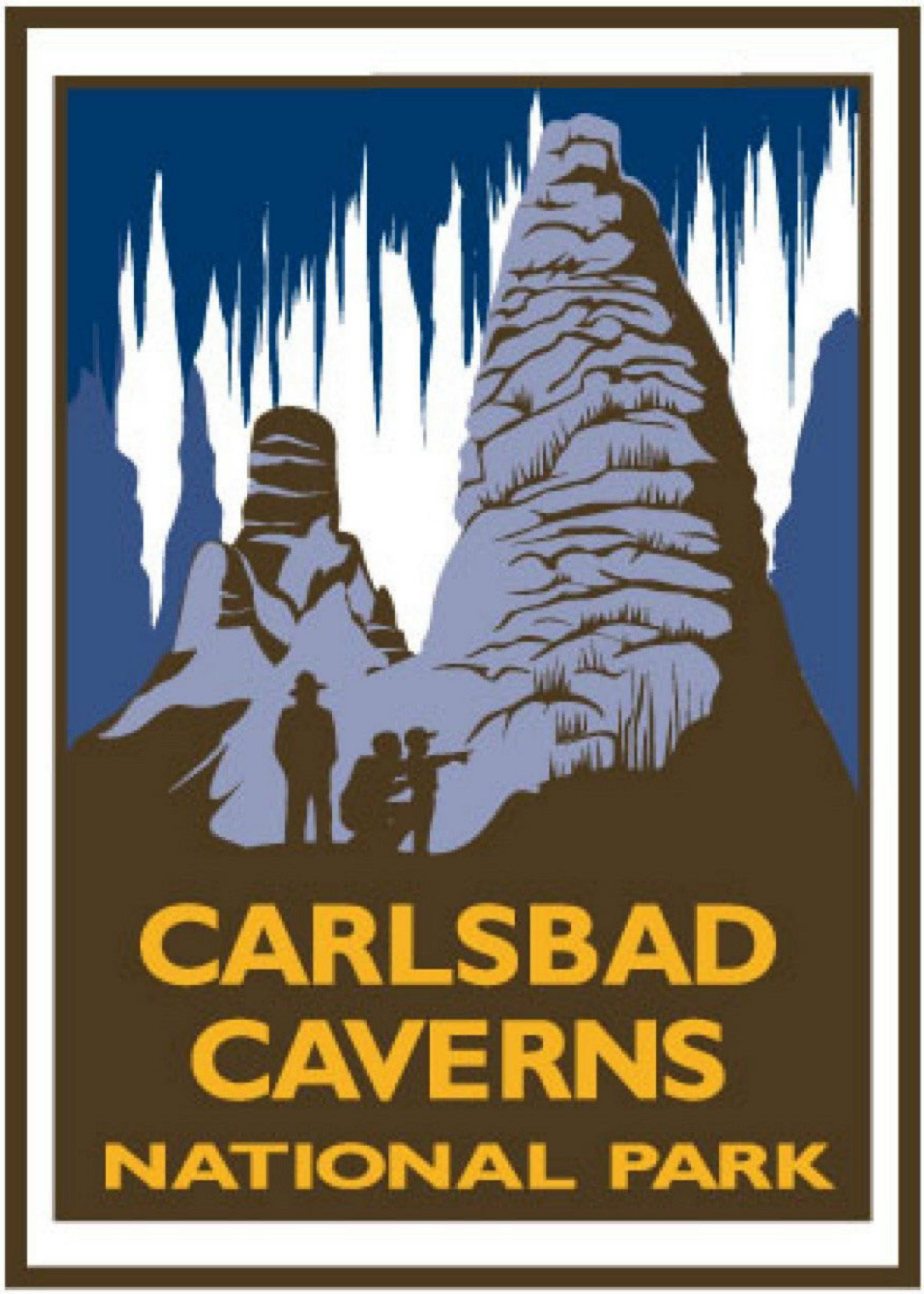
Caves, Canyons, Cactus & Critters

A curriculum and activity guide for Carlsbad Caverns National Park

Middle School Geology



Caves, Canyons, Cactus & Critters
Geology Curriculum

Hangy Downys, Sticky Upys and Other Pretty Cave Decorations

If you were to ask most people to describe a cave formation, they would probably describe "hangy downys and sticky upys", more properly known as stalactites and stalagmites. While these are probably the best-known cave formations, caves contain many other fascinating formations as well. Cave pearls, popcorn, hydromagnesite balloons, and selenite crystals are just a few examples of other features that grow in caves.

Other features found in caves result from the corrosion of bedrock and formations. These corrosion features are usually the result of the same compound, carbonic acid, which resulted in the formation of the large stalactites and stalagmites. However, the processes involved in corrosion features are quite different. A key player in the development of corrosion features is rising warm air.

A cave is a climate unto itself, and within a cave are many small variations in that climate. These "microclimates" often result in beautiful formations that can only occur in just the right set of conditions. Typically, the microclimates are a result of air movement, or the lack of it, within a cave system.

Water is another key player in the development of cave decorations. Without it, the Carlsbad Cavern would be a rather barren hole in the ground. Mildly acidic groundwater, migrating down through the limestone bedrock, carried dissolved calcite to the cavernous voids where it was deposited in the form of stalactites, stalagmites, and draperies. The migration of water from the surface to the cave has been the topic of many studies. A topic of concern recently has been the transportation of pollutants from the visitor center and office area into the cave by groundwater. Several studies have focused on determining the rate of groundwater infiltration into the cave in many areas.

Hangy Downys and Sticky Upys

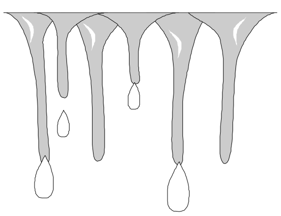
How do stalactites and stalagmites grow?

Summary: Students will describe and model the formation of stalagmites and stalactites.
Duration: Initial lesson and lab – one class period with formation growth going several days.
Setting: Classroom or lab
Vocabulary: flowstone, rimstone, speleothem, stalactite, stalagmite
Standards/Benchmarks Addressed: SC2-E3, SC4-E3, SC5-E2, SC6-E6

Objectives
Students will:

- describe how stalactites and stalagmites form.
- model stalactite and stalagmite formation.

Background

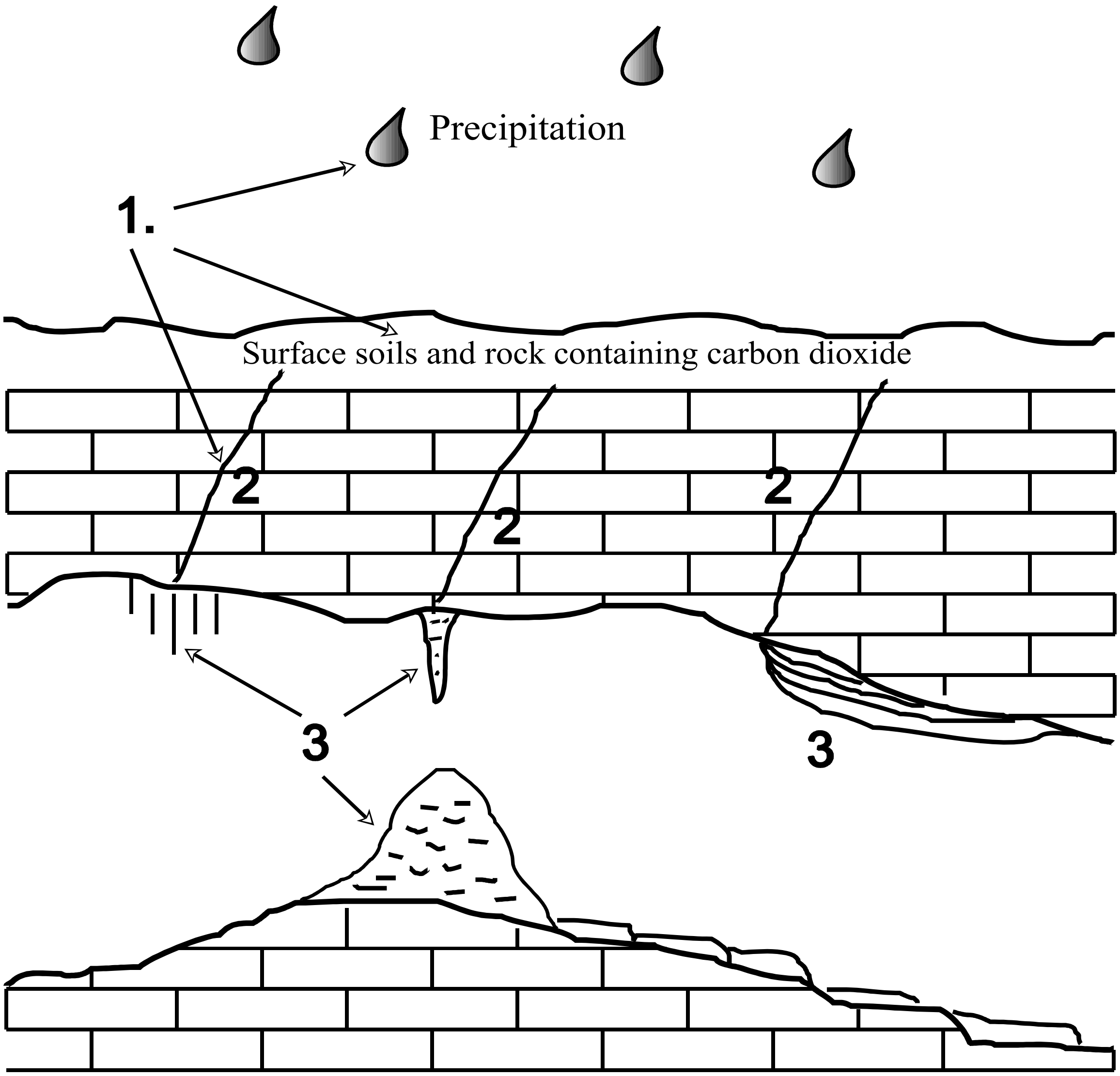


The speleothems found in caves are formed from many different minerals. In the book *Cave Minerals of the World*, Carol Hill and Paolo Forti describe 255 different minerals that have been identified in caves. Additionally, they describe 38 different types of speleothems. Obviously, there is a lot more to cave minerals and speleothems than just stalactites and stalagmites. This exercise is designed to introduce students to the idea of minerals being carried in solution from one location to another, where they are precipitated in the form of a *speleothem*.

Rain or other precipitation falling in the Guadalupe Mountains absorbs carbon dioxide from the air and from the soil as it seeps into the ground. This causes the water to become slightly acidic. This water infiltrates downward, first through pores in the soil and then through cracks, or joints, in the bedrock. As the water encounters limestone, it begins to slowly dissolve very small amounts of the calcite contained there and carries it downward.

On reaching the cave, it can hang on the ceiling, run down the side of the passage, or splash to the floor. Some of the carbon dioxide contained in the water is released into the cave air. With this change in the water chemistry, the calcite is no longer able to remain in solution and begins to precipitate out as a solid. As the calcite precipitates, the new crystals being formed attach themselves to existing calcite crystals and the speleothems on which they are deposited grow larger.

Sometimes the water will run, in a sheet, across the floor or down the wall of the cave. As this water flows, carbon dioxide is lost to the cave atmosphere and calcite will begin to precipitate onto the surface the water is flowing over. Eventually, this will result in a smooth calcite layer covering the original cave floor or wall. This layer is called *flowstone* and is seen throughout the Carlsbad Cavern.



1. Meteoric water infiltrating into the ground absorbs carbon dioxide from the air and from the soil it passes through.
2. This acidic water dissolves the mineral calcite as it moves downward through cracks, or joints, in the limestone bedrock and carries it down to the cave.
3. As the water hangs from the ceiling, runs down the side of the cave, or splashes to the ground, it releases carbon dioxide. Calcite then precipitates out of the water and attaches to the surface, forming soda straws, stalactites, stalagmites, draperies, and several other speleothems.

Often, water flowing across the floor of the cave will collect in pools. As water flows over the edge of these pools to continue downstream, it becomes turbulent. This causes carbon dioxide in the water to be released to the cave atmosphere. As a result, calcite begins to precipitate and attach to the edge of the pool. Over a period of time, the buildup of calcite at the edge of the pool can build a dam, actually deepening the pool. These *rimstone* dams, or gours, are found in many of the caves of Carlsbad Caverns National Park. Possibly the most spectacular of these is the Chinese Wall in Slaughter Canyon Cave.

The growth rate for speleothems varies from cave to cave and also varies between locations within the same cave. According to Hill and Forti, speleothem growth rates are affected by such factors as climate and water infiltration patterns. They cite studies in which wide ranges of growth rates were obtained for speleothems from several locations. In one study, growth rates ranged from 0.22 to 9.29 cm/100 years. They point out a study by Derek Ford in which he concludes that most cave travertine (calcite) grew during the last half of the Pleistocene Period, making it less than one million years old. However, in spite of the variability of calcite growth rates, it is still a very slow process on a human scale, with little growth being seen in the span of a human lifetime.

Students often ask how to remember which formation is a *stalactite* and which is a *stalagmite*. Stalactite has the letter 'c' in it like the word ceiling. Stalactites hang from the ceiling. Stalagmite has the letter 'g' in it like the word ground. Stalagmites grow from the ground. Stalactites must hang on 'tite' or they will fall. If they keep growing, stalagmites someday 'mite' reach the top of the cave. Most students will be able to use one of these methods to help them remember the difference in the two types of speleothem.

Materials

- Epsom salts
- small jars (two per set)
- cotton yarn
- washers or other items to be used as small weights
- scissors
- food coloring
- spoon
- aluminum foil
- paper

Procedure

Warm up: Show students photos of decorated cave passages. Have them describe the speleothems that they see. Ask them to write a summary of how they think the speleothems they see were formed.

Describe and discuss, as a class, the mechanisms by which the most common calcite speleothems are formed. Discuss the slow rate of speleothem growth and the factors influencing it.

Activity

1. Prepare a saturated Epsom salt solution. This can be done by filling each jar 2/3 full with Epsom salt and adding water to the same height. Stir.
2. Cut pieces of yarn 50 cm in length. Tie a weight to each end.
3. Place each end of the yarn in different jars and press the weight to the bottom of the jar.
4. Make a tray at least 60 cm long by folding and crimping the ends of a piece of aluminum foil.

5. Place the jars on the tray. The string should hang between them with the lowest part of the loop 2-3 cm above the tray.
6. Allow the jars to remain undisturbed for one week. Have the students check the speleothem growth daily. Have students draw the changes in the speleothems daily or plot the growth on a graph.
7. If desired, food coloring can be added to the Epsom salt solutions.

Wrap Up: Briefly, review the mechanisms of speleothem growth with the students. Discuss the strong and weak points of the Epsom salt model they have been observing for the past week. Tell the students that some cave formations are formed from the same mineral as that contained in Epsom salts. The mineral is called epsomite and has the chemical formula $MgSO_4 \cdot 7H_2O$. Epsomite speleothems grow much faster than calcite speleothems. According to Hill and Forti, some epsomite speleothems have been known to grow 25-35 cm in a matter of a few weeks.

Assessment

Have students

- submit drawing or graphs demonstrating the growth rate of the epsomite speleothems made in class.
- describe how calcite speleothems like stalactites and stalagmites form.
- describe three factors that affect the growth rate of speleothems.

Extensions

Use the procedure described above to create Epsom salt speleothems, but create them in a cave diorama. Several solutions with different colors can be used. Place the jars on top of the box in which the diorama will be built. Place the box on an aluminum foil tray or a shallow cookie sheet. Make hole in the top of the box that the yarn will pass through easily. Drape some pieces of yarn down through the box and back up to another jar. Other shorter pieces of yarn can be suspended with one end in a jar and the other hanging into the "cave." Encourage students to be creative in attempting to replicate several varieties of speleothems.

Resources

Ambrose, Janet, et.al. *eds.* 1999. *About Bats, Caves and Deserts.* Carlsbad, NM: Carlsbad Caverns National Park.

Hill, Carol and Forti, Paolo, 1997, *Cave Minerals of the World, 2nd ed.* Huntsville, AL: National Speleological Society, Inc.

Jagnow, David and Jagnow, Rebecca. 1992. *Stories from Stones: The Geology of the Guadalupe Mountains.* Carlsbad, NM: Carlsbad Caverns Guadalupe Mountains Association.

Van Cleave, Janice. 1991. *Earth Science For Every Kid.* New York, NY: John Wiley & Sons, Inc.

Not Just Your Average Decoration

Are there other types of formations that can be found in caves?

Summary: Students will use information learned in class discussion to model the formation of other cave decorations such as cave pearls, popcorn, and corrosion features.
Duration: One 50-minute class for initial lesson. Five to ten minutes daily for one to two weeks thereafter.
Setting: Classroom
Vocabulary: cave pearl, cave popcorn, condensation/corrosion, frostwork, saturated
Standards/Benchmarks Addressed: SC2-E3, SC4-E3, SC5-E2, SC6-E6

Objectives
Students will:

- describe how three other types of cave formations are formed.
- build a model showing how cave popcorn is formed.

Background

Caves contain many more speleothems than the stalagmites and stalactites most people are familiar with. Three of the other more common speleothems or features found in the caverns are cave pearls, directional frostwork and popcorn (a form of coralloid), and condensation/corrosion features.

Cave *pearls* grow in shallow pools of water saturated with the mineral calcite. Sand grains, bat bones, rock, shell, wood fragments, or other small pieces of calcite can form the nuclei around which the pearls will grow. As carbon dioxide is lost to the air, calcite is deposited on the object, as well as along the floor and edges of the pool. As more and more calcite is added, the pearls will become rounded. Agitation, typically from dripping water, is believed to keep the pearls from adhering to the bottom of the shallow pool.

Directional *frostwork*, directional *popcorn*, and *condensation/corrosion* features owe their existence to air circulation within a cave. Directional frostwork and popcorn form as cool, drier air descends into a cave during the winter months. For a detailed drawing and discussion of seasonal air circulation in caves, see the lesson *It's a Small World.* This drier air causes water to evaporate faster on the side of formations facing the entrance of a cave. As the water evaporates, calcite will precipitate and form the delicate frostwork forms or the coral-like popcorn. Several good examples of directional popcorn can be seen along the main passage in the Carlsbad Cavern between the natural entrance and the Iceberg Rock. In this area, popcorn grows on the entrance facing side of many stalactites and stalagmites. Some passages in the Left-Hand Tunnel, between the Lunchroom and Lake of the Clouds have excellent examples of directional frostwork.

Condensation/corrosion features are formed when carbon dioxide gas, released from water in the cave, is absorbed by water condensed on the cave wall or ceiling. According to Hill, three atmospheric conditions must be present for this to occur: a high carbon dioxide level in the air, high humidity in the air, and a temperature gradient, or difference, between the air in different passages. The carbon dioxide is released from pools in the cave, such as the Lake of the Clouds in Carlsbad Cavern. If the air near the pool is warmer than air in another upper passage, density driven air currents (see *It's a Small World*) will cause the warmer, moisture and carbon dioxide laden air to rise up to and along the ceiling. On reaching the ceiling and ceiling formations, the water will begin to condense onto these cooler surfaces. The carbon dioxide will dissolve into this fresh water, causing it to become acidic and aggressive to the calcite bedrock and formations. Over a period of time, the bedrock will become "punky," or soft and marked by corrosion. Speleothems will be etched by acidic water along the side facing into the rising airflow. The water (now saturated with calcium carbonate, or calcite) can then be moved to the edge of the corroded area by the gentle airflow. There, the carbon dioxide might again degas, causing the calcite to precipitate and causing rims to grow along the edge of the corroded area. This type of condensation/corrosion is very evident on the Creeping Ear, located in the Lake of the Clouds Passage, Carlsbad Cavern.

Materials

- Carbonated soda in a transparent plastic bottle
- Tap water
- Carbonated water
- White vinegar
- Three small spray bottles
- White chalk
- Clay
- Aluminum foil or small foil pans (about 10 cm diameter)

Procedure

This activity is designed to simulate condensation/corrosion processes in caves.

Warm up: While standing in the middle of the classroom, rapidly shake the soda and act like you are going to open it. When students seem to be concerned about this, ask why you shouldn't open the bottle. Discuss the carbonation of sodas and how it causes soda to fizz. Ask what happens if you leave the soda open overnight. Have students hypothesize what happens to the fizz. Lead them to an understanding of degassing, in which most of the carbon dioxide leaves the liquid and returns to the air. Ask students what would they think would happen if the degassed carbon dioxide encountered a drop of pure water with no carbon dioxide in it. During the discussion, lead them to understand that carbon dioxide will leave a soda where it is found in excess. It will also reenter, or dissolve into, pure water.

Describe and discuss the carbon dioxide degassing that occurs from pools in caves. Discuss the background material with students, being sure to cover the manner in which the less dense, warmer air rises and carries the carbon dioxide upward. Be sure to discuss the manner in which the carbon dioxide dissolves into condensed water along the cave wall, causing that water to become mildly acidic.

Activity

1. Place three balls of clay (about 1" diameter) in the bottom of separate aluminum pans. If using aluminum foil, fold the edges and tuck the corners to make trays about 10 cm long. Mark one of the pans "tap water," one of the pans "carbonated water," and the last "vinegar."

2. Stick one piece of chalk upright in each of the balls of clay.
3. In one spray bottle place tap water, in another place carbonated water, and in the third place vinegar. The carbonated water should be refreshed each day.
4. Using the spray bottles, *lightly mist* each piece of chalk with the liquid for which it is labeled. Do not drench the chalk! Take care not to spray the other pieces of chalk.
5. Place the pans where they will not be disturbed.
6. Once per day, examine the chalk. Have the students record their observations using written descriptions, drawings, or photographs.
7. Continue for one week, or until substantial differences can be seen.

Wrap Up: Have the class summarize what they observed with the chalk. Use class discussion or written work. Ask students to describe the ways in which the demonstration they have done in class is similar to the processes that occur in cave environments.

Assessment
Have students

- describe condensation/corrosion features found in caves.
- explain why popcorn is often found on the side of stalagmites facing the entrance of a cave.

Extensions
Using the Epsom salt speleothem model from the lesson *Hangy Downys and Sticky Upys*, have students design and build a model of directional popcorn. Remember that air currents used in the model must be very light.

Resources
Hill, Carol, 1987, *Geology of Carlsbad Cavern and Other Caves in the Guadalupe Mountains, New Mexico and Texas*. Socorro, NM: New Mexico Bureau of Mines & Mineral Resources Bulletin 117.

Hill, Carol and Forti, Paolo, 1997, *Cave Minerals of the World, 2nd ed.* Huntsville, AL: National Speleological Society, Inc.

Jagnow, David and Jagnow, Rebecca. 1992. *Stories from Stones: The Geology of the Guadalupe Mountains.* Carlsbad, NM: Carlsbad Caverns Guadalupe Mountains Association.

It’s a Small World

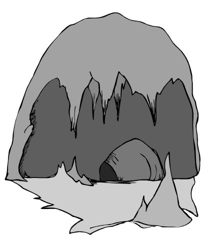
Why is the cave so cold and damp?

Summary: Students will observe and describe microclimates around their school.
Duration: One 50-minute class period
Setting: Classroom and around school
Vocabulary: circulation, dense, microclimate
Standards/Benchmarks Addressed: SC5-E2, SC6-E1, SC12-E7

Objectives
Students will:

- describe various natural microclimates.
- explain why caves are microclimates.
- search for and describe microclimates found around their school building.

Background



All caves have their own unique climates. These *microclimates*, as they are called, are determined by many factors such as entrance elevation, available moisture in the cave, shape and size of the passages, and mean annual temperature. Seasonal variations in the airflow of Carlsbad Cavern have resulted in a number of interesting directional speleothems (see *Not Just Your Average Decoration* lesson). When air on the surface cools during the fall and winter months, it becomes more *dense*. As the air near a cave entrance becomes denser, it begins to flow into the cave and down. It will continue to flow deeper into the cave until it reaches the lowest level of the cave or meets a layer of air with the same density. Meanwhile, the air in the cave is heated by the surrounding rock, causing it to become less dense and rise. In this way, convective cells of air circulation are set up in a cave system. Cool, drier surface air sinks in along the lower portion of cave passages, while warmer, more humid air from the cave rises along the ceiling toward high points in the cave. A *circulation* cell like this is responsible for the corrosion features found near Lake of the Clouds, Carlsbad Cavern.

This seasonal inflow causes seasonal fluctuations in temperature and humidity along the main pathways leading to the depths of the cave. However, along some passages, such as blind passages that have an entrance, but no outlet, there is very little air circulation. In these areas, the annual temperature and humidity variations are minimal.

Local tectonics and stratigraphy play a major role in the availability of moisture in a cave. Perched aquifers can intercept infiltrating water above one section of a cave and divert it to another. Additionally, cracks in the bedrock, or joints, provide preferential pathways for groundwater flow. Frequently these joints will cut across a perched aquifer, providing a pathway for water to descend toward the cave. As the groundwater flowing along joints intercepts a cave passage, a wetter section of the cave will be formed. In that region, flowstone, stalagmites, stalactites, draperies, columns, pools, and rimstone dams may be abundant.

The entrance area of a cave is a special climate zone. The cooler temperatures, increased humidity, availability of water, and shelter of the rock make this zone a haven for desert wildlife. Cave swallows frequently build nests along the cliffs found around cave entrances such as Carlsbad Cavern. These birds can be seen returning from a day of feeding just as the bats that live in the cave are leaving for a night foraging in the desert skies. Ringtail cats, skunks, porcupines, squirrels, and snakes are just a few of the other animals that enjoy the special ecosystem that exists in a cave entrance. Insects, arachnids, arthropods, and many smaller creatures thrive in the entrance as well. Guano deposits usually mark the path leading from the bat roost area to the entrance. Within these deposits, a microscopic world of living organisms is found.

Materials

- sling psychrometer (Celsius) NOTE: Alcohol thermometers are strongly recommended, rather than mercury!
- thermometer (Celsius)

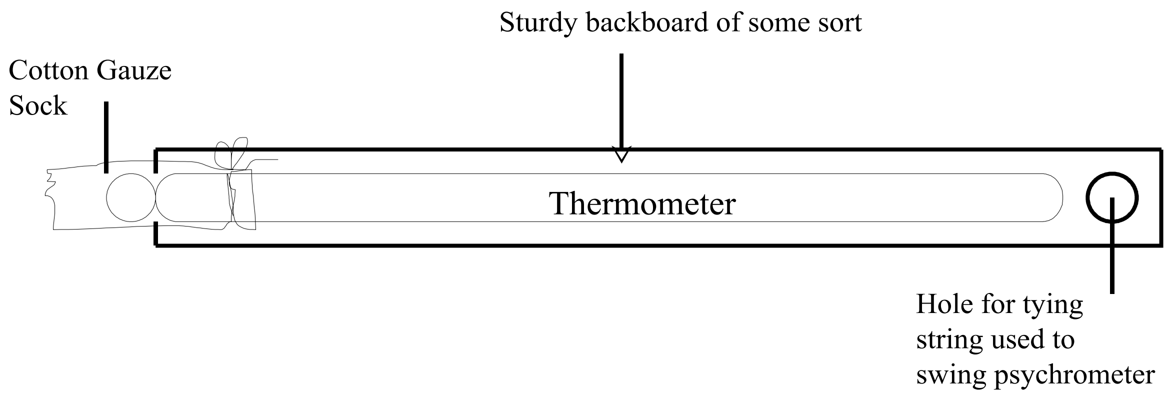
Procedure

Warm up: Ask students to estimate the temperature outside. Ask them to estimate the temperature inside the classroom. Ask them to estimate the temperature in the principal's office. Ask if they believe the air outside is more or less humid than the air inside.

Describe the concept of microclimates to the students. Point out that around a school, several microclimates can exist. On a hot, summer day, there can be a difference of several degrees between the hot, sunny, south side of the building and the comparatively cooler, shady, north side. Additionally, the humidity can vary in those areas as well. In this lab, students will look for several different microclimate zones in, and around, their school building. They will then compare those to the microclimates found in caves.

Activity

1. Have the student's list several places around the school building where they believe differences in temperature and humidity may be found. As a class, or in groups, select three or four of those locations to study.
2. At each of those locations, record the temperature and the wet and dry bulb readings from the psychrometer. Remember, the fabric sock on the wet bulb of the psychrometer must be moistened prior to use, preferably with distilled water. The psychrometer must then be spun gently for several minutes and checked periodically. This continues until the wet bulb temperature stabilizes.
3. Inexpensive sling psychrometers are available from several science supply houses. Some thermometers have a small eye at the top to which a string could be attached. However, this is not recommended, as these eyes tend to break fairly easily under these conditions. Simple student psychrometers can be built by taping, or gluing, small, inexpensive thermometers to a support, such as a thin piece of wood, and attaching a sock made of gauze to the bulb. The dry bulb temperature can be obtained from the regular thermometer being used to determine air temperature. Once the students have obtained their data, they can determine the relative humidity of their microclimate zones by using the data table provided with the psychrometer, or the data table provided at the end of this session. On the data table, they will need to find the dry bulb temperature along the vertical axis. They will need to calculate the difference in the wet and dry bulb temperatures and find this value on the horizontal axis of the table. Once both numbers have been found, the relative humidity can be determined.



Simple Sling Psychrometer

Wrap Up
Discuss any difference in temperature and relative humidity that the students observed.

Have the students attempt to explain why those differences were found. They should consider such things as shading, protection from wind, proximity to a source of moisture (leaky faucet, condensation dripping from evaporative cooler, evaporative coolers, etc.).

Have students list any factors they can think of that would be responsible for the existence of microclimates in a cave. Have them list and describe the consequences of several possible microclimates. As an example, a high amount of water and drier, inflowing air will result in increased evaporation and more speleothems.

End with a discussion of the various organisms that utilize the unique ecosystem and microclimate found in and near the entrance of a cave.

Assessment
Have students:

- describe several factors that contribute to the development of microclimates in caves.
- describe procedures and equipment that might be used by speleologists when studying microclimates in caves.

Extensions
Have students:

- Use the equipment from this lab to study microclimates around their community and to evaluate the impact these microclimates have. As an example, the Bataan Bridge crosses the Pecos River in Carlsbad, New Mexico and underneath a very interesting microclimate is found. The area under the bridge is slightly more humid, cooler, and darker. As a result, it is home to a healthy population of swallows and bats. It the water of the Pecos, the bridge also modifies the climate by creating shaded, cooler zones in the water. Fish are frequently found in these shaded areas during the hot, sunny summer months.

Resources
Feather, Ralph, et al. 1999. *Glencoe Earth Science.* Westerville, OH: Glencoe/McGraw-Hill. (Contains a lab activity for using a sling psychrometer on pp. 428-429, 719.)

Hill, Carol, 1987, *Geology of Carlsbad Cavern and Other Caves in the Guadalupe Mountains, New Mexico and Texas*. Socorro, NM: New Mexico Bureau of Mines & Mineral Resources Bulletin 117.

Relative Humidity in Percent

It's a Small World

T_{db} (°C)	Dry Bulb - Wet Bulb Temperatures (°C)														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20**
2	84	68	52	37	22	8									
4	85	70	56	42	29	26	3								
6	86	73	60	47	34	22	11								
8	87	75	63	51	39	28	18	7							
10	88	76	65	54	44	33	23	14	4						
12	89	78	67	57	47	38	29	20	11	3					
14	89	79	69	60	51	42	33	25	17	9					
15	90	80	71	62	54	45	37	29	22	14					
18	91	81	73	64	56	48	41	33	26	19	6				
20	91	82	74	66	58	51	44	37	30	24	11				
22	91	83	75	68	60	53	46	40	34	27	16	5			
24	92	84	76	69	62	55	49	43	37	31	20	9			
26	92	85	77	70	64	57	51	45	39	34	23	14	4		
28	92	85	78	72	65	59	53	47	42	37	26	17	8		
30	93	86	79	73	67	61	55	49	44	39	29	20	12	4	
32	93	86	80	74	68	62	56	51	46	41	32	23	15	8	1
34	93	87	81	75	69	63	58	53	48	43	34	26	18	11	5
36	93	87	81	75	70	64	59	54	50	45	36	28	21	14	8
38	94	88	82	76	71	65	60	56	51	47	38	31	23	17	11
40	94	88	82	77	72	66	62	57	52	48	40	33	26	19	13
42	94	88	83	77	72	67	63	58	54	50	42	34	28	21	16
44	94	89	82	78	73	68	64	59	55	51	43	36	29	23	18

Drip, Drip, Drip

How long does it take water to get from the surface into the cave?

Summary: Students will explore infiltration rates and the factors that affect it.
Duration: Two 50-minute class periods
Setting: Classroom or lab
Vocabulary: infiltration, groundwater, porosity, permeability, aquifer, aquiclude, water table, zone of aeration, zone of saturation
Standards/Benchmarks Addressed: SC2-E3, SC5-E2, SC6-E1, SC12-E7

Objectives
Students will:

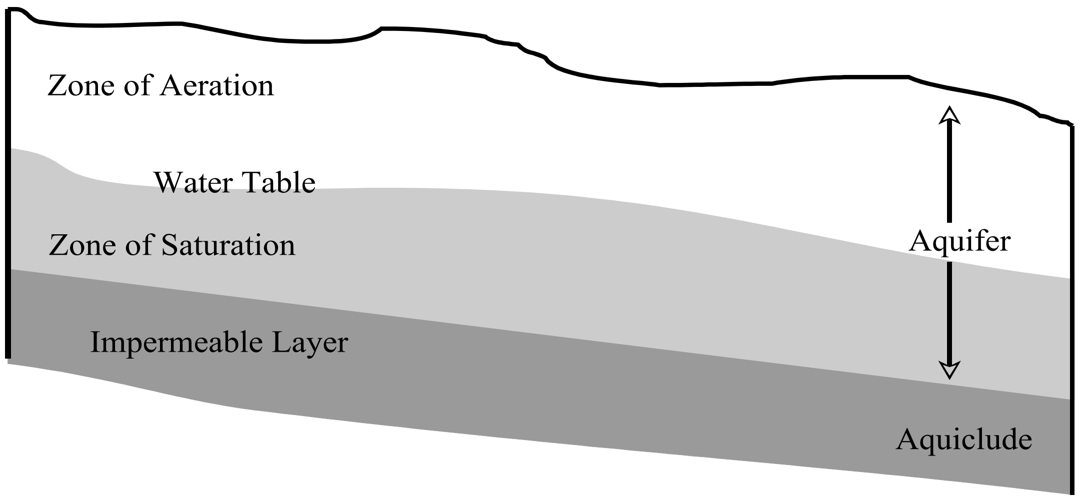
- describe factors influencing infiltration rates.
- build a model demonstrating the effect of different soil and rock types on infiltration.

Background
Much of the material in this lesson will duplicate that from *It's More Than Just Dead Dinosaurs!* That is because the ideas of porosity, permeability, and the flow of fluids through rock reservoirs are basically the same. The activity involves the use of the same bottles to model fluid flow underground.

As precipitation falls to the ground, one of three things can happen to it. It can evaporate and return to the atmosphere as water vapor. Sometimes this happens after the water has been intercepted and held on vegetation for a period of time. It can also happen as water evaporates from puddles left by a rainstorm or as the water held in muddy soil is drawn out and given the energy to evaporate by the sun. Other water can infiltrate into the ground, percolating downward to become *groundwater*. That which does not evaporate or infiltrate begins to seek low spots and, in the process of moving across the ground, becomes what is called runoff. Runoff can range from large rivers, such as the Mississippi River, to small rills along the edge of a mud puddle in a student's backyard.

This lesson will focus on *infiltration*. The principle factor affecting the rate of infiltration is the composition of the soil. As water begins to infiltrate it fills the openings, or pores, in the soil as it moves downward. Some soils contain gravel or sand. In these soils, the pores will be larger and the soil will be more *permeable*. This means that the water can move through the soil faster. The openings are smaller in soils with silt or clay sized particles. Water will move slower through these soils. Additionally, molecular attraction between water molecules and clay particles further slows the rate of infiltration. If the rate of precipitation exceeds the rate of infiltration, the ground becomes saturated with water. That is, all of the pore spaces in the soil fill with water. When this happens, any excess water begins to flow down gradient across the surface as runoff.

As water infiltrates downward, it will eventually reach a permeable layer in which groundwater is stored. This layer is called an *aquifer*. In the aquifer, the region in which most spaces are filled with air is called the *zone of aeration*. The region in which most spaces are water filled is called the *zone of saturation.* The top of the zone of saturation is referred to as a *water table*. The aquifer is bordered on the bottom, and sometimes on the top, by an impermeable layer called an *aquiclude*. Sometimes, a small aquiclude will be found higher than the main water table for a region and a small aquifer will form. These small aquifers found higher than the main regional water table are called perched aquifers. The area from which an aquifer receives water in the form of infiltrating precipitation is called the recharge zone.



Joints, or cracks, in the rock provide the main form of *porosity* along which groundwater infiltrates into the Carlsbad Cavern and other caves of the park. Evidence of this can be found by observing the long lines of stalactites, stalagmites, and columns formed along some of the major joint systems that cross the caves. However, recent research has shown that the infiltration rates are not uniform throughout the cave. A recent study seemed to indicate that some of the deeper sections of the cave actually see meteoric waters that infiltrate at a faster rate than some of the shallower sections of the cave. At this time, these studies are ongoing.

The location of the visitor center and offices over the Carlsbad Cavern has been a cause for concern for several years. Due to the location of these facilities, many sources of potential pollution exist directly above the cave. Runoff from the parking concentrates oil, anti-freeze, and other pollutants into areas where the water leaves the parking lot and infiltrates into the surrounding desert soils. Septic systems and leaking sewer lines have also been found to be potential sources of pollutants on the surface. Studies have shown that some of these pollutants are reaching the cave as infiltrating waters carry them down. As a result, proposals have been made to move some, or all, of the facilities to the bottom of the escarpment where they would no longer pose a threat to the water entering the Carlsbad Cavern.

Materials

- graduated 250 ml beakers – 3
- 100 ml beakers – 3
- several 2- or 3-liter soda bottles
- sand (several colors, if possible)
- gravel (several colors, if possible)
- scoria (holy lava rock, batman!)
- clay

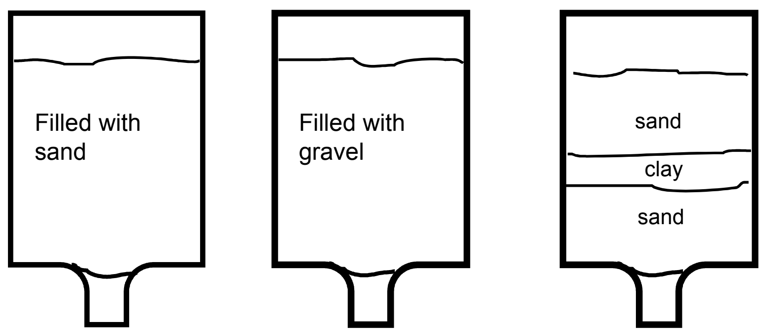
Procedure
Warm up: This activity is almost identical to *It's More Than Just Dead Dinosaurs!* However, it focuses on groundwater, rather than oil and gas migration.

Discuss the concept of groundwater, infiltration, and the movement of groundwater with the class. If possible, secure a groundwater model to use with the class discussion or bring in a speaker with groundwater experience. Your local Soil and Water Conservation offices, county extension office, National Park Service personnel, Forest Service Personnel, or Bureau of Land Management personnel may have the expertise and materials to help with this.

Discuss the role of infiltrating water in cave development and potential hazards posed by the infiltration of polluted water.

Activity

1. Set up three bottles as shown in the activity *It's More Than Just Dead Dinosaurs!*



   a. Cut the bottom 3 or 4 inches from three 3-liter bottles and turn them over.
   b. Glue a single layer of cloth into the bottom of each to keep the sand and gravel from coming out.
   c. Fill the bottles as shown.
2. Turn all three bottles upside-down with a graduated 250 ml beaker under each. Ask the students, "If I pour 100 ml of water into each of these at the same time, which will it travel through fastest?" Be open to all suggestions. Have the students justify their guesses. Have students assist you and pour 100 ml into each bottle at the same time. Monitor the 250 ml beakers to see which bottle the water passes through fastest. Discuss the results with the class. Solicit their hypothesis regarding the different rates of infiltration through the bottles.
3. Define porosity for the students. Show students a piece of scoria (lava rock with holes in it), a piece of sandstone, and a piece of conglomerate or a handful of gravel. Ask which of the samples exhibit porosity. Students should answer "all three." Ask which would form a rock through which fluids would move the easiest. Some students may select the scoria, due to the size of the pores. Point out to students that even though all three samples have porosity, the holes are not connected in the scoria, so fluid would not move through it as easily. The pores in the gravel are bigger than the pores in the sand or sandstone, so fluid would move through the gravel easier. Discuss the differences in porosity and permeability.
4. Ask the students what happen if the water reached an opening, like a cave. Have them describe what might happen to the dissolved minerals in the water as it hangs from the ceiling of a cave passage. Have them explain where those minerals come from.

5. Ask the students, “If the water is moving through the ground in a permeable layer of rock, what could stop it?” Entertain all suggestions. Describe aquifers and aquicludes to the students. Using overhead or board drawings, demonstrate and discuss zone of aeration, zone of saturation, aquifer and aquiclude.

Wrap Up: Review the role of groundwater in cave formation.

Ask the students where they get the water they drink. Lead to a discussion of how the water must come from a surface reservoir or from a well before it makes it to them. Discuss potential sources of pollution along that pathway and what should be done to protect their drinking water.

Assessment
Have students:

- describe the conditions necessary for an aquifer to form and for groundwater to move through it.
- explain how pollution could get into a cave system that has no entrance.

Extensions

- Build several bottle models and test other materials to see which is the most permeable.
- Conduct research on the local drinking water system. Have students find out where it comes from, how it is treated, etc.
- Study the local wastewater treatment system. Where does it go after you flush? How is it treated? What eventually happens to the water? Try to fit this in to a very large-scale discussion of the water cycle (There is no new water, just used water).

Resources
Chernicoff, S., Fos, H.A., and Venkatakrishnan, R. 1997. *Essentials of Geology.* New York, NY: Worth Publishers.

Feather, Ralph, et al. 1999. *Glencoe Earth Science.* Westerville, OH: Glencoe/McGraw-Hill.

Murck, B.W., Skinner, B.J., and Porter, S.C. 1996. *Environmental Geology.* New York, NY: John Wiley & Sons, Inc.

A River Runs Through it... Literally!

How do some other caves form?

Summary: Students will describe the processes in which caves are formed as moving water dissolves bedrock.
Duration: Initial lesson will take one 50-minute class with 5-10 minutes per day for several days after.
Setting: Classroom or lab
Vocabulary: karst, dissolve, soluble
Standards/Benchmarks Addressed: SC2-E3, SC5-E2, SC6-E1

Objectives
Students will:

- build a model of a cave or karst valley formed in bedrock dissolved by moving water.
- describe the processes by which moving water forms karst valleys or caves.

Background

Most of the caves in Carlsbad Caverns National Park were formed when rising H_2S gas from the Delaware Basin oxidized to form sulfuric acid near the water table (see the lesson *Stinky Gas and Alabaster*). This acid *dissolved* the limestone rock of the ancient Capitan Reef and the caves were created. However, most caves are not formed that way. Many of the gypsum caves on the Eastern Plains of New Mexico were formed as water, moving through joints in the gypsum bedrock, dissolved the rock, forming passages. Most of these gypsum caves only see water during the monsoon season when heavy rainfall from thunderstorms or prolonged rain floods them. However, some of the caves actually contain water year-round in the form of streams and pools. As the water makes its way through the cave system, it will eventually join a deep aquifer or resurface at a karst spring. Many of the big pools on the Delaware River near Carlsbad Caverns National Park are fed by these karst springs.

The longest cave in the world, Mammoth Cave, is found near Bowling Green, Kentucky. Much of Mammoth Cave lies within the borders of Mammoth Cave National Park. The bedrock in which the Mammoth Cave system was formed is limestone. As the meteoric waters infiltrated into the ground, they began to absorb carbon dioxide and became mildly acidic. This acidic water then began to dissolve the rock through which it was passing. Eventually, traversable passages were formed. With a total surveyed length of well over 300 miles, Mammoth Cave was formed from the interconnecting passages of many underground streams and rivers. These streams eventually fed into the Green River, the base level river for the area. Over the years, the Green River cut deeper and deeper into its canyon bottom. As it cut deeper, the streams and rivers forming Mammoth Cave also cut deeper. As a result, Mammoth Cave is formed on several levels, all corresponding to the down cutting of the Green River. In much of the United States, the caves that are found have been formed in this manner. Large numbers of limestone caves are found in the eastern US, on the Ozark Plateau, and in central Texas. Caves have not formed in this manner in the limestone of the Guadalupe Mountains in New Mexico and Texas. This is primarily due to the low amount of precipitation each year.

The gypsum caves of New Mexico and Mammoth Cave of Kentucky were formed by similar processes. However, they are formed on different time scales. Gypsum is typically ten times more *soluble* in water containing CO_2 than limestone is; depending on how much CO_2 is in the water. This means that gypsum caves will form at a faster rate than similar limestone caves.

Lave tubes are another type of cave found in New Mexico and other areas of the western US. Lava tubes are formed on the flanks of shield volcanoes. As lava flows away from a volcanic vent, that which is near the surface begins to cool and harden. Eventually, a seemingly solid surface can form. However, under that solid crust, liquid lava can still flow. As the eruption dies out, the level of the liquid lava will drop and a tube, or lava cave, will be left behind. Access to these caves is often gained through holes where the ceiling has collapsed.

Living in an area with soluble bedrock presents a number of unique problems. As caves form near the surface, the ceiling often collapses into them, creating sinkholes. A region in which the landscape contains cave entrances, sinkholes, sinking streams, and springs flowing from holes in the ground is called *karst*. While the development of sinkholes and other karst features may not be much of a problem in southeastern New Mexico, it is a big problem in Florida and on the Sinkhole Plain of Kentucky. Roadways and houses have been swallowed by sinkholes in these states. In these areas, caves are usually the primary storm drain system. If rainfall amounts exceed the amount of water the cave can process, or if a collapse has blocked some of a cave passage, water can back up in the system, causing flooding in sinkholes. Houses and buildings near these sinkholes can be flooded, even if they are miles from the nearest river. An even bigger problem is that of groundwater pollution. It is estimated that 25% of the world's population obtains its water from karst aquifers. Typically, in non-karst aquifers, impurities are filtered out as water infiltrates and makes its way down to the aquifer. In a karst aquifer, the routes from the surface to the aquifer are quite direct, allowing for very little filtration. Runoff from parking lots, feedlots, and dumps often feeds directly into cave systems. The Hidden River Cave system under Bowling Green, Kentucky, was such a problem. Cleanup efforts have improved the status of the cave, but pollution is still a constant threat. Most of the karst aquifers in the US are threatened due to pollution and development on the surface.

For more information on karst and cave development, refer to the lesson *Natural Acids*.

Materials

- sugar cubes
- distilled water
- cake pan
- dropper or bottle with sports lid that can slowly drop water
- photos of various types of caves

Procedure

Warm up: Have the students compare and contrast the various types of caves shown in the photos.

Describe the various processes of cave formation to the students.

Activity

1. Very lightly moisten the edges of the sugar cubes and stick them together on a cake pan or cookie sheet in a block 10 cubes wide x 5 cubes high x 20 cubes long (or whatever size you prefer).
2. Lift one edge of the pan or sheet 1 to 2 inches to give it a gentle slope. The pan will represent an impermeable lower layer of rock.
3. Select a point on top of the sugar block, near the upper end, on which you will slowly begin to drop water.
4. Begin slowly dropping water on the pre-selected spot at a rate of about 5 ml per day.
5. Over the course of several days, have students document the change in the block as the sugar is dissolved.
6. If you schedule does not allow for several days of observation, increase the rate at which you apply the water.

Wrap Up: Ask students what it would be like to live in an area where caves are actively forming underneath you. Discuss problems faces by those living in Florida and on the Sinkhole Plain near Bowling Green, KY.

Assessment
Have students:

- describe the processes that form caves like Mammoth Cave in Kentucky.
- describe the problems associated with living in an area where caves are actively forming.

Extensions
Have students build several sugar blocks and apply water at different rates. Have students monitor and document their observations. Lead students to draw conclusions about the possible effects of annual rainfall on the rate at which karst features form.

Resources

Moore, George, and Sullivan, Nicholas. 1978. *Speleology: The Study of Caves.* Teaneck, NJ: Zephyrus Press, Inc.

Veni, George, et.al. 2001. *Living With Karst.* Alexandria, VA: American Geological Institute Environmental Awareness Series, 4.