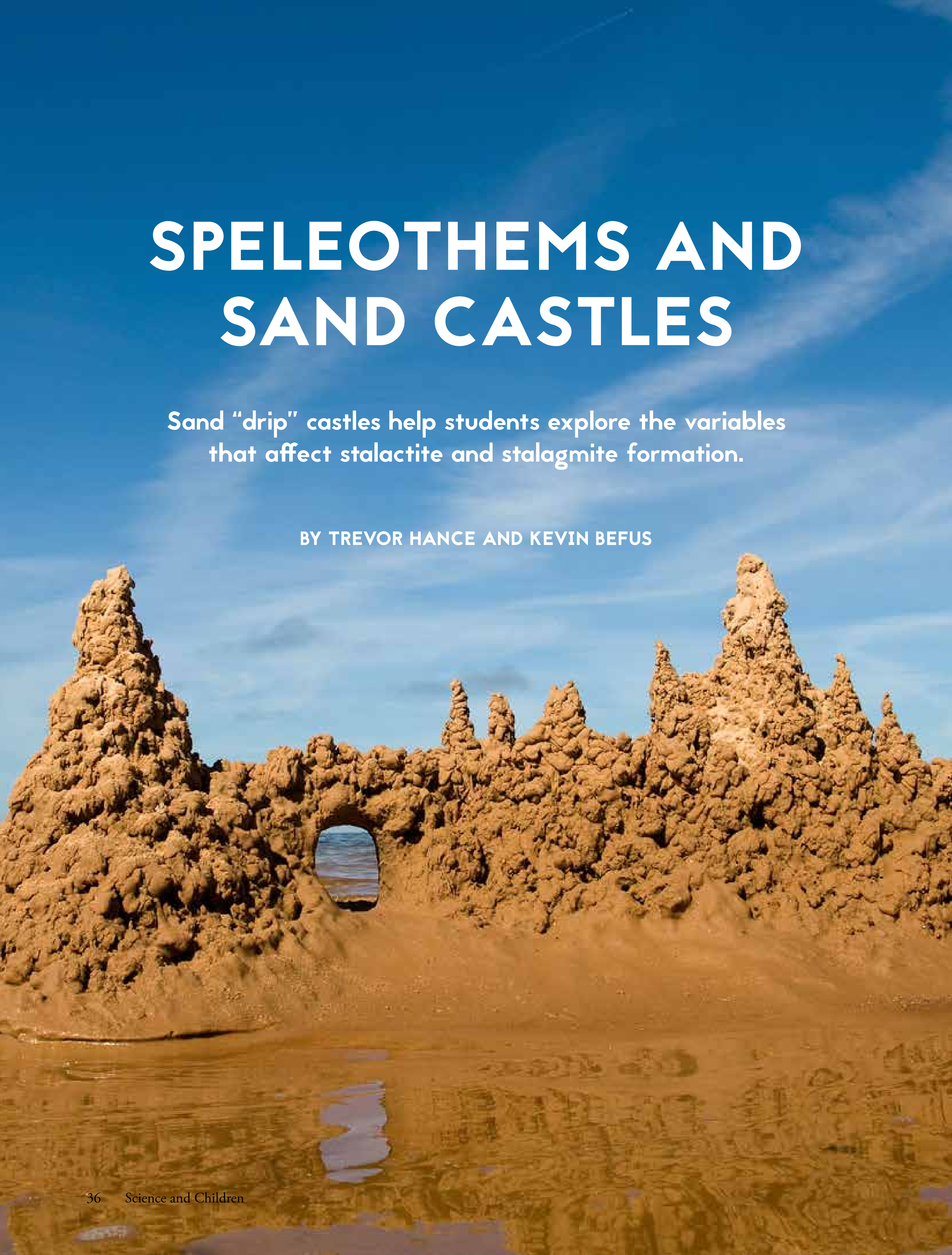
SPELEOTHEMS AND SAND CASTLES

Sand "drip" castles help students explore the variables that affect stalactite and stalagmite formation.

BY TREVOR HANCE AND KEVIN BEFUS



The idea of building sand castles evokes images of lazy summer days at the beach, listening to waves crash, enjoying salty breezes, and just unplugging for a while to let our inner child explore the wonderful natural toys beneath our feet. The idea of exploring caves might evoke feelings and images of claustrophobia or pioneers and Native Americans surviving with the land and its resources. In the classroom, sand castles and caves can help our student-scientists engage "the science behind climate science" in a deep, rich fashion and without the political undertones in the headlines. Specifically, "drip" sandcastles are wonderful models to demonstrate the way water, soil, and air/gases interact over time to create *speleothems*, structures that form in "soft-stone" caves through the deposition of minerals from water, like stalactites and stalagmites.

From a very simple perspective, weather is what is happening outside now ("minutes and months"), whereas climate describes long-term trends. This experiential lesson models the formation of stalactites and stalagmites, which are types of speleothems. Scientists use speleothems as a climate proxy in reconstructing climatic conditions over geologic time and have hypothesized that the more rainfall there is over a given period, the more quickly the formations develop (Banner et al. 2007). The lesson is the final in a series intended to help fifth-grade students develop a foundation for scale relating to geologic time (temporal magnitude)—a concept they will explore more richly in middle school when they study the history of the Earth. Our lesson does not offer a conclusion on climate *change* but instead contributes to a foundation and framework of climate *science literacy*, so as our students grow, they are able to ask questions that will help them analyze issues affecting our world and propose informed solutions to current or future environmental challenges.

While most would agree that understanding geologic time is beyond the capacity of 10-year-olds, introducing the topic appropriately helps students construct a proper conceptual framework that can be used to understand many topics, from geology to biology to climate sciences and the political, societal, and historical implications of each. In a recent article in the *Journal for Geoscience Education*, Professor Cesar Delgado demonstrated that in a constructivist-based learning platform at the undergraduate level, students were able to "anchor" landmark events when reviewing deep time in order to make sense of other events either before or after that event (Delgado 2013). We believe strongly in a constructivist approach to learning, with place-based, project-based, and service learning central to the design of learning experiences. As our final lesson in this series, speleothems provide a tangible "anchor" on a geologic scale for students as they start connecting Earth's patterns and systems to time, space, and place.

The Formation of Speleothems

Limestone is a "soft" stone, subject to "easy" weathering and erosion, and is pervasive in the United States, so speleothems provide an excellent and potentially local example that connects climate to geologic time in an experimental setting. Over time, water moving through limestone results in the formation of caves, karst landscapes, springs, and aquifers. One important limestone aquifer is the Edwards Aquifer, which provides the municipal water for America's seventh largest city, San Antonio. In addition to the fascinating opportunities to study water, these caves are also home to speleothems which include stalactites and stalagmites that can take hundreds of thousands of years to develop.

We realized we could extend our students' understanding of relevant curriculum requirements (such as erosion, deposition, the water cycle, mixtures, and solutions, as well as Earth's systems and cycles) with a speleothem growth model. In its natural state, the formation of a speleothem starts where surface water trickles through the topsoil, causing the water to become slightly acidic as gaseous carbon dioxide (CO_2) dissolves into it. As the water moves deeper, it passes through limestone and dissolves away carbonate mineral, forming a solution consisting of the molecular building blocks of limestone (calcite) in water. As the calcite-bearing water reaches a cave, the CO_2 escapes the water solution as a gas, much like opening a can of soda pop (but a lot less explosive and a lot slower). As the CO_2 is released, the acidity of the water drops, lowering the ability of the water to hold the calcite components, and the calcite from the solution is deposited, growing a speleothem formation.

"Big Time" Sand Castles

While the length of the lesson might vary from school to school depending on schedules and class length, our

PHOTOS COURTESY OF THE AUTHORS

Students examine "cave bacon."

lesson covered three class periods and called for students to create a "drip-castle stalagmite" in a large graduated cylinder using a mixture of water and playground sand. The first day we established the expectations for the investigation while reviewing weather patterns, climate, and speleothems. On day 2, students created their drip-castle stalagmites, recording their process and findings in their lab notebooks. Day 3 offered a chance to draw conclusions about the speleothem growth and connect the experience to all of the units covered to that point in the school year.

To maximize time available for students to conduct the investigation, we put the following materials in a tub for each group:

- Large beaker
- Small beaker
- Small graduated cylinder
- 1,000 ml of water
- 1,000 ml of playground sand
    - o The type of sand used is important. We learned through multiple trials in planning that colorful art sand is somewhat hydrophobic, resulting in some difficulty getting the mixture to the desired starting consistency. Additionally, paver sand is already wet, which distorts the mixture, making it hard to grow a speleothem model, therefore compromising the validity of the results.
- Large graduated cylinder filled to 500 ml with rocks, then layered with some paper towels (the rocks and paper towels decrease "splash")
- A small plastic bag with a small hole cut in one corner, with the hole placed over the center of the large graduated cylinder and draped over the edge.

FIGURE 1.

Speleothem column.

    - o This works as a funnel, focusing the drip to one spot and allowing growth of the speleothem (see Figure 1).

Each mixture of sand and water was "dripped" for one minute, with that minute to represent a 10,000 year time period. Students began with a mixture of 20 ml water to 40 ml of sand; this is the variable for the lesson and the proportion was modified by adjusting the amount of simulated "rainfall" (water) during each period. The students discussed what historic precipitation may have been, and they decided to add an additional 5 ml of water to the mixture in one trial and 10 ml of water to the next, testing to see if more water increased the growth rate of their speleothem. We were pleased to hear the students suggest that

FIGURE 2.

Student assessment piece.

this lesson. However, it is always advisable to get students in the habit of using goggles when working with mixtures and solutions, and we followed our normal protocols in that regard (see Safety First, p. 93). If you are fortunate enough to take a field trip to a cave system, staying on the path, "observing, not touching," watching for slip hazards, and low clearances are very important safety considerations.

CAUTION

With the procedural and safety expectations understood, groups developed a hypothesis about the periods they expected to have the most growth, conducted the investigation, and then compared the stalagmite formation rates between the various time periods and analyzed how growth related to climate during each of those periods

the number of rainfall events should be consistent among all groups to increase the reliability of their results by comparing with each other after the investigation.

Because we were working with playground sand and water, there were not any unique safety precautions for

Alignment and Assessments

For a more prescriptive outline of how we moved through the lesson, a 5E version of the lesson including a couple of assessment options is included online (see NSTA Connection). The *Next Generation Science Standards* call for fifth-grade students to analyze ways to determine how much water can be found in different places on Earth; this lesson gives them a window to one of the ways water moves (e.g., energy, hydrologic cycle) from the surface to ground water, and how the composition of water changes (mixtures and solutions) as it becomes more acidic when moving through the soil and limestone (erosion/weathering/gravity) before it degasses in the cave. Throughout the three-day learning experience, students answered formative questions relating to the ways speleothem formation relates to climate.

Additionally, the cumulative aspect of the lesson provided a midyear opportunity to comprehensively assess student understanding of the flow of energy from the Sun, tracing the path of water through the ways the

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013):

5-ESS2 Earth Systems

www.nextgenscience.org/5ess2-earth-systems

The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectations listed below. Additional supporting materials/lessons/activities will be required.

Performance Expectation	**Connections to Classroom Activity** *Students:*
5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.	• build speleothem models to observe the relationship between the geosphere, hydrosphere, and atmosphere in the process of speleothem formation and growth.
Science and Engineering Practice	
Developing and Using Models	• construct models of speleothems, specifically stalagmites. • construct explanations regarding the movement of water in the models and calculate the growth over periods of simulated time periods with variable rainfall amounts.
Disciplinary Core Idea	
ESS2.A: Earth Materials and Systems • Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes.	• recognize that speleothem models reflect changes in water chemistry as water moves from the atmosphere into the geosphere. • recognize the movement of water from surface water to groundwater.
Crosscutting Concept	
Systems and System Models	• "draw and label and explain" the connection between the Sun and the formation of speleothems beneath the Earth's surface.

geosphere, biosphere, hydrosphere, and/or atmosphere interact to form a speleothem. At the end of the lesson, students demonstrated their cumulative knowledge by answering the following question: "Using the Sun as a starting point, draw, label, and explain the formation of a speleothem using all relevant concepts we have covered this year." Responses were graded with a specific focus on whether the student demonstrated a clear understanding of the path from the Sun to the formation of a speleothem and the incorporation of relevant concepts such as weathering, erosion, mixtures, solutions and gravity in their explanation (see Figure 2, p. 39, for an example of student work).

But, There Is No "I" in "Speleothem"

Our students were fascinated to learn that these formations existed right under their feet. Several took their parents on "cave hunting expeditions" and even went on a tour of a local, privately owned cave system with colorful room names like "soda straw balcony" and "the ice cream parlour." On return, several of these students excitedly shared with the rest of the class about the discovery of the cave during the construction of the local interstate, the biodiversity of "cave creatures" like spiders and bats, and the importance of treating these formations as independent laboratories that should not be touched or disturbed (the oils on your hands can change the surface chemistry of speleothems, no longer allowing them to grow). Seeing students take initiative to learn more about these processes and systems outside of school demonstrated to us the effectiveness of the lesson.

For students like Cyntia, keeping her interested in science was the challenge. She is a very capable student, but after a quick discussion and glimpse at the outside of her notebook, you would see that she was one of our "art kids" and would rather spend time with a piece of parchment and a box of pastels than tromping across the playground "looking for holes in the ground" (as she explained it to one of her fellow students). Lessons like this help put an "A" (for art!) in "STEM" education for Cyntia, giving students like her places to plug in to science and realize the application of their interests to broader subjects. Because of the sculpting and drawing aspects of lessons like this, her parents thanked us at the end of the year for cultivating a true interest in science in their daughter as she moved on to middle school.

In addition to the engagement resulting from the lesson, the comprehensive "draw, label, and explain" assessment gave us an important window into the depth of learning our students were connecting through the experience. Through the drawings and explanations, students demonstrated their understanding of the role of the Sun in the hydrologic cycle and its connection to underground cave formations was thorough.

Conclusions

As populations, land use, energy exploration, and technology develop and change, climate science will continue to dominate the headlines. The magnitude of time and space are key crosscutting concepts for many subject areas. Establishing appropriate foundations about scales helps students better understand science in discussions about the climate. Whether through a study of ice cores or Thoreau's journals detailing the bloom of hundreds of flowers each spring in Massachusetts, authentic and relevant scientific investigations help encourage student learning and excite them about their futures.

Speleothem models help students understand ways the geosphere, biosphere, hydrosphere, and atmosphere interact in an authentic, place-based, experiential fashion, and cultivate a solid foundation for Earth and environmental science literacy.

Watch out world, these 10-year-olds might be ready for the big time. ■

Trevor Hance **(trevorhance@gmail.com)** ***is a grade 5 teacher and outdoor learning specialist at Laurel Mountain Elementary in Austin, Texas. Kevin Befus recently received his PhD in geology from the Jackson School of Geosciences at the Universty of Texas.***

Acknowledgment

Mr. Hance would like to thank his students for continually encouraging and pushing him to be a better teacher and reach them in ways that help excite them about their future.

References

Banner, J.L., A. Guilfoyle, E. James, L.A. Stern, and M. Musgrove. 2007. Seasonal variations in modern speleothem calcite growth in Central Texas, U.S.A. *Journal of Sedimentary Research* 77 (8): 615–622.

Delgado, C. 2013. Navigating deep time: Landmarks for time from the Big Bang to the present. *Journal of Geoscience Education* 61 (1):103–112.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

NSTA Connection

For the 5E lesson plan, visit *www.nsta.org/SC1510*.