SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 99, NUMBER 23
(End of Volume)

EVIDENCES OF EARLY OCCUPATION IN SANDIA CAVE, NEW MEXICO, AND OTHER SITES IN THE SANDIA-MANZANO REGION

BY
FRANK C. HIBBEN
University of New Mexico

WITH APPENDIX ON

CORRELATION OF THE DEPOSITS OF SANDIA CAVE, NEW MEXICO, WITH THE GLACIAL CHRONOLOGY

BY
KIRK BRYAN
Harvard University

(WITH 15 PLATES)

(PUBLICATION 3636)

CITY OF WASHINGTON
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FOREWORD

Foremost among those to whom the writer is indebted are the students who gave unstintingly of their time and abilities without compensation. Among those who worked in Sandia Cave are: Mary Dalby, Margaret Young, Henry Robertson, Anne Dietz, Jean Cady, William Witkind, Adolph Bitanny, Robert Sieglitz, Ruth Smith, Martha McNary, Julian Olmstead, Adger King, Dan McKnight, Barbara Clark, Louise Diltz, Mary Ann Garrett, Mary K. Higgs, Mary Lehmer, Jane Olson, Ernst Blumenthal, James Spuhler, Carroll Burroughs, Robert Ariss, Charles Lange, James Greenacre, Robert Easterday, and Gordon Page.

Wesley Hurt aided in locating Folsom material in the vicinity of Albuquerque and Manzano. Robert Bell photographed the excavations and Charles Kepner helped in the final photographing and cataloging of the artifacts. Robert Jones and Robert Sieglitz were the surveyors and engineers and Robert Lister the draughtsman who plotted the many sections and maps in their final form. Wesley Bliss, then at the University of New Mexico, excavated the Davis Cave and aided the writer in the initiation of the excavations of Sandia Cave itself.

The author is especially indebted to Prof. Kirk Bryan, Department of Geology and Geography, Harvard University, for the working out of the geologic aspects of Sandia Cave and for advice and suggestions on the interpretation of the information obtained in the excavations.

Acknowledgment is gratefully made to Dr. E. B. Howard, University Museum, Philadelphia, for many suggestions and ideas and for help in excavating Sandia Cave; to Dr. Chester Stock, California Institute of Technology, for coming from Pasadena to examine a hearth and some material in situ and for contributing valuable data from his great knowledge of Pleistocene fauna; to Donald Scott, Dr. Earnest A. Hooton, Dr. Helmuth de Terra, Dr. Stuart Northrop, and Dr. W. W. Hill for suggestions and comparative information offered when they visited the site during excavation.

Dr. Frank H. H. Roberts, Jr., Bureau of American Ethnology, Smithsonian Institution, assisted in the interpretation of the artifacts and stratigraphy of Sandia Cave, especially in the matter of comparisons with the Lindenmeier site. Frank M. Setzler, Head Curator of the Department of Anthropology, United States National Museum, contributed by aid and encouragement during the excavation and the preparation of the report. Dr. C. L. Gazin, Division of Paleontology, United States National Museum, and Dr. Bertrand Schultz, Museum of the University of Nebraska, identified the bulk of the specimens of faunal material from Sandia Cave.

Dr. Donald Brand, University of New Mexico, helped immeasureably with the many details involved in an excavation, and by his remarkable forebearance when the cave interfered with the writer's regular university duties. O. Fred Arthur, Supervisor, Cibola National Forest, showed gratifying interest throughout the progress of the excavations and aided in obtaining the permits that made them possible. Joseph Berman, Ceramic Laboratory, W. P. A. project 23676, University Museum, Philadelphia, made the analyses of the yellow ochre from Sandia Cave.

Not the least among those who made the investigations possible are Dr. E. G. Conklin and the other officers of the American Philosophical Society, who generously granted funds for the completion of the excavation.

FRANK C. HIBBEN.

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EVIDENCES OF EARLY OCCUPATION IN SANDIA CAVE, NEW MEXICO, AND OTHER SITES IN THE SANDIA-MANZANO REGION

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INTRODUCTION

As Roberts has pointed out (1940, pp. 51, 52), it is only within the last few years that the scientific vogue has again turned to the investigations of early man in the New World. An increasing series of significant discoveries has built up incontrovertible evidence that man was present in the New World in the late Pleistocene period.[1] Only recently has the accumulated evidence reached the summary or bibliographical stage (Roberts, 1940, pp. 100-109; Sellards, 1940), although even this is still in its rudimentary form. The sum of this evidence indicates the following points:

1. That human beings were present in the New World in the latter portion of the Pleistocene period.
2. These early American inhabitants existed on a hunting type of economy.
3. Large mammals which they hunted and with which their remains are associated are now extinct.
4. These hunters were coincident with the closing phases of a glacial period known in North America as the Wisconsin.
5. Some tools, notably projectile points, made by these early men are distinctive and may be recognized out of context.
6. Geologic and stratigraphic evidence indicates that this Paleo-Indian existed at least 10,000 years ago and was distinct from and earlier than New World cultures with an agricultural and economic basis.

Evidence also indicates as extremely probable but not absolutely certain:

1. That this Paleo-Indian was physically a modern type.
2. That he may be regarded as a legitimate progenitor, at least in part, of the modern American Indian.

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[1] See bibliography in connection with Roberts, 1940, pp. 109-116.

3. That he transmigrated in a hunting status from Asiatic sources via Bering Strait and the so-called Inland Corridor.

4. That this migration took place in Upper Paleolithic times as measured by European standards and terminology.

Obviously, one of the major problems to be solved, and certainly the most outstanding lacuna in the chronology of the New World, is the lengthy period of time between the early Paleo-Indian on the one hand and the so-called later cultures on the other, for instance the Basket Maker of the Southwest. Ever since the discovery of Folsom Man (Brown, 1929; Bryan, 1937; Cook, 1927; Figgins, 1927; Roberts, 1935, 1939, 1940), this gap has been apparent. It seemed probable that certain discoveries already made and certain sites already known would fill this gap as soon as adequate correlative material could be obtained. Signal Butte (Strong, 1935, pp. 224-236) was offered as such a possibility, but has not wholly fulfilled the requirements. Central Texas contains much material which may bridge this gap, although it has not yet done so. Recent discoveries in the trans-Pecos region (Albritton and Bryan, 1939) are especially indicative of an eventual post-Folsom chronology. The University of Arizona and Gila Pueblo have recently evolved a chronological sequence in the southern portion of Arizona,[2] which follows the Cochise finds and leads through nonpottery cultures up to and including pottery and agriculture.

The excavation of Sandia Cave unfortunately does nothing to improve our knowledge of the period between Folsom man and the earliest Basket Maker remains. Instead, the sequence established in the cave has indicated another and older type of culture, also with a hunting economy, preceding that of Folsom man. A tentative sequence, obtained from other caves in the Sandia-Manzano region, indicates post-Folsom cultures, especially those characterized by a projectile point that has been called the Gypsum Cave type. The chronology thus far found in the Sandia region, however, is early when regarded from the Basket Maker-modern Indian viewpoint and does not yet lead directly to later cultures.

Sandia Cave itself was first brought to our attention by Kenneth Davis, of Albuquerque, who had explored several caves in the region. He brought in to us, from Sandia Cave, some Pleistocene faunal material, notably a sloth claw which aroused our interest in the site. We are much indebted to Mr. Davis for his continued efforts and

[2] Antevs, 1937a, 1937b, 1938. Dr. Haury and Mr. Sayles have kindly outlined this sequence for the writer, although it is not yet in print.

interest in cave work in the region, and in recognition thereof, one of the caves of the Sandia group, Davis Cave, was named after him.

Even before the visit of Mr. Davis to Sandia Cave, certain Boy Scouts, especially of Troop 13 of Albuquerque, had made exploring trips through it. It was at this time (1927-1928) that they dug large quantities of the recent fill from the front of the cave, mainly to permit them to crawl farther back, and also dug one hole through the underlying calcium carbonate crust at our present meter-7 line. The hard nature of the underlying deposits, however, apparently discouraged them from looking any farther for treasure. Evidence of their digging, in the form of match sticks and other debris, was found in and around this hole.

The University of New Mexico began excavations in the cave in 1936 under the direction of the writer. As funds for excavation were not immediately forthcoming, the efforts during the first year were sporadic and exploratory. Enough evidence was gained, however, to warrant further excavations, and these were carried on, although not continuously, during the seasons of 1937, 1938, and 1939.

In the spring and summer of 1940 excavation was further facilitated by a generous grant from the American Philosophical Society. This not only permitted further digging with an increased staff, but especially made possible the installation of complete dust-removal equipment to eliminate one of the major hazards of the Sandia excavation. Yellow ochre, which pervades the cave in all but the very lowest strata, had rendered work extremely difficult and was chiefly responsible for its sporadic nature. As this yellow ochre has a basis of quartz, silicosis was an ever-present possibility and cumulative effects from exposure to it were noticed in all the workers.

Aided by the rapid progress made possible by the Philosophical Society grant, the excavations of 1940 completed the major portion of the cave deposits pertinent to the history of man. In addition tests were made throughout the length of the cave, as well as in other caves, to check the stratigraphic sequence.

THE CAVES AND OTHER SITES

Sandia Cave (fig. 1) is one of a group. There are five such holes or cavities in the Pennsylvanian limestone in the immediate vicinity, all of which show some degree of human habitation. Only two of these are of any considerable size—Davis Cave, some 45 meters to the north of Sandia Cave, and Guano Cave, still farther to the north. All the caves in the Sandia group were dug and tested extensively with a view to corroborating the Sandia material. Both the larger caves, Davis and Guano, have a small vestibule in the fore part, with a mass of detritus, fallen rock, and calcium carbonate accumulation completely blocking the passage a short distance within. No real attempt was made to break through this blockade, as was done in

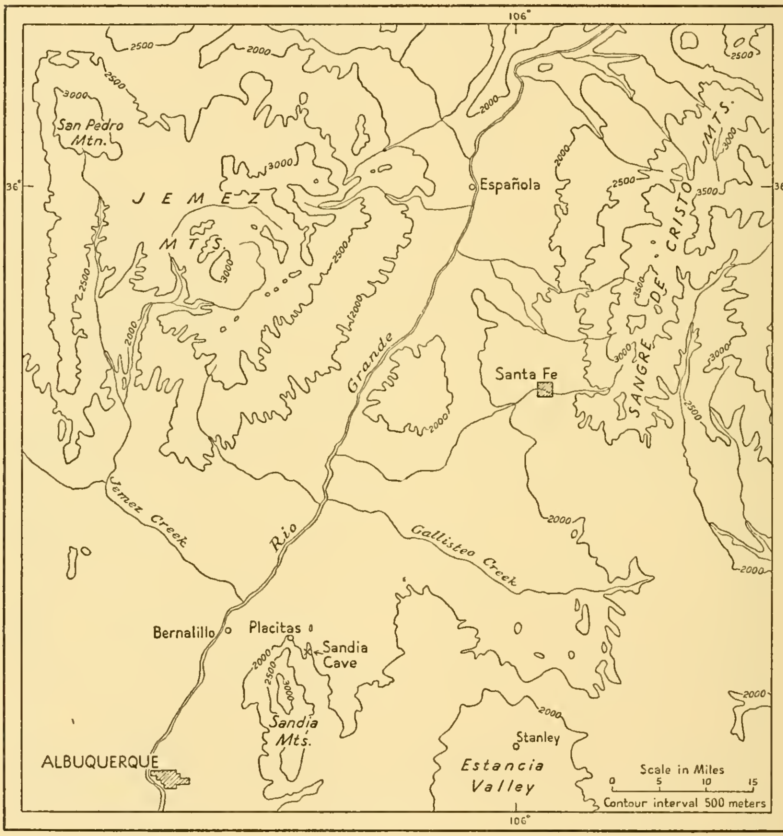


Fig. 1.—Map of part of central New Mexico showing location of Sandia Cave and relation of Sandia Mountains to the Jemez and Sangre de Cristo Mountains of the southern Rocky Mountain system. Redrawn from U. S. Geological Survey Base Map of New Mexico (Darton).

Sandia Cave, although in Davis Cave one small inner room was reached. The chief importance of the other caves in the group lies in the fact that the stratification is the same as in Sandia Cave, indicating apparently similar conditions. None of the test holes in the other caves of the Sandia group gave evidence of human material in the Pleistocene levels. Faunal material of late Pleistocene type was present in small quantities in the layers corresponding to the Sandia stratification.

The limestone strata, which form the entire east slope of the Sandia Mountains, contain many other holes and cavities, some of which approach true cave proportions. A few of these occur in Las Huertas Canyon and in the smaller canyons to the east. There is an especially large one just below the old Ellis ranch near the head of Las Huertas Canyon. Other small caves occur in the many canyons extending eastward along the flanks and foothills of the Sandia Range. All of any size indicate human occupation, for the most part sporadic and late. Late Pueblo glazes, Tewa polychrome, and the as yet unclassified Spanish Pueblo wares are common. Occasionally, earlier material is found, such as the prayer plumes in a coiled basket, probably dating from Pueblo III, found by Vance Davis, formerly of the University of New Mexico. To date, however, there are no evidences of stages earlier than this in the Pueblo series.

The Manzanita and Manzano Mountains continue to the southward of the Sandia Range, with the same geologic formation and apparently the same general conditions as in the Sandias. The Pennsylvanian limestone on the eastern slope is more folded in some instances and more horizontal in others than in the Sandias. The limestone, however, provides excellent conditions for caves. Many such caves are known, and undoubtedly there are many yet to be found. In general, in this survey, caves high in the mountains were ignored or left for future investigation. Those low on the slopes seemed to offer the best possibilities for early man. All indications of the earliest phases of human occupancy in the region of the Sandia Mountains have been found in caves of the Upper Sonoran zone or lower.

In the region near the small town of Manzano, just north of Mountainair, are a number of limestone caves, some of which are large. These have been only sporadically tested at the present writing, but they seem to offer possibilities for further information on the question at hand. A disturbing circumstance, however, is that most of the group are wet, and stalactites and stalagmites are still actively forming. This may be because the caves are low down on the flanks of the mountain where moisture, following the cleavage lines of the Pennsylvanian limestone, drains into rather than away from them. Test pits in three of them indicate extremely interesting material of possible post-Folsom date, as discussed in subsequent pages. Two Sandia-type points have also been found by local people in caves in the Mountainair region. This whole territory gives promise of additional and vital information.

The Manzano group of caves lies only a few miles in an air line, 3 or 4 miles in most instances, from the beach terraces of Pleistocene Lake Estancia to the east, which is supposed to coincide with the pluvial period indicated by the famous Black Water Draw, between Clovis and Portales, and other late Pleistocene evidences of a moister climate. The shore area of such a body of water as Lake Estancia probably would have been important to hunters in late Pleistocene times. That such was the case is substantiated by the finding of eight Folsom points on or near the beach levels in the vicinity of Manzano and Punta de Agua close to the cave groups. No definite Folsom site has been discovered here, however. Pleistocene bones, especially mammoth, are common in the vicinity of Punta de Agua. They occur just beneath a layer of alluvium on top of a bed of reddish clay. The clay, which changes to a bluish hue in some places, outcrops on the edges of many arroyos and benches in the region. A complete but disarticulated mammoth was excavated by the expedition near the ruins of Quarai.

Twenty miles due east of Sandia Cave, near the small town of Stanley (fig. 1), a Folsom site occurs on a terrace above one of the lake beds of the Galisteo Basin. These lakes, like Lake Estancia, are also correlated with the pluvial period and presumably would have attracted Pleistocene mammals and the men who hunted them. This is an open "blow-out" site and, in addition to Folsom objects, also displays later Plains material scattered over its surface. Although several typical Folsom points have been found here (see pl. 6, *e, f*), the site is relatively useless for chronological purposes. Its sole interest in this connection lies in the fact that it is the closest Folsom site to Sandia Cave. Sporadic Folsom points have been found throughout the Galisteo area, where there are evidences of a number of Pleistocene ponds and small lakes.

Interesting and possibly significant deposits lie 6 miles to the east of Bernalillo and 5 miles down the canyon from Sandia Cave. They are known as the Placitas deposits and have been worked as a geologic problem for some years under the direction of Dr. Stuart Northrop, of the University of New Mexico.[3] Although the small town of Placitas (fig. 1), around which the deposits lie, is considerably above the level of the Rio Grande Valley, the sediments are undoubtedly slack-water depositions. The body of water, presumably Pleistocene in date, responsible for them could never have been very large. As a

[3] The author is indebted to Dr. Stuart Northrop for the geologic and paleontologic information on these deposits.

result of the cutting of a large arroyo, extremely deep exposures have been made, permitting thorough study of these sediments. In the bottom of this wash or arroyo, residents of Placitas found two ungrooved Folsom-shaped points similar to those from Sandia Cave. They presumably washed out of the Placitas deposits. Fire areas, usually accompanied by sporadic chips of flint, are fairly frequent at several levels in the Placitas sediments. Most of these burned areas occur at a depth of some 9 feet below the present surface on what appears to be an old soil level or stratum darkened by vegetable material. Robert Ariss, of the Department of Geology of the University of New Mexico, has recovered a variety of Pleistocene remains from these deposits including horse (probably *Equus excelsus*) and mastodon (*Mamut americana*). Again, present interest in the Placitas sediments lies in the fact that they are close to Sandia Cave and indicate relatively early occupation of the area.

The location of Sandia Cave in relation to other sites containing similar material is of extreme importance with respect to its place in general late Pleistocene history. The nearness of classic Pueblo and Folsom sites is also significant in spite of the fact that the Sandia region is peripheral to the Plains area.

Sandia Cave

Sandia Cave is located on the east side of Las Huertas Canyon at the north end of the Sandia Mountains (fig. 1). The latter are a part of a great uplift just east of Albuquerque, which runs from the Sandias on the north to the Manzanitas and the Manzanos on the south. Canyon de las Huertas follows a fault line almost due north through the Magdalena limestones of the Sandia Mountains in the vicinity of the small town of Placitas. Here the mountains descend to a series of rugged foothills. In this area the Magdalena group of Pennsylvanian limestones is dominant. The underlying granitic rocks of the Sandia upthrust do not appear, and the overlying Manzano group and red beds do not figure except considerably east of the Las Huertas Canyon area. The Las Huertas fault is the largest of several secondary faults which mar the east slope of the Sandia range (Ellis, 1922).

The country to the east of Las Huertas Canyon falls off rapidly by easy stages to the foothills bordering the Galisteo Basin and the Estancia Valley. Las Huertas Canyon and Sandia Cave are more readily accessible from the east or northeast than from the west.

Sandia Cave and the others in the group lie entirely in the Upper Sonoran zone of vegetation, although a few transitional tree species extending below their legitimate zones occur in the creek bed of Las Huertas Canyon. The talus slope below the cave is covered with pinyon and juniper. Occasional patches of scrub oak occur in the canyon bottom. A clear and permanent trout stream makes Las Huertas Canyon one of the most desirable in all of the Sandia area.

Canyon de las Huertas, or Canyon of the Gardens, is precipitous on its eastern side where Sandia Cave is located, and rises somewhat gradually on its western side, for the most part following the slant of the limestone beds (see fig. 5, p. 12).

As noted previously, Sandia Cave is the most extensive cavity in the Sandia group. In general dimensions, it is tunnellike, with a length of 138 meters and an average diameter of 3 meters, although this diameter is affected by certain sections of the cave where pipes and fissures lead from the roof to a considerable height (see fig. 3, p. 11). The actual cave extends somewhat beyond the 138-meter mark, and by squeezing, a particularly adventurous person may go several meters farther. The end of the cave is pinched off by a considerable rock fall. As no advantage apparently could be gained by going farther, this stricture was not forced by the expedition. From its mouth, the cavern drops with the dip of the limestone strata in which it is located. This formation dips toward the east at an angle of 9 to 15 degrees, and the trend of the cavern is downward with this strike. In the 138 meters of actual length, the cave drops evenly to 22 meters below the mouth at the farther end.

Prof. Kirk Bryan suggests that in Pleistocene times this long corridorlike cavity may actually have had a much larger, cavernous mouth. There is considerable evidence to support this supposition. The cliff upon which it opens has obviously weathered back in comparatively recent times, taking sections of the cave mouth with it. Cultural material within would, in many cases, appear to have slid or worked down from a former habitation level in the front of the cave that has since disappeared.

The mouth of the cave (pl. 1) at present is some 3 meters above a small ledge from which it can be reached by means of a ladder. No animal of any size could have entered it in recent years. Today there is no evidence of any ledge or natural entrance, although one supposedly was present at one time. Nor is there evidence of water or moisture having entered the cave at its mouth at any time since its formation. The cave is now absolutely dry except at the extreme eastern or inner end, where a slight dampness occurs.

The Magdalena limestone in which the cave is formed is a hard, sometimes crystalline material containing large numbers of crinoids in the cave area. Indeed, crinoid stems from the surrounding limestone are common in the cave fill. The limestone in the cave area is generally massive, but with cleavage lines natural to this formation and dipping eastward with the general strike of the beds. Sporadic cherty concretions jut out from the wall of the cave (pl. 2, fig. 1, above framework). Some are sufficiently siliceous so that they break with a conchoidal fracture. A considerable portion of the artifacts from Sandia Cave were apparently made from these cherty concretions gathered locally. Iron nodules occur in the limestone, in some places in considerable quantities. Just above Guano Cave, one of the Sandia group, an old prospect hole was dug to explore iron deposits of this nature. The presence of these iron concretions in the limestone undoubtedly correlates with the deposition of the yellow ochre, so important in the cave stratigraphy (see p. 15).

Stalactites and stalagmites are few in the cave, although some activity of this sort is evident. Deposits of cave travertine are limited almost entirely to sheet formations flowing down the walls and thence over the surface of the cave floor. These calcium carbonate sheet formations are an important factor in the history of the cave.

Once the mouth is gained, Sandia Cave is easy to enter at the present time. Here and there throughout its length, however, to make progress one must crawl or even squirm between the tops of the piles of recent accumulation and the roof (pl. 2, fig. 2). There is ample evidence that at least once during its existence and possibly on several additional occasions the opening was completely closed. When originally discovered by Boy Scouts, the entrance back of the vestibule (pl. 2, fig. 1) was entirely blocked. Certain of the strata, such as the yellow ochre and the travertine crust discussed subsequently, give evidence of having been deposited when the cave had no outside entrance.

EXCAVATION PROCEDURE

Excavation necessarily started at the mouth or west end of the cave and proceeded eastward. All measurements were made in meters and subdivisions thereof and were recorded in permanent bench marks, triangulation points, stations, and individual meter sections placed in plaster of paris on the cave roof. Minor subdivisions, artifact locations, and lesser items pertinent to the survey were marked in paint.

Transit and level were used throughout, all measurements and levels being based on station 1 (see fig. 2) just inside the cave entrance.

Excavation proceeded in meter sections, each level of each section being removed separately. As the stratigraphy proved to be distinctive, each stratum of each meter was readily segregated. In sections of special interest, excavation was by one-half or one-quarter of a meter at a time. Owing to the general solidarity of the deposits below the topmost layer of recent accumulation, which was of dustlike consistency, comparatively perpendicular faces could be maintained.

The calcium carbonate crust, the deposits of Folsom age, and in some cases the yellow ochre stratum, necessarily had to be removed by forcible means. Miner's picks (pl. 3, fig. 1), geologist's picks, and frequently sledge hammers were the order of the day. As a consequence occasional specimens were fractured and many were not discovered in situ, but came to light only when lumps of cave breccia were disintegrated in the laboratory or put through a screen. The positions of cultural and paleontological specimens of special importance observed in place were carefully determined by means of the transit.

All the material from each meter or subdivision thereof, and from each stratum, was carried to the mouth of the cave in wheelbarrows and there screened, the lumps of breccia being broken up. A number of specimens came to light in this manner. Their locations can only be listed by stratum and meter.

In addition to the excavations at the mouth of the cave, a considerable portion of the fill was dug from meters 72-83 some distance back from the entrance (see fig. 2). This section seemed promising, as there was almost no modern accumulation on top of the calcium carbonate, but only one artifact, a large blade, was found in the whole section. Numerous test holes were also made in various places, as may be seen on the accompanying plan of the cave, for the purpose of checking the stratigraphy. Most of the excavations were carried to bedrock. In the rear of the cave there were some exceptions, noted on the vertical plan (see fig. 3), where large fragments of fallen rock interfered with such procedure.

Electric torches were used to light the cave, as all forms of acetylene equipment tended to clog with dust. Dust removal equipment consisted of a gasoline engine powering a centrifugal blower, an arrangement with steel-ribbed rubber exhaust and intake hoses, built by Dr. Victor Smith, of Sul Ross State Teachers College at Alpine, Tex., in accordance with certain ideas of cave excavation outlined by Frank M. Setzler.

VIEW OF SANDIA CAVE FROM TALUS BELOW CLIFF. SAFETY SCAFFOLDING SHOWS IN CAVE MOUTH

1. Sandia Cave Entrance at Narrowest Portion back of Antechamber

2. In Front Sections of Sandia Cave Debris is Piled Almost to the Roof

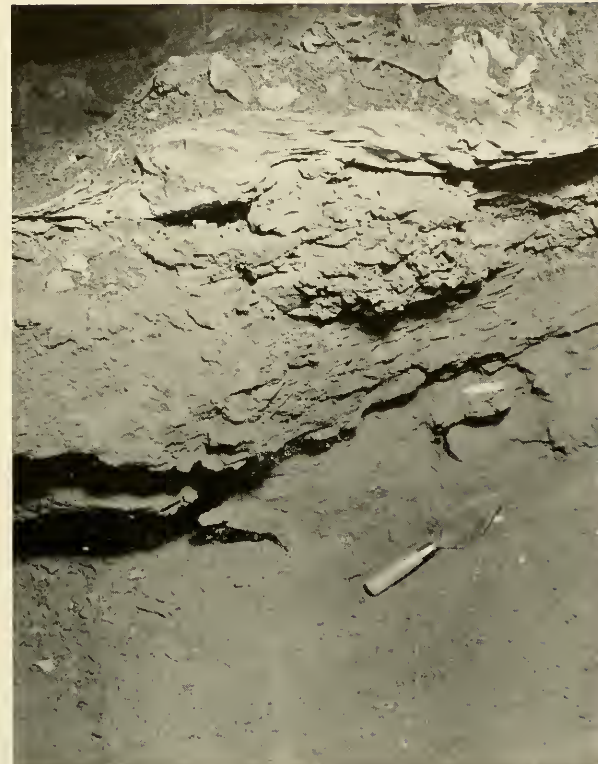
1. AT WORK ON TEST HOLE IN SANDIA CAVE

2. SECTION OF DEPOSITS AT METER 20 SHOWING STRATIGRAPHY

Travertine crust appears just above the shoulder of the figure; yellow ochre stratum by the left hand.

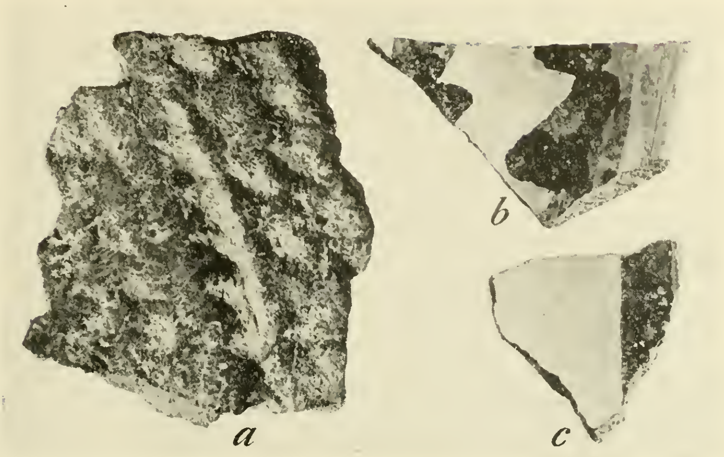
1. FOLSOM BLADE IN PLACE IN THE CAVE DEBRIS

A horse tooth is located just left of the trowel.



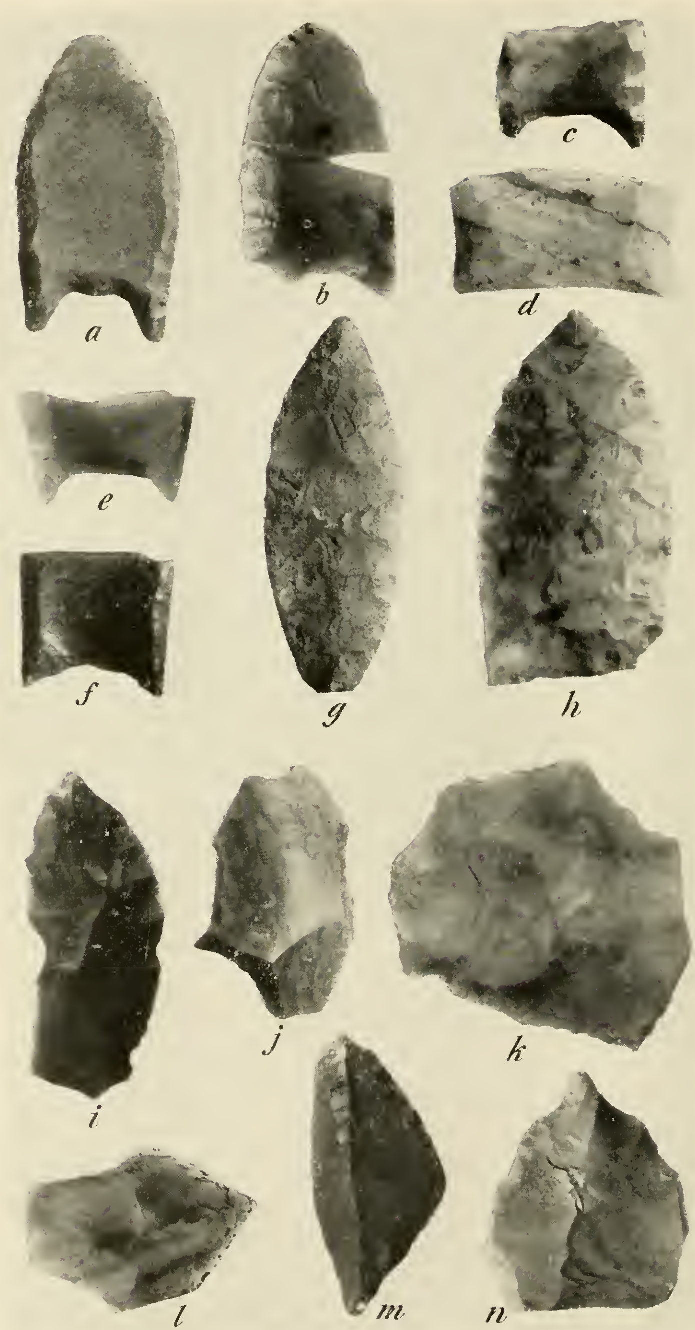
2. SANDIA POINT IN PLACE AT ONE EDGE OF CAVE CHAMBER

Deposits here are thin with yellow ochre, Folsom breccia, and travertine crust appearing above.



1. PUEBLO UTILITY AND GLAZE-WARE SHERDS FROM RECENT LAYER IN SANDIA CAVE

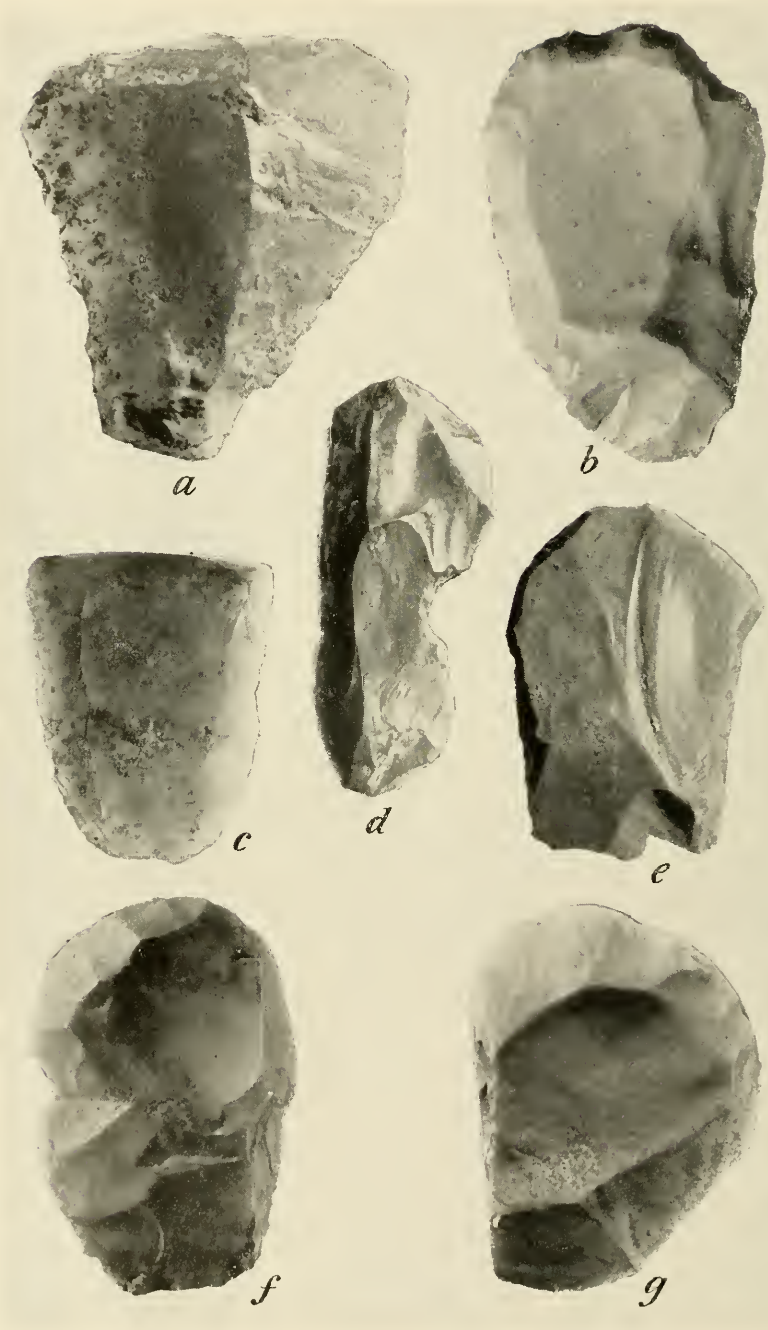
2. UNFLUTED FOLSOM-SHAPED POINT EMBEDDED IN DEBRIS FROM SANDIA CAVE



ARTIFACTS FROM SANDIA CAVE AND SURFACE SITE NEAR STANLEY

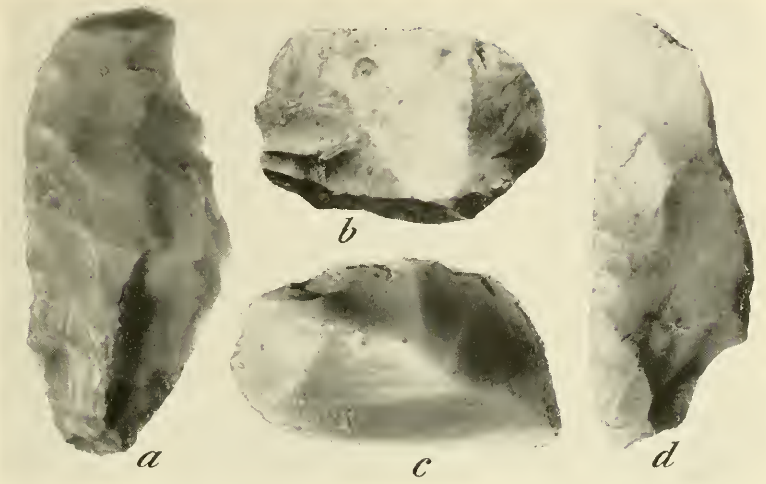
a, b, c, d, Folsom points and bases from Sandia Cave; *e, f,* bases from surface site near Stanley; *g, h,* other points from Folsom level; *i-n,* gravers from Folsom level.

FOLSOM BLADE EMBEDDED IN LOWER SURFACE OF TRAVERTINE CRUST
(Actual size.)



Snub-nosed Scrapers from Folsom Level of Sandia Cave

One, *d*, has additional feature of concave scraping surface in one side. (Approximately actual size.)



1. Side Scrapers from Folsom Level, Sandia Cave
(Approximately actual size.)

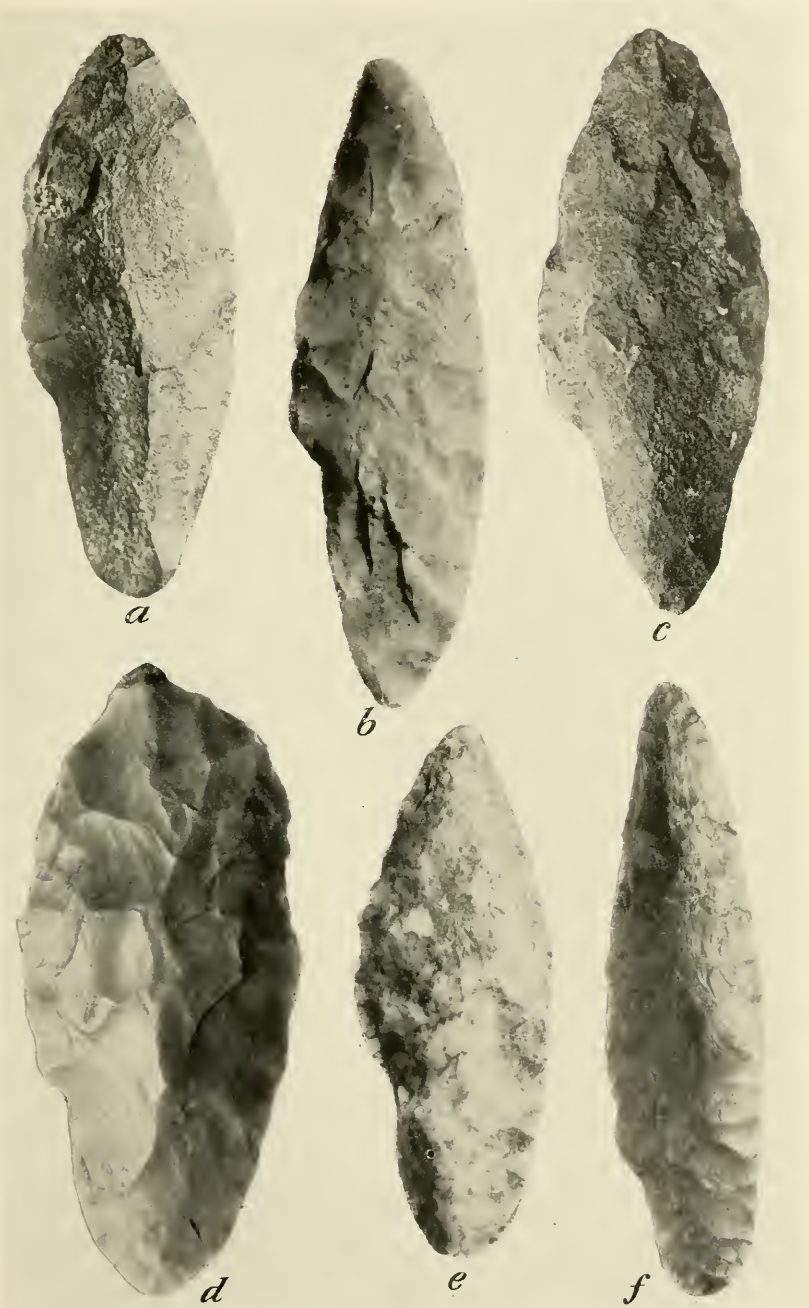
2. Flake Knives from Folsom Level, Sandia Cave
(Approximately actual size.)

1. Ivory Shaft with Ground Point from Sandia Cave Folsom Layer

(Approximately $\frac{3}{4}$ actual size.)

2. Sandia Points

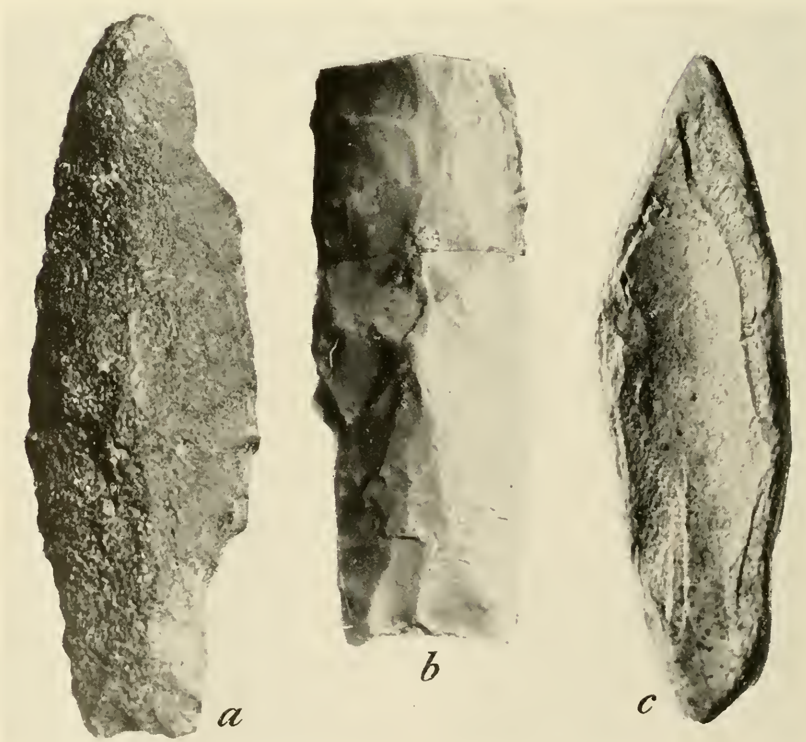
a, type 1; *b*, type 2. (Approximately actual size.)



SANDIA POINTS, TYPE 1
(Approximately actual size.)

1, SANDIA POINTS, TYPE 2

(*a* and *b* slightly smaller than actual size; *c* approximately actual size.)

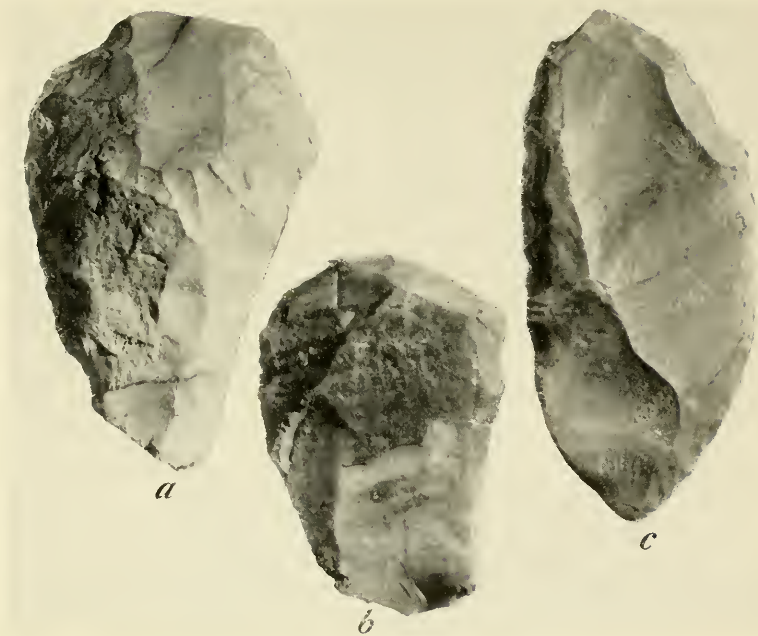


2. SANDIA POINTS, TYPE 2, AND BONE POINT

(*a* and *c* slightly enlarged; *b* approximately actual size.)

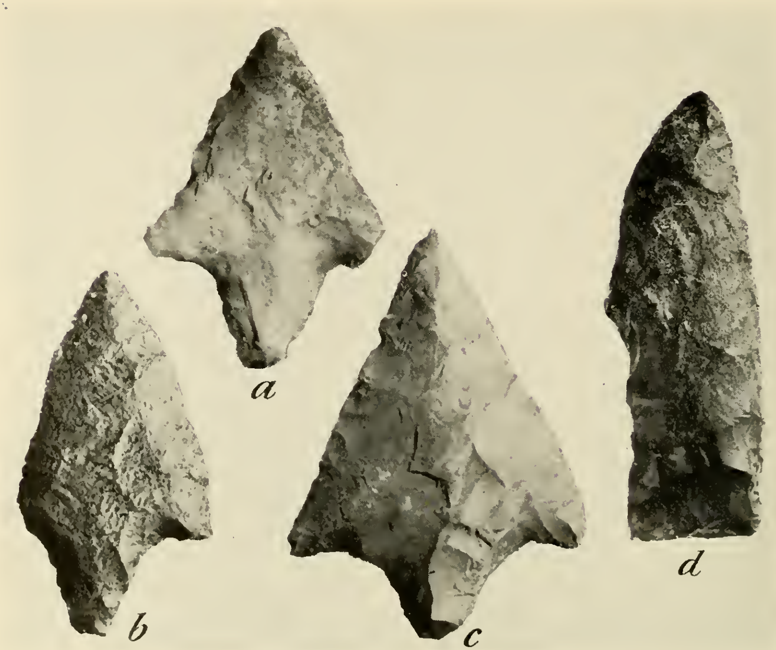
SANDIA POINT FRAGMENTS

a and *c* and crude point *b* from Sandia level. (*a* and *c* approximately actual size; *b* approximately ¾ actual size.)



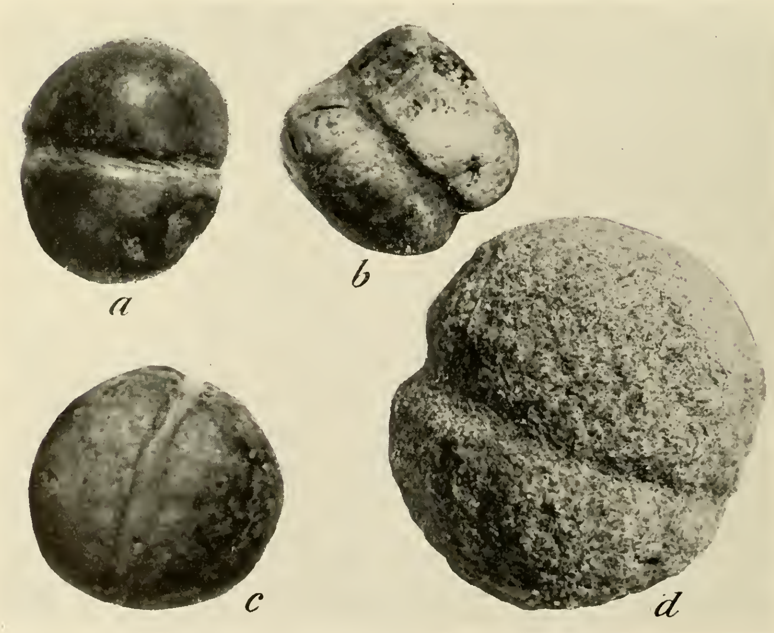
2. SCRAPERS FROM SANDIA LEVEL

a and *b*, snub-nosed scrapers; *c*, side scraper. (Approximately ¾ actual size.)



1. POINTS FROM MANZANO CAVE

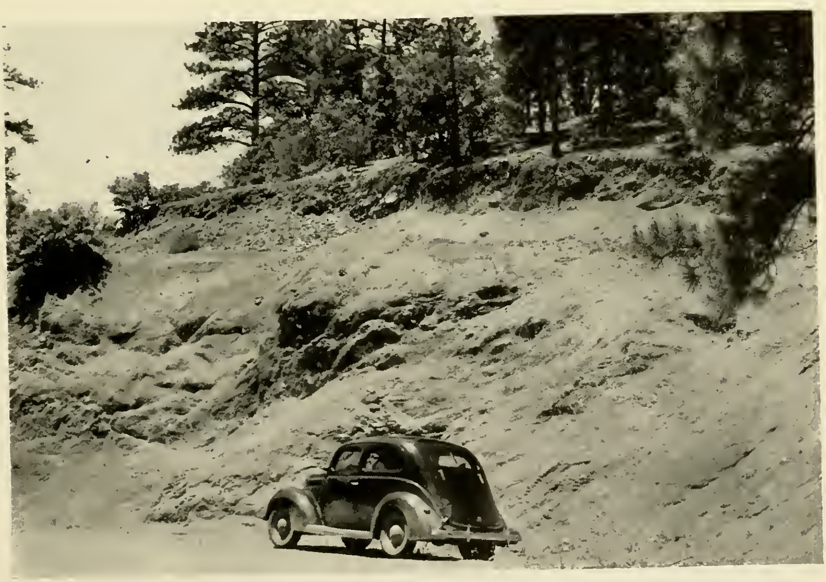
a-c, Manzano points; *d*, Sandia point. (Approximately $\frac{5}{6}$ actual size.)



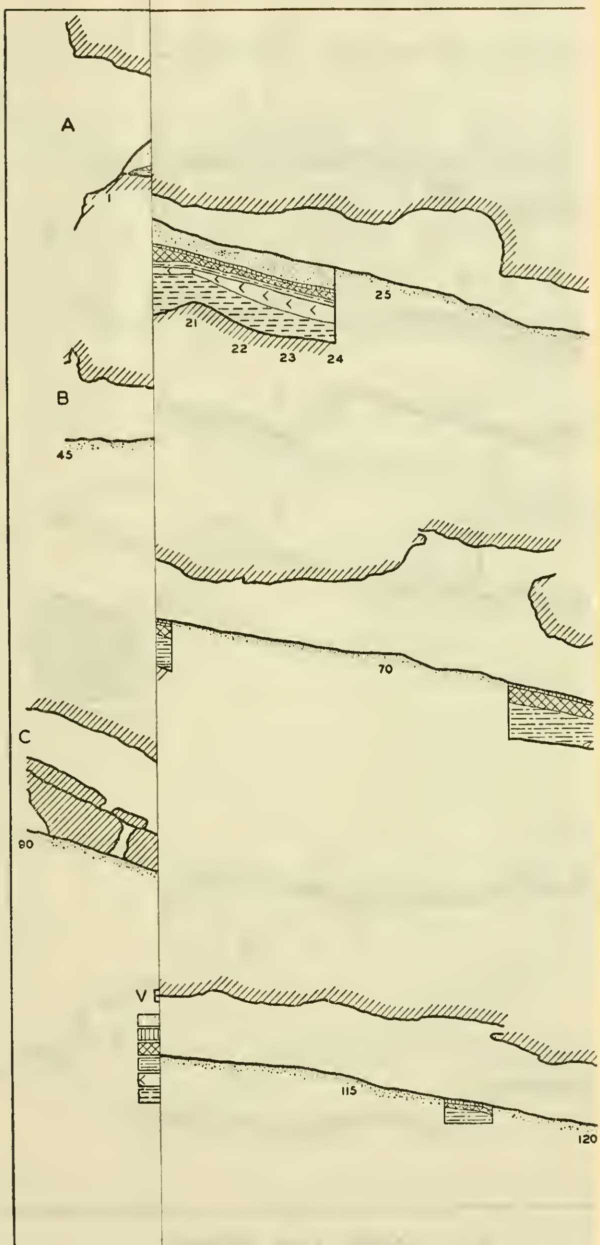
2. BOLA WEIGHTS FROM MANZANO CAVE

a-c, limestone; *d*, granite. (Approximately $\frac{5}{6}$ actual size.)

1. ROAD CUT IN SANDIA MOUNTAINS, FIR-SPRUCE ZONE, SHOWING SOLUTION-WIDENED JOINTS IN LIMESTONE CONTAINING LIMONITIC CLAY



2. ROAD CUT IN SANDIA MOUNTAINS, PINE ZONE, SHOWING DISINTEGRATED GRANITE WITH LIMONITIC STAIN



ave, vertical section showing stratigraphy.

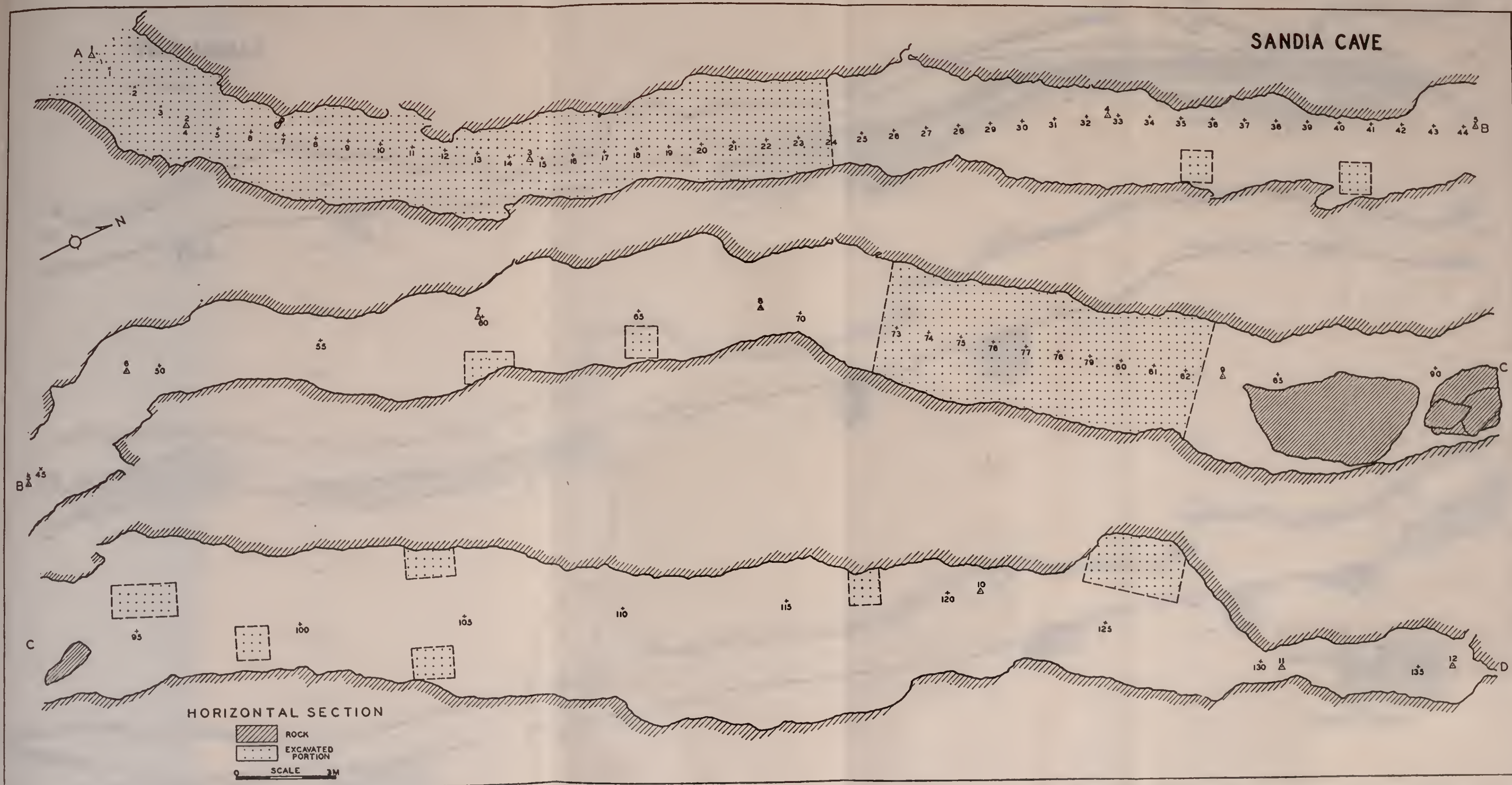


Fig. 2.—Sandia Cave, horizontal section.

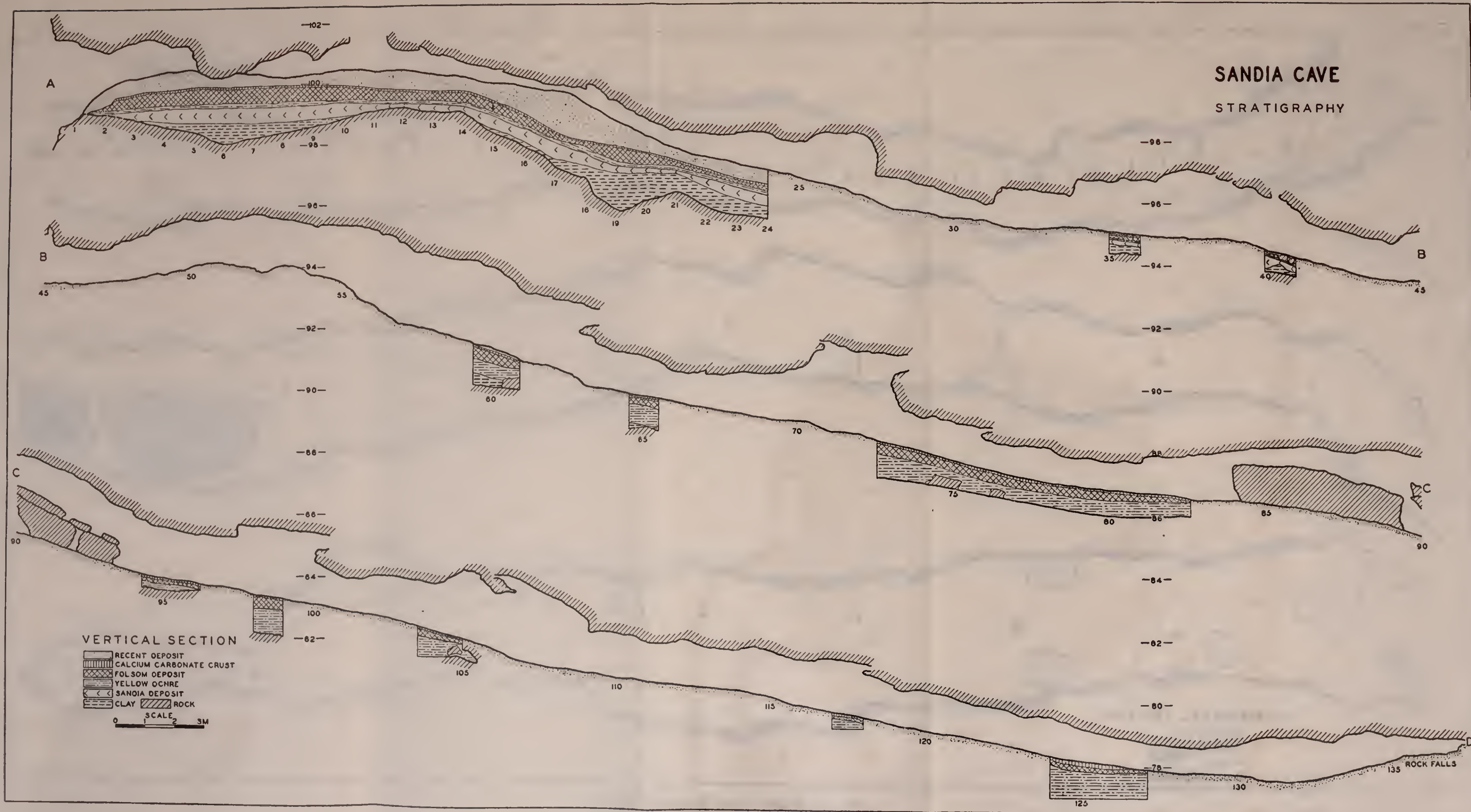
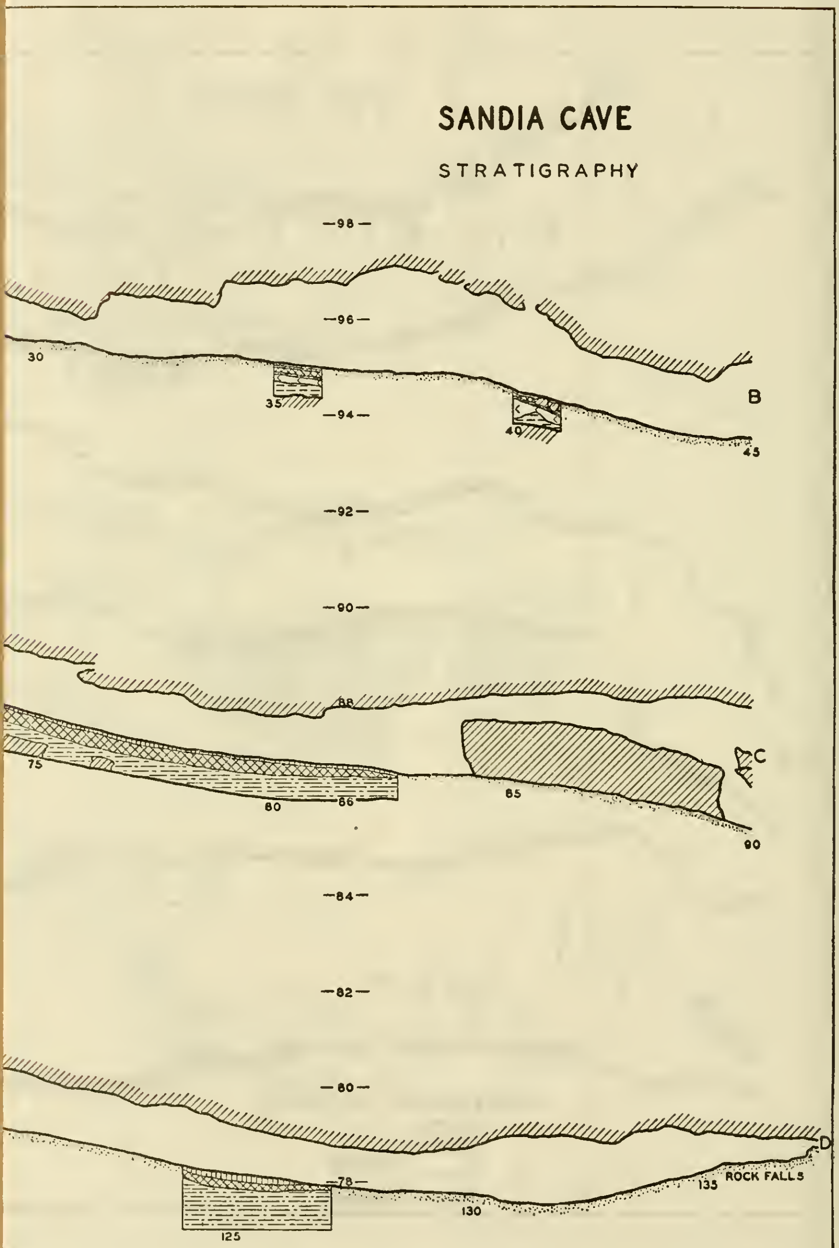


Fig. 3.—Sandia Cave, vertical section showing stratigraphy.


SANDIA CAVE
STRATIGRAPHY
—98—
—96—
30
35
—94—
40
45
B
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—90—
88
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ROCK FALLS
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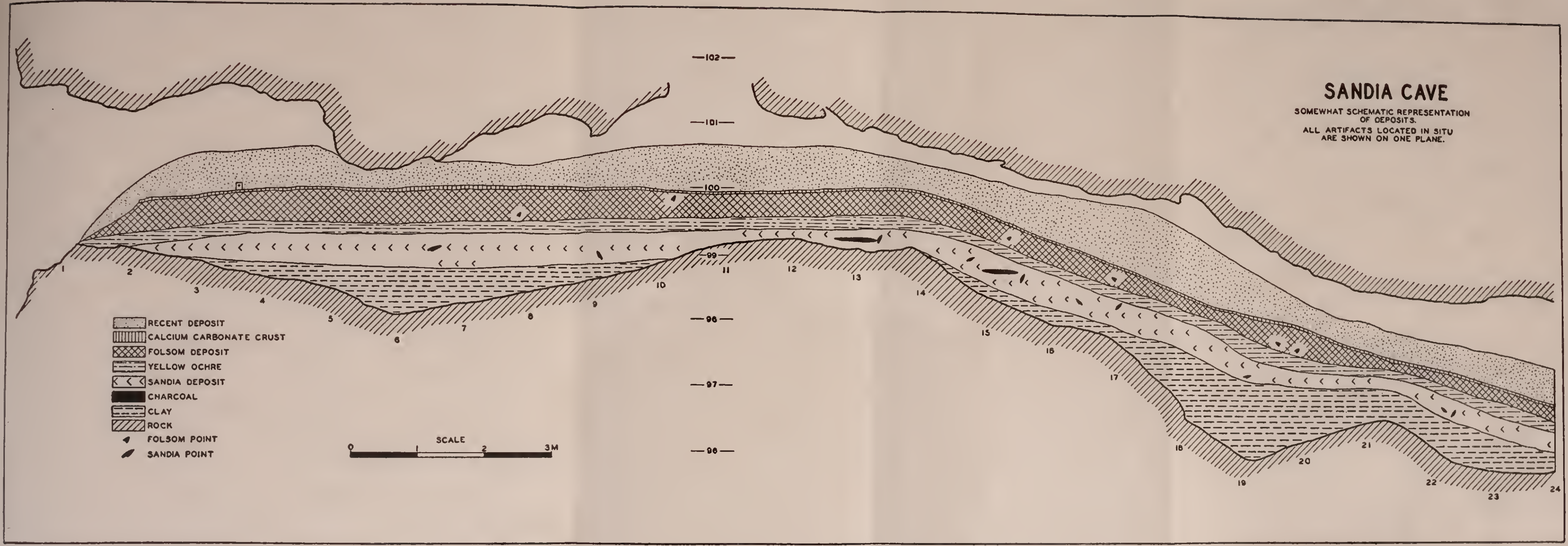

FIG. 4.—Sandia Cave, vertical section meters 1 to 24 showing location of artifacts and fire areas.

STRATIGRAPHIC SEQUENCE

The well-defined stratigraphy of Sandia Cave is one of its outstanding features. Figure 3 illustrates the precise nature of this stratigraphy and shows that it extends, with slight variations, throughout the cave. Stratigraphic sequences of this sort are of the utmost importance in determining relative chronology.

The deposits of Sandia Cave have no physical connection with any exterior deposits. For this reason, correlations with glacial phenomena and Pleistocene chronology known from open sites are somewhat difficult. Groupings of the strata within the cave necessarily are referable mainly to periods represented only by phenomena occurring within the cave. However, the problem of exterior factors such as stream erosion or accidental wash into or through the cave is practically eliminated. All objects and matter in the cave appear to have been deposited there originally. There was no deposition from the outside nor were original internal deposits redistributed by such factors as stream wash, solifluction, faulting, or other natural agencies of disturbance. These deposits, then, may be regarded as primary and may be judged in their relative positions. Such items as fire areas with undispersed lenses of charcoal reaffirm the undisturbed nature of the deposits. Naturally, a problem of this sort involves considerations different from those of a river-terrace or river-sediment site.

The uppermost stratum, labeled "recent deposit" in figure 3, is for the most part wind-blown dust, bat guano, and pack-rat dung. The guano deposits occur in the greatest concentrations in the front portion of the cave, thinning toward the back, and disappearing altogether at about meter 70. Beyond this, only a very light covering of dust represents the uppermost stratum. The make-up of this layer is varied in places by the addition of small rocks and large slabs that dropped from the roof in recent times (fig. 6) and, at the very mouth of the cave, by a considerable quantity of wind-blown and pack-rat-deposited leaves and vegetable material. This top layer is entirely dry. Owing to this circumstance, and also to the fact that mammal forms found in it are for the most part living species, it has been labeled "recent."

In several places this recent accumulation extended to the roof. This completely blocked the passage and possibly accounts for the fact that there is almost no wind-blown material in the rear portions of the cave. At several places, in the first meters, where the accumulation reached the roof it even extended up into fissures where bats formerly roosted. From some lenticular stratification in this recent layer, it appears that there were intervals when the bats did not use the cave, possibly when it was completely blocked and they could find no entrance.

Beneath this recent accumulation is the second definite stratum, a layer of calcium carbonate that extends in a continuous crust from the mouth to the extreme rear of the cave. This crust varies from a laminated lime formation a few centimeters thick to a crystalline cave-travertine layer as much as 30 centimeters thick. In some places sheets of stalagmitic material formed on the wall, and an occasional stalagmite protrudes upward from the calcium carbonate crust into the recent layer mentioned previously. Throughout the cave the crust

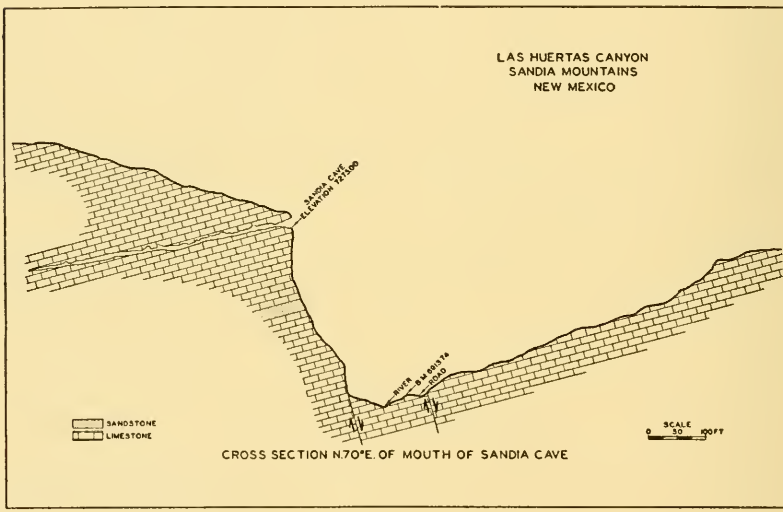

FIG. 5.—Las Huertas Canyon and Sandia Cave cross section.

was durable and practically impenetrable. In the front of the cave, near our meter 7, the Boy Scouts had dug through the crust to a limited extent in a search for treasure. The hardness of the lower layers, however, soon discouraged them. Near the rear of the cave, in two places at meter 75 and at meter 90, large sections of the roof had dropped subsequent to the formation of the calcium carbonate. These large pieces of rock broke completely through the crust and partially buried themselves in the debris below. At several places rocks of varying size from an earlier fall are incorporated in the crust. Most of them are completely encased in a layer of calcium carbonate.

Below the calcium carbonate capping is a stratum of cave debris. This has been termed the Folsom layer because typical Folsom artifacts are included in it (pl. 3, fig. 2). This Folsom stratum is composed of mixed material with a preponderance of stone and bone fragments. In addition, there are pieces of yellow ochre, crinoid stems, charcoal fragments, flint chips, and other cultural material. Orig-

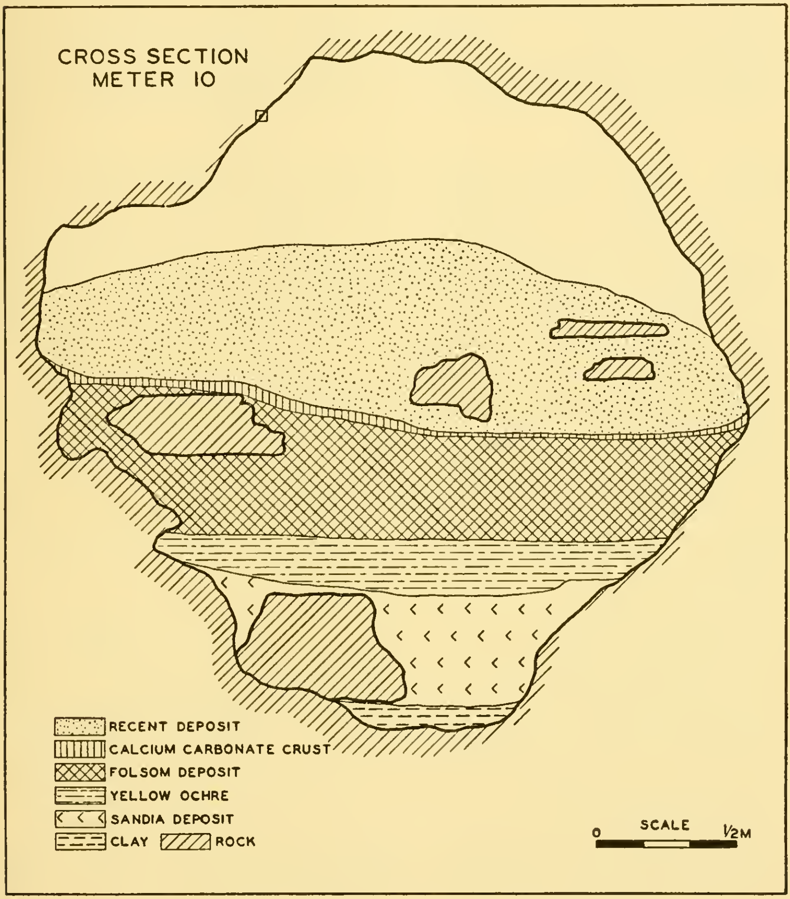

Fig. 6.—Cross section of Sandia Cave at meter 10.

inally, the Folsom layer apparently was a cave floor strewn with accumulated debris. Many of the fragments of animal bones represent the refuse of human occupation. Undoubtedly some of the bones also indicate the lairing of animals, either carnivores or cave-dwelling mammals in this same cavern. That the material was originally unconsolidated and loose seems evident from the size of the individual particles (see pl. 3, fig. 2) as well as from the fact that much of the material has drifted down the slant of the passageway toward the back of the cave, possibly as a result of the continual passing of animals, or men, or both.

The Folsom layer is now, however, consolidated into a cave breccia. Much of the material has a hardness comparable to somewhat friable concrete. Many of the fragments of stone, artifacts, and even some of the bone pieces are covered with crystalline calcite. Waters highly charged with calcium carbonate from the stalagmitic crust above the Folsom layer have consolidated most of the material into a solid mass. That moisture destroyed much of the bone material seems evident. Most of the fragments were almost completely disintegrated as far as the bony structure was concerned, their presence being indicated only by cavities left in the breccia or by the arrangement of the calcite crystals. Evidently because of the porous nature of the Folsom deposit and the amount of moisture once present there, only a small number of the bone pieces were fossilized, and then usually with the addition of a heavy calcium crust deposited on their surfaces.

Although charcoal in very small fragments was relatively abundant in some parts of the Folsom stratum, it was nowhere concentrated in what might be construed as a fire area or hearth. It is significant that charcoal fragments extended to the very surface of the layer. A few pieces are embedded in the lower portion of the stalagmitic crust.

The Folsom stratum extends considerably farther back in the cave than would be expected. Even at meter 100 it is thick enough to be readily distinguishable. Artifacts and signs of occupation are, however, limited to the front portion. Only one large blade referable to the Folsom complex was found in the excavated section from meters 72 to 83. The whole Folsom layer naturally thins toward the back of the cave (fig. 3).

Beneath the Folsom stratum and in unconformable contact with it, is a layer of sterile yellow ochre, finely laminated and evidently waterlaid (see pl. 3, fig. 2). The laminations consist of differentiating streaks of light and dark ochre of a vivid yellow hue. Here and there lenses of the material were consolidated almost to the consistency of rock, apparently by a binding of calcite. All the ochre, in spite of its seemingly pure nature, is pervaded with calcium carbonate. Its mode of deposition, a purely geologic problem, is discussed by Professor Bryan in the appendix to this paper.

The top surface of the yellow ochre layer obviously suffered some erosion, apparently physical. In some sections a path or passageway, worn by the movement of men or mammals back and forth through the cave, may be noted on the top of the layer. Folsom debris lies immediately above this unconformity, and the destruction of the topmost layers of the yellow ochre is indubitably referable to Folsom times.

The yellow ochre represents another wet period and is absolutely sterile as far as bones, cultural material, or even rock fragments are concerned. This sterility indicates a totally different set of conditions from those surrounding the deposition of the layers both above and below it.

The yellow ochre stratum, with the possible exception of the calcium carbonate crust, is the most constant in the cave. The layer increases in thickness toward the back of the cave (fig. 3), where, in certain test pits, it achieves considerable depth. In some places in the rear of the cave the yellow ochre extends to and rests on bedrock, to the exclusion of other strata.

A sample of the yellow ochre was submitted to Joseph Berman, Ceramic Laboratory, W. P. A. project 23676, University Museum, Philadelphia, who, after exhaustive tests, made the following report on it:

The sample of unconsolidated earth is a very fine ochre-brown clayey material which sifts through such fine pores that it is difficult to find a container to keep it intact. It feels only slightly gritty by touch and stains everything that contacts it with its rusty iron color. Owing to the almost complete covering of all the tiny mineral grains with a nearly opaque coat of iron oxide, there was much initial difficulty in making a petrographic examination. Finally this coating was removed with acids which also removed all of the small particles of calcite that were present. The final product turned out to be a monomineralogic aggregate of very tiny particles of quartz. They range in size from very fine silt to a maximum of 0.1 mm. diameter with the majority of the grains 0.01 mm. in diameter. The mineralogical composition of this sample is quartz, many with euhedral crystal outline, calcite (slightly dolomitic), and a great deal of hematite which coats all of the mineral grains. The chemical analysis also shows that there is some organic material present although it is of such small size and is so incrusted with iron oxide that identification is impossible. They definitely are not diatoms nor spicules.

Conclusion.—From the petrographical and chemical evidence, it can be definitely stated that the deposit was a local one and that it was deposited during a period of quiescence. If it were otherwise, there would certainly be a much greater assortment of minerals present and any disturbance would not have allowed the very fine material to be deposited in this cave.

Two theories may be advanced as to the mode and conditions of deposition. First, the floor of the cave may have had a shallow layer of water continuously covering it. The quartz particles present would then have been blown in as fine dust particles and trapped there by the water. Second, the deposit is the remains of dissolved limestone.

Evidence strongly favors the second theory. The absence of any alumina mineral argues against any but a local source. The fact that the cave slopes gently toward the rear "following the dip of the limestone strata" seems to preclude any shallow layer of water on the cave floor, and the presence of many small euhedral grains of quartz (as ordinarily occur in limestone) suggests very little transportation of the material. It is quite plausible that the deposit represents residual material remaining after the limestone has been removed in solution from the cave. All limestones have both iron oxide and small particles of quartz as impurities. Although these are present in small amounts, the dissolving away of calcium carbonate would tend to concentrate the quartz and iron oxide in the remaining material.

CHEMICAL ANALYSIS

SiO_2	12.78
Al_2O_3	Trace
Fe_2O_3	36.93
FeO	.28
MgO	2.10
CaO	22.00
Na_2	.48
K_2O	.14
H_2O	1.15
CO_2	13.60
TiO_2	.44
MnO	Faint trace
P_2O_5	.20
Loss on ignition (probably organic)	10.56
Total	100.66

Beneath the yellow ochre is another layer of cave debris. This represents the lowermost or earliest occupation of Sandia Cave. The material of this layer is more finely divided and less consolidated than that of the Folsom. It is composed of rock fragments, finely divided rock dust, bones, artifacts, charcoal, crinoid stems, and brownish-colored dirt, evidently wind-blown and mixed with vegetable and animal material. This stratum, because of the cultural items included, and its lower and distinct position in this cave, has been termed the Sandia level.

The top surface of this Sandia layer is not heavily consolidated and the yellow ochre rests directly upon it with no unconformity noted. Apparently, the yellow ochre was deposited directly on top of the cave debris, represented by the Sandia layer, with no disturbance other than the infiltration of the moisture carrying the ochre. There was, however, not sufficient calcium carbonate in the yellow ochre to consolidate completely the Sandia layer. Only in some isolated portions, usually near the top, has any consolidation taken place. Even this has not formed a breccia, as in the Folsom stratum, but a friable and noncrystalline mass. The yellow ochre has, however, heavily impregnated the Sandia level with the typical yellow, finely divided dust.

That the Sandia stratum as a whole was moistened by the superincumbent yellow ochre layer seems evident. Bones are poorly preserved, and most of the identifications were made from teeth. Cultural evidence seems to indicate occupation of the cave to the very surface or topmost portion of the Sandia layer, where the yellow ochre lies upon it. Presumably, the Sandia layer represents a dry period in the cave's history, interrupted and made untenable by the succeeding wet period of the yellow ochre.

Portions of this Sandia layer were less disturbed or "scuffled" than the Folsom layer above. Two hearths, to be discussed subsequently, were found in position. Occasionally, bones, partially articulated, and cultural remains were discovered in situations where apparently they had been covered over with little or no disturbance.

The Sandia layer does not extend as far back into the cave as the Folsom. As figure 3 indicates, the Sandia stratum has almost feathered out at meter 40. As a matter of fact, as in the case of the Folsom occupation, it is remarkable that evidence is found so far back. No cultural indication in the Sandia layer occurred beyond meter 23.

Beneath the Sandia stratum, in some places, is another layer. This is the so-called clay layer, an accumulation of disintegrated limestone, almost white in color. Except for the inclusion of large numbers of crinoid stem segments, the material is sterile. The clay is homogeneous and compact in nature. It is laminated, evidently water-deposited, and contains a considerable amount of calcium carbonate. The top surface is pitted sporadically with small hollows apparently of human origin. In many places, the clay stratum completely fills a stream course or channel associated with the original formation of Sandia Cave.

The clay layer also feathers out toward the rear of the cave, and apparently does not extend beyond meter 70. However, it may occur sporadically farther back than this.

SIGNIFICANCE OF THE STRATIGRAPHY

Stratigraphic sequences involving the Folsom complex have long been sought. Data on post-Folsom sequences were expected when the cave investigations were started, and they would have added to our knowledge of the cultural growth of the Paleo-Indian. But instead of another hunting culture to help fill the gap between Folsom man and the earliest Basket Maker remains in the Southwest, we have in Sandia Cave a complex earlier than the Folsom.

The priority of the lowermost, or Sandia, cave occupation is clear. How much time lapse occurred between the Sandia and Folsom levels is a matter of conjecture. Although there are cultural affinities between the two, over and above the fact that both represent a hunting economy, the interval between them was undoubtedly considerable. This seems indicated both by the evidence for an intervening wet period and by the thickness of the yellow ochre itself.

Since the initial use of the cave by man there has been a succession of dry periods interspersed and separated by wet ones. The yellow ochre layer, obviously water-laid, followed immediately after the Sandia occupation. The ensuing comparatively arid interval characterized by Folsom cultural material gave way to one with moisture sufficient to consolidate the deposit into a cave breccia and to form the overlying calcium carbonate or travertine crust that sealed in the lower strata and prevented the intrusion of later objects into earlier levels. The deposits accumulating during the subsequent dry period formed the stratum which is designated "recent." This succession of dry and wet periods has an important bearing on the chronological significance of the entire sequence in that it provides the basis for a geologic interpretation of the deposits and their correlation with Wisconsin glacial chronology. From the latter Professor Bryan concludes that the sterile ochre deposits correspond to the last ice advance of the Wisconsin and have a nominal date of 25,000± years. The Sandia group lived in the cave just before this nominal date and the Folsom just after it.

CULTURAL MATERIAL FROM THE CAVE

The Recent Layer

Cultural material in this stratum was confined entirely to the very front of the cave, in spite of the fact that the level itself extended some 60 to 70 meters from the mouth. This cultural material in no wise represents a continuous or long occupation. It is obviously sporadic, judging both from the paucity of the remains and the time sequences involved.

Of the 11 potsherds from the very mouth of the cave, 2 were of Pueblo III date of the black-on-white type known as Santa Fe black-on-white (Mera, 1935, p. 16). The remaining potsherds were distributed evenly between Glaze I black-on-red, and Glaze IV.[4] Two sherds of the typical late Glaze corrugated utility ware were also present (see pl. 5, fig. 1). This whole sequence represents a late and intermittent occupation of the mouth of the cave, presumably on trips into the mountains by Indians from pueblos on the Rio Grande, in the vicinity of Bernalillo. It is difficult to understand why the cave should have been used at all, as its mouth was so inaccessible in recent times.

A crude metate of the type which is common in many cave shelters and temporary habitation sites in the vicinity was found just inside the mouth of the cave. It was evidently manufactured locally from a sandstone slab that approximated the shape of a metate. No mano accompanied it.

At the very top of the fill at the front of the cave was found a section from the base of a mule-deer antler cut with a steel edge. This piece may indicate any date from early Spanish times to the present.

Albuquerque Troop 13 of the Boy Scouts of America had in their possession (although they are now lost) several fragments of yucca cordage, feather cord cloth, and twilled sandals from the front portion of the cave. W. E. Bambrook, of Albuquerque, has a fragment of a coiled basket found there at the time the Boy Scouts made their original investigations.

Those portions of the recent deposit beyond the low portion of the roof of the cave near the entrance are devoid of cultural remains. Evidently at the time of the recent or Pueblo occupation accumulated material already reached the roof so as to impede further progress into the interior of the cave without some digging. Pack rats had carried sticks, yucca leaves, pinyon cones, and other typical debris into crevices and cracks of the roof at many places near the entrance. These animals are still very common in the cave, and maintained their residence during excavating operations. In the very rear portion of the cave, however, even the pack rats were absent. Pack-rat debris and bat guano are not found back of meter 70. Beyond this point the recent stratum is represented only by a thin layer of finely divided dust.

Folsom Cultural Layer

The Folsom cave floor, as mentioned previously, rests upon the yellow ochre layer below and is capped by the travertine layer above. Although the Folsom stratum extends far back in the cave, to about

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[4] Kidder and Shepard, 1936. See discussion on glazes in pt. 1, pp. 1-263.

meter 100, cultural material is not found equally over this whole extent. Flint flakes, artifacts, and charcoal are fairly evenly distributed from the front of the cave back to meters 20 or 21. Beyond this, cultural remains are widely scattered. One blade referable to the Folsom occupation was found at meter 75—the only artifact found in this whole excavated section (pl. 4, fig. 1).

The Folsom cave occupation is dated by the occurrence in this layer of typical or classic Folsom points. Two entire specimens (pl. 6, *a*, *b*) and two Folsom bases (pl. 6, *c*, *d*) were obtained from this layer of the cave. The illustrations show these to be typical Folsom points with all the essential features, outlines, and size of those from the type site at Folsom (Brown, 1929) or the extensive Folsom camp at Lindenmeier. These Folsom points from Sandia Cave, it is true, have the appearance of being somewhat poorly made. This, however, does not prevent them from being placed in a pure Folsom category, as some of those from the type site also have channel chips broken off short, or slightly askew (Roberts, 1935, pl. 5, *a*, *b*). Folsom points from Sandia Cave are sufficiently close to already known Folsom areas so that their occurrence here is not totally unexpected. Their situation in a cave is unusual but not unique (Howard, 1935, p. 69).

The occurrence of Folsom bases with the other portions missing is rather usual. As has been observed by Roberts (1935, p. 21), the occurrence of bases is to be expected, as many points were broken off in the field and the butts apparently carried back in the shaft to the camp—in this case the cave—to be replaced with new points.

The channel flakes, typical of Folsom sites where points were manufactured, are absent in Sandia Cave. This is the first of the evidence indicating that the cave was a hunting station only and not a permanent habitation site.

In addition to the typical Folsom points, projectile points of another type occurred with them. These would under certain circumstances be described as Yuma types (Wormington, 1939, pp. 22-26), although the term "Yuma" has been much misused. In this instance they are regarded as Folsom points lacking the channel on either face, but identical with them in all other features. As the term "Folsomoid" has likewise been much misused, these points are classed as Folsom of a still different form, or unfluted Folsom-shaped points, although admittedly this does not clear the confusion. Two of these were found in place in the matrix of the Folsom layer (pl. 5, fig. 2), and an additional entire specimen was recovered in the screen (pl. 6, *h*).

Sandia unfluted Folsom-shaped points are similar to and probably identical with some of the so-called Yuma points recovered at Clovis by Howard (1935, pl. 39). There, as in Sandia Cave, they occur with the typical Folsom forms. Similar points have been found in association with *Bison taylori* at a site near Tucumcari, N. Mex., investigated by the University of New Mexico. Roberts (1935, pls. 5, *i*, 6, *i*) also found similar points with the Folsom material at Lindenmeier. Apparently there is no time differentiation, but a cultural difference is implied by the fact that these Folsom-shaped points are absent at Folsom itself and uncommon at Lindenmeier.

These points have the even flaking considered so typical of the Yuma series. In outline, they are much like the Folsom, even to the indented base. The edges of the base are ground to a very noticeable degree for about one-third the distance up the blade. However, this is not only a Folsom as well as a Yuma feature, but also is present on other types found elsewhere. Inasmuch as this type of point occurs occasionally in association with typical Folsoms, yet is absent from other Folsom sites, it possibly should be regarded as indicative of a group of peoples contemporaneous with, but possibly distinct from, the Folsom.

A single point, also found in the Folsom layer, falls into a different category (pl. 6, *g*). It displays chipping suggestive of the Yuma and, like the points described, lacks the longitudinal grooves. It differs in outline, however, in that the blade narrows perceptibly toward the base. This lanceolate type of point is occasionally found in surface situations in the southern Plains area. It apparently was contemporaneous with the Folsom and may be merely a variation from the foregoing series, although it could be from another complex.

Artifacts of other categories were also present. Now considered an accompaniment, although not necessarily a criterion, of the Folsom complex are large blades such as those found at Lindenmeier and at Clovis (Roberts, 1935, pl. 15; 1936, pls. 5, 6; Howard, 1935, pl. 29). Two complete blades and three fragments were recovered from Sandia Cave. One of the blades, as mentioned previously, was the only artifact that occurred in the section excavated between meters 72-83. This blade was solidified in the typical cave breccia. The other whole example occurred near the top level of the Folsom layer and was cemented into the lower side of the travertine crust near meter 15 (pl. 7).

These blades show none of the delicate chipping or fluting of the Folsom or Folsom-shaped points. It has been well established at Lindenmeier (Roberts, 1935) that the Folsom points themselves form only a small part of the Folsom complex, and that the tradition of fine workmanship as exemplified in the Folsom points does not necessarily carry over into other forms.

Gravers, considered as Folsom equipment although not exclusive to it, were also present. Five entire gravers of the usual type were found in the cave (pl. 6, *i, j, k, l, m*). These follow the outline of such artifacts occurring at Lindenmeier (Roberts, 1935, pl. 13) and were apparently used for the same purposes.[5]

Gravers have been divided by Wright (1940, pp. 31-48) into several types and classes on a basis of specimens found in Texas. Sandia Cave examples include both the sharp-beaked varieties and one example of a graver with a broader drill-like point (pl. 6, *n*). Both of these types occurred at Lindenmeier (Roberts, 1935, pl. 13; 1936, pl. 9). Although these gravers are apparently not exclusively Folsom in age or distribution, they may be taken with the accompanying artifacts as additional evidence that this particular level of Sandia Cave is Folsom in date.

Scrapers of three varieties also accompany the Folsom material of this level. Snub-nosed scrapers, side scrapers, and concave scrapers are all Folsom-complex adjuncts, although none of them may be considered distinctive or exclusive to Folsom areas or Folsom horizons. It has already been pointed out (Roberts, 1935, p. 23; Howard, 1935, pl. 31) that the snub-nosed scraper is practically timeless, and, for that matter, geographically useless as well. Snub-nosed scrapers from Plains sites are practically identical with Folsom specimens, in form as well as in their probable hafting and usage. Snub-nosed scrapers from the Danubian Neolithic[6] are indistinguishable from those of Sandia Cave.

Of the above three varieties of scraper forms, the snub-nosed is the most common in the Sandia Folsom deposits. Plate 8, *a, b, c, e, f,* and *g,* show these to be perfectly typical in all respects. Their chief distinction is to be noted in their size; the largest specimen from the Folsom level measures 4 centimeters in greatest dimension. As the scraper series from the Folsom deposits of Sandia Cave is comparatively small, it seems valueless to go into subtypes paralleling those of Roberts (1935, p. 23), although most of these subtypes seem to be present in the Sandia collection.

[5] Roberts (1936, p. 26) suggests that these gravers might have been used for tattooing as well as for engraving bone.

[6] Specimens in the collection of the Museum of Anthropology, University of New Mexico.

Four side scrapers make up the total of that type of implement from these deposits. They exhibit considerable range in size and degree of finish. All are distinguished by being formed from a flake, one or both edges of which were carefully dressed by rechipping. In general, the convex surface of these implements was chipped so that the concave edge could be used (p. 9, fig. 1).

A single scraper in the collection differs radically from the others (pl. 8, *d*). This might be termed an end scraper but is perhaps better described as a scraper with a concave cutting edge. This is very similar to one described from the Lindenmeier site (Roberts, 1936, fig. 3, *b*). It apparently combines ordinary scraping functions with shaft smoothing.

In addition to the above more or less definitely formed siliceous artifacts, there are also in the collection heterogeneous flakes of indefinite shapes. Many of these would serve well as knives and a few approach vaguely flake-knife forms of Neolithic horizons (pl. 9, fig 2). None of the latter are, however, of definite enough form to be included in a regular flake and core classification. A few flakes of irregular outline were apparently chosen for their sharp cutting edges. Flake knives of similar form are also Folsom accompaniments as at Lindenmeier (Roberts, 1935, pl. 14, *a, b, c, d, e;* 1936, pl. 11). Others are obviously merely waste material. It is interesting to note that such waste material is remarkably scarce in the cave, and the site may be in no wise regarded as a place where flint was worked extensively.

Also in the Folsom cave debris occurred occasional pieces of worked bone. These may have been at one time much more common than their sporadic occurrence in the collection would seem to indicate, as bone preservation in the Folsom level was not ideal. The largest and most interesting piece is a splinter apparently of ivory(?) (pl. 10, fig. 1). This has a generally elongated shape but flattish cross section. It was sharpened to a spatulalike point at one end by means of abrasion.

Two other bone splinters in the Folsom-stratum collection show slight signs of working along one edge but have no distinguishable form. This working may be secondary as a result of using the splinters for scraping purposes.

Also in the category of cultural material from the Folsom floor are numerous fragments of charcoal. For the most part these fragments were extremely small and were well mixed with the other debris. If any definite fire areas had existed in the Folsom level, they had been obliterated by the passage of men and beasts, by movements that would disturb such areas and tend to pulverize and mix the charcoal with other materials. Fragments of such charcoal occurred from the bottom of the Folsom level, where they actually were embedded in the yellow ochre, to the topmost portion of the deposit where some fragments were encased in the stalagmitic crust.

Cultural Material from the Sandia Layer

As the Sandia layer was less firmly consolidated than the Folsom above, its excavation was considerably facilitated and more artifacts were actually found in place in the cave, rather than in lumps of the breccia after they were moved to the laboratory, as was often the case with the Folsom material. Thus an exact check could be kept on the occurrence of the Sandia objects, especially as the accumulation of that stratum seems to have continued over a considerable period of time.

The projectile points from the Sandia deposit are its most distinctive cultural feature. Nineteen whole or broken points were recovered from this layer. They tend to separate into two main categories.

In the lowest levels occurred a type that may be described as lanceolate or rounded in general outline. The base has a side shoulder or notch on one side, in what may be accurately described as a Solutrean manner. These points may be matched detail for detail in Solutrean collections (MacCurdy, 1937). This similarity to Solutrean material does not necessarily imply connection or contemporaneity with it, although the resemblance is remarkable.

The chipping on the Sandia points from the lowest levels is good but not fine. It displays a chipping tradition differing radically from the careful retouch of the Folsom points in the level above. There is no suggestion of basal thinning or facial channels in these lowermost Sandia examples, although the edges of the base are ground. This form may be tentatively identified as Sandia type 1 (pl. 10, fig. 2, *a;* pl. 11).

At several places in the Sandia level as a whole, there are evidences, although not very clear ones, that the Sandia deposits represent a dual epoch. In the vicinity of meter 17 occur thin and sporadic sterile layers, as though the cave had been unoccupied for a short time. Above and below this somewhat uncertain separation, the projectile points of the Sandia show some differences. Sandia points from the upper levels of the stratum may be described as elongated, with parallel sides and straight or slightly indented bases. In cross section, this tends to be diamond-shaped rather than lenticular. Plate 10, figure 2, *b,* and plate 12, figure 1 and figure 2, *a, b,* show that this type also has the typical Sandia side notch. These points likewise may have parallels in Solutrean collections, and conform closely to the outlines of the famous late Solutrean points à cran (MacCurdy, 1932, fig. 22). These points, which may be designated as Sandia type 2, show some differences in chipping from the earlier ones. There is a tendency to thin the base, although the removal of such basal chips may not be considered in any sense as comparable to actual fluting. The chipping on the body of the blade is slightly suggestive of certain so-called Yuma types, as is the flattened, diamond-shaped cross section. Dr. Roberts, in a personal communication, has suggested that these points may be proto-Yuma forms. Their position below the Folsom in Sandia Cave possibly, although not necessarily, adds weight to such a supposition.

The side-notched form of Sandia type 2 connects it with type 1. Indeed, it is difficult to decide to which type certain specimens belong. Hence the present subtyping may not have validity under all conditions. Prevalence of the side shoulder or side notch establishes that feature as a distinguishing characteristic and the distinctness of both the Sandia types from the Folsom is a salient factor.

Certain of the points from the Sandia layer (pl. 13, fig. 1, *b, c*) are so nondescript in shape that they fit neither type. They may be regarded merely as crudities or aberrant specimens.

Snub-nosed scrapers also appeared in the Sandia level. Three of these were recovered (pl. 13, fig. 2, *a, b*). The main characteristic distinguishing these from similar scrapers of the Folsom stratum is size. Snub-nosed scrapers of Sandia times range from 7 to 10 centimeters in greatest dimensions, as contrasted with the very small examples from the layer above. Also, the Sandia snub-nosed scrapers are not so finely chipped or finished as those of the Folsom.

The snub-nosed scraper in the Sandia level adds another and earlier chapter to the long and varied history of this interesting implement. In spite of the comparative crudity and size of the Sandia examples, there is no doubt that they were used and possibly hafted much as were those of later times, such as the well-known Plains scrapers of this class. Their presence and consequent usage seems to indicate work on the skins of animals, as was apparently the case in Folsom and also later times. It is interesting to note that the snub-nosed scraper now has a chronological distribution as long as, or longer than, any other known type of artifact not excluding the arrowhead. Its geographical distribution is equally impressive. The snub-nosed scraper is common to both the Old and New Worlds. Exactly parallel forms occur in the European Neolithic, Siberian and

Chinese Neolithic, and in the New World. Bird (1937) discovered snub-nosed scrapers in very early levels in cave sites in southern Chile and Tierra del Fuego. Here he noted (1937, p. 36) a scraper sequence in which the small or "thumb-nail" scrapers of the snub-nosed variety appeared suddenly in an upper level.

There were numerous rough flakes in the Sandia level and although most of them may not be regarded as actual implements, a number were undoubtedly used for cutting purposes. Their natural sharp edges would have functioned well in such a capacity. Apparently this is but another indication that chipping techniques of the Sandia level were not advanced as far as those of the Folsom. Folsom blades or flake knives were struck off with some certainty as to the result of the final outline, the desirable form being an elongated shape with roughly parallel cutting edges. In the Sandia stratum nothing of the sort occurs.

Only one side scraper occurred in the Sandia level. This is made in the usual manner from a large flake and is chipped on both edges (see pl. 13, fig. 2, *c*). It differs in no radical way from similar scrapers of the Folsom or, for that matter, of many other later cultures. These side scrapers, both in the Sandia and the Folsom level, vary widely as to exact outline and degree of finish. Apparently, they were made on the spur of the moment, and their degree of refinement varied with the specific use for which they were intended.

Perhaps the most interesting variation of the Sandia level is the occurrence of two items of worked bone. They are points of bone seemingly similar in purpose to the projectile points of stone previously described. One of them (pl. 12, fig. 2, *c*) is especially well worked and approaches the general outlines of a Sandia point. A slight side shoulder or notch is present, and the base is rounded after the manner of a type 1 Sandia point. The other point, although fragmentary and in a poor state of preservation, is apparently similar, both in outline and in size. Both were made from a fragment of the shaft of a long bone from a medium-sized animal. From the general contours and curvature of the best-preserved point, this appears to be one of the long bones of *Camelops*.

Bone points are not out of place in the Sandia collection, and their occurrence in this instance occasions no surprise. Primitive hunters from Mousterian times on were accustomed to use either artificially shaped or accidentally splintered bones of various kinds. Roberts (1936, pl. 9, *c;* also personal communication) in the last seasons at Lindenmeier especially, has recovered an impressive collection of bone implements in connection with the Folsom industries there. The supposition is that both the Sandia and Folsom inhabitants of Sandia Cave utilized bone more extensively than the mediocre preservation in the cave would seem to indicate.

Two definite hearths, or fire areas, occurred in the Sandia level, although flecks of charcoal were fairly abundant throughout. Figure 4 shows both of these to be well within the mouth of the cave, although, as Professor Bryan suggests, there may well have been more in the portions of the cave now eroded away. The first hearth encountered, that at meter 13 (meter 7 according to the survey of the first year of excavation), was a large area of finely divided charred material measuring some 45 centimeters in greatest width by 30 centimeters in depth, and extending in small pockets or lenses down to and partially into the surface of the white clay layer below. The material itself was too finely divided to be identified specifically, but it represented oak and some species of resinous trees. Around the edge of this fire area was a partially enclosing circle of rounded boulders, averaging 10 centimeters in diameter. These rounded boulders, although also of limestone, apparently were brought from the creek in the bottom of the canyon and were in marked contrast to the angular fragments of stone usual in the cave debris. These small boulders roughly outlined the charcoal area and may have been used to keep the ashes from spreading or to act as supports or partial fire dogs for sticks, for roasting pieces of meat, or the like.

Just outside the fire pit and actually touching one of the boulders was a Sandia point (pl. 10, fig. 2, *a*). This point is of the rounded variety and is good evidence for assigning the hearth to the earlier phase of Sandia occupation.

The other hearth, at meter 15 (figs. 4, 7) was unembellished by any boulder ring. It contained a concentrated quantity of charcoal in finely powdered form. Mixed with the charcoal were charred fragments of bone and calcined remnants of other bone pieces cemented into a mass by calcium-charged waters seeping down from above.

A possible explanation for the preservation of hearths in the Sandia level, in contrast to their absence from the Folsom above, is that they probably were covered over before they could be dissipated by the passage of men and animals back and forth through the cave. Undoubtedly, other fire areas that existed in the Sandia level were so obliterated, as were similar ones in the Folsom horizon.

Materials Utilized in Cultural Objects

Flinty materials used in the manufacture of cultural objects in some cases give definite evidence as to origin. The sources of various varieties of flints, chalcedonies, cherts, and the like, are not as yet

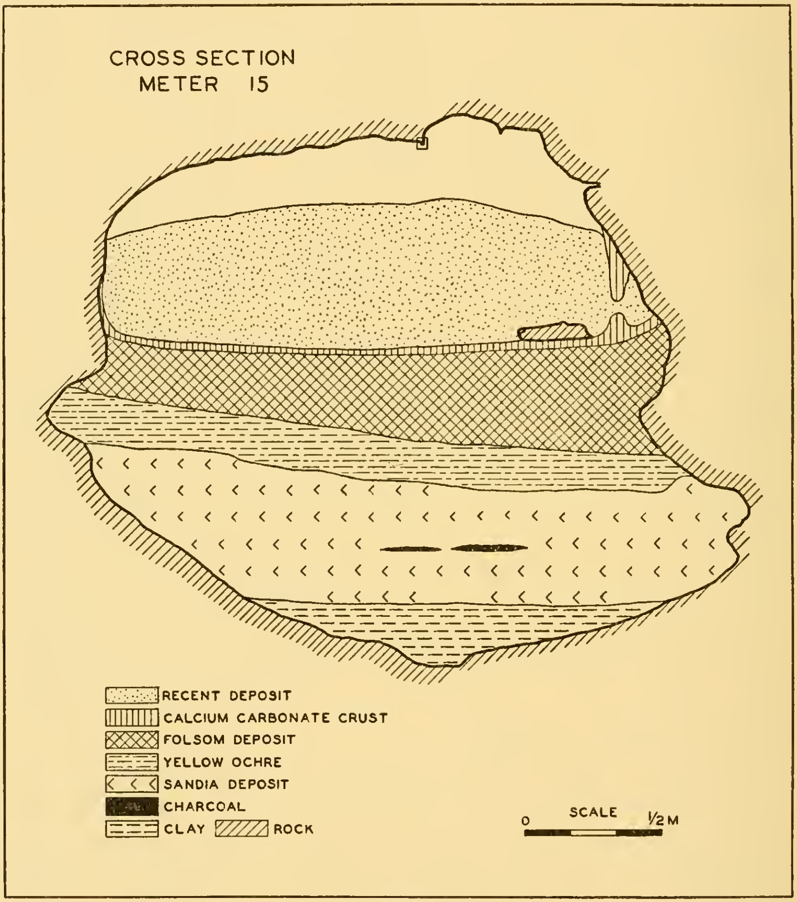

Fig. 7.—Cross section of Sandia Cave at meter 15.

well known in the Southwest, although studies of this nature are progressing at the present time (H. Holmes Ellis, 1940). The prehistoric quarries near Amarillo, Tex., are well known, and material from them can be identified, at least in most cases. Of more immediate moment are the chalcedony pits of the Pedernal region of New Mexico, especially as these give evidence of considerable antiquity (Bryan, 1939). Certain varieties of obsidian, that from the

Jemez Mountain area for example, are distinctive. Many and varying types of materials from quartzites to fine chalcedonies were used in the manufacture of tools in eastern and southeastern New Mexico in prehistoric times. Sources for most of these can only be suggested at the present writing, although even a rudimentary survey indicates that objects of similar materials tend to classify themselves into regions and areas.

Materials utilized in the manufacture of the artifacts from Sandia Cave, in both the Folsom and Sandia levels, are varied, although the general observation may be made that many are local or from the general Sandia-Manzano region. Quartzites are notably scarce in the collections. This is a distinctly negative feature by reason of the fact that quartzite scrapers in quantity—in some cases actual points—are present on the classic Folsom sites in eastern New Mexico and even on the Folsom site in the Estancia Valley near Stanley, only 20 miles east of Sandia Cave.

In the recent level of the cave, the few chips and artifacts present were all of the multihued and usually translucent chalcedony of the Pedernal variety (H. Holmes Ellis, 1940). This chalcedony, or cherty material, occurs commonly in the river terrace gravels along the Rio Grande at no great distance from Sandia Cave. The material on the Rio Grande terraces is usually in boulder form and is generally unsuitable for implement manufacture because of numerous fracture and cleavage planes as well as flaws. It was satisfactory, apparently, for such small items as rough scrapers, irregular flake knives, and the like.

The Folsom level of Sandia Cave presents a more varied list of materials. Pedernal chalcedony is present in the form of chips, flakes, and snub-nosed scrapers. The Folsom points themselves are of materials approaching the chalcedony classification but apparently of a different source. The unfluted point embedded in matrix shown in plate 5, figure 2, is of white chalcedony similar to material from the region around Clovis, N. Mex., although the exact source is unknown. The Folsom point shown in plate 6, *b,* is of brownish agate chalcedony not uncommon in southeastern New Mexico. The Folsom base, *d,* is of mottled purplish chert, a material occurring in the Texas Panhandle.

Of utmost importance is the observation that a considerable portion of the Folsom artifacts from the cave were apparently made from local materials. Cherty concretions in the Magdalena limestone of this region and in the very walls of the cave itself are of such a consistency that workable nodules may be found in some portions.

A fairly satisfactory mottled gray chert is rather common. Chert of a buff cast with a slightly gritty surface also occurs in the limestone and is undoubtedly the material represented in the Folsom point in plate 6, *a*. A number of the scrapers are also made from local materials.

The Sandia stratum is even more local, as far as material aspects are concerned. The Sandia points in plate 10, figure 2, *b*, and plate 13, figure 1, *b*, are made from cherty concretions of local origin. Chalcedony is not common in this level, although fragments occur. There are two fragments from points made from andesite.

Certain items in the Sandia collection appear foreign to this area. One Sandia point of a smooth-grained brown chert is unparalleled by any fragments of material from the Sandia-Manzano area.

The lack of complete information on source distributions of the flinty materials prevents the drawing of definite conclusions on the origins of Sandia objects. However, the fact that local materials were used to such a large extent is significant as evidence that there was more than a merely fortuitous occupation of the area by a transitory group.

Correlation of the Sandia Cultural Deposits

Certain definite conclusions may be drawn from the cultural material from Sandia Cave as well as from other less explored sites in the region. The significance of most of the material is self evident. Much of it has been paralleled in other places and can be regarded merely as additional supporting evidence. Certain factors, though, do contribute further information on the question of the Paleo-Indian.

The few potsherds found in the layer of recent material indicate definite affiliation with the Pueblos of the Rio Grande area. Glaze wares of this sort may be duplicated at Paako, Sandia, Kuaua, or Puarai. These sherds may be the results of sporadic excursions into the mountains by inhabitants of these late pueblos. It has been suggested that this late Glaze evidence may be correlated with the period of the Pueblo Revolt in 1680, when large portions of the pueblo population fled to refugee areas to escape the vengeance of the returning Spaniards. Even though some of the glazes are too early to fit into such a historical theory, there is a remarkable chronological parallelism in the sherd evidence of the many caves and rock shelters of the whole Sandia region. It seems that they were all used at about this time. Pottery is not usually carried on hunting trips.

Correlations of the Folsom layer with other sites of similar culture may be summed up as presenting three alternatives. The Folsom level of the Sandia Cave is:

1. Contemporaneous with previously known Folsom.
2. Peripheral to Folsom.
3. Later than classic Folsom.

Of these three alternatives, which of course do not exhaust the possibilities, the first seems to be the most logical. There is no reason to doubt that this level of the cave was contemporaneous with other Folsom centers, such as the type site at Folsom, N. Mex., Clovis, N. Mex., or Lindenmeier, Colo. Although not in as great a quantity, the list of implements accompanying the Folsom is typical in all respects and undiluted by any extraneous element of later date. Furthermore, the sealed-in character of the Folsom precluded the possibility of disturbance, a circumstance not present in most open sites.

The last two possibilities may be grouped together. Sandia Cave may be regarded as somewhat peripheral in relation to general Folsom distribution in spite of its nearness to the Estancia Valley, which was evidently good Folsom territory. In such a peripheral status, it may be argued that the Folsom of Sandia Cave would therefore be of later date. Such a contention is supported by the fact that the Folsom points of the cave are somewhat crudely made. Facial channels may be complete on one side and only partial on the other as a result of the too abrupt breaking off of the channel flakes. Materials chosen for some of the points are comparatively poor. Even all this evidence, however, does not sum up to a late date for the Sandia Folsom.

The faunal assemblage associated with the Folsom level of the cave is in every respect late Pleistocene in character. Only one animal, the sloth, might be considered as indicating a later date, but even *Nothrotherium* has been found in typical Pleistocene associations.

Sandia material, from the lower levels of the cave, is more difficult of correlation because of lack of parallels. The earlier status of this culture is evident. Its geographical extent is not nearly so plain. Since the original discovery of the Sandia level, the University of New Mexico has been at some pains, through its various agencies, to gather additional Sandia material. This has been extraordinarily scarce and hard to find. Some indications are, however, coming to the fore. Sandia points occur sporadically from southeastern Colorado to central Texas. The bulk of the Sandia points located so far come from the southern region of the Plains, centering about southeastern New Mexico and western Texas. Points of the earlier Sandia type, according to present information, seem to have the widest distribution. Some of these (the lanceolate or type 1) occur sporadically throughout the Mississippi Valley and along the eastern seaboard. The problem in this instance is remarkably parallel to that of the relationship of the classic Folsom point to the "Folsomoid" types found over such a wide area in North America.

Type 2 Sandia points or "proto-Yuma" types are apparently of more limited distribution, being confined entirely to southeastern New Mexico and adjacent portions of Texas. This distribution, of course, may be widened with additional information.

One fact becomes evident as the cultural material of both the Sandia and Folsom layers is viewed. There is no doubt that the cave was occupied only intermittently throughout both of these periods. There is no evidence of long habitation or of use of the cave as a workshop or chipping ground. Unfortunately also, a lamentable feature is that the cave was never used for burial. The Sandia Cave may be regarded, then, as a hunting station utilized successively by several cultures.

PALEONTOLOGIC IDENTIFICATIONS

Faunal material was not abundant in the cave in either the Sandia or Folsom levels, as preservation was generally poor, owing to the various wet periods in the history of the cave. Although fragments were generally small, and in many cases badly eroded, their aggregate number is large. A satisfying portion of the paleontologic collection consisted of teeth, which are generally very good for identification purposes. In certain areas of the various strata, owing to vagaries of the percolating, calcium-charged waters, bone preservation was better than the average. In such places "nests" of bone material were encountered, either highly fossilized or otherwise preserved, in some cases covered entirely with a coating of calcite crystals. Articulated, or semiarticulated limbs of *Camelops* and *Equus* were found under these circumstances. Such a large percentage of the bones, however, were represented only by splinters and fragments that artificial breakage to extract the marrow must be the explanation. It is somewhat more difficult to explain the presence in the cave of large numbers of teeth, including those of *Elephas* and *Mastodon.* It seems illogical that the bulky heads of such animals would have been carried into the cave by man, although, of course, there is some flesh on them. Indubitably, cave-dwelling carnivores intermittently added to the faunal aggregate of the cave material.

Mammals represented in the topmost or recent level of the Sandia Cave are listed below in order of the numerical importance of the bones represented, although this is only an approximation of the true relationships, as the collection contained many unidentifiable fragments.

Wood rat (*Neotoma* sp.)
Bat (*Tadarida mexicana,* also other sp.)
Mountain sheep (*Ovis canadensis*)
Elk (*Cervus* sp.)
Mule deer (*Odocoileus* sp.)
Ground sloth (*Nothrotherium* sp.)
Porcupine (*Erethizon* sp.)
Bear (*Ursus* sp.)

Mammal material from the Folsom layer includes the following, also roughly in order of importance:

Horse (*Equus* near *occidentalis*)
Camel (*Camelops* sp.)
Bison (*Bison,* near, but smaller than, *taylori*)
Mammoth (*Elephas* sp.)
Ground sloth (*Nothrotherium* sp.)
Wolf (*Canis,* cf. *lupus*)

The Sandia layer includes in its faunal assembly the following:

Horse (*Equus excelsus*)
Bison (*Bison antiquus*)
Camel (*Camelops* sp.)
Mastodon (*Mastodon americanus*)
Mammoth (*Elephas* sp.)

Outstanding among the considerations brought to light by this faunal assemblage is the occurrence of ground sloth on top of the crust in the lower portions of the recent layer. Several specimens attributable to sloth, including one claw core, were found in the rear of the cave directly on top of the travertine layer. As these were mingled with no human artifacts, the supposition is that the material was deposited by animals actually lairing in the cave. It has been already ascertained from the Gypsum Cave studies (Harrington, 1933) that ground sloths of the genus *Nothrotherium* habitually frequented caves. Because of the stratigraphic sequence in Sandia Cave, this adds valuable weight to the theory that the ground sloth lingered into early Recent times.

The remainder of the fauna of the recent layer is not at all remarkable and can be duplicated in any of the other caves of the Sandia group (in none of the other Sandia caves does sloth appear in the recent level). Both mountain sheep and elk have long been absent from the Sandia and Manzano regions, although the former has recently been reintroduced. Indeed, no species of elk has ever been recorded from the Sandia Mountains, presumably having become extinct at a very early date.

The fauna of the Folsom layer adds no radically new information to our knowledge of that period. Although this assemblage is comparatively large, associations of Folsom or Folsomlike material have been made with each of these mammals. Only the sloth is peculiar in this particular, but previous knowledge of the time in the Pleistocene occupied by the sloth readily admits of this association. Conkling Cavern (Conkling, 1932) also featured sloth with horse and camel. The sloth, in this instance, might argue a late date for the Folsom material from Sandia Cave.

The bison of the Folsom layer is believed by Gazin to be slightly smaller than the classic *Bison taylori* which normally accompanies Folsom material as at the type site at Folsom, N. Mex. The comparative scarcity of bison in the Folsom layer of the cave may be attributed to the character of the surrounding terrain, which is only partially Plainslike and consequently not particularly well adapted for bison habitat.

The Sandia layer is chiefly distinguished by the addition of the mastodon and the deletion of the sloth. It has been generally supposed—and this seems to be borne out in this instance—that the ground sloth was late Pleistocene and early Recent in date. The mastodon, however, has also been found in assemblages which indicate that it may have lasted late in some areas. The absence of the mastodon in the upper levels of Sandia Cave may indicate nothing, as a number of bone fragments referable to Proboscidia were unidentifiable.

Equus excelsus from the Sandia stratum has so far not been differentiated from the *occidentalis* form of the Folsom level. *Excelsus* is based upon material from Hays Springs, Nebr. It is believed to be very close to *Equus complicatus*. Indeed, some authorities believe that the original type material should have been so termed. Leidy (Gidley, 1901, quoting Leidy, 1869, p. 267) believed *occidentalis* indistinguishable from *excelsus*. Both forms are similar and close to *complicatus*. Both of these horses are medium-sized Pleistocene forms with possibly some differentiation in range. *Excelsus* has heretofore been considered a Plains type, whereas *occidentalis* has been thought of as coastal in distribution.

Manzano Cave

As previously mentioned, certain caves in the Manzano region south of the Sandia Mountains give indication of fitting in and adding to the Sandia sequence. One of these, especially, termed Manzano Cave, is the most important of this group. This cave is located 5 miles to the west of the small town of Manzano in the limestone foothills of the Manzano Mountains. Manzano Cave is considerably larger than Sandia Cave in general dimensions, although not nearly so long. This cave was brought to our attention in 1939 by guano diggers operating from the town of Manzano. One of these, M. Garcia, brought to the Museum a side-shouldered point apparently belonging to the Sandia complex (pl. 14, fig. 1, *d*). Spurred by this discovery, the University of New Mexico made some investigations in the cave. Unfortunately, however, digging operations by the local people had progressed so far that only a small portion of the original deposits remained. These were dug over with care and some information gleaned.

Manzano Cave contains a stratigraphic sequence which may parallel that of the Sandia site. On top is a recent deposit of considerable depth made up of dirt in sections where the cave is damp, and of guano where it is dry. This deposit, in places where it can still be measured, is over 2 meters thick. Below the recent deposit extends a layer of disintegrated limestone of sandy consistency, intermingled with small limestone fragments. This was cemented into a solid mass by calcium carbonate. This breccialike layer was 1 meter thick (slightly less in some places) and extended over the entire cave floor, apparently corresponding to the travertine layer of Sandia Cave. As far as could be ascertained, this layer was devoid of cultural content, although some unidentifiable bone fragments were recovered. Below the cave breccia occurred a layer of stratified disintegrated limestone mingled with lenses of yellow ochre. This stratum of varying thickness was also sterile. Mr. Garcia assured us that it was below the yellow ochre layer that he obtained the Sandia point. No excavations were made by our expedition beneath the yellow ochre because of the already disturbed nature of most of the deposits.

In a segment of Manzano Cave, on the west side of the main chamber, was recovered a quantity of cultural material embedded in rock fragments and limestone debris intermixed with disintegrated and amorphous dung. This section, less rich in returns, had been undisturbed by either the guano hunters or the relic hunters. In this small segment, on top of the cave breccia, and at the base of the accumulation of recent material, were found a number of stone balls and three projectile points. The only bones identified from this section were those of *Camelops* and *Nothrotherium.*

The projectile points are not arrowheads, and because of similar outline and technique, may be ascribed to the type known as Gypsum Cave points (Harrington, 1933, figs. 53, 54, and 55). Plate 14, figure 1, *a, b, c,* shows these to be remarkably similar to the atlatl points recovered by Harrington at Gypsum Cave, except that the Manzano specimens seem to have considerably more flare and definition of the shoulder. Because of their position in the cave debris and other associations, they may be attributed to a horizon corresponding with that of the Gypsum Cave material and may be contemporaneous with the sloth.

The stone balls found in this same area and at this level, add a different note to the picture. Three of these were found together and apparently represent a set (pl. 14, fig. 2, *a, b, c*). These are of approximately the same size (4 cm. in greatest dimensions), and are of equal weight (2 oz. each). Each of the three has a well-defined groove completely encircling it. All are of limestone, one of them containing a small fossil shell, apparently a brachiopod. One of the balls is of a decidedly reddish cast. After consultation with Junius Bird in connection with his South American explorations, where such things are common, these balls have been identified as bola balls.

In this same excavation two other balls apparently belonging to the same category were found. One of these is of limestone and the other a fragmentary specimen of granite. The granitic bola is grooved (pl. 14, fig. 2, *d*), the limestone one smooth and ungrooved. The limestone ball is 5 centimeters in diameter and weighs 5½ ounces.

Since the initial discovery a number of these stone balls, both grooved and ungrooved, have turned up. Some are slightly pear-shaped with a notch or pit in the pointed or elongated section.[7] Materials vary from limestone to granitic and volcanic rocks, with limestone the favorite.

Balls of this sort are not unusual in Southwestern collections, although their identification as bola weights has seldom heretofore been suggested.

Isleta Cave

Another cave in the vicinity of Albuquerque adds some weight to the chronological picture of the Sandia-Manzano-Albuquerque

[7] Mr. Bird has pointed out that this pit was for the accommodation of a knotted thong by which the bola ball was secured. See Bird, 1938, p. 17.

region. This site, known as Isleta Cave, is totally different in nature from either the Sandia or Manzano cave groups. Isleta Cave is located in the lava fields on the west side of the Rio Grande River approximately 10 miles due west of the pueblo of Isleta, on the Isleta Indian Reservation. This cave was also made known by guano hunters working under lease from the Isleta Indians.

Isleta Cave is a blowhole in the lava, one of those cavities so frequent in lava fields, and is of unusual size. The entrance is vertical, extending straight down through the oculus for a distance of 9 meters to the debris below. The major cave chamber itself is of considerable size, measuring some 20 meters in its greatest dimension north to south. Leading off from the main chamber are two passageways or enlarged cracks in the lava extending southeast and southwest. The southeastern one, especially, extends for a considerable distance—some 100 meters—and ends finally in a series of smaller fissures and cracks, which have not as yet been fully explored.

Amidst jumbled lava blocks in the east passage, unfortunately the area most disturbed by the guano hunters, were cultural and faunal evidences that shed some light on the prehistory of the region. Students from the University first recovered a series of atlatl shafts with the typical cupped butt and detachable foreshaft arrangement. In addition, there was a series of large bones accompanying the atlatl remains, but their exact relationship is uncertain, because of the disturbance. Subsequent explorations in the cave, although still of a preliminary nature, revealed other evidences. Flint material, which has been found for the most part around the cave mouth and never in association with atlatl fragments, consists of Folsom-shaped points and some 40 small snub-nosed scrapers. These evidences are nonconclusive and are quite as baffling as the classic "blow-out" sites of the Plains region. Faunal material from the cave, some of it found between lava fragments and in crevices immediately on the surface, includes the following:

Bison (*Bison* sp.)
Camel (*Camelops* sp.)
Mammoth (*Elephas* sp.)
Horse (*Equus* sp.)
Bear (*Ursus* sp.)
Lion (*Felis* sp.)
Lynx (*Lynx* sp.)
Antelope (*Antilocapra?*)

The faunal assemblage from Isleta Cave, although of uncertain association at the present writing, gives evidence of being late Pleistocene in character and adds to the Paleo-Indian material already collected in this area.

Small test pits in portions of the cave that appear to be least disturbed indicate a stratigraphy varying greatly from that of either Sandia or Manzano Caves. The almost complete disappearance of the recent layer may, of course, be attributed to the operations of the guano hunters. There is no travertine crust or anything corresponding to it, undoubtedly owing to the fact that the cave is formed in basalt which is practically insoluble. No definite Pleistocene cultural layer may be differentiated at the present time. Cultural material and bones of extinct mammals are mixed indiscriminately among large fragments of lava which defy stratigraphic differentiation.

SUMMARY AND CONCLUSIONS

During the seasons of 1936, 1937, 1938, 1939, and terminating in 1940, the University of New Mexico excavated a cave known as Sandia Cave, located in Las Huertas Canyon in the north end of the Sandia Mountain region just to the east of Albuquerque, N. Mex. In addition, Davis Cave and Guano Cave, two other cavities of the Sandia group, were partially excavated. One cave in the Manzano region, Manzano Cave, was tested, and another, Isleta Cave, was partially explored.

The findings in Sandia Cave are of major importance. The cave fill was stratified, with definite cultural objects in various strata, some of which could be identified as paralleling certain other known culture horizons. In the very mouth of the cave modern material was present in the form of potsherds. These are of black-on-white types of the Pueblo III period and late Glaze wares such as occur at Pueblo IV and Pueblo V sites in the Rio Grande Valley and in the Galisteo district. Other recent accumulation was represented by deposits of guano and pack-rat debris, diminishing toward the rear of the cave. Beneath this modern deposit extended a sheet of cave travertine or calcium carbonate representing a wet period preceding the recent. This calcium crust seems to represent roughly the end of the Pleistocene. Beneath this cave crust lies the uppermost of the two main cultural horizons. This one is termed the Folsom occupation because of included artifacts. It is characterized by loose debris cemented into a breccia by calcium-charged waters percolating from above. Below the Folsom floor is a sterile laminated stratum of yellow ochre representing another and earlier wet phase. Below the yellow ochre is the Sandia layer, the earliest cultural stratum of the site. The Sandia layer is less consolidated than the Folsom and contains fire areas or hearths. Below the Sandia occupation, between the Sandia and bedrock, lies an intermittent layer of disintegrated limestone of claylike consistency.

Artifacts of the Folsom layer comprise a series of tools and implements, including Folsom points and other objects considered typical of Folsom times. Classic Folsom points are represented by two whole points and two bases. Three unchanneled Folsom-shaped points are present, as well as one lanceolate Southern Plains type. Five large blades, six gravers, seven snub-nosed scrapers, four side scrapers, ten flake knives, one ivory shaft, and two worked splinters of bone make up the rest of the Folsom series.

The Sandia layer is equally distinctive. Sandia points are generally larger than typical Folsoms, and not so well chipped. These earlier points are distinguished by a side shoulder or notch suggestive of Solutrean points, although no contemporaneity or connection between them and the Old World forms is necessarily implied by such comparison. The Sandia points are further divided into two subtypes, both possessing the side-shouldered feature. Type 1 is lanceolate and rounded in outline. Type 2 is straight-shafted with paralleling sides. Type 1 is apparently slightly older than type 2. The rest of the Sandia collection comprises three snub-nosed scrapers, one side scraper, numerous flakes which may or may not have been used as knives, and two bone points.

Twelve species of animals are present in all the strata of Sandia Cave. In the recent layer, only the ground sloth is an extinct member. Sloth remains were found only in the lowermost portions of the recent deposit and in the rear of the cave. The Folsom layer is distinguished by horse, camel, bison, mammoth, ground sloth and wolf. The Sandia stratum includes in its faunal assemblage horse, bison, camel, mastodon, and mammoth. The paleontological grouping of Sandia Cave is chiefly valuable as contributing to knowledge of late Pleistocene and early Recent times. None of the species are particularly distinctive nor are the associations new. The sloth is again indicated as one of the last survivors of the many large Pleistocene mammals which became extinct at the end of that period and in the beginning of the Recent.

Sporadic testing in other caves of the Sandia-Manzano area, especially at the site known as Manzano Cave, has produced further results. In Manzano Cave strata were found which correspond roughly with Sandia material. In addition, a cultural level was segregated which may be described as early Recent, i.e., following the

Folsom. This later-than-Folsom culture is identified by a type of projectile point similar to those of Gypsum Cave, Nevada. In addition to a distinctive type of projectile, the Manzano Cave also produced spherical and sometimes grooved stone balls identified as bola weights.

In this region, then, and perhaps with validity applicable to a much larger area, a sequence has been erected. This is especially important as it involves the famous Folsom culture, already the center of a controversy concerning the antiquity of the Paleo-Indian in North America. The various components of the sequence occur in the following order:

Recent Pueblo occupation	
Considerable time interval	
Manzano (Gypsum Cave)	Early Recent
Wet period	End of Pleistocene
Folsom	Late Pleistocene or early Recent
Wet period	Late Pleistocene
Sandia	Late Pleistocene

This sequence involving an earlier-than-Folsom culture again brings to the fore the question of Old World connections. This problem is rendered the more pressing by reason of the remarkable resemblance between the Sandia points and certain Solutrean examples from the Old World. It has already been pointed out by many of those interested (McCown, 1939, pp. 150-152) that Solutrean cultural relationship is not to be suggested in the case of Folsom man because of the remoteness of true Solutrean (almost entirely within continental Europe) and the complete lack of demonstrable connection between Solutrean regions and the New World across the as yet unknown reaches of Asia. The perhaps fortuitous circumstance that the Sandia projectile points even more closely resemble certain Solutrean examples brings this question even more prominently to the fore. It is well known by those who have studied Solutrean collections in Europe that the bulk of the material is not distinguished by fine ripple flaking and delicately made points à cran. Indeed, European Solutrean is much closer to the Sandia than to the Folsom, especially as the Folsom is distinguished by a specialized facial channel unparalleled in European or Asiatic horizons. However, it is fruitless to discuss Solutrean connections or contemporaneity until Asiatic gaps of awe-inspiring magnitude have been bridged, a possibility at the present time extremely remote.

A school of thought advocating a Neolithic basis for all New World cultures exhibits an equal academic myopia concerning cultural phenomena as they are now known. Although some "Neolithic" cultures are known which existed on a hunting and fishing economy, their inclusion in Neolithic categories is dependent upon agricultural and animal husbandry centers in adjacent territories known to be contemporaneous. In other words, the classic text-book sequence of culture for Europe has already been demonstrated to be invalid for Asia, especially Siberia. Furthermore, rudimentary studies of agriculture show that of the New World to be distinct from that of the Old World both in the matter of species of plants and of methods. It must not be forgotten that the word Neolithic was coined for European problems originally and was brought into the New World to describe the status of the recent American Indian, which apparently paralleled certain European and Asiatic groups. This status in the Old World included agriculture, animal domestication, permanent habitations, bow and arrow, pottery, etc., all of which are lacking in the cultures now in question. Furthermore, the Neolithic even in Mesopotamia, its supposable point of origin, was definitely subsequent to the pluviations and climatic fluctuations attendant on the last retreat of the Würmian glaciation in its various stadia. There is no reason to believe that the continental glaciations in North America were not contemporaneous with those of Europe (Daly, 1934) stage for stage, although minor variations may have been localized in one hemisphere.

Folsom and Sandia have been definitely associated with extinct mammal forms and with climatic changes coincident with the last phases of the Wisconsin glaciation. There is no reason to deny these New World cultures an antiquity comparable with European and Asiatic cultural phenomena occurring under similar climatic circumstances and accompanying a like fauna. There is no need for correlations with definite European cultures especially by name, or even Asiatic ones. Horizons roughly corresponding to Folsom and Sandia have been described from southern and eastern, but not as yet northeastern, Siberia. These are usually lumped under an "Upper Paleolithic" category which is descriptive of a cultural status and time rather than of a European connection by name, although the blade industries of the European levels and the Near East are also represented in Asia (elaborations and variations of Aurignacian, Aurignacian-Magdalenian, and Gravettian). There seems little need to connect New World cultures, whether Sandia, Folsom, or any other, with Asiatic or European cultures when intervening areas, i.e., eastern and northeastern Siberia, are not known. Even Alaska is comparatively untouched as far as the question of the Paleo-Indian is concerned.

It is becoming more apparent, as a cultural sequence is being evolved for North America, that the first hunting groups of the New World arrived here in times corresponding to the Upper Paleolithic of Europe and Asia and with a tradition of flint chipping comparable with Siberian centers of the same age.[8] The famous facial channel that distinguishes the Folsom point is but a refinement of a blade-making technique that is, after all, the real basis of differentiation of some of the Old World Upper Paleolithic movements and changes. The Folsom graver is an instrument comparable to a burin although lacking the burin stroke. Refinements of basal technique, such as the striking off of blades, would logically differ in application in widely separated locales especially if contact with the points of origin had long been lost. We may postulate on this basis with fair certainty that the first comers to this continent came armed with a knowledge of blade making and a rudimentary idea of pressure flaking as well. The final development of this blade-making tradition was brought to an admirable conclusion in Neolithic Mexico as well as in Neolithic France (Grand Pressigny). Sandia and Folsom types of flint work represent some of the first variations on these basic techniques in the New World. If the Solutrean was a European outgrowth of this development in one direction, the New World manifestations may be logically suggested as an outgrowth in another, with no direct connection with or knowledge of the Solutrean implied. Climatic and faunal considerations all argue for a similar age. Indeed, it is becoming more evident that both Lower and Upper Paleolithic horizons in Europe, Africa, and Asia represent variant manifestations of the development of a few basic forms, such as the fist ax, the side scraper, and the blade.

In all considerations, the Sandia and Folsom aspects manifest themselves as Upper Paleolithic in character, but with no connection with Asiatic or European phases of specific nature beyond a common sharing of some basic ideas such, for example, as the blade.

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[8] Mal'ta on left bank of Belaya River near Lake Baikal. Obermaier, 1928; Petrie, 1932.

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APPENDIX

CORRELATION OF THE DEPOSITS OF SANDIA CAVE, NEW MEXICO, WITH THE GLACIAL CHRONOLOGY

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INTRODUCTION

The present report is based on brief visits to Sandia Cave in 1939 and 1940. It gives a geologic interpretation of the bedded cave deposits containing artifacts of the Folsom and heretofore unknown Sandia complex, both associated with the bones of extinct animals. The excavator of the cave, Dr. Frank C. Hibben, has described and discussed the cultural and animal remains and their archeological relationships. Hence the following paper is concerned mainly with the geologic aspects of the cave and an attempt to correlate the deposits with the glacial chronology.

This correlation leads to the conclusion that the artifact-bearing cave deposits were laid down during a time of greater moisture corresponding to the last ice advance of the Wisconsin stage of glaciation. The climax of this episode is represented by the sterile ochre deposits, which therefore have a nominal date in the accepted chronology of 25,000± years. People of the Folsom culture lived in the cave just later than, and those of the Sandia culture just previous to, this nominal date.

METHODS

The age of cave deposits is a problem that can rarely be solved by a direct attack. In general, as Dr. Hibben has already suggested, cave deposits have no physical connection with any deposits in the locality beyond the cave mouth. Hence the sequence of events recorded in the cave is not directly connected with other sequences that took place outside its limited and special space. In a few instances gravels and sands deposited by the sea or by ancient lakes have been deposited in caves. Such deposits give a sure connection with at least one event in a sequence of events in the outside world. Usually, however, general arguments are the only recourse in attempts to date cave deposits.

The contained human or animal remains may afford a partial or complete correlation with known geologic horizons. In North America the present rapidly expanding knowledge of ancient cultures and of Pleistocene vertebrates gives hope that this type of correlation will soon be more perfect than at present. If, however, the cave deposits can be interpreted as representing a sequence of events related to or in part the result of climatic fluctuations, an independent line of inquiry is available. The climatic implications of cave deposits may then be related to the rhythm of climatic fluctuations of the past. Thus a connection may be made with a general and world-wide chronology—the pulsations of climate characteristic of the Pleistocene.

Such a line of argument has obvious and unescapable faults. If the sequence of events within the cave based on the cave deposits is unassailable, the interpretation of the deposits in terms of climate may be faulty. If the latter is correct, it is always possible that the correlation with the general climatic rhythm is incorrect. Furthermore, our knowledge of the climatic rhythm, the number, length, and amplitude of its fluctuations, is still imperfect. As further knowledge of the Pleistocene and particularly of the late Pleistocene is acquired, the precision of the chronology of climatic fluctuations will increase. Present correlations may be confirmed or may be shifted, either forward or backward. In the meantime the use of the method is amply justified provided it is thoroughly checked against the anthropological probabilities. When, in the future, successive new localities provide a complete archeological sequence, the correlations based on reference to the general chronology of climatic pulsations will have an adequate frame of reference.

FACTS TO BE EXPLAINED

Sandia Cave and its deposits present for analysis and explanation a large array of geologic facts. These facts, mostly obtained by Hibben's excavations and recorded by him in detail in preceding pages, are here summarized for convenient reference.

The cave lies high on the steep eastern wall of Las Huertas Canyon, at an altitude of 7,275 feet, in the northern portion of the Sandia Mountains in Bernalillo County, N. Mex. (fig. 1, p. 4). It is 4 miles upstream from the village of Placitas (fig. 8). The cave is tunnel-like and extends eastward from its opening on the cliffy face of the limestone ridge that forms the eastern side of the canyon. The mean diameter is 7 to 10 feet (2 to 3 m.) and the mean slope is 72

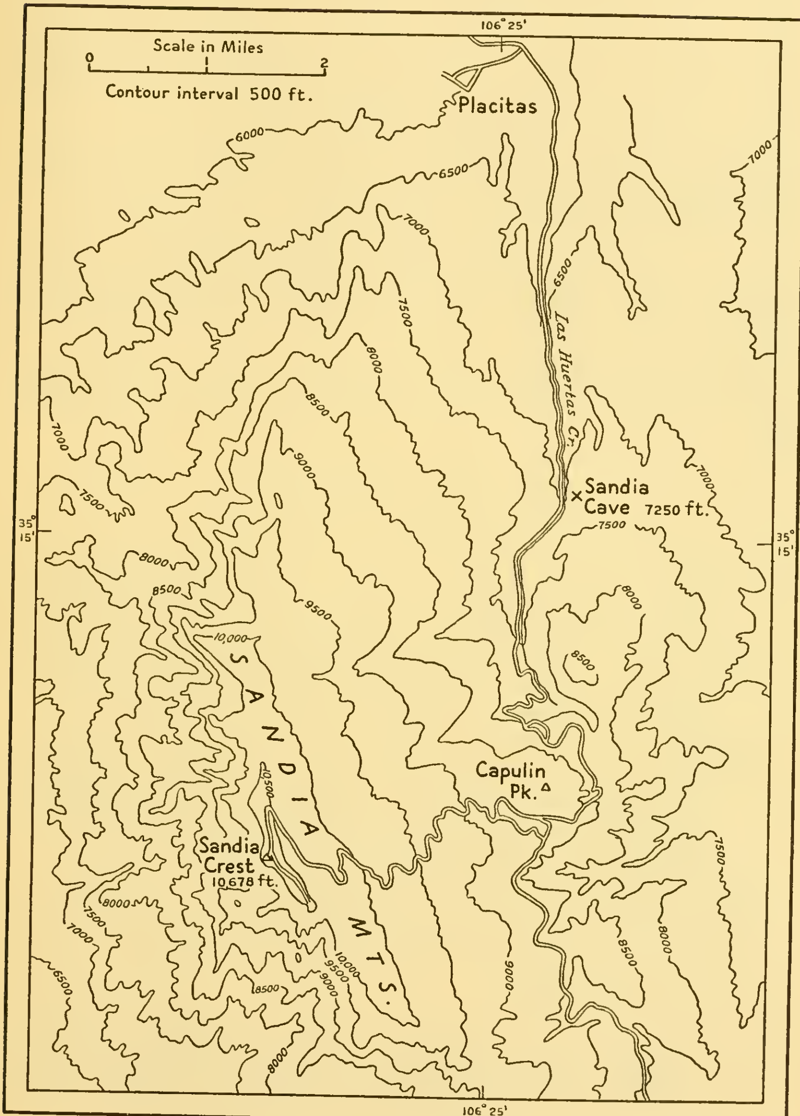

FIG. 8.—Northern portion of Sandia Mountains showing position of Sandia Cave with respect to Las Huertas Canyon and Sandia Crest. Redrawn from the U. S. Forest Service map of the Cibola National Forest, 1936.

feet (22 m.) in 453 feet (138 m.) or approximately 9 degrees, somewhat less steep than the dip of the limestone beds so that the cave begins in one bed and ends in a higher one. The beds belong to the Magdalena formation of Pennsylvanian age. As shown in the cross section, figure 5 (p. 12) in Hibben's report,[9] the cave is overlain by great thicknesses of limestone ranging from 50 feet (15.2 m.) at the opening to nearly 200 feet (61 m.) at the point 453 feet (138 m.) from the face where the cave closes in and beyond which it has not been explored. The cave at present is dry. In the first 328 feet (100 m.) the floor is dusty. Farther within and downward the dust will not lift from the floor, but the cave is not damp enough for moisture to be noticeable on the walls until the end of the explored portion is reached.

The deposits of the cave near its mouth consist of the following beds:

DEPOSITS OF SANDIA CAVE

(Arranged in order from top to bottom)

f. Dust, guano, and trash: decreasing in thickness from about 6 feet near the mouth to a thin layer of dust at meter 70. Contains pottery (late Glaze) of early Spanish or immediately pre-Spanish date (A. D. 1400-1600).

e. Stalagmite layer: 6 inches to paper thinness; granular and crystalline texture; in places "chalky;" the surface marked by small Tivoli-type cups. Contains a few stones and in places is broken by falls of blocks from the roof.

d. Upper cave breccia: 1 to 4 feet thick; consists of fragments of limestone, rounded and irregular masses of yellow ochre, fossil bone, artifacts, and charcoal, but no hearths; cemented by crystalline calcium carbonate which forms parallel films and stalagmite layers and also surrounds many individual fragments. Artifacts absent beyond meter 83.

c. Yellow ochre: 2 inches to 2 feet thick; consists of nearly uniformly fine-grained yellow ochre (limonite) banded and laminated, with a few thin layers of chalky granular calcium carbonate. No fossil bone, artifacts, or limestone fragments.

b. Lower cave breccia: 0 to 3 feet thick; consists of fragments of limestone, rounded and irregular fragments of limonite especially near top; fossil bone, artifacts, hearths, and charcoal; in places not cemented at the base, and in every place more cemented at and near the top by finely granular calcium carbonate. Hearths limited to first 15 meters of the cave.

a. Basal clay: 0 to 2 feet thick; gray clay with loose crinoid stems and with fragments of limestone showing solution surfaces; occurs mostly in depressions of the floor.

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[9] The faults shown in figure 5 were not mapped by the writer.

The cave and its contained deposits imply that the following events have occurred:

1. Period of cave formation.
2. Long interval of time.
3. Accumulation of basal clay. Entrance presumably closed as there is no occupation; perhaps overlapping with period 2.
4. Accumulation of lower cave breccia. Entrance open, occupation; increasing quantities of water dripping from the roof and producing cementation of breccia by reason of its contained calcium carbonate. Iron oxide (yellow ochre) also deposited in shallow pools. Strong evaporation.

   Open entrance chamber in which people lived and built fires. Hearths extend back into present cave. Bones and artifacts in part refuse that drifted down sloping floor of cave from living space which no longer exists.
5. Accumulation of yellow ochre. As this material is free of fossil bone and artifacts the entrance must have been closed or the drip from the roof so severe that the entrance chamber was uninhabitable. Closure by a rock fall would seem to be indicated as reduced air movement would inhibit evaporation and warming of the air with consequent deposition of calcium carbonate. It would also inhibit frost action near the mouth of the cave and therefore the production of fragments of rock that would slide down the slope. The factor of closure seems inadequate to explain the almost exclusive deposition of ochre and a strong drip, and therefore moister conditions are implied.
6. Accumulation of upper cave breccia. Entrance open. Strong drip from the roof depositing calcium carbonate and iron oxide. Cementation greater than in lower breccia. Zones of stalagmite in places.

   Open entrance chamber. No hearths within present cave. Fossil bone, artifacts, and many rock fragments, largely camp refuse which moved down sloping floor of cave from living space which no longer exists.
7. Deposition of stalagmite layer. The entrance was closed or inaccessible to man and animals, as supply of refuse ceased. It seems likely that a rock fall occurred by which the entrance chamber was sheared off and the cave became inaccessible but with free air circulation. The drip from the roof deposited the stalagmite layer but gradually ceased. Parts of the stalagmite layer consist of thin chalky plates implying deposition of calcium carbonate from weak drip under strong evaporation. Occasional rock falls during and after deposition of stalagmite.
8. No deposition over a long period. Entrance presumably closed and cave dry without drip from the roof.
9. Accumulation of guano and dust. Cave open and first 70 meters partly filled by wind-borne dust, bat and rat guano. During part of the time, used by the Pueblos as an occasional camping place.

CLIMATIC INTERPRETATION

The period of formation of the cave falls in a relatively remote period. At present, the roof consists of firm rock from which only a few fragments can be detached. Below meter 150 there are openings in the rocks extending downward and a strong air movement. As this area is damp, enlargement may be going on at present. Obviously the explored portion of the cave is not now being enlarged. Nor has it been much enlarged since the beginning of the period in which the cave deposits were accumulated. The excavation record shows that here and there blocks have fallen from the roof, but there has been no substantial growth of the cave since its original formation.

The formation of the cave must have required the movement of relatively large quantities of water through it. To account for large quantities of water it would seem necessary to suppose that Las Huertas Canyon did not exist or at least was much shallower than at present. If the floor of the canyon lay at an elevation above the cave an ample supply of water would be available for circulation down the eastward-dipping rocks. The limestone might by such a mechanism be dissolved and the cave formed.

The formation of the cave is thus remote in time. The period of occupation is comparatively recent. Between the period of formation and the beginning of deposition in the cave, there must have been a long interval of time. The cave and the cave deposits afford no evidence concerning the events or the climatic character of this interval.

The cave deposits begin with the basal clay, a discontinuous body which lies largely in the depressions of the floor. This clay is the residuum from solution of limestone—the less soluble parts of the original rock. It was presumably slowly accumulated, for if large amounts of water had been available, it seems probable that the clay would have been washed away. Presumably also the available water was not evaporated, or calcium carbonate would have been deposited.

Under present conditions, there is no visible inflow of water into the cave; the floor is largely dry but there is a strong draft of air. If the entrance were closed, it might be possible that the whole cave would be slightly damp and that slow solution would occur throughout the cave. Under such conditions, material like the basal clay would accumulate. It may, therefore, be inferred that the basal clay is the record of a climatic period somewhat similar to the present. As this clay is sterile, it presumably accumulated when the entrance was closed.

The lower breccia is largely uncemented at the base. It is a rubble of angular fragments of limestone with fossil bone and a few artifacts. Cementation increases toward the top. The calcium carbonate must have been deposited by drip from the roof, but deposition was rapid and took place under evaporating conditions. The calcium carbonate is granular and similar to the travertine deposited by lime-bearing spring waters in the open air. The increased amount of calcium carbonate in the upper layers implies that drip from the roof increased during the period of deposition. Limonite in the form of yellow ochre was deposited as laminated plates which were broken up into fragments and deposited as part of the breccia. It is probable that the limonite was first deposited in shallow pools by water which flowed down the sloping floor and built rimmed pools like those of the Tivoli springs. Little cups on the travertine surfaces show this process in miniature. These layers of limonite were presumably broken up by fragments of rock sliding down the slope and also by the trampling of men and animals. The presence of hearths indicates that for a distance of 15 meters from the present entrance the cave was at times dry enough and had a strong enough air current to make it habitable. The larger part of the bones and artifacts forming the breccia, however, were refuse from habitation in an entrance chamber which has now disappeared.

The layer of ochre presents a further problem and implies a change of conditions in the cave. Whereas previously the predominant material deposited was calcium carbonate, and iron oxide was subordinate, during this period conditions were reversed.

The reasons for the deposition of limonite in caves are not completely understood, and the following line of reasoning must be regarded as tentative. The water entering the cave must carry iron in solution presumably as the ferrous carbonate, Fe_2CO_3. In deposition oxygen must be added to form limonite, $Fe_2O_3nH_2O$. The cave must be sufficiently open so that oxygen is available, but some other factor must enter, else calcium carbonate would also be deposited. It seems probable that in this cave the quantity of water increased to such an extent that calcium carbonate was redissolved as rapidly as it was deposited.

The limonite layer contains no bones or artifacts and is also largely free of limestone fragments or roof falls. It must therefore be supposed that the cave entrance was closed or that the cave was so wet that even animals could not live in its entrance chamber. If the entrance were closed, the reduced circulation of air would reduce evaporation of the dripping water and thus inhibit the deposition of calcium carbonate. Thus the sterile layer probably implies a closed entrance and very wet conditions in the cave.

The upper breccia, like the lower breccia, consists of fragments of limestone, fragments of laminated yellow ochre, fossil bone, and artifacts. It is cemented by crystalline calcium carbonate which

(1) forms a layer around each fragment, (2) forms lenses within the breccia, and (3) grades upward into the overlying stalagmite layer. The cementing crystalline calcite of the upper breccia must have been deposited by water dripping from the roof and penetrating the mass of rubble. The fact that layers or lenslike masses of crystalline calcium carbonate exist proves that the process of deposition and therefore the drip persisted through the period of accumulation of the upper breccia. Limonite was also deposited in basins but tended to be broken up, and the fragments were incorporated into the breccia. The cave was open and accessible, as animal bones and artifacts of the Folsom culture occur. No hearths or other direct evidence of occupancy have been found, and thus it is reasonable to believe that an outer chamber existed where the people lived and that the upper breccia is essentially camp refuse which migrated down the sloping floor of the cave from this entrance chamber. The crystalline cement of the breccia implies that calcium carbonate was deposited without excessive evaporation and therefore that the drip was stronger and the cave wetter than at the beginning of deposition of the lower breccia.

The upper breccia is capped by the stalagmite layer. This layer, as shown by the excavation record, is variable in thickness and in character. The thickness varies from less than half an inch to 6 inches. In places, especially where it has no great thickness, it consists of paper-thin plates of granular chalky calcium carbonate. In other places it is a crystalline mass of great strength and compactness. In places the surface is marked by Tivoli cups, indicating that water flowed down the slope of the cave. In many places also this layer curves upward near the walls and forms a plaster against them. The stalagmite layer contains a very few small fragments of limestone, but is generally wholly composed of calcium carbonate deposited from solution. Yellow ochre (limonite) is generally absent. In a few places large rocks fallen from the roof have broken the layer. These falls are later than the time of deposition and no recementation has taken place.

It is obvious that during the period of deposition of the stalagmite layer the cave entrance again must have been closed or inaccessible. Whether man was present or not, wild animals would have used the cave had its entrance been open, and their bones or dung would presumably have been preserved. It seems likely that a great rock fall occurred on the east slope of Las Huertas Canyon at the close of the period represented by the upper breccia. The entrance chamber heretofore postulated was sheared off, and the mouth of the cave closed. Drip of water from the roof, similar to that which went on previously, continued for a time and then gradually ceased. The paper-thin layers formed here and there as the top of the stalagmite layer presumably represent the deposits of the last drip from the roof. In the closed cave deposition ceased, and a long period of time without recorded incident, except occasional falls of roof blocks, ensued.

At the time of the discovery of the cave the opening was choked by a mass of loose material overlying the stalagmite layer. Dust and the guano of bats and rats lay in the mouth of the cave and extended inward with decreasing thickness. Beyond meter 70 there was only a thin line of dust to indicate the layer. Pueblo potsherds were found in this mass. Consequently the use of the cave by Pueblo Indians as an occasional camping place is proved. As shown by Hibben, this occupation was in early Spanish or immediately pre-Spanish time. It is thus implied that a long period intervenes between the closing of the cave at the beginning of stalagmite deposition and the reoccupation at a time when it was as dry as at present and neither solution nor deposition was occurring.

GENERAL CLIMATE IMPLICATIONS OF THE CAVE DEPOSITS

Sandia Cave is now dry, whereas it was once wet. As there is no possibility that water from a stream channel could have been diverted toward it since its formation and original occupation, one must suppose that at one time more water was available on the ridge above than at present. The ridge above is largely bare limestone with a vegetation of scrub oak and scattered pinyons and junipers. The soil, where present, is a loose sandy rubble. There is a marked accumulation of powdery calcium carbonate on all rock fragments at depths of 6 inches to 2 feet below the surface. Thus this ridge has the soils and vegetation characteristic of areas of this altitude in central New Mexico.

For the cave to be wet, it would be necessary for more water to fall as rain or snow on the ridge. This would supply the larger quantities of water to seep downward through the rocks and form a drip. With such an increase in precipitation, there would be consequent changes in the vegetation and the soil.

The nature of these changes may be judged by a consideration of the vegetation on the higher parts of the Sandia Range. The North Peak rises to an altitude of 10,178 feet and lies only 4 miles southeast of Sandia Cave (fig. 8). This peak breaks off sharply to the west and slopes gently to the east and north parallel to the dip of the limestone beds. The peak is bare of trees, but firs and spruce occur within 50 feet of the top. Apparently the absence of trees on the peak is due to high winds. If the summit were broader, it seems likely that it would have the same dense fir-spruce forest that extends down the east slope.[10] The west slope is mostly bare rock and too steep for the maintenance of soil or forest except in scattered patches of spruce. At lower elevations pines grow in all suitable localities. On the east slope fir and spruce extend as an unbroken forest, except in areas of old burns, down to altitudes of about 8,500 feet. Below this altitude spruce grows in valleys and shaded slopes down to about 7,500 feet. The fir-spruce forest is succeeded below by a pine forest which in this area has been largely destroyed by lumbering and fires. The pine forest extends from altitudes of about 8,500 feet to about 7,500 feet, but groves and single trees exist in shaded places and along streams to altitudes of about 7,000 feet. Below this altitude begins the pinyon-juniper woodland. The foregoing altitudinal boundaries of the forest belts are more or less arbitrarily chosen. In an area where slopes are so steep and where fires have modified the distribution of trees, the vegetation boundaries are not easily traced. Also their lower limits are lower on east-facing and higher on west-facing slopes. Ridges such as that above the cave are relatively exposed and dry and on them the forest boundaries are higher. As previously described the ridge above the cave, although it has an altitude of 7,300 feet, is well within the woodland zone, and the lower boundary of the pine forest lies at an altitude of about 8,000 feet.

Within the area of the forests the soils are markedly different from those in the woodland zone. In the fir-spruce zone, there is below the forest duff a humus-bearing dark silty soil (A-horizon) 3 to 6 inches thick which overlies a more compact brown limonitic and clayey subsoil (B-horizon). The subsoil in places extends down into solution cavities in the limestone bedrock (pl. 15, fig. 1). The walls of the cracks show modern solution, and the brown clay contains roots in part alive and in part quite dead and reduced to humus. There are also fragments of limestone that show active modern solution.

In other localities and deeper in the limestone, limonite rather than clay extends down cracks in the limestone bedrock. On shale outcrops the content of limonite in the subsoil appears to be higher,

[10] See photograph of forests and swampy meadows on San Pedro Mountain (altitude 10,600 to 9,600 ft.), looking westward, in figure 8 of Church, F. E., and Hack, John T., An exhumed erosion surface in the Jemez Mountains, New Mexico. Journ. Geol., vol. 47, No. 6, pp. 613-629, 1939.

and below the soil the weathered bedrock has strong limonitic stains in the cracks and joints.

Granite in places is decomposed and stained by limonite to depths of 10 to 20 feet (pl. 15, fig. 2). In Tejano Canyon under a pine forest on granite the soil profile consists of humus-bearing silty soil as much as 6 inches thick. In places it contains fragments of sandstone which have drifted downhill from outcrops of the Magdalena formation above. In this layer, granite is incompletely decomposed, and there are grains of feldspar, but mica is largely absent. The subsoil is of irregular thickness, from 18 inches to 2 feet, and consists of a grit of feldspar and quartz grains embedded in brown clay. The feldspar is mostly a milky white with brown stains and is obviously undergoing chemical decomposition. Mica in this zone seems to be more resistant than in the upper soil but is in part decomposed and has a brownish, limonitic stain. Below these horizons, the lower zone (C-horizon) on steep slopes is colluvial with lenticular zones of coarse debris and occasional sandstone fragments from up-slope in a mass of granite fragments. This more or less colluvial material rests on weathered granite or in places may be absent. The weathered bedrock is disintegrated, in places so much as to be structureless, but elsewhere preserves the joints and minor structures of the original rock. Limonite as a stain and as films in the cracks gives the mass a brownish cast. Soda feldspars are more decomposed than orthoclase. In some localities, as at the head of Las Huertas Canyon (a mile from the junction of the Loop road and the main Tejano Canyon-Ellis Ranch road), the C-horizon consists of slightly weathered granite-gneiss. In the joints limonite is replacing a preexisting red iron oxide.

In the woodland zone soils developed on limestone, and the limestone rubble on steep slopes have an upper light gray A-horizon which is full of stone and obviously incipient with incomplete weathering. The B-horizon consists of a rubble of fragments stained with powdery calcium carbonate. In the deeper rock cuts, the joints show plates of crystalline calcium carbonate with manganese bands and an overlay of powdery calcium carbonate. It is obvious here that the deeper soil solutions once deposited crystalline calcite just as it was once deposited in the cave. At present powdery calcium carbonate is deposited.

The soils of the forest zones, both fir-spruce and pine, as developed on granite and on limestone or shale are pedalfers. Iron and aluminum are concentrated in the B-horizon and extend as films into the cracks or interstices of the C-horizon. Such soils are typical of humid climates and are the result of the greater precipitation at higher altitudes and the concomitant biochemical processes in the soils developed under a forest cover. The soils are not precisely similar to the soils of a strictly humid climate, because they are subject to prolonged drought conditions, but the main chemical reactions are similar.

The soils of the woodland zone are pedocals—that is to say, calcium carbonate is deposited in the B-horizon. Such soil types are also characteristic of much drier localities and are in marked contrast in their biochemical processes to the pedalfers of the forest zones.

It is also obvious that within the forest zone not only is limestone dissolved by excess water passing downward through the soil zone but that this water carries iron from the B-horizon. The iron is freed from the rocks in the A-horizon and perhaps below it and is temporarily deposited in the B-horizon. It is redissolved in, or perhaps passed through, the B-horizon downward into the underground, where it may be redeposited in the cracks of the rock. This phenomenon explains the presence of ochre in Sandia Cave. The increased precipitation necessary to furnish water to make the cave wet would also clothe the ridge in forest and result in a soil-making process that would furnish iron to the ground water.

The inference that a change in precipitation would also change the character of the soil is confirmed by the existence of the phenomenon of composite soils preserved in favorable places. Thus the occasional presence of red iron oxide in the cracks of the granite within the forest zone records a period in the past when red rather than yellow iron oxide was carried downward by the soil solution. As this process implies a warm humid rather than a cold humid climate, it must date back to one of the interglacial intervals. In Las Huertas Canyon within the woodland zone there are numerous localities where rock cuts show the downward penetration of finely granular calcium carbonate from the modern subsoil. This film of deposition is replacing preexisting films of limonite and coating previously deposited plates of crystalline calcium carbonate. There is thus implied a change in soil type from that of a more humid to that of the present arid climate.

CORRELATION WITH THE GLACIAL CHRONOLOGY

The inference is outlined in the foregoing pages that the cave deposits could have been laid down only under the following conditions: 1, greater precipitation on the ridge above the cave; 2, forest growth on the ridge; 3, pedalfer soils on the ridge to supply iron as well as calcium to the drip in the cave.

A strongly marked and prolonged period of humid climate in a mountainous area of moderate altitude may easily be the local response to the fluctuations of climate accompanying Pleistocene glaciation. If such an assumption is made, which glacial stage is implied? In the southern Rocky Mountains immediately north of Sandia Cave, there were three strong glacial advances and two minor advances in Wisconsin time.[11]

These glacial stages with their presumable American and European equivalents are shown in table 1.

TABLE 1.—*Glacial stages of the last Ice Age in the southern Rocky Mountains and elsewhere*

Short designation	Southern Rocky Mountains	Continental ice of North America	Continental ice of Europe
	Protalus rampart (position uncertain)	Subdivisions not established	Sub-Atlantic Sub-Boreal Atlantic Boreal
W_4	Long Draw	Cochrane	Fennoscandian (moraine)
W_3/W_4	Unnamed interval	Unnamed interval	Gothiglacial Daniglacial
W_3	Corral Creek	Mankato	Pomeranian
W_2/W_3	Unnamed interval	Two Creeks forest bed	
W_2	Home	Tazewell-Cary	Weichsel
W_1/W_2	Unnamed interval	"Peorian"	
W_1	Twin Lakes	Iowan	Warthe

The data on which this table is based are given by Bryan and Ray and by Ray in the papers cited and are not here repeated. It is sufficient to comment on the complications of the last or Wisconsin epoch of glaciation. It was marked by at least three great advances

[11] Bryan, Kirk, and Ray, Louis L., Geologic antiquity of the Lindenmeier site in Colorado. Smithsonian Misc. Coll., vol. 99, No. 2, 76 pp., 1940. Ray, Louis L., Glacial chronology in the southern Rocky Mountains. Bull. Geol. Soc. Amer., vol. 51, pp. 185-1918, 1940.

For a review of the European chronology see Zeuner, F. E., The Pleistocene chronology of central Europe. Geol. Mag., vol. 72, pp. 350-376, 1935; The climate of the countries adjoining the ice sheet of the Pleistocene. Proc. Geologists' Assoc., vol. 48, pp. 379-395, 1937; The chronology of the Pleistocene sea levels. Ann. and Mag. Nat. Hist., ser. 2, vol. 1, pp. 389-408, 1938.

of the ice or cold intervals, separated from each other by interstadial intervals in which the climate of the world was as warm as, or warmer than, the present. The last of these ice advances was followed by a long period of amelioration of climate. Two minor episodes of cold within this time of amelioration are recorded in the Southern Rocky Mountains and named the Long Draw and the Sprague substages.

Correlation of the Sandia Cave deposits with any one of the glacial episodes of the Wisconsin would be difficult were it not that the upper breccia contains artifacts of the Folsom culture. This culture at the Lindenmeier site in Colorado has been correlated with the closing stages of the Corral Creek glacial stage or W_3. The argument on which this correlation is made has been given in the paper by Bryan and Ray already cited. If the correlation is accepted, the cave deposits of Sandia Cave represent the last major ice advance of the Wisconsin; the lower breccia with evidence of increasing wetness represents the oncoming of glaciation, the yellow ochre, the climax, and the upper breccia, the period of retreat just after the climax.

The correlation of the Corral Creek glacial stage with the Mankato and Pomeranian stages yields a date in years. Antevs[12] fixes this glacial advance as having occurred 25,000± years ago. The Folsom culture falls just after this date and the Sandia culture just before. These relations with other pertinent data are brought out in figure 9.

It should be noted that such a correlation yields a date for the Sandia culture as recorded in this one locality. As occupation of the cave and the deposition of the lower breccia began together, it appears that the cave had previously been closed. Thus there is no geologic data as to the time when the people carrying the Sandia culture arrived in New Mexico or in the continent. Furthermore the cave was presumably closed during the period of deposition of the yellow ochre, and thus the end of occupation of the area by Sandia people lies at some undefined date within the time interval of the layer of yellow ochre. With regard to the people having the Folsom culture, Sandia cave affords no critical evidence as to the time of their entrance into the continent, but presumably the people of the culture entered the local area at some time in the period of deposition of the yellow ochre. As the cave is presumed to have been closed at the end of deposition of the upper breccia, there is no geologic evidence as to the termination of the Folsom culture.

[12] Antevs, Ernst, The recession of the last ice sheet in New England. Amer. Geogr. Soc. Res. Ser. No. 11, 1922; The last glaciation, with special reference to the ice retreat in northeastern North America. Amer. Geogr. Soc. Res. Ser. No. 17, 1928; Late-glacial correlation and ice recession in Manitoba. Canada Geol. Surv., Mem. 168, 1931.

Whether the time interval of the yellow ochre here correlated with the climax of the Corral Creek (Mankato-Pomeranian) ice advance was a period of overlap in culture or whether the local area was deserted is at present a question in the range of anthropological probabilities. Similarly the times when these cultures began to flourish or to die out are as yet undefined locally or on a continental basis. It appears, however, pertinent to consider anew the question of migration of man into the continent, although there is as yet no conclusive evidence of a time in which he was not present.

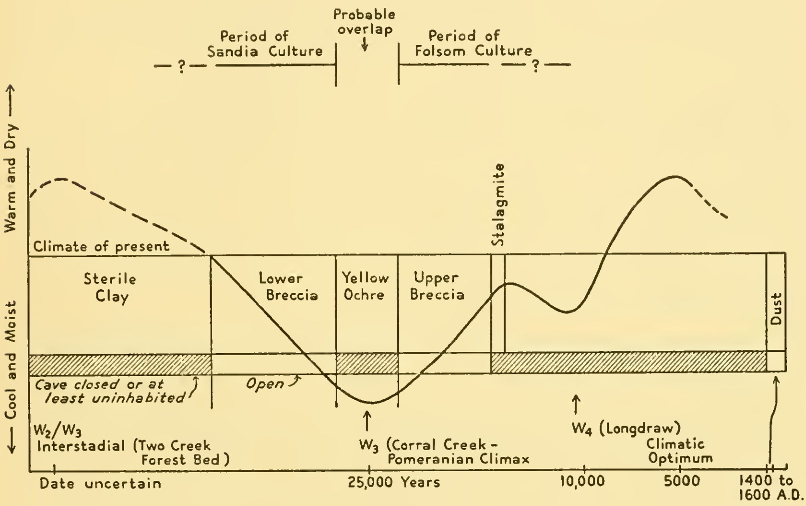

Fig. 9.—Diagram showing the relation of the deposits of Sandia Cave to the inferred climate of the late Pleistocene.

ANTIQUITY OF MAN IN NORTH AMERICA

With one possible exception [13] the Sandia culture is the only definitely established pre-Folsom culture. The antiquity of many finds has been challenged on the ground that entrance into North America must have occurred after the partial withdrawal of the ice. In its most definite form this theory is set forth by Antevs [14] who adopted from Johnston [15] the idea that the first opportunity for migration into

[13] Harrington, M. L., Pre-Folsom man in California. Master Key, vol. 12, No. 5, pp. 173-175, 1938. In this note Folsom points are reported in disturbed soil overlying stratified deposits containing artifacts. Full details are not yet available.

[14] Antevs, Ernst, The spread of aboriginal man to North America. Geogr. Rev., vol. 25, pp. 300-309, 1935.

[15] Johnston, W. H., Quaternary geology of North America in relation to the migration of man. *In* The American aborigines, ed. by D. Jenness, pp. 9-45, 1933.

the continent occurred when a corridor through the Canadian Great Plains was opened by the simultaneous retreat of the Cordilleran and Kewatin ice sheets. This event is connected with the geochronological sequence in Manitoba and is given a date of 15,000 years before our time or 10,000 years after the climax of the Mankato-Pomeranian ice advance (W_3). Antevs suggests the possibility that the route also was open for a time some 35,000 to 45,000 years ago, but does not imply its use by migrant peoples.

The view that the Wisconsin glacial epoch consisted of three main substages separated from each other by interstadial intervals of mild climate is relatively new. In the State of Wisconsin the Two Creeks forest bed [16] underlies Mankato till and overlies till of the next older stage and contains remains of a forest flora like that of present-day Minnesota or southern Manitoba. It records an amelioration of climate between W_2 and W_3 so great that one must suppose that little or no ice remained in Labrador. The idea that a long interval intervened between the Iowan, W_1, and the next younger Tazewell-Cary, W_2, substage is more familiar. It has long been known as the Peorian,[17] and in many localities it is supposed to be represented by loess. As now recognized by Leighton and others, the loess overlies unweathered Iowan till and cannot be much younger. It is essentially a "glacial," not an interstadial deposit. Thus near Lisbon, Iowa, where the "Peorian" loess is thick, its basal portion is unleached and calcareous. It rests on unweathered Iowan till.[18] There could have been no break in the prevailing cold climate between the retreat of the ice from this locality and the deposition of the loess. In the Farm Creek section [19] near Peoria, Ill., the "Peorian" (Tazewell or, better, Iowan) loess is blue-gray and contains bits of moss and larch twigs. It was, therefore, deposited in an environment of muskeg and scattered clumps of trees (Taiga). The climate was cold. The

[16] Wilson, L. R., The Two Creeks forest bed, Manitowoc Co., Wis. Wisconsin Acad. Sci. Trans., vol. 27, pp. 31-46, 1932.

[17] Note that the loess which lies between the Illinoisan loess and the Tazewell till in the Farm Creek section is now referred to as the Iowan loess. Peorian is applied to the usually indistinguishable combination of Iowan and Tazewell loess which overlies the area south of the Tazewell moraines. Thornbury, W. D., Weathered zones and glacial chronology in southern Indiana. Journ. Geol., vol. 48, pp. 449-475, 1940.

[18] Alden, W. C., and Leighton, M. M., The Iowan Drift: a review of the evidences of the Iowan stage of glaciation. Iowa Geol. Surv., vol. 26, pp. 156-157, 1915.

[19] Leighton, M. M., A notable type Pleistocene section: the Farm Creek exposure near Peoria, Ill. Journ. Geol., vol. 34, pp. 167-174, 1926.

overlying Shelbyville (Tazewell) till represents a new advance of the ice which sheared off the top of the loess. However, at the west end of the section a humus-bearing soil of infantile development is preserved.[20] West of Mackinaw, Ill., also, the loess has an infant soil development and is overlain by the Tazewell till. The Peorian interstadial is represented by these infantile soils, which reflect a milder climate. The length of the interval is attested not by these soils but by the relatively large amount of erosion that occurred between the deposition of the Iowan and Tazewell tills.[21] It should be kept in mind that many eminent students of the question have long held the view that the post-Iowan was a true interglacial stage and therefore had a longer and milder climate than here assumed.[22]

The evidence that an amelioration of climate occurred in North America in the W_2/W_3 interval thus is not wholly conclusive. If, however, on the basis of the complete European evidence this partial American evidence be accepted, and due weight is given to the Two Creeks forest bed, an important conclusion follows. The existence of these mild interstadial intervals in the Wisconsin implies that the route of migration through the Canadian plains was open twice during the Wisconsin. It would have been possible for the Sandia people to have entered the continent in the last one of these interstadials, W_2/W_3, when the Two Creeks forest bed was laid down under mild climatic conditions. They would then have had a relatively long period of time to reach New Mexico and to become well-established and perhaps have developed unique traits by the onset of the ensuing glaciation. This substage (W_3) was sufficiently well-advanced when the record begins in Sandia Cave, so that drip from the roof had begun. Whether the Folsom people also entered in this interstadial or whether the descendents of the Sandia people or some unknown people of the same antiquity developed the Folsom culture is an issue on which the geologic evidence sheds no light.

Estimates of the date in years of Pleistocene events previous to the Mankato-Pomeranian (W_3) substage are subject to large errors. Kay[23] has made an estimate of the age of Iowan and other drifts by consideration of the depth to which they have been leached of

[20] Leighton, M. M., The Peorian loess and the classification of the glacial drift sheets of the Mississippi Valley. Journ. Geol., vol. 39, pp. 48-50, 1931.

[21] Alden, W. C., and Leighton, M. M., op. cit.

[22] Leverett, Frank, The place of the Iowan Drift. Journ. Geol., vol. 47, pp. 398-407, 1939, and earlier papers.

[23] Kay, G. F., Classification and duration of the Pleistocene period. Bull. Geol. Soc. Amer., vol. 42, pp. 425-466, 1931.

calcium carbonate. This method is applicable to the drifts of the Middle West which have a high content of limestone pebbles. The average depth of leaching in Iowa in the Mankato (Des Moines lobe) is 2.5 feet. This material has been exposed to weathering for 25,000 years, or since the beginning of retreat of the ice of this substage, W_3. The rate of leaching is a tenth of a foot for each 1,000 years. Using this factor and extensive data on leaching, Kay has attained a date for the Iowan and also for the second interglacial. Thornbury in the paper previously cited has applied the same method to the Tazewell, W_2, substage in Indiana. These estimates are shown in table 2:

TABLE 2.—*Elapsed time to glacial stages and substages*

Substage or stage	Average depth of leaching in feet	Elapsed time in years
Mankato till	2.5	25,000
Tazewell till [a]	4.5	45,000
Iowan till	5.5	55,000
Sangamon (gravel, etc.)	12.0	120,000

[a] Thornbury's data from Indiana.

These estimates are based on two assumptions: that the rate of solution has been uniform; and that there has been no surface loss of material, or, if there has been, that this loss has been at a uniform rate. Neither of these assumptions can be so. When the ice began to melt away from its most advanced position in the Mankato, the climate must still have been cold, and it did not much ameliorate for a considerable period. We have in Europe an excellent record of the climate during the synchronous retreat of the ice from the moraine in the south shore of the Baltic across Sweden and Finland. It required about 15,000 years for the ice to reach the Fennoscandian moraine and during this time the climate was near-Arctic in type and the *Dryas* or tundra vegetation flourished. There was then a slight readvance of the ice occupying a period of 670 years.[24] Warmer conditions did not begin until about the beginning of the Post-glacial in the European sense or 16,000 years after the beginning of retreat. During this cold period there was some solifluction and removal of the surface of glacially deposited material. Doubtless also some solution occurred. One must conclude that the bulk of the solution of limestone in the exposed glacial deposits has occurred within the past 9,000 years.

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[24] Sauramo, Matti, The Quaternary geology of Finland. Bull. Comm. Geol. Finlande, No. 86, pp. 1-110, 1928.

If we consider the areas of the farthest advance of the Pomeranian or Mankato ice to the south, these areas must have had a near-Arctic climate during a large part of the advance, the climax, and the retreat of the ice. Not only was solution at a minimum, but removal of surface material by solifluction must have occurred. Thus part of the material leached during the mild climate of the previous interstadial must have been removed. On very flat undrained areas, such as those postulated in the great areas of the Illinois drift, removal may have been at a minimum.

INFERENCES FROM THE INTERSTADIAL ENTRANCE OF MAN

The evidence here presented that man existed in the early part of W_3 and that his probable entrance occurred in the interstadial W_2/W_3 illuminates other archeological finds. Of these one of the most important is the skeleton known as Minnesota man.[25] These bones, which are those of a young girl, were found with two shell ornaments and a bone knife in the silts deposited in a glacial lake in western Minnesota. This lake was a small water body which existed while an ice mass filled the Red River valley (basin of Lake Agassiz) and while the Big Stone moraine was being built. The water was ponded against the hills of the Altamont-Gary system of moraines, previously built by the same ice lobe. The controversy regarding the antiquity of these bones has made it plain that the objectors are not solely concerned with local details bearing on the provenance of the bones. They are appalled at the relatively great antiquity which must be assumed. The silts in which the skeleton was found were deposited in a lake contemporaneous with the Big Stone moraine. As this moraine formed after the climax of the Mankato substage, it must be of the order of 18,000 to 20,000 years old.[26] If, however, the Sandia people entered North America in the pre-Mankato interstadial W_2/W_3 there seems no good reason to suppose that the ancestors of the Minnesota girl may not have entered also. On such a supposition ample time would be available to develop several unlike cultures by the time of the beginning of retreat of the Mankato ice. Thus the disparity between the cultural objects found with the Minnesota girl and the Folsom and Sandia cultures might be explained, although their similarity to recent material still presents a problem. The marine shell found as an ornament with the Minnesota girl without doubt came from the Gulf

[25] Jenks, A. E., Pleistocene man in Minnesota, 197 pp. Univ. Minnesota Press, 1936.

[26] As estimated by Leverett and Antevs. See Jenks, op. cit.

Coast, but if settlement had been so long established, it might easily have been obtained through well-established trade between Minnesota and the Gulf.

The Folsom culture of the original site and of the Lindenmeier site are very similar. There are, however, other fluted points, widespread in their distribution, which show considerable typological variation. The anthropological explanation of this differentiation is facilitated by an enlargement of the time interval during which man has inhabited the continent. Similarly the complex differentiation of cultures represented by the wide array of cultural objects now included in "Yuma" is easier of explanation in view of the increased time allowed for such differentiation. Limitations on the time after the Corral Creek climax during which the Folsom culture flourished await the study of stratified Yuma sites and their successful geologic dating.