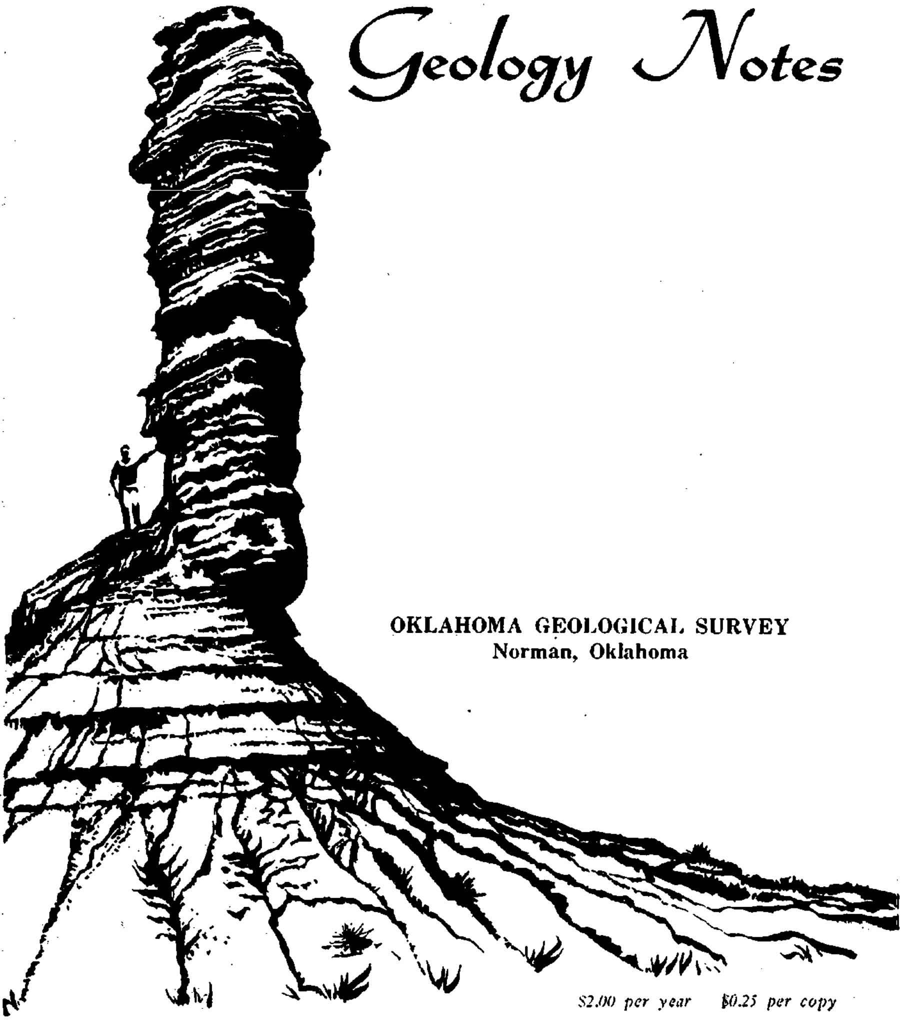
OKLAHOMA

Geology Notes



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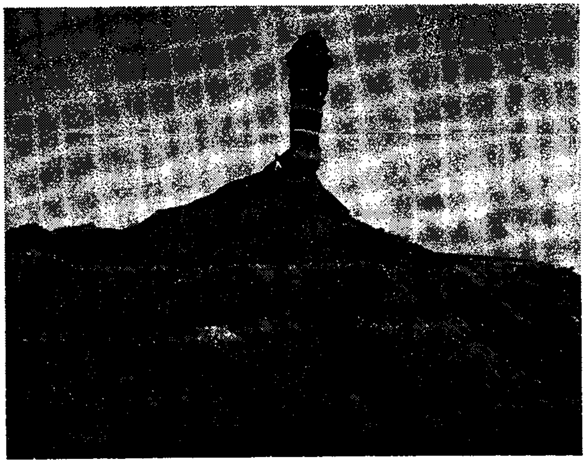


(Photograph by A. J. Myers)

Chimney Rock, A Permian Outcrop

Alex. Nicholson

For the cover of the 1961 volume (volume 21) of *Oklahoma Geology Notes* we have selected a sketch of Chimney Rock, drawn by Merrill Cason, art student at The University of Oklahoma.

Chimney Rock is in Woodward County about 8.5 miles southeast of Alabaster Caverns State Park and about 24 miles northeast of Woodward. It is a column of rock consisting of alternating layers of red shales and gypsum, rising approximately 30 feet above the head of the geologist (Alton O. Riley) pictured on the cover. To my knowledge it is the only example in the State of Oklahoma of this physiographic form, known variously as a monument, pinnacle rock, needle rock, or chimney rock. In this sense Chimney Rock is unique. But in another sense it symbolizes one of the greater challenges with which Nature confronts the Oklahoma geologist. Chimney Rock is a remnant of the Permian Flowerpot formation, and the Permian sequence is the most widely exposed geologic unit in Oklahoma. Rocks of Permian age underlie approximately 39,000 square miles or more than fifty percent of the area of the State. Over most of this area they crop out or are covered by Quaternary deposits. Near the western margin of the State they are covered by Mesozoic or Tertiary deposits in an area of less than 8,000 square miles. In addition to their areal extent, rocks of the Permian make up a significant part of the stratigraphic column, attaining a maximum thickness of approximately 6,500 feet in the Anadarko basin.

Yet, despite the volume of rock available for study since the first days of geological exploration in Oklahoma, the Permian still poses many unanswered questions. This arises from the nature of the beast. The lithologic character of its rocks is of a type subject to rapid weathering. This fact, and the large areas of Quaternary cover, account for the scarcity of good outcrops. The environments of deposition and diverse source areas which existed during Permian times produced facies changes, paucity of fossils, and rapid alternations and repetitions of monotonous sequences of evaporites, shales, siltstones, and sandstones. In addition, the extraordinary predominance of red color, extensive solution with slumping, and the generally low dips make study more difficult. Thus, the ability of the geologist to use his standard criteria, paleontology, lithology, color, structure, and stratigraphic succession, is taxed to the extreme, and he must apply these criteria with greater precision and discernment than is normally required. In spite of these difficulties, an adequate understanding of the Permian rocks of Oklahoma is not impossible. Persistent and detailed application of the traditional methods and prompt application of new ideas and methods, complemented by studies of the Permian in other parts of North America and the World, will lead inevitably to the solution of many problems.

In this issue of the *Notes* Ham and Jordan give a brief list of some of the work that has been done and is being done on the Permian rocks of Oklahoma. In addition to the studies cited by them (principally stratigraphic investigations), other significant investigations are also in progress. One is an investigation of the borate minerals in Permian rocks, being conducted by Ham, Mankin, and Schleicher. Another is the study of the palynology of the Flowerpot shale by Wilson. The results of these investigations will be published by the Survey in 1961. The clay mineralogy of the Permian rocks is being actively studied by Mankin and his students. The U. S. Geological Survey is currently engaged in ground-water and salt-water-contamination investigations related to Permian strata. These examples serve to give only an indication of the extent to which the Permian is significant in the geology of Oklahoma.

Survey Publications in Press

Two Oklahoma Geological Survey publications are currently in press and will be issued early in 1961. One is Circular 54, *Coal mining and landscape modification in Oklahoma*, by Arthur H. Doerr, associate professor of geography, The University of Oklahoma.

The other is Circular 56, *Pollen and spores from the Permian deposits of Cherdyn' and Aktyubinsk areas, Cis-Urals*, by S. R. Samoilovich. This document is a translation, by M. K. Elias, of a Russian study.

A Permian Stratigraphic Section in West-Central Oklahoma

W. E. Ham and Louise Jordan

The surface rocks in the western one-third of Oklahoma, exclusive of the Panhandle, are almost wholly of Permian age. They consist mostly of reddish-brown shales and sandstones, together with thinner sequences of gypsum or anhydrite and dolomite. Surface and subsurface studies have shown five evaporite units of anhydrite and gypsum, or of anhydrite with rock salt, or of rock salt alone, and these have been assigned in ascending order to the Wellington, Hennessey, Flowerpot, Blaine, and Cloud Chief formations.

The Oklahoma Geological Survey is currently sponsoring an integrated program of research on these Permian rocks. The major published reports, chiefly the results of outcrop mapping studies, include Scott and Ham on the Carter area (1957), Ham and Curtis on the Weatherford-Clinton district (1958), Myers on Harper County (1959), and Ham on southwestern Oklahoma (1960). Louise Jordan has published a description of salt in the Blaine formation from cores of a well drilled for underground storage of liquefied petroleum gas at the Elk City field in Beckham County (1959). R. O. Fay has a completed manuscript on Blaine County and on a stratigraphic study extending northward into Kansas; A. J. Myers is working in Woodward County; and D. L. Vosburg is completing a subsurface study over a wide area in western Oklahoma. Ten master's theses in geology at The University of Oklahoma have been completed in this region during the period 1955-60, and six additional thesis studies are in progress.

In spite of the work cited above, the uppermost Permian strata in west-central Oklahoma are poorly known because the outcrops are covered over wide areas, with the result that details of a fully reliable composite section have not been available. A search for samples from wells drilled for oil and gas revealed that samples from the upper 1,000-2,000 feet, including those critical to this study, generally are not saved. Being unproductive, strata above the Flowerpot and Blaine have little interest in routine petroleum geology and no interest at all in the drilling of field wells.

Through the courtesy of the Shell Oil Company, and Mr. Acus Edwards of the Shell office in Oklahoma City, we have been supplied with several sets of samples, a gamma ray-laterolog, resistivity logs, and a caliper log from which the composite section shown in figure 1 was made. The samples were examined and interpreted by Jordan. The section given fits reasonably well with outcrop studies, except for the abnormally thick section of the Blaine. We believe that it is substantially accurate and is the best approach to a standard section that can be obtained without continuous cores.

Quartermaster Formation. The Quartermaster formation is composed of the Elk City sandstone member above and the Doxey shale member below. The formation has a normal thickness of 375 feet. the top being everywhere eroded.

Elk City sandstone member. The youngest Permian beds in western Oklahoma are in the Elk City sandstone, which crops out in the axial part of the Anadarko basin in Washita, Beckham, and Roger Mills Counties. The top is eroded, and in Roger Mills County it is covered by the Ogalalla formation (Pliocene), so that its full thickness, as well as the character of the normally overlying beds, is not known in western Oklahoma. At most places the member is poorly exposed and in part is covered by high-terrace alluvium. Green (1936, p. 1474) reported that the Elk City is almost solid sandstone approximately 170 feet thick in the southeastern part of T. 11 N., R. 19 W., Washita County.

Drill cuttings in the Burns Flat area in T. 10 N., R. 19 W., Washita County, have been examined by B. L. Stacy of the U. S. Geological Survey at Norman, in connection with ground-water studies at the Sherman-Clinton Air Force Base. Study of numerous closely spaced wells shows that the Elk City sandstone in this area is 185 feet thick and consists of moderate reddish-brown sandstone interbedded with siltstone (fig. 1). Sandstone, mostly fine and medium grained but generally coarse grained at the base, makes up about 75 percent of the formation. The siltstone beds are irregular and discontinuous, and cannot be traced from well to well.

Burns Flat is in the central part of the largest outcrop area of the Elk City sandstone in western Oklahoma, and its thickness here is probably the maximum for the region.

Doxey shale member. Conchoidally fracturing reddish-brown silty mudstone characterizes the Doxey shale, and the general absence of sandstone easily separates it from the overlying Elk City member. The Doxey shales or mudstones are mostly devoid of bedding, as they have not been compacted by deep burial. About 15 percent of the stratigraphic section consists of well-stratified sandy siltstone beds six inches to two feet thick, and where the Doxey is well exposed in badlands these beds form prominent benches.

The member has a reasonably constant thickness of 175 feet. Green (1936, p. 1474) gives a range of 160 to 200 feet for the excellent outcrops in Beckham and Washita Counties, and a thickness of 165 feet was determined from well control as shown in figure 1.

Neither member of the Quartermaster formation contains gypsum or anhydrite and both are unfossiliferous, although they may contain plant spores.

CLOUD CHIEF FORMATION. The Cloud Chief formation is composed dominantly of pale-red fine-grained sandstone, siltstone, and silty shale, and is distinguished from the overlying Doxey shale by its lighter color and coarser grain size. At or near the base is a locally thick unit of gypsum-anhydrite evaporites. Thin beds of gypsum, together with much vein satin spar, also occur in the middle and upper parts of the formation, marking the highest occurrence of evaporites in Permian strata of western Oklahoma.

The lower and principal evaporite unit characterizes the eastern area of outcrop, chiefly in southeastern Custer County, eastern Washita County,

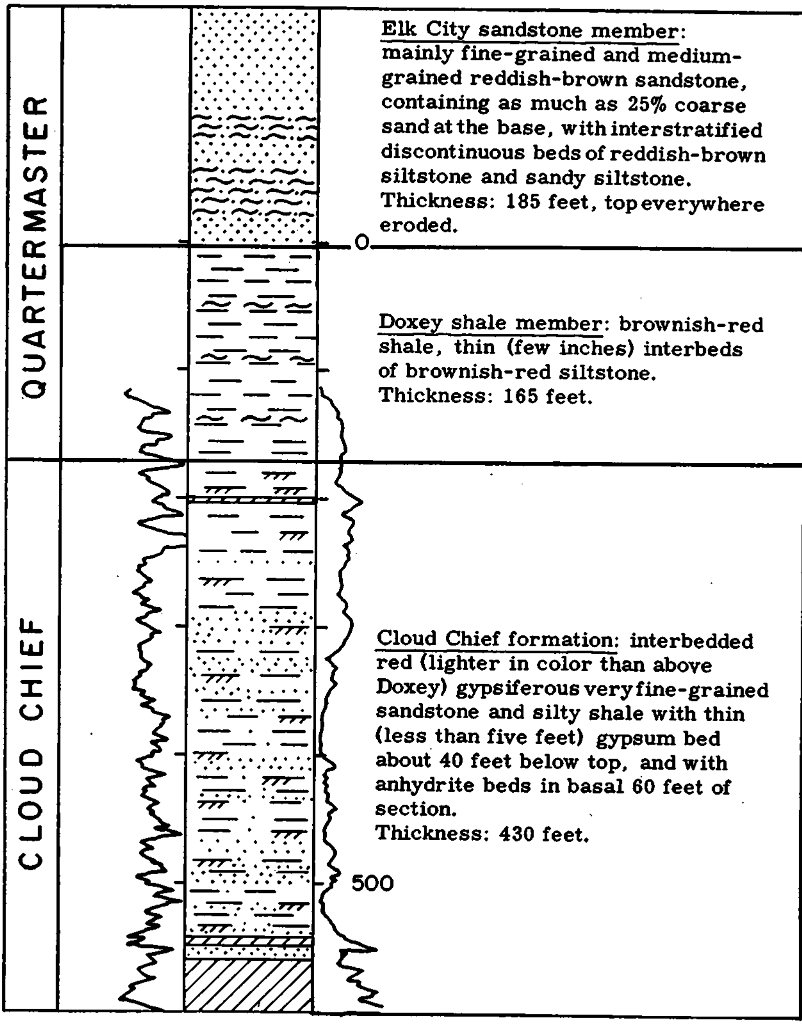
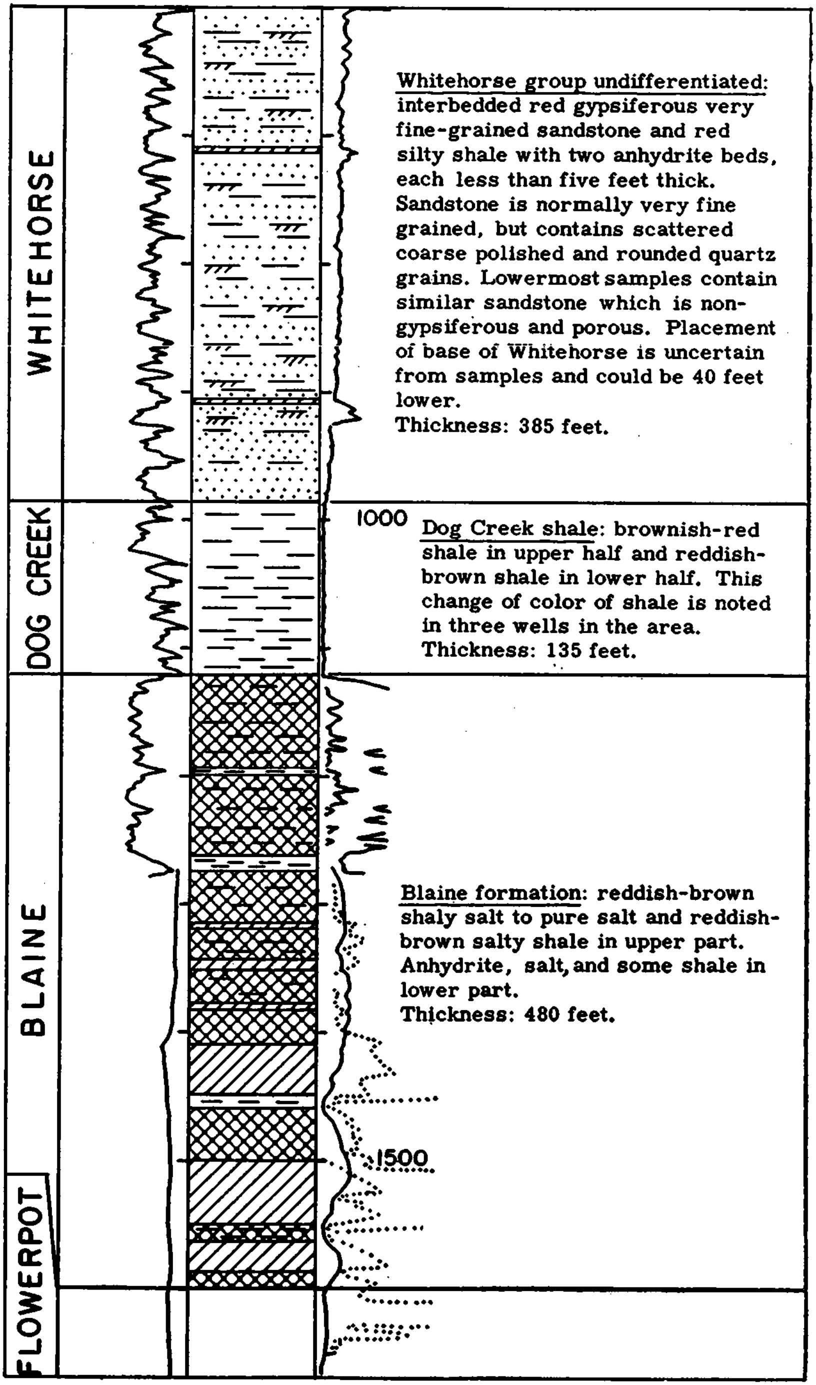


FIGURE 1. Post-Flowerpot Permian composite subsurface section in Beckham and Washita Counties, Oklahoma.

Elk City sandstone at top is composite log from data from three water wells drilled at Clinton-Sherman Air Force Base in SW¼ sec. 11, T. 10 N., R. 19 W., Washita County, Oklahoma, in area of known maximum thickness of Elk City; sample examination by B. L. Stacy, U. S. Geological Survey, Norman, Oklahoma.

Gamma ray-laterolog survey from 117 to 1,275 feet and cores from 1,126 to 1,413 feet from Shell Oil Co., No. 1, E. B. Yelton LPG (NE¼ SW¼ SE¼ sec. 15, T. 10 N., R. 21 W.). Resistivity log from 1,270 to 1,640 from Shell Oil Co., No. 1 Yelton (NW¼ SE¼ sec. 15, T. 10 N., R. 21 W.). Samples described from 0 to 1,106 from Shell Oil Co., No. 2 Yelton SWD (SW¼ SW¼ SW¼ SE¼ sec. 15, T. 10 N., R. 21 W.; and lithology interpreted in lower part of Blaine using caliper logs in NW¼ SE¼ sec. 9, T. 10 N., R. 21 W. and SE ¼ SE¼ SW¼ sec. 30, T. 10 N., R. 20 W. by Louise Jordan, Oklahoma Geological Survey.


WHITEHORSE
DOG CREEK
BLAINE
FLOWERPOT
1000
1500
Whitehorse group undifferentiated: interbedded red gypsiferous very fine-grained sandstone and red silty shale with two anhydrite beds, each less than five feet thick. Sandstone is normally very fine grained, but contains scattered coarse polished and rounded quartz grains. Lowermost samples contain similar sandstone which is non-gypsiferous and porous. Placement of base of Whitehorse is uncertain from samples and could be 40 feet lower.
Thickness: 385 feet.
Dog Creek shale: brownish-red shale in upper half and reddish-brown shale in lower half. This change of color of shale is noted in three wells in the area.
Thickness: 135 feet.
Blaine formation: reddish-brown shaly salt to pure salt and reddish-brown salty shale in upper part. Anhydrite, salt, and some shale in lower part.
Thickness: 480 feet.

and Caddo County. Extensive coring in southeastern Custer County has shown as much as 120 feet of continuous sulfate rock, consisting of gypsum at the surface and of anhydrite in the shallow subsurface (Ham and Curtis, 1958). Westward on the outcrop this evaporite unit thins notably, decreasing to only five feet in Roger Mills and Beckham Counties, where it marks the base of the formation. In the eastern area the Weatherford dolomite, one to five feet thick, is at the base locally.

In eastern Washita County the outcropping belt of the Cloud Chief formation is 15 to 20 miles wide, and over much of the area the exposures are so poor that no reliable estimates of thickness can be made. Green (1936, p. 1473) reported that on the north side of the Anadarko basin, northwest of Clinton in south-central Custer County, the formation is 250 feet thick and contains no thick beds of gypsum. Toward the south side of the Anadarko basin the Cloud Chief evidently increases to almost twice this thickness, as it is clearly 430 feet thick in the control well in eastern Beckham County (fig. 1). Evaporites in this well are mainly anhydrite beds in the basal 60 feet of the formation.

WHITEHORSE GROUP. Below the evaporites of the Cloud Chief formation are sandstones and shales of the Whitehorse group, divided into the Rush Springs sandstone above and Marlow formation below. The group has an extensive outcrop across western Oklahoma, but only that part which occurs in west-central Oklahoma, on the south flank of the Anadarko basin, is of interest in this report.

The eastern outcrops in Caddo and Grady Counties have been extensively investigated (Davis, 1955, p. 64, 69, and comprehensive bibliography; Green, 1936, p. 1469-1473). In that area the Marlow formation of red shales and fine-grained sandstone is normally 110 to 125 feet thick, and the Rush Springs formation of dominantly cross-bedded fine- and medium-grained sandstone is 200 to 300 feet thick. The group ranges in thickness between 300 and 400 feet in the eastern area, and it extends westward with loss of shales from the Marlow formation to the Carter area of southeastern Beckham County where the group is undivided and is 387 feet thick (Scott and Ham, 1957, p. 31). Beds of gypsum one or two feet thick are locally present in the basal 100 feet of the Whitehorse group in the eastern area, and a six-foot bed of massive gypsum, 30 feet above the base of the group, characterizes outcrops in the western area.

In figure 1 the thickness of the Whitehorse group in the control well in Beckham County is given as 385 feet, in close agreement with outcrop studies just to the south in the Carter area. The geologist in the field ordinarily has no difficulty in identifying the massive fine-grained sandstone of the Whitehorse group in basal contact with red shales of the underlying Dog Creek shale.

DOG CREEK AND BLAINE FORMATIONS. In southwestern Oklahoma the Dog Creek shale and underlying Blaine evaporites are complementary formations. Outcrop studies show that the Blaine ranges in thickness from 50 feet near Carnegie in Caddo County to 250 feet in

Harmon County. It thickens from the basin margin westward toward the basin center. The upper part represents the regressive phase of the evaporite megacycle, and the covering shales of the Dog Creek formation decrease in thickness westward in direct proportion to the buildup of evaporites (Ham, 1960). On the outcrop the Dog Creek consists of reddish-brown slightly silty shale 90 to 150 feet thick, interstratified with thin beds of microgranular dolomite and a few thin beds of siltstone, whereas the Blaine is about 75 percent gypsum, 5 percent dolomite, and 20 percent interbedded shale.

The normal thickness of the Blaine on the outcrop is approximately 175 feet in Beckham, Greer, Harmon, and Jackson Counties of southwestern Oklahoma, compared with approximately 100 feet in Blaine and Harper Counties of northwestern Oklahoma. In neither region is there outcrop evidence to indicate extensive leaching of salt. It seems probable that the 480 feet of Blaine shown in figure 1, from wells in east-central Beckham County, is abnormally thick and also is abnormal in containing about 75 percent rock salt, mostly in the upper half of the formation. Although salt beds are present in the Blaine formation in subsurface in other parts of western Oklahoma, there is no other area where such a great thickness is indicated, and we therefore believe that Beckham County, exclusive of the outcrops in its southern part, is underlain by a local basin of salt accumulated during Blaine time.

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The Blastoid Collection of the Philadelphia Academy of Natural Sciences

Robert O. Fay

The blastoid collection currently on deposit in the museum of the Philadelphia Academy of Natural Sciences comprises approximately 365 specimens belonging to 8 genera, and does not include even one recognizable type. The genera represented and the number of specimens of each are:

Cryptoblastus	9
Globoblastus	13
Metablastus	2
Nucleocrinus	8
Ellipticoblastus	2
Orophocrinus	3
Pentremites	300+
Schizoblastus	1

Most of these specimens are poorly labelled or unlabelled and it was impossible to recognize the types assignable to Thomas Say. It is doubted that the types of Thomas Say were ever on deposit with this museum, or if they were, the specimens were traded or lost. It is quite probable that the specimens were in Peale's Museum, which was sold at auction in 1850 and split into several parts, and later destroyed by fire in 1851 and in 1865.

Cryptoblastus Etheridge and Carpenter 1886

Of the 9 specimens only 2 are properly labelled. All belong to *Cryptoblastus melo* (Owen and Shumard) 1850. There are 2 specimens labelled "*Granatocrinus melo,* Burlington, Iowa, F. L. Sarmiento, purchase, 1892"; 1 specimen labelled "*Pentremites melo*"; 2 specimens labelled "*Olivanites* new, one of the two best preserved spms. found in the limestone"; and 4 specimens unlabelled.

Globoblastus Hambach 1903

Of the 13 specimens belonging to *Globoblastus norwoodi* (Owen and Shumard) 1850, there are 3 specimens labelled "*Pentremites norwoodi,* B. limestone, Burlington, Iowa, Dr. Jos. Wilson"; 6 specimens labelled "*Granatocrinus norwoodi,* U. Burlington limestone, Burlington, Iowa, coll. of C. Wachsmuth"; 2 specimens labelled "*Granatocrinus,* Burlington, Iowa, F. L. Sarmiento, by purchase"; 2 specimens unlabelled.

Metablastus Etheridge and Carpenter 1886
Plate III, figures 3-5

The 2 specimens belonging to *Metablastus lineatus* (Shumard) 1858 are in separate trays. One specimen is a fragment in rock labelled "*Pentremites lineatus,* Upper Burlington limestone, Burlington, Iowa." The other specimen (pl. III, figs. 3-5) is labelled "*Pentremites lineatus*, Burlington, Iowa, F. L. Sarmiento, by purchase 1892, #32." The latter specimen is 30 mm high by 10 mm wide, with vault 20 mm long and pelvis 10 mm long, ambulacra 12 mm long with 30 side plates in 10 mm, lancet plate completely covered by side plates, anal area divided into epideltoid and hypodeltoid with anal opening between and with two unnamed plates on either side of anus, pentagonal hypodeltoid partly destroyed but resting laterally upon bevelled edges of two unnamed plates which are overlapped by adjacent radial limbs, radial limbs overlap bevelled edges of other 4 deltoids, 5 paired spiracles, the anal opening separate from the spiracle on that side, except near extreme top, secondary or outer side plate broadly triangular in top view resting on the bevelled adoral and abmedial corner of the primary side plate with a small marginal pore at the junction of the handle of the next adoral side plate (medial referring to the line of the food groove), brachiolar pit on central adoral part of side plate at junction with secondary side plate, approxiately 6 cover-plate sockets per primary side plate (or simply side plate).

NUCLEOCRINUS Conrad 1842
Plate II, figures 1, 2

Of the 8 specimens belonging to *Nucleocrinus verneuili* (Troost) 1841, 5 specimens are labelled "*Nucleocrinus (Olivanites) verneuili*, Local by Falls of Ohio, 16 to 30 ft. below dark slate #56"; 2 specimens unlabelled with the number 1013 on one; 1 specimen unlabelled. Of the specimens from the Falls of the Ohio, one is a cross-sectioned specimen showing the hydrospires and a peculiar horn-shaped projection on the inside of the hypodeltoid (pl. II, fig. 1).

ELLIPTICOBLASTUS Fay 1960
Plate I, figures 1-5

The 2 specimens of *Ellipticoblastus orbicularis* (Sowerby) 1834 are probably from Lancashire, England. One is labelled "*Pentremites*, North America, Dr. Mantell" (pl. I, figs. 1, 2, 4), and the other is labelled "C. C. Mount. Limest. 94" (pl. I, figs. 3, 5). The first specimen is 12 mm high and 11 mm wide, subglobular, with linear ambulacra 14 mm long by 1.5 mm wide that recurve below, 20 side plates in 10 mm, with lancet plates exposed along middle one-third of ambulacra, deltoids extending beyond half the height of the specimen, spiracles 5, the anispiracle between the epideltoid (adoral) and hypodeltoid (aboral) plates, bounded laterally by what appear to be two unnamed plates, the epideltoid and deltoid lips of other 4 deltoids folded internally to form hydrospires and hydrospire plates, with the deltoid bodies and hypodeltoid partly concealing the hydrospire plate, pores between hydrospire plate and adjacent abmedial wall of hydrospire (medial referring to line of food groove) with two pores per side plate, radial limbs overlapping deltoids at high angle, 3 small basals in concave part of aboral surface, with azygous basal (Z) in right anterior interambulacral position (A-B). A slight grinding of the oral surface reveals that the 5 spiracles rapidly divide into two hydrospire canals each, except on the anal side where one large opening prevails.

These then would lead to one fold on each side of an ambulacrum (as shown by Etheridge and Carpenter, 1886), and end aborally in the substance of the radial plate. Admedially the hydrospire folds thicken to form a hydrospire plate, and thus the hydrospire plate includes infolded portions of both the radial and deltoid plates. The first specimen is weathered and not as well preserved as the second specimen. The second specimen (pl. I, figs. 3, 5) is 10 mm high by 9 mm wide, with ambulacra 12 mm long and 1 mm wide, 28 side plates in 10 mm, showing details of the side plates. The secondary side plate rests upon the bevelled abmedial and adoral margins of the primary side plate and is roughly triangular in top view. The pores between the hydrospire plate and abmedial wall of adjacent hydrospire fold are covered by side plates and adjacent radial and deltoid plates except near junctures of corners of abmedial margins of secondary side plates. At these places there are side-plate furrows, one short furrow at the aboral corner of the secondary side plate, one long furrow at the marginal adoral corner of the secondary side plate extending medially and adorally in a curved line to the center of the next adoral primary side plate. The brachiolar pit is centrally located along the suture between the primary and secondary side plates, with about 4 side cover-plate sockets along each side of a side food groove and 5 cover-plate sockets per side plate along the main food groove. The spiracles are slightly raised as in *Globoblastus norwoodi*, but the deltoids are extremely long and the lancet plate is exposed along its entire length, with only one

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Explanation of Plate I

Ellipticoblastus orbicularis (Sowerby) 1834

A—anal opening	L—lancet
Bp—brachiolar pit	O—oral opening
D—deltoid	PSp—primary side plate
ED—epideltoid	S—spiracle
Hc—hydrospire canal	SSp—secondary side plate
HD—hypodeltoid	U—unnamed plate
HP—hydrospire plate	Z—azygous basal in A-B position

FIGURE 1. Side view of specimen from left posterior (D) ambulacrum, x1.5, labelled "*Pentremites,* North America."

FIGURE 2. Basal view of basal plates, x15, of same specimen as in figure 1.

FIGURE 3. Detailed side plate view of right anterior ambulacrum near tip, x75.0, of specimen labelled "C. C. Mount Limest. 94."

FIGURE 4. Oral view of specimen shown in figure 1, x15.0, showing oral area slightly ground down.

FIGURE 5. Oral area of specimen shown in figure 3, x15.0, showing 4 raised spiracles, and anal area between epideltoid and broken hypodeltoid, with exposed hydrospire plate on one side. Shaded area broken away.

hydrospire fold beneath each side of an ambulacrum, thus distinguishing this genus from *Globoblastus* which lacks these features.

Orophocrinus von Seebach 1864
Plate III, figure 6

The 3 specimens are unlabelled but probably come from Burlington, Iowa. One specimen is *Orophocrinus stelliformis* (Owen and Shumard) 1850, labelled *Pentremites stelliformis,* without horizon or locality. A detailed ambulacral view is shown in plate III, figure 6. The secondary side

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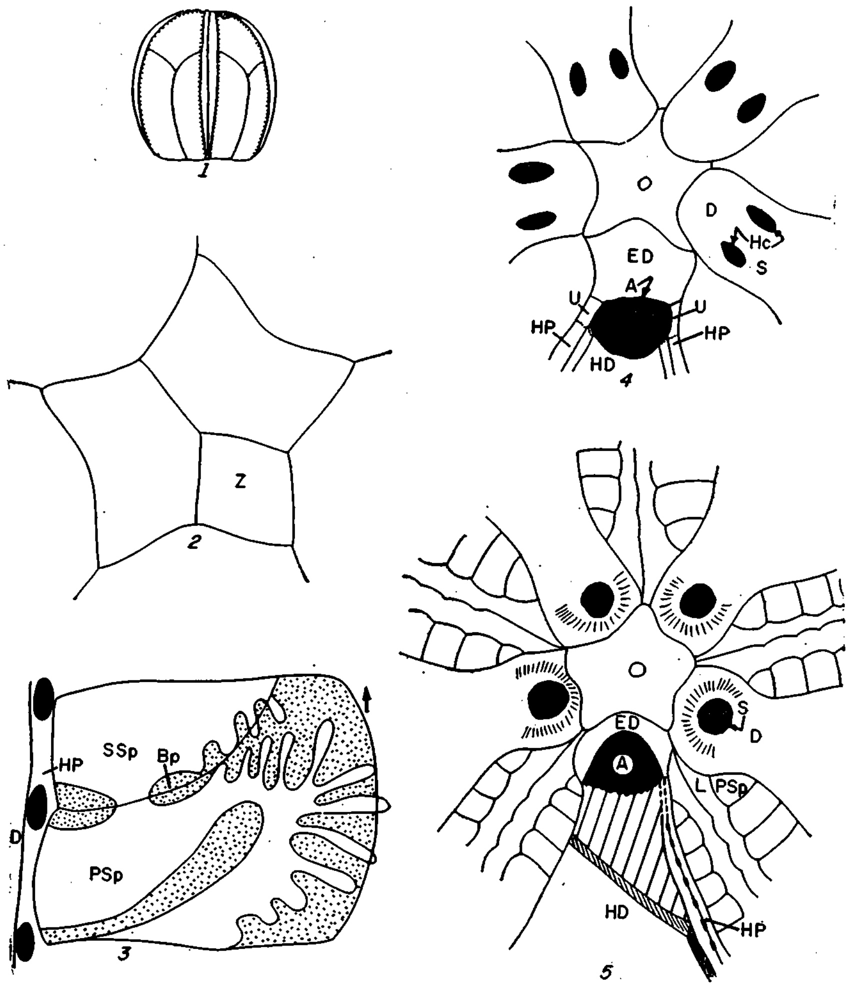
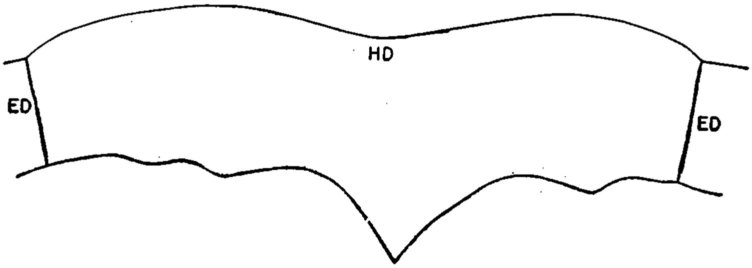
Plate I





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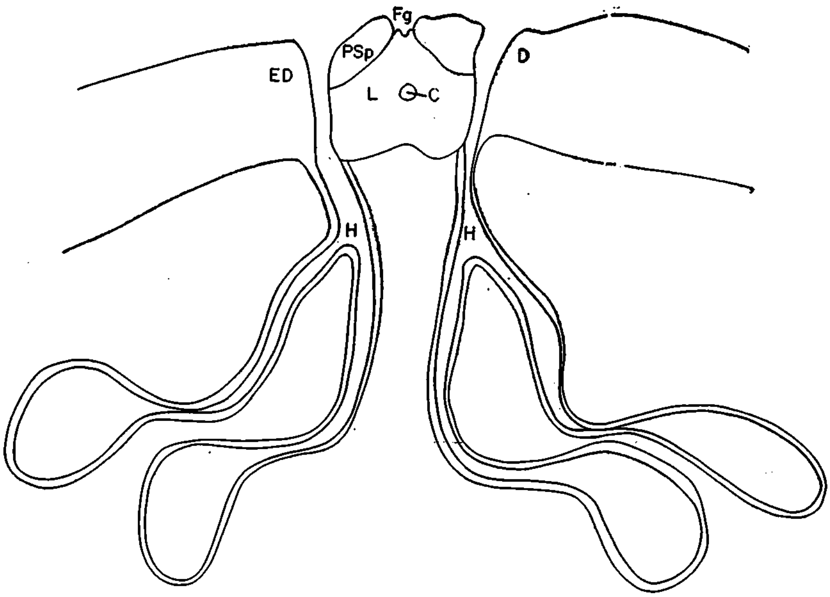

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PLATE II

Nucleocrinus verneuili (Troost) 1841

C—radial canal
D—deltoid
ED—epideltoid
Fg—food groove
H—hydrospires
HD—hypodeltoid
L—lancet
PSp—primary side plate

FIGURE 1. Cross section through the hypodeltoid plate on the anal side showing the inward horn-like projection, x12.5. Falls of the Ohio.

FIGURE 2. Cross section of a specimen showing the hydrospires of the left posterior (D) ambulacrum, x15.0.

plates are small lenticular plates resting upon the bevelled edges of the primary side plates, with what appears to be a brachiolar pit on the aboral and abmedial margins of each secondary side plate. The primary side plates extend beneath and around all sides of the secondary side plates. Each of the elongate spiracular slits ends adorally in a bulbous opening adjacent to the primary side plate which is second from the oral opening. The slits separate the side plates from the deltoids and radials, extending approximately the same length along the margins of both plates. This slit then opens internally into several hydrospire openings on each side of an ambulacrum.

The other two specimens belong to *Orophocrinus whitei* (Hall) 1861 and probably came from Burlington, Iowa. The one specimen is in a box with the above specimen and the other is in a box with a crinoid labelled "*Cyathocrinus* new."

SCHIZOBLASTUS Etheridge and Carpenter 1882

One specimen of *Schizoblastus sayi* (Shumard) 1855, probably from the Burlington limestone, but unlabelled, is in a small box with a *Pentremites*. The *Pentremites* has number 323 on it and must have been collected from another formation and locality.

PENTREMITES Say 1820
Plate III, figures 1, 2; plate IV, figures 1-6

Probably the original specimens of *Pentremites* from which Say described the various species have been destroyed. None is apparently in the collection of the Philadelphia Academy of Natural Sciences. One specimen, *Pentremites globosus* Say 1825, was in the Philadelphia, or Peale's, Museum, separate from the Academy of Sciences Museum, and it is well known that this entire collection was destroyed by fire. The Woodhouse collection, which probably contained the original suite of specimens sent to Parkinson before 1808 and therefore included the topotypes of *Pentremites godoni* (DeFrance) 1819 was also destroyed in this same fire. Probably all of Samuel Hazard's collection from Huntsville, Alabama, from which Say examined specimens for his descriptions of *Pentremites pyriformis* Say 1825 and *Pentremites florealis* (Schlotheim) 1820, were destroyed in the fire. Therefore, there are no type specimens of *Pentremites* in the collection. Of the more than 300 specimens of *Pentremites*, 10 are from Burlington, Iowa; 1 from Crawfordsville, Indiana; 6 from Spurgen's Hill, Indiana; 6 from West Virginia; 1 slab from Tower Island on the Ohio; 14 from Tennessee; 20 from Kentucky; and 257 from the Chesterian of Alabama.

PENTREMITES ELONGATUS Shumard 1855
Plate IV, figures 2, 6

Of the 9 specimens, one of 3 specimens, labelled "*Pentremites Burlingtonensis=P. elongatus*, Burlington, Iowa, Dr. Jos. Wilson," was examined to see the nature of the hydrospires. There are two hydrospires on each side of an ambulacrum. One specimen measured 17 mm high by 12 mm wide, with vault height of 15 mm and a pelvic height of 2 mm. The ambulacra are 16 mm long, petaloid, with 29 side plates in 10 mm. The stem is round with about 58 crenellae extending one-third of the radial distance from the periphery toward the center. The lumen is small, pentagonal, with angles of intersection of faces radial in position.

Of the remaining 6 specimens, 1 is labelled "*Pentremites longatus*, Burlington, Iowa, F. L. Sarmiento, by purchase, 1892"; 1 specimen labelled "*Pentremites Burlingtonensis*, Upper Burlington limestone, Burlington, Iowa"; 1 specimen labelled *Pentremites elongatus* in a box with a *Pentremites* probably from Chester beds; 2 specimens with a label "*Agaricocrinus*, Burlington, Iowa, F. L. Sarmiento, by purchase, 1892"; and 1 specimen, labelled "*Pentremites Burlingtonensis*, Burlington, Iowa, F. L. Sarmiento, by purchase, #11," in with a *Pentremites burlingtonensis*.

PENTREMITES BURLINGTONENSIS Meek and Worthen 1870
Plate IV, figure 5

One specimen labelled "*Pentremites Burlingtonensis*, Burlington, Iowa, F. A. Sarmiento, by purchase, #11," with a specimen of *Pentremites*

EXPLANATION OF PLATE III

Pentremites conoideus Hall 1856, *Metablastus lineatus* (Shumard) 1858, and *Orophocrinus stelliformis* (Owen and Shumard) 1850

A—anal opening	P—pore
Bp—brachiolar pit	PSp—primary side plate
D—deltoid	R—radial
ED—epideltoid	S—spiracle
Fg—food groove	Sl—spiracular slit
HD—hypodeltoid	SSp—secondary side plate
L—lancet	U—unnamed plate
O—oral opening	Z—azygous basal in A-B position

FIGURE 1. *Pentremites conoideus* Hall 1856. Detailed basal view of stem and supplementary basals, x15. Spurgen's Hill, Indiana.

FIGURE 2. Same, showing detailed ornamentation or growth lines along radio-deltoid suture, x15.0. Arrows point toward later growths of the radials and deltoids.

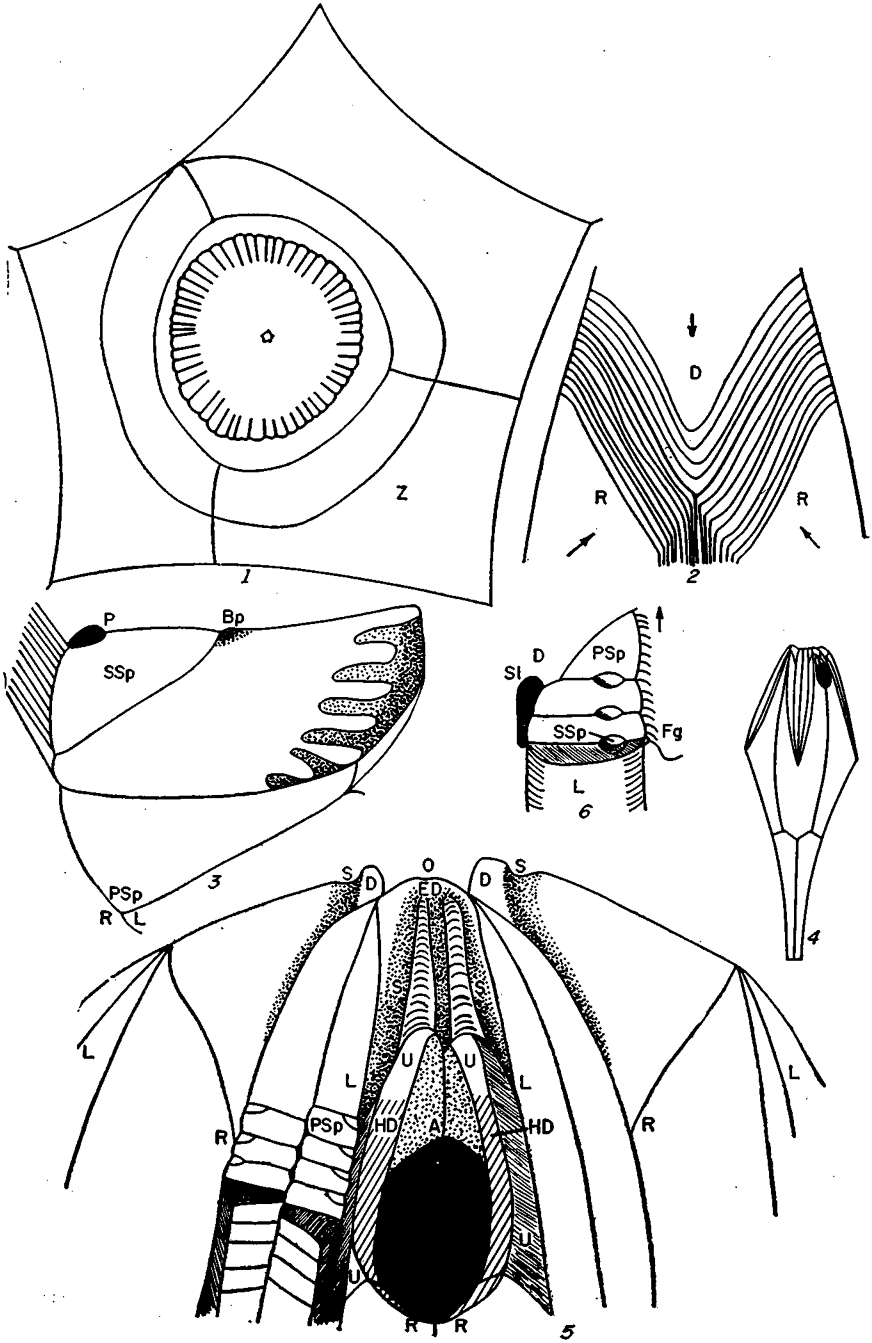
FIGURE 3. *Metablastus lineatus* (Shumard) 1858. Detailed view of side plate on left posterior (D) ambulacrum near radio-deltoid suture, x75.0. Burlington limestone, Burlington, Iowa.

FIGURE 4. Same, left posterior (D) radial view, x1.4.

FIGURE 5. Same, detailed anal view, x15.0, showing spiracles weathered away, and position of hypodeltoid with facets shaded obliquely to left around anal area.

FIGURE 6. *Orophocrinus stelliformis* (Owen and Shumard) 1850. Detailed view near adoral tip of right anterior (B) ambulacrum, x15.0, with arrow pointing toward direction of mouth. Probably from Burlington limestone, Burlington, Iowa.

PLATE III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elongatus. The end of the specimen is destroyed but the specimen is 23 mm wide and probably was 30 mm high, with vault 25 mm high and pelvis 5 mm long. The ambulacra are 30 mm long with 22 side plates in 10 mm, radials overlap deltoids. The spiracles are 5 in number but where weathered, exposing the hydrospire canals, they appear to be 10. There are two hydrospire folds on each side of an ambulacrum.

PENTREMITES CONOIDEUS Hall 1856
Plate III, figures 1, 2; plate IV, figure 3

Of the 6 specimens, one is labelled "*Pentremites konincki* #4, from Spurgen's Hill, Washington Co., Ind.," and is in a box with another apparently unrelated *Pentremites* collected from the Chesterian beds. The other 5 specimens are in a separate box and are labelled "*Pentremites conoideus*, Spurgen's Hill, Washington Co., Ind. Near base of the middle division of the Subcarboniferous L.S." One specimen was selected from this group for study and illustration (pls. III, IV). The specimen is 14.5 mm long by 10 mm wide, with vault 12 mm high and pelvis 2.5 mm long. The ambulacra are 13 mm long, with 28 side plates in 10 mm. There are three hydrospire folds on each side of an ambulacrum. There are approximately 54 crenellae extending one-third of the distance from the periphery toward the center of the round stem. The thickened top of

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EXPLANATION OF PLATE IV

Pentremites platybasis Weller 1920, *P. elongatus* Shumard 1855, *P. conoideus* Hall 1856, *P. symmetricus* Hall, 1858, and *P. burlingtonensis* Meek and Worthen 1870

C—radial canal	L—lancet
D—deltoid	PSp—primary side plate
Fg—food groove	R—radial
H—hydrospires	SSp—secondary side plate

Z—azygous basal in A-B position

FIGURE 1. *Pentremites platybasis* Weller 1920. Cross section of left anterior (E) ambulacrum x15.0. Kaskaskia group, Huntsville, Alabama.

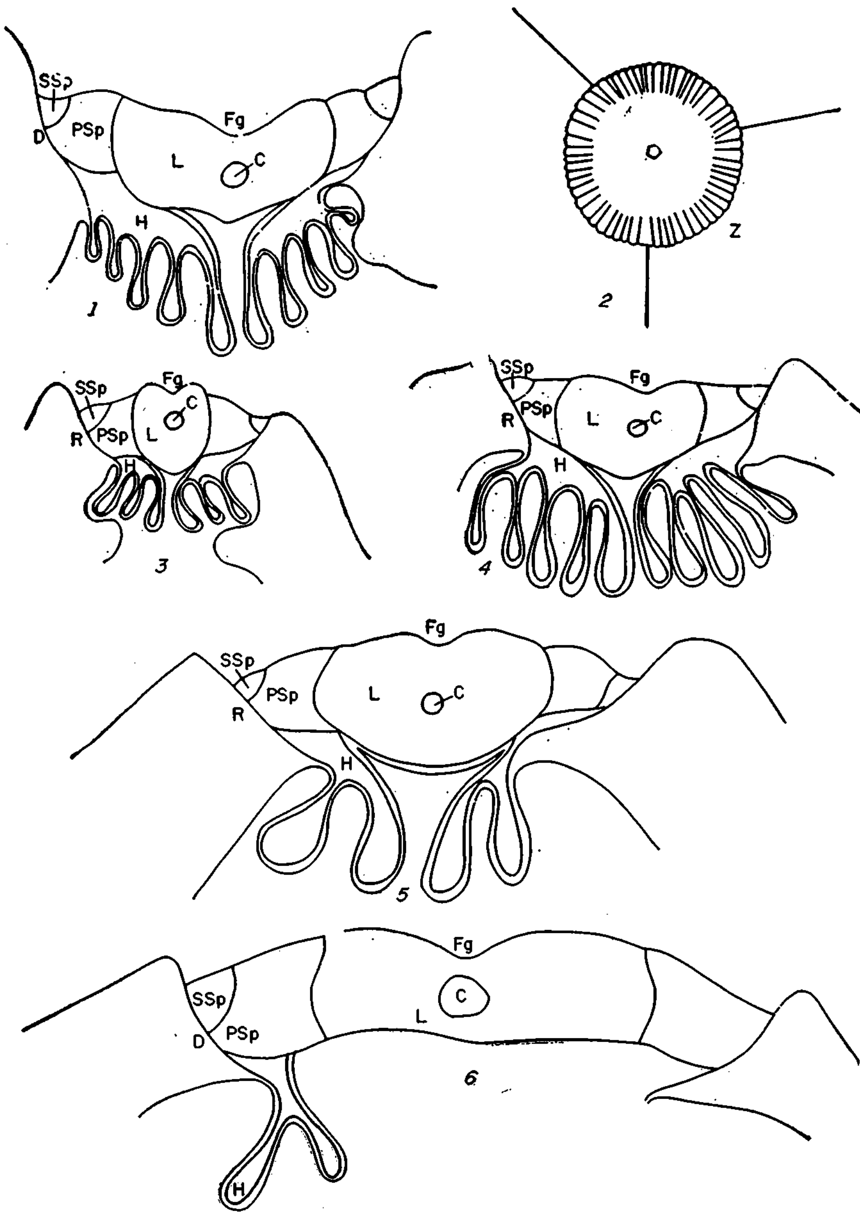
FIGURES 2, 6. *Pentremites elongatus* Shumard 1855. Figure 2, detailed basal view of stem, x15.0; figure 6, cross section of right anterior (B) ambulacrum, x15.0. From Burlington limestone, Burlington, Iowa.

FIGURE 3. *Pentremites conoideus* Hall 1856. Cross section of the anterior (A) ambulacrum, x15.0. Spurgen's Hill, Indiana.

FIGURE 4. *Pentremites symmetricus* Hall 1858. Cross section of right posterior (C) ambulacrum, x15.0. Alabama, probably Upper Mississippian.

FIGURE 5. *Pentremites burlingtonensis* Meek and Worthen 1870. Cross section of left posterior (D) ambulacrum near tip, x15.0. Burlington limestone, Burlington, Iowa.

PLATE IV



the stem is attached basally to three small sub-basal plates that are divided by sutures which are aligned with the interbasal sutures. The center of the stem is perforated by a small pentagonal lumen with angles that are radial in position. The growth striae of the deltoids and radials are parallel to the radio-deltoid suture, and on the radials there are vertical striae parallel to the suture between radial limbs. This shows that the deltoid plate grew in an aboral direction and that the radial plate grew outward from the radial lip.

PENTREMITES spp.
Plate IV, figures 1, 4

Of the remaining specimens, almost all are from Chesterian beds of North America. They belong mostly to *Pentremites clavatus, P. godoni, P. platybasis, P. pyramidatus, P. pyriformis, P. symmetricus,* and *P. welleri.* The illustrated specimens show that there are five hydrospire folds on each side of an ambulacrum in *Pentremites platybasis* (Kaskaskia group, Huntsville, Ala.) and in *Pentremites symmetricus* (Alabama, probably Upper Mississippian), which seems to be normal for Chesterian *Pentremites.* The specimens are listed by areas, almost all of them having come from Alabama.

Alabama

Pentremites clavatus Hambach 1880. 3 specimens, labelled "*Pentremites clavatus,* prob. Up. Miss., Alabama, Iden. by A. S. Horowitz, 1956, Indiana University."

Pentremites godoni (DeFrance) 1819. 9 specimens, one labelled "*Pentremites godoni,* Kaskaskia group, Huntsville, Alabama, coll. by Wachsmuth & Springer, Iden. by A. S. Horowitz, 1956, Indiana University"; one in a box of five with a torn label "*iformis,* Huntzville, Tenn."; and 7 specimens labelled "*Pentremites godoni,* Alabama, prob. Up. Miss., Iden. by A. S. Horowitz, 1956, Indiana University."

Pentremites platybasis Weller 1920. 225 specimens, 176 in one box unlabelled and including specimens of other species, apparently from Alabama; 30 specimens similar to the above, from which one was sectioned for illustration (pl. IV, fig. 1), labelled "*Pentremites godoni,* Kaskaskia group, Huntsville, Alabama, Wachsmuth & Springer, Iden. by A. S. Horowitz, 1956"; 4 specimens incompletely labelled with "#1093, donated by Dr. R. E. Griffith"; 3 specimens unlabelled; 10 specimens labelled "*Pentremites platybasis,* Alabama, prob. Up. Miss., Iden. by A. S. Horowitz 1956," with a number 438 in orange on one specimen; 1 specimen labelled "*Pentremites floralis,* Carboniferous, ½ mile south of Huntsville, Alabama"; 1 specimen labelled "*Pentremites globosus,* Carboniferous, ½ mile S. of Huntsville, Alabama."

Pentremites pyramidatus Ulrich 1905. 3 specimens, one labelled "*Pentremites pyramidatus* (narrow var.), Alabama, prob. U. Miss., Iden. by A. S. Horowitz 1956"; and two specimens labelled the same way in a separate box, but not "(narrow var.)".

Pentremites pyriformis Say 1825. 4 specimens, two specimens unlabelled in a box of five, but the other three specimens are from Huntsville, Alabama (belonging to other species); one specimen labelled "*Pentremites* 1254, Huntsville, Alab.," relabelled by A. S. Horowitz 1956 as "*Pentremites pyriformis*, ? Kaskaskia group, Huntsville, Alabama"; one specimen, labelled by A. S. Horowitz, Indiana University, as "Lectotype, *Pentremites pyriformis* Say (Alabama, prob. Up. Miss., until published provisional lectotype of *Pentremites pyriformis* Say 30428)." On the back of the label is inscribed "height 14.5 mm, width 10 mm, H/W is 1.5, vault is 7 mm, pelvis is 7.5 mm, V/P is 0.9." The exact stratigraphic and geographic placement of this specimen is in doubt and it is here invalidated as a type. Also it probably did not come from the original specimens seen by Say but probably was collected by Wachsmuth and Springer or by someone later than Say. Also Say's specimens did not necessarily come from Alabama.

Pentremites symmetricus Hall 1858. 12 specimens, labelled by A. S. Horowitz, 1956, Indiana University, as "*Pentremites symmetricus*, Alabama, prob. Up. Miss.," one specimen of which was sectioned and is illustrated on plate IV, figure 4.

Pentremites welleri Ulrich 1917. 1 specimen, labelled "*Pentremites welleri*, Alabama, prob. Up. Miss., Iden. by A. S. Horowitz, 1956, Indiana University."

Indiana

Pentremites welleri Ulrich 1917. 1 specimen, labelled "Carb. J. W. Pike, Crawfordsville, Ind."

Kentucky

Pentremites godoni (DeFrance) 1819. 9 specimens, any one of which would be stratigraphically and geographically close to the place where the type was probably originally collected by Dr. Samuel Brown of Lexington in 1805, but probably not from the exact spot, which is probably the Mammoth Cave; 1 specimen labelled "*Pentremites godoni*, R. Walton, Bowling Green, Ky."; 6 specimens labelled "*Pentremites godoni*, Kaskaskia group, Bowling Green, Ky., Wachsmuth and Springer"; and 2 specimens labelled *Pentremites godoni*, Sub-Carbon., E. P. Leas, 1891," in a glass vial.

Pentremites spp. 11 specimens, one labelled "*Pentremites*, 2nd Limestone, Crittenden County, Kentucky," showing small basal pieces (either "H7" or "117" or "#7" but I cannot make out the number); 10 specimens, mostly crushed, belonging to *P. pyramidatus* and *P. welleri*, labelled "*Pentremites* showing the condition of a majority of these specimens from 2nd limestone, Crittenden Co., Ky. 57."

Ohio River

Pentremites spp. 1 slab, broken into two parts, with many specimens on it, labelled "Hurricane Rock, near Tower Id., on the Ohio, J. P. W."

Tennessee

Pentremites godoni (DeFrance) 1819. 13 specimens labelled "*Pentremites godoni*, Kaskaskia group, Cowan, Tenn., Wachsmuth and Springer."

Pentremites pyriformis Say 1825. 1 specimen labelled "*Pentremites pyriformis*, Crab Orchard, Tenn., U. Miss., Paul M. Cope."

West Virginia

Pentremites godoni (DeFrance) 1819 and other species. 6 specimens in glass vial, labelled "*Pentremites godoni*, Sub-Carb., Lewisburg, West Va., Joseph Willcox." These are mostly pyriform types.

Unknown

Pentremites welleri Ulrich 1917. 3 specimens, two in one box unlabelled; one in another box with "*Actinocrinus turbinatus*, L. Burlington ls., Burlington, Iowa," and probably did not come from this horizon or locality.

Natural Gas in Oklahoma, 1959

Marketed production of natural gas in the United States totaled 12,046 billion cubic feet in 1959, 9 percent more than in 1958, according to the Bureau of Mines (*Mineral Market Report MMS No. 3132*, October 10, 1960).

The average wellhead value of natural gas was 12.9 cents per thousand cubic feet in 1959, 1.0 cent higher than in 1958. The average value at point of consumption increased from 46.2 cents in 1958 to 47.7 cents in 1959.

In Oklahoma in 1959, gross withdrawals amounted to 601 billion cubic feet from gas wells and 495 billion cubic feet from oil wells for a total of 1,096 billion cubic feet. Marketed production was 811,508 million cubic feet. Gas used for repressuring amounted to 102,022 million cubic feet, and 182,470 million cubic feet was vented and wasted.

In 1959, there were 540,000 residential consumers in Oklahoma who consumed 59,763 million cubic feet of gas with an average value of 66.8 cents per thousand. Commercial consumers numbered 58,000, used 27,602 million cubic feet at an average value of 43.3 cents per thousand. Gas used for drilling, pumping, and other field use amounted to 152,356 million cubic feet with an average value of 13.3 cents per thousand. That used as industrial fuel (including refineries) totaled 139,457 million cubic feet at an average value of 17.5 cents per thousand.

—L. J.

Notes on Two Chester Crinoids

Harrell L. Strimple

The University of Oklahoma recently acquired two crinoid specimens of considerable interest, collected by Mr. Allen Graffham in the Cookson Hills southeast of Ft. Gibson, Oklahoma. One specimen is the second specimen of *Mantikosocrinus castus* noted by Strimple (1951, p. 694) under the description of this genotype species. The other is a dorsal cup of *Bronaughocrinus figuratus* Strimple (1951) which permits observation of the features of the arm-articulating facets of the radials. The specimens are metatypes and are numbered 3910 and 3909, respectively, in the Paleontological Collections of The University of Oklahoma.

Mantikosocrinus castus Strimple
Figure 1

There are only two specimens of the species, and therefore of the monotypical genus, known at this time. Both were found in a yellow clay zone just below the massive limestone ledge that marks the base of the Pitkin limestone formation on Braggs Mountain. This bed is therefore uppermost Fayetteville formation, Chester series.

Measurements of the metatype in millimeters are as follows:

Height of calyx	5.3
Width of calyx (maximum)	13.2
Width of proximal columnal	2.2
Length of arms as preserved	16.0

It seems possible that *Mantikosocrinus* may have evolved from a form like the slightly older *Dicromyocrinus ? bowsheri* (Strimple, 1949) through regressive evolution. The later species has a calyx that is comparable in shape except for the sharply invaginated base, and both forms have ten uniserial arms, primitive arrangement of the three anal plates, and a small, round columnal. Normal or progressive evolution is from a high, turbinate calyx, with upflared infrabasals, to subhorizontal infrabasals, to a low bowl-shaped calyx with downflared infrabasals restricted to a basal concavity. However, there is an increasing amount of evidence disclosing a strong trend toward regressive evolution in several Late Paleozoic phylogenetic lines.

From present knowledge, it appears likely that *Mantikosocrinus*, or a comparable form, is ancestral to such forms as *Bronaughocrinus* Strimple (1951), *Cromyocrinus* Trautschold (1867), *Dicromyocrinus* Jaekel (1918) and *Ulocrinus* Miller and Gurley (1890). Normal evolution in arm structure is from uniserial to cuneiform to biserial. The arms of *Mantikosocrinus* are uniserial and are ten in number, bifurcation taking place with the first primibrach in all rays. *Dicromyocrinus* retains three anal plates in the posterior interradius, has a broadly depressed basal area and ten arms that are almost cuneiform. *Cromyocrinus* has a rounded, almost convex base and has progressively eliminated the RX plate from the posterior interradius but has reduced the number of arms to five which are uniserial in structure. *Bronaughocrinus* has a basal concavity, the three anal plates are retained in the posterior interradius but the radianal is greatly expanded in size toward elimination of RX from the cup, and there are ten biserial arms. *Ulocrinus* has decidedly upflared infrabasals, two anal plates, and ten biserial* arms.

It was not brought out in the original description of *Mantikosocrinus castus* that, although the primibrachs occupy the full width of the radials, there is a slight gaping along the sutures.

BRONAUGHOCRINUS FIGURATUS Strimple
Figures 2, 3

In 1951, I proposed the genus *Bronaughocrinus* with *B. figuratus* Strimple (1951) as the genotype species. At the time there was no dorsal cup, devoid of arms, available for study of the arm-articulating facets of the radials, although several crowns had been found. On a recent field trip to the type locality a young dorsal cup was found by Mr. Allen Graffham. The specimen has been purchased by The University of Oklahoma and has been designated a metatype, Paleontological Collections number 3909.

The dorsal cup has a maximum width of 13.7 mm, height of 5.5 mm. The normal radial plates are 11.8 mm wide and 4.1 mm long. Outer ligament area is subhorizontal and has a long, narrow ligament pit backed by a sharp transverse ridge. The transverse ridge is interrupted in midsection by the central pit. Inner ligament area slopes slighty inward, lateral furrows are well defined, intermuscular notch and furrow are weakly defined. Adsutural slopes and lateral ridges are well defined but do not reach the exterior of the cup, being cut off by the transverse ridge.

The presence of a strongly invaginated basal area, with downflared infrabasals, enlarged radianal, and ten, short, wide, biserial arms, serves to distinguish the genus readily from other forms. *Mantikosocrinus,* from the older Fayetteville formation, appears to be the most logical ancestral form. By lowering the cup height, enlarging the radianal, changing the base of the cup from mildly convex to concave, and changing the arms from uniserial to biserial, all of which are normal or progressive evolutionary changes, the form *Bronaughocrinus* could be produced out of *Mantikosocrinus.*

I formerly (1951) considered the Pennsylvanian species *Parulocrinus marquisi* Moore and Plummer (1940) and *Ethelocrinus oklahomensis* Moore and Plummer (1937) to belong under the genus *Bronaughocrinus,* based on the shape of the calyces and on the common existence of ten biserial arms. At the present time I am not so certain of this possible affinity, although Iam certain the Pennsylvanian species are intimately related and that neither belongs to the genus to which it was originally assigned. They both have heavy, long arms with well-rounded exteriors, whereas the arms of *Bronaughocrinus* are short and thin and have flattened exteriors.

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*Wright and Strimple (1945) reported ten uniserial arms for *Ulocrinus buttsi,* which was true of the specimen involved as far as the arms were preserved, but it is now known from undescribed material that the arms are fundamentally biserial.

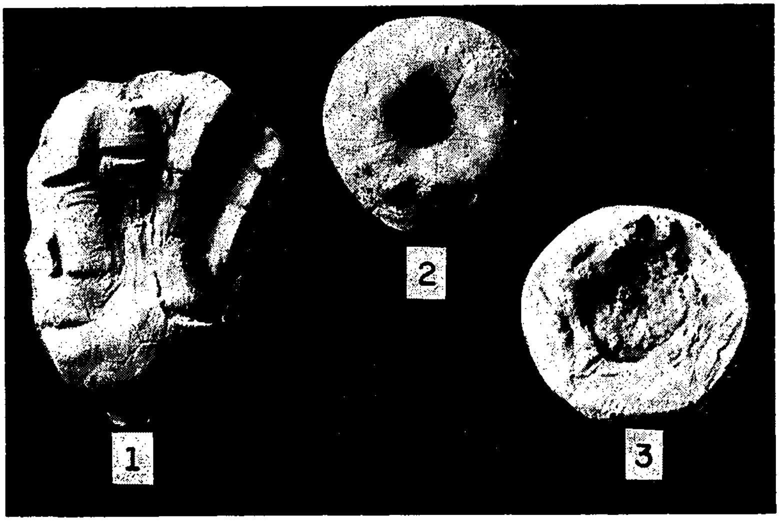

FIGURE 1. Unretouched photograph of metatype of *Mantikosocrinus castus* Strimple, posterior view.

FIGURE 2. Unretouched photograph of metatype dorsal cup of *Bronaughocrinus figuratus* Strimple, viewed from base.

FIGURE 3. Same as figure 2, view from above.

The presently considered specimen is a relatively young individual and has not attained the unusual width of calyx that is characteristic of the species. It has a remarkably similar appearance to normal representatives of the Pennsylvanian genus *Delocrinus* Miller and Gurley (1890). The arms of both forms are almost identical in structure. There is good reason to think that some relationship exists between these forms, although exact affinities are obscure at this time.

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_________ 1951, New Carboniferous crinoids: Jour. Paleontology, vol. 25, p. 673-674, pl. 98.

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The Upper Room of Alabaster Cavern, Woodward County, Oklahoma

Arthur J. Myers

Alabaster Caverns State Park in Woodward County, Oklahoma, contains at least four caves. The caves have formed in the essentially horizontal Blaine formation which consists of the following units (in ascending order): Medicine Lodge gypsum, 30 feet thick; unnamed shale, 13 feet thick; Nescatunga gypsum, 13 feet thick; unnamed shale, 7 feet thick; Shimer gypsum, 13 feet thick; unnamed shale, 4 feet thick; and Haskew gypsum, 4 feet thick.

Alabaster Cavern, which is open to the public, has formed principally in the Medicine Lodge gypsum. Part of the rotunda and some of the domes have their roofs at the base of the Nescatunga gypsum (Myers, 1960b). Owl Cave and Water Cave are also in the Medicine Lodge gypsum.

The Upper Room, however, has formed in the Nescatunga gypsum and in the underlying shale (figs. 1, 2). The cave is entered through an opening approximately 2 feet by 1½ feet at the top of the Nescatunga gypsum. Figure 3 is a map of the cave. No large opening was found which connects the Upper Room to Alabaster Cavern, but it is probable that there are small tubular connections.

The entrance room is approximately 75 feet long, ranges in width from 10 to 20 feet, and has a maximum height of 15 feet. The roof is in the Nescatunga gypsum and the floor is shale which is covered by gypsum boulders which have fallen from the roof. The Medicine Lodge gypsum is exposed at the lowest point of the cave and in the floor there is a vertical tubular opening about six inches in diameter and 10 to 15 feet deep. The sound of running water could be heard in the opening and it is believed to be made by water in one of the drainage channels which cross Alabaster Cavern in two places (fig. 1). These drainage channels are only a few inches high and are not mappable. The opening was at one time a drainage channel for the entrance room.

At the far end of the entrance room are two branches. One, the north passage, trends in a northerly direction, is entirely within the Nescatunga gypsum and is 50 feet long. It has an oval cross section which is 7 feet wide and 4 feet high. The floor slopes gently to the south and drains into the entrance room. In the ceiling at the terminus of the north passage is a vertical shaft which is 4 feet in diameter and approximately 15 feet high; the roof is probably at the base of the Shimer gypsum. In the same area collapse of a side wall has made an opening about a foot in diameter which leads to the entrance room.

The south passage is larger; it averages 12 feet wide, ranges in height from 3 to 12 feet, and is about 185 feet long. The floor is in the shale between the Medicine Lodge gypsum and the Nescatunga gypsum and the roof is in the Nescatunga gypsum except for the southernmost 60 feet where it is at the base of the Nescatunga gypsum. In the northern part the floor is partly covered with gypsum boulders which have fallen from the roof, but the southern part of the floor is entirely shale except

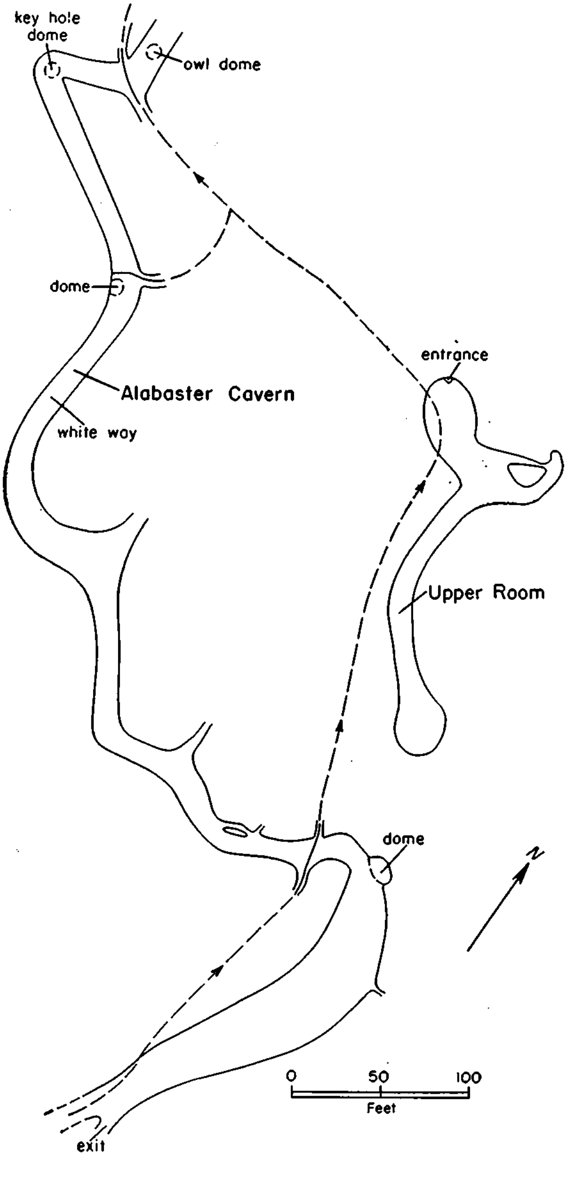

FIGURE 1. Map of southern end of Alabaster Cavern showing areal relationship of the Upper Room to the cavern. Dashed line indicates postulated course of the drainage which crosses Alabaster Cavern at two places. It is possible that the sink hole in the entrance room of the Upper Room connects with this drainage.

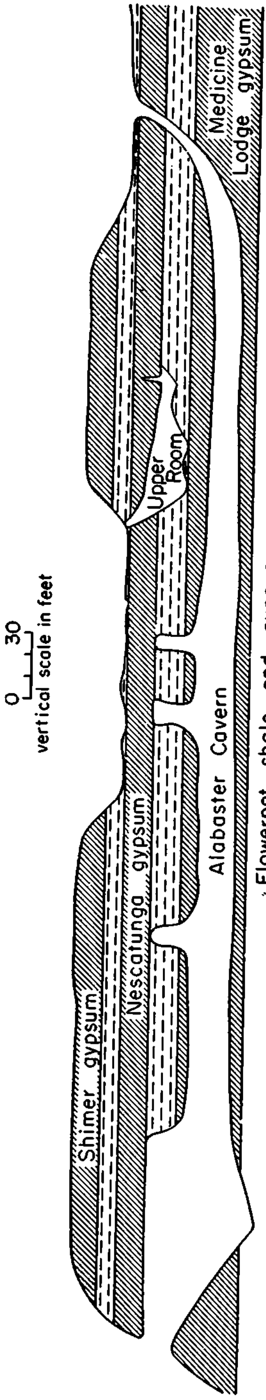

FIGURE 2. Schematic profile showing vertical and stratigraphic relationships between Alabaster Cavern and the Upper Room. Length of cross section is approximately 2,000 feet.

for one boulder in the terminus room. The terminus room is circular, about 30 feet in diameter, has a funnel-shaped floor, and a maximum height of 6.5 feet. About midway in the south passage is another vertical shaft in the ceiling. Its roof is probably at the base of the Shimer gypsum. A solution sink, about 40 feet from the entrance room, exposes Medicine

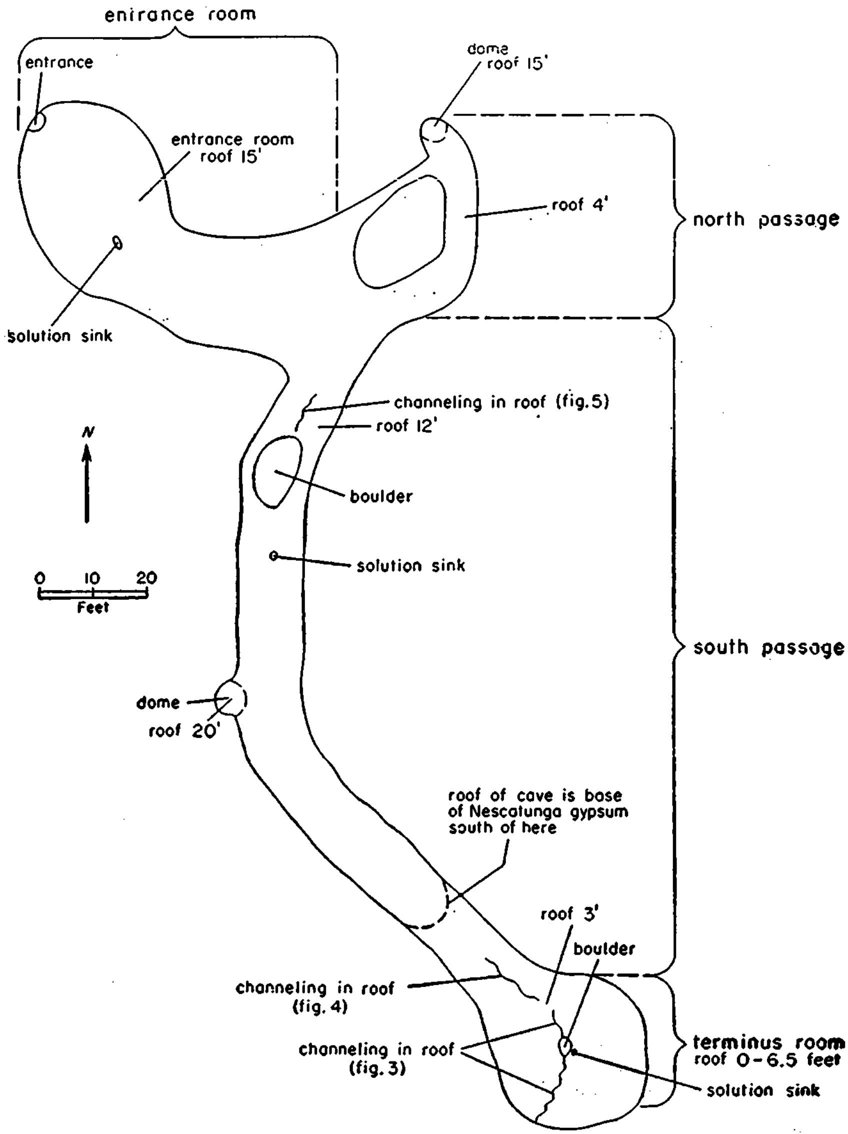

FIGURE 3. Map of the Upper Room of Alabaster Cavern, Woodward County, Oklahoma.

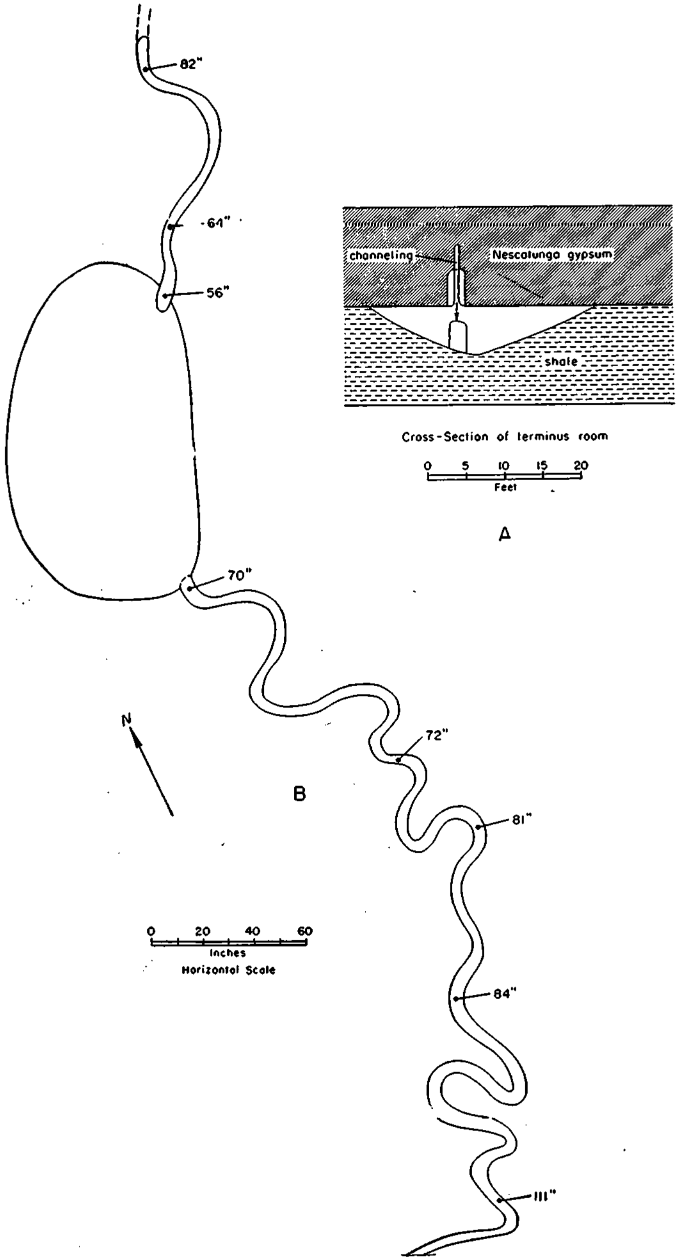

FIGURE 4. A—Cross section of terminus room of the Upper Room.
B—Map of channeling in the roof of the terminus room.
Height of channeling is indicated in inches.

Lodge gypsum, and was once the drainage outlet for the south passage, except for the extreme northern end which drained into the entrance room and the terminus room which is drained by a solution sink in the center of the room.

The small tubular north passage was formed by water flowing through the gypsum, but the larger entrance room and south passageway were formed because water cut through the gypsum and flowed on the shale. As it meandered across the shale it undercut the gypsum, which later collapsed. The funnel-shaped terminus room shows the removal of shale without collapse of the roof.

The floor of the cave is covered to a depth of 1 to 2 inches with powdered gypsum. The presence of the powder indicates that enough water seeps through to weather the massive gypsum but that practically no water flows through the cave at the present time.

The most interesting feature of the cave is the channeling in the roof of the south passage. The channeling has the appearance of an inverted entrenched meander. The channeling was done by vadose water as it percolated through the gypsum. A meandering course developed and further flowage resulted in a downward cutting maintaining the same pattern. Three relatively extensive channels were mapped (figs. 4-6). In some places they could not be traced because the water has not cut completely through the gypsum. It is the writer's opinion that these channels may be rather extensive in this area but are not exposed.

Figure 4 shows the meander channel which formed in the gypsum in the terminus room. There are two sections and, at the place where they meet, they caused the dislodgment of a boulder which is 133 inches long, 72 inches wide, and 56 inches high. As a result, near the center of the room, there is a flat-topped dome, the roof of which is along a bedding plane. The south channel is the longer and is even longer than mapped but it is not entirely accessible. Measurements made from the base of the gypsum to the top of the channel showed a maximum height of 111 inches and a minimum height of 72 inches, and indicated that it flowed to the north. The shorter north channel flowed southward.

Figure 5 is a sketch of another channel near the south end of the south passage. Measurements to the top of the channeling indicated a northward direction of flow. It appears that this channel and the south-flowing channel in the terminus room were connected and that water flowed in both directions.

Near the north end of the south passage two cycles of erosion are

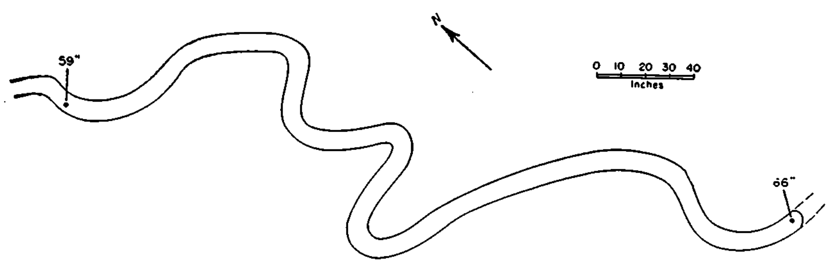

FIGURE 5. Map of channeling in roof near south end of the south passage.

evident (fig. 6). The early channel, which is higher in the roof, is a meandering channel. The width of the channel ranges from 10 inches on straight sections to 18 inches on the curves and it is approximately 32 inches deep. The latter channel is straight, about 4 feet wide, and 12 inches deep. Where the straight channel is superposed on the older, it has partially destroyed it by eroding the outer sides of the meanders.

Ground water in its descent through the gypsum of the Blaine formation moved horizontally in small braided channels along bedding planes. In places the water moved at the same level for tens of feet as can be seen on a bedding-plane surface of a larger boulder near the end of the collapse section of Alabaster Cavern. The boulder in the terminus room was dislodged by water moving along a bedding plane and then cutting partly around it. Elsewhere the water descended to different bedding planes in its horizontal movement as is evidenced by the measured distance to the top of the channeling in the circular terminus room of the Upper Room. Originally there may have been an intricate network of minor water routes, but as erosion continued one became **dominant over**

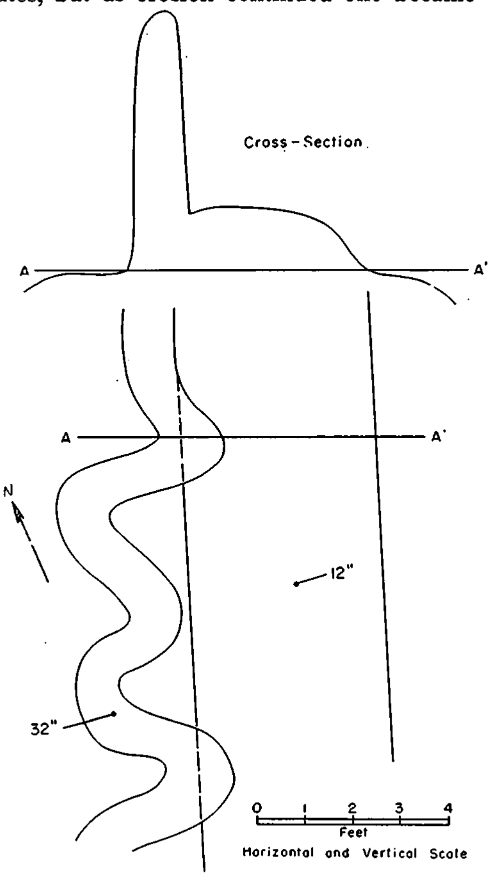

FIGURE 6. Map and cross section of channeling in roof near north end of the south passage.

the others and downcutting continued along this course. Once the shale layers were reached the water flowed across the surface until a downward passage was encountered. The vertical shafts are enlargements of such channels.

Alabaster Cavern is in an area of karst topography (Myers, 1960a). Sink holes are common and they divert much of the surface runoff to underground routes. In the park an area of approximately one square mile is drained by two streams which flow into sinks, which connect with Alabaster Cavern. Before the building of dams on these streams the cave would be completely filled with water after heavy rains (A. B. Eddings, personal communication).

The intricate channeling in the Upper Room has been preserved because ground water has been diverted away from the cave. At the surface above it is the Shimer gypsum, but around it the Nescatunga gypsum is exposed. However, ground water had at least started to alter and destroy the original meandering course. In the entrance room the original meandering has been destroyed by a partial collapse of the roof and in the south passage it has been partly destroyed.

Alabaster Cavern, which has formed in the lower part of the Medicine Lodge gypsum, must have originally consisted of small meandering channels flowing in various directions. The channeling in the south passage of the Upper Room indicates at least two directions of flow and there are three places of drainage to lower levels. A similar early stage of development must have prevailed in Alabaster Cavern as well, but water directed to the subsurface connected the small channels and destroyed their original shape. Some small openings, about a foot in diameter and having a gentle meandering course, are preserved, and one channel in the ceiling can be traced for a few hundred feet. As the number of sink holes increased and larger areas were drained into them, the diverted water enlarged the cave. The water that flowed through Alabaster Cavern after heavy rains carried large amounts of sand and silt which were effective eroding agents. There are places where the deposited material is 3 to 4 feet thick, and, wherever a tributary tunnel joins the main cavern, an alluvial deposit is present. The silt-laden water which completely filled the cave would erode the top as well as the sides and bottom. Collapse of the roof and continued erosion has resulted in the present size and shape of Alabaster Cavern.

Early Pleistocene deposits were extensive and are present on the divide between the Cimarron River and the North Canadian River. Deposits 50 feet thick are present 10 miles south of the park and rubble in the park indicates that Pleistocene deposits once covered the area. In northwestern Harper County the Cimarron River and its tributaries have dissected the Meade group (early Pleistocene). This indicates that the Cimarron River is post-Meade in its present channel. The erosion of the gypsum could not have begun until the Cimarron had eroded its channel through the Blaine formation; therefore the caves in Alabaster Caverns State Park did not begin to form until middle Pleistocene.

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