# Activity 3: What Can Craters Tell Us About a Planet?

## Purpose

To learn some basic concepts about craters on Mars using three investigative techniques: image interpretation, modeling, and Mars-Earth comparisons.

## Overview

Students examine images of Martian craters and speculate about what caused them. Next, they model the formation of an impact crater by dropping objects into a tray of powder. They examine the effects of each impact and the features each impact creates. Students re-examine the images of the Martian craters to see if their modeling experience gives them additional insights. They create hypotheses to try to explain a feature not seen in their models, a mud-flow-like ejecta blanket. Students write a plan to test one of the hypotheses and carry out their investigation. Finally, students apply their modeling experiences by making several inferences.

## Key Concepts

- Impact craters are caused when a bolide collides with a planet.
- A crater's size and features depend on the mass and velocity of the bolide.
- Impact craters provide insights into the age and geology of a planet's surface.
- The Martian surface contains thousands of impact craters because, unlike Earth, Mars has a stable crust, low erosion rate, and no active sources of lava. So, impact craters on Mars are not obliterated as they are on Earth.

## Skills

- *Interpreting* images of craters
- *Comparing* craters on Mars and Earth
- *Modeling* geologic processes
- *Designing* and *conducting* a Mars-related investigation
- *Collecting* and *interpreting* data from a classroom experiment
- *Drawing conclusions* and *Making inferences*

## Materials

- Image set
- One tray per group such as a dish pan, pizza box or lid from copy paper box
- Very fine, light and dark colored powders such as silica sand, flour, plaster, mortar powder or grout (comes in different colors), chocolate pudding, powdered cocoa, powdered charcoal or corn meal
- Bolides of various sizes such as golf balls and small rocks (1-4 cm)
- Sieve, large spoon or cheese cloth to sprinkle the dark powder
- Meter stick or string to measure the two-meter dropping height
- Balance
- Card or ruler to smooth the surface of the powder
- Newspaper or drop cloths
- Large sheets of paper to record ideas from the class discussions

## Time

| | |
|---|---|
| Day 1: | Steps 1-7 |
| Homework | Step 8 |
| Day 2: | Steps 9-11 |
| Day 3: | Step 12 |
| Homework | Steps 13 and 14 |

## Preparation

Copy necessary worksheets for Step 2 and, if appropriate, the Extension.

In Activity 2, students had a preliminary experience with image interpretation. In this activity, students use another method of inquiry central to both the scientific process and to the Mars module series – modeling. In this activity, physical models are used to answer two questions: What formed the circular shapes on the surface of Mars? and, What can they tell us about the nature of the surface?

This mini-investigation exemplifies the design of many activities in the Mars Exploration module series. The National Science Education Standards advocate a central role for investigations in science education. By having students ask questions, conduct experiments, collect data, and draw conclusions, this activity helps students learn how to design and conduct their own Mars-related investigations.

## Craters on Mars

*Bolides* are any falling body such as a meteorite and are commonly made of rock, ice, or a combination of rock and ice. When a bolide collides with a planet, it produces an *impact crater* (Figure 3.1). A crater's circular shape is due to material flying out evenly in all directions as a result of the explosion upon impact rather than as a result of the bolide having a circular shape. In fact, almost no bolides are spherical.

*Figure 3.1: A bolide smashes into Earth and creates an impact crater.*

Materials flung out at high speeds produce *rays*, straight lines radiating away from the impact crater. Materials flung out at slower speeds produce an *ejecta blanket*, a layer of material, sometimes quite thick, immediately surrounding the crater (Figure 3.2).

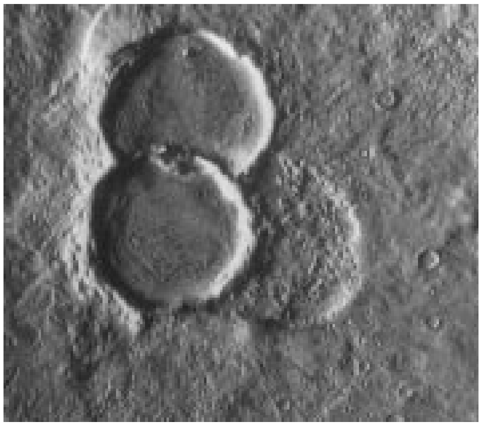


*Figure 3.2: Notice the rays below the craters and the ejecta blanket, primarily to the left. Image Set image 2.*

*Figure 3.3: The view across the Argyre basin, itself a 1200-km diameter impact basin, shows numerous craters of various sizes. The largest crater is 210-km in diameter. Image Set image 5.*

## • Craters come in different sizes

The largest crater on Mars (and, arguably the largest so far discovered in the solar system) is the Hellas basin measuring 1600 x 2000 km, roughly twice the size of Alaska. However, most Martian impact craters are smaller than 100 km (Figure 3.3). A crater's size depends on the mass and velocity of the bolide. The bigger, faster, or more massive the bolide, the bigger the crater.

## • Craters hint at the age of the surface

Scientists studying craters on Mars noticed that some areas of Mars have many craters while other areas have just a few (Figures 3.4 and 3.5). The generally accepted theory is that all areas on Mars used to be heavily cratered, and then surface changes such as lava flows, flowing water, or intense dust storms obliterated some of the craters, leaving a younger, smoother surface. Therefore, scientists interpret Figure 3.4 as an older surface (i.e., many craters) and Figure 3.5 as a younger surface (i.e., fewer craters).

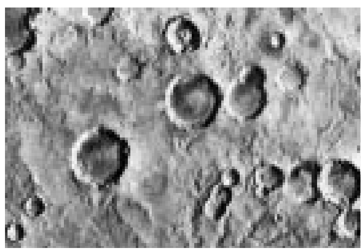


*Figure 3.4: Dense crater patterns are typical of ancient Martian terrain. Image is 250 km across.*

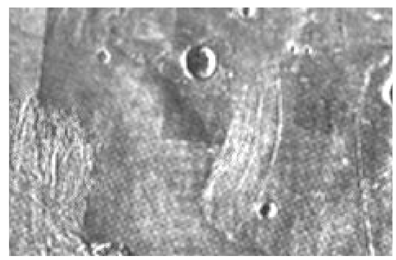


*Figure 3.5: Relatively recent lava flows have created a sparsely cratered plain. Crater in upper center is 18 km across.*

## • Craters hint at what's under the surface

The shape of an ejecta blanket depends on the characteristics of the surface hit by a bolide. Some craters on Mars have ejecta blankets like the ones seen in Figure 3.6. The mud-flow-like shape that surrounds the crater gives a clue about the nature of the surface. Scientists believe that the heat and pressure of an impact melted ice under the surface, forming mud. This mud flowed away from the crater, forming a lobed shape. Interestingly, only craters with diameters larger than five kilometers exhibit mud-flow ejecta blankets. Scientists think that meteorites below a certain size do not penetrate deeply enough to melt the permafrost.

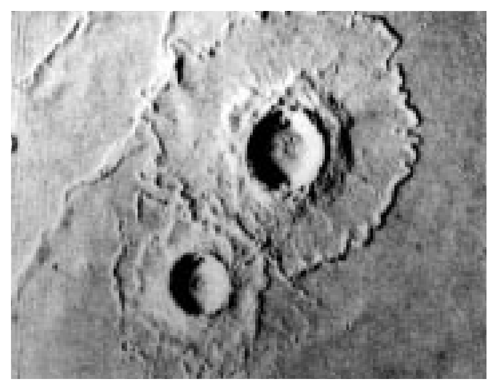


*Figure 3.6: Image Set image #3.*

## • On Earth, ancient craters have eroded away

Since their formation, tens of thousands of bolides have hit both Mars and Earth. However, very few impact craters on Earth can be seen because Earth's ancient surface has been worn by erosion, covered by lava, and recycled by plate tectonics. On the other hand, Mars has a stable crust and small scale, localized resurfacing, so most of the Martian impact craters still exist.

# PROCEDURE

1. Have your students examine Image Set images 2 and 3 and ask them what they think caused the circular shapes. Discuss their ideas and ask them how they might investigate them.
   *To investigate their questions, students might suggest: looking at additional images, making models to recreate a crater's features, finding similar crater features on another planet or moon, and, of course, going to Mars.*

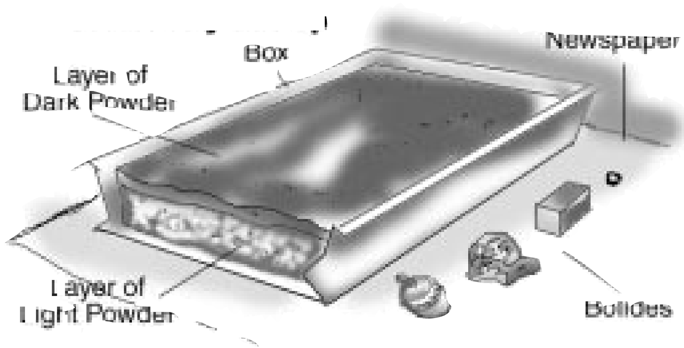



*Figure 3.7: Cut-Away view of Activity 3 Set Up.*

2. Have some members of the group prepare the test area by spreading newspaper or drop cloths over a cleared part of the floor and setting a box or tray in the center (Figure 3.7). Have the remaining members select the bolides and fill out Worksheet 1.
   *To understand crater formation and to identify the distinctive features of impact sites, it is best to begin by examining the simplest case – the effect of a bolide on a dry surface.*

3. Have students fill the container with about 5-10 cm of the light colored powder (larger bolides require a thicker layer of powder). Have them pack it lightly and smooth it with a card or ruler.
   *If cost or availability are factors, use fine sand for the first 5-10 centimeters and then sift a 1-2 cm layer of fine, light-colored powder such as grout over it.*

4. Have students sprinkle a 1-2 cm layer of dark powder over the light-colored powder, using enough to hide the light-colored powder. Have them gently smooth the dark layer with a card or ruler, being careful not to mix the two layers.

5. Have students drop the largest bolide onto a section of the surface from a height of two meters. Remove the bolide. In their Mars Journals, have students enter the bolide information from Worksheet 1, and sketch and describe the crater, the ejecta blanket and any changes to the surface.
   - Did the layers mix? If so, how?
   - Which layers are visible in the crater? At the rim? Beyond the rim?
   - Is the ejecta thrown out evenly in all directions?
   - How large is the crater compared with the bolide?
   - Are the bolides generally bigger, smaller or the same size as the craters they form?

   *To calculate the velocity at impact, use* $d = \frac{1}{2} at^2$. *Acceleration of free fall is 9.8 meters per second per second. Solving for t gives 0.64 seconds as the time to fall 2 meters. Therefore, the velocity (V=at) is 6.3 meters per second, or 22.6 kilometers per hour. To calculate the kinetic energy (K), use* $K = \frac{1}{2} MV^2$.

6. Have students repeat Step 5 with another bolide. Make sure the observations include comparisons between the craters. Continue until all bolides have been dropped.
   *Students should not smooth the surface between bolides because it is important for them to see the pattern of a heavily cratered surface with overlapping ejecta blankets.*

7. Have students enter their final observations in their Mars Journals. Then, set the trays aside for later use with student investigations and clean up the test area.

8. Have students open to Image Set images 2 and 3. How are these craters and the model alike and different?
   *The craters in the model are similar to the actual craters in that they have rims, ejecta, and a circular shape. The ejecta is deposited in all directions and may be striated in the same way as the ejecta below the craters in Image 2. The model is different because meteorites are usually completely destroyed upon impact. Also, the model lacks the features on the crater floors such as rings and dune fields, and the ejecta blanket in the model does not have the mud-flow pattern seen in Image 3.*

9. Have the class consider a question that confronted scientists: How did the mud-flow-like ejecta blankets form? Create a list of hypotheses that might include ideas such as:
   - the ground contained water or ice that melted after impact, and the muddy ejecta flowed instead of being thrown away from the crater;
   - the bolide was made of ice which melted upon impact turning the ground to mud which subsequently flowed;
   - the impact might have melted the ground and turned it into lava which flowed away from the crater.

   *The pattern of ejected material is actually used as a way to identify areas with possible water or ice in the surface layers. By investigating this question, students will mirror the way scientists created models to obtain insights about the Martian surface. Today, the first hypothesis above is the most widely accepted.*

10. Have the class decide which of their hypotheses are testable using their setup. Have each group write a plan to investigate one of the testable hypotheses.

11. Have each group describe their plan. Have the class comment on the strengths and weaknesses of each plan.

12. If you have time, let each group carry out their critiqued plan. Otherwise, have the class agree on one plan for you to do as a demonstration. *Consider creating a pool of mud outdoors where splattering is less of a concern. Another way to simulate the instant melting and flow of the surface is to heat jellybeans, grapes or potato chunks (a microwave works well) and drop them into pans filled with applesauce or a slurpee-like, ice-water mixture.*

*Figure 3.8: The Barringer Crater in Winslow, Arizona. Image Set image 10.*

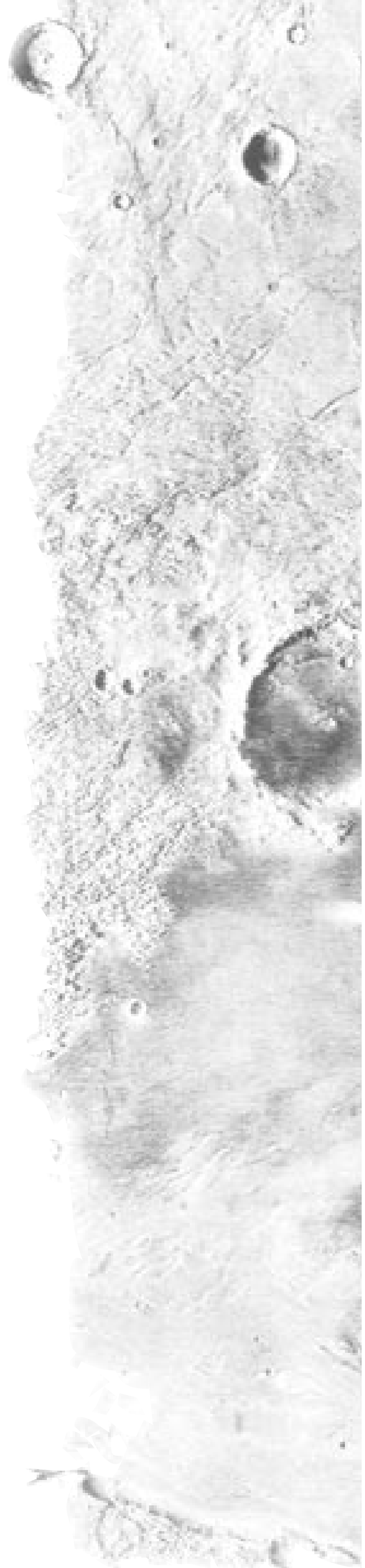
13. To demonstrate how models help people understand an unfamiliar situation, have students examine Image Set image 10 (Figure 3.8) and see what they can infer about the soil moisture content at the time of impact.
*Though erosion has obliterated most of the ejecta blanket, the traces of material indicate that Barringer Crater's ejecta blanket had a striated, not flowing, pattern. Consequently, one may conclude that the soil was dry at the time of the impact.*

14. Another inference students can make is about certain geologic processes on Mars. Since Earth and Mars are neighboring planets, one can assume they had similar cratering histories. Why then does Mars have so many more craters than Earth? What can students infer about the Martian atmosphere? The number of lava flows? The Martian crust?

*a) Water is the main agent of erosion on Earth. With so many well-preserved craters on its surface, Mars must not have water erosion. Students can reasonably infer that Mars has either a thin atmosphere or one without much water. This could lead to hypotheses about the climate.*

*b) Lava has covered large areas of the Earth. Students can reasonably infer that Mars had few active volcanoes in the past or that they are widely spaced. This could lead to hypotheses about the type of magma in the Martian core and about what conditions cause Martian volcanoes to emerge where they do.*

*c) On Earth, plate tectonics creates mountain ranges, recycles crust, causes continents to shift position and spawns volcanoes. Consequently, plate tectonics has altered almost all of Earth's crust and virtually no crust from Earth's early history exists today. Students can reasonably infer that Mars has a stable crust and lacks plate tectonics. This could lead to hypotheses about the Martian core and about the thickness of the Martian crust.*



# EXTENSIONS

Generating questions, developing hypotheses, and determining ways to investigate those hypotheses are core elements of the scientific process and are an important focus of this extension.

a) Have students examine Images Set images 2 and 3 and fill out Worksheet 2.
b) On the board or on a large sheet of paper, record how groups completed each column. Have them determine which questions are testable with their setup.
*To keep every group engaged, let each group make only one contribution at a time. Figure 3.9 shows examples of how students might complete the last two columns of Worksheet 2.*
c) Have groups design and conduct investigations examining one of their questions.
d) Have each group prepare a poster report about their investigation and conclusions.

| Possible Question | How the Question Might Be Investigated |
|---|---|
| Why didn't the upper-most crater in Image 2 obliterate the ones below it? | Model: Create craters on top of one another. |
| Does the bolide speed, size or shape make a difference in the pattern of ejected material? | Model: Drop different sized / shaped objects onto a surface and from different heights. |
| What caused the pattern of ejected material to be different in the two images? | Model: Drop the same bolide onto different surfaces or different bolides onto one surface. |
| Of the 2 patterns of ejected material in these images, which is more common on Mars? | Image Interpretation: Examine additional images. |
| Does the wetness of a surface make a difference in the pattern of ejected material? | Model: Drop an object onto dry, moist, and wet surfaces. |
| Does Earth have craters like those on Mars? | Image interpretation and Mars-Earth comparisons: Research the topic in a library or on the Web. |
| What would happen if our bolide disintegrated upon impact? | Model: Use mudballs instead of hard balls. |
| Can there be so many craters that new craters obliterate old craters, keeping the total number constant? | Model: Drop large numbers of bolides. |

*Figure 3.9: Examples of how students might complete the last two columns of Worksheet 2.*

e) Figure 3.10 shows how students can also launch their investigations by focusing on the variables that underlie each of their questions.

| Variable | How To Investigate | Implementation Recommendations |
|---|---|---|
| Nature of the Substrate | Drop the same bolide onto several surfaces, each made from different-sized particles. Students could also vary the moisture level. | Test only one variable at a time. |
| Bolide Speed | Drop the same bolide onto the same surface from different heights. | Throwing things in a classroom is dangerous. Therefore, drop the bolide from a number of heights. See Step 5 for how to calculate the velocity and kinetic energy. |
| Bolide Shape | Drop different shaped bolides onto the same surface from the same height. | To keep mass constant, reshape the same ball of clay each time. |
| Bolide Mass | Drop bolides of different masses onto the same surface from the same height. | To avoid changing two variables, use marbles and ball bearings of similar size or inject a pingpong ball with different amounts of water. |
| Bolide Size | Drop bolides of different sizes onto the same surface from the same height. | To avoid changing two variables, use different-sized spheres of similar mass such as ball bearings and rubber balls. |

*Figure 3.10: Students can launch investigations by focusing on the variables that underlie each of their questions.*

## Assessments

- Analyze students' entries in their Mars Journals.
- The most meaningful assessment is having students conduct their own investigation. Ask students to plan an investigation based on one of their own questions about craters or one you supply. If possible, have them carry out their plan.
- Ask how the craters modeled in this activity are similar to and different from craters on Mars.
- Ask what determines the size of an impact crater.
- Ask what kinds of inferences can be made and insights gained about a planet based on impact craters.
- Have students discuss the role of image interpretation, model making and comparisons with Earth when trying to understand a distant planet for which there is limited information.

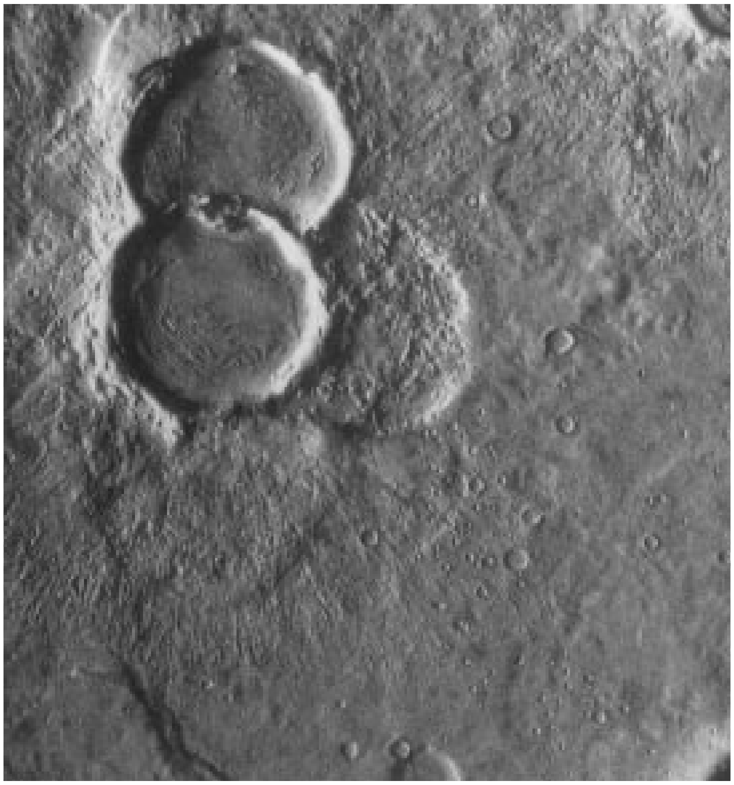
# WORKSHEET 1

| BOLIDE # | BOLIDE DIAMETER (mm) | BOLIDE MASS (g) | CRATER DIAMETER (mm) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

# WORKSHEET 2 FOR THE EXTENSION

**What Can We Say About the Craters in Image Set images 2 and 3?**

| Interpretations We're Reasonably Sure Of | Questions We Have | How We Might Answer Those Questions |
| --- | --- | --- |
| | | |



15 km Scale: Top crater is 15 km across.

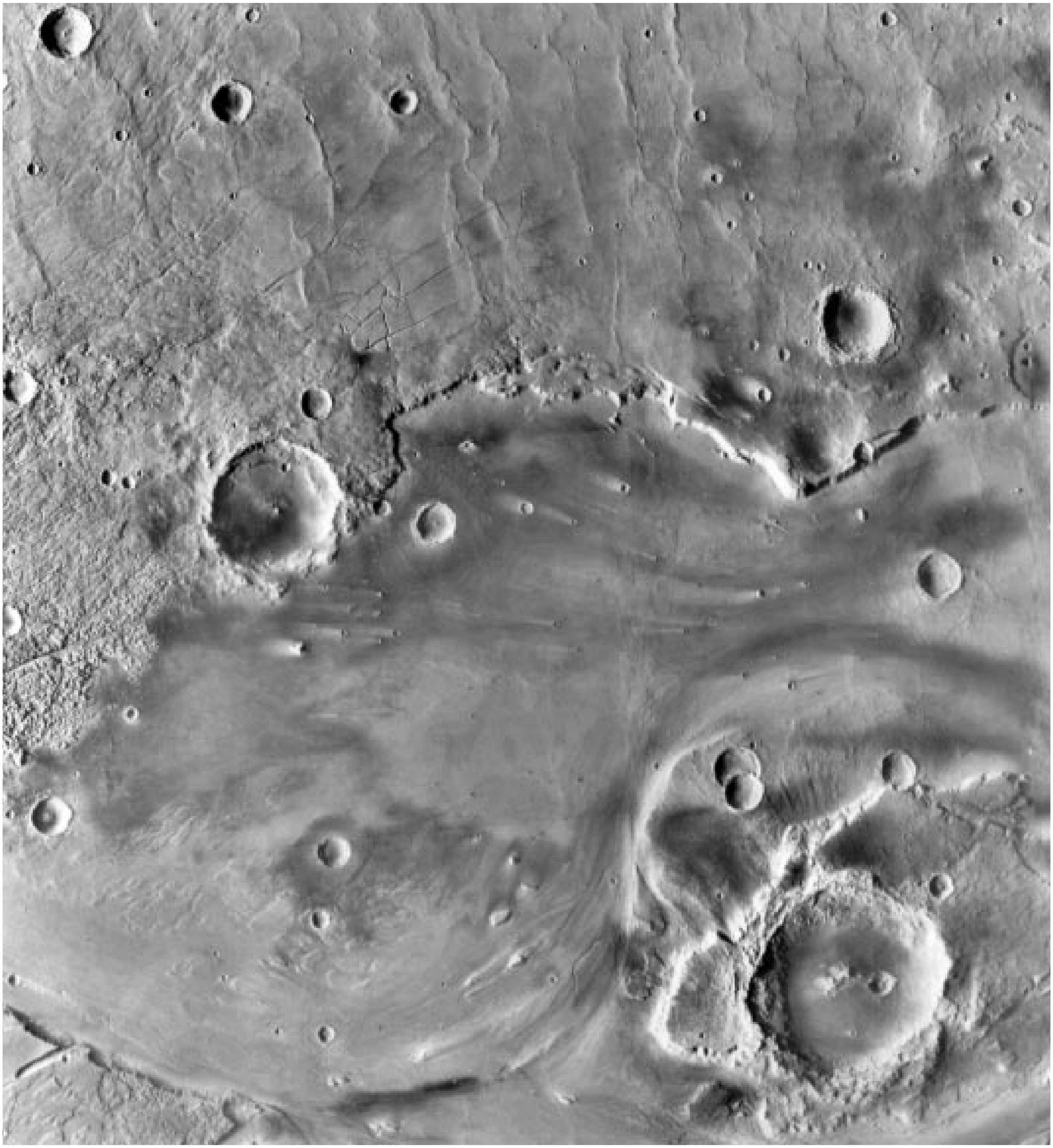
**Image 2**

- On Earth, what are some things about the size of these craters?
- Why do some of the craters overlap?
- In what order were the craters formed?
- What do the patterns around the craters reveal about the nature of the surface?
- Have you ever seen an impact crater?

30 km Scale: Large crater is 30 km across.

**Image 3**

- What do you think caused the shape around these craters?
- Were these craters formed at the same or at different times?



100 km Scale: The crater in the lower right is about 100 km across.

**Image 8**

- Which came first, the fractures or the large crater left of center?
- Which came first, the crater in the lower right or the channel?
- Which direction did the fluid flow? Is any fluid apparent now?
- What caused the “tails” behind the small craters in the channel?
- What sequence of events and processes makes most sense in explaining all these features?

Scale: Crater is 1.2 km in diameter.

**Image 10**

- What planet is this crater on? How can you tell?
- Is this crater more like the one in Image 2 or the one in Image 3? Why?
- Is this a fresh or an aged crater?
- How does this crater compare in size to those in Images 2 and 3?