

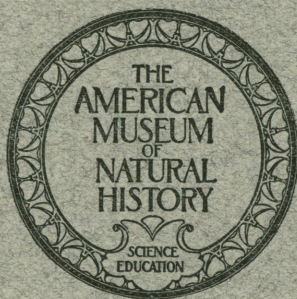
ANTHROPOLOGICAL PAPERS
OF
THE AMERICAN MUSEUM
OF NATURAL HISTORY

VOL. XIX, PART VI

THE ANTIQUITY OF THE DEPOSITS IN JACOB'S CAVERN

BY

VERNON C. ALLISON



AMERICAN MUSEUM PRESS

NEW YORK

1926

THE AMERICAN MUSEUM OF NATURAL HISTORY

PUBLICATIONS IN ANTHROPOLOGY

In 1906 the present series of Anthropological Papers was authorized by the Trustees of the Museum to record the results of research conducted by the Department of Anthropology. The series comprises octavo volumes of about 350 pages each, issued in parts at irregular intervals. Previous to 1906 articles devoted to anthropological subjects appeared as occasional papers in the Bulletin and also in the Memoir series of the Museum. Of the Anthropological Papers 26 volumes have been completed and 1 volume has been issued in part. A complete list of these publications with prices will be furnished when requested. All communications should be addressed to the Librarian of the Museum.

The current issue is:—

VOLUME XIX

I. The Whale House of the Chilkat. By George T. Emmons. Pp. 1-33, Plates I-IV, and 6 text figures. 1916. Price, \$1.00.

II. The History of Philippine Civilization as Reflected in Religious Nomenclature. By A. L. Kroeber. Pp. 35-67. 1918. Price, \$.25.

III. Kinship in the Philippines. By A. L. Kroeber. Pp. 69-84. 1919. Price, \$.25.

IV. Notes on Ceremonialism at Laguna. By Elsie Clews Parsons. Pp. 85-131, and 21 text figures. 1920. Price, \$.50.

V. Laguna Genealogies. By Elsie Clews Parsons. Pp. 133-292, and 22 text figures, 1 map. 1923. Price, \$2.00.

VI. The Antiquity of the Deposits in Jacob's Cavern. By Vernon C. Allison. Pp. 292-335, and 24 text figures. 1926. Price, \$.75.

ANTHROPOLOGICAL PAPERS
OF
THE AMERICAN MUSEUM
OF NATURAL HISTORY

VOL. XIX, PART VI

THE ANTIQUITY OF THE DEPOSITS IN JACOB'S CAVERN

BY

VERNON C. ALLISON



AMERICAN MUSEUM PRESS
NEW YORK
1926

THE ANTIQUITY OF THE DEPOSITS IN JACOB'S CAVERN

BY VERNON C. ALLISON

CONTENTS

	PAGE
INTRODUCTION.....	297
THE STALAGMITIC RECORD.....	299
CORRELATION WITH TREE-RING DATA.....	312
COMPOSITION AND AGE OF THE CAVE EARTH.....	317
CHARCOAL.....	321
THE ROCK FRAGMENTS.....	321
THE BONE FRAGMENTS.....	322
CONCLUSIONS.....	325
NOTES ON THE INCISED BONE.....	326
CONCLUSIONS.....	335

LIST OF ILLUSTRATIONS

TEXT FIGURES

	PAGE
1. The Entrance to Jacob's Cavern	301
2. View looking Outward from the Rear of Jacob's Cavern	302
3. Stalagmite No. 3, in Position in the Cavern	302
4. Plan of Jacob's Cavern	303
5. The Cavern after the Removal of Stalagmite No. 3	303
6. Diagrammatic Vertical Section of Stalagmite No. 3	305
7. Vertical Section of Stalagmite from Bear's Cave, near Hillside, Penn- sylvania	
8. Stalagmite grown at Experimental Mine	306
9. Jar in which Dust was collected as described in the Text	306
10. The Two Sections of Stalagmite No. 3, when first sawed Apart	307
11. Enlarged View of the Rear Half of Stalagmite No. 3	308
12. An Enlarged Section of the Stalagmite showing the Annual Layers	309
13. Comparison of Growth Curves of Sequoia D21 and Stalagmite No. 3	312
14. Part of a Chipped Object from the Face of Stalagmite No. 3	313
15. Cedar Pegs delineating Layer 3 in the 1921-1923 Test Pit	315
16. Transverse Section of the Cavern	317
17. One Square Meter of Layer 3 exposed	319
18. Bones from Layer 3	320
19. Layer 2 sloping down and away from the Center	323
20. "Mastodon" Side of the Carved Bone	327
21. The Reverse Side of the Carved Bone showing Additional Carvings	327
22. Panchromatic Plate, W. and W., Contrast Light Filter C. A, Recent carving on an old bone; B, Carving on the original bone; C, Recent carving on a fresh bone	329
23. Panchromatic Plate, W. and W., Contrast Light Filter F	329
24. X-Ray Photograph of the Bone Series	331

INTRODUCTION

The determination of the more or less precise age of a prehistoric cultural deposit has always offered considerable difficulty. The recovery of a prehistoric calendar or chronology greatly simplifies the problem, for the correlation of our historic time-sequence with the prehistoric time record is all that is then required; this may be done by deciphering or translating the ancient language or symbols, by comparison with periodic astronomical phenomena, and by other means. But the difficulties increase and many puzzling angles of the question appear in the absence of such positive, conscious, human records. If, however, a definite age can be determined for a vertical section through any such deposit, the possibilities are good that adjoining deposits may be dated by comparison.

An attempt is made in this paper to approach the problem from two separate viewpoints, each possessed of considerable exactness; the proof of the human origin of the deposit from the chemical and physical analyses of the undisturbed layers; and the assignment of a definite age to these layers through the determination of the age and growth conditions of stalagmites which grew and recorded contemporary events at the same time that the habitation layers were being deposited.

THE STALAGMITIC RECORD

Previous work upon the growth of stalagmites has indicated the possibility that certain favorably situated, slow-growing stalagmites may record major climatic fluctuations occurring during their lifetime. They are somewhat unique in that they record climatic variations by their external appearance—their shape—and thus yield certain information without necessitating the destruction of the stalagmite. These favorably located stalagmites also, in common with the big trees and the clay varves, add a growth ring or layer, a light band and a dark band, each year.

Several stalagmites in an open cavern¹ in southwestern Missouri were known to have shapes similar to those attributed to variation in climate and through the assistance of the American Association for the Advancement of Science these stalagmites were studied in reference to their natural environment.

There are five factors which influence the deposition of lime from the lime-water, after the solution has reached the cavern² interior. These are: rate of drip, humidity of the cavern air, amount of air circulation in the cavern, temperature of the cavern air, and the concentration of lime in the lime-water. When a stalactite is also present, it very largely takes care of the variation in the concentration so that the growth of its corresponding stalagmite is dependent only upon the drip, humidity, air circulation, and temperature.

A fast drip and a high humidity favor an increase in diameter of a stalagmite as do also a small air circulation and a low temperature. A stalagmite showing a sudden increase in diameter indicates that a change has occurred in one or more of the four factors influencing its diameter growth. If this change is very abrupt it further indicates that all four of the factors may have been so affected as to produce an increased diameter; the drip increased, the humidity increased, the air circulation and temperature decreased.

Fig. 1 shows the entrance to Jacob's Cavern, located in Taylor's bluff, on the right bank of the Little Sugar flood-plain, two and one half miles south-east of Pineville, McDonald County, Missouri. This cavern is in the St. Joe limestone, the lowest member of the Mississippian formation. The St. Joe limestone rests upon the Eureka shales³ which are

¹Peabody, Charles and Moorehead, W. K., "The Exploration of Jacob's Cavern," (*Bulletin 1, Department of Archeology, Phillips Academy, Andover, Mass., 1904*).

²Allison, Vernon C., "The Growth of Stalagmites and Stalactites" (*The Journal of Geology*, vol. 31, No. 2, February-March, 1923).

³Peabody and Moorehead, *ibid*.

probably of the Lower Silurian, the deep-well, water-bearing stratum of western Missouri and eastern Kansas and this water-tight stratum is also the level of most of the springs in southwestern Missouri. The Upper Silurian and Devonian are apparently missing. The evenness of the limestone roof layers of the cavern is shown in Fig. 2 which is a view looking outward from the rear of the cavern; this photograph was taken with the camera set at the place later occupied by the rear end of a trench dug for archæological purposes in the fall of 1923.

This cavern was first investigated archæologically in 1903 by Moorehead and Peabody¹ who described several stalagmites with "stools" or enlarged diameters. Gould² explained this mushrooming effect by the sponge-like action of the ash layer (the cavern was inhabited by man during the time of the growth of the stalagmites, as is clearly shown by the abundant flints, bones, charcoal, etc., found in the stalagmites) in spreading out the dripping lime water. But, in 1924, when one of the stalagmites was sawed in half vertically it was found that there was a distinct dividing line between a lower, almost white, limestone layer and a dark, upper layer contaminated with the bones, flints, charcoal, etc., and the "mushrooming" had occurred in the lower, uncontaminated, layer.

The enlargement of the diameter of this stalagmite, Fig. 3, was very abrupt and indicates a cool, damp, climatic period.

The plan of the cavern is shown in Fig. 4. The stalagmite which was removed, transported to Pittsburgh, Pennsylvania, sawed in half vertically, and polished, was No. 3 of this plan. This detailed examination was made possible through the assistance of the American Museum of Natural History. Fig. 3 shows stalagmite No. 3 in position in the cavern (with the black earth layer removed) and Fig. 5 shows the place after its removal. The kneeling man has his hand on the stump of the stalagmite while its place of attachment to the overhang above it is shown by the white patch over the man's head in Fig. 5. A stalagmitic dike, to the right and rear, is plainly shown in this figure while the man in the foreground is standing on the bed rock.

The diagrammatic vertical section of stalagmite No. 3 is shown in Fig. 6. It started growing from a small neck which represents the death of an older, underlying, stalagmite. Section A of this figure was accidentally detached while preparing for shipment. It will be noted that the diameter of this stalagmite increased very abruptly at the start, finally becoming so great that the lime water overflowed the face and formed the

¹Peabody and Moorehead, *ibid.*

²Peabody and Moorehead, *ibid.*

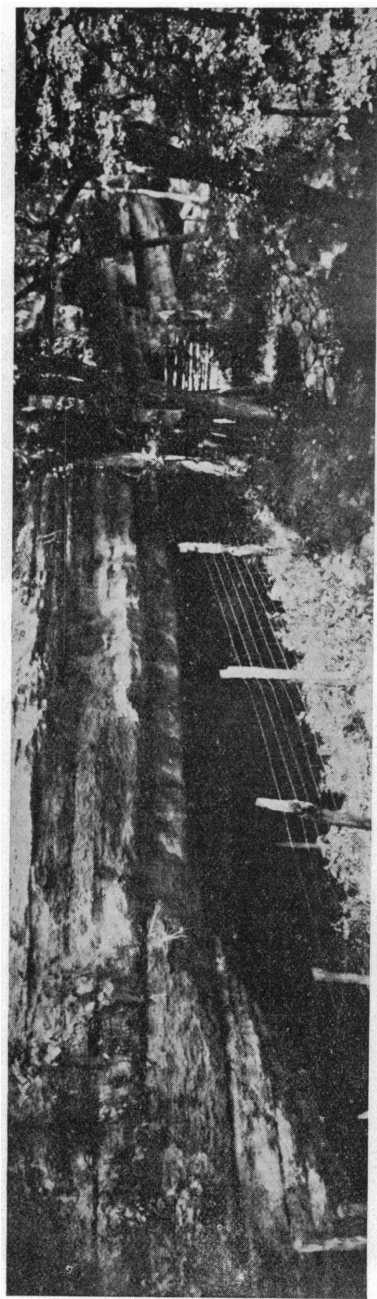


Fig. 1. The Entrance to Jacob's Cavern.



Fig. 2. View looking Outward from the Rear of Jacob's Cavern.

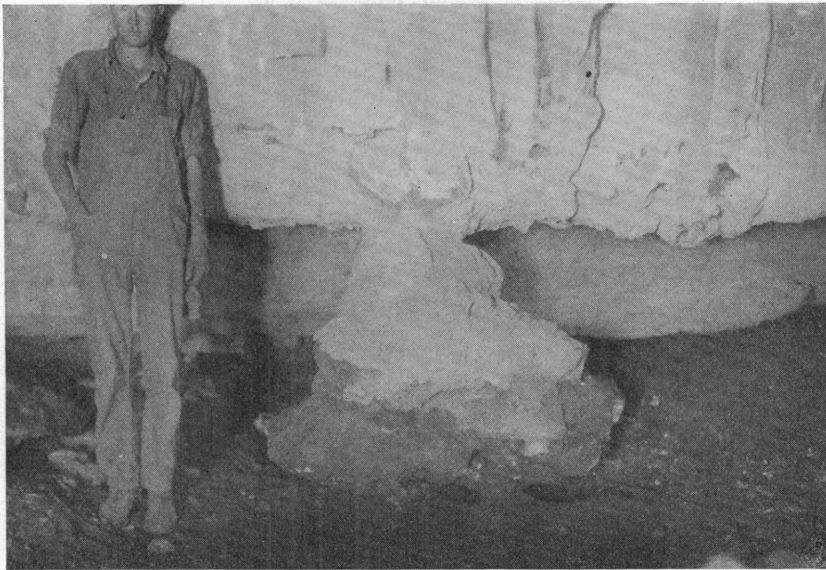


Fig. 3. Stalagmite No. 3, in Position in the Cavern.

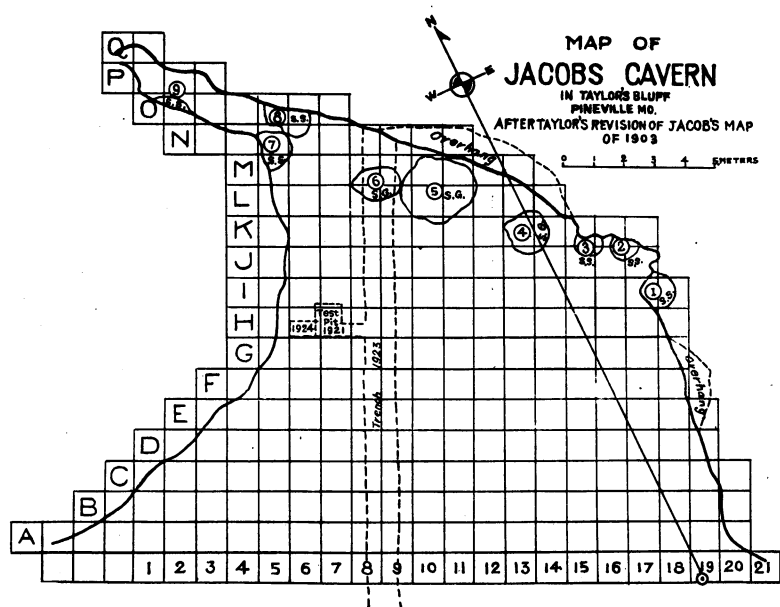


Fig. 4. Plan of Jacob's Cavern.

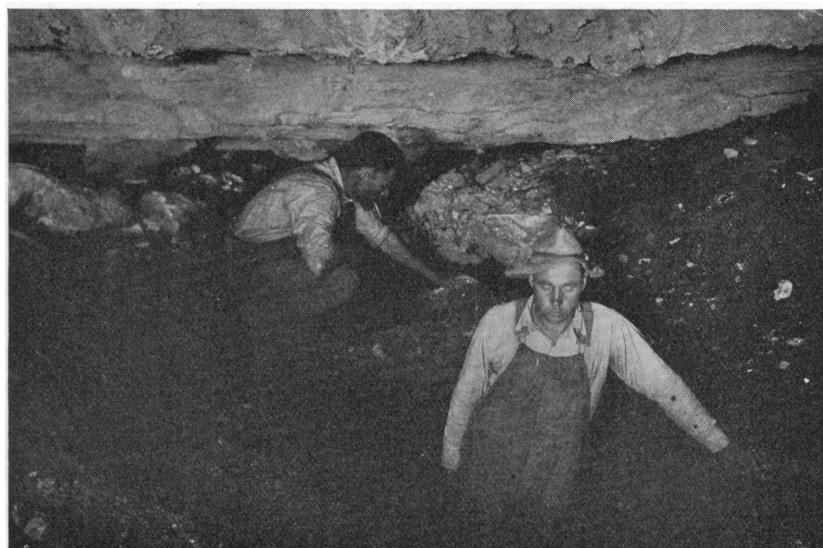


Fig. 5. The Cavern after the Removal of Stalagmite No. 3.

adjoining stalagmitic dike to the right and rear. The diameter increased to a maximum and then gradually decreased until the stalagmite reached the overhang above it, and continued on up this overhang as a leaf stalactite. This variation in diameter growth suggests a cool, rainy period which came on suddenly and passed away slowly, ending in a much drier period.

There are at least two situations in which a growing stalagmite records the seasonal climatic variation in the form of alternating light and dark bands. One of these situations may occur in a cave where the outside air has difficult access to the stalagmite and where there is soil containing much iron above a limestone cover which is not too thick. The iron in this surface soil above the cave is oxidized to the ferric, or red form, during the dry season and in the following wet season it is taken into more or less true solution as hydrated ferric oxide and accompanies the lime solution down through the limestone cover of the cave where it stains the stalagmite red. There are then, in this class, a red layer representing the wet season and a lighter layer representing the dry season; the sum of the two layers represents the growth during one year. Fig. 7 shows the vertical section of a small stalagmite of this type from Bear's Cave, near Hillside, Pennsylvania. A too-rapidly growing stalagmite of this type might record each succeeding rainstorm of the wet season, as a succession of red bands of decreasing thickness, instead of a single wet season red band. Yet, in this case, the succession of red bands would be of decreasing thickness because each succeeding rainstorm would remove from the surface soil overlying the cave, more and more of the ferric iron, oxidized during the preceding dry season.

The second situation in which a stalagmite may record seasonal climatic changes is when it grows in a location which permits free access of the outside air with its seasonal variation in dust content. The dry, dusty, season records itself as a dark band over the moist upright stalagmite face while the wet season records itself as a lighter band; the sum of one light and one dark band represents one year's growth. Fig. 8 shows such a stalagmite which grew in the Experimental Mine of the United States Bureau of Mines, near Bruceton, Pennsylvania. A too-rapidly growing stalagmite of this type might record each dust storm or each excessively dry period of the dry season. For example, the piece of stone described in the handbook of the British Museum and kept on exhibition in that institution.¹

¹"Guide to the Exhibition Galleries of Geology and Palaeontology" (*British Museum, Natural History*, 1923), 63.

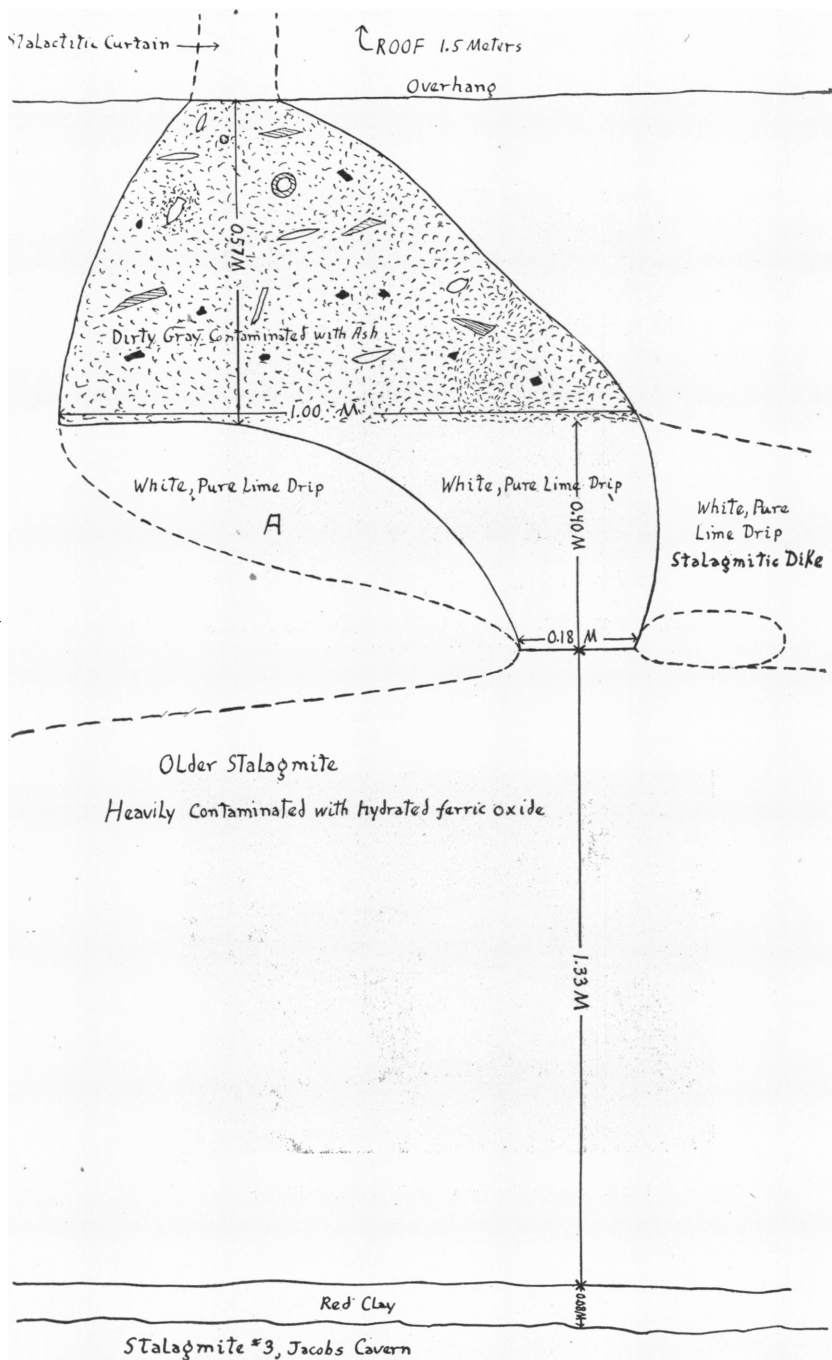


Fig. 6. Diagrammatic Vertical Section of Stalagmite No. 3.

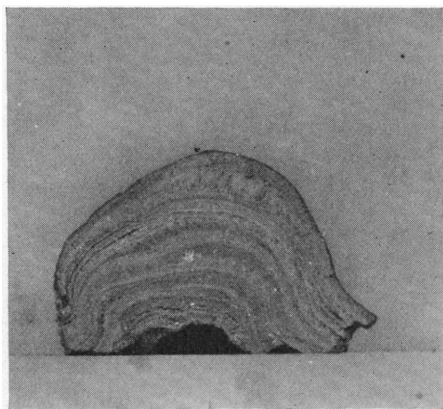


Fig. 7. Vertical Section of Stalagmite from Bear's Cave near Hillside, Pennsylvania.

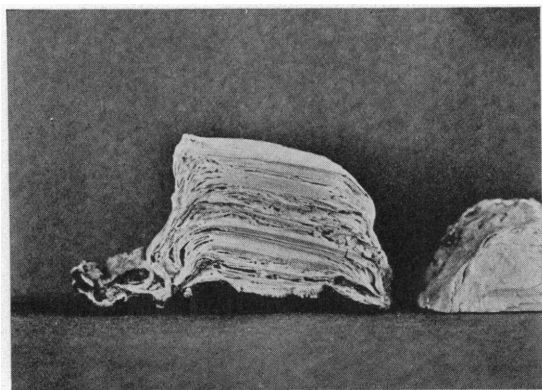


Fig 8. Stalagmite grown at Experimental Mine.

Among the specimens in wall-case 6b, the so-called Sunday-stone deserves notice. This is a limy deposit left in a wooden channel for running water in the grounds of a coal mine. The deposit was blackened by the coal dust in the air, but the nights are marked by clearer bands, and each recurring Sunday produced a broader white band.

It is well, therefore, at the present time, to confine the annual growth layer study to slow-growing stalagmites and to insist upon regularity of the recurring deposit; the seasonal variations are probably the most regular variations affecting stalagmitic vertical growth. A considerable series of such layers is also desirable.



Fig. 9. Jar in which Dust was collected as described in Text.

Some knowledge of the amount of dust annually deposited at the present time in the vicinity of Jacob's Cavern was desired. This cavern contains stalagmites of the second type—the dusty atmosphere recording type. A twelve gallon stone jar was accordingly placed on top of the

hill above the cavern and salt was placed in it to prevent the freezing of the accumulated rain and snow water and the consequent bursting of the jar. This jar, in position, is shown in Fig. 9. It was placed in position by J. L. B. Taylor, December 1, 1922, and was removed by the author, September 7, 1923, thus giving a dust fall record over a period of 0.77 year. The mixture of salt and dust was analysed with the following results:—

A total of 28.88 grams of dust was secured.

2.48 grams of the dust was a mottled white and red sandy material of from 10 to 20 mesh size and a loss on ignition of 6.2 percent.

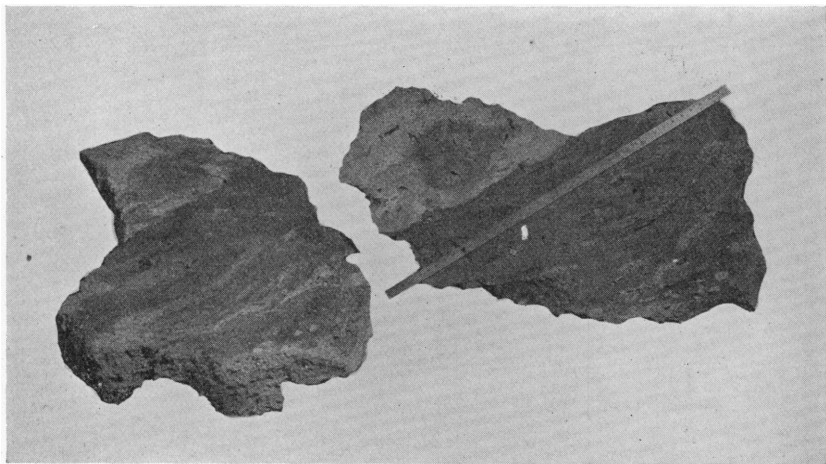


Fig. 10. The Two Sections of Stalagmite No. 3, when first sawed Apart.

26.4 grams of the dust was of a very fine reddish, ocherish material which was largely colloidal in solution and gave a loss on ignition of 37.5 per cent. Estimated by color, it contained about 5 per cent of iron.

The area of the opening of the jar was 0.106 square meters and 28.88 grams of dust was deposited over this area in 0.77 years; this gives an annual dust deposit, at the present time, of 354 grams per square meter per year in the vicinity of Jacob's Cavern.

Fig. 10 shows the two halves of stalagmite No. 3 with their polished vertical surfaces. Fig. 11 is an enlarged view of the rear half, the one shown diagrammatically in Fig. 6. The upper two thirds is so heavily contaminated with ash, bones, worked flints, flint chips, charcoal, bits of fire-burnt stones, etc., that it would not take a good polish. When the ash-level had reached the face of the growing stalagmite, the area of the cavern floor under the drip was only inhabitable during the dry season

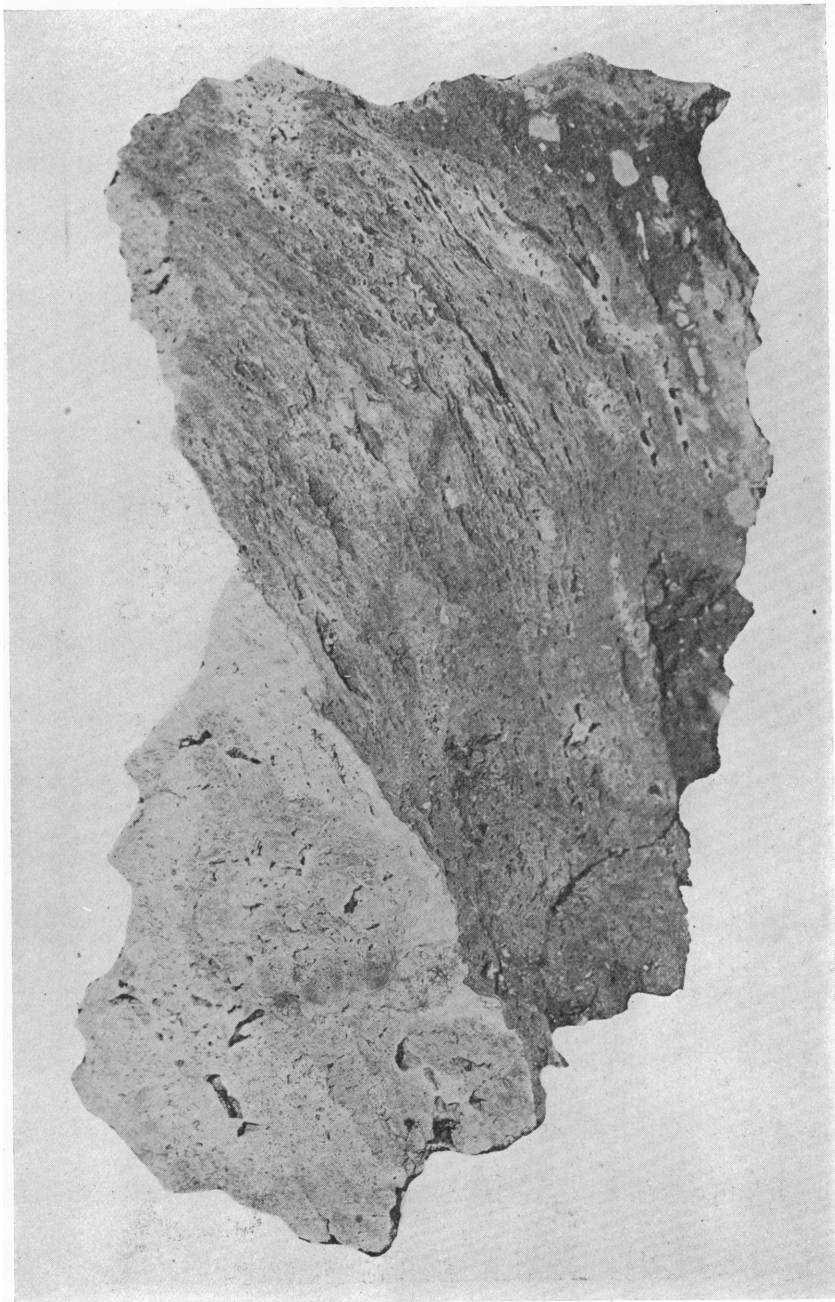


Fig. 11. Enlarged View of the Rear Half of Stalagmite No. 3.
The dark upper portion contains ashes, bones, flints, etc.

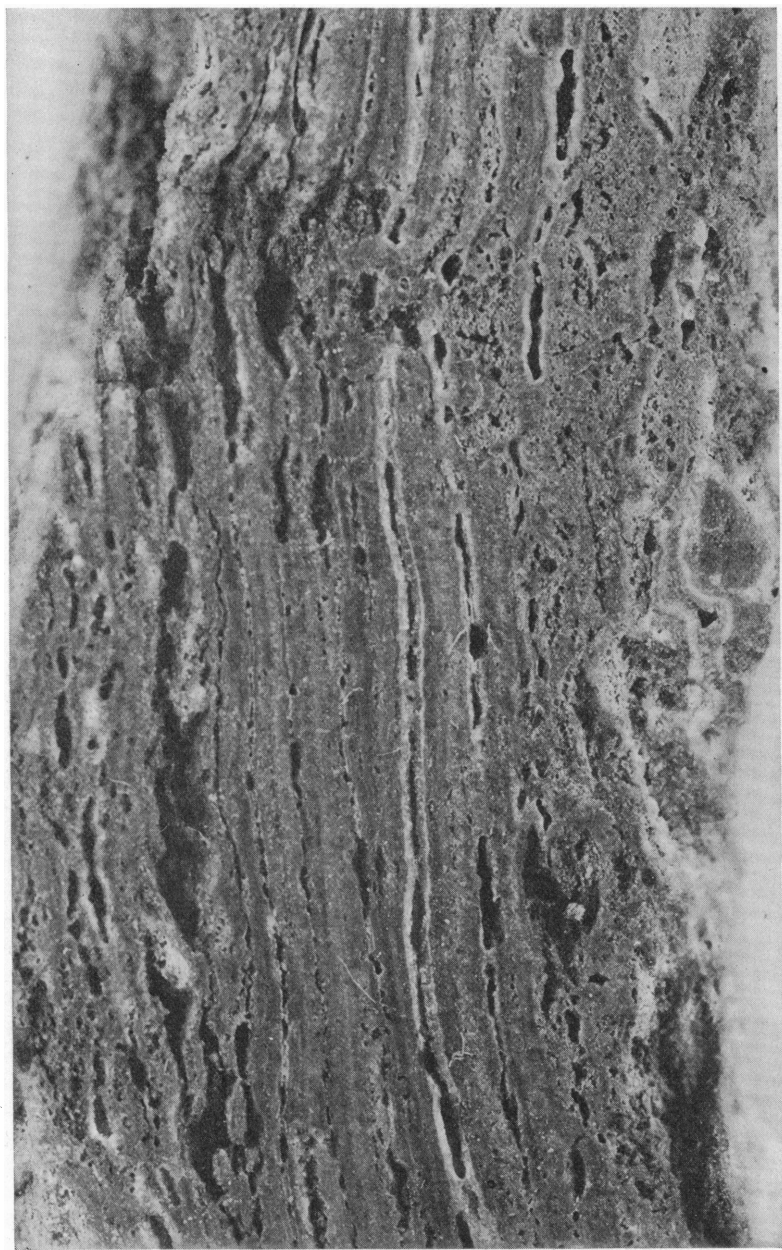


Fig. 12. An Enlarged Section of the Stalagmite showing the Annual Layers.

and a thin layer of ash and debris then accumulated. As the wet season appeared, the increased drip made this floor area too wet for comfort and it was vacated for this period. At the start of the wet season, then, the lime water first wet down and cemented the thin layer of ash and debris which had accumulated during the preceding dry season and then proceeded to deposit the wet season lighter layer. This effect was superimposed upon the effect of the seasonal variation in the dust content of the outside air. The lower third of the stalagmite is almost white and contains no bones, flints, or charcoal, although there is a slight darkening probably due to a small amount of ash and cavern dust. The yearly growth layer does not show very plainly in the white part, because there was very little dust present in the outside air during any season of the years involved in the cool, rainy, period at the time of growth of the stalagmite. This is why the yearly growth layer cannot be followed entirely across the width of the stalagmite in the dirty top part, on account of the great amount of foreign material which it contains. There are at least fifteen places, however, over the vertical face of the stalagmite, where the growth layers can be seen; each of these shows about twelve annual growth layers to one centimeter in height. These layers show up better when wet because the dirty layers absorb more water and darken proportionately much more than the purer part of the stalagmite.

A section of these annual layers, enlarged six diameters, is shown in Fig. 12. When fragments of the top dirty layer of the stalagmite are treated with dilute sulphuric acid the limestone (calcium carbonate, CaCO_3) dissolves and leaves behind (in addition to the fragments of flint, bone, charcoal, etc.) a fine-grained, reddish-brown material very similar in color and appearance to the colloidal part of the atmospheric dust collected from December 1, 1922, until September 7, 1923, on top of the hill above the cavern Fig. 9.

It appears, then, that the annual growth layer is $\frac{1}{12}$ cm. or about 0.8 mm. The total height of the stalagmite is 970 mm. and it thus required $970/0.8$ or 1213 years for this stalagmite to grow. This stalagmite also recorded a period of cool, rainy weather, which came on suddenly and changed slowly to a drier climate. The part of this period recorded in the stalagmite is 1213 years in length, but the stalagmite offers no evidence of when this 1213 year period began or ended.

CORRELATION WITH TREE-RING DATA

Douglass¹ has clearly shown the possibilities of obtaining records of climate from the growth rings of trees. Conifers are the best trees for this purpose because of the wide range of climate in which they grow and the prominence of their growth rings. The growth ring consists of a light colored part, which varies in width with the moisture fall during the wet season, and a red dry-season band, of practically uniform width for each tree. The growth rings are very sensitive to moisture fall variation in trees which grow upon slopes or upon soil overlying limestone—or any place where there are no water-tight underlying strata to hold the excess moisture of an unusually wet season and feed it back to the tree during the following less wet seasons.

Douglass and others have measured more than 75,000 growth rings in trees which grew between 34° N and 68° N latitude in Arizona, California, Oregon, Vermont, England, Sweden, Norway, Prussia, Bavaria, and Czecho-Slovakia, and have established a definite chronology and past climate history between 1308 B.C. and 1915 A.D.

Through the courtesy of Doctor A. E. Douglass, the writer secured the original data on Sequoia D21. This tree grew from 1308 B.C. to 1892 A.D. The width of its growth rings, in millimeters, is plotted against the time, in years, in Fig. 13. The average of twelve year periods was taken to compress the curve into a single sheet. This solid curve shows that D21 started out in 1308 B.C., with the enlarged center growth characteristic of trees, and that this growth steadily decreased with increasing years, as is also usual in trees. The width of the growth rings, as shown on the curve, indicates a sudden increase in the moisture fall, starting in 1226 B.C., coming on suddenly and passing away slowly, reaching a minimum moisture fall, lower than that of today, at about 520 A.D. These more or less actual dates are obtained by plotting the years instead of the average of twelve year periods over the range of time in question. This solid curve is very jagged due to the sun-spot cycles worked out by Douglass, the 5 to 6 year, the 10 to 13 year, the 21 to 24 year, the 32 to 35 year, and the 100 to 105 year sun-spot cycles. The jagged effect is also increased by the compression of the curve along the time axis.

The dotted line in Fig. 13 represents the diameter of stalagmite No. 3, in meters, plotted against the time in years.

The coincidence between the cool, rainy period shown by the increased diameter of stalagmite No. 3 from southwestern Missouri and

¹Douglass, A. E., "Climatic Cycles and Tree Growth" (*Carnegie Institution of Washington*, 1919.)

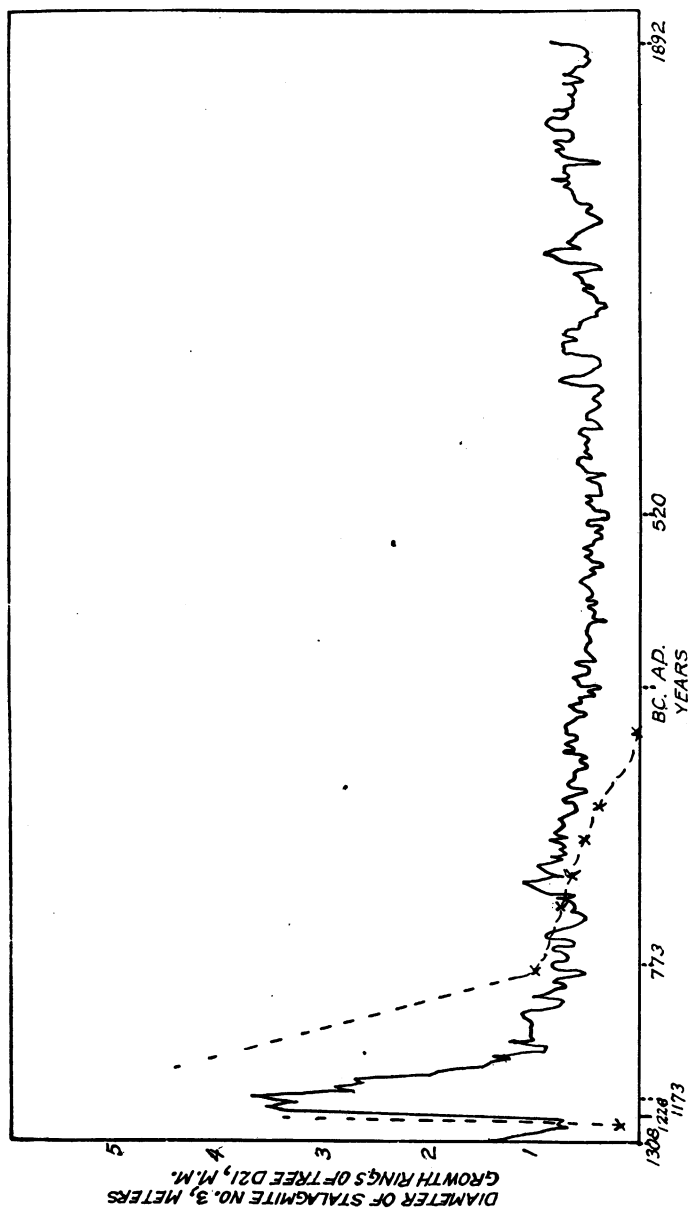


Fig. 13. Comparison of Growth of Curves of Sequoia D21 and Stalagmite No. 3.
Solid curve. Average of each successive 12 years tree growth rings, in millimeters, of Sequoia D21.
Broken curve. Diameter of Stalagmite No. 3 each successive 100 years, in meters.

the rainy period shown by the increased width of the growth rings of Sequoia D21 from California is very significant.

Antevs and Reeds¹ state that the fossil fauna and flora of Sweden record a cool moist period at about this same time. Dachnowski² correlates the Buhl, Gschnitz, and Daun Ice Advances in the Alps with the Dani-, Goti-, and Fini-Glacial of Scandinavia and with the Valparaiso-Kalamazoo, Lake Border, and Port Huron Ice Advances in the United States. There was then, a cool rainy period which occurred simultaneously in Sweden, the Alps, and the United States. This indicates that the period was at least general over the northern hemisphere and accordingly would have left its impress upon any stalagmite growing in an exposed place in southern Missouri.

Further, the growth ring-time curve of Sequoia D21 in Fig. 13 shows that no such general cool rainy period has occurred since 1226 B.C. Therefore, the cool rainy period recorded by stalagmite No. 3 in Jacob's Cavern is unhesitatingly assigned to its chronological position as shown in Fig. 13, the 1213 year interval between 1226 B.C. and 13 B.C.

The lower third of the stalagmite is almost pure limestone, but there is a slight grayish cast, probably due to the presence of a small quantity of ash and dust. The absence of flints, bones, charcoal, etc., from this part indicates that the ash-level was not yet as high as the face of the growing stalagmite. The slight darkening of this lower part, however, does show that the cavern was inhabited by man during this time; a small amount of ash and dust entered the stalagmite from the cavern atmosphere. The stalagmite was growing upon a center mound of wet sticky clay and the cavern was inhabited at this time only around the edges. The level of the accumulating ash slowly rose until it reached the level of the growing stalagmite and from then on the stalagmite contains all the debris of an occupied cavern floor. The rising ash-level reached the level of the growing stalagmite about 730 B.C.

The chemical analysis of the upper dirty part of stalagmite No. 3 is:

Silica (SiO_2).....	7.22
Calcium carbonate (CaCO_3).....	88.63
Magnesium carbonate (MgCO_3).....	0.74
Alumina (Al_2O_3).....	2.43
Iron oxide (Fe_2O_3).....	1.03

¹Osborn, Henry Fairfield, and Reeds, Chester A., "Old and New Standards of Pleistocene Division in Relation to the Prehistory of Man in Europe" (*Bulletin, Geological Society of America*, vol. 33, July 3, 1922), 443.

²Dachnowski, Alfred P., "The Correlation of Time Units and Climatic Changes in the Peat Deposits of the United States and Europe" (*Proceedings, National Academy of Sciences*, vol. 8, No. 7, Washington, 1922), 225.

This sample excluded the flint, bone, and charcoal fragments and shows the dust contamination of the top part of the stalagmite during the dry season of the years in which it grew.

Fig. 14 shows the upper part of a flint arrow or spear head which came from the dark area shown at the right side of the stalagmite and about half way down from the top in the dirty part (Fig. 11). This was a small pocket of ash and charcoal with much less limestone impregnation than the remainder of the stalagmite. This flint point dates from about 400 B.C.

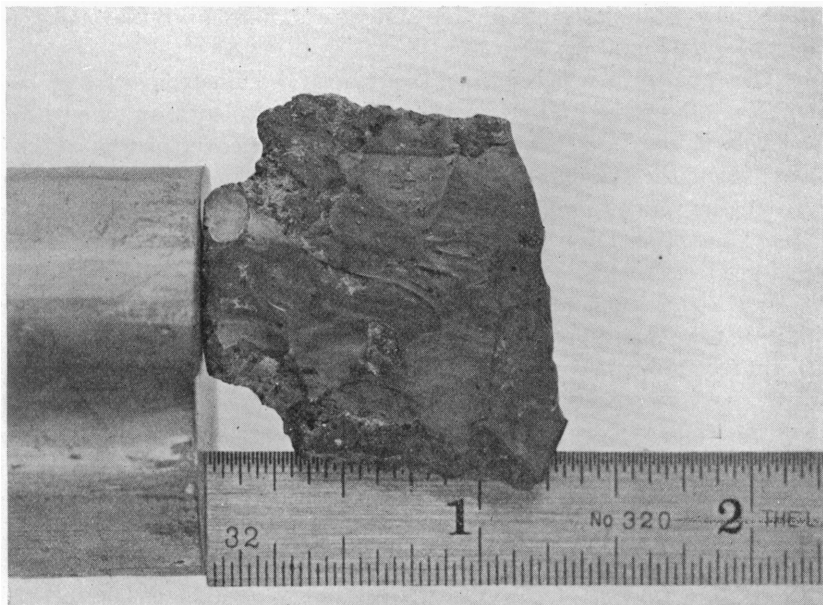


Fig. 14. Part of a Chipped Object from the Face of Stalagmite No. 3, F (fig. 11).
Approximate date, 400 B. C.

The stalagmite reached the overhang above it in 13 B.C. and Fig. 11 shows that the ash-level rose with it. Moorehead and Peabody¹ however, found 40 cm. of stalagmite No. 3 above the ash-level in 1903 A.D. The ash-level had settled 40 cm., in the 1916 year interval between 13 B.C. (or, possibly, some time later) and 1903 A.D.

It is evident from Jacob's map² that Moorehead and Peabody con-

¹Peabody and Moorehead, *ibid.*

²Peabody and Moorehead, *ibid.*

sidered the rear wall of the stalactite crevice as the rear wall of the cavern. Taylor's revision of this map (Fig. 4) shows, however, that this wall is an overhang and that there is a limited cavern area back of and beneath the rear wall of the stalactite crevice.

The ash level which was touching the overhang in 13 B.C. slowly settled until it was 40 cm. below the overhang in 1903 A.D. Even 40 cm. is too little to permit of human occupation; any sign, therefore, that the cavern area behind and beneath the overhanging rear wall of the stalactite crevice could have been occupied by man dates from before 13 B.C. Any artifacts of a later date from this part of the cavern would suggest the later use of this area as a storeroom, burial place, or cache of some kind.

The rapid drip which formed the increased diameter part of stalagmite No. 3 dissolved and removed the limestone to such an extent that relatively large channels were formed in the rock cover of the cavern. Later, when the stalagmite reached the overhang and continued up the overhanging wall as a leaf stalactite, the deposited limestone blocked the channels at their lower end so that the drip, then much diminished, was forced elsewhere.

When the stalagmite was removed in the fall of 1923 these large channels were again opened so that an intermittent drip now occurs in the wet season at the point where the stalagmite formerly existed. The drip starts very soon after a rainstorm, rapidly increases to its greatest flow, and then rapidly decreases after the rainstorm has ceased. This indicates the large size of the drip channels and their direct connection with the surface. The small time interval that this water spends in the limestone during its descent from the surface to the cavern interior, together with the present scarcity of surface soil above the cavern (presumably this soil was washed away in the rainy period starting in 1226 B.C.) explains the small amount of lime in the present drip and why there is so little stalactitic or stalagmitic deposition going on now. A thick soil above the cavern would grow a large amount of vegetation and retain the decayed vegetation. This would furnish carbonic acid to water percolating through it and thus confer upon this water the power to dissolve limestone and carry it down to the cavern interior where it would be deposited as stalactite or stalagmite. A limestone solution, containing all the limestone it can dissolve, carries 9.2 parts of limestone per 10,000 parts of water. A sample of the drip over the place formerly occupied by stalagmite No. 3, taken in the spring of 1924, imme-

diately after a rainstorm, by Vance Randolph, contained 1.25 parts of limestone in each 10,000 parts of water (analysis by L. R. Carl).

Hence, according to the stalagmite record, the human habitation of Jacob's Cavern started at the same time as the cool rainy period, about 1226 B.C., and continued for an indefinite period; at least somewhat later than 13 B.C. So, the upper, black earth layer, removed by Moorehead and Peabody¹ in 1903, was formed from 1226 B.C. up to and beyond 13 B.C. One may suspect then that the inhabitants of the locality entered the cavern to secure shelter from the cold and wet.

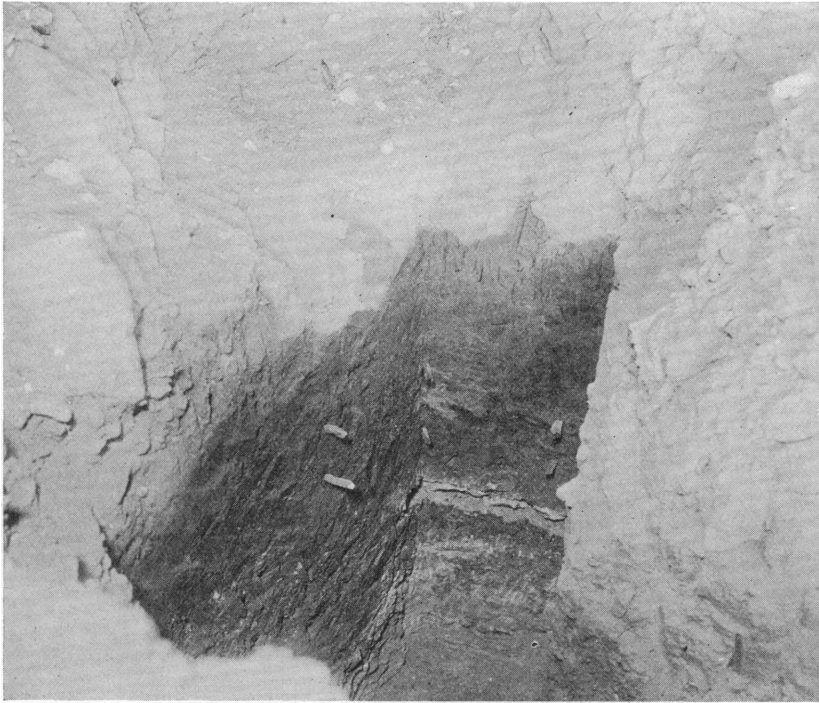


Fig. 15. Cedar Pegs delineating Layer 3 in the 1921-1923 Test Pit.

COMPOSITION AND AGE OF THE CAVE EARTH

In 1921 a test pit was sunk in the Cavern floor by Dr. Clark Wissler, Mr. J. L. B. Taylor, Mr. Vance Randolph, and the author. Indications of a second darker layer in the red clay, underlying the upper black layer,

¹Peabody and Moorehead, *ibid.*

were found and samples of the several layers were taken and subjected to chemical analysis.¹ The results were so promising that in 1923, when a trench was dug from the front to the rear of the cavern along the bed-rock, under the direction of Mr. N. C. Nelson, a connecting link was cut over from this trench to the 1921 test pit. This pit was then enlarged and the sides dressed perpendicularly to permit of accurate observation. An intermediate, well-defined, fine-grained, bluish clay layer, about 10 cm. thick, was found in the red cavern clay. This color contrast does not register in a flashlight photograph so this bluish layer was delineated with small cedar pegs and the photograph then taken; the correct placing of the cedar pegs was examined and vouched for by Messrs. Nelson, Taylor, and Randolph, just before taking the picture. This layer is shown in Fig. 15.

Careful samples were taken, of the several layers and the results of the chemical analysis of the samples follow.

Analysis of Layers in Jacob's Cavern
Location and Description of Layers Given in Fig. 16

Constituent.....	1st layer Light black fluffy dirt	2nd layer Compact red clay	3rd layer Fine- grained bluish clay	4th layer Compact reddish clay
Silica (SiO_2).....	20.50	71.44	60.20	47.56
Alumina (Al_2O_3).....	5.49	9.74	13.78	6.87
Iron Oxide (Fe_2O_3).....	1.46	4.21	4.21	2.48
Lime (CaO).....	41.36	2.06	3.70	18.83
Magnesia (MgO).....	0.94	1.66	1.26	1.04
Titania (TiO_2).....	0.25	0.65	0.65	0.65
Manganese (Mn).....	0.10	0.23	0.05	0.18
Phosphorous (P).....	1.76	0.13	0.34	0.09
Potash (K_2O).....	0.33	2.12	3.04	2.87
Soda (Na_2O).....	0.09	0.61	1.01	0.98
Ignition Loss.....	28.28	7.42	11.66	17.93

Attention is called to the amount of iron oxide and phosphorus in the four layers. There is so much organic matter in the top layer (Layer 1) that the color due to the iron content, 1.46 percent, cannot be discerned. Layer 3, however, even though it contains as much iron oxide

¹These samples were analysed by Mr. Harold Brandenburg, Mr. S. O. Jones, Mr. Charles Stelle, and Mr. Maurice Walker, under the supervision of Professors James A. Yates and J. B. Quig, all of the State Teachers College at Pittsburg, Kansas. When more valid samples were taken in 1923, it was thought best to have them examined by an expert in clay analysis. Doctor M. H. Thornberry of Rolla, Missouri, kindly consented to make the clay analyses, and to analyse the stalagmite. The author gratefully acknowledges his indebtedness to these men.

(4.21 percent) as layer 2 and more than layer 4 is not red but bluish. The iron in Layer 3 is ferrous iron and was reduced by organic matter.

The source of this organic matter is shown by the phosphorus content of the several layers. If 0.13 percent of phosphorus is considered as the phosphorus content of the surface clay of the region, all phosphorus over 0.13 per cent is derived from other sources. Deducting the 0.13 per cent, the phosphorus derived from other sources is:—

Layer 1	Layer 2	Layer 3	Layer 4
1.63	0.00	0.21	0.00

Layers 3 and 1 are seen to contain phosphorus derived from sources other than the surface clay of the region and Layer 1 still contains 2.65 percent of undecayed bones. Bones consist of sufficient calcium phos-

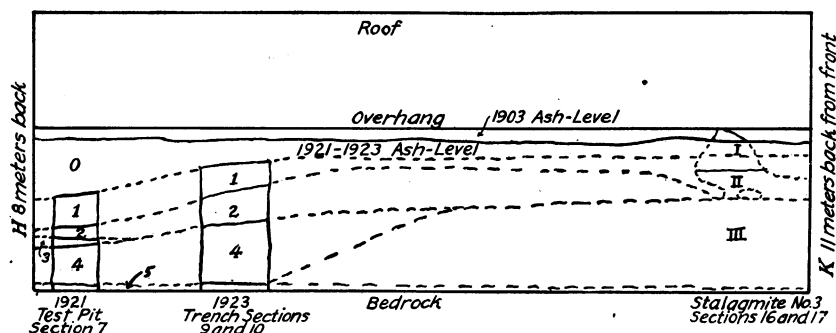


Fig. 16. Transverse Section of the Cavern. Section from H line on West to K lines on East (Fig. 4). Approximate scale 1 centimeter equals 0.5 meter.

- Layer 0 Removed by Moorehead and Peabody in 1901. Ash.
- Layer 1 Black, ash, loose dirt, charcoal, bones, and flints.
- Layer 2 Compact red clay. Few flints, no bones or charcoal.
- Layer 3 Bluish gray, compact clay, fined-grained. Bones, small amount of charcoal, and some foreign flint fragments.
- Layer 4 Red compact clay. Full of small slab rocks in several layers.
- Layer 5 Whitish, rotten, shaley rock.
- Stalagmite layer I Dirty gray with ash. Full of flints, bones, and charcoal.
- Stalagmite layer II White, almost pure calcium carbonate. No flints, bones, or charcoal.
- Stalagmite layer III Red. Heavily contaminated with clay.

phate to give about 40 percent of their weight as phosphorus. The percentage of decayed bone represented by the above amount of phosphorus is:—

Layer 1	Layer 3
4.0	0.53

Layer 3 is thus seen to be of animal origin, and from the large content of bone refuse, of carnivorous origin.

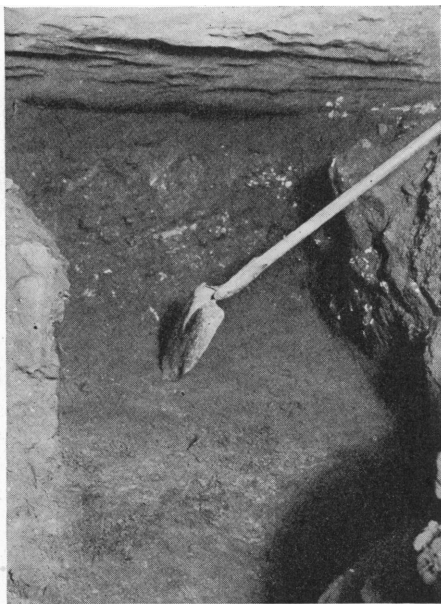


Fig. 17. One Square Meter of Layer 3 exposed.



Fig. 18. Bones from Layer 3.

The 1921 test pit was again opened in September, 1924, and Layer 3 readily located by means of the cedar pegs which had been left in place when the pit was filled up again at the close of the work in 1923. Layers 1 and 2 were completely removed, in a direction towards the nearest wall (Fig. 4), over an area of about one square meter and care taken that no material from Layers 1 and 2 fell down upon Layer 3. The one square meter area of Layer 3 is shown in Fig. 17.

Layer 3 was about 10 cm. thick and a little less than one half of one square meter of this layer was removed, giving about 80 kilograms of the bluish clay. Fifty-six kilograms, representative of the whole amount removed, was placed in two burlap bags, 28 kilograms to the bag, and carried down to Little Sugar Creek where the clay was removed by moving the burlap bags around in the water. The clay came out through the openings in the bag, suspended in the water, and was carried away by the running water. When the contents of the two bags had decreased to about 5 kilograms each, the entire 10 kilograms was carefully transferred to a muslin bag and the washing continued until the creek water was no longer colored by the clay from the interior of the bag.

The material remaining in the muslin bag, about 3 kilograms, was spread upon a blanket and, after drying about 30 grams of rock fragments mostly flints, and about 16 grams of bone fragments were culled from the mass of small rocks, pebbles, etc.

CHARCOAL

The remaining material was then placed in a large, shallow pan and again taken to the creek where the material was "panned." This resulted in the recovery of two or three very small pieces of a substance resembling charcoal. These were later identified, under the microscope, as charcoal, by Doctor Rheinhardt Thiessen, paleobotanist of the Bureau of Mines, Pittsburgh Station.

THE ROCK FRAGMENTS

Six or seven of the flint fragments consisted of flint which is not native to the vicinity of the cavern. None of these fragments could be positively referred to human origin although one of them was a small conchoidal flake, triangular, and about 1 cm. on the edge. Four of the rock fragments were of fire-burnt limestone and sandstone. The rock fragments were placed in dilute hydrochloric acid for cleaning purposes and after the acid bath had completed its work it was found that one of the small pieces, thought to be rock, had been, in reality, a small piece

of bone, mineralized and encrusted with calcium carbonate; the piece of bone was undeterminable and the only mineralized piece found.

THE BONE FRAGMENTS

These were identified by O. A. Peterson, Vertebrate Paleontologist of the Carnegie Museum of Pittsburgh; the snail was identified by Dr. A. E. Ortman, Invertebrate Paleontologist of the same Museum.

The identifiable fragments were as follows:—

Fish	Teleostean. One vertebra.
Rodents	{ Microtus, Species? Lower jaw with teeth and isolated teeth.
	{ Synaptomys, Species Cooperi? Fragment of jaw with one tooth and front of jaw referred to the same genus.
	{ Sciurid? Squirrel. Broken cheek tooth and incisors.
	{ Lepus? Hares. Isolated teeth representing perhaps two species.
Felid	Lynx? Canadensis?, or possibly, Felis pardalis. Upper sectorial (right side).
Snail	Endodontidæ Helicodiscus lineatus (Say).
	Numerous fragments of limb and foot bones of rodents and perhaps other small mammals in addition to many undeterminable fragments.

This list may be considered as a typical late Pleistocene cave fauna for this country (Peterson).

The bone fragments are shown in Fig. 17 where it will be noticed that about half of them are blackened; this blackening may be due either to slow oxidation or to charring by fire. At least part of the blackening of the bones is attributed to fire because of the presence of the small fire-burnt limestone and sandstone fragments and the small pieces of charcoal found with the bones. The presence of fire in a wet cave, 7 meters back from the entrance, indicates a human source for the fire. The fragments of flint, not native to the vicinity, also support this view.

One of the striking things about these bone fragments is the absence of large bone material. The presence of the phosphorus in the deposit shows that there was originally considerably more bone material in the layer than there is now. If the three or four fragments of bones marked A in Fig. 18 are examined it will be seen that they are shapeless pieces of large celled bones, or large bones.

The larger bones decay, in the presence of an abundant supply of oxygen of the air, more rapidly than the smaller bones, because the larger cells and more open structure permit of freer access of the oxygen. Herbivorous animal bones are also more easily oxidized than carnivorous animal bones, for the same reason. The few shapeless pieces of larger bones are the last remaining evidence of the larger bones of the deposit

which decayed and left behind their phosphorus content as calcium phosphate. The complete disappearance of the larger bones indicates a long period in which the cavern was open to the air, but unoccupied.

Fig. 19 shows the red Layer 2, sloping down and away from a central red clay mound lying beneath the stalactite crevice. It is possible to interpret the preceding chemical and physical data and with the aid of

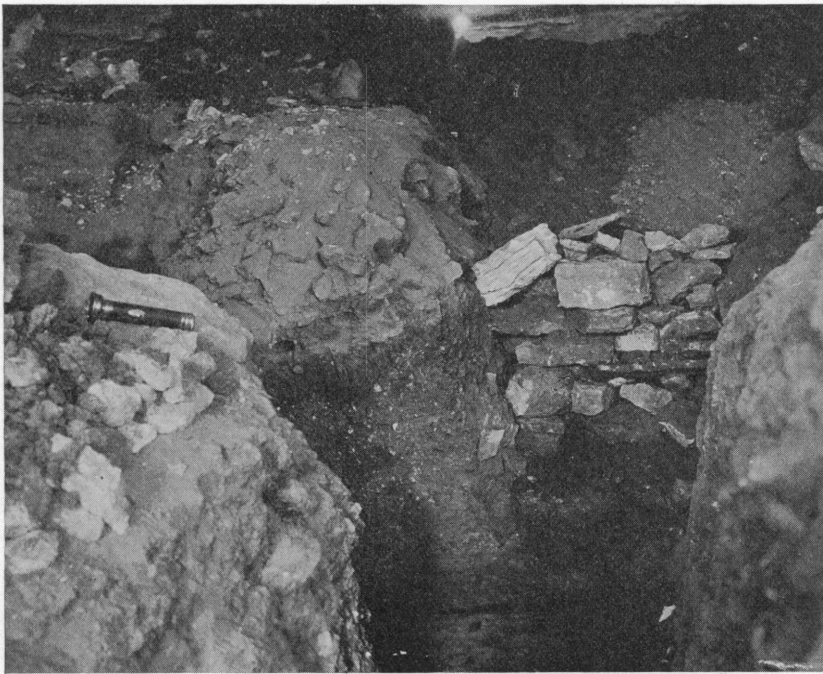


Fig. 19. Layer 2 sloping down and away from the Center.

Fig. 16 to reconstruct the past history of Jacob's Cavern. It was the first of a series of caves formed by the dissolving and removal of the limestone by carbonated water. The insoluble part of the limestone fell to the bottom of the cave and remains there as the thin, rotten, whitish layer of rock shown as Layer 5 in Fig. 16. Later, a large volume of water, flowing in, and completely filling the present flood plain of Little Sugar Creek, undermined the bluff to such an extent that the front part of the chain of caves fell away, leaving the series of open

caverns or shelters which still exist. This large flow of water was due to a cool, rainy climatic period which also caused a large amount of red clay to flow down the crevice at the rear of Jacob's Cavern; this crevice is the remains of the old sink-hole which was originally responsible for the formation of the chain of caves. This red clay formed a mound under the crevice, shown by Layer 4 in Fig. 16, and, as the cool rainy period slowly decreased, the amount of water entering the cavern through the crevice decreased to such an extent that no more clay flowed into the cavern. The flow of lime water was still sufficient to form the lower stalagmite, III of Fig. 16, which consists of the red clay mineralized by the lime water. Later, this flow of water almost entirely ceased, due to the final passing of the cool rainy period, and the stalagmite tapered off and practically died as shown by the narrow connecting neck between III and II in Fig. 16.

The cool rainy period would have forced the inhabitants of the region to seek shelter in caverns having a southerly exposure. We have shown that they entered Jacob's Cavern and could at first only inhabit the edges of the cavern, away from the wet sticky red clay mound in the center, but later occupied the whole cavern floor. The cavern was probably continuously, although possibly sparingly, inhabited for the duration of this cool, rainy period and the cool windy period which followed. This is estimated as from 16,080 B.C. to 11,730 B.C., dates proposed by the writer in an earlier publication.¹ About 11,730 B.C.,² a more genial climate, similar to that of today, returned and the inhabitants abandoned the cavern and lived in the open. The cavern was then unoccupied for a relatively long period, 10,500 years, and the oxygen of the air had ample time to oxidize almost completely the larger bones on the cavern floor.

Another cool rainy period occurred in 1226 B.C. and a second flow of red clay came down through the stalactite crevice and washed the loose debris of the cavern floor down to the edges of the central clay mound, forming Layer 3. This red clay then formed Layer 2 on top of Layer 3. Once again this cool rainy period would have forced the inhabitants of the region to seek shelters with a southerly exposure. The flow of red clay ceased and the formation of part II of the stalagmitic formation shown in Fig. 16 occurred while the inhabitants of the cavern occupied only the edges of the central clay mound. Later, they occupied the entire cavern floor, with the exception of immediately under the drips

¹Allison, Vernon C., "Quaternic and Tertic Chronology" (*The Pan-American Geologist*, vol. 42, no. 3, pp. 199-217, October, 1924).

²Allison, *ibid.*

in the wet season, and part I of the stalagmite grew at this time. The last continuous occupation of Jacob's Cavern was from 1226 B.C. to about 1 A.D.¹ when the present genial climatic conditions again returned and the cavern inhabitants abandoned the cavern for the open.

The cavern has probably been intermittently occupied by several different peoples since 1 A.D.

CONCLUSIONS

Jacob's Cavern was continuously, although perhaps sparingly inhabited for a period of about 4,350 years, from 16,080 B.C. to 11,730 B.C.² (Gschnitz Ice Advance of the Alps, Goti-Glacial of Scandinavia, and the Lake Border Ice Advance of the United States). The cavern was then unoccupied for a period of about 10,500 years, from 11,730 B.C.³ to 1226 B.C. (Gschnitz, Goti-Glacial, or Lake Border Interglacial period), and again continuously inhabited for a period of about 1,227 years, from 1226 B.C. to 1 A.D. (Daun Ice Advance of the Alps, Fini-Glacial of Scandinavia, and the Port Huron Ice Advance of the United States). The cavern has probably been intermittently occupied or visited by different aboriginal tribes from about 1 A.D. to historic times. (Recent or Daun, or Fini-Glacial, or Port Huron Interglacial.)

Jacob's Cavern and the talus slope below it should be completely excavated, horizontally, to investigate further the indicated occupation from 16,080 B.C. to 11,730 B.C.

¹This date, wherever used in this paper is merely approximate, indicating simply the beginning of the Christian Era.

²Allison, *ibid.*

³Allison, *ibid.*

NOTES ON THE INCISED BONE

These studies in Jacob's Cavern were inspired by the discovery of worked bones, one of which bore a design suggesting a mastodon. This puzzling specimen was critically studied by the author, for, this artifact, if authentic, is the first human record of the contemporary existence of man and the mastodon in America.¹ The co-existence of man and the woolly mammoth in Europe is now well known through the publications of Breuil, Mäska, E. Lartet, Osborn, and others; paintings and carvings of the woolly mammoth are found in many caverns and open stations in France, Spain, Moravia, etc.² There are three possibilities as to the mastodon carving from Jacob's Cavern: it may be an old carving upon an old bone; it may be a recent carving upon an old bone; or it may be a recent carving upon a recent bone. In the following pages the carved bone under discussion will be compared photographically, under several different wave lengths of light, with a recent carving upon an admittedly old bone and a recent carving upon a recent bone.

The age or genuineness of an artifact is only known, *a priori*, when it is found in a layer of material which can be confidently described as "undisturbed" by competent authority. All other cases must be labelled "doubtful" unless they respond favorably to later examination in which as definite tests as possible are applied, for too much trust may easily be placed in mere superficial examination. There should be no hesitancy in regard to the application of these more or less definite tests as a doubtful artifact is relatively worthless to science. The method of approach to the problem followed here depends upon the comparative response of the artifact to various limited wave lengths of light recorded upon photographic plates sensitive to the entire visible spectrum; several similar objects of a known age are necessary for comparison in this plan of investigation.

The carved bone under discussion is the left humerus (upper arm bone) of a deer; it is probably from an old male of a Virginia Deer and has the upper end broken. Fig. 20 shows the "mastodon" side and Fig. 21 shows the reverse of the bone. The carved bone was found on April 17, 1921, by J. L. B. Taylor and Vance Randolph in Jacob's Cavern.³ According to the accounts given by the discoverers, the bone was found in a small mound of loose dirt occupying the space formerly

¹Taylor, J. L. B., "Did the Indian Know the Mastodon" (*Natural History*, vol. 21, no. 6, pp. 591-597, 1921).

²Osborn, Henry Fairfield, *Men of the Old Stone Age*, New York, 1919 (283, 316, 348, 349, 397, 398).

³Taylor, J. L. B., "Discovery of a Prehistoric Engraving Representing a Mastodon" (*Science*, N. S. vol. 54, no. 1398, October 14, 1921, 357; *Natural History*, *ibid*).

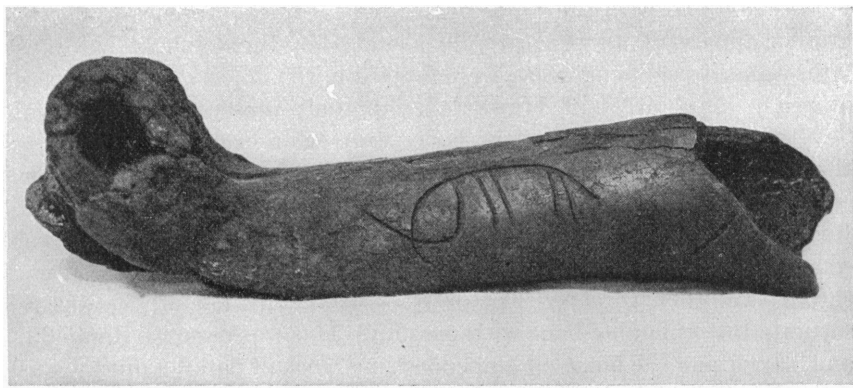


Fig. 20. "Mastodon" Side of the Carved Bone.

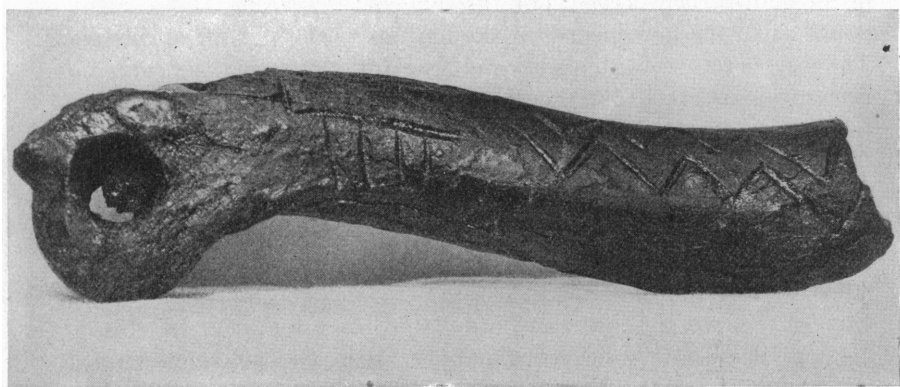


Fig. 21. The Reverse Side of Carved Bone showing Additional Carvings.

occupied by stalagmite No. 4 (Fig. 4). The bone was thought to have been removed from beneath the overhang by rodents or by people seeking to satisfy the universal curiosity inspired by caves. Seven other carved and perforated bones and one perforated mussel shell were reported as found with the "mastodon" bone. In the absence of photographic apparatus, all were carefully sketched by Randolph. Some days later signs of beginning decay were noticed in the objects and they were dipped in "hard oil" (boiled linseed oil), the only preservative available. Several weeks passed before the bones were again examined and it was then found that all the carved and perforated objects, with the sole exception of the "mastodon" bone, had completely disintegrated. Randolph immediately communicated with the author, who, in turn, sought the technical advice of the Carnegie Museum of Pittsburgh, through the then Director, Doctor W. J. Holland. The advice was to saturate the remaining bone with paraffin. This was done by Randolph and Taylor and the bone left embedded in a block of paraffin until it was melted out by the author in the presence of Doctor Clark Wissler, Curator of Anthropology, American Museum of Natural History in August, 1921.

Unfortunately, these engraved and perforated objects were not found in an undisturbed layer. For this and other reasons, the element of doubt as to the genuineness of the find arose at the time of discovery. The discoverers were so skeptical of the authenticity of the carved and perforated artifacts that they refused to permit details to be published until the matter had been investigated by competent authorities.

The cavern was investigated in September, 1923, by the American Museum of Natural History; the work was under the supervision of Mr. N. C. Nelson, Associate Curator of Archaeology in that Institution. Nelson trenched the talus and the deposit remaining in the cavern, but failed to find additional archaeological evidences of antiquity. On the basis of this work, there were formulated three tentative questions reflecting, in a purely negative manner, upon the genuineness of the "mastodon" bone.

1. Why were no other carved or perforated bones found in the cavern by previous investigators over a period of eighteen years, from 1903 to 1921?

2. Some 6,000 pieces of bones were removed from the cavern during the progress of the 1923 work. Why were none of these specimens carved or perforated?

3. Seven other carved and perforated bones and one perforated mussel shell were found with the "mastodon" bone. Why did all these

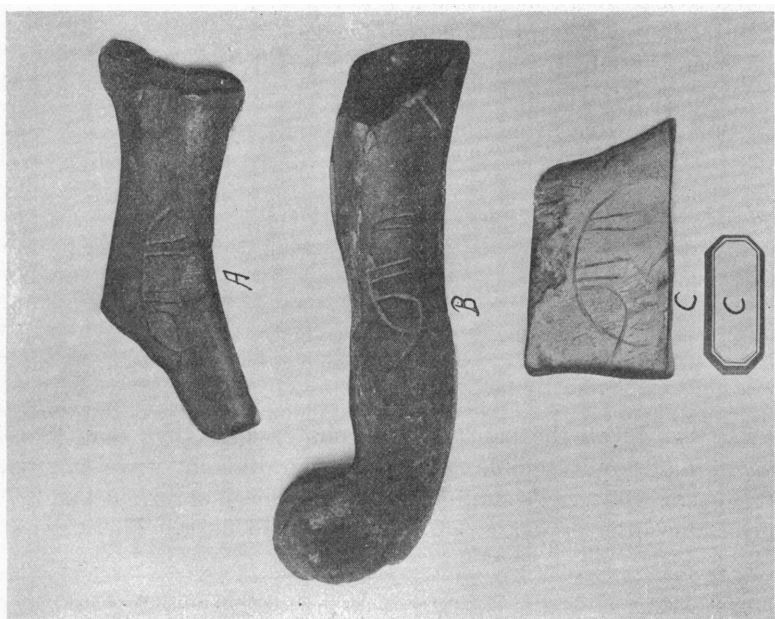


Fig. 22. Panchromatic Plate, W. and W. contrast Light Filter C.
A, Recent carving on an old bone; B, Carving on the original bone;
C, Recent carving on a fresh bone.

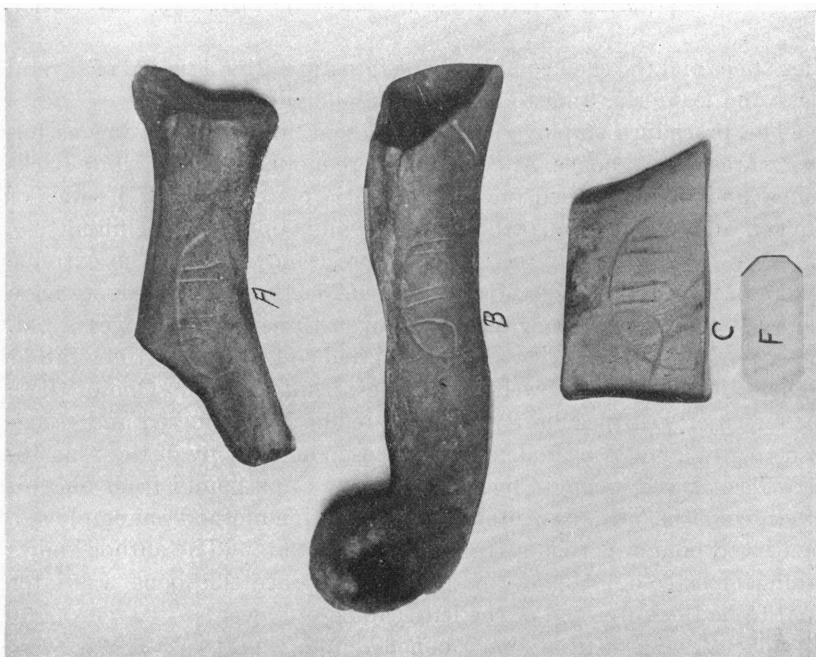


Fig. 23. Panchromatic Plate, W. and W. Contrast Light Filter F.

other bones and the shell completely disintegrate after a period of several weeks and leave the "mastodon" bone alone almost intact?

The procedure employed in the present investigation was as follows: three carved bones, A, B, and C, were mounted with a white background and photographed on panchromatic plates through a series of Wratten and Wainwright orthochromatic and contrast color filters.

Bone A. Several pieces of bone were removed from the extreme bottom of the top layer of the cavern in 1923; these specimens we have estimated in the preceding pages as over three thousand years old. These were laid away to dry and in 1924 had so far dried as to be rather fragile, but, however, showed no signs of disintegration. One of these specimens, of such peculiarity as to be readily remembered and recognized (badly gnawed by rodents) was chosen and a copy of the "mastodon" was carved upon it by the author. Flint points from Jacob's Cavern were the only edges used and the scraping method was employed. The carved bone was then saturated with paraffin. (The author knows nothing of osteology, but by a queer coincidence this bone was later found to be the lower end of the left scapula of a deer.¹)

Bone B. The "mastodon" bone.

Bone C. A fresh beef bone, "skinned" from the meat by a butcher, carved and treated in a similar manner as Bone A.

Each of the photographs thus contained:—

Bone A. Recent carving on admittedly old bone

Bone B. Carving of unknown age on bone of unknown age

Bone C. Recent carving on admittedly recent bone

Filter	Color
None	Normal daylight
K ²	Light yellow
G	Strong yellow
A	Orange red
B	Green
C	Deep blue
F	Deep red
X-ray ²	

It was seen in all the panchromatic photographs that Bone B is uniform in color, and resembles, through seven different wave lengths of light, Bone A, which is also uniform in color. This is shown in Fig. 22, C, or deep blue filter, and Fig. 23, F, or deep red filter. There are a

¹Identification by O. A. Peterson, Vertebrate Paleontologist, Carnegie Museum, Pittsburgh.

²X-ray picture through the courtesy of Doctor Lawrence F. Jablonski.

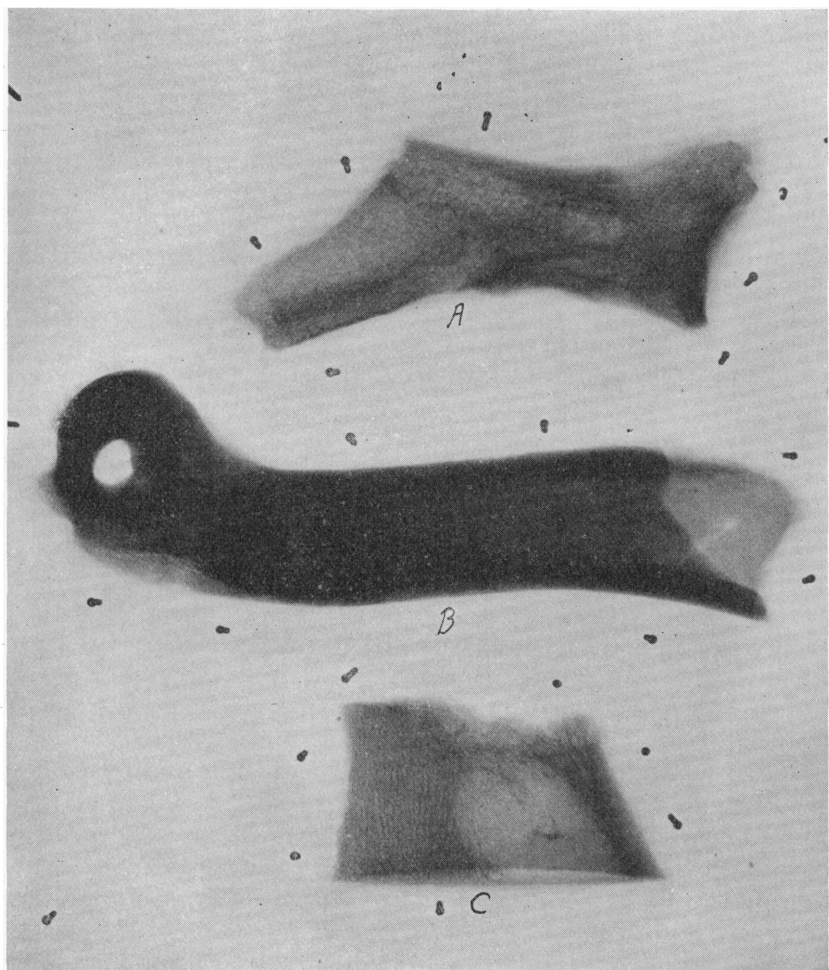


Fig. 24. X-Ray Photograph of the Bone Series.

number of methods of completely removing the mineral matter from a bone without much change in the organic matter content, with dilute acids, for example. However, to remove the organic matter completely from a bone and by so doing discolor the bone uniformly, is a difficult task. Boiling has been suggested as a method to produce this result, but the outcome is doubtful. It is asking too much of the law of probability that an artificially aged bone (or aged in a short time) could, through seven different wave lengths of light, so completely and uniformly resemble a bone which required three thousand years to age, according to the previous estimate. In any case the tests show that Bone B is as old as Bone A.

A careful examination of the seven panchromatic photographs also revealed that the ease with which the carving can be seen—the contrast between the carving and the bone—varies according to the following order.

Filter	Color	Order of Contrast		
None	Normal daylight	B	A	C
K ₂	Light yellow	B	A	C
G	Strong yellow	B	A	C
A	Orange red	B	A	C
B	Green	B	A	C
C	Deep blue	B	C	A
F	Deep red	A	B	C

The contrast between the bone and the carving is evidently greatest with the two older bones, A and B; the contrast is also greater with B than with A. The first is due to the color change induced by oxidation and the second is due to a combination of two effects:

a. The surface of Bone B, Fig. 22 and 23, has apparently been polished.

b. The substance at the bottom of the grooves in the carving on Bone B has been oxidized to approximately as great an extent as the bone surface itself and, composed of somewhat different material, has taken on a slightly different oxidation color.

This all points to the carving on Bone B as being as old as the bone itself, which we have estimated at more than 3,000 years.

Fig. 24 shows that Bone A is more mineralized—casts a deeper X-ray shadow—than the Bone C. This mineralization was obtained through the loss of organic matter content. Bone B is also seen to be more highly mineralized than Bone A. This added mineralization was obtained through impregnation with limestone (calcium carbonate, CaCO_3).

This is shown by the absence of the bone cell structure in the thin part of Bone B, at the extreme right of Fig. 24, and by the variation in the apparent specific gravity.

Bone	Apparently Specific Gravity at 25°C.
A	1.53
B	1.69
C	1.64

The bones are all saturated with paraffin which would tend to minimize the difference in apparent specific gravity. The limestone impregnation would shut off access of the oxygen to the bone and thus prevent further oxidation; the color of Bone B, however, shows that it had oxidized to as great an extent as Bone A before it was mineralized and Bone A required 3,000 years to be oxidized to its present condition (Bacterial action played a part in this oxidation). Careful scrutiny of the wavy marks on Bone B shows that these marks, at least, were made before the bone was mineralized. Hence, Bone B, with its "mastodon" carving, is older than 3,000 years, or the assumed age of Bone A.

The artist who carved Bone B was familiar with the mastodon and carved it at a time when the climate was so cool and rainy that the mastodon ranged as far south as the vicinity of Jacob's Cavern. (There is here a possibility that the bone was carved in the north and then brought southward to Jacob's Cavern.) Furthermore, this period preceded the cool rainy period which started in 1,226 B.C. Thus the period in which the bone was carved started in 16,080 B.C.¹ and corresponds to the Gschnitz Ice Advance in the Alps. As stated previously, Jacob's Cavern was inhabited during this cool rainy period; but later, when a genial interglacial climate (something similar to that of today) returned, the inhabitants abandoned the cavern and lived in the open. This was about 12,000 B.C. and for a long subsequent period, over 10,000 years, the cavern was not inhabited. During this long intervening period the bones in the cavern floor refuse were exposed to the air and the larger celled bones, those from larger animals, were almost completely oxidized and disappeared, leaving behind them only the smaller bones (those with smaller cells and thus, generally speaking, from smaller animals) and the calcium phosphate from their own decomposition. This calcium phosphate shows up in the chemical analysis of the layer formed from this deposit. The seven carved and perforated bones and the perforated

¹Allison, Vernon C., "Quaternic and Tertiary Chronology" (*Pan-American Geologist*, vol. 42, October 1924, pp. 199-216, Des Moines, 1924).

shell were strung as a necklace (possibly) and were cached under clay or cavern earth in such a manner as to be protected, to a certain degree, from the oxygen of the air; they did, however, oxidize to such an extent that when they were exposed to the air and dried out in 1921 A.D. all the carved and perforated objects, except one of the bones, disintegrated. The "mastodon" bone did not disintegrate because the end farthest away from the perforation had been mineralized at some period during its long rest in the cache. The mineralization was progressive and is heaviest at the end farthest away from the string and least at the string end, as shown by the fact that the broken end is so heavily mineralized that the difference in thickness between the wavy carving and the uncarved bone is important enough to be apparent in the X-ray shadow picture (Fig. 24) and also by the absence of bone cell structure at that end of the bone.

It is now possible to answer the three questions which emerged at the conclusion of the excavation of Jacob's Cavern in 1923 and which seemed to cast doubt upon the genuineness of the "mastodon" bone.

1. No other carved or perforated bones or shells were ever taken from Jacob's Cavern because these bones belong to the layer which started forming in 16,080 B.C. and this layer was not recognized until recently and has been merely touched upon in excavation work.

2. The 6,000 pieces of bone taken from Jacob's Cavern in 1923 were all from the layer which started forming in 1,226 B.C.; none from the layer which started forming in 16,080 B.C.

3. The carved and perforated bones (and the perforated shell) were so much older than any other bones or shells taken from Jacob's Cavern and had thus been so much more completely oxidized that they fell to pieces on losing their moisture when exposed to the air; the sole exception was the "mastodon" bone which had become impregnated with limestone.

Objection has been raised to the smoothness of the carvings upon the "mastodon" bone as indicating that they were not made with stone edge tools. The edges of the carving were exposed to the oxygen along two sides (about 90° apart) while the uncarved bone surface was exposed to the oxygen only on one side; the long exposure to oxidizing conditions would have this very effect of smoothing the carving, due to excessive oxidation of the edges of the carving. It is impossible to say what the carving looked like when it was first made.

Attention has also been called to the fact that the perforating of this bone has been from both sides, possibly to avoid chipping or splintering

an old bone when the drill emerged. This, and the fact that the two holes taper and grow smaller as they meet at the center of the bone (does not indicate a cylindrical drill), just as strongly indicates that the holes were made with a stone drill with its recognized limitations of shortness and taper. These two holes also meet each other at a slight angle; this would seem to dispel the conjecture that the "mastodon" bone was designed to be used as a shaft-straightener. The perforation was probably for the purpose of running a string through the bone to assist in carrying it.

Notice has also been directed to the effect that the carvings all miss the weathering cracks on the bone, or were carved after the cracks were made. Fig. 21, however, shows several diagonal cracks at the right end of the wavy lines and the head part of the animal at the left takes advantage of a crack; coincidental.

CONCLUSIONS

The physico-chemical evidence indicates that the carving of the "mastodon" reported as found in Jacob's Cavern on April 17, 1921, by J. L. B. Taylor and Vance Randolph, dates back to somewhere around 16,000 to 12,000 B.C., in the writer's chronological scheme, when the climate of this vicinity was such as appealed to the mastodon. This climate was cool and rainy and corresponds to the Lake Border glacial episode of America, the Goti-Glacial of Scandinavia, and the Gschnitz glacial episode of the Alps.¹ The carving may have been made further north and then brought southward to Jacob's Cavern. The date of 12,000 B.C. may then be of the nature of a minimum date.

¹Dachnowski, *ibid.*, 225.

TWO NEW BOOKS
ON
ANTHROPOLOGY

PUBLISHED BY
THE AMERICAN MUSEUM OF NATURAL HISTORY

LOCKE, L. L. THE ANCIENT QUIPU OR PERUVIAN KNOT RECORD

84 pages of text, 59 plates, 17 text figures, 1 map. R. 8vo., blue cloth.

Mr. Locke clearly demonstrates that the quipu was used for numerical records and points out the impossibility of recording history and folklore by this means, as early historians believed. Mr. Locke has succeeded in locating forty-nine quipus, of which forty-two are in the collections of The American Museum. Price, \$3.00.

SULLIVAN, LOUIS R. ESSENTIALS OF ANTHROPOMETRY

72 pages, 15 illustrations. Black leatherette, flexible, pocket size.

Dr. Sullivan has prepared this small book for the assistance of field workers in physical anthropology. Price, \$.75.

