LOOK AT WHAT NATURE HAS DONE!

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Purpose

The following is an exercise that can lead students to an understanding of how easy it is to break rock. With any luck the students will no longer think of the eternity of the Rock of Ages or the solidity of the Rock of Gibraltar.

Definitions

Weathering - the process of breaking rock into small particles. The process leads to the disintegration and decomposition of rock at or near the earth's surface.
Erosion - the transportation by water, wind, or ice of the broken material created by weathering.

Teacher Information

You may have always thought of rock as being symbolic of eternity and solidity. Our problem is that we think in the time frame of our lifetimes (averaging now about 72 years), centuries (the bicentennial of the United States, the 20th Century), or forever (Adam born 4004 B.C.). But when we talk about the earth, we have to think in millions and billions of years. Given this sort of time frame, rock is weak. If you will look at gravestones, even in Civil War cemeteries, the writing on them is worn and may even be gone. The surface of the tombstone has been weathered away. We can no longer think of phrases written in stone as being for the millennia, the rocks themselves are as impermanent as the sands of time.

Rocks can be broken down by natural and manmade chemicals existing in the environment. Many of the waters of the world are acid. Everyone should be aware of acid rain. Acid precipitation makes acid waters on the land. Acid water reacts with the rocks and breaks them down chemically. Acid rain is not the only source of acid water. It is hard to grow grass under evergreens and oaks because the soil under them is acid. You might want to test the soil to prove this. When you put lime on your lawn you are doing it to neutralize the acidity in the soil. In the north, you may have noticed that the streams are brown. The brown color is caused by tannic acid in the water. If you put any rock in water it will eventually dissolve (remember we are talking about geologic time). If you put the rock in acid water, it will react and dissolve much more quickly. The best way to demonstrate acid-rock relations is to use limestone and a very weak acid. You can watch the acid eat away at the rock. Seventeenth, eighteenth, and nineteenth century gravestones are slowly being dissolved by acid rain because many of them are made of marble, which has the same chemical composition as limestone. In the U.S., we can judge the speed of acid rain solution because the early twentieth century gravestones are worn as much as the Revolutionary War stones. The process of dissolving the markers has been going on for slightly more than a century because we have had acid rain only since the Industrial Revolution.

Physical processes can also break rocks. Who does not know about hitting a log with an ax and splitting it? The wedge shape of the axe head forces the log apart and makes little sticks out of big logs. Hit a rock with a hammer and you can break it. Drill a hole in rock, filling it with dynamite and blast it to smithereens. Even today, granite is cut by drilling holes and driving steel wedges into the holes until the rock splits. Have you ever had a bottle or a can filled with water or soda freeze? (If not, put a can of Coke or Pepsi in the freezer right now and see what happens!) If you drill a hole in a rock and fill it with water and the temperature goes below freezing (which happens even in the desert southwest), what will happen? The rock will split! What causes a pothole in a road? You get a warm day in the winter, the snow melts, water soaks into cracks in the road, at night, the temperature goes below freezing and cracks the pavement. The next warm day the

ice melts and the passing cars knock all the broken pavement out of the hole. The same thing happens with rocks. Rain or thaw provides water, it soaks into cracks in the rock, freezes and splits the rock.

When the Egyptians built the pyramids they did not have dynamite or even iron. The limestone blocks used in the construction were cut by drilling holes in the rock, filling the hole with wooden pegs, and then soaking them with water. The wood expanded and split the rock. In nature there is a similar process, but instead of using pegs and soaking them, trees grow on the land, the roots go down into cracks in the rocks and expand as they grow. A slow, but very effective way to split the rock.

Rock can be broken down just be heating and cooling. You may have seen fireplaces, especially in campsites, that are broken because a fire has been lit in them and then the fire has been put out by dousing it with water. Or you may have poured hot water into a glass and had it shatter. Ever put the wrong type of a dish in the microwave? When something is heated it expands. If it expands or contracts too much or too rapidly, it will shatter. If the surface of a rock is heated the outside will expand outward more than the colder inside. After many cycles of heating and cooling, the outside will eventually pull away from the inside and break off. A rock on the surface of the earth would be heated by the sun and cooled by the lack of sun. Try putting your hand on a sunlit black rock, even in winter it will be warm to your touch. Air temperature range is known to get as high as 100^{o}F in the day and as low as 0^{o}F in the desert. That much change in temperature over a series of days is enough to cause the rock to break down into its individual minerals. These temperature ranges occur in the dessert. Commonly, you will see a heap of minerals grains at the base of a rock or a pile of broken rocks at the bottom of a cliff in the dessert.

Material

Vinegar
$CaCO_3$ - limestone, marble, chalk, calcium supplement, or a calcium antacid such as Rolaids or Tums.
Ice cubes
Jars
Water

Student Exercise

This exercise includes two worksheets, one for chemical and one for physical weathering.

The chemical weathering exercise is the most fun, but requires supervision because you are using a very mild acid, vinegar (acetic acid). You probably should check with your principal to see if there are any rules regulating the use of acid in the classroom. The acid will not do any harm, vinegar is the basic ingredient in Italian salad dressing. Explain to the students that they are using the mineral calcite (Calcium Carbonate, $CaCO_3$) found in limestone and marble. Explain, also, that the acid they are using is no more acidic than acid rain. To make things easy for you, we suggest using a calcium antacid in this exercise, it works beautifully. Not all antacids are calcium carbonate, so check the label. If you put a pebble containing the mineral calcite (or an antacid tablet) in even a very mild acid, it will react with the acid releasing CO_2 and fizzing. Powder the Calcium Carbonate by grinding it or smashing it with a hammer (it does not have to be finely ground, just pulverized). When you put this into the vinegar it will react instantaneously and violently. So that you know what will happen, try it yourself first. We advise you to give the calcium carbonate to the students yourself and not let them help themselves. They will have so much fun that the exercise will soon get out of hand. After you have put enough Calcium Carbonate in the vinegar, it will neutralize the acid and no more reaction (weathering) will take place. This is the reason an antacid works. Just

pour in more vinegar. Do you realize that the only cure for a lake that has been made too acid by acid rain is to spread lime on it (the lime is ground up limestone, calcium carbonate)?

The second worksheet is Physical Weathering. The first question says to put an ice cube in hot water. Run the hot water tap until it is the hottest, then fill your jar 3/4 full and gently and carefully drop an ice cube in it. You do not want it to make any noise hitting the sides of the jar when you drop it in. Right off it will make a crackling sound and you may be able to see cracks in the cube. The crackling is caused by the rapid change in size of the outside of the ice cube caused by the addition of heat. [In this case, since an ice cube expands on cooling, it contracts on heating. This contraction causes the cracking. Most material expands on heating and that causes the cracking.] To demonstrate expansion with freezing of water, you might want to put a can of soda in a freezer and then bring it into class and ask the students why it is puffed out. Convincing the students that a root can crack a rock is going to be harder. Try asking them what happens to their tummies if they eat too much and it grows. Does it push against their belt or pop some buttons? What would have happened if they were still wearing the same shirts they wore two grades ago? (The comments you get on this analogy may stop all progress on this subject.) Another way to crack a rock is to have another one fall on it. Can you think of more ways? We even wear the rock away by walking on it. Maybe you are lucky enough to have an old school with warn steps.

WORKSHEET - CHEMICAL WEATHERING

1. Put a bit of powdered limestone (calcite) in a jar and add some dilute acid to the jar. What happens?

2. Put a small pebble of limestone in another jar and cover it with dilute acid. What happens?

3. Put a piece of quartz in another jar and cover it with dilute acid. What happens?

4. After an hour, what has happened to the limestone?

   Jar with limestone powder

   Jar with limestone pebble

   Jar with a piece of quartz

You are using weak acid. When the substance disappears into the acid, or salt disappears into water, it dissolves. Rainwater (acid rain) and much of the water you find in the ground is also a very weak acid.

5. What do you think happens when water from acid rain runs over limestone?

6. If the limestone is broken into very small pieces, will it take a longer or shorter time to dissolve than it would if it was a solid mountain?

7. Will a mountain of limestone dissolve?

8. If a rock is made up of quartz sand cemented together by calcite, what would be left if the rock were in acid rain for a long time?

9. What would happen if a stream ran over this rock for many, many years?

ANSWER SHEET - CHEMICAL WEATHERING

1. Put a bit of powdered limestone (calcite) in a jar and add some dilute acid to the jar. What happens?

   The calcite reacts bubbling and frothing and dissolves very quickly.

2. Put a small pebble of limestone in another jar and cover it with dilute acid. What happens?

   The calcite reacts slowly giving off a few bubbles.

3. Put a piece of quartz in another jar and cover it with dilute acid. What happens?

   Nothing happens. The quartz does not react at all.

4. After an hour, what has happened to the limestone?

   Jar with limestone powder **All the calcite disappeared.**

   Jar with limestone pebble **Some of the calcite may still be there.**

   Jar with a piece of quartz **Nothing. The quartz is all still there.**

You are using weak acid. When the substance disappears into the acid, or salt disappears into water, it dissolves. Rainwater (acid rain) and much of the water you find in the ground is also a very weak acid.

5. What do you think happens when water from acid rain runs over limestone?

   It dissolves it just the same way it dissolves the calcite because a limestone is made of calcite.

6. If the limestone is broken into very small pieces, will it take a longer or shorter time to dissolve than it would if it was a solid mountain?

   The smaller the particles of limestone the quicker they will react with the acid rain.

7. Will a mountain of limestone dissolve?

   Yes, but very slowly because it is a very large particle of limestone.

8. If a rock is made up of quartz sand cemented together by calcite, what would be left if the rock were in acid rain for a long time?

   The calcite cement will be dissolved away leaving the quartz grains as loose sand particles.

9. What would happen if a stream ran over this rock for many, many years?

   The stream would erode (wear) away the loose sand carrying it down stream, wearing the mountain away.

WORKSHEET - PHYSICAL WEATHERING

1. What happens when you take an ice cube from the freezer and put it into hot water?

2. What do you think would happen if solid rock were suddenly heated?

3. What might heat a rock on the surface of the earth?

4. When you freeze water, does the ice (crystalline water) take up more room or less room than the water (does it expand)?

5. If water gets into a crack in the rock and freezes, do you think the crack will get bigger or smaller?

6. Why will it get bigger or smaller?

7. What will happen to the rock?

8. What else might get into a crack in a rock and eventually make the crack bigger? [Clue - consider something living!]

9. Can you think of another way a rock might get cracked?

10. Will weathering be faster if both physical and chemical weathering are going on together? Why?

11. Would you expect weathering to be faster in New York or in Arizona? Why?

ANSWER SHEET - PHYSICAL WEATHERING

1. What happens when you take an ice cube from the freezer and put it into hot water?

   If you listen very carefully you will hear it snapping and crackling. If you look at it right after it crackles you can usually see cracks in it.

2. What do you think would happen if solid rock were suddenly heated?

   The same thing. It would crack.

3. What might heat a rock on the surface of the earth?

   The sun, forest fire, see if you can think of more ways.

4. When you freeze water, does the ice (crystalline water) take up more room or less room than the water (does it expand)?

   More, ice expands when it freezes. Most material expands when you heat it.

5. If water gets into a crack in the rock and freezes, do you think the crack will get bigger or smaller?

   Bigger.

6. Why will it get bigger or smaller?

   Ice expands when it freezes.

7. What will happen to the rock?

   The rock will be split apart.

8. What else might get into a crack in a rock and eventually make the crack bigger? [Clue - consider something living!]

   Tree roots.

9. Can you think of another way a rock might get cracked?

   Heating and cooling by the sun. Other rocks falling on it from above. People or animals walking on it. Cars driving on it. Can you think of more?

10. Will weathering be faster if both physical and chemical weathering are going on together? Why?

    Yes, because two processes will be working and two are faster than one. Each of these will make space for the other to work. Water is needed for chemical weathering and if you have water in a cold region it will freeze and thaw.

11. Would you expect weathering to be faster in New York or in Arizona? Why?

    In New York because you have lots of water and good freezing and thawing in the winter.