Craters on Mars

Time:
two separate 45-minute sessions

Objectives:
The lesson prepares students to interpret remote sensing images of craters for the presence of water or the lack thereof on the surface features of Mars.

Students will analyze and interpret the cause of crater formation on Mars (and other celestial bodies) and be able to predict the:
- relative age of the craters
- erosion processes
- relative water content of local impact areas
- relative mass and speed of impactors.

Content Standards
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry
- Understand how to measure using non standard and standard units
- Select an appropriate unit and tool for the attribute being measured.
- Use tools to measure
- Develop common referents for measures to make comparisons and estimates. Understand that measurements are approximations and how differences in units affect precision.
- Solve simple problems involving rates and derived measurements for such attributes as velocity and density.
- People have always had questions about their world. Science is one way of answering questions and explaining the natural world and solar system.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.
- Apply and adapt a variety of appropriate strategies to solve problems.

Equipment, materials, and tools:

For the teacher:

- 2-3 five pound bags of flour
- 1 can of hot cocoa mix or brown tempera paint
- 1-2 large deep dish pans or containers (at least 3-4 inches deep)
- a variety of projectiles of varying mass and size:
  - BBs,
  - marbles,
  - plastic beads,
  - steelys (steel marbles).
- a variety of pictures of craters on Mars taken by remote sensing orbiters.
- OPTIONAL: slingshot for increasing speed to projectiles (protective goggles should be used if a slingshot is used.)

For the student:

- pen or pencil
- 2 sheets of paper
- metric ruler

Materials to reproduce:

(suggest 1 copy per group of students)

- Figures 1-23

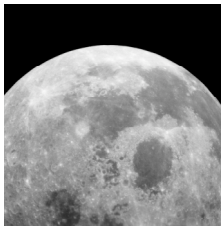
Student Skills:

- comparing models of terrain morphology to remote sensing images of Mars
- interpreting surface features of Mars
- understanding of the role of mass and speed on impactors

Background Information:

The relative age of craters:

With a few exceptions, craters have been found on all terrestrial planets and moons that have been imaged so far. Some are so densely cratered that further impacts simply wipeout or cover previous craters. The relative age of a crater in relation to others surrounding it can be determined by studying processes of erosion, the overlapping of craters on top of craters or crater ejecta over other craters.



Fresh, recently created craters have these similarities:

- a concave, bowl-shaped depression in the middle
- a raised rim higher than the surrounding topography
- a layer of ejecta (material thrown out of the crater at the time of impact) that surrounds the rim and covers other topographical features.

Older craters typically:

- have flatter depressions in the middle due to erosion filling them in
- have rims more rounded and flattened due to erosion
- have less noticeable ejecta due to erosion or being covered by newer impacts or ejecta.

The Mass and Speed of Impactors

When American astronauts visited Earth's moon, they reported that craters were everywhere (see Figure 23), ranging from millimeter wide pits to 50 miles across, all due to meteorite impact. Two factors determine the size of a crater: mass and speed. The greater the impactors mass and the faster its speed, the larger the crater formed.

The presence of sub-surface water or water-ice.
Water at the point of an impact influences the formation of the resultant crater and the pattern of the ejecta. Planetary scientists postulate that some craters on Mars that have a "splash" pattern of ejecta surrounding the crater are the result of the flash heating of sub-surface ice. These "splash" patterns differ significantly from typical Mars craters and are almost non-existent on other planets where there is virtually no surface or sub-surface ice.

Lesson Plan: Part 1 - What causes a crater on Mars?

1. Preparation before the lesson: Pour the flour into the deep-dish pan filling it to within one inch of the lip of the pan. Smooth the flour flat. Cover the surface of the flour with a one-quarter inch layer of hot cocoa mix or brown tempera paint. Cover it well enough so as not to see any flour.

2. Have the students review various pictures of craters, volcanoes, and erosion features of Mars (Figures 1-21). Ask them to brainstorm what forces created some of these features. Ask the students, "Which of these features was caused by something that was not a part of the planet?" (Answer: Craters).

   Questions to get the students thinking:
   a. What types of things impact planets?
   b. What are they made of?
   c. How big are they?
   d. How fast are they going?
   e. What causes them to speed up when approaching a planet?
   f. Why do some of them make small craters while others make much larger craters?

3. Have the students take a sheet of paper and fold it into 8 equal sections. In each of the boxes have the students write:
   a. Impactor:
   b. Mass:
   c. Speed at impact:
   d. Crater size:

4. Place the pan on a table or the floor (much more dramatic on the floor). Tell the students that you (or one of the students, if you dare) will be dropping projectiles onto the surface of "Mars". After each impact they will record information based on their observations. They will write one of the following for each impact:
   a. Impactor: Plastic bead, BB, marble, or steely based on what was dropped.
   b. Mass: Low for the plastic bead and BB, medium for the marble, and high for the steely.
   c. Speed at impact: Low or high, low for dropping the projectile and high for throwing or using a slingshot.
   d. Size of crater: Have one student measure the diameter of each crater after its formation with a metric ruler.

Note to Teacher:

There are many variations that can be used for the speed factor. Have students brainstorm the best method to ensure constant velocities during their experiment. They can drop the projectiles from different heights recording the height for each drop. They can simulate oblique angle impacts by using a PVC pipe or a flat surface (board, etc.) folded to form a trough. At the appropriate student level, the velocity at impact can be determined mathematically. You may have the students calculate the speed using the equation for free-falling objects:

$$V = V_o - g\,(t)$$

V = velocity, V_o = velocity at time 0, g = acceleration constant ($9.8 m/s^2$)

5. From a standing position or standing on a step stool or table, drop the first projectile. Have the students observe the crater, measure the diameter, and record the data. Then proceed to the next projectile. After finishing all 4 types of projectiles, repeat, but at a higher speed (It's highly recommended that the teacher perform this portion of the projecting ☺). Add extra force when dropping by throwing, using a slingshot, or dropping from a greater height. For safety sake, keep the students at a distance during the impacting. Have them observe the newly formed craters and record their data.

6. Lead the students in a discussion on what factors produced the largest craters.

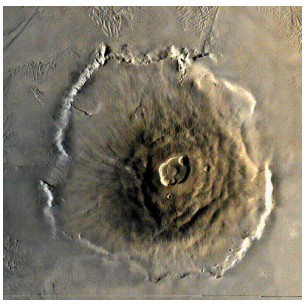
   Questions to consider?
   a. Which seems to have a greater effect, speed or mass of the projectile?
   b. What can cause a projectile to move faster?
   c. Where do these projectiles come from?
   d. What elements are found in asteroids, meteoroids, and comets?
   e. What are the real speeds of actual impactors?

7. Save the impacted flour mix for part 2 of the lesson.

Lesson Plan: Part 2 – What causes a crater on Mars?

1. Preparing for the lesson: Lightly tap or shake the pan so as to gently "erode" and cave in some of the craters. Then make some more craters. Try to place some of them close to the pre-existing craters. Don't be afraid to overlap some of them. Don't let the students watch you make the additional craters.

2. Using photos of craters (Figures 6, 7, 8, 16, 17, 18, 22) on the Moon and Mars have the students postulate which of the craters in the photos are relatively younger or older in comparison with others. Ask students to consider:
   a. What features show aging?
   b. If ejecta from crater "A" covers crater "B", which crater is more recent?
   c. The presence of rounded rims usually indicate what?



3. Show the students the newly created crater field (flour/cocoa mix) and see if they can organize the craters from youngest to oldest.

Note to Teacher: Many of the craters on the moon and Mars have been named. The students may enjoy naming the craters in the homemade crater field and then putting them in a list in order of age.

4. Fill the second deep-dish pan with sand or dirt. Fill it to about the same depth as the flour/cocoa mix. Wet the sand down thoroughly. Do not leave any standing water on the surface. That will make it too wet and messy.

   Discussion: What difference will a wet substrate make versus a dry substrate during the cratering process? What features can be expected? Have student make predictions.

5. Have student make craters on the wet substrate. The same process (four low speed, four high speed) as used in part 1 can be followed with the option to make just a few craters if time is short. The main idea to get across is that a wet substrate causes different features during cratering. Have students observe the new craters and record their observations
6. Using Figures 1, 6, 7, 8, 10, 11, 16, 17, and 21, show the students examples of craters on Mars. Have them guess which show possible evidence for water on Mars
   (The craters that scientists believe show evidence of sub-surface ice melt are: 1, 7, 10, 11,16).

NOTE: The results of the wet impact activity will not duplicate the suspected "wet impacts" seen on Mars. Scientists believe the features seen on Mars (e.g. Figure 16) are due to subsurface ice being super heated by meteor impact, melted and splashed out on the surface. This would be extremely difficult to replicate in the classroom ☺. However, some features will be evident and students should be able to predict which photos show evidence for water on Mars.

NOTE TO TEACHER: Teachers should feel free to experiment and try various ways to replicate the wet impact. Pudding, Jello, whipped cream, etc. Many different things can be added to sand and dirt to get substrate that mocks the remote sensing images from Mars.

Assessment: Criteria rubric (see figure 24 for duplication)

Name: _____ Teacher: Mr. J

Date : _____ Title of Work: _____

	Criteria				Points
	1	2	3	4	
Students will realize the importance of mass and speed of an asteroid or comet when it strikes a celestial body.	Student understands that speed and mass play a role in the cratering process.	Stundent understands that the higher the mass and speed, the wider and deeper the crater will be.	Student can predict crater sizes based on the given speed and mass of the impactor.	Student can apply information to a planetary scale and predict cratering processes on celestial bodies.	___
Students will be able to distinguish the relative ages of craters in a given area.	Student understands that there are ways to notice if a crater is older or younger than another.	Student can explain the methods of determining the relative ages of craters.	Student can tell which craters in a given area are older or younger than others.	Student can explain the erosional processes that "age" craters and therefor makes them different than other craters.	___
Students will be able to predict the water content of an area based on crater ejecta and structure.	Student understands that water has an influence on crater formation.	Student understands that watery impacts cause certain patterns in crater formation.	Student sees and notices the predicted patterns in orbital pictures taken from spacecraft.	Student can accurately select and predict which craters (out of a given selection) involve a watery substrate.	___
					___
					___
				Total---->	___

Teacher Comments:

_____

Questions:

1. What are craters?
2. What causes craters?
3. Where have craters been discovered on Earth?
4. Where have craters been discovered besides Earth?
5. What is the composition of the objects (impactors) causing craters?
6. What types of impactors have been found on Earth?
7. How fast are these objects traveling at impact?
8. How large can these objects get?
9. How small can these objects get?
10. Why do some planets and moons have more craters than others?
11. How often does Earth experience an impact?
12. What are the differences between a continental impact and an oceanic impact?
13. How would an impact on Earth from a large extra-terrestrial object affect human life?
14. What must be considered in spacecraft design for the investigation of asteroids and comets?
15. If scientists identify a possible extra-terrestrial impact in the future, can we stop it?

Figure 1

Figure 2

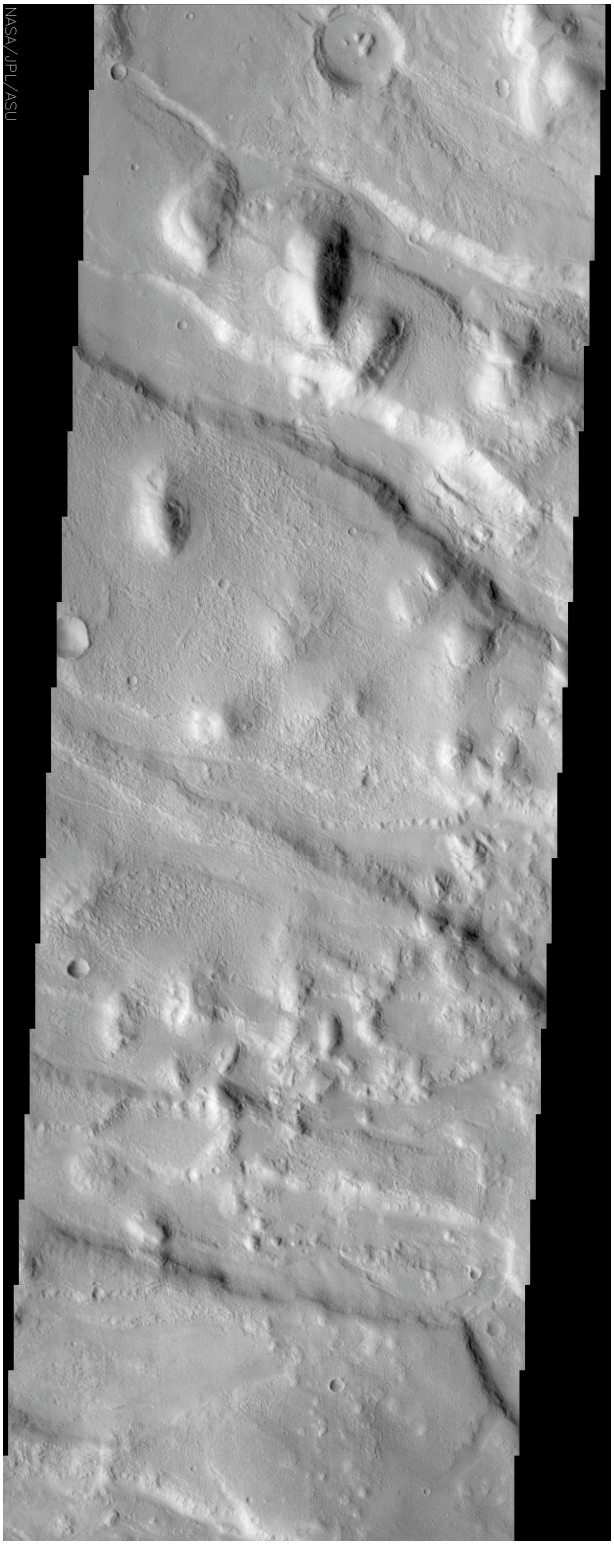


Figure 3

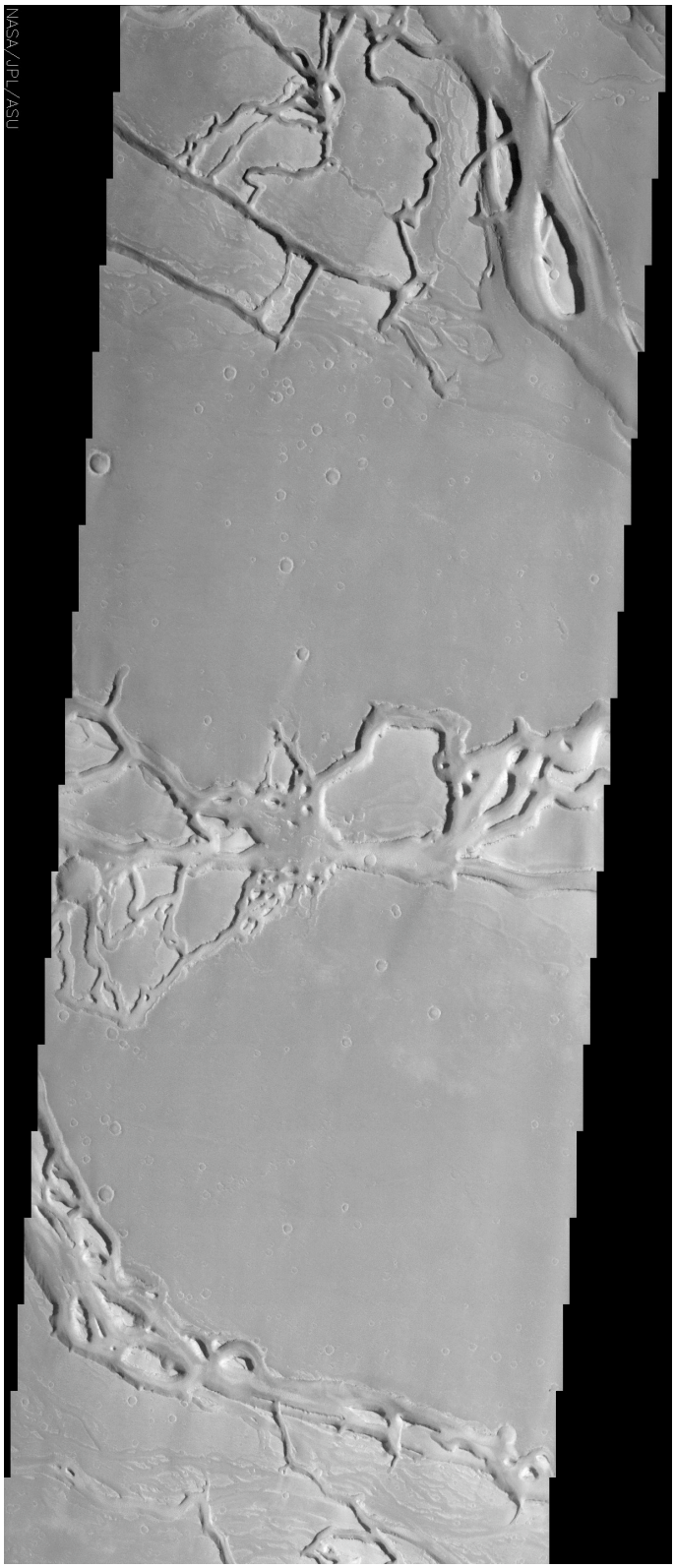


Figure 4

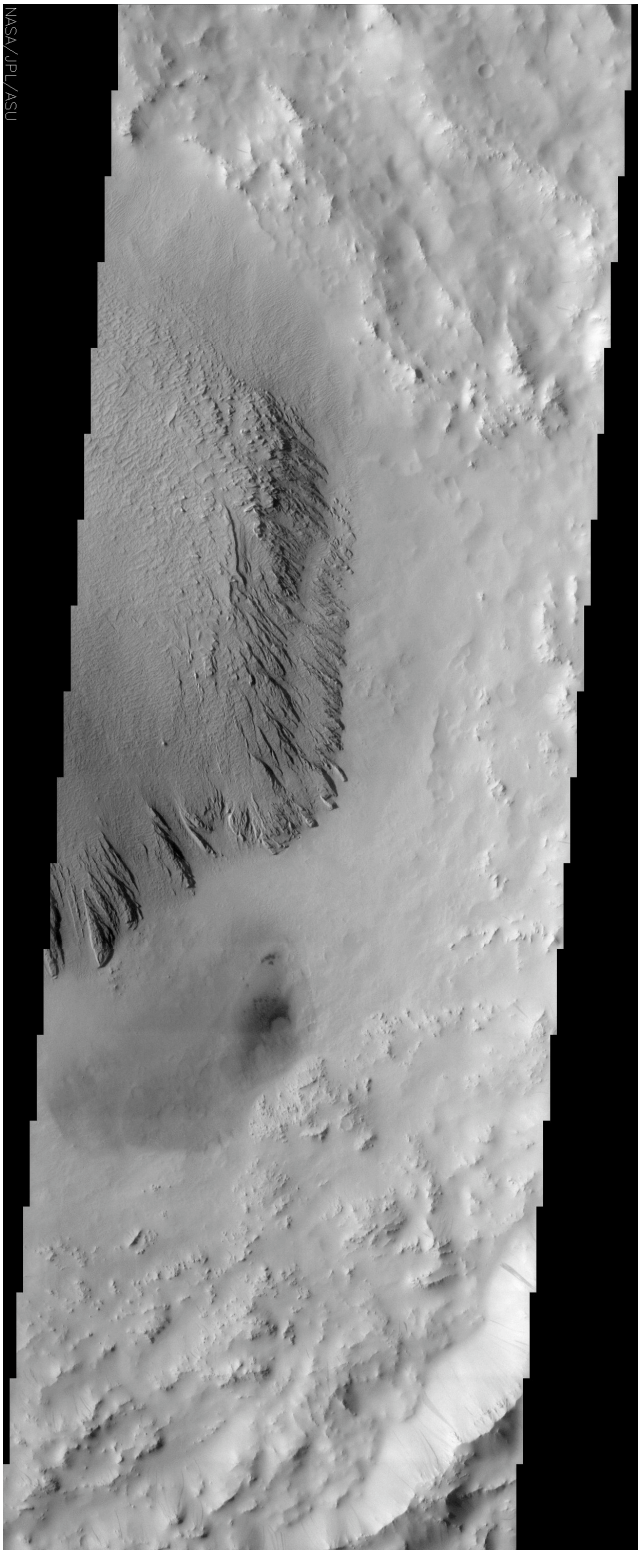


Figure 5

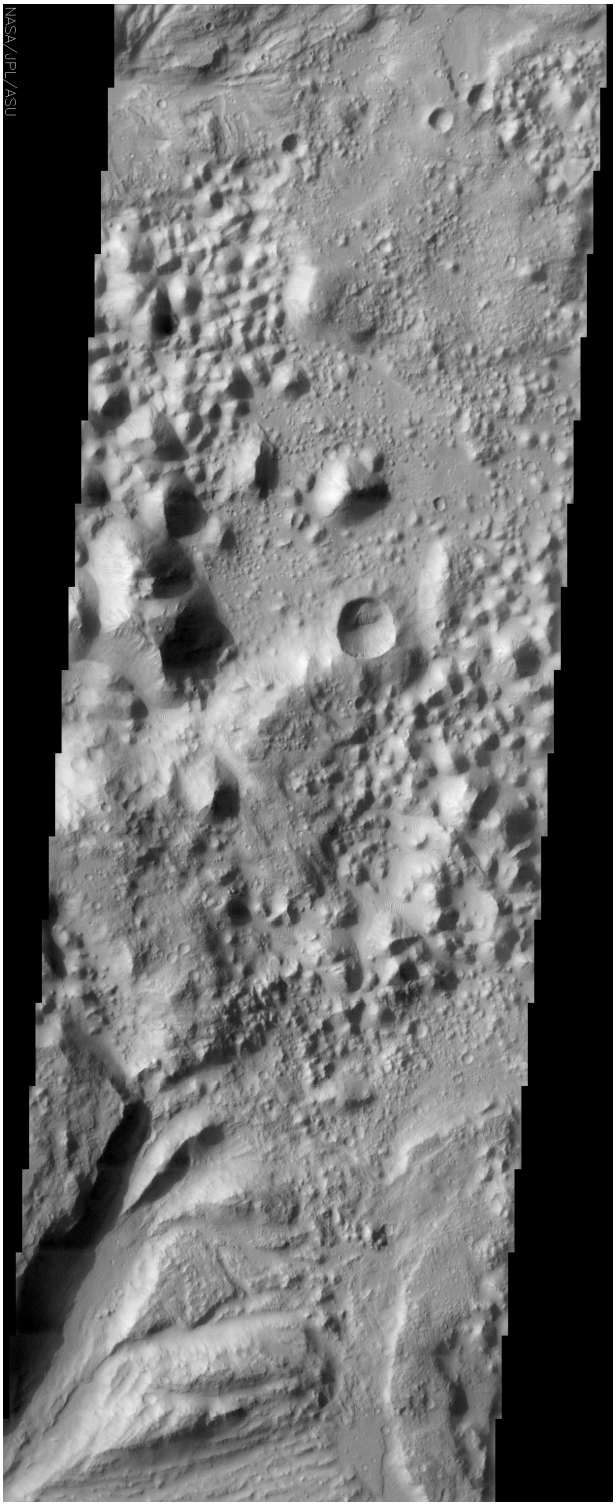


Figure 6

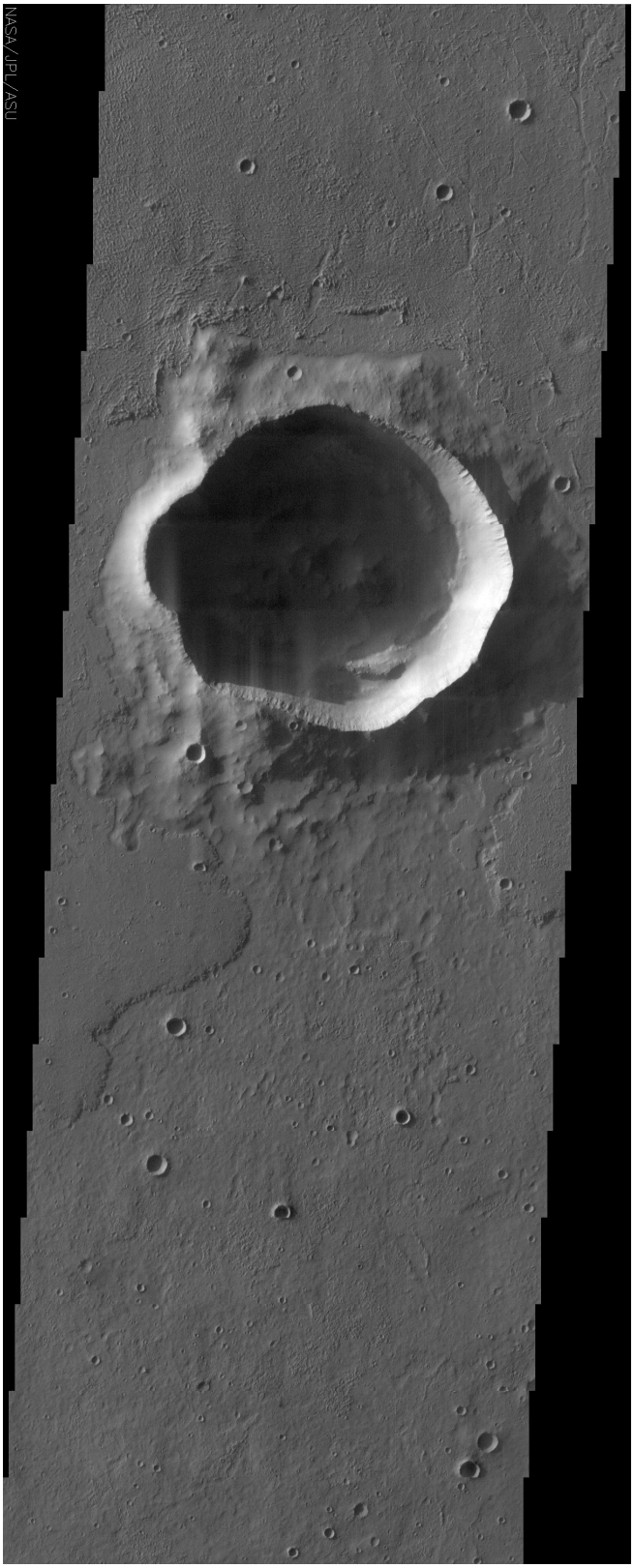


Figure 7

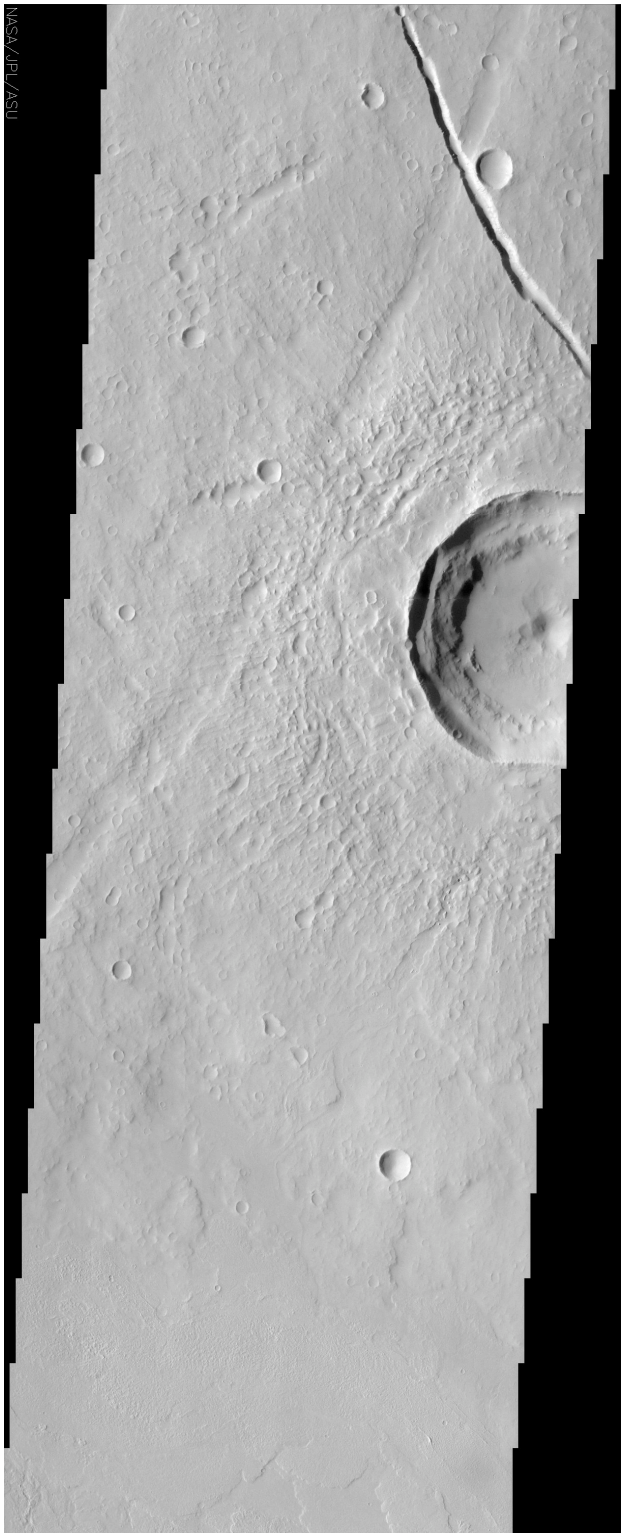


Figure 8

Figure 9

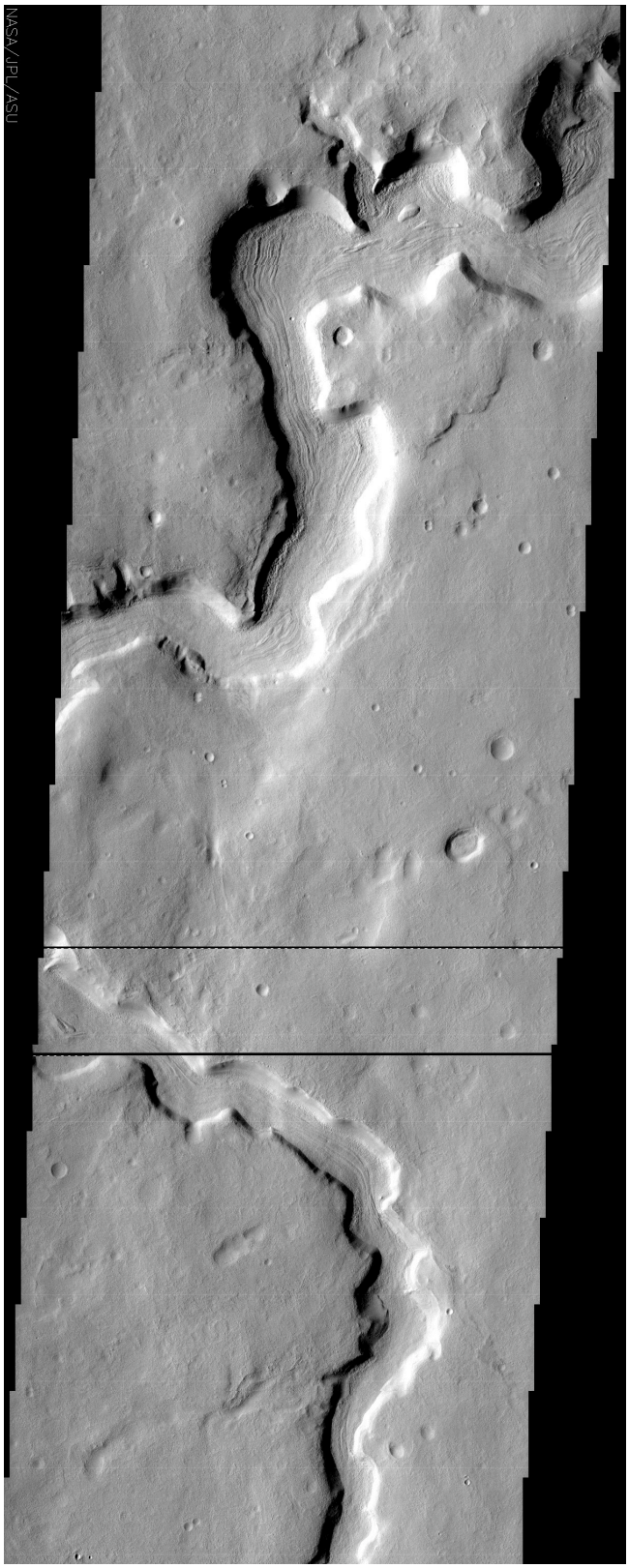


Figure 10

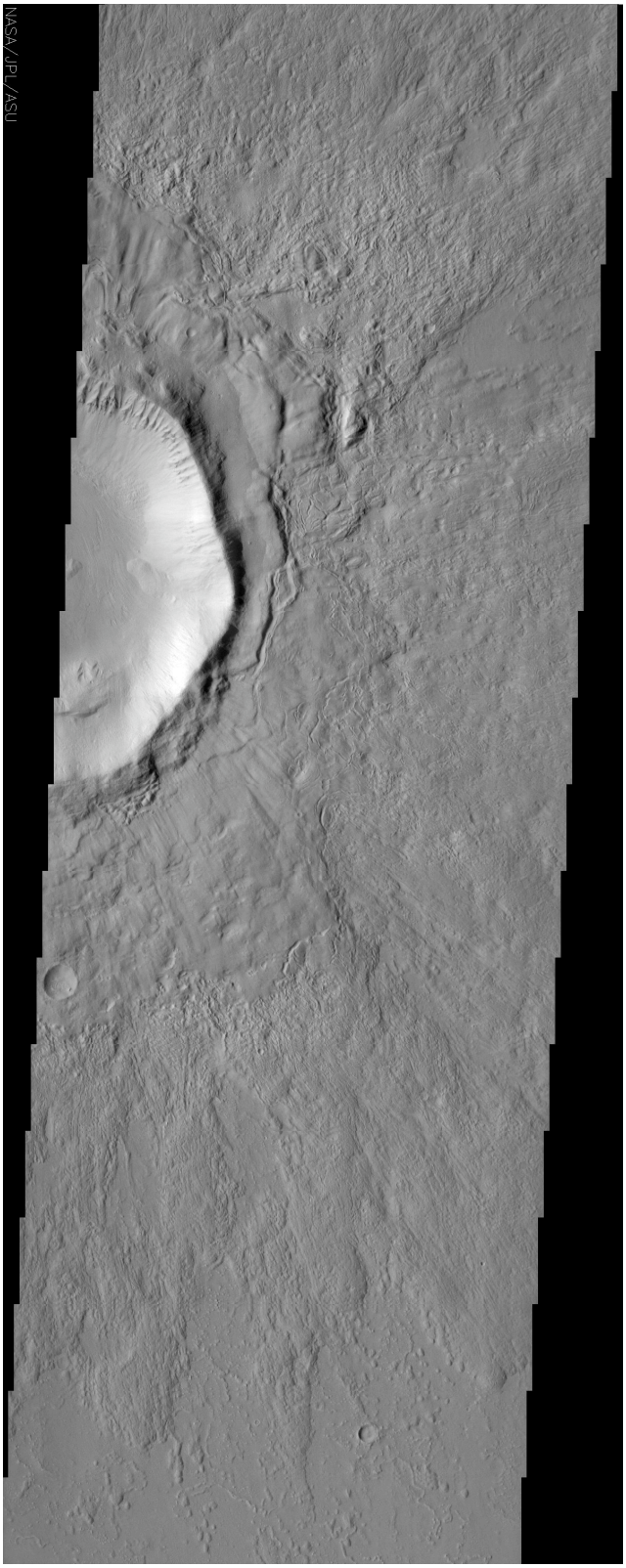


Figure 11

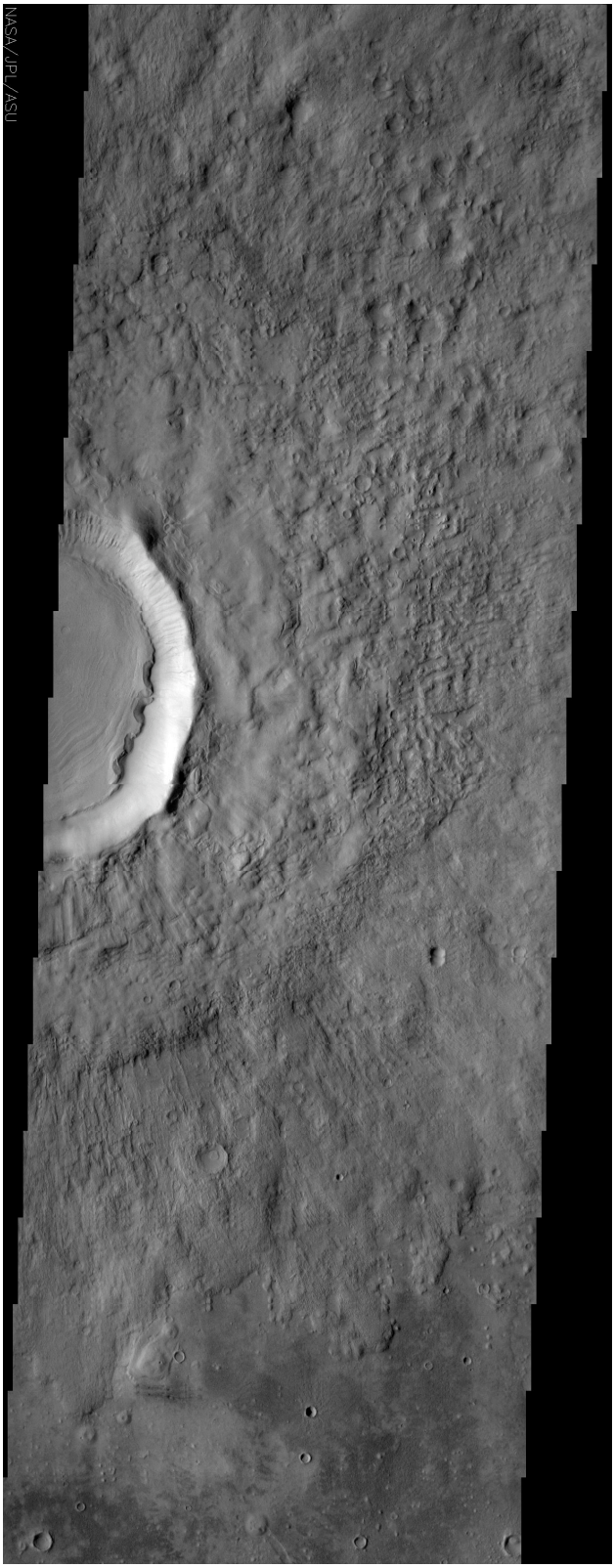


Figure 12

Figure 13

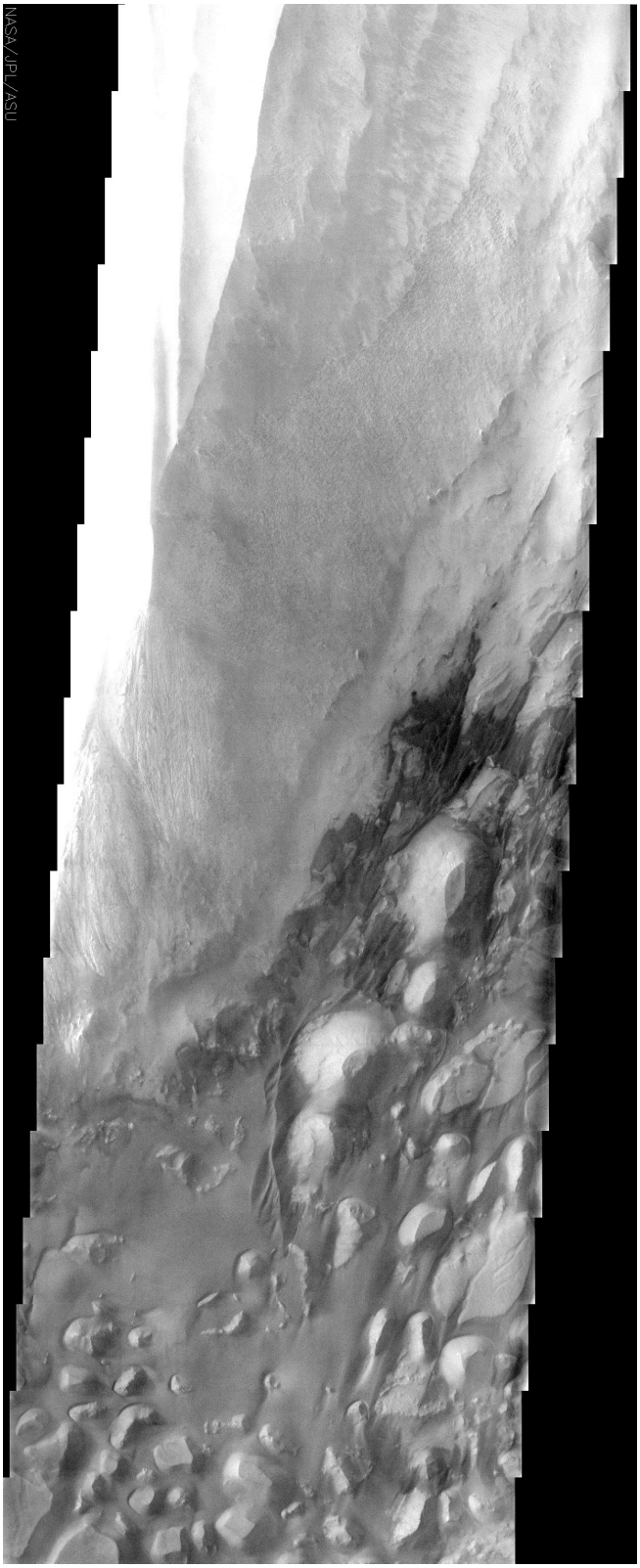


Figure 14

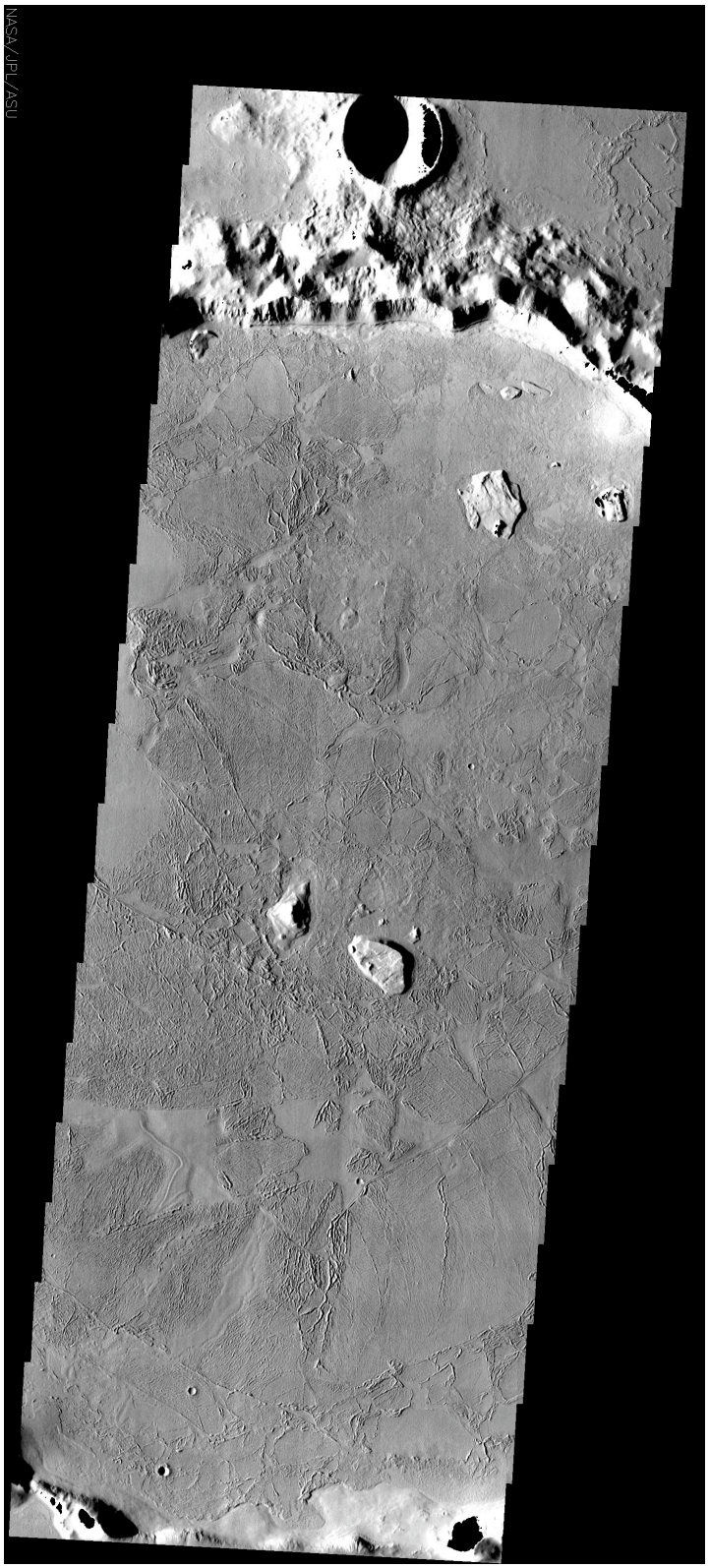


Figure 15

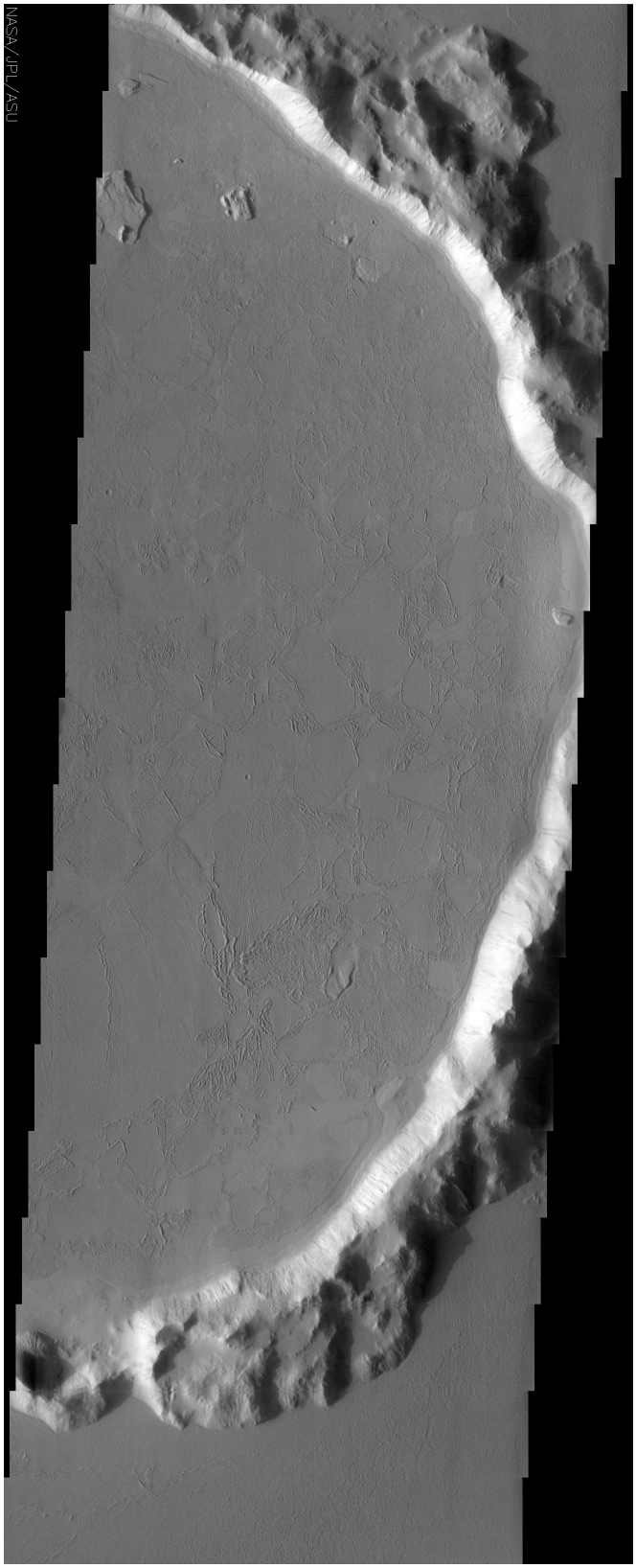


Figure 16

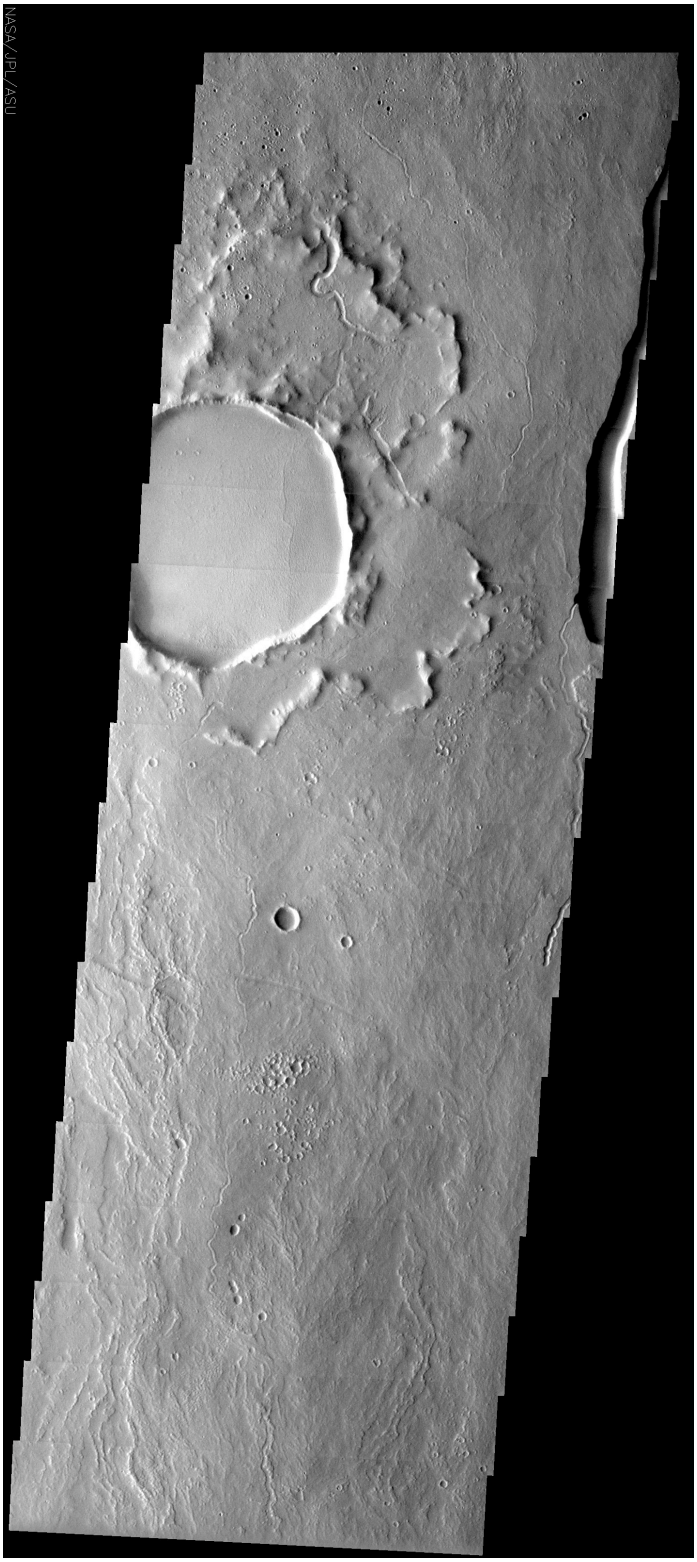


Figure 17

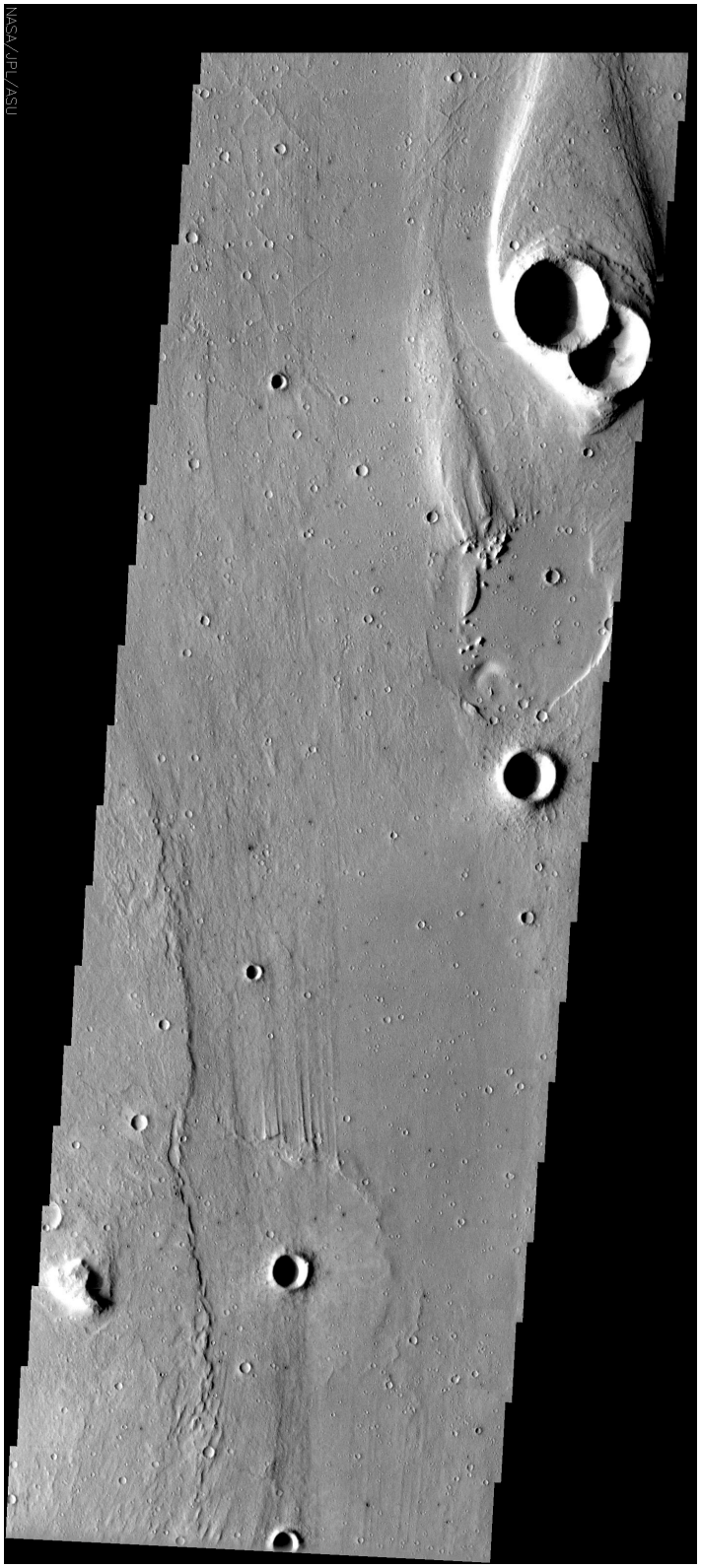


Figure 18

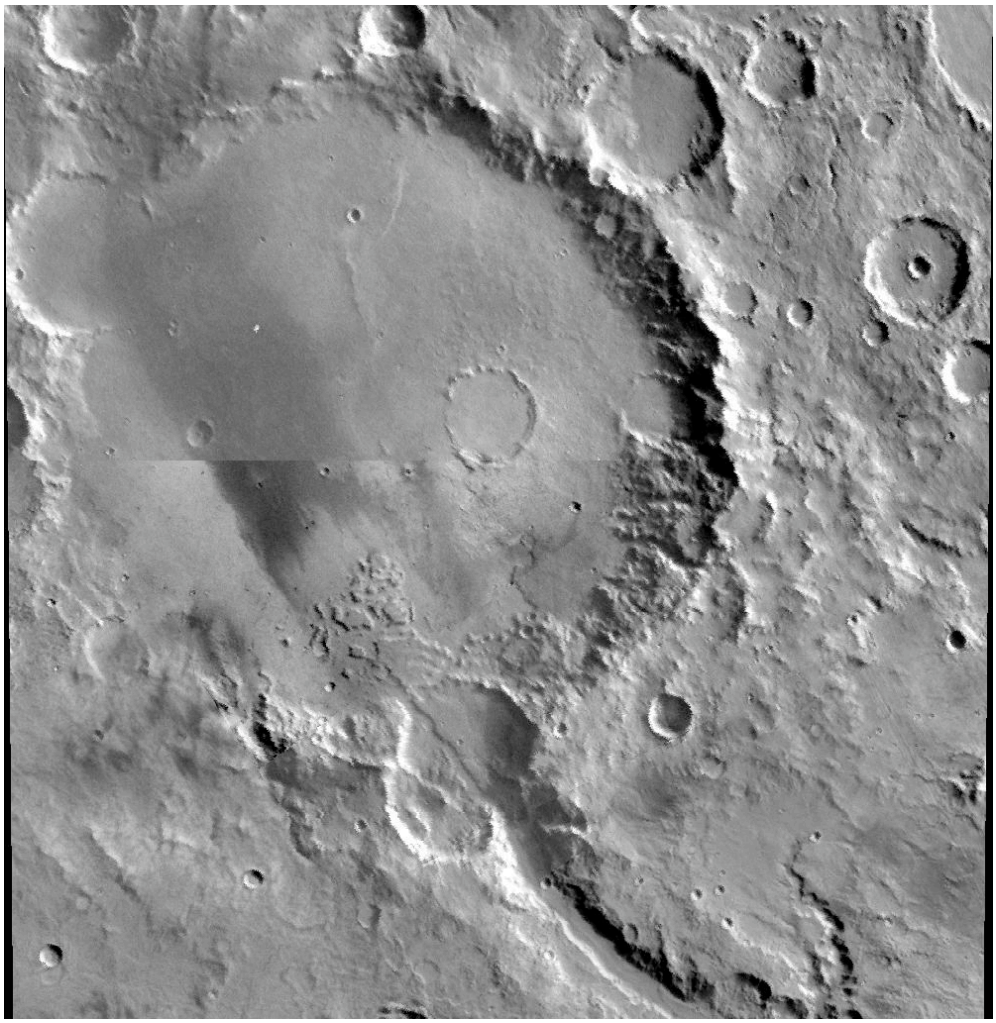


Figure 19

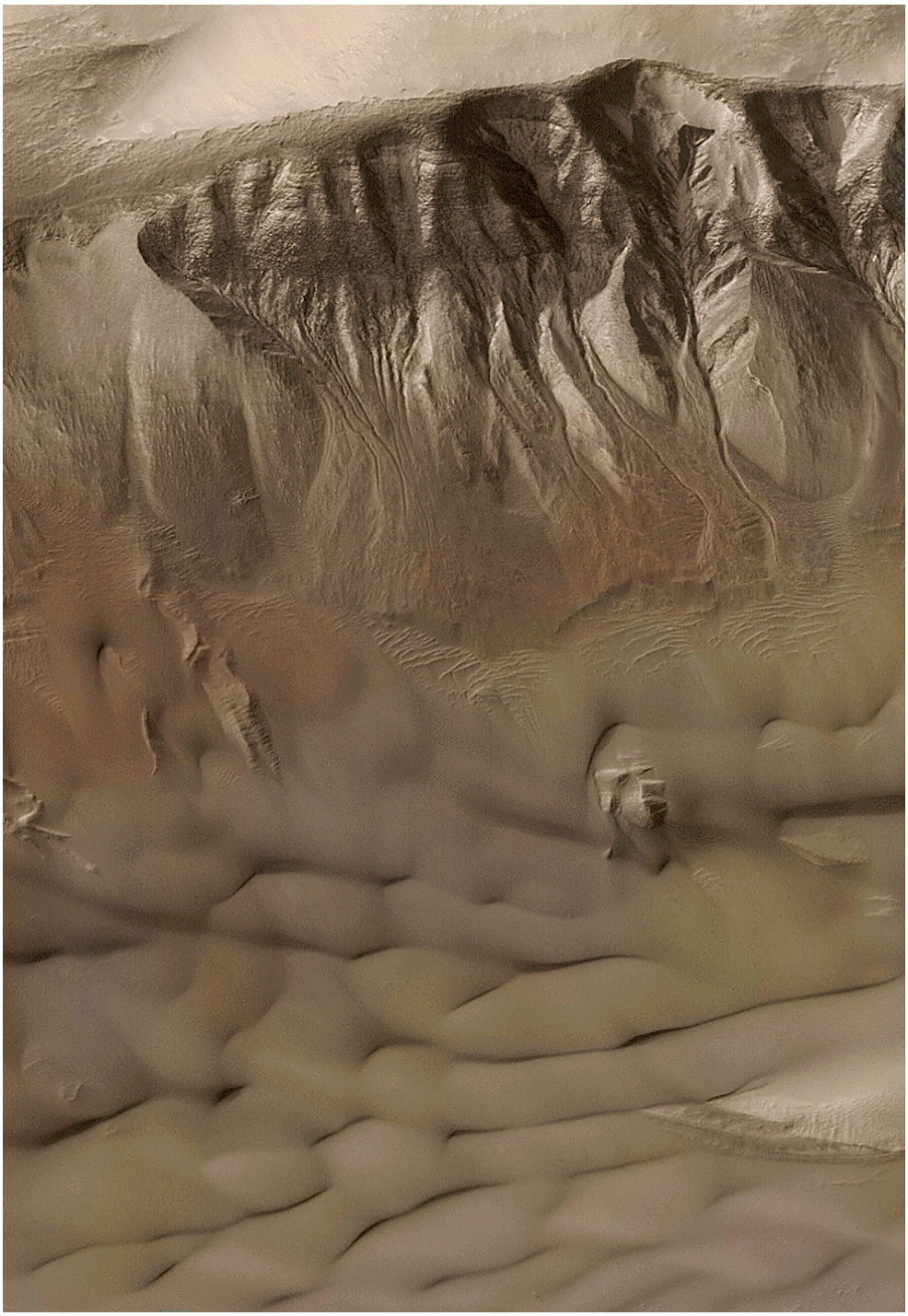


Figure 20

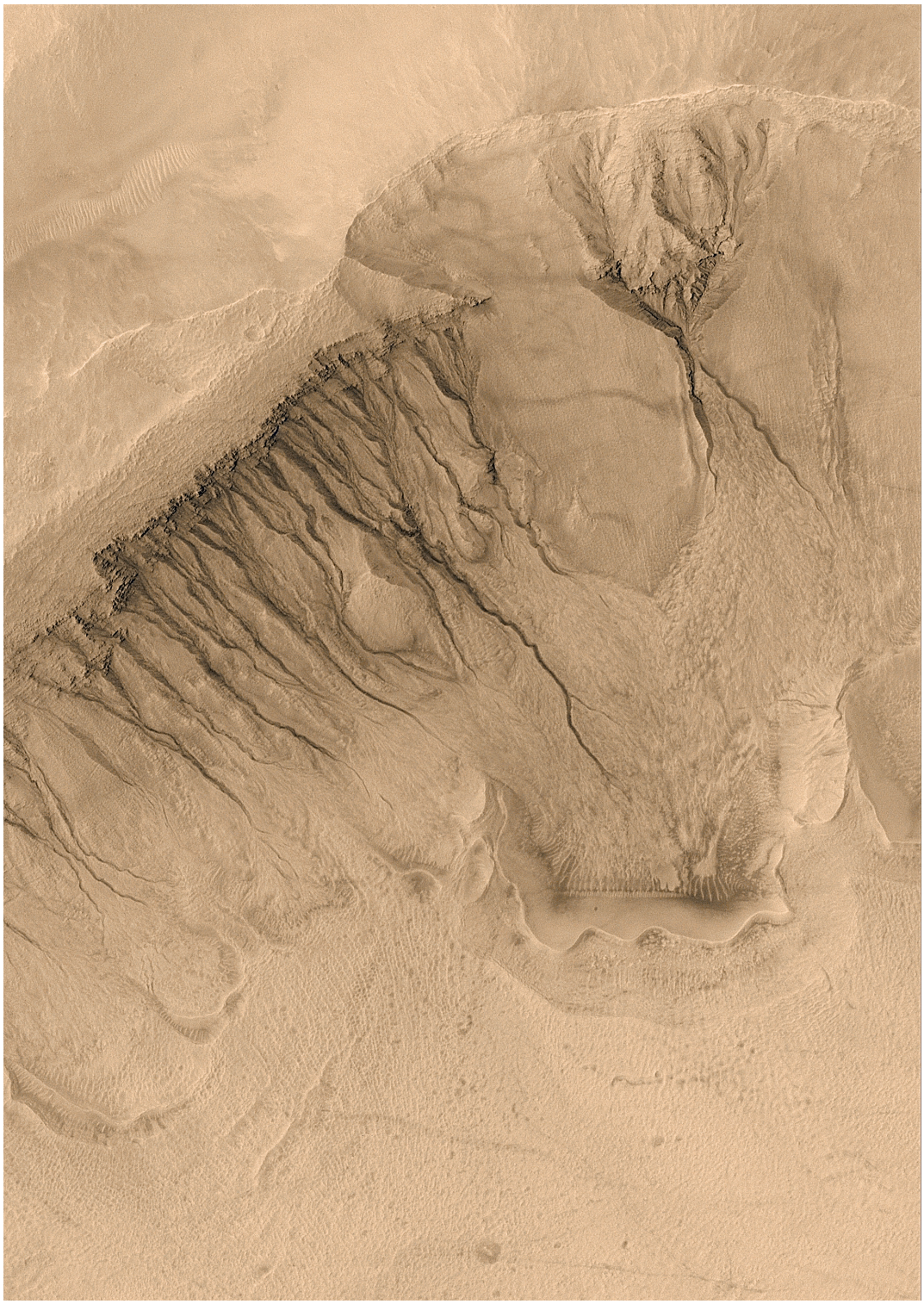


Figure 21

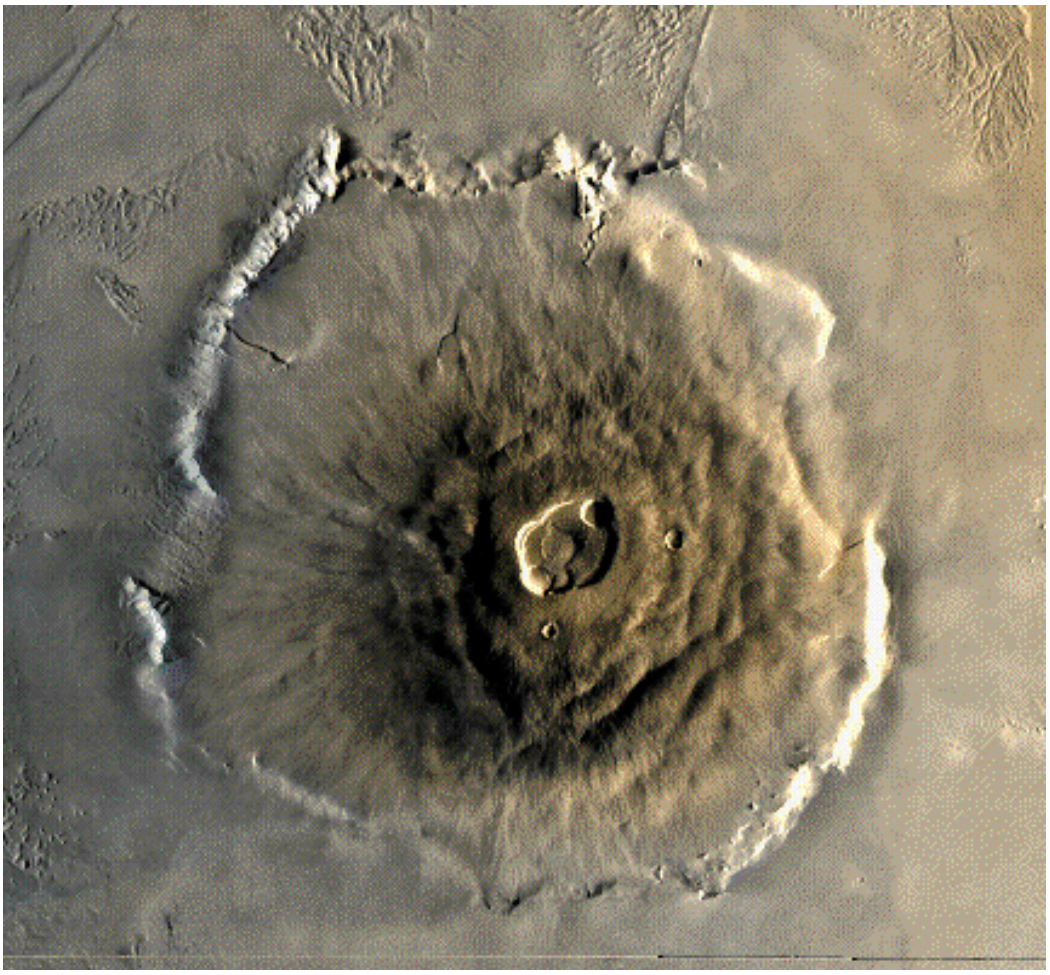


Figure 22

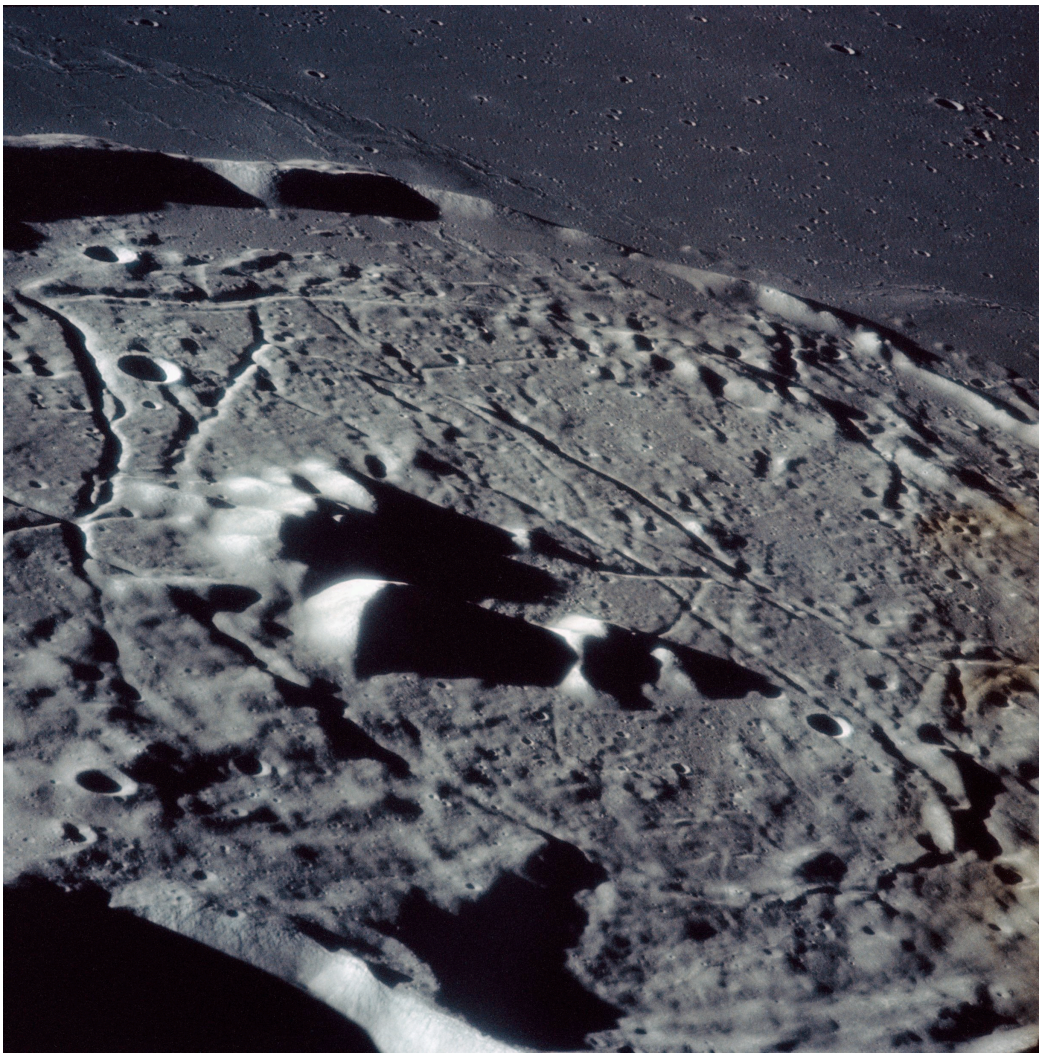


Figure 23

Figure 24 – **Assessment Rubric**

Name: _____Teacher: _____

Date: _____Title of Work: _____

	Criteria				**Points**
	1	2	3	4	
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				Total points →	

Teacher comments: