A Tale of Two Caves:

How Is Hurricane Crawl Cave Different From Crystal Cave?

Photo courtesy of Dave Bunnell, Under Earth Images.

Meet the Scientists

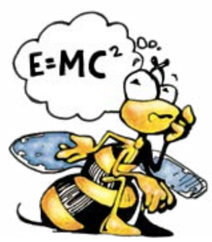
▶ **Joel D. Despain**, Hydrologist: My favorite scientific experiences involve understanding the **geomorphic** history of a given cave or cave area. Some geomorphic questions are, "Why did the cave form, and why did it form with these particular shapes and patterns? Is it random?"

It turns out that caves form in specific ways that tell us about past conditions. The history of the cave, the structure of the rock, the hydrology of the region, the **gradient**, and other factors all play big roles. Cave geologists are determining different types of caves and how they develop with greater precision every year. They do this through a better understanding of the shapes, forms, and patterns found within caves. This research is creating a much better understanding of caves that then informs our understanding and knowledge of regional geology and geologic history.

◀ **Benjamin W. Tobin**, Hydrologist: Each science experience is amazing, interesting, and fun in its own way. If I had to choose, however, my favorite would be conducting dye traces at the Grand Canyon. This work involves dumping a colored non-harmful dye into the ground up on the plateau above the canyon, then monitoring springs in the canyon to determine where the dye showed up. This is simple science. But the results tell us an incredible amount about how water moves below our feet and it never seems to do what we expect.

◀ **Greg M. Stock**, Geologist: My favorite science experience was mapping caves in Sequoia with Mr. Despain. We used those maps, along with dated **sediment** in the caves, to determine long-term river downcutting rates. The downcutting rate told us the speed at which erosion deepens a channel by removing material from a streambed or valley. It was the perfect mix of field, lab, and computer work, with a neat result.

Glossary words are **bold** and are defined on page 55.



Thinking About Science

Science, whether conducted indoors or outdoors, requires some safety **precautions**. For example, scientists use gloves and safety glasses when using chemicals in a laboratory. A forester may use safety glasses, a hard hat, and boots when working outside in the forest (**figure 1**). Before starting any activity in science, scientists first evaluate whether they need special equipment to ensure their safety.

The scientists in this study conducted their research in a cave. They needed safety gear specific to the cave environment, such as warm clothes, hard hats, gloves, headlights, and boots. As you read this article, remember to look at the photos of scientists in caves. What safety equipment are they wearing?

Figure 1. A forester may use many pieces of equipment to be safe when conducting research. What pieces of safety equipment can you identify in this photo? Photo courtesy of Natalie Van Doorn, USDA Forest Service.

What Kinds of Scientists Did This Research?

hydrologist: A scientist who studies water and the water cycle.

geologist: A scientist who studies Earth, the materials of which Earth is made, the structure of those materials, and the processes acting upon them.

Safety, however, is more than just about equipment. Good communication also is important to safety. Whether inside or outside, scientists must communicate when, where, and how they are conducting an experiment. To safely conduct the study described in this monograph, the scientists needed to communicate where and when they were going into the cave. This basic information ensured that the scientists could be helped if a problem occurred.

Thinking About the Environment

Water moves through and across Earth in a cycle, called the water cycle (**figure 2**). Water can change as it moves through the water cycle. Water may change forms between a liquid, a solid, and a gas.

Water also can change when it interacts with chemicals within the environment. For example, interactions between water and chemicals can result in the development of caves. Many caves in the United States are formed when groundwater or rainfall absorbs carbon dioxide. The combination of water and carbon dioxide forms carbonic acid, which is slightly **acidic**. Over time, the water enters **cavities** in the

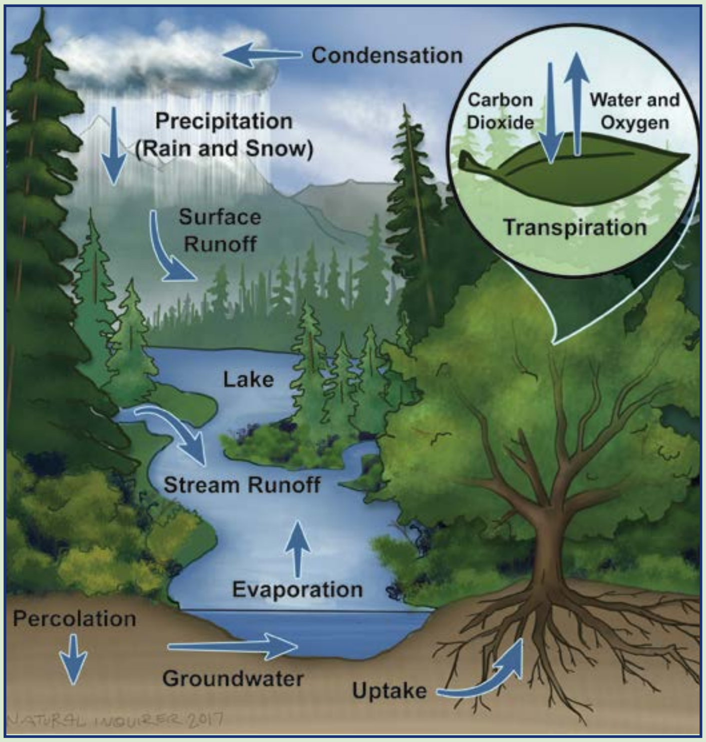


Figure 2. Water moves through and across Earth in the water cycle. Illustration by Stephanie Pfeiffer.

rock and slowly dissolves the cavities creating larger open areas.

This process also contributes to the formation of **speleothems** (**figures 3a-3c**). The slightly acidic water moves through rocks, dissolving calcite. The water has large amounts of carbon dioxide in it when it enters the cave. The cave air, however, only has a small amount of carbon dioxide, so some or all of carbon dioxide from water is released into the air. This process is similar to when you open a can of soda and the carbon dioxide creates bubbles as it leaves the liquid. The calcite is unable to stay in the water without carbon dioxide, so it is **deposited** onto cave floors, ceilings, and walls forming speleothems.

The scientists in this study found many different speleothems during their research, including large shields, rimstone pools, folia, spar crystals, curtains, and helictites. Some of the speleothems grew so large that they affected the movement of water and sediments through the cave. Speleothems illustrate a portion of the water cycle, as well as how chemicals, like calcium, cycle through the environment.

Figures 3a-3c. Speleothems come in many different shapes and sizes. You may have heard of some speleothems, like stalactites and stalagmites. Many other speleothems have interesting names, like soda straws, moonmilk, bacon, draperies, frostwork, cave popcorn, snottites, and curly-fries. Photos courtesy of Dave Bunnell, Under Earth Images.

Introduction

Caves are important natural features in Sequoia and Kings Canyon National Parks in California (**figure 4**). Past studies of caves in the area have focused on two of the largest caves, Lilburn Cave and Crystal Cave. Studies of these caves revealed information about the area's mountains, the formation of caves, and the age of rocks.

Another large cave in the area is Hurricane Crawl Cave. Hurricane Crawl Cave was first explored in 1988. Scientists mapped the cave's approximately 2 miles of passages between 1988 and 1995. The cave has two entrances, multiple levels, two canyons, two mazes, and one large room (**figures 5**). The main stream that passes through the cave is a sinking stream. This stream starts on Earth's surface, enters the cave for a period of time, and then returns to Earth's surface further downhill (**figure 6**).

The scientists knew that Hurricane Crawl Cave developed under similar conditions to Crystal Cave because they are located near one another. However, the scientists noted that Hurricane Crawl Cave had a different **morphology**, or structure, than Crystal Cave. Crystal Cave has many levels and mazes, but few canyons. The scientists wanted to know why the morphology is different between Hurricane Crawl Cave and Crystal Cave.

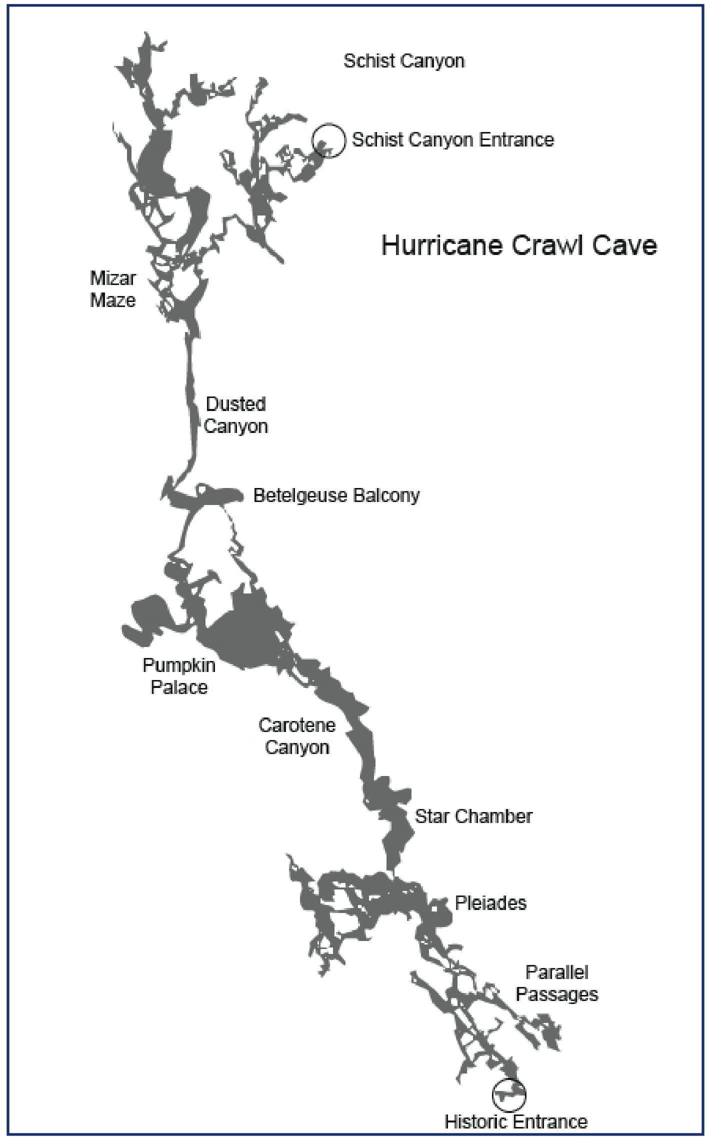


Figure 5. Mazes are located near both entrances to Hurricane Crawl Cave. Canyons, named Dusted Canyon and Carotene Canyon, are located near the mazes. The room, called Pumpkin Palace, is located in the middle of the cave. Illustration by Stephanie Pfeiffer.

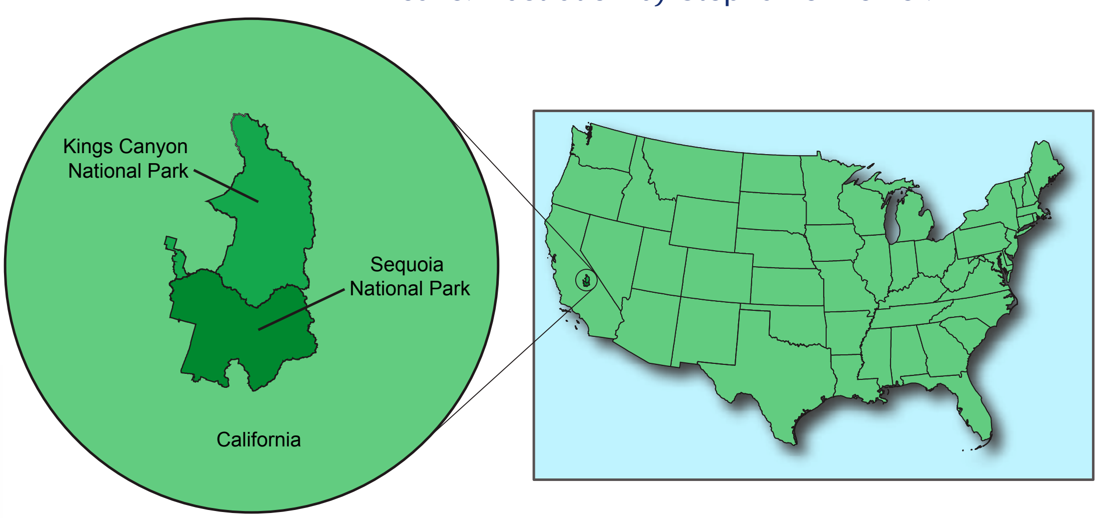


Figure 4. Sequoia and Kings Canyon National Parks are located in the central part of California. Map by Carey Burda and Stephanie Pfeiffer.

Figure 6. A sinking stream is a stream that flows below Earth's surface for some of its length. This sinking stream is about to go underground at Russell Cave National Monument in Alabama. Photo courtesy of Dale L. Pate, National Park Service.

Reflection Section

- Following the discovery of Hurricane Crawl Cave, scientists mapped the cave and its passages. Why is this an important first step when studying caves?
- Explain in your own words the question the scientists wanted to answer in this research.

Methods

To better understand Hurricane Crawl Cave, the scientists collected data regarding the cave's age. A previous study estimated the age of a rock from inside Hurricane Crawl Cave. From the rock's location, the scientists measured to the top of the cave and to the bottom of the cave. These measurements enabled them to estimate how long it took for the cave to develop both before and after the rock was deposited.

The scientists also collected information about the past and present movement of water through the cave. Current information about the flow of water was gathered between 2010 and 2012. Specifically, the scientists measured water **discharge**. The water discharge measurements were taken twice per year at the same location inside the cave, once during June and once during October (**figure 7**).

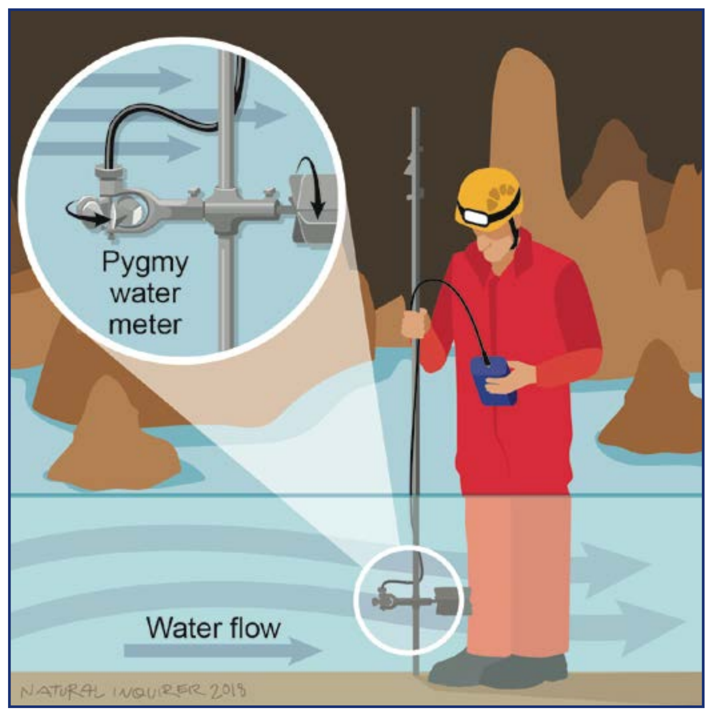


Figure 7. The scientists measured water discharge with a pygmy (**pig** mē) meter. A pygmy meter is placed in a stream and the water spins the bucket. The number of times the bucket spins in a specific amount of time helps determine the flow of water. Illustration by Stephanie Pfeiffer.

The scientists also conducted a dye trace (**figure 8**). A dye trace involves putting a non-harmful, colored dye in water. Scientists then track and observe the dye to understand the movement of water. Previous research indicated one stream that passed through the cave. In this study, the scientists used a dye trace on multiple streams to confirm if any other streams passed through the cave.

The scientists then chose four **transects** within Hurricane Crawl Cave to collect data about past water discharge (**figure 9**). Information about cave scallops and stream cobbles were collected at each transect (**figures 10 & 11**). You may have heard of animals called scallops, which live in the ocean, but cave scallops are nonliving. Cave scallops are **asymmetrical**, scoop-like formations on cave surfaces formed by water. Scallops can indicate the direction of water flow and the **velocity** of water. Stream cobbles are rocks that are carried in the flow of water. A mathematical formula enabled the scientists to determine the velocity of water needed to move the stream cobbles. A total of 327 scallops and 157 stream cobbles were measured across the four transects.

Figure 8. Scientists used a dye trace to track the movement of water. U.S. Geological Survey photo.

Figure 9. The transect locations in Hurricane Crawl Cave as viewed from the side. Illustration by Stephanie Pfeiffer.

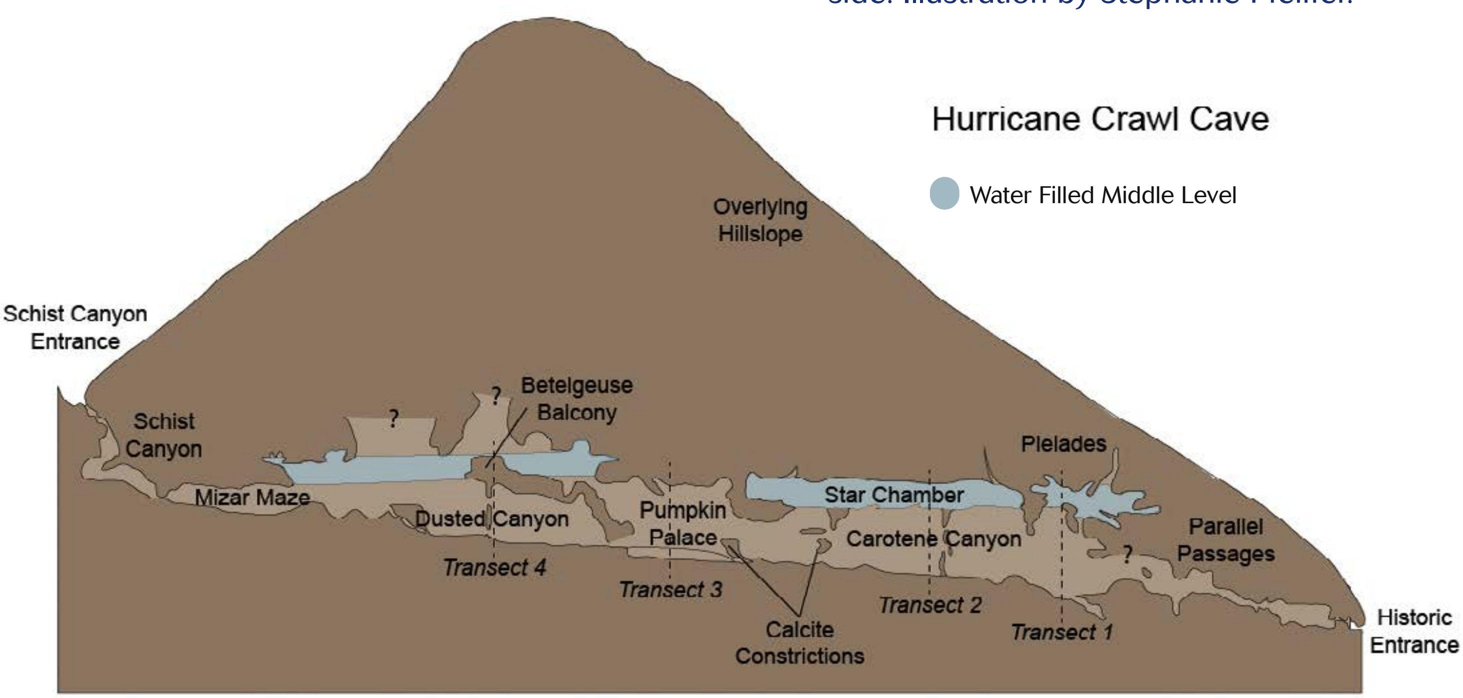


Figure 10. Scallops, like the ones pictured here on the ceiling and wall of the cave, can indicate the water velocity. Large scallops indicate slower flow of water, while small scallops indicate faster flow of water. Photo courtesy of Dave Bunnell, Under Earth Images.

Figure 11. Stream cobbles, like those at this person's feet, are often carried into and through a cave by water. The scientists measured the largest cobbles along each transect because they suggest the maximum velocity of the water. Photo courtesy of Dave Bunnell, Under Earth Images.

Reflection Section

- The scientists repeated a dye trace. How can scientists benefit from confirming the results of a previous study? What did they do to gather new information?
- Review **figure 9**, focusing specifically on the four transects. What do you notice about these transects? How are they similar or different? Why would the scientists choose these areas for transects to collect data?

Results

The scientists' observations, combined with the estimated age of the rocks, indicated that Hurricane Crawl Cave is approximately 1.4 million years old. Recall that the scientists also wanted to compare past and present water discharge in the cave.

Scallop measurements at the four transects indicated that the direction of water flow is similar between the past and present. Scallop measurements and stream cobbles both indicated that past discharge of water was greater than current discharge (**table 1 and figure 12**). Past discharge did not vary across the four transects. Instead, past discharge varied by passage type. Specifically, the wide, upper passages of the cave had very high discharge in the past.

When the scientists completed the dye trace, they found that one sinking stream could be traced through the cave. This finding confirmed previous research results. However, they also found other streams that began in the cave.

Table 1. Mean past discharge was different depending on the type of passage being measured. However, mean past discharge in all passages was higher than current discharge. The scientists measured the water discharge in meters cubed per second, or $m^3 s^{-1}$.

Current Discharge	0.002 – 0.042 $m^3 s^{-1}$
Past Discharge (Mean)	2.7 $m^3 s^{-1}$ (canyons) 27 $m^3 s^{-1}$ (wide, upper passages)

Reflection Section

- The scientists found additional streams that began inside the cave. How do you think streams form inside the cave? Do you think these streams contributed to the cave development? Why? (Hint: Think about the water cycle.)
- Are you surprised that the direction of water flow is similar between the past and present? Why or why not?

Discussion

The scientists determined that Hurricane Crawl Cave likely formed under two different conditions over the past approximately 1.4 million years. First, the wide, upper passages were formed at a time when the cave passages were full of water. The slightly acidic water sloshed like water in a pool, slowly enlarging the passages. Second, the narrow parts of the cave, like canyons and mazes, were formed as water moved downhill under the influence of gravity. The slightly acidic water and the stream cobbles also helped to enlarge the passages. This condition is most similar to what is occurring in the cave today.

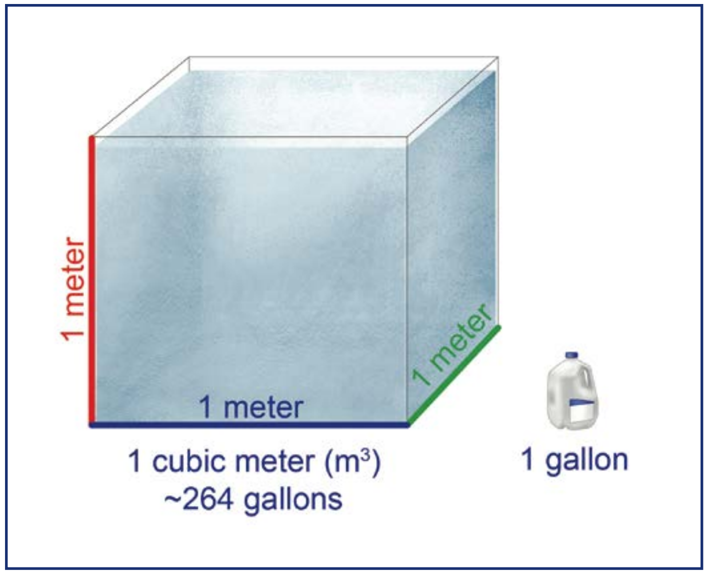


Figure 12. The scientists measured discharge in meters cubed per second. One meter cubed is equal to about 264 gallons. Illustration by Stephanie Pfeiffer.

In both of these past conditions, the high-water discharge was likely because climate conditions were different than current climate conditions. Past climate was cooler and wetter than at the present.

Although Hurricane Crawl Cave and Crystal Cave are located near one another and developed under similar conditions, their morphologies differ. The scientists concluded that the differences in morphology are likely a result of differing amounts of sediment transported through the caves.

Reflection Section

- The scientists determined that sediment was a major factor in differences between Hurricane Crawl and Crystal Caves. Do you think sediment has a role in the formation of caves? If so, how?
- Why do you believe it is important to know about how caves formed?

Number Crunches

0.002 $m^3 s^{-1}$ = 0.528 gallons per second

0.042 $m^3 s^{-1}$ = ____ gallons per second

2.7 $m^3 s^{-1}$ = ____ gallons per second

27 $m^3 s^{-1}$ = ____ gallons per second

(Hint: Filling each blank requires that you first divide, then multiply. For example, divide 0.042 by 0.002, then multiply the result by 0.528.)

Glossary

acidic (**a si** dik): Containing acid.

asymmetrical (ā sə **me** tri kəl): Having two sides or halves that are not the same.

cavity (**ka** və tē): A hollowed-out space.

climate (**klī** mət): The average condition of the weather over large areas, over a long time, or both.

deposit (**de** pə **zit**): To let fall (something, such as sediment).

discharge (dis **chärj**): To give forth fluid or other contents.

geomorphic (jē ə **mȯr** fik): Relating to the form of the landscape and other natural features of the earth's surface.

gradient (**grā** dē ənt): A part sloping upward or downward.

morphology (mȯr **fä** lə jē): (1) Structure; (2) Form.

precaution (pri **kȯ** shən): A measure taken beforehand to prevent harm or to bring about a good result.

sediment (**se** də mənt): Matter set down by wind or water, such as sand or soil.

speleothem (**spē** lē ō thəm): A cave formation formed by groundwater.

transect (tran(t) **sekt**): A sample area usually in the form of a long continuous strip.

velocity (və **lä** sə tē): Speed of movement.

*Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.*

Definitions are limited to the word's meaning in the article.

Adapted from Despain, J.D., Tobin, B.W., and Stock, G.M. 2016. Geomorphology and paleohydrology of Hurricane Crawl Cave, Sequoia National Park, California. Journal of Cave and Karst Studies. 78, 2: 72-84.

FACTivity

Note: This FACTivity was adapted from the National Park Service "Grow Your Own Stalactite" Lesson Plan. For more information, visit: https://www.nps.gov/ozar/learn/education/growown.htm.

Common Core Connection

Time Needed

Set-up: One class period

Follow-up: 5-10 minutes per day for 4 days

Materials

(for each student or group of students)

- Pictures of decorated cave passages
- Epsom salts, washing soda, or baking soda (Epsom salts and washing soda are more likely to form larger formations)
- Warm water
- 2 plastic cups the same size (preferably clear/see-through)
- 1 piece of aluminum foil to make a "tray" or a small plate/saucer
- 1 spoon
- 1 piece of cotton string or yarn (30-50 cm in length)
- 2 paper clips
- Permanent markers

Caves are well known for the formations that grow inside of them, called speleothems. In "A Tale of Two Caves," the scientists noted that speleothems were common and diverse in Hurricane Crawl Cave. They were so common, in fact, that some speleothems blocked the movement of water and sediment through the cave. Review the images of the speleothems from the "Thinking About the Environment" section.

Speleothems are formed when groundwater and rainwater absorb carbon dioxide, making the water slightly acidic. The acidic water dissolves calcite from nearby rocks as it moves through the Earth into the cave. When the water enters a cave, the carbon dioxide moves from the water, and the calcite is deposited on cave surfaces. This process is an important reminder of the natural cycling of water and chemicals through the environment.

At the end of this FACTivity, you answer the following question: What does this activity tell us about the formation of speleothems?

Methods

1. Using a spoon, dissolve as much of the chosen material (Epsom salt, washing soda, or baking soda) as possible into two cups that are filled at least halfway with very warm water. It will be easier to see the material being dissolved if the cups are clear/see-through, but it is not necessary. Repeat this process until the solution is well concentrated. A 2:1 ratio of material to water is best.

2. Mark the water level of each cup using a permanent marker. The water level should be similar between the two cups.

3. Tie a paperclip to each end of the piece of cotton string.

4. Soak the piece of string in the solution until it is completely saturated. Set the cup and the string aside.

5. Fold the piece of aluminum foil to form a small tray. This can be done by folding in the edges and molding the corners. Alternatively, use a small plate or saucer.

6. Your teacher will pick a couple of different locations within the classroom where you can place your tray and cups. Regardless of location, ensure that it is a place that will remain undisturbed for a few days.

7. Lay the string on the cup so that one end of the string (with paperclip) is well inside the solution in one cup and the other end of the string (with paperclip) is well inside the solution in the other cup. The middle section of the piece of string needs to dip below the water levels in the cups (**figure 13**).

FACTivity Continued

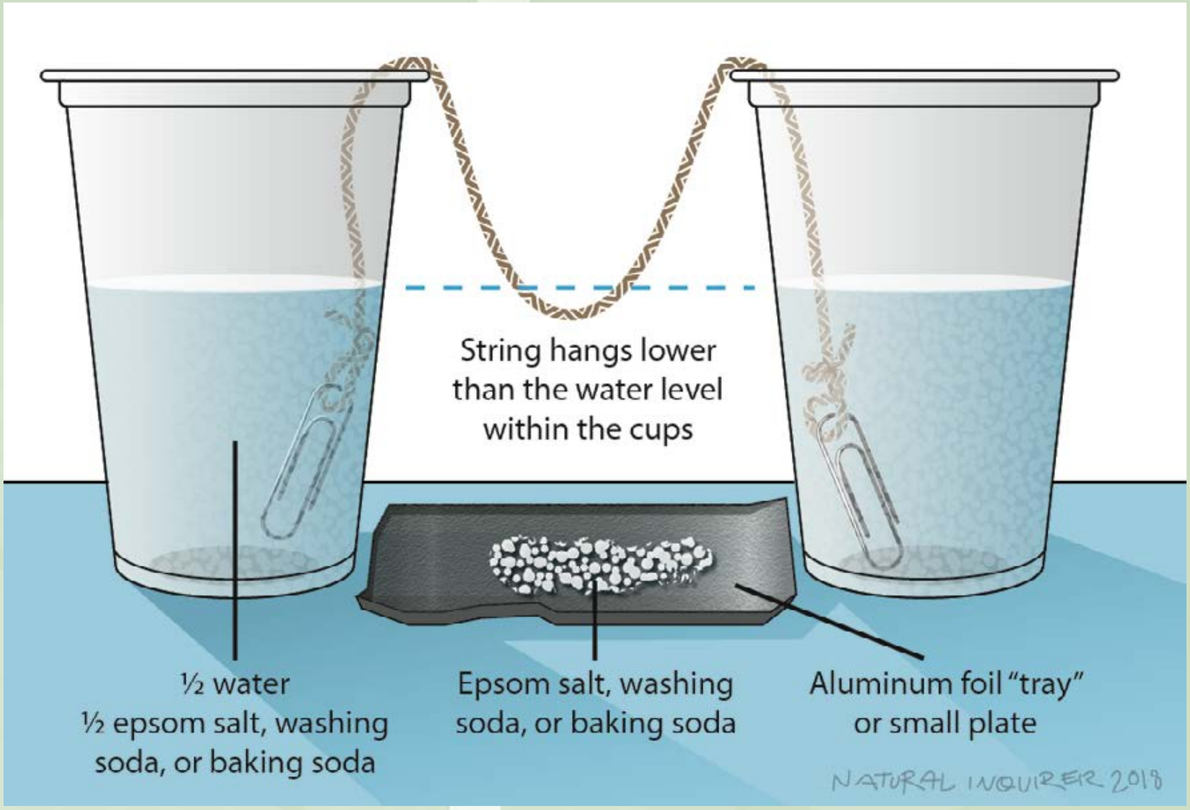


Figure 13. The string should be saturated, and the middle section should dip just below the water level of the cups. Illustration by Stephanie Pfeiffer.

8. Adjust the distance between the middle section of the piece of string and the tray to minimize the amount of splattering that may occur. This distance will depend on the height of the cups being used.

9. Place a small amount of dry material (Epsom salt, washing soda or baking soda depending on the solution being used) on the tray directly beneath the lowest part of the string.

10. Leave the cups for about 4 days.

11. Revisit the experiment to compare results with other students or groups of students. If the results are different, how? Why?

12. Your teacher will discuss with you how speleothem growth is dependent on a number of factors, including air temperature in the cave, precipitation on Earth's surface, the amount of calcium dissolved by groundwater, and the amount of carbon dioxide absorbed by groundwater.

13. How does this experiment, and the differences between the results, illustrate the potential differences in speleothem growth? Were there differences in the location of the experiments? Check the water level marked by permanent marker. Were the original water levels different between groups? Did the water drip or splash?