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Geology of Caves

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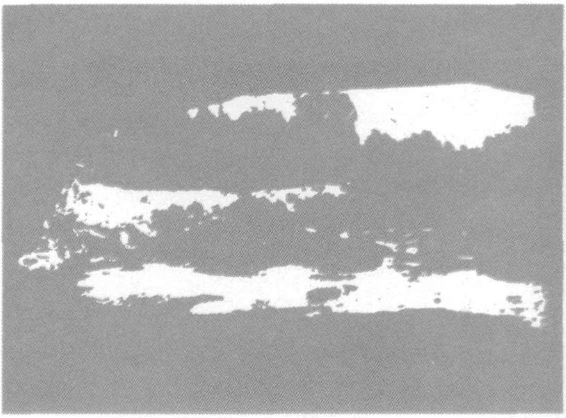
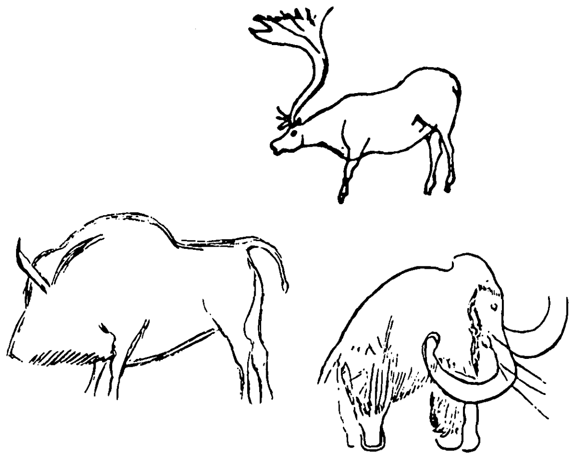
by W. E. Davies and I. M. Morgan



A cave is a natural opening in the ground extending beyond the zone of light and large enough to permit the entry of man. Occurring in a wide variety of rock types and caused by widely differing geological processes, caves range in size from single small rooms to interconnecting passages many miles long. The scientific study of caves is called speleology (from the Greek words *spelaion* for cave and *logos* for study). It is a composite science based on geology, hydrology, biology, and archaeology, and thus holds special interest for earth scientists of the U.S. Geological Survey.

Caves have been natural attractions since prehistoric times. Prolific evidence of early man's interest has been discovered in caves scattered throughout the world. Fragments of skeletons of some of the earliest manlike creatures (Australopithecines) have been discovered in cave deposits in South Africa, and the first evidence of primitive Neanderthal Man was found in a cave in the Neander Valley of Germany. Cro-Magnon Man created his remarkable murals on the walls of caves in southern France and northern Spain where he took refuge more than 10,000 years ago during the chill of the ice age.



Interest in caves has not dwindled. Although firm figures for cave visitors are not available, in 1974 about 1.5 million people toured Mammoth Cave in Kentucky, and more than 670,000 visited Carlsbad Caverns in New Mexico, two of the most famous caves in the United States.

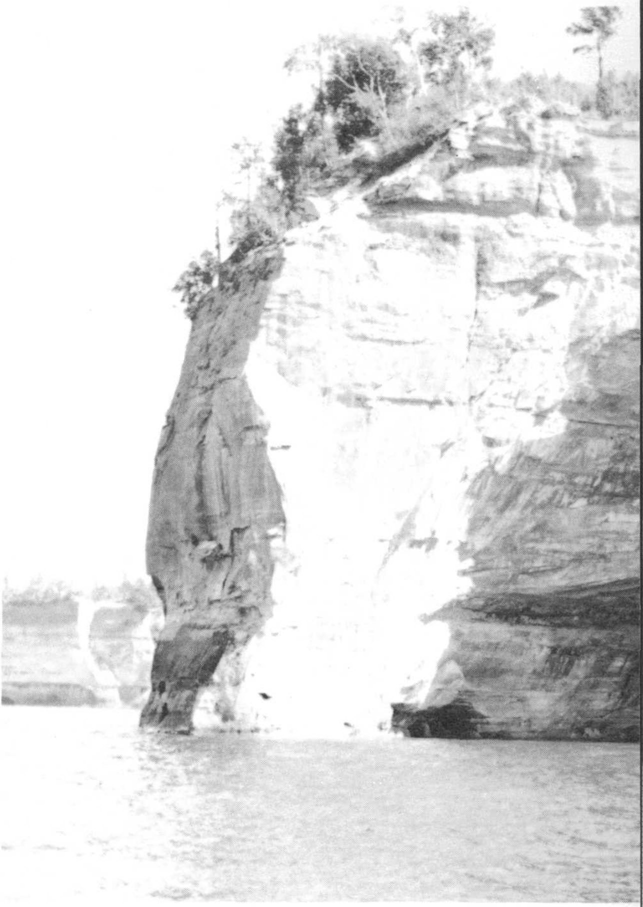
Types of Caves

A simple classification of caves includes four main types and several other relatively less important types.

- *Solution caves* are formed in carbonate and sulfate rocks such as limestone, dolomite, marble, and gypsum by the action of slowly moving ground water that dissolves the rock to form tunnels, irregular passages, and even large caverns along joints and bedding planes. Most of the caves in the world—as well as the largest—are of this type.
- *Lava caves* are tunnels or tubes in lava formed when the outer surface of a lava flow cools and hardens while the molten lava within continues to flow and eventually drains out through the newly formed tube.

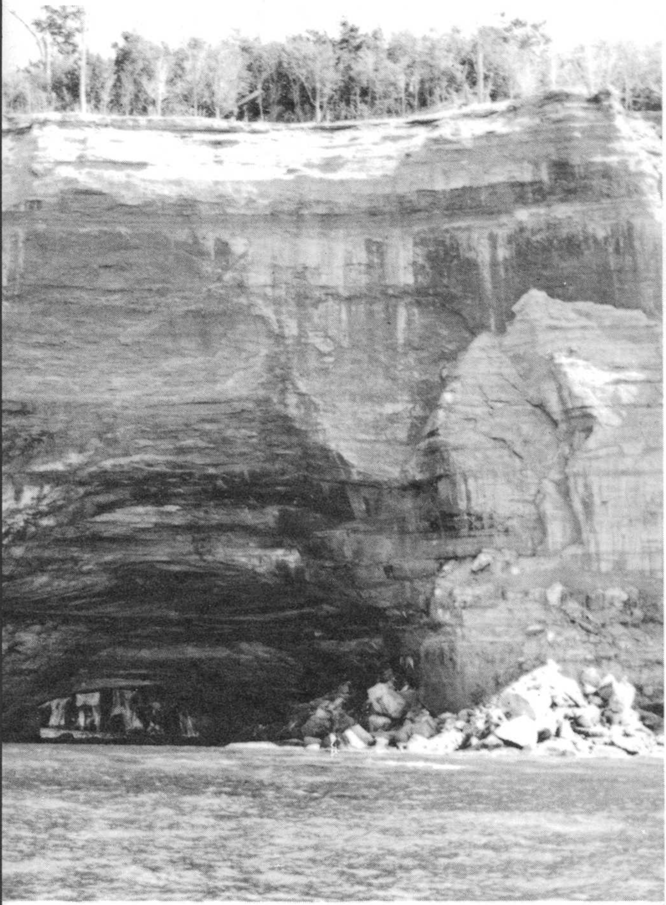
- *Sea caves* are formed by the constant action of waves which attacks the weaker portions of rocks lining the shores of oceans and large lakes. Such caves testify to the enormous pressures exerted by waves and to the corrosive power of wave-carried sand and gravel.
- *Glacier caves* are formed by melt water which excavates drainage tunnels through the ice.

Of entirely different origin and not to be included in the category of glacier caves are so-called "ice caves," which usually are either solution caves or lava caves within which ice forms and persists through all or most of the year.



Wave-cut cave, Lake Superior, Grand Marais, Michigan *(photo by W. E. Davies).*

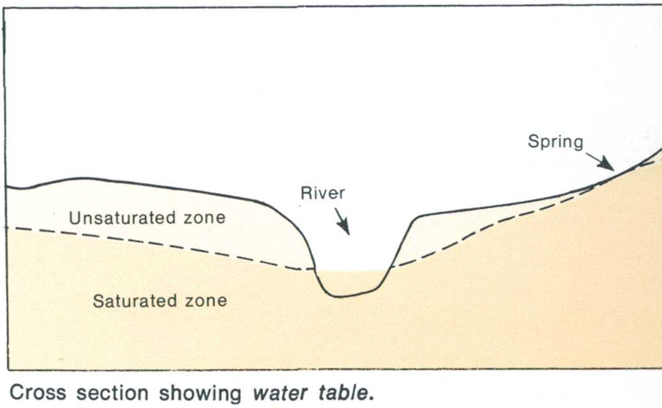
In desert areas, some shallow caves may be formed by the sandblasting effect of silt or fine sand being blown against a rock face. These *eolian* caves, some of which are spectacular in size, are surpassed in number by caves of other origins in most deserts. More common even in the driest deserts are sandstone caves eroded in part by water, particularly if the sandstone is limy. Caves commonly known as "wind caves," such as the one in Wind Cave National Park in South Dakota, are named not for the mode of origin of the cave but for the strong air currents that alternately blow in or out of the cave as the atmospheric pressure changes. Most wind caves are, in fact, solution caves.



How Caves Form

The melt-water streams draining out along the floor of a glacier cave or the surging, pounding waves at the mouth of a sea cave offer immediate evidence of the origin of these caves. Solution caves, however, have always been a source of wonder to man. How do these extensive, complex, and in some places beautifully decorated passageways develop?

Solution caves are formed in limestone and similar rocks by the action of water; they can be thought of as part of a huge subterranean plumbing system. After a rain, water seeps into cracks and pores of soil and rock and percolates beneath the land surface. Eventually some of the water reaches a zone where all the cracks and pores in the rock are already filled with water. The term *water table* refers to the upper surface of this saturated zone. Calcite (calcium carbonate), the main mineral of limestone, is barely soluble in pure water. Rainwater, however, absorbs some carbon dioxide as it passes through the atmosphere and even more as it drains through soil and decaying vegetation. The water, combining chemically with the carbon dioxide, forms a weak carbonic acid solution. This acid slowly dissolves calcite, forms solution cavities, and excavates passageways. The resulting calcium bicarbonate solution is carried off in the underground drainage system.

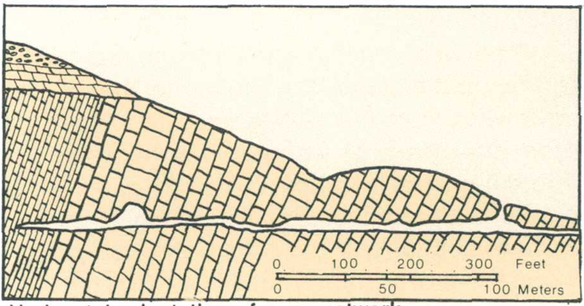


Cross section showing ***water table.***

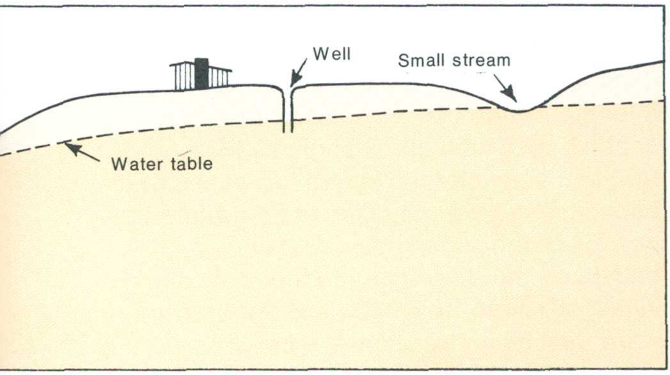
It was once believed that caves formed near the Earth's surface—above the saturated zone—where the water moved downward through the cracks and pore spaces. This view, however, left many cave features unexplained.

Why, for instance, are cave passages nearly horizontal, in places crossing folded or tilted rock structures? How would horizontal passages form at several different but persistent levels? Recent studies of the movement and chemistry of ground water have shown that the first stage in cave development—the dissolving of carbonate rocks and the formation of cavities and passageways—takes place principally just below the water table in the zone of saturation where continuous mass movement of water occurs.

A second stage in cave development occurs after a lowering of the water table (the water table normally sinks as the river valleys deepen). During this stage, the solution cavities are stranded in the unsaturated



Horizontal orientation of cave network.



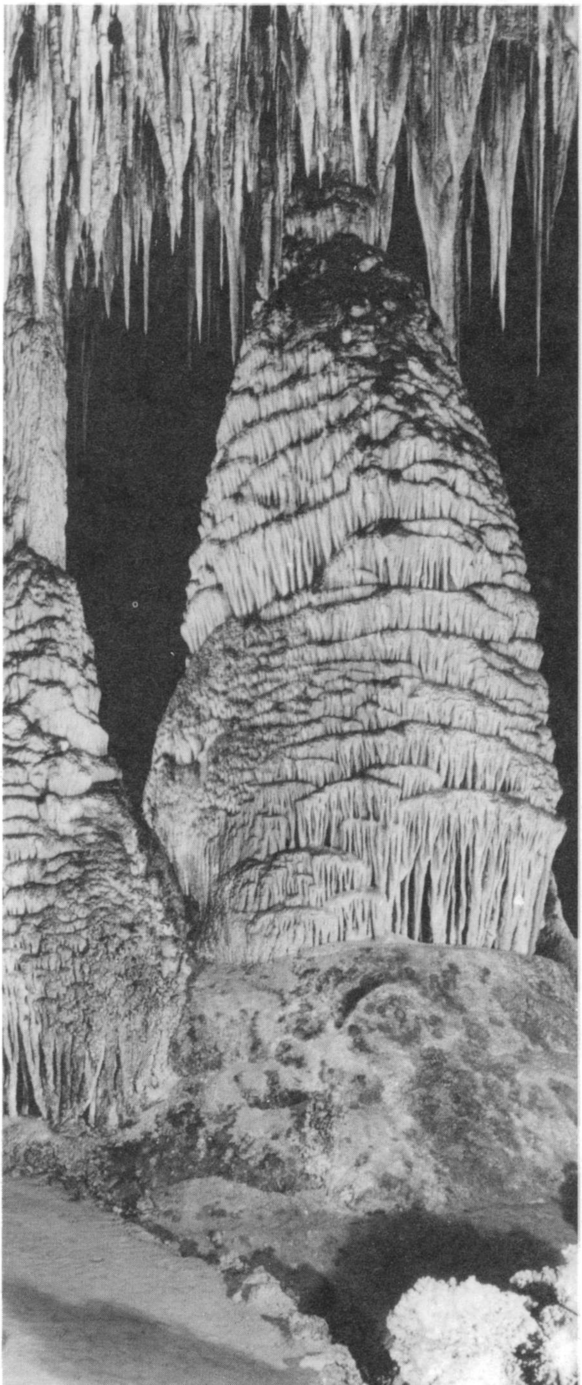
zone where air can enter. This leads to the deposition of calcite, which forms a wide variety of *dripstone* features.

The chemical process causing deposition of calcite is the reverse of the process of solution. Water in the unsaturated zone, which dissolved some calcite as it trickled down through the limestone above the cave, is still enriched with carbon dioxide when it reaches the ventilated cave. The carbon dioxide gas escapes from the water (just as it escapes from an opened bottle of soda pop). The acidity of the water is thereby reduced, the calcium bicarbonate cannot remain in solution, and calcite is deposited as dripstone.

Cave Features

The decorative dripstone features are called speleothems (from the Greek *spelaion* for cave and *thema* for deposit). When these structures are highlighted by lanterns or electric lights, they transform a cave into a natural wonderland.

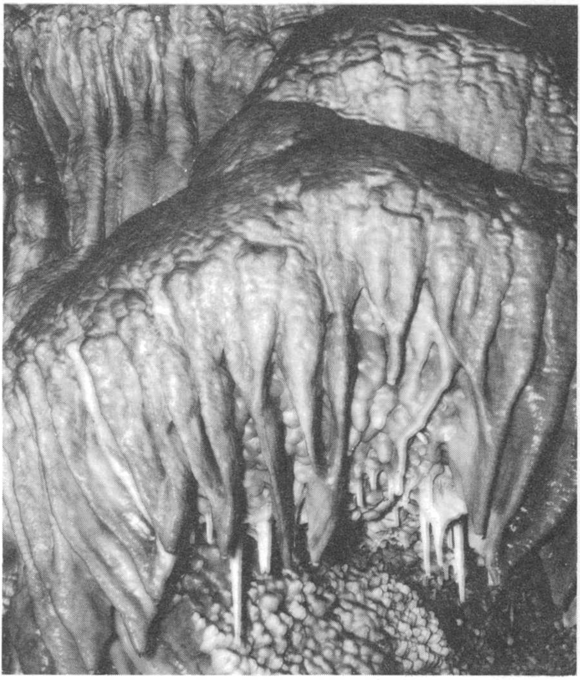
The most familiar speleothems are *stalactites* and *stalagmites.* Stalactites hang downward from the ceiling and are formed as drop after drop of water slowly trickles through cracks in the cave roof. As each drop of water hangs from the ceiling, it loses carbon dioxide and deposits a film of calcite. Successive drops add ring below ring, the water dripping through the hollow center of the rings, until a pendant cylinder forms. Tubular or "soda straw" stalactites grow in this way; most are fragile and have the diameter of a drop of water, but some reach a length of perhaps a yard or more. The large cone-shaped stalactites begin as these fragile tubes and then enlarge to cones when enough water accumulates to flow along the outside of the soda straws. Deposition of calcite on the outside of the tubes, most of which are near the ceiling and taper downward, results in the familiar cone shapes.



Columns up to 60 feet high in Carlsbad Caverns, New Mexico *(photo by National Park Service).*

Stalagmites grow upward from the floor of the cave generally as a result of water dripping from overhanging stalactites. A *column* forms when a stalactite and a stalagmite grow until they join. A *curtain* or *drapery* begins to form on an inclined ceiling when the drops of water trickle along a slope. Gradually a thin sheet of calcite grows downward from the ceiling and hangs in decorative folds like a drape. Sheets of calcite that are deposited on the walls or floor by flowing water are called *flowstone. Rimstone dams* are raised fencelike deposits of calcite on the cave floor that form around pools of water.

Helictites are curious twisted or spiraling cylinders or needles. They apparently develop when water seeps through the ceiling so slowly that slight chemical or physical changes can cause reorientation of the crystal structure of the calcite or gypsum. *Cave corals,* also formed by slowly seeping water, are small clusters of individual knobs.

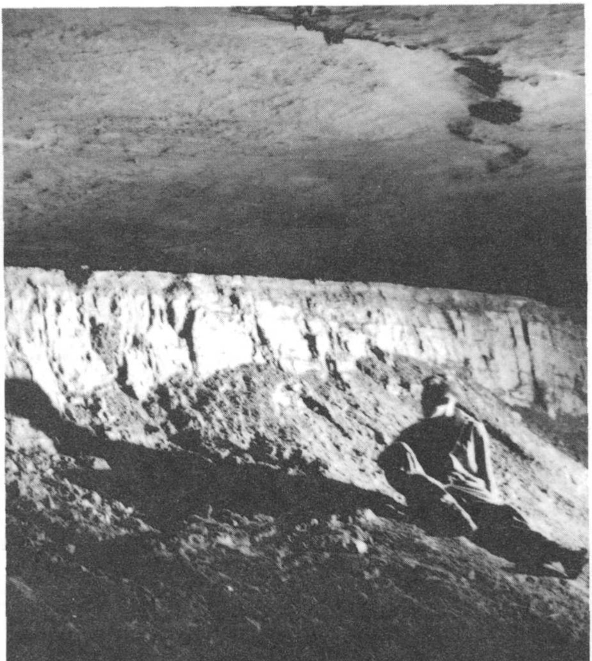


Flowstone drapery in Jewel Cave, South Dakota *(photo by W. E. Davies).*

Most cave passages contain deposits of material that have been washed into the cave. This material, known as *cave fill,* varies from sand and clay to stratified gravel. The pebbles in these deposits often are highly polished or frosted and sometimes are as large as 6 inches in diameter. Cave fills are particularly noteworthy because they contain materials that reflect a geologic history and a record of past climates of the surrounding area.

Rock material produced by the collapse of the ceiling or walls of a cave is called *breakdown* and may range in size from plates and chips to massive blocks. Most breakdown present in caves today appears to have occurred thousands of years ago. It is generally associated with the early history of cave development.

The size and depth of many caves in the United States are impressive. Seven caves have more than 15 passage miles. The longest is the Flint-Mammoth Cave system in



Cave fill, Laurel Creek Cave, West Virginia *(photo by W. E. Davies).*

Kentucky with more than 169 miles. The other six are Jewel Cave in South Dakota (54.4 miles), Organ Cave in West Virginia (32 miles), Wind Cave in South Dakota (28.7 miles), Cumberland Caverns in Tennessee (23.2 miles), Sloan Valley Cave system in Kentucky (22.4 miles), and Crevice Cave in Missouri (20.8 miles).

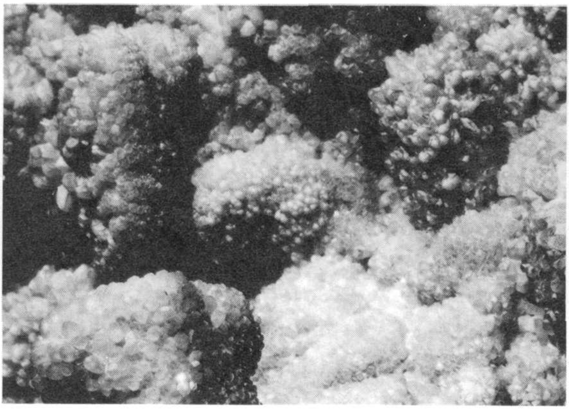
The deepest cave in the United States is Neff Canyon in Utah. There, a depth of 1,189 feet below the entrance is reached along a steeply sloping 1,700-foot passage. The second deepest cave is Carlsbad Caverns in New Mexico; its lowest point is 1,022 feet below the entrance. Ellisons Cave system in Georgia, a close rival of Carlsbad, has a depth of nearly 1,000 feet.

The largest cave room is in Carlsbad Caverns, where the Big Room covers 14 acres. This room is 1,800 feet long and ranges up to 1,100 feet wide. The maximum height of the ceiling is 225 feet. The size of the Big Room, the length of the caverns (14.9 miles, the 11th longest in the United States), and the depth probably make Carlsbad the biggest cave in the United States.

Minerals Found in Caves

Many interesting minerals are found in caves in addition to the calcite which forms the major features. Aragonite, a calcium carbonate mineral similar to calcite but not as common, often occurs in intricate needles known as *anthodites.* Gypsum (calcium sulfate) and related calcium sulfate minerals are next to calcite in abundance. Some caves, although they are developed in limestone, have extensive passages lined with fine, curling growths of gypsum flowers. In other caves, selenite (a less common variety of gypsum) forms long transparent rods or nests of fibrous crystals. Sulfates of sodium and magnesium are also found in caves, although they are less conspicuous than gypsum. Iron minerals in the form of oxides (limonite) and hydroxide (goethite) occur in caves and in some places form stalactites. Manganese minerals in caves are commonly present as thin, sooty coatings on walls and ceilings and in earth fills. Nitrocalcite (calcium nitrate) is abundant in earth fills in many caves, but individual fragments are generally microscopic. Barite (barium sulfate) and celestite (strontium sulfate) also occur in earth fills. In some solution caves, clay minerals exist in relatively pure forms; these include the less common varieties attapulgite and endellite.

In deep caves encountered during mining operations, a number of ore minerals have been found in the decorative wall draperies. Most common are azurite and malachite (forms of copper carbonate). About 50 other minerals also have been reported in cave deposits.



Crystals of dogtooth spar (calcite) from Jewel Cave, South Dakota *(photo by W. E. Davies).*

Uses of Caves

Today, caves in the United States are used mostly for recreation by sightseers and explorers or spelunkers (from the Latin word *spelunca,* which means cave), but the most enduring use of caves, from prehistoric times to the present, has been for shelter.

Recently, a number of large, dry, and easily accessible caves throughout the United States were designated as fallout shelters, and a large cave in southwestern Virginia is used as a natural tunnel by the Southern Railway. Studies are underway in Europe to extend the use of caves for domestic cold storage, air conditioning, and water-supply purposes.

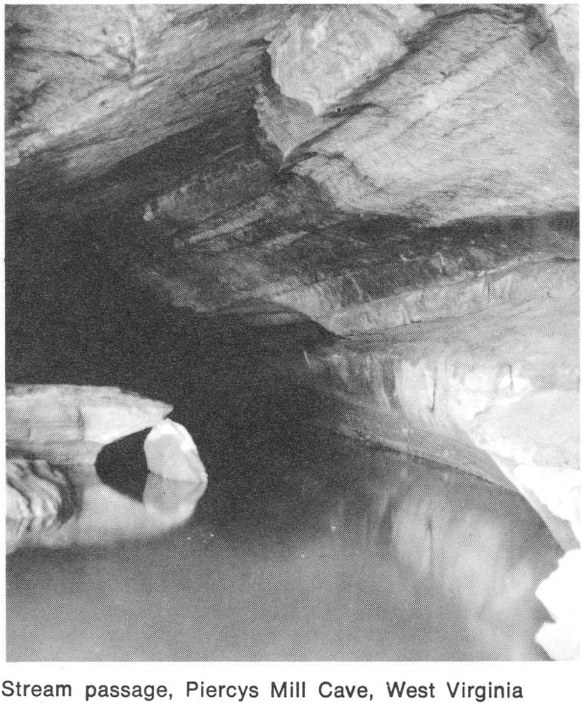
From the early 19th century through the Civil War, caves in Kentucky, Tennessee, Virginia, West Virginia, Alabama, Georgia, Arkansas, and Missouri were important sources of nitrates, an essential ingredient of gun powder. Surface or near-surface accumulations of nitrate salts form coatings on rock walls, fill cracks and crevices, and mingle with cave earth. The origin of the nitrate salts is not clearly understood, but the salts are believed to result from the action of nitrifying bacteria on organic matter or humus. Although no accurate records of production were kept, it has been estimated that over 15,000 tons of niter earth (producing 200 tons of potassium nitrate) were removed from Mammoth Cave in Kentucky between 1811 and 1814.

Caves have also been a source of bat guano, a material mined as a phosphate fertilizer in the Southern United States and Mexico. In general, the largest deposits have occurred in limestone caves within the flight range of the Mexican free-tailed bat.

Geological Survey Investigations

Scientists value caves as natural underground laboratories. Of paramount importance is the fact that caves and other solution cavities in limestone have a direct bearing on the underground water system. Cavernous limestone strata are among the most productive aquifers (water-bearing beds) in the United States and are therefore important sources of water. Because of this, U.S. Geological Survey research programs concerned with limestone regions commonly include studies of the path, rate of flow, amount, and quality of water circulating through caves and hidden passageways.

Saltpeter vats from War of 1812, Mammoth Cave, Kentucky *(photo by National Park Service).*

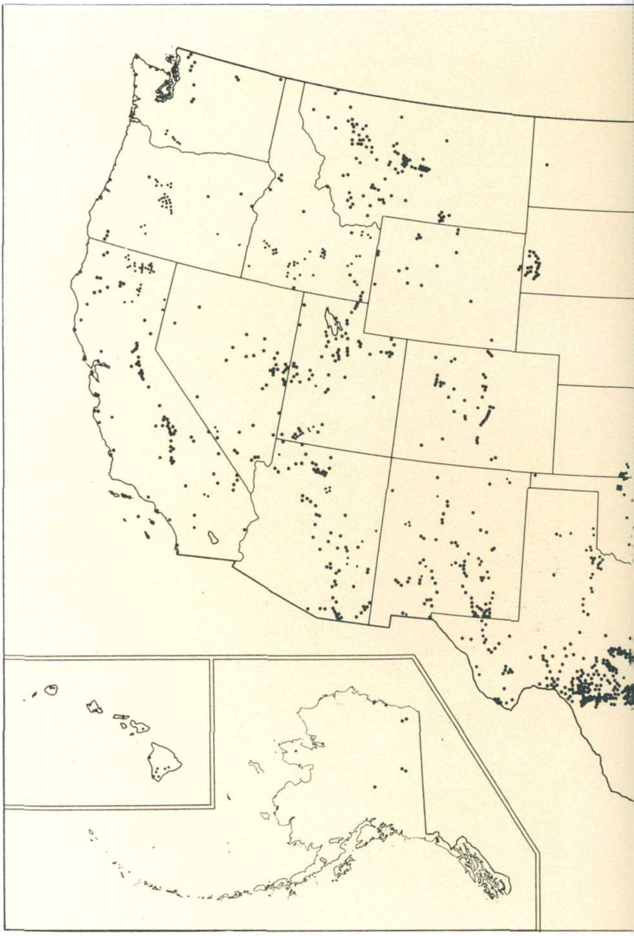


Stream passage, Piercys Mill Cave, West Virginia *(photo by W. E. Davies).*

Geological engineers and others concerned with ground stability are aware that regions underlain by cavernous limestone present special construction problems. Studies of the subsurface conditions are especially important in areas of limestone and gypsum because of the danger of ground failure and subsidence.

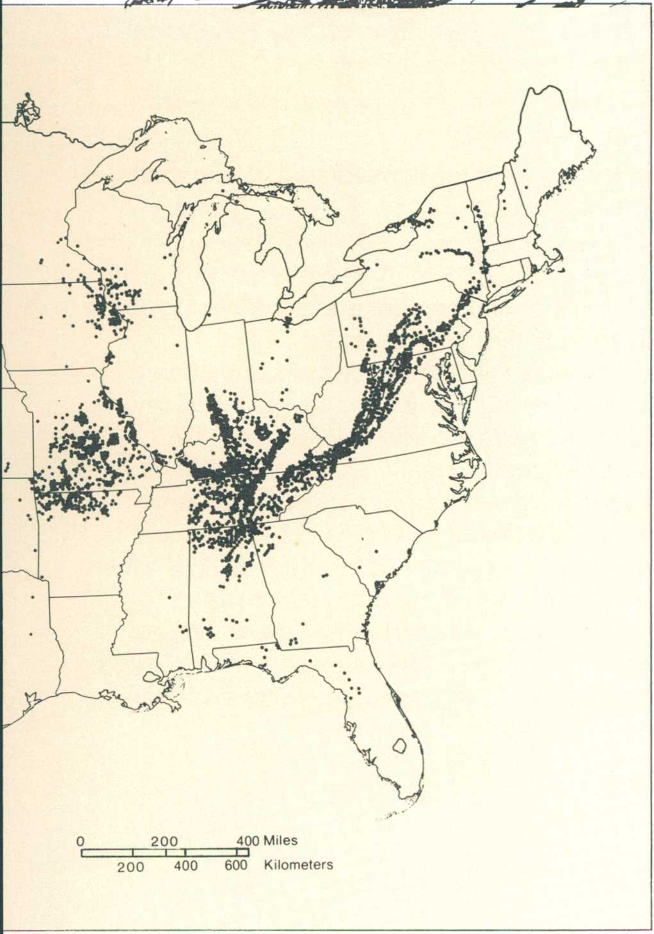
Caves To Explore

There are about 17,000 known caves in the United States. They occur in every State except Rhode Island and Louisiana. About 125 caves have been opened to the public for study and enjoyment. Of these, 15 are in national parks or monuments, and 30 are in



Cavern areas in the United States.

State parks. The remainder are privately owned and operated. Most of these caves are in the Appalachian Mountains, the Ozark Mountains, the Black Hills, and the limestone regions of Kentucky, Tennessee, and Indiana.



Caution

Exploring newly discovered or unattended caves can be extremely dangerous! Through experience, a set of safety rules has evolved that—if observed—may prevent accidents. If you plan to go cave exploring:

- Always tell someone where you are going and when you can be expected to return; obtain permission from the owner of the cave for the visit.
- Respect gates, whether they are in the field or at the cave entrance.
- Never enter a cave alone.
- Always carry several sources of light; do not depend solely on flashlights.
- Make sure you have proper equipment in good working condition.
- Never go beyond your physical and technical capabilities.
- For the sake of conservation, keep visits to a minimum.

Better yet, meet with knowledgeable and experienced cavers. Association with a group of experienced spelunkers is the best safety insurance that you can have.

Caves are natural features and should be protected, but many have been vandalized by careless visitors or damaged by poorly planned commercial development. Some caves have been stripped of speleothems which took thousands of years to form and in many places will not form again. All should try to prevent this random destruction of these natural wonderlands. Follow the footprints of others; look but don't touch; bring away only photographs; leave no evidence of your visit.

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