1 FOCUS

Section Objectives

22.7 **Describe** how the physical features of the lunar surface were created.

22.8 **Explain** the history of the moon.

Reading Focus

Build Vocabulary L2

Vocabulary Rating Chart Have students construct a chart with four columns labeled Term, Can Define or Use It, Heard or Seen It, and Don't Know. Have students copy the terms *crater*, *ray*, *mare*, *rille*, and *lunar regolith* into the first column and rate their term knowledge by putting a check in one of the other columns. Ask how many students actually know each term. Have them share their knowledge. Ask focused questions to help students predict text content based on the term, thus enabling them to have a purpose for reading. After students have read the section, have them rate their knowledge again.

Reading Strategy L2

a. Huge quantities of crust and mantle were ejected into space.
b. The debris began orbiting Earth.
c. Debris united to form the moon.

22.3 Earth's Moon

Reading Focus

Key Concepts

- What processes create surface features on the moon?
- How did the moon form?

Vocabulary

- crater
- ray
- mare
- rille
- lunar regolith

Reading Strategy

Sequencing Copy the flowchart below. As you read, fill in the stages leading to the formation of the moon.

Mars-size body impacted Earth. → a. ? → b. ? → c. ?

Earth now has hundreds of satellites. Only one natural satellite, the moon, accompanies us on our annual journey around the sun. Other planets have moons. But our planet-satellite system is unusual in the solar system, because Earth's moon is unusually large compared to its parent planet. The diameter of the moon is 3475 kilometers, about one-fourth of Earth's 12,756 kilometers.

Figure 18 This is what the moon's surface looks like from Earth when viewed through a telescope.

Much of what we know about the moon, shown in Figure 18, comes from data gathered by the *Apollo* moon missions. Six *Apollo* spacecraft landed on the moon between 1969 and 1972. Uncrewed spacecraft such as the *Lunar Prospector* have also explored the moon's surface. From calculation of the moon's mass, we know that its density is 3.3 times that of water. This density is comparable to that of mantle rocks on Earth. But it is considerably less than Earth's average density, which is 5.5 times that of water. Geologists have suggested that this difference can be accounted for if the moon's iron core is small. The gravitational attraction at the lunar surface is one-sixth of that experienced on Earth's surface. (A 150-pound person on Earth weighs only 25 pounds on the moon). This difference allows an astronaut to carry a heavy life-support system easily. An astronaut on the moon could jump six times higher than on Earth.

The Lunar Surface

When Galileo first pointed his telescope toward the moon, he saw two different types of landscape—dark lowlands and bright highlands. Because the dark regions resembled seas on Earth, they were later named maria, which comes from the Latin word for *sea.* Today we know that the moon has no atmosphere or water. Therefore, the moon doesn't have the weathering and erosion that continually change Earth's surface. Also, tectonic forces aren't active on the moon, therefore volcanic eruptions no longer occur. However, because the moon is unprotected by an atmosphere, a different kind of erosion occurs. Tiny particles from space continually bombard its surface and gradually smooth out the landscape. Moon rocks become slightly rounded on top after a long time at the lunar surface. Even so, it is unlikely that the moon has changed very much in the last 3 billion years, except for a few craters.

Craters The most obvious features of the lunar surface are **craters,** which are round depressions in the surface of the moon. There are many craters on the moon. The moon even has craters within craters! The larger craters are about 250 kilometers in diameter, about the width of Indiana. **Most craters were produced by the impact of rapidly moving debris.**

By contrast, Earth has only about a dozen easily recognized impact craters. Friction with Earth's atmosphere burns up small debris before it reaches the ground. Evidence for most of the craters that formed in Earth's history has been destroyed by erosion or tectonic processes.

The formation of an impact crater is modeled in Figure 19. Upon impact, the colliding object compresses the material it strikes. This process is similar to the splash that occurs when a rock is dropped into water. A central peak forms after the impact.

Most of the ejected material lands near the crater, building a rim around it. The heat generated by the impact is enough to melt rock. Astronauts have brought back samples of glass and rock formed when fragments and dust were welded together by the impact.

Formation of a Crater

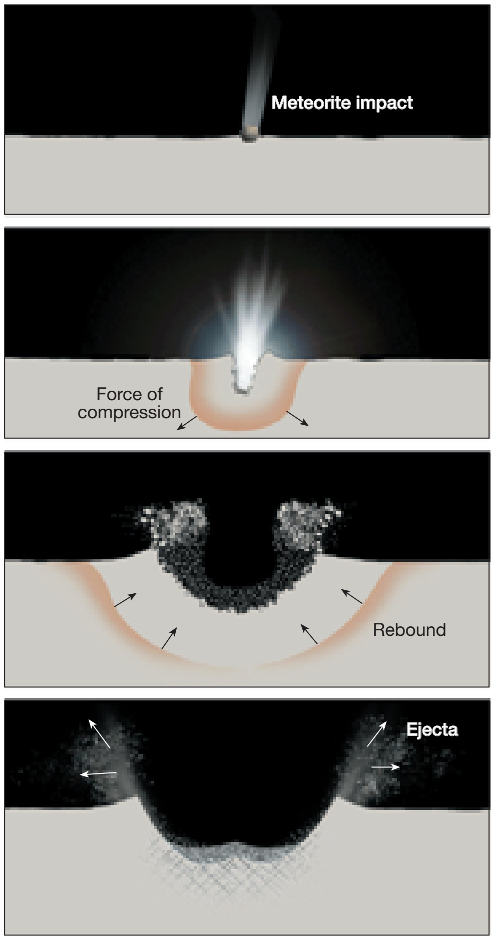


Figure 19 The energy of the rapidly moving meteoroid is transformed into heat energy. Rock compresses, then quickly rebounds. The rebounding rock causes debris to be ejected from the crater.

2 INSTRUCT

The Lunar Surface

Build Reading Literacy L1

Refer to **p. 306D** in **Chapter 11,** which provides the guidelines for KWL (Know/Want to Know/Learned) charts.

KWL Teach this independent study skill as a whole-class exercise.

1. Draw a three-column KWL chart on the board for students to copy.
2. Have students complete the Know column with facts, examples, and other information that they already know about the lunar surface.
3. Tell students to complete the Want to Know column with questions about the moon's surface.
4. Have students read pp. 631 and 632 about the moon. As they read, have them note answers to their questions in the Learned column, along with facts, examples, and details they learned.
5. Have students draw an Information I Expect to Use box below their KWL chart. Have them review the information in the Learned column and categorize the useful information in the box.

Verbal

Customize for Inclusion Students

Visually Impaired Have students with visual impairments feel the topography of the moon, using a relief globe or map of the moon. Assign visually-impaired students a partner to guide their fingers and to read the map or globe for them. Discuss with students what they have discovered about the surface of the moon.

Build Science Skills

L2

Using Models
Purpose Students will model the surface features of the lunar surface.

ACTIVITY

Materials foam poster board; soft modeling clay; toothpicks; narrow paper strips; tape; pencil, pen, or marker

Class Time 30 minutes

Procedure Have students use Figure 20 as a guide for their topographic map. First, instruct students to draw the physical features on the foam poster board. Next, have students use the soft modeling clay to build the surface features. Then students should create flag-type labels for the physical features, using narrow strips of paper, toothpicks, and tape. Finally, have students use the markers to identify the physical features on the surface of their topographical map.

Expected Outcome Students learn the major topographical surface features on the lunar surface.
Visual, Kinesthetic

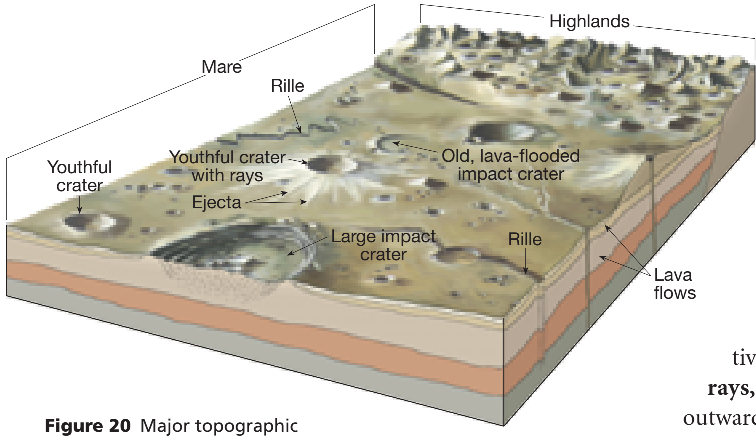


Figure 20 Major topographic features on the moon's surface include craters, maria, and highlands.
Identifying ***Where are rilles located?***

A meteoroid only 3 meters in diameter can blast out a 150-meter-wide crater. A few of the large craters, such as those named Kepler and Copernicus, formed from the impact of bodies 1 kilometer or more in diameter. These two large craters are thought to be relatively young because of the bright **rays,** or splash marks that radiate outward for hundreds of kilometers.

Highlands Most of the lunar surface is made up of densely pitted, light-colored areas known as highlands. In fact, highlands cover the surface of the far side of the moon. The same side of the moon always faces Earth. Within the highland regions are mountain ranges. The highest lunar peaks reach elevations of almost 8 kilometers. This is only 1 kilometer lower than Mount Everest. Figure 20 shows highlands and other features of the moon.

Maria The dark, relatively smooth area on the moon's surface is called a **mare** (plural: maria). **Maria, ancient beds of basaltic lava, originated when asteroids punctured the lunar surface, letting magma bleed out.** Apparently the craters were flooded with layer upon layer of very fluid basaltic lava somewhat resembling the Columbia Plateau in the northwestern United States. The lava flows are often over 30 meters thick. The total thickness of the material that fills the maria could reach thousands of meters.

Long channels called **rilles** are associated with maria. Rilles look somewhat similar to valleys or trenches. Rilles may be the remnants of ancient lava flows.

Regolith All lunar terrains are mantled with a layer of gray debris derived from a few billion years of bombardment from meteorites. This soil-like layer, called **lunar regolith,** is composed of igneous rocks, glass beads, and fine lunar dust. In the maria that have been explored by *Apollo* astronauts, the lunar regolith is just over 3 meters thick.

Reading Checkpoint ***What is lunar regolith?***

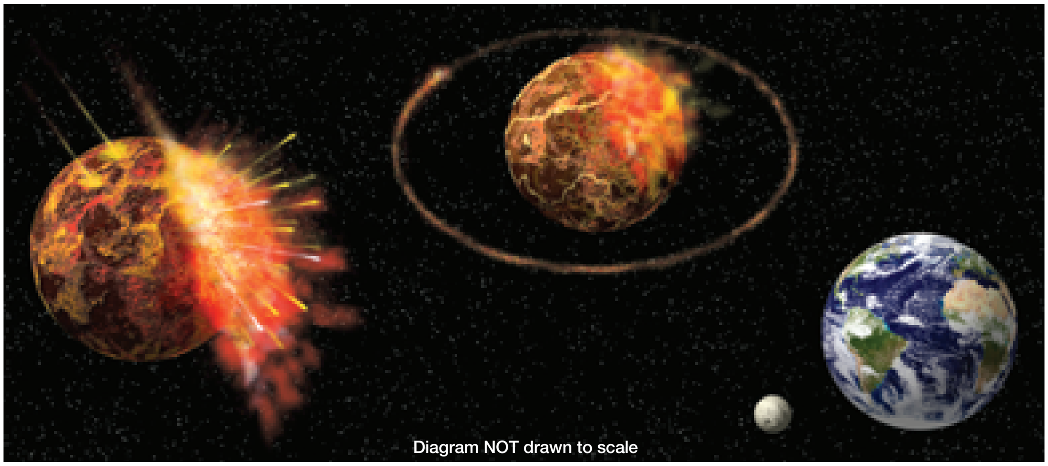


Figure 21 The moon may have formed when a large object collided with Earth. The resulting debris was ejected into space. The debris began orbiting around Earth and eventually united to form the moon.

Lunar History

The moon is our nearest planetary neighbor. Although astronauts have walked on its surface, much is still unknown about its origin. **The most widely accepted model for the origin of the moon is that when the solar system was forming, a body the size of Mars impacted Earth.** The impact, shown in Figure 21, would have liquefied Earth's surface and ejected huge quantities of crustal and mantle rock from an infant Earth. A portion of this ejected debris would have entered an orbit around Earth where it combined to form the moon.

The giant-impact hypothesis is consistent with other facts known about the moon. The ejected material would have been mostly iron-poor mantle and crustal rocks. These would account for the lack of a sizable iron core on the moon. The ejected material would have remained in orbit long enough to have lost the water that the moon lacks. Despite this supporting evidence, some questions remain unanswered.

Geologists have worked out the basic details of the moon's later history. One of their methods is to observe variations in crater density (the number of craters per unit area). The greater the crater density, the older the surface must be. From such evidence, scientists concluded that the moon evolved in three phases—the original crust (highlands), maria basins, and rayed craters.

During its early history, the moon was continually impacted as it swept up debris. This continuous attack, combined with radioactive decay, generated enough heat to melt the moon's outer shell and possibly the interior as well. Remnants of this original crust occupy the densely cratered highlands. These highlands have been estimated to be as much as 4.5 billion years old, about the same age as Earth.

Lunar History

Integrate Language Arts L2

Much of the scientific information that is known about the composition of the lunar surface is due to the Apollo Space Program. Have students research the scientific discoveries that were made as a result of this program. Students should prepare a presentation about the information they have learned. If possible, encourage students to make a computer presentation that includes actual photographs from the various missions.
Verbal, Portfolio

Use Visuals L1

Figure 21 Have students study this figure. Ask: **What evidence suggests that the moon came from mostly iron-poor mantle and crustal rocks from Earth?** *(The lack of a sizeable iron core on the moon)* **Why doesn't this ejected material contain water?** *(The material has been in orbit long enough to have lost any water that it may have had.)*
Verbal

Facts and Figures

The United States was not the only country with a space program. The former Union of Soviet Socialist Republics also had one. In fact, the U.S.S.R. was the first country to launch an artificial Earth satellite, *Sputnik 1*, in 1957. In early 1959, the Soviet spacecraft, *Luna 1*, became the first artificial object to orbit the sun. Later in 1959, *Luna 2* crashed into the moon to become the first artificial object on the lunar surface. Also in 1959, *Luna 3* took the first pictures of the moon's far side. The Soviet goal to send the first crewed spacecraft to the moon was never realized. In 1969, the United States became the first country that safely landed a person on the moon.

Answer to . . .

Figure 20 *Rilles are associated with maria.*

Reading Checkpoint *a soil-like layer of igneous rocks, glass beads, and fine lunar dust*

Section 22.3 (continued)

3 ASSESS

Evaluate Understanding

L2

Have students make flashcards on the details found in this section. Tell students to write a question on one side of the card and the answer on the other. Students can use these flashcards to quiz each other in class.

Reteach

L1

Write the headings *Lunar Surface* and *Lunar History* on the board. Ask students to give you facts from the section about each topic. Write the information under the appropriate heading. Students can copy this information from the board and use it as a study aid.

Connecting Concepts

Scientists observe variations in crater density. They also analyze material gathered from space missions.

Figure 22 Rayed craters such as Copernicus were the last major features to form on the moon.

One important event in the moon's evolution was the formation of maria basins. Radiometric dating of the maria basalts puts their age between 3.2 billion and 3.8 billion years, about a billion years younger than the initial crust. In places, the lava flows overlap the highlands, which also explains the younger age of the maria deposits.

The last prominent features to form were the rayed craters. Material ejected from these young depressions is clearly seen covering the surface of the maria and many older rayless craters. Even a relatively young crater like Copernicus, shown in Figure 22, must be millions of years old. If it had formed on Earth, erosional forces would have erased it long ago. If photographs of the moon taken several hundreds of millions of years ago were available, they would show that the moon has changed little. The moon is an inactive body wandering through space and time.

Section 22.3 Assessment

Reviewing Concepts

1. How do craters form?
2. How did maria originate?
3. What are the stages that formed the moon.

Critical Thinking

4. **Identifying** On Earth, the four major spheres (atmosphere, hydrosphere, solid Earth, and biosphere) interact as a system. Which of these spheres are absent, or nearly absent, on the moon? Based on your answer, identify at least five processes that operate on Earth but not on the moon.
5. **Inferring** Why are craters more common on the moon than on Earth, even though the moon is a much smaller target?

Connecting Concepts

Scientific Evidence Write a paragraph explaining what evidence scientists use to reconstruct the history of the moon.

Section 22.3 Assessment

1. Craters form from the impact of rapidly moving debris.
2. when asteroids punctuated the lunar surface, letting magma bleed out
3. A Mars-sized object collided with Earth. Huge quantities of crust and mantle were ejected into space. The debris began orbiting Earth and eventually united to form the moon.
4. Of the four spheres, the atmosphere, hydrosphere, and biosphere are absent, or nearly absent, on the moon. Because the moon lacks these spheres, processes such as chemical weathering, erosion, soil formation, weather in general, and sedimentation are all absent.
5. Erosion and subduction have removed most craters from Earth's surface.

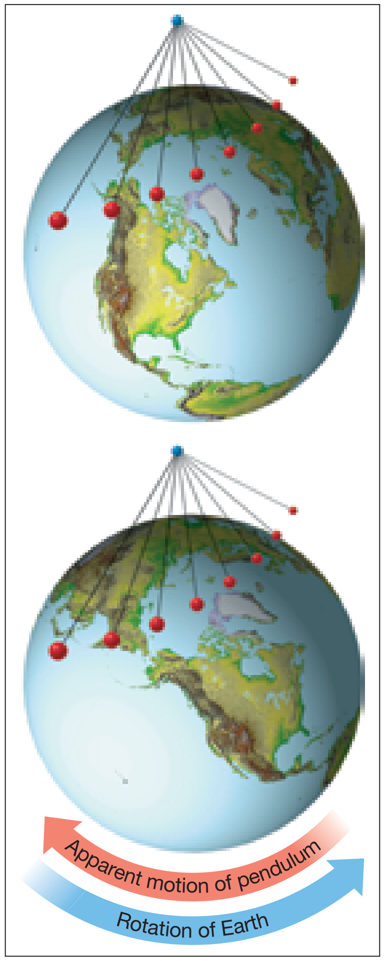
understanding EARTH

Foucault's Experiment

Earth rotates on its axis once each day to produce periods of daylight and darkness. However, day and night and the apparent motions of the stars can be accounted for equally well by a sun and celestial sphere that revolve around a stationary Earth. Copernicus realized that a rotating Earth greatly simplified the existing model of the universe. He was unable, however, to prove that Earth rotates. The first real proof was presented 300 years after his death by the French physicist Jean Foucault.

The Swinging Pendulum

In 1851, Foucault used a free-swinging pendulum to demonstrate that Earth does, in fact, turn on its axis. To picture Foucault's experiment, imagine a large pendulum swinging over the North Pole, as shown in the illustration on this page. Keep in mind that once a pendulum is put into motion, it continues swinging in the same plane unless acted upon by some outside force. Assume that a sharp point is attached to the bottom of this pendulum, marking the snow as it swings. If we were to observe the marks made by the point, we would see that the pendulum is slowly but continually changing position. At the end of 24 hours, the pendulum would have returned to its starting position.



Evidence of Earth's Rotation

No outside force acted on the pendulum to change its position. So what we observed must have been Earth rotating beneath the pendulum. Foucault conducted a similar experiment when he suspended a long pendulum from the dome of the Pantheon in Paris. Today, Foucault pendulums can be found in some museums to re-create this famous scientific experiment.

understanding EARTH

Foucault's Experiment L2

Background
The Foucault pendulum was constructed in 1851 by Jean Bernard Foucault and was demonstrated for the first time at the world's fair in Paris. The pendulum consisted of a 28-kg iron ball suspended from the dome of the Pantheon by a 67-m long steel wire.

Teaching Tips
After students have read p. 635, ask: **Once the pendulum is set in motion, it will continue to swing in the same direction unless it is pushed or pulled by a force. Why is this true?** *(The pendulum's motion will obey Newton's first law of motion.)*

What outside force is acting on the pendulum? *(There is no outside force acting on the pendulum.)*

Why does the pendulum change position over time? *(The pendulum did not change position, Earth moved beneath the pendulum.)*

How does this prove that Earth is rotating? *(The pendulum continued moving in the same direction because no outside force acted upon it. Since the pendulum did not change its motion, Earth beneath it must be moving.)*
Verbal

Origin of Modern Astronomy 635