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Field Recovery and Analysis of Horse Skeletal Remains

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ABSTRACT: In response to a request from an insurance company investigating a claim relative to the death of four race and show horses, allegedly as a result of deliberate starvation, physical anthropologists of the Louisiana State University (LSU) Department of Geography and Anthropology undertook the recovery and analysis of skeletal remains said to be those of the animals. The objectives were to determine the number and kinds of animals represented, their ages, and sexes, and, through morphometric evaluation of bone density at the LSU School of Veterinary Medicine, whether there was evidence of nutritional osteodystrophy. The skeletons were the remains of four horses. In comparisons of data derived from these skeletons with breeding records for the horses described in the insurance claim, it was established that the skeletons were those of mares, as were the insured animals, and that the relative ages of the four approximated those of the insured horses. The skeletal samples submitted for morphometric evaluation showed no evidence of nutritional osteodystrophy and, thus, provided no support for the contention that death had resulted from starvation. In one horse, the superior aspect of the right ascending ramus of the lower jaw below the coronoid process revealed a gunshot wound; the other skeletons showed no evidence of trauma.

KEYWORDS: physical anthropology, horses, species identification, animal abuse, musculoskeletal system

Background

In June 1987, the Department of Geography and Anthropology of Louisiana State University (LSU) received a request for assistance from an insurance company investigating a claim relative to the death of four horses in October 1985. The owner of the horses reported that they were valuable thoroughbreds—race horses and show jumpers—and asserted that the individual with whom arrangements had been made for the stabling, care, and feeding of the horses had deliberately permitted them to starve to death.

In response to the request, the forensic anthropology team undertook the recovery of skeletal remains said to be those of the animals and the sorting and analysis of these remains. In addition, metacarpal bones and crania were sent to the LSU School of Veterinary Medicine for, respectively, morphometric evaluation of nutritional condition

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and dental aging. The objectives were to determine the number of animals represented by the remains, their ages and sexes, whether the remains could be those of the four animals described in the insurance claim, and whether the bones showed evidence of nutritional osteodystrophy.

Methodology

The investigation began on 13 June 1987 with a visit to a wooded area where the horse remains were located. The investigator for the insurance company brought the team of anthropologists to the site, where they cleared the vegetation for accurate mapping and made a complete photographic record to document the regional geography and spatial distribution of elements within and around the site. The area was systematically surveyed by walking a 30-m perimeter to determine the extent of the site and the nature of postdepositional processes, such as plant, animal, and human disturbance and downslope transport, which would account for several bones being found some distance from the central cluster. After preparation of a map of the site, the larger bones were numbered in the field and their positions were recorded on the map (see Fig. 1). All the skeletal elements were then recovered and transferred to LSU for analysis.

The site and the surrounding woods yielded a total of 395 bones. The bone preservation was good, although there was some cortex (surface layer of bone) exfoliation as a result of weather exposure. The presence of very thin bones (nasal turbinals, hyoids, and lateral metapodials) and of several easily leached elements (calcified costal cartilage) indicated that bone disintegration was minimal. Although many bones were missing, there was little visible evidence of disturbance by animals (bite and gnawing marks). Some of the smaller skeletal elements (certain carpals and tarsals, fibulae, and sesamoids) were not recovered; these could have been covered with soil or washed down the slope at the far end of the site. As Table 1 indicates, virtually all skeletal elements were represented, with the exception of the distal phalanges or hooves: no hoof core or keratin sheath was found, nor were horseshoes present. (The possible causes of the absence of the hooves are not known; however, the high protein content of the hoof makes it attractive to scavengers. As the horses were not being raced or shown during the months preceding their demise, they may not have been shod, or if so, the shoes could have been removed from the hooves for reuse.)

After analysis of the remains to ascertain the number of animals, their ages, their sexes, their resemblance to the animals described in the insurance claim, and related information, the metacarpals (cannon bones) from three horses (those of one were not recovered) were sent to the LSU School of Veterinary Medicine. All the metacarpal bones were sectioned at midshaft and at right angles to the shaft, and thin sections were ground to approximately 30 to 40 μm. The thin sections were mounted on slides and evaluated microscopically using compensated polarized light. All measurements were made with a microscopic video image and computerized morphometric analysis system (Bioquant IV, bone morphometry, Nashville, Tennessee) after calibration using a stage micrometer. The following parameters were determined: the cortical thickness, mean osteon area per square millimetre, mean vascular space area per square millimetre, and the osteon/vascular area ratio. This ratio provides a measure of bone turnover or remodeling. The osteon/vascular space ratio can be used to determine whether the osteon vascular area space has increased, indicating an increase in remodeling or reabsorption of bone. All full cross sections were measured at intervals of approximately 36°, and all area measurements were made at $\times 6.3$ objective magnification. Only symmetrical osteons having a centrally placed vascular space were measured. Both the area and the accompanying vascular space were determined. The total number of osteons measured per field varied from five to eight.

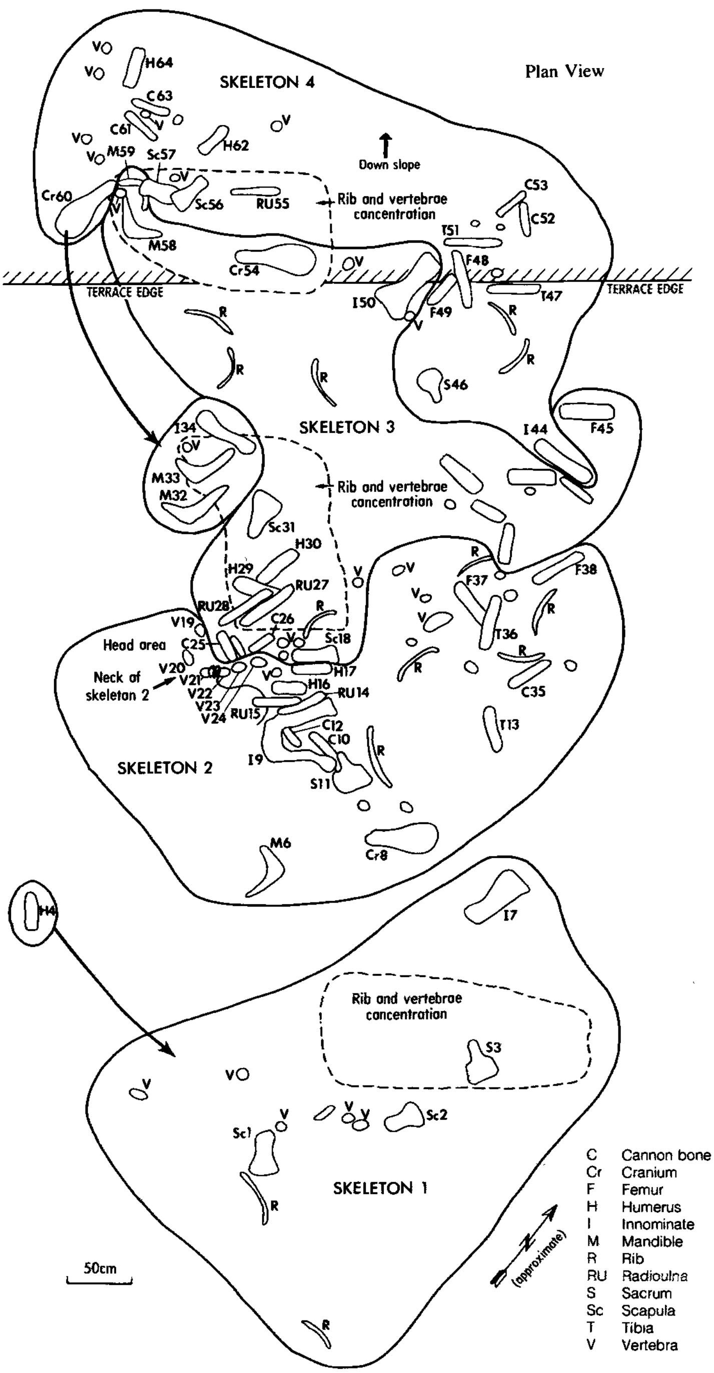

FIG. 1—*Map of the recovery site showing the distribution of skeletal remains.*

TABLE 1—*Inventory of the recovered bones.*

Skeletal Element (No. of Bones per Horse)	Skeleton Number 1	2	3	4
AXIAL SKELETON				
Head				
Skull (1)	...	1	1	1
Hyoids (3)	1	3	...	3
Mandible (1)	1	1	1	1
Vertebral column				
Cervical vertebrae (7)	1	7	7	7
Thoracic vertebrae (18)	16	18	14	18
Lumbar vertebrae (6)	6	6	5	6
Sacrum (1)	1	1	1	1
Caudal vertebrae (16)	1	...	5	...
Chest				
Ribs (36)	34	36	33	27
Calcified costal cartilage	2	1	10	...
Sternebral plates	...	2	3	3
APPENDICULAR SKELETON				
Forelimb				
Scapulae (2)	2	2	2	2
Humeri (2)	1	2	2	2
Radioulnae (2)	...	2	2	2
Carpals (4)	...	9	2	1
Metacarpals (6)	...	6	6	6
Sesamoids (4)	...	...	...	...
Proximal phalanges (2)	...	2	2	...
Medial phalanges (2)	...	...	...	...
Distal phalanges (2)	...	...	...	...
Hind limb				
Os coxae (2)	1	2	2	2
Femora (2)	1	2	2	2
Patellae (2)	...	2	2	2
Tibiae (2)	1	2	2	2
Fibulae (2)	...	...	...	...
Tarsals (12)	...	2	6	2
Metatarsals (6)	...	3	3	3
Sesamoids (4)	...	...	...	...
Proximal phalanges (2)	...	2	2	1
Medial phalanges (2)	...	2	...	1
Distal phalanges (2)	...	...	...	...
Total number of bones per skeleton	69	116	115	95

The skulls and mandibles of three horses and the mandible of one (its skull was missing) were sent to Dr. D. J. Hillmann of the LSU School of Veterinary Medicine for a determination of the individual age of each horse, based on analysis of dental eruption and patterns of wear.

Findings

Number of Animals

Analysis of the recovered remains indicated the presence of four horses (see Table 1). Despite considerable disarticulation, the orientation of the bones showed that the horses were lying on their right sides, with their spines parallel to the path (at the bottom of Fig. 1) and their heads lying to the left in the figure orientation. The skeletons were situated progressively farther from the path, and were arbitrarily numbered 1 to 4 according to their distance from the path leading to the site. No single element occurred in numbers suggesting more than four skeletons, and there was no indication of any animal remains other than those of horses.

The skeleton of a horse normally contains 205 bones [*1*]. Skeletons 1 through 4 differed in completeness (for example, see Fig. 2). Skeletons 2 and 3 (the second and third individuals, at the center of the site in Fig. 1) contained the most major elements; Skeleton 1 (closest to the path) and Skeleton 4 (farthest from the path and nearest to the slope) lacked a number of bones. Some elements, including the mandible and left femur, of Skeleton 1 were found in the nearby woods. Because of their closeness to the path, these remains could have suffered greater disturbance from people walking on the path than did the more distant Skeletons 2 and 3. The location of Skeleton 4 on the slope resulted in bones washing or rolling downslope and being buried by soil.

Sex

The three recovered skulls lacked canine teeth, and the four mandibles contained very small canines, indicating that all four horses were mares. Stallions (and geldings) have substantially larger upper and lower canines than do mares.

Age

The data concerning the relative and chronological ages of the four horses appear in Table 2. The anthropology team used comparative developmental dental and postcranial criteria to determine the relative ages of the skeletons. Dental criteria were the basis of assignments of individual ages based on comparisons of these specimens with skulls of known age. The eruption and wear of the incisors are particularly useful in determining the age of a horse (because of their accessibility in the living animal) and allow reasonable accuracy up to nine years of age [*2*].

Adult teeth form in crypts in the jaws, then rise within the jaw, and finally erupt into the mouth to occlude with the teeth in the opposing jaw. Teeth become more worn with increasing age, thus providing a comparative guide for determining age within a group of animals [*2*]. Deciduous incisors (dI) were being replaced in two horses by adult incisors (I). No deciduous premolars were present in these animals.

The individual vertebrae that comprise the sacrum become fused with age. A cartilage pad (epiphyseal plate) separates the shaft (diaphysis) in long bones from the growing ends (epiphyses) until growth ceases and fusion results. Similarly, the two hip bones (os coxae) fuse in the midline (pubic symphysis) as age increases. These developmental morphological criteria provided unambiguous evidence of the relative ages of the skeletons. The data indicate that Skeleton 1 was that of a late-stage juvenile; Skeleton 4 was that of a young adult; and Skeletons 2 and 3 were older, with Skeleton 3 being slightly older than Skeleton 2 (Table 2).

The dental eruption and wear showed seriation of the same relative age as that determined by the degree of skeletal maturity (epiphyseal closure) (see Table 2). Because of the presence of deciduous incisors and erupting permanent teeth, the estimated ages of the two younger animals were more nearly accurate than the age determination for the two older horses (see, for example, Figs. 3*a* and 3*b*). The determinations for the older animals were based on dental attrition, which is affected by the type of feed. (The diet of the insured horses consisted mainly of a commercial processed food and hay.)

FIG. 2—*The skeleton of Horse 4.*

TABLE 2—*Criteria for determining the relative ages of the four skeletons.*

	Skeleton Number			
Criterion[a]	1	4	2	3
Age, years[b]	4	5	8	8
dI_2	present	absent	absent	absent
dI_3	present	present	absent	absent
I_1	slight wear	missing (postmortem)	moderate wear	moderate wear
I_2	unerupted	erupted	erupted	erupted
I_3	unerupted	unerupted	slight wear	moderate wear
P_4	partially erupted	fully erupted	fully erupted	fully erupted
M_3	partially erupted	fully erupted	fully erupted	fully erupted
Sacral vertebrae	partially fused	partially fused	fully fused	fully fused
Limb epiphyses	unfused	fused	fused	fused
Posterior vertebral centra epiphysis	unfused	unfused	almost fully fused	fully fused
Os coxa epiphysis	unfused	unfused	almost fully fused	almost fully fused
Distal scapular epiphysis	unfused	unfused	unfused	unfused
Pubic symphysis	unfused	unfused	fused	fused

[a]Key to abbreviations:
dI_2 and dI_3 = second and third deciduous incisors.
I_1, I_2, I_3 = first, second, and third lower incisors.
P_4 = fourth lower premolar.
M_3 = third lower molar.
[b]Approximate chronological age based on the date of birth.

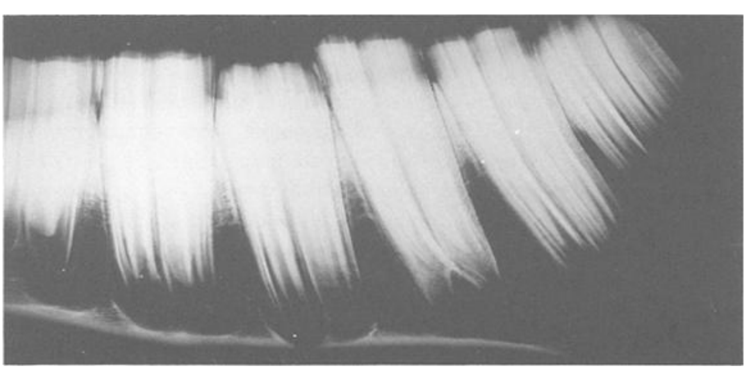

FIG. 3*a*—*X-ray of the mandible of Skeleton 1, showing a partially erupted fourth premolar and third molar* (arrows) *(also see Fig. 5*a*).*

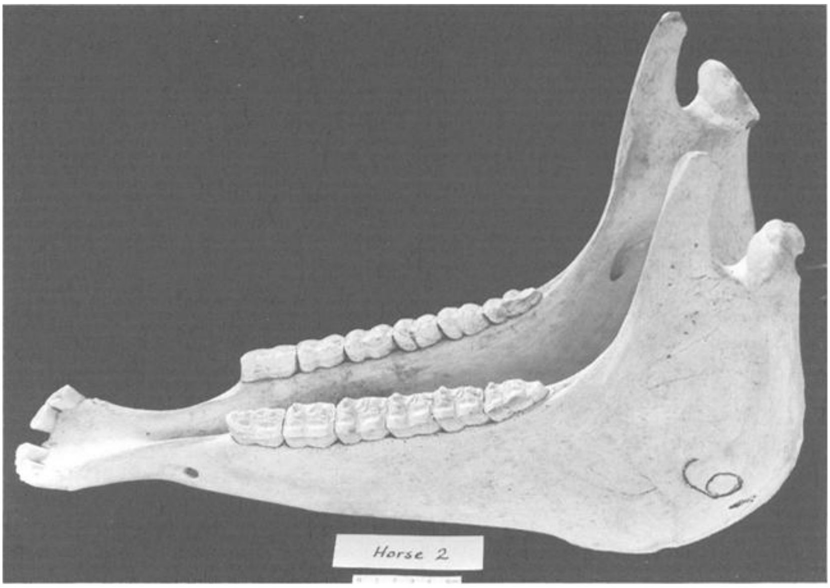

FIG. 3b—*Mandible of Skeleton 2, showing fully erupted premolars and molars.*

Morphometric Evaluation

Table 3 presents the results of the morphometric evaluation of bone density of the three skeletons for which metacarpals were available (Skeletons 2, 3, and 4). The numbers in the table are the mean values of the full cross sections measured at approximately 36° intervals. The basic structure of the long bone is the osteon-haversian system, which traverses the entire length of the bone. These structures are constantly being remodeled, that is, bone is being resorbed and then newly deposited. Under normal conditions, this process of resorption/formation is balanced by an overall net reduction in bone density as the animal ages (reduced osteon/vascular space ratio) [*3*]. In nutritional osteodystrophies, a pronounced reduction in the osteon/vascular space ratio should occur as a result of decreased bone density [*4*]. Figure 4 depicts the type of osteon-vascular structure that was measured. The samples of bone submitted for evaluation were structurally similar, having osteon/vascular space ratios ranging from 11.5 to 10.2. The lowest value represents the oldest horse. Comparative data for three additional horses of lesser and similar ages [three months (Horse No. 88N154), six months (No. 88N169), and seven years (No. 88N147)] are given in Table 3. The bones of these animals were considered normal. The oldest control animal (No. 88N147) had a mean osteon/vascular area ratio of 10.8, which is similar to the values of the samples studied. Three-month (18.3) and six-month (13.2) ratios are higher, which suggests minimal cortical remodeling at this age.

The bone density data collected from the three skeletal samples recovered from the field were morphologically normal; they did *not* provide evidence of any nutritional osteodystrophy.

Acute temporary starvation in the horse would probably not be reflected in the osteon architecture, although chronic starvation leading to death should be evident. Starvation or protein deficiency has been studied in the pig; in these studies, a thin cortical bone was developed in 132 days [5] and was accompanied by a reduced osteoid accretion rate.

TABLE 3—*Morphometric parameters of equine metacarpal midshaft cross-sectional areas.*

Animal Number	Age[a]	Cortical Thickness, cm[b]	Mean and SEM[c]	Mean Osteon Area,[d] mm^2	Mean Vascular Space Area,[e] mm^2	Osteon/ Vascular Space Ratio
88N154	3 months	0.40	Mean	0.188	0.010	18.3
			SEM	0.018	0.001	1.18
88N169	6 months	0.51	Mean	0.188	0.015	13.2
			SEM	0.016	0.001	1.00
4	5 years	0.973		0.195	0.021	9.2
				0.147	0.014	10.2
				0.206	0.019	10.8
				0.195	0.013	15.0
				0.251	0.020	12.5
				0.120	0.008	15.0
				0.150	0.017	8.8
				0.149	0.012	12.4
				0.125	0.013	9.6
				0.161	0.014	11.5
			Mean	0.169	0.015	11.5
			SEM	0.012	0.001	0.704
88N147	7 years	1.10	Mean	0.138	0.013	10.8
			SEM	0.013	0.001	0.636
2	8 years	0.80		0.146	0.015	9.7
				0.200	0.021	9.5
				0.181	0.016	11.3
				0.173	0.015	11.5
				0.147	0.013	11.3
				0.150	0.014	10.7
				0.139	0.014	9.9
				0.154	0.010	15.4
				0.158	0.009	17.5
				0.128	0.015	8.5
			Mean	0.157	0.014	11.5
			SEM	0.006	0.001	0.880
3	8 years	0.95		0.122	0.013	9.3
				0.169	0.150	11.2
				0.082	0.008	10.2
				0.103	0.009	11.4
				0.089	0.011	8.1
				0.126	0.012	10.5
				0.111	0.009	12.3
				0.093	0.010	9.3
				0.136	0.015	9.0
				0.131	0.012	10.9
			Mean	0.116	0.011	10.2
			SEM	0.008	0.007	0.402

[a]Chronological age determined from the birth records and the estimated date of death.
[b]Mean of thickness measured at 36° intervals.
[c]Mean = mean of 10 optic (× 6.3) fields measured; SEM = standard error of the mean.
[d]Mean measurable osteon area in a single (× 6.3) optic field.
[e]Mean vascular space of osteons measured.

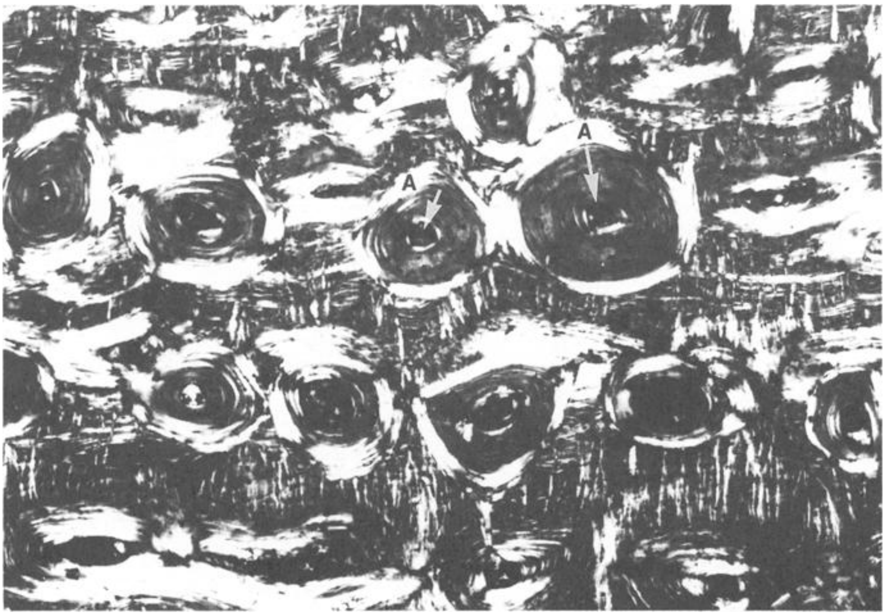

FIG. 4—*Metacarpal bone section from horse bone No. 25. Note the symmetrical osteon* (A) *and centrally placed vascular space* (arrow) *(compensated polarized light,* $\times$*6.3 objective magnification).*

The haversian canal structures were irregular in shape and size, indicating that the reabsorptive phase exceeded the formation phase of bone formation. Such studies have not been carried out in the horse; however, similar mechanisms should be operative and would result in enlarged haversian canals in relation to the osteon size. These particular animals did not show evidence of osteoporosis, as measured in terms of reduced tubular bone thickness: microscopically, there was no apparent indication of an increased number of resorption spaces, and the osteon/vascular space ratios were within normal limits. The usual osteodystrophy seen in the horse is "big-head" disease, a calcium/phosphorus imbalance in which too much concentrate (grain, such as oats) is fed while the hay intake is restricted. In such cases, there will be a 10-fold to 20-fold increase in the size of the vascular resorptive spaces (Roberts, unpublished data).

Breed

Although an analysis to determine the specific breed of the four skeletons was not undertaken, it was apparent that Skeleton 4 differed in many respects from Skeletons 2 and 3, which were similar to each other. As Skeleton 1 lacked a skull and many of the limb elements, a comparison with the other remains was not feasible. Though Skeleton 4 was from a younger animal than Skeletons 2 and 3, its skull was noticeably larger and its nasofrontal suture was more arched. The central part of the dorsal side of the skull was more domed, and the skull was more elongate (dolichocephalic). Further, the metapodials were shorter than those found in Skeletons 2 and 3. The large head and short third metacarpals and metatarsals (metapodials) suggest the genetic influence of a larger breed.

Trauma

The mandible of Skeleton 1 had a perforation and fracture as a result of a gunshot wound (Figs. 5*a* and 5*b*). The wound could have been inflicted at or near the time of death or after death before the bone had become desiccated. The bullet had entered the lateral side of the superior aspect of the right ascending ramus of the lower jaw below the coronoid process. The entrance wound was a circular sharp-margined hole (15.5 mm); the exit wound was jagged and beveled (24.8 mm), with two radiating fracture lines. No other traumatic injuries were observed in the other skeletal remains.

Conclusions

A comparison of the data derived from analysis of the four sets of skeletal remains present at the site with the breeding records for the four horses described in the insurance claim showed a good match for these reasons: (*a*) the recovered skeletons were all those of mares, as were the insured animals, and (*b*) the relative ages of the four recovered skeletons approximated the relative ages of the insured horses. The two oldest of the insured horses were born less than a month apart, on 12 March 1977 and 2 April 1977. Skeletons 2 and 3, the two oldest of the skeletal remains, were estimated to be quite close in age. Only the slightly greater wear on the third incisors and slightly greater fusion of the vertebral epiphyses showed that the animal represented by Skeleton 3 was older than that represented by Skeleton 2, both being about eight years old. The other two insured horses, born 7 March 1980 and at an unspecified date during 1981, were younger, and Skeletons 4 and 1 were found to be younger than Skeletons 2 and 3. Skeleton 4 was clearly older than Skeleton 1, which was that of a juvenile about four years old; however, Skeleton 4 was younger than Skeletons 2 and 3.

FIG. 5*a*—*Mandible of Skeleton 1, showing perforation of the right ascending ramus below the coronoid process as a result of a gunshot wound.*

FIG. 5*b*—*A closer view of the gunshot wound in Fig.* 5a.

The three skeleton samples submitted for morphometric evaluation showed no evidence of nutritional osteodystrophy and, thus, no support for the contention, in the insurance claim, that the demise of the animals resulted from deliberate starvation.

The youngest horse at the site, represented by Skeleton 1, had received a gunshot wound that could possibly have been related to her death, although later postmortem damage cannot be ruled out.

The case described here provides an example of the application of forensic osteological and physical anthropological field techniques and analytic methodology to questions relating to nonhuman remains. Through its presentation, the authors hope to stimulate organizations concerned with law enforcement and with legal and related questions to draw on the assistance that physical anthropologists can offer.

Acknowledgments

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