Environmental Systems
Aquatic Science
Chemistry

Karst Formation

Teacher Page

Enduring Understandings
Rainwater dissolves limestone to form recharge features in karst aquifers.

Vocabulary
Aquifer, carbonic acid (HCO_3^-), calcite (Ca^{2+}), dissolution, fault, fracture, groundwater, karst, limestone, recharge zone, sinkhole

Essential Questions:
Why are karst areas important and how do they form? Why and how should karst ecosystems be managed?

Topical Questions:
How does limestone dissolve to form recharge features of the Edwards Aquifer?

Objectives ***Students will:***
- Understand the chemical reactions involved in limestone dissolution.
- Identify rainwater and limestone as the two necessary parts of dissolution cave formation.
- Relate recharge features to aquifers.
- Understand how pollution enters our aquifer.

Teacher Management

Estimated Time for Completion
45-55 minutes


Karst limestone

Materials
- Groundwater video: "Austin Underground"
- Safety goggles (one pair for instructor)
- Chemical-resistant protective gloves (one pair for instructor)
- Large sample of limestone with karst dissolution features (holes)
- 10% hydrochloric acid (or other weak acid) with dropper
- Bromethyl blue (BTB) (or other pH indicator solution)
- Several small pieces of limestone (<2 inches)
- Small clear cup or container (just large enough to submerse the small pieces of limestone in 50 ml of water)
- pH water test kits (optional)

Materials per lab group (recommended 3-5 students per group)
- 24-36 sugar cubes (24 sugar cubes are needed for modeling a fracture or sinkholes; 36 sugar cubes are needed for modeling a fault)
- 1" cube of clay-based modeling clay
- 5 ml pipette/dropper
- toothpick
- popsicle stick or butter knife (something to cut the clay with)
- 15 ml of water
- a couple of drops of food coloring
- Small rectangular container (2½"L x 2"W x 1⅝"H) - 0.14 L or 0.15 L "Really Useful Boxes" from Office Depot (www.officedepot.com/a/products/640476/Really-Useful-Boxes-Plastic-Storage-Box/) or contact Watershed Protection Dept: 512-974-3540)

Teacher Prep
Note: This activity is designed to follow part 1 of the video "Austin Underground" and instruction on acids and bases.

Safety Considerations

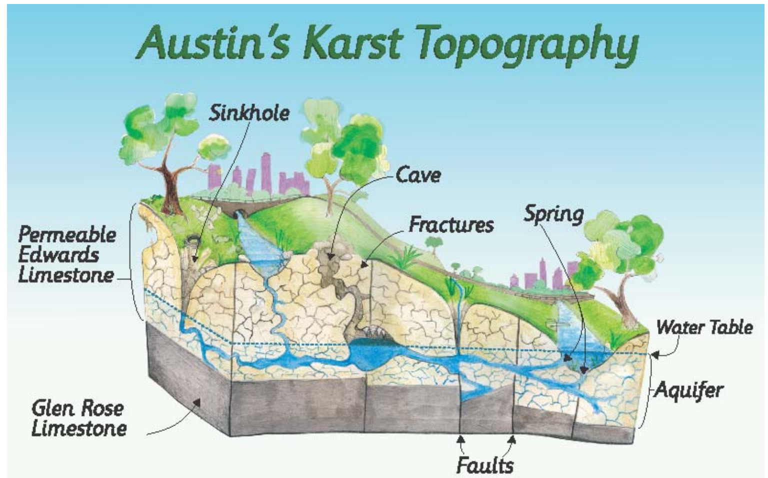
- Wear safety goggles and chemical–resistant protective gloves while using HCL
- Sugar models begin to mold after time and create air quality problem.

Vocabulary Building Strategies

Reinforce vocabulary by completing all lessons for the groundwater video.

Background Information for Teacher

Part 1 of the groundwater video briefly covers the geology and formation of the Edwards Aquifer. The Edwards Aquifer is a **karst** aquifer resulting from the particular physical properties of limestone. The term karst describes a distinctive topography that indicates dissolution of underlying soluble rocks by surface water or groundwater. **Dissolution** of rock to create **recharge** features such as caves and sinkholes is accomplished through chemical reactions. The reactions involve the incorporation of other chemicals into groundwater or surface water that then create acids capable of dissolving rocks.



The Edwards limestone formed in a shallow sea that covered most of Texas 100 million years ago. In Central Texas, the Edwards limestone was uplifted, fractured, and faulted along the Balcones fault zone about 15 million years ago. During this exposure, the upper layers eroded away, and holes and openings in the Edwards layer of limestone formed due to chemical weathering and erosion by rainwater. Faults and Fractures provide easy pathways for water (and pollution) to travel underground.

Limestone chemically reacts to weak acids by going into solution. This happens gradually over time with rain water. Rainwater (pH of ~5.6) becomes acidic as it comes in contact with carbon dioxide in the atmosphere and the soil, creating a mild carbonic acid (HCO_3^-). As this acid flows through carbonate rocks, the rocks are dissolved and the calcite (Ca^{2+}) is taken up into solution.

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca^{2+} + 2\ HCO_3^-$$

This process of dissolution continues in the formation through the rock layers as water seeps down conduits and fractures in its movement through the aquifer and enlarges cracks and caves.

Understanding caves and karst is important because 10% of the Earth's surface is occupied by karst landscape and as much as a quarter of the world's population depends upon water supplied from karst areas.

Misconceptions

- Some students may think holes in karst limestone were formed by animals or human forces, but they were formed by rainwater.
- Some students may think Austin's drinking water comes from the Edwards Aquifer or the ocean, but most of Austin's drinking water comes from the Colorado River.
- Some students may think the Edward's Aquifer is good at filtering pollution, but karst aquifers do not filter out pollution well.
- Some students may think aquifers are all the same, but aquifers made of sand, gravel, and limestone have very different properties.

Focus Activity/Warm up
Show Part 1 of groundwater video before this activity.

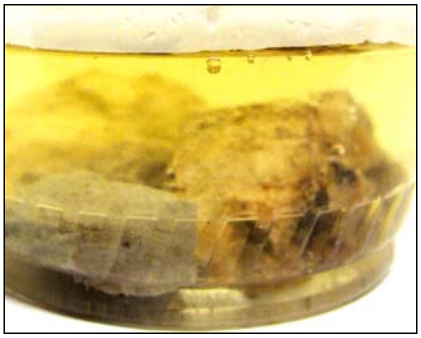
Engage
Hold up a piece of karst limestone. Ask students "what type of rock is this?" Why does it have holes and why does it form caves? Students may answer that water dissolved holes in the rock by chemical weathering. How does this process occur?

While wearing safety goggles and protective gloves, tell students you will now add a few drops of hydrochloric acid to the rock. Why does it fizz? Limestone is a calcium carbonate rock. The carbonate reacts with the H ion and creates a chemical reaction. Limestone is not very soluble so the rocks don't dissolve very quickly. If you add an acid however you add Hydrogen Ions (H^+) which will react with the carbonate to form hydrogen carbonate HCO_3^- ions which are very soluble in water, and the limestone will dissolve.

Write on the board the chemical reactions that occur to cause dissolution of karst:

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca^{2+} + 2\ HCO_3^-$$

Ask students how they think limestone affects the pH of water. Conduct a demonstration to show how slightly acidic water can become basic when it interacts with limestone. Pour 50 mL of slightly acidic water in a clear plastic cup or container. Add 10 drops of Bromethyl blue (BTB) indicator solution to show that the water is slightly acidic (if the water is slightly acidic it should become yellow). If the water is not acidic, you can add a drop or two of hydrochloric acid or vinegar to make the water slightly acidic. Submerse several small pieces of limestone in the slightly acidic water. The solution should become green when the water is neutral and blue when the water becomes basic. This process may take around 30 minutes so you should start the demonstration before the Explore activity so students can see how the solution starts as the color yellow (when the water is slightly acidic), then after their Explore activity, they can see how the solution turned blue (indicating the water became basic when it interacted with limestone. If you want to speed up the process, you can crush up the limestone or add pulverized chalk (which was originally made from limestone). Note: Universal indicator (or another pH indicator solution) can be used instead of BTB, but you should try the demonstration in advance to determine how long it takes the limestone to change the color of the solution from yellow to blue so you can plan your lesson accordingly. Optional: you can use pH kits to measure the pH of the water before and after it interacted with the limestone.

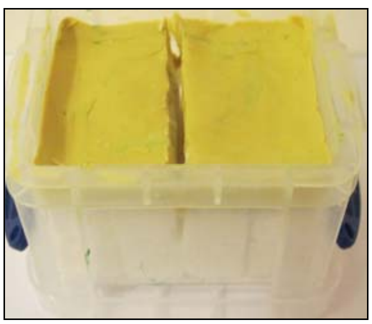


Limestone in acidic water with BTB starts out yellow

The water will eventually turn blue to indicate basic pH

Explore

Students work in teams (of 4-5 students) to build sugar karst models to observe karst formation. Designate students into groups and instruct them to build a feature of the recharge zone to model and observe how fractures, faults, and sinkholes affect groundwater transport. Use student sheet. Circulate from group to group and ask students questions to assess understanding. Have students present their models and key findings to the other groups.



Sugar karst model of a fracture.

Sugar karst model of fault

Sugar karst model of sinkholes

Explain

For the Engage activity: Explain to the students how slightly basic rainwater becomes slightly acidic as it interacts with Carbon in the atmosphere and soil, forming carbonic acid, which causes the limestone to dissolve. As the limestone dissolves it causes the solution to become basic.

For the Explore activity: Students will have the opportunity to see all of the models and share their results with the class in a discussion about how karst aquifers form in limestone, how the recharge feature they modeled (fracture, fault, or sinkholes) affects cave development, and how manipulating variables affected their results.

Probing questions: What do the sugar cubes represent? What does the clay represent? What happened inside of the model? How is limestone similar to and different from the sugar cubes? Discuss connections between the Engage activity and Explore activity and strengths and limitations of the models.

Extend/Elaborate

- Go to the following website to identify which watershed your school is in and whether or not you live in the Edwards Aquifer recharge zone**:** www.ci.austin.tx.us/watershed/learn_ws.htm
- Use water pH test kits to contrast pH of Austin rainwater (acidic) and creek water (basic due to limestone bedrock)
- Build a larger version of a karst model that shows faults, fractures, and sinkholes.

Evaluate

Student sheet

Closure/Daily Assessment TBD

Differentiation TBD

Resources

Carlsbad Caverns National Park, A curriculum and activity guide for Carlsbad Caverns National Park, high school geology www.nps.gov/cave/forteachers/highschool_geology.htm

Russell, Margaret. Deep Down Underground 5th grade lesson plan.

American Geologic Institute. Living with Karst, A fragile foundation www.agiweb.org/environment/publications/karst.html

Acknowledgments

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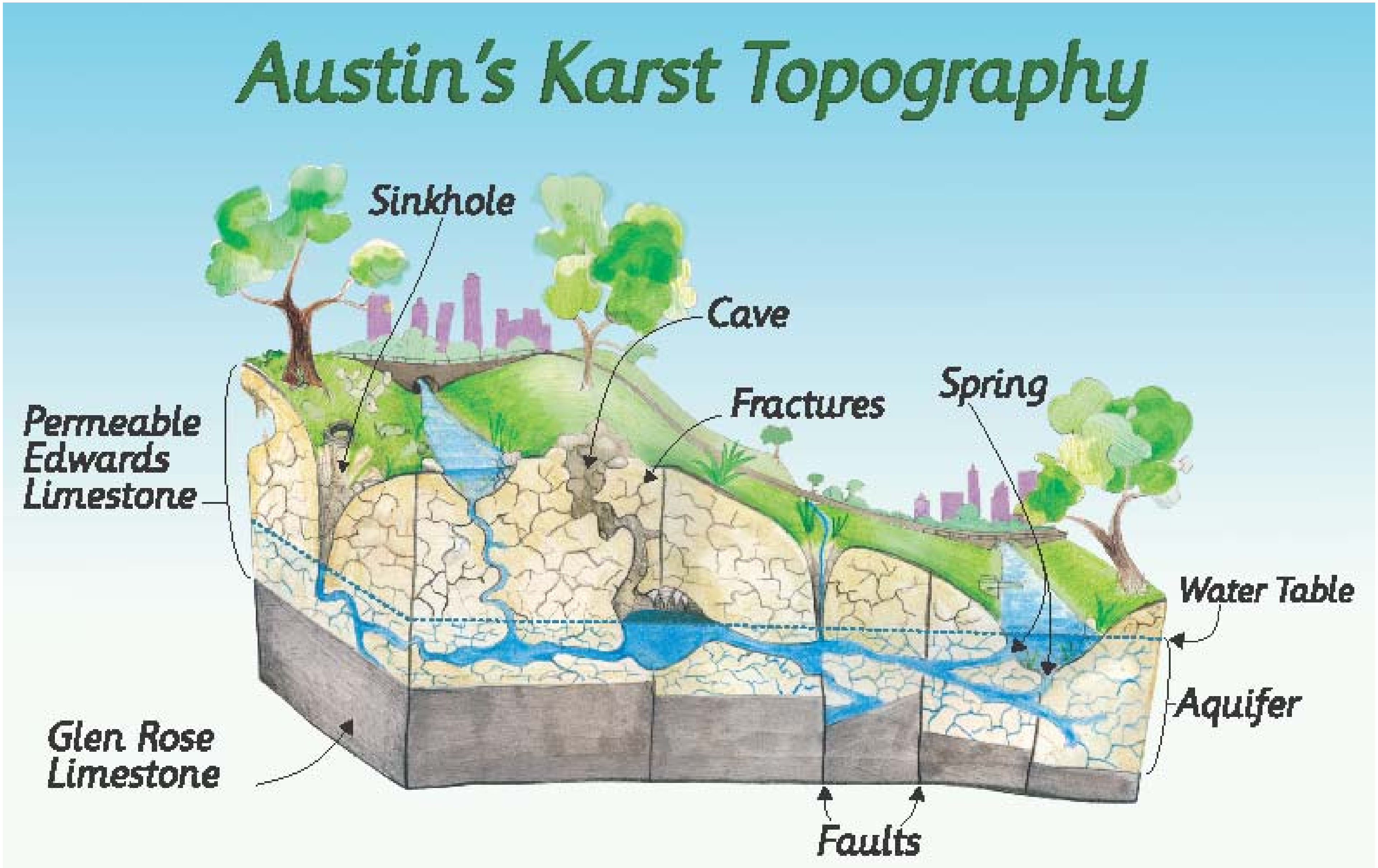
Austin's Karst Topography
Sinkhole
Cave
Spring
Fractures
Permeable
Edwards
Limestone
Water Table
Aquifer
Glen Rose
Limestone
Faults

Glossary

aquifer
Sediment or rocks, such as limestone or sand, which stores, conducts, and transmits large quantities of water easily.

carbonate
A sedimentary rock made mainly of calcium carbonate ($CaCO_3$). Limestone and dolomite are common carbonate sedimentary rocks.

carbonic acid
A mild acid (HCO_3^-) formed when water and carbon dioxide chemically combine in the atmosphere and soil. This acid is a very important component in the development of cave formations.

calcite
A mineral ($CaCO_3$) consisting of calcium carbonate crystallized in hexagonal form and including common limestone, chalk, and marble.

cave
A natural opening in the ground extending beyond the zone of light and large enough to permit the entry of an average human.

dissolution
the process of dissolving rocks and minerals with liquid (usually slightly acidic water).

fault
A fracture in rocks where one rock body slides past another

fracture
A break or crack in rock

groundwater
Water that is under the surface of the Earth, mostly in pores or cracks of grains; groundwater discharges as springs.

karst
A distinctive landscape (topography) that can develop where the underlying bedrock, often limestone or marble, is partially dissoved by surface or ground water.

limestone
A chemical sedimentary rock made mostly of the mineral calcite ($CaCO_3$). Limestone is usually formed from shells of once-living organisms or other organic processes, but may also form by inorganic precipitation. Chemical sedimentary rocks are composed of minerals that were precipitated from water. This process begins when water traveling through rock dissolves some of the minerals, carrying them away from their source. Eventually these minerals are re-deposited, or precipitated, when the water evaporates away or when the water becomes over-saturated.

recharge zone
A region of porous and permeable rock or sediment where water replenishes the aquifer.

sinkhole
A depression in the surface commonly found in karst landscapes. Sinkholes often form where limestone or some other soluble rock is partially dissolved by groundwater, then collapses to form a depression. Sinkholes are often "bowl-shaped" and can be a few to many hundreds of meters in diameter.

soluble
Capable of being dissolved or liquefied.

solution
A homogeneous mixture of two or more substances, which may be solids, liquids, gases, or a combination of these.

Name:____________________

Period:_____

Student Sheet-Karst Formation

Understanding karst is important since 10% of the Earth's surface is occupied by karst landscape and as much as a quarter of the world's population depends upon water supplied from karst aquifers. In Austin, our karst landscape is covered in recharge features like caves, faults, fractures and sinkholes that allow water to flow into the aquifer.

If limestone is not very soluble in water, how does the rock dissolve to form recharge features?

Write the chemical reaction of karst limestone dissolution:

Build a Karst Model

Your group will build a sugar karst model to observe how sinkholes and caves are formed in limestone. Your group will be assigned to model one of the following features of the recharge zone to see how fractures, faults, and sinkholes affect cave development.

<u>Groups 1 & 2:</u> Model a **fracture** (a break or crack in rock):

1. Fill the small rectangular container with two layers of sugar cubes (tightly packed).
2. Flatten a layer of clay on top of the sugar cubes. Seal the clay to the edges of the container (this creates an impermeable layer). Create a fracture by cutting through the clay with a Popsicle stick or butter knife (make sure fracture is wide enough for water to flow through).

<u>Groups 3 & 4:</u> Model a **fault** (a fracture in rocks where one rock body slides past another):

1. Fill the small rectangular container with two layers of sugar cubes (tightly packed) and add a third layer over half of the model.
2. Flatten a layer of clay on the half of the model that has two layers of sugar cubes and seal the clay to the edges of the container (make sure the clay is level). Do not use any clay where there are three layers of sugar cubes. In this model, the layer without clay moved up relative to the layer with clay. Both sides of the fault originally had a clay-rich layer of soil, but the uplifted layer was more exposed to erosive forces so the clay-rich soil eroded away leaving the limestone (sugar) exposed at the surface.

<u>Groups 5 & 6:</u> Model **sinkholes** (depressions in the surface):

1. Fill the small rectangular container with two layers of sugar cubes (tightly packed).
2. Flatten a layer of clay on top of the sugar cubes and seal the clay to the edges of the container (this creates an impermeable layer). Press down on the clay with a finger to form a depression. Next poke a toothpick through the depression and wiggle it around to make a sinkhole large enough for water to flow through. You may make a few large sinkholes or many small sinkholes (make sure some are near the edge of the container so you can see how they affect cave development and recharge to the aquifer).

<u>**All Groups**</u>: Show the model to your teacher to see if any modifications need to be made before proceeding with the following steps.

1. Add a couple of drops of food coloring (representing contamination) to the model then "rain" across the entire surface of your model by slowly adding 5 ml of water with a pipette. Observe and document observations for trial 1 on the next page. Add another 5 ml water. Observe and document observations for trial 2. Add another 5 ml water. Observe and record observations for trial 3.
2. Present your model and key findings to the other groups.

Data Sheet

Which recharge feature (fracture, fault, or sinkholes) did your group model?

Type of Recharge Feature: ________________________________

Draw your model and record observations after each trial:

Trial 1:	Trial 2:	Trial 3:
Observations:		

Answer the following questions:

1) What do the sugar cubes represent?___________________

2) What does the clay represent?________________________

3) What happened inside of the model?

4) How is limestone similar to and different from the sugar cubes?

Similar:

Different:

5) How does rainwater pH affect development of karst aquifers?_____________________

6) How does limestone affect the pH of water?___________________________________

7) How do features of the recharge zone (fractures, faults, and sinkholes) affect development of karst aquifers?

8) How can pollution travel from the land on the surface to contaminate the groundwater in the aquifer? What happened after you added the pollutant? Does the contamination show up anywhere else in the system? Does this type of contamination occur in the Edwards Aquifer? Give an example.

9) How should the Edwards Aquifer recharge zones be managed?