

## Parent Prologue

I was kicking rocks on the playground. One of the rocks caught the light from the sun. It sparkled and shined. I started to wonder. Wondering is a very important life skill. It causes amazement or a sense of awe in us. It is the “Ah-Hah!” emotional moment that creates thoughts and ponderings that can lead us to be curious. Curiosity goes further than wonder, because it causes us to take an action, which is the creation of a question about something we observed.

I was in wonder of my rock, because of its simple beauty. But when I looked closer (which is an important action for a scientist) I noticed that not all parts of the rock sparkled. Why some and not others?

I needed to find an answer. This is my journey with Lola in learning to read the rocks.

### Lola and the Rocks

On my way back from school, I passed by Lola, who was busy with her husband in the garden. They were collecting fruit off of their cacti (but that is another story). Stopping by her fence, I asked her if she could help me learn more about the rock I had found at school that day. You see, it is important in science to collaborate. That is another skill set that scientists use. We share information all the time so that we can learn from each other about nature.

“Lola, I was walking around the playground, and I kicked this rock. It seems special to me because it sparkles. But it doesn’t sparkle everywhere. Can you please help me to understand why?”, I asked.

Lola was more than happy to help and beckoned me over to her garden table. While she examined my rock, she started to explain, “It gives me pleasure to see that you are noticing rocks! So many people, when they are outside, notice the flowers and insects and birds, but few of them pay any attention to such seemingly commonplace things as rocks.”

“Rocks tell the story of the Earth! Think of the Earth as an immense book, and each rock is a page in that book. The language of each rock must be learned, and when their narratives are combined we have Earth’s history,” she continued.

“I wonder what page my rock is in the story?”, I inquired.

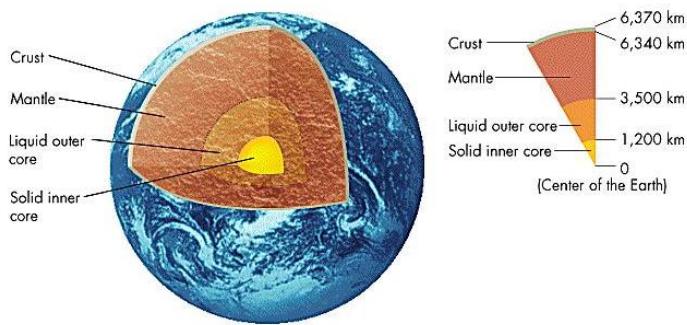
“Very good question. To answer it, we will need some tools. Let’s see, a magnifying glass, a copper penny, steel nail, vinegar and a medicine dropper are just the thing to use for our investigation,” she replied.

I was so excited as I helped her collect the materials we would need! I wondered how each of the implements would help us in figuring out the history of my rock.

“Before we talk about your rock, we need to categorize rocks in general. To categorize something is to place it into a group. Rocks can be grouped as sedimentary, metamorphic or igneous. We will also need to see how these categories fit into the Theory of Plate Tectonics”, she explained.

"Plate Tectonics? I haven't heard of this idea at school", I said.

Lola went on to describe how a tectonic plate is a massive slab of solid rock that moves very slowly over Earth's mantle. The Earth is composed of three layers: the crust, mantle and the core. If you think about the parts of an avocado (skin, the part we eat, the pit in the middle) it gives you an idea about the structure of the earth. The avocado serves as a model of the earth so that we can "see" how the earth is put together. Scientists use models to understand many things that are too big, too small, too fast, too slow to be observed easily. The skin of the avocado represents the crust of the Earth and the tectonic plates in earth's crust would be like having pieces of the avocado skin that could move around. The word tectonics comes from the Greek root 'to build.' Putting these two words together, we get the term plate tectonics, which refers to how the Earth's surface is built of plates.



The theory of plate tectonics states that the Earth's crust is fragmented into a dozen or more large and small plates that are moving relative to one another as they ride on top of the hotter material in the mantle called magma. The places where plates meet are called boundaries. The plates can be moving toward each other (at convergent plate boundaries), away from each other (at divergent plate boundaries), or past each other (at transform faults). The Earth's plates move around like a conveyor belt or escalator. In some places new crust is being formed and in other places old crust is being destroyed. It gets recycled in the mantle.

Lola took a Fig Newton Cookie from her lunch bag. As she pushed the ends of the cookie towards its middle, she told me that compression of plate against plate gives birth to new landscapes. "Notice how cracks formed and how the cookie buckled and bulged. This is a model of a convergent boundary. The cookie made 'mountains' at the bulge and made the cracks (called faults) where it buckled. This is an example of when two continental plates crash into each other forming mountains like Mount Everest.", she explained.

Lola told me that as the mountains are lifted higher and higher, they are exposed to wind, water, and ice. This causes them to breakdown into smaller pieces, or grains, producing soil. The grains (soil) are moved by wind and water - eventually deposited as sediments. The sediments are deposited in layers and become compacted and cemented forming sedimentary rocks. Sedimentary rocks form only on the surface of the Earth.

Removing a second Fig Newton cookie, Lola pushed one-half of the cookie under the other half. "Notice how one half bends under the other half of the cookie. This is another type of convergent zone called subduction. This happens because Earth's crust is made of two types of crust : heavy oceanic crust and lighter continental crust. When continental and oceanic plates collide, the oceanic crust melts as it is pushed under the continental crust into the mantle. This is called subduction. Volcanoes are usually present along subduction zones. They allow the heat and energy created by the grinding plates to escape to the surface of the Earth. When the melted rock reaches the surface it cools to form igneous rocks ", she elaborated.

Pulling out a third Fig Newton Cookie, Lola slowly pulled the ends of the cookie. I noticed that the nougat in the middle of the cookie started to thin and large cracks formed in the cookie crust. Lola said, "This is a model of a divergent boundary. At divergent boundaries or zones, hot magma rises to the surface, pushing the plates apart. Divergent boundaries also form volcanic islands, such as Iceland. The magma flows out into the ocean floor, also forming igneous rocks", she said.

"Lola then carefully broke a fourth cookie in half. She laterally slid each cookie piece past one another. "This is a model of a transform fault", she continued.

The plate movements are how rocks are recycled. However, the elements that make up rocks in the crust are never created or destroyed although they can be redistributed, transforming one rock type to another. This process is called the Rock Cycle.

As I carefully put my rock on her garden table, she asked me to describe what I saw using the magnifying glass. I commented that there were things in the rock that looked like glitter. The rock was colored with shades of gray and black.

"Well, the sparkle is coming from a mineral called mica. They sparkle because light is reflected on their flat surfaces. These surfaces are made where the mica breaks or is cleaved along very closely spaced flat surfaces that yield thin sheets. Minerals cleavage is the type of break that occurs along a lines of weakness in their structure", Lola explained. Lola took an Oreo cookie from her lunch bag. She asked, "What is the easiest way to 'break' the cookie?" "By twisting the top cookie off", I replied.

"Exactly, because that is the area that is weakest in the cookie. This is where the cookies 'cleaves'", she replied.

Lola then took from her bag a chocolate chip cookie, and asked where it was weakest.

"Well, the cookie doesn't break at all like the Oreo. It breaks into a lot of different pieces", I said.

"The chocolate cookie is fracturing. None of its pieces are the same. Fractures are breaks that occur when there is no weakness in the material at all. When a mineral is fractured, there are no two pieces that are the same, that is, there are going to be different angles and sizes. Minerals can be identified by the way that they break: cleavage or fractures", she said.

"What is a mineral, Lola?" I asked.

"Think of a rock as a chocolate chip cookie. The chips, flour, sugar and other ingredients are 'minerals' of the cookie", she replied. Minerals are the raw ingredients that combine within a rock.

"The mica is so pretty and small!", I said.

"Yes, it is. The mica is actually a crystal. Do you see how the crystals are overlapping? This give us a clue as to how this rock was formed. The rock had to be created in a place where the mineral crystals had time to grow slowly. This rock hadn't always been a solid. A long, long time ago, this rock was a liquid called magma. Magma comes from inside the Earth", she explained.

"Oh! You mean the rock was made from a volcano!", I exclaimed.

"The crystals tell the story. The rock didn't come from a volcano, because the rock would have cooled too quickly when it was blasted out of the volcano. This rock came from magma that cooled underground. Half-Dome in Yosemite was formed this way (about 65 million years ago) when molten, igneous rock solidified into granite deep within the Earth and was pushed up under pressure to the surface. The granite was shaped into domes as the uplifted, curved layers of rock cleaved off", she explained.

"Imagine slowly squeezing toothpaste out of its tube. It will form a dome like structure at the top. This is how Half-Dome formed", she continued.

"Like we discussed earlier, Rocks that come from magma are called igneous rocks. The word igneous means "fire". The rate of plate movements is directly related to the rate of igneous rock production. The most common igneous rock type is basalt and it makes up the bulk of oceanic plates. Basalt is formed at divergent plate boundaries." she continued.

Lola asked, "What else can you tell me about the rock?"

"It's very hard", I said.

"True, but we need a way to compare the hardness of this rock to other rocks. Scientists understand nature better through comparisons. For example, you might be tall compared to a toddler, but compared to my husband you are short. Let's walk to the garden and see if we can find some samples to test," she said.

Lola pointed to several large rocks that I had not noticed before. I had always been drawn to the animals and the plants. I was amazed at the variations in textures, colors, shading and shapes of her garden rocks. Black basalts and light colored rhyolites; feathery marbles and seashell hash limestones; angular pebbles cemented into breccia and reddish – tan layered sandstones added a surreal dimension to her landscape.

"Looking at these rocks gives one a feeling of deep time. The basalts, granites and rhyolites describe a time of fire; marbles and seashell hash limestones reveal a time of pressure and consolidation; and breccia and sandstone describe the erosion of mountains and the once thriving communities of life in past oceans", she whispered.

"To appreciate the form and structure of a rock is similar to an appreciation of music. Symphonies cannot exist without time. What would be noise is transformed by chords, notes and measures, which unfold in movements and motifs. Geology, the study of rocks, is only to be understood in the context of time as well".

"Does the hardness of rock give us a clue?", I asked curiously.

"Oh, yes dear! Because to make a rock like the one you found in the schoolyard, you need time to slowly cool the minerals in the magma", she explained. "Rocks like marble take even more time, because they have to encounter and be sustained under tremendous pressure and heat in order for the water in the rock to be squeezed out and the crystals to be rearranged", Lola elaborated. "The squeezing changes the rock. It is a process called metamorphosis. The rock you found is called granite. Granite can be metamorphosed into a rock called gneiss (pronounced "nice"). The pressure causes the minerals to line up, giving gneiss a banded appearance. Let's go see the gneiss!", she exclaimed.

Sitting under a prickly pear cactus was an extraordinary sample, indeed. It was striped with flowing rivers of color. Lola said this pattern is called foliation, which is caused by extreme compression.

"The random orientation of the minerals you see in your granite rock is a poor use of space. Think of wooden blocks scattered on your bedroom floor. Those blocks take up less space if you stack them the same way. This idea applies to minerals in the rocks, too. Granite is like rocky road ice cream - marshmallow and chopped almonds all mixed in the frozen cream. Gneiss is like ribbon candy – folded and swirled while hot, and then left to harden", she explained.

"Let's test our rocks. Try scratching both rocks with your finger, then with the copper penny and then lastly the nail", she said.

As asked, I tried scratching both rocks with my finger and copper penny. Neither one was marked. When I tried the nail it left a scrape on both rocks. Lola said this meant the rocks had a hardness of around 7. The scale of hardness is called the Mohs Hardness Scale. The hardness of the rock is measured against a scale by finding the softest material needed to scratch the rock. The scale is really measuring the resistance of the minerals in the rocks to scratching. The scale rates minerals and rocks from a scale of 1 to 10, with 1 being the softest material and 10 being the hardest material. A mineral can only be scratched by a harder substance. A hard mineral can scratch a softer mineral, but a soft mineral cannot scratch a harder mineral (no matter how hard you try). Pencil "lead" is softer than paper, so it writes. A toothpick is harder than paper so it tears the paper.

"Let's try the limestone next", she said encouragingly.

I dutifully scratched the limestone with my fingernail. It left a mark!

"Limestone formed from the condensed layers of ocean-dwelling creatures such as oysters, clams, mussels, coral and algae called foraminifera. You were able to scratch it with your fingernail, so it rates a 1 on the Mohs Hardness Scale. Did you know that the chalkboard chalk you use in your school is made from limestone, and that it was formed in ancient oceans millions and millions of years ago?", Lola asked.

"Wow! That's amazing! What makes the limestone so soft?, I wondered.

"Good question. It is connected to how the limestone was created. Limestone is a sedimentary rock, which means it was formed from small particles of rock (called sediments) and, in the case of limestone, shells that have been compacted by pressure. The sediments are formed when rocks are weathered by water, ice, wind and chemicals. This process is called erosion. All of the creatures encased in the limestone used calcium carbonate to create their shells. When they died, their shells are broken down by waves and settle on the ocean floor where they are compacted over time." she explained.

"Let's do a chemical test that will show us the presence of calcium carbonate", she said.

Lola instructed me to put a few drops of vinegar on the limestone. Instantly it began to bubble and fizz! Lola told me that the vinegar reacts with something called carbonate ions. As it reacts, it dissolves the limestone releasing a gas called carbon dioxide. It was this gas that made the bubbles. When the bubbling stopped she asked me to look at the limestone with the magnifying glass. I could see a powdery sediment, which she said were small particles of calcium acetate. Calcium acetate is a chemical made when the acid and carbonate react.

"Did you know that most caves are formed by this reaction? Water erodes the limestone bedrock over thousands to millions of years to form the caverns!", commented Lola.

"It is really exciting to think about this rock now. I am actually looking at an ancient ocean bed!", I exclaimed.

"Is the layering the reason it is soft?" I asked.

"Yes. You see, the layers are compressed, but there are still large gaps between the sediments. With metamorphic and igneous rocks, the pressing force is so intense, those gaps are filled", explained Lola.

"But, it is not always the case that sedimentary rocks are soft. The reason is the minerals. You see, the Mohs Hardness Test is best used with pure minerals. Rocks, as we discussed earlier, are a combination of two or more different minerals. This is called a mixture in chemistry. Each of those minerals has its own unique quality of hardness, which informs the rock. In the case of sedimentary rocks, as they break down in a process called erosion, the harder minerals tend to be able to travel longer distances down a river system", she said.

Lola picked up a white, glassy rock. She asked me to scratch it with the tools, and she rated it at 7, since no materials could scratch it until she tried the steel nail.

"Lola, this is a lovely rock!", I said.

"Yes, but it is also a pure mineral called quartz. Quartz is the most abundant and widely distributed mineral on Earth! Quartz can often undergo several cycles of erosion, movement by wind and water, and layering. Mineral hardness can also be seen to affect the layout of many landscapes. Quartz bearing rocks are more stubborn and resistant to weathering, and therefore will result in the stones (called capstones) that protect the tops of buttes and mesas from breaking down if they happen to be on top after plate tectonic forces have arranged things", elaborated Lola.

Lola asked, "Have you ever seen the Niagara Falls?"

"I've seen pictures of them in our books at school", I said.

"The cliffs that form the Falls are capped by hard, resistant sedimentary rocks containing quartz. The rocks under the cliffs are less resistant limestones and shales that don't contain any quartz", she explained. "So, you can clearly see, the minerals in the rock, not just that they are layered, affect the softness or hardness of a rock." Where the river flows below, the ancient waters washed away the limestone and shale, but the rims of the falls are protected by the sedimentary rocks that contain quartz.

"Can the limestone minerals be pressed closer together like the granite minerals?", I inquired.

"What a wonderful question. Yes, they can, and when this happens the rock called marble is created", Lola answered.

We wandered over to the large marble rock. Sticky monkey bush was bursting with bright orange flowers that were highlighted by the feathery orange of the marble. Lola explained that the orange color of the marble came from the second most common mineral on Earth, calcite. She said calcite is made from the same chemicals as limestone, calcium carbonate, and has a Mohs rating of 3. Marble is a metamorphic rock. The rate of plate motions is directly related to the rate of metamorphic rock production. Metamorphic rocks formed at areas of compression are formed at convergent plate boundaries. If one could increase the rate of plate tectonic movements, one would also increase the rate by which metamorphic rocks form. Metamorphic rocks are the oldest rocks on Earth.

Marble forms when limestone is subjected to intense heat and pressure. Under these conditions, the calcite in the limestone recrystallizes to form a new rock with interlocking calcite crystals. This changes the texture of the rock. In the early stages of its transformation, the calcite crystals are tiny. As the process progresses, the crystals continue to grow, obscuring the limestone's original fossils and sedimentary structures. The orange color of the marble comes from impurities such as iron oxide and feldspar, which create an orange-pink hue. Marbles can come in all the colors of the rainbow, which get their shades from different combinations of mineral deposited in the rocks.

I noticed that hummingbirds were buzzing around the orange monkey flowers. She said that geology can inform biology. When she learned that hummingbirds are attracted to shades of orange, she decided to place her treasured marble next to one of the bird's favorite nectar sources.

I asked Lola, "Is there a similar reason why you planted that spiky plant next to the limestone?", I wondered.

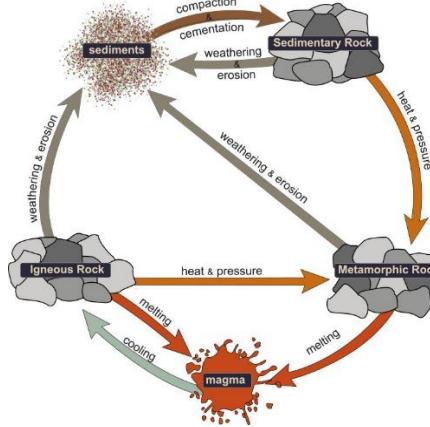
"That was a great inference! The spiky plant is called Mountain Agave, and it favors limestone soils. As the rock dissolves from sprinkler water or rain, it feeds the plant!", she replied.

Lola asked me to sit on a bench next to the limestone. She said, "I have learned a lot from collecting rocks. When I hunted for the best rocks to display in my garden, I noticed how each one differed from another. Color, layers, shapes, textures, patterns – there was something uniquely special about each one".

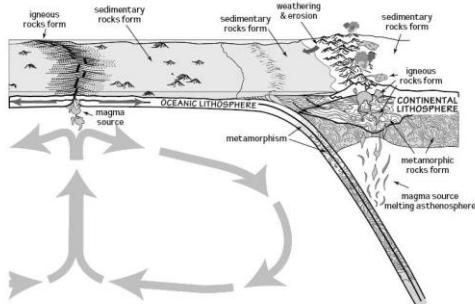
Just like rocks, each one of us is unique and special. Since that day with Lola, it has been embedded in me, how we all are conscious of this idea – that we are all unique beings, and yet we still measure ourselves against others. Success, happiness, beauty are, unfortunately, the drivers of our life. This can distract us from paying attention to specialness of others and ourselves.

When I was observing rocks, I wondered how they came into existence. Just like rocks, we are weathered, compressed and ignited by the circumstances and stresses which surround us. These conditions can push us out of our comfort zones, and metamorphize us.

Many might think the playground rock I found was merely an ordinary piece of granite. For me, I learned there is nothing ordinary in nature if one is ready to learn the story behind it.



### The Rock Cycle



Niagara Falls, NY

### Mohs Hardness Scale

#### Materials:

- Rocks, 3-5
- Penny
- Nail
- Cardboard (to protect table top)
- Mohs Hardness Scale, next last page of lesson

### Procedures:

- Explain:** Hardness is one measure of the strength of the structure of the mineral relative to the strength of its chemical bonds. It is not the same as brittleness, which is another measure of strength that is purely related to the structure of the mineral. Minerals with small atoms, packed tightly together with strong covalent bonds throughout tend to be the hardest minerals. The softest minerals have metallic bonds or even weaker van der Waals bonds as important components of their structure. Hardness is generally consistent because the chemistry of minerals is generally consistent.
- Tell:** Hardness can be tested through scratching. A scratch on a mineral is actually a groove produced by microfractures on the surface of the mineral. It requires either the breaking of bonds or the displacement of atoms (as in the metallic bonded minerals). A mineral can only be scratched by a harder substance. A hard mineral can scratch a softer mineral, but a soft mineral cannot scratch a harder mineral (no matter how hard you try). Pencil "lead" is softer than paper, so it writes. Try writing with a steel-tipped pencil and you'll see what I mean: now the pencil rips the paper. This is clearly related to the relative hardness of each substance. Hardness in minerals can vary due to impurities. We determine the relative hardness of minerals using a scale devised by mineralogist Friedrich Mohs. The scale assigns hardness to ten common index minerals, and is based upon the ability of one mineral to scratch another. The Mohs Hardness Scale starting with talc at 1 and ending with diamond at 10, is universally used around the world as a way of distinguishing minerals. Simply put; the higher the number, the harder the mineral.

## Mohs Hardness Scale

Name	Scale Number	Common Object
 Diamond	10	
 Corundum	9	
 Topaz	8	 ← Masonry Drill Bit / 8.5
 Quartz	7	 ← Steel Nail / 6.5
 Orthoclase	6	 ← Knife / 5.5
 Apatite	5	
 Fluorite	4	 ← Penny (Copper) / 3.5
 Calcite	3	
 Gypsum	2	 ← Fingernail / 2.5
 Talc	1	

- Tell:** We can first test our rocks by placing a sharp point of one rock specimen on an unmarked surface of another specimen.
  - With one hand, hold Rock #2 firmly against a table top so that the surface to be tested is exposed and accessible. The table top supports the specimen and helps you hold it motionless for the test. (If you are doing this test at a nice desk you may want to get a thick piece of cardboard, a thick rubber pad, or a sheet of some other material to protect the surface from being scratched.)

- Hold Rock #1 in the other hand and place a point of that specimen against the selected flat surface of Rock #2.
- Firmly press the point of Rock #1 against Rock #2, and with firm pressure, drag the point of Rock #1 across the surface of Rock #2.
- Examine the surface of Rock #2. With a finger, brush away any mineral fragments or powder that was produced. Did the test produce a scratch? Be careful not to confuse mineral powder or residue with a scratch. A scratch will be a distinct groove cut in the mineral surface, not a mark on the surface that wipes away. Use a magnifying glass to get a good look at what happened. The reference rock could be the softer and be scratched or disintegrate, leaving powder.
- Conduct the test a second time to confirm your results.
- Continue the test above with Rock #3. Use the harder of the two Rocks (#1 or #2) to test Rock #3. If Rock #3 is harder than the rock it was tested against, then it is now the hardest of the 3. If it is softer, then you will need to test against the other rock to see if Rock #3 is the softest of the three or is in the middle. In this way, with possibly many tests, you will be able to order your rocks by hardness.



4. **Engage:** As we learned from Lola, there are several simple "tools" people often have with them that can be useful in determining the relative hardness of an unknown mineral specimen. For example:

- Your fingernail has a hardness of 2.5. If you can scratch the surface of an unknown specimen with it, you will immediately know that its hardness is less than 2.5. In other words, it is slightly harder than gypsum ( $H=2$ ) but softer than calcite ( $H=3$ ).
- A penny has a hardness of 3.0 - slightly harder than your fingernail. So, if you can't scratch the specimen with your fingernail ( $H=2.5$ ), but a penny does the job, you immediately know that it is at least not quite as hard as calcite ( $H=3$ ).
- A steel nail usually has a hardness of about 6.0. If a penny does not scratch your unknown specimen but the steel nail does, then you can correctly conclude that it is harder than calcite ( $H=3$ ) but softer than orthoclase ( $H=6$ ).

5. Ask your child to find the softest and the hardest of all the rocks. Select one rock at a time.

### **Calcium Carbonate Test**

#### **Materials:**

- Chalk, 1 piece
- Water
- Cups (Tall enough for chalk)
- Vinegar or soy sauce
- Medicine Dropper or spoon
- Lemon juice (optional)

#### **Procedures:**

1. **Explain:** We learned in our story that chalk is made of calcium carbonate. The way to confirm the presence of this mineral testing the chalk with vinegar or soy sauce. To be sure the vinegar or soy sauce is dissolving the chalk, and not something else, we are going to compare how chalk reacts to vinegar or soy sauce with how chalk reacts to water.
2. Let's place one piece of chalk into a cup of water, and another piece of chalk into a cup of vinegar or soy sauce.  
**Note:** The chalk will immediately start reacting with the vinegar making a lot of bubbles!
3. **Ask:** What is happening in each cup? (Vinegar or Soy Sauce is bubbling, Water has no bubbles)
4. After an hour, pour off the liquid in each cup. Compare the chalk that was in the water to the chalk in the vinegar.
5. **Ask:** Is there sediment on the bottom of the vinegar or soy sauce cup? Is there sediment in the water cup?

### Open Investigations

Try the experiment with lemon juice, coca cola, and sprite.

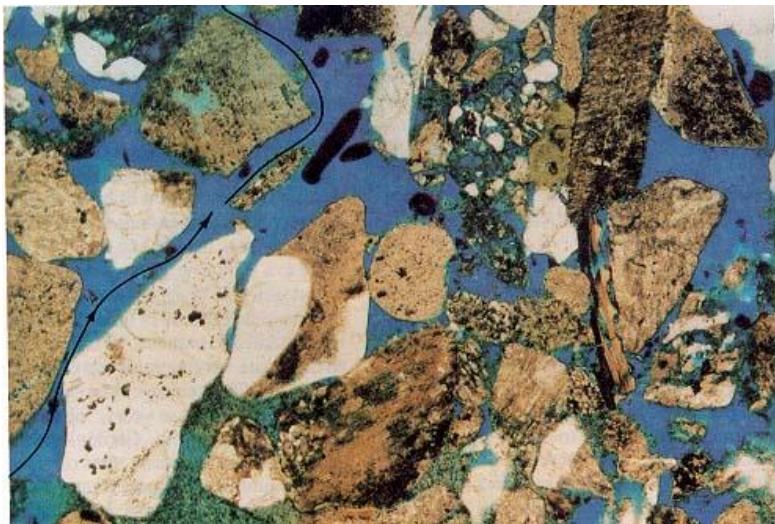
## Rock Sponges

### Materials:

- Chalk, 1 box
- Water
- Weight watchers scale, or a kitchen scale (older students)
- Sponge
- Small baking dish
- Cups (large enough to hold a piece of chalk)
- Magnified image of sandstone, last page of lesson
- Notebook
- Pen
- Ruler (older children)

### Procedures:

1. **Ask:** So how does water get into rocks? Rocks are solids, right?
2. **Tell:** Let's look at our sponge. It looks like a solid. It keeps its shape, it doesn't take on the shape of the container it is in and it cannot be poured. But there are also holes in the sponge. Put the sponge in a dish of water. Ask, what is happening to the water?
3. **Explain:** Just like the sponge, rocks have small holes, called pores that can be filled with water (and in some cases like pumice air; or oil – shale; or even natural gas – various types of sedimentary rocks).
4. **Show the picture of a greatly magnified image of sandstone:**



**5. Ask:**

- What colors do you see? (White grain is the mineral quartz; translucent grain is the mineral calcite; shades of brown is the mineral feldspar)
- Do you see spaces between the grains?
- Are they interconnected? (The arrow starting from the bottom left corner shows the direction of movement for a fluid).

**6. Elaborate:** Some rocks absorb more fluids than other rocks. These rocks are called porous.

**7. Engage:** This experiment will show us how much water a piece of chalk can absorb. Remember, chalk is made of limestone which is composed of the mineral calcium carbonate.

**8. Explain:** Before we setup our experiment, we need to learn more about the scientific method. The scientific method is a process for experimentation that is used to explore observations and answer questions. Scientists use the scientific method to search for cause and effect relationships in nature. In other words, they design an experiment so that changes to one item cause something else to vary in a predictable way.

The scientific method starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where?

And, in order for the scientific method to answer the question it must be about something that you can measure, preferably with a number.

Scientists use an experiment to search for cause and effect relationships in nature. In other words, they design an experiment so that changes to one item can cause something else to vary in a predictable way. The purpose of scientific research is not to test variables; rather, we test the relationship between them. A researcher's prediction of how the variables relate to each other is called the hypothesis. A hypothesis is a testable idea based on observation. You must state your hypothesis in a way that you can easily measure, and of course, your hypothesis should be constructed in a way to help you answer your original question.

A variable is any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled.

- The independent variable **is** the one that is changed by the scientist. To ensure a fair test, a good experiment has only one independent variable. As the scientist changes the independent variable, he or she observes what happens.

- The scientist focuses his or her observations on the dependent variable to see how it responds to the change made to the independent variable. The new value of the dependent variable is caused by and depends on the value of the independent variable.
  - Experiments also have controlled variables. Controlled variables are quantities that a scientist wants to remain constant, and we must observe them as carefully as the dependent variables. Most experiments have more than one controlled variable. Some people refer to controlled variables as "constant variables."
  - In a good experiment, the scientist must be able to measure the values for each variable.
9. **Engage:** We are going to conduct an experiment using our chalk. As we discussed earlier, it is important for our experiment to be a fair test. We are going to investigate how the chalk absorbs water.
10. **Ask:** How can we know how much water was absorbed (if any) by the chalk?
11. **Explain:** Well, we need to know the weight of the chalk before we put it in the water. Let's weigh the chalk and record its weight.
12. **Guiding your child:** Once the weight is recorded, place the chalk in a cup of water. Take the chalk out of the water after 5 minutes, dry it with a paper towel and weigh it again. Record the weight in your notebook. Repeat at five-minute intervals until the chalk no longer increases in weight.
13. **Ask:** What is the pattern of your data? Does the weight change? Does it always change by the same amount? Does it stop changing? Why did the chalk get heavier?
14. **Explain:** The chalk's weight increased because it was absorbing water.
15. **For older children:** You can calculate how much water was absorbed by volume using the following information:

**1 gram of water = 1 ml of water**

If, for example, the chalk gained 2 grams while in the water, that would mean it soaked up 2 ml of water!

You can also calculate what percentage of the chalk's volume was filled by the water.

Since the chalk is cylinder, your child can find is volume by the formula  $\text{Volume} = \pi r^2(h)$  where  $r$  is the radius and  $h$  is the height. (For example, if you have a piece of chalk 2 cm in diameter (1 cm in radius) and 5 cm long, the formula would be  $3.14 \times 1^2(5) = 15.7 \text{ cc.}$ )

## Resources

- **How Charles Darwin Classified His Mineral Collection:** <https://www.forbes.com/sites/davidbressan/2016/04/20/how-charles-darwin-classified-his-mineral-collection/#72744765381c>
- **When Rock Classification is not hard anymore, thank Mohs Scale of Hardness:** <https://blogs.scientificamerican.com/history-of-geology/when-rock-classification-is-not-hard-anymore-thank-mohs-scale-of-hardness/>
- **Scientists Discover a New Mineral “Nataliyamalikite”:** <http://www.geologypage.com/2017/07/scientists-discover-new-mineral-nataliyamalikite.html>
- **A New To Us Mineral Many Help Immobilize Nuclear Waste:** <https://knowridge.com/2018/10/a-new-to-us-mineral-may-help-immobilize-nuclear-waste/>
- **Why Are Minerals Colored?** <http://www.geologypage.com/2018/02/why-minerals-are-colored.html>
- **The Mysterious Microbes Living Deep Inside the Earth and How They could Help Humanity:** [https://www.ted.com/talks/karen\\_lloyd\\_the\\_mysterious\\_microbes\\_living\\_deep\\_inside\\_the\\_earth\\_and\\_how\\_they\\_could\\_help\\_humanity](https://www.ted.com/talks/karen_lloyd_the_mysterious_microbes_living_deep_inside_the_earth_and_how_they_could_help_humanity)

## Vocabulary

- **Compaction:** The compression of sediments by the weight of the deposited material above; compression alone can cause muds to become mudstones

- **Core:** The center of the Earth
- **Crust:** The outer layer of the Earth, upon which we all live. The crust is mainly composed of igneous and metamorphic rocks and is divided into plates that move very, very slowly
- **Erosion:** The process of moving weathered pieces of rocks and organic material
- **Deposition:** The laying down of material
- **Igneous Rock:** Cooled from magma. Igneous rocks form the bulk of the earth's crust
- **Hardness:** The resistance of a mineral to scratching. It does NOT refer to how easily the mineral is broken. Hardness is a measure of the bonding strength between atoms. If these bonds are strong, the mineral is not easily scratched. Minerals with weaker bonds are more easily scratched
- **Magma:** Liquid rock underneath the surface of the earth
- **Mantle:** The middle layer of the Earth, between the core and the crust
- **Metamorphic Rock:** Any rock whose mineralogy has changed due to changing environmental conditions. Metamorphic processes are commonly the result of increases in heat and/or pressure, with the resulting changes in mineralogy always reflecting an attempt by the elements in the rock to regain equilibrium with the new conditions
- **Mineralogy:** The minerals in the rock
- **Minerals:** Solid matter composed of elements in specific combinations and arrangements
- **Rocks:** Composed of minerals in specific combinations
- **Sedimentary Rock:** Secondary rocks formed from the accumulation of sediments, chemical precipitates, and/or biological residue
- **Streak:** The color of the powdered mineral. The test is usually performed by scraping the mineral across a piece of unglazed porcelain. Streak can be diagnostic. Good examples include hematite (always red-brown no matter what form it's in) and chromite (distinguished from the hundreds of other black minerals by its chocolate-brown streak)
- **Subduction:** The process of an oceanic plate in the Earth's crust being forced under a continental plate in the Earth's crust when the two plates collide.
- **Texture:** The way that the grains fit together
- **Weathering:** The chemical alteration and mechanical breakdown of rocks during exposure to air, moisture, and organic matter

# Mohs Hardness Scale

Name	Scale Number	Common Object
 Diamond	10	
 Corundum	9	
 Topaz	8	 Masonry Drill Bit / 8.5
 Quartz	7	 Steel Nail / 6.5
 Orthoclase	6	 Knife / 5.5
 Apatite	5	
 Fluorite	4	Penny (Copper) / 3.5
 Calcite	3	
 Gypsum	2	Fingernail / 2.5
 Talc	1	



Greatly magnified image of sandstone