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TECHNICAL NOTE

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A Report of Decomposition Rates of a Special Burial Type in Edmonton, Alberta from an Experimental Field Study*

ABSTRACT: Regional studies that examine decomposition rates of certain faunal remains can help to determine time since death. Forensic anthropologists have long used qualitative decomposition data, but linking these to more quantitative data could improve time since death estimations. Experiments were developed in which domestic pigs (*Sus scrofa)* were buried with varying characteristics then excavated and observed over a period of 15 months in Edmonton, Alberta. Data recorded after two weeks, five weeks, three months, one year, and 15 months were correlated with stages of decomposition as well as time since death, climate data, grave type, clothing, burial depth, and other factors. Results from these experiments provide useful regional information about stages of decomposition in a burial context. Pigs buried in June were skeletonized by approximately three to five weeks, while those buried in May were skeletonized between five weeks and three months. Climate data, insects, and grave type contributed the most to advanced decomposition, mainly in the form of mummification, and skeletonization.

KEYWORDS: forensic science, forensic taphonomy, time since death, decomposition

It has often been stated that the difficulty involved in estimating time since death in forensic investigations is in part due to the lack of a wide range of regional studies on the rate of decomposition of the human body (1–3). Studies of this nature that do exist are mainly limited to regions in the southern United States and often focus on bodies placed above ground rather than below. However, there is a high degree of variability between both the regional environments and immediate contexts or microenvironments of the deceased. This study focuses on decomposition of a variety of experimental burials in central Alberta and may help narrow the gap of knowledge that exists in time since death estimations particularly in this region.

Methods

A replicate cemetery site was constructed in Edmonton, Alberta as part of a large project aimed at understanding the role of certain taphonomic factors, mainly cultural, at a Late Neolithic/Early Bronze Age cemetery in the Lake Baikal region of Siberia. As the experiments progressed, it became apparent that the information gained also could be of forensic relevance and contribute unique data regarding decomposition rates.

The experimental site is located at the Ellerslie Biological Field Station (EBFS) in Edmonton. The area, a gently rolling morainal plain with fine-textured glaciolacustrine sediments, provides a large natural setting outside of the city. The site lays approximately 53°N latitude and 113°W longitude with an elevation of 686 meters above sea level. The average annual temperature range is approximately −14.1°C to 17.3°C, with mean monthly temperatures below freezing for five months of the year. Average annual precipitation is 450 mm (4).

In total, 21 domestic pigs (*Sus scrofa*) were buried in 21 pits (i.e., burials were single) at the site during the months of May, June, and August 2002. The use of domestic pigs as models for humans in taphonomy, decomposition, and forensic entomology experiments is well established as an adequate comparative model. Pigs were donated by an Edmonton area animal processing plant and had not been deceased for more than 72 hours prior to burial. During this time the pigs laid on the cement floor inside the building. Therefore, bodies were still considered fresh at the time of burial.

Burial no. 1 was created as the control burial. All other graves and corresponding burials were made to the same specifications as no. 1 with the exception of one variable, which was altered (and two variables in nos. 6, 8, 9, and 21). Due to the large number of experimental burials used in this investigation and limited time frame for conducting the experiments, replications of each burial were not constructed. Had fewer burial treatments been examined, then replicated studies would have been conducted for each. However, replication experiments are a recommendation for any future research.

The unclothed pig used in Burial no. 1 weighed 45–50 kg. It was placed in the pit in an extended position and as close to supine as possible, though leaning slightly toward one side. Maximum rigor mortis had already occurred; joints and muscles of all the pigs were relaxed at the time of burial. Pit dimensions, 68 cm wide by 214 cm long and 40 cm deep, were based on averages calculated at the cemetery in Siberia. Because the graves were initially constructed to help understand activity that occurred at an archaeological site, the construction conformed to that site as much as possible. Therefore,

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the grave for Burial no. 1 was built with approximately 20–30 large, flat paving stones placed directly over the top of the burial forming a cairn over the body.

Burial no. 2 differed from no. 1 only by the addition of clothing. The pig was dressed in a fur coat covering the torso region and a pair of leather moccasins covering the back feet. Burial no. 3 was covered with sediment rather than stone. Burial no. 4 was covered with 30–40 more stones than no. 1 and Burial no. 5 was covered with 19 fewer stones than no. 1. Burial no. 6 was covered in 20–30 more stones and was buried 25 cm deeper than no. 1; Burial no. 7 was 20 cm closer to the surface. Burial no. 8 was covered in a large stone cairn built suspended across a large 125 × 260 cm pit. The cairn did not come into contact with the pig as it did in all other burials but lay approximately 50 cm above the pig. Burial no. 9 was a small pig of approximately 25 kg in a relatively small pit of 40 × 95 cm. Burials no. 10–14 were used in a grave robbing experiment. Numbers 10 and 12 were dressed in leather jackets and nos. 11 and 13 were buried with various artifacts inside the pit. Number 14 matched no. 1 with no variation. Burials no. 15 through 20 were partially cremated. A fire using 5–11 kg of pine or birch was built over the thoracic region and allowed to burn for approximately two and a half to four hours. Burial no. 19 was wrapped in birch bark prior to cremation and no. 20 was covered in red ochre. Burial no. 21, though not exposed to fire, was also covered in red ochre and the grave was built with 30–40 more stones than no.1. Results from the looted, cremated, and ochre-treated burials will be discussed in other papers (5).

Grave pits were placed 3 m or more apart. Burials were placed west to east, with the head to the west, in an extended, supine position in as much as possible though sometimes resting on their side (nos. 15, 16, 19, 20, and 21). Pigs were deposited at different times of the year, nine in May, five in June, and seven in August of 2002. Climate data consisting of air temperature, relative humidity, precipitation, wind direction and speed, solar radiation, and soil temperature were recorded hourly and averaged daily for the duration of the project. General data on above ground insect activity were also recorded as frequently as possible (usually two to three days a week). Insects were not collected, as insect research has already been reported at this site (6). Soil data that had previously been collected at the site were also made available. Sediments in the research area consisted of Eluviated Black Chernozemic soils (7).

Graves were opened at various times after burial; two at two weeks (Burials no. 10 and 11), three at approximately five weeks (Burials no. 12–14), nine at three months (Burials no. 1–9), seven at one year (Burials no. 15–21), and nine were reopened at 15 months (Burials no. 1–9). The reason the graves were opened at these particular periods of time related to the individual studies that each was initially a part of (e.g. studies of Burials no. 15–21 regarding the mortuary use of fire, Burials no. 20–21 regarding red ochre, Burials no. 1–9 regarding grave architecture, and Burials no. 10–14 regarding grave disturbance). Observations were recorded and burials were photographed but the bodies were not disturbed. Instead they were reburied for future observations with the exception of nos. 10–14, which were dismantled after the looting experiments. An inventory of bone and teeth was taken only when visible without being too invasive. Decomposition stages were recorded using Galloway, et al.'s 1989 stages of decomposition (Table 1) (8).

TABLE 1—*Categories and stages of decomposition (Galloway et al. 1989).*

A. Fresh
1. Fresh, no discoloration or insect activity
2. Fresh burned

B. Early decomposition
1. Pink-white appearance with skin slippage and some hair loss
2. Gray to green discoloration; some flesh relatively fresh
3. Discoloration to brownish shades particularly at fingers, nose, and ears; some flesh still relatively fresh
4. Bloating with green discoloration
5. Post bloating following rupture of the abdominal gases, with discoloration going from green to dark
6. Brown to black discoloration 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 body fluids still present
2. Bones with dessicated 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

Results

Two Weeks after Burial

Characteristics of early decomposition at the two-week interval correlate well with that reported by Galloway, et al. (8). Burials no. 10 and 11 showed the least amount of decomposition of all experiments (stage B or early decomposition) as would be expected only two weeks after burial (Table 2). Burial no. 10 (stage B, 1–3) exhibited some fly larvae (maggot) activity at the nasal region upon initial exposure; maggots then dispersed after approximately 30 min. There were numerous flies concentrated around the cavities. The ears and nose were black and desiccated and there were patches of skin slippage on the torso region. Otherwise the pig appeared to be relatively fresh. Burial no. 11 (Stage B, 5–6) displayed more maggot activity than no. 10 but again the masses dispersed after approximately 30 min. There was intense chemical activity resulting from putrefaction, or the anaerobic stage of decomposition, in the form of a brown liquid foam over the thoracic region but this also disappeared after about 30 min after exposure. There was some skin slippage throughout the body. The head and upper thoracic region showed spots of black desiccated tissue. The left front leg was the most affected by insects with only ligaments and the far posterior tissue remaining, which was in direct contact with the surface of the pit.

During this two-week interval in June the average air temperature reached a high of 30.3°C on June 22, 2002 and low of 14.0°C, also on June 22, 2002, averaging 22.0°C for the day (Tables 3 and 4). This was the same day the pigs were excavated. Average solar radiation was also high on this day (1.5 kj/h); the maximum during the two weeks was 1.6 kj/h on June 12, 2002. The average air temperature of the entire two weeks was 16.1°C. Soil temperatures were also relatively high averaging 14.0°C at 5 cm deep and 11.1°C at 15 cm deep.

TABLE 2—*Burial and excavation dates and stages of decomposition.*

Grave No.	Wt. of Pig (kg)	Pit Dimensions (cm)	Depth (cm)	No. of Stones	Clothing	Fire	Burial Date	1st Excavation Date	Stage of Decomposition	2nd Excavation Date	Stage of Decomposition
1	45–50	68 × 214	40	20–30	No	No	5/31/2002	8/29/2002	C 5	8/26/2003	C 5
2	45–50	68 × 214	40	20–30	Yes	No	5/31/2002	8/29/2002	C 4–5	8/26/2003	C 5
3	45–50	68 × 214	40	0 (sediment)	No	No	5/31/2002	8/29/2002	C 2–3	8/26/2003	n/a (scavenged)
4	45–50	68 × 214	40	60	No	No	5/31/2002	8/29/2002	C 3–4	8/26/2003	C 4
5	45–50	68 × 214	40	20–30	No	No	5/31/2002	8/29/2002	C 5	8/28/2003	C 5
6	45–50	68 × 214	65	50	No	No	5/24/2002	8/28/2002	D 2–3	8/28/2003	D 2–3
7	45–50	68 × 214	20	20–30	No	No	5/24/2002	8/28/2002	C 4–5	8/28/2003	C 5
8	45–50	125 × 260	65	75 (suspended)	No	No	5/24/2002	8/28/2002	D 1	8/28/2003	D 2
9	25	40 × 95	50	20–30	No	No	5/24/2002	8/28/2002	D 1	8/26/2003	D 2
10	45–50	68 × 214	40	20–30	Yes	No	6/7/2002	6/22/2002	B 1–3	n/a	n/a
11	45–50	68 × 214	40	20–30	No	No	6/7/2002	6/22/2002	B 5–6	n/a	n/a
12	45–50	68 × 214	40	20–30	Yes	No	6/7/2002	7/14/2002	D 2–3	n/a	n/a
13	45–50	68 × 214	40	20–30	No	No	6/7/2002	7/14/2002	D 2–3	n/a	n/a
14	45–50	68 × 214	40	20–30	No	No	6/7/2002	7/14/2002	D 4	n/a	n/a
15	45–50	68 × 214	40	20–30	No	Yes (2.5 Hr)	8/18/2002	8/25/2003	D 2–3	n/a	n/a
16	45–50	68 × 214	40	20–30	No	Yes (3.5–4 Hr)	8/18/2002	8/25/2003	C 5	n/a	n/a
17	45–50	68 × 214	40	20–30	No	Yes (2.5 Hr)	8/18/2002	8/25/2003	D 2	n/a	n/a
18	45–50	68 × 214	40	20–30	No	Yes (2.5 Hr)	8/18/2002	8/26/2003	D 2	n/a	n/a
19	45–50	68 × 214	40	20–30	No	Yes (2.5 Hr)	8/18/2002	8/26/2003	D 2–3	n/a	n/a
20	45–50	68 × 214	40	20–30	No	Yes (3.5–4 Hr)	8/18/2002	8/26/2003	C 5	n/a	n/a
21	45–50	68 × 214	40	50–70	No	No	8/16/2002	8/25/2003	D 3	n/a	n/a

TABLE 3—*Summarized climate data for duration of experiments.*

	2 Weeks	5 Weeks	3 Months	12 Months	15 Months
Daily Maximum Air Temperature Mean (Celsius)	23.2	25.4	23.4	14.8	17.8
Daily Minimum Air Temperature Mean (Celsius)	7.2	9.4	15.9	...	...
Mean Air Temperature (Celsius)	16.1	18.2	7.6	5.8	5.0
Daily Maximum Relative Humidity Mean (%)	86.7	88.0	...	...	...
Daily Minimum Relative Humidity Mean (%)	28.4	28.3	16.6	...	...
Mean Relative Humidity (%)	52.9	54.8	...	...	...
Total Precipitation (mm)	4.0	30.2	...	...	...
Mean Total Precipitation (mm)	0.3	0.8	...	...	...
Mean Wind Speed (Km/Hr)	10.0	11.0	47.1	...	30.4
Mean Solar Radiation (Kj/m)	1.3	1.3	...	...	2.4
Daily Maximum Soil Temperature Mean at 5 cm (Celsius)	18.9	20.1	...	11.8	11.8
Daily Minimum Soil Temperature Mean at 5 cm (Celsius)	9.4	11.7	...	8.4	8.4
Mean Soil Temperature at 5 cm (Celsius)	14.0	15.7	20.2	7.5	11.6
Daily Maximum Soil Temperature Mean at 15 cm (Celsius)	14.4	15.5	15.2	8.2	10.4
Daily Minimum Soil Temperature Mean at 15 cm (Celsius)	9.3	11.8	11.0	6.2	7.9
Mean Soil Temperature at 15 cm (Celsius)	11.1	13.7	16.2	8.1	10.1

[a] Due to a power failure, data between November 12 and December 1, 2002 were not included. Missing data resulting from erroneous weather station readings are represented by dashes.

TABLE 4—*Daily ambient and soil temperature data at the two-week interval.*

Year	Day	Month	Daily Maximum Air Temp (°C)	Daily Minimum Air Temp (°C)	Average Air Temp (°C)	Daily Maximum Soil Temp 5 cm (°C)	Daily Minimum Soil Temp 5 cm (°C)	Average Soil Temp 5 cm (°C)	Daily Maximum Soil Temp 15 cm (°C)	Daily Minimum Soil Temp 15 cm (°C)	Average Soil Temp 15 cm (°C)
2002	7	6	18	0.6	11.1	16.3	7.1	11.6	12.9	5.3	10.2
2002	8	6	18.8	4.2	12.4	16.3	6.3	11.8	12.9	5.7	10.2
2002	9	6	21.1	8.6	14.3	15.6	8.4	12.4	12.7	8.2	10.7
2002	10	6	21.8	6.9	15.2	17.2	5.8	11.7	14.5	3.2	10.4
2002	11	6	21.8	7.8	15.5	16.9	6.7	12.4	13.3	7.4	10.7
2002	12	6	...	4	17.8	23.9	8.2	13.6	17.7	7	11.2
2002	13	6	27.1	7.8	19.2	17.2	10	14	13.1	10.3	11.9
2002	14	6	26	10.9	19.3	20.1	11.4	15.3	14.3	11	12.6
2002	15	6	29.5	8.6	20.5	21.3	11.1	15.9	15	11.2	13.1
2002	16	6	27.3	8.8	18.9	21.8	12	16.6	15.5	12	13.8
2002	17	6	18.7	8.4	12.6	18.3	12.4	15.4	14.8	12.4	13.6
2002	18	6	14.6	6.5	9.8	14.7	10.5	12.9	13.6	11.6	12.2
2002	19	6	20.8	3.3	13.4	18.8	8.5	13.4	13.7	9.8	11.7
2002	20	6	24.2	4.7	16.4	20.7	9.7	14.8	14.6	10.6	12.6
2002	21	6	27.5	9.4	19.3	21.9	11.1	16.2	15.6	11.5	13.5
2002	22	6	30.3	8.6	22	21.1	11.7	16.3	15.5	12.2	13.9

TABLE 5—*Daily ambient and soil temperature data at the five-week interval.*

Year	Day	Month	Daily Maximum Air Temp (°C)	Daily Minimum Air Temp (°C)	Average Air Temp (°C)	Daily Maximum Soil Temp 5 cm (°C)	Daily Minimum Soil Temp 5 cm (°C)	Average Soil Temp 5 cm (°C)	Daily Maximum Soil Temp 15 cm (°C)	Daily Minimum Soil Temp 15 cm (°C)	Average Soil Temp 15 cm (°C)
2002	7	6	18	0.6	11.1	16.3	7.1	11.6	12.9	5.3	10.2
2002	8	6	18.8	4.2	12.4	16.3	6.3	11.8	12.9	5.7	10.2
2002	9	6	21.1	8.6	14.3	15.6	8.4	12.4	12.7	8.2	10.7
2002	10	6	21.9	6.9	15.2	17.2	5.8	11.7	14.5	3.2	10.4
2002	11	6	21.8	7.8	15.5	16.9	6.7	12.4	13.3	7.4	10.7
2002	12	6	66.9	4.0	17.8	23.9	8.2	13.6	17.7	7	11.2
2002	13	6	27.1	7.8	19.2	17.2	10.0	14.0	13.1	10.3	11.9
2002	14	6	26	10.9	19.3	20.1	11.4	15.3	14.3	11	12.6
2002	15	6	29.5	8.6	20.5	21.3	11.1	15.9	15	11.2	13.1
2002	16	6	27.3	8.8	18.9	21.8	11.9	16.6	15.5	12	13.8
2002	17	6	18.7	8.4	12.6	18.3	12.4	15.4	14.8	12.4	13.6
2002	18	6	14.6	6.5	9.8	14.7	10.5	12.9	13.6	11.6	12.2
2002	19	6	20.8	3.5	13.4	18.8	8.5	13.4	13.7	9.8	11.7
2002	20	6	24.2	4.7	16.4	20.7	9.7	14.8	14.6	10.6	12.6
2002	21	6	27.5	9.4	19.3	21.9	11.1	16.2	15.6	11.5	13.5
2002	22	6	30.3	8.6	22.0	21.1	11.7	16.3	15.5	12.2	13.9
2002	23	6	31.5	15.2	22.8	22.4	13.7	17.7	16.4	13.1	14.7
2002	24	6	26.5	16.3	20.2	21.1	15.2	17.3	16	13.9	14.9
2002	25	6	29.2	14.5	22.1	24.1	14.3	18.7	17.5	13.7	15.5
2002	26	6	34.5	13.6	25.4	25.1	15.2	19.7	18.2	14.5	16.3
2002	27	6	32.6	16	23.6	24.7	16.4	19.9	18.3	15.4	16.9
2002	28	6	21.3	12.4	18.1	20.3	15.5	17.8	17.3	15.2	16.0
2002	29	6	24.1	10.6	16.1	20.1	8.5	15.2	16.1	12.4	13.3
2002	30	6	20.3	8.8	14.5	19.1	12.3	15.3	15.1	12.8	13.1
2002	6	7	24.4	4.0	15.8	19.6	10.3	14.6	14.7	11.5	13.1
2002	7	7	29	6.5	20.4	19.8	11.4	15.5	15.1	12.3	13.7
2002	9	7	26.6	11.9	20	21.6	13.1	16.9	16.1	13.0	14.4
2002	10	7	31	12.3	22.8	21.6	14.2	17.7	16.6	14	15.3
2002	11	7	34.7	15.7	25.5	24.6	15.6	19.6	18.1	15	16.4
2002	12	7	34.7	19	26.8	25.2	16.4	20.3	18.8	15.8	17.2
2002	13	7	33.7	18.3	26.2	24.1	17	20.4	18.6	16.4	17.6
2002	14	7	24.5	13.3	20.3	21.4	16.6	19.4	18.2	17	17.5

Five Weeks after Burial

All the burials that were examined after approximately five weeks (nos. 12, 13, and 14) were at a stage of skeletonization (stage D). They were more decomposed than some other burials that were left for longer periods (three months to 15 months). Burial no. 12 (stage D, 2–3) was dressed in a leather jacket and only the seams of the jacket remained at the time of observation. Bones were dry and stained although some ligaments remained. Skin and hair remained on the skull and ears as well as the lower feet. Burial no. 13 (stage D, 2–3) also displayed dry bones with some staining. Some mummified tissue and hair remained on both lower back legs and the skull. Burial no. 14 (stage D, 4) showed the most advanced decay of the three, with all of the bones appearing dry and relatively clean.

Air temperatures during the June and July five-week interval reached a high of 34.7°C on July 11, 2002 and low of .6°C on June 7, 2002 (Table 5). The average air temperature for the five weeks (18.2°C) was the highest of all time intervals. There was more precipitation (30.2 mm) than there was at the two-week interval (4.0 mm). Average soil temperatures were 15.7°C and 13.7°C at 5 cm and 15 cm deep, respectively.

Three Months after Burial

Burials no. 1–9 were opened after approximately three months. Nos. 1–5 and 7 were at an advanced stage of decomposition (stage C). Nos. 6, 8, and 9 were partially skeletonized (stage D). Burial no. 3 (stage C, 2–3) (covered in sediment) revealed the least amount of decomposition of this group. Bones of the arms, ribs, and pelvis were exposed but a large amount of pink flesh and other soft tissue still existed throughout. Burial no. 1 (stage C, 5) was mostly mummified with some hair remaining. There was exposure of the maxilla, mandible, right front leg bones, some upper right ribs, lumbar vertebrae, pelvic bones, and the head of the femora. Burial no. 4 (stage C, 3–4) was also mummified with some patches of hair and some bone exposure. The pig was damp in the thoracic and abdominal area. Three vertebrae, three lower ribs, and parts of the lower back leg bones of burial no. 7 (stage C, 4–5) were exposed. There was some mold on the upper left ribs and adipocere was present throughout the center thoracic region. Rodent gnawing was observed on the right patella. Burials no. 2 (stage C, 4–5), 5 (stage C, 5), and 7 (stage C, 4–5) were almost completely mummified. At least five mice were seen within the pit of burial no. 2 at the time it was opened and there was a nest between the two back legs.

Burial no. 6 (stage D, 2–3) was skeletonized but covered in white mold except the lower left ribs where a stone was placed directly over the bone and mold was potentially unable to grow. Burial no. 8 (stage D, 1) was mostly skeletonized with hair and skin present on the head, along the right side of the body, and the lower back legs. There was adipocere all through the thoracic region and the bones were damp and brown. Finally, Burial no. 9 (stage D, 1) was also covered in white mold and the bones were damp. The skull retained some mummified tissue.

The highest air temperature reached during the three-month interval was the same as the five-week interval, i.e., 34.7°C on July

11, 2002. The low temperature was 9.3°C on June 17, 2002. The average air temperature for the three months was relatively low (7.6°C). However, wind speed (20.2 km/hr) was relatively high. Average soil temperatures were the highest of all the time intervals, 20.2°C at 5 cm deep and 16.2°C at 15 cm deep.

One Year After Burial

The only graves to be excavated at a one-year interval were the six that were partially cremated (nos. 15–20) and the one covered in red ochre (no. 21). All were skeletonized (stage D) except two of them (nos. 16 and 20), which showed an advanced stage of decomposition (stage C). Surprisingly, these two burned for the longer durations than the skeletonized burials (3.5–4 h as opposed to 2.5 h). Burial no. 16 (stage C, 5) was mostly mummified particularly at the head, pelvis, and legs. Burial no. 20 (stage C, 5) was mummified at the mandible, cervical vertebrae, pelvis, front and back legs. A rodent nest was located inside the rib cage and there was some gnawing of ribs. All bones were stained red from the red ochre applied at the time of burial. Burial no. 15 (stage D, 2–3) was mostly skeletonized with some mold and dampness of bones and some mummified tissue. Two rodent nests were found within the burial, one just north of the skull and one next to the proximal end of the right femur. Burial no. 17 (stage D, 2) was mostly skeletonized with some mummification and hair on the skull and lower front legs and mold on the ribs. Burial no. 18 (stage D, 2) was mostly skeletonized with some mummification on the head, pelvic area, and lower back legs. Some mold was present on the thoracic vertebrae. One rodent nest was found in the thoracic region. Burial no. 19 (stage D, 2–3) was more skeletonized than 17 and 18. Some dry tissue remained on the lower thoracic/abdominal area, legs, and to a lesser degree on the head. Burial no. 21 (stage D, 3) was completely skeletonized and stained red from ochre.

Air temperatures during the one-year interval reached a high of 32.0°C on August 18, 2003. Unfortunately, due to an error in the weather station records, the low temperature was not reported. The yearly average air temperature was relatively low at 5.8°C. (Omitted sentence) Average soil temperatures at 5 cm and 15 cm deep were the lowest of all time intervals at 7.4°C and 8.1°C, respectively.

Fifteen Months After Burial

The same graves that were opened at a three-month interval were also reopened at 15 months (nos. 1–9). These nine graves were the only graves to be opened for observation, reburied, and opened again for a second observation. Opening of graves at the three-month interval can result in further insect colonization of remaining tissue and other additional variables such as scavenging. However, at this time all nine burials were at the same stage of decomposition that they were at after three months. There were only minor changes a year later (from August 2002 to August 2003) with slightly more bone exposure. Burial no. 3 was scavenged shortly after it was opened the first time likely by dog or coyote and, as a result, could not be observed at this time. Carnivore activity reportedly appears to occur during advanced decomposition and initial mummification (8) and since this was the only burial that was not covered in stone it was the only one affected.

Due to errors in the weather station records, some of the climate data from the 15-month interval is missing. Overall, averages during the 15 months appear to lay mid-range in all observable categories, without any extreme highs or lows.

Discussion

Time since Death

Based on the data supplied by the experiments, it appears that it takes approximately three to five weeks for pigs buried in June at a depth of 40 cm to skeletonize. It takes between five weeks and three months for those buried in May, deeper than 40 cm, to skeletonize. In a study involving 20 human advanced decay cases at the Edmonton Office of the Chief Medical Examiner, Komar (9) showed reduction to skeletal remains in less than six weeks in moderate summer temperatures. The depositional environments in Komar's study varied from aquatic to surface; only two of them were burials.

Climate Data

Temperature and humidity are said to be the most important factors affecting decomposition rates, the higher the temperature and humidity the greater the rate of decomposition (1). Accordingly, the development of fly larvae is almost entirely a function of temperature.

Regardless of any changes in climate during the two-week interval in June 2002, pigs likely would not decay beyond the early decomposition stage. This is true despite the high air and soil temperatures on the last day of this time interval. Yet, these high temperatures and high solar radiation on June 22, 2002 do explain in part the active decay observed during excavation, in particular the presence of maggot masses and active processes of putrefaction. Subsequently, maggot masses themselves generate a great amount of heat and this also explains why decomposition and skeletonization occurred so rapidly. Blow fly larvae were able to easily access the remains either prior to burial, during burial, or both through openings in the rocks.

June and July of 2002, the five-week interval, witnessed the highest average air temperature of all the time intervals combined accounting for the skeletonization of all three of the burials. Increased precipitation that may have seeped through the stones may have further separated the soft tissue from the bone.

Air temperatures were relatively low during the three-month interval in May–August, 2002 but soil temperatures were high. All of the skeletonized burials came from deeper burials (see section on Burial Depth) perhaps affected by temperatures closer to those of the soil than those of the air. Soil temperatures are very important in decomposition of buried bodies and agriculture station sub-soil temperature data can usually be obtained when working with buried body cases. The remaining burials in an advanced stage of decomposition lie closer to the surface. Mummification of these burials could partially be explained by high wind speed during this time (averaging 47.1 km/h). Wind may have traveled through the openings in the stones contributing to dessication of tissue.

At the one-year interval, average air and soil temperatures were relatively low. However, summer temperatures alone were high. Skeletonization during this period probably has more to do with the influence of summer temperatures as well as the application of fire.

Finally, at the 15-month interval, temperatures and other climate data were relatively moderate. The lack of any periods of extreme highs is demonstrated by the fact that stages of decomposition did not change between the three-month interval and the one-year interval.

Though Alberta typically features a dry, cold climate in the winter, summer temperatures often match that of more southerly regions and this helps explain the relatively rapid rates of decomposition. Studies at the University of Tennessee have shown that

bodies buried at one to two feet skeletonize in a few months to a year (1). The Tennesssee experimental studies also report that arid areas produce desiccated and mummified remains that show little destruction by insects under natural conditions and retain skin anywhere from two to six years after death (1). The Edmonton climate has lead to mummification similar to that seen in places known for their extreme aridity such as southern Arizona (8).

Insects

The exact time in which eggs were deposited on the burials is unknown. It is plausible that flies had access to the pigs very soon after death at the time the pigs were at the processing plant, prior to burial. However, this is also possible for real death case scenarios in which bodies lie on a surface before they are deposited in burials. Therefore, the immediate access of flies to the body is not an artificial but rather real phenomenon. An alternative experimental approach would be to euthanize animals at night at the site in order to avoid ovipositing of blow flies who are not active at night. This would ensure that fly eggs and maggots would not infest dead pigs prior to commencing the experiment, thus providing more accurate data.

Grave Type

Two types of graves were constructed in this investigation, a burial covered with a rock cairn and a pit filled with sediment over the burial (no. 3). The sediment-filled grave was much more susceptible to large scavengers than those covered with stone. The pig in Burial no. 3 was quickly removed after observations were made at three months. At the time of observation the pig in the sediment-filled grave was at the same stage of decomposition (advanced decomposition) as those covered with stone; it was only slightly less decomposed. The scavenging activity was likely prompted by the initial grave opening. In a report of insect succession on carrion by Anderson et al. (6) at the EBFS, pigs reportedly buried one foot below surface were scavenged two days after burial. The cairn-covered grave type is a very important factor when evaluating stages of decay. The random placement of stones allows for the passage of air, precipitation, insects, and rodents perhaps accounting for the overall rapid rate of skeletonization.

Clothing

The clothed burials include nos. 2, 10, and 12. Burial no. 2 (dressed in a fur coat and leather booties) was at the same stage of decomposition as most other non-clothed burials that were observed after three months and again after one year indicating that the clothing played little role in preservation. This was true also for Burial no. 12 (dressed in a leather jacket) and other experiments approximately five weeks after burial. However, at two weeks after burial, no. 10 (also dressed in a leather jacket) was less decomposed than the unclothed (no. 11). These results do not support statements that clothing speeds up the decay process (1) but supports others that showed clothing slows the decay process (8,9). It is also interesting to note the degradation of the modern leather textiles themselves. At two weeks after burial the jacket was still in good condition, which is in marked contrast to the five-week interval when only the seams of the jacket remained. The leather moccasins on burial no. 2 were well-preserved after one year. Other experiments have shown modern leather to be quite resistant to the burial environment, preserving far beyond five weeks (3). The preservation of clothing and the role that clothing plays in preservation of the individual likely depends upon whether the body is buried or deposited above ground and the season and corresponding temperature at the time of body disposal.

Burial Depth

The depth of burials 6, 8, and 9 was 10–25 cm deeper than the average of all other experiments. The depth of burial no. 7 was 20 cm shallower. Burial no. 7 was at the same stage of decomposition as others observed with it after three months and 15 months. Yet, nos. 6, 8, and 9 (the deeper burials) were all at a more advanced stage of decomposition. All three were skeletonized while other burials observed with them were in an advanced stage of decomposition after three months and again after 15 months. In this study deeper burials tended to decompose faster. This does not necessarily conflict with other studies in which deeper burials tend to decompose much slower (1) because 50 to 65 cm is still comparatively shallow. It is important to note that in one of these burials the pig was smaller, approximately half the size of the others. Children with relatively small skeletal elements typically go through decomposition processes in a much shorter time interval than adult remains, due in part, to the greater surface-to-volume ratio (3). Besides being interred deeper, the other two burials (nos. 6 and 8) also had more stones placed on them, which could help to account for their advanced decay. The extra mass overlying the body could have trapped and retained heat longer thereby accelerating decomposition.

Fire

Burials subjected to fire include nos. 15 to 20. Those burials that were skeletonized (nos. 15,17–19) were exposed to fire 60–90 min less than others that were at an advanced stage of decomposition (nos. 16 and 20). They also were burned with 3.5 to 8 kg less fuel than those at an advanced stage. Typically fire acts as a preservative of skeletal remains by mineralizing the bone. This doesn't explain, however, why the tissues of burials no. 16 and 20 were so well-preserved. Though half of these experiments were affected by rodent activity, this did not seem to impact decay rates either as pigs in both an advanced and skeletonized stage revealed evidence of rodents.

Summary

This study provides unique data for a specific forensic burial technique, rock covered, which may provide for estimation of time of death when in the Edmonton, Alberta region. A number of combined factors determine the rate of decay, though some take precedence over others. Climate, insects, and grave type are the most important factors driving rates of decay in this investigation. Aridity and freezing in the winter months combined with warm summer temperatures and wind had a large influence on bodies buried in this region most often resulting in mummification and skeletonization. Clothing, burial depth, the application of fire, and scavengers also play a role in decomposition rates. Some of the burials (nos. 1–9 and 15–21) will continue to be monitored through time and changes in stage of decomposition will be recorded.

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