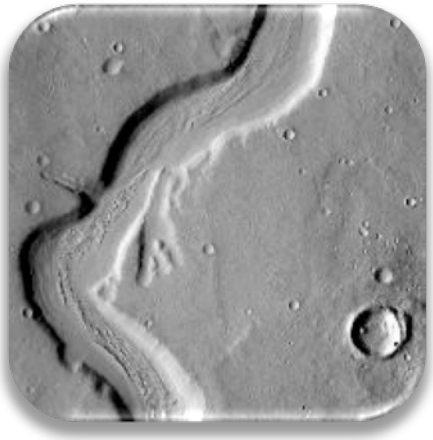
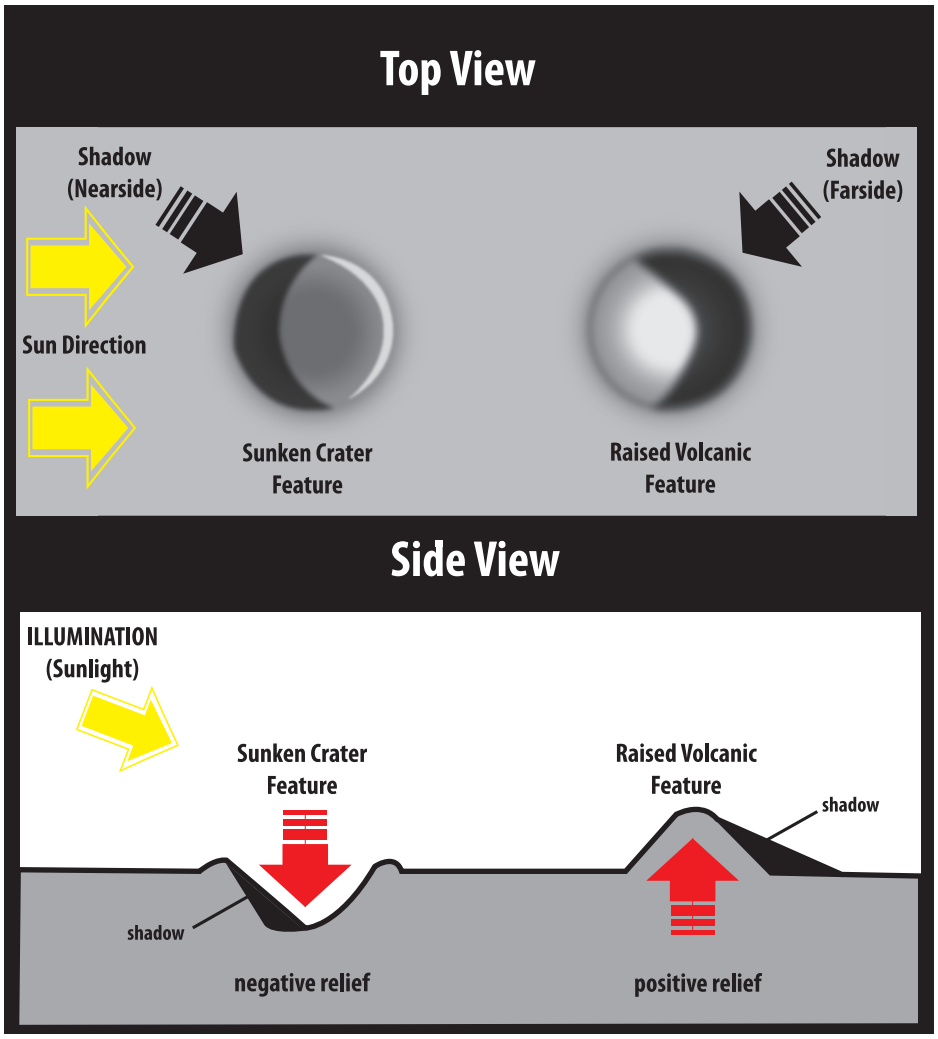
(E) Sunlight and Shadows

Observing the position of shadow and sunlit areas on Mars surface will help you identify areas of **positive (high) relief**, like volcanoes and ridges, and **negative (low) relief,** like craters and fractures.

See the key below for pointers on what to look for as you start working with Mars images.

When the Sun is low in the horizon, light strikes the surface at low angles making long shadows. This geometry enhances surface features (image at right).





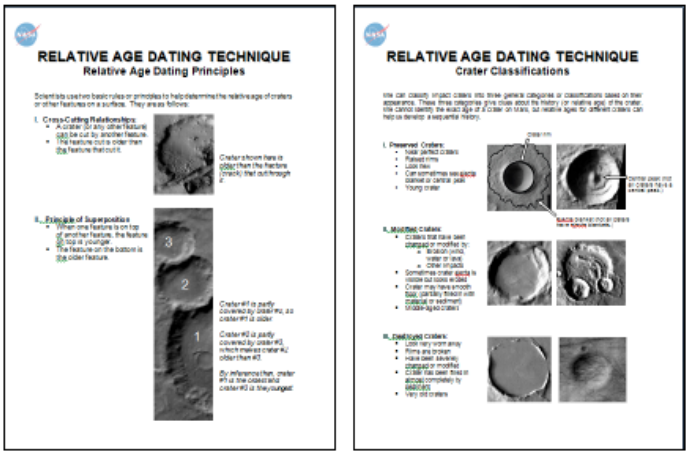
See Section 5.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.

(F) Determining the Relative Ages of Features

In this part of the activity, you will continue to analyze images of Mars. Now you will think about the history of the area by using relative-age-dating techniques. Commonly used age-dating techniques are:

- **Crater classifications:** Preserved, Modified, and Destroyed; and,
- **Relative Age Dating Principles:** Principal of Superposition and Crosscutting Relationships.

Use the **Relative Age Dating Technique handout** (sample below) as a tool to help you determine the relative ages of features on your images of Mars. Be ready to discuss what has happened (the geologic history) in your area of Mars.



RELATIVE AGE DATING TECHNIQUES

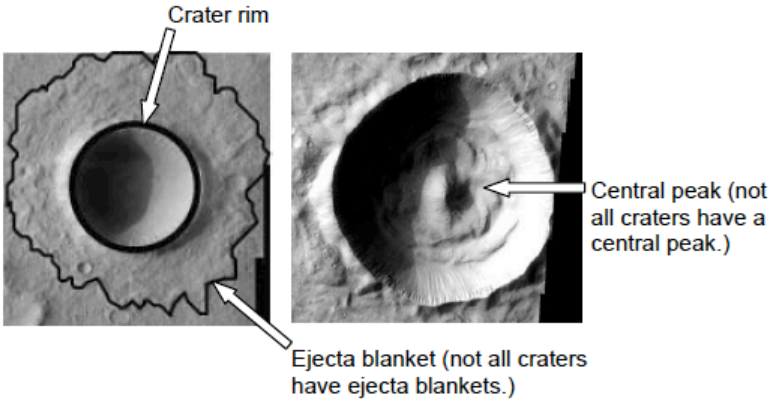
See Section 5.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.

(G) Crater Classification Guide

We can classify impact craters into three general categories or classifications based on their appearance. These three categories give clues about the history (or relative age) of the crater. We cannot identify the exact age of a crater on Mars, but relative ages for different craters can help us develop a sequential history.

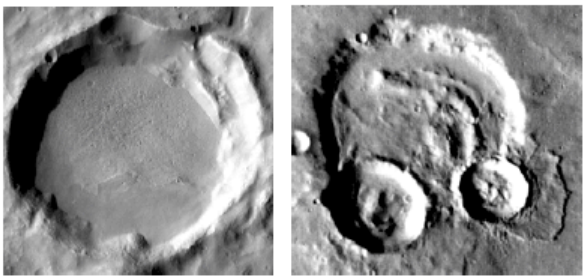
I. Preserved Craters:

- Near perfect craters
- Raised rims
- Look new
- Can sometimes see ejecta blanket or central peak
- Young crater



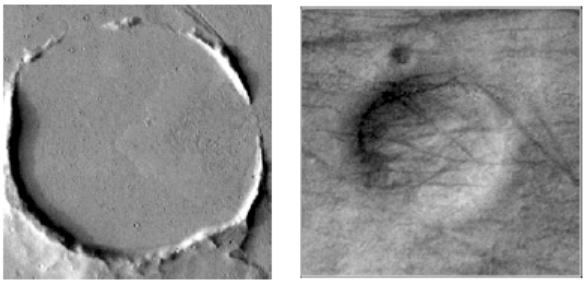
II. Modified Craters:

- Craters that have been changed or modified by:
  - Erosion (wind, water or lava)
  - Other impacts
- Sometimes crater ejecta is visible but looks eroded
- Crater may have smooth floor (partially filled in with material or sediment)
- Middle-aged craters



III. Destroyed Craters:

- Look very worn away
- Rims are broken
- Have been severely changed or modified
- Crater has been filled in almost completely by sediment
- Very old craters

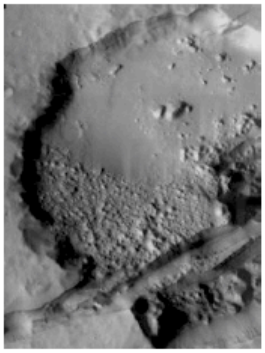


(H) Relative Age Dating Principles Guide

Scientists use two basic rules or principles to help determine the relative age of craters or other features on a surface. They are as follows:

I. Cross-Cutting Relationships:

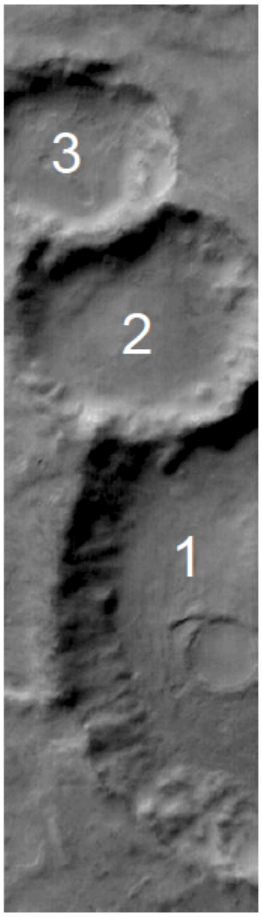
- A crater (or any other feature) can be cut by another feature.
- The feature cut is older than the feature that cut it.



Crater shown here is older than the fracture (crack) that cut through it.

II. Principle of Superposition

- When one feature is on top of another feature, the feature on top is younger.
- The feature on the bottom is the older feature.



Crater #1 is partly covered by crater #2, so crater #1 is older.

Crater #2 is partly covered by crater #3, which makes crater #2 older than #3.

By inference then, crater #1 is the oldest and crater #3 is the youngest.

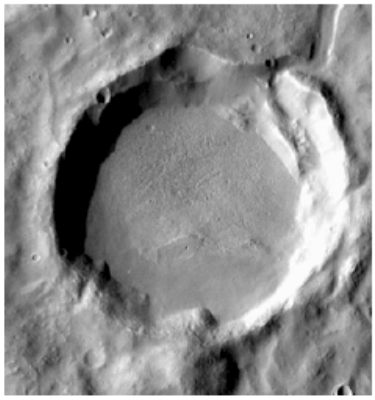
(I) Classifying Craters

NAME:_____

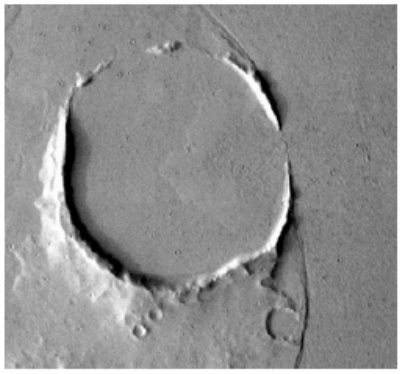
Based on the *Crater Classification* information sheet, classify the craters below. Be sure to explain your reasoning for each classification.

CRATER IMAGE	CRATER CLASSIFICATION (Preserved, Modified, or Destroyed)	EXPLAIN YOUR REASON
Crater A		
Crater B		
Crater C		
Crater D		

Crater A



Crater B



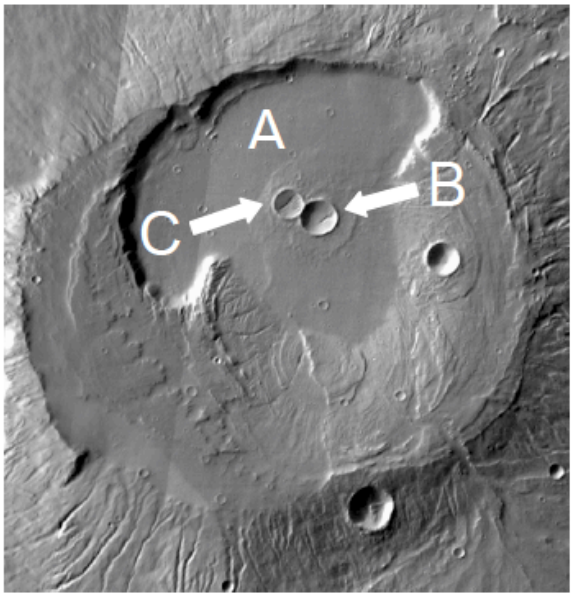
Crater C

Crater D

(J) Relative Age Dating Principles

NAME:_____

Based on the two relative age dating principles (cross-cutting relationships and superposition), write your interpretation of the relative ages of the features in the following images.



Oldest Feature: _____

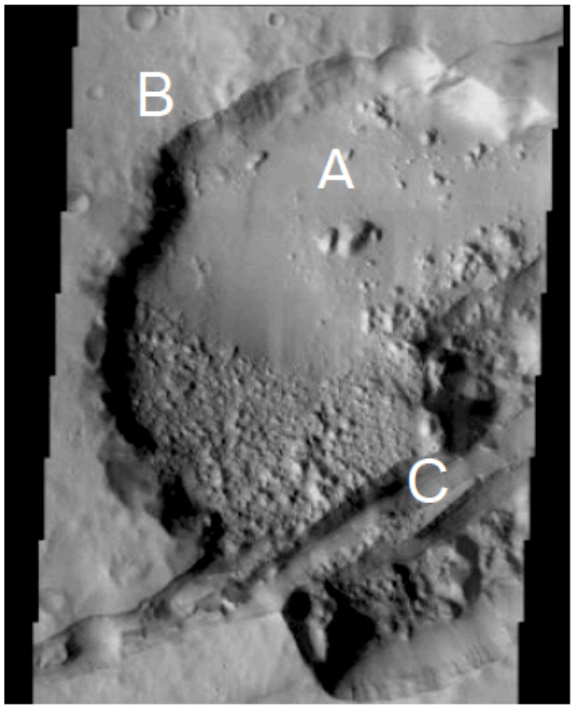
Younger Feature: _____

Youngest Feature: _____

Please explain your answers:

Which principle(s) did you use to choose your answer?

_____



Oldest Feature: _____

Younger Feature: _____

Youngest Feature: _____

Please explain your answers:

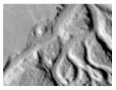
Which principle(s) did you use to choose your answer?

_____

(O) Using THEMIS Website to Make Scientific Observations

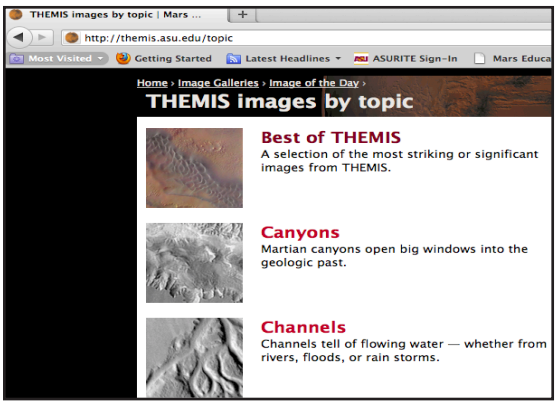
This activity will focus on THEMIS images that show details of many of the geologic features seen on the Mars surface. In this exercise, you will look at THEMIS images and log specific information about each image you observe. Here's what to do:

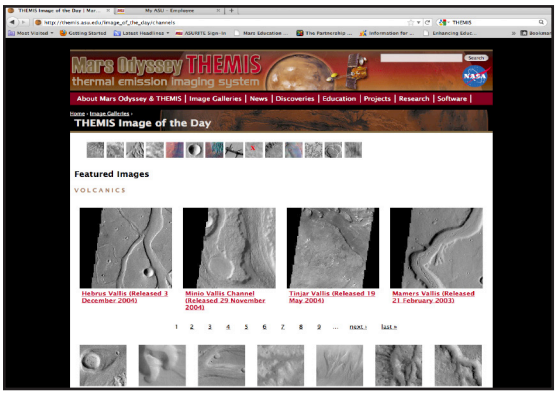
1. Go to the http://themis.asu.edu/topic website and click on the thumbnail (small square showing a part of a THEMIS image) of the topic your group will research:

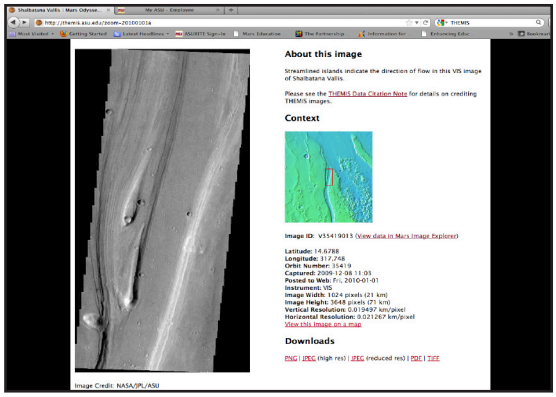
   

   Channels
   Channels tell of flowing water — whether from rivers, floods, or rain storms.

2. Click on any of the thumbnails to see a THEMIS image of Mars related to your topic:
   a. There are four large thumbnails at the top of the page.
   b. Below the top six thumbnails are more thumbnails of additional images.
   c. There are generally multiple pages of image thumbnails to choose from.
3. Click on a thumbnail to see a specific THEMIS image, context images showing the area where the image is located on Mars, and general information about the image.
   a. You can get an enlarged view of the THEMIS or context images by clicking on the image.
   b. Some images will have an Image ID #. To get more information on this image click on the "View data in Mars Image Explorer".
      i. This will open a new window showing the Image ID # and image information. Images that are not yet released will not have this link.





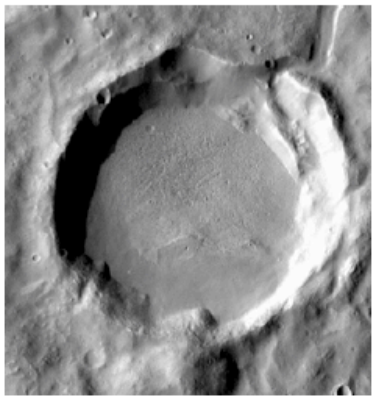


(V) Classifying Craters – Sample Answers

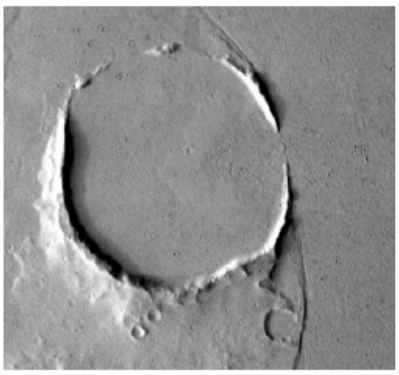
Based on the *Crater Classification* information sheet, classify the craters below. Be sure to explain your reasoning for each classification.

CRATER IMAGE	CRATER CLASSIFICATION (Preserved, Modified, or Destroyed)	EXPLAIN YOUR REASON
Crater A	***Preserved***	***Can see ejecta blanket clearly; has central peak; crater looks new***
Crater B	***Modified***	***Rim is broken by other impacts and a landslide; other small impacts are seen on the floor***
Crater C	***Destroyed***	***Rim are broken; crater appears to be almost completely filled in***
Crater D	***Preserved***	***Can see ejecta blanket; rim looks nearly perfect; crater looks new***

Crater A



Crater B

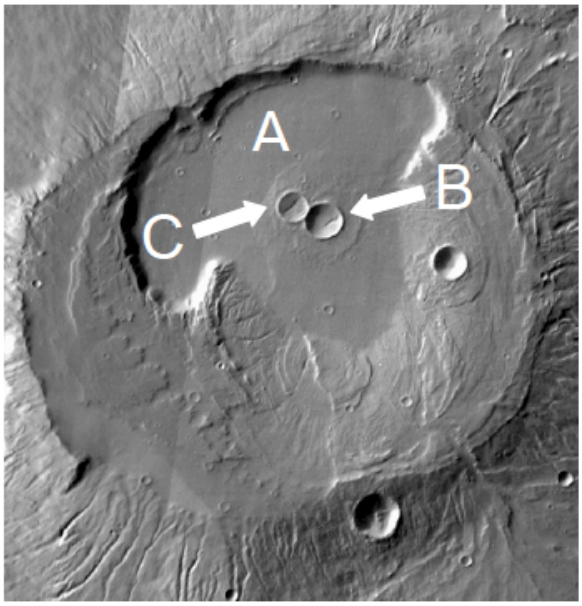


Crater C

Crater D

(W) Relative Age Dating Principles – Sample Answers

Based on the two relative age dating principles (cross-cutting relationships and superposition), write your interpretation of the relative ages of the features in the following images.



Oldest Feature: ___***A***___

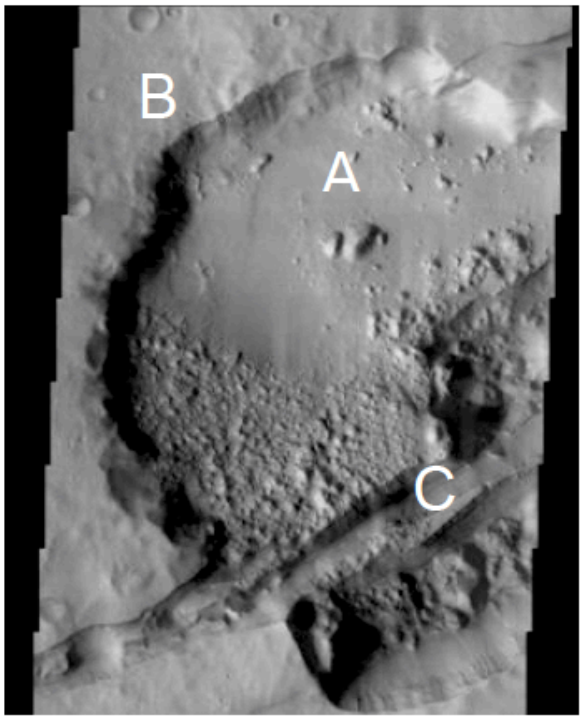
Younger Feature: ___***B***___

Youngest Feature: ___***C***___

Please explain your answers:

Crater C is on top of the ejecta blanket of Crater B so it is the youngest. Crater B and C are on top of the Crater A so Crater A is the oldest.

Which principle(s) did you use to choose your answer?
____***Principle of Superposition***____



Oldest Feature: ___***B***___

Younger Feature: ___***A***___

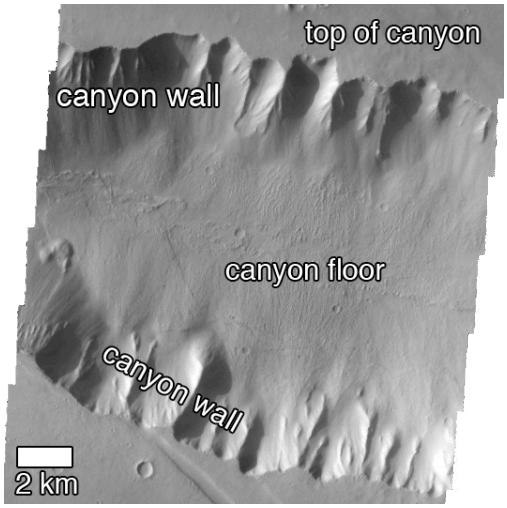
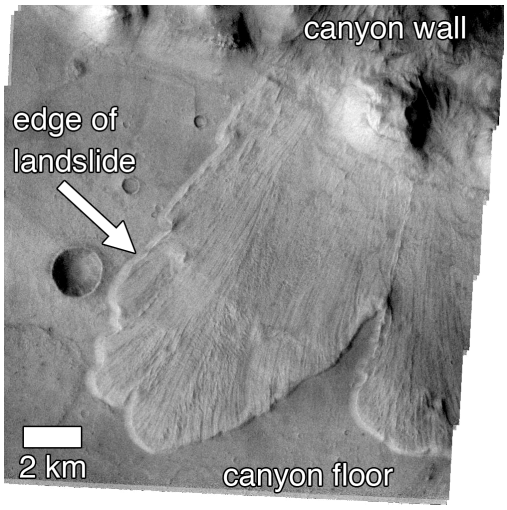
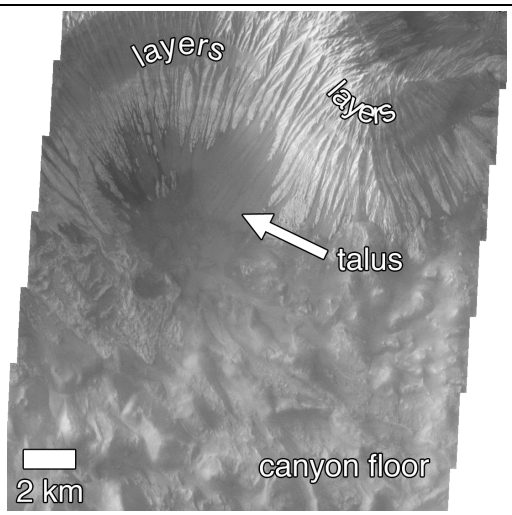
Youngest Feature: ___***C***___

Please explain your answers:

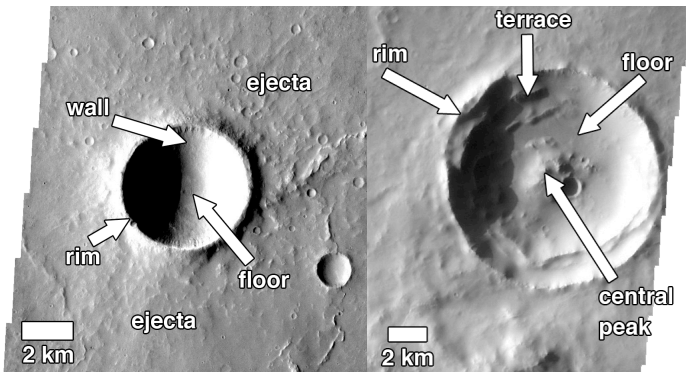
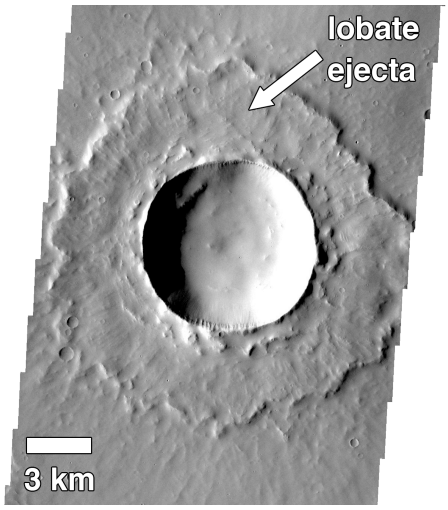
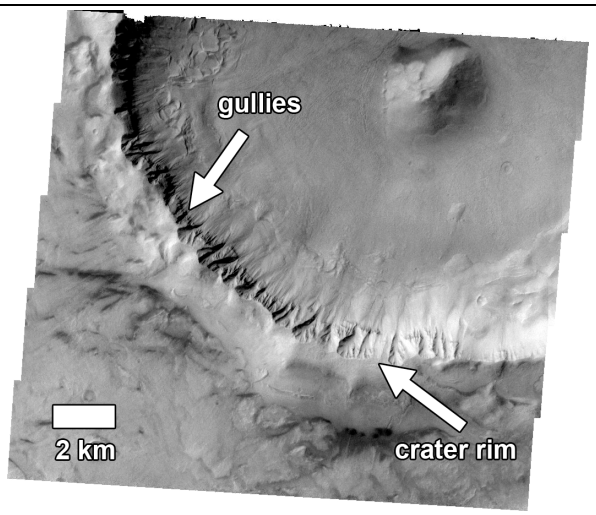
Feature C is on top of Feature A so it is younger than Feature A. Feature C is also cutting Feature A, so that also provides evidence that it is younger. Feature A is on top of Feature B, so A is younger than B. Feature B is on the bottom of both features, so it is the oldest.

Which principle(s) did you use to choose your answer?
***Cross Cutting and Superposition***

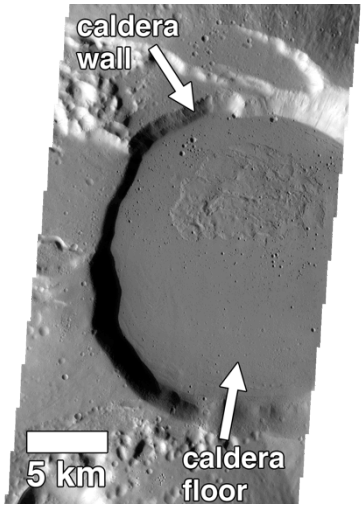
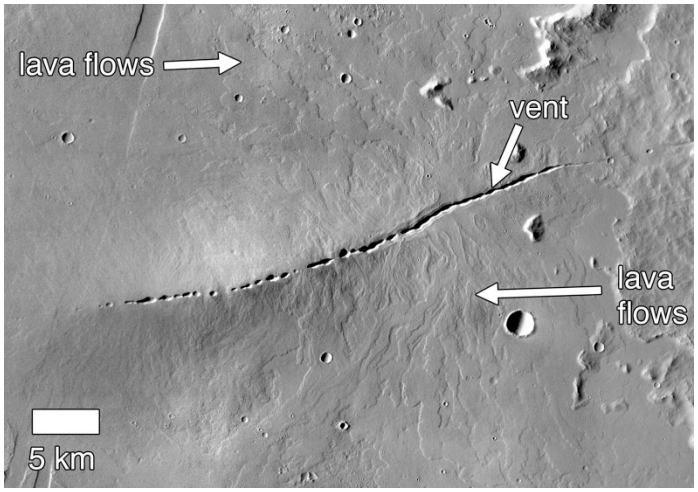
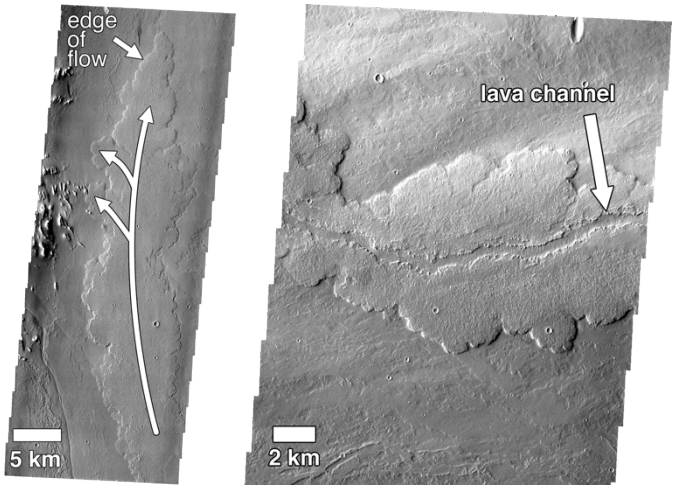
(S) Feature ID Charts – Canyons

Feature	Example	Description
Canyon		• Identified by a steep drop in elevation, similar to what is seen with canyons on Earth • Canyon walls often have been eroded, forming spurs and gullies • Top of canyon is generally flat and smooth
Landslide		• Material that has slid down the canyon wall • Often has linear (long and straight) grooves parallel to the direction of flow (white arrows on flow) • Edges of the landslide may look lobate (like fingers or tongues)
Layers		• May be found in canyon walls • Contain a record of previous conditions • Thickness may indicate relative deposition time or deposition rate • Talus (material that has fallen down slope) collects at the base of the canyon wall and in gullies

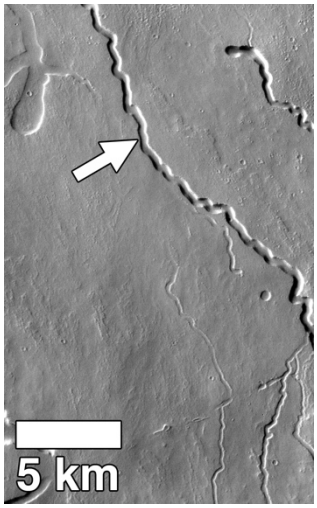
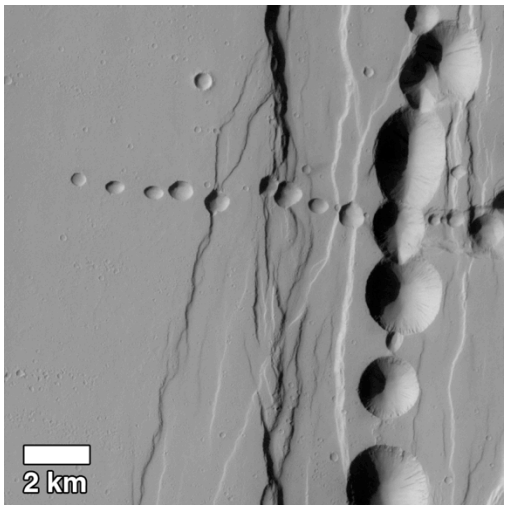
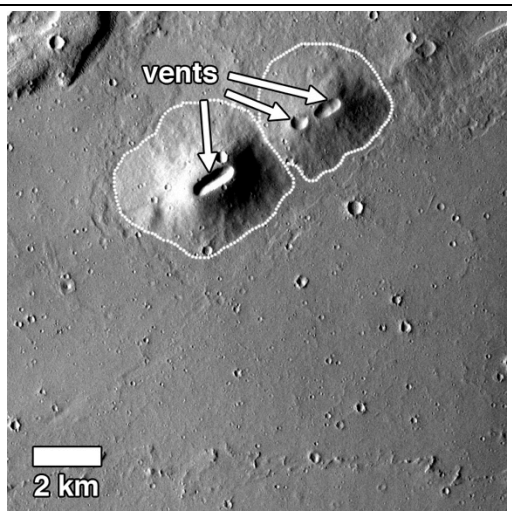
(S) Feature ID Charts – Craters

Feature	Example	Description
Simple & Complex Crater	 simple complex	• Formed by objects striking the surface • Usually circular in shape • Have a rim, floor, and walls • Smaller (simple) craters have a bowl shape while larger (complex) may have a central peak and terraced walls
Rampart Crater		• May form around both simple and complex craters • Have a special ejecta called lobate • Ejecta looks like it flowed away from the crater • Are associated with liquid water or ice being below the surface
Gullies		• Often found on crater walls or other steep slopes • Appear to be young • May be formed by liquid water or dry avalanches

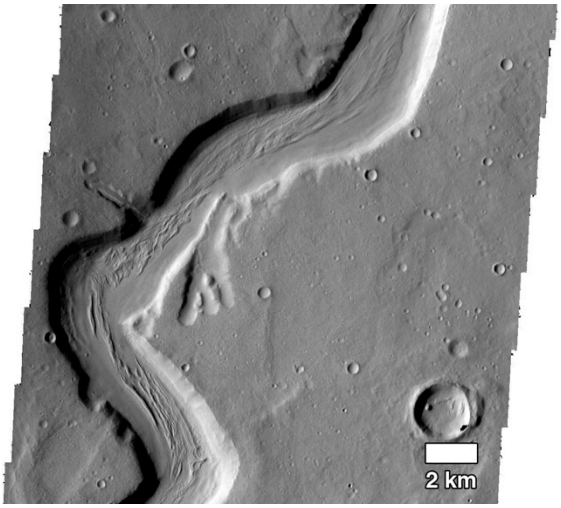
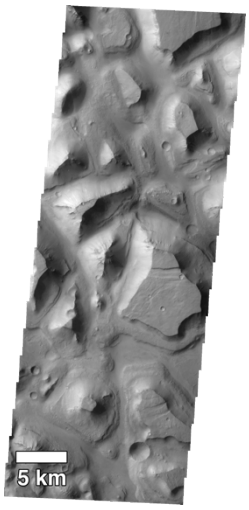
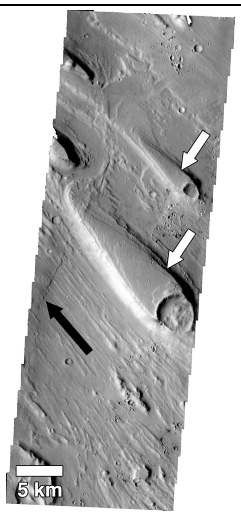
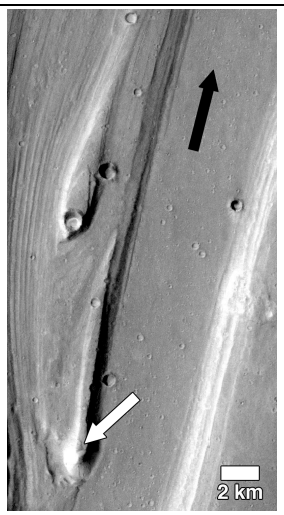
(S) Feature ID Charts – Volcanoes

Feature	Example	Description
Caldera		• A circular depression near the summit (top) of a volcano (some volcanoes have multiple calderas) • Likely form from collapse (after magma erupted, the top of the volcano collapses into empty magma chamber) • Sometimes called a central vent
Fissures		• Cracks in the crust where lava erupts, usually found near volcanoes • Multiple lava flows are seen trailing away from the crack • Highest point is at the vent with lavas sloping away from the vent
Lava Flows		• Formed by the eruption of magma (molten rock) at the surface • “Fingers” point in direction of flow (white arrows in left image) • Often multiple flows in an image • May have a central lava channel

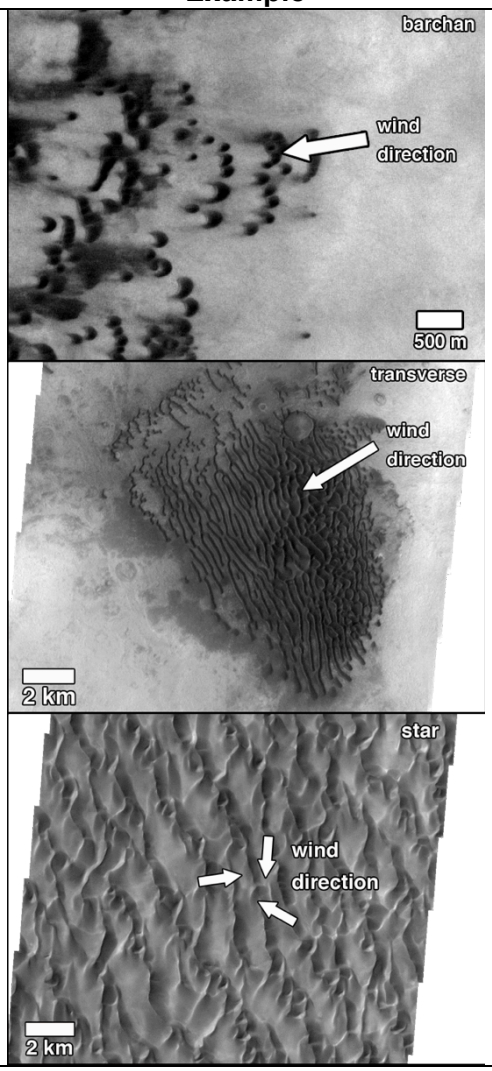
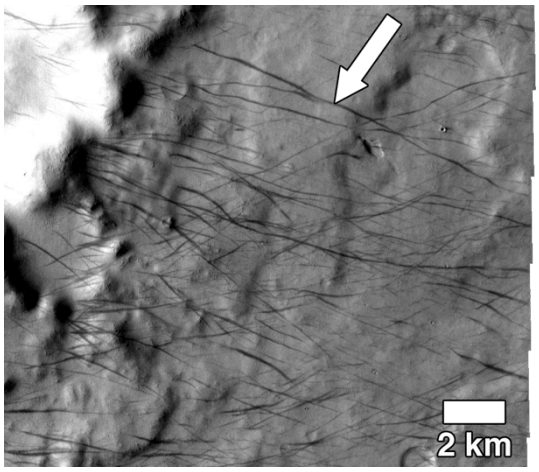
(S) Feature ID Charts – Volcanoes

Feature	Example	Description
Collapsed Lava Tubes		• Look similar to water channels but are more sinuous (“squiggly”) • Lava once flowed under ground through a tunnel and the roof collapsed into the empty tunnel • Often see multiple collapsed lava tubes in one image
Pit Chains		• Sometimes form over empty lava tubes • May form over faults (cracks in the surface) related to volcanism • Pits in a chain usually have similar diameters
Low Shield		• Small volcanoes that usually have central depression (vent) • Often found in fields or clusters • Not found in the Southern Highlands of Mars • May have smooth sides or radial (pointing away from the center) lava flows

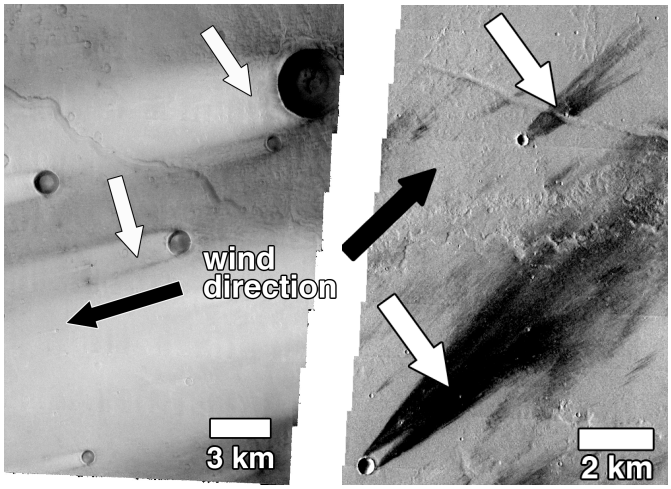
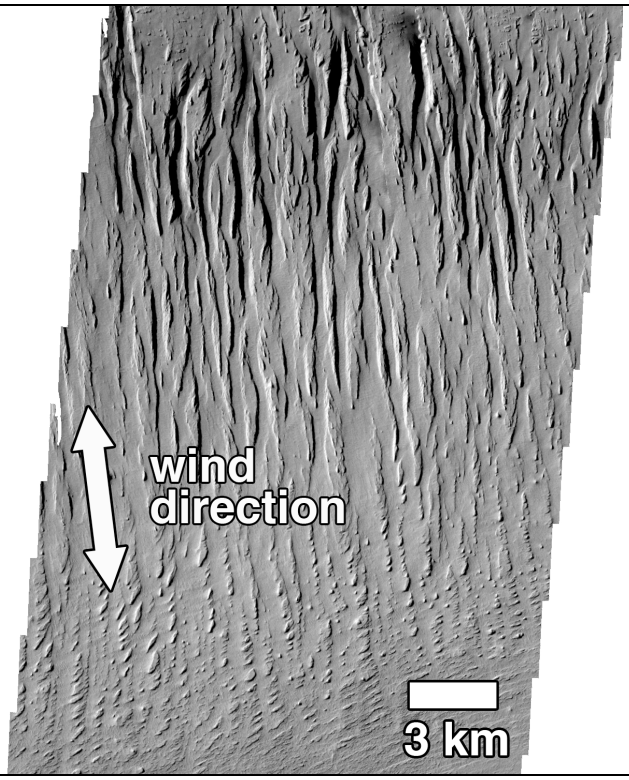
(S) Feature ID Charts – Water-Related (Fluvial) Processes

Feature	Example	Description
Simple Channels		• Likely formed by consistent flow of water over a long period of time • Has a meandering (curvy) shape
Chaotic Terrain		• Often found at the head (start) of large channels and looks chaotic (jumbled) • May have formed where water burst from the ground due to volcanic heating of subsurface ice or groundwater • Surface then collapsed into voids (holes) where the ice/water was
Streamlined Islands	 	• Thought to form by water flowing around a crater (left and right image) or ridge (right image) • Usually found in larger channels and indicate flow direction (black arrows) • Have a teardrop shape • “Pointy” end of the teardrop points in the direction of water flow

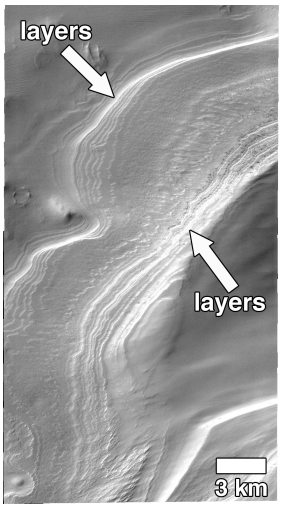
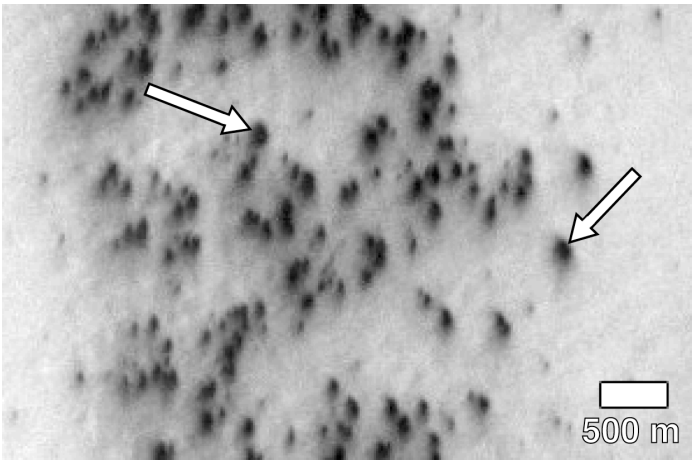
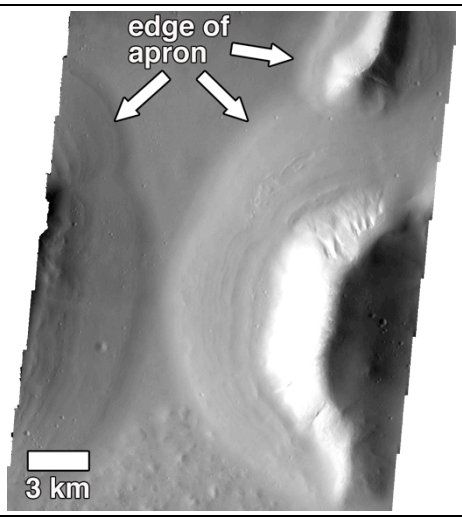
(S) Feature ID Charts – Wind-Related (Aeolian) Processes

Feature	Example	Description
Sand Dunes		• Form in windy areas and are usually darker than surrounding terrain (surface) • Show direction of wind when they formed (may be old and found in currently calm areas) • Barchan dunes have a crescent shape where the ends point in the down-wind direction • Transverse dunes are often found in fields and the upwind side is wider than the downwind side • Star dunes form where the wind blows in more than two directions
Dust Devil Tracks		• Dust devils pick up bright dust, exposing darker surface underneath • Darker tracks are usually younger and get lighter as dust slowly covers the track • Can help identify wind direction

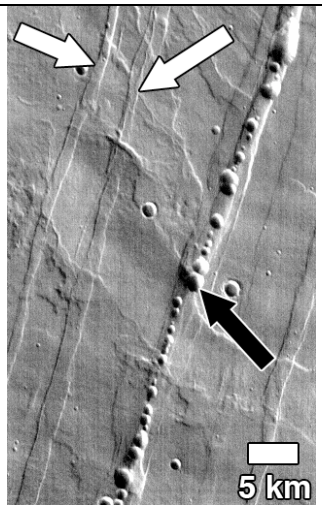
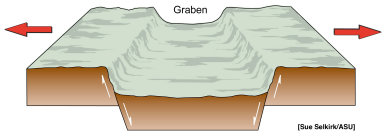
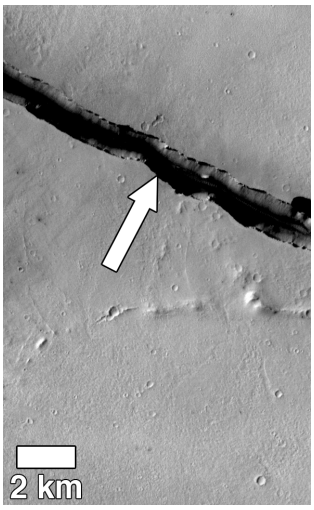
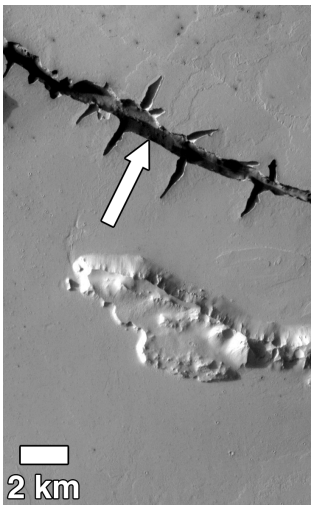
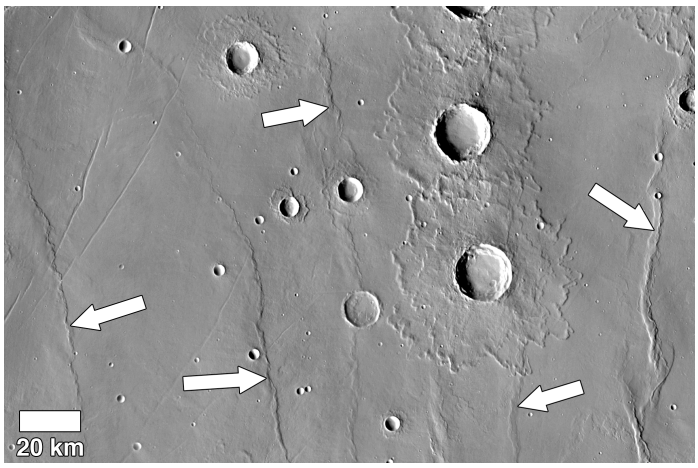
(S) Feature ID Charts – Wind-Related (Aeolian) Processes

Feature	Example	Description
Wind Streaks		• Can be light (left image) or dark (right image) • Often form behind craters or ridges • Light streaks are thought to form by deposition (deposit) of dust • Dark streaks are thought to from by erosion (removal) of surface material • Indicate prevailing wind direction (black arrows)
Yardangs		• Erosional feature formed by sand-sized particles being blown against a surface • Have a uniform direction • Are linear (straight and long) features • Found on surfaces that erode easily

(S) Feature ID Charts – Ice

Feature	Example	Description
Polar Ice Caps		• Found at the north and south pole • Layers represent changing conditions (seasonal or longer) • Stacked layers of dusty or sandy ice
Polar Spots		• Only found near the south polar ice cap • Form seasonally (same time of the year) and may be caused by geysers (jets) of carbon-dioxide gas carrying sand • Wind can blow the sand, leaving streaks which show wind direction
Lobate Debris Apron		• Found in low to mid latitudes around plateaus and ridges • Composed (made) of water ice and rocks (rock glaciers) • Can flow up to 15 km away from the base • Appear to be young features (very few impact craters on the surface)

(S) Feature ID Charts – Tectonics

Feature	Example	Description
Graben	 	• Graben are the most common tectonic feature on Mars and are long, narrow depressions with a down dropped block between the fault walls (white arrows) • Sometimes have collapse pits along the length of them (black arrow) and may be associated with volcanism
Tension Cracks	 	• May be hard to distinguish from graben • No downward dropped block between crack walls • Form when the surface is pulled apart (extension) • Different from collapsed lava tubes in that they should be straighter and not associated with collapse pits
Wrinkle Ridges		• Usually found on smooth volcanic plains • Are formed when the surface is pushed together (compression) • May be tens to hundreds of kilometers long and a few kilometers wide