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the Caves of Missouri

Dr. J. Harlen Bretz (1956)

Version Two: Searchable Text, but No Pictures.

If you enjoyed this version, then by all means, please keep an eye out for “Version One: Graphics-Heavy but No Search Functionality.”

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CAVES OF MISSOURI

J HARLEN BRETZ
Vol. XXXIX, Second Series

1956

STATE OF MISSOURI
Department of Business and Administration

Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
T. R. BEVERIDGE, State Geologist

Rolla, Missouri
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Caves of Missouri  

J HARLEN BRETZ

ABSTRACT

Subterranean cavities in calcareous rock are largely the solutional product of circulating water that enters the ground from the surface, chiefly from rain but locally from streams. In origin, therefore, such cavities are intimately related to geological conditions and changes of the present but particularly of the past. Missouri's numerous caves are historical records of factors once operating but in most cases now vanished. Descriptions and depictions alone fall short of a truly scientific approach to any problem. Our Present is largely a consequence of the Past and the leading theme of this investigation has been the interpretation, from cave features, of the past succession of geological events in cave-making in the Ozarks. This report aims to be more than a directory, dictionary, and tour guide. Air, surface streams, underground streams, gravity; all are enemies of caves. Most enterable caves are deteriorating under present geological conditions. The great majority of Missouri's caves tell of origin in completely water-saturated rock, long before the existing rugged Ozark topography was eroded. INTRODUCTION

The caves of Missouri are many and varied. No one will ever know how many caves Missouri has, nor is it possible that everyone will ever agree on a definition of a cave. Is a rock shelter, broad along the hillside but shallow in penetration of the hill a cave? Is a natural bridge a cave? Is a hole that can barely be crawled into for only a few feet a cave? Is it a cave if one's light shows an opening into which he can not force his way? Is it a cave if a former cavity has become completely filled with mud or broken rock? Even if we should rule out such cavities in limestone or dolomite, the State still has hundreds of underground openings into which one may penetrate beyond the reach of daylight. In terms of human experience, we generally think of a cave as being a natural roofed cavity in rock which may be penetrated for an appreciable distance by a human. Before this study was undertaken, the Missouri Geological Survey had already compiled a list which contained the names and locations of 210 caves distributed among 40 counties. This list, with much information about a number of the caves, was made during the spare time of Willard 1
2 Missouri Geological Survey and Water Resources Farrar, the Survey's cave enthusiast. Many of the caves were visited by him personally and printed sources were searched for information. State- ments from his manuscript which appear in this publication are identified by his name in parentheses. The list has now grown to include 437 caves in 55 counties. In this work, 250 of these caves have some description and 133 were investigated by the writer. By far the largest number of Missouri caves are located in the southern half of the State, which is generally referred to as the Ozark plateau or dome. Almost all of the State is underlain by limestone and dolomite formations in which ground water dissolves out caves. Thus, the area north of the Missouri River may well contain as large a proportion of caves as do the Ozarks, but the cover of glacial drift and the lack of deep stream valleys north of the river conspire to keep us ignorant of their existence. Most of Missouri's caves have had some attention from venturous individuals. Ask almost any old-timer in the Ozarks about wild caves in his region, and his answer usually will be, "When I was a boy, I explored back into- ". It has not been feasible for the Survey to collect in- formation on all the small, distant, or difficult caves. The guiding principle of this study has been to examine those that promised good re- turns without undue expenditure of time. The returns most desired were something more than locations, dimensions, and descriptions. A reading from Nature's record of the history of each cave has been sought. Only from that can we obtain an understanding of the changing geological con- ditions which have given us the caves of Missouri. A point stressed in the history of almost every cave is that it is older than the latest broad uparching of the Ozark dome. That regional uplift was responsible for the subsequent stream erosion which has today exposed the cavities that were made before the latest doming occurred. Most caves contain a partial fill of gravel, sand, mud, or clay; insoluble materials that have collected in them to bury the bedrock floor. Even if a cave has become completely filled with such detrital material, it is still a cave; a consequence of the solvent action of cir- culating ground water at some earlier time. It is now a filled cave. In a strict sense, all caves are filled. Many of Missouri's big springs are discharges from caves completely filled with water. The caves or chambers we can enter are filled with air. This is not a matter of mere words, for there is a fundamental relationship which we presently shall uncover. The argument will be developed repeatedly in the accounts of the individual caves that air- filling is a late episode in the history of most caves, that it was preceded by an earlier episode of clay-filling, and that still earlier, when the cave was growing, the clay-filling stage was pre- ceded by an event of water-filling. Very few Missouri caves are growing today. As open caves-air- filled cavities in the rock-almost all are clearly suffering destruction in one way or another, largely because they have become air-filled. Collapse
Caves of Missouri 3 of roofs has blocked many a cave chamber, sinkhole debris has filled large portions of them, dripstone and flowstone deposits have decreased chamber capacities, cave streams have deposited gravel in them, and outside creeks and rivers, by widening their valleys, have shortened cave lengths. Every one of these changes is still going on. The conditions of the present time distinctly do not favor cave-making in the rock of Missouri's hills, although the collapse of cavern roofs may give the impression that caves are still being formed. We think we see evidence of cave-making today on any noteworthy scale only in the big springs most of which emerge-some of them under hydrostatic pressure—at the bottoms of major valleys (Fig. 13). If this is correct, then the level or zone in which ground water makes and enlarges caves is below the valley bottoms of a region. Thus, it follows that the caves in the hills, the air-filled caves, the only caves we can enter and explore, are older than those hills. There are many published references of differing degrees of value about various caves in Missouri. Newspaper accounts and magazine articles about discoveries and explorations have been the most numerous and the least valuable. Geological papers by competent observers have dealt with certain aspects of certain caves, but no previous publication has ever attempted to cover the caves of the State; nor does this one. Our aim is to understand how and when and under what conditions Missouri's caves were made originally, and what subsequent vicissitudes have left their marks on them. Bats, blind fish, salamanders, crickets, and transparent crayfish in the caves are another subject, as are certain former inhabitants of cave mouths and rock shelters who have long since gone to the Happy Hunting Grounds. The zoologist and archaeologist (Fowke, 1922) must be called in for treatment of caves as habitations. As for caves with buried treasure, more than a dozen in Missouri have been searched—fruitlessly. Nor have shady heroes like Jesse James, Crabtree, the Younger Brothers, or Blackbeard left any trustworthy record of their reputed use of caves as hideaways. Many tales of pirate hangouts, robber dens, counterfeiter shops, bushwhacker and baldknobber rendezvous may be about as legendary as the stories of buried Spanish or pirate gold. Truthful parts of such stories are no longer identifiable. Two terms, speleologist and spelunker, have made a fairly recent appearance in (American) English. Both terms refer to individuals interested in caves, but they are not synonyms. The speleologist has an adequate geological background and is interested primarily in understanding the conditions which have made the cave we find today. He is a subspecies of the ground water hydrologist who, in turn, is a species of the genus "geologist". He gets his chief emotional thrill from collected observations which he builds into an acceptable explanation of "how" and "why" and "when".
Missouri Geological Survey and Water Resources

The spelunker's chief interest is in exploration, underground adventure, and esthetic appreciation. The modest spelunker is like the polar bear who never boasts about cold baths. He has no overwhelming urge to be photographed in full regalia or in difficult but readily avoidable cave situations. He has no need for newspaper or magazine publicity; caves are fun in their own right. His greatest reward probably is in penetrating where man has never penetrated before. Each Missouri cave opened for visitors and provided with guide service is treated in a separate section of this report. Each section is designed to describe and interpret the outstanding features of the cave in the sequence in which they are encountered along the visitor's route. For most of the caves, a map is provided with horizontal distances indicated. For some, it has been possible to make contour maps that show wall and ceiling shapes. So far as the writer is aware, these are the first cave surveys of this kind ever made. These maps are not read at a glance; they require and will repay careful study in the cave itself. Many wild caves of the State have also been examined and interpretations have been made of their more readily accessible parts. Some of these interpretations are accompanied by pace-and-compass maps. Most of these uncommercialized caves are as free to visitors as are the woods and hillsides of their environs. It would be the part of courtesy, however, to ask for permission before entering. The wild caves studied are grouped in this publication by counties. Known wild caves not visited are also listed by counties along with such information as has been learned from other publications and personal inquiry. The accounts of the wild caves are written primarily for those interested, like the author, in problems of origin. Many contain remarkable showings of significant features such as are described and explained (or confessedly not understood) in the two sections, Origin of Missouri's caves and Cave formations. There are many cave problems yet to be solved. There is probably less danger to persons of good judgment in caves than in automobiles. A ball of binder twine unrolled as one progresses is a sure guarantee for finding the way back. The miner's carbide lamp and the Coleman type of gasoline lantern are satisfactory lights, though an accessory flashlight should be taken for emergencies. Rope work is dangerous and should be attempted only with elaborate precautions against the dislodging and falling of loose fragments. Caves with evidence of stream floods in them can be dangerous within a short time after a torrential thundershower. An eye should be kept on cave ceilings for evidence of instability, and chambers with freshly fallen slabs on the floor should be avoided. Although the writer visited most of the wild caves herein described with only his dog as a companion, the procedure is not advisable. A party of two or three is by far to be preferred. If one goes alone, he should for obvious reasons so inform some one outside and announce his probable time of return.
Caves of Missouri 5 A kind of cult has been developed by some spelunkers. It is apparently designed to impress those on the outside. Indeed, an elaborate handbook is in print (in French) (Guerin, 1944) on equipment for and techniques of cave exploration. Organizations of cave enthusiasts exist in this and other countries. Of course underground situations may be met with where difficulties and dangers bristle. The thrill seeker hunts for them. The speleologist usually can avoid them without neglecting any important item in his study. The best maps one can get of the various parts of Missouri are the topographic maps or quadrangles. Approximately three-fourths of the State has now been mapped by the U. S. Geological Survey in co-operation with the Missouri Geological Survey at a rate that promises completion of the entire State at an early date. The quadrangle is a unit determined by latitude and longitude and has no fixed relation to political boundaries. The maps are printed in three to five colors: black for culture (towns, roads, railroads, section lines, schools, churches, etc.); blue for streams, ponds, and lakes; brown for contours; red (on most maps) for main highways, boundaries of state parks, national forests, counties, etc.; and green (on some maps) for woodlands. The quality of the nearly 500 maps in print decreases with increasing age. On some, the surveyors located the caves with an X as well as with a name; on some, only the name appears; and on many, there is no indication of the existence of caves in the area shown. Copies of these quadrangle maps may be purchased from the Missouri Geological Survey office in Rolla.

ACKNOWLEDGMENTS The field study on which this report is based was done during the autumn of 1947, the spring of 1948, and the spring of 1951. The author was given carte blanche for his investigations, and he had the privilege of frequent consultation and some field association with the members of the Missouri Geological Survey staff. Uncounted, helpful arrangements to further the work were made by owners and managers of the various commercialized caves of the State—kindnesses that came in spite of frequent differences between their interpretations and those of the author. Almost without exception, the operators were open-minded, and it is the author's fond belief that the quality of the geology taught to visitors has been improved through these friendly associations. A host of Missouri citizens, acquainted with local wild caves, deserve the thanks of the author for information and for assistance in finding and even in exploring many of the caves examined. Particularly, the Missouri boys who have delightedly accompanied the author should have his thanks.
To the Missouri Division of Resources and Development and their photographer, Gerald Massie, the author owes his thanks for a superb collection of cave photographs. All the maps for this study were made by the author, unless otherwise specified, and to the college students who have made the better maps, he owes thanks for their excellent work. The author also wishes to thank John W. Koenig of the Missouri Geological Survey for editing the typescript. Finally, thanks is accorded to the late Willard Farrar of the Missouri Geological Survey, who initiated this project and started the field work. Farrar laid down his life for his country in the battle of Port Moresby, New Guinea.

**ORIGIN OF MISSOURI'S CAVES**

The term ground water, as used in this report, refers to all water in the ground. This includes the water which is associated with interstitial air above the water table and the water which constitutes the saturated zone beneath. Students of geology will find in this usage a departure from the terminology of Meinzer as represented in the United States Geological Survey's Water Supply Paper 494 (1923), and as followed by Tolman (1937). Most caves in limestone or dolomite are, or have been, subterranean water courses and made by flowing water. In this limited sense, caves are valleys with roofs, but unlike surface stream valleys they are not made through abrasional deepening by streams or by slope-wash widening by weather. Instead of wearing away the solid rock with tools (sand grains and pebbles), ground water enlarges its initial passages by dissolving the rock. Instead of only deepening and widening the passages, many ground water streams also dissolve and remove the ceiling rock. This solutional action on the ceiling rock of some caves predominates over the solution and removal of the wall rock, thus the caves are deepened upward as well as downward. If this is so, then such ground water streams must fill their passageways as water fills a pipe. Therefore, the stream which we encounter on a cave floor today is not necessarily the stream, or the kind of stream, which made the cave.

Rainfall is disposed of in three major ways: by evaporation, by runoff down the land slopes, and by infiltration into the ground. This last way is the source for all the ground water with which we, as students of caves, are concerned. Gravity pulls this water down through any opening it can use, and the deeper openings in the rock which are not effectively sealed off from the surface become saturated. It is to this saturated zone that water wells must penetrate for a reliable supply. The upper limit of this saturated zone—above which the rock interstices contain air as well as water—is visualized as a definite surface and is referred to as the water table. It is accepted that rock with a continuously complete water saturation of its interstices exists beneath rock which contains associated air.
Caves of Missouri and water in varying proportions in place and time. Meinzer (1923, p. 32), Tolman (1937, p. 224), and Hubbert (1940, p. 898) have somewhat different interpretations of the nature of the contact. Whether or not there is in nature a definite contact between air and water above and water alone below does not concern us in cave theory. Whether or not this contact, or perhaps, gradational zone conforms as perfectly to the topography as our diagrams assume is another matter of no fundamental importance to our present interest. "Perched", water-saturated layers of rock may locally lie in the unsaturated zone, but the existence of a lower, completely saturated zone is in no wise challenged by this fact. In wet seasons, ground water rises higher in the rock; in droughts it drops lower. Its lowest levels are rarely below the valley bottoms of nearby perennial streams. Under divides, between such stream valleys, the upper limit of the saturated zone is higher, consequently, there is a slope to the water table comparable in direction to, but less than, the slopes of the land surface above (Fig. 1). The greatest seasonal fluctuation of the water table is under the hills—the slope becomes flatter during droughts. If no rain should fall in many months, the "hill" of saturation would completely flatten out. Fig. 1. Block Diagram Showing Relation of Water Table to Topography E. H. Woolrych, del. This lowering of the upper surface of the zone of saturation is due to lateral migration of the ground water down its slope toward and into the adjacent valleys where springs and seepages constitute its escape to the surface. Thus, we know that rain water entering the ground on the uplands goes downward as directly as possible until it reaches the top of the saturated zone, and that in the upper few feet of this zone the direction
8 Missouri Geological Survey and Water Resources of movement then becomes much more lateral, though there is still a downward flow. For a long time, geologists have held that this downward movement of the ground water in search of the water table is responsible for cave-making, and that caves are made in this upper zone (the vadose zone), or are developed within the horizon of fluctuating water table levels. This view considers that both air and water are in the cave from time to time while the cave is being dissolved out, and that caves with a stream are growing under present conditions. While many caves are, or have been, enlarged either by solutional attack of such descending water or by cave streams flowing on the bottom—and some may have been made entirely by such mechanics and are still growing—most caves have features which cannot be thus explained. To understand the conditions and the time when most caves took origin, these features must be examined critically and with an open mind. The conclusion reached will be that most cave-making starts and progresses far in the saturated zone (the phreatic zone) below the water table. How, then, do such caves ever become drained so that we now can freely enter them? The answer is found in what occurred on the land surface while the subterranean work was going on. Every limestone or dolomite cave region with which the author is personally acquainted has been uplifted from a former lowland condition so recently that it still is an upland, in spite of the vigorous attack of the rejuvenated surface streams. In terms of the erosion cycle, these streams are fairly young as their high gradients and their steep-walled, relatively narrow valleys testify. Far in the geological future, they will reach their depth limit, retain just enough gradient to carry their loads, and will widen their valleys, while concurrent weathering, slope wash, gullying, and smaller rill work will gentile their divide slopes. Cliffs and outcropping rock ledges will disappear, the base-leveled gradients of the major streams will creep up the tributary creeks and finally up the wet weather rills as running water performs its allotted task—the piecemeal carrying away of the upland to the sea, the reduction of an upland of uplift to a lowland of erosion. The Ozark country, since its latest uplift, has not yet gone halfway through this erosion cycle. The region is now in its early maturity, but before the broad doming occurred (Fig. 2), it was nearly a featureless lowland; its streams were old and sluggish, meandering in the great curves which characterize low-gradient rivers. To an amazing extent, the rejuvenated streams of today have trenched their new valleys along those old meandering courses and have thus preserved them (Fig. 3). This earlier lowland was itself the product of a cycle of erosion which essentially ran its full course from youth to old age. Hundreds of feet of stratified rock which had once overlain southern Missouri are known to have been eroded away in the making of this pre-dome lowland. It was, in the parlance of the geologist, a peneplain. Many square miles of that gently rolling oldland still survive in the "prairies" on the divide between the north and south-flowing streams of the plateau traversed.
Caves of Missouri 9 by U. S. Highway 66 and the Frisco Railroad between St. Louis and the Kansas state line. It is known as the Ozark peneplain and the Springfield plateau. In the central part of the Ozark dome, the peneplain was lifted probably more than a thousand feet. The south-flowing rivers with their Fig. 2. Generalized Contour Map of the Ozark Dome, Missouri After Marbut, 1896. Listen Neely, del. more direct courses to the Gulf of Mexico acquired higher gradients than the north-flowing streams whose water, after entering the Missouri River had to backtrack down the Mississippi a few hundred miles farther to reach the sea. Consequently, the southern slope of the dome is far more rugged, has many more valleys, has deeper valleys and swifter streams, and has almost no broad upland remnants of the peneplain left. Let us again ask the question: How could caves, situated below the water table and made under phreatic conditions of complete water-filling, ever become drained so that we today can explore them? The answer is that the deep-cut stream valleys of the present cycle of erosion now in its early maturity have lowered the water table. In other words,
The first challenge of the earlier idea that caves are the product of descending vadose water or of lateral movement of the water-table water came from America's most distinguished student of land forms and erosional processes, William Morris Davis. He raised the challenge when he was more than 80 years old - well past the age when underground exploration is advisable. Davis, therefore, read almost everything ever printed in English about caves. He studied such cave maps, cross sections, and diagrams as appeared worthy of attention. Through all this source material ran the concept which he was to challenge: that caves are dissolved out above the phreatic or completely saturated zone. When he had marshalled all the information, he probably knew more.
Caves of Missouri 11 Fig. 4. Diagram to Show Lowering of Water Table by Deepening of Surface Valleys E. H. Woolrych, del. about the subject of caves than any author in his bibliography of 98 titles. His paper, The Origin of Limestone Caverns, (1930, pp. 475-628) is a masterly, deductive study. In it, he argues: (1) that cave patterns, cave features, and cave relations to the overlying topography all point to an origin in the phreatic zone; (2) that surface stream entrenchment subsequently drains them; and (3) that vadose water dripping into them or flowing along their floors does more to destroy than to enlarge them. He termed his scheme two-cycle; the caves being formed deep below the land surface during the first cycle, and then being drained and exposed in the later cycle. According to this view, there are two epochs in the history of a cave: the first consists of solutional excavation, and the second, of depositional replenishment by dripstone and other secondary limestone deposits. Davis set up his theory and then made a searching analysis of what caves should be like if dissolved out under his imposed conditions. He sought in the literature for descriptions of such features, regardless of any author's interpretation of their meaning. He was severely limited because many things were inadequately described, and others, that should exist if he were right, were not reported at all. It has been the writer's privilege to do what Davis could not do, namely, to go into caves in search of criteria overlooked by earlier students, to find an array of features which support the master physiographer's conviction, and to distinguish among them the solutional features later superposed by vadose water on the phreatic cave forms. Much of this work has been done in the Ozark country of Missouri and adjacent Arkansas. The author's privilege has been to attack the cave problem inductively and to collect new evidence by which the rival interpretations could be tested. In so doing, he has come to an almost complete acceptance of the Davisian theory. In addition, a third epoch in cave history has come to light. The record of this epoch had been overlooked by previous observers and its place in the theoretical scheme had not been realized by Davis. This is the epoch of cave-filling with very fine textured red clay. It is recorded in the majority of the life histories of Ozark
12 Missouri Geological Survey and Water Resources caves and occurred after the original, phreatic, solutional cave-making was complete, but before the later vadose alterations were begun. Indeed, much of this later effect of water has been simply to remove the red clay, to reopen large portions of earlier caves, and to cause the first air-filling they have ever experienced. Many caves of the writer's experience in regions other than the Ozarks also record a time when phreatic chambers were filled with red clay and a later time when vadose water entered, eroded the clay, locally dissolved more bed rock, and initiated the deposition of the familiar cave "formations" of secondary limestone. This complete record is often lacking, however, under karst topographies where numerous sinking creeks and lost rivers promptly carry a large proportion of the rainfall directly into the caves, cleaning out the clay fill and destroying most of the phreatic solutional features. The complete record may also be lacking where shale and sandstone formations once overlay the cave region. Clay or mud deposits in such caves are gritty, may have inter-bedded sand and gravel layers, and may contain embedded flowstone and dripstone. Exceptionally, this clay of a later episode may also contain pebbly chunks of the true phreatic red clay, thus recording the former presence of the red clay and the manner of its destruction. This sequence of underground events in Ozark cave histories is paralleled by another sequence above ground. As in all regions where the writer has found clay-filled phreatic caves, the Ozark country is an uplifted old land surface (peneplain) undergoing dissection in a new cycle of erosion. In this fact, there is a suggestion of causal relations; a suggestion which becomes conviction when the following item is considered. Any erosional, old land surface development under a humid climate on limestone or dolomite must carry a deep mantle of insoluble residue of weathered material such as chert gravel, sand, and clay which the aged and low-gradient streams are unable to carry away. A decrease of ground water circulation coincides with the decreased vigor of the surface water movement, the common cause being the low relief and very gentle slopes of the land surface. Very fine-textured clay will remain suspended in water indefinitely with only a minimum of current or turbulence. Therefore, the clay fraction of a residual soil may be expected to migrate downward along joint planes and cracks almost as a part of the descending rain and surface water. It should be able to go almost anywhere in the saturated rock that water can go. Thus, reaching the deep caves formed by earlier and more vigorous phreatic circulation and finding them filled with almost motionless water, this clay should slowly settle. Given time enough after the oldland is well developed, these caves should become filled with a smooth, unctuous, tallow-like clay, the deep red color of which is no surprise because clay soils developed under a forest cover in a warm, humid climate (pedalfer soils) are characteristically a strong red in color. Most of the deep soil mantle of the Ozark peneplain has, of course, gone to the sea during the vigorous attack of the second cycle of erosion.
Caves of Missouri 13 on the Ozark uplift, but some soil still remains on some of the upland prairies. Accumulations of the very finest materials filtered down through the roof rock still linger in the caves. CAVE PATTERNS A part of this study is concerned with the depiction on maps of ground plans of caves. A few of the caves have been contoured to show the significant features of the floors, walls, and ceilings. A review of the maps shows that these caves have lengths which are hundreds of times their widths and heights. Cave chambers are linear. Even the most capacious are more like great corridors or hallways than rooms. Most caves also have branches or cross passages, and because of this there may be devised a classification of their ground plan patterns into two categories: a dendritic pattern and a network pattern. The dendritic, or tree-like, pattern resembles the ordinary surface drainage system of small valleys which converge and join to make larger ones. The network pattern has no resemblance whatever to any surface water-course system, for in it the passages run in two or more subparallel sets which cross each other like avenues, streets, and alleys of a city. The water in them moves as it does in the water mains under those streets; toward any open faucet or outlet in the system. Two structures which exist in the bedrock before cave-making begins are responsible in large part for these two patterns. One structure is the bedding or stratification which is a succession of layers made when calcareous mud was deposited in a shallow sea of exceedingly ancient time. Throughout most of Missouri, this stratification is so nearly horizontal that in most exposures the eye does not detect any deformation produced by earth movements (Fig. 5). The other structure is jointing. Shrinkage in the rock-making materials as they become consolidated, strains produced by earth movements after consolidation, and perhaps other causes make very obvious, nearly vertical, plane partings in dolomites and limestones. These partings are usually in two or three sets with all the joints of one set being semiparallel, but with different sets crossing each other at high angles. Both stratification and jointing provide initial water passages for gravity to move rain water downward and laterally. Where jointing is inadequately developed, the bedding plane passages become the water routes, and the long, sinuous, dendritic cave pattern is developed. Where jointing is dominant, the city street, network pattern characterizes the subsequent cave growth. Most common is a combination of the two structures; a bedding-determined main passage whose turns and bends are controlled by joints. Instead of a smoothy sinuous ground plan for the dominant
Many caves have fairly sharp turns and long straight stretches between the turns. Many caves have two or more imperfectly developed and imperfectly separated stories or levels. An interpretation of two story caves—one which Davis believed erroneous—was that they record different successive levels in the deepening of the outside valley and, therefore, are successive in development; the highest being oldest, and the lowest being youngest and still growing if conditions are favorable. The author is convinced that Davis was right in his skepticism, and that the entire system in three dimensions is developed simultaneously below the water table of its time. He allows for a succession only during the third epoch, when the vadose water is discovering phreatic passages and modifying them in its own ways. Then, as valley deepening progresses, these "levels" might be successively encountered, occupied, and then abandoned. SOLUTIONAL FEATURES The general theory of cave origins has now been outlined. Readers demanding evidence, not the word of authority, probably have been wondering just what those cave features are which deny the validity of the vadose theory and are explicable only by the phreatic theory. Based on a study of more than 100 caves in 15 states, the writer (1942, pp. 675-811) published a description and an interpretation of seven
Caves of Missouri 15 different, repetitive features which he considered to be criteria for establishing the phreatic origin of caves having those features. At least two more have been discovered since then. Six of these features have been found in Missouri caves. The 1942 study also contained a description of five different solutional features which can be ascribed only to the latest or vadose epoch of cave history. The argument for phreatic origin also involves the relation of the cave system to the overlying stream-eroded topography, and in itself is believed to be unchallengeable. Subterranean vadose streams with air above them and with their water flowing continuously downgrade are designated as free-surface cave streams. The Missouri cave forms and patterns believed to be formed under phreatic conditions and not by such subterranean streams are as follows: 1. Spongework 2. Wall and ceiling pockets 3. Bedding and joint plane anastomoses 4. Joint-determined wall and ceiling cavities 5. Continuous rock spans across cave chambers 6. Network patterns The forms later superposed by free-surface cave streams on existing phreatic caves are as follows: 1. Incised meanders in cave walls 2. Horizontal grooves in cave walls 3. Dome pits 4. Pendants 5. Ceiling channels PHREATIC SOLUTIONAL FEATURES Spongework.-No zoologist will like the use of this term to describe any cave feature for there are no definite incurrent and ex-current canals in the complex. Nor is the term "honeycomb" any more applicable. To the average observer, however, both terms are sufficiently definite. Many walls and ceilings of cave chambers have a complicated pattern of minor cavities and separating partitions, some of which possess the greatest imaginable complexity of shapes and orientations. The pattern is referred to as spongework. If connections exist back in the rock between the cavities, one may insert a finger or an arm through some of them, or simply shine the beam of a flashlight through (Fig. 83). The feature is common in dolomite caves, but it is rather rare in limestone caves. Specific explanation can go no further here than to say that the solubility of the rock is slightly variable so that it yields differentially when submerged in ground water. Because many dolomites were originally limestones which were later altered by a variable amount of replacement of calcium by magnesium, the variable solubility recorded by spongework may be the result of
16 Missouri Geological Survey and Water Resources slight variations in the proportions of calcium and magnesium in the formations. Clearly, the rock in some caves has been irregularly "eaten away". The cavities indicate no differential current attack. Their occurrence on ceilings, where they clearly are upward continuations of wall spongework, can have no explanation other than that the caves were full of water at all times during their formation, and that the ceilings suffered perhaps as much solution as the walls. In common with all types of ceiling solution cavities, the pits bear records of local, maximum solution. If one wishes to explain them as due to ceiling attack during flood stages of a vadose stream—for such streams do temporarily flood some chambers to the very ceiling—he has to allow a minimum of time for maximum solution, and he must dispose of the air inevitably trapped by the rising water before any "up-deepening" can begin. All such ceiling solution cavities are far more satisfactorily explained as first-epoch features.

Wall and ceiling pockets.—Pockets are larger than spongework cavities and commonly are separated by stretches of unaffected wall or ceiling (Fig. 163). Sizes may vary considerably among neighboring pockets. In outline, they are rudely circular with a rounded, kettle-like bottom. They may be deeper than wide, and nothing shows in the bedrock to indicate why solution penetrated so deeply. In cave quarrying for human passage, spongework has been shown to exist back in the rock beyond reach of probing, but wall and ceiling pockets have only solid limestone or dolomite back of them. There are probably more such pockets in the ceilings of Missouri caves than in the walls, though the preponderance runs the other way if all caves in the writer's experience be considered. An attractive idea regarding their origin is that they record eddies or whirlpools, and that they, therefore, result from differential attack rather than from differential yielding to a uniform attack. There is no accompanying evidence of current, however, and it is very difficult to see how those, deeper than wide could thus have been made, even if it is gratuitously assumed that an adequate current and a local cause for a persisting eddy existed. Bedding and joint plane anastomoses.—Anastomoses are systems of minor, curvilinear, tube-like, solution cavities lying in a plane and making an intricate pattern with their crooked courses and repeated intersections (Fig. 162). They are essentially linear units which occur along bedding planes and joint planes, are rarely seen except in cross section, and are seldom large enough to crawl into. In Mammoth Cave, Kentucky, where they are common, their cross sectional openings in the cave walls have been termed "pigeon holes" and "post office boxes". They record an incomplete development of what would have become low-ceilinged, tabular cave openings along bedding planes if solution had continued to widen them until the separating partitions had all been removed. Since joint plane anastomoses stand on edge, the idea of a free-surface cave stream making them is purely fanciful.
Caves of Missouri 17 The bedding plane anastomoses are not so easily dismissed as wholly phreatic. It can be said, however, that no free-surface cave streams, which now are using or clearly have used horizontal slots, have made minor anastomosing systems. The anastomoses are more closely akin to spongework, which certainly is not an aggregate of small, current-determined channel ways. Joint-determined wall and ceiling cavities.—The walls and ceilings of many cave chambers have deep, narrow, vertical slots dissolved out along the trace of a joint (Fig. 135). Some of the slots in the ceilings extend many feet up into the roof rock, but they generally taper out within reach of spotlight illumination. In such cases, the differential solution is due to guidance by a joint crack. In most slots, it is clear that the dissolving water penetrated upward from the larger chamber and did not enter the cave circulation by descending along the joint, thus indicating that only the phreatic theory can explain their development. Continuous rock spans across cave chambers.—Such spans may be natural bridges if approximately horizontal (Fig. 58), or partitions and pillars if nearly or quite vertical (Fig. 73). The determining structures are the bedding planes and joints of the strata. The bridges represent less soluble layers, and the partitions and pillars are commonly bounded by two closely spaced parallel joints. A down-cutting, free-surface cave stream would not be likely to leave rock bridges across its subterranean valley, or split or shift in such a fashion as to leave residual partitions or pillars in its course. Such features of cave architecture are probably all of phreatic origin; the two stories separated by the bridge and the two parallel chambers on either side of a partition being contemporaneous in their development. Network patterns.—Network patterns are referred without any hesitation to solution along controlling joints in completely saturated rock. This is very clear indeed in those caves where all the openings along one set of joints are capacious or high, or both, and the openings along a cross set are all narrow or low, or both (Figs. 20 and 72). The difference in such cases is clearly due to the greater original development of one set of joints over another. In some caves, widening of the joint chambers has gone so far that the "blocks", bounded by "streets" and "avenues", have been narrowed down to squat thick pillars and have even been completely severed to leave pedestals at floor level and upside-down replicas hanging from the ceiling.

VADOSE SOLUTIONAL FEATURES Incised meanders in cave walls.—The fairly uniform walls of many cave chambers have niches cut back into them. These niches begin some feet above the floor and in descending and enlarging back
18 Missouri Geological Survey and Water Resources into the wall they describe a rude arc or triangle which encloses a central rock core that is a part of the wall and is separated from the rest of the wall only by the curious niche (Fig. 6). This is one's first observation. The next thing one discovers is that the niche spreads farther back into the wall, just as it spreads lower down along the face of the wall. The niche or cavity is a generalized half cone in three dimensions, and so is the enclosed core of rock. Some niches are large enough to walk through; one leaves the main chamber only to re-enter it at the Fig. 6. Diagram of a Wall-Incised Meander Niche Diagrammatic depiction of a free-surface cave stream (A) in a half-cone meander-wall niche (B). The original phreatic chamber wall (E) was first incised by the meander when the clay floor (C) had been lowered only to the top of the shaded half-cone "island" (D). While the meander has been enlarging and deepening back in the wall, the clay fill has been lowered to the surface shown. E. H. Woolrych, del. other end of the half circle. The writer has seen more of these striking half-cone side passages in Missouri caves than in all the other caves of his experience. Although an explanation for them was first devised for a Wisconsin cave, it has remained for two Missouri caves (Ozark Caverns in Camden County and Smittle Cave in Wright County) to show the causal mechanism in operation and to prove that the theory is correct. The cause is a vadose cave stream meandering on a cave floor.
Caves of Missouri 19 In both these caves, the streams are trenching into red clay de- posits which filled the caverns well up toward the ceilings. When the episode of deposition of the fill ended and that of erosion began, the streams were flowing on the very top of the fill, close to, but not against the ceilings. The stream gradients were low; currents slow. Almost universally such streams develop sinuous courses, typified by the Meander River of Asia Minor. Hence the broad, swinging curves of any such stream channels are called meanders, and they inevitably come into contact on the outside of the meander curves with the rock walls. There they do the expectable thing; niche into the walls. Because they deepen their valleys in the cave floors and because meanders tend to enlarge as the current swings most strongly to the outside of the curves, the streams have remained in their incipient wall niches and have enlarged them as they have deepened their channels. In this way, imperfect half cones of wall rock have been isolated, becoming half-cone islands encircled on the back side by the meander niches and cliffed on the side toward the cave. The examples now forming fall short of the size and perfection of the dozens of abandoned ones known. Some of these still carry on their floors the gravel that the vanished streams were transporting when they ceased to flow or found other routes. One Missouri cave, Railroad Cave in Pulaski County, has no less than 29 such niches alternating from side to side through the length of the main chamber. It is perfectly obvious that in Smittle Cave and in Ozark Caverns capacious chambers had been made before the red clay was deposited. It is also clear that the present streams are removing that clay and in so doing are making vadose additions of this character to the total capacity of the caves. Horizontal grooves in cave walls.-Many a cave stream disap- pears into the bottom of a wall and reappears again farther along. Closer inspection shows that in such places it is flowing in a very low-ceilinged, horizontal slot which, like a wall-incised meander niche, is an addition to the total volume of the cave, but is quite out of harmony with the other shapes and proportions of the chamber. When a vadose stream abandons its route, the place it occupied will then con- stitute a horizontal groove or niche—a characteristic very common in Missouri caves—or it may hold its course while deepening occurs and so pass into the wall-incised meander niche type of vadose stream record. Dome pits.—Some cave walls have most strikingly carved pilasters and vertical moldings and groovings. The larger features are covered with a finer detail of similar vertical markings. In ground plan, they are likely to be curved; even circular (Figs. 7 and 8). Though verti- cal, their detail emphatically is not joint controlled. They are so clearly the solutional work of a descending film or sheet of water that their origin is apparent before any are ever found with the water flowing down them. Missouri contains only one example of this feature which is now growing in Meramec Caverns, Franklin County. The feature is in a side chamber and is difficult to reach. Kentucky and Tennessee
Fig. 7. Diagrams to Show Origin of Dome Pits by Coring Mechanism Fig. 7a shows a horizontal bedding plane anastomosis through which vadose water flows by various routes from the upper to the lower edge of the diagram. The water table has been greatly lowered in the rock since the anastomosis was made, but infiltrating water from the surface finds the network of little channels and uses them. At X, the vadose water discovers a joint by which it can drop farther down toward the water table. At the bottom of this drop, one must visualize a capacious chamber not shown in the set of diagrams. Falling along the joint crack, the water starts enlarging the crack for the full depth of its fall because there are two anastomosing passages converging here. The enlargement follows back up each passage. Fig. 7b shows that the resulting slots have become compound and that erosion has followed back up three of the more active little channels. Fig. 7c shows that two of these channels have so closely approached each other that a column of rock, Block I, has become almost completely separated. Because it is unsupported below, its weight causes it to fall into the capacious
Caves of Missouri 21 chamber below where it is exposed to both falling and flowing water and where it wastes away. Block II in figure 7c is almost ready to join it. Figure 7d shows that the second block has fallen and that the third is nearly ready to go. E. H. Woolrych, del. Fig. 8. Block Diagram to Show Origin of Dome Pits by Coring Mechanism The diagram shows a part of the dome pit cutting through an older linear chamber, one wall of which has been removed. The larger chamber which received the fallen blocks is lower than the bottom of the diagram. This coring mechanism is amply attested in many Kentucky and Tennessee caves by the lingering remnants of fallen cores at the bottoms of dome pits. Thus far, only one Missouri cave (Meramec Caverns) has been found with such fallen core blocks. It is in "Mud Alley", nearly 1000 feet back from the "Jungle Room". E. H. Woolrych, del.
Missouri Geological Survey and Water Resources contain many examples. In Mammoth and other caves, descending water may cling to the vertically grooved surfaces all the way down. Inspection of the top of a dome pit will show that the descending water arrives, or arrived, by way of a bedding plane anastomosis, tubular passages belonging to an older phreatic system and later used by vadose discharge. Where leakage occurs by direct descent from such an anastomosis to lower escape routes, the resulting vertically-walled, vertically sculptured cavity is a simon-pure, vadose feature. These groovings dissolved by descending vadose water deserve a name. They are very similar to the grooves and steep little channel ways made by rain water on some exposed limestone surfaces and are given the same name; lacies (Fig. 148). Lacies-marked cave walls are singularly like stonework which is vertically carved by artisans, and where cave chambers possess these regular and uniformly proportioned curves, combined with a steeply pitched Gothic arch at the top of a joint slot, they almost inevitably are named "The Cathedral". Alcoves and "chapels" which lead off from the "nave" are provided by the recessed walls where greater solution has occurred. The name of dome pit is best appreciated if one views such a vertically-elongated, vadose solution cavity from mid-height. The dome is the part above; the pit is below. It should be obvious that an older cavity-dissolved out under different conditions of ground water work was already here to provide for the fall that etched and grooved the walls. Pendants.-The name pendant is given to a native bedrock remnant which hangs from a ceiling or the flat bottom of an overhanging ledge. Pendants are almost invariably found in groups, and closely associated ones commonly have similar lengths (Fig. 140). They usually grade laterally into undifferentiated ceiling surfaces. They are not common in Missouri caves, but where they are found, they show accessory evidence of free-surface cave stream origin. Sometimes a stream is found still flowing close beneath them and flooding them in high-water stages—their time of growth. More commonly, remnants of a bed of old stream gravel, close beneath them, record their method of origin. Pendants are solutional remnants of once lower and more uniform ceilings. Ceiling channels.—No more extraordinary feature of caves may be found than the winding, channel-like, upside-down troughs or deep grooves incised into cave ceilings (Fig. 117). Though they are rare, such forms exist, and they persist for many feet along some ceilings. It is evident that a particular set of conditions existed in those caves having them. If the caves were turned upside-down, the ceilings becoming floors, no one would hesitate to call the incised grooves channels, and no one would doubt that they were younger than the associated spongework or solution pockets and cavities. It is because they are upside-down that the channel theory meets skepticism—nor can that doubt ever be allayed by pointing to the proposed mechanism at work.
Caves of Missouri 23 No cave can be entered when ceiling channels are being made, because the caves are then filled with debris and water, and there is no possibility of ever finding an example in the process of growth. Missouri caves afford at least five cases of ceiling channels. Previous to this study, the writer had found but one good example (Endless Caverns, Virginia) among more than 100 caves examined. Endless Caverns, however, has a feature not seen in any of the Missouri examples; the curves of the channel become larger with increasing depth up, just as the half cone wall niches do with increasing depth down. This stream meander characteristic, together with the known, former, filled condition of the cave, became the basis for the explanation here advanced. In whatever manner a cave is filled to the ceiling with clay, a localized stream came to flow on the top of the fill. You have already been told that such a stream erodes the fill of a cave, removes it, and allows air and humans to enter. Such was the case in Endless Caverns, but at the initiation of its flow, the stream was overburdened with clay and sand which it could not immediately remove and which, by deposition in the bottom of the channel, decreased the stream depth and persistently kept the water against the ceiling. The limestone or dolomite ceiling yielded to solution, and a pattern became etched out to fit the stream windings. As more sandy detritus arrived and decreased the channel depth, more solution continued to etch more deeply up into the ceiling. Shortly, the stream was entirely out of the original cave; the detrital fill pushing it up and following it up. The final touch for the completion of the process was the enlarging of the curves as the up-deepening continued.

TOPOGRAPHIC RELATIONS OF CAVES In a general way, the longer linear caves of Missouri are oriented to lead ground water from beneath uplands to adjacent valleys. Some of them do. Many are dry-bottomed now, but they contain either old cave stream gravel on their floors, or meander niches and horizontal groovings in their walls. Others have no record of any solutional or depositional vadose stream work, and the only evidence that streams have ever used them is the head room they have above a red clay fill. One has only to note the clay remnants left in the spongework or on the shelvings in the very top of such caves to be convinced that the clay once filled even their ceiling pockets and cavities. However, clay may go out of a cave by slipping down into slump pits which lead to lower and unenterable water courses. In such places, the vadose stream is beneath, perhaps tunneling under, the clay in the still-filled part; perhaps flowing in a lower chamber. It may be confidently said, therefore, that most caves have possessed free-surface, ground water streams which drained from beneath nearby hill lands toward lower elevations. The simple explanation is,
24 Missouri Geological Survey and Water Resources of course, that those streams made those caves, but when details of the topographic relations of these caves are sought, this explanation be- comes impossible for most of them. In some instances, the free-surface cave streams are surface streams detoured to underground routes by collapse of cave roofs immediately beneath their valley bottoms. They are lost rivers or sinking creeks which have discovered already existing caves that offered shorter, steeper routes to the main rivers of the region. Their water usually reappears in resurgences which are as turbid and as fluctuating in volume as the streams above the under- ground detours. The valleys they formerly used, downstream from the sinkholes, are still there, but are empty. The underground courses of the detoured streams are known, in several places, to pass under a hill; a divide of the surface drainage. Most of the subterranean routes examined possess phreatic features which vadose water of the present cycle of erosion is engaged in destroying. Other caves with vadose streams discharge their water from es- sentially rock-bottomed courses of low gradient out of a mouth situated well above the nearby, surface valley floors. The water flows out and abruptly descends in active cascades over the steep, outside slopes. The marked break in gradient is clear evidence that the cave streams are simply using routes they have found, that they are not deepening the caves, and that they are hanging up on the sides of the surface stream valleys. Obviously, such streams are not making the caves they occupy. A few dry caves have two hillside entrances at opposite ends of their linear chambers. A person may go through a hill in traversing such caves. Surely the rain falling on these hills and becoming the ground water under them never made such caves. Some caves which lie under ridges are elongated with the lengths of the ridges and are nearly as long as the ridges themselves. On the other hand, vadose water under a hill seeks the shortest way out and follows the steepest slope of the water table. It is not known whether the parallelism of the caves and ridges is coincidental or whether there is some undiscovered cause for the relationship, but one must be con- vinced that the caves are older than the valleys on either side; the deepening of which has made the ridges. Some caves, high in river cliffs, but with fairly level floors have several doors or windows which open out above the tops of the trees growing on the lower bluffs. The chamber walls and ceilings have all the spongework, pockets, and cavities that only phreatic caves may have. There may be no vadose alterations whatsoever. The rivers in making their valleys have cut through cave systems that were al- ready in existence. Sometimes vadose water will enter a cave from a small passage, not at an end, but on a side, and this water will use only a limited portion of the cave length; shortly finding egress through another minor passage. In many cases, the course of the vadose water cannot be followed
Caves of Missouri 25 either upstream from its entrance into a cave or downstream along its exit. It is presumably moving in response to the urge of gravity on the "hill" of ground water under the topographic hill. The large chamber it crosses at midlength was there first, was not satisfactorily oriented for the needs of the vadose discharge, and is used only in part. The older and larger cave does not conform to the demands for ground water flow under the present topography. To make the argument complete a situation is needed where a sur- face stream in deepening its valley has cut a cave system in two, leaving adequate remnants on either side to establish the fact. Missouri provides two excellent examples: the Bear Caves of Ozark County and the twin caves, Cameron and Mark Twain, of Marion County. In both, the cave ground plans are complex networks; patterns which have already been shown to be impossible for vadose streams to make.

Theoretically, one is justified in raising the question of abundance of caves. If local ground water escape be argued as the cave maker, why should some hills have elaborate and capacious caves, while all other hills in the same rock, under the same rainfall, and with the same relief lack them entirely? The obvious answer is that caves are not the product of present cycle ground water. It has already been said that, in a general way, the longer linear caves of Missouri are oriented to lead ground water from beneath uplands to adjacent valleys. The reader will also recall an earlier statement, to the effect that the streams on the old peneplain surface, rejuvenated by the Ozark dome-making, entrenched themselves largely along the meandering courses they had already developed. If these statements are correct, it follows that the linear caves which lead to present deep valleys formerly led to the shallow peneplain valleys. This idea may seem to be a satisfactory explanation until it is realized that the peneplain valley bottoms lay from 100 to more than 300 feet higher than the caves which, by the author's preferred theory, were contemporaneous with, and discharging to those valleys. It is now time to inquire into the nature of water flow in the phreatic zone below the water table. This inquiry must be theoretical, for direct observations on the subject are meager. Conceive of the Ozark region during maturity of the earlier cycle of erosion. The topography was much like that of today and was drawn on the same lineaments. There were hill lands standing where our upland prairies now lie, but they were held up by rock since eroded away. There were capacious valleys separating the hills of that time and strikingly recorded in the great entrenched meanders of today's rivers. Ground water stood higher under those hills than under the adjacent valleys. Visualized as columns of water above any selected level, there were higher columns under the hills and, therefore, greater pressure at a selected depth. If bedding and joint plane leakages were available, there must have been lateral movement at depth toward the valleys. Because the water columns under the valleys were shorter, there must have been an upward component to the movement through
26 Missouri Geological Survey and Water Resources available openings. Thus, throughout the entire mass of hill rock and valley bottom rock there was a graded series of imaginary columns; the water in the higher ones under the hills forcing the water at depth to rise in the lowest ones-curved paths were made up of intersecting, vertical joint cracks and horizontal bedding planes. This concept of the movement of ground water along curved paths-water which descends from beneath the hilltops to depths greater than adjacent valley bottoms and then rises to the valley bottoms for surface discharge-appears to date back to F. H. King (1899, pp. 59-294). Although not accepted by all geologists, it has been approved and used by Slichter (1902, p. 29), Tolman (1937, p. 224), and Hubbert (1940, p. 895) in their ground water studies. Davis also accepted it, but he modified the curved paths of the diagrammatic depiction in order to fit the conditions to limestone terranes. He depicted the paths as a series of steps; the treads were the bedding plane partings, and the risers the joint cracks. However, he was able to find no more facts bearing on the concept than King had 30 years before. Some inferences can now be made. Most of the resultant features are demonstrated in Missouri caves, and from them can be drawn the following conclusions: (1) that the caves pre-date the present cycle of erosion; (2) that there must have been a time for the deposition of the red clay fill, and that the late (peneplanation) stages of the preceding cycle of erosion constituted the only logical time for weathering to prepare the clay for its migration down into the caves; (3) that existing caves are prevalingly oriented to lead from the earlier uplands toward their contemporaneous lowlands; and (4) that the caves certainly were situated far below the vadose level of circulation, under the older land surface. If these four are trustworthy conclusions, then the King concept of deep-seated circulation must be accepted to account for the ground water movement which made the caves leading toward, but lying lower than the Ozark valley floors of that time. The accompanying diagrams (Figs. 9, 10, and 11) are necessarily idealized. They assume the absence of impervious beds. They also assume that the route of the return, upward component of the phreatic circulation has been destroyed by valley making in the present cycle of erosion, and that during the period of cave-making, springs existed in the valley bottoms. The curved courses through intersecting joints and bedding planes are intended only to show the direction of early circulation if all partings were equally permeable. As soon as solution begins, any original approximation of homogeneity must disappear. Routes with favoring permeability, solubility, and water supply develop earlier, obtain precedence, and eventually become linear caves. The vertical element in the suggested longitudinal sections (Figs. 9 to 11) may look disproportionately large because of the vertical exaggeration. When one has seen some of these joint-determined, cave ceiling cavities, he will realize why the course is drawn as great steps, down and up again, for the full depth of the hydraulic circulation. The diagrams
Caves of Missouri 27 Column Column 2 Fig. 9. Diagram Showing Conditions for Origin of a Phreatic Cave Liston Neely, del. Fig. 10. Diagram Showing Conditions for Deposition of a Red Clay Cave Filling The water table almost coincides with the surface of the land. Subterranean circulation is almost at a standstill, and the cave becomes filled with red clay from the deep residual soil. Liston Neely, del. Fig. 11. Diagram Showing Conditions Under Which a Phreatic Cave May Become Transferred to the Vadose Zone Early maturity of the present erosion cycle has been attained. The cave is now entirely in the vadose zone; may have a free-surface stream on its floor, dripstone and flowstone deposits, and sinkholes in its roof. It very probably still contains remnants of the red clay fill. Liston Neely, del.
Missouri Geological Survey and Water Resources might have included other possible cave routes, above and below the one shown. The attentive reader may have by this time raised a particular question regarding the preferred theory of this study. If so, he is not the first. Davis was a bit worried about the same thing. He also asked: Why couldn't this phreatic circulation, with consequent cave-making at depth, occur during the early stages of the present cycle? The rock, 100 feet to 300 feet below the Ozark peneplain, must have remained under phreatic conditions until the modern stream valleys had been deepened enough to drain it. According to the concept that has been set up, phreatic circulation must have prevailed for a long time after the Ozark uplift. Why not date the caves as early-present cycle? It is believed that the answer to that challenge is now known, and that the Davis concept stands. The answer is the almost universal red clay filling of these caves. There is no time in the history of the caves of an entire region when the solution work can stop and the widespread filling episode can occur, except when the vigor of movement becomes almost nil and the caves are full of standing water. During the youth and maturity of the present erosion cycle, no such time occurs. There is no time except that of peneplanation for dating the red clay. There is no time except that of peneplanation for dating the red clay. There is no time except that of peneplanation for dating the red clay. Because the earlier cycle went all the way to that penultimate stage, it can be confidently stated that the once clay-filled caves are two-cycle caves, and that they date back to maturity and late maturity of an earlier cycle of erosion. Other caves of that generation, not yet reached by present valley trenching, are, therefore, still in the phreatic zone and are still growing. They feed the big Ozark springs. As trunk routes, they either never received a clay fill or they lost it all in their post-uplift vigor of flow. They might be considered as one-cycle caves.

CAVE "FORMATIONS" The term "formations" as applied to cave features is almost universally used to include all secondary calcium carbonate (lime) deposits, and it generally refers to forms. Geologically, it is not a satisfactory term because to geologists, formations are layered rock units that can be portrayed on a map. To a geologist, caves are dissolved out of rock formations, such as: the Eminence dolomite, the Gasconade dolomite, and the Burlington limestone. Most of the known bedrock formations of Missouri consist of many feet of sedimentary deposits: dolomites, limestones, sandstones, and shales. Their ages date back hundreds of millions of years. Their marine or freshwater origin, as well as their relative ages, are attested by their fossils. How trifling in comparison, are these very limited and very young (even still growing) cave deposits or "formations."
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A delicate balance exists between solution and deposition by ground water, and very minor changes in physical conditions will shift the action from one to the other. It is not yet possible to say just what changes in those conditions cause the reversal. The field of cave deposition is full of problems, some of which will be solved by observation, some by experimentation. Secondary lime deposits are made in three contrasted cave situations: in air, at the contact of air and water, and under water. Though the forms are varied in each, those of one category never grow in another situation. The cause for deposition cannot be the same in all three; probably not in any two. It may well be that two or more conditions acting in conjunction are necessary for some of the deposits to be developed. A common name for secondary limestone or calcium carbonate (CaCO₃) of cave deposits, where they are massive and of adequate translucency, is onyx, or better, cave onyx. True onyx is composed of chalcedony, a translucent, cryptocrystalline form of quartz (SiO₂). A piece of a stalactite, stalagmite, or flowstone when sectioned and polished shows translucency and banding and is commonly but incorrectly called "onyx". The term "Mexican Onyx" has been used for translucent calcium carbonate. Alabaster, which to the mineralogist is gypsum, a hydrous calcium sulphate (CaSO₄·2H₂O), is also incorrectly used as an alternative name for travertine or stalagmite material. Obviously these terms are loose ones and describe only that material which yields certain desired results when worked by an artificer. The cause generally accepted for deposits made in air is partial evaporation, whereby dripwater becomes saturated with calcium carbonate. Another cause for deposition of dripstone may be the loss of carbon dioxide gas (CO₂) from the water drops that hang on the ceiling of a cave or from the film of water on the floor. Carbon dioxide which is secured from the air and from organic material on the surface of the ground is dissolved in rain water which later becomes ground water. Its presence greatly increases the ability of the ground water to attack calcareous rock. If such water should become nearly saturated with calcium carbonate, loss of a portion of the gas on exposure in a cave would necessarily produce deposition. Deposition of secondary lime under water results from the saturation of the pool water or stream water and is followed by a reduction in some way of the solvent ability of the water. Even less than complete saturation may suffice, if there are crystalline aggregates already growing in the water. The air-water contact, especially along edges of pools where anchorage is afforded, is a favorite place for deposits whose forms are controlled by the horizontal contact of air with water. Excessively thin sheets of "lime ice" may also form in the surface film of standing water without reference to the margins of a pool. In flowing water, deposition may occur on the bottom and sides of a channel. However, the most common and most striking forms made
Missouri Geological Survey and Water Resources in water with a current are built where the stream surface is broken by a riffle. A dam may grow up, pooling the current upstream and making a cascade which breaks the water surface even more effectively.

Deposits Made In Air Stalactites.-The simplest form is the straw-like stalactite (Fig. 86). In size as well as in form, it is a pretty good imitation of a thick, straw stem that has a continuous tube throughout its length. A growing stalactite demonstrates that the diameter of the tube is the approximate diameter of a drop of water at cave temperatures. Deposition leaves a ring around the edge of a hanging drop. That drop, or the next drop, then hangs on the ring and the ring thus widens downward. With a continuance of this procedure, the tube results. All the drip water presumably comes down the inside. Should a film of water find its way down the outside of the tube, deposition from the film will thicken the walls. The highest and oldest part will have the greatest thickening, and the growing tip will be but little more than a tube. The central tube may or may not be clogged by later deposition. Thus, the common icicle- or carrot-shaped stalactite is made (Fig. 19). Outside overgrowth may develop some curious variants of the simple stalactite form. There is no specific explanation for those forms which are corrugated with horizontal ring-like ridges which alternate with ring-like grooves, nor is there an explanation for the bulbous growths that resemble rutabagas, sugar beets, or upside-down pineapples (Fig. 122). These forms hang by relatively slender stems, thicken greatly a little below the ceiling, then taper rather abruptly to terminal points. They may be nearly as thick as long, and they generally show a series of vertical ridgings that may result from the fusion of a cluster of once-separate, simple stalactites hanging from the thickened, shelf-like part just below the stem. Indeed, the lower ends of some carry independent, icicle-like stalactites. The radish- or turnip-shaped stalactite is clearly related to the sugar beet or rutabaga type. Crooked stalactites are a puzzle (Fig. 26). Why should any stalactite of normal size and proportions depart from a consistent pointing toward the center of the earth, as the law of gravity requires? Yet, one occasionally starts on the right road of stalactite life, only to develop later, into a crook! It may be alone in its perversity or a whole group may go crooked. Generally, only angular turns exist. One thinks of an air current persistently pushing the water drop a little out of center, but he abandons that theory when he finds all others on the same ceiling going straight, and he (and the writer) finds the biggest mystery in a group where everybody is a crook, but each in a different direction. Virtually all stalactites, overhanging the double-tracked part of the Chicago subway, depart slightly from verticality; their inclination...
Caves of Missouri conforming with the direction of traffic beneath them. A strong air current, produced by each train's passage, is the obvious explanation. Because the current dies away between trains, it can affect stalactite growth for only a small fraction of time. If the total amount of air flow was evenly distributed throughout the day, it is doubtful that any shifting of the drop of water and consequent inclination of the stalactite would result. Air currents in caves, which are at all comparable to those in the subway, require very special conditions and are exceedingly rare. None of the groups of bent cave stalactites, which the writer has seen, hang where cave "drafts" now occur. Stalactiflats.—Of the many terms coined by cave managements to describe their exhibits, this is one which, although a hybrid word of Latin and Saxon roots, deserves inclusion in the list of cave "formations". A stalactite, or a group of them, grows down to touch a flat-topped, detrital fill which is not far below the ceiling. The floor surrounding the place of contact becomes covered with a flowstone sheeting. This is composed of the excess lime which would otherwise have added to the length of the stalactite. Then changed conditions bring about the removal of the clay or other detrital matter, and the compound drip-stone and flowstone form may hang well above the subsequent cave floor; a flat horizontal plate held to the ceiling by slender, stone stem work (Fig. 53). "Draperies".—Another common pendant dripstone form is the "drape". It is blade-shaped and hangs in curves or convolutions or "folds". Some "drapes" clearly start as wing-like expansions of icicle stalactites, while their original forms persist and grow. A film of ceiling water descends on one side of the stalactite and builds a vertical ridge which is widest at the top. The water descends the hanging edge of the blade and adds to the width of the "drape", while the thickness remains the same. The "folds" record the irregular course of the water which hangs to the ceiling by adhesion and surface tension and forms a tiny localized water flow. Where the blade form is thin and the deposit is translucent, the successive additions may be seen by transmitted light and are strikingly brought out if slight differences in the amount of iron or manganese oxides were present at different times as impurities (Fig. 123). Some of these "drapes" become "flags" when the bands are parallel to the free edge of the "drape". Elsewhere, they resemble alternating strips of fat and lean in slices of bacon. Where thick and opaque, they become "tobacco leaves", and a chamber properly decorated with them is the "Tobacco Barn". This explanation will take care of most "drapes", growing or inactive, but the outstanding challenge to one's ingenuity in explaining dripstone forms, probably is in those "drapes" that develop spirals or coils at their lower extremities, thus departing from a precise following of any initially crooked ceiling course of the contributing water. The tip of one Missouri spiral "drape" makes no less than three complete
32 Missouri Geological Survey and Water Resources turns in a total diameter of not more than five inches (Fig. 43). Any explanation must take account of the fact that there are many spiral-tipped "drapes" in the cave containing this feature (Fairy Cave, Stone County), whereas, most caves have none with a terminal coil. Another challenge is the saw-toothed, growing margin of many "drapes" which are found in some caves. The "saw teeth" are actually a series of tiny cups (Fig. 44). The small zigzags in the internal structure of the "drape", seen by transmitted light, prove that the characteristic existed during the entire making of the "drape". Stalagmites.-Pendant dripstone is usually accompanied by a complementary upbuilding on the floor of cylindrical growths known as stalagmites. The simplest and most readily understandable combination is a stalagmite beneath a stalactite where excess drip water continues to deposit after it leaves the stalactite. A simple stalagmite tapers but little, if at all. It is of sturdier physique than its overhead neighbor. However, there are stalagmites without overhanging stalactites and there are stalactites without dripstone growth beneath them (Fig. 47). Stalagmites vary less than do stalactites. In some caves, however, all the stalagmites are excessively thick; in others, moderately slender. In some, the stalagmite growths are compound, generally like crude candelabra or thick-stemmed, leafless cacti. The puzzle here is to account for the branch growths which, though vertical in themselves, are supported on arms which grow somewhat diagonally out of the main stem. Some stalagmites have small pits or craters in their tops. In places, it is certain that the drip water has stopped depositing and has begun redissolving. In other places, the pits look as though they are caused by splash, while growth continues uninterruptedly. Stalagmites develop compounded forms which are quite as complicated as stalactites. A favorite compound form is a kind of "Tower of Pisa" structure (Fig. 57) without the classical tilt of the original. The form consists of a series of terraces or shelves or "stories" with rows of stalagmitic and stalactitic columns connecting adjacent levels. No forms, comparable to the pendant "draperies", ever grow up from a cave floor. No stalagmite ever contains a central tube or ever tapers uniformly from base to tip. It was by this latter characteristic that the writer found stalactites which had been detached from a ceiling and "planted" upside down in the mud floor of a cave to supply a supposed need for stalagmites. Columns.-A downward growing stalactite may meet an upward growing stalagmite; or one may reach the floor, the other the ceiling. A column is the result. Some columns show the two component parts, even after union, by a number of characteristics. Others have so grown, after uniting, that they constitute columns of uniform exterior from top to bottom (Fig. 136). These columns may enlarge until they are exceedingly massive; being thicker than high.
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Stalagmitic domes.—The author hesitates to use the word dome, because caves contain domes of different origins. Stalagmites of thick, squat characteristics grade into stalagmitic domes which are fairly steeply sloped. They are better described as high, narrow cones of dripstone. If the growth is from a wall seep, the form is a half-dome. If there is an associated, flowstone dome, the growth invariably has a much lower slope, with a sharp break between the steep and the gentle slopes (Frontispiece).

Helictites.—From the most fragile and delicate of elongated, secondary growths of calcium carbonate (Fig. 121), helictites range to fairly thick, sturdy forms all of which are characteristically crooked in the extreme; crooked in every direction, and each one crooked according to its own whims. Though they may occur singly and alone, they usually form a literal tangle of ceiling and wall forms. The origin of helictites is obscure. Some contain a central capillary tube which may be probed with a hair—perhaps all did, originally. Laboratory experimentation with other substances much more soluble than calcium carbonate has produced helictite-like forms (Fig. 12) and has pointed to a possible method of helictite growth (Huff, 1940, pp. 641-659). At any rate, helictites are not true dripstone, for there never was enough water present for gravity to overcome capillary forces. In the laboratory experiments, fortuitous orientation of minute crystal additions at the ends of capillary tubes determined the exceedingly irregular, unpredictable turnings and twistings in each unit's growth. Helicites commonly appear to be later growths, encrusting and enveloping stalactites where the two are associated. They may become almost as bulky as the stalactite itself, forming projections that may resemble barbs on a straight, stone javelin.
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Crystal growths.-In a very few places, some Missouri caves have aggregates of exceedingly fine, needle-like crystals of calcium carbonate (Figs. 39 and 119). These crystals seem to grow in air, though they certainly are not the nature of dripstone. It seems that moisture in the native rock escapes by evaporation, and the crystals are of the nature of an efflorescence. In only one Missouri cave (Rice Cave, Jefferson County), have crystals of gypsum been found. The crystals are in two forms, and both are secondary deposits. One form is that of a rosette of radiating, blade-like crystals which have grown in a clay and silt deposit, chiefly at the contact of the deposit and the bedrock wall (Fig. 146). The other form is even more striking and is truly air-grown. It is a gypsum "flower", a crystalline aggregate whose component parts project from the wall rock and curve away from a central point or line, very much like the petals of an open flower corolla (Fig. 147). Each "petal" is composed of many closely crowded, long, and very slender, satin spar gypsum crystals. Apparently they grow from the base, and their curvature is due to unequal growth, larger in the center and least on the margins of the feeding crack in the wall rock. Huff (1940, pp. 641-659) has grown "flowers" of sodium thio-sulphate (Na2S2O3) from a solution which was allowed to evaporate in and through the pores of an unglazed porcelain plate. The analogy between his artificial product and the gypsum "flowers" of caves is very persuasive. The name, oulopholite has been used to identify such gypsum "flowers". "Crystal" caves which are actually geodes are rare. Only two Missouri caves of this character are known. Both were below the water table until mine pumping unwatered them. The formation of geodes requires cavities completely filled with water saturated with calcium carbonate or some other mineral. From the solutions grow the crystals that encrust the surrounding walls. Although most of Missouri's caves once were completely filled with water, that water remained in the dissolving phase throughout that part of their history. Deposition has occurred in them only locally, in time and place, during the present vadose epoch of cave destruction, and that deposition commonly has occurred in air instead of water. There is a real problem here. The statement made above, though true for the caves of Missouri and adjacent country, is not true for the caves of the Black Hills, South Dakota. Although the latter are solution-enlarged, joint and bedding plane cavities of phreatic origin, they have a spectacular development of crystalline lime on walls, ceilings, and floors. Furthermore, no evidence has yet been found in them for a red clay-filling episode. Deposits Made at the Air-Water Contact "Lily pads" and shelfstone.-A pool forms in a cave during its vadose history; dammed by rock falls or sinkhole debris or rim-
Caves of Missouri 35 stone growth. It exists long enough to leave a record in stone. Sometimes the rising pool partly drowns previously formed stalactites and stalagmites. These and the shoreline afford anchorage for deposits made from the pool water. Flat on top, conforming to the water surface, and rounded in outline, the deposits have a superficial resemblance which gives them their name, but they are not thin, floating, surface forms like lily pads. They extend down to the bottom of the pool as inverted cones or parts of cones and spread out on the surface only as the inconspicuous substratum grows (Fig. 106). Only the upper surface part grows at the air-water interface. Most of the bulk of a "lily pad" is a deposit made under water. Attaching themselves to partially submerged and older true dripstone forms, they constitute intriguing features after the pool has been drained and clearly record the level of the standing water. Their shapes and positions of attachment indicate the aptness of the general term shelf-stone. Calcite "ice".- There are not many caves that show this phenomenon of a coating of calcium carbonate on the surface of any of their pools. Only two caves in Missouri are known to contain this feature: Crystal Caverns in Barry County and Jacobs Cave in Morgan County. The "ice" is exceedingly thin. Although heavier than the water, it is held in position by surface tension. If touched the film is broken and the "ice" sinks to the bottom. Rimstone.- Streams commonly are engaged in deepening their channels or at least in keeping them open. Dam a stream and, all too often, it destroys that dam. Many cave streams are different; they frequently dam themselves. The dam grows by additions of calcium carbonate from the flowing water. The growth starts, apparently, where the flowing water surface is slightly riffled by some irregularity on the bottom. It soon grows into a wall across the stream and this accentuates the riffle. Additions are made to the upper edge, most extensively where the rippling is most marked; in other words, where the deepest discharge over the rim occurs. Thus, the points of growth are constantly being shifted along the rim to raise the low places and to make a resultant, uniform, transverse, submerged wall. This is rimstone (Frontispiece). Generally, the wall leans upstream, and the water slips down an apron spillway on the downstream side. This upstream inclination not uncommonly overhangs the deeper water back of the dam. Rimstone growth is a kind of epidemic in some cave streams. Little dam after little dam grows across the channel to make a stream staircase of what was at first a stream ramp (Fig. 50). These step-like dams may succeed each other in close array. They must grow simultaneously, for each one as it grows, raises the water level above riffling depth at the site of the next dam upstream. Missouri's caves contain many rimstone dams. The largest one known is at least five feet high. Most of them are not more than a
Missouri Geological Survey and Water Resources few inches high. A stream floor may simultaneously receive a layer of travertine; a flowstone deposit. Rimstone in such places may be considered a variety of flowstone, the special formative condition being a break in the smoothness of the water surface. Rimstone or dripstone.-The saw-toothed edges of some "drapes", stalactites, stalagmites, and stalagmitic cones and domes are really tiny rimstone dams. Where growth is occurring, these little cups contain water which overflows from one down to another. The reticulated pattern is intriguing, and the fact that some caves have this decoration in abundance while other caves do not is another puzzling problem. Deposits Made Under Water Flowstone or travertine.-Where a cave floor is flooded with ground water which is highly charged with calcium carbonate, it may become covered with a smooth coating of that material many inches thick and stratified. If thick enough and clear enough, it is cave onyx. A better name is flowstone. Travertine has been used as a name for this material, but that term also includes calcium carbonate deposits made on the surface by hot springs, or even cold springs, and by the streams flowing from both. Streams on the surface that go down through sinkholes into caves have little to do with the origin of flowstone because they contain too little calcium carbonate. Instead, they are more likely to destroy the flowstone through solution and erosion, or bury it beneath their transported sediments. "Popcorn", "coral", "cauliflower", "grapes".-One may see in many cave pools a subwater growth of secondary calcium carbonate which takes the form of rounded clustered aggregates, very irregular in detail, but in a generalized way consisting of small branching bulbous masses which as one may fancy resemble any of the things named above (Fig. 91). Because they are now found growing only below the surface of cave pools, they seem clearly to be of subaqueous origin. Hence, when "popcorn" and similar growths are found above water in cave chambers, encrusting the native limestone walls as well as older dripstone, it can be concluded that a pool existed there late in the history of the cave. Shelfstone commonly marks the upper limit of "popcorn" growth. In places, "popcorn" and related forms may grade into similarly branching, subsidiary growths which lack the rounded outlines, but instead, have crystal faces on their terminal tips. To what extent the rounded "popcorn" termini are made up of concentric layers and to what extent they are composed of radiating crystal structures with terminal faces, future investigators must decide. Cave "pearls".-Most rare and most highly prized among all secondary calcium carbonate deposits in caves are "pearls". They
Caves of Missouri are composed of concentric layers and, clearly, they grow while agitation in a stream turns them over and around. A waterfall is generally thought of to explain the rotation which keeps them free and subequally growing on all sides, but the foot of a waterfall is not the only place where they may form. The writer has found one wild, Missouri cave floor covered with hundreds of them, where the stream bed is simply a series of small rimstone dams and where the pools between dams are much wider than the dams are high. It must have been an ordinary current across the pools which turned the "pearls" frequently enough to prevent their attachment to the flowstone floor. These "pearls" show only a dark, dull material when broken and have but a rough, dull exterior. The concentric structure is very obvious, however, and at the center there is commonly a bit of chert, a sand grain, or a granule of clay; a nucleus on which the growth started. Keller (1937, pp. 108-109) has described an occurrence of cave "pearls" in Boone County, Missouri.

RATE OF GROWTH OF CAVE FORMATIONS

There are but few places where it is known how much secondary lime has been deposited in a given span of years. Usually, such a place involves a stalactite whose growth was renewed after the tip had been broken off at some datable time. One frequently hears such statements as, "When they worked the cave for saltpeter during the Civil War, they busted through here." There will be additional places of observation a few decades hence, for some cave managements have placed coins or copper wires on growing, stalagmite tips. Very thin-walled, straw stalactites in the Chicago subway have grown to lengths as great as 12 inches in less than a decade. From these observations, no one figure, such as "a cubic inch in a century", will be obtained because the rate of drip or flow and the rate of evaporation or of the loss of carbon dioxide (CO2) must vary from place to place and probably from time to time in the same place. There are unknown variables facing any computer. The figures that are often quoted by cave guides and local persons are pure guesswork without observational data.
Caves of Missouri 39 MISSOURI CAVES WITH PROVISIONS FOR VISITORS
Twenty-five privately owned Missouri caves provided with walks, guide service, etc., were open to visitors in 1955. Several others had so operated at some time in the past. Two caves in public parks were open in 1955 and two more had been so, previously. In addition, there are four park caves whose existence is obvious, but which never will be entered because of the large springs which possess and com- pletely fill the caves from which they discharge. Visitors may see the cave mouths and spectacular ground water emergences. Like most of the other great springs of the Ozarks, they are interpreted as caves in the making. Every commercialized Missouri cave is approved by the State Mines Inspector after it has been mapped and its walks, paths, and bridges constructed. The vertical range in a few is considerable, but safe stairways and ramps allow visitors relatively easy traverse. A little stooping is required here and there. There is no danger along the routes shown. Lighting is adequate, ventilation is good, ceiling rock is firm, and drainage of flood water is satisfactory. Only an earthquake, a cloud burst, or a guest's own neglect of ordinary pre- cations may be envisaged as menacing to one's safety underground. Possessing an almost unvarying temperature, the average for the year, caves are delightfully cool in summer, pleasantly warm in winter, and their humidity is rarely excessive.
Missouri Geological Survey and Water Resources

ALLEY SPRING AND CAVE

Alley Spring State Park Location: NW1/4 SE1/4 sec. 25, T. 29 N., R. 5 W., Shannon County

Not shown on Eminence Quadrangle map

It is perhaps incorrect to use the term 'cave' for Alley Spring. If the mouth of the spring—the tenth in size among Ozark springs—ever showed a cave opening, the building of the dam outside has completely submerged it. Linear solutional cavities there must be, to deliver the average daily discharge of nearly 90 million gallons. The basal portions of the 100-foot walls of the spring alcove show a dozen or more irregular phreatic tubes which are now drained because of valley deepening.

Alley Spring must have subterranean water courses like these which were inherited from earlier conditions and exposed by the geologically recent deepening of Jacks Fork valley. Bridge (1930, p. 41) tells of an abrupt decrease of flow in this spring. The level in the pool dropped 5 feet or so, remained thus for half a day, and then suddenly resumed normal flow but delivered muddy water for several days. This behavior coincided in time with the sudden collapse of the land surface about 15 miles to the north-west and the formation of a large sink there. Bridge's inference was that a part of the roof of a subterranean conduit for Alley Spring fell in and blocked the flow for that interval. That explanation could be elaborated upon by saying that blocking occurred, in theory, in only a part of the underground system, and that the total discharge was reduced accordingly. It could also be added that sinks must appear in a cavernous region in increasing numbers as the land is lowered by surface erosion. Their abrupt appearance is a part of the destruction wrought by a deep, integrated, phreatic, ground water flow through a pre-existing cave system. The conduits were there before the valleys were made, and it is into these valleys that their severed ends now discharge as springs.
Caves of Missouri 41 BIG SPRING AND CAVE Big Spring State Park Location: NW1/4 NE1/4 sec. 6, T. 26 N., R. 1 E., Carter County Shown on Grandin Quadrangle map This is the largest spring in the Missouri Ozarks (Fig. 13). It discharges an average of 250 million gallons per day. It should be rated also as the most spectacular, for the water escapes with an up- surging, spray-tossing turbulence unequalled by any spring of comparable magnitude in America. An aqueduct large enough to supply the city of St. Louis lies under the hill land to the west. Its terminal Fig. 13. Big Spring, Carter County A discharge of ground water under hydrostatic pressure from a large cave system which is now growing under phreatic conditions. Photograph by G. Massie, Missouri Resources Division. portion emerges below the level of Current River and only a 1000 feet away. Not for many centuries yet will any human enter this aqueduct-not until the Current River has deepened its valley enough to drain the cave, or conducting "tube" for the huge spring.
Spectacular also is the topographic setting for the spring. A great cliff of dolomite rises almost vertically 100 feet or so above the head of the discharging stream. In the base of this cliff and but little above the spring level, there are empty openings of former ground water courses which are now choked a little way back, but were, clearly, parts of a complex system of ground water routes which had operated before Current River valley attained its present depth. From where does the 250 million gallons come? Beckman and Hinchey (1944, p. 18) advance convincing arguments that it is not Current River water returning from some sinkhole intake farther upstream, nor Rocky Mountain water, nor Great Lakes water, nor water from any other extra-Missouri source. There is no source for this water other than the rainfall and minor stream water leakages in the hills to the west and northwest in the contiguous parts of Carter and Shannon Counties. This underground river is a magnificent demonstration of the functioning which makes a great cave system. It is a subwater-table stream, which discharges daily the almost incredible total of 175 tons of dissolved minerals (Grawe, 1945, p. 181). These minerals, mostly carbonates, come largely from the floors, walls, and ceilings of what must be a ramifying system of subterranean tributaries in the calcareous Eminence and Gasconade formations. Enlargement of such waterways must be going on beneath the surface to the west. Although no stream in the area goes abruptly underground, some of the valley bottoms "leak", and many sinks lose their water to subterranean conduits. Bridge (1930, p. 40) tells of the discharge of chemical waste into Davis Creek at the Midco furnace, 9 miles to the west of Big Spring, and of the almost immediate contamination of the spring. He believes that "the area which drains underground to Big Spring .... contains most of .... the drainage basin of Pike, Davis, and Sycamore creeks, the upper portion of Mill Creek, as well as a large territory south and east of the Eminence region. It may also receive a portion of its water from some of the dry valleys on the north side of Current River". If this last statement is correct, ground water must cross beneath the Current River valley. Bridge (1930, p. 42) believes that "the subterranean drainage is independent of the surface divides and is controlled by the major structural features of the region". The author is in complete agreement with this and would add that the subterranean drainage system is older than the drainage system on the surface. Deepening of stream valleys, here and there, cuts existing ground water routes, and springs like the one under discussion are consequences. Big Spring's mounded surges definitely indicate escape under hydrostatic pressure from a completely water-filled cave of adequate dimensions. Very probably, the spring water escapes upward through the roof of the conduit which has been broken through by the downcutting of Current River. A former continuation which
Caves of Missouri 43 served before the spring opening was made need not be looked for in the river bluffs. It is as deep underground as the part now functioning. The only alternatives to the above interpretation are that this great ground water discharge route-integrated, capacious, and extensive-has developed since the present depth of Current River valley has been attained, and that, while the river has been cutting its valley down to the present 500-foot depth in the uplifted peneplain, the large area never has had any subterranean drainage at all comparable. Both ideas seem extremely improbable. That huge "boiling" mound which is Big Spring testifies to some history other than that of ordinary seepages and springs which are water-table leakages on valley slopes. We can visualize, therefore, that beneath the adjacent parts of Carter and Shannon counties, there exists one of Missouri's largest cave systems; a system which originated in the mature heyday of an earlier cycle of erosion. The functioning of this system came almost to a stand-still when the peneplain stage was attained, because no adequate hydrostatic head then existed beneath the monotonous erosional plain. With the uplift of the Ozark dome, came a rejuvenation of ground water stream flow as well as surface stream flow. Lying 500 feet below the peneplain, the trunk portion of the ground water flow has remained as a phreatic circulation and will so remain until Current River deepens its valley below the present level of the main conduit. Then will come the vadose stage of cavern histories which the air-filled caves have already attained. However, there will be no red clay remnants along the then exposed trunk route. If such a deposit was ever made, this vigorously renewed phreatic functioning has long since swept it all away.
Missouri Geological Survey and Water Resources BLUFF DWELLERS' CAVE
Owner: C. A. Browning, Noel, Missouri Location: NW1/4 SW1/4 sec. 27, T. 21 N., R. 33 W., McDonald County Shown on Noel Quadrangle map One sees both openings to this cave from U. S. Highway 71. An artificial or made terrace, faced with a wall of dimension stone, stands in front of a low cliff containing two cave mouths less than 100 feet apart. The cliff disappears both to the north and the south. The developers of the cave tell us that prior to their work no cliff showed here, that the relatively smooth slopes to the right and left continued all the way across. A cliff was there, but it was buried up to its chin in debris from higher slopes. The southern opening was found from a ground hog hole. Debris was shovelled out and down in front until the present arched opening was exposed. Then exploration inside found that another opening, similarly blocked, lay farther north. Today, a good part of the space between the two openings still has Fig. 14. Bluff Dwellers' Cave, McDonald County that original debris slope, mounting nearly to the topmost ledge. Bluff Dwellers' Cave gets its name from the Indian relics found in the debris during the early clearing of the site. Bluff Dwellers' Cave is one of the few Missouri caves with a ground plan of intersecting passages which are somewhat like streets in a town (Fig. 14). It is the outstanding cave of the State for the
Caves of Missouri 45 development of lapies—the vertical groovings and moldings made by thin sheets of water descending already existing, nearly vertical walls. It has one of the most striking (perhaps the most striking) rimstone dams in Missouri. Its "Balanced Rock", which is not entirely the work of nature, is unique. Fig. 15. Bluff Dwellers' Cave, McDonald County The "Lobby": This room is an enlargement of a four-corner intersection of two joints and is probably the most impressive room in the cave. The ceiling is a dome, compounded of several smaller domes and all showing joint control in their making. Ground water under present conditions, although still using the joint, is engaged in an attempt to restore what it had earlier removed. Photograph by courtesy of owner, C. A. Browning. The "Lobby", (Fig. 15) about 40 or 50 feet inside the entrance gate, is the largest room in the cave. An intersection of two long, straight passages had its corners dissolved away and its ceiling dissolved upward to make the impressive room. One must in imagination remove all the splendid "drapery" to see the ceiling as it once was. It is not a simple, hollow dome. It is compounded of several smaller domes under the larger arching. Through the domed ceiling run the traces of the two joints or deep vertical cracks that determined the two intersecting passages. The trip through the cave follows the "First Lead" to the traversable end 200 feet from the "Lobby" and back. The passage, like the "Lobby", has two widenings, beyond which it is a straight, high, narrow slot which extends upward into the roof rock; in places it extends almost beyond the reach of the beam of one's flashlight.
46 Missouri Geological Survey and Water Resources Here the walls of the original joint have been dissolved away barely enough to satisfy the State laws which require pathways 18 inches in minimum width. At the "end" of this "First Lead", the cave best shows its special, characteristic, vertical flutings and moldings on vertical walls. The reasonableness that thin sheets of water descended these walls and dissolved out these vertical channellings and larger vertical concavities appeals to most beholders, and if the walls of this cave do not now possess such falling sheets of water, clinging to the face of the rock on the way down, other caves do. The results, whether made in the past or in the making today, are identical. Once the visitor recognizes this detail of wall sculpture, he will see it repeated to an amazing extent in every passage he traverses, but as in the "Lobby", one must mentally remove these interesting dripstone growths to see the solutional work unmasked and unmodified by a later cave product. Here the compound, red stalactite is largely of the drapery variety. Here we learn (if we did not already know) that stalactites may grow down without any complementary, upgrowing stalagmite beneath; and, vice versa. The term "end" is a correct one if we insist that "passage" means an opening through which the adult human may go with relative ease. Better be content with throwing the beam of the spotlight far down the continuation of the "First Lead", and then turn back. Returning to the "Lobby", we take another direct course, not very wide and not very high, westward for 200 feet to the "Second Lead". Its course is almost parallel to that of the first, its ceiling being another deep slot. It is twice as long as the "First Lead". The "Musical Chimes" are encountered a little less than a fourth of the way to the end. Almost every cave with a good crop of stalactites or "draperies" has its "chimes", its "xylophone", or its "harp". Few please the eye as much as does this. An almost impossible dripstone dome hangs high in the ceiling slot and fringes out below into separate "drapes" of nearly equal sizes (Fig. 16). Solid stones may yield musical tones when lightly tapped; listen and be convinced. The last 75 feet of the path along the "Second Lead" is a bridge built almost in mid-height (or depth) of a striking series of these vertically fluted and molded waterfall records. In Mammoth Cave and other closely associated caves of Kentucky, they are termed dome pits; a high dome above a pit below. Many dome pits show that their causal waterfall migrated by erosion of the rock, back out of the chamber in which they originated. Alcoves of this origin are well shown along the "Second Lead". One may note the gigantic "Elephant Ear" at the "end" of this lead; and the fact that it is not the end. Back now to the low-ceilinged, east-west passage and 220 feet farther west to the "Balanced Rock" and the "Third Lead". Again, shelves margin our east-west passage, shelves which probably are but channel remnants of a cave stream that widened this passage late in
Caves of Missouri 47 the history of the cave. The "Balanced Rock" is just a novelty. It is, of course, a remarkably large, thin slab of ceiling rock, and it lies almost exactly beneath the scar left by its fall. The balancing is a fortuitous combination of an irregular surface beneath it and someone's trimming off of one edge of the slab until the balance and the possibility of rocking it on two points was obtained. As a fallen slab, it may be many centuries old, but as a balanced rock it is not more than 30 years old. Fig. 16. Bluff Dwellers' Cave, McDonald County The "Musical Chimes": The ceiling slot at this point appears to be double, and from one slot an unusual variation of the drape-fringed stalactitic dome has grown down. Photography by courtesy of owner, C. A. Browning. As at the junction of this east-west, low ceilinged passage with the "First and Second Leads", also at the "Third Lead" junction, there is evidence that the leads cross the east-west passage and continue southeastward. An attempt to follow them in that direction is advisedly left to experienced cave explorers. Two of them have actually been traversed to join the "Lake Room" near the exit of the cave several hundred feet distant. This linearity, this constancy of two orientations, and these slot-like ceilings all record control of the initial circulation of water by two sets of joints. The slot and dome ceilings record an upward solutional attack, possible only if the cave was at one time continually full of water. To have such a condition today is impossible, for water is drained out of the hill by the nearby, deeper Butler Creek valley. For the original solution, we must go back in time to a southwestern Missouri that did not contain the river and creek valleys of today. The land surface
Forty-eight Missouri Geological Survey and Water Resources then was a continuous uniform plain, of which present-day ridge tops are the remnants, and all the rock beneath the plain was completely saturated. We ask for no great volume of ground water flow. There is no record of a current then. Given time enough, even such chambers as the "Lobby" can be made with a slow circulation. When, however, that great, broad bulge of southern Missouri (the Ozark dome) was made by uplift of the region, the sluggish surface streams and the slow underground circulation were quickened. The creeks and rivers cut their valleys, the saturated rock was drained, and air came into the abandoned openings. Only dripwater on its way down to the lowered zone of saturation was available for further alteration of the cave system, and solutional work by this water in Bluff Dwellers' Cave made the prevailing lapies moldings. Deposition made the various dripstone forms. They are all superposed on a cave system inherited from earlier conditions of ground water work. We have 230 feet to go to the end of easy traverse in the "Third Lead". Enroute, we pass the "Lilypad Pool". Look at the contrast in secondary growths in the different situations: above water, below water, and at the water's edge. Above water are the familiar stalagmites, stalactites, and "drapes". One group of broad, low stalagmites with corrugated surfaces are suggestive of "brains" and "sponges". Below water are little, rounded, crystalline aggregates usually termed "coral", but also called by many other names. The growths at the water's edge are the "lily pads", though on their under sides they are quite unlike waterlily leaves. The "Cathedral" at the far end of the "Third Lead" is the very best showing of the vertical lapies made by falling water late in the history of the cave. It actually is 75 feet long and bridged for that length. Exploration at the bottom of this compound pit has shown that there are lower passages, but they are tight, they are wet, and we are not to go farther. We now retrace our east-west path almost to the junction of the "First Lead" and turn right (southwest) to reach the "Lake Room". The "Lake" is supplied from the dripwater at the "Cathedral" and "Lilypad Pool". The route has been traversed, but is not shown on the sketch map. There are two outstanding features here; the extraordinarily wide, low, flat ceiling and the dam. The flatness of the ceiling is determined by the stratification in the limestone and by the fact that ground water widened its enlarging course without dissolving upward into the ceiling. The dam is constructed of rimstone; a not uncommon mode of deposition of secondary lime in small cave streams. The breaking of the water surface over the dam when it was growing caused deposition at that place, and the dam simply grew higher and higher on itself. Some surface streams heavily charged with calcium carbonate in solution do the same thing. Some hot springs build terraces which are successive dams of this kind. The inexplicable feature of the dam is its symmetrical repetition of curves in the ground plan.
Caves of Missouri 49 BRIDAL CAVE Owners: J. H. Banner, B. F. Krehbiel, R. L. Wilkerson, Camdenton, Missouri Location: NW1/4 NW1/4 sec. 22, T. 38 N., R. 17 W., Camden County Not shown on Green Bay Terrace Quadrangle map The superb view of the Niangua Arm of the Lake of the Ozarks from Lake Road 32 is alone worth the detour off Missouri State Highway No. 5. A walk through lavishly decorated Bridal Cave climaxes the trip. Bridal Cave's long corridor is so crowded with massive, dripstone displays that one rarely sees the hall-like effect of the subterranean room. Fig. 17.

BRIDAL CAVE CAMDEN COUNTY (surveyed by Stone and Webster Engr. Corp.)
The entrance which is in a rocky cliff overlooking the lake and about 25 feet above high water level was almost completely closed by hillside waste until 1948. The cave has been known, however, for more than a century and has borne the present name since 1827. Legend tells of Indian weddings in the "Bridal Chamber" by the "Pipe Organ", but one wonders by what name those vanished aborigines called that "organ". The long and fairly direct course of the part of Bridal Cave shown to visitors (Fig. 17) is determined by a vertical joint in the Gasconade formation dolomite. It tends approximately N. 30° E. In four places along this joint, the corridor is nearly closed by great, dripstone growths (Fig. 18). "Frozen Niagara" makes a complete blockade from wall to wall, and can be passed only by using a long ladder and by crawling over the top. Almost as much cave is known beyond; a continuation of the main corridor and a cross passage on another joint nearly at a right angle to the main. The "Pipe Organ" (Fig. 19) is one gigantic column, compounded of stalactitic "drapes" with an amazing development of radiating, fin-like ribs in the basal part. Some of the slots between fins penetrate as much as 5 feet back into the column which itself is nearly 25 feet high and 60 feet in circumference. The "Organ" almost completely fills the width of the corridor. The native bedrock is well exposed in nearby walls and ceilings, but is covered with secondary deposits almost everywhere else in the cave. These dolomite surfaces are strikingly diversified with large spongework cavities which have been dissolved back, even upward, into the rock at an early episode in cave history when the present Osage River valley system did not exist, when the land surface was a fairly uniform plain at the level of the present hilltops. Camdenton, about 3 miles away, is built on a broad remnant of that plain, but 300 feet higher than the level of Bridal Cave. At that distant time, all this rock was below the water table and was, therefore, completely saturated, and the cave was essentially a subterranean water main. Subsequent uplift of this part of the Ozarks gave the surface streams erosional ability to make the present deep valley systems. This lowered the water table, drained the cave, and allowed air to enter so that from then on only dripwater on its way down to the new water table has left any record which in Bridal Cave is an entirely depositional one. Also well shown in this part of the cave is an overgrowth of "popcorn on all surfaces a few feet above the floor. The "popcorn" records a relatively short-lived pool on the floor after much dripstone had already been formed. "Popcorn" is an underwater growth. The trail passes through three more constrictions; each at the summit of a "hill". At the "First Hill", the constriction and climb are caused by the "Onyx Forest" barricade of the corridor. Bridal Cave specializes in stalactites of drapery forms instead of the con-
Fig. 18. Bridal Cave, Camden County Compound, terraced, wall-attached "drapes". Photograph by Grant T. Richards, Camdenton, Missouri.
52 Missouri Geological Survey and Water Resources ventional icicle forms, and has far more stalactitic growths than it has stalagmites. Dripstone which hangs from a cave ceiling should theoretically point directly toward the center of the earth, but repeatedly, longer views in Bridal Cave show a downward divergence between such forms which hang on opposite walls. This is because of the "drapery's" habit of widening at ceiling level while it lengthens down into the cave. The divergence is actual and is not an effect of perspective. Several "drapery" tips show the beginning of a tight spiral coil; a rare and unexplained feature of long "drapes". The "Second Hill" in the trail is in part a tunnel which has been dug beneath another huge, compound, drape stalactite. This sta- lactite is largely attached to the southeast wall, but it locally extends across the corridor's full width. Excavation here has exposed a mass of deep, red clay beneath a deposit of secondary lime. It is almost completely free from any grit. You will see some more of it in pockets high on the northwest wall at the "Frozen Niagara". Its significance is discussed later. The "Third Hill" is demanded by the same conditions as the others—a near-blockade of hanging and columnar dripstone. The "Totem Pole" at this place, however, is wholly a stalagmite growth. "Frozen Niagara", at the trail's end, has thus far baffled the trail makers. Explorers and later surveyors have gone over it and have found at the far end two lakes of crystal-clear water. Each lake is more than 30 feet wide, about 100 feet long, and stands about 15 feet above the high-water level of the Lake of the Ozarks. The geological history of Bridal Cave is like that of most Ozark caves. The earliest episode was the time of enlargement when the circulation through the cave was deep below the water table of that time. The circulation amounted to a cave-full flow like the water flow in a gigantic water main. The land surface above had hills and valleys, and the ground water moved along deep joints and bedding planes from under the hills in order to reach the valleys. In time, the valleys were eroded down to their depth limits, and the inter- vening hills were softened down to gentle slopes. The country thus approached the penultimate stage of a cycle of stream erosion; a peneplain. The peneplain now exists only as flattish, hilltop frag- ments because later uplift initiated the present cycle of erosion. While this process of peneplanation was making a monotonous landscape of low relief, it also was necessarily depriving the deep circu- lation of the hydrostatic head the former hills had provided. The cave circulation, therefore, essentially came to an end, and solutional enlargement ceased. Now the red clay of the peneplain soil filtered gradually down into the cave through minute openings, was deposited, and the cavities were largely, if not completely, filled with it. The red clay dates from the time of the peneplain. This clay has no trace of stream sand or gravel, nor flowstone or dripstone deposits. The
Fig. 19. Bridal Cave, Camden County The "Pipe Organ". Photograph by Grant T. Richards, Camdenton, Missouri.
54 Missouri Geological Survey and Water Resources time for air to enter the cave, and, therefore, the time for stream water and dripwater to leave records, had to wait until the next uplift re-juvenated the peneplain streams which produced the existing valleys and drained the rock at cave level of its water of saturation. All the displays of Bridal Cave, except the spongework and the fine, ceiling dome cavity near the entrance, date from this latest episode.
Caves of Missouri 55 CAMERON CAVE Owner: Archibald Cameron, Hannibal, Missouri Location: NW1/4 NW1/4 sec. 35, T. 57 N., R. 4 W., Marion County Not shown on Hannibal Quadrangle map Even a more pronounced, network cave than its neighbor (Mark Twain Cave across the creek valley) Cameron Cave is the most remarkable underground labyrinth ever encountered in the writer's experience (Fig. 20). In an area of not more than 30 acres, there lie nearly 4 miles of closely spaced, intersecting passageways, the pattern of which is resolvable into four sets of determining joints. Numerous, blind ends are the result of complete detrital fills-blocked passages undoubtedly continuing. If Cameron Cave had no fills whatever, there might well be twice the mileage of enterable cave routes. Cameron Cave underlies a hill spur which is situated between Cave Creek Hollow and a minor tributary valley. The hill rises 160 feet above the creek. The open cave lies approximately 40 feet above the floodplain and perhaps 50 feet above average level of the Mississippi River which is less than half a mile away. The outline of the cave limits is the outline of the hill; the cave completely underlies it. One may go in the cave on one side of the hill, pass along beneath a roof more than a 100 feet thick, and come out on the opposite side. Like Mark Twain Cave (Figs. 23 and 72), there are about two dozen blockaded intersections of cave passages and hill slopes. Two were open when the cave was first explored. A third has been exca- vated for a better located entrance. The blockades which are to be seen only from the inside are of hillside waste and fallen slabs. This debris is cemented and almost completely covered by flowstone (Fig. 21). The walls of Cameron Cave are "weathered". One brushes a sandy material off on coat and hat, and one's knife blade can readily be thrust into the material in places for full length. Embedded in the wall rock, are many nodules of coarsely crystalline calcite. The walls of Mark Twain Cave contain them also, but they are far less conspicuous because of the prevalent smoke stain record of earlier days when torches were used. A shaly formation, the Hannibal shale, here about 30 feet thick, overlies the Louisiana limestone formation in which the cave has been dissolved (Fig. 22). In a few places, openings penetrate up to the shale, but the joint cracks in the limestone do not penetrate it. It forms as tight a roof as in Mark Twain Cave and the only flowstone, dripstone, and rimstone of the two caves are limited to the blockades where surface water may enter. It is immediately obvious, from
Caves of Missouri 57 this fact alone, that Cameron Cave never was dissolved by water descending through the rock above. In general, the ceilings of Cameron Cave are slots which higher up becomes slits. In some places, there are deeper ceiling pockets in these slits. They are local, upward enlargements that could have been made only when the cave rock was entirely in the saturated zone of ground water. A few, high-placed bridgings also have survived. The floor of Cameron Cave is entirely a detrital fill. From one slump pit in the clay floor, the depth of the fill is known to be at least 30 feet. The fill is a stratified silt with some sand and pebble layers. In the southern part, where the fill is close to the ceiling-only creeping will allow one to enter-the floor is covered with slabby gravel of limestone and chert, the texture of which becomes coarser with increasing distance southward. A few, smooth, rounded, vein-quartz pebbles in this gravel clinch the argument for a former surface stream's entrance into, and traverse of, a portion of the cave. As in Mark Twain Cave, we point to Cave Creek as the intruder, at a time when the creek valley floor was some 40 to 50 feet higher than now. The deepest slump pit reveals a downward continuation of an enlarged joint, with bare rock showing at the very bottom on two sides. The subsiding clay is continuously carried away by a free flow somewhere beneath the fill. In flood seasons, the water rises in this hole almost to the top. Neither Cameron Cave nor Mark Twain Cave has shown any traces of a former, red clay filling, and Cameron Cave has had its slump pit slopes sampled and some drill holes made in its floor. As an epoch of red clay fill has been so common an experience in limestone caves of the central United States, and as both these caves clearly have had the first epoch experience under conditions of complete saturation, it seems very probable that they have also had a special episode in their history during which their red clay fill was completely removed. Another Missouri cave seems to have had a parallel episode. Keener Cave in Wayne County lies low in the hills, and originally opened out into Black River valley close to the Mississippi trench. Keener Cave shows no record of a red clay fill nor of any other detrital fill. Its mouth is blocked by a big talus accumulation, back of which is a lake 40 feet deep. Dredging for gravel in the river valley just outside has gone down 40 feet also without finding a rock bottom. The talus dam is porous, at least to water, but it has kept backwater sediments from entering from the river while the 40 feet of gravel was deposited. By this view, Keener Cave lost its red clay fill during the deep-valley stage before the talus grew. As the river level has had to rise with the up-building of the floodplain, water only has come to fill Keener Cave. Black River's aggradation must be the result of similar changes in the Mississippi valley. The Mississippi valley at Hannibal and farther downstream is known to have a deep alluvial fill made during the Pleistocene or
Fig. 21. Cameron Cave, Marion County Dripstone and flowstone blockade: An intersection of a joint–determined passage, looking toward the outside hillslope. Photograph by G. Massie, Missouri Resources Division.
Fig. 22. Cameron Cave, Marion County Joint-determined passage: Note that the shaly limestone ceiling shows no joint. Photograph by G. Massie, Missouri Resources Division.
60 Missouri Geological Survey and Water Resources Glacial Period. It, therefore, had a deep-valley stage preceding the alluviation. Its little tributary, Cave Creek, must have gone through the same experience, at least in its lower half mile between the two caves. This fill in the master valley has stood higher than today's flood-plain, as numerous terrace remnants upstream toward Burlington, Iowa, show. Our theory calls for an alluviation in the two caves Fig. 23. Vicinity of Cameron and Mark Twain Caves, Marion County Enlargement of part of Hannibal and Vicinity Quadrangle map; United States Geological Survey. Contour interval 20 feet.
Caves of Missouri also. The silt, with some sand and gravel, was deposited in the empty caves by entering stream water during the Pleistocene. Someone is going to find an interesting problem here, for all low-lying caves of phreatic origin along the Mississippi should contribute to the history. There were four glaciations, three interglacial episodes and one post-glacial. Were these stream detrital fills made when the Mississippi was carrying the heavy load imposed on it by glacial melting? Do they record a higher sea level (and, therefore, a slackened Mississippi) during the interglacial intervals? May it be that more northerly caves were filled during a glaciation, more southerly ones during interglacial times? Is more than one episode of filling recorded in any cave? Can any record be found in these cave sediments of derangement of the Mississippi's course by invading ice-sheets? Cameron and Mark Twain caves (Fig. 23) are believed to be but severed portions of one original phreatic cave system. This view is supported by the existence of what appear to be blockaded entrances to another cave lying under the hill which is partly shown in the north-west part of the map of Cameron Cave. If there is a cave here, it also is a severed portion of the original cave; the minor tributary to Cave Creek having cut an early Cameron Cave into two parts. A very old cemetery lies on the hilltop over Cameron Cave, and the cave is reported to be haunted. The writer, with a party of eight or ten students, has twice slept in Cameron Cave for a night, with no one reporting any nocturnal disturbance more interesting than the rustling of hungry cave crickets about his bed roll.
There are two entrances to Cathedral Cave (Fig. 24). The low entrance by which the cave was discovered many years ago is heartily detestable and never used without some special reason. The artificial entrance for visitors is high on the hillside, 160 feet above the Meramec River which is less than a tenth of a mile distant (Fig. 25). Entering here, one walks westward and follows the course of wet weather streamlets on the floor for 1200 feet; most of the way is under a rather low ceiling. He then descends a steep 65-foot "hill" to reach the rocky bottom where a rapid little stream enters the cave at the base of a 77-foot, subterranean cliff. Visitors go down along this stream for 200 feet to see the great dripstone aggregate, the "Cathedral". The cave has five branches at this bottom level: one for the entering stream, one for the stream's exit, and three which are in a sense, tributaries. None is enterable without encountering difficulty with water and mud. One is so low that the explorer must crawl in the stream itself until he finds insufficient room to keep his nose out of water. Obviously, this entering route of the stream has not been mapped.
Just within the hillside entrance, one finds himself among great slabs of settled and tilted, dolomite, roof blocks which are overgrown in part with a huge half-dome that slopes into the cave and blends into the travertine (flowstone) floor. Some of the most massive dripstone deposits of the cave are located here; a characteristic of many caves where the roof is thin. The cave chamber is broad and low, and on the sloping, flattish floor there are wet-weather rivulets which flow back into the hill. A pronounced drip occurs 250 feet inside, and from it can be traced a stream channel which leads back into the cave, cuts into the travertine and clay, hugs the north wall, and gradually deepens for 550 feet to a point where it disappears under the cave floor. Another and smaller wet-weather channel parallels this, but persistently hugs the south wall. At the drip, a 7-foot drop in the cave floor forms a little cliff. A moment's inspection shows that a great, flat block about as wide as the cave itself (about 60 feet here) has fallen without much fracturing from the ceiling to make this cliff. Fig. 26. Cathedral Cave, Crawford County Crooked stalactites: Three types of stalactites are shown: "straws", "icicles", and "drapes". All are inclined (note the plumb line) away from the visitor's entrance high on the hillside and toward the stream's exit tunnel close to river level. Photograph by G. Massie, Missouri Resources Division.
Caves of Missouri 65 On top of the fallen roof block and extending 100 feet farther is the first of the three dripstone "forests" of the cave. Some huge, compound, central pillars are part of this "forest". The far one which terminates the group has a circumference of about 50 feet. Easily recognized are the stalactites and stalagmites of the "forest", though they are extensively overgrown by "popcorn" incrustations. Fig. 27. Cathedral Cave, Crawford County "Popcorn" on stalagmite: Virtually all stalagmites here carry a sharply localized overgrowth of the "popcorn", and most of them have it only on the side toward the visitor's entrance. Photograph by G. Massie, Missouri Resources Division. Peculiar to this "forest" are the curved forms of most of the stalactites (Fig. 26). There is as yet no acceptable explanation for their departure from verticality. Also unexplained, satisfactorily, is the prevailing localization of the "popcorn". It is much better developed and, in many places, completely limited to the east sides of the forms it grows on (Fig. 27). One thinks of a current of air for the curvature
66 Missouri Geological Survey and Water Resources of the stalactites and of either air or, more probably, water for the localization of the "popcorn". Certain it is that the stalagmites are earlier. Since "popcorn" growth has ceased, however, some drip-stone growth has been renewed and the "popcorn" forms have been covered over by later conventional dripstone. The big column at the far end of the forest shows no "popcorn" whatever. Sixty feet farther westward, along the cave chamber, the fairly uniform ceiling is interrupted by a number of chert pendants which are dark brown in contrast with the lighter colored, dolomite ceiling rock. As nodules, they are of enormous, vertical dimensions; as much as 5 feet. Where broken, they show a doughnut structure; a hollow center or perhaps a calcareous core. These chert masses are fossil, organic structures; perhaps colonial groups of algae that lived on the sea floor when this solid dolomite was first being deposited as lime mud. Their appearance in the cave ceiling is due wholly to the relative insolubility of the chert (a form of silica). They are in no sense dripstone deposits on the cave ceiling. A noteworthy feature of these chert pendants is shared by nearly half of them; glass-smooth surfaces bearing vertical striae or scratches. Also this has no relation to cave history. It records subsiding movements in the adjacent dolomite which underwent compaction and interstratal solution around each of the big chert nodules long before cave-making occurred. It is not an uncommon feature on the vertical sides of chert nodules in all calcareous rocks but is the most marked showing of this feature the writer has ever seen. A smaller dripstone "forest", easily passed on either side, is encountered some 200 feet farther along this low-ceilinged route. Here again, "popcorn" growths have marked preference for the eastern sides of the stalagmites they have grown on. In this "forest", many of the complete columns are broken across and the fractured surfaces are separated by a space of a few inches. The deep clay fill on which they have grown has settled from internal compaction since the growth ceased. The gap is a measure of the amount of consequent subsidence of the floor. Beyond this small "forest", one travels for some distance on a central ridge of broken roof rock, clay, and travertine and between two marginal, drainage routes to the third "forest" for more than 100 feet along the cave length. In this "forest", more "popcorn" growths which are limited to the east sides of stalagmites are encountered. At the far end, just before the trail descends down the slopes of the first slump pit, is the "Fairy Fountain", an exquisite group of white dripstone and flowstone forms enclosing a little pool of water. Now we encounter the first marked break in the cave floor (Fig. 25); the first slump pit. It is 50 feet deep, all in clay, fallen roof rock, and travertine, and does not expose the true bedrock floor of the cave. About 100 feet before reaching this slump pit, the right-
Caves of Missouri: 67 hand drainage ravine ends with the stream disappearing down into the floor. The pit is evidence of the stream's work beneath the clay floor. Clay has been removed from below by this stream to let the cave floor collapse for a depth of 50 feet to make this hole. Approximately 250 feet farther, is the second slump pit. It is not as deep as the first but shows a bedrock floor and a slot which can be followed down into a very narrow passage; farther than the surveyors carried their map. This passage is the work of the same wet weather stream. On the far side of the pit, the clay fill which has made the cave floor up to this point is still intact to the very ceiling. Long, extraordinarily delicate helictites are hidden down in the bottom slot, but only able-bodied persons will ever see them. Shortly, the trail descends a long slope into what had been a great slump pit at one time, but what now is the valley of the stream which enters the very bottom of the cave from the northwest. It is 65 feet down from the clay floor which we have been traversing to this stream, and the entire descent is over clay. The depth of the original cave, from the entrance to the stream, must be measured in similar dimensions. The original Cathedral Cave, before the clay-filling was deposited, was a lofty chamber, never to be explained by present ground water work. It all harks back to conditions earlier than those of the present topography, back to a time when no deep Meramec River valley existed, when this rock was completely saturated, and when ground water far below the surface of that time was moving under hydrostatic pressure; as water must move at depth. The clay fill came later and only the partial excavation of this fill can be ascribed to the present-day movement of ground water along the predetermined channels. Near the head of this descent, one may notice that the cave floor is sandy instead of clayey. This sand is a weathering product which has fallen from the ceiling rather recently in the cave's history. For some specific, local reason, the dolomitic limestone here yields a sandy-textured detritus. Mineralogically, it is not like most sand for it contains essentially no quartz which is the dominant sand-making mineral the world over. The walls are hardly 20 feet apart half way down this "hill" and, a little short of the ceiling, they are joined completely across by a natural bridge of native rock. At the bottom, our attention is given at once to the murmuring stream which emerges from its low-browed passage, coming some-where from the west, crossing under the high ceiling of the main cave chamber which we have been following, and entering a fairly wide, but rather low-ceilinged chamber to the east. In flood, this stream must completely fill its entrance route. At such times, it carries gravel through the flat tube into the main chamber and deposits it in a big bar on the broad floor of that chamber.
Missouri Geological Survey and Water Resources Once out in the big room, the stream encounters a mass of ragged boulders as black as ink from a coating of manganese dioxide (MnO₂). Among and over these, it cascades down a few feet. These boulders are almost all insoluble chert fragments, released from the bedrock through the solution of the surrounding calcareous matrix. The chert pebbles of the channel bars are likewise stained a glossy black from the same mineral, deposited by the stream water. Before we go downstream to see the "Cathedral", we should note here that the course of the main cave chamber has swung around so that in descending the hill to reach the stream we have been walking southward instead of westward. We should also be aware that this chamber continues southward beyond the stream and can be followed for a little more than 200 feet in that direction, but its floor rises 70 feet in that distance to reach the high ceiling. One who attempts this trip must expect to return well smeared with red clay. This chamber is still completely blocked with a clay deposit and no one knows how much more cave lies beyond the blockade. The clay slope up to the far end is really the opposite side of the former slump pit which was made by the stream; sapping from beneath where it crosses the main room. The slope once was well covered with flowstone, but that deposit is now being dissolved by the seepage water which makes the clay a mass of sticky mud. At the very top of the climb, there are blocks of fresh rubble and leaves. The surface of the hill cannot be far above this place. About 25 feet farther down stream on the right (south) side, another passage leads back into the wall rock. The passage is narrow and tight, and its course is very tortuous. At the head of it is a little waterfall where the splash has made cave "pearls" by constantly agitating particles which were growing from chemical precipitates in the basin. The writer saw some there when the first explorations of Cathedral Cave were being made, but there are none left today. This tortuous and very muddy passage is about as long as the southward continuation of the main cave beyond the stream but is lower. At one place, there is an irregular hole in its ceiling through which a light can be shone down through a hole in the wall of the larger chamber. Let's look at the "Cathedral" (Fig. 28). Almost all pure white, it towers nearly 25 feet directly above the stream. It is the greatest pillar of dripstone in the cave and is essentially a compound stalagmite which has been built on a flowstone dome which in turn was originally based on clay. There is still a considerable amount of clay beneath the dome. The stream detours around the left-hand (northern) base and cuts back into wall rock in a low but negotiable passage for 150 feet. Beyond this low-ceilinged route, one has head room and can climb up in back of the "Cathedral" and discover still more massive accumulations of secondary limestone. These accumulations are flowstone domes which are compounded on each other. They are dark-colored from incorporated clay and are not very showy. They
Fig. 28. Cathedral Cave, Crawford County The "Cathedral": The summit is about 25 feet above the stream. The lower 6 to 8 feet, on the left, is a flowstone apron built over the front of the red clay terrace on which the "Cathedral" stands. Between 20 and 30 successive shoulders are shown, each with depending stalactitic forms. Photograph by G. Massie, Missouri Resources Division.
70 Missouri Geological Survey and Water Resources stand in a nearly circular room 25 feet high. The "Cathedral" stands on the extreme north edge of this room. The really extraordinary part of Cathedral Cave is the further course of the stream to the Meramec (Fig. 24). Give all credit to the first explorer who, after crawling into a hole in the river valley wall nearly a mile away, went through this very long, and in places, very low passage. He waded and crawled in the stream most of the way and finally reached the "Cathedral Room" after a traverse of 4500 feet. Nowhere is this passage more than 12 feet high, and in places its ceiling is only one foot above the water. Almost nowhere are there banks above water to walk or crawl on. Forty-five hundred feet! Give credit also to the two girls, Florence Robinson and Florence Rucker, who in 1947 surveyed this route and verified the claim that it was nearly a mile long. It is almost three times as far to the outside by the stream route as it is to backtrack the way we have come; and many times as difficult! This stream passage is so different from the rest of Cathedral Cave that it must record different conditions of origin. Here, the present cave stream has had ample opportunity to develop large chambers, high ceilings, and natural bridges; that is, if cave streams like this make caves of such amplitude. For 4500 feet, it has failed to make anything similar to what we saw before reaching the "Cathedral". This failure is not due to the rock at this lower level being less soluble, for the "Big Room" at the stream crossing is developed in the same strata. Furthermore, there are no remnants of red clay terraces, or wall and ceiling pockets filled with the clay along this route. Still further, the two caves cross each other; the high-ceilinged, clay-filled, stream-less one being older than the low-ceilinged, present stream route. And, yet further, if a ceiling gradient means anything, that of the older, capacious cave descends 20 feet westward, whereas that of the stream-occupied, 4500-foot cave descends 20 feet eastward. We reason, therefore, that two episodes of cave-making have occurred here. In the earlier one, a capacious cave was formed in rock which now lies high up in the hills and borders today's deep Meramec valley. The cave's intersection with the present surface is not a place where the imagination can conceive of a big surface stream existing. Still less thinkable would it be to have such a stream go underground at this point and flow away from the Meramec. Nor can we logically imagine a cave stream flowing uphill to emerge here, on the hillside, 160 feet above the river. Therefore, we reason that the river valley did not exist when this upper large cave was made, that it had not yet been cut even when the cave fill was made, and that only long after the making of the easily traversable part of Cathedral Cave did the Meramec River make its deep valley and afford opportunity for the birth of the present cave stream.
Caves of Missouri

But one asks, how did this cave stream of today acquire its course? Subterranean streams cannot burrow through rock as an earthworm does through soil. The answer lies in two facts: first, ground water stands higher under hills than under valley slopes; and second, bedding planes in the nearly horizontal limestone are planes of leakage. Selective action of ground water solution, under present conditions, has determined most of the long, low stream course and has done so only since Meramec River valley has attained approximately its present depth. The last 1000 feet of the narrow, low, long, younger cave is stream-less. Entering the hole in the river bluff 15 to 20 feet above Meramec low water, one crawls back about 1000 feet before he encounters the stream which here escapes by an untraversable, somewhat lower route, and discharges (no one knows where) below the surface of the river. This dry segment is apparently a recently abandoned part of the newer cave system. Cathedral Cave, like its neighbors along the Meramec River, dates back to a period of deep-seated circulation before the river valley was ever cut. The country then lay a few hundred feet lower than it does today and had less relief. The ancestral Meramec flowed along the same course that it follows today, but on a valley bottom which the present river has destroyed. From beneath the hill lands at that time of maturity of the earlier cycle of erosion, ground water moved under hydrostatic pressure toward the ancient valley. The cave of today was then deep in the completely saturated zone and its water escaped as a large spring in that former valley floor. This was the first epoch in its history. When old age of the early cycle arrived, the deep circulation came almost to a standstill, and Cathedral Cave became filled with the red clay that constantly filtered down from the deep soil of the peneplain, but could not be carried farther. This was the cave's second epoch. Had there never been a later Ozark doming, Cathedral Cave and its neighbors would still lie well below a featureless land surface and still be filled with red clay. The doming awakened the sluggish ancestral Meramec, restored its youth, and set it the task of cutting still deeper in the bedrock of the region. In this way, the third epoch came about, and with it came the removal in part of the red clay, the entrance of air, the free-surface stream flow, the deposition of drip-stone and flowstone, and the development of the long, low tunnel to the present deep valley bottom.
CAVE SPRING ONYX CAVERNS
Owner: Lui Ring, Van Buren, Missouri
Location: NE1/4 SW1/4 sec. 26, T. 27 N., R. 1 W., Carter County
Not shown on Van Buren Quadrangle map
This cave appears to have been made entirely by the stream now flowing in it and to be still growing. It is one of the few Missouri caves for which this statement can be made. The contrasts between it and other caves of the State are worthy of the attention of adherents of the older theory—vigorously opposed and criticized in this report—that caves have been made and are being made by the water now using them. The cave is properly and consistently proportioned throughout to its stream. It has no ceiling domes or slots rising far above the average height, no wide chambers entered and left by relatively constricted passages, and no cross passages. The stream flows on, or very close to, a bedrock floor throughout the traversable length. The stream, although small, is much larger in proportion to the dimensions of its cave than almost any other cave stream of this study. In its winding course (Fig. 29), it nowhere gets out of the cave proper, and nowhere has it made horizontal niches in an obviously older MAP SUPPLIED BY LUI RING SCALE IN FEET
Caves of Missouri 73 chamber wall. Nowhere does it show that it ever has flowed on a cave fill of red clay or any other detrital material. In a few places, imperfect meander shelves have been left, but these are not cut into or superimposed on typical spongework. Only one place in the cave suggests an older solutional opening which has been intersected by the stream. For a domestic water supply, the stream has been dammed 230 feet back from the entrance, and the little waterfall thus made operates a hydraulic ram. Visitors go no farther, for water floods the farther recesses well up toward the ceiling. One may hear accounts of a much greater length and of remarkable chambers farther back, but we have no verifiable evidence of the correctness of such statements. The winding course of the stream appears to have been determined by bedding plane leakage of local ground water which has drained out of the hill land to the south and east and into the valley of Pike Creek during the present cycle of erosion. Few caves have had closer attention given to fancied resemblances in their dripstone, than has Cave Spring Onyx Caverns. One reviews his knowledge of mythology, of history, of art, of world literature; yes, of zoology and botany, in a trip through his cave. Geological history considered, it may be said that this cave, although one of the youngest in Missouri, has been dissolved from one of the oldest, cave-bearing formations; the Eminence dolomite.
74 Missouri Geological Survey and Water Resources CHEROKEE CAVE Owner: Lee Hess, 3352 South 13th St., St. Louis, Missouri Location: 3400 South Broadway, St. Louis, St. Louis County Not shown on Cahokia Quadrangle map Cherokee Cave is developed on two different levels. The higher level was made in a zone of complete saturation under phreatic conditions, and the lower level was made almost wholly under later vadose conditions. The higher, phreatic passages are oriented nearly north-south, and the vadose passages nearly east-west (Fig. 30). The cave has also had an extraordinary later history, the like of which is, to the writer's knowledge, possessed by no other Missouri cave. The only known natural entrance to Cherokee Cave was in the bottom of a sink hole. This opening was enlarged about 1850 by the CHEROKEE CAVE ST. LOUIS MO.
Caves of Missouri. Former Minnehaha Brewing Company, and a cavern was found at a depth of 50 feet. The limestone cavity proved large enough after excavation of a detrital fill for underground storage and ageing of beer. Two holes in the cave's ceiling still record the entrances made for ice and beer casks. The present entrance is a third breaching of the original cave roof. By it, we descent 25 steps and follow a ramp to the head of 47 steps, by which we enter the cave proper. We are immediately aware of the problems the brewers and the present cave owners have faced; the problems of excavating an almost complete fill of clay and silt and of shoring up some unstable ceilings with masonry walls and pillars. Cherokee Cave is a corridor cave along two sets of joints. One set is oriented not far from an east-west direction, and the other set curves from a N. 20° W. alignment to one almost northwest (Fig. 30). A traverse without back-tracking is mule possible by using an artificially excavated "tunnel" corridor, 150 feet or so long, which connects the two northerly-southerly corridors at the north end of the cave. The trail from the foot of the stairway follows westward for about 350 feet a narrow, somewhat sinuous passage that can hardly be called a corridor. In this lowest level of the cave, a stream enters from almost unrecognizable crevices, spills noisily into "Cherokee Lake", and then flows easterly to leave the cave by a corridor unentered by visitors but said to have been followed for 300 feet toward the nearby Mississippi. The two separate levels are best seen at the west end of this first passage. Here one climbs a flight of 15 steps to reach the bed rock floor of the northerly-trending corridor, finding that the floor is about at the level of the ceiling he has been under in the east-west passage. Although not followed by visitors, the continuation of both of these cave units southward and westward beyond the intersection is clearly apparent. The one to the south (left) leads to another portion of the cave system, known as the Lemp Brewery Cave (Fig. 30). The "Peccary Cemetery" marks a unique feature of this Missouri cave. It is an amazing deposit of vertebrate bones in a heterogeneous, unstratified mixture of mud, sand, gravel, and fragments of native limestone and secondary lime. Doctor G. G. Simpson (1946, pp. 252-259; 1949, pp. 1-46) of the American Muesum of Natural History has identified remains of armadillo, bear, beaver, peccary, porcupine, raccoon, wolf, and woodchuck. The main deposit was limited to the Lemp portion of the cave about 100 feet south of this stairway, although isolated bones have been found in several other places through- out Cherokee Cave. The main deposit was about 100 feet south of where the cemetery is now located. In 1946 when Dr. Simpson made his investigation, only about 250 feet of Cherokee Cave (then called Minnehaha Cave) had been excavated of its detrital fill. Since that time, continued excavation has revealed more than five times as much.
76 Missouri Geological Survey and Water Resources linear cave passage on the two joint sets and perhaps three times as much open space as nature had left. Simpson believes that a sink hole or capacious fissure in the roof rock over this part of the cave had trapped the animals in its boggy depths and that later failure of the cave roof (the sinkhole floor) had let the whole, water-soaked mass Fig. 31. Cherokee Cave, St. Louis County

"Thousand Columns": The nearly flat ceiling is a bedding plane, and the cracks in it are vertical joints in the roof rock. Downward leakage along these cracks has produced the rows of stalactites and columns. Photograph by Pictorial Press Service, St. Louis, Missouri. Many of the bones are broken; all are disarticulated. Simpson's interpretation is doubtless correct, although the site of the entrance of the bone-charged mud is still unknown. At the "Thousand Columns", farther along the northerly corridor, most of the abundant dripstone forms stalactites, not columns. A
Caves of Missouri 77 striking feature is the grouping of the stalactites in long rows (Fig. 31) determined by seepage down minor joints which also are well shown. All the ceilings in the northerly-southerly corridors of Cherokee Cave possess smooth rounded concavities, unquestionably made in the cave's early history when it lay below the water table, and therefore, before the present great Mississippi River valley had been cut. The stalactites hanging in some of these ceiling concavities (Fig. 32) record a later downward migration of soil water along the joints. The migration was contemporaneous with the detrital fillings and much younger than the subwater-table solution which made the corridor. Fig. 32. Cherokee Cave, St. Louis County Ceiling cavity with stalactite: This feature is directly over one's head. A joint crack in the ceiling rock invited greater upward solution along the crack during the cave's phreatic development. After lowering of the water table and entrance of air into the cave, dripwater descending this same crack built a stalactite in the very top of the solution cavity. Photograph by Pictorial Press Service, St. Louis, Missouri. Excavation of this corridor stopped 300 feet north of the intersection at the "Peccary Cemetery". The largest piece of dripstone in the cave, the "Black Dahlia", here overlooks the "Wishing Well" and dripwater from it feeds the pool. Apparently vigorous leakage at this place had early washed out a cavity in the clay fill, giving the stalactites and stalagmites room to grow. Beyond the pool, the fill
78 Missouri Geological Survey and Water Resources still remains tight against the ceiling although a crawlway has allowed penetration for another 70 feet. At the "Wishing Well", the trail descends eight steps and traverses a tunnel whose walls and ceilings show no smoothly rounded solution surfaces, no dripstone, and no trace of the detrital fill. This corridor or tunnel is entirely artificial. Yet thin, pebbly, clay pockets, along bedding planes, were found in the quarrying. They represent the merest beginnings of cave passages which, like the corridors, became filled when the later episode arrived. We turn southward in the eastern corridor of the two north-south corridors. The "Pit of Death" is the northward continuation of this passage and has been explored about 100 feet. South of the junction is the "Dragon's Den", an interesting accessory lateral passage about 75 feet long. You can all but see completely through it. Its ceiling is accordant with that above the trail but its clearance is about half. This, however, was the original clearance of the trail corridor. Comfortable walking height has been secured here, as along much of the trail elsewhere, by deepening the original cave. The ceiling at this place carries many solutional pockets or cavities of phreatic origin, elongated and arranged end to end to demonstrate the joint control in the early, upward, solutional attack. The fossils in the ceiling here are cross sections of imperfectly preserved solution modifications of parts of organisms in the limestone; probably cup corals. Some of the associated markings, suggesting centipedes, are not organically determined. The "Schmoo", about 50 feet south of the "Dragon's Den", is a small lateral cave opening, the broad upper part of whose cross section shows phreatic traits that date back to the early, submerged, solutional history. Later, surface water, descending along a crevice, made a vadose stream which eroded an inner and narrower chamber with excellent little reverse curves. Cherokee Cave's best stalactiflat hangs here, suspended almost in mid-height and mid-width. The fill on which it grew may have been older than the twisty little ravine beneath it. This "Schmoo" channel has almost as much vertical clearance as the main corridor which it enters. The vadose stream flowed southward here and made a similar little gorge, most of which has been destroyed in trail-making. Another lateral of the early cave pattern is the "Spaghetti Room" whose fill has not been adequately removed for a visitor to enter. This lateral chamber has been explored, however, for 200 feet. Its bed rock floor is accordant with the original floor of phreatic origin in the main corridor which it joins. A wealth of stalactites gives the room its name. A few bones have also been found here. Southward flow of the lower water along this phreatic corridor is recorded by well-shown, fore-set bedding in the cut banks of the remaining fill. This fill appears to be largely loess from the surface,
(av(E' of MA'issouri 79 buit having been stream-handled subseque-ntly, it contains bits of c(helr, san d lnes, and some flowstone. We now re-enter the large room with the Minnehaha Brewery's hoist hole in the ceiling. The room's capacity as a cavity in lime- stone( has probably been doubled during the excavation for use by man. As an air-filled cavity, it probably now has three times the open space found in 1850. The writer knows of no cave in Missouri which has undergone so much re-excavation of fill and additional excavation of bed rock as has Cherokee Cave. Entering "Indian, Tunnel" (Fig. 30) which is the escape route for all lte c(ave( water, we talk eastward for about 80 feet and see that the tunnel continues indefinitely. It has been explored for about 300 feet. Bley(on this distance1, only the flowing water knows the way. An intrsting speculation is that it enters the Mississippi below low walter levels. When the ciavC was being cleaned out (1944-1950), all the walter from hydraulic jets used on the clay fill went down this eastern contintuation of "Indian Tunnel", but no one during that time ever saw any emergence of muddy "spring" water along the river b)luffs east of Cherokee Cave. However, the mud may have (been trapped:(l in some other cavity enroute to the river. "Indian Tunne(l" is another part of the passage we first followed west to t the "IPe(cary Cemeltery" and appears to be of vadose origin thlrotul. The tunnel represents work done by vadose water during the later part of the cave's history, after the Mississippi valley had b}(; cut below the original cave level and the water table in the cevern(ous rock had been lowered so that air could enter the older, l)hrelatic palssage, and, streams could flow on the floor. Its walls carry excell(ent c(urrent-made facets or flutes and some good horizontal mTealndr niches. It was only a crawlway when first explored; much excavation of rock has made passage for upright humans. The 50- foot traverse from "Indian Tunnel" to the foot of the entrance stairs is entirely a quarried corridor. Summarized; Cherokee Cave's history began with phreatic circu- lation along the nearly north-south corridors which were well below the water table of that time--before the present hills and valleys of the region existed. There doubtless was a Mississippi River at that early stage, but its valley bottom was probably no lower than the old, river gravel deposits commonly called Lafayette and known at Grover, in the western part of St. Louis County, to lie about 300 feet higher than the land surface which is now above the cave. Rejuvenation of the surface streams, whereby the Mississippi valley was deepened to and below the early cave corridors, worked a revolution in the ground water circulation at the site of the cave. The completely saturated condition vanished when the water table was sufficiently lowered. Air then entered the two corridors, and the only water present was rainfall seepage on its way to the lowered water table. The empty corridors collected some of this which, flowing along the corridor floors, made vadose trenches in them.
The direction of final escape was eastward, to the adjacent, deepened, Mississippi valley. Thus, there was formed an entirely new water route; the wholly vadose "Indian Tunnel" with its unnamed extensions leading, as today, directly to that valley. Following this period, the vadose circulation became supplied with more surface clay, silt, and sand than it could transport. Probably sink hole development was a large factor in this overloading. Thus, there ensued an episode of filling, and late in that episode came the unique event of a sink hole's, abrupt emptying into the cave of a huge collection of mammalian bones mixed with clay, silt, and coarser debris. For the geologist interested in Pleistocene history, Cherokee Cave contains an interesting problem. Simpson found the fauna to be definitely Pleistocene. Because it records the armadillo's farthest known, northern occurrence and contains no subarctic forms, the sink hole trap made its catch during one of the interglacial stages. Simpson found two earlier detrital deposits beneath the bone-bearing material; disconformities separate the three. With a fourth deposit disconformably overlying the bone beds, there were four definite times of filling and three times of partial erosion. Are the fills interglacial and postglacial in age? Are the times of erosion to be correlated with three of the four known glaciations in the Mississippi drainage area north of St. Louis? The southern limit of glacial drift is so near to the latitude of Cherokee Cave that one is justified, a priori, in suspecting that the ground above the cave was permanently frozen during glaciations, hence, that detritus could not enter nor could much erosion occur. The sections studied by Simpson still exist, and some day, some geologist is going to answer our questions. A question for further speleological study is the absence of any phreatic, red clay deposits. Two other caves near the Mississippi trench (Keener Cave in Wayne County and Cameron Cave in Marion County) seem to show similar, total absence of red clay. Is it not possible, since the caves are so near to the deep master valley, that early vadose drainage was vigorous enough to clean out the deposits from those portions of phreatic origin before Pleistocene events brought about a partial refilling under later, vadose conditions?
Caves of Missouri 81 CRYSTAL CAVE Owner: The Misses Mann Location: NW1/4 NE1/4 sec. 17, T. 30 N., R. 21 W., Greene County Shown on Ebenezer Quadrangle map The entrance to Crystal Cave is a shallow, hillside sinkhole. The only exposed bedrock is in the uphill slope of the sink. Much hillside waste has migrated diagonally down into the nearer cave chambers from this sink and has been trenched for a considerable distance to make a passage to the lower and more extensive chambers of this complicated cavern (Fig. 33). Essentially no water enters here and no marked dripstone exists in the "First Room". Fig. 33. Crystal Cave, Greene County The ceiling of the "First Room" is the bottom of the ledge in the uphill side of the sinkhole. The ledge is formed by a very cherty horizon in the Grand Falls limestone. The ceiling of the room is about 25 feet above a detrital fill which is made over in part by stairways and landings. There are three egresses from this room that lead into other parts of the system; all are close to the bottom of the room's walls. One brings the wet-weather stream of the cave into the room, another takes it out. The third egress is the trail route; equally low, but never taking the stream water.
82 Missouri Geological Survey and Water Resources Visitors turn left from the "First Room" and descend somewhat to traverse 30 feet or so of a footway excavated in the talus that has spread out in these lower levels from the sinkhole. In about 60 feet, one comes to a four-way intersection of chambers. If he goes left (southeast), he is stopped by a blockade of dry cave mud in about Fig. 34. Crystal Cave, Greene County The "Upside-down Well": A diagonally upward view of one side, showing the projecting insoluble chert layers. An appreciation of the depth will come with recognition that the six or seven alternating chert and limestone layers are horizontal. Photograph by G. Massie, Missouri Resources Division. 75 feet. If he goes straight ahead (southwest) across the intersection, he comes in the same distance to a blockade of cherty rubble; surface wastage that has come down into the cave from another small sinkhole. Before turning right (north and northwest) along the path, he should scrutinize the ceiling over this intersection. Its monotonously
Caves of Missouri 83 smooth surface is interrupted by an extraordinary, conical, hollow dome; an upside down "well", 12 feet deep (up) in the roof rock and only 6 to 7 feet in maximum diameter (Fig. 34). Note how the dissolving water which made it left the flat chert nodules projecting into it like shelves. Crystal Cave has many other solution cavities in its ceilings--of much significance in cave theory--but none to equal this. Fig. 35. Cross Section of "Concert Hall", Crystal Cave Looking northeast toward the stairs. E. H. Woolrych, del. We take the right-hand (northwest) turn, and under that 7-foot ceiling, walk about 100 feet to the "Concert Hall". Though the excavated footway is limited, the passage is the widest one in the cave. It is about half as wide as it is long. A large, dry mud bank on the right occupies most of its width and fills the cavity nearly to the ceiling. Entering the "Concert Hall", we find a bifurcation of the path at another four-way intersection. The left-hand (southwest) chamber is very limited in length. One path leads half-left (west) under a low "bridge" to the "Rocky Mountains" chamber, the other turns full right (northeast) to climb a stairway to the "Cathedral" which is the most impressive display of dripstone and flowstone the cave possesses. "Concert Hall" has a curious cross section (Fig. 35). Its ceiling on the right (southeast) is a continuation of that 7-foot clearance we have walked under since descending from the "First Room", but in
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Midlength of this largest chamber, the ceiling lifts like a clerestory to a height of 20 feet and so continues northeastward to the top of the stairway to the "Cathedral". This is almost as high as the ceiling of the "First Room" and is made entirely of a chert (flint) layer. When we climb to the "Cathedral", we will pass through a hole in that ceiling. Note the little perforations scattered through it; gaps in the original layer and not solution-made in the chert itself. Closer scrutiny of the high part of "Concert Hall" shows that there had been an intermediate floor here at one time that later dissolved and fell away and left a ledge on either side. Examination also shows that the original ceiling for the lowest part of this room was the same low monotonous surface under which we have walked to get to "Concert Hall". Indeed, it was even lower, for the "Low Bridge" over the path leading left (west) is a surviving part of it. Fracture-failure has in part destroyed this low ceiling and has given us the headroom we now have. The height of "Concert Hall" is the result of the destruction of a former "floor-ceiling" between two stories; making them one. To the right and close to the floor of "Concert Hall" is the very low roof of the cave stream course which enters from its equally low-ceilinged exit from the "First Room". This stream, crossing "Concert Hall" and flowing under the "Low Bridge", follows alongside the "Rocky Mountains" and disappears at the far (southwest) end of this chamber to reappear outside as a spring at the base of the Little Sac valley slope about 400 feet farther southwest. Ducking under the "Low Bridge", one walks west about 70 feet to some striking dripstone growths: the "Castle", the "Rock of Ages", the "Washington Monument" (Fig. 36), and an array of minor accompanying forms. Even the ceiling dome, similar in origin to, but smaller than the one we saw earlier, has its share of decoration from the secondary calcite growths. Many of the stalactites are distributed in fairly straight lines, their location being determined by vertical joint cracks in the roof rock, down which the percolating water has come. Here also is a truly massive dripstone column, about three times as thick as it is high. The "Rocky Mountains" are on one's left as he passes the "Castle" and walks southwest for the remaining 100 feet. A chamber, probably larger than any now surviving in the cave system, once existed here and has almost completely collapsed. The trail follows along the right-hand margin of that chamber; the only part, so far as we know, that did not fail. At the far end, it did fail and the "mountains" of fallen rock cut off all further human progress. Only the cave stream knows a way through that great jumble of fallen rock. Only an oak tree knows a way down from the surface above; its living roots gripping into the "mountain" blocks at the far end. And only some aboriginal redskin can claim priority of entry at this place. He paid a heavy price for his claim—his skull is still here, partially embedded in flow-stone.
Fig. 36. Crystal Cave, Greene County "Washington Monument": This steep conical stalagmitic dome is sur- mounted by four more conventional stalagmites, grouped as two Siamese twin couples. Photograph by G. Massie, Missouri Resources Division.
The climb upstairs to the "Cathedral" is over or alongside a mass of fallen debris and deep red clay which, with "Rainbow Falls" flowstone, apparently constitute the blockade and the filling of the "Concert Hall" chamber farther northeast. Thus the "Cathedral" chamber, its floor and ceiling both higher than those of "Concert Hall" but in the same northeast-southwest alignment, is an illustration of how, by ceiling failure, a cave chamber can migrate upward in the bedrock. Its upward migration, however, appears to have entered other higher, solutional chambers, for much of the ceiling and wall rock together with a remarkable side passage at this high level bear unmistakable evidence of a dominantly solutional origin. The average visitor does not enter this left-hand passage off the "Cathedral" room; he is not dressed or emotionally conditioned for the trip. There's stooping and creeping and crawling to be done, and some pretty sticky red mud to be crossed. The ceiling solution cavities along this route, however, are the best in the entire cavern. One of these is a symmetrical, flat dome with an extraordinary rim of chert all the way around its lower edge. The "Cathedral" is a splendid complex of stalactites, stalagmites, columns, "draperies", flowstone cones, "popcorn", "grapes", and "coral". The columnar form predominates, and at least three little rooms that one can squeeze into have been partitioned off by column growth in this upper chamber. One who squeezes far enough is rewarded by seeing, through a hole in the far wall, light entering from the ceiling of the "First Room". But do not try to worry your way farther along; there's a sheer fall of 25 feet ahead of you. That there is much red clay in the foundation of the "Cathedral" is obvious in the fracturing and offsetting of some of its columns. A vertical separation of two inches, together with a horizontal offset of five inches, is shown in two adjacent columns. Others show simple fracture and a later healing of the wound. Compaction of the underlying clay seems indicated as the cause of the breakage. The "popcorn", "grapes", and "coral" are a record of standing water that flooded the stalagmites after most of their growth had ceased. There are several places in the cave where rimstone dams have formerly held back little pools in which these bulbous growths have been made below the water line. Another curious feature of Crystal Cave's dripstone which is seen in several places, is a saw-toothed edge to the "draperies". It is not a very common phenomenon and for it, there is no adequately specific explanation. Perhaps you have had enough and are ready for outdoors again. If not, try a traverse up the cave stream course from the "First Room". You will be able to walk a long way up the dry (let's hope) channel. The course is winding, the footing rather slippery, and the head room somewhat limited in places. The reward for attempting the first 250 feet of this long, mud-floored passage is the view of high ceiling slots which cut far up into the roof rock, as straight as though laid out by a surveyor and utterly impossible for the stream to have made. Like
Caves of Missouri 87 the ceiling domes already seen, these slots record the earliest conditions under which this cave was made. The rock containing the cave at that time was completely saturated; there was no air above the water. Solution was occurring along favored intersections of vertical joints and horizontal bedding planes; both being possible passages for ground water. Ceilings suffered as much solution as did walls and floors. As such a completely saturated condition is impossible today, with Little Sac valley cut, deeper than the cave levels and draining all its water out at bottom level, we are forced to visualize a time when there was no such outside valley, when the present hilltops were only part of a continuous upland plain. Only then could this limestone have been completely saturated and the remarkable ceiling solution pockets have been made. No one going upstream from the "First Room" along this stream course can logically believe that the present stream made the entire cave. It is today a very much attenuated underground drainage way that has inherited and is using a few of the passages of an originally very complex cave. The cave is older than the hills and valleys of the region. Alfred Mann, who came to America from Brighton, England, in 1882, obtained possession of this farm in 1892 and always said that what he brought was the cave; the land was thrown in. He early constructed steps and trails, and Crystal Cave has been open to the public since 1894. His three daughters, Ada, Agnes, and Margaret, have carried on since Alfred's death in 1925. Mr. Mann had some knowledge of surveying, and for one thing, mapped the cave stream course back from its entrance into the "First Room". Finding that it passed very near his house, he drilled a well 102 feet deep and hit the stream which has since supplied the family well water. The well casing can be seen, if one persists in following up this lowest and longest of all chambers of Crystal Cave. The spring exit of the cave stream is a better-looking cave mouth than the actual entrance. It is a cliff with a good archway in it, but the rock is badly fractured, much has fallen, and the archway is dangerous to enter. The spring emerges from among a rubble of fallen rocks almost at river level. The Grand Falls limestone, in which Crystal Cave has been made, contains fossil crinoid (stone lily) stem joints. The crinoid calyx, which grew on the stem and constitutes the marine animal's resemblance to a lily, is much more rare. One ceiling in Crystal Cave has what may be unique among Ozark caves-two perfect, fossil, crinoid calyxes. The poor Indian who died back by the "Castle" may have been the inscriber of the concentric circles on this same ceiling. In one place, an arrow also was scratched in the rock, pointing in a general way out of the cave. Indian pottery and flint arrow heads have been found in trail-making in the entrance passage and on the "First Room" floor. Though not a picturesque, rock shelter type of entrance, with
88 Missouri Geological Survey and Water Resources a big sheltering ledge for a visor, "First Room" may well have been more comfortable than such in winter weather. Enlargement of the chambers of Crystal Cave has been irregular, and one is hardly aware that all of them started as slots along joints. The evidence comes to light when the cave is mapped (Fig. 33). The upland flats a mile or so north of the Little Sac valley have altitudes between 1275 and 1300 feet and are doubtless remnants of the former Springfield lowland which has been greatly eroded because of stream rejuvenation by the Ozark uplift. The cave lies below 1175 feet. Most of the solutional work which made it appears, therefore, to have occurred more than 100 feet below what finally became, during that earlier erosion cycle, the Springfield peneplain.
Caves of Missouri 89 CRYSTAL CAVERNS Owner: Mrs. John T. McFarlin, Cassville, Missouri Location: SW1/4 NE1/4 sec. 20, T. 23 N., R. 27 W., Barry County Not shown on Cassville Quadrangle map The entrance to Crystal Caverns has been artificially made. There is no known, natural opening from the outside world. The cave was discovered because of a persistent, little, winter fog or "smoke" that had come out of the ground where the cave house now stands. Cave air maintains a constant temperature throughout the year; the average temperature for southern Missouri being about 65° Fahrenheit. It, therefore, is definitely warmer than winter temperatures above ground. A spectacled person entering a cave in winter time has his glasses fogged at once. He wipes them, and they promptly fog again and again until the glass becomes warm. Similarly, cave air escaping Fig. 37. Crystal Caverns, Barry County
Missouri Geological Survey and Water Resources outside in winter becomes foggy. An air leakage made the fog by which this cave was found. The entrance is down a stairway, partly through the roof of the cave to a huge compound chamber, subdivided for convenience of description to visitors into "rooms", "passages", and "levels". The same great domed ceiling covers all. The huge chamber is a collapse cavity; ceiling and wall rock having fallen in the distant past to develop the dome in which the principle of the arch has maintained a status quo, while stalagnites and flowstone have grown through centuries on the last slabs and blocks to fall. This ancient collapsing apparently opened a hole up through the rock to the outside, for much of the debris is subsoil material of clay, sand, and chert fragments. Because this debris is deficient in limestone detritus, it must have been derived from surface weathering instead of cave collapse, but so long ago did this enter that the sinkhole itself has become filled, and its site can only be approximated. The floor of fallen slabs and blocks in the great chamber is itself dome-shaped and is but little below the domed ceiling. Thus, at all places along the descending zigzag trail, that part of the ceiling above one only appears to meet the floor. Both floor and ceiling actually slope off out of sight to greater depths. The great domed room really has no walls. On the map (Fig. 37) only an approximation of the actual perimeter of the room is shown. The zigzag trail follows an easy grade down and across the dome-shaped, debris pile; its flatter stretches are the "levels". On the ceiling above the first "level" are stalactites, helictites (crooked growths on the stalactites themselves), and incipient "drapes", all of the purest, pearly white calcite one is ever likely to see. More of these translucent growths hang along the second "level". Some of the "drapes" terminate in "straws", each of which has a tube through the middle exactly the diameter of the drop of water which hangs from its tip. At the third "level", a row of stalactites, as black as the first ones seen are white (Fig. 38), crosses the trail overhead. Manganese dioxide is not uncommon in cave water. It stains the wetted rock an inky black, but very rarely does it color stalactites as it does here. Descent to the fourth "level", also called the "Statue Room", is along a narrow, rock-walled passage. The right-hand rock is in place, whereas that on the left is the fractured edge of an enormous block that fell from the ceiling. In places, it is obvious that the surface of a fallen block would fit the irregularities of the wall, if brought into juxtaposition. At this fourth "level" a lateral chamber leads off to the right, under a ceiling of its own. Almost no roof fall has occurred here. The chamber is an abandoned water route of that earlier time when the cave was first being dissolved; before the main chamber had been widened past the limits of the strength of a flat span in this rock.
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Fig. 38. Crystal Caverns, Barry County
Black stalactites: This group of manganese dioxide-stained stalactites, almost inky black, is surrounded by almost pearly white ones. Photograph by G. Massie, Missouri Resources Division. This lateral chamber, and another at the end of the trail, never were over-expanded and never have suffered collapse. If one can persuade his guide to make a short detour back along this lateral chamber, he will see a remarkable, cotton-like aggregate of the finest, needle-sized crystals of calcium carbonate imaginable (Fig. 39). They are not dripstone, or flowstone, nor apparently were they ever deposited in a pool of water. There seems to be no better explanation for them than that of efflorescence. They appear to have grown out of the pores of the rock to which they are attached. To the mineralogist, they are aragonite, not calcite. The ceiling of the fourth "level" is studded with uncountable thousands of "buttons" which are separated joints of disarticulated, fossil, crinoid stems. Several portions of stems, with joints still connected (two of them six inches long), make clear the identity of the buttons. Crinoids, or sea lilies, are living in deep ocean water today, and their remains are seldom picked up on the beach. Many forms were, and still are, anchored animals. Their holdfasts (like roots in that sense), stem, and calyx suggest a single-stemmed flower With five petals. They are fossil records—along with the brachiopod
92 Missouri Geological Survey and Water Resources Fig. 39. Crystal Caverns, Barry County Aragonite crystals: This cluster has grown on a chert nodule in the cave wall. "Popcorn" in upper, middle, and right. Photograph by G. Massie, Missouri Resources Division. Bivalve shells also seen in some of Crystal Cave's ceilings—of organisms whose life and death millions of years ago gave origin to the lime mud which is now consolidated rock, and in which the cave was much later dissolved out. One now traverses a passage under the lowest ceiling in the cave. After this lowest chamber had been dissolved out, it became entirely filled with a very fine textured red clay. Our passage is through a trench dug in that clay. We are, here, 80 feet below the entrance. Emerging from this stoopway, one enters the "Fossil Room" with ample head and elbow space. The floor is composed largely of the red clay, the depth of which we do not know. The "Fossil Room", the "Statue Room", and the filled chamber traversed by the trenched footway are solutional in origin and are only slightly modified by breakdowns. We think, therefore, that this is the level of the original system of water-dissolved cavities, that all higher rooms have become so because of subtraction of rock from the ceiling and its addition to the floor. In this fashion, cave chambers may actually migrate upward and even reach the surface, becoming the site of sink holes. "Fossil Room" is named for the extraordinary abundance of crinoid stem joints in the ceiling. Inconspicuous, but very interesting, is the "fossil chat" on the surface of the clay floor. It is a fine gravel.
If the Al2issourit-93 composed of crinoid "buttons" which have weathered out of the ceiling and have fallen to the floor. At the far end of this room is the "Frozen Lake", a pool lying partially under a big fallen and tilted slab. There is calcite "ice" along the margins of this pool, floating in the surface film of the water. The least disturbance of that water surface would break the "ice", which, being heavier than the water, would sink to the bottom. The "Frozen Lake" also has calcite crystals growing beneath the surface along the edge, and its bottom is covered with growing "coral"; rounded forms which in aggregates are variously called "coral", "popcorn", grapeses", and "cauliflower". Elsewhere in "Fossil Room" are remarkable, tattered arborescent, branchy growths on the under sides of sheltering slabs, somewhat like, but coarser than, the needle-sized forms in the lateral (hall higher off "Statue Room". Whether these are efflorescences or have grown under water, we do not know. Returning, we must, by stairway to the "Mezzanine Room", a chamber made by the fall of at least two big blocks from ceiling and wall. They landed right-side up 1.0 or 1.2 feet directly below the scars their detachment left. Further climbing of stairs brings us to the "Queen's Attic", the highest room in the cave below the great half dome of the higher "levels" and 40 feet below the entrance. Here are large dripstone forms of snowy whiteness; stalactitic and (rapery forms called "The Turkeys", stalagmite forms with fancied resemblances to certain historical characters, and "drape" so thin and translucent that even without transmitted light one sees all their internal structure. The (Idiately shaded) bandings are the successive zones of growth. The saw-tooth edging of the lower margins of these "drapes" has been persistent feature during their growth, as the waviness of the bands shows. The stalagmites possess a delicate rimstone, or a series of reticulated, little dams which held tiny pools of water when growth was active. These curious little reticulations are characteristic of most caves in the Mississippian limestones of the Ozark country. The red clay of the lowest "levels" apparently never has been higher in the cave. We reason, therefore, that the episode of collapse, when the higher rooms were made, was later than the time when the clay came in. As clay is being made by weathering on the surface today, some special conditions for its accumulation in such quantities in so pure a form (no grit, no sand, no gravel) must then have existed and have since disappeared. There must of course have been existing chambers to contain the clay. It seems probable that the original cave was dissolved out before the present valleys and hills were carved by today's surface streams, and that it was made at least 100 to 150 feet below the original lowland whose uplift and consequent carving has made the rugged Missouri topography. If so, then the clay fill must also date back to a time when the upland, prairie surfaces extended all across this part of the State, when surface drainage and subsurface drainage alike was sluggish and ineffective.
DOLING CITY PARK CAVE
Location: 2600 North Campbell Avenue, Springfield, Missouri NW1/4 SW1/4 sec. 1, T. 29 N., R. 22 W., Greene County Not shown on Springfield Quadrangle map. The entrance arch covers two cave openings (Fig. 40). It is hardly an arch, for the total span is 60 feet and the height uniformly about 7 to 8 feet. The 15 feet of roof rock is supported in part by the central pillar between the two openings. The smaller opening is 21 feet wide by 7 feet high but immediately dwindles to two crawlway phreatic tubes which lead back at right angles to each other. They are only 7 to 8 feet high and are partly hidden behind the tilted, fallen roof blocks. Corroded old stalagmites record an unroofing of this part of the cave since they grew. Photograph by G. Massie, Missouri Resources Division. The entrance roof span: The smaller cave mouth is on the right, partly hidden behind the tilted, fallen roof blocks. Corroded old stalagmites record an unroofing of this part of the cave since they grew. Photograph by G. Massie, Missouri Resources Division.
Caves of Missouri 95 probably are completely clogged a short distance farther back and probably have rock floors with dripstone cover. The cave proper is 30 feet wide and 7 or 8 feet high at the gate. The ceiling height decreases gradually to a stoopway in the 600-foot length of the cave. At this point, an artificial dam holds stream water nearly to the ceiling. There are stumps of old, corroded, stalactitic masses near the entrance, but no stalactites farther in. About 100 feet inside and on the left, there is a large, wall-attached, stalagmitic growth; almost a half dome. One hundred and fifty feet inside and also on the left side is a group of wall-attached columns; one of them has delicate, pure white, rimstone terraces as an overgrowth. Approximately 440 feet from the entrance, an old 8 inch, city well casing, now plugged, penetrates the cave. Five hundred feet back, there is a tributary passage from the left which is floored at its mouth with flowstone. From 400 to 600 feet inside, there are many curious remnants of flowstone deposits along the lower 2 feet of wall. Inclined laminae in them and outlines of their forms suggest former rimstone dams which are now completely cut through with only buttresses left. These former dams all had a steep dip upstream. They must all have grown at the same time and rate, for the stream gradient is so low that any one, once full-grown, would back up water too deep for any more to start growing. Some of them were only a few feet apart; closer together than they were high. In front of the entrance arch, there is a rock-walled alcove as wide as the arch and 130 feet long. Big vertically tilted blocks on its floor and recesses in its walls indicate it to be a ruined portion of the original cave. Apparently the two present openings joined here to become one larger chamber, for there is no trace of the separating bedrock out in the floor of the alcove. An Indian grinding mill is on a ledge of the partition beneath the arch. It probably was originally the socket of a chert nodule which cracked and crumbled out, the resulting bowl-shaped cavity then being adopted for use as a mortar. At the north end of the east wall of the alcove and 50 feet offside, some close-set shearing surfaces dip 60 degrees away from the alcove. At least 3 feet of rock is affected. These shear surfaces, this far out from the actual cave arch, seem to indicate, not only a big load of rock that has since been eroded away, but also a subjacent cave chamber for which there is no other indication. It is difficult to diagnose this cave. It is not too wide or too high to impute it to the work of the present stream. There are no indications of spongework, ceiling or wall cavities, networks, or joint slots. The nearest approach to a showing of phreatic traits is in the smaller opening. The stream must lie above the present saturated zone and not far from the trace of the former peneplain. It is perennial, though variable in volume. The only strong suggestion of deep-seated origin is the shearing.
Fairy Cave is essentially one large joint chamber. Its orientation is between N. 50° E. and N. 25° E., its length back into the hill is 225 feet, and its width ranges up to 40 feet, and its height to about 100 feet. Except for the great dripstone growth in midlength, one would be able with adequate lighting to see the entire chamber from almost any place in the cave. The entrance is housed over. It is just above the level of the flat ceiling, and descent is made by a series of seven irregularly placed and spaced, zigzag, stair flights and one ramp to the bottom level. The last flight is most irregular in itself, having four changes in its general northward direction. At the bottom, the visitor walks northward along the length of the cave. This involves some reversed, short flights and ramps to cross the small hill in the floor and to bridge the "Fairy Lake" which is beneath the magnificent "Fairy Cathedral" (Fig. 41). At the north end of the cave, an optional climb may be made to an observation platform which is situated about halfway up towards the ceiling. Returning, one uses an almost wholly different route by going through the "Cathedral draperies" in two places, walking a narrow balcony along the side well above the floor, climbing some more zigzag stair flights, and joining, at six flights below the entrance, the route by which he descended. Stairs in caves are sometimes a bit dangerous. Wood will deteriorate and steps will become slippery from mud and drip water, but all of the stairs in Fairy Cave are of concrete, all the supports and hand rails are reinforced with steel, and nowhere does one cross a muddy bottom or (except in springtime) go under dripping water. No cave in the Ozarks has presented comparable problems of engineering design. Probably no different planning than that followed could have more successfully met those problems or interfered less with the natural beauty of the cave. Every landing at a turn in the zig-zag is a viewpoint; some for near features, some for distant views. The cave without its ornamentations would be an impressive corridor. The fairies, however, have lavishly draped and decorated their home; have subdivided the corridor into halls, alcoves, grottoes, little chambers, and balconies; have colored and spangled their constructions; have made a lake beneath their "Cathedral"; and have even created a most striking, monumental column for the cave's first explorer. Few bare walls remain; the wealth of ornamentation is almost everywhere, and the variety of styles used is almost without equal in the writer's experience. Let us start the hour's trip through Fairyland!
Fig. 41. Fairy Cave, Stone County The "Cathedral". Photograph by G. Massie, Missouri Resources Division.
We descend two or three of the zigzags and from examples close at hand learn the elements of dripstone forms. Most stalactites do not catch all the lime which dripwater contains. Complementary stalagmites beneath them make the common, paired groupings which, with sufficient down-growth from above and upward growth from below, join to make columnar forms. Descending water that has had a surface to flow over may leave an enamelling or armoring of the native limestone walls and floors, appropriately termed flowstone. A compound of hanging dripstone, fused with wall flowstone, is first encountered at the foot of the fourth flight of steps. Halfway down the fifth flight is the "Flag"; an outstanding ample of the drapery form of hanging dripstone. The bars of the "Flag", clearly shown by transmitted light through the translucent cave onyx, are successively added to its lower edge as downward growth of the "drap" progresses. The waves in these "drapes" may seem easily explained by original curves, as the growth started from the ceiling, but try to explain the "Scroll" just beyond the "Flag" where the terminal portion describes a coil of one and one half complete turns. Test your theory by imagining a further downward growth of a foot or two. Would the spiral be continued, tighter and tighter, until it fused into a simple icicle-like form? We pause at the landing along the fifth zigzag and add infinitesimally to the human hand polish on tops of conveniently placed, sturdy stalagmites. On the right-hand (east) wall, we take note of a great frieze of wall-attached, dripstone forms which include the "Organ Pipes" group of stalactites hanging from a high ledge and enclosing a grotto back of them, and the "Family Group" of wall-anchored, bracket-like stalagmites lower down. High above all and more distant is the "Statue of Liberty", a columnar growth impossible to describe as any simple form because it is obviously a compound of several. On our left (west) is vividly colored, native limestone without secondary overgrowths. At the foot of the fifth flight, one turns south to face the "Truman Powell Monument" (Fig. 42), a magnificent compound of stalactites, stalagmites, and "draperies". The upper portion of it is designated as the "Angel". Farther back in the alcove is the "Angel's Wardrobe"; more of the spirally shaped and striped or banded "draperies". The basal, conical domes of the "Monument" carry a pure white, delicately constructed pattern of reticulated ridges; a pattern which is repeated in many other places and which is actually growing on the concrete steps and pillars that make our visit possible. A broad shelf on the left, with its halfdome top and fringe of stalactites on the lower edge, is a record of a flat-topped, clay deposit once here and since eroded away. Behind the column, one sees the native limestone walls approach each other and realizes the improbability that the cave ever extended any farther out toward the hillside. Continuing down the sixth flight and its following ramp, one may go in behind the column and look up into those rare and puzzling
Fig. 42. Fairy Cave, Stone County "Powell Monument." Photograph by G. Massie, Missouri Resources Division.
Missouri Geological Survey and Water Resources coiled or spiral "drapes" (Fig. 43). Rare in general, they surely are, but Fairy Cave has them in a dozen places. If caves have habits in their dripstones, one of Fairy Cave's certainly is to wind up the termini of her "drapes". Another habit is that of the delicate reticulation of Fig. 43. Fairy Cave, Stone County Spiral tip on compound "drape": Although the photograph could not be taken to show it all, there are three and a half complete coils in this tip. Photograph by G. Massie, Missouri Resources Division. very fine, rimstone coatings. Look half way down the seventh and last flight and see it on both the vertical and horizontal surfaces of the concrete posts and beams. It has grown since 1929 when the old wooden structures were replaced with walkways of concrete; mostly calcium carbonate, the cave's own material.
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At this pause, listen to the "Fairy's Harp", the lowest notes on the left, ringing in perfect order to the right, every note true and sweet as a harp in tune, but produced by tapping limestone stalactites instead of plucking taut, steel strings. At the bottom of the southern half of the cave is the "Temple of the Gods". Here one climbs up over a small hill of clay, rock fragments, and stalagmite growths; all but the more massive stalagmites are now buried under concrete steps. From here, he descends into the "Lake Room". The "Fairies' Lake" extends completely through beneath that huge piece of dripstone, the "Fairies' Cathedral" (Fig. 41). Huge the "Cathedral" surely is, 85 feet high and 50 feet across, but like so many cathedrals, massiveness is lightened by an infinity of detail, some of which we shall examine on our return. At the lake level there is one of the few lateral, solutional passages of the main cave. The "Dragon's Mouth", at the right (east), has been crawled into for perhaps 75 feet. In excessively wet weather, water pours out of this mouth to flood the "Lake Room" 10 feet above the ordinary level of the pool, but this flood, after the crest is reached, will lower at the rate of 2 feet an hour. To cross the lake, we walk a bridge of two inclines, up to and down from a central pier in the basal part of the "Cathedral". At the high point on the bridge, we pass between stone "drapes" realistically parted for our passage. A closer look will show that the stalagmite is mounting up and engulfing the tip of the "drapes", but the resemblance to parted curtains is most striking. Twice more we shall pass between parted "curtains" before we return. More spiral tips of coiled "drapes" are beneath the "Cathedral", and more of the dainty rimstone corrugations are on the stalagmites and on the concrete work itself. The little cups contain tiny crystaline growths, and where the concrete extends below the level of the lake, "coral" growths, an inch in maximum projection, have formed in the past 20 years. Emerging from beneath the "Cathedral" in that farther portion of the cave known as the "Grand Crevasse", we face back to see the "Cathedral" from the opposite side. On this side, it is compounded of six "stories", each of which is a unit with a rounded shoulder from the top of which hang "draperies" that coalesce with the next, rounded, shelf-like shoulder beneath. The shoulders are, in effect, steep stalagmite growths, and the back-curved "draperies" are variations of the simple stalactite form. The ensemble is an amazing piece of cave decoration and the fairies should be complimented on their artistic skill in form, in color, and in the exquisite frost-like spangling of their work. To get the best view, climb to the observation platform at the far north end of the open cave. Opposite the "Cathedral" are the "Theatre Boxes"; nearly as large vertically as the "Cathedral", but built on a design which uses straight stalactites instead of recurved "drapes". The "Boxes" are screened by these rows of stalactites. In the ceiling of the cave are
102 Missouri Geological Survey and Water Resources curved rows of stalactites. Each row is an independent unit and each is determined by a curved crack in the roof rock from which seepage water has come. As we walk back toward the entrance, we use a rising ramp and steps to pass under the "Theatre Boxes" and to reach the "Cathedral". Rimstone corrugations on these steps have grown in 20 years, despite the traffic the steps have carried. Here also there hangs that unbelievable, tip-spiralled "drape", with no less than three complete coils in a total diameter of 4 or 5 inches. The "Throne Room", inside the "Cathedral", is entered and left between two more pairs of parted "curtains". It is a small room, but wonderfully furnished. "Elephant Ears" hung up in a "Cathedral" may be a puzzle to us, but the fairies knew what they liked, and they liked elephant ears BIG. Twelve feet is a really respectable length for such a big game trophy. Duck, or you will bump your head against its tip. Here is a "drapes" that terminates in a conventional stalactite which hangs 8 inches in the clear. Here are "drapes" that do not quite touch the stalagmite cones beneath. Here are "drapes" with no stalagmitic growths at all beneath them. Most of the cones are reaching up on, and are shortening, the "drapes". Two more groups of parted "curtains" may be seen, but are not used as passage- ways. A ramp bridge leads us well above the walk we used at the lake level and joins that walk at the top of the hill composed of clay-rock fragments and stalagmites. From thence, we follow another balcony-like walk on the east wall of the "Temple of the Gods" and walk past some curious, bracket-like, wall-attached stalagmites to the path's junction with the entrance, zigzag stairway at the level of the sixth flight down. We look back at the "Cathedral". On the south side of this structure are eleven definite, rounded, shoulder-like shelves with hanging fringes of back-curving "drapery". We look again at the "Flag" and the adjacent "Scroll" and note the saw-toothed edges that may have escaped our notice the first time we passed it. We further examine the orange-red, native rock in the west wall and see the best display of "coral" the cave has to offer (or "popcorn", or "grapes", depending on the fancy of the cave management). At this level, there is a slightly difficult, balcony passage to another of the few lateral openings in the wall of the cave. Only a few people can negotiate it at one time, and most people do not care to try after one look at the way. It is the last room in Fairy Cave we may see and perhaps the most intriguing. There really are two, perhaps three, solution chambers here, so overgrown and filled with dripstone forms that they are hardly recognized from viewpoints in the main cave. The cave characteristic at this place is that of corrugated stalactites (Fig. 44), with ribs and grooves horizontally circling each unit. Some of these ribs become little cup-like shelves, and series of them extend from top to bottom of the stalactite on one side or two, or all around. Associated "drapes" may have one straight
Caves of Missouri 103 edge which is an icicle-shaped stalactite with a flung-out, "drapery" wing. The edges of some of these wings, likewise, have descending series of little cups, made by that delicate rimstone growth. About every possible gradation of these forms is to be seen in this room, the "Fairy Shrine". Fig. 44. Fairy Cave, Stone County Corrugated and serrate-edged stalactites: These forms are in the "Fairy Shrine". Photograph by G. Massie, Missouri Resources Division. There has been violence at some time in that "Shrine". The columns have all been broken. The fairies have mended some; others have suffered so much separation and offsetting at the fractures as to have defied their skill in repair work. We may be looking at a record of the 1811-1812 New Madrid earthquake! We have walked vertically and horizontally a total of 750 feet. Coming out, many of us will wish we could turn around and do the whole trip right over again.
The entrance to Fantastic Caverns (formerly known as Temple Cave, Percy Cave, and Knox Cave) is on the west side of Little Sac valley at the head of a cliffed ravine or short gorge about 800 feet from the river and about 75 feet above (Fig. 45). The cliffs converge here, and the roof rock of the cave entrance is continuous with their uppermost few feet. The roof over the entrance is only 4 or 5 feet thick at the free edge, the entrance itself is 7 to 8 feet high and 45 feet
Caves of Missouri are wide with a flat ceiling. A terrace in front of the entrance is largely "made land", or debris from the excavation of what was originally a waste slope that mounted to the ceiling level and concealed the entrance to the cave. Only a crawlway at the east end gave the first explorers access in 1867, and the names of the 12 women explorers are painted on the cave wall somewhat more than half way back to the end of the trail. About 30 horizontal feet of this fill in the mouth of the cave has been excavated, the remaining 15 feet at the east end still exhibits the original crawlway. A section of that original blockade shows flowstone, intermixed with and superposed on slabby, fallen rock and some thick, short stalagmites. The flowstone has a 10-degree dip back into the cave (Fig. 46). Immediately on entering the cave, one is in the midst of a great collection of dripstone forms. In the first 100 feet, there are no less than 15 columns connecting ceiling and floor. Twelve of them are very massive, and some are actually thicker than high. They are all built on fallen, rock slabs. They may actually support the present ceiling, for immediately beyond them, where there are no such supports, the ceiling has collapsed to make a dome 150 feet across and 30 feet high, with a hill of dripstone-capped, slabby debris beneath it. "Straw" stalactites are numerous on the ceiling near the entrance. Some of them contain fine rootlets of the trees growing on the surface above; rootlets that have grown down into their central tubes. A habit of stalagmitic dripstone in Fantastic Caverns is that of the formation of very small, rimstone terraces on the more dome-like forms. The best example is just inside the entrance. Another habit of Fantastic Caverns' dripstone is the development of large calcite crystals whose faces are flush with the surface of the dripstone. The fresher dripstone sparkles under the illumination of the cave lights as though frost-coated. A third habit is the growth of the sugar beet type of stalactite which locally characterizes most of these forms and in some places has another "beet" growing from the tip of the one attached to the ceiling. A fourth habit is the formation of the saw-toothed edging on the lower parts of "drapes". Why dripstone in different caves, even in different parts of the same cave, shows these different habits is a problem not yet solved. Approximately 150 feet from the entrance gate, one sees on the right, marked evidence of shearing in the wall rock. It is continuous for 30 feet or so, but is seen nowhere else in the cave. The marks, produced by the shear, dip back into the wall at an angle of 45 to 50 degrees. Most of the fallen, slabby rocks in the trail are sheared slabs, not bedding slabs. This structure was produced, almost surely, by yielding of wall rock, where inadequately supported, under the weight of overlying rock. Because no adequate thickness of roof rock now exists here, this structure must date back to an earlier time when the roof was much thicker and, therefore, the ground surface above was much higher than today.
About 450 feet from the entrance is the "Auditorium". Its flat, clay floor lies beneath a broad and equally flat ceiling which is nowhere more than 15 feet high. This great room is nearly 100 feet wide and 250 feet long, and has perfect acoustics. Three hundred voices once sang the "Hallelujah Chorus" in this "Auditorium".

The ceiling here and for the remainder of the cave's length is the solutional top of the cavity, and rarely does one see any fallen ceiling rock. From the "Auditorium", there branches off to the left a lateral member of the cave system not regularly traversed by visitors. It is
Caves of Missouri 107 a stoopway for 100 feet, beyond which it has 250 feet of walking height to a place where the clay floor rises so near the ceiling that crawling is necessary for further penetration. A little more than 100 feet back in it, excellent rimstone makes a series of little pools on the floor. This passage also is entirely of solutional origin. There is some fair sponge-work on its walls. In the "Auditorium" area there is a bridge of concrete slabs. Just beyond this bridge is the "K K K Rostrum Rock", a huge wall block 70 feet long which has settled about 6 feet from the east wall and tilted 10 degrees in so doing. A sheet-iron, hooded rider and horse, almost life size, and a fiery cross still stand atop this rock. Mr. I. B. England financed the purchase of the cave for the Ku Klux Klan in its heyday, but had to foreclose when the Klan failed to discharge its mortgaged indebtedness. At a place 630 feet inside, is the first showing of rows of stalactites on the ceiling. Each row is determined by a vertical crack or joint in the roof rock. These joints strike about northeast. A little beyond this place, is a display on the east wall of old drip-stone, orange in color, which has performed a difficult feat during its growth. Where the wall overhangs, dripstone has followed the curvature down the underside of the overhang and has remained attached to the wall instead of making vertical stalactites. Some of this is a 30 degree overhang. About 800 feet inside the cave, one is a bit surprised to see an iron pipe extending vertically from the ceiling to the floor. It is a well. Drillers often report that, in limestone and dolomite, their drill suddenly drops a few feet. The reason is clearly shown here. The well is at the cabin, three houses south from the cave entrance. We have passed under the road in reaching this place. About 1000 feet along the trail, the main cave is transected by a storm water course which has cut deeply into the clay floor and is crossed by a bridge. The ceiling of this cross passage is lower than the level of the clay floor. When it carries a discharge, water comes somewhere from the west and immediately disappears in the base of the eastern wall. Its outlet to the surface is in the Little Sac River cliffs 1000 feet to the east and about 100 feet lower than this crossing. Fantastic Caverns is indubitably a subterranean water course, but it was never made by this stream. Yet in the 1400 feet, more or less, of traversable length of Fantastic Caverns, this is the only stream the cave now possesses. These discordant relations tell unequivocally of great changes in ground water circulation since cave-making started here. Well back toward the end of the traversable cave, a coarse gravel deposit lies close under the ceiling. The inclined (imbricated), slabby pebbles record the northward flow of a gravel-carrying stream; one that operated long before the lower cross passage under the bridge came into existence. The great mud fill, however, is still older than
108 Missouri Geological Survey and Water Resources this former stream, for the gravel overlies it. And the main cave must be older than the mud fill. Our return trail passes through the "Forest Temple" and crosses the hill of fallen roof slabs under the collapsed dome. Along this trail are more showings of the delicate rimstone growths on stalagmitic Fig. 47. Fantastic Caverns, Greene County The "Non-identical Twins": One of these massive drip- stone forms has grown down from the ceiling to the floor, the other has grown up from the floor almost to the ceiling. Photograph by G. Massie, Missouri Resources Division. domes and more showings of the sparkle of calcite crystals in the stalagmites. Here also we encounter a feature for which there is no specific explanation; craters in the tops of stalagmites. All we can say is that the dripwater which once built the stalagmites has changed its attitude toward its creations and has started destroying what it once constructed. The craters are being dissolved out of earlier deposits made by the same drip. Two closely set columns seen on the return trip possess an intriguing relationship. One obviously is an aggregate of stalactites
Caves of Missouri and "drapes" which have grown down from the ceiling. Its neighbor, equally massive, is a huge compound stalagmite that has just about reached the ceiling (Fig. 47). If there is any specific reason for this contrast, the writer has no glimmering of what it is. When we emerge from Fantastic Caverns and look over the topography between the cave mouth and the river, we begin to understand the cavern's history. A cave system lies out here, its roofs destroyed, its solution-pocked walls exposed to daylight, almost as large as the system still existing underground. Virtually all the way to the Little Sac River, 800 feet distant and 80 feet lower, the ravine or gorge between the cave and mouth of the ravine is only an unroofed cave. So is the very striking, tributary valley from the south which describes a complete letter S for 400 feet upstream from its junction with the cave ravine (Fig. 48). All of these cliffed valleys are old cave chambers, ruined by the work of the streams now using them. The making of Fantastic Cavern is a thing of the past. It now is being destroyed, both by erosion and by the deposition of detrital material. Fig. 48. Fantastic Caverns, Greene County Collapse portion of Fantastic Caverns: View of one of the sharp turns in the S-shaped, collapse-formed gorge just east of the cave entrance. In the dark shadow, there is a steep cliff, a relic of a former cave wall. Contrast this with the gentle slope where no collapse has occurred. Photograph by G. Massie, Missouri Resources Division.
This destruction was initiated by the downcutting of Little Sac River. The cavern system was made before the river valley existed; made by water moving along every possible passage (joint plane and bedding plane), filling these passages completely, and allowing no air to enter as it does today. This cave, like almost all other Ozark caverns, is older than the present hills and valleys of the region. If you hesitate to accept this interpretation, walk south from the mouth of the cave ravine along the bluff of the Little Sac River and see the solution holes, the former cave walls now exposed, the cemented mass of fallen rock, and the red clay which fills other former chambers now exposed by the cutting of the river valley. We can actually see the dripstone once made in those former cave chambers. There was a much larger, more elaborate system here than now survives, and it was made before the Little Sac had cut its valley down to the level of that system. These isolated parts of Fantastic Cave's former system in the river bluff are all lower than the cave we have seen. So is the ruined chamber recorded by the S-shaped tributary gorge, but that does not mean that they are younger parts. All parts are conceived as contemporaneous in development, the larger ones being older only in the sense of having experienced more solutional enlargement during the same time. The altitude of the old peneplain surface, hereabouts, is approximately 1250 feet. The cave lies close to 1150 feet. We are convinced that it was made long before the uplift which gave Little Sac the energy to cut its present valley and was made beneath the water table during the maturity of that earlier erosion cycle whose final product was the peneplain. If the cave now lies 100 feet below the peneplain remnants, it must have been even deeper, below rock now vanished, when it was being made.
Caves of Missouri 111 FISHER CAVE Manager: Hugh Dill, Sullivan, Missouri, Superintendent, Meramec State Park Location: SW1/4 SW1/4 sec. 6, T. 40 N., R. 1 W., Franklin County Shown on Meramec State Park Quadrangle map Though there are some names written on the stalactites, now illegible from the overgrowths of additional calcite, the earliest human record in Fisher Cave is that of the Indian youth whose bones, shallowly buried, were found in trail-making just inside the entrance. Local historians tell of an inaugural ball given by Governor Fletcher in 1865 in the cave's largest room now appropriately called the "Ballroom". The cave was first operated commercially in 1910. When Meramec State Forest was established in 1926, the cave became State property. Until 1933, Lester Dill (the original boy guide of 1910 to 1917) held a concession to show the cave. Since then, the State of Missouri has had the sole administration of the cave. FIG.49- FISHER CAVE FRANKLIN COUNTY Surveyed by Jane Myers & Jean Simmons 1947
The entrance to Fisher Cave is almost as low as the Meramec River floodplain at the foot of the hill containing the cave. Its span is about 20 feet, its height about 8 feet. A thick flat ledge of dolomite constitutes the roof and departs about 5 degrees from horizontality. There is no cliff above the opening, though a few hundred feet farther north the bluff becomes strongly cliffed. A small tributary stream just south of the cave mouth has cut its surface valley as low as is the subterranean "valley" we are about to enter. This entrance passage, although 600 feet long, is only a small part of the cave. In another sense, it becomes smaller before we enter the real cave, for we must traverse a stoopway for about as long as an adult in only average physical condition cares to negotiate. Bending exercises are reputedly beneficial; let us go on (Fig. 49). For 450 feet, or as far as to the marked dripstone aggregate along this passage, there is adequate headroom. We pass two lateral openings on our left, but neither can be followed back very far. The first, still within reach of daylight, is obviously compounded of two or more irregularly connected passages. It is a small network that looks very unlike the entrance passage we follow. The second is wider and contains possibly the best developed and best displayed rimstone "river" in all Ozark caves (Fig. 50). The water has ceased to flow, but it has left a record in stone that can hardly be misread. Call it, in fancy, a "Lava River", but it tells of flowing cold water, not flowing molten rock. Call it a "river", but keep in mind that it is simply a series of little pools in those step-like basins, and little trickles from one basin down to the next. The last dam and stepdown in the series is the largest of all, about 4 feet high. There must be hundreds of the rimstone-dammed pockets (once pools) over its surface. If we look at the ceiling between these two left-hand laterals, we see a splendid display of cellular chert (flint) aggregates in relief; the soluble, dolomitic matrix having largely been dissolved out and the insoluble silica left. In no sense are these aggregates cave deposits; the cherty material was an original constituent of the bedrock from which the cave, much later, was dissoluted. If we look at the floor, we see something uncommon in caves; a bedrock floor. If we look at the walls we see an excellent exhibition of sponge-work developed in the native rock by differential solution. It extends up on the ceiling and is an undeniable record that the passage was completely full of water when these amazingly intricate, connecting "pores" were made. No stream like the one which uses the passage today ever could have done that solutional work on the ceiling. The thicket of dripstone deposits along this passage is but a faint foretaste of what is still ahead. Columns from floor to ceiling dominate, although there are numerous separate stalactites and stalagmites. Now for the stoopway, and then the big cave beyond. Straightening up and getting a deep breath, we see a ceiling far above us, and
Caves of Missouri 113 what looks like a mezzanine floor some 10 feet higher than the walk. By steps and a ramp, we are shortly up to that floor. It is no mezzanine. It is the main floor of the cave. We entered on the basement level. Fig. 50. Fisher Cave, Franklin County Rimstone "river": A series of many little pools, each with its own rimstone dam. Photograph by G. Massie, Missouri Resources Division. The floor to which we have climbed is not bedrock. It is clay, yellowish-tan in color, with a striking, vertical, columnar structure. It is cut some 15 feet deep by a stream-made gully that makes a complete hairpin turn at this place. The stream flows east and then, discovering that it cannot escape that way, doubles back to the west and flows to that small entrance passage. What a huge chamber it leaves for such an insignificant route. Using a bridge which crosses the gully, we make a circuit on this same clay floor in the east end of the main, open cave. There is a wealth of dripstone here that might be held responsible for the cave's closure at this end, for surely no main, subterranean watercourse could ever have ended so abruptly. Closer inspection shows that native dolomite walls behind the dripstone come down essentially to
If there is a continuation of the cave farther east, it is now completely clay-filled. And a continuation there must be. We return to the bridge. On the right, the surface of the clay is marked with a polygonal pattern of cracks (Fig. 51). Shrinkage cracks in the clay bottoms of dried-up puddles are familiar to all. The column-cracks in clay: Shrinkage cracks like these, penetrating downward, outline columns along which the clay may later break away. Photograph by G. Massie, Missouri Resources Division. The structure along the ramp is very closely related to such shrinkage cracks and so is the polygonal pattern. The clay has dried out and cracked deeply since the gully was cut. Indeed, a large portion of the clay floor has settled at this place; away from a terrace-like remnant that still clings to the wall. The thin calcite seams in the cracks were deposited later. The dripstone forms above the trail are engaging. They are not simple, icicle-like stalactites; they possess a kind of coarse, tangled, hairy overgrowth which is also composed of calcium carbonate, but which ignores the law of gravity. They are helictites; very fine specimens. Nobody really knows how they were formed.
Caves of Missouri 115 The trail follows the crest of a very narrow peninsula of clay fill. Earlier users of this ridge were bears; this summit was originally pitted with their hibernation beds. Beyond the bear site, the trail runs along a broad flat and thus reaches the second bridge. Thank the Civilian Conservation Corps for these bridges in Fisher Cave. Across (west of) this bridge, there is the first "Petrified Forest". Most of the "trees" here grow down from their "sky". Some connect "heaven" and earth, or once did, for settlement of the clay floor has broken a large proportion of them. The crooked path through the "forest" brings us to the third bridge across the stream-cut gully in the clay floor. After crossing this bridge, we have a straight trail for 125 feet under an abruptly lifted ceiling of remarkable flatness. The collection of "Old Ivory" dripstone forms is on our left and, a little farther on, the "Cemetery". On both sides of the cave at this point, there are mute evidences of the reason for that abrupt rise in the ceiling level. It is not of solutional origin; instead it has been left by the breaking away, long ago, of about 9 feet of roof rock. At this place, there is no stream gully and no stream in sight. Yet the next bridge, the fourth, is necessary, because here, there is that same little stream gully in the clay; the water flows east toward the entrance (its exit) passage. How does the water get from the fourth to the third bridge? Farther along, we'll find an answer. This fourth bridge takes us to an island of clay; a gully on each side of it close to the bedrock walls. The true solution-marked ceiling over this bridge is low. The fifth bridge is down in the gully. Before we descend, let us look at this unusual dripstone dome on the left. It all but joins the ceiling and it has almost vertical sides. It is 20 feet or more in diameter. Do you think it is solid dripstone? Might it not be simply a plating of calcium carbonate over an earlier form of some other kind of material? When we come back, by another trail, the answer will be clear. Beyond this low fifth bridge is the second and larger "Petrified Forest". The giant Sequoias might have here early practiced their techniques for growing huge trunks. Great columns of dripstone reach from floor to ceiling, or did, before the clay settled to fracture them. There is tilting of the lower portions, thus, offsetting is added to the separation. The "Ballroom" is another broad surviving part of the original continuous, clay floor of the main portion of Fisher Cave. Two streams enter here; one from the southwest (the "Weeping Willow" section) and one from the northwest. They both flow eastward on opposite sides of the "Ballroom" and join at the low bridge we have just crossed. The big, petrified, tree trunks semi-enclose the "Ballroom" on the east; bedrock walls constitute all the other sides.
116 Missouri Geological Survey and Water Resources The trail which goes a short
distance up the southwest stream course leads us to the "Weeping Willow" wall dripstone,
the great collection of clustered, stalactitic "draperies" hanging from the ceiling, and
exposures of the tan-colored, jointed clay beneath some of the fractured columns.
Dripstone growths, too dense for passage, stop further penetration, but there must be
adequate cave space beyond for gathering the water that emerges and makes the larger of
the two streams. The right-hand (northwest) passage has three connections with the
"Ballroom"; a low one used by the stream, a high one for us, and an intermediate one of
small diameter and tortuous twistings. We climb over a hill of clay and are confined
between walls much closer than those in the main cave. We note that the clay is deep red,
not yellowish tan. If curious enough, we may note another difference; the tan-colored
clay is gritty, but the red clay is as smooth as butter. They are two different deposits, and
the red clay is the older. Descending this hill into the "Grand Canyon", the trail crosses
the gravel of the stream which, from this point, follows a separate route to the "Ballroom".
The route is traversable, but not worth the effort nor the muddiness it would entail to
follow it. The existence of this route, however, answers the query of what became of the
cave stream back in the "Old Ivory" and "Cemetery" room. There is very little evidence
of ceiling or wall collapse along this right-hand or "Grand Canyon" section. Everywhere,
the native rock has smooth and rounded outlines. It has none of the sharp, fractured
surfaces which collapse leaves. The upside-down "wash- tubs" and "bathtubs" in the
ceiling tell unequivocally of a cave full of water at all times when this part of the cavern
was being made. The pockets of red clay in them tell of a once complete clay filling after
the solution work was finished, and of the endeavor of the present stream to remove that
clay. That is about all that any of the running water is now doing any- where in Fisher
Cave; removing the red clay and the tan clay. Cer- tainly, the cave never was made
originally by water flowing only on the bottom, as it now does. The original conditions
were those of complete saturation and of water held against all bounding, rock surfaces
under pressure, like water in a gigantic water main. The sixth bridge along the cave path
has two more features worth noting. One is the "Cave Explorer's Paradise"; 700 feet of
low, narrow creep-and-crawlway, with cross passages of comparable magni- tude and
extremely varied with a complexity of shapes and orientations. One may crawl over and
under passages he has already used. In places, the floors and ceilings rise or descend
steeply. It is literally a tangle in three dimensions of old waterways made under earlier
conditions of a complete water-filling; a tangle impossible to show on the map. Should
you try to negotiate the passage, you must marvel at the grit of the two girl surveyors, Jane
Myers and Jean Simmons,
Caves of Missouri who made the map. The far end of this route encounters a large high room which one can look into from a hole in the wall. With a rope, one may go even farther than the map shows. The other feature is high in the ceiling where a thin layer of insoluble chert makes a bridge (the "Free Bridge") from wall to wall. There is no charge for using this bridge, but no users. From this bridge, the path leads to the "Ozark Sunset Room" which makes up the largest portion of the right-hand section. Observing eyes will see, along this stretch, that the dolomite strata in the walls are not all horizontal. There was slight folding of the bedrock layers long before cave-making started. The amount of tilting is comparable to that seen on the outside in the roof of the entrance. One may recognize two low folds; an anticline (upfold) and a syncline (downfold). A prominent ledge marks the walls of the "Sunset Room"; a ledge with an inward sloping, upper surface and a flat bottom overhang. A heavy layer of chert makes, or made, that overhang. The ledge was undercut locally to widths too great for the strength of the projecting rock, and fallen portions have left the angular scars of fracture where the great ledge blocks lie on the floor. One of the most extraordinary solutional features of Fisher Cave is the "Grotto" in the northeast wall of the "Sunset Room". The over-hanging ledge which serves as a false ceiling has had two closely placed, ceiling domes dissolved upward from its under side. These became enlarged until they joined to make a double dome. They penetrated so far up into the ledge that with the ledge's own reduction on the upper slope they finally caused a double perforation completely through the ledge (Fig. 52). The cave was drained just in time to leave things in this incomplete state; a rather fragile, natural bridge still recording the once complete surface of the ledge. Had the work stopped just a little earlier, this bridge would have been left with a three-point suspension. It is but little farther to the end of the visitor's trail. From the broad floor of the "Sunset Room", steps lead down to the entrance point for most of the water supplying this section of the stream. The "Fountain of Youth" (where is there a cave without one?) at this place is a waterfall, the volume of which depends on season and weather. The conducting passages are bedding plane slots, imperfectly opened and probably of fairly recent development. The "Devil's Coal Bin" is another small waterfall and the "coalpile" is simply fallen, ceiling fragments now coated with a thin, glossy, black enamel of manganese dioxide. The "Bride's Chamber" has an almost ideal showing of the relations of solution shapes produced under the two different solutional episodes which Fisher Cave has experienced. The earlier episode was one of complete water-filling, the later and present one of a free-surface stream working only on the floor. The rock is almost honeycombed with an intricate network of irregularly shaped, sized, and oriented
Missouri Geological Survey and Water Resources cavities too small to enter, and through this network is the downward gashing of a free-surface stream. The "Old Maid's Room" is reached by a narrow, tortuous passage which seems to come to a blind end in the little bare room. This passage is one more of the many abandoned waterways of that earlier circulation, when the entire body of the rock was saturated at all times. Still more of them have been mapped at this place. If invited to traverse them, the average visitor may be trusted wisely to refuse. Woolrych, del. On the return trip, we use a different path for two different stretches between the "Ballroom" and the "Entrance Passage". Along the first, we pass that vertically-sided, enormous dome of dripstone at the east end of the second "Petrified Forest" and at the west end of the clay island. Just before reaching it, we encounter a stalactiflat, an assemblage of dripstone and flowstone now oddly hanging in the air (Fig. 53). The stream and the developers of the cave trails have together almost completely removed the tan clay deposit from beneath the base of the flowstone. The surface of the clay originally determined the position of the flat, flowstone base. Excavation has also revealed the nature of the dome. Two stages of growth are clearly discernible. An earlier one is recorded by the main mass whose foot is seen from this side to stand 4 feet or so lower than the flat, clay floor of the island. After the dome had grown down into the stream trench, that trench became filled, or nearly so, and then partially re-excavated. Dome growth shifted over onto a rem-
Caves of Missouri nant of the second fill and built a "Fisher Body Top", an armor of calcite, down the steep face of the little clay terrace. Since then, enough removal of the clay foundation has occurred to reveal the sequences of this history. Do you not think it a good guess that the main dome is but a surviving mass of a clay fill which once extended to the very ceiling? Along the second stretch of return trail, we may look across to the left and see that the first "Petrified Forest" started growing before the tan-colored clay fill was ever made, just as the dome largely ante-dates that later fill. The evidence is in the stalagnites which are being uncovered as the stream erodes its trench and in the stalactitic masses whose tips are buried in the clay. Before we leave, let us stand under the "Santa Claus Chimney" near the second bridge and look up with the aid of a spotlight into that 35-foot high (deep up) Fig. 53. The "Stalactiflat", Fisher Cave E. H. Woolrych, del. hole in the ceiling. It is but a ceiling dome of which the cave has many, but it is so vertically exaggerated as to be hardly believable, even when we see it. The fat old gentlemen for whom it is named must have a struggle to get back up against those drapery "barbs". It is clear that Fisher Cave has had a long and varied history. The latest event appears to be the discovery and use, by the cave stream, of the long, narrow route by which we entered. That route surely was not open when the tan-colored, clay deposit was made, for there are no remnants of such clay in the spongework or lateral openings. Figure 54 which combines a map of the cave with the overlying topography shows that the main cave is headed for an exit in the cliff a few hundred feet north of the visitor's entrance. So far as it is an open cavity, it ends about 150 feet from the cliff, and its ceiling descends at the far end to within about 40 feet of the level of the Meramec flood-plain at the foot of the cliff. Should there not be in the cliff outside some showing of where the original continuation of Fisher Cave and the cliff intersect?
120 Missouri Geological Survey and Water Resources Fig. 54. Relation of Present Topography to Fisher Cave Cave map by Jane Myers and Jean Simmons. Topography from Meramec State Park Quadrangle map; United States Geological Survey. Contour interval 20 feet. If, after returning to the outside world, one will walk 700 feet along this cliff northward from the cave entrance, he will find Indian Cave; an opening in the rock wall about 30 feet above the Meramec floodplain. It is a deeply filled cave which may be penetrated for about 130 feet; beyond this distance the fill rises to the ceiling. In going into it, one turns about 50 degrees to the left; the right direction to go if this cave is to connect with the blockaded lower end of Fisher Cave. The straight-line distance between the two cave ends is about 350 feet. We think, therefore, that a clay-filled portion of the original Fisher Cave, of this length, connects the two. Otherwise, in consistency, we must carry the continuation of Fisher Cave out below the bottom of the cliff and assume that Meramec River has not yet cut deeply enough to intersect it. Contemporaneous with the recent discovery and use of the present outlet for the cave stream, has been the gullying in the clay floor of the main chambers and the growth of dripstone and flowstone deposits. As gullying advances, buried stalagmites are being found in the clay deposit. Therefore, the deposition of that once continuous, tan clay fill occurred after dripstone formation had begun. The level floor is
Caves of Missouri 121 the upper surface of the deposit. It is a record either of standing water or of very slowly flowing water held back by some blockade along the inferred, older exit. The gullying began when the present, outlet route was discovered. Unlike this late, tan clay deposit, the older, red clay occurs in pockets in the very ceiling and along the "Grand Canyon" section (higher than the "Ballroom" floor) and is the only considerable body of red clay to be seen on the bedrock floor. Its widespread occurrence and its remnants in the highest parts are convincing evidence that the cave had already been excavated, almost in its entirety, and that the red clay had been very largely removed before the tan clay deposit was made. The cave could never be so completely filled today. The red clay-filling dates back to a time when no Meramec valley existed; at least with anything like present dimensions. This clay is so extremely fine that, once in suspension, it will settle out only in almost perfectly still water. Such water stood against the highest ceiling, 50 feet higher than the present "Ballroom" floor and nearly 100 feet above today's Meramec River surface. A long time is recorded by the accumulation of the red clay which constituted the original fill. Yet the cave, as capacious as today, must have been here still earlier, and its making must have required a water circulation. Because no deep Meramec valley then existed, the site of the cave was far below the land surface of that time and the body of the rock was completely filled with water. Although gravity was the cause of the circulation, the water was moving in any and every direction where it could find lower pressures and eventual escape. This little hill above the cave, a spur between two minor ravines (Fig. 54) is only 2000 feet long by 1000 feet wide, and the cave penetrates up into it for a fourth of its total height. That part of the rainfall which becomes ground water under this hill never could have made the cave. It has been responsible only for the dripstone and flowstone, the tan clay fill, and the later gullying. Fisher Cave dates back to a time when the present rugged Ozark country was a nearly featureless plain. Remnants of that plain occur along U. S. Highway 66 farther west, well away from the major streams whose downcutting, with that of their tributaries, has made today's marked relief. These streams existed on that former plain, but had so little gradient that they meandered widely as slow streams do. The event which gave the streams the ability to erode the present deep valleys, to drain the water-filled caves that lay well below that plain, and to expose them here and there for our examination, was the making of the broad Ozark dome in southern Missouri and adjacent Arkansas. In consequence of that uplift, the rivers entrenched them selves along their old, meandering courses, little tributary valleys began gnawing headward away from them, and the old plain became so much dissected that in this particular region its remnants are difficult to recognize today.
The episode of the red clay-filling appears to record a very long existence for the old, low-lying plain; the former peneplain. It records a great decrease in the vigor of ground water circulation after the main cave-making had occurred. Integration of the deep, subterranean, drainage routes had left many of them off the main routes and in a condition to catch and retain the red clay which filtered down from the thick, surface mantle of weathered material of that time. This interpretation of the history of Fisher Cave is not invalidated by the red clay with the interstratified, sandy lens and even gravel along the passage of the "Fountain of Youth". That deposit is a reworking of the original clay by fairly recent stream action. There is inclined current bedding here, and pebble-like chunks of the red clay are associated with the chert pebbles. The true, red clay deposit has no sand, no pebbles, and no dripstone or flowstone in it. All these came later, after the Meramec River valley had been eroded, and the cave had been drained so that air and a free-surface stream could replace the earlier, completely water-filled, and later completely clay-filled cave. Superposition of the cave map on the topographic map of its immediate vicinity (Fig. 54) reveals some very significant relations. The two cave streams which join at the sixth bridge and continue as one to emerge at the entrance both flow to their junction point in the opposite direction from that of water on the hillslope above them. The one followed by the visitor's path descends about 40 feet to the junction (670 feet to 630 feet), whereas the hill surface above rises more than 60 feet in that distance. Thus, the roof rock thickens downstream (but uphill by outside gradients) from 50 feet the mapped head to 150 feet over the junction. One thing is clear; no water table, determined by the shape of the hill above the cave, ever initiated the ground water flow which made that eastern arm of the cave. The remainder of the cave pattern is also incongruously disposed and sloped to fit the topography. The two little valleys which bound the hill on the north and south are younger than the cave itself, as is also the valley of the Meramec River. It is true that the cave leads, and its branches converge, toward that master valley, but this, we believe, is only because Fisher Cave, while growing, led its pressure-directed water to an ancestral Meramec, a river of an earlier cycle of erosion, and there discharged as a big spring. Were Fisher Cave the product of ground water of the present cycle, it should logically be situated where that ground water in the Meramec River's, bordering, higher land is greatest in volume flow. It should lie beneath one of the two minor valleys where there would be far greater supply for leakage down into the rock. It should not lie under a hill whose slopes, like a roof, shed most of the rainfall off so quickly that a very minimum has an opportunity to seep down for cave-making activities.
Caves of Missouri

CAVES IN THE VICINITY OF HAHATONKA

Owner: L. J. Snyder, Route 1, Camdenton, Missouri
Location: sec. 2, T. 37 N., R. 17 W., Camden County
Shown on Hahatonka Quadrangle map

Should we attempt to appraise cavern localities in Missouri, none could take precedence over Hahatonka. This is not because its four caves are superlatively showy, not because of the presence of the great spring, nor because of the striking, local scenery. Hahatonka and its vicinity stand out in our appreciation because the caves, the spring, Fig. 55. Environ of Hahatonka Spring, Camden County Enlargement of part of Hahatonka Quadrangle map; United States Geological Survey. Horizontal scale 1/17,600. Contour interval 20 feet.
Missouri Geological Survey and Water Resources the sinks, and the great cliffs fit perfectly into a coherent and understandable sequence of events, and almost nothing is lacking to make a complete picture of the physiographic history of the region. Figure 55 is a topographic map of about 1 square mile with the spring centrally situated. The spring branch which discharges an average of 48,000,000 gallons daily has been dammed to make the Trout Glen pool. The rising water level would have found another discharge route had not another dam been built to the same height. Water spills over both dams, and thus two streams instead of one carry away the output of the spring to the Niangua Arm of the Lake of the Ozarks. In this way, an island has been made of a small hill that stands down in the bottom of the precipitously walled Hahatonka gorge, or chasm, or gulf. When the Lake of the Ozarks is full, water rises slightly above both dam crests, and the hill is truly an island in the lake. When the lake is lowered in preparation for the Osage River spring floods, both dams discharge and the hill becomes a river island. The region is wooded, and a significant point regarding its topography may for that reason be overlooked. It is that the steep-walled gorge, shown by crowded contour lines, is essentially a great rift in the summit and west flank of a hill whose other slopes are relatively gentle, as the widely spaced contours show. The remnant of the former, complete summit, crowned by the ruined castle on the north side of the gorge, stands nearly 250 feet above the high level of the lake. The corresponding southern remnant stands more than 180 feet above. The gorge is a rift in all literalness. If gorge means to you a stream-eroded feature, let us drop the word and say gulf or chasm. It is a double chasm where the island stands. The manner of the rifting, whereby the hill has been cut almost through, becomes clear when the four caves, the six sinkholes, and the one natural bridge of the map area are studied. River Cave.—This cave, also known as Mystic River Cave (Fig. 56), is entered from the bottom of a steep-walled sinkhole, 50 feet deep in the floor of the stream-made valley of Dry Hollow. The contents of what is now the sinkhole have not all been removed by solution, for the upper walls are of insoluble sandstone; the Gunter member of the Gasconade formation. The sandstone has fallen in great blocks into a former cavity below the sink floor; a cavity capacious enough to contain them and still remain 50 feet deep. Only a very small proportion of the sandstone has gone out of the sink along the cave stream which is encountered at the very entrance to the cave. Appreciating this, one readily sees in the cave an uncollapsed portion of the original cavity; a cave older than the sinkhole. A feature not duplicated in any cave known to the writer is the course of the stream just inside the entrance. It flows toward the entrance from the east and cascades down over a bare, faceted, bed-rock floor. As it reaches the debris fill at the bottom of the sink, it...
Caves of Missouri 125 turns sharply back underground through an angle of at least 300 degrees and flows toward the 700 feet of traversable cave length, leaving the site of Dry Hollow valley to go somewhere under a hill, the summit of which is 250 feet above the stream. The stream is undoubtedly a tributary to Hahatonka Spring which is less than half a mile away and 60 feet or so lower. Fig. 56. River Cave, Camden County The cave stream is the pirated, surface stream of the upper reaches of Dry Hollow valley. There is another smaller collapse sink 100 feet or so farther up the hollow from the cave entrance sink. It catches even the largest flood discharges and brings the torrent water down over the subterranean cascades and rock basins to that extraordinary about-face. Thence, the water flows back underground in the general direction from which it has come. Except for very local contributions,
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Dry Hollow valley is streamless from the site of this piracy to the little more than a mile distant to the northwest. Hence, ti propriate name. Between the two sinks, there is a surviving portion of t] stream valley floor of bare, sandstone rock. Its strata are tilted, and sagged by reason of the slow and fairly uniform removal dolomite from beneath. It is essentially a natural bridge, bi passage beneath is barely crawlable from one sink bottom to the A solid dolomite bottom is in evidence everywhere. There nev, a capacious chamber here, and, thus, there never has been a re lase. So we argue that each sink records a former cave chl and the bent and fractured but intact bridge records a forme separating the two chambers. In describing the cave stream, we have said "torrent" adv: Look at the size of the sandstone blocks the stream has rolled along its course in the cave, far from any source rock in the w the two sinks. Only a torrent could do that. Look at the c Forest litter is lodged in the spongework pockets over your head the time of the writer's first visit, a six-foot log, eight inches ameter, hung precariously above the cave, jammed tightly enough the ceiling spongework to remain after the cave-full flood had sul: But note also that the deeper ceiling pockets in the spongework c contain litter. They probably remained full of trapped air thrue the flood. The cave stream of today, even though it may reach ceiling pockets in the spongework, is not the agent which disl out those pockets. The readily traversed part of River Cave is the discharge ro the pirated surface stream. We follow it downstream for aboi feet along a relatively small passage, walking on stream grave( the torrent-carried sandstone slabs to reach a large chamber, a of great alcove offside the stream course. Its floor of silt and < about as high as the ceiling from under which we have emerge( its own dome-like ceiling is 20 feet or so above its floor. In this room, there is one of the outstanding stalagmitic coll domes of the Ozark country (Fig. 57); unusually white, unu large, unusually symmetrical, and unusually lacking in asso dripstone which usually competes for our attention. Stream which reach the ceiling of the passage we have come through appae never do more than provide a back-water ponding over the fli this room. The chamber cannot possibly be ascribed to the w, the stream. It was here before the underground piracy gav4 Hollow Creek its subterranean route. The walls and ceiling of this domed room are diversified elaborate spongework, and in the pockets are remnants of a complete filling of red clay. The room was here before even t] clay was deposited. Both the stalagmitic columnar dome an present mud floor were made after the red clay had been almo tirely removed.
Fig. 57. River Cave, Camden County Stalagmitic column: This column is in the large offside chamber of River Cave and is above the highest flood levels in the cave. Photograph by G. Massie, Missouri Resources Division.
A rimstone cascade is actively growing in another widening of River Cave near the domed room with its stalagmitic column. It is supplied by a subterranean stream which emerges from an untraversable small conduit in the wall. It is a larger stream, ordinarily, than the one from Dry Hollow. To obtain the lime it is now depositing, it must have a fairly long course through the dolomite, and it can hardly be another surface stream which has been detoured to an underground route. One continues along this discharge chamber route to find, 500 feet from the entrance, a natural bridge which is simply a spongework span of native dolomite, springing from wall to wall at about mid-height of the chamber (Fig. 58). No gravel has crossed it, but forest litter has become stranded on top and in the overhanging ceiling pockets. Two hundred feet farther the traverse ends, and the spongework which projects down from the ceiling and in from the walls makes, with the mounting fill of gravel on the floor, a barrier past which the human body can be forced only with difficulty. This is the bottleneck which has caused flooding to the ceiling of the upstream portion. The stream has been in the cave so short a time that the barrier has not yet been broken down. Indeed, the stream has been so loaded with gravel which could not be passed farther along that it has contributed to the bottlenecking action. Let us leave River Cave and look at the Natural Bridge (Fig. 59) which is crossed by the private road to the Castle only a short distance from the public road to the old, stone, Hahatonka post office and store building. One sees the bridge only when he gets off the road. It is thick and strong, and the opening beneath might better be considered a short tunnel. The bridge spans the western end of an elongated sinkhole which is shown on the map as two sinks. About 15 feet of the Gunter sandstone is exposed in the bridge. That much has, of course, fallen into the sinks on either side and must lie below the present bottom of the cavities. A lower cavity, a former cave chamber in the dolomite beneath, is required for disposal of this insoluble sandstone debris. As the collapsed chambers for the bridged sink and for the entrance sink of River Cave are only 1250 feet apart and as the bottoms of each collapse are at about the same altitude, it is altogether likely that the same cave system is involved. Counterfeitors' Cave and Robbers' Cave.—This idea is strengthened when Counterfeitors' Cave and Robbers' Cave, down almost in the bottom of this sink, are considered. The mouth of each is in a rock wall at the sink bottom, some 60 feet or more below the bridge level, and each can be reached only by ladder. Not traversable for any distance like River Cave, they nevertheless tell precisely the same thing. They are surviving portions of a cave system which existed before roofs began falling in, and sinkholes were made. Next on our itinerary is the island and its two marginal "valleys" down in the bottom of the Hahatonka chasm. An old cart road leads
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Fig. 58. River Cave, Camden County Natural bridge. Photograph by G. Massie, Missouri Resources Division. Fig. 59. Natural Bridge, Camden County Used by road to Hahatonka Castle. Photograph by G. Massie, Missouri Resources Division.
130 Missouri Geological Survey and Water Resources diagonally down the southern cliff of the gulf from the group of buildings called Hahatonka on the map. The road descends 160 feet to reach the dam on the south side of the island where, in low water time, a crossing can be made. The trail thence leads up over the west end of the island and down to the other and larger dam. As you climb up over the island, you will pass a small unenterable cave mouth and find a serrated, craggy, ridge crest on your left. Some of these crags are isolated, irregular pillars higher than they are thick, perforated by spongework cavities, and unlike almost anything else in Missouri topography. Some special item of physiographic history obviously is involved in their making. Spongework, at least of this kind, is not the product of surface weathering. This special item becomes clear when one has seen the bed of the stream below the dam on the north side of the island. Again we say, there is nothing in Missouri like what we see in this stream, but we will see it only if the Lake of the Ozarks is low, because this stream bed is completely under water at high lake level. The streamway for 100 feet is amazingly obstructed by big, fallen and tilted blocks of dolomite (Fig. 60). The tilting is at every possible angle and bedding in the blocks is oriented in every possible direction. Every block is honeycombed with spongework pockets. At least ten such blocks are 10 feet or more in maximum dimensions. Over and around and under this welter of displaced blocks cascades the spring's discharge from the dam. Although all the exposed blocks lie in the streamway or project from its steep banks, the prevailing tilt is toward the north and the larger accumulation is on the south side. All these blocks appear to have fallen from the island's north slope which, though steep and full of spongy ledges, is not cliffed. The great cliff on the opposite side of the streamway rising 100 feet sheer from the water (Fig. 61) has but little talus, and at present, contains but few big blocks. Almost no spongework shows in its wall. We are seeing the wreckage of a collapsed cave. The wreckage is kept clean and unburied by the spring discharge and was perhaps undercut in part by the stream and toppled from the adjacent island slope. We are here but little more than 1500 feet from the bridged sink and about 80 feet lower. Is not this wrecked cave chamber a part of that same cave system we were trying to reconstruct? If the island's craggy western end and collapsed southern side are relics of a former cave system, we can hope that chambers might still survive in the island mass itself. So we climb back part way up the northern slope, follow a trail leading off to the left, and in a few hundred feet find the very thing we hoped for; a cave entrance. It is the mouth of Island Cave, near the top of the hill. Island Cave.—In cross section, Island Cave is like an inverted L, and in orientation, is elongated at right angles to the length of the hill and must nearly cross it. An opened joint in the cliff on the south
Fig. 60. Cave Wreckage, Hahatonka Spring Wreckage of cave wall rock and roof rock. Photograph by G. Massie, Missouri Resources Division. Fig. 61. The Castle, Hahatonka Spring Hahatonka's northern cliff, Trout Glen at the bottom. Photograph by G. Massie, Missouri Resources Division.
132 Missouri Geological Survey and Water Resources side has many fallen blocks in it and may well be the former inter-section of the cave with this slope. Island Cave has a vertical range of nearly 50 feet, several times its width except at the top of the inverted L. Spongework on its walls is well displayed, despite an over-growth of "popcorn". There is spongework also on the outside cliff face at the entrance. Very obviously, Island Cave was formed before the island hill was made. Before our examination of the vicinity is complete, we should take the path to the northern summit of the cleft hill. The gentle outer slopes and the precipitous inner slopes are strongly in contrast. Be-low us lie the ruins of one of nature's constructions; the former Haha-tonka cave system. Alongside, rise the fire-gutted ruins of one of man's constructions; the former Hahatonka Castle and Tower. There, on the brink of the great north wall of the rift made by cave collapse, 240 feet above the lake's high level, are perched the white walls of the burned castle (Fig. 61). The four, chimneyed and windowed, gable ends rise three stories high; spectral in any light, needing only ivy and a hooting owl to complete the poetic picture of former greatness fallen to ruin. The associated tower is still intact and can be seen for miles. Summarizing the physiographic features of the vicinity of Haha-tonka, we have examined: (1) the 250-foot hill, cut almost in two; (2) the great rift which cuts the hill almost in two; (3) the island in the middle of the rift; (4) the cave in the island and spongework in its cliffs; (5) the wreckage of spongeworked, great boulders in the streamway; (6) the Natural Bridge and its sink; (7) Counterfeiters' and Robbers' Caves in the bottom of this sink; (8) River Cave with the extraordinary turnabout in its stream; and (9) the subterranean piracy which has made Dry Hollow dry. Let us add that there are no other caves, or sinkholes, or sponge-work cliff faces, or natural bridges, or precipitously walled rifts cutting into older hill lands, or valley bottoms clogged with collapsed sponge-work boulders, or big springs in the immediate vicinity of this remarkable square mile which we have been studying. Our final judgment is that a cave system which had been developed here before the present streams started cutting their valleys was discovered by those streams and was greatly modified and largely destroyed by their valley cutting. The big spring is but the successor of the hydraulic circulation that made the cave system 300 feet or more below the old peneplain. Only one other region in Missouri affords an approximate parallelism to what has happened here. It is Grand Gulf in Oregon County.
Caves of Missouri 133 HONEY BRANCH CAVE Owner: Leroy Swearengen, Springfield, Missouri Location: SW1/4 sec. 27, T. 27 N., R. 17 W., Douglas County Not shown on Fordland Quadrangle map For two separate caves to open on the same hillside only a few hundred yards apart is rare. For the smaller cave to discharge a lively stream and the larger one to be streamless is surprising. For the stream to take a 10-foot clear leap into the air at the instant of escape from underground is very exceptional. The two Honey Branch caves open on the hill slopes of Swan Creek valley nearly 100 feet below the level land traversed by State Highway 14 on the Springfield Plateau, but 300 feet higher than the Fig. 62. Honey Branch Cave, Douglas County little town of Ongo a mile distant down Swan Creek, and 200 feet higher than the city of Ava 10 airline miles distant. The Honey Branch caves are the only ones known to the author that open in the face of the great Eureka Springs escarpment which separates the higher Springfield Plateau from the lower Salem Plateau. The smaller cave has never been explored for more than a few hundred feet because of the tightness of the passages. A pool of water formed by a dam now floods this cave back of a small entrance chamber. The larger cave (Fig. 62) can be readily traversed on a nearly level path without stooping for 1320 feet. Its ceiling is more nearly level than its floor. Throughout this length, it is fairly uniform in
134 Missouri Geological Survey and Water Resources width except toward the far end
where several larger rooms are passed. The visitor's trail ends with a view of extensive,
broad, low, crawlways which have been only partially explored in the cave's known
(human) history of 100 years. "Coral" is the most common secondary lime deposit of the
larger Honey Branch Cave. It covers most of the walls near the entrance well up toward
the ceiling and records a former, long narrow cave pool. This former pool was the latest
event in the cave's history before the bears adopted it as their winter resort. The nearly
uniform width of this strikingly linear cave indicates a former main conduit for ground
water. That water undoubtedly flowed southeastward from under the Springfield upland
toward the White River drainage system just as does the present discharge from the
smaller cave. The large cave records two different episodes of such flow that are radically
different in character. The latest flow occurred before the "coral" growth was made in
standing water. The current of this flow is recorded in two places. Near the entrance are
meander niches cut back in an already existing cave wall by the vanished stream. At the
far end, the record of flowing water is in the banks of stream gravel that once filled this
tract to the ceiling. The earlier flow was not a free-surface stream with air above it, but
was a completely tube-full discharge, like water in a main. It was this earlier flow which
dissolved out most of the rock and really made the cave. Its record is in solution patterns
in the ceiling, particularly that spectacular ceiling cavity called "Job's Coffin". At this very
early date in cave history, there was no Swan Creek valley because there was, as yet, no
deep White River valley. The entire region to the south and east of this part of the
Springfield Plateau was then approximately at the same level; an old land without notable
relief features of ravines and valleys and their separating ridges. Under that extensive
former land surface, the rock was completely saturated with very slowly moving ground
water. Integration of flow developing and enlarged the subterranean "water mains", one
of which is Honey Branch Cave. Thus, with uplift of that former Springfield lowland, the
surface streams became rejuvenated, deepened their shallow valleys, and began the making
of today's rugged topography. This lowered the water table and brought the first episode
to an end. The upland flat carrying Highway 14 is one of the lingering remnants of that
uplifted lowland, and the original cave is part of the record that a low-land existed
when the major solution occurred. There is undoubtedly a great deal more of the early
subterranean drainage system beyond the inner end of the visitor's route. It is now largely
filled with clay and gravel. Perhaps the smaller cave is a part of that system, although there
are no known connections. There undoubtedly was much more of the early cave
extending to the south and east where now is only empty air above the subse-quently
developed ravines and ridges whose erosion has destroyed that missing part.
Caves of Missouri 135 INCA CAVE Owner: F. L. Hammitt, Eldon, Missouri Location: SW1/4 SW1/4 sec. 15, T. 35 N., R. 12 W., Pulaski County Shown as Maxey Cave on Waynesville Quadrangle map The visitor to Inca Cave (Fig. 63) parks his car on the broad summit of a spur ridge which projects eastward into Roubidoux Creek valley. By an inclined "railroad" with two counter-balanced cable Fig. 63. Inca Cave, Pulaski County cars, he descends 150 feet to the huge cave mouth at the valley bottom. The slightly asymmetrical, arched opening in the base of the steep but uncliffed bluff is 30 feet high and 70 feet wide. The opening faces
136 Missouri Geological Survey and Water Resources south, and sunlight penetrates for an unusual distance back into the cave. This impressive cave mouth (Fig. 64) is not, of course, original with the cave-making. The cave has been shortened an indeterminate amount by Roubidoux Creek valley erosion. The cliff east of the entrance is part of the original cave wall. Two sharply cut ravines which flank the present mouth are largely collapsed chambers of the original cave system. Failure of the main cave's ceiling rock has occurred extensively, making considerable hills which the trail crosses by easy grades. Thus, much of the present ceiling is fracture-determined. Huge, inverted, platter-shaped, flattish domes span the larger halls. All this fracturing appears to be very old. At the back end of the cave, there are two essentially impassable collapse piles. They probably mark two tributary prongs of the original cavern. Spongework of phreatic origin is well developed in most of Inca Cave's walls and ceilings which are not seriously affected by later fracturing. Even where such fracturing has obviously occurred, spongework, once well back in the ceiling or wall rock, has come to light. Similar in distribution to this spongework are the larger unit concavities which also date back to the earliest cave-making. Some appear to lead off into untraversable, satellite caves. The outstanding satellite cave of this Inca Cave complex is used by the trail along the east side of the main chamber. For 200 feet, one follows a narrow passage between solutional walls with collapse showing only where two windows and a door open out into the main chamber. The satellitic member is a kind of enclosed balcony; its windows and door being high in the main chamber wall. Considerable quantities of red clay of the late phreatic period appear to underlie the piles of fallen ceiling block. The cave's spongework rarely contains any remnants of that clay fill, although, by the author's theory, the clay post-dates the spongework. The satellite passage carries a former free-surface cave stream's deposit of clay, sand, and some fine gravel. Visitors walk along the passage without stooping only because the management has dug a foot trench in this deposit. Some of the excavated material is of red clay completely free of grit, but its structure is that of clay pebbles and granules. It is rehandled, phreatic clay which dates from the early part of the present vadose episode. The unsolved problem of Inca Cave is the presence of this stream deposit. No free-surface, gradient-controlled stream could possibly flow here unless the main chamber alongside has contained a fill as high as the satellite's floor. Such a fill could have been red clay which, subsequently, has all been removed down to the present, main floor level. In other words, the early vadose stream of the narrow, sinuous, lateral passage later abandoned that passage for the main cave route.
Fig. 64. Inca Cave, Pulaski County Entrance arch to Inca Cave. Photograph by G. Massie, Missouri Resources Division. Fig. 65. Inca Cave, Pulaski County The "Chief". Photograph by G. Massie, Missouri Resources Division.
Missouri Geological Survey and Water Resources and left a sand and clay deposit which almost filled it. But if so, there should be a record of the red clay episode back in some of the intricate spongework of the main chamber. There should also be some record of the vadose stream's work in that chamber, both as stream deposits, such as the satellite passage has, and as horizontal or half-cone niches cut into its spongework. None of these criteria has been positively identified, and the problem remains open. The "Chief" (Fig. 65) is Inca Cave's best dripstone display. It is many centuries old, but it still receives a little dripwater. Its massiveness on the top of the "hill" of fallen rock slabs tells of the even greater antiquity of the collapsing.
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JACOB'S CAVE
Owner: Russell Hall, Versailles, Missouri
Location: SE1/4 NE1/4 sec. 6, T. 41 N., R. 18 W., Morgan County
Shown on Gravois Quadrangle map

A phreatic origin of the presently traversable Jacob's Cave is recorded on every ceiling and every wall which dripstone has not yet covered and is locally recognizable even beneath such a cover. This origin is recorded in the spongework which ranges from incipient pocketings to an extreme development of actual coalescence among the pockets or "pores" back in the rock. Vadose enlargement, subsequent to the making of the spongework, is recorded in some excellent horizontal slots and half-cone meander niches, but the wealth of dripstone, some of which is very massive, has reduced the original cave volume more than the wall slots have increased it. The cave's flat-topped, hillside opening, now concealed by the entrance house, has a very unusual lintel; a flattish body of flowstone which grew on an almost complete debris blockade, recently removed by bulldozing. Furthermore, this lintel was made by water entering, not escaping from, the cave. Look back at that visor or porch shelter effect in its absurd inside position and in the inward slope of its roof. Jacob's Cave has been described as two connected caves; each with a hillside opening (Fig. 66). A visitor looks into the cave and sees, directly across the foyer, a narrow doorway in the far wall. By devious windings and cross passages which we do not follow, the passage back of this doorway leads to the "other" cave. Both caves, of course, are only parts of one system. The capacious entrance chamber has the best spongework of the entire cave (Fig. 67). The lower half of this chamber's wall height, however, is diversified with large horizontal slots or grooves which cut into and almost destroy the original spongework. Some of these great grooves have a central island of rock with a groove passing around and behind it. No commercialized Missouri cave has a better showing of this feature than at "Jacob's Altar" (Fig. 68), 200 feet inside the entrance gate. The "Altar" is an island as noted above, and the audience floor is the big groove. "Jacob's Pulpit" is another island of the same origin. In the introductory portion of this volume, a vadose stream mechanism for the incision of these grooves or half-cone indentations in already existing cave walls is outlined. The process requires a meandering stream on a floor of detrital material which once filled the cave up to the level of what is now the island summit. Meander curves become enlarged on their convex sides, even in limestone and dolomite, and the enlarging is accompanied by deepening. Afterward, the cave floor stream adopts a new course out in the cham-
Caves of Missouri. The cave stream, abandons the broad loop in the wall, and subsequently erodes the detrital floor down to present level. Jacob's Cave possesses almost all varieties of secondary lime "formations", but it specializes in an unusual form; the canopy (Fig. 69). The visitor's path passes under several. Some hang with their Fig. 67. Jacob's Cave, Morgan County Ceiling spongework: This spongework is in the ceiling of the "Foyer". Photograph by Speidel Photo Service Co. Most of them have stalactitic growths which apparently act as "guy ropes" attached to the ceiling. It is a question, however, whether these heavy "guys" are really such, or whether they are themselves held up by the canopy. The origin of the canopy seems to be a simple problem. The only needed elements are a sloping bank of clay, a dripstone and flowstone deposit on top, and the subsequent removal of the underlying clay by the cave stream. Stalactites and stalagmites are still simpler problems, for Jacob's Cave has thousands of them still growing. But why are so many crooked instead of straight? If you incline to the theory of air currents, why are there so many more straight ones in the same group? And why do some crook in one direction while their neighbors crook in other directions? Don't ask the writer; he doesn't know.
Missouri Geological Survey and Water Resources A fifteen minute episode of great anxiety which occurred during the construction of the cave trail is narrated by your guide at the site of "Snow White's Bower". When the ceiling of an especially low place was being shot off, a portion at a time, with the last shot a deluge of water came out of that ceiling, and they wondered, "Have we tapped an underground river above the cave? Is all our work going to be flooded out, and we with it?" But the flood ceased in a quarter of an hour and you can now look up into that once water-filled cavity and see how the bottom of the "Bower" had been closed by a flowstone growth which produced the pocket that came to hold the water. You can also see the calcite "ice" which subsequently has formed on the surface of the tiny residual pool. Where a stalactite meets a stalagmite, a column is formed. Let later settlement of the stalagmite's foundation occur and the column will become fractured and perhaps offset. Jacob's Cave has striking examples of both effects. In the case of a fractured column, subse-
Fig. 69. Jacob's Cave, Morgan County The "Canopy": Originally this canopy was a flowstone capping on a bank of clay. Later came removal of the clay by the cave stream and growth of all the stalactitic drapery shown in the illustration. Photograph by Grant T. Richards, Camdenton, Missouri.
144 Missouri Geological Survey and Water Resources quent stalactitic growth on the bottom of the hanging half has failed to reheal the fracture because the offset is so great (Fig. 70). There undoubtedly is much more to Jacob's Cave than is now readily traversable. This is most obvious if one ventures into the intricately interconnected, narrow, and largely unmapped passages between Jacob's Cave and the "other" cave. Strikingly (and significantly for cave theory), the drainage from Jacob's Cave does not discharge from the entrance mouth. Instead, the stream leaves the northern pool (Fig. 66) and follows a narrow passage, not completely mapped, toward the "other" cave. Somewhere along this route it plunges with a roar in flood time to lower and inaccessible levels. A natural exit on the surface is unknown. The water must discharge near the bottom of the nearby tributary valley that leads to Gravois Creek. Although the long, linear course of the main cave looks appealingly like the product of the ground water now draining along it, a critical observer will see several objections to this interpretation. One just noted is that the stream deserts the main cave when almost outside and flows back in the rock along a low, narrow, scarcely traversable passage, thus going four or five times as far to reach outdoors as by the main entrance and encountering a cascade-making gradient enroute. This illogical use of very minor passages by the escaping water is duplicated in every place where flowing water enters this cave. There, passages are all untraversably low and tight. Another objection is the clear evidence that spongework ceilings and walls existed before any free-surface cave stream, flowing on a continuous downhill gradient, left a record of its meandering in the walls, grooves, and niches. Another objection is the irregular network pattern of the unmapped portion between the two entrances. A further objection is the former existence of a red clay filling that reached even the ceiling spongework. The present stream transports and locally deposits clay but in that clay are sand lenses, disseminated grittiness, bits of chert and limestone gravel, and secondary dripstone and flowstone. The total lack of these features in the red clay bespeaks of deposition in very quiet waters, and the ceiling remnants tell of a complete water-filling at one time. Jacob's Cave, therefore, is interpreted as older than the present topography. Jacob's Cave could not be filled with water to the ceiling today. It could not receive a deposit of smooth, gritless clay; let alone have that deposit reach the very ceiling. Jacob's Cave originally was dissolved out as a main conduit below the water table of its time, and it lay below that water table when the clay filling was deposited. Only after the deep Osage River valley and its tributaries had been eroded could present ground water conditions become established, the red clay be eroded away, and the spectacular, meander wall niches be made.
Fig. 70. Jacob's Cave, Morgan County Fractured and offset columns: Settlement in a clay foundation for the stalactite-stalagmite columnar group which produced this dislocation has been so recent that rehealing of the fractures has hardly begun. Photograph by Grant T. Richards, Camdenton, Missouri.
146 Missouri Geological Survey and Water Resources Remnants of a former peneplain constitute the flattish hilltops between the cave and Versailles. That town is situated on one such remnant. Caves made by deep hydraulic circulation must antedate the peneplain because that culmination of an erosion cycle essentially destroys all hydrostatic head between divides and valleys. Such caves then must have become essentially subterranean lakes; full to the ceiling. This is the time for the red clay of the peneplain soil to migrate down and fill the many Ozark phreatic caves. Jacob's Cave shares with Cherokee Cave the distinction of possessing a bone bed in the upper part of its fill. In Jacob's Cave, the bone bed is known only in the long, narrow, slot-like passage whose doorway is directly across the foyer from the main entrance. More collecting and study are promised. The bone bed is peculiarly situated, far from either hillside and with no evidence of engulfment from a sink above it.
Caves of Missouri 147 KEENER CAVE Owner: Howard LeGrand, Williamsville, Missouri Location: SE1/4 sec. 4, T. 26 N., R. 5 E., Wayne County Shown as Keener Cave Resort on Williamsville Quadrangle map Keener Cave is unusually interesting from the viewpoint of cave origins. Its floor is entirely flooded and the cave can be visited only by boat. The surface of this cave lake is only a few feet above low water level of nearby Black River, and the water has a maximum known depth of 40 feet. This means that this cavity is free from any sedimentary deposits 40 feet below the level of the floodplain of the river. Keener Cave is largely a single joint plane chamber. It averages about 10 feet wide between the walls, and its ceiling is about 20 feet above the lake surface, or 60 feet above the bottom. How much mud and fallen rock overlie the true rock bottom is anybody's guess. The orientation of the chamber is N. 35° E. to N. 40° E. and is paralleled by five named streams in the vicinity which enter the river from the same side of the valley. Indeed, if it were not for a right-angled turn in its lower course, one of these streams (Ligett Creek) would enter the river almost exactly along the course of the cave. It appears that the joint control in the underlying rock has determined the surface as well as the subterranean drainage courses. The cave entrance is back in a sharply expressed, cliff re-entrant in the valley bluff, about 60 feet above the river. The re-entrant is filled to this height with debris, and a steep slope descends back into the cave to the same level. The writer calls this kind of debris accumulation a two-way talus. A stairway makes the descent down into the cave much easier than it was when the Indians dragged their dugout to the subterranean lake. The dugout was retrieved from the bottom some years ago, but it sank again in water so deep that its precise location is in doubt. The cave is so short that one may see to the far end from the boat dock. The roughly vertical walls close around that end with hardly a sign that the determining joint cuts through and continues, as it must. In this respect also, Keener Cave is exceptional, if not unique. In other caves, joint-determined passages "terminate" because the opening becomes too tight for traverse, or a cave-floor filling of debris rises to the ceiling, or the ceiling descends to meet the floor. In all such situations, we are sure that the joint continues and that the cave continues farther than we can. In Keener Cave, the only indication of such a continuation is a barely crawlable hole at the top of this end wall. The determining joint is not vertical, but dips steeply southeastward and in some places gives the cross section of the cave a definite
Missouri Geological Survey and Water Resources slant (Fig. 71). This slant is probably most pronounced beneath the water. An electric light, submerged some 15 or 20 feet, shows craggy overhanging ledges on the southeast side of the chamber. Most of the dripstone in Keener Cave is high on the northwest wall and apparently has ceased growing. Some very fair displays are to be seen from the boat. One may scramble up the side near the boat dock and find an irregular, rather small, upper chamber that departs from the joint. One may also see a sinkhole on the outside slope near the cave re-entrant. This sink probably records collapse of still another chamber off the joint. An attempt to make a frog pond of this sink was a complete failure; the water ran out of the bottom as fast as it was pumped in. However, it did not, so far as known, discharge into the cave.

The cave roof is a sandstone at the base of the Roubidoux formation. The cave, therefore, is in the upper 60 feet of the Gasconade dolomite. A dip of a few degrees southward brings the sandstone down to river level about 1000 feet south of the cave mouth. Two springs issue from the foot of the Keener Resort river bluff. The southern and larger one discharges from bedding plane partings in the sandstone where it comes down to river level. The smaller one is at the foot of the two-way talus which so nearly closes the big slot that constitutes the cave. This smaller spring is the discharge of the cave lake. The water passes through the basal part of the talus, and no bedrock shows at its exit. No inlet to the lake is known. It may receive its water from submerged conduits. In high river floods, the outlet spring reverses and the lake level rises with the river. Probably the first question a speleologist would ask in viewing Keener Cave would deal with this extraordinary depth of water below the surface of the river just outside. Why should there not be a fill of mud and other detritus and, therefore, a floor at river level instead of a deep lake? The answer appears to be given by the large scale dredging operations in the river. At the time of the writer's examination, drag-line excavation was bringing up gravel from depths of 40 feet below the floodplain. The bedrock bottom of Black River valley is buried at least that deep in chert gravel. The river has partially filled its own valley. With this fact in mind, we go back in time to that deeper valley when the river's surface was only 320 feet instead of 360 feet above sea level. No lake could have been retained by the talus then, even if the talus blockade existed, and during this early time the talus probably did not exist. The cave opening then was a great cleft in the lower bluff. We reason this way because: (1) the high narrow cave is older than the hills and valleys of its vicinity; (2) it almost surely had an epoch of red clay-filling which 90 percent of Missouri's phreatic caves record; and (3) the red clay fill has been entirely removed (above water level). The removal of the clay occurred during
Fig 71. Keener Cave, Wayne County Typical cross section of Keener Cave: Looking toward the boat dock and talus blockade. The departure of the controlling joint from verticality is shown by the inclined walls which continue under water with about the same slant. Water here is twice as deep as the ceiling is high. Photograph by G. Massie, Missouri Resources Division.
Missouri Geological Survey and Water Resources the deep-valley stage of Black River and before the talus blockade had been formed. To keep the cave from filling with debris while the valley aggradation was occurring, we assume that the talus grew more rapidly than the floodplain and that essentially no mud was brought into the cave by underground water during that time. A further argument, that the cave is older than the topography, can be drawn from the contour map. Project the line of Ligett Creek northeastward. This is the line of the cave. It crosses a low spur between lower Ligett and the main valley almost at a right angle. Were the cave long enough, it would perforate that spur. But the creek, never having used the cave route to the river, certainly never made it. Nor could rainfall, entering the ground from this little spur, ever contribute the necessary water or ever demand the route which the cave follows. Indeed, for a mile back into the hills from the cave, the topography is nicely developed to shed runoff and to guide ground water out to the north and to the south; never toward the east along the length of the ridge to reach the cave. There are remnants of the former peneplain in the upland which is followed by U. S. Highway 60 near the Carter-Butler county line, seven miles southwest of Keener Cave at altitudes of 680 to 750 feet above the sea level. The trace of this old land surface across the dissected country nearer the river could hardly have been 100 feet lower than these altitudes. If the cave was made during this early cycle, it developed some 250 to 300 feet below the finally attained peneplain. Keener Cave is on the property of the Keener Resort and is not open to the general public, but guests of the resort are permitted to tour the cave.
Caves of Missouri 151 MARK TWAIN CAVE Owner: Archibald Cameron, Hannibal, Missouri Location: SW1/4 NW1/4 sec. 34, T. 57 N., R. 4 W., Marion County Shown on Hannibal Quadrangle map Two caves, Mark Twain and Cameron, lie in Cave Hollow on opposite sides of the valley and low in the slopes. They are remarkably similar and remarkably unlike almost all other Missouri caves (Figs. 72
Getting lost in a cave is a widespread apprehension, and it certainly has some justification here, for each cave is a perfect labyrinth of very similar passages. Without guide, or compass, or map, or ball of string, the chance of getting lost on one's first visit would be excellent. Tom Sawyer, Becky Thatcher, and especially Indian Joe could testify to this. The labyrinthine pattern is determined by three or more intersecting sets of joints subequally opened in the limestone (Louisiana formation). Almost opposite each other, with the valley between (Fig. 23), the caves look like two severed portions of a once-continuous cave system. When these caves are studied in detail, this impression becomes conviction. Most caves have but one hillside opening and never have had more. Mark Twain Cave has 23, and 20 of them are now blocked with fallen rock, soil debris, and flowstone, but indubitably are transections of cave passages by that valley slope. Although concealed on the outside, the blockades are obvious enough from the inside. Of the three still open, two are barricaded crawlways that let only light in. The third has been enlarged for the visitor's entrance. The route through the cave has been chosen from perhaps a dozen alternatives for its adequate roominess and certain features shown to the visitors. Not all the "passages" shown on the map (Fig. 72) are readily traversed, as some have been followed through only by a spotlight beam. Not all have the adequate headroom of the visitor's route. The typical opening, however, wide enough for comfortable walking, tapers up to a mere slit 10 to 20 feet overhead and has a floor of silt and clay. No bedrock floors are known. In a few places along the trail (and in many places, the entire cave considered), there are slump pits in the detrital floor. They lead, or led, down to lower portions of these same passageways. In excessively wet weather, running water can be heard down in them. In some, the water rises high enough to be seen, but no exploration is possible; even in drought. The joint control has produced some interesting features. Joints have a characteristic of splitting into two segments which run side by side and then reunite. Ground water, using two close-set, parallel joints in part, will open two slots and then proceed to dissolve the intervening wall. Incomplete partitions which rise from the floor or hang from the ceiling are the result. One particular partition in the cave makes a complete vertical bridging; its lower attachment being on one wall, its upper on the opposite wall (Fig. 73). Where two joints intersect at a low angle, a sharp prow-like form is made of the converging walls (Fig. 74). At "Five Points" five different passages radiate from a common center. Since joints cross strata which differ in solubility, the cave walls have horizontal grooves along the edges of the more soluble layers and horizontal ridges along those less so. These are paired across the cavity. Certain passages, however, have such deep wall grooves that
Caves of Missouri they are better termed "inset" shelves; especially since the lower sides of the grooves are nearly flat (Fig. 75). That these must have had a different origin is obvious when one sees that any one of them varies in width and becomes discontinuous along the wall, and that the shelves are not consistently paired. Along "Grand Avenue", some Fig. 73. Mark Twain Cave, Marion County Natural bridge: This nearly vertical natural bridge along the visitor's route is a surviving portion of a partition between two joint-determined slots of the phreatic network. Photograph by courtesy of owner, Archibald Cameron. Of these shelves have very smooth, almost polished, surfaces and shallow basins in them. The problem of their origin is solved by a feature of "Grand Avenue" off the visitor's route. It is a deposit of gravel lying on a shelf 250 feet south of the point where the trail enters the "Avenue". It is stream gravel overlain by stream silt. The shelves are records
154 Missouri Geological Survey and Water Resources of ordinary, gravity-directed stream flow through several different cave passages and at several different levels. The narrow, vertically-walled, joint-determined openings were already in existence. Either they had become filled up to the highest shelf levels and the stream was engaged in removing the detritus—the highest shelves then being the oldest—or they were being filled and the stream was burying earlier ones while the mounting fill was lifting it higher in the passage. In either case, the stream, in impinging against the walls here and there, produced this widening by undercutting some of the older cave walls, and its traction load did the smoothing and basining. Fig. 74. Mark Twain Cave, Marion County

The "Five Points": An intersection of two joint-determined passages. Photograph by courtesy of owner, Archibald Cameron. What stream? The gravel deposit supplies that answer also. It contains hackberry seeds and shells of the ordinary woodland snail and has yielded a three-inch cobble of diorite; an igneous rock which could have come only from glacial drift. The stream was the creek of Cave Hollow. Engaged in making (or re-excavating) its present valley, it found, some 15 feet above present bottom levels, a system of cavities in the bedrock it was eroding. For a time, it was detoured for a few hundred feet underground. Remember that there are 23 places where the hillside has had perforations some time late in the valley-making; the perforations made because the cave system was already there.
Caves of Missouri

The visitor's route takes one close to two of these blockaded holes which lead out of the hill and into the valley. Fallen rock slabs, cemented by flowstone material and in some places entirely covered by it, constitute the blockade materials. The water which deposited the flowstone entered the cave at some of these blockades. The map shows many blind endings of cave passages, but we are confident that they do not end as shown. Our open passage ends only because the detrital floor rises there to the ceiling or the ceiling descends to the floor. There must be filled continuations beyond these "ends".

Fig. 75. Mark Twain Cave, Marion County

The "Parlor": Vadose widening of a phreatic passage. Photograph by courtesy of owner, Archibald Cameron. A curious feature of Mark Twain Cave, which deserves more study than it receives here, is shown in numerous junctions where the ceiling of one passage is a narrowing slot far above the floor, while that of the other may be close to the floor level. Other caves developed on joint plane networks show the same thing. Why do the ceilings of some joint-controlled passages consistently go so much higher in the rock than those of intersecting passages? The making of an elaborate grid pattern cave like Mark Twain Cave can never be ascribed to any conceivable shifting of a cave stream consecutively from one joint to another, nor to any conceivable...
156 Missouri Geological Survey and Water Resources group of cave streams acting contemporaneously. To make Mark Twain Cave, we must saturate the entire formation. No outside valley could then have existed. We must then put a hydrostatic pressure on the contained water so that it will seek escape along every possible initial opening. No trunk course was formed during the development of the system. All routes suffered about the same amount of solution. This could have happened only deep below the surface; unaffected by minor topographic features above. As there is a gentle northward dip of the rocks here, the water probably moved in that direction. Overlying and underlying shales confine the limestone containing the cave, and the circulation may have been artesian. Certainly the water table of the time was far above the cave, and all passages were completely filled with water during this epoch. This is saying that the cave is older than the Mississippi River now flowing almost past its door. A point which will interest geologists is that, so far as is known, neither Mark Twain Cave nor Cameron Cave show any remnants of the almost universal red clay found in most of Missouri's caves. This item is treated more at length in the interpretation of Cameron Cave. The great trench of the Mississippi River has bred a large crop of closely spaced tributary ravines and valleys, and to find any broad uplands approximating the level of the former peneplain we must go some 10 miles off to the southwest to the vicinity of New London. Altitudes there are 700 feet to nearly 750 feet above sea level. The cave lies a little above 500 feet. Assuming that there was, during the early cycle of erosion, a Mississippi valley along the general course followed today, and allowing its floor an altitude 100 feet below these surviving uplands, the cave was formed 100 feet to 150 feet below the valley bottoms of its time. The entire region has been elevated since that time; the surface of the master stream now being less than 475 feet above sea level. Salt River, Bear Creek, and a host of other tributary streams have trenched into and drained the rock; air and free-surface stream water have succeeded that original, completely saturated condition. The network has been cut into, but not completely through. About two dozen entrances to the abandoned cave system have been made, and then closed by rock fall by downhill creep of weathering waste and by flowstone deposition. A peculiar feature of Mark Twain Cave is the localization of all of its secondary lime deposits at the blockades. Because of the water-tight roof of the Hannibal shale, no drip water has entered the cave through its ceiling. The only vadose stream recorded is that which brought in the silt, gravel, and snail shells, and which made the shelves as it wandered through the maze looking for a way out.
Caves of Missouri MARVEL CAVE Owners: Misses Miram and Genevieve Lynch
Lessee: Mrs. Hugo Herschend, Branson, Missouri Location: SE1/4 NW1/4 sec. 29, T. 23
N., R. 22 W., Stone County Shown as Marble Cave on Forsyth Quadrangle map The
entrance to Marvel Cave (Fig. 76) is on the summit of the divide (Roark Mountain)
between Indian Creek and Jake's Creek, three miles north of White River and more than
600 feet above it. The entrance is one of the outstanding features of the cave. It is a Fig.
76 MARVEL CAVE STONE COUNTY SCALE IN FEET 0 100 200 Surveyed by S. F
Prince combination of a rock-walled sinkhole connected by two openings with a huge,
dome-shaped chamber below in hour-glass fashion. The "Sands of Time" falling from the
upper part have made a conical hill in the bottom of the lower part. A stairway descends
the sinkhole wall, then by a series of zigzags and landings, goes down a tower-like
structure to reach the top of the pile of fallen debris. Thence, a winding
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158 Missouri Geological Survey and Water Resources path of stepping stones leads down to the floor of the chamber. It is 210 feet from top to bottom, and the view back up through the two rock-bound ceiling holes to the sky (Fig. 77) is alone worth the trip. As one starts down, he sees that the two openings are aligned on a vertical joint fracture which cuts through the sinkhole. A natural bridge remains to separate the two black openings. As he looks back from the bottom, the same controlling structure is seen in reverse illumination; the black holes are now the only lighted areas in the subterranean "sky". On the platform by the "Liberty Bell", he should realize that the great hollow dome above him, the "Cathedral Room", owes its vaulted form to the falling away of unsupported wall and ceiling rock of an originally lower chamber; a falling which continued until the architectural principle of the arch was realized and collapse ceased.

The "Cathedral Room" apparently has grown higher and higher until it has tapped the bottom of the sinkhole above. Appreciating this, one asks,"Where has the fallen material gone?" The conical hill on the floor can contain only a small fraction of it. The answer is that the original cave chamber in this place was much deeper in the rock; its bedrock floor far below this present bottom. As the ceiling migrated up, the floor followed until it is now about at the level of the original ceiling. This will be clearer after we have seen the real depths of Marvel Cave. At the far south end of the "Cathedral Room", protected by projecting wall rock that has not failed, stands one of the great dripstone units of all Ozark caves; the symmetrical "Liberty Bell" (Fig. 78). It is a solid, cave onyx dome, 55 feet in total height and nearly 200 feet in circumference at the base. One may walk all the way around it, may climb to its summit, and may go inside. It is a compound of at least two major domes. The lower dome is not quite half a dome in the clear. It is this older, lower portion which produces the flare in the lower slope of the "Bell", and the imperfect junction of the two domes makes the little inside room (Fig. 79). Situated 150 feet away from the nearest sky opening, "Liberty Bell" grew in total darkness before the "Cathedral" ceiling was formed and light finally penetrated. Probably the growth of the "Bell" ceased about the time the light of the sky-even direct rays of the sun at the proper time of day and year-first illuminated the finally completed "Cathedral Room". After that time, drip water which had built the "Bell" through centuries of slow patient work reversed the concept of its duty and began to dissolve the cave onyx. A half-well was excavated on the back side of the upper dome of the "Bell" by vertically falling water which, itself, has long since ceased to flow. Near the "Bell" stands the 20-foot "Sentinel", rigidly at attention, guarding the entrance to the "Spring Room" and the "Shower Bath Room"; both well named. The "Sentinel", also a dripstone form and probably contemporaneous with the "Bell", is in striking contrast with its gigantic neighbor. There is no suggestion of overfeeding here;
Fig. 77. Marvel Cave, Stone County The "Skylights": Verticality is shown in the stairway tower supports. These lighted, joint-determined, slot-like holes are in the bottom of the sinkhole but far above the observer in the cave. Photograph by G. Massie, Missouri Resources Division.
160 Missouri Geological Survey and Water Resources it is as trim and well-conditioned a figure as the "Bell" is fat and bulgy. Back of the "Sentinel" are huge, fractured pieces of the "rind" of a wrecked, cave onyx dome which formerly overhung its "sentry box". The "Cathedral Room" has three known exits to other parts of the cave, two of which lead to the "Corridor" on the northwest (another high chamber of collapse origin) and one to the "Serpentine Passage". The visitor's route follows the "Serpentine" for about 200 feet to a chamber so complex that it bears different names for three distinctly different parts. This "Serpentine" is well named. One stoops a little here and there and for most of the way can touch both walls with outstretched hands. It is entirely of solutional origin; no collapse of wall or ceiling rock has occurred since the subterranean water flow abandoned it. One sees two similar passages enroute; both considerably choked with debris fill. The rock floor is well below the level at which one walks. Were the passage in its pristine form, one would be traversing a much deeper, equally narrow slot. As it is, he walks close to that once high ceiling. Emerging from the "Serpentine", one has floor and head space in that part of the complex chamber which has the "Sphinx" profile in the bedrock wall and the "Sarcophagi" along the southeast side; hence this part is called the "Egyptian Room". The "Sarcophagi" are parts of a great fallen wall block which, in falling, parted along another vertical joint fracture and left a high, straight wall on the northwest side. One's guide lights a candle on the end of a long, narrow board which then is thrust horizontally southward out on a track made for it. The candle almost touches the nose of the "Sphinx" and overhangs impenetrable darkness beneath. Below the candle is the "Gulf of Doom", a second part of the complex chamber, but one sees nothing of those depths from the candle's little light. Nor does the light from a battery-powered, automobile head lamp do much better. The "Gulf of Doom" seems bottomless, but later in the trip, that little glimmer will appear again, nearly 100 feet above us. The third part of this chamber is called "Cloudland" and has a relatively low ceiling of very irregular design of what may be fancied as stone clouds hanging close above one's head. This is perhaps the best showing the cave has of differential solution on the ceiling of a chamber. If ever a free-surface cave stream traversed the floor, it reached this ceiling only in flood time. Yet here is a maximum amount of solution to make the irregularities called "clouds". A better concept is that this "Cloudland" ceiling was made when it was well below the lowest drought levels of ground water. In other words, it was full of water at all times. Such an experience would be impossible in Indian Ridge today; the bounding valleys are too deep and the under-ground drainage too good. The argument leads us to believe that the "Cloudland" chamber was dissolved out before Indian Creek had
Fig. 78. Marvel Cave, Stone County The "Liberty Bell": Having grown upward from the cave floor, this huge deposit (55 feet high) belongs to the stalagmitic group of dripstone forms but is better described as a dome. The habit of developing flow-stone shelves fringed with stalactitic masses is excellently shown. Photograph by G. Massie, Missouri Resources Division. Fig. 79. Cross Section of "Liberty Bell", Marvel Cave E.H. Woolrych, del.
Missouri Geological Survey and Water Resources cut its valley to a comparable depth in the rock. The most torrential rains now falling on Indian Ridge do not flood the cave within 50 feet of this level. Looking back and up toward the "Sarcophagi", one sees better the nature of the great, fallen wall mass. He sees also that the big block fell on a deposit of deep red, very smooth, non-gritty clay. The clay, therefore, is older. But still earlier, there must have been a cave chamber here to receive the clay. Throughout Marvel Cave, one repeatedly finds relics of this unctuous, red clay fill. Aside from the chambers or parts of chambers made by collapse, the rooms of the cave and passages are all older than the clay fill, just as the secondary dripstone and flowstone are younger than the clay; younger than, or contemporaneous with, the extensive removal of that clay fill. Leaving "Cloudland", one follows down the zigzag stairway of "Santa Claus' Chimney" to a route chosen from a complex of irregularly shaped passages which are relatively high and narrow in general. Down, down he goes until he stands on the bridge at the bottom of the "Gulf of Doom" and sees the little candle flame, like an evening star in the cavern "sky", glimmering 90 vertical feet above (Fig. 80). The "Gulf of Doom" tells convincingly of the great depths which chambers like the "Cathedral Room" had before the episode of collapsing began. The narrow passage we followed down, with its associated more difficult passages, tells of a complex of high, narrow, largely subparallel slots accompanying the larger chambers. This pre-clay cave system was made when all the rock mass in the area of Indian Ridge was completely saturated. Water moved slowly in whatever direction the pressure demanded and bedding planes and joint planes afforded an opportunity. Late in this episode, the red clay was introduced and deposited in the system. It was derived from the very finest products of weathering on the surface of that time. When Indian Creek and other creeks cut their valleys, the water was drained out and surface water, on its way down to new, lower levels, removed much of the clay and in some places dissolved more rock or deposited secondary dripstone and flowstone forms. One of the places where this later solution is well recorded is the "Gulf of Doom". A vertically walled, semi-circular alcove of the "Gulf" extends from the bottom upward as far as one can see. Its walls are vertically grooved with the marks of a former sheet of water which fell or trickled down from above. The "Gulf" then was much as it now is; filled mostly with air. Its extinct water fall may have been fed by the flow that today spills 50 feet in the clear at a still lower chamber on the visitor's route. One should realize, however, that the "Gulf" itself belongs to the earlier episode of cave-making. To reach the "Waterfall Room", one follows the "Royal Gorge" which is another high, narrow passage and descends until at the bottom he is 350 feet below the entrance. Marvel Cave is the deepest cave known in Missouri. An optional route, the "Grand Canyon", will
Fig. 80. Marvel Cave, Stone County The "Evening Star": Horizontality is indicated by the apparently inclined bedding in the upper left and verticality by the lapies groovings in the middle and lower left. The candle is 90 feet above the observer. Photograph by G. Massie, Missouri Resources Division.
164 Missouri Geological Survey and Water Resources take one to the "Kewpie Lakes" at the brink of the falls. By either route, one sees dripstone and flowstone and rimstone growing, or at least surviving, in a strong flow of water. We commonly think of these cave deposits as fed by very small trickles. Here it may be otherwise. The "Kewpie Lakes" are rimstone-dammed pools just above the falls. The brink of the falls is strikingly reinforced by a fringe of orange-colored, depositional forms, halfway between sta- lactites and "draperies", which intriguingly curve back under the ledge they hang on and actually entice the water to curve back also before it falls from their free ends. The wall below the brink of the fall has its share of descending water and dripstone growth of unusually strong color and remarkably bulbous forms. At the base, there is a broad, low, compound dome of the same material, heavily splashed even in dry weather, and apparently growing under those conditions. Perhaps another "Liberty Bell" is starting to grow here. Against this idea, however, is the fact that another part of the waterfall hits the lower slopes of the broad dome and is leaving no evidence of deposition. Excessive and long-continued rains have flooded the "Waterfall Room" to the level of the bridge at the bottom of the "Gulf of Doom" and almost to the "draperies" that reinforce the lip of the waterfall itself, but, in a few hours it all drains away. There is much more to Marvel Cave than the average visitor is prepared to see. Beyond the "Waterfall Room", there is a very muddy climb over a red clay fill which still occupies its slot. The names of "Clay Ladder" and "Pilgrim's Progress" suggest its character. Few have made the traverse up to the ceiling and on for 300 feet of muddy crawling to Marvel Cave's most beautiful display of growing dripstone; "Blondie's" or "Fairy Chamber". Back in "Cloudland", another climb would take one northeast to the "Vestibule" (a collapse chamber) and to an upstream portion of "Lost River". This route has been traversed for at least 2000 feet; the "river" being forded repeatedly. The stream flows southward from the "Vestibule" along a humanly impassable course to reappear in sight at three different cataracts. It finally leaps the waterfall and disappears for the last time. Dyes introduced here reappear in Neely's Spring, two miles away, down toward the bottom of Indian Creek valley. Still another route for explorers leads off the corridor by a crawl-way, "Wind Passage", to the beautifully decorated "Epsom Rooms", thence, by another crawlway, "Dust Crawl", to the "Grand Crevasse" which contains lakes "Genevieve" and "Miriam" and another subterranean stream. The map shows a dominant, sub-parallel elongation of virtually all the rooms, between north-south and northeast-southwest. The joint we saw at the bottom of the sinkhole entrance strikes N. 40° E., as does the joint-determined passage called "Total Depravity". There is also that significant side-by-side relationship which further argues
Caves of Missouri for complete saturation of the rock when the original solution occurred and, therefore, for a greater age of the cave system than that of the surface and subterranean streams of today. A further argument is the red clay. There is almost no grit in it to record any current. There was far more clay, when the fill was complete, than ever could have come down from that limited ridge summit of the present. Again, we say that this part of the Ozarks must have been a wide, low plain without valleys of any consequence when the clay was brought in. Since the time when that old land (the peneplain) was uplifted by the Ozark doing and the rejuvenated creeks began trenching, Marvel Cave has undergone: (1) draining of the once complete water filling; (2) removal of most of the red clay fill; (3) collapse of wall and ceiling rock; (4) local solution by free-surface flowing and falling water; (5) deposition of secondary limestone forms; and (6) formation of sinkholes above the more excessively collapsed portions. Marvel Cave contains an epitome of virtually all the important events in the evolution of a cave, from a completely hidden subterranean drainage of complete saturation to explorable conditions.
The arched entrance to Meramec Caverns (Fig. 81) is in the basal part of a nearly vertical, dolomite bluff of Meramec River valley. Its width is about 50 feet, its height about 20 feet. The floor of the arch is not of solid rock, as are the walls and roof. You walk on an earthy fill of unknown depth; a fill made much later than the making of the cavern itself. The true rock bottom of the cavern may well be lower than the nearby river bottom. This floor, the top of the fill, is 30 feet above Meramec River's low water and constitutes the "Second Level" of the cavern. Exceptionally high water has at least twice flooded back into this entrance chamber through the spacious archway. Floodings occurred in August 1915 and again in June 1945 when the river reached 33 feet above zero, low water level. In 1945, water stood 3.5 feet deep in the entrance, and the first or lowest level was flooded completely to the ceiling throughout much of its length. The linear "Entrance Chamber" leads straight back 150 feet under the bluff to the gate where it joins the largest and in some ways the oddest room of the cave. This is the "Big Room" or "Ballroom". It is 300 feet long and its maximum width is nearly 100 feet, but it has two equally spaced constrictions with widths of only 25 to 30 feet, which so pinch the "Big Room" down as to give the impression of three rooms connected in series by broad arches (Fig. 82). At the far end of this three-in-one room, two cave routes diverge. One descends to the extensive "First Level" which carries the cave stream, and the other ascends by a stairway to the highly ornamented "Third", "Fourth", and "Fifth Level". One learns shortly that the word "level" as used in a cave would never please a surveyor or civil engineer. The dance floor (50 by 50 feet) is in the middle of the enlarged portion of the "Big Room". The room in its entirety has contained 2100 people; the occasion being a meeting of the Oddfellows Lodge in 1934. Automobiles can be driven back beyond the far end of this room. There is parking room here for an estimated 300 cars. The walls and ceiling of the "Entrance Chamber" and the "Big Room" are highly diversified with innumerable pockets and projections of the native limestone. This gives the effect of very coarse sponge-work. Very little of this irregular surface is the result of the breaking off of the rock. Almost all of it is the record of irregular solution of the rock at a time, far back of the present, when the cave was com-
FIG. 8 - MERAMEC CAVERNS FRANKLIN COUNTY SCALE IN FEET
SURVEYED BY CHAS. HIGGINS, JR. 1946
Missouri Geological Survey and Water Resources plentely full of water which, through centuries and millenia, "ate into" the more soluble portions of the rock and left less easily dissolved portions projecting. Many adjacent pockets are connected back in the wall (Fig. 83). One such pocket has been crawled through with difficulty for a distance of 45 feet although the two open ends in the cave wall are only 15 feet apart. The intervening projections constitute small, natural bridgings and produce the spongework effect. As well developed on the ceiling as on the walls, these pocketings demand the explanation that this compound "Big Room" was full of water and had no air whatever in it when the spongework was made. The stairway passage to the upper levels has been artificially enlarged from a spongework connection between the "Big Room" and the higher levels. Originally, it was too small for a man to crawl through. Let us leave this route for later examination and follow the main route down to the lowest level. A chamber somewhat lower and narrower than the "Big Room" leads back another 100 feet. Its ceiling becomes lower and its sponge-work walls approach each other until we reach the end of the flat floor. The low, narrow passage ahead, where we must duck to get through and where we can touch the walls on either side, is "Lumbago Alley" or the "Submarine Gardens". It is 50 feet long and in shape is an inverted siphon. It is the only open connection between the "Second" and "First Level". Through it, we enter the "Jesse James Submarine Room", by far the longest chamber in the cave, and the only one containing a stream. And who can prove that Jesse James was never here? As late as 1941, this siphon stood full of water to its ceiling, and although the lowest level had been entered by another and very difficult route no one really knew that a connection was possible here.
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In December of that year, the writer, two graduate students, the owners of the cave (Dill and Peterson), and a few other helpers succeeded in making the first traverse through this water-filled passage. Our plan was simple. We would bail out enough water to make room for a rowboat to pass under that ceiling. Fig. 83. Meramec Caverns, Franklin County Spongework: Numerous bridgings, such as that shown, may be seen where these solution made holes unite back in the wall rock. Photograph by G. Massie, Missouri Resources Division. Across the gentle slope of the earthen floor on the near side of the pool, we dug a trench, made a dam of the excavated earth, and in
170 Missouri Geological Survey and Water Resources back of this we emptied the buckets we had dipped full from the pool. After some three hours of this work, with repeated strengthening and raising of the crest of the dam, we lowered the surface of the pool 8 or 10 inches below the wetted ceiling. Then we chopped a rowboat out of the ice along the river's edge, dragged it into the cave by auto-mobile, and launched it on our lowered pool. Three of us lay down in the boat bottom, and by pushing with our hands against the ceiling we submerged the boat sufficiently to inch our way under and through. Mr. Dill, remaining behind, wished audibly that the cave could get some newspaper publicity out of this stunt. The suggestion was immediately made that he needed only to break the earthen dike after we were through, and then there would be front-page headlines in next day's Chicago papers about one professor and two students of the University of Chicago trapped in his cave; slowly freezing, starving, perhaps drowning. He did not break the dike. About 25 feet of this unusual rowboating was necessary. Beyond this distance the ceiling was adequately high, and another earthen floor was found at about the same level as that from which we had launched. Disembarking and walking another 200 feet, we found ourselves in the main chamber of the lowest level, on a floor about 15 feet lower and trenched by a clear little stream with a gravelly bed. The pool has since been drained, concrete walks laid, and bridges built where we encountered water and much sticky mud in our exploration. A permanent record, in stone, of the former pool lines this inverted siphon passage. This record is found in the decorative, secondary calcium carbonate enamelling of the rough, native dolomite surface. This enamelling was precipitated from the pool water on the lower walls, and it terminates upward in a definite, water-line rim of the same material. The precipitate gives origin to the name, "Submarine Gardens". The waterfall whose noise one hears today at this junction of the "First" and "Second Level" is artificial. The long pond, "Mirror River", on the upstream side of the waterfall was made by building a concrete dam across the earthen trench of the former stream a little to the northeast along the "First Level" chamber. Below the dam, the stream follows a sinuous course in its deep trench for several hundred feet under a very low dolomite ceiling and eventually emerges through very constricted openings as La Jolla Spring at the foot of the bluff, about 50 feet from the archway entrance and about 20 feet lower. At the junction of "First" and "Second Level", there are several interesting features: "Lava River", "Loot Rock", and "Bear Den". Like most place names in caves, one must allow for the free play of somebody's fancy. Resemblances to familiar objects are most commonly resorted to, but profiles of historical or literary characters, assumed or actual uses of chambers, mythological references, and other sources are utilized. Rarely do these names have any explanatory value, but "Bear Den" may be a correct interpretation of the
Caves of Missouri 171 broad, shallow pits in the clay floor of the little alcove so named. The alcove itself and the several, closely associated, similar cavities are wall pockets which were dissolved out when the spongework was made. Although unusually large, these wall pockets are only blind-end cavities, or spongework on a very large scale. They do not lead into continuous linear chambers. "Lava River" is the product of a small stream which is hardly more than a trickle today, and which is fed by seepage from the upper levels, down through the "Second Level's" ceiling. Having dissolved calcium carbonate on its way, the water of this little stream, in flowing over the clay floor down to the "First Level", precipitated lime to make a series of rimstone dams, each of which ponded a portion of the original flow. In miniature, it is something like the series of TVA dams on the Tennessee River. "Loot Rock" is another portion of the secondary lime which was deposited on the clay floor by that little tributary. The "Rock's" dark color is due to incorporation of brownish clay during all stages of its growth. Successive layers are clearly shown where later erosion has partially breached the "Loot Rock" deposit. This lime and clay deposit grew in the form of a succession of terraces, with flattish tops and sloping fronts; not as rimstone damming a little pool. The highest terrace top is about 10 feet above the stream level. Not far along the trail beyond "Loot Rock" is a low ceiling for 150 feet; much lower than any ceiling thus far, except for the one in "Lumbago Alley". Here, very minutely ragged masses of brown rock material project a few inches below the light-colored, dolomite ceiling. They are nodular aggregates of chert; a form of silica or quartz not uncommon in limestones and dolomites the world over. Chert is almost insoluble. Ground water which once completely filled the cave dissolved away the surrounding carbonate matrix and left the cherty masses in relief. The low ceiling continues for about 75 feet beyond the footbridge on the trail. Along this trail on the right are banks of dense, reddish-orange, laminated clay. They reach almost to the ceiling and clearly are remnants of a once continuous fill. Because the stream is eroding it away, the clay fill must be older than the present cave drainage, but because the clay once entirely filled the cave, it must be younger than the cave making. In the next 75 feet, the ceiling rises 35 feet; as high as the highest ceiling in the "Big Room". Immediately, it descends again; the clay floor remaining essentially level. We have passed beneath a great hollow dome in the cave ceilings (Figs. 84 and 85). High domes in many cave ceilings have beneath them great piles of fallen rock fragments and are easily understood as the result of local collapse of roof rock immediately above the pile. These piles may be fancied and named as subterranean mountains, and some entail a considerable climb to pass them. It is not so here. There is no fallen rock material on the floor.
Fig. 84. Meramec Caverns, Franklin County The "Great Dome": The solution-made ceiling here rises 35 feet higher than either up- or down-stream from it. (To see it better, turn the picture upside down.) A bank of red clay lies beyond the stream, and there are pockets of the same clay in the spongework in the top of the dome. Photograph by G. Massie, Missouri Resources Division. Fig. 85. Profiles of the "Great Dome", Meramec Caverns E. H. Woolrych, del.
Caves of Missouri 173 The spongework in the ceiling of the dome indicates a solutional origin. For solution to occur up in such a hollow dome, the cave at one time must have been completely filled with water. No stream like that of the present could ever do such work. This is another bit of evidence like that of the clay fill remnants. The lowest level of Meramec Caverns was never made by the stream which now occupies the trench cut in the clay floor. The widest place in Meramec Caverns is a short distance upstream from the high dome. It is nearly 125 feet across, but its ceiling is low. The trail goes completely around this room, circling about the "Indian Mound", a central hill of the original clay-filling which at this place still almost reaches the ceiling. Pockets in the ceiling also contain the red clay. The hill has been isolated by the erosional work of two cave streams; the main stream we have been following and a tributary stream which enters from the north (right). Except in wet weather, this tributary stream channel is dry. Though there is no difficulty in going up the tributary, the regular tour omits it. The sign here reads "Atomic Bomb Refuge". The tributary cave chamber has some interesting features. Lamination or stratification in remnants of the red clay fill is very clearly shown a short distance upstream. That stratification is definitely warped as much as 35 to 40 degrees from the horizontal where contact is made with the wall rock. In such thinly laminated clay, deposited surely in quiet water, the laminae must have been originally horizontal. The warping is ascribed to compaction of the clay in the central part of the fill, and the amount of deformation shown is an argument for a very deep fill and for a rock bottom far below the present stream bed. Therefore, the original cave was made under conditions quite different from those of the present. Again, the conclusion is reached that the streams of today are only re-excavating the clay fill and are not the agents which made the pre-clay cavern. The tributary chamber can be traversed for 1000 feet or so, but it has no stream on its floor beyond a point about 200 feet up from the junction. It does, however, have an excellent record of a former stream. A bank 4.5 feet thick consists of cherty gravel which contains pebbles and chunks of the red clay. Since the red clay itself does not have any pebbles, sandy layers, or grit of any kind, it must be a record of quiet water, and this gravel deposit with the red clay chunks must have come later and must have been made by running water. Thus, in this place, there are records of two episodes of filling and one of intervening erosion. The first or red clay episode was succeeded by one of stream channeling and the making of red clay pebbles. That was followed by the episode of gravel deposition. Another interesting feature of this lateral or tributary cave is the fine showing of ragged, cherty projections which hang as much as 8 to 10 inches below the dolomite ceiling.
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This tributary cave possesses a number of roof and wall pockets which contain clusters of barite crystals. The largest group of these is in the ceiling on the north side of the trail loop at the junction of the tributary and the main cave. It is a veritable geode; a cavity lined with in-pointing crystals. A recent discovery in Meramec Caverns is a series or compound group of great, vertical, sinuous slots about 100 feet high and about 1000 feet back up the small tributary, "Mud Alley", which joins the main cave just above the footbridge leading to the "Jungle Room". These slots are excellent copies of the Mammoth Cave dome pit slots and are due to the same mechanism. Indeed, this mechanism is at work today. A drip which is almost a water fall occurs at the top of one of the domes, even after weeks of dry weather. This drip is at the far end of the complex system of interconnected slots, as it should be. The complexity of the ground pattern probably exceeds anything in Mammoth Cave. Some walls of the slots are perfectly vertical for the full height and in places suggest the columns in the bas-relief of the famous Temple of Karnak in Egypt. The vertical groovings, or lapies, in this dolomite which is so prone elsewhere to develop sponge-work are nearly as perfect on some faces as those in the Ste. Genevieve limestone at Mammoth Cave. As in Mammoth Cave, coring also has occurred and great blocks have fallen to the bottom of the ensemble and have been partially dissolved away by later falling water. The dome pit with the greatest diameter in the complex has a considerable pile of manganese-stained chert fragments in the conical heap on its central floor. Associated blocks of dolomite show detailed, solutional etching from the falling water. Far more dolomite than chert certainly has fallen, yet more chert lies in this conical heap than dolomite. Clearly, the fallen dolomite rock is dissolved from the bottom about as fast as it accumulates. The long horizontal passage to the bottom of this group of dome pits is as clearly phreatic in its origin as any other such members of this cave system. The "Jungle Room" (Fig. 86) is aptly named, for passage through it is like going through a dense forest of close-set tree trunks. Some of these "trunks" are complete columns of coalescing stalactites and stalagmites. The abundance of these dripstone growths in this room almost closing the "First Level" chamber to passage, and their paucity or total absence elsewhere along the visitor's route can be explained only in general terms. The "Jungle Room's" roof leaks. A peculiar, dripstone deposit which is associated with the stalactites, stalagmites, and columns of the "Jungle Room" has received the name stalactiflat. It consists of a thin, flat, horizontal sheet of secondary calcite which hangs from the ceiling by numerous short stalactitic columns. It was formed when the "Jungle Room" was filled with clay to within a few inches of the ceiling. On the surface of this clay was deposited a thin, travertine layer, down to which grew the now-supporting, short stalactites. Removal of this easily
Caves of Missouri eroded clay left the odd form suspended in the air. A much better display of stalactiflats lies 1000 feet farther back in the cave than the trail goes. The visitor to Meramec Caverns sees less than a third of the total surveyed length (4200 feet) of the lowest level. Most of this length Fig. 86. Meramec Caverns, Franklin County Straw-type stalactites: Ceiling of an alcove off the "Jungle Room". A few icicle-type forms are interspersed among the "straws". Each "straw's" diameter is essentially that of the water drop on the end. A few fail to hang perfectly vertical. Photograph by G. Massie, Missouri Resources Division. lies upstream from the "Jungle Room", is traversable only with difficulty because of a low ceiling and soft mud banks, and yields little that differs from the features along the trails. There are two mapped tributaries which enter from the north farther up this chamber, thus, making a total of four from that side and none from the south. There are also four remarkable slots which intersect the cave stream chamber. One or two of these slots were presumably caused by falling water from a higher, water-carrying horizon. They form retreating waterfalls like those making domes and pits. Like the complex group up "Mud Alley", their own ceilings are about 100 feet above the stream level.
When we return to "Loot Rock" and the dam, let us give a moment's consideration to another part of the cave we shall not see; the 550-foot surveyed extension below the dam. For nearly 500 feet the cave maintains its width, but the ceiling descends gradually until it is so low above the clay fill (Fig. 87) that one may continue only by getting down in the stream-cut trench and wading in mud, thus decidedly muddying La Jolla Spring outside. About 50 feet farther on, the clay fill makes contact with the ceiling and the broad cave ends, in so far as being an air-filled cavity is concerned. At this point, the stream takes a very small lateral route which is comparable to what you see at the spring mouth outside and so finds escape by leaving the main cave. What becomes of the main cave? It surely does not end at this place. Yet the river cliffs overlooking La Jolla Forest show no place where the original and now clay-filled main chamber emerged. Fig. 88. Longitudinal Section of Meramec Caverns Between Dam and Spring E. H. Woolrych, del. Our conviction is that the lowering, bedrock ceiling descends enough to pass beneath the Meramec floodplain (Fig. 88). The river has not yet deepened its valley sufficiently to expose it. The present, little, free-surface stream cannot clean out the clay fill beyond the
Caves of Missouri 177 explorable end for centuries yet to come; not until Meramec River has eroded its valley much deeper than at present. The stream, therefore, has found egress along a new route, a bedding plane leakage, and has been using that route for so short a time that the passage is too small to allow a survey and is negotiable only by crawling in the water. This route is one of the youngest parts of the cave; as young probably as the dome pits slots described earlier. This is the final convincing evidence that the La Jolla Spring stream never made Meramec Caverns. To understand how the theoretical, original, hydraulic flow was succeeded by the present stream, we must recognize that the cave floor throughout is of clay, not of rock. The depth of this clay in Meramec Caverns is unknown. By analogy with Onondaga Cave, Cathedral Cave, and other similar caves where great slump pits show something of the thickness of the clay fill, it may well be 75 to 100 feet or more to the true bedrock floor. This clay fill could not have been made until there was a cave of present proportions to receive it. From an erosional history, Meramec Caverns passed to one of deposition, and it became completely filled, as shown by the terrace remnants and the "Indian Mound". After that filling was completed, and the cave as a water conduit was obliterated, there came the conditions of the present. Ground water, descending through cracks in the bed rock of the hill on its way toward river level, found the clay-filled, old water route and readily eroded away the upper part of the fill. This upper part of the earlier cave which is now filled with air for the first time is the cave that we examine today. In the cave air, dripwater now can build the various drip- stone and flowstone deposits. They never could have been formed in either the solutional-erosional episode or the clay-filling episode. Nor could the concentrated drip which makes the water fall far back up "Mud Alley" have had, during earlier episodes, that sheer drop of approximately 100 feet which has made the complex of great dome pits. They, and probably some of the high slots upstream from the "Jungle Room", date from this third and present episode of the history of the cave. These high, narrow chambers, wholly unlike any others in the entire system, are the only solutional additions made in the main cave after the clay-fill episode. The upper levels of Meramec are remarkably ornamented and diversified by secondary deposits whose range in form and size and color is perhaps unexcelled in the Ozark country and rarely excelled anywhere. To one who is interested in deciphering the conditions under which these upper level rooms were first dissolved out, this wealth of secondary lime is more than a nuisance; it is almost a complete obliteration of the record he seeks. The complex of these upper levels (Fig. 89) is distinctly separate from the great linear chambers of the "First" and "Second Level". It is not more than 220 feet long (north-south) or more than 150 feet.
178 Missouri Geological Survey and Water Resources wide (east-west), and its vertical range is 95 feet. The rooms are exceedingly irregular in all outlines and in their horizontal and vertical Fig. 89. Meramec Caverns, Franklin County Map of the upper levels of Meramec Caverns. Surveyed by Charles Higgins, Jr., 1946, placing and spacing. There was never any marked linearity in the pattern, and before the excavations for the present passageways, there were almost no connections among these rooms.
Caves of Missouri 179 These stairway routes of the upper levels feature dripstone, flowstone, rimstone, and shelfstone deposits which are named very largely from fancied, mythical resemblances. The first one seen on the climb is the "Devil's Bathtub" (Fig. 90). The visitor stands in the tub (despite the accompanying sign) and looks down over the sloping, Fig. 90. Meramec Caverns, Franklin County Rimstone dam: This huge dam was the overflow edge of the "Devil's Bath- tub". The water long since has found another route, and the tub has gone dry. Photograph by G. Massie, Missouri Resources Division. outer edge of a rimstone dam; one of the largest and best shown in all Missouri caves. The "Bathtub" stood full of water, but now is filled and floored with concrete. Water constantly ran over its edge and added to the rimstone dam which thus grew higher and thicker through- out the life of the vanished pool. The dam also grew slopingly and made an overhang toward the inside of the pool. Deeper in the water grew aggregates of semi-spherical, secondary calcite called botryoidal forms from their limited resemblance to bunches of grapes. The out- side slope of the dam is much smoother because it grew in the film of over-flowing water instead of being deposited like the botryoids under standing water. This slope should be called flowstone.
180 Missouri Geological Survey and Water Resources "Echo Room" and "Crystal Lake", also on the "Third Level", contain a splendid exhibition of stalactites, stalagmites, "draperies", and columns. The lake is artificially dammed, as the stalagmites rising from its water testify. They never could start growing from the bottom of a pool; they were here before the pool was made. The room was much larger before the present episode of replenishment began. A dome, "Onyx Mountain", which has grown in the middle of the room has almost divided it into two. The dome might be considered a very broad, very gently sloped stalagmite. Or it might be classified as a great aggregate of small, concentrically placed rimstones. It clearly grew after the "Devil's Bathtub" had lost its pool. The stairway from the "Bathtub" up to the "Fourth" and "Fifth Level" follows a route artificially excavated, in part, out of native bedrock. An appreciation of the original constrictions along this route is gained by contrasting the extent of the rough, hackly, quarried walls with the smoother surfaces of the more irregular, natural sponge work. Perhaps the culminating piece of nature's work as an interior decorator in Meramec Caverns is the "Wine Room" in the fifth and top level. There is no country rock to be seen, because every original wall and ceiling surface has been lavishly ornamented with as varied an assortment of secondary forms as any room of its size could ever contain. In addition to the bunches of "grapes" over all the lower walls, there are "apples", "oranges", "pumpkins", and "popcorn", if your imagination is lively enough. There also are ridged "draperies", stalactites, helictites, and strips of "bacon" hanging from the upper walls and ceiling. The crowning touch, however, is the centrally placed, two-storied "Wine Table". Its lower surfaces contain piled masses of "fruit", and its flat top carries several "wine glasses" and a "bottle". The table effect is extraordinary, for it stands clear of the floor on three sturdy legs (Fig. 91). The succession of events which made the "table" is easily decoded. The three legs are stalagmites which grew up subequally from a dry floor. Then the room became flooded approximately to the level of the lower story of the "table". The three stalagmite tips, as islands, each developed a shelf at the water's edge similar to the shelf now margining the room and separating the two types of wall decorations. These shelves eventually joined and made the first or lower "table top". On this top grew new stalagmites; the central one much exceeding the others in size. It was then a simple "wine table" with a big "decanter" in the middle. The water level then rose to the top of the upper story, presumably submerging the entire structure. From the water, there was deposited the overgrowth of bulbous and botryoidal forms that cover the first story and its "tableware". The "popcorn" (or perhaps "Delaware grapes") that cover the three legs also was deposited under water. This overgrowth apparently pyramided until it reached the surface.
Fig. 91. Meramec Caverns, Franklin County The "Wine Table": An extraordinary compound form of dripstone, shelf-stone, and under-water growths, with a history as complicated as the form. Photograph by G. Massie, Missouri Resources Division.
Missouri Geological Survey and Water Resources of the second pool, whereupon, shelf stone or "lilypad" stone made the second "table top" somewhat after the fashion in which ice forms on a pond around a projecting stump or other object. This second and higher pool surface is eloquently recorded in the shelf around the wall. The pendant forms hang above the shelf and the bulbous growths of various proportions and sizes are below it. The bulbous forms seem to have been made only under water, whereas the drip-stone can form only in air. The "wine glasses" and "bottle" on the top may have grown at this time or may date from the stalactites that fringe the shore shelf. This fringe, of course, could not grow until the water began to subside from the shore shelf level. The lateral offset in the structure between upper and lower levels is difficult to explain specifically. There can hardly be any undiscovered, higher levels in Meramec Caverns. Surveys show that the surface of the hill above is probably not 15 feet higher than the "Wine Room" ceiling. The complexity of this group of chambers increases as one climbs higher. It is essentially impossible to keep one's bearings on the upper trails. Even to recognize routes he has already travelled in the labyrinth is difficult. What can be said with confidence regarding the origin of these upper chambers is that the spongework of the walls and ceilings (especially well shown near the "Sphinx") tell of solution under completely saturated conditions, comparable to and probably contemporaneous with the first episode of the history of the lower level, but they were apart from the main flow, never even tributary to it. What is called the "Fourth Level" is the largest of these rooms and is reached by stairways. Nature was determined to subdivide it, but here she tried a different method. A great vertical curtain of dripstone, compounded of stalactites, hanging "draperies", stalagmites, columns, pilasters, and intermediate benches or shelves of flowstone from which hang more dripstone forms, cuts the room into an audience floor, a stage, and a backstage. The great curtain (Fig. 92) is appropriately the backdrop of the stage of the subterranean theatre. Color and form are beautiful under ordinary electric light, but when the elaborate special lighting system is used, the scene is truly unlike anything the sun has ever shone upon. The little theatre has held 224 persons at a "Mock Session" of the Missouri State Legislature (1945). There remains for consideration the relation of the cave pattern to that of the overlying topography (Fig. 93). The cave is under a hill, but is so low in the rock that one can hardly believe the overlying topography ever could influence the direction of ground water flow. The fact that it never has is clear from the map. If it had, the stream at "Loot Rock" would escape to the surface at the south and there, almost immediately, would enter the deep little ravine which is shown in figure 93. Instead, it flows eastward and, in so doing, goes into and through a hill whose surface rises 150 feet higher than the surface over
Fig. 92. Meramec Caverns, Franklin County The "Stage Curtains": This great compound growth of dripstone "drap- eries" spans 40 feet between the ceiling and floor. Conventional icicle-type stalactites hang from the nearer ceiling, and the floor consists of a spreading flow- stone "buttress". Photograph by G. Massie, Missouri Resources Division.
184 Missouri Geological Survey and Water Resources Fig. 93. Relation of Present Topography to Meramec Caverns Cave map by Charles Higgins, Jr., 1946. Topography from Meramec State Park Quadrangle map; United States Geological Survey. Contour interval 20 feet. "Loot Rock". Streamless "Big Room" is a former subterranean water route which does exactly the same thing and almost parallels the present cave stream route. Upstream from "Loot Rock", the surveyed course of Meramec Caverns runs for 2000 feet parallel to and beneath the overlying hillside. Its stream water logically should escape southward out of that hillside to reach Copper Hollow. Instead, it flows several times as far eastward, crosses under the little ravine above noted, then plunges into and through the 150-foot hill. We conclude, therefore, from convincing evidence, that Copper Hollow and Meramec valley both are younger than Meramec Caverns, and that the cave was developed when the surface of the region was everywhere about at the level of the present hilltops. These uplands are surviving remnants of that former surface peneplain, but were lowlands at that time. The uplift of the Ozark dome made possible the deep Meramec valley of today and the drainage of the cave. The red clay deposited in the later stages of the earlier cycle of erosion has been going out with the present cave drainage ever since the river cut down to the deep cave level. There is still much to be removed.
Cates of Missouri 185 MOUNT SHIRA CAVE Owner: George Mosser, Noel, Missouri Location: NW1/4 sec. 11, T. 21 N., R. 33 W., McDonald County Not shown on Noel Quadrangle map Mount Shira Cave is one of five commercially developed caves in McDonald County, but it is not currently being operated and has not been open to the public for the past three or four years. These five caves are in Mississippian limestone and are alike in being remarkably straight, uniformly narrow, and having fairly high openings along joints. SCALE IN FEET Fig. 94. Mt. Shira Cave, McDonald County U. S. Highway 71, in the base of the Elk River bluffs. A visitor walks almost due north from the entrance for 225 feet along a passage so straight that, although it is narrow, its entire length can be seen from The entrance to Mount Shira Cave (Fig. 94) is directly alongside U. S. Highway 71, in the base of the Elk River bluffs. A visitor walks almost due north from the entrance for 225 feet along a passage so straight that, although it is narrow, its entire length can be seen from
186 Missouri Geological Survey and Water Resources the entrance. Walking height has been secured by digging out perhaps 2 feet of sand and gravel on the floor and quarrying another 2 or 3 feet into the black shale (Chattanooga formation) which here constituted the original cave floor. When first explored, this stretch was only a crawlway under the present ceiling, and the cave stream, now in a Fig. 95. Mt. Shira Cave, McDonald County The "Petrified Waterfall". Photograph by Mrs. George Mosser, Noel, Missouri. trench dug alongside the concrete walk, was flowing on top of the gravel fill. Throughout this 225 feet, the ceiling is shaped like a big half tube below which the passage width is increased by recessed shelves carrying the sand and gravel deposits.
Caves of Missouri 187 At the end of this straight passage, the ceiling rises to perhaps 35 feet above the walk and an inaccessible, upper, narrow chamber is visible. The largest assemblage of dripstone forms in the cave hangs from its upper room as the "Petrified Waterfall" (Fig. 95) and the "Acorn" (Fig. 96). Fig. 96. Mt. Shira Cave, McDonald County The "Acorn". Photograph by Mrs. George Mosser, Noel, Missouri. The next 40 or 50 feet of traverse takes one through a passage used also by the stream, but possessing a lower ceiling than the one just followed. Around an interrupting curve in this cave's otherwise direct linear course, a visitor finds himself again under a high ceiling;
Missouri Geological Survey and Water Resources the walls converging to make the upper part a narrow slot. At this place the stream enters the visitor's passage from an untraversably low route at the contact of limestone and shale. A concrete stairway of 17 steps here leads up to a streamless, higher bedrock floor which for 80 feet is bounded by essentially vertical walls interestingly sculptured by the vertical grooves and ridges known as lapies. They are now dry, but when the sculpturing was done, these walls undoubtedly were wet with descending films or thin sheets of water. That water must have entered from a bedding plane at ceiling level. In some places, wide blades separating the larger grooves are only a few inches thick and seen from below look almost like long, free-hanging "drapes". They, however, are composed of the native limestone rock, not of dripstone. Descending another stairway, we reach the end of the visitor's route and face a waterfall (not petrified) where the stream we lost at the foot of the first stairway spills into an enlarged part of the passage and immediately disappears at floor level into the narrowly circumscribed passage from which we saw it emerging at the curved jog about 100 feet farther back along the trail. With a flashlight, one may see that the natural passage continues for at least 50 feet farther. Explorers have gone even farther. Another room, similar to the one we stand in, is reported to exist along this explored stretch. On the return, one may better appreciate, as he descends from the high floor to the lower one carrying the stream, that the high, narrow passage actually continues southward in the rock, well above all floors. It is excessively narrow and cannot be followed very far. Just before emerging to daylight again, a visitor may realize that he did not enter by way of a cave mouth. That mouth is completely blockaded by a large flowstone and dripstone deposit. The open entrance of today is entirely a quarried-out passage. Although the cave stream is undoubtedly enlarging its course by solution and abrasion today and has made the shelves on which the gravel and sand now lie half way up the walls, it clearly did not make the original cave. Those high, narrow slots were completely full of water when they were made along the controlling joints, solution occurring upward as well as downward. Only the lapies' groovings and the lower widened places with stream gravel are to be attributed to a ground water circulation like that of today; a circulation when the cave otherwise contained only air. Mount Shira Cave could never become filled with water to those high ceilings today. Only before Elk River had eroded its valley and, therefore, before ground water could escape freely from the bluffs, could this rock have remained completely saturated. These high-ceilinged parts, therefore, are older than the present topography. They date back at least to another earlier plain country which lay as high as the neighboring hilltops, but which is now largely destroyed by the development of Elk River valley and its tributaries.
MUSHROOM CAVE

Location: SW1/4 NW1/4 sec. 13, T. 40 N., R. 2 W., Franklin County

Shown on Meramec State Park Quadrangle map

The entrance to Mushroom Cave (Fig. 97) is almost 150 feet above the Meramec River and only 2500 feet from it. There are two other openings. One of them is 500 feet nearer the river, and the third is a crawlway which must be stumbled over to be found in the forest on the hillslope. All lie at about the same altitude, and their total horizontal spread is about 1100 feet. Not one of them is a real cross section of the cave chamber. All are the result of erosional intersection of the cave by widening of Meramec valley. Fig. 97. Mushroom Cave, Franklin County

Surveyed by Jane Myers and Jean Simmons, 1947.

The length of Mushroom Cave totals 1400 feet and has a nearly horizontal floor throughout. It lies subparallel to the hillside and is more than 100 feet below the summit. As a drainage way for ground water out of the hill, it has no function whatever and carries no record of ever having so served. It is another of Missouri's many caves whose location, proportions, and gradient are totally out of harmony with the needs of ground water today. Mushroom Cave was formerly shown to visitors, but the Park Administration is now wisely keeping it closed. It has some treacher-
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ous-looking ceilings, waiting for the last inch of slow splitting from the roof rock to crash down on the floor. Although much higher above the Meramec River than its neighbors, Meramec Caverns and Fisher Cave, Mushroom Cave otherwise is very similar. There is a marked linearity, a fair uniformity of width and ceiling level, and a low gradient of the floor. The clay floor, like those in the other two caves, is only a record of a free-surface stream working long after the cave itself was made. For the floor of Mushroom Cave to be so gently sloped that water in places does not drain off, means that no discharge from the cave has occurred during the long time that Meramec River has been eroding the last 150 feet of its valley. Mushroom Cave was undoubtedly a much more extensive cave when it was being formed. The western "end" is only a blockade because of the later filling. The eastern "end" probably is similarly determined. Somewhere on the forested slope, dimples should exist to mark the places where the hillside transects former extensions of the main cave. All of these caves have lost original terminal portions because of subsequent valley-making. This cave is a product of subwater table solution in an earlier cycle of erosion. Ceilings bear the same irregular solutional pits and pockets and cavities as the walls. The cave was completely full of water while it was being formed. This would be an utter impossibility today. The eventual product of that earlier cycle of erosion was the upland peneplain, traces of which are identified a little farther west at altitudes of 900 to 950 feet above sea level; 200 feet or more above the cave level. As the cave must have been made when the deep circulation was most effective, it antedates the peneplain and, therefore, was formed even deeper than the present land surface; below the land surface of its time.

Comparison of the altitudes of Fisher Cave and Mushroom Cave brings up an interesting point. The caves are only two miles apart, they are on the same side of the valley, in the same formation, and are much alike, as above noted. Why should the entrance of Fisher Cave be more than 100 feet lower than that of Mushroom Cave? We suspect that the comparison of altitudes should not be between the two "entrances", neither of which is a cross section of the main cave chamber. It should be between the far inner termini of Fisher Cave (nearly 700 feet above sea level) and the hillside entrances of Mushroom Cave (but little above 700 feet). The writer believes that both caves had comparable altitudes for comparable portions. What is left of Mushroom Cave is to be compared only with those most distant portions of Fisher Cave. Most of Fisher Cave should be compared with the lost portions, the lower stretches, of Mushroom Cave where now is the open Meramec valley. The ancestral Meramec River lay perhaps a mile farther east of what is left of Mushroom Cave than it did east of Fisher Cave.
Caves of Missouri 191 OLD SPANISH CAVE Owner: R. W. Wilson, Jr., Reeds Spring, Missouri Location: NE1/4 NE1/4 sec. 7, T. 24 N., R. 22 W., Stone County Not shown on Forsyth Quadrangle map The intriguing name of Old Spanish Cave (Fig. 98) is derived from a story of a Spanish miner who died in Webb City in 1885, and Fig. 98. Old Spanish Cave, Stone County Surveyed by R. W. Wilson, Jr.
192 Missouri Geological Survey and Water Resources who left a map purporting to locate a "very rich silver mine" some- where within a radius of 125 miles. Marginal notations indicated that the map makers, also Spanish, had left two of their number buried in the mine and when departing in 1830 had blazed certain trees with crescent-shaped markings. Believers in the 1885 story and map began searching the 50,000 square miles involved, and seven years later they found the trees with the 62 year old blazes still dis- cernible (!) and, thus, also discovered that the "mine" was in a blockaded cave. Excavations then and later at the cave mouth, which is recessed back under a rock shelter, have uncovered two human skulls, quantities of animal and human bones, flint implements, frag- ments of crude pottery, traces of decomposed blankets and woven cane fabrics, and a deep bed of ashes. The only article reported from this shelter that surely is not of Indian origin is a battered, copper drinking cup, apparently made of spun copper with a handle made from a bent piece of copper tubing. Eager seekers for the vein of silver since 1892 have dug four different holes, 10 feet or more deep, in fallen slab rock back in the cave's larger rooms. They found only an accumulation of centuries of ceiling spalls. Indeed, the diggers in one place had to break through a flowstone deposit which lay upon the fallen debris. The deposit itself was certainly some centuries old. The "crucibles" which were uncovered have long ago disappeared, the original map was lost decades ago, the pictograph drawings re- ported in the rock shelter are gone, the last of the blazed trees has fallen, and the silver vein has successfully eluded all post-Spanish search. One marvels at the original discoverers' alleged ability ever to have found the vein and then so successfully to have obliterated all trace of their activity. The entrance opening (Fig. 99) is a narrow little ravine cut in greenish, shaly limestone below a roof of heavy-beded limestone 50 to 60 feet thick. A perennial stream flows from the cave and is augmented considerably in flood time, as is shown by the gravel banks inside the cave above the stream level. The cave entrance is 190 feet below highway level, but is easily reached by automobile. One walks along a narrow curving passage for 300 feet before reaching the "Great Room". On entering this room, one sees a huge tilted block that has fallen from the left. At least 20 vertical feet of the wall came off in this fall. All around the sides of this room are other great wall blocks, fallen somewhat and tilted many degrees, invariably toward the center of the room. This, like the other two large rooms, is entirely a collapse chamber though of a very remote date. No recently fallen masses are seen anywhere in the cave. On the big block to one's left are long parallel groovings that cross the bedding at right angles. They record water falling vertically over the rock face before the block fell to its present position. The bedding departs from horizontality exactly as much as the groovings depart from verticality.
Because the entire room is a collapse cavity, there must have been originally an equally large, solution-made chamber beneath. The fallen material now fills it and, by its falling, has made the higher ceiling above us and the room we are in. We reason that a central collapse first occurred, leaving vertical walls down which water cascaded or flowed as a sheet to make the groovings. Later came the falling of this grooved wall rock, widening the chamber, but littering the margin with all these in-tilted blocks. Joint control is well shown in these collapse-determined rooms (Fig. 100). One dominant joint strikes N. 70° W., another one N. 40° E. Two N. 70 W. joints make the southwest and northeast sides of the "Great Room" and, farther along, the northeast side of
Missouri Geological Survey and Water Resources the "Treasure Room". A third joint, recorded only by a great slot in the ceiling, almost exactly bisects the 110 degree angle made by these two walls in the "Second Room". Both rooms have connections with the surface. A large debris cone spreads out into the "Great Room" from the eastern side, and Fig. 100. Old Spanish Cave, Stone County Joint-determined wall: This wall is a joint-determined fracture surface in the "Great Room". Photograph by courtesy of owner, R. W. Wilson, Jr., Reed Springs, Missouri. One in the "Treasure Room" spreads out from the south. The relatively fine material which has come down presumably from a surface sinkhole reaches completely across the large room at one place. The cone makes almost a half circle on the floor and is, thus, a nearly complete half-cone, not simply a convex fan. A feature which the writer has never seen in any other Missouri cave, but which is repeatedly exhibited in the "Treasure Room" is the existence of drip holes which have been dissolved in fallen slabs.
Caves of Missouri 195 The holes do not exceed 2 inches in diameter, but some actually penetrate completely through a slab 10 inches thick. None of the slabs bearing these drip holes has tilted since they were formed. Why did this dripping water dissolve rock instead of building stalagmites? Two other outstanding places in the cave are shown to visitors; "Rebecca's Well" and the "Cathedral Room". The route to "Rebecca's Well" is along a solution-determined passage. The wall and ceiling rock is "carved", not fractured. Differential solution has made a pattern wholly unlike that in the large rooms and, indeed, unlike that of the tunnel-like entrance passage. This solution pattern is shown at its best in the last 30 to 40 feet of the approach to the "Well". Here, there is a very striking ceiling slot above the broader chamber at the level of the "Well". Without it, one would have to stoop considerably instead of walking erect with his head up in the lower part of the slot. The water now using this passage never dissolved that ceiling slot (Fig. 101), yet the slot, indubitably, is not of fracture origin. One sees, just beyond the "Well", a fine lit- tie statuary group of dripstone growths. There are two more solution channels (hardly passages now) at the north end of the slot chamber of "Rebecca's Well". They separate like the arms of a horizonaxial Y and are parts of the horizonaxial Y and are parts of the Fig. 101. Cross section of Pas- earlier cave system which sur- sage to "Rebecca's Well", Old Spanish Cave vived the collapse which else- where is so conspicuous. E. H. Woolrych, del. To reach the "Cathedral Room", one must follow another narrow route which twists and turns and rises and falls in a very complicated way. Although solution originally was responsible, one travels most of the 185 feet of this route between fracture walls and over a bottom of fallen blocks. There has been tremendous wreckage of an earlier cave system in Old Spanish Cave. The reward for persevering along this route is a sight unsurpassed in Missouri caves, so far as the writer is aware. The lofty "Cathedral" at this place differs from most other cave "Cathedrals" of the Ozarks. Its walls are native limestone, not dripstone. The walls are vertical for the first 20 to 30 feet up, then they begin to close in for a fine "Gothic" arched ceiling 40 to nearly 100 feet above the floor. The cathedral effect, however, is found more in the vertical carvings; those pilasters of bedrock that everywhere rise from the floor approxi- mately to the same level before the wholly different, intricately pat- terned, steep ceiling arch begins to close in. A specific name for these carvings is lapies. Here are groovings or lapies on a grand
196 Missouri Geological Survey and Water Resources scale and still vertical, just as they were formed by films or sheets of water descending from now-abandoned water routes along those intricately irregular openings in the very cherty ceiling rock. In only one Missouri cave (Meramec Caverns) has the writer seen them actually being formed under descending water. In most cases, the water has found some other route and the work is complete. The "Cathedral" has a complicated ground plan, though the essence of it is a central "nave" with accessory "chapels" opening off of the "nave". Each "Chapel" is likewise bounded by these lapies-marked, pilastered walls. All this grooving required an earlier open cavity for the water to fall into. All the collapsing on display likewise required earlier cavities. The "Entrance Tunnel" is, for 300 feet, smaller than almost any other passage in the cave and it is not much lower than the floor of any of the collapse rooms. This fact shows clearly that the original chambers, now so largely collapsed and filled, must lie deeper in the rock than the bottom of the ravine hollow to which the cave stream now discharges. In other words, the "Entrance Tunnel" is a recent affair developed during the later history of cavern collapse and ravine entrenchment. The making of the first cave system occurred before this ravine was cut. The cave stream has made its tunnel since and has done so because a large cavern system, already existing back under the hill, was collecting ground water and had no place to discharge it. If most of Old Spanish Cave was dissolved out before this ravine at its mouth had been eroded, then the original cave-making antedates the rugged, stream-carved topography of the entire region. We conclude here, from somewhat different evidence than elsewhere, that Ozark caves are older than the latest uplift of the Ozark dome. Highway 65 is on a surviving ridge of, or close to, the peneplain level. The original phreatic cave was developed more than 200 feet beneath that surface. Old Spanish Cave is near the headwaters of a tributary of Bear Creek, itself not a major stream of the present nor of the peneplain drainage system. Where the phreatic discharge of the cave entered the main drainage of the peneplain is unknown. It was not by the present ravine route to the west fork of Bear Creek.
Caves of Missouri 197 ONONDAGA CAVE  
Owner: Crawford County Caverns, Inc.
Location: NW1/4 NW1/4 sec. 35, T. 39 N., R. 3 W., Crawford County
Shown on Sullivan Quadrangle map

The visitor's entrance to this large cave was formerly by way of a narrow tunnel, the floor of which was in complete possession of a cave stream (Fig. 102). Damming of the stream for water power a little outside the cave mouth occurred in pioneer days and was continued to solve the problem of traversing the narrow chamber. The ponded condition made possible an interesting, subterranean boat trip for about 200 feet and brought the visitor dryshod to higher floors within the cave. The pond, however, (below trail levels), backs up for nearly half the length of the cave. Popularity of this cave has so increased that an artificial entrance with a flight of steps has been necessary, and the boat trip has been abandoned. This stairway leads to the inner dock of the former, subterranean boat ride at the southern end of the "Entrance Chamber". Thence, on a fairly level walk along about 500 feet of the length of this chamber, one reaches the "Big Room". In the "Big Room", the trail climbs and descends and turns and doubles and divides for several hundreds of feet. The ponded water of the stream is a dead level which is in sight and, therefore, convenient for reference throughout much of the trip. Ceilings in general also hold fairly constant levels, though they vary in height above the floor from room to room. It is in the shapes of the walls, in the variations in widths of chambers, and in the interruptions in the floor that much of the history of the cave is read. Entrance Chamber.--The "Natural Bridge", at the junction of the "Tunnel" and the "Entrance Chamber", is a deposit of lime made rather late in the history of the cave on a bank of mud which has since been eroded away. Although its butresses are of the native rock in which the cave has been eroded the "Bridge" is of secondary limestone, or cave formation rock. The history of the "Entrance Chamber" is epitomized in a typical cross section (Fig. 103) seen 75 feet beyond (north of) the "Witch's Well", and the general chronology, as here deciphered, is duplicated in more than a dozen other places in Onondaga Cave. The trail at this station has been cut in a bank of red clay that formerly had a continuous smooth slope down to the platform-like rock on the opposite side. The stratification in the clay and the similarity of altitude indicate that the cave at this place was once clay-filled from side to side. Scrutiny of the ceiling pockets here and elsewhere will show other and smaller remnants of the clay, in-
Caves of Missouri 199 dicating that the fill must have extended at one time completely to the top of the chamber. But the red clay is limited to the upper broad portion of the chamber and nowhere exists in the narrow, trench-like lower part. This is true throughout Onondaga Cave, where chambers have a capacious upper part and an offset, narrow, lower part with a stream in the bottom. SCALE IN FEET Fig. 103. Cross section of the "Entrance Chamber", Onondaga Cave E. H. Woolrych, del. Reading the history backward, we first conclude that the stream at the bottom of the trench has made that trench below trail level. Because no red clay exists in it, we may well think that the trench is younger than the clay, and that the original bottom of the clay deposit was about at the level of the platform. As we are confident that the broad, upper part of the chamber once was completely full of the clay, we reason that the present stream began its excavation in clay at the very top of the broad part of the chamber above the trail, and that it has had to work in solid rock ever since in making the trench. In ground plan, this trench describes a large curve out from the upper part of the chamber and back again. The stream, at the apex of the curve, actually is farther over in the native dolomite wall than is the far edge of the upper, broad part. We walk 30 feet or so along the trail and cross the stream on an artificial rock bridging. The deep stream trench, now on our left, is undercut below us in a broad curve on this opposite side and to about the same extent as it was on our right.
There is actually a series of eight reversing curves in this trench pattern along the "Entrance Chamber", the stream being crossed by the trail five times between the "Natural Bridge" and the "Queen's Canopy". Everybody has seen such reverse curves, or meanders, in surface streams of low velocity. We therefore conclude that the cave stream, meandering on a clay floor in the upper part of the room, carried that meandering characteristic with it as it deepened to, and finally entered, bedrock where it began making its narrow trench. Because of deepening in this trench, great blocks of the wall rock have here and there become unstable and have fallen or tilted over toward the stream. The trail crosses one; "Hogback Ridge". The tilting of this block has been fairly recent in the development of the cave, for the stalagmites which have grown on its flat upper surface still are here, tilted from the vertical as much as the flat surface is from the horizontal. Only a few vertical stalagmites (the "Weeping Widow" is one) have grown on the block since movement ceased. Another record of the same kind is that curious stalagmite called the "Hitchhiker". One almost instantly recognizes that the inclination of the main stem is due to settling of the ledge it had grown on, and that the "thumb" of the "Hitchhiker" is but a renewed, stalagmitic growth. The broad upper part of the "Entrance Chamber" must have existed as such before ever a red clay fill could have been deposited and, therefore, must be much older than the platform and trench part. Was it also made by a stream like that of today; a stream which was downcutting its roofed, subterranean valley as any surface stream erodes its open-to-the-sky valley? Certainly, it has features unlike those of the trench. Certainly, it lacks the features the trench part has. The answer, given here in advance of the evidence, is that the ground water flow which made the upper, pre-clay part of the "Entrance Chamber" was very different, that this upper, flattened "tube" was completely full of water during its entire history, that it was dissolved out by upward as well as sidewise and downward attack, that the flow was like that in a water main, under pressure, and that no air whatever was in the cave at that time. The significant facts supporting this interpretation are better recorded in other parts of Onondaga Cave and will be explained as we examine them. Two places in "Entrance Chamber" can have only this interpretation. One is the "Two Lane" character, the doubling of the upper part near the stalagmite group known as the "City of Alton". Only the eastern one suffered the later trenching, so that it alone carries the trail and the stream. The other place is the "Witch's Well", a deep solution pit which no stream flow like that of today could ever have made. Big Room—From the inner end of the "Entrance Chamber", one emerges at the "Queen's Canopy" (Fig. 105) into the "Big Room". The trail descends somewhat, the trench we have been seeing dis-
Caves of Missouri 201 appears, the floor becomes broad and low, and the ponded stream covering most of it is justifiably termed a subterranean lake. The ceiling is likewise broad and flat and hangs 25 feet or so higher than the ceiling in "Entrance Chamber", or nearly 80 feet above the lake. Running along the middle of this ceiling is the trace of the vertical joint which determined the course of the first ground water whose cumulative work has given us the "Big Room". Here the trail divides; the right-hand branch again crosses the stream and nearly encircles the lake. Beyond that, it rises by a long stairway to a group of small but exquisitely beautiful rooms entirely enclosed by the outstanding dripstone aggregate of the entire cavern. We shall take this trail later. At present we follow the guide up "San Juan Hill" along the left-hand trail branch, walk past the "Twins" (two huge equiproportional stalagmites which stand on a clay fill), go under the "Great Dome" in the high ceiling, and pass "Little Brother" and the "Xylophone" (it should be called the Petrophone). In doing so we are climbing an erosional slope in a deep, original clay fill. We cross the two barbed wire fences which mark the property line between the original Onondaga Cave (which we have been traversing) and the northern part of the same cave, once known and operated as Missouri Caverns. The guide probably will describe the legal battle in which the fences figured. The summit of "San Juan Hill" is 35 feet above the lake level. It is a ridge of clay, ornamented and veneered in places with much dripstone and flowstone. The far side, now visible, descends much more steeply, and at its foot is the cave stream rippling audibly as it emerges from a very low-roofed passage on the left-hand (west) wall and enters the "Big Room". It crosses that room and disappears into another low-roofed passage in the right-hand (east) wall. This is a curious behavior and must mean something about the history of the cave. The most obvious thing is apparent after we have gone another 200 feet along the trail and have crossed the 100-foot bridge. Neglecting the "King's Canopy" (a huge flowstone dome which almost overhangs the stream), we see that the "Grand Canyon", below the trail and bridge level and containing this short transverse course of the stream, has two steep clay slopes. Unlike any other "Grand Canyon", this deep cave valley has not been gradually cut down from the top to its present depth. It is a huge slump pit in the clay fill. The stream, finding or making a route through the clay at the bottom level, has carried away all the clay that has slumped and still continues to slump down into it. The "King's Canopy" is a later growth down in the pit and was made by drip water descending the pit slope from higher levels. Thus we must visualize an original, upper, clay fill surface continuously across the site of the pit at the present level of the crests of "San Juan Hill" and the far (northern) clay abutment of the "Dan'l Boone Bridge". The stream obviously found this part of the "Big Room" already existing and almost wholly clay-filled. It is not the
202 Missouri Geological Survey and Water Resources stream which made the "Big Room". All that the stream has done here is to make the slump pit by sapping the clay from below. If we continue on the trail beyond the far end of the "Dan'l Boone Bridge", we shall travel on a flat floor and at the same level as the top of "San Juan Hill". Nowhere is this trail more than 20 or 25 feet below the ceiling. This floor appears to be the top of the undisturbed clay fill, and because there is no stream beneath it, no slump pits or other erosional forms have developed. This nearly level floor and accompanying low ceiling continue as far as the cave can be followed. The ceiling actually is as high here as it is above the lake in the "Big Room". The difference in appearance is simply that the clay fill in the "Big Room" has been removed to a much greater extent than in this former Missouri Caverns part of Onondaga Cave. Some extraordinary features of Onondaga Cave occur in the vicinity of the big slump pit, "Grand Canyon". One is the stream course after it crosses "Grand Canyon". The stream penetrates into the east wall for a short distance but comes back to look again into the slump pit through a great window which can be seen from the "Dan'l Boone Bridge". It then re-enters the wall, and by a low- ceilinged route it eventually emerges at the low bridge along the margin of the lake. We last saw it here before climbing "San Juan Hill" to rediscover it in the slump pit. Obviously, the stream does not belong to the "Big Room" or the "Missouri Caverns Room". Instead of following this long and continuous chamber, where water must have flowed when the great cavity in limestone was first made, the stream of today enters the cave at a point 75 to 85 feet be- low the ceiling, crosses and promptly leaves the cave, only to re-enter at the lake in the "Big Room", and again to leave it and to use the "Entrance Chamber" and "Tunnel" to reach Meramec valley. One may paddle a canoe upstream from the lake and pass completely through the hidden, subterranean passage to reach the bottom of the slump pit. It is a low-ceilinged route throughout. Big and Little Bear Trails, and Gallery.-

How the stream ever got such a course becomes clearer after one has traversed the "Big" and "Little Bear Trails". The "Big Bear Trail" may be entered from the "Gallery" by descending a 15-foot flight of stairs. One then walks along a small and winding, tunnel-like chamber with an almost level floor for some 75 feet and abruptly emerges again into the "Big Room" at the great alcove alongside "San Juan Hill". Here, he re-joins the main trail near "Little Brother", the "Xylophone", and the "City of Rome". Although he has not used the same route which can be followed by canoe on the stream, he has gone through the same mass of wall rock. Enroute, he has been directed to look back and has seen that the nearly level portion of the "Big Bear Trail" can be backtracked from the foot of the stairway to a hole in the eastern wall of the slump pit and about 25 feet above the bottom of it. Also he
Caves of Missouri 203 has seen the two connected, well-like cavities in the floor of the "Gallery", the "Devil's Barbecue Pit" and an unnamed hole. He has noted the extraordinary spongework in the walls along the "Big Bear" stairway and the relatively smooth walls and ceiling of the 75-foot level of this tunnel. If he now traverses the "Little Bear Trail", he descends by the devious windings of another tunnel, with spongework walls throughout, with extraordinary variations in ceiling heights, and with no rock floor showing anywhere, until the ponded water of the stream in its own lower tunnel (the canoe route) can be seen. A spotlight directed downward from the "Little Bear Tunnel" at an angle of about 45 degrees is reflected back up through the window above noted to the far end of the "Dan'l Boone Bridge". The unavoidable conclusion is that this massive, eastern wall in the vicinity of the "Gallery" is perforated by at least three irregular, small, tunnel-like cave passages. The lowest one is occupied by the stream, the other two are the "Bear" trails. None of them is a clean-cut tunnel, all are pocketed and have spongework openings in their walls. Undoubtedly, if a higher one were water-filled today, it would leak into the lower. This anastomosing pattern of pockety water routes, twisting in the horizontal and the vertical, can never be ascribed to the work of the present, free-surface cave stream. The water which made this complex completely filled the "Big Room" too. Red clay remnants show that this solutional work was earlier than the clay fill which, as we have seen repeatedly, was made before the present stream began its work. For the solutional pockets to develop in the ceiling of these passages, no air is allowable in the cavities. For the flow to be uphill and downhill, as it was, no gravity-controlled, free-surface cave stream can have been responsible. We must conclude that the original cave-making was accomplished under completely saturated conditions, and that the water flowed under hydrostatic pressure and moved, not necessarily downhill, but toward any direction of less pressure. These conditions disappeared about the time of the clay-filling, and whatever conditions brought about that episode of filling disappeared in turn, to be succeeded by those of the present; those of a free-surface cave stream with air above it and with a continuous downgrade to give it a current. During this latest and present episode, the "Entrance Chamber" has been deepened by a series of meander trenches. The rock floor of the "Big Room" is unknown, but lies somewhere below the stream of today and doubtless has not been modified. The "Big Bear Trail" also carries an unmistakable record of modification by a later, free-surface cave stream. The spongework has been smoothed off, and there are remnants of a gravel bed along its lower margins. This former stream surely entered from the hole in the wall above the slump pit bottom which was some 25 feet higher than it is today. The discharge point of this former stream into the alcove of the "Big Room" is one of the most interesting places in Onondaga Cave. As far as known, its features are unique among Ozark caves. At
204 Missouri Geological Survey and Water Resources this point, the free-surface cave stream built a rimstone dam about 2.5 feet high; a dam which grew in a leaning position out over the cliff below it and whose lip developed a pronounced pout. Later, this dam became deeply notched. Still later, it became perforated near the base, and the hole enlarged to make what is called the "Giant's Mouth" (Fig. 104). The spillover from this mouth in turn built a lower pouting lip. Seen from below, the contact of the reddish, secondary limestone of the dam with the white, native dolomite bedrock is Fig. 104. Diagram of the "Giant's Mouth", Onondaga Cave sharply outlined. Either before or after this "Giant's Mouth" dam was built, the stream built another rimstone dam about 6 feet farther upstream. Most of this has been destroyed by later stream erosion. The vanished stream which used the "Big Bear Trail" and made this rimstone, waterfall lip was a predecessor of the present stream. Because its channel is some 35 or 40 feet higher, it must record water which today does not enter the cave at that level. It functioned about the time the meandering trenches of the "Entrance Chamber" were being started; at a time when the lower slopes of "San Juan Hill" had not yet been eroded. Its record has remained unchanged all the while the meandering slots of the "Entrance Chamber" have been in the making. Yet this vanished "Bear Trail" stream is not the oldest one recorded in the cave since the clay-filling episode ended. The "Gallery", by which one by-passes a part of the big slump pit, "Grand Canyon", to reach the "Dan'l Boone Bridge", is itself a free-surface streamway
Caves of Missouri 205 and appears to have been made before there was a slump pit; even perhaps before the "Entrance Chamber" had secured its first, free-surface stream flow just under its ceiling. The 100-foot long "Gallery" is the modification of a passage like the "Big Bear Trail". For some reason, this route was favored for a time. The "Devil's Barbecue Pit" was, of course, filled with clay at that time, as were both "Bear Trails", the "Grand Canyon" slump pit, and the low-ceilinged canoe route on the present stream. Furthermore, the long, flattish floor of former Missouri Caverns appears to be the upstream product of this earliest recorded, free-surface stream in the cavern. Missouri Caverns Chamber.-This high-floored, deeply clay-filled part of Onondaga Cave is sharply partitioned off from the rest of the cave by the remarkable "Colonnade", essentially a double row of largely coalesced dripstone columns extending from the floor to the ceiling. Only by quarrying out a passageway through the barricade has it been possible to cross it. Just beyond this low doorway is the most striking stalagmite of the cavern; the "Rock of Ages". It is straight-shafted and ornamented with horizontal shelvings and vertical pilasters like some un-leaning Tower of Pisa. Another remarkably beautiful dripstone group is the "Musicians' Balcony"; massive columns correctly placed for the support of a penthouse roof over the balcony. Five hundred feet beyond the "Colonnade" is the greatest single flowstone cone or dome of the cavern. It is 25 feet high and reaches from floor to ceiling. At its foot, there is a series of parallel, subequal, rimstone dams built apparently by water flowing from the slopes of the dome. The water evidently flowed northward to the small slump pit at the far end of the trail. One cannot fail to note that the floor of the "Missouri Caverns Chamber" is repeatedly fractured and that many of the columns are broken across with their lower parts separated from the upper. Both features are due to the same cause; compaction of the deep clay fill since the dripstone columns and the flowstone floor were formed. The amount of settlement varies; the maximum being 20 inches. This subsidence in the central part of the chamber has broken even the "Great Dome", and the fracture thus produced is still widening. In the memory of older guides, it has increased from 6 inches to about 2 feet. The freshest-looking fracture and offset in the flowstone floor is just north of the "Musicians' Balcony". Other diversifications of the floor of the "Missouri Caverns Chamber" are readily interpreted as fallen ceiling blocks and irregular dripstone growths on that floor. Where blocks have fallen, their hackly outlines and the corresponding irregularities of the ceiling have, in some places, been smoothed out by subsequent solution. Queen's Canopy Rooms.-A former continuation of the "Big Room", now all but filled with later deposits, leads northeastward from the lake. The "Queen's Canopy", a great compound half cone,
206 Missouri Geological Survey and Water Resources descends almost from the ceiling down for more than 40 feet to hang suspended just above the water of the lake (Fig. 105). Its flat bottom grew originally on a clay surface, subsequently removed by the stream, so that only its wall anchorage suspends it in the clear. In part, this anchorage is attached to native rock, and the mass also partly rests on remnants of the thick clay deposit which is largely concealed by the wealth of secondary calcite. A stairway alongside the "Queen's Canopy" ascends this slope for 47 feet. A little short of the summit it divides, and the two branches are parallel and close together for 30 feet or more of trail length, but are separated by the "Wall of Jericho". This wall is a row of stalagmites which stand directly under a joint trace in the ceiling and are obviously the result of leakage down along that crack. The largest stalagmite in the wall is nearly 20 feet high and all but touches the ceiling. The "Wall of Jericho" ends in a huge, compound, columnar mass whose stalactite members affect a drapery type of dripstone. The column is about 25 feet high and 35 feet in circumference. Other columns and "draperies" farther back on the summit divide the original solutional chamber into five recognizable rooms: "Onyx Hall", "Cathedral Hall", two "Lilypad Rooms", and the unique "Submarine Room" which is highest and farthest back in the traversable portion. From a point a little beyond the "Submarine Room", one may look farther than he may go and see daylight through an opening in the hillside at his level. Long before this part of the main cave chamber was clay-filled, and still longer before the great dripstone and flowstone aggregates grew, the original Onondaga Cave must have continued northeastward out into what is now the Meramec River valley. A broad sag or sink on the surface outside very probably marks the place. The river has made its valley since the cave was made. Indeed, the river valley is younger than the clay fill. Only the present stream and its work is to be considered contemporaneous with the erosion of Meramec River valley and its tributaries. A fine showing of ragged chert masses hangs from the ceiling in "Onyx Hall". The insoluble chert has been left in relief while the surrounding dolomite has been dissolved away. These pendant masses must not be confused with dripstone growths; they are part of the native bedrock. The fact that all this dripstone and flowstone rests on a high clay fill seems to be indicated in "Onyx Hall" by the evidences of slight settlement of the foundation flowstone and the breaking of the columns. This is similar to the subsidence features in the "Missouri Caverns Chamber". One place shows a crack—a breaking away from the rock—which is 3 feet wide and at least 15 feet deep. Winding a devious course through the "forest" of dripstone forms, we enter the first or higher "Lilypad Room" and see the first of the subaqueously precipitated, secondary cave "formations" which are
Fig. 105. Onondaga Cave, Crawford County The "Queen's Canopy". Photograph by G. Massie, Missouri Resources Division. Fig. 106. Onondaga Cave, Crawford County The "Lilypad Room". Photograph by G. Massie, Missouri Resources Division.
208 Missouri Geological Survey and Water Resources growing today in the pool. The "lily pads" are unusual forms made at the surface of the water on any available anchorage; the shore, stalagmite islands, or stalactite tips which touch the water. All the "pads" have a definite rim and are shallow "dishes" in effect, because the pool level slowly rose about 2 inches late in their growth. A submerged electric light in this pool has to be cleaned frequently of a filamentous, green algal growth that mistakes the electric light for sunlight. Also conspicuous is a submerged rimstone dam which was once the barrier to a lower, smaller pool and which is now thickly over- grown with calcite deposited from the water of the present pool. The second "Lilypad Room" (Fig. 106) shows curious under- water, bulb-shaped growths which appear to have started their growth around some fragment, or excrescence, or small stalagmite made be- fore the pool was formed. Some of these support island-like "lily pads", but it is the shores that best display this type of growth. The "pads" are shelfstone accretions which, if the pool were to be drained, would eloquently record its former surface. The secondary lime deposits below, at, and above the water line belong to three different categories. The "Submarine Room" (Fig. 107) is the most interesting and instructive of all these rooms above the "Queen's Canopy". The pool formerly here was drained in 1932, and the three types of second- arily precipitated forms are very distinct. The shelfstone, former "lily pads", separate the dripstone forms above water from the pre- vailingly bulbous forms that grew below the water level. It is obvious that the pool was formed rather late in the history of this room, and that before it was formed, there was the usual collection of stalagmites and stalactites. When the pool formed, deposition below water much exceeded that above, and the submerged original dripstone forms received a marked overgrowth that almost obliterated the original forms. A remarkable, perhaps unique, feature of the "Submarine Room" is the multitude of fallen stalactites on the bottom of the former pool. They lie in every possible position and are all overgrown and even cemented together by the excess calcium carbonate deposited from the water (Fig. 108). Every stalactite which hangs down below the former pool level, every stalagmite which projects above, tells the same story. Less obvious is a record of two successive pools separated by an interval when air-deposited dripstone grew below what had been, and was again to be, a pool surface. The second pool surface appears to have been 2 inches or so higher than the earlier one. Cave "popcorn" is well shown in "Cathedral Hall", coating various dripstone deposits. Its origin is still largely a problem. In many caves, it is clearly an underwater growth, but in Onondaga Cave that explanation may not be acceptable. Perhaps there are different kinds of "popcorn", some forming in air, some in water, and we have not yet learned how to distinguish them.
Fig. 107. Onondaga Cave, Crawford County The "Submarine Room". Photograph by G. Massie, Missouri Resources Division. Fig. 108. Onondaga Cave, Crawford County Fallen stalactites. Photograph by G. Massie, Missouri Resources Division.
A visitor to almost any cave is likely to hear estimates of the rate of growth of secondary calcium carbonate. At present, there are no known measurements on which to base these estimates. In Onondaga Cave, markers have been placed in places where the growth is occurring, and sometime we shall know definitely how fast certain stalagmites and stalactites have been growing during that particular time, but even then we shall not dare to use those figures in computing the age of any particular "Rock of Ages" or "Twins" or "Wall of Jericho". The rate of growth must be exceedingly variable in different situations. It must vary in the same situation from time to time. Age estimates of any stalagmite or stalactite are to be viewed with a jaundiced eye; they are only guesses. Red clay.—Where the red clay came from and how it entered the cave is no problem at Onondaga Cave. Grading for the higher part of the parking lot at the cave office has exposed the subsoil and its contact with bedrock. The red color is conspicuous. It is not a clay, but it contains clay, and it is the clay which gives that red color. Mingled with fragments of chert (also residual from wasting away of dolomite), this subsoil is the insoluble residuum of hillside rock whose carbonates have been dissolved by rain and soil water and carried down the Meramec River. As long as weathering has been taking place on these slopes, red clay has been in constant production. Some remains on the surface, although, doubtless, much has been washed away along with the dissolved carbonates. The underlying rock is cut by vertical cracks or joints; not open cracks but partings along which the rock breaks when quarried. Water uses these cracks in percolating down toward the saturated zone. Can the clay fraction of the subsoil penetrate these cracks along with the water? Certainly silt and sand particles could not be expected to do so. One answer to that question is the fact that the red cave clay has a very smooth, unctuous feel between the fingers; almost like a fat or grease. One Ozark cave owner says he has actually marketed it for facial clay. If this red clay was originally part of a surface weathering product, an extraordinarily effective sieving process has operated between the surface and the cave. Sinkholes will not do this, for the muddy water must be strained of every particle except microscopic ones. Another answer is found in the fractured surface of native dolomite just to the left of the "Giant's Mouth". The rock has been split off in trailmaking and the flat split face is as red as the clay we are studying. But the redness is only a film which is traceable laterally into unfractured rock, and there it shows in cross section as a line thinner than a sheet of paper. This is the kind of sieving which has let only the finest clay down into the cave. A very long time, and the weathering away of a large amount of dolomite must be asked for, if this explanation is to be accepted.
Caves of Missouri 211 An overall view of the history of Onondaga Cave involves three markedly different epochs: first, the original cave making epoch under conditions of complete saturation and hydraulic circulation; second, the epoch of red clay-filling when circulation came essentially to a standstill; and third, the present epoch of (a) clay removal, (b) new and different solutional work, and (c) deposition of secondary lime "formations". The sequence of these three epochs was determined by changes in the regional history which are well recorded above ground. The flattish upland near Onondaga Cave averages close to 1000 feet above sea level, and within a mile of the cave, the broad hilltops are 925 to 950 feet above sea level. These uplands are taken to be remnants of a former peneplain; the old lowland which, since its uplift, has been so deeply and complexly dissected by modern streams. The clay fill of Onondaga Cave must be contemporaneous with a topography which required only the very minimum of ground water movement. That means a topography with a minimum of relief. There is no time before the peneplanation was completed which satisfies the requirements, nor has there been such a time since the present erosion cycle started. We, therefore, confidently interpret the clay fill as a consequence of the peneplanation. Thus, the first solutional epoch occurred during the earlier stages of the peneplain cycle, and the last epoch had its cause in the Ozark dome-making and in the rejuvenation of the old peneplain streams. The levels of Onondaga Cave lie approximately 250 to 300 feet below the nearer peneplain remnants. The Meramec River valley bottom of the earlier cycle has been completely destroyed during the present cycle, and we need not try to find remnants, but it could hardly have been more than 50 feet lower than the 925-foot remnant a mile distant. If these figures can be trusted, the deep hydraulic circulation which made Onondaga Cave in pre-peneplain time was active 200 feet below the level of the Meramec valley bottom when the peneplain was finally completed. This circulation seems to require the existence of hill lands, earlier and higher than the peneplain, from which ground water under hydrostatic pressure flowed through the conduits of Onondaga Cave. If so, we must move the time of the first epoch of the history of the cave back to somewhere near the middle of the earlier cycle.
Ozark Caverns, formerly Coakley Cave, (Fig. 109) possesses three unlike sections: a wide smooth- cei-led stretch back from the entrance for 200 feet; a narrow, rough- Fig. 109. Ozark Caverns, Camden County walled and twisting passage of equal length; and a uniformly pro- portioned and somewhat crooked but capacious chamber to the end of the visitor's route, another 970 feet beyond. These three con- trasted portions have each had a somewhat different history which is recorded in the different features possessed by each section. The low, broad arch of dolomite marking the cave entrance (the exit of the cave stream) is the only outcropping bedrock of the immediate valley slope. We find this feature is common to many other Missouri caves that are entered low down on valley slopes. It may mean in some cases that vigor of an escaping cave stream, now or in the past, had prevented slope waste accumulations in the proximity of cave mouths, but where a visor or penthouse of the roof rock projects out farther than the valley slopes on either side, as noted for other caves, some other explanation must be sought. It has not yet been found.
Caves of Missouri 213 The unusually smooth and nearly level ceiling of the first section is intimately related to the banks of gravel, sand, and clay conspicuous for almost the full length of this section. In many places, their remnants reach almost to the smooth ceiling. Obviously this first section has been filled at some time so full of this stream-carried debris that the cave stream has been held up against the ceiling and at that time did the smoothing. A few caves have an additional record of a former fill of gravel and sand in the existence of an upside-down channel in their ceilings. Even without this, the interpretation here presented is sound. The present capacious cave at this place has had most of that fill carried out later by the cave stream. The second section is in strong contrast with the first. Although almost equally high, it is very narrow and crooked. The path almost twists out from under one's feet, and some sides overhang so much in the curves that bending one's body sidewise is required to pass them. It is crooked both in ground plan and in vertical cross section. There is no difficulty in accepting this sinuous, narrow section as the product of the stream now flowing along its floor. A considerable increase in width at the very bottom of the close-set walls of this winding section shows that it is now being enlarged by that stream. If a gravel, sand, and clay fill has ever existed here, it has been almost entirely removed by the present stream. Along the zigzags of this second section, visitors must walk in single file. Emergence from its confines into the third section, the main cave, is abrupt. Here is room for a large group to gather about the cave's greatest spectacle, the "Angel's Shower Bath" (Fig. 110). From the ceiling in the middle of the large room, there hang huge stalactitic growths that suggest closely folded drapes. Below them, there are even more massive, bulbous, stalagmitic forms, like crowded and imperfect domes. The shower is a continuous and heavy rain from one stalactitic group that falls 6 feet or so in the clear into a basin whose rim has been built up by the lateral splashing into a unique, broad, massive stalagmite. The basin is at least 3 feet deep; nearly half as deep as the stalagmitic growth is high. The "Shower" does not perceptibly slacken during drought. The nearest parallel to this display is the "Waterfall" at the bottom of Marvel Cave in Stone County, but Marvel Cave's "Waterfall" is caused by a cave stream whose course can be explored. The source of the never-ending discharge through Ozark Cave's ceiling is unknown. It seems to come out of the solid ceiling rock. Spectacularity of the "Angel's Shower Bath" may distract one's attention from the great change in cave proportions at this place. Thence to the end of the visited portion, the cave maintains approximately the same considerable width, averaging ten times the width of the twisty second section although having about the same height of ceiling above the floor. This remarkable increase in width has a significant bearing on the cave's history. When we have gone to the
214 Missouri Geological Survey and Water Resources far end and come back to the "Angel's Shower", we can better comprehend the meaning of this great change of proportion. There are nearly a dozen local displays of dripstone growths along the next 970 feet; "Rainbow Falls", "Old Faithful", "Capitol Dome", "Mountains of the Moon", "Frozen Cascade", etc. ending with the "Holy City". The ceiling in many places is almost covered with a growth of fine-textured helictites. All are "live" deposits. therefore, they are among the youngest features of the cave. There are considerable remnants along this section of the cave of a once nearly complete fill of detrital material interbedded with old flowstone. As in the first section, it is obvious here also that there has been stream deposition followed by stream erosion; both events occurring after a capacious cave had already been provided. Three narrow places exist along the trail in this section. Each is indicated on the accompanying map as a meander slot. At each meander the main chamber is still largely filled with the stream deposit. The present trickle on the floor, the path and its bridges, and the visitor, all must skirt around that fill in a narrow bypass. The stream made the bypass and is still enlarging it. At these three places, meander loops, impinging against the dolomite walls, incised horizontal grooves at the contact. As gradual deepening in the fill occurred, the stream in these grooves was forced to deepen in the wall rock. The narrow slots, therefore, are channels younger than the fill which is, of course, younger than the original cave. The ceiling and upper walls of the third section are characterized by spongework of surprising complexity. Probing with a flashlight beam reveals holes of very irregular shapes and sizes penetrating back in the rock and uniting and dividing in an inextricable tangle. The same words will describe the separating partitions of remaining rock in the spongework. In places, there is more empty space involved than surviving partitions. Spongework is the result of differential solution in the dolomite; less soluble rock constituting the sponge framework. Any attempt to explain it by differential current attack in homogeneous rock is hopeless. The almost uninterrupted spread of this spongework in Ozark Cavern's third section, and its absence or scarcity in the other two sections convince us that the long corridor has had a different history than the rest of the cave. Spongework on upper walls or ceiling is irrefutable evidence that this section was completely full of water and was essentially a subterranean aqueduct when the solutional attack occurred. Obviously this must have been long before Osage River and its tributary valleys existed. Spongework is one of the oldest records in the cave. An alternative explanation is that the upper spongework was made when the cave was nearly filled with the sand, clay, and gravel so that the stream could reach the ceiling. But the ceiling of the first section has also had that experience of detrital filling and it is
Fig. 110. Ozark Caverns, Camden County The "Angel's Shower Bath". Photograph by Johnson.
216 Missouri Geological Survey and Water Resources unusually smooth; wholly innocent of any spongework. Indeed, it may have had such a ceiling earlier, and those diversified forms have been destroyed when the complete fill brought the stream against that now plane ceiling. If this idea is valid, then the third section has never been completely filled. Another prominent feature of the third section's ceiling and upper walls is the display of ragged chert; insoluble constituents of the bed-rock left projecting in relief among the spongework pockets and partitions. This chert is far older than the earliest cave-making from which the spongework dates. In contrast, the delicate overgrowth of helictites may be about the youngest feature of Ozark Caverns. When the visitor returns to the "Angel's Shower Bath", he should look at the cave wall beyond it. The full width of the chamber, really the end of the first section, is not the bedrock dolomite. It is a wall of clay with interbedded layers of sand, gravel and old, dis-integrating flowstone. It is a complete cross section of the cave's former fill. But if one stops his consideration of the eastern end of the third section at this (correct) conclusion, he misses the most significant item in Ozark Caverns' history. Let us ask if the long, third section was once completely water-filled, and was a subterranean aqueduct, where did that water go and from where did it come? A blind ending like this to the original cave is impossible. This "blind" terminus is only a blockade-provided end. The original cave continued eastward to some discharge place, presumably a large spring of that time, long before Coakley Hollow was eroded, therefore, long before the present Osage River system existed. The filling of this original cave extended well up towards the ceiling and was a much later affair, requiring a free-surface cave stream. Its included flowstone records air in the cave at the time. Erosional removal of that fill is almost complete today and has come about because of Coakley Hollow's erosion. However, with the blockade still intact, by what route was the debris carried out? The map (Fig. 109) provides the answer. A new route was made. The second section did not exist before the episode of re-excavation. When it began to develop, it tied across from one original cave (third section) to a neighboring one (first section) of that early generation and thence escaped outdoors. For some reason this was an easier route for the ground water to reach present valleys. One item of cave history commonly on record in the Ozark country (the red clay fill) has left no trace in Ozark Caverns. We feel sure that if it ever did exist here, it was only a partial fill. Had the spongework cavities ever been filled with red clay, they could never have been so completely cleaned out subsequently.
Caves of Missouri 217 OZARK WONDER CAVE Owner: James A. Vance, Noel, Missouri Location: SW1/4 NW1/4 sec. 1, T. 21 N., R. 33 W., McDonald County Not shown on Noel Quadrangle map Ozark Wonder Cave or Elk Springs Cave (Fig. 111) is strikingly situated in a very narrow, long, cliffed hill on the inside of an entrenched meander of Elk River. The hill is three-fourths of a mile long, has a width of 1000 feet at river level, and a height ranging between 60 Fig. 111. Ozark Wonder Cave, McDonald County and 120 feet. The cave is as strikingly oriented as it is situated. The hill salient is elongated almost straight north-south; so is the cave. Though the explorable length of the cave is probably not much more than 350 feet, it is developed throughout on a joint or a pair of joints that are somewhat sinuous, but their strike lies between north-south and N. 70° W. Joints of the same set show in the high, straight walls left by the quarrying by which the cave was discovered. The entrance of Ozark Wonder Cave faces west and is just a door set flush with the high, vertical, north-south wall made by the quarrying years ago. The passage inside trends south by southeast (N. 40° W.) and departs 40 degrees from parallelism with this wall. Farther
218 Missouri Geological Survey and Water Resources in, a few slight turns bring most of the strikingly linear cave into precise parallelism. Had this quarry wall been driven about 30 feet farther east, back into the hill, and been extended about 200 feet farther south, the entire known cave length would have been exposed. Much of its northern part would have been destroyed. The quarry walls are clearly joint-determined; almost north-south and almost east-west. Deep vertical cracks which cut the horizontal stratification of the Mississippian limestone rock formed convenient working faces and were left so little scarred that, now weathered, they look like nature's own cliffs. But nature does not decorate her outdoor cliff faces with stalactite "drapes", and one of these walls does carry a sheet of stalactite growths. That wall was originally the east side of a narrow, slot-like cavity, probably too narrow for entrance before men destroyed the west wall. Ground water circulating in greater volume along one joint of the north-south set dissolved away so much wall rock, under different conditions than now exist, that we today can freely walk along the high narrow passage it left. Then those earlier conditions which avored solution of bedrock changed to conditions which demanded deposition of secondary limestone (cave "formation" rock, or cave onyx), so that Ozark Wonder Cave's fine display of air-deposited dripstone and flowstone, and of water-deposited "coral" growths was begun and is still being augmented. One enters along a passage which had to be somewhat enlarged and which has a ceiling barely high enough for head clearance. Shortly the ceiling lifts, the sides retreat from each other, and one finds himself in the natural cave, with only paths, stairs, bridges, and electric lights added. The joint control is obvious almost everywhere in the ceiling (Fig. 112); deep slots, fringed with stalactites and "drapes", or simple cracks, marked by rows of stalactites. In places, there is a complementary row of stalagmites on the floor, exactly beneath. Fifty feet inside the cave is the "Spare Bedroom"; a room reached by a flight of steps up into a higher part of the joint crack. It must be the "guest bedroom", it is so strikingly adorned. Five dripstone columns reach from its floor to its ceiling. Two are simple forms, made by the junction of a drape-type of stalactite with the conventional form of stalagmite. The other three are compounded of several, partially fused, vertical forms which are difficult to resolve into component units. Many of the icicle-like stalactites are still growing. At the far southern end, two ribbon-like growths hang edgewise; almost pure pearl in appearance. Some of the simple stalagmites have terminal cups which are probably due to splash, but possibly due to the dripwater having reversed its procedure; dissolving away a part of what it had previously deposited. Cave "popcorn" or "coral" growths occur on the south wall. "Popcorn", however, is far better shown at the far end of the cave. Among the columns are flowstone "cascades" somewhat younger than the "coral" and the columns they lap onto.
Caves of Missouri 219 Eighty feet inside, one climbs 20 steps. The ceiling rises even more. We are climbing up on a fill of clay and dripstone that has completely blocked the lower part of the cleft which is Ozark Wonder Cave. Here, there is greater width also, because the joint is double and the intervening rock is only 5 feet thick. Here, there is the best Fig. 112. Ozark Wonder Cave, McDonald County Joint-determined passage: This joint-controlled passage shows an irregular development in the ceiling that makes narrow slots which connect the large ceiling cavities. Widening of the joint to make the main part of the section is apparently due to greater solubility of the limestone stratum at this level. Photograph by G. Massie, Missouri Resources Division. showing of a row of stalactites along a ceiling joint. They are accompanied by a row of stalagmites beneath. At the top of the flight of stairs on the main trail, the cave widens considerably because the wall rock on both sides has fallen away into once open, lower depths; now filled. A dome shape has been given to the ceiling of the chamber. That the collapse occurred many centuries ago is evident from the growth of stalagmites all over the fallen blocks.
About 185 feet farther along, the trail brings one to the first bridge. It spans a double dome pit; two domes above, two pits below. The architecture of the cave walls at this place is distinctly different from most of the rest of the cave. Instead of horizontal ridges and grooves marking the edges of layers of different solubility, these dome pit walls are vertical and their corrugations are also vertical. They are grooves made by water which fell, late in the history of the cave, down whatever surfaces it found. The water dissolved vertical channels, or lapies, as it fell. In some caves, this grooving action is still going on. In Ozark Wonder Cave, the water has been diverted and the falls are dry. Above them, and older than the waterfalls, there is a narrow, conical dome which was dissolved upward into the ceiling joint slot at a time when the cave was completely full of water under pressure, like the water in a water main. Most of the cave was made under these earlier conditions of complete saturation. No air ever entered and no free fall or free-surface flow was then ever possible. Only here and there has the later episode caused cave enlargement (as in dome pits). Almost everywhere it has deposited material to decrease the original amount of open cavity. At a distance of 210 feet from the entrance, one comes to a longer bridge over a bowl-shaped solution cavity in the bedrock. A visible bedrock floor is a rare thing in caves; waste material and secondary lime deposits commonly conceal it. Theoretically, the bedrock floor should be like the more commonly seen bedrock ceiling which is marked by enlargement of the determining joint to make slots or domes. Here both show; the bedrock bowl being below the bridge and the "Liberty Bell" hollow dome above it. The "Bell" is but a solutional enlargement of the slot that runs almost throughout the cave length. Twenty feet beyond the bridge and 250 feet inside the cave, there is a showing of surface waste, mostly chert gravel, that obviously has come down from a hole in the roof; a former sinkhole. Just beyond is the "Old Covered Wagon Room" which is mostly a solutional enlargement of the joint. Its lower part is at least 20 feet wide, but its upper part is only that ceiling slot which we have been seeing repeatedly. Here, it reaches 30 feet or more above our heads, and its sides are hung with innumerable, drape-like dripstones. The "Covered Wagon" conceit is based on a series of vertical shrinkage cracks in a seam of red clay that lies back in a horizontal niche which runs around the walls of the room. At the end of the trail, approximately 310 feet from the entrance, one may see about 40 feet farther, where crawling would be necessary and where, apparently, debris finally blocks all further progress. Here is the best display of that peculiar form of secondary lime; the "popcorn" or "coral" growth. It occurs on almost every piece of dripstone and flowstone. From other caves where water pools exist, we know that this is a deposit made under water, not in air. Its occurrence at intervals throughout Ozark Wonder Cave shows that, later than much of the dripstone and flowstone, the drainage of the cave became blocked,
Caves of Missouri and air for a time was displaced by standing water. These temporary pondings are common enough in almost all cave histories, but unlike that earlier history of solution under conditions of complete saturation, this later episode was one of deposition. The topographic setting of Ozark Wonder Cave is remarkable. The hill containing it is three quarters of a mile long and only 1000 feet wide in its widest place. The cave trail in one place rises 30 feet above the entrance, and at this point the roof is probably not much more than 20 feet thick. Fine tree roots, hanging from the higher ceilings in several places, attest the nearness of out-of-doors above. Both this long, narrow hill and the long, narrow cave extend essentially north-south. The deep valley of Elk River is on both sides of the hill and 20 feet or so lower than the lowest levels of the cave. Water entering the cave represents part of the rainfall of the hill. It is small in amount and never can logically be visualized as the water which once occupied this joint chamber completely to the ceiling. Certainly such water never would have flowed along the length of the hill. To explain the origin of Ozark Wonder Cave, we must go back to a time when there was no Elk River valley and, therefore, no long, narrow hill. The entire region was probably as flat and its surface as high as that of the upland prairies still surviving farther north about Neosho, but at that time it was all lowland. Under such conditions, there was no drainage of water out of the rock like that of today. The limestone remained completely saturated year in and year out, and the water, under hydrostatic pressure, moved slowly along the joints in the limestone. Time enough must have been available for the solution that occurred. Following this, there came a time when the vigor of circulation decreased and the finest clay, derived from weathering of limestone on the surface of that time, filtered down through infinitesimal cracks and finally filled the cave with the tallow-like material. Then came the uplift of the Ozark dome in southern Missouri and in adjacent Arkansas. The sluggish streams of the ancient low land thus rejuvenated began eroding the present deep valleys and draining the remaining rock in the hills. Rain water entered the cave in its passage downward toward the lowered, saturated zone and eroded much of the clay, made waterfall groovings, and deposited the dripstone and flowstone. The history of Ozark Wonder Cave, thus briefly outlined, is the history of almost every cave in Missouri. Details differ, but the three epochs: (1) solution, (2) clay-filling, and (3) clay removal which is accompanied by the deposition of drip and flowstone, and some limited solution on a wholly different pattern, are found recorded over and over. That "popcorn" subepoch was a purely local, tempo- rary damming late in the third epoch; the dripstone and flowstone epoch, and the epoch of air in the cave.
PIKE'S PEAK CAVE
Owner: G. Swanson, Waynesville, Missouri
Location: NW1/4 SE1/4 NE1/4 sec. 14, T. 36 N., R. 12 W., Pulaski County
Shown as Kraft Cave on Waynesville Quadrangle map Fig. 113.
Pike's Peak Cave, Pulaski County
Surveyed by Willard Farrar, 1932.
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223 Pike's Peak Cave (formerly Kraft Cave or Roubidoux Cave) is a double-mouthed cave (Fig. 113) in a prominent, cliffed salient overlooking Roubidoux Creek along Missouri Highway 17. The entrance is picturesque but hidden from the highway when the trees are in leaf. The lowest place in the entrance is 60 feet above the creek. The rock floor of the upper opening is 95 feet above, and the ceiling of this upper opening is 110 feet above the stream (Fig. 114). The larger, lower Fig. 114. Diagram of Entrances to Pike's Peak Cave E. H. Woolrych, del. entrance contains a building for visitors, a cafe, and dance floor. The "Musicians' Balcony" is up in the connecting passage between the two openings, back of the outside cliff wall. These two cavities in the cliff face join 25 feet inside to become one. The room back of the smaller, upper opening becomes only a side chamber with its floor not far from the same level as that of the rock terrace on the right side of the main chamber, and its ceiling becomes the ceiling of the main room. The rock terrace can best be seen if one looks back after walking just far enough into the cave to lose sight of the sky through the entrance arch. It is readily recognized also from the dance and cafe floor. The terrace is about half as high and half as wide as the total dimensions of the main chamber. Its floor once was continuous with the floor of the smaller opening; the lower half of the main chamber was made later. On this rock terrace or bench, there is perched a huge, tilted block which is kept from completing its fall by an engagement with the ceiling (Fig. 115). Less easily recognized but significant is the fact that the ceiling of the big arch for 20 feet back in from the outside cliff is nearly as low as the terrace floor and the floor of the smaller opening. It is nearly 15 feet lower than the ceiling level over the dance floor. Another significant item of the architecture of this cave mouth is the existence of nearly horizontal slots that have been eroded back into the walls at about the level of the terrace floor by a former free-surface cave stream. From the dance floor, some slots can be seen on the east wall, but the best showing is from the "Musicians' Balcony". From here a horizontal slot can be seen which cuts back under the
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wall of the upper room farther than one can see. It was here that most of the Indian relics were found in this cave. As we know that many slow streams develop exaggerated reverse curves (meanders) because of greater erosion on the outside where the strongest current flows, Fig. 115. Diagram of "Balanced and as we know also that only Rock" on the Terrace of a subterranean stream could have Pike's Peak Cave made these slots, it is interesting E. H. Woolrych, del. to reconstruct in our imagination the course of the former cave stream at the level of the slots. At the time that the terrace floor and the floor of the upper opening were the bottom of the cave—before the lower half of the cave and the lower opening had been made—this vanished stream was coming from somewhere back in the hill, swinging in broad curves from side to side, and escaping from the cave by way of the very marked, horizontal floor level in the upper opening. The cave then had only one mouth. There must have been a big curve in the course of this vanished stream which reached from the slots above the terrace in the southeast wall to those back of the "Musicians' Balcony". The outside of this curve was not far from the face of the then-intact cliff where the larger, lower mouth now is. By continuously enlarging this curve, the stream finally cut its way right through the face of the cliff and out of the cave. Immediately, it appropriated this new opening for its discharge and abandoned the old one; the upper one (Fig. 116). In subsequent time, this new opening became the larger one, chiefly through failure of the cliff rock and disposal of fallen blocks down the bluff below. The cave building stands on rubble from the making of this larger, lower arch. In contrast, the floor of the upper opening is on bedrock. Let us now explore the cave farther back than daylight reaches. Some distance beyond the dance floor, there is an opening in the lower part of the left-hand wall. It is a small tributary chamber that can readily be traversed for 80 to 100 feet back. Almost at its mouth is a natural bridge built mostly of flowstone at a time when the passage was filled with debris to that level. At the far end of the traverse is a series of rimstone dams holding up little pools of seepage water. It is certain, however, that a larger flow than that of today dissolved out this lateral passage. Its walls are very irregularly diversified with many-shaped pockets and their separating projections. This spongework clearly is the result of ground water solution, but the pattern produced is very different from that made by a meandering stream. We shall return to further consideration of this point.
Caves of Missouri 225 Farther back in the main chamber, the 20-foot ceiling abruptly turns right and disappears in an alcove whose floor hangs about 15 feet above the gravel floor on which we are walking. It can be entered only by ladder. It is another lateral passage with the same grotesque, spongework wall sculpturing of irregular holes and partitions. This passage has a dry, red clay floor which gradually rises until we must crawl. It would be interesting to explore this farther. Fig. 116. Map of Outer Part of Pike's Peak Cave Returning to the main chamber, we notice that the ceiling drops abruptly to the level of the floor of the alcove side passage and so continues for another 200 feet, or as far as the cave trail is developed. As the gravel floor gradually rises as one walks upstream, the clearance becomes less until stooping is required. Here the trail ends. However, in this cave, if one is willing to stoop, to creep on all fours, to crawl snake-wise, to get himself wet and smeared with sticky red clay, and in one place to force himself through about as tight a passage as the average adult can hope to negotiate, he may explore a perfect labyrinth of hundreds of feet of twisting, dividing, and uniting old waterways, some of which still carry water. All are on much the same general level in the rock, but upper ones cross lower ones in an almost unmappable confusion. The red clay in the upper ones is only a remnant of a fill which once reached completely to the ceiling. There is little danger of getting lost. Enough explorers have crawled through here to mark what is unmistakably the main route. This last stretch under the abruptly lowered ceiling beyond the ladder carries a truly remarkable feature throughout. It is an up-side-down channel in the ceiling (Fig. 117). Meanders are beautifully recorded in it, but there is no bottom to this channel. It is an extraordinary feature, surely, and it requires an unusual explanation. This writer has seen five other clear-cut cases of this phenomenon: one in a Virginia cave, one in a Kentucky cave, and three in wild caves.
226 Missouri Geological Survey and Water Resources of Pulaski County, Missouri. There is accessory evidence in each case to support his interpretation, although the interpretation has not convinced all geologists who have heard it. Let the reader stand under this upside-down channel and try to make it out as something other than a channel. Fig. 117. Pike's Peak Cave, Pulaski County Upside-down ceiling channel: Lighting had to be from unusual angles, and confusing shadows insisted on appearing. Turn the photograph upside-down and see this meandering channel as a normal right-side-up channel. Better yet, come and see its full length in the cave itself. Photograph by G. Massie, Missouri Resources Division. Briefly, the cave at some time has been completely filled with a very greasy or tallow-like red clay. Almost motionless water was required for the extremely fine clay to settle and for no sand or silt to enter. Such a condition could never exist here now, with the Roubidoux and Gasconade River valleys just outside and 50 to 100 feet lower than the cave chambers. The clay which antedates the present stream valleys was deposited in the chambers which then lay below the level of complete ground water saturation of the rock. Therefore, the clay antedates the channel in the ceiling. As rivers and creeks of the Ozark drainage gradually cut their valleys deeper and deeper, these clay-filled chambers eventually came
Caves of Missouri lie at stream-bed level. Visualize the Roubidoux Creek, flowing on a valley bottom at the foot of the big cliff but just at the level of the channeled ceiling. The hill here at that time was only half as high as now. Some of its rainfall was percolating down through the rock as it does today. At the Roubidoux Creek level which we are visualizing, the water in the hill rock ceased descending and sought lateral exit. It found that exit at the very top of the clay-filled chamber we are now discussing, but the flow was sluggish, as the meanderings testify. As the water was flowing against the ceiling, the soluble dolomite above yielded more than the dense and insoluble clay below. Now conceive that the Roubidoux Creek at that time shifted its course on its floodplain to the far side of the valley, 2000 feet away from the foot of the cliff. A slight building up of the floodplain in front of the cliff would become inevitable. This would decrease the gradient of the stream in the cave and some of the insoluble sediment it was carrying would be deposited in this channel. Such shallowing of the channel in the original clay floor would hold the stream against the ceiling for further up-deepening of the upside-down channel we are now considering. How much of a cave system existed here before the red-clay depositing epoch? How much, and what parts, are of later origin? Where extensive remnants of the clay linger, the evidence is clear. We conclude, therefore, that virtually all of the labyrinth of minor passages is pre-clay and that only the meander niches associated with them have been made by the stream water which has cleared out most of the once complete fill. In the part of this cave seen by the average visitor, this criterion is unavailable, except in the two side passages where there still is red clay. But where we can see meander slots incised in a wall high up above the floor, we must admit that a wall already existed and that there must have been a floor on which that stream meandered. We believe it is justifiable to use the red-clay fill for this floor. This seems satisfactory evidence that a cave at the level of the upper opening preceded the clay-depositing epoch. Of course we do not visualize for that time a cliff and an opening like those of today. We first must provide for the slack water necessary to get the clay to settle in this primitive cave. What, then, were the conditions of subterranean flow for making the earliest, the pre-clay cave chambers? There are two lines of evidence to consider: the spongework and the big springs like Roubidoux Spring just south of Waynesville, and Boiling Spring 9 miles downstream from Pike's Peak Cave. The spongework is the result of differential solutional attack on cave walls and ceilings. The pockets of the spongework indicate greater solubility, not greater vigor of attack. No definite current is indicated and no air is allowable above the water. This is proved by the existence of ceiling pockets in Pike's Peak Cave. These pockets were dissolved upward a few feet into the ceiling and were completely
The spongework was made under conditions of complete saturation and below the level of the ground water surface of the time, before the stream valleys outside were made. Water did flow, of course, through these water-main type of cave chambers, but it flowed in the direction of least pressure, which locally could be uphill, and it emerged like the water does from Roubidoux Spring or Boiling Spring. It came up under the pressure of the water standing higher back under the hills of that time. What parts of Pike's Peak Cave have been made by the free-surface (vadose) streams which we see today or find recorded by meander slots? The lower half of the main chamber near the entrance probably is largely of vadose origin. But even here, this vadose portion is only an enlargement of a pre-existing phreatic or water-main type of cave tube. This is proved by the side chamber to the left just back of the dance floor, whose striking spongework tells of an early pressure-directed circulation. So far as we know, the outlet may have been at the back end of this lateral passage. Pike's Peak Cave is deficient in dripstone display. The best showing is far back up a crawlway behind what is about the worst "Fat Man's Misery" that any cave could have. There is some wall-attached dripstone on the right of the main chamber, almost at the far end of the trail, and some interesting, orange-colored rimstone up the left-hand side passage. All such deposits, though they may be very old in years and centuries, are as young as anything to be found in a cave (except Indian flints and white man's bottles). In many places in this cave, there are wall and ceiling excrescences and protuberances, composed of flint (chert). They are the part of the native rock left in relief because of their almost complete insolubility after the dolomite matrix has been dissolved away. These protuberances are wholly different in origin from the secondary drip-stone deposits which occur on cave walls and ceilings. The major development of Pike's Peak Cave occurred at the same time that most of Missouri's caves were made; the middle or mature stage of a preceding cycle of erosion. During the making, the rock remained completely saturated and lay well below the lowest, water table levels. When the cycle had run on to old age, the hills of Ozark time had been reduced to slopes so gentle that erosion came almost to a standstill. The cave then lay beneath a peneplain; an almost featureless lowland. There was inadequate relief to maintain a hydraulic circulation through the cave, and it became filled with the butter-smooth red clay that migrated down from the deep soil of the peneplain. Traces of that peneplain still survive, despite the re-newed stream erosion which has followed the Ozark uplift. The broad uplands to the north, about Helm and Dixon, are remnants. Indeed, the summit of the hill land above the cave itself probably comes close to the old lowland trace. It appears, therefore, that Pike's Peak Cave was formed more than 200 feet below the surface of its time.
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ROARING RIVER SPRING AND CAVE Roaring River State Park
Location: SE1/4 NE1/4 sec. 27, T. 22 N., R. 27 W., Barry County
Shown as Roaring River Spring on Cassville Quadrangle map
Roaring River in dry weather heads in a large spring from a small cave at the very bottom of a deep valley. Even before the dam was built a little outside the mouth, the cave from which the spring issues was not traversable for any considerable distance. It now is flooded to the ceiling a short way back. The cave opening looks tubular in cross section, but may be much deeper than it appears. A narrow, solution-enlarged slot cuts vertically up into the dolomite (Cotter formation) from the top of the tube and terminates rather abruptly in the cliff face. The slot could be interpreted as a subterranean canyon which was gradually deepened by the spring stream, as the open valley to which it is tributary, Roaring River Hollow, was deepened by a main stream on the surface. Against that view, however, are the following considerations:

(1) The two open valleys converging here are 500 feet deep, and they carry water only during and shortly after wet weather. Each is proportioned in length and width to its share of the total runoff from about 33 square miles above the convergence. (2) The spring which discharges between 6 1/2 million and nearly 70 million gallons daily is all that keeps Roaring River from going dry during part of the year. The spring is the head of the river; it is the main stream. (3) The spring is on the side of the smaller of the two converging valleys; less than half a mile upstream from the junction. The cave stream has no surface valley of its own. (4) Of the 33 square miles of drainage area, more than 20 are intricately and deeply dissected by hundreds of ravines and hollows whose steep slopes carry off a large part of the rainfall before it can enter the ground. (5) This drainage area lies within the concavity of a half circle west of the convergence, and the multitude of stream courses constitute rude radii of that arc. This exceedingly well-drained country cannot conceivably contribute more than a small fraction of the ground water which is discharged by the spring. (6) The spring is on the east side of the valley to which it discharges; on the wrong side to receive any ground water coning out of the hills within the half circle. If it is fed by local ground water, it must be supplied from the east, not the west.
230 Missouri Geological Survey and Water Resources (7) In the first two and a half miles east of the spring there are two steep-sided valleys; their bottoms are as low as the spring mouth. They are taking the lion's share of precipitation here. If the feeding grounds of the spring are determined by local topography, they are limited to about 2 square miles of country to the east. There is no possibility that even the minimum discharge can thus be accounted for. There is no possibility that the spring has been cutting down in a subterranean canyon as the surface valley has been deepened. The spring is a recent acquisition to Roaring River drainage; discovered only since the outside stream has cut down to the cave level. The spring must gather its 6 1/2 to 70 million gallons daily from some adjacent region which is large enough and gently sloped enough to catch an adequate amount of rainfall to maintain the discharge. Surface runoff from the 33 square miles, even though it provides for only part-time working streams, has done all the valley deepening we see, and most of it was done before a spring ever existed. All this deeply dissected Roaring River country is a part of the very ragged, southeast-facing, Eureka Springs escarpment in Barry County. Most of the surface drainage above the back of the scarp crest goes northward, away from Roaring River, to the slightly entrenched and gently graded tributaries and headwaters of Flat Creek. Large areas have a deep cover of residual waste of the peneplain, of which this upland is a part. Depths of 150 feet are known. This is the region from which Roaring River Spring must get its water. Beckman and Hinchey (1944, pp. 108-112) report a large sinkhole on the plateau back of the scarp (apparently in sec. 14, T. 22 N., R. 28 W.) which contained a lake of several acres for a number of years, but which sometime in 1939 or 1940 abruptly lost its standing water. Coinciding with this, Roaring River Spring became "very muddy for several hours causing a near disaster in the rearing pools for baby trout" at the spring mouth. The sink is five miles northwest of the spring and 350 feet higher. If we accept the conclusion that the spring water comes from the northwest, then the ground water under the upland must move in nearly the opposite direction to that of surface drainage, and the particular ground water trunk for the spring must go under Roaring River valley in order to discharge on the east side of that valley. All these considerations are body blows to the simple concept that the cave is post-valley in age. There must have been a deep water main under the peneplain, leading southward or southeastward, and it must still be carrying water. Today's surface streams have only recently cut down to it and have made this spring possible. The cave is still wholly below the water table. The spring is a recently made leakage up through its ceiling. In this report, we repeatedly cite caves with spongework walls and ceilings but without red clay remnants. If it is granted that the cave containing Roaring River Spring Cave became clay-filled during the
Caves of Missouri 231 long peneplain stage of inactive, ground water circulation, we can see in this big spring activity of the present cycle a perfectly adequate mechanism for the removal of every vestige of that clay fill. Most caves of the earlier cycle were not so situated that they later became big spring trunks. Most caves have lost their red clay fill by the action of small vadose streams; perhaps only trickles of water, hence, they have remnants which are adequate to establish the verity of the clay-filling epoch. Although our argument against the vadose origin of Roaring River Spring and Cave may seem incontrovertible, we are but little short of amazed when we take the final step in the chosen theory. That cave, now discovered by valley deepening in southern Barry County was nearly 500 feet below the peneplain surface. Will not some interested reader go back through the preceding argument, with the Cassville Quadrangle map in hand, and see if the writer has made a mistake somewhere in the linkage of his data for the picture he draws?
232 Missouri Geological Survey and Water Resources ROUND SPRING CAVERN
Owner: C. M. Patterson, Round Spring, Missouri Location: NE1/4 SE1/4 sec. 19, T. 30
N., R. 4 W., Shannon County Shown on Round Spring Quadrangle map Fig. 118.
Round Spring Cavern, Shannon County Surveyed by Florence Robinson and Florence
Rucker, 1947.
Caves of Missouri 233 The entrance to Round Spring Cavern (Fig. 118) is in a sheer bluff of Spring Valley 60 feet above the stream. One climbs to the mouth over talus, although a little way down the creek, the cliffs stand with their feet in the stream. A fine Gothic arched ceiling at the very entrance leads back for a considerable distance. Though the sides of this arch are marked with spongework cavities, the old, ridged flowstone on the walls has smoothed out much of the spongework irregularity which, farther in, characterizes this tunnel-like entrance to the capacious cave beyond. Still farther back, there are exceptionally good spongework cavities. One tubular "pore" is capable of being crawled into and through, so that one emerges again in the passage 16 feet farther along. But there is no other spongework in the entire cavern. A cave stream has used this passage since the spongework walls were developed, has smoothed off the greater irregularities in places, especially in the upper half, and here and there has cut some very good meander slots. Noteworthy is a complete, reverse curve which has been cut into the walls 150 feet inside the entrance. It is best seen on the way in. The rock has not yielded smoothly flowing surfaces and outlines, so these meander ceilings, walls, and floors are rough, and they simulate the older spongework. The older spongework represents differential, pockety solution by water that once completely filled the passage and dissolved holes in the ceiling as well as in the walls. No free-flowing cave stream with air above it in the cavity could do this. We must visualize a flow like that in a city water main. Superposition of the meanders on the spongework indicates the sequence from the earlier, pressure-directed flow to the later, gravity-directed stream which swung from side to side in the passage it inherited. The only rock floor showing in Round Spring Cavern is along the "Entrance Passage". As in most caves, a floor of clay, gravel, flowstone, and fallen ceiling fragments completely buries the true bedrock floor farther back. This narrow, crooked, tunnel-like "Entrance Passage" is 400 feet long. One emerges from its inner end into the great corridor of the cavern. He finds its detrital floor, mostly clay, to be 12 feet or so higher than that of the "Entrance Passage", or 6 feet higher than its ceiling, and to continue southward at this level for 200 feet. But northward, this detrital floor drops off within 100 feet and is again at the level of the little stream from the north which discharges through the "Entrance Passage". At this junction, one is struck by the remarkable change in cavern proportions. Instead of being so narrow that outstretched hands may touch both sides simultaneously, there is a floor width of 25 feet. Instead of a duck-under ceiling, a clear span as high as the roof of a two-storied house looms overhead. Another surprising thing is that we have entered the great corridor at midlength. It is 2200 feet
234 Missouri Geological Survey and Water Resources northward (right) to the end of the traversable portion and 2050 feet southward (left) to the opposite end. Both ends are blockades; the cave undoubtedly was once more than 4250 feet long. The "Entrance Passage" is a minor chamber; the real cavern has no known opening of its own to the outside. Southward and northward mean nothing to this corridor. In following its windings, one eventually walks in every possible horizontal direction. The right-hand portion leads northwestward for 1200 feet, then eastward for 850 feet to the grinning "Dragon's Mouth". If one follows the left-hand trail, he travels mostly southwest by west, around a series of curves for the total 2050 feet. A notable branch chamber exists along both routes. Let us follow the guide along this left-hand trail first. Left-hand route.—The high-ceilinged corridor becomes narrower almost as soon as we start from the broad floor where we emerged from the "Entrance Passage" and continues with a level floor for 100 feet. A very large, fallen, ceiling-and-wall block interrupts it, but the block is by-passed by the trail; inbound traffic climbing around the left side, and outbound taking a narrow passage almost under the big block. Just beyond this block, an extraordinary widening is encountered with its ceiling nearly twice as high as at the starting point. We have entered one of the great rooms of the cavern. It is 100 feet wide and nearly 150 feet long, but so nearly filled with a central hill that one can easily fail to realize its magnitude. "Theatre Hill" is composed mostly of red clay and is crowned with an impressive collection of domes, stalagmites, columns, and pillars. The ceiling is covered with stalactitic forms. A fallen giant of a stalagmite has been overgrown by one of the biggest, dome-like stalagmites here. Down the far (south) side of the hill is a rimstone pool and, closely associated with it a small, pure white stalagmite which is being cratered; its interior dissolving away in the dripwater which first built it. So delicate is the balance between solution and deposition that most caves show some instance like this where the water that once nourished the secondary growth now is destroying its earlier work. At the pool, we can hear the sound of running water somewhere ahead. In another 125 feet, we see a stream. It is doing an extraordinary thing. It is leaving the capacious cave and apparently flowing into the very rock of the left-hand wall. Almost no opening is visible; the water seems simply to flow up against the wall and disappear. We have encountered the only perennial stream of the cavern, and we shall have it in sight and hearing to the end of this trail. At that end, it enters the cave by a series of cascades that come out of the right-hand wall. Where does the water go? Why has it not made a cave of its escape route? Why does it leave a cavern already existing for it to flow in? Why has it not used the "Entrance Passage" as water from the right-hand end of the long corridor does?
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An answer to the first question can readily be found on the valley bluff. At the same altitude as the entrance archway floor and only 100 feet south of it, this stream emerges from a small untraversable cave under a dolomite ledge. The water cascades down 60 feet to the creek and has cut no real gully or ravine in the slope.

Answers to the other questions must wait until we have seen more of the cavern. A little farther along the trail, on the right-hand side, is a vertical bluff of clay whose bedding departs from horizontality in a haphazard manner. Settling has not deformed it. The clay and sand layers here were deposited on stream channel slopes, and as the deposit accumulated, the channels were filled up and new channels in higher layers were formed.

In one place, the stream cut down a little into the subjacent layers and eroded away the upper part of an earlier deposit. It then laid down its own strata across the cut edges of the lower layers. This exposed section tells clearly that the gritty clay banks which are seen in so many places in the cave were stream-deposited. A free-surface stream originally filled the cave up with clay and sand, at least to the top of the highest clay hills, and later took on the present assignment of removing its earlier deposit. Further evidence that there was air in the cave above the clay and sand-depositing stream is the presence in this bluff of decomposed fragments and layers of travertine (flowstone). The marker for the best showing of these depositional features is the "Broken Stump" stalagnite along the trail.

The clay bluff can be located also by reference to two natural bridges which are almost at the ceiling level; the exposure is between them. Beyond this point, the stream has deposited a flowstone floor of rusty-colored travertine. In places, this takes the form of a series of rimstone dams. The best showing the cavern has of a meander niche which is cut into the original cave wall is on the right-hand side of the trail near the bat guano pile.

This abandoned erosional channel of the present stream makes a curved course 8 feet deep, 10 feet back into the wall rock, and 25 feet between the two ends. Coarse pebbles left by this stream lie on its floor. The flattish ones lie imbricated or "shingled" against each other and record the same northward direction of flow as that of today. The half-cone of dolomite outlined by this semicircular niche is the slip-off slope. As the channel in the wall rock was deepened, it also grew to have a larger curvature, just as do meanders in surface streams. Look back in this abandoned meander channel and see the little travertine bridge. It was built as a floor originally and then tunnelled beneath and left hanging as the stream continued its deepening. The "Tobacco Barn", just beyond the "Wishing Well" (itself a part of the stream channel), is the largest room of the cavern. It is actually the enlarged junction of two corridors, the left one which, for two good reasons (liquid mud and low ceiling), is not entered by the
236 Missouri Geological Survey and Water Resources visitor. The trail makes a complete circuit 450 feet long around this room. This circuit is not along the periphery as measured by the base of the walls. You are hereby challenged to realize this as one room. Like the "Theatre Hill" room, "Tobacco Barn" contains a central, clay hill 25 feet high which is amazingly overgrown with gi- Fig. 119. Round Spring Cavern, Shannon County Crystalline overgrowths: Aragonite crystalline overgrowths on dripstone in the "Tobacco Barn". It probably took more like three centuries than three weeks to grow these beards in the local pool they record. Photograph by G. Massie, Missouri Resources Division. gantic stalagmites that suggest tree trunks standing after a forest fire. Further obscuring the magnitude of this room, are the enormous drapery-like stalactites which hang from the 40-foot ceiling and suggest the name which the chamber bears. An interesting detail of the secondary growths in the "Tobacco Barn" is the "three-week's beard" many of the stalagmites wear (Fig. 119). The "whiskers" are tiny projecting crystals of calcium carbonate, deposited in local pools that have stood here and there in this assemblage of stalagmites since most of the crystal growths oc- curred. Closely related to these crystalline incrustations are the
Caves of Missouri rounded "popcorn" growths; here and elsewhere. Both seem clearly to require submergence in a free-surface pool for their formation. The "Frozen Waterfall", 160 feet beyond the "Tobacco Barn", has a little rimstone dammed pool at its base in which calcium carbonate crystals are growing. On one side of it, there is also a shelfstone growth which is developing outward from the shore at the surface of the water. On the opposite side of the trail, there are good slicken-sides in the clay. Slickensides are vertical groovings and scratches on a smoothed clay surface where slippage has occurred. However, they are so much better shown in the right-hand route that further explanation of their cause will be deferred. A rimstone dam across the cave stream is encountered 120 feet farther along the trail. It is of interest because it poses the unsolved problem of why rimstone dams lean upstream. This one leans downstream. At this point the trail divides, to unite again in the "Ballroom" and again divide and re-unite before one reaches the end; the "Waterfall". For nearly half this distance, the cave stream disappears entirely from sight and hearing, beneath the clay fill on which we are traveling. The "Waterfall" has a clear drop of 10 feet below four separate cascades, three of which are rimstone dammed. The glossy black color on the lips of the cascades and on the rocks at the bottom of the fall is surface staining by manganese dioxide. This coloring is a fairly common feature in cave streams where the water is agitated and its surface broken. The lip of the fall, although subject to vigorous attack by running water, shows no notching. There is a perfectly adequate explanation for this. The rock forming the lip is not dolomite. It is insoluble sandstone. A stratum of sandstone which averages about 4 feet in thickness extends through this part of the cave from the "Tobacco Barn" to the "Waterfall". It constitutes ceilings most of the way, and those ceilings are very smooth, flat, and deficient in dripstone. At a number of places, a strong spotlight beam will illuminate casts of ripple marks on the under surface of this sandstone. These casts are records left by the waves of an ancient sea in which the sand was originally deposited, long before any Round Spring Cavern was ever dreamed of. The tributary chamber which brings the stream into the main corridor at this point has been followed back for 175 feet. It is very small, has a dangerously unstable ceiling, and wisely has not been explored farther. Standing at the "Waterfall", we can now see the blockade which bars further traversing of the corridor. It is a great slope of blocky detritus which rises 55 feet above and extends 150 feet beyond the waterfall. Here, the detritus meets the ceiling which itself rises 35 feet in that distance. A great breakdown in the cave roof has occurred here, and a survey shows that the hillside cannot be far above. It is altogether likely that the cavern roof has been breached here by
238 Missouri Geological Survey and Water Resources the deepening of a ravine on the hilltop above. Water enters at all times and courses down each side of the talus cone to join the main stream below the waterfall; its quantity is much increased in wet weather. It is obvious at this end of the cavern, as it is in many other places, that neither the present stream nor the stream which deposited the gritty clay were the agents which dissolved out the dolomite to make the cave in the first place. These later streams found the cave already existing; a cave which fails to fit the needs of today's percolating ground water on its way down through the rock hill to Spring Valley Creek. The cavern system was made before Current River and its tributaries had cut their valleys and had left the hills as divides. The land surface at the time of the original cave-making had no relief comparable to that of today. Its valleys were shallow, and their bottoms were somewhere near the level of today's ridges and hilltops. This was the peneplain which was made before the latest doming occurred in the Ozark country. It was these movements that brought destruction to the topographic predecessor of our present rugged country. Remnants of the former, flat lowland still survive in the upland prairies between the White River and Missouri River drainage areas. During that earlier cycle, ground water of the Ozark dome, at depth and under pressure, was searching out all possible joint plane and bedding plane passages and was using them to escape to the Missouri River and the White River of that time. This ground water was the causal agent for the original cave-making. The caves, while being made, were completely filled with water at all times. The water flow was hydrostatically determined, and solution occurred upward, to make the cave domes and ceiling pockets, as well as downward and sidewise. Returning from the southwest end of the left-hand route, we use the lower trail wherever there is a bifurcation. One of these should be noted. Just upstream from the rimstone dam with the unconventional reverse slope, we traverse a low-ceilinged route with a beautifully smooth, regular ceiling; the work of the stream which now has so deepened its channel that the ceiling is safe from further attack. This chamber is an addition to the original cave, like the wall-entrenched meander slots with half cones. It did not exist until today's stream, in cutting through the clay fill, became locally detoured into the earlier wall of the cave. Higher levels formed in the making of this passage are recorded in the gravel banks almost at ceiling level. Numerous, ragged, cherty projections are well-shown in the smooth ceiling at this place. Their insoluble silica resisted solution while the dolomite was dissolved away around them. Dolomite pendants are also well-shown here. They are curious, down-hanging remnants of the ceiling bedrock. They (Fig. 120) simulate stalactites, but are of an entirely different origin.
Caves of Missouri 239 Fig. 120. Round Spring Cavern, Shannon County Pendants: This is ceiling sculpture in bedrock made by the present stream when the now open passage beneath was entirely gravel-filled. Photograph by G. Massie, Missouri Resources Division. The finest exhibit of delicate helictite growths in the cavern also is found in this low passage. They have grown so densely on the left-hand wall that one thinks of a coating of moss (Fig. 121). Right-hand route.—Let us return to our starting point, the low "Entrance Passage", and examine the right-hand route. First to be noted, 100 feet north of the low tunnel entrance, is the course of the smaller of the two cave streams. The course has been undercut in the base of the dolomite wall and is all but completely concealed back in a meander niche which is now being made by the stream. It shows how those reverse meander curves in the "Entrance Passage" must have been made by the same stream when flowing at a higher level. Above us is a great ceiling dome which is elongate with the corridor and dates back to the original cave-making. The trail follows close to the stream level for a short distance. Two hundred feet along the corridor from the entrance, there is a large fallen roof block on the left which almost fills the cave floor. Just downstream from it is a reverse meander curve in the stream course,
240 Missouri Geological Survey and Water Resources and both walls are now being undercut as were the walls along the "Entrance Passage". About 100 feet farther is another fallen block which, like the first, is heavily overlain with red clay. This second block shows an un- Fig. 121. Round Spring Cavern, Shannon County Heliictite overgrowth on stalactites: These whiskers grew when the cave was air-filled, as did the stalactites to which they are attached. Contrast with "popcorn" overgrowths shown for Cathedral Cave, Crawford County and other caves; forms presumed to be of subaqueous origin. Photograph by G. Massie, Missouri Resources Division. usually thin dolomite bed in it. This bed also shows in the two walls. By matching the bed in place with the one in the block, we find that the big block has fallen only about 6 feet. After it fell, it became buried in red clay. On the surface of this clay, a layer of travertine flowstone was deposited, and up on top (out of sight from the trail), stalagmites grew. Following this, more clay filling was deposited;
Caves of Missouri perhaps to the ceiling. Then came the re-excavation of the clay by today's stream to make the present open cave. A part of this second clay fill covers the travertine and the stalagmites. One must be careful to distinguish the slopes in the clay fill from the dolomite surfaces that carry a smear of clay. Where a fine stratification (lamination) shows in the slope, that slope is of clay. Four hundred feet farther along the trail, there is an interesting natural bridge of travertine which is easily missed because the trail goes over it. The passage, with convenient walking width only at the bottom, follows this naturally roofed stream course for 45 feet. The stream goes under, you walk over. The clay everywhere is slightly gritty to the fingers. It has a certain portion of silt or fine sand in it. It is not the fat, unctuous clay so common in caves. It also has layers of gravel which may be seen at all levels, from the top down to the stream channel, but which rarely are deeply covered with clay. In a few places, the shells of hackberry seeds have been found in it. An extraordinary feature of Round Spring Cavern which appears in a number of places but most strikingly along a narrow footway 350 feet upstream from the travertine bridge is slickensides in the clay. Slickensides are very smooth surfaces marked by parallel grooves and striae (scratches) which indicate the direction in which masses of rock have shifted along two sides of a parting while being held tightly together. Slickensides commonly occur along faults (planes of displacement). These slickensides in Round Spring Cavern occur on both sides of the passage and clearly are due to subsidence of a central mass of clay that has subsided and slipped on itself along two tight, marginal fractures or faults. The best shown are actually glossy from the pressure and from the freshness of the exposure. The black films are manganese dioxide. Though hardly realizing it, one now turns from a northwest-by-north course and swings more than 90 degrees to the right, around a great curve, to a course about due east. The cave is broad and low in this curve, and on the right side there is a wide, flat, clay bottom which is uninteresting, perhaps, until the irregularly distributed small, natural steps of this flat are noted. They are fault scarps; little cliffs formed by differential settling from compaction of the clay beneath. If excavation were made along these offsets, slickensides would undoubtedly be found. Both the little scarps here and the slickensides at many places testify to a much deeper cave than we see. There must be a deep fill to allow the differential settling movements cumulatively to make the displacements shown. A shallow clay fill never would have this feature at its top. There is much greater height of ceiling above the true bedrock floor than we are seeing above the clay floor. Our argument leads us to envisage an original corridor whose bottom may be below the level of Spring Valley Creek outside.
The "Fountain of Youth" stands beyond this fractured and faulted clay flat. It is a compound stalactite-stalagmite, yet it is not a column such as usually results from their union. It is unusual, not only for its peculiar form, but also for its attachment to the wall rock by a shelf. The stalagmitic cone at the bottom stands on a broad, gently sloping cone of flowstone which has curious little rimstone dams that hold pools of clear water on the slopes. At the very base of this cone, there once was a larger pool which is now drained. Its rimstone dam makes incipient lilypad-like projections over the basin edge. The basin is lined with thick growths of the most delicately constructed "popcorn" one is likely ever to see. This pygmy "popcorn" clearly was precipitated from the pool water and is not in any sense a drip-stone or flowstone growth. The corridor floor at this place is composed of flowstone from the "Fountain" and the flowstone extends completely across to the opposite wall. Three hundred feet farther, one begins to climb "Onyx Mountain" after entering its "forest" of dripstone still earlier. The "Mountain" is simply a higher, central hill of clay which is now all but concealed by an aggregate of fantastic variations of two simple motifs; stalactite and stalagnite. Columns from the union of the two are common. Stalactites here affect an unusual characteristic which manifests itself in a relatively slender stem at the ceiling, a marked broadening a few inches below the ceiling, and then in a tapering down to the terminus of a compound group of fused minor stalactitic forms. Should they be compared in form to a rutabaga? A sugar beet? A pineapple? We choose to call them "mangelwurzels" (Fig. 122). Another common form in this forest is the drapery or curtain type of stalactite which resembles folds of cloth hanging from the ceiling. The culminating drapery-like fold is on the "Mountain's" summit. It has completely closed on itself to make a hollow hanging form which is open at the bottom. Illuminated from the inside, the translucent calcite shows by its parallel bands its successive stages of growth (Fig. 123). The other features here are the overgrowths on the stalactites of those delicate, tortuously twisted forms called helictites, and on the lower surfaces, the very coarse-textured "popcorn" which might better be described as botryoidal (grapelike). The "forest" shows many fractured columns. Settlement of the clay beneath has separated the broken ends by a few inches. At "Onyx Mountain", the trail divides and enters each of the two branches of the corridor. The left-hand branch, 400 feet long, shows splendidly one particular feature. To see it, keep looking up. It is a curvilinear, vertical slot; a deep-cut meander trench made by a former, larger stream than the trickle here today. You are in the bottom of the trench. The inherited passage in which this meandering started is high above and difficult to see, but the reversing curves of the subterranean canyon are almost diagrammatically clear. When one
Fig. 122. Round Spring Cavern, Shannon County "Mangelwurzel" stalactite: Although the attachment to the ceiling could not be shown, it obviously must be by only a small stem. Photograph by G. Massie, Missouri Resources Division.
244 Missouri Geological Survey and Water Resources starts to trace this trench back up the branch corridor, he abruptly encounters a discontinuity in its course. If the interruption were of native limestone, our theory would be disproved at once, but it is only a surviving remnant of a clay fill which came later than the meander downcutting and has been largely removed. Fig. 123. Round Spring Cavern, Shannon County "Drape" by transmitted light: Successive additions, as the stalactitic "drape" grew, are shown by differences in translucency. Photograph by G. Massie, Missouri Resources Division. Returning to "Onyx Mountain", we are sure to be shown some bones partially covered by flowstone. Both opposum and bear have been identified. Bears surely used the caves for winter quarters. Many caves have roundish hollows in the dry clay floors that would very comfortably contain curled-up bears.
Caves of Missouri 245 Up the right-hand branch which is nearly as long as the left-hand one is the "Shrine"; another drip-and-flow-and-rimstone deposit much like the "Fountain of Youth" but more complex. Nevertheless, it can readily be analyzed into its components and sequences as follows: (1) a cave; (2) a clay fill in this cave up to the shelf level of the "Shrine"; (3) a partial travertine floor on that clay fill surface; (4) deposition of more clay to make a higher flat surface; (5) another partial, travertine floor, to account for the higher shelf; (6) removal of the clay fill, leaving two shelves; (7) a hole in the ceiling for dripwater to bring down dripstone materials in solution; (8) probably simultaneous growth of stalagmites on both shelves and of stalactite "draperies" above each stalagmite.

The end of this chamber is a huge compound stalagmite dome which is partially hidden by the nearer "draperies" and stalactites. The "Dragon's Mouth" (Fig. 124) consists of two shelves of travertine. Water, dripping from the edge of the upper shelf, makes the stalactites which form upper jaw teeth, and the stalagmite growth on the lower shelf form the teeth of the lower jaw. We have seen that the two cave streams use independent escape-ways from the eastern side of the cavern. We have traversed one of them (the "Entrance Passage") and have seen the meander niches cut into the older spongework walls while the stream was removing the clay fill that it found there. The spongework in the ceiling as well as in the walls belongs to an earlier cave-making episode; before there was a Spring Valley outside. The "Entrance Archway", there-fore, is only an enlarged part of a passage that originally extended out farther into what is now empty air. This former extension was destroyed in the making of the creek valley. The exit of the other stream, the perennial one from the left-hand route, is smaller but otherwise looks like the "Entrance Archway". Spongework is to be found there, although wall flowstone has smoothed and partially obliterated it. It is a smaller route-though it carries the larger stream-and can be crawled back into for only a short distance. Both escapeways are minor parts of the original cave system. Both were discovered when Spring Valley Creek cut down to their level, and both probably have been used as escape routes ever since. From then on, time can be measured by the 60 feet of further deepening of the valley.

However, neither escaping stream has more than slightly marred the slope below its exit. If they have been powerless to do more, then it certainly follows that they never could have made the big corridors. Again we reach the familiar conclusion: the cave is older than the topography. Where, however, did the free-draining cave water go before these low routes were discovered and cleaned out? Enormous amounts of clay had been stream deposited and stream eroded above the low levels.
Fig. 124. Round Spring Cavern, Shannon County The "Dragon's Mouth": A blockade of secondary lime deposits at the northeast end of the cave. Photograph by G. Massie, Missouri Resources Division.
Caves of Missouri 247 of these two exits. In all likelihood, it went northward and eastward, toward an earlier Current River which was perhaps 100 feet less deep in its valley than it is now. If the "Dragon's Mouth" could speak, it might declare itself and its associated deposits as the blockade of the earlier exit. Should there not be some surface indication of an earlier and higher escape route for free-flowing water? There is, although it is not spectacular. A ravine in the woods which, by survey, lies almost directly above the "Dragon's Mouth", has a marked steepening of slopes and bare ledges of rock cropping out at the proper place to record a former perforation of the hillside. This perforation is now largely concealed by subsequent slope waste. Probably the leakage from the ravine has made the great growth of dripstone that forms the interior blockade.
248 Missouri Geological Survey and Water Resources SEQUIOTA SPRING AND CAVE Sequiota State Park Location: SE1/4 NW1/4 sec. 9, T. 28 N., R. 21 W., Greene County Shown as Sequiota State Park on Ozark and Galloway Quadrangle maps The combined cave and spring opening to this cave which is referred to by Shepard (1898, p. 38) as Fisher Cave is in a short, cliffy stretch on the east side of a creek valley in the northern part of the town of Galloway (Fig. 125). It is 25 feet to the top of the cliff above the cave mouth. The cliff is higher and steeper here than in either Fig. 125. Cave Entrance Area, Sequiota State Park and Hatchery, Greene County direction along the valley. Quarrying has somewhat modified the original cave opening. In natural and quarried walls, there are three cavern openings. The largest one discharges the spring stream. A dam 4 feet high and about 200 feet outside the arch backs up water into the cave for an estimated 1000 feet. Thus, the cave can be entered only by boat. At the time of the writer's visit, the only available boat was sunk, with a hole stove in its bottom. It is reported that there is a waterfall 2.5 feet high at the end of the 1000 feet. Beyond the waterfall, the cave is reported to fork. The right-hand passage brings in muddy water in rainy weather, and the water in
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The left-hand passage may rise at that time but flows clear. A well at the third house from the road jog at the top of the hill, penetrates to the cave stream. Years ago, the owner discovered from time to time that his well was clogged. He had to go back into the cave to remove burlap that had been stuffed into the bottom of the pipe by local boys with whom he was in disfavor. Sometimes the well would yield dilute red clay as another mark of disapproval. Of the other two cave openings, the larger one was used by Major Charles Galloway for several years before 1900 as a store; the only store then in Galloway. About 85 feet back in this chamber is a sink-hole blockade. The passage is oriented N. 12° W., and its opening is 9 feet wide by 15 feet high. There is weathered sheeting on its walls at the mouth and dripstone and ridged, wall flowstone all the way back. Much of this dripstone has tiny rimcups on the surface. There is a ceiling pocket at the back end of the cave and phreatic wall pockets along its length. The smallest of the three openings has an estimated, crawlable length of 300 feet. Its course is on both east-west and north-south joints. It probably joins the "Galloway Store" chamber back of the sinkhole blockade. An isolated block was left in front of these caves by the quarrying operations. It is 6 to 10 feet high, 15 feet wide and 40 feet long. The bottom of the block is completely undercut by elaborate, small anastomoses which are still largely filled with red clay. If all the clay was cleaned out, one could probably see through beneath the block in any direction.
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SMITTLE CAVE

Owner: Dave Smittle, Grove Spring, Missouri
Location: NW1/4 SW1/4 sec. 30, T. 32 N., R. 15 W., Wright County

The impressive, arched mouth of Smittle Cave (Fig. 126) is in the tip end of a ridge between two hollows. Its floor is on about the same level as the bottom of the hollow on either side. Even more unusual is the fact that there are two mouths in the end of this narrow hill spur. Both lead back into the same cave, both are clearly of solutional origin, and, neglecting the debris which largely closes one, both are of nearly the same dimensions. The ceilings are at the same level and the widths are each 35 or 40 feet. A cave stream has kept the northern mouth clear of debris from the hillside above, whereas the southern one has a two-way talus of fallen detritus which slopes down to the valley outside and has a gentler slope back into the cave. So far as is indicated, the southern one had originally the same height as the northern one; about 30 feet. Its present clearance above the two-way talus is about 9 feet. Smittle Cave can be traversed without climbing or creeping for 2500 feet in an approximately westward direction at right angles to the length of the creek valley a few hundred feet from the cave mouths. A stream flows throughout this length and has three subterranean tributaries of lesser size; only one of which is perennial. Most long, linear caves decrease in width back beneath the hill they underlie, but the unusual length of Smittle Cave is accompanied all the way by an unusually uniform width. The ceiling altitude appears to remain origin, and, neglecting the debris which largely closes one, both are of valley outside and has a gentler slope back into the cave. So far as is indicated, the southern one had originally the same height as the northern one; about 30 feet. Its present clearance above the two-way talus is about 9 feet. Smittle Cave can be traversed without climbing or creeping for 2500 feet in an approximately westward direction at right angles to the length of the creek valley a few hundred feet from the cave mouths. A stream flows throughout this length and has three subterranean tributaries of lesser size; only one of which is perennial. Most long, linear caves decrease in width back beneath the hill they underlie, but the unusual length of Smittle Cave is accompanied all the way by an unusually uniform width. The ceiling altitude appears to remain
Caves of Missouri fairly constant. The floor, however, rises gradually until finally not even walking height remains. Yet the cave may be followed, if one is willing to creep and crawl, for an undetermined, greater distance. Smittle Cave has an exposed bedrock floor in the stream channel in several places. But most of the floor is of later deposits; chiefly a very smooth, deep red clay which commonly has a cover of stream gravel and roof slabs. As far as we have any evidence, it is this de-trital floor which rises until it almost, if not quite, reaches the ceiling. The stream emerging from beneath the great archway has been dammed to make a subterranean lake which covers the gravel bottom for 1000 feet back in the cave. A board walk on low stilts and a low caisway of flat stones and gravel enables one to pass the lake dry-shod. Nearly at the end of this walk is the entrance of a tributary, lateral passage on the left (south). This passage contains the best display the cave has of secondary lime deposits. Dripstone in the form of stalactites, "drapes", and stalagmites predominates and ranges through a great variety of shapes and sizes (Fig. 127). There is much "live" dripstone, although the ceiling drips do not interfere with one's examination. Flowstone covers the floor for the entire 550 feet of this passage that can be walked. It is a strong orange in color, in marked contrast with the white and gray colors of the associated drip-stone. The many little basins in the floor are the result of small rim-stone growths on the surface of the flowstone. The lateral chamber can be struggled into for some distance farther, if one is willing to squeeze through the jungle of moist dripstone growths. Although the ceiling and walls are heavily encrusted with a wealth of these secondary deposits, it is obvious that the native rock (Jefferson City dolomite) lies close behind the masking, and that this lateral passage gradually diminishes from the entrance dimensions of 5 by 15 feet to the terminal proportions of 6 by 7 feet. Groups of curious, little bulbous and arborescent forms cover much of the dripstone on the walls of this passage; definitely an in- crustation on the stalactites and stalagmites. But other dripstone is completely free from it; indeed, is growing over it. This is the so-called "popcorn" or "coral" or "cauliflower" deposit found in many caves. It is no longer growing here. It grew under water, and it, therefore, records a time in the history of the cave when, after air had been present for a long time (proved by the older dripstone), the cave must have been blocked farther downstream and standing water must have backed up nearly to the ceiling here. Eventual failure of the blockade and draining away of this water has allowed the younger dripstone and flowstone on the floor to form and, in places, to over-grow the "popcorn". About 1700 feet back in the main cave, there is another lateral passage which carries a wet-weather stream. This one enters from the right (north). It can be walked for 260 feet, and it maintains a height about that of the main chamber; 18 to 20 feet. Its width is considerably less, averaging 6 to 8 feet. If one goes farther, he must
Fig. 127. Smittle Cave, Wright County The "Queen's Chair": Dripstone "drapes", stalactites, and stalagmites. Flowstone on the floor and the "chair seat". Rimstone on the floor flowstone. Photograph by courtesy of owner, Darrell Smittle.
Caves of Missouri climb and crawl over much smeary red clay. There is something worth seeing back here beyond the limit of walking, but we will comment on it a little later. Returning to the main cave, we should not miss the "Lilypad Pool" close to the junction of this lateral chamber. Little, flat-topped islands of secondary calcium carbonate are growing at the edge of the pool. This formation is best termed shelfstone. The "pads" are not thin growths, however. One may readily learn that they are the tops of conical deposits with the apex of each cone resting on the bottom of the pool. Under the water, the secondary lime is encrusting the cone with deposits much like the "popcorn" and "coral" we saw in the first lateral passage. About 2000 feet back in the main cave, the stream does an extraordinary thing. It leaves the big, capacious chamber, flows back in a relatively small, semi-circular niche in the north wall, and emerges again into the main cave. The niche is being deepened vertically and enlarged horizontally by the running water. An island of rock stands between the semi-circular niche and the main chamber. This is not the only place in Smittle Cave where such a procedure is being followed, nor are these niches, with the little islands partially separating them from the large chamber, all in use today. There are several abandoned ones. We have already passed three of them and will pause on the way out to examine one more closely. These curved wall niches, abandoned or still in use, are additions being made to the total volume of the cave. Being made? But how did the stream ever start them several feet above the floor? The red clay fill now being channeled and eroded away is the answer to that question. It once constituted a complete fill; it is still almost a complete fill back in the far end. Gradual lowering of the surface of the clay deposit is still going on. Some centuries ago the stream was flowing on a higher surface of that clay. Its gradient was not steep, and its current was slow enough for curves to have developed along its course. These curves, or meanders, became larger because the current eroding them swung harder against the outside of the curve. Thus, in some places where a meander on an earlier, higher level of the clay floor impinged against a dolomite wall, it cut a horizontal, arc-shaped niche in that wall. If it cut back far enough, it became caught in the new course as lowering went on and was forced to stay there, to deepen and widen in the bedrock. Had you undertaken to crawl over the smeary red clay which still largely fills the first, right-hand lateral, you would have found an especially fine showing of these wall niches, alternating from side to side and made by the little tributary stream as it accompanied its master stream in the task of downcutting and removing the red clay. This digression into events of the history of Smittle Cave takes us back as far as the recognition that an original cave must have preceded the episode of clay-filling. The clay contains no gravel, no sand,
254 Missouri Geological Survey and Water Resources no silt, and no flowstone. It buries no dripstone, no "popcorn", or "coral" growths. Clearly the original cave was not made by any stream like the present one which flows continuously downgrade with a gravel-carrying current and has, as contemporaries, the growing dripstone and flowstone deposits. Two more features are yet to be seen before we attempt the full explanation. There is another long, lateral passage on the left (south) side, about 50 feet farther back. It can be walked for 300 feet. Better say "waded"; for its little stream makes a succession of pools that all but cover its floor. Like the first one on the left, this also contains an array of exceedingly varied dripstone, and it also contains a human skeleton partially embedded in flowstone. The junction of its stream and the stream of the main cave involves a curious thing. One may wade up the tributary, but he can-not well follow the stream in the main chamber. Like a spring, it apparently emerges from the rock wall itself, at the very bottom of the cave, with almost no clearance above the water level. The main cave for some distance farther back contains no stream. In following the trail, we climb up over a red clay slope which is littered with fallen ceiling slabs until we are so near the ceiling that we must walk stooped for more than 300 feet on a flat, high clay floor. Then we find the stream again, down in a deep channel in the clay. It apparently comes out of the right-hand (north) wall, crosses the main chamber at right angles, and apparently goes into the left-hand wall, and disappears for 300 feet. Could there be better evidence that the flowing water now using Smittle Cave is not the circulation which made the pre-clay cave? There could be; there is! Here, near the far end of easy traversability, is the best showing the cave has of solution holes in the ceiling. They are numerous and some are large. Find the one that penetrates 10 feet up; an upside-down cavity. And see the remnants of the red clay hanging on shelves and in pockets almost to the very top of this cavity. Surely no stream like the present one could ever have done that work. When these ceiling holes were made, the entire body of the rock had every possible water passage completely filled. There never could have been a Parks Creek valley at that time, for it is that valley which has drained the rock of its water. The history of Smittle Cave is now fully outlined. Before Parks Creek had eroded its valley, before the upland prairie country-like that still surviving about Lebanon-had been trenched by streams, or had ever become an upland, ground water made the larger chamber and lateral passages of Smittle Cave. Still completely waterfilled, the cave then became the site of deposition. The red clay fill rose to the ceiling and up into the ceiling cavities. There was so little current that the clay has almost no trace of grittiness. A very long time must have been demanded for this slow filling.
Then came that important event in Ozark history; the uplift which made the former low peneplain an elevated plateau. Now the formerly sluggish streams renewed their youth, became vigorous again, began making new deep valleys. This left hills standing between the new valleys. The caves became drained, and some portions were destroyed by the valley-making. Under these conditions, some of the rain falling on the hills went as directly downward as it could, in search of the lowered saturated zone. That seepage, continuing today, made the dripwater and the cave streams we have seen. It made the secondary deposits whose varied forms and colors we admire. It removed large portions of the red clay, and it cut the semi-circular niches in the walls of the primitive pre-clay cave. Smittle Cave contains a record of the entire sequence. It is one of only three caves known to the writer where a stream today is making those wall niches. As we go out, look for the best one of the group, now abandoned, with its floor hanging halfway down from the ceiling. It is on your right (south) at a sharp, right-hand turn, about 800 feet back from the entrance, and it spans 50 feet of cave wall.
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STARK CAVERNS

Owner: F. L. Hammitt, Eldon, Missouri

Location: NE1/4 NW1/4 sec. 28, T. 41 N., R. 15 W., Miller County

Not shown on Eldon Quadrangle map

Stark Caverns is readily reached from U. S. Highway 54, a few miles south of Eldon. The cave is easily traversed on broad, dry, gravel walks uninterruped by stairways or stoopways. The cave should remain in one’s memory for its magnificent spongework. The visitor’s trail totals about 1000 feet, and throughout the cave the contrast between the earlier phreatic and the later vadose development is marked. The entrance arch is 14 feet high and 55 feet wide and is mostly a flat, slab roof span. The visor effect which is seen in many cave mouths in the Gasconade formation is well developed at the crest of the arch. The entrance is in a small hollow on whose other slopes there are only faintly showing ledges. For 400 feet inside, the cave is a big, fairly uniform chamber with a gravel floor which shows bed rock through the gravel farther back. Daylight could be seen for this distance before the canvas barrier against bats and outside air was constructed. Thence, the cave has a narrow winding course of complex ground plan (Fig. 128). Fig. 128. Stark Caverns, Miller County
Caves of Missouri 257 One must marvel at the complexity of spongework in this cave (Fig. 129). Connections between the sponge "pores" a few feet back in the wall rock are readily seen by the use of a spotlight. Phreatic tubes large enough for crawling passage are numerous. They open off of and return to the main chamber, pass above and below one another, and possess all orientations and almost every conceivable irregularity. The prize of the display is the "Garden of the Gods". It has no superior in all Missouri. But there are no joint slots leading up into the ceiling, although the map clearly indicates joint control of most passages. The cave pattern appears to be a network rather than a dendritic system of converging routes. There is undoubtedly much more to this network at the far end of the cave where it is still largely unexplored because it is still filled with a gritless red clay. Vadose alterations in the traversed portions of the original phreatic cave are limited to the new course followed by the "River Styx" and to extensive undercutting of the phreatic spongework walls which
258 Missouri Geological Survey and Water Resources so largely overhang both sides of the main chamber for the first 350 feet. There are two cave floor streams today. Each enters the lofty, phreatic passages from tight, low, scarcely traversable routes lacking in spongework. One of them, the "River Styx", crosses the phreatic chamber it enters and immediately disappears at the "Wildcat Lair" into another tight, low, although crawlable route, then reappears to spill down into the main chamber as the "Fountain of Youth" (Fig. 130). The straight line distance between "Lair" and "Fountain" is Fig. 130. Stark Caverns, Miller County The "Fountain of Youth": The "Fountain" is the discharge point of the "River Styx" into the capacious main chamber. Compare the ceiling spongework of phreatic origin with the later, narrow vadose channel. Photograph by Grant T. Richards, Camdenton, Missouri. 75 feet. About a third of that distance is along the sinuosities of the high-ceilinged phreatic route. The vadose "Styx" has only begun cave-making along a route permitted or demanded by wholly different conditions than obtained when the high, narrow, and sinuous phreatic course was made. The map shows several other lateral openings along the visitor's route. Some of these are abandoned vadose stream ways, but in
Caves of Missouri 259 the "Onyx Circle", a region where all passages are very high, narrow aisles or hallways, explorers tell of more narrow routes which are filled with red clay almost to their ceilings. One assertion is that such a clay-floored crawlway can be followed to a high window in the wall opposite the "Garden of the Gods". One of the duties of vadose cave water is to remove the red clay fill in the older passages it chooses to use. Little of this work has yet been done at the back end of Stark Caverns; indeed, the easy traverse at "High Point" is possible only because the cave management took over the unfinished job and dug out that clay. Pinch some between thumb and finger. Is butter smoother? A red clay deposit, without grit, pebbles, or secondary lime, is a common feature of Ozark caves. Because it fills spongework pockets, it obviously is later than the original, phreatic cave-making. The total lack of stream-carried, coarser debris, flowstone, and dripstone in it indicates that it was deposited before the vadose epoch began. As explained earlier in this volume, the unctuous red clay is interpreted as a slow infiltration from the deep soil of an overlying peneplain when the hydraulic circulation that made the phreatic chambers had dwindled to a bare minimum, and when the cave system was still full of almost standing water. All of Stark Caverns' older chambers and corridors have been thus clay-filled, as the high-placed spongework containing remnants of the clay testify. Those chambers would still be entirely filled with red clay had not the latest Ozark doming occurred. The rivers of the peneplain, re-juvenated by that uplift, have made new valleys deep in the bottoms of the old ones, have thus made inter-valley hills and ridges, have lowered the water table under those hills, and have made possible the present vadose circulation. Some dolomite and limestone have been removed in this latest and present epoch, but the weak red clay has suffered most from the attack. The compound of the "Garden of the Gods" and "Onyx Falls" is Stark Caverns' outstanding feature. One must look up into that great aggregate of huge, interosculating ceiling cavities, with their surviving irregular rock spans and bridges, to believe that such a thing could ever be formed. Only under conditions of complete saturation could ground water so attack and so deeply penetrate up. Fortuitously, surface water now enters somewhere at the top and drips to one of the shelvings of the complex. Overflowing here, it has deposited a striking "Onyx Falls" over the lower wall. Here, vadose water has subtracted nothing; instead, it has added. Wall flowstone which extends for 100 feet back from the mouth can hardly be a tufa growth aided by mosses and liverworts. But beyond 100 feet inside the entrance, there is none. Other secondary lime will be in view along the trails-air-deposited like the stalactites, stalagnites, "drapes", and helictites— and one stretch of water-de- posited "popcorn", "cauliflower", or "coral" where a pool stood for a time.
260 Missouri Geological Survey and Water Resources The two united cave streams flow with a gentle gradient to the very mouth of the cave. There the stream drops 60 feet in about 600 feet of horizontal distance to reach Wright's Creek where it again flows on a gentle gradient. This steep stretch between cave mouth and valley bottom is a measure of the creek's greater erosion and of the relative inability of the cave stream to deepen the cave it uses. It is another bit of evidence that the cave was never made by the stream now in it. A recurring, flood-time entrance of vadose stream water embarrassed the cave management until the minor valley just east of Wright's Creek at this place was examined. In this valley bottom, a small sinkhole was found. It was diked off, and trenching farther down the stream aided in disposing of the runoff from heavy rains. Promptly the flood waters ceased to enter Stark Caverns. Perhaps the original phreatic system extends eastward under this minor drainage way. Perhaps vadose water has made a bedding plane passage under the ridge. Other cave managers who are bothered by influx of flood-time discharge might take a leaf from the experience of the management of Stark Caverns.
Caves of Missouri 261 TRUITT'S CAVE Owner: G. H. Faulkner, P. O. Box 34, Lanagan, Missouri Location: SE1/4 SW1/4 sec. 25, T. 22 N., R. 33 W., McDonald County Not shown on Noel Quadrangle map The entrance to Truitt's Cave (Fig. 131) is in plain sight from the junction of Highways 71 and 88, about 25 feet above the floodplain of Indian Creek. The opening is in a cliff at the bottom of a ravine which drains from the west. Fig. 131. Truitt's County Cave, McDonald The cliff is about 300 feet long and 20 to 30 feet high. It is highest over the rock shelter in the back of which are two openings. One of these leads to the linear cave and the other to a large cave room without visible connection with other passages. This room is used for the underground dining room. The span of the rock shelter is about 75 feet.
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The underground cafe (Fig. 132) merits a special note. A "living" stream crosses its concrete floor, flows under the fireplace, and supplies a trout pool in the floor. The fireplace chimney is a natural vent; a solution slot in the ceiling. Smoke escapes well up on the hillside, perhaps 90 feet above the cafe. There is a capacity for 65 diners and the room is, of course, naturally air-conditioned. Its smooth ceiling is determined by a bedding plane in the Mississippian limestone. A few feet of rock were excavated at the back end, chiefly from the ceiling, but in the large, this glass-fronted, rock-bound dining hall is nature's own work. The original entrance by which the cave was discovered is now walled up, and the passage as far as the first turn to the left is artificial. At this turn, one enters on the longest straightaway of the cave. There are some lateral and vertical openings in its walls, but no passages lead out of it. For 475 feet, the visitor follows one of the best paths.
Caves of Missouri 263 in one of the cleanest caves in the Ozarks. The path terminates at the spring at the far end. Here, the water supply is obtained for the cabins and dining room. One should pause almost immediately on starting this walk, for just inside the quarried entrance way, the cave reveals an epitome of its history. A narrow dome overhead extends far up in the roof rock. It penetrates at least 15 feet above the broad, flattish ceiling of the rest of the passage. In contrast with this high, narrow, upward extension of the cavity is the width at head and shoulder height under the ceiling. Another contrast, is the narrowing of the passage in its lowest 3 or 4 feet. This fundamental shape (Fig. 133), with many variations, goes all through the cave and should be interpreted before we proceed. Evidence supporting the interpretation will be encountered at almost every turn. Fig. 133. Cross Sections of Truitt's Cave The high, narrow, vertical part of the cave was made prior to the erosion of Indian Creek valley and under phreatic conditions. The wide, low, horizontal part is later vadose stream work. E. H. Woolrych, del. Briefly, the shape and orientation of the cave is largely controlled by vertical joints which trend consistently about N. 250 E. Along such a joint or crack, circulating ground water has moved in the past to dissolve away the rock of the two originally very close walls, and so has widened the crack to its present dimensions. This ground water operated on ceilings as well as on walls. It dissolved the walls of the joint in variable amounts, here making only a slot, there a dome, and elsewhere perhaps an upside-down "bathtub". To do this, that water had to be against the ceiling just as much as it was against the
The joint crack was full of water all the time. Obviously, such a condition of saturation could not be obtained today, with the open valley of Indian Creek just outside and lower than this cave. We reason, therefore, that the ceiling slots and domes were dissolved out before the outside valley had been deepened to the level of the cave, and that they were made under conditions of complete saturation of the rock by ground water. Next, we see the notable width of the cave chamber just below the broad, low ceiling, and the rock shelves that constitute the floor of the wide portion. Either here or a little farther in, you will be convinced that that widening and those shelves are of stream-channel character, that when they were made, water did not fill the entire height to the loftiest ceiling but flowed on a floor at shelf level, just as Indian Creek or any other creek flows on its valley bottom. These shelves represent a widening of the original joint slot by a cave stream, flowing like streams outdoors, in a channel, continuously downhill, with air above the surface of the water. That cave stream flowed with meandering curves just like a low-gradient, outdoor stream, and these meanders cut laterally into the walls of the slot which the stream had found already made. The gravel one sees on these shelves is a record of the stream of this second epoch. Here then, in brief, is the history of Truitt's Cave. Its initial form was a slot and a series of domes before Indian Creek valley was eroded. There was no air in the cave at that time. Later, when the outside valley had been eroded, the rock was drained of its completely saturated condition. Then rainwater, falling on the hill left by the erosion of Indian Creek, became ground water in the hill rock and found its way to the valley through passages already dissolved out. It was then that the widening and the shelves were made. Then and later, came the dripstone and flowstone deposits which give so much variety to the cave. For about 200 feet the cave passage is almost as straight as a taut string. The narrow ceiling slot is conspicuous for much of that distance. Its presence is accentuated in places by stalactites and "draperies" which, in the latest epoch of the cave, have grown from dripwater descending along that crack into the cave. There are interruptions and additional features. An intriguing variation 100 feet along this stretch looks at first like a nearly flat bridge halfway up to the ceiling. It is not of the native limestone composing the wall rock. It is a secondary lime deposit; a sheet of travertine made by water flowing on the floor of the cave, but not the present floor. Look beneath the bridge to see the chert gravel embedded in its under side. The cave at that time was filled with gravel to this level and has since had the gravel removed, leaving the bridge. One of the diagrams in figure 133 is a view of this bridge from the far side, looking back toward the entrance. From either side one
Caves of Missouri recognizes that there are two side-by-side passages; one with the slot in the ceiling, the other a short curved passage that leaves and then rejoins the deeper and higher main one. Once that is seen, attention centers on the curious, island-like projection of native limestone which extends upward from the floor between the two. It and the curved short passage become intelligible if one visualizes a time when the main cave passage was filled with gravel up to the level of what is now that curious projection, and adds to his mental picture a meandering cave stream flowing on the gravel fill. A meander here swung against the west wall and undercut (or underdissolved) it to make a nearly horizontal curved niche in the wall. Flowstone, growing out from the east wall at the same time, made what is now the bridge. Because the cave stream was slowly removing the gravel fill at this time, it was lowering its bed and the curved wall niche was becoming deeper. Because meanders tend to enlarge themselves, the deepening niche in this wall developed a larger curve. Allowing for a few vagaries of stream course back in the wall, the lateral passage becomes a record of solutional enlargement under these special conditions during the second epoch of cave enlargement. One side of that central pier is essentially the wall of the original cave; the other side is a new wall, made much later.

Between the two times of cave-making, we must allow for a time of gravel filling. There are no less than five well-shown cases of meander cutting in the original wall rock of Truitt's Cave, and a dozen other cases where the free-surface stream found passage through the gravel fill after it had started, but before it had completed the meander, niche-cutting job. A stairway of 12 stone steps about 75 feet farther along the cave walk leads to a small upper story; a local enlargement of the ceiling joint. In this chamber is a great display of dripstone and flowstone forms. The floor is a sloping sheet of travertine or flowstone cave onyx and supports a dense population of stalagmites. The ceiling carries innumerable stalactites and "draperies". A large short column in the background is apparently a compound of many dripstone units which, growing both down and up, have met and coalesced. A curious characteristic of stalactites here-rare indeed in caves in general—may be described as turnip- or radish-shaped; a nearly spherical upper part with a long narrow tapering root. There is no specific explanation known for this. An observation platform a few steps above the path stands at the far end of this long straightaway. From it one sees, in another upper room, three successive flowstone sheets, separated by debris. One of the sheets still bridges the room. The uppermost sheet has an extraordinary relationship to some dripstones. Five stalagnites which had grown on the next lower sheet protrude up through it and one compound stalactite, also older, protrudes down through it (Fig. 134). We now come to the first departure of the cave course from joint control. A semi-circular curve in the passage takes us out from under
266 Missouri Geological Survey and Water Resources Fig. 134. Truitt's Cave, McDonald County Flowstone bridging: Three-story, flowstone bridging; only two of which could be gotten into the photograph. The stalagmites are older than the uppermost bridge. Photograph by G. Massie, Missouri Resources Division. the ceiling slot, but in another 50 feet it brings us back under it again. Just how this half circle, curved course was made is not clear. It had a very low ceiling, and some quarry work was necessary here to get head room for visitors. After passing the curve and getting back on the joint trace, one may see that the joint does go straight through, and that it once was well opened at a higher level. We may also recognize another meander niche cut in the west wall. The top of it is closed completely with an old flowstone bridging. A little farther along, the path becomes a series of curves, eight all told, which leave the joint we have been following and wind their way across two more joint cracks having the same orientation. Shelves bearing segments of the channel left by the free-surface stream are very much in evidence along these curves. All are lateral additions to the original cave and many of them carry cemented remnants of the gravel fill we have been seeing all along. The "Cave Man's Bath-tub" is one of these. It fills by seepage from its own wall rock and then only in the wetter part of the year. That particular cave man did not get a bath daily through the year.
Caves of Missouri 267 Here is a very interesting bit of Truitt's Cave's architecture. The observer (see diagram in Fig. 133) looks toward the far end of the cave. Remains of the first solutional cave (phreatic) follow the joint. When the free-surface stream took possession, it first made the high, horizontal slot, then it got offside by (vadose) meandering and made the larger and continuous passage followed by the path. Another peculiar record of the work of the free-surface stream is shown in the "Musical Ledges". They are of native limestone, not flowstone, and were spared in the downcutting (or down-dissolving) done by that later water work. Near the end of the path, there is a fine showing of a ceiling dome, modified by the later growth of "draperies" down into it. It penetrates at least 12 feet above the later-made, flat, wide ceiling and has a ceiling of its own, of ragged insoluble chert (or flint) nodules which project from their partially dissolved limestone matrix. The joint control for this dome is very obvious. At the far end a smaller dome (Fig. 135) was uncompleted when the first epoch of solution closed. Note the bridging which still crosses it. The shelves left by the later stream are as well shown here as anywhere in this cave; as well shown as in any Missouri cave the writer has seen. The small cave stream of today, the "spring", is dammed at this point to make a reservoir which supplies the needs of the cave and the cabins outside. But this is not the "end" of the cave. One may look farther and see that debris almost fills the cavity in the native rock. Were it desirable, that could be excavated and much more cave length opened. Caves are caves, whether filled with air or water or detritus. And the water that did the work which we have been witnessing did not spring into existence at this point. It came from perhaps miles of hill country farther westward. A dripstone feature that still remains a puzzle is the saw-toothed edging of some "draperies". It is well shown at this far end of Truitt's Cave. One may have noted in his traverse certain vertical walls with vertical groovings engraved on them. They are best shown at this far end. They are no problem, for some caves show the descending film or thin sheet of water clinging to the walls at the task of making the grooves. A more specific term for them is lapisies. Let us now summarize the succession of chief events which have given us Truitt's Cave. We must start with the idea that this cave had its initial development along straight, vertical joints or cracks in the limestone at a very remote time when this part of Missouri was only a gently rolling, nearly featureless plain; the upland peneplain. Remnants of that plain still exist only a mile to the west and 300 feet higher than the cave. The Mississippian limestone of the cave was far below the surface of saturated rock at that time. Water in the rock was under hydrostatic pressure and flowed at the behest of that
Missouri Geological Survey and Water Resources pressure wherever any parting made it possible. Probably it was a very slow circulation, but if enough time be granted, the work done can be accounted for. Then came the doming of the Ozark country, the rejuvenation of its sluggish streams, and the deep incision to make such valleys as Fig. 135. Truitt's Cave, McDonald County Ceiling cavity: The cavity lies along a joint with a relic of a former bridge. The observer is looking up at a high angle. The strata are horizontal. Photograph by G. Massie, Missouri Resources Division. Indian Creek and Elk River. With this incision the water was drained out of the rock above valley bottom levels, and a radical change took place in the character of the ground water circulation. As the surface of the saturated zone dropped below cave level, air entered, and what water was present was seepage and drip from rain on the local hilltop.
Caves of Missouri 269 on its way down toward the water table which was approximately at the valley bottom level. Now a free-surface stream formed in the abandoned joint-plane cave. About the first thing such water did was to make the wide shelves and ceilings and perhaps some of the meander niches. Then conditions changed so that the stream became overburdened with gravel and it filled the cave well up toward the top with gravel. Again conditions affecting the regimen of the cave stream changed. It found new energy to transport its load, it began to remove the gravel and to make other shelves and meander niches. Dripwater now began building the ever-interesting, secondary, limestone forms on ceilings and floors. Finally came man. Actuated by needs and curiosities no other animal has ever approximated, he opened the cave for the satisfactions of one sort or another which a cave affords. And he has even attempted to read the history of events by which the cave came to be.
270 Missouri Geological Survey and Water Resources WONDER CAVE
Owner: J. A. Wallace, Reeds Spring, Missouri
Location: SE1/4 SE1/4 sec. 27, T. 24 N., R. 22 W.,
Taney County
Not shown on Forsyth Quadrangle map
The visitor to Wonder Cave turns off Highway 65 about three miles east of Reeds Spring junction and drives less than a mile down a ravine road. The descent is more than 200 feet to the parking place. Here he climbs about 50 feet up a trail on the ravine slope to the housed-over entrance. It has been enlarged from what must have been originally a mere gopher hole on the hillside. Two other much more conspicuous openings exist, but the human body cannot be squeezed thin enough to pass. Only a stream of water has ever gotten through. Were all entrances completely concealed, a geologist would nevertheless know that a cave lay beneath. One of the remarkable features of Wonder Cave, not duplicated so far as is known by any other Missouri cave, is an outcrop of onyx on the hillside. It is weathered cave onyx and much of it is broken into boulders, but it is as different in appearance from the native bedrock in adjacent ledges as two consolidated calcareous rocks could well be. It is slightly translucent, vertically laminated in intricate, curvilinear patterns, and crystalline. The crystals stand at right angles to the laminae. It is cave flowstone projecting above the surface of the ground. A belt of this flowstone can be traced for a quarter of a mile or more along the hillside which lies above the cave we have come to see, and which lies above much more cave that we know exists but cannot enter. The other two openings are along this belt. One is a sinkhole at whose bottom an underground stream can be seen passing across from northeast to southwest. The other is down almost at ravine bottom and serves as the exit for that same stream. The cave lies between, and the stream traverses its lower level. The cave is a straight, deep, narrow, vertical gash in the rock underlying the hillside and is oriented almost northeast-southwest. Two hundred lineal feet of it are readily traversable now. The original entry was by rope. One descends 50 feet by three flights of stairs to reach the southwest end of the gash-like cave chamber, walks 200 feet toward the northeast, and descends 20 feet more in one place to the end of the traversable part of the cave. Exploration has shown that a hole in this bottom, now bridged across but very obvious to a visitor, leads down perhaps another 50 feet. At that depth a short horizontal passage toward the northwest, at right angles to the cave length, allows entrance into another long, narrow chamber almost exactly parallel to the one we are in. This lower chamber contains the stream seen in the sinkhole to the northeast and emerging in the ravine bottom.
Caves of Missouri 271 to the southwest. It contains stalactites which that stream is wearing away. At the bottom of the 50-foot stairway, both walls are of native rock (Mississippian limestone). Elsewhere throughout the entire 200-foot length and 70-foot height, the northwest wall is wholly of cave formation rock; only the southeast wall is of bedrock. This is an extraordinary thing which is not duplicated in any other cave the writer has seen in Missouri. There are two landings along the descent. At the second landing, there is a curious group of thick, bulgy stalagmites; the "Potato Hill". Here one also sees, hanging from the ceiling, fine rootlets of trees growing on the slope above the cave. These rootlets have grown down in the cave air for at least 3 feet. At the foot of the stairway, one may see the nearly filled upper portion of the cave extending toward the southwest. The red clay with which it is filled is a consistent feature of most limestone and dolomite caves and records an epoch intermediate in time between the original cavity-making and the later dripstone-making. The cave appears to have been, at one time, completely filled with the clay. Those parts which later lost the red clay fill have caught the dripwater from the surface and have thus received the striking display of dripstone on the northwest wall. To these varied dripstone forms, we now turn. The mass of pendant forms on our left is but the lower portion of that cave onyx outcrop on the hillside above. The dominant form is the stalactite. Many separate, icicle-like forms hang from the ceiling. Where they are on the wall, however, they tend to grow as a heavy fringe, which coalesces at the thickened top, is partly attached at the back, and grades downward into "fins" or "wings" or "drapes". A few of these "drapes" have a curious terminal coiling. Where grown together, they may form half-dome masses with stalactite pilasters. There are a few examples of the "sugar beet" or "mangelwurzel" form where a stem attaches the bulbous growth to the ceiling. "Straw" stalactites are those whose growth has been only from the rim of a drop of water. Like soda straws, they are hollow. But since even the "icicle" or "carrot" forms have a similar hollow tube, we believe that additional lime deposited on the outside of "straw" stalactites is responsible for their thickening, and that all stalactites in primitive form are "straws". The stalagmites are less numerous and less massive. The "Potato Hill" group, the "Desert Cactus" and the "King on his Throne" are examples. Several have that peculiar upward branching best shown in the "Desert Cactus". Columns generally are made by a down-growing stalactite joining an up-growing stalagmite beneath, and generally the two component parts are readily recognized. Wonder Cave has one splendid column, 12 feet long and almost uniformly 3 to 4 inches thick throughout its length, on which it is difficult to identify the two parts (Fig. 136).
Fig. 136. Wonder Cave, Taney County Dripstone column: A remarkably slender dripstone column connecting the ceiling and the debris floor. Photograph by G. Massie, Missouri Resources Division.
Caves of Missouri 273 Wonder Cave has some excellent specimens of helictites; crooked projections from ceilings and the sides or tips of stalactites. They probably are not true dripstone growths, but are the result of fortuitous formation of crystalline growths in a film so thin that capillarity, rather than gravity, has controlled its movement and its deposits. The tendril-like roots seen hanging above the second landing of the stairway afford the basis of a theory for some small, root-like formations the guide will show you. If rootlets ever did penetrate to this place, and did become covered with secondary lime, the result would very closely resemble these tiny curvilinear ridges on older drip-stone. Most of the dripstone growths and most of the southeast wall of native rock carry an overgrowth of little bulbous forms, variously called "popcorn", "grapes", "cauliflower", and "coral". It is not dripstone. It has been deposited from standing water and in many caves is still growing beneath the surface of pools. Its distribution from top to bottom of Wonder Cave indicates that the latest episode of the cave (before the present) was a complete filling with water which stood here long enough for the overgrowth to form. The south-east wall of bedrock has the best display, and in some places these little excrescences are really crystalline growths. All gradations between crystal tips and the "popcorn" rounded tips are shown. Some dripstone appears to have formed later than the bulbous forms. The "popcorn" has been curiously selective as to where it would anchor itself; barren areas are closely adjacent to densely covered areas on the same piece of dripstone. At the far northeast end of Wonder Cave, one may see that the cavity originally continued farther than it now can be traversed, and continued toward the sinkhole on the hillside already noted. Back in this tight opening, there is another kind of cave formation; a rim-stone dam made by the overflow from a small pool, now empty. The initial excavation of Wonder Cave occurred long before the ravine hollow was eroded. The rock which contains the cave was far below the land surface of that time and was completely saturated all the while. Vertical joints (tight, deep cracks across the bedding) determined the sites of maximum flow, and that flow dissolved the wall rock to make the narrow, deep cavity, oriented along a joint N. 40° E. Later came the episode of filling with the smooth gritless clay. Then came its partial removal as the ravine was deepened, and the rock lost its complete water-saturated condition and came to have air in the openings. Now came the time for dripstone to form, and air allowing evaporation on the pendant tips and deposition of the dissolved lime. A relatively recent ponding fortuitously interrupted this later, air-filled history; the "popcorn" overgrowth is its record. The outcrop of cave onyx on the surface is a record of ravine widening which accompanied the deepening. In other words, Wonder Cave originally was higher, and its upper portion extended up into what is now empty air. No other cave in Missouri, so far as is known, shows this feature.
Caves of Missouri 275 UNDEVELOPED AND WILD CAVES OF MISSOURI
BARRY COUNTY Fourteen named caves are known in Barry County. Four have been examined during this study. The others have been reported to the Survey or their names have been found on the quadrangle maps. Crystal Caverns, a mile north of Cassville, and Roaring River Spring and Cave have special sections devoted to them in the first part of this report. Crystal Caverns is the only cave in the county with facilities for visitors. Ash Cave NE1/4 NE1/4 sec. 9, T. 23 N., R. 27 W., Barry County Not shown on Cassville Quadrangle map This cave is a mile north of Black School and close to the floodplain level of Flat Creek. It is a completely ruined phreatic cave; not a solutional feature is left. Collapse has occurred into chambers that must lie below the valley bottom of Flat Creek. There is no deep alluvial fill in the creek valley, therefore, the true cave, now filled with collapsed rock, must still lie below the top of the saturated zone. There are two entrances in the base of a 50-foot cliff. The larger one is 20 feet high and 30 feet wide at the base and is recessed under the concave front for 50 feet. But they are entrances to nothing. The cave is completely filled with fallen rock back of this rock shelter. A pillar-like buttress of Mississippian bedrock separates the two openings. A well-shown joint in the ceiling of the larger recess strikes N. 10° W. Flat Creek must have cut away a considerable portion of the upper parts of this cave and must be flowing over the levels which, in front of the bluff, have collapsed to make what shows today. Because there is a large quantity of spring water entering Flat Creek near Cassville, we reason that there must be other such caves in this region that are being used by ground water today. Caves now below the water table and serving as ground water conduits presumably are growing larger in phreatic fashion as solution of ceilings and walls increases their capacity. Why should we not accept the view that their origin and entire existence have followed the incision of the stream valley to which they discharge? Why should they be dated back to the earlier cycle of erosion? By the time Flat Creek has deepened its valley another few tens of feet, such caves should become drained or explorable and should show the
276 Missouri Geological Survey and Water Resources spongework, the joint slots, the wall and ceiling cavities, and the anastomosis of minor passages which only a completely water-filled cave may develop. Admittedly, this view cannot be disproved. Such caves may be one-cycle phreatic caves, but when they do become drained and are explored, no remnants of a red clay fill will ever be found in them, for that epoch of filling will never have been in their history. The red clay records an almost complete stagnation which only peneplanation can provide. Because the great majority of our limestone and dolomite caves have received their clay fill after most of the solutional work was completed, we date them as pre-Ozark doming. Blowing Cave NW1/4 SW1/4 sec. 12, T. 24 N., R. 26 W., Barry County Shown on Aurora Quadrangle map This cave is about 175 feet above the adjacent valley bottom and 140 feet below the summit of a narrow ridge. Buzzard Cave SE¼ sec. 11, T. 24 N., R. 26 W., Barry County Shown on Aurora Quadrangle map This cave is almost in the bottom of a ravine, 180 feet below the ridge summit. Cave Spring SE1/4 SW1/4 sec. 17, T. 24 N., R. 25 W., Barry County Shown on Aurora Quadrangle map The cave is near the head of Cave Spring Hollow. McCann Cave NW1/4 sec. 24, T. 21 N., R. 28 W., Barry County Shown on Cassville Quadrangle map Panther Cave NW1/4 sec. 20, T. 22 N., R. 26 W., Barry County Shown on Cassville Quadrangle map Pigeon Roost Cave SE1/4 SE1/4 sec. 19, T. 26 N., R. 25 W., Barry County Shown on Aurora Quadrangle map
Caves of Missouri 277 Piney Creek Cave Sec. 19, T. 23 N., R. 24 W., Barry County Not shown on Shell Knob Quadrangle map On the authority of W. Farrar, this cave is situated approximately on the Stone-Barry county line in the valley of Piney Creek. Roaring Springs Cave NW¼ NE¼ sec. 26, T. 25 N., R. 26 W., Barry County Shown on Aurora Quadrangle map Rockhouse Cave Owner: L. F. Reno, Cassville, Missouri SE¼ SW¼ sec. 28, T. 23 N., R. 26 W., Barry County Not shown on either Shell Knob or Cassville Quadrangle maps This cave is almost on the line between the Shell Knob and Cassville quadrangles. The cliffed cave mouth opens at the bottom of Rockhouse Creek valley, about 1280 feet above sea level and about 100 feet below the trace of the peneplain. The cliff is most pronounced over the entrance and dies away on either side. The brink is concave toward the valley and the cave mouth beneath is recessed under the overhang. Weathering has made the marked recess, but the vigorous cliff over it is a puzzle. Mouths of caves in Gasconade dolomite usually open under a convex salient or visor, but Mississippian rock such as this commonly makes a concave one. The cliff above the mouth is 40 feet high. The opening has re-entrants and projections, but it averages 20 feet wide. It is 25 feet high above the debris floor. On the left, 190 feet from the entrance, a vadose stream has cut a beautiful meander canyon 20 feet deep. The meanders have enlarged their curvatures very little during the downcutting. There is some very old dripstone and wall flowstone in the main chamber. Rockhouse Cave is another of the numerous Missouri caves which are reputed to contain buried treasure. The story is that a huge cache of plundered Aztec gold bullion was hidden here (very well indeed) by Spaniards who were pursued by Indians. The one survivor of the Spanish party is said to have made a "map" which, found (?) in Cuba some 20 years ago, has guided one searcher unerringly from Mexico to this Barry County cave. He never found the bullion, however, and left for parts unknown, disconsolate and disillusioned. The treasure hunt, still active, has thus been broadened to include the quest for this man and his 400 year old map.
Two caves are known in the county; one of them is reported on here. An unsolved problem in its history is outlined in the hope that others with opportunity to study this cave more thoroughly may find the solution. Buzzard Cave Bluff W1/2 sec. 34, T. 39 N., R. 22 W., Benton County Shown on Fristoe Quadrangle map Cole Camp Cave SW1/4 SE1/4 sec. 16, T. 41 N., R. 21 W., Benton County Shown as Cave on Lakeview Heights Quadrangle map The cave mouth is on the west bluff of Cole Camp Creek and is about 30 feet above the creek and 70 feet below the road. The bluff is a wooded, irregular cliff on the northeast side of a narrow ridge between Cole Camp Creek and its tributary, Duran Creek. The distance through this ridge at the cave level is about 800 feet. It is another striking case where the hill could never have supplied the ground water for the work which had been accomplished. Add to this the facts that the cave is horizontal, capacious, lies well above Cole Camp Creek, has in the past been filled to low places in its ceiling with cobble gravel imbricated to show flow toward the larger creek, has fine spongework and wall pockets where its walls are well exposed and a fine ceiling slot along a joint. It follows that Cole Camp Cave is older than the topography. It is impossible to pace the length of the cave. It has a mud floor that slopes consistently northward down to some small slump pits and pools and is very slippery. The traversable length of the cave is estimated as not more than 300 feet. A big, dripstone, compound half-dome which is built on a remnant of the former gravel fill blocks further progress in the main chamber. It may be possible to pass this on the lower right, but water and mud and extreme slipperiness made the attempt impracticable at the time of examination.
Caves of Missouri

The record of the cobble fill is not obvious, for the old stream gravel is interpenetrated and covered with flowstone, and on most walls has been entirely removed. But it once filled the main cave and also a branch phreatic chamber at the right to the lower places in their ceilings. The stream flow was toward Cole Camp Creek. Duran Creek is the only possible source for this cobble gravel which was 10 or more feet thick. That stream detoured from its valley for a time and entered the cave about a mile in a straight line upstream from the present junction of the surface valleys. This detour was like that of Tunnel Cave in Pulaski County or Sinkin Cave in Shannon County, but as in the case of Mark Twain Cave in Marion County, the creek has since returned to its surface valley. If this is the correct explanation, the detour occurred when Cole Camp Creek still had to do 30 feet of down-cutting to produce its present valley. Duran Creek then had a correspondingly high valley floor, and to find this already existing phreatic passage, it must have dropped into a sink in its valley bottom or at the base of its eastern valley slope. Inadequate gradient along the cave through the hill caused it to choke with gravel, and the stream was forced to resume its former valley course. Whether or not a rock floor lies close beneath the mud is a question. How the gravel fill became so largely removed is another question. The later mud fill was nearly as high in the cave as the gravel. This seems impossible if the Cole Camp Creek level then was where it is now. It would be better to date the mud fill also from the time the floodplain of the larger creek lay 30 feet higher than now. A considerable remnant of a flat upland which is close to the level of the top of the bluff lies along U. S. Highway 65, four or five miles distant from the cave in the north-central part of the Schuyler Quadrangle, at an altitude between 900 and 940 feet above sea level. This upland is believed to record the summit peneplain. The cave lies at about 730 feet above sea level, 170 to 210 feet below the peneplain level. However, the peneplain surface probably was lower over the site of the cave, for the cave was a peneplain drainage way just as it is one today. The entrenched meanders are unequivocal evidence for this conclusion. The cave mouth is incorrectly located in altitude on the map. It is shown as almost at stream level, 100 feet below the road.

BOONE COUNTY Five named caves and one unnamed cave are known in Boone County. Thus, there are more known caves here than in any other county north of the Missouri River. All the caves are in Mississippian limestones.
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Connor's Cave and Devil's Ice Box
NW1/4 sec. 7, T. 47 N., R. 12 W., Boone County
Shown as Devil's Icebox and Rock Bridge on Columbia Quadrangle map
These caves which are shown on the detail map (Fig. 137) lie in the drainage area of Gans Creek which flows southwest, then west, Fig. 137. Environ of Devil's Ice Box, Connor's Cave, and Rockbridge, Boone County
Caves of Missouri 281 then southwest. Most of its tributaries come from the northeast, but Rockbridge Creek (the cave stream) comes from the south, from an area of numerous sinkholes. The Columbia Quadrangle map shows no sinkholes to the north in the Gans Creek drainage area. Rockbridge Creek flows beneath a natural bridge (Fig. 138), and its tunnel route is 150 feet long, averages 50 feet in width, and is 25 feet high above a gravel floor. The bridge is about 40 feet thick and is a remnant of a cave roof. Fig. 138.

Rockbridge, Boone County Natural bridge over Rockbridge Creek: The tunnel, remnant of a cave, is 150 feet long, 50 feet wide, and 10 to 20 feet high. A dam holds up the stream at the far end of the tunnel. Photograph by G. Massie, Missouri Resources Division. A cross chamber located about midlength of the tunnel follows a curved joint which strikes approximately N. 85° E. This is also the orientation of the north face of the bridge. This joint is marked by well-shown phreatic slots in the ceiling. On the east, the joint-controlled cross chamber can be followed back for 80 feet by climbing up a detrital fill on a low rock floor. There, the cross chamber is creepable and crawlable along what appears to be a tube (though it
282 Missouri Geological Survey and Water Resources may be a nearly filled slot) for a considerable distance farther. The east end of the cross chamber is wholly phreatic, as is shown by wall and ceiling pockets. The opening off the tunnel into the cross chamber is about 15 by 15 feet. On the west side of the tunnel, this joint-determined cross chamber is also wholly phreatic. It can be crawled into for about 50 feet, beyond which the fill meets the ceiling. Branching off from this chamber, farther back and out of sight from the tunnel, there is a north-leading chamber about 30 feet long. Its mud fill reaches its ceiling in that distance, but above the fill at the terminus, there is a solutional dome in the ceiling, 12 feet wide and consisting of three minor domes. The opening off the tunnel to the western part of the cross chamber is about 15 feet high and 20 feet wide. The tunnel, therefore, contains adequate evidence that it was originally a phreatic cave with a cross chamber whose ceiling in part and floor entirely are above present corresponding tunnel levels. The bedrock tunnel floor is completely covered by gravel. Collapse debris in the west end of the cross chamber has not come from the ceiling immediately above but has descended diagonally from farther west where the chamber has a higher ceiling. Because the bridge abutment at this end is relatively thin and has no surface sinkhole from which the debris could have come, it seems that rock higher than now exists once constituted the west end of the bridge abutment. The south side of the bridge cliff strikes about N. 40° W. to N. 60° W. The tunnel itself is oriented N. 5° W., and the north-facing cliff of the bridge strikes N. 65° E. Both cliffed faces of the bridge are vertical to overhanging as they lead into the tunnel. Both look precisely like the majority of cave mouths seen in the Gasconade formation, except for the Gasconade characteristic of having a strongly developed visor. But this is Mississippian rock. Caves in this rock only rarely have an entrance visor. Upstream from the bridge, there is 250 feet of open valley to the mouth of the cave. Connor's Cave is not enterable here because of ponding (Fig. 139). The mouth of the cave is much smaller than the tunnel. It is 6 to 8 feet high and 10 feet wide. What looks like a minor, horizontal meander slot on the east wall of the cave may be seen from the outside. This open valley between the tunnel and the cave has rock ledges at stream level and in the stream bed. They crop out at least 6 feet higher than the gravel bed in the tunnel. Probably the lowest 4 to 8 feet of the tunnel wall records vadose stream deepening of the original phreatic chamber. The open valley between the tunnel and the cave is interpreted as a large, collapsed chamber. Rock ledges, other than those in the stream bed, show only at the top of the detrital slopes which enclose the open valley. The span between the ledges on opposite sides of
Caves of Missouri 283 the valley is all of 200 feet (except at the tunnel and cave mouths). Huge, settled, tilted blocks occur close to the tunnel mouth; their bedding unlike the massive bedding in the tunnel walls. They are assumed to be roof and wall blocks which have subsided from a higher level. Just to the west of the cave mouth, there is a steeply graded, gully-like re-entrant in the wall rock that records not gullying but a phreatic slot which has lost its roof. Orientation of the slot is N. 700 E.; parallel to the transverse wall which contains the cave mouth and terminates the open valley upstream. Fig. 139.

Connor's Cave, Boone County Exit of Rockbridge Creek from Connor's Cave: Approximately 250 feet farther downstream, the stream goes through the tunnel under the natural bridge. Photograph by G. Massie, Missouri Resources Division. Though much wider than the tunnel and especially wider than the cave mouth, the floor of this collapsed chamber is definitely higher than that of the tunnel, as ledges in the stream bed and on the lower walls of the open valley show. Its collapse debris could only have gone out, north, through the tunnel under the bridge or down into a much deeper chamber than seems to be indicated. Azimuth from the cave mouth to tunnel is N. 25° E.
This open valley has two small hanging valleys. One is the old discharge route a little south of the western end of the bridge. The other is the old entryway for surface drainage from the ravine just east of the cave mouth. Each hangs about 20 feet above the present floor. This surface stream appears to have traversed the open valley on collapse debris until it discovered the tunnel route. It never crossed on top of the roof of the vanished chamber. That roof, at the very least, was 30 to 40 feet higher. The segmented ravine is much younger than the collapse, but by this interpretation it is older than the vadose occupancy of the tunnel and the removal of the collapse debris. Much later than this subterranean piracy by the discovery of the tunnel exit and later than the removal of the collapse debris through the tunnel, there has been a blockade of the tunnel. The consequent accumulation of stratified mud and sandy mud floored the entire 250 feet of the open valley. Territory remnants of the mud, today, are about 15 feet above the stream which has removed most of the mud fill. The mud fill may be the deposit of a little lake which spilled out of the hanging valley at the north end at the time of the later blockade. It is estimated that the lake was still 5 feet deep at the close of its history. Also, the damming may not have been in the tunnel at all; the mud fill may record some blocking farther downstream; down Gans Creek itself. The pendants on the tunnel ceiling (Fig. 140) probably date from this damming. In the wall at the south end of the open valley east of the cave mouth, are cavities elongated with the bedding. They may be of solutional origin, or they may be the site of chert nodules which have weathered out. West of the wall, is the steep "gully", N. 70° E., which is referred to as an unroofed, phreatic slot. If one now follows up the little hanging ravine east of the cave mouth for a distance of 75 feet, he comes to a collapse sink (ponor) in the bottom of the ravine. This sink is small, fairly recent, and has a slot-like outline. The two parallel walls are solution-marked, and the elongation is N. 70° E. It is really a partially unroofed, joint-determined, phreatic ceiling slot of the cave beneath. There is a marked dimple in the hillside to the west along the projection of the slot. This indicates that the slot continues farther west under the hill, and its roof there has collapsed only enough to produce a surface depression. One hundred and twenty feet farther up the ravine, is a larger collapse sinkhole with the same orientation, 30 or more feet deep, 5 feet wide at the bottom, and about 30 feet in exposed length. It clearly continues under a roof farther west under the hillslope. The stream can be heard down here, but it is out of sight under the hill. Ten to 20 feet farther is the Devil's Ice Box. It is a more flaring pono (collapse sink) but of the same type, same depth, and same length. One can scramble down here and actually crawl under a broad low arch.
Caves of Missouri 285 -either a horizontal phreatic slot or a chamber, debris-filled almost to its ceiling—over into the bottom of the one just noted. Here, he can see the stream in it farther west. These three ponors lie in a nearly north-south line. If the stream in the cave is low and the investigator not afraid of getting wet, he may crawl back from the bottom of the Ice Box into the Fig. 140. Rockbridge, Boone County Pendants: These pendants are on the ceiling of the tunnel of the natural bridge over Rockbridge Creek. Photograph by G. Massie, Missouri Resources Division. cave and find that joint-controlled ceiling slots are much better developed there than they are on the ceiling of the tunnel. These are remnants of the former, phreatic cave system. It would be impossible for the free-surface stream of today to have made them. There is probably an indication of still another collapsed chamber north of the bridge. It is a steep little "gully" which is very much like and oriented similarly to the one west of the cave mouth. Here, one climbs to the top of the bridge from the north. Collapse rock fills its western end, and there are solution holes in the north wall of the "gully" facing the bridge. Thrust your arm into one of these holes.
286 Missouri Geological Survey and Water Resources You cannot reach the bottom of it. It is no more than 6 inches in diameter. No weathering out of a chert nodule made this hole. The tunnel remnant of this phreatic cave system shows repeatedly, on walls and ceilings, a sheeting structure, a parting in the limestone that parallels the cave and cliff, turns around both vertical and horizontal curves to do so and has all possible orientations in space. It appears to be a feature of cave wall weathering in Mississippian limestone.

The Devil's Ice Box and associated features constitute a consider-ably damaged, phreatic cave system. The vadose cave stream has done its share, but surface erosion has done more to unroof it. There are five places, if interpretations here are correct, where the system's original roof has failed. If the theory of phreatic origin of this and almost all other Missouri caves is correct, the solutional work must have occurred down in the saturated zone beneath the older land surface which is now being dissected. Because there could be only a very minimum of hydrostatic head under the peneplain, we argue that these caves must date back to the maturity of an earlier cycle. The flattish uplands between Hinkson and Gans creeks lie very close to the trace of the old peneplain surface. Their altitude is approximately 800 feet above sea level. The tunnel mouth is 618 feet above sea level. The cave was made, therefore, at a depth of nearly 200 feet below the level at which the peneplain developed. All that the Rockbridge record lacks to make it complete is remnants of the red clay fill; the contribution of the peneplain to the story. There has been too much vadose reworking. Possibly there are remnants back in the cross chamber, buried under later deposits. Holton Cave NW1/4 sec. 30, T. 49 N., R. 13 W., Boone County Not shown on Sturgeon Quadrangle map Cave pearls from Holton Cave are described and interpreted by Keller (1937, pp. 108-109). Kintz Cave Sec. 7, T. 48 N., R. 14 W., Boone County Not shown on Rocheport Quadrangle map Kintz Cave is approximately located by Farrar along the Missouri, Kansas and Texas railroad tracks, a mile or two east of Rocheport. It is described as having been the home of a hermit for several years, the hermit having been found dead in it in 1925.
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 Kirby Cave SW1/4 SW1/4 sec. 31, T. 49 N., R. 13 W., Boone County Not shown on Columbia Quadrangle map Kirby (or McCrory) Cave is entered at the foot of the east slope of Cave Branch of Callahan Creek which is a tributary of Perche Creek. The entrance is at the head of a steep-sided alcove 30 feet deep, 50 feet wide, and 100 feet long. The slopes of this alcove are unlike any other valley slopes in the area. All other slopes are gentle and soil-covered; this alcove is a steep-walled relic of a former extension of the cave. At the cave entrance, the cliff is 50 feet high, but it is flanked by waste slopes on either side which come down to the margin of the stream as it emerges. The entrance looks like a flattened tube, 15 feet high by 20 feet wide; the bottom is stream debris. No rock bottom is exposed. For 250 feet, the slightly winding chamber has walking height, and the width is rarely less than 10 feet. A gravel bed covers the floor, but it appears to indicate only small flood discharge. Growing rimstone dams and low cascades indicate the same thing. For about 100 feet farther the stream chamber ceiling is rather low, and progress on all fours is necessary if one is to continue along this passage. However, this low stretch can be by-passed. At the beginning of the low-ceilinged stretch, openings in the right-hand wall lead into several clay-floored, winding, anastomosing, tube-like passages which are higher than the stream level. From the numerous broad, shallow pits in the floor, one judges that a whole dormitory full of bears once hibernated here. The left-hand, tube-like passage (true depth not known) leads into a well-developed, joint-determined slot which intersects the tube at a high angle in ground plan. In this slot, with far more head room than needed and with solution pockets in the ceiling, one walks edgewise to the left and shortly finds a 4-foot jump-off from the clay floor down to the stream again. At this place, the stream is using no such chamber as the one followed back for the first 250 feet. It is flowing in the slot itself. It leaves this slot for the 100-foot, low-ceilinged passage (which we avoided) and the 250-foot adequately ceilinged, winding passage to reach out-of-doors. The stream has done almost nothing to enlarge the slot which continues with little narrowing toward the right for a considerable distance beyond the point where the stream leaves it. Some of the creepable, phreatic passages lead up to levels which are apparently higher in the rock than the ceiling of the slot chamber which is also phreatic in origin. One leads toward the right and apparently connects with a notably broad alcove chamber which is almost filled with debris and is about 100 feet inside the entrance. No red clay remnants and no spongework were seen in this cave.
Rocheport Cave NE¼ NE1/4 sec. 20, T. 48 N., R. 14 W., Boone County Shown on Rocheport Quadrangle map This is another "river" cave in terms of flood discharge. There is a greater display of cobbly and bouldery stream gravel in Rocheport Cave than in River Cave (Camden County), because of a wider floor (average 30 feet) which is virtually all covered in flood. An older and now indurated gravel of equal coarseness is being eroded away. Flat-tish pieces in both the older and the present gravel are strikingly imbricated. This old deposit is trenched to depths of 6, 8, and even 15 and 20 feet. Remnants of the fill remain in alcove recesses and on the inside of the swing of the present underground stream. The cave is readily traversed for 575 feet back to a pool which completely covers the floor. The width of the Missouri River valley at Rocheport is 2 miles which is adequate to justify the use of Salisbury's (1904, pp. 705-715) topographic unconformity principle in explanation; i.e., the Missouri River was on the far side of its valley at the time the old, high-lying, detrital fill was made, and hence the cave stream had to aggrade in order to have an adequate gradient for carrying its load. This vadose torrent in flood time has all but destroyed the original phreatic features of the cave. It has brought in quantities of forest debris. Logs as long as 18 feet and as thick as 18 inches are found 300 feet back from the mouth stranded on the upstream side of obstacles. The Missouri River with its valley cliff 1200 feet distant never floods back this high. A big sinkhole entrance in the bottom of Sinking Creek valley a quarter of a mile farther north, undoubtedly is the source of the water and driftwood. The creek drains about 3 square miles. Because of the coarseness of the gravel, there must be a good upgrade in the cave floor along this rubbly deposit. The ceiling, however, remains high throughout, though its phreatic features almost all disappear back in the cave. It is possible that this part of the cave is almost entirely a vadose cavern that lies above the older phreatic cavern which is now filled. A very few phreatic slots and pockets still survive near the entrance; most of them are high in the walls. There are some ceiling cavities, although most of the ceiling has a smooth, fracture surface. Many great slabs lie directly below the scars left by their fall. One large, fairly symmetrical dome, not far from equidimensional, appears to be entirely of collapse origin. One joint in the ceiling and walls near the entrance is diagonal to the chamber length and has a wall niche on each side and four good ceiling cavities which are largely along the joint. These surely are phreatic.
Caves of Missouri 289 We have been examining the larger cave at this place. Two hundred feet farther south along the 100-foot cliff, there is another opening of comparable dimensions (30 to 40 feet wide by 15 to 20 feet high) which leads back not more than 50 feet to a debris cone that mounts to the ceiling and is actively growing. The walls that show here, however, are good phreatic features, with no vadose stream widening or undercutting as in the major cave. Nearly all of the cliff wall between the two caves is solution-smoothed at the cavern level. These two caves are parts of one, former, continuous cavern. They have become separated by a collapse on the side of the ravine which now takes the cave stream to the Missouri River. The downcutting of the ravine to the level of the large cavity beneath caused the collapse and the consequent separation into two caves. The ravine course and cave course are subparallel, and they simply happened to overlap, or nearly so, at this place. Presumably the sinkhole supplying the flood water had already found the phreatic route and made the first perforation of the ravine slope. There is still a third cave opening in the base of this unstable cliff. It is farther downstream and is at a lower level. Its ceiling descends within a few feet inside to meet the top of a detrital fill which is almost at outside stream level. This opening, with its slotted walls and ceiling and ceiling holes, is entirely phreatic. One may climb diagonally up through a phreatic tube to emerge at the foot of the debris cone in the second cave opening. The outstanding feature of this third opening is that the wall rock appears to be "sheared". Some of the slabs are only a few inches thick, and the dips are 50 to 60 degrees in opposite directions like the slopes of a gabled roof; the opening being the attic. And so it probably is the attic part of a much bigger chamber whose walls are mostly still below stream grade, and whose roof is mostly collapsed where the ravine now lies. These diagonal "shearings" extend back laterally on both sides of the attic-like ceiling through as much as 6 feet of rock. They record incipient failure, but no falling, of the archway of the theoretical, broader, deeper chamber, apparently because of the weight of the superjacent rock. This failure probably occurred long before the vadose epoch began. Unnamed Cave Sec. 28?, T. 47 N., R. 11 W., Boone County Not shown on Millersburg Quadrangle map According to Farrar's notes, an unnamed cave is situated about half a mile east of Englewood.
290 Missouri Geological Survey and Water Resources CAMDEN COUNTY Camden County is reported to have a total of 15 named caves. Most of these have not been located precisely, but if an approximate location is known, it is so stated in the text. Ozark Caverns, River or Mystic River Cave, and Bridal Cave are the commercially operated caves in the county at present, and they have special sections devoted to them in this report. Five caves have been examined in Camden County in the course of this study.

Arnholdt Cave NW1/4 SE1/4 sec. 5, T. 38 N., R. 17 W., Camden County Not shown on Green Bay Terrace Quadrangle map Farrar says the cave is in the Gasconade formation. Cave onyx was formerly quarried in this cave. Arnholdt Cave has been completely flooded in making the Lake of the Ozarks. Bunch Cave SW1/4 SW1/4 sec. 27, T. 38 N., R. 17 W., Camden County Not shown on Hahatonka Quadrangle map The entrance to this cave is a fine arched opening 20 feet wide and 25 feet high in the cliff overlooking the Niangua Arm of the Lake of the Ozarks. Its floor is about 20 feet above lake level. The entrance walls are smoothed with the flowstone cover common to such situations. Bunch Cave is a long, sinuous, unbranched cave (Fig. 141). The cross section near the entrance averages 10 to 15 feet wide and 6 to 8 feet high, but the sides close in fairly uniformly so that nearly 400 feet Fig. 141. Bunch Cave, Camden County
Caves of Missouri 291 back there is a minimum width of about 6 feet. A gravel floor rises through this distance to decrease head room so much that stooping becomes necessary, even though the former operators had cut a foot trench in the clayey gravel. Throughout this distance, there are no outstanding solutional or depositional features. There are some horizontal wall slots. A fairly smooth solutional ceiling extends throughout. About 400 feet inside, one encounters a surprise. He enters a chamber which is about 30 feet wide and has a steeply sloped, hollow dome for a ceiling, 30 feet above the gravel and clay floor. From this dome, the cave continues as a somewhat winding, walled, dome room. Beyond this the passage is low and narrow, and the floor is under water. The domes are surely phreatic. The long passage leading to them may in large part be vadose. It has no truly phreatic features, and its gravel floor tells of a rather recent vadose stream. But near the entrance, it is certainly a large cave for one of vadose origin. We are inclined to think of it as vadose-deepened from a phreatic origin. The hill in which the cave lies is nearly isolated by two, broad, low-bot- tomed, tributary valleys, and by the Niangua Arm of the lake. The total area of the hill is not much more than a quarter of a square mile, and not a quarter of this area can be argued as discharging its vadose water by the cave route. If Bunch Cave had been made by vadose water draining out from under only one-fourth of this hill, there should be three more caves of comparable size and length to care for the other three-fourths. Indeed, all the hills of the region should be riddled with vadose caves. It appears far more probable that the cave originated at a lower level than the valley bottoms of an earlier topography, and that it predates the Osage River system which has deep, steep-sided valleys and narrow divides. In common with so many other caves, Bunch Cave appears to date back to an earlier cycle of erosion. It is not too far away to be considered a dismembered portion of the former Hahatonka cavern system. The decrease observed in heights and widths of so many long, sinuous, linear caves of Missouri, when they are traced back under the hills, can be explained satisfactorily for Bunch Cave and for most other caves by the rising gradient of a detrital floor; the width becomes less as the floor becomes higher between upward-converging walls. There is some showy dripstone in a few places, particularly back in the dome rooms. Dry Cave NW1/4 SW1/4 sec. 4, T. 37 N., R. 17 W., Camden County Not shown on Hahatonka Quadrangle map This cave is reported by Farrar to be a rather small one.
Laswell Cave This cave is indefinitely located by Farrar as "east of Barnumton". Morgan Cave This cave is reported to be rather small and "on Morgan's farm, near Hahatonka". This may be another of the seven caves said to be in the vicinity of the great spring. Onyx Cave SW1/4 SW1/4 sec. 4, T. 37 N., R. 14 W., Camden County Shown on Hahatonka Quadrangle map Fowke (1922, p. 90) mentions two caves with this name in Camden County. It is possible that at one time Arnholdt Cave was also known as Onyx Cave. Tunnel Dam Cave NW1/4 sec. 19, T. 37 N., R. 17 W., Camden County Not shown on Macks Creek Quadrangle map A cave of tunnel character once almost completely perforated a narrow ridge which separates two entrenched meanders of the Niangua River at this place. The ridge is about an eighth of a mile wide and 200 feet high and has a notch about 160 feet deep across it. The river is dammed for power purposes a little upstream from the notch and the original tailrace utilized the cave, after local enlargement of a mere gopher hole at the south end, for discharge through the ridge. Later, an entirely artificial tunnel was excavated, the power house relocated at its northern end, and the cave route spillway abandoned. This provides a head of 43 feet. Niangua River floods, today, rise high enough to spill in part through the cave. Genesis of the cave offers a unique problem. Why did not the Niangua adopt this subterranean route in entirety as it consummated the last few feet of its valley deepening? Why is there not a cut-off here, and an abandonment of the 6 miles of entrenched meander be- tween the two ends of the cave? What part does the unusual notch play in the history of this tract's physiography? It is impossible that the cave can be younger than the valley, for its ceiling and walls are covered with spongework and the river bluff has associated satellitic cavities. Was it a phreatic cave so completely plugged with red clay that the river failed to discover it? If so, how did the cave become cleaned out subsequently? The original opening at the south end apparently never had taken more than a minimal fraction of river water through the hill. Dake and Bridge (1923, p. 11 and fig. 6) describe the situation before the dam was built but do not discuss any of these questions.
Caves of Missouri 293 Unnamed Caves Farrar lists two unnamed caves; one in sec. 14, T. 39 N., R. 16 W., half a mile from Zebra, and the other "near Climax Springs". The latter is said to contain a very large lake. Nothing else is known about them. Newspaper accounts of rowboat voyages in the cave lake for a "mile in a straight line" without "even approaching the opposite shore" are, in the opinion of the writer, effusions of some enraptured reporter. Wildcat Cave Sec. 27, T. 39 N., R. 16 W., Camden County Not shown on Camdenton Quadrangle map Farrar locates this cave "about 100 yards east, downhill, toward head of Brushy Creek" from "old salt trail". The entrance is 100 feet wide, 30 feet high, and is through a sink, 150 feet above the creek. The cave has been explored for 350 feet. CARTER COUNTY The county has ten named caves. The two caves which are advertised for visitors, Cave Spring Onyx Caverns and Big Spring and Cave, have special sections devoted to them in the first part of this report. Camp Yarn Cave Center, sec. 22, T. 27 N., R. 2 W., Carter County Not shown on Van Buren Quadrangle map Cave Spring Cave SW 1/4 SW 1/4 sec. 29, T. 27 N., R. 1 W., Carter County Not shown on Van Buren Quadrangle map Deerhorn Cave SE 1/4 sec. 32, T. 27 N., R. 1 W., Carter County Not shown on Van Buren Quadrangle map This is a newly discovered cave, but it has been closed by the owners because of danger from an unstable ceiling. Granite Quarry Cave Center, sec. 32, T. 27 N., R. 1 E., Carter County Not shown on Grandin Quadrangle map
Lost Man Cave NE1/4 NW1/4 sec. 19, T. 26 N., R. 2 E., Carter County Shown on Grandin Quadrangle map. The opening to this cave is a double hole in the roof of a joint-determined chamber. Only a rope descent is possible. At the time of examination, the spotlight showed only the top of a half cone of debris. Rocks which were thrown down into the opening bounded several times and descended probably 40 feet or so. Curiously, there seems to be only one inhabitant of the nearby village of Hunter who has ever been in this cave, and he was away fishing at the time the cave was investigated. The entrance is shown on the map as on the 560-foot contour. This position is 140 feet above the Current River floodplain, three-fourths of a mile distant, 300 feet below the high remnant of a peneplain divide, and a mile and a half to the east and about 50 feet below the summit of the narrow ridge in which the cave occurs. Cave Spring is less than half a mile distant; 160 feet lower, and on the opposite side of the ridge. Midco Cave Owner: C. P. Turley, Van Buren, Missouri NE1/4 SW1/4 sec. 27, T. 27 N., R. 2 W., Carter County Not shown on Van Buren Quadrangle map. The entrance to this cave is at valley bottom level and is about 60 feet wide and 10 feet high. The ceiling for 100 feet inside is a flat span that carries elaborate, large, solution pittings in an equally elaborate pattern of chert formations in relief. These chert formations are unusual in being sinuously linear, fairly uniform in cross section, and repeatedly branched as though they record some algal growth. Farther back than this pitted, solutional ceiling and upper half of walls, there is a smoother but equally flat ceiling which is about 6 feet higher and is wholly of fracture origin. Under this ceiling the cave becomes a stoopway because of additional, fallen ceiling blocks and a rising mud floor. Past this stoopway, one descends to the level of the cave stream and continues under a 10- to 25-foot ceiling to a complete ponding on the cave floor where very soft, deep mud is beneath the water. The ceiling appears lower farther back; perhaps the cave again becomes a stoopway. The stream, just below the ponding, flows over bed rock which it has faceted rather extensively and intensively. At the time of examination, the stream was not flowing out of the cave mouth, though in flood time it does so. There must be buried gravel and coarse, fragmental material beneath the mud fill to take care of the ordinary
Caves of Missouri flow, because the stream disappears into the floor before the entrance is reached. The stoopway clay hill is by-passed by the vadose stream. Apparently the stream has made a lateral enlargement on the south side of the phreatic chamber which, at the hill, is now filled with clay and a roof rock deposit. The clay is almost bright red beneath the thin surface cover of dark mud. There are no sections in it to show structure, but it clearly is a large remnant of a complete or nearly complete cave fill and very probably is phreatic. The visible, bed rock stream floor may be limited to the vadose additions of the cave. If all the clay were removed, the phreatic cave floor might be found to be much lower. The cave lies under a hill spur 200 feet high. This spur is part of a nearly isolated hill 240 feet above Pike Creek and is less than a square mile in total area. No local sinks are shown on the map. From where does the flood volume come? From where does the driftwood back in the cave come? Possibly a sink, low on the slopes of Pike Creek farther upstream, allows a swollen Pike Creek to discharge part of its high water into and through the cave. Midco Spring SE1/4 SE1/4 sec. 22, T. 27 N., R. 2 W., Carter County Not shown on Van Buren Quadrangle map The spectacular overhanging cliff at the spring is a former cave wall. Two large, cave dripstone masses still stand under its 30-foot (maximum) overhang. One is a complete column 10 feet high and 10 feet thick at the base and has passage room back of it. The cliff is smooth-faced almost throughout its 300 feet of length. Its ground plan is slightly concave toward Midco Hollow, and the vanished roof and other wall stood out in the hollow somewhere. There are a few solution pockets in this wall also, although many exposed cave walls have a far better showing. There is no known cave in the hill back of the spring mouth. The spring emerges about halfway up the talus slope. It surely is not any lineal descendant of the underground circulation which made the great chamber, now ruined, whose elongation was at right angles to the present flow. Richbark Cave NW1/4 sec. 24, T. 27 N., R. 1 W., Carter County Not shown on Cardareva Quadrangle map This cave is almost within the city limits of Van Buren, in the bluff on the east side of Current River.
Missouri Geological Survey and Water Resources Secesh Cave Center, sec. 17, T. 26 N., R. 1 W., Carter County Not shown on Van Buren Quadrangle map This cave is in the bottom of Secesh Hollow and is so named because of its reputed use as an overnight hiding place by Secessionists who moved south out of Missouri during the Civil War.

Spout Spring Cave Center, sec. 1, T. 25 N., R. 2 W., Carter County Shown on Van Buren Quadrangle map CEDAR COUNTY There is but one known cave in the county. It lies essentially beneath the city of Stockton. Stockton Cave Sees. 8 and 9, T. 34 N., R. 26 W., Cedar County Not shown on Stockton Quadrangle map The story that this county seat is entirely underlain by a cave is a myth. There is a cave beneath the town, but it is a poor little thing on which to base this widely circulated statement. The cave "spring" flows from the bottom of the south slope of a shallow valley in the city park north of the business district. It has been enclosed by an arch of stone blocks which is just about large enough to creep under with most of one's body in the water. One may see bedrock 10 feet or so back. As seen from the outside, it is definitely not an inviting cave to enter and explore. Reliable local sources state that two branches have been explored. The one leading southwest toward the old sinkhole on the southwest margin of town is very low, and its floor is the subterranean stream bed. This sinkhole has been partially filled but formerly showed a stream that flowed from the south side across to the north side. A dug well in town showed the same thing at a depth of about 35 feet which is the proper depth for the "spring" stream. It is said that boys have thrown green apples into the sinkhole and that they then ran to the spring to see them emerge. Stockton, until about 1937, depended on private wells for water. Shelby Osborn, Stockton's mayor, says that there are more than 100 wells in the area. Of these, he knows that not more than half a dozen ever entered any cave or cavity in the drilling, although all the wells got their water from about the same level as the subterranean flow above noted. The local theatre sank its air-conditioning shaft in 1936 and
Caves of Missouri tapped the cave one looks into at the spring about a block distant. When the court house was built 15 years ago two men were hired to explore the cave, with a view to air-conditioning that building. All they found was the very low passage noted above, and the scheme was abandoned. CHRISTIAN COUNTY Christian County has six named caves which have been located. A seventh is reported. None is commercialized. Descriptions of three of the six follow. Baldknobbers' Cave S 1/2 sec. 18, T. 26 N., R. 19 W., Christian County Not shown on Forsyth Quadrangle map Baldknobbers' Cave is a very low-ceilinged cave with a perennial stream. It lies in Mississippian limestone just above the Northview (?) shale. It is a vadose cave, as far as it was examined. Only creeping will allow passage. One marvels at the Baldknobbers' intensity of purpose, if they really crawled into this cave for their meetings. Unless there are phreatic chambers of adequate spaciousness a little farther back, one cannot believe the story. The cave, so far as seen, has little to recommend it, either to Baldknobbers or to spelunkers. There is another spring nearby in this ravine. It also is on top of the shale, but no cave has been developed by it. Finley Cave T. 25 N., R. 20 W., Christian County Not shown on Forsyth Quadrangle map This cave is listed and located on Farrar's authority. The entrance is reported as 98 feet wide and 60 feet high. Farrar says Finley Creek disappears in a sink and emerges at the mouth of this cave three-fourths of a mile distant. But Finley Creek gets no drainage from this township. Inquiry in the region failed to find any one who knew of a cave by that name. Fitzpatrick Cave Sec. 36, T. 28 N., R. 22 W., Christian County Not shown on Republic Quadrangle map The two entrances to this cave face north and overlook James River valley. The larger opening is about 10 by 10 feet and the cave has been penetrated for some hundreds of feet.
Missouri Geological Survey and Water Resources Garrison Cave SE1/4 SW1/4 sec. 24, T. 27 N., R. 21 W., Christian County Shown on Ozark Quadrangle map This cave is at the head of a narrow, steep-walled ravine which has an abrupt amphitheatre-like head. Our inference is that the ravine is the result of collapse of the downstream portion of the original cave. Johnson Cave S1/2 sec. 13, T. 27 N., R. 20 W., Christian County Shown on Ozark Quadrangle map Shelf Cave NE1/4 NE1/4 NE1/4 sec. 34, T. 28 N., R. 22 W., Christian County Shown on Republic Quadrangle map Smallin Cave NW1/4 SW1/4 sec. 12, T. 27 N., R. 21 W., Christian County Shown on Ozark Quadrangle map The valley of Finley Creek in the region of Smallin Cave has a broad terrace which is 80 to 100 feet above the stream and a quarter to half a mile wide. The cave mouth is at the head of a steep-walled ravine cut in this terrace. It is perhaps the largest and most impressive arched cave entrance seen during this study; a magnificent symmetrical span 50 feet high and 100 feet wide (Fig. 142). Beneath it emerges a perennial, gravel-carrying stream that obviously is occasionally subject to torrential floods. The roof of the arch is amazingly thin; there being scarcely 10 feet of rock and no soil above. The cave is spacious for at least 600 feet inside, but the entrance is traversable beyond that distance only by wading deep pools. It has been followed back for more than half a mile to an emergence in the bottom of a narrow sinkhole which is more than 60 feet in maximum depth and half a mile in length. This elongation is a fairly direct continuation of the length of the cave and clearly is largely but a collapsed portion. Furthermore, the cliffed ravine carrying the stream beyond and below the mouth is also a collapsed portion which has phreatic solution cavities and dripstone remnants on its walls. Thus, it seems fair to interpret Smallin Cave as originally at least a mile long—one of the longer caves recorded in Missouri. Less than a square mile of direct surface drainage is caught by this sink, but the map shows seven other smaller sinks near enough to contribute to the cave stream. If they do so, exploration of Smallin Cave should reveal tributary passages which enter from the west.
Fig. 142. Smallin Cave, Christian County Entrance arch: The smoothness of the wall and ceiling is due to two things: exfoliation by weathering which has destroyed much of the spongework and a plating of wall flowstone whose ribbed outlines can be seen in the photograph. The cliff outside the entrance contains solution-made pockets which mark it as originally a cave wall. Photograph by G. Massie, Missouri Resources Division. The outstanding scenic feature of Smallin Cave is its splendid flowstone half-dome and double rimstone dam near the entrance. The pool at the foot of the dam is kept flushed out by storm water torrents and is too deep for wading. The cave, therefore, is entered by climbing 20 feet or so up over the half-dome, using a series of finger holes and toe holds which have been chiseled in the cave onyx. The rock is as polished as in the three-by-five doorway of that remarkable Indian shelter, Miller Cave, in Pulaski County; and for the same reason. The water falls about 5 feet over this dam. Another rimstone dam, at the end of ready traversability, is 4 feet high. Two other lower dams—each built alongside a huge, fallen roof block—lie between.
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None of these dams has a pool above it. The gravel floor is graded up to the rim of each. The dams appear to be suffering destruction today from the abrasive action of the chert gravel which is being carried over them. It, therefore, seems likely that the collapse which formed the large sink is a fairly recent affair in the history of the cave. The cave, most assuredly, has not been made under present conditions. Smallin Cave exhibits as good a development of ridged, wall flowstone as any cave in the State. These ridges are found only near entrances, nowhere farther back than 100 feet or so. The cause for their limited distribution is not understood. The drainage of Smallin Cave comes from remnants of the upland peneplain of the immediate region which here is on Mississippian rock. The terrace at the cave mouth seems to be part of an old valley bottom of a later and incomplete erosion cycle which was interrupted by the uplift which inaugurated the valley cutting of the present cycle. Smallin Cave was a product of deep, ground water flow before Finley Creek valley was cut to its present level. If reckoned as dating from the cycle that produced the region's peneplain, this cave was developed between 50 and 100 feet below the level finally attained by the peneplain. Elsewhere in southwestern Missouri, there are still higher (and older) peneplained uplands, and if the making of Smallin Cave's phreatic features occurred during that earliest cycle, these figures should be increased by about 100 feet. Woody Cave SW1/4 NW1/4 sec. 5, T. 27 N., R. 20 W., Christian County Shown as Wood Cave on Ozark Quadrangle map The entrance to Woody Cave is at the head of a vertically cliffed ravine whose walls converge to the width of the entrance arch; about 100 feet. The arch is 30 feet high, but convergence of walls and down-slope of ceiling reduce the dimensions to 15 feet high by 50 or 60 feet wide at the first rimstone dam, the height of which also contributes to decrease the ceiling height above the floor. This rise of the gravel floor, but more especially the back downslope of the ceiling, brings an end to upright walking in 100 feet of length (Fig. 143). Crawling on stream gravel, with a clearance of about 2 feet below the flat, solutional ceiling, is possible for 40 feet or so farther. Beyond this, creeping and stooping height for some distance is reported. Further examination, however, was impracticable at the time. All the great flaring increase in dimensions which impresses one as he returns to the mouth is due to weathering and rock fall. The cave itself is not capacious, despite the promise of that great entrance arch. Under the rimstone dam at the entrance, under the fallen rock 60 feet back in the cave, there is a deposit of older, partially indurated stream gravel. Indeed, it is correct to visualize a cave of once adequate
Caves of Missouri 301 vertical dimensions that is now largely filled with sinkhole-contributed gravel. This aggradation has come about because of an extraordinary growth of tufa outside the cave mouth for a distance of 200 feet or so down along the stream; essentially the full length of the strongly cliffed alcove. The descent of the stream from the cave mouth across these tufa barriers is 30 feet. Fig. 143. Diagrammatic profile of Woody Cave, Christian County E. H. Woolrych, del. Accessory small caves in the western wall of the alcove are largely remains of collapsed, former extensions of the main cave. On the east side of the alcove, there are good solution pockets. These also are remnants of this former extension. CLAY COUNTY The Missouri Geological Survey lists only one known cave in this county. Mosby Cave This cave is stated to lie essentially at the contact of the Stranger (now Tonganoxie) sandstone formation and the Stanton limestone and shale formation. Its location is given as "just north of Kansas City". At the entrance and for some distance back, the ceiling and wall rock are of sandstone, but farther along its explored length of 250 feet limestone walls appear, and at the far end the cave is entirely in the underlying limestone. The entrance opening has been enlarged upward and sidewise by the crumbling of the sandstone and by the removal of its debris. In this way, the proximal part of the cave has been extended upward into the sandstone while the farther portions, unaffected by this procedure, show by their wall and ceiling rock that Mosby Cave originally was a normal solutional feature. Its unaltered cross section, back of the entrance portion, averages only 2 feet in height and width.
Three caves in Cole County have come to the notice of the Missouri Geological Survey during this investigation. One of them has been studied. Arch Cave SE1/4 SW1/4 sec. 31, T. 42 N., R. 12 W., Cole County Not shown on Eugene Quadrangle map. The cave is in the same line of Osage River cliffs as the locally famous Crabtree Cave, but it is about two miles farther west. Perhaps Arch Cave should not be called a cave, for it is open at both ends, is only 50 feet long, and averages 20 by 20 feet in cross section. It lies well up toward the summit of the river cliffs, its roof is less than 20 feet thick, and it stands fully half as high above the valley bottom as the highest bluff tops nearby. The south-facing and larger of the two openings, although in the cliff, opens in a broad re-entrant. Vertical walls below the mouth descend almost to the river which is 75 feet, more or less, below. There are some big, fallen roof blocks on the slope. Some are even out in the river channel. The tunnel beneath the arch, the adjacent river cliff walls, and even some rock walls exposed in the collapse sag north of the bridge are all diversified with good phreatic pockets. Arch Cave is but the ruins of a former phreatic cavern. Old flowstone and dripstone still cling to some walls. Crabtree Cave SW1/4 SW1/4 sec. 33, T. 42 N., R. 12 W., Cole County Not shown on Eugene Quadrangle map. The cave in which the outlaw Crabtree hid after being wounded is along the river road between Morss Ferry and Henley. The opening is up in the cliff face. It is reported that a cedar tree at the mouth of the cave was made into a ladder by Indians and used by Crabtree. The cave is reported to be small in cross section but long. Close to it on the east, there is an unnamed cave with a large opening, but it is not traversable very far. Natural Bridge Cave SE1/4 SE1/4 sec. 36, T. 42 N., R. 13 W., Cole County Not shown on Eugene Quadrangle map. Fowke (1922, p. 100) says that the opening to this cave is 10 by 10 feet, and that 10 feet back it is nearly closed by a stalagmitic deposit.
Caves of Missouri 303 CRAWFORD COUNTY There are six named caves in this county. One of them is widely advertised at present. Plans exist for the reopening of a second cave which is now closed to the public but was formerly a commercialized cave. Special sections in the first part of this report are given to both Cathedral Cave and Onondaga Cave. As in other counties, there may be more caves in this county that have not come to the attention of the writer. Bat Cave SW1/4 sec. 12, T. 38 N., R. 3 W., Crawford County Not shown on Sullivan Quadrangle map Bear Cave SW1/4 sec. 12, T. 38 N., R. 3 W., Crawford County Not shown on Sullivan Quadrangle map Fault Cave SE1/4 sec. 12, T. 38 N., R. 3 W., Crawford County Not shown on Sullivan Quadrangle map The Gasconade formation in the cliff of Huzzah Creek at this location is tilted 15 to 20 degrees down toward the east. It is part of a deformed belt which accompanies or is a part of the Leasburg fault. The fault plane itself is not shown. The cave is developed as a nearly horizontal but irregular tube that goes back into the hill from the base of the cliff at nearly a right angle to it. The cave can readily be entered for 150 feet, but it gradually diminishes in cross section until it is only a crawlway 200 feet back. Its orientation is approximately N. 80° E. The mouth is a slot elongated along the dipping beds, and its lowest place is about 30 feet above the creek. In wet weather, a small stream spills down the talus to the valley bottom. Inspection of the cave walls and the cliff face shows that the earliest solution work in this place made a plexus of irregular, small but connected openings along a particular bedding plane. The spongework character and the control by the dipping strata strongly suggest a phreatic origin which preceded the erosion of the creek valley and the making of the cliff. Convincing evidence that this suggestion is correct is found in the cave tube itself. The enterable cave is a nearly horizontal, linear passage which lies along the strike of the zone of pockety solution. It is an elongated
enlargement of a series of pockets that makes a continuous and relatively large opening through the plexus. The gravel on the floor and on the shelvings along the sides of this tube makes clear the method of enlargement. Vadose ground water which drains from the adjacent upland through the already-existing pockety zone supplies the wet-weather, free-surface stream which is still enlarging the tubular tunnel. This vadose course was established when Huzzah Creek valley was about 30 feet less in depth than today. As the creek deepened its valley, the underground stream found that the phreatic plexus farther down-dip was so filled with debris that it was not able to shift to newer, lower courses, and that its volume was too small and ineffective to do much in attacking the dolomite floor. It may well be that the development of the ravines in the upland has taken a larger share of the rainfall as direct runoff and, thus, has caused a decrease in the size and effectiveness of the vadose discharge of the cave. A little higher up-dip, there is a considerably smaller but similar horizontal tube which also lies in the plane of this same pockety zone. It looks like an earlier, short-lived, vadose drainage way. To reach Fault Cave, one wades the creek at the gravel bar near the Huzzah Country Club house. Puckett Cave SW\(\frac{1}{4}\) sec. 10, T. 38 N., R. 3 W., Crawford County Not shown on Sullivan Quadrangle map A small rock shelter in the Meramec River cliff enjoyed some brief fame in 1933 because of the discovery in its earthen floor of a complete human skeleton. The St. Louis Post-Dispatch featured the discovery in its rotogravure section June 11, 1933, averring the skeleton to be 8 feet in length. The published photograph fails to prove this. Unnamed Caves NE\(\frac{1}{4}\) sec. 16, T. 39 N., R. 2 W., Crawford County Shown as Caves on Sullivan Quadrangle map DADE COUNTY Dade County has one group of small caves in its central, southern portion. One of these caves was examined during the progress of this study. Unnamed Cave NW\(\frac{1}{4}\) sec. 26, T. 30 N., R. 27 W., Dade County Not shown on the Greenfield Quadrangle map A broad and rather shallow sink near Pennsboro is drained from its west side by a low-ceilinged cave which leads laterally farther west to an
Caves of Missouri 305 unknown discharge point. A large volume of storm water has carried fallen ceiling slabs well back into the cave. It is a low-ceilinged cave at the entrance and becomes gradually lower inside because of the mounting stream debris. The ceiling in places still has solution cavities to indicate phreatic origin. Some of these have been connected by ceiling channels made under essentially present conditions of ground water work when the detrital floor was up almost against the ceiling. The cave lies close to a fault which is probably a continuation of the Chesapeake fault, so well shown in Lawrence County. The strong tilt of the bedding in the ceiling and walls of the cave is doubtless associated with this faulting. DENT COUNTY There are nine named caves known in Dent County. Eight of these have been located. Two caves (one unnamed) are located approximately. Only one Dent County cave was examined in this study. Brief descriptions of some others are given from other sources. Apparently all are small caves. Ashley Cave NW1/4 SW1/4 SW 1/4 sec. 32, T. 32 N., R. 7 W., Dent County Shown as Saltpeter Cave on Montauk Quadrangle map This cave was originally shown as Ashley Cave on Missouri School of Mines map. Black Cave Sec. 10, T. 32 N., R. 7 W., Dent County Not shown on Montauk Quadrangle map Guthoerl Cave Sec. 24, T. 34 N., R. 5 W., Dent County Not shown on Stone Hill Quadrangle map Farrar says this is a small cave and has been entered for 100 feet but has not been thoroughly explored. Fowke (1922. p. 20) says it is small and muddy. Indian Hill Cave Sec. 2, T. 35 N., R. 7 W., Dent County Not shown on Meramec Springs Quadrangle map
Marsh Cave Sec. 10?, T. 35 N., R. 8 W., Dent County Not shown on Yancy Mills Quadrangle map This cave is apparently in Dent County but very close to the Phelps County Line. Fowke (1922, p. 23) says it is a shelter cave, 35 feet wide, 15 feet high, and 60 feet deep. It has a rock floor at the entrance and a wet weather stream.

Money Cave SW1/4 NE1/4 sec. 13, T. 35 N., R. 5 W., Dent County Not shown on Steelville Quadrangle map The entrance to this cave is 500 feet downstream from the crossing of Meramec River by Missouri Highway 19. The river bluff is somewhat cliffed in places near the crossing but most markedly so over the entrance which is plainly visible from the highway bridge. The Gothic, arched opening springs 20 feet clear above a mud floor which is 15 to 20 feet wide. This mud floor which is only 20 feet above Meramec River's low water level is a floodtime backwater deposit of the river that is identifiable as such for 200 feet in from the entrance. There is walking height for 430 feet. Farther back, the floor is higher and the cave width less. At this distance, there is a slump pit and dripstone growths that are awkward to pass. Apparently the cave continues but becomes much narrower. The mud here is very red and surely has not been deposited by a flooded river. The ground plan of the cave is winding, but the turns are rather sharp, and the course may have been determined by intersecting joints. There are, however, no cross passages or blind end, lateral chambers. Money Cave originated as a phreatic water course, antecedent to the erosion of the present river valley. Throughout the part examined, there are excellent spongework ceilings associated with larger cavities which, as seen from below, are empty ceiling domes. One of the largest of these domes is just inside the entrance. Its ceiling rises half again as high as that of the entrance arch. A vadose stream has used the cave. It flowed at about half the present open height, left cherty gravel on wall ledges, cut some horizontal meander niches, and made at least two very good half-cone niches under the entrance. This stream flowed on a red clay fill, remnants of which exist farther back. In removing the fill, the stream appears to have ceased meandering rather abruptly and to have cleaned out the rest of the clay rather rapidly. Much digging has been done in the mud floor. Fowke (1922, p. 21) tells of Indians who, heavily laden with gold and either fleeing pursuers or finding nothing to spend their money on, cached a treasure here. However, digging in the floor and hammering on the walls has never
Caves of Missouri 307 yielded anything so far but sad experience, and doubtless never will. People in the neighborhood add tales of counterfeiting and bootlegging activities which centered about this cave. Saltpeter Cave Sec. 13, T. 35 N., R. 5 W., Dent County Not shown on Steelville Quadrangle map Farrar, and Fowke (1922, p. 21) locate this cave in Dent County, three-quarters of a mile north of Short Bend Post Office. A length of at least 300 feet is reported. There is a side passage on the right, 15 feet inside the mouth.

Short Bend Cave Sec. 13 or 24, T. 35 N., R. 5 W., Dent County Not shown on Stone Hill Quadrangle map Farrar, and Fowke (1922, p. 20) locate this cave in Dent County, half a mile east of Short Bend Post Office. Fowke (1922, p. 21) says that it is a quarter of a mile up the river from Money Cave. The mouth is 25 by 25 feet, and it is 10 feet above the Meramec River in the Gasconade formation. The cave is known to be at least 150 feet long. One may walk upright for 80 feet back. The talus pile at the cave mouth is all that keeps Meramec River in flood from inundating the cave. Unnamed Cave An unnamed cave between Money Cave and Short Bend Cave is noted by Fowke (1922, p. 21). It has an entrance 15 by 15 feet, and daylight penetrates for 40 feet back. It is so low in the bluff that the Meramec River floods back into it. Watson Cave This cave is reported by Fowke (1922, p. 22)—who seldom if ever gives land locations—as "Watson, Twin, or Onyx Caves". He says that it is 14 miles north of Salem on the Meramec River. It consists of two parallel caves with a 10- to 12-foot partition separating them. The ceiling and floor meet 100 feet back. DOUGLAS COUNTY Only one cave is known in Douglas County. Its outer 2600 feet of length was examined during this study.
A very fine Gothic arch, 20 by 20 feet, with a rock floor, opens in the east bluff of Bryant Creek valley, about 30 feet above the floodplain. For the first 600 feet in the cave, the floor is covered with angular gravel. For more than 2000 feet beyond this distance, the floor consists of low terraces and slip-off slopes of a tan-colored slightly gritty clay. A small stream trench 2 to 3 feet deep cuts into the clay floor and makes the terraces. This stream, ordinarily only a much attenuated mud puddle, has been meandering and undercutting the bedrock walls apparently since the clay terraced floor was formed. In numerous places, tan-colored, clay remnants reach the ceiling. One needs rubber boots for traversing this long stretch. Beyond a distance of 2650 feet the writer gave up wading in deepening mud. The cave obviously continues much farther. The cross section of the cave at this point is as large as the average along the entire traverse. As there is no gravel floor for the last 2000 feet, there is no gradually rising gradient to bring that floor up too close to the ceiling for further passage. The ceiling is 10 feet above the floor virtually all the way. A curious feature of Brown’s Cave is that, although it is a simple linear passage without branches or cross chambers, the first half of its examined length has a definitely smaller cross section than the second half, and that the change in dimensions is as abrupt as in those caves where one enters a main chamber from a tributary passage. However, there is no T junction where the change occurs, nor any indications that there ever was one that has since become blocked. The cave is one simple, continuous, ground water conduit. Why the abrupt change in its caliber occurs is not understood. The ground plan has some reverse curves as tight as a letter S. They are most pronounced at floor level, although the entire chamber, 12 to 15 feet high, has the curves. The cave where these curves occur looks very much like a winding subterranean gorge that a vadose stream would make. However, the cave cannot be of vadose origin. The character of its walls and ceilings, the character of the topography under which it lies, and the orientation of the cave under that topography all bespeak a phreatic origin. The excellently developed spongework in the walls and ceilings, the many ceiling cavities and pockets, and a few broad domes which are twice as high above the floor as the average ceiling level indicate a phreatic origin. The meander slots are all near the floor. None of them is a wall-incised, half-cone niche. Little vadose alteration has occurred. The cave lies under a ridge between two north-south, parallel valleys; Bryant Creek on the west and an unnamed tributary on the east. The ridge is only 2000 feet across at cave level, along an east-west line drawn through the cave mouth. The summit width of the ridge is
Caves of Missouri nowhere more than 1000 feet, and its height above Bryant Creek is more than 200 feet. The cave is so much longer than the ridge is wide that only its prevailing northeast-southwest elongation allows it to be contained under the ridge, and even thus, its water must flow in a diagonal course essentially through the ridge. It may be that this water is leakage from the bottom of the tributary valley, and that a sinkhole in the bottom of the tributary is scheduled for some time in the future. At that time, gravel will enter, and the floor will be aggraded up close to the ceiling, as in so many caves thus related to sinks. It is certain that the ground water of this ridge never made a cave of this orientation and of this length in its rock. FRANKLIN COUNTY An unusually dense "population" of caves occurs in the south-central part of Franklin County. There are eleven named caves here. Nine of them are within the limits of the overlap map of Meramec State Park, and eight are in the park itself. One of these, Meramec Caverns, is widely advertised for visitors. Two others, Fisher Cave and Mushroom Cave, are managed by the State Park Board. Each of these caves has a special section devoted to it in the first part of this report. Each also has a detailed map made during this investigation. Most of the land locations of the minor caves are by Farrar. Bat Cave Owner: Lester Dill, Stanton, Missouri NE1/4 SE1/4 sec. 36, T. 41 N., R. 2 W., Franklin County. Not shown on Meramec State Park Quadrangle map. There are three entrances to Bat (or Mystery) Cave in the bluff half a mile downstream from Meramec Caverns. Two of them are cross sections of phreatic chambers, and only the lowest is a recent small vadose opening. The cave has no permanent stream, but in several places it shows much gullying and washed gravel on the floor, all leading toward the bluff. One phreatic opening is as low as the entrance of Meramec Caverns. The other opening is nearly at the top of the bluff, though its floor here is deeply covered by cliff talus which slopes both into the cave and out toward the river (two-way talus). The cave pattern consists of a rude T or Y of the large phreatic chamber type possessed by Meramec Caverns. Through the lower entrance, one enters the end of the T stem. The right-hand end of the T bar is much longer than the stem and leads one out onto the hillside but much higher up; nearly to the top of the bluff. The other end is a blockade of washed debris, clay, and fallen rock blocks. All of the large chamber characteristics of Meramec Caverns are here, along with a winding course without obvious joint control, roof.
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310 Missouri Geological Survey and Water Resources pockets, wall pockets, a fairly constant width, and a high ceiling. In addition, Bat Cave has suffered from so much collapse that the original solution ceilings in places are surely all destroyed. This collapse has occurred lately; as late as the slump pit and gully development; as late as the later dripstone. One could hardly argue that a new solutional ceiling could have been made by either phreatic or vadose water since the great fragments fell. Yet the ceiling, above floor aggregates of large angular roof blocks, has pockets and irregularities caused by differential solution. There is only one explanation for this. It is that the dolomite, if opened up and exposed almost anywhere in the vicinity of a main phreatic water way, will reveal solution cavities of the spongework type. The rock is already honeycombed with anastomosing phreatic pockets which prevailingly are too small to crawl through. They are satellite caves. Fall of ceiling slabs and blocks makes them a part of the main cave. Bat Cave has had a red clay fill; essentially up to the ceiling. This clay is without pebbles or dripstone, so far as can be seen. But the cave also contains in places, between slump pits, a fill of beautifully banded red clay. The laminae are of postcard thickness. The cave also contains strata of clay pebbles and chert pebbles. These strata are composed of reworked red clay and were deposited under vadose conditions. They are together at least 6 feet thick in section, and they occur so high above the slump pits and gullies that they must date back to a time when the Meramec valley floor was 50 to 75 feet above that of the present. Bear Cave NE1/4 SE1/4 sec. 2, T. 40 N., R. 2 W., Franklin County Not shown on Meramec State Park Quadrangle map Farrar reports a very small entrance which is difficult to find. A room beyond the entrance slopes steeply down to another small opening. Beyond this, the cave continues easterly. The cave is muddy, and in wet weather, much of it is flooded. Eddy Cave NE1/4 NW1/4 sec. 5, T. 40 N., R. 1 W., Franklin County Not shown on Meramec State Park Quadrangle map This cave is on the line of the old Spanish land grant. The entrance, says Farrar, is small, and the cave is low and muddy. Greene Cave SE1/4 SE1/4 sec. 31, T. 41 N., R. 1 W., Franklin County Not shown on Meramec State Park Quadrangle map This cave is in the bluff on the north side of the Meramec River.
Caves of Missouri 311 Indian Cave SW1/4 NW1/4 sec. 6, T. 40 N., R. 1 W., Franklin County Not shown on Meramec State Park Quadrangle map This cave is described in the discussion of Fisher Cave in the first part of this report. Mud Cave Center of south line, sec. 10, T. 40 N., R. 2 W., Franklin County Not shown on Sullivan Quadrangle map Farrar says that "one entrance to this cave is in Crawford County". Cave onyx was mined here in 1890. Sheep Cave NE1/4 NW1/4 sec. 13, T. 40 N., R. 2 W., Franklin County Not shown on Meramec State Park Quadrangle map This cave is at the mouth of Campbell Hollow and is now used as a bear den for the Park zoo. Apparently the cave has (or had) two open- ings. Farrar reports that it is "said to go through the hill". Unnamed Caves That part of the Park which is in Franklin County has at least six caves without names. One is in Campbell Hollow in the SE1/4 SW1/4 sec. 12, T. 40 N., R. 2 W. The known opening on the south side of the Hollow has a strong indraft, although no other openings have ever been found. It is a tunnel-like cave with numerous bottle necks. Another unnamed cave which can be reached only by boat on the river is in the SE1/4 SW1/4 sec. 2, T. 40 N., R. 2 W. A third is reported to be near the center of sec. 6, T. 40 N., R. 1 W., in the Meramec River bluff. The locations of the others are a bit indefinite, and none of these caves is shown on the Meramec State Park Quadrangle map. Walker Cave NW1/4 SE1/4 sec. 6, T. 40 N., R. 1 W., Franklin County Not shown on Meramec State Park Quadrangle map Walker Cave is also known as Onyx Cave. It is located near the western base of Lone Hill which carries the fire observation tower. Farrar says that it is a narrow fissure about 2200 feet long, and that in places it is very wet and muddy.
One cave is known in Gasconade County. Although it is not enterable for very far, it is extraordinarily interesting to a geologist. Cave Hill Cave NE1/4 NW1/4 sec. 14, T. 43 N., R. 6 W., Gasconade County Shown on Bland Quadrangle map This cave is not in the hill named on the map as Cave Hill but lies in the narrow ridge connecting it with another hill to the south. The entrance to the cave is about 1000 feet south of U. S. Highway 50. The entrance is a ponor, or collapse sinkhole, which is 50 feet or more in depth and is located in the center of the ridge crest. One should have a few feet of rope for passing the chert ledges on the brink. The remainder of the descent is over a talus cone which slopes steeply down from the eastern side and extends well under the western overhanging wall. It is a "live" cone which is fed by rock falls from the overhang. There is also some danger involved in going under the failing rock roof which overhangs the lower slope of the cone. Although a century-old elm has grown on the upper part of the cone, the collapse that made this sinkhole should be reckoned as not much older. The talus has grown notably within the memory of older residents, and our forecast is that another century will see the opening of the cave at the bottom completely obliterated. Apparently no one has ever gone more than 100 feet along the horizontal chamber to which the ponor leads. The cave contains a deep pool which reaches from one side to the other; a pool which at the time of this examination stood against the ceiling some 30 feet back in the cave. The pool is somewhat lower during summer drought, and at such a time a turn to the left may be reached and passed for perhaps 50 feet. Nothing more is known about the cave's extent. The southern wall is composed of massive Pennsylvanian sandstone for 40 feet down, and beneath the sandstone, there is a hard, blocky shale. The other walls consist of the shale which is capped by an irregular layer or irregular masses of chert. The vertical contact of shale against sandstone is very conspicuous where the overhanging western wall joins the nearly vertical southern wall. That contact is a plane of displacement; a fault. Not only is faulting shown, but also marked folding and squeezing of the shale is evident. This folding is brought out very clearly, because of some purple-colored layers in the otherwise grayish shale. The shale is folded or wrinkled by compression in approximately a north-south direction. The shortening by this compression produced the folding. No open cavity, like that whose roof collapse made the ponor, could possibly survive this squeezing and faulting of the Pennsylvanian.
Caves of Missouri 313 rocks. The cave is unquestionably a later, solutional feature developed in the subjacent Jefferson City dolomite, none of which shows above the water level. When the entire, filled sink structure at this place is considered, the cave itself is seen to be a very small affair. Two deep cuts along U. S. Highway 50 and three pits for refractory clay north of the highway show closely related deformations of subsided Pennsylvanian shale and sandstone. The summit of Cave Hill is essentially ringed with outcrops of "rim rock" (tilted sandstone dipping radially in toward a center). Perhaps half a square mile is so affected. The deformations are very complicated, but they appear to show that several different, smaller, "sink" structures are combined in a larger compound structure. Yet, as far as is known, Cave Hill Cave is unique among Missouri caves, if not among all caves. It is unique in its geologic setting, for it occurs in one of those localized subsidence structures known as filled sinks. These structures occur in more than 20 counties south of the Missouri River, and they commonly contain masses of rock which have settled into them from above. The rock in many of them has come from formations which no longer exist on the surface of the environs. Anyone familiar with Missouri's economic geology knows of them as possible containers of coal, refractory clay, pyrite, or hematite. Localized ground water solution in subjacent calcareous rock (Jefferson City formation, Gasconade formation, Eminence formation, perhaps Potosi formation) has made the cavities which contain the subsided younger rock and, in some, the deposits of economic value. The above is purposely a colorless statement of fact. The theorizing of the origin of the filled sinks has favored three ideas: (1) original surface sinkholes which became filled on that surface; (2) the collapse of cavern roofs which caused the younger rock to fall in; and (3) gradual solution beneath which allowed overlying rock slowly to subside, as the cavity in soluble rock below became enlarged. The relative merits of these three theories are not treated here (see Bretz, 1950). However, we want to know whether this cave is older or younger than the filled sink structure in which it occurs. The walls of the ponor answer that question unequivocally. The cave is in a steep-sloped, narrow ridge between the valleys of Pinoak Creek and Holte Creek. The floor of each valley is 100 feet lower than the crest of the ridge, 1000 to 1500 feet distant. The cave itself is some 40 to 50 feet above these valleys. Its solutional development must have preceded the ridge-and valley-making. If the flat top of Cave Hill records the former peneplain, as seems very probable, this cave lies at least 150 feet below that old land surface. Why should a cave in such a ridge-crest situation hold water? Our only suggestion is that sufficient clay shale has fallen into it to become a water-tight mud seal for the bottom. The water must be a standing pool, not a stream.
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GREENE COUNTY

There are at least twelve named caves known in Greene County. Three of them are provided with guide service. Seven were found and examined. The others have been located only approximately. Ash Grove Cave S1/2 sec. 20, T. 30 N., R. 25 W., Greene County. Not shown on Greenfield Quadrangle map. This cave, which was formerly known as Mason Cave (Shepard, 1898, p. 37), is located in the western part of the town of Ash Grove. The entire drainage of Dry Fork Creek enters the cave mouth and flows about 1000 feet underground to emerge on the opposite side of the ridge it underpasses. The drainage area of Dry Fork Creek covers only a few square miles, but heavy rains have given the cave about all the water it can carry. Stranded driftwood can be seen in the ceiling ledges through almost the entire length of the cave. The cave has three entry places: the intake mouth, the discharge mouth, and a skylight hole. The stream entrance opening is a symmetrical arch consisting of the ceiling and upper walls of an original solutional cave which was cut across by sinkhole collapse at the time Dry Fork Creek first discovered this subterranean short cut to Sac River. The stream exit opening is also a broad arch, but its walls and ceiling are wholly fracture-outlined. The original solutional outline has been destroyed by the fall of the huge angular blocks that cover the floor. The skylight which is 200 to 300 feet from the exit mouth is a minor sinkhole where the roof rock has wholly failed. Entrance here is easily negotiable on the talus debris. Mud bars, fallen roof rock, and dripstone partially interrupt the continuity of the cave. Except for these, Ash Grove Cave has adequate head room and a generous width of 20 to 30 feet, but it is not a simple tunnel through the hill. Repeatedly, one sees branch passages which lead off from the main passage but shortly become impassable, because of the rise, back along them, of the detrital floor or, in one place, because of a dripstone blockade. In another place, two routes separate and farther along reunite. The lower one is used by the stream, the higher one by cave-curious intruders. Apparently, the cave system consisted originally of an anastomosis of subequal passages. Stream debris has since blocked most of them. This anastomosis is satisfactory evidence that a cave existed before Dry Fork Creek drainage entered the picture. Further good evidence is the fact that the cave cross section in one place is inadequate for the flash floods. The bottleneck has not only flooded the cave upstream to the ceiling, but has ponded Dry Fork valley almost enough to cause overflow into the pirated and abandoned lower part of the
Caves of Missouri 315 original stream course. More evidence is also found in this abandoned, old valley bottom in the extreme western part of the town and in the young (rejuvenated) inner gully which reaches from the cave up Dry Fork Creek as far as the bridge on County Road F. Ash Grove Cave was made by a deep circulation that followed the intersection of joints and bedding planes in this rock before it has been carved by surface streams into the existing valleys and ridges. Dry Fork water today is doing much to destroy the cave, and almost nothing anywhere to enlarge it. Fig. 144. Diagram of fracturing or slicing in the wall of Ash Grove Cave, Greene County E. H. Woolrych, del.

Failure of the wall rock in several places is caused by the fall of great curved slices whose fracture planes dip steeply back into the base of the wall (Fig. 144). This fracture pattern may be related to the "shearing" reported for a number of other caves, and imputed to a former greater roof load. It is, however, not true shearing, for there has been no displacement along the plane of separation. The slices are several feet thick and only one slice shows in any one wall. Fulbright Spring and Cave NW1/4 NW1/4 sec. 2, T. 29 N., R. 22 W., Green County Shown as Springfield Water Works on Ebenezer Quadrangle map The spring is one of several sources drawn on by the Missouri Water Company for supplying the city of Springfield. It is at the base of the eastern valley wall of Pea Ridge Creek where the slope of the valley wall is 100 feet high and mostly cliffed. The spring orifice is now entirely enclosed in a concrete housing, but it is described as a cave which has been explored by the Water Company for a distance of a quarter to half a mile. The cliff for 30 feet above the spring contains a dozen or so solution pockets, tubes, and slots. Two of them have been boarded up because they can be followed back down to the level of the water course. All of these are parts of an anastomosing plexus. They all functioned together at one time, but the upper ones are abandoned now because of valley deepening by Pea Ridge Creek. Other parts of the structure are reported to exist nearby but are concealed by the vegetation. Pea Ridge Creek enters South Dry Sac Creek about 1000 feet downstream from the spring. Three and three-tenths miles in a straight
316 Missouri Geological Survey and Water Resources line up South Dry Sac Creek from this junction, there are two springs in the stream bed that discharge a volume of water comparable to that of Fulbright Spring. Years ago a dam was built below these springs, and a water power grist mill, the Valley Water Mills, was operated at intervals when sufficient water had accumulated behind the dam. The Missouri Water Company, already operating at Fulbright Spring, was dismayed to have its spring entirely fail after the dam had been completed and the millpond back of it was being filled for the first time. They soon found that Fulbright Spring flowed with original volume only when the reservoir at Valley Water Mills was discharging, and the spring's flow greatly decreased or ceased altogether when that reservoir had been depleted and its spillway was closed for refilling. The Water Company's practice for some time was to send grists of corn to Valley Water Mills when the Fulbright flow dropped toward a danger point. The Mill's property finally was purchased by the Water Company for its own protection and a new dam was constructed. Today, the reservoir water is conducted through a pipe for about a quarter of a mile below the dam to a crevice in the bottom part of the valley. This water traverses the three miles to Fulbright in about five hours. Not all the flow is discharged at Fulbright. Dye tracers show that part of Valley Mills water is discharged at Ritter Springs, about a mile west of the waterworks. There is an extraordinary feature involved in this subterranean course. It essentially parallels the surface valley of South Dry Sac Creek. Water leaves the creek valley for an underground route that lies almost alongside the surface drainage route. The altitudes of intake and discharge are almost precisely the same as those of the surface valleyway at the two points. It is inconceivable that such an underground drainage route ever could have developed, subsequent to the making of South Dry Sac valley. It seems impossible to avoid the conclusion that Dry Sac Creek and its tributary, Pea Ridge Creek, have, at two places, incised an already developed, ground water, conduit system. The subparallelism and the common direction of flow are fortuitous. Descent of the ground water for this distance is 90 feet, that of South Dry Sac Creek, 100 feet. The actual, total, underground distance and the precise course are both unknown. By stream course, it is a little more than the straight-line distance above noted. Rather recently, in terms of valley development, South Dry Sac Creek has shortened its course by nearly a mile. Look at the cutoff and abandoned, incised meander in section 36 of the Ebenezer Quadrangle map. This cut-off may well have begun through discovery of a cave route at the incision. Compare this with Sinkin Creek in Shannon County.
Caves of Missouri

317 Jones Cave SW1/4 NE1/4 sec. 27, T. 29 N., R. 21 W., Greene County. Shown as Jones Spring on Galloway Quadrangle map. It is stated by E. M. Shepard (1898, p. 38) that this is "the cave from which Jones spring issues". Lake Cave T. 29 N., R. 22 W., Greene County. Farrar locates this cave "in City Park, Springfield".

Lapham Caves Sec. 23?, T. 30 N., R. 23 W., Greene County. Not shown on Willard Quadrangle map. Shepard (1898, p. 38) lists "the Lapham caves and sinks in Cass township", and gives the section, township, and range, but the Willard Quadrangle map, with a contour interval of 10 feet, shows no sinks or caves in section 23.

Little Yosemite Cave Sec. 28, T. 29 N., R. 21 W., Greene County. Not shown on Galloway Quadrangle map. This cave's location is given by Shepard (1898, p. 38). Mason Cave Sec. 3, T. 30 N., R. 24 W., Greene County. Not shown on Greenfield Quadrangle map. This cave's location is given by Farrar who further states that it is "unexplored" and "southwest of Phoenix, Missouri".

Steuery Cave SE1/4 SE1/4 NE1/4 sec. 21, T. 29 N., R. 21 W., Greene County. Not shown on either Galloway or Ozark Quadrangle maps. A collapse sinkhole entrance 50 feet deep leads to this narrow, joint-determined cave. A vertical slot cuts the lowest 15 to 20 feet of the slope of the hole. The sink is used for the disposal of all manner of castoff human equipment, and the bottom was flooded and very muddy at the time of examination. It is obvious that no capacious cave exists here; noisily flowing water, farther back, can be heard from the bottom of the sinkhole.
318 Missouri Geological Survey and Water Resources Winoka Spring and Cave Adjacent corners (SW and NW) sees. 15 and 22, T. 28 N., R. 21 W., Greene County Not shown on Ozark Quadrangle map The spring is adequately described by Beckman and Hinchey (1944, pp. 126-127). There seems to be no air-filled space above the discharging water at any of the openings along the water-carrying horizon. The spring mouth is the hillside transection of a bedding plane anastomosis in Mississippian limestone. No central trunk route has developed; no vertical deepening has occurred. Yet the water cascades, immediately on emerging, down steep, valley wall slopes. There is little here that could be called a spring alcove. The spring appears to be a rather recent vadose occupation of a phreatic, bedding plane slot. The purity of its water is to be questioned. The cave which is probably not 1000 feet distant has no relation to the spring in the present cycle of erosion, although both subterranean courses may have been parts of one phreatic system originally. The cave mouth is set back somewhat from the river bluffs in a minor ravine. At this place, there is the only cliffing along the ravine, and the mouth is about all the enterable cave there is. Much storm water discharges from the cave into the side of the ravine. Fallen ceiling slabs are nicely faceted by it. There is no forest litter and little or no chert gravel on the floor. The slabby fill is so close to the ceiling that only crawling space exists farther than 50 feet from the entrance. Just to the north of the cave, there is a marked little re-entrant in the river bluff. Its walls are 100 feet high and are largely cliffed. A small cave is reported to be in these cliffs. There is a sinkhole on top, in line with the elongation of the alcove. The ensemble of spring, cave, and alcove should be interpreted as the ruins of a phreatic cavern system; ruined because of the valley-making of the James River. HICKORY COUNTY One cave in the unmapped, eastern portion of Hickory County, has been studied. Almon Cave SW1/4 SE1/4 sec. 11, T. 37 N., R. 20 W., Hickory County The entrance to this cave is about 100 feet above Little Niangua River at the foot of a 140-foot cliff of Gasconade dolomite. It is a marked cliff at this place for only about 350 feet along the valley wall, and there are only detrital slopes both north and south of the convex,
Caves of Missouri 319 valley wall buttress. Solution pockets and truncated, phreatic tubes occur in the cliff face at all levels, but they occur most abundantly at the horizon of the cave. Indeed, the big overhang that makes the beetling brow, under which the cave mouth is situated, is itself only one wall and part of a ceiling of a former cave chamber that was much more capacious than anything still surviving here. Actually, a massive dripstone unit of the wrecked chamber still stands under the overhang. It is 8 feet high and 4 to 5 feet in diameter. Several hundred feet farther south and overlooking the river in the same fashion, there is a smaller, less marked, rock buttress that tells the same thing; the wreckage by the river of a cave. In both cases, the old chamber and the present Little Niangua River coincided. Possibly the two chamber relics should be considered as part of one larger system that carried the pre-Niangua, phreatic, ground water flow down the north slope of the Ozark dome. The flaring mouth of the cave measures about 25 feet by 25 feet. Inside, the height remains the same for some distance, but the width decreases to approximately half the height and so continues for 175 feet. Beyond that point, the cave is a creepway, straddleway, stoopway, and squeezeway. It is not especially difficult to negotiate, but it necessitates a good bit of body contact with rock walls. About 75 feet inside, the cave is divided by a pillar of native dolomite about 45 feet in circumference. Each of the two passages on either side of it is smaller than the undivided cave, and their ceilings differ in height by at least 6 feet. The upper half of the first 175 feet of capacious cave length appears to be phreatic in origin, for very well-developed spongework covers its walls. But the lower half of the chamber height shows almost no such features and may well be vadose. The cave, the mouth of which is about 100 feet above the Little Niangua River and in Gasconade-Van Buren rock, is a bedding plane-determined route back to the end. If a vadose stream had widened this lower half, it did so when the river valley was only about half as deep as it is today; about halfway back in the present cycle of erosion. The pillar with the ceilings of different heights on either side surely is of phreatic origin. A constricted passage which can be followed for 300 feet farther is full of marked turns. Some of the turns are as much as 150 degrees, and each is rather sharp. There is an enlargement of the passage 475 feet from the entrance where truly magnificent spongework is found in the ceiling and walls. But beyond this point a red clay which is obvious in the last 100 feet or so completely closes the cave, and the dolomite rock is cut through repeatedly by thin seams of red clay. This 300 feet of length is a phreatic tube. About a third of its length has a fine, little, vadose gorge cut in the floor. Most of the gorge stays within the width of the tube, but in places it disappears back in a low meander slot under the phreatic wall.
320 Missouri Geological Survey and Water Resources High school students who have penetrated to the (faintly gritty), red clay-filled region have left a moulded devil sitting on a ledge. He is a rather small devil, obviously of subordinate rank, and is hardly to be feared. Yet in that same constricted passage, a local character of somewhat more limited mentality than most of us became confused and never came out alive. He had gone hunting, and the woods were searched for two weeks before the cave was examined and his body found in it. Almon Cave shows no branching passages, but the abundance of solutional openings in the cliff outside indicates that it was only the main route of an entire system of phreatic circulation routes before the valley of the Little Niangua River was made. There is very little dripstone in Almon Cave. There are wall ridges of flowstone within 100 feet and less of the entrance, and there is a sheet of wall flowstone on the exposed cliff. The conditions under which such deposits are made are not clearly understood. HOWARD COUNTY A group of small caves has been examined in the Missouri River bluffs of the southeastern portion of Howard County. The only one carrying a name is reported on here. Jackman Cave Sec. 2 or 3, T. 48 N., R. 15 W., Howard County Not shown on Rocheport Quadrangle map Jackman Cave is along the Missouri, Kansas, and Texas Railroad tracks between Rocheport and the viaduct on U. S. Highway 40. According to local accounts, Jackman was a Confederate "general" who hid in the cave until his broken leg mended. He was fed by his sister "old lady Mullins", an inhabitant of Rocheport. Legend also says that Jesse James and his men sheltered their horses in Jackman Cave. To reach the cave, one walks the railroad tracks and scrutinizes the closely parallel cliff. There are at least a dozen solution holes in the distance indicated above that are large enough to crawl into, but only one extends back beyond the reach of daylight. Only one of these shelter-like holes is large enough to allow a horse to enter, and its floor would afford bedding-down space for not more than half a dozen horses. All of these rock shelters are remnants of solution caves and are intersected by the river cliff. None is a weathering niche. Most of them show some solutionally rounded surfaces, but all are badly broken down by roof collapse. The fallen debris is now firmly cemented in place. Much of the collapse occurred before the river made the cliff. Some of the cavities are widened joints, but most of them are controlled
Caves of Missouri 321 by bedding planes. None looks as though it ever was a major cave. A sheeting structure, probably caused by weathering, shows on some cliff faces. It begins or ends abruptly at contact of certain strata; apparently developing preferentially in some layers. HOWELL COUNTY Only two caves have ever been reported to the Survey from Howell County. One has been seen during the present study. Stalactite Cave NW1/4 NE1/4 sec. 5, T. 23 N., R. 7 W., Howell County Not shown on West Plains Quadrangle map The entrance to this cave is by an asymmetrical collapse sinkhole about 50 feet deep. At the bottom of this sink, the talus debris continues down under a ledge-like roof rock to a rock platform. Below that, there is a 20-foot vertical cliff which can be by-passed by means of a narrow canyon-like slot cut by water descending from the sinkhole bottom. Talus debris has gone over this cliff and has encountered another shelf-like, irregular platform, but most of this debris has continued over the edge to make a perfect cone at the bottom of the large chamber of the cave. Ladders are necessary in two places for this descent. The total height of the tortuously shaped, solutional ceiling above this lowest floor of debris and mud is about 100 feet. The ceiling is essentially at the level of the sinkhole bottom. Hence, the total depth is about 150 feet, and the descent, smoothed out, is at an angle of about 45 degrees. The cave floor is nearly circular and has a diameter of about 150 feet. The high irregular ceiling is off-center. It is nearly over the lower shelf just noted, and it crosses the room in one direction. Because of its generalized slot outline, two sides of the large chamber have much lower rock for ceiling; scarcely 8 feet above the flattish floor on which the debris cone stands. On the entrance side of the chamber, this ceiling is the underside of the lowest shelf crossed in the descent. The shelf is probably not 10 feet thick, but it overhangs the circular floor for a chord length of 60 feet and a radial distance of about 25 feet. It is surprising that this shelf holds its own weight. It is even more surprising when one considers the large aggregate of rimstone on the top of the shelf and the accompanying dripstone fringework on the free edge. The overhang of this shelf results from the collapse of wall rock beneath it. The fallen material has disappeared somewhere below the debris floor. Only the uppermost stratum of the former wall has remained.
Missouri Geological Survey and Water Resources Such collapse requires a sufficiently large solutional cavity beneath to receive the fallen rock. The low-ceilinged portion directly opposite has been made in the same way. Almost all the walls at the bottom of the cave are fracture-determined. A huge solutional cavity must have once existed lower than the present floor. Stalactite Cave originally had an unusual shape and a most unusual height. The big chamber is noteworthy also for its large dripstone aggregates. Stalactitic groups, massive stalagmites, and a number of large columns are under these low ceilings and on the high wall opposite the entrance route. Some of this dripstone is now undergoing solution. There are stalagmites with craters and solution furrows. There is "drapery" dissolving away to thin frayed edges. The pattern of their growth is still to be seen in them. There is another chamber in this cave that is quite unlike the big chamber. It branches off from the upper walls and can be entered only by a precarious, ledge-perched trail from the top of the highest shelf encountered in the descent. It is a ragged-ceilinged and ragged-walled, horizontal tunnel, without dripstone or fall rock. It is almost entirely solutional in origin, and the raggedness bespeaks phreatic solution. Projecting chert layers and masses are prominent, and there is much irregularity in the yielding of the dolomite itself. This high side passage has quantities of red clay for its floor and some walls, and patches of it lie in pockets up to the ceiling level. It is doubtfully a phreatic clay. It is also doubtful if the big chamber may have been made entirely by failure of older cavities below. The ragged ceiling of that large chamber, however, surely is phreatic and should be considered a floorless continuation of the tunnel passage. A hundred feet or so back in the tunnel, the clay fill is so close to the ceiling that further traverse is barred. The most surprising feature of Stalactite Cave is the disappearance of drip water and rimstone pool overflow beneath one wall at the cave bottom, more than 100 feet below the level of Little Greasy Creek (spelled "Gressy" on the West Plains map) valley bottom less than 750 feet distant. The sinkhole bottom itself is 15 feet below the level of the creek bridge. Missouri caves display few examples of this kind, and certainly none so striking. There clearly is, in these hills, no water table adjusted to the surface streams. From this and other evidence, the water table is far below valley bottoms, and this indicates well-developed, subterranean drainage. Where the water disappears at the bottom of the big chamber, the altitude is, by estimate, something like 750 feet above sea level. To find a place in Howell Creek bed as low, one must go downstream at least seven miles in a straight line, and since some gradient for the subterranean drainage must be allowed for, that distance must be correspondingly increased. It is doubtful if there is any emergence of this disappearing cave water short of Mammoth Spring, Arkansas. The region of West Plains is almost without springs. The northern half of the West Plains Quadrangle and most of the Thayer Quadrangle
Caves of Missouri 323 is replete with sinkholes; many of them are the steep-walled, collapse type. Grand Gulf, itself in Oregon County, is the uncovered part of a considerable length of linear cave which is well below present valley bottoms. The deep subterranean drainage which is revealed by Grand Gulf, Stalactite Cave, and some of the deep ponors in the area is well integrated and far below adjacent valley bottoms. Because of this underground drainage, the water table is low, and springs are lacking. The subterranean drainage routes are not the consequence of a low water table, for they, having a prior existence, have forbidden the development of any higher water table. Thus, we are arguing again that the caves are older than the surface valleys. Three times, under observation, the subterranean system of Stalactite Cave has become filled. On these occasions, water stood in the cave up to the stream level outside. But, like several other caves that become deeply flooded in times of excessive rain, this water drained out in a few hours after the rain ceased. An extraordinary subterranean drainage encountered in 1948 during prospect drilling south of Flat River and Elvins in St. Francois County in the NE 1/4 SE 1/4 sec. 31, T. 36 N., R. 5 E., seems to require the same picture of integrated, underground drainage. This drainage is far below surface valley bottoms, and the escape to the surface must be many miles distant. The drilling rig was set up on an alluvial terrace in the St. Francis River valley, about 30 feet above stream level. From a depth of 33 to 70 feet the drill penetrated solid rock. At 70 feet the drill entered a cavity which was filled with mud and water. Passing this, the drill continued in rock to 330 feet where it dropped 3 feet into another cavity. Immediately, the water and mud at the 70-foot level ran down the drill hole with a roar that was audible 50 feet away from the drilling rig. Within an hour or so, small sinks began developing in the surface of the alluvial flat close to the rig. In two days nearly 20 such sinks had been formed within a radial distance of 500 feet. By this time, casing had been set past the 330-foot level and the roaring had stopped. Except for minor deepening of three or four of the sinks, the collapsing also ceased. Two groups of sinks were formed. One group of four developed under a wooded tract NNE from the drill hole. The largest sink carried a tree 12 inches in diameter down for 4 feet and tipped it over. The other group, averaging about 500 feet distant in an easterly direction, contains more than 15 sinks. The largest sink is 90 feet long and 20 feet wide. It is straight and is aligned about northeast-southwest. The others are approximately equidimensional. The deepest one has a vertical cliff 12 feet high on one side and a diameter of about 20 feet. Another sink dropped a tract of a cornfield 20 by 20 feet for 4 feet; the corn still standing vertically. Although the sinks vary in size and shape, the charac-
324 Missouri Geological Survey and Water Resources teristics of each are similar. Invariably the outline of a sink is marked by a series of parallel fractures which are, in turn, parallel to the edge of the sink. The marginal fractures have vertical displacements which range from 2 inches to 12 inches with the greater displacements toward the center of the sink. They are 6 to 18 inches apart, and there are from 3 to 8 of these fractures. Thus, a series of steps is formed that lead toward the center of the sink. The area affected in the sinks probably is wider than the opening through which the supporting material flowed to escape down the drill hole. This is analogous to the cone-shaped slumpage observable in a sand-filled hourglass. However, the linear form of the sinks suggest a linear form for the outlet. Therefore, it is deduced that the outlets were vertical or nearly vertical joints in the subjacent bedrock and were connected to the crevice at 70 feet. This crevice had probably been enlarged by solution and filled with water-saturated sand and mud. When the supporting material was allowed to escape through this crevice, down the drill hole into the crevice at 330 feet, a readjustment of the surface resulted. Onyx Cave SW1/4 sec. 34, T. 26 N., R. 7 W., Howell County Shown on Montier Quadrangle map JACKSON COUNTY James Brothers' Cave E1/2 sec. 35, T. 47 N., R. 31 W., Jackson County Not shown on Pleasant Hill Quadrangle map Farrar reports that the entrance to this cave is 4 feet by 4 feet, and that local authorities claim the ubiquitous James boys used the cave for a hideaway. The boys would appear, considering all the claims of this kind, to have been Missouri's first and most active spelunkers. Of the same order of trustworthiness, there are reports that the cave has been explored for two miles. JASPER COUNTY Two caves are known and located in Jasper County. One is filled with water today, although it once was exhibited to visitors. The other is locked against all but members of the Ku Klux Klan.
Caves of Missouri 325 Crystal Cave SW1/4 NE1/4 SW1/4 sec. 3, T. 27 N., R. 33 W., Jasper County Fourth Street and Picher Avenue, Joplin This is a true crystal cave; i.e., a cave completely lined with crystals; a huge geode. It was discovered about 50 years ago when heavy pumping in adjacent mines drained it of a formerly complete water fill. For a decade or so, it was operated as a subterranean dance hall. The shaft opening was housed over, and a stairway with concrete retaining walls was constructed about 30 feet below street level. When the mining activities stopped, the water rose again; the cave returned to its earlier condition, and has so remained. Winslow (1894, pp. 566-567) said that "the entire surface of the cave, top and bottom, is lined with calcite crystals so closely packed as to form a continuous sheet, and most of them are of great size and with well formed faces". He noted many to be a foot or so in length and the maximum length to be two feet. "The entire absence of anything like stalactites is noticeable." His sketches show a chamber about 55 feet wide, 225 feet long, and 10 to 15 feet high that is elongated northeast-southwest. The cave extends northeast from the intersection of Picher Avenue and Fourth Street almost to the next street north. Walls of the entrance house were still standing in 1947. They were built mostly of limestone and chert blocks but contained some calcite and sphalerite crystalline masses, taken from the cave, that measure up to 2 feet in diameter. Ku Klux Cave N1/2 sec. 26, T. 28 N., R. 34 W., Jasper County Not shown on Joplin Quadrangle map Farrar's notes indicate a cave at this place called Spanish Treasure Cave, but the writer found no one who knew it by that name. All called it Ku Klux Cave. It lies about a mile west of old Bellville (Zincite P. O.) on the Joplin folio map; about half a mile from the Kansas line. Entrance could not be obtained. Three "trustees" were all out of reach by telephone, and the local caretaker was adamant. The opening is housed over with two big iron doors; one for automobile entrance and one for persons. Not only were the doors locked, but they were bolted with big machine bolts. The caretaker says there is room inside for 100 cars to park. The Ku Klux Klan platform and paraphernalia are reported to be still in there. The cave is said to have a large, high auditorium and "queer upside-down holes" in the ceiling.
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The opening is in a much subdued and wooded low cliff of Mississippian limestone. Apparently, it is a true solution cave. A level floor for cars and an audience room would be impossible in most collapse chambers. The Joplin, 10-foot contour map shows Turkey Creek valley here to be more than 100 feet deep. The summit country is flattish; a peneplain remnant. This cave, if of phreatic origin, lies more than 100 feet below that peneplain. JEFFERSON COUNTY

Of the two caves known in this county, only one was examined during this study. Rice Cave

Owner: C. M. Rice*, 408 Olive Street, St. Louis, Missouri NW1/4 sec. 4, T. 41 N., R. 5 E., Jefferson County

Not shown on Kimmswick Quadrangle map A spring emerges at valley bottom level from the very low opening of Rice (or Ice Box) Cave with just enough air above the water to allow crawling. The first explorers, after 400 feet of crawling, reached the real cave; the high chamber which now is entered by a vertical shaft and ladder. The cave is joint-controlled, but its course steps over from one joint to another, of a set which strikes N. 45° E. to N. 60° E. The visitor goes northeast from the valley for several hundred feet to the traversable end of this cave system. The pattern is a series of slightly overlapping en echelon slots. Most of the overlaps have, in addition, one or two very minor joint slots (Fig. 145). The cave is widest at Fig. 145. En Echelon Joint-Determined Passages, Rice Cave, Jefferson County E. H. Woolrych, del. these overlaps. All the overlaps are to the left. This regular complexity in a cave pattern is unique in the writer's experience. Well back toward the end of this system, there is a slot of quite different character. It is not straight and obviously does not have joint *Deceased. Currently owned by heirs of the Rice estate.
Fig. 146. Rice Cave, Jefferson County Gypsum rosettes and blades. Photograph by G. Massie, Missouri Resources Division. Fig. 147. Rice Cave, Jefferson County Oulopholite or gypsum "flower". Photograph by G. Massie, Missouri Resources Division.
Missouri Geological Survey and Water Resources control. Its windings increase with increasing depth, like subterranean gorges which meandering cave streams make, but its ceiling and floor, which is a fill, correspond in level with the ceiling and floor of the joint chamber. The entire cave is in about the same stratigraphic level. The ceilings taper up into slots which, in most places, have very thin perforated chert layers projecting, or even completely spanning, the uppermost foot or so. Solution above these fragile layers has made much elongated, upside-down, closed, trough-like basins back of the partial bridging. This looks far more like phreatic than vadose work. There are also some bowl-like ceiling cavities that quite surely are phreatic. There is no spongework in the cave. Only one truly good meander niche was seen along the joint chamber walls. It begins more than halfway up to the ceiling and seems to have carried the vadose stream during all of that deepening. If so, the adjacent joint slot, of phreatic origin, must still be clay filled. The cave shows no red clay, although there is much stratified silt which the cave stream has deposited during the present epoch. Because the cave floor is higher than the valley floor, the cave, if phreatic, should be truncated by the valley slope. However, no dimple indicates the place. The present natural opening, with its low roof of unjointed bedrock, is off the strike of the joint chamber and evidently is a fairly recent route discovered since the present depth of the valley was attained. The second unique feature of the cave, among Missouri caves, is its secondary gypsum. Well back in the cave, some walls carry aggregates of flat, clustered, gypsum crystals which hug the rock face (Fig. 146). Some apparently have grown out into the clayey silt filling. Two or three are several inches long but, now lying loose, are not certainly growths once anchored to the wall rock. There also are gypsum flower growths (oulropholites) on the walls. Most of them are small and much elongated along bedding cracks. All have petals or blades that recurve away from each other on opposite sides of the crack (Fig. 147). The cave is kept locked and entrance is only by permission of the owner. Unnamed Cave Near line between sees. 8 and 17, T. 4 N., R. 38 E., Jefferson County Not shown on DeSoto Quadrangle map This cave is reported to be a deep (75 feet) Indian rock shelter with an opening 40 feet wide and 20 feet high. A funnel-like extension leads farther back, but it is choked with dripstone.
Caves of Missouri 329 LACLEDE COUNTY Two named caves are known in this county, and both are shown on the Lebanon Quadrangle map. One of these caves has been studied during this investigation. Howell Cave NW1/4 NE1/4 sec. 8, T. 32 N., R. 15 W., Laclede County Shown on Lebanon Quadrangle map A beautifully proportioned, Gothic archway, which is about 20 feet high and 20 feet wide at the bottom and is situated in a cliff of the Osage Fork, leads back into Howell Cave. The floor is a bedrock ledge which hangs about 10 feet above the river terrace at the base. It is about 20 feet above the abandoned river meander below the narrow terrace. A short ladder is used to climb this little cliff. The arch walls carry some fine, large, phreatic pockets which are irregularly spaced. Farther back, there is excellent, ceiling sponge-work. The cave apparently is of the simple, sinuous, linear type. Its width decreases gradually as far as traversed, and because of a smoothly rising floor, head height decreases as well. This probably is due to the rising detrital and flowstone floor which brings one up into the narrower, upper part of the cave's cross section. Because of an unfortunate failure of the investigator's lighting equipment, and because of the lack of opportunity to revisit Howell Cave, not much was seen of its more remote portions. Local accounts agree that it has been entered a long way, and that there is walking height farther back than the lowered ceiling noted. Apparently, there is also some wading to be done. No vadose erosional features were seen, but the floor obviously is stream-graded and has a flowstone armor on top or close to the surface. The trickle of today has made a tiny channel in that floor. Another interesting item regarding the floor is that in places it is covered with small cave "pearls"; irregular and warty or lobate in shape and composed of impure, chocolate brown calcite with excellent banding. The "pearls" are rather old and soft and break readily into concentric shells. Elsewhere, the gravel on the floor is of irregular chert pebbles, and the individual pieces are coated with the same brown calcite. Concentric banding is very obvious also, and in some instances a warty surface covers the smooth, conchoidal, fracture surfaces of the chert. There is flowstone beneath these "pearls" and coated pebbles, but no rimstone pools are indicated, and surely no splash has occurred where they grew. The only dripstone seen is a large, much-weathered, columnar mass just inside the entrance.
A short distance north of the cave entrance, a lively clear stream emerges from the cliff not far above floodplain level. The terrace is missing at this place. Apparently the terrace, continuous at one time, had been eroded through by this stream. If so, ground water discharge at this place is a recent affair. The manner of the stream's appearance is unusual. No localized spring mouth is seen. The stream flows parallel to the base of the cliff in a kind of trench between the cliff on one side and a low ridge, either of talus or of a slice of subsided rock, on the other. There is no enterable cave at this place, but an older, ground water passage at the very bottom of the valley apparently has been recently discovered and taken over. When one has seen the numerous solution holes along the several hundred feet of this cliff, he realizes that Osage Fork has been cutting laterally into an older phreatic complex. One stratum which is below the cave floor but above the terrace should probably be described as having a bedding plane anastomosis. There is another cave still farther north in the same cliff. Its opening is forbiddingly low, and it is reported to be a wet cave. All these features go together as members of one complex. They are all situated in the steep, blunt end of a narrow ridge 100 feet high, less than 1000 feet wide, and more than 3500 feet long. This ridge is bounded by sharply cut ravines which carry only ephemeral streams. The ridge cannot be thought of as the source for the ground water stream. The subterranean stream course must lie either 100 feet deep in the ridge or very shallowly beneath a ravine bottom. Were it in the latter place, the stream almost surely would have its spring exit in a ravine. However, the entire system is that of a phreatic, ground water system which is now drained by modern valleys. Part of the system carries vadose water by a route out of harmony with the topography. Howell Cave is nearly 200 feet below the flattish, divide top which, at 1300 feet above sea level, seems clearly to be a remnant of a former peneplain. Saltpeter Cave NE1/4 NW1/4 sec. 24, T. 33 N., R. 15 W., Laclede County Shown on Lebanon Quadrangle map LAWRENCE COUNTY Unnamed Cave SW1/4 sec. 29, T. 29 N., R. 25 W., Lawrence County Not shown on Halltown Quadrangle map This unnamed cave is the only cave reported for Lawrence County. It was not seen during this study.
Caves of Missouri 331 LINCOLN COUNTY Two caves were visited in Lincoln County during this investigation. A third cave is reported, but it is not definitely located. Fern Cave SE¼ SE1/4 sec. 34, T. 50 N., R. 1 E., Lincoln County Shown on Elsberry Quadrangle map This small cave is apparently entirely vadose in origin. Previously unopened joint cracks now drain small shallow sinks, a quarter of a mile distant, to the bottom of Bob's Creek valley. The solution cave is tubular in cross section and has strongly facetted sides and a rock bottom. The opening is a crumbling, unsafe archway which was made by the weathering away of the cliff rock at the mouth. One may walk back into the cave less than 100 feet. Beyond this distance Fern Cave is a creepway and crawlway. Local informants say that there is head room farther inside. The limestone in the cliff dips about 7 degrees to the south. According to the State Geological Map it is Devonian in age, and its dip may be associated with a minor fault in the next township to the east; a fault which strikes directly toward the cave. Foley Cave Foley Cave is reported to be "a couple of miles" from the village of Foley, Lincoln County. Gentry Cave SW1/4. NE1/4 sec. 31, T. 50 N., R. 2 E., Lincoln County Not shown on Elsberry Quadrangle map The mouth of Gentry Cave is close to the bottom of the valley of Little Sandy Creek, and its water must come largely from small sinks in the southern part of the section. The opening which is about 6 feet high and 12 feet wide is a nearly perfect cross section of the cave passage to which it leads. Gentry Cave is rock-floored throughout, except for some inky-black, manganese dioxide-stained, chert gravel. For 50 to 75 feet, a remarkable little trench about a foot deep and equally wide, with excellent fluting of the bottom, is cut into the wider floor. Almost immediately inside, the cave is a stoopway, and shortly beyond, it is only a creepway for an undetermined distance. Although most of its height and width are clearly of vadose origin, it had a phreatic predecessor. Remnants of the phreatic cave are in the joint-determined cavities of the ceiling. One such remnant is a half-tube which is a perfect example of Malott's Indiana "primitive caves" (Malott, 1932 and 1938). It is about the only one the writer has seen in Missouri.
Missouri Geological Survey and Water Resources MARIES COUNTY There are at least nine caves in the county which carry names. Two have been examined during this study. Boulware Cave SE1/4 NW1/4 sec. 13, T. 38 N., R. 10 W., Maries County Shown on Vienna Quadrangle map Daniel Caves SE1/4 NE1/4 sec. 17, T. 39 N., R. 8 W., Maries County Not shown on Vienna Quadrangle map Both caves are entered close to the valley bottom of Spring Creek. Both are said to have headroom for some distance. One is said to have crawlways by which a person comes back to the place where he started. This (the north one) also has a second entrance which is higher on the hillside. There is no known connection between the two caves. The topographic setting is a challenge to the theory of vadose origin. The caves are out on the tip of a long, narrow hill spur, Weaver Ridge. This ridge is 100 feet high, more than half a mile long, and 1000 feet to 1500 feet wide at the base, except at the expanded terminus. There is very limited summit area; almost all of it is in slopes. Only about 40 acres of hill surface could contribute ground water for the making of these two caves—a totally inadequate amount. It seems altogether likely that, when Daniel Caves are studied in detail, they will be found to belong to the overwhelming majority of Ozark caves; those formed well below the water table of an earlier land surface that lay well above the present hills and valleys of Maries County. Hurricane Bluff Cave NE1/4 sec. 8, T. 40 N., R. 8 W., Maries County Not shown on Vienna Quadrangle map Fowke (1922, p. 97) says this is only a rock shelter, 85 feet long, 15 feet deep, and 6 feet high at the back. Indian Ford Cave NE1/4 NE1/4 sec. 27, T. 40 N., R. 9 W., Maries County Not shown on Vienna Quadrangle map The cave mouth is in the Gasconade River cliff nearly half a mile south of Indian Ford Bridge and 110 feet above the floodplain. The
Caves of Missouri 333 entrance is back in a collapse re-entrant in the 150-foot cliff at this place. There is a steep climb up over talus to the mouth, then a descent of about 15 feet over a gently sloped, inside debris accumulation to the cave floor. The small cave-water trickle does not escape through this debris pile. Indian Ford Cave is readily traversed for 350 feet, mostly on a mud floor which thinly covers a chert gravel fill with a fairly level surface. Near the back end of the cave a flowstone-armored, talus cone rises to the ceiling. The main cave remains wide, back to this blockade and is really a series of three short, broad, joint chambers which are arranged with slight overlaps. These chambers are broadly connected, somewhat like Meramec Caverns' "Big Room". Joints are shown by deep wall and ceiling slots. Other wall and ceiling cavities, without joint control, are exceedingly irregular in distribution, in sizes, and in shapes. On the outside cliff there are other solutional openings that must belong to a phreatic net-work of which the openings off the cave walls and ceiling are a part. The master conduit, the cave proper, surely does not end where the fill rises to the ceiling. Its magnitude-20 to 30 feet wide and certainly of greater depth than the 10 to 15 feet of present clearance—demands a cave whose length would compare with Smittle Cave, Round Spring Cave, or Meramec Caverns. But a comparable length, at this altitude of 100 feet above the river, could be possible only if the occluded portion of the cave coincided with the nearly north-south elongation of the narrow ridge it is in. As far as traversed, the elongation of the cave is more nearly east-west, and this orientation would bring any cave 1000 feet long just under the bottom of the north-draining hollow which is back of and parallel to the cliff. No suggestion of this is found in the examined length. Indian Ford Cave seems to be another cave which cannot owe its orientation or size to the vadose water from the hill in which it lies. No vadose solution forms were seen. There is also no flowstone, unless it is under the mud at the terminal, detrital cone. There is almost no dripstone. Except for the chert gravel beneath the mud, there is no evidence anywhere of a vadose stream. The chert gravel, however, makes a fairly level floor, and this strongly suggests much more stream water than the trickle of the present. The gravel also suggests that such a stream of the past functioned at the time when the Gasconade River still had 100 feet of its present valley to erode. The presence of the gravel further seems to need a subterranean detour of a surface stream. Indian Creek of today would be the logical stream except that it is not near enough. The north-draining hollow could better be used except that it does not seen large enough. The depth of the cave is unknown, but it might be comparable to Cathedral Cave, because the cave is said to have thee stories. No openings off the main chamber were seen, but there are crawlways.
334 Missouri Geological Survey and Water Resources in the phreatic tubes which were too wet to enter at the time of the examination. James Brothers' Cave NE1/4 SW1/4 sec. 25, T. 40 N., R. 9 W., Maries County Not shown on Vienna Quadrangle map The James Brothers themselves were unaware that their cave had any name. The entrance to the cave is near the base of the Gasconade River valley slope. The cave is said to have two fairly capacious openings. The upper one is well up on the bluff. The connection, however, is a crawlway. The Missouri School of Mines map is in error in its location. It is possible that the county map symbol for a cave in S 1/2 sec. 31, T. 40 N., R. 8 W., does locate a cave, but it is not on the James Brothers' land. Incidentally, this James Brothers' Cave is named for two honest citizens. No one has tried to connect it with the activities of those dubious heroes who seem to have spent so much time hiding in so many of Missouri's caves.

Lackaye's Bluff Cave NE1/4 sec. 8, T. 40 N., R. 8 W., Maries County Not shown on Vienna Quadrangle map Fowke (1922, p. 97) reports the presence of a talus at this cave's mouth, back of which the cave is 10 feet wide and high enough to allow a man to stand erect. Natural Bridge NW1/4 sec. 12, T. 38 N., R. 10 W., Maries County Shown on Vienna Quadrangle map Ramsay Cave SE1/4 sec. 14, T. 38 N., R. 10 W., Maries County Not shown on Vienna Quadrangle map Stratman Cave NW1/4 sec. 30, T. 41 N., R. 8 W., Maries County Not shown on Linn Quadrangle map The mouth of this cave is 75 to 100 feet above the Gasconade River in a slight re-entrant in the cliff. It is reached by climbing a steep detrital cone, down which archaeologists have dumped their excavated waste. The flaring mouth is mostly a weathering enlargement. Almost all surfaces are fracture-outlined, and the 12 feet of archaeological excavation has been largely in fallen, fragmental material.
Caves of Missouri 335 The floor which is on a detrital fill rises rather sharply, although the
cave is walkable for about 100 feet. The end of this 100-foot passage is apparently the end
of the large chamber. The cave continues only as two small passages. One passage is a
crawlway, and the other is very narrow and crooked, but about 5 feet high. This one
looks like a little vadose gorge. Another crawlway may be entered near the ceiling halfway
back from the entrance. If followed, it leads back into the cave chamber. Stratman Cave
appears to be a plexus of crooked, phreatic passages. The wall and ceiling cavities belong
to the same category. There is no dripstone and but little vadose alteration. MARION
COUNTY There are five caves reported from this county. The two which have been
studied, Cameron Cave and Mark Twain Cave, lie close together in the extreme
southeastern corner of the county. Both are commercialized and have special sections
devoted to their description and interpretation in the first part of this report. Bootleggers'
Cave Located "near Palmyra", according to Farrar. Murphy's Cave Located in Ide's Hill,
near center of Hannibal, according to Farrar. Ure's Cave Located "in rear of Ide's Hill",
near center of Hannibal according to Farrar. McDONALD COUNTY Five named caves
have been located, and seven others have been reported from McDonald County. Three
caves are open to visitors, and three others have been so in the past. Special descriptions
and inter-pretations of Bluff Dwellers' Cave, Mt. Shira Cave, Ozark Wonder Cave, and
Truitt's Cave, appear in the first part of this report. Bluffdwellers' Cave This cave is near
Jane. It once was open for visitors, but is now closed. No precise location was obtained.
Not to be confused with Bluff Dwellers' Cave near Noel.
Jacob's Cave
This cave is three miles southeast of Pineville on Little Sugar Creek. It is more of a rock shelter than a cave, and it is well known among archaeologists.

Long Cave
Long Cave is a small cave near Pineville. Nothing else is known about it.

Mystery Cave
Owner: Oscar Talley, Lanagan, Missouri NE1/4 SE1/4 sec. 25, T. 22 N., R. 33 W., McDonald County
Not shown on Noel Quadrangle map
Two sets of joints control the chambers of this cave. The vertical extent of the openings is 30 feet or more. They are very narrow at the top, with very ragged edges of thin strata projecting between thin re-entrants. These projections are so irregular that overlaps prevent one from seeing to the top in places. Most of the cave is on one joint set. The simple, joint-determined aisles have been made somewhat irregular by two processes of vadose enlargement. A meandering stream has made several horizontal, semicircular, wall niches. Some of the niches are fairly good half-cones, and their origin is perfectly clear. This meandering extends through a vertical range of only 5 to 6 feet.

Above and below this range, there are phreatic slots without much vadose modification. No clay fill remnants are conspicuous, but the need for a former fill on which the meandering stream could flow is very obvious. The second vadose modification is the dome pits made by vertical falls of water from one vadose stream level to another; 20 to 30 feet below in the same slot. These falls have made vertical lapies (Fig. 148) that pass from one projecting stratum to another across re-entrants which are 3 to 6 inches deep, back in the wall. Apparently a thin sheet of falling water, rather than a film, made the lapies. The mechanism which produced these lapies-marked dome pits seems to be that of a retreating waterfall. The fall began near the face of the subterranean cliff and retreated back under the 100-foot hill away from Indian Creek for a distance of 40 feet or so. Then a subterranean piracy took place at a point a little upstream from the head of the fall, and the stream was diverted to a new route down the clay-filled slot to a lower level than had been used during the formation of the big dome pit. Thus a new fall began, and a tight section of the old phreatic slot was left between the abandoned dome pit and the second dome pit when the new one began. Before much retreat of this new fall had taken place, another piracy happened, and the same kind of a shift occurred. Thus, there are three dome pits. The last two were used but a short time and, hence, are very little elongated.
Caves of Missouri 337 stream went after it abandoned the third dome pit is not known. It may have gone somewhere farther up gradient, into the still clay-filled portion toward the east. Much more cave probably lies back under the hill, behind the dirt fill at the end of the traversable chamber. Fig. 148. Mystery Cave, McDonald County Lapies: Vertical groovings or lapies on the wall of a dome pit. Photograph by G. F. Shepherd. All three dome pits have a bell-like expansion at or near the bottom. It is believed that this was caused by splash from the base of the fall. The cave, as a commercial venture, has fallen on evil days. The stream on the floor was once bridged longitudinally with a wooden walk.
Missouri Geological Survey and Water Resources The stream had to be waded in 1947, and ladders and stairs were unsafe. Even the ford by which the cave is reached was almost impassable for cars at that time. Panther Cave All that is known about this cave is that it is small and near Pineville. Polar Bear Cave This cave is situated about a mile downstream from Noel, along Elk River and on the south side of the valley. Farrar reports 5000 feet of penetration, very fine rooms, and a wonderful hallway. The entrance is 8 feet wide and 6 feet high. Saltpeter Cave Saltpeter Cave is reported to lie two miles east-northeast of Pineville. Shingle Hollow Cave Shingle Hollow Cave is apparently only a rock shelter. It is situated on Little Sugar Creek near Jacob's Cave. MILLER COUNTY Miller County has eighteen named and located caves. One of these eighteen (Stark Caverns) is commercialized at present, and a detailed account of it appears in the first part of this report. Four of the caves have been studied during this investigation. The locations of four named caves are in doubt. Bagnell Cave Fowke (1922, p. 94) reports that this cave is also known as Bat Cave and is on top of "Bagnell Hill", three miles from Bagnell on the south side of the Osage River. He describes it as a large cave with a small opening. Farrar claims that it has been explored 50 feet from the entrance. Barnett Cave SW1/4 sec. 2, T. 38 N., R. 13 W., Miller County Not shown on Iberia Quadrangle map
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Bat Cave NW¼ NE1/4 sec. 7, T. 41 N., R. 12 W., Miller County
Shown on Eugene Quadrangle map This cave is situated high in a cliff of Osage River, and it is said to require a 60-foot ladder to reach. It is reported to be divided farther back into three large chambers. Beckman Cave SE1/4 sec. 28, T. 41 N., R. 12 W., Miller County Not shown on Eugene Quadrangle map According to Ball and Smith (1903, p. 12) there are two caves at this place. The larger cave is a quarter of a mile long. The entrance is under a miniature natural bridge which was formed by a partial falling in of the roof. Ben Bode Cave Ben Bode Cave is reported by Fowke (1922, p. 94) to lie half a mile south of St. Elizabeth and to have a natural bridge in front of the entrance opening. This feature is considered to be a record of a former greater extent of the cave. Bone Cave Sec. 2, T. 38 N., R. 15 W., Miller County Not shown on Toronto Quadrangle map Daerhoff Cave NW1/4 sec. 17, T. 41 N., R. 12 W., Miller County Not shown on Eugene Quadrangle map Fowke (1922, p. 95) says the entrance is 55 feet wide and 8 feet high. There is daylight for 120 feet inside, and the cave is muddy beyond a distance of 55 feet. Flanders Cave NE1/4 SE1/4 sec. 29, T. 41 N., R. 15 W., Miller County Not shown on Eldon Quadrangle map The entrance to this cave is at the foot of a low slope and is almost on the nose of a small spur ridge between two minor valleys. The clearance of 4 feet at the opening has been secured by excavating a foot trench in a detrital fill. Any deeper excavation would have made a pool instead of a path. Back in the cave where the ceiling is a little higher, the trench has been dug through 4 feet of rubbly stream debris which
340 Missouri Geological Survey and Water Resources contains much red sandy matrix. The cave, nevertheless, is a stoopway for nearly half its length. Flanders Cave appears to be almost wholly vadose. If there was any older, phreatic, ground water passage, it has been greatly modified, and its characteristic traits have been obliterated. About 100 feet from the entrance, a very narrow vertical slot cuts 25 feet upward into the roof rock. This slot has a winding course and looks much like a subterranean gorge which could have been made earlier by the free-surface stream of the cave. If it is a vadose feature, it could not have been made until the outside valley had reached its present depth. Discovery of a vertical leakage seems to have then occurred from some higher, bedding plane course which is now abandoned. If the cave is of vadose origin, most of its enlargement had to be completed before decrease in gradient, from changes in the outside valley, caused the filling episode. The cave has a good deal of dripstone, rather dull and mediocre. In one place, the dripstone has closed the vertical slot. The cave was commercialized for 10 years, prior to the gasoline rationing of 1942. Jurggenmeyer Cave SW1/4 NE1/4 sec. 35, T. 41 N., R. 12 W., Miller County Shown as Arch Cave on Meta Quadrangle map This cave is reported by Fowke (1922, p. 94) to be two and a half miles east of St. Elizabeth. It is a tunnel only 200 feet long that is developed along a northeast-southwest joint. Its span is 50 feet, and its height is 20 feet. A few stalactites hang from its ceiling. There is an open ravine upstream from the tunnel. Local people, and Ball and Smith (1903, p. 13), refer to this cave as a natural bridge. Jurggen-meyer Cave is locally specified as a large cave in section 17, T. 40 N., R. 12 W., three miles south of St. Elizabeth. Kemma Cave SW1/4 sec. 11, T. 41 N., R. 15 W., Miller County Not shown on Eldon Quadrangle map This cave which is also known as Klinner Cave or Vernon Cave is reported to be a stoopway with deep mud on the floor. Klinger's Cave Sec. 17, T. 41 N., R. 14 W., Miller County Not shown on Eugene Quadrangle map Ball and Smith (1903, p. 12) report that the entrance to this cave is 30 feet wide by 15 feet high. Seventy-five feet from the entrance, there is a chamber 40 feet wide with 3 to 5 feet of water on the floor.
Caves of Missouri 341 Klug's Cave NE1/4 SE1/4 sec. 28, T. 41 N., R. 13 W., Miller County. Shown on Eugene Quadrangle map. Luckenhoff Cave Fowke (1922, p. 94) describes this as a small cave three-fourths of a mile south of St. Elizabeth. Its mouth is reported to be nearly blocked by a stalagmite mass. Miller County Cave This cave is reported by Farrar as being two miles north-northeast of Bagnell, possibly in sec. 3, T. 40 N., R. 15 W. He also notes that it is probably the largest cave in the county. The writer did not see it, nor did he find any local people who had ever heard of a cave by that name. Ramsay Cave Sec. 22, T. 40 N., R. 13 W., Miller County. Not shown on Iberia Quadrangle map. Entrance to this cave is said to be possible only by rope. Yet "seven pony loads of dish gold" were let down into it and buried there during the Civil War. If this is true, the treasure is still there. However, earnest and expensive effort in 1929 certainly demonstrated that the treasure seekers dug in the wrong place, if, indeed, there is a right place. Unnamed Caves Sec. 8, T. 41 N., R. 12 W., Miller County. Not shown on Eugene Quadrangle map. This cave is noted by Fowke (1922, p. 95) as being situated in the bluff of Tavern Creek, one half mile above its junction with Osage River. It is said that the opening is 10 feet by 10 feet, and that daylight penetrates it for 45 feet. SE1/4 NE1/4 sec. 21, T. 40 N., R. 15 W., Miller County. Not shown on Bagnell Quadrangle map. NW1/4 SW1/4 sec. 24, T. 40 N., R. 14 W., Miller County. Not shown on Iberia Quadrangle map. NW1/4 NE1/4 sec. 23, T. 40 N., R. 12 W., Miller County. Not shown on Tavern Quadrangle map. These three caves are listed by Ball and Smith (1903, p. 13) as occurring in the upper part of the Gasconade limestone.
342 Missouri Geological Survey and Water Resources Wilson Cave SE1/4 sec. 35, T. 40 N., R. 13 W., Miller County Not shown on Iberia Quadrangle map The entrance to this cave is at the top of the talus along cliffs on the north side of Brushy Creek, a tributary of Tavern Creek. There probably is not more than 10 feet of roof rock over the entrance. Seen from the inside, this entrance has the unusual feature of a small window at the upper left; a remnant of a former phreatic tube. If these big cave mouths have been made by coalescence of phreatic tubes, this sort of a relationship is the expectable thing. The cave has a rock floor at the entrance, and the ledges below are wholly unnotched by the little vadose stream which discharges over them. The mouth of the stream hangs 60 feet or more above the valley floor. The entrance to the cave is 30 feet high and has a span of 75 feet. The cave can be readily penetrated for 285 feet. It ends, so far as continuous traverse is concerned, at a dripstone blockade. There are splendid wall pockets and ceiling holes near the entrance, and the outside cliff has excellent tubes and pockets. Farther back, walls and ceilings are rather noncommittal. The dirt floor rises by a gentle grade to the back end. No red clay remnants were seen. There are no vadose wall incisions. Phreatic holes extend down almost to the floor level. This is the cave made famous by its first owner, John Wilson. The stories extant contain variants and to some extent dispute each other. All agree, however, that Wilson lived in the cave for a winter or so when he came here in early pioneer days to clear the land and make a farm. All the stories agree that, as he felt his end approaching, he ordered that his body be sealed up in one of the phreatic tubes which are transected by the cave wall and the outside cliff. People now living on the farm say the selected crypt was the second hole in the cliff, east of the mouth of the cave. It can be reached only by a long ladder. The more engaging stories insist that Wilson ordered that he be eviscerated and filled with salt, that a keg of whiskey be sealed in with him, and that he and it be left in undisturbed companionship for seven years. At the end of that time the masonry closure was to be broken open and the 100 dollars which he had left in trust was to be spent on a merry party for all surviving friends. By that time, he figured that his body would be petrified, and that it could be propped up in the convivial circle. Then, and only then, would he be ready to be buried in the nearby cemetery. But the Civil War came shortly after Wilson's death, and since the region was almost a part of the front, everybody forgot the plans for the party. When peace came, someone recalled Wilson's scheme, but the
Caves of Missouri 343 holder of the trust fund had disappeared. So, alas, (when the crypt's seal was broken) had the whiskey. Either there was a "back-door" entrance from above, or thirsty marauders had made one. Local boys report that they have gone down on a rope through a hole on the summit, back from the cliff face, and have seen Wilson's bones still in the crypt. No, he did not become petrified, nor was he preserved by the salt like so much bully beef. Wright Cave SW1/4 sec. 30, T. 39 N., R. 14 W., Miller County Not shown on Toronto Quadrangle map This cave opens at the eastern end of a cliff about an eighth of a mile long and is on the north side of Mill Creek valley. The entrance is about 30 feet above the floodplain. It has the usual flaring mouth and makes an impressive entrance arch. Inside this entrance, whose width and height (especially the former) are difficult to measure since the flare blends with the outside cliff, the cave mouth itself is about 20 feet wide by 12 feet high. The cliff to the west has good spongework cavities and should be interpreted as an old cave wall. The cave can be traversed for 375 feet. It has no branch chambers and no phreatic slots or tubes in its walls. The floor is of mud and rises gently toward the back of the cave. The walls converge as the cave course is followed around several pronounced curves. This convergence gradually reduces the dimensions of comfortable walking space to all but creeping progress. At this point, the cave is a phreatic tube with good spongework. Its bottom is cut by a small vadose stream slot which is too narrow to walk along. There is good spongework throughout the upper portions of the cave. The lower part may be vadose in origin, though the detrital floor—without evidence of shallowly covered rock—is perhaps 30 feet above the floodplain. Wall ribs of problematical, ridged or ribbed flowstone exist in excellent development 150 feet back from the entrance (Fig. 149). In this instance, the ridges project several inches; perhaps three times as far out in the cave as they are wide on the wall. They grade down into a stalagmitic, very steep cone which stands on a broad rimstone base. They are true cave deposits, but they do not occur farther back from the entrance. When broken, their structure commonly is seen to be composed of loosely aggregated, closely parallel, thin, curved plates elongated with the length of the deposit. Open spaces in the aggregate are comparably shaped and oriented. It may well be that this problematical, wall flowstone which occurs at and near many cave entrances is but a weathering alteration of a former dense deposit that was made before valley widening shortened the cave and thus brought about a partial exposure to outdoor conditions. Certainly, most cave-deposited lime
Fig. 149. Wright Cave, Miller County Ribbed or ridged wall flowstone: Three ribs grade down into a stalagmite behind the dog. The others continue as ribs to the cave floor. Photograph by G. Massie, Missouri Resources Division.
Caves of Missouri 345 stone, when brought outside, weathers far more rapidly than does bed-rock limestone or dolomite. There is a slight eastward dip to the strata in the roof and in the outside cliff at the entrance, but it is of no significance in determining the location of the cave. MONITEAU COUNTY So far as is known Moniteau County has only one named cave. Two unnamed caves have been reported. Bruce Cave NE1/4 sec. 36, T. 48 N., R. 15 W., Moniteau County Not shown on Rocheport Quadrangle map. The cave is fairly high up on a ravined, wooded slope of the Missouri River valley about a quarter of a mile southeast of the former Bruce Schoolhouse. The Bruce farm on the summit upland has some rather steeply sloped sinks, 30 feet or so deep, which almost certainly are related to the cavern system, though only one of them is known to be connected. This one resulted from a relatively recent failure of the rock floor of a steep ravine leading east from Bruce's house. Storm water uses it, although the hole does not take care of very heavy rains. The cave can be entered at this place by a messy route involving unpleasant intimacies with muddy rock walls. Approximately 475 to 500 feet farther down along the rock-floored ravine, a little stream (a spring) emerges from a bedding plane escape route about 3 feet up on the ravine side. Because this flows merrily and cascades down to the ravine bottom when the sink just noted is dry, there must be an adequate ground water supply for the stream. Its source is the cave itself. About 275 to 300 feet farther down the ravine which at this distance is still rock-bottomed, there is a larger and more logical entrance to Bruce Cave in a rock-walled, alcove re-entrant on the north slope of the ravine. This alcove records the collapse of about 50 feet of cave length. The cave mouth discharges a flood-water stream which, on emerging, cascades down over bare rock for 15 vertical feet in that 50 feet of horizontal distance. The entrance does not have a visor, but it does have a local cliff at the head of the alcove. For 50 feet inside, it has been enlarged, as have so many cave entrances, by frost action on exposed cave walls. The ceiling and walls which certainly are not the original cave outlines exhibit very excellent spongework. The spongework interconnections are well shown back in the wall rock, and some exceedingly thin parti-
346 Missouri Geological Survey and Water Resources tions can be seen. These solutional features were well back in the rock before frost action spalled off the original cave wall. One may readily follow this cave back under the hill for 350 feet and walk on a floor of chert fragments that are in transport every time a flood discharge occurs. Some striking cavities penetrate upward into the ceiling. Three hundred feet back, one encounters the stream which comes from the west and disappears in a small hole in the rock floor to emerge outside, as above described. The course of the cave is somewhat winding. Most of it is 7 to 10 feet high and 5 to 6 feet wide. Its walls are characterized by sponge-work, but it is without tributary or distributary tubes or branch passages. About 30 feet short of the place where the stream disappears, there is a re-entrant in the right wall where the pockets dissolved back into it show the influence of joint control for a short stretch. In that 30 feet of length, one passes diagonally across to another and better shown joint chamber which he enters from the side where it runs both to the left and to the right. To the left, the chamber shortly ends in a blockade of detritus and is penetrated in the ceiling by tree roots. Daylight shows through three small holes. To the right, one may go another 50 feet along the stream to a dripstone semiblockade, beyond which is a pool completely covering the floor. Here one may continue, if he insists, and emerge at the bottom of a small sink in the ravine bed. This joint-determined chamber is fairly high and narrow. It shows no solutional enlargement by the stream which only recently has found the hole in the floor and, thus, a shorter route to the ravine. It parallels the other, shorter, less definitely shown, joint-determined chamber. What looks like a collapse dimple on the ravine slope near the entrance is explained as the scar left many years ago by excavators in search of buried pirate gold. It is this excavation which makes the three daylight holes in the ceiling over the larger, stream-occupied joint passage. Blackbeard, a "river pirate" of early days, pursued by a posse, is reported to have buried his tainted lucre somewhere in or near Bruce Cave. Enthusiasts assert that 40 pack-mule loads of gold were hid den somewhere hereabouts, but they have dug fruitlessly to date. Believers in the efficacy of the doodle bug are many, and apparently always will be. As late as the early 1940's, such believers dug in the cave debris and even drilled and blasted in the solid limestone wall. But failures of doodle bug guidance are fully as numerous as the believers in its indications. No pirate gold was found, even where the bug pointed to it. Bruce Cave has no red clay remnants, no meander niches, no vadose facetting. It has only recently been discovered by surface water. The vadose stream enters by a tight passage; it leaves by a tighter one. It never used the cave until the youthful ravine cut down to the already-
Caves of Missouri 347 existing, nearly horizontal, and in part, joint-determined, phreatic passages. These passages pre-date the present topography; they pre-date the Missouri valley that has been cut down 300 feet, more or less, into the Mississippian strata. Yet the cave is elongated at right angles to the course of the later major valley and is apparently leading toward it. This is a common relationship among Missouri caves. It is interpreted as a record of deep ground water flow, under hydrostatic pressure, from vanished higher uplands of pre-peneplain time, toward a Missouri River at approximately the peneplain level. It is reported that near the former Bruce School, almost at the level of the hilltop, youngsters digging out a ground hog discovered a cave room. If this belongs to the Bruce Cave system, that system must have vertical dimensions of at least 100 feet. Van Horn (1905, p. 14) says that Bruce Cave is at the contact of the Burlington and Chouteau formations. Unnamed Caves El/2 NE1/4 sec. 7, T. 46 N., R. 14 W., Moniteau County Not shown on Columbia Quadrangle map Van Horn (1905, p. 14) states that "there is a spring, called 'Cave' spring, issuing from a very small cavern in the Burlington Limestone" at the above locality. Center, SW1/4 sec. 28, T. 47 N., R. 14 W., Moniteau County Not shown on Columbia Quadrangle map Van Horn (1905, p. 14) notes the presence of this cave as being "in the middle of the SW1/4 of sec. 28, T. 47 N., R. 11 W.,--at the contact of the Burlington and Chouteau limestones". According to his map, the range should read R. 14 W., since the entire county is situated many miles west of R. 11 W. Van Horn states that this cave has an opening 10 feet wide by 5 feet high, that it can be crawled into for a distance of 150 feet, and that a spring issues from its mouth. MORGAN COUNTY This county has three located caves. One of these, Jacob's Cave, is commercially operated. It was the only one seen during this study. Chairback Cave Farrar reports that this cave is located "between Stover and Hurri- cane Deck, west of Proctor, at Ivy Bend". This might be in Camden County.
Missouri Geological Survey and Water Resources Dry Branch Cave SE1/4 NW1/4 sec. 12, T. 41 N., R. 17 W., Morgan County Shown as Cave on Gravois Mills Quadrangle map The entrance to this cave is reported to be 25 feet wide and equally high. It opens into a former "dance hall" where at a function years ago, a knife and gun fight resulted in violent death of the knife-wielder. No dances have since been held here. A good-sized cave stream with fairly uniform volume follows the cave's quarter mile length. Some respectable dripstone deposits are reported. Purvis Cave Farrar indicates that this cave is "on the Lizzie Hildebrant farm, in the valley of Mill Creek, in the southern part of Morgan County". Spears Cave NE1/4 SE1/4 sec. 19, T. 42 N., R. 18 W., Morgan County Shown on Gravois Mills Quadrangle map NEWTON COUNTY Four named caves are known in this county, two of these can be entered only by crawling in perennial streams, or "springs". One cave has a concrete entranceway, but otherwise it is little improved for visitors. Three of the caves were seen during this investigation. Ben Lassiter Cave NE1/4 NE1/4 sec. 13, T. 24 N., R. 33 W., Newton County Not shown on Neosho Quadrangle map Entrance is by a 20-foot ladder, apparently in the bottom of a sink. The shaft leads to a room reported to be 100 feet by 200 feet by 20 feet in maximum height. A stream 10 feet wide crosses the room, but apparently its course has not been explored. Jolly Cave NW1/4 SW1/4 sec. 11, T. 25 N., R. 29 W., Newton County Shown on Ritchey Quadrangle map A concrete-walled, "cellarway" entrance to the cave opens along the roadside. The cave was used for a time by the Ku Klux Klan. The date in the concrete is 1922.
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The red clay floor is about 35 feet above the floodplain level of Capps Creek near its junction with Shoal Creek, or about half way up from the floodplain to the top of the bluff. The entrance is through a breakdown in the roof; a small ponor. Jolly Cave is traversable for 300 feet along a chamber 40 to 60 feet wide. At the far end, there is a huge breakdown. According to local accounts, it can be by-passed to reach larger rooms. Penetration for 900 feet has been made. There is a solution-made ceiling back toward this terminal breakdown, but most of the ceilings of the cave are collapse-determined. The cave is capacious, but it is floored with sticky, slippery mud far back. No vadose stream work was seen. The dripstone is old and dull. The cave lies about 100 feet below peneplain remnants in nearby upland prairies. Neosho Big Spring Park Cave SW1/4 SW1/4 sec. 19, T. 25 N., R. 31 W., Newton County Not shown on Neosho Quadrangle map The park is an amphitheater-like tract in the heart of the city. It is best interpreted as the record of a foundered cave. On the west side, the Big Spring emerges from very low-roofed openings that, although they are caves, cannot be explored because of the volume of water. On the east side, excavations, intended to open up a cave, revealed a fill of debris in a limestone cavity. The deposit yielded bones of a mammoth and of a dog-like animal which could not be more specifically identified by the U. S. National Museum authorities. Panther Den Cave SE1/4 SE1/4 sec. 9, T. 25 N., R. 33 W., Newton County Not shown on the Racine Quadrangle map This cave is almost on the line between sections 9 and 10, and has at least two openings. One is very low and, because the emerging stream has been dammed, no entrance is possible today. The other opening is a dug shaft 10 or 15 feet deep. From the bottom of this shaft, one must crawl 20 feet to reach a large room which is 100 feet or so in length. From this room, a small passageway leads to other large openings, but the quantity of water in the cave has prevented any adequate explorations. Probably both openings lead into the same cave complex. OREGON COUNTY At least nine named caves occur in this county, two of these have not been located, and two others are commonly referred to as springs. Three of the caves have had the attention of the writer.
350 Missouri Geological Survey and Water Resources Bat Cave This cave is listed by Farrar, but its location is unknown, other than that it is "twelve miles from Alton". Big Mouth Cave NW1/4 SE1/4 sec. 22, T. 25 N., R. 6 W., Oregon County Shown on Montier Quadrangle map Grand Gulf S1/2 sec. 20, and N1/2 sec. 29, T. 25 N., R. 6 W., Oregon County Shown on Thayer Quadrangle map This collapse chasm is without equal in the State. It stands alone also in the sense that there are no associated minor features of similar origin near it. The region (Fig. 150) is not characterized by a karst (sinkhole) topography; it has but few sinks, and these are mere saucers. Grand Gulf, in contrast, has vertical to even overhanging walls 100 feet Fig. 150. Environ of Grand Gulf, Oregon County Enlargement of part of Thayer Quadrangle map; United States Geological Survey. Horizontal scale approximately 1/33,600. Contour interval 20 feet.
Caves of Missouri 351 high and some steep detrital slopes 25 or more feet high which descend to the brink of the cliffs. Furthermore, the chasm has received a large amount of bouldery debris from the erosion of tributary gorges since the Fig. 151. Grand Gulf, Oregon County This view from the east shows the narrow chasm in the mid-length of the gulf. Fault slicing is seen on the left. Photo- graph by G. Massie, Missouri Resources Division. collapse occurred, and most of this debris surely is still in the bottom under the mud floor. This debris correspondingly decreases the original depth. Grand Gulf is truly a chasm. Even today it is deeper than wide (Fig. 151).
352 Missouri Geological Survey and Water Resources Fig. 152. Grand Gulf, Oregon County This view is on the west side of the natural bridge across the gulf. The tunnel beneath is 200 feet long and leads to the sinkhole containing the entrance to the surviving portion of the old cave. The nearby rock in the lower right is the top of an isolated pillar which has not yet fallen. The gulf lies between it and the wall on the left. Note the nearly vertical shearing in both the pillar and the left-hand wall; a part of the zone of faulting. The faulting is best seen from the bottom of the gulf. Photograph by G. Massie, Missouri Resources Division. One approaches Grand Gulf from the east, parks his car on a fairly broad, flat-topped peninsula that separates the main chasm from a smaller branch of the gulf, walks to the edge, and finds himself looking down from the very brink of a sheer cliff. He sees a great isolated block out in the middle of the gash rising almost as high as his standpoint. He walks off toward the right, and in a few hundred feet finds himself crossing the yawning depths on a wooded natural bridge wide enough for a one-way drive. A little farther westward, after crossing the bridge, he sees this bridge clearly as an uncollapsed portion of a former cave roof (Fig. 152). Three small gorges lead to the brink, and their wet-weather discharges cascade into the gulf. The one at the far western end of the collapse is the largest, and its stream in flood is 8 feet deep in places. Despite the additional water from all the detrital slopes, the gulf
Caves of Missouri 353 stands empty most of the year. The remaining uncollapsed portion of the former cave, to the east, still serves as an outlet. The falling of rocks from the cliffs and the sliding of loose, surface materials into the gulf is still occurring. The collapse is so recent, geologically, that the detrital slopes are not yet stabilized. The subterranean outlet is deeply filled with mud. Hence, its ceiling is relatively very low, and the conduit cannot be followed very far. Owen (1898) reports that she went more than 500 feet into it. In times of heavy rains, so much floating debris is carried into the outlet opening that it becomes temporarily dammed. At such times, the passage under the natural bridge is completely submerged at the east end where its ceiling is lowest. The thickness of the remaining cave roof (the bridge) on the east side is nearly as great as the present depth of the chasm. It seems almost impossible that so thick a roof over so narrow a cave would ever have failed. But there is a very special reason why it did fail, and why the bridge remains. One does not see it well from the top, but it is very obvious to an observer who traverses the bottom. The location, the orientation, and the proportions of the original cave were determined by a fault in the Jefferson City dolomite. Along this nearly vertical zone of faulted, broken, brecciated rock, ground water long ago found easy passage in its search for a surface outlet in some neighboring valley. Solution occurred where the flow was strongest; a deep, narrow cave along the fault was the eventual result. At the the site of the bridge, the cave did not follow the fault precisely; it developed a little to the south. Therefore, when collapse occurred, this part of the cave roof, being unfaulted, remained, and the adjacent portion of the fault, having no cave along it, also escaped the catastrophe. At the extreme eastern end of the collapse, east of the bridge, the fault is double; one offset showing on each side of the mouth of the gulf's outlet. The displacement is clearly seen to be down to the south in each fault, the total being perhaps 20 to 30 feet. Displacement did not occur along a sharply defined plane. Instead, one sees an irregular, nearly vertical zone of sheared and crushed rock, with down-drag of adjacent strata on one side and up-drag on the opposite side of each zone. The original cave ceiling had about 100 feet of roof above it. The cave must have been very deep (from ceiling to floor) to have engulfed all the roof rock which has since disappeared. Because the effect of faulting was presumably deep, the cave could develop as far down as there was vigor of circulation for solutional work. But, because a root remained for a long time, we know that solution did not occur to any extent along the upper part of the fault. We reason, therefore, that it was not water descending from the surface but water at depth, in the saturated zone of the rock; water that moved laterally, not vertically downward, in the faulted zone.
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Except where the bridge stands, the cave roof rock was faulted clear to the surface. Such a roof was unsound, and a time came when it failed. That part of Grand Gulf Cave along the fault then became Grand Gulf Chasm. If one goes to the far western end of the gulf, he may, in the bed of the gorge there, walk on the bent and broken and brecciated dolomite along the fault where no cave was developed (Fig. 153). The displacement is less, but the fact of the movement is very clearly shown. In one place, a small syncline crosses the gorge at a low angle to its course. Fig. 153. Grand Gulf, Oregon County The deformed, dislocated strata are part of the synclinal fold associated with the Grand Gulf fault in the bottom of Bussell Branch gorge. Photograph by G. Massie, Missouri Resources Division. Bussell Branch, the stream which has made the gorge that forms the entrance to the western end of Grand Gulf, drains an area of twenty square miles of country west of Koshkonong and south of Brandsville. Before the collapse occurred, Bussell Branch crossed over the cave and joined English Creek about a mile farther on. Pirated to a subterranean course when the collapsing began, this mile of its lower course
Caves of Missouri 355 was abandoned. Only an empty valley lies here today, and cultivated fields stretch from one side to the other with no interrupting gravel wash. This empty valley floor is comparable in every way, except for altitude, with Bussell Branch valley above the head of the gorge. It lies, however, 10 to 15 feet lower and thus indicates the amount of gradient of the pre-collapse stream along the mile of what has since become gulf and gorge. Bussell Branch is another of Missouri's "lost" creeks. When it was offered a new gradient of 60 feet in that mile by a plunge into the newly formed collapse sink in exchange for the old gradient of 10 to 15 feet, it could not resist. The local rejuvenation, thus caused, has been geologically recent, for the gorge is barely more than a quarter of a mile long. Farther up-stream, the branch is placidly following its old, low-gradient, entrenched meander course, unaware of what lies ahead. Flat uplands, remnants of the old Ozark lowland, constitute the divide followed by U. S. Highway 63 and the St. Louis and San Francisco Railroad between Koshkonong and Brandsville. The altitudes of these uplands average 950 feet above sea level. Allowing the Bussell Branch valley of that earlier time a depth of 50 feet below these uplands, we conclude that the Grand Gulf lay at least 200 to 250 feet below that old land surface before doming brought about the present cycle of erosion and the uncovering of the cave to make the Grand Gulf we see today. Greer Springs and Cave SW1/4 SW1/4 sec. 36, T. 25 N., R. 4 W., Oregon County Shown on Birch Tree Quadrangle map About a mile north of the town of Greer, two springs discharge within a few hundred feet of each other at the bottom and essentially at the head of a short, deep ravine. A mile and a quarter away and about 60 feet lower, the spring branch enters Eleven Point River which is some 250 feet below the brink of its bordering cliffs. The river valley bottom does not average 1000 feet in width. Stream erosion has done but little, thus far, to degrade the environs of Greer Springs. Topographically, the region is very young. The combined discharge of the springs (214 million gallons daily, averaged over 20 years) makes the two together the third largest spring of the Ozarks. The subterranean drainage system which is required to supply Greer Springs must be better developed than the surface stream system. The smaller of the two springs discharges from a low-ceiled cave. The larger one rises in the bottom of the stream which flows from the smaller one, and the nature of its conduit is completely concealed. The cave associated with the smaller spring can be entered for a short distance. A domed room with a 20-foot ceiling lies back of
356 Missouri Geological Survey and Water Resources the nearly water-filled entrance. Although subterranean voyages are possible in some caves, the writer has not learned of any on this stream beyond the domed room. The upper spring, however, is, so far as is known, a free-surface underground stream, but it is vastly larger in proportion to its cave than any other free-surface cave stream known to the writer that is not considered a lost river. The larger spring rises under hydrostatic pressure, and its conduit must lie in the saturated zone below the water table. It must, therefore, be completely water-filled in all seasons. Both streams are, of course, enlarging the cross section of their conduits by solution. The larger one, it may be believed, is dissolving ceiling rock as well as wall rock and floor rock. It is operating under phreatic conditions. Only when the sharply expressed ravine has been deepened another 10, 20, or 30 feet will the larger one become a free-surface stream at the water table level; with air between the cave ceiling and the stream. Looking back in time, instead of forward, we theorize that the smaller spring was also a phreatic discharge when the ravine was 10 or 20 feet less deep than it is now. This picture assumes that here, there are only two conduits in the Gasconade dolomite. As soon as one scrutinizes the low cliffs at the spring site, he suspects this to be an erroneous assumption. As at Alley Spring, Big Spring, and many now essentially streamless caves, the adjoining cliffs of Greer Springs show numerous, interconnecting solution holes which are now empty or clay filled. These cliffs, certainly, once bounded subterranean water courses. Our idea is that these water courses once belonged to a closely connected family or system of underground drainage routes that have been trenched by the downcutting of the ravine. It may well be that, before this incision occurred—therefore, before springs had appeared here—one continuous ground water route passed beneath the site of the ravine. It was not as simple as a city water main because it had what we are calling satellitic, minor members which were all connected so that the water in them flowed under the same hydrostatic pressure. We visualize the Greer Springs of today as an intermediate stage in the revealing of a phreatic cave system which antedates the valley-making of Eleven Point River and its tributaries. The making of this subterranean system is to be dated back at least to the period of maturity when a former erosion cycle produced, as its end product, the flattish uplands well shown toward the southwest. If this be correct, then the underground water courses had ample time for development and for integration, and the contained water had an ample hydrostatic head for circulation. There are obvious objections to the idea that this large and effective ground water, drainage system is no older than the canyon-like surface valleys, in the very bottom of which the springs occur. This, our only alternative explanation, is therefore rejected.
Caves of Missouri 357 Kelly Hollow Cave SW1/4 SE1/4 sec. 22, T. 25 N., R. 3 W., Oregon County Shown on Birch Tree Quadrangle map The mouth of Kelly Hollow Cave is 200 feet above the bottom of adjacent Cave Hollow and 100 feet below the summit of the narrow ridge in which the cave lies. Marble Cave SW1/4 SW1/4 sec. 23, T. 25 N., R. 6 W., Oregon County Shown on Montier Quadrangle map Trantham Cave NW1/4 NW1/4 sec. 30, T. 24 N., R. 5 W., Oregon County Shown on Thayer Quadrangle map Turner Spring and Cave Owners: Turner Brothers, Alton, Missouri SE1/4 sec. 3, T. 24 N., R. 3 W., Oregon County Shown as Turner's Mill on Birch Tree Quadrangle map The Turner brothers and the writer dragged a boat 1000 feet from the river up to the spring mouth, 35 feet higher. We launched it in the forebay of the old mill flume. We prepared for half a day of under-ground boating. We quit and reversed less than 500 feet inside. Whoever said he got three miles into the cave in a boat was gifted with imagination. The cave ceiling is so low that if the outside dam lip had been 6 inches higher (to give us deeper water to float the boat) we could not have gone more than 100 feet. The water was so shallow that we were constantly struggling, while bent double or lying flat, to get the boat over rock bottom ledges. We left a trail of broken little stalactites; our heads and shoulders the battering rams for the destruction. From what we saw in that few hundred feet, we concluded that the cave which is used by the subterranean stream that makes the spring is almost entirely a bedding plane tunnel, and that it is almost wholly lacking in phreatic traits. Only two well developed, elongated, ceiling cavities (upside-down, bathtub style) were seen. Perhaps vadose water has greatly altered what was here before. The stream flows swiftly and brokenly in places over its rock floor. Its outstanding break in gradient, however, is at the mouth where it has cut only a trifling notch in the old spillway lip which is now restored with masonry.
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If, with its bedload of sand and this drop of 20 feet or more at the very point of emergence, the stream's tunnel today is two to five times as wide as high and hangs up in the cliff, it follows that this tunnel never was made to present proportions under present conditions. If we wish to consider the passage as largely vadose, its widening had to occur when Eleven Point River valley lacked 35 feet of its present depth. How to maintain the hanging mouth in subsequent time is a problem. One is strongly inclined to consider that the passage is largely phreatic and that the present cave stream is so young, relatively, that it has not yet had time to destroy the "hang".

There is much broken rock along the western side of the cave near the entrance. It cannot be reached without crawling on one's belly in the spring water, but it looks very much as though failure of a higher chamber had occurred there. This could be a part of the early phreatic system. Peneplain traces, close to the gorge-like valley of Eleven Point River in this region, are more than 900 feet above sea level. A bench mark near the mill at the valley bottom is 516 feet above sea level, nearly 400 feet lower. Greer Springs, four and a half miles distant, is 565 feet, and the peneplain a mile west of the springs is more than 960 feet in maximum altitude. Turner Spring and Cave is very probably a phreatic route. It is 400 feet below the peneplain. Unnamed Cave NW1/4 sec. 4, T. 24 N., R. 3 W., Oregon County Shown as Cave on Birch Tree Quadrangle map. This cave is about a mile up Eleven Point River from Turner's Mill and on the opposite side of the valley. OSAGE COUNTY. Of the four named caves known in this county, one has been studied in this investigation. Homan Cave SI/2 sec. 15, T. 41 N., R. 11 W., Osage County Not shown on Meta Quadrangle map. The opening to this cave which is also known as Sugar Creek Cave is on a graded hillslope on the south side of an unnamed tributary to Sugar Creek valley. It is 15 feet above stream level and in a low local cliff. The cave has a cross section 10 feet by 10 feet for the first 200 feet inside and a total walking length of 350 feet. The cave has a bedrock floor which is bare or just beneath cherty stream gravel. The
Caves of Missouri 359 floor has a gentle gradient as far back as the fallen rock, dripstone, and flowstone blockade at the far end. The upper half of the cave's cross section is clearly phreatic, and there are many irregular pockets in the walls and ceiling and some branch passages which are crawlable on fill for a considerable distance. The lower half of the cave's cross section is probably vadose, for it lacks the pockety wall characteristics. The cave's stream probably comes from a sinkhole on the hilltop less than half a mile to the south. Apparently, collapse there has been recent. It is said the trees which fell in are still living. One can squeeze through the blockade. There are said to be two other "cells" beyond. River Cave Fowke (1922, p. 98) locates this cave as at the foot of a bluff of the Gasconade River two and a half miles below Gascondy. It is reported that a perennial stream discharges over a rock floor and that the cave has been entered for 100 feet. Steuffer Cave Fowke (1922, p. 99) found this cave to be four miles east of Freeburg, and to have an entrance and a chamber 8 feet wide by 12 feet high. About 50 feet inside the cave, there is "a turn". The cave gets its alternative name, Beer Cave, from its one-time use as a storage room for the brewery built in front of it. Tunnel Cave NW1/4 sec. 3, T. 41 N., R. 8 W., Osage County Not shown on Linn Quadrangle map Farrar's location for this cave is very doubtful and his notation that it is "known only from the Missouri School of Mines map of Maries County" is evidently in error. Unnamed Cave NE1/4 NE1/4 sec. 22, T. 43 N., R. 9 W., Osage County Shown as Cave on Linn Quadrangle map OZARK COUNTY Three named caves are shown on the Cureall Quadrangle map. Four other caves are known and located, and four more are less definitely located.
360 Missouri Geological Survey and Water Resources Bear Caves S1/2 NW1/4 sec. 35, T. 22 N., R. 14 W., Ozark County Not shown on Gainesville Quadrangle map There are two caves in the area that are scarcely 250 feet apart. They are on opposite sides of a ravine and lie at the same level. Each cave is a network of curvilinear intersecting passages of subequal widths. Joint control seems indicated by the network, but the writer has never seen elsewhere so much curvature of small radius in a joint pattern. The ceilings show no joint traces, and most of the intersections are three-way, rather than crossings of two passages. Only mapping will shed light on the possibility of dominant directions. One walks freely through almost all passages of Little Bear Cave, the cave on the south side of the ravine, on a fairly level floor of hard clay. By turning right at every branching, one comes at least three times to a talus blockade formed of hillside waste similar to the debris which nearly closes the entrance. Still another opening, too small for passage, lies alongside the entrance. Thus, Little Bear Cave has five passages which are transected by the ravine slope. In Big Bear Cave, there are at least three such blockades. The Jefferson City dolomite ceiling rock in both caves looks distinctly clayey, but it does have broad, shallow, solution holes up in it. If the rock is jointed, as seems necessary for such cave systems, the joints do not carry through the clayey dolomite ceiling. In several places, Little Bear Cave has masses of red sandy and silty clay perched on the shelves of the widened, upper portions of the passages. It is vadose-deposited material, and the shelves may be wall niches made by a vadose stream. If the cave were mapped, it might be found that these shelves and perched clayey sediments make a continuous series through the network. Certainly the system in both caves was originally phreatic, and certainly the ravine deepening has made two caves of what was once a single system. The caves lie an estimated 150 feet below Missouri Highway 5 which here is on an undulating ridge, the crest of which ranges between 1100 and 1200 feet above sea level. Lick Creek valley parallels this ridge on the east. Broad-topped spurs project out into this valley from both sides, and their lower termini are 880 feet to 900 feet above sea level. Lilly Ridge which is followed by U. S. Highway 160 east of Gainesville carries the same surface at 1000 feet in altitude. Although these flattish summits descend to 800 feet along Bryant Creek, a major stream farther east, apparently they all belong together as records of a low-gradient, old erosion surface which is now dissected by modern streams.
Caves of Missouri 361 Bear Mountain Cave SE1/4 sec. 7, T. 23 N., R. 13 W., Ozark County Shown on Gainesville Quadrangle map This cave is known only from the name of the mountain on the Gainesville Quadrangle map. The cave probably lies in the southern half of the section. Cold Cave NW1/4 NW1/4 sec. 13, T. 23 N., R. 11 W., Ozark County Shown on Cureall Quadrangle map The opening to this cave is at the valley bottom, about 150 feet below the summit of a spur inside of an entrenched meander of Spring Creek. The cave lies about 250 feet below the trace of the peneplain. Cowpen Hollow Cave NE1/4 NE1/4 sec. 18, T. 21 N., R. 15 W., Ozark County Not shown on Thornfield Quadrangle map The cave opening is indicated on the map by a small sink on the ridge top immediately north of Cowpen Hollow. Cropper Cave NE1/4 NE1/4 sec. 29, T. 24 N., R. 12 W., Ozark County Not shown on Gainesville Quadrangle map The entrance is about 40 feet wide and 8 feet high and lies in the northern slope of the valley of Bryant Creek. Fogey Cave SE1/4 NW1/4 sec. 15, T. 23 N., R. 11 W., Ozark County Shown on Cureall Quadrangle map The entrance to this cave is 150 feet lower than the hilltop above it and about 250 feet below the level of the old peneplain. Ozark Cave The location given by Farrar is very inadequate, "T. 23 and 24 N., R. 12 and 13 W.". However, he claims that the entrance is 35 feet wide and 30 feet high and that the cave has been explored for a distance of 7000 feet from the entrance.
Missouri Geological Survey and Water Resources Peter Cave Peter Cave Hollow runs through the mutual corners of townships 21 and 22 north and ranges 15 and 16 west on the Thornfield Quadrangle map. The cave should be somewhere along this ravine. Pontiac Cave SW1/4 NE1/4 NE1/4 sec. 9, T. 21 N., R. 15 W., Ozark County Not shown on Thornfield Quadrangle map This cave which is also known as Potato Cave has two extra-ordinarily small entrances which are scarcely detectable on the hillside slope. Like Bear Caves, it is developed on sinuous joints. It is possible, by continually taking right-hand or left-hand turns, to crawl around and return to the starting point. The mouths are only about halfway down the slope from the village of Pontiac in a small ravine east of White River. The cave, nevertheless, is still nearly filled with clay, and most of the passages are only crawlways. One passage which is well over to the right of the system has a fairly high ceiling. This is due, first, to a slump pit that has lowered the clay floor, and, second, to a ceiling that is actually 5 feet higher in the formation than the ceilings of the crawlways. The crawlway ceilings are smoothly rounded, flatly arched, and they blend uniformly into the walls. The ceiling of the higher passage is in greenish, rather clayey-looking rock, is nearly flat, and the passage is widest at the top. Clay masses lie up almost against this ceiling. The clay is red and smooth, only faintly gritty, and it is a fair interpretation that all the clay in Pontiac Cave is phreatic. Certainly, the clay that is exposed in the slump pit is very red and very sticky and shows what the filling must be elsewhere. No trace of a vadose stream was seen in any of the passages entered. At least three of the passages of the system are transected by the hillside. In Little Bear Cave, great blocks of wall rock have subsided 2 or 3 inches, thus opening horizontal cracks. This shows that there is a deep clay fill in the narrow passages; that they are slots. But neither the Bear Caves nor Pontiac Cave have any narrow slits that taper upward into the ceilings. In all three caves, the ceilings are flattish and show no continuing joints upward. No dripstone was seen in any of these caves. Potato Cave NE1/4 NW1/4 sec. 32, T. 24 N., R. 11 W., Ozark County Shown on Cureall Quadrangle map Unnamed Cave N1/2 sec. 9, T. 22 N., R. 16 W., Ozark County Not shown on Thornfield Quadrangle map
Caves of Missouri 363 PERRY COUNTY Four named caves have been located in this county, and reports indicate that there are several unnamed ones. Beer Cave and Cashion Cave Sec. 19, T. 35 N., R. 11 E., Perry County Not shown on Perryville Quadrangle map Both of these caves are beneath the city of Perryville, and they very probably are two parts of the same cave system. Neither one is enterable today, and apparently neither one was earlier a cave of any note. They are in a dolomite which probably is the Joachim (Ordovician) formation. Beer Cave had a large antechamber which was "large enough to drive a team and wagon in". It was used for the storage of beer until the city's demand for residential property along St. Joseph Street resulted in regrading and the obliteration of this chamber. A lateral of Beer Cave is used today for the disposal of sewage from nearly a block of residences. One may lift a manhole cover in the sidewalk along St. Joseph Street, north of the courthouse square, and look down 15 to 20 feet into this passage. Where the waste goes is unknown, but storm water flushings keep the cavity clear. The entrance to Cashion Cave, in the southwest part of town, is filled with rubbish. Harrington Cave SW1/4 SW1/4 sec. 4, T. 34 N., R. 11 E., Perry County Not shown on Perryville Quadrangle map The inconspicuous entrance to this cave is close to the north-south road that crosses section 4, and it is on the gentle slopes of a saucer-shaped sink (doline) which contains a permanent pond. The entrance is really a small asymmetrical collapse sink (ponor), the uphill wall of which constitutes the thin roof and the entrance way. Surface water runs back into the cave for 250 feet along a slightly sinuous, joint-controlled, narrow passage to the largest room of the cave. The detrital floor gradually descends, while the ceiling remains in about the same horizontal rock stratum. The walls of the passage are smoothly molded because of the differential solutional attack on the strata edges. The large room of the cave is entered abruptly, and just as abruptly the wet-weather stream turns left and cascades down into a large lower opening. As its floor is covered with big, angular, fallen blocks which are coated with and half buried in mud, it was not entered. The entering surface water here executes almost a complete about-face and
Missouri Geological Survey and Water Resources disappears in the direction of the permanent pond. No exit for this water on the lower slopes of the doline is known, and it may well escape somewhere beneath the bottom of the pond basin. The large room is 100 feet long, about 12 feet high, and 20 feet wide. Its flat ceiling is fracture-determined along bedding planes, its walls are partly fracture-outlined, and its floor is a detrital fill of unknown depth. Beyond this room, there is a continuation of the joint corridor for 400 feet. It has a smooth earthen floor, a height of 12 to 15 feet, and very variable widths. Most of the walls are solutionally outlined, but the extra wide places are apparently due to loss, by fracturing, of the original, solutional wall surfaces. That this corridor has a deep detrital fill which buries the fallen blocks, and that the corridor had a considerable, original width in the buried part, is evident from the horizontal thickness of the blocks that have dropped off the lower walls and have disappeared, leaving wide sub-ceilings which are terraces in reverse. One of these blocks has not entirely disappeared, and its bent and broken strata can be seen to dip into the cave. It has settled without tilting away from the remaining wall. The character of Harrington Cave changes notably at the end of this smooth-floored corridor. The easy walking ends abruptly at the foot of a pile of fallen slabs which completely fill the solutional cave. By their fall, the ceiling has been raised correspondingly. One climbs about 30 feet up over the mud-smeared rock pile, creeps through a small opening at the top and finds, high in this collapse chamber, many feet of stoopway and creepway ahead. The ceiling rock, overhanging the slope one climbs, is ready to let go and be added to the pile. A section several feet thick is already parted from the roof rock and is downbowed under its own weight. There will be no preliminary slab falls announcing the event a few weeks or months in advance. It will all come down together. The place is definitely unsafe. Local reports state that this collapsed portion leads to at least as much more solutional cave as has already been traversed, and that there is another big room with much dripstone. Harrington Cave can have no great thickness of roof anywhere. The entrance is on the 580-foot contour, and the hilltop to the south, toward which the cave leads, just catches the 620-foot contour. There are many square miles of flat upland at about the 600-foot contour that contain hundreds of small, collapse sinks (ponors) and many broad, saucer-like sinks (dolines). At least a township of land has only sink-hole drainage. The ponors are surface evidence of the presence of many caves or of several, large cave systems beneath. This 550 to 600-foot upland flat is an erosional plane in the Joachim and Plattin (Ordovician) formations. Traced northward from the Perryville Quadrangle and halfway across the Chester Quadrangle, it crosses a fault whose displacement is several hundred feet. The flat there bevels, on the upthrow side, several Ordovician formations and cuts Mississippian rocks on the downthrow side.
Caves of Missouri 365 The caves and ponors are chiefly in the post-St. Peter, Ordovician dolomite and must be as shallowly situated as Beer Cave, Cashion Cave, and Harrington Cave. If they are phreatic in origin, it seems that they must pre-date the erosional plane above them. Harrington Cave is, however, older than the doline sink whose slope it intersects. Also, Harrington Cave descends and becomes larger farther back under the low hill, a feature which does not indicate vadose origin. There is an unsolved problem in cave histories in Perry County. Lost Cave SE1/4 NE1/4 sec. 4, T. 34 N., R. 11 E., Perry County Not shown on Perryville Quadrangle map. This cave is reported to be smaller than its neighbor, Harrington Cave. The two might well be severed portions of the same cave system. PHELPS COUNTY As a cave county, Phelps County ranks next to the leader, Pulaski County. It has no less than 54 named caves and two unnamed ones whose locations are known. None of these is commercialized; most of them are small. The data on Phelps County caves presented here came largely from Willard Farrar's investigations, and in smaller part from Gerard Fowke's (1922) archaeological studies. Four of the caves in this county were examined during the present study. Arlington Cave NW1/4 sec. 24, T. 37 N., R. 10 W., Phelps County Not shown on Newburg Quadrangle map. A small cave, near the top of the Gasconade River bluff, a little above the junction of Little Piney Creek. Debris from a collapse sinkhole on the bluff summit has blocked what probably was once a longer cave. The cave carries the drainage from the sink after a very hard rain. (Farrar) Ash Spring Cave Sec. 32, T. 35 N., R. 9 W., Phelps County Not shown on Edgar Springs Quadrangle map. Bell Bluff Cave NE1/4 SE1/4 sec. 8, T. 38 N., R. 9 W., Phelps County Shown as Bell Cave on Vienna Quadrangle map.
This cave is in the bluff of the same name, about 150 feet above the Gasconade River, less than a mile above the confluence of this stream and Cave Spring Creek or Tick Creek. The entrance, partially screened by vegetation, is about 50 feet wide and 35 feet high, and it is possible to enter the cave for about 200 feet without stooping. The cave floor rises slightly in the interior, and at the end of the cave, some 400 feet from the entrance, there are terraces of cave onyx. A small amount of dripstone was seen on the ceiling throughout, but the cave is not particularly pretty. The chief attraction in the vicinity is the splendid view of the Gasconade River valley from the top of Bell Bluff. (Farrar) Belton Cave SW1/4 NW1/4 SW1/4 sec. 7, T. 37 N., R. 9 W., Phelps County Not shown on Newburg Quadrangle map This cave is about one mile southwest of Gottschall School in the same hollow as Mareno Cave and Gottschall Cave, and about 40 feet above the ravine floor. The entrance is very small, but inside the cave, there is a passage about 5 feet high and 7 feet wide which can be followed for about 250 feet. The passage ends in a small and very muddy room which contains a little poorly developed flowstone. The entire cave is wet and muddy. (Farrar) Berry Hance Cave Sec. 12, T. 36 N., R. 10 W., Phelps County Not shown on Kaintuck Hollow Quadrangle map Black Cave Sec. 21 ?, T. 35 N., R. 8 W., Phelps County Not shown on Edgar Springs Quadrangle map The Missouri School of Mines map of Phelps County indicates that this cave is in sec. 21, T. 35 N., R. 8 W., Phelps County. Farrar's notes specify sec. 22, which is across the county line in Dent County. Brookshire Cave SE1/4 NW1/4 sec. 6, T. 34 N., R. 9 W., Phelps County Not shown on Edgar Springs Quadrangle map Castlemain Cave Farrar gives no location for this cave other than the statement that it is somewhere in the area covered by the Meramec Springs Quadrangle map.
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The entrance is a hole about a foot wide and 3 feet long. The opening goes vertically downward 4 or 5 feet and there inclines sharply downward for a vertical distance of 60 feet. At the foot of this incline, there is a room 25 feet wide, 9 feet high, and 100 feet long. The roof and walls of this room are of sandstone, and the floor is covered with blocks of broken sandstone. The back of this room tapers off into a passage which shortly becomes too small to follow. (Farrar)

Easter Cave
NW1/4 SW1/4 sec. 19, T. 35 N., R. 9 W., Phelps County
Shown as Cave Spring on Edgar Springs Quadrangle map

This cave is near Spencer Cave in the second hollow entering Bloom Hollow valley from the west. The entrance is very difficult to find, as it is only 24 inches wide and 18 inches high. It is developed at the contact of the Roubidoux and Gasconade formations, and the passage slopes sharply downward for about 20 feet. A winding passage, the floor of which is quite rough, gradually increases in size, and eventually a room about 20 feet long and approximately the same height is reached. A pool of water about 10 feet in diameter is found in this room, and the water issuing from the ceiling makes considerable noise in falling into the pool. The cave ends at this point, about 400 feet from the entrance. (Farrar)

Gottschall Cave
NW1/4 NE1/4 NE1/4 sec. 7, T. 37 N., R. 9 W., Phelps County
Not shown on Newburg Quadrangle map

This small cave has two entrances which are about 100 feet apart. They are in the north side of a large ravine about half a mile south of the Gottschall Schoolhouse and 30 feet above the ravine floor in the Gasconade formation. The cave is a very small winding tunnel about 150 feet long through which crawling is necessary. There are only a few very poorly developed cave formations in it. (Farrar)

Gourd Creek Cave
SE1/4 SE1/4 NW1/4 sec. 19, T. 36 N., R. 8 W., Phelps County
Shown on Yancy Mills Quadrangle map

A lively stream of clear water discharges down, 30 feet or so, over coarse talus debris from the cave mouth and flows into Gourd
Missouri Geological Survey and Water Resources Creek. The stream leaves the cave by percolating through the earthen floor which is built on the top of this talus and soon emerges to begin its cascading descent. Thence back for 500 feet or so, the stream runs on a bedrock floor. At the back end (unless one goes farther by crawling Fig. 154. Profile and Cross Sections of Gourd Creek Cave, Phelps County E. H. Woolrych, del. in the water) the stream is almost against the ceiling. It divides into little rock-cut gorges, cascades repeatedly, and has almost no still-water pools.
Caves of Missouri 369 The bedding-determined ceiling is almost level throughout. From this back end with its rough bedrock floor, the vadose gorge deepens towards the entrance and thus yields a 50-foot height. The cave widens within reach of daylight. The ceiling width of 20 feet or more continues all the way back to where floor and ceiling essentially meet (Fig. 154). This cave, before the stream discovered it—before Gourd Creek valley was eroded below the cave mouth so that the vadose water could use and deepen the cave—was seven times as wide as high, was hardly 3 feet in the clear—2 feet would be a better figure. The water had no gradient for excess bottom attack. Solution was lateral because of the relative solubility of a particular layer. This was phreatic solution. Further evidence is found in the ragged ceiling slots and the deep pockets along the joints. One of these joints certainly connects with a high capacious chamber filled with red clay which is oozing down as a flow of almost liquid mud. It is reported that individuals have crawled farther back than 500 feet and have found an "upstairs" cave. It may be, however, that the "upstairs" chamber was reached via the mud slope noted. Fowke (1922, p. 29) says that one party penetrated until "they reached an opening on the other side of the hill" but could not squeeze through. A strong breeze blows through the cave in stormy weather, its direction depends on outside winds. Joint chambers cross the course of the horizontal slot, but they do not seem to continue far offside the margins of that slot. Lower phreatic members (Fig. 154) have been discovered in the vadose deepening of the cave gorge, and they now are wall pockets. The horizontal, slot chamber seems to record an integration and a directed, sub-surface stream which flowed toward a spring discharge somewhere, at the time this chamber was being made. Local residents say that other smaller, connected caves exist on the opposite side of the hill. A prospect hole may be seen on one side, back in the cave, under a vertical ceiling slot. It probably owes its existence to the persistently surviving legend that a squaw, the sole survivor of a massacre, buried seven pony loads of gold coin ($100,000 worth) in the cave. It should have been wampum, not gold. Possibly Bill Wilson and his fellow bushwhackers, who reportedly hid in the cave during Civil War days, responded to a need for the buried coins. The only secondary lime deposits in Gourd Creek Cave are the big, compound, wall-attached half-dome on the right of the stream and some associated, minor, wall flowstone and dripstone where the gorge is narrowest. Granny Baker Cave 9 SW1/4 SW1/4 SW1/4 sec. 9, T. 38 N., R. W., Phelps County Shown on Vienna Quadrangle map Granny Baker Cave is situated 10 miles northwest of Rolla and about one and one-half miles north of Saltpeter Cave. The entrance is
370 Missouri Geological Survey and Water Resources about 50 feet above Cave Spring Creek or Tick Creek and is developed in the Gasconade dolomite. The opening is about 60 feet in width and varies from 7 to 12 feet in height. A small wet weather stream emerges from the south-facing entrance. It was an ideal shelter for prehistoric people. The cave earth is about 6 feet deep here and extends into the interior for about 100 feet. Aboriginal occupation is proved by the abundance of mussel shells and potsherds. The cave consists of a combination of winding passages and rooms. The main passage continues north about 150 feet. At this distance, a fork is reached. The right passage terminates in a mass of fallen blocks and dripstone a short distance from this fork. If one follows the left passage and squeezes through a narrow opening which is choked with dripstone, he will reach a large room full of poorly developed formations. The passage at this point is about 20 by 30 feet, and it continues in a northwesterly direction. Very little crawling is necessary from this point on. At a distance of 500 feet from the entrance, some fallen blocks of limestone are reached. No attempt was made to go around these blocks because of bad roof conditions. It is possible that the cave continues beyond this point. (Farrar) Hamilton Cave NE1/4 NW1/4 SW1/4 sec. 23, T. 35 N., R. 10 W., Phelps County Not shown on Big Piney Quadrangle map The entrance to this cave is 100 feet above the valley floor of Cave Spring Creek in the Gasconade formation. It is only 3 feet by 3 feet in dimensions, but it leads to rooms as much as 40 feet high and 30 feet wide. It may be entered for 400 feet of walking distance and has been penetrated for another 100 feet, though this was not to the end of the traversable passage. (Farrar) Hanley Cave SE1/4 SW1/4 SE1/4 sec. 12, T. 36 N., R. 10 W., Phelps County Not shown on Kaintuck Hollow Quadrangle map The main cave entrance is about 5 feet high and 20 feet wide, but there is an auxiliary entrance about 2 feet in diameter a short distance to the north. The main passage of the cave is rather wet. A waterfall issues from an opening in the roof at the end of this passage, but it is impossible to reach this crevice without a ladder. There is considerable flowstone developed on the walls and roofs. One side passage ends in a blank wall 150 feet from its junction with the main passage. The other side passage reaches the small entrance about 100 feet from its junction with the main passage. (Farrar)
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Haven Cave SE1/4 NE1/4 NW1/4 sec. 13, T. 35 N., R. 9 W., Phelps County Not shown on Yancy Mills Quadrangle map

Hide Hollow Cave SW¼ NE¼ SW¼ sec. 24, T. 37 N., R. 9 W., Phelps County Not shown on Rolla Quadrangle map

Jake Hollow Cave NW1/4 NE1/4 SE1/4 sec. ?, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map

"Hardly justifies the name of cave". (Farrar)

Jim Phelps Cave NE1/4 SW1/4 NE1/4 sec. 21, T. 35 N., R. 8 W., Phelps County Not shown on Edgar Springs Quadrangle map

Jones Cave NE1/4 NE1/4 NW1/4 sec. 4, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map

This cave is also known as Rocky Hollow Cave and is in the valley wall of a small tributary of Little Piney Creek. Its entrance is about 20 feet wide and 10 feet high and is in the Gasconade dolomite about 25 feet below the base of the Roubidoux sandstone. The cave is essentially a winding passage containing a stream and was explored for about 300 feet. (Farrar)

Another Jones Cave is listed by Farrar as in NW1/4 sec. 25, T. 37 N., R. 10 W. It is not shown on the Newburg Quadrangle map. Kaintuck Tunnel SW1/4 NE 1/4 NE1/4 sec. 16, T. 36 N., R. 9 W., Phelps County Shown as Natural Bridge on Kaintuck Hollow Quadrangle map

This is probably a surviving portion of a former cave roof. It is 120 feet deep, precipitously walled, and situated less than five miles northeast of Kings Sink. Farrar notes its precise location only, but Dake and Bridge (1923, p. 7) provide a map, photographs, a brief description, and an interpretation.
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Lamar Cave NE1/4 sec. 1, T. 36 N., R. 10 W., Phelps County
Not shown on Newburg Quadrangle map

This cave is in a branch of Smith Hollow about three miles south of Arlington. The entrance is on the north slope of a hillside and is difficult to find because it is a vertical crevice only 4 feet in diameter at the bottom of a recently formed sink. At the time the cave was explored, a rope ladder was used, and a descent of about 60 feet was made. At the bottom of the crevice, an opening large enough to admit a man was made by digging in the jumbled mass of boulders, and this led into a room about 30 feet high and about the same length. A stream flows on the far side of this room, and a narrow passage leads thence to a small room which contains a pool of water about 10 feet in diameter. A large amount of water falls from the ceiling into this pool and, from a position in the large room of the cave, this sounds like a waterfall. It was impossible to explore downstream because of the smallness of the opening, but it is probable that this cave is the upper room of a large cave system. No flowstone of any kind was seen in either the rooms or passages. The cave was named for Earl Lamar of Arlington, who was one of the original explores. Farrar was the actual discoverer of this cave.

Lennox Cave SW1/4 NW1/4 NW1/4 sec. 35, T. 36 N., R. 7 W., Phelps County
Not shown on Meramec Springs Quadrangle map

This cave is in the south wall of the valley of Duncan Creek about two miles above its mouth and about five miles east of Dixon. The entrance is 4 feet high and 12 feet wide, but the passage shortly becomes large enough to walk upright in, and it winds back into the hill for about 250 feet to a fork. The smaller or southwest fork soon terminates in a large room containing well-developed flowstone. The stream disappears under the wall of the room and follows an unknown course to its emergence several hundred feet from the entrance. The other passage can be followed for about 1500 feet before it becomes too small for further exploration. It is dry throughout its length and has no flowstone. Another smaller cave, 300 feet to the west, is also known as Light Cave. (Farrar)
Caves of Missouri 373 Little Beaver Cave NW1/4 NE1/4 NE1/4 sec. 19, T. 37 N., R. 8 W., Phelps County Not shown on Rolla Quadrangle map This cave is in the west wall of Little Beaver valley about 100 feet above the bottom and approximately 30 feet below the contact of the Gasconade dolomite and the Roubidoux sandstone. The entrance is about 6 feet wide and 3 feet high, and at no place in the cave is it possible to stand upright. The cave is a winding passage about 10 feet wide and was explored for about 300 feet. Part of the unstable roof is covered with small stalactites. (Farrar) Marcellus Cave NW1/4 NW1/4 NW1/4 sec. 17, T. 37 N., R. 6 W., Phelps County Not shown on Meramec Springs Quadrangle map The cave's mouth is about 3 feet by 4 feet in size, and it is developed in the upper beds of the Gasconade dolomite about 10 feet below the bottom of the Roubidoux sandstone and about 30 feet above the bed of Dry Fork. Upon entering the cave, one finds that the floor of the entrance room slopes sharply downward to a small tunnel through which it is necessary to crawl to reach the interior. Here the passage is larger and reaches a height of about 15 feet. A short distance over a very muddy floor brings one to a stream which is about 4 feet wide and one foot deep. This stream sinks into the floor of the cave a short distance from another and smaller entrance. To proceed farther, it is necessary to wade the stream which varies considerably in size, becoming 12 feet wide and nearly 2 feet deep in many places. The passage winds on and on. Through most of the distance, it is 10 feet high, but some stooping is occasionally necessary. About 1500 feet from the entrance, a crevice extends up into the ceiling for an unknown distance. A large amount of water falls from this crevice, and the rock forming the sides is so badly weathered that any attempt to climb the crevice would probably end in a severe fall for the explorer. The large slabs of rock in the bed of the stream in many places are evidently from the roof which is rather dangerous in those areas. At one place, the stream flows through a small tunnel while explorers travel over a jumbled mass of mud-covered boulders in a room 20 feet high and 50 feet long. The cave has been explored for a distance of 3000 feet from its mouth, and through most of this distance, one wades a stream which flows in a winding tunnel without any ornamentation. Only a very small amount of poorly developed dripstone was seen in the cave. A crevice somewhere beyond the explored portion of the cave must connect with the overlying Roubidoux sandstone because miniature,
Missouri Geological Survey and Water Resources modern, sand bars showing current type ripple marks were found beyond the crevice previously mentioned. Exploration was discontinued because of the depth of the water in the passage. (Farrar) Marcellus Cave is unusually long, and the overlying topography is a narrow, nearly north-south ridge. To have such a length, the cave stream must flow longitudinally in this ridge. Since today's ground water drainage of the ridge would never take such a course, the cave must be older than the hill. This is another cave to add to the list of those which follow along ridge trends. Mareno Cave SW1/4 SE1/4 NW1/4 sec. 7, T. 37 N., R. 9 W., Phelps County Not shown on Newburg Quadrangle map This cave is in a large ravine southeast of the Gottschall School. The entrance is about 40 feet wide and 7 feet high with a stream covering the entire cave floor and flowing from it. The passage can be followed for about 300 feet, but over much of this distance, crawling is necessary because the passage is partly choked by poorly developed dripstone. The cave is in the Gasconade formation. (Farrar) Marsh Cave SE1/4 SE1/4 SE1/4 sec. 9, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map Fowke (1922, p. 23) states that Marsh Cave is a rock shelter cave two miles south of Yancy Mills, facing Little Piney valley. It is 35 feet wide and 15 feet high and has a wet-weather stream and bedrock floor at the entrance. It can be penetrated along a winding narrow passage for 60 feet. This same cave is also listed for Dent County. McClure Cave SW1/4 sec. 25, T. 36 N., R. 7 W., Phelps County Not shown on Meramec Quadrangle map McCormick Cave NW1/4 SE¼ NW1/4 sec. 24, T. 37 N., R. 9 W., Phelps County Not shown on Rolla Quadrangle map This cave is situated at the end of a small valley entering Poole Hollow about a mile above the mouth. A small stream flows from the mouth of the cave which is about 25 feet wide and 12 feet high. The cave was entered for about 250 feet without stooping. Beyond this the passage is small and very wet, and exploration was discontinued. The cave is in the Gasconade formation. (Farrar)
Caves of Missouri 375 Mill Creek Cave SW1/4 NW1/4 NW1/4 sec. 4, T. 36 N., R. 9 W., Phelps County Not shown on Kaintuck Hollow Quadrangle map This cave is in the north wall of a small ravine which enters Mill Creek valley from the west about one-fourth of a mile north of the junction of Mill Creek and Kaintuck Hollow. The cave is about 100 yards from the road and a faint path leads to it. The entrance which is about 3 feet high and 8 feet wide is developed in the Gasconade dolomite about 25 feet below the base of the overlying Roubidoux sandstone. The cave floor slopes gently downward from the mouth, and a short distance inside it is covered with water. The passage is about 8 feet high and 10 or more feet wide at this point. There is considerable dripstone developed throughout the entire length of the passage (300 feet), and the depth of the water varies from 1 to 3 feet. (Farrar) Moke Cave SW1/4 SW1/4 sec. 36, T. 36 N., R. 9 W., Phelps County Not shown on Kaintuck Hollow Quadrangle map Muench Cave Owner: H. Wellston, Duke, Missouri SE1/4 NE1/4 sec. 10, T. 36 N., R. 10 W., Phelps County Not shown on Waynesville Quadrangle map The entrance to Muench Cave or Zook Cave (Fig. 155) is under Roubidoux sandstone ledges on the east side of a small, gently sloped sink. A torrent of water which resulted from the grading and blocking of the normal slope drainage along County Highway P has entered this opening since 1932 and has eroded a 6-foot trench in the gently graded, detrital slope that preceded it. The trend of this trench is eastward. At this place, there is a 30-foot descent over large sandstone slabs to a more nearly level floor. A huge residual terrace of unctuous red clay with pieces of limestone in it lies on the right. Because this is below the sandstone, these slabs must be wall ledges which project through the clay. The cave has two branches, one leading south, and one northeast from the junction. The one leading south narrows to 8 or 10 feet and is 20 to 30 feet high. Stream water follows it but must escape mostly through the floor. Only mud and leaves have been carried to its far end. When visited, this branch shortly before had been filled almost to the ceiling with standing water. The only continuation, other than the impassable stream leakage at the bottom between wall and fill, is on top of a bank of red clay and rock fragments that stands 25 feet high at the end of the passage and almost reaches the
Behind this bank, there is a slump pit. Then another big room lies south of the slump pit at the "end" of the south branch. This southern chamber is the only part of the cave where walls show solution; everywhere else there are fracture walls and ceilings. The northeast branch is longer, has a trickle stream, and shows that the present cave chamber is wholly due to collapse into a true solution cave which is now completely filled. An interesting and significant fact about the small solutional pockets is that they are developed along a bedding plane slot whose former floor was sandstone. The sandstone slabs have subsequently fallen off and have revealed the upper solutional surface. Though it is now a solution-marked ceiling, it is not the original ceiling of the true cave chamber. There is a broad saucer (doline) type of sink just east and south of the owner's house. According to the cave map, the northeast branch of the cave leads from it. The map shows a very broad, semicircular room around the western periphery of the sink, but provides no profile for it, and there is a questionable connection underground. At the far end of the traverse in the northeast chamber, the roof consists of ripple-marked sandstone, and the floor which is almost up against it is littered with what looked like freshly fallen blocks. It was too dangerous to justify further penetration.
Caves of Missouri 377 Slaughter Sink (200 feet deep) and Conical Sink (80 feet deep), both with cliffed sides, lie on the ridge top which U. S. Highway 66 follows through Powellville. Muench Cave is also located on the same ridge. Its entrance is 1020 feet above sea level or 320 feet above the Gasconade River two and one-half miles distant to the northwest. The ridge has farm land on top and is probably a remnant of a peneplain. Muench Cave is not more than 100 feet below the peneplain flat. Its pattern is phreatic. Vadose water has entered it only since the breaching of the sink wall. The little entrance sink very probably represents a collapsed portion of Roubidoux sandstone. Hence, there should be more cavern chamber farther west that is now blocked off by the debris in the entrance scrambleway. Indeed, all the sinks under this Roubidoux sandstone cap must be of ponor origin, even though they exhibit doline profiles. The geologic map of the Rolla Quadrangle (Lee, 1913) indicates that the Gasconade–Roubidoux contact in the cave area may be approximately 900 feet above sea level. Hence, there is probably about 100 feet of Roubidoux formation under the 1000 foot summit. Extensive cavern systems in these ridges must have preceded the formation of the sinkholes. This inference seems (as do the character and altitude of Muench Cave) to indicate caves under the peneplain. If Muench Cave were of vadose origin during the present erosion cycle, it should not have remained in the upper part of the Gasconade formation. Its stream should have cut down as the Gasconade River deepened, and its chambers should be very high (deep). At least those in the upper part of the formation should be vertically transected, and their drainage should plunge to much deeper levels than Muench Cave. Mungy Cave NW1/4NE1/4 SW1/4 sec. 26, T. 38 N., R. 10 W., Phelps County Not shown on Newburg Quadrangle map A small cave south of Mungy Schoolhouse. The entrance is 10 feet wide by 6 feet high, and it faces north. The cave floor is wet for the first 200 feet. Beyond this distance, it is too small for exploration. The highest ceiling within this distance is only 4 feet. (Farrar) Phelps Cave Sec. 7, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map A very small cave in a hollow which enters Kitchens Branch from the west. The passage which has a maximum width of 8 feet slopes downward from the mouth and is quite low throughout its entire length of about 100 feet. The cave is about 15 feet below the Roubidoux–Gasconade contact. (Farrar)
Pillman Cave NW1/4 NW1/4 SE1/4 sec. 10, T. 35 N., R. 10 W., Phelps County Not shown on Waynesville Quadrangle map Near the top of a bluff of Gasconade dolomite, close to the confluence of Spring Creek and Big Piney River is a small cave with an entrance about 20 feet in diameter. A winding passage can be followed into the hill for about 250 feet where it is choked with blocks of Roubidoux sandstone. There is no flowstone. The cave is in the Gasconade formation. Pillman Cave is also known as Spring Creek Cave.

Piney Spring Cave NE1/4 SW1/4 SE1/4 sec. 4, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map This cave is on the east side of Little Piney valley near Piney Spring (locally called Big Spring). The entrance is about 100 feet above the floor of the valley and about 25 feet below the contact of the Gasconade dolomite and the overlying Roubidoux sandstone. The opening is small (3 feet by 4 feet), and the tunnel inclines downward for about 20 feet. A room 40 feet in width and about 25 feet long opens out. Several large columns of cave onyx form a partial partition, and near them there is a "frozen river" in the floor. The room is from 4 to 7 feet high, and the roof is studded with stalactites. A small winding passage which contains a small stream inclines downward from the northeast of this room. The stream has a mud bottom and no attempt was made to explore it.

Poole Hollow Cave SW1/4 SW1/4 NE1/4 sec. 13, T. 37 N., R. 9 W., Phelps County Not shown on Rolla Quadrangle map This cave is about two miles above the mouth of a large hollow which enters Little Piney Creek. The entrance is about 12 feet high, 75 feet wide, and it can be seen for a considerable distance down the valley. The entrance room tapers slightly to the rear, and at a distance of about 150 feet from the mouth the passage swings to the northeast. It becomes rapidly smaller beyond this point and crawling is necessary if one wishes to explore farther. The floor of the cave is largely under water, and a stream flows along the west wall. This feature probably prevented the cave from being used for living quarters by the aborigines.

Relfe Cave SW1/4 NW¼ NW¼ sec. 36, T. 35 N., R. 10 W., Phelps County Not shown on Edgar Springs Quadrangle map
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Renaud Cave SW\(1/4\) SW\(1/4\) sec. 33, T. 35 N., R. 8 W., Phelps County Not shown on Edgar Springs Quadrangle map

The opening to this cave is in the lower cliffed slopes of Little Piney valley, about 100 feet above the river and back under an overhang which is several times as high and wide as the cave mouth. The bluff face under the overhang is solution-marked. There is no possibility of fracture origin for it. It is the back wall of a very large chamber, or perhaps two chambers, most of which has been destroyed by the deepening and widening of the valley of Little Piney. The solution-rounded wall is traceable northward along the margin of a talus cone to a level at least 30 feet lower than the cave entrance floor. A big, horizontal limestone block lies or crops out at the head of the talus. It may be a roof block. If so, it fell or settled some 15 feet or more. It might also be the remnant of an island between two chambers. The block does not show solutional markings. The cliff which extends several hundred feet northward from the cave mouth contains the cross sectional openings of several, minor, solutional channels. These channels are remnants of what once was an extensive, phreatic, drainage system at this level. In the cave, there is an earthen floor throughout. A trickle of seepage water on the floor leaks down out of sight and appears in the lower cliff face outside where it emerges from a bedding plane slot. The depth of the fill is not known. The floor slopes back into the cave for some distance from the entrance. Roof slabs litter the floor for 50 feet. Because of the flaring mouth, frost action has probably split them off this far back. The cave ceiling is low and flat, and it spans a width of as much as 25 or 30 feet. There are a few shallow roof pockets. The ground plan is clearly phreatic. There are several chambers. Some appear to have blind ends, others seem to be untraversable tunnelways, and some clearly are interconnected around great, residual, pillar islands. The ceiling level changes from room to room. The largest enterable room appears as an enormous side pocket. From the evidence in the face of the cliff, it is altogether likely that if there were no fill, most of these big, blind-ending chambers would interconnect. The back end of the cave is a collapsed rubble cone which is perhaps 400 feet from the entrance. This obstacle has been by-passed to enter more cave chambers beyond, but at the time of the writer's visit very freshly fallen rock debris lay on its surface, and he went no farther. No red clay episode is on record. No vadose alteration was seen anywhere. A spring along the road 1000 feet distant and approximately at cave level comes out of a bedding plane opening only a few inches high. It has a perennial flow and was the only source of water for local stock during a recent drought. This vadose stream looks like the maker
380 Missouri Geological Survey and Water Resources of its low opening. It is only when we consider the multitude of such bedding plane slots in the river-facing cliff--none of which shows any notching of its lip--that we see this passage as one unit of an extensive, older, cave system now favored by vadose water. The cave has no dripstone or flowstone in the part examined. It is developed in the Gasconade formation. Like Gourd Creek Cave, Renaud Cave is reported to have been one of the hideouts of the notorious bushwhacker of the Civil War, Bill Wilson. St. James Tunnel SW1/4 sec. 27, T. 38 N., R. 6 W., Phelps County Shown as Natural Bridge on Meramec Springs Quadrangle map. This is another cave which perforates a ridge and carries a surface stream underground and then allows it to emerge and become a surface stream again. Pulaski County has Tunnel Cave, Shannon County has Sinkin Cave, and Greene County has Ash Grove Cave. All of them are shortcuts for streams. All are due to discovery--as the streams deepened their valleys--of subjacent caves properly oriented to afford shortcuts. All but one stream found these cave routes because of sinkhole collapse in the bottoms of the valleys. St. James Tunnel is 200 feet long, from stream entrance to stream exit, and its course underground is at right angles to the valley it leaves and the ridge it perforates. Each opening is essentially a full cross section of this cave remnant and is about 10 feet high and 20 to 30 feet wide. A farm road formerly used the tunnel. A barn now stands under the rock shelter exit and blocks free passage through it. Although worked over by the surface stream from the ceiling down, the upper walls of the tunnel still carry plenty of phreatic solution pockets and spongework. In one place, a phreatic lateral passage, out of and back into the main chamber, was utilized by the vadose stream when it had a debris fill close to the ceiling. About that time, multitudes of shallowly etched pendants were made on the flat stretches of fracture-determined ceiling. The best showing of pendants is in the by-pass above noted. The contrast between the abandoned and the still functioning portions of the pirated little valley is marked. Upstream from the point of capture, the valley has a bottom flat and relatively gentle, soil-man-tied slopes which descend to it. Because these are adjusted to the cave floor level, they have all been made since the sinkhole developed. The abandoned portion of the valley is narrow and has no bottom flat. It also is 25 feet higher at the sinkhole than the floor of the functioning portion. There seems to be no escape from the conclusion that 25 feet of deepening and all this valley widening upstream has occurred since the piracy, and that all the material eroded in this enlargement has
Caves of Missouri 381 gone through the tunnel. It is surprising that the tunnel shows so little alteration from the original phreatic cave. St. James Tunnel is but a surviving part of a larger cave which has been destroyed by the valley-making of Dry Fork. The exit is in a fine, big, cave chamber wall. One of these pockets can be crawled through to re-enter the rock shelter. There is much to suggest that the system began as a series of bedding plane anastomoses, and that many satellitic water routes still accompanied the system when the larger openings of phreatic origin were completed. See Dake and Bridge (1923, p. 5) for a map, photographs, and a brief statement of the tunnel's features and history. Saltpeter Cave SW1/4 NW1/4 NE1/4 sec. 21, T. 38 N., R. 9 W., Phelps County Shown on Vienna Quadrangle map The cave mouth is about 65 feet wide, 25 feet high and faces north-west. Higher on the hill to the west, a small artificial opening leads into a room alongside the entrance chamber, and this offers a dryer, more direct route into the interior. This room contains most of the drip-stone seen in the cave, much of which has been spoiled by visitors breaking specimens of cave onyx. The cave consists chiefly of a winding, branching passage along which small rooms are developed at intervals. One fork may be entered for about 300 feet. It ends in a room which is about 40 feet wide by 30 feet high and has no outlet. The other fork of the passage was not explored to its end because the opening became extremely small and the air quite close. The larger room just off the entrance and a small room at the end of the longer fork are the only places where cave onyx is developed. The remainder of the cave is a damp, wet passage, through some of which crawling is necessary. (Farrar) Schoolhouse Cave SE1/4 NW1/4 SE1/4 sec. 5, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map This cave is about half a mile south of the bridge on U. S. Highway 63 that crosses over Little Piney Creek near Yancy Mills. The cave is on the west side of Kitchens Branch in the upper beds of the Gasconade dolomite, about 20 feet below the base of the Roubidoux sandstone. The entrance is about 2 feet by 2 feet, but a winding passage in the interior reaches a maximum width of 20 feet and is about 5 feet high. The floor is muddy, and a stream is said to flow from the cave in wet weather. (Farrar)
Shelton Cave SE1/4 NE1/4 NE1/4 sec. 21, T. 36 N., R. 7 W., Phelps County Not shown on Meramec Springs Quadrangle map The entrance to Shelton Cave is in a small sinkhole about one-fourth of a mile south of the Central School. The cave was not explored, because the entrance was almost completely blocked by material which had fallen from the sides of the sink. One exploring party went back into the cave the length of a five-pound ball of binder twine and is said to have reported that the cave consisted of rooms connected by small passages. (Farrar) Spencer Cave SE1/4 SW1/4 sec. 1, T. 38 N., R. 9 W., Phelps County Shown on Vienna Quadrangle map The cave entrance which is about 25 feet wide and 10 feet high is in the Gasconade formation about 30 feet below the base of the Roubidoux sandstone. A stream about 3 feet wide and 6 inches deep issues from the entrance and can be followed to its source in a crevice at the end of the cave, about 700 feet from the entrance. The cave is a winding passage with a few short branches. Throughout most of this passage, it is possible to walk upright, but some stoop- ing is necessary in a few places. To reach the room at the end of the cave, it is necessary to crawl about 20 feet through a very low muddy passage. The room contains the only flowstone observed in the cave. (Farrar) Tick Creek Cave SW1/4 NW1/4 NE1/4 sec. 3, T. 37 N., R. 9 W., Phelps County Not shown on Newburg Quadrangle map The entrance to Tick Creek Cave or Friede's Cave is about 35 feet wide, 7 feet high, and is about 25 feet above the valley bottom of Tick Creek. A winding passage can be followed back for about 250 feet until it becomes too narrow to permit further exploration. A shallow stream emerges from the eastern side of the cave mouth, but a large portion of the entrance is dry, and as the cave mouth faces south it was almost ideally situated for use as living quarters by primitive people. Cave earth is about 8 feet deep in the entrance room, and it is reported that several skeletons and some very good specimens of pottery have been found in it. (Farrar)
Caves of Missouri 383 Treeman Cave NW1/4 NW1/4 SW1/4 sec. 36, T. 35 N., R. 10 W., Phelps County Not shown on Edgar Springs Quadrangle map Turner Cave SW1/4 NE1/4 NW1/4 sec. 3, T. 37 N., R. 9 W., Phelps County Not shown on Newburg Quadrangle map Unnamed Caves Sec. 16, T. 37 N., R. 16 W., Phelps County Not shown on Meramec Quadrangle map This cave is "near the mouth of Norman Creek" (Farrar). Sec. 13 or 14, T. 37 N., R. 7 W., Phelps County Not shown on Meramec Quadrangle map This cave is "near the mouth of Little Dry Fork" (Farrar). Wild Hog Cave Sec. 9, T. 35 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map This cave is so close to the Phelps-Dent County line that Farrar locates it in Dent County. Fowke (1922, p. 23) says it is small and tunnel-like, with a bedrock floor. It is a quarter of a mile from Marsh Cave which is also listed for Dent County. Its mouth is on the north side of Wild Hog Hollow, about 50 feet above the valley bottom. It is developed in the upper beds of the Gasconade dolomite; the mouth being about 35 feet below the contact between the Gasconade dolomite and the reddish sandstone of the Roubidoux formation. There are rock shelters at this horizon close to the mouth of the tunnel-like entrance, and, being somewhat larger than the cave mouth, they serve as guides to its location. The entrance is about 3 feet wide and 4 feet high. Its small size and plainness hold no promise of the spacious room within. After one follows a tunnel for about 75 feet, he enters a room with a sloping floor which is about 130 feet long, 20 feet wide, and 15 feet high. The ceiling is dotted with stalactites, some of which are in large clusters. At the western end of this room, a winding passage continues for about 200 feet. In two places, crawling is necessary, although elsewhere the passage affords ample head room. This passage which ends in a small room about 20 feet in diameter has three very small passages leading from it. None of these was explored. The lowermost passage has a small stream in it, but the rest of the cave is perfectly dry. (Farrar)
Wilkins Cave Sec. 28, T. 36 N., R. 9 W., Phelps County Not shown on Kaintuck Hollow Quadrangle map
Windy Cave NE1/4 SW1/4 sec. 22, T. 37 N., R. 9 W., Phelps County Not shown on Newburg Quadrangle map
Yancy Mills Cave NE1/4 SW1/4 SW1/4 sec. 32, T. 36 N., R. 8 W., Phelps County Not shown on Yancy Mills Quadrangle map
The cave is in a steep bluff on the west side of the spring branch, about half a mile below Yancy Mills Spring and about 120 feet above the floor of the valley. The cave consists principally of a low winding passage which may be followed with comparative ease for about 400 feet. Beyond this, the passage becomes quite low, and a traverse was not attempted. No good cave formations were seen, and the floor is damp except for a short distance at the entrance. Yancy Mills Cave is in the Gasconade formation, about 40 feet below the contact of the overlying Roubidoux sandstone. (Farrar)

PIKE COUNTY
Seven named caves are reported in Pike County. Two of them were examined for this study. Buzzard Cave NW1/4 sec. 5, T. 53 N., R. 4 W., Pike County Not shown on Vandalia Quadrangle map
Buzzard Cave is an entirely fracture-outlined cave; not a solutional outline remains on walls or ceiling. The original cavity has been entirely filled by the fall of ceiling and wall rock, the cave migrated upward in consequence. The arched entrance is exceedingly unsafe. Many freshly fallen blocks on the enormous pile of great, roof rock masses must be climbed over to enter the cave. The cavity is very low and very wide. It is only a creepway at the best and a crawlway for the most part. Back of the entrance, ceiling rock has fallen in relatively thin slabs. These slabs plus some vadose stream aggradation back of the talus at the mouth make a fairly flat floor. Stream water from the cave escapes through the base of the great pile of recently fallen rock.
It is impossible to determine if the cave had a phreatic beginning or was entirely vadose in origin. A suggestion that it was wholly vadose is in the outcrop of a greenish-gray shale at the bottom of the ravine just outside the foot of the cave mouth talus. Vadose caves are most likely to develop just above such an impervious layer. Cave Creek Cave Sec. 30, T. 54 N., R. 4 W., Pike County Not shown on Vandalia Quadrangle map The name and location of this cave are listed in Survey records. Rowley (1907, p. 9) mentions that among the caves in Pike County "the largest and most interesting are in the bluffs of Burlington and Chouteau limestone along (South) Spencer Creek, near Spencerburg". Moore Cave NE1/4 sec. 36, T. 54 N., R. 5 W., Pike County Not shown on Vandalia Quadrangle map Shy Cave This cave is noted by Rowley (1907, p. 9) as being in the "Trenton limestone further up Buffalo Creek" from Buffalo Bluff which is located in the N1/2 sec. 28, T. 54 N., R. 1 W., Pike County. Stillhouse Cave NW1/4 sec. 5, T. 53 N., R. 4 W., Pike County Shown on Vandalia Quadrangle map This cave is in the same bluff of Clifty Fork (South Spencer Creek) as is Buzzard Cave and is scarcely more than 1000 feet distant. But it is very different in character. The entrance is a nearly cylindrical tunnel 8 feet in diameter. It is centrally situated back at the foot of a cliff which weathering has shaped into the semblance of a band shell. It is a promising entrance, but the cave fails to measure up to that promise. A short distance inside, the cave narrows to a slot which has deep pools on the floor and no adequate, low wall ledges for straddling. Anyone who goes back into Stillhouse Cave probably will do considerable wading. Local information does not indicate that the cave changes character farther back. The cross section of Stillhouse Cave is almost wholly vadose in origin. The only relics of earlier phreatic solution are the termini of two or three tubes truncated by the fracture wall. One of these, just inside the cliff, was discharging a cascade of clear water down the lower
386 Missouri Geological Survey and Water Resources slope of the cave wall at the time of examination. Absence of any notching at this discharge indicates recent discovery of the phreatic route by vadose water. The symmetrical, tube-like cross section at the entrance is entirely fracture-outlined. Just inside, there are two right-angled turns in the cave course that indicate joint control. Less than 100 feet inside, there is a 4-foot cascade over rock bottom ledges. Tapley Cave NW1/4 sec. 30, T. 54 N., R. 4 W., Pike County Not shown on Vandalia Quadrangle map Woodson Cave E1/2 sec. 30, T. 53 N., R. 4 W., Pike County Not shown on Vandalia Quadrangle map. This cave is said to "go under the road" along the east edge of the section. PULASKI COUNTY Pulaski County is the premier county of Missouri in the number of caves. Ninety-six named caves occur under its hills and most of them have been located. A dozen others are located but seem to have no generally accepted names. The 1935 Pulaski County map (now out of print) by the Missouri School of Mines has symbols for a total of 103 cave openings. Thirty-eight of these are named on this map. The grand total of known caves in Pulaski County is 110. Of this wealth of caves, only two are offered to the visiting public. One, now called Pike's Peak Cave, was formerly named Kraft Cave, and still earlier, Roubidoux Cave. The other, now named Inca Cave, is listed on the Waynesville Quadrangle map as Maxey Cave. Both caves receive special attention in the first part of the present report. Twenty-four caves were entered and studied during this investigation. Several others are described in Farrar's notes or in print. Ash Cave SE1/4 NW1/4 sec. 16, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map. The mouth of this cave is 75 feet or so higher than the water level of Emerald Lake which is shown on the Waynesville Quadrangle map. The opening is on the clifled side of a valley with no cliffs elsewhere in sight. The cave mouth, however, is not in a terrace, as are those of
Caves of Missouri 387 most caves in Gasconade dolomite. The summit of the cave's cliff is close to the top of the spur ridge. The ceiling of the entrance arch is 50 feet above an emerging stream and 20 feet above an untrenched talus hill. The span of the arch is nearly 100 feet. The entire archway is fracture-determined. The level of the solutional cave ceiling, farther back in, is 40 feet or so lower. The entrance arch constitutes a great half dome. Even back where the ceiling becomes level, there are enormous flat slabs of roof rock lying nearly horizontally on the floor and characterizing the first 150 feet of cave length. Beyond that distance, the ceiling is lower and solution-pocked to a point 300 feet from the entrance. Here a great collapse of rock mounts far up into a high narrow dome. It appears that the collapse was cylindrical with nearly vertical walls. A clear space above the debris cone can be seen with the aid of a spotlight. The cone was passed, but only more collapsed rock was seen, and the cave was not examined farther. There are two good phreatic tubes on the left. Traced back, they were found to be nearly filled with red clay and traversable only by crawling. The only dripstone seen was at the back end of one of these tubes. Extensive failure of the ceiling rock of the arch has revealed a phreatic pocketing, almost a spongework stratum, which lies well above the level of the solutional ceiling. This is a satellitic aggregate of solution cavities that shows how water sought every possible route of flow to escape the urge of hydrostatic pressure. Thus, the fact is shown that solution pockets now found in cave walls or ceilings may not have been dissolved back from the cave wall as it now is. The neighboring rock was already riddled. Only later enlargement by wall or ceiling failure or by vadose streamwork has made them a part of the present cave walls. Ballard Cave SW1/4 SE1/4 sec. 36?, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map This cave is reported to have an entrance opening 8 feet high by 30 feet wide and to have daylight penetration for 100 feet back. It is a wet cave with much dripstone. Bat Cave NW1/4 NE1/4 sec. 4, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map Bat (or Page) Cave is 1500 feet south of the western mouth of Tunnel Cave. The entrance is in a Gasconade River cliff which here has strong development and gives adequate buttresses and a marked, arch opening 30 feet high and 40 feet wide. The large chamber inside, with
388 Missouri Geological Survey and Water Resources its 20- to 30-foot ceiling, continues back for nearly 200 feet, and its floor gradually rises on a debris fill. The wet weather stream of the cave has a cobbled-paved trench 4 to 6 feet deep in this fill and reaches bedrock at the entrance, about 30 feet above the Gasconade floodplain. The stream bed can be readily traversed for about 250 feet to a point where the water enters from under a ceiling too low except for crawling. However, one can walk another 100 feet back because of the head room provided by a roughly outlined but continuous winding slot incised some 3 or 4 feet up into the ceiling. At 350 feet, this slot has a clay floor and very little clearance above. It looks like another ceiling channel of the Endless Caverns type, but its sides and top are so irregularly dissolved as to be almost a spongework. The stream of today is not making any such sinuous ceiling channel. It is cutting sidewise enough to use almost the entire width of the large chamber. Two hundred feet inside the entrance, the ceiling of the large chamber abruptly lowers and so continues until crawling is necessary. But just above the place where it lowers, another, still higher chamber crosses the one with the stream, oriented at a high angle. There has been a floor between the two, but it is now gone. At this place, the ceiling is 40 feet or more above the present floor. To the right, this upper chamber can be seen outlined in the high wall, but it is filled with clay. To the left, one may climb up into it over a fairly steep clay slope which is 40 feet high, until he stands just under this high ceiling. Turning gradually more and more to the left, the chamber may be followed on a fairly level clay floor—this means a fill of 40 feet or more—for 500 feet. The first 100 feet of this stretch is narrow and has badly failing wall rock but a level ceiling. Then for another 100 feet, there is a greater width and solutional ceiling and walls. Then, another 100 feet of length has a fracture-determined, higher ceiling. The next 200 feet has an unfractured, solutional ceiling. At this distance in the upper chamber, one stands on the brink of a very narrow, sinuous deep slot which leads off into the left-hand wall of the lower entrance chamber. It is surely a vadose slot. The upper chamber floor drops somewhat precipitously at this point, but the broad, flat, solutional ceiling continues. It is reported that one can cross the slot, go on in this upper chamber and eventually emerge on the hillside about 75 feet higher than the entrance chamber floor and an eighth of a mile farther south. If this is so, then this upper chamber crosses the entrance chamber above its ceiling to make this exit south of the mouth. Thus, the upper chamber crosses the lower one twice. At the crossing 200 feet back from the entrance, the floor-ceiling has been destroyed. At the other crossing the floor-ceiling is intact, though it is nearer to the Gasconade valley slope. Both of these chambers have been vadose-modified from a phreatic origin. The testimony of the vadose, narrow, deep channel in the upper one and the upside-down ceiling channel in the lower one is convincing.
Caves of Missouri 389 Add to that the fact that the spongework of the lower ceiling, although supplied with splendid phreatic pockets which penetrate 6 to 8 feet up and have a diameter of 1 to 8 feet, is definitely smoothed off. Vadose water has been right against that original phreatic, rugose surface, held up there by a cobble deposit. The gravel, still remaining up to this level in a number of places, is stratigraphically younger than the slightly gritty, red clay fill of the upper chamber. Bat Cave, therefore, is an originally phreatic assemblage of two levels; the upper one deeper than wide, the lower one with reverse pro- portions. The two developed separately but contemporaneously until the floor-ceiling was perforated. Then the clay-fill episode followed, and finally, when the Gasconade River had cut low enough, vadose water found and used such routes as favored its escape to the river valley. Bat Cave has apparently seen an increase in vadose discharge throughout its later history. Many other caves have shown that vadose water used them for a time but finally abandoned them for other lower routes as the water table lowered. Most of Bat Cave is phreatic in origin. The cave is in the Gas- conade formation. Bell's Cave Sec. 23 or 24, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map The cave opening of Bell's Cave is well up in the bluff bordering the west side of Roubidoux Creek valley, about a mile from Waynesville. It is 27 feet wide and 12 feet high. Seventy feet inside, the ceiling and floor almost meet, but if one can pass this, there is open space farther along. The cave is in the Gasconade formation. (Fowke, 1922, p. 51); (Farrar) Berry Cave SW1/4 NW1/4 SW1/4 sec. 35, T. 35 N., R. 12 W., Pulaski County Shown on Big Piney Quadrangle map This cave is reported to be large and dry and to have a wealth of varied dripstone forms. It has not been examined by either Farrar or the writer. Biscuit Bluff Caves W1/2 SW1/4 sec. 17, T. 34 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map Five small caves are reported to occur in a row in the bluff of Big Piney River in this section. They have not been examined by either Farrar or the writer.
Missouri Geological Survey and Water Resources Blue Springs Cave NE1/4 NE1/4 SW1/4 sec. 24, T. 36 N., R. 11 W., Pulaski County Shown as Shanghai Spring on Waynesville Quadrangle map Apparently Blue Springs is an alternative name for Shanghai Spring, and the spring apparently issues from a small cave. It is not reported by Farrar and has not been seen by the writer. Breeden Cave SE1/4 NE1/4 sec. 24, T. 34 N., R. 12 W., Pulaski County Not shown on Big Piney Quadrangle map Reported to be a fairly long cave with a small cross section through-out. Brooks Cave This cave which is reported by Fowke (1922, p. 56) is said to be 11 miles southeast of Waynesville and is entered from a sinkhole in a level field. It is said to be "small and dark". Brown Cave NW1/4 SE1/4 sec. 33, T. 35 N., R. 13 W., Pulaski County Not shown on Drynob Quadrangle map It is reported that one may "go through this cave and come out on top of the hill". The mouth is 8 feet high by 40 feet wide. Bruce Cave NE1/4 SE1/4 sec. 16, T. 37 N., R. 10 W., Pulaski County Shown on Waynesville Quadrangle map The opening of Bruce (or Goat Bluff) Cave (Fig. 156) is about 125 feet above the Gasconade River in a continuous cliff. There are many satellitic cavities in the cliff face on each side of the cave mouth. The two-way talus hill at the cave's mouth is composed of fragments fallen from the arched ceiling and is about 15 feet high. The solutional ceiling, however, comes close to the outside; within 30 horizontal feet of the brink of the overhanging ledge. The arch is 75 feet wide and 25 feet high. It discharges no stream now, but the horizontal meander niches in the wall throughout testify to such a stream in the past. The stream started on a high fill and has since removed it to the present floor level.
Caves of Missouri 391 The wall and ceiling have suffered very little failure and carry excellent interconnecting phreatic pockets. Two hundred and eighty feet back, the surface of the fill rises so close to the ceiling that crawling is necessary. NOTE: Only a small part of this exceedingly long cave is shown. A continuous passage has been surveyed for 10,100 feet or about 5 times as long as the entrance chambers shown in figure 156. A lateral passage 7600 feet back in the cave will allow one to find exit by way of Ash Cave whose mouth is about 3000 feet northeast of the entrance to Bruce Cave. The two openings belong to the same cave system. A complete map of Bruce Cave is on file with the Missouri Geological Survey. Fig. 156. Bruce Cave, Pulaski County Surveyed by C. R. Bieling, B. L. Butterfield, and L. M. Krueger, 1953. For about 200 feet, the ceiling of Bruce Cave possesses a winding, upside-down channel. It varies in dimensions and proportions but averages about 3 feet in depth. Widths vary more than this; the average is 2 to 3 feet, but in places is 6 to 8 feet. The curves of the ceiling channel did not shift very much as it was dissolved upward, yet these remarkable sinuosities in a fairly straight chamber can mean only a
392 Missouri Geological Survey and Water Resources vadose stream. It is impossible for this stream to have started at the top of its ceiling channel and to have cut down to the larger chamber below. The interpretation for this feature is taken from the ceiling channels in Endless Caverns, Shenandoah Valley, Virginia, where meander shifting did occur. The vanished stream of Bruce Cave cut upward; forced to do so at that time by a mounting fill of insoluble debris. What at first sight seems to be an objection to the interpretation of this as the effect of vadose water, is the prevalent spongework in its walls and top. But this spongework is older. The channel was cut up into a stratum already riddled with sponge pores. Far back in the cave, the floor rises on a red clay fill, until all that is left is this upside-down channel. Here it is broader and has a smoother ceiling (bottom) because it is above the spongework horizon. Only a snake-like crawl enabled the surveyors to go farther up this course. No rock floor is known and no dripstone was seen in the cave by the author. Bucher Cave Bucher Cave is located by Fowke (1922, p. 51) as two miles north-east of Waynesville. The Missouri School of Mines map of Pulaski County shows a cave in this place. It must be well up toward the summit of the hill and is reported to have a small entrance. Bushwhacker Cave NW1/4 SE1/4 sec. 20, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map Bushwhacker Cave is known only from a designation on the Missouri School of Mines map of Pulaski County. Campbell Cave SW1/4 sec. 20, T. 36 N., R. 12 W., Pulaski County Not shown on Richland Quadrangle map The entrance is at valley bottom level in apparently the only cliff in this one and one-half mile-long valley, which enters Collie Hollow from the south. The cliff is pocketed with associated solution holes of phreatic type, identical with those on the ceilings and upper walls of the cave. The cave pattern is simple and unvarying for 530 feet back from the entrance. There is a uniform stream gravel floor with only a small channel to carry the flowing water at a gentle gradient out into the floodplain of the outside valley. The uniform width of the cave is about 20 feet, and its height is about 8 to 10 feet. The height gradually becomes less, but the ceiling must have a slight gradient which corre-
Caves of Missouri 393 sponds in direction to that of the floor. The course is smoothly curved. It is without marked straight stretches or abrupt angles and has no obvious joints in the ceiling. The cave contains no dripstone or flowstone. There are a few small branch chambers and a few roof-rock slots of very ragged cross section. The branch chambers have sponge-work walls and ceiling pocketings which are commonly not connected back in the wall because of the wide spacing of the pockets. But in the main chamber ceiling, there are some very striking connections with residual bridgings. The cross section has a consistent pattern. The upper walls and ceiling carry the spongework, while the lower walls which are much smoother bear many horizontal meander slots. These slots are much longer than deep, and not all are clearly of this origin—the association with other good ones is the convincing evidence of their nature. No spongework was seen in the meander slots. In some ceilings, the projecting ridges and points of the spongework are definitely smoothed off to a common plane that has a broader, smoother, different-looking surface than the one back in the pockets themselves. This consistent cross section of Campbell Cave may be controlled by the stratification to some extent; the upper layers in the cave wall developing a different solutional pattern from the lower layers. The chief reason, however, for the contrast is the difference in experience with ground water. The cave was originally an excellent phreatic tube. As the little valley outside was deepened to the cave level, vadose water collected from rain on the hill land to the east and came to flow as it now does but perhaps in larger quantity than today. It flowed on top of a clay fill which is now gone from this 530 feet of cave length. It meandered, horizontally trenched the upper walls, locally flowed against the ceiling, and smoothed off the spongework projections in such places. Here and there, a meander was made along a phreatic spongework bedding plane. Such a meander itself has a smoothed spongework ceiling. Then the vadose stream of the cave, in a rather short time, received a definite rejuvenation from changes in the open valley to which it was tributary. The remainder of the fill was removed to the present gravel floor level too rapidly to permit meandering to develop more than local or incipient horizontal slots. Yet the absence of spongework on the lower walls must be explained. Perhaps enough impingement by the stream, as lowering progressed, cleaned the spongework off. Perhaps the character of the lower strata did not favor spongework formation during the phreatic episode. The above interpretation should stand on its own merits, but there is further evidence of its correctness, as follows: (1) From 530 feet back for perhaps another 100 feet, the cave is very complicated. It consists of several small chambers which are separated by incomplete, perforated partitions instead of the uniform tube shape; (2) There is
The stream is cutting a narrow trench in this floor, is wandering from one room to another, and is now making low horizontal meander slots in the walls of these rooms. Back here, the walls are covered with spongework down to the bedrock floor which is being trenched; (4) Remnants of a clay fill lie on those floors that do not carry stream drainage; (5) The solutional pattern made by the vadose stream in the bedrock floor is a hackly surface of rounded pockets from one inch to a few inches in diameter that are variously oriented and separated by irregular blades and points. It is a kind of minute spongework that is consistently limited to the modern channel in the rock floor. This cannot be due to a particular stratum's peculiar way of responding to solution, because the same stratum runs into the wall from the floor level as one approaches the outside, and there the pattern does not occur. The pattern must be the result of a particular method of attack by the free-surface cave stream. In interpreting the history of this cave, one must not neglect the numerous phreatic pockets in the outside cliff face. None seems to be a cross section of a long tube. These tubes look much more like spongework pockets. We know from other caves that main phreatic routes with spongework are commonly accompanied by minor spongework passages which penetrate back into the wall rock bedding planes and joints which are transected by the main cave route. These, at the mouth of Campbell Cave, thus seem to be a part of a satellitic system. One should also note, that just inside the entrance (which is not much larger in cross section than the cave itself), there is a marked broadening on the south side, so large that it has been fenced for a stock shelter. This cannot be ascribed to the vadose stream. It belongs to the phreatic irregular rooms and branch tube system. Campground Cave Fowke (1922, p. 51) says this cave is three-fourths of a mile west of Waynesville, is small and has a muddy floor. No other information is at hand. Cave Lodge Cave S1/2 sec. 11, T. 36 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map The mouth of this cave is said to have two openings, each of which is 20 feet to 30 feet wide by 8 feet high and leads to a single chamber about 400 feet long. Clark Cave NW1/4 NW1/4 sec. 32, T. 35 N., R. 13 W., Pulaski County Not shown on Drynob Quadrangle map Reported to have a mouth about 12 feet wide by 4 feet high and to be "about a mile long" with a low ceiling throughout.
Caves of Missouri 395 Clemmons Creek Cave W1/2 sec. 9, T. 37 N., R. 11 W., Pulaski County Not shown on Waynesville Quadrangle map The yawning mouth of Clemmons Creek Cave which is also known as Fruit Farm Cave is a vaulted opening 55 feet wide and 40 feet high. It is in the face of a high bluff of Gasconade dolomite, and the bottom of the opening is about 60 feet below the basal sandstone of the Roubidoux formation. The cave mouth faces southwest, and along the southern wall, a stream winds its way through a mass of jumbled boulders. The rear of the entrance room rises sharply, and at the northeast corner, a passage leads on an upper level to a room of smaller size which is choked with talus at the rear. A stream issues from the southeastern corner of the lower room and can be followed for about 600 feet. A waterfall about 2 feet wide and 3 feet high is found in the second room of the cave, but in general, the stream is wide and quiet. For a considerable distance, the stream stretches from wall to wall; a crossing is effected by means of stepping stones. Exploration along the stream course was discontinued where the stream issues from a passage about 3 feet wide and 10 feet high, and the dryer main passage was followed into the interior. Branches lead off the main passage at several places, and the cave for a considerable distance is developed on three distinct levels. One such branch trends in the general direction of the entrance, and a winding canyon 5 feet wide and 15 feet high was followed for about 400 feet until it ended in a blank wall with a small crevice leading up into the roof. About 2000 feet from the entrance, the main passage forks and the southeastern fork was followed for 700 feet. It was necessary to stoop through part of this distance, although a room about 15 feet high and 20 feet in diameter was found. Exploration was finally stopped in a boulder-strewn room about 8 feet high and 15 feet in diameter, as the passage leading on from this was only about 2.5 feet high, and the ceiling was not very safe. The other fork of this passage was followed for about 600 feet without reaching an end. The passage averaged 12 feet wide and 20 feet high and had a somewhat irregular floor of sticky red clay. The floor finally became so soft that the exploring party sank knee-deep in mud and water, and it was necessary to discontinue the exploration. The passage continued, but no turn was seen within the range of the lights; two ordinary miner's cap carbide lamps. This cave is impressive by reason of its size, as it was explored for about 2700 feet, without reaching an end in either fork of the main passage. To those individuals who enjoy cave exploration, the cave will be fascinating. (Farrar)
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Cox Cave NW1/4 sec. 22, T. 36 N., R. 12 W., Pulaski County
Not shown on Big Piney Quadrangle map

This cave is reported to be rather large and to have a stream on the floor. Its entrance is said to be 15 feet wide and 5 feet high. Crane Island Cave NW1/4 sec. 10, T. 36 N., R. 11 W., Pulaski County
Not shown on Waynesville Quadrangle map

This cave is reported to have an entrance opening 10 feet high by 40 feet wide. It is stated that the cave extends back for 300 feet where it comes out on top of a hill, enters the ground again, and runs through the hill to come out at the foot of it some 3000 feet from the first entrance. Many large rooms are also reported. Crismon Cave SW1/4 sec. 3, T. 34 N., R. 12 W., Pulaski County
Not shown on Big Piney Quadrangle map

Nothing is known about this cave except that it is shown on the Missouri School of Mines map of Pulaski County on the inside of an entrenched meander of Roubidoux Creek. It is in a ridge which is so pronounced that it is called the Devil’s Backbone. The writer is confident that when the cave is investigated it will be found to be older than that ridge. Davis Caves SW1/4 sec. 11, NW1/4 sec. 14, T. 34 N., R. 12 W., Pulaski County
Not shown on Big Piney Quadrangle map

Fowke (1922, p. 42) notes that there are three caves in the bluff facing Roubidoux Creek. The largest has an entrance 30 feet wide and 8 feet high, is 40 to 50 feet above the floor of the bluff, and is penetrated by daylight for a distance of 120 feet. The opening to the second cave is 30 feet wide, 10 feet high, and is lighted for 40 feet back from the mouth. The third is only a rock shelter. Dead Man Cave SE1/4 SE1/4 sec. 25, T. 34 N., R. 12 W., Pulaski County
Not shown on Big Piney Quadrangle map

Information is that this is a dry cave with a mouth 15 feet wide by 8 feet high.
Caves of Missouri 397 Decker Cave NE¼ SW1/4 sec. 1, T. 34 N., R. 13 W., Pulaski County. Not shown on Drynob Quadrangle map. Decker Cave is reported to open at the foot of a cliff. The entrance is about 60 feet wide and 10 feet high. Daylight extends back for 150 feet.

Double Cave SW1/4 NW1/4 sec. 1, T. 36 N., R. 12 W., Pulaski County. Not shown on Waynesville Quadrangle map. The two openings to Double Cave are in the cliffed mid-height of the Gasconade River bluff, about halfway up to the summit from the river level. Talus reaches almost from river level to the cave entrances, and above them, ledges carry smaller talus slopes that extend to the summit. The cliff itself is 50 feet high. The two openings are nearly equal in size; approximately 12 feet high by 20 feet wide. Both have a detrital fill which is mostly a hard mud on the surface and has angular, stream-carried debris and some fall rock revealed in it. The depths of the fill are unknown but probably are not great. The ceiling of the western opening is about 12 feet higher than that of the eastern one. The detrital floor is a continuation of the flat floor under the western arch. It is intact almost to the line of cliffs. There has been no water escaping from this opening since the Gasconade River flowed at this level. But the fill in the eastern opening has suffered so much erosion that all of it is a slope which descends from the back end of the triangular buttress separating the two; the slope continues down the talus outside. Neither of these mouths is fracture-outlined. Both are good arches of solution walls which blend into a solution ceiling. Seen from the outside, each is a fine big phreatic tube in cross section. All walls and ceilings are splendidly diversified with pockets of all shapes. It is not precisely spongework, for the cavities are too large, and intra-cavity spaces too extensive. But coalescence back in the wall is repeatedly shown. There is an abundance of this phreatic solution work for more than 100 feet back in the cave, but beyond that distance it disappears almost entirely. In part, this disappearance is perhaps caused by the rising detrital floor that covers the lower walls. It appears possible also that vadose stream work has smoothed off the remainder, from this place on back for 450 feet. Horizontal and half-cone meander niches are common, and the ceiling carries an upside-down channel of vadose origin. Cemented angular gravel, poorly sorted and showing no stratification, is exposed in many places; at floor
Missouri Geological Survey and Water Resources level, on wall ledges, and as shelves projecting out under the margins of the ceiling channel itself. Here it clearly had been the floor of the stream that made the channel, and here a chamber became filled to its ceiling, and the stream was forced to attack that original ceiling and to make the channel. Since this aggradation, the vadose stream has cut into it and removed much of the coarse fill. At a distance of 400 feet inside, the wide cave ends, and a broad, low, smooth-ceiled passage with horizontal meander slots in all walls is followed. This passage is probably above the phreatic chamber entirely. This part of the open cave is essentially all vadose. A detrital fill constitutes the floor, and there is no evidence to show how deep the passage is in bedrock. The division of the big chamber into two parts, 40 feet short of the exits, is impossible to explain as the work of a vadose stream. The pillar separating them is as much diversified with irregular pockets as are other walls. There was no Gasconade valley here when they were made. The vadose record must be put back to a time when the 200-foot deep Gasconade valley had not more than half its present depth. There are two field facts to support this interpretation. One, already referred to, is the low gradient of the floor-fill of gravel and the record of the meandering behavior of the cave stream. The other is the need for a good-sized stream and an adequate source for the gravel. The Waynesville Quadrangle map shows the upland on top of the Gasconade bluffs to be a relatively narrow tract between the river on the south and an unnamed creek subparallel to the river on the north. The drainage of the creek comes from as far north as Hamilton Road and includes 3.5 square miles upstream. At some earlier time when the creek was making its own valley, it discovered a northern extension of Double Cave, entered it and used the cave to reach the river. It then proceeded to choke the cave with chert gravel and was thus forced up against the ceiling to cut the upside-down channel. Finally, it so reduced its gradient through the hill that it went back to its surface valley route and has stayed there ever since. Double Cave lies no more than 150 feet below the trace of the summit plain along the Gasconade River. But if the Dixon upland plain which is 150 feet still higher is thought of as a remnant of the peneplain across the region, the cave was 300 to 350 feet beneath it. Doyle Cave Sec. 25 or 26, T. 37 N., R. 11 W., Pulaski County Not shown on Waynesville Quadrangle map Doyle Cave, located along the Gasconade River near State Highway 28, has a large mouth which is reported to be 80 feet wide and 30 feet high. The cave is dry throughout.
Caves of Missouri 399 Dry Creek Cave Fowke (1922, p. 56) states that this cave is on Dry Creek and north of Lane's Cave which is a little more than a mile north of Big Piney Post Office. The cave is small and high in a cliff. Dye Cave SE1/4 NW1/4 sec. 30, T. 36 N., R. 12 W., Pulaski County Not shown on Richland Quadrangle map Reported to be a wet cave with an entrance opening 10 feet wide by 4 feet high. Finley Cave SE1/4 sec. 19, T. 36 N., R. 12 W., Pulaski County Not shown on Richland Quadrangle map Another cave of the same name is reported to be in NE 1/4 sec. 28, T. 36 N., R. 12 W.; apparently neither cave has any remarkable features. Fish Dam Creek Cave NW1/4 NW1/4 sec. 31, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map Fish Dam Creek Cave is on the north side of the Gasconade River near the crossing of Highway 28. It is reported to be a very dry cave with an entrance 25 feet wide by 10 feet high. Freeman's Cave SW1/4 sec. 29, T. 35 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map Fowke (1922, p. 81) lists this cave as Ramsey's Cave, but says that it is "better known as Freeman's Cave". The entrance is a symmetrical arch 75 feet wide by 20 feet high and is about 260 feet above Big Piney River in a 500-foot bluff. Seventy feet of length are traversable, beyond which is a blockade of sinkhole debris. Fowke (1922, p. 82) notes "chambers on each side near the entrance"; probably in the cliff face outside the cave. If so, these are satellitic caves which are comparable to many others in the Gasconade formation and other formations in the Ozarks. Freeman's Cave is in a high, steeply sloped spur ridge, the Devil's Backbone, inside a deeply entrenched meander of the river. This is no place for a cave of vadose origin during the present cycle of erosion.
Missouri Geological Survey and Water Resources Gier Cave NE1/4 NW1/4 sec. 5, T. 35 N., R. 13 W., Pulaski County. Not shown on Richland Quadrangle map Graham Cave Fowke (1922, p. 83) states that Graham Cave is located opposite the mouth of Spring Creek high in a bluff facing Big Piney. It is reportedly small and difficult to reach. Grempczynski Cave NW1/4 SW1/4 sec. 33, T. 38 N., R. 10 W., Pulaski County. Not shown on Waynesville Quadrangle map. This cave, located in the valley of Mill Creek, is extraordinarily interesting. It carries a ground water stream (not a sinking creek) which in flood must reach the ceiling of the lowest level, yet it has left only bars of mud. Water from the cave emerges, offside the entrance and about 20 feet lower, from a very low-roofed passage. Flood time has seen this escapeway inadequate to discharge all the water, and the excess water then flows also from the larger and higher cave entrance. The extraordinary feature of Grempczynski Cave is its two-storied character. One wades in mud and water, with some stooping, for 300 feet or so back to a place where further following of the chamber must be done by creeping on all fours in the water. But one has seen, less than 100 feet inside, a ceiling opening that reveals another equally capacious chamber higher up. Not more than a 3-foot floor separates the two. The 6-foot overhanging junction makes a climb impracticable without a rope or a ladder or a boost, but about 200 feet farther in the cave, the floor of this same upper chamber is again missing, and here one can climb. There are two places to climb that are rather close to each other. If one takes the nearer place, he will be able to follow the upper chamber back toward the entrance for 170 feet and see the chamber he just traversed below him at one place through a small hole in the floor. He will emerge at the 6-foot jump-off, though the upper chamber level continues on as an untraversable route. In this 170 feet he has crossed the course of the stream-occupied lower chamber. He climbed up out of it on his left. Returning by the upper route, he encounters it on his left. The holes in the floor mark the crossing. If one climbs at the second possible place, he follows another segment of this abandoned, upper chamber stream route for 100 feet, to find himself again looking down on the stream only 20 feet from where he climbed. Both levels are very sinuous, but the twisting in each follows a different pattern. Both chambers bear much evidence of meandering by a vadose stream; the same stream which now is using the lower route.
Caves of Missouri 401 Both routes carry phreatic wall and ceiling pockets. Both chambers show modification of these phreatic routes into vadose streamways. Why should the vadose stream have abruptly abandoned the upper one and abruptly begun the use of the lower one? Why should it thus leave a "bridge" 200 feet long? Why, also, should it today leave the lower level before reaching the cave mouth, and make or find another still lower route, the very low one by which it now reaches daylight? The only satisfactory answer is that this rock already had at least three different phreatic routes at three different levels, where the character of the rock favored their development before Mill Creek valley was cut. When the surface stream cut down to the first and highest level, vadose flow replaced phreatic in the cave, meandering occurred, and the phreatic network of interconnected cavities was made over into the "upstairs" part of the cave. This continued to be used by vadose water until Mill Creek had cut down below its level and to the next lower phreatic, bedding plane system of passages. Then, somewhere farther back in the cave, this lower route was discovered, and adequate perforation down to it pirated the entire vadose discharge, whereupon the second and present level of vadose circulation was begun. Today, Mill Creek has deepened enough to allow a third and still lower, phreatic, bedding drainage system to be used. The ordinary flow escapes (leaks) into it and the "spring" is the result. In some millennia to come, this will be sufficiently enlarged and deepened by vadose water so that a third level of the cave will be formed, and the present lower enterable route will be entirely dry. There is a marked cliff here in the valley slope, and in it are the spring opening and the cave opening. It is not so marked a rock bench as many others, but it is a cliff which does not continue along the valley slope much beyond the site of these openings. There must be, now concealed on the slope, a former opening of the upper story which does not show in the cliff face. One high-ceilinged place in the cave that has one side of it filled with red clay apparently does not lead to any higher chambers; it is just a phreatic slot. There are several views in the cave of higher spongework openings which have a total vertical range of about 30 feet. Perhaps in these upper parts, there is a considerably wrecked fourth or top story, phreatic-vadose, chamber route. Hamilton Cave SE1/4 sec. 13, T. 37 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map Hancock Cave SE1/4 NE1/4 sec. 15, T. 37 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map
Henshaw Cave NW1/4 NW1/4 sec. 25, T. 34 N., R. 12 W., Pulaski County Not shown on Big Piney Quadrangle map
This cave has an entrance 40 feet wide by 6 feet high that leads back into a dry cave. Nothing else is known about it.

Jacob's Cave NE1/4 SW1/4 sec. 10, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map
The entrance to this cave is 15 feet wide and 30 feet high. It is in a cliff, and it can be reached only by a ladder. The cave has been penetrated to a distance of only 50 feet. (Farrar)

Jim Jones Cave SE1/4 SE1/4 sec. 28, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map
The opening of this cave which is also known as Little Queen Cave is on the lower slopes of Hickory Hollow. If a fallen rock pile were cleared away, the cave floor would be about even with the rock floor of the hollow. The back end of the cave, however, is still lower. Water collecting there must escape into subjacent cavities below the bottom of the hollow. Certainly, the horizontal and vertical placing of this junction of cave mouth and valley bottom is no argument for vadose origin. The cave is largely intact. There is little fall rock. The walls and ceilings are solutional. There are enormous cave onyx deposits of flowstone and dripstone. Much quarrying for cave onyx has been done, and big angular rejected blocks cover the floor in places. Indeed, this cave is completely walled off at the back end, some 250 feet from the entrance, by a compound half dome. There is much irregularity of pocketing in the native rock of the walls and ceilings, but it is not quite as deep or interconnecting as a spongework usually is. One place in mid-length is narrow and winding. What looks like a meander slot in the dolomite occurs here, but it shows no shifting of these supposed meanders, and with the remainder of the cave as it is, this slot cannot be very strongly argued for as truly of meander origin.

Johnson Cave NW1/4 NE1/4 sec. 26, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map
This cave is reported to be a wet one. It is entered from a mouth which is 30 feet wide by 8 feet high.
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Kelly Cave
NW\1/4 SW\1/4 sec. 16, T. 34 N., R. 10 W., Pulaski County
Not shown on Big Piney Quadrangle map
This cave is reported to extend about 100 feet back from an entrance which is 30 feet wide by 12 feet high. It is said to be a dry cave.

Kempton Cave
SE\1/4 NE\1/4 sec. 28, T. 37 N., R. 10 W., Pulaski County
Not shown on Waynesville Quadrangle map
The entrance to Kempton Cave which is also called Big Queen's Cave is about 125 feet above the floor of a small valley, half a mile from the Gasconade River and about 10 feet below the contact between the Roubidoux sandstone and the Gasconade dolomite. The mouth of the cave is about 6 feet wide and 8 feet high. The passage slopes downward from the entrance so that, 50 feet from the mouth, it is about 20 feet high. Stalactites are plentiful, and in the 1890's considerable quantities of cave onyx were mined from this and other caves in the area. The passage swings to the northeast, and the floor is strewn with large blocks of stone. To the northwest, and about 10 feet lower than the average level of the floor of the passage, there is a stream which is 5 to 15 feet wide and several feet in depth. The mud in the bottom of this stream shows drying cracks, indicating that at certain seasons the water is entirely gone. But at the time the cave was explored, this water blocked exploration about 600 feet from the entrance. People living in this area say that the cave onyx was floated from the interior of the cave on a flat boat to a landing about 200 feet from the entrance, and there it was loaded on small cars. Part of the track still remains, but all evidence of the boat and landing stage has disappeared. Cave onyx is well developed throughout the entire portion of the cave that was explored. Many long, slender white tubes (straw stalactites) that hang from the ceiling are about one-fourth inch in diameter and as much as a foot long. (Farrar) Kerr Cave
Sl/2 sec. 7, T. 35 N., R. 11 W., Pulaski County
Not shown on Waynesville Quadrangle map
Fowke (1922, p. 44) reports that this is a rather small cave which is about 60 feet up in the bluff of Roubidoux Creek valley at the foot of a cliff. It is 40 feet wide, 15 feet high, and 45 feet deep. At the back end, a passage 5 to 6 feet wide leads farther back.
Kiesewetter Cave SE1/4 SE1/4 sec. 22, T. 36 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map. This cave is reported to be a wet and muddy cave but to contain "worlds of formations". Lane's Cave Fowke (1922, p. 56) states that this small cave lies a little more than a mile north of Big Piney Post Office in a cliff, and that it is difficult to reach. Lipscomb Cave S1/2 sec. 21, T. 37 N., R. 11 W., Pulaski County Not shown on Waynesville Quadrangle map. Reported to be a long cave with several large rooms, to have a wet floor, and to contain much dripstone. Little Cave Sec. 20, T. 36 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map. Little Cave is reported to be a small dry cave with an entrance 30 feet wide and 5 feet high. Little Freeman Cave SW1/4 SW1/4 sec. 29, T. 35 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map. Little Freeman Cave is apparently a small cave. Its mouth is reported to be 6 feet wide and 3 feet high. Logan Cave NE1/4 NW1/4 sec. 1, T. 35 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map. Logan Cave appears to be a small cave. It has a mouth 4 feet wide and 7 feet high. It is reported to be dry and to contain some attractive dripstone deposits. Lost Cave NE1/4 NE1/4 sec. 26, T. 35 N., R. 11 W., Pulaski County Not shown on Big Piney Quadrangle map. An entrance about 5 feet wide and 5 feet high is reported to lead steeply down for 10 or 15 feet to a dry cave about a quarter of a mile long.
Caves of Missouri 405 McCann Cave Sec. 29, T. 34 N., R. 11 W., Pulaski County Not shown on Big Piney Quadrangle map McWilliams Cave Sec. 29 or 33, T. 34 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map Martin Cave NW1/4 NE1/4 sec. 11, T. 34 N., R. 12 W., Pulaski County Not shown on Big Piney Quadrangle map Martin Cave is reported to be a long cave which contains several large rooms with abundant dripstone deposits. Merrell Cave W1/2 sec. 20, T. 36 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map The entrance to Merrell Cave which is also known as Big Woodland Cave or Woodland Hollow Cave is a large archway under a big rock terrace whose front is a cliff. There is no continuation of this cliff as outcropping ledges elsewhere in the valley. All other slopes are gentle and uniform and are interrupted only by a few wet-ground dimples which are low down on the ravine slope. These dimples are assumed to be the sites of collapsed and filled cave chambers. The cave mouth is at the head of the ravine. The entrance archway is 75 feet wide and 20 feet high and stands above a floor built on fragments whose fall from the ceiling has made the archway higher than the solutional ceiling farther back. A stream trickles out, cuts through the mound at the mouth, and gurgles down for a few hundred feet over large rock fragments. No rock floor is seen except well back in the cave. The cave stream in flood must be considerably larger, but it is not a big cave stream. It is now undercutting the walls at floor level more extensively than it had during its earlier removal of an original fill of red clay. One may walk back in this cave for 300 feet. The ceiling has phreatic pockets, but the walls are hackly and show little solution other than the horizontal meander slots. There are one or two good, half-cone slip-offs. The widest place in the cave is 50 feet back from the entrance at a junction of the left-hand chamber with the main chamber. This chamber is 75 feet long and is largely phreatic, but it also has some meander slots which have been used by Indians or bears for sleeping places. Three hundred feet beyond, the ceiling is low, and creeping is necessary. The ceiling is also smooth. Furthermore, the cross section
406 Missouri Geological Survey and Water Resources here is that of slip-offs into low meander curves that alternate from side to side. The slip-off slopes are largely floored with flowstone-covered, red clay, therefore, there must be a phreatic chamber at this place still deeply filled with clay. The stream is just beginning to clean it out. Either a rock floor in the mouth or a blockade of fallen arch ceiling rocks is holding up the stream. It meanders with a low gradient in the cave, but once outside it cascades down to the main valley. Far back, in one place in the stream bed, there is a stream-etched rock floor. The cave was penetrated for 1300 feet by Farrar. Miller Cave SW¼ NW1/4 NE1/4 sec. 4, T. 36 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map The cave is on the northeast slope of a small hollow, tributary to the Gasconade River. The entrance, about 3 feet square, is difficult to find, because it is partly hidden by vegetation. The hillside is covered by large slumped boulders of Roubidoux sandstone. The Gasconade- Roubidoux contact is about 10 feet above the cave entrance. A passage about 15 feet long, through which it is necessary to crawl, leads into the first room of the cave. The passage slopes sharply downward to a "jump-off" which is passed by means of a shaky ladder. The floor of this room is covered with water to a depth of about 2 feet. There is also some rather poorly developed flowstone. A passage opens high up in the wall beyond the pool and brings the explorer to a room about 30 feet wide and 15 feet high. Cave onyx is fairly well developed in this chamber but is stained by red clay. Beyond this room, a winding crawlway passage was explored for about 600 feet. Ripple-marked Roubidoux sandstone which shows in some places in the ceiling of this passage indicates that the cave is close to the top of the Gasconade formation. (Farrar) Miller Cave NE1/4 NE1/4 sec. 6, T. 34 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map Miller Cave is in Big Piney valley, 1200 feet along the river down- stream from the junction of Miller Spring Branch. This cave has a rock shelter opening in a Gasconade dolomite cliff and is 150 above the river which flows at its base and 75 feet below contact with sandstone of the Roubidoux formation. The main opening in the cliff is 10 feet high and 40 feet to 50 feet across. It has an almost unscalable cliff below it. There are three other openings, two windows and a back door, to this rock shelter. One window is 20 feet wide and 18 feet high, and the other is about 3 feet wide and 3 feet high. The door, which is the only feasible entrance to
Caves of Missouri the large rock shelter part, is about 12 feet wide and 7 feet high. The main part of the cave extends along the cliff face, and with these openings, resembles somewhat the cave of Jules Verne's imagination on Mysterious Island. The overall length is 140 feet. The cave really consists of two chambers (Fig. 157) which are connected by a small doorway, 3 feet wide and 5 feet high whose sides and rock bottom are polished by the hands and feet of Indians who used the cave as an ideal natural shelter; ideal except when the wind blows in, at which time the dry floor yields a cloud of dust. Fig. 157.

Miller Cave, Pulaski County
On the floor at this point and at the top of the talus are about 10 feet of fine debris littered with clam shell fragments, bone fragments, deer teeth, and flint chips, and reddened here and there by fire. The surface of the fill slopes for 50 feet back into the cave to a pool of water. Beyond this pool, the chamber swings around toward the south and in another 150 feet back is blocked by a rising fill of fine detritus. There has been very little roof failure anywhere. The rock floor is obvious in the cliff face below all openings except the back door where detritus, higher than any other floor, slopes inward (Fig. 158). Fig. 158. Cross Sections of Miller Cave E. H. Woolrych, del. As obvious as anything could be is that an older cave has been transected by a younger river cliff. A wealth of accessory evidence lies in the extraordinary abundance and variety of wall and ceiling pockets and tubes, and the extraordinary space relations they have. Note first that there are two main chambers, each opening widely to empty air 150 feet above the river. Then note that there are two closely parallel, constricted connections between these chambers, the lower and smaller one being just large enough to crawl through and paralleling the cliff face only a few feet back in the rock wall. Then note the crawlway in the large chamber which penetrates through the tip of the salient projecting into it from its south side. Now note that the small chamber is open at both ends, there being a re-entrant in the cliff at this place. The small chamber, therefore, traced northward, comes out of empty air and goes back into empty air, yet is 10 feet high and 10 or more feet wide. The topographic map shows that the cave is in a long and very narrow ridge whose summit is 200 feet to 240 feet above the river. One side of this ridge is the long cliff which is undercut by the river—a talus slope reaches halfway up. The other side is determined by a short, steeply graded northward-flowing tributary. At the level and site of the cave, this ridge is barely more than 1000 feet wide between the river valley and the tributary valley. The river is 150 feet below the cave, and the tributary valley bottom is 40 feet to 50 feet below it.
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Miller Cave cannot have been produced by the ground water work in this small ridge during the present valley-cutting cycle. The wall, ceiling pockets, slots, and tubes possess every conceivable shape that solution could make in a calcareous rock, every conceivable orientation, every conceivable kind of connection among them, and every conceivable size up to the maximum of the large chamber. There is no trace of current-directed attack on ceiling or walls anywhere. Miller Cave is another cave that cannot be explained except as phreatic in its entirety and as older than the valley on whose side it opens. Gerard Fowke must have been happy at Miller Cave. He reports that he sent back to the United States National Museum the following finds from his excavations: 12 skulls, 8 fragments of skulls, 10 partial skeletons, 74 objects fashioned from shells, 711 worked flint objects, 10 grooved axes, tomahawks, and hammers, 10 mortars, 40 pestles and rubbing stones, 413 objects fashioned from bone and horn, 2 clay pipes and 1 box of pottery fragments (Fowke, 1922, p. 81). In addition, he left in the cave more than 60 mortars, probably 20 pestles, hammers, etc., and several wagon loads of shells, bones and broken pottery. He estimates that the cave was inhabited for several centuries. He believes, from broken human bones, that cannibalism was practiced here at times. He has 25 pages of text on his archeological finds, with 18 plates (Fowke, 1922, pp. 57-81). Mix Cave SW1/4 NE1/4 sec. 2, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map This cave which is reported by Fowke (1922, p. 53) and Farrar is on the north side of the Gasconade River. The mouth is in the bluff and is 75 feet wide by 20 feet high. Daylight penetrates it for 140 feet. One may walk without stooping for 250 feet back in this cave. This cave which is in the same bluff with and close to Wingo Cave is described with Wingo Cave. Mud Cave NW1/4 SW¼ sec. 20, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map The entrance to Mud Cave is a well-proportioned arch 50 feet wide and 25 feet high in a rock terrace or bench which has a cliffed face 40 feet in total height, including the entrance opening. The adjacent slopes are without rock ledges; indeed, none was seen on any slopes along the hollow. These local cliffs which are just large enough to give adequate framing for cave mouths are a repeating phenomenon for which no satisfactory explanation has been found in this study. The cave has a wet floor. One needs boots, although there is no deep mud wading.
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The ceiling is solutional to the very front of the arch. Some of the best phreatic pockets of the cave occur in the entrance ceiling. The entire cave walls and ceilings are well supplied with pockets, tubes, and slot openings off the main chamber. The chamber is sinuous in ground plan and uniform in width for 300 feet to 400 feet back. It has a flat gravel floor swept by flood water, but no torrential action is indicated. Back of this, head-room decreases, width becomes much less, and the cave is divided into a network of spongework-walled, old phreatic passages as far as can be readily followed. Some carry flowing water, some are filled or almost filled with a slightly gritty red clay, some lack both. Fig. 159. Back Portion of Mud Cave, Pulaski County

The map shown here is very sketchy and hardly to be considered a map (Fig. 159). It shows only the general scheme of relationships back in the phreatic plexus. Water entering at the upper left is divided by rimstone dams to flow in two opposite downstream directions. These water routes commonly have a cross section. the upper part of which is without detectable vadose modification, the lower and commonly meander-looped part is wholly of vadose origin. Probably more than half the solution work in making this cave has been by vadose water. There are only a few slip-off half-cones. There are essentially no rock fall fragments in the cave. Ridged wall flowstone occurs only at and near the entrance. The structure of these ridges records a concentric growth which has formed an open-work aggregate that is separable into different irregular laminae with un-
Caves of Missouri 411 filled spaces between them. It looks somewhat like a pastry that has been rolled and rolled before it is baked. Perhaps it is a tufa, with mosses responsible in part for its growth. (See Wright Cave, Miller County, for an alternative interpretation.) Apparently none of the present drainage of this cave disappears in the floor before reaching the entrance. There is a sharp increase in gradient as the water flows down 30 feet over and through broken rock, from the entrance to the bed of the hollow. The only good dripstone in Mud Cave occurs in a noticeable shaft-like chamber which is much deeper than wide and off the main chamber near the cave entrance. Onyx Cave NE1/4 SW1/4 sec. 33, T. 37 N., R. 10 W., Pulaski County Shown on Waynesville Quadrangle map The entrance to this cave is at least 150 feet above the Gasconade River in a wooded cliff just below a steepened break in the slope. It is more than 50 feet wide and 8 feet high above a hill of fallen roof ledge rock. It is still a very striking rock shelter type of roof ledge, with a big fallen block appearing to serve as a pillar in the entrance span. There is a descent of 20 feet to 25 feet down the inside talus slope to the cave floor. The water which collects in the cave seeps out through the debris pile which nearly blocks the cave mouth. The chamber is a huge room, and its walls are partly covered with well-ribbed flowstone, as in dozens of Missouri caves. There are two routes back into the cave. To the left, the ceiling of the big room lowers, and the floor lies under fallen blocks. Beyond 250 feet to 300 feet it is just a crawlway. To the right, a low chamber brings a stream to the large room. Mud banks extend nearly to the ceiling of this chamber. As the water was deep and the mud very soft at the time of this examination, no further penetration was made. Mr. Joseph Fabra, who owned almost all the land the cave under-lies, said that this mud-filled room leads to other large rooms. Up on the hilltop, there is an opening of a 126-foot shaft where cave onyx was lifted out some years before 1918. The room where the cave onyx was quarried is reached by this low-ceilinged mud route. There are two or three good meander niches in the walls of the great entrance hall, but no other evidence for vadose work was seen. Many chambers and passages are reported to exist back where the cave onyx was taken, perhaps 750 feet to 1000 feet back in the hill from the bluff entrance. Vadose water today is simply bringing in mud and is incapable of keeping the mouth of the cave open. The pattern, the topographic position, the altitude of the floor and the mouth, all indicate a cave older than the Gasconade River valley.
Boiling Spring, close by Mr. Fabra's house but 150 feet vertically lower and out in the river, is very striking. Its clear water is in strong contrast with the Gasconade turbid water, and the spring makes a turbulent bulge on the river surface which shows at all stages. This means that the spring is operating under artesian conditions and must have a completely submerged conduit back of the orifice. At low water, it can be seen to come up out of the gravel on the river bottom. No rock opening shows. Its average discharge of 42,000,000 gallons per day is far more than the volume of any vadose stream in Ozark caves. Rising from the water table, it must be a phreatic circulation which is under pressure from a higher water table in the hills to the eastward. No lost rivers are involved. No surface water enters directly from any such sinks as Slaughter Sink or Conical Sink. The surface water must become filtered in passing down to the saturated zone, for, according to Fabra, the spring discharge has been turbid only once in the past 30 years and maintains a fairly consistent volume, even in droughts. Boiling Spring marks another phreatic cave still in the making. Peterson Cave Sec. 8, T. 36 N., R. 12 W., Pulaski County Not shown on Richland Quadrangle map Phillips Cave NE1/4 NW¼ sec. 25, T. 36 N., R. 12 W., Pulaski County Shown as Roubidoux Spring on Waynesville Quadrangle map Phillips Cave is a small cave up in the cliff above Roubidoux Spring or Waynesville Spring in the southern part of the city of Waynesville. The variations of the spring discharge are about as great as those of surface streams. When dry weather prevails, Roubidoux Creek bed goes dry from about the Devil's Backbone down to the spring, but it never goes dry upstream from the Backbone. When the creek bed is dry, however, heavy rain in the Cooksville region but not at Waynesville will cause, in six to eight hours, a definite increase in the flow of the spring and a turbidity that did not exist before the rain. The descent of the floodplain between the Backbone and the spring is 100 feet. The distance by valley routes is about 18 miles, but in a straight line it is 10 miles. The State Health Department has condemned the water of this spring. The discharge of the spring is not an underflow in alluvial fill. It is a subterranean, bed-rock drainage route. At maximum discharge, the turbulent up-boilings break and throw spray. The spring is using an already existing cave of phreatic origin and probably is enlarging it. One of two things is in store for the future: Either Roubidoux Creek will go completely underground and become a "lost river" or, more probably, the downcutting of the creek will drain the cave of its completely waterfilled condition, as almost all known caves of the region have become drained.
Caves of Missouri 413 Piney Cave SE1/4 sec. 31, T. 37 N., R. 10 W., Pulaski County
Not shown on Waynesville Quadrangle map This cave is in a bluff on the north side of
the Gasconade River, directly opposite the mouth of Big Piney River. The entrance is
about 60 feet wide and 30 feet high and is developed in the upper beds of the Gasconade
dolomite about 40 feet below the base of the Roubidoux sandstone. In the entrance
room, there is considerable cave earth, mixed with shells, fragments of bone, and flints. As
the cave faces south, at the junction of two rivers, it would seem to be ideally suited for
use as living quarters by pre-historic man. The cave has three forks, all of which were
followed to their end. The longest is about three-eighths of a mile in length. A
considerable amount of crawling is necessary to reach the rooms in the interior, and none
of them has attractive formations. The largest room entered was about 30 feet in length
and height and about 15 feet wide. (Farrar) Piquet Cave SW1/4 SW1/4 sec. 4, T. 37 N.,
R. 11 W., Pulaski County Shown on Waynesville Quadrangle map The rock floor of this
cave which is also known as Davis Cave extends through the entrance and projects a little
outside the arch. The discharging stream drops rapidly after passing the arch through a
short gorge and descends 35 feet to the road level. The entrance arch is 35 feet high and
60 feet wide. The lower part is partly blocked by huge fall-rock fragments. There is
another opening entirely solutional, in the same cliff, less than 50 feet to the south, about
4 or 5 feet in dimensions. Its floor is at the level of the top of the arch span. Its walls are all
of spongework, as is also the cliff face. There is no more cliff in sight along the valley wall
north or south; all slopes are smooth. The big entrance arch is fractured, though
smoothed. There is little fall rock on the entrance chamber floor for 100 feet back. The
chamber dimensions and proportions remain constant for this distance. The chamber is 25
feet high and 40 feet wide. For 40 feet, its ceiling exhibits a 4-foot by 5-foot tube which
has a separate opening in the lipf. Its walls and ceiling are strikingly phreatic solution-
pocked. The ceiling of the entrance chamber is similarly marked, but this may be only the
top of a bedding plane used by phreatic water and now exposed from the fall of ceiling
rock. About 100 feet in, the ceiling level drops somewhat by reason of a chert layer
bridging. A low, wide opening is visible above the layer.
Beyond this broad, thin chert bridge, the chamber is higher because of rock fall. Then another step-up occurs to the highest ceiling, which is broad and flat but entirely solutional. Pockets and a marked slotting up at the top show that it is not fracture-determined. Here is the foot of the huge debris cone of the cave, the basal slopes of which can be seen from outdoors. They have about the angle of stability. The cone is composed dominantly of small chert fragments. It is not so much roof rock as sinkhole debris, though the map shows no sinkhole on the ridge above. Debris enters from a big hole in the upper wall, but the ceiling is hardly affected. The lower edge of this debris cone curves through an area of more than 90 degrees. It is interrupted by a massive, dolomite, pillar-like mass. On the left of this, the cone has broken into and partly filled the left-hand chamber of the two original chambers back of the entrance lobby. The cone can be climbed to the ceiling at the left, and it is 60 feet above the entrance floor under the arch. No further passage is possible. The toes of the two members of the cone join around the surviving pillar. The stream comes from the right-hand chamber which can be followed for 650 feet from the arch. For perhaps 100 feet, this stream in spilling over ledges of bed rock makes excellent stream-etched surfaces. At the far end, it covers the floor, and further traverse was abandoned. It probably can be followed much farther. There are few caves in the Ozarks with such good evidence for a former phreatic network. There are at least 23 minor openings off the walls of the horizontal Y formed by the entrance chamber and its two branches that can be wormed or crawled into. A few are high and narrow, but most are irregular tubes with very well developed sponge-work and no evidence of vadose alteration in them. Some cross each other or leave and re-enter the main chambers. They occur at all altitudes in all walls and have about all orientations. Most of them are high and impossible to reach without a ladder. The spongework walls in places have their pores so widely spaced that the term is inapplicable. Instead, the appearance is that of separate holes of exceedingly irregular outline and variable dimensions. Some of them penetrate the wall for 2 or 3 feet, although they may be only 6 inches or so in diameter. Few show connections with each other. There is little vadose stream work. No good meander scars on the walls were seen. The ceiling, 600 feet back, is smoothed-off sponge-work; a vadose modification. Smaller phreatic tubes show floors and half-fills of red, clayey sand, probably of vadose origin. Although no phreatic red clay remnants were seen, there is no possible doubt that the cave system is largely a phreatic plexus. A much larger ground water discharge comes from a spring at the level of the valley floor terrace, about 10 feet higher than the road, and a few hundred feet north of the entrance arch. There are no signs
Caves of Missouri 415 of a cave mouth here. This spring probably discharges water which is gathered in the cave beyond the left-hand blockade. It probably is using a phreatic bedding plane at a level in the rock that is lower than the entrance chamber floor.

Railroad Cave W1/2 sec. 10, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map This is a cave fully worth seeing if one doubts the validity of the writer's theory of cave origins. There are two openings (Fig. 160); both of them high on opposite sides of a ridge between two ravined Fig. 160. Railroad Cave, Pulaski County tributaries of the Gasconade River. The cave goes through the ridge for a total length of 1680 feet and in so doing goes under a shallower ravine cut into the ridge crest. No cave in the writer's experience
416 Missouri Geological Survey and Water Resources shows wall-incised, half-cone meander niches in such numbers or of such magnitudes. Yet the cave has no stream and never could have had a stream supplied by the ground water from the ridge itself. In its location and orientation, Railroad Cave perforates the ridge near the crest. The cave is in wooded country, and its two openings are quite inconspicuous. Approach is made from the north end of the river bridge on the old Waynesville-Crocker road. One walks southwest along the river bank for half a mile to the mouth of the first gravel-carrying tributary stream. This place is also marked by a small field on the river floodplain. A few hundred feet up this valley is the junction of a tributary ravine from the left. A dim trail leads diagonally along its southern slope to the opening, about two-thirds of the way to the top. This opening, and also the one at the opposite end of the cave, is nearly closed by hillside waste. In entering, one descends an inside talus slope to a flat floor which is composed of detrital materials with little fallen rock from walls and ceilings throughout the entire length of the cave. A few slump pits interrupt the floor. In some places their cause is seen to be a very minor stream that apparently flows between clay fill and wall rock in an untraversable route. The red clay fill is well exposed in one such pit; faintly gritty, but probably a remnant of the earliest filling the cave has had. The big, open, corridor-like tunnel through the hill lost the upper part of this original fill before the slump pits were formed. Although the removal mechanism is no longer operating, the method of removal is perfectly clear. The corridor walls are cut into by no less than 29 semi-circular meander slots, and each has a half-cone slip-off "island" of native rock. They alternate with each other on the two walls, and many are large enough for passage. If one of them is followed, the investigator goes out of the main chamber, traverses a curved course, and returns again to the big corridor. One of these penetrates 35 feet to 40 feet into the wall rock. Another curved course is 120 feet from one end to the other, although the two ends are only 30 feet apart in the chamber wall. This particular one was deepened 25 feet, as it was enlarged to its present horizontal dimensions. Many originated near the present ceiling; others came into existence at lower levels, as the vadose or free-surface stream lowered the fill. Some did the surprising thing of developing minor meanders that shifted from side to side and made of the larger meander niche a descending series of zigzags (Fig. 161). In at least one, the half-cone island was so undercut by a secondary meander that it has toppled. Pebbles left by the stream still lie on some of these meander floors. At several places where the stream early became caught in a wall niche, clay remnants still lie close to the phreatic ceiling and denote a once complete or nearly complete fill. At a time early in the dissection of the present land surface, the two ravine streams which bound the ridge cut down into the phreatic
Caves of Missouri 417 cave which offered a steeper gradient for one of them, presumably the southern one, and an exit into the other ravine. For a long time this surface water went through the ridge, beginning at the top of the fill and lowering it by removal of the clay. The meander niches date from this time. Fig. 161. Vertical Section of Compound Meander Wall Niche, Railroad Cave E. H. Woolrych, del. The cause for abandonment of the cave route and return to an outside course is not clear. But the fact is obvious, for the trickle now working down in and under the clay surely is not the niche-making stream. It may be that the entrance to the cave became clogged with chert gravel. The southwest opening is a tight hole to crawl through today, and the inside slope is much gentler than a talus slope. Perhaps this is the cause for the return of the stream to its old route. Obvious, also, is the phreatic origin of the main chamber. The ceiling is largely solutional with many fine circular ceiling pockets. Some of these show a constriction at the lower edge because of a layer of less soluble rock. There are several high, ragged joint openings also in the ceiling and some really magnificent spongework. Near the mid-length of Railroad Cave, there is a large dripstone-affected area with one great trunk-like column connecting floor and ceiling. There is also a lateral chamber which is a vadose dome pit that one views from mid-height. The writer is confident that this vadose record of both solution and deposition lies immediately below the shallow ravine noted as grooving the main ridge. Leakage from its storm water has made the only dome pit of the cave and the cave's outstanding, secondary lime deposits. If the phreatic history of Railroad Cave is to be tied in with the summit peneplain, good remnants of which occur at Helm and Dixon, the cave developed approximately 300 feet below the level of that peneplain, but, of course, before the peneplain stage had been reached.
Ramsey's Cave SW1/4 SE1/4 sec. 29, T. 35 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map

Ramsey's Cave is reported to have an entrance only 4 feet wide by 3 feet high and to be enterable only by ladder. This cave evidently is one of the side chambers mentioned by Fowke (1922, p. 82) which are near the entrance of Freeman's Cave. Fowke refers to Freeman's Cave as Ramsey's Cave. Red Bluff Cave Sec. 21 or 22, T. 36 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map This cave is in or near the Gasconade River cliff shown on the Richland Quadrangle map as Red Bluff, near the highway between Richland and Laquey. The entrance is reported to be 40 feet wide by 20 feet high. The cave is said to be dry. Richland Cave SE1/4 SE1/4 sec. 34, T. 36 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map Richland Cave is also known as Onyx Cave and is located a quarter of a mile below the McKane Bridge on the Laquey-Richland road. The cave mouth is close to 100 feet above the Gasconade River and a little back in a re-entrant in the cliffs on the south side. Only a vadose trickle discharges from it; never a real stream. Farther back is a larger vadose flow that must get lost down in the floor before it reaches the entrance. The entrance is an imposing rock shelter formed mostly from rock falling from ceiling and walls of an originally smaller opening. There is much fallen rock throughout the cave as far as it was penetrated; 250 feet more or less. Farther back, the roof appears to have come down in one big unit instead of many separate slab falls. One may crawl be- tween this and the ceiling, but the rest of the cave appears to be nothing more than a crawlway. A red clay fill obviously underlies the ceiling debris and has been entirely removed only at and near the cave entrance. No vadose stream erosion is recorded. Phreatic solutional attack is recorded in one particular stratum by a row of "pigeon holes" (large enough for turkeys) which occur on both sides of the entrance (Fig. 162). Some of these features may be seen to interconnect back in the wall. Probably phreatic solution along this stratum made the main cave chamber- where there are excellent ceiling cavities–out of continued enlargement of such "pigeon holes" and left only these minor associated waterways lying laterally offside. They closely resemble the bedding plane an-
Caves of Missouri astomoses so common in the Mississippian limestone of Mammoth Cave and associated caves of the Ohio River drainage area. Fig. 162. Richland Cave, Pulaski County "Turkey Holes"; Though larger than the "Pigeon Holes" of Mammoth Cave, Kentucky, and not so obviously interconnected back in the wall, they appear to belong to the same category of solutional cavities made under phreatic con- ditions. Malott has styled similar forms, "primitive caves". In this report they are termed "bedding plane astomoses". Photograph by G. Massie, Missouri Resources Division. Riddle Cave Riddle Cave seems to be an alternative name for Wildwood Cave which is shown on the Missouri School of Mines map of Pulaski County. It is a small cave and is entered from a sinkhole. It is located by Fowke (1922, p. 56) as on "Schord's farm near Wildwood". Riverview Cave SE1/4 NW1/4 sec. 31, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map This cave is in a bluff on the north (left) bank of the Gasconade River, about 200 feet above river level, and the various mouths are
420 Missouri Geological Survey and Water Resources visible from Missouri Highway 28. Only one entrance can be reached without the aid of a ladder. This is about 15 feet wide and 10 feet high, and a well marked path on a narrow ledge leads to it. The cave is a winding, branching passage which can be entered without stooping for about 150 feet. It is necessary to crawl through small passages to reach the other entrances which are holes about 10 feet in diameter and are high up in a bluff of Gasconade dolomite. (Farrar)

Roach Cave Sec. 15 or 22, T. 36 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map This cave is near Ozark Springs on the Gasconade River. It is said to be a wet cave that is entered through an opening 12 feet wide by 6 feet high. Rollins Caves S1/2 sec. 15, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map There are two large caves. One is half a mile above the mouth of Roubidoux Creek, the other a mile above, and both are in Gasconade River bluffs on the south side of the river. The main entrance of the first cave is 50 feet above the foot of the hill, but it has two other entrances. Forty-five feet inside the cave, if one follows the east wall, he goes for 120 feet farther to an exit in the side of a shallow, west- trending ravine and climbs 40 feet up over an inside talus. If one follows the west wall, he comes in a total traverse of 70 feet to a third opening which is 25 feet wide by 20 feet high. It also has a steep inside talus. The main entrance is 45 feet wide by 36 feet high. The second Rollins Cave entrance is 60 feet wide by 10 feet high. Standing water covers the floor 65 feet inside. (Fowke, 1922, pp. 52-53) Ross Cave NE1/4 sec. 8, T. 34 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map This cave is reported to be in a bluff of Big Piney River. Entrance is only by ladder or rope. Nothing else is known about it.

Ryden Cave, Sealed Cave, and Stockpen Cave Sec. 16, T. 34 N., R. 10 W., Pulaski County Shown as Ryden Cave on Big Piney Quadrangle map Ryden Cave and Stockpen Cave are located south of the road between Ross Bridge and Duke, and there are at least three caves
Caves of Missouri 421 within less than a mile of each other here. The one shown on the Big Piney Quadrangle map as Ryden Cave is called Sealed Cave by local residents, a second one is Stockpen Cave, and the third and largest is Ryden Cave proper. Sealed Cave had no natural opening and was located from a persistent little pillar of fog on the hillside in frosty weather. Over its wide entrance, Stockpen Cave has a big, out-jutting ledge of rock like the visor of a cap. There is room for two stock corrals inside. Many caves, especially those in the Gasconade formation, have their mouths in the cliffed fronts of marked rock benches which interrupt the otherwise smooth hillslopes. Such benches fade out laterally away from the mouths, and most of them are most strongly cliffed at the entrances themselves. The explanation for this is not yet apparent. The inconspicuous entrance to Ryden Cave is a crawlway for 20 feet and opens under a small ledge about 75 feet above the bottom of the hollow. The course of the cave back in the hill swings around to parallel the hillside for at least the first 300 to 400 feet, as far back as the "Devil's Stairway". The cave is a big phreatic tube, modified largely by dripstone and associated growths of excellent form, but old and dull. There are abandoned rimstone dams and one growing dam down in a slump pit. The "Devil's Stairway" is a climb out of a slump pit, up over flowstone and dripstone which partially covers the clay slope of the slump. The cave beyond was not examined but is reported to have little dripstone or flowstone, and to be low. The clay fill still occupies it. An unusual stalactiflat, a circular disk 4 feet in diameter with one central stem, hangs nearly over the slump pit. The debris floor slopes inward, and the cave dripwater probably escapes as the "spring" back in Stockpen Cave which is 50 feet lower on the hillside. A meandering stream has used Ryden Cave. One spectacular meander slot with vertical dimensions of 20 feet has five zigzags which were cut as the meander shifted back in the dolomite wall. Stockpen Cave has a stream gravel floor which rises 50 feet back from the entrance. Here, it is so close to the ceiling as to forbid further entry. Originally, however, Stockpen Cave was probably a large phreatic chamber and is really a part, a lower part, of Ryden Cave. There were upper parts to Ryden Cave, too, that have been destroyed by erosion. The "air hole", seen along the trail down to the cave entrance, is 50 feet deep and no larger in cross section than a dug well. From inside the cave, daylight can be seen up through this well. Sealed Cave was not examined. Saltpeter Caves The Saltpeter Cave mentioned by Fowke (1922, p. 57) is a little more than a mile north of Big Piney Post Office. It is near Lane's
422 Missouri Geological Survey and Water Resources Cave and Dry Creek Cave in the drainage area of McCourtney Hollow. Nothing more is known about it. Two other Saltpeter caves are reported. One is near Boiling Spring in the NE1/4 SW1/4 sec. 33, T. 37 N., R. 10 W., and can be entered only by ladder. The other is in the SE1/4 SW1/4 sec. 11, T. 34 N., R. 12 W., along Roubidoux Creek. This latter cave is said to have an entrance 40 feet wide and 8 feet high, and it quite possibly is the same cave as the larger of the three Davis Caves, previously described. Sell Cave SE1/4 SW1/4 sec. 25, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map A prominent north-facing ridge salient between Roubidoux Creek valley and Bradford Hollow, just south of Waynesville, rises 180 feet above the creek and contains the cave. Its height in the ridge is not specified by Fowke (1922, p. 45). He found the entrance nearly blocked with fallen, roof ledge rock overlying red clay and had to use dynamite to uncover his archaeological treasures. The ceiling descends to a mud fill 35 feet inside the cave. He found a great deal of sand in his excavations and correctly attributed it to the former presence of the Roubidoux sandstone which is now all eroded from the narrow ridge crest. He devotes six pages of text and two plates to his findings (Fowke, 1922, pp. 45-51). The writer believes that Sell Cave, like many other caves in sharply expressed and narrow ridges, is but a remnant of an earlier ground water circulation system which ceased to function when the ridge began to be carved out by the two streams. The ridge stands isolated for half its height. There is a broad, shallow, empty valley on the southeast side which connects the upper Bradford Hollow with the larger valley. It is not difficult to picture a former, sharply bent, entrenched meander of Roubidoux Creek as having encircled this hill, as it now does the Devil's Backbone about 10 miles farther upstream. Perhaps Sell Cave, Phillips Cave, and the Roubidoux Spring conduit were once parts of one system until valley cutting of the present cycle separated them. Sieb Cave NE1/4 SW1/4 sec. 32, T. 37 N., R. 10 W., Pulaski County Not shown on Waynesville Quadrangle map This apparently is a small cave. The reported height of the opening is only 3 feet.
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Skaggs Cave SE1/4 NW1/4 sec. 3, T. 36 N., R. 12 W., Pulaski County
Not shown on Waynesville Quadrangle map
This cave is half a mile northwest of the Gasconade River on the old Waynesville-Crocker road. The cave mouth is perhaps 30 feet above the adjacent valley floor but at the head of a small draw with scarcely any cliff being involved. There is walking height through the entrance and for a few hundred feet back. The direct route into the cave ends in what appears to be an impassable blockade of fallen roof rock. A branch chamber turns right a short way in, and one begins almost at once to ascend the gentle slope of a rimstone river which correspondingly decreases headroom. Penetration beyond the splendid dripstone aggregates (see frontispiece) from the base of which the rimstone terraces descend must be by stooping and shortly by creeping. There is standing water on the floor except in dry weather, but no vadose stream is recorded by gravels or by characteristic wall sculpture. The cave appears to be almost wholly phreatic in origin. The display of secondary lime deposits is superior to that of any other of the half-dozen caves within a three-mile radius. The cave also has a problematical, ridged wall flowstone which, wherever found, occurs within reach of daylight. The outstanding feature of the cave is its "pearls". Hundreds of these, from the size of peas to that of hickory nuts, lie in the rimstone pools; in some places two or three layers deep. They are all rough and dark and are "pearls" only in the sense that each has been formed of successive layers of calcium carbonate surrounding a tiny nucleus of foreign material. When sectioned and polished, they show the concentric structure of pisolithic concretions. These "pearls" should be studied with a view to determining the conditions of origin. They obviously have not grown at the bottom of any splash cup. Spring Cave NW1/4 SE1/4 sec. 33, T. 37 N., R. 12 W., Pulaski County
Not shown on Richland Quadrangle map
This cave is 1000 feet north of the junction of the old and new Waynesville-Crocker highways, at floodplain level, west of Clifford William's farm. It apparently is entirely a vadose cave. A good stream emerges and cascades 20 feet or so to the floodplain. The cave has a ragged solutional chamber of bedrock floor, walls, and ceiling. This is not spongework; it more nearly resembles worm-eaten wood. It is a small cave which cannot easily be followed back for more than 100 feet.
This cave is reported to be fairly long, of small cross section, and to have a stream along its floor. Steckle Caves Sec. 23, T. 36 N., R. 13 W., Pulaski County Not shown on Richland Quadrangle map Two caves by this name lie in the neighborhood of Ozark Springs. The larger one is reported to be 40 feet wide and only 50 feet long. Sweet Potato Cave SW1/4 sec. 3, T. 36 N., R. 11 W., Pulaski County Not shown on Waynesville Quadrangle map This cave is reported to be fairly capacious and in the Gasconade River cliffs. Trower Cave SW1/4 sec. 28, T. 36 N., R. 12 W., Pulaski County Not shown on Richland Quadrangle map This cave is reported to have an entrance 25 feet wide by 8 feet high. It is said to be wet. Tunnel Cave SW1/4 SE1/4 sec. 33, T. 37 N., R. 12 W., Pulaski County Shown on both Richland and Waynesville Quadrangle maps Tunnel Cave completely perforates Bear Ridge which is the narrow upland traversed longitudinally by Missouri Highway 17 immediately north of Gasconade River. The cave's eastern (intake) mouth (Fig. 163) is the bottom of a sinkhole, and its western (discharge) mouth is at the base of a cliff on the Gasconade River. The distance between the two openings is about 1000 feet. A wet weather stream which drains about one square mile and is a torrent in rainy seasons enters the cave at the sinkhole. Even during a drought, one must wade deep, rock basin pools to get through the cave. Few caves show so well a young, canyon-like lower portion, cut into the bottom of a cave that was made long before the ridge it perforates was carved.
Fig. 163. Tunnel Cave, Pulaski County Intake entrance: Spongework and ceiling pocket can be seen above the stream-cut gorge. Photograph by G. Massie, Missouri Resources Division. The stream, now pirated by the sinkhole and flowing westward through the cave, formerly continued southeastward toward the Gasconade River and descended about 150 feet in a mile and a half. The cave lay approximately 75 feet (the depth of the sinkhole) beneath this stream. When the first collapsing began, a vertical drop of 75 feet was offered in lieu of the gradient of 100 feet to the mile down along the stream's valley. Accepting this, the stream shortened its route to the river by more than a mile. Rejuvenation of the stream above the sinkhole was inevitable. A sharply cut, little, rock-walled gorge was incised in the older valley floor. Southeast from the sink, the old valley lies empty for half a mile (Fig. 164). Beyond this, the junction of two tributaries brings in enough surface drainage to give the old valley a central, flood-wash gully which is floored with chert gravel.
426 Missouri Geological Survey and Water Resources Both openings of Tunnel Cave have excellent showings of sponge-work and wall and ceiling cavities which are unmodified on the ceilings and upper walls except by rock fall, but are greatly modified on the lower walls and bedrock floor from the abrasional effect of gravel carried through in flood time. The descent is about 50 feet for the length of the cave. Fig. 164.

Abandoned Valley Downstream From Tunnel Cave Photograph by G. Massie, Missouri Resources Division. Tunnel Cave could hardly be improved for the purpose of convincingly demonstrating a pre-existing cave which has, by later capture of surface drainage, become a free-surface underground stream course. Peneplain remnants in the vicinity lie at about 1000 feet above sea level. The original cave-making, if it occurred during the peneplain cycle, took place more than 400 feet below the level the peneplain eventually produced. If the cave is to be dated back only to a later, lower, and incompletely developed surface, it was made nearly 200 feet below the overlying land surface. Dake and Bridge (1923, p. 9) briefly describe Tunnel Cave but advance no interpretation.
Caves of Missouri 427 Twin Cave Sec. 31 or 32, T. 37 N., R. 11 W., Pulaski County Not shown on Waynesville Quadrangle map Twin Cave's name is derived from the existence of two closely placed caves, each with its own capacious entrance in a Gasconade River bluff. A minor passage connects them, making the twins Siamese. They were not reported by Fowke or Farrar and were not seen by the writer. Willie Lane Cave NW1/4 NW1/4 sec. 16, T. 34 N., R. 10 W., Pulaski County Not shown on Big Piney Quadrangle map This cave is reported to have an entrance 25 feet wide by 12 feet high and to have daylight penetration for 60 feet. Wilson Cave NE1/4 SW1/4 sec. 12, T. 35 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map This cave is reported to be enterable for 400 feet through an opening 30 feet wide by 10 feet high. Wingo Cave SW1/4 NE1/4 sec. 2, T. 36 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map Wingo Cave is located on the north side of the Gasconade River, one-half to three-fourths of a mile east of the bridge on the old Waynesville-Crocker road. There are two caves at this point in the river bluff, Wingo Cave and Mix Cave. The western one, which is Mix Cave (previously noted in this report), is half a mile east of the bridge. It can be followed back for 250 feet to a lowering and narrowing that will stop the average investigator. Its mouth is 20 feet wide and 15 feet high, but the rock shelter under which it opens is 20 feet high and extends for 75 feet along the cliff. The river cliff, though continuous for some distance, is most pronounced over the entrance. Twenty-five feet inside, there is a chert layer in the ceiling which serves for 20 lineal feet as a floor for a 1-foot to 2-foot upper chamber. Nearer the entrance, this chert layer has a curious relationship for four well-developed wall pockets. In one place, the gravel floor of the small vadose discharge has pebbles coated with concretionary, secondary calcite, like cave pearls.
428 Missouri Geological Survey and Water Resources in origin and structure. Both up and down stream from this place, the chert pebbles are uncoated. The eastern cave, which is Wingo Cave, is traversable for 175 feet on a gravel floor. Rimstone in the back end closes the route. Here, also, the floor has risen almost to the ceiling. The entrance arch is 15 feet high and 50 feet wide, with an over-hanging, visor-like ledge. There are no meander slots in either of these caves. One hundred and twenty-five feet back in Wingo Cave, there is a narrow tributary passage 6 to 7 feet high and 3 feet in average width that has very pockety walls on a small scale and some minor meander niches. Evidently, vadose water started work in the main chamber of Wingo Cave at the very ceiling level. Many little pockets and shelves hold cemented gravel which in one place makes the ceiling itself. No remnants were seen of a red clay fill on which this gravel could have been deposited. The narrow tributary passage has a very sinous course for 150 feet. It lies at right angles to the main chamber to the end of the feasible traverse. Both the tributary and main stream are in the same stratum and originally were parts of a horizontal phreatic plexus. Most of the work in making the cave has been done by later vadose water. The mouth hangs 100 feet above the river. The vadose stream abruptly abandoned this cave at that stage of the Gasconade down-cutting. Woodruff Cave SW1/4 NE1/4 sec. 30, T. 36 N., R. 11 W., Pulaski County Not shown on Waynesville Quadrangle map Woodruff Cave is reported to be a dry cave with some attractive formations in it. Its entrance is about 8 feet wide by 12 feet high. Yoark Cave SE1/4 sec. 15, T. 35 N., R. 12 W., Pulaski County Not shown on Waynesville Quadrangle map According to Fowke (1922, p. 43) the entrance to Yoark Cave is in the bluff of Roubidoux Creek. It is 40 feet wide and 30 feet high. Daylight penetrates the cave for 150 feet. RALLS COUNTY One named cave is known in Ralls County, and it has been investigated for this report.
Caves of Missouri 429 Fisher Cave NE1/4 NW1/4 NW1/4 sec. 22, T. 55 N., R. 4 W., Rails County Shown on Hannibal Quadrangle map The symmetrically arched mouth of this cave is 20 feet high and 90 feet wide. A lively stream discharges from it and spills down in a series of waterfalls over broad, flat rock ledges to the bottom of the bluff. The largest fall is 12 feet in the clear, and the others total nearly twice as much. The cave floor is also composed of flat rock ledges, but the stream gradient inside is very much less, and only ripples and minor cascades occur. Another striking contrast is the widespread solutional pitting, even channeling in places, of the stream-swept rock floor inside, while nothing of the kind is seen outside. Yet in places, the faceted and pitted cave floor is interrupted by areas of rimstone and flowstone, where the flowstone appears to have spread out over the solutional pitting. Two streams enter the cave complex not more than 200 feet back from the big archway. Each enters from a different unit of the complicated, phreatic anastomosis, and each can be waded by stooping for at least a few hundred feet farther. The entrance is a flaring, weather-enlarged cross section of the main cave chamber. Back of the flare, the chamber is 30 feet to 40 feet wide and about 12 feet high. It spans a thinly covered rock floor. But the big room ends abruptly. There apparently is a blockade at the far end, intact to the ceiling. An artificial ponding on the cave floor, a large colony of disturbed bats, and a little farther in, a guano-covered floor and an acrid stench deterred this investigator from a detailed examination. Very probably, the blockade is the remnant of a subterranean or alluvial fill. It surely is not a rock-filled blockade. The ceiling of the "Bat Chamber", over and beyond the pond, has several very symmetrical inverted "bowls" in it, undefaced by any later fracturing; perfect examples of phreatic solutional attack. On the left-hand wall, there are three open, phreatic lateral passages and two that are filled. By entering the first, one may by-pass most of the deeper water and return to the big room through the second lateral. Where roof rock has fallen in large blocks to make the talus dam at the cave mouth, both the blocks and the fractured edges remaining in the ceiling are as full of spongework holes as those lying in Hahatonka stream (Fig. 60). The spongework obviously penetrates several feet back from the present cave walls and ceiling. It is the best showing of cave-associated spongework, which was not developed on the cave surfaces themselves, that the writer has ever seen. The pores in this spongework are relatively small. Almost none is more than 2 or 3 inches across. The detail is comparable in magni-
Missouri Geological Survey and Water Resources 430 to that of the floor pitting but in other respects is very different, indeed. The outlines of the sponge pores are ragged and branching, and they interconnect back in the rock. The floor pits are separate cups, with pinnacles and cups and bladed partitions between. The ragged appearance here depends on the projections, not the indentations. As interesting and informative as anything in Fisher Cave, is a spongework complex on the west wall of the entrance. The accompanying sketch (Fig. 165) shows its features better than words. The cavities, shown in black, are not continuous openings in the rock. The two separate and slightly settled blocks are, of course, not floating; they interlock with each other and with the wall rock a short distance back from the face of the exposure. The complex is about 6 feet in diameter and shows how the dissolving water penetrated and attacked every possible parting along which it could move. Had the procedure gone much farther, the central West Wall of Entrance to blocks would have disappeared Fisher Cave Ralls County and a conventional phreatic passage would have developed. Estimated height 8 feet. E. oped. H. Woolrych, del. Fisher Cave, although largely phreatic in origin, has been worked over by vadose streams almost from the ceiling down to the floor. Stream debris on shelves, sidecut into the wall by a free-surface flow, indicate that, however deep the original phreatic cave was, it was later filled almost to the ceiling. The vadose water work on the walls came with the removal of this fill. The cave mouth is a little more than half-way down Spencer Creek's 100-foot bluff, close to the top of the cliff. Three sinkholes lie back on the summit. They are elongated and converge toward the cave in the same way as do also their higher slopes above the depression contours. The convergence is a dendritic stream pattern. But no notch in the bluff summit records a former entrance of a tributary to Spencer Creek here. It is altogether likely, therefore, that the material eroded in making these minor drainageways has all gone through the sinkhole bottoms to and through the cave. Most of their growth must have waited on the downcutting of Spencer Creek to the cave level.
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REYNOLDS COUNTY

One cave and one "cave spring" are known from this county. Neither was seen during this study. Cave Spring NE1/4 SE1/4 sec. 23, T. 31 N., R. 2 E., Reynolds County. Shown on Lesterville Quadrangle map.

Wicks Cave NW1/4 NW1/4 sec. 9, T. 32 N., R. 2 E., Reynolds County. Shown on Lesterville Quadrangle map. Wicks Cave is on the west side of the East Fork of Black River, one and a half miles north of Lesterville. Its opening in the cliff is reported to be about 75 feet above the river and to be 12 feet high by 70 feet wide. There is walking height for about 200 feet, and the cave inside the wide entrance becomes a narrow slot. The walls of this passage carry meander grooves or slots which record a higher (detrital) floor at one time for the cave stream. There is much dripstone in the cave.

RIPLEY COUNTY

So far as known, Ripley County has but one named cave. Lewis Cave SW1/4 NE1/4 sec. 30, T. 25 N., R. 1 E., Ripley County. Shown on Grandin Quadrangle map. The mouth of Lewis Cave is almost at the foot of the valley slope of Big Barren Creek. It has no cliff above or alongside, and before the entrance house was built, it was inconspicuous because of a nearly complete talus blockade. The slope of the blockade in the cave is relatively gentle and covered with old flowstone. One traverses 850 feet of capacious cave back to a chert bridge which crosses the cave at about mid-height of the walls. Only a little stooping is required to walk under it. Beyond the bridge, the chert layer has broken down into a rubble of big blocks on the floor, under and through which the cave stream noiselessly finds its way. Beyond the blockade, the cave floor is essentially at the level of the top of the bridge and requires stooping double, even creeping, to traverse.
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Most of the cave is easily traversed. It must be 30 feet wide in places and has an unusually smooth, flat ceiling which lacks good evidence for either solutional or fracture origin. Along the sides, there are banks of gritty red clay mounting up tight against the ceiling. The clay contains tiny bits of chert here and there and clearly shows stratification. It should be considered a vadose water product. The stream today, however, is leaving sand bars; not clay or mud bars. The stream crosses the main chamber twice, each time to disappear or partially disappear under overhanging rock walls and re-appear farther along. The clay deposit into which it has trenched was made before the present regimen of the stream was established. Because no stream emerges from the cave mouth, its exit must be somewhere through or beneath the talus and below the level of the floodplain of Big Barren Creek. But no one seems to know of a fairly large spring in the valley nearby. The upper half or more of the main chamber is probably phreatic, despite the lack of spongework, wall and ceiling pockets, joint slots, and all other criteria for phreatic origin. The change in size and proportions and character, from the chert bridge back into the cave, is very marked and this inner part of the cave probably is wholly vadose. The dolomite walls have current etching and fluting from bottom to top, and the chert layer constitutes the floor. This interpretation calls for the entrance of a vadose ground water flow through the wall of an older and larger phreatic chamber, and requires a continuation of the phreatic chamber above that point of entry. That continuation, now completely clay-filled, probably exists on the north side of the cave, where for 50 feet or more there is no sign of wall rock, although the clay bank slopes back rather gently in places. If there were rock ledges behind it, they should show. The cave has been commercially operated. ST. CLAIR COUNTY

Five named caves are known in St. Clair County. One of these was visited during the present investigation. Bat Cave NW1/4 NW1/4 sec. 5, T. 36 N., R. 26 W., St. Clair County Shown on Roscoe Quadrangle map Boy Scout Camp Cave NW1/4 SE1/4 sec. 33, T. 39 N., R. 24 W., St. Clair County Not shown on Iconium Quadrangle map Entrance to this cave is by ladder. One goes down a vertically walled sinkhole 12 feet deep and enters, through the ceiling, a room 16
Caves of Missouri 433 feet high and 20 feet wide. From this, two passages lead off for about 30 feet in opposite directions to a debris blockade in one and a drip-stone blockade in the other. Cleveland Cave NE1/4 NW1/4 sec. 25, T. 38 N., R. 27 W., St. Clair County Not shown on Monegaw Springs Quadrangle map Cleveland Cave is on the west bank of Little Monegaw Creek valley, three quarters of a mile north of the east-west county road through Monegaw Springs. The cave mouth is about 50 feet above the floodplain of the creek on a soil-mantled slope which is broken by a dimple with a 10-foot sand-stone ledge holding its upper margin. This sandstone is conglomeratic, cross-bedded, and ripple-marked. It rests on Mississippian limestone and determines the ceiling of the cave as far as penetrated; several hundred feet. The cave is very narrow, and no really fat man will ever see the deeper recesses. Sidewise progress is necessary in several places. The detrital floor descends for 50 feet from the low entrance opening at the sandstone-limestone contact to the first slump pit, about 200 feet back. The cave is undoubtedly that deep elsewhere, but the trail leads up-and downhill over remnants of a once-continuous fill. In one especially narrow place, a detrital bridge still clings to the walls and the visitor goes under it. Several limestone bridgings also survive. Some must be crawled under. The joint which determined the form and orientation of this very marked slot cave strikes about N. 45° E. In places, the joint doubles, even triples, and two and even three imperfectly developed slot passages lie side by side. The separating walls are hardly more than 5 feet thick, in places only one foot, and are perforated with spongework holes that connect the two adjacent passages. The best showing of this feature is at the second slump pit. The joint shows very well in the ripple-marked sandstone ceiling In places, it divides into several very close-set cracks. The sandstone slabs have sagged unequally, making offsets in the ceiling; some have fallen. The first and deepest slump pit, 200 feet back, has flowing water in the bottom and is crossed on a wooden bridge. Its bottom can hardly be more than 10 feet above the level of the river floodplain outside. The red clay is really gritty. It could hardly be otherwise with that sandstone ceiling. The cave has excellent spongework, older than the red clay. It has no driptstone and no vadose solutional work what-ever. It has one right-angled, branch, phreatic chamber which is hardly 30 feet long, filled almost to the ceiling, and lower than the joint chamber ceiling.
434 Missouri Geological Survey and Water Resources Several recent and older collapse sinks lie on the wooded slopes. There must be more cavernous rock hereabouts. A ravine on the slope seems clearly to cross the cave whose roof here can hardly be more than 15 to 20 feet thick, but no dripwater enters the cave beneath nor has done so in the past. The upland flat of the region is on Pennsylvanian rocks and lies between 850 and 920 feet above sea level. The contact of the Pennsylvanian sandstone roof rock with the Mississippian limestone is about 750 feet above sea level. This phreatic cave developed some 150 to 200 feet below the surface of the finally attained peneplain. Cleveland Cave was once operated commercially on a small scale. Monegaw Cave S1/2 sec. 25, T. 38 N., R. 27 W., St. Clair County Not shown on Monegaw Spring Quadrangle map This cave is in an Osage River bluff, half a mile south of the village. Farrar's notes on Cleveland Cave are apparently a description of Monegaw Cave. He says, "Entry is to a big room 20 by 30 by 20 feet high, then through a crawlway not 6 feet high anywhere to a bigger room, then 10 feet down a ladder to a smaller room, on one side of which is a well 8 feet in diameter. Another passage leads off to Lookout Entry." This remark seems to indicate that the cave has two entrances, one of which must be well up in the 100-foot cliff. Farrar says that the James and Younger boys hid in this cave. How they ever found time for their crimes is a puzzle; they were so busy just hiding around in Missouri caves! Rockhouse Cave SW1/4 NE1/4 SE1/4 sec. 28, T. 37 N., R. 26 W., St. Clair County Shown on Roscoe Quadrangle map ST. FRANCOIS COUNTY There are only two unnamed caves known in St. Francois County. Neither was seen during this study. Unnamed Caves NW1/4 NW1/4 sec. 18, T. 38 N., R. 4 E., St. Francois County Shown as Cave on Tiff Quadrangle map NE1/4 sec. 17, T. 36 N., R. 5 E., St. Francois County Not shown on Farmington Quadrangle map This cave is reported to extend into the hill a long distance and to consist of numerous large chambers which exhibit usual cave formations.
Caves of Missouri 435 STE. GENEVIEVE COUNTY Four named caves are reported for this county, and all but one was examined for this study. Eisner Caves W1/2 sec. 29, T. 38 N., R. 8 E., Ste. Genevieve County Not shown on Weingarten Quadrangle map. There are two cave mouths here within 1000 feet of each other. Each is a very broad, very flat arch, produced by weathering of St. Peter sandstone. Each cave is at the bottom of a ponor which has the cave mouth side cliffed and the other slopes graded. Each takes surface water back under a ceiling which lowers more per unit of distance than does the floor until progress of any kind becomes impossible. Both caves are in sandstone, owing to the failure of a ceiling of a deeper-lying solutional cave in the underlying Everton formation. The dolomite can be reached in one of the caves, if one is determined enough and can bridge himself on toes and arms across a central pool on the floor. The entrance arches are by no means stabilized. They are being enlarged by crumbling, by spalling, and by the falling of large blocks of the sandstone. Very recent falls have occurred and there will be more in the near future. The narrow ridge carrying the ponors and the caves also carries a remnant of an old erosion surface over the caves at 620 feet above sea level. Salt peter Cave Sec. 24, T. 36 N., R. 8 E., Ste. Genevieve County Not shown on Weingarten Quadrangle map. Zell Cave SW1/4 sec. 34, T. 38 N., R. 8 E., Ste. Genevieve County Not shown on Weingarten Quadrangle map. Our party, somewhat affected by the heat of a summer's day, stopped at a welcome sign, went into the tavern, and ordered what we thought would be good for us. Said the bar keeper, "Would you like to drink it in the basement? It's cooler down there." The "basement" was a cave beneath the building! While we drank and studied the cave walls surrounding our tables, the proprietor joined us. "A long time ago" he said, "there was a little brewery in Zell, and their product was aged down here. One night a hogshead sprang a leak. It was empty by morning, and all the beer had disappeared down cracks in the floor. About the middle of that forenoon, a German farmer in the valley below, came into town wildly excited. 'Mein Gott, Mein Gott!' he cried, 'mein schpring, she is running beer!'"
436 Missouri Geological Survey and Water Resources The cave floor is about 35 feet below ground level, its ceiling 20 feet below. For nearly 100 feet, the cave floor width is about 12 feet. This straight, corridor-like chamber is developed along a N. 45° E. joint. Another 50 feet of length is a meandering trench with a lowered ceiling, a rising detrital floor, and a narrowed width. All wall and ceiling surfaces are solutional in origin. Some marked pockets and tube mouths interrupt the walls. A flight of stone steps is at one end of the cave and undoubtedly is built on a fill. There is more cave beyond those steps. But the memory of the oldest inhabitant of Zell does not go back to the building of the steps. The walls also carry stream-made shelves and, on these shelves, stream debris. It appears that Zell Cave is almost wholly vadose in its present form, but that this vadose work was localized because of a phreatic bedding plane anastomosis in the Joachim (Ordovician) dolomite and intersected by a phreatically enlarged joint plane. Vadose water, falling vertically in one place along a joint fracture, has made a well, the bottom of which is in the cave ceiling, the top in the middle of the street. One may lift a manhole cover and look down into the well. Zell Cave, also known as Tavern Cave, has lately had its annoying wet-weather leaks caulked. ST. LOUIS COUNTY Several caves have been reported to the Missouri Geological Survey from this county. The following undeveloped caves have been located, and two of them were examined during this study. Cherokee Cave is commercially operated and is described in the first part of this report. Clausmann Cave is at the site of the former Clausmann brewery. It was once used as a schmierkase garden. Cliff Cave SE1/4 sec. 13, T. 43 N., R. 6 E., St. Louis County Shown on Kimmswick Quadrangle map The entrance to Cliff Cave, or Indian Cave, is at the head of a ravine where a perennial stream discharges from the rock-floored cave. The entrance owes part of its spaciousness to weather-fracturing of the wall and ceiling rock. The cave can be walked in for a distance of 700 feet. The rock floor gradually rises until at that distance, one must creep in the stream to go farther. Perhaps 100 to 150 feet more of length was thus explored, but it yielded no new information.
Caves of Missouri 437 Cliff Cave is almost entirely vadose and is being enlarged today by a down-cutting of the floor rock. The finest showing of solution facett-ing and fluting in Missouri occurs on its floor and walls about 500 feet from the entrance. Yet in one stretch, this same rock floor is receiving a flowstone deposit. A 3-foot cascade, almost a waterfall, is getting the heaviest deposit. A priori, one would expect this cascade to be the site of the most vigorous solution. The cave follows, in zigzag fashion, a joint pattern. Its turns, from one joint to the other, are sharp angles, and a joint which the stream is leaving can be traced into the wall as a blind end or blocked slot. The two joints sets approximate N. 45° to 65° E. and N. 25° to 30° W. The vadose stream selected its course initially from a phreatic network in these two joint sets. The passages not taken by the stream are debris-filled a little way back from the vadose-enlarged route. Other evidence for the phreatic origin of the original cave is in the solutional ceilings. Elongated along the joints are "bathtubs" and half-tubes. Some of the cavities are nearly 6 feet deep (up) in the ceiling. The most remarkable of these phreatic cavities is 600 feet from the entrance. It is a wall cavity, somewhat elongated along a joint. It is all of 6 feet wide and high, but it has only a window-like opening to the vadose stream chamber. One crawls through this opening to stand erect with plenty of room around him. Vadose enlargement appears to have made the connection late in the history of the cave, the wall pocket having previously been completely separated from the phreatic predecessor of the main cave. Perhaps no Missouri cave, so largely vadose, records so well its phreatic ancestry. Rankin Cave NW1/4 SE1/4 sec. 34, T. 44 N., R. 4 E., St. Louis County Not shown on Manchester Quadrangle map This cave is in the west end of a spur ridge north of Little Antire Creek about 100 feet above creek level in the Beaumont Scout Reser- vation. An inconspicuous opening, a mere crawlway for a few feet, leads over broken-down roof rock from a former westward extension of the cave. A descent over inside talus is made to a linear passage with walking and stooping height for several hundred feet eastward along the length of the ridge. It lies, throughout, within a horizontal range of a few feet. The passage is joint-controlled, with two joint sets involved and in one place an en echelon overlap of two opened joints of the same set. The dripstone, flowstone, and rimstone in Rankin Cave are all old and stained and muddy. The floor mud is not deep, being largely underlain by rimstone and flowstone, but is particularly sticky.
Missouri Geological Survey and Water Resources Rankin Cave, as with many others in the writer's knowledge, lies elongated under an elongated hill. The parallelism is not understood at present, but surely it is not to be explained as the solutional result of the ground water flow of this sharp, narrow spur. Rankin Cave is older than the topography of the region. Schneider's Cave Schneider's Cave is at Chouteau Avenue and 18th Street in the city of St. Louis beneath the site of the Union Station. Stifel Cave Stifel Cave is beneath the site of the Post Office in the city of St. Louis at 17th Street and Market Street. Uhrig's Cave Uhrig's Cave is at the corner of Jefferson Avenue and Washington Boulevard in the city of St. Louis. The land on which the cave is located was originally part of a 25-acre Spanish land grant. From 1852 to 1855, it was the estate of Dr. William Beaumont, famed surgeon who was first to observe the action of gastric juices in the human stomach. And from 1857 to about 1869, the Reverend William Greenleaf Eliot, first president of Washington University, lived there. In the 1880's and 1890's it was a famous beer garden. This cave is a man-made subterranean chamber 20 feet high and 210 feet long. Its ceiling is 26 feet below street level. It was excavated sometime in the 1850's and used until 1879 for beer storage. Uhrig and Kraut leased it in that year to Pat Short, manager of the Olympic Theatre, who erected a stage and pavilion in the grove at the site for presenting alfresco opera. The premiere performance in the United States of "The Mikado", "Cavaleria Rusticana" and several other light operas occurred here. McNeary Brothers operated both the cave and the shows from 1888 until about 1903. The cave later became a roller skating rink, then a bowling alley until the coliseum was built at the site. This has since been torn down. A history of this "cave" was printed in the St. Louis Globe-Democrat for September 2, 1933, and on June 10, 1956, the story was repeated in the St. Louis Post-Dispatch in connection with the announcement of the opening of the new Jefferson Bank and Trust Company building which now occupies this historic site. Unnamed Caves Unnamed caves in St. Louis and St. Louis County are at: (1) Didier Road and 25th Street; (2) Blendon Place to Echoff and Man
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Caves of Missouri 439 chest Avenue; (3) Forest Park; (4) Ivanhoe and Marmaduke Avenue; and (5) 3500 Sullivan Street. SHANNON COUNTY Eighteen cave names are known in this county, but because of possible duplications of names and indefinite locations, the total number may be two or three less than this. Four have been studied during the field work for this book. One cave, Round Spring Cavern is commercialized, and a cave spring, Alley Spring, is in a State Park. Both are given special attention in the first part of this report. Banker Cave NW1/4 NE¼ sec. 25, T. 29 N., R. 2 W., Shannon County Shown on Cardareva Quadrangle map Josiah Bridge (1930, p. 44) says this cave is a single twisting passage about one-fourth of a mile long. Sticks and leaves at the far end indicate that a sinkhole connects there with the surface. Bat Cave Sec. 34, T. 31 N., R. 5 W., Shannon County Not shown on Round Spring Quadrangle map Fowke (1922, p. 18) says this cave is 6 miles above the mouth of Sinkin Creek and is fully 300 feet above the river. His map (Fowke, 1922, Pl. 3) indicates that it may be on Current River. Its entrance is 30 feet wide and 10 feet high. It has been explored about 75 feet. Big Creek Cave Sec. 36, T. 30 N., R. 4 W., Shannon County Not shown on either Eminence or Round Spring Quadrangle map The entrance is a large, arched recess beneath the overhanging cliff of Current River. Fowke (1922, p. 18) says the cave is so low in the bluff of Big Creek that it is flooded by every freshet. There are two narrow passages. One is said to extend through the spur and come out in Big Creek valley. Branson Cave NE1/4 NW1/4 sec. 26, T. 29 N., R. 5 W., Shannon County Not shown on Eminence Quadrangle map This cave is in the north slope of a tributary valley at a fork in both a valley and a road two and a half miles upstream from Alley. The
440 Missouri Geological Survey and Water Resources foot trail to the cave leads upward in zigzag diagonals almost from the road fork. The cave mouth is in a cliffed salient of the hillside. Step-like ledges above overhang the 20- to 40-foot cliff below. The entrance is a picturesque, low, flat archway with a centrally placed, keystone-like pendant which is a remnant of a thick massive dripstone, perhaps added to by tufa growth. There are tufa pendants and clinging masses on the cave walls near daylight. The cliff immediately below the mouth is deeply notched, and only a stone fill built across this notch makes the platform in front of the cave. The earthen floor is a dark, dry mud for 50 feet back, beyond which it is red clay wherever exposed. This floor slopes back into the cave and, though there is seepage water, it escapes somewhere through the floor. There probably are three such leaky places. The cave is 1100 feet long and has a markedly winding course without detectable joint control. There is no general gradient to the floor or ceiling. The ceiling is uniformly smooth and is slightly arched. There are some nearly circular and excellently exhibited ceiling pockets, a few of which have a marked constriction at the junction with the ceiling profile. There are also a few very good wall pockets. The uniform width of the cave is four to five times the uniform height of 8 to 10 feet. Four hundred feet from the entrance, there is a right, backhand, branch chamber 100 feet long with the same kind of cross section and dimensions as the main cave. It is terminated by a rubble half-cone, and there is no evidence of much entering water. The cone apparently grew after the present surface of the red clay fill was determined. Six hundred and thirty feet from the entrance on the right-hand side, there is a doubling of chambers for about 30 feet. The side chamber is smaller but higher than the main one and is still largely filled with smooth, red clay. This is a phreatic feature. Here red clay remnants cling to shelves close to the ceiling. At the far end of the main cave, there is a complete blockade made by a half-dome of flowstone which likewise is younger than the clay floor. There is no suggestion of meander niches in the wall or other vadose solutional work. This 1100-foot long cave with its clay fill hangs 150 feet above the valley floor and opens on a steep slope. It apparently has never had a vadose stream discharge from its mouth. It may possibly have had such a flow in the opposite direction where it is now flowstone-blockaded, for if there is any general slope, it is in that direction. But if so, water ceased entering the cave to make such a stream before the flowstone half-dome was built. There is no evidence of present-day ponding, and little evidence of any ponding since the blockading. The branching is a phreatic trait; as is the doubling and as are the ceiling and wall pockets. This cave and its red clay fill antedate the cutting of the creek valley. The cave mouth is simply the transection of a former continuation out into what is now empty air.
Caves of Missouri 441 The heaviest dripstone deposits occur near the entrance under the thinning roof. This is a cave characteristic in many regions besides the Ozarks. The vadose theory for the origin of these Ozark caves, which are so out of harmony with the topography above them, must explain why most of the limestone and dolomite hills, ridges, and divides in any one district have no caverns. They all have the same rock, the same relief, the same rainfall, and the same time for development. It is impossible that so many caves do exist and simply have not been discovered. By the vadose theory, the present is their time of growth, for they are functional discharges of the present rainfall of the hills. Every spring should come from a cave, every cave should have or have had a stream, else the vadose theory is suspect. The Eminence Quadrangle map shows the topography over Branson Cave as a very narrow, flat-topped spur, which projects southward into Alley Branch about 2000 feet. At the cave level, 100 feet below the summit, the width of this ridge does not exceed 750 feet. In this ridge, at this altitude, and with this width for it to squirm in, lies the 1100-foot Branson Cave. Make all allowances for sketchiness of the map (it was surveyed in 1915), still the topographic relations of the cave are remarkable. The cave is simply impossible as a vadose feature as young as the present topography. The two blockades strongly suggest transection by, or near approach to, the two sides of the ridge. Is a linear phreatic cave so remarkably fitting a younger topographic ridge purely coincidence? There are too many such to accept that explanation. They have been encountered by the writer everywhere he has studied caves. But, if there is a causal relation, we do not yet understand it. Cave Hollow Cave S1/2 sec. 1, T. 30 N., R. 4 W., Shannon County Not shown on Eminence Quadrangle map Bridge (1930, p. 44) says the opening to this cave is very small, but that the cave is larger farther back and may be followed for half a mile or more. Cave Spring Sec. 28, T. 31 N., R. 5 W., Shannon County Not shown on Round Spring Quadrangle map Cave Spring or Fishing Spring Cave is a short but very significant cave. Its mouth is at the foot of a sheer 45-foot cliff on the north-east side of Current River valley, at river level. It can be adequately examined only by boat, although about a third of its length can be traversed on foot.
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The spring discharge has a measured range between 16 million and 47 million gallons per day. At low water stages of Current River (which are also low stages for the spring) a strong current flows out of the cave. In high water river stages, the cave is completely submerged. During low water stages, the ceiling of the entrance is between 15 and 20 feet above the cave stream. The entrance width is about 40 feet. The total enterable cave length is less than 150 feet. Except for a mud-covered rock shelf on the left, which one may follow for 50 feet or so inside, and for another shelf on the right, unreachable except by boat, the entire cave bottom is submerged by the spring pool and its discharge channel. This pool has diameters ranging from 25 to about 60 feet. Three well spaced soundings made by the writer found depths of 73, 74, and 77 feet below low-water stage. Rock walls come down to the water surface completely around it, except at the outlet. By the use of spotlight and sounding line, one knows that these walls descend vertically to those amazing depths on all but a portion of the far side. At that place, slightly under low-water surface, the wall overhangs. This may be only a slight overhang, or it may be the mouth of another cave chamber, completely submerged. Yet rock bottom of the outlet channel is clearly visible throughout its length and in one place makes a submerged weir only 3 or 4 feet under water. Fig. 166. Cross Section of Cave Spring, Shannon County E. H. Woolrych, del. Because the cave ceiling is level from the entrance arch to the far end, the combined air-filled and water-filled portions constitute, in cross section, an inverted capital L, each bar of about the same length (Fig. 166). Wall slots and ceiling slots show that the vertical
Caves of Missouri 443 shaft, descending 75 feet below the water, is determined by jointing. The horizontal, air-filled part of the cross section of the cave fails to follow the two joints which determine the wall slots. It apparently was entirely determined by original bedding plane partings. The joints, striking at a moderate angle to the face of the cliff, do not show in that face. Apparently they die out horizontally a short distance back in the wall rock which surrounds the spring pool. Spongework is not well shown, but there are enough ceiling cavities to make, with the slots, a good case for phreatic origin of the air-filled part of the cave. This is argued despite the evidence that some fall of ceiling slabs has occurred, and that the discharging stream has cut a vadose channel for itself. Whether the spring water rises from the bottom of this great, well-like shaft, or enters laterally from beneath the overhanging part of the pool's bounding walls, is not perfectly clear. There surely must be some considerable fraction of the total discharge rising from the very bottom, otherwise mud from backwater of river floods would long since have filled the shaft as it has covered the shelves. A vertical current for the original enlargement of the joints determining this shaft is surely required in any satisfactory explanation for the conduits of this spring. And of course, it must have been an upward-flowing current. The cross-sectional area bespeaks a considerable volume, or a very long time, or both. Conditions below the upper surface of the pool are phreatic today, and they never have been otherwise. Only the upper part of the cave, the air-filled part, is in the vadose zone. Only since Current River cut its last 30 feet of valley depth has that air-filled part been shifted from the completely water-filled condition the rest of the cave still has. It is as impossible to explain this spring as a ground water product of the last few millennia of the present cycle of erosion as it is to make post-topography springs of most of Missouri's large springs. Only one of them (Roubidoux Spring, Pulaski County) is the resurgence of a sinking creek or a lost river. Cave Spring or Fishing Spring Cave supplies one link of evidence for the theoretical picture which no other spring gives us, unless it be Welch Spring in Shannon County. At Cave Spring, we know, from actual observation and measurement, that deep-seated ground water may rise in vertical shafts under valley bottoms to reach spring discharges. When the theory was built, this link was not known actually to exist. Figures 9 and 10 show where such flow is required by the theory. Figure 11 shows how later valley erosion destroys those upward-discharging shafts. But, at this spring, Current River valley has not yet been deepened enough, nor widened enough. It has not yet obliterated all of those most vulnerable parts of the subterranean drainage system of the earlier cycle; those terminal escape conduits for the rising component of the hydraulic circulation.
During the experience the upper part of the cave has had with vadose conditions, a large cave onyx dome has grown on the rock shelf across the pool. Some thick, clumsy, stalactite-like pendant forms hang from the ceiling near the entrance. They incline markedly from the vertical and lean toward the entrance. If they are, as they appear to be, of stalactitic origin, they must have grown in air. Whence came the air current which, by one theory, causes bent stalactites? Can flooding of the cave by river water have been a part of the cause? Fishermen with a mid-winter yearning to wet a line might find Fishing Spring Cave or Cave Spring interesting. It is a favorite winter resort for Current River goggle eyes. Cave Spring Cave SE1/4 NE1/4 sec. 15, T. 31 N., R. 4 W., Shannon County Shown on Round Spring Quadrangle map. Cook Stove Cave Sec. 7, T. 29 N., R. 2 W., Shannon County Not shown on Cardareva Quadrangle map. Cook Stove Cave is also known as Holmes Cave. It is also recorded as Blair Creek Cave, but this may be the name of another cave. Cyclops Cave SE1/4 SW1/4 sec. 29, T. 30 N., R. 4 W., Shannon County Shown on Round Spring Quadrangle map. This cave is entered by rope from a hillside break-down of roof rock. The entrance is a ponor with an overhanging, 5-foot ledge of Gunter sandstone which also makes the fracture ceiling of the large chamber just inside. This ceiling is 25 feet in maximum height above a floor of mud, roof fragments, and flowstone. Less than 50 feet inside, the ceiling drops until it is only 6 to 8 feet high. Here it is solutional in origin, as is shown by chert in relief. There are two big rimstone mounds with appropriate stalagmitic central cones under this lower limestone ceiling. Two joint-determined ceiling slots cross this room and to some extent determine the lineup of stalactites and stalagmites. Their strike is N. 60° E. One hundred feet back from the mouth, the ceiling again drops rather abruptly to the level of the rimstone-covered floor, and the floor drops off under it. One may crawl 10 feet farther, but there is no possibility of penetrating the dripstone barrier ahead. There probably is or was a capacious phreatic cave back in the valley bluff at this place. Its place of incision by Jacks Fork Creek.
Caves of Missouri 445 is 25 feet below the ponor entrance, but nothing shows on the bluff slope to indicate where. Cyclops Cave has a slightly gritty, red clay fill, though there are only small remnants now. The highest remnants are close to the top of the high chamber and, therefore, seem to postdate the fracture ceiling. However, these remnants may just as logically be considered the record of a fill in the satellitic spongework which lies above the original ceiling and is now revealed by rockfall. Where has the fallen rock gone? If it was not dissolved away, it must be buried in the detrital floor, and that would indicate a cave originally at least 20 feet deep below the level of the fill which now constitutes the floor. Devil's Well SE 1/4 SW 1/4 sec. 16, T. 31 N., R. 5 W., Shannon County Shown on Round Spring Quadrangle map This sinkhole is close to the bottom of a ravine which is eroded 300 feet below adjacent ridge tops and perhaps 400 feet below the original peneplain. Investigators have gone down on a bosun's chair a reported 100 feet to the pool which covers the bottom of the "well", and they have sounded another 76 feet. Apparently the sinkhole is of collapse origin over a cave, but the great depth of the water and the very limited air space above it have forbidden much exploration, even by rubber boat. Fluorescin dye, introduced, has not reappeared in nearby Spring Cave, but the escape route of the underground stream at the bottom of the well, as yet unknown, must be to Current River. The submerged part of the cave probably never has had air in it. Jam Up Cave SE 1/4 SE 1/4 sec. 4, T. 27 N., R. 6 W., Shannon County Shown on Summersville Quadrangle map A curious drainage pattern exists at this place. Jam Up Creek comes within less than 1000 feet horizontally of Jacks Fork where only a low ridge separates the two creek valley bottoms. The valley of Jam Up Creek lies at 900 feet above sea level, that of the Fork, at 800 feet. Here, Jam Up Creek turns away from the larger valley and becomes Lost Hollow. It leads eastward parallel to Jacks Fork and flows for about two miles before finally joining the Fork. A small tributary of Lost Hollow does the same thing in two places along its valley, and so does Johnny Hollow Creek farther east, though the contrast in altitude is not as great as in the first situation. Dake and Bridge (1923, p. 7) give us a vivid description of this cave, its capture of Jam Up Creek, and the beheading which has left the lower two miles of its former valley (Lost Hollow) essentially stream- less. The cave completely perforates the low ridge above noted and carries Jam Up Creek water under that ridge directly to Jacks Fork.
Missouri Geological Survey and Water Resources They describe a sink about 60 feet deep in the floor of the creek valley a little south of the cave. At the bottom of this sink, the stream disappears into the cave under an arch about 15 feet high and 30 feet wide. It can be followed for only about 100 feet. From the north end of the subterranean water course in the bluff of Jacks Fork, traverse upstream is possible for about 400 feet to a waterfall which is reportedly impassable. Between entrance and egress of the pirated stream, there are two more sinks by which the cave may be reached although no traverse is feasible. The total length of the underground route is more than a quarter of a mile. Jam Up Cave thus may belong in the same category with Tunnel Cave in Pulaski County, St. James Tunnel in Phelps County, River Cave in Camden County, Ash Grove Cave in Greene County, Sinkin Creek Cave in Shannon County, and several others in the Ozark country. Caves already existed which were properly located for minor surface streams to discover as they deepened their valleys and to utilize as shorter routes to their master streams. But the small caliber of much of Jam Up Cave speaks for a minor original cave and a rather recent piracy. It is perhaps as good an interpretation to consider that leakage along joints and bedding planes under the divide caused the piracy. In such case, the cave is entirely vadose in origin and younger than the valleys. Medlock Cave NW1/4 SW1/4 SW¼ sec. 10, T. 31 N., R. 6 W., Shannon County Shown on Cedargrove Quadrangle map Powder Mill Creek Cave NE¼ SW1/4 sec. 9, T. 29 N., R. 2 W., Shannon County Not shown on Cardareva Quadrangle map Bridge (1930, p. 44) states that Powder Mill Creek has its permanent source in a stream which issues from this small cave. Sinkin Cave NW1/4 NW1/4 sec. 27, T. 31 N., R. 4 W., Shannon County Shown as Sinks on Round Spring Quadrangle map Here is a spectacular instance of a surface stream which has discovered and is using a pre-existing cave. Sinkin Creek, in an entrenched, meandering course inherited from an earlier cycle, has cut its crooked valley nearly 400 feet below the trace of the Ozark oldland. At the Sinks, it has been enlarging one of these inherited curves as it deepened and has left a slip-off slope on the inside of the enlarging
Caves of Missouri 447 curve. The nose of the slip-off descends gently down into the valley, while the outside of the curve has become a nearly vertical cliff 300 feet high. This is, of course, because the creek, while deepening the valley, has been constantly moving farther away from the slip-off spur and persistently under-cutting the cliff. Fig. 167. Sinkin Cave, Shannon County Looking through from the outlet end. Photograph by G. Massie, Missouri Resources Division. Rather recently, in terms of topographic changes, a cave came to light in the bottom of the deepening valley; a cave oriented by chance exactly across under the spur. It offered the creek a more direct route than the long swing around the outside of the curve. The creek accepted the offer and, abandoning its long loop, now goes through the hill as though following a railroad or highway tunnel (Fig. 167). Obviously, there once was more cave than now. The creek has destroyed the immediate extensions of the cave at either end. Enough remains, however, to tell clearly that the stream valley never had anything to do with determining the ground water circulation that made the cave. It is the cave which has determined the curious behavior of the stream.
rejected, alternative interpretation is that joint or bedding plane leakage through the slip-off slope from the upstream side gave origin to the subterranean cut-off. Because the creek rejoins itself, there is too little immediate increase in gradient gained along the subterranean short cut ever to have demanded its making de novo. Welch Spring and Cave SW 1/4 SW 1/4 sec. 11, T. 31 N., R. 6 W., Shannon County Shown on Cedargrove Quadrangle map This is a place of extraordinary interest for cave theory, but as yet, quite inadequately studied. We have information about the cave from both Fowke (1922) and Farrar and about the spring from Beckman and Hinchey (1944). The writer's visit yielded little besides disappointment and frustration. Fowke's information is simply that the cave can be entered only by boat and that the floor is wet and muddy (Fowke, 1922, p. 18). Farrar locates it to the quarter section of the quarter section and adds the following information: "There is a subterranean lake a short distance inside, from the bottom of which rises the water which discharges from the cave mouth as the big spring. The lake has a diameter of 200 feet and a depth of 75 feet. Beyond the lake is a room, an 'auditorium', 120 feet long, 20 feet wide, and 75 feet high." Farrar comments on "many side tunnels and crevices". Because he quotes no source for his data, he obviously visited the cave and the figures, therefore, may be accepted as good estimates. Beckman and Hinchey (1944, p. 124) say nothing about the cave. Welch Spring is, they say, the fifth largest in the Ozark group of big springs, having a minimum measured daily discharge of nearly 50 million gallons and a maximum of more than 200 million. They suggest with good reason that its water comes from the poorly drained upland to the north, perhaps as far away as Salem. W. L. Doll (1940, p. 33) believes from stream flow and rainfall records, that both Welch and Montauk Springs are supplied in large part from the Meramec drainage area, the ground water crossing under the main divide of the Ozark plateau to discharge into the deeper Current River valley. This cave, with a huge spring in it, poses at once the recurring question. Did the spring make the cave? Or did an already existing cave make this spring possible? The topographic setting must first be understood. The river at the spring lies 460 feet, more or less, below Jadwin which is on the upland divide and eight miles to the north. Almost all this descent occurs along the mile of private road which leads from County Highway K down to the spring. The upland is part of the Ozark peneplain in its type locality. Into it, Current River has cut its deep, steep-walled valley. The spring discharges at the bottom of a cliff in the very
Caves of Missouri 449 base of this slope of the valley. There could have been no Welch Spring of present character before the valley reached approximately its present dimensions. No great spring discharge can exist without a large and well-integrated underground drainage system back of the orifice. It is impossible that the system supplying Welch Spring could have developed since Current River deepened its valley to the spring mouth level. But one may think of the underground drainage as deepening, or as finding new and deeper routes, to keep pace with surface valley deepening. If that has occurred, abandoned old spring openings must exist higher in the cliff. For such, the cliff was searched in vain. None is shown, not even any of the phreatic solution pockets that commonly occur in river bluffs close to cave mouths. As important as the topographic setting in answering our question of priority, spring versus cave, is the character of the cave. Here we know but little more than Farrar reported. When the writer visited Welch Spring the house over the cave mouth was windowless and abandoned and nobody was living near the spring. Although the cave entrance door was open, there was no boat available, and no means or materials for making a raft. Inside the entrance, the spotlight showed a rather narrow, straight, essentially vertical slot, its ceiling perhaps 15 feet above the water. No turbulence was evident, hence the slot must be adequately deep below the water surface. About 100 feet of this could be seen; beyond, there apparently was a turn. The subterranean lake and the "auditorium room" must be around the turn. But Farrar's notes indicate that the spring enters the cave from below, and near the mouth. The cave lies higher than the ground water conduit of the spring. The "lake" is 75 feet deep and only Current River fish, coming inside to winter, will ever investigate that functioning route. One of the most significant facts we now possess is this rise from a completely water-filled, big, trunk route some 65 feet below the river bottom. As to the origin of the air-filled cave beyond the lake, Farrar's statement regarding "many side tunnels and crevices" is illuminating. This is a characteristic of caves of phreatic origin. The side passages presumably record earlier, completely saturated conditions at this level. Rather recently, geologically speaking, river valley deepening has drained them. They correspond to the earliest and highest spring opening in this cliff; the visitors' entrance, some 10 feet to 15 feet maximum above spring level of today. After the fall of ledge rock in the cliff base provided the present spring exit, nature blocked up this entrance with debris and flowstone. Man has chiseled it open again. The air-filled cave and the deeper water-filled cave belong to the same system, a phreatic drainage system that antedates the Current River valley and all the rugged country its tributaries have made since.
Missouri Geological Survey and Water Resources the Ozark uplift. The cave system developed during the earlier erosion cycle, and it developed 500 feet or so beneath the final result of that cycle, the peneplain. The last bit of evidence for completing this picture, for making our theory unassailable, is a red clay fill. Some fortunate reader, with better success in entering Welch Cave than the writer had, should find remnants of the red clay, the record of the peneplain, back in the "many side tunnels and crevices". If none exists, it still may be argued that Welch Cave, although perhaps a one-cycle cave, surely is a sub-water table product, and that the cave preceded the spring. Whaley Cave SW1/4 SE1/4 sec. 17, T. 31 N., R. 4 W., Shannon County Shown on Round Spring Quadrangle map STODDARD COUNTY Three named caves have been located in Stoddard County, but none of them was investigated by the author. Bland Cave NW1/4 lot 7, sec. 5, T. 27 N., R. 10 E., Stoddard County Not shown on Advance Quadrangle map The entrance is reported as 3 feet by 4 feet, and the total vertical range of the cave is 5 feet. It has an explored length of 40 feet. Forked Cave NW1/4 NW1/4 sec. 27, T. 27 N., R. 8 E., Stoddard County Not shown on Puxico Quadrangle map Rockhouse Cave NW1/4 NW1/4 sec. 26, T. 27 N., R. 8 E., Stoddard County Not shown on Puxico Quadrangle map The entrance is 3 feet by 4 feet, and the cave has been entered for 12 feet. STONE COUNTY Eleven named caves have been located in Stone County, and five more are reported. Three of the county's caves are provided with
Caves of Missouri 451 guide service, and they are given special attention in the first part of this work. They are Fairy Cave, Marvel Cave, and Old Spanish Cave. Five caves in Stone County have been studied in the preparation of this report. Breadtray Cave Sec. 25, T. 22 N., R. 24 W., Stone County Not shown on Forsyth Quadrangle map The cave is in Breadtray Hill, the summit of which is shown on the Forsyth Quadrangle map as being 1361 feet above sea level. The hill extends 100 feet above its immediate surroundings and is clearly an outlier of the uplands a mile or so to the east. There appear to be at least two erosion levels; the oldest on formations of Mississippian age, and a younger erosional plain at 1200 feet or so on the Jefferson City formation which is Ordovician in age. On this lower plain, Breadtray Hill is in a sense a monadnock. Who has a theory for a cave in a monadnock? Gentry Cave NW¼ NW1/4 sec. 13, T. 24 N., R. 23 W., Stone County Not shown on Forsyth Quadrangle map A rock shelter at Camp Ramona, 85 feet below cliff top and 50 feet above James River, contains four of the five entrances to this joint-controlled cave system. Words are useless in describing the detailed interrelations of passages; the cave pattern is too complicated (Fig. 168). Entrances are more like doorways than archways, and one of them must be crept into. The cliff face in which all five open has a strike of N. 30° E. From every one of these entranceways, one may emerge from the cave by another. Joint control is obvious. An advanced stage of solutional enlargement is also obvious in places where the joint-bounded blocks have been reduced almost to pillars. Ceilings are exceedingly variable in height above what seems to be a rock-determined, detritus-covered, bedding plane floor. Some passages are stoopways; most of them have 10 feet or more of head room, some are 30 feet, even 40 feet high. Two distinct stratigraphic levels are involved, and a rusty, cherty horizon figures as the lowest ceiling determiner for the narrower side passages that were not followed out. This layer is cut through upward to make most of the 10-foot ceilings. One passage, very narrow and 30 feet to 40 feet high, must penetrate up nearly halfway to the cliff summit. There are some beautiful ceiling domes. No fall rock was seen. One place in the cave showed cherty gravel, but there is no other evidence for vadose occupation of this splendid phreatic cave system No red clay remnants and very little dripstone were seen anywhere in the cave.
Well up toward the top of the cliff, a greenish shaly member makes a re-entrant, something like a rock shelter. There is one joint-de-termined, solution cavity, high and narrow, in the cover rock of the ledge shelter. SCALE IN FEET 0 25 50 Fig. 168. Gentry Cave, Stone County

Halfway down to the river, there is a horizon with numerous solution holes back in the bedding plane; one is large enough to creep into. These also are surely phreatic. It is reported that far back in Gentry Cave there is a beautifully clear stream of water. But where it emerges is not known. It probably finds a joint and falls to river level back in the cliff.

Hermit's Cave

The only reported location for this cave is that it lies "a few miles from Galena". It is said that a hermit wrote "sermons" on cliff faces within his range. He built a coffin for himself in his cave and planned to meet his final summons in it but was found dead in the forest outside.
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Indian Creek Cave

NW1/4 sec. 5, T. 21 N., R. 23 W., Stone County
Not shown on Forsyth Quadrangle map

There is one long, main passage to Indian Creek (or Powell) Cave and a good-sized stream which discharges to the outside valley of Little Indian Creek at grade. Above the stream passage, there are two upper, dry "stories". The floor of each is cut through to the next below by a narrow gash. This ensemble records three more soluble layers and two less soluble ones, rather than three successive levels of cave development. In one place, a vadose, water-made gash heads like a young ravine in the floor of an upper channel or chamber and leads down to the floor of the next one below. One horizon in the walls of this cave has solution potholes; almost the only ones seen in any Missouri Cave during this study. A clay fill has once occupied Indian Creek Cave from the lowest floor to the highest ceiling. The lower chamber, well back, has central pillars which are ragged and undercut and even perforated; clearly the product of the present stream. But there are large numbers of lateral chambers still farther back in the cave. They are apparently along joints and are remnants of the phreatic network which this cave originally was. These passages are all narrow, but they are as high as the main one. Since the cave stream emerges at the level of the outside valley bottom, it could not have made the cave until that valley was as deep as it now is. The low ceiling proves that no vadose stream ever emerged from its higher chambers at any higher level. The upper dry chambers could not have been made after the cave stream found its present outlet. They must date back to earlier and different conditions of ground water circulation, before the present rugged topography had been eroded out of the domed-up peneplain which the accordant summits of the region record.

Keithley Cave

NW1/4 SE1/4 sec. 7, T. 23 N., R. 22 W., Stone County
Shown on Forsyth Quadrangle map

Massey Cave Sec. 28, T. 25 N., R. 23 W., Stone County
Not shown on Forsyth Quadrangle map

Mill Cave

This cave is reported to be in the "northeast portion of the county, about 12 miles from Galena". A stream from the cave ran a water mill in early days.
Pine Run Cave Sec. 31, T. 25 N., R. 23 W., Stone County Not Shown on Forsyth Quadrangle map The entrance to this cave is along the Galena-Marionville road. It is 15 feet wide and 10 feet high. The cave has been traversed for 500 feet. Beautiful rimstone is reported to occur on the floor at the far end. Near the entry, a hole in the cave ceiling leads to an upper room. Reynard Cave Sec. 31, T. 25 N., R. 23 W., Stone County Not shown on Forsyth Quadrangle map The cave is reported to be nearly filled with dripstone deposits. Saltpeter Cave Sec. 6, T. 23 N., R. 23 W., Stone County Not shown on Forsyth Quadrangle map Sugar Tree Hollow Cave T. 24 N., R. 23 W., Stone County Not shown on Forsyth Quadrangle map This cave is reported to be "two miles from Galena". Its entrance is 2 feet by 3 feet, and the cave has been explored for 300 feet. TANEY COUNTY Three named caves are known in Taney County. One of these (Wonder Cave) has guide service and is described and interpreted in some detail in the first part of this report. The other two have been located only by section number, township, and range. Cathedral Cave Sec. 3, T. 22 N., R. 19 W., Taney County Not shown on Forsyth Quadrangle map The entrance to Cathedral (or Ozark Wonder) Cave is on the east side of White River at the mouth of Cedar Creek. Its opening is 12 feet wide and 3 feet high. It is said to have two levels.
Caves of Missouri 455 Wildcat Cave Sec. 15, T. 23 N., R. 21 W., Taney County Not shown on Forsyth Quadrangle map TEXAS COUNTY A total of twenty-seven named caves is known in Texas County. All of them are located approximately. None is commercially operated. As in many other counties, some are used for storage of vegetables or for stock shelters. Six caves in Texas County have been studied during this investigation. The caves not seen were located from the map issued by the Missouri School of Mines (now out of print). Texas County caves, although numerous, are rather small. Anderson Cave NW1/4 sec. 6, T. 32 N., R. 9 W., Texas County Not shown on Edgar Springs Quadrangle map Bat Cave SW1/4 sec. 1, T. 32 N., R. 10 W., Texas County Not shown on Edgar Springs Quadrangle map Bearclaw Cave SW1/4 sec. 33, T. 30 N., R. 8 W., Texas County Not shown on Raymondville Quadrangle map The cave mouth is said to be in the cliffs along the east side of Big Creek a little below the bridge on Missouri Highway 17. The cliff was scrutinized, but the screen of summer vegetation concealed most of it. A rock shelter was examined, and this may be the cave, for it has a creepway solution hole leading back. Although the cliff was scrambled along for several hundred feet, nothing else was seen which could be the cave. Our information was that the cave mouth could be seen from the highway. Only this rock shelter would answer such description. Bearclaw Spring, half a mile away, has no connection with the cave and never had. Blankenship Cave SW1/4 NE1/4 sec. 25, T. 31 N., R. 10 W., Texas County Shown on Houston Quadrangle map
Brandon Cave SW1/4 SW1/4 sec. 25, T. 31 N., R. 9 W., Texas County Not shown on Houston Quadrangle map

This is a very low-ceilinged cave. The mud fill reaches almost to the broad ceiling. The mouth is at valley bottom level. It is impossible to read the history of the cave. Brandon Cave may be only a vadose bedding-plane slot, or it may have a fill going well below the valley bottom.

Bushwhacker Cave SW1/4 sec. 25, T. 33 N., R. 12 W., Texas County Not shown on Big Piney Quadrangle map

Buzzard Cave E1/2 sec. 16, T. 33 N., R. 10 W., Texas County Not shown on Big Piney Quadrangle map

Chimney Rock Cave NW1/4 sec. 28, T. 28 N., R. 7 W., Texas County Shown on Summersville Quadrangle map

Chimney Rock Cave is also known as Spring Cave.

Counterfeit Cave W1/2 sec. 2, T. 33 N., R. 12 W., Texas County Not shown on Big Piney Quadrangle map

Goat Cave NE1/4 sec. 2, T. 30 N., R. 9 W., Texas County Not shown on Houston Quadrangle map

Lancaster Cave NW¼ SE1/4 sec. 1, T. 31 N., R. 7 W., Texas County Shown on Montauk Quadrangle map

Mineral Spring Cave SW1/4 sec. 29, T. 31 N., R. 9 W., Texas County Not shown on Houston Quadrangle map
Caves of Missouri 457 Morgan Cave Sec. 18, T. 29 N., R. 8 W., Texas County Not shown on Clear Springs Quadrangle map This is a very low-ceilinged cave with a mud fill almost to the broad ceiling. Its entrance is at valley bottom level. It is impossible to tell whether the cave is only a vadose bedding-plane slot, or has a fill going well below the valley bottom. Onyx Cave NW1/4 NE1/4 sec. 21, T. 28 N., R. 11 W., Texas County Shown on Cabool SW Quadrangle map The opening to Onyx Cave is back in an alcove-like indentation in the hillside 30 feet to 40 feet above the spring which also comes from the cave. Little can be seen of the cave's form. A room 30 feet to 50 feet in diameter and 10 to 15 feet high is entered directly. Its floor is littered with great tabular roof blocks. Much of the wall is fracture-determined. Solutional wall shapes are evident in the back end of the room, and associated solution tubes lead off into impassable routes of what appears to have been an anastomosis along a favored bedding plane. The original cave also had considerable vertical extent. In spite of collapse debris, one may find his way down to the water-bearing level which is marked by the spring. There is much reddish silt and sand on the shelves and in the pockets in the big room. This silt contains small, scattered chert pebbles and must be vadose. The anastomosis itself could be vadose in origin. This cave is definitely noncommittal as to its origin. A mass of recrystallized flowstone gives the cave its name. No other secondary lime deposits are known. It is reported that one can crawl about 30 feet back in one of the anastomosis tubes, and there find a room high enough to stand up in. Ranch Cave NE1/4 sec. 15, T. 29 N., R. 8 W., Texas County Not shown on Clear Springs Quadrangle map Rattlesnake Cave NW1/4 SE1/4 sec. 23, T. 28 N., R. 8 W., Texas County Not shown on Clear Springs Quadrangle map
Saltpeter Cave
Sec. 35 or 36, T. 32 N., R. 8 W., Texas County
Not shown on Licking Quadrangle map
Fowke (1922, p. 19) reports a double entrance, separated by a triangular mass of rock which is 30 feet wide and extends 20 feet back into the cave. The larger opening is 90 feet wide and 15 feet high. The smaller one is 30 feet wide and 10 feet high and carries the cave stream. Near the entrance, there is a "large mass of breccia composed of small angular limestone fragments cemented throughout with stalagmite material" (Fowke, 1922, p. 20).

Simmons Cave
NW1/4 SE1/4 sec. 34, T. 30 N., R. 10 W., Texas County
Shown on Bado Quadrangle map
The mouth of this cave is 30 feet up in a bluff of the Big Piney River. It resembles Morgan Cave and Brandon Cave, except that it has head room for an entrance chamber. Back of this, there are two or three former passages which are now all but completely filled with old stream debris. Simmons Cave may be of phreatic origin, and the stream waste may be a later deposit by vadose cave water, or by Big Piney at a higher valley bottom level.

Smith Caves
N1/2 sec. 26, T. 31 N., R. 7 W., Texas County
Not shown on Hartshorn Quadrangle map
Fowke (1922, p. 19) reports three caves. One has a 5-foot by 5-foot opening which shortly narrows to a crevice. Another, 20 feet wide and 4 or 5 feet high at the entrance, is dry for 50 feet. Beyond that distance, its floor slopes down toward the rear, and the ceiling maintains its height. The third has an entrance 30 feet wide and 20 feet high. It is dry for 20 feet, beyond which water covers the entire floor.

Stallcup Cave
SE1/4 NE1/4 sec. 30, T. 31 N., R. 11 W., Texas County
Shown on Bado Quadrangle map
The entrance to Stallcup Cave is a shallow ponor on the lower slope of the West Fork of Roubidoux Creek valley. It is 30 to 40 feet above the floodplain. No outcropping ledges are shown except in the uphill wall of the sink. The cave leads eastward, small angular turns shifting the orientation of its straight length between N. 65° E. and N. 80° E. The cavity, as far as it was entered, is essentially an enlarged joint. No widths are greater than 10 feet. They average a little less, but there are no tight places.
Caves of Missouri 459 The ceiling is a flat fracture at about the same level throughout. The floor is quite irregular because of masses of fallen rock and an irregular topography of the clay. The clay is now going out through slump pits. The cave has been clay-filled to the ceiling. At 200 to 250 feet inside, beyond a slump pit, "Jacob's Ladder" is a very steep, very slippery climb over a remaining clay mass that reaches so close to the ceiling that only a tight crawl-hole remains. Examination went no farther. Reports are that there is much more cave beyond this barricade. At "Jacob's Ladder", the joint, a double one, can be seen in the far wall. Here the open cavity is deepest because of the slump pit. It is about 35 feet from top to bottom. There has been some vadose undercutting close to present floor level near the entrance. It was apparently done when that floor was the stream bottom. Some wall blocks have settled and tilted as a result. The present hillside debris fill in the mouth is later than any such stream. The phreatic origin of this cave is indicated by its high, narrow, joint-determined proportions, together with the absence of meander wall slots throughout most of its examined length. The clay is silty, and in "Jacob's Ladder" it shows stratification. It is not phreatic red clay. The only secondary lime deposits seen were a flowstone cone and some wall "popcorn" near the entrance. The old erosion surface is well shown in the region at 1350 feet above sea level. The cave mouth is about 1250 feet above sea level. This is ceiling level, and if there were no clay or other debris, its bottom would be probably as low as 1200 feet above sea level. The peneplain remnants in the divide two miles farther west reach 1450 feet above sea level. The cave hill itself touches 1400 feet and seems to be an erosionally lowered part of a still older peneplain. The phreatic making of the cave can be theorized as of either or both erosion cycles. If 200 feet is a favorable depth for its initiation; that is, if it developed during the earlier cycle, it must have remained under phreatic conditions through the later cycle and have been a functional ground water route, even if such caves normally tend to originate at greater depths. Sweet Potato Cave S1/2 sec. 22, T. 33 N., R. 10 W., Texas County Not shown on Big Piney Quadrangle map Sweet Potato Cave NW1/4 sec. 6, T. 32 N., R. 9 W., Texas County Not shown on Edgar Springs Quadrangle map This cave may be Anderson Cave because the location is the same for both.
460 Missouri Geological Survey and Water Resources Sycamore Cave SW1/4 SW1/4 sec. 31, T. 31 N., R. 9 W., Texas County Not shown on Houston Quadrangle map Venable Cave NW1/4 NW1/4 sec. 36, T. 32 N., R. 10 W., Texas County Shown on Prescott Quadrangle map Weber Cave NW1/4 NW1/4 sec. 35, T. 33 N., R. 10 W., Texas County Not shown on Big Piney Quadrangle map Wildcat Cave NE1/4 sec. 22, T. 29 N., R. 8 W., Texas County Not shown on Clear Springs Quadrangle map Wildcat Cave SE1/4 SW1/4 sec. 13, T. 32 N., R. 10 W., Texas County Not shown on Prescott Quadrangle map Wildcat Cave is also known as Mud Cave. WASHINGTON COUNTY Four caves are reported from Washington County. Three have been located but none was seen by the writer. Alum Cave Farrar states that this cave is "in Bellview Valley". No other location is known. Green's Cave SW1/4 SE1/4 sec. 24, T. 40 N., R. 2 W., Washington County Shown on Meramec State Park Quadrangle map This cave is reported by Farrar to be a long, narrow fissure with a large entrance in the Eminence dolomite. Hamilton Cave SE1/4 SW1/4 sec. 30, T. 40 N., R. 1 W., Washington County Shown on Meramec State Park Quadrangle map
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Unnamed Caves NW1/4 sec. 24, T. 37 N., R. 2 W., Washington County
Not shown on Berryman Quadrangle map
This cave is reported to lead through the tip of the divide between Lost Creek and Courtois Creek.

SE1/4 SW1/4 sec. 30, T. 40 N., R. 1 W., Washington County
Shown as Cave on Sullivan Quadrangle map

WAYNE COUNTY
Wayne County possesses at least three named caves, two of which were visited during this study. Holmes Cave
Owner: Ben Holmes, Patterson, Missouri
SE1/4 SW1/4 sec. 10, T. 29 N., R. 5 E., Wayne County
Not shown on Greenville Quadrangle map

The entrance to Holmes Cave is in a broad, shallow collapse sink (ponor), about 50 feet in diameter with continuous rock walls. The cave extends eastward for 250 feet under a low hill. The roof rock at the entrance is 20 feet thick. Fifty feet back in the cave, there is a break through the roof where direct sunlight may fall on the cave floor. The proportions of the cave are similar in all cross sections. There is an irregular ceiling 8 to 10 feet above the flowstone and mud floor. Walls about 20 feet apart descend nearly but not quite to that floor. Just above the floor, there is a marked widening under what is apparently a fracture-determined, lateral slot, too low to enter without crawling. The mud fill, now largely armored with flowstone and old rimstone, must be deep, for there is no trace of fallen wall blocks. There are some very fine ceiling pockets which extend 6 feet above the general ceiling surface. The irregularity elsewhere, both in ceiling and walls, is phreatic solutional work. The cave contains much heavy old dripstone and is terminated by a compound of such forms. It can be passed only by a thin person and is reported to lead to another room; dimensions unknown by the owner. A westward continuation of the cave is indicated by a crawlway in the ponor wall. Mr. Holmes says that when he was a boy he entered also from lower down the slope to the west. Most of the massive dripstone is probably older than the collapse which made the ponor. A large mass of weathered cave onyx which is
Missouri Geological Survey and Water Resources partially ensconced in the remaining half of a former ceiling pocket in the cliff on the north side of the entrance testifies to this. Yancey Cave NE¼ SE1/4 sec. 35, T. 30 N., R. 4 E., Wayne County Shown on Piedmont Quadrangle map The entrance to this cave is at the top of a gentle slope which rises 100 feet above the floodplain level of Camp Creek, less than half a mile to the east. It is 600 feet below the summit of Frenchman Hill (Yancey Mountain), half a mile to the west. The Geological Map of Missouri (1939) shows that the hill is composed of pre-Cambrian rock. The level of the cave is in Cambrian sediments which occupy an embayment among the resurrected pre-Cambrian hills. Local residents say that the horizontal passage leading in from the entrance ends about 30 feet back, and the cave there descends vertically for possibly 50 feet, and that this descent is negotiable only with ladders or rope. One man who has been down says that the "real cave" is at the bottom of this shaft, that one can go by various walkways (some crawlways interrupting) "all under Yancey Mountain", and that by continually turning right or left at intersections one can in places return to the place where he started. All this network is essentially horizontal. Passages are reported to average 10 feet by 10 feet in cross section. WEBSTER COUNTY Three named caves are reported from Webster County. One was examined during this study. Devil's Cave NE1/4 NW1/4 sec. 3, T. 28 N., R. 19 W., Webster County Not shown on Ozark Quadrangle map Devil's Cave which is also known as Panther Den is a picturesque ponor, made by roof collapse of a joint-determined cave chamber. The joint is double. At the time of examination the surface of a pool in the sink stood about 50 feet below the lowest place in the rim and had recently stood 20 feet higher. A remnant of the cave shows at the northeastern end, half-way down to the water. Shepard (1898, p. 40) reports that this cave has been entered for 245 feet. There was only a ramshackle ladder for descending, and the writer chose not to try it, for all other walls were vertical for 40 feet above the water.
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**Goss Cave**
Sec. 27, T. 28 N., R. 17 W., Webster County
Not shown on Fordland Quadrangle map

**Silver Cave**
SW1/4 sec. 6, T. 27 N., R. 19 W., Webster County
Shown on Ozark Quadrangle map

**WRIGHT COUNTY**

Wright County has at least three named caves, one of which (Smittle Cave) is shown to visitors by the owner, and has a special section given to it in the first part of this report. The other two caves have not been definitely located.

**Calhoun Cave**
This cave is reported to be halfway between Macomb and Norwood. It has a large entrance which has served as a stock shelter.

**Onyx Cave**
Onyx Cave is reported to lie two miles southwest of Macomb. It is entered by a ladder, by which one descends vertically about 40 feet. One then stoops and crawls some distance and finally enters a "spacious chamber".
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Caves of Missouri 467 GLOSSARY Compiled by John W. Koenig This glossary of terms is prepared for the lay reader and is not intended for, geologists or physiographers. The scientific reader will realize that full and accurate explanations of most scientific terms in familiar language are impossible, and only a rough approximation to the full meaning can usually be given. Although source references are given, most of the definitions have been paraphrased to fit the requirements of this glossary. The definitions are not direct quotations. Angle of repose.-When loose material such as sand or gravel is dumped in a pile on a level surface, the material on the upper slanting surface of the pile falls and slides to a position of rest. The angle thus assumed by the loose surface material with the level surface on which the pile rests is known as the angle of repose. This angle is usually about 33 to 35 degrees. (Lahee, 1941). Anticline.-The layers of rock in the earth's surface when subjected to compressive pressures can be bent and folded like layers of soft plastic or cloth. Therefore, if one were experimentally to crumple a table cloth, the folds of the cloth thus formed which project upward or are convex upward are anticlinal, and they are similar to the folds which in layered rocks are called anticlines. Conversely, the related and adjacent folds of the cloth which project downward are synclinal and are called synclines. (Billings, 1946). See Syncline. Base level.-When rain, wind, and moving water actively come in contact with the land masses of the earth's surface, those masses are eroded or worn away. Theoretically, if this process of erosion goes on unhindered, the waste material is eventually washed and blown into the sea, and the hills and plains are reduced in elevation. The land masses are thus leveled off. The lowest possible level to which these flattened land surfaces can be eroded is practically considered to be sea level. This level is referred to as base level. Locally, on the land masses themselves, temporary base levels can be established at almost any elevation by the level of a lake, a large river, or a particularly resistant layer of rock. (Bryan, 1922). See Peneplain. Bed.-A bed of rock is the smallest unit in a stack of such units; just as a sheet of paper is the smallest unit in a stack of paper. A bed of rock is thus thought of as being marked by a more or less well defined divisional plane from its neighbors above and below. (Fay, 1920) See Stratum.
Surveyors and map makers require permanent points of reference on the earth's surface on which they can base their horizontal and vertical measurements. Such reference points are called bench marks and are permanently established stone or concrete monuments which are erected at points of known geographic position and elevation. (Cox, Dake, and Muilenburg, 1921).

Cycle of erosion.-When an elevated, mountainous land mass is subjected to the slow destructive processes of erosion, it in time is theoretically worn down to where the surface of the land mass is a broad featureless plain (peneplain) which is at base level. (See Base level). The interval between the beginning and end of this destructive process is called the cycle of erosion. The reason why it is called a cycle instead of a period or some other appropriate term is because the process is a recurrent phenomenon which has been brought about throughout the earth's history by repeated uplifts of the earth's surface. Since the erosion cycle is commonly thought of in relation to the wearing action of running water, it is often described in terms of stream erosion and the sculptured land forms which are produced by the streams. In this sense, the cycle of erosion is referred to as the stream cycle. However, the erosion cycle is equally applicable to the process of wind erosion in a desert or to the process of wave erosion on a coast line. For convenience of analysis the cycle of erosion is divided into three stages, youth, maturity, and old age. (Rice, 1951). See Stages, erosional.

Dendritic drainage pattern.-When a stream flows over the surface of the ground, the direction in which it and its tributaries flow is largely controlled by the shape and slope of the ground surface. If this surface has no definite pattern or arrangement, the stream pattern will be essentially tree-like in its organization in having a twisted main stem and many minor limbs and branches which extend in many directions at almost any angle. (Thornbury, 1954).

Dip.-The angle of dip can be readily understood by the simple act of placing a rectangular card on a table so that one edge of the card is in full contact with the top of the table, and the rest of it is tilted at an angle to the table top. Essentially, the angle thus formed between the bottom of the tilted card and the top of the table is the angle of dip of the card. In geology, the dip of a bed of rock (like the tilted card) is a measure of the angle formed by the dipping bed and a horizontal plane. (Billings, 1946). See Strike.

Doline.-Limestone is especially subject to solution where it is broken or cracked. If a stream of water encounters a crack in a bed of limestone, it will flow into the crack and dissolve the rock around it. If the solution process continues, a saucer or funnel-shaped depression is formed in the limestone which is called a doline. Some
Caves of Missouri dolines range in size and form from mere chimney-like shafts which may be 300 or more feet deep, to the representative funnel-shaped occurrences ranging from 30 to 400 feet in diameter and 6 to 75 feet deep. (Von Engeln, 1948). See Sinkhole. Downthrown side.-A term used to describe the apparent downward movement of one side of a fault in relation to the other side. (Cox, Dake, and Muilenburg, 1921). See Fault and Upthrown side. Fault.-A fault in a bed of rock is a break or parting along which movement has occurred parallel to the surface of the break. The amount of relative displacement of the two sides of the fault may be a few inches or thousands of feet. (Billings, 1946). See Joint. Fault plane (zone).-In a fault, the break along which displacement takes place forms a plane, called the fault plane. If the break is complex and the rock around the break is broken, shattered, and faulted for some distance on either side of it, the break is called a fault zone. (Billings, 1946). Graded stream.--A stream is said to be graded when the slope throughout its course and its amount of water supply is such that the stream's velocity is just sufficient to carry the erosional waste and debris brought to it from all sides. Such a stream theoretically does not erode its channel nor does it deposit any of its load of debris. In nature, such a delicate balance is very seldom attained because of the constant changes in the stream's environment. (Lobeck, 1939). Horizon.-The term horizon, as used in geology, refers to a given horizontal extension of a particular bed of rock (stratum) or a particular level in a bed of rock which is marked by some important feature such as a distinctive fossil or mineral. (Cox, Dake, and Muilenburg, 1921). Joint.-A joint in a bed of rock is a break along which there has been no movement parallel to the surface of the break. Some joints are so tight that a knife blade cannot be inserted into them, but movement at right angles to the breaks will produce open fractures, some of which are several feet wide. (Billings, 1946). See Fault. Maturity.-That stage in the development of the erosion cycle at which the processes of erosion are operating with a maximum of vigor and efficiency. (Fay, 1920). See Stages, erosional, Cycle of erosion, Youth, and Maturity. Peneplain.-A peneplain is a broad, featureless, land surface of slight relief and very gentle slopes. It is generally considered as
Missouri Geological Survey and Water Resources the end product of the cycle of erosion. After prolonged attack by the destructive agents of erosion, an uplifted land mass is reduced to a featureless plain over which slow moving, meandering streams flow with almost complete loss of vigor and efficiency. These conditions characterize the stage of old age in the cycle of erosion. (Fay, 1920). See Stages, erosional, Cycle of erosion, and Old age. Perched ground water.-Ground water is said to be perched if it is separated from the underlying main body of ground water by a barrier of impermeable rock. Thus, a small body of perched ground water may lie beneath the surface of a hill on top of an impermeable bed of clay, with the main body of ground water several dozens of feet beneath the clay bed. (Meinzer, 1923). Perched water table.-The upper surface of perched ground water is called the perched water table as distinct from the upper surface of the main body of ground water. (Meinzer, 1923). Phreatic water (zone).-Under normal temperate zone conditions, if one digs a hole, he will first encounter a few inches of dry to slightly moist top soil. As the hole gets deeper, he will find that the moisture content of the rock and soil increases. Damp sticky clay will stick to his shovel. Finally, as the hole is deepened, the bottom will become quite muddy. The digger at this point has encountered the top of the water table. If he continues to dig, he will find that the hole will have standing water in it. This standing water is phreatic water, or water which occurs in the fully saturated zone beneath the water table. The zone or layer of earth in which this water occurs is called the phreatic zone. The damp, partially water saturated earth through which the hole had been dug is called the vadose zone. (Meinzer, 1923). See Vadose water, Water table, and Saturated zone. Piracy, stream.-Stream piracy implies the diversion or capture of the water of one stream by another through the active erosional attack of one stream upon the drainage system of the other. There are several types of stream piracy-subterranean diversion being one of them—but in most cases the more active or pirate stream has an advantage over its victim because it either cuts its valley in more easily erosible rocks or has a steeper gradient. For example, if one of two adjacent streams happens to erode its channel more rapidly than its opponent, it will entrench itself more quickly and aggressively. Eventually, the deeply cut gullies and channels of the aggressor will cut into the drainage system of the less active stream and will divert its water. Thus, the active stream will have captured or pirated the water of its opponent. (Thornbury, 1954). Ponor.-A ponor is a saucer or bowl-shaped depression in the surface of the ground which is caused by the roof collapse of a subterranean chamber or cavity. Normally, such a depression is thought of as a sink hole. (Bretz, 1950). See Doline and Sinkhole.
Caves of Missouri 471 Saturated zone.—The saturated zone beneath the surface of the ground is the same as the phreatic zone. It is the zone or layer beneath the surface of the ground which is completely saturated with water. In other words, the permeable beds of rock within this zone are very much in the same condition as a thoroughly wet sponge, even to the extent that if it were possible to squeeze the rock, the water would run out of it as from a wet sponge. (Meinzer, 1923). See Phreatic water (zone). Sinkhole.—Sinkhole is a general term which is applied to any shallow saucer-shaped depression in the surface of the ground which is formed either directly or indirectly by the solvent action of ground water beneath the surface. Commonly, such depressions are roughly circular in outline and look like large kettles or bowls. Rain water and debris collect in the bottom of some of them, and they become quite marshy and tangled with brush and undergrowth. In others, the surface water seeps through openings in the bottom and drains out into lower subterranean drainage routes much like the drain—water in a bath-tub or wash bowl. (Von Engeln, 1948). See Ponor and Doline. Slip-off slope.—In a meandering stream, the water on the inner upstream side of the meander curve tends to flow at a slower rate than the water on the outside downstream side of the curve. This slack water, therefore, slips down and away from the inner upstream side of the channel, and because of its lower velocity and direction of movement tends to shape the inside of the meander curve into a gently sloping bank which is called the slip-off slope of the meander curve. (Longwell, Knopf, and Flint, 1939). See Under-cut slope. Stages, erosional.—Since a cycle of erosion consists of a series of continuous formative processes which operate over a period of time, it is similar in many respects to the biological life span of an individual from birth to death. This analogy is so apt that the terms which are used to designate the developmental stages in the erosion cycle have been adopted from the biological terms of youth, maturity, and old age in the life span of an organism. The geologist uses these terms to describe particular periods within the erosion cycle when the destructive processes of erosion are actively shaping and sculpturing the physical features of the earth's surface. He defines these periods in terms of the shapes attained by the land forms. Thus, a peneplain is a characteristic land form of the erosional stage of old age. (Von Engeln, 1948). See Youth, Maturity, Old Age, Cycle of erosion, and Peneplain. Stratum.—Stratum is used synonymously with bed, and pertains to a layer of rock which has essentially the same appearance throughout its vertical and horizontal extent. It is also spoken of as a distinct lithologic unit. (Cox, Dake, and Muilenburg, 1921). See Bed.
472 Missouri Geological Survey and Water Resources Strike.—The term strike can be readily understood by the simple act of placing one edge of a rectangular card in full contact with a level flat surface such as a table top and by holding the card at some angle or vertical to the table top. The strike of the card is the line of contact of the edge of the card and the table top. In geology, the strike of a bed of rock is at the line of intersection of the sloping bed of rock and a horizontal surface. The strike is then designated by its compass direction. (Cox, Dake, and Muilenburg). See Dip. Syncline.—See Anticline.

Undercut slope.—In a meandering stream, the water on the outer downstream side of the meander curve tends to flow at a more rapid rate than the water on the inner upstream side of the curve. This rapidly moving water cuts into the bank on the downstream side of the channel and forms a sharp, vertical scarp which is called the undercut slope of the meander curve. (Longwell, Knopf, and Flint, 1939). See Slip-off slope. Unsaturated zone.—The unsaturated zone beneath the surface of the ground is the same as the vadose zone. It is the zone or layer beneath the surface of the ground which is only partially saturated with water. Rain water seeps down through this unsaturated zone to reach the saturated or phreatic zone beneath. It is the moist, sticky clay zone through which one must dig to reach the top of the saturated zone. (Meinzer, 1923). See Unsaturated zone, Phreatic water (zone), Water table, and Vadose water (zone). Upthrown side.—A term used to describe the apparent upward movement of one side of a fault in relation to the other side. (Cox, Dake, and Muilenburg, 1921). See Fault and Downthrown side. Vadose water (zone).—When rain falls on the surface of the ground, part of it drains off into the gullies and streams, and part of it soaks into the ground. The water which soaks into the ground percolates down through the soil and interstices in the beds of rock until it reaches a point beyond which it cannot penetrate. This point is called the saturated or phreatic zone, and the zone of soil and rock through which the water has passed on its way down from the surface is called the vadose zone. The water which passes through this zone is called vadose water. (Meinzer, 1923). See Unsaturated zone, Water table, Phreatic water (zone), and Saturated zone. Water table.—The water table is the upper surface of the saturated or phreatic zone and lies between it and the unsaturated or vadose zone. (Meinzer, 1923). See Saturated zone, Phreatic water (zone), Unsaturated zone, and Vadose water (zone).
Caves of Missouri 473 Youth.-That stage in the development of the erosion cycle at which the processes of erosion are operating with increasing vigor and efficiency and are just beginning to shape the land masses into forms of greater complexity. (Fay, 1920).

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