Exercise Two is suggested as an introductory exercise.

■ ★ 1.0 hours

Geologic Features of Venus

Instructor Notes

Suggested Correlation of Topics

Venus geomorphology, impact cratering, radar, remote sensing, tectonism, volcanism

Purpose

The objective of this exercise is to introduce the student to the remote sensing technique of radar imaging and to introduce the surface features found on Venus.

Materials

Suggested: clear acetate or overhead projector film, overhead projector markers, tape, 25 cm piece of string

Substitutions: tracing paper, pencil, ruler

Background

This exercise introduces the use of radar images for geologic feature identification. Most people are not familiar with radar as an imaging system. Consequently, the student introduction contains extensive information to aid in completing this exercise. With completion of the exercise, the student should be able to recognize and identify some of the major geologic features found on Venus and understand the use of radar as a remote sensing technique.

The explanation of radar and radar imaging in this exercise is highly simplified, focusing only on surface roughness. Factors such as wavelength, incidence angle, polarization and signal processing are not presented, although these factors are very important controls on the appearance of radar images. Students may only be familiar with the use of radar for weather satellites, air traffic control monitors, and police speed guns. Air traffic control radar and police speed guns work because the metal in cars and airplanes is highly reflective at radar wavelengths. Because radar is an active system (it emits energy), it is not dependent on the sun or good weather for use; it can be used at night and is an important safety measure for air travel. Weather satellite radar systems use relatively short wavelengths, small enough for individual ice crystals and water droplets in clouds to reflect the signal back to the satellite, producing the images we see on the evening newscast. The Magellan spacecraft at Venus used a longer wavelength system that penetrated the thick cloud cover that shrouds the planet.

The vertical stripes on some images of Venus (most obvious in figures 12.4, 12.5 and 12.9) are artifacts of the Magellan imaging system. Each stripe represents a single orbit of the spacecraft. Black stripes are present where the spacecraft did not image.

Teacher Recommendations

The instructor is encouraged to present the electromagnetic spectrum before working this exercise, and to explain the radar part of the spectrum. The exercise is divided into three parts. The first part examines Venus features and asks the student to answer questions based on the images. The second part has the student identify various features within a region of Venus. The third part has the student design a rover journey to some of the features identified in part two. The "rover" part of this exercise will produce many and varied paths, depending on features identified, features chosen for a rover visit, and the rover starting point. The map in the answer key identifies all the features students are asked to locate, and includes two sample rover paths. The test for rover path accuracy is in the distance used (25 cm maximum) and whether the rover stays on the dark (smooth) plains while traveling to the selected features of interest. This exercise can be done in groups or by individual students. A further suggestion for this exercise is to plot all the rover paths on a single page (or on an overhead projector viewgraph) and have the class decide on the path that is best, providing the most interesting scientific results with the least risk to the rover. Such a discussion closely simulates planning meetings for NASA missions. For further interdisciplinary application, rover groups could assign different tasks within each group: someone to draw a picture of the rover, someone to draw pictures of what the rover might see, a science group to plan the rover path, a "reporter" to write up a travelogue of what the rover did and saw, and any other tasks that the students consider to be important to the mission.

Science Standards

- Earth and Space Science
  - Origin and evolution of the Earth system

Mathematics Standards

- Measurement

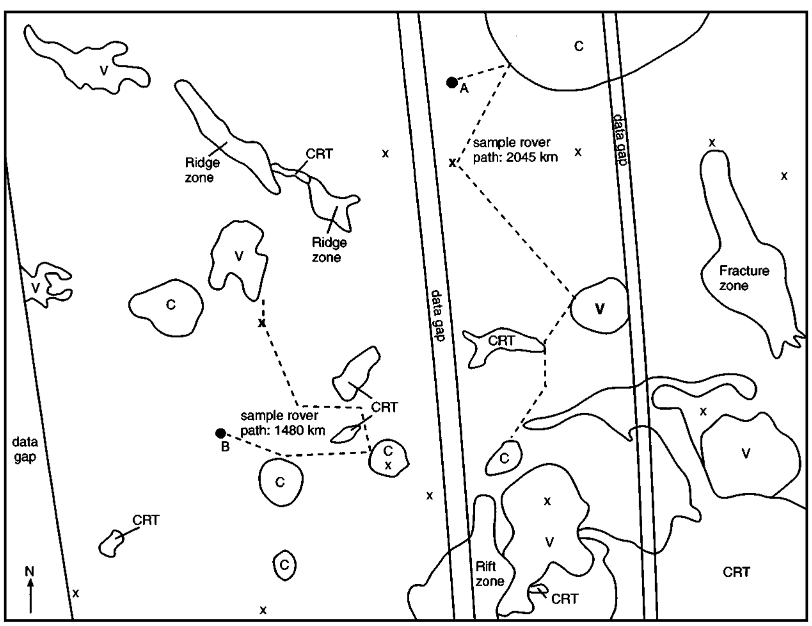
Answer Key

1. **a.** The ejecta, rim, and central peak consist of broken rock fragments and have a rough texture which appear bright in the image. The crater floor is smooth and appears dark in the image.

   b. Feature A has a rough texture.
2. Crater is older. It had to already be there to be rifted by later tectonic activity.
3. No. The same tectonic activity that formed the complex ridged terrain has not affected the volcanic plains, meaning that the plains are younger, and that either that style of tectonism has ceased, or that it is episodic and has not occurred since the plains were emplaced.
4. Almost all appear to have a central summit crater, and to be cone shaped. Some are brighter than others indicating differences in texture.
5. Flow textures are both rough (bright) and smooth (dark). The flows have lobate outlines and contain "feeder" channels (usually dark in tone) that supplied the lava to the flow front.
6. ~200 km in diameter
7. a. Flows are rough (bright on the image).

   b. ~150 km

NOTE: On the student maps, they will label all tectonic zones as "rift zones." On the answer key, these zones are marked as rift zones, ridge zones, and fracture zones. Ridge zones have positive relief, rift zones have negative relief, and fracture zones have not had any displacement (neither positive nor negative).



Name ______________________________

Geologic Features of Venus

Purpose

To learn about geologic features on Venus and the use of radar images.

Materials

Clear acetate, overhead projector markers, tape, 25cm piece of string

Introduction

Radar is an imaging and detection system that uses the microwave section (~1mm to ~1m wavelengths) of the **electromagnetic spectrum.** By changing the wavelength used by radar, different objects can be detected. Radar is an active system in that the signal energy is transmitted from and received by the instrument. Our eyes are a passive system, we only receive reflected energy (as from the sun or a light bulb). Because radar produces and receives its own energy, it is not generally dependent on environmental conditions for its use. It can be used during the day and at night, and because radar wavelengths can penetrate clouds, it can be used during most kinds of weather.

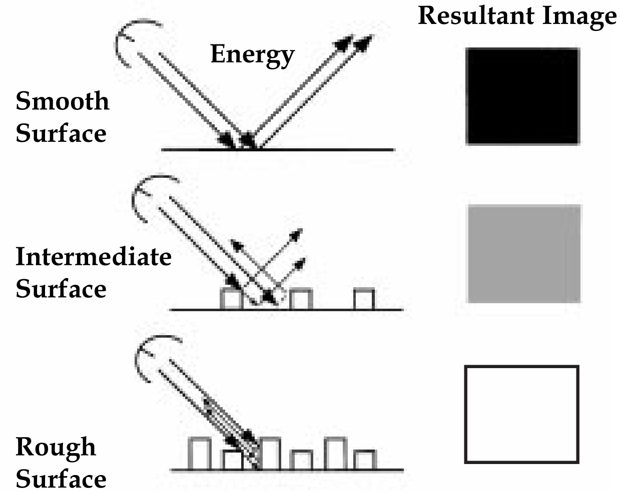


__Figure 12.1.__ Diagram of radar reflectance and effect on resultant image. Smooth surfaces reflect the incident energy away from the antenna, producing a dark tone (non-return) on the image. A rough surface scatters the incident energy, some of which will be returned to the antenna and produce a bright tone on the image.

All electromagnetic energy interacts with the objects and surfaces it encounters by being absorbed, transmitted, or reflected. We see only the light that is reflected (bounced) toward our eyes. The radar system will only "see" the radar waves reflected back to the antenna (Figure 12.1). The more energy reflected back to the antenna, the brighter the tone created in the resultant image. In general, smooth surfaces are dark in a radar image and rough surfaces appear bright. One way to think about radar is that it shows how the surface "feels" (rough or smooth), whereas a conventional photograph shows how a surface "looks" (color and brightness). Because we are not accustomed to thinking about a surface in terms of its texture, working with radar images can be difficult at first.

Figures 12.2 a and b show the same area of the Mojave Desert of California. Figure 12.2a is a visible wavelength Landsat satellite photo and 12.2b is a Seasat radar image. The feature marked A is a lava flow. In the Landsat photo it is dark, because the rocks are dark in visual appearance; but on the radar image the lava flow is very bright, because the surface is very rough and scatters the radar energy back to the antenna. The feature marked B is a dry lake bed. In the Landsat photo it is light, because the materials are light colored sands and clays. In the radar image, the lake bed is very dark and difficult to distinguish from the surrounding dark area. This is because both the lake bed and the surrounding sands are very smooth. Mountains appear bright in the radar image. It is easier to distinguish mountains from the surrounding sand deposits in the radar image than in the Landsat photo. Because of the radar's sensitivity to surface texture, it is able to image structural features (such as faults and fractures) that may be undetected in a visible wavelength photo. Note that a cinder cone within the lava flow (marked C) is easier to see in the radar image than in the Landsat photo.

Radar was used to image the surface of Venus because thick cloud cover makes the use of visible wavelength imaging impossible. The Venus radar images in this exercise were acquired by the Magellan spacecraft, which orbited Venus from 1990 to 1994. The vertical black stripes on some images are missing data, places where the spacecraft did not image the surface.

Questions and Procedures

Part A

Figure 12.3 shows two impact craters on Venus. They are surrounded by smooth volcanic plains, which are dark on the radar image. The crater rims are easily identified, as are the **ejecta** deposits.

1. **a.** Describe the ejecta, rim, floor, and central peak of the smaller crater in terms of texture.

   b. The ejecta of the larger crater is different from that of the smaller crater. Part of the ejecta of the larger crater was molten, melted rock and formed flows. What is the texture of the ejecta flow labeled A?

The right side of Figure 12.4 shows a rift zone on Venus. Although the rift zone appears almost flat in the image, the topography of this area is more like the Grand Canyon of Arizona, with steep cliffs and deep valleys. The other bright lineaments in this figure are fractures and faults.

2. Note the crater at A. Is it younger or older than the rift? How do you know?

Figure 12.5 shows an area of "complex ridged terrain," the term used for some mountains and highlands on Venus. This area has been fractured, faulted, rifted, uplifted and surrounded by younger smooth (dark) plains. The deformed area is very bright in the radar image because the complex structures have produced very rough terrain.

3. Does the tectonic activity that formed the complex ridged terrain appear to have affected the volcanic plains? What does this indicate about tectonic activity in this area and the age of the volcanic plains?

Figure 12.6 shows many small (1–10 km in diameter) volcanoes, constituting a "volcanic shield field." Volcanism has played a major role in the formation of the surface of Venus, and shield fields are common.

4. List any similarities and differences among the individual volcanoes.

Most dark (smooth) plains on Venus are volcanic. However, not all volcanic flows on Venus are dark; some are bright. Figure 12.7 shows an area of volcanic flows.

5. Describe the field of flows shown in the image. Include information as to texture, outline, and any other interesting features.

So far all the figures have shown features that can be found on Earth as well as on Venus. Figure 12.8 shows features that may be unique to Venus. Termed "coronae" (the singular is "corona"), these features are identified by circular sets of fractures. Some form low, circular domes that can have associated volcanic flows (for example, the flows to the north and northwest of the corona marked A); or the centers may have subsided, leaving bowl-shaped depressions, which can be filled by lava flows. Radial fractures commonly surround coronae, giving a "buglike" appearance.

6. What is the diameter of the largest corona in the image?

7. **a.** Are the flows to the north and northwest of the corona labeled A rough or smooth in texture?

   b. How far from the letter A did the volcanic material flow to the northwest?

Part B

Figure 12.9 shows part of the Carson Quadrangle of Venus, centered at 11°S, 345°E. The area shown is equal to about two-thirds of the continental United States. All the types of features shown in the previous figures can be found on this image; however, due to their small size, shield fields are very difficult to see. The black areas are regions that were not imaged by Magellan. The bright circular spots are where meteoritic material struck the surface without forming an impact crater. These are called "splotches." Be sure to note the difference in scale between this figure and the previous ones.

Tape a piece of clear acetate to the figure. Draw a box outlining the image. Trace the scale bar and north arrow. On the acetate, identify all the features listed below.

A. Identify as many coronae as you can. Trace their outline and place a "C" within the outline.

B. Identify and mark with an "x" all the craters in the image area.

C. Outline and label with the letters "CRT" all areas of complex ridged terrain.

D. Outline and label with an "R" all rift zones.

E. Outline and label with a "V" areas of volcanic flows. Do not include the extensive smooth plains flows. Look for the variation in texture as seen in Figure 12.7.

Part C

One day, planetary scientists hope to send a robotic rover to the surface of Venus. Because the surface temperature is about 470°C (~870°F), people will probably never set foot on this planet. In this part of the exercise you will plan a rover journey.

In planning the rover path remember these rules: 1) the robotic rover can only travel on smooth terrain (dark plains); 2) it cannot cross rift zones or complex ridged terrain; 3) it must travel in straight lines (turns are allowed, but the path will be lines and angled turns rather than curves); and 4) the rover can *cross* the black non-imaged parts of the image, but you cannot drive for any great distance inside the black areas, because there may be unknown obstacles.

You should develop a rover path to include a visit to at least 1 crater, 2 coronae, the edge of a region of complex ridged terrain, and an area of volcanic flows (not including the smooth plains). Spacecraft and rover engineers designed the rover to travel a maximum distance of 3430 km (a distance of 25 cm on the image) starting from either landing point A or B. Because of the high temperatures on the surface and the limited fuel carried by the rover, 3430 km is the maximum lifetime-distance expected of the rover. Optimizing your path to travel less than 3430 km is highly recommended by the design team. Use the string (or a ruler), the image, and your acetate map with the features identified to plan a rover path to visit the five features listed above.

You may choose any individual feature to visit, but you must begin at either point A or B, and you must complete the path to all five features in 3430 km (25 cm) or less. You do not need to return to the starting point. If you are having difficulty in planning the rover path, ask your instructor to check that you have identified all possible locations for each type of feature. Once you have settled on the features to visit and the rover path, trace the path onto your acetate "map."

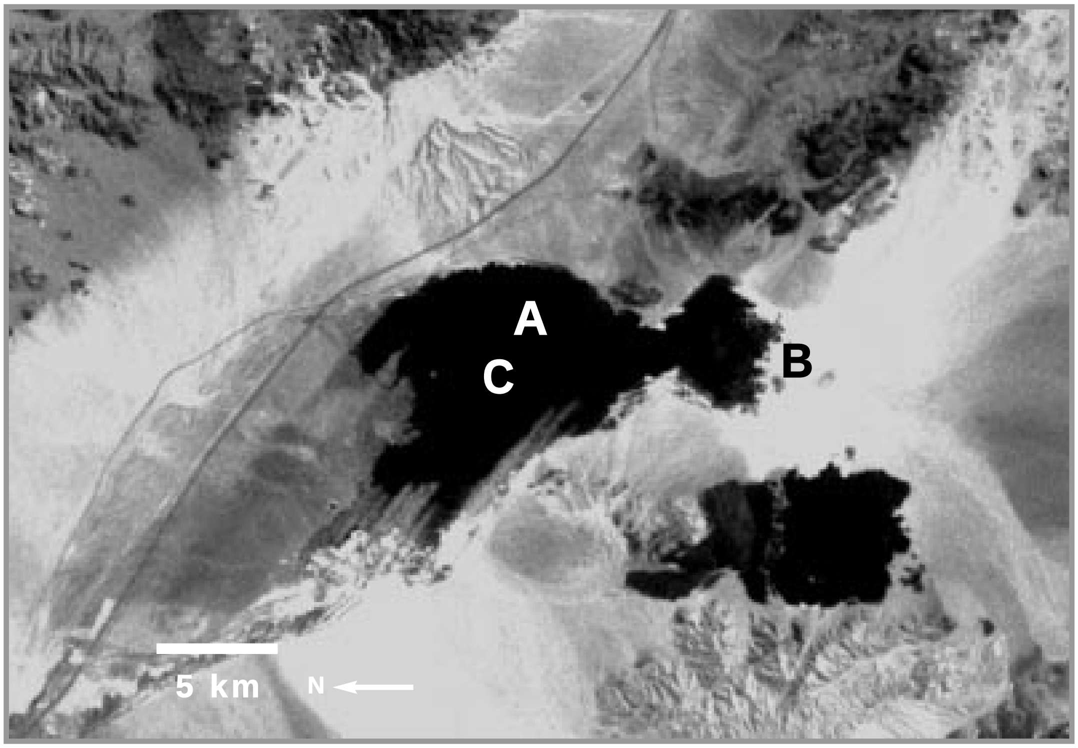


Figure 12.2.a. *Landsat photo of part of the Mojave Desert, CA.*

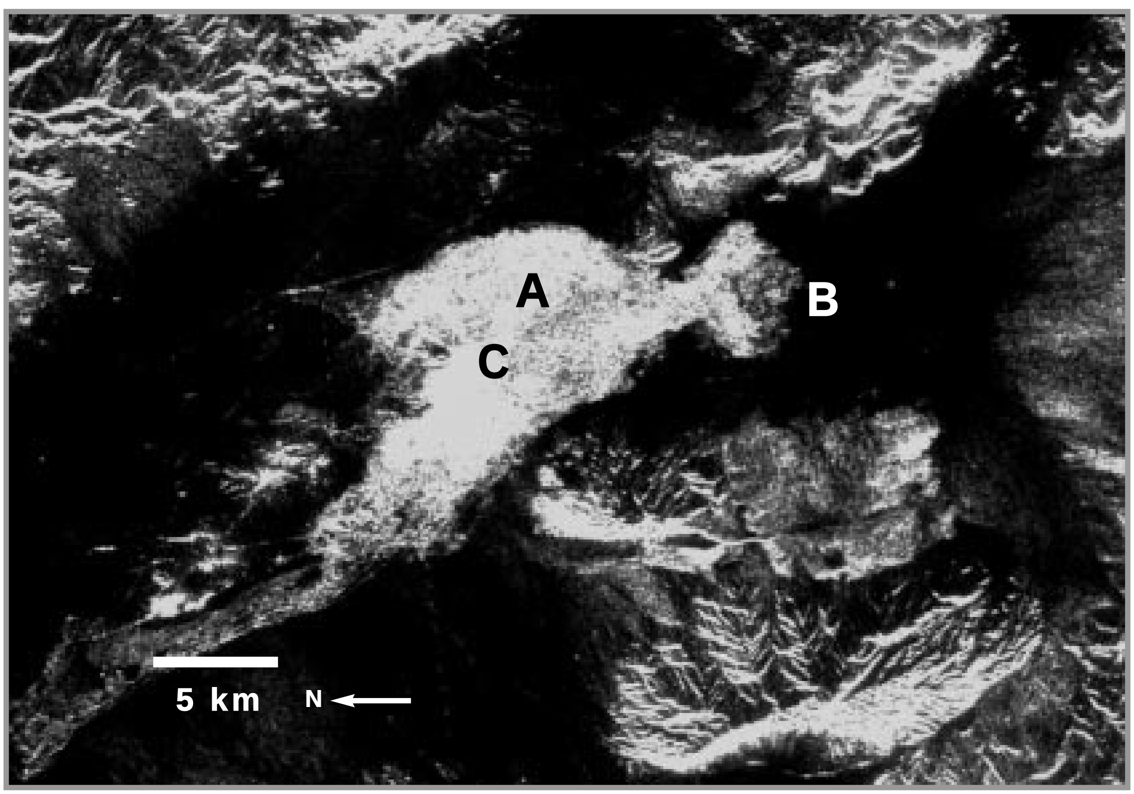


Figure 12.2b. *Seasat radar image of the same part of the Mojave Desert, CA as shown in Figure 12.1a. The feature labeled A is the Pisgah lava flow. The feature labeled B is a dry lake bed. The feature labeled C is a cinder cone.*

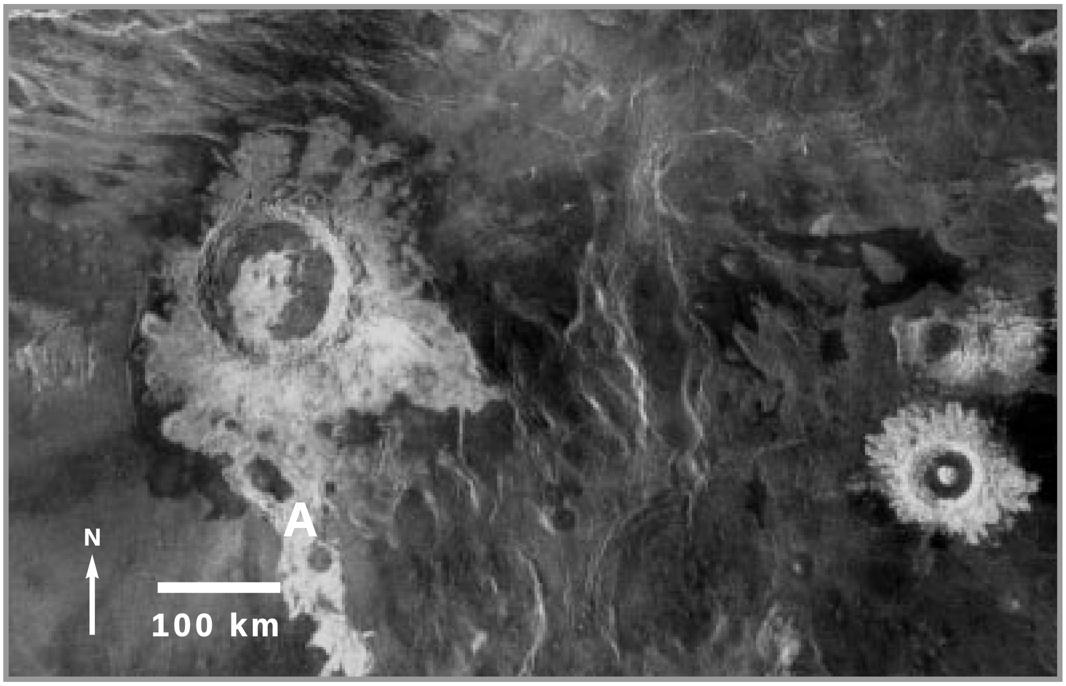


Figure 12.3. *The prominent circular features in this image are impact craters. Magellan radar image (F-MIDR 30N287). North is to the top.*

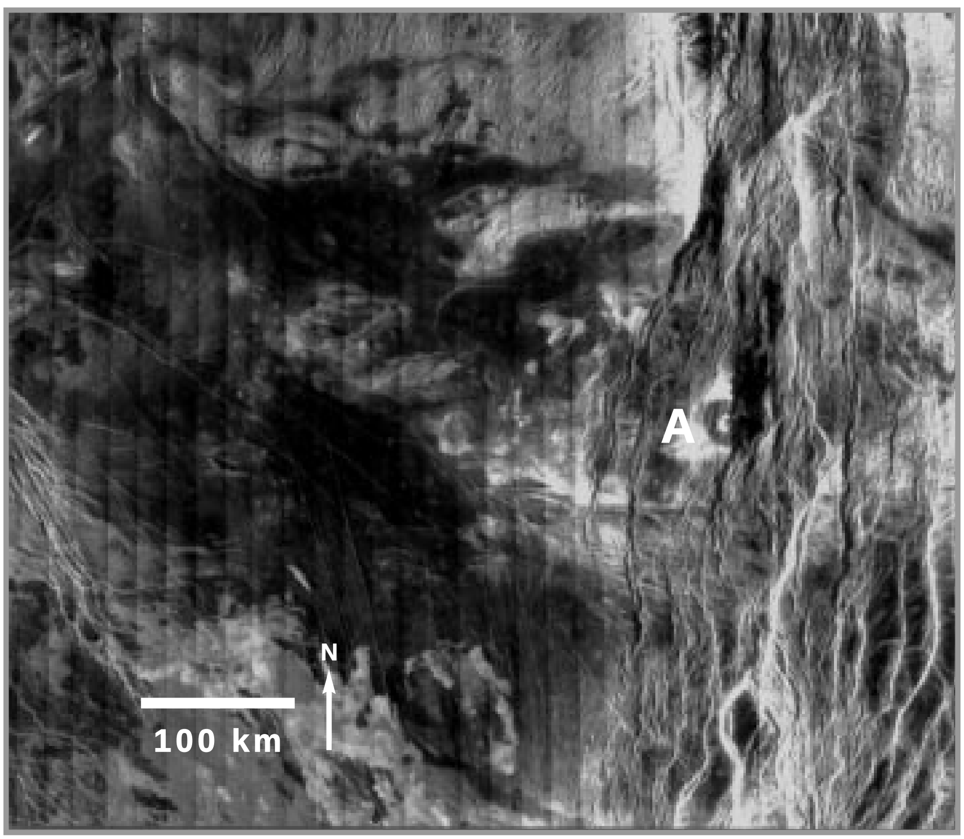


Figure 12.4. *The right side of this image shows a major zone of rifting. Note that the crater labeled A has been cut by the rift, with part of the crater visible on both sides of the rift. The thin linear features in the southern portion of this image are faults and fractures. Magellan radar image (F-MIDR 30N281). North is to the top.*

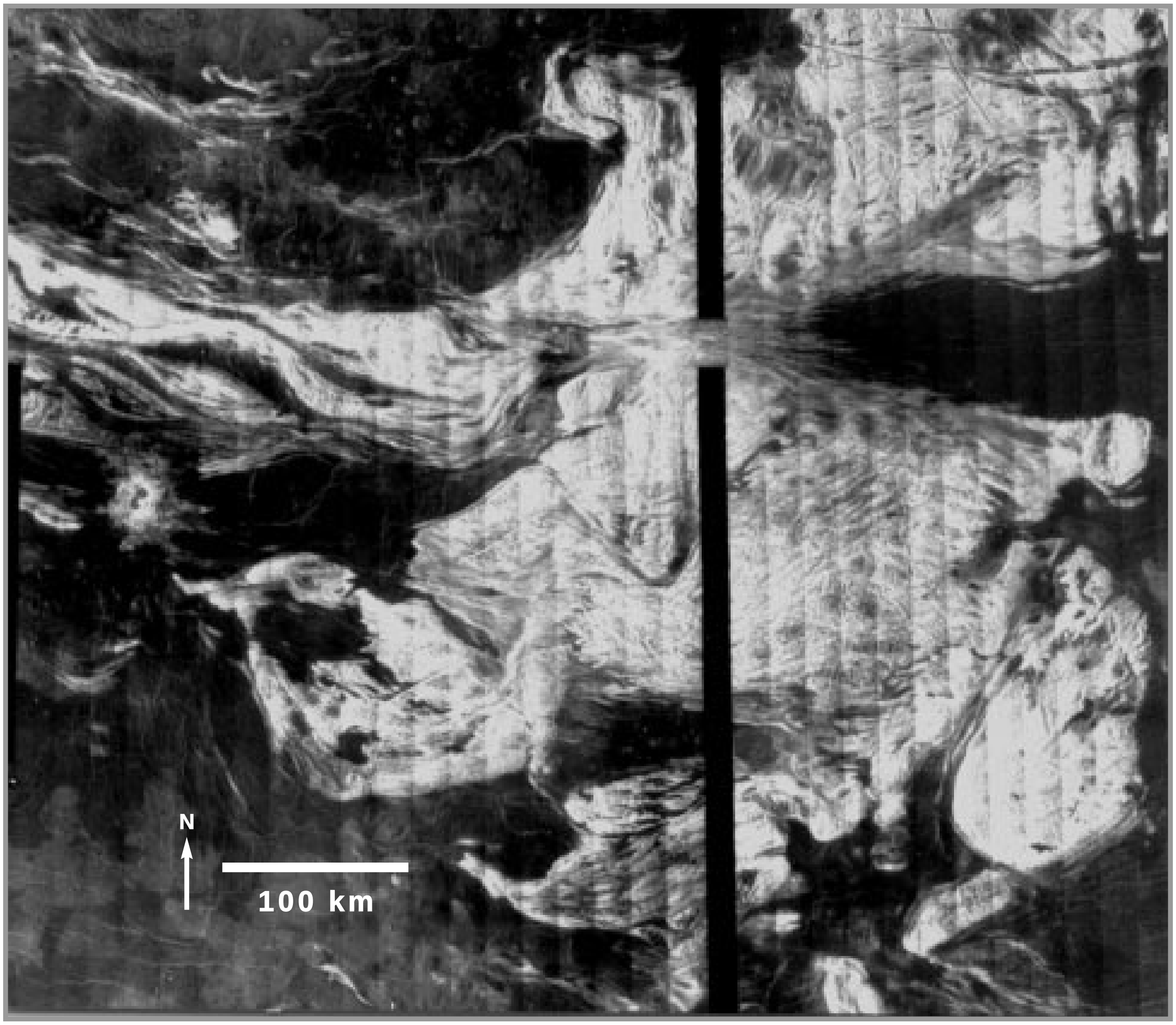


Figure 12.5. *This image shows the terrain termed "complex ridged terrain" or "tessera" on Venus. Considered by many to be the oldest surface terrain, it has been subject to extensive faulting and fracturing. It generally forms highlands above the surrounding volcanic plains. Magellan radar image (F-MIDR 30N123). North is to the top.*

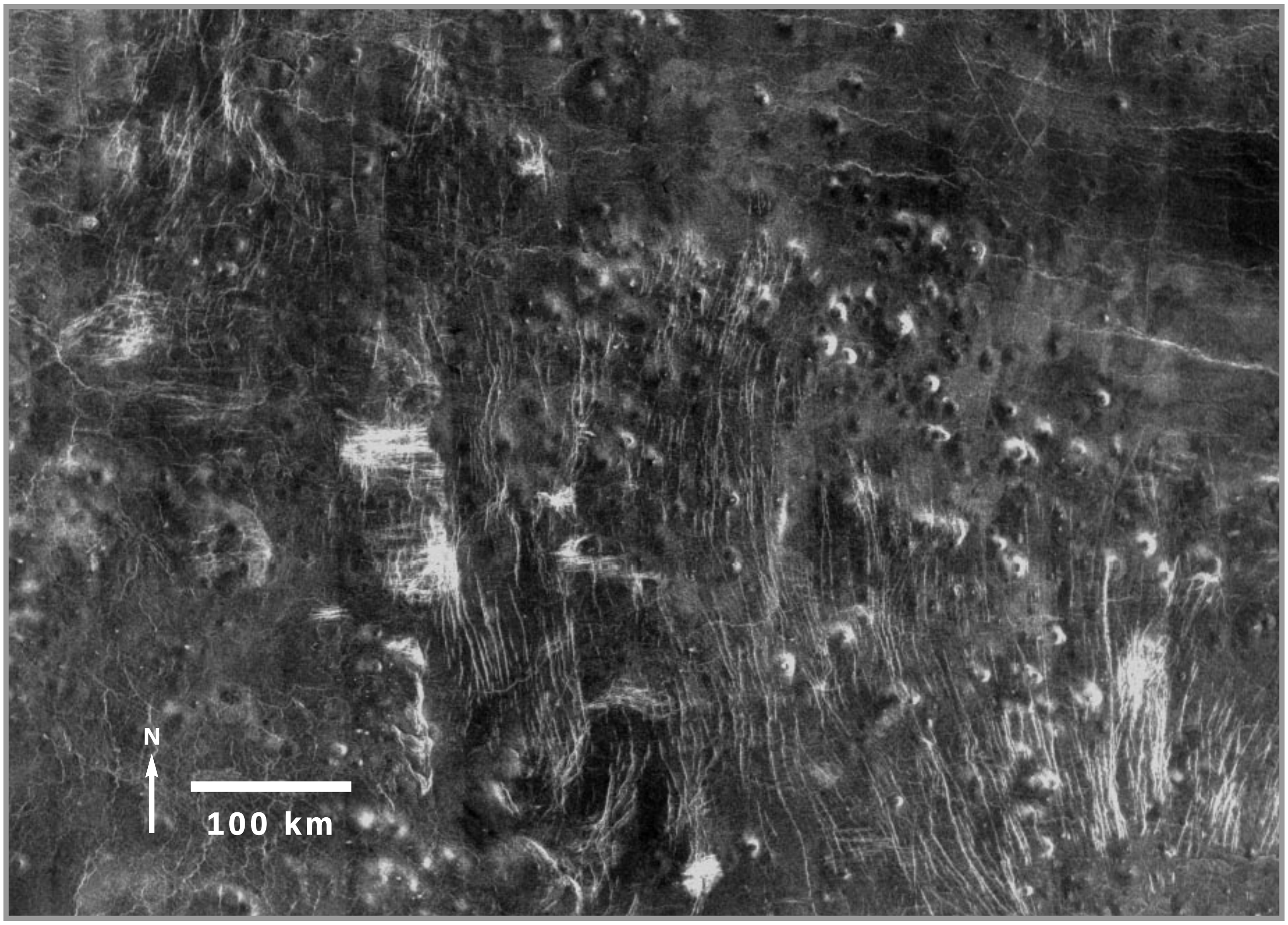


Figure 12.6. *Volcanoes come in all sizes on Venus. The ones in this image range from 1 to 10 kilometers in diameter. While volcanoes of this type and size are sometimes found as an isolated structure within the volcanic plains, they are generally found in clusters, termed "shield fields," like the field shown here. Magellan radar image (F-MIDR 45N119). North is to the top.*

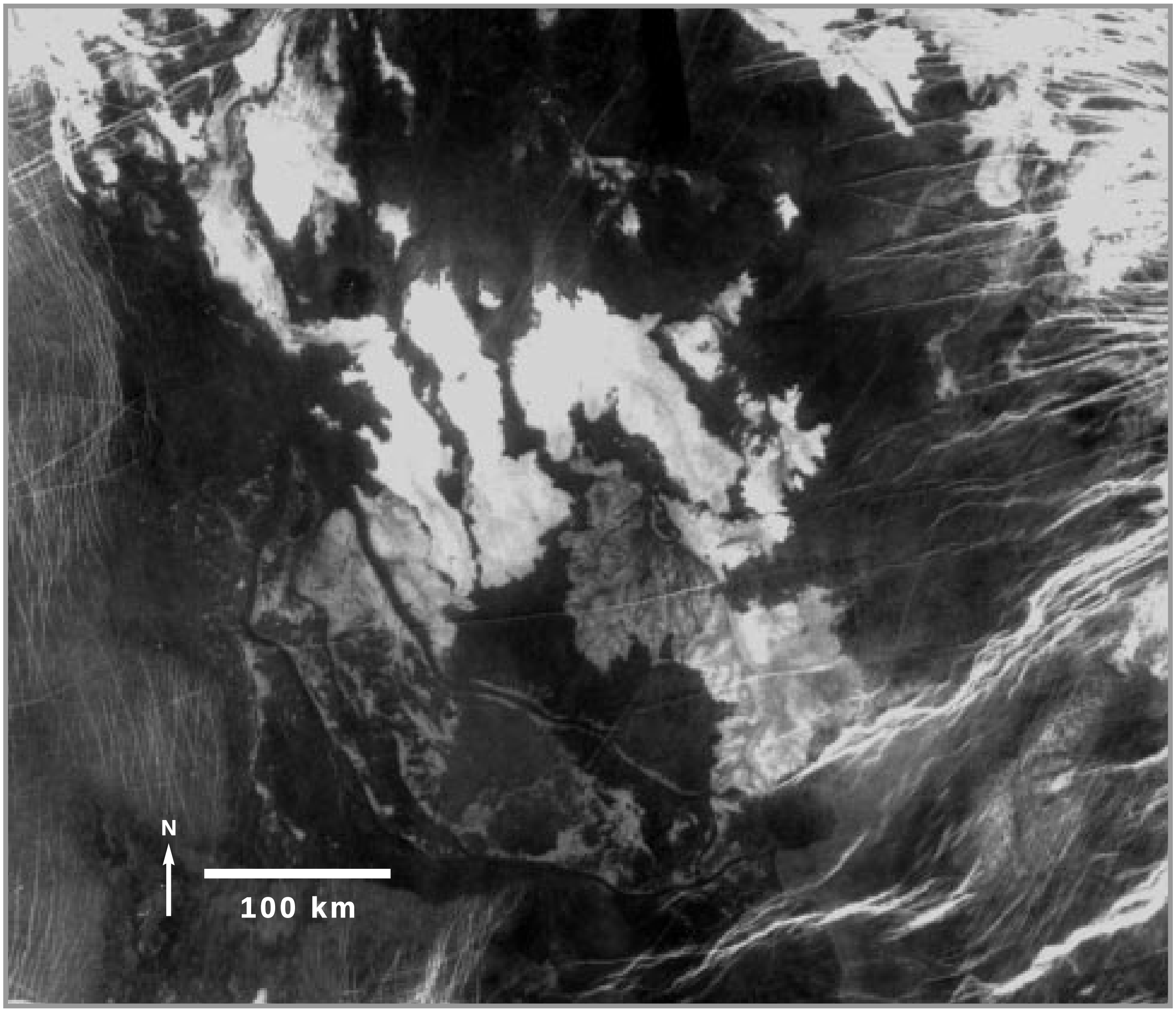


Figure 12.7. *This image shows an area of young volcanic flows. Magellan radar image (F-MIDR 20S180). North is to the top.*

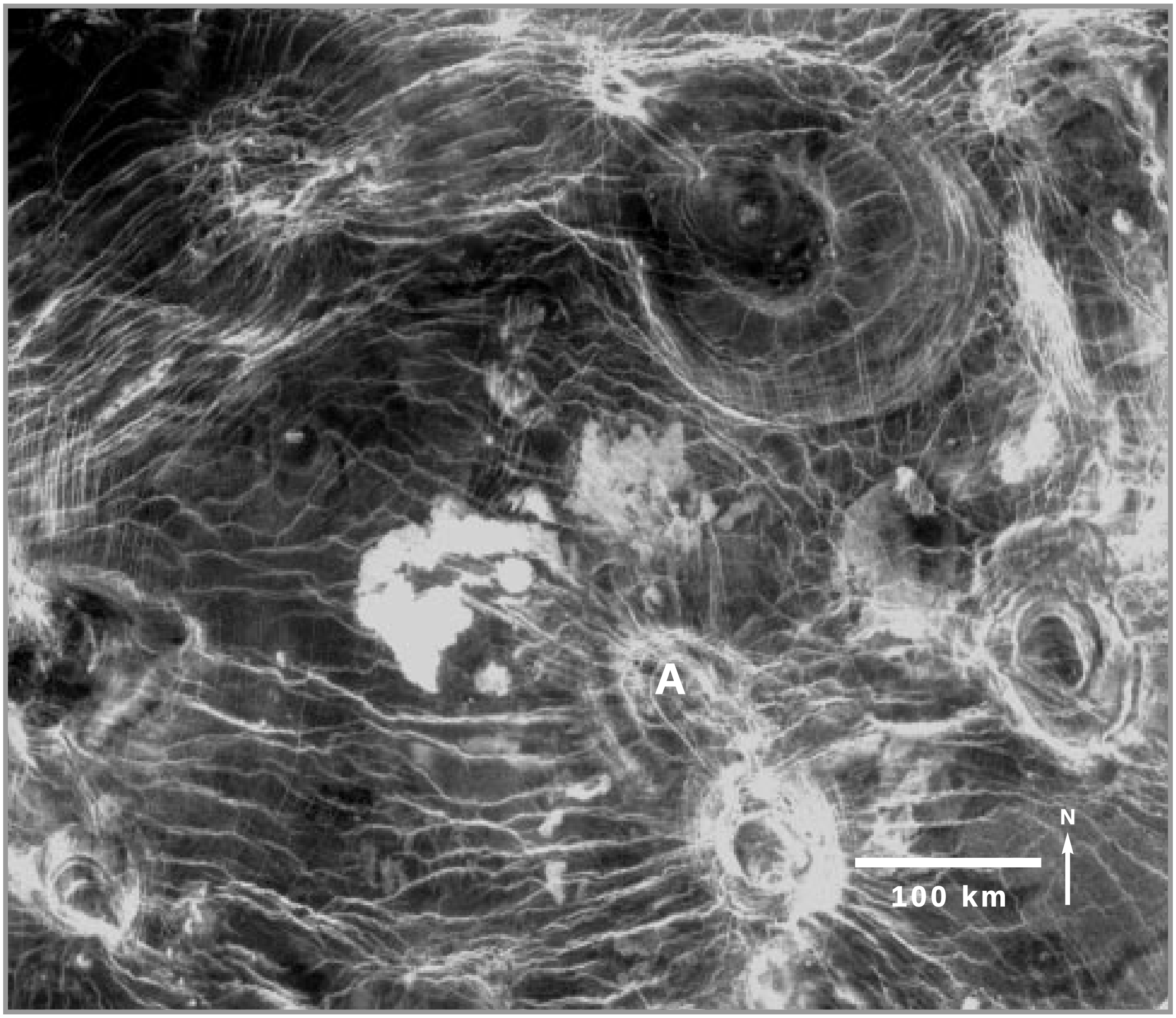


***Figure 12.8.** The circular features in this image are termed "coronae" (singular: "corona"). Interpreted to have formed by the rise and then subsidence of subsurface plumes of material, these features are easily identified by the characteristic circular and radial fracture patterns. Some coronae have been the site of volcanic flows, such as at the corona labeled A. Magellan radar image (F-MIDR 40N018). North is to the top.*

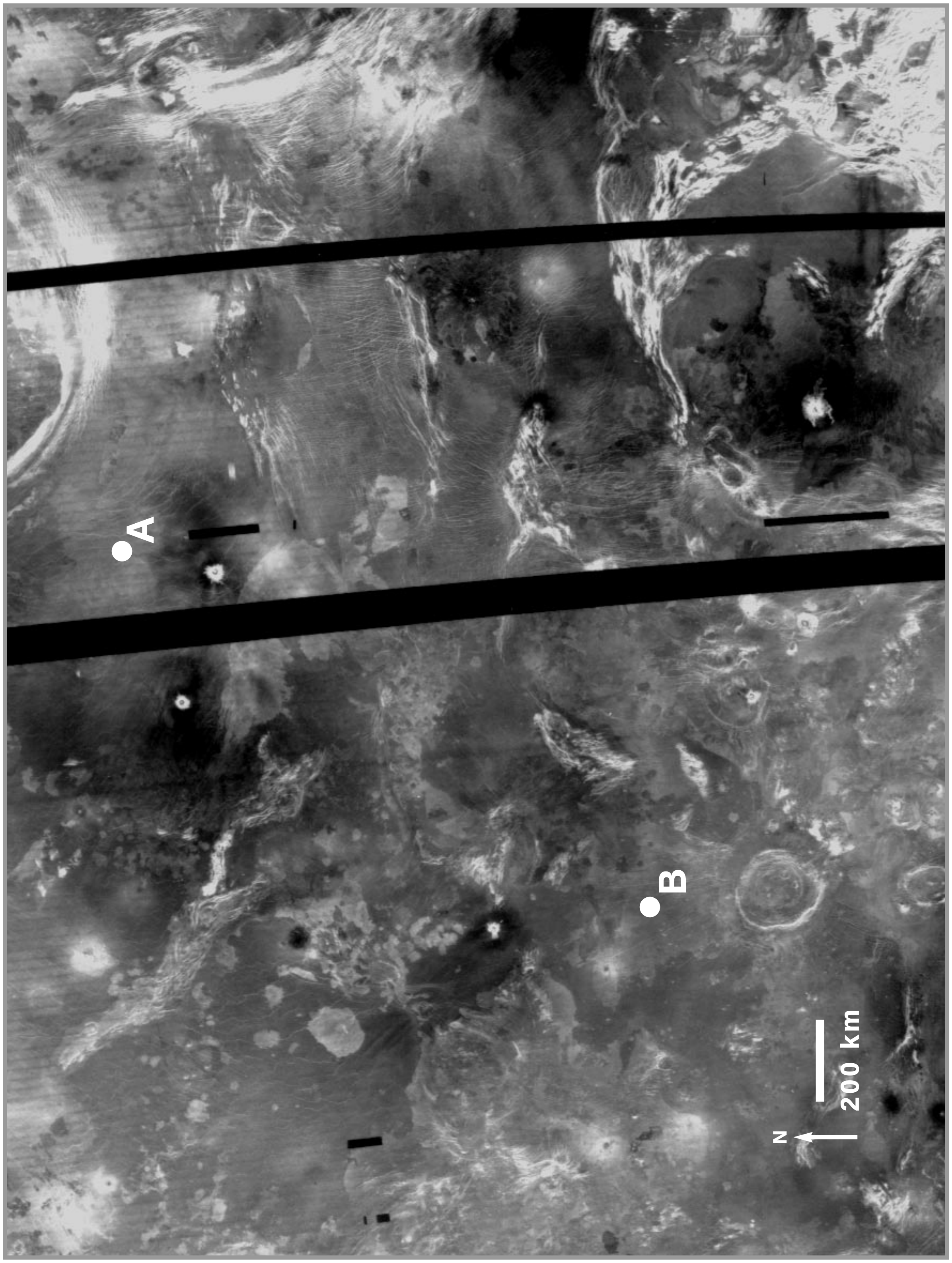


Figure 12.9. *Magellan radar image of part of the Carson Quadrangle, Venus (C2-MIDR 00N337;2). North is to the top.*