Impact Craters

Purpose

To determine the factors affecting the appearance of impact craters and ejecta.

Background [also see "Teacher's Guide" Pages 1, 2, photo on 8, 12, and photo on 13]

The circular features so obvious on the Moon's surface are **impact craters** formed when **impactors** smashed into the surface. The explosion and excavation of materials at the impacted site created piles of rock (called **ejecta**) around the circular hole as well as bright streaks of target material (called **rays**) thrown for great distances.

Two basic methods forming craters in nature are:
1) impact of a **projectile** on the surface and 2) collapse of the top of a **volcano** creating a crater termed *caldera.* By studying all types of craters on Earth and by creating impact craters in experimental laboratories geologists concluded that the Moon's craters are impact in origin.

The factors affecting the appearance of impact craters and ejecta are the size and velocity of the impactor, and the geology of the target surface.

By recording the number, size, and extent of erosion of craters, **lunar geologists** can determine the ages of different surface units on the Moon and can piece together the geologic history. This technique works because older surfaces are exposed to impacting **meteorites** for a longer period of time than are younger surfaces.

Impact craters are not unique to the Moon. They are found on all the terrestrial planets and on many moons of the outer planets.

On Earth, impact craters are not as easily recognized because of weathering and erosion. Famous impact craters on Earth are Meteor Crater in Arizona, U.S.A.; Manicouagan in Quebec, Canada; Sudbury in Ontario, Canada; Ries Crater in Germany, and Chicxulub on the Yucatan coast in Mexico. Chicxulub is considered by most scientists as the source crater of the catastrophe that led to the extinction of the dinosaurs at the end of the Cretaceous period. An interesting fact about the Chicxulub crater is that you cannot see it. Its circular structure is nearly a kilometer below the surface and was originally identified from magnetic and gravity data.

Impact Craters

Aristarchus

Typical characteristics of a lunar impact crater are labeled on this photograph of Aristarchus, 42 km in diameter, located West of Mare Imbrium.
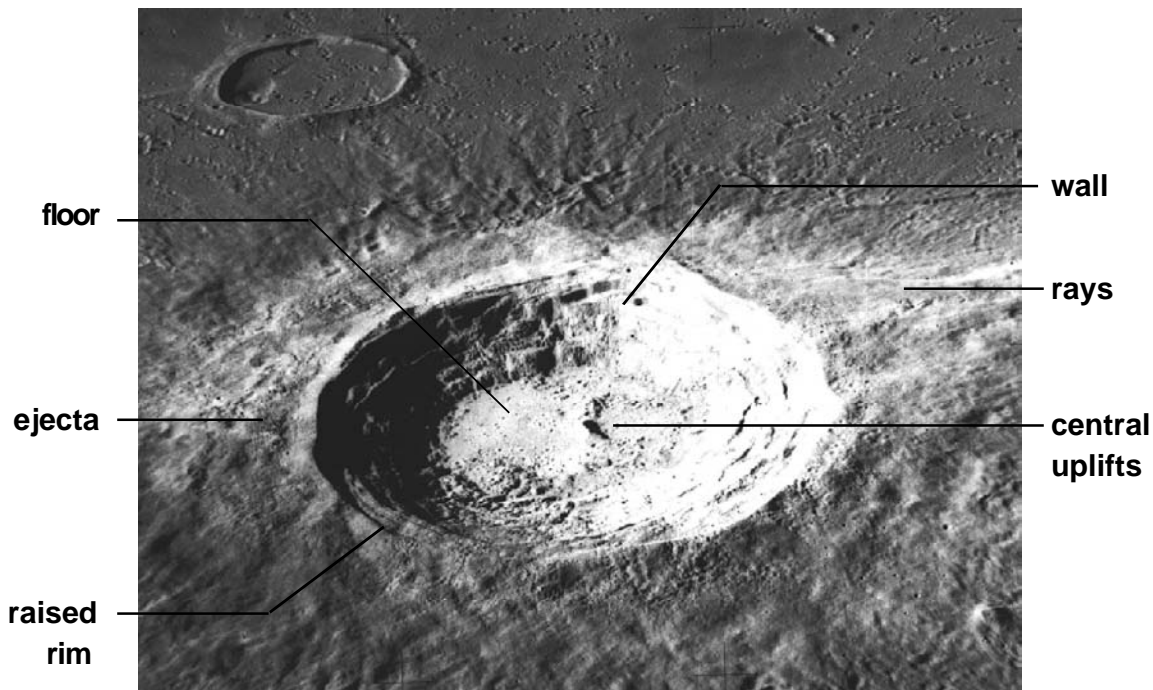
raised rim — rock thrown out of the crater and deposited as a ring-shaped pile of debris at the crater's edge during the explosion and excavcation of an impact event.

floor — bowl shaped or flat, characteristically below surrounding ground level unless filled in with lava.

central uplifts — mountains formed because of the huge increase and rapid decrease in pressure during the impact event. They occur only in the center of craters that are larger than 40 km diameter. See Tycho crater for another example.

walls — characteristically steep and may have giant stairs called terraces.

ejecta — blanket of material surrounding the crater that was excavated during the impact event. Ejecta becomes thinner away from the crater.

rays — bright streaks starting from a crater and extending away for great distances. See Copernicus crater for another example.

Impact Craters

Preparation

Review and prepare materials listed on the student sheet.

In this activity, marbles or other spheres such as steel shot, ball bearings, golf, or wooden balls are used as impactors dropped from a series of heights onto a prepared "lunar surface." Using impactors of different mass dropped from the same height will allow students to study the relationship of mass of the impactor to crater size. Dropping impactors from different heights will allow students to study the realtionship of velocity of the impactor to crater size.

The following materials work well as a base for the "lunar surface" topped with a dusting of dry tempera paint or other material in a contrasting color:

all purpose flour	- Reusable in this activity and keeps well in a covered container.
baking soda	- It can be recycled for use in the lava layer activity or for many other science activities. Reusable in this activity, even if colored, by adding a clean layer of new white baking soda on top. Keeps indefinitely in a covered container. Baking soda mixed (1:1) with table salt also works.
corn meal	- Reusable in this activity but probably not recyclable. Keeps only in freezer in airtight container.
sand and corn starch	- Mixed (1:1), sand must be very dry. Keeps only in freezer in airtight container.
dry tempera paint or powdered drink mixes or glitter	- Sift on top; use a sieve, screen, or flour sifter. A contrasting color to the base materials gives striking results.

Pans should be plastic, aluminum, or cardboard. Do not use glass. They should be at least 7.5 cm deep. Basic 10"x12" aluminum pans or plastic tubs work fine, but the larger the better to avoid misses. Also, a larger pan may allow students to drop more marbles before having to resurface the target materials.

A reproducible student "Data Chart" is included; students will need a separate chart for each impactor used in the activity.

Impact Craters

In Class

1. Begin by looking at craters in photographs of the Moon and asking students their ideas of how craters formed.

2. During this activity, the flour, baking soda, or dry paint may fall onto the floor and the baking soda may even be disbursed into the air. Spread newspapers under the pan(s) to catch spills or consider doing the activity outside. Under supervision, students have successfully dropped marbles from second-story balconies. Resurface the pan before a high drop.

3. Have the students agree beforehand on the method they will use to "smooth" and resurface the material in the pan between impacts. The material need not be packed down. Shaking or tilting the pan back and forth produces a smooth surface. Then be sure to reapply a fresh dusting of dry tempera paint or other material. Remind students that better experimental control is achieved with consistent handling of the materials. For instance, cratering results may vary if the material is packed down for some trials and not for others.

4. Allow some practice time for dropping marbles and resurfacing the materials in the pan before actually recording data.

5. Because of the low velocity of the marbles compared with the velocity of real impactors, the experimental impact craters may not have raised rims. Central uplifts and terraced walls will be absent.

6. The higher the drop height, the greater the velocity of the marble, so a larger crater will be made and the ejecta will spread out farther.

7. If the impactor were dropped from 6 meters, then the crater would be larger. The students need to extrapolate the graph out far enough to read the predicted crater diameter.

Wrap-Up

Have the class compare and contrast their hypotheses on what things affect the appearance of craters and ejecta.

Impact Craters

Extensions

1. As a grand finale for your students, demonstrate a more forceful impact using a slingshot.

2. What would happen if you change the angle of impact? How could this be tested? Try it! Do the results support your hypothesis?

   If the angle of impact is changed, then the rays will be concentrated and longer in the direction of impact. A more horizontal impact angle produces a more skewed crater shape.

3. To focus attention on the rays produced during an impact, place a paper bulls-eye target with a central hole on top of a large, flour-filled pan. Students drop a marble through the hole to measure ray lengths and orientations.

4. Use plaster of Paris or wet sand instead of dry materials.

5. Videotape the activity.

6. Some people think the extinction of the dinosaurs was caused by massive global climate changes because of a meteorite impact on Earth. Summarize the exciting work that has been done at Chicxulub on the Yucatan coast of Mexico.

7. Some people think Earth was hit by an object the size of Mars that caused a large part of Earth to "splash" into space, forming the Moon. Do you agree or disagree? Explain your answer.

8. Physics students could calculate the velocities of the impactors from various heights. (Answers from heights of 30 cm, 60 cm, 90 cm, and 2 m should, of course, agree with the velocity values shown on the "Impact Craters - Data Chart".

Name: _____

impactor # [ ]

[ ] gm

Date: _____

Impact Craters - Data Chart

		trial 1	trial 2	trial 3	total	average
drop height = 30 cm velocity = 242 cm/s	crater diameter					
	crater depth					
	average length of all rays					
drop height = 60 cm velocity = 343 cm/s	crater diameter					
	crater depth					
	average length of all rays					
drop height = 90 cm velocity = 420 cm/s	crater diameter					
	crater depth					
	average length of all rays					
drop height = 2 meters velocity = 626 cm/s	crater diameter					
	crater depth					
	average length of all rays					

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Key Words

impact

impactor

ejecta

Materials

1 pan

"lunar" surface material

tempera paint, dry

sieve or sifter
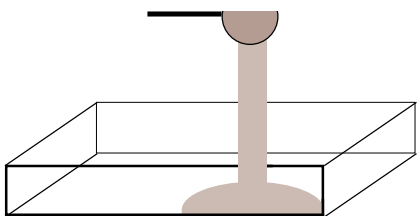
balance

3 impactors (marbles or other spheres)

meter stick

ruler, plastic with middle depression

protractor

"Data Chart" for each impactor

graph paper

Procedure

Making an hypothesis

1. After looking at photographs of the Moon, how do you think the craters were formed?

_____

_____

_____

_____

_____

2. What do you think are factors that affect the appearance and size of craters and ejecta?

_____

_____

_____

_____

_____

Preparing a "lunar" test surface

1. Fill a **pan** with **surface material** to a depth of about 2.5 cm. Smooth the surface, then tap the pan to make the materials settle evenly.

2. Sprinkle a fine layer of **dry tempera paint** evenly and completely over the surface. Use a **sieve** or **sifter** for more uniform layering.

3. What does this "lunar" surface look like before testing?

_____

_____

_____

Cratering Process

1. Use the **balance** to measure the mass of each **impactor**. Record the mass on the "**Data Chart**" for this impactor.

2. Drop impactor #1 from a height of 30 cm onto the prepared surface.

3. **Measure** the diameter and depth of the resulting crater.

4. Note the presence of ejecta (rays). Count the rays, measure, and determine the average length of all the rays.

5. Record measurements and any other observations you have about the appearance of the crater on the Data Chart. Make three trials and compute the average values.

6. Repeat steps 2 through 5 for impactor #1, increasing the drop heights to 60 cm, 90 cm, and 2 meters. Complete the Data Chart for this impactor. Note that the higher the drop height, the faster the impactor hits the surface.

7. Now repeat steps 1 through 6 for two more impactors. Use a separate Data Chart for each impactor.

8. Graph your results.
   Graph #1: Average crater diameter vs. impactor height or velocity.
   Graph #2: Average ejecta (ray) length vs. impactor height or velocity.
   Note: on the graphs, use different symbols (e.g., dot, triangle, plus, etc.) for different impactors.

Results

1. Is your hypothesis about what affects the appearance and size of craters supported by test data? Explain why or why not.

   _____

   _____

   _____

   _____

2. What do the data reveal about the relationship between crater size and velocity of impactor?

   _____

   _____

   _____

3. What do the data reveal about the relationship between ejecta (ray) length and velocity of impactor?

   _____

   _____

   _____

4. If the impactor were dropped from 6 meters, would the crater be larger or smaller? How much larger or smaller?
   (Note: the velocity of the impactor would be 1,084 cm/s.)
   Explain your answer.

   _____

   _____

   _____

   _____

5. Based on the experimental data, describe the appearance of an impact crater.

   _____

   _____

   _____

6. The size of a crater made during an impact depends not only on the mass and velocity of the impactor, but also on the amount of kinetic energy possessed by the impacting object. Kinetic energy, energy in motion, is described as:

KE = 1/2(mv²)

where, m = mass and v = velocity.
During impact, the kinetic energy of an asteroid is transferred to the target surface, breaking up rock and moving the particles around.

7. How does the kinetic energy of an impacting object relate to crater diameter?

_____

_____

8. Looking at the results in your Data Tables, which is the most imporant factor controlling the kinetic energy of a projectile, its diameter, its mass, or its velocity?

_____

_____

9. Does this make sense? How do your results compare to the kinetic energy equation?

_____

_____

_____

_____

10. Try plotting crater diameter vs. kinetic energy as Graph #3. The product of mass (in gm) and velocity (in cm/s) squared is a new unit called "erg."