Geology of Klump's Cave, Perry County, Missouri

Ernest L. Kern
Western Michigan University

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GEOLOGY OF KLUMP'S CAVE,
PERRY COUNTY, MISSOURI

by

Ernest L. Kern

A Project Report
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Specialist in Arts Degree

Western Michigan University
Kalamazoo, Michigan
December 1974
ACKNOWLEDGEMENTS

Special acknowledgement and appreciation is extended to the members of the writer's specialist committee, Doctors W. Thomas Straw, chairman, Richard Passero, and Paul E. Holkeboer, for their encouragement, suggestions, and critical reading of the manuscript. Further acknowledgement is extended to Jerry Vineyard of the Missouri Geological Survey and Ray Knox and Louis Unfer of the Department of Earth Science at Southeast Missouri State University. Each took a personal interest in this study and contributed with numerous oral and written communications over the past two years.

Special appreciation is expressed to four of the writer's students who have become excellent cavers. These are Mary Grither, Jim Palmer, Dave Warren, and John Wilson who assisted the writer with the exploration and mapping of Klump's Cave.

Sincere thanks also to Mr. and Mrs. Leo Klump, owners of the cave. They kindly allowed the writer and his assistants complete freedom during the research of the system. In addition, they allow the cave to be visited freely by speleology classes from the university.

Finally, a sincere acknowledgement to my wife, Jan, for her continued encouragement and sacrifices during the research and writing of the manuscript.

Ernest L. Kern

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CHAPTER I
INTRODUCTION

Scope and Purpose

Missouri has long been noted as one of the major cave states, and, as of January, 1974, the number of known caves was listed at 3051 (Jerry Vineyard, personal communication). As a result, the Missouri Geological Survey has placed great importance on the science of speleology.

The contributions made from the scientific study of caves are numerous. For example, the understanding of the geology and speleogenesis of caves is valuable in determining the geologic and geomorphologic history of an area. Evidence of past events which may be absent or indiscernible on the surface are often clearly preserved in the subsurface caverns. Valuable contributions are also made in the area of highway, dam, and building construction. A long and costly delay resulted during the construction of Interstate 55 through the karst area of Perry County, Missouri due to an encounter with an unreported cave system. Cavernous conditions have also plagued dam-building efforts in southern Missouri and northern Arkansas (Jerry Vineyard, personal communication). It is thus necessary that the construction engineer have data available on the location and extent of caves in the construction area. In addition to the two mentioned above, the list of disciplines which may benefit from cave studies goes on—ground-water hydrology, economic geology, paleontology, etc.
It is obvious, then, that cave data must be available for individuals in various disciplines and professions to draw upon. When one considers the great abundance of caves in Missouri, it becomes clear why the Missouri Geological Survey strongly encourages the exploration and scientific study of caves and related features.

The primary goal of the research reported herein was to add to the available knowledge of Missouri caves by the scientific study of a fairly large cave-system in Perry County, Missouri. The research included detailed descriptions of the cave passages and evaluations of the stratigraphic position of the cave, structural and topographic relationships, hydrology, and speleogenesis. The study was limited to this single cave-system and the area in its immediate vicinity.

In view of the large number of Missouri caves yet to be explored and studied, this contribution seems small, although hopefully significant, and a great deal of work remains before a complete knowledge of Missouri cave systems is achieved.

Location and General Setting

Klump's Cave is a large, horizontal cave-system located in the eastern flank of the Ozark Dome approximately 1.2 miles northeast of Perryville, Missouri. Only two passable entrances to the cave exist. The main entrance is in the S1/2, NE1/4, NW1/4, SW1/4, SE1/4, Section 17, T. 35 N., R. 11 E., Perryville Quadrangle, Perry, Cape Girardeau, and Boilinger Counties, Missouri (figure 1). The smaller,
secondary entrance is situated approximately 100 feet to the northeast of the main entrance.

Primary access to the cave is gained from the base of a collapse sink in limestone. This sink is roughly circular in outline with a diameter of twenty feet and a depth of ten feet (figure 2). A small, intermittent stream enters the cave through this sink. The secondary entrance is at the base of a ponor some fifteen feet in depth and three feet in diameter at the surface, widening slightly with depth. In addition to its size and depth, access here is made even more difficult due to brush and rubbish dumped into the sink by the owner.
Figure 2. Collapse sink providing the main entrance to Klump's Cave. Note the breakdown in the base of the sink.

(figure 3). Another intermittent stream enters Klump's Cave via this ponor (figure 4). The cave consists of three major passages or avenues: the east–west extending Left Fork Passage, the Rim Passage which extends north–south, and the Right Fork Passage which meanders between northwest and east (plate I). Total length of explorable passage in Klump's Cave is in excess of 4000 feet. The entire system underlies the partially dissected areas of an upland surface which is 160 to 180 feet above the floor of Cinque Hommes Creek valley.

The cave is in the lower part of the Rock Levee and the upper portion of the Joachim formations, both of Ordovician age. Slightly less than one mile to the east of the entrance, the younger
Figure 3. Secondary entrance to Klump's Cave.

Plattin formation (Ordovician) is present at the surface and outcrops in a wide belt which extends almost to the Mississippi River.

Surface drainage in the area is generally to the northeast via Cinque Hommes Creek, situated approximately 1.3 miles southwest of Klump's Cave.

Methods of Investigation

Cave passages were surveyed by the compass and tape method during September and October of 1973. Brunton compasses and metallic tapes were used. Passage details were sketched by eye on the traverse framework. Passage heights and widths were estimated when less than ten feet, although periodic measurements were taken to insure the accuracy of the estimates. All heights and widths greater than ten feet were measured where such measurements could
be carried out safely.

Speleological information concerning Klump's Cave was obtained solely through observations of the writer as was surface aspects in the vicinity of the cave. Data on the geology outside the proximity of the cave were in part obtained through personal observations and in part through the literature and personal communications. The original cave map was drafted by the writer on a scale of 1:375.

Previous Work

Caving activities in Perry and adjoining counties has been conducted mainly by three local chapters (grottoes) of the National Speleological Society: Southeast Missouri State Grotto (based at Southeast Missouri State University, Cape Girardeau), Little Egypt
Student Grotto (based at Southern Illinois University, Carbondale), and Middle Mississippi Valley Grotto (based in St. Louis). The efforts of these organizations, however, has been limited almost exclusively to exploration and mapping, with very little work being done on the geology of the systems. Consequently, most of the literature on Perry County and other southeast Missouri caves is in the form of cave maps, trip logs, and general descriptions.

Dr. Ray Knox, director of the Southeast Missouri State Grotto, is presently working on the geology of Crevice Cave, an extensive system (over twelve miles of mapped passage) located just north of Perryville. At the time of this writing, however, his work had not progressed to the point where definite conclusions or interpretations can be made (Ray Knox, personal communication). Yokum (1972a) has completed a preliminary study of Kohms Cave, located near Ste. Genevieve, Missouri. Although more work remains to be done, he thinks that the cave displays ample evidence of an initial phreatic genesis, followed by vadose modification of that initial configuration.

Surprisingly, a similar situation (that is, a general lack of detailed scientific studies) exists regarding caves in other parts of Missouri (Jerry Vineyard, personal communication) with only a few notable exceptions. Carroll Cave, located in the northern slope of the Ozark Dome in Camden County, Missouri, was studied in detail by Helwig (1964, 1965). It is dissolved into the upper part of the Gasconade dolomite of Ordovician age, and is postulated to have originated under shallow-phreatic conditions during the Pliocene. Following his research on Miller County caves, Barnholtz (1961) concluded
that they originated in mid-Tertiary time, and in addition, demonstrated the influence of jointing on cavern development.

Brod (1964) made an extensive study of the fissure caves (those characterized by high, narrow passages) of east-central Missouri. Evidence again indicated that these caves were formed primarily by solution under phreatic conditions. Although the outstanding feature of the fissure caves is joint control, this alone does not suffice as an explanation for the high, narrow passage character. Rather, it is Brod's contention that the lithologic characteristics of the host rock plays an equally important role. The great majority of the fissure caves are in the Plattin formation of middle Ordovician age, a hard, sublithographic limestone with a high percentage of insoluble material. In fact, all known caves in the Plattin are of the fissure type. Conversely, although the caves in other formations within the study area (the overlying Decorah and Kimmswick and the underlying Rock Levee and Joachim, all of Ordovician age) often exhibit joint-controlled orientations, the passages themselves do not regularly exhibit the fissure structure so typical of Plattin caves. Since the frequency of jointing is similar in all the above formations, Brod concluded that it is the lithologic differences between the Plattin and the other formations that accounts for the fissure structure.

Bretz (1942, 1953, 1956) has spent considerable time studying the caves of Missouri. Based on these studies, he concluded that most of Missouri's caves developed under completely subaqueous (phreatic) conditions by waters circulating under hydrostatic
pressure beneath the mature topography of the early Ozark region. As the topography attained old age, the drastic reduction in relief caused the ground-water circulation to nearly cease, the result being the deposition and filling of the caves with red, unctuous clay (terra rosa) derived from the soil on the overlying erosion surface (peneplain). Stream downcutting with an accompanying lowering of the water table coincided with rejuvenation of the area. The caves were thus drained and subsequently became occupied by subterranean free-surface (vadose) streams. Their action caused the removal of much of the clay fill and the modification of the phreatic character of the caves. It is during this vadose cycle that the speleothems developed.

Bretz's theory of cave genesis is similar to that set forth by Davis (1930), the major exception being the addition of a clay-filling episode. And although he questions the great significance placed on the presence of fine clay as an indication of phreatic origin, Thornbury (1954) basically agrees with Bretz's conclusions regarding Missouri caves as evidenced by his statement, "there seems to be a strong probability that most of Missouri's caverns formed in this way."

The criteria indicative of phreatic solution which Bretz (1956) observed in Missouri caves are:

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

Bretz (1956) also listed five criteria indicative of vadose action, later superimposed on existing caves formed under phreatic conditions:

1. Incised meanders in cave walls
2. Horizontal grooves in cave walls
3. Dome pits
4. Pendants
5. Ceiling channels

The occurrence of springs or resurgences is also directly related to the geology and genesis of cavern systems. Some notable work has been done on the springs of Missouri, especially that by Beckman and Hinchey (1944) and Vineyard (1963).

With the major exceptions previously noted, most of the literature on Missouri caves, like that on the caves of southeastern Missouri, is limited to maps, descriptions, and trip logs.

Generalized Geology of Perry County

Stratigraphy. The stratigraphic succession exposed in Perry County consists of a sedimentary sequence of forty-one units, exclusive of surficial deposits (table I). The rocks range in age from Ordovician through Mississippian, and reach a total maximum thickness of more than 2900 feet (Flint, 1925). They form a part of an eroded, irregularly homoclinal succession extending eastward into the Upper Mississippian and Pennsylvanian rocks in Illinois and westward into
the Cambrian and Precambrian units of the St. Francois Mountains.

Klump's Cave is thought to be restricted to only two of these units, the Rock Levee and Joachim formations.

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<td>Joachim— thin, evenly bedded, fine grained, argillaceous dolomite. Color of weathered surfaces varies from yellowish-brown to grayish-brown to olive-gray. Interbedded limestone and shale is found in its lower part as are scattered quartz sand grains. Chert is absent except for a thin, persistent, nodular-chert bed at its top, although it is inconspicuous in surface exposures. Fossils are scarce (Martin, Knight, and Hays, 1961).</td>
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Detailed geologic maps have not been completed for the southeastern Missouri area including Perry County. The Missouri Geological Survey is presently mapping the Perryville area in detail, but their completion date is still several months in the future. Flint's (1925) work in parts of Perry County was completed in 1925. Since that time, many of the rock units mapped have been subdivided in other studies, and as a consequence, his unpublished map is out of date. As a result, the geologic map of Perry County (figure 5) is generalized with most of the formations not being differentiated, but rather grouped in Series subdivisions. In addition, a number of the Series units which
Figure 5. Generalized geologic map of Perry County, Missouri.

have only limited areas of exposure have been omitted. For the purposes of this report, and because the study cave is restricted to just two formations, this generalized map suffices to illustrate the regional geologic setting and its effects on cavern development.
Structural geology. Structurally, Perry County may be divided into two parts: (1) a narrow (less than one-half mile in width) belt of faulting and folding in the extreme northwest portion of the county; and (2) a broad area of gently homoclinal units with very little associated faulting or folding.

The belt of faulting forms part of a continuous east-west fractured zone which has been recognized in northern Perry County and westward into Ste. Genevieve, St. Francois, Washington, Jefferson, and Franklin Counties, Missouri (Flint, 1925).

This fault-fold zone is relatively far removed from the Klump's Cave area which is located approximately seven miles to the south in the homoclinal region. As a result, it appears that this zone of deformation has had no effect on the origin, development, or orientation of the study cave. Consequently, only a brief description of the deformed area is included below.

Flint (1925) recognized a number of major faults in this zone, among the most important being the Red Rock thrust, Union School fault, Wittenburg faults, and Omete Creek faults. The fault planes dip toward the south, and one can note in figure 5 the juxtaposition of Mississippian strata against Ordovician units as a result of displacement along these faults. Although a number of folds are associated with the fault zone, the most prominent is the Mahnken Branch fold. This structure is an asymmetrical anticline trending N. 50° W. with the southern limb having dips of only 10° to 15°, while the steeper northern limb dips at an angle of 40° (Flint, 1925).

The homoclinal area forms part of a large belt of rocks that
dip eastward away from the St. Francois Mountains into the Illinois Basin. This area represents the eastern limb of the Ozark Dome. All of Perry County is included in this homoclinal area with the exception of the fault zone mentioned above.

Regional strike of the strata is predominantly northwest, although it swings to nearly north-south near the southern boundary of the county. Dips are locally variable, but on the whole are gentle and uniform, ranging between one and six degrees to the northeast and east (Flint, 1925; Yokum, 1972a; Ray Knox, personal communication). It is this gentle, homoclinal structure which dominates the area, with recognizable zones of deformation being virtually absent. A few minor folds are present in the extreme southern portion of Perry County and Cape Girardeau County (Ray Knox, personal communication; Gealy, 1955).

The strata in the homoclinal area are jointed, and in the vicinity of Perryville an observable, but comparatively poorly developed, joint system can be identified in the Joachim and Rock Levee formations. This system consists of four joint-sets having strikes of: E.- W., N. 15° W., N. 60° W., and N. 28° E. (Louis Unfer, personal communication). The dip of these sets is almost vertical.

The only other noteworthy structures in the homoclinal area are subsidence and collapse features. Although dips associated with the slumped units may be relatively steep, these structures are extremely local in nature and occur after cavern development.

Caverns and related karst features are restricted mainly to
the homoclinal area, with no known caves having been located in the
fault-zone region. The most extensive caves are dissolved in the
Joachim, Rock Levee, Plattin, and Decorah formations of Ordovician age.

Generalized Topography of Perry County

Topographic features. Perry County lies within that physiographic
province known as the Ozark Highlands, the southern boundary of
which extends from Cape Girardeau southwestward through Popular Bluff,
Missouri (Grohskopf, 1955). South of this boundary lies the
Mississippi Embayment or Tertiary Lowlands (Marbut, 1896), an area
of broad alluvial lowlands separated by ridges of resistant rock.

The Ozark uplands of Perry County are characterized by moderate
to well-dissected plains irregularly separated by a series of escarp­
ments. This series of scarps and plains is controlled by the homo­
clinal structure of strata of unequal resistence dipping northeast
and east away from the Ozark Dome. The scarps thus have roughly the
same orientation as the regional strike and all face inward (west­
ward) toward the St. Francois Mountains. The major topographic fea­
tures represented in Perry County are: (1) Crystal (St. Peter--
Joachim) escarpment, (2) Salem platform, (3) Zell platform, (4)
Burlington escarpment, (5) Barton platform, and (6) Baily escarp­
ment and platform (figure 6) (Flint, 1925).

The Crystal (St. Peter--Joachim) escarpment is capped by the
Ordovician St. Peter and Joachim formations (Flint, 1925; Thornbury,
1965; Ray Knox, personal communication). It is quite distinct in
Ste. Genevieve County and counties to the northwest, and Marbut (1896)
Figure 6. Position of major topographic escarpments and platforms in Perry County, Missouri. Abbreviations are defined as: S.P., Salem platform; C.E., Crystal escarpment; Ba.P., Barton platform; Bu.E., Burlington escarpment; Z.P., Zell platform; Bay.E., Baily escarpment; and Bay.P., Baily platform. Hachures indicate the inward (steep) face of the escarpments.

shows this scarp as terminating in northwestern Perry County. Flint (1925), however, described a subdued extension of the Crystal escarpment trending irregularly northwest-southeast to north-south across the western portion of Perry County. Although recognizable, it is not well defined in this area, and its crest is nowhere more than 180 feet above the stream at its base.

The Salem platform, developed on the Gasconade and Roubidoux formations, comprises that area lying west of the Crystal escarpment and constitutes the western one-third of Perry County. Although it cannot be considered rugged topography, it is moderately to well dissected with local reliefs in excess of 200 feet being common (Bretz, 1965).
The Zell platform is defined as the plain lying between the Crystal and Burlington escarpments (Marbut, 1896). This plain constitutes the greater part of Perry County, extending from the northern to the southern boundary and restricted on the west by the Crystal escarpment and on the east by the Burlington escarpment, the Mississippi River, and the Baily escarpment successively from north to south (Flint, 1925). It is characterized by gentle relief produced by moderate dissection of the upland plain. The elevation of the Zell platform is approximately 600 feet at its western border, descending gradually toward the east.

The Burlington escarpment is present only in the extreme northwestern tip of Perry County (Marbut, 1896; Bretz, 1965) where it terminates at the Mississippi River. Its total length in the area is no more than two miles. Within its small extent, however, it is quite distinct, attaining a height of 160 feet which compares similarly with heights of the scarp in other parts of the state. It is capped by the resistant Burlington and Keokuk formations (Thornbury, 1965) which are cherty limestones of Mississippian age. In view of its limited extent, this scarp must be considered as only a minor topographic feature of Perry County.

The area lying between the Burlington escarpment and the Mississippi River is known as the Barton platform (Marbut, 1896). It, too, is only a minor topographic feature since its total area is no more than two square miles. It is terminated on the south and west by the Burlington escarpment, on the east by the Mississippi River, and extends northward into Ste. Genevieve County. Throughout its
limited extent, it is characterized by well-dissected slopes.

The Baily escarpment consists of a distinct and persistent ridge facing southwest and west onto the Zell platform. It is situated approximately nine miles southeast of Perryville, and continues south and southeastward to the vicinity of Cape Girardeau (Flint, 1925). Its height ranges from 100 to 250 feet, the greater heights occurring at its southern extent in Cape Girardeau County. It is continuous except for a gap in the vicinity of Wittenburg. The scarp is held up by the resistant, cherty limestones of the Baily formation (Devonian).

The Baily platform is that plain lying between the Baily escarpment and the Mississippi River. It is deeply dissected by steep-sided valleys and descends eastward at a rate of about 50 feet per mile to the Mississippi River (Flint, 1925). The Baily platform comprises the southeastern one-fourth of Perry County and extends into Cape Girardeau County to the south. To the north, it merges imperceptibly with the Zell platform.

Drainage. The Mississippi River is the master stream controlling the drainage in Perry County and determines the general eastward flow of the major tributary drainage in the area. The four major tributaries are, from north to south: Cinque Hommes Creek, Omete Creek, Brazean Creek, and Apple Creek. Many smaller tributary streams also exist. Not including these lower-order tributaries, the only exception to the general eastward surface drainage is Saline Creek and South Fork Saline Creek in western Perry County. These streams
flow north and northwest out of the county before turning east and joining the Mississippi River. All the principal tributary streams have comparatively well-developed floodplains and alluvial terraces, especially in their lower reaches. The region on the whole is exceedingly well drained.

Karst topography. One of the most conspicuous topographic characteristics of Perry County is its karst terrain (plate II). The southeast Missouri karst plain comprises a twenty-mile wide northwest-southeast trending belt through Ste. Genevieve, Perry, and northern Cape Girardeau Counties. In Perry County it is developed primarily in the Ordovician Joachim, Rock Levee, Plattin, and Decorah formations. This karst terrain is mature and well developed except in extreme southern Perry County and Cape Girardeau County where the variety and abundance of karst features decrease rapidly.

A great variety of karst and related features can be observed in Perry County. Much of the area is covered by a mantle of fine clay, the residue remaining after the solution of limestone. In most cases, this clay is reddish and thus may be referred to as terra rosa. Small, local areas of lapies are frequently found on the crests of ridges and hills where the clay mantle has been removed. To the writer's knowledge, however, no extensive areas of lapies occur in the county.

The most typical expression of karst is the presence of sinkholes, thousands of which occur in Perry County. They range in area from a few square yards to an acre or more, and in depth from
a foot or so to over fifty feet. Both collapse sinks and dolines exist, although the dolines probably comprise a majority of the sinkholes in the area. Most sinks are singular in nature; however, many of those shown as single depressions on the Perryville Quadrangle are actually compound in nature and consist of several small depressions separated by irregular ridges.

Special sink forms also exist. While exploring many of the caves in the county, the writer has observed several well-developed uvalas, solution pans, and ponors.

On the whole, most of the sinkholes are well drained, and although not characteristic of the larger streams, many of the smaller, intermittent streams descend through swallow holes and thus may be classified as sinking creeks. This subsurface flow often resurges along the valley walls of the larger streams, especially Cinque Hommes Creek. In some sinks drainage is hindered or stopped by quantities of fine, insoluble material which is carried into the basin and clogs the outlets. In such cases, sinkhole ponds develop, and these dot the landscape of Perry County.

Sinkhole development in this area is going on irregularly and continuously. Submerged trees and fences can be observed in some depressions; and during the past year, the writer has been called upon to investigate two large, deep collapse-sinks which developed overnight.

Another characteristic feature of well-developed karst is the presence of caves, and Perry County contains a great abundance of these. Based on the latest count, Perry County contained 213 known
caves which ranks it third in the state (Jerry Vineyard, personal communication). The caves range from simple, deep, cave pits to short walk or crawlways to extensive cave-systems having lengths of many miles. For example, Southeast Missouri State Grotto Club has mapped over twelve miles of passage in Crevice Cave, located just north of Perryville (Ray Knox, personal communication); and Little Egypt Student Grotto has over nineteen miles mapped in Mystery Cave, located several miles southeast of Perryville (Ray Knox, personal communication). Based on personal observations and numerous discussions with cavers from Southeast Missouri State University, Southern Illinois University, and St. Louis, it appears that most of the caves in the area can be classified as horizontal in nature, although deep, subterranean pits, shafts, and drops are not totally uncommon features in the larger systems. In addition, the majority of the caves exhibit at least some evidence of joint control.
CHAPTER II
DESCRIPTION OF KLUMP'S CAVE

General Statement

For purposes of description, Klump's Cave may be divided into nine sections: Main Entrance Passage, Secondary Entrance Passage, Meeting Room, Left Fork Passage, Formation Room, Rim Passage, Devil's Crawlway, Right Fork Passage, and the Sewer Passage. All descriptively named points and passages that are mentioned in the text have been marked on the cave map (plate I). A total of eight lithologic units was observed in the cave, and to simplify discussion, these have been assigned descriptive names (figure 7).

Main Entrance Passage

The Main Entrance Passage (figure 8) is a short avenue extending northwest from the primary entrance sink to the Meeting Room. Its total surveyed length is approximately ninety feet. Except for a widened area just inside the entrance, it has a uniform width of fifteen feet, and its maximum height increases from six feet at the entrance to fifteen feet in its middle portion to eighteen feet where it joins the Meeting Room.

The passage is normally dry, although a small, rectangular stream-channel measuring three feet in width and one foot in depth is notched in the floor. This formed from the intermittent flow of water funneled into the cave from the large entrance sink during periods of precipitation.
DENSE LITHOGRAPHIC LIMESTONE
(UPPER LIMESTONE UNIT)

STROMATOLITE ZONE

DENSE CRYSTALLINE DOLOMITE
(UPPER CRYSTALLINE UNIT)

ARGILLACEOUS DOLOMITE
(UPPER ARGILLACEOUS UNIT)

CHERT PEBBLE ZONE

DENSE CRYSTALLINE DOLOMITE
(MIDDLE CRYSTALLINE UNIT)

ARGILLACEOUS DOLOMITE
(LOWER ARGILLACEOUS UNIT)

DENSE CRYSTALLINE DOLOMITE
(LOWER CRYSTALLINE UNIT)

Figure 7. Stratigraphic sequence of lithologic units observed in Klump's Cave. Descriptive names assigned to the units are included in parentheses and will be used throughout this report. Vertical scale is one inch to four feet.

The floor of the passage slopes downward toward the Meeting Room at an angle of twenty degrees, and is strewn with small slab and chip breakdown. The ceiling in this section is smooth with no spalling apparent. It is evident, therefore, that the source of this material is the collapse debris in the base of the entrance sink and material in the immediate entrance area where breakdown has occurred; and that this material has been washed deeper into the cave by fast
Figure 8. Main Entrance Passage looking outward towards the primary entrance sink. Note the relatively steep slope of the floor and the presence of slab and chip breakdown.

running water during periods of intense precipitation.

With the exception of minor amounts of flowstone near the base of the walls, speleothems are absent in this passage. A well-developed stromatolite zone (figure 9) can be observed in the walls. At the entrance, it is located about five feet above the floor but becomes increasingly higher deeper in the cave as the floor slopes downward. In the lower reaches of the passage, a thin, nodular-chert zone appears in the walls approximately nine feet below the stromatolite zone. It is covered by flowstone in most places, but enough exposures are present to indicate it is continuous rather than localized in occurrence. Poorly-developed wall pockets also characterize
the walls through the greater extent of the Main Entrance Passage.

A small offshoot-passage is located in the south wall of the Main Entrance Passage just prior to its intersection with the Meeting Room. The rock floor of the offshoot is at the same level as the main passage, and its original height was eight to ten feet. It is now almost totally filled, and access to open passage is achieved only by climbing a steeply-sloping, six-foot mud bank. Consequently, it gives the false appearance of being upper level. Oriented roughly parallel to the main passage, the total length of explorable void is fifty feet; and except for an initial fifteen feet of stoopway, it is a low, tight crawlway three feet in width and one to two feet in height. Its total length is unknown since low ceiling-heights
prevented further exploration.

The floor of the crawlway is a well-layered silt with minor amounts of sand. After digging down two to three feet, old, faded defacings were found on the walls, indicating relatively recent fill of the passage. It is thought that recent sinkhole development to the south of the primary entrance provided direct access of surface water to this offshoot. As the water drained toward the Meeting Room, its flow was hindered by the narrow constriction near the entrance of the offshoot, causing subsequent back-up and ponding of the water. During these periods of ponding and reduced velocity, the silts and sands were deposited. The well-developed layers, then, record individual episodes of ponding, most likely during periods of heavy precipitation.

Secondary Entrance Passage

The Secondary Entrance Passage is a low crawlway that descends generally westward from the secondary entrance for 172 feet before intersecting with the Right Fork Passage. It has a roughly rectangular cross-section throughout with heights ranging between two and three feet and widths between five and eight feet. The only exception is in its lower reaches where it widens and branches around a fine-clay fill that extends to the ceiling.

The floor is covered with small breakdown except in the branching area where a wet, sticky, reddish-brown clay floor is encountered. The passage is drained by an intermittent stream that descends subsurface via the secondary entrance. Although the stream
undoubtedly washes some collapse material from the ponor into the deeper reaches of the passage, most of the breakdown is probably of passage origin since the ceiling throughout most of its length shows ample evidence of spalling. In many places, large ceiling-slabs and blocks appear ready to fall at the slightest disturbance. Consequently, this is a dangerous passage, and except for surveying and passing observation, it was not studied in detail.

It was noticed that the passage exhibits evidence of joint influence, especially in its upper reaches. In this section the passage descends in a series of three bedrock-steps six inches to a foot in height with flat, smooth, horizontal bedrock between each step. The steps strike N. 30° E. and represent the intersection of joints and minor bedding-planes. They are also evident in the ceiling and are the cause of the intense breakdown. An especially good example of this joint influence is observed roughly fifty feet from the ponor entrance where there is a three-foot vertical bedrock-cliff or drop. Directly above the drop is a distinct joint-trace with an associated joint dome (cavity).

Meeting Room

The Meeting Room is the largest room in Klump's Cave and is divided into three general areas: the main room, a short extension-passage leading to the Right Fork, and a large offshoot-passage extending northwest from the back of the room.

The main room is roughly rectangular in outline and is fifty feet long in a north-south direction, while its east-west dimension
measures approximately twenty feet. Its high ceiling has a uniform height of twenty-five feet. The floor is littered with block, slab, and chip breakdown from the ceiling and walls of the room. Toward the northern end of the room, the bedrock floor descends abruptly into a six-foot deep stream-channel which can be followed into the Right Fork Passage. The small, but well defined, stream-channel notched in the Main Entrance Passage can be traced across the eastern side of the room until it connects with this deeper channel.

The western side of the room is a bedrock partition separating the offshoot passage from the Left Fork Passage. The stromatolite zone recognized in the Main Entrance Passage is easily observable about ten feet up this partition as well as in the other walls of the room. A chert zone can also be observed eight to nine feet below the stromatolite zone.

A well-developed joint-slot is located in the eastern wall of the main room (figure 10). It strikes east-west and is thought to be the trace of a major joint along which the Left Fork Passage was dissolved. Examination of the slot revealed that it is filled with fine, reddish-brown clay to nearly the height of the ceiling.

Spongework is present in the walls and ceiling of much of the room (figure 11). Small amounts of fine clay were also present in some of the spongework pockets, and with the exception of the joint slot, such clay could be found nowhere else in the room.

It appears that this room has resulted from solution at the convergence of several tributary passages, predominantly the Left Fork Passage, the Main Entrance Passage, and the major northwest-
Figure 10. East-west striking joint-slot in the east wall of the Meeting Room. Note the presence of clay fill. Approximate foreground scale is one inch to two feet.

southeast trending offshoot.

At the northeast corner of the main room, the ceiling drops rapidly to a height of eight feet as one enters the short extension-passage that leads southeastward for thirty-five feet to the Right Fork and Secondary Entrance Passages. Its width is approximately fifteen feet and heights gradually lower to five feet at the intersection with the Right Fork.

The floor of its southern half is a mixture of silt, sand (both intermittent-stream deposits), and chip breakdown, while on its northern side the floor descends steeply into the stream channel (figure 12). The channel terminates at the beginning of the Right Fork, but the stream continues on in an underlying passage. A well-
developed stream-channel leading from the Secondary Entrance Passage is notched across the floor, eventually uniting with the deeper channel.

The ceiling of the extension passage has a well-developed joint-dome striking approximately N. 60° W. (figure 13). The joint trace in the cavity is easily observable, and it appears that the offshoot to the rear of the room was dissolved along this joint.

Although speleothems are largely absent, the lower walls are covered with flowstone, and spongework characterizes much of the walls and ceiling.

The offshoot passage extends northwestward for 100 feet from the northwest corner of the main room. Widths decrease gradually from eighteen feet at the entrance to about three feet at the passage extremity. The floor is fine, reddish clay and slopes steadily.
Figure 12. Deep stream-channel along the northern end of the Meeting Room and extension passage. Open access terminates here at its intersection with the Right Fork Passage under which it continues as an underlying passage.

downward toward the main room at an angle of about twenty-five degrees. Consequently, even though the roof maintains a constant level, passage heights decrease from twenty-five feet to less than a foot at the end of the passage. At the base of the clay bank, the floor drops abruptly into the deep stream-channel. Large blocks of breakdown material are present at the base of the clay bank; however, the walls and ceiling of the offshoot show no evidence of instability, and the breakdown appears not to have originated in this area.

The stromatolite zone can be observed a short distance in the offshoot to the point at which it is covered by the clay fill. In
Figure 13. Joint dome and trace in ceiling of extension passage off the Meeting Room. Approximate foreground scale is one inch to three feet.

addition, poorly-formed anastomoses are present in the south wall.

Left Fork Passage

The Left Fork Passage is a major avenue, 473 feet long, extending due west along a fairly straight course from the Meeting Room to the Formation Room. It has an almost monotonous uniformity in character with the exception of the initial twenty feet of extension.

The Left Fork emanates from the southwest corner of the Meeting Room. At this point (and in direct line with the bedrock partition separating this passage from the major offshoot described earlier) the ceiling drops vertically some eighteen feet so that initial heights in the Left Fork are only seven feet. The ceiling remains at
this constant level for the entire length of the passage except in three areas where joint domes occur. Approximately eight feet past the ceiling drop, the floor drops vertically about five feet, resulting in a maximum ceiling height of twelve feet. This maximum height also remains essentially constant through the entire remaining length of passage. From the point of floor drop to the narrow constriction (approximately twenty feet from the passage entrance), the floor is densely littered with huge block and slab breakdown (figure 14). The ceiling and walls of this section are smooth, showing no evidence of instability. The source appears to be a short connecting-passage extending twenty-five feet northeast from this area to the major offshoot from the Meeting Room. Although the original height of this connector was similar to that of the Left Fork, it is now almost completely filled with block and slab breakdown so that the present clearance is only two to three feet. The walls and ceiling are very irregular, blocky, and unstable. One large block which is attached to the ceiling only at one end has a one-inch space between it and the ceiling throughout most of its length. Apparently, then, massive breakdown has occurred in this connector, almost filling it, with some of the debris spilling out into the Left Fork and the major offshoot-passage. This would explain the presence of the breakdown in these two areas.

Other than the occurrence of a natural bridge thirty-five feet from the entrance (figure 15), the remainder of the passage is relatively constant in character. The ceiling is broad and only very slightly arched. The only deviations are the three distinct joint-
Figure 14. Block breakdown near the beginning of the Left Fork Passage.

domes within which the joint traces are readily visible (figure 16). These cavities extend two to three feet into the ceiling and all three strike N. 15° W. Maximum heights and widths in the passage are everywhere about twelve feet.

From the base of the almost flat ceiling, the walls drop vertically and then slope inward until they reach a height of about five feet above the floor, thus forming a vertical constriction similar to the upper half of an hourglass. This "upper hourglass" configuration is typical of the entire avenue with no exceptions. Below the vertical constriction, three different configurations exist: (1) both walls again slope outward until reaching the passage floor, thus giving a true "hourglass" shape to the total cross-section; (2) the "hourglass" cross-section is modified by the right side of the lower half.
extending horizontally into the cave wall, thus producing a right-skewed configuration; and (3) the left side of the lower half extends into the cave wall producing a left-skewed configuration (figure 17).

Both the upper and lower portions of the "hourglass" exhibit ample evidence of phreatic origin: joint ceiling-domes occur as was discussed earlier (figure 16); a natural bridge is located near the entrance to the passage (figure 15); wall pockets can be observed in several different areas in both the upper and lower chambers (figure 18) as can minor bedding-plane anastomoses (figure 19). Abundant popcorn is also present throughout the passage (figure 20).

Vadose influence can only be found in the lower chamber of the "hourglass." This is seen in the occurrence of distinct incised
Figure 16. Joint ceiling-dome striking N. 15° W. across the Left Fork Passage. Approximate foreground scale is one inch to three feet.

wall-meanders which constitute the right and left-skewed configurations illustrated in figure 17.

It should also be noted that at several locations in the Left Fork, clay banks extend across the passage at the level of the vertical constriction, with the area above and below the clay being open (diagram C of figure 17).

As will be discussed in detail in a later section, the Left Fork is interpreted as being of a phreatic origin with secondary vadose modification occurring in the lower "hourglass" portion. The "hourglass" configuration so typical of this passage (and almost the entire cave) appears to be the result of differential resistences of the rock units to solution. The widened portions of the "hourglass" occur
Figure 17. Three cross-sections typical of the Left Fork Passage. (A) True "hourglass" configuration. (B) "Hourglass" cross-section with right-skewed configuration. (C) "Hourglass" cross-section with left-skewed configuration. Diagram A includes the stratigraphic position of the passage in relation to the rock units observed in the Klump's Cave system. Diagram C illustrates the extension of clay fill across the constriction as observed at several different locations; this extension also occurs in association with the other two cross-section types. Scale is one inch to five feet.
in association with beds of argillaceous dolomite, while the vertical constriction is in a bed of dense, crystalline dolomite (figure 17). The vertical development of the passage appears to have been affected by the presence of units of dense, crystalline dolomite which, in association with the middle "constriction" unit, bracket the argillaceous units and thus aided in the horizontal widening in these less resistant beds.

As would be expected, the natural bridge near the entrance to the Left Fork is actually an extension of the middle crystalline unit. In addition, the bedrock floor of the Meeting Room is also composed of this unit.

An intermittent stream drains the entire length of the Left Fork Passage, flowing eastward toward the Meeting Room. It continues
beneath the room in an underlying passage dissolved in the lower argillaceous unit before turning sharply northwestward and finally joining the deep stream-channel at the base of the major offshoot. Meanders in the stream generally coincide with the incised wall-meanders.

Detrital sediments in this section are limited mainly to a fine, reddish-brown clay mantle on the inward sloping walls of the upper "hourglass" chamber. These clay banks are of considerable thickness, ranging between one and two feet, and in some areas this mantle extends entirely across the passage at the general level of the constriction. Some stream gravels can be observed on the floor of the cave, usually on the inward side of the meanders.

Thirty-five feet from the terminus of the Left Fork an upper-
level offshoot-passage extends due south for an explorable distance of twenty feet. Widths gradually taper from ten to five feet, and heights lower from an initial two feet to less than a foot, thus preventing further exploration. Although actually a passage, this offshoot has been named the Spaghetti Room due to the great abundance of soda straws which almost completely cover the ceiling (figure 21).

With the exception of the Spaghetti Room, speleothems are comparatively rare in the Left Fork. Flowstone can be observed along the lower walls in a few areas; and at the terminus, poorly-developed stalactites occur in association with three small columns superimposed on a stalagmitic dome (figure 22).

The stromatolite zone which was traced from the primary cave entrance into the Meeting Room is not found in the Left Fork. On
Figure 21. Spaghetti Room, located thirty-five feet from the terminus of the Left Fork Passage. Note the abundance of soda straws and young stalagmites and columns. Maximum vertical distance is approximately two feet.

The rear (west) partition of the Meeting Room, it was located ten feet above the floor or three feet above the entrance to the Left Fork. It is thought, then, that this avenue is dissolved some three feet below the zone (figure 17), especially in light of the fact that it is present in the Formation Room where ceiling heights increase. The chert zone which is positioned about eight feet below the stromatolite zone was also not observed. It is probable that this zone does occur since it, too, is present in the Formation Room, but that it is hidden by the clay mantling the side slopes of the passage (figure 17).

Closely-spaced vertical grooves line the upper walls of the
Figure 22. Poorly-developed stalactites and columns superimposed on a stalagmitic dome at the terminus of the Left Fork Passage.

Left Fork Passage (figure 23). The writer has personally explored a relatively large number of Missouri caves but has never observed such features before. At the writer's suggestion, they were examined by several experienced cavers who also indicated that they had never before observed these phenomena. A search of the caving literature revealed no description or mention of vertically oriented wall-grooves, although Bretz (1956) described horizontal grooves as evidence of vadose flow. Therefore, to the writer's knowledge, vertical grooving appears distinctive to Klump's Cave. It should be noted, however, that the grooves are relatively small and shallow and thus blend in with the cave wall; in other words, they are not very obvious. It is probable that vertical grooving exists in other caves but were overlooked during exploration and mapping, or that such
small, seemingly minor features were viewed as unimportant and not
reported (it will be remembered that although a large number of
Missouri caves have been explored and mapped, usually by non­
scientists, comparatively few have been scientifically studied in
detail by trained personnel). Regardless of the reasons, it pres­
tently appears that this paper is the first to report their occur­
rence, and consequently, they are described in detail below.

The grooves line the upper portion of both walls of the Left
Fork Passage. They are also present in two other avenues of the cave: the Rim and the Right Fork Passage, both of which extend generally
northward from the Left Fork. However, as one progresses away from
the Left Fork in these two passages, the grooves decrease in num­
ber until they are no longer observed. Thus, they seem to be

Figure 23. Vertical grooves in the upper
wall of the Left Fork Passage.
localized in the general vicinity of the Left Fork.

The grooves are very closely spaced, and an estimated eighty-five to ninety-five percent are vertically oriented—only a few are oriented diagonally (figure 23). Where intersections do occur, the grooves usually cross each other without interruption which would seemingly eliminate the possibility that they are erosion channels produced by water drainage down the walls.

The grooves are relatively small, on the average measuring one-fourth to one-half inch in width and one-fourth inch in depth. In cross section, they are V-shaped, their width tapering inward with depth.

Of particular interest is the vertical distribution of the grooves. Their upward extension is abruptly terminated at a horizontal solution-groove along a minor bedding plane within the upper argillaceous unit. This is true for an estimated ninety-five percent of the grooves, with only a very few extending a short distance (few inches) above this line. They extend downward approximately two to three feet until lost beneath the clay mantle. Inspection of the lower chamber of the "hourglass" revealed the presence of identical grooves, all of which were wholly contained in the argillaceous unit. Thus, the grooves are limited to the two argillaceous units.

Again with reference to the more easily studied upper chamber, the majority of the grooves are continuous; however, some terminate before reaching the clay bank, and others are contained wholly within the central portion of the "groove zone." Almost all extend in a straight line with very few exhibiting any type of curvature.
At present no definite explanation of the wall grooves can be presented by this writer or any of his colleagues. Speculatively, their restricted horizontal distribution in units that can be traced throughout most of the cave might indicate that they are secondary rather than primary features. The fact that they are limited to only the argillaceous units might suggest that the different lithology of these units (as compared to the dense, crystalline dolomite units) caused them to be less competent, and that the grooves are a result of differential solution along closely spaced, minor fractures. If this is the case, the question still remains as to what caused the fracturing forces: a slight, localized flexure of the rock units followed by rebound back to their original attitude, volume alterations, load pressure?

The occurrence of the wall grooves presents an interesting and challenging problem, and definite conclusions can only be made following a detailed, concentrated study of these features.

Formation Room

The Formation Room is a large room with massive speleothems and is one of the most beautiful areas in the cave. Its description is made somewhat difficult due to its complexity—no less than six passages radiate from it. There is no true wall at the northern end; rather, it is composed of two passages separated by a thin bedrock partition: the Rim Passage and a short offshoot passage. The Left Fork intersects the room at the northern end of the east wall; short southward trending offshoots emanate from the southeast and southwest
corners of the room; and a comparatively long crawlway extends westward from the southwest corner.

The room is roughly rectangular in outline with its long dimension oriented north-south and measuring sixty-five feet, while its width ranges from thirty feet at the northern end to twenty feet at the southern extremity. The room has a maximum height of sixteen feet in that area between the Left Fork and Rim Passage where the floor is at the same level as the vertical constriction in the passages. Both northward and southward from this area, the floor slopes steeply upward in clay banks, causing ceiling heights to decrease to eight feet and five feet at the northern and southern ends of the room, respectively.

The northern offshoot extends northeast for forty feet with a fairly constant width of six to eight feet. It has a reddish-clay floor which slopes steeply upward from the Formation Room until finally reaching the passage ceiling. Thus, heights in this offshoot gradually decrease from eight feet at the entrance to less than a foot at the end. Total depth of the clay is unknown.

The room everywhere has a clay floor, and as mentioned previously, south of the area of maximum height, this clay floor slopes steeply upward before leveling off approximately five feet from the ceiling. Thus, the floor of the entire southern two-thirds of the room is composed of this large clay-bank. Although exposed in several places, the clay is largely covered by a thin layer of flowstone, and at the top of the bank in the leveled area, rimstone dams and rimstone pools are well developed (figure 24).
In the immediate vicinity of the rimstone dams, massive, multi-colored speleothems also occur. Many varieties are present and include stalactites, stalagmites, columns (figure 25), stalagmitic columns (figure 26), and curtains (figure 27). In addition, the ceiling is characterized by numerous small stalactites. Traces of minor joints are visible in the ceiling with two orientations dominating: N. 15° W. and N. 60° W. In many cases, the stalactites are developed in straight lines along these joints (figure 28), a result of increased water seepage.

The offshoot at the southeast corner is a three-foot wide crawlway extending southward for a total explorable distance of only twelve feet. The again upward sloping clay floor causes heights to change from an initial three feet to less than a foot. The depth
of the clay at this location is also unknown.

In the southwest corner, another offshoot curves toward the southwest. Other than its orientation, the only significant difference between it and the one just described is that the clay floor slopes upward at a lesser angle, allowing penetration for a distance of about thirty feet.

In this same southwest corner, another offshoot extends due west for an explorable distance of fifty feet. It consists of a low, narrow crawlway one and a half to two feet in height and two feet in width. It, too, has a clay floor which eventually reaches the ceiling.

Like the Meeting Room, the Formation Room represents an area of increased lateral solution due to the convergence of several
Figure 26. Stalagmitic column in association with stalactites and stalagmites in the Formation Room.

tributary passages at this point.

The stromatolite zone observed in the upper reaches of the cave reappears again in this room (figure 29). The zone is located approximately ten feet above the floor at the area of maximum height, and can be traced continuously along the walls until covered by the clay banks. The chert zone was also observed some eight feet below the stromatolite zone except in areas where hidden by the clay banks.

A small stream-channel is notched in the floor of the room connecting the Left Fork and Rim Passages; however, it only carries water during periods of intense precipitation. The main cave stream flows in an underlying passage connecting the above two avenues. The walls and ceiling of this low (four feet) connector are composed of clay, with only the floor resting on the lower crystalline unit that
comprises the floor in the Left Fork Passage (and most other areas in the cave as well). It therefore seems likely that the entire Formation Room, the northeast offshoot, and possibly the smaller offshoots at the southern end are all dissolved downward to this unit which would, consequently, also represent the base of the clay fill in these areas. In addition, evidence indicates that the fill once extended to the ceiling of the room: small quantities of clay were found in several of the wall and ceiling pockets, and a stalactiflat-like feature is located near the southern wall approximately one to two feet from the ceiling (figure 30).

The clay was (and is) removed by vadose stream flow passing from the Rim Passage, through the Formation Room, and into the Left Fork Passage. Flushing should be most efficient in the immediate
Figure 28. Small stalactites developed along a minor joint in the ceiling of the Formation Room. The stalactites in the foreground are about two inches in length.

area of stream flow and progressively decrease in effectiveness as distance from the stream channel increases. Thus, areas comparatively far removed from the normal stream flow would experience vadose clay-removal only during periods of cave flooding. This explains why ceiling heights (clay removal) are greatest in that area of the room between the Rim and Left Fork and then progressively decrease away from this area until finally reaching the ceiling in the offshoots. At sometime during the flushing process, the stream undercut through the clay and now flows in a passage under the clay fill.

Also of interest is the presence of abundant speleothems and flowstone at the southern end of the room atop the clay bank.
Convexity of the rimstone dams indicate that water flow is from south to north down the clay bank. There are no streams entering from the southern end of the room, and the source of the water producing the dams and flowstone was, until recently, unknown. It was thought that the only possible source was seepage from the ceiling; however, as observed on all previous trips, ceiling seepage was not significant enough to produce the well-developed dams and flowstone covering. It should be noted, however, that all previous trips were conducted during times of fairly dry weather.

On the possibility that significant seepage might occur during rainy periods, a special trip was made (contrary to safe caving procedures) during a period of relatively heavy precipitation. During this trip, significant seepage was indeed observed. In fact, the
term "seepage" does not convey the actual situation. Great, continuous streams and cascades of water emanated from the ceiling fractures and around the speleothems. This resulted in large-scale flow down the bank and eventually into the Left Fork stream channel. Several trips under similar conditions have been made since then, and the same situation occurred each time. It is evident, therefore, that the flowstone has developed over the clay floor during periods of precipitation. Such ceiling seepage would also explain the presence of the massive speleothems in this section of the cave.

It can be noted in plate II that a large solution-sink occurs over the Formation Room. This sink is thought to be the cause of the intense seepage. During times of precipitation, the sink

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Figure 30. Stalactiflat-like feature one to two feet below the ceiling in the Formation Room.
funnels water directly downward toward the room. It is this funneling action that causes the intense ceiling-flow here but not in most other areas of the cave (one similar situation exists in the Right Fork Passage). It is not presently known, however, how far above the ceiling the actual base of the sink lies.

Rim Passage

At the entrance to the Rim Passage, the clay floor of the Formation Room slopes steeply downward until reaching the lower crystalline unit about five feet below the floor of the room. At this point the ceiling also drops vertically some eleven feet so that maximum height just inside the entrance of the Rim is ten feet.

From its entrance the passage extends northeastward for 140 feet before branching into two leads: the left lead which is still referred to as part of the Rim Passage, and the right lead which is called Devil's Crawlway.

From the entrance to the fork, the Rim is very similar to the Left Fork. The ceiling is broad and almost flat with the only exception being a distinct joint ceiling-dome striking N. 60° W. about sixty-five feet down the passage. Maximum height is everywhere about ten feet, and widths range between eight and twelve feet, the southern extension of the passage generally characterized by the greater widths.

In cross section, the "true hourglass" configuration is again observed in this section. Phreatic features characterize both portions of the hourglass: the joint dome mentioned previously, wall and ceiling pockets, and minor bedding-plane anastomoses. Popcorn
is abundant along the lower portion of the walls. The same rock units and their relationship to the passage void can also be observed; thus, the interpretation applied to the Left Fork also applies here. The only difference is the absence of the upper crystalline unit which comprises the roof in the Left Fork. In the Rim Passage, the ceiling and walls of the upper chamber are dissolved wholly in the upper argillaceous unit. Absence of the upper crystalline unit can be explained by noting the difference in passage height between this section of the Rim (ten feet) and the Left Fork (twelve feet). This change was accomplished at the expense of the ceiling (two feet lower in the Rim), which would put the upper crystalline unit about two feet above the roof (figure 31). This conclusion was verified in Devil's Crawlway where the ceiling level rises and the upper crystalline unit reappears as expected.

Just before the fork in the Rim Passage, two short offshoots emanate from the east wall. One extends northeastward for twenty feet, and the other trends southeastward for thirty feet; both have constant widths of five to six feet. Both have clay floors which slope upward from the main passage until reaching their ceilings at the extremities. Total depth of the clay fill is unknown, although based on previous observations in areas of the cave already discussed, it is thought that the fill probably extends downward to the level of the lower crystalline unit which has represented the floor of the cave up to this point. These two offshoots appear to have developed along major joints striking approximately N. 30° E. and N. 15° W., both of which have been mentioned previously and are
Figure 31. Typical cross-section and stratigraphic position of the main Rim Passage. Vertical and horizontal scale is one inch to four feet.

expressed in joint domes elsewhere in the cave.

This section of Rim Passage is comparatively barren of speleothems. Some small, poorly-developed stalactites and stalagmites exist, and relatively rare serrated-stalactites are present in the joint dome mentioned earlier (figure 32).

At the fork, the Rim Passage turns and takes a meandering course toward the northwest, eventually connecting with a small room. The total length of this section is 175 feet with a constant width of
Figure 32. Serrated stalactites in a joint ceiling-dome in the Rim Passage. Approximate foreground scale is one inch to one foot.

five feet. At its entrance the ceiling drops vertically some seven feet, resulting in initial passage height of only three feet, and throughout most of this section, heights range from less than a foot to two feet. After roughly eighty feet of initial penetration, low ceiling-height prevented further exploration; however, the upper reaches of this section can be entered from a small room via Devil's Crawlway. Visual connection was made between the two explorable sections revealing a straight passage with ceiling heights of about eight inches. Unfortunately, low heights also prevented further northward exploration of the Rim Passage.

The floor of the left lead rests on the lower crystalline unit, while the remainder of the chamber throughout the entire extension of this section of the Rim is contained in the lower argillaceous
Figure 33. Typical cross-section and stratigraphic position of the left lead of the Rim Passage. Vertical and horizontal scale is one inch to four feet.

unit (figure 33). In cross section, the passage is oval in appearance.

A series of five large rimstone-dams and pools characterize the initial fifty feet of length, and a joint ceiling-dome, striking N. 29° W., is located just inside the entrance.

Devil's Crawlway

The right lead at the fork in the Rim Passage is called Devil's Crawlway (figure 34). It is a long, torturous crawlway extending in
Figure 34. Portion of Devil's Crawlway.

a broad, northwest-curved orientation for a total distance of 140 feet where it connects with a small room. The ceiling level, where it intersects with the Rim Passage, rises vertically two feet and then maintains this constant level. The upper crystalline unit re-appears due to this increase and is the roof rock throughout the passage (figure 35).

The floor is composed of sticky, reddish-brown clay and slopes gradually upward from the Rim Passage for a distance of eighteen feet before leveling off two feet from the ceiling. Thus, ceiling heights decrease rapidly from an initial ten feet to two feet. The latter value is constant through the remaining section. Passage widths are fairly uniform, ranging between four and five feet.

Depth of the fill is unknown, but again it is suspected that the clay continues downward to the lower crystalline unit (about
Figure 35. Typical cross-section and stratigraphic position of Devil's Crawlway. Vertical and horizontal scale is one inch to four feet.

twelve feet from the ceiling).

A distinct joint ceiling-dome and joint wall-slots occur at the ninety-foot mark. The dome extends three feet into the roof, and the slots increase the passage width to ten feet. The joint trace is easily visible in the dome, and it strikes N. 30° E.

The only significant speleothems occur just prior to the intersection with the small room. Here, stalactites, stalagmites, and columns almost choke off the passage. In addition, popcorn is developed along the walls in several areas.

Where Devil's Crawlway connects with the small room at its
extremity, the floor drops vertically five feet to the bedrock floor of the room. The room is roughly rectangular in outline, its long dimension being oriented northeast-southwest and measuring thirty-five feet; widths are everywhere about ten feet.

A shallow pool occupies the northeast end of the room. Five feet above the floor in the northwest wall, another crawlway, identical to Devil's Crawlway, emanates. It was penetrated for thirty feet before a speleothem choke was encountered, preventing additional exploration. At the southwest end of the room, the floor descends steeply about five feet and here connects with the upper reaches of the Rim Passage.

The room again represents the sequence of rock units first observed in the Left Fork. The roof is composed of the upper crystalline unit, and the room itself is dissolved mainly in the upper argillaceous unit with the middle crystalline unit comprising the floor. At the southwest end of the room, the Rim Passage, developed in the lower argillaceous unit and resting on the lower crystalline unit, lies some five feet below the room floor.

Devil's Crawlway, the small room at its extremity, and the short offshoot emanating from the room all contain evidence of phreatic origin. This evidence includes a joint ceiling-cavity, distinct joint wall-slots, abundant wall-pockets (especially in Devil's Crawlway), spongework in the walls and roof of the room, and minor bedding-plane anastomoses in the room.

Fills in the Rim Passage and Devil's Crawlway are limited mainly to the reddish-brown clay so prevalent throughout the system. One
to two feet of it covers the inward sloping walls in that section between the Formation Room and the fork. In one area a few feet down the Rim Passage, this clay fill extends across the chamber at the level of the vertical constriction, forming a large block under which the stream flows.

Clay also fills the two offshoots just prior to the fork as well as Devil's Crawlway. Some gravel litters the small stream-channel through the Rim Passage, and minor amounts of gravel and sand are also present in the small room and Devil's Crawlway.

The intermittent stream flows down the Rim Passage until eventually turning into the Left Fork. It has completely removed all fill from the low, narrow section of the Rim, but has been less successful in the larger section between the fork and the Formation Room, its effects virtually bypassing the two offshoots.

It is thought that flow down Devil's Crawlway only occurs during periods of heavy precipitation. During these times, the extremely low section of the Rim Passage (that through which only a visual connection could be made) would be unable to accommodate a heavy influx of water. Thus, it would back up into the small room and eventually spill over into Devil's Crawlway. In this way, the water bypasses the constriction and flows into the larger portions of the Rim Passage. This would account for the minor amounts of stream gravel and sand in the room and Devil's Crawlway. In addition, no other source for the pooled water in the room is present.

How frequently such flooding occurs is unknown; however, considering the extremely small cross-sectional area in the low-ceiling
section of the Rim, the writer feels that influx from a typical summer
thunderstorm of moderate intensity might be enough to cause the over­
flow. The writer has made numerous trips into Klump's Cave, and on
those taken a day or two after even a moderate storm, Devil's Crawlway
has been very wet and muddy, and in some areas of the crawl, pooled
water has even been observed. On the other hand, the crawl has
been relatively dry on trips preceded by a week or so of fair weather
or only light precipitation. Regardless of the frequency of flow,
it is evident that the clay fill is definitely being removed from
Devil's Crawlway.

The stromatolite zone was not observed in either the Rim Passage
or Devil's Crawlway. It was located ten feet above the floor in the
Formation Room; however, both of the above passages lie below this
level, and it appears that a situation exists analogous to that in
the Left Fork: that these passages are dissolved three to five feet
(depending on location) below the zone (figures 31 and 35). Unlike
the Left Fork, the chert zone recognized in the Meeting Room and
Formation Room was observed three feet below the ceiling at two lo­
cations in the Rim Passage where the clay mantle was absent.

Right Fork Passage

The Right Fork Passage is the longest continuous avenue in
Klump's Cave. It extends generally northwestward and northeast­
ward from the extension passage of the Meeting Room for a total dis­
tance in excess of 2100 feet where it connects with the Sewer Passage.

With reference to passage heights, the Right Fork can be divided
into three sections, each having distinct characteristics. At the entrance to the Right Fork, the floor descends vertically five feet to the level of the lower crystalline unit. This results in a maximum height of twelve feet, this value remaining fairly constant for approximately the first 625 feet of extension (to that point roughly 225 feet past the Jungle Room where the long east-west oriented section of passage begins). Walk heights, however, range between six and seven feet in those areas where clay extends across the passage at the level of the vertical constriction.

Heights increase significantly in that section between the beginning of the long east-west oriented avenue and Needle's Eye. Here, maximum heights range between fourteen and eighteen feet. This increase is mostly at the expense of the ceiling which is dissolved upwards an additional one to seven feet as compared to previously described areas of the cave. The greater upward extensions occur in the central portion of this section, gradually lowering as the two ends are approached. Due to clay extension across the passage in several areas (some of which are rather extensive), walk heights in these areas range between four and twelve feet, with nine to ten feet being most common.

From Needle's Eye to the terminus of the Right Fork, heights again return to that typically observed in most of Klump's Cave. Maximum height is eleven feet except where clay extensions occur—these points values of four to six feet occur. This decrease, as indicated earlier, is mainly at the expense of the ceiling which descends in the vicinity of Needle's Eye. The only significant
exception to the above is in the last forty-five feet of passage length (that section which turns sharply northwestward) where high, eighteen-foot ceilings reoccur.

Passage widths are, for the most part, constant throughout the Right Fork Passage, ranging between eight and twelve feet, with ten feet being most typical. There are only four major exceptions. Just past the Jungle Room the passage forks, with the left branch being the main cave passage. Widths here are comparatively narrow, ranging between four and five feet. An almost identical situation occurs at the Turnpike except that the right branch is defined as the main passage. Two areas of exceptionally wide passage exist roughly sixty feet past the beginning of the long, east-west oriented section and immediately past the Turnpike where the two passages reunite. From a map view, each of these areas appears to consist of two distinct passages. Actually, these are a single avenue with a width of twenty to twenty-five feet. The false impression is due to clay fill which extends to the ceiling in the central portion, with void on each side.

In cross section, the "hourglass" configuration characterizes the entire Right Fork Passage. Not only does the true "hourglass" shape exist, but the presence of numerous incised wall-meanders causes the frequent occurrence of the right and left-skewed modifications as well. A great abundance of phreatic features characterizes both chambers of the "hourglass" from the beginning to the end of this avenue. Two joint ceiling-cavities with associated wall-slots occur in the initial and central portions of the passage, their
strikes being east-west and N. 15° W., respectively. Wall and ceiling pockets are common; and although observed less frequently, minor bedding and joint-plane anastomoses exist in a few areas. A natural bridge is located approximately 205 feet from the passage entrance, and as would be expected, it joins the middle crystalline unit.

Vadose features can also be observed superimposed on the phreatic chamber. Very common is the presence of incised wall-meanders. As in other parts of the cave, they are generally located low in the passage walls at or near the present floor level. In addition, horizontal wall-grooves were observed in two areas near the passage terminus and in the middle portion. Although distinct, they were limited in extension and were positioned just above the cave floor. Also, a small stream-channel is notched into the floor of that area between the long, east-west oriented section and Needle's Eye. Lastly, the best developed ceiling-channel the writer has ever observed (either in person or in photograph) is found in this avenue of Klump's Cave (figure 36). It can be traced continuously from Needle's Eye to the high-ceiling section at the passage terminus, and its course is characterized by both straight and meandering portions. Near the passage terminus, the channel cuts four feet into the ceiling; midway between the terminus and Needle's Eye, it extends only one and a half feet into the roof; and it continues to progressively decrease in size and depth until, at Needle's Eye, it is only a very faint ceiling-indentation. It cannot be recognized anywhere on the entrance side of Needle's Eye. This channel significantly relates to the cave hydrology and will be discussed in detail in that chapter.
Figure 36. Ceiling channel in the Right Fork Passage between Needle's Eye and the passage terminus. Width of the channel in the foreground is approximately four feet.

of this report.

The same rock units involved in the development of passages previously discussed can be traced throughout the Right Fork. The only significant difference is the amount (vertically) of the upper and lower crystalline units that is exposed and the presence of an additional unit (a lithographic limestone) in the two high-ceiling portions of the passage. Although not previously mentioned, this unit was identified in two other localized areas of the cave: the Meeting Room and the Formation Room, both of which contain high ceilings. This is the only instance, however, where the limestone is involved in passage development. In the Left Fork, the contact between the upper crystalline and the upper argillaceous units is
at approximately the level of the ceiling, and that separating the lower crystalline and lower argillaceous units is at approximately the level of the floor, a difference of about eleven or twelve feet. This same relationship was generally maintained through the first 625 feet of the Right Fork (figure 37). Between that point and Needle's Eye, however, increased upward solution exposed the entire upper crystalline unit (four feet in thickness) and up to one and a half feet of the overlying dense, lithographic limestone (figure 38).
In addition, vadose downcutting has exposed an additional one to two feet of the lower crystalline unit. This is also true for the high-ceiling section at the terminus with the exception of the downcutting into the lower unit.

In the area of passage between Needle's Eye and the high-ceiling terminus, the upper crystalline unit is not exposed, but rather is situated about one foot above the roof as can be observed in the higher-ceiling sections just prior to the entrance and just after
the exit from this lower-ceiling area.

In addition to those mentioned earlier, the only other major nondepositional feature exhibited in the Right Fork is a fifteen-foot pit located about 240 feet past the Jungle Room (figure 39).

The stromatolite zone was observed continuously in the high-ceiling sections of the Right Fork (figure 38). The lower sections appear to be dissolved three to four feet below this zone, similar to that in the Left Fork and Rim Passages (figure 37). The chert zone is also present in the walls at several different locations where the clay banks have been removed (for example, that area along the left wall just beyond the natural bridge). In these areas, the eight-foot vertical separation of the chert zone below the stromatolite zone is maintained. It thus appears evident that these two zones are definitely continuous throughout the system; however, observations of them are limited to those areas of increased ceiling height and the absence of the clay mantle along the walls.

Fills are limited almost exclusively to sticky, reddish-brown clay. With only a few exceptions, it mantles most of the vertical extent of the walls in the upper chamber of the "hourglass." As in other parts of the system, it frequently extends across the cave passage at the general level of the vertical constriction, dividing the two open chambers of the "hourglass." This clay divide is often developed for rather extensive lengths, especially in the central portion of the passage. The thickness of the clay divide is variable. In some places it is at least several feet thick, but in others it is less than a foot and a half. In one section approximately
Figure 39. Deep (15 feet) pit located about 640 feet from the entrance to the Right Fork Passage.

seventy-five feet past the natural bridge, the divide is so thin that a portion of it collapsed into the lower chamber under the weight of the writer and his assistants. As mentioned earlier, in two separate locations in this avenue, the clay extends to the ceiling in the central portion of the passage but not to either side. Apparently, the vadose flushing-process removed the clay from the sides in the upper portion of the chamber, but then became concentrated on one side where removal to the bedrock floor was achieved. The only other occurrences of the clay extending completely down to the cave floor are in the offshoots which will be discussed separately. Small amounts of clay can also be found in the ceiling pockets all along the Right Fork, indicating that this avenue was once completely filled.
Figure 40. Slab and block breakdown in the initial reaches of the Right Fork Passage. Approximate foreground scale is one inch to two feet.

The lower chamber of the "hourglass" is comparatively barren of sediment with the exception of minor amounts of stream gravel generally limited to the stream channel at meander points.

Some breakdown is also present, especially in the initial twenty-five feet of passage where intense slab and block material densely litters the floor (figure 40). The ceiling and walls in this area are very irregular and seem to be the source of the debris.

The only other area of significant breakdown is at Needle's Eye. A large, rectangular block measuring fifteen by eight by four feet has broken from the roof and become embedded edgewise in the clay fill. Passage can only be accomplished by squeezing between the block and the wall (a width of about fifteen inches), and hence the
name "Needle's Eye" (figure 41).

A large variety of speleothems exists in the Right Fork Passage but most are comparatively small and poorly developed (figure 42). The Jungle Room (figure 43) is the only area where massive dripstone formations occur. Not actually a room, the Jungle is a forty-foot section of passage (located about 400 feet from the entrance) almost completely choked with large columns (most of which are stalagmitic in nature), stalactites, stalagmites, and curtains. Their abundance is so great that one must literally pretzel himself in and around the formations to negotiate this section. The size, density, and multicolored appearance of the speleothems make the Jungle Room the most beautiful area in Klump's Cave.

Cause of the localization of massive dripstone formations to
Figure 42. Small stalactites and stalagmites in the Right Fork Passage with popcorn and flowstone along the lower wall. Small stalactites in the immediate foreground are approximately two inches long.

This small area of the Right Fork appears analogous to the situation in the Formation Room in that a large doline is positioned directly above the room (plate II).

Six offshoots emanate from the Right Fork. Just past the Jungle Room, the passage branches but then rejoins after a short distance. The left lead is completely open with no fill present and is, therefore, defined as the major passage. The right lead, defined as the offshoot, has a similar width but contains a clay fill. At its entrance the fill slopes steeply upward until leveling off approximately two feet from the roof, sloping downward again to the level of the main passage at its exit. Depth of the fill is not known, but it seems likely that it extends down to the level of the...
lower crystalline unit which represents the floor in most areas of the cave. The roof of the offshoot is the upper crystalline unit, while the open void is dissolved in the upper argillaceous unit. It seems likely that flushing processes initially removed the clay from both leads; but after vadose flow became well established, it took the more direct left-lead, resulting in the total removal of fill from that avenue. Flushing of the right lead is accomplished now only during periods of very heavy precipitation which causes a back-up and flooding of the Right Fork Passage.

The second offshoot occurs at the Turnpike. The order is reversed here with the right lead being the direct stream-passage and the left lead the upper level, clay-filled offshoot. In all other respects, this situation is identical to that just discussed except
that a clay divide extends across the main passage. Wall and ceiling pockets are abundant in the offshoots, and minor amounts of reddish-brown clay were found in many of these, indicating complete filling at some time during the history of the cave.

The third offshoot is located on the north wall of the main avenue about twenty-five feet east of Needle's Eye. It is a small crawlway two to three feet wide and one to two feet high. It is developed at the floor level of the main passage and dissolved within the lower argillaceous unit. Penetration is possible only for a distance of eight feet at which point ceiling heights become too low for further exploration. It is completely barren, lacking any fill or speleothems.

The fourth offshoot extends generally eastward at that point near the terminus of the Right Fork where the passage makes a sharp bend to the northwest. It has a uniform width of nine feet; however, heights gradually decrease from eight feet to less than a foot at its terminus due to its clay floor which slopes upward from the main passage. The low heights prevented further exploration after a surveyed distance of thirty feet. Entrance to the offshoot can be gained only from the upper chamber of the main passage as the east wall of the lower chamber is solid bedrock. It is evident, therefore, that the offshoot is dissolved primarily in the upper argillaceous unit with some development into the upper crystalline unit. Although mostly covered with clay, it can be observed at the entrance that the floor of the offshoot corresponds with the middle crystalline unit. Other than the stromatolite zone which can be

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traced along the walls until hidden by the fill, the only significant features present are minor bedding-plane anastomoses and wall and ceiling pockets. Primary vadose flow has bypassed this offshoot, and this explains the presence of clay fill which deepens as distance from the main passage increases.

At the end of the Right Fork, the passage branches into three separate leads: the right lead is referred to as the Sewer Passage and will be treated in the upcoming section; the center and left leads are defined as offshoots, and due to their similarity, they will be discussed together. Both trend toward the northwest with constant widths of five feet. For the most part, vadose flow has bypassed these offshoots; thus, clay banks slope upward into the leads from the main passage, and passage heights gradually diminish from nine feet to less than a foot. Consequently, total surveyed lengths are only sixty-three and thirty-two feet for the left and center lead, respectively. Both are dissolved mainly in the upper argillaceous unit and the upper crystalline unit. The floors of these leads, and therefore the depth of clay fill, is unknown. It seems likely that the floor is formed by either the lower crystalline unit as in most areas of the cave or the center crystalline unit as is the case in the fourth offshoot previously discussed. Again the only noteworthy features are the occurrence of wall and ceiling pockets and anastomoses.

Sewer Passage

The Sewer Passage is the last major avenue in Klump's Cave.
It extends northwestward and northeastward for a total distance of 220 feet from the lower chamber at the end of the Right Fork to shortly past the terminal siphon. It has a fairly constant width of five feet except at its entrance where one must squeeze through an opening only fifteen inches wide, the small room near its terminus where widths increase to ten feet, and the short extension past the room where widths decrease to about two feet. With the exception of a four-foot height in the small room, a height of two feet characterizes the passage throughout.

The Sewer has a flat floor developed in the lower crystalline unit and a flat ceiling dissolved in the lower argillaceous unit (figure 44). No fills of any type are present except in the small room where the floor is covered by a layer of mixed silt and clay.

The passage is comparatively void of features and formations. A few phreatic features do occur and include bedding-plane anastomoses, wall and ceiling pockets, and the network pattern of passage orientation. Vadose horizontal-grooves can also be observed at several locations. The only speleothems present are two small rimstone-dams located about 140 feet from the entrance. This again suggests an initial phreatic origin followed at a later time by the superimposition of vadose characteristics.

Moderate precipitation occurred the day before this passage was explored and surveyed. At that time significant flow was observed, with the stream covering the entire passage floor to a depth of one foot. By the time the small room was reached, however, all flow had ceased. The pooled water here and in the extension.
passage beyond was stagnated with a dense, three-inch mat of floating debris (leaves, grass, twigs, etc.). Backtracking, the cause of the change in flow character was found to be a very small siphon about seven feet from the room in the west wall at the level of the floor. It is roughly circular in outline with an estimated (since it was below water level) diameter of about ten inches. This siphon carries the major stream flow, that water bypassing it becoming pooled in the room and extension passage where its stagnated nature
allows the settling of clay and silt.

The siphon appeared to just be handling the discharge into the Sewer Passage. The writer and his assistants were in the passage for approximately two hours, and no noticeable change in the stream level was observed. Yet, it is evident that such a small opening can only accommodate a limited supply of water. A sudden thunderstorm would cause a significant increase in the influx of water into the Sewer and result in rapid flooding of the passage. (As will be discussed in the chapter on hydrology, such occurrences are not uncommon, and in addition, much of the Right Fork floods up to the ceiling as well). Thus, the Sewer is an extremely dangerous section. In addition to the danger, low ceiling-heights (only one foot of air space) and the fact that the surveyors were constantly in a prone position made accurate survey and detailed study difficult. Consequently, although it is felt that the survey is accurate, the writer wishes to acknowledge that it was made under the worst possible conditions.
CHAPTER III  
STRATIGRAPHIC POSITION OF KLUMP'S CAVE

Based on previous geologic mapping of Perry County, the location of Klump's Cave falls within the rock belt comprised of the Joachim and Rock Levee formations, both of Ordovician age (figure 5). It will be noticed that the contact between these two formations is not included in the generalized map. The reason for its omission is because of the strong similarity between the two formations, especially in the contact vicinity, and the difficulty in distinguishing between them in field mapping. The contact is presently defined as a thin, persistent chert-pebble zone lying at the top of the Joachim (Martin, Knight, and Hayes, 1961). This chert zone, however, is "not at all conspicuous" in weathered surface exposures, and in field mapping, "the Rock Levee is grouped with the Joachim;" it is, on the other hand, "a recognizable subsurface marker" (Martin, Knight, and Hayes, 1961). Only generalized geologic mapping has been carried out in Perry County. Flint's (1925) detailed study was completed some forty-nine years ago, and at that time, the Rock Levee formation did not exist by definition; rather, its lower units were assigned to the Joachim and its upper units to the Plattin formation.

Based on its location, it might be assumed that Klump's Cave is dissolved in one or both of the above formations, the main problem being the delineation of the stratigraphic position of the cave with reference to these two units. As will be brought out, this assumption proved to be correct.
In addition to the chert-pebble zone as a contact marker between the Joachim and Rock Levee formations, another marker has been observed in the Perry County area. This consists of a continuous stromatolite zone located six to eight feet above the contact, that is, the chert zone (Yokum, 1972b), and it has been observed in several caves in Perry County, for example, the Moore Cave system (Yokum, 1972b). It is not known how wide spread this stromatolite zone is; its absence from the literature for areas outside the Perry County region suggests that it may be fairly localized.

Eight distinct lithologic units can be observed in Klump's Cave, most of which can be traced continuously throughout the system except in those areas where they are covered by clay fill or where upward solution has not penetrated the higher units. The continuous extent and constant thickness of the units provide a base for determining whether increased ceiling-heights are a result of upward solution, downward solution, or both. These eight units (figure 45) are composed of (from older to younger):

1. A dense, finely crystalline dolomite (lower crystalline unit) which comprises the floor in all the cave avenues except the two entrance passages, the Meeting Room, and Devil's Crawlway (although it seems likely that the clay fill here probably extends down to this unit). Total thickness of the unit is not known, but is at least two feet as observed in the high-ceiling portion of the central Right Fork Passage where downward solution into this unit is greatest.

2. An argillaceous dolomite (lower argillaceous unit) which coincides with the widened lower chamber of the "hourglass" cross-section so typical of the passages in the cave. In addition, the northern half of the Rim Passage and the Sewer Passage are dissolved primarily within this unit. Total thickness of the unit is uniform at three feet.
Figure 45. Stratigraphic sequence of minor units within the Joachim and Rock Levee formations as observed in Klump's Cave. A cross section of the Left Fork Passage is included for comparison. Vertical and horizontal scale is one inch to four feet.

3. A dense, finely crystalline dolomite (middle crystalline unit) which coincides with the vertical constriction of the "hourglass" cross-section due to its greater solutional resistance. The floor of the Meeting Room and Secondary Entrance Passage rests upon this unit. Total thickness of the layer is constant at three feet.

4. A scattered chert-pebble zone ranging in thickness between six inches and one foot.

5. An argillaceous dolomite (upper argillaceous unit) into which the widened dolomite of the "hourglass" configuration is dissolved. This unit has a constant thickness of four feet.

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6. A dense, finely crystalline dolomite (upper crystalline unit) which represents the ceiling throughout the greater extent of the cave. Exceptions are the high-ceiling portions of the system where greater upward solution has occurred—the Meeting Room, Formation Room, Main Entrance Passage, and the two high-ceiling sections of the Right Fork Passage. A constant thickness of four feet characterizes this unit.

7. A stromatolite zone ranging in thickness between one and two feet, with the latter value being most characteristic.

8. A dense, lithographic limestone (upper limestone unit) which comprises the upper walls and ceilings in the high-roof portions of the cave mentioned previously. Total thickness of this unit is unknown, but is at least fifteen feet as observed in the Meeting Room where greatest upward solution has taken place.

The stromatolite zone is readily observable in several different sections of the cave. These sections include the Main Entrance Passage, Meeting Room, northwest offshoot from the Meeting Room, Formation Room, middle section of the Right Fork Passage, and the terminus of the Right Fork. Each of these sections is a high-ceiling area of the cave, the height increase due mainly to greater upward solution. The fact that this zone is observed at different locations throughout the system in the same stratigraphic sequence indicates that it is definitely continuous, with those sections between observation areas being dissolved below the zone.

In light of its position six to eight feet above the Joachim-Rock Levee contact in other areas of Perry County, the occurrence of the stromatolite zone in Klump's Cave strongly suggests that the cave is dissolved into both of the above formations. This suggestion is verified by the presence of a thin chert-pebble zone in several different sections of the system, here interpreted to be the contact.
Figure 46. Chert-pebble zone between the upper argillaceous unit and the middle crystalline unit (between the Joachim and Rock Levee formations) in the lower reaches of the Main Entrance Passage. Almost all of the middle crystalline unit and much of the chert zone is covered by flowstone. Still, several of the chert pebbles can be observed.

between the two formations. These sections include the lower reaches of the Main Entrance Passage, Meeting Room, Formation Room, two locations in the Rim Passage, and four locations in the Right Fork Passage. The chert fragments are roughly rectangular and average about three-eighths inch thick and three-fourths inch long. The zone everywhere retains the same stratigraphic position, namely, between the middle crystalline unit and the upper argillaceous unit (figure 46). Due to its repeated occurrence in different areas of the cave and to its constant stratigraphic position, this zone is thought to be continuous and to represent the contact between the Joachim and
Rock Levee formations (figure 45).

Considering its stratigraphic relationship to passage void, one might wonder why the chert zone cannot be traced continuously throughout the system: it should be present in the walls of all main passages except the Sewer Passage and the northern half of the Rim Passage (both dissolved completely in lower units). This can be answered simply by noting its position with reference to the typical "hourglass" configuration of the passages. The zone is between the middle crystalline unit which comprises the vertical constriction and the upper argillaceous unit which corresponds to the upper chamber of the "hourglass." Thus, the zone lies just above the vertical constriction (ledges). Throughout almost the entire system, thick clay-banks mantle these ledges, extending upward along the cave walls. The result, of course, is the covering of the chert zone, preventing its observation. This clay mantle is absent only at a few locations, but where it has been removed, the chert zone is always observed. In addition, where observed in conjunction with the stromatolite zone, the two zones are separated by a distance of approximately eight feet. This is consistent with the six to eight feet separation between the two zones observed in other caves in Perry County.

In summary, Klump's Cave is dissolved along the contact between the Joachim and Rock Levee formations. This conclusion is based mainly on three observations: (a) the occurrence of a continuous stromatolite zone reported in other caves in Perry County to be six to eight feet above the contact between the two above formations; (b) the occurrence of a chert-pebble zone eight feet below
the stromatolite zone and interpreted as being the upper unit of the Joachim formation; and (c) the location of the cave in the previously mapped belt of grouped Joachim and Rock Levee formations.

The cave is dissolved roughly equally into each formation. Its greatest extent into the Rock Levee is approximately twenty-three feet, while its maximum extent into the Joachim is about nine feet. For the majority of the cave length, however, values of five to six feet into the Rock Levee and seven to eight feet into the Joachim are more typical.
CHAPTER IV
RELATIONSHIP OF KLUMP'S CAVE TO GEOLOGIC STRUCTURE

General Statement

Klump's Cave is located in the eastern flank of the Ozark Dome which is characterized by strata having gentle east and northeast dips. In the vicinity of the cave, the strata are almost horizontal, dipping toward the northeast at only one to two degrees.

It will be remembered that no significant fault or fold structures exist in that area of Perry County in which the cave is located. This area was previously referred to as the homoclinal area where only the gentle east and northeast dips of the rock units dominate. The absence of any complicating geologic structures (especially folds) has resulted in a relatively simple cave-pattern (plate I). This pattern, as a consequence, must be interpreted on the basis of the two types of "structures" that do characterize the area, namely, an extensive joint-system and the bedding plane between the Joachim and Rock Levee formations, both of which provide zones for concentrated phreatic flow and solution.

Joint Versus Bedding-Plane Control

The relative importance of joint and bedding-plane control of passage development and orientation can be ascertained by evaluating four general categories of passage characteristics: (a) the abundance of joint and associated features, (b) the appearance of
the passages in cross section, especially with reference to ceiling configuration, (c) the vertical distribution of passages, and (d) the visual appearance of passage orientations.

**Joint features.** In true joint-controlled systems, an abundance of joint and associated features generally characterizes the passages. The most important of these include visible joint-traces along the ceilings, joint ceiling-domes or cavities, and joint wall-slots or cavities. In the area of Klump's Cave, a joint system consisting of four sets can be recognized in surface exposures of the Joachim and Rock Levee formations (Louis Unfer, personal communication). It is important to note, however, that this system cannot be considered well developed as evidenced by their comparatively poor expression in surface exposures (Louis Unfer, personal communication).

In the chapter on passage descriptions, it was seen that these joints are expressed subsurface in the form of joint ceiling-domes and wall-slots (most with visible joint-traces), each of which is oriented in one of the four directions characterizing the surface joint-exposures. Of importance here, however, is also the fact that only ten such features exists in the entire cave system. In a strongly joint-controlled cavern system, one would expect a significantly greater number of such features. Therefore, although indicating that the joints are expressed in the subsurface, their limited number suggests that their influence on passage development and orientation is relatively minor.

**Ceiling configuration.** Ceiling configurations are a strong indication
of the relative importance of joint and bedding-plane control. Joint-controlled passages characteristically have very high, upward-tapering ceilings—much in the fashion of a long, thin, inverted "V". This results from the concentrated vertical solution along the joint plane. In contrast, bedding-plane controlled passages generally exhibit relatively low, flat ceilings due to the absence of major vertical "weak" zones (joints), thus preventing significant vertical solution into the strata.

High, tapering ceilings can be observed nowhere in Klump's Cave; to the contrary, every section of major and minor passage exhibits comparatively low, flat ceilings. Even in the few areas where heights are above average, the ceilings retain their flat character. It appears, then, that bedding-plane influence has greatly predominated in the vertical development of the cave passages.

**Vertical distribution of passages.** In the vertical dimension, Klump's Cave is entirely restricted to a single plane, namely, the Joachim-Rock Levee contact and its immediate vicinity. Every major passage, minor passage, and room is situated along or near this plane, making Klump's a single-level cave.

This contrasts to many major joint-controlled systems as described in the literature and as personally observed by the writer. Due to the concentrated vertical movement of phreatic water along joints, these systems often exhibit two or more levels or stories and/or the passages are characterized by great vertical descents and ascents. As stated above, this is not the situation in Klump's Cave: the cave is limited to a single, almost horizontal level, and there is no
evidence that multiple levels ever existed. Along this same line and as discussed previously, even the passage heights in the cave are greatly restricted and do not penetrate to any great distance into the surrounding rock units; and the single cave-pit is localized and terminal.

Obviously, the concentrated phreatic flow that initially dissolved the passages was restricted vertically to that zone corresponding to the Joachim-Rock Levee bedding plane. Therefore, bedding-plane rather than joint control again appears to have been the predominant factor in the vertical development of the cave system.

Passage orientations. Bedding-plane control of the vertical distribution of Klump's Cave has been demonstrated thus far in spite of the existence of an inadequately-developed joint system. It is possible, however, that this joint system influenced the horizontal orientation of passages as the phreatic waters moved along the formation contact, making the cave both bedding-plane and joint controlled. An appraisal of this possibility can be gained by studying the horizontal pattern of passage orientations (plate I).

The passages of a strongly joint-controlled cave generally exhibit a network or "city street" appearance: passages are characterized by long, relatively straight sections, and they often run in two or more parallel or subparallel sets which intersect and/or cross each other at high angles. In contrast, true bedding-plane-controlled systems contain passages which are smoothly sinuous in appearance, do not trend parallel if more than one avenue exists, and may even take on a branching or dendritic pattern.
The map reveals evidence suggesting that both controls were in operation. Evidence for bedding-plane control includes: (a) other than the Left Fork, lower Rim, and the east-west trending portion in the central Right Fork, few truly long, straight sections exist; (b) even the three above mentioned sections are slightly sinuous in character; (c) parallelism or subparallelism between many passages or sections is lacking; and (d) an obvious network-pattern between passages is lacking. On the other hand, the following evidence can be observed for joint influence. (a) The Left Fork Passage and central Right Fork Passage are both long and relatively straight, and both are oriented in a direction parallel to an existing east-west joint-set. (b) Many sections of passage (especially in the Right Fork), although short, are fairly straight and trend in directions parallel to known existing joint-sets. Thus a step-like pattern rather than a truly sinuous or meandering pattern results. (c) Not everywhere present, a subdued form of parallelism between sections does exist, for example, between the approximately N. 15° W. trending short sections in the Right Fork. In some areas parallelism is outstanding: between the Left Fork, central Right Fork, offshoot in the southwest corner of the Formation Room, and possibly the slightly northwest trending section of the Right Fork between Needle's Eye and the terminus; also between the northeast trending offshoots from the Formation Room and the Rim Passage. (d) A somewhat more distinct network-pattern would appear, albeit not well developed, if the clay-filled offshoots were extended on the map. (e) Turns between sections of passage are, for the most
part, quite sharp.

Most speleologists agree that rarely is a cave solely joint controlled or solely bedding-plane controlled. Rather, both generally operate together, although the influence of one usually dominates over that of the other. Bretz (1956) in discussing the effects of these two controls, states that "the most common is a combination of the two structures." The result is a ground plan of fairly straight sections with sharp bends controlled by joints (Bretz, 1956). The less adequately developed the joint system is, the shorter the sections, the more sinuous their routes become, and the more poorly developed the network pattern becomes. This latter description fairly accurately describes Klump's Cave.

Summary

Bedding-plane control due to concentrated phreatic flow along the Joachim-Rock Levee contact has been the prime factor in the development of Klump's Cave, especially with reference to the vertical distribution and development of the passages. An inadequately-developed joint-system does exist, however, and although it has had little effect on the vertical development of the cave, it apparently has had some influence on the horizontal orientation of passages by providing "weak" zones for concentrated phreatic flow as water moved along the formation contact.

Although influencing the general orientation of many sections of passage, the joints apparently are not developed adequately enough to result in the long, straight passages (with the major exception
of the Left Fork) exhibiting a strong network-pattern. In addition, several sections seem to be solely bedding-plane controlled as evidenced by their sinuosity and/or their orientation in a direction other than that parallel to one of the joint sets (for example, Devil's Crawlway, lower Rim Passage, and several sections along the Right Fork).

Some strong bedding-plane caves do exist in Ste. Genevieve County to the north which virtually lack any evidence of joint influence; likewise, a few strong joint-controlled systems are located just south of the fault zone in northern Perry County. Still, Klump's Cave conforms to the majority of caves in Perry County: predominantly bedding-plane-controlled systems with less significant joint control expressing itself in horizontal orientations.

Due to its nearly horizontal attitude, the slope of the Joachim-Rock Levee contact has had little, if any, effect on passage orientations. Indeed, many authorities (for example, Bretz, 1956), for purposes of study, classify Missouri caves as situated in horizontal strata. As mentioned earlier, the strata do dip gently (one to two degrees) to the northeast in the Klump's Cave area. Although taking a widely deviating course, the "net" direction of passage orientation in Klump's Cave is northeast-southwest. It is not known whether this is coincidence or a result of the gross, regional effect of the gentle dip.
CHAPTER V
RELATIONSHIP OF KLUMP'S CAVE TO PRESENT SURFACE TOPOGRAPHY

The surface topography in the Klump's Cave area (plate II) is typical of the karst terrain in Perry County. The two entrance sinks to the cave are at elevations between 560 and 580 feet, the best estimates being 565 and 562 feet for the main and secondary entrances, respectively. The entire cave system is located beneath a small, dissected, upland sinkhole-plain some 160 to 180 feet above Cinque Hommes Creek to the south. Specific passage orientations, however, do not exhibit any relationship with the present overlying topography. The avenues do not parallel existing topographic forms, are not contained by any such forms, nor do they extend across the contours in such a fashion so as to correspond to existing surface-flow.

It can be noted that present surface drainage in the area is to the south and southeast towards Cinque Hommes Creek in areas north of the creek. Subsurface flow in the primary trunk-passage of the Crevice-Mertz Cave system is also in a general southeast direction until resurfing along the creek valley. This same situation (that is, subsurface flow towards Cinque Hommes Creek) is also true for other caves in the Perryville vicinity. Thus, vadose flow in the primary passages of extremely extensive cave-systems mirrors fairly well present surface-drainage.

This is not true for the smaller, secondary systems, however. These carry water in directions contrary to surface drainage, and
Klump's Cave falls into this category. Flow extends completely beneath a small, surface ridge (surface divide) located above the terminus of the Right Fork and proceeds on to the northeast. In addition, subsurface flow almost bisects the minor southwest-trending ridge outlined by the 560-foot contour in two areas: Rim-Left Fork Passage and the southern half of the Right Fork Passage.

Fairly large solution-sinks overlie the cave at two locations: directly above the Formation Room and the Jungle Room. As explained earlier, these two sinks are thought to be the cause of the abundant, massive formations located in these two rooms. Nowhere else does the cave underlie sinks of significant size, and nowhere else in the system are massive, dripstone formations found.

In summary, there is no observable relationship between Klump's Cave and overlying topography, either with reference to passage orientation and distribution or subsurface drainage. As discussed more fully in a later section, this suggests origin and development under an earlier, somewhat different topography. The only exceptions are the relationships between massive, abundant, formation growth and large, overlying sinks, and the fact that sinks presently provide direct routes for the diversion of surface water to a subsurface course.
CHAPTER VI
HYDROLOGY OF KLUMP'S CAVE

General Considerations

Klump's Cave is an excellent example of what is referred to as a "sewer cave" in that it contains significant vadose flow only during periods of precipitation. When precipitation ceases, the volume of stream flow slowly diminishes until flow virtually stops. During his study of the cave, the writer has observed stream flow under a variety of different conditions. During or shortly after precipitation, the cave carries large volumes of water. For example, on one instance the cave was entered an hour after a heavy thunderstorm, and the water covered the natural bridge in the Right Fork, making its depth about six feet. On many other occasions, study was carried out after several weeks of dry weather. At these times, no flow at all could be observed--only areas of standing, pooled water in the stream channel. The stream occupying the cave, therefore, is classified as intermittent and, of course, indicates that the cave is located in the vadose zone completely above the water table and that no perennial stream drains into the cave system.

Source of Subsurface Flow

When significant water is available, the main stream flows from the upper reaches of the Rim Passage toward and under the Formation Room, down the Left Fork Passage, beneath the Meeting Room, down the Right Fork Passage, and into the Sewer Passage where it eventually
reaches the terminal siphon.

Its source of water is, of course, local seepage and drainage during periods of wet weather. The water enters the system at a number of different points. One of these is at the explorable terminus of the Rim Passage. It will be remembered that low ceiling-height prevented further exploration up the Rim; yet, water is commonly observed flowing from the unexplorable reaches into the main system. Due to its inaccessibility, the exact point or points of surface influx into the passage is not known.

All of Klump's Cave lies beneath an upland sinkhole-plain, and an especially large number of collapse sinks are located about 300 to 400 feet to the west and northwest of the Rim. It is thought, therefore, that the Rim Passage probably extends west and northwest for at least this distance where it obtains direct surface-influx from one or more of these sinks. This seems likely for three reasons. (a) Rapid increases in the volume of water discharged into the main Rim Passage has personally been observed. This can only be accounted for by rapid, direct influx of water into the passage via a collapse sink; slow bedrock-seepage would not suffice. (b) Large quantities of surface debris (grass, twigs, leaves, etc.) have been observed in the water draining the unexplorable reaches of the Rim Passage. This again requires a direct, open access to the surface, much like that of the Main and Secondary Entrance Passages. (c) These sinks are the nearest possible points of entry that could provide the direct access necessary.

Many of these sinks were examined in hope that entrance to the
Rim Passage could be achieved. Several proved quite promising—intermittent-stream channels drained into the openings, there was an outflow of cool air, and initial penetration into small crawl-ways was achieved. In each case, however, the crawl narrowed to the point that further penetration was impossible. Consequently, although the writer is certain that this sink area is the source of Rim Passage water, the length of the unexplorable section of the passage and the exact point or points of entrance remain unknown.

Two other points of entry of surface water into the cave occur at the main and secondary entrances. Small, intermittent streams drain into each of these collapse sinks, and it is only a short distance to where the channels intersect the main cave stream.

Water also enters into the Meeting Room and joins the main stream from the small offshoot running subparallel to the Main Entrance Passage. It is likely that this offshoot extends to a small sink about fifty feet to the south of the main entrance. Cool air could be felt emanating from the sink, but access again proved impossible due to the smallness of the opening at the sink base.

In addition to the four just discussed, two other areas of rapid influx exist in the cave. One of these is the Formation Room where, during precipitation, great streams of water flow from the ceiling. An analogous situation appears also to exist in the Jungle Room.

The only other known points of entry of surface water is the slow seepage that occurs along the roof and upper walls of the passages. This, of course, is quite minor and would not significantly
Outlet of Subsurface Flow

Stream flow exits from the cave at the terminal siphon in the west wall of the Sewer Passage. It is not known with certainty whether this is a horizontal or vertical siphon. The complete lack of any evidence of a lower level to the cave and the siphon's position in the lower wall rather than the floor leads the writer to strongly suspect a horizontal siphon. Specifically, it is thought that one of the two offshoots at the terminus of the Right Fork (most probably the left offshoot) extends parallel or subparallel along and past the Sewer Passage. Their exploration was not prevented by a decrease in actual passage size, but rather by an increase in clay fill. It is not uncommon for a section of passage to be completely blocked by clay fill, only to open up again some distance beyond the blockage as observed by following a bypass crawl or another passage that connects at some point past the fill.

It is this type of situation that is thought to occur here, that is, the clay blockage in one or both of the offshoots is temporary, with passage again becoming open or partially open at some point prior to the general area of the terminal siphon. The water would then drain laterally into the reopened passage and continue its general northeastward flow. This seems far more likely than the presence of a new, lower level of passage or the presence of a completely distinct, separated cave-system located this close to Klump's Cave (so close in the fact that water can be heard draining into a larger
opening or passage which cannot be more than ten or twenty feet away).

A major avenue of the extensive Crevice Cave system trends to the southeast to the north of Klump's Cave (plate II). The water flow in the over twelve miles of mapped Crevice passage drains along this passage and resurges along Cinque Hommes Creek valley (Ray Knox, personal communication). The distance to this avenue from the terminus of the Sewer Passage is roughly 4500 feet in a northeast direction (plate II). It is interesting to note that a southwest offshoot carrying intermittent flow intersects the Crevice trunk-passage, and the source of this flow has not yet been located due to a low-ceiling area 2000 feet down the offshoot (Ray Knox, personal communication). Even more interesting is the fact that if this southwest trending offshoot were extended, it would pass roughly within 1000 feet of the Sewer terminus (plate II). If one allows for meandering, there is a strong possibility that this Crevice offshoot and the proposed re-opened passage of Klump's Cave into which flow is laterally siphoned are one in the same. No other outlet for water from Klump's Cave can be proposed—there are no known resurgences on the north side of Cinque Hommes Creek south of the Crevice resurgence until several miles south of Klump's Cave. It appears highly unlikely that water from the cave would alter its general northeast flow, turn south, and travel several miles to an outlet.

Both the present writer and Dr. Knox feel that this proposed drainage of Klump's Cave water into Crevice Cave is a definite likelihood, and dye tracing is planned for the fall of 1974 to test the hypothesis. If, as suspected, this does prove to be the case, Klump's
Cave would be classified as yet another tributary to the Crevice system.

Passage Flooding

One of the most fascinating hydrologic aspects of Klump's Cave is the rapid flooding of the passages during periods of intense precipitation. Due to increased supply during wet periods, some flooding is characteristic of all sewer caves, with stream depths increasing by several feet or more. In several sections of the Klump's system, however, this flooding is intense, and water levels reach the ceiling. This is verified by the position of water marks along the walls (figure 47) and by surface debris (grass, leaves, etc.) hanging from the cave roof.

While flooding is significant in all passages of the cave, there are only two sections where water reaches the ceiling. These are the upper Rim Passage (north of the fork) and the Right Fork and Sewer Passages from approximately just south of Needle's Eye all the way to the terminus of the Sewer with the exception of the short, high-ceiling section at the end of the Right Fork.

Flooding of the upper Rim Passage has been treated earlier in the passage descriptions. It is caused by the extremely small passage size which cannot accommodate a heavy influx of water; thus, it backs up, flooding the passage, and eventually spills over into Devil's Crawlway.

Of primary concern at this time is the flooding of the more extensive section of the Right Fork and Sewer Passages. The cause of
flooding here has long been thought to be a result of a situation similar to that in the Rim Passage: the presence of a narrow, low constriction which cannot handle the increased discharge during heavy precipitation. It was not until the writer explored the previously virgin Sewer Passage that the actual cause was located. Rather than a true passage-constriction, the cause of the flooding is the presence of the small terminal-siphon near the end of the Sewer Passage. Only some ten inches in diameter, such a small drain could only accommodate a very limited supply of water. Thus, during times of intense rainfall, flow is blocked and the water backs up, similar to the analogy of a slightly tilted pipe (the cave passage) which is virtually blocked at the lower end.
First evidence of flow at roof level is found a few feet south of Needle's Eye. Here only a few widely scattered remains of old surface-debris could be found on the ceiling. As one traverses deeper into the cave, the amount of debris increases, until just prior to the high-ceiling area at the end of the Right Fork, the roof is literally coated with a heavy mat of fresh surface-debris. As one would suspect, this evidence indicates that the frequency of ceiling-level flooding increases as the terminus of the cave is approached. In other words, only a moderate rainfall might flood the Sewer and part of the Right Fork section; a more intense rainfall would flood a greater length of the Right Fork and so on until Needle' Eye where flooding must occur only during comparatively infrequent, extremely intense thunderstorms.

Ceiling flooding of this area of the cave explains the presence of the vadose ceiling-channel located along this section. It also explains its change in character between Needle's Eye and the high-ceiling section of the Right Fork (that is, gradually increasing in size and depth from Needle's Eye toward the terminus). Since areas near the terminus would flood more frequently than those near Needle's Eye, the associated ceiling channel would correspondingly be better developed as the terminus is approached. Due to the eighteen-foot ceiling height at the end of the Right Fork, roof-level flooding apparently never occurs in this short section. Likewise, the ceiling channel also ends abruptly as this high-ceiling section is entered. The Sewer Passage does not contain a distinct ceiling-channel; rather, its roof is more in the form of a large, square notch (see cross
section on cave map). It is thought that flooding occurs so frequently in this passage that virtually its entire ceiling corresponds to that of a vadose ceiling-channel.

Channel Depth

Another aspect concerning the hydrology of Klump's Cave is with reference to the vadose stream-channel notched in the passage floors. Due to the absence of perennial flow, these channels are not well developed, usually averaging only a foot or so in depth. The channels contain the entire flow only during times of slack water-supply; during wet periods, the entire floor is covered, and there has undoubtedly been some vadose lowering of the whole cave-floor. In addition to the deep channel at the northeastern end of the Meeting Room, it was observed that in two sections of the cave there is a minor, yet noticeable, deepening of the channel by one-half to one and a half feet. These sections are the lower Rim Passage between the fork and the Formation Room and the east-west trending portion of the Right Fork which begins in the vicinity of the cave pit.

It will be recalled that throughout its length, Klump's Cave is dissolved along or near the Joachim-Rock Levee bedding plane. A few relatively short sections of passage are oriented so that stream flow occurs in some direction up contact. This is not possible for vadose stream flow, and these slightly deepened channels are interpreted as the result of accentuated vadose downcutting so as to achieve a constant downslope (albeit not truly down dip) gradient.

With such a gentle dip, a short, temporary swing up contact would
not result in a very significant upward slope, especially since nowhere does a section trend in a true up-dip direction—only in some direction obliquely up contact which would cause an even lesser slope. Thus, only minor channel-downcutting would be necessary to achieve the downslope flow. Some extra deepening probably also occurs in the two or three other short sections which trend slightly up contact; however, due to their short length, such deepening was not noticed.

The deep channel in the Meeting Room appears to be the result of the significant difference between original floor levels in the Right and Left Forks and the Meeting Room.

This consideration of vadose channel depths also sheds light on the initial phreatic character of the cave. When one considers the cave floor configuration prior to the incision of the vadose stream-channels, the absence of a graded, longitudinal cave-profile becomes apparent.

Phreatic Flow at Time of Cave Origin

Of major concern in the treatment of the hydrology of any cave system is the direction of phreatic flow at the time of cavern formation. The study of a single, relatively short cave such as Klump's can shed little light in this area. Dr. B. Ray Knox is presently studying the subsurface drainage of Perry County. Although not yet completed, it does suggest some tentative ideas for caves in the Joachim-Rock Levee belt.

Cinque Hommes Creek serves as local base level in the Perryville area as it drains northeastward and eastward toward the Mississippi
River (Ray Knox, personal communication). It was noticed that the primary passages of the extremely long caves (over two miles) located north of the creek were oriented northwest-southeast, with present vadose flow resurging along the creek valley. To the south of the creek, however, primary passages trend northeast-southwest, with resurgence again along the creek valley. When viewed on a map, the pattern is very similar to that of many surface streams—Cinque Hommes Creek—with their branching tributaries—the major cave-passage.

The pattern becomes even more striking when the secondary cave-passages are included in that they branch off, as do lower-order surface tributaries, from the primary avenues, and consequently, they have somewhat different general orientations. The similarity can be carried even further since the secondary passages themselves have branching lower-order offshoots. The final result is a dendritic pattern of cave passages.

It is tentatively thought that the overlying topography was such at the time of cavern origin that local, phreatic movement was generally to the southeast north of the creek and to the northeast south of the creek. This would result in movement roughly parallel to three of the existing joint-sets, those striking N. 15° W. and N. 60° W. north of the creek, and that set oriented N. 30° E. south of the creek. Such movement along joint strike could possibly be the explanation for the huge, capacious primary-passages the longer caves exhibit, the sharp bends in which are largely due to crossing joints. Smaller, more localized topographic variations would cause phreatic flow in other directions, all eventually coalescing with that of
primary movement—again similar to that of surface streams today. Secondary-passage enlargement and general orientations would then take place along those joint sets most closely approximating this "secondary" concentrated-flow. Accordingly, phreatic flow at the time of Klump's Cave origin would have been generally to the northeast.

It might be noted that the primary phreatic-flow corresponds generally to present surface topography and drainage. This is probably the result of the retention of at least a similar general-regional topography that existed at the time of cave origin. Original phreatic movement that created the lower-order, branching passages, however, in a great many cases would not parallel present surface topography and drainage, a consequence of the more temporal nature of relatively small, localized topographic features. Klump's Cave is a good example. Surface flow (at least in the area over the southern two-thirds of the system) is to the south and southeast. Phreatic flow at the time of its origin was to the northeast, actually passing beneath presently existing, minor surface-divides.
CHAPTER VII
CONCLUSIONS: THE SPELEOGENESIS OF KLUMP'S CAVE

General Statement

One of the primary goals of a detailed study of a cavern system is the determination of the cave's history. This consists of a set of conclusions based upon study of the more directly observable aspects of the cave (features, relation to structure, hydrology, etc.).

There are three major considerations relating to the speleogenesis of any cave system. These are: (a) the general environment of cave origin, namely, the vadose or phreatic zone; (b) the specific environment of cave origin; for example, if phreatic in origin, the position within the saturated zone (deep versus shallow) at which passage solution was accomplished; and (c) the time of cave origin and the aggradation and degradation of passage fills.

Phreatic Versus Vadose Origin

As directly inferred throughout the earlier portions of this report, Klump's Cave formed under phreatic conditions. Evidence supporting this conclusion is outstanding and takes the form of abundant phreatic features located in all the major passages and most of the offshoots of the system. These features consist of: (a) two well-developed, continuous rock-spans (natural bridges) across the cave chambers, (b) ceiling spongework, (c) a number of joint-determined wall and ceiling-cavities, (d) abundant wall and ceiling-pockets, (e) a few minor-bedding-plane and joint-plane anastomoses, (f) the
absence of an original, graded, longitudinal cave-profile prior to vadose downcutting, and (g) even a subdued network-pattern for certain areas of the system.

Fewer vadose features formed by the action of free-flowing streams are found. Those observed consist of: (a) incised wall-meanders, (b) an excellent ceiling-channel, (c) horizontal grooves in the walls in a few widely spaced sections, and (d) stream channels notched in the cave floor.

In all cases, the position of the vadose features and their relationship to the entire cave system indicate that they were superimposed on an already existing phreatic chamber, for example, horizontal grooves cutting through wall pockets. Thus, Klump's Cave is a phreatic system which has been slightly modified by vadose streams following a lowering of the water table with accompanying drainage of the cave so as to allow the entrance of the surface flow. This agrees with the interpretation of Bretz (1942, 1956) for most Missouri caves.

Position within the Phreatic Zone at Time of Origin

In the chapter on cave hydrology, the relationships between passage orientations, existing joint-sets, and the direction of phreatic flow at the time of origin was discussed for caves in the general vicinity of the study cave. It was suggested that the pattern of passage orientations was a result of multidirectional phreatic flow—the gross, regional topography controlling the primary direction of flow (and thus the general orientation of large, primary passages.
of the large caves), while more localized features resulted in temporary phreatic-movement in other directions until eventually attaining primary-flow direction (thus the orientation of the smaller, shorter, tributary caves). In other words, it appears unlikely at this time that the dendritic pattern of passage orientations in association with existing joint-sets could have been the result of unidirectional phreatic-flow.

It is known that the rate of flow and the variation in flow direction decreases as depth in the phreatic zone increases. Deep-phreatic water moves sluggishly in unidirectional flow controlled by the major, regional topography. The influence of more localized, minor topographic features is only recognized in the shallow-phreatic zone since their control gradually gives way to that of the general, regional topography as depth increases.

It follows then, that if the pattern of passage orientations in the Klump's Cave area is even partially a consequence of multidirectional flow, these passages must have originated under shallow-phreatic conditions. This would be especially true for tributary caves, such as Klump's, since their orientation deviates significantly from that of primary flow and the major passages of the long, "trunk" caves.

Time of Cave Origin and Aggradation and Degradation of Cave Fills

The occurrence of speleogenetic events in a cavern system is directly related to the geomorphologic history of the area. The Ozark region has been studied by a number of workers, most of whom
recognize the existence of three erosional surfaces (peneplains of Bretz, 1956, 1965). These are, from oldest to youngest, the Boston Mountain Plateau, Springfield Plateau, and Salem Plateau. These erosional surfaces were largely destroyed by deep dissection during periods of regional uplift and rejuvenation. The present geomorphologic cycle for the Ozark region is one of such dissection resulting from the last major uplift.

Bretz's (1942, 1953, 1956) three-cycle theory regarding the origin of Missouri caves hinges largely on the above geomorphologic history. He has proposed that cavern development takes place in the phreatic zone during periods of uplift and rejuvenation. These were times of greatest surface relief, causing the phreatic circulation necessary for cavern solution. As the topography eroded down to an erosional surface (peneplain), ground-water circulation virtually ceased beneath the overlying, flat topography. The decreased competency of phreatic movement resulted in the deposition and filling of the caves by fine, red clay--residual surface-material that was washed down to the phreatic zone. This was the only method Bretz could propose to explain the presence of the large quantities of such clay found in Missouri caves--free-flowing vadose streams could not deposit such large amounts of so fine a material. The third cycle was initiated when rejuvenation with accompanying surface dissection occurred. In this stage, entrenchment of stream valleys caused a lowering of the water table with subsequent draining of the caves, placing them now in the vadose zone. At this time, the caves were entered by free-flowing surface streams which removed the
clay fill; it is also during this time that secondary dripstone and flowstone growth occurred.

Most students of Missouri caves generally accept this theory of origin, and Thornbury's (1954) only major objection is the necessity of a clay-filling episode. He was of the opinion that such material can be deposited by vadose streams after they enter the phreatic chambers.

The present writer is convinced that Bretz's three-cycle theory definitely applies to the origin of Klump's Cave. First, the cave is certainly phreatic in origin. Secondly, the pattern of passage orientations in the Klump's Cave area strongly suggest multidirectional flow of these phreatic waters, such that would occur under an uplifted, mature topography. Flow under the low relief during erosional-surface periods would be sluggish and mainly unidirectional. And thirdly, it is agreed that clay deposition in caverns by free-flowing vadose streams does occur; however, such deposition would not likely be extensive, and even if this was possible, the clay should show some evidence of stream deposition, for example, stratification, zones of coarser material deposited under a different flow regime, etc.

The clay deposits in Klump's Cave are very extensive. Clay is found in almost every passage and offshoot, and in several areas, it completely blocks an entire passage, attaining depths of twelve feet or more. In addition, evidence is substantial that clay once filled the entire cave-system to the ceiling. This evidence, of course, consists of clay in ceiling pockets and spongework. Certainly no stream could deposit enough clay to completely fill an entire system.
In addition, the clay shows no evidence of stream deposition. As observed in steep clay-banks and in several pits dug by the writer and his assistants, no stratification could be recognized, and no zones of coarser material were present. Coarse deposits that were observed were restricted to and around the present stream-channels and in scattered areas on top of clay banks where they do not extend to the ceiling, a consequence of the present cycle of vadose deposition.

It is firmly believed, therefore, that the clay fill in Klump's Cave could only have been deposited by virtually stagnated phreatic water such as would occur under an erosional surface of extremely low relief. As mentioned, evidence indicates that the cave was once completely filled with clay, and even though large amounts remain, much has been removed by vadose flow. Thus, the three cycles of Bretz's theory are well represented in Klump's Cave.

The three-cycle theory of Bretz is supported here because of the phreatic origin of Klump's Cave, and especially because evidence indicates that the cave has gone through the cycle of events proposed in the theory. Although not definitely stated, it might be inferred, however, that Bretz theorized cave origin in the moderate to deep-phreatic zone. This does not appear to be the case with Klump's Cave. Swinnerton (1932) thought that cavern origin took place at the water table where lateral subsurface-flow is greatest. Although basically a vadose theory, shallow-phreatic origin (just below the water table) was not strictly discounted. Klump's Cave is definitely phreatic, but evidence also indicates that it originated in the shallow portion of that zone where the water movement is still influenced by minor
topographic features. Exactly how shallow in the phreatic zone the origin took place is not known. Thus, the origin of Klump's Cave may well fit the basic ideas of Swinnerton (importance of lateral water-movement controlled by the overlying topography) as well as it does those of Bretz (phreatic origin). As far as the development of the cave after origin, however, Bretz's three-cycle theory applies very well.

The general subsurface and surficial environments during the origin of the cave and aggradation of clay fill having been established, the question of age still remains. That is, which particular erosional surface and which stage of mature, rejuvenated topography are involved.

Study of the clay fills strongly suggests origin under the last rejuvenation-cycle (that separating development of the Springfield and Salem Plateaus) and aggradation of fills beneath the Salem Plateau. As already described, the clay fills exhibit no zones of coarser material with the exception of some silt and fine sand atop a few clay banks which represents present vadose deposition. This suggests one, single episode of clay deposition, and that such must have taken place during the last erosional-surface period—the Salem Plateau, and that cave origin occurred during the cycle of mature topography immediately preceding its development. If cave origin had taken place during an earlier stage, say for example, that preceding the Springfield Plateau, two episodes of clay aggradation (Springfield and Salem) and two episodes of vadose action (that separating the two erosional surfaces and the present) should be represented in the clay.
deposits. This should result in a vertical sequence consisting of a lower clay-deposit, a zone of coarser material representing deposition by more competent vadose flow, an upper clay-zone, and finally coarse material at the top resulting from vadose deposition during the present cycle. Such a sequence could be found nowhere in the cave. The sequence that is observed, then, indicates development as outlined earlier: cave origin, one episode of clay aggradation, and present vadose influence.

One might suggest another possibility, namely, that cave origin occurred earlier than presently proposed but that subsequent valley entrenchment in later stages was not great enough to place the cave in the vadose zone. As a consequence, the clay fills might represent more than one episode of aggradation, but with no intervening vadose zone of coarser material separating them. Although possible for caves of deep-seated phreatic origin, this appears unlikely in the case of Klump's Cave for two reasons. First, it appears likely that cave origin took place under shallow-phreatic conditions. If one assumes even moderate lowering of the water table during subsequent periods of rejuvenation and valley entrenchment, the cave would be placed in the vadose zone and vadose-stream deposits should be observable separating the clay zones. Secondly, even if the above was possible for Klump's Cave, one would expect at least some minor variation in the clays deposited under the different erosional surfaces. Such was not the case here: the clay was identical throughout, both vertically and horizontally.

Another suggestion along the same lines as that above might be
that the clay deposited under the earlier erosional surface was completely removed during the mature stage prior to the formation of the Salem Plateau. Although possible, it appears unlikely that all traces of clay from an earlier episode would be removed from a system as large as Klump's.

The abundance and excellent preservation of phreatic features in the study cave also argues for cavern origin under the last stage of mature topography. Had cave development taken place during some earlier stage, the passages would have been subjected to more than one period of vadose modification. This would surely have resulted in greater vadose modification of passage configurations, more numerous and better-developed vadose features, and less abundant, more highly altered phreatic features than is presently the case. The obvious conclusion is that vadose influence has only been in operation during the present cycle of rejuvenation.

It has been shown that aggradation of clay fill in Klump's Cave occurred beneath the last erosional surface (Salem Plateau), and that cave origin took place during the rejuvenation stage directly preceding the development of that plateau. The speleologist must rely on the work of geomorphologists for the dating of these events. There is some range in interpretations among the various students of Ozark geomorphology. Fenneman (1938) recognized only two erosional surfaces and correlated the youngest with the Lancaster surface (peneplain) in the Driftless area. Thornbury (1965) lists the Lancaster as a mid-Tertiary peneplain. Bretz (1965), after an extensive study of the Ozark region, also correlated the Salem Plateau.
with the mid-Tertiary Lancaster, while he correlated the older Springfield Plateau with the Dodgeville erosional surface of early-middle Tertiary age. The Dodgeville was first recognized in the Driftless area of Wisconsin (Trowbridge, 1921) and later in northwestern Illinois (Horberg, 1946). Both Tarr (1924) and Fenneman (1938) have presented convincing arguements for late Pliocene up-lift and rejuvenation, initiating the present cycle of erosion.

Quinn (1956, 1958) and Knox (1966) differ with the above in that they date the Springfield and Salem Plateaus with the Yarmouth and Sangamon interglacial stages, respectively.

As to which of the proposed ages for the origin of the Springfield and Salem Plateaus and associated periods of rejuvenation are correct, the writer cannot, of course, state with certainty. However, it is the writer's opinion that the Bretz-Fenneman-Tarr proposals are far more convincing than those of Quinn and Knox. Therefore, until future studies firmly establish otherwise, it is believed that cave origin took place under mature topography of early-middle to mid-Tertiary age; that aggradation of cave fills occurred under the Salem Plateau of mid-Tertiary age; and that the present vadose cycle was initiated by rejuvenation and valley entrenchment in late Tertiary time.

Summary

Following is a summary of the proposed sequence of major events in the history of Klump's Cave.
1. Solution and passage enlargement in the Joachim and Rock Levee formations by generally shallow, multi-directional phreatic flow under hydrostatic head beneath mature topography. This concentrated flow was controlled primarily (both vertically and horizontally) by the Joachim-Rock Levee bedding plane, although joint planes also had a significant influence on the horizontal development of the avenues. (early-middle to mid-Tertiary)

2. Development of the Salem Plateau which resulted in a drastic reduction of hydrostatic pressure with an accompanying decrease in phreatic movement. This led to the deposition and filling of the cave with fine, reddish-brown clay. (mid-Tertiary)

3. Uplift and valley entrenchment causing a lowering of the water table, placing the cave in the vadose zone. (late Tertiary (Pliocene))

4. Entrance of free-flowing vadose streams, permitting degradation of much of the clay fill and deposition of coarser sediment. (late Tertiary to present)

5. Breakdown-collapse enlargement and partial filling of passages by flowstone-dripstone formations. (late Tertiary to present)

The study of many Missouri caves known to occur in a similar stratigraphic position, especially in Perry County, may serve to strengthen or disprove the writer's interpretation.
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