Disappearing Rocks

SUBJECT: Science
GRADES: 4-8
DURATION: approximately 20 minutes
ACTIVITY SUMMARY: Students will drip vinegar onto rocks to demonstrate the weathering effect of a weak acid on limestone.

OBJECTIVES:
Students will be able to:

1. Analyze whether rocks have undergone a physical or chemical change.
2. Classify rocks as metamorphic, igneous, or sedimentary

VOCABULARY: limestone, carbonic acid, bedrock, weathering

MATERIALS REQUIRED:

- Safety goggles
- White table vinegar
- Squeeze droppers or straws
- Samples of rocks, one being limestone
- Dishes or shallow containers

Note: You may obtain rock samples by contacting your states minerals agency or a local aggregate organization or by purchasing them.

BACKGROUND:

Most karst is formed where carbonate rocks such as dolostone and limestone are exposed at the earth's surface. The largest and greatest number of caves are found in areas of extensive deposits of limestone. Limestone is composed mainly of the mineral calcite ($CaCO_3$), with minor amounts of insoluble minerals (clays, quartz, feldspar). Limestone is rather soluble as rocks go, but only in acidic water. Raindrops reaching the earth's surface are generally not acidic (except in rare cases of acid rain caused by industrial emissions or volcanoes). In the underlying soil, however, aerobic bacteria break down dead organisms, producing carbon dioxide concentrations of ten to twenty times that of the outside atmosphere. As precipitation percolates though the soil, some of this CO_2 dissolves to form a carbonic acid solution. This slightly acidic water (essentially very flat seltzer water) seeps through cracks in the ground and slowly dissolves calcite out of the limestone and carries it away in the solution of water. People who live in karst areas and depend on well water can see evidence of the dissolved rock first-hand, including mineral deposits formed in their teakettles and hot water heaters. These minerals were originally part of the underlying bedrock.

The most active dissolution of bedrock occurs just below the water table, where fresh, acidic water from the surface comes in contact with submerged limestone. The water table is the elevation below which fractures and voids in the bedrock are completely filled with water. Over thousands of years the water continues to dissolve along underground fractures and rock layers, and it hollows out spaces within the rock. These spaces are called passageways and caverns, or caves.

Rock which has not been significantly eroded and is still connected to the underlying strata is called bedrock. The decomposition of bedrock by the forces of weathering produces a zone of weathered rocks and soil. This layer has been most affected by the forces of weathering (breaking up of rocks, both chemically and physically) and erosion (removal of the weathered materials). Wind, water, and freezing and thawing are constant contributors to the weathering and erosion processes and explain the varying sizes and shapes of sediments found within this top layer. This fairly porous layer has a relatively fast rate of water permeability when compared to the underlying bedrock.

Chemical weathering changes the minerals within the rock, typically softening and weakening them. Rainwater dissolves carbon dioxide in the air and in the soil, where it is produced by organisms and during the decay of organic material. This forms a weak acidic solution of carbonic acid that moves through the ground towards the water table. Some minerals react with the acid to make new minerals and release chemicals into solution. The best examples of this are the feldspars, a group of minerals commonly found in granites and some sandstones. Other minerals are soluble—they dissolve completely into acidic water but at varying rates. These soluble materials *including halite (table salt), gypsum, calcite, and dolomite+ dissolve more slowly, and produce a characteristic landscape, called karst when exposed at the earth's surface. Because limestone (dominantly calcite) and dolostone (dominantly dolomite) is much more common than rock gypsum, most of the world's karst topography forms where these rocks are exposed at the earth's surface. A notable exception is the Guadalupe Mountains of New Mexico, which have karst topography developed dominantly in gypsum.

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PROCEDURE:

1. Explain to students that one can often tell what kinds of minerals are found in rocks by the physical properties of the rock (appearance and characteristics such as their grain sizes, hardness, color, texture, and whether they can be dissolved). Explain solubility by discussing (or demonstrating) how sugar added to iced tea or jello mix added to hot water "disappears" into solution.
2. Explain to students that most caves form in limestone areas. Limestone (and dolostone) is somewhat unique because its mineral grains can be dissolved in nature by a very mild carbonic acid. The weak acid forms from a mixture of water (from rain) and carbon dioxide (from air and soil). Remind students they breathe in oxygen and breathe out carbon dioxide. When the carbonic acid comes in contact with calcite, it dissolves small amounts of the calcite and carries it away (in solution) through cracks and pores in the rock, leaving behind a slightly larger opening. Over a very long time, these holes can become large, interconnected cave passages.
3. Tell students that one of the samples of rock is limestone and ask if they can suggest a way to determine which one it is. The rock samples can be tested for calcite by checking to see which ones dissolve. Explain that they will participate in a Bubble Test. The samples with calcite will bubble and those without calcite will not. Have students test each sample first with water to serve as a comparison. None of the samples should see the formation of bubbles. Next, have students apply drops of vinegar on the samples. Because this is such a vivid demonstration, be prepared to allow extra time for each student to try it and comment.
4. Ask the students to identify the bubbles (carbon dioxide). (For older students: ask if this is evidence of a physical or chemical change. Carbon dioxide and a salt--calcium acetate--are the new products formed.)
5. Ask students to determine which rock sample is the limestone. Identify the other samples.
6. Ask students what might happen if a limestone layer of rock is sandwiched between harder rock layers, or rock layers which would not dissolve. Guide students to an understanding that the water will seep or flow through available cracks and crevices to the lowest point possible and pool or run down slope along any non-permeable low angle planes. Over thousands of years, the chemical weathering by the weak acidic water solution will further erode and hollow out areas of the limestone creating passageways and caverns, or caves.

EVALUATION:

Students will be evaluated through the analysis questions.

VARIATION FOR THE BUBBLE TEST:

Note: appropriate laboratory safety procedures should be followed when using hydrochloric acid. (You may substitute vinegar, which is safer but gives a less dramatic effect.)

Partially fill two breakers with a 5% solution of hydrochloric acid (HCl). Select two samples of rock, one limestone and one non-carbonate rock, and weigh or measure them before placing them in the solution. The limestone will readily fizz when placed in the acid; the non-carbonate will not react. Check the level of activity every ten to fifteen minutes. (The dissolving action will stop if either the acid or the calcite is no longer available to react. If this happens, the solution from the breaker can be tested on a separate, dry sample of limestone. As determination of the cause requires, you can add more acid or break the rock (exposing more accessible calcite). In approximately one hour, the limestone sample will be noticeably smaller in size. After drying, the samples can be reweighed to determine the changes due to dissolution.

EXTENSIONS:

1. To provide a visual opportunity to discuss variation in rates of geologic processes, a third beaker of hydrochloric acid (do not substitute vinegar) can be used to demonstrate dissolution of a sample of dolostone. (The dolostone contains the mineral dolomite, which is similar to calcite.) Ask the students which rock will form caves more quickly: limestone or dolostone. (The dolomite will react to the acid but much more slowly than the calcite. Caves will form more quickly in limestone because of its higher solubility.)
2. Place the limestone and dolostone samples in seltzer water and let the samples sit for a month, changing the water daily. Use another sample of distilled water as a control. This emphasizes the relative slowness of geologic time.
3. Have students write the formula for carbonic acid ($H_2O + CO_2 = H_2CO_3$). Given the compounds, where does the "H" come from in carbonic acid?

Name: _____

Disappearing Rocks

Background:

The types of minerals that are found in rocks can often be determined by the physical properties of the rock (appearance and characteristics such as their grain sizes, hardness, color, texture, and whether they can be dissolved).

Most caves form in limestone areas. Limestone (and dolostone) is somewhat unique because its mineral grains can be dissolved in nature by a very mild carbonic acid. The weak acid forms from a mixture of water (from rain) and carbon dioxide (from air and soil—remember, you breathe in oxygen and breathe out carbon dioxide). When the carbonic acid comes in contact with calcite, it dissolves small amounts of the calcite and carries it away (in solution) through cracks and pores in the rock, leaving behind a slightly larger opening. Over a very long time, these holes can become large, interconnected cave passages.

Natural Bridge Caverns are made of limestone, a sedimentary rock.

Today you will do a test to determine which one of your rock samples is limestone. You will do the Bubble Test to see which sample dissolves when a weak acid (vinegar) comes in contact with it. The calcite in the rocks will react with the vinegar to produce gas bubbles.

Procedure:

Hypothesis: Based on the characteristics of the rocks, which sample do you think is limestone? _____

1. Put on safety goggles.
2. Put a couple of drops of water on your first sample and record your observations in the data table. Repeat for all rock samples.
3. Repeat step 2, this time using vinegar.
4. Answer the Analysis Questions.

Data Table

Sample	Water	Vinegar

Analysis Questions

1. When vinegar was dropped onto the limestone, what did you observe?

2. Explain what causes the bubbles on the rock.

3. Is this a physical or a chemical change?

4. Thinking about what you have just observed and the background information, what could happen if a layer of limestone rock is sandwiched between harder rock layers?

TEKS ADDRESSED:

Science

4th Grade

1(A) ask questions and define problems based on observations or information from text, phenomena, models, or investigations
1(B) use scientific practices to plan and conduct descriptive investigations and use engineering practices to design solutions to problems
1(C) demonstrate safe practices and the use of safety equipment during classroom and field investigations as outlined in Texas Education Agency-approved safety standards
1(D) use tools, including hand lenses; metric rulers; Celsius thermometers; calculators; laser pointers; mirrors; digital scales; balances; graduated cylinders; beakers; hot plates; metersticks; magnets; notebooks; timing devices; sieves; materials for building circuits materials to support observation of habitats of organisms such as terrariums, aquariums, and collecting nets; and materials to support digital data collection such as computers, tablets, and cameras, to observe, measure, test, and analyze information
1(E) collect observations and measurements as evidence
1(F) construct appropriate graphic organizers used to collect data, including tables, bar graphs, line graphs, tree maps, concept maps, Venn diagrams, flow charts or sequence maps, and input-output tables that show cause and effect
1(G) develop and use models to represent phenomena, objects, and processes or design a prototype for a solution to a problem
2(A) identify advantages and limitations of models such as their size, scale, properties, and materials
2(B) analyze data by identifying any significant features, patterns, or sources of error
2(C) use mathematical calculations to compare patterns and relationships
3(B) communicate explanations and solutions individually and collaboratively in a variety of settings and formats
3(C) listen actively to others' explanations to identify relevant evidence and engage respectfully in scientific discussion
10(B) model and describe slow changes to Earth's surface caused by weathering, erosion, and deposition from water, wind, and ice
11(C) determine the physical properties of rocks that allow Earth's natural resources to be stored there.

5th Grade

1(A) ask questions and define problems based on observations or information from text, phenomena, models, or investigations
1(B) use scientific practices to plan and conduct descriptive and simple experimental investigations and use engineering practices to design solutions to problems
1(C) demonstrate safe practices and the use of safety equipment during classroom and field investigations as outlined in Texas Education Agency-approved safety standards
1(D) use tools, including calculators, microscopes, hand lenses, metric rulers, Celsius thermometers, prisms, concave and convex lenses, laser pointers, mirrors, digital scales, balances, spring scales, graduated cylinders, beakers, hot plates, meter sticks, magnets, collecting nets, notebooks, timing devices, materials for building circuits, materials to support observations of habitats or materials to support digital data collection such as computers, tablets, and cameras to observe, measure, test, and analyze information;
1(E) collect observations and measurements as evidence
1(F) construct appropriate graphic organizers used to collect data, including tables, bar graphs, line graphs, tree maps, concept maps, Venn diagrams, flow charts or sequence maps, and input-output tables that show cause and effect; and
1(G) develop and use models to represent phenomena, objects, and processes or design a prototype for a solution to a problem.
2(B) analyze data by identifying any significant features, patterns, or sources of error
3(A) develop explanations and propose solutions supported by data and models
3(B) communicate explanations and solutions individually and collaboratively in a variety of settings and formats
3(C) listen actively to others' explanations to identify relevant evidence and engage respectfully in scientific discussion
10(B) model and describe the processes that led to the formation of sedimentary rocks and fossil fuels

6th Grade

1(A) ask questions and define problems based on observations or information from text, phenomena, models, or investigations
1(B) use scientific practices to plan and conduct descriptive, comparative, and experimental investigations and use engineering practices to design solutions to problems
1(C) use appropriate safety equipment and practices during laboratory, classroom, and field investigations as outlined in Texas Education Agency-approved safety standards
1(D) use appropriate tools such as graduated cylinders, metric rulers, periodic tables, balances, scales, thermometers, temperature probes, laboratory ware, timing devices, pH indicators, hot plates, models, microscopes, slides, life science models, petri dishes, dissecting kits, magnets, spring scales or force sensors, tools that model wave behavior, satellite images, hand lenses, and lab notebooks or journals
1(E) collect quantitative data using the International System of Units (SI) and qualitative data as evidence
1(F) construct appropriate tables, graphs, maps, and charts using repeated trials and means to organize data
1(G) develop and use models to represent phenomena, systems, processes, or solutions to engineering problems
2(A) identify advantages and limitations of models such as their size, scale, properties, and materials
2(B) analyze data by identifying any significant descriptive statistical features, patterns, sources of error, or limitations
2(C) use mathematical calculations to assess quantitative relationships in data; and
2(D) evaluate experimental and engineering designs.
6(E) identify the formation of a new substance by using the evidence of a possible chemical change, including production of a gas, change in thermal energy, production of a precipitate, and color change.
10(C) describe how metamorphic, igneous, and sedimentary rocks form and change through geologic processes in the rock cycle

7th Grade

1(A) ask questions and define problems based on observations or information from text, phenomena, models, or investigations
1(B) use scientific practices to plan and conduct descriptive, comparative, and experimental investigations and use engineering practices to design solutions to problems
1(C) use appropriate safety equipment and practices during laboratory, classroom, and field investigations as outlined in Texas Education Agency-approved safety standards
1(D) use appropriate tools such as graduated cylinders, metric rulers, periodic tables, balances, scales, thermometers, temperature probes, laboratory ware, timing devices, pH indicators, hot plates, models, microscopes, slides, life science models, petri dishes, dissecting kits, magnets, spring scales or force sensors, tools that model wave behavior, satellite images, hand lenses, and lab notebooks or journals
1(E) collect quantitative data using the International System of Units (SI) and qualitative data as evidence
1(F) construct appropriate tables, graphs, maps, and charts using repeated trials and means to organize data
1(G) develop and use models to represent phenomena, systems, processes, or solutions to engineering problems
2(A) identify advantages and limitations of models such as their size, properties, and materials
2(B) analyze data by identifying any significant descriptive statistical features, patterns, sources of error, or limitations
2(C) use mathematical calculations to assess quantitative relationships in data
5(B) identify and investigate cause-and-effect relationships to explain scientific phenomena or analyze problems

TEKS CONTINUED:

8th Grade

1(A) ask questions and define problems based on observations or information from text, phenomena, models, or investigations
1(B) use scientific practices to plan and conduct descriptive, comparative, and experimental investigations and use engineering practices to design solutions to problems
1(C) use appropriate safety equipment and practices during laboratory, classroom, and field investigations as outlined in Texas Education Agency-approved safety standards
1(D) use appropriate tools such as graduated cylinders, metric rulers, periodic tables, balances, scales, thermometers, temperature probes, laboratory ware, timing devices, pH indicators, hot plates, models, microscopes, slides, life science models, petri dishes, dissecting kits, magnets, spring scales or force sensors, tools that model wave behavior, satellite images, weather maps, hand lenses, and lab notebooks or journals
1(E) collect quantitative data using the International System of Units (SI) and qualitative data as evidence
1(F) construct appropriate tables, graphs, maps, and charts using repeated trials and means to organize data
1(G) develop and use models to represent phenomena, systems, processes, or solutions to engineering problems; and (H) distinguish between scientific hypotheses, theories, and laws
2(A)analyze data by identifying any significant descriptive statistical features, patterns, sources of error, or limitations
2(C) use mathematical calculations to assess quantitative relationships in data