Lite Geology

Caves in New Mexico and the Southwest

fall 2013
issue 34

The Doll's Theater—Big Room route, Carlsbad Cavern. *Photo by Peter Jones, courtesy of Carlsbad Caverns National Park.*

In This Issue...

New Mexico Bureau Of Geology & Mineral Resources a division of new mexico tech

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Cave Development

A cave is a naturally-formed underground cavity, usually with a connection to the surface that humans can enter. Caves, like sinkholes, are karst features. Karst is a type of landform that results when circulating groundwater causes voids to form due to dissolution of soluble bedrock. Karst terrain is characterized by sinkholes, caves, disappearing streams, large springs, and underground drainage.

The largest and most common caves form by dissolution of limestone or dolomite, and are referred to as solution caves. Limestone and dolomite rock are composed of the minerals calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), which are soluble in weak acids such as carbonic acid (H_2CO_3), and are thus vulnerable to dissolution by groundwater.

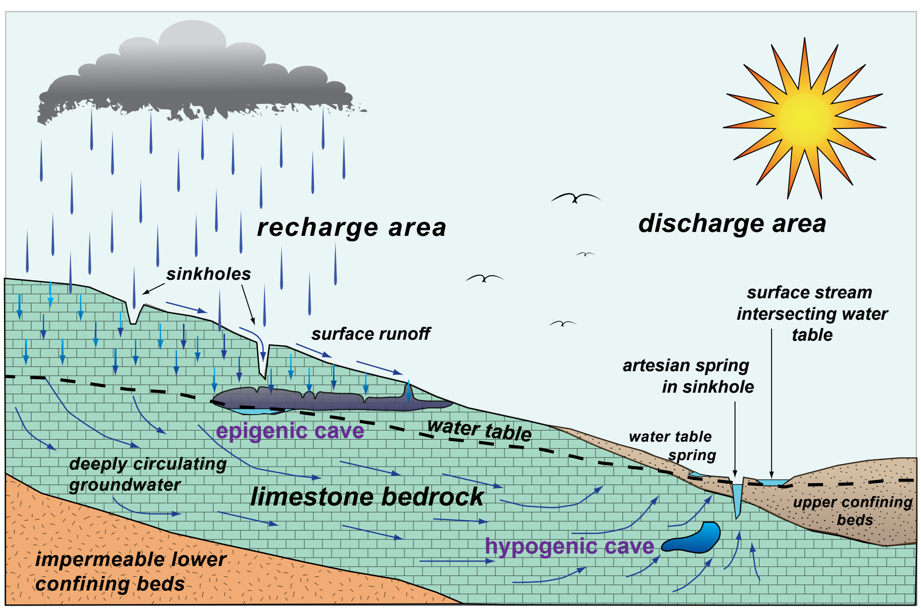
The traditional model for the formation of solution caves involves rainwater soaking down through the soil horizon, where the water becomes charged with carbonic acid derived from organic material or elevated carbon dioxide in the soil. This slightly acidic water continues to move downward through naturally occurring fractures and pore spaces in limestone or dolomite bedrock. In the process, the acidic water dissolves and enlarges these openings to form cave passages. Most solution caves require many tens of thousands of years to grow large enough for human entry.

Caves that form by this process are referred to as epigenic caves, meaning they formed in a near-surface environment, a few tens to hundreds of feet below ground level, by water flowing downward from the surface. Epigenic caves can be very long. The longest cave in the world is the Mammoth Cave system in western Kentucky, with a surveyed length of more than 400 miles (643 km).

The author attempting to squeeze into the natural entrance to Wind Cave. *Photo by Lewis Land.*

In recent years, scientists have begun to recognize that many caves are hypogenic in origin, meaning that they were dissolved by the upward flow of groundwater from below. Because of the way they formed, hypogenic caves may have very limited or even non-existent connection to the surface. For example, Wind Cave, in the Black Hills of South Dakota, has over 140 miles (226 km) of known passages, but for many years there was only one known natural entrance less than a meter in diameter. In 1984 a second small entrance to Wind Cave was discovered (there is now an improved man-made entrance for park visitors).

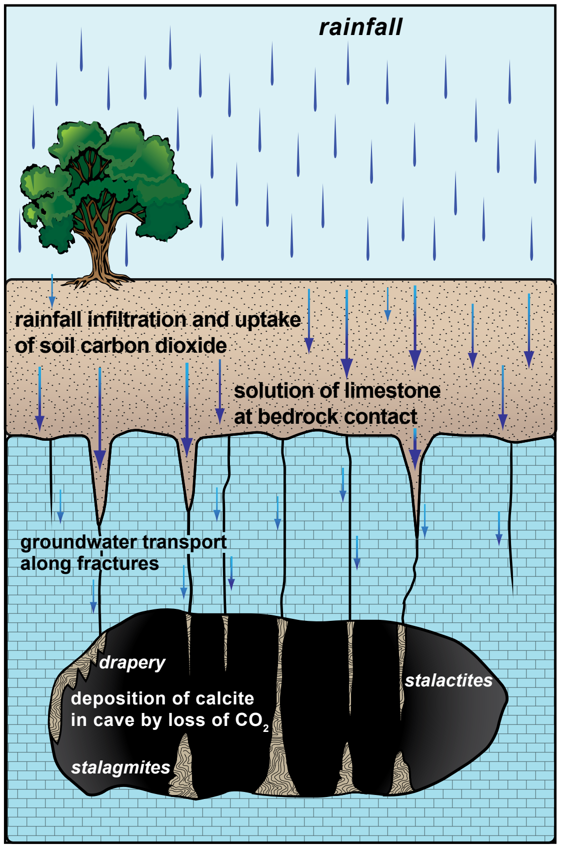
Carlsbad Cavern, in the Guadalupe Mountains of southeastern New Mexico, is also a hypogenic cave. Four to six million years ago, groundwater charged with hydrogen sulfide (H_2S) derived from petroleum accumulations in the Delaware Basin migrated upward through fractures and faults into the Capitan Reef limestone. When this hypogenic groundwater mixed with rainwater moving downward from the surface, the hydrogen sulfide combined with oxygen carried by the surface water to form sulfuric acid (H_2SO_4), a chemical agent much more powerful than carbonic acid. Groundwater charged with sulfuric acid then began to dissolve the limestone bedrock and form cave passages. This process, referred to as sulfuric acid speleogenesis, excavated the famous Big Room in Carlsbad Cavern, the sixth largest cave chamber in North America and one of the largest in the world. Lechuguilla Cave, another hypogenic cave in the Guadalupe Mountains, is 1,604 feet (489 m) deep, making it the deepest cave in the continental United States.



Generalized model of cave formation, showing relation to surface water and groundwater circulation. Epigenic caves form by acidic groundwater descending from the surface. Hypogenic caves form by upwelling of deeply circulating groundwater. Carlsbad Cavern is a type of hypogenic cave formed by upwelling of groundwater charged with sulfuric acid. *Illustration by Lewis Land.*

Cave Formations

Many caves are decorated with formations known as speleothems. Such features include stalactites, drapery, and soda straws, which are all suspended from cave ceilings, and stalagmites, which extend upward from the cave floor. Speleothems form when groundwater moving through fractures in the overlying bedrock enters the cave environment as ceiling drips. At this point a process known as carbon dioxide (CO_2) degassing occurs. CO_2 is released from the dripwater, making it less acidic and thus less able to keep calcite in a dissolved state, causing calcite to crystallize on the ceiling and floor. Because stalactites and stalagmites are often formed by the same drip source they may occur in pairs, sometimes merging to form columns. Carlsbad Cavern is regarded as one of the most spectacularly decorated caves in the world. A smaller but equally impressive example of a spectacularly decorated cave is Caverns of Sonora in west Texas.



Formation of speleothems by descending groundwater. *Illustration by Lewis Land.*

Twin Giant Domes. *Photo by Peter Jones, courtesy of Carlsbad Caverns National Park.*

Evaporite Karst

Most caves and other karst features in the eastern United States are formed in limestone or dolomite. However, west of approximately the longitude of Wichita, Kansas, karst features formed in evaporitic bedrock become increasingly common. Evaporites are a type of sedimentary rock produced by the evaporation of saline water. The most common types of evaporitic rock are gypsum, composed of calcium sulfate ($CaSO_4 \cdot 2H_2O$), and halite (rock salt), composed of sodium chloride (NaCl). Thick deposits of gypsum and halite are present at the surface and in the subsurface throughout the Permian Basin region of west Texas, southeastern New Mexico, and western Oklahoma.

Halite is very soluble in water, and for this reason caves formed in halite tend to be small, short-lived, and rare except in extremely arid regions. Good examples of salt caves can be found in Israel, Iran, and eastern Spain. Caves formed in gypsum, which is less soluble than halite, are far more common than salt caves. In southeastern New Mexico, literally hundreds of gypsum caves can be found in the lower Pecos Valley region. Caves formed by dissolution of gypsum are similar to limestone caves in their length, shape, and the pattern of their passages, although large rooms in

Spring discharging from one of the entrances of Parks Ranch Cave, Chosa Draw, southeastern New Mexico. *Photo by Lewis Land.*

gypsum caves are rare and speleothems are less common. Parks Ranch Cave, south of Carlsbad, N.M., at more than four miles (6.6 km) long, is the second longest gypsum cave in the U.S. The longest gypsum cave known in the world is Optimisticheskaya in western Ukraine, with more than 146 miles (236 km) of surveyed passage.

Gypsum caves are found more frequently in the western U.S. because gypsum is many times more soluble than calcite, the mineral that makes up limestone. The eastern U.S. receives almost three times as much rainfall as some parts of the western United States, so gypsum outcrops are rare in the east. In semi-arid regions of the west and southwest, the less soluble limestone outcrops are more likely to form cliffs rather than caves, and gypsum caves and sinkholes are more widespread.

Lava Tubes

Caves may also form in volcanic rock when the surface of a lava flow hardens to form a roof over a still-flowing lava stream on or near the flank of a volcano. After the lava drains out, it leaves behind an empty conduit. Such caves are known as lava tubes, because they tend to form as relatively unidirectional passages that are roughly circular in cross-section. Lava tubes are referred to as a type of pseudokarst, because they do not form by dissolution of soluble bedrock, in contrast to limestone or gypsum caves.

Manjang lava tube cave, Jeju Island, Republic of Korea. *Photo courtesy of Dr. George Veni, National Cave and Karst Research Institute.*

Lava tube caves can be very long. The world's longest lava tube formed on the flanks of the active Mauna Loa volcano in Hawaii, and extends 41 miles (65 meters) from its highest point, descending 3,614 feet (1,101 km) to near the ocean. Lava tube caves are also found in areas that are no longer volcanically active, such as the lava flow at El Malpais National Monument in northwestern New Mexico.

Caves and Karst Aquifers

Caves commonly form important components of karst aquifers. Aquifers are rock formations that store and transport groundwater. Water in karst aquifers is mostly transported through caves and similar conduits formed by dissolution of the rock. Because caves are continuous conduits in the subsurface, they can act as integrated drains for the rapid and efficient movement of groundwater through karstic limestone to water supply wells. The outlets of these conduits are sometimes very large springs. The Floridan Aquifer, which underlies most of the state of Florida, contains many extensive submerged cave passages that discharge water into world-class springs that are popular tourist destinations, such as Wakulla Springs near Tallahassee. Caves and solution conduits are an integral component of the Edwards limestone aquifer system in central Texas. Farmers in the Roswell Artesian Basin of southeastern New Mexico receive almost their entire water supply for irrigation from the karstic San Andres limestone aquifer. The San Andres limestone is also the host rock for Fort Stanton Cave in the Sacramento Mountains west of Roswell, the third longest cave in New Mexico. And residents of Carlsbad derive their drinking water entirely from a karstic aquifer in the Capitan Reef limestone, the same formation within which Carlsbad Cavern is formed.

Groundwater can move very rapidly through cave passages within karstic aquifers, sometimes as fast as several thousand feet per day. Karstic aquifers may thus yield very high volumes of water to supply wells. However, karstic aquifers also very efficiently transport contaminants to wells. The large size of the conduits in such aquifers does not provide the type of natural filtration that occurs in many non-karstic aquifers. For this reason, water quality is of greater concern in regions where karstic aquifers provide the community water supply. In the United States, it is estimated that approximately 20% of the land surface is underlain by caves and other karst landforms, and about 40% of the water supply comes from karstic aquifers. On a global scale, roughly 25% of Earth's population either lives on karst terrain or derives its water from karstic aquifers.

Societal impact of caves and karst

Because of the hazards posed by catastrophic collapse, caves may be a significant geohazard in some parts of the world. In 2008, two large sinkholes formed in southeastern New Mexico when artificial caves produced by brine well operations north of Carlsbad abruptly collapsed. On the other hand, karstic aquifers may provide the sole source of water supply for irrigation and human consumption in semi-arid regions. The population of the Pecos Valley in southeastern New Mexico would be much smaller without the availability of groundwater from karstic limestone aquifers in that region. Thus, caves and other karst features can have a profound societal impact on human populations.

Cave Dwellers Maureen Wilks

Caves dwellers in New Mexico have learned over the years to live on both scarce nutrients and water. The subterranean pools and streams that do exist can be oases for cave-adapted species. Despite being extreme environments, caves provide shelter to a wide range of life. Animals like coyotes, raccoons, javelina, and mountain lions seek temporary refuge from the outside elements in caves, and in some cases use them as den sites to raise their young. In the Sinkhole Flat region of Eddy County, animals reported using the caves include a great horned owl, barn owl, and the western diamondback rattle snake. Some creatures like bats and cave swallows live part of their lives inside caves, and some creatures never leave them. During the day visitors to Carlsbad Caverns are welcomed by cave swallows that make open cup-shaped nests out of mud on the limestone walls. A little deeper inside the cave over 400,000 Mexican free-tailed bats roost during the summer months and wow visitors every evening with their spectacular out flights into the surrounding desert to forage for insects. As you descend deeper into total darkness, troglobites, animals that spend their entire lives underground, thrive in the perpetual darkness. Troglobites include spiders, cave crickets, isopods, shrimp, crayfish, and fish that over generations have adapted to the darkness. These animals often lack skin pigmentation and eyes, and have elongated appendages that help them move more efficiently, thus conserving energy. Invertebrate specimens in El Malpais National Monument lava tubes include spiders, springtails, booklice, beetles, and flies. Troglobitic invertebrates have grown longer hairs and antennae than their surface counterparts to help them sense their surroundings in complete darkness.

Not all creatures that inhabit caves are so clearly visible to the naked eye. Many single-cell organisms or microbes live in caves, and are some of the organisms best adapted to life in caves. Some microbes can feed on the minerals found on rocks or within subterranean pools, and others even filter nutrients from the air. Microbes ride in on air currents, flowing water, insects, bats and humans. Within a cave, any place with sufficient moisture may contain microbes. These tiny organisms can be very important to cave ecosystems, and in some cases, microbes can serve as the center of a cave's food web. Microbes like bacteria and fungi that make their home in caves are important for several reasons. Because of their long isolation from the surface and because of their existence in very low nutrient environments, some cave microbes appear to have evolved to produce specialized chemical compounds, or toxins, with which to fend off neighbors. These microbial chemical compounds may be useful to humans in the fight against disease or pollution.

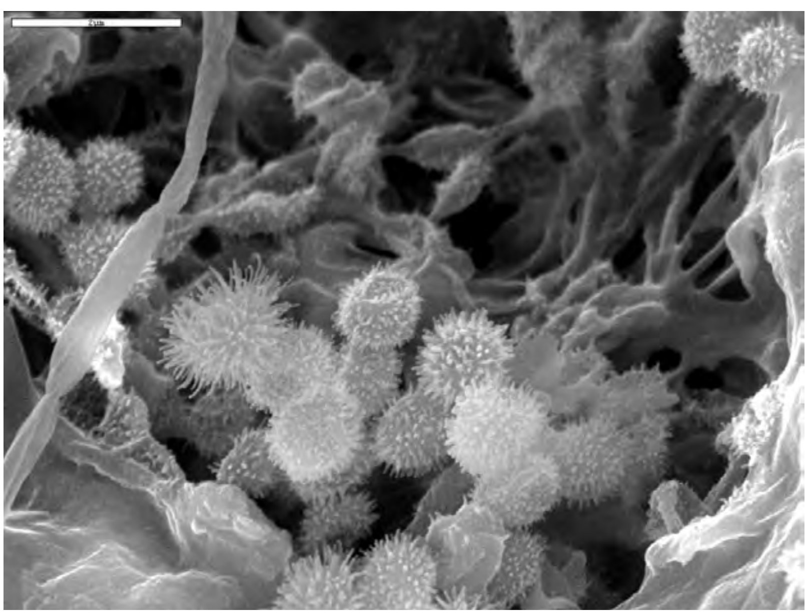
Human Impact on Caves

Unfortunately, the delicate cave ecosystems that have evolved over thousands of years can be wiped out in an instant. Even seemingly harmless activities, such as shining a light into a maternity colony of bats, may cause some species of bats to leave their roosts and abandon their pups. Humans entering and exploring caves bring in microbes and organic matter in the form of skin, hair, food, urine, and possibly even feces. A human sheds tens of thousands of skin fragments per minute! This additional organic matter does the most harm. Native cave microbes often live in very low nutrient environments and may not be able to survive in richer environments. If we add too much organic matter, the cave habitat will cease to be a good place for native bacteria to live and will become, instead, a good place for transient, surface microbes to thrive.

See the next pages for a gallery of cave dwellers.

Cave Dwellers Maureen Wilks

From top left clockwise: Pigment-free crayfish, (Orconectes pellucidus) with eggs, Mammoth Cave, KY. Length including claws, is about 7 cm; Rafineque's big-eared bat. Width about 5 cm; Cluster of Indiana bats hanging from cave ceiling (cluster is about 30 cm wide); Collembola (springtails) in a cave pool. Each is about 2 mm long. *All photos courtesy Rickard A. Olson.*



From top left clockwise: Southern cavefish (Typhlichthys subterraneus), Mammoth Cave, KY. Length ~ 4 cm; Cave beetle (Neaphaenops tellkamfi) in Great Onyx Cave, KY. Note holes in sand that it has produced in the search for the eggs of cave crickets. Beetle length ~4 mm[1]; Cave cricket, El Malpais National Monument, NM[2]; Chrysanthemum microbe garden[3]; Salamander (Eurycea lucifuga Rafinesque) White's Cave, KY. Visible length about 8 cm[1]. *Photos Courtesy 1) Rickard A. Olson; 2) Kenneth Ingham; 3) Penny Boston.*

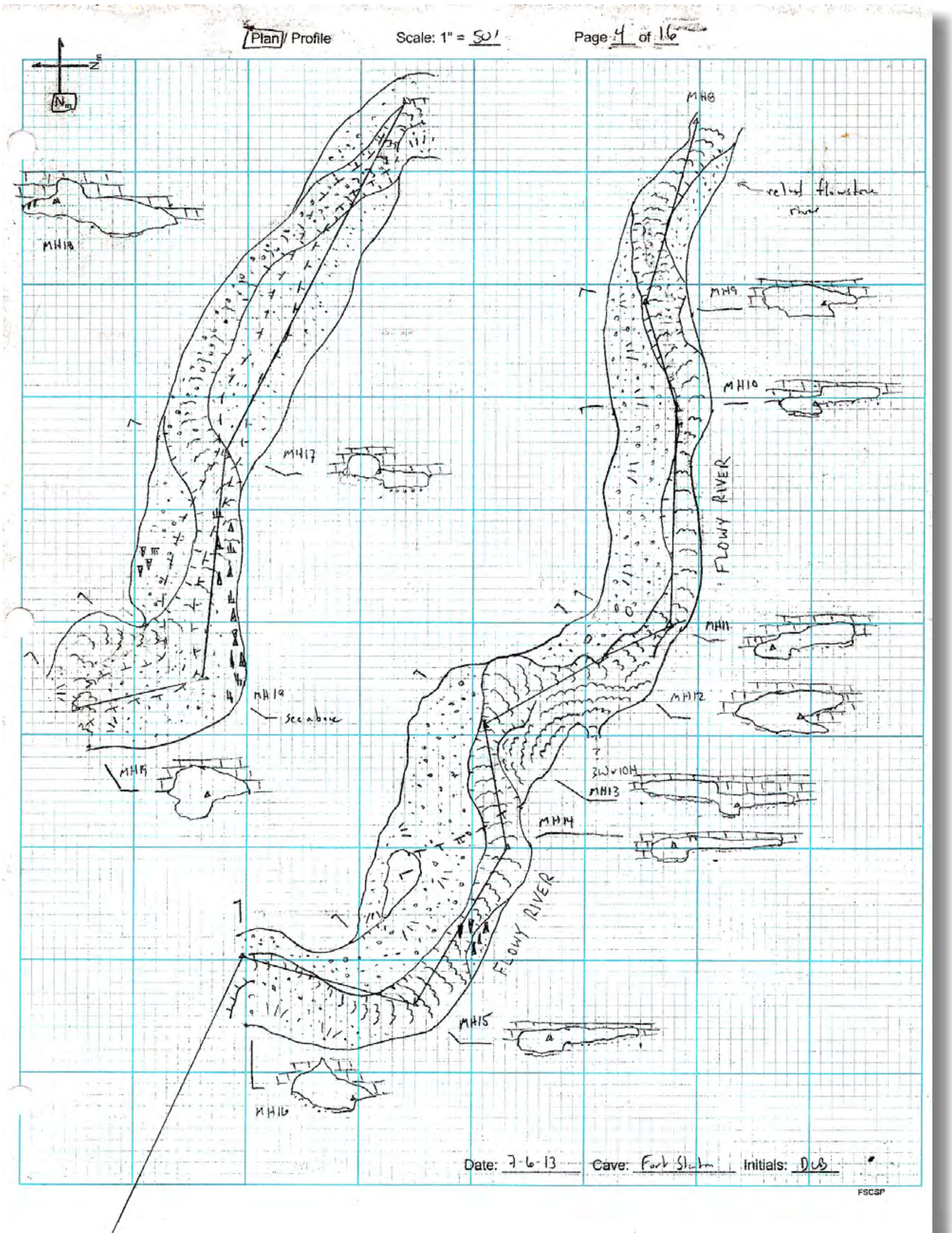
Mapping Caves Talon Newton

Cavers are very passionate about exploring caves. The strange crystals and cave formations (speleothems) they encounter remind them of alien worlds they read about in science fiction novels. Cavers are fully aware of the delicate nature of these wondrous underground landscapes, and try hard to minimize impacts as they walk, climb, crawl, and squeeze through these subsurface labyrinths. Most cavers recognize that the most responsible way to explore a newly discovered cave is by surveying, or making a map of the cave as they go. This map is a tool that will allow future navigation of the cave with minimal impact. Part of the mapping process entails the systematic identification and characterization of geologic formations and mineral inventories throughout the cave. These detailed descriptions of certain areas of the cave can be used to monitor future human or natural impacts within the cave. Ultimately, a cave map provides a three dimensional model of the cave that can be used by cave explorers and scientists to protect and learn more about these precious natural resources.

Surveying a passage in Fort Stanton Cave, New Mexico. The sketcher (Janice Tucker) is recording data while Linda Starr is measuring inclination (the vertical angle between two survey points). *Photo courtesy of the Fort Stanton Cave Study Project and Jennifer Foote.*

The most common method of cave surveying involves a team of three or four cavers. As they move through the cave, the person on "point" sets survey stations, or points, which are commonly located on the floor, walls, or ceiling of the cave. Consecutive survey stations are set within line of sight of each other. The distance between consecutive points is measured with a tape measure. The "instrument person" uses a handheld compass and clinometer to shoot an azimuth and measure the vertical angle between consecutive points. Meanwhile, the "sketcher" records the data and plots the survey points on graph paper. Based on the position of the survey points relative to each other, the cave walls, floor, ceiling, and other prominent features of the cave, the sketcher draws the cave passage to scale in the cave. The map is drawn in two main views: viewing from above (plan view) and viewing from the side (profile view). The sketcher also draws several cross-sections that depict the shape of the passage if sliced vertically perpendicular to the passage. In addition, the sketcher includes symbols that represent specific features such as trails, speleothems, and botanical, hydrologic, and cultural features. All these details on the cave map help map users navigate the cave. As the survey progresses, a working map is drawn outside the cave, based on data collected and sketches drawn inside the cave.

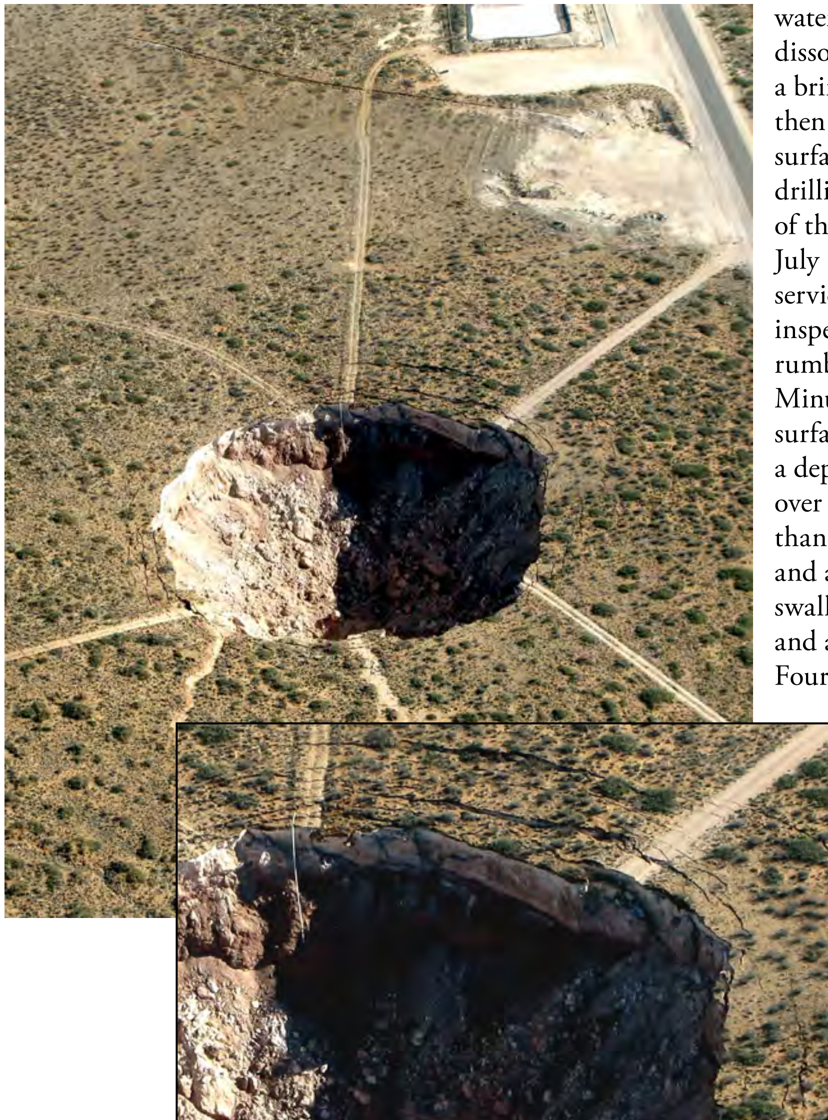
The final stage of making a cave map is drawing the final map from the working map. Traditionally, the final map is drawn by tracing the working map in pen on paper or film. However, these days the final map is commonly constructed digitally on a computer by tracing a scanned image of the working map. A finished cave map is not only a visually pleasing work of art that shows intricate details of the cave, but it is also a valuable tool that can be used by cavers and scientists to learn about and protect the cave. (See the next page for a full-sized cave map sketch).



This sketch from a recent survey in Fort Stanton Cave, by Derek Bristol, shows a plan view of the passage and cross-sections at different points in the cave. The straight lines connect consecutive survey points. *Courtesy of the Fort Stanton Cave Study Project.*

Earth Briefs—Suddenly Sinkholes Douglas Bland

Sinkholes are collapse features that form depressions on the land surface, and are related to caves. There are two main types of sinkholes. Subsidence sinkholes form when surface soil washes into cracks or cavities in stable bedrock below. Collapse sinkholes form when a relatively thin bedrock cap gives way and falls into a cavity below. Both types form in areas where near-surface bedrock (typically limestone, gypsum, dolomite, or salt) can be dissolved by water, forming underground caves and solution conduits.



The JWS Sinkhole in Eddy County, New Mexico is over 300 feet across. The inset is a close-up view of ring fractures formed around the edge of the sinkhole. *Photo courtesy of Lewis Land, National Cave and Karst Research Institute.*

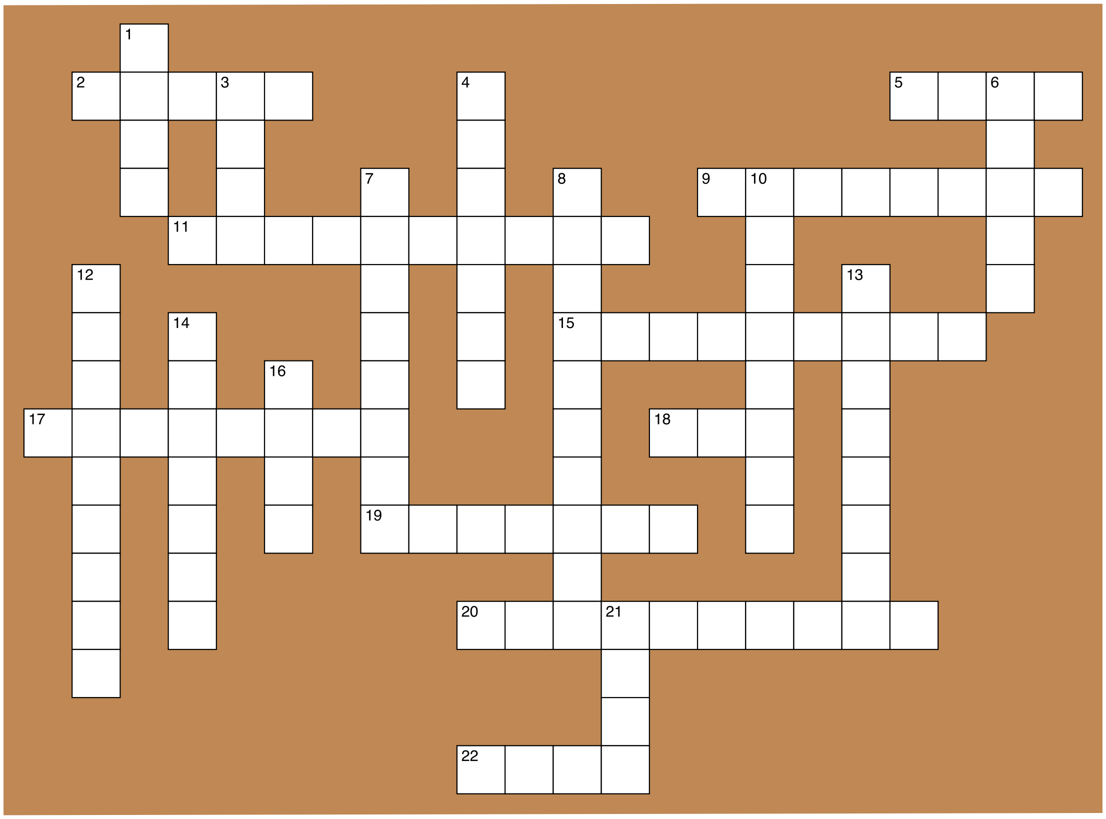
Most sinkholes seen on Earth's surface formed through natural processes with the underground "plumbing" developing over long periods of time. Good examples are found in Bottomless Lakes State Park near Roswell, New Mexico, featured in the "Enchanting Geology" article in this issue of *Lite Geology*. However, many sinkholes that form today are caused by human activities such as pumping groundwater and mine pit de-watering that cause a drop in the water table. This exposes cavities previously filled with water, allowing overlying soil or loose rock to wash into newly created voids. Surface collapse follows. This sort of geologic event catches the media's attention when, for example, a sinkhole formed under a house in Florida in 2013, swallowing a man who was sleeping inside. He was never found. Leaking or broken water or sewer lines can also cause similar problems, although usually smaller in scale.

In New Mexico, two new sinkholes formed in 2008, about 25 miles northeast of Carlsbad in Eddy County. In both cases, collapse was related to a well that was drilled into a thick salt formation about 600 feet below the surface. Fresh water was injected, which dissolved salt and created a brine solution that was then pumped back to the surface for use as oil field drilling fluid. In the case of the JWS sinkhole, on July 16, 2008 a local water service company employee inspecting the well noticed rumbling, and quickly left. Minutes later the ground surface collapsed, creating a depression that grew over two weeks to more than 300 feet in diameter and almost 150 feet deep, swallowing the brine well and associated structures. Four months later, the Loco Hills sinkhole formed about ten miles to the northeast, engulfing the well, nearby structures, a large water storage tank, and part of a brine pit. In both cases, large cavities formed where the salt had been dissolved and removed, and the overlying rock and soil formations collapsed into the new caverns.

Carlsbad, famous for natural caverns of the same name, may become known for something else. Another brine well within the city limits has created a near-surface underground cavern several hundred feet in diameter. After the Eddy County sinkholes formed, the Carlsbad well was shut down. However, the sub-surface cavity remains, as does fear that collapse could occur. Experts think collapse is very possible, but do not know when. Above it are two highways, a railroad, church, feed store, irrigation canal, and a mobile home park. Regulations governing brine wells have been strengthened, but potential problems remain.

Sinkholes Crossword Puzzle

Douglas Bland



Across

2. landform resulting from dissolution of bedrock

5. type of lava cave

9. type of cave that forms near the surface

11. this feature 'might' reach the cave ceiling someday

15. solution caves form from dissolution of this

17. the largest caves are this type

18. speleogenesis formed this room in Carlsbad Cavern

19. $CaCO_3$ is the chemical formula for this

20. decorative cave formation

22. caves can be decorated with these straws

Down

1. naturally occurring underground cavity

3. type of evaporitic rock

4. longest cave in the world

6. well type that created sinkholes near Carlsbad

7. rain flowing through soil becomes charged with this acid

8. this feature sticks 'tight' to the cave ceiling

10. acidic water dissolves openings to form these

12. cave formed by upward flow of groundwater

13. $CaMg(CO_3)_2$ is the chemical formula for this

14. rock formation that stores and transports water

16. cave in the Black Hills

21. volcanic rock type that can form caves

The answers to the clues are located in the Caves of New Mexico and the Southwest article in this issue of *Lite Geology*.

The solution to the puzzle is found on page 18 of this issue.

New Mexico's Most WANTED MINERALS

HYDROMAGNESITE

Virgil W. Lueth

Hydromagnesite cave balloon from Lechugilla Cave, Eddy County, New Mexico. *Photo courtesy of Michael Nichols, National Geographic Creative.*

DESCRIPTION: Hydromagnesite is a white magnesium carbonate mineral with the formula $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$. Unlike most carbonate minerals, it has a monoclinic to pseudo-orthorhombic crystal structure rather than hexagonal, so the crystals tend to be platy rather than box-like. It is soft with a Mohs hardness of 3.5. It has two cleavage directions, one perfect and the second distinct. Crystals tend to be elongated and acicular; twinning along its length (polysynthetic) is common. The luster is quite variable ranging from vitreous (glassy), to silky, pearly, or earthy (dull). It tends to be brittle, but most often the mineral occurs as a powder. Hydromagnesite is commonly fluorescent, appearing green in shortwave ultraviolet, and blue-white in longwave ultraviolet. Perhaps it's most spectacular occurrence is as cave balloons. It was first described in 1827 by H.G.T. Wachmeister.

WANTED FOR: Hydromagnesite is commonly mixed with the mineral huntite as a flame retardant in polymers. It endothermically decomposes on heating, giving off water and carbon dioxide, and leaving behind magnesium oxide. For centuries it was mined in Greece and used for whitewashing buildings.

HIDEOUT: The mineral is commonly found in caves as speleothems and moonmilk. It is deposited from waters that have seeped through magnesium-rich rocks. In caves this is usually dolomite. It also occurs in veins and incrustations in ultramafic rocks and serpentine, but these rock types are rarely found in New Mexico. A freshwater lake in Turkey contains stromatolites precipitated by diatoms and cyanobacteria made of hydromagnesite.

LAST SEEN AT LARGE: Lechuguilla cave in southern New Mexico is famous for its cave balloons that are rare elsewhere in the world. Moonmilk from Carlsbad Caverns consists of hydromagnesite. It is reported from the South Canyon area of the Organ Mountains as an alteration product of brucite marble. It has also been reported from the Fierro-Hanover area in Grant County as a weathering product of serpentine.

ALIASES: The mineral gets its name in allusion to its water content and similarity to the magnesium carbonate mineral, magnesite. Moonmilk is a common alias along with the less common term, giorgiosite.

New Mexico's Enchanting Geology

Stacy Timmons

WHERE IS THIS?

Mirror Lake is made up of two sinkholes formed in the Seven Rivers Formation. The deepest part of this sinkhole is about 50 feet (15 meters) deep. *Photo courtesy of Lewis Land.*

Bottomless Lakes State Park is located approximately 20 miles southeast of Roswell, New Mexico. The lakes, which in fact do have bottoms, are actually sinkholes ranging in depth from 17 to 90 feet, and are fed by groundwater rather than surface water. The sinkholes formed because gypsum, salt, and siltstone of the Seven Rivers Formation have been dissolved by upward flow of groundwater. Water flows from higher elevation regions to the west, traveling in the subsurface through limestone caves and karst of the San Andres Formation. When groundwater nears the area of Bottomless Lakes, it is under confining pressure from overlying rock layers, creating artesian (upward) flow of water to the bottom of these sinkholes. Because the groundwater flows through geologic layers with high salt content, the water in the sinkholes is brackish, or saline.

Lea Lake is the largest sinkhole in Bottomless Lakes State Park, offering opportunities for water fun such as swimming, scuba diving and pedal-boating. *Photo courtesy of Lewis Land.*

GEOLOGY ROCKS! SINKHOLE IN A CUP

This lesson demonstrates how a sinkhole is formed, and includes examples of some sinkhole lakes in New Mexico. It was adapted from a curriculum developed for the New Mexico Outdoor Classroom Program by the State Parks Division of the New Mexico Energy, Minerals and Natural Resources Department. A link to the full lesson in PDF format is provided at the end of this lesson.

Grade Level: **Grades 4–8**

Objectives:

Students will:

1) Demonstrate how groundwater travels upward and dissolves *gypsum* and *siltstone* to form sinkholes.

2) Observe how chemicals are absorbed into groundwater and pollute surface water.

3) Understand how over-pumping groundwater affects sinkhole water levels.

Teacher Background:

The lakes at Bottomless Lakes State Park are steep-walled, water-filled sinkholes, known as cenotes in Spanish (se no' tes). Sinkholes are formed when groundwater dissolves rocks and minerals, creating underground caverns. Caverns may eventually become large enough that the ceiling above collapses. You may be surprised to know that the water doesn't come from the nearby Pecos River but from water that traveled slowly underground from the Sacramento and Capitan Mountains sixty miles west of Roswell!

Materials:

- 2-8 oz. Styrofoam or plastic cups per group
- a scouring pad or a thin sponge
- an empty plastic 2-liter soda bottle
- sugar
- sand
- scissors
- empty paper towel or toilet paper tube
- empty plastic syringe
- food coloring

Method:

Procedure A:

1. Poke a hole the size of your thumb in the bottom of the cup.

2. Cut a circle the size of the bottom of the cup out of the sponge and put it at the bottom of the cup.

3. Insert tube, it should be the height of the cup and half as wide. Place in the middle of the cup over the hole.

4. Fill the tube with sugar.

5. Surround it with sand.

6. Carefully take out the tube.

7. Put a thin layer of sand over the sugar.

8. Cut off the bottom of the coke bottle.

9. Fill it with water, about a third full. It will symbolize ground water.

10. Put the cup in the water.

11. Watch the water dissolve the sugar and collapse the sand above. You may need to take the cup out of the water to see the sinkhole form.

Procedure B.

1. Mix a few drops of food coloring with ½ cup of water. Add mixture to the 'groundwater' in the plastic bottle. The food coloring represents groundwater contaminants or chemicals.

2. Watch as the food coloring 'contaminants' are absorbed into the ground water and the sinkhole.

3. Have students discuss what kinds of chemicals might be found in ground water and how they could be prevented.

Procedure C:

1. Take plastic syringe and place tip in 'groundwater'. Make sure plunger is pushed in all the way before placing in water.

2. Slowly pull up plunger, drawing out water and filling syringe. This represents groundwater being pumped out.

3. Observe what happens to the water level in the sinkhole.

4. Have students discuss impacts of excessive groundwater pumping and ways to reduce it.

Stages of Sinkhole Formation

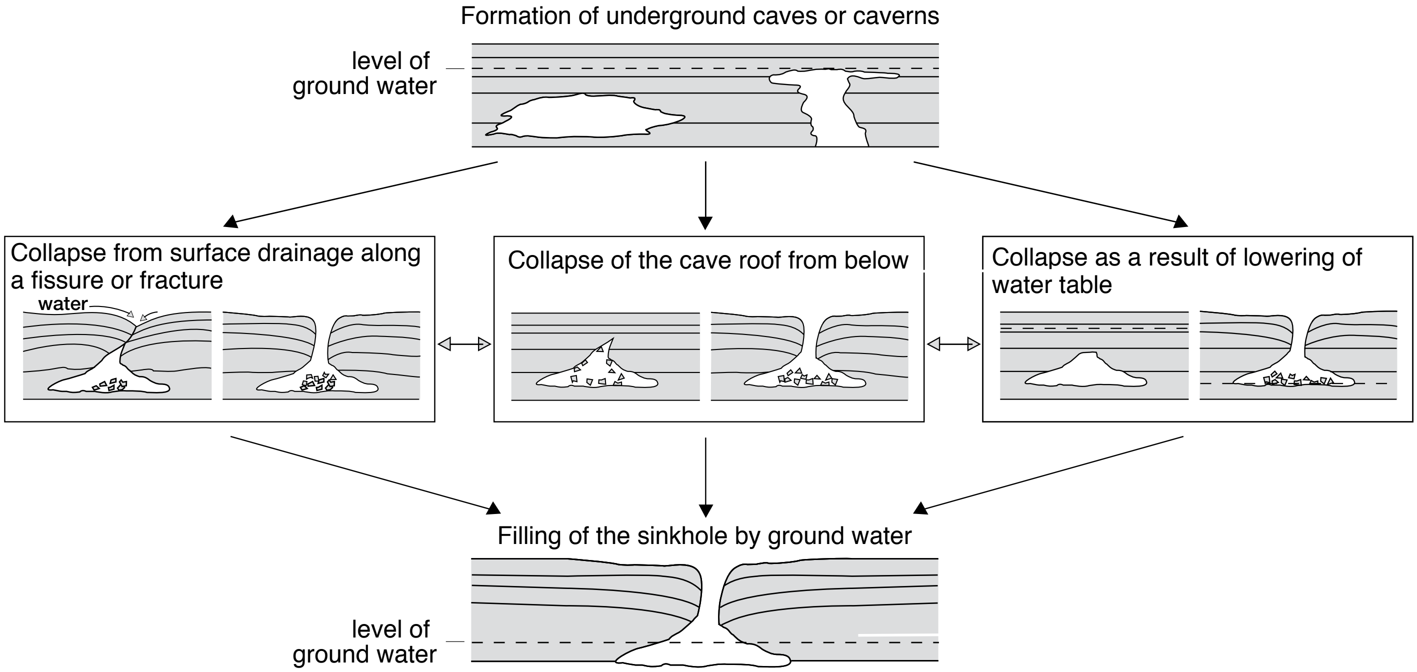


Diagram showing the stages of sinkhole formation. At Bottomless Lakes, water flows through the San Andres Formation, predominantly from the Sacramento Mountains to the west. It slowly dissolves bedrock, forming underground caves and caverns. Eventually, rocks overlying the caverns collapse from their own weight. A combination of all three processes, solution, collapse, and water-table fluctuations, forms the sinkholes. The lakes at Bottomless Lakes formed when the sinkholes extended below the water table. *Figure courtesy of New Mexico Bureau of Geology and Mineral Resources; New Mexico Geology, May 1999.*

Source:

The full lesson *Geology Rocks! Sinkhole in a Cup* in PDF format can be accessed at the following web address:
http://www.emnrd.state.nm.us/SPD/documents/SinkholeinaCup_Feb2010_000.pdf

PROFILE OF A NEW MEXICO EARTH SCIENCE TEACHER

Teaching is a second career for Sherie Pennebaker, who has been a 6th and 8th grade science teacher at Jefferson Middle School in Albuquerque for seven years. Her first career was at Honeywell, where she was responsible for repairing circuit boards and assembling environmental control units, along with monitoring quality control, and health and safety. Sherie is an experienced caver and explores caves in New Mexico and many other parts of the world. She is able to integrate her enthusiasm for geology and caving into her classroom teaching.

Robber Baron Cave is an extensive limestone cave located in San Antonio, Texas. *Photo courtesy of Sherie Penebaker.*

Educational background:

B.S. Earth and Planetary Science, University of New Mexico

Masters of Science for Teachers (MST) program, New Mexico Tech (currently enrolled)

Previously studied Electronic Technology and Health and Safety at Central New Mexico Community College

Why is it important for students to learn about Earth Science? Earth Science is all around us, and it's important for students to understand our planet. Earth Science encompasses all the sciences, so it can be integrated into anything I am teaching. For example, fossil sequences help students understand adaptations and evolution; understanding mineralogy involves chemistry instruction; earthquakes and mountain building help kids understand physics.

Why did you become a science educator? I chose teaching science because I like science and I think that science is interesting to kids. Science labs are fun, and are a great way to teach kids. I enjoy the freedom I have as a teacher to create interesting and relevant lessons, and to experiment with different approaches to teaching a subject. I also enjoy running after-school programs, where kids who have special interests can get extra time to foster their passions. Currently, I run a Strategic Games club after-school program, where kids can play board games and card games. These games help kids with math, teamwork, strategy, and planning. In the past, I've worked with MESA (Mathematics, Engineering, Science Achievement) kids after school, which has really opened my eyes to how excited kids can become when they are given a problem to solve and limited resources with which to solve it.

Advice or suggestions for other Earth Science teachers: A lot of times teachers can feel bogged down with lessons, grading, clubs, and all the other duties we have. It's a good idea to get outside and do something that gets you excited about teaching Earth Science. New Mexico has a lot of professional development opportunities for educators. I suggest taking a class like Rockin' Around New Mexico at New Mexico Tech to expand your knowledge about New Mexico's geologic history. Materials Science Camp at Sandia Labs is also a good way to expand your knowledge about STEM (Science, Technology, Engineering and Math) subjects.

Favorite lesson in Earth Science: I use a lesson based on the U.S. Geological Survey curriculum called Karst Topography. This activity helps students understand how complex a cave system can be as they construct a three-dimensional model of a cave. The full lesson is USGS Open-file Report 97-536-A and can be found online at: **http://pubs.usgs.gov/of/1997/0536a/report.pdf**. After students build the model, we learn about karst systems, such as what happens to water when it falls on karst, and whether contaminants follow the same path as the water. Cave formation and cave mineralogy are covered, and in 8th grade, the chemistry of ground water and cave minerals are investigated. Since kids remember the model they made, I can refer back to it in later units, for example, when we cover natural resources.

When did you fall in love with geology? When I was a kid, my mom said that I used to look at the ground wherever we went. I grew up in the Chicago area, where there are a lot of glacial deposits. I collected some really excellent fossils, as well as some cool rocks that I later learned had been deposited by glaciers in the Pleistocene Epoch. I still collect rocks.

What hobbies do you have that relate to your science teaching? Besides caving, I love hiking, reading and watching science fiction, and making stuff. I like to travel and go to conventions (caving and science fiction). I've caved in many areas, including New Mexico, Georgia, Tennessee, Alabama, West Virginia, Maine, Illinois, Indiana, Texas, California, Mexico (Yucatan Peninsula), Europe, and Belize.

Describe how you became a caver, and some of the projects you have done: My dad was a caver, and while I did not go to any wild caves with him, I read about caves all the time in science fiction books while growing up. I met my husband, who was already an experienced caver, in 1996. We went to Alabaster Cave, in the San Ysidro, New Mexico area for my first wild caving trip. I loved caving the moment I experienced it! I loved the dark, chilly, obstacle-course of the cave, and it was one of the only times that I had ever felt truly safe. I think that the lack of outside stimulation and the feeling of walls all around me added to an overall comfort that I can't experience any other place.

What are the safety and environmental concerns when visiting caves? When you visit a cave, you need at least two other people with you, and permission to enter the cave. You should contact the landowner, Bureau of Land Management, Forest Service, or Tribal authorities. If you are interested in caving and don't know where to start, contact your local caving grotto or the National Speleological Society.

The equipment you will need includes a good helmet, three sources of light (one on your helmet), extra batteries, good boots, gloves, kneepads, a backpack with a few bottles of water, some high energy food that won't easily crush, an empty plastic bottle, a plastic bag (for protection from hypothermia and other uses), a small medical kit, duct tape (for binding ankles or wrapping just about anything), an extra jacket or polypropylene shirt, and if you are entering a cave that has vertical drops, your vertical gear. Be sure to dress warmly. New Mexico caves are generally somewhat warm and dry, but don't count on it. Dress in layers, preferably wool or synthetic fabrics. Unless you know that a cave is warm and dry, do not wear cotton clothing in the cave. See this site for more information: **http://nss.caves.org/safety/techniques.shtml**.

What is your favorite geologic feature in New Mexico? Fort Stanton Cave near Capitan has an interesting cultural history and also is an important cave study area. It has many stunning features including beautiful cave velvet, helictites, and selenite needles. Visiting Fort Stanton Cave is fun because there is always fascinating work going on. I've counted bats, done cave restoration, helped with surface resistivity tests, dug out rocks, and lately have hauled concrete to support the entrance to Snowy River passage. Snowy River is an area where limestone that had been dissolved has recrystallized on the cave floor in a very long, white passage. Snowy River is possibly the longest calcite formation in North America, and cavers have been diligently mapping and surveying the formation since its discovery. The Fort Stanton Cave Study Project has won numerous awards for its contributions to cave conservation and exploration.

Hidden Cave is a nicely decorated cave located in the Guadalupe Mountains in southeastern New Mexico.
Photo courtesy of Sherie Penebaker.

What are your favorite web links for science resources?

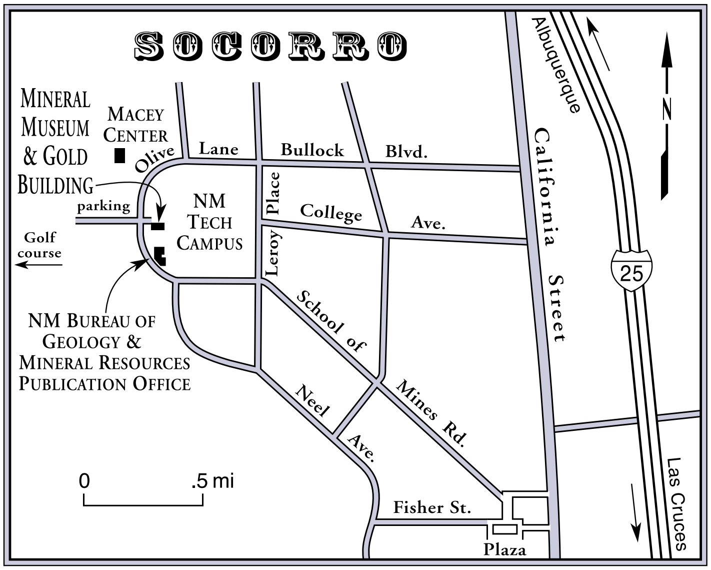
The National Speleological Society has a website that offers information about exploring, studying, and conserving cave and karst resources. Visit their site at: **http://www.caves.org/**

The United States Geological Survey has an extensive website for earth science education for teachers and students. The main page to access this information is located at: **http://education.usgs.gov/**

The Fort Stanton Study Project website is available at **http://fscsp.org/**.

The Texas Cave Management Association has a website with lots of information about Robber Baron cave, including a great example of a cave map with legend, which can be found at **http://www.tcmacaves.org/robberbaron/index.php**

Short Items of Interest to Teachers and the Public



The Mineral Museum on the Campus of New Mexico Tech in Socorro, New Mexico

Hours:

8 a.m. to 5 p.m., Monday through Friday

10 a.m. to 3 p.m., Saturday and Sunday

Closed on New Mexico Tech holidays

The Mineral Museum is located in the Gold Building on the campus of New Mexico Tech in Socorro. The bureau's mineralogical collection contains more than 16,000 specimens of minerals from New Mexico, the United States, and around the world, along with mining artifacts and fossils. About 2,500 minerals are on display at a time.

For teachers, students, and other groups, we offer free tours of the museum. We like to show off our home state minerals, as well as give students an idea of how minerals end up in products we use every day. Museum staff can also identify rocks or minerals for visitors. Please call ahead to ensure someone will be available. For more information on the museum, please visit our website at: http://geoinfo.nmt.edu/museum/

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To Schedule a Museum Tour, Contact:

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Manager, Geologic Extension Service
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The Publication Sales Office at the New Mexico Bureau of Geology and Mineral Resources (on the campus of New Mexico Tech)

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The Publication Sales Office has many resources for teachers, including publications on New Mexico's geology. Many are written for the amateur geologist and general public.

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- Topographic maps for the entire state of New Mexico
- Geologic maps for selected areas of New Mexico
- Popular and educational geologic publications
- U.S. Forest Service maps
- A 20% discount for teachers

Upcoming Events for Teachers and the Public

Earth Science Week 2013

October 13–19

Take part in the 2013 Earth Science Week (ESW)! This year, Earth Science Week will promote awareness of the many exciting uses of maps and mapping technologies in the geosciences. "Mapping Our World," the theme of ESW 2013, engages young people and the public in learning how geoscientists, geographers, and other mapping professionals use maps to represent land formations, natural resource deposits, bodies of water, fault lines, volcanic activity, weather patterns, travel routes, parks, businesses, population distribution, our shared geologic heritage, and more. Maps help show how the Earth systems—geosphere, hydrosphere, atmosphere, and biosphere—interact. Find out more and order your Earth Science Week Planning Toolkit at: http://www.earthsciweek.org/

Fall 2013 Science, Math, and Environmental Educators Conference
November 1–3
Location: Las Cruces, New Mexico

Centennial High School

1950 S. Sonoma Ranch Blvd.

Las Cruces, NM

Find more information and register online at
http://www.nmsta.org/

The focus of this year's conference is Science, Technology, Engineering and Mathematics (STEM) and will integrate the following:

- Alignment with Common Core Standards
- Alignment with Next Gen Science Standards
- Environmental Literacy
- Quality Professional Development
- Partnerships in Formal/Informal Education

This annual fall conference is jointly held by:

-New Mexico Science Teachers Association
-New Mexico Council of Teachers of Mathematics
-Environmental Education Association of New Mexico

Curriculum on Caves and Karsts for K-12 Classrooms

Project Underground—A Natural Resource Guidebook, Edited by Carol Zokaites

This 120-page curriculum guidebook contains classroom activities and information to help teach about caves and karst, including their biological, geological, hydrological, and historical diversities and values. The lessons are designed by educators and experts in the various disciplines of speleology. The activities are interdisciplinary and correlated by grade level.

Purchase the *Project Underground—A Natural Resource Guidebook* from the National Speleological Society online bookstore at: **http://nssbookstore.org/index.php?mode=homepage.html**

Credits:

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SOLUTION TO CROSSWORD PUZZLE