

BULLETIN

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NATIONAL SPELEOLOGICAL SOCIETY

VOLUME 26

NUMBER 4

Contents

NEW PARIS NO. 4: A PLEISTOCENE

CAVE DEPOSIT IN BEDFORD COUNTY, PENNSYLVANIA

OCTOBER 1964

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New Paris No. 4:

A Late Pleistocene Cave Deposit In Bedford County, Pennsylvania

By John E. Guilday*, Paul S. Martin**, Allen D. McCrady*

ABSTRACT

Excavation of a 10-meter column of surface-derived matrix from Sink-hole No. 4 at New Paris, Bedford County, Pennsylvania produced a late Pleistocene biota: over 2,700 vertebrates, with an accompanying pollen profile. C-14 date is approximately 11,300 B.P. The indicated environment is cool taiga parkland during the early phase of infill with progressive reforestation during a subsequent warming (but still boreal) period.

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* Carnegie Museum

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INTRODUCTION

The excavation of Sinkhole No. 4 near New Paris, Pennsylvania, provides the first detailed record of late-glacial range adjustments made by many boreal species of birds and mammals in the late Pleistocene period of eastern North America. Excavation of about 10 meters of unstratified mud and rubble fill from the sinkhole produced skeletal remains of at least 2,769 vertebrates associated with plant pollen and carbon.

In the modern environmental gradient of eastern North America a zoo-geographer may recognize (from north to south) Arctic-Alpine, Hudsonian, Canadian and Austral life-zones corresponding respectively to the tundra, boreal woodland, boreal forest, and deciduous forest of the ecologist. A major objective in current studies of the Pleistocene has been to determine the fate of these environments. Were they dissolved, amalgamated, or otherwise drastically altered? Did they endure, albeit compressed and somewhat modified, during glaciation? What can the Pleistocene fossil record tell us about the nature of plant and animal communities beyond the ice sheet?

Throughout our text we will attempt to make a distinction we believe is important

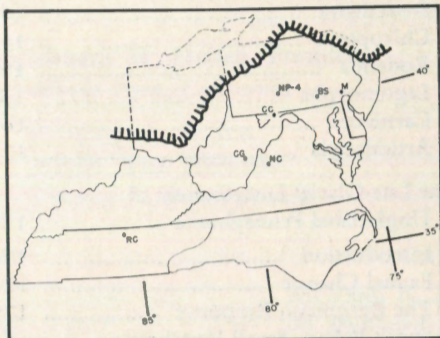


Figure 1.

Map of east-central United States. Hachured line delimits approximate southern limit of Wisconsin glaciation. NP = New Paris No. 4, Pa. BS = Bootlegger Sink, Pa. M = Marsh, Pa. CC = Cumberland Cave, Md. NC = Natural Chimneys, Va. CG = Cranberry Glades, W. Va. RC = Robinson Cave, Tenn.

in Pleistocene paleoecology, that of separating (whenever possible) boreal forest from boreal woodland (see Martin, 1959).

The term *open boreal woodland* is applied by Hare to the type of tree growth seen in the foreground of O. J. Muries's photo of Great Whale River (fig. 5) in which "tall and well-developed spruce (more rarely other conifers) stand scattered in a sea of *Cladonia*." (Hare, 1950, p. 624). This is a very different environment from the more familiar *boreal forest* to the south, where more than 90 per cent of the spruce pulpwood of Canada is cut. While the same species of trees may dominate in both the woodland and the forest, they form a closed canopy, grow more rapidly, and to a greater height in the latter.

In the fossil pollen record criteria for distinguishing boreal forest from boreal woodland are not clearly established; even tundra may be difficult to recognize from the pollen record alone. Fortunately, certain of the small vertebrate remains found in such abundance in New Paris No. 4 appear to be sensitive indicators of tundra, woodland, and forest. The vertebrates make it possible to determine more precisely the nature of the late-glacial environment in Pennsylvania than would be possible from pollen evidence alone.

Morphological and ecological analysis of the mammals represents the contribution of Guilday; the excavation proper and its description is the contribution of McCrady, while the results of pollen analysis are presented by Martin. A chapter on reptiles and amphibians is provided by Neil D. Richmond. Our concluding statement on "Late-glacial environment and life in unglaciated Pennsylvania" represents a joint effort. We recognize that the Pleistocene fossil record from the unglaciated East is highly fragmentary and poorly dated. Our conclusions may wither in the face of more definitive fossil evidence or more perceptive ecological insight. Certain contradictions remain to be resolved through analysis of yet undiscovered late Pleistocene fossil deposits.

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We are indebted to Mr. and Mrs. Oscar Miller and their children, the owners of the

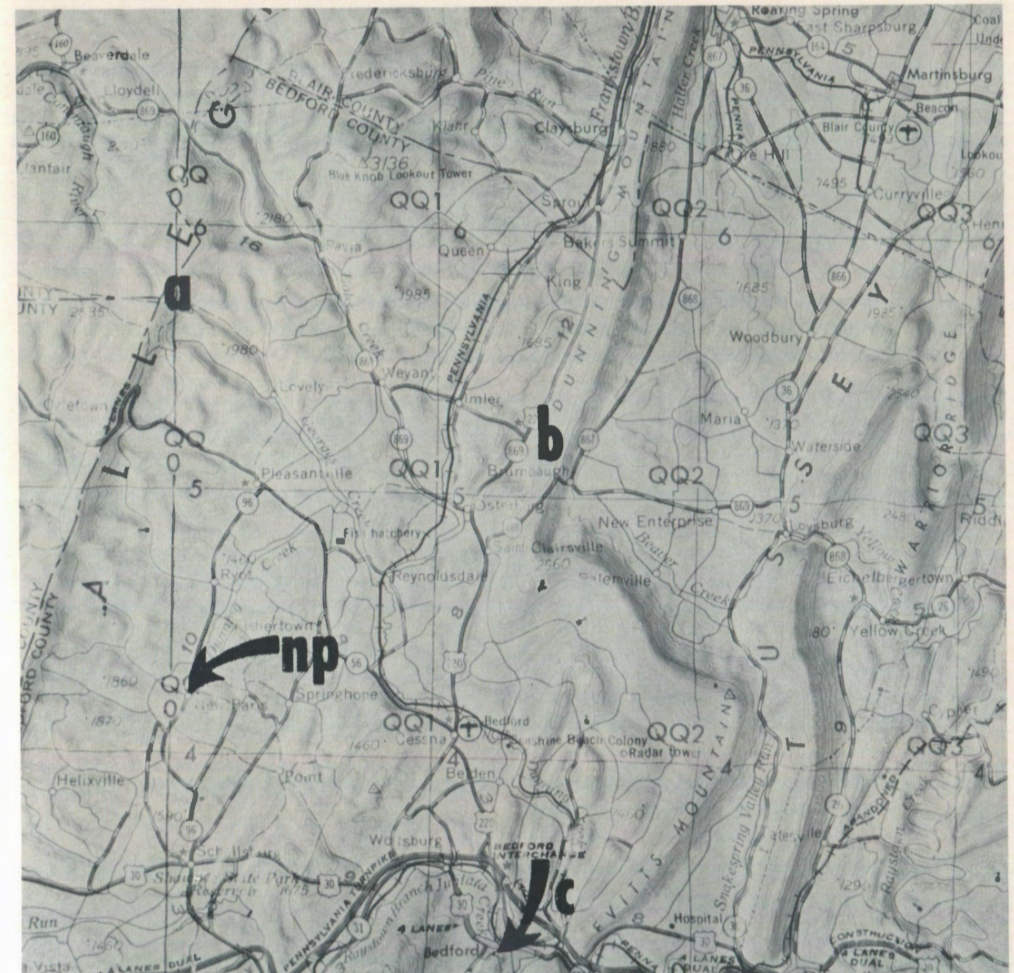


Figure 2.

Northern Bedford County, Pennsylvania. a. Eastern rim of Appalachian Plateau, Allegheny Mountain. b. Dunning Mountain. c. Bedford, Pa. NP = New Paris, Pa. Base Map = U. S. Army Corps of Engineers NK 17-12. Series V501P. Grid = 10 km.

site, who have been wonderful and gracious to the steady stream of cavers who have descended on them through the years.

We thank the following people who donated time and varied talents to the excavation of New Paris No. 4. Without them this project would have been impossible. We can only hope that other institutions will be so blessed with such a capable field force: Susan Allardice, Kenneth Acklin, C. Dale Acklin, Charles Barton, Hugh Barton, Mr. and Mrs. W. Galen

Barton, the late Martin S. Bender, Ralph C. Bossart (field supervisor), Susan Booth, John Devlin, Mr. and Mrs. Gerald Frederick, Bruce Godwin, Daniel Green, Mr. and Mrs. Allan P. Haarr, Roscoe Hall, Mr. (field supervisor) and Mrs. Harold W. Hamilton, Mr. and Mrs. George Howard, William Hunter, Mr. and Mrs. Paul Imblum, W. Roswell Jones, Viera Kulamer, John B. Leppla, John A. Leppla (field supervisor), Ann Montgomery, Jerry Paulich, Frank Potter, Monica Rectenwald,



Figure 3.

Looking west from New Paris sinkholes toward Allegheny Mountain. Miller house, center foreground. Dunning Creek appears as wooded corridor running from left to right beyond farm.



Figure 4.

Looking east across valley of Dunning Creek to Chestnut Ridge. Arrow points to site of New Paris sinkholes.



Figure 5.

Coniferous forest with tundra intervals. Northern edge of Hudsonian life-zone. Great Whale River, lat. 55° 17' N., Quebec, Canada. Similar conditions prevailed at New Paris during the Wisconsin glaciation about 12,000 years ago. From Todd, 1963.

John Reigler, Mr. and Mrs. Edmund Taylor, Frank Varchulik, Marjorie Shaw, Valerie Whitehead.

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The roster of museum colleagues that have assisted through the project includes them all. We shall single out only Albert C. Lloyd (the "Lloyd's Rockhole" Lloyd) for years of help and encouragement and Joseph Y. Quil, clerical

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Art work was by Richard Lang (figs. 13, 18, 19, 22, 26), Monica Rectenwald (fig. 6), and Donald P. Tanner (figs. 1, 7, 12, 14, 15, 27 through 34). Photography was by W. Galen Barton (figs. 2, 3, 4, 10, 16, 17, 20, 21, 24, 25), John A. Leppla (figs. 8, 11, 23), M. Graham Netting (fig. 9) and Olaus J. Murie (fig. 5). The color plates, center leaf are by Harry K. Clench and A. D. McCrady. We wish to thank Clifford J. Morrow, Chief, Special Exhibits Staff, Carnegie Museum for technical advice. We wish to thank W. E. Clyde Todd, Curator Emeritus of Birds, Carnegie Museum, for permission to publish fig. 5.

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HISTORY OF INVESTIGATION

The New Paris sinkholes were initially investigated in 1932 by Charles E. Mohr, now Director of Kalamazoo Nature Center and were described by him in Stone, 1932. In April, 1948, members of the Pittsburgh Grotto, National Speleological Society (N.S.S.), revisited the site and secured a partial elk (*Cervus canadensis*) skeleton from Sinkhole No. 2. Carnegie Museum, under a grant from the A. W. Mellon Educational and Charitable Trust, excavated Sinkhole No. 2 (or Elk Hole) in 1949 and 1950. A recent fauna of 26 species of mammals was recovered (Guilday and Bender, 1958). In August of

1956 the Pittsburgh Grotto (N.S.S.), working in conjunction with Dr. J. LeRoy Kay, Curator Emeritus, Section of Vertebrate Fossils, Carnegie Museum, began the excavation of Sinkhole No. 4, or "Lloyd's Rock Hole." Excavation continued until March of 1963 when sterile cave-derived sediments were encountered at a depth of 9.1 m and bedrock 0.6 m lower.

GEOLOGY

Sinkhole No. 4 or Lloyd's Rock Hole (2.4 km [1.5 mi.], northeast of New Paris, West St. Clair Township, Bedford County, Pennsylvania; lat. 40° 5' N., long. 78° 39' W., alt. 465 m [1500 feet]. See map, Guilday and Bender, 1958), is one of many along the west flank of Chestnut Ridge*, an anticline of upper Silurian-lower Devonian marine limestone and sandstone (fig. 4). The ridge itself is capped by the Lower Devonian Oriskany sandstone. Streams draining the ridge have formed small coves that locally have exposed the underlying Helderberg limestone. Ground water circulation, locally governed by the joint system of the limestone, has produced a series of domepits along the joint structure. Some of these have intersected the present land surface and are filling with surface-derived material, soils, humus, rocks, plant and animal remains. Others, as exposed in a local quarry, have not reached the surface. They are in the form of deep, crack-like caves floored with sterile, yellow-brown clay derived from the silicious and argillaceous residue of the chemical breakdown of the parent limestone. Still others have had surface connections in the past and have been filled to the surface. Some still show a slight funnel-shaped depression on the surface of the ground. Others have no surface indication.

Open sinkholes reach a depth of over 26 meters. Their walls bell out below the surface into typical dome-pit conformation (see Pohl, 1955 and Merrill, 1960). Solution fluting and relatively insoluble fossil inclusions protruding from the moist walls indicate that solution initiated by humic-rich groundwaters

* not to be confused with the more widely known Chestnut Ridge 80 km to the west on the Appalachian Plateau.

is further enlarging the pits. Infilling is extremely slow at the present time due to the thin soil mantle which averages 0.5 meters in thickness. Infilling may have been more rapid during late Pleistocene times under the influence of frost-wedging.

A skeleton of a Recent timber wolf (*Canis lupus*) from New Paris No. 2 yielded an age of 1,875 ± 100 years B.P. (I-743). The animal was buried beneath about 2 meters of mud and rubble. This date provides a crude estimate of the rate of infill, about 1 meter per 1000 years. At the same rate the 9.1 meters of fill in New Paris No. 4 would have required some 10,000 years. Internal evidence suggests that the rate of infilling of New Paris No. 4 was more rapid during the initial phase of accumulation when the local climate was colder, and slower during the terminal phase. Accepting Y-727 (11,300 ± 1,000 B.P.) as a reliable date for the 5.7 m level; the upper half of the cave fill accumulated at a minimum rate of 0.5 m per thousand years.

GEOGRAPHY OF AREA

Chestnut Ridge (fig. 4) is the low 488 m anticline upon which the sinkhole is located. It lies in an intermontane valley (fig. 2) 30 to 40 km wide and over 160 km long. The valley floor is approximately 425 m above sea level. It is bounded on the northwest by 885 m Allegheny Mountain (fig. 3), the eastern rim of the Appalachian Plateau, and on the southeast by a long, narrow 700 m ridge variously named Bald Eagle, Canoe, Lock, Loop, Dunning, Evitt's, and Will's Mountain depending upon its local sinuous configuration and the presence of water and of windbreaks. Blue Knob, a local outlier of Allegheny Mountain some 19 km north of the sinkholes, rises to 956 m — one of the highest points in the state.

In addition to its karst drainage, which contributes to its surface dryness, Chestnut Ridge lies within the rain shadow of Allegheny Mountain. Prevailing winds are from the west and mean annual precipitation may be 25 to 38 cm less east of Allegheny Mountain. Average annual precipitation at Somerset, 40 km west of New Paris on the Appalachian Plateau (elev. 640 m) is 129.5 cm per year

(Gifford and Whitebread, 1951). A few kilometers east of the Appalachian Plateau at Hyndman, 40 km south of New Paris in the same intermontane valley, it drops to 89.3 cm per year (Kauffman, 1960). A prehistoric rain shadow is also quite likely.

It is conceivable that the relative aridity of the site may have been attractive to jack pine (*Pinus Banksiana*) during late Pleistocene times. This species finds its best development at the present time on well-drained sandy tracts throughout the northern coniferous forest belt of North America. Contemporaneously, the poorly drained rim of the Appalachian Plateau 8 km west and 460 m higher may have supported a tundra/taiga biota. It seems evident, both from the make-up of the New Paris No. 4 local fauna and the complicated physiography of the area, that several biotic zones could live in juxtaposition under a critical climatic regime. They do so today, but only to a limited extent. Snowshoe hares (*Lepus americanus*), for example, formerly occurred in hemlock bogs along the crest of Allegheny Mountain within 16 km of New Paris (Rhoads, 1903) but not at New Paris where the lagomorph fauna during Recent times contained only cottontails (*Sylvilagus floridanus* and *S. transitionalis*). Canadian life-zone conditions are suggested in a few places, such as the Allegheny Mountain crest, but the biota is generally transitional in character.

Gifford and Whitebread (1951, p. 18) states: "The part of this sector (south-central Pennsylvania) that lies south and east of Blue Mountain (Dauphin County) would properly be considered part of the Carolinian Biotic Province of Dice (1943). While the areas along the Allegheny Front... are most like the southern portion of the Canadian Biotic Province of Dice. However, the Ridge and Valley section generally is difficult to assign to either of these broad classes. Although it has many of the features of a transitional zone between the two biotic provinces, it is also an area where the distribution of plants and animals is strongly influenced by the local and varied topography and soils with the result that the distribution of many of the plants and animals found in this area appear to be primarily

determined by the availability of suitable habitats and the adaptability of the species."

HISTORY OF EXCAVATIONS, MATERIALS AND METHODS

Initially, Sinkhole No. 4 resembled at the surface a bowl-shaped depression 9 m in diameter, 2 m deep in its center (fig. 8). A 2 x 2 m shaft (Station 1) was dug in the sinkhole fill directly in the center of the depression (fig. 6). No contact was made with the walls of the sinkhole and square-set shoring was required to a depth of 7.6 m. This shaft produced no bones. At the bottom of the shaft, on the west side, a passage (Station 2) led to an intersecting dome-pit. Talus from its bottom revealed a rich deposit of late Pleistocene bones (Station 3). Excavation of this collapse material, which had lost its original stratigraphy, was not conducted by levels. At this point, 5.2 m southwest of the original shaft, a second shaft was started from the surface. There was no surface indication of this shaft prior to excavation. Shoring was not required below ground level because this narrow fissure was separated from the original shaft by a limestone wall. The excavation was rich in organic inclusions (bone, pollen, charcoal) to a depth of 9.1 m, below which it was abruptly underlain by sterile yellow cave-derived sediments which could be traced into the original shaft demonstrating that the two shafts were originally part of the same subterranean system (figs. 10 and 11).

The large doline represented by the surface depression was a massive collapse phenomenon apparently the result of the failure of the ceiling of a large cave room. Surface fill rapidly slumped in from the large feed-cone at the surface. This collapse was apparently too large in diameter and consequently too gentle in slope to function as an efficient trap. The small dome-pit (Station 3) on the other hand, had a restricted surface opening due to its narrow width. With a small debris-cone, a slow rate of infilling and vertical walls, it served as an efficient trap (fig. 6).

There was no apparent internal stratigraphy to the 9.1 m column of debris. Deposition took the form of a conical talus so that an object falling in may have gone no further,

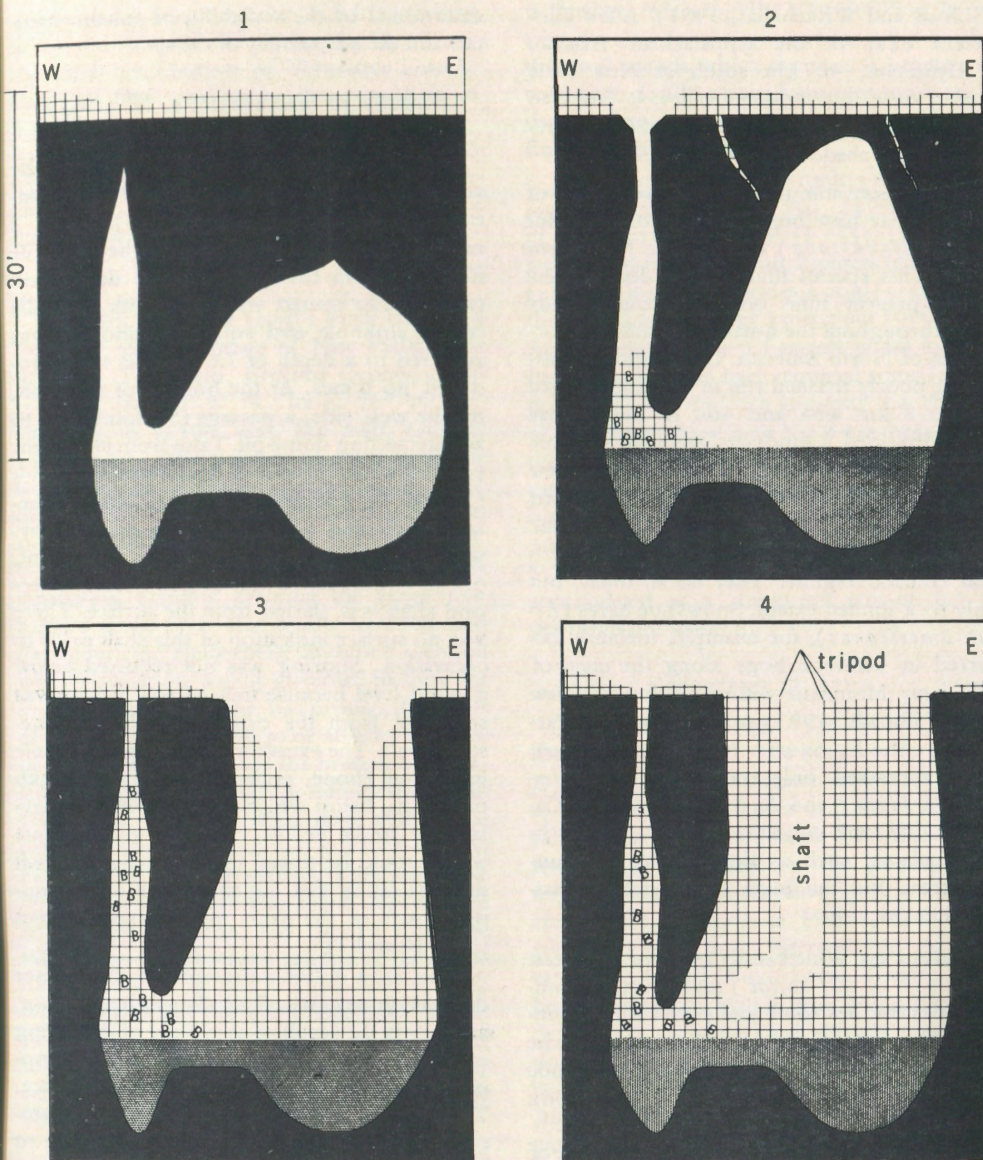


Figure 6.

Postulated steps in the history of the New Paris No. 4 bone deposit. Black = bedrock. Gray = cave-derived sediments. Hatched = surface-derived materials. B = bones, etc.

or may have worked its way down slope or deep into a crack. Remains of the one peccary (*Mylobyus*) recovered, although in a semi-articulated condition, were scattered over a vertical distance of 1.5 m indicating

considerable slope or slumpage. On the other hand many of the skeletons recovered were uncrushed and still in articulation, indicating that little if any post-depositional disturbance had occurred. A few rodent-gnawed snow-

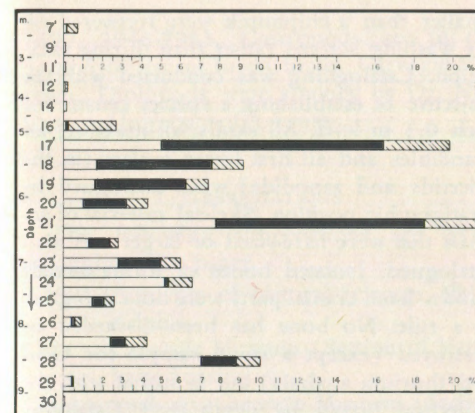


Figure 7.

Percentage of total catalogued bones and teeth recovered per level in Station 3, Sinkhole No. 4, New Paris, Pa. White = Microtinae. Black = Chiroptera. Hatched = others.



Figure 8.

Sinkhole No. 4, New Paris, Pa. Original test shaft, Station 2, view southwest.

shoe hare bones and the recovery of a concentration of rodent droppings containing a modern pollen flora (see p. 137) indicate that there must have been some disturbance. Despite the homogeneous nature of the fill, and the uneven deposition, a convincing faunal and floral succession can be demonstrated. Similar sites are known from the late-Würm of eastern Europe and demonstrate parallel ecological replacement. Different species are involved of course but the similarity is too close to be ignored.



Figure 9.

Sinkhole No. 4, New Paris, Pa. Washing and screening. Coarse screen above, fine screen below. Water recirculated by pump.

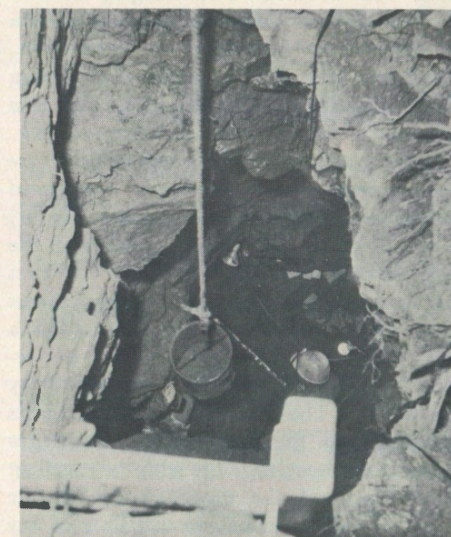


Figure 10.

Sinkhole No. 4, New Paris, Pa. Looking from surface to the 7.0 m level. Excavation in progress, view southwest.

PROCEDURE

Excavation of the original test shaft and the connecting passage (Stations 1 and 2) proceeded with no stratigraphic controls. As soon as the bone deposit was encountered and the second surface shaft (Station 3) was begun,



Figure 11.

Sinkhole No. 4, New Paris, Pa. Contact between surface-derived fossiliferous material above and sterile, cave-derived sediments below. Southwest face, 9.1 m level.

strict stratigraphic control of all excavated matrix was initiated. The roughly circular shaft was divided into four quarters. Matrix was removed in 0.3 m (one foot) levels. Labeled lots of matrix were placed on drying racks consisting of an upper screen of 6 mm mesh and a lower screen of 1.5 mm mesh. When the matrix was dry enough to break the colloidal bonds of the mud, it was hosed through these two grades of screens (fig. 9) and any bones or teeth placed in vials with the proper stratigraphic data. Picking of the finest grade of matrix was carried out largely without the aid of magnification. It is certain that a small percentage of microfauna was not recovered that could have been picked up by magnification. The large number of specimens recovered, and the meaningful percentages derived from them, together with the excellent preservation and the thoroughness of the search, all lead us to believe that little of any consequence to the project was missed. This would not be true where the objective was morphological reconstruction of poorly-known or new forms, but the primary objective here was establishing percentage relationships in a numerically rich and morphologically well-known fauna. A minimum of 125 tons of matrix were processed.

It was possible in some instances to recover articulated skeletons even of some of the smaller shrews. These were excavated and preserved as such. But almost all of the specimens

smaller than a chipmunk were recovered on the washing screens rather than during excavation. Cataloguing was conducted with the objective of establishing a species census for each 0.3 m level. All skulls, all maxillae, all mandibles and all first lower molars (in the cricetids and zapodids) were catalogued by stratigraphic position. Skeletal material of animals that were hare-sized or larger was also catalogued. Isolated bones of forms already known from cranial parts were not catalogued as a rule. No bone has been discarded or destroyed (except a small sample for C-14 and thorium analysis) but is stored with the collection boxed by depth level. Catalogue information was placed on punch cards and analyzed stratigraphically. Census percentages are based upon minimum number of individuals per level. This was based solely upon skulls or skull parts, and may not coincide with the minimum number of individuals present in the whole deposit. The total number of yellow-cheeked voles (*Microtus xanthognathus*), for instance, is derived from a count of all lower first molars of that form that were recovered. But two other species of the genus, the rock vole (*M. chrotorrhinus*) and the meadow vole (*M. pennsylvanicus*), cannot be told apart by the morphology of the lower first molar. The skulls, or the upper dentitions of all three forms are separable, and their use in establishing percentages by level gives a truer relative picture than if lower teeth of the first and upper teeth of the second and third form were employed. Skulls or maxillae of the two bats of the genus *Myotis* present are readily separated, but mandibles are difficult to identify to species in many cases with any real assurance. Due to the presence of so many well-preserved bat skulls this was not attempted. There were more sets of mandibles than there were skull parts recovered, so that the minimum number of bats of the genus *Myotis* (based upon mandibles) is greater than the sum of the individual species of that genus (based upon skull parts). This is true for some other groups as well. The mammal, bird and reptile remains are catalogued in the Section of Vertebrate Fossils, Carnegie Museum: Accession numbers 18786 and 19109; catalogue numbers 5440-5503, 5505-5515, 5517-5931, 6004-6386, 6647-

7890, 7948-7953. Gastropods are in the Section of Recent Invertebrates, Carnegie Museum. Diplopods were retained by Dr. Nell Causey, University of Arkansas.

ABBREVIATIONS

The following abbreviations are used throughout this paper.

- ANSP Academy of Natural Sciences, Philadelphia.
 CM Carnegie Museum (Section of Vertebrate Fossils).
 CM mammal no. Carnegie Museum (Section of Mammals).
 UMMP University of Michigan, Museum of Paleontology.
 USNM United States National Museum.
 TMM Texas Memorial Museum.
 BP Before present.
 C Canine tooth
 d. Deciduous dentition
 I Incisor tooth
 M Molar tooth
 P Premolar tooth
 NAP Non-arboreal pollen
 N Sample size
 X Sample mean
 σ Standard deviation
 V Coefficient of variation
 O.R. Observed range.

The following cave faunas from the central Appalachian Region are mentioned repeatedly in the text. The references are listed here to avoid needless repetition.

Cave Fauna	Primary Reference
Port Kennedy Cave, Pennsylvania	Cope, 1899
Frankstown Cave, Pennsylvania	Peterson, 1926
Hartman's Cave, Pennsylvania	Leidy, 1889
New Paris No. 2, Pennsylvania	Gulday and Bender, 1958
Bootlegger Sink, Pennsylvania	Gulday, Hamilton, McCrady, in press
Cavetown, Maryland	Hay, 1920
Cumberland Cave, Maryland	Gidley and Gazin, 1938
Robinson Cave, Tennessee	McCrady and Schmidt, 1963
Natural Chimneys, Virginia	Gulday, 1962

QUALITATIVE CHEMICAL ANALYSIS OF BONE

Snowshoe hare bone from the sinkhole was submitted to the Alcoa Research Laboratories, Aluminum Company of America, New Kensington, Pa., for qualitative chemical analysis. This was compared with a sample of modern

snowshoe hare bones from an animal furnished by the Pennsylvania Game Commission. The modern bones were degreased in benzene, the fossil sample cleared of matrix in a water bath. Both samples were leached in a 50 ml. bath of hot HCL for 30 minutes. Samples were then ashed and a qualitative spectroscopic analysis run. Results are summarized below:

	Fossil sample		Modern sample	
Weight of bones	6.8351 gm.		6.5996 gm.	
Weight after leach	2.2033		2.8923	
% of original bone after leach	32.3%		43.8%	
Weight of ash of bones	1.9444		0.6895	
% of original bone after ashing	28.5%		10.4%	

Relative concentration	Elements detected in ash			
	Leach of old bones	Old bones after leach	Leach of new bones	New bones after leach
10 to 100%	Calcium	Calcium Silicon Aluminum	Calcium	Calcium
1 to 10%	Phosphorus	Phosphorus Iron Potassium	Phosphorus	Phosphorus
.1 to 1%	Aluminum Iron Sodium Silicon Magnesium Strontium	Sodium Magnesium Titanium	Magnesium Sodium Potassium Strontium	Sodium Magnesium
.01 to .1%	Barium Potassium Manganese	Strontium Barium Rubidium Boron Lithium Zirconium	Barium Iron	Iron Strontium Barium Potassium Zinc Silicon Lead Aluminum
less than .01%	Boron Lithium Copper Nickel Chromium Lead	Manganese Lead Ytterbium Vanadium Gallium Chromium Copper Nickel Beryllium	Silicon Lead Aluminum Boron Manganese Copper	Boron Lithium Manganese Copper Chromium Nickel
ash at 500 C	81.32%	88.17%	95.77%	23.84%

The fossil bones are much higher in aluminum and silicon than their modern counterparts, with a percentage rise of from less than one-tenth of one percent to over 10 percent. Iron and potassium showed a comparable increase. Traces of the original clay matrix infiltrating the bone may be responsible for some of this increase. Elements present in the fossil bone but not recorded from the modern sample include titanium, rubidium, zirconium, vanadium, ytterbium, gallium, and beryllium. The fluorine in modern hare bones was 0.25 percent, in the fossil sample, 1.69 percent.

The fossil sample was lower in water and organic constituents, with a total loss on ashing of 16.3 percent in weight compared with a 35.8 percent weight loss of modern hare bone.

RADIOMETRIC ANALYSIS OF BONE

Selected samples of snowshoe hare long bones and vertebrae distributed from the 3.0 m to 5.8 m levels, and a sample of the clay matrix from the 6.1 m level, were submitted for radiometric analysis to Dr. Lewis H. Binford, then with the Phoenix Memorial Laboratories, University of Michigan. The results will be published elsewhere, but a brief summary is presented here. Two problems were involved: 1. Did bone samples from various stratigraphic levels show significant differences in terms of beta radiation that would bring any evidence to bear on the rate of the infilling of the sinkhole? 2. Since samples of both vertebrae and limb bones were submitted from each level, did these two types of bones, one cancellous, one dense, absorb radioactive thorium salts at the same rate? Binford concluded:

"The radiometric analysis of bone and soil specimens from Lloyd's Rock Hole, (Sinkhole No. 4), has revealed that there is no real difference in the beta radiation characteristic of bone specimens from levels 15 (5 m) through 19 (6.3 m) (this is also probably true as high as level 10 [3.3 m]). The distribution of the specimens of long bone from these levels was found to be a normal curve with a negative skew. Although no conclusive demonstration was possible, this was interpreted as indicative of a slight shift in the rate of accumulation of the deposit, accumulation having occurred rather rapidly for the mass of the deposit with a diminished accretion over a period of time at least as long as that required for the original deposition of the mass of the deposit.

"In addition to the findings relative to the interpretation of the deposits in Lloyd's Rock Hole, it was found that long bones and vertebrae, both from *Lepus americanus* and taken from the same levels, represented distinct populations with respect to beta count. These findings were interpreted, at least for the time being, as indicative of differential absorptive

properties for soft, spongy bone as opposed to hard, compact bone. These findings make it imperative that in further investigations designed for answering questions about depositional or hydrological history of deposit specimens of the same species and preferably bones of the same anatomical part be used for comparisons." (Binford [1960], p. 7-8).

CARBON - 14 DATES, NEW PARIS No. 4

Carbon-14 dating tests were run by two laboratories, one on charcoal particles, presumably derived from a forest fire, by Yale Geochronometric Laboratory through the courtesy of Dr. Edward S. Deevey; the other on bone, primarily *Lepus americanus*, by Michigan Memorial Phoenix Project Radiocarbon Laboratory, University of Michigan through the courtesy of Dr. James B. Griffin.

Sample	Depth from surface	Date
Y-727 charcoal	4.6 m	11,300 ± 1,000 yrs. B.P.
M-1067 bones, small mammals	5.2 m - 6.4 m	9,540 ± 500 yrs. B.P.

Dr. Binford (letter of Dec. 28, 1960) commented on the above dates:

"The observed difference, 1760 years, can be expressed in units of the standard error - 1760/1118.03 = 1.57 standard errors (a value expressed in this standard form is called "t"), and from a table of areas of the normal curve or of "t" for infinite degrees of freedom the probability of obtaining so large a value can be read off.

"In your case the probability is greater than 10 per cent. That is, you would expect to obtain so large a discrepancy, more than ten out of a hundred separate runs on the identical specimen. This information, plus the fact that the Michigan date was a short run, suggests that both dates are estimates of a single "true date" and that it is likely that the "true date" is closer to the 11,300 estimate than to the 9,540 estimate."

CARBON - 14 DATES, NEW PARIS No. 2

A carbon-14 date is now available for Sinkhole No. 2, 183 m to the east of Sinkhole No. 4. The fauna has been reported on by Guilday

and Bender, 1958 and is Recent in age. Samples of wolf (*Canis lupus*) limb bones from this deposit were dated at 1,875 ± 100 yrs. B.P., sample no. I-743 by Isotopes, Inc.

FAUNAL LIST, NEW PARIS NUMBER 4

ARTHROPODA

Diplopoda (identifications by Dr. Nell B. Causey)

Dixidesmus or *Pseudopolydesmus* sp.
Scytonotus sp.
Abacyon sp.

MOLLUSCA

(identifications by Juan J. Parodiz)

GASTROPODA

CIONELLIDAE

Cionella lubrica (Mueller)

HAPLOTREMATIDAE

Haplotrema concava (Say)

VALLONIIDAE

Vallonia costata (Mueller)

SUCCINEIDAE

Succinea ovalis Say
Succinea avara Say

POLYGYRIDAE

Triodopsis albolabris Say
Triodopsis denotata (Ferussac)
Triodopsis tridentata (Say)
Mesodon thyroideus (Say)
Stenotrema hirsutum (Say)
Stenotrema stenotrema Ferussac
Stenotrema fraternum cavum (Pilsbry & Vannata)

ENDODONTIDAE

Helicodiscus parallelus (Say)
Discus patalus (Deshayes)
Discus cronkhitei (Newcomb)
Anguispira alternata Say
Anguispira alternata mordax (Shuttleworth)

ZONITIDAE

Euconulus fulvus (Mueller)
Mesomphix sp.
Retinella indentata (Say)
Retinella virginica Morr
Retinella sculptilis Bland
Hawatia minuscula (A. Binney)

Striatura ferrea Morse
Ventridens intertextus Binney
STROBILOPSIDAE
Strobilops aenea Pilsbry

CHORDATA

Amphibia (identifications by Neil D. Richmond)

CAUDATA

AMBYSTOMIDAE

Ambystoma sp. salamander

PLETHODONTIDAE

Plethodon cf. *glutinosus* (Green)
slimy salamander
Diemictylus cf. *viridescens* (Rafinesque)
red-spotted newt
Desmognathus sp.
salamander
Eurycea?
salamander

SALIENTIA

Bufo cf. *americanus americanus* (Holbrook)
American toad
Bufo cf. *americanus copei* (Yarrow and Henshaw)
Hudson Bay toad
Hyla cf. *crucifer* Wied
spring peeper
Rana cf. *pipiens* Schreber
leopard frog
Rana sylvatica (LeConte)
wood frog

Minimum No.
of Individuals

74

66

REPTILIA

(identifications by Neil D. Richmond)

SERPENTES

CROTALIDAE

Crotalus horridus (Linnaeus)
timber rattlesnake
Ancistrodon cf. *contortrix* (Daudin)
copperhead

COLUBRINAE

COLUBRIDAE

Elaphe cf. *obsoleta* (Say)
rat snake
Coluber cf. *constrictor* (Linnaeus)
black racer

<i>Diadophis cf. punctatus</i> (Linnaeus) ring-necked snake		<i>Sorex cinereus</i> Kerr masked shrew	35
<i>Carphophis amoenus</i> (Say) worm snake		<i>Sorex fumeus</i> Miller smoky shrew	1
<i>Lampropeltis cf. doliata</i> (Lacépède) milk snake		<i>Sorex dispar</i> Batchelder big-tailed shrew	4
		<i>Sorex arcticus</i> Kerr arctic shrew	6
NATRICINAE		<i>Sorex palustris</i> Richardson water shrew	1
<i>Natrix cf. sipedon</i> (Linnaeus) water snake		<i>Sorex sp.</i>	12
<i>Thamnophis cf. sirtalus</i> (Linnaeus) garter snake		<i>Blarina brevicauda</i> (Say) short-tailed shrew	37
<i>Storeria</i> , species? brown and/or red-bellied snake			
Natricinae, unidentified.		CHIROPTERA	
AVES		VESPERTILIONIDAE	
(identifications by Alexander Wetmore)		<i>Eptesicus cf. grandis</i> (Brown) big-brown bat	1
TETRAONIDAE	Minimum No. of Individuals	<i>Pipistrellus cf. subflavus</i> (F. Cuvier) pipistrelle	13
<i>Bonasa umbellus</i> (Linnaeus) ruffed grouse	3	<i>Myotis keenii</i> (Merriam) Keen's bat	302
<i>Pedioecetes phasianellus</i> (Linnaeus) sharp-tailed grouse	1	<i>Myotis cf. lucifugus</i> (Le Conte) little brown bat	225
MELEAGRIDAE		<i>Myotis sp. probably keenii</i> or <i>lucifugus</i>	694
<i>Meleagris gallopavo</i> Linnaeus turkey	1		
PICIDAE		RODENTIA	
<i>Colaptes auratus</i> (Linnaeus) yellow-shafted flicker	1	SCIURIDAE	
<i>Dryocopus pilatus</i> (Linnaeus) pileated woodpecker	1	<i>Marmota monax</i> Linnaeus woodchuck	1
MIMIDAE		<i>Citellus tridecemlineatus</i> (Mitchell) 13-lined ground squirrel	8
<i>Toxostoma rufum</i> (Linnaeus) brown thrasher	1	<i>Tamias striatus</i> (Linnaeus) chipmunk	27
FRINGILLIDAE		<i>Glaucomys sabrinus</i> (Shaw) northern flying squirrel	15
<i>Passerella iliaca</i> (Merrem) fox sparrow	1	<i>Glaucomys volans</i> (Linnaeus) southern flying squirrel	2
MAMMALIA		<i>Tamiasciurus hudsonicus</i> <i>tenuidens</i> (Hay) red squirrel	30
(identifications by John E. Guilday)			
INSECTIVORA		CRICETIDAE	
TALPIDAE		<i>Neotoma cf. floridana</i> (Ord) woodrat	3
<i>Condylura cristata</i> (Linnaeus) star-nosed mole	2	<i>Peromyscus leucopus</i> (Rafinesque) white-footed mouse	11
<i>Parascalops breweri</i> (Bachman) hairy-tailed mole	1	<i>Peromyscus maniculatus</i> (Wagner) deer mouse	128
SORICIDAE		<i>Peromyscus sp.</i> (<i>leucopus</i> or <i>maniculatus</i>)	96
<i>Microsorex boyi</i> (Baird) pygmy shrew	11		

	Minimum No. of Individuals
<i>Dicrostonyx hudsonius</i> (Pallas) Labrador collared lemming	3
<i>Phenacomys cf. ungava</i> Merriam spruce vole	46
<i>Synaptomys cooperi</i> Baird southern bog lemming	16
<i>Synaptomys borealis</i> (Richardson) northern bog lemming	71
<i>Clethrionomys gapperi</i> (Vigors) red-backed vole	260
<i>Microtus pennsylvanicus</i> (Ord) meadow vole	164
<i>Microtus chrotorrhinus</i> (Miller) rock vole	45
<i>Microtus xanthognathus</i> (Leach) yellow-cheeked vole	344
<i>Microtus sp.</i>	460
<i>Pitymys pinetorum</i> (Le Conte) pine vole	12
<i>Ondatra zibethicus</i> (Linnaeus) muskrat	1
ZAPODIDAE	
<i>Zapus hudsonicus</i> (Zimmermann) meadow jumping mouse	4
<i>Napaeozapus insignis</i> (Miller) woodland jumping mouse	13
ERETHIZONTIDAE	
<i>Erethizon dorsatum</i> (Erxleben) porcupine	3
LAGOMORPHA	
LEPORIDAE	
<i>Lepus americanus</i> Erxleben snowshoe hare	52
CARNIVORA	
MUSTELIDAE	
<i>Mustela cf. rixosa</i> (Bangs) least ? weasel	3
<i>Martes americana</i> (Turton) pine marten	1
<i>Martes pennanti</i> (Erxleben) fisher	1
ARTIODACTYLA	
TAYASSUIDAE	
<i>Mylohyus nasutus</i> (Leidy) long-nosed peccary	1

POLLEN ANALYSIS - INTRODUCTION

The interpretation of fossil pollen counts is often burdened with uncertainty. Before describing results of pollen analysis at New Paris, it seems desirable to make explicit a few of the difficulties to be expected.

Pollen profiles of full-glacial or late-glacial age from near an ice margin commonly contain more shrub and herb (non arboreal or NAP) pollen than those from a post-glacial forest. A high frequency of herb pollen would be expected either in treeless landscape akin to Arctic tundra or else one in which scattered trees form a boreal woodland similar to that shown in fig. 5. But ecologists have recognized that the late-glacial herb pollen zones could be explained in other ways and that the presence of grass and sedge pollen is by no means proof of either tundra, woodland, or steppe. For example, in a glaciated region a certain portion of the NAP might be attributed to primary plant succession, in which an environment otherwise suitable for tree growth was temporarily dominated by herbs during early stages of plant succession. Thus, while the 70-90 percent NAP found in Zone I at Madelia, Minnesota could indicate cold climate herbs and open vegetation, Jelgersma (1962) felt it represented the pioneer phase of plant succession following ice retreat. In geologically stable unglaciated areas, such as New Paris primary plant succession cannot be invoked to explain the record of herb pollen found in late- or full-glacial deposits.

A second problem encountered in many pollen studies and inescapable in the present case is the question of rebedding. Within the glaciated region the oldest late-glacial silts may contain large amounts of temperate forest pollen washed out of adjacent glacial till. Redeposition can also complicate ecological interpretations of the pollen record south of the ice margin, as in the Carolina Bays (Frey, 1953).

At New Paris redeposition from till was out of the question, but there was another source of older microfossils - the easily recognized Devonian-age spores in the limestone enclosing the sinkholes. More vexing was the matter of intrusion of younger pollen into older fill, established with reasonable certainty

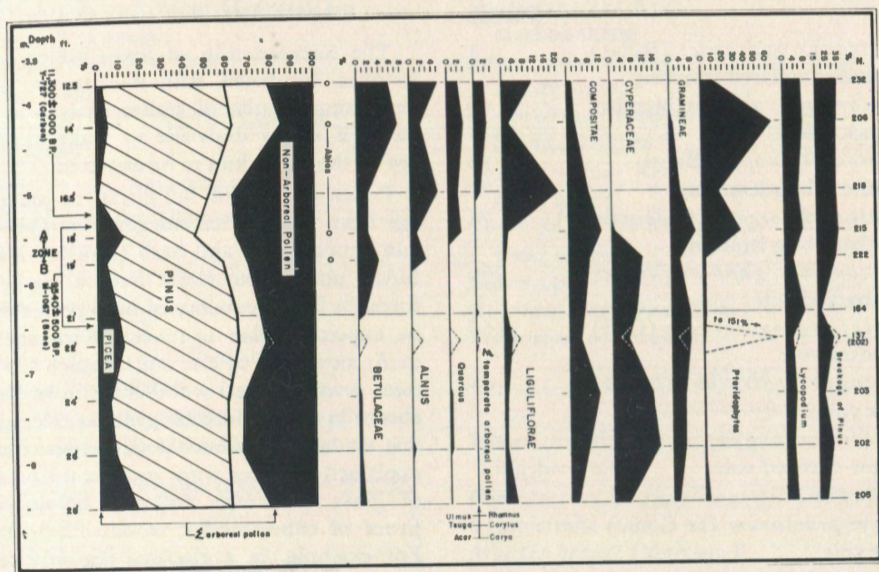


Figure 12.

Pollen analysis, Sinkhole No. 4, New Paris, Pa.

in the case of rodent scats and "cave earth" from 5.9 m (table 1), less certain but suspected in one of two samples from 6.7 m (table 2) and admittedly possible in all samples. Intrusion may also account for the record of the pine vole (*Pitymys pinetorum*) and the white-footed mouse (*Peromyscus leucopus*) from certain levels.

A third problem confronting those who would interpret pollen profiles is the matter of how much came from the upland "climatic climax." In regions of closed-canopy forest, large amounts of non-arboreal pollen may sometimes appear in sediments. The source can generally be traced to local hygic habitats near the site under study. In the late- or full-glacial of the ice margin the major herb pollen types - grass, sedge, and much of the Composites - could be derived from either an upland climax tundra or from poorly drained hygic habitats within either tundra, woodland, or forest.

For topographic reasons the New Paris sinkholes should be ideally suited to trap pollen only from a well-drained upland habitat. In this regard they resemble the steep-walled

kettles recommended by Iversen (1960) as desirable in describing the nature of the Atlantic climax forest from the Danish pollen record. Unfortunately, a major disadvantage of sub-aerial deposits such as sinkhole fill is the tendency for poor pollen preservation. Furthermore, if sufficient light can reach the bottom of the sinkhole, plants may grow on the debris cone, to be "over represented" in the fossil record. But this does not seem to be the case with the narrow shaft of Sinkhole No. 4.

In the absence of primary plant succession, with little likelihood of unrecognized redeposition of older pollen, and under a topography that precludes hygic plant communities, New Paris Sinkhole No. 4 offers decided advantages in paleo-ecological interpretations. Weighed against these must be the matter of poor pollen preservation, possible over representation of pollen from plants growing on the fill, and the intrusion of younger pollen.

The major paleo-ecological opportunity presented by the sinkhole is the association of a pollen-bearing matrix with a fauna of nearly 3,000 identified birds and mammals. Small vertebrates are generally viewed as much more dependent on the local environment than are large vertebrates and in this regard are com-

Unit	Depth in meters	Pinus	Alnus	Pinus	Trapa	Betula	Alnus	Saxif	Juglans	Quercus	Ulmus	Corylus	Rhamnus	Juglans	Acer	Gramineae	Cyperaceae	Liguliflorae	Compositae	low spine	low spine	Compositae	Artemisia	Caryophyllaceae	Chenopodiaceae	Thalictrum	Urtica	N	Periodophytes	Lycopodium	% Pinus
A	3.81	7	2	138	1	13	12	1	5	1	1	1	1	1	1	1	27	3	1	1	1	1	1	1	15	232	31	15	36.1		
"	4.27	12	2	131	1	16	4	1	6	1	1	1	1	1	1	3	2	5	7	1	2	1	9	206	137	15	34.5				
"	5.03	1	1	113	7	11	1	1	4	1	1	1	1	1	1	6	45	12	5	2	1	9	218	33	6	33.8					
"	5.49	25	3	96	4	2	3	3	1	1	1	1	1	1	1	19	3	4	22	2	3	3	2	1	18	215	74	8	35.3		
"	5.79	9	1	127	9	6	1	1	1	1	1	1	1	1	1	25	1	14	4	1	1	17	222	6	1	35.1					
B	6.40	17	1	118	2	2	1	1	1	1	1	1	1	1	1	13	17	2	6	5	2	1	184	5	8	17.9					
A	6.71	18	1	129	3	4	1	1	4	1	1	1	1	1	1	5	7	12	8	3	1	2	3	2	202	162	5	35.5			
B	6.71	15	1	88	1	1	1	1	1	1	1	1	1	1	1	10	8	5	5	1	2	3	137	3	1	29.5					
"	7.32	10	1	119	1	1	1	1	1	1	1	1	1	1	1	10	30	3	10	13	1	1	3	205	3	3	11.8				
"	7.92	15	1	119	1	1	1	1	1	1	1	1	1	1	1	9	35	2	9	5	1	1	1	2	202	1	29.0				
"	8.53	35	1	124	2	1	1	1	1	1	1	1	1	1	1	4	12	9	6	1	6	2	5	205	17	3	23.4				
Total		164	8	1302	2	60	40	2	4	26	5	3	1	1	1	86	140	115	102	39	5	20	12	5	83	2226	471	65			
Unit A		72	8	734	2	34	37	2	3	24	4	3	1	1	1	40	38	94	66	15	4	9	9	2	71	1295	445	50			
"		5.6	0.6	56.8	0.2	4.2	2.9	0.2	0.2	1.9	0.3	0.2	0.1	0.1	0.1	3.1	2.9	7.3	5.1	1.2	0.3	0.7	0.7	0.2	5.5	100.4	34.2	5.9			
Unit B		92	1	568	6	1	1	2	1	1	1	1	1	1	1	46	102	21	36	24	1	11	3	3	13	931	28	15			
"		9.9	1	61.0	0.6	0.1	0.1	0.2	0.1	1	0.2	0.1	0.1	0.1	0.1	4.9	11.0	2.3	3.9	2.6	0.1	1.2	0.3	0.3	1.4	100.0	3.0	1.6			

Table 2. - Fossil pollen counts from New Paris No. 4

parable to many plants in their sensitivity as ecological indicators.

Evidently the vertebrate fauna of the late-glacial was quite different from that known in

the region today. While most of the small vertebrates recovered near the bottom of the sinkhole presently occupy boreal environments of southern and central Canada, two represent prairie and one a tundra species.

Source

1. Duff	20	1	4	1	72	2	1	3			4	1	2	6	117	4		60	2	2	1	1	13	200	1	PSM
2. "Cave earth"	13	1	11		103	3	1	3			2	3		11	151	15	1	30	4		1	5	22	229	1	"
3. Scat a	3		3		165	2	1						1	3	178	4		12		1		1	4	200		"
4. "	6		1		129	1		1	1					1	140	4		9				2	4	159		JG
5. Scat b	18		6	1	75	6		2	3	1	3	1		7	123	18	1	53	1		3	3	20	222		PSM
6. "	7		6	1	42	1				2	1			3	63	8		9			2	2	7	91		JG
7. Mixture of 5 scats	29		5		105	5	4	1	1					6	156	22	1	21			2		11	213	1	PSM
Total	96	2	36	3	691	20	7	10	4	4	10	5	3	37	928	75	3	194	7	3	9	14	81	1314	3	

Table 1. - Miscellaneous modern pollen samples from New Paris No. 4. Although samples 2-7 came from matrix between 5.9 and 6.1 m depth within the sinkhole, their pollen content closely resembles that of Sample 1 from leaf mould outside the cave and probably represent contamination. All samples are considered less than 200 years old.

During the excavation of New Paris Sinkhole No. 4 samples of both fill and of rodent feces were saved for fossil pollen analysis. Field collectors sought to avoid surface contamination and to find samples that were intimately associated with the fossil bones. Pollen sampling did not begin until the excavation was at the 5.8 m level; remnants of matrix left in the walls of the sinkhole above this point were collected to represent the upper parts of the deposit. Below 5.8 m samples were collected at the time excavation was in progress.

The New Paris sinkholes lie on the boundary of Braun's Oak-Chesnut Forest region and Mixed Mesophytic Forest region, immediately south of the Hemlock-White Pine-Northern Hardwoods Forest region (Braun, 1950). They are surrounded by red oak-red maple woods; other trees in the immediate vicinity include big tooth aspen, white oak, white pine, and formerly chestnut. The woods are free of an understory and are relatively dry. The dominant pollen type found in the modern pollen rain is oak (*Quercus*); large numbers of ragweed (*Ambrosia*) pollen grains blow into the forest from adjacent cultivated lands.

Extraction and Analysis: A few grams of each sample were subjected to HCl and HF extraction following the schedule of Faegri and Iversen (1950); the residue was stained in fuchsin and mounted in glycerine. In most cases at least 200 pollen grains were present and counted on each slide.

Pollen was well preserved and abundant in rodent scats collected at the 5.9 m level and in a mixed sample of humus collected in May of 1961 from beneath the leaf litter at four points near the sinkhole. In contrast pollen from the sinkhole fill was poorly preserved compared with the humus-dung sample and with Pleistocene alluvial clays from Marsh, Pa. and Cranberry Glades, West Virginia.

Four samples from New Paris Sinkhole No. 8 (0.5 m, 2.6 m, 5.3 m and 7.5 m) proved sterile. At Sinkhole No. 4 sufficient pollen for analysis was obtained in 12 of 15 fill samples, with sterile samples coming from 2.0 m, 7.6 m and 8.7 m. The 8.7 m level was regarded by the excavators as solution material deposited prior to perforation of the sinkhole. Rebedded Paleozoic spores were es-

pecially numerous between 6.7 m and 7.3 m, presumably weathered from the Devonian limestone forming the cave. In addition to their distinctive morphology the spores were easily recognized by their failure to stain in fuchsin and by their flattened appearance.

Poor preservation of certain fill samples complicated the problem of pollen identification. Within the Betulaceae well-preserved examples of birch (*Betula*), hornbeam/ironwood (*Carpinus-Ostrya*), and rarely, hazelnut (*Corylus*) were encountered, but the high frequency of poorly preserved grains in the triporate group made it impossible to determine relative numbers accurately. Most of the fern spores were of the monolete, bean-shaped Polypodiaceae. Fungal spores were common in scat and forest duff samples but not in samples of fill.

Dr. Jane Gray kindly analyzed two of the rodent scat slides and reported sycamore (*Platanus*). Otherwise, her list of pollen types and her percent estimates were similar to those of P.S. Martin (see table 1).

Results: Pollen counts from 11 samples between 3.8 m and 8.5 m are shown in table 2 and fig. 12. The dominant type throughout is pine pollen of small size. The counts can be divided into two units. The upper, 3.8 m to 5.8 m (unit A) contains more pollen of oak (*Quercus*), alder (*Alnus*), fir (*Abies*), Betulaceae, temperate trees, Liguliflorae, unknowns, and ferns than the lower (unit B), 6.4 m to 8.5 m, which contains more pollen of sedges and spruce (table 2). Above 5.0 m the ratio of arboreal to non-arboreal pollen rises. Pine breakage is significantly lower below 5.8 m than above. The better preservation of pine in the deeper levels suggests a more rapid rate of filling under a climate more favorable for frost action than the present one. Means of pine bladder measurements (20 grains each) in unit B are 6.4 m - 33.5 μ , 6.7 m - 32.2 μ , 7.3 m - 33.4 μ , 7.9 m - 33.0 μ , and 8.5 m - 34.6 μ . Those from unit A may be slightly larger, 5.8 m - 37.5 μ , 5.5 m - 30.1 μ , 5.0 m - 34.8 μ , 4.3 m - 38.8 μ , 3.8 m - 34.9 μ . These means resemble those obtained from Zones F-2 and F-4 in Chester County alluvium (Martin, 1958) and are much smaller than means of post-glacial pine pollen from that area.

The changes in fossil pollen content are accompanied by changes in the character of the vertebrate fauna. Above 6.0 m there are more temperate elements both in the vertebrate record and in the pollen count. Below 6.0 m in a pollen zone with sedge and virtually no temperate deciduous tree pollen, the vertebrate fauna is dominated by cold woodland (boreal) species with very few elements characteristic of the temperate zone.

Two counts were made at the 6.7 m level, one relatively poor in pollen but similar in pollen content to adjacent levels. The other count, shown as a dotted line on fig. 12 and as part of unit A on table 2, was matrix associated with the foot of a peccary, *Mylobyus*. This pollen count resembles levels of unit A more than those of unit B and may represent contamination of unit B by matrix from unit A. If so, the peccary foot may also be intrusive.

Intrusion of much younger (post-settlement) pollen is evident in both matrix and rodent scats thought to be contemporaneous with the fossil fauna from the 5.9 m level. A sample of matrix at this depth very closely resembles the count of pollen in decayed forest litter adjacent to the cave (table 1). In the case of the rodent scats there is relatively high variation between samples, as one commonly expects in animal dung. Nevertheless, the counts closely resemble the modern forest litter, especially in a relatively large amount of oak and ragweed pollen (listed as low-spine Compositae in table 1). For this reason the rodent scats must postdate the clearing, cultivation, and accompanying ragweed invasion of central Pennsylvania within the last 200 years. In view of the extirpation of chestnut (*Castanea*) 40 years ago it is of interest to find chestnut pollen present in two of the rodent scat samples.

Correlation: Presence of only two pollen units in 4.7 m of late-glacial fill is likely to reflect rapid deposition. During excavation no evidence of soil formation or other stratigraphic break was seen. Two radiocarbon dates associated with the matrix are shown in fig. 12. The upper, Y-727 (11,300 $\pm$ 1000 yrs. B.P.), is of charcoal and is considered more reliable than M-1067 (9,540 $\pm$ 500 yrs. B.P.),

which is on bone. Accepting Y-727 at face value, pollen unit A (above 6.0 m) can be correlated with the Alleröd oscillation of Europe and with pollen zone A₃ of New England. Both pollen content and vertebrate remains in unit A indicate that while still relatively cool the climate in Pennsylvania at that time was decidedly warmer than during deposition of unit B. If unit A is contemporaneous with the pollen zone A₃ of southern New England, unit B with its higher frequency of herb pollen and much lower frequency of deciduous tree pollen should correlate with either pollen zones A₂, A₁, or with zone T of southern New England. As Davis (1961) has shown, the distinction between A₁, A₂, and A₃ is slight. At Cambridge, Massachusetts Davis found a pronounced rise in birch (*Betula*), oak (*Quercus*), and a small but significant increase in other tree pollen types on the boundary between A₁ and T. Above the T zone there was an accompanying decrease in grasses and sedges. The change from unit B to unit A at New Paris No. 4 is quite comparable. Unit A at New Paris may represent not only zone A₃ but also A₁ and A₂ of southern New England, while unit B at New Paris is equivalent to New England zone T. Can the New Paris record be correlated with the pollen record farther south?

Schrock (1944) analyzed cores taken from Glade Run Bog, Somerset County, Pennsylvania, 80 km southwest of New Paris at an altitude of 825 m in the Negro Mountains, approximately 160 km south of the Wisconsin terminal moraine. An undated early-pine-maximum containing large amounts of spruce and traces of fir, hemlock, Betulaceae and oak preceded the spruce-fir-maximum. She states (*ibid.* p. 30) "The pines represented are doubtless several species, those of the lower levels as well as those of the top levels being definitely of larger size than the ones present in the spruce-fir-maximum." She suggests that jack pine (*Pinus Banksiana*) is represented by the small pollen associated with her spruce-fir maximum. Correlation with the New Paris No. 4 pollen record is not possible at the present time. Dr. Schrock believes that the early-pine-maximum at Glade Run Bog preceded the glacial maximum to which she assigns

Locality	Depth in meters	<i>Pinus</i>	<i>Picea</i>	<i>Abies</i>	<i>Taxus</i>	<i>Betula</i>	<i>Quercus</i>	<i>Alnus</i>	<i>Salix</i>	<i>Juniperus</i>	Other AP	AP	<i>Cyperaceae</i>	<i>Gramineae</i>	Low spine Compositae	High spine Compositae	<i>Liguliflorae</i>	<i>Artemisia</i>	<i>Thalictrum</i>	<i>Caryophyllaceae</i>	Other NAP	NAP	N
Cranberry Glade, W. Va.	1.70	11.5	20.5	3.7	7.1	11.5	10.4	6.7	1.1		3.0	75.5	11.9	7.4		3.0		0.7	0.4		1.1	24.5	269
"	1.95	30.0	24.5			.5	1.0	1.0				57.0	28.5	9.0		3.5		1.0		1.0		43.0	200
"	2.20	23.1	17.6	2.2		2.2	1.1	1.1				47.3	43.4	6.6	0.5	0.5		0.5	0.5	0.5		52.5	182
"	2.45	21.5	17.5	.5					.5	.5	1.0	41.5	41.0	16.5		0.5			0.5			58.5	200
Marsh, Pa. M ₁	0.74- 1.15	22.0	7.7	1.2	0.1	1.8	1.1	2.2	0.6	0.1	0.7	37.5	37.7	20.3	0.5	1.2		0.2	0.5	0.3	2.0	62.7	3668
	1.82- 2.07	19.3	1.7	0.0	0.1	1.3	0.4	0.5	0.5		0.4	24.2	34.5	37.4	0.5	1.0		0.2	1.0	0.5	0.6	75.7	2415
Marsh, Pa. M ₂	0.95- 1.45	17.2	10.1	5.3	0.1	2.3	0.8	3.5	0.5		0.4	40.2	28.3	21.6	0.7	2.7	0.1	0.1	0.6	0.2	5.6	59.9	2176
New Paris No. 4, Unit B	6.40- 8.55	61.0	9.9			0.6	0.2	0.1		0.1	0.1	72.0	11.0	4.9	2.6	3.9	2.3	0.1	0.3	1.2	1.7	28.0	931

Table 3. - Late or full-glacial pollen records from unglaciated areas

the over-lying spruce-fir maximum. If this is so it is of extreme importance in reconstructing full-glacial conditions in the central Appalachians. It is probable, however, that the Glade Run Bog spruce-fir maximum may be a late-glacial readvance of the ice front, such as the Valdres. Only arboreal species were considered. It would be of interest to examine the NAP picture as well.

Martin (1958) reported that the F zones in alluvium of Marsh, eastern Pennsylvania, contained less than 40 percent tree pollen, mainly of small-sized pine grains and of spruce (see table 3). The upper part of the F zones yielded radiocarbon dates of about 13,500 years (Y-478 and Y-479). Are the F zones unique to Marsh? One of the more promising localities for a pollen comparison with Marsh appeared to be Cranberry Glades, West Virginia where Darlington (1943) reported clays of unknown age beneath a post-glacial peat profile dated at its base as 9,434±840 years B.P. (C-336).

In November of 1957 Martin visited Cranberry Glades briefly and obtained a 1.5 m core from the clays beneath peat found in Round Glade. Pollen is abundant and well preserved in this material. The counts of two samples below 2 m in depth (table 3) from Round Glade contain approximately 50 per-

cent tree pollen, almost exclusively of pine and spruce, with 40 percent sedge. There is extremely little temperate tree pollen in these lower samples (table 3). The two upper samples contain more tree pollen, with oak, birch, hemlock, and alder common in the uppermost level. The deeper clay samples from Cranberry Glades contain somewhat more spruce and less grass than similar clays from the F zone at Marsh, but in general the two sets of counts are quite similar and may be contemporaneous. They are quite different from the post-glacial records in eastern North America.

Can New Paris pollen unit B be considered contemporaneous with the F zones of Marsh and of Cranberry Glades? In the latter localities non-arboreal pollen is much more abundant and pine pollen much less abundant than in the New Paris Sinkhole. During accumulation of extensive flood plain deposits of clay and silt there were disturbed habitats in which trees could not grow and in which local herb pollen production was especially heavy. The relatively high concentration of herb pollen close to the site of alluvial deposition would profoundly affect the local pollen rain along Marsh Creek and at Cranberry Glades, as it does in alluvial flood plains in the southwest (Martin, 1963). On the other hand, at New Paris No. 4 the pollen-collecting surface - a feed cone in the

top of a sinkhole - existed in the middle of an upland environment without the flood plain plant communities and flood plain pollen rain. Unless large numbers of herbs grew on the disturbed top of the debris come in the sinkhole (while may indeed be the case of the Liguliflorae and ferns in unit A), the sinkhole would be likely to trap only the natural upland pollen, free of any riparian influence.

The main difference between counts from New Paris No. 4, unit B, and the F zones of both Marsh and Cranberry Glades is the higher frequency of pine pollen and the lower frequency of sedge and grass. This difference could simply mean that hygric communities of grass and sedge, which certainly occurred at the Marsh and Cranberry Glades, did not exist around the New Paris sinkholes. Tentatively we suggest that pollen unit B in the New Paris sinkhole was contemporaneous with the top of pollen zone F-4 from Marsh. Beyond a greater representation of spruce, conditions were similar at Cranberry Glades. The T zone of New England may locally contain more pollen of *Betula* or *Populus* than known from Cranberry Glades or the Marsh, but it is clear that the T zone of southern New England is more like Marsh zone F than any other part of the New England pollen record. Although it has more pine pollen, New Paris unit B seems best correlated with New England T zones. Admittedly, stratigraphic control and radiocarbon dating of sites south of the ice margins is insufficient for a vigorous defense of this or any other correlation scheme.

INVERTEBRATES

Three species of millipedes and 26 species of land snails were recovered. All may be found in western Pennsylvania and the sinkholes area today.

It is difficult to separate the land snails that were contemporaneous with the late Pleistocene fauna of Sinkhole No. 4 from those that kept infiltrating during the years of excavation. Snails are very common in this limestone area and preservation very good.

Two general observations could be made however: the numbers of all species of snails dropped from common in the upper and

mid portion of the stratigraphic column to rare in the lower levels. The numbers of the large woodland snail *Triodopsis albolabris* Say diminished dramatically below the 7.0 m level. The commonest snail in all upper levels, it appeared to have been absent from the lower 2.7 m of the deposit.

AMPHIBIA — AMPHIBIANS

by Neil D. Richmond

Caudata-salamander

Remarks: Most of the salamander vertebrae from this deposit have not been studied. Only those sufficiently large or distinctive in structure to be easily recognized have been identified. The five genera are all forms found at the site today and while the red-spotted newt (*Diemictylus*) remains represent trapped specimens, the other species are fossorial and tend to follow crevices in the limestone and could be expected alive at almost any depth in this formation.

Salientia-frogs and toads

Bufo-toads

Material: This genus is represented at all levels. A total of 116 ilia, 34 fronto-parietals and 18 sacral vertebrae were recovered as well as large numbers of limb bones, vertebrae and miscellaneous skull elements. At least 74 individuals are represented in this material.

Remarks: On the basis of the ilia it would be possible to assign three names to this collection; using the more diagnostic fronto-parietals, only two groups appear. Since there are changes in the ilia and fronto-parietals from the top of the deposit to the bottom, and since they are both well represented, I am assuming that only two forms occurred here, that they were separated by time, and were allopatric. The form at the top and mid-depths is identified as the American toad (*Bufo a. americanus*) and the form in the lower levels as the Hudson Bay toad (*B. a. copei*). Admittedly to recognize subspecies on the basis of skeletal remains is a dubious procedure especially when the subspecies involved is also a questionable one. For a discussion of the current status of *copei* see Logier and Toner, 1961. Most of the skeletal characters of *B. a. copei* are also those of small but sexually

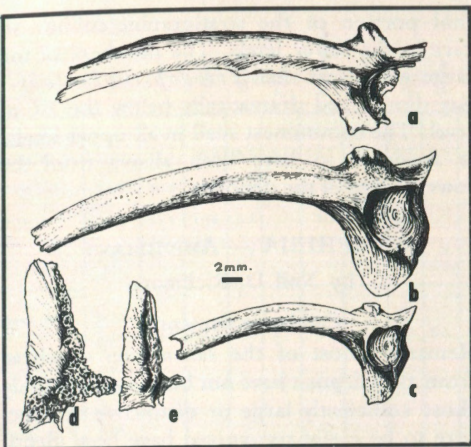


Figure 13.

ilia (a, b, c,) and fronto-parietals (d, e), *Bufo americanus*, Sinkhole No. 4, New Paris, Pa.

- a. CM 7950 - *B. a. americanus*, level ?
- b. CM 7952 - *B. a. americanus*, level ?
- c. CM 7951 - *B. a. copei*, 8.5 m level
- d. CM 7949 - *B. a. americanus*, 6.4 m level.
- e. CM 7948 - *B. a. copei*, 8.5 m level

mature *B. a. americanus*, i.e., open fronto-parietal canals and relatively low ilial prominences. The assumption that the lower levels of this deposit received only juveniles while the upper levels received only large adults seems unlikely. Instead, I believe that the lower, earlier levels received a small form (*B. a. copei*) while the upper, more recent levels, the larger form *B. a. americanus*.

Most ilia in the upper levels are easily assigned to *Bufo a. americanus*. Associated with these bones are others that have a spike-like dorsal prominence (fig. 13a) resembling such forms as *B. hibbardi* and *B. repentinus*. (See Tihen, 1962 for figures of these species.) Since only two types of fronto-parietals were recovered, these large ilia are considered to be from very large old specimens of *B. a. americanus*. Associated with size and age are changes of shape and hypertrophy of the various areas of muscular attachment.

Rana-frogs

Material: 102 ilia, 29 sacral vertebrae, numer-

ous limb bones. At least 66 individuals represented.

Remarks: This genus is well represented in the deposit. Most of the identifiable bones appear to be those of the leopard frog (*R. pipiens*). Only one illium, CM 8017, has the pronounced knob-like dorsal prominence characteristic of the wood frog (*R. sylvatica*). The bull frog (*Rana catesbeiana*), the green frog (*Rana clamitans*), and the pickerel frog (*Rana palustris*), all common in the New Paris area today, appear to be absent from the fossil material.

REPTILIA — REPTILES

Serpentes — snakes

Material: Vertebrae, frontals and toothed elements were recovered. Most of the determinations are based on precaudal vertebrae and in some cases on maxillae.

Remarks: Several features of this large collection are noteworthy. One of the surprising features is the relative frequency of the rattlesnake (*Crotalus horridus*) compared with that of the copperhead (*Ancistrodon contortrix*). Rattlesnake vertebrae were abundant near the top of the deposit and represented all sizes from newborn to individuals larger than most modern specimens. By contrast only a few copperhead vertebrae were recovered and only 2 maxillae, all in the upper part of the deposit. Most of the rattlesnakes (12 maxillae) were in the upper portion but occurred at all levels possibly as a contaminant from above. (See fig. 34).

The most numerous snake vertebrae were natricine, most of which are probably garter snake (*Thamnophis* sp.). Only those vertebrae that represented mature individuals and that compared in detail with Recent material were named. Unlike the colubrine genera which became scarcer with depth, the natricine genera were abundant from top to bottom (fig. 34). This is not surprising in view of the wide environmental tolerance of the garter snake (*Thamnophis sirtalis*) today. Its present range, from the Labrador Peninsula to Florida, includes all of the climatic possibilities that might have been in the vicinity of the sinkhole at any time in its history. Nor is the garter snake sensitive to changes from forest to grass-

land. It has been recorded as far north as Churchill, Manitoba, Lat. 58° N. at the juncture of the Hudsonian and Arctic life zones. (Shelford and Twomey, 1941). Only two snakes in this collection are southern in their affinities, the worm snake (*Carphophis*) and the copperhead (*Ancistrodon*). Their remains were confined to the upper levels of the sinkhole. Although both of these range farther north along the coast they are near the northern edge of their present range at New Paris. All of the other forms in this deposit range at least into southern Canada today.

Sauria and Chelonii—lizards and turtles

Material: None

Remarks: The absence of both lizard and turtle remains is probably significant. Today there are three species of lizards in the New Paris area. The Recent faunas of Sinkholes 2 and 3 both contained box turtle (*Terrapene carolina*), but the boreal climate of New Paris No. 4 times was too severe for terrestrial turtles to survive. The range of the box turtle does not extend much farther north than Pennsylvania today.

AVES — BIRDS

In contrast to the birds of the Natural Chimneys local fauna (40 species, 78 individuals) bird remains were scarce in the New Paris No. 4 deposit. (7 species, 13 individuals).

The Natural Chimneys deposit was accumulated primarily by carnivorous birds. The numerous avian remains include both shore and upland game species and a variety of swallows, woodpeckers, jays, and smaller song birds of varied habits that had fallen as prey and were brought into the cave.

New Paris No. 4, however, was a sinkhole trap fed from above by animals that accidentally fell in. Once a bird blundered into the shaft (like a bird in a chimney), despite its ability for horizontal flight it was trapped in this vertical passage. All of the species with the exception of the pileated woodpecker are prone to search for food on the surface of the ground.

Pedioecetes phasianellus — (Linnaeus)

Sharp-tailed grouse

Material: CM 5440, partial skeleton.

Remarks: This nearly complete skeleton (discussed in Wetmore, 1959) was found against the north wall at the 5.2 m level. The skeleton was uncrushed and in essential articulation. The skull was not recovered and had presumably been crushed or removed by later rock falls. The species has also been recorded from the Natural Chimneys local fauna of Virginia.

Several limb bones of the ruffed grouse (*Bonasa umbellus*) also catalogued under CM 5440 were found in association with the skeleton.

The presence of both sharp-tailed and ruffed grouse in the upper levels of the sinkhole suggests a closing forest canopy. *Bonasa* is essentially a forest species with a preference for coniferous-deciduous forest-edges situations (Aldrich and Duvall, 1955; Edminister, 1947). *Pedioecetes* is a grouse of narrow habitat requirements. It inhabits mixed prairie-forest-edge situations and can tolerate neither open prairie where it is replaced by the prairie chicken (*Tympanuchus cupido*) in the more southerly portions of its range, nor forest situations where the canopy is too dense to support an understory of grasses. In the northern part of its range it is found typically in open or brushy muskeg situations interspersed in coniferous forest. Ammann (1957) working with this grouse in Michigan states that 20-40 percent woody cover is optimum for the species if the trees occur in copses. Occasional individuals were found in areas with up to 75 percent woody cover. It was found that a minimum of slightly under one square mile of near-optimum habitat is required to sustain a population although individual birds may occupy areas as small as 10-15 acres in size.

It is possible that *Pedioecetes* and *Bonasa* did not occupy the immediate area contemporaneously. Charcoal particles in the matrix indicates at least one forest fire during the period of infilling. This would impose vegetational changes of shorter duration than those dictated by climatic change. The two grouse may then have inhabited the area successively—*Pedioecetes* being replaced by *Bonasa* as forest cover returned in the wake of fire.

It cannot be assumed that the one speci-

men of *Pedioecetes* represents optimum range conditions for that species in the sinkhole area. Its presence, however, in the unit A fauna points to areas of open ground still lingering in the vicinity. Conditions were such that the bird, now largely confined to portions of the Canadian and Hudsonian life-zones south and east to northern Michigan, occurred in late Wisconsin time, south at least as far as lat. 38° in what is now the Carolinian life-zone of Virginia's Shenandoah Valley.

Meleagris gallopavo Linnaeus -
Wild Turkey

Material: CM 5896, 5897, 5900. 1 tarsometatarsus, 1 humerus, 5 vertebrae, 2 phalanges. Stratigraphy: 5.2 m - 6.7 m level.

Remarks: The wild turkey is considered to be a bird of the deciduous forests of the southern portions of the continent north to the northern boundary of the Carolinian life-zone. Cleland, 1963, found turkey remains at the Juntenen Site (20 Mk 1), an archaeological site on Bois Blanc Island in Lake Huron, 200 km north of its known historic limit and within the Canadian life-zone, lat. 45°. Even in the light of Recent distributional patterns, it is possible for the turkey to have been a member of the unit A avifauna, advancing its range as the glacier receded. Turkey remains are also known from Frankstown Cave, Port Kennedy Cave, and Natural Chimneys, Virginia.

MAMMALIA — MAMMALS

Order: Insectivora

Family: Talpidae

Condylura cristata (Linnaeus) — Star-nosed mole

Material: 1 left, 3 right humeri; 2 left, 2 right partial mandibles; 2 right scapulae; 1 left, 2 right tibiae; 1 left, 1 right femur; 1 radius. Stratigraphy: from 5.5 m to 7.0 m level (fig. 27).

Remarks: Ranging farther north than any other North American mole, throughout the Canadian life-zone and locally, into the Hudsonian life-zone (Edwards, 1963), this is the only species of mole that occurred beneath the 6.0 m level. Only three individuals were present. This mole is considered to be semi-

aquatic and partial to saturated soils and its distribution is usually governed by this, but it is occasionally taken in some numbers in well-drained atypical upland sites (Richmond and Rosland [sic], 1949, p. 36).

Specimens are more robust than modern Pennsylvania material. An additional individual from Station 2, CM 6952, is believed to be Recent. Its limb bones are less robust and appear peculiarly "greasy."

Condylura cristata, at the present time, shows a slight, positive "Bergmann's response." (Jackson, 1915, p. 90). The New Paris No. 4 specimens, in common with so many other species from the deposit, find modern size equivalents in the northern portion of their present range.

The alveolar length of P_4-M_3 measured 6.8 mm, 6.9 mm and 7.2 mm.

Parascalops breweri (Bachman) — Hairy-tailed mole

Material: 1 left mandible, no dentition; 1 humerus; 1 ulna; 1 isolated M_1 .

Stratigraphy: upper levels to 6.0 m (fig. 27).

Remarks: Possibly two individuals are present. Specimens agree in all particulars with modern Pennsylvania material. This mole, as well as *Condylura cristata*, is common in the area today. Because of a positive "Bergmann's response," the latter is believed to be a member of the late Pleistocene fauna. *Parascalops breweri* may or may not have been although it does range extensively throughout the Canadian life-zone today. It has been recorded from Frankstown Cave, Pa., Bootlegger Sink, Pa., Natural Chimneys, Va., and Robinson Cave, Tenn.

Family: Soricidae

Microsorex boyi (Baird) — Pygmy shrew

Material: 4 partial skulls; 2 left, 2 right maxillae, 11 left, 11 right mandibles.

Stratigraphy: evenly distributed from the 5.2 m through the 8.5 m level (fig. 31).

Remarks: This was the third commonest shrew in the deposit. The pygmy shrew is rare in Recent mammal collections from eastern North America. There is only one modern Pennsylvania record (Roslund, 1951, p. 40). This shrew was apparently widespread and common

in the East during the late Pleistocene. It is known from Natural Chimneys, Va., Robinson Cave, Tenn., and Bootlegger Sink, Pa.

Measurements of the New Paris No. 4 specimens appear to be average for the species as defined and measured by Jackson (1928); smaller than modern far-northern races, but larger than the southern *M. b. winnemana*. Both *M. minutus* Brown (1908) and *M. pratensis* Hibbard are reported to be larger than modern *M. boyi* (Paulson, 1961, p. 134).

Table 4 — Measurements in mm. *Microsorex boyi* (Baird)
New Paris No. 4, Pa.
Mandible

Cat. No.	M_1-M_3	height, ascending ramus	total length, including I_1	total length dentary
6240	2.8	3.0	8.0	6.5
6667	2.8	2.9	8.2	6.6
6672	2.9	2.9	7.9	6.5
6676	—	3.0	8.2	6.6
7102	2.8	3.0	7.6(worn)	6.6
7330	2.8	2.9	7.7	6.4
7330b	2.9	2.9	7.8	6.4
7428	—	2.9	7.8	6.4
7103	2.8	3.0	8.1	6.4
7104	3.1	—	8.4	6.6
mean	2.86	2.94	7.97	6.50

Skull
(measurements, see Jackson, 1928, p. 13)

Cat. No.	Maxillary Width	Palatal Length	Interorbital Breadth	P^4-M^3
5849	4.0	5.2	2.9	3.4
6239	4.2	5.3	2.9	3.5
7330	4.3	5.1	2.8	3.4
4755	4.1	5.3	2.9	3.5
mean	4.15	5.2	2.87	3.45

Sorex cinereus Kerr — Masked shrew

Material: 13 partial skulls; 35 left, 35 right mandibles.

Stratigraphy: common at all levels from 4.9 m to 8.5 m (fig. 31).

Remarks: This animal has the widest range of any North American soricid, including almost all of the central and northern por-

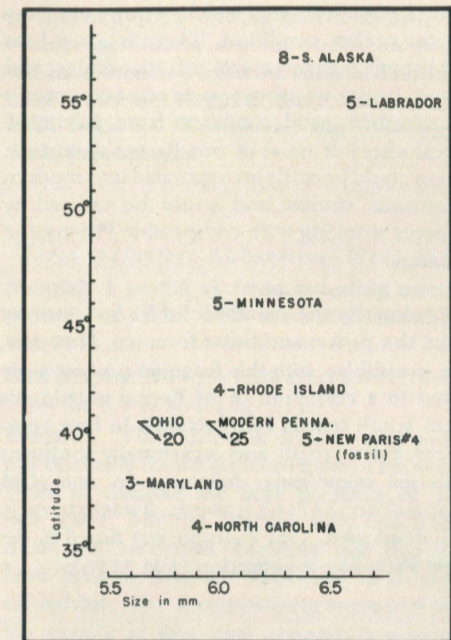


Figure 14.

Increase in mean length of palate with increase in latitude. *Sorex cinereus*, various Recent North American localities and Sinkhole No. 4, New Paris, Pa. Late Pleistocene. Data, in part, from Jackson, 1928; Bole and Moulthrop, 1942.

tions of the continent. It tolerates a wide variety of habitats and with the exception of *Microsorex* is the only insectivore found at all levels of the sinkhole that produced an adequate sample.

Sorex cinereus, in accordance with Bergmann's Rule, exhibits a positive correlation between size and latitude except in the tundra area of the western Nearctic where it undergoes a reduction in size. (Jackson, 1928, p. 38). Measurements of the New Paris No. 4 population are larger than those from more southerly areas of the animal's range (fig. 14) and agree in superior size with modern northern populations. Unfortunately, all published measurements dealing with the neotaxonomy of *S. cinereus* are confined to either external measurements which are of little use when dealing with skeletal material or to a few

cranial measurements which require skulls in almost perfect condition. There is a need for published measurements of mandibles and lower dentitions (those parts most commonly recovered in good condition from paleontological sites) of most of our Recent mammals. These could be easily incorporated into modern taxonomic studies and could be utilized by students working with comparable Pleistocene material.

Ordinarily the mandible of *Sorex cinereus* lacks the post-mandibular foramen. However, five mandibles with this foramen present were noted in a collection of 24 Recent individuals from south central Pennsylvania. In four specimens it was small and occasionally confluent with the mandibular foramen. In one (CM mammal no. 33716), however, it was extremely well-developed. One example was noted in the New Paris No. 4 collection (CM 7116).

Table 5 - Size of third unicuspid relative to fourth, *Sorex cinereus*.

	larger	equal	smaller
Modern south-central Pa.	10	12	1
New Paris No. 4	2	0	0

Sorex fumeus Miller--Smoky shrew

Material: 1 right mandible. CM 6673.

Stratigraphy: 3.9 m level (fig. 31).

Remarks: This shrew is found in a variety of wooded situations in the Appalachian area. It occurs in Bedford County at the present time but the immediate sinkhole area would appear to be too dry to support it. Conditions seem never to have been optimum for it throughout the period of infill. C₁-M₃ measured 4.7 mm.

Sorex dispar Batchelder--Big-tailed shrew

Material: 4 left, 1 right mandible.

Table 6 - Selected Measurements, *Sorex cinereus*, measurements in millimeters

Locality	$\bar{X}$	O.R.	σ	V	N
Total length, condyle to most anterior point of dentary					
New Paris No. 4	7.6 ± .06	7.2-7.8	.27 ± .05	3.55 ± .60	17
Modern Penna.	7.28 ± .02	7.1-7.7	.10 ± .01	1.37 ± .20	22
C ₁ -M ₃ , antero-posterior crown length					
New Paris No. 4	3.9 ± .04	3.7-4.3	.16 ± .02	4.09 ± .53	29
Modern Penna.	3.69 ± .01	3.6-3.9	.07 ± .01	1.89 ± .29	20
M ₁ , length of crown					
New Paris No. 4	1.33 ± .01	1.2-1.5	.05 ± .005	3.75 ± .39	44
Modern Penna.	1.28 ± .02	1.2-1.4	.07 ± .01	6.01 ± .90	22
Length of palate*					
New Paris No. 4	6.4	6.3-6.6	-	-	5
Modern Penna.	6.09 ± .04	5.5-6.6	.21 ± .03	3.44 ± .50	23
Interorbital breadth*					
New Paris No. 4	3.05	3.0-3.1	-	-	2
Modern Penna.	2.99 ± .01	2.9-3.1	.05 ± .007	.67 ± .24	23
Maxillary breadth*					
New Paris No. 4	4.2	4.0-4.4	-	-	4
Modern Penna.	4.23 ± .02	4.0-4.5	.11 ± .01	2.60 ± .39	22
P ⁴ -M ³ , antero-posterior crown length					
New Paris No. 4	3.7	3.5-4.0	-	-	5
Modern Penna.	3.52 ± .02	3.4-3.7	.10 ± .01	2.83 ± .41	23

* Defined: Jackson, 1928.

Stratigraphy: 3.6 m to 7.3 m level (fig. 31). Remarks: This animal, endemic to the Appalachians, requires cool, moist, rocky mountain forest. The presence of surface cover seems less essential than deep passages beneath loosely piled talus. *Sorex dispar* does not occur at the site today but is not uncommon in suitable areas of moist talus along the flanks of the Appalachian Mountains and at no greater altitude (Richmond and Grimm, 1950).

Table 7 - Measurements in millimeters, *Sorex dispar*, New Paris No. 4, Pa.

CM	Dentary	C ₁ -M ₃	M ₁
6243	-	-	1.3
6241	8.2	4.3	1.3
7116	8.2	-	1.4

Sorex arcticus Kerr--Arctic shrew

Material: 4 partial skulls; 6 left, 5 right mandibles.

Stratigraphy: 6.1 m to 8.5 m level (fig. 31).

Remarks: The Arctic shrew inhabits northern North America south to Wisconsin and New Brunswick. It is most often found in coniferous forest boglands. Although it is a minor component of the fauna, it did persist to the deeper levels and is a distinct boreal element replacing more southerly forms such as the smoky shrew (*S. fumeus*), the big-tailed shrew (*S. dispar*), and the short-tailed shrew

Table 8 - Measurements in millimeters, *Sorex arcticus*, New Paris No. 4, Pa.

CM	Dentary	C ₁ -M ₃	M ₁
6643	8.7	4.2	1.4
6662	8.7	4.5	1.5
6941	9.2	4.4	1.4
6942	8.7	4.5	1.5
7101	9.3	4.5	1.5
7109	-	-	1.5
7111	-	4.4	1.3
Mean	8.9	4.4	1.4
7738	Length of palate	7.8 mm.	

(*Blarina*). This is the fourth known late Pleistocene locality for the Arctic shrew. It has been reported from the Natural Chimneys local fauna of Virginia, the Robinson Cave local fauna of Tennessee, and Bootlegger Sink, Pennsylvania.

Sorex palustris Richardson--Water shrew

Material: 1 partial skeleton including anterior portion of skull with associated mandible. CM 7251.

Stratigraphy: A single individual was recovered from the 8.5 m level (fig. 31).

Remarks: This shrew is semi-aquatic and is not normally found far from water. This would seem to indicate the near presence of surface water, but the fact that only one individual was recovered suggests that this may have been an itinerant individual in an atypical habitat. The accompanying fauna and pollen profile at that level suggests a relatively dry environment.

Table 9 - Measurements, *Sorex palustris*, CM 7251, New Paris No. 4, Pa.

Total length of dentary (to and including condyle but not angular process)	9.5 mm.
Length C ₁ -M ₃	5.2 mm.
Length M ₁	1.6 mm.
Length of palate	8.3 mm.
P ⁴ -M ³	5.0 mm.

Sorex, species ?

Material: 4 partial skulls; 1 right maxilla; 8 left, 12 right partial mandibles.

Remarks: All of this material is exceedingly fragmentary. It is doubtful if any unrecognized species is present.

Blarina brevicauda (Say)--Short-tailed shrew

Material: 17 partial skulls; 6 left, 7 right maxillae; 37 left, 25 right mandibles.

Stratigraphy: Commonest insectivore in upper and middle levels of sinkhole from 2.1 m to 7.0 m. Absent in lower levels (fig. 31).

Remarks: The *Blarina* material from Sinkhole No. 4 presents a mixture of two genetic stocks. One, presumably *B. b. kirtlandi*, is indistinguishable from the living form in the area. The other is a large, late Pleistocene form, typical examples of which are readily distinguishable from modern *B. b. kirtlandi* but not from the modern Minnesota specimens of *B. b. brevicauda* used as comparative material.

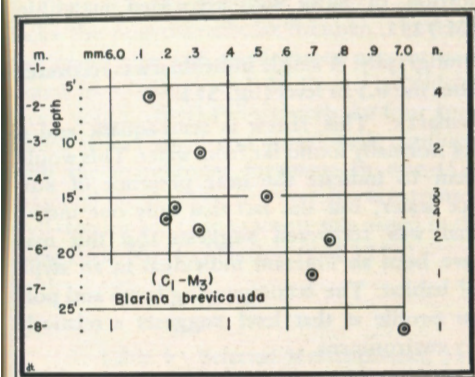


Figure 15.

Increase in mean length C_1-M_3 with depth. *Blarina brevicauda*, Sinkhole No. 4, New Paris, Pa.

Figure 15 illustrates the increase in an average size of specimens of *Blarina* correlated with depth. At each station, representatives of both "races" could be picked out as well as unassignable intermediates. The high coefficients of variation of the entire sample of *Blarina* from the sinkhole and the bimodality of certain measurements (condylewidth, C_1-M_3) suggests that it was made up of more than one population.

The increase in size with depth shown by figure 15, although seemingly correlated with time, is apparently not. There are two populations present at all levels from which a large enough sample was available to decide. This increase is due rather to a shift in the racial composition of the samples from each level. The presence of boreal forms in the upper levels, the pollen picture, and the results of the thorium analysis of the snowshoe

hare bones indicate that infilling was relatively rapid and was completed during the boreal episode. The sinkhole filled to the top during late Pleistocene-early Recent times. The probable explanation for the correlation is an increasing contamination of the deposit by modern shrews as one approaches the surface. The late Pleistocene *B. b. cf. brevicauda* extended throughout the stratigraphic column but became increasingly contaminated by the remains of the smaller modern *B. b. kirtlandi* burrowing, or pursuing cracks from the surface.

That the large sinkhole *Blarina* finds its modern population equivalent in the northwestern sector of its present range, and is indeed of *B. b. brevicauda* stock is quite probable, and in harmony with the range changes of the yellow-cheeked vole (*Microtus xanthognathus*), the thirteen-lined ground squirrel (*Citellus tridecemlineatus*), and the sharp-tailed grouse (*Pedioecetes phasianellus*), which have shown similar shifts.

The late Pleistocene occurrence of a living subspecies south of its present range in what is now the territory of a morphologically distinct subspecies has been elsewhere demonstrated by finds of the Scandinavian red fox (*Vulpes v. vulpes*) associated with the arctic fox (*Alopex lagopus*) in cave deposits in Württemberg, Germany (Lehmann, 1954), Willendorf, Austria (Thenius, 1959) and Karnten, Austria (Thenius, 1960). *Vulpes v. crucigera*, the present middle European fox, is a smaller animal with pronounced dental differences (see Thenius, 1960, p. 37). Hibbard (1963) discusses a large form of *Blarina brevicauda*, from the late Illinoian of Kansas which is indistinguishable from *B. b. brevicauda* the large modern northern race. This form is apparently succeeded in Sangamon deposits from the same area by a small *B. b. cf. carolinensis*.

A skull of *Blarina b. cf. brevicauda* complete and uncrushed (fig. 16a) was recovered from the 5.2 m level of the sinkhole. Its measurements (table 10) are greater than the maximum observed in over 1,100 crania of *Blarina b. kirtlandi* from Pennsylvania, but can be matched by Minnesota speci-

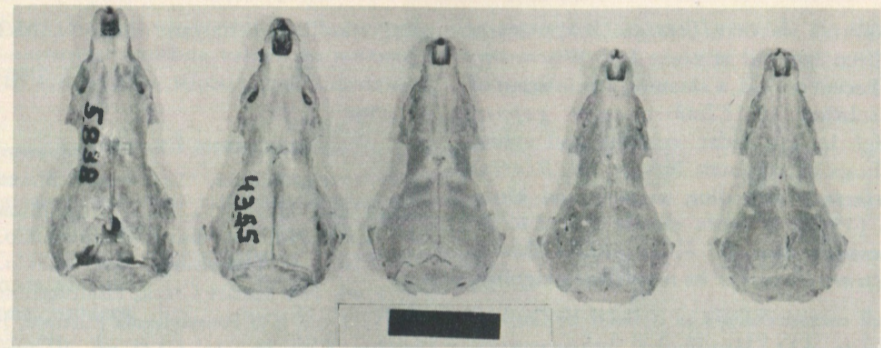


Figure 16.

Skulls of *Blarina brevicauda*, dorsal view. Note positive "Bergmann's response." Bar = 1 cm. CM 5838 - *B. b. cf. brevicauda*, 5.8-6.4 m level, Sinkhole No. 4, New Paris, Pa. Late Pleistocene. CM Mammal 4355 - *B. b. brevicauda*, Minnesota. Recent. Remainder - *B. b. kirtlandi*, Western Pa., Recent.

mens of *Blarina b. brevicauda*. Its extreme ruggedness and the accentuated crests and fossae for muscular attachments seem to indicate its advanced physiological age and can be approached by large, old skulls of *B. b. brevicauda*.

Blarina remains have been recovered from at least five other Appalachian cave deposits.

1. Frankstown Cave, Pennsylvania. Three mandibles indistinguishable from modern Pennsylvania stock. Due to the circumstances of recovery of the Frankstown local fauna there is no guarantee that the specimens are, in fact, Pleistocene.

2. Port Kennedy Cave, Pennsylvania. A single mandible, the type specimen of *Blarina simplicidens* Cope. Re-examined by Hibbard (1957) the species *B. simplicidens* was found to be invalid, a misinterpretation of a broken specimen of *B. brevicauda*.

3. Cumberland Cave, Maryland. "... rostral portion of a skull ... two maxillary fragments ... eight lower jaws." (Gidley and Gazin, 1938). These specimens were described as of a "size somewhat greater than the average in Recent specimens."

4. Wytheville, Virginia (Cope, 1869). One mandible in breccia. Lost before any observations could be made on it.

5. Natural Chimneys, Virginia. 100 mandibles, 4 partial skulls, 11 maxillae, Measurements presented below. This collection ap-



Figure 17.

Mandibles of *Blarina brevicauda* from Sinkhole No. 4, New Paris, Pa. Bar = 1 cm. *B. b. cf. kirtlandi*, CM 5848a, b, 2.4 - 3.3 m level. *B. b. cf. brevicauda*, CM 5843, 5847, 6027, 6087, 3.6 - 6.1 m level.

pears comparable to New Paris No. 4 in that there is a mixture of smaller (presumably *kirtlandi*) and large (*B. b. cf. brevicauda*) specimens. If the value for length of C_1-M_3 is disregarded due to the small sample size, the coefficients of variation appear quite large when compared with modern samples, suggesting that the collection consists of more than one population.

The late Pleistocene occurrence of a large form of *Blarina* in lowland Virginia is also suggested by the weekly differentiated *Blarina telmalestes* Merriam, a relatively large form confined to Dismal Swamp and surrounded by the small race of the southern

lowlands *B. b. carolinensis*. It appears to have been isolated at some late Wisconsin/early Recent period, a situation reminiscent of the isolation of *Clethrionomys gapperi roadsi* in the cedar swamps and sphagnum bogs of southern New Jersey. *Blarina telmalestes*, according to Bole and Moulthrop (1942) is more closely related to the northeastern race *B. b. talpoides* than to *B. b. carolinensis*, its immediate neighbor.

Skull measurements as defined by Guilday (1957, p. 43). Mandibular measurements: 1. Condyle - greatest length of condyle, measured as jaw lies on buccal surface. 2. C-M₃ - greatest length, crowns. 3. Depth of lower

incisor, from dorsal to ventral border at junction of incisor and first unicuspid. Measurements with ocular micrometer at 10X in mm.

SPECIMENS EXAMINED

Carnegie Museum: Section of Mammals. Moorhead, Minnesota 13; Detroit, Minnesota 1; 1 mi. NE Osterburg, Bedford Co., Pa. 9; 2 mi. E. Osterburg, Bedford Co., Pa. 3; 1 mi. NE Spruce Creek, Huntingdon Co., Pa. 5; 2 mi. SW Pennsylvania Furnace, Huntingdon Co., Pa. 1; 1-1/2 mi. W Immler, Bedford Co., Pa. 2; 7 mi. NW Immler, Bedford Co., Pa. 1; 3-1/2 mi. E Tyrone, Blair Co., Pa. 2.

Table 10- Summary, cranial measurements in millimeters, *Blarina brevicauda*

Locality	N	$\bar{X}$	O.R.	δ	V
Total length of skull					
Minnesota	14	24.15	23.5-25.7	.70	2.90
E. Springfield, Pa.	73	23.44	21.8-25.0	.57	2.43
Sink No. 4, CM 5838	1	25.6	—	—	—
Cranial Breadth					
Minnesota	15	12.94	12.3-13.9	.41	3.16
E. Springfield, Pa.	72	12.51	11.7-13.2	.33	2.63
Rostral breadth					
Minnesota	21	3.55	3.2-3.9	.19	5.46
E. Springfield, Pa.	77	3.14	2.9-3.4	.13	4.14
Sink No. 4	2	3.55	3.4-3.7	—	—
Natural Chimneys	3	3.40	3.2-3.7	—	—
Maxillary breadth					
Minnesota	21	8.43	8.0-9.2	.35	4.13
E. Springfield, Pa.	77	7.84	7.0-8.3	.22	2.80
Sink No. 4	2	8.50	8.1-8.9	—	—
Natural Chimneys	4	8.31	8.0-8.7	—	—
Upper tooththrow					
Minnesota	21	6.42	5.6-7.2	.41	6.33
E. Springfield, Pa.	77	6.25	5.8-6.6	.19	3.04
Sink No. 4	2	6.45	6.2-6.7	—	—
Natural Chimneys	8	6.59	6.4-6.8	.18	2.73
Interorbital breadth					
Minnesota	17	6.24	5.7-7.0	—	4.65
E. Springfield, Pa.	77	5.95	5.7-6.6	.19	3.19
Sink No. 4	1	6.30	—	—	—
Natural Chimneys	2	6.15	6.0-6.3	—	—

Table 11- Summary of mandibular measurements in millimeters, *Blarina brevicauda*

Locality	N	$\bar{X}$	O.R.	δ	V
Total length					
Minnesota	19	16.20	14.9-17.6	.67	4.13
Penna., modern	17	15.15	14.6-16.0	.32	2.09
Sink No. 4	29	15.33	13.8-17.2	.88	5.74
Tooththrow, C ₁ -M ₃					
Minnesota	20	6.29 ± .04	5.8-6.6	.19	3.02
Penna., modern	24	6.06 ± .03	5.7-6.3	.19	3.13
Sink No. 4	36	6.14 ± .06	5.5-6.8	.39	6.48
Natural Chimneys	9	6.43	6.2-6.6	.13	2.02
Width of lower incisor					
Minnesota	19	1.49	1.3-1.6	.07	4.69
Penna., modern	22	1.31	1.2-1.5	.08	5.92
Sink No. 4	41	1.42	1.3-1.6	.09	6.84
Frankstown Cave	1	1.3	—	—	—
Natural Chimneys	16	1.39	1.3-1.45	.07	5.03
Width of mandibular condyle					
Minnesota	22	4.16	3.9-4.6	.19	4.56
Penna., modern	24	3.85	3.7-4.1	.13	3.37
Sink No. 4	37	3.91	3.3-4.5	.30	7.67
Frankstown Cave	3	3.80	3.7-3.9	—	—

Carnegie Museum: Section of Vertebrate Fossils. Natural Chimneys local fauna, Augusta Co., Va., entire collection; Frankstown Cave, Blair Co., Pa., entire collection; Sinkhole No. 4, New Paris, Bedford Co., Pa., entire collection.

Minnesota Museum of Natural History. 1 mi. NE Valentine Lake, Ramsey Co., 3; Corlos Avery Game Refuge, Anoko Co., 1; 2 mi. S of Reno, Houston Co., 1; La Crescent, Houston Co., 2; Washington Co., 1.

Order: Chiroptera

Family: Vespertilionidae

Myotis keenii (Merriam)-Keen's bat

Material: 261 partial skulls; 41 left, 40 right maxillae.

Stratigraphy: From 4.3 m to 8.5 m level; diminishing in numbers with depth. At 4.3 m, 24 percent of all individual animals were of this species. At 8.5 m, only 2 percent (fig. 28).

Remarks: *Myotis keenii* was the commonest bat at all levels of the deposit. (302 *M. keenii*,

225 *M. cf. lucifugus*, 13 *Pipistrellus*, 1 *Eptesicus*). It was also the commonest *Myotis* at Natural Chimneys, Va. (39 *M. keenii*, 5 *Myotis* sp.). Keen's bat is not the commonest *Myotis* in the area today. The Pennsylvania mammal survey during the years 1946 to 1951 collected an average of 6 *M. lucifugus* for every *Myotis keenii* (see bibliography, Roberts and Early, 1952).

Myotis cf. lucifugus (LeConte)-Little brown bat

Material: 194 partial skulls; 29 left, 31 right maxillae.

Stratigraphy: From 4.3 m to 8.5 m level; diminishing in numbers with depth. At the 5.2 level, 14 percent of all individual animals were of this species; at the 8.5 m level, only 2 percent (fig. 28).

Remarks: This is the commonest species of *Myotis* in the Appalachians today. The identification remains provisional because of the close similarity of skeletal remains of *M. lucifugus*, *M. sodalis* and *M. austroripar-*

us. Both *M. keenii* and *M. lucifugus* range north into the Canadian life-zone today and are the only eastern species of *Myotis* to do so.

Myotis, species ?—Little brown bat

Material: 1,221 left, 1,216 right mandibles; 106 left, 98 right maxillae; 34 partial skulls.

Stratigraphy: From the 2.3 m to the 9.7 m level. (see fig. 28).

Remarks: No attempt was made to identify mandibles or skull fragments beyond genus. No specimens were observed that fell into the large *M. griseescens* size range nor the small *M. s. leibii* class. It is felt that most if not all of these specimens are *M. keenii* and *M. cf. lucifugus* as represented by the cranial material in the two previous species accounts.

Pipistrellus cf. subflavus (F. Cuvier)—

Pipistrelle

Material: 1 skull; 4 left, 1 right maxilla; 8 left, 13 right mandibles.

Stratigraphy: From the 4.3 m to the 6.4 m level. Absent from lower levels (fig. 28)

Remarks: *Pipistrellus* occurs only locally in the southern portions of the Canadian life zone today.

Eptesicus cf. grandis (Brown)—Big brown bat

Material: 1 mandible; 1 maxilla with P^4-M^3 , 1 humerus.

Stratigraphy: From 5.2 m and 6.4 m level (fig. 28).

Remarks: Referred to *E. grandis* because of size. Measurements agree with the type series and are larger than modern Pennsylvania specimens. Whether *E. grandis* is a subspecies (Brown, 1908), a species (Gidley and Gazin, 1938) or is invalid as a taxon must await further studies on both living and fossil brown bat populations.

Order: Rodentia

Family: Scuridae

Marmota monax Linnaeus—Woodchuck

Material: 1 left mandible with M_1 to M_3 , 3 isolated molars, 2 partial incisors.

Stratigraphy: From the 6.0 m level.

Remarks: At least one animal was represented.

Burrowing rodents, such as the woodchuck, are a constant source of contamination of older by younger material in archaeological sites throughout the East. The New Paris No. 4 specimen may or may not have been intrusive although *Marmota* is common in most late Pleistocene deposits in the area and ranges north to 65° N lat. Alveolar length P_4 to M_3 measured 19.6 mm (CM 5746), a small adult.

Citellus tridecemlineatus (Mitchell)—

Thirteen-lined ground squirrel

Material: 2 partial skulls; 3 left, 5 right maxillae; 8 left, 6 right partial mandibles.

Stratigraphy: From 5.2 m level to the 8.2 m level (fig. 29).

Remarks: A minimum of eight animals were represented. Seven were immature with deciduous premolars. One, CM 6041, a right maxilla with M^2-M^3 was a young adult.

The specimens appear to be slightly larger than the average for the modern northern race *C. t. tridecemlineatus* (Mitchell) but well within its range of variation (Howell, 1938, p. 107).

Though never common in any one eastern late Pleistocene deposit, these ground squirrels are known from four other sites in what is now the forested East: Cumberland Cave, Maryland; Bootlegger Sink, Pennsylvania; Natural Chimneys, Virginia; and Robinson Cave, Tennessee.

The animal is presently confined to areas of well-drained upland prairie north to central Alberta and Saskatchewan. Its presence throughout a large area of the East in early post-glacial time is compelling evidence for the former presence of grasslands in that area.

Tamias striatus (Linnaeus)—Chipmunk

Material: 1 partial skull; 5 left, 9 right maxillae; 24 left, 27 right mandibles.

Stratigraphy: From the 3.3 m level to the 7.3 m level. They were not present in the bottom 2 m of the deposit (fig. 29).

Remarks: Chipmunks constituted 32 percent of the sciurids from New Paris No. 4 and are represented by at least 27 individuals. In the Recent New Paris No. 2 collection they account for 83 percent (114 individuals) of all sciurids.

No correlation was found between stratigraphic position in the sinkhole and size. However, Sinkhole No. 4 specimens were larger than Recent Pennsylvania material, as represented by the Sinkhole No. 2 collection. Alveolar length of the lower cheek teeth was compared and the results are presented below. The populations differ significantly. The probability of their means being drawn from the same population is less than .1 percent.

Table 12 — *Tamias striatus* (Linnaeus), alveolar length, P^4-M^3 , measurements in millimeters.

Locality	Approx. Age	$\bar{X}$	O.R.	σ	V	N
New Paris No. 4	11,300 B.P.	6.74	6.3–7.1	.2	6.67	30
New Paris No. 2	1,875 B.P.	6.28	5.8–6.8	.18	2.86	114

One left maxilla, CM 6044, with full dentition, had a well developed P^3 (see fig. 18c). This is a character of the genus *Eutamias* (see Jones, 1960 for exception) but virtually unknown in *Tamias*. One unilateral example of P^3 was found in an examination of 360 modern skulls (an adult male, Erie County, Pa., CM Mammal No. 25145, fig. 18b). Despite the presence of other midwestern forms in the deposit (*Pedioecetes*, *Citellus*), CM 6044 is more probably an aberrant *Tamias* rather than a *Eutamias*. Its size agrees with the rest of the Sinkhole No. 4 chipmunk material, and is much larger than *Eutamias minimus* the only "eastern" species of the genus occurring as far east as western Quebec about 800 km north of New Paris. Unless additional material can be found to substantiate the presence of *Eutamias* in the late Pleistocene of the Appalachians, this specimen, despite the presence of P^3 , is considered a *Tamias*. Unfortunately, the maxilla shows no other diagnostic characters.

Glaucomys sabrinus (Shaw)—Northern flying squirrel

Material: 13 left, 15 right maxillae; 13 left, 14 right mandibles.

Stratigraphy: From 5.2 m to 6.7 m levels (fig. 29).

Remarks: *Glaucomys sabrinus* is another species that follows "Bergmann's Rule." Specimens from eastern United States are the smallest. Size increases to the north and to the west. Specimens from New Paris No. 4 and

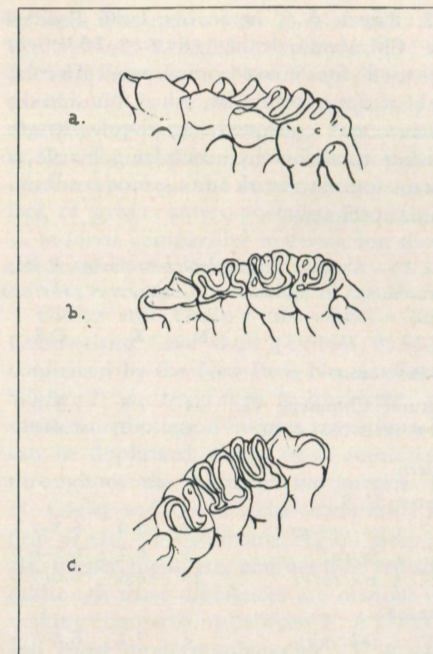


Figure 18.

Presence or absence of P^3 in chipmunks. a. CM Mammal 12679 — *Eutamias* sp., right P^3-M^3 . Note normal, well developed P^3 at right. b. CM Mammal 25145 — *Tamias striatus*, right P^3-M^3 . Note abnormal presence of P^3 at right. c. CM 6044 — cf. *Tamias striatus*. Sinkhole No. 4, New Paris, Pa. 5.2 m level. Left upper toothrow, note P^3 at left.

from the Natural Chimneys local fauna are of equal size and both are larger than modern material from the area. Measurements for length of lower toothrow ($n=17$) were larger than the observed maximum of 37 *G. s. macrotus*, *fuscus*, and *coloratus* from the eastern Appalachians. The fossil material averaged 13 percent larger than modern Pennsylvania *G. s. macrotus*, 7 percent larger than central Canadian *G. s. sabrinus* (4 specimens), and can be matched by Alaskan specimens of *G. s. yukonensis* and *G. s. zaphaeus*. They are exceeded in size by specimens of *G. s. bullatus* from Idaho. Comparative measurements are given below. Measurements were taken from Howell, 1918; Handley, 1953; and Guilday,

1962. Fifteen *G. s. macrotus* from Pennsylvania (CM Mammal no. 31612-17; 36390-9) were used for direct comparison. Alveolar length of upper tooththrow, when found in the literature, was converted into alveolar length of lower tooththrow by multiplying by .94, a constant found to work among modern Pennsylvania specimens.

Table 13 - Alveolar length, lower tooththrow, P_4-M_3 , measurements in millimeters, *Glaucmys sabrinus*

	N	$\bar{X}$	O.R.
Late Pleistocene			
Natural Chimneys, Va.	14	7.8	7.3-8.4
New Paris No. 4, Pa.	3	7.7	7.6-8.1
Modern			
Eastern U. S.			
<i>G. s. coloratus</i>	7	6.9	6.7-7.1
<i>G. s. fuscus</i>	5	6.7	6.5-6.9
<i>G. s. macrotus</i>	23	6.6	6.0-7.0
Canada			
<i>G. s. sabrinus</i>	4	7.2	6.8-7.6
<i>G. s. makkovikensis</i>	2	7.1	6.9-7.4
Alaska			
<i>G. s. yukonensis</i>			
<i>G. s. zapbaeus</i>	5	7.6	7.3-7.9
Idaho			
<i>G. s. bullatus</i>	3	8.7	8.6-8.7

Glaucmys volans (Linnaeus)-Southern flying squirrel

Material: 2 left maxillae; 1 left, 1 right partial mandible, fragmentary.

Stratigraphy: From the 2.7 m to 6.1 m levels (fig. 29).

Remarks: *Glaucmys volans* can usually be distinguished from *Glaucmys sabrinus* by its inferior size. Occasional individuals of *G. sabrinus* from the southeastern portion of their modern range are as small as some *G. volans*. If the dental measurements of a particular individual fall within this area of overlap, specific identification by those characters is not possible.

There are two sharply differentiated species of flying squirrels in both the New Paris No. 4 and the Natural Chimneys local faunas. The larger has been identified as *G. sabrinus*. It was found, on the basis of dental measure-

ments, to average 16 percent larger than the smaller form in those deposits. There was no overlap in measurements. This late Pleistocene *G. sabrinus* is 13 percent larger than modern Appalachian races of that species, again with no overlap in measurements. Comparable sized individuals are found in northern and western races today (see table 13, p. 154). The smaller late Pleistocene species has been identified as *G. volans*. Unfortunately, their measurements average larger than modern *G. volans* by some 8 percent. This makes them as large as many modern *G. sabrinus macrotus*. The size difference is not statistically significant and the ranges are almost identical.

The smaller late Pleistocene form is identified as *G. volans*, not on morphological grounds - in this respect they are significantly smaller than the *G. sabrinus* with which they occur. In other words, the slightly larger *G. volans* from the late Pleistocene cannot be confidently separated from modern *G. s. macrotus* of the same area, but can be differentiated from the extremely large *G. sabrinus* from these same late Pleistocene deposits.

An alternate treatment assigning the smaller group to *G. s. macrotus* and assuming a chronocline would require the presence of intermediate individuals. These are not present. Likewise, the assumption that the smaller form is *G. sabrinus* while the larger form is an undescribed taxon is equally as unrealistic. The best explanation appears to be that both *G. volans* and *G. sabrinus* were of larger size during the late Pleistocene in the central Appalachian region.

Table 14 - Alveolar length, lower tooththrow, P_4-M_3 , measurements in millimeters, *Glaucmys volans*

	N	$\bar{X}$	O.R.
Modern, Pennsylvania*			
	38	6.0	5.6-6.4
Late Pleistocene			
Natural Chimneys	17	6.5	6.3-6.9
New Paris No. 4	2	6.4	—

Data from Howell, 1918; Guilday, 1962; Douth, unpubl.*

Tamiasciurus hudsonicus tenuidens (Hay) -Red squirrel

Sciurus tenuidens Hay, 1920

Sciurus (Tamiasciurus) tenuidens Hay,

Gidley and Gazin, 1938

Material: 18 partial skulls; 10 left, 12 right maxillae; 17 left, 21 right mandibles, plus associated skeletal material.

Stratigraphy: From 3.6 m to 8.2 m level (fig. 29).

Remarks: The extinct *Tamiasciurus tenuidens* Hay was based upon a lower right jaw fragment and incisor, mistaken by its describer for an upper left incisor and premaxillary fragment. The characters given in the type description (Hay, 1920, p. 105): "Upper incisors broad and unusually thin; front border rounded." merely describe differences between upper and lower incisors of tree squirrels, rather than any interspecific difference. Gidley and Gazin (1938, pp. 54-56, fig. 30) redescribed the form using three partial skulls and four mandibles from the Cumberland Cave, Maryland. Seven partial mandibles, two maxillae and one humerus from Natural Chimneys, Virginia are referred to this form as well.

The additional well preserved material from New Paris No. 4, representing the remains of at least 30 animals, allows the reappraisal of the taxonomic status of the form *tenuidens*. It is here considered an extinct subspecies of the modern *Tamiasciurus hudsonicus* (Erxleben).

In their redescription of *T. b. tenuidens*, Gidley and Gazin (1938, p. 54) stated that the type incisor "is relatively narrow transversely and of greater antero-posterior diameter than in *S. hudsonicus*" and that the lower incisors of the Cumberland Cave material are "of greater antero-posterior diameter" than in modern *hudsonicus*. Neither Hay's nor Gidley and Gazin's measurements bear this out, however. The ratios of transverse diameter to antero-posterior diameter, based upon their measurements, are 33-1/3 percent and 42.8 percent respectively. Modern ratios vary from 32 percent to 44 percent, a range which includes all of the fossil material

as well. The ratio in 36 *T. b. loquax* from Pennsylvania averaged 38 percent; in 30 *T. b. tenuidens* from New Paris No. 4, 37 percent. *T. b. tenuidens* had a relatively massive jaw apparatus averaging 10 percent larger than the modern Appalachian populations of the species. The lower incisors are, in fact, of greater antero-posterior diameter than in modern comparative material, but they are not relatively narrower.

Gidley and Gazin's observations on the Cumberland Cave skull (USNM 8164) are confirmed by the New Paris No. 4 collection. While *T. b. tenuidens* is distinctive, none of its morphological features are unique. They can be duplicated, singly or in combination, throughout the range of the species. Most of Gidley and Gazin's characters are a function of size - broad frontal region, deep muzzle, deeper jugal, etc, and are thus redundant (although these differences are obvious when making comparisons between *T. b. tenuidens* and most modern subspecies). *T. b. tenuidens* is equaled in size by *T. b. fremonti* and exceeds all eastern forms in dental measurements. Measurements of body elements, if anything, are a little smaller than modern Pennsylvania material, however (table 15).

Viewed from the side, the dorsal profile of the skull is stated to be flatter than in the modern "species". This is true if the comparison is made between *T. b. tenuidens* and *T. b. loquax*, but a series of *T. b. preblei* from Aklavik, Northwest Territories agreed with *T. b. tenuidens*, and the character appears to be of subspecific value at most.

Inflation of the auditory bullae, noticeable in *T. b. tenuidens*, appears to be correlated with latitude in modern populations. It is more pronounced in specimens of *T. b. preblei* and *T. b. ungavensis*, less so in *T. b. minnesota* and *T. b. loquax*.

The most striking character complex seen in *T. b. tenuidens* is that associated with the jaw musculature. The zygomatic plate of the maxilla is flaring and deeply excavated above the infra-orbital foramen. Ridges and fossae for attachment of masticatory musculature, both on the skull and mandible, are

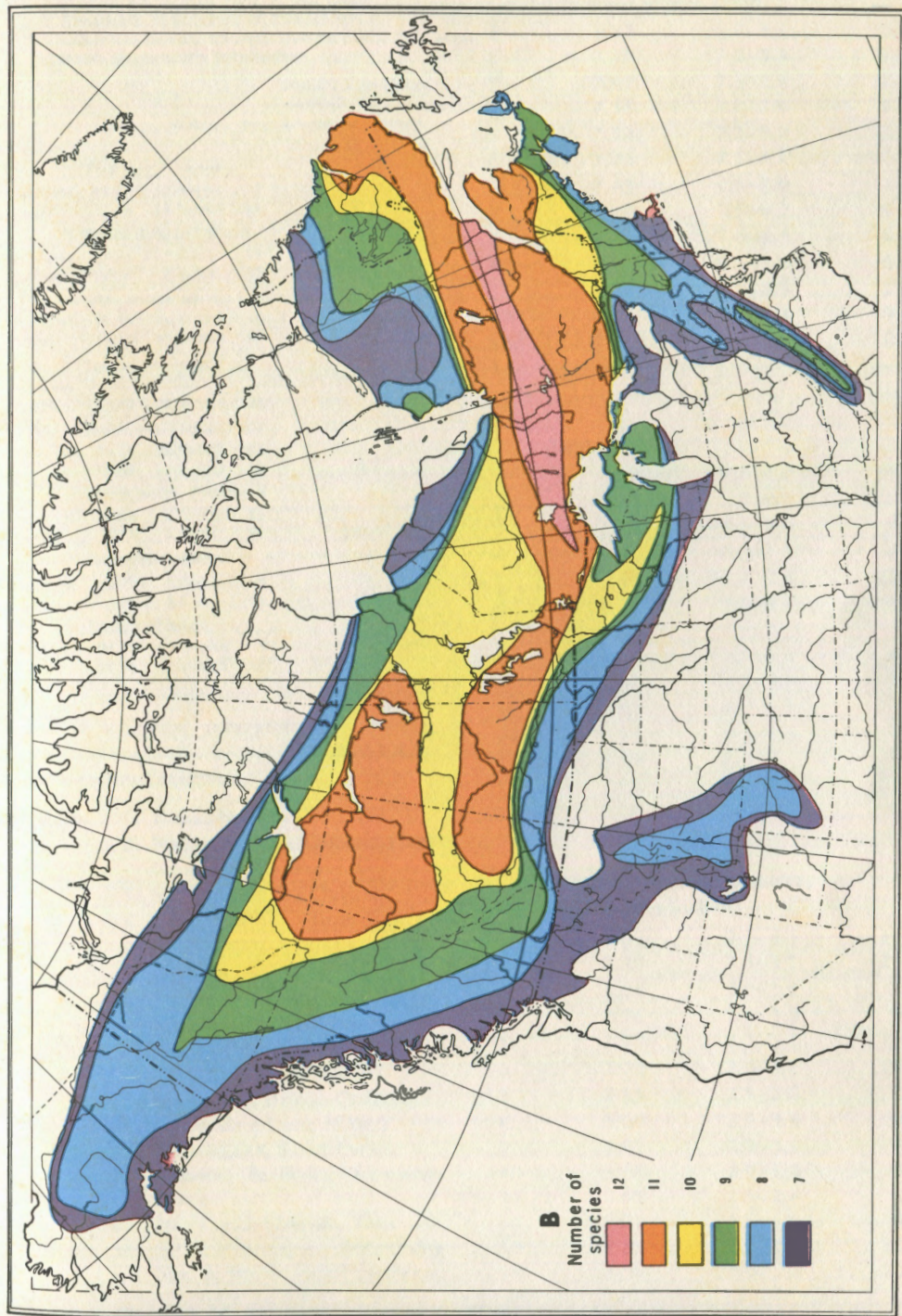
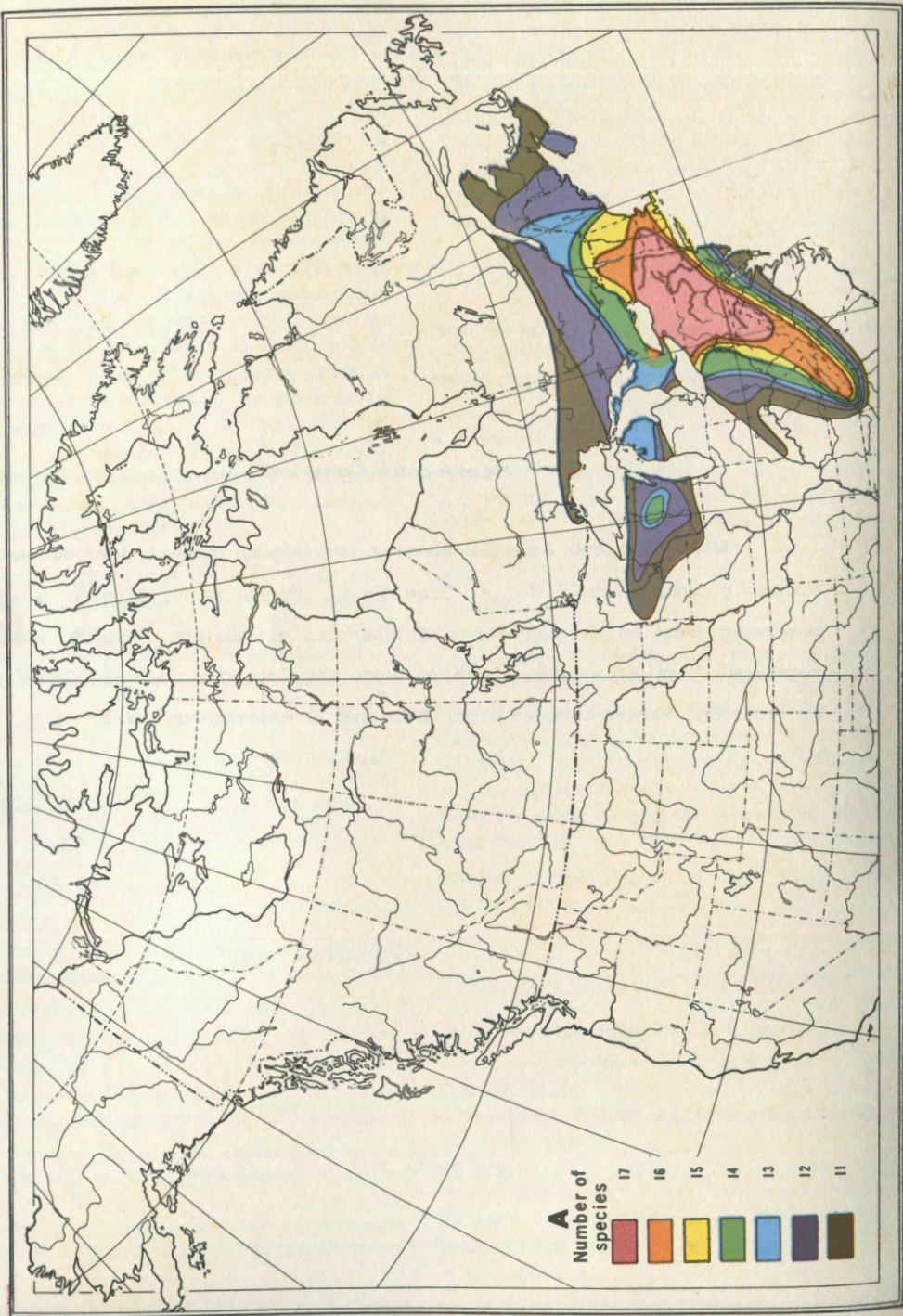


Table 15 - Skeletal measurements: *Tamiasciurus budsonicus tenuidens* (Hay), from Sinkhole No. 4, New Paris, Pa. and Recent Pennsylvania specimens of *Tamiasciurus budsonicus loquax*, Carnegie Museum Collection. Measurements in millimeters.

	$\bar{X}$	O.R.	N	Size of <i>T. h. tenuidens</i> relative to that of <i>T. h. loquax</i> - percent
Total length, humerus				
<i>tenuidens</i>	31.07	30.4-33.1	7	
<i>loquax</i>	31.76	28.9-33.6	31	97.8
Width, distal end of ulna				
<i>tenuidens</i>	7.93	7.4-8.4	10	
<i>loquax</i>	7.98	7.3-8.8	32	99.4
Ulna, total length				
<i>tenuidens</i>	35.33	33.4-37.5	6	
<i>loquax</i>	35.25	33.6-37.8	20	100.2
Radius, total length				
<i>tenuidens</i>	—	—	—	—
<i>loquax</i>	29.32	27.5-31.3	22	
Femur, total length				
<i>tenuidens</i>	39.18	38.5-40.3	11	
<i>loquax</i>	39.69	35.6-41.9	32	98.7
Femur, width of distal end				
<i>tenuidens</i>	6.83	6.6-6.9	12	
<i>loquax</i>	6.72	6.0-7.5	31	101.64
Femur, shaft diameter				
<i>tenuidens</i>	2.79	2.7-3.2	16	
<i>loquax</i>	2.94	2.7-3.3	32	94.9
Tibia, total length				
<i>tenuidens</i>	44.32	44.0-44.6	5	
<i>loquax</i>	44.40	41.2-47.6	17	99.8

Table 16 - Cranial measurements, in mm, *Tamiasciurus budsonicus* (Erxleben), Carnegie Museum Collection.

Localities:	1. Pennsylvania
	2. Natishquan R., Quebec; Hamilton R., Labrador
	3. St. Margaret R., Quebec
	4. Charleton Is., James Bay, N. W. T.
	5. Ontario
	6. Hudson Bay, Rupert House to Richmond Gulf, Quebec
	7. Fort Chimo, Quebec
	8. Churchill, Manitoba
	9. Snowshoe, British Columbia
	10. Great Slave Lake, N.W.T.
	11. Emma Lake, Saskatchewan
	12. Aklavik, N.W.T.; Seward, Alaska
	13. Moorhead, Detroit, Minn.
	14. <i>T. b. tenuidens</i> , New Paris No. 4, Penna., late Pleistocene

Locality	$\bar{X}$	O.R.	N
Occlusal length, P^4-M^3			
1	7.37	6.7-8.1	30
2	7.58	7.2-8.4	17
3	7.47	7.3-7.7	4
4	7.36	7.0-7.6	6
5	7.52	7.1-8.0	19
6	7.75	7.5-8.1	16
7	7.45	7.3-7.6	2
8	8.00	7.8-8.2	4
9	7.95	7.6-8.3	4
10	8.16	8.1-8.2	3
11	8.25	8.2-8.3	2
12	8.09	7.7-8.4	9
13	7.85	7.2-8.4	10
14	—	—	—
Length, P_4-M_3			
1	7.39	6.8-7.8	33
2	7.66	7.3-8.0	20
3	7.65	7.3-8.0	4
4	7.31	6.9-7.5	6
5	7.58	7.1-7.8	19
6	7.84	7.6-8.2	15
7	7.60	7.5-7.7	2
8	7.95	7.8-8.1	4
9	8.05	7.7-8.5	4
10	8.23	8.0-8.4	3
11	8.30	8.3-8.3	2
12	8.20	8.0-8.4	9
13	7.92	7.2-8.5	11
14	8.20	8.0-8.3	4
Antero-posterior diameter, lower incisor			
1	3.00	2.5-3.3	36
2	2.80	2.4-3.1	23
3	2.90	2.8-3.0	4
4	2.76	2.4-3.0	6
5	2.95	2.7-3.1	19
6	2.72	2.6-3.1	15
7	2.55	2.5-2.6	2
8	3.00	2.7-3.3	4
9	3.07	2.9-3.4	4
10	3.00	2.9-3.2	3
11	2.60	2.6-2.6	2
12	2.79	2.6-3.0	9
13	2.94	2.3-3.2	13
14	3.30	3.0-3.6	29

Table 16 (Continued)
Transverse diameter, lower incisor

1	1.00	.9-1.2	36
2	.95	.8-1.1	23
3	1.02	1.0-1.1	4
4	.95	.9-1.0	6
5	1.03	.9-1.2	19
6	.97	.8-1.1	15
7	.85	.8- .9	2
8	1.05	1.0-1.1	4
9	1.05	1.0-1.1	4
10	1.10	1.1-1.1	3
11	.90	.9- .9	2
12	1.04	1.0-1.1	9
13	1.19	1.0-1.5	13
14	1.20	1.0-1.6	29

Inter-orbital width

1	13.68	13.0-14.5	36
2	13.17	12.0-14.1	21
3	13.65	13.1-13.9	4
4	13.3	12.8-14.3	6
5	13.3	12.2-15.1	18
6	13.8	12.8-14.4	14
7	12.2	12.1-12.4	2
8	13.2	13.0-13.5	4
9	14.2	13.5-15.0	4
10	13.7	13.0-14.5	3
11	12.8	12.7-13.0	2
12	14.2	13.6-14.8	9
13	13.6	12.0-14.5	13
14	13.9	13.3-14.7	10

Family: Cricetidae

Subfamily: Cricetinae

Neotoma cf. *floridana* (Ord)-Wood rat
Material: 1 partial left mandible, M_1-M_2 ; 1 partial left mandible, M_2-M_3 ; 1 right M^1 ; 2 upper, 1 lower incisor; 1 left, 1 right M^1 .
Stratigraphy: 5.5 m to 6.4 m level.

Remarks: Two animals were represented. The presence of flowstone on one mandible, CM 5751, argues for some age. *Neotoma*, despite the fact that it ranges only two degrees further north today, may have been a member of the Pleistocene fauna. Its modern distribution in the East is enigmatic - present in the Appalachian mountains and in the Atlantic lowlands of the South as far north as Virginia, but absent from the intervening Piedmont north

of Georgia. Despite the fact that the well-marked race *N. f. magister* ranges only as far as lat. 42°, it does not act like a "southern" form. It may occur on mountain summits in excess of 900 m throughout its range, and appears restricted to the Appalachian mountain and plateau region. *Neotoma* has been recorded from Cumberland Cave, Maryland, Natural Chimneys, Virginia and Robinson Cave, Tennessee-all late Pleistocene in age. It also inhabits most of the caves in the region today.

Schwartz and Odum (1957, pp. 197-199) suggest that *Neotoma floridana* invaded the southern United States from the southwest; one branch, the "magister" stock, ascending the Appalachians; the other, more southerly "floridana" stock, invading the southern lowlands and ascending the Atlantic coastal area. This invasion presumably was post-Wisconsin.

It would appear probable, in the light of the animal's presence as far north as New Paris during the late Pleistocene, that *N. f. magister*, the largest, and, morphologically and ecologically, the most well-marked subspecies, survived the Wisconsin glaciation in the southern Appalachians. It then repossessed the northern sector of its present range very rapidly after deglaciation had commenced. Its northern advance may have been halted more by the lack of cliff-talus-cave habitat to which it appears strongly attracted than by climatic factors.

Peromyscus cf. *maniculatus* (Wagner)-Deer mouse

Material: 4 partial skulls; 72 left, 93 right maxillae; 128 left, 117 right mandibles.

Peromyscus cf. *leucopus* (Rafinesque)-White-footed mouse

Material: 2 left, 1 right maxillae; 7 left, 11 right mandibles.

Peromyscus, species ?

Material: 3 partial skulls; 72 left, 93 right maxillae; 64 left, 70 right mandibles.

Remarks: Mice of the genus *Peromyscus* were common throughout the deposit. *P. leucopus* (the only *Peromyscus* living at the site today) occurred uncommonly at all levels with little change of numbers while *P. mani-*

culatus increased markedly in the middle and lower levels.

Table 17 - Stratigraphic distribution of two species of *Peromyscus*, New Paris No. 4, Pa.

Species	Depth in Meters			
	0.25 m	2.6-5.5 m	5.6-8.5 m	8.6-10.0 m
<i>P. leucopus</i>	100%	10%	7%	4%
<i>P. maniculatus</i>	0	90%	93%	96%
individuals	3	10	86	24

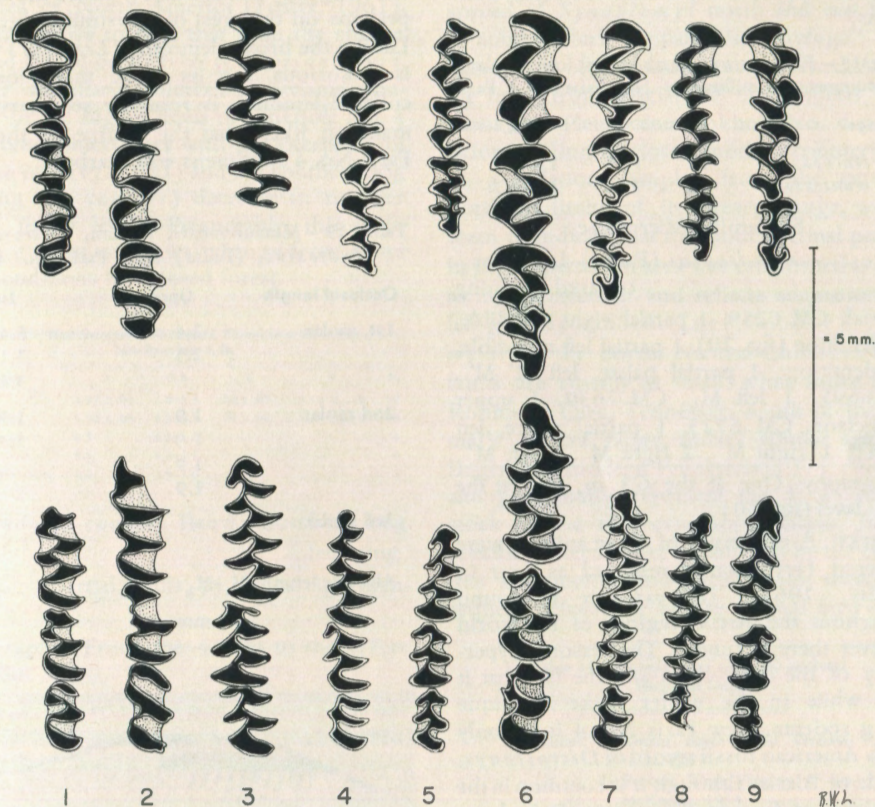


Figure 19.

Crown patterns, upper and lower molars, Microtinae, Sinkhole No. 4, New Paris, Pa.

1. CM 5633, 6267 - *Synaptomys cooperi*, left M^1-M^3 , left M_1-M_3
2. CM 6911, 6724 - *Synaptomys borealis*, right M^1-M^3 , left M_1-M_3
3. CM 6723, 6258 - *Dicrostonyx hudsonius*, left M^1-M^2 , left M_1-M_3
4. CM 6725, 5869 - *Phenacomys* cf. *ungava*, left M^1-M^3 , left M_1-M_3
5. CM 5647, 6701 - *Clethrionomys gapperi*, left M^1-M^3 , left M_1-M_3
6. CM 6249, 5541 - *Microtus xanthognathus*, left M^1-M^3 , left M_1-M_3
7. CM 6188 - *Microtus pennsylvanicus*, left M^1-M^3 , left M_1-M_3
8. CM 5595, 6186 - *Microtus chrotorrhinus*, left M^1-M^3 , right M_1-M_3
9. CM 5683, 6015 - *Pitymys pinetorum*, right M^1-M^3 , right M_1-M_3

P. leucopus is probably not a member of the late Pleistocene fauna. The presence of modern rodent droppings at the 5.9 m level plus the ever present possibility of contamination of the lower levels by modern *P. leucopus* (and *Pitymys pinetorum*) falling in during the four year excavation period leaves the presence of this temperate species in the primary boreal fauna open to question.

P. leucopus ranges throughout central and eastern North America north to lat. 46° N. It is usually a deciduous forest form and does not penetrate far into the coniferous forests of the Canadian life-zone. *P. maniculatus* ranges over most of North America except the lowlands of the southeastern United States and the far northern tundra. It ranges locally into the Arctic life zone (Harper, 1961), and its presence is quite compatible with boreal conditions.

Table 18 - *Peromyscus*, length of first lower molar, measurements in millimeters, New Paris No. 4, Pa.

Species	N	$\bar{x}$	O.R.
<i>P. leucopus</i>	18	1.58	1.4-1.7
<i>P. maniculatus</i>	48	1.52	1.4-1.7

Subfamily: Microtinae

Dicrostonyx hudsonius (Pallas)-Labrador collared lemming

Material: CM 6258. 1 partial right mandible, full dentition (fig. 20). 1 partial left mandible, full dentition; 1 partial palate, left M^1-M^2 . CM 6695. 1 left M_1 . CM 7639. 1 upper left incisor. CM 6723. 1 partial palate, left M^1-M^2 , 1 right M^1 , 2 right M^2 , 1 left M^1 . Stratigraphy: One at the 6.1 m, two at the 6.4 m level (fig. 30)

Remarks: A minimum of three animals were recovered (erroneously reported as four in Guilday, 1963). *Dicrostonyx* is found throughout the Arctic regions of the world wherever there is tundra. The seasonal hypertrophy of the front claws and the fact that it turns white in the winter make it unique among rodents. New Paris No. 4 is the only North American fossil record of *Dicrostonyx*, outside of Alaska although it is common in the Pleistocene of Europe. The species *D. hudsonius* is isolated at the present time on the Ungava Peninsula of northern Quebec and Labrador. It is differentiated from *D. groenlandicus* of the western Nearctic, the Canadian Archipelago and Greenland, by characters in both upper and lower dentitions (Anderson and Rand, 1945; Hall and Kelson, 1962). On the basis of these, the New Paris No. 4 specimens are *D. hudsonius*. (See fig. 19 for drawing of dental pattern.) The possible biogeographical history of *Dicrostonyx* in North America during the late Pleistocene is discussed in Guilday, 1963.

Presence of this lemming is strong evidence for the near presence of tundra. It may occasionally range into the fringes of the Hudsonian life-zone (Harper, 1961) but is a true barren-ground form. The fact that only three animals were recovered suggests that typical tundra *per se* did not persist near the mouth of the sinkhole during the period of infill. The source could have been a relict colony on Allegheny Mountain 10 km to the west or perhaps on the crest of Chestnut Ridge itself. Unlike the brown lemming (*Lemmus*) which is notorious for its cyclic migrations the collared lemming is relatively sedentary. This makes it likely that the source of the New Paris No. 4 specimens was nearby.

Table 19 - Measurements, in mm, *Dicrostonyx hudsonius* (Pallas) New Paris No. 4, Pa.

Occlusal length	Upper	Lower
1st molar	2.4 mm 2.5	3.4 mm 3.1 3.4
2nd molar	1.9 1.9 1.9 1.9	1.7 1.7
3rd molar		1.5 1.5
Alveolar length, M_1-M_3	6.8 mm 7.3	

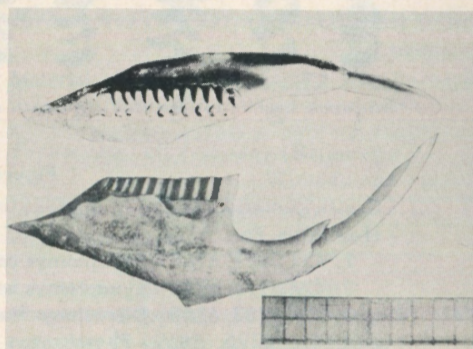


Figure 20.

CM 6258 - *Dicrostonyx hudsonius*. Sinkhole No. 4, New Paris, Pa. Crown and buccal view, right mandible, mm grid.

Phenacomys cf. ungava Merriam--Spruce vole

Material: 13 partial skulls; 2 left, 4 right maxillae; 46 left, 37 right mandibles, or M_1 's. Stratigraphy: General from the 4.9 m through the 8.5 m level, becoming scarcer with depth (fig. 30).

Remarks: The spruce vole lives in pine and spruce forests of the Canadian and Hudsonian life-zones of North America (Foster, 1961). It is instructive to note that both the spruce vole and the red-backed vole (*Clethrionomys*), another woodland microtine, become commoner in the higher levels of Sinkhole No. 4 while other microtines with the exception of the pine vole (*Pitymys*) and the southern bog lemming (*S. cooperi*) decrease in number in the upper levels. Presumably, this is in response to an ecological change from more open conditions to a closed forest.

Table 20 - Measurements in millimeters, *Phenacomys cf. ungava*, New Paris No. 4, Pa.

Measurement	$\bar{x}$	O.R.	σ	V	N
length, M_1	2.67 $\pm$.01	1.8-3.3	.08 $\pm$.007	3.10 $\pm$.28	59
length, M_1-M_3	5.50 $\pm$.09	4.9-6.1	.29 $\pm$.06	5.27 $\pm$ 1.17	10
length, M^1-M^2	4.5	4.3-5.0			4
incisive foramen	3.5	3.3-3.7			4
inter-orbital breadth	2.9	2.9-3.0			3

Synaptomys cooperi Baird - Southern bog lemming

Material: 2 partial skulls; 15 left, 16 right mandibles or M_1 's.

Stratigraphy: From the 4.9 m to the 6.7 m level (fig. 30).

Remarks: The southern bog lemming was one of only four microtines from Sinkhole No. 4 (*Clethrionomys*, *Pitymys*, *Phenacomys*, *S. cooperi*) that did not increase in numbers with depth. It was concentrated in the upper levels of the deposit in contrast to the northern bog lemming *S. borealis* which replaced it in the lower levels of the sinkhole. The Sinkhole No. 4 population of *S. cooperi* differs significantly in size from a modern sample of *Synaptomys c. cooperi* Baird from the same area (south-central Pennsylvania). It is smaller in all dimensions. It agrees most closely with specimens from eastern Quebec and Canada. *Synaptomys cooperi* exhibits a negative Bergmann's response. It is largest in the southern and western portions

of its present range, becoming smaller with increasing latitude. Smallest modern populations are from eastern Canada.

Measurements of one specimen from the Recent Sinkhole No. 2 fauna lie at the upper limit of the modern Pennsylvania material and are significantly larger than those of the late Pleistocene Sinkhole No. 4 sample.

Wetzel, 1955, postulated a post-glacial spread of *Synaptomys* north and east from a southwestern Appalachian "refuge" into those areas of central and eastern North America freed from glacial ice or its effects. The small late Pleistocene Sinkhole No. 4 population, finding its closest modern counterparts in population samples from the extreme northern limits of its present range, would seem to indicate that the modern clinal pattern in the Appalachian area was established as early as the Wisconsin and reflects adaptations to full-glacial conditions. Late Pleistocene *S. cooperi* from the boreal Natural Chimneys local fauna are equally as small, while those from Robinson Cave, Tennessee, south of the animal's present range, and of similar age, are larger than modern Pennsylvania *S. c. cooperi* and presumably represent the *S. c. stoneri* stock of the southern Appalachians. If subspecific patterns were established by the rigorous selection of full-glacial times, then subsequent reinvasion by the animal into more

Table 21 - *Synaptomys cooperi*, occlusal length M_1-M_3 , Measurements in millimeters.

- Localities: 1. Recent south-central Pennsylvania, CM
2. Recent, West Virginia. From McKeever, 1954.
3. Recent, Sinkhole No. 2, New Paris, Pennsylvania. CM
4. Recent, Quebec, Canada. CM
5. Late Pleistocene, Sinkhole No. 4, New Paris, Pennsylvania. CM
6. Late Pleistocene, Natural Chimneys, Virginia. CM
7. Late Pleistocene, Robinson Cave, Tennessee. CM

Locality	$\bar{x}$	O.R.	σ	V	N
1.	5.92 $\pm$.07	5.3-6.6	.36 $\pm$.05	6.08 $\pm$.85	25
2.	6.35	5.9-6.8			17
3.	6.6				1
4.	5.77 $\pm$.09	5.6-6.1	.21 $\pm$.06	3.63 $\pm$ 1.15	5
5.	5.62 $\pm$.04	5.4-5.9	.13 $\pm$.03	2.30 $\pm$.57	8
6.	5.5	5.4-5.6			2
7.	6.25	6.1-6.4			2

Table 22 - *Synaptomys cooperi*, occlusal length M_1 , measurements in millimeters.

Localities as in Table 21 (Locality 2 and 4 omitted).

Locality	$\bar{X}$	O.R.	σ	V	N
1.	2.48 ± .03	2.1-2.7	.19 ± .02	7.66 ± 1.08	25
3.	2.80				1
5.	2.41 ± .02	4.3-2.5	.09 ± .01	3.73 ± .60	20
6.	2.39 ± .01	2.2-2.5	.05 ± .01	2.92 ± .55	14
7.	2.57 ± .04	2.3-2.9	.20 ± .03	7.78 ± 1.26	19

northerly areas has kept pace with climatic retreat. Modern clinal variation in this form represents the Pleistocene clinal pattern, displaced to the north and undoubtedly modified by local conditions, but still discernible in broad outline.

Synaptomys borealis (Richardson)-

Northern bog lemming

Material: 31 partial skulls; 71 left, 66 right mandibles or M_1 's.

Stratigraphy: From the 4.9 m through the 8.5 level. Becomes commoner in lower levels (fig. 30).

Remarks: At the 5.2 m level, southern bog lemming remains exceeded those of the northern bog lemming (8 *S. cooperi*, 3 *S. borealis*), but below this level *S. borealis* became the commoner of the two. From the 7.0 m to the 8.8 m level only the northern bog lemming was found.

These two species co-exist today only in a narrow belt of southeastern Canada at the juncture of the Hudsonian and Canadian life-zones. All lines of evidence from Sinkhole No. 4 indicate that similar ecological conditions occurred during the deposition of the matrix. Changing proportions of the two species with depth is taken as an indication of climatic change during deposition.

Slightly over four *S. borealis* were recovered for every one *S. cooperi*. At Natural Chimneys, Virginia lat. 38° 22' N, the situation was reversed with four *S. cooperi* for every one *S. borealis*.

Table 23 - Cranial measurements in millimeters, *Synaptomys borealis* (Richardson), New Paris No. 4, Pa.

Measurement	$\bar{X}$	O.R.	σ	V	N
M_1 , occlusal length	2.91 ± .01	2.3-3.2	.17 ± .01	5.84 ± .46	80
M_1-M_2 , occlusal length	6.61 ± .03	6.0-7.0	.24 ± .03	3.63 ± .54	22
M^1-M^2 , occlusal length	6.94 ± .04	6.6-7.3	.14 ± .02	2.01 ± .41	12
incisive foramen length	5.03	4.4-5.4	—	—	6
inter-orbital width	3.45	3.1-3.8	—	—	4

Clethrionomys gapperi (Vigors)-

Red-backed vole

Material: 15 partial skulls; 254 left, 260 right mandibles or M_1 's; 54 left, 51 right maxillae. Stratigraphy: Present at all levels below 4.0 m. At 4.9 m *Clethrionomys* was the commonest small rodent in the deposit. Below 5.8 m it became progressively scarcer (although most microtines increased in numbers) (fig. 30).

Remarks: *Clethrionomys gapperi* and *C. rutilus* of the western Nearctic are identical in dental pattern but can be differentiated by the degree of ossification of the hard palate. Using this as a criterion, where this character could be observed, our specimens are *C. gapperi*. The post-palatal bridge was incomplete on one immature specimen, complete on each of five adults. Bee (Bee and Hall, 1956, p. 116-117) suggests that the degree of closure of the post-palatal bridge may be a function of the length of growing season, and that this character may have no real taxonomic value.

Clethrionomys does not now occur at New Paris*. Extensive trapping by the Pennsylvania Mammal Survey failed to produce it at the site, although it is common on the crest of Allegheny Mountain 10 km to the west. *Clethrionomys* occurs throughout the northern and mountainous areas in the state today in cool, moist, rocky forest with good ground cover. It was not present in the Recent Sinkhole No. 2 microtine component. At present the site appears to be too dry to support this vole. Its presence in Sinkhole No. 4 fauna is presumed to be indicative of moister, cooler conditions. Its reduction in numbers with depth, associated with an increase of grassland microtines and a decrease in other woodland forms, is an indication of less heavily forested conditions during the initial phases of infilling.

* Although both Dr. Douth and the senior author watched what they took to be a *Clethrionomys* for a full ten minutes about 2:00 p.m., April 29, 1962, making repeated short forays for dead leaves from the log shoring of the entrance to Sinkhole No. 4.

Comparison of Sinkhole No. 4 *Clethrionomys* material with modern Pennsylvania specimens from Pike County revealed no significant differences.

Table 24 - Measurements in millimeters, *Clethrionomys gapperi*, New Paris No. 4, Pa.

$\bar{X}$	O.R.	σ	V	N
	Occlusal length M^1-M^2			
5.07 ± .07	4.3-5.6	.31 ± .05	6.11 ± 1.03	17
	Occlusal length M_1-M_2			
5.04 ± .03	4.5-5.4	.22 ± .02	4.36 ± .50	37
	Occlusal length M_1			
2.23 ± .004	1.8-2.7	.07 ± .003	3.13 ± .13	254

Microtus pennsylvanicus (Ord)- Meadow vole

Material: 156 partial skulls; 8 left, 8 right maxillae; 1 left, 1 right mandible.

Stratigraphy: Found in increasing numbers from the 4.9 m level to the bottom of the sinkhole (fig. 30).

Remarks: The present taxonomic picture of *Microtus pennsylvanicus* lacks clarity at the subspecific level. Bailey (1900) presents a picture of decreasing size with increasing latitude. Rand (1943) is in agreement but states (p. 115) that while, in general, northern races (*drummondii*) are smaller than southern races (*pennsylvanicus*, *modestus*), some northern populations of *drummondii* are larger than others further south. Edwards (1963) records specimens (cf. *labradorius*) from Richmond Gulf, Quebec as large or larger than *M. p. pennsylvanicus* from central New York (Hamilton, 1943). Snyder (1954) demonstrated that cranial differences between local populations of this vole from Pennsylvania, even when rigorously selected for age and sex, could equal or exceed what had formerly been considered subspecific thresholds for some currently recognized forms (*fontigenus*, *enixus*, *labradorius*).

The New Paris No. 4 *Microtus pennsylvanicus* sample, unaged and unsexed, but with a low coefficient of variation, is large enough to assess the population from which it was drawn. Compared with modern Pennsylvania material these were small animals with short upper molar rows, deep pterygoid pits, small auditory bullae, and diverging upper tooth rows.

Table 25 - Length in millimeters M^1-M^2 , *Microtus pennsylvanicus*

A. Modern Pennsylvania (data from Goin, 1943)
B. Late Pleistocene, New Paris No. 4, Pa.
C. Modern, New Paris No. 2, Pa.

Loc.	Sex	$\bar{X}$	O.R.	σ	V	N
A.	male	6.46 ± .05	—	.51 ± .03	7.88 ± .52	56
A.	female	6.42 ± .04	—	.45 ± .03	6.99 ± .48	48
B.	—	5.72 ± .03	5.0-6.4	.22 ± .02	3.89 ± .34	65
C.	—	6.16	6.0-6.4	—	—	3

The one intact skull from New Paris No. 4, CM 6945, measured 27.7 mm in total length. Judging from Snyder's data (*Ibid.*, p. 211), this is not a small skull. Goin (*Ibid.*, p. 216) gives 27.2 mm as the average total length of skull of population A (above). The fossil skull, CM 6945 (assuming standard mensuration techniques) is larger than the average of that Recent population but the length of its upper molar teeth, 5.9 mm is only slightly larger than the mean of the sample from which it was drawn, and significantly smaller than Modern Pennsylvania material. Observations such as this, coupled with the lack of knowledge, on a continental scale, of cranial variation in this vole, make it impossible to assess the taxonomic standing of the Sinkhole No. 4 population. It is hoped this collection will be restudied by a student versed in the Recent geographical variation of the species.

Microtus chrotorrhinus (Miller)-Rock vole
Material: 39 partial skulls; 3 left, 6 right maxillae; 1 right mandible.

Stratigraphy: From the 2.7 m to the 8.8 m level (fig. 30).

Remarks: The rock vole occurs in the Canadian life-zone east of 95° W. long. In Pennsylvania it is known only from Wayne, Sullivan, and Luzerne counties approximately 320 km north-east of New Paris. It is rare and local in cool, rocky forest situations.

There was no correlation between stratigraphic position and gross size or dental pattern. The alveolar length of the upper molars was compared with that of 52 modern individuals from six localities in the Appalachian Mountain area from Labrador south to North Carolina. A size cline is indicated with the New Paris No. 4 material agreeing most closely with Labrador-Quebec specimens.

Table 26 - Alveolar length in millimeters, M¹-M³, *Microtus chrotorrhinus*

Locality	Lat.	X̄	O.R.	σ	V	N
*Labrador	53	5.9	5.4-6.5	-	-	7
Quebec	50	6.2	5.5-6.7	.3	4.86	20
*New Hampshire	44	6.5	6.2-6.9	-	-	7
Penna. & W. Va.	40	6.4	5.6-7.2	.5	7.62	10
**West Virginia	38	6.6	6.4-7.0	-	-	7
*North Carolina	35	7.1	-	-	-	1
New Paris No. 4 (fossil)		6.0	5.4-6.7	.4	6.18	27

*Data from Komarek, 1932.

**Data from McKeever, 1954.

There appear to be significant differences in the dental pattern of the upper third molar between modern Quebec and Pennsylvania/West Virginia specimens as presented below. The Sinkhole No. 4 material agrees with modern Pennsylvania/West Virginia specimens in this respect. (fig. 19)

The degree of isolation of the individual triangles, presence or absence of posterior buccal and lingual salient angles, and the degree of development of the fourth lingual re-entrant valley, all appear to vary significantly in the M³'s of the samples studied (20 skulls from southern Quebec, 10 skulls from Pennsylvania and West Virginia, and 29 fossil specimens from New Paris No. 4, all Carnegie Museum specimens).

Microtus chrotorrhinus is usually stated to have an M³ pattern of an anterior crescent followed by five closed alternating triangles (Hall and Kelson, p. 741). This appears to be the exception rather than the rule. It was so in only 30 percent of the Quebec specimens, 10 percent of the Pennsylvania and West Virginia material, and not at all in the New Paris No. 4 material. "Normal" pattern in all three population samples was: an anterior crescent, triangles 1 and 2 confluent, triangle 3 isolated, triangle 4 and 5 confluent. Triangle closure was more advanced in the Quebec material than in any other.

Table 27 - *Microtus chrotorrhinus*, M³ dental patterns

Triangles isolated or confluent	Quebec	Penna./W. Va.	New Paris No. 4
a. 1, 2, 3, 4, 5 isolated	6	1	0
b. 1, 2, 3 isolated; 4-5 confluent	1	2	6
c. 1-2 confluent; 3 isolated; 4-5 confluent	11	7	23
d. 1-2 confluent; 3, 4, 5, isolated	1	0	0
e. 1-2-3-4-5 confluent	1	0	0

Buccal and lingual salient angles varied from four to six as follows:

Table 28 - *Microtus chrotorrhinus*, M³ dental pattern, salient angles

Locality	N	Buccal Aver.	N	Lingual Aver.
Penna./W. Va.	9	4.3	9	4.4
Quebec	22	4.3	20	4.8
New Paris No.	28	4.4	29	4.8

The fourth lingual re-entrant varies from fully developed, i.e., deep, cement-filled, curving caudally, to barely suggested by a slight, shallow concavity in all three samples. It was more highly developed in the Quebec material (60 percent) than in either the modern Penna./W. Va. material (25 percent) or New Paris No. 4 (10 percent).

M¹ and M² are as in *M. xanthognathus*, except for their much smaller size. Mandibles and lower dentitions of *M. chrotorrhinus* are indistinguishable from those of *M. pennsylvanicus*. The one listed above was found in association with a *M. chrotorrhinus* skull.

In summary, the New Paris No. 4 cranial material agrees most closely in gross size with modern specimens from Labrador and Quebec and more like Penna./W. Va. material in the seemingly more primitive dental pattern of M³ (triangles not as tightly isolated; shallow or non-existent fourth lingual re-entrant).

Microtus xanthognathus (Leach)-Yellow-checked vole

Material: 134 partial skulls; 8 left, 6 right maxillae; 344 left, 317 right mandibles or M¹'s (fig. 21).

Stratigraphy: The commonest terrestrial mammal in the deposit. Remains were found in steadily increasing numbers from the 2.1 m through the 8.8 m level where it accounted for over 40 percent of all mammals recovered (fig. 30).

Remarks: This is a rare mammal in modern museum collections but it is widespread in the western Nearctic throughout the Hudsonian life-zone. It is extremely local and subject to extreme fluctuations in population size. Due to these factors it is often missed by tra-

versing collecting parties. That it may become common at times is evident by Lensink's statement that ... "Trappers in the vicinity have remarked upon its abundance and consider it the primary food of martens." (Lensink, 1954, p. 259) and Preble's observation of a colony on the Athabaska River that ... "must have comprised many thousands of individuals, and occupied a heavily wooded area, at least a half a mile (0.8 km) square." (Preble, 1908). Primary sources dealing with the habitat of *M. xanthognathus* are few. Preble gives: 1. "a strip of young, mixed woods bordering a swamp... burrows... were in dry ground in the woods or shrubbery and evidently were quite deep, as I saw nearly a bushel of dirt at the entrance to a single burrow." 2. "...contrary to their usual habit... this colony had extended their runways into a wet, sphagnum swamp." 3. "Deep, mixed woods on the summit of the hills bordering the valley of the Athabaska." 4. "at the base of a limestone cliff." 5. "a willow covered island." 6. "poplar woods." 7. "heavily-wooded area... on the gently sloping sides of a valley."

Lensink describes the habitat at Castle Rock, Alaska, "thin, boreal forest, black spruce, larch, white spruce, birch and aspen, ground cover sphagnum moss and lichen with scattered clumps of sedge, cotton grass and horse-tail... runways and diggings were found throughout the entire area although they were most common in lowlands and swampy areas. Runways frequently crossed small puddles."

Preble mentions trapping meadow vole (*Microtus pennsylvanicus* ["drummondii"]) and least weasel (*Mustela rixosa*) in *M. xanthognathus* runways.

All of the accounts mention boreal woodland, ranging from "heavily-wooded" to "thin", elevations ranging from hilltop to island. Ground conditions range from dry and well-drained to swampy.

Despite its seeming rarity, *M. xanthognathus* appears to be adaptable to a variety of habitats within the boreal forest. Grasslands as such are not mentioned and it does not occur on the barren ground. Full habitat descriptions, however, such as Lensink's, are

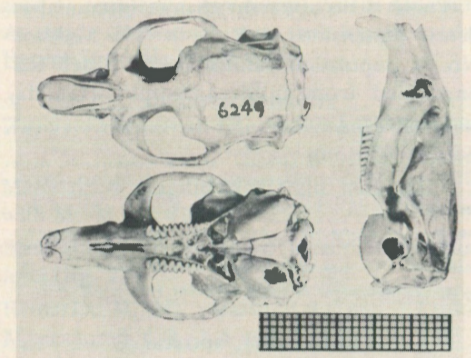


Figure 21.

Microtus xanthognathus skull. Dorsal, ventral, lateral view. CM 6249. Sinkhole No. 4, New Paris, Pa. 7.0 m level, mm grid.

almost non-existent and the life history of the animal is unknown.

Both authors mention this vole's fondness for horse tail (*Equisetum*) and Lensink mentions lichens in stomach contents.

Sinkhole No. 4 *Microtus xanthognathus* appears to have been the dominant microtine below the 7.3 m level.

The presence of *M. xanthognathus* in ever increasing numbers with depth indicates that full tundra conditions were either never attained at the site or occurred prior to the filling of the sinkhole. Remains of the collared lemming would appear to indicate the near presence of tundra. It is conceivable that during the periods of cyclic abundance, wandering individuals might encroach into adjoining habitats but as far as we know the two species do not normally occupy common ground today although both may inhabit the same general area. The large number of *M. xanthognathus* from the lower levels of Sinkhole No. 4 would seem to indicate a suitable habitat at the mouth of the sinkhole rather than the trapping of itinerant animals such as may have been the case with the lemming (*Dicrostonyx*).

Yellow-checked vole remains have also been reported from late Pleistocene deposits at Natural Chimneys, Augusta County, Virginia, and Bootlegger Sink, York County, Pennsylvania.

There is no apparent change in cranial or dental dimensions with depth. The Sinkhole No. 4 population cannot be adequately distinguished from modern samples (Guilday and Bender, 1960).

Table 29 - Measurements in millimeters, *Microtus xanthognathus* (Leach), New Paris No. 4, Pa.

Measurement	X	O.R.	σ	V	N
length M_1	3.4 ± .02	2.7-4.0	.23 ± .01	6.68 ± .48	100
length M_1-M_3	7.33 ± .04	5.6-8.2	.44 ± .03	6.00 ± .44	91
length M_1-M_3	7.38 ± .04	6.0-8.3	.39 ± .03	5.28 ± .42	78

For additional measurements, see Guilday and Bender, 1960.

Microtus, species?

Material: 21 partial skulls; 460 left, 411 right mandibles or M_1 's.

Remarks: Most of the material, lower jaws and teeth, are either *M. pennsylvanicus* or *M. chrotorrhinus*. *M. xanthognathus* mandibles and M_1 's are identifiable by large size and usually distinctive pattern of M_1 and M_3 . Young *M. xanthognathus* cannot always be identified, however, and approximately 10 percent of the mandibles (based upon M_1 pattern) may be juvenile *M. xanthognathus*.

Although three species of *Microtus* are believed to be represented in this collection the following notes on M_1 variation may be profitable in the analyses of other such deposits. All three species normally possess five alternating triangles. Five alternating triangles were present in 93 percent of this collection; six alternating triangles in 6.7 percent and even in .3 percent. One rather consistent variant (5.5 percent) is the suppression of the fourth buccal re-entrant valley (fig. 22, CM 6272, 5615, 6271) producing a pattern identical to the Alaskan *M. miurus* (see Bee and Hall, 1956, p. 58). Initially, it was suspected in the light of the presence of other high latitude forms in the deposit that *M. miurus* might well have been present. There appears to be no stratigraphic pattern to the distribution of the "miurus" variant in the sinkhole. No cranial material of this form was discovered and a skull of *M. pennsylvanicus* with an articulated mandible of the "miurus" pattern was unearthed. Every possible variation between a typical "miurus" (fig. 22, CM 6272) and a typical "pennsylvanicus" pattern (fig. 22, CM 6213, 6225b) were present in the collection. It is interesting to note that the same

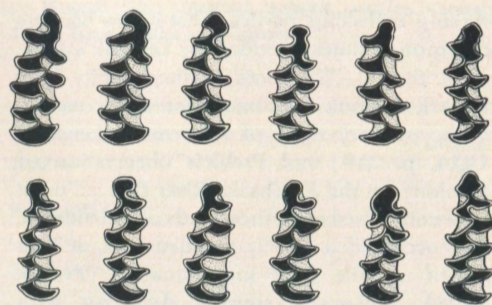


Figure 22.

First lower molars of *Microtus* (presumably *M. pennsylvanicus* or *chrotorrhinus*) from Sinkhole No. 4, New Paris, Pa., showing variation of trefoil from "miurus" to "pennsylvanicus" pattern. CM 6272, 5615, 5618, 5884, 5616, 6213. CM 6271, 6211, 5607, 6225, 6225b, 5618b.

pattern occurs in M_1 's of the Recent European *M. arvalis* as an uncommon variant and is there referred to as the "gregaloider" type. Both *M. gregalis* Pallas and *M. miurus* Osgood are in the subgenus *Stenocranium* Kastschenko. (Jánosy and Schmidt, 1960). Such variants were given names in the past—"forma assimilis" (Rorig and Borner, 1905 and Schaefer, 1935), but the practice was discontinued as the true nature of such variations became clear.

The M_1 of a microtine is of diagnostic value at the generic level and occasionally to subgenus, but it is of dubious value at the specific level (unless we are dealing with Recent monotypic forms).

Much of the material above undoubtedly belongs to the cranial material listed under the appropriate species.

Pitymys pinetorum (LeConte)—Pine vole

Material: 1 partial skull; 10 left, 12 right mandibles or M_1 's.

Stratigraphy: Sporadic from 2.1 m to 8.5 m level (fig. 30).

Remarks: One of the rarest microtines in the deposit, the pine mouse is the only microtine represented that does not occur north of the southern fringes of the Canadian life-zone which it reaches only sporadically (Hamilton,

1938). In contrast the pine mouse was the commonest microtine in the Recent Sinkhole No. 2 fauna, and is the common microtine at the site today.

In contrast to the chipmunk and southern bog lemming populations, no difference could be found between the *Pitymys* studied from Sinkhole No. 2 and those from Sinkhole No. 4. There appears to be evidence for contamination of the upper levels of Sinkhole No. 4 by modern short-tailed shrews. Rodent droppings recovered, apparently *in situ*, at the 5.9 m level contain an unmistakably modern pollen spectrum. One dead *Pitymys*, demonstrably recent, was found embedded in the mud and was discarded during the excavation. Rabbits (*Sylvilagus*), woodchuck (*Marmota*), and opossum (*Didelphis*) were also recovered between excavating trips. These were easily recognized as Recent, but the small size of *Pitymys* (and of *Peromyscus leucopus*) might allow them to escape detection until their teeth or jaws showed up in the washing trays. We suspect that all *Pitymys* are intrusive.

Table 30 - Occlusal length, M_1 in millimeters, *Pitymys pinetorum*, New Paris, Pa.

Site	X	O.R.	σ	V	N
Sinkhole No. 2	2.65 ± .01	2.4-2.9	.12 ± .008	4.52 ± .30	110
Sinkhole No. 4	2.62 ± .05	2.0-2.9	.22 ± .03	8.39 ± 1.39	18

The highly variable fourth buccal re-entrant of M_1 behaved in the same fashion in both sinkhole samples. (fig. 19).

Table 31 - Fourth buccal re-entrant M_1 , *Pitymys pinetorum*

	New Paris No. 2, Pa.		New Paris No. 4, Pa.	
absent	14	12.5%	3	26.3%
shallow, no cement present	42			
shallow, cement present	49	43.7	6	
medium, cement present	6	43.7	6	31.5
deep, cement present	1	.8		
Sample size	112			

Ondatra zibethicus (Linnaeus)—Muskrat

Material: 1 right humerus, 1 M^3 , 1 partial incisor.

Stratigraphy: depth unknown.

Remarks: although muskrats are semi-aquatic marsh dwellers they are also extensive wanderers at times. They are found over a wide

area of temperate and boreal North America. A single individual was also found in the Recent Sinkhole No. 2 fauna.

Family: Zapodidae

Zapus hudsonicus (Zimmermann)—Meadow jumping mouse.

Material: 4 fragmentary right mandibles, 2 with M_1-M_3 , 2 with M_1 .

Stratigraphy: From the 5.1 m to the 7.2 m level (fig. 27)

Remarks: M_1-M_3 measured 3.6 and 3.7 mm. M_1 measured 1.3, 1.4 and 1.4 mm in total length.

Napaeozapus insignis (Miller)—Woodland jumping mouse

Material: 1 partial skull; 7 left, 4 right maxillae; 13 left, 12 right mandibles.

Stratigraphy: From 4.9 m to 8.5 m levels (fig. 27).

Remarks: The New Paris No. 4 and the Natural Chimneys *Napaeozapus*, both late Pleistocene, differ significantly in size from modern central Appalachian material. They average 10 percent larger in all dimensions and have correspondingly heavier, more pronounced muscle attachments. The two Pleistocene collections appear closely related if size is taken as a criterion of relationship. This late Pleistocene form may be worthy of formal subspecific recognition. Although the cave population samples are significantly different from Pennsylvania material, their true relationships with modern populations, especially far northern ones, must await a more detailed study of geographic variation within the species. The woodland jumping mouse is also recorded from Cumberland Cave, Maryland; Natural Chimneys, Virginia, Bootlegger Sink, Pennsylvania, and Robinson Cave, Tennessee.

SPECIMENS EXAMINED

Modern specimens. CM Mammal No. 1818, 3035, 4057, 37013-14, 370116-26, 370128-35.

Natural Chimneys, Augusta County, Virginia. CM 7529.

Family: Erethizontidae

Erethizon dorsatum (Erxleben)—Porcupine

Table 32 – Measurements in millimeters, *Napaeozapus insignis*,
Carnegie Museum collection

Locality	$\bar{X}$	O.R.	σ	V	N
Occlusal length, M_1					
Pennsylvania, modern	1.6 ± .008	1.5–1.8	.04 ± .006	2.50 ± .39	20
Quebec, modern	1.6	—	—	—	2
Ontario, modern	1.6	—	—	—	1
New Paris No. 4, Pleistocene	1.8 ± .027	1.7–2.1	.09 ± .019	5.00 ± 1.06	11
Natural Chimneys, Pleistocene	1.7	1.6–1.7	—	—	6
Occlusal length, M_1-M_3					
Pennsylvania, modern	3.17 ± .023	2.9–3.4	.11 ± .016	3.47 ± .52	22
Quebec, modern	3.15	—	—	—	2
Ontario, modern	3.21	—	—	—	1
New Paris No. 4, Pleistocene	3.43	3.2–3.6	—	—	4
Natural Chimneys, Pleistocene	3.45	3.3–3.6	—	—	6
Occlusal length, lower molar row, M_1-M_3					
Pennsylvania, modern	4.06 ± .03	3.8–4.3	.13 ± .02	3.20 ± .53	18
Quebec, modern	4.15	4.0–4.2	—	—	2
Ontario, modern	4.22	—	—	—	1
New Paris No. 4, Pleistocene	4.31	4.2–4.4	—	—	2
Natural Chimneys, Pleistocene	4.41	4.2–4.6	—	—	2

Material: 2 immature skulls with associated mandibles and partial skeletons; 1 left mandible, adult.

Stratigraphy: From 5.5 m to 6.4 m level.

Remarks: Porcupine remains are known from the Recent fauna of New Paris No. 2. It is still found in the northern part of the state today and occurs throughout the Canadian and Hudsonian life-zones of North America.

Order: Lagomorpha

Family: Leporidae

Lepus americanus (Erxleben) –
Snowshoe hare

Material: 32 partial skulls; 20 left, 13 right maxillae; 49 left, 48 right mandibles. Skeletal material representing at least 49 animals. One mounted composite skeleton (fig. 24).

Stratigraphy: Commonest at 5.8 m level where it composed 7.4 percent of the recovered fauna. Below the 6.4 m level it virtually disappeared from the fauna (fig. 27).

Remarks: These hares deserve more detailed study. The effect of physiological age upon the skull and dentition is considerable and may influence the sample parameters. Most specimens of snowshoe hare in museum collections are adults collected by open hunting. The sinkhole population has a much wider age span from obvious nestlings on. Measurements below were taken from what was considered to be adults but no detailed selection was made.

Remarks: Modern snowshoe hares, contrary to "Bergmann's Rule", attain their smallest average size in the northern portion of their range. The largest eastern individuals are found in the central Appalachians. Smallest average size occurs from the James Bay area north (fig. 23).

The snowshoe hare sample from Sinkhole No. 4 is composed of small individuals. They are significantly smaller in some measurements than *L. a. virginianus* now in Penn-

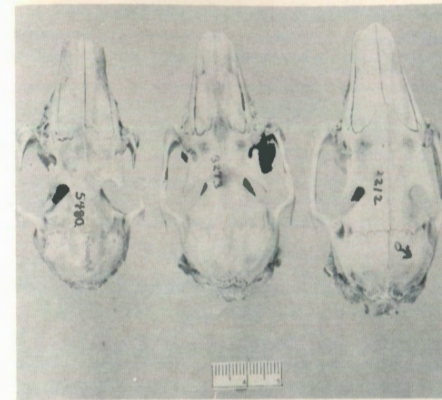


Figure 23.

Skulls of *Lepus americanus*. Negative "Bergmann's response." CM 5480. Sinkhole No. 4, New Paris, Pa. 5.8–6.4 m level, late Pleistocene. CM Mammal 3273 – James Bay, Quebec. Recent. CM Mammal 2212 – Pennsylvania. Recent.

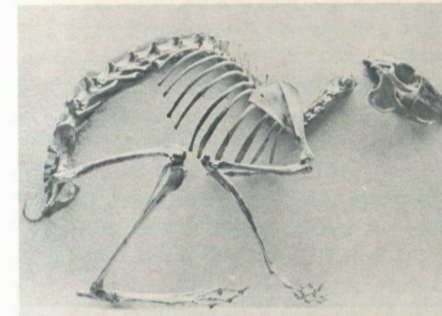


Figure 24.

Lepus americanus composite skeleton, Sinkhole No. 4, New Paris, Pa. CM 5944. Hind foot = 115 mm.

sylvania,* but not distinguished from modern *L. a. americanus* from the James Bay area of Ontario and Quebec.

The significance of the disappearance of the snowshoe hare from the lowest levels of Sinkhole No. 4 may be related to the gen-

* Stocking programs have altered the situation in many areas and make it difficult to obtain racially pure comparative material.

eral decrease of woodland forms (red squirrel, flying squirrel, pine vole, spruce vole, short-tailed shrew, red-backed vole, woodland jumping mouse) and the increase in grassland forms (most microtines, thirteen-lined ground squirrel) at the lower levels.

Rabbits of the genus *Sylvilagus*, which did not occur in the Sinkhole No. 4 fauna, occupy the area today to the exclusion of *Lepus*, and apparently did so during the past several thousand years at least. *Sylvilagus* occurred in the Sinkhole No. 2 local fauna (C-14 date of 1,875 ± 100 yrs. B.P.) *Lepus* did not.

During the excavation of Sinkhole No. 4, five or six cottontail rabbits (*Sylvilagus*) fell into the hole and expired.

Order: Carnivora

Family: Mustelidae

Martes americana (Turton) –
Pine marten

Material: Partial rostrum of skull containing left I^3 , C^1 , P^2 , P^4 , right P^2-P^4 . CM 5737.

Stratigraphy: Recovered from the 5.2 m level.

Remarks: In some portions of its modern range, *Microtus xanthognathus* is the primary prey of the marten (Lensink, 1954, p. 259), a relationship which probably held during the late Pleistocene as well. Pine martens occurred in the northern and mountainous sectors of the state during early settlement days, but probably not in the immediate sinkhole area.

Marten remains have been recovered from Natural Chimneys, Virginia and Robinson Cave, Tennessee.

Martes pennanti (Erxleben) – Fisher

Material: 1 M^1 .

Stratigraphy: 6.1 m level.

Mustela rixoa (Bangs) – Least weasel

Material: 1 right P_3 , P_4 .

Stratigraphy: 5.5 m level.

Remarks: Specimens are referred to *M. rixosa* solely on their small size.

Table 33 - *Lepus americanus*, modern and Pleistocene localities.
Measurements in millimeters.

Locality	$\bar{X}$	O.R.	σ	V	N
Lower incisor width					
Penna., Mich., modern	2.5 ± .03	2.3-2.6	.10 ± .03	4.00 ± 1.00	8
Moose Factory, Ont., modern	2.35 ± .04	2.2-2.6	.14 ± .03	5.95 ± 1.48	8
New Paris No. 4, late Pleistocene	2.32 ± .02	2.0-2.5	.13 ± .01	5.60 ± .79	25
Lower tooththrow length					
Penna., modern	16.0	14.3-17.4			6
Michigan, modern	15.9	15.7-16.2			2
Moose Factory, Ont., modern	15.8	14.5-19.9			8
New Paris No. 4, late Pleistocene	14.4 ± .18	12.7-15.9	.89 ± .12	3.70 ± .53	24
Upper tooththrow length					
Penna., modern	15.6	14.2-16.6			6
Michigan, modern	15.25	15.2-15.3			2
Moose Factory, Ont., modern	15.25	14.5-16.8			8
New Paris No. 4, late Pleistocene	14.53 ± .15	13.6-15.8	.63 ± .10	4.33 ± .74	17
Maxillary width					
Penna., modern	37.81	34.2-40.1			6
Michigan, modern	36.60	35.8-37.4			2
Moose Factory, Ont., modern	36.82	35.0-39.1			8
New Paris No. 4, late Pleistocene	35.5 ± .41	33.0-38.1	1.55 ± .29	4.36 ± .82	14
Incisive foramen					
Penna., modern	19.90	19.4-20.8			6
Michigan, modern	20.10	19.2-21.0			2
Moose Factory, Ont., modern	19.88	19.2-20.6			8
New Paris No. 4, late Pleistocene	18.53 ± .29	16.6-20.5	1.05 ± .20	8.07 ± 1.58	13
Inter-orbital breadth					
Penna., modern	11.7	10.2-13.7			6
Michigan, modern	10.7	10.2-11.2			2
Moose Factory, Ont., modern	10.5	9.7-11.4			8
New Paris No. 4, late Pleistocene	10.4 ± .48	9.0-11.7	1.7 ± .34	16.71 ± 3.28	13

Table 34 - Measurements in millimeters, *P. Mustela*, various species

Catalogue No.	Species	Sex	Locality	Age	Length	Width
CM 6021	<i>M. rixosa</i>	?	New Paris No. 4	Late Pleistocene	3.3	1.5
CM Mammal No. 24917	<i>M. rixosa</i>	♀	Pennsylvania	modern	3.2	1.6
CM Mammal No. 28275	<i>M. rixosa</i>	♂	Pennsylvania	modern	3.3	1.6
CM Mammal No. 36275	<i>M. erminea</i>	♀	Pennsylvania	modern	3.6	1.8

Order: Artiodactyla

Family: Tayassuidae

Mylobyus nasutus (Leidy) -

Long-nosed peccary

Material: 1 partial skeleton. CM 5860 (figs. 25, 26).

Stratigraphy: Remains were scattered over a vertical span of 1.5 m from the 5.2 m level to the 6.7 m level.

Remarks: All other species of small vertebrates from New Paris No. 4 are living today. The presence of the peccary in association with the flora and fauna of boreal character presently living within the Canadian and Hudsonian life zones may come as a surprise. The Pennsylvania peccary has been regarded as an indicator of warm climates. In the Port Kennedy fauna Mercer (1899, p. 285) wrote: "Judged by the presence of such animals as the subtropical tapir and peccary, a winter climate milder than the present probably then prevailed." But Matthew (in Twenhofel, 1932) observed that the peccary in the Pleistocene of Pennsylvania and New Jersey may be associated with such northern animals as wolverine, musk ox, and caribou, thus signifying a cold climate. Such discord in the ecological interpretation of large mammals has brought their use as palaeoclimatic indicators into disrepute and strengthened the case for a non-climatic cause for their extinction. Evidently *Mylobyus* occupied a wide range of environments until its extinction and disappeared along with other Pleistocene "big game" less than 11,000 years ago. The only continent-wide environmental change that is known with certainty for this time interval is the arrival of big game hunters, the Paleo-Indians.

This is not to imply that *Mylobyus* was necessarily a direct victim of human predation. This has yet to be demonstrated. Pre-

sence of both *Mylobyus* and Indian cultural material at Hartman's Cave in eastern Pennsylvania is suggestive but the association may well have been fortuitous. It is probable that *Mylobyus* like so many other Pleistocene large mammals was a victim of a long chain of ecological events initiated by the appearance of a new and efficient predator, the Paleo-Indian in the area. Lundelius (1960, p. 34) is of the opinion that *Mylobyus* is the ecological equivalent of the Old World *Sus*. Its environmental niche in the Appalachian area is now probably filled by the black bear (*Ursus americanus*), another forest omnivore. Introduced European wild boar are now feral in Tennessee and other wooded parts of the Appalachians but apparently cannot successfully compete with the black bear (Stegeman, 1938).

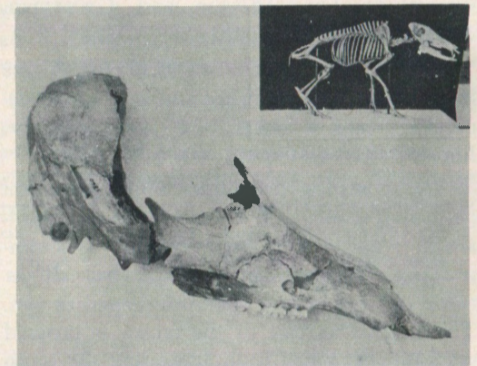


Figure 25.

Restored skull, juvenile *Mylobyus nasutus*. CM 5860. Sinkhole No. 4, New Paris, Pa. Frontal bones and mandibles not recovered. Insert upper right, adult skeleton. TMM 1407, Friesenhahn Cave, Texas.

The New Paris No. 4 specimen was a piglet. All cranial sutures with the exception of the lambdoidal and the sagittal were open, including those between the basi-, ex-, and supra-occipital. The lambdoid suture was fused and its course, both externally and internally, could be followed only a short distance toward lambda beyond the asterion. The sagittal suture was barely discernible. It could be traced from bregma back 12 mm at which point it joined the barely discernible lamb-

doidal sutures. The course of the sagittal suture was obliterated internally.

Neuro-central sutures and epiphyseal disks of the vertebra were unfused. The odontoid process of the axis was separate. The sacrum consisted of at least four unfused units. Ilium, ischium and pubis were separate. Epiphyses on ribs and all major limb bones were open. No trace could be seen of the proximal epiphyses of the metapodials. Fusion, as in other artiodactyla, took place before birth. The distal epiphyses were unfused. Metatarsals III and IV, fused in the adult into a cannon bone, were closely adpressed but not fused.

The lumbar region was fortunately well preserved. There were five lumbar vertebrae as in *Tayassu*, one or two less than in *Sus*. (Six or seven lumbar occur with equal frequency in *Sus*. [Sisson and Grossman, 1938].)

The mandibles were not recovered. Three lower deciduous incisors and one lower deciduous canine were recovered during screening operations. They appear slightly worn.

The complete deciduous upper dentition (fig. 26), 2 incisors, 1 canine and milk molars 2, 3 and 4 were recovered. dl^2 is a simple peg, 2.1 mm in diameter but dl^1 is twice as large with a spatulate-shaped crown. The lingual surface of the crown is crossed vertically by a low loph separating the tooth into two basins. They show no wear. The canines are scimitar-shaped and project 15.6 mm from their sockets. They are oval in cross-section, 5.4 mm x 4.0 mm and are slightly worn. Immediately in front of each canine socket is a small hole 5 mm in diameter through which the tip of the developing permanent canine can be seen. An enigmatic hole immediately behind each dl^1 probably represents the site of the eruption of a future permanent incisor.

The milk molars are fully erupted but show no signs of wear. The first permanent molar was deep within the maxilla and still forming.

Two sets of *Mylohyus* deciduous dentitions are available for direct comparison, a cast of USNM 8160 (*M. exortivus*), Cum-

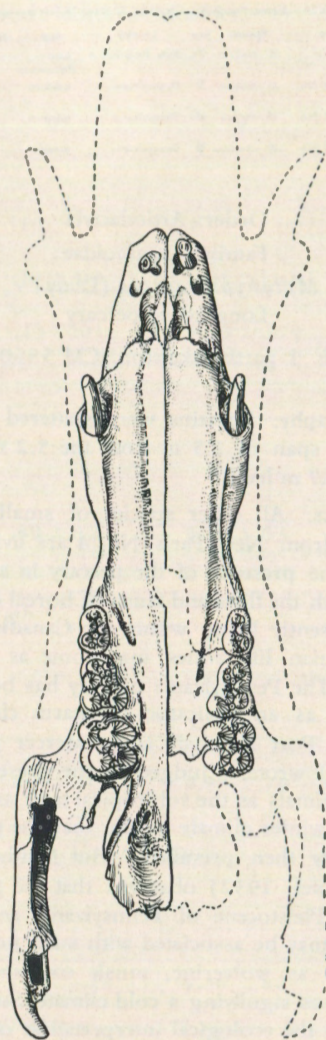


Figure 26.

Palate and upper deciduous dentition, *Mylohyus nasutus*. CM 5860. Sinkhole No. 4, New Paris, Pa. In background to same scale, profile of adult skull TMM 1407, Friesenhahn Cave, Texas (from Lundelius, 1960). First upper permanent molars superimposed.

berland Cave, Maryland and a cast of ANSP type no. 26 (*M. pennsylvanicus*), Hartman's Cave, Pennsylvania. Both New Paris No. 4 and Cumberland dentitions show no tooth wear. Cumberland is somewhat older, M^1

beginning to erupt. Hartman's has M^1 fully erupted and dp^3 and dp^4 show considerable wear. dp^2 is missing.

Table 35 - Measurement in millimeters, *Mylohyus*, milk dentitions

	New Paris No. 4	Cumberland	Hartman's	Friesenhahn	Organ - Hedrick's Cave, W. Va.
dp^1 length	10.9	10.0	-	-	-
dp^1 width	7.7	7.5	-	-	-
dp^2 length	13.6	12.5	13.0	12.8	12.1
dp^2 width	10.8	9.0	10.0	9.2	10.8
dp^3 length	14.4	12.0	14.0	13.1	-
dp^3 width	15.6	14.0	16.0	12.6	-
	CM 5860	USNM 8160 Gidley and Gazin 1938	ANSP 26	TMM-1407 Lundelius 1960	UMMP 27728 Handley 1956

The minor differences in size and complexity of cusplets between these dentitions could be accounted for by individual variation alone. Gidley and Gazin (1938, p. 86) state that the amount of individual variation present in any of the nominal "species" is unknown. All were described from fragmentary material.

Lundelius has assigned all of the late Pleistocene *Mylohyus* to two "species", *M. nasutus* (including *M. pennsylvanicus* and *M. browni*), a larger western and northern form and *M. fossilis* (including *M. exortivus*) a smaller southeastern form. This is admittedly a tentative classification. No adequate study of differences due to age, sex, or individual variation is possible until more material is available. The relatively minor differences that differentiate the *nasutus* and *fossilis* groups may be of infra-specific nature.

Following Lundelius, the New Paris No. 4 specimen is referred to *M. nasutus*. It is somewhat larger than *M. exortivus*, USNM 8160 from Cumberland Cave and identical with the type of *M. pennsylvanicus* from Hartman's Cave, Pennsylvania.

Several interesting growth gradients become apparent if corresponding elements of the juvenile CM 5860 and the adult TMM 1407 from Friesenhahn Cave are compared. Relative lengths of limb elements were compared (table 36). A proximal-distal negative growth gradient is apparent; distal elements growing at a slower post-natal rate than proximal elements. The young of most, if not all cursorial ungulates are born with relatively large limbs and exhibit a similar growth gra-

dient. Huxley (1932) looks upon this as an adaptation enabling the young animal to accompany its dam as soon as possible. Proximal limb elements were some 60 percent adult size (taking into consideration that we are comparing only two animals of unknown age and sex from widely separated areas), while distal limb segments were some 80 percent adult size. A similar gradient was not apparent in the width of limb segments. They averaged about 80 percent of adult size throughout (table 37).

Comparative measurements of the restored New Paris juvenile skull* and the Friesenhahn adult skull indicated that the juvenile skull was only 59 percent of adult size. But there were proportional differences. The post-glenoid length of the juvenile skull was 69 percent adult size but the pre-glenoid length was only 56 percent adult size. This juvenile peccary had a relatively shorter snout than the adult, a well high universal mammalian characteristic. There appears to be considerable differential growth within the snout, however. The post-canine diastema was only 52 percent of adult size while the pre-canine diastema was already 77 percent of adult size. Width, as measured between the canines, was already 93 percent of that of the Friesenhahn skull.

Table 36 - Growth Comparison, *Mylohyus nasutus*
Length, limb elements

	Adult Friesenhahn*	Juvenile New Paris No. 4**	Percent (Juv.)/(Adult)
scapula length	236mm	120mm	50.8
pelvis length	240	145	60.4
humerus length	219	137	62.5
femur length	212	150	70.7
radius length	182	125	68.7
ulna length	244	150	61.5
tibia length	228	163	71.5
metacarpal 2	71.5	65	89.5
metacarpal 3	100.8	83	82.3
metacarpal 4	102.7	82	79.8
metatarsal 3	113	91	80.5
metatarsal 4	115	88	76.5
astragalus length	43	35	81.3

* Data from Lundelius, 1960.

** Estimated lengths taking into consideration missing cartilage between epiphyses and diaphyses.

* All sutures were open and the skull elements were recovered separately.

Subjectively, the dorsal profile of the snout was more concave, the zygoma less flaring, the nuchal crest not as well developed, and all areas of muscle attachment less defined than in the adult.

Table 37 - Growth Comparison, *Mylobius nasutus*
Width, limb elements

	Adult Friesenhahn*	Juvenile New Paris No. 4	Percent (Juv.)/(Adult)
Snout, prox. width	53 mm	43 mm	81
distal width	52	42	81
Orbit, prox. width	53	44	83
distal width	53	26	78
Metatarsal, width	22	18	81
Metatarsal 3 and 4			
prox. width	27	22	81
distal width	32	27	84

Data from Lundelius, 1960.

Table 38 - Growth Comparison, Cranial Measurements, *Mylobius nasutus*

	Adult Friesenhahn*	Juvenile New Paris No. 4	Percent (Juv.)/(Adult)
Post-canine diastema	71 mm	37 mm	52
Pre-canine diastema	30	23	77
Width between canine alveoli	30	28?	93
Condyles to premaxilla	357	210	59
Int. origin of zygomatic ridge to tip of premaxilla	195	110	56
Int. origin of zygomatic ridge to condyles	152	105	69

Data from Lundelius, 1960.

THE LATE-GLACIAL ENVIRONMENT OF UNGLACIATED PENNSYLVANIA

Introduction: The last maximum of continental glaciation, presumably the extreme development of ice-margin climates during the 10,000 years of the Wisconsin glaciation, took place about 20,000 years ago (Flint, 1962). Undated fossil remains of Canadian-borne mammals such as the Arctic shrew (*Sorex arcticus*), northern bog lemming (*Synaptomys borealis*), northern flying squirrel (*Glaucomys sabrinus*), pine marten (*Martes americana*), and caribou (*Rangifer*) as far south as Robinson Cave in north-central Tennessee (lat. 36° N.) suggest boreal conditions far south of the Wisconsin terminal moraine.

Evidence of boreal conditions during the

Wisconsin is not limited to the vertebrate fossil record. Frey (1953) encountered a dominance of small-sized pine pollen with a low frequency of spruce in the Carolina coastal plain during the Wisconsin maximum to which Whitehead (1963) has added the pollen of cool temperate plants such as dwarf mistletoe (*Arceuthobium*), Canadian burnet (*Sanguisorba canadensis*), curly grass (*Schizaea*). *Lycopodium lucidulum*, and other club mosses. Older Wisconsin deposits of the Carolina Piedmont also indicate the penetration of northern species (Whitehead and Barghoorn, 1962). In the Pennsylvania Piedmont an alluvial pollen record dominated by herb and pine pollen is thought to represent Wisconsin-age tundra and taiga (Martin, 1958).

More difficult to establish is whether a greater mixing of boreal and temperate elements occurred in Pleistocene biotic communities than is evident today. In this and other matters concerning life during the time of maximum ice advance 20,000 years ago, a richer fossil record is essential if we wish to reduce our present biogeographic uncertainty.

During the last maximum of continental glaciation ice extended below 40° in latitude almost to the Ohio valley. Although the exact position of the ice margin in the Appalachian region is uncertain, it lay close to 42° N. latitude, some 240 km north of New Paris. Because of the southerly dip of the glacial front west of the Appalachians across northwestern Pennsylvania and into southern Ohio, the glacial border lay slightly closer to New Paris on the northwest side (fig. 1). Evidently at that time Sinkhole No. 4 was not open to the surface and it will not help to reveal the biota of full-glacial times.

On the basis of two radiocarbon dates we estimate the rate of post-glacial filling of Sinkhole No. 4 at from 0.5 to 1.0 m per thousand years. The latter figure is probably too low under a late-glacial climate of more intense frost action. Accepting one meter as a minimum estimate of the rate of infill, the lower three meters (pollen unit B) should represent late-glacial conditions 12,000 to more than 15,000 years ago. Unfortunately,

organic material below 6 meters was scarce and the equivocal result of a carbonate date from bone at 5.4 m - 6.5 m (M-1067) adds to our uncertainty. Nevertheless, we view the fill from 6 - 9 meters as reflecting local conditions in an Appalachian valley roughly 5,000 years after the last glacial maximum, at a time when the continental glacial front had retreated to a point some 600 km or more to the north of New Paris. It is surprising to find an Arctic tundra species, the collared lemming, lingering at this relatively late date and intriguing to find it in association with boreal species plus a prairie rodent and a prairie grouse.

Faunal change: Faunal changes in the 9.1 m column of matrix were surprisingly well marked despite the lack of any obvious stratification and the irregular deposition of the matrix. Faunal changes were not apparent until the minimum numbers of each species were plotted by .91 m (three foot) intervals. Difficulties presented themselves. Chief among them was the likelihood of contamination of older by younger matrix from above. All obvious cases were discarded but the site was excavated on the average of one week-end a month over a four-year period and during this time a small amount of unrecorded slumpage may have occurred. This may explain such seeming anomalies as the white-footed mouse (*Peromyscus leucopus*) and the pine vole (*Pitymys pinetorum*) (one mandible each) recorded from the deepest levels. There was also the possibility of unauthorized tampering with the drying racks during periods when the site was unattended. Several trays of matrix, although labeled stratigraphically, were processed as "depth unknown" because it was suspected that they had been tampered with in just such a fashion.

The relative percentages of most mammalian families in the Sinkhole No. 4 fauna (Talpidae, Soricidae, Zapodidae, Leporidae, Vespertilionidae, fig. 27) declined with depth. Only the Cricetinae and the Microtinae remained as abundant or increased.

Microtine rodents, abundant rich in species, and of diverse habitat requirements, furnish the best guide to ecological fluctuation during the period of infilling. Microtines as

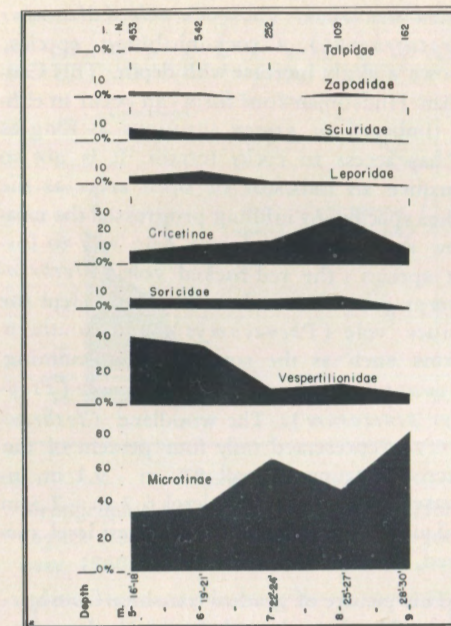


Figure 27.

Stratigraphic distribution of selected mammalian families and subfamilies. Sinkhole No. 4, New Paris, Pa.

a group increased from 34 percent of the fauna at the 4.9 m - 5.5 m level to 80 percent at the lowest levels. Fig. 30 presents the relative status of nine microtine species from Sinkhole No. 4. All of the species, with the exception of the pine vole (*Pitymys pinetorum*) and the southern bog lemming (*Synaptomys cooperi*), range north today at least to the northern edge of the boreal woodland (Hudsonian life-zone). The collared lemming (*Dicrostonyx hudsonius*) is now confined to the tundra areas of the Arctic life-zone. Its rarity (three animals out of a total microtine population of 1,423 individuals) indicates submarginal habitat for that form. Tundra conditions may have existed in the area (perhaps along the crest of Chestnut Ridge, higher than the mouth of the sinkhole) but not around the sinkhole. During level 8.5 m - 9.1 m time, boreal and grassland microtines, yellow-cheeked vole (*Microtus xanthognathus*), meadow vole (*Microtus pennsylvanicus*) and northern bog lemming (*Synaptomys borealis*) dom-

ated the fauna. The rock vole (*Microtus chrotorrhinus*), a rock-inhabiting species, shows a slight increase with depth. This Canadian Hudsonian-zone form can occur in either timbered or grassy situations as long as it has access to rocky terrain. It is not so sensitive an indicator of open areas as the other species. As infilling progressed the meadow and woodland forms gave way to forest species – the red-backed vole (*Clethrionomys gapperi*) and to a limited extent the spruce vole (*Phenacomys*); and southern forms such as the southern bog lemming (*Synaptomys cooperi*) and pine vole (*Pitymys pinetorum*). The woodland *Clethrionomys* represented only four percent of the microtine fauna at level 8.5 m - 9.1 m, increased to 11 percent at level 6.7 m - 7.3 m and up to 50 percent at the highest level analyzed, 4.9 m - 5.5 m.

This picture of gradual transition from boreal parkland to boreal forest is also reinforced by the stratigraphic fate of other species. Bats (fig. 28) and squirrels (fig. 29) increase both in species and in individuals from bottom to top. The thirteen-lined ground squirrel, *Citellus tridecemlineatus*, gave place in the upper levels to the tree squirrels; the woodland shrew, *Blarina brevicauda*, a nominally southern form, does not occur in the lower levels (fig. 31), but is the commonest shrew in the higher levels of the sinkhole.

Faunal changes were also apparent in the amphibians (fig. 33) and the reptiles (fig. 34). Among the snakes the Crotalidae and the Colubrinae decreased with depth. At the deepest levels only the garter snake (*Thamnophis*) persisted. This genus ranges further north than any other North American reptile. It has been recorded from the juncture of the Hudsonian and Arctic life-zones of Churchill, Manitoba (Shelford and Twomey, 1941). Both the collared lemming (*Dicrostonyx*) and the yellow-cheeked vole (*Microtus xanthognathus*) have been reported from Churchill (Hall and Kelson, 1959). The only amphibian that occurred at the bottom levels was the Hudson Bay toad (*Bufo a. copei*) which apparently was re-

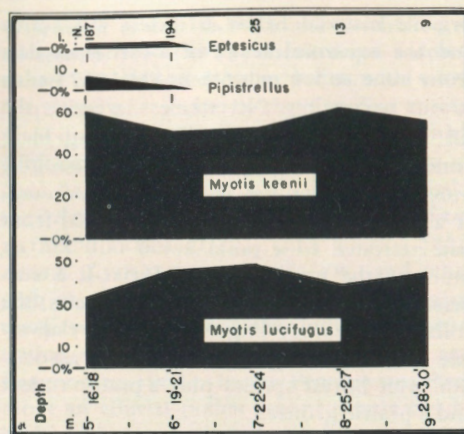


Figure 28.
Stratigraphic distribution of bats (Chiroptera). Sinkhole No. 4, New Paris, Pa.

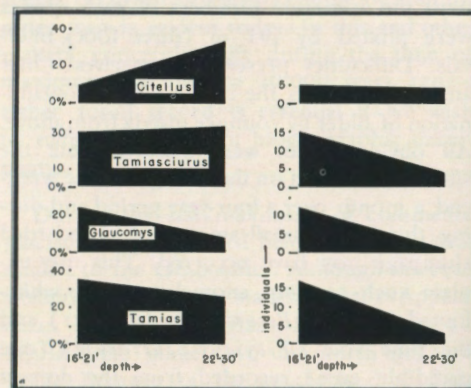


Figure 29.
Stratigraphic distribution of squirrels (Sciuridae). Sinkhole No. 4, New Paris, Pa.

placed by *B. a. americanus* in the upper levels of Sinkhole No. 4.

If the mean depth of each species of mammal represented by more than one individual in Sinkhole No. 4 is calculated (minimum number of individuals at each level multiplied by distance from surface, the entire sum then divided by total number of individuals), and the species are then arranged in order of increasing mean depth from the surface, a pronounced trend is not-

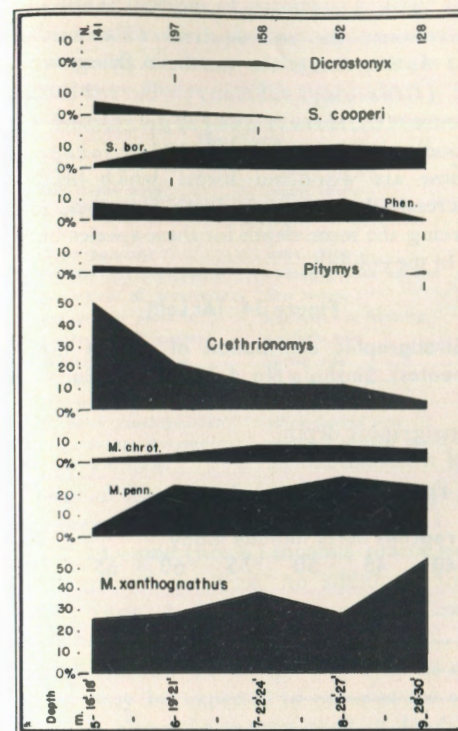


Figure 30.
Stratigraphic distribution of voles and lemmings (microtinae). Sinkhole No. 4, New Paris, Pa.

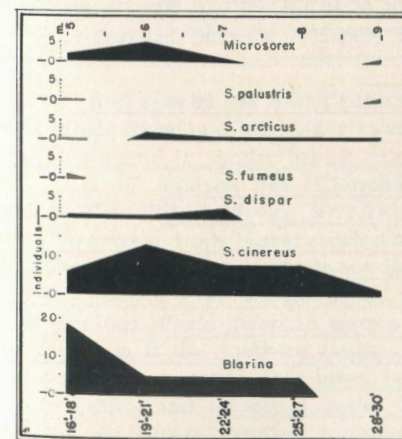


Figure 31.
Stratigraphic distribution of shrews (Soricidae). Sinkhole No. 4, New Paris, Pa.

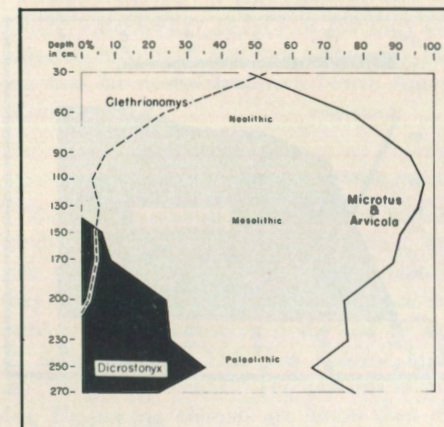


Figure 32.
Stratigraphic distribution of Microtinae, Janakovich Höhle, Hungary. Adapted from Jánossy, 1960.

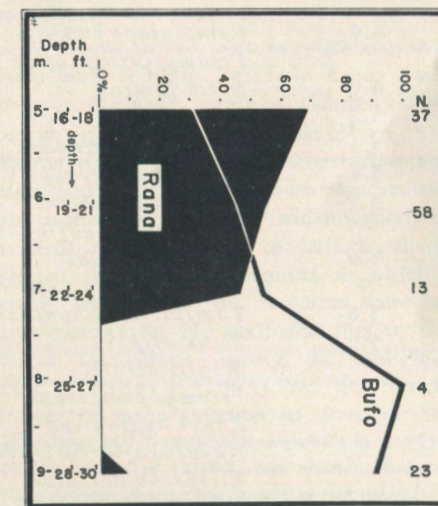
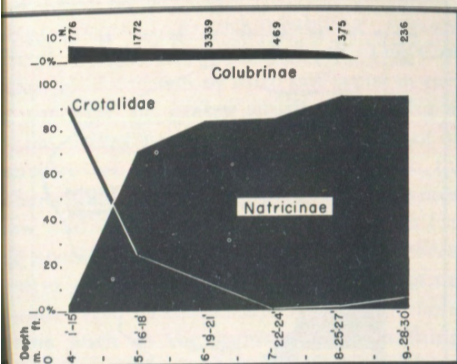


Figure 33.
Stratigraphic distribution of frogs and toads (Salientia). Sinkhole No. 4, New Paris, Pa.

ed. If the maximum northern limits of individual species are then plotted (table 39) it becomes apparent that there is a correlation between increase in average depth and latitude. There appears to be a point (c. 5.9 m) below which maximum ranges are consistently boreal. Above this point maximum ranges tend to be temperate, 50° N. lat. or



less, with some conspicuous and interesting exceptions: the red squirrel (*Tamiasciurus hudsonicus*), the northern flying squirrel (*Glaucomys sabrinus*) the red-backed mouse (*Clethrionomys gapperi*), and the woodland jumping mouse (*Napaeozapus*). These are woodland forms which become increasingly scarce as depth increases, thus forcing the mean depth for these species higher in the column.

Figure 34. (At Left)

Stratigraphic distribution of snakes (Serpentes). Sinkhole No. 4, New Paris, Pa.

Table 39 – Average stratigraphic depth, various species of mammals, New Paris No. 4, Pennsylvania

Average depth in meters	Species	reaches north latitude today						
		40	45	50	55	60	65	70
4.4	<i>Parascalops breweri</i>	_____						
"	<i>Peromyscus leucopus</i>	_____						
4.9	<i>Sorex fumeus</i>	_____						
5.2	<i>Synaptomys cooperi</i>	_____						
5.3	<i>Blarina brevicauda</i>	_____						
5.4	<i>Glaucomys volans</i>	_____						
5.5	<i>Glaucomys sabrinus</i>	_____						
"	<i>Pipistrellus subflavus</i>	_____						
5.6	<i>Tamias striatus</i>	_____						
"	<i>Clethrionomys gapperi</i>	_____						
5.8	<i>Tamiasciurus hudsonicus</i>	_____						
5.9	<i>Sorex dispar</i>	_____						
"	<i>Myotis keenii</i>	_____						
"	<i>Pitymys pinetorum</i>	_____						
"	<i>Zapus hudsonicus</i>	_____						
"	<i>Napaeozapus insignis</i>	_____						
"	<i>Erethizon dorsatum</i>	_____						
6.1	<i>Myotis lucifugus</i>	_____						
"	<i>Peromyscus maniculatus</i>	_____						
6.2	<i>Lepus americanus</i>	_____						
"	<i>Condylura cristata</i>	_____						
6.4	<i>Microsorex hoyi</i>	_____						
"	<i>Phenacomys ungava</i>	_____						
6.7	<i>Sorex cinereus</i>	_____						
"	<i>Dicrostonyx hudsonius</i>	_____						
"	<i>Microtus chrotorrhinus</i>	_____						
6.8	<i>Microtus pennsylvanicus</i>	_____						
"	<i>Microtus xanthognathus</i>	_____						
7.0	<i>Synaptomys borealis</i>	_____						
7.1	<i>Sorex arcticus</i>	_____						

Fourteen species of mammals and one amphibian occurred in the bottom one meter of the deposit. All occur, at least in part, in the Canadian or Hudsonian life-zone today.

Table 40 – Species from the bottom one meter of New Paris No. 4, Pennsylvania.

1. <i>Bufo cf. americanus copei</i>	Hudson Bay toad	6-8
2. <i>Microsorex hoyi</i>	pygmy shrew	1
3. <i>Sorex cinereus</i>	masked shrew	2
4. <i>Sorex arcticus</i>	Arctic shrew	1
5. <i>Sorex palustris</i>	water shrew	1
6. <i>Citellus tridecemlineatus</i>	13-lined ground squirrel	1
7. <i>Peromyscus cf. maniculatus</i>	deer mouse	16
8. <i>Synaptomys borealis</i>	northern bog lemming	12
9. <i>Clethrionomys gapperi</i>	red-back vole	5
10. <i>Phenacomys ungava</i>	spruce vole	1
11. <i>Microtus chrotorrhinus</i>	rock vole	8
12. <i>Microtus pennsylvanicus</i>	meadow vole	30
13. <i>Microtus xanthognathus</i>	yellow-cheeked vole	69
14. <i>Napaeozapus insignis</i>	woodland jumping mouse	1
15. <i>Lepus americanus</i>	snowshoe hare	1

Five of these 15 forms do not range as far south as Pennsylvania today: nos. 1, 4, 8, 10, 13 – one (no. 6) inhabits prairie west and north of the state. An additional four species (nos. 2, 5, 11, 15) are either rare or occur as boreal relicts in the state. By way of contrast 11 of the above forms occur or may be expected to occur at the site of fig. 5 along the eastern coast of Hudson Bay at Great Whale River, Ontario, Lat. 55° N. Here, the Arctic and Hudsonian life-zones meet. The collared lemming (*Dicrostonyx*) may be found here as well and while it is a true tundra animal it may occasionally range very slightly into the northern fringes of the Hudsonian life-zone (Harper, 1961, p. 21).

Of the four species not found presently at Great Whale River one, *Microtus xanthognathus*, is found in similar habitat from the west shore of Hudson Bay (Churchill) to Alaska. The shrews *Sorex arcticus* and *Sorex palustris* both characteristic Canadian life-zone species reach the James Bay region (lat. 52° N.) but are not found as far north as Great Whale River. In eastern Canada they stop at the southern limits of the Hudsonian life-zone and at a lower latitude than in central and western Canada. *Citellus tridecemlineatus* reaches a similar latitude in the northern Great Plains of central Canada.

With the exception of the wood frog

(*Rana sylvatica*), The Hudson Bay toad (*Bufo americanus copei*) is the only cold-blooded terrestrial vertebrate presently ranging that far north in eastern North America (Conant, 1958).

THE BERGMANN RESPONSE

Zoologists commonly find that within a given species of warm-blooded animal, body size will increase with latitude, an adaptation they believe serves to decrease surface/mass ratio and thus conserve body heat in colder environments. This has become known as "Bergmann's rule." The remains of many late Pleistocene animals are larger than their present-day counterparts (fig. 16). Since the environment of periglacial North America was profoundly modified by a decrease in temperature it would be logical to suspect a "Bergmann's response" from some species.

In some forms size is negatively correlated with latitude (fig. 23). *Lepus americanus*, *Mustela erminea* (Kurtén, 1960) and many burrowing mammals (Mayr, 1963). Kurtén (*ibid.*), using mid-Pleistocene hamsters and stoats whose modern representatives are respectively positively and negatively correlated in size relative to latitude, demonstrated that in those deposits in which the stoats were small, the hamsters were large and vice versa. He attributed this to cold/warm oscillations during the mid-Pleistocene. Hibbard (1963) has demonstrated much the same situation in *Blarina* from Illinoian and Sangamon deposits in the Great Plains. Hooijer (1947) has shown that many East-Asiatic mammals, such as the tiger (*Panthera tigris*), underwent a diminution in size (climatically dictated?) from Pleistocene to recent times.

A response to climatic change is also clearly demonstrated in the mammal fauna from New Paris No. 4, and serves to corroborate the conclusions of these workers. In many species from the deposit a "Bergmann's response", either positive or negative, was present.

Although a demonstrable change was present in the pollen frequency profile, and the

species composition of the fauna also changed with depth, there appeared to be no morphological change within a given species throughout the stratigraphic column. The one apparent exception, *Blarina*, (fig. 16) is believed due to modern contamination. From this we infer that boreal conditions prevailed throughout the period of infilling.

When the remains of many species from

New Paris No. 4 are compared with their modern mid-Appalachian equivalents, those forms with a modern positive "Bergmann's response" are larger while those with a modern negative "Bergmann's response" are smaller than their representatives which live in that area today. This is discussed and statistics presented for each species under individual species accounts. They are summarized below.

Table 41 - Mammals with a modern positive "Bergmann's response",
New Paris No. 4, Pennsylvania.

Species		Percent increase, New Paris No. 4 vs Modern central Appalachian populations based upon length of tooth rows
<i>Condylura cristata</i>	star-nosed mole	1.3*
<i>Blarina brevicauda</i>	short-tailed shrew	
<i>Microsorex boylii</i>	pygmy shrew	
<i>Sorex cinereus</i>	masked shrew	5.0
<i>Tamias striatus</i>	chipmunk	7.0
<i>Glaucomys sabrinus</i>	northern flying squirrel	13.0
<i>Glaucomys volans</i>	southern flying squirrel	8.0
<i>Tamiasciurus ludovicianus</i>	red squirrel	9.0
<i>Napaeozapus insignis</i>	woodland jumping mouse	6.0

* Sample believed contaminated.

Table 42 - Mammals with a modern negative "Bergmann's response",
New Paris No. 4, Pennsylvania.

Species		Percent decrease, New Paris No. 4 vs Modern central Appalachian populations based upon length of tooth rows
<i>Synaptomys cooperi</i>	southern bog lemming	12.0
<i>Microtus chrotorrhinus</i>	rock vole	5.0
<i>Microtus pennsylvanicus</i>	meadow vole	11.0
<i>Lepus americanus</i>	snowshoe hare	10.0

Of the 13 species studied for "Bergmann's response", nine were positive, four were negative, exactly as they are today, and evolutionary change as a function of time alone seems not to be involved. The evidence appears overwhelming that these species were adjusted for boreal conditions as are their modern population equivalents in the present-day Hudsonian/Canadian life-zones of Canada.

Kurtén's and Hibbard's evidence would

seem to imply that climatic adjustments similar to those observed today may predate the last glaciation in both hemispheres. The New Paris No. 4 record demonstrates that the late Pleistocene boreal small mammal fauna was adapted much as is its modern sub-Arctic equivalent. Johnston and Selander (1964) have demonstrated in North American populations of the house sparrow (*Passer domesticus*) a positive Bergmann's response which de-

veloped within less than 100 years after the bird was introduced into the continent.

FOSSIL POLLEN, SMALL VERTEBRATES, AND THE LATE-GLACIAL CLIMATE

Below six meters the pollen record at New Paris No. 4 yielded an average of 15 percent grass and sedge pollen, much less than that found in clays from Cranberry Glades, West Virginia, from the Marsh, Pennsylvania, or from the T-zones of New England, and slightly more than would be expected within a closed-canopy forest. The non-arboreal pollen in late-glacial deposits is generally viewed as originating at least in part in upland areas and blowing, along with tree pollen, into basins or alluvial depressions which serve as pollen traps. This assumption is seldom proved and may be challenged in the case of those basins surrounded by a fringe of hygric plant communities particularly favorable to the growth of sedges and grasses. In the absence of riparian habitats near the sinkholes the sedge-grass pollen in New Paris No. 4 is best attributed to an upland source. The abundance of microtine rodents and other species typical of grassy meadows within the boreal woodland (Hudsonian-zone) is a more substantial demonstration of the lack of closed-canopy forest. But the rodents do not indicate a completely treeless tundra or steppe-tundra. The pollen record suggests that at least a few jack pines and spruce must have grown in the vicinity of the sinkhole. At 8.5 m a pollen sample of 20 percent NAP was taken in a bone pocket beneath a rock which yielded the remains of 35 *Microtus xanthognathus*, 10 *M. pennsylvanicus*, two *M. chrotorrhinus*, eight *Synaptomys borealis*, one *Sorex palustris*, and six to eight *Bufo americanus* cf. *copei*. The fauna from this pocket is of either grassland or woodland species of sub-Arctic distribution. Neither extensive closed-canopy forest nor a treeless tundra or prairie would support such a fauna.

An overlapping distribution map prepared for the 12 species of mammals with their mean abundance below six meters in the deposit is shown in map B, center leaf. Such a map reveals the geographical areas in which the largest number of species found in the

fossil record are coexisting today. Recognizing that the late-glacial woodland environment must have had unique climatic attributes which can no longer be matched from any part of North America, it appears that the present geographical center for the fauna represented in New Paris No. 4 during pre-Alleröd time is found in eastern Canada at approximately 50° N. latitude and in central Canada west of Hudson Bay at approximately 57° N. latitude. In view of the fact that many of the fossil forms found in the deposit can be related to populations at or near the northern limit of the species today, our "center of abundance" maps which are based on the total range of each species have a southerly bias. For example, in the case of the snowshoe rabbits, flying squirrels, and voles (to name a few), the late-glacial populations represented at New Paris No. 4 have size attributes of populations at or near the northern limits of the ranges of these forms so that the center of maximum overlap shown in map B, center leaf, is probably several degrees of latitude too far south. A second difficulty is the fact that the maps for units above and below six meters share no species in common, thus exaggerating the differences between the faunas. Map A, center leaf, is more southerly than should be the case.

Above 6.0 meters a decrease in the boreal woodland element and an increase in boreal forest-temperate forest species such as *Clethrionomys* and *Glaucomys* suggests a denser growth of trees. In matrix from this zone there is a sharp reduction in the relative abundance of grass and sedge pollen, although the non-arboreal sum remains relatively constant. The grass and sedges are replaced largely by composite pollen of the subfamily Liguliflorae. At the same time fern spores (Polypodiaceae) increase markedly. Liguliflorae pollen is not typical of lake sediments, and to find more than a few percent of it strongly suggests a dense local population of one species rather than wind transport from a distant point. The appearance of oak and betulaceous pollen types above 6.0 meters further suggest a forest of the type one presently finds in southern Canada and

the northern Lake States. While the local vegetation, whose pollen is represented in unit A, was probably an open jackpine-spruce woodland, that of pollen unit B was likely to have been a closed-canopy forest with hardwoods starting to invade the jackpine.

A center of abundance map plotted for the vertebrates present above 6.0 meters is shown in map A, center leaf. In this case the center is considerably south of that shown in map B, center leaf, and focuses in the northern Appalachians from West Virginia to northern Vermont. The westerly component strongly marked in map B, center leaf, is probably represented by a distributional high in Wisconsin and northern Michigan. However, the center of abundance is over the northern hardwoods region of the eastern deciduous forest at latitude 40-40° N. Again, it should be pointed out that while the boreal woodland element has greatly diminished in the fauna, it is still present, and the center of abundance map shown in map A, center leaf, does not take into consideration the fact that the species ranges used to plot the map include the total range of the species, whereas the measurements of the populations at New Paris, Pennsylvania strongly indicate only the northerly populations of each species were represented in the fossil record.

Both below and above six meters the dominant pollen type, pine, is of small size. Difficulties in relating pine pollen size to modern species have been discussed by Whitehead (1962) who emphasized that the presence of small-sized pine pollen in Wisconsin-age strata is far from *proof* of the presence of jack-pine. The most that might be said is that it is ecologically reasonable to visualize an association of sub-Arctic shrubs, voles and lemmings, pines, spruces, and various herbs in which the dominant conifer would be jackpine. Any other pine with such a fauna would be anomalous in terms of modern distribution of boreal plants and animals.

Pine pollen (often of small size) is the dominant tree type found outside the ice margin in late-glacial and full-glacial deposits of unglaciated Pennsylvania, West Virginia,

and the Carolinas. Curiously, in the late-glacial of Minnesota (Fries, 1962; Jelgersma, 1962; Wright, Winter and Patten, 1963), other parts of the midwest (for example West, 1961; Kapp and Gooding, 1964; Benninghoff and Hibbard, 1961), and east to extreme western Pennsylvania (Walker and Hartman, 1960) pine pollen frequencies are quite low until the early post-glacial "pine period". In the deeper levels of midwestern diagrams spruce rather than pine is the dominant tree pollen type. Wood from late-glacial deposits in Iowa is mainly of mesic conifers such as hemlock (*Tsuga*), fir (*Abies*), tamarack [*Larix*], spruce (*Picea*) and yew (*Taxus*). (Ruhe, Rubin and Scholtes, 1957). Pollen of *Abies*, *Larix* and *Tsuga* dominated below 3.6 m in Muscotah Marsh, Kansas (Horr, 1955), dated at 10.8 m as 15,500 ± 1,500 B.P. (M-352).

The relatively poor spruce record in unglaciated eastern and central Pennsylvania invites further study. Is it possible that during the late-glacial precipitation was heavier along the midwestern ice margin, allowing forests of spruce, fir, yew, hemlock and tamarack to extend from eastern Kansas and Iowa to western Pennsylvania, while east of the Alleghenies there was a relatively dry woodland of jackpine?

Whatever the meaning of the apparent regional difference in tree distribution in the late-glacial, it gives little support to the biogeographic theory of the Appalachians as a Pleistocene refugium for hemlock-white pine-northern hardwoods. Not only is hemlock reported from west of the Mississippi where it shouldn't have been, but also pollen of hemlock-northern hardwoods is quite rare in the late-glacial deposits of unglaciated Pennsylvania where this community supposedly endured during glacial times. The presence of pine-NAP in matrix containing boreal woodland mammals including *Microtus xanthognathus* as a dominant species, *Sorex arcticus*, *Bufo americanus copei*, and at least one tundra mammal - *Dicrostonyx* - should help dispel doubts about major biotic changes in unglaciated Pennsylvania in the late Pleis-

tocene. Only in the absence of a late-glacial fossil record was it possible to imagine that: "The Hemlock-White Pine-Northern Hardwoods Forest of the Lake region and the Northeast has resulted from postglacial expansion of a forest *persisting throughout the Pleistocene in mountainous portions of the East, particularly on the Allegheny Plateau and Allegheny Mountains of Pennsylvania, where this forest still maintains itself on unglaciated land.*" (Braun, 1950: 524, italics ours). The late-glacial biotic community at New Paris reveals no Hemlock-White Pine-Hardwood Forest, or indeed, any closed-canopy forest, in the Allegheny Mountains 12,000 years ago. Conditions 20,000 years ago remain to be determined, but should certainly be no more favorable for hardwoods than during the late-glacial. The biogeographic interpretation of temperate refugia along the ice margin during glacial times can be maintained only by interpreting animal remains of rodents we believe are clearly intrusive (*Pitymys*, *Peromyscus leucopus*) as actually contemporaneous with sub-Arctic species.

Any attempt to uncover the full-glacial fossil record from unglaciated areas east of the Mississippi is confronted with certain difficulties, including: (1) a shortage of lakes and bogs, the traditional sources of a rich sedimentary record, (2) uncertainty in how to proceed when sampling and interpreting "unconventional" pollen deposits such as flood plain alluvium or cave fill which may be the only local sources of late Pleistocene sediment, and (3) the problem of obtaining radiocarbon-dated sediments *exactly* contemporaneous with the time of maximum biotic displacement, to coincide with maximum ice advance of 17,000 - 23,000 years ago. Like many others the fossil record from New Paris No. 4 is almost surely too young to represent the full-glacial climate of the Wisconsin maximum. Nevertheless, it indicates major climatic change. And while the New Paris No. 4 fossil record includes some mammal species which presently do not coexist in any single area, the mixture is not one of deciduous forest and boreal forest elements. Rather it is a mixture of species

from different parts of the boreal forest (Canadian-zone) and the boreal woodland (Hudsonian-zone), with a suggestion of tundra and prairie. The latter element reopens an old biogeographic question - that of the prairie peninsula.

THE PRAIRIE PENINSULA PROBLEM

Before the development of post-glacial pollen stratigraphy in North America Gleason (1923) invoked an eastward extension of prairie to explain the relict pattern of prairie plant distribution in the midwest. Gleason envisioned tundra growing on top of the ice with a narrow broken fringe of boreal coniferous forest along the margin. After deglaciation he postulated the advance of prairie to the east and northeast following the withdrawal of coniferous forests and before the invasion of deciduous forest species in post-glacial time. Transeau (1935) mapped the distribution of prairie relicts and postulated the prairie expansion during mid-post-glacial time, after, not before, the initial invasion of deciduous forest.

In an article describing in detail the number of reptile-amphibian distributions that fit the prairie peninsula pattern, Schmidt maintained that it was a late-glacial, not a post-glacial, event. "By analogy with the situation in Europe, and indeed on theoretic grounds, there must have been a broad belt of tundra, succeeded by steppe, parallel to the retreating front of the great glacier in eastern North America. This belt of open country, broadly connected with the plains region to the west, and extending eastward to Pennsylvania and sometimes even to the Atlantic Coast, to the north of the southeastern hardwood forest, obviously afforded a natural highway for the eastward spread of a part of the western steppefauna." (Schmidt, 1938).

With the development of American post-glacial palynology and the initial failure to find tundra or steppe pollen in sediments from the deciduous forest region, Schmidt's idea of tundra succeeded by steppe fell into eclipse. Most of the more recent discussions of the prairie peninsula have predicated its being a post-glacial event (Deevey, 1949; Braun, 1950; Smith, 1957) with some un-

certainty about possible prairie conditions during the early post-glacial pine period (pollen zone B, see Deevey, 1949: 1386).

The present record of two prairie species, the thirteen-lined ground squirrel (*Citellus decemlineatus*) and the sharp-tailed grouse (*Pedioecetes phasianellus*), in the east 11,000 years ago, restores currency to Schmidt's view. Undated records of the thirteen-lined ground squirrel, in association with boreal species but presumably of late-glacial age, do come from Bootlegger Sink in the Piedmont of eastern Pennsylvania, Cumberland Cave, western Maryland, Natural Chimneys in the Shenandoah Valley of Virginia, and Binson Cave in north-central Tennessee. The western magpie (*Pica pica*) and the sharp-tailed grouse (*Pedioecetes phasianellus*) are known from Natural Chimneys, Virginia. Cumberland Cave, Maryland also produced such western forms as badger (*Taxidea*), coyote (*Canis* - subgenus *Thos*), and coney (*Ochotona*). Cumberland Cave fossils may be pre-Wisconsin in age. Those from Port Kennedy Cave in eastern Pennsylvania, which include badger and coyote, almost certainly are pre-Wisconsin. While earlier invasions of western species moving east may also have occurred, the evidence of a late-glacial invasion leads us to re-examine the post-glacial evidence.

Archaeofaunal sites dating back 5000 years include the period of the climatic optimum include the following: Kentucky (Webb, 1946), Illinois (Fowler and Parmalee, 1959), West Virginia (Mayer-Oakes, 1955), Pennsylvania (Guilday and Parmalee, [1960]), and New York State (Guilday, [1963]). These faunas are composed of birds, mammals, reptiles, amphibians, and molluscs found in those areas as today. No major faunal change is indicated as might be expected if there were eastward penetration of prairie into the deciduous forest. Minor range extensions of new (not strictly prairie) species include the box turtle (*Terrapene carolina*) and the chipmunk squirrel (*Sciurus niger*) in central New York State at the Archaic Lamoka Site (Guilday, *ibid.*). This represents an eastward movement of approximately 160 km from the Erie area during the mid-post-glacial.

Smith (1957) distinguished between "climatic optimum" and "xerothermic" type distributions, the former of southern species left isolated at northerly outposts, the latter of prairie peninsula species isolated in eastward outposts. If relict northerly distributions of southern species are to be explained in terms of climatic change, then the climatic optimum is certainly the most likely time of isolation, as Smith points out. Admittedly, climatic change may not always provide the better explanation of the southern relicts. For example, rice rat (*Oryzomys palustris*) remains in archaeological sites several hundred kilometers north of the present limit of the species are not likely to be the result of warmer temperatures during the climatic optimum. Fossil records of rice rats are closely associated with the cultivation of prehistoric maize. Furthermore, all of these records are from Indian villages of late prehistoric age, post-dating the Climatic Optimum by several thousand years.

Thus, while some of the prairie relicts may trace their origin to one or several post-glacial warm, dry periods, and while some southern species probably extended farther north during the "Climatic Optimum" as Smith concludes, at least one of the latter, the rice rat (*Oryzomys*), is more likely a cultural than a climatic extension. The only dramatic fossil evidence for an eastern spread of prairie border vertebrates, *Citellus*, *Pedioecetes*, *Pica*, etc., evidently predates the post-glacial.

In an unpublished account of the fossil pollen record and post-glacial plant geography from the midwest, Benninghoff (MS) has reached a similar conclusion - that the late-glacial was the last episode of important prairie movement eastward. While prairie plants are often difficult to distinguish from tundra or woodland species in the pollen record, the presence of *Ambrosia*-type pollen ("low-spine Compositae" in table 2) would not be expected in a modern tundra pollen rain (Wright, Winter and Patten, 1963: 1386; Benninghoff, MS).

A mixture of mid-latitude heliophytes, including steppe plants, with an Arctic-montane

element has long been recognized in the late-glacial flora of Europe (see especially, Iversen, 1954). While some plants and animals did move north during boreal and Atlantic times of the post-glacial, such as the turtle (*Emys orbicularis*, see Degerbol and Krog, 1951), the steppe invasion took place earlier. Analysis of stratified deposits of small mammals from cave sites spanning this period (see Jánossy, 1961, for summary) shows steppe forms immediately succeeding tundra species such as the lemming (*Dicrostonyx*) and preceding woodland forms such as the wood mouse (*Apodemus*), the dormice (*Glis*, *Muscardinus*), and the red-backed vole (*Clethrionomys*). As the woodland forms increase in relative numbers in such deposits (see records from Jankovitch-Höhle and Petenyi-Höhle, Hungary, Jánossy, 1960), the steppe forms become correspondingly scarce and are eventually replaced during the early post-Würm reforestation of the area (fig. 32).

There is evidence for a steppe phase leading into the Würm glaciation as well as one immediately succeeding it (Jánossy, 1961). A similar sequence may be anticipated during early Wisconsin time in the central Appalachians. If steppe elements were present during both early-glacial and late-glacial time the correlation of cave deposits by their faunal make-up alone will require considerable caution.

As Schmidt anticipated, the post-Wisconsin invasion of prairie species in eastern United States is the mirror image of the post-Würm steppe invasion of Europe in which the prairie elements withdrew as forest invasion proceeded under an ameliorating climate. To date evidence for a mid-post-glacial invasion of prairie species during "Hypsithermal" time is more difficult to find in the fossil record. Unless such evidence emerges it seems futile to assign a period of isolation - either inter-glacial, late-glacial, or post-glacial - to such prairie relicts as the heath hen (*Tympanuchus cupido*), the small-headed garter snake (*Thamnophis brachystoma*), the massasauga (*Sistrurus catenatus*), and the chorus frog (*Pseudacris nigrita kalmi*).

Plants with Coastal Plain affinities such as the bushy beard grass (*Andropogon virginicus* var. *abbreviatus*), marsh milkwort (*Polygala cruciata* var. *aquilonia*), beaked rush (*Rhynchospora globularis* var. *recognita*), nut rush (*Scleria triglomerata*), file-leaved aster (*Aster radula*) and the Allegheny glade gentian (*Gentiana Saponaria* var. *allegheniensis*) are found in isolated mountain glades of Fayette County, 150 m higher and some 60 km southwest of New Paris. Such relicts have been looked upon as remnants of a Cretaceous flora that survived Tertiary uplift and the rigors of the Pleistocene *in situ* (see Jennings, 1953 for summary). A more likely assumption is that they are late-glacial immigrants in that area.

Such mid-western prairie forms as the blazing star (*Liatris spicata*), big-bluestem grass (*Andropogon furcatus*), gray-headed-coneflower (*Ratibida pinnata*), green milkweed (*Asclepias viridiflora*), and false boneset (*Kubnia eupatorioides*), have been regarded as post-glacial "Prairie Peninsula" species in western Pennsylvania, associated with the Hypsithermal (Jennings, 1953). Unfortunately, serious botanical work in northwestern Pennsylvania did not begin until after the country had been cleared and planted. Colonial agriculture created, in effect, its own "Prairie Peninsula," one in which wind-dispersed seeds could easily colonize. Whether these species were native to the region prior to colonial deforestation will probably never be known. Speculation as to their time of arrival in the region can only remain that. They may or may not be valid "Prairie Peninsula" indicators in the central Appalachians.

EARLY MAN IN THE EASTERN LATE-GLACIAL

Our knowledge of early man in eastern North America grows steadily. Characteristic chipped stone artifacts of what are presumed to be big game hunters of the late Pleistocene ice margin are common in the East. Precise dating is not yet possible, but in Michigan (Mason, 1958) and Ohio (Prufert and Baby, 1963) sub-types of Paleo-Indian artifacts may be correlated with Wisconsin terminal moraines. Throughout the retreat

of the Wisconsin Ice Sheet, an evolution of artifact styles can be associated with successively younger moraines.

"The Paleo-Indian artifacts south of the Wisconsin maximum boundary theoretically could date from a period earlier than 17,000 years ago. The remarkably consistent radiocarbon dates marking the maximum advance of the Wisconsin ice suggests that the retreat of the glacier began about 17,000 years ago. It follows that the Paleo-Indian penetration of the glaciated tracts of the state cannot be earlier than that date.

"A second terminus is provided by a date for the Wabash Moraine. The retreating ice margin had reached that position approximately 14,500 years ago. It follows, again, that the area north of the Wabash Moraine could not have been occupied by Early Man prior to that date.

"Datable evidence of early human occupancy south of the Wabash Moraine is lacking. Nevertheless the relatively heavy concentration of dated points in central and south-central Ohio, and the known existence of Pleistocene mammals in the area indicate the probable penetration of Early Man at least as early as 11,000 years ago," (Prufer and Baby, 1963, p. 55).

These early people are envisioned as hunters of big game that roamed the open areas of the glacial fore-front. Witthoft (1952, p. 94), speaking specifically of the Paleo-Indian occupation at the Shoop Site at Enterline, Pennsylvania, about 160 km northeast of New Paris, commented: "They were probably the first thin vanguard in the settlement of the Northeast. Highly mobile, nomadic hunters of large game, contemporary with extinct mammals of the closing Pleistocene." In discussing the topographical situation of the site, he says, (p. 467): "The hill itself commands a large area of Armstrong's Valley north of Dividing Ridge, but is much too elevated and in too isolated a location for one to expect an archaeological site." The valley is broad and rough-floored, walled by mountains on three sides and broadly open to the Susquehanna River on the west.

"The weathering stage of the flints, the absence of ground stone tools, and the ele-

mental nature of the tool industry also indicate that the Shoop Site represents the occupation of very early hunters of large game animals. At this time such areas of rugged physiography as the North Mountain section may not have been heavily wooded, and much of Pennsylvania may have been prairie. Such a difference in biota would help explain the location of the Enterline industry sites on high ground."

The location of this site is apparently inexplicable in the light of the preferences of later cultures who utilized the area when it was heavily forested. It would be an advantageous site for hunters of large grassland mammals if the country had been open or sparsely forested - a lookout from which the Paleo-Indian hunter could locate roving herds. Sites believed to be of this time period, such as Bull Brook in Massachusetts (Byers, 1954), Shoop in Pennsylvania (Witthoft, *ibid.*), Parrish in Kentucky (Webb, 1951), Williamson in Virginia (McCary, 1951), various sites in Ohio (Prufer and Baby, *ibid.*), Well's Creek Crater Site in Tennessee (Dragoo, unpubl.); have been in such exposed situations.

Mounting paleontological evidence, especially the integrated faunal and floral picture presented by New Paris No. 4, points to an open woodland during late-glacial times. This agrees with the interpretations of the archaeologist. If the thirteen-lined ground squirrel (*Citellus tridecemlineatus*) is used as a prairie indicator as it is today, then late Pleistocene woodland openings extended as far south as northern Tennessee (Robinson Cave), as far east as eastern Pennsylvania (Bootlegger Sink, in press) and central Virginia during Paleo-Indian times, i.e. 11,300 B.P. if the New Paris No. 4 carbon date is taken at face value.

The Modoc Rockshelter in southern Illinois (Fowler and Parmalee, 1959) and the Sheep Rock Shelter of central Pennsylvania (unpublished faunal report by Guilday and Parmalee, 1960) demonstrate that the faunas of these areas have remained essentially unchanged during the past six to seven thousand years. The record is especially conclusive at Sheep Rock because the fauna is com-

posed mainly of small mammals from owl pellets that accumulated on the aggrading shelter floor coincident with the Indian occupation. The collection, freed therefore from any selective bias on the part of the Indians, consisted primarily of ecologically sensitive rodents and insectivores of the area. At Sheep Rock, a stratigraphic change was noted in the relative numbers of cottontail rabbit (*Sylvilagus* sp.) and southern flying squirrel (*Glaucomys volans*) bones. According to Dr. Anton Kovar, Pennsylvania State University, this correlates with an increase in non-arboreal pollen from these levels. This is probably due to the clearing of the area by late Prehistoric peoples for the growing of crops during Late Prehistoric times. The fauna, even in the oldest levels (c. 6000 years ago), was a Recent one.

CONCLUSIONS

A picture of late-glacial climate and life in unglaciated Pennsylvania can be gained from the fossil content of nine meters of cave fill in a sinkhole near New Paris, Bedford County. A total of almost 3000 identified vertebrates associated with a pollen profile and radiocarbon date of 11,300 $\pm$ 1000 years B.P. (Y-727) indicate boreal woodland and boreal forest environments. The fossil-bearing portion of the deposit can be divided into two units: the lower from nine to six meters (unit B) is dominated by woodland (Hudsonian-zone) vertebrates whose modern center of distribution lies southeast and west of Hudson Bay in central Canada (map B, center leaf). The pollen record suggests that spruce and pine (probably jackpine) were the only trees present with open ground separating them. The upper unit (unit A) from six to four meters, may correspond to the Alleröd of Europe and to pollen zone A-3 of New England. In it the relative proportion of forest (Canadian-zone) species of vertebrates increases and the center of their modern distribution lies well to the south of the species dominant in the lower unit (map A, center leaf). In unit A the pollen of broad-leaved trees increases and some, such as birch and oak, may have invaded the pine-spruce community.

If the Paleo-Indian hunters were present in this area during late Pleistocene times, as indications seem to point, they would presumably be associated with a boreal fauna such as that of New Paris No. 4. While direct evidence of prehistoric man is lacking at New Paris, his effectiveness as a hunter may be reflected in the disappearance of the pecary (*Mylohyus*) in Pennsylvania and elsewhere in eastern North America at this time. The peculiar nature of late Pleistocene extinction, which affected only large-sized terrestrial genera, has been so often mentioned that it seems unnecessary to point it out again in the case of the New Paris No. 4 fossil record. It is very difficult to account for the pattern of late Pleistocene extinction without appealing to Early Man as a major cause (see also Martin, 1963).

Where critical comparisons can be made between fossil and modern populations within a wide-ranging species, as in the case of snowshoe hare (*Lepus americanus*), northern flying squirrel (*Glaucomys sabrinus*) or the short-tailed shrew (*Blarina brevicauda*), the late-glacial population reveals size-attributes of populations now living in southern or central Canada. In those modern cases in which Bergmann's Rule is violated, i.e. small-sized animals characterize the populations to the north, the New Paris fossils are also relatively small. Modern and fossil populations are indistinguishable only in the case of suspected contamination (*Pitymys pinetorum*, *Peromyscus leucopus*), where fossil material is insufficient for critical comparisons, or in species that are now confined to the Arctic or sub-Arctic (*Microtus xanthognathus*, *Dicrostonyx hudsonius*).

Although the cave fill is dominated by boreal woodland or boreal forest species, it contained the first Pleistocene record from North America of the Labrador collared lemming (*Dicrostonyx hudsonius*), whose modern distribution lies almost entirely within the tundra of northern Quebec. In addition there were bones of two prairie species, the thirteen-lined ground squirrel (*Ci-*

llus tridecemlineatus) and the sharp-tailed grouse (*Pedioecetes phasianellus*). The colored lemming may be a relict from full-glacial times which lingered on the tops of the Allegheny Mountains during the late-glacial, while the ground squirrel and sharp-tailed grouse indicate a steppe invasion much earlier than that commonly attributed to the perithermic or Hypsithermal of the pollen stratigrapher (pollen zone C-2). A late-glacial steppe invasion mirroring that known in Europe was postulated by Schmidt (1938). Whether all prairie relicts in the East date back to the late-glacial is problematic, but as far as a fossil prairie element is clearly seen only in deposits which we consider late-glacial or older and is not known from mid-post-glacial deposits.

With the exception of the long-nosed peccary (*Mylobyus nasutus*) none of the New Paris animals identified to date are unequivocally extinct species. *Mylobyus* has been found previously in association with boreal animals in the East and its occurrence at New Paris No. 4 cannot be taken as evidence for warm climates, much less for an ecologically anomalous mixture of subtropical and boreal species. While details of the sequence of events which led to the extinction without replacement of large vertebrates in the late Pleistocene is unknown, *Mylobyus* was so wide-ranging throughout eastern North America at the time (to Texas and Florida) that appeal to climate as cause of extinction seems out of the question. The local geography of the Shoop Site 60 km north of New Paris and the suspected dates of man's arrival in eastern North America make it seem likely that Paleo-In-

dians were contemporaries of the long-nosed peccary during the boreal woodland period, but no direct association was evident in the record of Sinkhole No. 4.

The New Paris fossil record is only of indirect help in establishing the climate of the Appalachian Mountains in Pennsylvania during the maximum advance of Wisconsin ice 20,000 years ago. The involved physiography of the region may have allowed tundra and taiga to interdigitate over 200 km in a north-south direction as Martin (1958) concluded when he discovered a high frequency of NAP associated with small-size pine pollen and spruce in a swale in the Pennsylvania Piedmont. Evidently a pollen deposit similar to that of the Piedmont occurs in basal clays at Cranberry Glades, West Virginia. Additional evidence for major Wisconsin-age biotic displacement in the unglaciated East may be inferred from the recovery of boreal plant pollen in the Carolinas (Frey, 1953, 1955; Whitehead, 1963) boreal vertebrates in Tennessee (Robinson Cave), and also in the record of the collared lemming (*Dicrostonyx hudsonius*) at New Paris, perhaps 5000 years after the glacial maximum. While suggestive, none of the assembled evidence is conclusive proof for tundra as a distinct vegetation zone outside the ice margin. Even the presence of lyesotundra (the boreal woodland-tundra ecotone) cannot be claimed with certainty. At the same time the boreal aspect of the late-glacial biota from New Paris No. 4 provides little support for the biogeographic view that the unglaciated Appalachians in this region served as an ice refugium for temperate species of plant and animal life.

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