A DIRE WOLF SKELETON AND POWDER MILL CREEK CAVE, MISSOURI

EDWIN C. GALBREATH

Southern Illinois University, Carbondale

ABSTRACT.—Associated bones of *Canis (Aenocyon) dirus* were recovered from Powder Mill Creek Cave in Shannon County, Missouri. Radiocarbon tests of the bones give an age of 13,170 ± 600 years B.P. The dimensions of the bones indicate that this individual had limb and foot proportions similar to those of present day wolves and to the large dire wolves rather than the short forearm, shank and feet so characteristic of the smaller specimens found at Rancho La Brea and assigned to this species. A description of Powder Mill Creek Cave and the site of discovery is presented.

In the late fall of 1963, members of the Marion, Illinois, Explorer Post 25 (Boy Scouts of America) discovered several parts of the skeleton of a Dire Wolf, *Canis (Aenocyon) dirus* Leidy, in Power Mill Creek Cave on Powder Mill Creek in the NE¼ SW¼ part of Sec. 9, T. 29N. R. 2W., Shannon County, Missouri.

After all of the available parts were collected, the ribs were used for a raidocarbon test and the remainder of the material was catalogued under No. P-429 in the Vertebrate Paleontological Research Collection in the Zoology Department of Southern Illinois University.

The opportunity to observe Powder Mill Creek Cave during a period of extreme drought induces me to present more information on the cave than otherwise would be done.

POWDER MILL CREEK CAVE

In the part of Shannon County where this cave is located, the exposed geological section consists of more than 200 feet of Eminence Dolomite (Lower Ordovician) overlain by 15 feet of Gunter Sandstone, and capped by the Van Buren and Gasconade Dolomites. The main channel of the cave is cut in the Eminence Dolomite. In the farther reaches of the cave, crevices extend upward through the Gunter Sandstone and into the overlying dolomites.

The entrance (properly—the exit?) to Powder Mill Creek Cave is located on the east side of the 300-foot ridge that lies, locally, between the Current River and Powder Mill Creek. The cave extends, essentially, in a north-south direction (Fig. 1). It is a wet cave. Before the recent drop in water level, the previously known part of the cave could best be explored by using a canoe. Bridge (1930, p. 49) estimated the flow of water in the cave to be 2½ million gallons a day, and Beckman and Hinchey (1944, p. 70) reported the flow [named Cove Spring for some reason] to be 2,390,000 gallons per day in November, 1942. Such was the situation in 1961. By January of 1964, only a trickle of water issued from the cave and I was able to walk through the heretofore known part of the main channel, passing over shallows, gravel and sandbars, and skirting or wading the larger pools. Presumably, this decrease in the amount of water issuing from the cave can be attributed to the current drought in the Middle West.

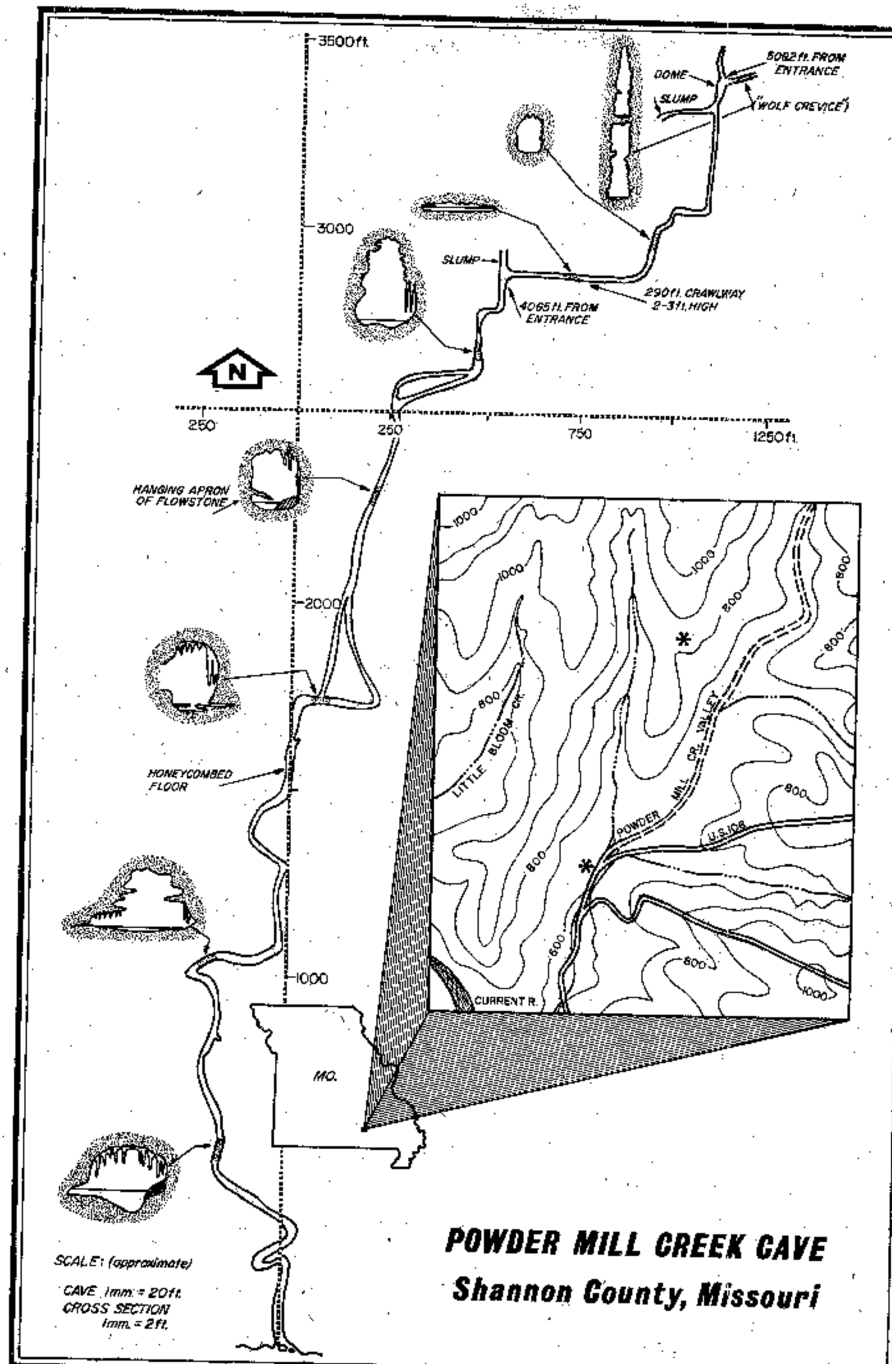

FIGURE 1.—Map of Powder Mill Creek Cave, Owls Bend, Shannon County, Missouri. Inset map, adapted from the Eminence Quadrangle, United States Geological Survey, of area northeast of Owls Bend shows location of Powder Mill Creek Cave. Lower star marks position of entrance in NE ¼ of SW ¼ of Sec. 9, T29N, R2W. Together, the stars mark the approximate position of the part of the cave that has been mapped. Map prepared by Cartographic Office, Southern Illinois University.

Bridge (1930, p. 44) and Bretz (1956, p. 446) described the cave as "small." When compared to caves in Missouri that have large open rooms, this description is just. On the other hand, the temporary low level of the stream in the main channel makes accessible passages that gives a length that can be matched by but few caves in Missouri. In April, 1964, the Marion Explorers and I, using a 300 foot steel tape, obtained a measured distance of 5082 feet plus an estimated additional length that would not exceed 300 yards. Without question, the cave is more than a mile long. The measured distances in the cave may be grouped as follows: from entrance to the beginning of a long (290 ft.) and low (2-3 ft.) horizontal crawlway, 4065 ft.; from the beginning of the crawlway to a crevice (hereafter referred to as the "wolf crevice", Fig. 1), 1017 ft.; from the wolf crevice onward in the main channel, which reduces rapidly in size and is passable by crawling and swimming, not more than 200 yds. It is possible to climb and walk eastward and northward through wolf crevice and an area of honeycombed parent rock for an estimated several hundred yards.

I think the "spring in the cave" referred to by Bridges (1930, p. 44) was the 2½ million gallons of water boiling out of the crawlway and marked the end of the cave at that time.

For the most part, the main channel is broad and tunnel-like with sponge-work, wall and ceiling pockets (some filled with red clay), and a relatively flat or rounded ceiling. Cave "formations" are present, of course, including some remarkable examples of helicites. Two elevated passages lead away from and back to the main channel. The only cross passage is wolf crevice and its mate on the opposite side of the main passage. This cross passage, an obvious product of joint solution, has a rather high, large dome at its junction with the main passage. The western part of this cross passage contains much of the red clay that Bretz (1956, p. 12) regards as a significant feature found in the developmental history of Ozark caves. A massive slump and collapse of the roof has blocked this passage. Possibly it once joined the passage that leads north from the outer end of the crawlway.

Upon entering the "wolf crevice" one climbs up into a narrow, elongate, high (or distressingly deep when it is necessary to creep with a foot on each wall to pass some cavity) crevice and over or through honeycombed parent rock. The crevice might be described as a vertical, elongate maze 50 to 75 feet high and varying in width from inches to many feet, thus being wide or narrow at various levels. Complete and incomplete bridges cross from wall to wall, and, at places, the dissection of the parent rock resembles a massive honeycomb. Great masses of red clay cling to some walls of the crevice.

Red clay deposits, rubble and silt fills, and cave formations contribute to a tendency to distinguish levels in wolf crevice according to the ability of the observer to move through the passageway. Thus discontinuous levels are present and one climbs up or down to a level more conducive to progress. Subsequent to the deposition of the red clay the crevice has undergone alteration by repeated cycles of cut and fill by vadose streams.

The site where the bones were found offers an example of the repeated cycles of deposition and abrasion that took place after the crevice was formed in the parent rock. Extending from wall to wall of the crevice (Fig. 2-3) is a mass of well-eroded Gunter Sandstone, sands, silts, fragments of stalactites, bat bones, and dire wolf bones cemented together in some spots and completely uncemented in others. This mass, about five feet wide, four feet long, and one and a half feet thick, in effect formed a "bridge" across the crevice inasmuch as it now arches over a channel that is open both "upstream and downstream." A remnant of coarse rubble-fill clings to one wall of the crevice below this arch. Some of this rubble bears a striking resemblance to the characteristic gravel of the Ozark streams.

The sandstone that forms the bridge seems to be a solid single piece across the downstream side of the arch, although it is dissected in the area where the bones reposed. Consequently, this relict "bridge" is, in part, a true bridge of parent rock. In all respects the rock appears to be typical Gunter Sandstone. The ascent of the cave passage is relatively regular and certainly is great enough to reach the Gunter. Nonetheless, as presently mapped, the position of the cave in relation to the surface topography requires that the passage go under a small valley and to the area where the Gunter Sandstone has not been removed by erosion. The cave reaches that area but not by a margin that precludes a question of doubt or more investigation.

The sequence of events at the site seem to be as follows:

1. Formation of the crevice with the Gunter Sandstone remaining as a bridge, probably but not necessarily in its present eroded condition.

2. An epoch of red clay fill inferred from evidence of clay in other parts of the crevice.

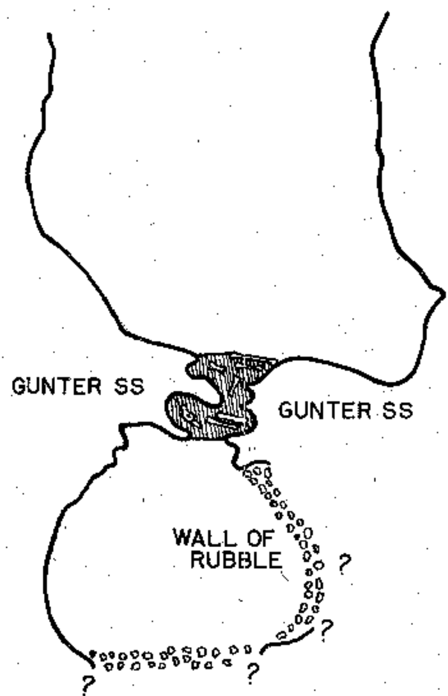

FIGURE 2.—Diagrammatic cross-section of "wolf-crevice" in Powder Mill Creek Cave at the site where the dire wolf was buried, showing the bridge of Gunter Sandstone and uncemented red silt containing free bones and bones cemented to the sandstone, chunks of cemented sandy silt containing bat bones, and fragments of stalactites.

FIGURE 3.—Photograph made by Mr. Robert Blankenship of site during excavation of the dire wolf skeleton. Orientation is essentially the same as that in Figure 2. The individual in the foreground (with back to camera) is peering into the channel below the bridge; the individual not wearing his helmet is kneeling on the "downstream" edge of the bridge. Chest of rotund individual with the cigar obliterates view of area where most of the bones were buried

3. Removal of red clay in, at least, the immediate area of the bridge.

4. Undetermined number of cycles of abrasion and deposition with the relic mass of rubble under the arch being part of one of the cycles.

5. Filling of the crevice to the level of the sandstone bridge so that a stream of vadose water could carry and lodge the skeleton, debris, and silt in the honeycombed and basined midsection of the bridge.

6. Hypothetical period wherein the accumulation of silts may have continued, covering the bones, or stopped, leaving the uppermost bones exposed as they were at the time of discovery.

7. Removal of the fill, if any, from over the skeleton; removal of the fill, whatever it was, from under the bridge; and removal of enough of the floor of the channel upstream from the bridge to reform a passage under the bridge.

The morphology of Powder Mill Creek Cave well fits Bretz's concept of caves. "Thus Bretz has argued (1942, 1953, 1956) that many phreatic caves may have had three epochs, the one in which the cave developed by solution, the clay-fill epoch, and the one in which the fall of the water table drained the cave. During the third epoch, vadose streams removed part of the clay and vadose dripwater began replenishment." (Bretz and Harris, 1961, p. 15). Bretz (1956, p. 15) listed six features of a cave that he regarded as criteria for identifying a cave formed below the water table—a phreatic cave. Of the six features, Powder Mill Creek Cave has spongework, wall and ceiling pockets, honeycomb structure and bridges. I cannot comment with authority on bedding and joint plane anastomoses or joint determined wall and ceiling cavities in this cave. I do think the rare side passages can be regarded as contributing to an incipient network pattern. The presence of red clay testifies to the existence of the second epoch in the cave's history. The third epoch, characterized by the action of vadose dripwater and vadose streams is evident.

I do not regard Powder Mill Creek Cave to be an isolated unit. Rather, I think it is one segment of a system of caverns of horizontal and vertical extent in this area of northeastern Shannon County. The presence of other caves in the area and the presence of Blue Spring, approximately two miles south-southeast of Powder Mill Creek Cave make an interesting combination of "possibilities" that offers credence to such a supposition. In fact, these observations, at this time, would fit the diagram of a typical cave system presented by Bretz and Harris (1961, Fig. 1).

Subsequent to writing these words, I was pleased to discover that Bridge (1930, p. 40-41) regarded Blue Spring as the outlet for subterranean drainage in the northwest-southeast trough of a shallow, sharply asymmetrical syncline and the gently dipping beds that lead to this trough from the Logan Creek drainage system six miles to the northeast. This conclusion was based on the correlation of the flow from Blue Spring with rainfall that drains into numerous sinks in the upper part of the Logan Creek.

At present, only one entrance is known to the cave, but air currents have been noted in the parts of the cave beyond the site where the dire wolf was found and fresh raccoon tracks have been found in the cross passage. For reasons to be considered below, a high entrance or entrances must have existed in Pleistocene times.

Discovery and Recovery of the Wolf

Powder Mill Creek Cave has been the object of exploration by the Marion Explorers for several years. As the water level in the main channel continued to drop during the early winter of 1963, the crawlway became free enough of water to allow passage into heretofore unvisited parts of the cave. The skeleton of the dire wolf was found by the Marion Explorers during their first visit into wolf crevice. After a second visit, the Scouts had recovered in complete or damaged condition all but thirteen of the parts listed in Table 1. This was evidence that compelled me to visit the site.

As has already been described, the skeleton was buried and subsequently exposed in such a way that it was possible to excavate for bones from above, below, and at the upstream end of the bridge. The evidence at hand suggests that the bones were trapped in the eroded pockets and channel in the Gunter Sandstone and surrounded by red silt. Subsequent to deposition, some of the bones were cemented to the sandstone.

TABLE 1. — Parts of the Skeleton of *Canis* (*Aenocyon*) *dirus* (No. P-429, S. I. U.) Recovered from Powder Mill Creek Cave in Shannon County, Missouri.

Right jaw:	fragments with P_4, M_1, and M_2
Left jaw:	fragments with C (damaged), M_1, M_2, and alveolus of M_3
Atlas:	damaged
Axis:	slightly damaged
Cervical vertebrae No. 3, 4, 5, 6, 7:	slightly damaged
Thoracic vertebra No. ?5:	damaged
Ribs:	fragments of several, most of which were used for a determination of the age
Sternum:	one segment
Scapula:	fragments of right and left
Humerus:	right damaged; left, distal end
Ulna:	right, lacks tip of olecranon process
Radius:	right and left
Metacarpals:	right II, III. IV, and V; left V
Magnum (os capitatum):	right
Pisiform:	right
Innominate:	right, lacks blade of ilium
Femur:	Right and left
Tibia:	left, slightly damaged; and right
Fibula:	left, proximal half
Calcaneum:	left
Astragulus:	left
Cuboid:	left
Navicular:	left
Metatarsals:	left II, IV (proximal end), and V
Proximal phalanges:	seven
Medial phalanges:	five
Distal phalanx:	one
Plantar sesamoid bones:	four

I judge that the bones of the dire wolf were carried into the trap formed by the sandstone before they were completely disassociated. Although in disarray, the parts showed a general orientation that placed the rump of the animal upstream. Parts of the right hind leg were reasonably well-associated so as to suggest that they were bound together by shreds of tissue when buried. The left humerus and pelvis were broken at the time of burial and were among the few bones to be damaged prior to excavation. Not a fragment of bone was recovered that could be a part of the skull. I am sure the lower jaws were complete, when buried, inasmuch as all the recovered fragments show new fracture surfaces; but a most diligent search failed to yield the missing fragments. A Scout is neat, and it is my duty to report that these Scouts kept a neat cave. They dumped the tailings of their digging down a hole!

The evidence of the site and the skeleton suggest to me that the wolf came from "upstream" and was swept to its place of lodgement. This, in turn, suggests that there was a flow of water in the crevice, and that the main channel had a good water supply and was not passable. If such were so, then I presume the wolf entered the cave by some entrance located high above and far from the present known opening.

I cannot resist reviewing the circumstances to which we owe the preservation of this remarkable specimen. To have a goodly part of one dire wolf trapped, to have the segment of fill bearing the bones preserved as it was, and to discover the otherwise unaccessible site during a period of drought seems to be far beyond the reasonable expectations of coincidence.

AGE OF THE BONES

The radiocarbon age determination of these bones, 13,170 ± 600 years, was made by Geochron Laboratories, Cambridge. This age determination is roughly a thousand years less than the possible dates reported by Howard (1960) for pit 3 at Rancho La Brea. Assuming that the age of the dire wolf bones in pit 3 bear a relationship to the age of the tree and tar samples that provided the dates, I would regard the Missouri dire wolf to be essentially contemporaneous (paleontologically speaking) with the dire wolves of pit 3.

Description of the Bones

The known skeletal parts of this specimen of *Canus dirus* resemble those parts of *Canus lupus* in many features. Were it not for proportional differences in size of individual bones when associated together, one would be hard put to prove that the skeleton should not be assigned to *C. lupus*. Differences in the post-cranial skeleton, other than proportional differences, that do exist may or may not be significant, and I question which of such differences could be attributed to being a different species. Nonethless, the following features are recorded.

Size. — Table 2 presents the dimensions of the bones of this individual.

Table 2.—Dimension (in mm) of Parts of the Skeleton of *Canis (Aenocyon) dirus*, No. P-249, Department of Zoology, Southern Illinois University. Except where noted, the measurements are parallel to or perpendicular to a plane of orientation, an axis of the bone, or an axis of the structure named. Measurements marked "est." involve cemented parts or are made from a center line to one side.

Atlas	
Length; plane of trans. processes horizontal	58.0
Width (est.)	113.0
Axis	
Height of axis; plane of post. articular surface of centrum perpendicular	62.0
Length of neural arch; plane of post. articular surface of centrum perpendicular	74.0
Length of neural arch regardless of orientation	74.0
Width of neural arch at post. end (est.)	44.6
Length of centrum from tip of odontoid process to post. articular surface of centrum; plane of post. articular surface perpendicular	73.0
Length of centrum from tip of odontoid process to post. end of centrum regardless of orientation	74.0
Width of ant. articular surface of centrum (est.)	44.0
Height of post. articular surface of centrum (est.)	19.5
Width of post. articular surface of centrum	30.1
Width of trans. processes	55.4
Third Cervical Vertebra	
Height of vertebra; plane of post. articular surface of centrum perpendicular	52.5
Length of neural arch; plane of post. articular surface of centrum perpendicular	55.2
Length of neural arch regardless of orientation	56.4
Greatest width of neural arch	44.4
Width of neural arch at ant. zygapophyses	40.1
Width of neural arch at post. zygapophyses	43.8
Length of centrum; plane of post. articular surface of centrum perpendicular	39.5
Height of ant. articular surface of centrum	17.9
Width of ant. articular surface of centrum	26.8
Height of post. articular surface of centrum	21.4
Width of post. articular surface of centrum	28.4
Width of trans. processes	76.0

Fourth Cervical Vertebra

Height of vertebra; plane of post. articular surface of centrum perpendicular	59.0+
Length of neural arch; plane of post. articular surface of centrum perpendicular	59.7
Length of neural arch regardless of orientation	57.8
Width of neural arch at ant. zygapophyses	50.0
Width of neural arch at post. zygapophyses	45.0
Length of centrum; plane of post. articular surface of centrum perpendicular	36.0
Height of ant. articular surface of centrum	18.8
Width of ant. articular surface of centrum	25.0
Height of post. articular surface of centrum	23.6
Width of post. articular surface of centrum	29.1
Width of trans. processes	70.0

Fifth Cervical Vertebra

Height of vertebra; plane of post. articular surface of centrum perpendicular	68.0
Length of neural arch; plane of post. articular surface of centrum perpendicular	50.0
Length of neural arch regardless of orientation	51.0
Width of neural arch at ant. zygapophyses	51.7
Width of neural arch at post. zygapophyses	46.9
Length of centrum; plane of post. articular surface of centrum perpendicular	32.6
Height of ant. articular surface of centrum	19.1
Width of ant. articular surface of centrum	28.1
Height of post. articular surface of centrum	23.5
Width of post. articular surface of centrum	26.6
Width of trans. processes	64.6

Sixth Cervical Vertebra

Length of neural arch; plane of post. articular surface of centrum perpendicular	43.0+
Length of neural arch regardless of orientation	42.8+
Width of neural arch at ant. zygapophyses	48.1
Width of neural arch at post. zygapophyses (est.)	44.0
Length of centrum; plane of post. articular surface of centrum perpendicular	31.1
Height of ant. articular surface of centrum	21.0
Width of ant. articular surface of centrum	22.1
Height of post. articular surface of centrum	23.9
Width of post. articular surface of centrum	26.2
Width of trans. processes (est.)	62.0

Seventh Cervical Vertebra

Length of neural arch; plane of post. articular surface of centrum perpendicular	42.0
Length of neural arch regardless of orientation	42.0
Width of neural arch at ant. zygapophyses	46.0
Width of neural arch at post. zygapophyses (est.)	41.2
Height of post. articular surface of centrum	21.6
Width of post. articular surface of centrum	28.5
Width of trans. processes (est.)	66.0

Fifth Thoracic Vertebra

Greatest width of neural arch	50.2
Width of articular surface of ant. zygapophyses	19.5
Width of articular surface of post. zygapophyses	17.1
Length of centrum; plane of post. articular surface of centrum perperpendicular	26.2
Height of ant. articular surface of centrum	20.5

Width of ant. articular surface of centrum		23.5
Height of post. articular surface of centrum		20.2
Width of post. articular surface of centrum		22.5
Width of ant. demifacets		32.2
Width of post. demifacets		37.3

Sternebral Element

Length		32.2
Depth at midpoint		18.2
Trans. width at midpoint		9.5

Pelvic Girdle

Orientation: vent. surface of symphysis horizontal.		
Length from ant. edge of pubic symphysis to post. end of ischium		110.
Distance between dorsal edges of acetabular lips (est.)		100.
Vertical diameter of acetabular cup		32.7

Teeth

	Left	Right
$P_{\overline{4}}$ — $M_{\overline{2}}$, length		65.7
C(lower); anteropost. diameter at base of enamel	18.0	
C(lower); trans. width at base of enamel (est.)	11.8	
$P_{\overline{4}}$, anteropost. length		19.5
$P_{\overline{4}}$, trans. width		9.5
$M_{\overline{1}}$, anteropost. length	34.7	34.9
$M_{\overline{1}}$, trans. width	13.6	13.7
$M_{\overline{2}}$, anteropost. length	13.9	14.0
$M_{\overline{2}}$, trans. width	10.0	10.0

Lower Jaw

	Left	Right
Length, ant. end of ramus to middle of condyle (est. based on ratios of dimensions of known parts to those of other specimens)	233.0	
Depth at a point below the paraconid-protoconid notch of $M_{\overline{1}}$ to midpoint of ventral surface of jaw	36.9	
Depth at a point below the hypoconid of $M_{\overline{1}}$ to midpoint of ventral surface of jaw	35.5	
Thickness below protoconid of $M_{\overline{1}}$	18.3	

Scapula

	Left	Right
Greatest anteropost. diameter of head	49.7	49.7
Greatest anteropost. diameter of glenoid fossa	40.0	40.0
Greatest trans. width of glenoid fossa	29.+	29.4

Humerus

	Left	Right
Length (est.)		247.0
Anteropost. diameter of head		68. +
Anteropost. diameter of shaft at midpoint		24.5
Trans. width of shaft at midpoint		23.8
Trans. width of distal end	56.2	57.5

Ulna

	Left	Right
Length (est.)		285.6
Length from dist. end to prox. lips of semilunar notch		258.0
Least anteropost. diameter from dist. border of radial facet to prox. lip of semilunar notch		32.5
Trans. width at coronoid process		27.5

Radius

	Left	Right
Length	236.0	235.0
Width of prox. end	31.6	31.3
Width of dist. end	40.9	41.0

Metacarpal II

Length		93.0
Depth of prox. end		19.2
Width of prox. articular surface		11.2
Width of dist. articular surface		14.4

Metacarpal III

Length (est.; surface abraded)		105.0
Width of dist. articular surface		13.5

Metacarpal IV

Length		104.7
Depth of prox. end		18.0
Width of prox. articular surface		12.0
Width of dist. articular surface		13.2

Metacarpal V

Length	92.0	92.0
Depth of prox. end	17.1+	17.3
Width of prox. articular surface	18.4	18.9
Width of dist. articular surface	15.1	14.5

Magnum

Proximodistal length		24.6
Anteropost. depth		16.4
Width		13.0

Pisiform

Anteropost. length		29.0
Depth of prox. end; medial half of ulnar facet horizontal		17.5
Width of prox. end; orientation same as above		18.5

Femur

Length	270.0	270.0
Trans. width of prox. end	66.0	66.0
Anteropost. diameter of shaft at midpoint	21.1	20.9
Trans. width of shaft at midpoint	21.3	21.1
Trans. width of dist. end		55.0

Tibia

Length		265.0
Anteropost. diameter at prox. end		63.+
Trans. width at prox. end		56.+
Trans. width at dist. end	36.5	36.0
Length of fibular scar	122.0	

Fibula

Length (est.)	245.0
Anteropost. diameter of prox. end	20.5

Calcaneum

Orientation: same as Figures 1-3, Galbreath, 1955.

Proximodistal length	71.0
Mediolateral width	30.0
Dorsoplantar depth	32.0

Astragalus

Proximodistal length	41.5
Mediolateral width	34.0
Dorsoplantar depth	24.0
Width of body	29.0
Width of tibular facet	24.2
Trans. width of head	19.5
Dorsoplantar depth of head	20.4

Cuboid

Proximodistal length	30.0
Mediolateral width	22.5
Dorsoplantar depth	22.0

Navicular

Anteropost. length	26.4
Greatest height on outer surface	16.8

Metatarsal II

Length	99.8
Depth of prox. end	21.7
Width of prox. articular surface	9.0
Width of dist. articular surface	13.5

Metatarsal IV

Length (est. based on ratios of existing parts compared to *Canis lupus hudsonicus*)	117.0
Depth of prox. end	19.5
Width of prox. articular surface	15.1

Metatarsal V

Length	104.4
Depth of prox. end	17.2
Width of prox. end including processes	18.0
Width of dist. articular surface	12.5

Proximal Phalanges III and IV

Length, greatest	38.5	39.0	39.7	40.4
Width of prox. articular surface	14.0	13.5	13.5	13.8
Width of dist. articular surface	11.6		10.9	10.9

Proximal Phalanges II and V

Length, greatest		34.6	35.0	35.7
Width of prox. articular surface		13.5	12.7	13.7
Width of dist. articular surface		11.4	10.3	11.3

Medial Phalanges III and IV

Length, greatest			28.6	29.2
Width of prox. articular surface			12.3	11.9
Width of dist. articular surface			12.1	11.8

Medial Phalanges II and V

Length, greatest		23.3	23.7	22.5
Width of prox. articular surface		11.3	13.3	11.4
Width of dist. articular surface		10.6	11.8	10.2

Distal Phalanyx

Length, greatest				27.2
Width at prox. end				11.1
Depth at prox. end				18.1

Individual Age. — The teeth are well-worn and all parts of all the bones are firmly fused. There is no question that this skeleton is that of an adult female.

Disease. — The cuboid and one proximal phalanyx show bony growths similar to exostosis. The growth on the phalanyx may have limited the use of the one toe. Many bones bear roughened eminences for muscle attachments or contact with neighboring bones such as that between the radius and ulna. These eminences seem large and exaggerated when compared to bones of

Canis lupus, yet I cannot think that they are indicative of disease.

Lower jaw and teeth. — The preserved parts of the lower jaw are massive. Unfortunately, the anterior mental foramen is damaged and there is no true indication of its size. It does terminate under the anterior root of P_{-2}. An incipient groove on the postero-lingual side of P_{-4} tends to separate the posterior basal tubercle from the cingulum. However, this separation has not extended to the degree of forming a notch like that described for No. 10727 by Merriam (1912, p. 230). Although well worn, the metaconid of the first molar has one of the secondary tubercles preserved that Merriam (p. 230) regarded as common on the molars of *C. dirus*. The M_{-2} most resembles the tooth depicted in figure 8 of Merriam (1912).

Atlas. — The lateral processes of the atlas are short and stubby, having a posterior border perpendicular to the long aixs something more like that seen in *Canis latrans*. Of the features listed by Merriam (1912, p. 235), this atlas has the large open transverse foramen passing "normally" through the blade, and the transverse processes not projecting far behind the posterior ends of the facets for articulation with the axis. On the other hand, the notches on the anterior border of the processes are deep, well-developed and actually have spines extending toward the midline but not completely enclosing the space. An additional feature of the transverse foramen worthy of note is that the medial border on the ventral side is excavated thus making the nutrient foramen, that runs medial from the canal, open and visible.

Axis. — Merriam described the axis of *C. dirus* as near that of *Canis lupus* in form, differing in certain proportions. The notch on each side of the spine and medial to the tuberosities above each posterior zypopophysis is present. The dorsal border of the neural arch appears to be more flattened than in some of the axes from Rancho La Brea that I have examined or that figured by Merriam (1912, fig. 17). The root of the odontoid process is wide thus, when coupled with the relative shortness of this structure, gives a blunted, conical appearance to the process. The posterior end of the neural arch is bifurcated. The facets for articulation with the atlas are not bluntly rounded on the posterior border but are extended upward and posteriorly thus being comparable with the pattern seen on the axis of *Canis latrans*.

Pelvis. — The pattern of the anterior border of the pelvic canal is like that seen in Recent female wolves, and I do not doubt that this specimen is correctly sexed. The pelves of individuals from Rancho La Brea that I have examined are equally easy to divide into those belonging to males or females. A feature of this and other female pelves that I have seen is the recessed or excavated area for the Obturator internus muscle that lies far posterior to and medial to the borders of the obturator foramen. The depth and extent of the excavation varies in individuals, being 5 to 10 mm deep, and having the borders literally overhanging the area of muscle origin to a greater or lesser entent.

Radius. — The ulnar facet at the distal end of the radius is short and broad. The groove for the tendon of the Extensor ossis metacarpi pollicis is as well-marked as some of those found on specimens from Rancho La Brea. The anterior notch in the margin of the proximal end is deep.

Pisiform. — The lateral corner of the proximal end of this bone projects anteriorly thus producing a "hook" that fitted around the distal end of the ulna.

Metacarpal II. — Merriam (1912, p. 237) reasoned that the narrowness of the medial facet of the scapholunar bone in *Canis dirus* should be accompained by a transversely narrow trapezoid and proximal end on metacarpal II. Such was not the case in the Rancho La Brea specimens or in this specimen from Missouri. The head of metacarpal II is relatively wider than that of *C. lupus hudsonicus.* I am inclined to think that this is a problem involving the size of the individual as well as width and depth of the bone.

Femur. — The medial border of the linea aspera is weak. Insofar as I can ascertan, this is a variable character. The medial crest bordering the patellar groove is greatly enlarged and projects anteriorly far beyond the lateral crest. The greater trochanter is similar to the average condition seen in most of such known bones.

Metatarsal IV. — The articular tubercle on the medial side of the proximal end of metatarsal IV is as large as that seen on similar bones from Rancho La Brea. However, unlike the round, hummocklike, medially directed facet seen normally, only the dorsal surface bears an articular area. Such a condition appears to be intermediate between the structure seen on *C. lupus* and *C. dirus.*

Metatarsal V. — The lateral proximal process of metatarsal V is well-developed here as in Rancho La Brea specimens. On the ventral side only a very weak groove separates this process from the process bearing the articular surface for the sesamoid bone. This latter facet is triangular in shape with the short sides of the triangle on the proximal and medial borders of the process.

Body Proportions

Such body proportions as robustness and relative lengths of the bones of *Canis dirus* have been commented upon by Merriam (1912), Nigra and Lance (1947), and Stock and Lance (1948). Their studies were, of course, based upon a multitude of bones and guided by the sensible idea that big individuals had big bones and medium-sized animals had medium-sized bones (for example see Stock, Lance, and Nigra, 1946). Despite the large size of some of the bones and the recognized variation in length between bones from different pits, *Canis dirus* at Rancho La Brea is, and probably will continue to be, regarded as a homogeneous assemblage. When all the components of the skeleton have been studied in detail and absolute ages determined for each pit, we shall probably realize that the differences in bones from pit to pit are inconsequential. Meanwhile, it is rewarding to have the bones of a single individual that may be regarded as one test of the Rancho La Brea material.

I have prepared Figure 4, after the method demonstrated by Simp-

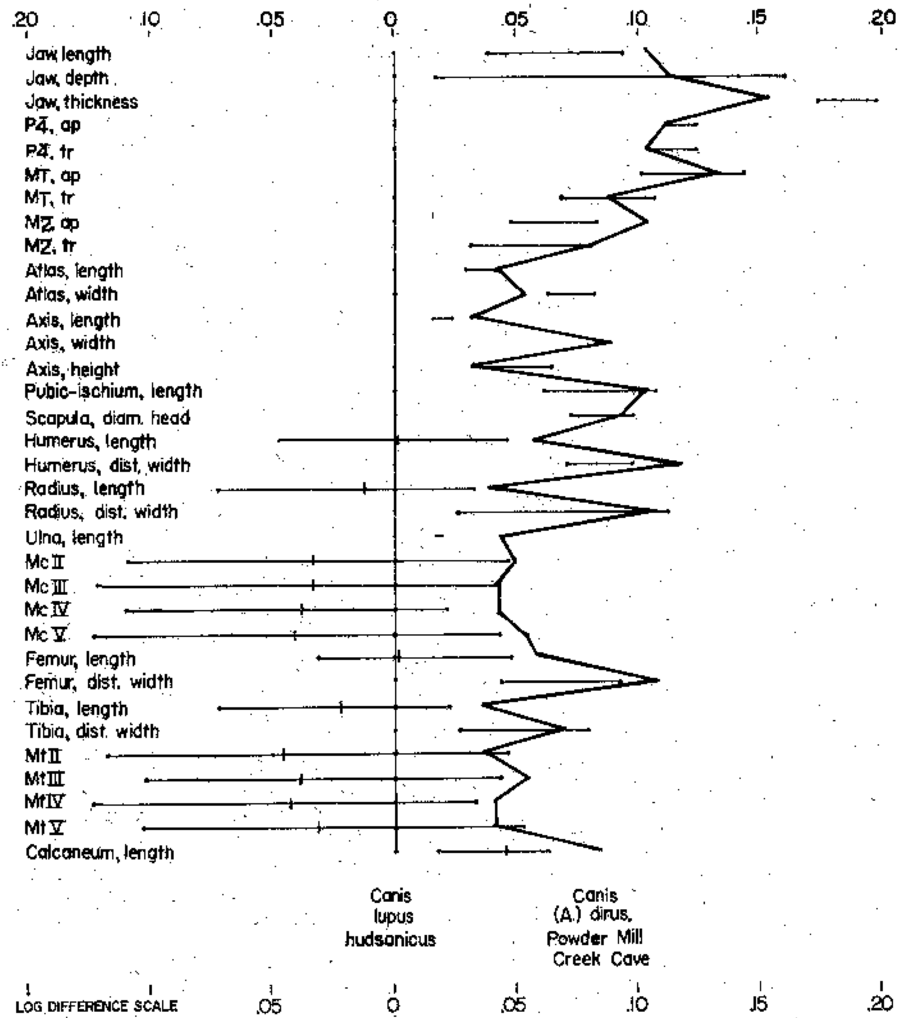

FIGURE 4.—Ratio diagrams (based on a log difference scale) of dimensions of *Canis dirus* from Rancho La Brea Tar Pits, of skeleton of *Canis dirus* from Powder Mill Creek Cave, and skeleton of *Canis lupus hudsonicus* from northern Manitoba (adult female No. 0-1557, Zoology Department, Southern Illinois University).

The ranges of the humerus, radius, femur, tibia, metacarpals, and metatarsals from Rancho La Brea are calculated from the measurements reported by Nigra and Lance (1947) and Stock and Lance (1948). The means reported by these authors are indicated by vertical bars. Other ranges of Rancho La Brea material are based on measurements reported by Merriam (1912) or on measurements made by me. The dimensions of *Canis lupus hudsonicus* were used as a basis for determining the ratios.

son (1941), as a visual demonstration of some of the proportional relationships. Figure 4 is based on measurements taken from Merriam, Nigra and Lance, Stock and Lance, measurements made by me on a small number of bones from Rancho La Brea, measurements of the Missouri skeleton and measurements of an average-sized Recent female wolf. Inadequate as the chart may be in some respects, I think it does present a picture of *C. dirus* that is reasonably reliable, thanks to data collected by Stock, Lance, and Nigra in measuring the limb bones and metapodials from Rancho La Brea.

Inter-memberal proportions. — Dire wolf bones are robust compared to those of Recent wolves. Most of the bones of this specimen from Missouri demonstrate such robustness, to a greater or lesser degree, particularly in having relatively larger dimensions in planes perpendicular to the long axes of the bones. Figure 4 depicts some examples of this condition where the dimensions have been plotted in relation to the length of the structures concerned. While I am convinced that robustness of the bones is one of the features that distinguishes *Canis dirus* from *Canis lupus,* I would hesitate to use this feature to assign isolated, single bones of the post-cranial skeleton to one or the other species. Recognition of the species in special circumstances, such as the metapodials in small individuals as compared to those of the large individuals, emphasizes the need for more study of inter-memberal proportions.

Intra-memberal proportions. — As will be recalled, *C. dirus* is regarded as having a body size ranging from smaller to larger than medium-sized Recent wolves, an inordinately large head, long, deep, and thick lower jaw with a large carnassial, large scapula and pelvis, forearm and shank (epipodial elements) relatively shorter than humerus and femur (propodial elements), and body and extermities more robust. To this body of common knowledge should be added the fact that the calcaneum is proportionately larger. In the past, the feet have been regarded as being relatively smaller in relation to the forearm and shank in contrast to the condition seen in the modern wolf. This is true most of the time; but, the relationship varies with the actual size of the individual. An inspection of the data presented by Nigra and Lance (1947) and Stock and Lance (1948) suggests that within the *C. dirus* entity the metapodials tend to be relatively shorter in smaller individuals and longer in larger individuals. Consequently, the largest individuals and the modern wolves have a similar foot-limb ratio. This new specimen has, from the evidence of the teeth and jaws, a head at least the size of that of medium-sized individuals of *C. dirus* from Rancho La Brea, limbs and body the size of the largest dire wolves, but with metapodials proportionally larger—being near the metapodial to humeral and femoral proportions seen in the Recent wolves. I cannot take an extrapolation of some jaw and teeth measurements of this female too seriously in determining the size of the head. Using the minimal figures, of course, makes the size of the head nearer, relatively, the proportions seen in

Recent wolves. Nonetheless, the parts at hand indicate that the actual size of the head and jaws would yet exceed the size found in the largest Recent wolves, while the body is smaller.

Discussion

When this skeleton was discovered, I assigned it to *Canis (Aenocyon) dirus* on the basis of the similarity in the size and pattern of the teeth and preserved part of the jaw to specimens from Ranco La Brea, and assumed that I had a good post-cranial skeleton to support the decision. Time has tempered such rash confidence. *Canis dirus* can be distinguished from the Recent wolves by the fact that it has structural differences in the skull, proportionally larger head and teeth, proportionally shorter forearm and shank, and more robust body and extremities. Criteria, other than the structural differences in the skull, are best used together. Used separately, it is necessary to take into account the actual size of the bone or bones concerned or have some associated bones; then only a part of such bones could be identified.

Prime significance may be attached to the proportions of the parts of this specimen from Missouri because they represent the relationships found in the bones of one individual. Furthermore, these proportions match, within reason (that is to say, considering that unknown factor—individual variation), the proportions that exist between the largest bones from Rancho La Brea that have been assigned to the dire wolf. Inasmuch as such proportions do exist, I think it is valid to assume that the large bones from Rancho La Brea belong together. Moreover, the doubt expressed by Nigra and Lance (1947, p. 28) that the largest metapodials included in their sample did not belong to the dire wolf becomes less bothersome.

Table 3 presents a series of indices derived from the relationships between the lengths of the metapodials and the lengths of the epopodial and propodial elements of the extremities of the dire wolf and the Recent wolf. I regard the indices to be of interest more for what they suggest in the way of future problems than as evidence to prove a point. Hildebrand (1952 and 1954) regarded the ratio of metapodial length to epipodial and propodial lengths to be rather constant in the Recent canid skeletons. He did not emphasize individual variation or variation among populations. Obviously, a significant amount of data derived from the bones of associated skeletons of the modern wolves are needed to determine whether or not proportional relationships similar to those found in the dire wolf exist. Any data derived from associated bones of the dire wolf would be welcome. Such data would be a test of the validity of the suggested relationships found in the Rancho La Brea material—particularly if it can be determined that these proportional relationships are unique for the dire wolf.

At present I consider this specimen from Missouri to be a *Canis dirus* and to be reasonably similar to the *Canis dirus* from Rancho La Brea. I think that the material from Rancho La Brea must be regarded as a homogeneous population in the

TABLE 3.—Indices Derived from the Dimensions of Bones of the Extremities of the Dire Wolf and Recent Wolf to Demonstrate Proportional Relationships.

	C. dirus from Rancho La Brea			*C. dirus* from Missouri, No. P-429.	*C. lupus hudsonicus* from Manitoba, No. Q-1557	*C. lupus* (average of eight specimens)[2]
	Minimal size[1]	Average size[1]	Maximum size[1]			
Mc III / Radius x 100	39.3	42.	45.	44.5	44.1	43.5
Mt III / Tibia x 100	39.3	40.6	44.3	43.7[3]	43.8	42.5
Mc III / Humerus x 100	36.9	40.4	43.5	42.5	43.9	42.7
Mt III / Femur x 100	36.8	38.9	43.1	42.9[3]	43.4	43.6

[1] Data for indices from Nigra and Lance (1947) and Stock and Lance (1948).
[2] Data for indices from Stock and Lance (1948).
[3] Based on an estimated length of 116 mm for Mt III.

paleontological sense. The variation in size of the metapodials from the different pits, noted by Nigra and Lance (1947), is too little to demonstrate otherwise.

One might argue that having a female as large as the largest Rancho La Brea material would indicate that even larger males probably lived in Missouri. Such a postulation could lead to the suggestion that, compared to the population at Rancho La Brea, a larger subspecies lived in Missouri at a slightly later date. Such a chronocline may have existed but I do not think the present information about *Canis dirus* is useful enough to debate the issue.

COMMENTS ADDED IN GALLEY PROOF

Belatedly, I have discovered the paper by Hawksley, et al. (Missouri Speleology, 5:63-72, 1963) reporting the large dire wolves from Camden and Pulaski Counties, Missouri. Professor William Elder (University of Missouri) and Professor Oscar Hawksley (Central Missouri State College) permitted me to examine the specimens. I think the skeleton (2870; CM 14) from Camden County is that of a large male. The angle between the anterior borders of the pubic rami is acute and the area for the origin of the internal obturator muscle is not recessed. The calcaneum of this individual is 69 mm long (see Hawksley, et al., p. 70) and an unreported left metatarsal II is 110 mm long.

I am impressed by the fact that only large dire wolves have been found in the Ozark region. These specimens, by reason of geographic proximity, could form a hypodigm to accompany Leidy's type of *Canis dirus*. On the other hand, we cannot ignore the evidence of size of individuals from Rancho La Brea when judging the Missouri specimens. Nor am I unmindful of the smaller, and possibly older, dire wolf bones from Frankstown Cave, of *Canis ayersi* Sellards; the several discoveries of isolated parts of dire wolves in North America, and the composition of the genus *Canis* when I join Hawksley, et al. in urging the use of caution in formulating answers to the questions arising from the discovery of these large specimens.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the credit due to Mr. Gerald Gotway, a science teacher in the Marion, Illinois High School System for recognizing the value of this find and in obtaining the material for Southern Illinois University.

Words are weak terms to express my gratitude to Mr. Robert Blankenship, and to members of the Marion, Illinois Explorer Post 25 for their help to me in obtaining the skeleton and mapping the cave. It was necessary for Mr. Dee Reynolds, Mr. Dale Norman, and Mr. Gotway, all of Marion, Illinois, to accompany the Explorers. I appreciate the contribution of time and material to the extra trips that were involved. Above all, I shall not forget the kindness, patience, consideration, and genuine solicitude with which I was carefully and tenderly conducted into and out of the cave.

Professor Stanley E. Harris gave much-needed advice on cave work. Authorities and friends at the Smithsonian Institution, University of Colorado Museum, Museum of Natural History, University of Kansas, and Chicago Natural History Museum gave assistance when needed during this study.

The office of Research and Projects and the Zoology Department at Southern Illinois University contributed funds to the study.

LITERATURE CITED

BECKMAN, H. C., and N. S. HINCHEY. 1944. The large springs of Missouri. Missouri Geol. Survey and Water Resources 2nd ser. 29:1-141, 17 pls.

BRETZ, J. H. 1942. Vadose and phreatic features of limestone caves. J. Geol. 50:675-811.

———— 1953. Genetic relations of caves to peneplains and big springs in the Ozarks. Am. J. Sci. 251:1-24.

———— 1956. Caves of Missouri. Missouri Geol. Survey and Water Resources. 39:1-490.

BRETZ, J. H., and S. E. HARRIS, JR. 1961. Caves of Illinois. Illinois Geol. Survey, Rep. Inv. 215.

BRIDGE, J. 1930. Geology of the Eminence and Cardareva Quadrangles. Missouri Bur. of Geology and Mines. 24:i-iv, 1-228, 22 pls.

GALBREATH, E. C. 1955. Skeleton of a mustelid, Brachypsalis, from the Miocene of northeastern Colorado. Univ. Kansas Paleont. Contrib., Vertebrata 5, 1-15, 2 pls.

HILDEBRAND, M. 1952. An analysis of body proportions in the Canidae. Am. J. Anat. 90(2):217-256.

———— 1954. Comparative morphology of the body skeleton in recent Canidae. Univ. Calif. Publ. Zool. 52 (5):399-470.

HOWARD, H. 1960. Significance of carbon—14 dates for Rancho La Brea. Science. 131(No. 3402):712-714.

MERRIAM, J. C. 1912. The fauna of Rancho La Brea. Mem. Univ. Calif. 1(2): 215-272.

NIGRA, J. O., and J. F. LANCE. 1947. A statistical study of the metapodials of the dire wolf group. Bull. So. Calif. Acad. Sci. 46(1):26-34.

SIMPSON, G. G. 1941. Large Pleistocene Felines of North America. Am. Mus. Novitates 1136.

STOCK, C., and J. F. LANCE. 1948. The relative lengths of limb elements in Canis dirus. Bull. So. Calif. Acad. Sci. 47(3):79-84.

———— J. F. LANCE, and J. O. NIGRA. 1946. A newly mounted skeleton of the extinct dire wolf from the Pleistocene of Rancho La Brea. Bull. So. Calif. Acad. Sci. 45(2):108-110.

Manuscript received August 1, 1964.