10.2: Dynamically Modelling The Moon’s Surface in Flour

This activity is larger, messier, and a lot more fun that the clay model we made in Activity #25. In the last activity, we pressed various size balls into a clay surface to make ‘craters’, depressions that were smooth and round, but not very exciting or dynamic. We’re going to take this up a notch and let kids see the crater making process as it happens! By dropping weights into pans of flour to look at the resulting craters, plus the ***ejecta*** – material which is blasted out of the crater on impact.

Academic Standards

Science and Engineering Practices

- Developing and using Models.
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Constructing explanations.

Crosscutting Concepts

- Cause and effect.
- 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).

For the Educator

Facts you need to know

As large and impressive as craters may be, they change the landscape in a matter of seconds. The Barringer Crater near Winslow, Arizona has as much volume at 400 professional football stadiums; even so, it was excavated in under 5 seconds.

Craters average between 10-20 times as large as the asteroid that created them. Crater Tycho on the Moon is over 90 kilometers wide, it took a 6-10 km wide rock to create it. This mountain-sized impactor is about the same size at the Chixulub impactor which killed the dinosaurs.

Craters are typically a bowl-shaped depression with a raised rim around them, they also sometimes feature a raised ***central mount*** in their centers.

Ejecta includes all the material blasted out of the crater at impact time. There is an ***ejecta blanket***, a bright layer of material that surrounds the crater. There are also ***rays***, streaks of material radiating away from the center of the crater. Rays can be very long, sometimes more than ten times the diameter of the crater itself.

Teaching and Pedagogy

If you don’t want to fool with dying corn meal, you can cover your flour surface with black spray paint instead. This method is quicker and you can stir the flour after the experiment and use it again immediately.

Flour covered with paint is a reasonable analog for the lunar surface. Almost waterless, the lunar rock pulverizes into dust when an asteroid of any size strikes the surface into a fine powder very similar in consistency to flour. The sunlight darkens the surface of the Moon over time in a process called ***radiation darkening***, we’ve used paint to simulate this. When the light colored rock is blasted out of a crater, it falls back onto the surface making a sunburst or splatter shape we call ***rays***. Can you see evidence of rays on any of your craters? Have the children draw what they see here.

How far do the rays go out from the central crater? Can you measure this? Is the ratio of crater diameter to ray length the same for all craters of any size? This is an interesting investigation to do; it takes patience and a little measuring, but the math is very simple. Make a chart showing the size of the crater, the size of the rays, and the ratio between them. You may find that your larger craters blasted flour right out of the pan and onto the floor! Don't worry about that (you did use that plastic tarp, right!?), use the smaller craters for your investigation and see what you find!

Want another example or the ray-making process in action? Toss a water balloon high up in the air and let it splatter on the dry pavement of a parking lot or play area – you will see the same splatter pattern with 'rays' of water streaking away from the center of the impact!

Impact craters on the Moon also have ***raised crater rims***. These are areas where the blast force has pushed the rock back from the center of the impact, causing it to pile up like snow in a freshly plowed parking lot. This happens because the solid rocky surface of the Moon forces the blast energy to turn 90-degrees, from straight down to horizontal. Look at your lunar-flour surface, can you see evidence of raised crater rims? See if you can measure the height of the rims above the flat surface. Is there a relationship between crater size and rim height? Another chart can help you settle this question!

Want to do it again? Just stir the flour well with a spoon, add a little more as needed and then re-smooth and repaint the surface. You can do this activity many times! If you want to keep the flour in the pan and try again tomorrow, I strongly recommend putting a cover of plastic wrap or aluminum foil over the pan to protect the flour from moisture and insects!

You can also save the flour in large zip-shut plastic bags or plastic jars and save it for salt dough art projects! Don't forget to sift the flour to get the pebbles, marbles, and other "asteroids" out of it before you use it! Do you find that the black paint has tinted the flour a bit? Don't worry, a little paint won't hurt the salt dough at all – just don't reuse it for cooking!

Student Outcomes

What will the student discover?

1. Crater making is a dynamic, violent process. The Moon's surface may look static and unchanging, but it is in fact a record of titanic collisions and explosions. Impacts of the size that killed off the dinosaurs (100 km craters) are just large enough to be detected on the Moon's surface with the naked eye. Most of the impact sites you can easily see are far larger than this!
2. Craters change the landscape not only by scooping out huge, bowl-shaped depressions in the ground, but by burying the surrounding landscape in tons of rock and debris we call ***ejecta.***
3. The ratios between the size of the impactor, the size of the crater, and the size of the ejecta blanket are remarkably consistent. This indicates that the crater making process is a consistent and understandable physical process.

What will your students learn about science?

1. Processes that happen on distant moons or planets can help us understand the forces that have shaped our own planet. This is one of many reasons why space exploration is both valuable and important to those of us here on Earth!
2. It is not possible – or safe! – to recreate the crater making process here on Earth because the process is too dangerous and destructive. We can recreate these processes in miniature to help us understand for forces that shape every moon and planet in our solar system.

Conducting the Activity

Materials

1. 10 lb bag of flour.
2. A deep dish pie or cake pan
3. A 2 lb box of corn meal
4. Several bottles of dark blue/black food coloring, or a bottle of black ink
5. A large 12-ft square tarp or plastic sheet. Check the paint department of your local home improvement store for this, sometimes sold as a 'plastic drop cloth' for protecting floors and furniture while you paint.
6. A roll of masking tape to hold the plastic sheeting securely down on your floor and prevent tripping.
7. An assortment of small pebbles, marbles, etc. Nothing larger than 1-inch diameter.

Building the Impact Crater Model

1. Dilute two bottles of dark food coloring in ½ cup of water. Put the corn meal in a large bowl, add the colored water and stir for several minutes until well mixed (a kitchen blender works well if you have one.)
2. Spread the corn meal out on cookie sheets or aluminum foil and allow to dry. You can put the cookie sheets in a low (180 degree) oven for an hour or so if you wish to speed the process. Once dry and cool, return the corn meal to a bowl and stir

thoroughly to insure all granules are separate. Store in original box or in a zip-shut plastic bag.
3. Lay the tarp or drop cloth out on the floor and tape it down securely – you're going to need a large area for this so you may want to push the desks aside!
4. Put the large pan or box-top in the middle of the tarp and fill with flour to the top. You can overfill a bit and use a yard stick to strike off the top to make a smooth, flat surface.
5. Sprinkle a thin, even layer of dark corn meal on top of the flour.

Exploring the Impact Crater Model

1. Have everyone gather round and pick up an edge of the tarp; most should stand well back to keep splattering flour off shoes and clothes.
2. Choose a lucky student to drop a pebble or marble into the flour from a height of about 1 meter.
3. Students can now inspect, photograph, and sketch the crater they have created. Have your students look for the crater basin, crater rim, ejecta blanket, and rays.
4. Measure carefully and see how large the crater was compared to the impactor that made it. How about the size of the ejecta blanket compared to the crater? How far do the rays extend away from the crater?
5. Want to try again? (My students always wanted to do this multiple times!) Try using different size pebbles, comparing the effects of large and small weights. Don't let children ***throw*** their pebble, as that can make a real mess!

Discussion Questions

1. How was this model different from the clay model you made last time?
    - **Answer:** This model shows the crater-making process as it happens instead of just modeling the shape of finished craters.
    - **Answer:** This model is ***dynamic***, we see it in action as it is being created.
2. What does this model show you that the other clay model did not?
    - **Answer:** The crater formation process (asteroid impacts as they happen!)
    - **Answer:** Crater rims and crater rays.
3. What have you learned about the size of the impactor compared to the size of the crater and the ejecta blanket that surrounds it?
    - **Answer:** Craters are always significantly larger than the impactors that create them. The size of the ejecta blanket and rays are truly enormous compared to the impactor. A 100 meter impactor (the size of a football field) could throw ejecta material more than 25 kilometers from the impact site!

Supplemental Materials

Going Deeper

How are craters discovered? From our work here, you might think that you just have to look for a crater to find them. On the Moon, finding craters is fairly easy, but not so on our own Earth!

Craters on the Moon are visible to anyone with a pair of binoculars; if you have access to a telescope, you can see thousands of craters. The Moon is a unique environment, there is no air, no water, and almost no erosion on the surface at all. Unlike Earth where rain, wind, and even earthquakes and volcanoes disturb and reshape the surface, our Moon is ***geologically dead***, there are no active reshaping processes there. The only weather and erosion on the Moon comes from rocks falling from space to strike the surface.

If you could go back in time 100 million years, the Earth would look very different. Apart from dinosaurs, even the continents would be in different locations! Mountains that look old and rounded now would have looked new and rugged then; some mountains that we are familiar with would not even have been formed then!

Our active Earth wears away, buries, and destroys most craters in just a few million years. Most of the known craters on Earth have been discovered from space, either from the space shuttle (1981 – 2011) or from the International Space Station.

Being an Astronomer

Telescope time again! Now it is time to take another good look at some craters on the Moon's surface. Can you see the features we discussed such as crater rims, ejecta, rays, and central mounts in lunar craters? Can you find overlapping craters where one impact destroyed evidence of another earlier impact?

You will find that some craters appear bright – these are relatively new, less than 100 million years old! Other craters show eroded rims indicating they must be a billion years old, or even older. You may also find ***maria***; dark, circular basins filled with dark colored lava. These maria are impacts so tremendous that they cracked open the Moon's crust allowing lava to flow in from deep within the interior. The Moon's interior is all frozen solid today so no impact, no matter how large, could cause a maria to form in modern times.

Being a Scientist

Sometimes the size and scope of the damage that an impact event can create are hard for students to imagine. If you have older students (6th grade and up), you may wish to have them investigate what an impactor could do if it struck the Earth.

Purdue University in Indiana has a wonderful website called *Impact Earth!***(www.purdue.edu/impactearth)** which allows students to enter data on the size of an impactor, its speed, angle, and the type of terrain that is struck. Once you enter the data, your students can indicate how far away they are and see how the impact effects them.

The *Impact Earth!* website shows blast damage, heat damage, ejecta damage, and seismic damage from the impact and describes in detail what the impact would be like for the observer on the ground.

Following Up

Earth, Mars, Venus, Mercury, and the Moon all show substantial impact damage from asteroids striking their surfaces, but larger planets like Jupiter, Saturn, Uranus, and Neptune do not.

Investigate these planets and compare them to our own Earth and Mars. Why would our inner planets all show impact damage but these large worlds do not?

Answer: These larger worlds are ***Jovian planets***, sometimes known as 'Gas Giants' – they have no solid surfaces at all. Asteroids may impact them, but they easily penetrate into the planet's interior without leaving a mark on the gaseous surface.
