Caves in Kansas

James Young and Jonathan Beard

Kansas Geological Survey

Educational Series 9

1993

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Also available:

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Land of the post rock, its origins, history, and people, by *G. Muilenburg* and *A. Swineford*, 1975, University Press of Kansas, 221 p.

Geologic highway map of Kansas, 1988, Western Geographics, scale 1:1,000,000 (folded only)

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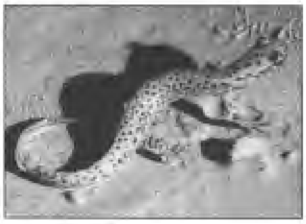

Kansas Geological Survey
Lawrence, KS 66047–3726

Preface

The information contained in this publication was compiled by members of the Kansas Speleological Society and the Kansas cave explorers that preceded them. These cavers, through their cooperation with each other and their dedication to the study of Kansas caves, have assembled an impressive body of knowledge. Before 1960 only 30 caves were known in the state. This number has now grown to more than 800 caves in 51 counties.

A group of cavers gathered in Topeka, Kansas, on January 14, 1984, and formed the Kansas Speleological Society (KSS). The KSS was chartered in the National Speleological Society on May 30, 1984, and became an official nonprofit corporation in Topeka, Kansas, on July 22, 1985. The Articles of Incorporation define the purposes of the KSS:

> To further explore, study and promote conservation of Kansas' caves, rock shelters and other natural underground resources; to include water and land drainage, items of historical and archaeological import, formations and speleothemic deposits and wildlife—both animal and plant. Furthermore, the Kansas Speleological Society seeks to enhance public awareness and knowledge of the above resources through a continuing process of information dissemination and publication. Safety, intra- and interstate cooperation and consideration are also part of our organizational purpose.

It is our sincerest wish that this publication serve those objectives and contribute to greater understanding of Kansas caves and the state's geologic diversity. Undoubtedly this publication will increase Kansas cave visitation, which could have a negative effect on the caves through vandalism and wildlife disturbance. However, Kansas caves are already being destroyed at an alarming rate by pollution and filling. It is estimated that the 42 caves now known in Butler County represent about half the caves originally in that area. These caves have been filled with rock (for road construction), inundated by lake water, polluted by petroleum, or in some cases used as illegal dumps. It is hoped that through better public education about Kansas caves, more caves can be saved for the future.

We thank Rex Buchanan, Catherine Evans, and Mimi Braverman for assisting with the writing of this book and the reviewers for their many helpful suggestions.

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Edited by Mimi Braverman.

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(center section)

After exploring caves in Missouri for several years, I became curious about whether there were any caves in my own state, Kansas. I was doubtful but went to the Kansas Geological Survey, where I learned that there is a cave called Spring Cave that was reportedly a mile long. Jon Beard and I located the cave and attempted to explore it. Upon entering the cave, we walked straight back a few hundred feet in a narrow passage to a mud choke. Well, it was a cave, but no big deal. Back near the entrance we rested, enjoying our little cave a few more minutes. We noticed that water was coming from a mostly water-filled passage off to the right. In my years of hiking through the mud-filled passages of Missouri caves, it had never occurred to me that a cave passage might be filled with water. With great apprehension we slowly inched our way down this water-filled conduit. The water was cold, but we just had to know where it came from! After about 100 feet (30 meters) we came to a small room and a right-angle turn. Our lights revealed a walking passage as far as we could see. We rapidly covered 1,000 feet (300 meters) of passage until we were stopped by a low area and our own shivering. We were to return with wet suits and surveying equipment many times to this cave. We were hooked on Kansas caving!

As we learned, few people think of Kansas when caves are mentioned. Most people envision vacation spots—Carlsbad Caverns in New Mexico, Mammoth Cave in Kentucky, and other American commercial caves. Yet Kansas ranks eighteenth in terms of the number of known caves among the 50 states, all of which have caves. More than 800 caves have been cataloged in 51 of the 105 Kansas counties.

What is a cave? Webster's *Dictionary* defines it as a natural underground chamber with an opening to the surface. This definition, however, leaves many questions unanswered. How big does a cavity have to be before it is considered a cave? If someone quarries or otherwise alters a cavity, is it still a cave? It seems that no two speleologists—scientists who study caves—agree on the answers to these and other questions. The caves included in this publication fit the following definition:

> A cave is an underground void that is the result of the solution or erosion of the earth by natural causes and is large enough to accommodate an adult. Overhang shelters caused by weathering are defined as caves only when they are at least 20 feet long, including vertical and horizontal cave passages.

No matter the definition, questions still remain. To some cavers, a cavity is not a cave until it goes beyond the range of sunlight. But some caves are positioned in such a way that sunlight travels hundreds of feet into the cave. Other caves have so many "skylight" openings that they are literally bathed in sunlight along their entire length. To put it simply, if one person calls it a cave and can find someone to agree, it's a cave.

Many different types of caves are found throughout Kansas. Some were created by solution of the rock by surface and ground water. Others were formed by other erosive forces, such as wind, rain, and fluctuating temperature. Kansas caves have formed in sandstone, limestone, gypsum, chalk, conglomerate, and loess. These sedimentary materials were deposited over millions of years during the Mississippian, Pennsylvanian, Permian, Cretaceous, Tertiary, and Quaternary periods of geologic history (fig. 1). The caves are found in several different physiographic regions of Kansas (fig. 2). Each region is unique, and the caves found within reflect each region's characteristics. The purpose of this book is to describe the caves found in several of the physiographic regions of Kansas, focusing particularly on the geology of the caves, how the caves formed, the kinds of animals that are found within the caves, and in some cases how the caves have been used by people.

This book is aimed primarily at a nontechnical audience that knows little about caves or the geology of Kansas. Although it is written with such readers in mind, the book occasionally uses somewhat technical terms or words that are unfamiliar to some readers. Thus a glossary at the end of the book provides nontechnical definitions of many of these terms.

— *Jim Young*

ERAS	PERIODS	EPOCHS	EST. LENGTH (YEARS)	DESCRIPTION	MILLION YEARS PAST
CENOZOIC	QUAT.	Holocene	10,000+	Early, land stable with some erosion. At least two glaciations in northeast. Later, dry climate; wind formed sand dunes in west.	
		Pleistocene	1,590,000		1.6
	TERTIARY	Pliocene	3,700,000	Rocks found are part of Ogallala Formation containing large quantity of ground water and occurring only in western third of state. No rocks formed in eastern Kansas	
		Miocene	18,400,000		
		Oligocene	12,900,000		
		Eocene	21,200,000		
		Paleocene	8,600,000		66
MESOZOIC	CRETACEOUS	Late, Early	77,600,000	Much of western half covered by seas. Limestone, sandstone, and chalk formed from sea deposits. Fossils can be found in these rocks, cropping out in central and western Kansas.	138
	JURASSIC	Late, Middle, Early	64,000,000	Most rock in Kansas underground in west. A few small outcrops in southwest corner.	205
	TRIASSIC	Late, Middle, Early	37,000,000	No rocks have been found in Kansas.	~240
PALEOZOIC	PERMIAN	Late, Early	41,000,000	Several seas rose and fell; limestone, shale, and chert deposited. Flint Hills formed. When seas dried up, salt and gypsum left. Salt now mined underground in central Kansas. Red Hills formed from shale, siltstone, sandstone, gypsum, and dolomite.	290
	PENNSYLVANIAN	Late, Middle, Early	34,000,000	Most of period, land was flat. Seas and swamps came and went; dead plants formed coal in swamps. Shale, limestone, sandstone, chert, and conglomerates deposited. Two ridges of hills, Nemaha ridge and Central Kansas uplift, appeared; both are now buried. Pennsylvanian rocks found at surface in eastern Kansas.	~330
	MISSISSIPPIAN	Late, Early	40,000,000	Repeated layers of limestone, shale,and sand-stone indicate seas rose and fell. Mississippian rocks are oldest found at the surface and are in southeast corner; elswhere these rocks only underground.	360
	DEVONIAN	Late, Middle, Early	48,000,000	Seas covered Kansas during much of period. Limestone, shale, and sandstone deposits only underground.	410
	SILURIAN	Late, Middle, Early	30,000,000	Land uplifted and seas disappeared. Limestone deposits found underground.	435
	ORDOVICIAN	Late, Middle, Early	67,000,000	Seas covered parts of Kansas during much of period. Dolomite and sandstone only underground.	500
	CAMBRIAN	Late, Middle, Early	65,000,000	Early, climate was dry and many rocks eroded. Later, parts of Kansas covered by seas. Dolomite, sandstone, limestone, and shale now underground.	~570
PRECAMBRIAN			3,930,000,000	These rocks are oldest on earth. In Kansas, only found deep below surface. Many are igneous and metamorphic.	3,800?

Eons not shown

Figure 1. Geologic time scale.

Visiting caves

A cave is an often inspiring, typically fragile environment that is home to small, usually harmless, and even beneficial animals that could not survive in the harsher environment outside. A cave is a living museum and should be treated as such by those who enter. Like an art museum, a cave and its contents are delicate masterpieces and must not be harmed.

Unfortunately, much of the aesthetic beauty of caves has been needlessly and permanently scarred or destroyed by vandals. Destruction includes graffiti, such as spray painting or carving (plate 1), trash dumping in passages and sinkholes (fig. 3), ground-water pollution, missing or broken rock forms, wildlife kills, and habitat destruction. To preserve caves, all cave visitors should abide by the National Speleological Society motto, the golden rule of cave exploring:

Take nothing but pictures. Leave nothing but footprints. Kill nothing but time.

Those who would like to visit a noncommercial cave should first learn the proper way to do it. The right way can be learned by accompanying experienced cavers, who can be reached through the National Speleological Society (NSS) (Cave Avenue, Huntsville, AL 35810).

Safe and proper caving requires specialized equipment and adequate training. Caving with NSS members offers education and camaraderie and helps prevent injury to both cave explorers and caves.

Because of the need to protect fragile cave environments from human destruction, cave locations—except for a few on publicly owned land—have not been included in this book. This policy also protects private landowners from trespassing by novice cave visitors.

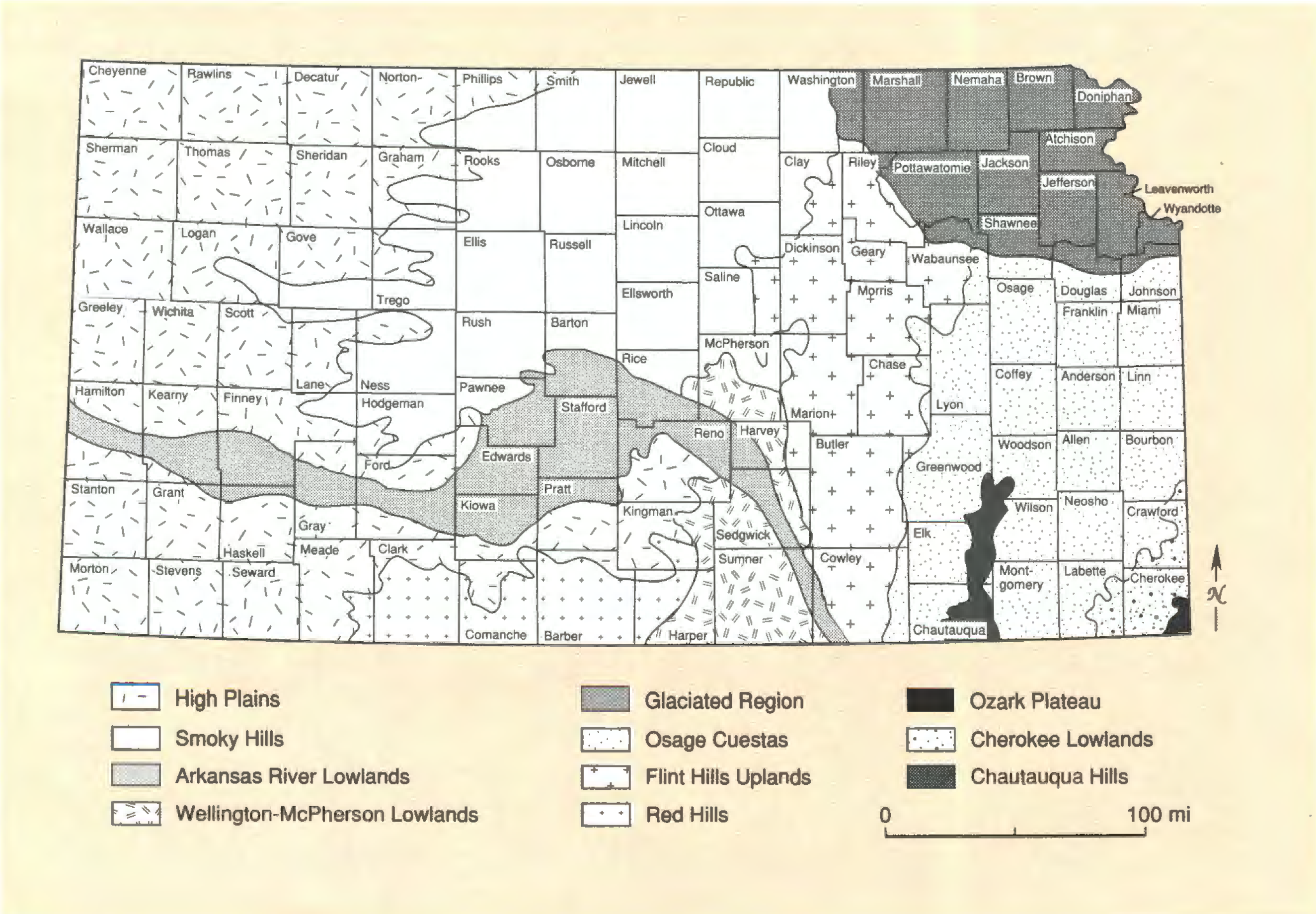


Figure 2. General physiographic map of Kansas.

Geologic history of Kansas

Understanding Kansas caves and their formation requires a little knowledge of the geologic history of the state (fig. 1). Most of the rocks found at the surface of Kansas are sedimentary, deposited from the wind, rivers, or shallow seas that covered the state during various times in its geologic history.

The oldest sedimentary rocks found at the surface in Kansas were deposited during the Mississippian Period, about 350 million years ago, when a shallow sea covered much of the state. During the Mississippian, a sea deposited limestones and shales that today crop out only in the southeasternmost corner of Kansas, although they are present in the subsurface in most of the rest of the state. Several limestone caves are found in these outcrops in Cherokee County; they are described in the section on the Kansas Ozarks.

The rocks that cover the rest of the eastern third of Kansas were deposited during the next period of geologic history, the Pennsylvanian Period or "Coal Age." During this time, about 300 million years ago, a shallow sea again covered much of the state. As the sea level fluctuated, layers of limestone and shale with occasional beds of sandstone were laid down. At times, brackish water around the edges of the seas gave rise to great swamps, the vegetation of which eventually became layers of coal. A few caves are found in these Pennsylvanian limestones. The caves are described in the section on the Osage cuestas. In places, ancient rivers deposited sand, which became sandstone. Caves in Pennsylvanian sandstones are discussed in the section on sandstone caves.

The Permian Period of geologic history occurred about 250 million years ago. Conditions in Kansas during the Early Permian were much the same as during the Pennsylvanian, which immediately preceded it; the Permian was a time of fluctuating shallow seas that left behind limestones, shales, and some chert in eastern Kansas. Bedrock deposited during the Permian forms the Flint Hills; one section of this book is devoted to caves in the Flint Hills. Later in the Permian, saline bays in south-central Kansas laid down layers of salt, gypsum, and anhydrite enclosed in red shale and sandstone. Erosion of these rocks created a landscape known

Figure 3. Trash-filled sink, Butler County (photo by Jim Young).

today as the Red Hills. The Red Hills area contains more caves than any other part of Kansas, and a section of this book is devoted to them.

During the Cretaceous Period of geologic history, about 100 million years ago, Kansas was once again covered by seawater. Along the edges of those seas and in the deltas of rivers that drained into them, huge stretches of sand were deposited; this sand eventually formed sandstone. The sandstone is soft and easily eroded and contains many caves, particularly in central Kansas. These are discussed in the section on sandstone caves. Farther west, the seas deposited limestone, and where the seas were deepest, chalk was deposited. The few caves in those limestones and chalks are described in the section about the caves of western Kansas. That section also describes caves that are formed in more recent geologic materials, such as the sands and gravels of the Ogallala Formation and the siltlike material called loess. Both were deposited during the past few million years of geologic history.

Stratigraphic nomenclature

The descriptions of Kansas caves in this book often include the name of the particular rock layer in which the cave is found. It is helpful to know how these rock layers are named, a process called stratigraphic nomenclature.

Geologists group rock layers of similar age and lithology (physical characteristics) into packages called formations. A formation is the fundamental unit in stratigraphic nomenclature and is usually the smallest unit used in geologic mapping. Formations are named for places or characteristics, and the name is applied for as far as the lithologic character is recognizable or until human geopolitical processes interfere (state lines, etc.). The formation name includes the place name and often the name of the type of rock most commonly found in that formation. Thus the Winfield Limestone is a formation that is found in the area around Winfield and is made up mainly of layers of limestone, but it also includes thin layers of shale.

Formations are often divided into thinner rock layers called members. The Winfield Limestone is a formation composed of the Cresswell Limestone Member, the Grant Shale Member, and the Stovall Limestone Member. Two or more formations can be lumped together for mapping purposes into a group. The group is also named for a geographic locality. Thus the Cresswell Limestone Member is part of the Winfield Limestone, which is part of the Chase Group, named for Chase County. These names provide a kind of common language for geologists and others who discuss rocks, geology, and speleology (fig. 4).

Speleogenesis

Speleology is the scientific study of caves, including their physical, geologic, and biologic characteristics. Speleogenesis, then, refers to the creation of caves. The making of caves is perhaps the most often discussed subject within the science of speleology and is perhaps why many people consider speleology a topic of study in terms of geology, although paleontology, archeology, biology, and other scientific fields are also extensively studied in relation to caves.

Speleogenesis of limestone caves

Almost all limestone caves still in existence today were formed within the last 10 million years, during the Miocene or Pliocene Epoch of the Tertiary Period (Moore and Sullivan, 1978). Therefore caves are a rather young feature, a small but common occurrence in the outer skin of the earth's ever-changing crust.

Although limestone caves differ dramatically from one locale to another, the processes that create them have many similarities. In this section we deal with limestone caves that were formed by solutional processes of ground water. Throughout the world only a small percentage of limestone caves were formed by other means, such as faulting of rock, tunnels within talus or glacial debris, action of sea waves, or the exterior erosive forces of wind and freezing and thawing.

Most limestone solution caves are primarily phreatic in origin. That is, they were formed at or below the water table (fig. 5), having been dissolved out of rock by slightly acidic water (fig. 6).

The ground water that creates caves travels through cracks in limestone. Limestone and other types of rock can be heavily jointed and cracked. Layers of rock can be separated by bedding planes, which were originally horizontal. Rocks also can break along these bedding planes. Cracks that normally run almost perpendicular to bedding planes are joints; these are usually vertical and are caused by stresses put on the rock by regional movement of the earth's crust (faulting), uplifting or buckling of the area, and especially the earth tide, which is the solid earth's response to the forces that produce ocean tides, that is, the moon's gravitational pull. Because limestone and other rocks are not flexible, they crack in patterns recognized by geologists. The major joint sets in Kansas trend northeast, with perpendicular joints trending northwest.

When rainwater passes through the atmosphere, which contains some carbon dioxide (CO_2), and then passes through decaying organic matter on the ground that contains additional concentrated carbon dioxide, the water acquires some carbon dioxide and becomes a weak solution of carbonic acid (H_2CO_3)—also known as carbonated water, the fizz in soda pop. As the solution percolates down and laterally through the limestone, it dissolves a small amount of the rock. The mineral calcite ($CaCO_3$) is the main component of limestone, and calcite dissolves in the presence of acid, such as carbonic acid.

To form a sizable cave, water has to remain acidic until it reaches some point below the water table in limestone. If the water is neutralized too rapidly, caves may not form. Geologist William White (1975) believed that caves develop near the water table where CO_2 concentration is highest. White also concluded that, once a conduit exceeded 5 millimeters (0.2 inch) in width (or about the diameter of a pencil), the amount of CO_2 in the water would be at its optimum concentration for dissolving limestone and could create turbulence, an important dissolving mechanism. Once turbulence can take place, larger conduits rob nearby

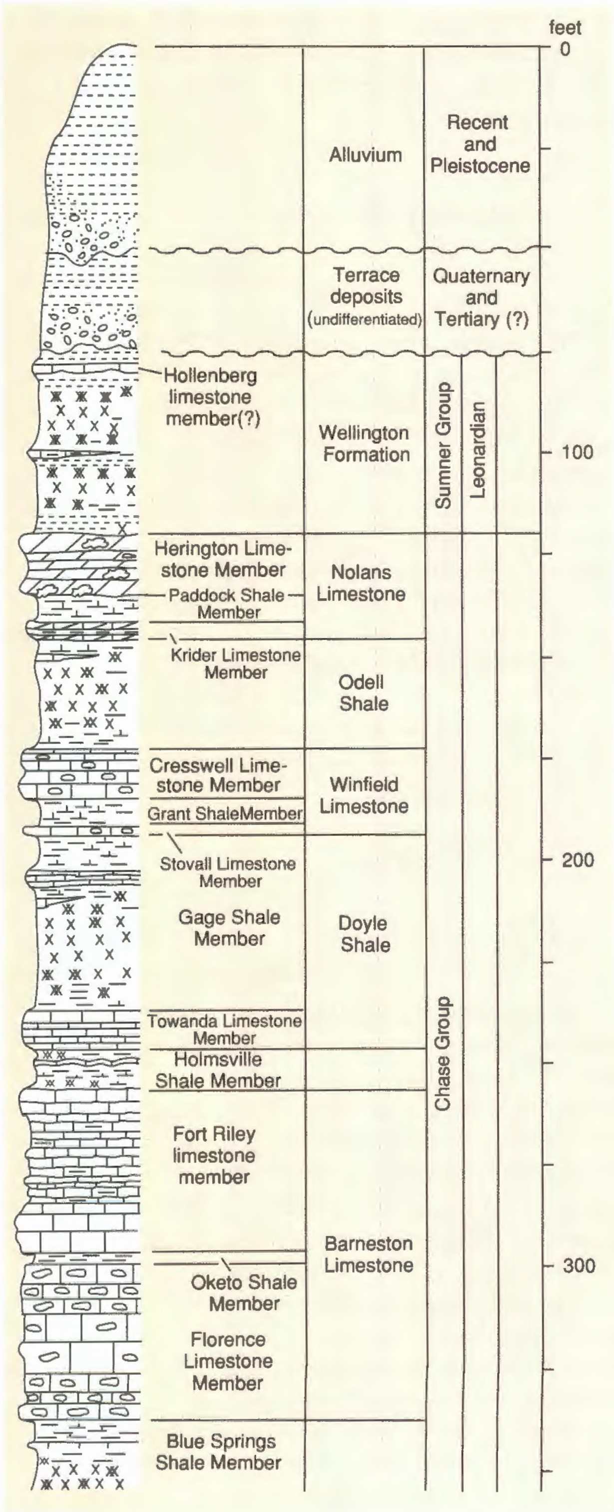


Figure 4. Stratigraphic column showing Winfield Limestone [from Moore et al. (1951)].

conduits of their flow and enlarge at faster rates, eventually becoming a cave passage. Most nearby pirated fractures remain smaller than 5 millimeters (0.2 inch) in width, except those that become tributary passages.

Speleologists have several theories about the formation of limestone caves. Before 1930 it was generally believed that all caves were formed above the water table in the vadose (or aerated) zone. William M. Davis (1930) challenged that belief by stating that caves formed in the phreatic (or saturated) zone and subsequently drained when the surface valley lowered, lowering the water table as well. When the water table dropped enough to drain the conduit, the conduit became filled with air, stalactites grew, and vadose water altered the cave. In fact, rather than forming the cave, vadose water was doing much to destroy it. The water filled the cave with silt, gravel, and calcite deposits, eroded and dissolved the walls, and removed the ceiling support, causing the roof to collapse.

Most speleologists agree with geologist Arthur Palmer's (1981) explanation that most surface and ground waters flow from upland surfaces down toward base level (major valleys) and that ground water that dissolves caves rarely ventures far below the water table before exiting the rock through springs in these valleys.

The direction of the water's movement through rock to base level is determined by two factors: gravity and hydrostatic pressure. Gravity pulls the water down through the vadose zone and to a much lesser degree through the phreatic zone toward base level. Hydrostatic pressure is the principal force that moves water through the phreatic zone, moving it forward in any direction to a zone of lesser pressure. This is demonstrated in artesian wells, in which water flows upward, pushed by the pressure created by the hydrostatic head of water behind it.

Today, many speleologists believe that most phreatic speleogenesis occurs at or just below the water table. Water too far below the table is probably already saturated with calcite and moves little compared to the swifter, more turbulent phreatic water at or near the water table. Because most limestone caves in Kansas are horizontal (except shafts created by vadose waters) and parallel to the water table, the water table is the chief factor that determines the character and direction of most caves. This is evident even when faulting and folding have caused distortion of rock strata before cave creation.

For a cave to become air-filled as we see it today, the water table must drop. A drop in the water table can be accomplished by the downcutting of the surface stream, which acts as the local base level of the aquifer. Downcutting of surface streams proceeds in all land surfaces but can be accelerated by some climate changes or tectonic uplift.

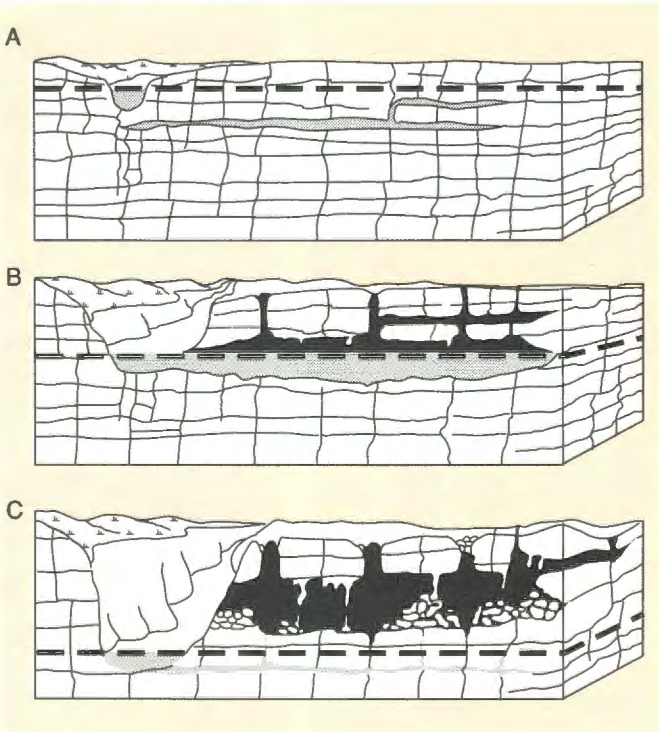


Figure 6. Limestone cave formation. (A) Acidified surface water seeps through vertical joints in the limestone until it reaches the water table, where it travels horizontally toward a natural outlet, such as a river. (B) As the river erodes the valley floor, the water table drops. The acidified surface water falls farther and faster, enlarging vertical joints to form sinkholes. The increased flow of water helps carry away the dissolved material faster, enlarging the main passage. (C) Increased river erosion causes the water table to lower farther and the cave seeks lower joints, draining the main passage. Weak portions of the ceiling collapse and under the proper conditions limestone can be redeposited to form stalactites, stalagmites, and other speleothems.

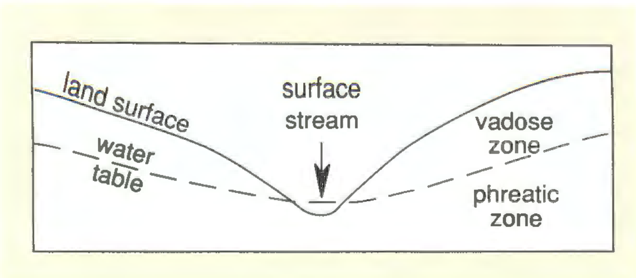


Figure 5. Position of water table, phreatic zone, and vadose zone.

Speleogenesis of sandstone caves

Most sandstone caves are the result of exposure to the elements and erosion by ground water (Cronin, 1970). Weak zones in the rock are attacked and excavated by rain, wind-driven sand, freezing and thawing, and hydration and drying. Water that seeps through cracks aids in the quarrying process, as do plant roots that grow into the rocks or are wedged between blocks.

Kansas sandstone caves can be divided into three groups based on their formation. The first and easiest to identify is the *stream meander group*. These shelters have high, dome-shaped structures (the entrance is the largest cross section) with few fissures in the walls and ceiling. They are formed by the erosive action of streams or rivers on exposed sandstone cliffs. Examples of the stream meander group are Jesse James Hideout Cave (fig. 7) in Franklin County and Prehistoric Cave in Woodson County.

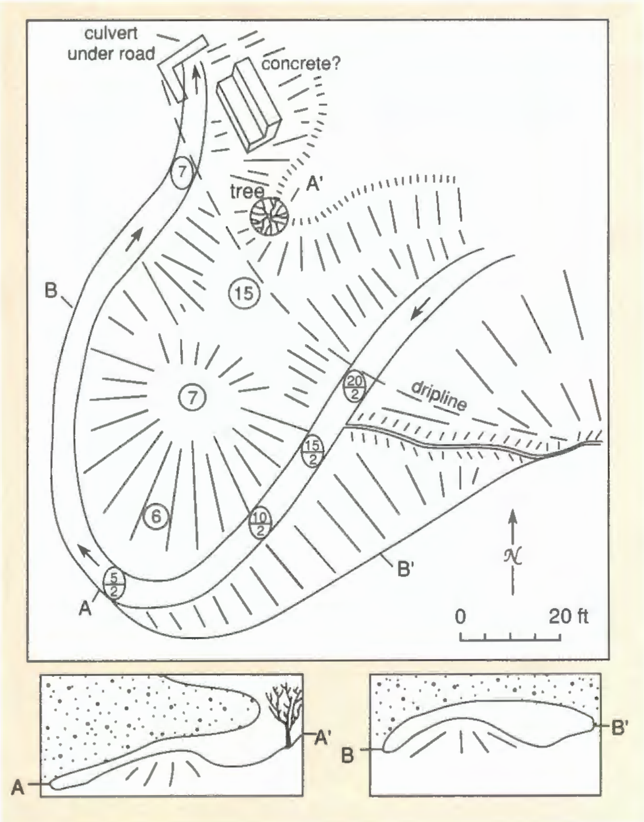


Figure 7. Jesse James Hideout Cave, an example of the stream meander group. Total surveyed length is 72.8 ft. Surveyed by Jonathan B. Beard and James J. Young. In this and other cave maps, the circled numbers indicate passage height. A single number signifies an air-filled passage, whereas a fractionlike number signifies the height of the air-filled portion of the passage (top number) and the height of the water-filled portion (bottom number).

Caves of the *exterior erosion group* are formed along joints in the rock. These caves have large entrances, are relatively high and narrow, and are open to the elements, which eroded the rock and thus created the caves. Some Kansas sandstone caves, like Crow and Palmer's caves, appear to fit the exterior erosion group from the outside but also have evidence of ground-water erosion.

The third type of sandstone cave is the *ground-water erosion group*. These caves are formed by the erosive action of ground water. A secondary force, gravity, also contributes to erosion, because it causes particles of stone to flake from the ceiling. Ground water acts on the sandstone either along joints or bedding planes. Usually a small hole can be found in the rear of these caves where the ground water started traveling through the joint or bedding plane. Joint-controlled ground-water erosion caves tend to be high and narrow, whereas caves formed by erosion along bedding planes are low and flat. Elgin Cave (fig. 8), about 30 feet (9 meters) long and with a ceiling high enough for standing, is a good example of a joint-controlled cave. Because exterior erosional forces also are at work on these caves, their entrances may be the largest cross section. However, the length bears no

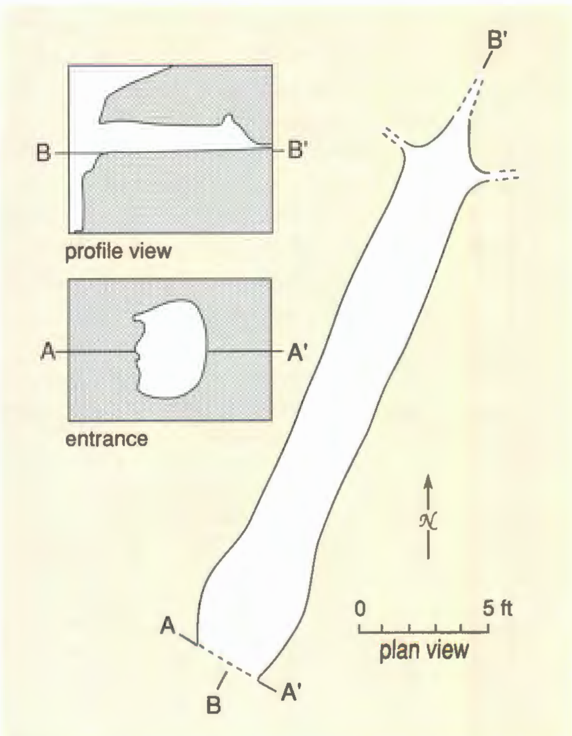


Figure 8. Elgin Cave, an example of the ground-water erosion group. Surveyed by James J. Young and Renard Gervais.

relation to the size of the entrance. Formation along a bedding plane is obvious in the rear passage of Crow Cave. In most Kansas sandstone caves ground-water erosion is a contributing factor to growth.

Speleothems (cave formations)

The term "speleothem" comes from two Greek words, *spelaion* (cave) and *thema* (deposit). And that is what speleothems are—mineral deposits formed within the cave. Most of these formations consist of the mineral calcite, or calcium carbonate, the principal component of limestone. Carbonic acid in vadose water dissolves calcite; eventually the water becomes saturated and can no longer dissolve the rock. Some time after the water enters the cave, carbon dioxide escapes to the cave atmosphere, lowering the carbonic acid concentration in the water. This CO_2 diffusion leaves the water in a saturated state, and calcite is deposited.

The name given to the speleothem is determined by its content, where it was deposited, and its shape. Speleothem names with Latin or Greek roots reflect study by the scientific community; other names come from comparison to common objects. The following speleothems are found in Kansas caves (fig. 9). *Stalactites* are formed on the ceiling and grow downward. They usually begin as strawlike forms when consecutive crystals are added to the hollow, circular tips. The hollow centers are eventually plugged with crystals that have formed within the "straws" (plate 2). They then take on a carrot-shaped appearance when dripping water is forced to flow down the outside of the stalactite.

Often below stalactites are *stalagmites*, which grow upward from the floor. Stalagmites result from water droplets splashing down and depositing calcite or other minerals on the cave floor. When a stalactite and stalagmite grow together, a *column* is formed. These are the primary *dripstone* growths found in most longer limestone caves. If water flows slowly in sheets on the floor or downward along sloping walls, *flowstone* growths result (plate 3). Water flowing over ridges or riffles on the floor forms *rimstone* growths on the ridges (plate 4).

In quiet pools, gnarled bulbous or pointed coatings of surfaces are called *coral* or *popcorn*. Strange, twisted "wormlike" formations on ceilings are called *helictites*; they form in the same way as stalactites except their hollow tube centers are so small that the water and precipitation of dissolved minerals are controlled by surface tension rather than by gravity. Instead of growing only downward, they can grow in any direction. They are usually short because they grow slowly and their centers are soon plugged.

Most speleothems in Kansas caves consist of calcite, but they also can be composed of calcium sulfate, which forms the mineral gypsum. This mineral can be found in limestone caves, but in Kansas it is usually found only in gypsum caves in the Red Hills. Besides being deposited by water, gypsum can be extruded from ceilings, walls, and floors. Extruded forms are forced out of clay or rock—much like toothpaste is forced out of a tube—instead of being deposited from water onto a surface. The formations are created by pressure from a chemical process rather than from water movement. Needlelike, flowerlike, or crustlike forms are the result of gypsum extrusions. Other minerals, including hematite, sphalerite, galena, and manganite, can also be found in speleothems, but they are much less common than calcite or gypsum.

Most of these curiously beautiful formations grow very slowly—some are no longer growing at all. The typical stalactite may take hundreds of years to form. It is therefore important for people visiting caves to not touch the speleothems. They are brittle and break easily, and the oil from human hands can leave a brown coating on the formations, possibly inhibiting future growth. Speleothems should never be considered for souvenirs because future cave visitors will not have the chance to see their unique beauty. Moreover, most speleothems, when taken out of the cave environment, eventually lose their luster and end up in the trash can.

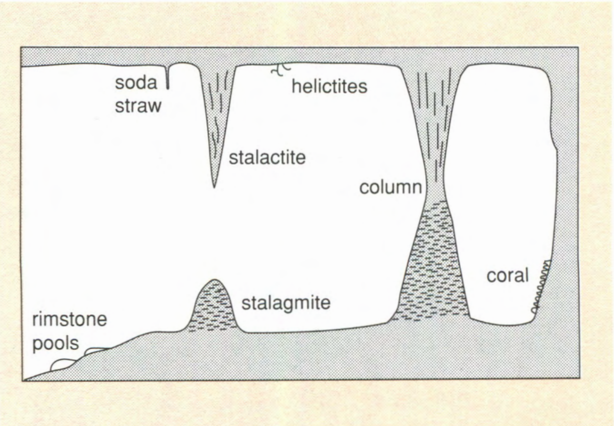


Figure 9. Speleothems.

Speleogens

Speleogens are bedrock forms that result from differential solution of cave passages, a phenomenon by which some sections of rock are dissolved faster than other sections, sometimes leaving oddly shaped bedrock remnants (fig. 10A, B). Bedrock masses suspended from the ceiling are known as *pendants* (fig. 10A) and either consist of rock that is more resistant to solutional attack (chert, mineral concretions, etc.) or are remnant rocks between closely spaced joints. The same holds true for *natural bridges* and vertical *pillars* of bedrock. Series of holes aligned with bedding planes are known as *anastomoses* (fig. 10B). When these holes are closely interconnected, they are separated by pillars. Curious semicircular dimples on bedrock cave walls, ceilings, and floors that resemble enlarged golf ball surfaces are called *scallops* and result from moving water—the faster the water, the smaller the scallops. The direction of the water movement can be determined by looking closely at the scallops; the upstream side is the steeper side. The diameters of the scallops range from less than 1 inch (2.5 centimeters) to a few feet.

Figure 10A. Pendants in a gypsum cave.

Figure 10B. Anastomosis entrance of Jack Spring Cave, Chase County, Kansas.

Caves of the Kansas Ozarks

The Ozarks, although best known in Missouri, Arkansas, and Oklahoma, are not limited to those three states. Famous for their beautiful, scenic ridges and thick oak and hickory forests, the Ozark plateaus—knowing no state boundaries or political ties—also are found in southwestern Illinois and the southeastern corner of Kansas. Although the Kansas Ozarks do not cover a large area, they figure prominently in the historical growth of Kansas, and they contain 14 caves that, for many reasons, are not typical for Kansas.

Of the 11 physiographic regions of Kansas, the Ozark uplands are the smallest, occupying only 55 square miles of the extreme southeast corner of the state. The area is characterized by rolling hills and steep river bluffs of the Springfield plateau, one of three major regions of the Ozarks. This topography is abruptly different from the lower, flatter Cherokee lowland to the west and north. The Kansas Ozarks are drained by the Short and Shoal creeks, which run into Spring River, which marks the southern flank of the Kansas Ozarks. Except for a few isolated remnants of younger Pennsylvanian rock, the exposed strata of the Kansas Ozark uplands are Mississippian in age and thus were deposited 330 to 360 million years ago, making them the oldest exposed rocks in the state.

The region is approximately midway through the process of surface valley development with sinkholes and other evidence of subsurface drainage development superimposed on it. The subject of surface valley development is a book in itself. Briefly, erosion occurs on all surface areas but concentrates on valley bottoms where water collects, thus eroding surfaces much faster than hills and ridges. As the valleys approach base level, that is, as their gradient decreases, they erode less and the erosion of uplands begins to dominate. Eventually the entire area obtains a low gradient and diminished features—a flat lowland.

The Kansas Ozarks can be described as a series of valleys and ridges, with the Spring River acting as the base level, attracting its tributaries that cut through the section from east to west, a contrast to the general southeastward drainage of the Central Plains west of the Mississippi River. The rock strata dip slightly to the west from the Ozark summits in Missouri and Arkansas.

Geologists believe that the Ozarks were last uplifted during the Tertiary Period, 40 million years ago, into a broad, gently sloping dome. This dome consists of three distinct plateaus: the Boston Mountains, capped by Pennsylvanian rocks; the Springfield plateau, capped by Mississippian rocks; and the Salem plateau, capped by Ordovician rocks. The rocks of the Ozark region are highly fractured because of the stresses of the modest uplifting and earth tides. Not only is the area highly jointed, but there are also hundreds of major and minor faults that contribute to the formation of more than 8,000 caves in the five-state Ozark region.

Two Mississippian rock units exposed in southeastern Kansas contain caves. They are the Warsaw Limestone—up to 150 feet (46 meters) thick—and the 100-foot-thick (30-meter-thick) Keokuk Limestone, situated below the Warsaw. Some small caves are found in the Warsaw, which is exposed in hills above the major drainages, but the major caves of the area are found in the Keokuk, at or near the valley floors.

The Warsaw and Keokuk Limestones contain abundant chert (silicon dioxide). The chert, which does not dissolve readily and is much harder than calcite, remains as gravel on hillsides, stream beds, and cave floors after the limestone has been dissolved away.

The Warsaw and Keokuk Limestones look similar in this area and are difficult to distinguish. Both consist of highly fossiliferous rock with chert nodules and lenses. In general, the Keokuk has more chert and a higher concentration of crinoid fossils. Crinoids are sea animals of the echinoderm phylum (Echinodermata) (fig. 11). They resemble plants and for this reason are often called sea lilies. Their heads (calyxes), stems, and stem rings are plainly visible in weathered rock. Other fossils found in the two limestones are bryozoans, brachiopods, and horn corals (fig. 11).

Caves in this area are typical of the Ozarks but not of Kansas. Most limestone caves in Kansas are

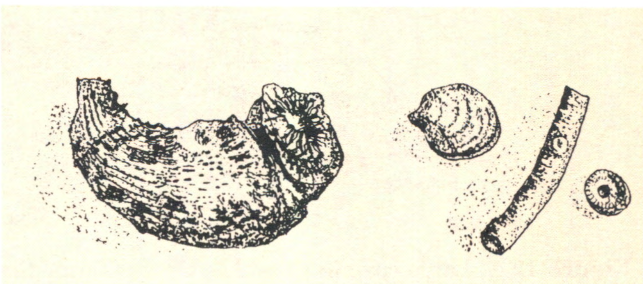


Figure 11. Horn coral, brachiopod, and crinoids.

strongly determined by joints; their passages are narrow and straight, and their turns and bends are abrupt and severe. However, most Ozark limestone caves tend to be more sinuous and not so narrow and have gentle turns that suggest that their joint-determined passages are also more affected by horizontal bedding planes than most other Kansas limestone caves. Most caves in the general Ozarks area, because of their massive limestone roofs and the area's more humid climate, tend to have more and larger speleothems than other Kansas limestone caves. Only one large cave with any appreciable speleothems has been found in the Kansas Ozarks. Although these cave formations are more colorful than those found in most other Kansas caves, they are still not spectacular compared with many other Ozark caves.

Many small caves are found in the bluffs along the major streams. The longest of these caves is about 25 feet (8 meters) long. These small caves may be remnants of longer caves that have been all but destroyed by collapse or erosion or they were perhaps never large in the first place. Most of these caves are straight and parallel to joints, have regular cross sections, and are the result of phreatic solution.

Other caves in the area were found during lead and zinc mining. Mississippian rock units have been commercially and culturally important in the Tri-state district, the area encompassing southeast Kansas, northeast Oklahoma, and southwest Missouri. Lead and zinc mining, which began in Kansas in 1870 and ceased in 1970, was a major industry in southeastern Kansas. Mine workings and open pits were a common sight, and the cities of Baxter Springs and Galena grew and prospered. When the focus of mining moved to the south and west, lead and zinc mining waned in Kansas. Today, deserted processing plants and mine tailings cover much of the landscape as ghostly reminders of the past. The tailings contain pyrite and other minerals, which, when exposed to rainwater, produce sulfuric acid and other groundwater pollutants.

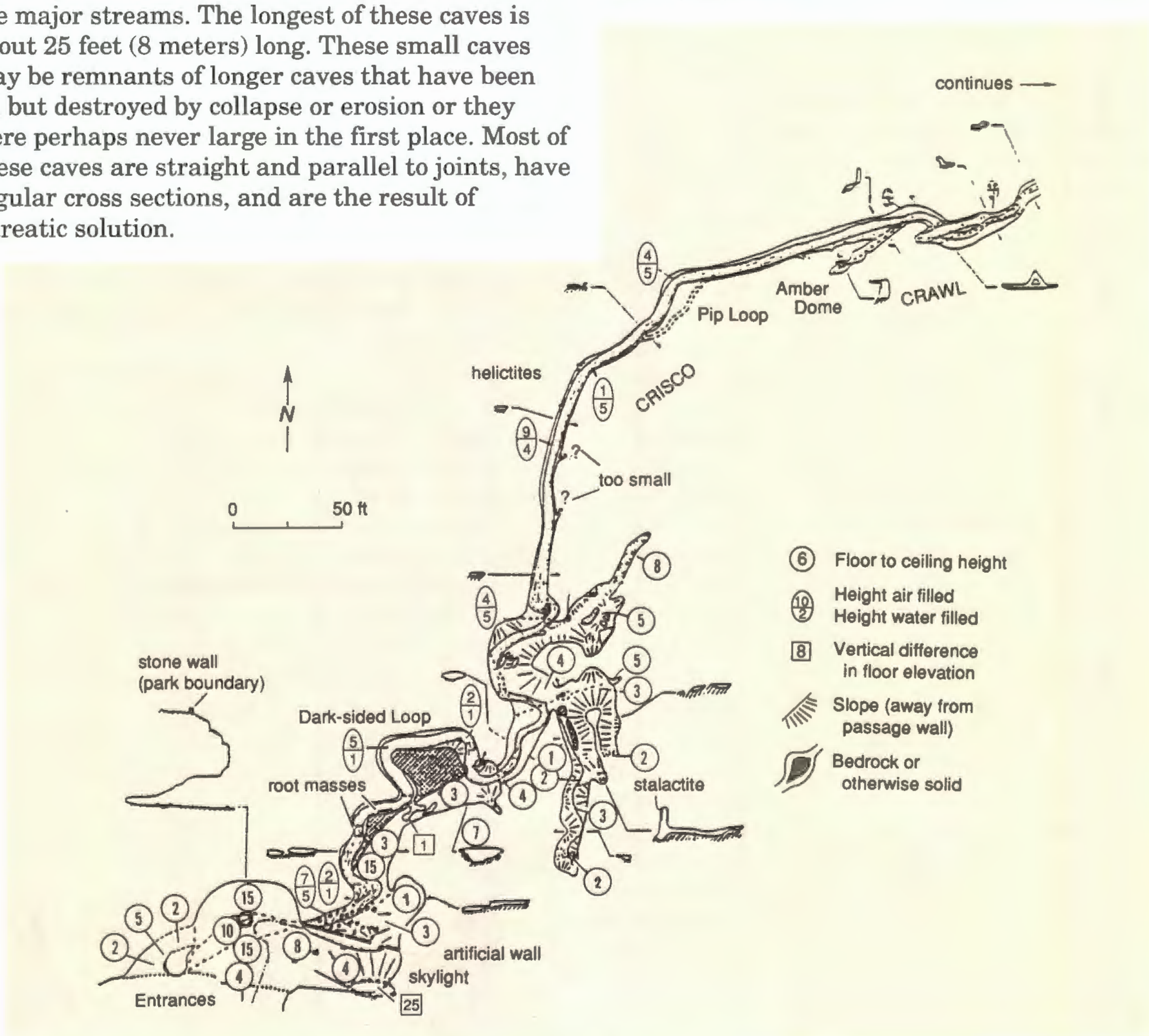
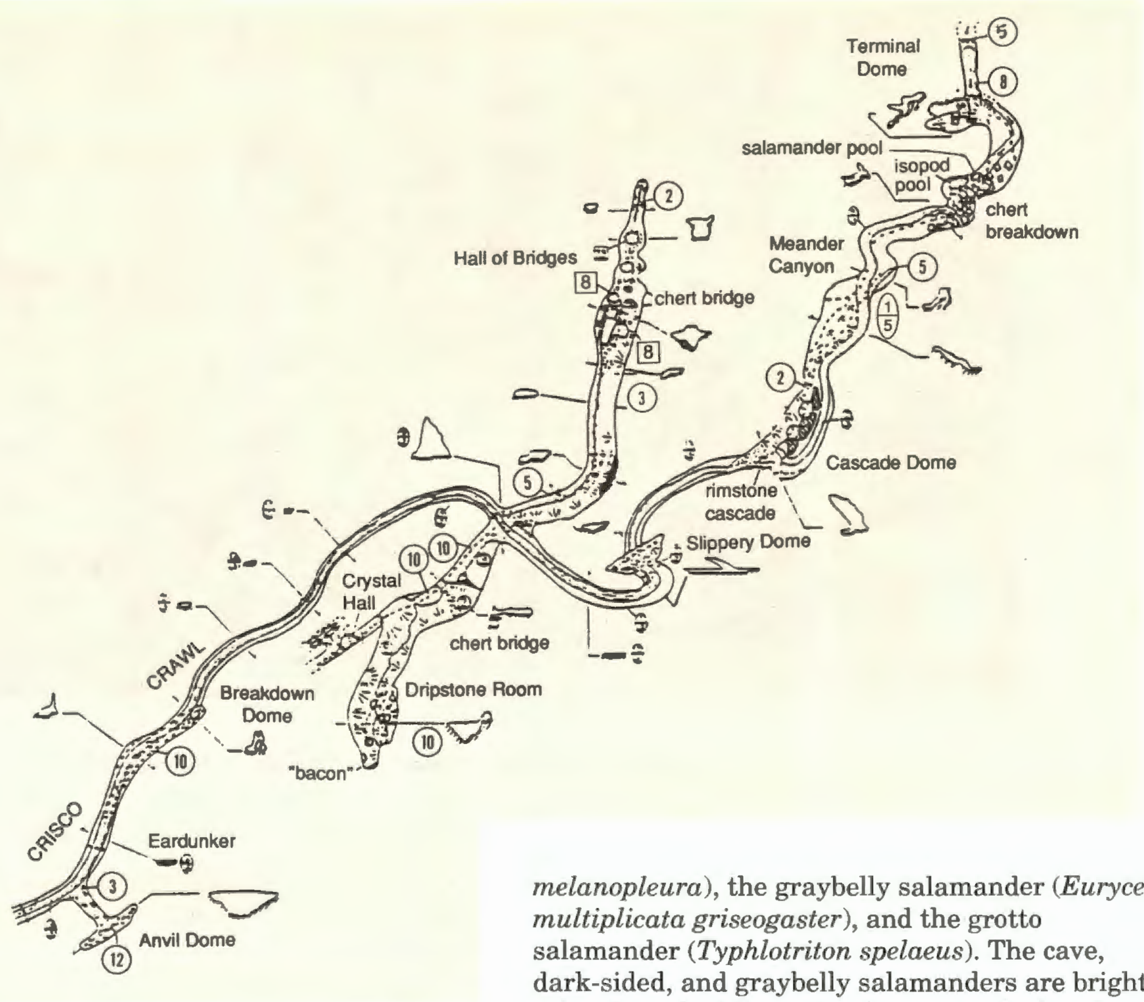


Figure 12. Large cave in Cherokee County formed in the Keokuk Limestone. Cave length is 2,566 feet (782 meters). Surveyed by Jonathan Beard, James Young, Gary Simmons, Wayne White, Chris Beard, and Janet Williams.



Unusual phenomena have resulted from extensive lead and zinc mining. Pumps were used to prevent the mines from filling with water, a process that lowered the surrounding water table. As a result, surface sinkholes developed, some several miles away from the pumping, because they lost the support of the water below. Most of these "new" sinkholes are actually fossil sinkholes that formed long ago, refilled later with rock and mud, and now are empty again.

Four Kansas Ozarks caves

The largest cave in Cherokee County formed in the Keokuk Limestone. Its large entrance dimensions [58 x 20 feet (18 x 6 meters)] are somewhat misleading—within 80 feet (24 meters) of the dripline, the passage becomes a crawlway that has been mapped to a length of 2,566 feet (782 meters). This cave is the only known significant Kansas habitat for four Ozark species: the cave salamander (*Eurycea lucifuga*) (plate 5), the dark-sided salamander (*Eurycea longicauda melanopleura*), the graybelly salamander (*Eurycea multiplicata griseogaster*), and the grotto salamander (*Typhlotriton spelaeus*). The cave, dark-sided, and graybelly salamanders are brightly colored troglophiles or trogloxenes and often forage for food outside the cave when conditions are cool and damp, but the troglobitic grotto salamander is nonpigmented and blind as an adult and cannot survive outside the cave. Other animals living in this cave include troglobitic aquatic isopods (crustaceans), numerous leopard frogs, eastern pipistrelle bats, and occasional migratory gray bats. Because of the presence of these species, some officials consider this cave the most faunistically important cave in Kansas and thus in need of protection.

As the map of the cave shows (fig. 12), most of the passage is a low streambed that rarely exceeds 2 feet (0.6 meter) in height. This stream is not the cave stream that created the large front section of the cave or the major cross-passage near the end of the cave (plate 6). At one time the main passage of the cave was rather large, extending from the far reaches of the cave to the entrance. The cross-passage was a section of the original cave passage before a collapse and clay fill cut off the main passage. When the main passage became blocked, the cave stream abandoned it, dropping to a lower

Figure 13. Calcite "dog tooth spar" crystals, Crystal Cave (formerly known as Tiff Cave), Jasper County, Missouri (photo courtesy of Tri-state Mineral Museum, Joplin).

base level. This low stream passage is now the only continuous passage in the cave. Because of its low nature, the cave is dangerous. Cave explorers can easily get hypothermia in the cave stream. In addition, the cave is prone to dramatic flooding, as evidenced by flood debris in the ceiling cracks.

Jennings Cave is 201 feet (61 meters) long. It is a strong contrast to the preceding cave in that it is short and dry and developed in the Warsaw Limestone far above an active stream. It has a small sink entrance that leads to a twisting, contorted passage with crawlways and loops. Except for its unusual dryness, it is a good example of a typical Ozarks cave. Perhaps the most notable feature of this cave is the contrast between the ceiling rock and the inner-wall rock. Although both rocks are bedrock, the ceiling (and outer-wall) rock is fractured and cherty, whereas the inner-wall rock is not fractured, has no chert, and has been dissolved to form grotesque shapes. There is no consensus among geologists on the cause of this phenomenon.

One Kansas cave in the Tri-state area, named the Tri-state Mine Cave, was discovered by mining operations. It is a short, 80-foot-long (24-meter-long) cave that has two entrances that soon merge inside; it is presently submerged in an inundated, abandoned pit mine. Many small caves in the Tri-state district were found during mining, the most famous of which, Crystal Cave [formerly called Tiff Cave; 220 feet (67 meters) long], was a commercial cave in Joplin, Missouri, until 1914 (fig. 13). Often these small caves contain galena and sphalerite crystals and calcite. Some are so completely crystal lined that they can be considered giant geodes. Most mines were fossil sinkholes filled with ore-rich breccia. These mines, which have a large concentration of ore in one place, are called "circles." The caves found diverging from the circles, also filled with ore, were called "runs." Tri-state Mine Cave is such a cave, but it is currently inaccessible.

Also in Cherokee County is a fossil sinkhole cave. This collapse is 100 feet (30 meters) wide and 80 feet (24 meters) deep. Although the sinkhole is not within the Kansas Ozarks (actually, it is in the Cherokee lowland), it owes its current existence to the mining in the Ozarks. The small cave at its bottom is developed in the same cherty, crinoidal Warsaw Limestone as several nearby Ozarks caves. It is nearly all crawlway and extends approximately 120 feet (37 meters) to a complete mud plug. However, local residents say the cave has occasionally been washed out by floods and has been explored much farther. The owner has forbidden anyone to enter the sinkhole or the cave.

Limestone caves of the Osage cuestas

The Osage cuestas region covers much of the eastern third of Kansas—from the state line west to the Flint Hills. Bedrock in the Osage cuestas formed during the Pennsylvanian Period of geologic history, about 290–330 million years ago. Residual soil, alluvium of stream valleys, glacial deposits (in northeastern Kansas), and wind-blown materials (loess) cover much of the bedrock. However, the Pennsylvanian bedrock is exposed in the walls of stream valleys. The caves of the Osage cuestas are located in these valley walls.

Warm climates and swampy land were characteristic of the environment during the Pennsylvanian, when these rocks were deposited. Dense tropical forests of giant club mosses and huge hollow-stemmed horsetails—whose rotted and highly compressed remains form the seams of coal found today—covered this landscape. Coal beds and some of the shales in the Osage cuestas were created in those Pennsylvanian forests, but the cave-containing limestones and most of the shale divisions were deposited in shallow seas.

Rock layers in this region reflect repeated inundations by shallow Pennsylvanian seas. Evidence of shoreline fluctuations can be seen in the sequence of repeated rock layers that is typical in this area: interbedded limestones and shales. In general, shale was formed from mud left behind by growing or receding seas, and limestone formed from the calcite of organism remains in the open sea. Dozens of these sequences of rock layers are found in the Osage cuestas. The more extensive and longer-lasting submergences built the thicker limestone layers necessary for cave formation.

Caves in the region are formed in hills called "cuestas," which are characterized by steep inclines on one side and gentle slopes on the other. Because the Pennsylvanian rocks dip gently to the west, hills in the Osage cuestas have steeply sloping east faces and gently sloping west faces. Harder cave-containing rocks, such as limestones and sandstones, cap the uplands, which face eastward, whereas weaker rocks, chiefly shales, form gently rolling plains and lowlands between the outcropping escarpments (fig. 14). It is easy to imagine a cave perched high on an east-facing cliff of an Osage cuesta. Caves are sometimes located on the face of the cuesta, but just as often they are located on the south side, where an eastward-flowing stream cut has exposed the opening.

By 1990, the Kansas Speleological Society had recorded over 100 limestone caves in Pennsylvanian rocks in 16 counties covered by the Osage cuestas. These caves are relatively small because the limestone units are thin, generally only a few feet thick. The longest cave in the region, Cave Spring Cave in Miami County, has been mapped to a length of 629 feet (192 meters). Only 11 other caves located in the Pennsylvanian limestone are over 100 feet (30 meters) long. Some are as short as 7 feet (2 meters)—the distances explorers are able to crawl into small spring caves. Several shelter caves in the vicinity of Table Mound, east of Elk City Lake in northwestern Montgomery County, have lengths between 10 and 31 feet (3–9 meters) and three in Jefferson County have recorded lengths of 8, 12, and 20 feet (2, 4, and 6 meters).

Caves in the Argentine Limestone Member

Cave Spring Cave, the longest cave in Pennsylvanian limestone in Kansas, is found in the Argentine Limestone Member of the Wyandotte Limestone (fig. 15). West-flowing South Wea Creek has cut through the Argentine limestone, exposing this Miami County cave in the valley wall. The cave's passage trends north-northwest, and its south-southeast-facing entrance drains its water into a pond whose overflow runs into South Wea Creek.

The Argentine Limestone Member is light olive gray to grayish orange, thin-bedded, and cherty in the area of Cave Spring Cave. The 629 feet (192 meters) of surveyed passage in the cave is mostly a stooping or hands-and-knees crawling passage through water. In several places cave explorers

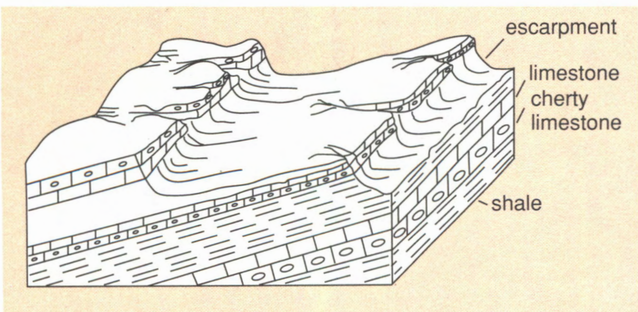


Figure 14. Diagram of a cuesta.

must lie in water to slide under areas of low ceiling. Chert nodules protruding from the ceiling and walls make the crawl more difficult. As in

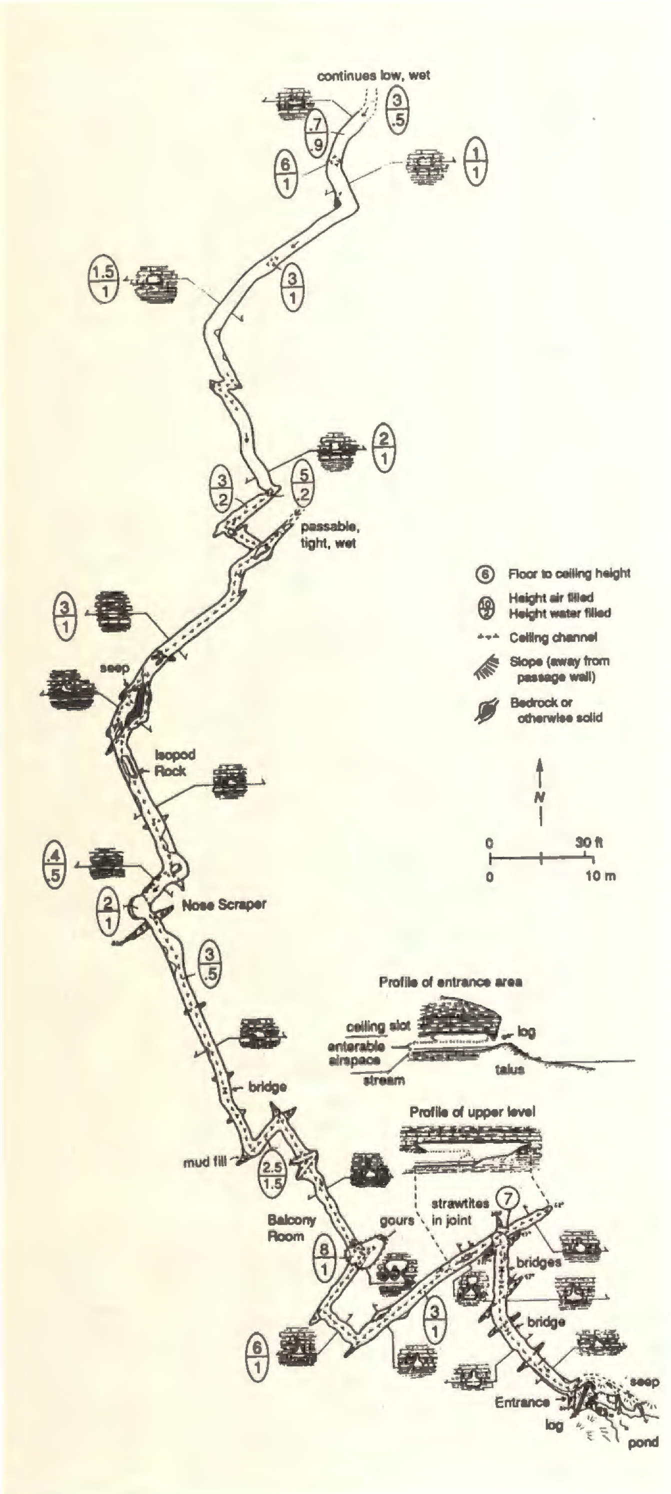


Figure 15. Cave Spring Cave. Cave length is 629.1 feet (191.8 meters). Surveyed by Jonathan Beard and James Young.

Jack Spring Cave in the Flint Hills, Cave Spring Cave's cold water and demanding passage make a wet suit mandatory to avoid the danger of hypothermia.

Of the seven Argentine limestone caves recorded in Miami and Johnson counties, the most notable is Blackbob Cave in Johnson County (plate 7). This cave is an east-southeast-facing spring cave with 94 feet (29 meters) of traversable passage. The stooping passage ends at a travertine waterfall rising 3 feet (0.9 meter) above the 2.5-foot-deep (0.7-meter-deep) water. An 8-foot-wide (2-meter-wide) dam, which comes within inches of the ceiling, blocks further passage. The cave is best known as a source of drinking water for Indians and early settlers in Johnson County.

Caves in the Captain Creek Limestone Member

Several small caves are located in the Captain Creek Limestone Member of the Stanton Limestone. The Captain Creek is a gray limestone that weathers to almost white; it is cavernous in the upper part. The limestone is locally fossiliferous and contains calcite veinlets. Four small spring caves are formed in the Captain Creek in Wilson and Montgomery counties. Of the three spring caves in Wilson County, Harper Spring Cave is the longest. At the base of a 30-foot (9-meter) cliff, along Crooked Creek, are two entrances, one 18 × 24 inches (0.5 × 0.6 meter) and the other 6 × 24 inches (0.2 × 0.6 meter). They are 20 feet (6 meters) apart, and the water flowing through them is about 6 inches (0.2 meter) deep. The landowner, who uses the cave water for drinking, does not encourage cave exploring. The owner claims that the cave has a room tall enough to stand in at a distance of 300 feet (90 meters) from the entrance.

The majority of caves found in the Captain Creek Limestone Member are located on Table Mound in Montgomery County. Here 20 shelter caves are formed under boulders at the edge of the hilltop. Caves formed in this fashion are called talus caves, but only two of the 20 caves can really be considered talus caves. The group of 20 caves is often called the Drop Leaf Caves in reference to Table Mound. The Osage Indians lived in this area and sometimes used these caves for shelter. Some of the caves are located on the hiking trail at the top of Table Mound (fig. 16).

Caves in the Plattsmouth Limestone Member

The Plattsmouth Limestone Member of the Oread Limestone is younger than the other cave-bearing limestones in the Osage cuestas. It is light gray, thin, and irregularly bedded. The Plattsmouth Limestone contains seven caves over 100 feet (30 meters) long.

Thirteen of the 16 caves in Chautauqua County formed in the Plattsmouth limestone. Most are small crawlways or shelter caves (fig. 17). The four longest caves have estimated lengths of 120, 150, 400, and 600 feet (37, 46, 120, and 180 meters). However, attempts at surveying the caves have all been foiled by high water levels.

Six caves in Franklin County are unlike other caves in the state. These caves formed not in an individual rock unit but between two units—the Plattsmouth Limestone Member and the underlying Heebner Shale Member (also part of the Oread Limestone). This type of cave is called a contact cave because the surface where two rock units meet is called a contact. Ceilings in these caves are Plattsmouth limestone, whereas the walls and floors are washed-out Heebner shale. The caves

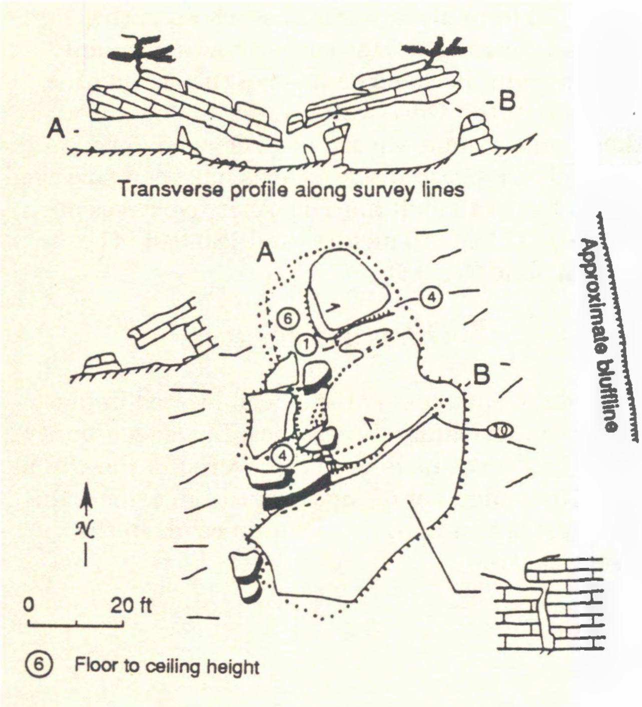


Figure 16. Talus Cave. Cave length is 81.9 feet. Surveyed by Jonathan Beard, Orlan Underwood, James Potts, Sherry Ashberger, Joe Page, Don Koller, and Eve Wright.

Figure 17. Entrance to Dry Crawl Cave, Chautauqua County (photo by Jim Young).

appear to form along joints observable in the limestone ceilings; these caves show some joint enlargement, perhaps because of the action of phreatic water. Once water began to flow through these joints, shale was rapidly removed, forming the caves. The longest of these caves has been surveyed to 465 feet (142 meters). The other five caves are between 32 feet (10 meters) and 136 feet (41 meters) long (fig. 18).

Other small caves

To date, small caves have been located in four other Pennsylvanian limestones. In Osage County three tiny caves have been discovered in the Utopia Limestone Member of the Howard Limestone, the youngest strata known to contain caves in the Osage cuestas.

Four shelter caves near Independence in Montgomery County are formed in the Drum Limestone—the oldest known cave-bearing rock in Kansas Pennsylvanian units. Because they are located near Independence and have not been protected, these caves have been heavily vandalized.

Two caves have been discovered in the Ervine Creek Limestone Member of the Deer Creek Limestone. One, in Elk County, is a small shelter cave with a spring. The other, in Greenwood County, is reportedly a 200-foot-long (60-meter-long) tight, wet crawlway.

An additional cave-bearing limestone is the Toronto Limestone Member at the base of the Oread Limestone. Three talus caves in Jefferson County have formed in large blocks of Toronto limestone. Some of their history is revealed by their names—Bear's Den Cave, Animal Fissure Cave, and Fissure Too Cave.

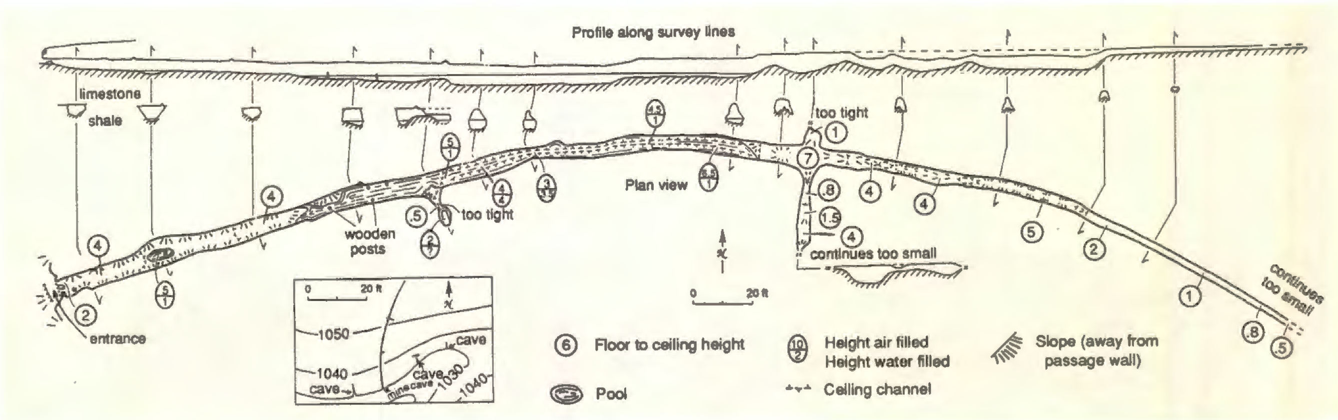


Figure 18. Mine Cave, one of the longer contact caves in Franklin County. Cave length is 465.2 feet. Surveyed by Jonathan Beard, James Young, and Thomas Grey.

Caves of the Flint Hills

As settlers moved across eastern Kansas in the 1800's, they were quickly discouraged from farming by the thick chert gravel—also called flint—that blanketed the earth in a swath from Washington County in the north to Cowley County in the south. Instead of cultivating the ground, they turned to ranching. The Flint Hills remain a largely treeless grassland, mostly the result of shallow soils, prairie fires, and drought that limit trees to stream bottoms.

The eastern escarpment of the Flint Hills rises 200–300 feet (60–90 meters) above the Osage cuestas, commonly in two or three closely spaced steps with broad uplands in between. Alternating layers of limestone and shale crop out in belts running in a north-south direction. The limestone layers, which are more resistant to weathering, form benches or escarpments, and the softer shale layers, which weather more readily, form steep eastward-facing slopes between the limestone ledges. These upland surfaces slope gently westward. The regional dip of the surface strata varies from 40 to 80 feet per mile (8–15 meters per kilometer), or less than 1°. Westward-sloping steplike hills also are found in the Osage cuestas to the east, but they lack the chert that accentuates the resistance of the hard limestone layers.

Limestones of the Flint Hills were deposited early in the Permian Period, about 280 million years ago. Chert-bearing rocks in the Flint Hills have an overall thickness of 800 feet (240 meters) and are divided into three groups (in descending order, from youngest to oldest): the Chase, Council Grove, and Admire Groups.

Caves have been found in five limestone beds in the Flint Hills. Four of these units—the Cresswell Limestone Member, the Fort Riley Limestone, the Florence Limestone Member, and the Threemile Limestone Member—are in the Chase Group (see fig. 4). A few small pits have been found in a biostrome—a bed of rock formed by layers of marine fossils—within the Bennett Shale Member of the Red Eagle Limestone in the Council Grove Group. Flint Hills caves can be grouped according to the age of the strata in which they are formed. The following discussion begins with caves in the youngest strata and then proceeds chronologically to the oldest. The character of the caves is controlled by the limestone unit in which the caves formed.

Caves in the Cresswell Limestone Member

The Cresswell Limestone Member is the youngest cave-bearing limestone in the Flint Hills, but only a few tiny caves have been found in the Cresswell in Butler and Cowley counties. One small cave, located in the Cresswell east of the spillway at Santa Fe Lake, is an excellent example of how joints control the formation of caves in the southern Flint Hills (fig. 19). The customary state lake fee must be paid to gain access to the cave, but no special permission is required. Between the spillway and the cave to the east, large cracks in the flat limestone form a distinctive checkerboard pattern. The edge of this limestone plateau is directly over the cave. Cracks—enlarged joints—can be easily traced directly above the cave's passages, and the direct relationship between the cave and the joints is easily seen. The pattern of these joints remains the same throughout the southern Flint Hills and controls the direction of cave passages and the stream pattern and major drainage ways.

Caves in the Fort Riley Limestone Member

The Fort Riley Limestone Member of the Barneston Limestone is older than the Cresswell and contains most of the Flint Hills caves, including some of the state's longest caves. Most of these

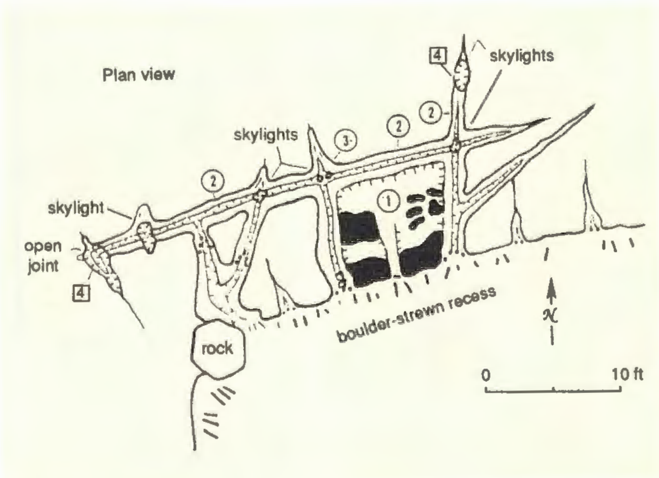


Figure 19. Santa Fe Lake Cave, whose passages are determined by joints in the Cresswell Limestone Member. Surveyed by Jonathan Beard and James Young.

caves are wet and must be entered through sinkholes either by rope or by cable ladder. Entering these caves requires special training and equipment, and, as is necessary with all privately owned caves, the caver must have the owner's permission.

Unlike most Flint Hills limestones, the Fort Riley contains no chert. It is divided into three layers. The upper layer is the thickest—up to 25 feet (8 meters). This layer is porous and forms sinkholes, which drain water from the relatively flat uplands. Boulders around these sinks are honeycombed and look like gray Swiss cheese (fig. 20). The middle layer—approximately 20 feet (6 meters) thick—is interbedded with shale and forms the roof of the horizontal cave passages. The passages themselves have developed in the third layer—a pure light-gray limestone in the lower 10 feet (3 meters) of the Fort Riley.

The Kansas Speleological Society knows of approximately 70 caves in the Fort Riley limestone, most of which are in Butler and Cowley counties. This rock layer is relatively thick in these counties [44–55 feet (13–17 meters)]. In places, karst topography extends over several square miles. The Fort Riley Limestone Member is even thicker in Morris County [averaging 67 feet (20 meters) thick], but any sinks and cave passages that may have existed here have been plugged by silt created by years of cultivation. The northernmost cave in the Fort Riley limestone is in Pottawatomie County, in the uplands near Tuttle Creek Lake.

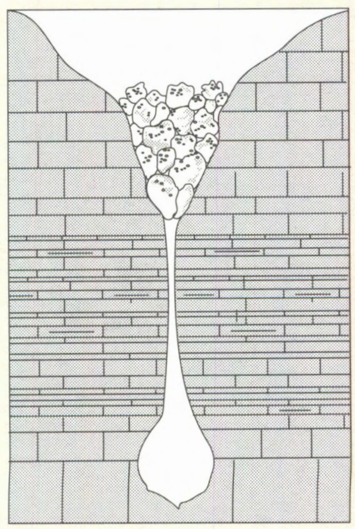


Figure 20. Cross section of a cave passage in the Fort Riley Limestone.

The longest mapped caves in Kansas are found in the Fort Riley limestone of Butler County. Spring Cave and Smith Cave have been mapped to lengths of 8,529 feet (2,512 meters) and 7,285 feet (2,185 meters), respectively (fig. 21). Spring Cave has the only large walk-in entrance left in the Flint Hills, although one once existed in a cave just west of the town of Towanda. The entrance to Smith Cave is typical for the area: a small body-size hole above a 42-foot-deep (13-meter-deep) vertical shaft. Legend has it that boards thrown in the entrance to Smith Cave floated out the Spring Cave entrance, but explorers have not yet made a physical connection between these caves. Unless explorers have a full wet suit to prevent hypothermia, proper caving equipment, and training, these caves are dangerous. Property owners do *not* allow entrance to Smith Cave, but Spring Cave can be entered with permission.

Because cattle ranching is the primary use of land in the southern Flint Hills, many of the sinkhole entrances have been filled to prevent cattle from falling into them. Fill material includes used barbed wire, concrete rubble, asphalt, cars, large appliances, tires, and household refuse. Ironically, ranching has also saved many of the entrances. Water for cattle is provided by windmills located directly above cave streams in natural sinkhole openings called karst windows. Because sinkholes on the surface are directly related to horizontally flowing water below, landowners should exercise care in disposing of wastes in their sinks. In one area a cave stream in a sinkhole was traced to a spring 5 miles (8 kilometers) away.

Hourglass Cave, located in the Fort Riley Limestone Member in Butler County, has been mapped by the Kansas Speleological Society to a length of 3,461 feet (1,055 meters) (fig. 22). It is typical of caves in the southern Flint Hills. The entrance is through a sinkhole 30 feet (9 meters) above the floor of the largest room of the cave. The room is approximately 8 × 12 feet (2.4 × 3.7 meters) with the ceiling nearly as high as the sink entrance. Cave explorers must use rappeling equipment to enter the cave (fig. 23) and, once in the cave, put on full wet suits and protective gear. To explore the cave, one must squeeze into a low-water crawlway over a bedrock floor, which continues for more than 100 feet (30 meters). This is followed by a passage of stooping—and occasionally standing and crawling—height. The standing areas are domes, often located under surface sinks.

These areas occasionally have stalactites, flowstone, and gours, tiny rimstone dams that form on sloping flowstone.

An active cave stream covers the entire floor of the cave. In the entrance it runs under a pile of rubble, and in places large rimstone dams are found in the cave stream. The water depth ranges from a few inches to 3 feet (0.9 meter). Explorers must occasionally totally submerge to negotiate the passage. With a cave temperature of 54°, explorers will chill rapidly without a wet suit for protection.

Several forms of life have been found in Hourglass Cave, including tiger salamanders, leopard frogs, cave crickets, crayfish, isopods (fig. 24), snails, and amphipods. Bats are occasionally found

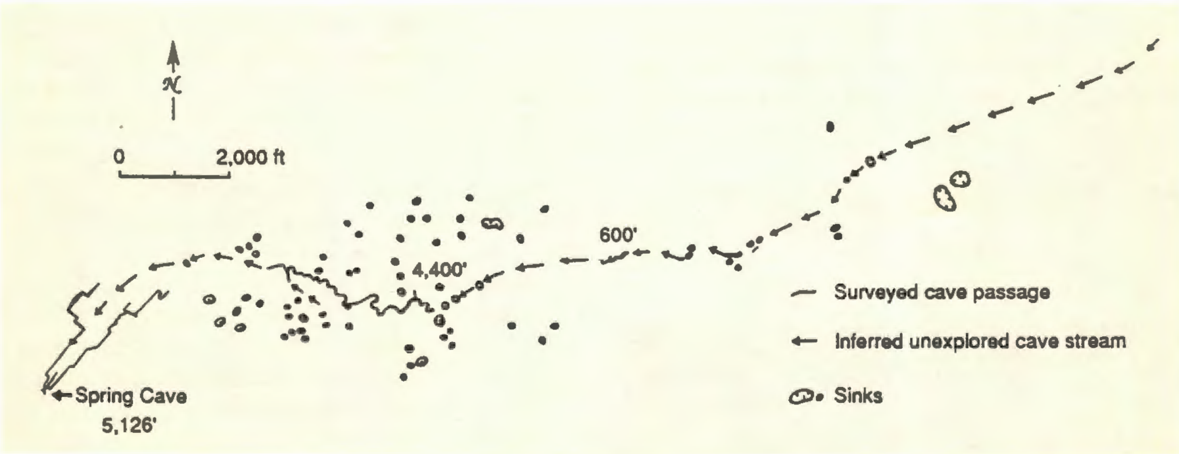


Figure 21. Spring Cave System. Map by Jonathan Beard and Charles Van Arsdale.

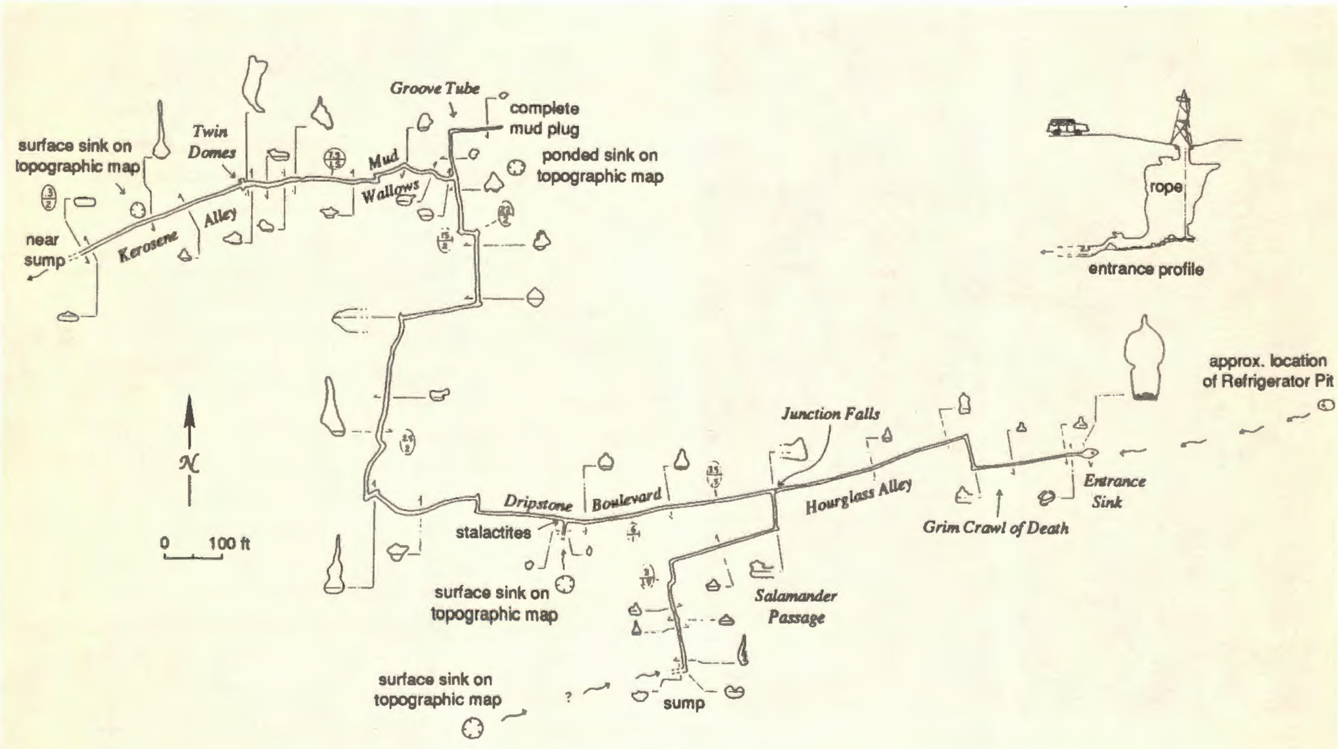


Figure 22. Hourglass Cave. Total surveyed length is 3,460.7 feet. Surveyed by Jonathan Beard, James Young, and Donald Koller.

in other caves in the Fort Riley Limestone Member, but not in large numbers. Members of the KSS have observed fish in Spring Cave, but they are probably from nearby ponds outside the caves and are not a special cave-adapted animal.

Caves in the Florence Limestone Member

A third cave-forming limestone in the Flint Hills is the Florence Limestone Member. It makes up the lower part of the Barneston Limestone and is located below the Fort Riley Limestone Member. The Fort Riley and the Florence Limestone Members are separated by the Oketo Shale Member (see fig. 4). Early geologists referred to the Florence limestone as the Florence flint. It forms a prominent steep hill because of the abundance of chert in it and is one of the limestones that gives the Flint Hills its name. The chert found in the Florence limestone occurs in lenses (bands of side-by-side chert nodules). Chert makes the Florence limestone easily distinguishable from the chert-free rock of the Fort Riley Member.

Figure 23. Looking up into the sinkhole entrance of Hourglass Cave, Butler County. Photo by Jim Young.

Springs and seeps are common along the lower part of the Florence Limestone Member. These are easily recognized from a distance on the prairie by a line of shrubs and green vegetation. The upper layer of Florence limestone forms the gentle slopes of the Flint Hills, which are strewn with residual chert. The edge of the hill is formed by a sparsely cherty limestone that is cellular and porous in many places. Cave passages can form within this middle layer. The floor of the cave is formed by a third layer that has two or more thin fossiliferous shale breaks. The creeks near the springs are floored in shale of the Blue Springs Shale Member, which lies directly below the Florence Limestone Member.

Jack Spring, the largest spring in Chase County, is one such prairie oasis. During periods of low flow it discharges 95 gallons (360 liters) of water per minute, or about 50 million gallons (190 million liters) per year. During periods of increased precipitation, a much greater volume of water is discharged.

The entrance to Jack Spring Cave is picturesque (plate 8). Water flows from several small holes in the base of the limestone wall. The water then cascades over a "hill" of travertine covered with watercress into a small stream. To gain entrance, a caver has to crawl through the flowing water through a hole 18 inches (0.5 meter) in diameter. The hole is better suited for raccoons, which have left their footprints thousands of feet into the cave. After a 40-foot (12-meter) entrance crawl, a stooping passage leads to a small room with a mud bank (fig. 25). Two short, dead-end passages, which lead from this room, suggest previous entrances. The ceiling height in the main passage is approximately 3 feet (0.9 meter); the width of the main passage is 6 feet (2 meters), and there is 6 inches (0.2 meter) of water and mud on the floor. About 1,000 feet (300 meters) into the cave, the ceiling drops to an 18-inch (0.5-meter) maximum height and continues as such for 670 feet (204 meters). In this passage the explorer must slither like a salamander. The latter section of the passage is littered with broken

Plate 1. Graffiti in a Cherokee County cave. Photo by Jonathan Beard.

Plate 2. Strawtites in a Cherokee County cave. These strawtites are 1 inch (2.5 centimeters) long. Photo by Jonathan Beard.

Plate 3. Flowstone. Photo by Jonathan Beard.

Plate 4. Rimstone dam. Photo by James Young.

Plate 5. Cave salamander in a Cherokee County cave. Photo by Jonathan Beard.

Plate 6. Cave location in Cherokee County. Photo by Jonathan Beard.

Plate 8. Entrance to Jack Spring Cave. Photo by James Young.

Plate 7. Blackbob Cave, Johnson County, Kansas. The cave is located in the Osage cuestas region in a Pennsylvanian limestone. Photo by James Young.

Plate 9. Red Hills topography. Photo by James Young.

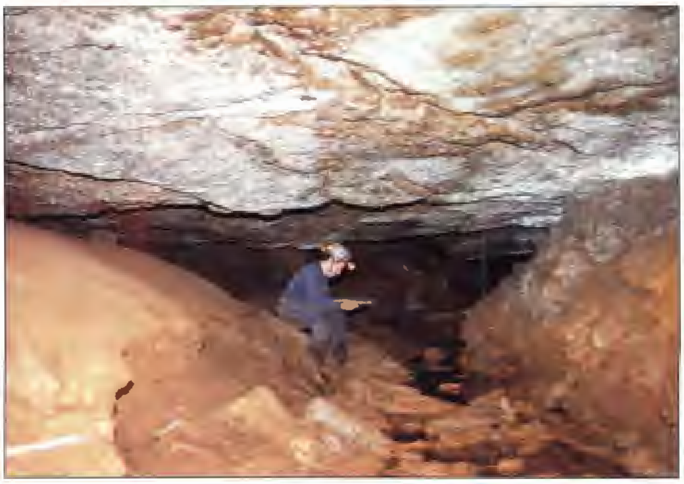


Plate 10. Gypsum passage in Fitch Bat Cave (Comanche County) in the Red Hills region of Kansas. Photo by James Young.

Plate 11. Sink entrance to Long Crawl Cave, Comanche County. Photo by James Young.

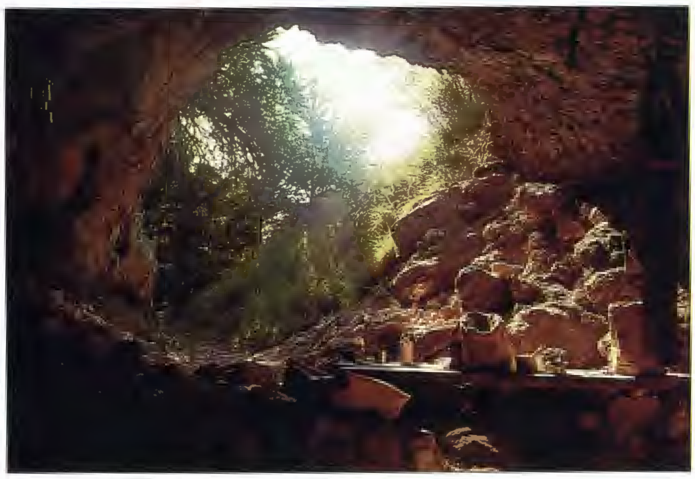


Plate 13. One of several entrances to D.E.S. Cave. Photo by Jonathan Beard.

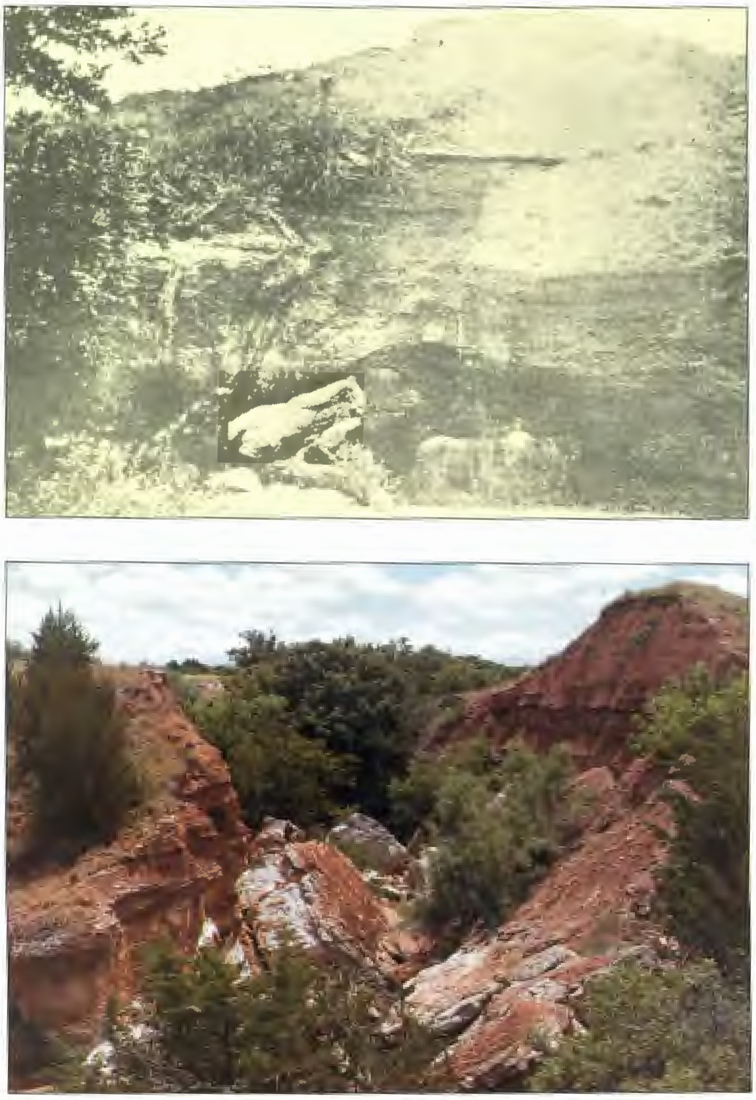


Plate 12. Before and after the collapse of the Sun City Natural Bridge. Precollapse photo by the Kansas Geological Survey. After-collapse photo by Jonathan Beard.

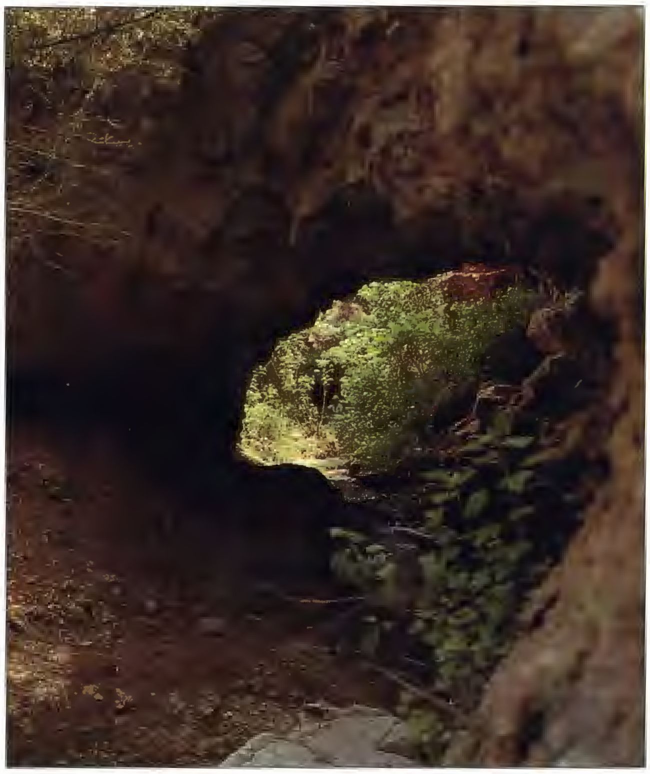


Plate 14. Natural bridges. Photo by Jonathan Beard.

Plate 15. Tiger salamander. Photo by Jonathan Beard.

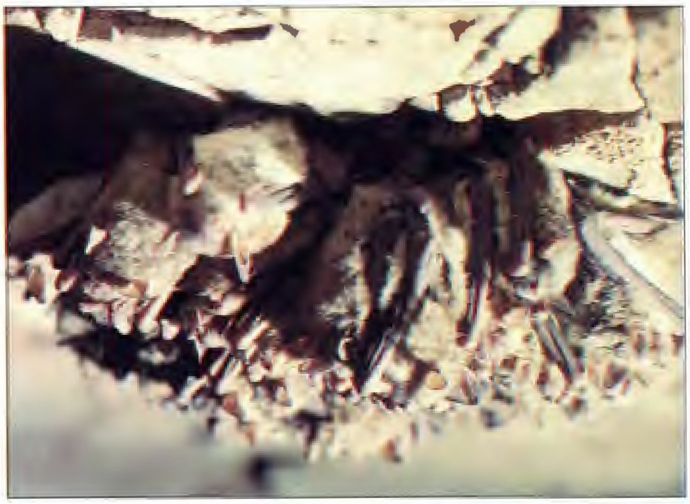


Plate 16. *Myotis velifer* colony. Photo by James Young.

Plate 17. Petroglyph of reclining figure. Photo by Jonathan Beard.

pieces of chert hidden beneath the muddy water—a reminder of Native Americans' use of flint for arrowheads, spear points, and knives. After this area, the cave enlarges to a passage high enough to walk stooped over in and continues as such with periodic crawls for a surveyed length of 4,872 feet (1,435 meters).

This cave is safe only for properly equipped and experienced cavers. Actually this cave is so physically demanding that many experienced cavers have vowed never to return. Without a full wet suit, protective gear, and three or more good waterproof lights, the likelihood of hypothermia and injury is almost assured. Visitation to this

Figure 24. Isopods, Turner's Cave, Butler County (photo by David Griffith). These isopods are about 1 inch (2.5 centimeters) long.

Figure 25. Entering the mud room, Jack Spring Cave, Chase County. Photo by Jim Young.

cave is discouraged because the owner would like the area to remain in a natural, undisturbed state.

Shelter caves in the Wreford Limestone

Another cave-bearing limestone, older and below the Florence Limestone Member, is the Threemile Limestone Member, which is the lowest member of the Wreford Limestone and the lowest member of the Chase Group. Its thickness ranges from 13 feet to 23 feet (4–7 meters). Small shelter caves have formed in a small area in Chase and Wabaunsee counties, where the Wreford has above-normal thicknesses of 25 feet (7.6 meters) and 36 feet (11 meters), respectively, with caves forming in a middle zone of the Threemile limestone that contains few chert nodules.

These caves are dry, small shelters located high on the banks of small creeks formed in the Speiser Shale, which is immediately below the Wreford. These small caves are heavily used by Flint Hills wildlife because they are a source of shelter and are near water and trees. Signs of raccoons, skunks, and pack rats are found frequently; turkey vultures use the caves in Chase County to nest and raise their young in the spring and summer. The vultures' habitat is probably further enhanced by a nearby highway, which provides wildlife killed by passing vehicles.

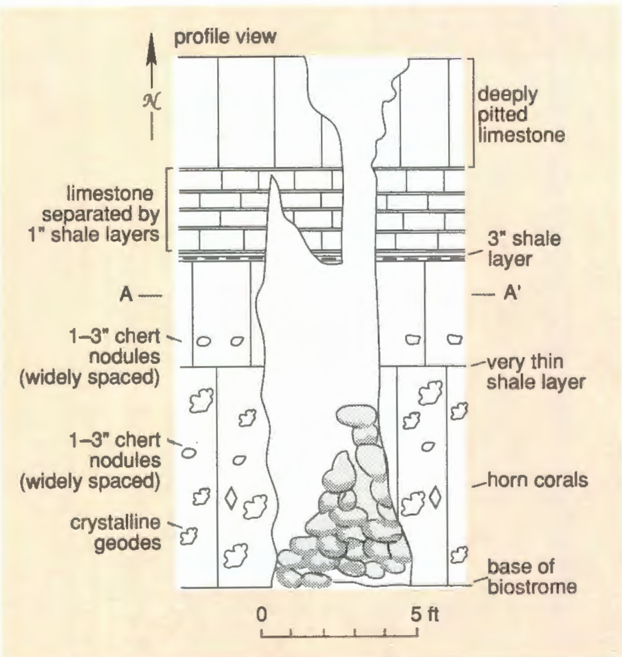


Figure 26. Bobcat Sink Cave, which formed in a biostrome in the Bennett Shale Member. Surveyed by James Young and Gaylen Garinger.

If you discover a Flint Hills shelter cave, please leave things as you find them. They are on private property and require landowner permission to explore. If you encounter an animal in a cave, leave it alone and explore another cave; a trapped animal may attack. Only with everyone's effort can we preserve the scenic Flint Hills and their remaining wildlife.

Biostrome in the Bennett Shale Member

The oldest cave-bearing limestone in the Flint Hills is a biostrome located in the Bennett Shale Member. A biostrome is a limestone layer composed of marine fossils and surrounded by rock of a different kind, in this case the Bennett Shale Member of the Red Eagle Limestone. This biostrome is 1.5 miles (3 kilometers) wide and generally 14 feet (4 meters) thick. It is thicker on the west side and slopes gently to the east. The layer's maximum thickness is 28 feet (8.5 meters) in Lyon County.

To date, four caves have been found in this biostrome, all small pits in Wabaunsee County. They range in size from 5-foot-deep (1.5-meter-deep) Coyote Den Cave to 17-foot-deep (5.2-meter-deep) Bobcat Sink Cave (fig. 26). The caves are merely small rooms with no horizontal passage. In an 1881 description published in the *Transactions of the Kansas Academy of Science*, Joseph Savage tells of his 1879 visit to "a series of caverns of considerable dimensions" in the area of the biostrome. "The caves were ornamented with numerous stalactites and stalagmites, and one little grotto of columnar structures was so finely scalloped and finished, as to almost if not quite excel in beauty of finish any statuary work of man's device" (Savage, 1881, p. 27). This cave has not been found and may be located in one of the trash-filled sinks in the area.

Although the caves of the Flint Hills are usually small and often difficult to explore, they are an important part of the Flint Hills environment. The springs, shelters, and karst landscape are an integral part of the ecology and scenic beauty of the Flint Hills region and must be preserved.

Caves of the Red Hills

The caves of the Red Hills are located in the watersheds of several tributaries of the Arkansas River in south-central Kansas. This area features colorful flat-topped hills and steep canyons with caves and natural bridges so fragile that some have collapsed within memory of residents and visitors. Red Hills caves are among the youngest in the state, and because they are formed in soft gypsum, will be among the first to crumble and wash away.

Sedimentary rocks of the Red Hills were deposited during the Permian Period, 260 million years ago—slightly later than deposition of rocks of the Flint Hills. The Red Hills formed from deposits left behind by the northern section of an ancient inland sea; this section is known by geologists as the Permian basin (fig. 27). The basin covers present-day eastern New Mexico, southeast Colorado, western Texas, western Oklahoma, and the western two-thirds of Kansas. Unlike the Flint Hills, with their thick, cherty limestones and shales, the Red Hills of Barber and Comanche counties are composed of massive gypsum layers, numerous red beds—thick shales and sandstones stained red with hematite (ferric iron oxide)—and minor strata of gray dolomite and green shale. The red beds are the source of the color that led to the naming of the Red Hills. The area shines a brilliant orange-red in the afternoon sun, reminiscent of the Arizona Painted Desert (plate 9). Gypsum, which caps many of the mesalike knobs, is responsible for another of the region's nicknames, the Gyp Hills. Kansas gypsum caves are limited to this region, except for one cave in Dickinson County and a now-filled cave in Sedgwick County.

Gypsum, or hydrated calcium sulfate ($CaSO_4{\cdot}2H_2O$), is a rather soft and brittle soluble mineral. Limestone requires an acidic solution to be dissolved, but gypsum can dissolve in plain water. However, the solubility properties of gypsum have peculiarities, as shown by various chemical tests. Because pure water becomes saturated with gypsum at a concentration of about 1 part gypsum per 400 parts water, dissolving a large quantity of gypsum requires contact with a large quantity of water over a long period of time. The bulk of solution work that creates caves is done when the water is near the saturation point, after the water has already dissolved surface gypsum in the process of flowing toward the eventual cave. Temperature may also play a somewhat minor role, because gypsum dissolves faster as temperature increases to its optimum solubility at 100°F (in which case the saturation point is 1 part gypsum per 368 parts water). If salt [that is, the mineral halite (NaCl)], which is common in the Permian basin, is dissolved in the

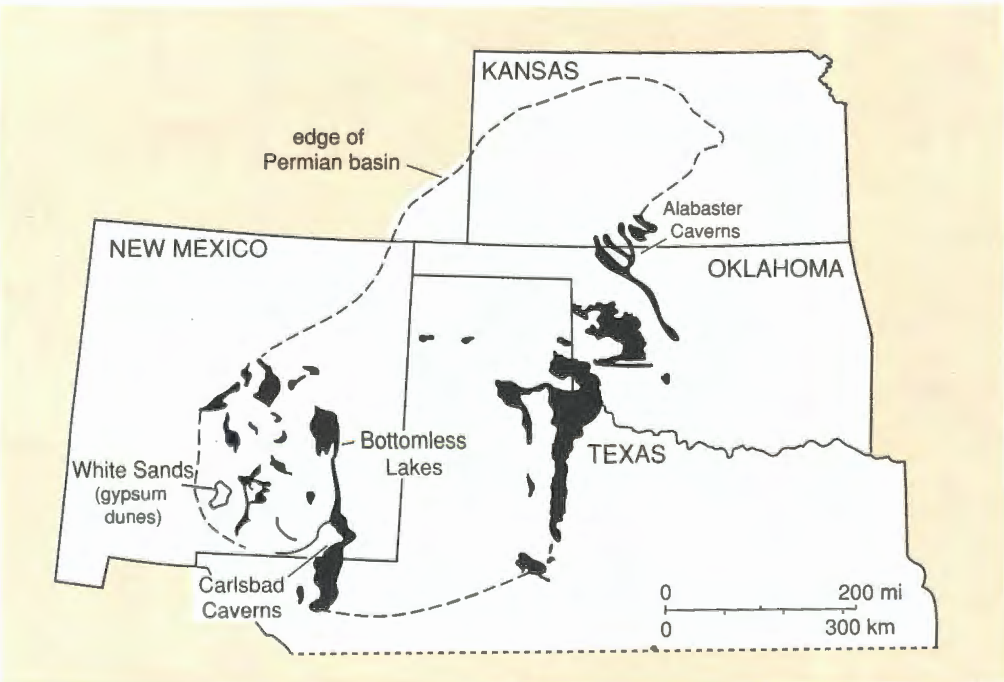


Figure 27. Location of Permian basin. Reprinted from *NSS News* (August 1978).

water before the water comes in contact with subsurface gypsum, the water can more readily dissolve gypsum.

Saturation is quickly achieved when small amounts of water are present. Thus a small amount of water, even over a long time, could never form a large gypsum cave. Some geologists believe that most of the solutional work in the Permian basin caves required periodic flood pulses—good spring rains and strong summer thundershowers. Other geologists believe that, because most of the cave making in gypsum involves nearly saturated water, it can occur with any amount of water if that water is in contact with gypsum long enough to become a stronger dissolving medium. Although gypsum and limestone speleogenesis are similar, the exact cave-making mechanics are not fully understood. Few articles or books have been published on gypsum speleogenesis.

Because of the comparatively rapid solution of gypsum under ideal conditions (gypsum is up to 100 times more soluble than limestone) and because of gypsum's soft and brittle nature, most Kansas gypsum caves are thought to be only a few thousand years old compared to most limestone caves, which are thought to be generally 100,000 to 10 million years old.

Gypsum caves, like limestone caves, form at or just below the water table where water flows through cracks and crevices toward a surface base-level resurgence, or spring (fig. 28). Downward and laterally flowing water below the water table finds joint cracks and bedding planes and, when given enough time, enlarges these cracks through the process of solution, forming passageways. Gypsum caves are subsequently carved by vadose water (water, such as a stream, that flows above the zone of saturation), perhaps more so than limestone caves are and limestone is a harder, more resistant rock. Vadose water not only can dissolve gypsum but can also erode gypsum surfaces by abrasion. Like limestone caves, gypsum caves may contain many original passages created through the action of phreatic water that have been subsequently carved by a cave stream (vadose water) to create vadose trenches or canyons. Caves can be further altered by collapse of unsupported weak ceilings and by filling with silt and debris brought in by cave streams (plate 10). Collapse and subsequent removal of the breakdown by cave streams can cause high-ceilinged chambers in otherwise small caves.

Typical Kansas gypsum caves are 100–300 feet (30–90 meters) long. The caves are located within or near the walls of a surface ravine or canyon and have two or more entrances, including one or more sinkhole entrances (plate 11) that lead to a trunk passage emptying into the ravine (or spring) at an exit opening.

Perhaps the most striking aspect of Red Hills caves is that so many exist in such a small area. The cavernous gypsum outcrops can be found in areas that, if combined, would fit within the city of

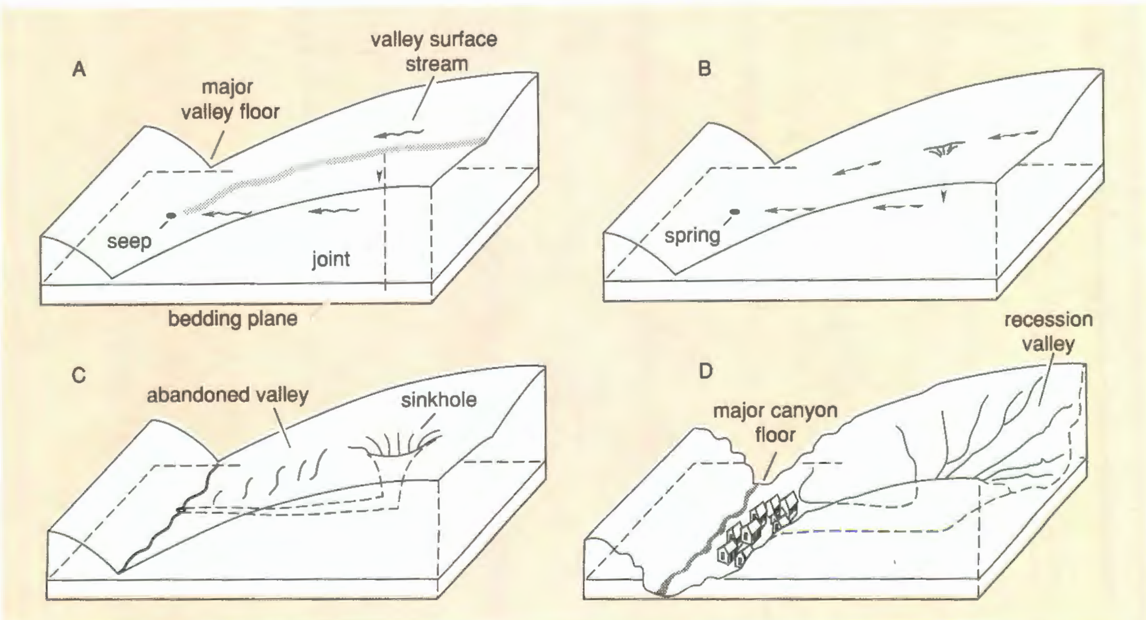


Figure 28. Kansas gypsum speleogenesis. (A) Surface stream is partially robbed of flow by joint in gypsum. (B) More surface water is pirated as joints and bedding plane are enlarged. (C) All water is pirated by enlarged joint-determined sinkhole. (D) Cave as seen today.

Topeka. Yet in that small area there are over 440 caves, ranging from 20-foot (6-meter) shelter caves to 2,930-foot (860-meter) systems. Although most of the passages are crawlways through water or collapse areas, some passages yield 40-foot-high (12-meter-high) rooms.

Barber and Comanche counties, not surprisingly, contain more caves than the other Kansas cave counties combined. Comanche has over 235 known caves. Barber is not far behind with over 205.

Although Kansas can boast of a wealth of gypsum caves, it is greatly humbled by its neighbor to the south. Oklahoma has three Red Hills–type gypsum cave regions, one of which is home to the longest surveyed gypsum cave outside eastern Europe. Jester Cave, at over 6 miles (10 kilometers) in length, has 67 entrances, more than any other known cave in the world. Oklahoma also has the only commercial gypsum cave in the United States: Alabaster Caverns, just south of the Kansas state line in the same gypsum belt as the Kansas Red Hills. For those who shy away from wild, untamed, nontourist caves, this is a good example of a gypsum cave.

Many of the narrower, steeper canyons in the Red Hills are gypsum caves that are unroofed, in whole or in part. The evidence is often ambiguous, but there are some obvious signs—natural bridges and short tunnels that span the canyons. At least sections of some big canyons were caves at one time. How far the ancient caves extended both up-canyon and down is speculation at this point, but it is possible that most or all of the steep-walled portions of the canyons are unroofed caves. Some, if not all, of the present caves of these canyons were side passages to the main caves that are now completely or nearly destroyed. The ancient cave systems in Kansas may have rivaled some of the longest Permian basin caves in other states. Even most modern caves can be considered long bridges or tunnels between sinks and canyons. These too may be destroyed within the next few thousand years.

Some of the sights in the Red Hills cave region have been publicized in the past. The Sun City Natural Bridge was photographed a century ago and was once a tourist attraction. However, in 1963, it collapsed, leaving a pile of gypsum rubble (plate 12). Though gone, it is survived by perhaps a hundred similar bridges of various sizes in the region. These are surviving cave remnants, all that may be left of many former typical caves. The bridges illustrate how short-lived and fragile these caves can be.

Carbonates make up most speleothems worldwide; yet carbonates are rare in the Red Hills, so these caves are nearly devoid of the splendor of stalactites, stalagmites, and other calcite forms normally associated with caves. What few are found are small because of the lack of carbonates and the relative youth of the caves. The longest stalactites here rarely exceed 12 inches (0.3 meter) in length (fig. 29). Besides stalactites, other small speleothems found are stalagmites, ribbed-wall flowstone, boxwork (fig. 30), rimstone dams, cave coral, and cave pearls. Gypsum speleothems are also found, but they too are small. Besides the forms listed for carbonate speleothems, gypsum needles, which precipitate out of silt, and gypsum flowers, which are extruded from walls and ceilings, also occur.

Although speleothems are scarce and often so small that gypsum caves are not considered beautiful by many people, there are some fascinating aspects of this mineral. Gypsum can be found in a variety of colors and textures. Most of the time it is white or gray, but it can be yellow, red, or brown if other minerals such as iron oxide are present. It is also found in the rare form of alabaster, abundant massive rock gypsum, glass-clear selenite, and curiously fibrous satin spar. Add to this some weird, grotesque solutional forms left after the cave's speleogenesis, and there is plenty of beauty.

Progression of cave ruin

Any air-filled cave seen today is undergoing attack from various destructive forces: water that dissolves the cracks in ceilings through which it seeps; rain-swollen cave streams that undermine supporting walls and fill the caves with gravel, silt, and other debris; winds that erode entrance areas; tectonic forces that create cracks in ceilings and walls; and temperatures that freeze water, which in turn acts like a lever to break rocks apart. These forces are especially noticeable in Red Hills caves.

Some caves are young enough or protected enough against these elements to be almost completely intact; they retain the same, virtually unchanged phreatic character as when they were spring systems. However, most caves are suffering from the various causes of ruin. The following examples help illustrate these forces and give the understanding that the existence of most caves, placed into the giant clock of geologic time, is but a few strokes of the second hand.

Caves in their entirety One cave in Kansas typifies a long gypsum cave system. D.E.S. Cave was mapped from 1986 to 1988 at 2,003 feet (611 meters) in length (fig. 31). It drains a small piracy valley in two locations—upper and lower sinks (plate 13). Each sink drains its section of the small valley that once brought the water toward a major canyon before being pirated. The water is still carried to the major canyon, but it is the cave that takes the water most of the way.

The upper sink has eight openings, most of which are skylights (some of which are karst windows) within the outline of the complex sink. These afford entrance for surface water and wildlife. The sink marks the uppermost boundary of the present cave; the narrow gully upstream of the sink is not a collapsed section of the cave but a recession canyon recently deepened by the sink's piracy. The sink is actually a coalescing group of solutional sinks, which, in time, will become one. Passages leading from the sinks soon join at the main passage, which is the streambed.

The main passage—a low, wide streamway—proceeds from the upper sink area to the northeast. After a few hundred feet the passage reaches a large circular sink, the floor of which has been determined by breakdown; that is, the features were not formed from solutional activity. The walls along the southern rim are steep. The large sink is another piracy sink, but the roof along the southern side has collapsed, nearly segmenting the cave. This sink is known as the D.E.S. or Bat Sink.

The passage from the sink is taller than the passage upstream. In several hundred feet it exits the cave by way of a nearly breakdown-blocked resurgence in the deep, unpirated portion of the valley. A wide room near the Bat Sink houses large seasonal colonies of *Myotis velifer* bats, as do other large caves in the area. Just before the resurgence, two upper-level slots drain the upper section of the cave, which is almost completely determined by breakdown, and the lowermost part of the valley.

Because the cave is aligned with the abandoned surface valley above, water from the surface stream found joints, plunged to a bedding plane (often the contact between the gypsum and the Flowerpot Shale below), and began to form the cave. Eventually the joint enlarged enough to rob the surface valley of its water, forming the present drainage.

Segmented systems A typical Kansas gypsum cave system will, on its path to destruction, segment into smaller caves separated by collapse sinks before the roof entirely disappears by means of erosion, solution, or further collapse. A Red Hills cave illustrates the first step in that process. This 518-foot (158-meter) cave is the uppermost segment of a once-long system that was comparable to the afore-mentioned cave, but it is

Figure 29. Gypsum stalactites, Gypform Cave, Comanche County. Photo by Jim Young.

now truncated into three caves primarily by collapse (fig. 32). This cave is a largely intact passage with phreatic features and typical vadose trenches and with little breakdown except near its intake and exit sink openings. The two downstream segments of the broken system are mired with breakdown and silt.

This cave (fig. 32) begins as a horizontal opening at the north end of a wide shallow sink that has cliffed walls only at the cave entrance. The passage is determined by breakdown for the first 50 feet (15 meters) before it changes character. At a left turn, the walls and ceiling are rounded and have all the characteristics of a phreatic solutional passage. A slot in the right wall is the beginning of a loop that rejoins the main passage in less than 100 feet (30 meters). It, too, is free of breakdown. As the cave continues downstream, an ever-deepening vadose trench can be seen. Occasionally, large breakdown boulders can be seen. In a few places, what first appear to be large boulders are, on closer inspection, remnant bedrock forms of the original floor or walls that have not yet been dissolved away.

In the middle of the cave is a right-hand side-passage that decreases in height in its 100 feet (30 meters) of negotiable length. The vadose trench, normally dry in the upstream half of the cave, holds pools of water, even in dry times, near its exit mouth in the bottom of a small but deep, steep-walled sink that completely separates this cave from the middle segment. The cave has bedrock ceiling pendants and some minor dripstone.

Breakdown of caves At the time it was mapped, another breakdown-determined cave in the Red Hills had 339 feet (103 meters) of negotiable passage and large dimensions (fig. 33); it is an example of further decay of a cave system. It is entirely determined by breakdown; that is, no phreatic features remain. The upstream end of the cave has a number of sink skylights. At the time of the survey, its lower entrance, 20 feet (6 meters) high and 25 feet (8 meters) wide, was the largest known horizontal opening in Barber County (fig. 34). However, because of the collapse of the first 20 feet (6 meters) of the entrance area in the summer of 1989, the entrance is noticeably smaller and is strewn with breakdown. The cave has a simple plan view—a main passage with side-passage loops on both sides (see fig. 33).

This cave parallels a ravine. In fact, the ravine's surface stream is pirated by the cave through a short, low slot; the stream travels the length of the main passage and exits at the breakdown-strewn mouth. But this cave isn't the only cave that the ravine waters use. Upstream is another cave in an even further stage of collapse—the 200-foot-long (60-meter-long) Breakdown Cave (fig. 35). It is assumed that the two caves were once one but were severed by the erosion and collapse caused by the encroachment of the surface stream, the brittleness of the rock, and, of course, time.

Figure 30. Calcite boxwork, Fine Arch Cave, Comanche County. Photo by Jonathan Beard.

Slumping of caves A few canyons away from the large Barber County cave mentioned in the preceding section is Sinking Stream Canyon. Much of it is a narrow, vertical-walled canyon. Where it does not have cliffs, it is paralleled by truncated cave segments in advanced stages of ruin. It is believed that the steep-walled sections of the canyon are unroofed cave passages and that under the gentler slopes of the canyon are slowly crumbling roofed segments of cave.

One cave, the canyon's namesake, pirates the surface stream for a short distance before the stream exits, only to enter a second cave, on the opposite side of the canyon, through a small slot. This second cave, Three Level Cave (fig. 36), was surveyed to a length of 239 feet (73 meters). The main passage begins at a small canyonside sink and descends through stream-carved breakdown collapse for virtually its entire length, even after its junction with the heretofore tight stream passage. The stream exits the cave by way of a small slot. There are so many skylights that most of the cave has at least indirect light during the daylight hours.

The surface above the cave is riddled with cracks, holes, and obvious slump. This cave is bound for complete destruction in the not-too-distant future.

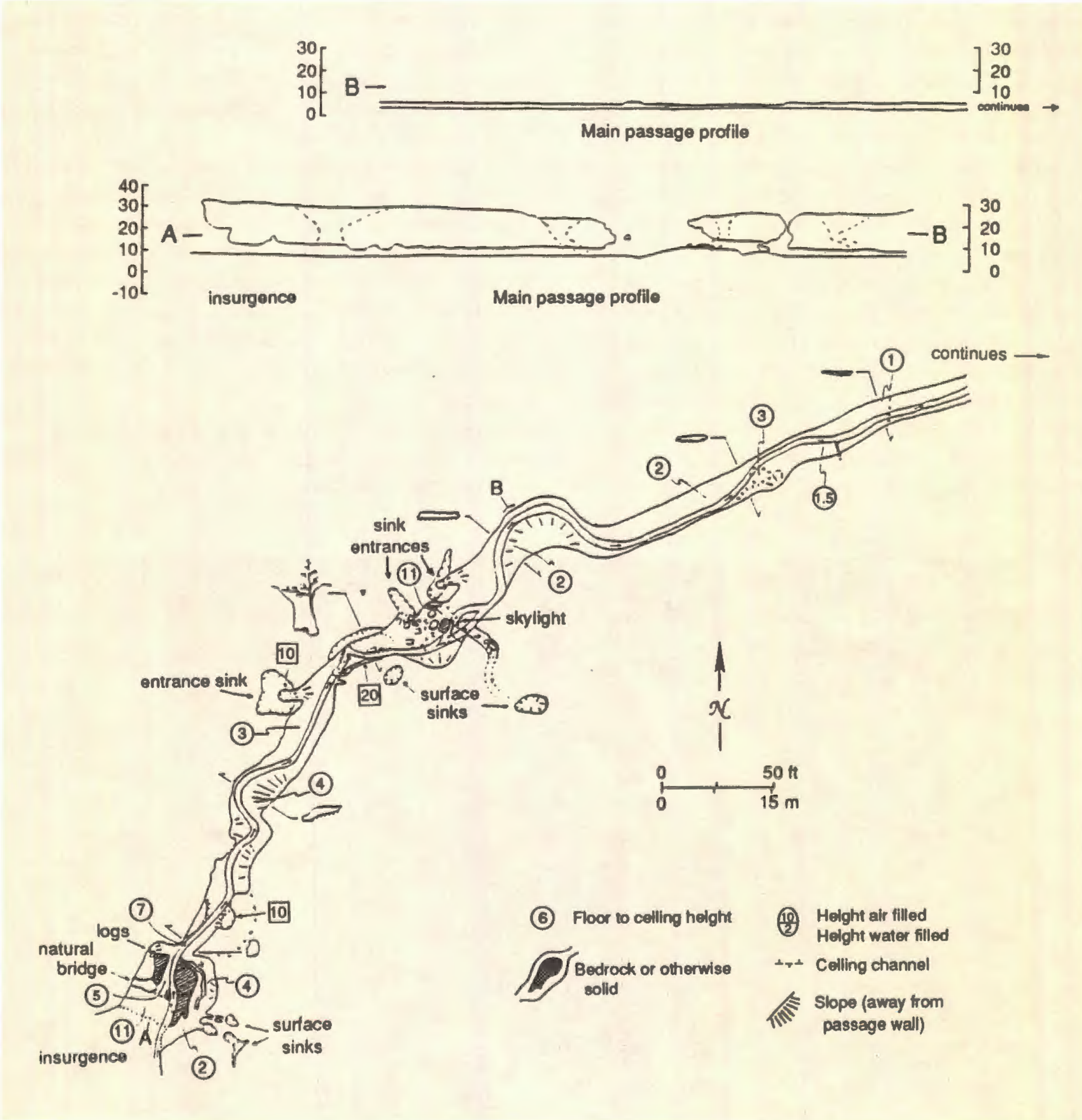


Figure 31. D.E.S. Cave. Total length is 2,003.4 feet (610.6 meters). Surveyed by Jonathan Beard, James Young, and Arlin Pound.

Natural bridges The caves discussed so far are in various stages of erosion and collapse, although the caves are not in complete ruin. There are few recognizable examples of total ruin of giant systems, but the canyon where the next two caves are located may soon be such a case. The roof of a lengthy, ancient trunk passage is totally gone except for two short spans along the canyon. These two natural bridges were surveyed to 108 feet (33 meters) and 41 feet (12 meters) (fig. 37).

They are close enough together that one immediately precedes the other. It is obvious that a long cave once existed here (plate 14). The walls of the narrow canyon on either end of, and between the bridges, are nearly vertical. One can only imagine what this giant cave once looked like. Perhaps it resembled one of the giant 4,000-foot (1,200-meter) systems nearby in Oklahoma. Eventually, all caves in the Kansas Red Hills may look like this section of the canyon—narrow ravines with precipitous walls.

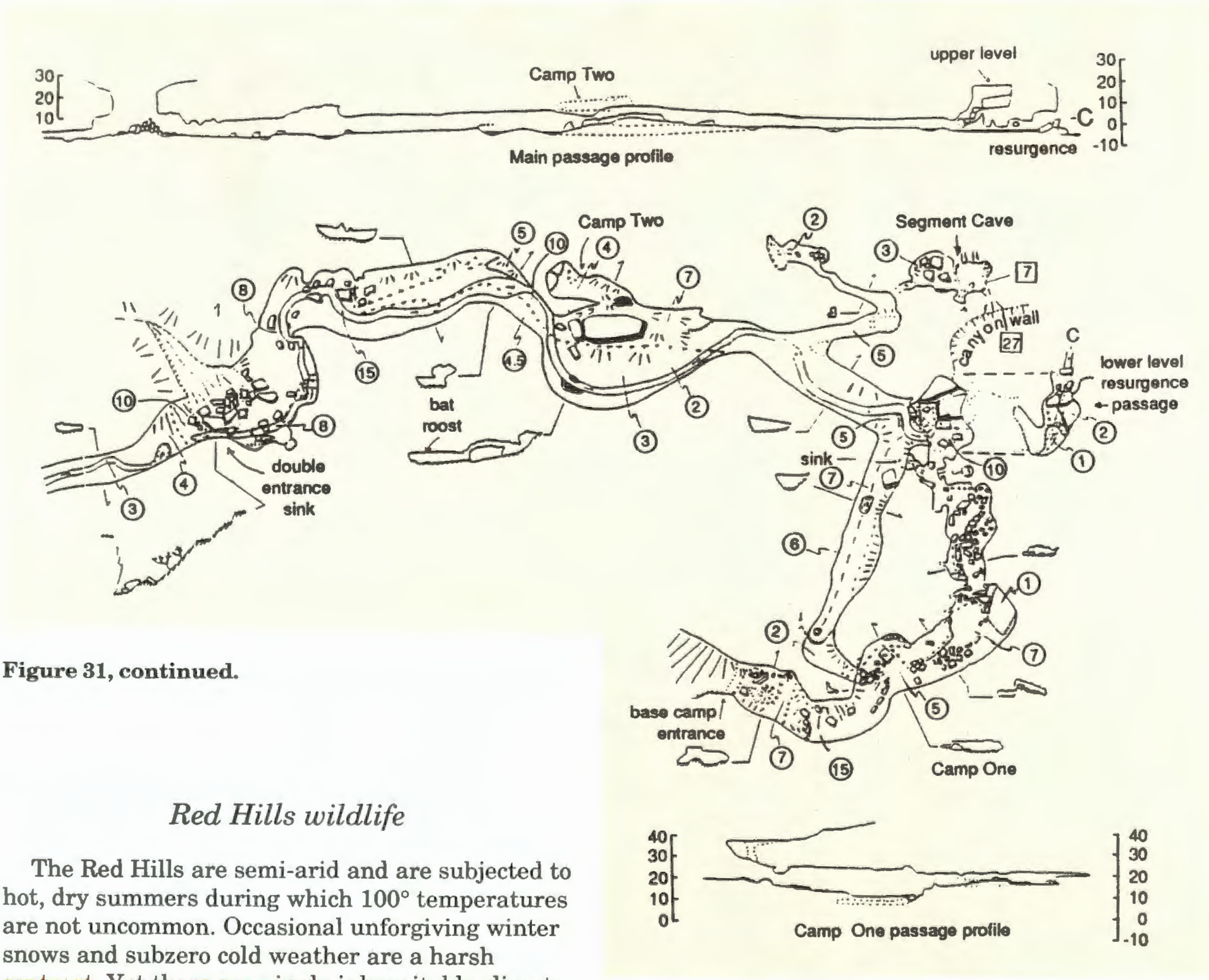


Figure 31, continued.

Red Hills wildlife

The Red Hills are semi-arid and are subjected to hot, dry summers during which 100° temperatures are not uncommon. Occasional unforgiving winter snows and subzero cold weather are a harsh contrast. Yet these seemingly inhospitable climate extremes do not deter the animals found here. Pronghorn antelope stand alert for packs of coyotes, prairie dogs bustle about, birds, including wild turkeys, roadrunners, and burrowing owls, are seen at ground level as vultures wheel in the sky, and collared lizards scurry about. Native plant life consists of such greenery as prairie grasses, pincushion and prickly pear cacti, and occasional trees, such as elm, sumac, red cedar, sandhill plum, and willows, near surface streams and ponds.

Underneath the gypsum canyon walls, however, is a completely different environment. Here the temperatures are much less harsh; in the longer

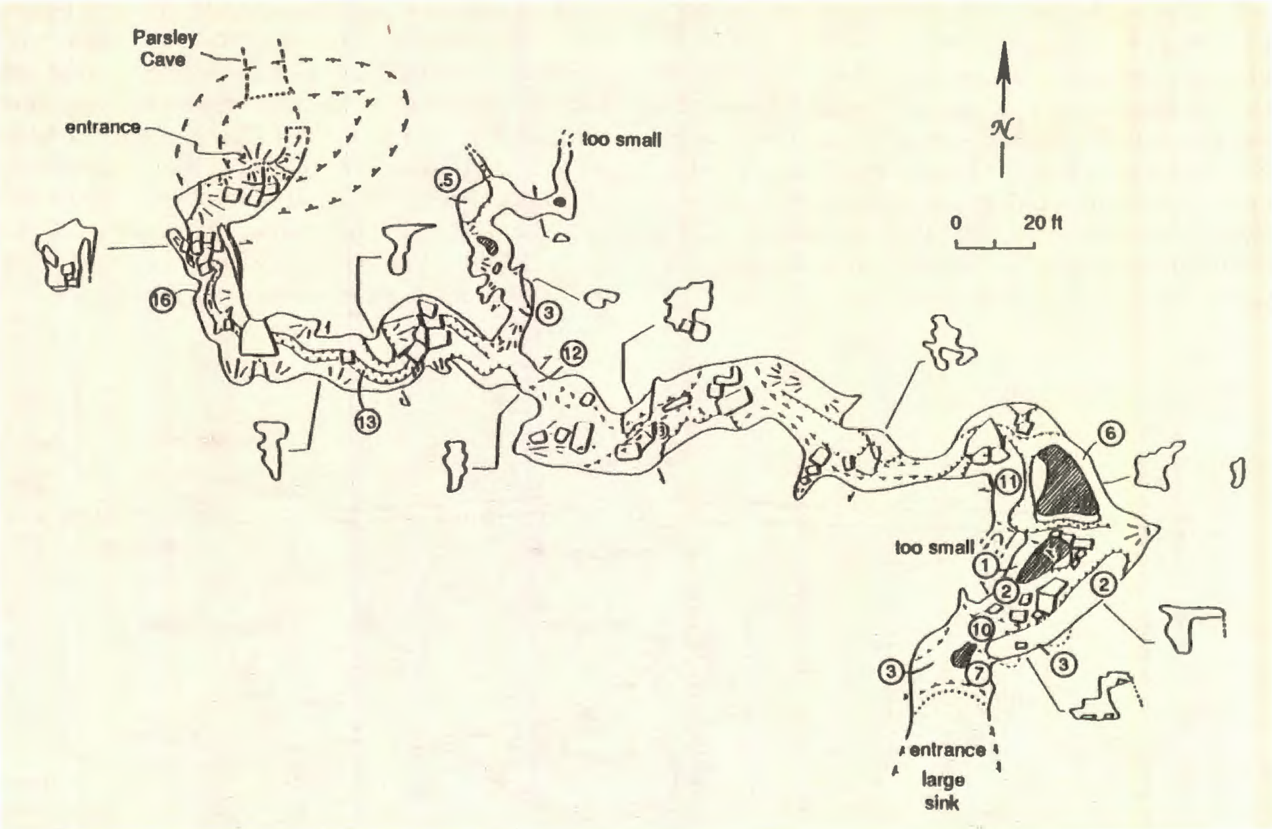


Figure 32. Segmented cave. Total length is 518.4 feet. Surveyed by Jonathan Beard and James Young.

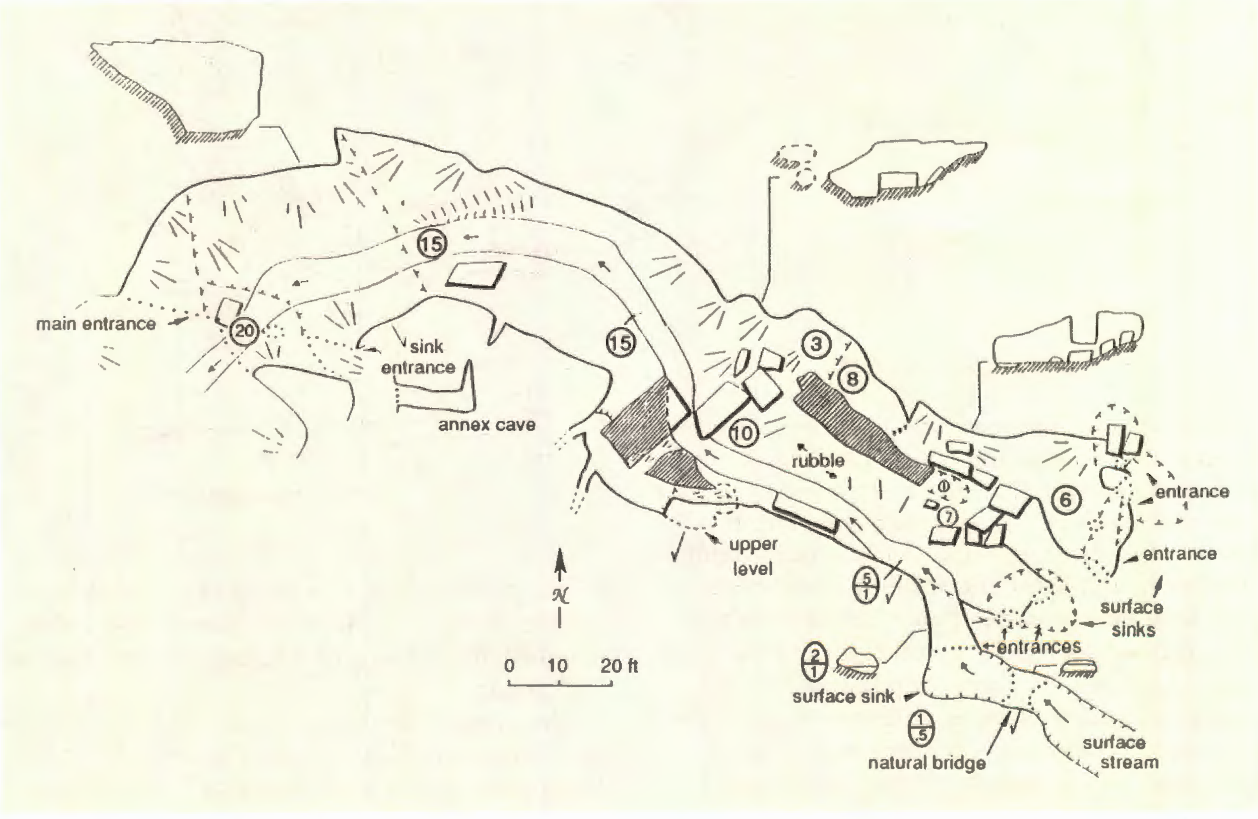


Figure 33. A breakdown-determined cave, which has decayed severely. Surveyed length is 338.8 feet. Surveyed by Jonathan Beard, Arlin Pound, Wayne White, and Renard Gervais.

Figure 34. Entrance of cave in fig. 32 (before collapse) in Barber County. Photo by Jim Young.

caves the temperature varies little, staying a fairly constant 50°–60° all year. The humidity stays relatively high, providing a suitable habitat for such trogloxenic fauna as the tiger salamander and a few species of toads normally associated with rivers, ponds, and marshes. The tiger salamander (plate 15) is the largest terrestrial salamander in the world, sometimes achieving a length of 12 inches (0.3 meter). Other fauna that frequent these caves are mice and rats, whose nests are found in crevices and on ledges; porcupines, whose discarded needles are a bit of a bother for cavers in crawlways; and coyotes and raccoons looking for food and shelter. Less-appreciated prairie rattlesnakes, tarantulas, scorpions, centipedes, and birds such as barn owls and cliff swallows also find homes here.

But the best-known cave inhabitants of the Red Hills, and the most ecologically important, are bats. These much-maligned distant cousins to shrews have incorrectly been given a bad name. They don't turn into Draculas, they are not a major carrier of rabies, they are not blind, they don't get caught in people's hair, they don't attack people, and they don't come from hell. These normally docile, timid creatures are the only flying mammals, and they have perfectly good eyesight. They are expert flyers and are able to change speed and direction better than

Figure 35. Surface slumpage at Breakdown Cave, Barber County. Photo by Jim Young.

most species of birds. Bats are famous for their sonar or, more correctly, echo location. They emit ultrasonic clicks that humans cannot hear. By using their supersensitive ears to catch the echo of their clicks, they are able to determine the size, shape, direction of movement, and distance of objects in front of them. This is useful because bats do most of their feeding at night when their eyes, like ours, cannot see very well.

Kansas bats are ecologically important. A single 2-inch-long (5-centimeter-long) bat will consume 2,000 to 3,000 flying insects each night, including flying bugs such as crop-destroying moths and mosquitos. These insects are capable of transmitting diseases such as encephalitis, meningitis, malaria, typhus, and yellow fever. Bats also do much for caves. The guano (or feces) they produce is the base of a remarkable food chain. Micro-organisms and fungus feed on the guano and in turn become food for insects, which are eaten by larger animals, such as tiger salamanders or mice.

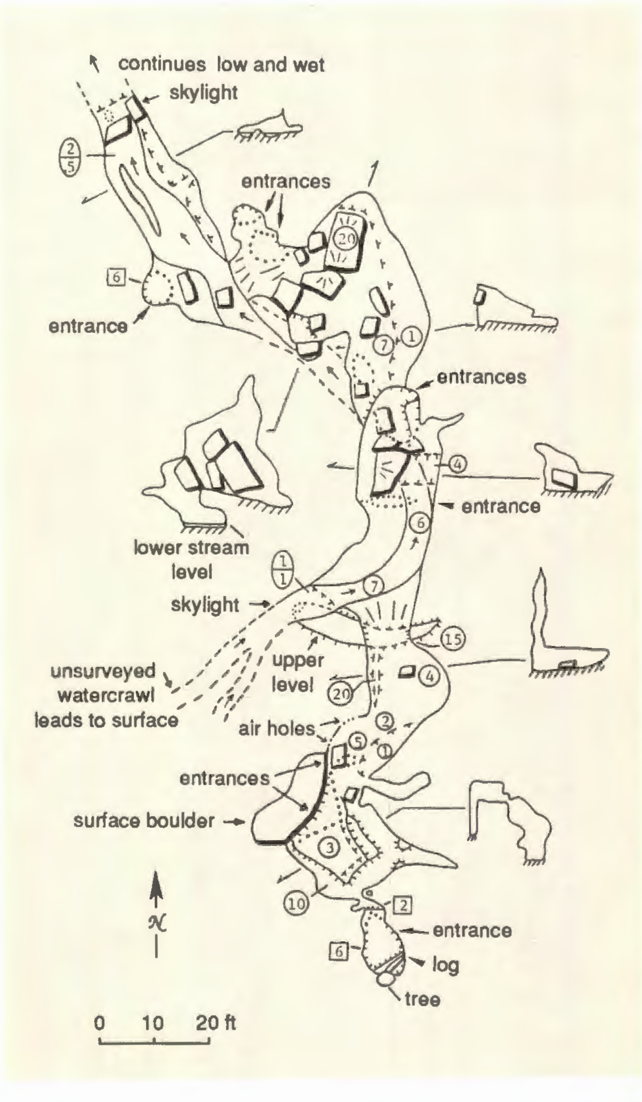


Figure 36. Three Level Cave. Surveyed length is 238.9 feet. Surveyed by Jonathan Beard, Bruce Baker, David Kowalski, and James Young.

Worldwide there are many types of bats that are known as nectar and fruit bats. These largest of bats pollinate flowers and disperse seeds over much of the temperate tropical zones (currently none are found north of Texas). Many medicines, cosmetics, and other products derived from these plants would not be available were it not for bats. Not only do bats help prevent the spread of malaria by eating the carrier mosquitos, but they also help propagate the cinchona, a plant that provides quinine, a treatment for malaria.

Bats must not be disturbed. During hibernation, disturbance may awaken them and cause them to use their stored fat too soon, leading to starvation. During the spring and summer, disturbed females may abandon and thus kill their helpless young, or they may spontaneously abort their pregnancies. Even disturbing a group of grown males can cause them to abandon their safe roosting site.

Just as the Red Hills are home to the largest concentration of caves in Kansas, they are home to the largest populations of cave bats, and there are several species. *Myotis velifer*, the cave bat, is the most populous species here (plate 16). This is a social bat, often congregating in groups of hundreds if not thousands of individuals. A colony of 5,000 is not uncommon (each year a colony of this size can consume 3 billion bugs). Another social bat found in gypsum caves is the western big-eared bat, *Plecotus townsendii*, whose U.S. population is dwindling rapidly. Less common bats are the pallid bat (*Androzous pallidus*), the big brown bat (*Eptesicus fuscus*), and the eastern pipistrelle bat (*Pipistrellus subflavus*). Another bat that makes rare pit stops in Kansas is the Mexican free-tail bat, the species made famous by Carlsbad Cavern.

Perhaps because of the relative youth of gypsum caves in the Permian basin or perhaps because of other unknown causes, there are few, if any, known troglobitic (completely cave-adapted) life forms. It is perhaps another signal that gypsum caves are short-lived and may be further evidence that most animal species require a substantial amount of time to completely evolve from a species adapted to one environment to one adapted to a different climate. The limestone caves of the Flint Hills, Osage cuestas, and Ozarks all have troglobitic isopods and amphipods, and the Ozarks have one troglobitic salamander. The Red Hills thus far have none.

The Red Hills area is sparsely populated; many of the caves that the KSS has explored have never before been entered by humans. The concentration of caves and the lack of human intervention have thus far guaranteed the survival of the cave biota and have provided a relatively unspoiled natural resource (although some sinks have already been used as trash dumps). There is but one Kansas Red Hills. We must, as responsible caretakers of our environment, ensure that this area is kept in as natural a state as possible.

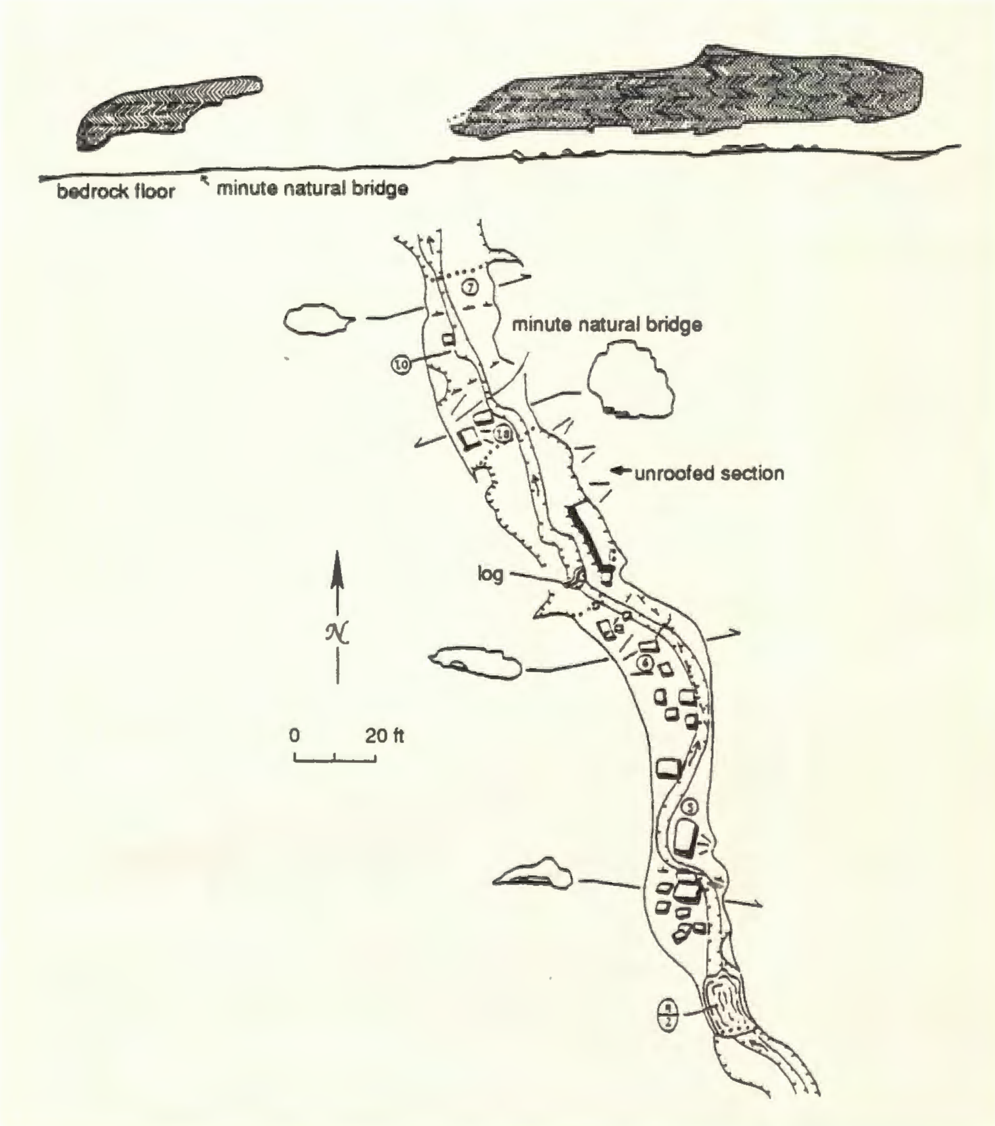


Figure 37. Natural bridges. Surveyed by Jonathan Beard and James Young.

Sandstone caves of Kansas

A pioneer, stopping to water his horse in an unsettled land, noticed a dark spot in an orange sandstone ridge above him. As he climbed the hill, the earth became muddy beneath his feet. He looked up. The water flowed from a seep in the ground, under a large picture of a reclining Indian in full headdress carved into the sandstone wall. Near the seep was the entrance to a small cave—the dark spot he had seen from below (fig. 38).

Cautiously the pioneer entered the cave. He found that it was unoccupied and large enough to shelter himself and his horse from an approaching rainstorm. As the storm raged outside, he studied petroglyphs—ancient rock carvings—on the cave walls by firelight. He felt secure, yet the cave stimulated his imagination. Who had been there before him?

People may have used the cave for hundreds, even thousands of years before the pioneer, yet the cave existed long before its first human visitors arrived. The cave, later named Palmer's Cave (fig. 39), was formed sometime in the last two million years in sandstone in the Dakota sandstone in Ellsworth County. The Dakota sandstone was formed from sand deposited along deltas of rivers and shorelines of ancient Kansas seas during the Cretaceous Period, approximately 100 million years ago.

At the time the sandstone was deposited, the environment here was subtropical, evidenced today by fossils of cycads and figs, which are indigenous to tropical environments. In Ellsworth County sand piled up to depths of 250 feet (76 meters). The sand—composed of rock particles (for example, quartz, feldspar, and white mica) ranging in size from 1/20 of a millimeter to 2 millimeters (0.002–0.08 inch)—was then buried, compacted, and cemented to form rocks. Iron oxides, the main cementing agents, gave the rock its red, brown, and yellow color. Crossbedding, angular lines in the sandstone that indicate the direction of the current that deposited the sand, is common in the Dakota sandstone.

Most of the state's 50 known sandstone caves are in the Dakota Formation, including 168-foot-long (51-meter-long) Sand Cave, the state's longest sandstone cave (fig. 40). Thirty-four sandstone caves have been found in Clay, Ellsworth, Lincoln, Ottawa, Rice, and Russell counties. Ellsworth County leads with 16. A couple of these small shelters are located in Kanopolis Lake State Park and can be visited after obtaining a permit from the park. Petroglyphs are common in this area, although most are obliterated by the markings of more recent visitors.

Figure 38. West entrance to Palmer's Cave, Ellsworth County. Photo by Jim Young.

Old by human standards, the Dakota sandstone is relatively young geologically. The oldest Kansas sandstone with caves—the Cottage Grove Sandstone Member of the Chanute Shale in the Chautauqua Hills—was formed during the Pennsylvanian Period, 300 million years ago. Four caves formed in this rock south of Independence, including one known locally as Lover's Leap Cave. A 50-foot (15-meter) cave in the slightly younger sandstone of the Stranger Formation has been found in Montgomery County. This cave, formed under large boulders, is long enough to have total darkness in its farthest reaches. Eastern pipistrelle bats have been observed in the back of the cave.

Five caves have been found in the Elgin Sandstone Member of the Kanwaka Shale, also Pennsylvanian in age. Three are in Chautauqua County, and two are in Woodson County. The Ireland Sandstone Member of the Lawrence Shale also has caves. One, a small water hole by an overhang in Douglas County, is known as Hole in the Rock. Franklin County also has four caves, one with a 108-foot (33-meter) entrance—the largest cave entrance in Kansas. Although it is named Jesse James Hideout Cave (see fig. 7), it is unknown whether the outlaw ever used it.

Animals and petroglyphs in sandstone caves

Because sandstone caves are relatively short and usually dry, they do not contain any troglobites or cave-adapted animals. They do provide shelter for wood rats and skunks. Rat scat and collected piles of twigs are commonly found in these shelters. In the spring and summer, turkey vultures often use the caves to nest and raise their young. Cave crickets and bats also have been observed in Kansas sandstone caves but are not common.

Evidence of Native American use has been found in some sandstone caves. Archeologists have found no sign of long-term habitation, but evidence indicates that the caves were used by hunting parties; at least three caves are located near bison trails, and one site in Ellsworth County overlooks a creek valley where the bottomlands contain bison bones and stone tools used for butchering.

Unfortunately, the petroglyphs, such as the reclining Indian at Palmer's Cave (plate 17), reveal little about the human inhabitants (see O'Neill, 1981). Archeologists have determined from pottery fragments that at least three separate cultures of pottery-making Native American groups lived near Palmer's Cave. The earliest were the Woodlands Indians, who prospered about A.D. 1000. This culture was replaced by the Quivira Indians, who were still in the area when Coronado arrived in 1541. They were followed by the Plains Indians—buffalo-hunting Arapaho, Cheyenne, and Pawnee—who lived in the area as late as 1870. Some petroglyphs of figures with

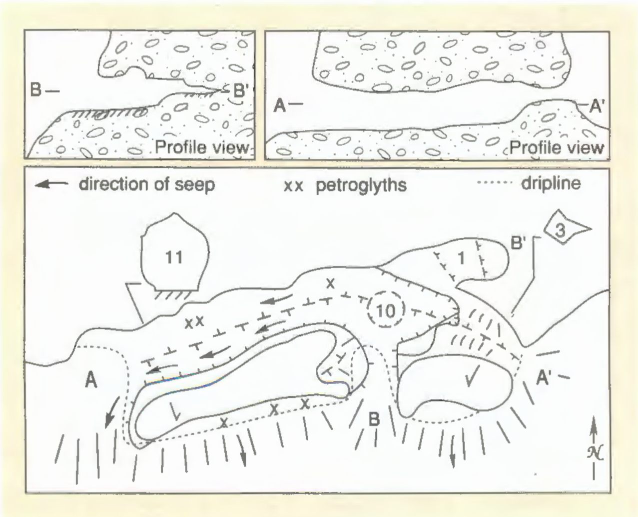


Figure 39. Palmer's Cave. Cave length is 81.8 feet. Surveyed by Jonathan Beard, James Young, and David Mead.

Figure 40. Sand Cave (length is 168.0 feet) and Little Sand Cave (length is 62.3 feet). Surveyed by Jonathan Beard, James Young, and Arlin Pound.

guns or horses were created after the arrival of settlers.

Sandstone shelters in Kansas are valuable historical landmarks and should be protected. Erosion will destroy the incised petroglyphs quickly by geologic measures, but several generations of visitors should be able to see them before they fade away. There is little else in our physical environment to remind us of our not-too-distant past.

Caves of western Kansas

The youngest cave-bearing rocks in Kansas are found in western Kansas, which, in this account, is defined far more broadly than usual, as the area west of the Flint Hills and north of the Red Hills. The rock outcrops of this area are all younger than Permian in age, deposited during the last 100 million years of geologic history. Rocks of Cretaceous age form caves in the Fort Hays Limestone Member and the Smoky Hill Chalk Member of the Niobrara Chalk. Farther west, a few shelters are found in the Ogallala Formation, deposited during Tertiary time. Far western Kansas even has a cave formed in loess deposited during the Pleistocene Epoch.

The first cave-bearing rock younger than the Dakota Sandstone is the lowest member of the Niobrara Chalk, the Fort Hays Limestone Member. This relatively resistant, massive, chalky limestone caps bluffs in the Smoky Hills and is up to 70 feet (21 meters) thick in some exposures. Only five caves have been reported in the Fort Hays, although it is likely more will be found.

The best known cave in the Fort Hays limestone is Devil's Cave in Rooks County (fig. 41). Only 150 feet (46 meters) long with an average ceiling height of 6 feet (2 meters) and a width of 5 feet (1.5 meters), this cave has a dry straight passage, making it ideal for novice explorers. This cave has been visited by locals since the 1800's, and many have left their initials and dates carved into the soft, formationless walls. Although bats have been reported to use some caves in the Fort Hays limestone, none were observed at Devil's Cave in the summer of 1985.

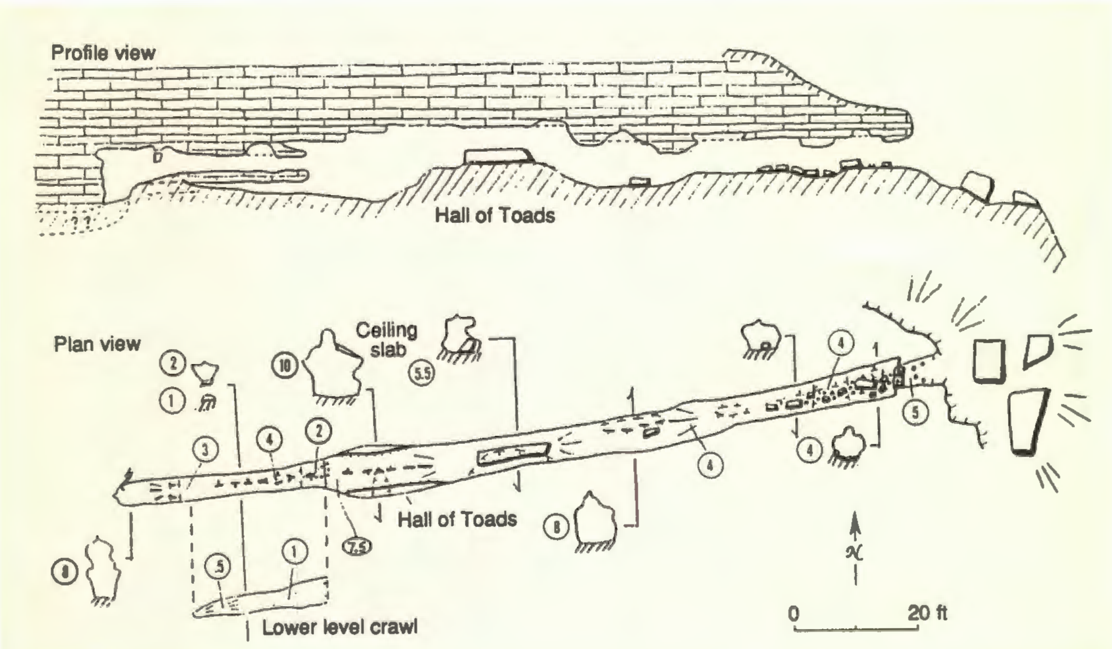


Figure 41. Devil's Cave. Cave length is 148.7 feet. Surveyed by Jonathan Beard, James Young, and Wayne White.

Among the best-known rock outcrops in western Kansas is an exposure of the Smoky Hill Chalk Member. This rock layer, commonly visited by travelers who venture south of I–70 at Castle Rock and Monument Rocks, is composed primarily of the skeletal remains of golden-brown algae. These remains and those of other plants and animals accumulated as seafloor ooze in a broad seaway that extended from the Gulf of Mexico to Arctic Canada in Late Cretaceous time. This debris was compacted as the weight of additional sediments pressed down from above. Because this chalk was formed by compaction and is not well cemented, much of it has been eroded away, leaving only remnants like Monument Rocks.

Caves formed in the chalk are usually small solutional tubes found near the top of chalk bluffs or roofed canyons in the badlands. The solutional tubes, just about big enough for a person to crawl into, are best suited for nesting barn owls, whose white droppings are splattered in the entrance. Roofed canyon caves are much more pleasant for human visitors; such a cave is Cobra Rock Cave at Castle Rock in Gove County (fig. 42). This cave has an entrance near the base of a rock pillar called Cobra Rock and consists of a meandering walking passage with a skylight; the cave's exit opens into a meandering chalk canyon.

Toward the end of the Cretaceous, the Rocky Mountains were formed. During the Tertiary Period, only a few million years ago, the mountains continued to be slowly uplifted while eastward-flowing streams carried tons of eroded material toward Kansas. The amount of eroded sand and gravel was so great that it overflowed the stream valleys and spread out over the uplands. By the end of the Tertiary, the upper surface of this sheet of sand and gravel formed a gently eastward-sloping plain extending from the eastern front of the Rockies to the western slope of the Flint Hills. The High Plains of western Kansas are the remnants of this extensive plain. This porous mass of silt, sand, and gravel can reach 600 feet (280 meters) in thickness in southwestern Kansas and is known as the Ogallala Formation, famous for its ground-water-yielding ability.

A few small shelter caves are found in the Ogallala Formation where it crops out as mortar beds. This rock layer got its name because settlers could heat the limy material over open fires and use it as mortar when building with native stone.

Figure 42. Lower entrance to Cobra Rock Cave, Gove County. Photo by Jim Young.

The rock looks like concrete and is formed where caliche, deposited by evaporating ground water, glues the sand and gravel of the Ogallala together. A small shelter known as Squaws Den Cave near Scott County State Lake is a well-known example of a mortar bed cave (fig. 43). Although Squaws Den Cave measures only 20 × 15 feet (6 × 5 meters) (fig. 44), it was reportedly used in 1878 by a group of Northern Cheyenne Indians for shelter when they escaped from Ft. Reno, Oklahoma, and moved through Kansas in an attempt to return to their native lands in Montana.

Most of western Kansas is covered with loess, a wind-blown silt that was deposited during the Pleistocene Epoch of the Quaternary Period. Vast areas of dry mud were exposed as the ice sheets from the four major glacial advances melted. Huge dust storms spread this silt over much of the midcontinent. Loess deposits are thickest in

Figure 43. Entrance to Squaws Den Cave, Scott County. Photo by Randi Young.

northern Kansas, up to 180 feet (55 meters), where they were close to the receding glacier.

A small cave or natural bridge, less than 20 feet (6 meters) long, has formed in loess in Cheyenne County in the extreme northwestern corner of the state. This erosional feature, known as Horsethief Cave (fig. 45), exists because loess can maintain a nearly vertical face without caving in or slumping. Water has eroded an opening through a small loess bluff. Although this cave is a temporary feature, compared to limestone caves, it does seem a fitting ending to a discussion of Kansas caves. In the stereotypical image of Kansas as a flat, featureless landscape, perhaps this loess cave is what some may think of as a typical Kansas cave. Although it is not really typical, it does represent one extreme in the variety of cavernous features in the Kansas landscape.

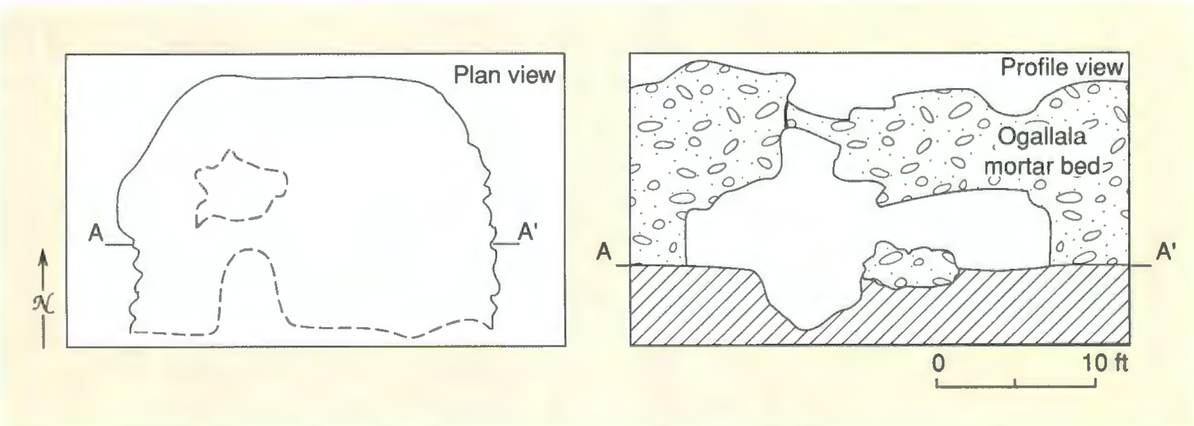


Figure 44. Squaws Den Cave. Surveyed by James Young and Randi Young.

Figure 45. Horsethief Cave entrance, Cheyenne County. Photo by KGS.

Conclusions

Caves yield their secrets slowly. Recently, almost ten years after our first visit to Spring Cave in Butler County, we made our eighth visit there. On this trip, with Ron Flory and Tom Grey, we added 500 feet (152 meters) to the surveyed length, bringing the total length of surveyed passage to 8,529 feet (2,513 meters). This cave, which was unimpressive at first, is now the longest surveyed cave in Kansas.

Our last survey trip to Spring Cave ended in a totally water-filled passage, yet the mystery remains. Can the passage be followed farther in times of drought? Have we overlooked a side passage that will continue?

Caves cannot be conquered. The more we know about them, the more we know there is to learn. The mysteries of caves are never-ending, beckoning us back into the darkness again and again.

Glossary

accidental—Any animal found in a cave that is normally found outside caves that is in the cave not by choice (e.g., an animal washed into the cave by floodwaters or an animal that has fallen into a pit). An accidental is one of four classifications of fauna found in caves; the other three classes are troglobite, troglophile, and trogloxene.

alabaster—A fine-grained massive variety of gypsum that may be white, pink, gray, or even black. It can be polished and made into attractive objects of art.

amphipod—An invertebrate animal, member of the biologic order Amphipoda. Amphipods are small segmented crustaceans. Some amphipods are nonpigmented cave-adapted species.

anastomosis—A network of tubular passages or holes in a cave or in a solution-sculptured rock. A complex of many irregular and repeatedly connected passages. A labyrinth.

anhydrite—A mineral usually associated with gypsum and of nearly the same chemical composition. Anhydrite cannot be scratched with the fingernail, as gypsum can be. Anhydrite is distinguished from gypsum in that it lacks water, as its name implies.

aquifer—A porous water-yielding stratum of rock. Sandstone beds and the Ogallala Formation are some of the best water-producing layers in Kansas and are used extensively for private and municipal water supplies. They also produce numerous springs.

bacon—Banded flowstone that resembles bacon and forms along sloping cave walls.

base level—In general, the lowest point in the water table in a given area. Water in the area flows toward this destination by gravity and hydrostatic pressure.

bedding—The layering in rocks produced by deposition. This layering is initially horizontal, but tectonic force can cause it to tilt.

bedrock—The solid rock that underlies any unconsolidated sediment or soil. Limestone and sandstone are common types of bedrock in Kansas.

biostrome—A layer of rock composed of the remains of various fossilized animals, such as crinoids and coral.

breakdown—Rock (often found in heaps) that has collapsed from the walls and ceiling of a cave.

breccia—Profusely cracked, broken rock cemented by calcite or other minerals. In the Tri-state area, which includes southeast Kansas, breccia consisting of chert and limestone is often found with deposits of lead and zinc ore.

calcite—A mineral composed of calcium carbonate; it is the principal component of limestone.

caliche—A type of calcite-cemented sandstone that forms in the soil of dry regions. Generally impure and soft.

carbonate—A class of minerals. Calcite is calcium carbonate ($CaCO_3$). Dolomite is calcium-magnesium carbonate [$CaMg(CO_3)_2$]. Calcite is a main constituent of many Kansas limestones. The mineral dolomite, less common, is the principal mineral in the rock dolomite, also sometimes referred to as dolostone.

cave—A natural cavity or chamber beneath the surface of the earth that is large enough to permit entry to people.

cave pearl—A speleothem consisting of concentric layers of calcite usually formed in pools of water. A small particle, as it is turned by moving water, will have calcite deposited on its surface. Pearls range in diameter from 1 millimeter to several centimeters.

chalk—A soft form of limestone that is not well cemented and thus is often powdery and brittle.

chert—Silicon dioxide (SiO_2), commonly known as flint. Chert occurs as irregular beds or rounded nodules within limestone formations. It hardly dissolves at all in water and juts out from weathered surfaces as ledges or knobs. It can form by the accumulation of silicon dioxide on the seafloor or by the replacement of preexisting sedimentary rock by SiO_2 that is carried by water seeping through the rocks. Chert has the same chemical formula as the mineral quartz.

column—A secondary deposit of calcite or other minerals that extends from ceiling to floor, usually created by the joining of a stalactite and a stalagmite.

conglomerate—Rock that consists of nonsorted, cemented particles usually containing sand and gravel. Resembles concrete.

contact—The surface where two different layers of rock meet. The contact is sometimes marked by a bedding plane, and sometimes caves are eroded or dissolved out of the rock at a contact. Caves formed in this manner are known as contact caves.

cuesta—A ridge with a steep face on one side and a gently sloping face on the other. Such topography characterizes part of eastern Kansas, which is called the Osage cuestas.

dip—In geology, dip is the angle at which a rock layer is inclined relative to the horizontal. In Kansas most rock layers dip, or get deeper, as you move from east to west.

dissolution—*See* solution.

dolomite—The mineral dolomite [$CaMg(CO_3)_2$] is similar to calcite ($CaCO_3$) and is the principal mineral in the rock dolomite, also called dolostone. The rock dolomite is cavernous in some states but is so rare and so thin in Kansas that no caves have been found in it.

dripline—Beginning "entrance" of a horizontal cave. It is the line left by surface dripwater falling from the edge of the roof onto the floor.

dripstone—Secondary mineralization in caves formed by dripping water, as opposed to flowing water (*see* flowstone). Dripstone includes stalactites, stalagmites, helictites, and columns (columns can also involve flowing water).

erosion—The natural force that removes rock and soil, involving wind, rain, temperature, ground water, chemical processes, and gravity. Types of erosion include solution, corrosion, and abrasion. Most limestone and gypsum caves are formed mainly by solution. Shelter caves and many sandstone caves are formed by abrasion.

escarpment—A steep slope or cliff.

fault—A fracture or separation usually resulting from tectonic stresses along which movement of the rock has occurred. The movement can be slight or catastrophic (such as earthquakes). Most faults are relatively minor with movement involving only a few feet.

flowstone—Speleothems formed by flowing water. Includes bacon, rimstone dams, travertine, and columns.

fossiliferous—Describing a rock in which fossils are profuse. Many of Kansas limestones are studied for such fossils as crinoids, brachiopods, and other marine invertebrates. In the chalk beds of western Kansas, large fossils of reptiles and fish of the Cretaceous Period are found.

galena—Lead sulfide (PbS), one of the lead ores mined in southeast Kansas.

gour—Small rimstone found on stalagmites and flowstones often measuring less than 1 inch in diameter.

ground water—Water existing beneath the earth's surface. Includes water above and below the water table (*see* phreatic and vadose).

gypsum—A soft mineral composed of calcium sulfate with water ($CaSO_4 \cdot 2H_2O$). Gypsum can be found as rock gypsum, selenite, alabaster, or satin spar. Some secondary cave formations can consist of gypsum, especially in the Red Hills.

helictites—Twisting, wormlike speleothems similar to strawtites but controlled by surface tension rather than by gravity.

hydrostatic pressure—Pressure exerted by water at any given point in a body of water at rest.

hypothermia—Subnormal body temperature. Hypothermia occurs when the body loses heat to its surroundings faster than it can replace it (in caving, generally when wet). It is characterized by five stages of reduction of the body's core temperature: (1) from the normal 98.6°F to 96°F (intense shivering); (2) from 95° to 91° (reduced ability to think, difficulty in speaking, poor coordination, disorientation); (3) from 90° to 86° (muscular rigidity with erratic movement; possible amnesia); (4) from 86° to 85° (unconsciousness or glassy stare, slow pulse, slow respiration); and (5) 85° to 77° (death). Few victims survive if their core temperature drops below 80°F. The best way to prevent hypothermia is to avoid becoming wet in the first place; wearing a wet suit in a wet cave is ideal.

insurgence—A sinkhole opening that permits flowing surface water to be captured and transported underground, to later reemerge as a spring (resurgence). Includes piracy openings.

isopod—An invertebrate animal in the biologic order Isopoda. Isopods are small segmented crustaceans, the best known of which are sow bugs and other land-dwelling species. In caves aquatic isopods are often studied because many are troglobitic and depend on caves for survival.

joint—In geologic terms, a natural fracture, usually vertical, in a rock. Joints are common in limestones, and caves usually form along joints and bedding planes.

karst—A terrain or type of topography generally underlain by soluble rocks, such as limestone, gypsum, and dolomite, in which the topography is chiefly formed by dissolving the rock; karst is characterized by sinkholes, depressions, caves, and underground drainage. The term karst is a derivative of *Kras*, a Germanic name for a cave region in Yugoslavia, one of the first areas to be extensively studied, giving rise to the science of speleology.

karst window—A sinkhole by which an underground stream can be observed and studied.

limestone—A soluble rock primarily consisting of the mineral calcium carbonate ($CaCO_3$). More caves are found in limestone worldwide than any other rock. However, in Kansas more caves are found in gypsum.

loess—A silty, dusty sediment that has been deposited by the wind. Loess is found throughout Kansas but is especially common in the northeastern and northwestern parts of the state.

pendant—Remnant of ceiling rock left by differential solution. Differential solution can be caused by resistant rocks (such as chert) or by closely spaced joints.

petroglyph—An archeological term for carvings or lines cut into rock. Petroglyphs have been carved into soft sandstones in central Kansas.

phreatic—Indicating the water-saturated zone below the water table. The phreatic zone is the area of the subsurface that is saturated with water.

physiography—Description of the natural physical features (landforms) of the earth.

piracy—Geologically, the diversion or capture of part of the drainage basin of one stream by another stream or by a cave passage diverting the surface stream underground.

popcorn—A term given to gnarled, bulbous, or pointed cave formations that form either from slow seeping of mineralized water from porous bedrock or as coatings on submerged walls and floors. Also known as cave coral.

porous—Geologically, this term describes rock that permits movement of water through small, often microscopic openings, much as water moving through a sponge.

red bed—Red sedimentary units of Permian age in south-central Kansas. Consists of shale and sandstone.

resurgence—A speleologic term for spring or the exit of ground water to the surface. Often refers to the downstream cave opening. An opening where flowing surface water enters the subsurface is known as an insurgence.

rimstone—A speleothem that results from the movement of water over a ridge where minerals are deposited on the ridge. With time the ridge gradually builds upward in an upstream direction forming a rimstone dam. Pools are formed behind these dams, and cave pearls and cave popcorn may form in these pools.

sandstone—Rock formed by the compaction and/or cementing of sand. Cement (matrix) material can be calcite, hematite (FeO_2), or other materials.

scallop—A speleothem formed from solution by water movement on bedrock surfaces. Abrasion erosion on rock surfaces forms flat surfaces on rock, but solutional erosion often produces a dimpled surface like that of a golf ball. The steeper side of the dimple is the upstream side.

shale—Rock that is often impervious to water (will not allow water to move through it) but rather soft, brittle, and easily eroded. Shale is the result of compaction of silt or mud. Much of the Permian and Pennsylvanian strata in Kansas consist of various shales, often brightly colored.

sink (sinkhole)—A surface depression caused by solution and/or collapse of rock. A sink is an entry point for water into cave and spring systems. The sink may or may not contain an obvious hole and is often referred to as a sinkhole when the hole is readily apparent. All sinks will carry water into the subsurface.

solution—Geologically, the action of the dissolving of rock by water or the term to describe the water that dissolves the rock. Limestone dissolves in acidic solutions; gypsum can be dissolved in pure water. On dissolving the rock, the water becomes a calcite solution (the calcite may later be redeposited).

speleogen—A bedrock form that results from differential solution of cave passages. Speleogens are forms that are left behind after solution rather than forms created by deposition (speleothems).

speleogenesis—The study of cave formation, the primary geologic cave topic. Each cave has a unique origin that results in no two caves being exactly alike.

speleology—The science of the cave environment. It embraces several branches of biology and geology as well as chemistry, meteorology, and soil science.

speleothem—A secondary mineral deposit formed within a cave, such as stalactites and stalagmites.

sphalerite—Zinc sulfide (ZnS), the principal zinc ore mined from Tri-state deposits in southeast Kansas, usually found in breccia in ancient refilled sinks and caves.

stalactite—A normally cylindrical deposit of minerals suspended from the ceiling of a cave. In Kansas stalactites are generally found in limestone caves.

stalagmite—A column of mineral deposits that grow upward from the floor, often from water dripping down from a stalactite above.

strawtite—Also known as a soda straw, this term describes stalactites in their infant stage. When calcite-laden dripwater hangs on the ceiling and falls, movement releases carbon dioxide and a ring of calcite is deposited at the point from which it fell. As the formation grows, it resembles a drinking straw and can be several inches long. Eventually, most soda straws will become clogged by calcite growths within them. Then the water is forced to flow down the outside of the strawtites, and minerals are deposited on the outer surface. Ultimately, the stalactite becomes the carrot-shaped form usually seen in caves.

talus—Fallen or broken rock that is found at the foot of a steep slope. The spaces between talus boulders may be interconnected and large enough to be considered caves. One such cave in New England, Polar Cave, is a commercial cave several hundred feet long. The longest talus cave in Kansas is 81 feet long (Talus Cave in Montgomery County).

tectonics—The study of the movement of the earth's outer crust. Tectonics includes the study of earthquakes and other faulting, mountain uplifting, and plate tectonics.

travertine—A finely crystalline limestone deposited by ground water and surface water. Travertine can be found in Kansas caves and around springs and some waterfalls.

troglobite—One of four classes of cavernicoles (life forms found in caves). These four classes are (1) accidental (animals washed into caves or those that fall into sinkholes), (2) trogloxene (animals that visit caves; *see* trogloxene), (3) troglophile (animals that live in caves; *see* troglophile), and (4) troglobite. A troglobite is a cave-adapted animal living permanently underground in the dark zone of caves and only accidentally leaving it. It is completely dependent on caves for survival and cannot survive outside caves for long periods. Includes all nonpigmented blind species such as isopods, amphipods (which have no eyes and are white), and the grotto salamander of the Ozarks. Does *not* include accidentals, such as surface fish washed into caves that become nonpigmented, because others of the same species on the surface are pigmented and are able to survive outside the cave. Troglobites are nonpigmented even when placed on the surface.

troglophile—"Cave lover." An animal that habitually enters or lives permanently within the dark zone of a cave but is also capable of living outside because it is *not* evolved or adapted specifically to caves. Surface species of some fish, crustaceans, insects, and amphibians are known to live their entire lives and to breed in caves; yet others of the same species can live their entire lives outside caves. Troglophiles include most salamanders, beetles, and any surface species that is able to find enough food in caves to survive permanently in them. Some accidentals are capable of becoming troglophiles if they are able to survive in caves.

trogloxene—An animal that visits caves but is dependent on the outside for food. Trogloxenes include all cave bats, people, raccoons, and other surface species that must spend part of their lives outside caves to survive. Although bats may depend on caves for shelter, they must feed outside of caves because their food supply of flying insects is not plentiful in caves. Some species, such as some salamanders, can be classified as either troglophiles or trogloxenes, depending on the particular cave they live in (some caves have adequate food for a troglophilic existence; some caves do not, and thus a trogloxenic existence is mandated). Cave salamanders and dark-sided salamanders of the Ozarks are two examples of trogloxenes.

truncated—Shortened. A cave passage that has been filled with rock debris or that has been separated into segments by collapse or other blockades has been truncated.

vadose—Indicating the area below the earth surface but above the water table. Includes all ground water above the water table. In caves vadose water forms stalactites and other dripstone speleothems. Vadose cave streams carve trenches and canyons and vertical pits as the water table lowers with time.

water table—A fluctuating demarcation line between the unsaturated (vadose) zone and the saturated (phreatic) zone that forms an aquifer. It may rise or fall depending on precipitation (rainfall) trends. The water table is semiparallel to the land surface above but is not always a consistent straight line. Because of impervious beds of shale, etc., local water tables can be perched above the area's average water table.

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