

Lesson 6 — Impact Craters— Holes in the Ground!

Objectives

Students will:

- model impact craters in the lab.
- identify various structures caused by the cratering process.
- manipulate the conditions that control the size and appearance of impact craters.
- state the relationships between the size of the crater, size of the projectile, and velocity.
- demonstrate the transfer of energy in the cratering process.

Background

Impact craters are formed when pieces of asteroids or comets strike the surface of a planetary body. Craters are found on all the terrestrial planets, on the Earth's Moon, and on most satellites of planets.

Various geological clues and studies of the lunar rocks returned by the Apollo missions indicate that about 3.9 billion years ago asteroid-size chunks of matter were abundant in the solar system. This was a time of intense bombardment of the young planets, affecting Earth by breaking up and modifying parts of the crust. Mountain building, plate tectonics, weathering and erosion have largely removed the traces of Earth's early cratering period. But the near absence of weathering on the Moon has allowed the evidence of this ancient time to be preserved.

Impact craters are formed by the transfer of energy from a moving mass (meteorite) to a stationary body (planet). Kinetic energy is the energy of motion. It is defined as one half the mass of an object, times the velocity of the object squared ($K.E. = 1/2 Mv^2$). Objects in space move very fast, so this can be a huge amount of energy! In an impact the kinetic energy of a meteorite is changed into heat that melts rocks and energy that pulverizes and excavates rock. Simplified

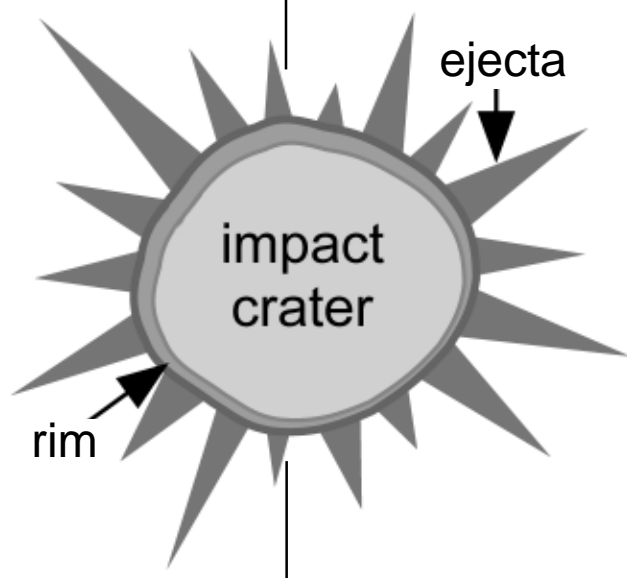
“Where do they come from?”

About This Lesson

This lesson allows students to create impact craters in plaster of Paris or layered dry materials. They perform controlled experiments by varying the velocity or mass of an object and observing and measuring the effects.

Vocabulary

crater, impact, projectile, velocity, kinetic energy, mass, gravity, ejecta, rim, meteor



demonstrations of this transfer of energy can be made by creating impacts in powdered materials. If identical objects are impacted into powdered materials from different heights or using different propulsion systems to increase velocities, then students can determine the effect velocity has on the cratering process. Likewise if projectiles of different masses are impacted from the same height and the same velocity, students will be able to identify the relationship of mass to crater formation.

The high velocity impact and explosion of an iron meteorite about 30 meters in diameter could make a crater over one kilometer wide. This is how Meteor Crater in Arizona was formed. In the classroom the low velocities and low masses will make craters much closer in size to the impacting bodies.

Energy Calculations for Advanced Classes

K.E. = kinetic energy

M = mass of impacting object (projectile)

v = velocity of impacting object (projectile)

g = gravity constant for Earth (980 cm/sec²)

h = height of release of impacting object

erg = grams × cm² × sec (measure of K.E.)



$$K.E. = 1/2 Mv^2 \text{ (meteorite impacts like Meteor Crater)}$$

$$v = \sqrt{2gh} \text{ (free fall)}$$

thus

$$K.E. = Mgh \text{ (for classroom experiments)}$$

Classroom Experiment Example

projectile - 10 grams = M

drop height - 2 meters = h

gravity effect - 980 cm/sec² = g

$$K.E. = 1/2 \times 10 \text{ grams} \times 2 \times 980 \text{ cm/sec}^2 \times 200 \text{ cm}$$

$$K.E. = \sim 2 \times 10^6 \text{ ergs}$$

Meteor Crater Estimate

projectile was 30 meters in diameter

iron nickel sphere (meteorite with a density of 8 g/cm³)

projectile 1.1 × 10¹¹ grams = M

$$4/3 \Pi (1.5 \times 10^3)^3 \text{ cm}^3 = v$$

$$(1.4 \times 10^{10} \text{ cm}^3) = v$$

$$K.E. = 1/2 Mv^2$$

$$K.E. = 1/2 \times 1.1 \times 10^{11} \text{ grams} \times (2 \times 10^6)^2$$

$$K.E. = \sim 2 \times 10^{23} \text{ ergs}$$

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Activity A: Making Craters in Plaster of Paris

Objectives

Students will:

- produce easily recognizable crater forms.
- simulate impacts into wet materials.

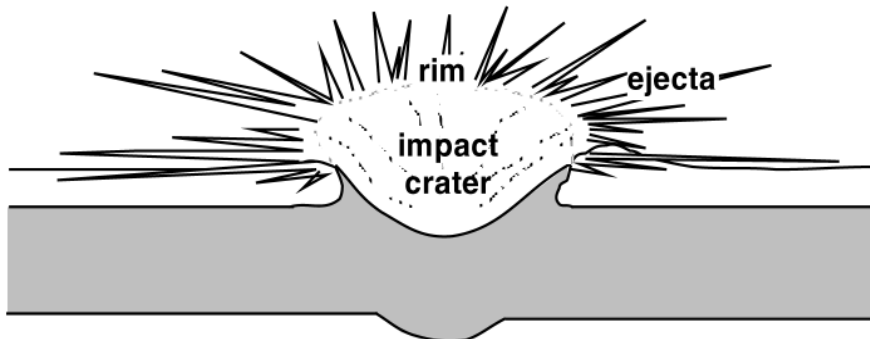
Procedure

Advanced Preparation

1. Assemble materials.
2. Practice mixing plaster of Paris to get a feel for the hardening time under classroom or outdoor conditions. Plaster for classroom use should be mixed at time of demonstration.
3. Copy one Student Procedure per group.
4. If Lesson 7 will not be completed, then consider whether crater slides could be used in this lesson.
5. Prepare plaster or direct students to mix plaster.
 - Mix the plaster of Paris. A mixture of two parts plaster of Paris to one part water works best. **REMINDER:** The plaster hardens in 10 to 20 minutes, so you must work quickly. Have Data Chart complete and all materials assembled before plaster is mixed.
 - Pour a 5 cm or more layer of plaster in a small deep disposable container.
 - **Optional:** Using a kitchen strainer or a shaker, sprinkle a thin layer of powdered tempera paint over the plaster (use a dust mask and do not get paint on clothes).

Classroom Procedure

1. Discuss background before or during activity.
2. Students work in small groups or conduct classroom demonstration.
3. Follow Student Procedure.
4. Discuss questions.



About This Activity

In this activity students create impact craters in plaster of Paris. They may perform controlled experiments by varying the velocity or mass of an object and observing the effects.

Materials for Activity A

- plaster of Paris
- 1 large disposable pan or box (*if used as a whole class demonstration*) or 3-4 small and deep containers such as margarine tubs or loaf pans (*for individuals or groups*)
- mixing container
- stirring sticks
- water (*1 part water to two parts plaster*)
- projectiles (*marbles, pebbles, steel shot, lead fishing sinkers, ball bearings*)
- dry tempera paint, (*optional*) red or blue - (*enough to sprinkle over the surface of the plaster*) or substitute baby powder, flour, corn starch, fine-colored sand, powdered gelatin, or cocoa
- strainer, shaker or sifter to distribute paint evenly
- meter stick
- Student Procedure (*pgs. 6.5-6.6, one per student*)
- dust mask
- Data Charts (*pg. 6.9, one per group*)

About This Activity

Students do controlled cratering experiments in dry materials. They vary the impactor velocity or mass and observe and measure the effects.

Materials for Activity B

- large tray or sturdy box 8-10 cm deep and about 1/2 m on each side (*a cat litter pan works nicely*); 2 per class or 1 per group
- baking soda (2-3 1.8 kg-boxes) per tray, or flour (2 bags, 2.26 kg), or fine sand (*sandbox sand, 3 kg per tray*)
- dry tempera paint - red and/or blue; enough for a thin layer to cover the dry material surface. (*Very fine craft glitter may be used as one color.*) **A nose and mouth dust mask should be used when sprinkling paint.** Suggested substitutes for paint may be found in the materials list for Activity A.
- projectiles (*provide one set of either type for each group of students*)
SET A - (*provide enough sets for all groups*) four marbles, ball bearings, or large sinkers of **identical size and weight**
SET B - (*provide one or two sets per class*) three spheres of **equal size** but **different materials** so that they will have different mass (*example: glass, plastic, rubber, steel, wood*)
- strainer or sifter to distribute the paint
- metric rulers & meter sticks
- lab balance (*one per class*)
- Data Chart (*pg. 6.9, per grp.*)
- Student Procedure (*pgs. 6.7-6.8, one per group*)

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Activity B: Making Craters in Dry Materials

Objectives

Students will:

- manipulate the variables of velocity and mass to investigate crater formation.
- recognize the conditions that control the size and appearance of impact craters.
- state the relationships between the size of the crater, size of the projectile, and velocity.

Procedure

Advanced Preparation

1. Assemble equipment.
2. Prepare projectile sets and label.
3. Copy Student Procedure and Data Charts as needed.
4. Prepare target trays of dry material and paint.
(*Optional: students prepare*)
 - Place 3 cm even layer of dry material in the bottom of a the tray (or box).
 - Sprinkle a thin layer of red powdered tempera paint over the dry material with a kitchen strainer.
 - Place another very thin (2-3 mm) even layer of dry material on top of the tempera paint, just enough to conceal paint.
 - **Optional:** Sprinkle another layer of blue powdered tempera paint on top of the second layer of dry material. Repeat step 6. (*Very fine craft glitter can be used in place of tempera paint for “sparkle” effect.*)

Classroom Procedure

Note: *This procedure is for small groups, it must be modified if the entire class will act as a single group.*

1. Students should work in small groups. Each group should choose at least three projectiles from SET A or SET B.
2. Write a description of each projectile on your Data Chart.
3. Measure the mass, dimensions of each projectile and record on the Data Chart.
4. Drop projectiles into the dry material.
Set A - Drop all projectiles from the same height or several series of experiments may be conducted from different heights. Record data and crater observations.
Set B - Drop the projectiles from different heights (suggest 2-3 m). Record all height data and crater observations.
5. Discuss the effects caused by the variables.

Student Procedure: Activity A



Materials - Per Group

- prepared plaster in container
- projectiles
- tempera paint and sifter (*optional*)
- meter stick
- Data Chart

Procedure

1. Form groups and distribute Data Charts.
2. Each group should choose at least three projectiles.
3. Write a description of each projectile on the Data Chart, including the mass and dimensions.
4. Prepare plaster according to directions from your teacher.
5. Drop the projectiles at 2 minute intervals, recording appropriate information. Each projectile requires an area of about 5x5 cm square. If you drop too many projectiles in an area, your craters will be distorted (though overlapping craters are interesting too).
6. Optional experiment — drop identical projectiles from different heights. Record heights.
7. Leave the projectiles in the plaster and allow it to harden.
8. Write a description of the experiment on the Data Chart. Illustrate and label the craters using the following terms: **rim, ejecta, impact crater.**

Questions

1. Where do you find the thickest ejecta?

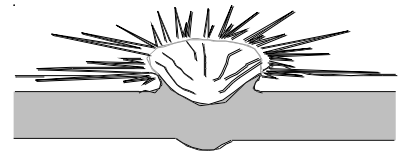
2. How do you think the crater rim formed?

3. The powder represents the planet's surface. Any material beneath the top layer must have formed at an earlier time (making it physically older).
If you were to examine a crater on the Moon, where would you find the older material?

Where would you find the younger material? Why?

4. What effect did the time intervals have on crater formation? Why?
5. What effect did different projectiles have on crater formation? (If different projectiles were used.) Why?
6. Since large meteorites often explode at or near the surface, how would the explosion affect impact crater formation?
7. How does the increased drop height affect crater formation? Why?

Student Procedure: Activity B



Materials - Per Group

- projectiles SET A and/or SET B (*optional*)
 - SET A** - four marbles, ball bearings, or large sinkers of **identical size and weight**
 - SET B** - three spheres of **equal size** but **different materials** so that they will have different mass
- strainer or sifter to distribute the dry material
- metric ruler and meter stick lab balance (*one per class*) Data Chart

Procedure

1. Each group should choose at least three projectiles from SET A or SET B.
2. Write a description of each projectile on your Data Chart.
3. Measure the mass, dimensions of each projectile and record on the Data Chart.
4. Prepare dry material layers according to directions from your teacher.
5. Drop projectiles into the dry material.
 - Set A** - Drop all projectiles from the same height or several series of experiments may be conducted from different heights. Record data and crater observations.
 - Set B** - Drop the projectiles from different heights. Record all height data and crater observations.
6. Experiment with different velocities by throwing projectiles into dry materials.
7. Discuss the effects caused by the variables.

Options:

- Plot ray length vs. mass when projectile velocity is equal.
- Plot ray length vs. velocity at a constant projectile mass. (Measure ray length from the center of crater to the end of the longest ray for each crater.)

Questions

1. What evidence was there that the energy of the falling projectile was transferred to the ground?

2. How does the velocity of a projectile affect the cratering process?
3. How does the mass of a projectile affect the cratering process?
4. If the projectile exploded just above the surface, as often happens, what changes might you see in the craters?

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Data Chart: Activity A and B



Date _____
 Names _____

Projectile Description <i>mass (g)</i> <i>dimensions (cm)</i>	Time <i>Activity A only</i>	Height	Longest Ray <i>if available</i>	Sketch of Crater <i>and comments</i> <i>(note diameter and depth)</i>

