Exercises Two, Three, Ten, Eleven, Twelve, and Thirteen are suggested as introductory exercises.

■ ★ 2.0 hours

Exercise Fourteen

Planets in Stereo

Instructor Notes

Suggested Correlation of Topics

Comparative planetology, impact craters, stereoscopic photography

Purpose

The objective of this exercise is to apply the techniques of stereoscopic photograph analysis to the interpretation of the geology and history of planetary bodies.

Materials

For each student group: Stereoscope

Background

Unit One introduced students to the four geologic processes: volcanism, tectonism, gradation, and impact cratering. In Exercise Three, stereoscopic photographs were used to acquaint students with the three dimensional shapes of some terrestrial landforms created by these processes. Here, these themes are extended to other planets and planetary bodies.

This exercise builds upon previous ones. It would be useful to review the four geologic processes of Unit One before proceeding. The procedure for using stereoscopic photographs is briefly reviewed in the student section of this exercise, but for more detail, refer to Exercise Three: Geologic Processes Seen on Stereoscopic Photos.

This exercise promotes comparisons among the planetary bodies examined, including the Moon, Mars, Venus, and several outer planet satellites. It is useful for the student to have completed previous exercises (10 through 13) which introduce the geology of these bodies, although this exercise can be worked independently.

This exercise has many parts. If time does not permit completion of the entire exercise by all students, then groups of students might be assigned the different parts. Class discussion could then be used to share and synthesize what has been learned.

Science Standards

■ Earth and Space Science

- Origin and evolution of the Earth system

Answer Key

1. a. The contact is sharp and abrupt. The plains appear to lap up against the hills.

   b. The indication is that the plains are younger, having filled low-lying regions.

2. The plains consist of volcanic lava flows. Hadley Rille transported some of these lavas.

3. **a.** Hadley is a bowl shaped crater. Its rim is upraised above the surroundings.

   b. These characteristics suggest an impact origin.

4. Hadley Rille is older, as the crater's ejecta appears to cover part of the rille.

5. The rim is raised and slopes continuously upward from the surrounding plains. Ejecta deposits are superposed on the plains. Moreover, the crater is superimposed on, and thus younger than, Hadley Rille (which probably formed at the same time as the plains).

6. **a.** The crater shows a raised rim, a central peak, terraced walls, and a relatively flat floor.

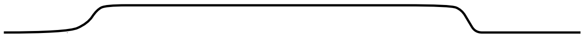
   b. These characteristics suggest an impact origin.

7. The crater forms the rounded edge of the "island." It might have served as a barrier to liquid that flowed around the crater, eroding away material to either side, and leaving an island downstream of the crater. This island might be in a dry river bed. The process is gradation.

8. The material appears to be layered.

9. **a.** Tectonism.

   b. Crater material has slid down a steep slope into the trough below, leaving a rough (radar bright) landslide deposit. This is an example of gradation.

10. a. 

    b. Volcanism.

    c. They are irregular depressions (pits), formed volcanically.

11. **a.** There are many large, irregular depressions. Some smaller depressions are linear or aligned in chains. Some depressions are long and sinuous.

    b. The similarity in shape suggests that the sinuous depressions on Venus may have formed as lava channels and collapsed tubes similar to Hadley Rille on the Moon.

    c. Volcanism.

12. Ida is irregularly shaped rather than spherical. Its outline consists of concavities (some of which are large craters) and ridge-shaped features between them.

13. Cratering; the concavities, ridges, and irregular shape probably resulted from the shattering of a larger parent asteroid and repeated impact bombardment.

14. Cratering.

15. Craters on Rhea have irregular outlines, and they overlap one another. Dione's craters are more circular, and there are fewer craters on Dione, so there is less overlapping. Both satellites show some central peak craters.

16. **a.** Rhea's surface is older, as it is much more heavily cratered.

    b. Dione may have been volcanically resurfaced in the past. This would have obliterated its older craters. The craters we see have all formed since this event.

17. **a.** A large rift cuts across Titania. It shows curved fault segments and a jagged overall trace.

    b. Tectonism.

18. **a.** The material is smooth appearing and is convex-upward in shape.

    b. 

    c. Tectonism and volcanism.

19. **a.** The coronae show ridges and troughs. This is different from the cratered terrain, which shows few scarps. The cratered terrain is more heavily cratered.

    b. Tectonism, and probably volcanism. Tectonism produced the ridges, grooves, and scarps. Volcanism may be responsible for light and dark patches within the coronae.

Name ______________________________

Exercise Fourteen

Planets in Stereo

Purpose

To apply techniques of stereoscopic photograph analysis to the interpretation of the geology and history of planetary bodies.

Materials

For each student group: stereoscope

Introduction

Geologists are concerned with rock formations and landforms as three dimensional units. An understanding of the geometry of a geologic formation is important to the interpretation of its origin and history. Topographic information can be obtained in a variety of ways. The most simple and reliable is by means of stereoscopic photographs.

We see in three dimensions and are able to judge the distances to objects because our eyes are spaced about 65 mm apart. We see the same scene from two different angles, and the brain is able to interpret this information to give us a perception of depth. The same principle is used to view a pair of stereoscopic photographs taken from spacecraft.

A stereoscopic pair is made by taking two images of the same scene from slightly different angles. This can be done by a spacecraft as it moves above the surface of a planetary body. For example, the metric mapping cameras of the Apollo orbiter took sequential pictures that overlap by 78%. That is similar to the overlap that our two eyes provide for the same scene.

To observe the three-dimensional stereoscopic effect, each photograph of the stereo pair must be viewed by a separate eye. This can be accomplished by viewing through a stereoscope. Center the stereoscope on the seam between the photographs of a stereo pair, relax your eyes, and let the photos merge together into one image in order to observe the stereo effect. Try placing your index fingers on the same object within each photo of the stereo pair, and then focus until your fingers appear to overlap. When you remove your fingers, the stereo effect should become apparent. Some people cannot see stereo at all; for most others, it simply takes patience and practice.

In analyzing the stereo photographs of this exercise, recall the four geologic processes: **volcanism**, **tectonism**, **gradation**, and **impact cratering**. You will be asked to recognize the processes that have shaped planetary surfaces based on the three-dimensional appearances of the visible **landforms**.

Questions

Part A. Moon.

Examine Figure 14.1, which shows the area of Hadley **Rille**, landing site of Apollo 15. Hadley Rille, the sinuous trough winding across the region, is an ancient lava channel that carried active flows into the dark plains (maria). Hadley crater is the prominent crater beside the rille.

1. Study the **contact** (boundary where two different types of materials meet) between the bright, rough hills and the smooth, dark plains.

   a. Describe this contact. What is the character of the boundary?

b. What conclusions can you draw about the age relationship between the hills and plains?

2. How might the plains have formed?

3. Examine the appearance of Hadley crater.

   a. Describe the crater's shape and characteristics, including its rim and interior.

   b. These characteristics suggest what kind of origin for Hadley crater?

4. Which is older, Hadley Rille or Hadley crater? How can you tell?

5. What evidence is there that Hadley crater is younger than the plains lavas, instead of the plains lavas having flowed around an old pre-existing crater?

Part B. Mars.

Examine Figure 14.2, which shows part of Ares Vallis on Mars.

6. Notice the prominent 7 km crater.

   a. Describe the shape and characteristics of the crater, including its rim and interior.

   b. Based on these characteristics, what geologic process formed this crater?

7. What is the relationship between the crater and the teardrop shaped "island"? How might the teardrop feature have formed? What is the geologic process?

8. Look carefully at the sides of the teardrop "island," and also at the steep cliff near the top of the photo. What can you say about the material near the surface of Mars, as revealed by the cross sections exposed in the cliffs?

Part C. Venus.

The surface of Venus is hidden from direct view by its thick clouds. To penetrate the clouds, **radar** has been used to map the surface of Venus. In general, rough areas appear bright in these radar images, and smooth areas appear dark. (For an introduction to the interpretation of radar images and the geology of Venus, see Exercise Twelve: Geologic Features of Venus.)

9. Examine the stereo images of Figure 14.3, showing the region surrounding crater Geopert-Meyer.

   a. Which of the four geologic processes has most affected this region of Venus?

   b. Notice the rough (radar bright) material aside crater Geopert-Meyer, and its relationship to the prominent trough. What has happened here?

10. Figure 14.4 shows the Eistla region of Venus.

    a. Sketch a cross-section of the shape of the broad domes as they might appear from the surface of Venus. Use the sketch area below.

Sketch area

   b. Which geologic process could have created these domes?

   c. Notice the small depressions on the crests of the broad domes. What is their shape, and what process likely created them?

11. Examine the topographic depressions in Aphrodite Terra seen in Figure 14.5.

    a. Describe the shapes of the topographic depressions that you see.

    b. Compare this image of Aphrodite Terra to the Hadley Rille area of the Moon (Figure 14.1). What does the comparison suggest as to the possible origin of the sinuous depressions on Venus?

    c. Which of the geologic process was most important in shaping this region?

Part D. Asteroid Ida.

A stereoscopic view of asteroid 243 Ida is shown in Figure 14.6.

12. Compare the overall shape of Ida to that of other planetary bodies you have studied. What is unusual about the asteroid's shape?

13. What geological process has affected the surface of Ida? How might this process account for the asteroid's overall shape?

Part E. Outer Planet Satellites.

The following figures show stereoscopic images of some of the **satellites** of Saturn and Uranus. Only five satellites are shown, a sampling of the dozens of moons of the outer planets. All of the moons shown have ice-rich surfaces, and none have atmospheres. Figures 14.7 and 14.8 show Rhea and Dione, respectively. These are two of Saturn's icy satellites.

14. What geologic process has most shaped the surface of Rhea?

15. Compare the appearance of craters on Dione to those on Rhea. Include both similarities and differences in their **morphologies**.

16. **a.** Which satellite appears to have an older surface, Rhea or Dione? How can you tell?

    b. What does this say about whether these satellites might have been resurfaced by volcanism at some time in the past?

Figures 14.9, 14.10, and 14.11 show Titania, Ariel, and Miranda, respectively. These are icy satellites of planet Uranus.

17. Notice the prominent feature that stretches across the surface of Titania (Figure 14.9).

    a. Describe this feature.

    b. What process is responsible for its formation?

18. Several valleys cross the surface of Ariel , especially near the **terminator** (the day/night line), visible on the right side of the stereo image (Figure 14.10).

    a. What is unusual about the appearance of the material in these valleys?

b. Sketch what a profile across a typical one of these valleys might look like in the sketch area below.

Sketch area

c. What two processes probably acted together to form these features?

19. The surface of Miranda (Figure 14.11) consists of cratered terrain and several regions termed **"coronae"** (singular: corona). In contrast to the cratered terrain, the coronae consist of light and dark materials.

a. Describe the topography and character of the coronae as compared to the cratered terrain which surrounds them.

b. What process(es) have likely shaped the coronae of Miranda?

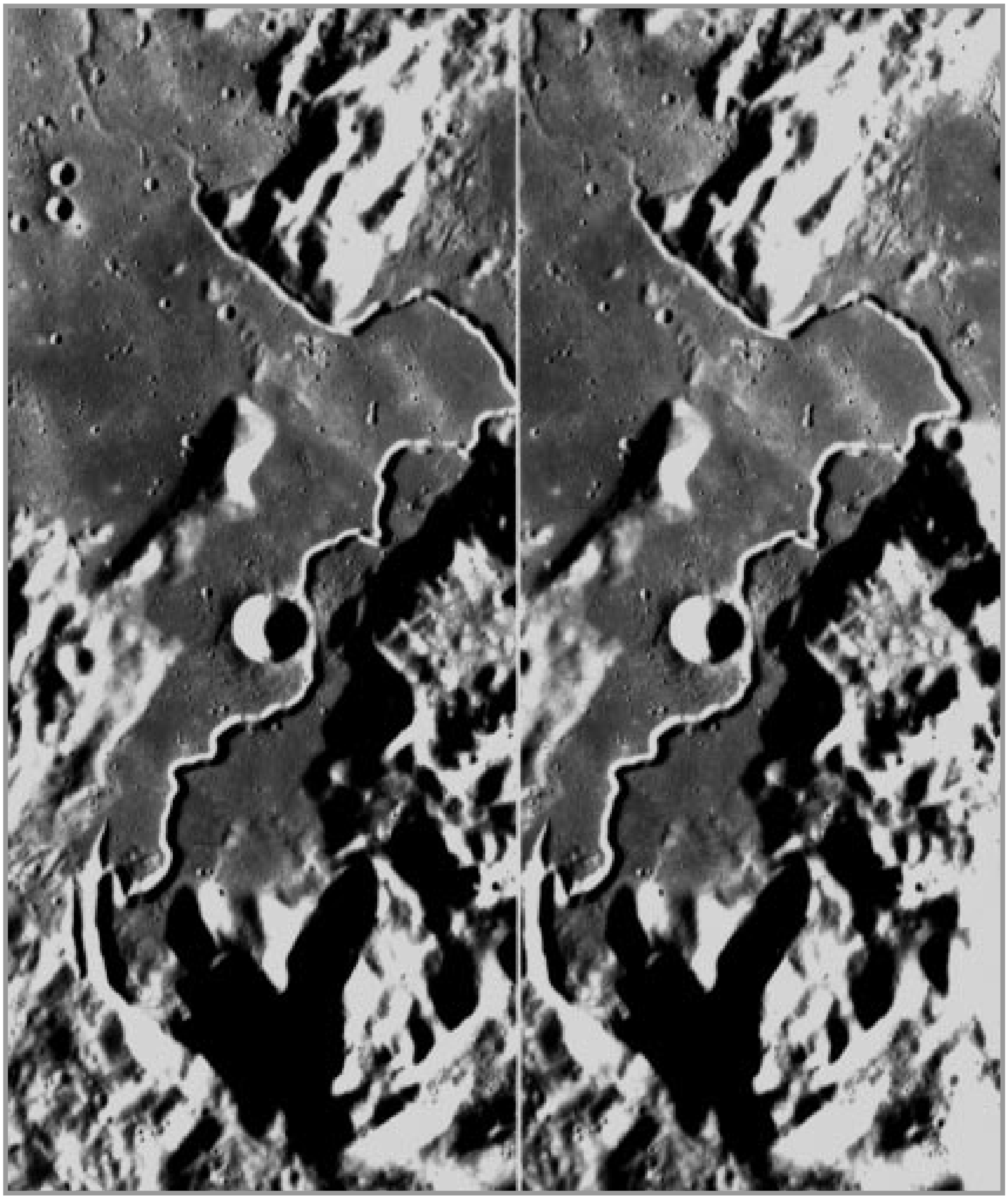


Figure 14.1. *Stereoscopic photographs of the Hadley Rille area of the Moon, landing site of Apollo 15. The sinuous trough (Hadley Rille) is about 300 m deep. The prominent crater, Hadley, is 5.7 km in diameter. North is toward the top. (Left half is part of AS15-0586, right half, AS15-0585. Spacecraft motion was from left to right parallel to the bottom edges of the photos).*

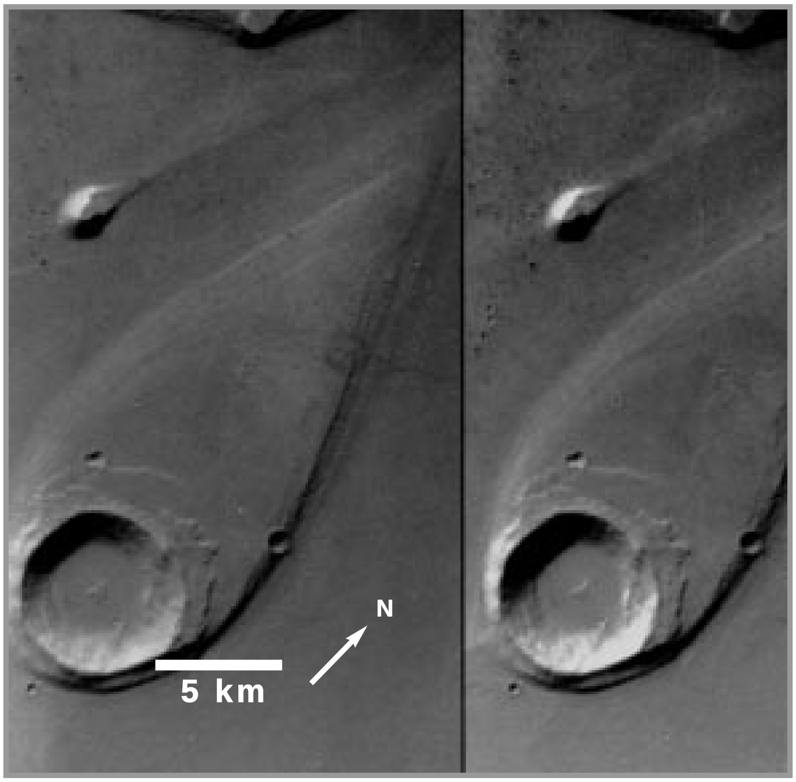


Figure 14.2. *Stereoscopic photographs of the Ares Vallis region of Mars, constructed from Viking orbiter images. North is toward the upper right. The prominent crater is about 7 km across. The Viking 1 Lander site is about 800 km to the west. (Viking Orbiter 004A52, left, and 004A93, right).*

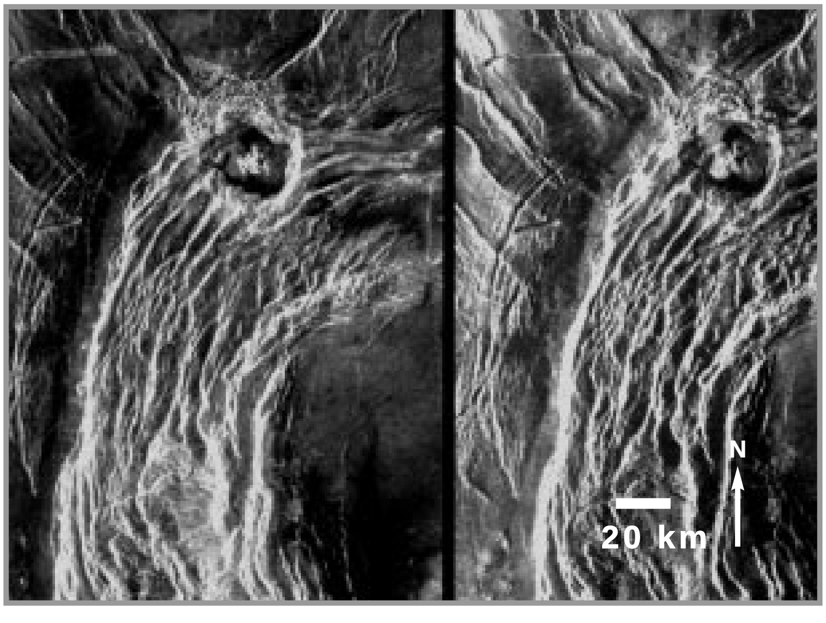


Figure 14.3. *Crater Geopert-Meyer and surrounding features on Venus. The prominent trough is about 1 km deep, and the scene is about 154 km across. North is toward the top (NASA P-42612).*

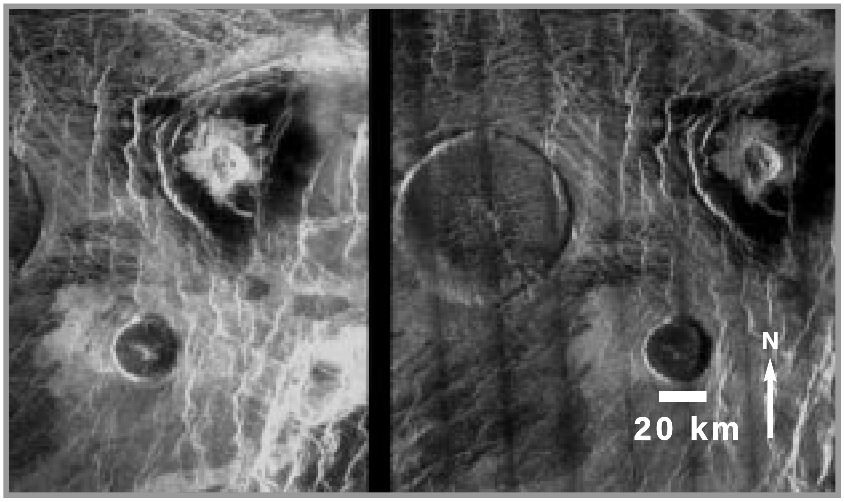


Figure 14.4. *Domes in the Eistla region of Venus. The largest is about 65 km across but less than 1 km in height. North is toward the top (NASA P-42684).*

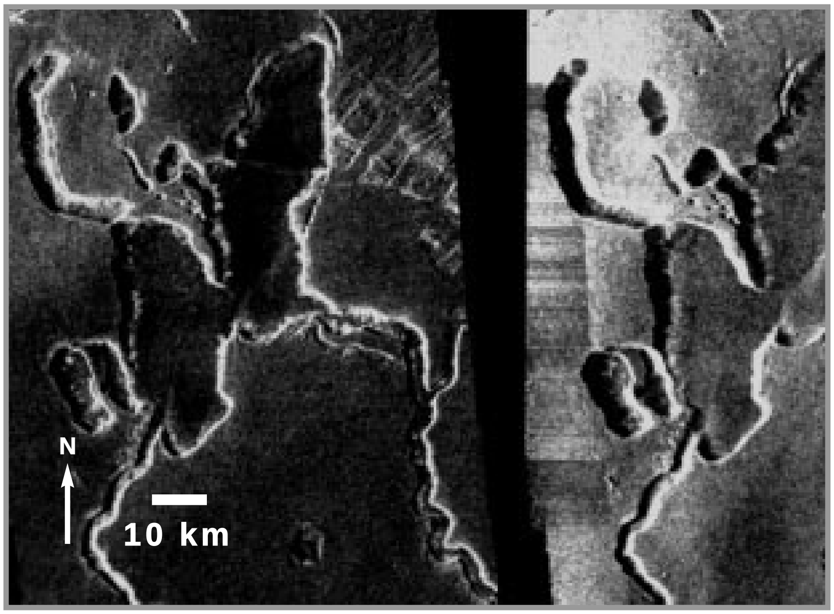


Figure 14.5. *Part of the Aphrodite Terra highlands, Venus. Depths here are as great as 1 km. The image is 73 km wide, and north is toward the top (NASA P-42611).*

Figure 14.6. *Stereoscopic view of asteroid 243 Ida. The asteroid is about 60 km long and 18 km wide. Resolution is 60 m/pixel. (Stereo image courtesy Peter Thomas, Cornell University; from Galileo spacecraft images s0202561945 [left] and s0202562000 [right]).*

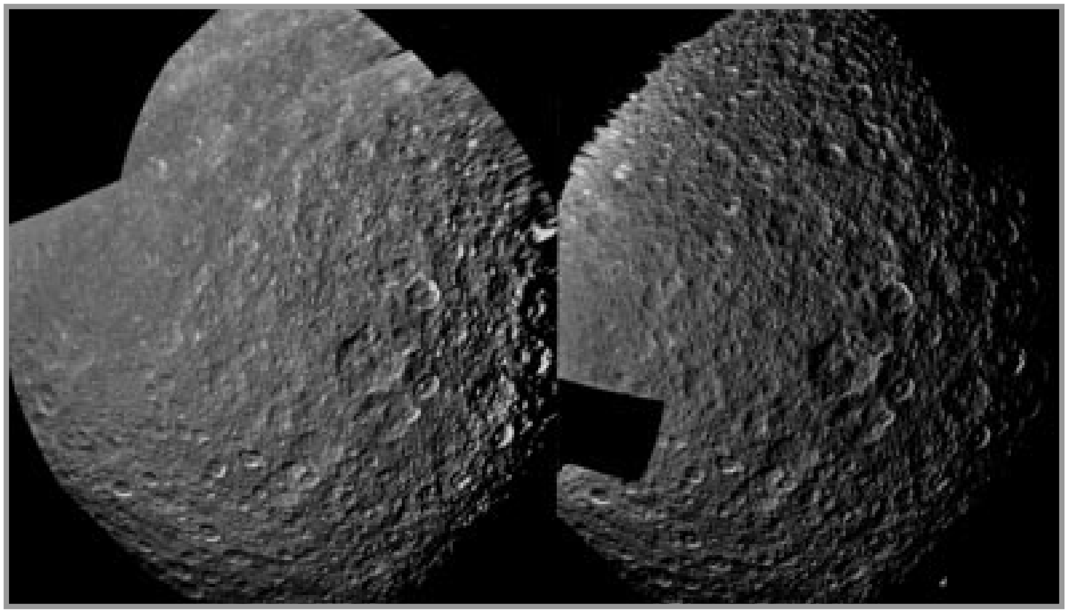


Figure 14.7. *Saturn's icy satellite Rhea is seen in this stereo pair. (Image courtesy Paul Schenk, Lunar and Planetary Laboratory, Houston; reprojected mosaics of Voyager frames FDS 34950.29, .35, .41, .47, and .53 [left] and 34952.53, .55, .57, .59, 34953.01, .03, and .07 [right]).*

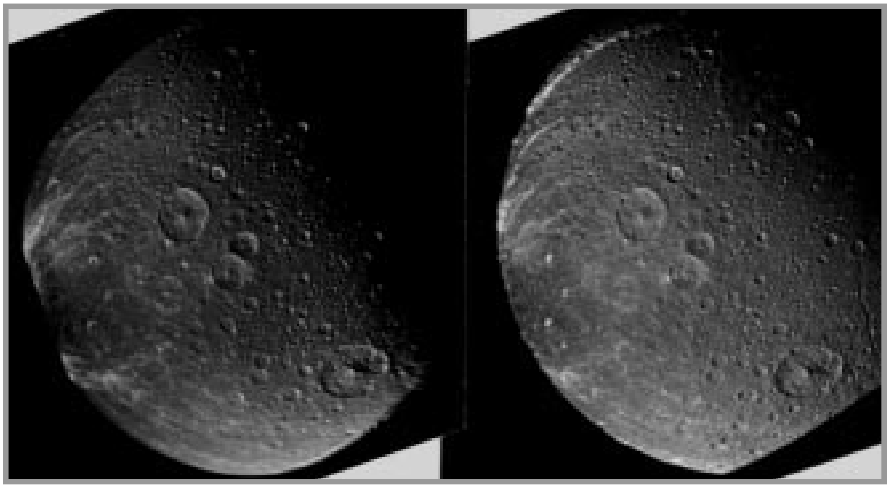


__Figure 14.8.__ Dione, an icy satellite of Saturn. (Image courtesy Paul Schenk, Lunar and Planetary Laboratory, Houston; reprojected Voyager frames FDS 34944.58 [left] and 34948.28 [right]).

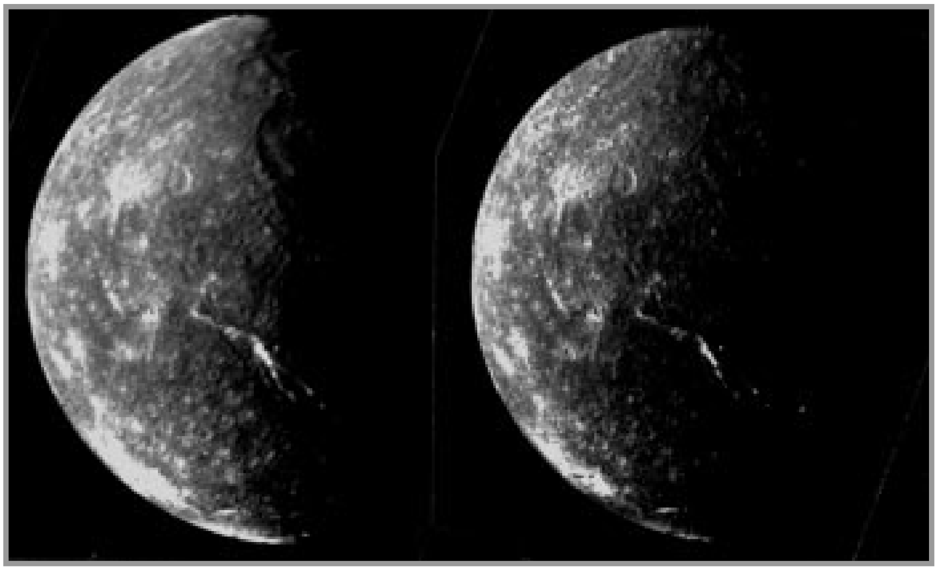


__Figure 14.9.__ The icy satellite Titania, a moon of Uranus. (Stereo image courtesy Paul Schenk, Lunar and Planetary Laboratory, Houston; reprojected Voyager frames FDS 26836.55 [left] and 26843.13 [right]).

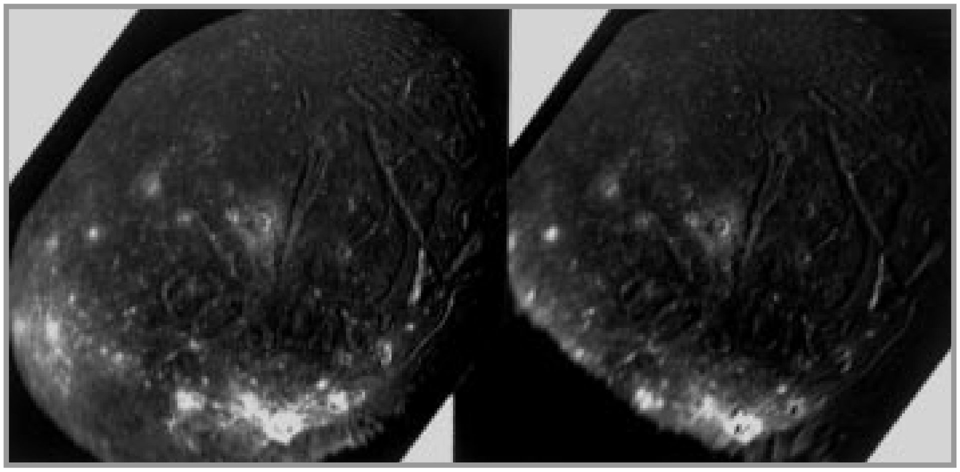


Figure 14.10. *The icy uranian satellite Ariel is seen in this stereo pair. (Image courtesy Paul Schenk, Lunar and Planetary Laboratory, Houston; reprojected Voyager frame FDS 26843.40 [left] and reprojected mosaic of frames 26845.33, .35, .37, and .39 [right]).*

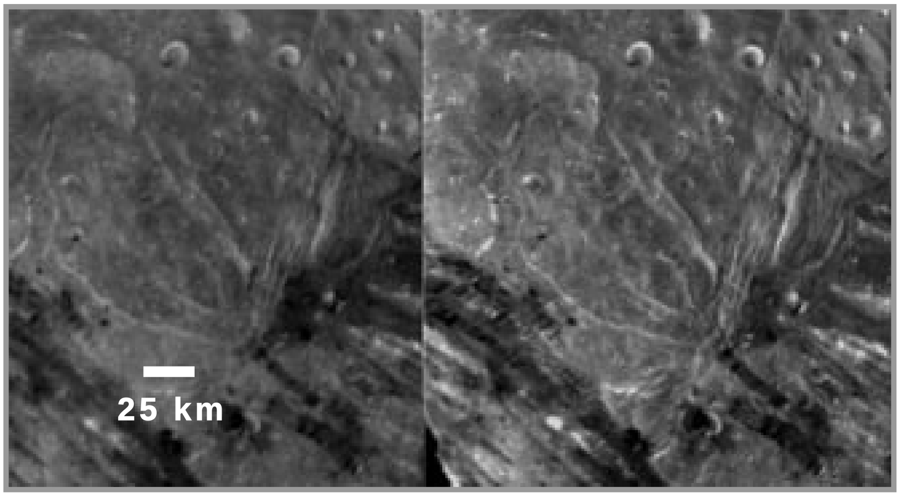


Figure 14.11. *Miranda, the innermost of the five major icy moons of Uranus, seen in stereo. (Image courtesy Paul Schenk, Lunar and Planetary Laboratory, Houston; a reprojected mosaic of Voyager frames FDS 26846.11 and .14 [left] and reprojected frame 26846.26 [right]).*