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Decomposition of Buried Bodies and Methods That May Aid in Their Location

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ABSTRACT: This is the second report on an ongoing study conducted to collect data on the decompositional rates of human cadavers and the first on buried cadavers. Six unembalmed human cadavers were buried separately in unlined trenches of various depths and allowed to naturally decompose for a time period ranging from a month to a year. During the period of burial, data were collected daily on the air, soil, and cadaver temperature at each burial site. At the end of each specified burial period the cadavers were exhumed and examined for the degree of decomposition which had taken place as well as changes in the soil pH, surface vegetation, and carrion insect activity. Analysis of the data shows that the decomposition rate of buried cadavers is highly dependent on the depth of burial and environmental temperatures. The depth at which the cadaver was buried also directly affected the degree of soil and vegetational changes as well as access by carrion insects. Application of this information can contribute to a more accurate estimation of time since death of a buried corpse and may aid in the location of such corpses.

KEYWORDS: pathology and biology, decomposition, postmortem examinations, time since death, carrion insects

Many homicide victims are disposed of by burial. The discovery and exhumation of a decomposing corpse presents the forensic scientist with many questions to be answered. The time interval since death is considered one of the most important questions. Establishing the time since death of an exhumed corpse is in many cases crucial to establishing the identity of the victim and linking a suspect to the crime. At present there is little information pertaining to estimation of time since death of a buried body. This lack of information has resulted in gross estimations of time since death, which are often based on either a minimum of experience from previously known cases or various nonspecific criteria.

The purpose of this two-year study was to provide more reliable criteria for determining time interval since death of a buried corpse. Methods that might aid in the location of a buried corpse were also considered in this study. Bass and Birkby [*1*] have reported on techniques for locating and removing buried bodies. Application of these criteria and methods can provide the forensic scientist with a more accurate means of locating buried corpses and determining the time interval since death.

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Previous Studies on Decay Rates

Most research concerning decay rates has employed an entomological approach. The great majority of literature dealing with decay rates and insect activity appears in the entomological journals and primarily has been conducted with other mammals as decompositional subjects. Several decompositional studies conducted by Payne and his associates have been reported in the literature. One such publication reported on the arthropod succession and decomposition of buried pigs [*2*]. In this investigation Payne noted the various stages of decomposition and the amount of time it took each subject to reach the various stages.

Other forensic scientists have approached this problem by studying the degree of deterioration of associated material (clothing, leather items, paper, and so forth) that had been exposed to the environment over various time periods. Such studies have been reported by Daily [*3*] as well as by Morse et al [*4*].

A previous study on the aboveground decomposition rates of human cadavers, believed to be the first of its kind, was reported in 1983 by Rodriguez and Bass [*5*]. This study, which is still ongoing, recorded observations of the complete decompositional process of several nude unembalmed cadavers under outdoor conditions. The various changes associated with decomposition and the length of time required to reach particular decompositional stages were outlined in this first report. Entomological and climatological data in relationship to human decay rates were also noted by the authors.

An early entomological study of human decomposition was conducted by Motter [*6*], who reported on the various insect fauna observed in association with human disinterments. Motter noted the gross tissue changes of each corpse, grave soil conditions, and the length of burial. The reported observations of Motter are to some extent helpful, but the subjects of these observations were individuals who had been embalmed to some extent and had been buried in various types of coffins. This produced an unnatural and delayed decomposition of the corpses, as they were protected from most environmental elements for some period of time after burial.

Although noteworthy, the studies mentioned using other mammals as decay subjects cannot provide specific information on the rate of human decomposition because of the obvious differences in body size and morphology. Thus it is imperative that human cadaver studies be conducted to provide specific data on decomposition rates and their relationship to time since death.

Materials and Methods

The unembalmed cadavers of six adult white males were used in this study. All six cadavers were donated to the University of Tennessee Department of Anthropology for the purpose of scientific research. Information concerning the age, weight, stature, and cause of death of each individual was recorded. Four of the cadavers were completely intact with the fifth and sixth cadavers having been autopsied with brain and vital organs removed. Four of the six subjects had died of cardiorespiratory arrest; the other two died from small caliber gunshots of the head.

All six subjects were buried at the field research facility within 48 h of their death. Between the time of death and the time of burial, the cadavers were stored in morgue coolers. Before and during the burial process, care was taken not to expose the cadavers to carrion insects. A single-digit identification number was assigned to each cadaver.

Experimental studies were conducted at the Department of Anthropology's decay research facility. This facility is located in an open-wooded area of Knoxville, TN. Six trenches measuring approximately 1.8 by 0.9 m (6 by 3 ft) were excavated for placement of the cadavers. Four of the trenches were 0.3 m (1 ft) deep, one was 0.6 m (2 ft) deep, and the last was 1.2 m (4 ft) deep. Each of the trenches were spaced at distances of approximately 1.5 m (5 ft) apart.

The cadavers were placed in the burial trenches at separate times of the year, dependent on the time of death. Subjects were placed on their backs with the face up (facing skyward), arms positioned to the sides, and legs spread slightly apart. Thermometers with remote temperature probes were placed above ground next to each burial trench. The remote probe of each thermometer was placed at the bottom of the trench directly against the right side of each cadaver, lateral to the navel. The autopsied cadavers, Subjects 5 and 6, were not monitored with temperature probes.

After placement of the temperature probes, each cadaver was covered with the soil initially removed during the excavation of the trenches. After burial the soil was lightly packed with hand shovels. Burial and exhumation dates of each cadaver, depth of burial, and amount of clothing present at burial are listed in Table 1.

Data concerning climatic conditions and above-ground insect activity were recorded daily. Climatic data consisted of air, soil, and cadaver temperature as well as relative humidity, rainfall, and local sky conditions. Air temperature and relative humidity were measured 24 h a day with a Belfort continuous temperature/humidity recorder. Rainfall was measured with the aid of a plastic rain gage, and local sky conditions were judged by visual observations.

In addition to daily records of the maximum temperature of each cadaver, soil temperatures at depths of 0.3, 0.6, and 1.2 m (1, 2, and 4 ft) feet were also recorded by remote temperature probes. Before the burial of each cadaver, soil samples were collected from the bottom of each trench in order to obtain pH values.

After a predetermined period, each cadaver was exhumed for observation. At exhumation each burial was carefully excavated with hand shovels and trowels. None of the burial subjects were removed from the trenches at exhumation, to avoid repositioning the body and producing postmortem artifacts, as the subjects were reburied for later reexhumation.

Data on the decompositional state of each cadaver and insect activity were recorded by means of photographs and written documentation. Kodak 400 ASA Ektachrome® slide film was used for photographing the cadavers. Photographs were taken with an Olympus® OM-10 quartz camera in conjuction with wide-angle, telephoto, and macro lenses. In addition to written and photographic records, insect specimens were collected for identification purposes. Flying insects that were observed above ground during the period of burial were collected with an aerial insect net and crawling insects observed above and below the soil were collected with dissecting forceps. Insects collected for identification were taken from various areas of the cadavers and nearby soil.

Identification of insects was established according to various taxonomic manuals. Microscopic examination and various dissecting techniques were used to determine the sex and species of certain insect forms. All insects collected were preserved in a solution containing 85 cm^3 of 90% alcohol, 10 cm^3 of 40% formalin, and 5 cm^3 of glycerin.

TABLE 1—*Burial and exhumation dates and burial conditions.*

Subject	Burial Depth, ft[a]	Burial Date	Exhumation Date	Clothing Present
1	4 ft	5/18/82	5/18/83	synthetic trousers
2	2 ft	6/4/84	12/7/83	cotton trousers and leather boots
3	1 ft	8/24/83	11/7/83	synthetic trousers
5	1 ft	1/23/84	4/11/84	none
6	1 ft	1/23/84	4/11/84	none
4	1 ft	10/14/83	11/20/83	cotton trousers

[a]1 ft = 0.3 m.

Results

Climatological and decompositional data on the six cadavers were recorded between May 1982 and January 1984. After exhumation of all six cadavers it was evident that the decomposition rate of human cadavers is directly dependent on the environmental conditions of the soil and above-ground temperature.

The geographic location of the burials provided climatic conditions that were neither excessively hot nor cold during the period of study. Mean maximum temperature during the spring and summer months of the study rarely exceeded 29°C (85°F), with fall and winter temperatures rarely falling below freezing. Normal and actual monthly temperatures and precipitation during the period of study are shown in Fig. 1.

Soil temperatures, which were taken daily at depths of 0.3, 0.6, and 1.2 m (1, 2, and 4 ft), exhibited normal daily and seasonal fluctuation patterns. Daily fluctuation of the soil temperature occurred in the soil at a depth of 0.3 m (1 ft). At 0.6 and 1.2 m (2 and 4 ft), there were practically no daily fluctuations in soil temperature. However, at all depths there were seasonal fluctuations in temperature. All these findings are consistent with those reported by Flucker [7] in his five-year study of soil temperatures at various depths. A comparison of mean monthly soil and air temperatures recorded during this study are shown in Figs. 2 and 3.

After exhumation of the cadavers, various degrees of decomposition were observed. The decomposition of the cadaver tissues and organs is primarily brought about by aerobic and anaerobic bacterial action. This degradation process in turn produces various amounts of heat in the tissues. Increased heat production in the tissues of a corpse is at its greatest during exposure to high environmental temperatures during the active decay stage of decomposition [5]. In many cases involving a decomposing corpse located above ground in warm weather, the remains of the corpse can be so hot that it is uncomfortable to examine with one's bare hands.

The cadaver temperatures collected during this study showed a marked increase over soil temperatures taken at the same depth. Subject 1, which was buried at a depth of 1.2 m (4 ft), exhibited an increase in temperature beginning at approximately four and a half weeks after burial and continuing for approximately three and a half weeks. Subject 2, which was buried at a depth of 0.6 m (2 ft), exhibited an increase in temperature beginning at approximately two weeks after burial and continuing for approximately four and a half weeks.

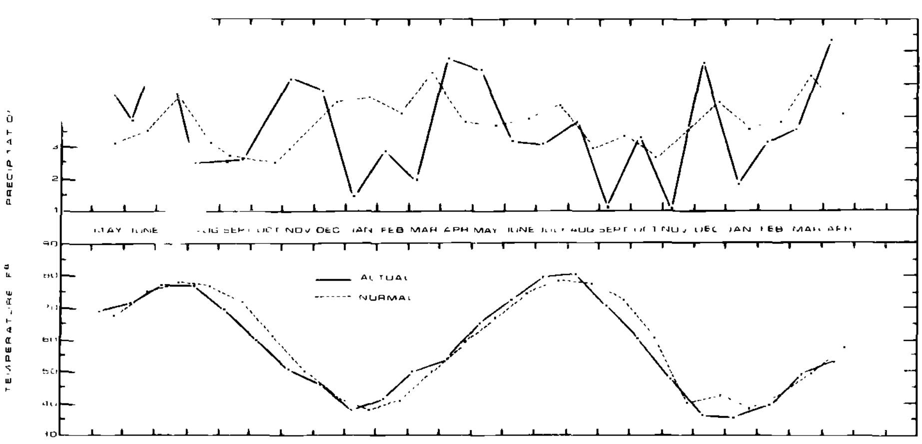

FIG. 1—*Normal temperatures, normal precipitation, and deviations from normal for May 1982 to April 1984.*

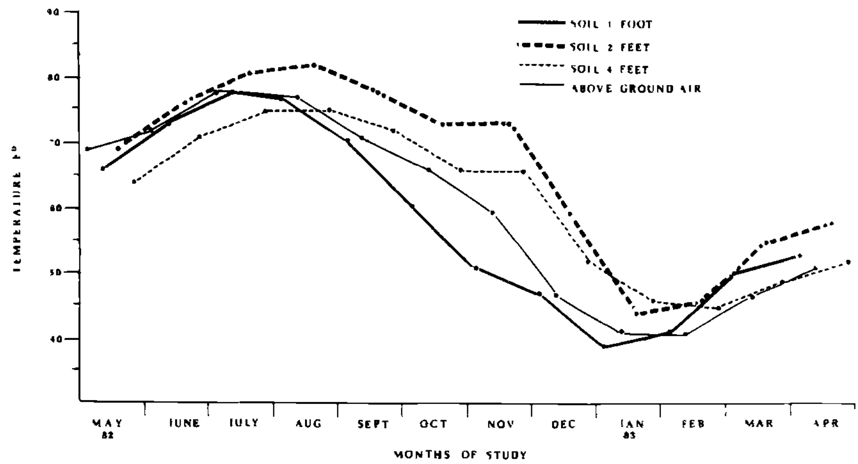

FIG. 2—*Comparison of mean monthly soil and air temperatures for May 1982 to April 1982.*

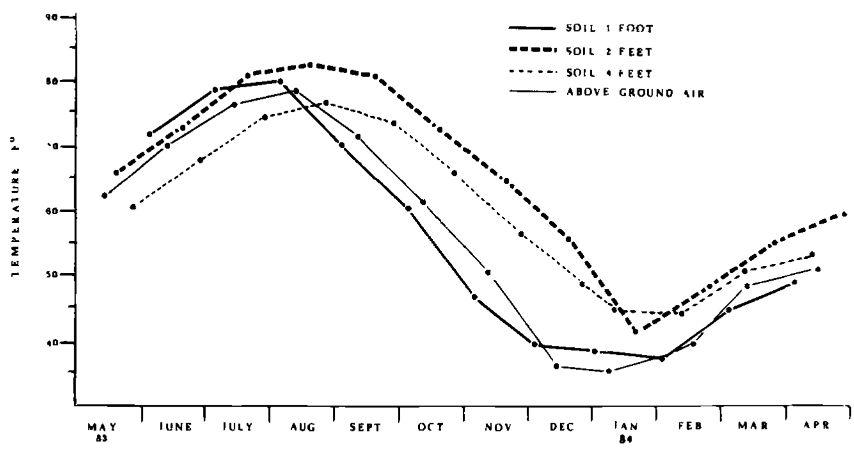

FIG. 3—*Comparison of mean monthly soil and air temperatures for May 1983 to April 1984.*

Subjects 3 and 4, which were buried at depths of 0.3 m (1 ft), also showed an increase in body temperature over that of soil. Subject 3 exhibited an increase in body temperature beginning at approximately one week and continuing for approximately seven weeks. Subject 4 also showed an increase in body temperature beginning at approximately two weeks and continuing up until the time of exhumation (three and a half weeks later). Figures 4 through 7 show the daily maximum temperatures for each cadaver and corresponding soil depth from the time of burial until thermal equilibrium was reached.

The observed increase in temperature of each cadaver during decomposition was found to be directly proportional to the depth of burial. This temperature differential decreased with lower burial depths. At a burial depth of 1.2 m (4 ft), Subject 1 showed a mean temperature differential of approximately +3.4°C (+6.2°F) over the soil. Subject 2, buried at a depth of 0.6 m (2 ft), showed a mean temperature differential of approximately +5°C (+9.0°F) over the soil. At a burial depth of 0.3 m (1 ft), Subjects 3 and 4 showed a mean temperature

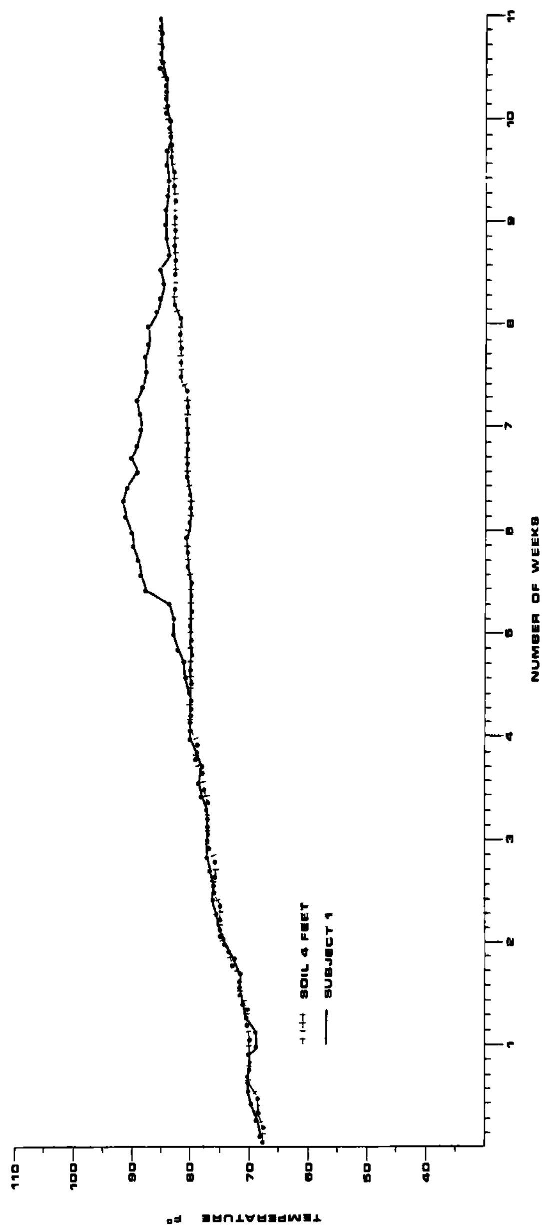

FIG. 4—*Daily maximum temperatures for Subject 1 and corresponding soil depth from the time of burial until thermal equilibrium.*

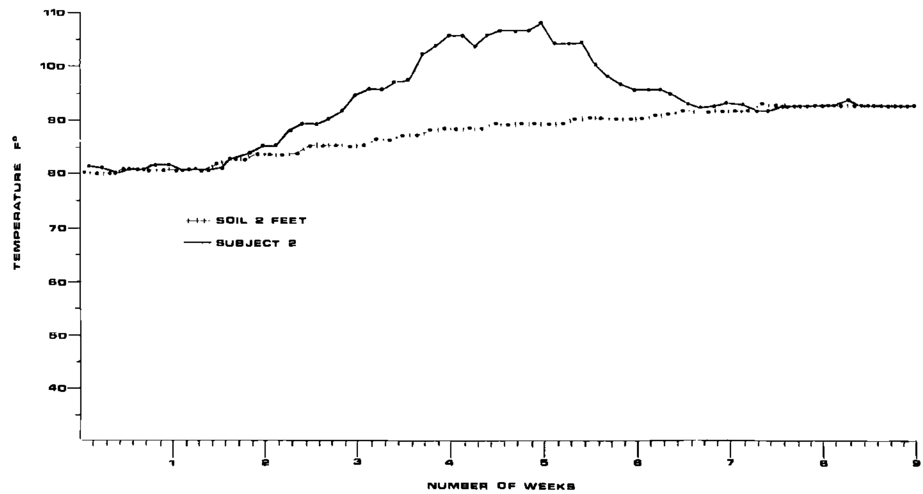

FIG. 5—*Daily maximum temperatures for Subject 2 and corresponding soil depth from the time of burial until thermal equilibrium.*

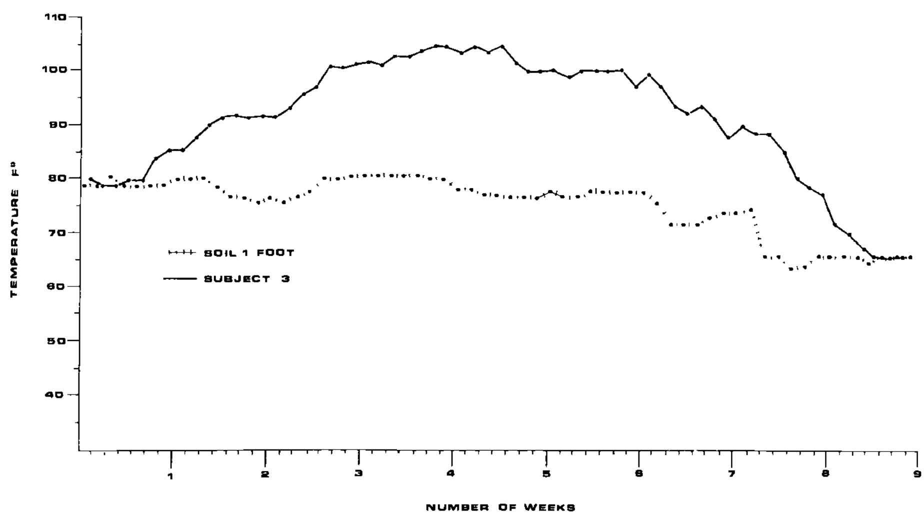

FIG. 6—*Daily maximum temperatures for Subject 3 and corresponding soil depth from th time of burial until thermal equilibrium.*

differential of approximately +10 and +7°C (+18.0 and +12.6°F), respectively of soil. (Subject 4 was still exhibiting an active temperature rise at exhumation.)

Close observation of each cadaver after exhumation revealed various stages of deco... tion. Subject 1, buried at a depth of 1.2 m (4 ft) for a year, showed remarkable preservatio... Skeletonization was minimum and limited to the head, hands, and feet. Large amo... tissue were observed on the skull, with the eye orbits and nasal aperature fully ex... Small amounts of hair were still attached to the sides of the head and the mandible wa... articulated with the skull. The great majority of the body was heavily covered in white adip... cere, with the chest and abdomen slightly depressed.

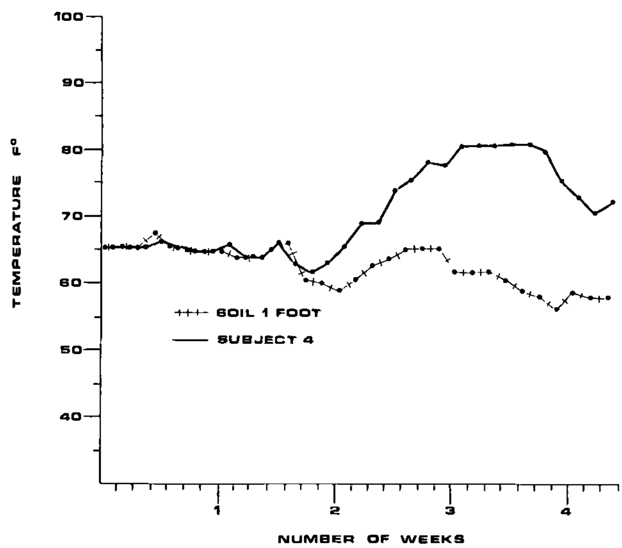

FIG. 7—*Daily maximum temperatures for Subject 4 and corresponding soil depth from the time of burial until thermal equilibrium.*

There was some shrinkage of tissue observed in the lower arms and legs outlining the major long bones. It was also observed that the penis and scrotum were still intact, although shrunken, with large amounts of pubic hair remaining attached. No carrion insect activity was observed on this subject and the synthetic fabric trousers worn by the subject showed no signs of degradation (macroscopically). Figures 8 and 9 provide a full body and upper torso view of Subject 1.

Subject 2, buried at a depth of 0.6 m (2 ft) for a period of six months, exhibited little decomposition. The head was fully covered with tissue, except in the area of the maxilla and mandible. Both eye orbits and nasal aperture were exposed and void of tissue. Head hair was still attached to the sides of the scalp and a full beard was also present. The remaining scalp hair and beard had changed from gray in coloring to a bright golden yellow.

All the bones of the hands and feet were skeletonized, with slight exposure of the lower tibia in each leg. The chest was intact and only slightly depressed; however, the abdominal area was highly depressed. Both the penis and scrotum were partially decomposed but still attached, with scarce amounts of pubic hair remaining. The overall coloration of the body was a dark brown with moderate amounts of white adipocere on the areas of the chest and legs. No carrion insect activity was observed on this subject; cotton fabric trousers and leather boots showed some signs of degradation.

Subject 3, buried at a depth of 0.3 m (1 ft) for three months, exhibited extensive decomposition. The skull and mandible were completely void of tissue and hair, with the mandible being fully disarticulated. Skeletonization of both the arms and legs was complete and there was disarticulation at the major long bone joints. The bones of the hands were fully exposed; however, the feet were still covered with tissue in a mummified state.

The vertebrae of the thoracic and lumbar area were exposed and the innominates, which were sparsely covered with tissue, had become disarticulated at the pubic symphysis. Partial collapse of the sternum was observed, with only the distal ends of the clavicles, the upper four ribs, and the associated costal cartilages still articulated to the mesosternum. No internal organs remained and small amounts of white adipocere were observed along the remaining walls of the upper chest cavity.

FIG. 8—*Full body view of Subject 1, who was buried for one year at 1.2 m (4 ft). Note the good preservation.*

FIG. 9—*Close-up view of the upper torso of Subject 1.*

The subject's synthetic fabric trousers showed little signs of degradation, with only small patches of mold and fungi. An important observation were the numerous dipterous larvae and hatched and unhatched pupal cases, as well as some adult Diptera. Figures 10 and 11 show the full body and upper torso view of the Subject 3.

Subject 5, buried at a depth of 0.3 m (1 ft) for two and a half months, exhibited moderate decomposition. The midfacial area of the skull was exposed, with tissue still remaining in the eye orbits and nasal aperture. Hair remained attached to the scalp, with the exception of small patches alongside the head. Slight dropping of the mandible was evident, along with partial decomposition of the neck tissues. Both the arms and legs were still muscular in appearance and there were slight traces of white adipocere formation along the entire length of the legs. Only slight decomposition of the penis and scrotum was observed, with pubic hair still attached.

The hands and feet were still intact with the exception of the right foot, which was skeletonized from the phalanges down to the metatarsals. Several of the phalanges had been gnawed on by carnivores as they were exposed from animal digging. Figure 12 shows the remains of the right foot protruding above the ground prior to exhumation. The overall body coloration of the subject was a dark pinkish brown. Insect specimens in the form of a few dipterous larvae were observed on the face and abdominal area of the subject. (Subject 5 had been autopsied before burial, with the brain and internal organs removed.)

Subject 6, also buried at a depth of 0.3 m (1 ft) for two and a half months, exhibited a similar state of decomposition. The midfacial area of the skull was exposed, with some tissue remaining in the eye orbits and nasal apertures. Hair was observed to be absent from the scalp, with small amounts of fluid leaking from the mouth and ears. The mandible had dropped in position and there was partial decomposition of the neck tissues.

Both the arms and legs exhibited a full muscular appearance, with some shrinkage at the

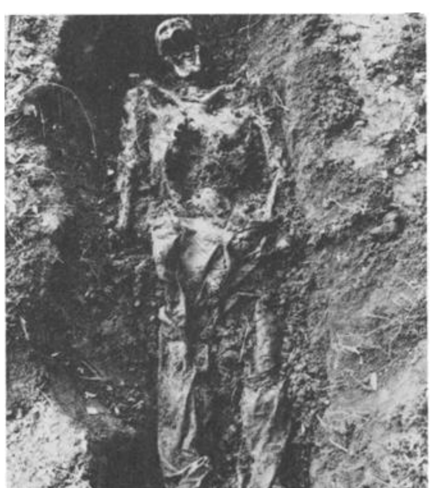

FIG. 10—*Full body view of Subject 3, who was buried for three months, at 0.3 m (1 ft). Note the extensive state of decomposition.*

FIG. 11—*Close-up view of the upper torso of Subject 3.*

wrist and ankle joints. The hands and feet were intact, with slight exposure of the phalanges in one hand. Only minor shrinkage of the penis and scrotum were observed and most of the pubic hair was still attached. Overall body coloration of the subject was a dark pinkish brown, with very small patches of black fungus along the sides of the exposed chest. A small number of dipterous larvae were found in the lower abdominal area of the subject. (Subject 6 had been autopsied before burial, with brain and internal organs removed.)

Subject 4, also buried at a depth of 0.3 m (1 ft), but only for one month, exhibited little if

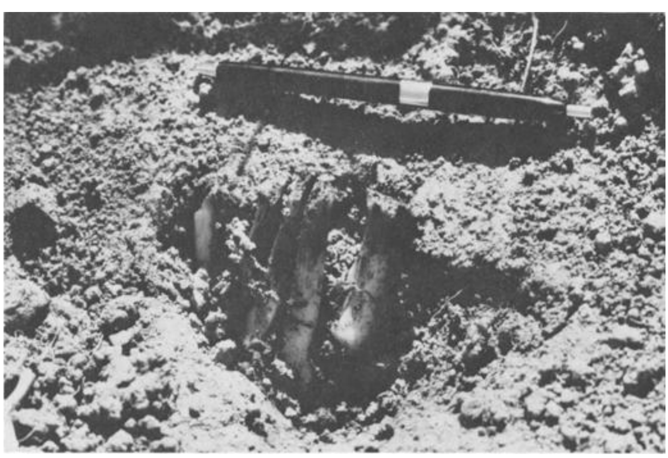

FIG. 12—*The exposed and gnawed right foot of Subject 5.*

any decomposition. The face was slightly bloated, with some distortion of facial characteristics. Both eyes were absent and head hair still remained attached to the scalp. The chest showed no signs of depression and the abdomen was very bloated. Also observed were the moderate amounts of body fluids flowing from the nose, mouth, and rectum of the subject.

No other areas of the body showed marked decomposition, with the hands and feet being remarkably preserved and lifelike. The penis and scrotum were intact and swollen, with pubic hair remaining. Both the arms and legs were firm and showed no shrinkage of tissue. Overall body coloration was a dark pink, with some patches of dark brown on the upper thighs.

The subject's cotton blue jeans were extensively covered in fungus growth. A small number of dipterous larvae were observed on the face and lower abdomen of the subject. Figure 13 shows a close-up view of the good preservation of the right hand of Subject 4.

Soil samples collected before burial and after each exhumation were tested for their pH value. It was found that the soil pH at the base of each burial trench and a quarter of an inch directly above each cadaver had significantly increased in alkalinity. Table 2 shows the mean pH values of the soil samples taken before and after exhumation of each cadaver.

Daily observation of the ground surface of each burial also provided important data. One of the most evident changes that occurred above ground was the settling of topsoil into each burial trench. This slow settling of soil into the trenches produced very distinctive depres-

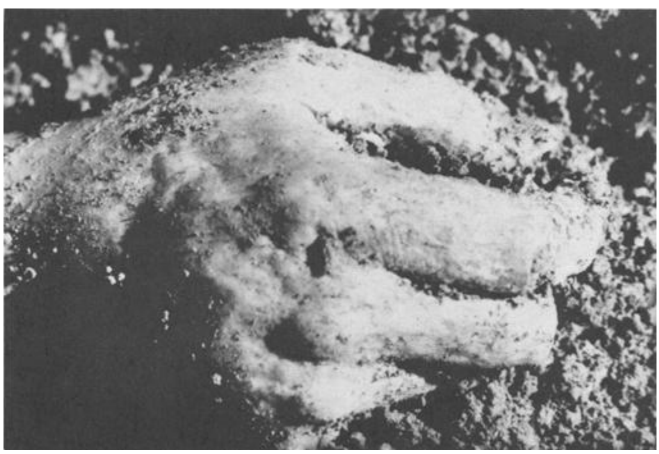

FIG. 13—*Example of good preservation as seen in the right hand of Subject 4.*

TABLE 2—*Mean pH values of soil at burial and after exhumation.*

Subject	Burial Depth, ft[a]	Burial Time, months	Soil pH Prior to Burial	Soil pH After Exhumation	pH Increase
1	4 ft	12	5.3	5.8	0.5
2	2 ft	6 mo	4.6	5.7	1.1
3	1 ft	3 mo	4.8	6.9	2.1
5	1 ft	2.5 mo	5.8	5.9	0.1
6	1 ft	2.5 mo	5.8	5.8	0.0
4	1 ft	1 mo	5.7	5.9	0.2

[a]1 ft = 0.3 m.

sions. These depressions, routinely referred to as soil compaction sites, were observed to take anywhere from a week to a few months to occur. As expected, the greater burial depths of 0.6 and 1.2 m (2 and 4 ft) produced deeper depressions than the 0.3-m (1-ft) burials.

The 0.6- and 0.3-m (2- and 1-ft) burials exhibited secondary depressions within the primary depression. These depressions, as described by Morse [*4*], "will normally be found only over a grave of about 24 to 30 inches in depth." Morse also states that these secondary depressions are created by "the settlement of soil into the body's abdominal cavity as it decomposes and the cavity collapses."

The burial trench of Subject 4 did not exhibit a secondary depression, probably because this subject's very bloated abdomen prevented soil compaction. Figure 14 shows the extensive soil compaction over Subject 1, who was buried at a depth of 1.2 m (4 ft) for a year.

Differential plant growth was only observed at the burial sites of Subjects 1 and 2, who were buried at depths of 1.2 and 0.6 m (4 and 2 ft), respectively. Plant growth was found to occur more quickly over Subject 2 than Subject 1. The plants growing over Burial 1 were observed to be much shorter than over Burial 2, even though they had an increased period for growth. This differential growth can most likely be attributed to the greater disturbance and removal of topsoil in the 1.2-m (4-ft) trench.

Differences in the topsoil coloration of the burials were noted. The topsoil covering the burial sites was much darker than the undisturbed surrounding soil. This difference was due to the redeposition of deeper subsoil to the surface. Over an extended period of time—six months to a year—these coloration differences were observed to lessen.

Carrion insect activity was only observed on the four cadavers that were buried at a depth of 0.3 m (1 ft). The carrion insects observed were identified as dipterous larvae, pupae, and adults. Further identification of these Diptera forms show them to belong to both the family Calliphoridae (blow flies) and Scarcophagidae (flesh flies). During the burial periods of these cadavers, numerous adult blow flies and flesh flies were observed on the surface of the burials. Many of the flies were also observed trying to make their way down towards the burial subject through small cracks and crevices in the soil. This particular activity was most prevalent the day following a heavy rain.

Also on days following a heavy rain, where the topsoil of the burials remained moist, female flies were observed depositing eggs on the soil surface. Upon hatching of these eggs the

FIG. 14—*Extensive soil compaction over Subject 1, who was buried at 1.2 m (4 ft).*

immature larvae apparently migrated down to the cadavers, at which point they began feeding and developing on the decomposing tissues.

Exhumation of Subject 3, who was buried during the summer, revealed numerous fly larvae and a few pupae and immature adults. The larvae observed appeared to be fairly active and ranged in size from 5 to 11 mm long. A few of the observed for pupariums were empty with immature adults located nearby, all of which were dead.

Exhumation of Subjects 4, 5, and 6, which were buried during the fall and winter, revealed fewer fly larvae than observed on Subject 3. It must also be noted that no fly pupae or adults were observed on any of the three subjects. The fly larvae observed on these subjects varied greatly in size, with the largest and most numerous individuals being present on Subject 4.

Other carrion insect activity observed during this study were the frequent gatherings of Family Scarabaeidae (lamellicorn) and Family Staphylinidae (rove) beetles on the surface of Burials 3 and 4. These particular beetles did not appear to be feeding, but merely investigating the surrounding soil. During above-ground decomposition of human cadavers, both rove and lamellicorn beetles were present in large numbers, feeding on fly larvae and other carrion materials [5].

Scavenger activity was not only restricted to insects in this study; mammalian carnivores were also active. Throughout the burial study many signs of digging by mammalian carnivores were observed. Digging in attempts to reach the buried cadavers was restricted to the 0.3-m (1-ft) burials. The right foot of Subject 5 was successfully exposed by carnivore digging and was heavily gnawed. Footprints at the burial sites suggested the carnivores to include raccoons, opposums, and domestic dogs.

Discussion and Conclusions

It was evident in this study that the decomposition of buried human cadavers occurs at a much slower rate than that of cadavers placed above ground. This greatly reduced rate of decomposition is brought about by two basic factors. The first and most important factor is that of decreased or absent carrion insect activity. Burial of a human cadaver restricts the access of many carrion insects to the cadaver. This is most apparent in the breeding activity of the blow flies, which represent the most numerous carrion insect group. Another important insect scavenger group that faces restricted access to buried cadavers are the carrion beetles.

During this study it was observed that cadavers buried at depths of 0.3 m (1 ft) provided limited access to some carrion insects. Adult blow flies were observed trying to make their way down to the cadavers through small cracks and crevices in the soil. Also observed was the depositing of eggs in the small soil cracks by the adult flies following a hard rain. Exhumation of these cadavers revealed numerous blow fly larvae feeding on the decomposing tissues. It must be assumed that the above-surface egg laying by blow fies resulted in the migration and the further development of the larvae on the cadavers, as all possible steps were taken to prevent the introduction of these insects before burial.

The second factor responsible for decreased decompositional rates below ground is the cooler temperatures. Environmental temperature data show that soil provides an efficient insulation barrier to solar radiation. Soil temperatures and the fluctuation of those temperatures were found to decrease with increasing in soil depth. It was evident in this study that preservation of the cadaver increased with the depth of burial.

One unexpected observation was the significant increase in the cadaver body temperature over that of the soil. It was first assumed that the cadavers would remain in temperature equilibrium with the surrounding soil; however, this was not the case. Decomposition of the cadavers did produce significant temperature increases ranging from a mean of 3.4 to 10°C

(6.2 to 10.8°F). This body temperature increase was also directly correlated with burial depth. Shallow burial depths produced higher body temperatures during decomposition. Also, with decreased burial depths the rise in body temperature occurred sooner and lasted longer.

In a study concerning the above-ground decomposition rates of baby pigs, Payne [8] reported that during the bloated and active decay stages of decomposition, the body temperature of the pigs was found to be considerably higher than the soil temperature. He also noted that the mean carcass temperature was approximately 1.7°C (3°F) greater than the surface soil temperature; on one occasion a temperature difference of 8.3°C (15°F) was recorded. Another study by Reed [9] reported similar results on decompositional studies with dogs.

The increases in body temperatures reported by Payne [8] and Reed [9] have also been recorded during our ongoing surface decomposition studies of human cadavers. During surface decomposition, the increase in body temperature over that of soil and air is a result of the high metabolic rates of dipterous larvae and bacteria. However, in the case of buried cadavers, dipterous larvae activity is very limited or nonexistent. Bacterial degradation of the buried cadavers continues, but with the lower environmental temperatures and fluctuating oxygen and pH levels, bacterial action should be somewhat decreased.

The cadaver temperatures reported in this study are much higher than those reported by Payne [8] and Reed [9] but they are much lower than temperatures found in surface decompostion of human cadavers in our ongoing studies. The continuing studies of decomposition in buried cadavers will hopefully permit a better evaluation of the associated temperature changes.

Soil pH changes were also observed to occur with the presence of a decomposing cadaver. In all buried trenches the soil was found to increase in alkalinity between 0.5 to 2.1 pH levels. This increase in alkalinity was also observed by Reed [9] in pH measurements taken 12.7 mm (0.5 in.) below decomposing dog carcasses. He noted that on the average the soil pH increased in alkalinity during the bloated and active decay stage and leveled off at the dry stage of decomposition.

It was clearly evident that cadavers buried at 0.3 m (1 ft) or less below the soil surface attracted various carrion insects and mammalian carnivores. The odors that are given off by a decomposing cadaver in a shallow burial site appear to be easily detected by various carrion insects. It is well established that insects have highly developed olfactory systems that are capable of detecting odors or chemical substance that may only be present in microscopic quantities. Although not as sensitive as in insects, the olfactory systems of certain mammals are also well developed. As previously stated in this report, evidence of digging activity by raccoons, opposums, and domestic dogs was frequent at the shallow (0.3-m [1-ft]) burial sites.

It is very important for forensic investigators to be aware of carrion insects and mammalian carnivores associated with human corpses in shallow burials, for two basic reasons. First, carrion insects can provide an important means of determining the time since death of the corpse, based on their developmental rates and seasonality. And second, mammalian carnivores and other mammalian forms such as rodents can produce postmortem artifacts on a corpse that might be later misinterpreted as wounds, lesions, or trauma by the inexperienced investigator.

The observations made of foliage and soil changes in this study can also be of importance to forensic investigators. Many of the changes observed can be used in locating a buried body. Soil sinking or compaction is one of the most obvious signs of burial. An abrupt change in the foilage over a burial area is also usually evident. The deeper the burial the greater the disturbance to the soil, thus reducing the plant growth.

Plant growth will be greatly increased over shallow burials that have been in place for a extended period of time (approximately a year or more) [1]. This increase in foliage over the surrounding area is due to the organic materials that are released from a decomposed body into the soil as a form of natural fertilizer. This observation has been used successfully in our case work, permitting the location of a buried body by a large open field where soil compaction sites were difficult to spot and search time was limited.

Changes in the soil pH and cadaver temperatures as recorded in this study offer other methods by which forensic investigators might locate a buried body. Soil conductivity, temperature, or pH probes could be inserted into the soil at expected burial sites to make such tests. Devices such as these are already in use by archaeologists to locate buried habitation sites and funeral pits.

Also to be noted is that the sternal area (mesosternum and costal cartilages) of the cadavers observed in our study withstood major decomposition. This resistance of the costal cartilages and mesosternum is mainly due to the mummification of the cartilage and the amount of ossification present in the cartilage (particularly in individuals 50 years and older). This finding offers an additional and possibly a more accurate means of aging older adults, by means of radiographic examination of the degree of costal cartilage ossification, which is known to increase proportionately with age [*10*].

It must be noted that there are many other variables that can affect the decomposition rates of buried cadavers. The soil type and drainage patterns are but two of the variables that can be expected to affect the rate of decomposition. Other important variables to consider are the physical size and body build of an individual and the amount or type of clothing present. This initial burial study tested only a few of these variables. Additional research, testing other variables and experimental conditions including decomposition rates below water, are in progress or planned for the future.

Based on the information acquired in this study, it can be concluded that there is a direct correlation between the decay rates of human cadavers and the depth of burial in soil. Knowledge and better understanding of this relationship can aid in establishing the time since death of a buried corpse, as well as assisting in the location of such a corpse.

Summary

Six unembalmed human cadavers were separately buried in an open wooded area of eastern Tennessee and allowed to decay naturally. The burial trenches in which the cadavers were placed measured 0.3, 0.6, and 1.2 m (1, 2, and 4 ft) in depth. At predetermined time periods of one year, six months, two and a half months, and one month, the cadavers were exhumed and examined for the state of decomposition. Daily temperatures of the cadavers, soil and air were recorded.

It was found that the greater the depth of the burial the greater the preservation of the body. Also noted was that the temperature of the cadavers increased significantly over that of the soil. Other observed changes included an increase in soil alkalinity, soil compaction, and differential plant growth at the burial sites. Burials at 0.3 m (1 ft) were found not to exclude particular carrion insects and mammalian carnivores from having access to the cadavers.

This study has shown that data on the decompositional rates of buried cadavers, along with various environmental data, can be a valuable aid in determining time since death of an exhumed corpse. Methods for locating a buried corpse can also be developed from these data.

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