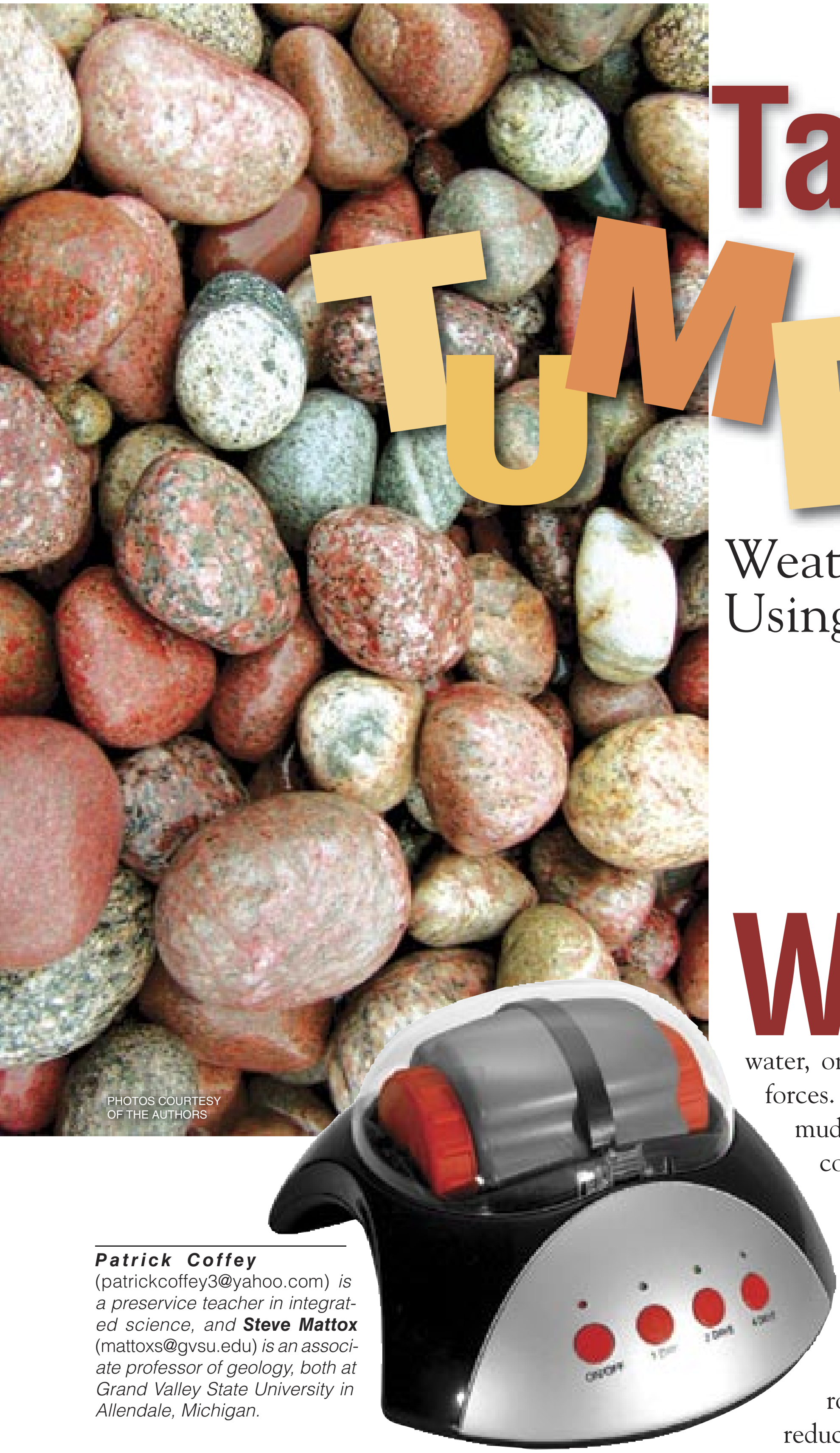
Take a TUMBLE

Weathering and Erosion Using a Rock Tumbler

by Patrick Coffey and Steve Mattox



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Weathering—the physical and chemical breakdown of geologic materials—and *erosion*—the transport of materials by wind, water, or ice—can be subtle, yet powerful forces. For example, shale, a rock made of mud-sized particles, is by far the most common sedimentary rock, a testament to the ability of weathering and erosion to take a rock and reduce it to particles too small for us to see with our naked eye. Also, mountain ranges, such as the Appalachians that once rose as high as the Himalayas, are reduced in only a few hundred million years to subdued topographic features.

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Weathering and erosion operate on a scale of crystals and grains over tens of millions of years, and over distances of thousands of kilometers. These subtle effects are difficult to convey to students. However, through this activity, students can use a rock tumbler to gain a personal and scientific perspective on weathering and erosion. Students have the opportunity to demonstrate their understanding of these concepts and work with geologic materials as they make predictions and measurements, record data, and do simple calculations (McKnight 1989).

Before the activity

Little background knowledge is needed for the activity. Ideally, the students will have some familiarity with types of rocks. This will assist them in estimating resistance to weathering and erosion. Some knowledge of weathering and erosion, especially distinguishing between these two processes, would be useful but can be done after engaging the students' interest. This lesson fits well prior to a complete description of sedimentary rocks (Where does sediment come from?) or to wrap up a unit on rocks.

Setup for the experiment is minimal and consists mainly of obtaining the tumbler and rock samples. Begin by selecting five different types of rocks, basing your choice on their physical characteristics, type, and availability. We selected granite, sandstone, limestone, gabbro, and slate, all of which were readily available from local countertop and landscape suppliers. Before class, break the samples into roughly disk-shaped pieces about 7.5 cm in diameter and 2.5 cm in width using a rock hammer (it's a good idea to do this outside). We have found that most rock suppliers generously provide small amounts of scrap rock for free. Only a few different rocks are needed for each class. An alternative experiment would be to tumble rocks collected locally.

The rock tumbler we used was donated to the geology department and was handmade. It runs on a 0.5 horsepower motor that turns a flywheel. A belt connects the flywheel to bracket that holds two 25 cm diameter drums. The soft rubber interior of the drum is six-sided, 15 cm across, and 25 cm deep. Tumblers with one or two barrels are available from lapidary suppliers on the internet for approximately $100–200 (search on "rock tumbler"). Ideally each class will run its own experiment. If needed, stagger the experiments throughout the term or have each class make their own measurements during a single experiment (the time needed to measure is small compared to tumbling the samples 24 hours per day). We kept the tumbler in our prep room to reduce noise.

Method

The experiment is best done as a class lesson. All students can be involved. Different groups of students can measure the mass of the rocks each day, allowing each student to contribute to the data set. Opening the tumbler takes only a few minutes. Each student might need one or two minutes to identify and determine the mass of the rock and record the data. Depending on the hardness of the rocks selected, at least four or five days of data must be collected for clear trends to emerge and for students to test their hy-

FIGURE 1 **Visible erosion**

Changes in rock samples after two (top) and three (bottom) days of erosion by abrasion in a rock tumbler. Samples are sandstone (top right), limestone (bottom right), granite (bottom left), gabbro (top left), and slate (center).

Tumbler erosion activity

Objective
To model the weathering and erosion of rocks by abrasion.
Materials
- five different rock samples, each approximately 7.5 cm in diameter by 2.5 cm in width
- rock tumbler
- sand
- water
- balance

Procedure
Before the experiment
1. Describe and identify the rock samples in your science notebook.
2. Write one-sentence definitions of *weathering* and *erosion*.
3. Create an experiment, using a rock tumbler, to quantify (evaluate with numbers) the rate at which different rocks weather and erode.
4. Predict which rock will be most resistant? Least resistant? Place all five rocks in order from most resistant to least resistant.
5. Justify your predictions based on what you know about each rock.
6. Determine the mass of each rock sample and record the data in the table below.

Mass (g) loss of rock samples over time:

	Gabbro	Slate	Granite	Limestone	Sandstone
Original mass					
Day 1					
Day 2					
Day 3					
Day 4					
Day 5					
Day 6					
Day 7					
Day 8					
Day 9					
Day 10					

During the experiment
7. After the first 24 hours of tumbling, decide if the rocks are weathering and eroding in the order you predicted. If you wish, based on the new data, modify your predictions.
8. Place the samples back in the tumbler. Run the tumbler for 24 hours. Rinse the mud from the rocks. Determine the mass of the samples again. Repeat for several 24-hour periods until clear patterns emerge or specimens are abraded to mud.

After the experiment
9. Once you have completed all rounds of tumbling, graph your mass results. Place all five rocks in order from most resistant to least resistant. Does the order match your original prediction? Why or why not? Consider and comment on how the rock's origin might influence its hardness.
10. After discussing the results of the experiment as a class, estimate how far the rocks travel in one day. Show your work.
11. How far would the rocks travel in 10 days? Compare this distance to the length of some well-known rivers in the United States.
12. Do you think the water in most rivers travels at a high enough speed to move rocks of the initial weight? Explain your answer.
13. Have you seen cobble-sized rocks, similar to the rocks in the experiment, in a natural setting? If yes, describe the physical setting and geologic forces present.

potheses. Since data collection and discussion might take 10–15 minutes per class, this lesson might be one component of a larger investigation of weathering and erosion.

On the first day of the activity, have students describe and identify the rock samples in their science notebooks as well as write one-sentence definitions of weathering and erosion (see Tumbler erosion activity). Students are provided an opportunity to design an experiment with the tumbler. Students should also answer the prediction questions from the activity sheet. Justifying their predictions provides insights into their understanding of rocks, weathering, and erosion. Other experiments might be equally valid, but here we guide you to an easy and significant example.

For simplicity, we decided that mass would be the most useful and easiest parameter to measure. Students determine the mass of each rock and record the initial mass in a data table. Once measured, we load the tumbler with the samples, roughly 250–500 mL of beach or river sand (to serve as an abrasive), and enough water to cover all the materials. Overall, the hardness of the rocks is going to dictate the results. The type of rock tumbler will have little effect. We ran the tumbler for periods of 24 hours. At the end of each run students remove, rinse, dry, and mass the rocks (see Figure 2). The data are recorded on the activity sheet. Have a different set of students measure and record the data each day and, as a group, discuss the trends in the data each day and allow students to modify their hypotheses.

Results

Within a few days, clear trends in the data emerge. Students continue to determine the mass of the rocks and record the data after every

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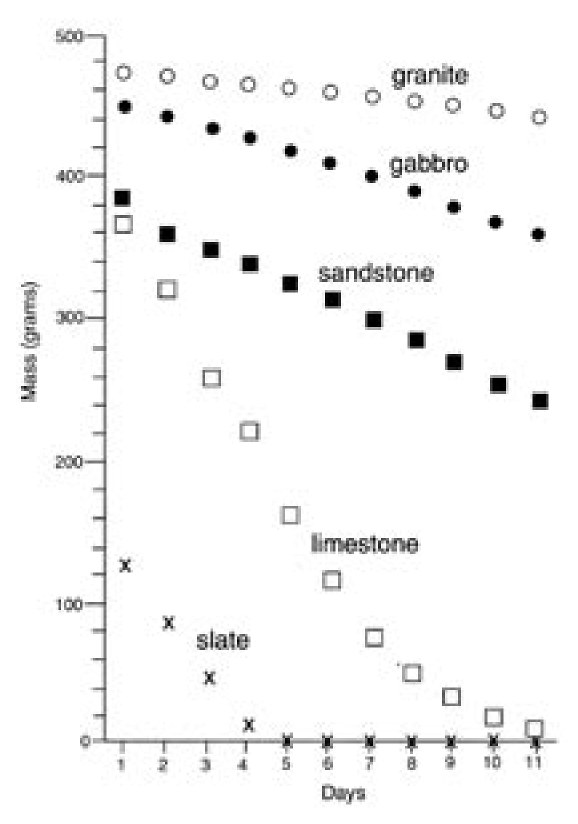
round. Depending on the rocks you select, the experiment should run for 5 to 10 days to allow the results to be apparent and dramatic. Students can graph their data each day or at the conclusion of the experiment. Our results showed that the weight of the granite disk changed little, reflecting its high resistance to weathering by abrasion. In order of decreasing resistance to weathering, the other samples were gabbro, sandstone, limestone, and slate. Surprisingly, all of the slate was ground down to sand-size particles within four days. After 10 days the limestone was nearly gone.

FIGURE 2 **Graph of time versus mass for the five different rock samples**



Discussion

A class discussion emphasizes the key points to raise and stress with students. In this experiment, weathering and erosion are closely linked. The weathering is the physical abrasion of rocks hitting one another or the walls or grinding against the sand. The erosion, or transport, is the constant tumbling (rolling, falling) of the stones in the tumbler. The experiment highlights the physical characteristics of these rocks. The most resistant rocks, granite and gabbro, are intrusive igneous rocks. These rocks formed in a slowly cooling magma chamber. As the magma cooled, the crystals grew larger and formed an interlocking texture. Because the minerals are silicates, made with an anion of silicon and oxygen, they are hard (resistant to physical attack). The minerals in the granite are slightly harder than those in the gabbro, thus it is more resistant.

The next two rocks, sandstone and limestone, are sedimentary. Both were formed when particles or grains became cemented or glued together by another mineral. The sandstone is made of sand-sized grains made of quartz (silicon and oxygen) held together by a quartz cement, making it one of the harder, or more resistant, sedimentary rocks. In contrast, the limestone is made of particles (pieces) of ground-up fossils (made of the carbonate mineral calcite) in cement made of calcite. On the hardness scale calcite is three (quartz is seven).

The slate poses the greatest challenge. The minerals are too small to be seen by the naked eye, so students can't use their identification skills to solve the problem. The teacher might hint that the minerals are silicates of varying hardness. So why doesn't the slate resist weathering better than the sedimentary rocks? The texture of the rock is critical. Slate is a metamorphic rock that forms during mountain-building events as crustal rocks get squeezed. Slate is made of minute, new crystals that grow perpendicular to the direction of compression. The preferred direction of growth produces a texture in most metamorphic rocks called *foliation*. Foliation is Latin and refers to "leaves." The parallel layering within the rock is the foliation. Herein lies the weakness of the slate. As the rock tumbled it occasionally hit along the plane of foliation, essentially a weak zone running through the rock. Cracks developed that cleaved the rock into thinner and more numerous pieces. The internal weakness of the slate led to its rapid weathering.

Is the model realistic?

Where, if anywhere, do conditions like those in our experiment exist on Earth? Most of us have at least seen a photograph of a rock called *conglomerate*, a sedimentary rock made of *cobbles*, fist-sized pieces of pre-existing rock. If pressed, some of your students might remember seeing cobbles along a stream channel or on a beach. Cobbles can also be in, on, and under glaciers or along the steep slopes of eroded mountains. Geologists have related cobble layers in rock units to such extreme events as hurricanes and tsunamis.

How can our experiment approximate these environments? Each rock falls about 15 cm (the diameter of our tumbler) with each revolution. We can quickly estimate the distance each cobble travels per day:

$$15 \text{ cm} \times 20 \text{ revolutions} \times 60 \text{ minutes} \times 24 \text{ hours} = 432{,}000 \text{ cm}$$

This is equal to about 4,320 m or 4.3 km (2.7 miles) per day. Going back to the data collected, we can estimate how far a rock travels before it would be abraded to silt or mud-sized particles. For example, the slate survived about four days. Each day it traveled about 4 km. So, by the time it had been transported only 16 kilometers from its source, it had been worn down to mud-sized particles. Weathering and erosion would reduce the limestone cobble to fine particles after about 30 days of transport.

Experimental research has shown that water must flow at 5 m/s to move cobbles. Such high velocities are rare in most rivers but are approached by rivers in steep areas, such as mountains, or even slow moving rivers during a flood. Field measurements are another way to approach the problem (Hjulstrom 1939). Research has shown that cobbles 5 cm in diameter began moving at a velocity of 0.8 m/s (Harris et al. 1996). Cobbles move, on average, about 250 m per month, but 500 to 3,500 meters during single large storms (Takeshi 1998). In a study of a delta in Baja California, a more modest transport rate of 1 meter per month for cobbles was found (Semmens 1997). Even at this low rate, given millenniums to work, abrasion can reduce cobbles to sand or smaller particles.

Perhaps rivers and beaches can only produce high water velocities during rare floods or big storms. This raises the important role of time with respect to weathering and erosion. Even if the velocity needed to transport/abrade the cobbles is reached only one day per decade, century, or millennium, the slate cobble would still be reduced in 40 years, 400 years, or 4,000 years, respectively. From the perspective of geologic time, if you blink your eyes you might miss it.

Assessment and extensions

Students should be able to convert their observations into useful interpretations of geologic landscapes. For example, provide students with a hypothetical cross-section of the geology of an area that contains the five rock types you have been investigating. Have them answer questions, such as, "How would the surface of the landscape appear after an extended period of weathering and erosion, say one million years?"

There are several possibilities for extending this lesson:

- Use local rocks and compare your results to your local landscape.
- Change the pH of the water (or another element of the experiment setup) in the tumbler to be more acidic (taking appropriate safety precautions). Predict changes in your results.
- Using the observed transport rate of cobbles, calculate how many days the granite, gabbro, and sandstone will need to travel before they are reduced to sand? What distance is this equal to? ■

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