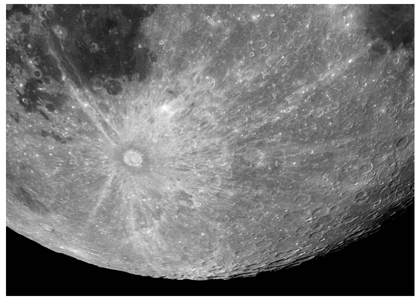
10.3: Exploring Crater Rays in Detail

Many students are fascinated by crater rays. Once you've seen one of them on the Moon's surface, you just can't help looking for them like shamrocks among the clover. Ray systems occur in almost all craters on the airless Moon, but they are virtually unknown on the Earth – why do you think that is?



The answer has to do with our thick atmosphere – and the Moon's complete lack of air. On Earth, if an asteroid is large enough to strike the surface and make a crater, the blast will look rather like a mushroom cloud from a nuclear test explosion. The extreme heat creates a rising column of hot air that carries pulverized rock high aloft into the stratosphere. If you look at the rising plume from a large volcanic eruption in a photo or a video, you will have an idea of the amount of energy such an impact can release.

Things are completely different on the Moon; with no air, it doesn't matter how much heat the impact generates, there will be no plume of dust and smoke because there is no air to rise and carry it aloft. Pulverized rock dust sprays out more like water from a hose, flying in perfect parabolic curves with no wind to disturb or distort its path. Modeling a single impact on Earth in your classroom requires a little ingenuity, but we can do it easily!

Academic Standards

Science and Engineering Practices

- Developing and using models.
- Planning and carrying out investigations.
- Using mathematics.

Crosscutting Concepts

- Cause and effect.
- Scale, proportion, and quantity.
- Systems and system models.
- Energy flows, cycles, and conservation.

Next Generation Science Standards

- Space systems (K-5, 6-8, 9-12).
- Earth shaping processes (K-5, 6-8, 9-12).
- History of Earth (K-5, 6-8, 9-12).
- The Earth-Moon system (6-8, 9-12).
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For the Educator

Facts you need to know

1. Rays are made of pulverized material ejected from the crater during an impact. The reason we see streaks of material is because the irregularities in the rim alternately block and channel the flow of material flowing outward.
2. Ray material is often as fine as sand, or even flour in real life.
3. Earth's atmosphere stops rays from forming. The dust is suspended in the air as a dust cloud which drifts away on the wind. On the airless Moon, or nearly airless Mars, rays are distinct and easy to see.
4. Rays stand out because the finely powdered material is bright and more reflective than the darker ground on which it lies.

5. Rays on the Moon are easiest to see in the days just before and after the full moon.

Teaching and Pedagogy

Rays on the Moon are made of very finely pulverized rock that is as fine as flour. Jagged edges along the irregular crater rim channel the explosive power of the impact and help create the streamers of powdered rock we call ***crater rays***.

One of the most famous crater and ray systems on the Moon is from Crater Tycho. Tycho is almost 90 miles wide and 4 miles deep – it is a virtual twin of the impact that destroyed the dinosaurs here on Earth 65 million years ago, some scientists even hypothesize that the Crater Tycho on the Moon and the Crater Chixulub on Earth were made from two pieces from a single asteroid that broke apart and fell into the inner solar system at about the same time.

The rays from Crater Tycho run for more than a thousand miles across the surface of the Moon and are easy to see with any small telescope on a full moon night. It is likely that the rays from your crater went out much further than your students expected them to! In fact, if you were skeptical about why I asked you to put down a 5-ft wide spread of craft paper, you probably aren't any longer!

Rays and crater volume are both a good measure of ***impact energy***. It requires energy to excavate a crater and lift out all the rock and soil that used to be where the crater is now. The famous ***Meteor Crater*** in Arizona has a volume about 400 times larger than a football stadium, and this huge crater was excavated in just a few seconds.

Rays are also a measure of impact energy. Like excavating a crater, it takes energy to first pulverize the rock, and then to lift and throw it over great distances. The rays from great craters like Tycho are rarely more than an inch thick, but they extend over vast distances. These rays represent thousands, even millions of tons of rock that was smashed to powder and then thrown across tremendous distances! How much larger was your ejecta blanket than your actual crater? What was the size ratio between the crater and your ray systems? All of these things represent impact energy from the asteroid smash that created your crater!

Student Outcomes

What will the student discover?

1. You can learn a lot from looking at a rock! We tend to think of rocks as hard, virtually indestructible things, but on a planetary scale, rock is soft enough to record the scars and impacts that have formed all the planets in our solar system, including the Earth and Moon.
2. The Earth is quite different from the Moon, geologically active with earthquakes and volcanoes, scoured by wind and rain, these things tend to erase the record of early impacts that formed our Earth billions of years ago. The Moon with its airless, waterless environment has virtually no erosion. The Moon's interior is also almost completely solidified, any molten material remaining is so deeply buried that it can never affect the lunar surface again with volcanic eruptions or earthquakes – we say that the Moon is ***geologically dead*** and almost completely unchanging.
3. It is this very lack of geological and environmental activity that makes the lunar surface such a perfect record of events both ancient and modern. To the scientist, the shapes of the lunar landscape as well as the types and age of the rocks there tell a story that stretches back over four billion years to a time when the Moon was newly formed and still molten on the inside.

What will you learn about science?

1. You often hear people challenge scientists, saying: 'How do you know that?' or 'What evidence do you have?' But in the case of the Moon and its ancient and violent history, the evidence is right in front of us. We see it every time we look up at the man in the Moon.
2. This insight into how the scientist looks at the commonplace things around us and sees more than their neighbors do is quite valuable. It is sad, but true, that the adults in a child's life often shut down the myriad of questions that a child has when they see something new. When we teach young children about science, we need to give them a different message; we need to remind them to keep asking those questions, and to cherish and pursue the most difficult ones. It can be the beginning of a lifetime of adventure!

Conducting the Activity

Materials

1. Flour and black spray paint (See Activity #22.)
2. Two pieces of 5-ft long x 30-inch wide black or dark blue craft paper (any color will work here as long as it is as dark as possible.)

3. A 10-inch spring form cake pan – $10 (You may get paint on this, so don't bring a nice one from home!)

Building the Crater Ray Model

1. Tape your two pieces of black craft paper down to the floor – this should give you a nice 5-ft square area to work in.
2. Put your spring form pan ring down on the paper (don't attach the bottom!) and carefully fill it with flour to the top. Use a ruler to strike off the excess and sweep it away carefully with a soft paint brush. Try not to leave any stray flour on the black paper.
3. Lift the ring straight up. The flour will slump a little around the edges and leave you a nice mound about 2-½ deep in the center. Spray black paint over the mound of flour keeping the can at least 18-inches away from the surface. If you would rather not work with paint in the classroom, try putting some black or dark blue food coloring into a bowl with about 2-3 cups of flour. Keep stirring the flour with a whisk and gradually add food coloring until the flour is a dark, uniform color. You can then put the dark flour in a sifter and sift a dark surface layer over your pile of white flour. The color is only for contrast, and this works just about as well as paint.

Exploring the Crater Ray Model

1. You are now ready to drop a weight into the flour pile. If you have access to some disk-shaped weights common to science labs, these work wonderfully. If not, a large marble or slightly flattened 2-inch ball of clay will work well. Drop the weight from about 2-feet up; if you are using disk weights or flattened balls of clay, be sure to drop them so they land flat against the surface!
2. The impact on your pile of flour will not only make a satisfying crater, but a very dramatic system of rays spreading out over your black paper surface. It is often advisable to photograph the crater and its rays with your smartphone camera before children start to measure and explore!
3. Measure the ***crater diameter*** from one edge of the rim to the other and record this.
4. Measure the ***ejecta blanket*** from one edge to the other and record this. The ejecta blanket is the more or less continuous circle of material thrown out of the crater at the time of impact.
5. Measure the rays spreading out from the crater from the crater's rim out to the tip where the ray disappears. Measure enough of them so that you can get a good average. If there are enough rays, each child can measure one or two. Record the shortest and longest rays, and calculate the average length of rays for your crater.

Discussion Questions

1. What did this activity show you about craters that the last activity did not?
   - **Answer:** Rays are awesome! Crater rays extend for great distances – much farther than most people might think.
2. What does this activity show you about the energy of asteroid impacts?
   - **Answer:** When we remember that crater rays are made of ***powdered stone***, we begin to realize how much energy it must take; first to pulverize solid stone into a powder, and then to blast this powder hundreds of miles across the lunar surface.
3. Why don't craters made on Earth have any rays?
   - **Answer:** The powdered stone would be carried away as smoke or dust on the wind instead of falling in neat lines.
   - **Answer:** The powdered stone would be washed away by rain and wind in a relatively short time. Any rays created on Earth would not exist just a few years after the impact crater was created!

Supplemental Materials

Going Deeper

We haven't always discussed "impact craters" on the lunar surface. When I was young, we were taught that almost all the craters on the Moon were volcanic in nature, and that the idea of something large enough to strike the Earth or Moon and make a large crater was a ridiculous idea.

The discovery of the true nature of impact craters is tied up with two men, and one giant impact crater in northern Arizona. Daniel Barringer purchased what became known as ***Barringer Crater*** in 1903, hoping to mine the site for tons of meteoric iron he assumed must be buried there. Barringer published many articles in scientific journals claiming to prove that the crater was made by a giant meteorite striking the Earth. Although the scientific community never accepted Barringer's work as conclusive – the Barringer family steadfastly claims that he discovered the meteoric nature of impact craters before anyone else.

Gene Shoemaker first came to Barringer Crater in the late 1950's and continued to study the site into the early 1960's. Shoemaker's analysis of shocked quartz proved that the crater had to be of meteoric origin. Shoemaker was slated to be an Apollo Astronaut, but a heart ailment kept him from flying. Never the less, his work on impact craters was verified by the Apollo astronauts, and today we all know that almost every crater on the Moon was caused by the impact of asteroids from space – not volcanic explosions!

Being an Astronomer and Scientist

We combine the astronomer and scientist sections for this activity because they are so closely interwoven. If you have a telescope, so much the better, but if you do not then a high quality photograph of the full Moon will serve.

1. At or around the full moon, take your telescope an hour or so after sunset when the Moon is well above the horizon. Viewing the Moon at 80-100x, scan for craters with bright ray systems.
2. Have your students draw a crater and a ray system as accurately as they can, paying attention to the crater diameter and ray length. If you can determine the extent of the ejecta blanket, add that to your sketch!
3. After sketching, measure the size of the crater and compare it to the length of the rays and extent of the ejecta blanket.
4. Calculate the ratio of the sized of the crater compared to the ejecta, and to the rays. Compare these ratios among the students – can you find a consistent relationship between crater size and ray length?

Following Up

A class visit to Barringer Crater (also known as Meteor Crater) in Arizona might not be possible for your class – however there are many videos that will take you there without leaving the comfort of your own school room. As with all videos on the web, be sure to preview them to insure that the content is age appropriate for your students.
