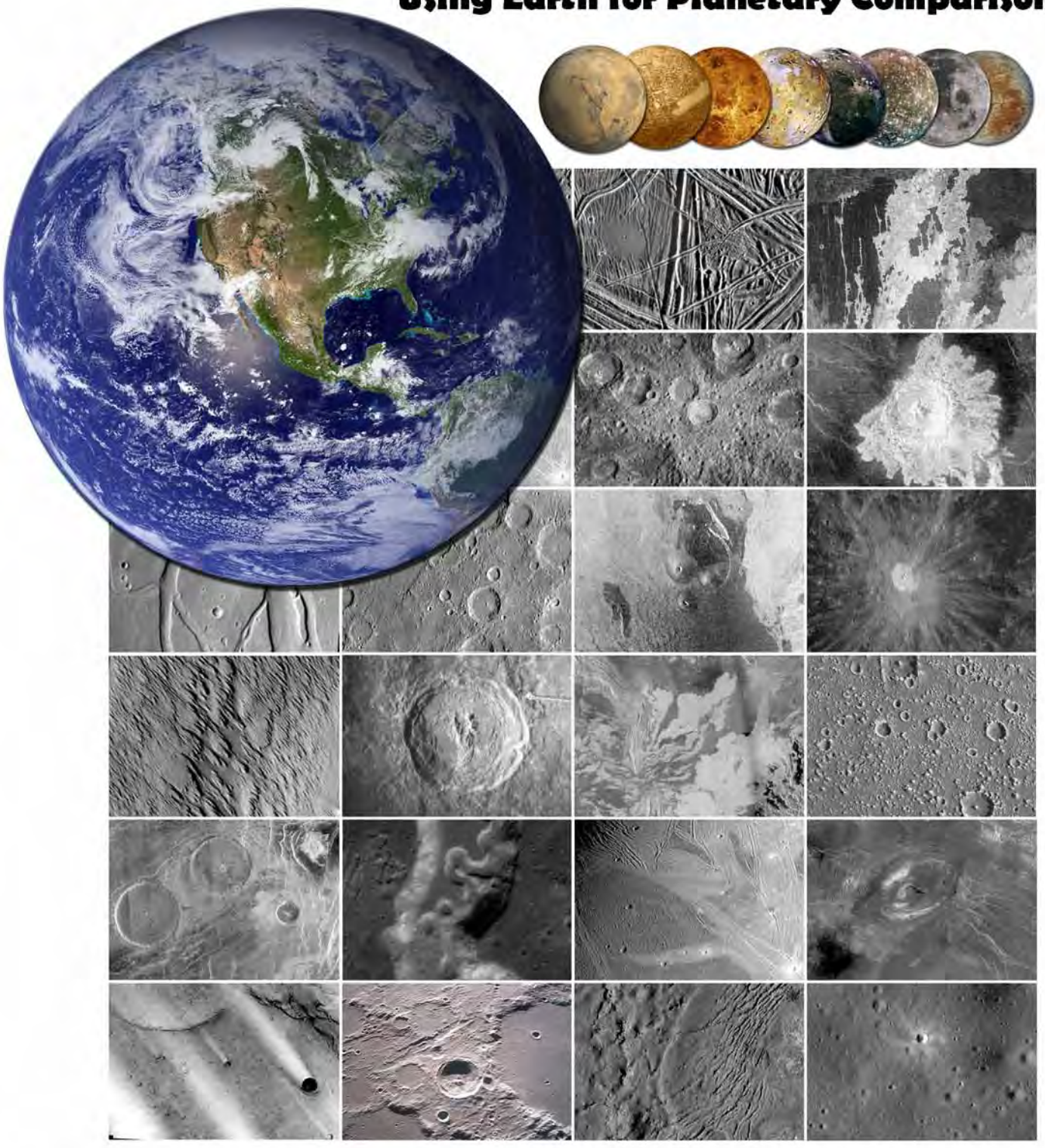
National Aeronautics and Space Administration

Blue Marble Matches

Using Earth for Planetary Comparisons



TEACHER GUIDE

National Aeronautics and Space Administration

Blue Marble Matches

Using Earth For Planetary Comparisons

Written and Developed by:

Paige Valderrama Graff
Science Education Specialist, Expedition Earth and Beyond Director
Astromaterials Research and Exploration Science (ARES) Directorate
ARES Education Program, NASA Johnson Space Center
JACOBS - Engineering Science Contract Group (ESCG)

Edited by the following educators and scientists within the Astromaterials Research and Exploration Science (ARES) Directorate at the NASA Johnson Space Center:

Jaclyn Allen, *Science Education Specialist*
Marshalyn Baker, *Classroom Teacher*
Trevor Graff, *Planetary Scientist*
Charles Lindgren, *Classroom Teacher*
Michele Mailhot, *Mathematics Specialist*
Timothy McCollum, *Classroom Teacher*
Susan Runco, *Physical Scientist*
William Stefanov, *Senior Geoscientist*
Kay Tobola, *Science Education Specialist*
Kim Willis, *Principal Geoscientist*

Additional Reviewers include:
Joshua Bandfield, *Research Assistant Professor Earth and Space Sciences, University of Washington*

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ARES Astromaterials Research & Exploration Science

National Aeronautics and Space Administration

BLUE MARBLE MATCHES

Using Earth For Planetary Comparisons

5-E Activity - Teacher's Guide

Goal: This activity is designed to introduce students to geologic processes on Earth and how to identify geologic features in images. It will also introduce students to how scientists use Earth to gain a better understanding of other planetary bodies in the solar system.

Objectives: Students will:

1. Identify common characteristics to describe features in images.
2. Identify geologic features and how they form on Earth.
3. Create a list of criteria to identify geologic features.
4. Identify geologic features in images of other planetary bodies.
5. List observations, interpretations, and draw conclusions about processes that shape the surface of other planetary bodies.

Grade Level: 3* – 12+ *See adaptations throughout the *Teacher Guide* for activity suggestions for younger students.

Time Requirements: 2 – 4+ class periods

Materials:

Resource	Notes About Resource	Section of Activity
Teacher Guide	Addendum sheets including *Earth Feature Review Images*, *Quick Reference Sheet* & student answer pages (from *Student Guide*) are included at the end of this guide.	n/a
Student Guide	It is recommended to print the entire guide for students if possible.	Parts 1-5
BMM Explore Cards	Cut into 8 separate cards as well as display /project on screen for class.	Part 1
BMM Feature Charts (Earth)	4 Feature Charts: Aeolian, Volcanic, Fluvial, Impact Charts include 4 double-sided pages: 4 image pages (front) and text pages (back). Designed to be printed on 11 x 17" paper but can be printed on 8½ x 11" paper if necessary. Lamination recommended to preserve charts.	Part 2
BMM Earth Feature Review Images	Can print for student groups or project on screen for class. Designed to be printed on 8½ X 11" paper.	Part 3
BMM Feature Image Charts (Planetary Bodies)	Single sided Planetary Body Feature Images: **Mars** (2 pages), **Venus** (1 page), **Mercury** (1 page), **Earth's Moon** (1 page), **Jovian Moons** (1 page). Also designed to be printed on 11 x 17" paper.	Part 4
BMM Quick Reference Sheet	Optional. Can be used as a reference sheet as students look at *Planetary Body Feature Images*.	Part 4
Planetary Resource Information	Optional. Use any available resource information you may have about planetary bodies in the solar system.	Parts 4, 5

National Science Education Standards:

CONTENT STANDARD A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Communicate scientific procedures and explanations
- Think critically and logically to make the relationships between evidence and explanations

CONTENT STANDARD D: Earth and Space Science

- Develop an understanding of the structure of the Earth system
- Develop an understanding of Earth's history
- Develop an understanding of Earth in the Solar System

CONTENT STANDARD G: History and Nature of Science

- Develop an understanding of science as a human endeavor
- Develop an understanding of the nature of science
- Develop an understanding of the history of science

Useful Websites for Additional Background Knowledge:

- Gateway to Astronaut Photography: http://eol.jsc.nasa.gov
- Planetary Photojournal: http://photojournal.jpl.nasa.gov
- NASA Science: http://nasascience.nasa.gov/
- NASA Home Page: http://www.nasa.gov
- Google Earth: http://earth.google.com/
- NASA Earth Observatory: http://earthobservatory.nasa.gov
- NASA Career Resources: http://www.nasa.gov/about/career/index.html
- NASA Career Resources: http://www.nasa.gov/audience/forstudents/careers-index.html
- People involved in Solar System Exploration: http://solarsystem.nasa.gov/people/index.cfm
- Exploring the Planets: http://www.nasm.si.edu/etp/

Adaptations:

- Depending on the level of your students you may decide to focus on 1 Earth process and/or 1 planetary body comparison at a time.
- Images provided on each Feature Chart can be cut into individual "cards" for students to manipulate.
- Adaptations for younger students are included as call out boxes within this *Teacher Guide*.

Extensions:

- Students can investigate other planetary bodies for additional comparisons.
- Students can further investigate specific types of features and geologic processes in more detail. For example, they can research different types of:
    - Sand dunes: Barchan, longitudinal, star, crescent, etc.
    - Volcanoes: Stratovolcanoes, shield volcanoes, cinder cones, etc.
    - Channels: Braided, drainage network, etc.

- Students can research and determine scales or measurements of features in images provided. To do this for Earth images, students can determine the location of an image on Earth (using the image identification number and finding the image on the http://eol.jsc.nasa.gov website.) Using the KML link provided (or the latitude/longitude), students can then locate the image on Google Earth or Google Maps and determine the size of a specific feature using measurement tools available. This will allow them to extrapolate the size of other features in their image. Students should keep in mind that images of Earth are often taken at oblique angles. Images taken at oblique angles do not allow for one consistent scale bar to be used to determine sizes of different features throughout an image.
- Students can further investigate planetary comparisons of geologic features in more detail. For this type of comparative research determining the scale of features would be necessary. For example:
    - Complex craters versus simple craters: For this type of study, being able to know the scale of an image to determine crater sizes would be necessary.
- Students can further research planetary bodies and discuss the similarities and differences between Earth systems (atmosphere, biosphere, hydrosphere, litho/geosphere) and systems (those that exist) of these other planetary bodies.
- Students can conduct their own authentic research project by participating in the ***Expedition Earth and Beyond (EEAB)*** program. ***EEAB*** facilitates authentic research of Earth and/or planetary body comparisons. For more information visit http://ares.jsc.nasa.gov/ares/education/eeab/index.cfm or contact Paige Graff at paige.v.graff@nasa.gov.

Teacher Note: The *Blue Marble Matches Student Guide* is designed to include activity sheets and text to allow students to rely less on the teacher for information and instruction, and more on themselves as independent learners. You are encouraged to review information with students to ensure understanding of concepts and instructions.

Printing Alternative: As your resources permit, you can download the pdf of the *Student Guide* on your student computers and have students fill in answers to questions, save their work, and continue each day without printing anything. You will need to have a program that will enable this. One recommendation is FoxIt. FoxIt allows you to open pdfs, type in answers, and save your work. It is a free download available at: http://www.foxitsoftware.com/pdf/reader/. You may want to check to make sure documents save correctly before students finish their work. Adobe reader will not save typed in work. Other alternatives may be available.

Introduction and Background

This activity is designed to introduce students to geologic processes on Earth and how to identify geologic features in images. It connects the shape of the Earth's surface (and the names of the features that correspond to those shapes and textures) to the processes that form them. Students should work to gain an understanding of how the processes work as opposed to just remembering the names of features. For younger students this may be somewhat challenging and require higher order thinking skills. Understanding the processes that create the features is an extremely important concept. This activity will also introduce students to how scientists use Earth to gain a better understanding of other planetary bodies in the solar system.

Scientists who study Earth oftentimes study it using an Earth Systems Science approach. This approach looks at Earth being made up of different parts (systems) that work together to make up the planet as a whole. The following 4 "spheres" is one way to break down Earth's systems: 1) **Atmosphere**: mixture of gases and small particles above the surface and surrounding the planet; 2) **Biosphere:** related to living systems (life); 3) **Hydrosphere:** water in solid and liquid states; and 4) **Lithosphere** (sometimes referred to as the **Geosphere):** rocks, soils, and sediment. These different Earth systems are all connected and combined make up our unique planet (see Figure 1 on page four of the *Student Guide*). Other terrestrial (rocky) bodies in our solar system (the Moon, Mars, Venus, etc.) have a lithosphere -- they have rocks -- but they may not have any of these other systems that make up Earth. For example, some also have atmospheres, others do not. No other planetary body in our solar system has a biosphere that we know of…yet. This activity will focus on geologic features which are a part of the litho/geosphere. Although the systems approach to studying other planetary bodies is not the focus of this activity, an introduction to the importance of the interaction of different systems on Earth is important. The interaction of different systems on other planetary bodies will play a role in the past, present, and future of these bodies, just as they do on Earth.

The table below indicates what section each objective of this activity will be introduced:

OBJECTIVES	ACTIVITY SECTION
Identify common characteristics to describe features in images.	Part 1
Identify geologic features and how they form on Earth.	Parts 1 and 2
Create a list of criteria to identify geologic features.	Parts 2 and 3
Identify geologic features in images of other planetary bodies.	Part 4
List observations, interpretations, and draw conclusions about processes that shape the surface of other planetary bodies.	Part 5

5-E INQUIRY MODEL OF INSTRUCTION

The 5-E model is an inquiry based model of instruction based on a constructive approach to learning (learners build or construct ideas by comparing new experiences to their existing framework of knowledge). The 5-E model of instruction breaks this approach into 5 phases. The phases are: *Engagement, Exploration, Explanation, Elaboration,* and *Evaluation*. This model builds on prior knowledge and common experiences of students and teachers to construct or build meaning and connections to new concepts while also correcting any inaccuracies. This model and the *Blue Marble*

Matches activity is designed as guided discovery to maintain a structure for learning for your students.

The table below breaks down each phase of the 5-E model. It provides a general description of each phase and how the *Blue Marble Matches* activity applies each phase within the lesson.

5-E Phase	General Description	Blue Marble Matches Activity
Engagement	Teachers engage students using an activity, image, or discussion to focus students' thinking on an important aspect or learning outcome(s) of the activity.	Students make observations and describe what they see in an image using descriptive words or characteristics.
Exploration	Students actively explore and make discoveries using hands-on materials. Students develop concepts, processes and skills to establish an understanding of content.	Students read background information to gain knowledge & understand geologic processes on Earth. Students explore images of Earth to develop a list of identification criteria used to identify different features.
Explanation	Students communicate and explain concepts they have been exploring. Students use formal language and vocabulary associated with content.	Students use identification criteria to reinforce feature recognition. Students review and revise criteria as necessary. Students use vocabulary learned from previous parts of the activity.
Elaboration	Students extend conceptual understandings to new problems or experiences. Students reinforce and develop a deeper understanding of concepts and skills.	Students apply knowledge of Earth-based geologic features to identify features in images of other planetary bodies.
Evaluation	Teachers and students assess new knowledge and understanding of key concepts.	Students create a list of observations and interpretations to draw conclusions about processes that shape the surface of other planetary bodies.

ACTIVITY PROCEDURE

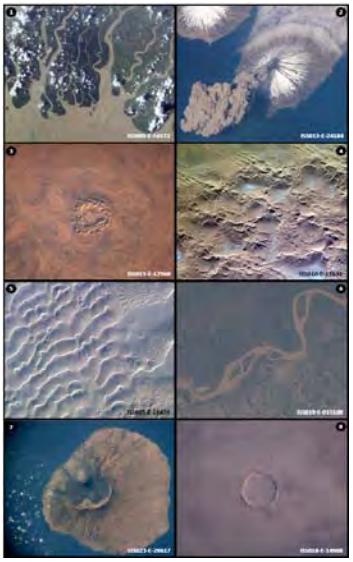
This activity procedure is provided as a suggested guide for the *Blue Marble Matches* activity. *Estimated times* for each section are provided but can vary depending on your level of students and time you feel is necessary for engagement in discussion. This procedure includes thumbnails of student pages and images/feature charts used for each part of the activity for your reference.

Part 1: Observations and Descriptions (Engage Activity)

Estimated time for Part 1: ~20-30 minutes for image observations (pages 1 & 2); 30-50 minutes for Background Information discussion (pages 3-5)

Materials needed:

- *BMM Explore Cards (cut into 8 separate image cards: 1 image per group; also have set of BMM Explore Cards available to project on screen for the class)*
- *Pages 1 and 2 of the Blue Marble Matches Student Guide (for the initial part of the activity)*
- *Background Information: Pages 3 – 5 of the Blue Marble Matches Student Guide*




BLUE MARBLE MATCHES
Using Earth for Planetary Comparisons

1. Read over the introduction information on page one to introduce information related to the activity. Once this information is discussed, divide students into groups of 2. Give each group of students one of the cut up *BMM Explore Cards* and have them write a description of what they see. Students should not name features in the image, they should simply use descriptive words to describe their image.

2. Display the set of *BMM Explore Cards* on the overhead projector. As student groups finish writing their descriptions, have them read their descriptions to other groups to see if they can identify the image being described. As students go through this process, ask them to discuss how they could improve image descriptions. Students should list 3-5 useful characteristics or descriptive ways to describe features in images.

3. After discussing useful ways to describe features in images, discuss with students how these images focus on features related to four different geologic processes that help shape the surface of our planet. The processes are related to wind, water, volcanoes, and impacts (meteors striking the surface). In groups of 2-4, have students observe the set of *BMM Explore Cards* projected on a screen in the front of the class. Students should make observations and do the following as they fill out the table on page 2 of the *Student Guide*:
    a. Discuss how they would group the images in pairs that relate to the same geologic process.
    b. List which of the four given geologic processes they think created those features. They should choose from wind, water, volcanic, or impact.
    c. If they think they know the names of any features in these images they should list their best guesses.

Below is an example of how the table can be filled out. Feature names are optional. You can revisit the feature names during part 3 of the activity.

	IMAGES (use numbers 1-8)	GEOLOGIC PROCESS (Wind, Water, Volcanic, or Impact)	FEATURE NAMES (optional)
Group 1	1 & 6	Water	Channels
Group 2	2 & 7	Volcanic	Volcano and ash plume; volcano and lava flows
Group 3	3 & 8	Impact	Impact craters
Group 4	4 & 5	Wind	Sand dunes

4. As a class, discuss student answers. Allow students to discuss how and why they grouped images the way they did. Even if they grouped images incorrectly, it is not essential to correct them at this point in time. As students continue with the activity, you can go back and discuss this table again with students. (A good time to do this is during Part 3 of the activity.) It will be more powerful to have students self-correct than it is to correct them at this point of the activity. Students will also likely want to know the names of the features in the images. Allow students to state their guesses but again, this can be revisited later in the activity (during Part 3).

5. Ask students if they know any details about these geologic features – how they form; if they think any of these features exist on other planets in our solar system; how scientists use what they know about Earth to explore other planets. Let them know that this activity will help them understand and answer these questions.

The **BACKGROUND INFORMATION** is provided after the initial *engage* activity to introduce concepts and information students will need for the rest of the activity. Students should read this information and it should be discussed as a class. One suggestion is to assign a different part of the reading to different groups in the class to report on – using a jigsaw technique. The three pages of background information can be divided in many ways. The following is one suggested way to divide up the background information into 7 separate sections:

- ***Suggested Division #1: Defining Characteristics of Geologic Features:*** Overview: Reinforces types of descriptor characteristics (relative size, shape, texture, position/orientation and color/tone) students and scientists can use to describe features in images based on their observations.

- ***Suggested Division #2: Systems Science*:** Overview: Provides introductory information on Earth systems to give students a brief overview of how the interaction of different systems (atmosphere, biosphere, hydrosphere and litho/geosphere) plays an important role on Earth and possibly other planetary bodies. Students should note that this activity will focus on features associated with the litho/geosphere.

- ***Suggested Division #3-6: Earth Processes and Geologic Features:*** Overview: General information is provided on 4 geologic processes and associated features discussed throughout this activity. Assign 1 group to each geologic process:
  - **Group 3:** Aeolian Processes and Features
  - **Group 4:** Impact Processes and Features
  - **Group 5:** Fluvial Processes and Features
  - **Group 6:** Volcanic Processes and Features

- ***Suggested Division #7: Planetary Comparisons:*** Overview: Reinforces to students how scientists use their knowledge of the formation of features on Earth and other background knowledge they have about a planetary body to identify features and hypothesize about how those features may form on these other worlds. These comparisons enable scientists to decipher the history of other planets and the processes that shape their surfaces.

It is suggested that you spend some time going over the geologic processes and features as the remainder of this lesson will rely on students having a good grasp of this information. Students do not need to be "experts" on how these features form, but they should have a general understanding that they can apply to features they will see in other images both on Earth and other planetary bodies.

You may consider having students read through the information on these pages for homework to reinforce what was discussed in class.

PART 1: ADAPTATION FOR YOUNGER STUDENTS

For younger students you may want to rely more on class discussions rather than have students read and fill out information in the Student Guide.

- Provide pairs of students with one of the images from the *BMM Explore Cards* and have them describe what they see without naming features. Have students share their descriptions with the class to see if others can figure out which image they are describing.
- Alternatively, show students the *BMM Explore Cards* in the front of the room. Describe an image and have students guess which image you are describing. Once you have done a couple of examples, see if you have any volunteers to describe an image.
- Discuss different types of words they can use to describe features in images. Descriptive words they may come up with are color, shape, texture, position, etc.
- Provide student groups with a complete set of the 8 individually cut *BMM Explore Cards* and have them arrange the cards in pairs that they think belong together. Have students explain why they paired the images the way they did. Answers will vary but students may pair images by color, or shape, or some other characteristic. Accept any answers provided that students explain their answers with a reasonable explanation.
- Briefly discuss with students about different forces of nature (wind, water, volcanoes, or impacts created by meteors (space junk) striking the surface). Ask students which image(s) they think may be associated with each force.

BACKGROUND INFORMATION: ADAPTATION FOR YOUNGER STUDENTS

For younger students you may want to discuss and create lists of the information listed below. Use the whiteboard or easel paper to list important points using simplified text:

- *Defining Characteristics of Geologic Features* **(Descriptive Words)*:*** Let students know that scientists describe features they see in images of Earth using the same types of words they used to describe the images in Part 1 of this activity. Have them recall the types of words they used to describe features. Their list may include descriptive words that relate to size (relative size), shape, position, color, and texture.
- *System Science* **(Parts of Earth)*:*** You may consider briefly discussing how Earth is made up of different parts (systems) that all play a role in the Earth as a whole. These can be referred to as air, water, land, and life. You can try to use hints to allow students to brainstorm and name these parts of Earth. For example, what makes up ¾ (or most) of our Earth? (Water). What surrounds us and is necessary for us to breathe? (Air).
- *Earth Processes and Geologic Features* **(Forces of Nature):** Discuss again how different forces or processes help shape the surface of the Earth. Try to use hints to allow students to guess these forces or processes: 1)Wind, 2)Water, 3)Volcanoes, and 4)Impacts (Meteors from space).
- *Planetary Comparisons* **(Learning About Other Planets)***:* Let students know that scientists use what we see and know about Earth to compare and learn about other planets and moons.

Part 2: Identification Criteria (Explore)

Estimated time for Part 2: ~10-15 minutes per Earth Feature Chart and Geologic Process Table (Discussion time may vary: ~10-15 minutes per geologic process)

Materials needed:

- *Background Information Pages 3 – 5 of the Blue Marble Matches Student Guide* as a reference
- *Pages 6–7 Blue Marble Matches Student Guide (pages include a table for each geologic process)*
- *Earth Features Charts (Aeolian Features, Volcanic Features, Fluvial Features, Impact Features)*

There are 4 sets of *Earth Feature Charts (aeolian, volcanic, impact and fluvial processes)*. Each includes 8 images and accompanying text. It is recommended to print these front to back.

1. Familiarize Students with Materials: After reading and discussing the background information students should be familiar with the types of features they may observe in images and how those features form on Earth. Depending on the level of your students, prior to handing out the Earth Features Charts, make sure students are familiar with the following:

   a. **Geologic Process/Identification Criteria Tables on pages 6 and 7:** These tables (organized by geologic process) include identification criteria students can use to identify common characteristics helpful to identify features. Suggested identification criteria has been listed for students but students can change or shorten these if they wish. Students should create their own additional criteria in the rows labeled *"Other"* on each table.

   b. ***Earth Features Charts*:** Each feature chart is also categorized by geologic process. Information about each image is provided on the back and includes the following:

   - Main Geologic Process and Feature shown in image
   - Geographic location of image
   - Image identification number
   - Global view of Earth with a circle representing the general area of where the image is located
   - General information about the image
   - List of OTHER VISIBLE FEATURES to allow students to identify other features visible in the image

2. Once students are familiar with materials, distribute one *Earth Features Chart* at a time to each group of 2-4 students. Have students examine all the images on their feature chart and then determine which **2 criteria** on the tables (pages 6 and 7) provide the best description of each feature. Be sure students create their own additional identification criteria for each feature. Note: Remind students they can change the provided identification criteria if they feel it is necessary.

3. Once student groups have finished filling out the identification criteria table for one geologic process have them exchange their current *Earth Feature Chart* for a different one. This will enable students to fill out the identification criteria tables (pages 6 and 7) for each geologic process and associated features. If some groups finish early you can have them discuss and debate their selected criteria with other groups.

4. Discuss the identification criteria students selected and created for each feature as a class. Students should connect each geologic feature to a process that formed it. By the end of the discussion each student should be able to use their selected and created identification criteria to identify each geologic feature in any image of Earth (or other planetary body). Additionally, students should make a connection between features and the processes that form them. **Note:** Identification criteria for a given feature may vary from student to student.

PART 2: ADAPTATION FOR YOUNGER STUDENTS

For younger students refer to notes you have written on the board/easel to discuss the feature cards with students. You may want to focus on one geologic process at a time. The *Earth Feature Cards* are designed to be printed with the images on the front and text on the back. For your younger students, you may want to print the images only.

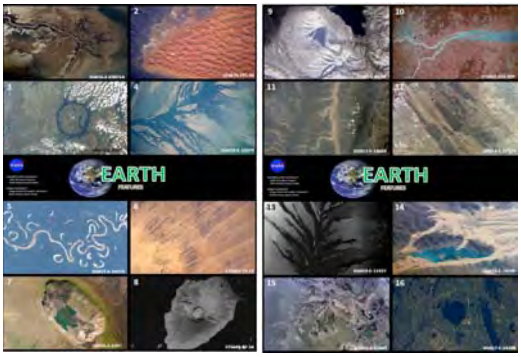
- Cut up 1 set of feature cards and have students group features that look the same.
- Have students identify common aspects of features that led them to group features together. These aspects could be descriptor characteristics such as color, shape, texture, etc.
- Have students decide which force of nature (geologic process) these image cards are associated with (wind, water, volcanoes, or impacts).
- Depending on the grade level of your students, have students learn the names of the different geologic features. Create a list on the board/easel.
- Depending on the level of students you have you may or may not want to get into the process and formation of each feature. This depends on what you feel is appropriate for your level of students.
- Repeat this with each of the other feature cards. In the end, students will have discovered different features associated with each force of nature (geologic process).

Part 3: Feature Recognition and Review (Explain)

Estimated time for Part 3: ~20-30 minutes

Materials needed:

- *Earth Feature Review Images (included at the end of the Teacher Guide)*
- *Pages 8 and 9 of the Blue Marble Matches Student Guide*
- *Geologic Process/Identification Criteria Tables (pages 6-7 of Student Guide) for reference*
- *Optional: Explore Images from Part 1 of the activity*



It is extremely important that students use their created identification criteria to help support their identification of features.

It is important for students to reinforce and review their identification criteria for each feature before they move on to the planetary comparison section of the activity. To reinforce the use of their created identification criteria, show students the *Earth Feature Review Images* and have them identify 3 items:

1. Identification criteria used to help identify each feature,
2. The main geologic feature in each image,
3. The main geologic process (aeolian, fluvial, volcanic, or impact).

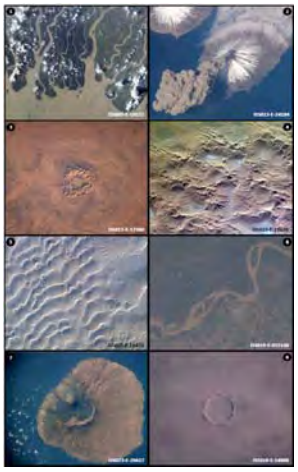
For this part of the activity you can have students formally discuss and record their answers on the Feature Recognition and Review sheet (pages 8, 9) or you can do this orally as a class. You can choose to go over all 16 images or select a handful of images that you feel will allow for reinforcement of the use of identification criteria as evidence to support and identify features.

As you discuss answers as a class, you and your students may also experience how scientists (both professionals and students) do not always agree! Students should understand that scientific debate and using evidence to back up interpretations are key elements of science. They should be open to changing their original identification of a feature if they can be convinced. **It is not all about what answer is right or wrong. More importantly, it is about evidence and criteria that support students interpretations.** Students should realize that not all scientists agree, which is an important aspect of how science progresses.

The following "answers" are provided as a guide. Some answers may be debatable. Identification criteria will vary but it is important that you discuss criteria with students.

Identification Criteria	Main Feature	Geologic Process
1. Answers will vary	Delta	Fluvial
2. Answers will vary	Sand dunes	Aeolian
3. Answers will vary	Impact crater	Impact
4. Answers will vary	Lava flows	Volcanic
5. Answers will vary	Channel	Fluvial
6. Answers will vary	Wind streaks or yardangs	Aeolian
7. Answers will vary	Caldera	Volcanic
8. Answers will vary	Volcano, caldera and/or lava flows	Volcanic
9. Answers will vary	Volcano, caldera, and/or lava flows	Volcanic
10. Answers will vary	Channel	Fluvial
11. Answers will vary	Valley/Drainage network	Fluvial
12. Answers will vary	Wind streaks	Aeolian
13. Answers will vary	Lava flows	Volcanic
14. Answers will vary	Sand dunes	Aeolian
15. Answers will vary	Delta	Fluvial
16. Answers will vary	Impact crater	Impact

At this time you may also want to revisit the *BMM Explore Cards* from Part 1 of the activity. Using that set of images, you can help students self correct, as necessary, what they did in the first part of the activity. You can also use the *BMM Explore Cards* to reinforce feature recognition and review.



Identification Criteria	Main Feature	Geologic Process
1. Answers will vary	Channels	Fluvial
2. Answers will vary	Volcano	Volcanic
3. Answers will vary	Impact crater	Impact
4. Answers will vary	Sand dunes	Aeolian
5. Answers will vary	Sand dunes	Aeolian
6. Answers will vary	Channel	Fluvial
7. Answers will vary	Volcano, lava flows	Volcanic
8. Answers will vary	Impact crater	Impact

PART 3: ADAPTATION FOR YOUNGER STUDENTS

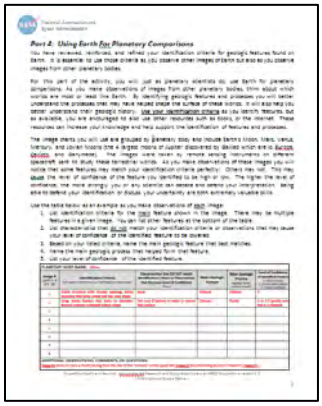
- As a class, discuss at least the force of nature (process) associated with each image (or selected images). Forces would include would include wind, water, volcanoes or impact. If you had students learn the names of individual features, discuss this with students as well. Be sure to ask students to provide some justification/explanation to their answers.
- Alternatively, cut up the images into separate cards and have students group the images by force of nature (process). Have students discuss why they grouped the images they way they did.

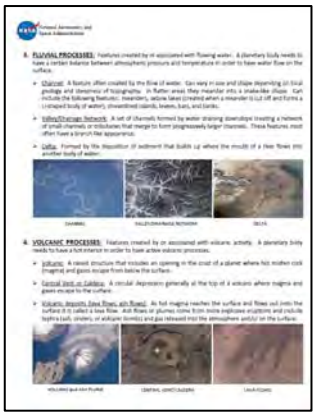
Part 4: Using Earth For Planetary Comparisons (Elaborate)

Estimated time for Part 4: ~15-20 minutes/planetary body and "Planetary Comparison Feature Table" (Discussion time may vary: ~10-20 minutes per planetary body)

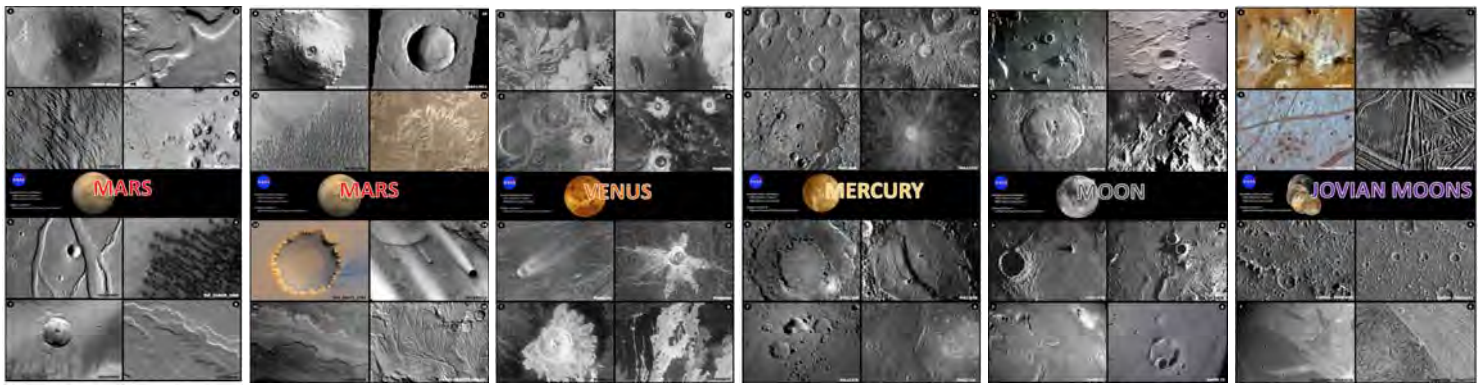
Materials needed:

- *Pages 10 – 12 of the Blue Marble Matches Student Guide (Additional "Planetary Comparison Feature Tables" can be printed if necessary)*
- *Identification Criteria for each geologic feature (pages 6-7 of Student Guide) for reference*
- *BMM Quick Reference Sheet (optional)*
- *Planetary Body Feature Image Charts (Mars, Venus, Mercury, Earth's Moon, Jovian Moons)*
- *Optional information on planetary bodies in the solar system you may have available (books, lithographs, internet)*





It is extremely important that students use their previously created identification criteria to help support their identification of features on other planetary bodies.



Students will now have a basis for looking at images of other planetary bodies and identifying geologic features that look similar to those they identified on Earth. It is recommended to have the class focus on one *Planetary Body Feature Image Chart* at a time so a rich class discussion can take place. If you don't have enough copies of the image charts for each group of 2-4 students, project an image chart in the front of the room to allow students to make their observations.

The image charts are grouped by planetary body. The images were taken by remote sensing instruments on different spacecraft sent to study these terrestrial worlds in our solar system. Student observations will help them make inferences to better understand the history and processes affecting the surfaces of these other worlds. As they make their observations they should be sure to use the identification criteria they already created. Some features may match perfectly. Others may not. This may cause the level of confidence of their identification to be high or low. They should realize that planetary scientists deal with this as well. Scientists often debate and do not always agree with each other's interpretation of a feature or the process that created a feature. Students should remember that justification and having evidence to back up their statements is key! Students should be prepared to defend their identification or discuss their uncertainty -- both of which are extremely valuable skills.

1. Familiarize Students with Materials: It is important that students are familiar with the items they will be working with for this portion of the activity. These items are as follows:
    a. ***Planetary Body Comparison Features Table* on pages 10, 11 and 12:** A sample table is provided on the bottom of page 10 to give students an idea as to how they might fill out this table for the planetary body they are observing. Review this sample table with students as necessary.
    b. ***Identification Criteria (pages 6 & 7):*** Students are already familiar with these criteria but you should reinforce that they must use the criteria they established to support their identification of geologic features on other planetary bodies.
    c. ***Quick Reference Sheet (optional):*** This is an optional handout you can provide to students. This will help remind students about the different geologic processes and features, and how each feature forms on Earth.
    d. ***Planetary Body Feature Image Charts*:** Each image chart is categorized by planetary body. No information is provided on the back as students will decide what features they believe are included in each image. There are two image charts for Mars, and one for Venus, Mercury, Earth's Moon, and Jovian Moons (moons of Jupiter). Images have been cropped to focus on specific features.
    e. ***Resource Information on planetary bodies (optional):*** Resource information would be useful to provide students with a means in which to learn some facts about the planetary body they are working with. You can use lithographs, books, the internet or any other available resources you may have available.

2. Once students are familiar with materials, distribute one *Planetary Body Feature Image Chart*, the optional *Quick Reference Sheet* and optional *Resource Information* to each group of students.

3. Have students make observations of the images to determine the main geologic feature visible in each image. Students should fill out the *Planetary Body Comparison Features Table* for the planetary body they observe. Students should use their created lists of identification criteria to help support their identification of features on these other terrestrial bodies.
4. Once student groups have finished filling out the *Planetary Body Comparisons Features Table* for one planetary body, discuss answers as a class. If some students finish early you can optionally have them make observations of another planetary body. Note: You can choose to focus on 1 or more planetary bodies, as desired.
5. Display the *Planetary Body Feature Image Chart* for the class and have groups report their observations on a specific image. After each group reports their observations, discuss as a class.

This is a sample table filled out Mars. The level of detail your students include will vary depending on the grade level of your students and their background knowledge.

PLANETARY BODY NAME: Mars

Image # (use #'s 1 - 8 or 9 - 16)	Identification Criteria (list specific criteria from your identification criteria tables)	Characteristics that DO NOT match Identification Criteria or Observations that Decrease Level of Confidence (if any)	Main Geologic Feature	Main Geologic Process (aeolian, fluvial, volcanic, impact)	Level of Confidence of Identified Feature 1 = Not Confident 2 = Somewhat Confident 3 = Totally Confident
1	Entire structure with circular opening; entire structure that looks raised and has cone shape	none	Volcano	Volcanic	3
2	Long, windy feature that looks to meander; feature contains u-shaped oxbow shape	Not sure if feature is raised or carved into surface	Channel	Fluvial	2 or 2.5 (pretty sure this is a channel)
3					
4					
5					
6					
7					
8					

ADDITIONAL OBSERVATIONS, COMMENTS, OR QUESTIONS:
Image #1 seems to have a chunk missing from the side of this "volcano" on the upper left. Other visible features include a caldera and impact craters; Image #2 has interesting layers in the channel. Other features include impact craters; Image #3...

PART 4: ADAPTATION FOR YOUNGER STUDENTS

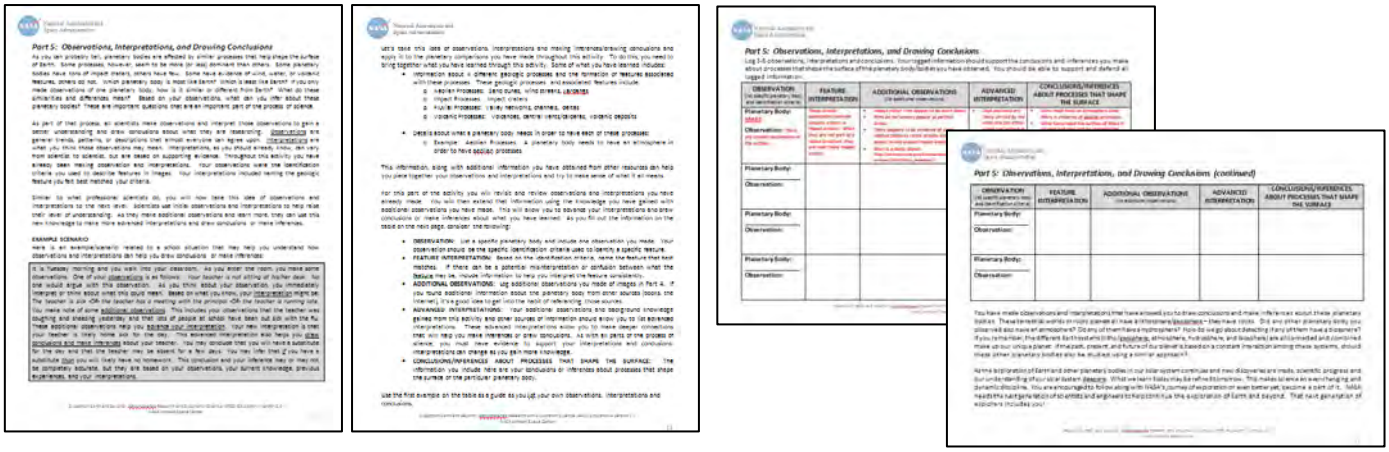
- For younger students you may want to cut up the *Planetary Body Feature Images* into individual manipulative for each planet. You can set up stations and have students arrange the images for each planetary body into groups based on the forces of nature that have been discussed throughout the activity. These would include wind, water, volcanoes or impact. Alternatively you can have student groups all working on the same planetary body.
- For each planetary body, as a class, discuss which images they would group with which process. Discuss why they grouped the images they way they did.
- Discuss if these other worlds are similar or different from Earth, and how.
- Students will likely disagree with one another. This is the perfect time to let them know that scientists don't always agree either. Explain to students that they (and professionals) need to have evidence to back up their decisions. Let students know that in the end, they do not all have to agree, but should be open to changing their minds based on evidence given by other students.

Part 5: Observations, Interpretations, and Drawing Conclusions (Evaluate)

Estimated time for Part 5: ~30-45 minutes (this includes discussion time)

Materials needed:

- *Pages 13-16 of the Student Guide*



Students should now have a good sense of how planetary bodies are affected by similar processes that help shape the surface of Earth. They may notice that some processes, seem to be more (or less) dominant than others. Some planetary bodies have tons of impact craters. Others have no trace of wind or water features. Students should think about which planetary body is most or least like Earth? If they only made observations of one planetary body, they should think about how is it similar or different from Earth? They should consider what these similarities and differences mean? Their observations will help them make inferences about these planetary bodies.

This part of the activity has students synthesize what they have learned. The first section of Part 5 reiterates what observations and interpretations are - - which is what students have been doing throughout the activity. (**Observations** = identification criteria; **Interpretations** = name of geologic feature and process.) This part of the activity extends these general observations and interpretations and has students make additional observations, advanced interpretations, and draw conclusions or make inferences. This requires higher order thinking skills and may be difficult for some students.

1. Discuss with students the whole idea of observations and interpretations. Have students read the call out box in the *Student Guide* which provides a simple example/scenario to help them understand observations, interpretations, advanced observations and interpretations and drawing conclusions/making inferences.

2. Have students read page 14 to see how the idea of observations, interpretations, and making inferences/drawing conclusions can be applied to planetary comparisons. Students must take what they have learned throughout the activity (information on the geologic processes and features, including how they form; as well as details about what a planetary body needs in order to have each of the processes). Students should combine this knowledge with outside information obtained from books, the internet, along with observations they made during Part 4

of the activity. They should synthesize what they have learned by logging at least 3 observations, interpretations, and conclusions on the table provided on pages 15 and 16. An example has been provided for them. There are no correct or incorrect answers for this part of the activity, however, students should be able to justify/support information they log.

Example Observations, Interpretations, Drawing Conclusions table:

OBSERVATION (list specific planetary body and identification criteria)	**FEATURE INTERPRETATION**	**ADDITIONAL OBSERVATIONS** (list additional observations)	**ADVANCED INTERPRETATION**	**CONCLUSIONS/INFERENCES ABOUT PROCESSES THAT SHAPE THE SURFACE**
Planetary Body: ***MARS*** **Observation:** ***There are circular depressions on the surface.***	***These circular depressions could be volcanic craters or impact craters. When they are not part of a raised structure, they are most likely impact craters.***	• ***Impact crater rims appear to be worn down.*** • ***Rims do not always appear as perfect circles.*** • ***There appears to be evidence of wind related features (wind streaks and sand dunes) in and around impact craters.*** • ***Mars is a dusty planet. (http://science.nasa.gov/science-news/science-at-nasa/2003/09jul_marsdust/)***	• ***Dust and sand are likely carried by the wind and can either erode the surface or be deposited on the surface.*** • ***Impact craters have likely been affected by these processes.***	• ***Mars must have an atmosphere since there is evidence of aeolian processes.*** • ***Wind has eroded the surface of Mars in its past and may still be changing the surface today.*** • ***Dust and sand likely erode the surface.*** • ***The atmosphere is thick enough to have wind but not thick enough to prevent meteors from striking the surface.***

3. Discuss *Observations, Interpretations* and *Conclusions/Inferences* with students as desired. This discussion should help reinforce what has been learned throughout the lesson.

NOTE: The *Student Guide* ends with a few statements encouraging students to continue to follow or become a part of the exploration of Earth and other planetary bodies. It is your students who could be NASA's next generation of scientists and engineers. They can play an active role in exploration now by participating in programs such as Expedition Earth and Beyond. Additionally, students can look at potential NASA Careers by visiting the NASA Career Resources websites such as

- http://www.nasa.gov/audience/forstudents/careers-index.html
- http://solarsystem.nasa.gov/people/index.cfm

PART 5: ADAPTATION FOR YOUNGER STUDENTS

Part 5 is too complex for younger students. Therefore, for the last part of this activity, it is recommended that you discuss and review main aspects of this activity.

- Ask students to state the 4 main forces of nature on Earth that they have discussed through the activity.
- If you had students learn the names of individual features, review and discuss as desired.
- Ask students to consider if these same forces are affecting the surfaces of other planetary bodies in the solar system. Be sure to ask them to justify their answers.
- Have students discuss what intrigues them about planets in our solar system, including Earth.
- Share information about NASA careers.

ABOUT THE IMAGES

The images used for this activity come from a variety of sources. The images provided are not of the same scale. Students should not try to compare sizes of features from one image to another or one planetary body to another without determine the scales of each image. Each image is labeled with an image identification or the name of the camera or spacecraft that acquired the image. The Expedition Earth and Beyond website does allow you to click on each image to get to a page where you can further investigate information about images and their scales. The link to access images from the *Feature Charts* is: http://ares.jsc.nasa.gov/ares/education/eeab/featurecharts.cfm

Earth Images: There are 32 images of Earth used in this activity. These images were all acquired by astronauts onboard the Space Shuttle or the International Space Station (ISS) and are courtesy of the Image Science and Analysis Laboratory at the NASA Johnson Space Center. Images are categorized into geologic process categories: Aeolian, volcanic, impact and fluvial processes. Images have been cropped for use on the *Earth Feature Charts*.

Mars Images: There are 16 images of Mars used in this activity. Images were acquired by different cameras onboard a variety of spacecraft orbiting Mars. They are visible images, most of which have been cropped to focus on specific geologic features to include on the *Mars Features Chart*. Images show geologic features found on Mars that are similar to features found on Earth related to aeolian, volcanic, impact and fluvial processes. Overall, Mars has the most similar features representing each of the geologic processes discussed for Earth. The following is provided as a guide for features in each image. Answers can be debatable and should be accepted if students can justify their answers:

1. Volcano
2. Channel
3. Yardangs
4. Volcanoes (These are small cone-like volcanoes. Some may interpret these as impact craters.)
5. Channel and impact craters
6. Sand dunes
7. Impact crater and wind streaks
8. Lava flows
9. Volcano
10. Impact crater
11. Sand dunes
12. Delta (Some may interpret this feature to be lava flows.)
13. Impact crater with sand dunes (inside crater) & dark wind streaks (lower right side of image)
14. Impact craters and wind streaks
15. Lava flows
16. Valley/drainage network

Earth's Moon Images: There are 8 images of the Moon used in this activity. These images were acquired by different cameras used by astronauts or orbiting spacecraft. They are visible images, most of which have been cropped to focus on specific geologic features found on the Moon that have similarities to Earth features used. The Moon is thought to be dominated by impact and volcanic features. Many of the images include smooth lava plains, although these do not show the same lava flow features or morphologies (shape) as lava flows seen in images of Earth. The following is provided as a guide for features in each image. Answers can be debatable and should be accepted if students can justify their answers:

1. Impact craters
2. Impact craters (center crater has visible central peak)
3. Impact crater (with visible central peak)
4. Impact crater, mountains/ridges, lava channel (channel is likely associated with lava flows as opposed to water flow. Students may "argue" that the feature fits their identification criteria for a channel related to water. This is where background information and knowledge about a planetary body is key. It is not believed that water freely flowed across the surface of the Moon.)
5. Impact crater
6. Impact craters
7. Impact craters with lava channels/lava tubes (Again, some students may interpret these to be water-related features but they are associated with volcanic processes.)
8. Impact craters

Venus Images: There are 8 images of Venus used in this activity. The majority of the images were acquired by the Magellan spacecraft and an imaging radar instrument. Differences in color (bright versus dark) is due to slopes and different textures on the surface. Radar images can generally be used as though they were black and white images. Images included in this activity are primarily of impact craters, and volcanic features. A common volcano found on Venus is the pancake dome volcano. These can be confused with impact craters as they look circular and flat. Venus image #3 (PIA00084) includes pancake dome volcanoes. The following is provided as a guide for features in each image. Answers can be debatable and should be accepted if students can justify their answers:

1. Lava flows
2. Volcanoes and lava flows
3. Volcanoes and impact crater (Note: Some students may interpret the large circular features to be impact craters as they probably meet student identification criteria for impact craters. This can allow for great discussion on how it is not always easy to identify features on other planetary bodies. There is an impact crater in the upper right corner of the image.)
4. Impact craters
5. Volcano and wind streak
6. Impact crater
7. Impact crater
8. Lava flows

Mercury Images: The images of Mercury provided were acquired by the Mercury Messenger spacecraft. Images included in this activity are primarily of impact craters. There have been new images of Mercury that show evidence of volcanic activity on the planet as well. The following is provided as a guide for features in each image. Answers can be debatable and should be accepted if students can justify their answers:

1. Impact craters
2. Impact craters
3. Impact craters
4. Impact crater with bright eject blanket
5. Multi-ringed impact crater
6. Impact crater
7. Potential volcanic feature (feature to the left of center). (Note: Most students will identify impact craters and not identify this feature as being volcanic.)
8. Impact craters

Jovian Moon Images (moons of Jupiter): Two images from 4 different Jovian Moons (moons of Jupiter) are included in this activity. These moons are terrestrial and have features that have intrigued many and are common on other planetary bodies in the solar system. The image of Io is of a volcano that is active today. The images of Europa, Ganymede and Callisto all include impact craters. Many of the features included in these images may not match the criteria for features/processes previously investigated. This is designed to help spark discussions about other processes that have not been previously discussed. Additionally, it encourages students to not "force fit" and "pretend" a feature fits their criteria. The linear-like features on Europa and Ganymede may be related to faults and ice. The following is provided as a guide for features in each image. Answers can be debatable and should be accepted if students can justify their answers:

1. Io: Volcano, caldera, and lava flows
2. Io: Volcano, caldera, and lava flows
3. Europa: There may be impact craters in this image, but image is thought to be showing ice-related features that may be melting due to heat from inside this moon.
4. Europa: Ice-related features. There are also impact craters in this image.
5. Callisto: Impact craters
6. Callisto: Impact craters
7. Ganymede: Ice-related features and impact craters
8. Ganymede: Ice-related features and impact craters (note that the left side of the image and the right side of the image appear to have 2 distinctly different terrains. Right side appears bright compared to the left side.)

There are many other terrestrial planetary bodies (planetary moons, asteroids, etc) within our solar system that students could also investigate. For additional images of Earth or other planetary bodies visit the following websites:

- Gateway to Astronaut Photography: http://eol.jsc.nasa.gov
- Planetary Photojournal: http://photojournal.jpl.nasa.gov
- NASA Science: http://nasascience.nasa.gov/

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BLUE MARBLE MATCHES

Using Earth for Planetary Comparisons

Part 1: Observations and Descriptions

NASA explores planetary bodies, including Earth, to better understand the Solar System in which we live. Various types of spacecraft and scientific instruments are used to explore and gather data. Scientists use the data returned from these spacecraft to make observations which they record, analyze, and interpret. One technique or process of gathering data from a distance using spacecraft, or even aircraft, is called remote sensing. Remote sensing allows you to gather data of a location you might not be able to visit in person.

One application of remote sensing is using images to identify geologic features on different planets. How do scientists determine what geologic features exist on other planets? This activity will help you understand part of that process. It starts with making good observations, being descriptive, and using what we know about Earth. For the first part of this activity, we will test your skills in how observant and descriptive you can be.

The remote sensing images of Earth you will observe in this activity were taken by astronauts from the International Space Station or Space Shuttle using hand held cameras. To begin, you will be given one image to observe and describe in the space below. As you write your description, do not name features or objects in the image. Instead, use descriptive words to describe what you see. Someone will attempt to identify the image you describe.

IMAGE DESCRIPTION **Use descriptive words to describe your image. Do not name features or objects.**

Now we will see how descriptive you were! A set of images will be shown to the class. You will read your description to other students to see if they can correctly identify your image. Discuss how you could improve image descriptions as you go through this process.

Based on your discussion with other students, list 3-5 useful characteristics or ways to describe features in images:

a.

b.

c.

d.

e.

So, what are these images all about? They are remote sensing images of Earth that focus on features related to four different geologic processes that help shape the surface of our planet. These processes are related to wind, water, volcanoes, and impacts (meteors striking the surface). Based on what you may know, do the following:

1. Discuss how you would group the images in pairs that relate to the same geologic process.
2. List which of the four given geologic processes you think created those features. Choose from wind, water, volcanic, or impact.
3. If you think you know the names of any features in these images, feel free to list your best guesses!

As you make your observations and discuss as a group, fill out the table below.

	IMAGES (use numbers 1-8)	**GEOLOGIC PROCESS** (Wind, Water, Volcanic, or Impact)	**FEATURE NAMES** (optional)
Group 1			
Group 2			
Group 3			
Group 4			

Now that you have an idea of how you can be descriptive and have some thoughts about the geologic processes related to the images you observed, let's investigate further. Did you know the names of these geologic features? Do you know how they form? Are these same features found on other planets in our solar system? How do scientists use what they know about Earth to explore other planets? This activity will help you understand and answer these questions. Let's explore!

Part 2: Identification Criteria

You will now make observations of other astronaut photographs of Earth. Your logged observations of these images will help you learn to identify specific features associated with different geologic processes (aeolian, impact, fluvial, and volcanic). The feature charts you will examine include images grouped by process. Information is included on the back of each image to help you. As you make observations, think about how each feature is formed and be prepared to select and create identification criteria for each feature in the tables below.

Once you have a feature chart, you will:

1. Make observations of the different geologic features visible in the images on the feature chart.
2. In the tables below, use 2 check marks for each column to indicate which **2 criteria** best describe **each** feature. Make changes or adjustments to listed criteria if you wish.
3. Create your own descriptions that can be used as other identification criteria for each feature.

AEOLIAN PROCESSES Features created by or associated with the effects of WIND			
IDENTIFICATION CRITERIA	**SAND DUNES**	**WIND STREAKS**	**YARDANGS**
Look like a smear across the surface			
Has a ripple-like appearance			
Look "cut into" the surface forming criss-crossing or parallel lines			
Sand-sized particles closely grouped together on the surface			
Look like a series of grooves scratched into the surface			
Look like a faint mixture of light or dark smudges on the surface			
Other:			
Other:			
Other:			

IMPACT PROCESSES Features created by or associated with a meteor striking the surface	
IDENTIFICATION CRITERIA	**IMPACT CRATER**
Circular feature that sometimes has a raised rim and a smooth, flat floor	
Flat, roundish feature that looks eroded and is sometimes filled in or outlined by water	
Other:	
Other:	

FLUVIAL PROCESSES Features created by or associated with the effects of WATER			
IDENTIFICATION CRITERIA	**CHANNEL**	**DRAINAGE NETWORK**	**DELTA**
Feature has a very dendritic-like pattern; similar to the vein-like pattern within a leaf			
Long extended feature that curves or meanders through an area; sometimes has two or three smaller channels connected to it			
Long windy feature that sometimes contains features such as U-shaped oxbow lakes, meander scars or tear-drop shaped island(s)			
Has a fan-like or triangular shape			
Sometimes looks like a triangle or birds foot where sediment is built up and deposited			
Numerous small channels or tributaries that feed into larger channels or valleys			
Other:			
Other:			
Other:			

VOLCANIC PROCESSES Features created by or associated with volcanic activity			
IDENTIFICATION CRITERIA	**VOLCANO**	**CENTRAL VENT/CALDERA**	**LAVA FLOWS**
Looks similar to an impact crater and is circular in shape			
An entire structure that includes a circular opening at the top and has flanks or sides			
An entire structure that may look raised and have a cone or dome or steeple-like shape			
Channel-like flow or fingery appearance with uneven edges			
Single or multiple circular depressions at the center or top of volcano			
Flow-like material that appears to be darker than the surrounding surface			
Other:			
Other:			
Other:			

Part 3: Feature Recognition and Review

The identification criteria you just developed should help you recognize these different geologic features in other images with confidence. You must use those criteria to support your identification of these features. Feel free to refine or add to your criteria as you continue with this activity.

In order to help reinforce and review your feature recognition skills you will receive a new set of images to observe. In the table below you will:

1. List identification criteria for the main feature shown in the image.
2. Based on your listed criteria, name the main geologic feature that best matches.
3. Name the main geologic process that helped form that feature.

As you discuss your answers, you may experience how scientists (both professionals and students) do not always agree! Scientific debate and using evidence to back up interpretations are key elements of science. Be open to changing your original identification of a feature if you can be convinced. It is not all about what answer is right or wrong. More importantly, it is about evidence that support your interpretation. Not all scientists agree, which is an important aspect of how science progresses.

Fill out the table below as you make observations of the images provided:

Image #	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)
1			
2			
3			
4			
5			
6			
7			
8			

Image #	Identification Criteria (list specific criteria from your identification criteria tables)	Main Geologic Feature	Main Geologic Process (aeolian, fluvial, volcanic, impact)
9			
10			
11			
12			
13			
14			
15			
16			

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Part 4: Using Earth For Planetary Comparisons

Fill out the table below for the planetary body image chart you are given. Use the identification criteria you developed and refined for features on Earth. You must use those criteria as evidence to support your identification of these features. If there are characteristics that do not match your criteria for the feature on Earth or if you are making observations that cause you to be unsure about the identification of the feature, be sure to list those in the table. Based on your observations and how well your criteria match a given feature, list your level of confidence in the last column. Be ready to defend your identification or discuss your uncertainty.

As you discuss your answers, you will likely experience again how scientists do not always agree! Remember, scientific debate and using evidence to back up your interpretations are key elements of science. It is not all about what answer is right or wrong. More importantly, it is about evidence and criteria that support your interpretation!

PLANETARY BODY NAME:

Image # (use #'s 1 - 8 or 9 - 16)	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Characteristics that DO NOT match Identification Criteria or Observations that Decrease Level of Confidence** (if any)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)	**Level of Confidence of Identified Feature** 1 = Not Confident 2 = Somewhat Confident 3 = Totally Confident

ADDITIONAL OBSERVATIONS, COMMENTS, OR QUESTIONS:

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Part 5: Observations, Interpretations, and Drawing Conclusions

Log at least 3 observations, interpretations and conclusions. Your logged information should support the conclusions and inferences you make about processes that shape the surface of the planetary body/bodies you have observed. You should be able to support and defend all logged information.

OBSERVATION (list specific planetary body and identification criteria)	**FEATURE INTERPRETATION**	**ADDITIONAL OBSERVATIONS** (list additional observations)	**ADVANCED INTERPRETATION**	**CONCLUSIONS/INFERENCES ABOUT PROCESSES THAT SHAPE THE SURFACE**
Planetary Body: ***MARS*** **Observation:** *There are circular depressions on the surface.*	*These circular depressions could be volcanic craters or impact craters. When they are not part of a raised structure, they are most likely impact craters.*	• *Impact crater rims appear to be worn down.* • *Rims do not always appear as perfect circles.* • *There appears to be evidence of wind related features (wind streaks and sand dunes) in and around impact craters.* • *Mars is a dusty planet. (http://science.nasa.gov/science-news/science-at-nasa/2003/09jul_marsdust/)*	• *Dust and sand are likely carried by the wind and can either erode the surface or be deposited on the surface.* • *Impact craters have likely been affected by these processes.*	• *Mars must have an atmosphere since there is evidence of aeolian processes.* • *Wind has eroded the surface of Mars in its past and may still be changing the surface today.* • *Dust and sand likely erode the surface.* • *The atmosphere is thick enough to have wind but not thick enough to prevent meteors from striking the surface.*
Planetary Body: _____ **Observation:**				
Planetary Body: _____ **Observation:**				

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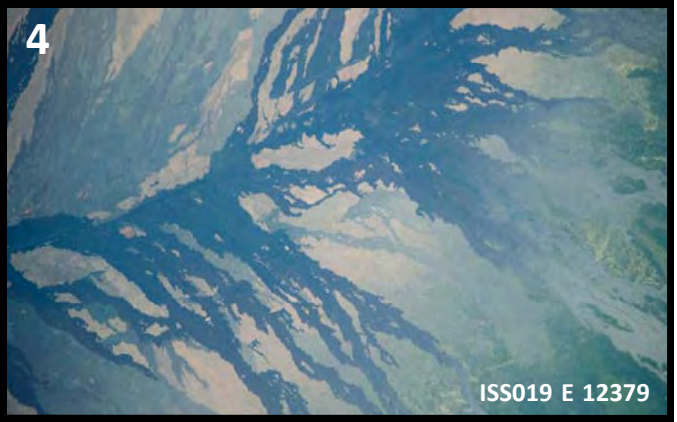
Part 5: Observations, Interpretations, and Drawing Conclusions (continued)

OBSERVATION (list specific planetary body and identification criteria)	**FEATURE INTERPRETATION**	**ADDITIONAL OBSERVATIONS** (list additional observations)	**ADVANCED INTERPRETATION**	**CONCLUSIONS/INFERENCES ABOUT PROCESSES THAT SHAPE THE SURFACE**
Planetary Body: _____ **Observation:**				

You have made observations and interpretations that have allowed you to draw conclusions and make inferences about the planetary bodies you investigated. These terrestrial worlds or rocky planets all have a lithosphere/geosphere – they have rocks. Did any other planetary body you observed also have an atmosphere? Do any of them have a hydrosphere? How do we go about detecting if any of them have a biosphere? If you remember, the different Earth systems (litho/geosphere, atmosphere, hydrosphere, and biosphere) are all connected and combined make up our unique planet. The interaction of different systems on other planetary bodies likely play a role in the past, present, and future of these bodies, just as they do on Earth. There is so much yet to be discovered!

As the exploration of Earth and other planetary bodies in our solar system continues and new discoveries are made, scientific progress and our understanding of our solar system deepens. What we learn today may be refined tomorrow. This makes science an ever-changing and dynamic discipline. You are encouraged to follow along with NASA's journey of exploration or even better yet, become a part of it. NASA needs the next generation of scientists and engineers to help continue the exploration of Earth and beyond. That next generation of explorers includes you!

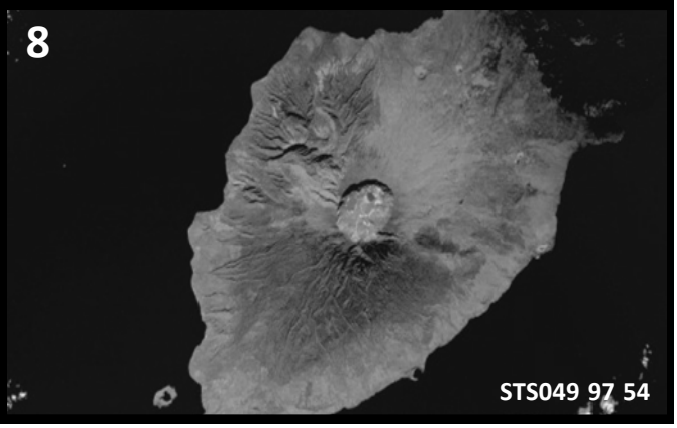


Expedition Earth and Beyond
ARES Education Program
NASA Johnson Space Center

Images courtesy of:
Image Science & Analysis Laboratory
NASA Johnson Space Center

EARTH

FEATURES



Expedition Earth and Beyond
ARES Education Program
NASA Johnson Space Center

Images courtesy of:
Image Science & Analysis Laboratory
NASA Johnson Space Center

EARTH

FEATURES

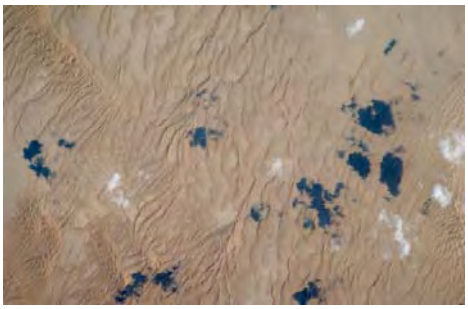
National Aeronautics and Space Administration

BLUE MARBLE MATCHES

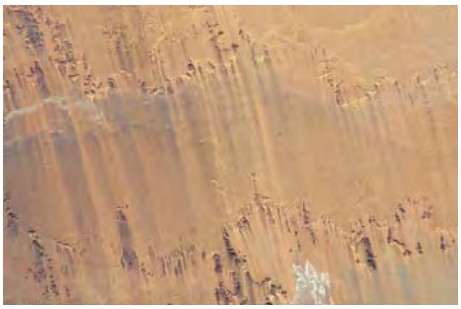
GEOLOGIC PROCESSES & FEATURES
Quick Reference Sheet

1. **AEOLIAN PROCESSES:** Features created by or associated with the effects of wind. A planetary body needs to have an atmosphere in order to have aeolian processes.

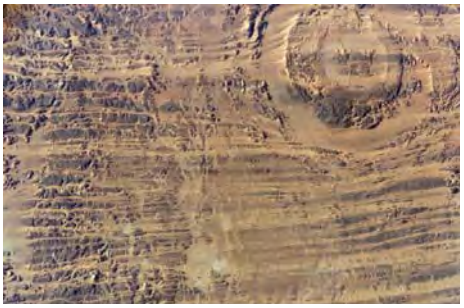
   - Sand Dune: A mound of sand formed by windblown sand-sized particles. There are different sand dune types or shapes such as crescent, barchan, longitudinal, star, etc.
   - Wind Streak: Formed when wind blows sand or dust-sized particles off the surface (erosional) or onto the surface (depositional).
   - Yardang: A sharp ridge or multiple ridges oriented in the same direction formed by sand-sized particles eroding exposed rock.



SAND DUNES



WIND STREAKS



YARDANGS

2. **IMPACT PROCESSES:** Features created by or associated with a meteor striking the surface. The thickness of an atmosphere plays a role in the size and number of impactors that strike the surface. Planetary bodies with active geologic processes can cause impact craters to erode or get filled in.

   - Impact Crater: A circular depression in the surface formed by the result of a meteor striking the surface at a high velocity.
     Note: Sometimes a central peak or uplift is visible in the center of an impact crater. This feature is an exposed set of uplifted rocks that show evidence of fracturing and shock that occurs during impact. Not all craters have this feature.

IMPACT CRATER

IMPACT CRATERS

IMPACT CRATER

National Aeronautics and
Space Administration

3. **FLUVIAL PROCESSES:** Features created by or associated with flowing water. A planetary body needs to have a certain balance between atmospheric pressure and temperature in order to have water flow on the surface.

   - Channel: A feature often created by the flow of water. Can vary in size and shape depending on local geology and steepness of topography. In flatter areas they meander into a snake-like shape. Can include the following features: meanders, oxbow lakes (created when a meander is cut off and forms a U-shaped body of water), streamlined islands, levees, bars, and banks.

   - Valley/Drainage Network: A set of channels formed by water draining downslope creating a network of small channels or tributaries that merge to form progressively larger channels. These features most often have a branch like appearance.

   - Delta: Formed by the deposition of sediment that builds up where the mouth of a river flows into another body of water.

CHANNEL

VALLEY/DRAINAGE NETWORK

DELTA

4. **VOLCANIC PROCESSES:** Features created by or associated with volcanic activity. A planetary body needs to have a hot interior in order to have active volcanic processes.

   - Volcano: A raised structure that includes an opening in the crust of a planet where hot molten rock (magma) and gases escape from below the surface.

   - Central Vent or Caldera: A circular depression generally at the top of a volcano where magma and gases escape to the surface.

   - Volcanic deposits (lava flows, ash flows): As hot magma reaches the surface and flows out onto the surface it is called a lava flow. Ash flows or plumes come from more explosive eruptions and include tephra (ash, cinders, or volcanic bombs) and gas released into the atmosphere and/or on the surface.

VOLCANO and ASH PLUME

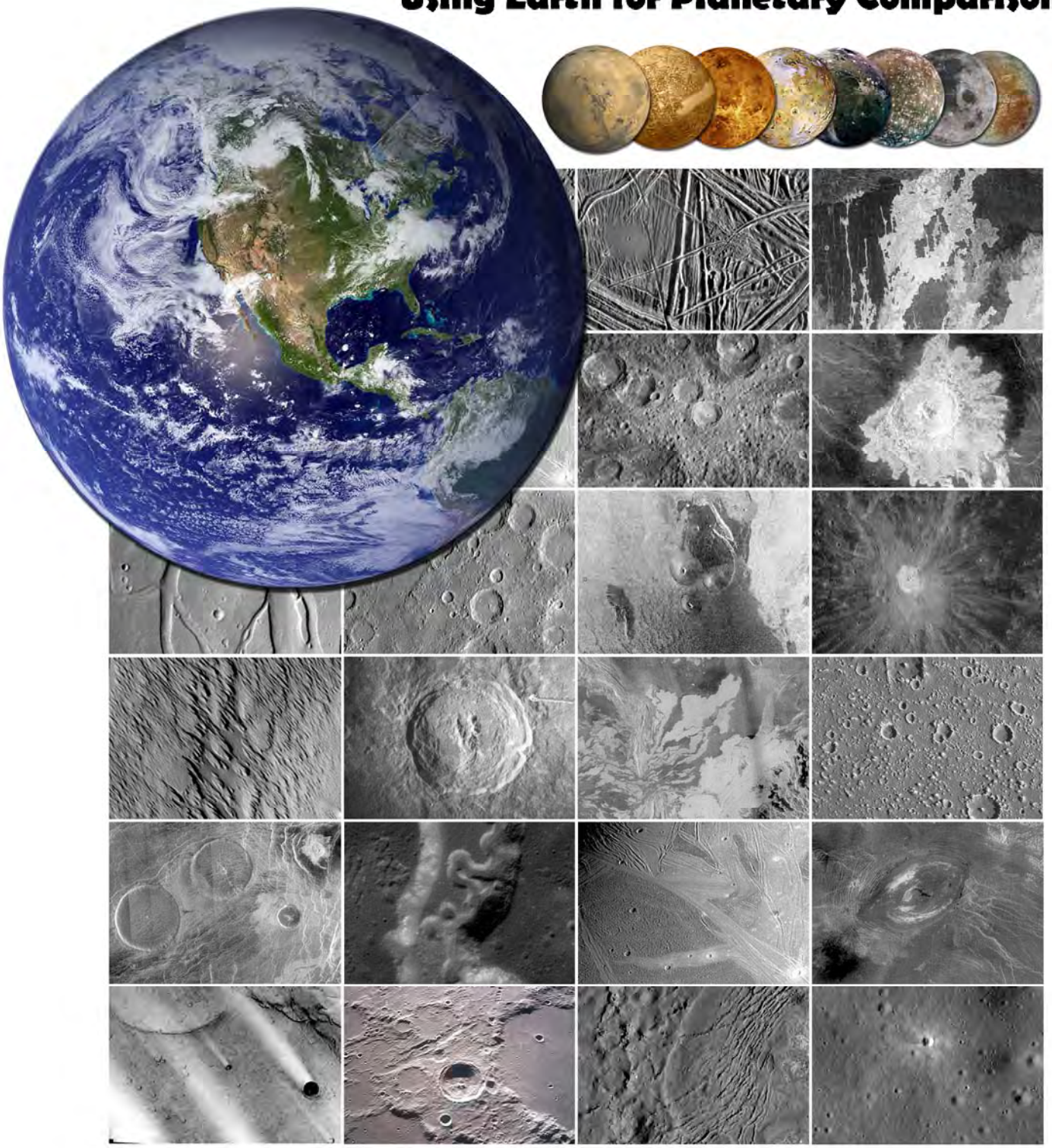
CENTRAL VENT/CALDERA

LAVA FLOWS

National Aeronautics and Space Administration

Blue Marble Matches

Using Earth for Planetary Comparisons



STUDENT GUIDE

National Aeronautics and
Space Administration

Blue Marble Matches

Using Earth For Planetary Comparisons

Written and Developed by:

Paige Valderrama Graff
Science Education Specialist, Expedition Earth and Beyond Director
Astromaterials Research and Exploration Science (ARES) Directorate
ARES Education Program, NASA Johnson Space Center
JACOBS - Engineering Science Contract Group (ESCG)

Edited by the following educators and scientists within the Astromaterials Research and Exploration Science (ARES) Directorate at the NASA Johnson Space Center:

Jaclyn Allen, *Science Education Specialist*
Marshalyn Baker, *Classroom Teacher*
Trevor Graff, *Planetary Scientist*
Charles Lindgren, *Classroom Teacher*
Michele Mailhot, *Mathematics Specialist*
Timothy McCollum, *Classroom Teacher*
Susan Runco, *Physical Scientist*
William Stefanov, *Senior Geoscientist*
Kay Tobola, *Science Education Specialist*
Kim Willis, *Principal Geoscientist*

Additional Reviewers include:
Joshua Bandfield, *Research Assistant Professor Earth and Space Sciences, University of Washington*

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Space Administration

BLUE MARBLE MATCHES

Using Earth for Planetary Comparisons

Part 1: Observations and Descriptions

NASA explores planetary bodies, including Earth, to better understand the Solar System in which we live. Various types of spacecraft and scientific instruments are used to explore and gather data. Scientists use the data returned from these spacecraft to make observations which they record, analyze, and interpret. One technique or process of gathering data from a distance using spacecraft, or even aircraft, is called remote sensing. Remote sensing allows you to gather data of a location you might not be able to visit in person.

One application of remote sensing is using images to identify geologic features on different planets. How do scientists determine what geologic features exist on other planets? This activity will help you understand part of that process. It starts with making good observations, being descriptive, and using what we know about Earth. For the first part of this activity, we will test your skills in how observant and descriptive you can be.

The remote sensing images of Earth you will observe in this activity were taken by astronauts from the International Space Station or Space Shuttle using hand held cameras. To begin, you will be given one image to observe and describe in the space below. As you write your description, do not name features or objects in the image. Instead, use descriptive words to describe what you see. Someone will attempt to identify the image you describe.

IMAGE DESCRIPTION **Use descriptive words to describe your image. Do not name features or objects.**

Now we will see how descriptive you were! A set of images will be shown to the class. You will read your description to other students to see if they can correctly identify your image. Discuss how you could improve image descriptions as you go through this process.

Based on your discussion with other students, list 3-5 useful characteristics or ways to describe features in images:

a.

b.

c.

d.

e.

So, what are these images all about? They are remote sensing images of Earth that focus on features related to four different geologic processes that help shape the surface of our planet. These processes are related to wind, water, volcanoes, and impacts (meteors striking the surface). Based on what you may know, do the following:

1. Discuss how you would group the images in pairs that relate to the same geologic process.
2. List which of the four given geologic processes you think created those features. Choose from wind, water, volcanic, or impact.
3. If you think you know the names of any features in these images, feel free to list your best guesses!

As you make your observations and discuss as a group, fill out the table below.

	IMAGES (use numbers 1-8)	**GEOLOGIC PROCESS** (Wind, Water, Volcanic, or Impact)	**FEATURE NAMES** (optional)
Group 1			
Group 2			
Group 3			
Group 4			

Now that you have an idea of how you can be descriptive and have some thoughts about the geologic processes related to the images you observed, let's investigate further. Did you know the names of these geologic features? Do you know how they form? Are these same features found on other planets in our solar system? How do scientists use what they know about Earth to explore other planets? This activity will help you understand and answer these questions. Let's explore!

BACKGROUND INFORMATION

Defining Characteristics of Geologic Features

Just as you experienced in the beginning of this lesson, planetary scientists who make observations of geologic features on Earth need to have useful ways to describe those features. This becomes especially important as they compare geologic features on Earth to features being observed on other planets. When using images to identify and compare features, scientists must create identification criteria. These criteria are common characteristics that can be used to identify a feature. What types of useful ways did you come up with to describe features? Below is a list of characteristics scientists often use to describe geologic features in images based on their observations.

DESCRIPTOR CHARACTERISTICS:

1. **Size:** Features can be described in terms of actual or relative size. For a detailed planetary comparison study, image scales and actual sizes of features becomes necessary. If the exact size of a feature is not known, relative or comparative sizes of features within the same image can be described. In this lesson we will focus on relative sizes.
   Useful Descriptors: Larger than, longer than, smaller than, shorter than, narrow, wide, thick, thin, tall, short, etc.
2. **Shape:** Features can be described in terms of geometric shape.
   Useful Descriptors: Roundish, oblong, square, etc.
3. **Texture:** Features can be described as having a certain texture.
   Useful Descriptors: Smooth, rough, jagged, scalloped, smeared, etc.
4. **Position/Orientation:** Features can be described in terms of their location relative to other features in an image.
   Useful Descriptors: On top of, next to, below, under, slanted, parallel, perpendicular, etc.
5. **Color/Tone:** Features can be described in terms of their actual color or shade variations/tone.
   Useful Descriptors: Darker, lighter, bright, dull, bluish, reddish, grayish, etc.

Keep in mind that the same geologic feature does not always look *exactly* the same, even on Earth. Most features, however, will have common characteristics. As you create a list of identification criteria for each geologic feature later in this activity, use as many of the above descriptor characteristics that apply.

Systems Science

Scientists who study Earth oftentimes study it using an Earth Systems Science approach. This approach looks at Earth being made up of different parts, or systems, that work together to make up the planet as a whole. The following 4 "spheres" is one way to break down Earth's systems: 1) **Atmosphere**: mixture of gases and small particles above the surface and surrounding the planet; 2) **Biosphere:** related to living systems (life); 3) **Hydrosphere:** water in solid and liquid states; and 4) **Lithosphere** (sometimes referred to as the **Geosphere):** rocks, soils, and sediment. These different Earth systems are all connected, and combined make up our unique planet (see Figure 1). The past, present, and future of our planet is based on a constant interaction among these systems.

Other terrestrial (rocky) bodies in our solar system (the Moon, Mars, Venus, etc.), all have a lithosphere -- they have rocks -- but they may not have the other systems that make up Earth. For example, some also have atmospheres, others do not. No other planetary body in our solar system has a biosphere that we know of…yet. In this activity we will focus on geologic features that are part of the litho/geosphere.

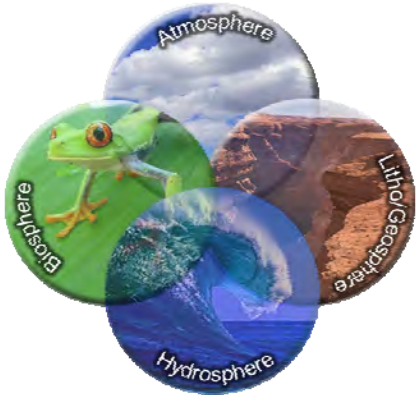


Figure 1: Earth's linked systems

Earth is used as our home laboratory and helps scientists learn how systems and processes work. There is still a lot to learn and scientists continue to conduct research about Earth to better understand our home planet. Let's take a closer look at geologic processes and features on Earth.

Earth Processes and Geologic Features

The information below is listed to help you understand four different types of geologic processes on Earth (aeolian, impact, fluvial, and volcanic) and features associated with them. The features listed are not the only features associated with each process. They will, however, give you a starting point to learn about the different processes. You will want to keep this information in mind later as you look for these features in images. Knowing how a feature forms can help you better understand the processes that shape the surface of a planet.

AEOLIAN PROCESSES: Features created by or associated with the effects of wind. A planetary body needs to have an atmosphere in order to have aeolian processes.

- Sand Dune: A mound of sand formed by windblown sand-sized particles. There are different sand dune types or shapes such as crescent, barchan, longitudinal, and star.
- Wind Streak: A feature formed when wind blows sand or dust-sized particles off the surface (erosional) or onto the surface (depositional).
- Yardang: A sharp ridge or multiple ridges oriented in the same direction formed by sand-sized particles eroding exposed rock.

IMPACT PROCESSES: Features created by or associated with a meteor striking the surface. The thickness of an atmosphere plays a role in the size and number of impactors that strike the surface. Planetary bodies with active geologic processes can cause impact craters to erode or get filled in.

- Impact Crater: A circular hole (depression) in the surface formed by the result of a meteor striking the surface at a high velocity.
  Note: Sometimes a central peak or uplift is visible in the center of an impact crater. This feature is an exposed set of uplifted rocks that show evidence of fracturing and shock that occurs during impact. Not all craters have this feature.

FLUVIAL PROCESSES: Features created by or associated with flowing water. A planetary body needs to have a certain balance between atmospheric pressure and temperature in order to have water flow on the surface.

- Channel: A feature often created by the flow of water. Can vary in size and shape depending on local geology and steepness of topography. In flatter areas they meander into a snake-like shape. Can include the following features: meanders, oxbow lakes (created when a meander is cut off and forms a U-shaped body of water), streamlined islands, levees, bars, and banks.
- Valley/Drainage Network: A set of channels formed by water draining downslope creating a network of small channels or tributaries that merge to form progressively larger channels. These features most often have a branch like appearance.
- Delta: A feature formed by the deposition of sediment that builds up where the mouth of a river flows into another body of water.

VOLCANIC PROCESSES: Features created by or associated with volcanic activity. A planetary body needs to have a hot interior in order to have active volcanic processes.

- Volcano: A raised structure that includes an opening in the crust of a planet where hot molten rock (magma) and gases escape from below the surface.
- Central Vent or Caldera: A circular depression generally at the top of a volcano where magma and gas escape to the surface. These terms are closely related. When a magma chamber is empty enough for the central vent to collapse it is referred to as a caldera.
- Volcanic deposits (lava flows, ash flows): As hot magma reaches the surface and flows out onto the surface it is called a lava flow. Ash flows or plumes come from more explosive eruptions and include tephra (ash, cinders, or volcanic bombs) and gas released into the atmosphere and/or on the surface.

Planetary Comparisons

Scientists use what they know about the formation of features on Earth to develop and test hypotheses, make inferences, and draw conclusions about what may be happening on other planetary bodies. This type of science is called comparative planetology. As scientists make planetary comparisons, they base their conclusions on their observations and interpretations, as well as what information is already known about the planet(s) they are studying. This information includes factors such as the composition of the planet, temperatures, the atmosphere (if one exists), the interior, the surface features, etc. The more knowledge scientists have about the planet as a whole, the better they can draw conclusions with supporting evidence. Scientists cannot assume a certain process has occurred on another planet just because of the identification of a feature that looks like one on Earth. They sometimes consider alternate hypotheses. By conducting planetary comparisons, scientists are able to better understand the history of other planets and the processes that shape their surfaces.

As you complete this activity and use Earth for planetary comparisons, keep in mind that you should consider what you know, but also acknowledge there may be a lot you do not know. Science involves building knowledge to deepen your understanding of how something may work based on new research. What you learn today may be refined tomorrow based on new information gained.

Part 2: Identification Criteria

You will now make observations of other astronaut photographs of Earth. Your logged observations of these images will help you learn to identify specific features associated with different geologic processes (aeolian, impact, fluvial, and volcanic). The feature charts you will examine include images grouped by process. Information is included on the back of each image to help you. As you make observations, think about how each feature is formed and be prepared to select and create identification criteria for each feature in the tables below.

Once you have a feature chart, you will:

1. Make observations of the different geologic features visible in the images on the feature chart.
2. In the tables below, use 2 check marks for each column to indicate which **2 criteria** best describe **each** feature. Make changes or adjustments to listed criteria if you wish.
3. Create your own descriptions that can be used as other identification criteria for each feature.

AEOLIAN PROCESSES Features created by or associated with the effects of WIND			
IDENTIFICATION CRITERIA	**SAND DUNES**	**WIND STREAKS**	**YARDANGS**
Look like a smear across the surface			
Has a ripple-like appearance			
Look "cut into" the surface forming criss-crossing or parallel lines			
Sand-sized particles closely grouped together on the surface			
Look like a series of grooves scratched into the surface			
Look like a faint mixture of light or dark smudges on the surface			
Other:			
Other:			
Other:			

IMPACT PROCESSES Features created by or associated with a meteor striking the surface	
IDENTIFICATION CRITERIA	**IMPACT CRATER**
Circular feature that sometimes has a raised rim and a smooth, flat floor	
Flat, roundish feature that looks eroded and is sometimes filled in or outlined by water	
Other:	
Other:	

FLUVIAL PROCESSES Features created by or associated with the effects of WATER			
IDENTIFICATION CRITERIA	**CHANNEL**	**DRAINAGE NETWORK**	**DELTA**
Feature has a very dendritic-like pattern; similar to the vein-like pattern within a leaf			
Long extended feature that curves or meanders through an area; sometimes has two or three smaller channels connected to it			
Long windy feature that sometimes contains features such as U-shaped oxbow lakes, meander scars or tear-drop shaped island(s)			
Has a fan-like or triangular shape			
Sometimes looks like a triangle or birds foot where sediment is built up and deposited			
Numerous small channels or tributaries that feed into larger channels or valleys			
Other:			
Other:			
Other:			

VOLCANIC PROCESSES Features created by or associated with volcanic activity			
IDENTIFICATION CRITERIA	**VOLCANO**	**CENTRAL VENT/CALDERA**	**LAVA FLOWS**
Looks similar to an impact crater and is circular in shape			
An entire structure that includes a circular opening at the top and has flanks or sides			
An entire structure that may look raised and have a cone or dome or steeple-like shape			
Channel-like flow or fingery appearance with uneven edges			
Single or multiple circular depressions at the center or top of volcano			
Flow-like material that appears to be darker than the surrounding surface			
Other:			
Other:			
Other:			

Part 3: Feature Recognition and Review

The identification criteria you just developed should help you recognize these different geologic features in other images with confidence. You must use those criteria to support your identification of these features. Feel free to refine or add to your criteria as you continue with this activity.

In order to help reinforce and review your feature recognition skills you will receive a new set of images to observe. In the table below you will:

1. List identification criteria for the main feature shown in the image.
2. Based on your listed criteria, name the main geologic feature that best matches.
3. Name the main geologic process that helped form that feature.

As you discuss your answers, you may experience how scientists (both professionals and students) do not always agree! Scientific debate and using evidence to back up interpretations are key elements of science. Be open to changing your original identification of a feature if you can be convinced. It is not all about what answer is right or wrong. More importantly, it is about evidence that support your interpretation. Not all scientists agree, which is an important aspect of how science progresses.

Fill out the table below as you make observations of the images provided:

Image #	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)
1			
2			
3			
4			
5			
6			
7			
8			

Image #	Identification Criteria (list specific criteria from your identification criteria tables)	Main Geologic Feature	Main Geologic Process (aeolian, fluvial, volcanic, impact)
9			
10			
11			
12			
13			
14			
15			
16			

Part 4: Using Earth For Planetary Comparisons

You have reviewed, reinforced, and refined your identification criteria for geologic features found on Earth. It is essential to use those criteria as you observe other images of Earth but also as you observe images from other planetary bodies.

For this part of the activity, you will, just as planetary scientists do, use Earth for planetary comparisons. As you make observations of images from other planetary bodies, think about which worlds are most or least like Earth. By identifying geologic features you will better understand the processes that may have helped shape the surface of these worlds. It will also help you better understand their geologic history. **Use your identification criteria** as you identify features, but as available, you are encouraged to also use other resources such as books, or the internet. These resources can increase your knowledge and help support the identification of features and processes.

The image charts you will use are grouped by planetary body and include Earth's Moon, Mars, Venus, Mercury, and Jovian Moons (the 4 largest moons of Jupiter discovered by Galileo which are Io, Europa, Callisto, and Ganymede). The images were taken by remote sensing instruments on different spacecraft sent to study these terrestrial worlds. As you make observations of these images you will notice that some features may match your identification criteria perfectly! Others may not. This may cause the level of confidence of the feature you identified to be high or low. The higher the level of confidence, the more strongly you, or any scientist, can debate and defend your interpretation. Being able to defend your identification or discuss your uncertainty are both extremely valuable skills.

Use the table below as an example as you make observations of each image:

1. List identification criteria for the main feature shown in the image. There may be multiple features in a given image. You can list other features at the bottom of the table.
2. List characteristics that do not match your identification criteria or observations that may cause your level of confidence of the identified feature to be lowered.
3. Based on your listed criteria, name the main geologic feature that best matches.
4. Name the main geologic process that helped form that feature.
5. List your level of confidence of the identified feature (and process).

PLANETARY BODY NAME: Mars

Image # (use #'s 1 - 8 or 9 - 16)	Identification Criteria (list specific criteria from your identification criteria tables)	Characteristics that DO NOT match Identification Criteria or Observations that Decrease Level of Confidence (if any)	Main Geologic Feature	Main Geologic Process (aeolian, fluvial, volcanic, impact)	Level of Confidence of Identified Feature 1 = Not Confident 2 = Somewhat Confident 3 = Totally Confident
1	Entire structure with circular opening; entire structure that looks raised and has cone shape	none	Volcano	Volcanic	3
2	Long, windy feature that looks to meander; feature contains u-shaped oxbow shape	Not sure if feature is raised or carved into surface	Channel	Fluvial	2 or 2.5 (pretty sure this is a channel)
3					
4					
5					
6					
7					
8					

ADDITIONAL OBSERVATIONS, COMMENTS, OR QUESTIONS:
Image #1 seems to have a chunk missing from the side of this "volcano" on the upper left. Other visible features include a caldera and impact craters; Image #2 has interesting layers in the channel. Other features include impact craters; Image #3...

Part 4: Using Earth For Planetary Comparisons

Fill out the table below for the planetary body image chart you are given. Use the identification criteria you developed and refined for features on Earth. You must use those criteria as evidence to support your identification of these features. If there are characteristics that do not match your criteria for the feature on Earth or if you are making observations that cause you to be unsure about the identification of the feature, be sure to list those in the table. Based on your observations and how well your criteria match a given feature, list your level of confidence in the last column. Be ready to defend your identification or discuss your uncertainty.

As you discuss your answers, you will likely experience again how scientists do not always agree! Remember, scientific debate and using evidence to back up your interpretations are key elements of science. It is not all about what answer is right or wrong. More importantly, it is about evidence and criteria that support your interpretation!

PLANETARY BODY NAME:

Image # (use #'s 1 - 8 or 9 - 16)	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Characteristics that DO NOT match Identification Criteria or Observations that Decrease Level of Confidence** (if any)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)	**Level of Confidence of Identified Feature** 1 = Not Confident 2 = Somewhat Confident 3 = Totally Confident

ADDITIONAL OBSERVATIONS, COMMENTS, OR QUESTIONS:

Part 4: Using Earth For Planetary Comparisons

Fill out the table below for the planetary body image chart you are given. Use the identification criteria you developed and refined for features on Earth. You must use those criteria as evidence to support your identification of these features. If there are characteristics that do not match your criteria for the feature on Earth or if you are making observations that cause you to be unsure about the identification of the feature, be sure to list those in the table. Based on your observations and how well your criteria match a given feature, list your level of confidence in the last column. Be ready to defend your identification or discuss your uncertainty.

As you discuss your answers, you will likely experience again how scientists do not always agree! Remember, scientific debate and using evidence to back up your interpretations are key elements of science. It is not all about what answer is right or wrong. More importantly, it is about evidence and criteria that support your interpretation!

PLANETARY BODY NAME:

Image # (use #'s 1 - 8 or 9 - 16)	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Characteristics that DO NOT match Identification Criteria or Observations that Decrease Level of Confidence** (if any)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)	**Level of Confidence of Identified Feature** 1 = Not Confident 2 = Somewhat Confident 3 = Totally Confident

ADDITIONAL OBSERVATIONS, COMMENTS, OR QUESTIONS:

Part 5: Observations, Interpretations, and Drawing Conclusions

As you can probably tell, planetary bodies are affected by similar processes that help shape the surface of Earth. Some processes, however, seem to be more (or less) dominant than others. Some planetary bodies have tons of impact craters, others have few. Some have evidence of wind, water, or volcanic features, others do not. Which planetary body is most like Earth? Which is least like Earth? If you only made observations of one planetary body, how is it similar or different from Earth? What do these similarities and differences mean? Based on your observations, what can you infer about these planetary bodies? These are important questions that are an important part of the process of science.

As part of that process, all scientists make observations and interpret those observations to gain a better understanding and draw conclusions about what they are researching. Observations are general trends, patterns, or descriptions that almost everyone can agree upon. Interpretations are what you think those observations may mean. Interpretations, as you should already know, can vary from scientist to scientist, but are based on supporting evidence. Throughout this activity you have already been making observations and interpretations. Your observations were the identification criteria you used to describe features in images. Your interpretations included naming the geologic feature you felt best matched your criteria.

Similar to what professional scientists do, you will now take this idea of observations and interpretations to the next level. Scientists use initial observations and interpretations to help raise their level of understanding. As they make additional observations and learn more, they can use this new knowledge to make more advanced interpretations and draw conclusions or make inferences.

EXAMPLE SCENARIO

Here is an example/scenario related to a school situation that may help you understand how observations and interpretations can help you draw conclusions or make inferences:

It is Tuesday morning and you walk into your classroom. As you enter the room, you make some observations. One of your observations is as follows: *Your teacher is not sitting at his/her desk.* No one would argue with this observation. As you think about your observation, you immediately interpret or think about what this could mean. Based on what you know, your interpretation might be: *The teacher is sick -OR- the teacher has a meeting with the principal -OR- the teacher is running late.* You make note of some additional observations. This includes your observations that the teacher was coughing and sneezing yesterday and that lots of people at school have been out sick with the flu. These additional observations help you advance your interpretation. Your new interpretation is that your teacher is likely home sick for the day. This advanced interpretation also helps you draw conclusions and make inferences about your teacher. You may conclude that you will have a substitute for the day and that the teacher may be absent for a few days. You may infer that *if* you have a substitute *than* you will likely have no homework. This conclusion and your inference may or may not be completely accurate, but they are based on your overall observations, your current knowledge, previous experiences, and your interpretations.

Let's take this idea of observations, interpretations and making inferences/drawing conclusions and apply it to the planetary comparisons you have made throughout this activity. To do this, you need to bring together what you have learned through this activity. Some of what you have learned includes:

- Information about 4 different geologic processes and the formation of features associated with these processes. These geologic processes and associated features include:
  - Aeolian Processes: Sand dunes, wind streaks, yardangs
  - Impact Processes: Impact craters
  - Fluvial Processes: Channels, valley/drainage networks, deltas
  - Volcanic Processes: Volcanoes, central vents/calderas, volcanic deposits

- Details about what a planetary body needs in order to have each of these processes:
  - Example: Aeolian Processes: A planetary body needs to have an atmosphere in order to have aeolian processes.

This information, along with additional information you have obtained from other resources can help you piece together your observations and interpretations and try to make sense of what it all means.

For this part of the activity you will revisit and review observations and interpretations you have already made. You will then extend that information using the knowledge you have gained and additional observations you have made. This will allow you to advance your interpretations and draw conclusions or make inferences about what you have learned. As you fill out information in the table on the next page, consider the following:

- **OBSERVATION:** List a specific planetary body and include one observation you made. Your observation should be the specific identification criteria used to identify a specific feature.
- **FEATURE INTERPRETATION**: Based on the identification criteria, name the feature that best matches. If there can be a potential misinterpretation or confusion between what the feature may be, include information to help you interpret the feature consistently.
- **ADDITIONAL OBSERVATIONS**: Log additional observations you made of images in Part 4. If you found additional information about the planetary body from other sources (books, the internet), it's a good idea to get into the habit of referencing those sources.
- **ADVANCED INTERPRETATIONS**: Your additional observations and background knowledge gained from this activity and other sources of information should allow you to list advanced interpretations. These advanced interpretations allow you to make deeper connections that will help you make inferences or draw conclusions. As with all parts of the process of science, you must have evidence to support your interpretations and conclusions. Interpretations can change as you gain more knowledge.
- **CONCLUSIONS/INFERENCES ABOUT PROCESSES THAT SHAPE THE SURFACE**: The information you include here are your conclusions or inferences about processes that shape the surface of the particular planetary body.

Use the first example on the table as a guide as you list your own observations, interpretations and conclusions.

Part 5: Observations, Interpretations, and Drawing Conclusions

Log at least 3 observations, interpretations and conclusions. Your logged information should support the conclusions and inferences you make about processes that shape the surface of the planetary body/bodies you have observed. You should be able to support and defend all logged information.

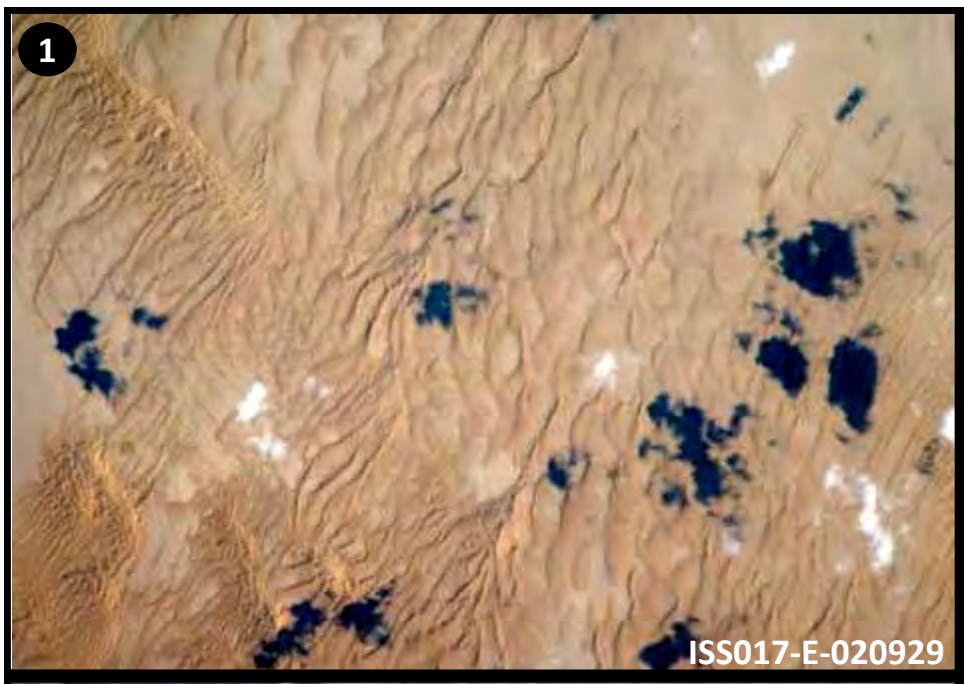
OBSERVATION (list specific planetary body and identification criteria)	**FEATURE INTERPRETATION**	**ADDITIONAL OBSERVATIONS** (list additional observations)	**ADVANCED INTERPRETATION**	**CONCLUSIONS/INFERENCES ABOUT PROCESSES THAT SHAPE THE SURFACE**
Planetary Body: ***MARS*** **Observation:** *There are circular depressions on the surface.*	*These circular depressions could be volcanic craters or impact craters. When they are not part of a raised structure, they are most likely impact craters.*	• *Impact crater rims appear to be worn down.* • *Rims do not always appear as perfect circles.* • *There appears to be evidence of wind related features (wind streaks and sand dunes) in and around impact craters.* • *Mars is a dusty planet. (http://science.nasa.gov/science-news/science-at-nasa/2003/09jul_marsdust/)*	• *Dust and sand are likely carried by the wind and can either erode the surface or be deposited on the surface.* • *Impact craters have likely been affected by these processes.*	• *Mars must have an atmosphere since there is evidence of aeolian processes.* • *Wind has eroded the surface of Mars in its past and may still be changing the surface today.* • *Dust and sand likely erode the surface.* • *The atmosphere is thick enough to have wind but not thick enough to prevent meteors from striking the surface.*
Planetary Body: _____ **Observation:**				
Planetary Body: _____ **Observation:**				

Part 5: Observations, Interpretations, and Drawing Conclusions (continued)

OBSERVATION (list specific planetary body and identification criteria)	**FEATURE INTERPRETATION**	**ADDITIONAL OBSERVATIONS** (list additional observations)	**ADVANCED INTERPRETATION**	**CONCLUSIONS/INFERENCES ABOUT PROCESSES THAT SHAPE THE SURFACE**
Planetary Body: _____ **Observation:**				

You have made observations and interpretations that have allowed you to draw conclusions and make inferences about the planetary bodies you investigated. These terrestrial worlds or rocky planets all have a lithosphere/geosphere – they have rocks. Did any other planetary body you observed also have an atmosphere? Do any of them have a hydrosphere? How do we go about detecting if any of them have a biosphere? If you remember, the different Earth systems (litho/geosphere, atmosphere, hydrosphere, and biosphere) are all connected and combined make up our unique planet. The interaction of different systems on other planetary bodies likely play a role in the past, present, and future of these bodies, just as they do on Earth. There is so much yet to be discovered!

As the exploration of Earth and other planetary bodies in our solar system continues and new discoveries are made, scientific progress and our understanding of our solar system deepens. What we learn today may be refined tomorrow. This makes science an ever-changing and dynamic discipline. You are encouraged to follow along with NASA's journey of exploration or even better yet, become a part of it. NASA needs the next generation of scientists and engineers to help continue the exploration of Earth and beyond. That next generation of explorers includes you!



EARTH

AEOLIAN FEATURES

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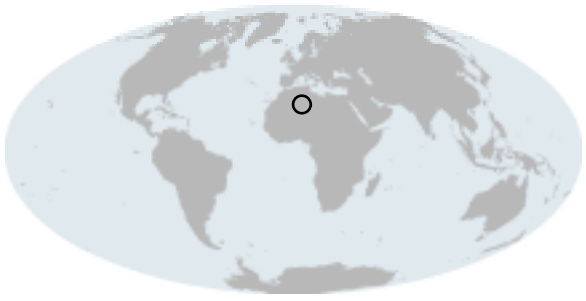
2

AEOLIAN FEATURE: SAND DUNES

Geographic Location: ALGERIA
Image ID#: STS070-705-94



- This astronaut image is showing a large area of orange colored sand dunes in Algeria called the Tifernine Dunes. This area is part of the Sahara desert. Drainage channels show where water once flowed through the area when the climate was wetter.
- **OTHER VISIBLE FEATURE(S): Drainage channels**

AEOLIAN FEATURE: SAND DUNES

1

Geographic Location: EGYPT
Image ID#: ISS017-E-020929

- This astronaut image is taken of an area in northern Egypt almost completely covered in sand dunes. This area, west of Cairo, is part of the Sahara Desert.
- **OTHER VISIBLE FEATURE(S): Clouds, cloud shadows**

4

AEOLIAN FEATURE: YARDANGS

Geographic Location: NAMIBIA
Image ID#: STS040-17-26

- This astronaut image is taken of yardangs in an area along the northern coast of Namibia called the Skeleton Coast.
- **OTHER VISIBLE FEATURE(S): Coastline**

AEOLIAN FEATURE: SAND DUNES

3

Geographic Location: UNITED STATES
Image ID#: ISS016-E-6986

- This astronaut image is taken of the Sangre de Cristo Mountains and sand dunes located in Great Sand Dunes National Park in Colorado.
- The mountains are outlined by dark green forests at lower elevations and white, snow-capped peaks at the highest elevations.
- **OTHER VISIBLE FEATURE(S): Mountains, forests, snow**

EARTH

AEOLIAN FEATURES

6

AEOLIAN FEATURE: YARDANGS

Geographic Location: NIGER
Image ID#: STS052-73-12

- This astronaut image is taken of yardangs in the Djado plateau of Niger. This area is located in the Sahara and is heavily eroded by wind.
- **OTHER VISIBLE FEATURE(S): n/a**

AEOLIAN FEATURE: YARDANGS

5

Geographic Location: CHAD
Image ID#: ISS012-E-09638

- This astronaut image is taken of wind eroded ridges (yardangs) that have modified a multi-ringed impact crater called Aorounga. The Aorounga crater is located to the southeast of Emi Koussi (a volcano not seen in this image) on the Tibesti mountains in Chad.
- **OTHER VISIBLE FEATURE(S): Impact crater**

8

AEOLIAN FEATURE: WIND STREAKS

Geographic Location: SUDAN
Image ID#: ISS013-E-18533

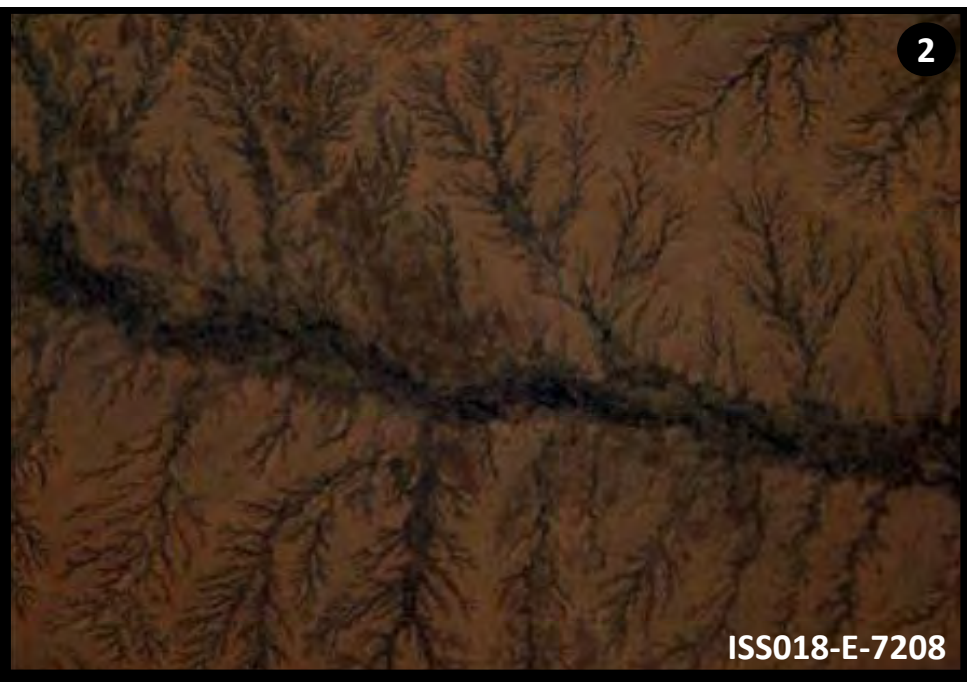
- This astronaut image showing numerous wind streaks is taken of an area affected by strong winds in the northern part of Sudan.
- **OTHER VISIBLE FEATURE(S): Escarpments**

AEOLIAN FEATURE: WIND STREAKS

7

Geographic Location: CHAD
Image ID#: ISS016-E-16058

- This astronaut image is taken of an area where a channel once flowed that is now affected by strong winds on the Tibesti mountains in Chad. This image is dominated by features created by effects of wind erosion.
- **OTHER VISIBLE FEATURE(S): Channel (visible in the center of image)**



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FLUVIAL FEATURES

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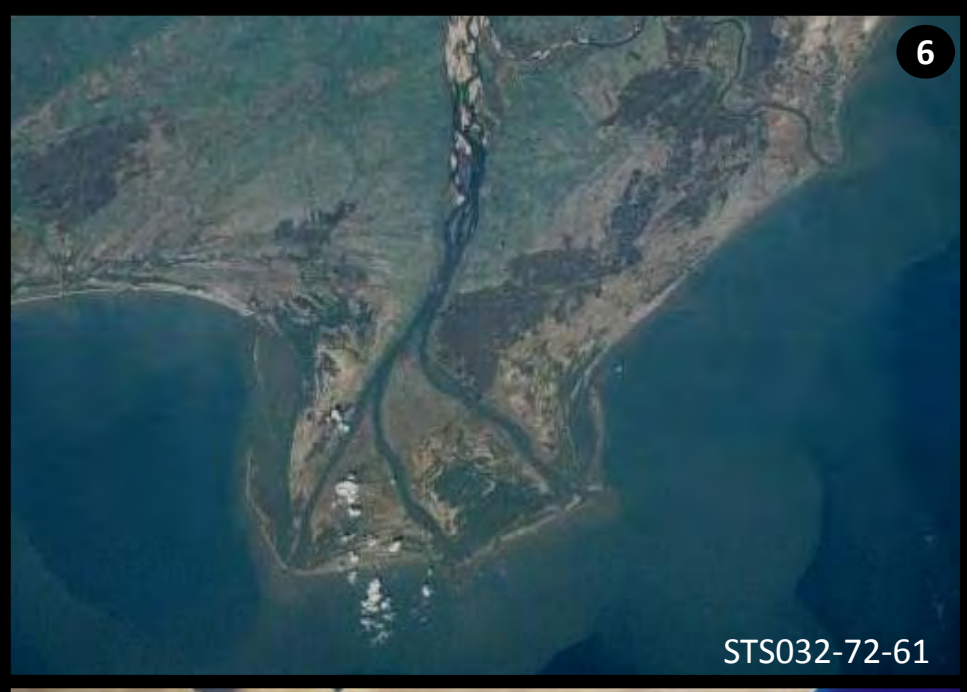
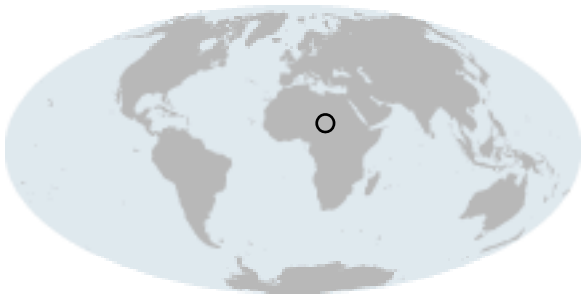


2 FLUVIAL FEATURE: DRAINAGE NETWORK

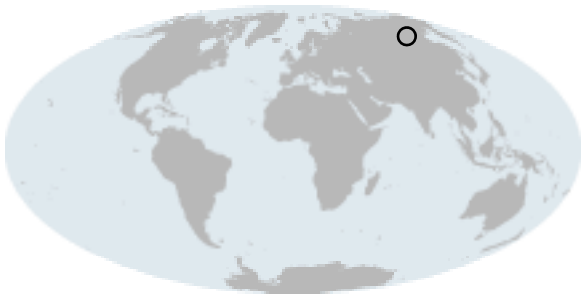
Geographic Location: CHAD
Image ID#: ISS018-E-7208



- This astronaut image is centered on a set of valley or drainage networks in Chad, Africa. In arid regions these drainage networks consist of a network of wadis. Wadis are channel-like features that are dry but have intermittent streamflow during periods of rain.
- **OTHER VISIBLE FEATURE(S): n/a**

FLUVIAL FEATURE: DRAINAGE NETWORK 1

Geographic Location: CHINA
Image ID#: ISS014-E-20488



- This astronaut image is centered on valley or drainage networks located in China. The dendritic pattern as seen in this image is common for these networks.
- **OTHER VISIBLE FEATURE(S): Snow**

4 FLUVIAL FEATURE: CHANNEL

Geographic Location: ARGENTINA
Image ID#: ISS010-E-5070

- This astronaut image is centered on the Parana River in northern Argentina just to the south of Paraguay. The Parana River is the third largest river in South America. Sun glint on the river gives it a silvery glow and allows varying currents to be visible.
- **OTHER VISIBLE FEATURE(S): Urban area, channel islands, meander scars**

FLUVIAL FEATURE: CHANNEL 3

Geographic Location: ARGENTINA
Image ID#: ISS012-E-13327

- This astronaut image is centered on the Bermejo River in northern Argentina. This river meanders along the dark green dense forests visible on both sides of its banks. The lighter green squares are agricultural areas.
- **OTHER VISIBLE FEATURE(S): Forests, agricultural areas**

6 FLUVIAL FEATURE: DELTA

Geographic Location: INDIA
Image ID#: STS032-72-61

- This astronaut image highlights a portion of the Krishna River Delta that flows into the Bay of Bengal in India. Sediment deposits are tan to brownish in color.
- **OTHER VISIBLE FEATURE(S): River channel, sediment deposits, bay**

FLUVIAL FEATURE: CHANNEL 5

Geographic Location: PERU
Image ID#: ISS007-E-14816

- This astronaut image is centered on the Ucayali River east of the Andes Mountains in Peru. This river is one of four rivers considered as the main headwater of the Amazon River.
- **OTHER VISIBLE FEATURE(S): Oxbow lakes, meander scars**

8 FLUVIAL FEATURE: DELTA

Geographic Location: EGYPT
Image ID#: STS077-718-56

- This astronaut image is centered on the Nile River Delta in Egypt. This area is where the Nile River spreads out and drains into the Mediterranean Sea.
- **OTHER VISIBLE FEATURE(S): River channel, sea, clouds**

FLUVIAL FEATURE: DELTA 7

Geographic Location: RUSSIA
Image ID#: STS059-213-65

- This astronaut image is centered on the Selenga River Delta flowing into Lake Baikal in Russia. Sunglint gives a silver-white sheen to the water surface of Lake Baikal. The Selenga River is the main river that stretches between Mongolia and Russia.
- **OTHER VISIBLE FEATURE(S): Lake, river channels, clouds**

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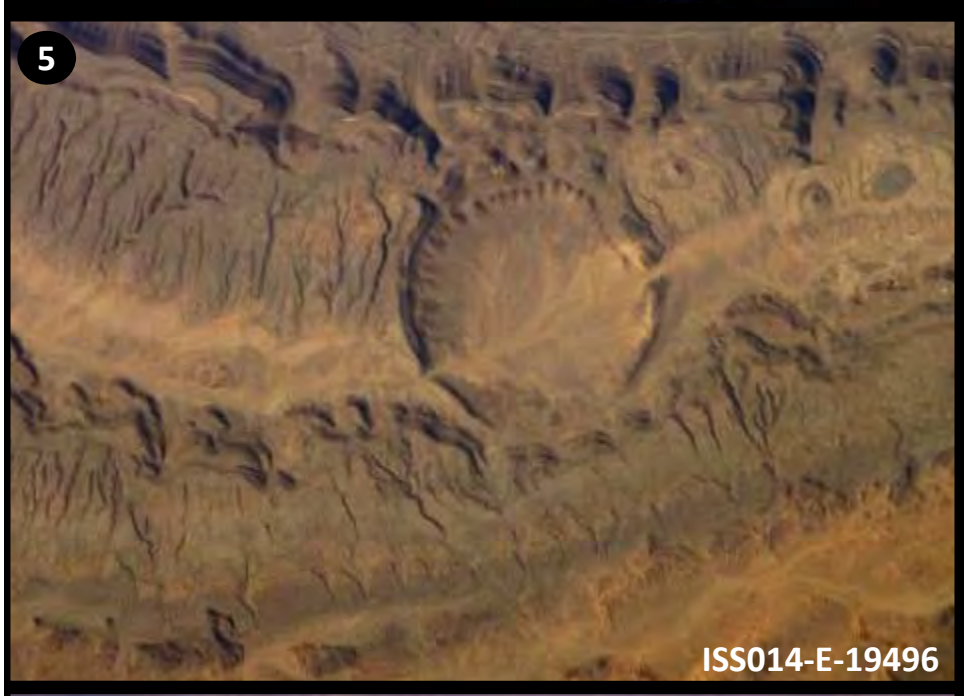
IMPACT FEATURES



2

IMPACT FEATURE: CRATER

Geographic Location: CANADA
Image ID#: ISS012-E-15881

- This astronaut image is centered on the Manicouagan Impact Crater located in Quebec, Canada. The rim of the crater is now filled with water and referred to as the Manicouagan reservoir. Part of the central mound of the crater is still visible.
- **OTHER VISIBLE FEATURE(S): Reservoir or lakes**

IMPACT FEATURE: CRATER

1

Geographic Location: NAMIBIA
Image ID#: ISS006-E-16068

- This astronaut image is taken of the Roter Kamm Impact Crater, found in the Namib Desert in Namibia.
- **OTHER VISIBLE FEATURE(S): Sand dunes, mountains**

4

IMPACT FEATURE: CRATER

Geographic Location: UNITED STATES
Image ID#: ISS014-E-15775

- This astronaut image is centered on Barringer Crater (also know as Meteor Crater) located in northern Arizona. It is one of the best-known impact craters in the world.
- **OTHER VISIBLE FEATURE(S): River channel, wind streak**

IMPACT FEATURE: CRATER

3

Geographic Location: LIBYA
Image ID#: ISS014-E-11841

- This astronaut image is centered on the Oasis Impact Crater found in the Sahara Desert in Libya.
- **OTHER VISIBLE FEATURE(S): n/a**

EARTH

IMPACT FEATURES

6

IMPACT FEATURE: CRATER

Geographic Location: AUSTRALIA
Image ID#: ISS015-E-17360

- This astronaut image is centered on Gosses Bluff, an impact crater located in Australia's Northern Territory.
- **OTHER VISIBLE FEATURE(S): River channel**

IMPACT FEATURE: CRATER

5

Geographic Location: ALGERIA
Image ID#: ISS014-E-19496

- This astronaut image shows the Ouarkziz Impact Crater and sedimentary layers located in western Algeria close to the border of Morocco.
- **OTHER VISIBLE FEATURE(S): Sedimentary rocks & layers, small circular hills**

8

IMPACT FEATURE: CRATER

Geographic Location: INDIA
Image ID#: ISS018-E-23713

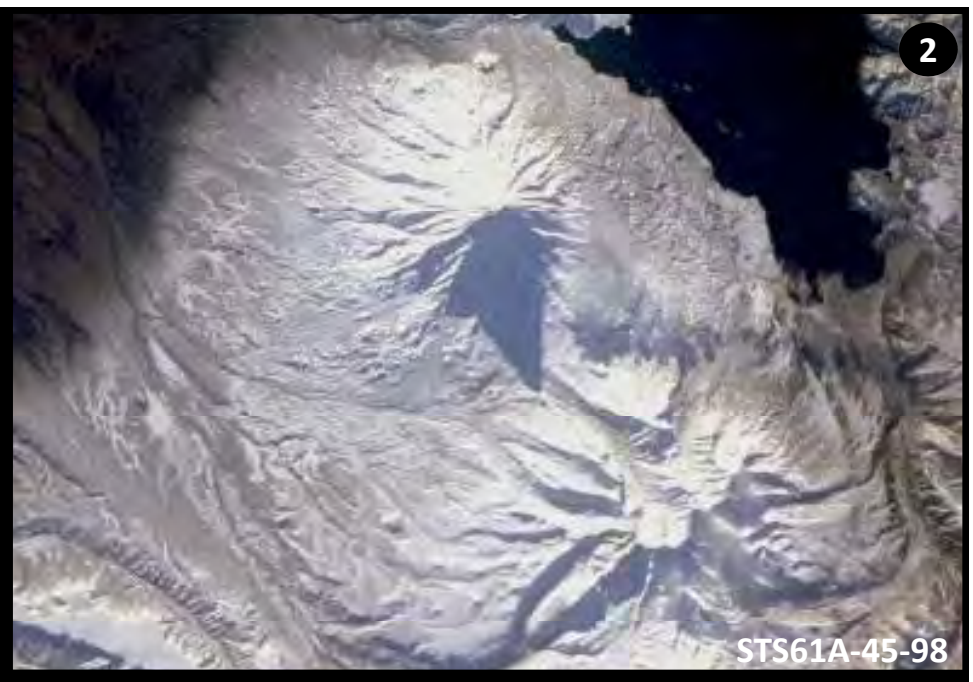
- This astronaut image is centered on the Lonar Impact Crater located in Central India. The central portion of this crater is now filled with water.
- **OTHER VISIBLE FEATURE(S): Lake, agricultural fields, urban area**

IMPACT FEATURE: CRATER

7

Geographic Location: MAURITANIA
Image ID#: ISS018-E-14908

- This astronaut image is centered on the Tenoumer Impact Crater located in the Sahara Desert in Mauritania.
- **OTHER VISIBLE FEATURE(S): n/a**



EARTH

VOLCANIC FEATURES

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2

VOLCANIC FEATURE: VOLCANOES

Geographic Location: RUSSIA
Image ID#: STS61A-45-98

- This astronaut image includes two of more than 100 volcanoes that exist in this region. These snow covered volcanoes are located in the Kamchatka Penninsula in Russia. This area is part of the "Ring of Fire" and has many active volcanoes.
- **OTHER VISIBLE FEATURE(S): Caldera, lava drainage channels, snow, lake**

1

VOLCANIC FEATURE: VOLCANOES

Geographic Location: UNITED STATES
Image ID#: ISS013-E-24184

- This astronaut image captured the beginning of an eruption of a stratovolcano in Alaska called the Cleveland Volcano. Carlisle Island, another volcano, is visible in the upper left hand portion of the image.
- **OTHER VISIBLE FEATURE(S): Ash plume, central vent, ocean, snow**

4

VOLCANIC FEATURES: VOLCANO, CALDERA, LAVA FLOWS

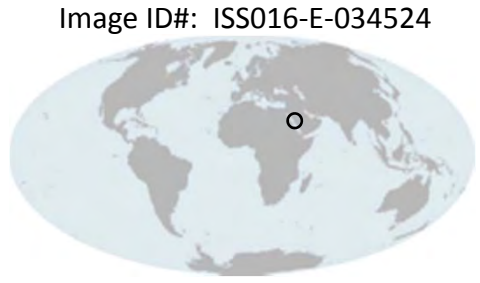
Geographic Location: CHAD
Image ID#: ISS016-E-8402

- This astronaut image shows the Emi Koussi Volcano located at the south end of the Tibesti Mountains in Chad. Extensive lava flows are visible all around the volcano.
- **OTHER VISIBLE FEATURE(S): n/a**

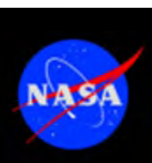
3

VOLCANIC FEATURES: VOLCANOES, CALDERAS, LAVA FLOWS

Geographic Location: SAUDI ARABIA
Image ID#: ISS016-E-034524



- This astronaut image is taken of a volcanic field in Saudi Arabia. There are volcanoes of different sizes, shapes, and chemical compositions. Lava flows vary in color. Features that look like impact craters were actually caused by volcanic eruptions in the presence of water (some of which are now filled with light-colored sand and silt).
- **OTHER VISIBLE FEATURE(S): n/a**



EARTH

VOLCANIC FEATURES

6

VOLCANIC FEATURES: LAVA FLOWS, CALDERA

Geographic Location: UNITED STATES
Image ID#: ISS017-E-013065

- This astronaut image shows lava flows on either side of the summit caldera of the tallest volcano on Earth. Mauna Loa, located on the Big Island of Hawaii rises ~9 km (~5.6 mi) above the sea floor.
- **OTHER VISIBLE FEATURE(S): Clouds**

5

VOLCANIC FEATURE: CALDERA

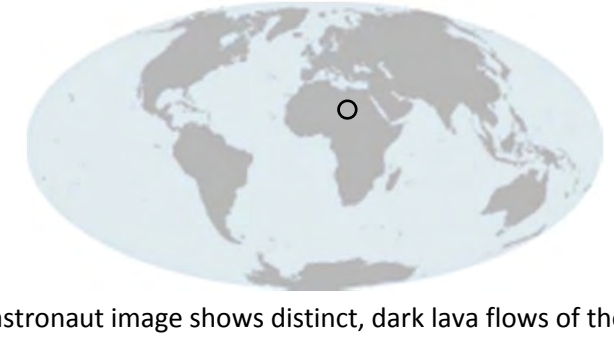
Geographic Location: SUDAN
Image ID#: ISS018-E-6051

- This astronaut images is taken of the Deriba Caldera, a dormant volcanic structure located at the top of the Marra Mountains in western Sudan. Numerous drainage networks are visible around the caldera. Within the caldera are two inner volcanic depressions called craters.
- **OTHER VISIBLE FEATURE(S): Drainage networks, inner crater lakes**

8

VOLCANIC FEATURE: LAVA FLOWS

Geographic Location: CHAD
Image ID#: ISS016-E-035095

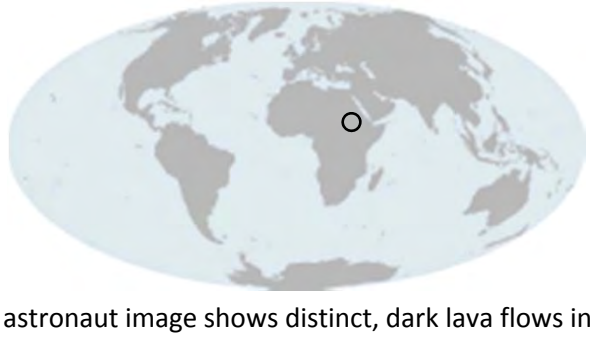


- This astronaut image shows distinct, dark lava flows of the Tousside Peak Volcano in Chad. The Tousside Peak Volcano (not shown in this image) is the westernmost volcano of the Tibesti Mountains in northwestern Chad.
- **OTHER VISIBLE FEATURE(S): n/a**

7

VOLCANIC FEATURE: LAVA FLOWS

Geographic Location: ETHIOPIA
Image ID#: ISS017-E-5656



- This astronaut image shows distinct, dark lava flows in the Afar volcanic region of Ethiopia. Although not visible in this image, three large volcanoes are located to the north of these lava flows.
- **OTHER VISIBLE FEATURE(S): n/a**

1

ISS005-E-16572

2

ISS013-E-24184

3

ISS015-E-17360

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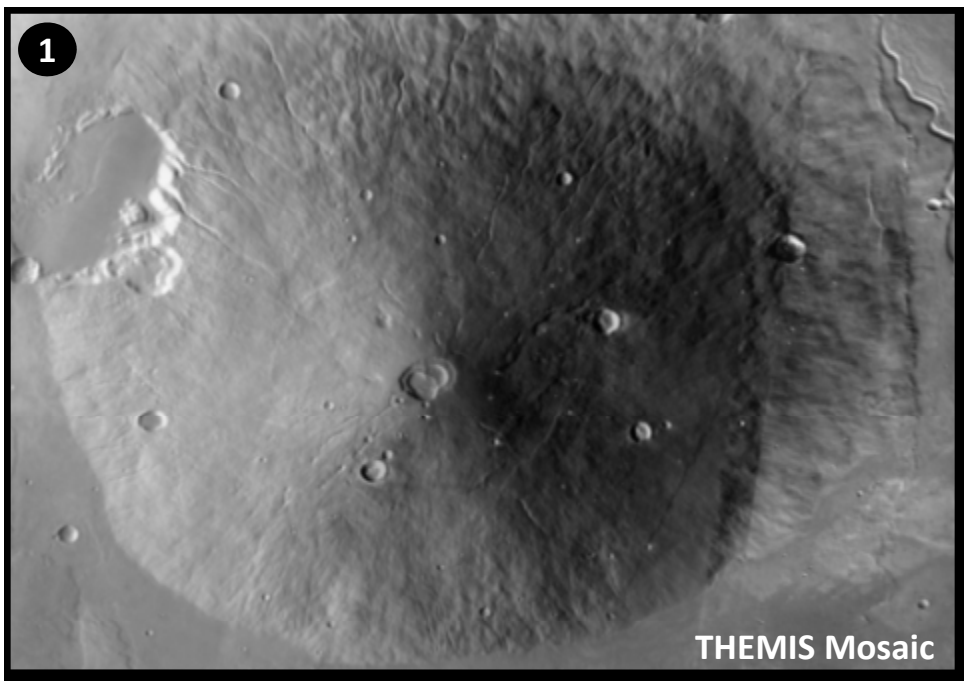

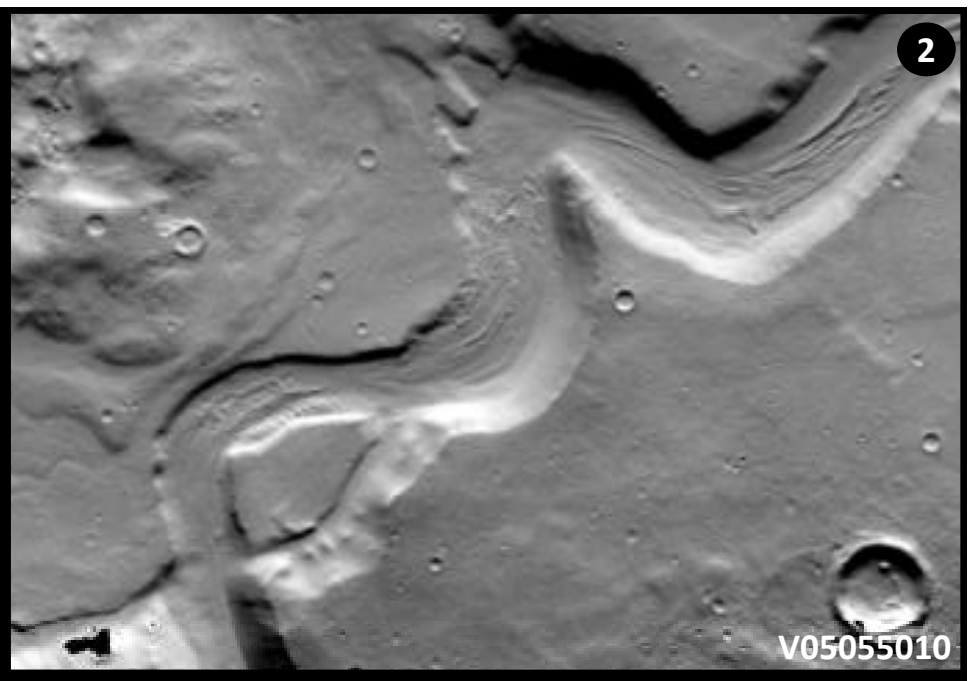

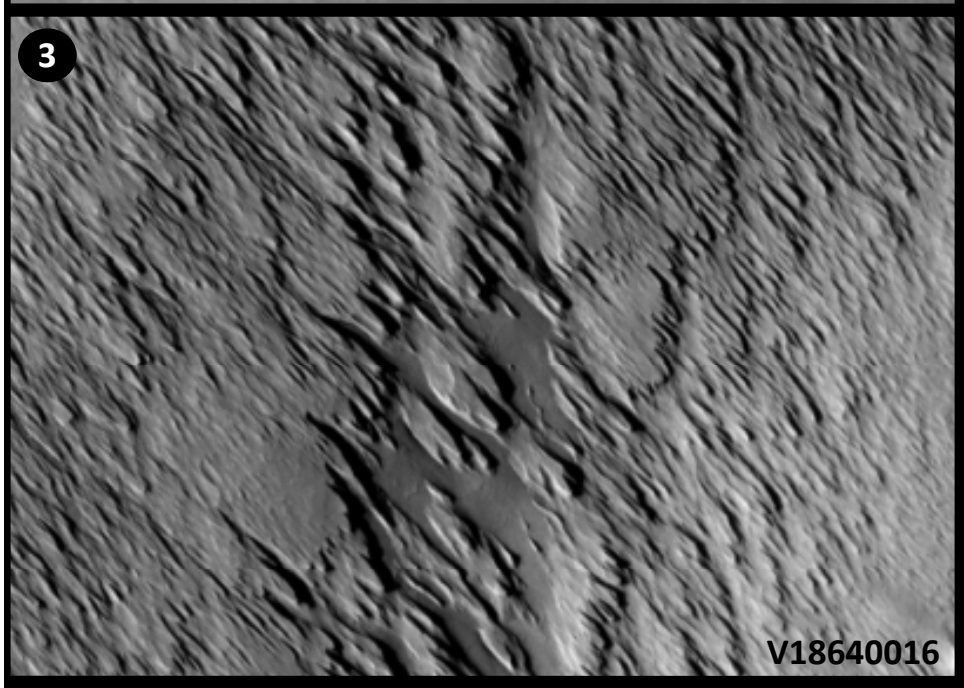

MARS

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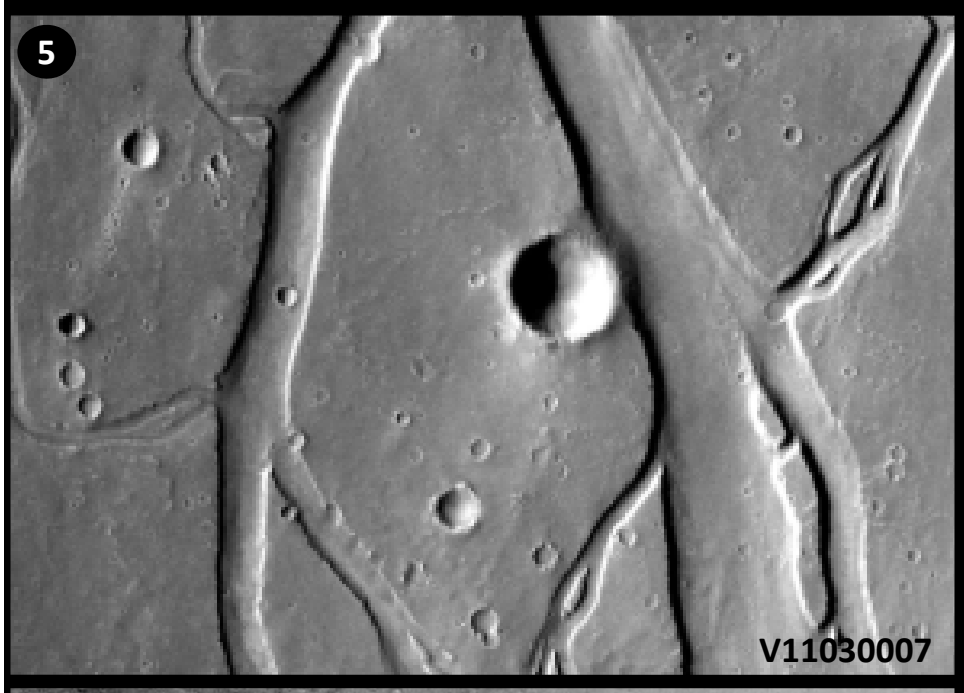

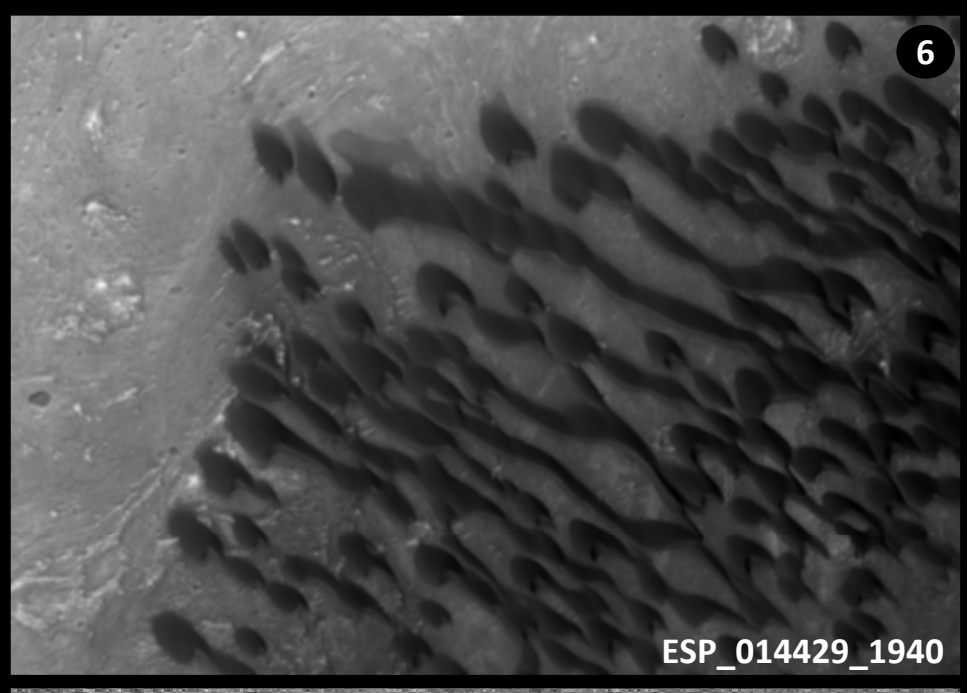

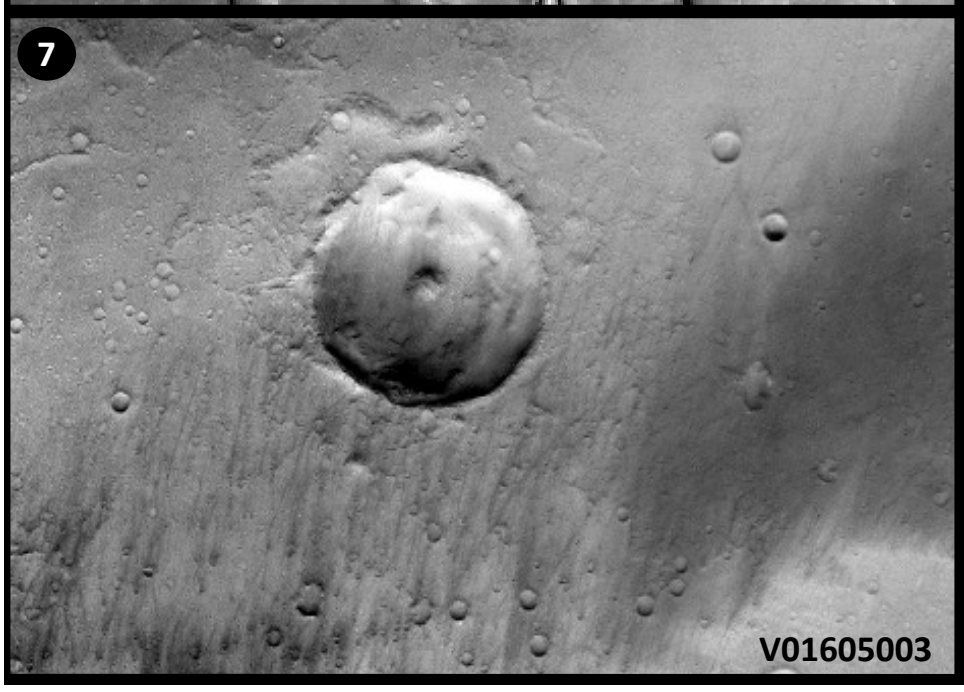

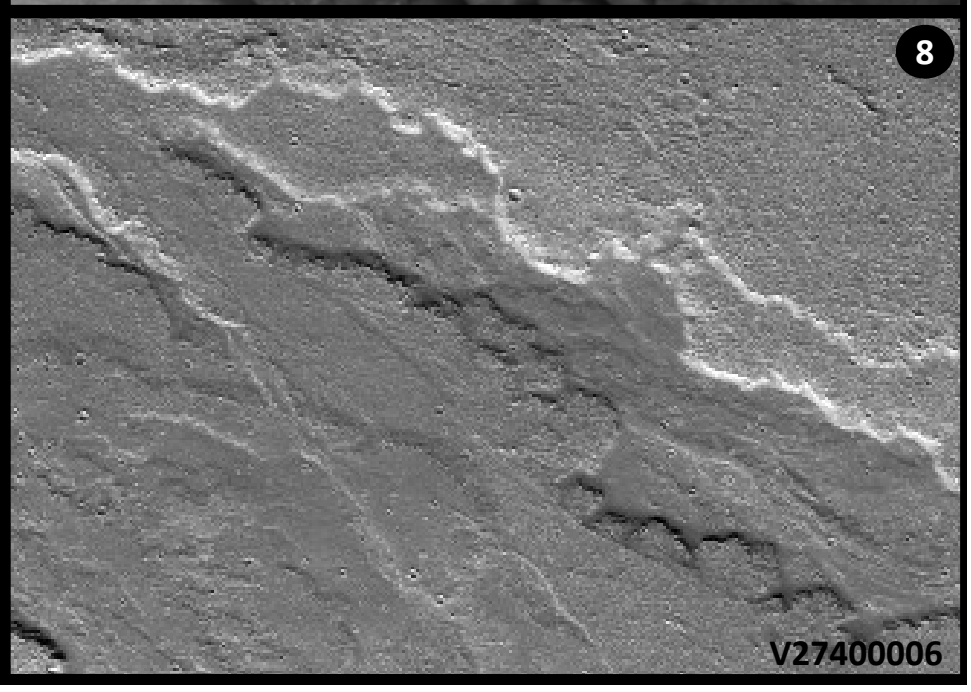

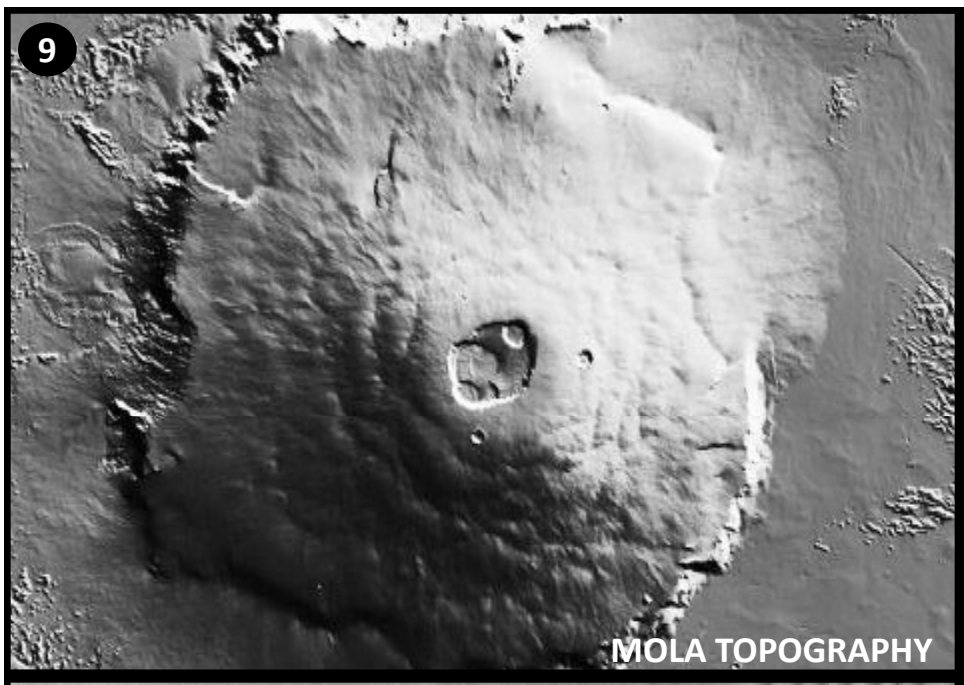

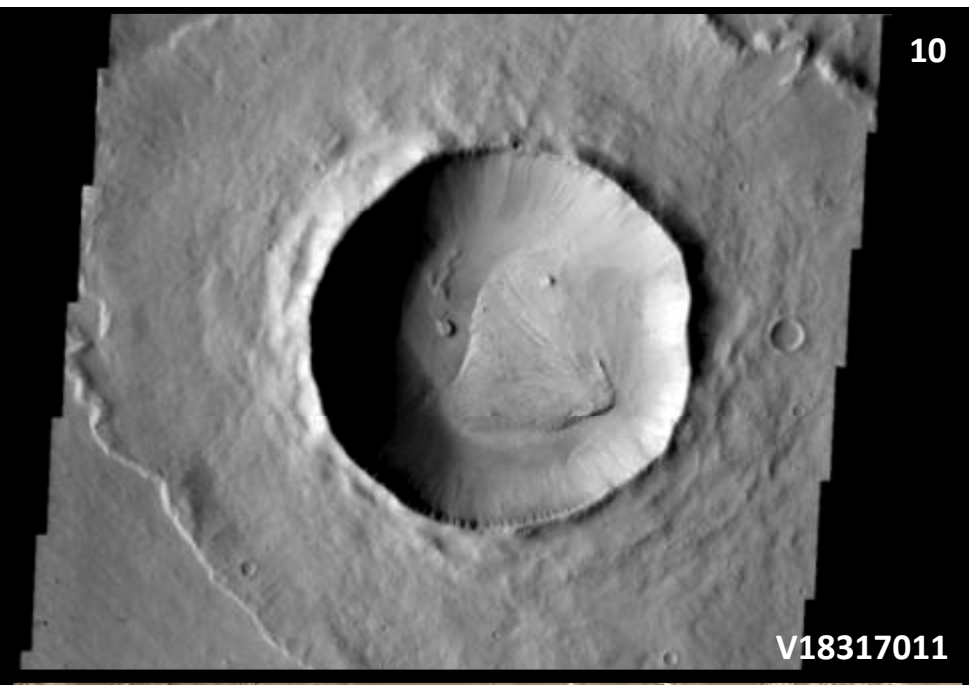

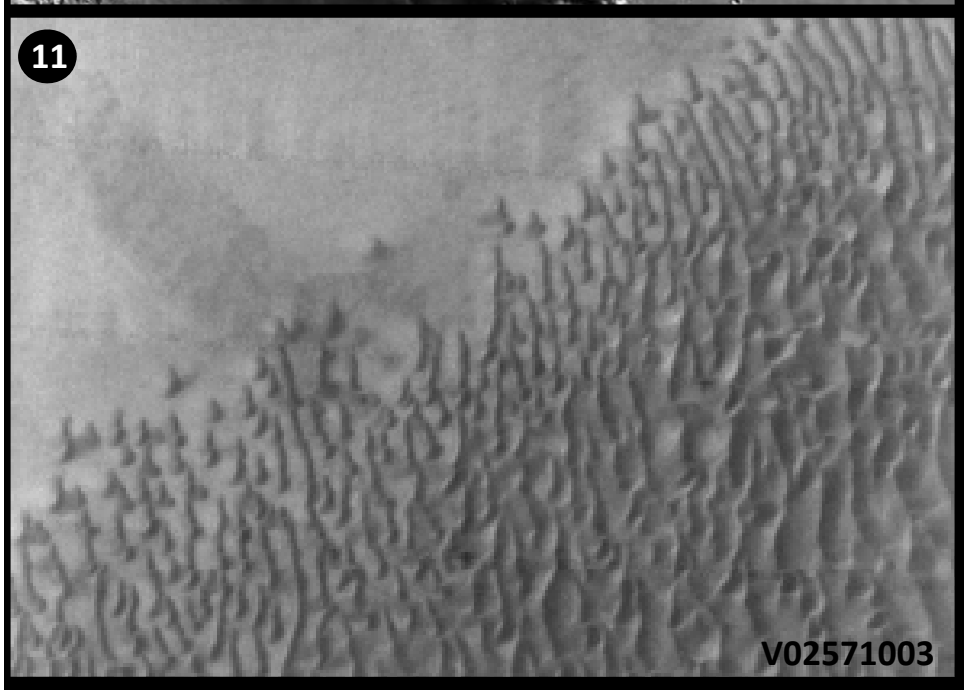

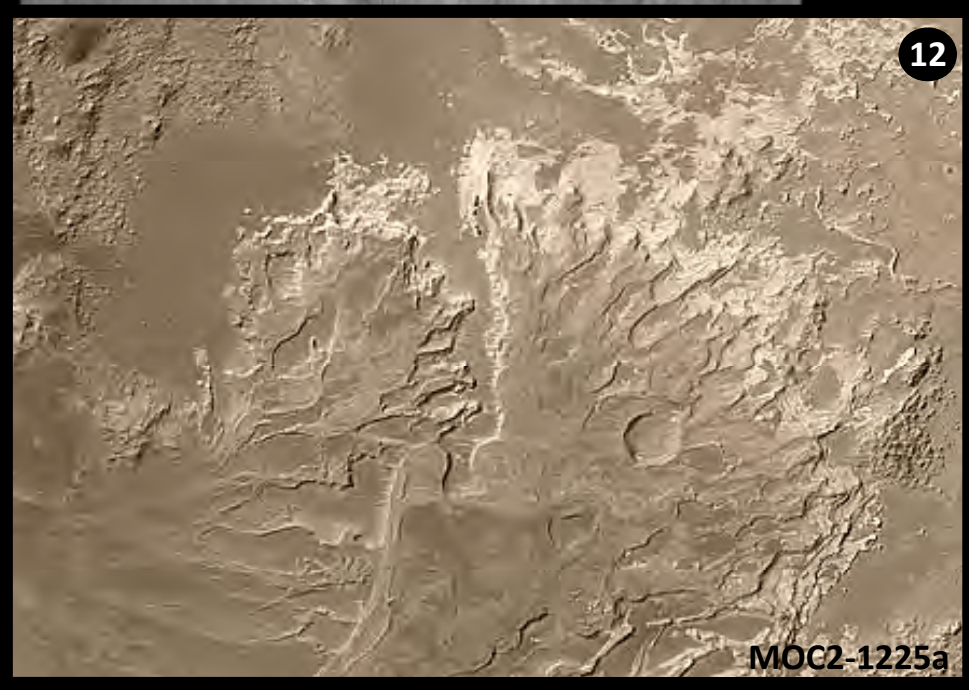

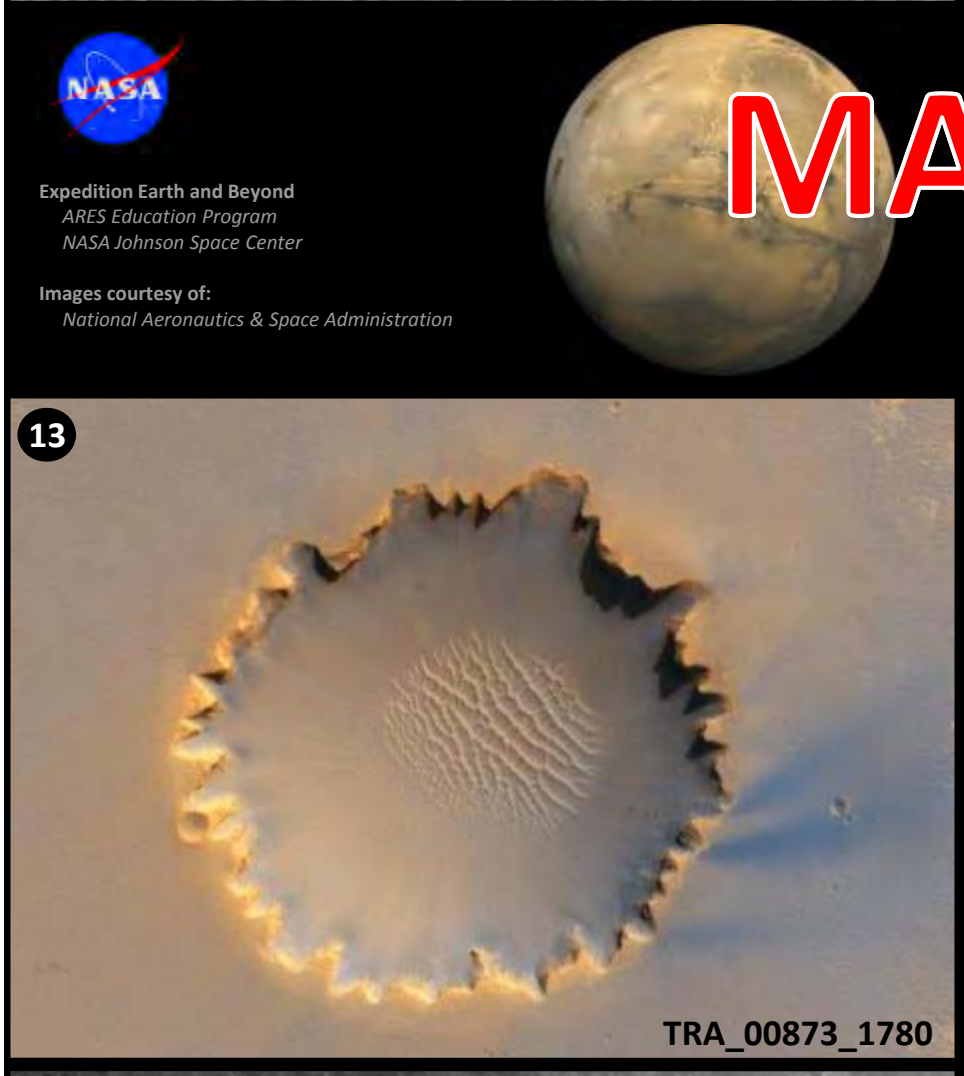

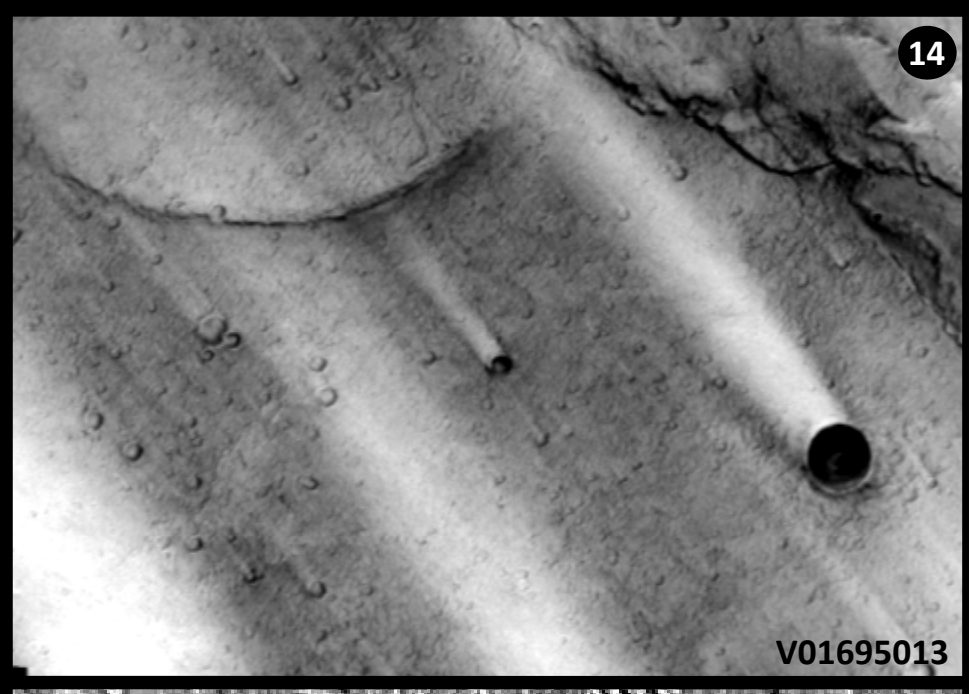

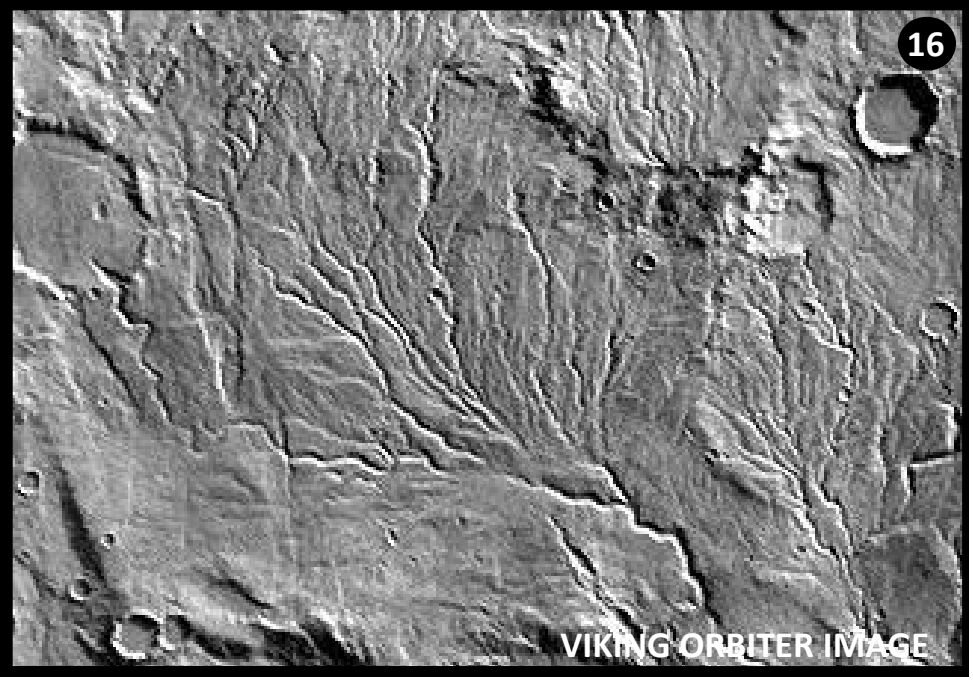

MARS

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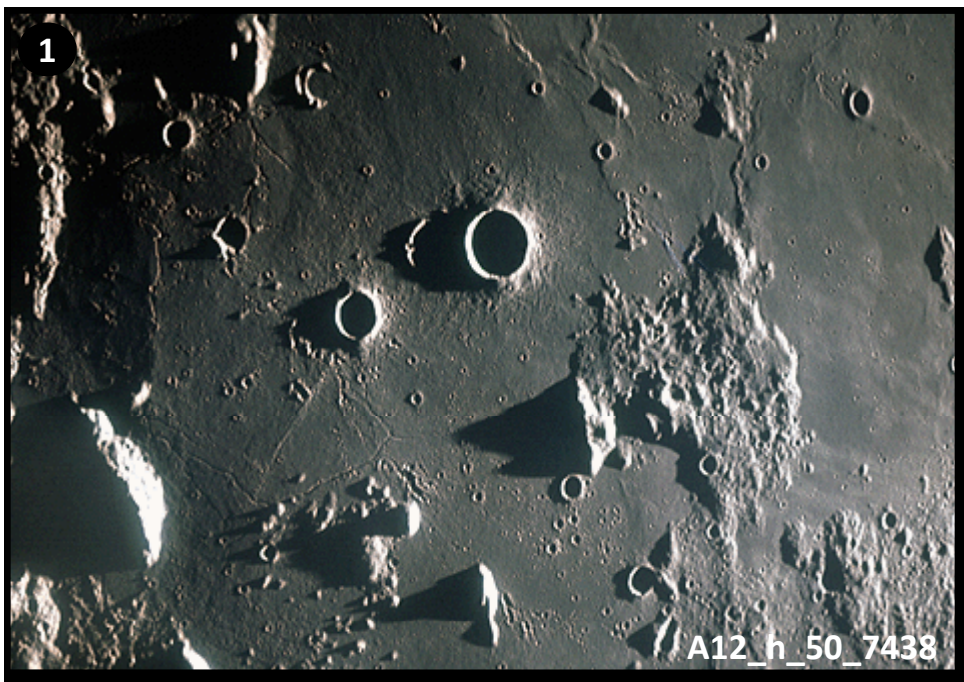

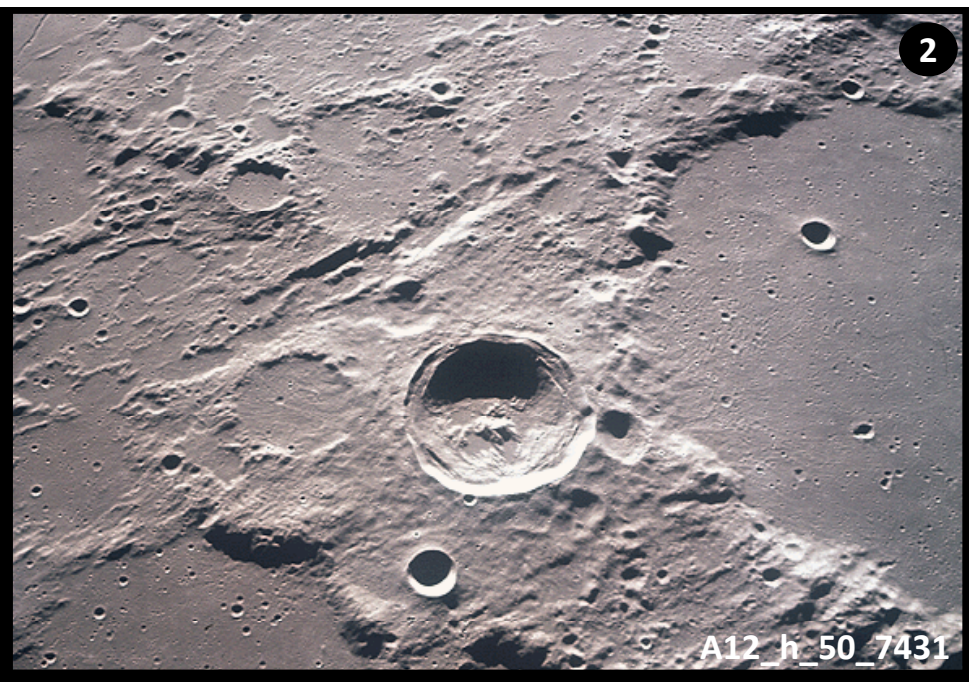

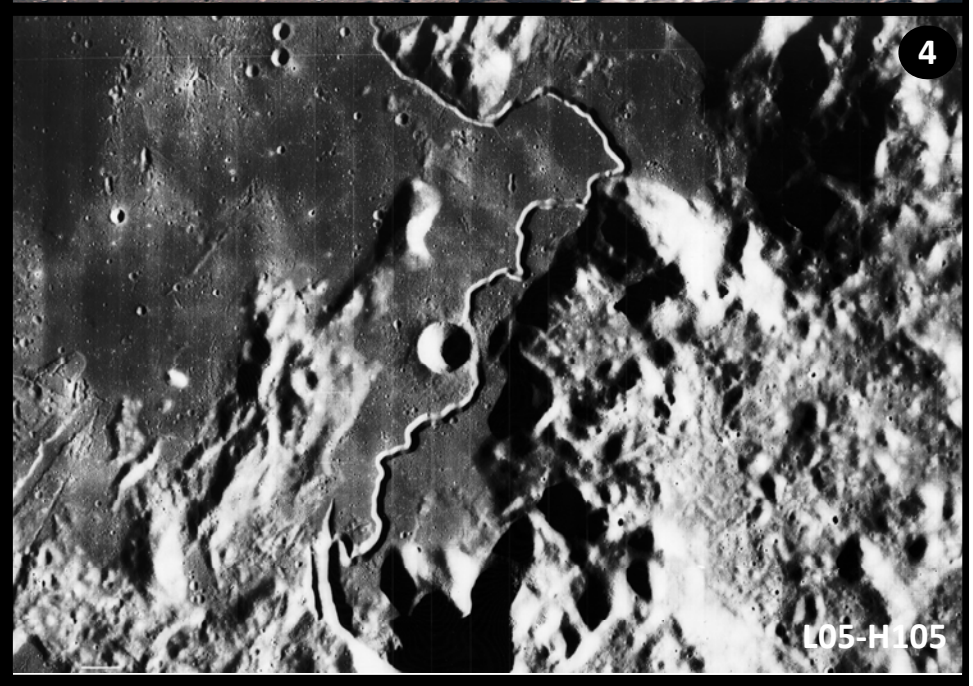

EARTH'S MOON

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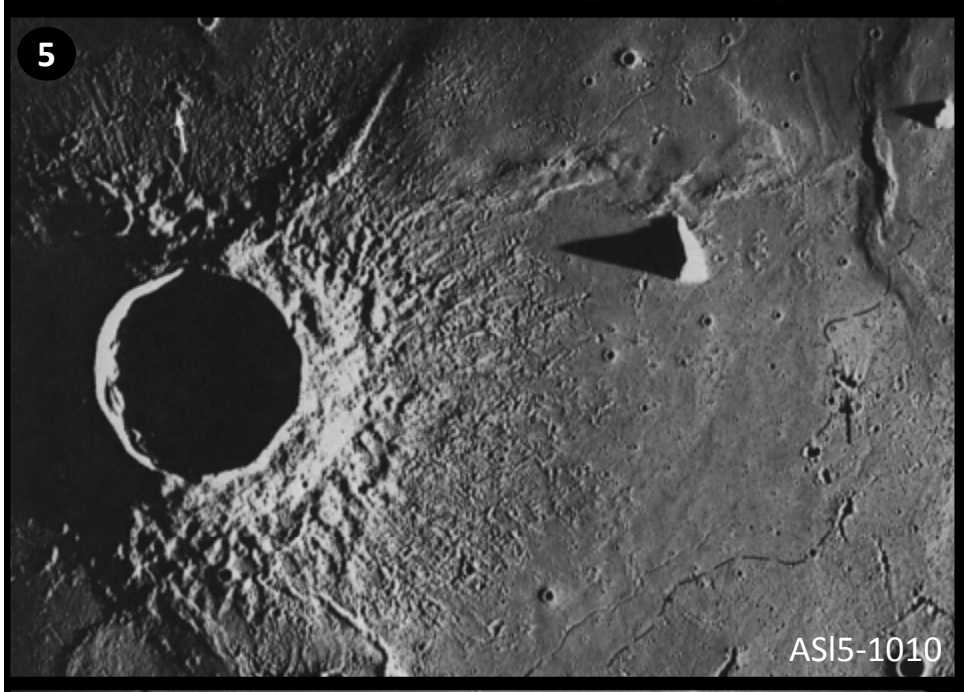

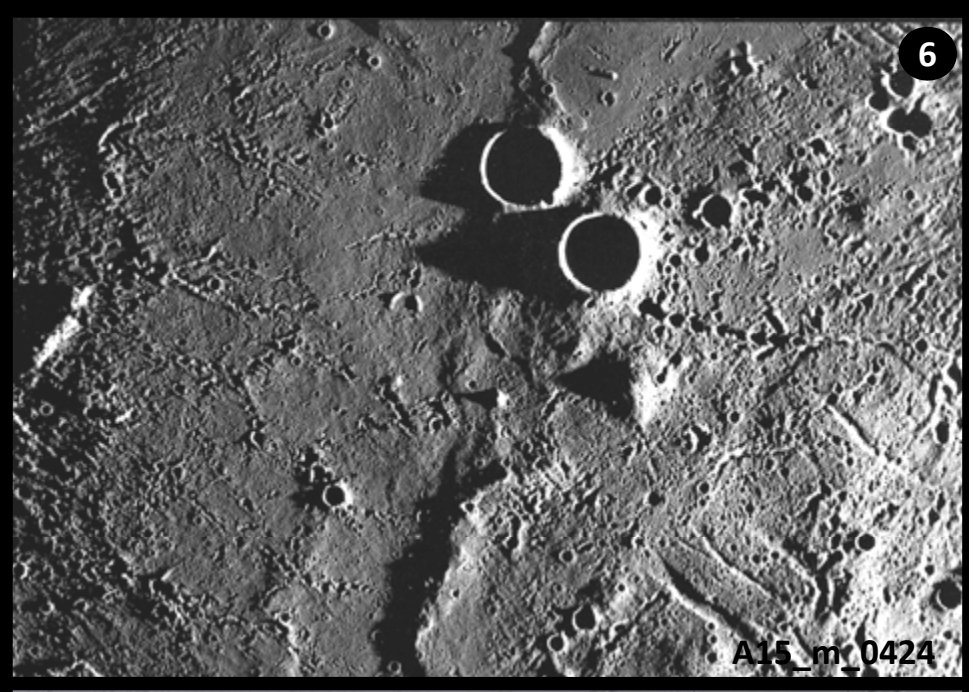

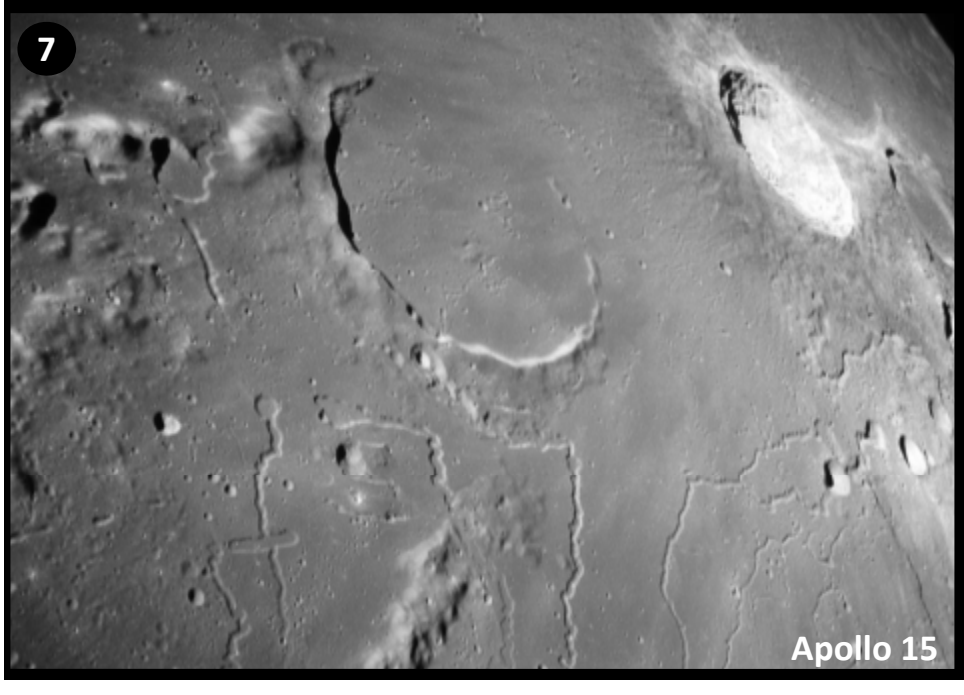

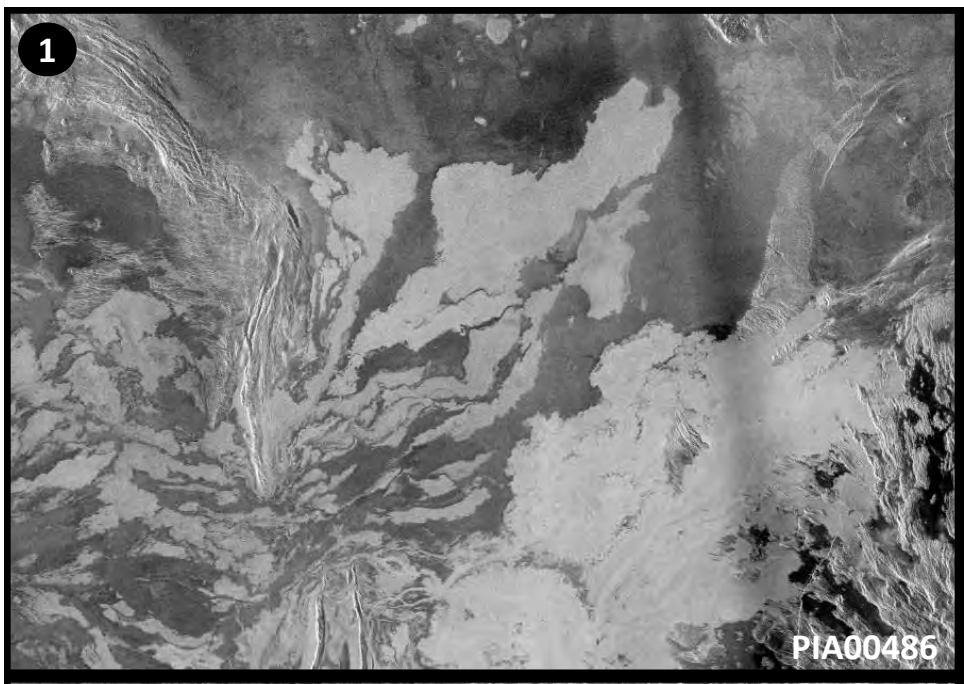

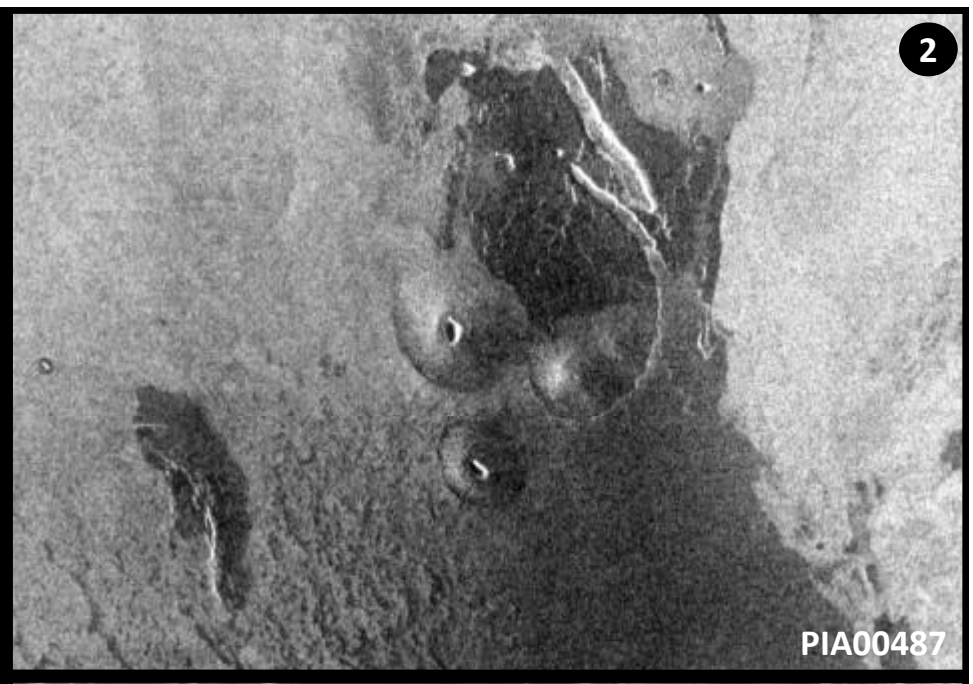

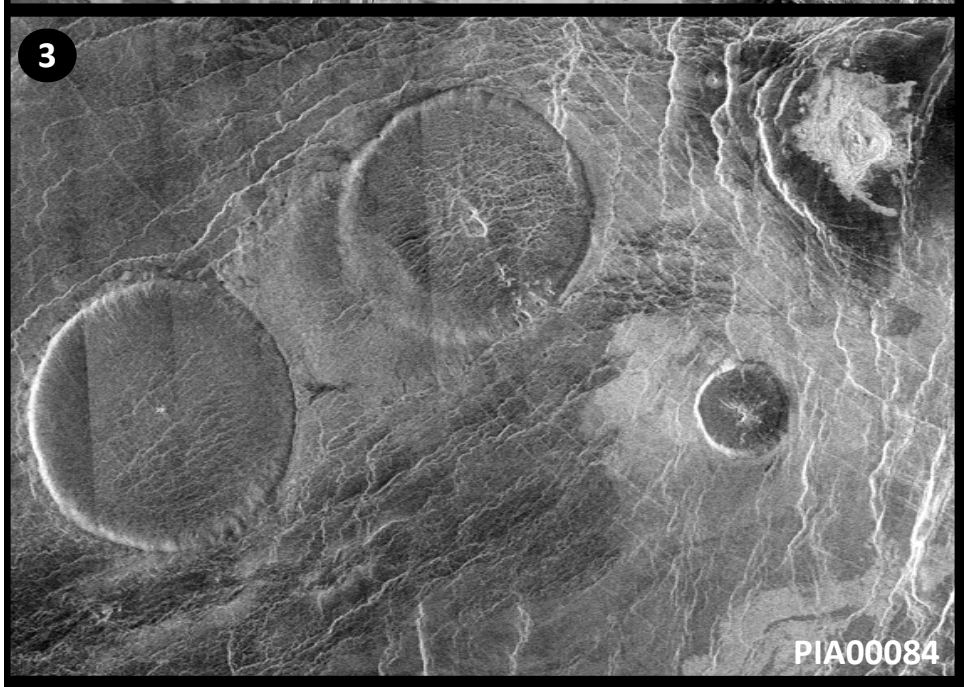

VENUS

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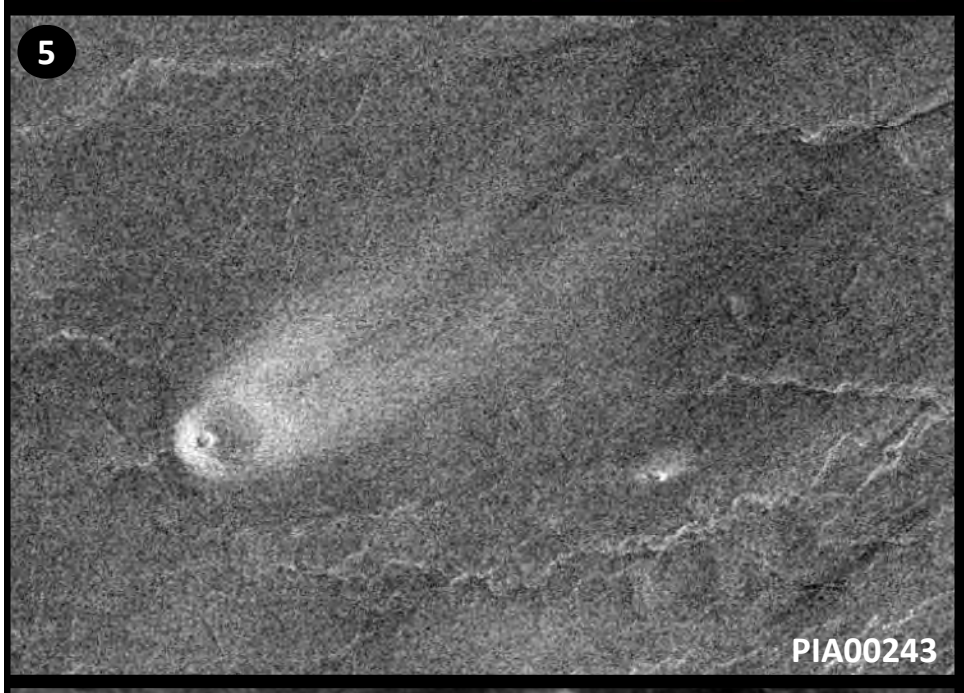

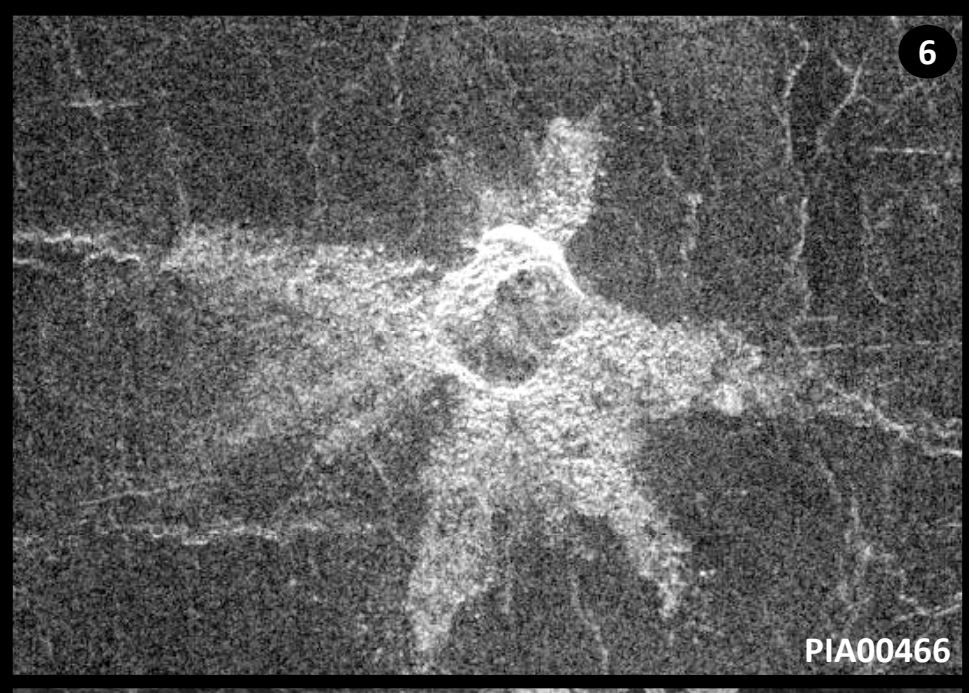

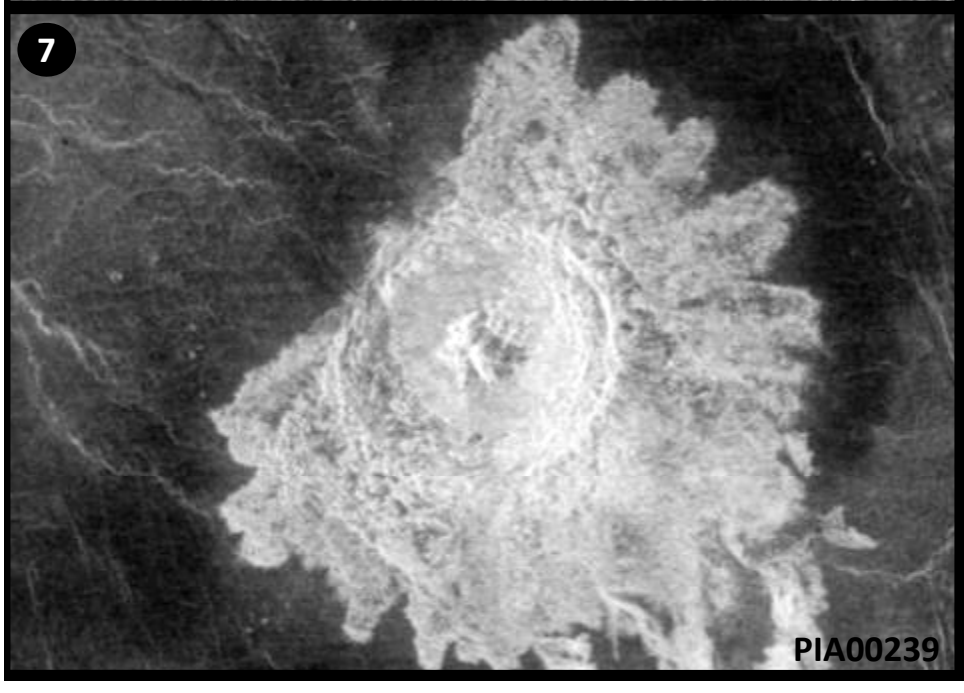

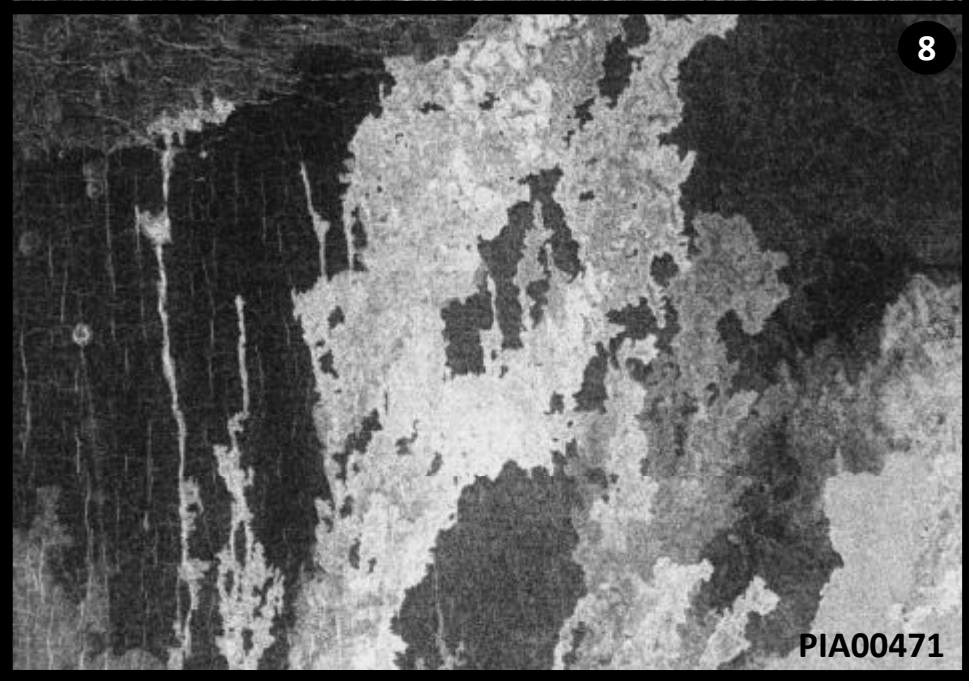

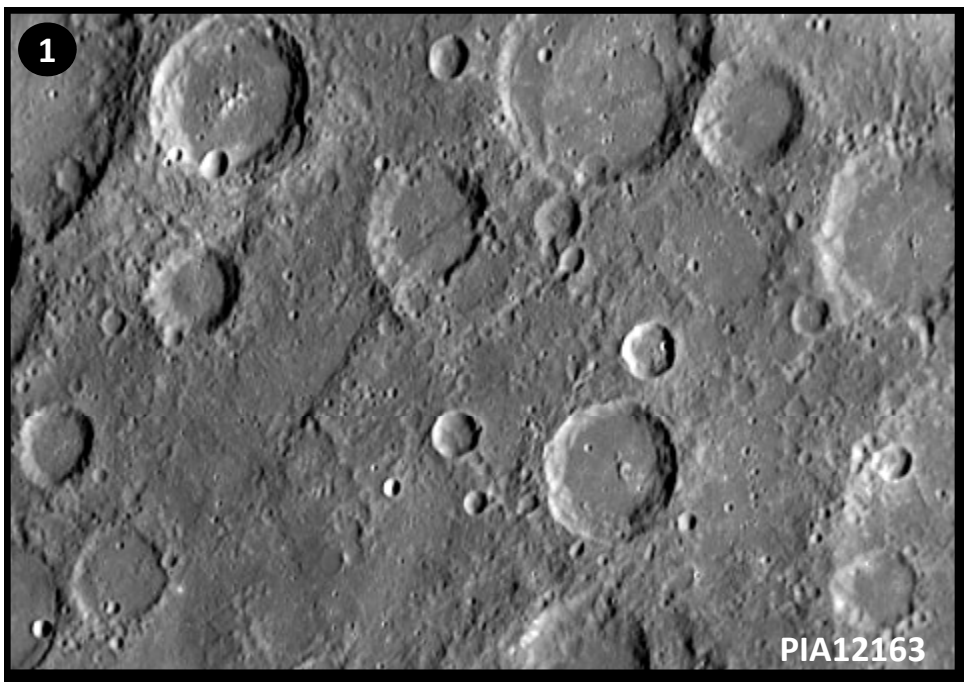

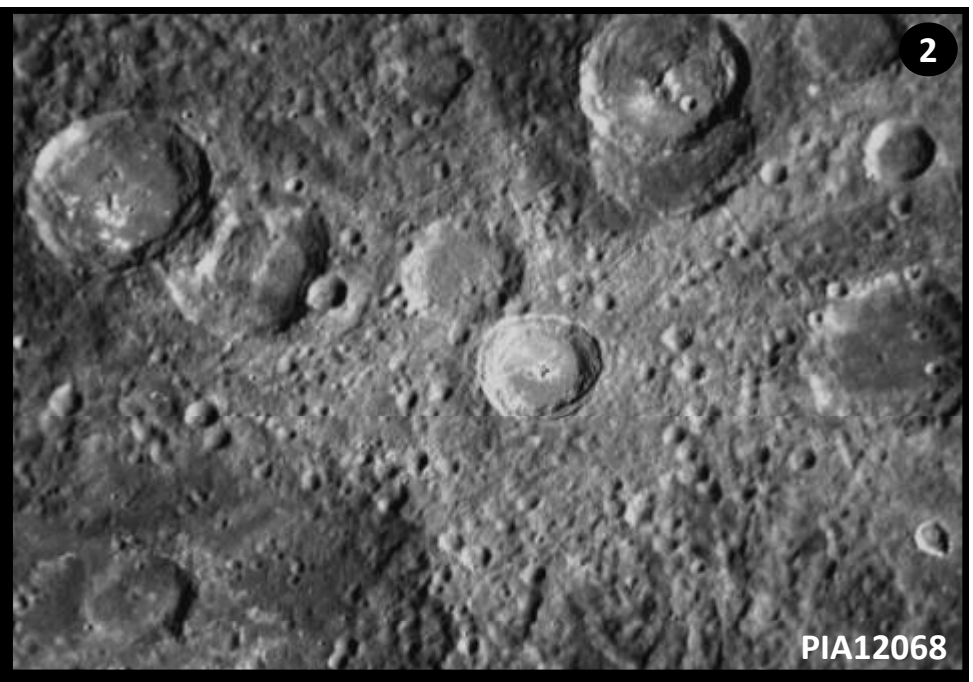

MERCURY

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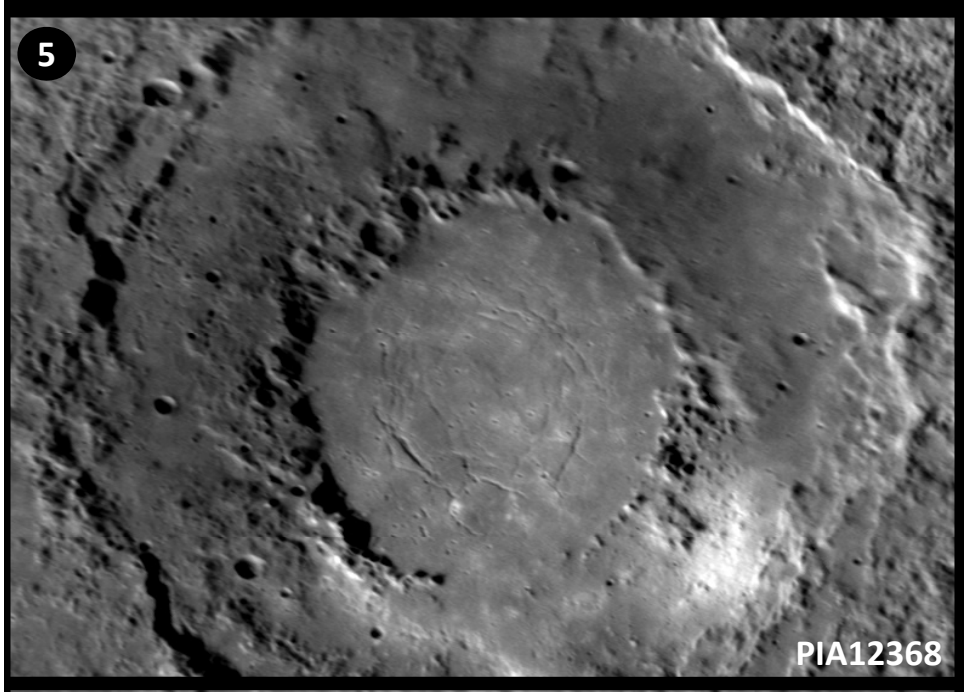

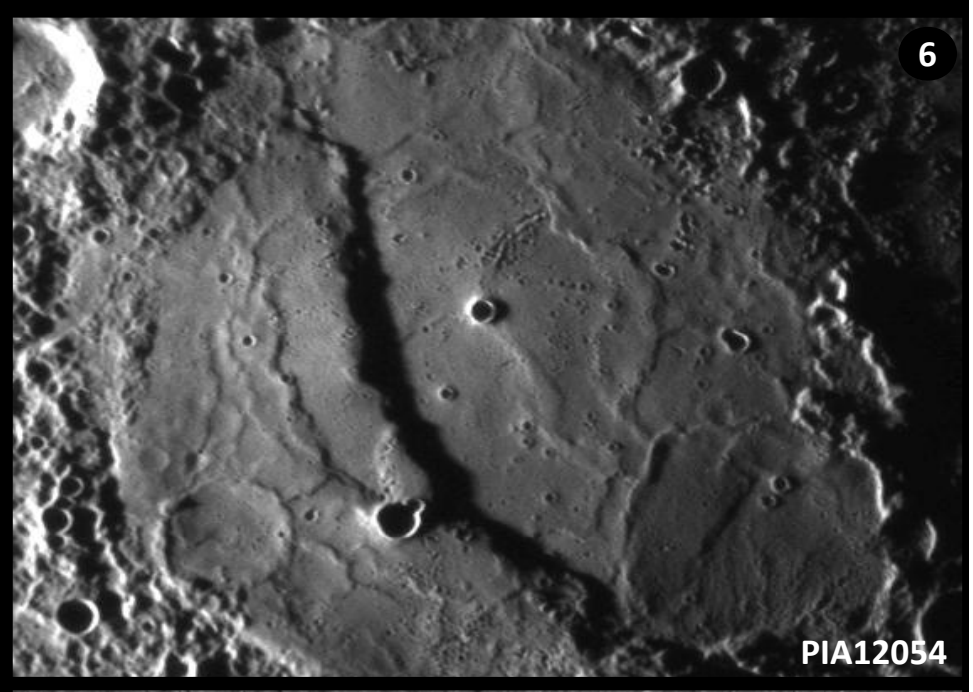

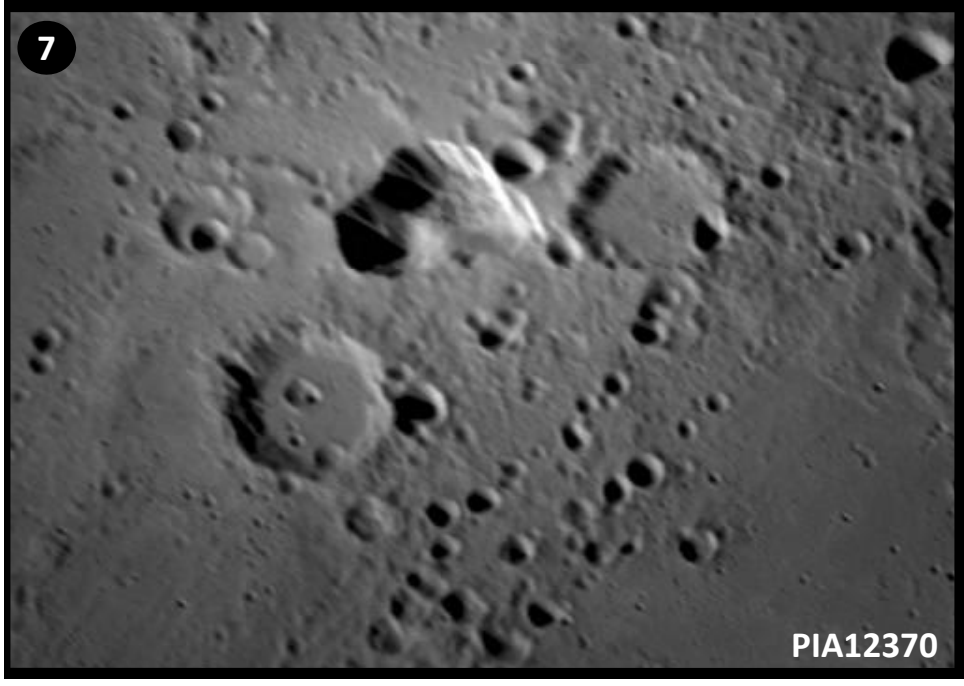

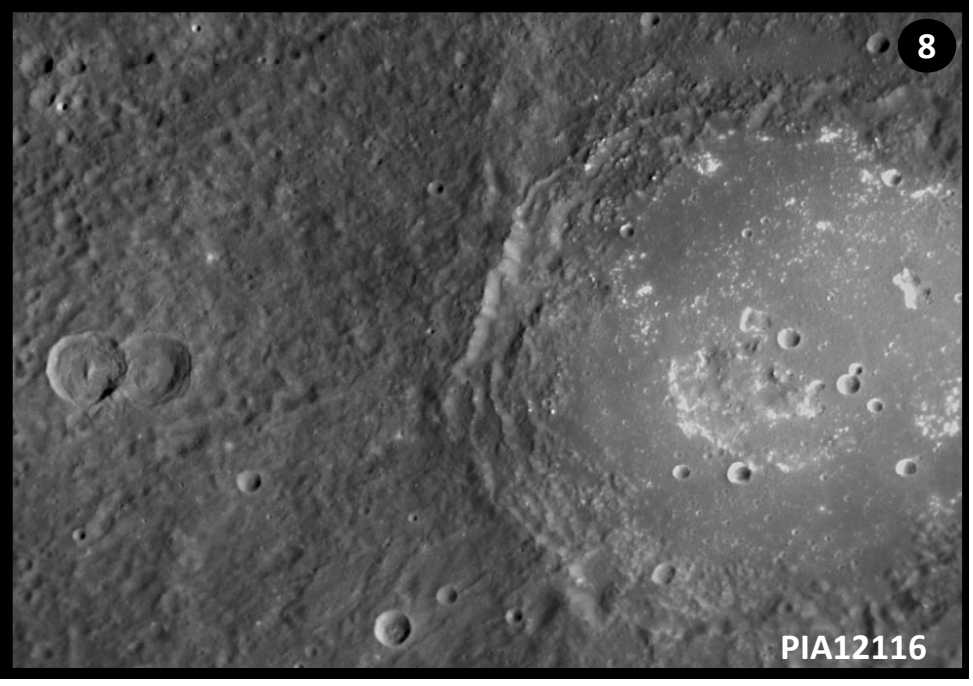

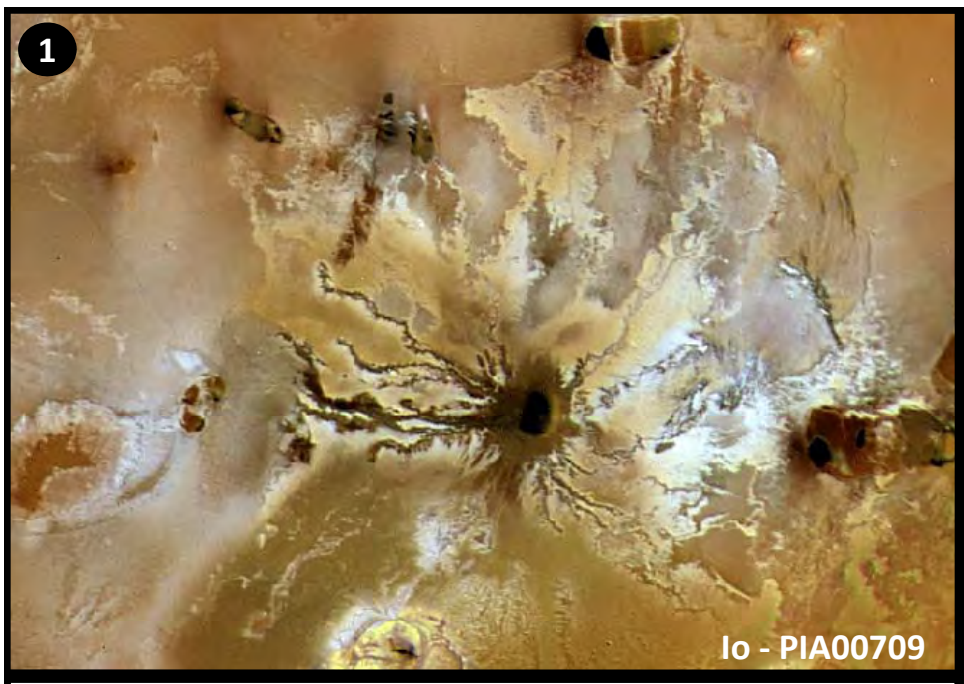

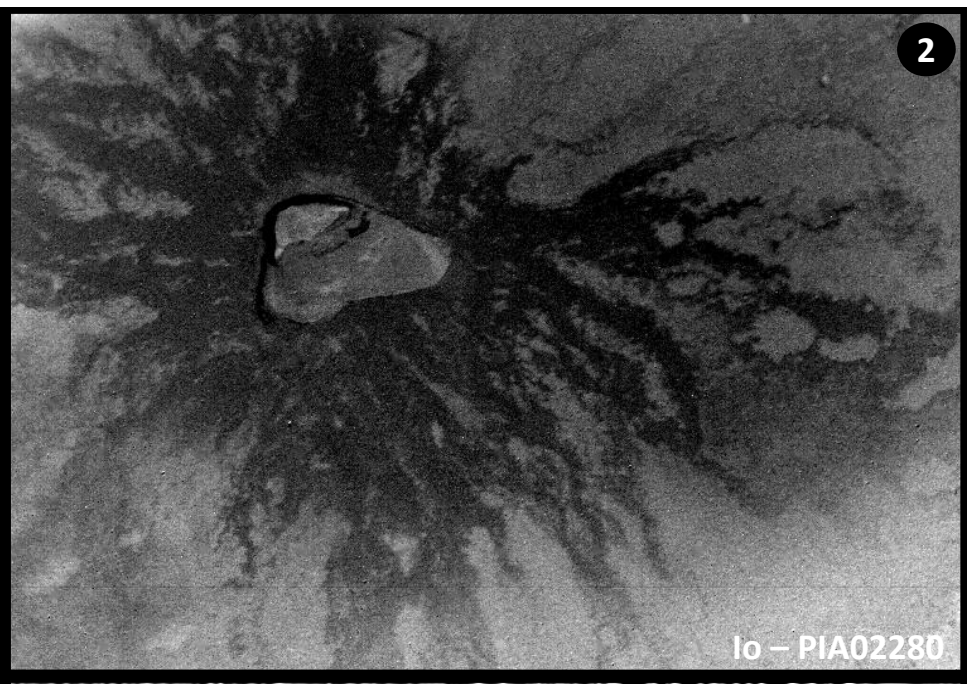

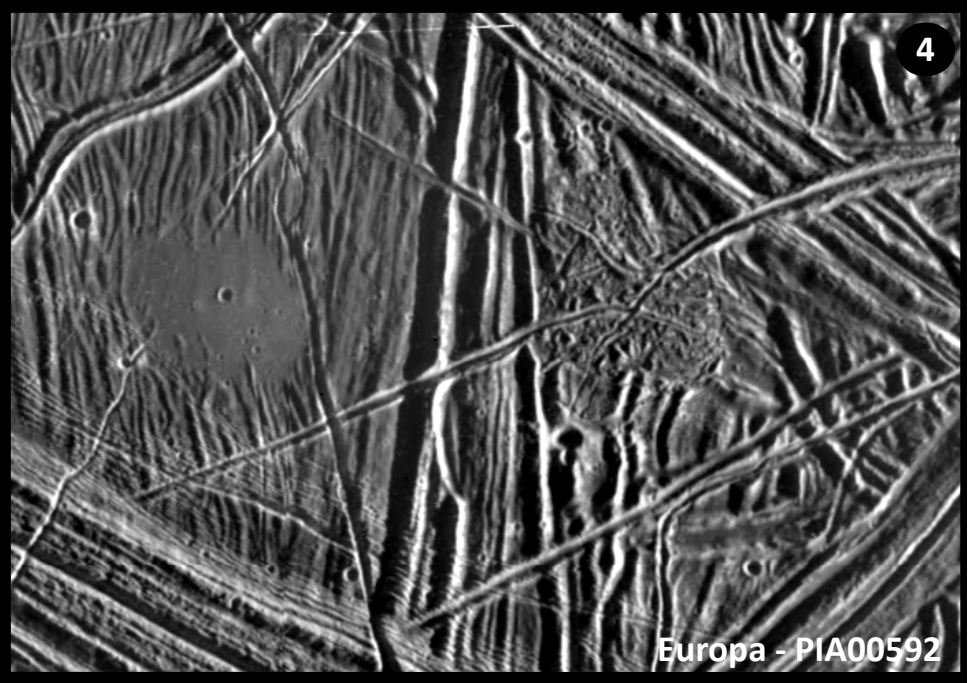

JOVIAN MOONS

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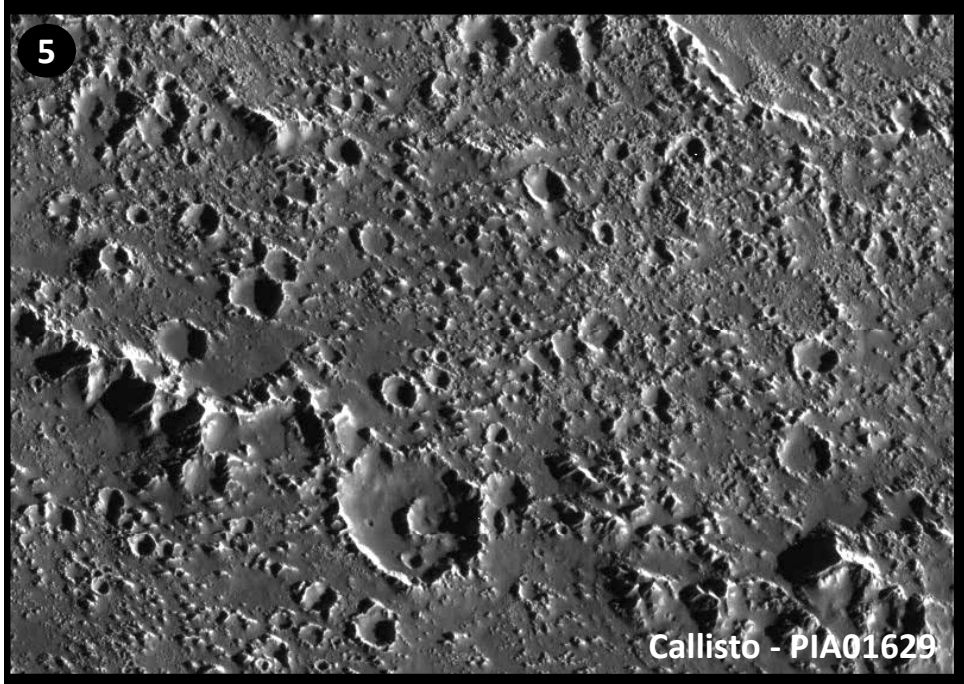

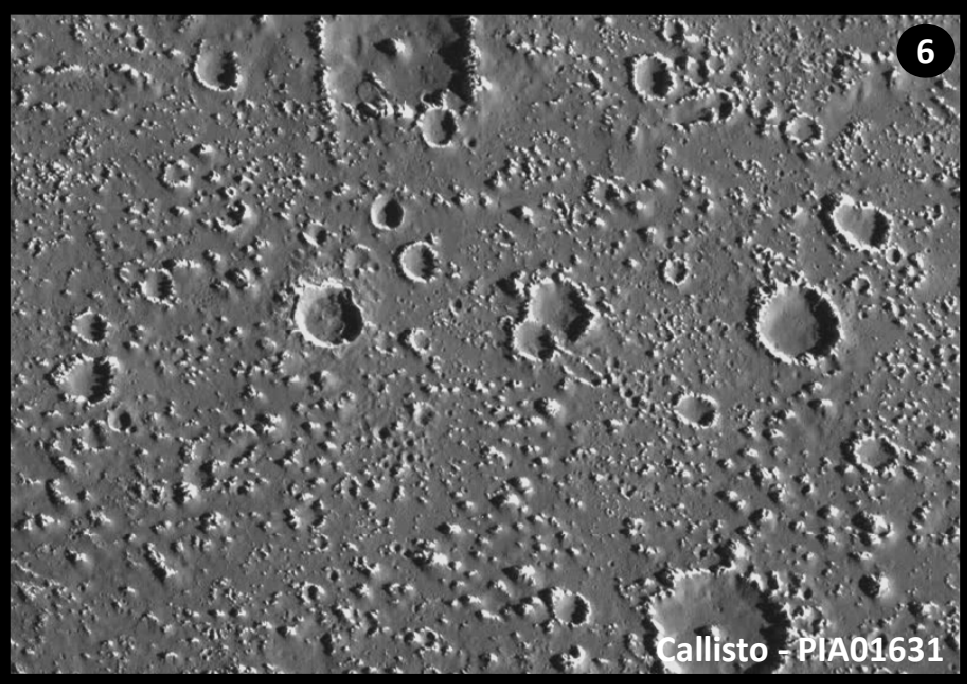

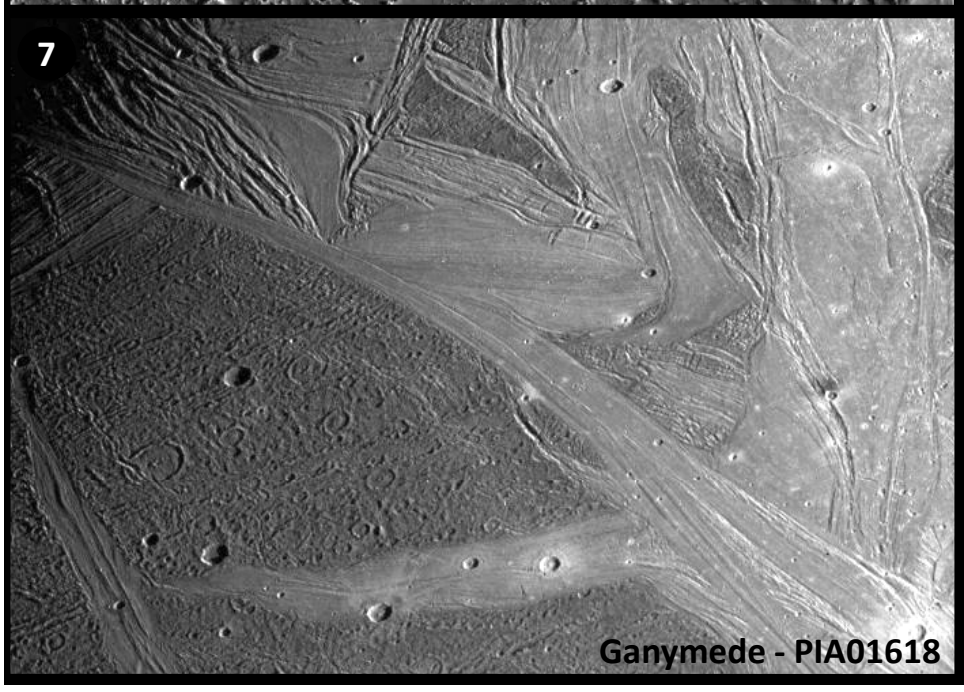

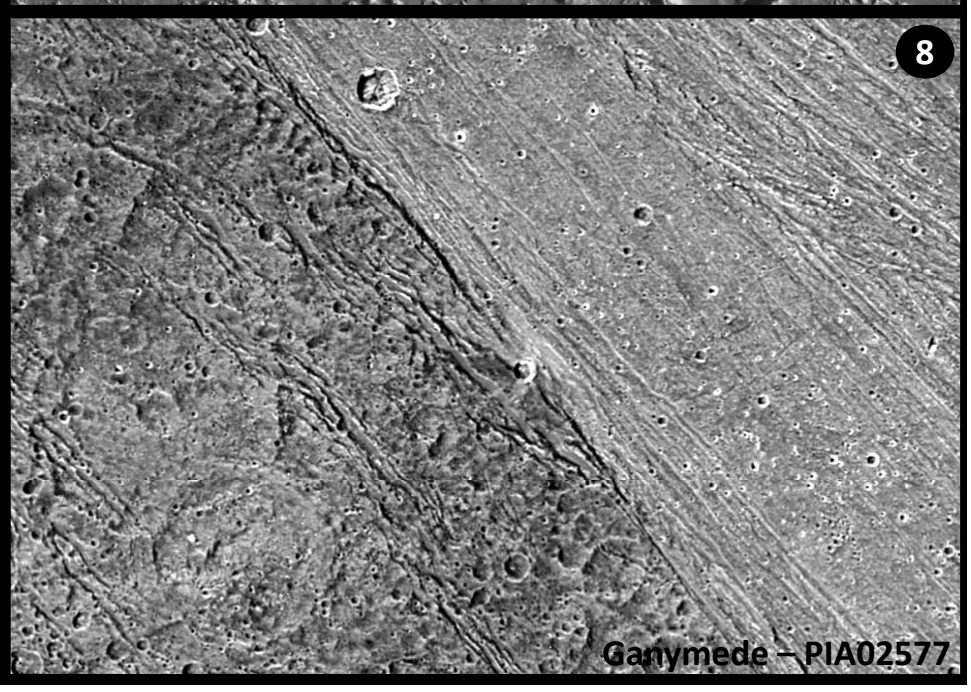

National Aeronautics and
Space Administration

BLUE MARBLE MATCHES

Using Earth for Planetary Comparisons

Part 1: Observations and Descriptions

NASA explores planetary bodies, including Earth, to better understand the Solar System in which we live. Various types of spacecraft and scientific instruments are used to explore and gather data. Scientists use the data returned from these spacecraft to make observations which they record, analyze, and interpret. One technique or process of gathering data from a distance using spacecraft, or even aircraft, is called remote sensing. Remote sensing allows you to gather data of a location you might not be able to visit in person.

One application of remote sensing is using images to identify geologic features on different planets. How do scientists determine what geologic features exist on other planets? This activity will help you understand part of that process. It starts with making good observations, being descriptive, and using what we know about Earth. For the first part of this activity, we will test your skills in how observant and descriptive you can be.

The remote sensing images of Earth you will observe in this activity were taken by astronauts from the International Space Station or Space Shuttle using hand held cameras. To begin, you will be given one image to observe and describe in the space below. As you write your description, do not name features or objects in the image. Instead, use descriptive words to describe what you see. Someone will attempt to identify the image you describe.

IMAGE DESCRIPTION **Use descriptive words to describe your image. Do not name features or objects.**

Now we will see how descriptive you were! A set of images will be shown to the class. You will read your description to other students to see if they can correctly identify your image. Discuss how you could improve image descriptions as you go through this process.

Based on your discussion with other students, list 3-5 useful characteristics or ways to describe features in images:

a.

b.

c.

d.

e.

So, what are these images all about? They are remote sensing images of Earth that focus on features related to four different geologic processes that help shape the surface of our planet. These processes are related to wind, water, volcanoes, and impacts (meteors striking the surface). Based on what you may know, do the following:

1. Discuss how you would group the images in pairs that relate to the same geologic process.
2. List which of the four given geologic processes you think created those features. Choose from wind, water, volcanic, or impact.
3. If you think you know the names of any features in these images, feel free to list your best guesses!

As you make your observations and discuss as a group, fill out the table below.

	IMAGES (use numbers 1-8)	**GEOLOGIC PROCESS** (Wind, Water, Volcanic, or Impact)	**FEATURE NAMES** (optional)
Group 1			
Group 2			
Group 3			
Group 4			

Now that you have an idea of how you can be descriptive and have some thoughts about the geologic processes related to the images you observed, let's investigate further. Did you know the names of these geologic features? Do you know how they form? Are these same features found on other planets in our solar system? How do scientists use what they know about Earth to explore other planets? This activity will help you understand and answer these questions. Let's explore!

Part 2: Identification Criteria

You will now make observations of other astronaut photographs of Earth. Your logged observations of these images will help you learn to identify specific features associated with different geologic processes (aeolian, impact, fluvial, and volcanic). The feature charts you will examine include images grouped by process. Information is included on the back of each image to help you. As you make observations, think about how each feature is formed and be prepared to select and create identification criteria for each feature in the tables below.

Once you have a feature chart, you will:

1. Make observations of the different geologic features visible in the images on the feature chart.
2. In the tables below, use 2 check marks for each column to indicate which **2 criteria** best describe **each** feature. Make changes or adjustments to listed criteria if you wish.
3. Create your own descriptions that can be used as other identification criteria for each feature.

AEOLIAN PROCESSES Features created by or associated with the effects of WIND			
IDENTIFICATION CRITERIA	**SAND DUNES**	**WIND STREAKS**	**YARDANGS**
Look like a smear across the surface			
Has a ripple-like appearance			
Look "cut into" the surface forming criss-crossing or parallel lines			
Sand-sized particles closely grouped together on the surface			
Look like a series of grooves scratched into the surface			
Look like a faint mixture of light or dark smudges on the surface			
Other:			
Other:			
Other:			

IMPACT PROCESSES Features created by or associated with a meteor striking the surface	
IDENTIFICATION CRITERIA	**IMPACT CRATER**
Circular feature that sometimes has a raised rim and a smooth, flat floor	
Flat, roundish feature that looks eroded and is sometimes filled in or outlined by water	
Other:	
Other:	

FLUVIAL PROCESSES Features created by or associated with the effects of WATER			
IDENTIFICATION CRITERIA	**CHANNEL**	**DRAINAGE NETWORK**	**DELTA**
Feature has a very dendritic-like pattern; similar to the vein-like pattern within a leaf			
Long extended feature that curves or meanders through an area; sometimes has two or three smaller channels connected to it			
Long windy feature that sometimes contains features such as U-shaped oxbow lakes, meander scars or tear-drop shaped island(s)			
Has a fan-like or triangular shape			
Sometimes looks like a triangle or birds foot where sediment is built up and deposited			
Numerous small channels or tributaries that feed into larger channels or valleys			
Other:			
Other:			
Other:			

VOLCANIC PROCESSES Features created by or associated with volcanic activity			
IDENTIFICATION CRITERIA	**VOLCANO**	**CENTRAL VENT/CALDERA**	**LAVA FLOWS**
Looks similar to an impact crater and is circular in shape			
An entire structure that includes a circular opening at the top and has flanks or sides			
An entire structure that may look raised and have a cone or dome or steeple-like shape			
Channel-like flow or fingery appearance with uneven edges			
Single or multiple circular depressions at the center or top of volcano			
Flow-like material that appears to be darker than the surrounding surface			
Other:			
Other:			
Other:			

Part 3: Feature Recognition and Review

The identification criteria you just developed should help you recognize these different geologic features in other images with confidence. You must use those criteria to support your identification of these features. Feel free to refine or add to your criteria as you continue with this activity.

In order to help reinforce and review your feature recognition skills you will receive a new set of images to observe. In the table below you will:

1. List identification criteria for the main feature shown in the image.
2. Based on your listed criteria, name the main geologic feature that best matches.
3. Name the main geologic process that helped form that feature.

As you discuss your answers, you may experience how scientists (both professionals and students) do not always agree! Scientific debate and using evidence to back up interpretations are key elements of science. Be open to changing your original identification of a feature if you can be convinced. It is not all about what answer is right or wrong. More importantly, it is about evidence that support your interpretation. Not all scientists agree, which is an important aspect of how science progresses.

Fill out the table below as you make observations of the images provided:

Image #	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)
1			
2			
3			
4			
5			
6			
7			
8			

Image #	Identification Criteria (list specific criteria from your identification criteria tables)	Main Geologic Feature	Main Geologic Process (aeolian, fluvial, volcanic, impact)
9			
10			
11			
12			
13			
14			
15			
16			

Part 4: Using Earth For Planetary Comparisons

Fill out the table below for the planetary body image chart you are given. Use the identification criteria you developed and refined for features on Earth. You must use those criteria as evidence to support your identification of these features. If there are characteristics that do not match your criteria for the feature on Earth or if you are making observations that cause you to be unsure about the identification of the feature, be sure to list those in the table. Based on your observations and how well your criteria match a given feature, list your level of confidence in the last column. Be ready to defend your identification or discuss your uncertainty.

As you discuss your answers, you will likely experience again how scientists do not always agree! Remember, scientific debate and using evidence to back up your interpretations are key elements of science. It is not all about what answer is right or wrong. More importantly, it is about evidence and criteria that support your interpretation!

PLANETARY BODY NAME:

Image # (use #'s 1 - 8 or 9 - 16)	**Identification Criteria** (list specific criteria from your identification criteria tables)	**Characteristics that DO NOT match Identification Criteria or Observations that Decrease Level of Confidence** (if any)	**Main Geologic Feature**	**Main Geologic Process** (aeolian, fluvial, volcanic, impact)	**Level of Confidence of Identified Feature** 1 = Not Confident 2 = Somewhat Confident 3 = Totally Confident

ADDITIONAL OBSERVATIONS, COMMENTS, OR QUESTIONS:

BLUE MARBLE MATCHES

Research Planning

Based on your observations of images, answer the following questions. This may help you get started on a possible research investigation.

1. List three visible features observed in images that interest you along with their associated geologic process. In the third column, indicate a specific aspect or characteristic of each feature you find interesting. An example has been provided for you.

Feature	Geologic Process	Aspect of feature that is interesting
Example: Sand dunes	***Aeolian***	***Color and shape of sand dunes***
1.		
2.		
3.		

2. Think about each of the features and aspects you listed above. Focus on <u>one</u> of those aspects and create a question that could be investigated further using astronaut photos and potentially other data. Include an explanation of what methods you would use to go about answering that question. Be as detailed as possible include what specific data/metadata you would want to log from each image observed. (Use additional paper if necessary.)

Feature Aspect	***Example:*** *Color and shape of sand dunes*	
Question	*Is there a relationship between the color and shapes of sand dunes and geographic location?*	
Explanation of Research Methods	*I would need to look at multiple images of sand dunes in different locations on Earth. I would log the image id#, the location of the image (latitude, longitude, country name and desert name), and log observations of the color of the dunes and also the shape of the dunes.*	