Exercise Four is suggested as an introductory exercise.

■ ★ 2.0 hours

Comparative Cratering Processes

Instructor Notes

Suggested Correlation of Topics

Craters on planets and satellites, gradation, impact mechanics, physics

Purpose

The objective of this exercise is to learn how different cratering processes produce different surface features. This exercise will explore three cratering processes: impact, volcanic explosion, and volcanic eruption.

Materials

Suggested: For each student group (or single set if done as instructor demonstration):

- tray (kitty litter box)
- very fine dry sand
- safety goggles (for everyone)
- marbles
- slingshot
- video camera
- VCR (4-head is best for stop action) and TV
- black posterboard (2′ x 3′)
- 3-foot-long narrow diameter flexible plastic tubing(surgical tubing)
- bicycle pump
- thin skinned balloons
- hose clamp
- sheet of clear heavy plastic (to protect camera)

Substitutions:

- instant camera with cable release
- 3 packs of instant black and white film
- high intensity strobe light (variable to at least 15 flashes per second)

  [Note: strobes can be dangerous to persons with epilepsy]
- 2 boxes or stacks of books: one for the camera, one for the strobe

Background

Impact craters are found on nearly all solid surface planets and satellites. However, other geologic processes, such as volcanic explosions and eruptions, can form craters as well. The differences between craters formed by impact and explosion can be very slight. Non-explosive volcanic craters can usually be distinguished from impact craters by their irregular shape and the association of volcanic flows and other volcanic materials. An exception is that impact craters on Venus often have associated flows of melted material.

This exercise demonstrates three processes that can form craters. Because the simulations in this activity do not scale in size to natural geologic events, the variations noted by the students may be very slight.

The use of the slingshot in this exercise can be dangerous. This exercise can be done as a demonstration to avoid accidents and to expedite its completion.

Science Standards

- Earth and Space Science
  - Energy in the Earth system

Mathematics Standards

- Geometry

Instant Camera Instructions

Instant cameras give the students an opportunity to have an instant and permanent record of the exercise. Action is "stopped" by use of the strobe light and students can reshoot if necessary. If using a instant with an electric eye, set the film speed setting to 75 (even though the film speed is 3000) and the exposure control on front of the camera to "Darker." This permits a longer exposure and a smaller f/stop (larger lens opening). If the Instant does not have an electric eye, but has numbered settings, set the number to "6" and flip the exposure from "I" to "B" before each picture. If the resulting photographs are too light, increase the number accordingly. Focus the camera on the target surface and place the black posterboard and the strobe light as shown in Figure 5.3. The flash rate on the strobe should seem like rapid blinks. Too many flashes during the exposure produces a dispersed cloud; too few, and the event may be missed entirely. In using the camera, it is best if you have a cable release attached to the Instant—this will help eliminate jarring the camera unnecessarily. If the camera does not accept a cable release, be sure that the camera is on a firm surface; push the button and release carefully. To get good photos, the film must be exposed long enough to catch 2 flashes from the strobe light (about 1/8 second). Start the exposure just before the marble is fired and stop it right after it appears to hit the sand. Be sure the student photographers know how to operate the camera before starting the activity. Although the instructions and precautions may seem involved, this exercise can be done easily and successfully with a little practice.

Answer Key

1. **a**. Answers will vary, student may say in straight lines or arcs.

   b. (See Figure 5.1) The formation of an impact crater is a relatively well ordered event in which the ejecta leaves the surface at approximately a 45° angle from the horizontal (upper left picture Figure 5.1). As the crater enlarges (middle left), the inverted cone sheet of ejecta, called the ejecta plume, enlarges. Ejecta falls first close to the crater, and as crater formation continues (bottom left), the ejecta strike the surface at increasing distances. Note how the base of the ejecta plume has enlarged with time.

2. **a.** Ejecta from the vertical impact are thrown out at about a 45° angle. The sheet of ejecta moves outward in a symmetrical pattern, producing the appearance of an enlarging, inverted cone. For the 45° impact, the ejecta cone becomes asymmetrical and distorted in the down-range direction.

   b. (See Figure 5.2) As the angle of impact departs from the vertical, the ejecta cone or plume becomes asymmetric. For the relatively low velocities represented in the figure (20 m/s), asymmetry is not apparent until the impact angle is greater than 20°. At 20° (upper right), the sequence of ejecta remains relatively symmetric. At 60° (lower left) and 75° (lower right) from the vertical, the ejecta cone is distorted in the downrange direction. For impacts of much greater velocities (2 km/s), the asymmetry does not occur until much larger departures (80°) from the vertical.

3. **a.** (See Figure 5.1.) The upper and middle right pictures in the figure show the relatively chaotic and dispersed nature of the ejecta caused by this type of cratering process.

   b. In appearance, the crater shape is similar. However, the ejecta pattern is chaotic and dispersed with ejecta thrown at all angles. Note that the ejecta pattern and crater appearance will vary with different depths of burial of the balloon.

4. (See Figure 5.1) The bottom right picture shows the formation of the eruptive crater. Ejecta is blown straight up and lands right around the crater.

5. **a.** All three craters contain similar parts: crater, rim, ejecta.

   b. Answers will vary, but many students will note that the explosive and volcanic craters are not as symmetrical as the impact craters. The volcanic eruption crater will be the most irregular.

   c. All craters formed have raised rims.

   d. Answers may vary. The crater ejecta patterns will probably be widest.

   e. Impact has the greatest effect.

6. **a.** Olympus Mons (Figure 5.5) is volcanic; Timocharis crater (Figure 5.6) is of impact origin.

   b. Timocharis has well developed ejecta patterns; the crater on Olympus Mons is irregular in outline and shows no ejecta patterns.

   c. Impact craters have large, well-defined ejecta patterns; the ejecta patterns of volcanic explosion craters may not be as well-organized; volcanic eruption craters have little ejecta or poorly organized ejecta patterns.

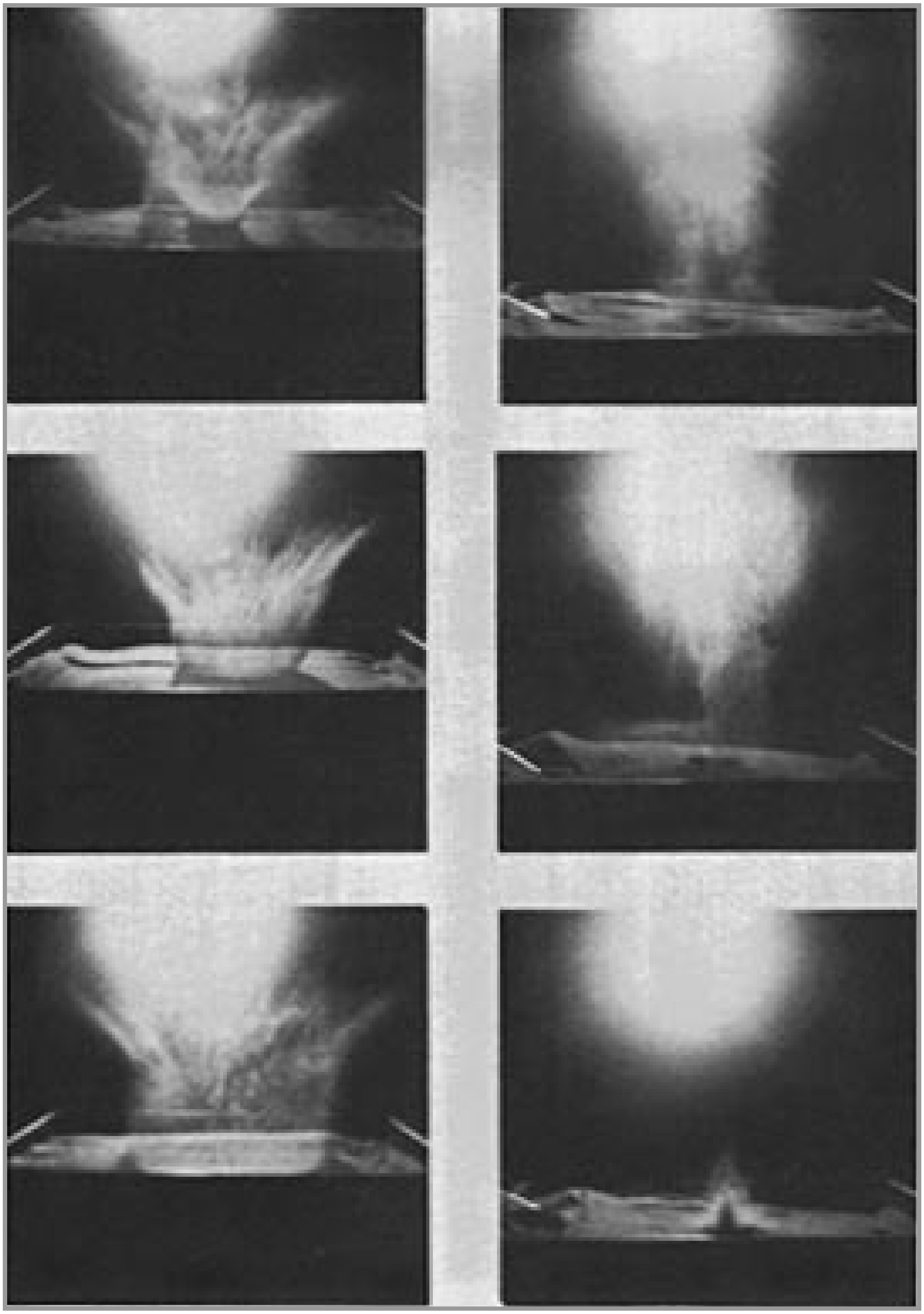

Figure 5.1. Comparison of the formation of an impact crater (left side), a low-energy explosion crater (top two photos on the right side), and simulated volcanic eruptive crater (bottom right). All craters were formed in a sand box and recorded using a strobe light.

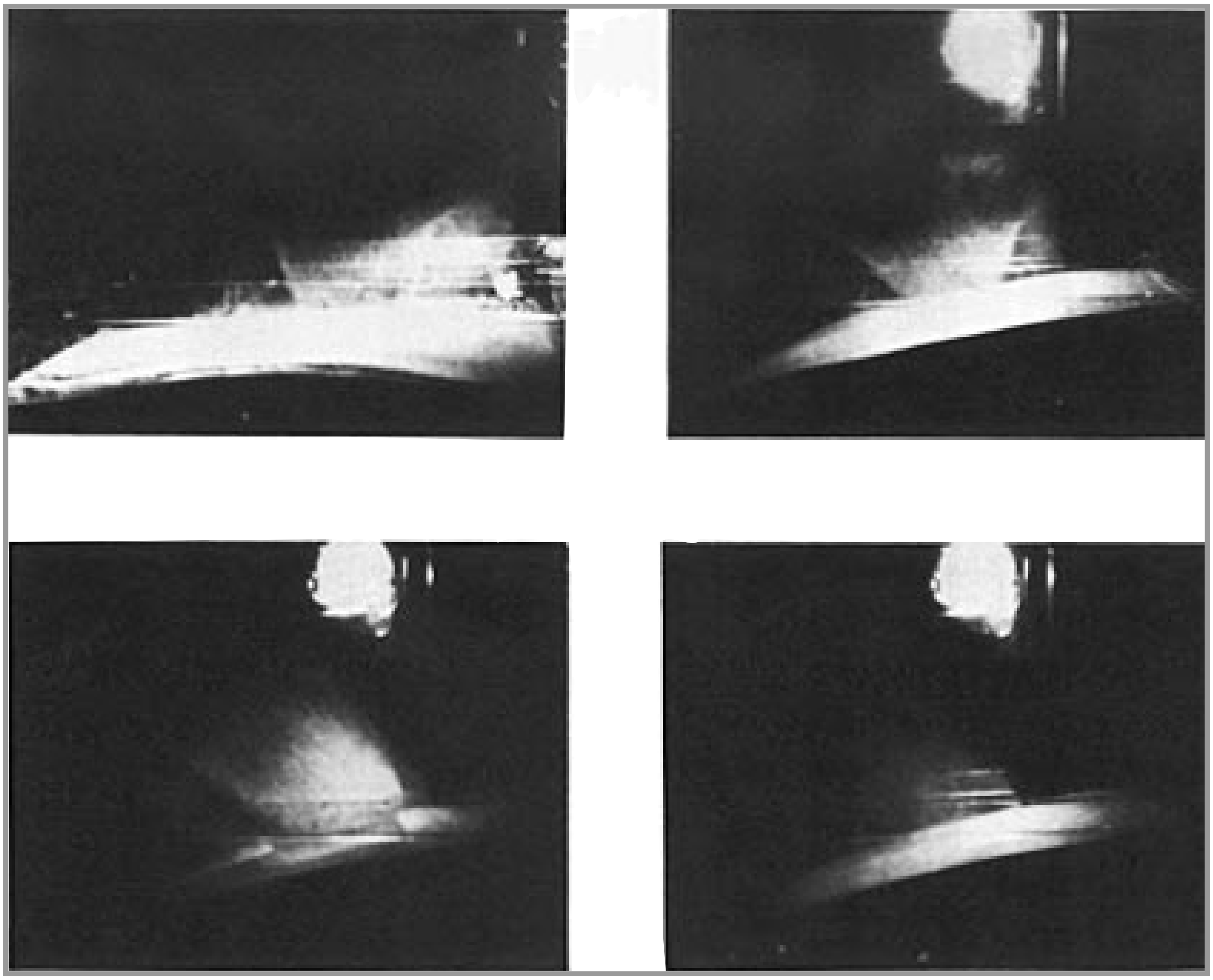

Figure 5.2. *Strobe light instant photographs of impacts into fine sand at different angles of incidence. Photograph records two flashes of the strobe light in each illustration. The upper left image is for a vertical impact, upper right is at 20° from vertical, lower left is at 60° from vertical, and the lower right is 75° from vertical.*

Name ______________________________

Comparative Cratering Processes

Purpose

To illustrate the similarities and differences in craters formed by three different cratering processes: impact, volcanic explosion, and volcanic eruption.

Materials

For each student group: tray (kitty litter box), very fine sand, safety goggles (for all students), marbles, slingshot, video camera, VCR and TV, black posterboard (2′ x 3′), 3-foot-long narrow diameter flexible plastic tubing, bicycle pump, thin skinned balloons, hose clamp, sheet of heavy clear plastic (to protect the camera)

Introduction

In examining a planetary surface, it is important to identify the processes that shaped the surface. Not all craters form by impact processes; some result from volcanic explosions and volcanic eruptions. This exercise examines the crater forms which result from these three processes: impact, explosion, and eruption.

Procedure and Questions

Part A: Impact Cratering Process

Use Figure 5.3 to set up the equipment for this part of the exercise. **All students must wear safety goggles during this part of the exercise.** Hold the slingshot 70 to 90 cm above the target. While video taping the tray, fire a marble straight down (vertically) into the sand tray using the slingshot . The goal is to photograph the **ejecta** (material thrown out of the crater) while it is airborne and after it has landed. You may need to repeat this part several times to get a good photographic record.

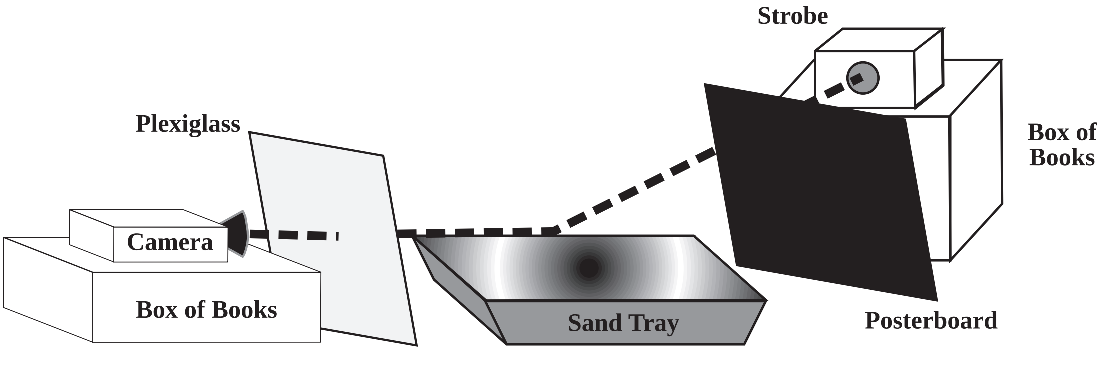

Figure 5.3. *Diagram showing the setup for photographing the impact experiment.*

1. **a.** Before examining the video or photographs, describe how you think the ejecta will appear, and what path you think the ejecta took in the air.

   b. Observe the video or photographs. Sketch the crater, the path the material appears to take in the air, and the pattern of ejecta deposited on the surface based on the photographic record and your observations. Use the pause or stop action ability of the VCR to view the tape.

Sketch area

Remove the marble and smooth the sand surface. Record another impact while firing the marble at an angle of 45° into the target surface. The slingshot should be 70 to 90 cm from the target. Be sure that no one is down range and that you stand to one side and fire into the tray between the camera and posterboard. The projectile flight path should parallel the posterboard.

2. **a.** How are the ejecta paths through the air different from those during the vertical impact?

   b. Sketch the crater, the path the material appears to take in the air, and the pattern of ejecta deposited on the surface, based on the photographic record and your observations.

Sketch area

Part B: Volcanic Explosive Cratering Process

Set up the equipment as shown in Figure 5.4. Place the bike pump where the person stood in Part A. Attach the plastic tube to the bicycle pump. Check for air leaks. Next, pull the balloon tightly over the other end of the tube and slip on the clamp. You are using only a small portion of the balloon and the balloon should burst easily when the pump is used. Bury the tube in the sand but turn up its end in the center of the box so that it is almost vertical and about 2 centimeters below the surface of the sand. Smooth the surface of the sand over the tube. Start your video or photographing and then give a quick, hard, single push of the bicycle pump. If the balloon did not burst, check for air leaks or tighten the clamp on the balloon and try again.

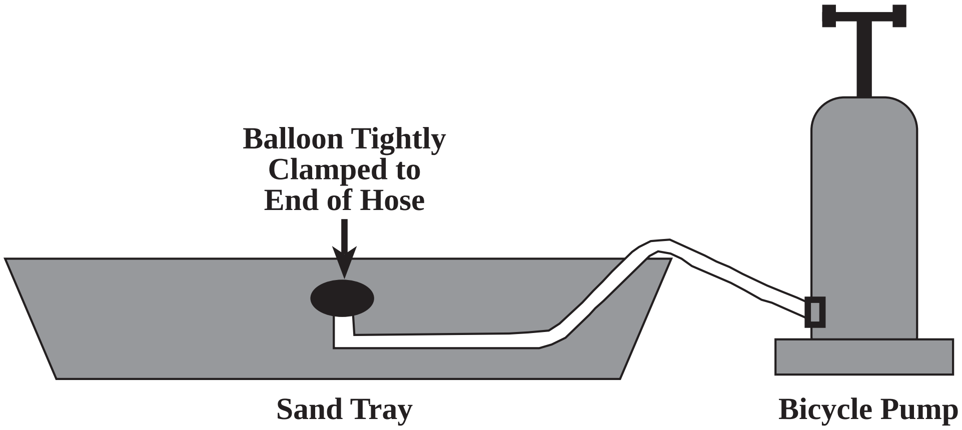

Figure 5.4. *Diagram showing the setup for photographing the explosive experiment.*

3. **a.** Sketch the crater, the path the material appears to take in the air, and the pattern of ejecta deposited on the surface based on the photographic record and your observations.

Sketch area

b. How does the resulting low-energy explosion crater compare with the impact crater?

Part C: Volcanic Eruptive Cratering Process

Remove the burst balloon and the clamp from the end of the tube. Rebury the tube in the sand, this time without a balloon. Again make sure the end is turned up almost vertical in the center of the sand tray and that it is only about 2 centimeters below the surface. Smooth the surface of the sand over the end of the tube. Start video taping or photographing before pushing the pump. Do not push as hard as for the balloon. Push the pump two more times for a total of three pushes.

4. **a.** Sketch the crater, the path the material appears to take in the air, and the pattern of ejecta deposited on the surface based on the photographic record and your observations.

Sketch area

Compare the craters and features formed by each of the three processes.

5. **a.** How are all three similar?

   b. How are they different?

   c. Which craters have raised rims?

   d. Which crater formed the widest ejecta pattern?

   e. Which process affected the surrounding material most?

Examine Figures 5.5 and 5.6.

6. **a.** Which feature is probably volcanic in origin? Which feature is probably impact?

   b. What evidence did you use to reach your conclusion?

   c. If you were searching for a crater produced by an explosion, what features would you look for that would distinguish it from a crater formed by volcanic eruption or impact?

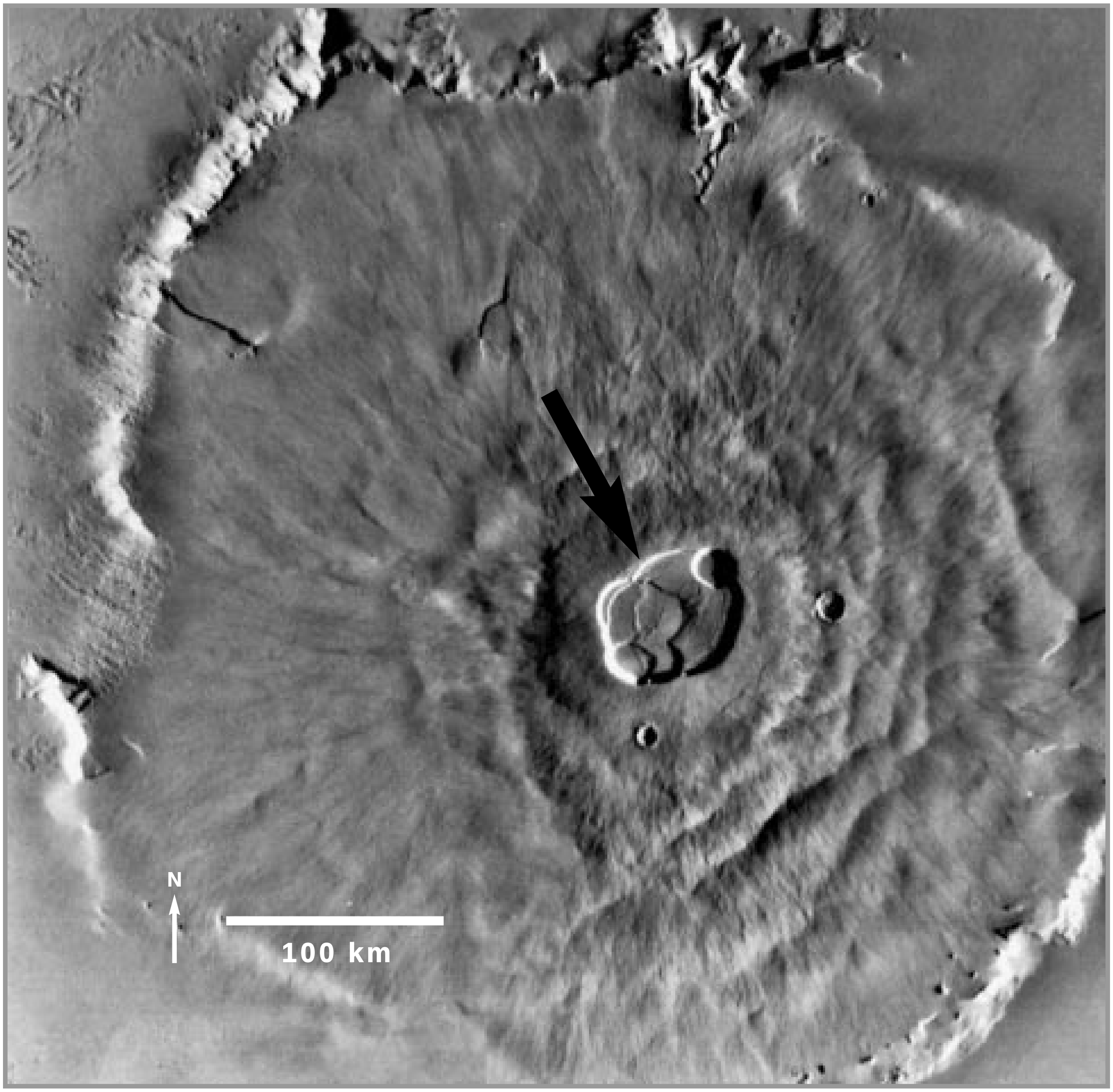

Figure 5.5. *Olympus Mons, Mars, showing the 80-km in diameter summit crater (arrow). North is to the top. (Viking MDIM mosaic 211-5360.)*

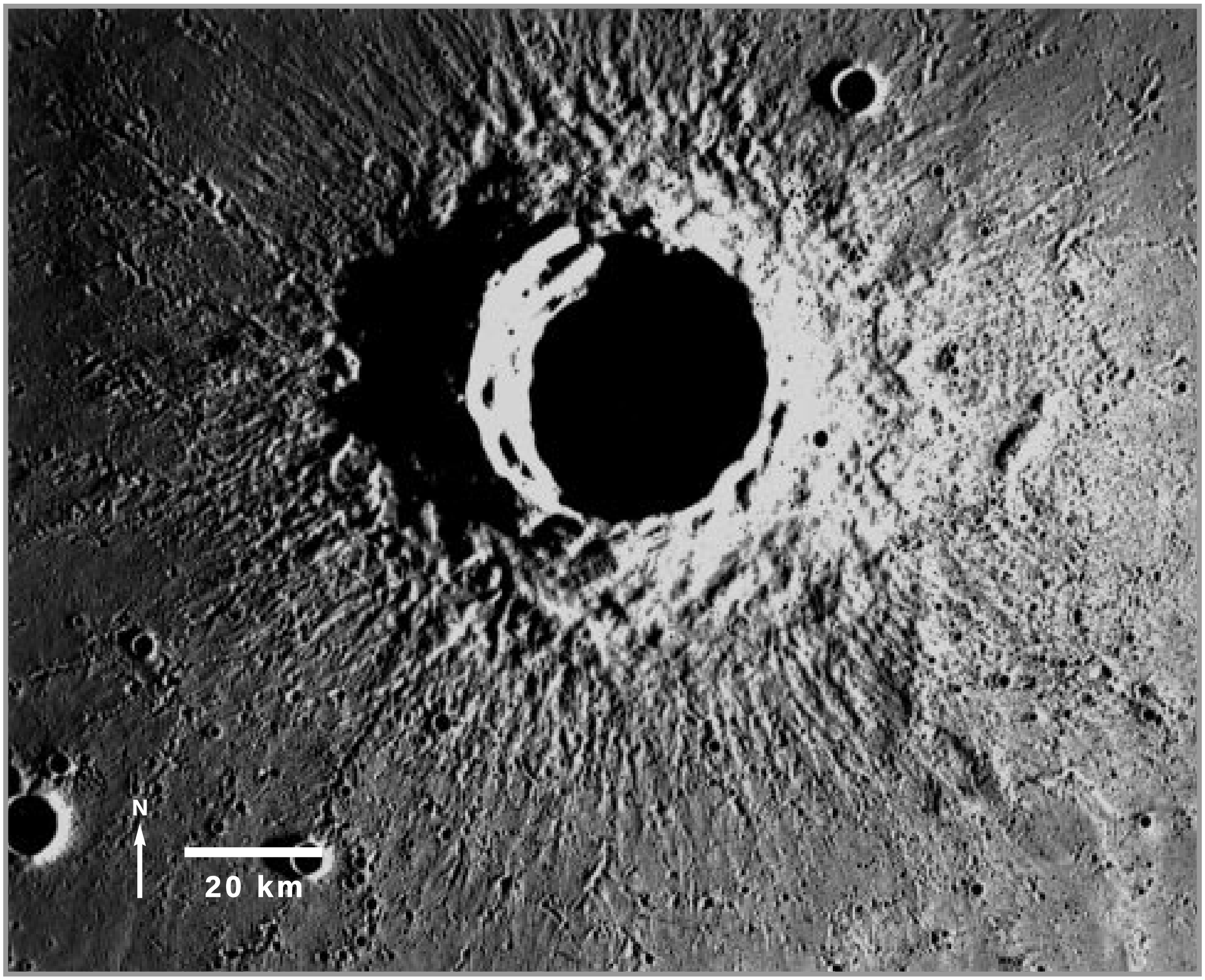

Figure 5.6. *Timocharis, Moon. North is to the top. The crater is 33 kilometers in diameter. (Apollo 15 metric frame AS15 0598.)*