Craters: Real and Simulated

Looking at the Moon through a telescope, the first things you notice are the craters. Big craters, little craters, huge craters, and even craters that overlap.

Some areas seem devoid of craters while others are covered. What created the craters on the Moon? Was it mostly volcanic activity or impacts? For years, scientists were not sure. Two geologists debated these questions in the early 1960s. Jack Green (1925–2014) thought the craters were inactive volcanoes. Gene Shoemaker (1928–1997) thought the craters were scars from impacts on the Moon’s surface.

Both geologists looked for evidence to support their claims. One piece of the evidence that helped answer the question was shocked quartz. This mineral turned up in underground test sites for nuclear bombs. Shocked quartz forms under tremendous pressure, like that generated by a nuclear explosion. Shoemaker found shocked quartz inside the Barringer Crater in Arizona. The shocked quartz confirmed that this crater resulted from an impact. A volcano would not generate enough pressure to create shocked quartz.

The Moon’s surface is pocked with thousands of craters, from microscopic to massive. Scientific evidence solved the mystery of their formation.
Green and Shoemaker agreed that if they could examine Moon rocks from the larger craters, they would have enough evidence to know which process produced the craters on the Moon. The Apollo missions provided the rock samples that confirmed the impact theory.

**Collisions**

The solar system was young over 4 billion years ago. A huge number of small objects were flying around and colliding. Sometimes, the objects broke into smaller pieces. Other times, they stuck together. In the first half billion years of the solar system, violent collisions were very frequent. There was no chance of life on any planet with all these collisions.

Even today, countless small- and medium-sized pieces of rock and metal, called *meteoroids*, orbit the Sun. Tiny particles rain down on Earth every day. Most of them slow down and burn up in Earth’s atmosphere. Slightly larger ones, gravel- and pebble-sized, streak across the night sky. These *meteors* are also known as shooting stars.
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But the atmosphere only slows and burns small objects. Larger objects move right through the atmosphere as easily as a stone through a spider web. Some of these are relatively small, and some are the size of cities. These larger objects are called **asteroids**. Many asteroids are orbiting the Sun between the orbits of Mars and Jupiter. This region is the **asteroid belt**. Many other asteroids have orbits that go through the inner solar system. When a meteoroid or an asteroid hits a moon or a planet, it creates a crater. Tiny meteors make craters that are microscopic. Large asteroids can produce huge craters. You could walk many hours or even days to cross one of these craters.

Icy objects, called **comets**, sometimes fly through the inner solar system. Comets orbit the Sun. Most of the time, they are beyond the outermost planets in the solar system, in the **Oort Cloud**.

A comet can take decades or even hundreds of years to complete one orbit. A comet might end up on a collision course with a moon or a planet. Comet Shoemaker-Levy 9 neared Jupiter in 1994. Jupiter’s gravity ripped it into more than 20 pieces, which hit the planet. If a comet or an asteroid of this magnitude were to hit the Moon, the resulting crater would be a major feature on the Moon’s surface.

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Simulations

Scientists and students can simulate impacts to study crater formation. Sand or flour simulates the Moon's surface. Marbles or rocks simulate meteoroids. The "meteoroids" drop on the surface material. The resulting craters have the characteristic hole, rim, ejecta, and rays of natural craters. But one thing is different. The speed of the marble or rock is far slower than the speed of debris traveling through space. It is impossible for a marble to represent what really happens when a meteoroid or an asteroid slams into the Moon.

A meteoroid traveling 72,000 kilometers (km) per hour (20 km per second) crashing into the Moon will cause major damage. The impact releases a tremendous amount of energy. The force of the impact creates so much pressure and thermal energy that the meteoroid can explode and disappear. The explosion creates the crater by blasting the soil away.

Scientists have studied crater formation on Earth. They observe the results of explosions at bomb test sites in large expanses of sand. These events are similar to what happens when a meteoroid hits.

Take Note

Review the procedure and findings of the crater experiment from class. Make a new notebook entry. Explain how your experiment was similar to and different from an actual meteoroid impact.

Dropping marbles into flour is one way you can simulate crater formation on the Moon's surface.
Simple and Complex Craters

Small explosions produce small bowl-shaped craters with a fairly even blanket of ejecta around the rim. These are called simple craters.

Larger explosions produce a lot of pressure below the impact. The shock wave after the explosion often pushes up a big mountain in the middle of the crater. Complex craters often have central peaks, and ejecta thrown out in long rays.

Really big complex craters also have terraces. They look like giant steps leading from the crater floor up to the rim.

Simple Craters

Simple craters are circular, bowl-shaped depressions.

Terraced craters have stepped walls caused by landslides.

This typical complex crater has a central peak.

Can you see the circular shape of the original impact crater? Can you see craters that have since formed on the dark surface of the mare?

In the past, the Moon had a molten core. Sometimes, an impact was so huge that it cracked the outer layers of the Moon. Magma would seep up and create a flooded crater. When the magma cooled, the dark rock became smooth and uniform. This rock creates a mare (plural maria). Later impacts can make new marks in the mare.

Take Note

Describe the shape of the original impact crater. Can you see craters that have formed on the dark surface of the mare? What is older, the mare or the craters?
Comparing Models to Actual Craters

In class, you simulated the formation of craters on the Moon by dropping marbles into flour. You produced craters like those seen on the Moon. How are these craters like real Moon craters, and how are they different?

**Size of craters.** Your craters are 2–3 centimeters (cm) in **diameter**. The smallest Moon craters are microscopic. The largest one, the Aitken basin at the Moon’s south pole, is 2,500 km across and 13 km deep. It would cover most of the United States! The Imbrium basin (Mare Imbrium), another large impact crater, is 1,200 km across.

**Size of projectiles.** Your marbles are approximately 1.5 cm in diameter. Scientists believe the asteroid that created the Imbrium basin was 100 km in diameter. A meteoroid as large as New Hampshire can create a crater almost as large as the continental United States. The objects that made the craters on the Moon varied in size.

This impact crater was formed 50,000 years ago when a meteorite struck Earth in the Arizona desert. Scientists believe that the nickel-iron meteorite, 45 m wide and weighing 300,000 tons, vaporized on impact.
**Speed of projectiles.** Dropped from a height of 200 cm, or 2 meters (m), your marbles reach a speed of perhaps 1 km per hour. The asteroids and meteoroids that struck the Moon were traveling at speeds of about 72,000 km per hour! Unlike Earth, the Moon has no atmosphere to slow a meteoroid as it approaches the surface.

**Impact.** When your marbles strike the flour, a splash of flour sprays out across the surface of the pan. On the Moon, large meteoroids hit and exploded. The thermal energy generated by the impact is so intense that the rock and the meteoroid instantly vaporize. Expanding gases cause an explosion. It blasts a huge hole and throws debris in all directions. So a 100 km object can create a crater with a diameter of 1,200 km.

**Take Note**
Draw a line of learning under your notebook entry that compares the crater experiment to an actual impact. Add ideas using information from this article.

**Think Questions**
The photo below is Barringer Crater in Arizona. Think about how it might have formed.
1. Is it a simple or complex crater?
2. How old do you think it might be? Why?
3. Why do you think Earth has so few craters and the Moon has so many?