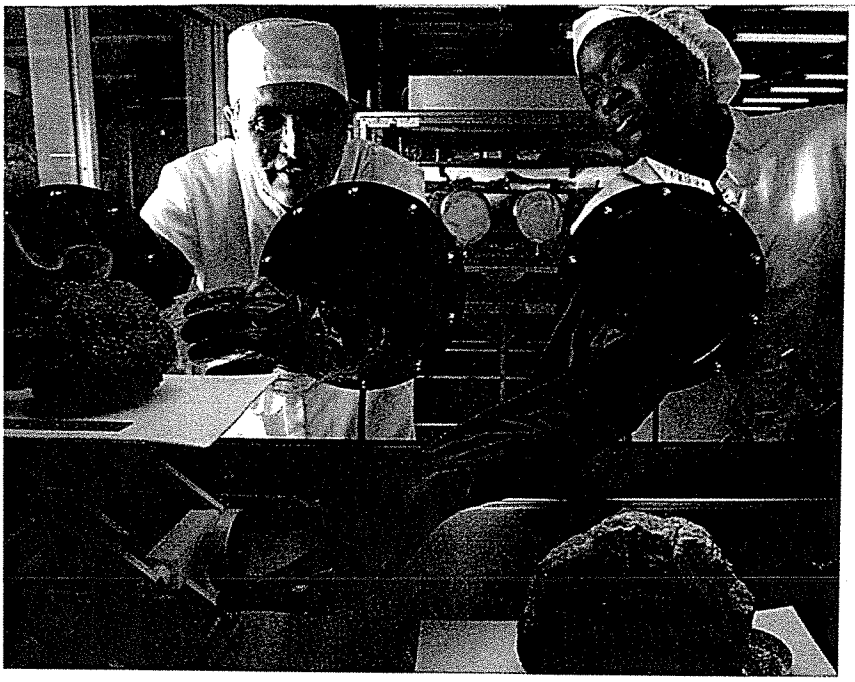


Figure 14 Moon rocks collected by astronauts provide scientists with information about the Moon and Earth.

The Moon in History Studying the Moon's phases and eclipses led to the conclusion that both Earth and the Moon were in motion around the Sun. The curved shadow Earth casts on the Moon indicated to early scientists that Earth was spherical. When Galileo first turned his telescope toward the Moon, he found a surface scarred by craters and maria. Before that time, many people believed that all planetary bodies were perfectly smooth and lacking surface features. Now, actual moon rocks are available for scientists to study, as seen in **Figure 14.** By doing so, they hope to learn more about Earth.

Reading Check *How has observing the Moon been important to science?*

SECTION 2 REVIEW

Summary

Motions of the Moon

- The Moon rotates on its axis about once each month.
- The Moon also revolves around Earth about once every 27.3 days.
- The Moon shines because it reflects sunlight.

Phases of the Moon

- During the waxing phases, the illuminated portion of the Moon grows larger.
- During waning phases, the illuminated portion of the Moon grows smaller.
- Earth passing directly between the Sun and the Moon causes a lunar eclipse.
- The Moon passing between Earth and the Sun causes a solar eclipse.

Structure and Origin of the Moon

- The Moon's surface is covered with depressions called impact craters.
- Flat, dark regions within craters are called maria.
- The Moon may have formed as the result of a collision between Earth and a Mars-sized object.

Self Check

1. **Explain** how the Sun, Moon, and Earth are positioned relative to each other during a new moon and how this alignment changes to produce a full moon.
2. **Describe** what phase the Moon must be in to have a lunar eclipse. A solar eclipse?
3. **Define** the terms *umbra* and *penumbra* and explain how they relate to eclipses.
4. **Explain** why lunar eclipses are more common than solar eclipses and why so few people ever have a chance to view a total solar eclipse.
5. **Think Critically** What do the surface features and their distribution on the Moon's surface tell you about its history?

Applying Math

6. **Solve Simple Equations** The Moon travels in its orbit at about 3,400 km/h. Therefore, during a solar eclipse, its shadow sweeps at this speed from west to east. However, Earth rotates from west to east at about 1,670 km/h near the equator. At what speed does the shadow really move across this part of Earth's surface?

section 3

Exploring Earth's Moon

as you read

What You'll Learn

- **Describe** recent discoveries about the Moon.
- **Examine** facts about the Moon that might influence future space travel.

Why It's Important

Continuing moon missions may result in discoveries about Earth's origin.

Review Vocabulary

comet: space object orbiting the Sun formed from dust and rock particles mixed with frozen water, methane, and ammonia

New Vocabulary

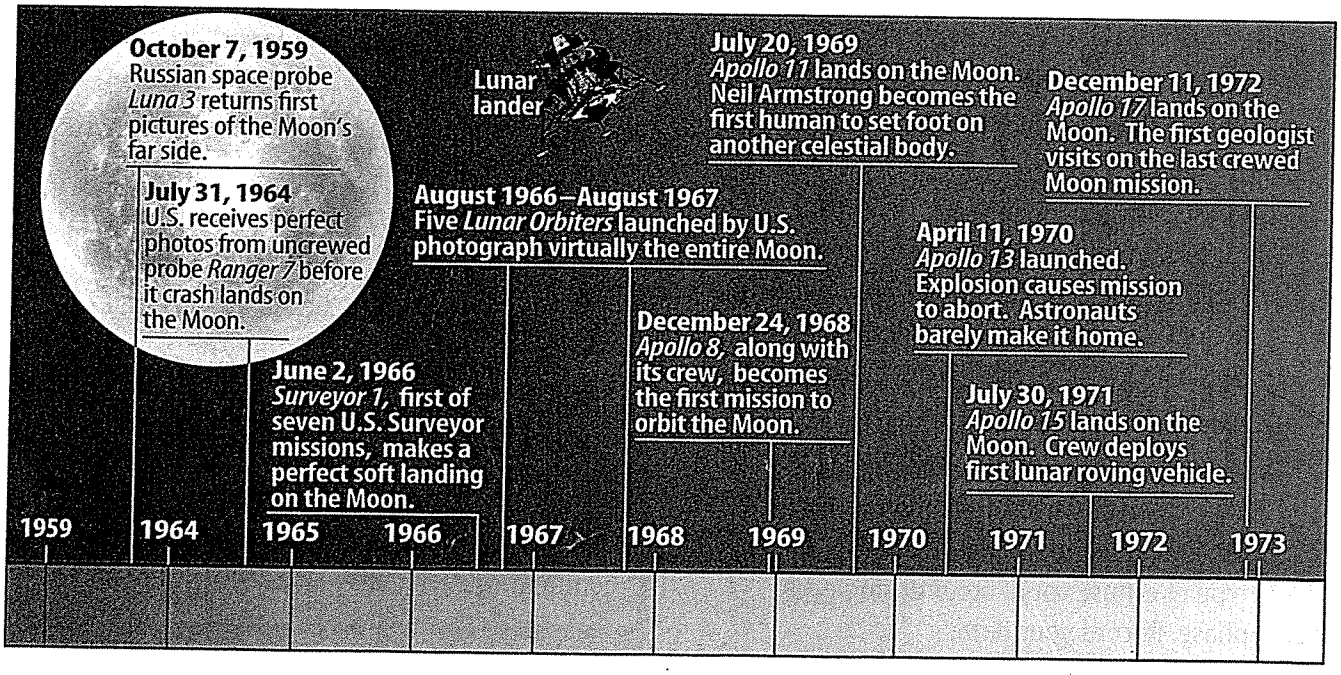
- impact basin

Missions to the Moon

The Moon has always fascinated humanity. People have made up stories about how it formed. Children's stories even suggested it was made of cheese. Of course, for centuries astronomers also have studied the Moon for clues to its makeup and origin. In 1959, the former Soviet Union launched the first *Luna* spacecraft, enabling up-close study of the Moon. Two years later, the United States began a similar program with the first *Ranger* spacecraft and a series of *Lunar Orbiters*. The spacecraft in these early missions took detailed photographs of the Moon.

The next step was the *Surveyor* spacecraft designed to take more detailed photographs and actually land on the Moon. Five of these spacecraft successfully touched down on the lunar surface and performed the first analysis of lunar soil. The goal of the *Surveyor* program was to prepare for landing astronauts on the Moon. This goal was achieved in 1969 by the astronauts of *Apollo 11*. By 1972, when the *Apollo* missions ended, 12 U.S. astronauts had walked on the Moon. A time line of these important moon missions can be seen in **Figure 15.**

Figure 15 This time line illustrates some of the most important events in the history of moon exploration.



Surveying the Moon There is still much to learn about the Moon and, for this reason, the United States resumed its studies. In 1994, the *Clementine* was placed into lunar orbit. Its goal was to conduct a two-month survey of the Moon's surface. An important aspect of this study was collecting data on the mineral content of Moon rocks. In fact, this part of its mission was instrumental in naming the spacecraft. Clementine was the daughter of a miner in the ballad *My Darlin' Clementine.* While in orbit, *Clementine* also mapped features on the Moon's surface, including huge impact basins.

Reading Check ***Why was* Clementine *placed in lunar orbit?***

Impact Basins When meteorites and other objects strike the Moon, they leave behind depressions in the Moon's surface. The depression left behind by an object striking the Moon is known as an **impact basin,** or impact crater. The South Pole-Aitken Basin is the oldest identifiable impact feature on the Moon's surface. At 12 km in depth and 2,500 km in diameter, it is also the largest and deepest impact basin in the solar system.

Impact basins at the poles were of special interest to scientists. Because the Sun's rays never strike directly, the crater bottoms remain always in shadow. Temperatures in shadowed areas, as shown in **Figure 16,** would be extremely low, probably never more than −173°C. Scientists hypothesize that any ice deposited by comets impacting the Moon throughout its history would remain in these shadowed areas. Indeed, early signals from *Clementine* indicated the presence of water. This was intriguing, because it could be a source of water for future moon colonies.

Science Online

Topic: The Far Side

Visit earth.msscience.com for Web links to information about the far side of the Moon.

Activity Compare the image of the far side of the Moon with that of the near side shown in **Figure 12.** Make a list of all the differences you note and then compare them with lists made by other students.

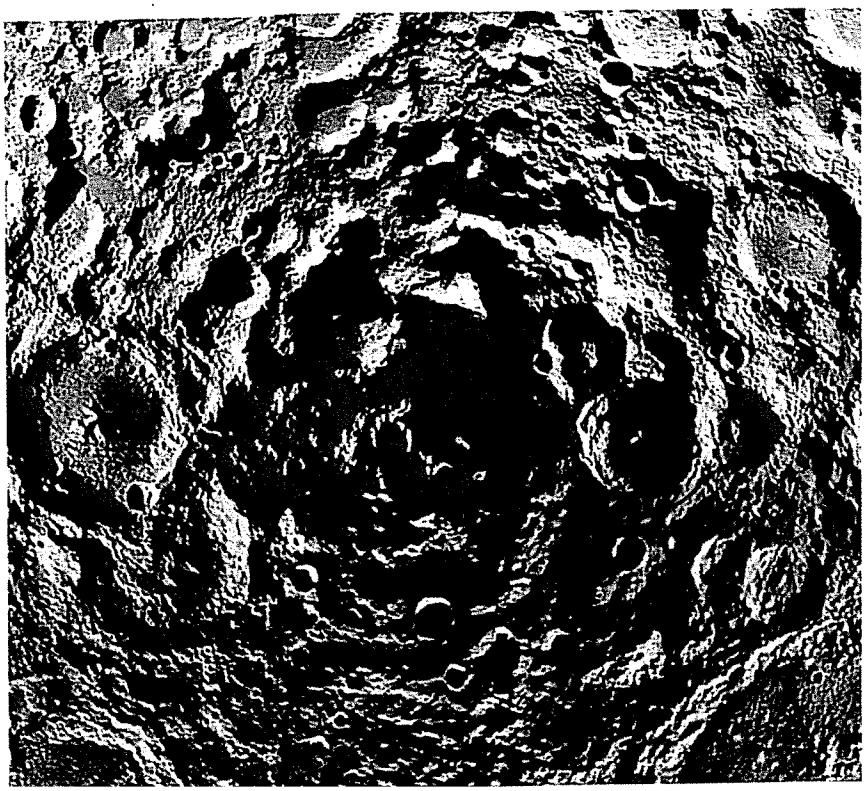


Figure 16 The South Pole-Aitken Basin is the largest of its kind found anywhere in the solar system. The deepest craters in the basin stay in shadow throughout the Moon's rotation. Ice deposits from impacting comets are thought to have collected at the bottom of these craters.

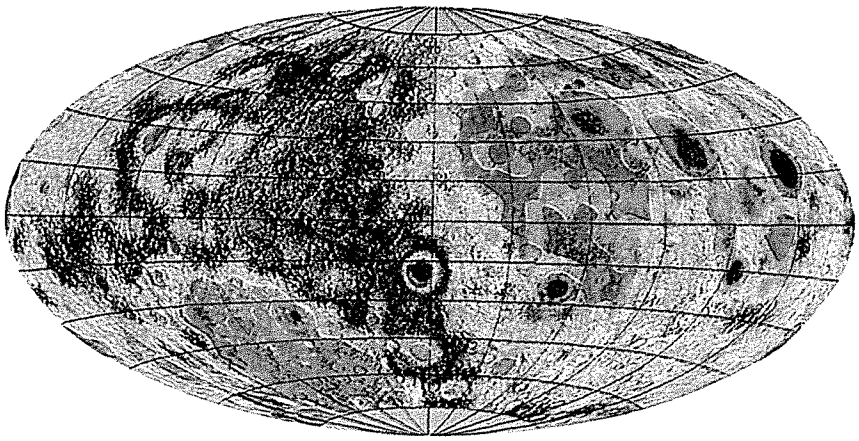


Figure 17 This computer-enhanced map based on *Clementine* data indicates the thickness of the Moon's crust. The crust of the side of the Moon facing Earth, shown mostly in red, is thinner than the crust on the far side of the Moon.

Mapping the Moon

A large part of *Clementine's* mission included taking high-resolution photographs so a detailed map of the Moon's surface could be compiled. *Clementine* carried cameras and other instruments to collect data at wavelengths ranging from infrared to ultraviolet. One camera could resolve features as small as 20 m across. One image resulting from *Clementine* data is shown in **Figure 17.** It shows that the crust on the side of the Moon that faces Earth is much thinner than the crust on the far side. Additional information shows that the Moon's crust is thinnest under impact basins. Based on analysis of the light data received from *Clementine,* a global map of the Moon also was created that shows its composition, as seen in **Figure 18.**

Reading Check ***What information about the Moon did scientists learn from* Clementine?**

The Lunar Prospector The success of Clementine opened the door for further moon missions. In 1998, NASA launched the desk-sized *Lunar Prospector,* shown in **Figure 18,** into lunar orbit. The spacecraft spent a year orbiting the Moon from pole to pole, once every two hours. The resulting maps confirmed the *Clementine* data. Also, data from *Lunar Prospector* confirmed that the Moon has a small, iron-rich core about 600 km in diameter. A small core supports the impact theory of how the Moon formed—only a small amount of iron could be blasted away from Earth.

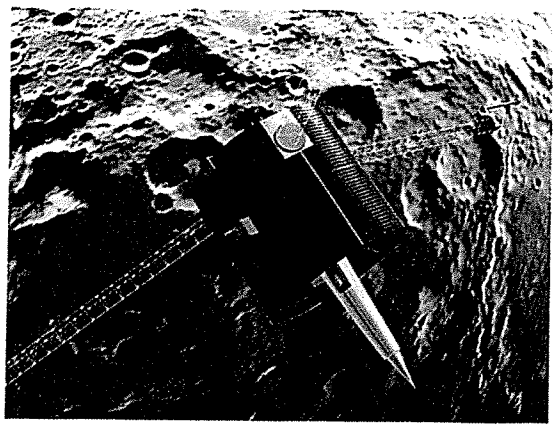


Figure 18 *Lunar Prospector* performed high-resolution mapping of the lunar surface and had instruments that detected water ice at the lunar poles.

Icy Poles In addition to photographing the surface, *Lunar Prospector* carried instruments designed to map the Moon's gravity, magnetic field, and the abundances of 11 elements in the lunar crust. This provided scientists with data from the entire lunar surface rather than just the areas around the Moon's equator, which had been gathered earlier. Also, *Lunar Prospector* confirmed the findings of *Clementine* that water ice was present in deep craters at both lunar poles.

Later estimates concluded that as much as 3 billion metric tons of water ice was present at the poles, with a bit more at the north pole. Using data from *Lunar Prospector*, scientists prepared maps showing the location of water ice at each pole. **Figure 19** shows how water may be distributed at the Moon's north pole. At first it was thought that ice crystals were mixed with lunar soil, but most recent results suggest that the ice may be in the form of more compact deposits.

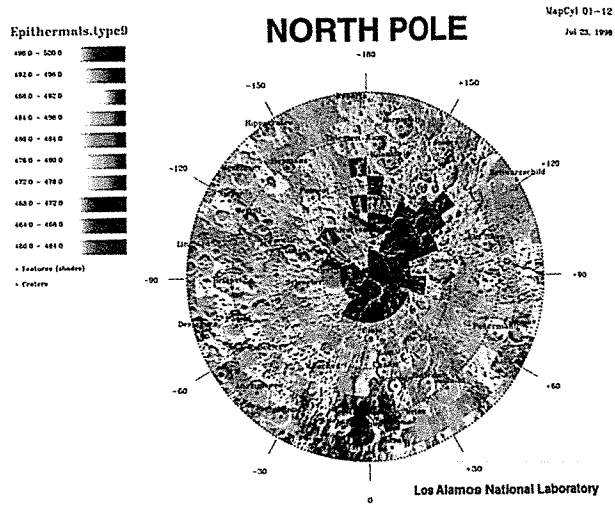


Figure 19 The *Lunar Prospector* data indicates that ice exists in crater shadows at the Moon's poles.

section 3 review

Summary

Missions to the Moon

- The first lunar surveys were done by *Luna,* launched by the former Soviet Union, and U.S.-launched *Ranger* and *Lunar Orbiters.*
- Five *Surveyor* probes landed on the Moon.
- U.S. Astronauts landed on and explored the Moon in the *Apollo* program.
- *Clementine,* a lunar orbiter, mapped the lunar surface and collected data on rocks.
- *Clementine* found that the lunar crust is thinner on the side facing Earth.
- Data from *Clementine* indicated that water ice could exist in shaded areas of impact basins.

Mapping the Moon

- *Lunar Prospector* orbited the Moon from pole to pole, collecting data that confirm *Clementine* results and that the Moon has a small iron-rich core.
- Data from *Lunar Prospector* indicate the presence of large quantities of water ice in craters at the lunar poles.

Self Check

1. **Name** the first U.S. spacecraft to successfully land on the Moon. What was the major purpose of this program?
2. **Explain** why scientists continue to study the Moon long after the *Apollo* program ended and list some of the types of data that have been collected.
3. **Explain** how water ice might be preserved in portions of deep impact craters.
4. **Describe** how the detection of a small iron-rich core supports the theory that the Moon was formed from a collision between Earth and a Mars-sized object.
5. **Think Critically** Why might the discovery of ice in impact basins at the Moon's poles be important to future space flights?

Applying Skills

6. **Infer** why it might be better to build a future moon base on a brightly lit plateau near a lunar pole in the vicinity of a deep crater. Why not build a base in the crater itself?