10.4: Dynamically Modeling The Lunar Surface in Plaster

This is a fascinating (and messy!) activity which always seems to delight children. The fact that the asteroid impacts which shape the worlds and moons in our solar system are violent and sudden affairs is easily brought home to everyone with this exciting activity! This activity will take a bit more preparation, and practice, than anything else we have done before. The practice involves timing, because wet plaster hardens quickly and if you start too soon, impacting rocks will simply disappear as though you've tossed them into a bucket of water – but wait too long and they will just bounce off the surface without affecting anything! You will need to try this on a small scale by yourself before you do the larger activity with students!

Academic Standards

Science and Engineering Practices

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

Crosscutting Concepts

- Cause and effect.
- Systems and system models.
- Stability and change.

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

1. Working with Plaster of Paris takes practice. Plaster can be a messy medium and your best choice will be working outdoors. Likewise, plaster can damage clothing and shoes – children will need to wear old clothes and shoes if possible for this activity!
2. You may wish to ask your custodians for help with this project. You will be mixing and pouring heavy materials, and chances are that your custodial team has more experience working with mortar than you do! The custodial team at my school loved working with me on these projects, I'm sure yours will be happy to help too!
3. A permanent model offers many advantages over a temporary clay or flour model. Permanent models can be touched, painted, measured, photographed, and displayed for parents and administrators.

Teaching and Pedagogy

Your new plaster model of the lunar surface has quite a few features that other models lacked. The dark painted surface contrasts very well with the ***ejecta blanket*** material (white plaster) so you and your students can clearly see that material was ejected from the craters as they were formed.

You may wish to measure the size of the ejecta blanket (calculating the approximate area of such a feature can be an interesting geometry problem for older students!) Is there a correlation between the size of the crater and the size of its ejecta blanket? Modern geologists and astronomers are investigating questions like these even today!

No doubt you will also notice that later events (the small rocks) made marks ***on top of*** older features. This is exactly what happens on the lunar surface as we have discussed before. Your model shows you geological timelines forming in action! Have your students map your landscape on a piece of construction paper and name the major craters. Can they construct a timeline that shows when these craters were formed?

The maria made of dark plaster also offers areas for investigation. If you took photos before and after the maria was formed, how many features were obscured by the lava flows as the original crater filled and became a maria? How does this formation relate to our timeline? Can your students notice ripples or inconsistencies in the lava flow now that it has hardened? These features still exist on the Moon today billions of years after these lava flows hardened into stone.

You may also have noticed that our model lacks some features that the others possess. Our flour models showed beautiful rays, but our plaster model shows none. Ask your students why not? In fact, our flour model was made of powdery material that was perfect for forming rays made of streaks of fine powder grains. Our plaster model was made wet – and our little rocks could in no way strike the surface hard enough to pulverize it into a powder again!

Student Outcomes

What will the student discover?

1. We tend to learn about things like continental drift, earthquakes, and mountain building that take millions of years to change the surface of a planet. Impact craters are titanic events that change the surface of a planet in minutes – and sometimes extinguish much of the life on the surface and even deep in the oceans.
2. Craters come in all different sizes – and all different impact energies! The smallest craters on the Moon were found in small beads of glass; these microscopic craters were made by granules much smaller than a grain of sand. The largest know crater in the solar system is called Aitken Basin – it is 2200 km wide (larger than Germany) and is up to 15 km deep!
3. Craters not only disturb and shape the surface of a planet – sometimes they affect the interior as well. Maria on the Moon are examples of craters so deep that they allowed lava from the Moon's interior to flow to the surface and fill these giant basins.

What will your students learn about science?

1. Taken together, these various models show us something unique about the scientific process. Specifically, even though each model was quite good, none of them showed every feature and fact that we already know to be true about the lunar surface. Modern science tries to build models to help us understand how nature works, but we are limited by are time, money, tools, and even by things we haven't yet discovered or don't understand.
2. Scientists often build multiple models to help them understand various aspects of nature. Some of these models are physical, rather like the ones you have made in your classroom. Other models may be much farther removed from the actual processes, others may be entirely mathematical and have no physical components at all!
3. When we see that scientists have multiple models of something, or even multiple explanations for a single phenomenon, that doesn't mean that the scientists are 'doing a bad job' or that they don't understand what is going on. Science is a rich activity, full of nuance and subtlety.
4. When we are modeling something as wonderful and complex and forming the surface of an entire planet, it can take a series of models to help us understand nature more completely. Sometimes a single model cannot show us everything we want; and some things, like asteroid collisions, are so tremendous in their energy and size that we simply cannot model them completely in our laboratories or classrooms.

Conducting the Activity

Materials

1. 25 lb bag of plaster of paris – (See your local home improvement store for this, the paint department usually has it!)
2. 25 – 50 lb bag of "play sand" – Play sand is finer than builder's sand and does a better job for us with this project. The biggest problem is lugging the stuff around, but it can be used for lots of classroom projects!
3. A very large dish pan or cafeteria pan and a large metal spoon or garden trowel to mix the plaster. A wheelbarrow can also be used if your custodian has one.
4. Can of flat black spray paint (any dark color will do.)
5. The top from a case of copy paper
6. A roll of duct tape
7. A quantity of black, water-based classroom paint (about ½ cup.) Black food coloring can also be used for this if available.
8. Large trash bag or aluminum foil for lining the box top
9. Assorted rocks and pebbles from fingernail size up to egg size. Use only one of the largest size (2-inch) rocks, 5-7 of the 1-inch size, and everyone else gets a smaller size.
10. Large tarp or drop cloth, ***at least*** 12 x 12 ft. (See Activity #22)

Building the Lunar Landscape Model

1. **Everyone** wears old clothes for this. The plaster may splatter about a bit, and it will not really come out of clothing or off of shoes. The tarp will help, but just be aware of this issue.
2. Reinforce all the corners of the box top with strips of duct tape. Be sure you use enough, the plaster mixture will be heavy and if it bursts out of your box, the activity will be ruined!
3. Lay out the tarp and the cardboard box top from the copy paper and line the box with a large trash bag or a generous layer of aluminum foil. Have all your materials at hand, pre-shake the can of spray paint, and make sure everyone has a rock to throw.
4. In your large dish pan (even a wheel barrow works well!) mix 2 parts dry plaster to one part dry sand. It is fine if you have extra sand, but too little will not do, be sure to make enough! If you end up with more wet plaster than you need, the extra can be dumped onto a plastic trash bag to set and then thrown away when hardened. Follow the directions on the bag, but mix the plaster **wet**, add just a bit more water than strictly needed. The mixture will be like cake batter when mixed properly. Make sure you use the spoon to dig into the bottom and corners of the pan so that all the plaster is mixed in. If you feel you've made it a bit too runny, you can add another cup of plaster in – don't worry, it **will** thicken up and harden!
5. When mixed, pour the plaster into your cardboard box mold, filling it to the top. Immediately spray paint the top of the plaster. This is an excellent time to have a volunteer rinse out your dish pan thoroughly with a garden hose! If you have some extra plaster, pour it into a paper cup as a tester. Poke into this mixture with a stick – if the plaster is no longer runny and the stick leaves any sort of permanent mark, you are ready to begin. This won't take long, perhaps a not even a minute.
6. Have your students each hold the edge of the tarp and lift it up in front of themselves as an apron or splash guard. (Don't lift up the box of wet plaster and spill it!) Begin with the student holding the largest rock, toss it vigorously into the middle of the box. After this, the students with mid-sized rocks can toss them in one at a time. Don't drop them, you must throw them down into the plaster to make a large enough impression. Finish up with all the smaller rocks. If you have 30 students, you will have an excellent landscape – if fewer, some students can toss an extra rock or two.

Exploring the Lunar Landscape Model

1. Allow the plaster to harden for at least an hour before you move it, then carry it inside. It will be heavy, get some help with this! Be sure you display it on a sturdy table where it will not fall!
2. Now it's time to fill in the maria! You may wish to take a photo of the landscape before and after you make the maria for comparison! Put a couple of cups of plaster (no sand this time) in a large mixing bowl, add ½ cup black paint or squirt a whole bottle of dark blue or black food coloring into the required water. Mix the plaster and make sure it is thin and runny! Pour this plaster carefully into the largest crater in your landscape – your maria is filling with lava! If some of the dark plaster-lava overflows the maria and runs out onto the surface, that is excellent – just like it happens on the Moon! You will notice that some of the craters are filled in and obliterated by the lava flow, point this out to the students as it happens!
3. For extra realism, you may wish to toss in some very small rocks (less than ¼-inch) to make small craters on the maria floor.
4. [Optional] You can use a ***chalk snap-line*** to mark lines of longitude and latitude on your model. Ask your custodial staff about this, chances are good that they may have one which you can use already; if not, one of them will probably know how to use it and be able to help you with this. If you do not have a snap line – you can use colored builder's twine (available at any home improvement store.) Leave your model in the cardboard box and cut notches every inch along the edges of the box. Thread the twine back and forth through the notches – first lengthwise, then crosswise. The twine will mark out lines of longitude and latitude that will help your students draw and map the landscape they have made!

Discussion Questions

1. How is this model better than the flour models we made earlier?
   - **Answer:** This model gives us a permanent record that is easier to study over a period of days and weeks after we made it.
2. Why doesn't this model show crater rays like the flour model did?
   - **Answer** The plaster in our new model starts out as a liquid and splashes on impact. The flour is already ground to a powder and is capable of being blasted out of the crater much like pulverized stone from a real crater!
3. What did you notice when your teacher started to fill the maria with dark-colored plaster?
   - **Answer** This dark plaster is like lava coming from deep within the lunar interior. The plaster fills the maria, making a smooth, level surface. The plaster also fills, covers, and destroys some of the smaller craters as it flows across the surface.

Supplemental Materials

Going Deeper

Map making is one of the oldest mathematical activities. Maps make visible, physical representations of sizes, distances, and spatial relationships that transcend language. This is why map making is one of the most powerful techniques a science teacher has for effectively teaching the ESL student.

Once you have put longitude and latitude lines in place on your model, have students make a grid on a piece of construction paper. Have the students map the features of your lunar model onto their own paper – this makes a great activity station for group work day.

Tell the students how many miles or kilometers each square represents, then have them use the grid to determine things like x-y location of various craters, sizes of craters and maria, and the distances between various features using the Pythagorean theorem or just by measuring with a ruler.

Being an Astronomer

Another night at the telescope looking at the Moon? Sure! The Moon is beautiful and mysterious and worthy of a lifetime of study. If you have been doing these lunar surface activities through a semester, your classes will be bringing more knowledge to the eyepiece each and every time they look.

When we come to the telescope with a mental model of the Moon, its craters and maria fresh in our minds, then we come prepared to explore and discover new things. In short, we are primed for learning – not just seeing.

If your students have another opportunity to study the Moon through a telescope, have them look for evidence of geological processes such as lava flows, landslides inside the walls of giant craters, even geological erosion of ancient crater rims.

Being a Scientist

Craters, in spite of their great age, tell us a lot about the ***impact energy*** of the asteroid that made them. Larger craters obviously indicate more energy, but how to measure this? With your plaster model, you have a fun and easy way to investigate this. By filling a plaster crater with water to the very brim, you can measure the volume of the crater quite precisely; more volume indicates that more surface material was blasted away, and hence more impact energy!

To measure the water, you will either need a ***graduated cylinder*** (a very precise measuring cup of sorts), or a scale that can weigh in grams. A graduated cylinder is measured precisely to allow you to record how many milliliters of liquid are inside. Start with a cylinder with 100 mL of water, and after you have filled a crater you have 13 mL left – then you have used 87 mL of water to fill the crater – this is the crater's volume, and a direct measure of the energy that created the crater in the first place.

A bottle of water and a digital scale work just as well. Weigh the full bottle in grams, and weigh it again after you have filled the crater. If your bottle weighs 1000 grams full, and 835 grams after filling the crater, you have used 165 grams of water to fill the crater. Interestingly, this means your crater volume is 165 mL. This exact correlation between grams and mL of water is not a coincidence – French scientists designed the metric system with water in mind so that 1 mL of water was defined to be exactly 1 gram of mass.

One thing your students will notice is that they cannot directly measure the volume of the maria you have created because you have filled them with plaster 'lava'. Scientists and astronomers on Earth have the same problem when studying the Moon! Have your students measure and record the diameter of the craters alongside their volumes. Can you find any correlation between energy and diameter? Try graphing your craters with energy on the vertical axis and diameter on the horizontal axis!

After naming, mapping, and measuring the volume of the craters, record the crater energy (volume in mL) on their maps. Make a list of the craters on your map and classify the size of the impacts. This little adventure into a more mathematical analysis of your lunar landscape can be both exciting and fun.

Following Up

Craters are everywhere in our solar system. Take some time on the internet to search for photos of Mars, Mercury, even Pluto, these bodies are loaded with craters! Try searching for images of 'Moons of Saturn', or 'Moons of Jupiter' – there are more than 120 of these moons for you to explore, and all of them have craters.

How large are these craters compared to the little moons themselves? Take a look at a crater named Stickney on the Martian moon Phobos. This crater covers a substantial portion of the surface of the Martian moon. How large a crater do you think a moon or planet can have without being destroyed? Scientists debate and study this issue today!

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1. Astronomy is rife with interesting names and nomenclature and there is much debate over what does and does not qualify as a planet. Large objects (more than 50 miles across) are sometimes called protoplanets, planetessimals, or even planetoids. In order to keep things simple, I have restricted myself to meteoroid (small rock invisible from Earth) and asteroid (large enough to be seen with a telescope). An object becomes a planet when it is large enough to become spherical in shape. ↵
