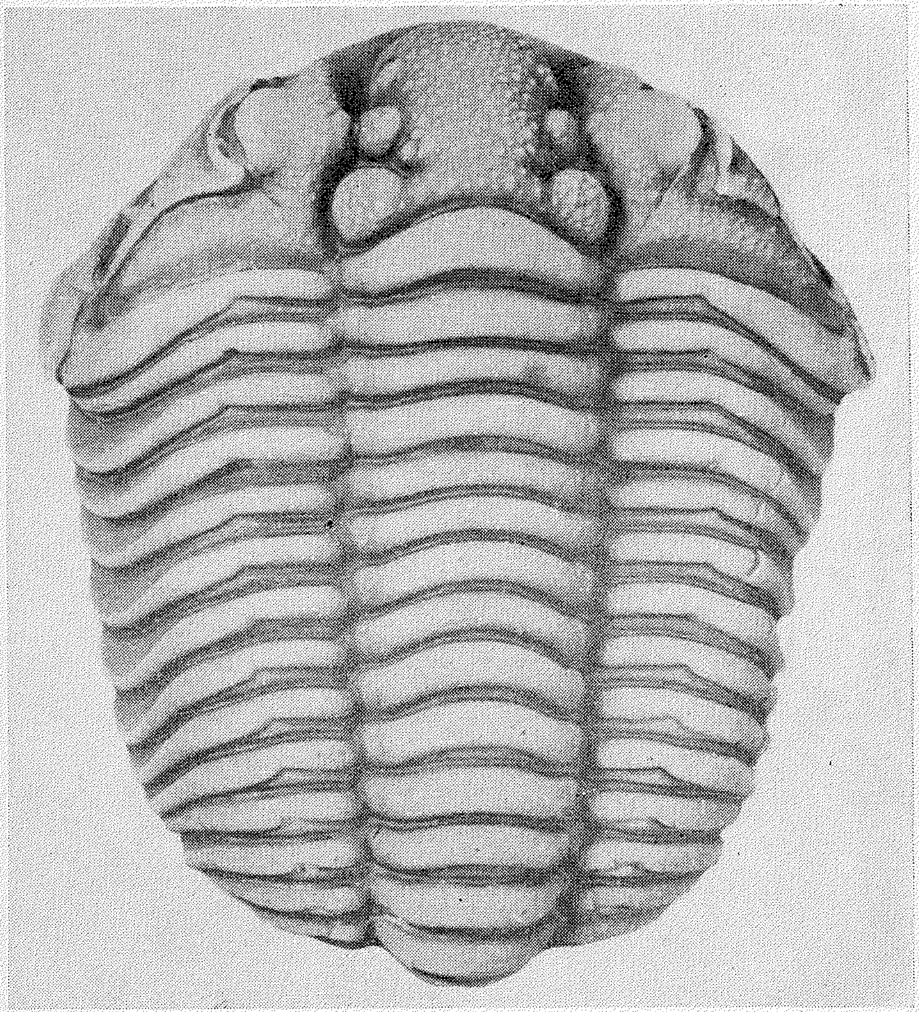
OKLAHOMA GEOLOGY NOTES



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A Remarkable Specimen of the Trilobite *Isotelus* From the Viola Limestone

Thomas W. Amsden and W. E. Ham

Mr. Virgil Smith, who is Assistant General Superintendent of the Dolese Bros. Co., has recently given the Oklahoma Geological Survey an unusually large and well preserved specimen of *Isotelus*. This specimen came from the lower part of the Viola limestone in the Dolese Bros. Quarry, center of sec. 31, T. 1 S., R. 8 E., Coal County, Oklahoma. The Viola limestone is of Middle Ordovician age and is correlated with the Trenton limestone of New York.

Complete, articulated skeletons of *Isotelus* are uncommon, and specimens of the size donated by Mr. Smith are a rarity. This individual, which is illustrated in figure 1 at a somewhat reduced scale, measures 8 inches long with the anterior portion of the cephalon missing, so when complete it must have been nearly 9 inches in length. It is 5 inches wide at the posterior end of the cephalon. A considerable portion of the original skeleton is preserved, but unfortunately both eye lobes are broken.

This is the only complete Viola specimen which we have seen and it is therefore somewhat difficult to make a comparison with previously described species of *Isotelus*. Quite possibly smaller individuals from the Viola would show different proportions. Our specimen is in many respects similar to *I. gigas* Dekay from the Trenton limestone of New York (Hall 1847, pls. 61 to 63); however, adult representatives of the New York species lack genal spines (Raymond 1914, p. 253, figs. 2-6; see also Bradley 1930, p. 248) whereas the Viola specimen, which is certainly full grown, has spines. *I. iowensis* Owen (Raymond 1914, p. 255, pls. 2, 3) has genal spines in the adult stage, but appears to have a narrower pygidium than does the Oklahoma specimen. Apparently *I. maximus* Locke has a more rounded pygidium. A more representative Viola collection is needed before a more precise identification can be made.

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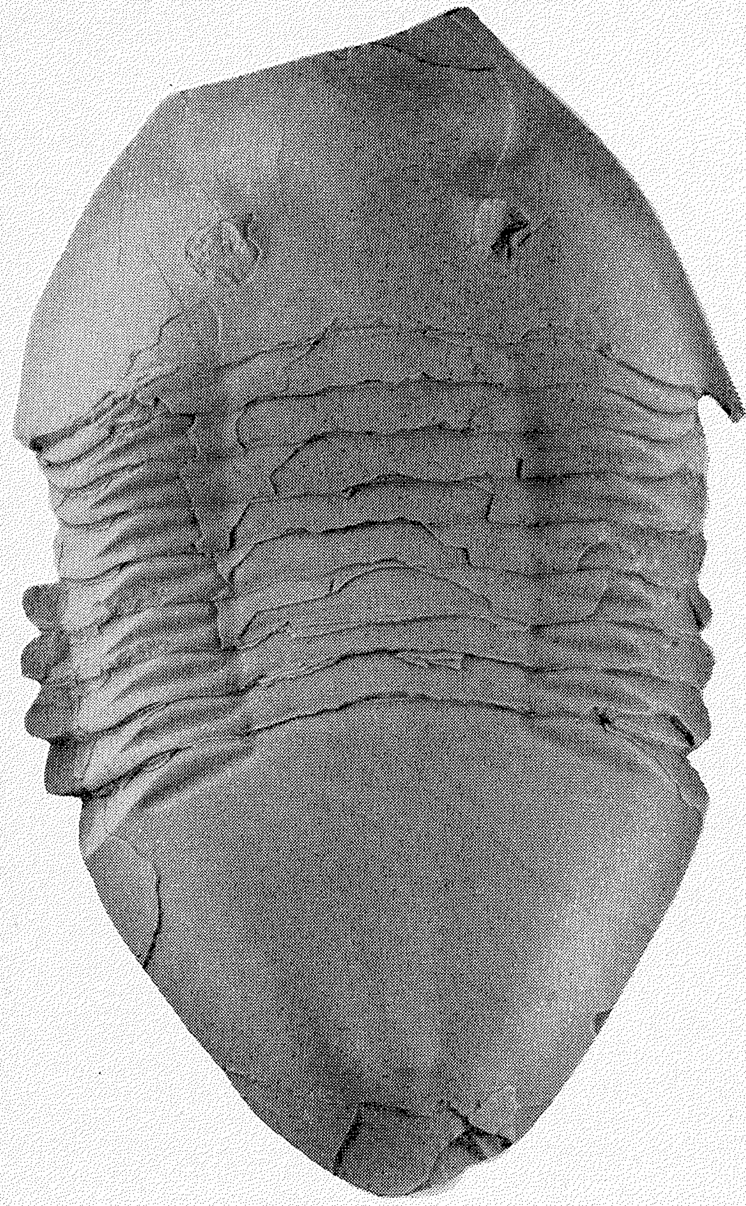

Figure 1. *Isotelus* sp. from the lower part of the Viola limestone, Dolese Bros. Bromide Quarry, center sec. 31, T. 1 S., R. 8 E., Coal Co., Oklahoma. About ¾th natural size; the specimen measures 8 inches long. O. U. catalog number 3119.

CAVES IN THE ARBUCKLE MOUNTAINS AREA, OKLAHOMA

NEVILLE M. CURTIS, JR.

In recent months several inquiries have been made of the Oklahoma Geological Survey regarding caves in Oklahoma. In attempting to answer these inquiries it became apparent that published literature on caves in Oklahoma is rare indeed. The major source of information is newspaper accounts of caves and the people who explore them. "Speelunkers" (people who explore caves) throughout the state have their personal records of caves they have explored but these are not readily available to the public.

The following is taken from a letter written in 1933 to a citizen of Lawton, Oklahoma:

> "The Partial Index to Caves of the World, printed in the last Bulletin (Bulletin of the National Speleological Society), seems to indicate you have only one record of caves in Oklahoma."

The writer of the above continued in the letter to state that he knew of at least twelve caves in Oklahoma. Since 1933 many interested people have located and explored caves in Oklahoma. Jim Schermerhorn of Tulsa,

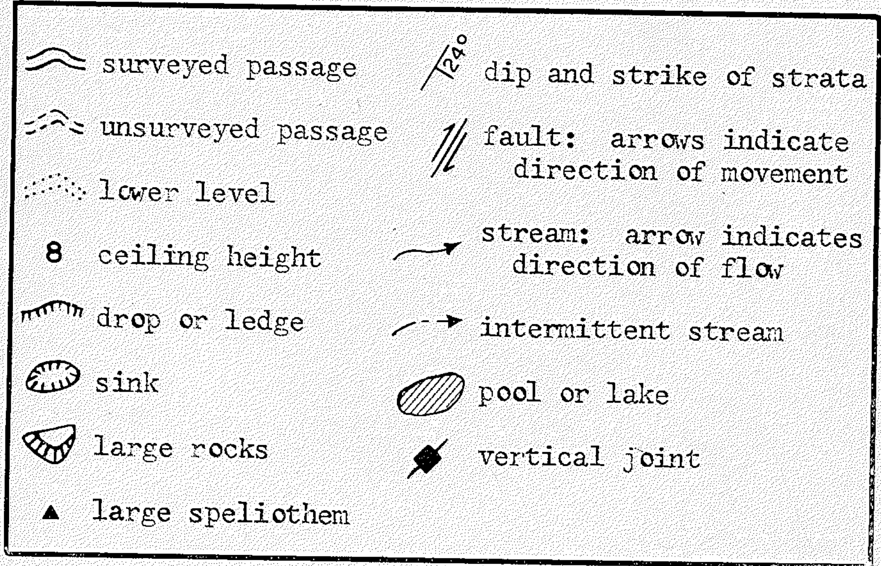

FIGURE 1. Symbols used on maps.

Oklahoma, in a personal letter (1958) to Jack Burch of Springer, Oklahoma, refers to a possible file of over 200 caves in Oklahoma. Perhaps this file still exists, perhaps it never existed, in any event it is not available to the public at this time.

The Oklahoma Geological Survey is attempting to build a file relative to caves in Oklahoma. This file would be of value to the geologist, biologist, archeologist, historian, and "speelunker."

When exploring caves it is important to OBTAIN PERMISSION OF THE PROPERTY OWNER BEFORE GOING INTO THE CAVE. Another important fact to remember is that IT IS NOT WISE FOR A PERSON TO EXPLORE A CAVE ALONE.

The Oklahoma Geological Survey wishes to express appreciation for the cooperation of Jack Burch and Jim Papadakis. They supplied the Survey with maps, photographs, and cave data used in this report.

The following descriptive material is not to be considered comprehensive but rather a résumé of the better known caves in the Arbuckle Mountain region. The origin of the caves and detailed geology involved is beyond the scope of this report.

BIG CRYSTAL CAVE

Location: SE¼ NE¼ SW¼ NW¼ sec. 11, T. 2 S., R. 1 E., Murray County.

Geology: cave has developed in the Kindblade formation, which is in the Arbuckle group, Lower Ordovician.

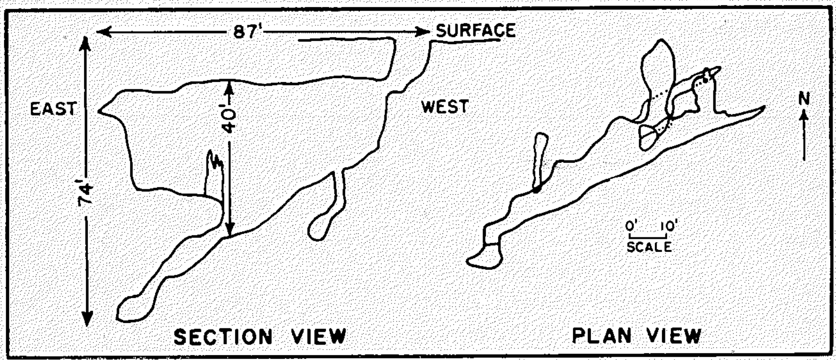

FIGURE 2. Big Crystal Cave, surveyed by Jack Burch and Jim Papadakis.

BIRDS EYE CAVE

Location: SE¼ NW¼ sec. 12, T. 1 S., R. 1 W., Murray County. In order to locate this cave it is necessary first to locate Womac Cave. After locating Womac Cave proceed on an azimuth of 338° for 294 feet. Cave entrance is near large cedar tree on top of hill.

Description: 20 foot drop from entrance to floor of cave. One of the interesting cave formations is a tree root covered with calcium carbonate. No pools were encountered and therefore the cave is considered "dry." There is no apparent flow of air through the cave.

Geology: cave has developed in the Kindblade limestone beds which dip gently to the west. The Kindblade formation is in the Arbuckle group, which is Lower Ordovician.

Remarks: no special equipment is needed in order to explore this cave. It was mapped by L. C. Perryman and Jack Burch, January 18, 1958 and is on property owned by P. A. Cornell of Springer, Oklahoma.

Folklore: cave was used by the Spaniards as a jail for prisoners.

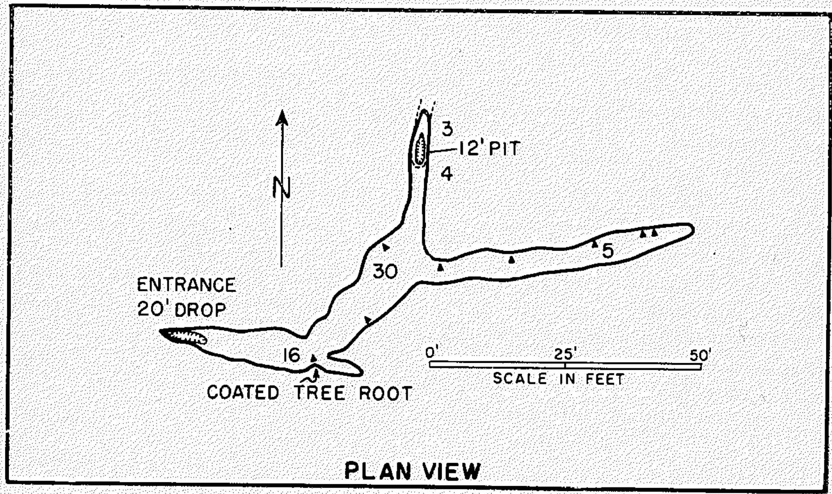

FIGURE 3. Birds Eye Cave, surveyed January 18, 1958 by L. C. Perryman and Jack Burch.

BITTER ENDERS CAVE

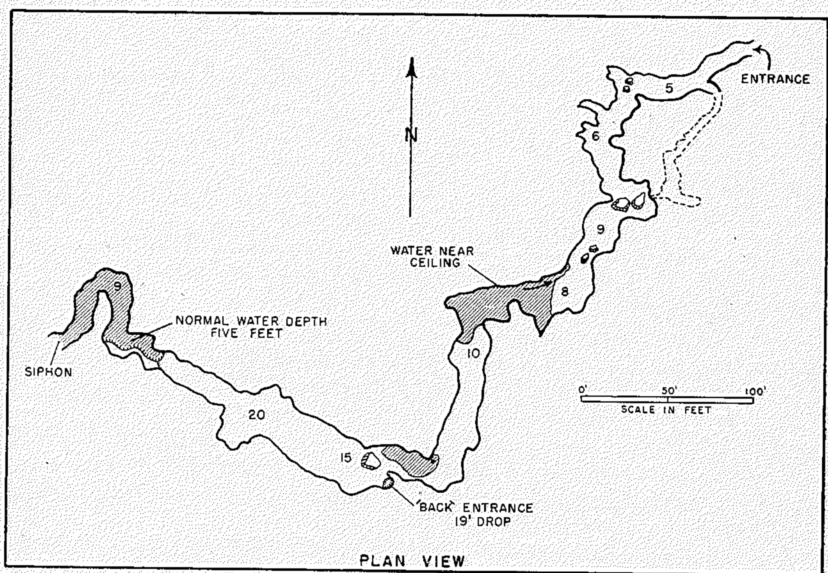

FIGURE 4. Bitter Enders Cave, surveyed by Jack Burch.

Location: main entrance in SE¼ NW¼ NW¼ SW¼ sec. 2, T. 2 S., R. 1 E., Murray County.

Geology: cave is located in the Cool Creek formation, which is in the Arbuckle group in the Lower Ordovician.

Remarks: mapped by Jack Burch, Springer, Oklahoma.

CORKSCREW CAVE

Location: NE¼ NW¼ SW¼ SE¼ sec. 36, T. 1 S., R. 1 E., Murray County.

Geology: cave developed in the McKenzie Hill formation, Arbuckle group, Lower Ordovician.

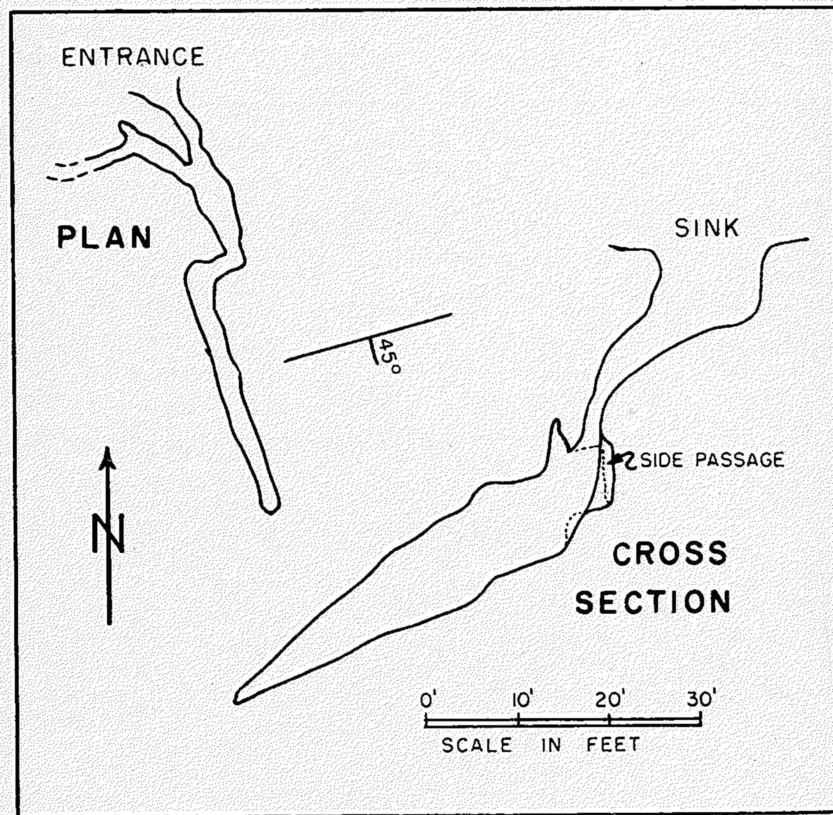

FIGURE 5. Corkscrew Cave, surveyed February 2, 1958 by Jack Burch, Jim Papadakis, and Calvin Perryman.

Remarks: Corkscrew Cave was mapped by Jack Burch, Jim Papadakis, and Calvin Perryman February 2, 1958.

LITTLE CRYSTAL CAVE (ARROW CAVE)

Location: NE¼ SW¼ SE¼ SE¼ sec. 36, T. 1 S., R. 1 E., Murray County. Start from Turner Falls. Follow trail (azimuth 150°) from Turner Falls area along dry stream branch for approximately 2,500 feet to 5-wire fence. Cave entrance is located about 100 feet east of stream and 30 feet north of wire fence.

Description: cave contains a few flowstone formations formed on the cave wall. Floor of cave covered with mud and no air flow was detected. Cave crickets and three bats were noted.

Geology: Little Crystal Cave developed in the McKenzie Hill formation, which is in the Arbuckle group.

Remarks: no special equipment is needed. Little Crystal Cave was mapped by Jack Burch, Jim Papadakis, and Calvin Perryman February 2, 1958. The cave is on property owned by the City of Davis, Oklahoma.

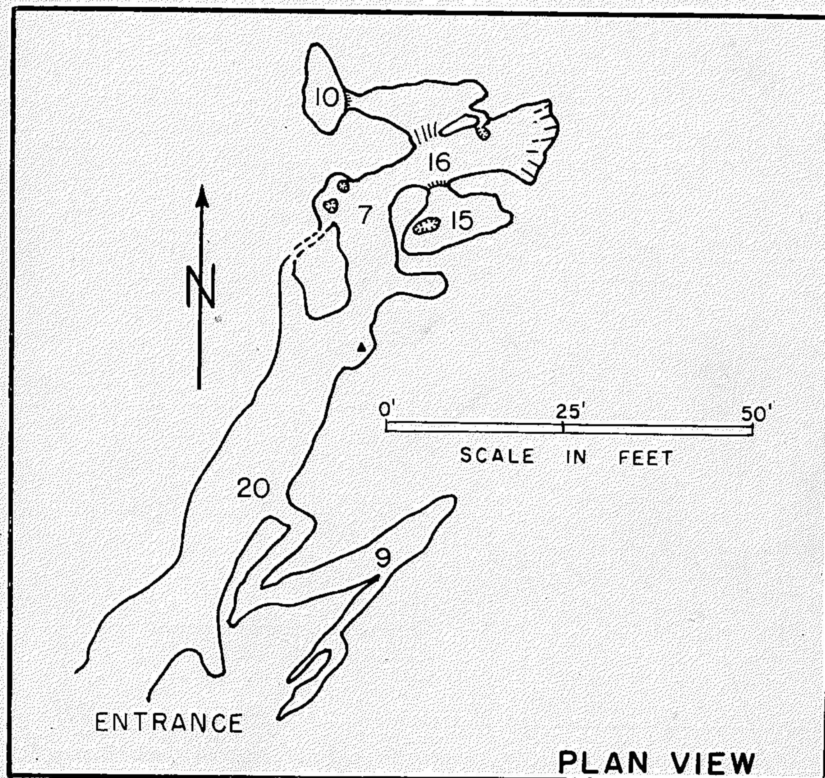

Figure 6. Little Crystal Cave, surveyed by Jack Burch, Jim Papadakis, and Calvin Perryman February 2, 1958.

MYSTIC CAVE

Location: (probable location) SW¼ SE¼ sec. 19, T. 2 S., R. 4 E., Murray County.

Description: entrance to cave is made through a sink-hole. From the bottom of the sink there is a narrow passage leading to a room 60 feet wide whose ceiling is 50 feet above the floor. In one corner of the room is a 15 foot drop to a clear stream. This stream can quickly collect groundwater from surrounding saturated fields and gullies and become a roaring torrent of muddy water. There are many mud-colored stalactites and stalagmites which in the future will connect to form columns.

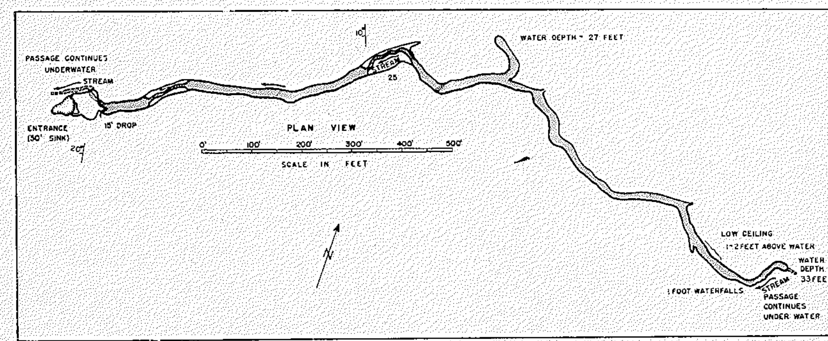

Figure 7. Mystic Cave, modified from map by Jack Burch and Jim Papadakis.

Geology: Mystic Cave was formed in the West Spring Creek formation of the Arbuckle group in the Lower Ordovician.

Remarks: Mystic Cave was mapped by Jack Burch and Jim Papadakis.

STRIBBLING CAVE

Location: NE¼ SE¼ sec. 36, T. 2 S., R. 2 E., Carter County. Travel south from Springer, Oklahoma, for 0.6 mile on U.S. 77 to intersection with Oklahoma state highway 53—turn left (East) and proceed 5.8 miles east on state highway 53 to railroad track, continue east on state highway 53 for 0.4 mile to Ardmore Air Base entrance then turn left (North) on gravel road, go north on this road for 1.2 miles (road curves here). Proceed due north to creek (no bridge), this is a distance of 0.5 mile, the main gravel road turns right. Cross creek and go 0.2 mile to old house on right side of road. Park car near gate. Follow railroad track north approximately 0.5 mile to railroad bridge across Washita River. Climb steep hill on west side of railroad track at south end of railroad bridge. Cave is located approximately 175 feet from northeast end of bridge and 45 feet northwest of ridge top.

Description: deepest known solution shaft in Oklahoma. The cave is the "dry" type, has fresh air at bottom but no apparent air flow. When this cave was explored, one cave formation two feet in length, three bats, and several cave crickets were noted.

Geology: cave has developed in the Viola limestone, which dips 67° southeast and strikes N 30° E.

Remarks: at least 130 feet of rope and 90 feet of cable ladder is needed in order to explore cave. Stribbling Cave was mapped by Jack Burch and Jim Papadakis March 1, 1958. The cave property is owned by Jimmie Stribbling, Tishomingo, Oklahoma.

Folklore: cave was excavated for hidden treasure in 1954 as evidenced by the following equipment found in the cave: 2 buckets, 1 crowbar, 1 kerosene lantern, 1 trace chain, and wooden troughs extending from entrance to bottom of cave.

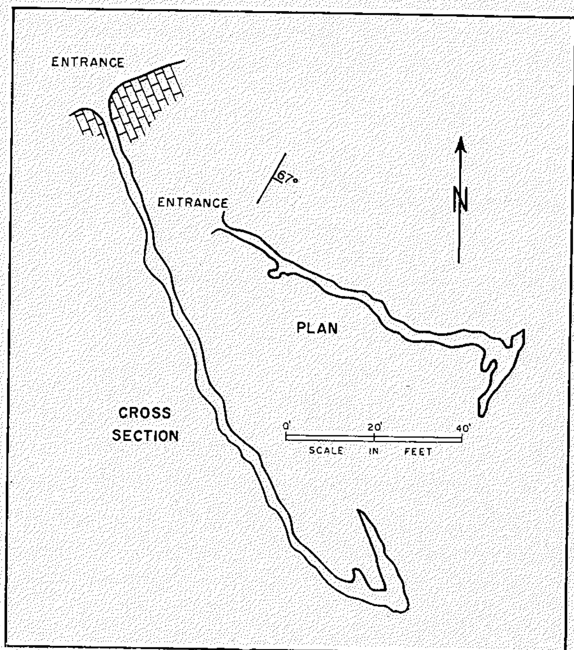

FIGURE 8. Stribbling Cave, surveyed by Jack Burch and Jim Papadakis, March 1, 1958.

WAGON WHEEL CAVE

Location: SE¼ SW¼ NE¼ SE¼ sec. 36, T. 1 S., R. 1 E., Murray County.

Geology: cave is located in the Cool Creek formation, which is in the Arbuckle group, Lower Ordovician.

Remarks: mapped February 2, 1958 by Jack Burch, Jim Papadakis, and Calvin Perryman.

WHITE WOMAN CAVE

Location: NW¼ SW¼ SW¼ NW¼ sec. 14, T. 1 S., R. 1 W., Murray County. Cave entrance is 2,095 feet south of northwest corner of section 14 and 171 feet east in T. 1 S., R. 1 W.

Description: several white speliothems. White Woman is the most outstanding speliothem and the cave is named for it. One white cave rat, typical cave crickets and centipedes were encountered in the cave. This cave is considered to be the "dry" type.

Geology: cave has developed in the Royer dolomite, which belongs to the Arbuckle group and is Cambrian in age.

Remarks: 20 foot rope is needed for entrance to cave. White Woman Cave is on land owned by Lulla Washburn, Hennepin, Oklahoma. The cave was mapped by Jack Burch, Jim Papadakis, and Calvin Perryman on February 1, 1958.

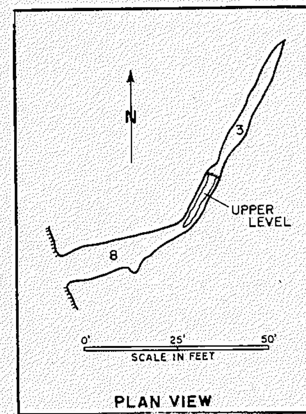

FIGURE 9. Wagon Wheel Cave, surveyed by Jack Burch, Jim Papadakis, and Calvin Peryman, February 2, 1958.

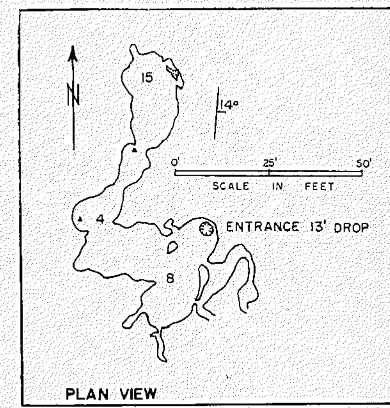

FIGURE 10. White Woman Cave, surveyed by Jack Burch, Jim Papadakis, and Calvin Perryman, February 1, 1958.

WILD WOMAN CAVE

Location: NW¼ SW¼ NW¼ SW¼ sec. 3, T. 2 S., R. 1 E., Murray County (lat. 34°24'48" N.; long. 97°11'53" E.), elevation at entrance is 1200 feet above mean sea level. The above location is given for the original entrance. Jack Burch has opened a new entrance in a sink-hole 1,464 feet (azimuth: 74°) from the original entrance. This new entrance makes descent into the cave much easier with no special equipment required. Also, it makes it possible to enter the cave without getting wet and avoids the long, low crawl in the water passage. Just north of Springer, Oklahoma, is the junction of State Highway 53 with U.S. Highway 77. From this intersection proceed north on Highway 77, 1.9 miles, to gravel road. Turn left on this road which leads to the cave. The azimuth of the gravel road at the intersection is 290° (magnetic).

Description: the following is a description, written by Jack Burch and Jim Papadakis, of one trip into the cave:

"On August 12, 1956 we entered Wild Woman Cave determined to go as far as possible in the low water passage that extended off in a northeasterly direction.

Prior to this date the known portion of Wild Woman Cave was very small. It consisted of a sink-hole entrance with a vertical drop of 44 feet to a chamber about 60 feet long with a maximum width of about 15 feet. A crevice in the floor of this chamber leads to another level 6 feet below, which is the water passage. The ceiling of this level is

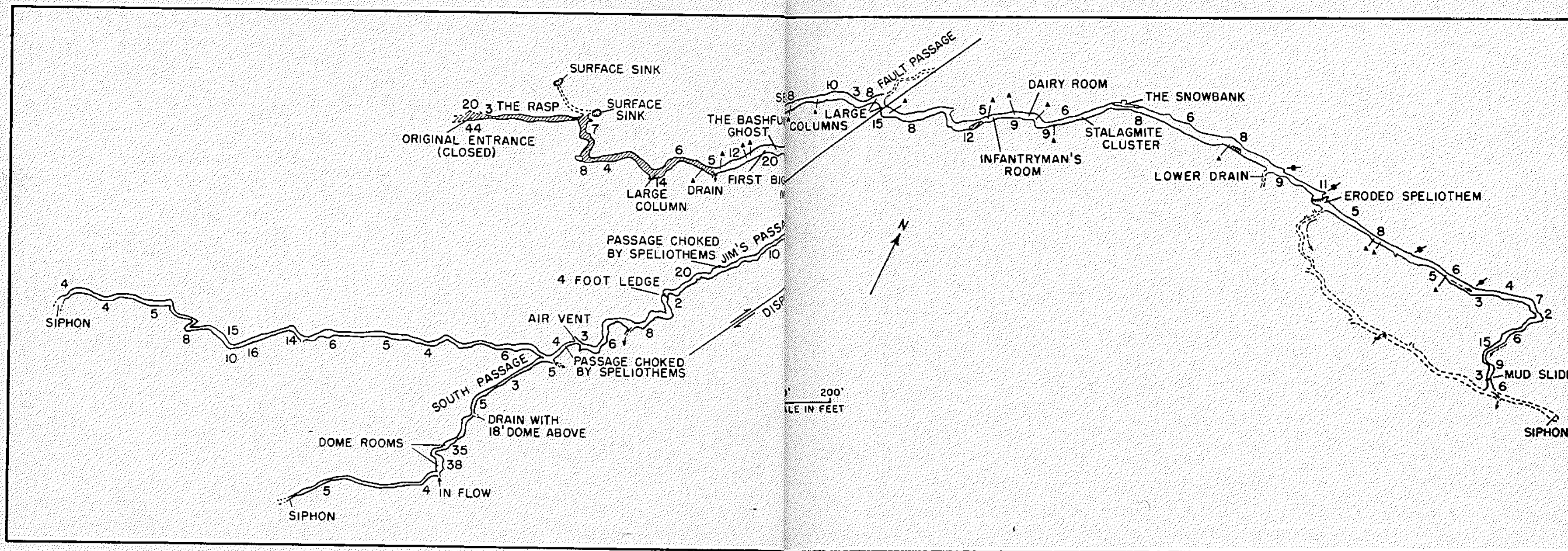

FIGURE 11. Wild Woman Cave, modified from map by Jack Burch.

low (from 1 to 3 feet). A side passage (about 60 feet long) parallels the lower level. The side passage has more headroom (about 6 feet) and leads into another chamber about 40 feet long. Altogether then, the known portion of the cave consisted of 250 to 300 feet of passage. Jack Burch was aware that the lower water passage continued indefinitely in a NE and SW direction from the known cave. At times of flood the water would roar through this level. Even in the dry season the high water level discouraged exploration. However, in August after a prolonged drought, the water level was much lower than Jack had ever seen it before and we decided to try it.

The going was rough, although not as bad as we had anticipated. The ceiling is, in most places, from 2 to 3 feet high with about 1 foot of water covering the floor, which is extremely irregular and composed of a calcium carbonate deposit. The evaporation of standing water in this area has caused the precipitation of the calcium carbonate. When water flows it erodes this irregular floor and the result is rounded off points tending to lean in the direction of flow (NE). Later, we decided to call this passage "The Rasp". "The Rasp" is 350 feet long, and then the ceiling rises suddenly to 6 feet and the water becomes deeper. This water passage continues for about another 500 feet with the ceiling height varying from a minimum of about 3 feet to a maximum of about 12 feet. At 900 feet from the entrance the water ended and we stepped out on dry land into a big walking cave.

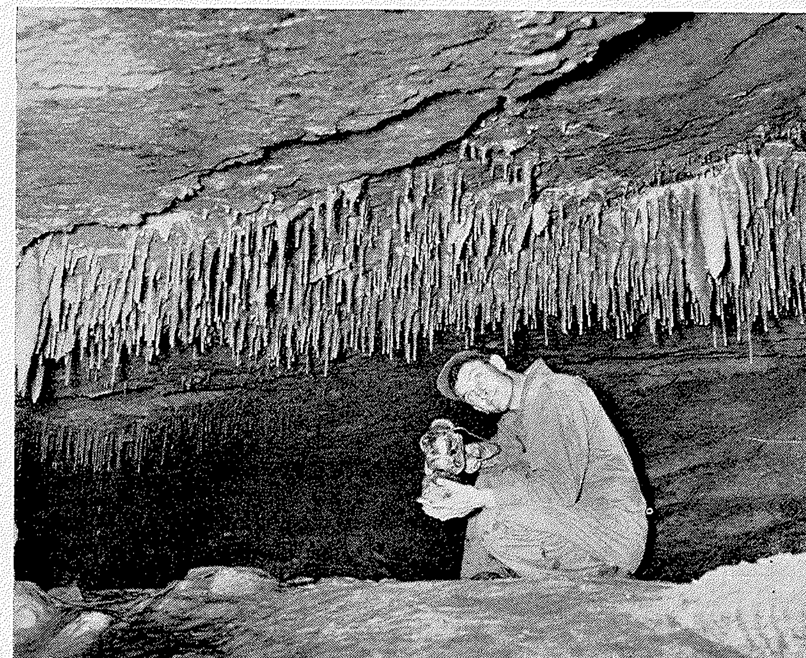

FIGURE 12. Cave formations hanging from roof of Wild Woman Cave. Photograph by William A. McGalliard.

Wild Woman Cave contains many interesting features including abundant speliothems, some large and unusual. Of course, there has been no vandalism in the cave.

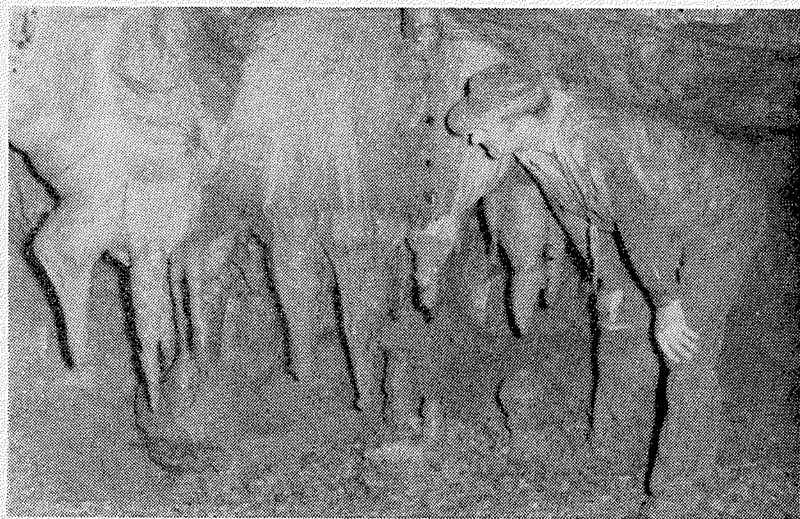

FIGURE 13. Stalactites in main passage of Wild Woman Cave. Photograph by Jim Papadakis.

We have surveyed 7,250 feet of passage and have explored an estimated 3 miles. More of the cave will be surveyed and when this work is completed a map will be sent to the NSS (National Speleological Society) together with a more detailed report. Twelve color photographs have been taken in the cave to date. The present plans call for taking a number of black and white photographs and prints of these will be included with the next report.

Jack and I believe that we were the first ever to get through "The Rasp". We have been unable to find any trace of human activity beyond it."

Geology: Wild Woman Cave has developed in the Cool Creek formation.

Remarks: *DANGER*—do not enter cave if there is danger of rain. It is part of a large underground drainage system. The cave entrance is on property owned by Mr. J. A. Chapman, Tulsa, Oklahoma. Trespassers are not allowed on the property and anyone wishing to see the cave should contact Jack Burch, Springer, Oklahoma.

WOMAC CAVE

Location: SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 12, T. 1 S., R. 1 W., Murray County. About 6 miles west of Davis, Oklahoma, is the Indian Meridian. Four miles west of this is Garrison Creek. Follow Garrison Creek upstream approximately 4 miles. The creek divides at this point and the main stream continues to the west. Just below fork in creek is cave entrance on east side of creek, water flows from this entrance. Womac Cave is on hill to southeast of this spring. The cave is about 175 feet above Garrison Creek and is on east side of steep hill. Cave entrance is about 40 feet below crest of hill and slopes into hill at about 30°.

Description: the cave has three main rooms with the floor sloping steeply to the right (southwest?) in the largest room. Formations are abun-

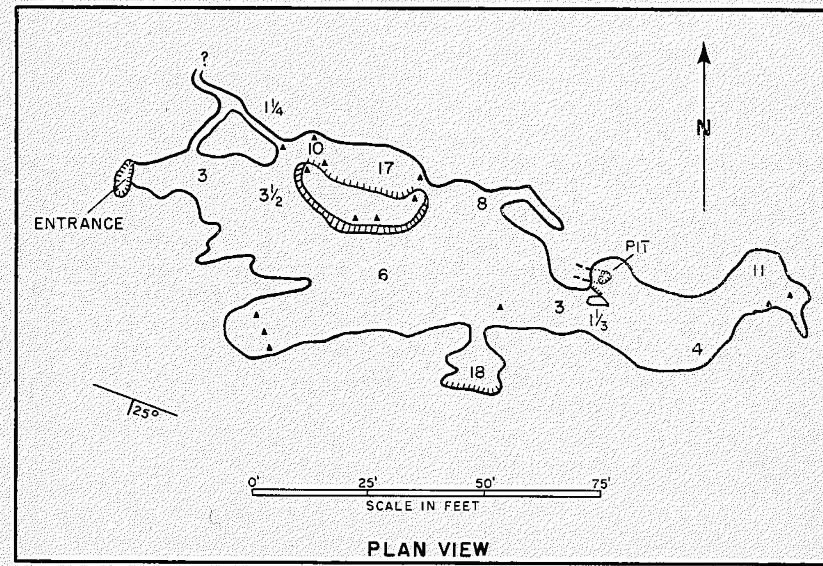

FIGURE 14. Womac Cave, surveyed by L. C. Perryman and Jack Burch, January 18, 1958.

dant—especially in the north dome room. The cave has a well reported to be 75 feet deep. One PIPISTRILLE bat was noted in the north dome room. Crickets and an orange and black millipede were also noted. The cave has no apparent air flow and the temperature is fairly high. There are no pools in the cave, although there is reported to be water in the bottom reaches of the well. This cave would be considered a "dry" cave.

Geology: Womac Cave has formed in the Kindblade formation.

Remarks: no special equipment is needed unless an attempt is made to reach the bottom of the small well. The cave is on land owned by Phil A. Cornell of Springer, Oklahoma, and was surveyed in 1958 by L. C. Perryman and Jack Burch.

Folklore: Spanish treasure is supposed to have been buried in cave.

Reversible Chemical Reactions

Inorganic chemical reactions involving double decomposition can occur in dilute and concentrated aqueous solutions, in nonaqueous solvents, and in fusions. Also they can occur when finely divided reactants are sintered, that is in making the mixture coherent through partial fusion. The extent or degree to which such reactions can progress is usually determined by the temperature, pressure, and the relative proportions of the reactants.

As is well known to the petroleum producer, when a connate water containing barium chloride comes in contact with another water containing a sulfate there results troublesome insoluble barium sulfate (barite). The reaction may be shown as follows:

$$CaSO_4 + BaCl_2 \rightleftarrows BaSO_4 + CaCl_2$$

It will be noted that the reaction is shown as reversible. Under the conditions in an oil well the reaction proceeds from left to right until a point of equilibrium is reached, which is probably close to but not attaining 100 percent. Now the question arises as to what are the conditions necessary to reverse the reaction. Professor R. Norris Shreve and his students and co-workers at Purdue University began research on the subject as far back as 1935. His latest publication dealing with this reaction is in the May 1957 issue of Industrial and Engineering Chemistry. A process is outlined for the production of barium chloride by reacting a hot concentrated solution of calcium chloride with finely ground barium sulfate and recovering the barium chloride through the use of a nonaqueous solvent. Formerly the process called for separation of the soluble barium chloride from the relatively insoluble calcium sulfate by filtration, yielding an impure barium chloride because an equilibrium is established leaving considerable unreacted calcium chloride. A similar reversible reaction exists in the case of strontium sulfate and calcium chloride.

The subject of double decomposition of inorganic materials in nature, the conditions under which an equilibrium is established, and how the reaction may be reversed should be of interest to the geologist and mineralogist. It does not appear that much research has been done in this direction.

A. L. B.

Underground Storage in Salt, Elk City Field

LOUISE JORDAN

Elk City Field in Beckham County, Oklahoma, is not only the site of the second deepest well drilled for oil in the world, but also of the only underground storage of hydrocarbons in a salt layer in Oklahoma. In 1953, Shell Oil Company decided to supplement the steel propane storage tanks at the Elk City processing and gas cycling plant by washing out a cavity in a salt bed of the Blaine formation. Additional storage of 16,000 barrels was provided at a considerable saving compared with the cost of above-ground storage.

On August 2, the Shell Oil Company No. 1-LPG Yelton was spudded in NE¼ SW¼ SE¼ sec. 15, T. 10 N., R. 21 W. The test was drilled to 1,091 feet and 40,000 pounds of salt was added to the mud before coring was commenced with a 6⅛-inch OD diamond core head. The first core was taken from 1,091 to 1,126 feet. Five feet of brown shale containing sandy gray shale inclusions and two inches of salt in the core catcher were recovered. The rock section from 1,128 to 1,179.5 feet was recovered completely in the second core. It consists of coarse crystalline salt with thin (average: 7 inches) interbeds of brown shale. About 20 percent of the core can be called shale. The shale and salt are not clearly separated as large salt crystals are in the shale and some shale is present in the purest salt beds. The test was then drilled from 1,180 to 1,301 feet in salt and shale. The third core was taken from 1,301 to 1,342 feet; 41 feet of salt with thin interbeds of brown and gray-green shale was recovered.

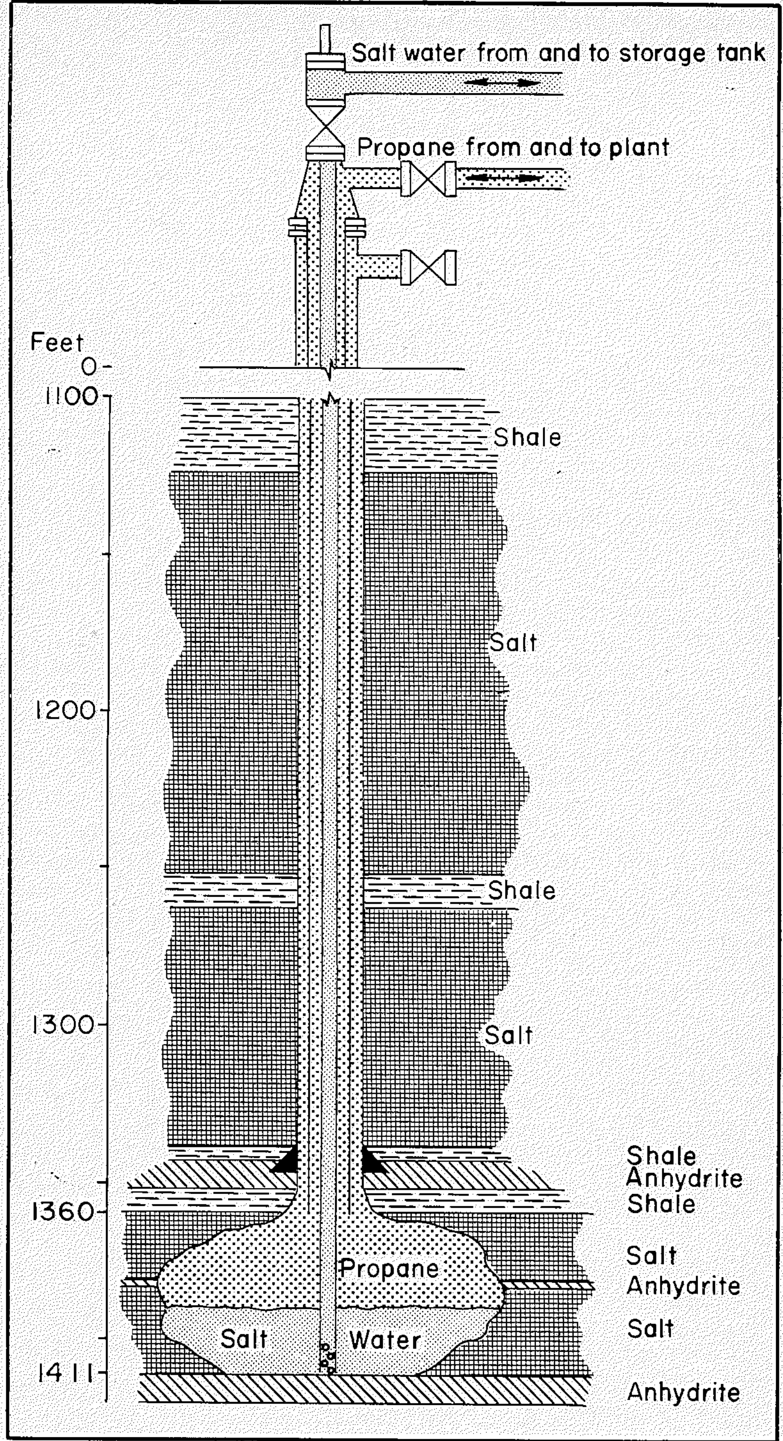

FIGURE 1. Diagrammatic sketch of borehole drilled by Shell Oil Company at Elk City Field for the purpose of underground storage of propane showing the upper 300 feet of evaporite rocks and the stratigraphic position and depth of storage cavern.

Coring continued to the total depth of 1,420 feet and a complete rock section was recovered. Although admixture of rock types is the normal condition, the section consists essentially of the following (in feet): 1,343-1,352, anhydrite; 1,352-1,360, brown and gray-green shale; 1,360-1,381, salt; 1,381-1,384, anhydrite; 1,384-1,389, salt; 1,389-1,390, shale; 1,390-1,391, salt; 1,391-1,392, shale; 1,392-1,411, salt; and 1,411-1,420, anhydrite. The hole was plugged back to 1,413 feet.

In late August, fresh water was circulated into the salt layer at a depth of 1,360 to 1,411 feet. The water dissolved the salt forming an underground cavern of 16,000-barrel capacity. The washing-out process and the installation on the surface of a 16,000-barrel salt water storage tank were completed in December 1953. After testing and completion were accomplished, the underground "jug" was ready for storing propane by January 1954. The reservoir is filled by pumping propane into the annulus of the well, displacing salt water through tubing into the salt water storage tank. Propane is withdrawn from the well as needed by gravitating salt water from the surface down the tubing (see figure).

By comparison of the rock section in this hole with that in nearby wells (Shell No. 1 Yelton, C SW¼ SE¼, sec. 15, T. 10 N., R. 21 W. and Shell No. 1 Walters, C NE¼ SW¼, sec. 14, T. 10 N., R. 21 W.) for which electric and sample logs are available, the base of the Blaine formation would be penetrated at 1,600 feet. Thus an evaporite section of at least 475 feet exists in this area. Ham (1958, p. 90) reports that the Blaine formation cropping out in southwestern Oklahoma ranges in thickness from 130 to 200 feet. Westward it thickens by the addition of gypsum at the top, and eastward it becomes indistinguishable from the Dog Creek and Flowerpot formations by gradation into shale. The upper boundary is one of gradation with the Dog Creek shale, which in this area measures about 90 feet thick.

Several of the thin dolomite beds in the Dog Creek are characterized by casts of hopper-shaped salt (halite) crystals (Scott and Ham, 1957, p. 29) indicating a saline environment for the Dog Creek sediments at the outcrop. Gould (1910, p. 71) reports salt water springs issuing from beneath gypsum ledges of the Blaine formation along Boggy Creek where he describes a salt plain occupying about 40 acres in secs. 10, 11, 14, 15. T. 8 N., R. 22 W. It is probable also that the abrupt changes in dip and strike observable on the surface in sec. 5, T. 9 N., R. 22 W. (Ham, 1957, p. 2) north of the Blaine outcrop are the result of slumping due to solution of salt in the underlying evaporite sequence which may be equivalent to both the Dog Creek and Blaine formations.

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Geological History of the Gnetales*

L. R. Wilson

Fossil Gnetales pollen recently found in the Flowerpot formation, a Middle Permian unit, in Oklahoma has created considerable interest in the history of that order of gymnosperms. A survey of the gnetalean literature has revealed a surprising lack of knowledge concerning the paleontology and the phylogenetic relations of the Gnetales. To both of these subjects the fossil pollen record can add material information.

The gymnosperms are divided into seven orders and the Gnetales are considered the mostly highly evolved. This order contains three families, Ephedraceae, Welwitchiaceae, and Gnetaceae. Each family contains a single living genus, *Ephedra, Welwitchia,* and *Gnetum* respectively. A fourth family, Sarcopodaceae with a single genus, *Sarcopus,* was placed in the order Gnetales, but later removed and assigned to the family Santalaceae in the angiosperms.

The genus *Ephedra* has approximately 42 living species, distributed widely in arid tropic and temperate regions. The growth habit of most species is shrubby, the superficial appearance is that of a much branched *Equisetum*. Of the Gnetales, *Ephedra* has the most characteristic gymnosperm life cycle. Eighteen species of *Ephedra* occur in the Canary Islands, Mediterranean region, Persia, India, China, and Siberia. North American species number 15 and are most abundant in California, Arizona. New Mexico, and Old Mexico. Seven species grow as far east as Texas (Cutler, 1939). One species is found in southwestern Oklahoma. Nine or eleven species live in South America distributed from Bolivia to Patagonia.

The genus *Welwitchia* contains a single species, *W. mirabilis,* and according to Chamberlain (1935) it is "the most bizarre of all gymnosperms, if not of all seed plants." Its appearance is that of a gigantic turnip, reaching 1.2 meters in diameter. A depressed two-lobed crown stands approximately 45 centimeters above the ground and two strap-like leaves are attached to the lobes. The leaves grow from an embryonic region at their bases and persist throughout the life of the plant. They may attain the length of two meters and split into ribbons toward the ends. *Welwitchia* is distributed sporadically in the desert region of southwest Africa, seldom found more than 100 miles inland, and extends from 14° to 22° 85′ south latitude.

Gnetum is a genus of more than 30 living species and all of them are wet tropic plants, an ecology in sharp contrast to the other genera. Most of the species are lianas; a few are shrubs or trees. The leaves resemble those of dicotyledons; they are net-veined, broad, and possess a short petiole but no stipules. Pearson (1929) gives the distribution of *Gnetum* as follows: 19 species in tropical Asia and islands between Asia and Australia, two African species, seven species in the Amazon region of Brazil, one species in Ecuador, and one species in the West Indies.

The Gnetales possess both gymnosperm and angiosperm characters. The naked seed habit, and the presence of an archegonium in *Ephedra* are

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gymnospermous. Vessels in the secondary wood and absence of resin canals are angiospermous. Each family differs markedly from the others and some students of the Gnetales suggest that these differences are of such magnitude that each family warrants the status of an order. The transitionary type of anatomy has several times prompted the idea that the Gnetales may be the ancestors of the angiosperms. Chamberlain (1935) states: "a strong objection to such a theory of relationships is that no Gnetales have been found below the Tertiary, while angiosperms were abundant in the Cretaceous, and certainly existed in the Jurassic." There are few persons who now would suggest such ancestory for the angiosperms, although the discovery of gnetalean pollen in Permian rocks considerably antedates any authentic angiosperm fossils.

PLATE 1

Modern and fossil gnetalean pollen.

FIG. 1. *Gnetum nodiflorum* Brongn. (modern) Near Saramacca River, Surinam. The pollen grain appears smooth but under high magnification minute spines are visible. Diameter: 12.1 microns. OGS Slide No. 319-1-2. From the Chicago Museum of Natural History Herbarium, Col. No. FM 1226994.

FIGS. 2 and 3. *Welwitchia mirabilis* Hooker f. (modern). Mossamedes Desert, Angola. Parallel ridges and the single germinal furrow (colpus) shown in the photomicrographs are characteristic of *Welwitchia* pollen grains. Dimensions: 26.2 X 47.2 microns, OGS Slide No. 320-1-1; 28.3 X 43 microns, OGS Slide No. 320-1-5. Chicago Museum of Natural History Herbarium, Col. No. FM 1179505.

FIGS. 4 and 5. *Welwitchia mirabilis* Hooker f. (modern). Mossamedes Desert, Angola. Showing parallel ridges on side distal to the germinal furrow. Dimensions: 27.3 X 47.2 microns, OGS Slide No. 320-1; 27.3 X 47.2 microns, OGS Slide No. 320-1-3.

FIG. 6. Cf. *Welwitchia* sp. (fossil) Flowerpot formation. A single germinal furrow is shown in the medial longitudinal position of the illustration, suggesting affinity with *Welwitchia* rather than with *Ephedra*. Dimensions: 26.2 X 48.3 microns, OGS Slide No. F1-3-7.

FIG. 7. *Ephedra americana* H. & B. (modern). Rio Marañon, Peru. The depressions between the parallel ridges each contain a germinal furrow in contrast to the single furrow of *Welwitchia* pollen. Dimensions: 29.4 X 31.5 microns, OGS Slide No. 321-1-1. Chicago Museum of Natural History Herbarium, Col. No. FM 518786.

FIG. 8. *Ephedripites* Bolchowitina sp. (fossil) Flowerpot formation. Dimensions: 27 X 42 microns. Photomicrograph from a temporary slide.

FIG. 9. *Ephedripites* Bolchowitina sp. (fossil) Flowerpot formation. Dimensions: 39.9 X 84 microns. OGGS Slide No. F1-8-4.

FIG. 10. *Ephedripites* Bolchowitina sp. (fossil) Flowerpot formation. Dimensions: 42 X 76 microns. Photomicrograph from a temporary slide.

FIG. 11. *Ephedripites* Bolchowitina sp. (fossil) Flowerpot formation. A distorted fossil pollen; similar grains are found in species of modern *Ephedra*. Dimensions: 28.3 X 62 microns. OGS Slide No. F1-2-7.

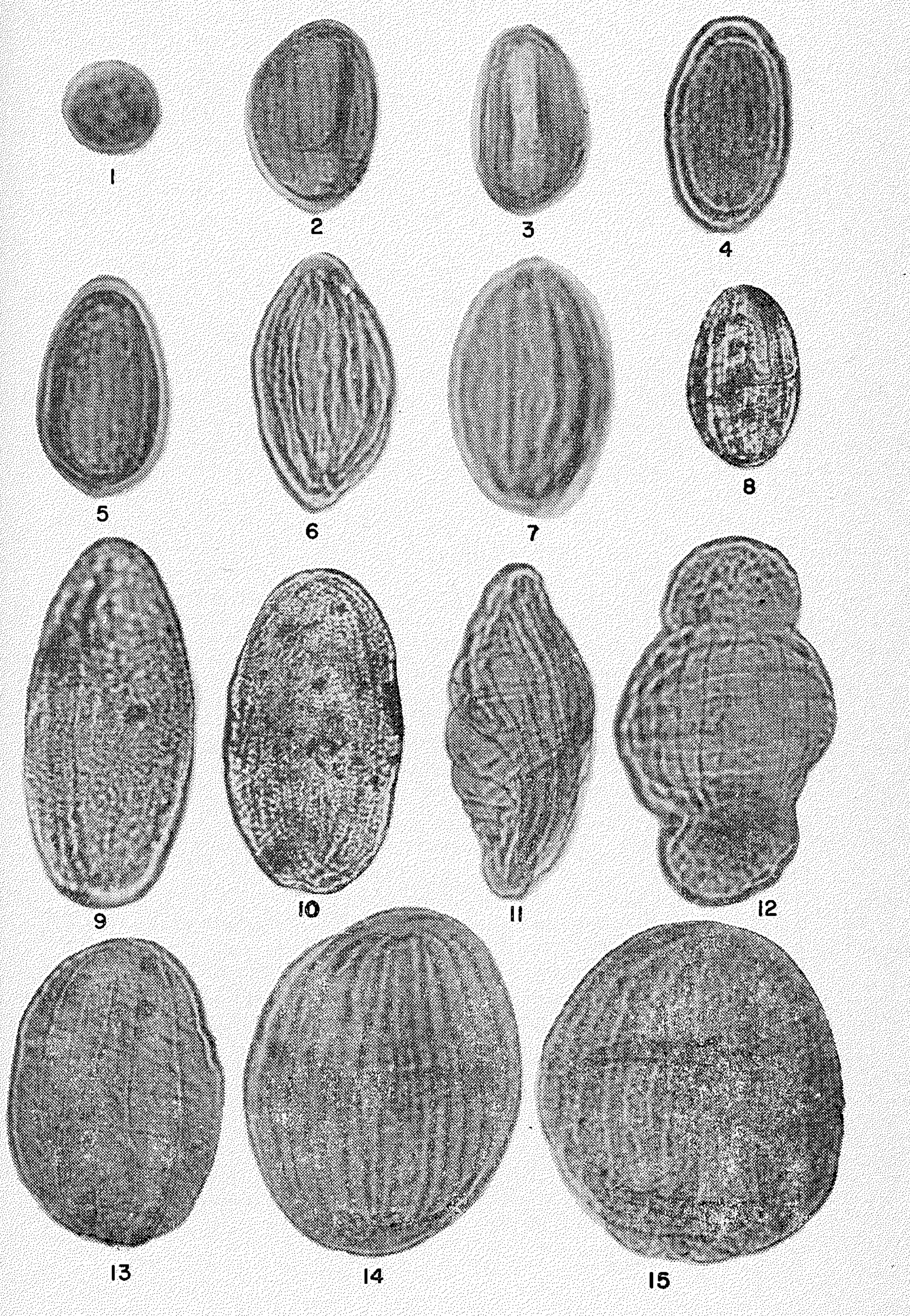
FIG. 12. An ephedran type of pollen which may warrant generic status since it is distinctive and an abundant fossil in the Flowerpot formation. Dimensions: Total length 68.25 microns, center body 33.6 X 40 microns. OGS Slide No. F1-3-12.

FIG. 13. *Ephedripites* Bolchowitina sp. (fossil) Flowerpot formation. Some modern *Ephedra* species have pollen grains with broad ridges similar to those shown in Figs. 13 and 14. For that reason they are assigned to the genus *Ephedripites*. Dimensions: 48.3 X 69.3 microns. OGS Slide No. F1-3-1.

FIG. 14. *Ephedripites* Bolchowitina sp. (fossil) Flowerpot formation. Dimensions: 52.5 X 66.1 microns. OGS Slide No. F1-8-4.

FIG. 15. *Vittatina* Luber sp. (fossil) Flowerpot formation. The ridges of this pollen type are irregular, frequently dividing and rejoining similar to the fossils described as *Vittatina* and as *Welwitschiopites* Bolchowitina. Resemblance appears to be greater to the former genus. Dimensions: 57.7 X 65.1 microns. OGS Slide No. F1-3-10.

PLATE 1



The fossil record of Gnetales, aside from pollen, is meager. A single *Ephedra* stem from the Miocene, of Colorado (Wodehouse, 1934), and two doubtful species of *Ephedrites* from the Tertiary of Europe appear to be its known extent. Two other fossil species have been assigned to the family Loranthaceae, and the Paleozoic seeds which Renault (1885) regarded as gnetalean are now thought to have no connection with the group (Arber and Parkin, 1908). All fossil leaves assigned to *Gnetum* are problematic, since there exists a very great similarity between the leaves of that genus and many dicotyledons. Some of the Cretaceous and Tertiary leaves assigned to dicotyledon genera on restudy may prove to be species of *Gnetum*. Several contributing factors appear to be responsible for the apparent absence of gnetalean megafossils. The arid habitats in which *Ephedra* and *Welwitchia* presently live are not places where large plant tissues are apt to become fossilized, except possibly in playas. Present species of *Gnetum* also live in habitats where fossilization infrequently occurs. Further search of our southwestern redbeds and other sedimentary rocks formed under arid conditions may reveal additional gnetalean megafossils.

There is strong indirect evidence from gnetalean anatomy that the order has a geological history much more ancient than that of the angiosperms. The wide geographic distribution of the living species, and their ecological relations, are also indications of considerable antiquity. Since the discovery of fossil *Ephedra* and *Welwitchia* pollen in the Permian rocks, and the reported occurrence of fossil *Gnetum* pollen in Russia, the lineage of the Gnetales is less mysterious. Chamberlain (1935) stated that "the Gnetales, like Minerva, seem to have sprung, full armed, from the head of Jove; but it is possible that the discovery of some new group, like the Caytoniales, may prepare the way for a less fanciful theory of origin." It now appears probable that the fossil pollen record of *Ephedra* and *Welwitchia* will serve, at least in part, to demonstrate affinity to the Coniferales with which they have other morphological features in common. Instead of discovering a "new group" of plants, as suggested above, the occurrence of fossil pollen of the Gnetales has given a new insight into the geological history of the group.

The modern pollen like other anatomical structures of the living Gnetales, appear to have bearing upon the interrelations of the three genera. *Ephedra* and *Welwitchia* have pollen grains that are bilaterally symmetrical whereas *Gnetum* pollen grains are essentially radially symmetrical. The first two genera possess longitudinal ridges while *Gnetum* is covered with small or vestigial spines. *Gnetum* does not possess any external germinal mechanism, *Ephedra* is polycolpate, and *Welwitchia* monocolpate. Some fossil species of *Ephedra* and *Welwitchia* have reduced saclike structures at the distal ends of the grains, similar to the pollen of certain genera of conifers. These pollen features suggest that *Ephedra* and *Welwitchia* are more closely related to one another than to *Gnetum*. *Ephedra* is wind pollinated, *Welwitchia* is known to have some pollination by insects, and the same is suspected for *Gnetum*. The spiny character of *Gnetum* pollen suggests that in its early history *Gnetum* may have been pollinated by insects as in many angiosperm groups. Wodehouse (1935) discussing the pollen of the Gnetales states: "the possession of spines in the reduced form in which they occur in the grains of *Gnetum* makes it

seem improbable that this grain is derived from a gymnosperm ancestor, unless by a most indirect route, but suggests instead, that *Gnetum* may be a reduced angiosperm."

Fossil pollen of *Ephedra* is as widely spread as are the living species. Although *Welwitchia* is restricted to western Africa, fossil pollen of the genus has been found in Russia, Australia, and Oklahoma. The stratigraphic range of both genera is from the Middle Permian to the present. The genus *Ephedra* may now contain fewer species than it did in the past; forty-two are still livng. Several fossil pollen species of *Welwitchia* are apparent but the genus is now reduced to one species. In this respect it resembles *Ginkgo*, the classic example of a once flourishing family of gymnosperms now extinct except for one species native to China. The known geological history of *Gnetum* is much shorter. There is a report of fossil *Gnetum* pollen from the Tertiary of Russia (Zaklinskaya, 1957) but its authenticity is difficult to establish since similar pollen grains exist in various angiosperm families.

The occurrence of *Ephedra* and *Welwitchia* in the redbeds of Oklahoma has bearing upon the climatic conditions under which those sediments were deposited. If the fossil Gnetales lived in the same arid or semiarid ecology as the living species, then it may be assumed that the Flowerpot sediments were derived from an adjacent arid or semiarid land mass. Other fossil spores and pollen associated with the gnetalean pollen also strongly suggest a semi-arid climate.

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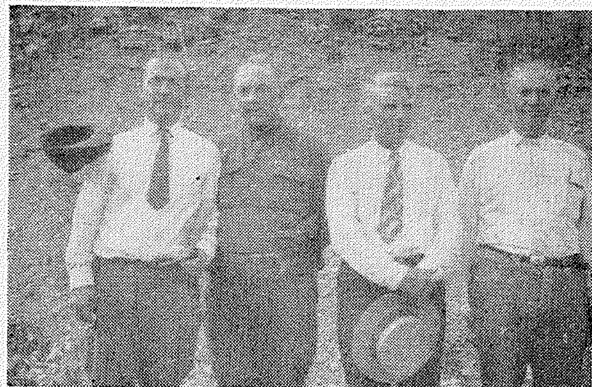

Four State Geologists

The First Field Conference of the Kansas Geological Society was held in September, 1927. The route was through Missouri and Iowa. The picture here reproduced was taken during that trip and was found in the files of the Oklahoma Geological Survey. The four gentlemen shown were then the state geologists of (left to right) Kansas (R. C. Moore), Nebraska (G. C. Condra), Iowa (G. F. Kay), and Oklahoma (C. N. Gould).

Raymond C. Moore is now president of the Geological Society of America, Principal Geologist of the Kansas Geological Survey, and Distinguished Professor at the University of Kansas.

George C. Condra retired as State Geologist of Nebraska in 1950 and died on August 7, 1958 at the age of 89.

George F. Kay resigned as State Geologist of Iowa in 1934. He was Dean of the College of Liberal Arts at the University of Iowa until his retirement in 1941 and he died on July 19, 1943, aged 70.

Charles N. Gould served as State Geologist of Oklahoma until 1931. He died at Norman, Oklahoma, on August 13, 1949, aged 81. C. C. B.