THE BARRINGER METEORITE CRATER

www.barringercrater.com

Teacher Lesson 4: Are Craters Always Round?

Overview

Most of the craters we have seen on Mars, Mercury and the Moon are round, but is that always the case? Daniel Barringer experimented with this idea by firing bullets from different angles into mud and rocks to see if he could produce different shapes. He discovered that a projectile coming in at an oblique angle would still make a round hole.

In an impact event, when the projectile hits the target material, there is a tremendous amount of kinetic energy released (the energy of the impact at Barringer Meteorite Crater has been estimated to have been the equivalent of 2.5 Megatons of TNT!). Ejecta from the blast are thrown out of the crater in all directions, usually resulting in a circular crater when the excavation is complete. Non-circular craters require a very low impact angle, somewhere below ~30 degrees (measured from the horizontal).

PURPOSE

Students will conduct a controlled experiment to demonstrate whether the angle of impact affects the shape of the crater.

COMPLETION TIME

2 class periods/2 hours

LEARNING OBJECTIVES

☐ Students will work in teams to conduct a controlled experiment that will test one variable – the angle of impact of a projectile.

☐ Students will determine whether the angle of impact affects the final shape of the crater.

TOOLS/MATERIALS

☐ Computer access and ability to project images (see links below) or copies of the images of Amaral's color Palette, & QiBaishi/Hovnatania.

☐

For each team:

☐1 box (the tops of copy paper boxes work well, as do similar-sized plastic tubs or aluminum pans)

☐ Flour

☐ Colored sand or cocoa

☐ Marbles (same-sized for all)

Meter stick

Protractor

Copies of student data sheet “Are Craters always Round?”

Note: This activity is best done outdoors or with a protective covering on the floor (Plastic tablecloth, plastic sheet, or newspapers.)

Procedure

BEFORE THE ACTIVITY

- Prepare the target material boxes. Fill the bottom with flour, then layer the top with a thin layer of colored sand or cocoa.
- Copy the student data sheets.
- Print out copies of the image of the craters or prepare to project them to the class

ON THE DAY OF THE ACTIVITY

1. Ignite Curiosity about Crater Shapes (10 minutes)

- Show the class the image of craters (Moon) http://hyperphysics.phy-astr.gsu.edu/hbase/solar/mooncrater.html
- Craters on Mercury/Rustaveli Basin (basin = large crater) http://messenger.jhuapl.edu/Explore/Science-Images-Database/pics/Rustaveli_2015.png
- Ask them: How would you describe the shape of most of the craters seen here? (they’re round or circular)
- Ask: From what direction do you think the meteoroids, asteroids or comets were coming in from to create these round craters? (from right above, different directions – accept all answers)
- Remind them that Daniel Barringer thought that the meteorite in Arizona came straight down on impact.
- Explain that projectiles bombard the planets and the Moon from different directions, measured in angles from the horizontal.
- Ask: But if they’re coming in at different angles, will the craters always be circular? (Accept all answers and build sense of mystery)
- Tell them that Barringer wondered the same thing and he tested his idea by shooting bullets from a rifle at mud and rocks from different angles.

Explain that they will have a chance to see for themselves if the impact angle affects the shape of a crater.

(Note: Don't reveal too much about the results of his tests or offer information from the overview until their investigations are complete!)

2. Lecture: New Information on Controlled Experiments and Variables (20 minutes)

- Hand out the data sheets and read over the directions together.
- Explain that they will conduct a controlled experiment.The problem they are investigating is **whether the impact angle of a projectile affects the shape of the final crater.**
- Remind them that in a fair test (or controlled experiment), one condition or variable, affects the outcome of another condition, while all other conditions remain the same.
- Write Definitions on Board: Independent Variable, Dependent Variables, and Controlled Variables (Independent - What I change; Dependent - What I Observe; Controlled Variables- What I keep the same.) Have students write definitions in notebook.
- Write Example on Board: Apply definition to an example (baking cookies). See if the class can use the terms correctly. (possible baking cookies example: Independent Variable - length of time in oven/ Dependent Variable- chewiness/Controlled Variables- ingredients, heat of oven)
- Tell them that for this experiment the condition that will change **(independent variable) is the impact angle.**
- The condition that will be **affected (dependent variable) will be the shape of the crater.**
- The condition that remains constant **(control variable) will be the height from which the projectile will be released.**

3. Solve Data- Gathering Questions (15 minutes)

- Develop a plan with your class on how to describe the shape of the craters produced: circular, ellipse, other? Is there a way to measure it? (maybe measure diameter in 2 different locations?) How will you determine if it's a circle or an ellipse?
- Tell the students to make a prediction about how the shape of the crater might or might not change with the impact angle before they begin. (And write it on their data sheet)

- Tell them to document all of their data in their science notebooks – they will need to develop their own table or chart using the variables discussed after the investigation! Some students may be able to design one themselves; others may need your help.

- Read through the components of the required conclusion. (on student handout)

4. Review Data-Gathering Process (5 minutes)

- Explain how to make the throws:

  Point out that the 45° angle and the low angle impacts will be approximations.

  Draw the angles on a whiteboard or have them draw them on a poster board to give them a sense of what the angled throws will look like.

  Note: Statistically, the most common angle of impact is 45 degrees as derived by Karl Gilbert, and again by Gene Shoemaker.

- **Remind** them that the **only** variable that should change will be the angle of impact.

  Tell them it's important that all throws begin no higher than 100 cm from the target box so that the speed remains about the same. (The marble will gain speed as it falls, so the farther it falls, the faster its speed when it hits the target material.)

  Also, tell them that they need to **throw** the marble straight down, not just drop it or else there will be an inherent velocity difference when doing an angled throw.

- Explain that they are looking for the shape of the crater, not the size. Measurements will only help them decide if it's circular.

6. Apply Data-Gathering Process (30 minutes)

If cameras are available, have students photograph results.

7. Prepare and Deliver Experiment Results (30 minutes)

- Create data table/graph to present data (by hand or with computer)
- Write conclusion that includes all the points on the handout.
- Summarize findings for class (give clear criteria on time limit)

8. Scientific Results (10 minutes)

- After all the teams have reported, share the results of Barringer's tests.
- Explain that most impacts produce round craters, the exceptions being impacts at very low angles.

- Show them the image of the low angle impacts (Qibaishi & Hovnatania) from NASA's photojournal.

QiBaishi & Hovnatania craters
http://photojournal.jpl.nasa.gov/figures/PIA12039_fig1.jpg

- Ask them what they see (ejecta in different patterns?) How did this happen? (accept all answers)

- Explain that when an impact angle is low (about 30 degrees) the ejecta develops an uprange zone of avoidance – basically no ejecta falls in a small arc that points back uprange. If you see ejecta like this, you can tell what direction the impactor came from (direction where there is no ejecta). If the angle is even lower (about 10 degrees), you get the same uprange zone of avoidance and also a downrange zone of avoidance. The ejecta looks like a butterfly. In this case, you can tell one of two directions the impactor came from, but can't narrow it down to one!

ASSESSMENT CRITERIA

Did the students stay within the parameters of the experiment?

Did the students complete all aspects of the experiment?

Did the students show an understanding of the different kinds of variables?

Did the students communicate an understanding of the relationship between angle of impact and the shape of the crater?

Did the student develop a reasonable conclusion that communicates understanding of the investigation?

Extension: A Square Crater?

Show the students the satellite image of Barringer Meteorite Crater:
http://www.barringercrater.com/livewhale/content/images/1/18_800px-meteor_crater_-_arizona.jpg

- Most craters are round or nearly round. Barringer Meteor Crater appears almost square in shape. Why? It has to do with the tectonic structure of the target area. The pre-impact target area had fractures or joints lying at roughly right angles to one another. These represent weakness directions, and when the impact occurred, excavation was more efficient in certain directions, creating the square shape!
- Read more about square craters on Eros (a near-earth asteroid) here:

http://science.nasa.gov/science-news/science-at-nasa/2000/ast26sep_1/

Links

Moon Image: http://hyperphysics.phy-astr.gsu.edu/hbase/solar/mooncrater.html

Satellite image of the Barringer Meteor Crater:
http://www.barringercrater.com/livewhale/content/images/1/18_800px-meteor_crater_-_arizona.jpg

Craters on Mercury/Rustaveli Basin (basin = large crater)
http://messenger.jhuapl.edu/Explore/Science-Images-Database/pics/Rustaveli_2015.png

QiBaishi & Hovnatania craters
http://photojournal.jpl.nasa.gov/figures/PIA12039_fig1.jpg

Hands-on classroom activities simulating impacts are available on the following sites:

Mapping the Moon, Mercury, Mars and more…:http://cosmoquest.org/
(students will need to login in to participate)

Activity design by Lollie Garay in collaboration with Dr. Carolyn Ernst, adapted from Exploring Meteorite Mysteries, ARES/JSC/NASA