in which an actual core and periphery of bodies is created. Bodies on the periphery decompose at faster rates than those in the core. This type of environment was not recreated in the EMG since the pigs were in a row; however, they were still in contact, and some pigs were surrounded by other pigs to a greater or lesser extent than others (see Figure 1-6). Observations of the pigs in the center of the row (pigs 4 and 5), as well as the piglet (pig 8), will be discussed later.

Figure 1-6 – Positions of pig carcasses within the grave. From bottom to top: Pig 1 (outlier), 2, 8 (piglet), 3, 4, 5, 6, and 7. Scale is 1.0 m.

Other Characteristics

Temperature during the pre-burial period - The average daily temperatures for the two days before burial, collected by a weather station at the Ellerslie Research Station, were 0.6 °C on November 18, 2008, and -9.1 °C on November 19, 2008. On these two days the pigs were either outdoors or being stored in an outdoor barn. On the day of burial, November 20, 2008, the average daily temperature was -7.0 °C.

Moisture - The area in which the grave was located is considered to be well to moderately well drained (24). On average, Edmonton receives 476.9 mm of precipitation per annum, of which 365.7 mm is rain and 123.5 mm is snow (19). Throughout the experiment it was noticed that the grave fill seemed to contain moisture provided by the bodies of the pigs in the area immediately surrounding the carcasses. No other areas of fluid collection were observed anywhere in the grave.

Disturbance/post-burial exposure of the remains to the atmosphere - Half of the experimental body mass (pigs 5, 6, and 7) was exposed twice for a period of approximately two hours, on May 9, 2009 (day 170), and June 27, 2009 (day 219), to make periodical observations. Such actions created two situations similar to intentional disturbance or vandalism.

Carnivore scavenging - The EMG is located in an area frequented by numerous carnivores, including coyotes, domestic dogs, and badgers. Based on this fact, and warnings issued by past researchers, it was decided that measures had to be taken to control this taphonomic variable and prevent destruction of the grave and experiment. To do this the area of the grave overlying the bodies was covered by a large mesh of stucco wire, which was staked and tied down. It is interesting to note that throughout the entire experiment the only animal evidence observed were footprints in the snow. No evidence of digging or attempted access to the bodies was seen.

Summary of the Burial Scenario

- Within the same grave were six adult individuals of various body sizes buried in contact, one baby buried in contact with two adults, and one adult individual buried separately.
- The bodies were naked.
- The victims were killed by blunt force trauma to the head. This was performed with a sledgehammer.
- The bodies were deposited in a machine (tractor with a front-end loader) dug pit on November 20, 2008.
- The bodies were buried in an orderly placement fashion.
- The grave was filled by a machine (tractor with a front-end loader).
- The grave was left for about 10 months (296 days), from November 20, 2008 to September 12, 2009.
- Half of the bodies within the body mass were disturbed/exposed twice on May 9, 2009 (day 170), and June 27, 2009 (day 219).
- The grave was located south of Edmonton, Alberta, Canada at 53°25’07.42” N 113°33’09.40” W.

1.4 - Thesis Outline and the Key Research Questions

This thesis research explores three aspects of taphonomy relating to mass graves, as outlined below along with key research questions.

First, the issue of how body assemblage characteristics affect decomposition rates will be investigated. Bodies in contact will decompose differently than single bodies, and this will depend on the arrangement of the bodies, as well as position relative to the core or perimeter of the body mass, with bodies on the perimeter decomposing faster than bodies in the core (4,12,14). Additionally, examining stages of decay and the timing of when corpses begin to become easily disarticulated and damaged in mass versus single graves will aid in planning future mass grave excavations and exhumation management. Questions of focus are:

- How does decomposition of a body mass differ from a single body?
- How does location within an orderly placement mass grave effect decomposition of a specific body?
- How do bodies in contact affect each other as they decompose? What are the factors at work here?
- What other factors are at play in such a scenario?
- Can observations made at the time of complete exhumation (in this experiment, in September, 2009) prove that burial occurred a specific number of months earlier (in this experiment, November, 2008)? Can seasonality or time since death and/or burial (elapsed time) be established?

- How is this knowledge applicable in real world mass grave scenarios?

Secondly, the issue of intentional grave vandalism and disturbance, a problem that has been encountered by investigators (15,16,27,28), will be explored next by evaluating how periodical disturbance to the EMG and certain bodies affected resultant data and observations when compared to undisturbed bodies and areas of the EMG. In this experiment, half of the body mass (pigs 5, 6, and 7) was exposed on two occasions, May 9, 2009 (day 170), and June 27, 2009 (day 219), to make visual observations. The differences observed at final exhumation between the disturbed bodies and the undisturbed bodies, and causes of these differences, will be explored.

- How is the decomposition process altered if a buried body is disturbed?
- How does the decomposition of a disturbed section of a body mass differ from the undisturbed part of the same mass? Why?
- Why is this important to consider in real-world mass grave investigations?

Lastly, the issue of temperature change of the body mass and single body is investigated last. Temperature probes placed within the grave in conjuncture with periodically collected climatic data are used to examine temperature profiles of the decomposing bodies. Temperature is a key factor determining rate of decomposition (29-31), and body temperature is known to rise, spike, and fall as the decomposition process proceeds. Such profiles of the body mass are compared with the single control body.

- What can the collected temperature data tell us regarding the insulating properties of soil and snow in the Edmonton region?
- What differences in temperature profiles are there between bodies decomposing in a mass and a single body?

A summary concludes the thesis. The results of the research are evaluated in relation to other taphonomic experiments and real life observations of single and multiple burials, taking into account geographic and climatic similarities and differences.

- Can the collected data/results/observations be applied to the real world during investigations of mass graves, and if so, how?
- What is the value of doing this research with a small, low-density, orderly placement mass grave?
- Are the data/results/observations useful in other geographical areas?
- Can the data/results/observations be applied to mass graves of a larger scale or different type?
- How do the data/results/observations compare to previous research done in the Edmonton area?
- What form should the direction of future research on this topic take?

Appendices are presented at the end of the thesis.

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CHAPTER 2 – BODY ASSEMBLAGE CHARACTERISTICS AND EFFECTS ON DECOMPOSITION OF BURIED REMAINS

2.1 - Introduction

This chapter presents experimental research and analyses performed with the goal of gaining a further understanding of how body assemblage characteristics affect decomposition of buried remains. “Body assemblage” refers to the volume and dimensions of a group of bodies within a grave, as well as the position of a certain body relative to the core and perimeter of such a grouping (1). Potential differences in decomposition characteristics between a body mass and a single body buried under identical conditions will be investigated, as well as any differences in decomposition between bodies in different locations within a body mass. Observations and comments regarding overall decomposition rates and characteristics of bodies in contact will be presented.

Considerable experimental research has been done on the topic of decomposition rates and stages of remains involving single bodies, whether buried (2-5) or exposed on the surface (6-9). However, little work has been done on body masses or on two or more bodies in contact with one another, and what has been published typically relates to anecdotal observations made on real mass graves (1,10,11). As with most taphonomic experiments, the one presented here is geographically/climatically dependant and specific.

As stated in Chapter 1, there is no formal agreement as to what defines a mass grave. The EMG involved in this thesis can be termed an “orderly placement" mass grave (12). It contained six adult pig bodies in contact with one another and arranged in an orderly row, all facing the same direction. Added to this grouping was a single infant pig body lying between two adults and pointed in the opposite direction. Published research by Haglund (1) and Mant (10,13) describes decomposition of mass graves that are in the configuration of an "erratically commingled" (12) body mass with a definite inner taphonomic zone (core; a zone where bodies are completely surrounded by other bodies), and peripheral taphonomic zone (outer margin in which there is a body/grave fill taphonomic interface). Both authors state that decomposition between the inner and peripheral taphonomic zones will differ, with bodies in the inner taphonomic zone being less decomposed than those in the peripheral. In the EMG all bodies would be considered in the peripheral taphonomic zone; however, bodies in the center of the row were still surrounded by more biomass than those on the ends of the row.

An understanding of how and why bodies within mass graves decompose is critical when collecting evidence from a mass grave scene (1,14,15). Competent observation and documentation of the state of decomposition at the time of exhumation should result in a more accurate reconstruction of original grave and body characteristics, a better understanding of how these have changed, and an opportunity to establish seasonality (what season the bodies were buried in) or time since death and/or burial. Such information can be compared with other evidence, such as witness testimony. Additionally, examining stages of decay and the timing of when corpses become easily disarticulated and damaged in mass-versus-single graves will aid in planning future mass grave excavations and exhumation management.

The following key questions relating to body assemblage and decomposition are addressed in this chapter:

- How does decomposition of a body mass differ from a single body?
- How does location within an orderly placement mass grave effect decomposition of a specific body?
- How do bodies in contact affect each other as they decompose? What are the factors at work here?
- What other factors are at play in such a scenario?
- Can observations made at the time of complete exhumation (in this experiment, in September, 2009) prove that burial occurred a specific number of months earlier (in this experiment, November, 2008)? Can seasonality or time since death and/or burial (elapsed time) be established?
- How is this knowledge applicable in real world mass grave scenarios?

2.2 - Materials and Methods

Complete descriptions of the grave and body characteristics have been provided in Chapter 1. An outline of the experimental procedure follows:

The eight pigs were deposited and buried on November 20, 2008 (Day 0) after a post-mortem period of approximately 24 to 48 hours. During this period they were stored at temperatures below -1.0 °C. The grave was left untouched over the winter, and visual observations were made of the surface and surroundings every 3 weeks.

The eastern half of the row of eight bodies (pigs 5, 6, and 7) was exposed twice for periodical observation. This occurred after the winter thaw on May 9, 2009 (Day 170), and again on June 27, 2009 (Day 219). The May date was selected to get a view of what condition the bodies would be in immediately after the winter thaw, and presumably after thawing themselves. This was also the earliest time that the soil was in a state allowing shovel excavation by hand. The June date was selected as an approximate midway point between the May exposure and the final exposure in September. A pit of restricted size (~1.5 m x 2.0 m) was excavated (see Appendix B for a layout image of the excavated area), soil overlying the bodies removed, and the bodies cleaned using trowels, brushes, and wooden sculpting tools. The bodies were examined and extensively documented and photographed. The original backfill was then shovelled back into the hole. Total exposure time was kept to a minimum, ~ 2 hours. A bug screen canopy was placed over the grave for the whole exercise to minimize the possibility of insects interacting with the bodies and grave fill. While insect interaction during instances of disturbance would be considered more realistic, this was done due to the original experimental plan not including an investigation of disturbance and the need to maintain the grave environment as if it was never disturbed. Overall the canopy was not effective and flies were observed in the canopy space and on the bodies, which proved to better for the experimental plan in the end. After the first exposure the visual above-ground grave check interval was decreased to between seven and ten days.

Final exposure of the entire grave was performed on September 12 (Day 296) and 13 (Day 297), 2009. The area excavated was approximately 2.5 m x 5.0 m and constituted the region overlying the bodies with an additional 30 cm to 50 cm border (see Appendix B for a layout image of the excavated area). Soil was skimmed off layer by layer with shovels until the bodies were located. Then, small trowels, buckets, brushes and wooden sculpting tools were employed. The bodies were ~3/4 exposed at the end of September 12. After some initial observations were recorded and the bodies were photographed they were securely covered with tarps and stucco wire overnight, and cleaning resumed and was completed on September 13, which is when most of the data collection occurred and most photos were taken. Temperature probes were gathered on both days as they were exposed. Also, when all other tasks were completed on September 13, pig 2 was flipped over to allow examination of the underside of the pig and the soil on which it laid. After observation, data collection, and photodocumentation were completed, the bodies were reburied in the same location, orientation (except for pig 2 which was left in the flipped position), and depth for future research purposes.

2.3 - Results

This section reports on the key observations made during the course of the experiment and at the times of exposure. Stages of decomposition described are based on Galloway and colleagues (16) and Wilson and colleagues (17) (see Appendix C for full explanations). The Galloway and colleagues (16) approach was intended to describe surface remains, while that of Wilson and colleagues (17) focused on buried remains. Both approaches are included, since both provide some measure of relevant detail and focus; however, Wilson and colleagues (17) is regarded as more appropriate to this experiment and is used more extensively since the focus is on buried remains, and a number of descriptors presented by Galloway and colleagues (16) do not apply.

2.3.1 - Periodical Visual Inspections of the Grave

The average grave site visiting interval was approximately once every three weeks during the winter and once every week during the spring and summer. Upkeep of the perimeter warning tape and stakes was performed regularly to ensure safety and to discourage people from entering the site. Photographs were taken on a regular basis. Overall observations and interesting circumstances are as follows:

- During the whole experimental time frame nothing appears to have compromised the grave. No evidence of attempted access to the grave by animals (such as digging) was observed, nor any other damage caused by outside agents. It can confidently be said that the grave remained secure and uncompromised throughout the experiment. This can be attributed to four factors. First, the depth of the grave (60 cm pit, with the upper surfaces of the pig bodies lying ~30 cm below the surface) is seen as sufficient in concealing odours and preventing insects and scavengers from being attracted to the area (2); second, for the first ~4 months of burial temperatures were sub-zero, with the ground and pigs being frozen and covered in snow, thus restricting access; third, the stucco wire that was staked to the ground over the grave area likely worked to deter any animals that did come to the area and prevented any digging, though it should be noted that no evidence of animal presence was seen even after the first two partial exposures were performed, resulting is some mixing of pig tissue products throughout the backfill (i.e. bringing decomposition odours to the surface and immediate subsurface of the grave); and lastly, due to the continued encroachment of housing developments surrounding the Ellerslie Research Station there are likely fewer wild scavengers (though this is possibly partly or significantly offset by the increase in domestic dog numbers).

- Throughout the winter a few animal, such as deer, and human tracks were seen over the grave. See Figure 2-1.
- A subtle but distinct slump was noted over the east half of the grave a few weeks after the first exposure took place, and again a few weeks after the second. It was not possible to measure exactly the amount of slump, but it was determined to be less than 10 cm, and uneven.

- Beginning in spring, weeds and some grasses repopulated the soil over the grave (see Figure 2-2). This was considered minimal compared to the surrounding field, and in September it was still obvious where the grave was located. It is interesting to note that after the second exposure nothing grew over this most recently disturbed area of the grave.
- On June 1, 2009 (Day 193) it was noted that temperature probe 8, which was placed 3.0-5.0 cm below the surface away from the pig bodies and not underneath the stucco wire, had been removed from the ground, moved about a meter, and left on the surface. It was noticed that other garbage which was present in the area previously was gone. Perhaps someone cleaning up the area noticed the orange tape that was tied onto the probe sticking out of the ground and pulled it up, thinking it was garbage. Another possible culprit is a magpie. This probe was replaced and, based on the observations made on the previous site visit, could only have been uncovered for a maximum of five days.
- After both the first and second exposures were performed, it was observed that cracks formed around the edge of the pit that was excavated for the exposures. This represents the soil settling and drying away from the edge of the pit. It is interesting to note that not many cracks were observed bordering the entire grave area itself. Perhaps the soil type, along with freezing and settling conditions, prevented grave outline cracks from forming.

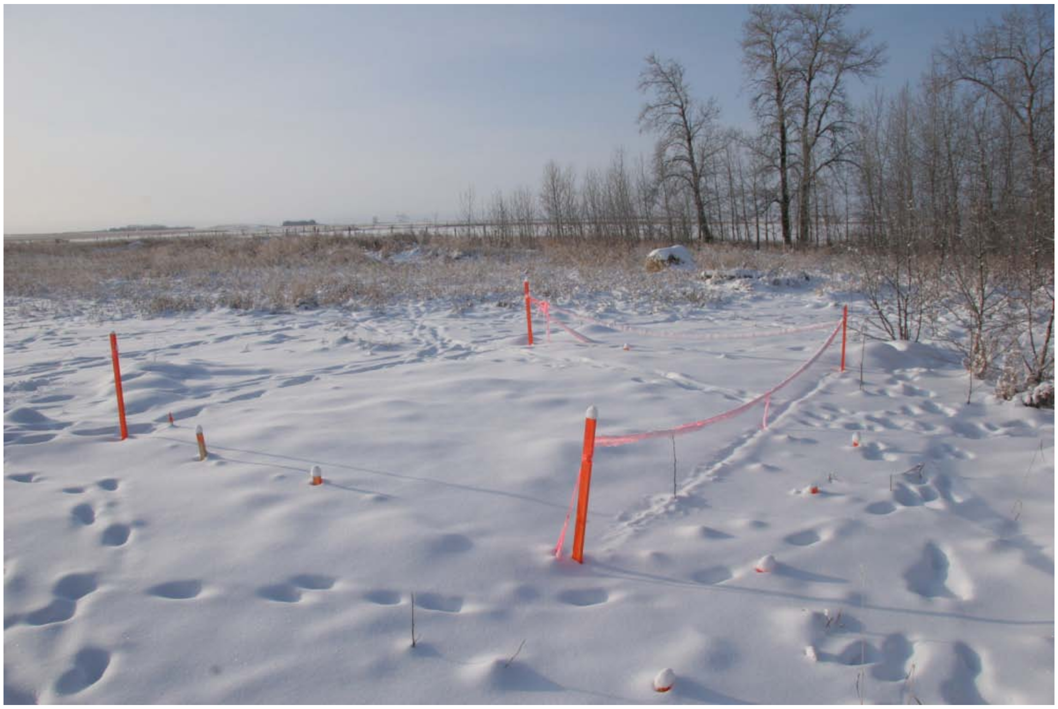

Figure 2-1 – The surface of the grave on December 19, 2008 facing southwest.

Figure 2-2 – The surface of the grave on August 10, 2009 facing southwest.

<u>2.3.2 - Observations – First Exposure – May 9, 2009 (Day 170)</u>

Presented here are observations of the carcasses and grave obtained at the time of the first exposure. It must be kept in mind that these observations were made of the bodies *in situ*; that is, the observational view consisted of the cleaned bodies as they lay in the grave, unmoved. Observations of blunt force trauma refer to the intentional trauma inflicted with a sledgehammer to the forehead of each pig at the time of burial. "Mousse-like substance" refers to liquefied or partially liquefied fat, muscle, skin, etc. in combination with gases, such as methane, hydrogen sulphide, and carbon dioxide, released by bacterial putrefaction.

Pig 5 – This pig was situated immediately east of the middle of the row of bodies. No insects of any kind were observed on the body. The abdomen was still filled with gas and was extended slightly. Skin tones were darker and browner than they were when fresh. The skin would slip when contacted with excavation tools and brushes, exposing an underlying white, mousse-like substance. Of the three pigs exposed at this time pig 5 exhibited the greatest degree of skin slippage. Skin, flesh, and fat in the head region were not solid when disturbed, and were greasy and odorous. Tissues under the skin were greasy, odorous, and were white and pink in colour. No evidence of the blunt force trauma was observable.

- Stage B3-B4 (16)

B. Early Decomposition

3. Discolouration to brownish shades particularly at extremities, nose, ears; some flesh still relatively fresh.

4. Bloating with green discolouration

- Primary Bloat Stage (II) (17)

Pig 6 – This pig was located in the middle of the three exposed pigs. No insects were observed on the body. The abdomen of pig 6 was extensively bloated upon burial, a condition which was still apparent and identical upon exposure. Skin tones were darker and browner than they were when fresh. Only limb skin slipped when contacted with tools. The tissue underneath was white, pink, and fresh looking. The head region and ears were greasy and shiny, and omitted a pungent odour; however the head retained most of its skin. Pig 6 was not as decomposed as pig 5. No evidence of the blunt force trauma was observable.

- Stage B3-B4 (16)

B. Early Decomposition

3. Discolouration to brownish shades particularly at extremities, nose, ears; some flesh still relatively fresh.

4. Bloating with green discolouration

- Primary Bloat Stage (II) (17)

Pig 7 – This pig was situated on the east edge of the body mass. No insects of any kind were observed on the body. The abdomen was minimally bloated but was not collapsed. Skin tones were darker and browner than they were when fresh. Skin slippage due to excavation damage only occurred over the shoulder and hip, and was not as extensive as in pig 5. Tissues underneath were white, pink, and well preserved. The head and ears were smelly and greasy, but not as decomposed as those of pig 5. The region of the left eye, where inflicted blunt force trauma was focused, appeared whitish-pink. The rump/anal region was greasy and smelly with fluids spilling from the anus.

- Stage B3-B4 (16)

B. Early Decomposition

3. Discolouration to brownish shades particularly at extremities, nose, ears; some flesh still relatively fresh.

4. Bloating with green discolouration

- Primary Bloat Stage (II) (17)

Figure 2-3 – From top to bottom, pigs 5, 6, and 7 at the time of first exposure (May 9, 2009 – Day 170). Scale is 20 cm.

Figure 2-4 – Close up of the head of pig 7 and the left forelimb of pig 6. Note the skin slippage on the forelimb of pig 6 due to excavation damage (yellow arrow). Scale is 10 cm.

Table 2-1 – Observations of the surface and interior of the grave at the time of first exposure (May 9, 2009 – Day 170).

Grave Observations	
Surface	**Within Grave**
Insects	
- No insects were present at the surface. - A small number of flies were seen in the area before we started digging. They did not seem particularly attracted to the grave.	- No insects/larvae/eggs were present on the pigs as they were exposed. - However, as we dug deeper, and particularly when we started removing soil that was in contact with the pigs, many various flies converged on the scene. They focused on the dirt we were removing. Flies were restrained by the bug canopy and were waved off if they got to the pigs. They did not seem interested in the actual pig bodies for the ~two hours of exposure.
Vegetation	
- A minimal amount of grass and weeds were growing on the grave cover. This was not substantial and there were no noticeable areas of concentration.	- No vegetation was observed below ground.
Soil	
- There was minimal slumping in the central area above the pig mass. This was not considered substantial.	- The soil was not discoloured. - There were many areas of heavy clay. - The soil was moist and chunky. - Soil in certain areas in contact with the pigs was greasy and pungent smelling. - The soil was difficult to remove.
Odour	
- No odour was recognizable from the surface.	- A pungent odour was present when the pigs were uncovered. During the exposure period the smell extended well beyond the area of excavation. - The odour was aggressive and most noticeable in the areas of skin slippage and moist, greasy decomposition.

2.3.3 - Observations – Second Exposure – June 27, 2009 (Day 219)

The following observation summaries detail the bodies and grave at the time of second exposure. It must be kept in mind that these observations were made of the bodies *in situ*; that is, the observational view consisted of the cleaned bodies as they lay in the grave, unmoved. Observations of blunt force trauma refer to the intentional trauma inflicted with a sledgehammer to the forehead of each pig at the time of burial. "Mousse-like substance" refers to liquefied or partially liquefied fat, muscle, skin, etc. in combination with gases, such as methane, hydrogen sulphide, and carbon dioxide, released by bacterial putrefaction.

Pig 5 – This pig was situated immediately east of the middle of the row of bodies. No insects of any kind were observed on the body. The abdomen still contained gas, which was noticeable upon contact. Skin and hair readily peeled off with the soil or when contacted with excavation tools. Most of the outer tissue was broken down and appeared as a white, greasy, rank, mousse-like substance. Muscle tissue, which appeared fresh, was observable underneath this substance on the front leg, shoulder, and between the ribs. Four ribs were exposed and were disarticulating. The head region was a moist collection of flesh and fat, and was unrecognizable. No evidence of the blunt force trauma could be observed. The intestines were delicate and were torn during the excavation, revealing their contents consisting of brown-green grain/grass/vegetation.

- Stage B4, C2 (16)

B. Early Decomposition

4. Bloating with green discolouration.

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure (minimal bone exposure here).

- Secondary Bloat Stage (III) (17)

Pig 6 – This pig was located in the middle of the three exposed pigs. No insects were observed on the body. The abdomen was still extensively bloated. Both upper limbs were disarticulating but their position was maintained and observable (See Figure 2-6). Skin and hair readily peeled off with the soil or when contacted with excavation tools. Most of the outer tissue was broken down and appeared as a white, greasy, rank, mousse-like substance. Muscle tissue, which appeared fresh, was observable underneath this substance on the rump and abdomen. Six ribs were exposed and were disarticulating. The head was observable but featureless since it consisted of a mass of moist skin, flesh, and fat (See Figure 2-6). No evidence of the blunt force trauma was observable.

- Stage B4, C2 (16)

B. Early Decomposition

4. Bloating with green discolouration.

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure (minimal bone exposure here).

- Secondary Bloat Stage (III) (17)

Pig 7 – This pig was situated on the east edge of the body mass. No insects were observed on the body. The abdomen still contained gas, which was noticeable upon contact. Skin and hair readily peeled off with the soil or when contacted with excavation tools. Most of the outer tissue was broken down and appeared as a white, greasy, rank, mousse-like substance. Muscle tissue, which appeared fresh, was only observable underneath this substance on the abdomen. The least amount of muscle tissue was observable on this pig, relative to the two other exposed pigs. The upper portion of the body was a structureless moist collection of flesh and fat. This pig was the most difficult to expose. No evidence of the blunt force trauma could be observed on the head. The intestines were minimally damaged during excavation.

- Stage B4, C2 (16)

B. Early Decomposition

4. Bloating with green discolouration.

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure (minimal bone exposure here).

- Secondary Bloat Stage (III) (17)

Figure 2-5 – From top to bottom, pigs 5, 6, and 7 at second exposure (June 27, 2009 – Day 219). Note the rib exposure of pig 5, the disarticulating forelimbs of pig 6, and the fresh muscle on the rump of pig 6. The pigs were moist and difficult to clean. Scale is 20 cm.

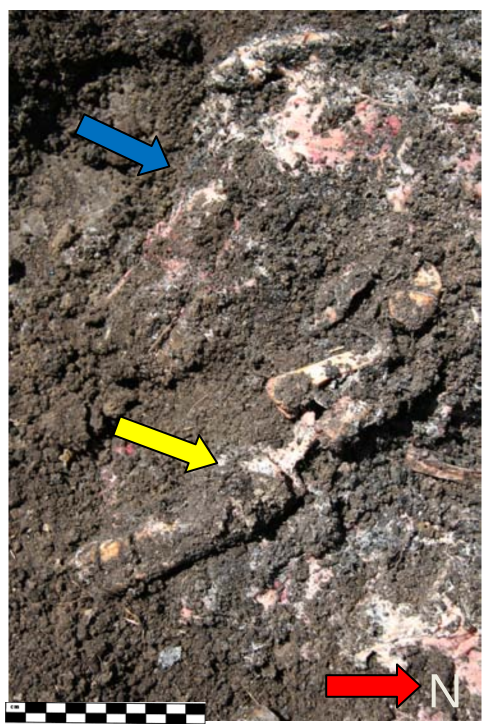

Figure 2-6 – Close up of the head (blue arrow) and disarticulating left forelimb (yellow arrow) of pig 6 at second exposure (June 27, 2009 – Day 219). Scale is 10 cm.

Table 2-2 – Observations of the surface and interior of the grave at the time of second exposure (June 27, 2009 – Day 219).

Grave Observations	
Surface	**Within Grave**
Insects	
- Ants were the only insects observed at the surface.	- No insects/larvae/eggs were present on the pigs as they were exposed. - Flies congregated once the odour became present at a depth of ~30 cm. - Flies were present and were landing on the soil after the pit was refilled.
Vegetation	
- Grass and weeds were growing sparsely on the grave. - There was more vegetation growing at edges of the grave.	- No vegetation was observed below ground.
Soil	
- Soil was drier than at the time of first exposure. - The soil was easier to dig than at the time of first exposure. - Cracks in the soil were observed along the border of the area that was excavated at the time of first exposure. - The grave outline was fairly clear. - There was a slight slump on half of the area which was previously dug.	- Soil was dry but got moister with increased depth. - Close to bodies the soil was greasy, rank, and moist. - The soil stuck to the skin of the pigs, which would result in the skin being peeled off with the soil at times.
Odour	
- No odour was recognizable from the surface.	- The odour was pungent when the pigs were uncovered. During the exposure period the smell extended well beyond the area of excavation. - Odour became noticeable at about 30 cm of depth.

<u>2.3.4 - Observations – Final Exposure of the Complete Grave - September 12 (Day 296)-13 (Day 297), 2009</u>

Presented here are observations of the cadavers and grave obtained at the time of final exposure. It must be kept in mind that unless noted these observations were made of the bodies *in situ*; that is, the observational view consisted of the cleaned bodies as they lay in the grave, unmoved. Observations of blunt force trauma refer to the intentional trauma inflicted with a sledgehammer to the forehead of each pig at the time of burial. "Mousse-like substance" refers to liquefied or partially liquefied fat, muscle, skin, etc. in combination with gases, such as methane, hydrogen sulphide, and carbon dioxide, released by bacterial putrefaction.

Pig 1 – This pig was the outlier/control pig, and was situated one meter to the west of the row of pigs and within the same grave. No insects or their effects were observed on the body. The body was in a state of moist decomposition and was not bloated. Pooling of fluids occurred as the body was left exposed at two places on top of the body and around its perimeter. Skin and hair were still present. Soil adhered to the skin, and would take it with it when removed. When the body was allowed to dry the soil became caked on. Outer tissues consisted of a frothy, mousse-like substance that was rank, although intact muscle and more solid tissues were observed underneath this in regions such as the rump. The limb bones were exposed and easily disarticulated. A small number of rib bones and costal cartilages were exposed, but this was due to excavation damage. The head was still fleshed but tissues were breaking down and moist. No evidence of the head trauma could be clearly observed.

- Stage C1-C2 (16)

C. Advanced Decomposition

1. Decomposition of tissues producing sagging of the flesh, caving in of the abdominal cavity, often accompanied by extensive maggot activity (not the case here).

2. Moist decomposition in which there is bone exposure.

- Active Decay Stage (IV) (17)

Figure 2-7 – Pig 1 at final exhumation. Notice the skeletonization of only the limbs, the pooling of fluids, and dried-on soil. Scale is 10 cm.

Figure 2-8 – Close up of the head and forelimbs of pig 1. Notice the skeletonized and disarticulating forelimbs, the pooling of fluids under the chin, and the dried-on soil overlying extensive remaining tissue. Scale is 10 cm.

Pig 2 – This pig was located at the far west end of the row of bodies and was not previously exposed. It was in contact with pigs 3 and 8. No insects or their effects were observed on the body. Skin was still present on the rump, shoulder, and over the abdomen, although it completely sloughed off when contacted/cleaned. Tissues appeared as a wet, frothy, mousse-like substance. There was some adipocere formation. The rump and shoulder still had some flesh on them, which was liquefying. The bones of almost all the left ribs, left scapula, and left limbs were exposed. The head was still covered in pale tissues, but the skin was largely gone. No evidence of the head trauma could be clearly observed. Pig 8 (the piglet) was occupying the abdominal/thoracic area of pig 2, and was largely engulfed in the frothy, mousse-like substance. Pooling of fluids was observed in this area as well.

- Stage C2, C6 (16)

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure.

6. Adipocere development

- Late Active Decay Stage (IV) – Advanced Decay Stage (V) (17)

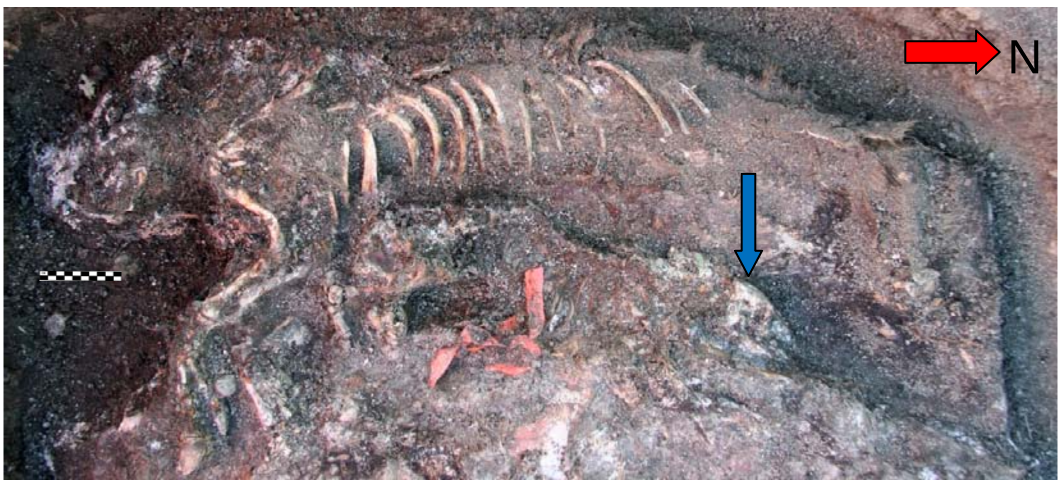

Figure 2-9 – Close up of pig 2 (top) and pig 8 (piglet, blue arrow points to skull). Note the tissues remaining on the head and rump, as well as the pooling of fluids under the chin and in the groin area. Scale is 10 cm.

Underside of Pig 2 – Pig 2 was manually flipped with shovels to reveal the underside of the body and the soil beneath it. Settling of fluids was clearly demonstrated. Tissues (flesh, fat, skin) were largely in a liquefied state and appeared as a frothy, mousse-like substance. A surprisingly detailed imprint of the pig was left in the soil. Areas of primarily fat and muscle were white, thoracic contents were light brown and red, and abdominal contents were brown and green. The right eye globe was still recognizable. Remaining skin and hair was left adhered to the soil. The skeleton, particularly the thoracic rib cage and vertebral column was observed to be articulated; the cartilage was not yet broken down. The right os coxae, right thoracic cage, vertebral column, right scapula, and right side of the skull (snout portion) were visible.

Figure 2-10 – Pig 2 after it had been flipped. Liquefaction of tissues is clear. Note the exposed and articulated bones, and the different colours defining fat/muscle, abdominal contents, and thoracic contents.

Pig 3 – This pig was situated between pigs 2 and 4 in the unexposed half of the body mass. Pig 3 was also in contact with pig 8, was the second largest pig in the body mass, and was the least decomposed pig in the body mass. No insects or their effects were observed on the body. The rump, abdomen, thorax, and head were still covered in skin, fat, and flesh, which were partially broken down into a moist, frothy, mousse-like substance. This substance would come off to some extent with the soil as the body was cleaned. More solid tissues were present beneath. In other words, all tissues were not completely liquefied. Skin over the collapsed abdomen was still observable and fluids were pooling in the groin region. The head was still fleshed and had considerable skin on it, and no evidence of the head trauma was observable. This head was the best preserved head in the body mass. No skeletonization was observed except of the limbs. Some adipocere formation was seen. This pig had a ruptured abdomen at the time of burial; however, no evidence or anything unusual relating to this occurrence was identified at final exposure.

- Stage C1-C2, C6 (16)

C. Advanced Decomposition

1. Decomposition of tissues producing sagging of the flesh, caving in of the abdominal cavity, often accompanied by extensive maggot activity (not the case here).

2. Moist decomposition in which there is bone exposure (limited).

6. Adipocere development

- Active Decay Stage (IV) (17)

Figure 2-11 – Close up of pig 3. The head is on the left of the photo, and the limbs are at the bottom. Note the extensive tissue mass still present.

Pig 4 – This pig was located immediately west of the middle of the row of bodies, between pigs 3 and 5. It was part of the undisturbed half of the grave. No insects or their effects were observed on the body. Skin, fat, and flesh were still present in some areas (particularly the rump), and consisted of a moist, frothy, mousse-like substance which would smear around as soil was removed. Skin over the thorax and abdomen was gone, and thoracic and abdominal contents were observable. Grass and grain, constituting food eaten shortly before the time of death, was seen in the abdominal area. The bones of the limbs, which were easily disarticulated, and ribs, which were not easily disarticulated, were easily exposed. Portions of the scapula and os coxae were observable and were not disarticulated. Some bone exposure was seen on the head, particularly the mandible; however, the majority of it was still covered in a moist, white, mousse-like substance. No evidence of the head trauma was observed.

- Stage C2 (16)

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure.

- Advanced Decay Stage (V) (17)

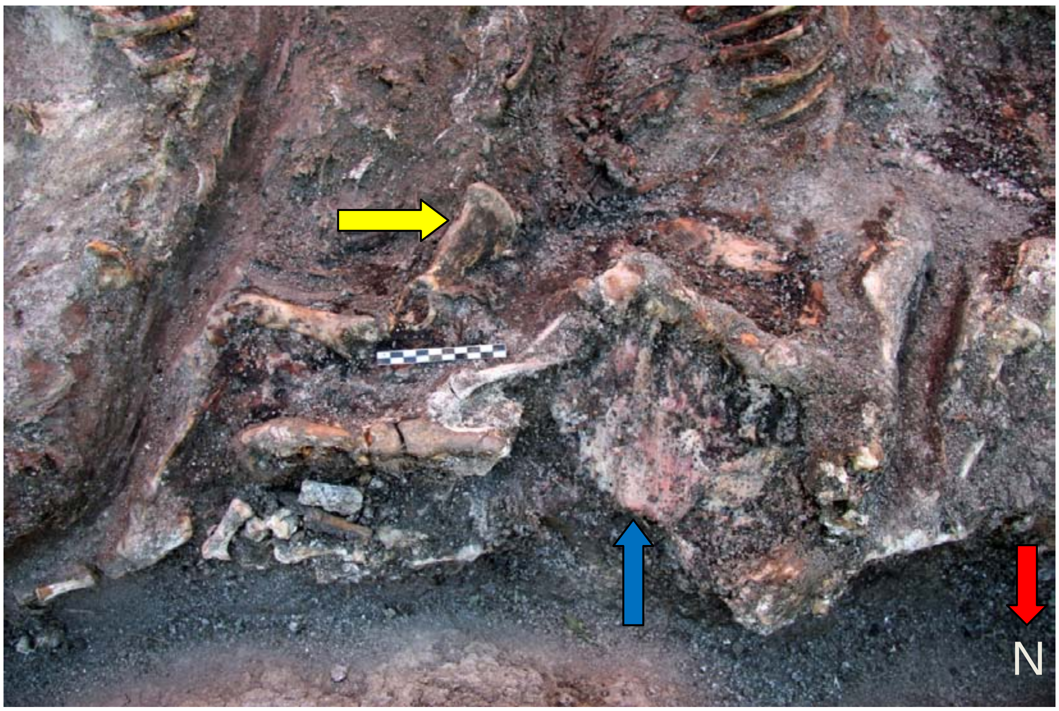

Figure 2-12 – Close up of the rump area of pig 4 (right) and pig 5 (left). Notice the frothy, mousse-like substance (decomposed flesh, fat, and skin) under the hind limb of pig 4 (blue arrow). Also notice the disarticulated os coxae of pig 5 (yellow arrow). Scale is 10 cm.

Pig 5 – This pig was situated between pigs 5 and 3 and was previously exposed. No insects or their effects were observed on the body. The skin had mostly sloughed off and was drying in some areas. The abdomen was absent of skin and contents could be seen. The tissues, remains, and soil were predominantly dry, but still moist around the edges of the body. The head, limbs, shoulder, hip, and ribs were all skeletonized and were easily disarticulated. Evidence of the head trauma in the form of observable bone fragments was seen.

- Stage C2, D1 (16)

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure.

D. Skeletonization

1. Bones with greasy substances and decomposed tissue, sometimes with decompositional fluids still present.

- Advanced Decay Stage (V) – Skeletonization Stage (VI) (17)

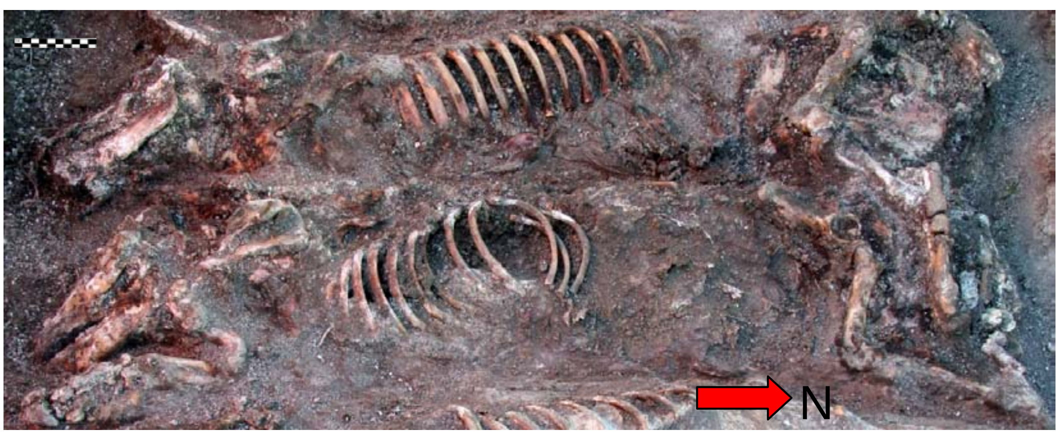

Figure 2-13 – Close up of pig 4 (top) and pig 5 (bottom). The bones of pig 5 were easily disarticulated, while those of pig 4 were not. There was less remaining liquefied tissue on pig 5. Scale is 10 cm.

Pig 6 – This pig was located in the middle of the previously exposed half of the grave, between pigs 5 and 7. Pig 6 was the largest pig of the experiment. No insects or their effects were observed in association with the body. The tissues, remains, and soil were predominantly dry, but still moist around the edges of the body. Most of the skin was gone, except over the deflated abdomen. This abdominal skin was dry, flakey, and tough. The rump and shoulder regions were still moist with flakey tissues in the surrounding areas. The skull, limb bones, scapula, sternum, and ribs were all easily exposed and disarticulated. A moist pool of fluid collected under the chin. The skull appeared in-tact, and no evidence of the head trauma was observed.

- Stage C2, D1 (16)

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure.

D. Skeletonization

1. Bones with greasy substances and decomposed tissue, sometimes with decompositional fluids still present.

- Advanced Decay Stage (V) – Skeletonization Stage (VI) (17)

Figure 2-14 – Close up of pig 6. Notice the extensive skeletonization (including the entire skull), and the condition of deflated and dried abdominal skin. The forelimbs are draped over pig 7. Scale is 20 cm.

Pig 7 – This pig was situated on the edge of the exposed half of the grave, in contact with pig 6. No insects were observed in association with the body. This pig was the most skeletonized of all pigs in the experiment. The tissues, remains, and soil were predominantly dry, but still moist around the edges of the body. The skin and tissues were flakey. The skin over the abdomen was gone and abdominal contents, constituting food eaten shortly before the time of death, could be observed. There was still some flesh in the rump area, but below the exposed left hind limb bones. The bones of the head, both limbs, ribs, both girdles, and the lumbar spine were easily exposed and disarticulated. Evidence of head trauma was clear; the forehead portion of the skull was clearly observed to be fractured into many loose bone fragments.

- Stage C2, D1 (16)

    C. Advanced Decomposition

        2. Moist decomposition in which there is bone exposure.

    D. Skeletonization

        1. Bones with greasy substances and decomposed tissue, sometimes with decompositional fluids still present.

- Advanced Decay Stage (V) – Skeletonization Stage (VI) (17)

Figure 2-15 – Close up of pig 7. Notice the extensive skeletonization. The shattered condition of the skull is visible in the top left. Scale is 10 cm.

Pig 8 – This pig was a piglet weighing 6.5 lbs. It was placed on top of and between pigs 2 and 3, on the unexposed half of the grave. At the time of final exposure its final position was in the abdominal/thoracic region of pig 2. No insects or their effects were observed in association with this pig. Pig 8 was immersed in a frothy, mousse-like substance of decomposed tissues and adipocere derived from itself and pigs 2 and 3. Clearly moisture had collected here. This substance was difficult to separate from the soil and could literally be wiped away to reveal the skeleton of pig 8. No decipherable skin could be seen. Skeletonized skull, ribs, spine, both girdles, and all limbs were cleaned to the furthest extent possible. They were readily disarticulated. No clear evidence of the head trauma could be seen.

- Stage C2, C6, D1 (16)

C. Advanced Decomposition

2. Moist decomposition in which there is bone exposure.

6. Adipocere development

D. Skeletonization

1. Bones with greasy substances and decomposed tissue, sometimes with decompositional fluids still present.

- Advanced Decay Stage (V) – Skeletonization Stage (VI) (17)

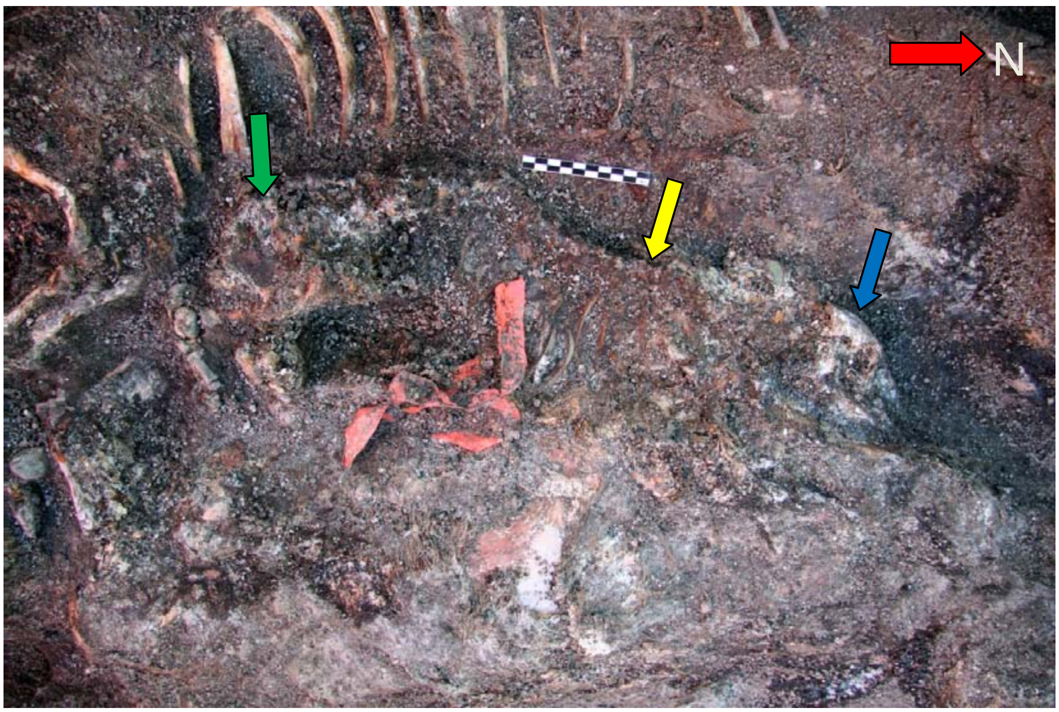

Figure 2-16 – Close up of pig 8. The blue arrow points to the head, yellow arrow to the spine, and green arrow to the pelvic girdle. Note the area of moisture in which the remains are sitting, as well as the extensive skeletonization. The orange tape is attached to temperature probe 2. Scale is 10 cm.

Overall Photographs

Figure 2-17 – Photo of the grave scene after the final exposure was completed, facing southwest. Pig 1 is separate, while pig 2 is on the edge of the west (right in photo) end of the body mass and pig 7 is on the east (left).

Figure 2-18 – Overall view of the final exposure of the body mass. From left to right pigs 2, 8 (piglet in between pigs 2 and 3), 3, and 4 make up the undisturbed half of the body mass, and pigs 5, 6, and 7 were disturbed. The orange tape marks the location of temperature probe 2. Scale is 20 cm.

Figure 2-19 – Overhead shot of the grave scene at final exposure. Pig 1 is separate, while pig 2 is on the edge of the west (bottom in photo) end of the body mass and pig 7 is on the east (top). Scale is 1.0 m.

Figure 2-20 – Heads and thoraxes of (top to bottom) pigs 2, 3, 4, 5, 6, and 7 at final exposure.

Table 2-3 – Observations of the surface and interior of the grave at the time of final exposure (September 12-13, 2009 - Days 296-297).

Grave Observations	
Surface	**Within Grave**
Insects	
- Insects that would be expected in this environment at this time of year were observed on the surface of the grave. For example: grasshoppers, ants, wasps, and flies. They did not seem to be attracted to the grave.	Day 1 - Many wasps were present throughout the day. They seemed attracted to the area even as we just broke the surface. - Flies (bottle, blow) came around gradually but in not near as many numbers as during the previous two excavations. - A beetle larva was found and collected while digging in the first foot of grave fill. Day 2 - Fewer wasps were present the second day. There were, however, many flies this time. They were especially attracted to the wet fluid-pooling areas on the pig carcasses. - Two beetles were seen. It is suspected that they came from the surface and got into the grave, as opposed to actually living under the ground.
Vegetation	
- Sporadic growth of various species over the entire grave was observed. Canadian thistle and grass were the most common. - The area that was disturbed previously was largely devoid of vegetation.	- Minimal vegetation was observed underground except for bits that were clearly in the grave backfill from before. - A few small live roots were seen, but nothing near the bodies.
Soil	
- A slight slump was observable over the area that was previously excavated. The depth of slump was ~5.0 cm but uneven.	- As we dug, the soil was observed to be mixed with many deposits of clay. Some large chunks were encountered. Otherwise, the soil was dark and once it dried it became crumbly.

- Cracks were present outlining the pit that was excavated previously. - The soil on the surface was dry and crumbly.	- Around the bodies the soil was wet and moist, and would stick to skin and flesh. Soil contacting the bodies was greasy and had bits of white fat in it. - Once it dried, the soil created a shell/seal on the pigs. This occurred if the soil was not cleaned off in time. - The soil below flipped pig 2 was extremely black, moist, and greasy. The imprint left by the body was scraped away to reveal the soil as described above. A stain in the soil was clearly left by the body.
Odour	
- No odour was detectable at the surface.	- The odour was pungent, strong, and enduring once the surface was broken. It would stick with you for hours.

2.4 - Discussion

The observations recorded throughout this experiment reveal some thought-provoking and important aspects of body mass decomposition, and also bring forth some enticing questions and issues. This section will present and discuss interpretations of the findings, as well as touch on more minor points and thoughts.

2.4.1 - Low-Density Mass vs. Single Body

The first issue to discuss is itself the overall theme and purpose of this thesis: how does decomposition of a group of bodies buried together differ from decomposition of a single buried body? What little published material on this issue that there is relates primarily to anecdotal observations obtained from real mass grave exhumations (1,10,13,14). These publications detail decomposition of erratically commingled mass graves, those which involve a large number of bodies creating a mass in which there is a core and periphery. Under these conditions the core of the mass is less decomposed than the periphery, due to retention of moisture and buffering from the surrounding substrate. Additionally, satellite remains, those separate from the body mass and not in contact with any other bodies but still deposited in the same grave, are observed to be the most decomposed. Recreating such conditions in an experimental setting would pose logistical and practical challenges beyond the scope of this thesis. Therefore, decomposition of low-density, orderly placement mass graves in which bodies are in contact with one another in a row became the focus. Though such conditions have been observed in the real world, such as by Haglund and Beattie (18) in Somalia, and Skinner and colleagues (11) at Tasovcic, Bosnia-Herzegovina, no literature could be found regarding actual decomposition of an orderly placement mass grave. The following discusses what was observed in this experiment.

Upon first observation (see previously presented figures and Figure 2-21) it would appear that the outlier body (pig 1) decomposed less than the overall body mass. Pig 1 is in a state of active decay, with minimal bone exposure and disarticulation, as well as considerable non-liquefied tissues still present. All of the pigs in the row except pig 3 are at least partially skeletonized with extensive liquefaction of the majority of tissues. It would appear as though the bodies buried in contact have decomposed to a greater extent than the single body. While this is accepted as true, there are a number of factors at work here that prevent such a simple conclusion. Firstly, pigs 5, 6, and 7 were exposed twice before final exhumation to make observations. This is discussed further in Chapter 3, but it is concluded that exposure and disturbance of the grave significantly altered the decomposition process and environment of the three exposed pigs, and as such these pigs cannot be considered to have been exposed to an identical burial environment as that of pig 1. The second issue is body size and its effects on decomposition. Pigs 6, 1, and 3 were the largest pigs used in the experiment, in order of descending weight. Morton and Lord (19) state that child-sized remains decompose at a faster rate than adult remains due in part to smaller size and greater surface-to-volume ratios. Komar and Beattie (7), performing surface experiments in the Edmonton area, observed that smaller sized pigs (42-57 lbs) decomposed at significantly faster rates than medium sized (79-170 lbs) or large sized (344-357 lbs) carcasses. In this experiment pigs 1 and 3 were the least decomposed, and were both in a similar state of active decay at the time of final exposure. It would appear as though larger bodies decompose more slowly; however, it is still interpreted that the bodies in contact decomposed faster than the single body since 1) the bodies (with the exception of the piglet, pig 8) were all over 100 lbs in weight and were therefore considered mid-sized pigs and were heavier than most human children, 2) pig 6, the largest pig, although it was exposed, was in a state of advanced decay/skeletonization, and 3) with the exception of no longer being bloated at final exposure, pig 1 appeared similar to how pig 6 did 78 days earlier at second exposure (frothy, mousse-like outer tissues with more solid muscle still non-liquefied underneath, along with disarticulation of limbs). Additionally, if one was to think of the body mass as a single entity, which is an understandable and justified way of thinking due to tight contact and circumstance, then that entity is in a more advanced state of decomposition than the entity of pig 1.

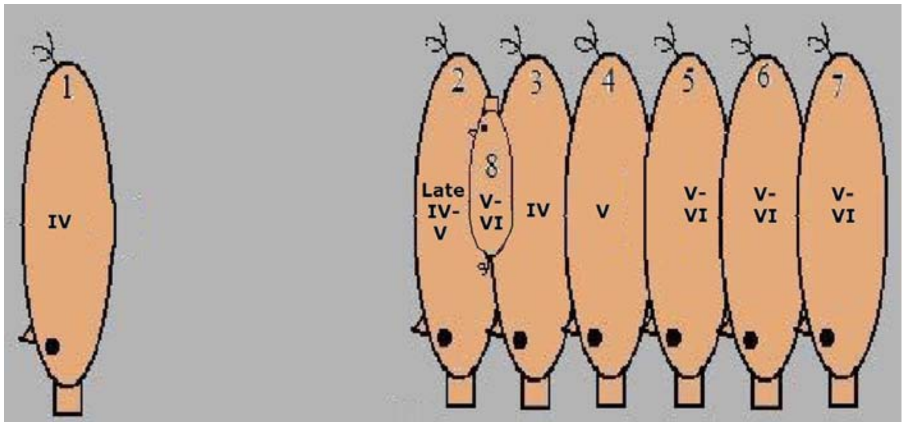

Figure 2-21 – Grave and pig layout denoting stage of decomposition (based on Wilson et al. (17)) at time of final exposure (September 13, 2009 – Day 297). North is up.

2.4.2 - Location Within a Low-Density Mass

A topic along similar lines as that discussed above is a specific body's location within a mass grave as a factor influencing decomposition. As mentioned earlier, Haglund (1) and Mant (10,13) describe three types of remains in an erratically commingled mass grave scenario: core remains, peripheral remains, and satellite remains. According to these authors, the decomposition rate of a set of remains increases in that order. In the orderly placement EMG a similar model was not observed. Despite some bodies being surrounded to a greater or lesser degree by substrate or other bodies, no real trends were observed. It appears as though differential decomposition within the body mass was primarily due to either disturbance or variation in body size. In the unexposed half of the grave pig 6 was the least decomposed and pig 8, the piglet, the most. Clearly the environment differs dramatically between the two types of mass graves, resulting in different observations and explanations for variation in decomposition rate. Regardless, some interesting notes on location can be made based on observations of the EMG. Pig 7 was located at the east end of the row of bodies only in contact with pig 6. It was the most decomposed body with extensive bone exposure and disarticulation, most uniquely seen in the head and lumbar spine. These observations would seem to agree with the model presented by Haglund (1) and Mant (10,13); however, pig 7 was exposed twice, and it was the smallest non-piglet body. Also, pig 2, the body at the west end of the row, was not nearly as decomposed as pig 7. The two bodies in the middle of the row, pigs 4 and 5, were not more preserved. Pig 1 would be considered a set of satellite remains, and this body was the least decomposed, quite in contrast with what the authors had observed. The most interesting body to observe was pig 8, the piglet. These remains were in an advanced/skeletonized state of decomposition, and were located in a unique place, between pigs 2 and 3. At the time of final exposure pig 8 had settled into a depression between pigs 2 and 3. This depression collected moisture and subsequently pig 8 was surrounded in a mass of rank, frothy, mousse-like broken down tissue and adipocere. What was most intriguing was how this substance could literally be wiped away to reveal the skeleton of pig 8. Similar conditions were observed in regions of contact between two bodies. These areas seemed to retain moisture, and as such tissues present here were moist and liquefied. Despite body size, such conditions and positions would likely be created in real world mass graves of both erratically commingled and orderly placement mass graves. The above observations clearly highlight different decomposition rates, processes, and factors between these two mass grave types.

2.4.3 - How Buried Bodies in Contact Decompose

In relation to the previous two topics of discussion it is worth examining why the bodies were in the state that they were when exposed. How do buried bodies in contact affect each other as they decompose? Decomposition of a buried corpse generally proceeds at a rate of eight times slower than a corpse on the surface (20). This is due to two main factors, both of which are functions of burial depth and geographic location of the grave.

First, the limitation of access granted to carrion insects and animal scavengers greatly reduces the rate of tissue breakdown. In some regions the vast majority of soft-tissue destruction of surface remains is due to insect feeding (21). In the Edmonton region this is true for the times of year in which insects are present, but during the late fall, winter, and early spring birds and carnivores may have more of an effect (8). Therefore, the breakdown of tissues in a burial is primarily the result of autolysis (enzymatic self-digestion of cells) and bacterial putrefaction performed by both enteric and soil bacteria (22). In this experiment, the bodies were buried at a depth of 30-45 cm below the surface, deep enough to limit the release of odour and not attract insects or other scavengers (2,20). During the two episodes of exposure insects were attracted to the area and were able to land on the grave fill and bodies, in spite of attempts to prevent this, for a period of approximately two hours. Despite this, no lasting effects or insect eggs/larvae/subsequent generations were observed at future exposures. It is believed that the time period of granted access was too short to allow for extensive feeding or egg laying, and that the depth of the grave and soil conditions, once refilled, prevented survival of any eggs. Nothing of note in relation to the row of bodies versus the single body was observed with regards to this issue; however, it is hypothesized that insects, if granted access and survivable conditions, would spread throughout a buried body mass by passing between contacting carcasses as if they were one large single body. This could be investigated by creating a group of bodies buried in contact on a sloped grave, or at various depths, with one or more bodies granting access to insects. It would be interesting to see if insects would follow the body mass deeper into the ground. It is also interesting to note that VanLaerhoven and Anderson (23) did observe a variety of insects associated with experimental single pigs buried at similar depths in the Coastal Western Hemlock and Sub-boreal Spruce biogeoclimatic zones of south-western British Columbia. However, no maggot masses were observed, demonstrating a difference between buried remains and those deposited on the surface. While the authors' study was more in depth with regards to this topic than the thesis presented here, it does highlight the issue of entomological differences between regions even in regards to buried bodies. Also, in the EMG, a metal mesh was placed over the grave to prevent animal scavengers from accessing the grave and remains. This was done on the recommendation of past researchers at the Ellerslie Research Station who had lost entire burial experiments to scavengers. Despite this, no scavenger footprints or observations of attempted access were ever noted.

The second major factor responsible for reduced decomposition rates of buried remains is the soil environment and subsequent effects on temperature within the burial (2,20). In the summer, temperature and temperature fluctuations, both of which are major factors of decomposition, decrease with increased depth of burial, a result of the soil creating a barrier to solar radiation. In the winter, soil and snow create insulation, and temperature increases with depth, to a certain point. Temperature fluctuations behave the same in winter as they do in summer. Temperature profiles will be described further in Chapter 4; however, some aspects will be mentioned here. Using eight temperature probes placed in various locations within the grave, data was recorded throughout the experiment. Full calibration of each probe was not performed for this experiment. Instead, the probes were tested for group consistency against known temperatures, with successful results. It is realized that there are more advanced methods available for gathering temperature data; however, the intentions here were exploratory, and data recovered was valuable. Of interest here are three probes: probe 1 (contacting pig 1), probe 4 (in the middle of the row of bodies between pigs 4 and 5), and probe 7 (placed on the bottom of the grave 1.5 m east of the east end of the row of bodies to collect soil temperature). All probes stabilized during the winter months between -2.5 °C and -0.5 °C; however, once temperatures warmed, beginning in early April, probe 4 recorded higher temperatures than probe 1 and probe 7. Since the cold temperatures of the winter months (November to early April) would have greatly reduced or halted the decomposition of the buried remains (20,24), it is deemed that early April marks the beginning of major decomposition. For example, on May 1st at noon probe 4 recorded a temperature of 6.0 °C, probe 1, 4.5 °C, and probe 7, 4.0 °C, and on June 1st at noon probe 4 recorded a temperature of 16.5 °C, probe 1, 12.5 °C, and probe 7, 12.0 °C. Unfortunately probes 4 and 1 failed due to loss of power (i.e. depleted batteries) in early-mid June. A body temperature spike above that of soil during early stages of decomposition has been noted experimentally by Rodriguez and Bass (2). Such a spike is the result of aerobic and anaerobic bacteria only, and does not relate to heat created by larval infestation, since this does not occur at such depths. Increased temperature, within certain parameters, results in increased enzymatic reactions associated with autolysis as well as faster rates of bacterial growth and subsequent putrefaction (24,25). The greater increase in temperature recorded by probe 4 for the center of the row of bodies implies that decomposition would have begun earlier and would have proceeded at a faster rate within the body mass than it would have proceeded in pig 1, the single body. This statement is, however, inconclusive, largely due to the fact that at the time the probes failed (early-mid June) temperatures within the grave still had not reached high enough levels for effective decomposition to take place (the upper end of a range between 15.0 and 39.0 °C). It is unfortunate that the probes failed and did not last for the entire experiment; however, it is clear that a decomposing group of bodies generate more heat than a single body, and as such this likely increases the rate of initial decomposition and would have ultimately resulted in the body mass appearing more decomposed at the time of final exposure. It would be informative and interesting to attempt to measure heat retention and release by the buried pig bodies from above ground utilizing thermal imaging technology such as infrared. This would provide important information regarding differences between a single burial and a multiple burial, timing of most heat generation, and differences between seasons.

2.4.4 - Freezing

In relation to the above subject of temperature profiles is the issue of freezing and possible effects this had on subsequent decomposition once the bodies thawed. This is a geographically important taphonomic issue relevant to the EMG located in the region of Edmonton, Alberta, Canada. During freezing the withdrawal of water from cells leads to a decrease in diffusion and material transfer between cells (26). This leads to inhibition of chemical reactions, including those active during autolysis. Also, bacterial growth is severally retarded at temperatures at and below 4.0 °C (25). Thus, as was observed in the EMG, great reduction and a halt of decomposition of tissue occurs. Freezing damages skeletal muscle due to the formation of ice crystals (26). Micozzi (27,28) observed experimentally that freezing and thawing of rat cadavers effected subsequent decomposition above ground. Frozen-thawed animals decomposed from the "outside in" (predominantly due to death of enteric bacteria during freezing allowing insects and microorganisms from the outside to have more of an effect once thawed), while fresh-killed animals decomposed from the "inside-out" (predominantly enteric bacterial putrefaction). It was also observed that frozen-thawed remains disarticulated at a faster rate. In relation to this Stokes and colleagues (29) found that, when buried in soil, decomposition of skeletal muscle is unaffected by previous freezing. Due to the fact that the carcasses within the

EMG only advanced from fresh to early bloat stages of decomposition between burial and first exposure (170 days over winter) it is determined that they froze over the winter months, and that gross decomposition did not take place. Temperature probes within the grave and in contact with the bodies recorded ranges of – 2.5 °C to 0.0 °C throughout the winter; however, it is unclear how this period of freezing affected decomposition once the bodies thawed. More frequent periodical observations would have to have been made to observe possible "inside-out" or "outside-in" decomposition. Regardless, this freeze-thaw cycle is characteristic of the geographic location of Edmonton, and it is an important taphonomic factor to consider. If an identical experiment was performed at more southern latitudes where freezing does not occur, then clearly results would have been much different, with remains reaching decomposition stages observed in this experiment over a much shorter time period. Other issues may also be at work at different latitudes, for example, Rodriguez and Bass (2) observed mummification of corpses in Tennessee that were left in burials over winter and recovered in the spring or summer - clearly much different results than were obtained in Edmonton.

2.4.5 - Vertical Decomposition

As mentioned previously, visual observations were made of the bodies *in situ*. That is, the observational view consisted of the cleaned bodies as they lay in the EMG, unmoved. This brings up the question of whether the top of the bodies would be in the same state of decomposition as the bottom. Are there differences vertically in rate of decomposition? To investigate this, pig 2 was flipped, giving a view of the bottom of the carcass as well as the soil on which the pig laid. The major issue here was the settling of body fluids and moisture; however, the overall state of decomposition appeared nearly consistent with what was observed of the body *in situ*. The soil below pig 2 and the underside of the carcass were extremely wet. Tissues were extensively liquefied. Areas of primarily fat and muscle were white in colour, thoracic contents were light brown and red, and abdominal contents were brown and green. Remaining skin and hair had adhered to the soil. The right os coxae, right thoracic cage, vertebral column, right scapula, and right side of the skull (snout portion) were visible. Liquefied tissues could be wiped away from the bone. The extent of bone exposure and articulation, and adherence of skin and hair to soil is similar to what was seen on the top side of the body. Everything was wetter on the bottom side of the corpse, but in the same state of decomposition as the top. This relates to erratically commingled mass graves since such conditions exist on a larger scale.

2.4.6 - Adipocere

Adipocere is a soap-like substance formed by the hydrolysis and hydrogenation of fatty tissue during the later stages of decomposition (30-32). Its formation and presence is environmentally dependent, with optimal conditions being a damp, warm, anaerobic environment. It was once thought that adipocere formation required submersion in water or a waterlogged environment, but it has also been revealed to occur in burials as a result of soil retaining moisture derived from rain, groundwater, or the bodies themselves. In this experiment it is worth mentioning that adipocere was indeed observed, to a minimal amount. It was only seen at the time of final exposure, not at the two earlier partial exposures, where moisture had pooled or collected, such as between bodies. It was only seen in the undisturbed half of the row of bodies, and was represented by a flakey, whitish, cheese-smelling substance. The main area where it was observed was in the interface between pigs 2, 8 (piglet), and 3. Here, pig 8 had sunken between pigs 2 and 3, and was immersed in a moist collection of decomposition products, including adipocere. It is apparent that the soil conditions in the Edmonton region are conducive to the formation of adipocere, and that a row of bodies provides areas of moisture collection necessary for its development.

2.4.7 - Trauma

On day 0, immediately before the carcasses were buried, each pig was subjected to one strike on the forehead with a sledgehammer to simulate blunt force trauma as cause of death in the experimental scenario, and to induce sites of laceration for the evaluation of potential decompositional factors associated with these types of injuries. The strike was hard enough to deform the head and break bone. While this was not the primary focus of the experiment some interesting observations were made, which relate to collection of evidence and how noticeable such trauma would be during exhumation in the real world. Overall this trauma was not easily or clearly observable until the final exhumation, and even then it was only clearly seen in two pigs, pigs 5 and 7. Decomposing tissue obstructed the view of the traumatized area and held the bone fragments together. In some cases tissue was moveable and it was apparent that the underlying skull was fractured even though this wasn't visually evident. While such trauma would undoubtedly be recognized and documented during detailed examination or autopsy in the real world, despite the state of decomposition, these observations highlight how unrecognizable some important pieces of physical evidence can be during exposure and exhumation. Great care must always be exercised when handling human remains regardless of the state of decomposition to ensure such evidence as ante/perimortem trauma is not compromised or missed.

2.4.8 - Time Since Death and/or Burial

Establishing time since death and/or burial is one of the primary goals of forensic taphonomy (12). This estimate involves determining seasonality; that is, in what season the remains being investigated were deposited. Clearly the goal is to generate an accurate and useable timeframe in which the alleged crime actually took place. In the arena of international mass grave investigation this is particularly important when corroborating with witness testimony in order to locate a specific grave linked to a specific event. Forensic entomology, the study of insects associated with carrion, is typically the most accurate method for determining time since death beyond 72 hours (6,23,33); however, in instances of burial where insects could not access the body, other methods must be used. Here we will focus on the rate that a body goes through established stages of decomposition, and how this experiment is geographically and climatically dependant.

Bodies decompose in a known sequence of definable stages. This experiment utilized Wilson and colleagues (17) and Galloway and colleagues (16) as templates to classify the experimental bodies (see Appendix C). Plotting the rate that a body goes through these stages of decomposition can lead to an estimation of time since death, based on past experimental research and real world observations. There are, however, many problems associated with doing this. As detailed throughout this paper there are a number of taphonomic factors that affect a cadaver as it decomposes, altering the rate that it will reach certain stages. Two different sets of recovered remains that were decomposing for the same amount of time will rarely be identical. Of paramount importance is climate and geographic location, which influence such taphonomic factors as temperature, precipitation, moisture levels, and what species of insect and animal are present to interact with the remains. Edmonton is located in a northern continental climate with extreme seasonal temperatures. The average annual temperature range is approximately -11.7 °C to 17.5 °C with average monthly temperatures below freezing for five months of the year; therefore, this research, like all research of its kind, can only be directly applied to similar climatic and geological areas. There are, however, more broad indirect applications.

The goal of this research was not to establish a concrete decomposition sequence for this specific scenario. That would be unjustified without extensive further research since this is the first experimental low-density mass grave created in this region. With regards to time since death estimations, the goal was to perform the experiment and report on what was observed over the nearly 10 month long period for this specific region. The following chart details stages of decomposition at the three exposure times.

Table 2-4 – Decomposition stages of carcasses at various instances of exposure

Pig Number	**State of Decomposition at Time of Burial – Nov 20, 2008 - Day 0**	**State of Decomposition at Time of First Exposure – May 9, 2009 – Day 170**	**State of Decomposition at Time of Second Exposure – June 27, 2009 - Day 219**	**State of Decomposition at Time of Final Exposure – Sept 12-13, 2009 - Days 296-297**
1	W – I G – A1	n/a	n/a	W – IV G – C1-C2
2	W – early II G – B4	n/a	n/a	W – IV-V G – C2, C6
3	W – I G – A1	n/a	n/a	W – IV G – C1-C2, C6
4	W – I G – A1	n/a	n/a	W – V G – C2
5	W – early II G – B4	W – II G – B3-B4	W – III G – B4, C2	W – V-VI G – C2, D1
6	W – II G – B4	W – II G – B3-B4	W – III G – B4, C2	W – V-VI G – C2, D1
7	W – I G – A1	W – II G – B3-B4	W – III G – B4, C2	W – V-VI G – C2, D1
8	W – I G – A1	n/a	n/a	W – V-VI G – C2, C6, D1

W – Wilson et al. (17)   G – Galloway et al. (16)

Over the total 297 days none of the bodies had become fully skeletonized, and in fact most of them were still in active and advanced decay stages. In one full year it would not be expected that the remains would fully skeletonize, since temperatures were already on the decline at the time of final exhumation, and the winter freeze would again greatly reduce or halt decomposition. It would appear as though bodies, whether in a low-density mass or single grave, buried 30 cm below the surface in the Edmonton region will not fully skeletonize within one year or one full cycle of seasons. Past research done in the same region report different results; however, variables differed as well. Weitzel (34) performed experimental single burials at the Ellerslie Research Station and reported that it would take approximately three to five weeks for pigs buried in June at a depth of 40 cm to fully skeletonize, and that it would take between five weeks and three months for pigs buried in May, deeper than 40 cm, to skeletonize. The main difference here was that her graves were filled with large rock slabs, not sediment, and thus there was considerable access granted to air, insects, moisture, etc, and that most of the bodies were altered in some way, such as burning. The one pig that she did cover in sediment and that was buried for the months of June, July and August reached a decomposition stage of C2-C3 (16). This is in fact similar to what was observed in this experiment over the summer, considering that the bodies were frozen over the winter months. Komar (35) investigated 20 cases at the Edmonton Office of the Chief Medical Examiner and found that during the summer a body deposited on the surface can skeletonize in less than six weeks, and that during the winter this can take place in as little as four months. These differences highlight how different scenarios (type of burial, surface) within the same climatic and geographical region can involve diverse taphonomic factors resulting in varying rates of decomposition.

Disarticulation of remains was occurring at the time of second exposure on day 219, but not at the time of the first exposure on day 170. At the later date the limb bones were beginning to disarticulate but connective tissue was still present to hold them somewhat in place. At the time of final exposure on day 296 the limbs of all bodies were disarticulating as well as many other parts of most of the skeletons, particularly within the body mass. The single body was the least disarticulated on day 296. Therefore, if a body is deposited at the end of fall under similar conditions it can be expected to begin disarticulating at between ~24 and ~31 weeks. If one considers the winter thaw to halt decomposition totally, then disarticulation of a buried body under similar conditions can be expect to occur in as little as ~7 weeks (50 days) in the spring and summer. During real world mass grave investigations, having an idea of what to expect can greatly increase efficiency and competence of the exhumation of remains and evidence collection.

The fact that Edmonton experiences sub-zero temperatures for five months of the year creates an interesting taphonomic arena for decomposing remains. In this experiment it appears as though the remains were almost suspended in time over the period from burial (November 20, 2008, just before the winter freeze set in) until first exposure (May 9, 2009, just after the winter thaw). Over this 170 day (~24 weeks) period the bodies only advanced from fresh to primary bloat/early decomposition stage. It would be interesting to create a similar experiment that began in early May and ran until early September. This would create more information on how a winter freeze affects a low-density mass grave, as well as a buried single body. This information would be important to consider when investigating mass graves in areas that experience winter freezes, since remains may appear in a much earlier state of decomposition than expected given the time period. Such a freeze would create a halt in the decomposition process and knowing this would help in establishing seasonality. Bodies discovered in spring and summer may appear much less decomposed than expected if they were deposited in the fall, while bodies deposited in summer and not discovered until the following spring would again appear less decomposed than expected. This highlights the importance of considering local climate in forensic investigations.

Results obtained from this experiment suggest that body masses decompose at a slightly faster rate than single bodies (see previous subsection 2.4.1), and that disturbed remains will decompose faster than undisturbed ones (see Chapter 3). Both these issues, as well as the ones described above, must be kept in mind when taking on the considerable challenge of competently estimating time since death and/or burial.

2.5 - Conclusion

As detailed throughout this section a further understanding of how a group of buried bodies in contact decomposes was gained by performing this experiment. Further research is clearly needed to justify and clarify certain determinations; however, the following summarizes what was seen in this first-time experiment. The orderly placement body mass appeared to decompose faster than the single outlier body, while position within this orderly placement mass grave had no observable effect on rate of decomposition. A greater degree of heat generated by the body mass than the single body is proposed as a possible reason for the faster rate of decomposition under these conditions. Freezing occurred over the winter months, but it is unclear as to how this effected subsequent decomposition of the thawed pigs. Observations lend to the conclusion that there is not much of a difference vertically in decomposition of a body, despite settling of moisture, and it is suspected that this would be at least partially true for large scale erratically commingled mass graves. It is apparent that adipocere is able to form in the soil conditions of the Edmonton region, and that a row of bodies is conducive to creating moisture pockets in which this formation can occur. Observations throughout the experiment of inflicted head trauma made at the time of burial highlight how unrecognizable these important pieces of physical evidence can be during exposure and exhumation of partially fleshed remains. With regards to elapsed time estimations, it can be stated that in the Edmonton region a body, whether part of a mass or single burial, buried at a depth of 30 cm below the surface will likely not fully skeletonize within one year. Disarticulation of remains in these conditions can take more than 31 weeks if remains are deposited over winter, and less than 7 weeks if remains are deposited in spring or summer. The freeze-thaw cycle must be considered as it greatly retards and even halts the decomposition process. Therefore, the majority of decomposition occurs in the spring, summer, and autumn. Also, disturbance or exposure of a set of remains will increase its rate of decomposition.

The information gained from this experiment is important for a number of reasons. As stated previously, witness corroboration is a key tool utilized in the real world to locate and verify specific mass graves from specific events. When climate and geography is considered when a set of remains is examined then a more competent estimation of time since death and/or burial can be made to be compared to witness testimony. This research provides a template of what to expect under similar conditions. Additionally, a knowledge of how a body mass decomposes and how this differs from a single body is vital when planning exhumation of a mass grave and when gathering evidence. Having an idea of the extent of disarticulation and state of decomposition will ease planning and training. Also, in real world mass grave scenarios it is possible for satellite/single remains to exist. These are remains representing victims from the same event that were buried at the same time, but are not in contact with the main body mass. Observations from this experiment suggest that such remains will be less decomposed than an orderly placement body mass. It must be appreciated that two sets of remains, particularly a single and a mass, buried within the same grave can exhibit two distinct stages of decomposition but can represent victims from the same event and have the same time since death.

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CHAPTER 3 – THE EFFECTS OF INTENTIONAL DISTURBANCE ON DECOMPOSITION RATES OF BODIES IN A LOW-DENSITY MASS GRAVE

3.1 - Introduction

The phenomenon of intentional exposure, disturbance, or vandalism of bodies within a mass grave, or of the mass grave itself, is an important and relevant problem experienced by investigators in the real world (1-4). Such disturbance may occur for a variety of reasons including clandestine destruction or removal of physical evidence with intention to destroy or hide said evidence, family members seeking the recovery of remains of loved ones, body trading, or mandated wartime exhumations. In any case, these actions can impact and change the condition of remains within a grave and the grave environment, and can further alter future decomposition and taphonomic processes. It is important that evidence of such actions be recognized and interpreted by investigators. Such recognition leads to accurate recreation of events that have occurred since burial, which in turn can lead to recording of further crimes and corroboration with witness testimony or other evidence in order to attribute properly a specific grave to a specific event and group of victims. Disturbance or exposure can affect the process of decomposition (5), and may result in body conditions differing from what would be expected otherwise.

The research reported in this chapter examines the following key questions:

- How is the decomposition process altered if a buried body is disturbed?
- How does the decomposition of a disturbed section of a body mass differ from the undisturbed part of the same mass? Why?
- Why is this important to consider in real-world mass grave investigations?

3.2 - Materials and Methods

Complete descriptions of grave and body characteristics are provided in Chapter 1. In this experiment, the eastern half of the row of eight bodies (pigs 5, 6, and 7) was exposed twice for periodical observation. This occurred after the winter thaw on May 9, 2009 (Day 170), and again on June 27, 2009 (Day 219). The May date was selected to get a view of what condition the bodies would be in immediately after the spring thaw, and presumably after thawing themselves. This was also the earliest time that the soil was movable. The June date was selected as an approximate midway point between the May exposure and the final exposure in September. A pit of minimal size (~1.5 m x 2.0 m) was excavated (see Appendix B for diagram of excavated area), soil overlying the bodies removed, and the bodies cleaned using trowels, brushes, and wooden sculpting tools. The bodies were examined and thoroughly described and photographed. The original backfill was then immediately shovelled back into the hole. Total exposure time was kept to ~2 hours. A bug screen canopy was placed over the grave for the whole exercise to minimize the possibility of insects interacting with the bodies and grave fill. While insect interaction during instances of disturbance would be considered more realistic, this was done due to the original experimental plan not including an investigation of disturbance and the need to maintain the grave environment as if it was never disturbed. Overall the canopy was not effective and flies were observed in the canopy space and on the bodies, which proved to better for the experimental plan in the end. The above procedures created two situations of disturbance and exposure to half of the grave, and the effects of these events constitute the focus of this chapter.

3.3 - Results

This section reports differences and similarities observed between the disturbed/exposed (east) half of the grave and the undisturbed/unexposed (west) half. Observation summaries of the pig bodies and grave at the times of the two exposures, and at final exhumation, were presented in Chapter 2.

3.3.1 - Observations and Comparisons – Final Exposure - September 12 (Day 296)-13 (Day 297), 2009

The following observations were made at the time of final exposure of the entire grave. Comparisons are made between the disturbed/exposed half (pigs 5, 6, and 7) and undisturbed/unexposed half (pigs 2, 3, 4, and 8) of the body mass. Descriptions of the bodies and grave at the time of final exposure are presented in Chapter 2. It must be kept in mind that these observations were made of the bodies *in situ*; that is, the observational view consisted of the cleaned bodies as they lay in the grave, unmoved. Observations of blunt force trauma refer to the intentional trauma inflicted with a sledgehammer to the forehead of each pig at the time of burial.

Table 3-1 – Comparisons of disturbed and undisturbed carcasses at the time of final exposure (September 12-13, 2009 - Days 296-297)

Disturbed Half of Grave – Observations of Pigs 5, 6, and 7	**Undisturbed Half of Grave – Observations of Pigs 2, 3, 4, and 8**
- Overall, the carcasses were more decomposed/skeletonized/disarticulated than pigs 2, 3, 4, and 8.	- Overall, the carcasses were less decomposed/skeletonized/disarticulated than pigs 5, 6, and 7.
- More dry bone was present. This bone did not require difficult or extensive cleaning, particularly the areas that were exposed during previous exhumations (ex. ribs of pigs 5 and 6).	- Minimal dry bone was present and the remains were more fleshed. Bone was exposed during the cleaning process, which was what occurred to pigs 5, 6, and 7 during previous exposures.
- More desiccated tissue, which was flakey or leathery, was present.	- Tissues were moist and often consisted of an extensive white, frothy, mousse-like substance.
- Limb bones and ribs were readily disarticulated with little connective tissue or muscle left, and what was present was desiccated.	- Limb bones and ribs were easily disarticulated but still covered in wet and moist decomposing skin, fat, and muscle.
- Rumps were skeletonized or covered with a small degree of thin, desiccated tissue.	- Muscle and fat were present over the rumps, particularly on pigs 2 and 3.
- Heads/skulls were skeletonized, easily cleaned, and starting to disarticulate. Evidence of the head trauma was apparent on pigs 5 and 7.	- Heads/skulls were covered in decomposing skin, fat and muscle. A white, mousse-like substance containing hair was present throughout. These areas were difficult to clean. Pig 3 had the most flesh remaining on its skull, followed by pig 2 and pig 4. No evidence of the head trauma was observable.
- Pig 6 (the largest pig on the disturbed half) had a deflated abdomen covered with a tough, leathery skin.	- Pig 3 (the largest pig on the undisturbed half) had a deflated abdomen with skin that was moist and pliable with white, frothy, mousse-like substance throughout.

Table 3-2 – Comparisons of disturbed and undisturbed grave features at the time of final exposure (September 12-13, 2009 - Days 296-297)

Disturbed Half of Grave – Observations of Grave Features	**Undisturbed Half of Grave – Observations of Grave Features**
- Overlying grave fill was looser and easier to shovel.	- Overlying grave fill was compact and more difficult to shovel.
- Cracks were observed in the soil outlining the area that had been excavated previously.	- No outline cracks were observed.
- Vegetation was sparse (only a few weeds) over the area that had been excavated previously.	- Vegetation was extensive over the undisturbed area of the grave, but not more than the area surrounding the grave that was never excavated. Primarily weeds, small shrubs, and some sparse grasses were present.

Figure 3-1 – Overall view of the final exhumation. From left to right pigs 2, 8 (piglet in between pigs 2 and 3), 3, and 4 make up the undisturbed half of the grave, and pigs 5, 6, and 7 were disturbed. The orange tape is attached to temperature probe 2. Scale is 30 cm.

Figure 3-2 – From top to bottom, close up of pigs 4, 5, 6, and 7. Note the more skeletonized condition of the heads and rumps. Scale is 20 cm.

Figure 3-3 – Close up of pigs 2, 8 (piglet in between pigs 2 and 3), 3, and 4 (from top to bottom). Note the more fleshed condition of the heads and rumps. The orange tape marks the location of temperature probe 2. Scale is 20 cm.

Figure 3-4 – Close up of the head and shoulder of pig 3. Note the presence of flesh and hair. Scale is 10 cm.

Figure 3-5 – Close up of the skeletonized heads and shoulders of pigs 6 (top) and 7 (bottom). Note the bone fragments of pig 7 due to blunt force head trauma. Scale is 10 cm.

3.4 - Discussion

The primary issues to consider are: why is there a difference in the final condition of the disturbed/exposed bodies when compared to the undisturbed/ unexposed bodies? And, how was the decomposition process of the disturbed carcasses altered? The bodies that were exposed for observation were not moved and were physically disturbed to the least extent achievable. They were cleaned of as much soil as possible and left exposed for no more than two hours. It is interpreted that there are five possible factors that may or may not have affected the decomposition process of the remains: 1) insects, 2) exposure to air, 3) changes to the compaction of soil, 4) excavation damage, and 5) short term rise in temperature associated with exposure to the ambient air temperature.

Throughout the experiment it was apparent that insects had no effect on the bodies within the EMG. This is significant, as insects are seen as one of the major factors of decomposition of exposed (6) and buried bodies (7). The depth of the EMG (60 cm deep with bodies lying 30 cm below the surface) and soil conditions prevented insects from accessing the bodies. Rodriguez (8) and Rodriguez and Bass (7) found that when a body is buried deeper than 30 cm below the surface (as is the case in this experiment) decompositional odours from the carcass cannot penetrate the soil, and thus insects and other scavengers are not attracted to the remains. In this experiment, no insects of any stage were found at any time on or interacting with the bodies, with the exception of the two brief (~2 hour) intervals of exposure, as detailed below. No insect activity or development was naturally occurring under the ground. During the two instances of exposure, attempts were made to prevent insects from coming in contact with the bodies or the grave fill, but this was ultimately impossible. Insects (mainly flies) managed to get to the bodies and were seen gathering on the removed grave fill; however, despite the fact that insects were able to access the bodies and grave fill for a period of about two hours, no lasting effects, such as consumption, considerable body damage, or egg lying and development, were observed at subsequent exposures. The time of exposure, the clay-like nature of the soil, and the depth of the grave prevented insects from establishing and flourishing on the bodies. Therefore, in this experiment, the difference in rate of decomposition of the disturbed/exposed bodies when compared to the undisturbed/unexposed bodies was not due to insect action.

Secondly, as the bodies were uncovered and cleaned, their tissues were exposed to air. The clay-like nature of the Eluviated Black Chernozemic soil allowed it to adhere to the bodies and caused difficulty during removal. This often resulted in layers of skin and fat being pulled off the bodies as the soil was cleaned away. Macroscopically, this resulted in a two hour period in which skin and uncovered tissue were exposed to air and allowed to dry, thus altering them. This event was not experienced by the unexposed bodies on the west side of the grave.

Thirdly, as the bodies were exposed, the overlying soil in contact with them was disturbed and broken up. This soil had been settling for 170 days over winter by the time of the first exposure, and was difficult to remove and clean, due to settling and the clay-like nature of the soil. Once redeposited into the grave this soil was not as compacted as the soil that was not disturbed, and thus larger air spaces existed and the settled nature of the grave fill was not regained. This would have allowed more air to continue to interact with the exposed bodies than was experienced by the unexposed bodies. This fact, along with the previously mentioned issue of a two hour drying period, led to increased aeration of the disturbed half of the grave, a factor that has been documented to contribute to a faster rate of decomposition (9). It would also allow moisture to penetrate deeper than in the compacted soil. Additionally, as discussed further in Chapter 4, three temperature probes were placed 5.0 cm below the soil surface at various locations to record hourly temperature. One of the probes was unearthed three times to check if it was still recording. This probe, which was redeposited exactly as it was buried initially, recorded far greater daily fluctuations in temperature than did the undisturbed probes. This suggests that the disturbed soil over pigs 5, 6, and 7 would have subjected the bodies to greater temperature fluctuations and a reduced insulating barrier. This may have resulted in a more accelerated rate of decomposition due to warmer temperatures gained during the spring thaw and throughout the summer. Unfortunately, temperature probes were not placed in contact with pigs 5, 6, and 7, so this statement cannot be fully confirmed.

Fourth, as was mentioned earlier, the grave fill consisted of Eluviated Black Chernozemic soil, which was clay-like, chunky, heavy, and adhesive. This soil was difficult to remove and clean from the bodies properly. Despite careful excavation techniques, some damage was still sustained by the remains. This primarily involved skin and fat being torn off along with soil due to how the soil adhered to the bodies. This resulted in unintentional muscle, rib, and intestinal content exposure. Such situations occurred to a minor degree during the first exposure, but at a significantly higher rate during the second exposure. This allowed tissues that would have remained covered by overlying skin and fat to be exposed to air for a short period of time, followed by direct contact with soil upon reburial, thus promoting further decomposition of deeper layers.

Lastly, as the bodies were uncovered they were briefly exposed to the warmer ambient air temperature. Air temperature at the time of exposure (12:00 pm) on May 9, 2009 was 12.4 °C, and at the same time at second exposure on June 27, 2009 was 18.7 °C. Temperature probes 4 and 5, which were situated between the bodies within the center of the grave, recorded temperatures of 9.0-9.5 °C on May 9 at midday, but unfortunately had failed by the time of the second exposure. This represents a ~3.0 °C temperature rise experienced by the exposed bodies at the time of the first exposure. It is well known that higher ambient temperatures lead to quicker rates of decomposition (6,8,10), primarily due to increased insect and bacterial activity at higher temperatures, as well as an increase in the velocity of chemical reactions associated with decomposition (11). However, due to the short time of exposure (~2 hours) preventing insect establishment and any macroscopically observable increases in decomposition rate, it is interpreted that exposure to warmer ambient air temperature had little impact on the final condition of the disturbed/exposed bodies.

Air exposure and subsequent moisture loss, and reduced soil compaction, both contributed to increased aeration and temperature fluctuations experienced by the disturbed bodies. Additionally, excavation damage, due to soil conditions, resulted in exposure of deeper tissues. It is concluded that these are the primary causes of the more advanced stage of decomposition seen in the disturbed/ exposed bodies than in the undisturbed/unexposed bodies.

Adlam and Simmons (5) performed an experiment, using rabbit carcasses, which investigated the effects of disturbance caused by taphonomic data collection on decomposition and its marker variables (weight loss and carcass temperature). Their goal was to see if necessary and unavoidable disturbance caused by data collection throughout the duration of a taphonomic experiment actually created false data and disrupted the process. The experiment concerned surface remains, not burials. The authors found that repeated disturbance significantly affected weight loss rate and carcass temperature, but did not significantly affect overall decomposition. They suggested that repeated physical disturbance caused disruption of normal insect activity. In contrast, concerning this current experiment, it was observed that disturbance did significantly affect overall decomposition. It appears that buried remains are affected by disturbance and exposure to a greater degree than surface remains, and that factors other than insects are involved. This must be kept in mind when evaluating past taphonomic research involving burials and necessary disturbance.

Wilson and colleagues (17) performed research on changes to the grave microenvironment due to the presence of a decomposing body in three contrasting field sites. The authors suggest that disturbance to the grave in order to make scientific observations would be associated with significant alterations in the microbiology, chemistry/redox, and thermodynamics of the involved microenvironment. They propose that this would result in accelerated decomposition and would encourage scavenger activity. The research presented in this thesis did not investigate these micro factors, with the exception of thermodynamics which will be presented in Chapter 4, and thus legitimate comments on these findings cannot be made; however, observations are consistent with an altered grave microenvironment and a resultant accelerated rate of decomposition.

The information gained from this experiment shows that disturbance/ exposure of a body or bodies buried within a grave can significantly alter their rate of decomposition. Applying this knowledge would be important during mass grave exhumation planning, and when investigators in the real world attempt to make determinations of time since death and/or burial of individuals in a mass grave. Remains within a disturbed grave would appear to be in a more advanced stage of decomposition than would be expected given the time frame. As listed previously, mass graves may be disturbed for a variety of reasons including clandestine destruction or removal of physical evidence, family members seeking the recovery of remains of loved ones, body trading, or mandated wartime exhumations (3,4). In many instances the remains within mass graves are exhumed haphazardly and incompletely. Graves in Iraq have been disturbed in such a manner as family members attempted to recover remains of their loved ones (4,12,13). Secondary mass graves are those that hold bodies of victims originally interred in primary graves (14). The bodies have been moved from one grave to another, usually clandestinely, in an attempt to destroy or hide evidence. Heavy machinery is often used and subsequently the remains within secondary graves are typically severely disarticulated and commingled. Many of the graves containing victims of the Srebrenica massacre of 1995 in Bosnia were moved to secondary graves (15,16). Clearly the observations obtained during this experiment are not applicable to instances of such extensive disturbance, but they highlight the importance of recognizing when a mass grave has been tampered with. Skinner and colleagues (3) report on a scenario more akin to the EMG scenario in which graves in a Croatian cemetery were opened and remains exposed, but not moved, by family members to verify identification. The bodies had been buried without family members present and without formal rites. Such a situation would involve exposure but not removal of the remains, as in the experiment presented, and would likely have affected decomposition to some extent.

3.5 - Conclusion

Air exposure and subsequent moisture loss, reduced soil compaction, and excavation damage are seen as important and linked factors acting on a disturbed/ exposed buried body. These factors will subsequently accelerate the rate of decomposition, as was observed in this experiment in which disturbed remains were significantly more decomposed than undisturbed remains. This information is absolutely critical to consider when planning mass grave exhumations, when estimating time since death and/or burial of victims within disturbed mass graves, and when evaluating past taphonomic research.

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CHAPTER 4 – TEMPERATURE PROFILES OF A DECOMPOSING LOW-DENSITY BODY MASS VERSUS A SINGLE BODY

4.1 - Introduction

Temperature is the most important factor determining the rate of decomposition by influencing the dwell-time a body stays in a particular decompositional stage and the overall velocity of the process (1-4). Three major variables are dependent on temperature: action of intracellular enzymes, bacterial growth, and insect presence and development. The temperature that a body or group of bodies is exposed to as they decompose is dependent on region and climate, and placement of the body (indoors, outdoors, surface, burial, depth of burial, etc.). During forensic investigations, temperature data, including weather data, ambient temperature, and body temperature, is used primarily to determine time since death by estimating rate of decomposition dependent on the previously mentioned variables (2,5).

Living chemistry in humans occurs at 37.0 °C and in pigs at 38.8 °C (6), and cooling or heating a body above or below this value slows or speeds cell metabolism by effecting enzymes that regulate reactions (1). It has been observed that each 10.0 °C increase or decrease will speed or slow these reactions by about one to three times. Autolysis, the process of self-destruction of living and dead cells by enzymatic self-digestion that occurs during decomposition, is dependent on temperature.

Bacterial growth and reproduction is also directly dependent on temperature (7,8). At temperatures below 12.0 °C bacterial growth is severely retarded, and at temperatures between 0.0 °C and 5.0 °C bacterial division stops entirely and the time required for a single cell to divide approaches infinity. Therefore, 4.0 °C is seen as the low temperature threshold of bacterial growth. Bacterial-induced decomposition, known as putrefaction, primarily occurs, and is most rapid in its development, between 15.0 °C and 37.0/38.8 °C (body temperature in humans and pigs). With an increase of only a few degrees above 37.0/38.8 °C the time required for bacterial cell division to occur rapidly approaches infinity.

Forensic entomology is the study of insects and their associations with cadavers, and has the primary goal of estimating time since death (5,7,9). This is done by studying and collecting insects associated with a recovered body. The insects are analyzed for type/species and stage of development. Since developmental rates and timing are known for many species of necrophagous insects, an estimate of the time since death can be made. During such analysis the temperature of a body prior to discovery must be predicted in order to determine the postmortem interval using maggot developmental rates. This is usually achieved by comparing ambient or soil temperature data taken at the scene to a nearby weather station. If there is a good correlation then weather station data can be used to predict past temperatures at the scene. Temperature influences insect activity and developmental rate (7), with warmer temperatures increasing the number and type of carrion insects as well as the rate of decomposition of the body due to increased insect activity.

The focus of this study is a low-density, orderly placement body mass buried 30 cm below the surface in the Edmonton, Alberta region. Relevant detailed geographic and climatic data is presented in Chapter 1. Burials themselves present unique microenvironments that differ greatly from conditions on the surface. Soil creates an efficient barrier to solar radiation, and in the summer, temperature and temperature fluctuations, both of which are major factors of decomposition, decrease with increased depth of burial (3,10). In the winter, soil and snow create insulation, and temperature increases as depth increases, to a certain point. Temperature fluctuations behave the same in winter as they do in summer.

Body temperature has been observed to rise above, spike, and eventually become equilibrated with the soil or ambient temperature during the decomposition process, primarily at the decay stages, and in both buried (10,11) and surface (9) contexts. The goal of this section of the thesis is to compare temperature data collected with temperature probes of a single buried decomposing body to a low-density mass burial. The following questions will be addressed:

- What can the collected temperature data tell us regarding the insulating properties of soil and snow in the Edmonton region?
- What differences in temperature profiles are there between bodies decomposing in a mass and a single body?

Answers to these questions will provide a greater understanding of the burial environment in the Edmonton region, and will allow investigators to have more confidence when interpreting elapsed time since death and/or burial, or evaluating circumstances of burial disturbance.

4.2 - Materials and Methods

Details regarding the burial site, grave features, and bodies are presented in Chapter 1. At the time of burial on November 20, 2008 (day 0) eight temperature probes were placed throughout the grave site and in various positions contacting the pig cadavers. These probes were EL-USB-1 Temperature Data Loggers manufactured by Lascar Electronics. It is realized that there are more advanced methods available for gathering temperature data; however, the intentions here were exploratory, and data recovered was valuable. The loggers have various timing options, and for this experiment they were programmed to record a reading every hour. Prior to the experiment the probes were tested for individual accuracy and group consistency, and were found to vary by no more than 0.5 °C, an occurrence which took place rarely.

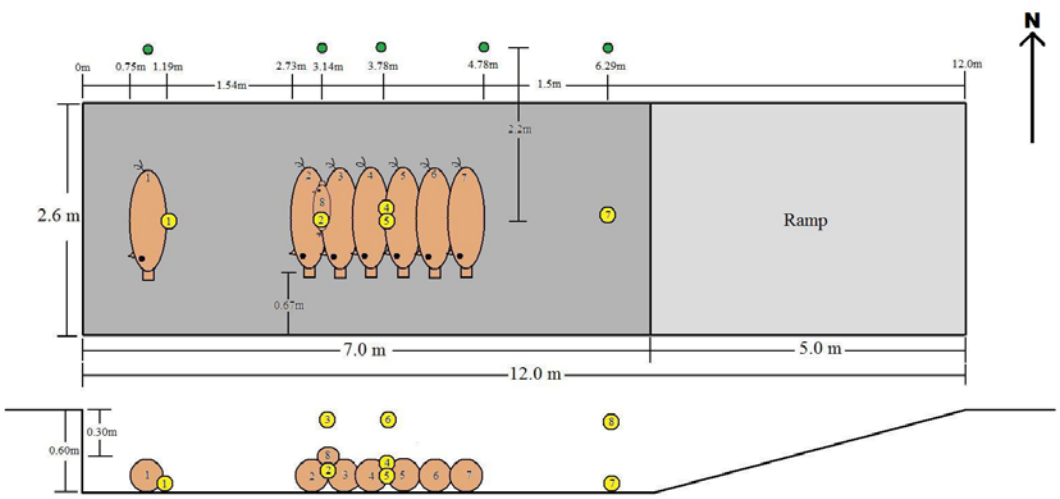


Figure 4-1 – Grave layout. Yellow circles indicate temperature probes and are numbered. See Appendix B for larger figure.

Table 4-1 – Positions of temperature probes throughout the grave

Probe Number	Position
1	On the grave floor at 60 cm depth, in contact with the belly of pig 1
2	Between pigs 2 and 3 and in contact with them, beneath pig 8, approx. 50 cm below surface
3	5.0 cm below the surface, above the position of pig 8
4	Between pigs 4 and 5 and in contact with them, approx. 50 cm below surface
5	Between pigs 4 and 5 and in contact with them, approx. 50 cm below surface
6	5.0 cm below the surface, above the center of the body mass
7	On grave floor, 60 cm depth, 1.5 m east of the edge of the pig mass
8	5.0 cm below the surface, above the position of probe 7

Probes were activated at 00:00 on November 20, 2008 (day 0). They were double bagged in small Ziploc bags and a piece of orange flagging tape was tied around each one to aid in relocation. All probes, with the exception of probe 8, were left untouched for the duration of the experiment. Probe 8 was checked on January 1, 2009 (day 42), and at the two instances of partial exposure on May 9, 2009 (day 170), and June 27, 2009 (day 219). It was observed to still be recording on all three instances. All probes were recovered at final exposure. Probes 1, 3, 4, 5, 6, 7, and 8 were recovered on September 12, 2009 (day 296), and probe 2 on September 13, 2009 (day 297). Data was downloaded on the evening of September 13, 2009.

4.3 - Results

All probes except probes 7 and 8 had failed by the time of recovery. Battery depletion accounts for all failures. Due to being out of the ground for most of day 296 and 297, data for these dates on probe 7 and 8 was deleted. Similarly, the probes were placed in the ground at approximately 16:00 on November 20, 2008, therefore data collected before this was deleted on all probes. A summary chart of the probes and their readings is presented below.

Table 4-2 – Summary of temperature probe readings

Probe Number	Date and Time Began	Date and Time Failed or Stopped	Number of Readings
1	20/11/2008 – 00:00	17/06/2009 – 18:00	5035
2	20/11/2008 – 00:00	12/04/2009 – 12:00	3445
3	20/11/2008 – 00:00	20/07/2009 – 19:00	5829
4	20/11/2008 – 00:00	06/06/2009 – 21:00	4774
5	20/11/2008 – 00:00	19/05/2009 – 12:00	4333
6	20/11/2008 – 00:00	10/07/2009 – 2:00	5517
7	20/11/2008 – 00:00	13/09/2009 – 18:00	7147
8	20/11/2008 – 00:00	13/09/2009 – 18:00	7147

To demonstrate the insulating properties of soil, probe 7, which was buried separate from the cadavers but at the same depth (60 cm), is compared with ambient air temperature collected by the weather station at the Ellerslie Research Station, see Figure 4-2. The weather station is located approximately 500 m from the grave site, at similar elevation, and with similar sun and wind exposure characteristics. The ambient air temperature was observed to fluctuate daily and hourly, while the soil temperature did not. Most striking is the thermal stabilization reached by probe 7 during the winter months that was much warmer than the fluctuating ambient air temperature. Probe 7 never got below -3.0 °C, while temperatures recorded outside reached as low as the negative thirties. As temperatures warmed in the spring and summer, probe 7 appeared to have recorded temperatures similar to the average ambient temperature trend recorded by the weather station. This implies that while daily temperature fluctuations decrease with depth, overall fluctuations with season still occur.

Figure 4-2 - Temperature fluctuations in air and soil

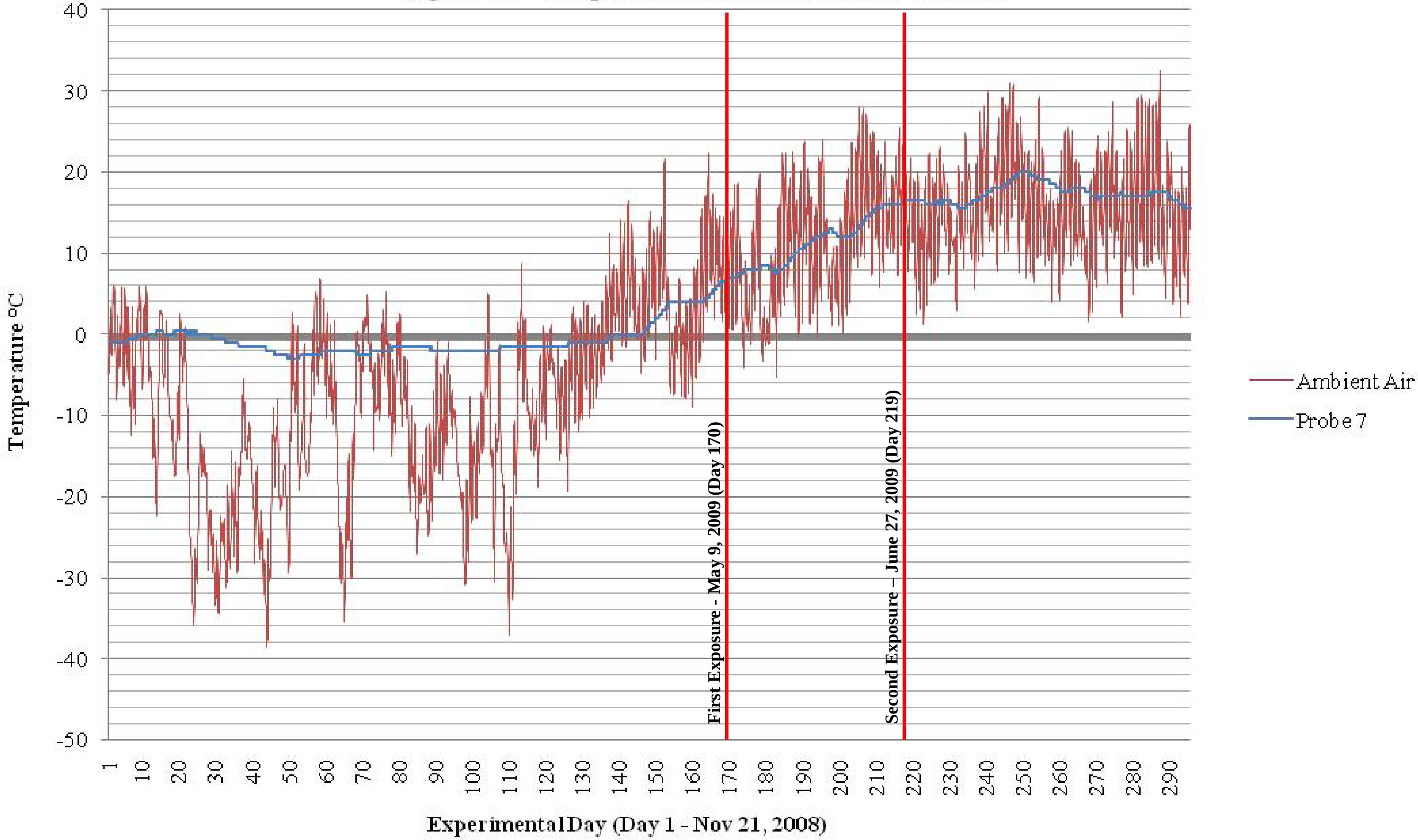


Figure 4-3 displays the readings of probes 3, 6, and 8, as well as ambient air temperature recorded by the weather station. These probes were all placed just below the surface at a depth of approximately 5.0 cm. Probes 3 and 6 failed before the experiment finished. The intention was to see if heat released by the body mass as it decomposed would rise to the surface and be recordable. This was not observed, and all three probes had similar average readings, as demonstrated by linear regression lines. Also, it is clear that probe 8 was subjected to daily temperature fluctuations to a greater degree than probes 3 and 6. This observation is investigated further in the discussion section. The ambient air temperature, when compared to probes 3 and 6, fluctuated much more strongly, indicating that even 5.0 cm of soil will provide some insulation against hourly and daily temperature fluctuations. During the spring and summer months the temperature of soil at 5.0 cm was recorded as slightly higher than ambient.

Figure 4-3 - Temperature fluctuations at 5 cm depth

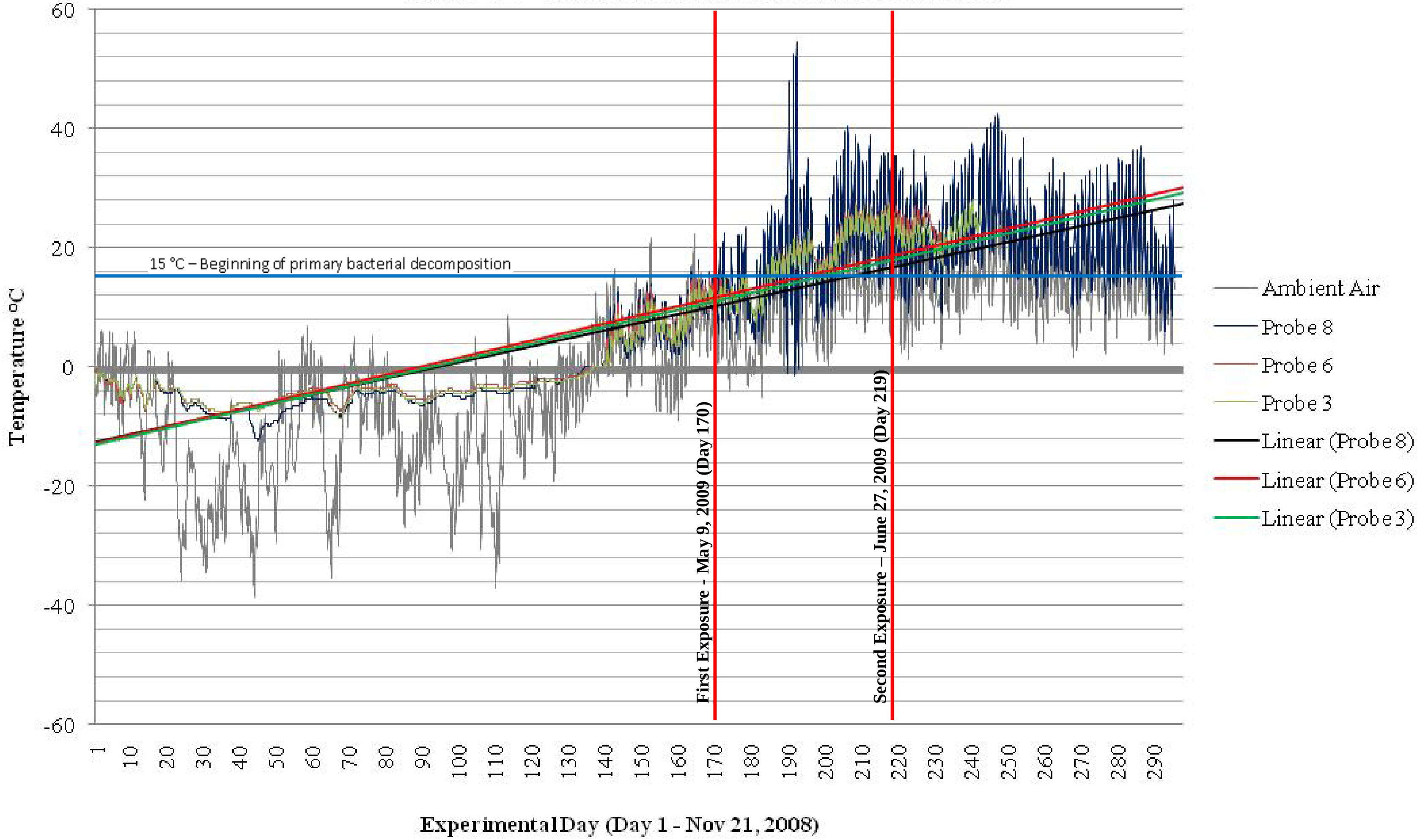
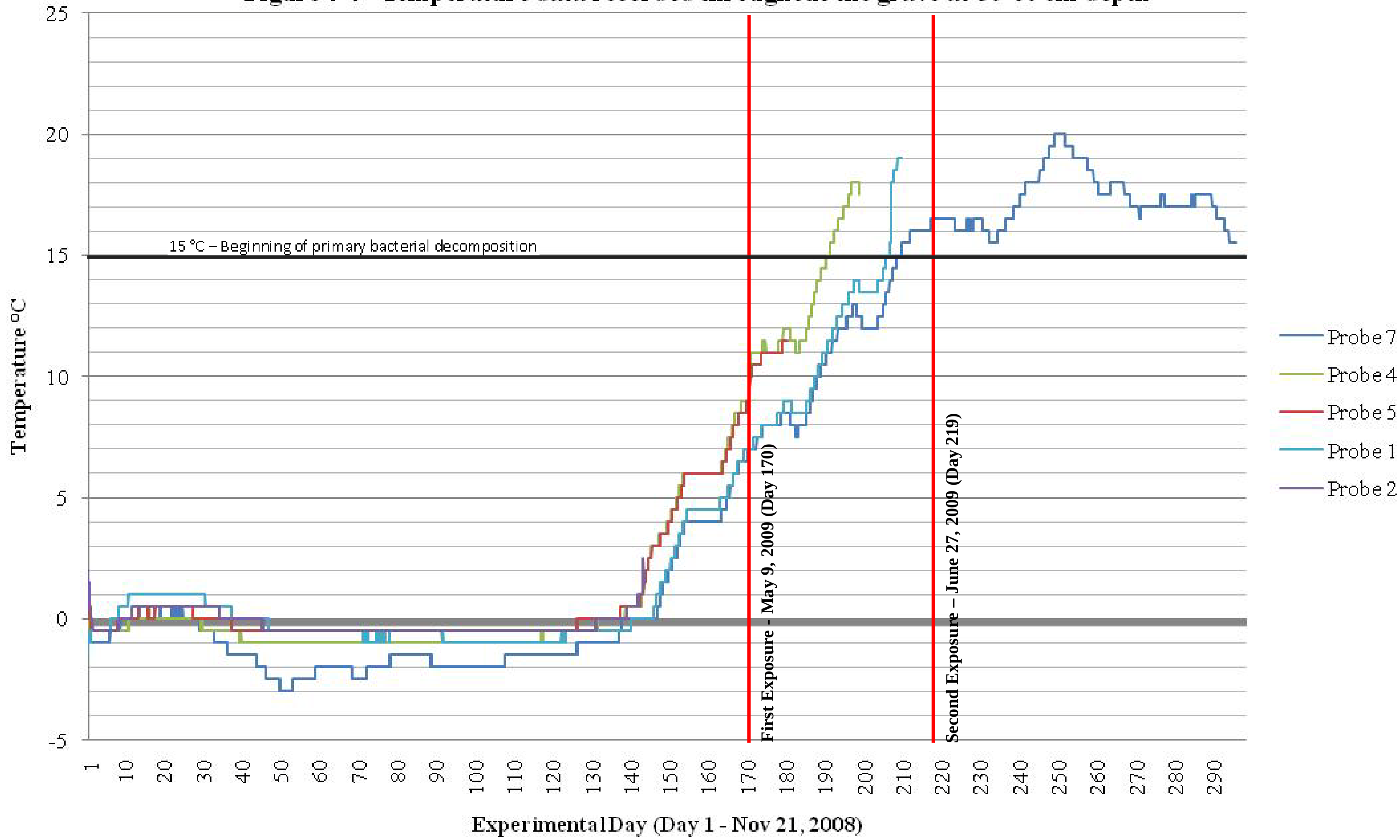


Figure 4-4 details the five probes that were buried between 50 and 60 cm and were in contact with the bodies. Throughout the duration of the experiment daily fluctuations in temperature were minimal, less than those observed by probes 3, 6, and 8, which were placed only 5.0 cm below the surface (see Figure 4-3). During the winter months all probes showed thermal stabilization just below 0.0 °C, with probe 7 being slightly cooler. All probes also recorded a few degrees increase in temperature between approximately days 10 and 40. Around day 140, in April, temperatures within the grave began to rise. Probe 2 failed around this time. As time progressed the four remaining probes maintained their relationships to each other. Probe 7, soil temperature, was the coolest. Probe 1, in contact with pig 1, was only a degree or so warmer than probe 7 until just before it failed, when it rose above probe 7 by 4.0 °C. Probes 4 and 5, which were in the center of the mass, were consistently a few degrees warmer than the other two probes. The maximum difference between probe 4 and probe 1 was 4.0 °C, and between probe 4 and probe 7 was 5.0 °C. Unfortunately probes 1, 4, and 5 all failed around the time they were reaching optimal decomposition temperatures. Probe 7 ran the entire experiment.

Figure 4-4 - Temperature data recorded throughout the grave at 50-60 cm depth



4.4 - Discussion

This discussion will focus on two topics relating to the temperature data which was collected by the eight probes throughout the duration of the experiment. First the insulating properties of soil and snow in the Edmonton region will be investigated, and second the differences between temperature profiles of decomposing single burials and decomposing low-density, orderly placement mass graves will be examined.

4.4.1 - Insulating Properties of Soil and Snow

Temperature data collected throughout the experiment revealed some interesting information regarding the insulating properties of the Eluviated Black Chernozemic soil present in the Edmonton region, as well as that of snow. While this is not the focus of the experiment presented here, it does relate to temperatures experienced by the buried cadavers, and thus influences the rate of decomposition.

Rodriguez (3) states that in soil, thermal stabilization generally occurs at depths greater than 60 cm, and at such depths there are no significant temperature fluctuations other than according to season. While the top surfaces of the experimental bodies were 30 cm below the surface, thermal stabilization was still observed via temperature probes at 50 – 60 cm depth. Hourly temperatures recorded by the eight probes were dependent on season and burial depth. During the winter months all probes experienced thermal stabilization, with those probes deeper and in contact with the bodies being more steady and slightly warmer than those placed 5.0 cm below the surface. It is hypothesized that this is due to the presence of at least 30 cm of snow over the grave site during the winter months. The snow provided added insulation for both the deep and shallow probes, therefore allowing them to reach thermal stabilization. During the spring and summer months, temperatures began to warm and all probes began recording warmer temperatures. The temperature of soil at 60 cm was near to the average overall trend of the ambient temperature, while the temperature of soil at 5.0 cm was recorded as slightly higher than ambient. This is likely due to direct sunlight contacting the dark coloured soil 5.0 cm above the probes, and warming them to a temperature higher than that of the air.

Daily fluctuation in temperature was also affected by season and burial depth. Probes that were located between 50 and 60 cm of depth did not fluctuate at all with daily temperature. At such depths the Eluviated Black Chernozemic soil provided ample insulation to prevent daily fluctuation. Seasonal fluctuation was seen in these probes, but interesting differences were observed between winter and summer. Winter temperatures did not dip below -5.0 °C, despite ambient air temperature averaging far below this. Summer temperatures recorded near to the average overall trend of ambient air temperature. This is again likely due to the covering of snow over the grave during the winter months, adding to the overall insulation. Winter conditions of a covering of soil and snow appear to provide a stronger insulting barrier to cold than only soil does to heat during the summer. Slight daily fluctuation was seen in probes that were 5.0 cm below the surface. This was minimal during the winter months, again, likely due to the snow covering, and increased to about a 2.0 °C daily fluctuation during the spring and summer. Overall, the Eluviated Black Chernozemic soil in combination with snow provides an effective insulation to winter temperatures, even at depths as shallow as 5.0 cm below the surface. At depths of 50-60 cm fluctuation in temperature is experienced seasonally, not daily.

An additional aspect of soil insulation was revealed by probe 8, and the fact that it was unearthed three times in order to check its status. This occurred on January 1, 2009 (day 42), and at the two instances of partial exposure on May 9, 2009 (day 170), and June 27, 2009 (day 219). After probe 8 was redeposited it was observed to record daily temperature fluctuations to a far greater degree than probes 3 or 6, which were undisturbed. Despite the fact that the probe was only out of the ground for a matter of minutes and was redeposited in the exact manner in which it was buried, disruption clearly changed the microenvironment and broke the insulating barrier of the soil. Examination of Figure 4-3 reveals a deviation after day 42 when the probe was first checked. After day 170 (first exposure) fluctuations recorded by probe 8 were far stronger than probes 3 and 6. This data demonstrates the insulating properties of undisturbed soil. It also implies, as discussed in Chapter 3, that the pig cadavers that were exposed twice may have been subjected to greater temperature fluctuations than the unexposed bodies, due to the disturbed soil above them. This likely resulted in a more accelerated rate of decomposition due to the warmer temperatures experienced.

4.4.2 - Temperature Profiles of a Single Decomposing Body vs. a Low-Density Mass

The overall goal of this section is to compare the temperature profile of a decomposing buried single carcass to that of a buried low-density mass of carcasses. Temperature probes have been used in multiple experiments in the past involving buried (5,10-12) and surface (9) remains with the goal of gaining an understanding of the heat released by a decomposing body. A study performed by Rodriguez and Bass (11) at the University of Tennessee involving experiments with buried human cadavers at various depths showed significant temperature increases above that of soil as the bodies decomposed. This increase over soil temperature occurred mainly during the decay stages and would last a number of weeks depending on burial depth. Body temperature would then gradually equilibrate with soil temperature. The degree of temperature difference between the body and the soil was directly correlated with burial depth; at 1.2 m they found a mean temperature differential of 3.4 °C over the soil, at 60 cm it was 5.0 °C, and at 30 cm it was 7.0-10.0 °C. Such results have not been replicated to the same exactness by subsequent research. Wilson and colleagues (10), performing experiments near West Yorkshire UK, did observe that pig decomposition raised the temperature of the burial microenvironment relative to similar control pits, but these differences were only a few degrees higher than soil during the summer and negligible during winter. They observed much smaller temperature changes which may indicate less seasonal fluctuation in the UK. In research conducted in south-western British Columbia, VanLaerhoven and Anderson (5) did not observe temperature spikes above soil in decomposing buried pigs; however, above-ground carcasses did show a spike (9). Clearly, climatic, geographical, and soil differences had some bearing on results. The aim of this experiment is to examine temperature differences such as these, and to see if a low-density mass of bodies will generate more heat than a single body.

Figure 4-4 displays the results of the four probes that were in contact with the pig carcasses (probes 1, 2, 4, and 5) as well as the probe which recorded soil temperature (probe 7). It can be seen that during the winter months all the pig-contacting probes recorded more steady temperatures than the soil probe, and that their recordings were a few degrees warmer. It would appear as though being in contact with a carcass provided a small measure of insulation from cooler soil temperatures and allowed measurement of any heat which was generated by minimal decomposition. It is not clear as to why all probes recorded a small (1-2 degree) rise and fall in temperature between days 10 and 40. This does not correlate with ambient air temperature and was not recorded by the probes 5.0 cm below the surface. A possible explanation is movement and release of trapped gasses within the soil and bodies in relation to the probes. Temperatures below the ground remained at or below 0.0 °C until approximately day 140, in early April. Before this time it is determined that the pigs were frozen under the ground, having spent the winter in this state. Probe 2 failed at this time.

As the spring thaw took place and temperatures rose, the soil probe (probe 7) and the single pig probe (probe 1) recorded similar temperatures that were consistently 1-2 degrees cooler than the probes placed in the center of the body mass (probes 4 and 5). Probes 4 and 5 reached 4.0 °C at ~day 150 and probes 1 and 7 reached this about a week later. Four degrees Celsius is seen as the low temperature threshold for bacterial growth (8), although such growth is severely retarded. It is from this point on that decomposition likely took place, although greatly impeded at first. At the time of first exposure on May 9, 2009 (day 170) temperatures within the grave measured just below 10.0 °C, which makes sense given the minimal decomposition observed. Probe 4 (probe 5 failed at ~day 180) reached 15.0 °C at ~day 190 while probes 1 and 7 didn't reach this temperature until ~20 days later. Between 15.0 and 37.0/38.8 °C bacterial induced decomposition occurs most efficiently. Autolysis will still be greatly impeded at the lower end of this spectrum. It is interesting to note that the difference between the temperatures recorded by probe 4 (mass) and probe 7 (soil) begins to increase once above 15.0 °C, and that probe 1 (single) begins to rise dramatically above probe 7 at this point as well. Unfortunately, probes 5 and 1 failed at this time, in the month of June.

A number of valuable statements can be made as a result of the collected temperature data. Firstly, we see that the pigs didn't begin to decompose in earnest until ~day 150 at the earliest, or half way through the entire experiment. Similar to what was observed by Wilson and colleagues (10), differences between body and soil temperatures were negligible during the winter months, but this makes sense since no decomposition was occurring. Differences appeared once temperatures rose and decomposition began. The few degree elevation of body mass temperature above that of the single body and soil indicates that the body mass likely began decomposing at accelerated rates about 20 days before the single body. Over time this early start, as well as the slightly elevated rates of bacterial decomposition and autolysis brought on by slightly warmer temperatures, may have contributed to the more advanced state of decomposition seen in the body mass relative to the single body at the time of final exposure.

Had the trend continued once the probes failed it is hypothesized that temperatures of both the body mass and single body would have climbed significantly higher than soil temperature, peaked, and eventually dropped back to soil temperature, although not before this experiment was terminated based on the states of decomposition observed at final exposure. Also, it is hypothesized that the body mass would have maintained a slightly higher temperature than the single body. It is unfortunate that most of the probes did not survive the length of the experiment.

4.5 - Conclusion

Temperature is the most important factor determining rate of decomposition due to its influence on three variables: action of intracellular enzymes, bacterial growth, and insect presence and development. Temperature data collected in this experiment suggests that at the point when probes 1 and 4 failed (~day 200 in spring), the rate of autolysis would still have been reduced three to six times relative to normal rates. Autolysis is greatly impeded by the relatively cold temperatures experienced by buried cadavers throughout the year in the Edmonton region. Bacterial growth and induced decomposition was also greatly retarded by the low temperatures experienced during the winter. Not until day 150 in mid-April (at about 5 months/half-way through the experiment), could bacterial action even begin to take place, and not until 40-50 days later could it begin to reach prime levels. This implies that a body or bodies buried during the winter in the Edmonton region will not begin to decompose in earnest until June, or ~2 months after the spring thaw begins. It is hypothesized that during the summer the greatest temperature differences between decomposing bodies and soil, as well as between a body mass and a single body, would be seen. The presence and action of insects was of no impact throughout this experiment, as burial conditions prevented their accessing the body.

Data collected by temperature probes proved that 30 cm of Eluviated Black Chernozemic soil covering, along with snow in the winter months, prevented daily fluctuation in temperature experienced by the buried carcasses. Thermal stabilization was obtained at 50 cm depth in these conditions. Collected data also suggests objects buried below disturbed soil will experience greater fluctuations in daily temperature. While it was not the focus of this experiment, it is concluded that more attention should be given to soil thermodynamics and insulation, and the interaction of these phenomena with a decomposing buried body or body mass, in future research of this nature.

The collected temperature data strongly suggests that collections of bodies arranged in an orderly placement manner will generate more heat than a single body under the same conditions, and thus the processes of decomposition will occur faster. This conclusion differs from real world observations by Haglund (13) and Mant (14,15), and suggests that orderly placement mass graves decompose differently than erratically commingled mass graves. The authors observed that in an erratically commingled mass grave, core bodies (those surrounded by other bodies) will be more preserved than peripheral bodies (those maintaining an interface between soil and other bodies), which in turn will be more preserved than satellite (separate) bodies. While the exact dynamics of heat and decomposition in such a situation has not been experimentally researched or published, one would intuitively assume that more heat would be generated inside the body mass; however, according to real world observations, this does not result in accelerated decomposition. It appears as though the interaction of peripheral bodies with soil (the presence of a soil-body interface) accelerates decomposition to a greater degree than does the possible higher temperatures experienced by core bodies. Such assumptions may not be true and other factors and dynamics may be at work; therefore, further research is warranted.

Mass graves in the real world have been known to contain tens to hundreds of bodies (16,17), and probably thousands (18). On such a scale the heat generated may be significantly higher than that generated by a single burial, resulting in a substantially accelerated rate of decomposition. Such information could be used to estimate the possible state of decomposition bodies within a mass grave may be in, and would be useful to those planning mass grave exhumations and investigations. Bodies may be more decomposed than expected given the time period.

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CHAPTER 5 – SUMMARY AND CONCLUSION

This final section of the thesis presents a holistic discussion pertaining to the topic of taphonomy of low-density, orderly placement mass graves and what was observed during this experimental study. The results of this research are evaluated, and are analyzed in relation to other taphonomic experiments and real life observations of single and multiple burials, taking into account geographic and climatic similarities and differences. The following questions will be discussed:

- Can the collected data/results/observations be applied to the real world during investigations of mass graves, and if so, how?
- What is the value of doing this research with a small, low-density, orderly placement mass grave?
- Are the data/results/observations useful in other geographical areas?
- Can the data/results/observations be applied to mass graves of a larger scale or different type?
- How do the data/results/observations compare to previous research done in the Edmonton area?
- What form should the direction of future research on this topic take?

5.1 - An Evaluation of Results and Observations and Their Use in the Real World

The low-density EMG was created to investigate decomposition of bodies in contact with one another, and how this differs from a single body buried in the same environment. This section will relate what was observed to the possibility of using this information in the real world. At this point it must be clarified that this was the first experimental study investigating this topic, and as such all holistic statements require further peer investigation and research to justify them. Also, as with all taphonomic experiments, results and observations are restricted to the geographical region in which the experiment took place, or regions with similar climate, soil conditions, etc. This issue will be examined in a later sub-section.

By utilizing physical observations and temperature data an understanding of decomposition processes and rates of a low-density, orderly placement mass grave in a northern continental climate was gained. There are three primary avenues in which the information obtained can be applied to the real world: estimation of elapsed time since death and/or burial in a mass grave scenario, planning mass grave investigations and reducing the loss of evidence, and evaluating post-burial disturbance or intentional vandalism. These relate in some way to four of the five primary goals of forensic taphonomy presented in Chapter 1.

Estimating elapsed time since death and/or burial from human remains in a mass grave scenario can be an important undertaking when corroborating witness testimony, or when defining a specific grave from a specific event based on other evidence. The goal is to match the grave under investigation to a specific event that took place at a certain time. To do this an understanding of processes and rates of decomposition must be known. A number of observations were made during this experiment that could contribute to such an undertaking. Firstly, the effects of a winter freeze were clearly demonstrated. Visual observations and temperature data established that zero, or an extremely small amount of, decomposition took place in the first ~150 days of burial. This time ran from late-November to mid-April when the bodies and ground were indeed frozen. Also, it was observed that decomposition did not begin in earnest until ~2 months after the beginning of the spring thaw. The presence and length of a winter freeze and spring thaw must be acknowledged and taken into account during investigations in regions in which this takes place. Secondly, bodies in a mass may be more decomposed than expected given past observations of single burials and comparative elapsed time. Visual observations suggest that an orderly placement body mass will decompose slightly faster than a single body. Despite the small size and orderly placement layout of the EMG, a more advanced overall state of decomposition was observed in the body mass than in the single control burial. Temperature data also revealed more heat being produced by the decomposing body mass, which likely translates into an earlier beginning of, and more accelerate rate of, decomposition. Also, in real world mass grave scenarios it is possible for satellite/single remains to exist. These are remains which represent victims from the same event that were buried at the same time, but are not in contact with the main body mass. Observations from this experiment suggest that such remains will be less decomposed than an orderly placement body mass. It must be appreciated that two sets of remains, particularly a single and a mass, buried within the same grave can exhibit two distinct stages of decomposition but can represent victims from the same event and have the same time since death and/or burial. Thirdly, insect presence and development is often used to determine time since death; however, this was not possible in the EMG since conditions prevented insects from coming in contact with the carcasses. This also caused a reduced rate of decomposition due to the absence of a major contributing factor. Under similar conditions insect absence may occur in the real world. Lastly, overall it would appear as though bodies, a low-density mass or single, buried 30 cm below the surface in the Edmonton region will not fully skeletonize within one year or one full cycle of seasons. It will take longer than this. The research presented here helps to define factors that must be considered when estimating elapsed time since death and/or burial of real world mass graves in similar geographical and climatic regions.

Planning mass grave investigation is an intense and complex undertaking, and needs to be done efficiently, competently, and in a controlled manner (1-3). Of concern here is planning of the excavation of the grave, exhumation of the bodies, collection of evidence, and analysis of what is recovered. Observations and results obtained in this experiment can give investigators an idea of what to expect given a certain time frame. This would be helpful in instances where a grave is known to contain bodies from a certain incident which occurred a known length of time in the past. This is similar to what was discussed in the previous paragraph only the reverse is true and the state of the bodies must be estimated based on elapsed time. Observations obtained throughout this experiment showed that in similar scenarios and regions winter freezes will halt decomposition, low-density, orderly placement mass graves will take over a year to skeletonize, decomposition takes place at a reduced rate during the spring thaw, a row of contacting bodies may decompose faster than a single body, disarticulation can take place in as little as 2 months or as long as 8 months depending on the winter freeze, trauma experienced near the time of burial may be difficult to observe superficially when exhuming, and insects may play no role in decomposition. Knowing this, the state of decomposition or extent of skeletonization and disarticulation of remains held within a grave can be estimated. This is important when planning the personnel make-up of an investigatory team (number of anthropologists vs. number of pathologists), when evaluating health concerns such as possibility of disease transmission (3), when obtaining required equipment, and when estimating the amount of time it will take to complete the investigation of the grave. Whether remains are mostly fleshed, partly fleshed, fully skeletonized, or commingled will affect all the previous decisions. Also, competent planning will ultimately result in more efficient evidence collection and a reduction in the loss of evidence, which, clearly, is of upmost importance.

Intentional exposure, disturbance, or vandalism of the bodies within a mass grave, or of the mass grave itself, is an important and relevant problem experienced by investigators in the real world (3-7). Such disturbance may occur for a variety of reasons including clandestine destruction or removal of physical evidence with intention to destroy or hide said evidence, family members seeking the recovery of remains of loved ones, body trading, or mandated wartime exhumations. This experiment provided ample evidence that disturbance, in this case, two instances of two hours exposure during the spring and summer months, can significantly affect the decomposition process of buried remains. At the time of final exposure it was observed that the half of the row of bodies which was exposed twice previously was significantly more skeletonized than the unexposed half, particularly the heads and rumps. Temperature probes revealed greater daily fluctuations in a probe that was unearthed and reburied. While there is an abundance of other evidence that will help to identify a disturbed or secondary mass grave, it must be kept in mind that remains within such graves will probably not decompose as expected, and will likely be disarticulated or skeletonized to a greater degree (8). This prediction relates to the above two topics of estimating time since death and/or burial, and mass grave investigation planning. Also, this information may lead us to question the reliability of past taphonomic experiments in which disturbance is necessary during the data collection process.

5.2 - The Value of Taphonomic Research of a Small, Low-Density, Orderly Placement Mass Grave

When discussing mass graves one is inclined to think on the scale of hundreds of victims, a reality which is all too true; however, mass graves containing a smaller number of individuals do commonly exist. For example, in 2002 preliminary assessment of alleged mass gravesites, performed by a team representing Physicians for Human Rights (PHR), in the area of Mazar-I-Sharif, Afghanistan revealed at least two gravesites containing an estimated number of victims below ten (9). Another investigation by PHR conducted in 2007 involved a grave of eight activists in Nigeria (10). A greater understanding of how bodies within such smaller mass graves decomposed is of value, and this research is the first to investigate experimentally the issue of a grave containing multiple individuals, whatever the number. This was done due to the near logistical impossibility of creating an experimental mass grave containing hundreds of corpses, and the above mentioned reality that such small graves do exist and must be understood. This arrangement of the carcasses was chosen over an erratically commingled arrangement due to the low number of bodies (seven) being unable to make an actual body mass with a legitimate core and periphery.

A large number of people can indeed be murdered and buried in multiple and separate low-density mass graves. Haglund and Beattie (11) observed such a scenario in Somalia (Somaliland). At multiple alleged mass grave sites in the vicinity of Hargeisa in north-western Somalia numerous mounds of earth were observed, each suspected to represent a grave containing a small number of individuals. Test excavations supported this suspicion, with a total estimated number of victims being in the hundreds.

Orderly placement mass graves exist in the real world and often imply respect or care for the victims by the people carrying out the burial (12). Such a scenario may occur in instances where victims were left to be buried by survivors or loved ones, or when perpetrators force a certain group of people to bury the dead. Skinner and colleagues (6) observed such a grave at Tasovcic, Bosnia-Herzegovina. Such graves may also include victims of natural or man-made disasters who have been buried by survivors.

5.3 - Geographical and Climatic Restriction of Results

As with all taphonomic experiments, the observations and results of this thesis are ultimately restricted to similar geographical, climatic, and geological conditions. Edmonton, Alberta, Canada experiences a northern continental climate with extreme seasonal temperatures, and is situated in a gently rolling morainal plain with Eluviated Black Chernozemic soil. Highly populated areas experiencing a similar climate across the globe include: southern Canadian shield and prairie regions of Canada, the Great Lakes regions of Canada and the United States of America, some regions of Central and Eastern Europe, and Western Russia (13). Application is not, unfortunately, so simple, and many others factors such as insect diversity and species present, and soil conditions play vital roles in the decomposition process. However, interesting statements can be applied across regions. The possibility of a low-density mass grave being created in the Edmonton region or a similar region in the future is by no means an impossibility. Mass disasters, war, human rights abuses, or even serial murderers could all produce mass burials.

While Edmonton experiences extremes in winter temperatures, any area with at least a few months of winter freeze will see a decrease or halt of decomposition during this time in buried remains. Bodies buried at a depth of at least 30 cm in areas with a similar type of soil (a soil that is primarily top soil but has a fair amount of clay in it) will likely see a reduction or absence of insect activity. Regardless of where a mass grave is located, it can still be expected that an orderly placement mass grave will release and retain more heat and decompose faster than a single body in the same conditions. Similarly, disturbance or exposure of buried remains will significantly affect the decomposition process and will likely accelerate it wherever this occurs.

Interpretations based on these results must be applied with discretion, especially until further research is conducted. For example, numerous insects were collected, although no maggot masses were observed, by VanLaerhoven and Anderson (14) in experimental single burials of similar depth as the EMG in two biogeoclimatic zones in south-western British Columbia. Soil conditions and a warmer yearly average ambient temperature allowed for the access of a more diverse array of insects than is present in the Edmonton region.

5.4 - Larger Mass Graves and Erratically Commingled Mass Graves

A review of the literature quickly reveals that most publications are based on observations of erratically commingled mass graves containing hundreds of bodies. This does not mean that the majority of mass burials across the globe are of this nature, though they do attract the most attention. The value of understanding low-density, orderly placement mass graves is detailed above. Here we will examine how the results and observations obtained throughout this experiment can or cannot be applied to larger mass graves, and those of an erratically commingled nature.

Firstly, the observations obtained in this experiment can be applied to orderly placement mass graves containing any number of bodies. This is due to the fact that the bodies are contacting in a row, and the length of the row will not make a dramatic difference in decomposition between bodies in different locations within the row, excluding the two end bodies. In the EMG, no patterns were observed reflecting different decomposition rates in various locations throughout the row of bodies. It was determined that differential decomposition was due to disturbance and varying body size rather than location within the body mass.

Results of this experiment, when compared to real world observations by Haglund (11) and Mant (15,16), suggest that orderly placement mass graves decompose differently than erratically commingled mass graves. The authors observed that in an erratically commingled mass grave core bodies will be more preserved than peripheral bodies, which in turn will be more preserved than satellite (separate) bodies. There are no such distinctions, except satellite bodies, in orderly placement mass graves. Observations of the EMG show that bodies arranged in a contacting row will decompose faster than a single body, quite the opposite of what was observed by Haglund (11) and Mant (15,16). Additionally, no difference in rate of decomposition was observed based on location within the row of bodies. However, each body still appeared to decompose independently and the body mass could not be considered one big single body. A significant finding was the retention of moisture and body fluids in areas of body to body contact. This was noticeable between adjacent bodies, although these areas did not appear to be more preserved overall. They were simply moister. Significantly, this was notable in the area where the piglet had fallen between two more mature pigs and was engulfed in a mass of frothy, mousse-like broken down tissue and adipocere. Despite this, the skeleton could literally be wiped clean, and the overall state of decomposition was one of advanced decay and skeletonization. Also, when one of the pigs was flipped over it was observed that the underside of the pig was extremely moist but tissues were still in an advanced state of decay and the same areas of the skeleton that were observable on the top, cleaned side of the pig were observable on the underside. Erratically commingled mass graves would involve similar scenarios, only on a much larger scale, and would involve various other factors that are clearly unobservable in an orderly placement mass grave. The real world observations of Haglund (11) and Mant (15,16) cannot be disputed, and it is believed that they are fully accurate. It seems clear that decomposition processes differ greatly between the two types of mass graves, and that results of this experiment cannot, and should not, be applied to graves of an erratically commingled nature.

5.5 - Other Research in the Edmonton Area

It is worth comparing the current research with other taphonomic research that has been conducted in the Edmonton area. As stated before, this is the first experimental research investigating taphonomy of mass graves and the decomposition of a body mass, and as such comparisons are made to decomposition of surface and buried single bodies.

Weitzel (17) conducted experimental burials at the Ellerslie Research Station with the intention of investigating various archaeological context cemetery burial scenarios. All of her burials but one consisted of a pig carcass in a pit covered with stone slabs instead of sediment. Under these conditions, and at a similar depth to this experiment (40 cm), it took between three and five weeks for the pigs, buried in June, to skeletonize. When compared to the observations obtained throughout this experiment it becomes clear that soil creates an efficient barrier to outside factors of decomposition such as wind, moisture, and insects that the pigs covered in stones were subjected to. In the current experiment pigs buried at 30 cm and covered with sediment did not fully skeletonize over 296 days, and it is apparent that it would likely take over a year. Weitzel (17) did conduct one burial with sediment instead of stones as grave fill, and observed that over the months of June, July, and August the pig reached a moist decomposition stage with some bone exposure, mummification, and retention of internal organs (Stage C2-C3 (18)). This observation is consistent with what was observed in this experiment.

Komar (19) conducted a survey of twenty cases of advanced decomposition investigated by the Office of the Chief Medical Examiner in Edmonton between 1990 and 1996. Overall she determined that in the Edmonton region, during the summer, skeletonization can occur in less than six weeks, and during the winter this can occur in as little as four months. These minimum times represent surface remains, and when compared to the results of this experiment the preservation provided by burial is apparent. Two of the cases Komar (19) evaluated involved victims that had been buried, one in a deep grave and one in a shallow grave. The body within the deeper grave was undisturbed by carnivores and reached an advanced state of decay with soft tissue present within 12 months. The victim buried in the shallow grave was scavenged by animals resulting in the loss of most skeletal elements; however, what remains were recovered had become fully skeletonized over 45 days from the end of June to the beginning of August. These two cases demonstrate again how depth of burial can influence many factors of decomposition, including animal scavenging, resulting in increased preservation. Decomposition in this experiment was similar to the deeper burial, and, despite the fact that no exact burial depth was provided, Komar's real world observations help to solidify the hypothesis that it would take over a year for remains buried at a considerable depth below the surface in the Edmonton region to skeletonize fully.

Komar and Beattie (20), performing surface experiments in the Edmonton area, observed that smaller sized pigs (42-57 lbs) decomposed at significantly faster rates than did medium sized (79-170 lbs) or large sized (344-357 lbs) carcasses. This experiment involved pigs that would all be classified as medium sized; however, the larger, undisturbed bodies were the least decomposed at final exposure. The smaller bodies were not significantly more decomposed than the others, although weight ranges were not as drastic as those investigated by Komar and Beattie (20). This issue would be significant and important to keep in mind during the investigation of real world mass graves due to the presence of victims of various ages and sizes.

5.6 – Recommendations for the Future

The first and foremost direction of future research that is recommended is that this experimental procedure be repeated on a larger scale and over a longer period of time in order to test the conclusions presented here. This would include using more sophisticated temperature probes that would run for the duration of the experiment. Such an approach would bring further clarity to the question: does a body mass indeed decompose faster than a single body, and why? These are the key questions of this thesis. Letting the experiment run for a longer period of time would clarify the time it takes for bodies to skeletonize under these experimental conditions. It would be valuable to obtain this information for both the orderly placement mass grave and single grave.

Questions relating to the role of varying climate and geology must be investigated. This could be accomplished by repeating this experimental procedure in various other locations across the globe, paying particular attention to climate and soil type. This would be valuable in that a global bank of data and observations would be created that could be compared - and applied - to real world mass graves in a variety of regions. Work on developing an index in association with accumulated degree days (ADDs) is currently underway. This would allow standardizing the timing it took for remains under these experimental conditions to reach the decompositional stages that they did, therefore allowing comparisons of these observations and results with other research across the globe.

An experimental mass grave containing hundreds of cadavers would be a dramatic undertaking. While the possibility and logistics of doing this may be nearly impossible, the question of how erratically commingled mass graves with a defined core and periphery decompose is undeniably important, due to the prevalence of mass graves of such an orientation, and interesting. There have been past publications on this topic, although they consist of real world observations, not experimental ones. Haglund (11) and Mant (15,16) observed core bodies to be less decomposed than peripheral bodies, which in turn will be less decomposed than satellite (separate) bodies. Since these observations differ from what was observed in the low-density, orderly placement EMG, it would be interesting and important to evaluate this experimentally. This question may be investigated by using the least number of bodies possible to create an erratically commingled mass grave. This may be accomplished with around 15 carcasses, and a definite core and periphery could be created. Temperature probes placed throughout would generate fascinating and potentially valuable data.

Again concerning temperature probes, it would be interesting to take readings of the disturbed/exposed half of the grave to reveal the degree of temperature fluctuation after soil disturbance at more than 30 cm depth. Temperature probes could be placed inside the body cavities of carcasses to see if there is a difference in internal body temperature fluctuation. It would also be informative and interesting to attempt to measure heat retention and release by the buried pig bodies from above ground utilizing thermal imaging technology such as infrared. This would provide important information regarding differences between a single burial and a multiple burial, timing of most heat generation, and differences between seasons.

Relating to disturbance and exposure of remains, it would be valuable to dedicate entire projects to this question, and to imitate actual disturbance scenarios such as removal, relocation, and reburial of remains by hand or by machine. This would draw a greater understanding of how and to what degree decomposition is affected by such disturbance. It would also be valuable to examine methods of recognizing intentional disturbance in the real world, and to identify the kinds of evidence left behind by these actions.

Finally, two avenues of research relating to how burials in the Edmonton area could be further understood would follow questions regarding insects and winter freezes. Burials, singles or masses, could be created at different depths to discover the minimum depth at which insects can reach a buried body in Eluviated Black Chernozemic soil. In relation to body masses it would be interesting to have a group of contacting bodies buried on a slope or at various depths to each other in order to see if insects will interact with the exposed body of the series and proceed deeper into the ground as subsequent bodies are discovered. Winter freezes are clearly considerably important in relation to rate of decomposition in northern continental climates. To investigate the effect of a winter freeze on the decomposition of a buried body or body mass one could repeat the experiment presented here, only start it as soon as the ground thaws in the spring and have it run until mid-September. Comparing the final exposure observations between such an experiment and the EMG would reveal more clearly the effects of a winter freeze on buried bodies.

5.7 - Final Words

The research presented in this thesis utilized the science of taphonomy to gain a further understanding of how a low-density, orderly placement mass grave changes from the time victims are killed and/or interred until the time they are exhumed. This research has expanded the limited knowledge of how and why body masses decompose the way they do. The effects of intentional disturbance were also further understood and documented. Applications of this information in the real world include estimating time since death and/or burial, mass grave investigation planning and reducing the loss of evidence, and accounting for disturbance or vandalism to remains within a mass grave or of the grave itself. While further research is always needed, the information gained throughout this experiment can hopefully contribute to mass grave investigations in various arenas including human rights violations and war crimes, and natural and man-made disasters.

5.8 - Bibliography

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APPENDIX A – CALENDAR OF EVENTS AND PERIODICAL CHECKS

November 19/08

- Grave pit was marked and dug with a tractor with a front-end loader
- All pigs were obtained from Northern Alberta Processing Co.
- Pigs were transported in a covered and secure trailer to the Ellerslie Research Station, and stored in a secure shed overnight.

November 20/08 – Day 0

- Pigs were weighed, placed in grave, and buried.
- Temperature probes were activated and placed within grave.
- Photos and observations were recorded.

November 21/08 – Day 1

- Grave was secured with staked-down stucco wire covering the area overlying the bodies.
- Grave was clearly marked off with fluorescent tape and stakes.

November 25/08 – Day 5

- Undisturbed except for broken ribbon which was fixed.

November 29/08 – Day 9

- Undisturbed.

December 11/08 – Day 21

- ~10 cm of snow cover
- Undisturbed
- Lots of animal tracks in the area but none near grave

December 19/08 – Day 29

- Pictures
- ~25 cm of snow cover with minimal animal tracks
- Undisturbed

January 1/09 – Day 42

- Checked probe 8 and was still running

January 25/09 – Day 66

- Tracks over the grave present including some human

February 8/09 – Day 80

- Snow melting

February 15/09 – Day 87

- Pictures

March 15/09 – Day 115

- After cold spell, snow covered.

March 29/09 – Day 129

- Snow beginning to melt

April 7/09 – Day 138

- Grave half exposed due to melting snow
- No disturbance
- Pictures

April 15/09 – Day 146

- All snow gone from grave site but ground wet
- Ground undisturbed
- Center of grave looks very slightly slumped
- Pictures

April 23/09 – Day 154

- Drying out
- Undisturbed

***May 9/09 – Day 170**

- First Exposure
- No disturbance

May 12/09 – Day 173

- Cold and rainy
- No odour
- Still secure and good after exposure
- Pictures

May 20/09 - 181

- No disturbance
- After cold snap
- Nothing observed on soil except ants
- Weeds regrowing

May 26/09 – Day 187

- Soil drying up

June 1/09 – Day 193

- Probe 8 was sitting on the surface for unknown reason a meter from where it should be.
- Someone probably grabbed the tape.
- Replaced probe 8.
- No disturbance
- Grass growing in

June 8/09 – Day 200

- Undisturbed

June 13/09 – Day 205

- Saw a coyote in the field

***June 27/09 – Day 219**

- Day of Second Exposure
- Grass growing heavily around, sparse on grave
- Dry cracks around the edge of grave and some where we dug up last time
- No disturbance
- Pictures

June 29/09 – Day 221

- Soil drying
- There was a faint odour

July 2/09 – Day 224

- Undisturbed

July 13/09 – Day 235
- Settling occurring at center of excavation

July 21/09 – Day 243
- Settling occurring

August 2/09 – Day 255
- Settling

August 10/09 – Day 263
- Weeds growing sparsely on grave except where grave was dug up before
- Pictures

August 18/09 – Day 271
- After rain
- Still a tiny slump
- Absence of weeds where excavated

August 26/09 – Day 279
- Nothing growing on disturbed area
- No disturbance
- Soil that was disturbed cracked a bit
- Little bit cracking on border of disturbed area
- Pictures

September 6/09 – Day 290
- No disturbance
- Slumping and cracks more apparent
- Pictures

***September 12/09 – Day 296**
- First day of final exposure
- No disturbance
- Nothing new
- Lots of grasshoppers
- Still slump and crack
- Pictures

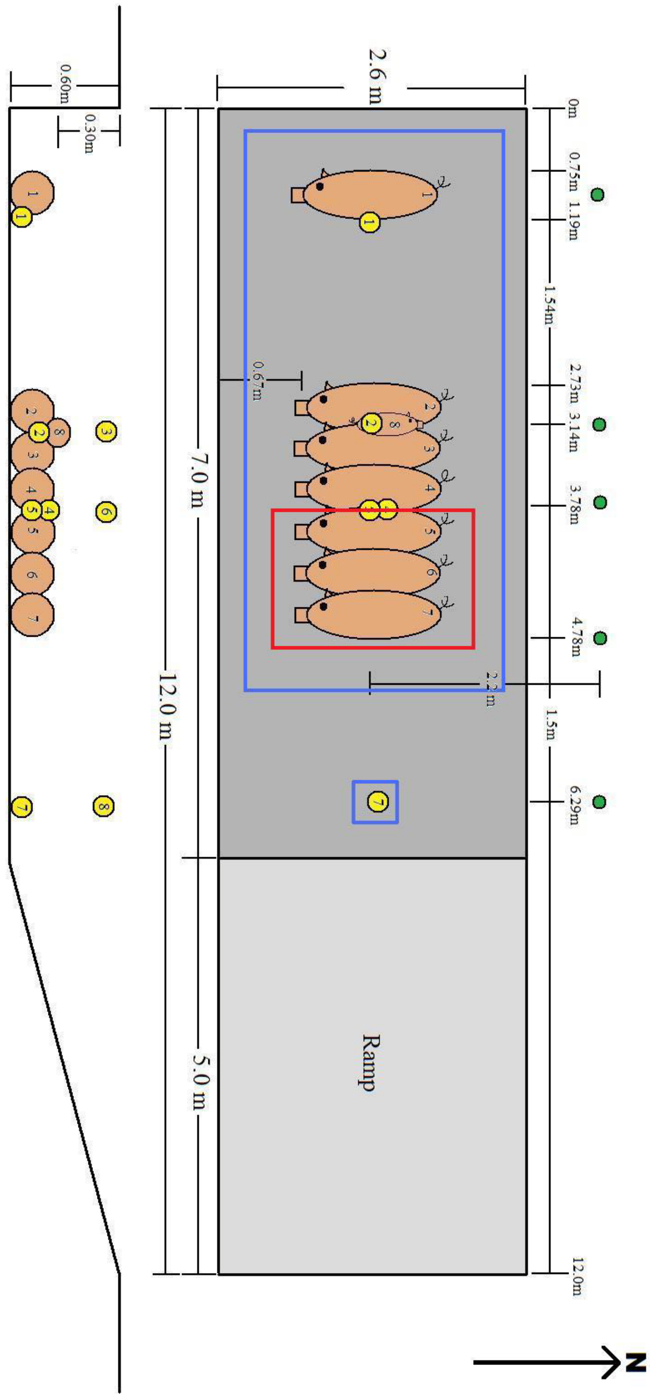
***September 13/09 – Day 297**
- Second day of final exposure
- Completed cleaning/exposure of the bodies
- Collected majority of data/observations
- Photos
- Grave partially filled back in

September 20 – 1 week after
- Grave looks exactly like how we left it
- Dirt and area still smell, faint
- Soil dry
- No evidence of disturbance

October 24, 2009
- Grave was completely filled and everything was removed.
- Only the stakes marking the pig's locations were left.

APPENDIX B – GRAVE LAYOUT

Figure AB-1 - Grave layout, large image. This image details the dimensions of the grave, locations of pigs, and locations of temperature probes (yellow circles). Red square represents area excavated at the two instances of partial exposure on May 9, 2009 (Day 170), and June 27, 2009 (Day 219). Blue squares represent areas excavated at final exhumation on September 12-13, 2009 (Days 296-297). Markers are also present. Pigs and probes are identified by number.



APPENDIX C – DECOMPOSITION TEMPLATES

Wilson AS, Janaway RC, Holland AD, Dodson HI, Baran E, Pollard AM, et al. Modeling the buried human body environment in upland climes using three contrasting field sites. Forensic Science International 2007;169:6-18.

Stages in the decomposition of buried pigs

Fresh Stage (I)
- Begun at death, includes rigor mortis, post-mortem hypostasis and cooling
- Continues until bloating of the carcass visible
- Skin intact/hair firmly anchored

Primary Bloat Stage (II)
- Accumulation of gasses within the body
- No disarticulation
- Hair and epidermis loose
- Soil-skin interface grey
- Strong odour

Secondary Bloat Stage (III)
- Body still bloated
- Disarticulation of limbs
- Purging
- Soil-skin interface black
- Strong odour

Active Decay Stage (IV)
- Deflation of the carcass
- Disarticulation of the limbs and head
- Flesh still present
- Carcass very wet
- Strong odour

Advanced Decay Stage (V)
- Collapse of abdomen/rib cage
- Most of the flesh liquefied/gone
- Skin, bone, fat and cartilage may remain
- Carcass very wet
- Adipocere formation

Skeletonisation Stage (VI)
- Flesh, skin, fat, and cartilage disappear
- Some adipocere and ligaments may remain

Galloway A, Birkby WH, Jones AM, Henry TE, Parks BO. Decay rates of human remains in an arid environment. Journal of Forensic Sciences 1989;34(3):607-16.

Categories and stages of decomposition (surface remains)

A. Fresh
   1. Fresh, no discolouration or insect activity
   2. Fresh burned
B. Early Decomposition
   1. Pink-white appearance with skin slippage and some hair loss
   2. Grey to green discolouration, some flesh relatively fresh
   3. Discolouration to brownish shades particularly at fingers, nose, ears; some flesh still relatively fresh
   4. Bloating with green discolouration
   5. Post bloating following rupture of the abdominal gases with discolouration going from green to dark
   6. Brown to black discolouration of arms and legs, skin having leathery appearance
C. Advanced Decomposition
   1. Decomposition of tissues producing sagging of the flesh, caving in of the abdominal cavity, often accompanied by extensive maggot activity.
   2. Moist decomposition in which there is bone exposure
   3. Mummification with some retention of internal structures
   4. Mummification of outer tissues only with internal organs lost through autolysis or insect activity
   5. Mummification with bone exposure of less than one half the skeleton
   6. Adipocere development
D. Skeletonization
   1. Bones with greasy substances and decomposed tissue, sometimes with decompositional fluids still present
   2. Bones with desiccated tissue or mummified tissue covering less than one half the skeleton
   3. Bones largely dry but still retaining some grease
   4. Dry bone
E. Extreme Decomposition
   1. Skeletonization with bleaching
   2. Skeletonization with exfoliation
   3. Skeletonization with metaphyseal loss with long bones and cancellous exposure of the vertebrae