National Aeronautics and Space Administration

BLUE MARBLE MATCHES

Using Earth For Planetary Comparisons

5-E Activity
Teacher's Guide

Written and developed by Paige Valderrama Graff
Astromaterials Research and Exploration Science (ARES) Directorate, ARES Education Program,
NASA Johnson Space Center, Engineering Science Contract Group (ESCG)

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

Objectives: Students will:

1. Identify common descriptor characteristics used by scientists to describe geologic features in images.
2. Identify geologic features and how they form on Earth.
3. Create a list of defining/distinguishing characteristics of geologic features.
4. Identify geologic features in images of other planetary bodies.
5. List observations and interpretations about planetary body comparisons.
6. Create summary statements about planetary body comparisons.

Grade Level: 3* – 12+
(*see adaptations throughout the Teacher Guide for activity suggestions for younger students)

Time Requirements: 2 – 4+ class periods

Materials:

- Laminated Feature Charts:
  - Earth Features (4 pages)
  - Mars Feature Images (2 pages)
  - Venus Feature Images (1 page)
  - Moon Feature Images (1 page)
  - Other Planetary Body Feature Images (1 page)

  (Note: If you cannot laminate image pages, have students use post-it notes to label features.)
- Erasable Markers (1-4 markers per group)
- *Blue Marble Matches Student Guide*
- *Blue Marble Matches Teacher Guide*

National Science Standards:
CONTENT STANDARD A: Science as Inquiry
CONTENT STANDARD D: Earth and Space Science
CONTENT STANDARD E: Science and Technology
CONTENT STANDARD G: History and Nature 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 Home Page: http://www.nasa.gov
- Google Earth: http://earth.google.com/
- NASA Earth Observatory: http://earthobservatory.nasa.gov

Adaptations:

- Depending on the level of your students you may decide to focus on 1 Earth process at a time.
- Depending on the level of your students you may decide to conduct 1 planetary body comparison at a time.
- Adaptations for younger students are included as call out boxes within this Teacher Guide.

Extensions:

- Students can investigate other planetary bodies within our Solar system 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.
    - River Channels: Braided, drainage network, etc.
- 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 discuss the similarities and differences between Earth systems (atmosphere, biosphere, hydrosphere, litho/geosphere) and potential systems of other planetary bodies. Students can further research planetary bodies discussed in the activity and create their own illustration of the possible interrelated systems associated with these other bodies.
- Students can conduct their own authentic research project focusing on a geologic feature on Earth by participating in the Expedition Earth and Beyond project. Expedition Earth and Beyond facilitates classroom authentic research of Earth or planetary body comparisons. For more information contact Paige Graff at paige.v.graff@nasa.gov.

Introduction and Background

This activity allows students to model how scientists use what is known about Earth and apply that knowledge to understand geologic features and how they may form on other planetary bodies.

Many scientists who study the Earth use an Earth Systems Science approach. Our Earth is made up of different systems: the atmosphere, biosphere, hydrosphere and lithosphere sometimes referred to as the geosphere (see Figure 1 on page two 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 our 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.

Below is a table that describes the specific objectives of this activity and what section the objective will be introduced:

OBJECTIVES	ACTIVITY SECTION
Identify common descriptor characteristics used by scientists to describe geologic features in images.	Part 1
Identify geologic features and how they form on Earth.	Parts 1 and 2
Create a list of defining/distinguishing characteristics of geologic features.	Part 2
Identify geologic features in images of other planetary bodies.	Part 3
List observations and interpretations about planetary body comparisons.	Part 4
Create summary statements about planetary body comparisons.	Part 4

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 new 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 on the following page breaks down each phase of the 5-E model. The table 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 the learning outcomes of an activity.	Students 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 and explore images of Earth to identify visible geologic features.
Explanation	Students communicate and explain concepts they have been exploring. Students use formal language and vocabulary associated with content.	Students create a list of distinguishing characteristics of geologic features in images of Earth. Students use vocabulary previewed in the background information provided in Part 1 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 similar features in images of other planetary bodies and hypothesize about the formation of those features.
Evaluation	Teachers and students assess new knowledge and understanding of key concepts.	Students create a list of observations and interpretations to assess what they have learned about planetary comparisons. Students also list summary statements about what they have learned.

ACTIVITY PROCEDURE

This activity procedure is provided as a suggested guide for the *Blue Marble Matches* activity.

Part 1: Be Descriptive! (Engage Activity)

Materials needed:

- *Page 1 of the Blue Marble Matches Student Guide (for the initial part of the activity)*
- *Background Information: Pages 2 – 4 of the Blue Marble Matches Student Guide*

This engage activity will allow students to discuss ways of describing features (or objects) in an image without stating the names of objects they may be familiar with.

1. Have students in groups of 2-4 brainstorm how to describe the marble image provided. This will enable students to build on descriptive skills they may already have. Being able to describe features in images will be key throughout the activity.

2. Once students have brainstormed, have volunteer groups report their description to the class. After groups have stated their descriptions, discuss common ways students described objects or features in the image. If you can encourage students to categorize descriptor characteristics they used as size, shape, texture, position/orientation and color or tone that would reinforce the types of descriptor characteristics used by the students, but also used by scientists when describing features in images.

PART 1: ADAPTATION FOR YOUNGER STUDENTS

- Show the marble image and discuss it as a class.
- Ask direct questions to bring out useful descriptor characteristics. For example,
  - What shapes do you see in the image?
  - Tell me about the colors in the image.
  - How can you describe where the yellow round object is compared to the red round object?
  - Are all the round objects in the image the same size or is one larger or smaller than the other?

You can reinforce to students that they used size (relative size), shape, position, color, texture (whichever you discussed) to describe the image. These are the same types of descriptions scientists use to describe objects or features in images.

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.

Background information is provided on each of following sections:

- *Defining Characteristics of Geologic Features:* Reinforces types of descriptive strategies you can use to describe features.

- *Earth Processes and Geologic Features*: 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. Additional information is provided that focuses on features associated with the litho/geosphere. General information is provided on aeolian, volcanic, impact, and fluvial processes, associated features, and how they form on Earth.

- *Using Features on Earth to Learn About Other Planetary Bodies:* Reinforces to students about how scientists use their knowledge of the formation of features on Earth to hypothesize about features and how they may form on other planetary bodies.

BACKGROUND INFORMATION: ADAPTATION FOR YOUNGER STUDENTS

For younger students you may want to go over very basic information such as:

- *Defining Characteristics of Geologic Features:* Let students know that scientists describe features they see in images of Earth using the same words they used to describe the image of the marbles: size (relative size), shape, position, color, and texture.
- *Earth Processes and Geologic Features*: Discuss with students different factors or forces that affect the surface of the Earth such as: 1)Wind, 2)Water, 3)Volcanoes, and 4)Meteors from space.
- *Using Features on Earth to Learn About Other Planetary Bodies:* Let students know scientists compare what we see on Earth to features we see on other planets and moons (planetary or terrestrial bodies).

Part 2: Distinguishing Characteristics (Explore and Explain)

Materials needed:

- *Pages 2 – 7 of the Blue Marble Matches Student Guide*
- *Earth Features Charts (Aeolian Features, Volcanic Features, Fluvial Features, Impact Features)*
- *Erasable markers*

After reading and discussing the background information students should be ready to look at the categorized images of Earth and identify features. On the back of each Earth image there are 4 pieces of information provided:

a. A title of the image (main features and country) and the image identification number.
b. A global view of Earth with a circle representing the general area of where the image is located.
c. General information about the image.
d. A list of DOMINANT FEATURES IN IMAGE to allow students to more easily identify features in the image.

1. Distribute the *Earth Features Charts* to students groups of 2-4 and briefly discuss how each image chart is organized. Each image chart is categorized by geologic process. Depending on the level of your students you may decide to provide each group of 2-4 students with only one *Earth Features Chart* at a time.

Each *Earth Features Chart* is entitled with the name of the general geologic process associated with the types of features being illustrated. There are 4 *Earth Feature Chart* categories: Aeolian, Volcanic, Fluvial, and Impact Features.

2. Have students identify features on the laminated images using the erasable markers. Students should be able to label features based on the descriptions given on the back of each image.

3. Once student groups have identified features in the categorized *Earth Feature Chart* images, have them create a list of distinguishing characteristics to identify each geologic feature listed on the tables provided. Students should provide information based on the characteristics they feel are appropriate for the description. These may include size, shape, texture, position/orientation, and color/tone. The distinguishing characteristics should be based on their overall observations of each feature from all the images they observed.

   In the *Student Guide* there is a table that includes features associated with each process (aeolian, volcanic, fluvial and impact). Students should create a list of distinguishing characteristics for each feature listed as well as any other feature they wish to include, provided that it is related to the overall geologic process.

   Aeolian Processes table with sample description of sand dunes included:

AEOLIAN PROCESSES	
Feature	**Distinguishing Characteristics**
Sand Dunes	• *Vary in size and shape* • *Sometimes line up in rows or have a parallel formation* • *Have a ripple like appearance* • *Tanish in color*
Wind Streaks	

4. If you gave different groups of students individual *Earth Feature Charts* to work with, you should have students present their distinguishing characteristics of associated features to the class. If each group had all 4 *Earth Feature Charts*, you should discuss the distinguishing characteristics of each geologic feature with the class as a whole. Students can refine their lists as they wish. There are no "correct" distinguishing characteristics answers. As long as students described the features using some of the descriptor characteristics (size, shape, etc.) their list of distinguishing characteristics should be acceptable.

As you discuss feature characteristics, reinforce with students how each feature forms. This information will be used as they work on Part 3 of the activity.

PART 2: ADAPTATION FOR YOUNGER STUDENTS

- For younger students you may want them to make observations of one category of *Earth Features* at a time.
- Without naming feature, have students identify features that *look* the same using different colored erasable markers. They do not need to identify all features included in the activity.
- Once students identify features you can discuss what aspects of those features looked the same or different (color, shape, etc.). After the discussion you can give students the geologic names of the features.

Part 3: Using Earth For Planetary Comparisons (Elaborate)

Materials needed:

- *Pages 8 – 12 of the Blue Marble Matches Student Guide*
- *Planetary Body Feature Charts (Moon, Mars, Venus, Other Planetary bodies)*
- *Erasable markers*

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. Depending on the level of your students, you can have each group of students work on one or more planetary body image comparisons.

1. Distribute the *Planetary Body Feature Charts* to each group of students. Make sure students take note of which planetary body/bodies they are working with. There are two feature charts for Mars, and one for the Moon, Venus and Other Planetary Bodies. The Other Planetary Bodies chart includes images of Mercury and 4 Jovian Moons (Io, Europa, Ganymede, and Callisto). Images have been cropped to focus on specific features.

2. Have students use their created list of distinguishing characteristics to identify features on these other planetary bodies. As they identify features they should fill out the provided table for the appropriate planetary body. The table should include the following:
   a. Feature: The name of the feature they have identified
   b. Formation hypothesis: Students can base this on what they know about how the feature forms on Earth. If they have other background knowledge about a particular planetary body and the formation of features they can include that information.
   c. Uncertainties/questions or comments about hypothesis: Students can write in any questions, uncertainties, or comments they may have about the formation hypothesis. This portion of the table is to allow students to think about what they know or don't know about another planetary body. Allowing students to comment or question a hypothesis allows them to engage in critical thinking.

Below is a sample *Mars Features* table with a description of two identified features included. These list of features do not have to be organized by process as not all planetary bodies will have features from each process (Aeolian, volcanic, fluvial, impact).

MARS FEATURES		
Feature	**Formation hypothesis**	**Uncertainties/questions or comments about hypothesis**
Sand Dunes	*Sand dunes form when wind blows sand-sized particles into a mound(s).*	*Does this mean Mars has an atmosphere?*
River Channels	*River channels form by water flowing through an area.*	*I don't know if there is or ever was water on Mars so I'm not sure if these channels were formed by water.*

PART 3: ADAPTATION FOR YOUNGER STUDENTS

- For younger students you may want to use one *Planetary Body Feature Chart* at a time and have students identify features that *look* the same as features they saw on Earth.
- Students can name these features based on the names they used for the Earth features.
- Discuss with students what general factor or force may have created the features they identify.

Part 4: Observations and Interpretations (Evaluate)

Materials needed:

- *Pages 13-14 of the Student Guide*

Students should now have a good sense of features found on Earth as well as similar features that are found on other planetary bodies. For this part of the activity they will put together some summarizing thoughts based on what they have learned. The first section of part 4 focuses on observations and interpretations. These require higher order thinking skills and may be difficult for some students. The last section asks students to create summary statements.

1. Discuss with students the whole idea of observations and interpretations. The call out box in the Student Guide gives students a simple example/scenario to help them understand how to create observations and interpretations. The table below the given example/scenario provides leading questions to allow students to think about what they have observed. Students should answer each question and then indicate what they think it may mean. There are no correct or incorrect answers for the Potential Interpretations section of the table as long as students relate their interpretation to the observation. There are also two areas within the table for students to write in their own observations and interpretations. These can be optional based on your level of students.

Sample Observations and Potential Interpretation(s) table:

OBSERVATIONS: (fill in missing information)	**POTENTIAL INTERPRETATION(S):** What does/could that mean?
1)_____*Impact Craters*_____ is the most common feature found on the planetary body images observed.	• *No planetary body is safe from meteors (space junk) flying around in space.* • *Meteors can slam into the surface of a planet whether it has an atmosphere or not.*
2)_____*Mars*_____ (list the planetary bodies) show evidence of wind related (aeolian) features?	• *Mars is the only other planetary body (that we looked at) that has an atmosphere.* *-OR-* • *Mars is the only other planetary body (that we looked at) that has wind.*
3)_____ (list the planetary bodies) show evidence of water related (fluvial) features?	
4)_____ (list the planetary bodies) show evidence of volcanic related features?	

2. Once students have created their observations and interpretations, have them write 3-5 summary or concluding statements. These should summarize what they have learned about planetary comparisons.

Sample Conclusions/Summary Statements:

CONCLUSIONS/SUMMARY STATEMENTS
1. *Most planetary bodies have been affected by impacts.*
2. *Moons and other planets have volcanoes.*
3. *Volcanoes can have different shapes and sizes.*

PART 4: ADAPTATION FOR YOUNGER STUDENTS

- Discuss summary statements or questions that students can answer based on the observations they have made. These summary statements should be simple. For example:
  - What round feature is found on almost all planetary bodies in the solar system?
  - Name which planets or moons in the solar system have volcanoes on them?

Alternatively, you can ask students to state something they learned from the activity.

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. Each image is labeled with an image identification or the name of the camera or spacecraft that acquired the image.

As students identify features on other planetary bodies (Mars, Moon, Venus, etc.) as long as they have a justification for their identification of a feature their answers should be accepted. This lesson does not go into every detail of every geologic process, therefore, based on the knowledge of the students/teachers and the distinguishing characteristics created, most answers should be accepted.

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. The 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. These 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.

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.

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. 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. Images PIA00084, PIA00485 are of pancake dome volcanoes.

Other Planetary Body Images: Images of the following "other planetary bodies" have been included:

- Mercury: There are 4 images of Mercury provided that 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.

- Moons of Jupiter (Jovian Moons): One image from 4 different Jovian Moons are included in this activity. These moons are terrestrial and have features that have intrigued many and that 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. The linear-like features on Europa and Ganymede may be related to ice.

There are many other terrestrial planetary bodies (planetary moons, asteroids, etc) within our solar system that students could also investigate. For additional images go to:

- Gateway to Astronaut Photography: http://eol.jsc.nasa.gov
- Planetary Photojournal: http://photojournal.jpl.nasa.gov
- NASA Home Page: http://www.nasa.gov

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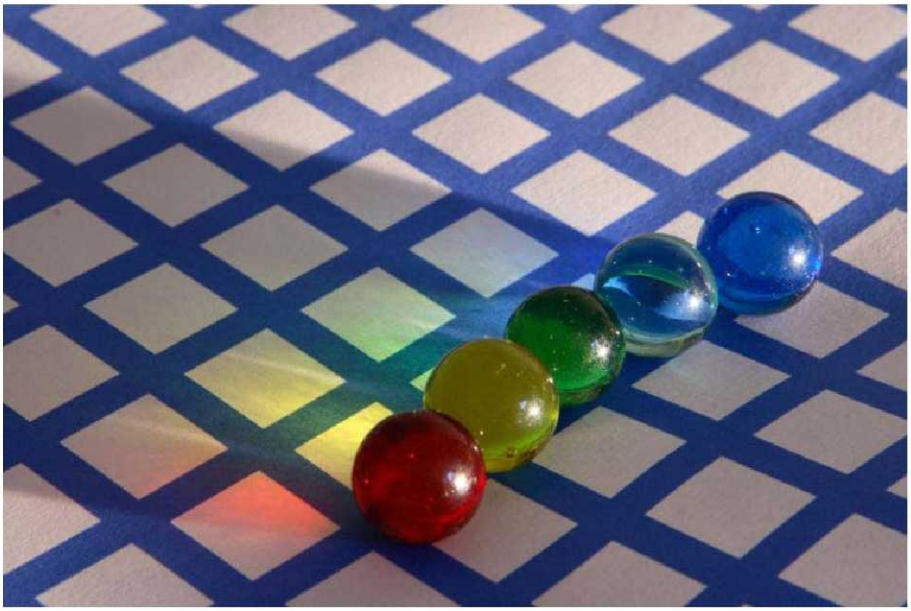
BLUE MARBLE MATCHES

Using Earth for Planetary Comparisons

Part 1: Be Descriptive!

Write a description of what you see in the image below. Do not name the objects that you see, rather describe the characteristics of the different features in the image.



http://en.wikipedia.org/wiki/Marbles

IMAGE DESCRIPTION

As you perhaps experienced in the first part of this activity, if you are asked to describe the characteristics of something you are familiar with, you might want to simply name the object(s) you see. Being able to describe the characteristics of an object or a feature however, requires you to use specific descriptor words. In your group, discuss useful ways you can use to describe objects or features in an image.

BACKGROUND INFORMATION

Defining Characteristics of Geologic Features

Scientists comparing geologic features on Earth in order to study other planetary bodies in our solar system need to have criteria to identify these features. These criteria are based on defining characteristics. Just as you discussed useful descriptor words to describe the image on page one, scientists use the following set of descriptor characteristics to describe geologic features in images.

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 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, oval, square, etc.

3. **Texture:** Features can be described as having a certain texture in appearance.
   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.

Keep in mind that geologic features are never exactly the same, but most will have similar distinguishing characteristics. Be sure to remember and use the suggested descriptor characteristics above when you create your list of distinguishing characteristics of geologic features later in this activity.

Earth Processes and Geologic Features

Scientists who study the Earth oftentimes study it using an Earth Systems Science approach. Our Earth is made up of different systems: the atmosphere, biosphere, hydrosphere and lithosphere sometimes referred to as the geosphere (see Figure 1). These different Earth systems are interrelated and combined make up our unique planet. The past, present, and future of our planet is based on this constant interaction of systems.

This activity will focus on geologic features that are part of the litho/geosphere. Keep in mind, however that other systems play a role in the formation of geologic features. What about other planetary bodies? Do they have any of these systems?

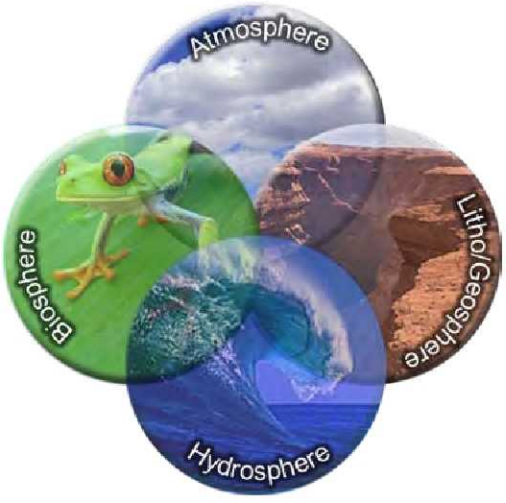


Figure 1: Earth's interrelated systems

Other terrestrial (rocky) bodies in our solar system (the Moon, Mars, Venus, etc.) have many similarities and differences compared to Earth and its systems. These other rocky planetary bodies all have a lithosphere – they have rocks -- but they may not have the other systems that make up our 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. To keep this lesson focused, we will look at geologic features (litho/geosphere).

Scientists today have discovered so much about the Moon, Mars, and other planetary bodies in the solar system. How do they study these terrestrial bodies? How do scientists know if what they hypothesize about these places is correct? They must rely on knowledge and facts from a known source. What terrestrial body do we know a lot about that we can use as a comparison for studying other planetary bodies in our solar system? The answer lies in the blue marble we live on – our Earth.

Scientists have used Earth as a laboratory to learn how systems and processes work. There is still much to learn about Earth, however, what we do know we can apply to learn about other terrestrial bodies in our solar system. As we learn more about these other terrestrial bodies, we inevitably learn more about our Earth as well.

The information below is listed to help you understand four different types of geologic processes on Earth and features associated with them. You will be asked to apply this information later to hypothesize how similar features found on other planetary bodies may have formed.

AEOLIAN PROCESSES: Features created by or associated with the effects of wind.

- 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: A feature formed when wind blows sand or dust-sized particles off the surface.
- Yardang: A ridge or multiple ridges formed by sand-sized particles eroding exposed rock.

VOLCANIC PROCESSES: Features created by or associated with volcanic activity.

- Volcano: 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 escapes 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 are more explosive eruptions and include tephra (gas and rock) that is emitted into the atmosphere.

IMPACT PROCESSES: Features created by or associated with a meteor striking the surface.

- Impact Crater: A circular depression in the surface formed by the result of a meteor striking the surface at a high velocity.
- Central Peak or Uplift: A feature found at the center of an impact crater formed during the impact event. 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.

- River channel: A feature created by water flow. River channels can vary in size and shape and generally meander in a snake-like shape following the topography. Multiple small river channels can often feed into larger ones.
- Oxbow lake: A feature created when a meander of a river is cut off and forms a U-shaped body of water.
- Delta: A feature formed by the deposition of sediment that builds up where the mouth of a river flows into another body of water or onto an arid plain (inland delta).

The features listed above are not the only features associated with each process. There are other features you may identify as you work through this activity. The listed features above will give you a starting point to learn about different processes that affect our Earth and other planetary bodies.

Using Features on Earth to Learn about Other Planetary Bodies

Scientists use what they know about the formation of features on Earth to hypothesize about what may be happening on other planetary bodies with the same or similar features. This is called planetary comparisons. As scientists make planetary comparisons, they take into account what they know about these other planetary bodies. These allow them to put together the pieces and gain a greater understanding of processes that are currently or have potentially affected the planetary surface. When making planetary comparisons, scientists need to build evidence to support their hypotheses. They cannot assume that a certain processes may have occurred just because it looks like a feature on Earth. They must consider alternate hypotheses based on what is known about these other planetary bodies.

Part 2: Distinguishing Characteristics

Now you will start making observations of images and learn to identify features associated with different geologic processes (aeolian, impact, fluvial, and volcanic processes). You will use the observations you make of features to create your own list of distinguishing characteristics.

Using the images, written text and erasable markers for this part of the activity you will:

1. Examine the images of Earth you have been given. Images are grouped into categories representing different processes.
2. Label geologic features you can identify on each image.
3. After identifying features in the images provided, think about the common and distinguishing characteristics of each feature. Create a list of distinguishing characters of the features listed in the tables below. Additional features can be included.

AEOLIAN PROCESSES	
Feature	**Distinguishing Characteristics**
Sand Dunes	
Wind Streaks	
Yardangs	
Other?_____	

IMPACT PROCESSES	
Feature	**Distinguishing Characteristics**
Impact Craters	
Central Uplift/Peak	
Other?_____	

FLUVIAL PROCESSES	
Name of Feature	**Distinguishing Characteristics of Feature**
River Channels	
Oxbow Lakes	
Deltas	
Other?_____	

VOLCANIC PROCESSES	
Feature	**Distinguishing Characteristics**
Volcanoes	
Central Vent/ Caldera	
Lava Flows	
Ash Flows/Plume	
Other?_____	

Part 3: Using Earth For Planetary Comparisons

Now that you have identified distinguishing characteristics of features found on Earth, you will now start making observations of images from other planetary bodies (the Moon, Mars, Venus, Mercury, and Jovian Moons (Io, Europa, Callisto, and Ganymede). As you observe the images, look for geologic features you can identify.

Using the images provided, for this part of the activity you will:

1. Examine the images provided.
2. Label geologic features you can identify on each image. (Use your created list of distinguishing characteristics of geologic features as a guide.)
3. After identifying features in the images provided, think about the features you have identified on each planetary body and fill out the tables below. As you fill out the tables be sure to include the following information:
   a. Feature: Based on your list of distinguishing characteristics, name each feature you are able to identify for each planetary body.
   b. Formation hypothesis: Based on what you know about how this features forms on Earth, how might it have formed on this planetary body?
   c. Uncertainties/questions or comments about hypothesis: What questions or uncertainties do you have about this hypothesis? Think about what you may (or may not) know about the planetary body and if the formation hypothesis doesn't seem to make sense.

As you fill out the tables below, think about what evidence you would need to support the formation hypothesis of each feature. This is something scientists consider as well. As mentioned earlier, just because a feature on another planetary body may look the same as a feature found on Earth, that does not mean it formed (or forms) the same way.

MARS FEATURES		
Feature	**Formation hypothesis**	**Uncertainties/questions or comments about hypothesis**

Continue on the next page

MARS FEATURES		
Feature	**Formation hypothesis**	**Uncertainties/questions or comments about hypothesis**

MOON FEATURES		
Feature	**Formation hypothesis**	**Uncertainties/questions or comments about hypothesis**

VENUS FEATURES		
Feature	**Formation hypothesis**	**Uncertainties/questions or comments about hypothesis**

OTHER PLANETARY BODY FEATURES		
Feature (also name planetary body)	**Formation hypothesis**	**Uncertainties/questions or comments about hypothesis**

Part 4: Observations and Interpretations

As part of the process of science, all scientists make observations and interpret those observations to gain a better understanding of what they are studying. Observations are general trends or patterns or identified features that almost everyone can agree upon. Interpretations on the other hand are what you think that may mean. You may have multiple potential interpretations but in the end you will base your conclusions on those interpretations you feel most strongly about. Interpretations can vary from scientist to scientist.

Here is a simple example/scenario:

It is Monday 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 dispute this observation. As you think about your observation, you think about what this could mean (potential interpretations). Based on what you know, your potential interpretations might be: *The teacher is sick -OR- the teacher has a meeting with the principal -OR- the teacher is running late.* In the end, you may conclude that you will have a substitute for the day. This conclusion may or may not be true, but it is what you conclude based on your observations, your knowledge, and your interpretations.

In this part of the activity you will:

1. State observations and potential interpretations of those observations using the tables below.
2. List conclusions or summary statements on planetary body comparisons.

OBSERVATIONS: (fill in missing information)	**POTENTIAL INTERPRETATION(S):** What does/could that mean?
1)_____ is the most common feature found on the planetary body images observed.	
2)_____ (list the planetary bodies) show evidence of wind related (aeolian) features?	
3)_____ (list the planetary bodies) show evidence of water related (fluvial) features?	
4)_____ (list the planetary bodies) show evidence of volcanic related features?	

OBSERVATIONS: (fill in missing information)	**POTENTIAL INTERPRETATION(S):** What does/could that mean?
5)_____ (list the planetary bodies) show evidence of impact related features?	
6)_____ (list the planetary bodies) show evidence of water related (fluvial) features?	
(create your own)	
(create your own)	

Based on your observations and potential interpretations, list three to five conclusions or summary statements about planetary body comparisons.

CONCLUSIONS/SUMMARY STATEMENTS
1.
2.
3.
4.
5.


ISS017-E-020929


ISS010-E-13539


ISS016-E-6986


STS040-17-26

Expedition Earth and Beyond
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NASA Johnson Space Center

EARTH
AEOLIAN FEATURES


ISS012-E-09638


ISS018-E-005746


ISS016-E-16058

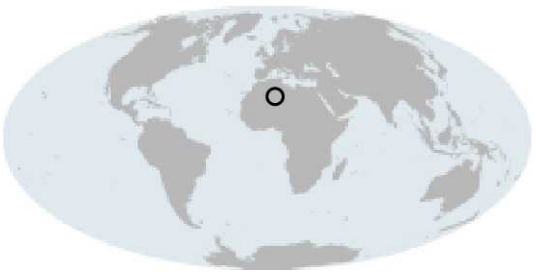

ISS013-E-18533

EARTH

AEOLIAN FEATURES

SAND DUNES IN ALGERIA

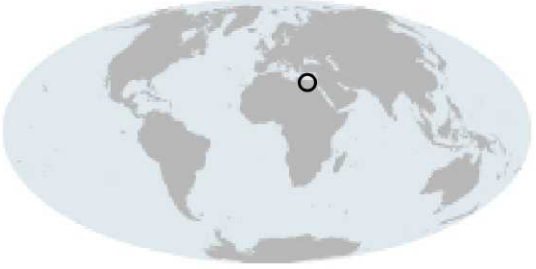
Image ID#: ISS010-E-13539



- This astronaut image gives a view of a large sand sea, called the Issaouane Erg, located in eastern Algeria. This area is considered part of the Sahara desert.
- Occasional rain fills basins with water, leaving salt deposits behind when the water evaporates (seen as bluish-white areas).
- DOMINENT FEATURES IN IMAGE: Sand dunes

SAND DUNES IN EGYPT

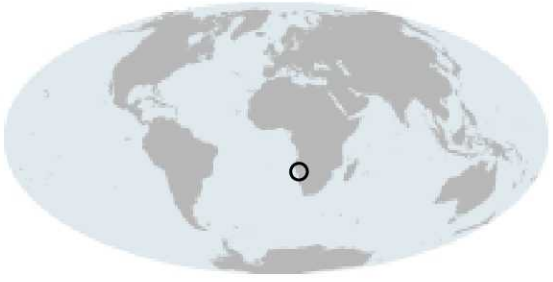
Image ID#: ISS017-E-020929



- This astronaut image gives a view of an area almost completely covered in sand dunes. The image was taken in the northern part of Egypt. This area, west of Cairo, is part of the Sahara Desert.
- DOMINENT FEATURES IN IMAGE: Sand dunes, clouds

YARDANGS IN NAMIBIA

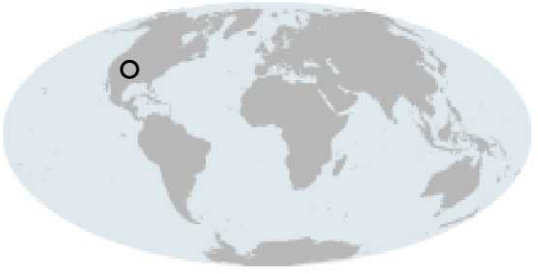
Image ID#: STS040-17-26



- This astronaut image is taken of yardangs in an area along the northern coast of Namibia in Africa called the Skeleton Coast.
- DOMINENT FEATURES IN IMAGE: Yardangs, coastline

SAND DUNES IN THE U.S.A.

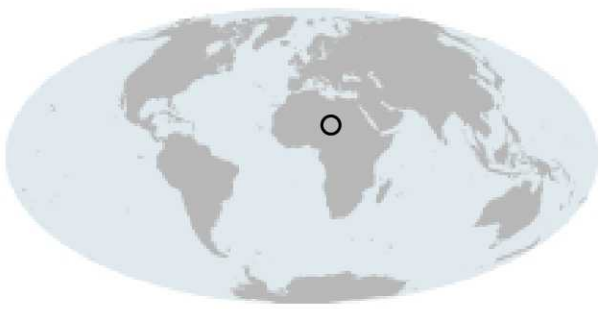
Image ID#: ISS016-E-6986



- This astronaut image is taken of the Sangre de Cristo Mountains and sand dunes located in the Great Sand Dunes National Park in south-central Colorado, USA.
- The mountains are outlined by dark green forests at lower elevations and white, snow-capped peaks at the highest elevations.
- DOMINENT FEATURES IN IMAGE: Mountains, sand dunes, forests

YARDANGS & WIND STREAKS IN CHAD

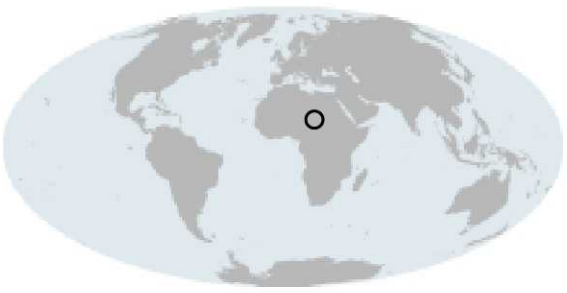
Image ID#: ISS018-E-005746



- This astronaut image is taken of a the Aorounga impact crater (also seen in image ISS012-E-09638 from a different perspective). This crater and the general area has been modified by yardangs and windstreaks. This is located on the Tibesti mountains in Chad.
- DOMINENT FEATURES IN IMAGE: Yardangs, wind streaks, impact crater

YARDANGS & IMPACT CRATER IN CHAD

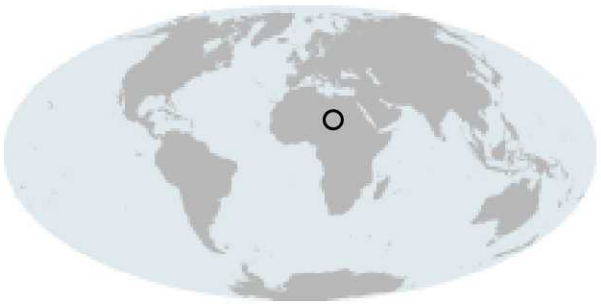
Image ID#: ISS012-E-09638



- This astronaut image is taken of a multi-ringed impact crater called Aorounga that has been modified by numerous yardangs. The Aorounga crater is located to the southeast of Emi Koussi (a volcano not seen in this image) on the Tibesti mountains in Chad.
- DOMINENT FEATURES IN IMAGE: Impact crater, central peak, yardangs

WIND STREAKS IN SUDAN

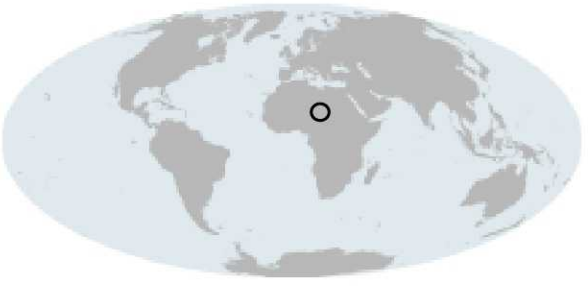
Image ID#: ISS013-E-18533



- This astronaut image showing numerous wind streaks is taken of an area affected by strong winds in the northern part of Sudan.
- DOMINENT FEATURES IN IMAGE: Wind streaks

YARDANGS & WIND STREAKS IN 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.
- DOMINENT FEATURES IN IMAGE: Channel, wind streaks, yardangs


ISS012-E-15035


ISS007-E-14816


ISS012-E-13327


ISS010-E-5070

EARTH
FLUVIAL FEATURES

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ISS005-E-10926


ISS015-E-07649

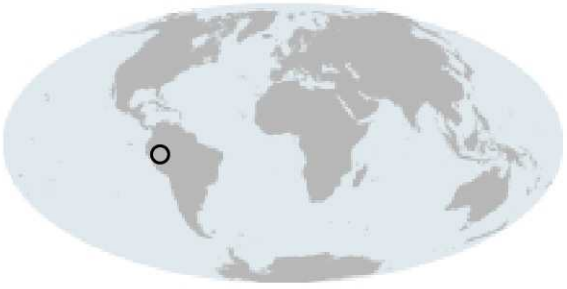

STS059-213-65


STS077-718-56

EARTH
FLUVIAL FEATURES

RIVER CHANNELS IN PERU

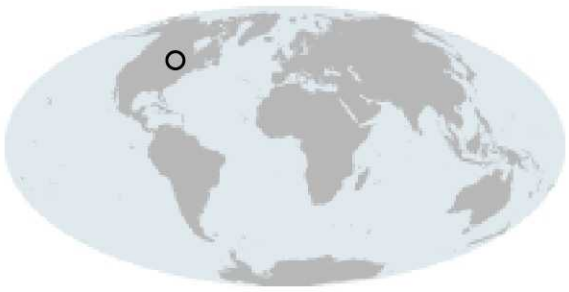
Image ID#: ISS007-E-14816



- 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.
- DOMINENT FEATURES IN IMAGE: River channel, oxbow lakes, meander scars

RIVER CHANNELS IN THE U.S.A.

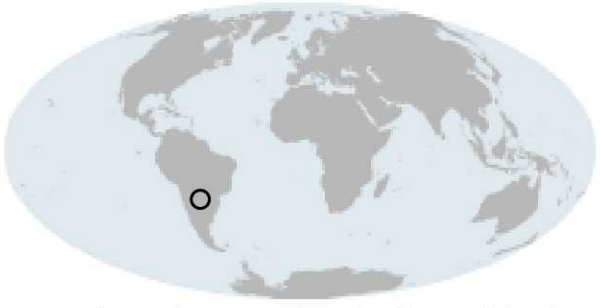
Image ID#: ISS012-E-15035



- This astronaut image is centered on the location where the Ohio and Mississippi Rivers converge near the small city of Cairo, Illinois, USA. The Ohio River, on the left, is brownish in color because of the sediments flowing downstream. The Mississippi River, on the right, is green and relatively sediment poor.
- DOMINENT FEATURES IN IMAGE: River channels, agricultural fields

RIVER CHANNEL IN ARGENTINA

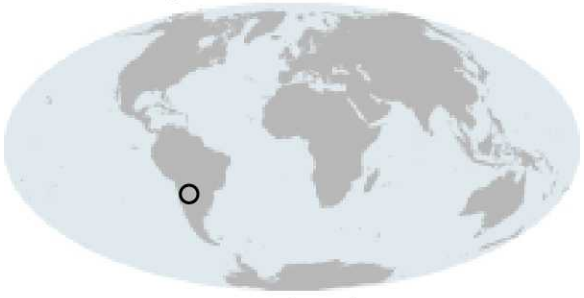
Image ID#: ISS010-E-5070



- 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.
- DOMINENT FEATURES IN IMAGE: River channel, urban area, channel islands, meander scars

RIVER CHANNELS IN ARGENTINA

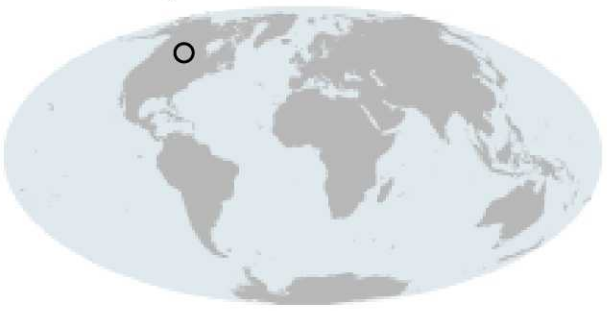
Image ID#: ISS012-E-13327



- 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.
- DOMINENT FEATURES IN IMAGE: River channel, oxbow lakes, forests, agricultural areas

DELTA IN CANADA

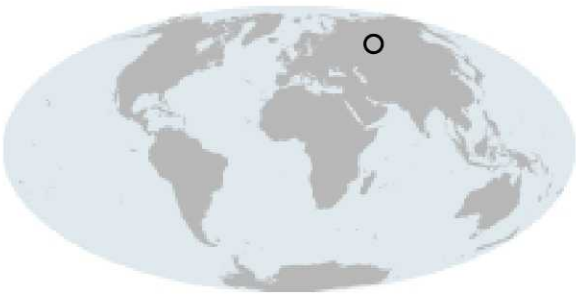
Image ID#: ISS015-E-07649



- This astronaut image highlights a portion of the Saskatchewan River delta extending into Cedar Lake in the Province of Manitoba, Canada. Shallow muddy lakes are dark green to gray colored areas. Sediment deposits are light tan to gray colored areas.
- DOMINENT FEATURES IN IMAGE: Delta, river channels

RIVER CHANNELS IN HUNGARY

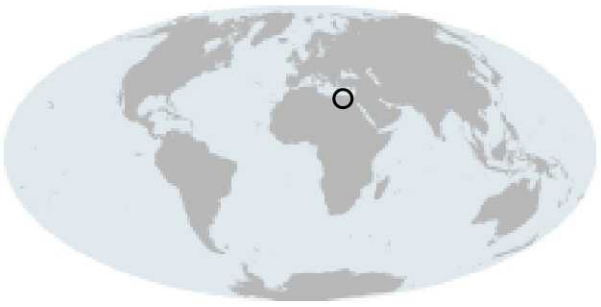
Image ID#: ISS005-E-10926



- This astronaut image is centered on part of the Danube River just north of Budapest near the city of Vac, Hungary.
- DOMINENT FEATURES IN IMAGE: River channels, urban area, agricultural fields

DELTA IN EGYPT

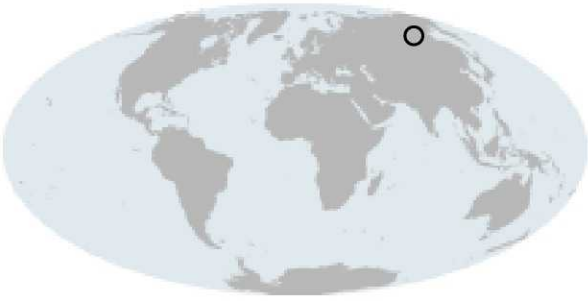
Image ID#: STS077-718-56



- 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.
- DOMINENT FEATURES IN IMAGE: Delta, river channel, sea, clouds

DELTA IN 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.
- DOMINENT FEATURES IN IMAGE: Delta, lake, river channels, clouds

ISS006-E-16068

ISS012-E-15881

ISS014-E-11841

ISS014-E-15775

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IMPACT FEATURES

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ISS014-E-19496

ISS015-E-17360

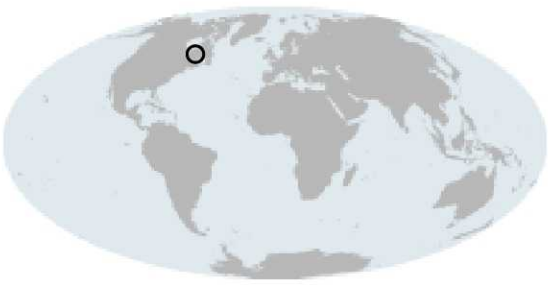
ISS018-E-14908

ISS018-E-023713

EARTH
IMPACT FEATURES

IMPACT CRATER IN CANADA

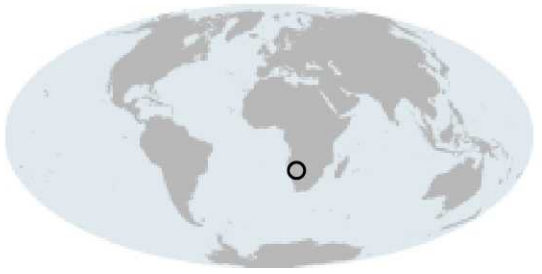
Image ID#: ISS012-E-15881



- This astronaut image is centered on the Manacouagan impact crater found in Quebec, Canada. The rim of the crater is now filled with water and referred to as the Manacouagan reservoir. The central mound is still visible.
- DOMINENT FEATURES IN IMAGE: Impact crater, central uplift/mound, reservoir or lakes

IMPACT CRATER IN NAMIBIA

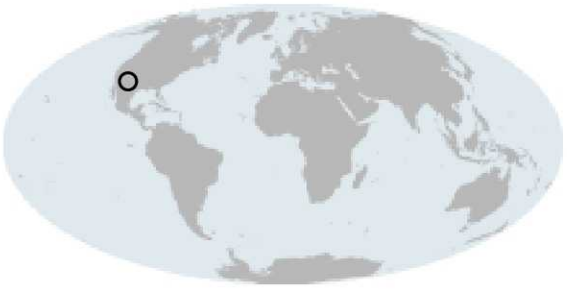
Image ID#: ISS006-E-16068



- This astronaut image is taken of the Roter Kamm impact crater, found in the Namib Desert in Namibia.
- DOMINENT FEATURES IN IMAGE: Impact crater, sand dunes, mountains

IMPACT CRATER IN THE U.S.A.

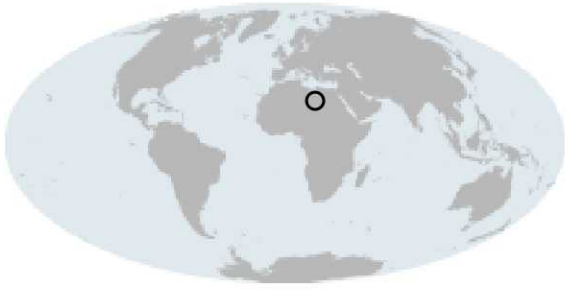
Image ID#: ISS014-E-15775



- 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.
- DOMINENT FEATURES IN IMAGE: Impact crater, river channel, wind streaks

IMPACT CRATER IN LIBYA

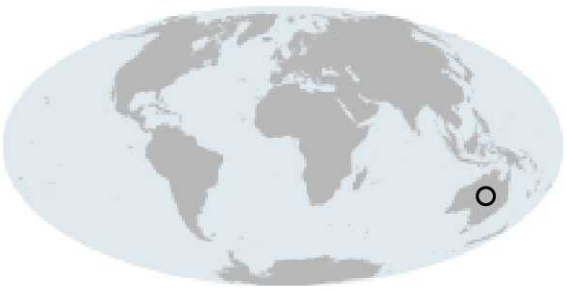
Image ID#: ISS014-E-11841



- This astronaut image is centered on the Oasis impact crater found in the Sahara Desert in Libya.
- DOMINENT FEATURES IN IMAGE: Impact crater

IMPACT CRATER IN AUSTRALIA

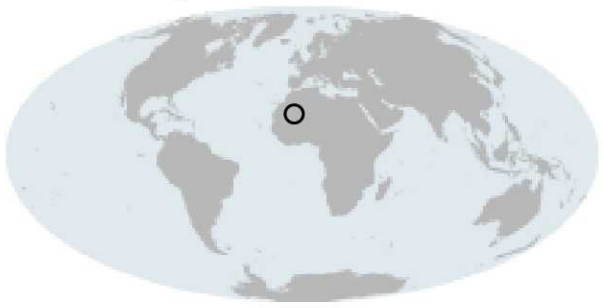
Image ID#: ISS015-E-17360



- This astronaut image is centered on Gosses Bluff, an impact crater located in Australia's Northern Territory.
- DOMINENT FEATURES IN IMAGE: Impact crater, river channel

IMPACT CRATER IN ALGERIA

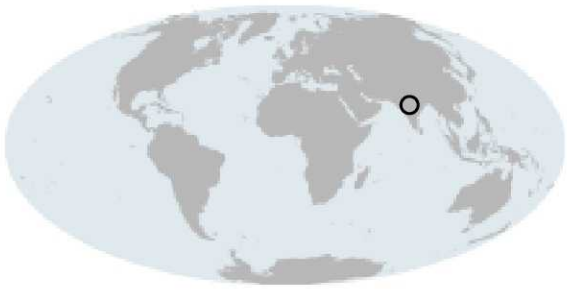
Image ID#: ISS014-E-19496



- This astronaut image shows the Quarkziz impact crater and sedimentary layers located in western Algeria close to the border of Morocco.
- DOMINENT FEATURES IN IMAGE: Impact crater, sedimentary rocks and layers, small circular hills

IMPACT CRATER IN INDIA

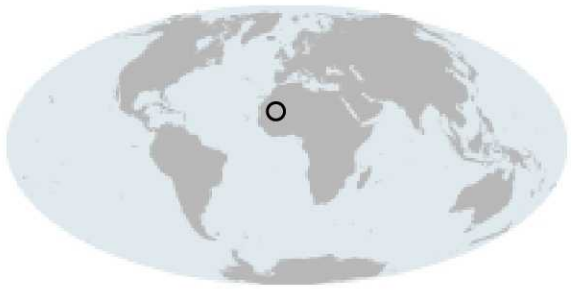
Image ID#: ISS018-E-023713



- This astronaut image contains the Lonar Impact Crater located in Central India. The central portion of this crater is now filled with water.
- DOMINENT FEATURES IN IMAGE: Impact crater, lake, agricultural fields, urban area

IMPACT CRATER IN MAURITANIA

Image ID#: ISS018-E-14908



- This astronaut image is centered on the Tenoumer Impact Crater located in the Sahara Desert in Mauritania.
- DOMINENT FEATURES IN IMAGE: Impact crater

ISS013-E-24184

ISS016-E-012623

ISS016-E-034524

ISS016-E-035095

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EARTH

VOLCANIC FEATURES

ISS017-E-5656

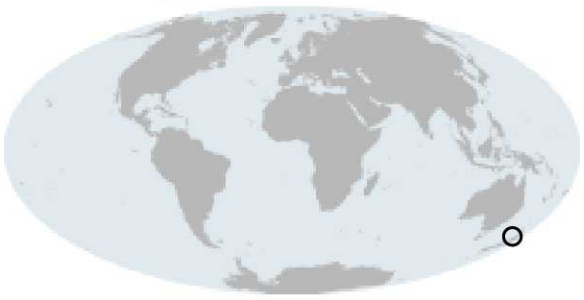
ISS017-E-013065

ISS018-E-6051

ISS016-E-8402

VOLCANO IN NEW ZEALAND

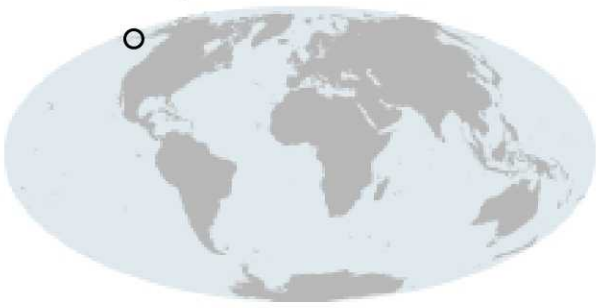
Image ID#: ISS016-E-012623



- This astronaut image is showing an oblique view of Mount Ruapehu, which is an active stratovolcano in New Zealand. This volcano is on the southern end of the Taupo Volcanic Zone. This is one of the world's most active volcanoes.
- DOMINENT FEATURES IN IMAGE: Volcano, central vent, lava flows, snow

VOLCANO IN THE U.S.A.

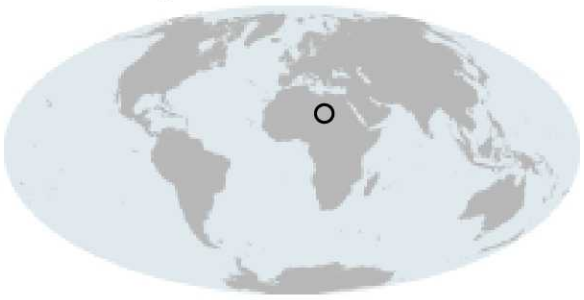
Image ID#: ISS013-E-24184



- This astronaut image captured the beginning of an eruption of one of the stratovolcanoes in Alaska, called the Cleveland Volcano. Carlisle Island, another volcano, is visible in the upper left hand portion of the image.
- DOMINENT FEATURES IN IMAGE: Volcano, ash plume, central vent, ocean, snow

LAVA FLOWS IN CHAD

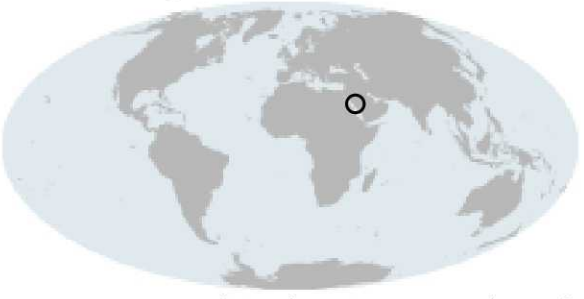
Image ID#: ISS016-E-035095



- 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.
- DOMINENT FEATURES IN IMAGE: Lava flows

VOLCANIC FIELD IN SAUDI ARABIA

Image ID#: ISS016-E-034524



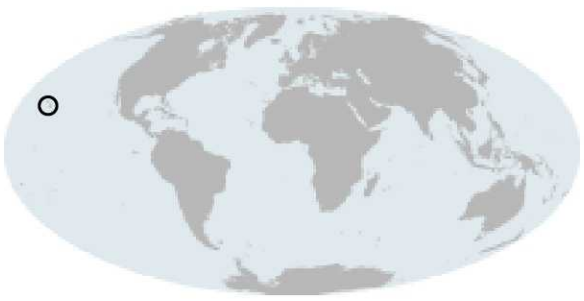
- This astronaut image is taken of an extensive volcanic field in the western half of the Saudi Arabian peninsula. There is a variety of volcanic features of different sizes, shapes, and chemical compositions. Lava flows vary in color. Features that look like impact craters were actually caused by volcanic eruptions in the present of water; some of which are now filled with light-colored sand and silt.
- DOMINENT FEATURES IN IMAGE: Volcanoes, lava flows

EARTH

VOLCANIC FEATURES

LAVA FLOWS IN THE U.S.A.

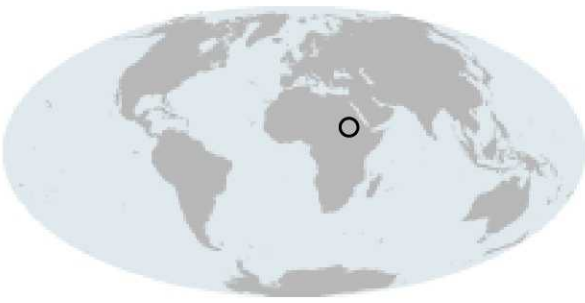
Image ID#: ISS017-E-013065



- This astronaut image is of the summit caldera of the largest volcano on Earth. Mauna Loa, located on the Big Island of Hawaii rises ~9 km (~5.6 mi) above the sea floor.
- DOMINENT FEATURES IN IMAGE: Caldera, lava flows, clouds

LAVA FLOWS IN ETHOPIA

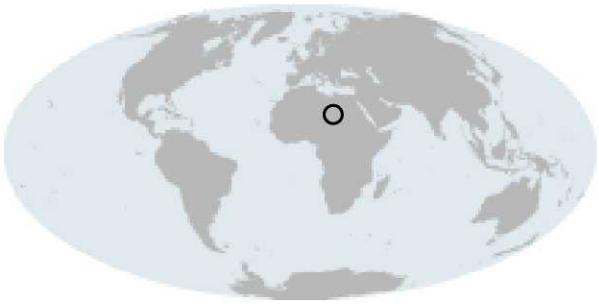
Image ID#: ISS017-E-5656



- 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.
- DOMINENT FEATURES IN IMAGE: Lava flows

VOLCANO IN CHAD

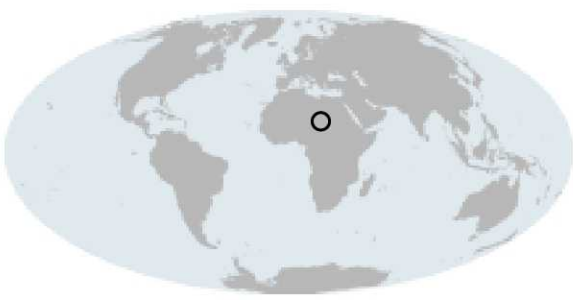
Image ID#: ISS016-E-8402



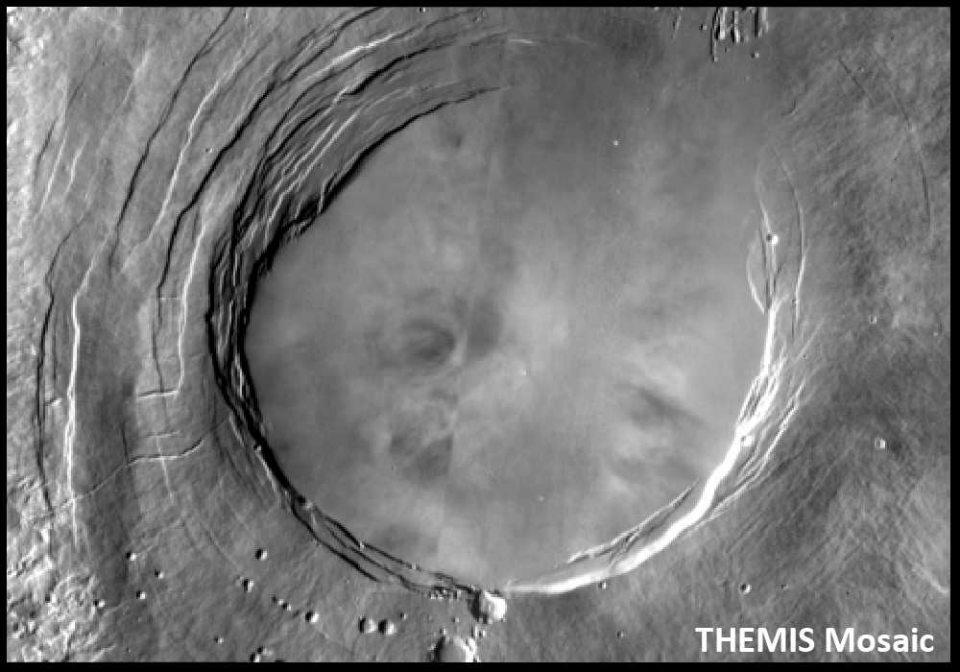
- This astronaut image shows the Emi Koussi volcano located at the south end of the Tibesti Mountains in Chad. Extensive lava flows are visible all around the volcano.
- DOMINENT FEATURES IN IMAGE: Volcano, caldera, lava flows

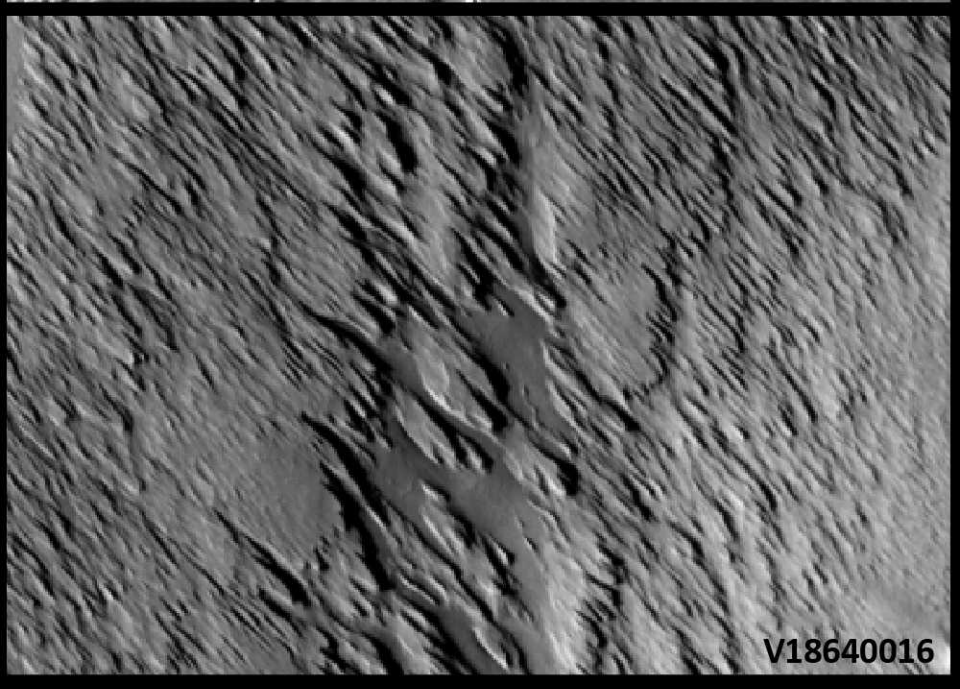
CALDERA IN SUDAN

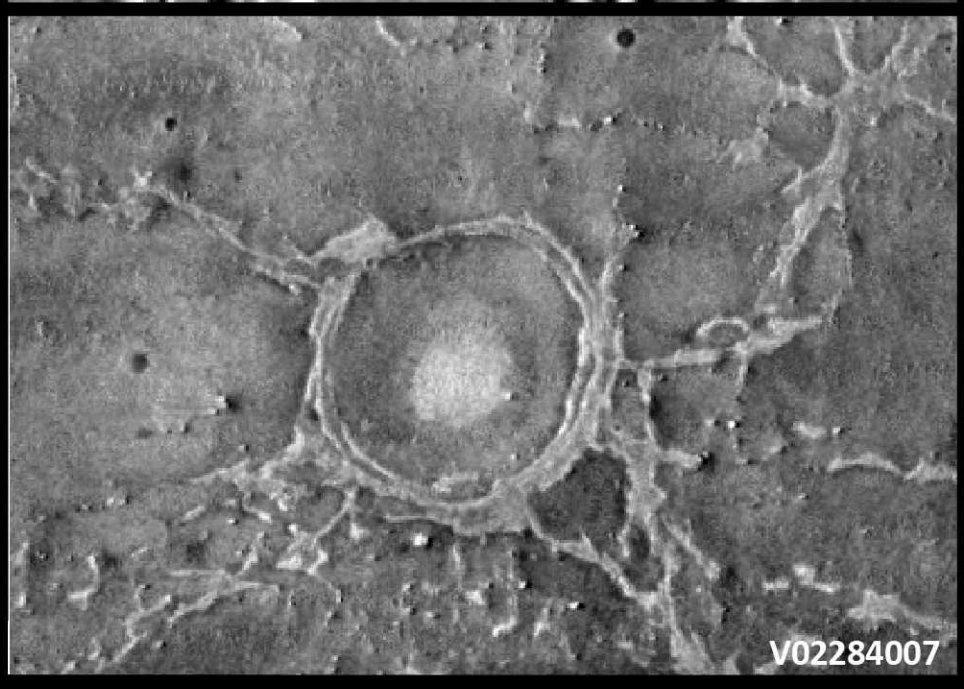
Image ID#: ISS018-E-6051



- This astronaut images is taken of the Deriba Caldera, a dormant volcanic structure located at the top of the Marra Mountains of western Sudan.
- DOMINENT FEATURES IN IMAGE: Caldera, lake, drainage network







MARS

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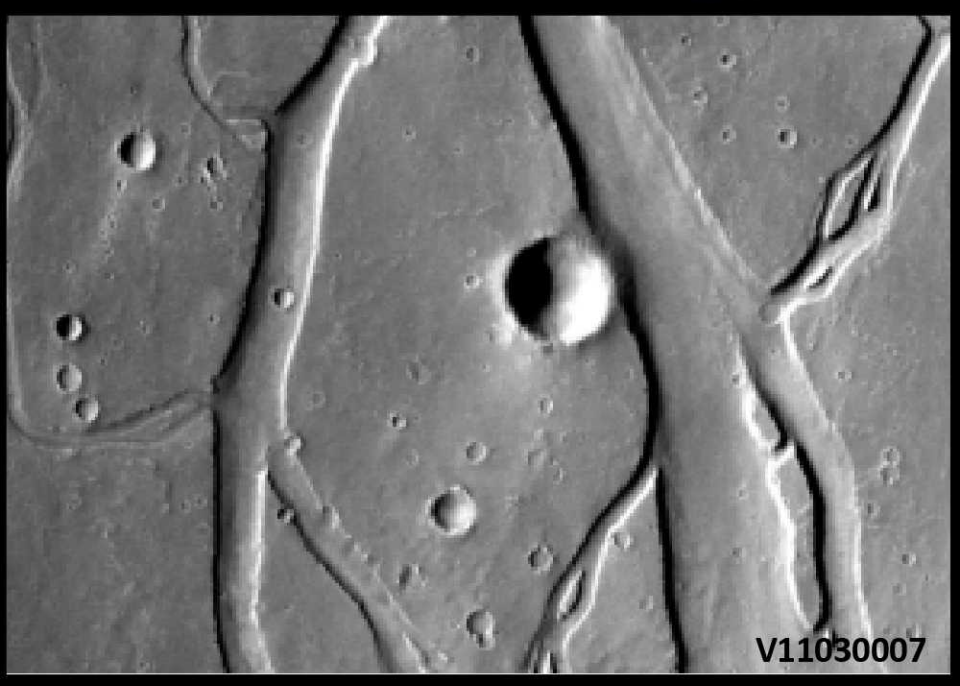

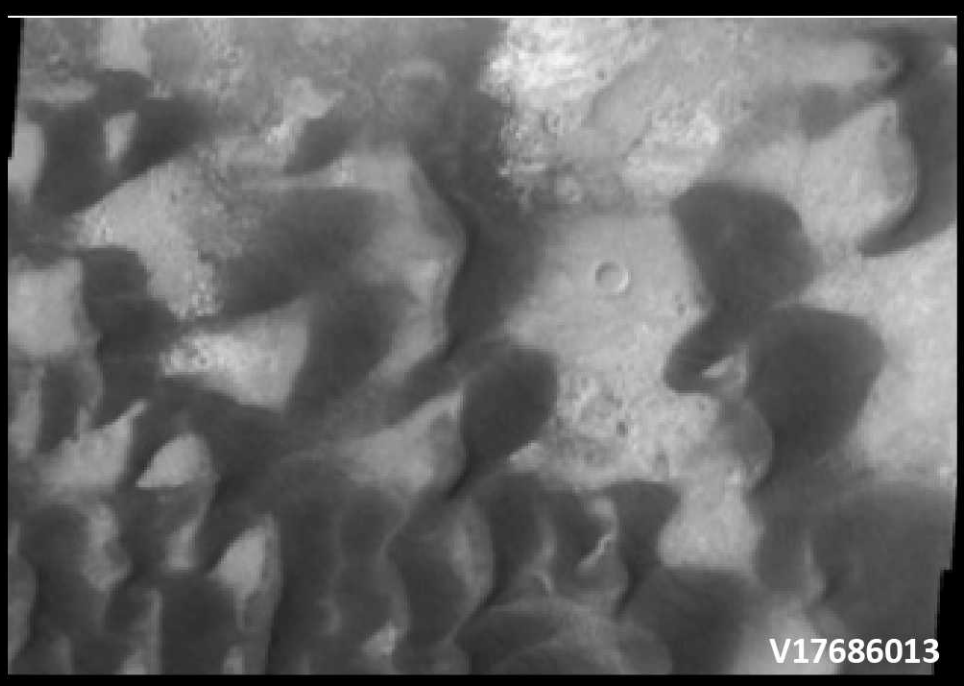

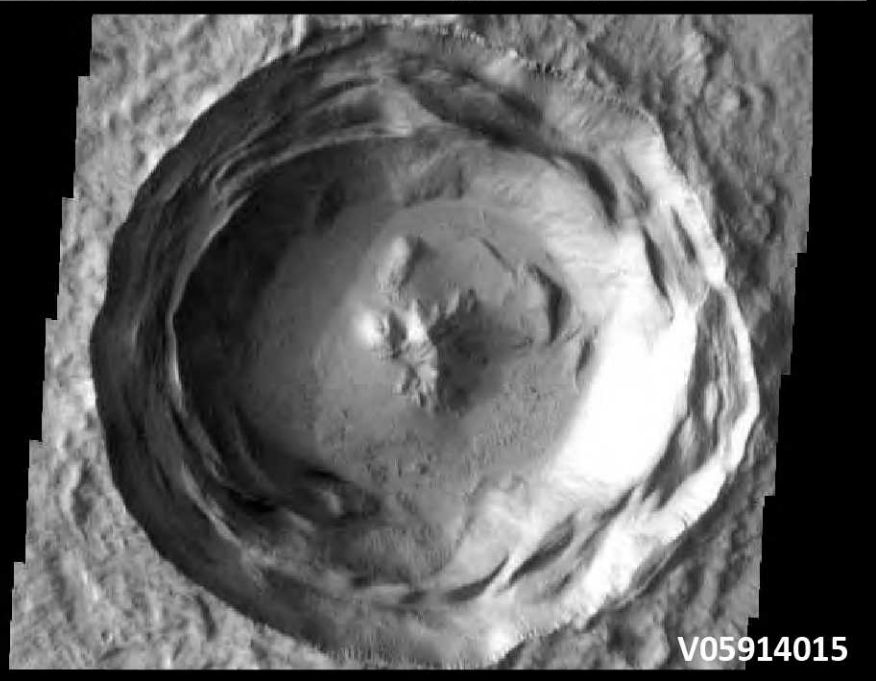

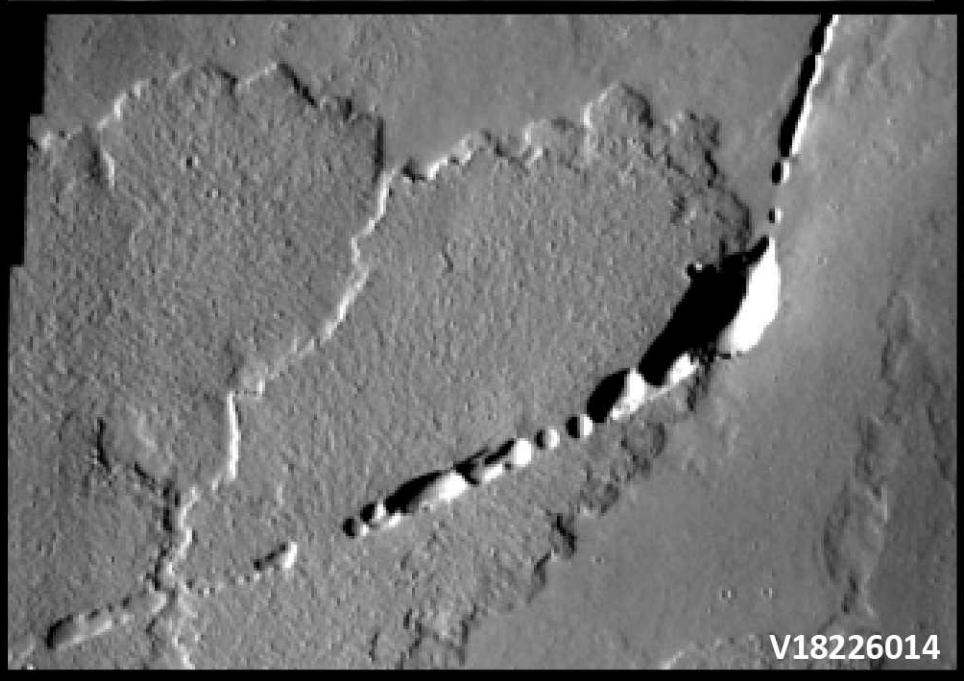

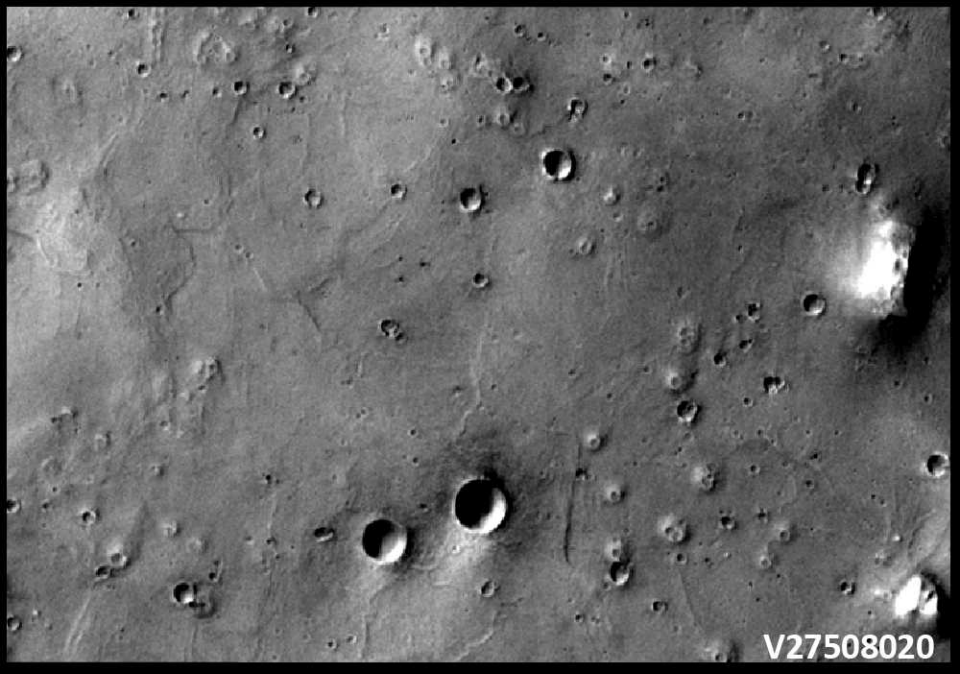

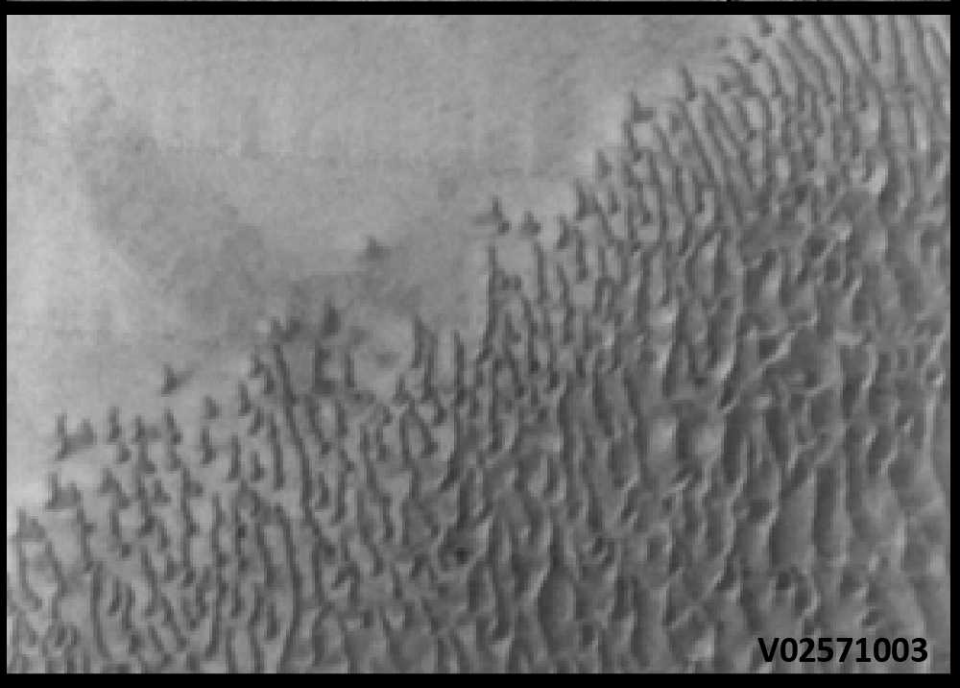

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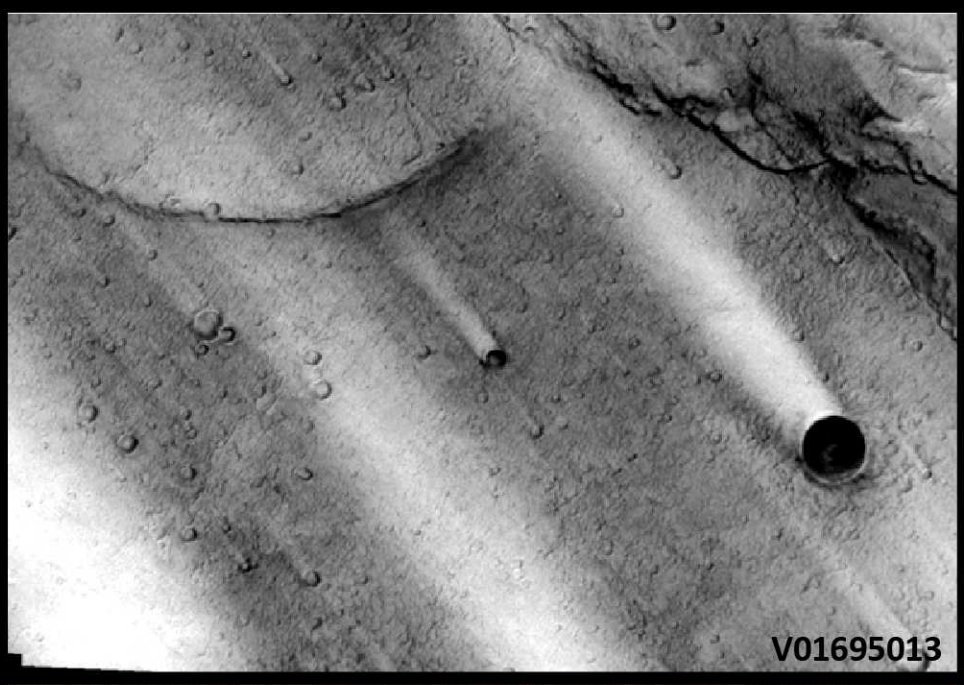

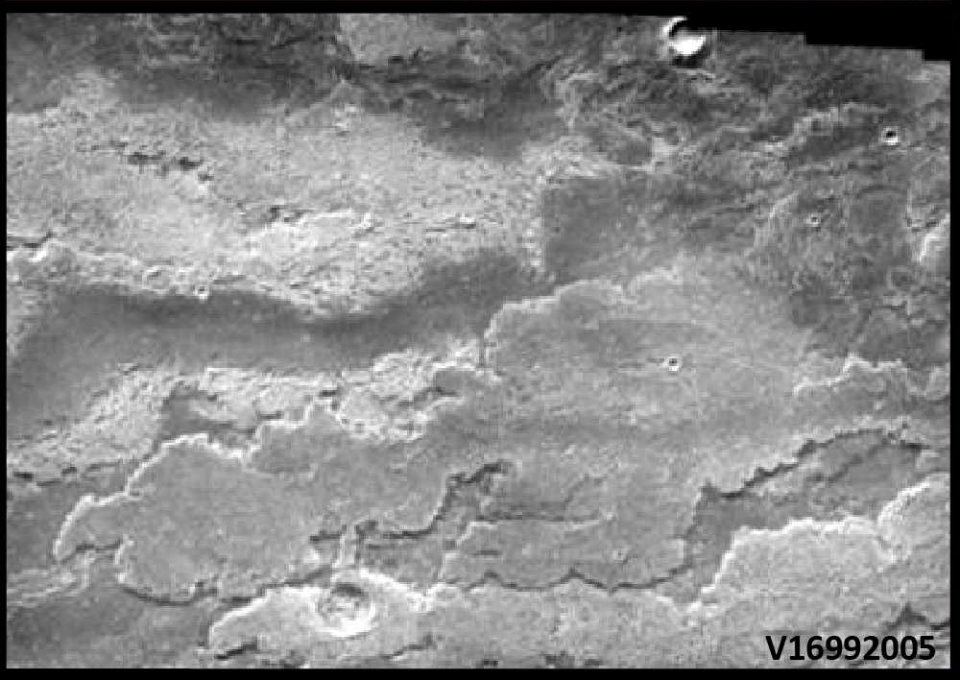

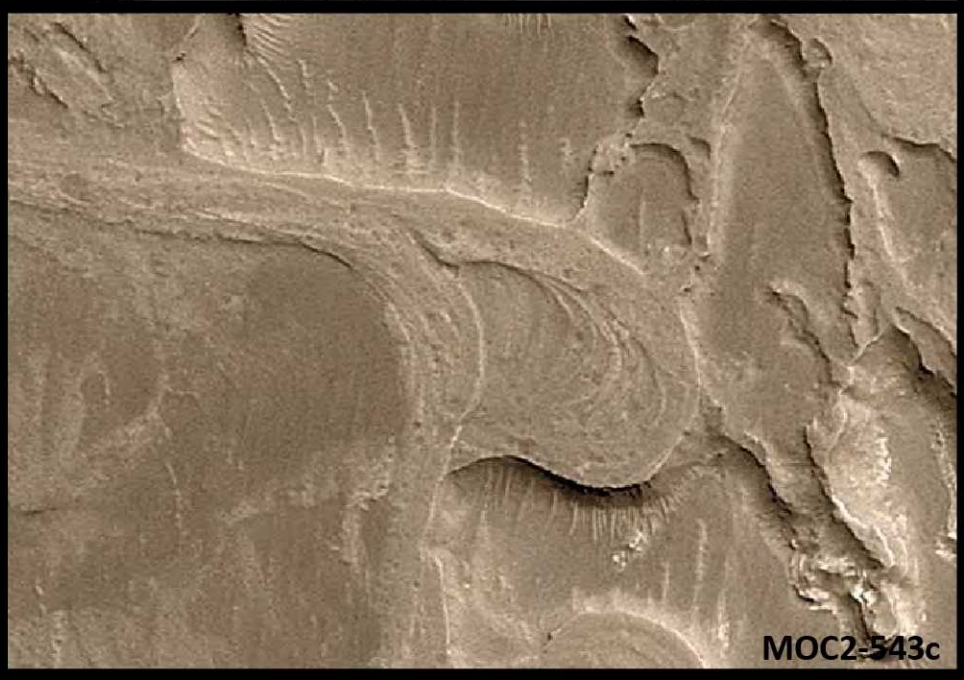

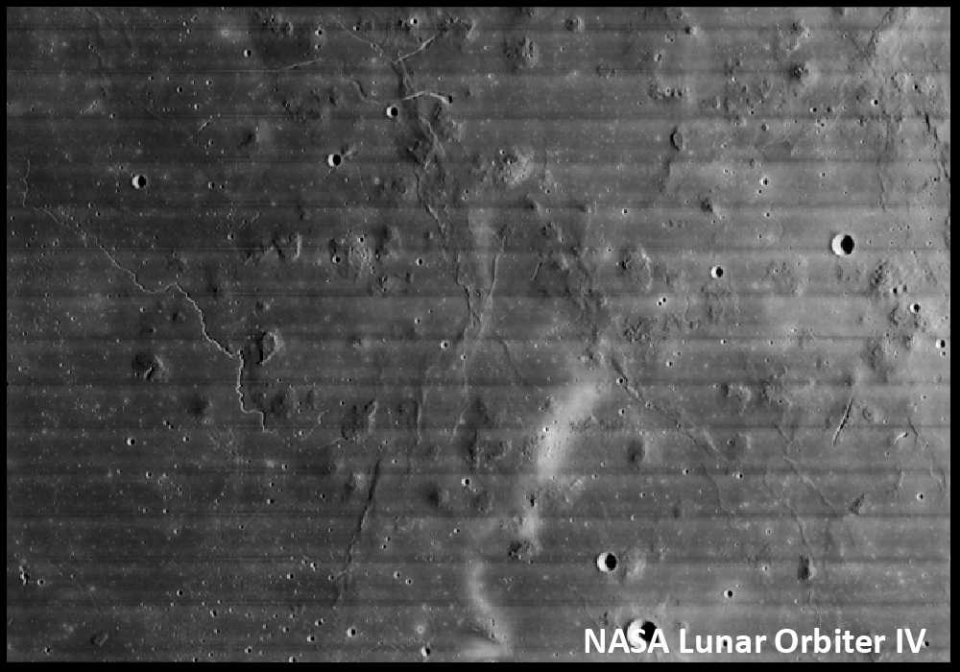

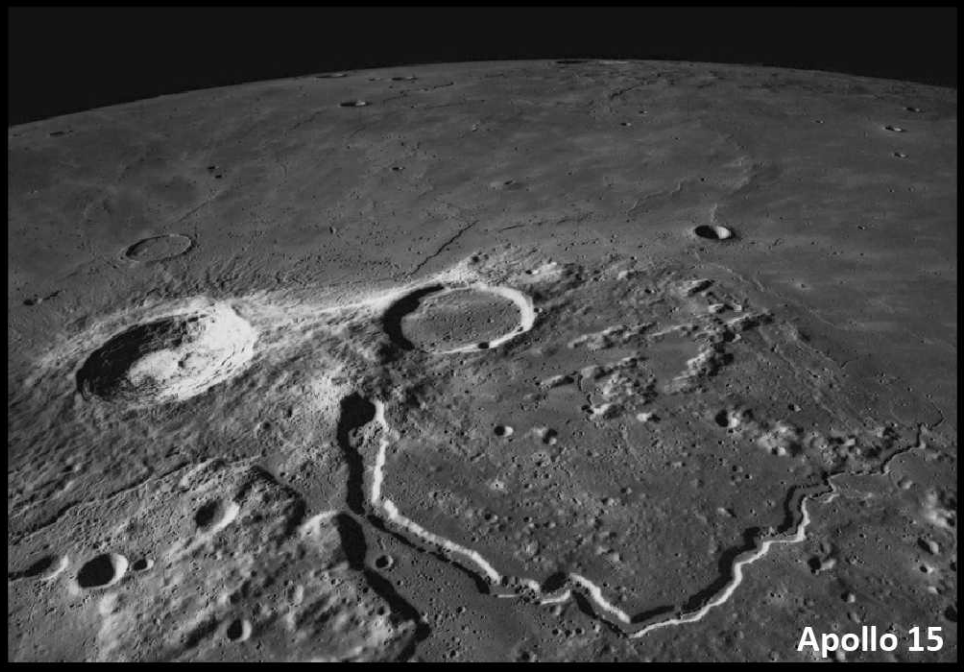

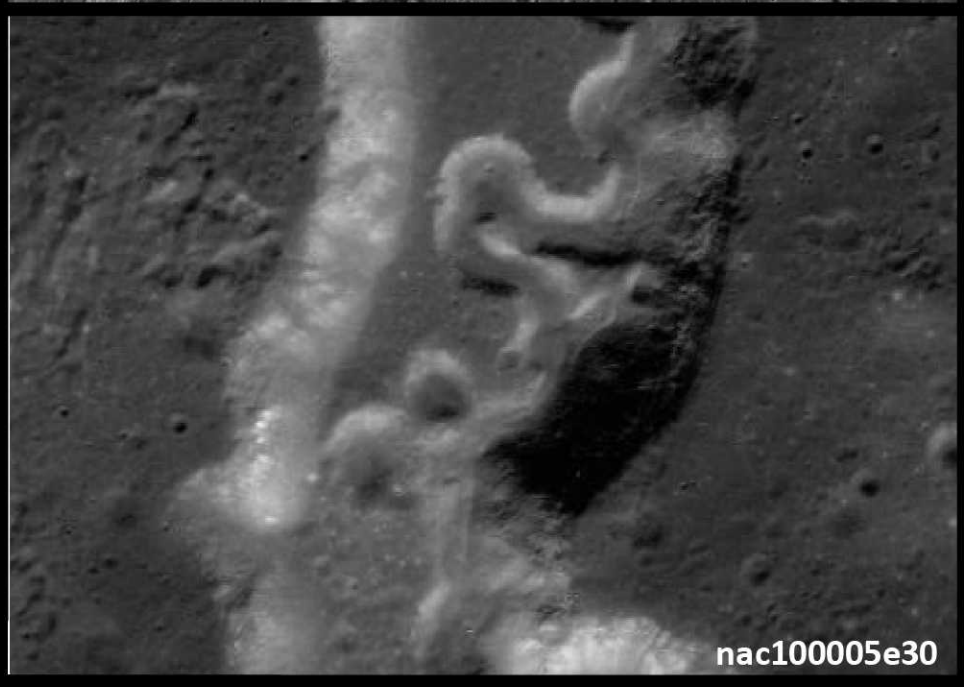

EARTH'S MOON

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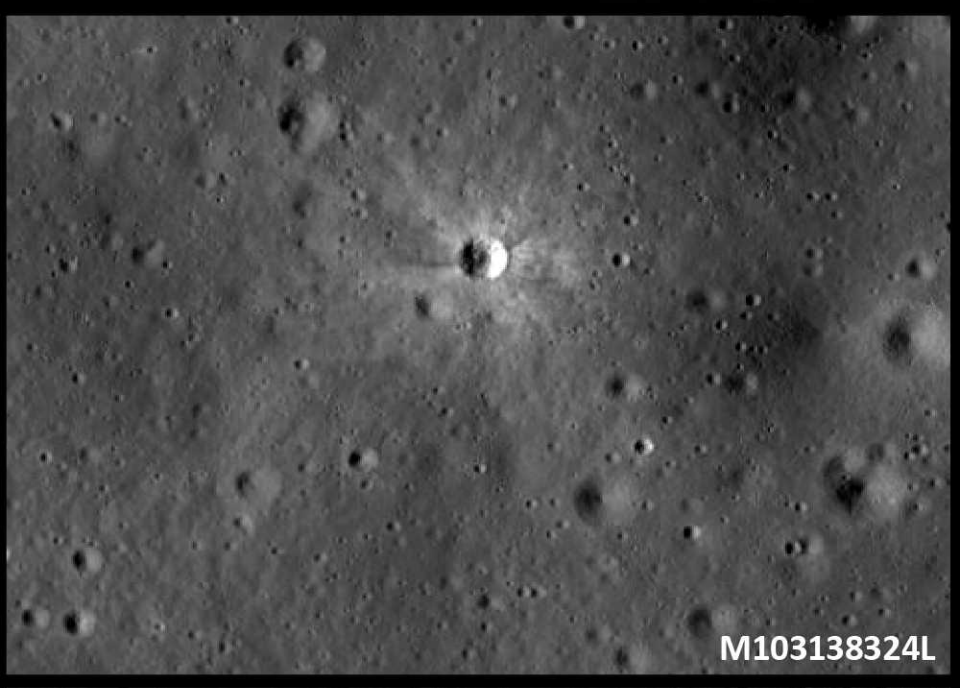

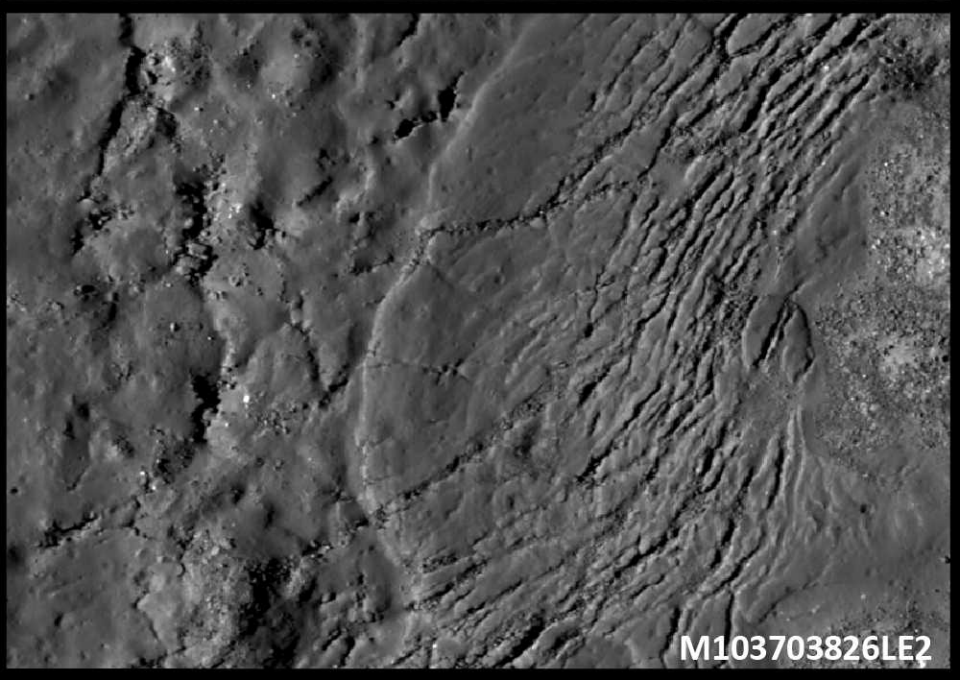

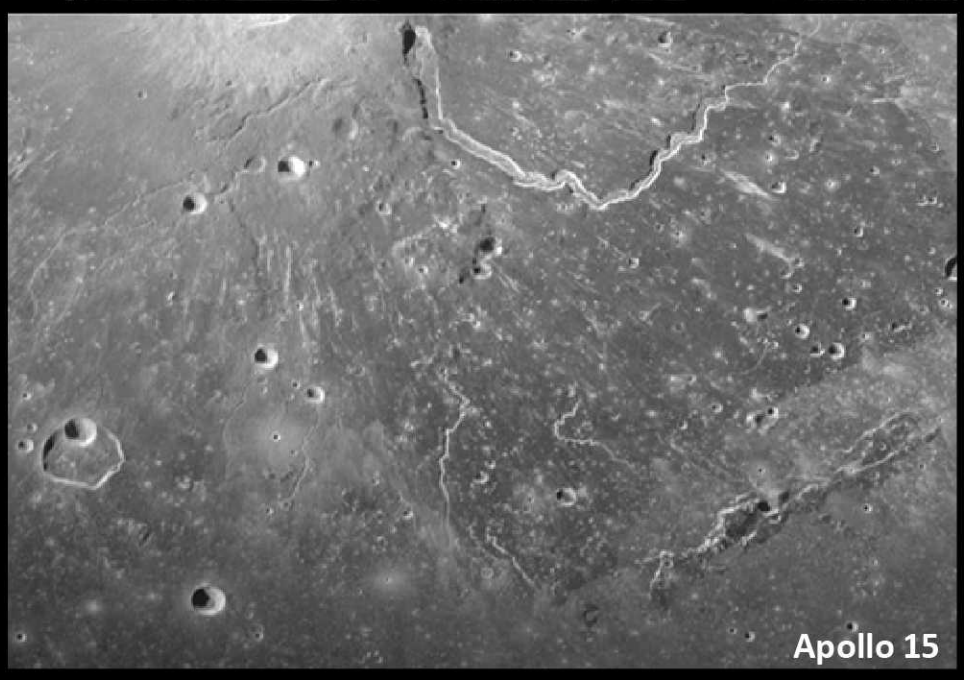

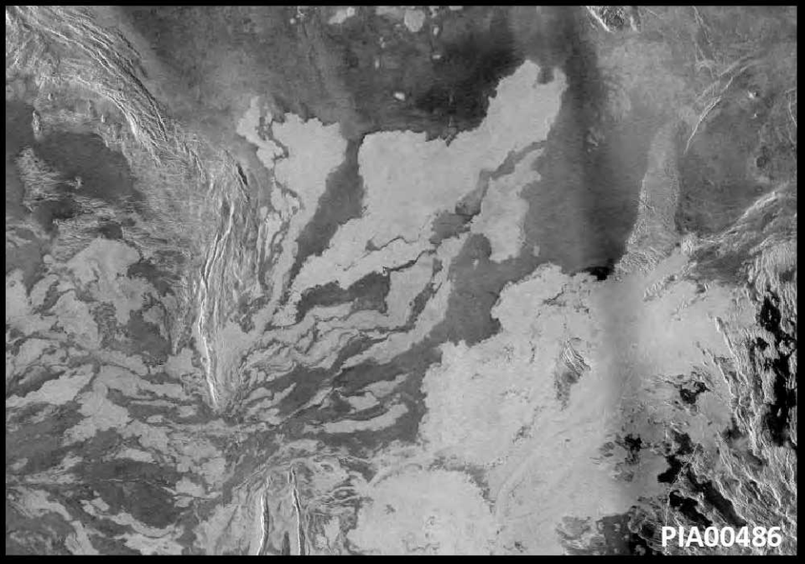
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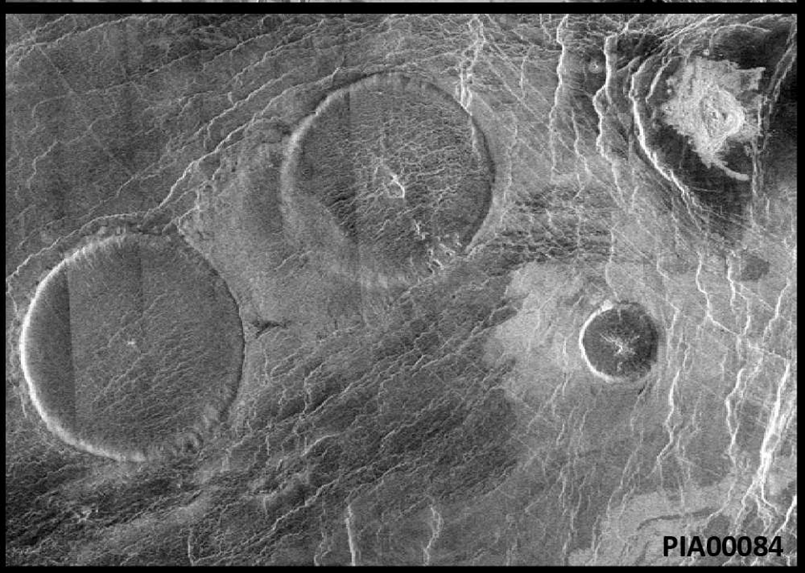
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PIA00086

VENUS

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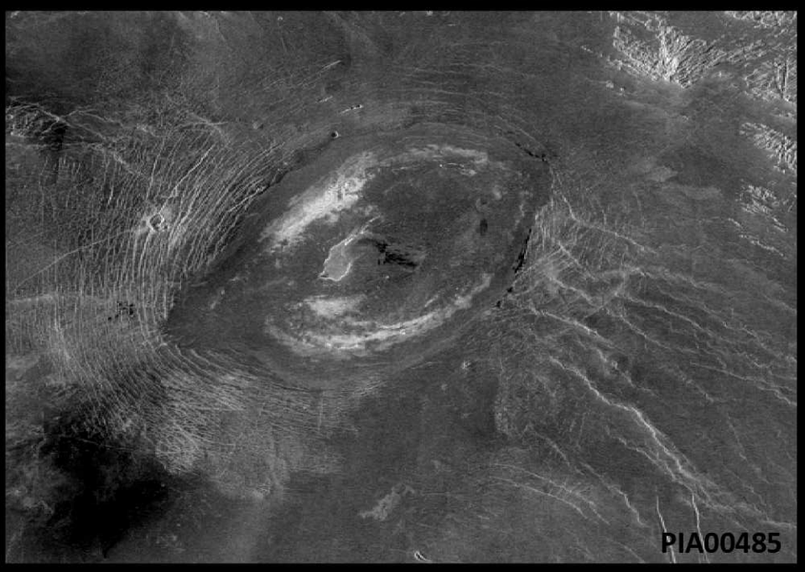
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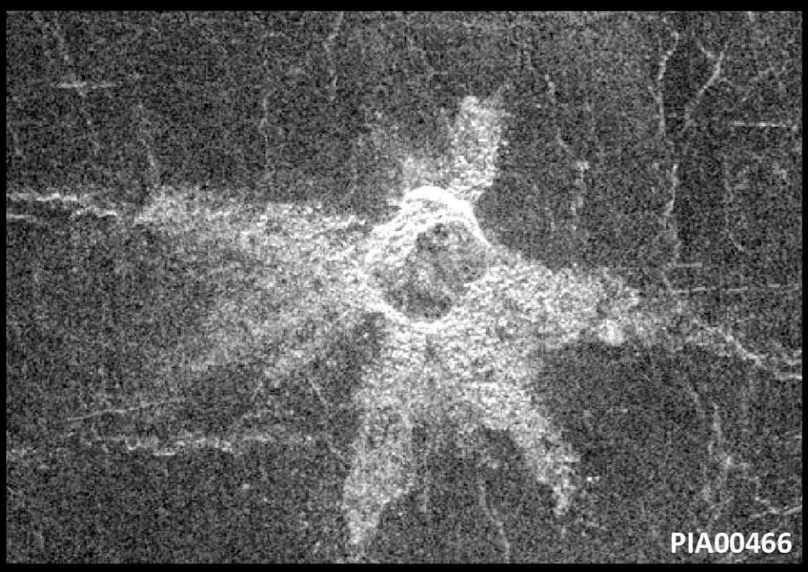
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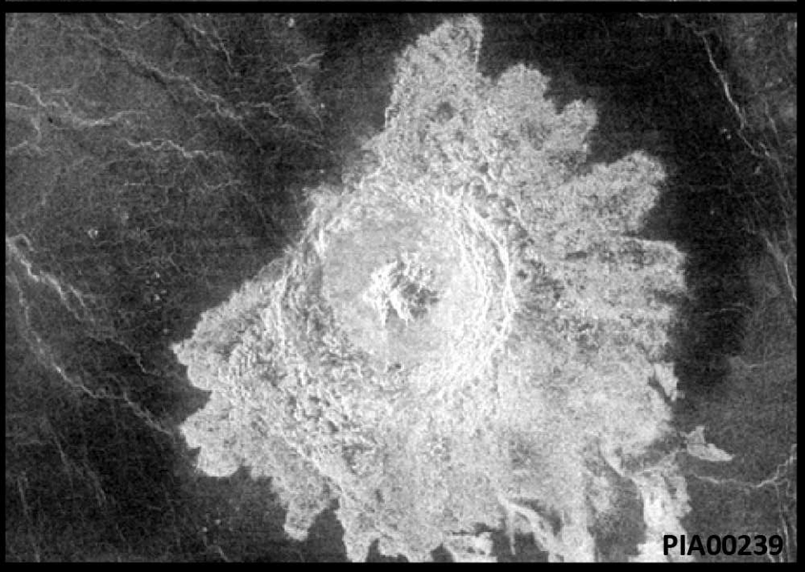
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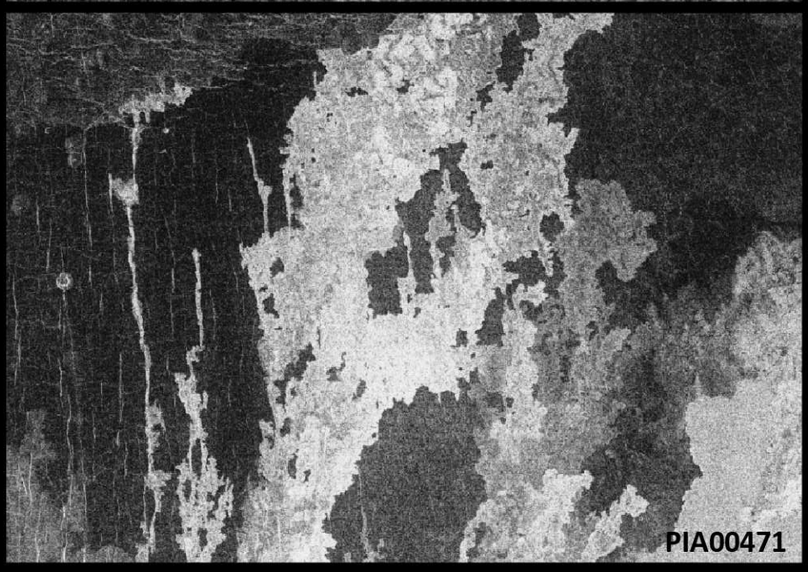
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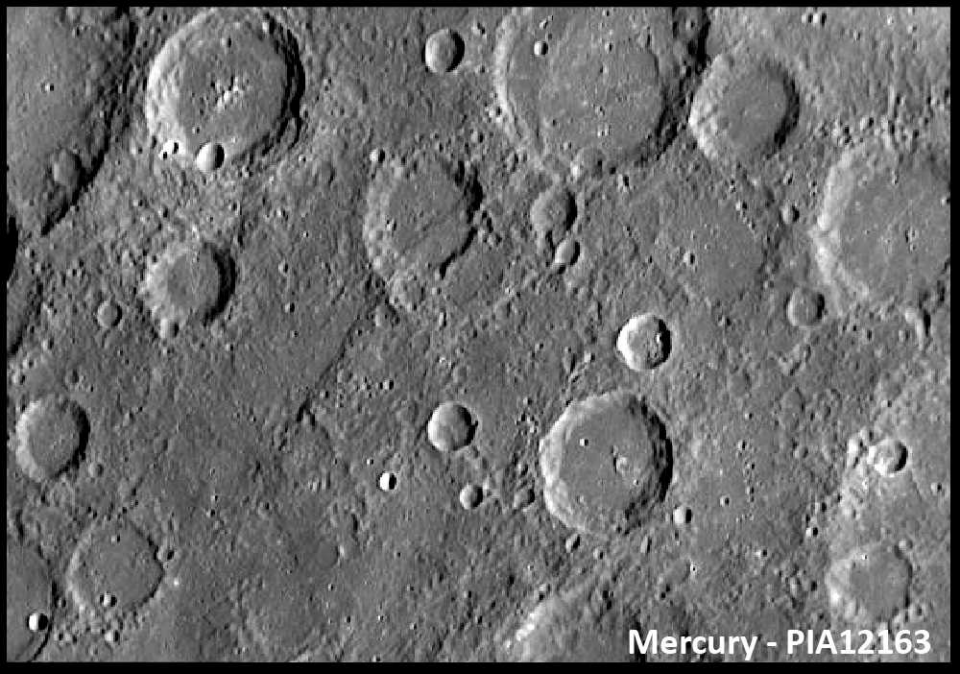

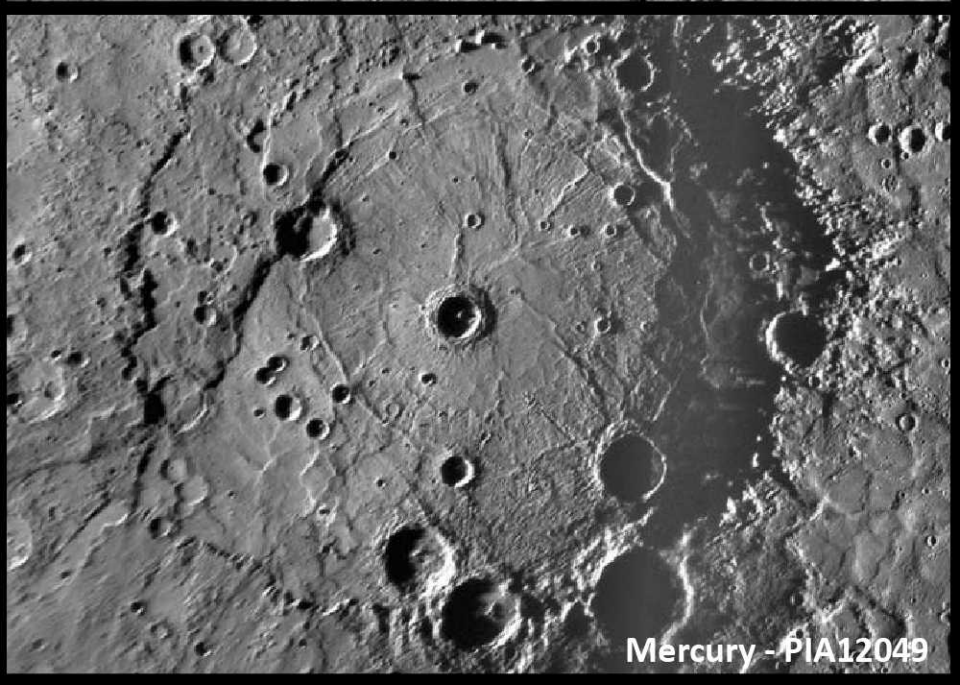

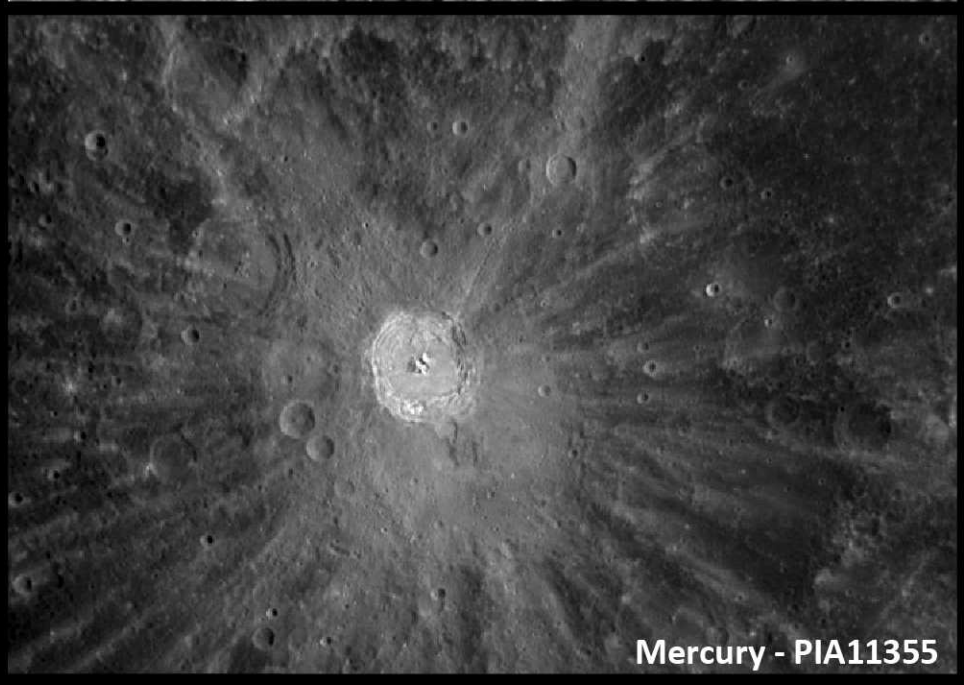

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