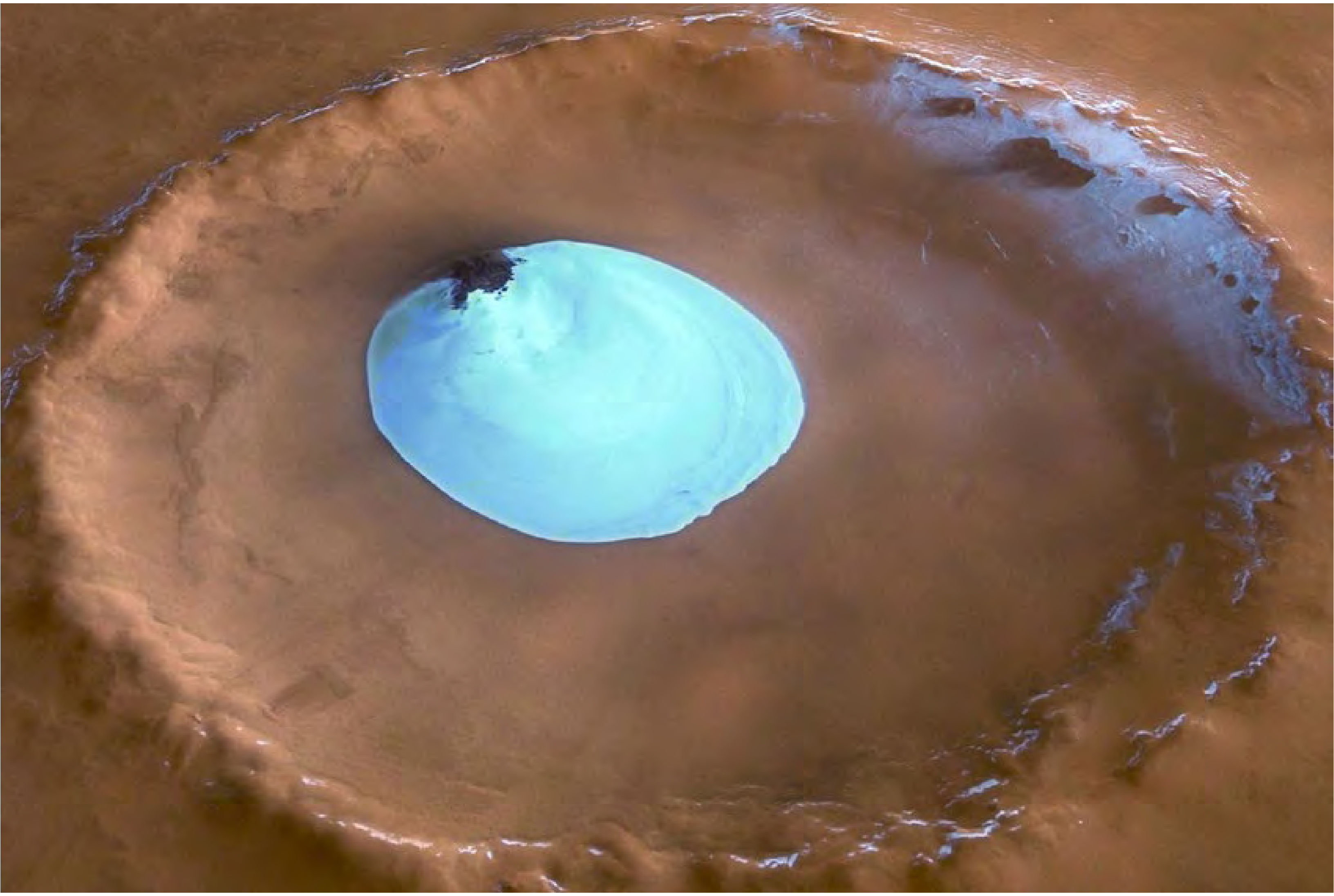
ESSENTIAL LENS

ANALYZING PHOTOGRAPHS ACROSS THE CURRICULUM



Processes of Science: Mars, a Case Study

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Processes of Science: Mars, a Case Study

This collection is unique as it focuses on the Next Generation Science Standards eight practices of science and engineering using Mars as the case study.

Standards

The content is in accordance with the Next Generation Science Standards (NGSS), Appendices F and H, on the nature and practices of science; and Disciplinary Core Ideas: Earth and Space Sciences ESS3, Earth and Human Activity from the 2012 Framework for K-12 Science Education from the National Research Council of the National Academy of Science. (See References and Further Reading.)

Prerequisite Knowledge

This photo collection and its activities require only general knowledge about the effects of water on Earth's features. The activities in this collection might be appropriate for the beginning of the school year. The activities and questions will give students a background in the nature of science, as well as skills in the practice of science that they can use for more specific science content later in the year.

Introduction

Understanding the nature and practice of science is important for the critical thinking skills required in the 21st century. This understanding is a key part of the Framework for K-12 Education in Science, is considered essential for learning science, and is one of the strands woven into all of the NGSS performance expectations.

In this collection, the investigation of water on Mars illustrates selected parts of the NGSS goals for understanding the nature of science and the processes of science and engineering. The collection illustrates how photographs are an essential data source for scientific investigation of remote and inaccessible locations, such as other planets.

Of the eight practices of science and engineering in the NGSS, students will model the following in the activities for this collection:

- Asking questions (for science) and defining problems (for engineering)
- Analyzing and interpreting data
- Constructing explanations (for science) and designing solutions (for engineering)

Curriculum Snapshot

- The nature and processes of science: what scientists and engineers do and how they do it
- Using photographs to study inaccessible locations such as Mars

Grade Level

Middle school and high school

Classroom Connections

Earth and Space Sciences; Engineering

- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

The specific NGSS goals about the nature of science that are illustrated by this collection are:

- Scientific investigations use a variety of methods.
- Scientific knowledge is based on empirical evidence.
- Scientific knowledge is open to revision in light of new evidence.
- Science models, laws, mechanisms, and theories explain natural phenomena.

Students will use photos from the National Aeronautics and Space Administration (NASA) Mars Exploration Rover mission as a source of data, engaging in some of the practices of science while learning more about the Mars Rover mission, including the search for evidence of water.

Key Learning Targets

Students will:

- Learn that photographs can be a data source for scientific investigation and evaluation.
- Have the opportunity to critically evaluate information from photographs, similar to the way they evaluate observations and measurements obtained through other methods.
- Understand the nature of science.
- Develop skills related to the practices of science and engineering in the context of the NASA Mars Rover mission.

Essential Questions

These big ideas or essential questions organize the content and topics of this collection of photographs. Students will consider the following questions:

- What are some methods that scientists use to study inaccessible places, such as other planets?
- What part do photographs play in observing and learning about Mars?
- What challenges do scientists have to overcome to study remote locations?
- What are some general practices that scientists use no matter what topic they are studying?

ACTIVITY 1:
Activating Students' Prior Knowledge

In pairs or small groups, have students look at photos of locations on Earth that show the effects of seasonal water: dry river beds, lake beds, and canyons. To apply the NGSS science and engineering practice of analyzing and interpreting data—specifically data from photos—students will observe, discuss, and list the evidence in the photos that indicates that water was once present. Have students review the photographic evidence of the impact of water and make a chart of the similarities and differences in the photos. (For example, students might notice patterns or placements of rocks that suggest they were moved by water. They might observe soil or rock erosion that suggests a current.)

Photographs for This Activity
(Appendix, pg 12-15)

6026, 6035, 6036, 6037

ACTIVITY 2:
Water on Mars: A Case Study

Learning Targets:

- I can ask testable scientific questions based on observations.
- I can make observations, gather evidence, provide explanations and alternative explanations, and formulate hypotheses to explain natural phenomena.
- I can engage in arguments based on evidence and provide appropriate evidence, including photographic evidence, to support claims.
- I can communicate science and engineering information.

Background

The Mars Exploration Rover Mission is part of a larger NASA Mars Exploration program. The two NASA Mars rovers, named Spirit and Opportunity, are solar-powered, six-wheeled robots that are 1.5 meters (4.9 feet) tall and 1.6 meters (5.2 feet) long. They weigh 174 kilograms (384 pounds). They have special suspension for driving over rough terrain, airbags for cushioning their landing, and a lot of equipment for taking images and sending them back to Earth.

In 2000, NASA decided to send two rovers to Mars in summer 2003, when the orbits of Earth and Mars would bring the planets exceptionally close together. The initial cost to build, launch, and land the rovers was $280 million. Four extensions of the exploration since the initial phase have cost $104 million.

The rovers collect data on the current and past conditions of Mars to see if the planet could have supported life as we know it on Earth. The rovers carry equipment to take samples and test their chemical compositions. They also carry cameras as an additional method for gathering scientific data. One question the mission wanted to answer by taking photographs of the terrain and other features of Mars was if the planet once had water on its surface.

Scientists are examining the evidence the rovers have found so far, including photographs of landscapes that look like former riverbeds or lake basins, and images that resemble the formation, weathering, and erosion of rocks by water. The rovers sent test results that suggest the presence of chemicals and minerals that, on Earth, form in the presence of liquid water. NASA lost contact with Spirit in 2010. As of 2014, Opportunity was still active.

Photographs for This Activity
(Appendix, pg 16-46)

All Photos in the Collection.

Begin the Activity

Part 1

Give students, working in pairs or small groups, a sample of photos of Earth and Mars. Tell the students which photos show Earth and which show Mars, and ask them to group photos that show similar features on the two planets. Have the student teams study the photos carefully to identify similarities and differences of the features. Examples of photos they might match are **6037** and **6026** (Earth riverbeds) with **6012, 6017, 6018**, or **6021** (Mars); craters in **6031** (Earth) with **6023** (Mars); rocky hills and ridges in **6032** and **6034** (Earth) with **6011, 6012**, or **6019** (Mars); and whole planets in **6030** (Earth) and **6029** (Mars). As in the warm-up activity, students might notice features such as rock movement and rock and soil erosion.

Part 2

Have the students create a list of questions prompted by looking at the photos and comparing features of Earth and Mars. Since Mars is less familiar, ask the students what additional questions come to mind when they study the Mars photos. (Optional: Students can view additional images of Mars on the NASA website and choose other photos to study. A link is provided in References and Further Reading). For example, students might think of engineering problems that have to be overcome to explore Mars. Encourage students to ask each other questions about what they saw in the photos that led to each question.

> *Note for teachers: Emphasize that at this point, no questions are considered right or wrong. This exercise is to experience the science and engineering practice of asking questions.*

As a class, have groups share what they saw when they compared in their Earth and Mars photos and what questions the photos generated. (Teachers can choose whether the questions should be somewhat realistic or if students should share any ideas they had, no matter how fanciful.) As a class, make a list of science questions and engineering problems from the small groups. Ask students if they have possible explanations for any of the questions or solutions to the problems (either their own ideas or ideas they have heard from other sources).

> *Optional: Have students choose a question and research it outside of class time to find out if scientists are studying the question.*

Part 3

From the list of questions from the class list generated in Part 2, ask students to point out which questions are testable, meaning they could be answered if the appropriate data were available. Mark the testable questions (for example, with a star).

Optional: Ask students to list the problems engineers had to overcome to create the rovers and get the photos and other evidence. Have students discuss possible ways to overcome the problems.

Note for teachers: This exercise aligns with NGSS practices of science and engineering: asking questions (for science) and defining problems (for engineering). It reinforces the NGSS goal about understanding the nature of science by illustrating that science uses a variety of methods and that scientific knowledge is based on empirical evidence.

Part 4

From the questions that the students labeled as testable, mark the questions that are related to finding out if Mars ever had water. (See Extensions for activities using the other questions.) If necessary, reframe the questions as a single, testable, scientific question about water on Mars, such as "Is there evidence that Mars ever had water? If so, what is it?"

In pairs or small groups, have students study the photos of Mars and look for evidence that does or does not support the hypothesis that water activity on Mars in the past shaped the current features of the planet. Ask the students to write an explanation based on the evidence they see. Their explanation should include alternate explanations for the evidence. (Having students use a "claim, evidence, reasoning" framework helps them structure their explanation.)

Optional: Have groups of students create a poster instead of writing their explanation. On copies of pictures, students could draw arrows and specifically label the evidence they see and provide a few brief sentences that describe the evidence.

Tell students that some scientists think that the available evidence about Mars so far supports previous life, while others think it does not. Ask students to choose one side or the other based on the evidence from the photographs they saw. Encourage students to think about the needs and characteristics of living things (with a mini-lecture on these points if students have not learned these concepts yet). Give students the opportunity to work with a partner representing the opposing side. Students will develop a strategy to construct and present

Having students use a "claim, evidence, reasoning" framework helps them structure their explanation.

arguments based on empirical evidence and scientific reasoning, share their ideas, compare and respectfully critique arguments, get advice from their partner, and revise their own work.

Finally, have students communicate their combined information in a slideshow presentation, or write a paper, that shares the photos they used as evidence. The presentation should explain how the photos support or do not support the hypothesis of past life on Mars. Students should include ideas they revised as a result of working with their partner and should be prepared to answer questions from the teacher or classmates.

> *Note for teachers: This exercise aligns with NGSS practices of science and engineering, specifically engaging in argument from evidence; analyzing and interpreting data; developing models; and obtaining, evaluating, and communicating information. It models how scientists present information at conferences. It reinforces the NGSS concepts about understanding the nature of science that state that scientific knowledge is based on empirical evidence and is open to revision in light of new evidence, and that science models, laws, mechanisms, and theories explain natural phenomena.*

Extension Activities

1. The class generated a list of testable questions and problems from looking at the Mars photos. Choose one of the questions or problems that was not about water on Mars, and then write a paper or prepare a presentation with photographs about it. Some questions to answer might be:

- Are scientists and engineers investigating this question or problem? If so, what are they finding?
- How are photographs providing data to answer the question or solve the problem? (Or how might they provide data to answer the question?)
- What challenges to answering the question or solving the problem remain and what are some potential solutions? How could photography help?

2. Think of another scientific topic that is difficult to study without photographs (for example, a location is difficult to access). List some testable questions about the topic that might be answered with photographs. Write a paper or prepare a presentation (possibly using photographs), describing how photography allows us to study the topic and how photographs could allow us to study testable questions on the topic. Potential areas are microbiology, the study of remote areas (such as the Earth's poles and oceans), the study of other features of space, and observing and comparing events over time, such as changes in polar ice caps.

Optional issues to explore are other ways to gather data and engineering solutions for photographing inaccessible locations.

3. Look at one of the Mars photographs that has been enhanced (such as **6002, 6012**, or **6022**). As a class or in small groups, discuss whether altering the color, contrast, or other features of a photograph changes its use as a scientific data source. How does editing change (1) the usefulness of the photograph, (2) the objectivity with which a scientist might analyze and interpret the information in the photograph, (3) whether the photograph can be used as evidence, and (4) how the photograph might be used to communicate scientific information?

References and Further Reading

Next Generation Science Standards, Appendices F (Science and Engineering Practices) and H (Nature of Science)
http://www.nextgenscience.org/next-generation-science-standards

Framework for Science Education
A Framework for K–12 Science Education. Practices, Crosscutting Concepts, and Core Ideas
http://www.nap.edu/catalog.php?record_id=13165

Mars Exploration Program, National Aeronautics and Space Administration
http://mars.jpl.nasa.gov

Additional Images of Mars
http://mars.jpl.nasa.gov/multimedia/images

Essential Lens Video Connection

Watch ***A Closer Look*** to learn more about analyzing photographs .

APPENDIX

Activity 1

pgs 12-15

6026, 6035, 6036, 6037

Activity 2

pgs 16-46

All Photos in the Collection.

Note: For ease of use, some NASA captions have been edited for length. To view full caption, go to the NASA photo website at www.nasa.gov/multimedia/index.html.

Activity 1 - **6026** - ***Riverbed***
Desert on the West Bank of the Jordan River. 2013. (iStock)

Activity 1 - **6035** - ***Desert Canyon***

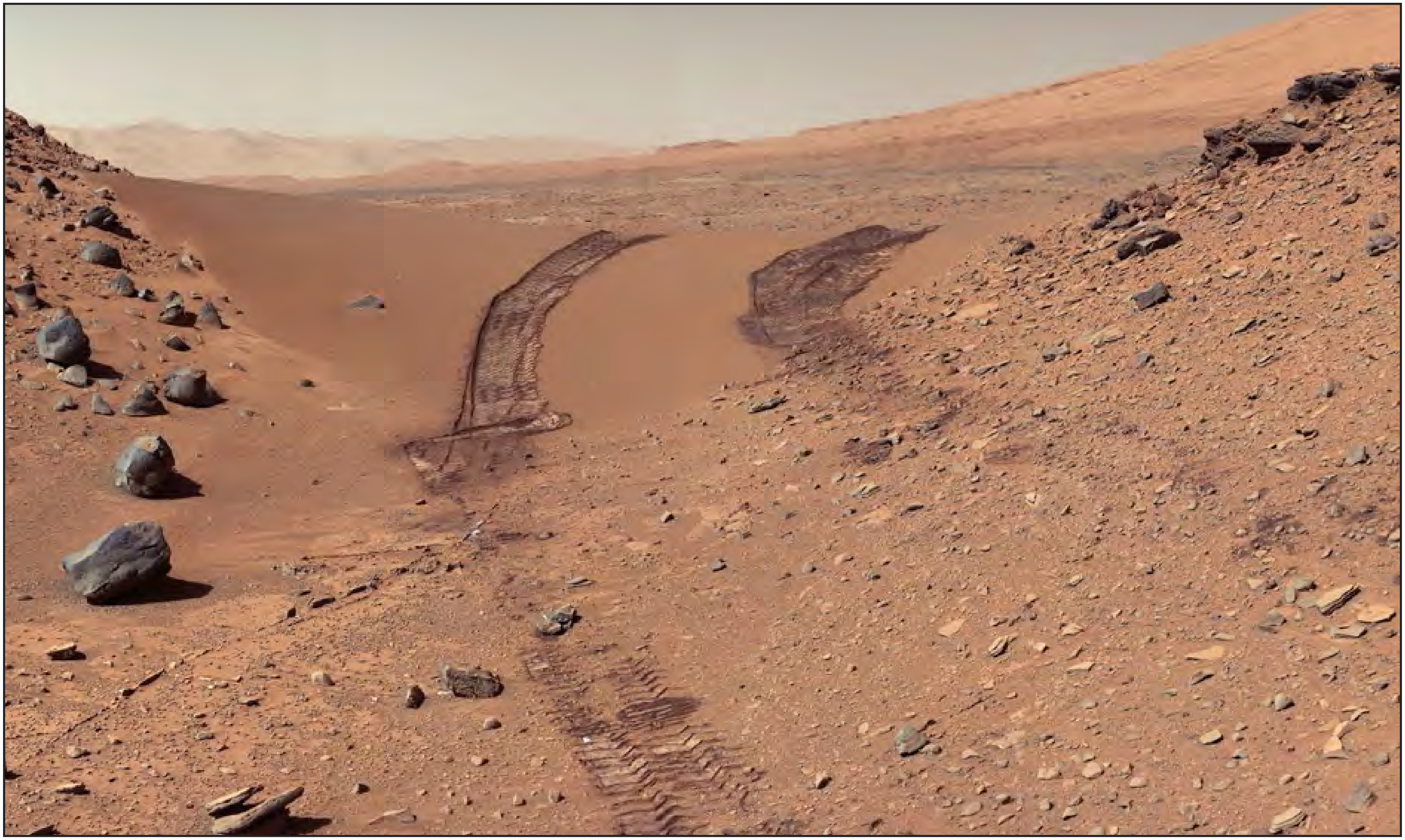
The Perazim canyon. Judean Desert nature reserve, Israel. 2009. (iStock)

Activity 1 - **6036** - ***Playa***

Racetrack Playa is a seasonally dry lake (a playa), located in the northern part of the Panamint Mountains in Death Valley National Park, California. 2009. (iStock)

Activity 1 - **6037** - ***River Valley***

Rocks and gravel are heavy substances, and thus are not generally moved by wind. They can be easily displaced by the flow of water, however. 2012. Kali Gandaki river valley with Himalayan mountains in the background. (iStock)



Activity 2 - **6001** - ***Dune***

This looks back at a dune across which NASA's Mars Rover Curiosity drove. The rover's Mast Camera (Mastcam) took this photo during the 538th Martian day, or sol, of Curiosity's work on Mars (Feb. 9, 2014). The rover drove over the dune three days earlier.

For scale, the distance between the parallel wheel tracks is about 9 feet (2.7 meters). The dune is about 3 feet (1 meter) tall in the middle of its span across an opening called "Dingo Gap." This view is looking eastward. The image has been white-balanced to show what the Martian surface materials would look like if under the light of Earth's sky. February 9, 2014. (NASA/JPL-Caltech/MSSS)

Activity 2 - **6002** - ***Murray Ridge***

After driving uphill about 139 feet (42.5 meters) during the 3,485th Martian day, or sol, of its work on Mars (Nov. 12, 2013), NASA's Mars Exploration Rover, Opportunity, captured this image with its navigation camera. The climb ascended Murray Ridge above Solander Point on the western rim of Endeavour Crater.

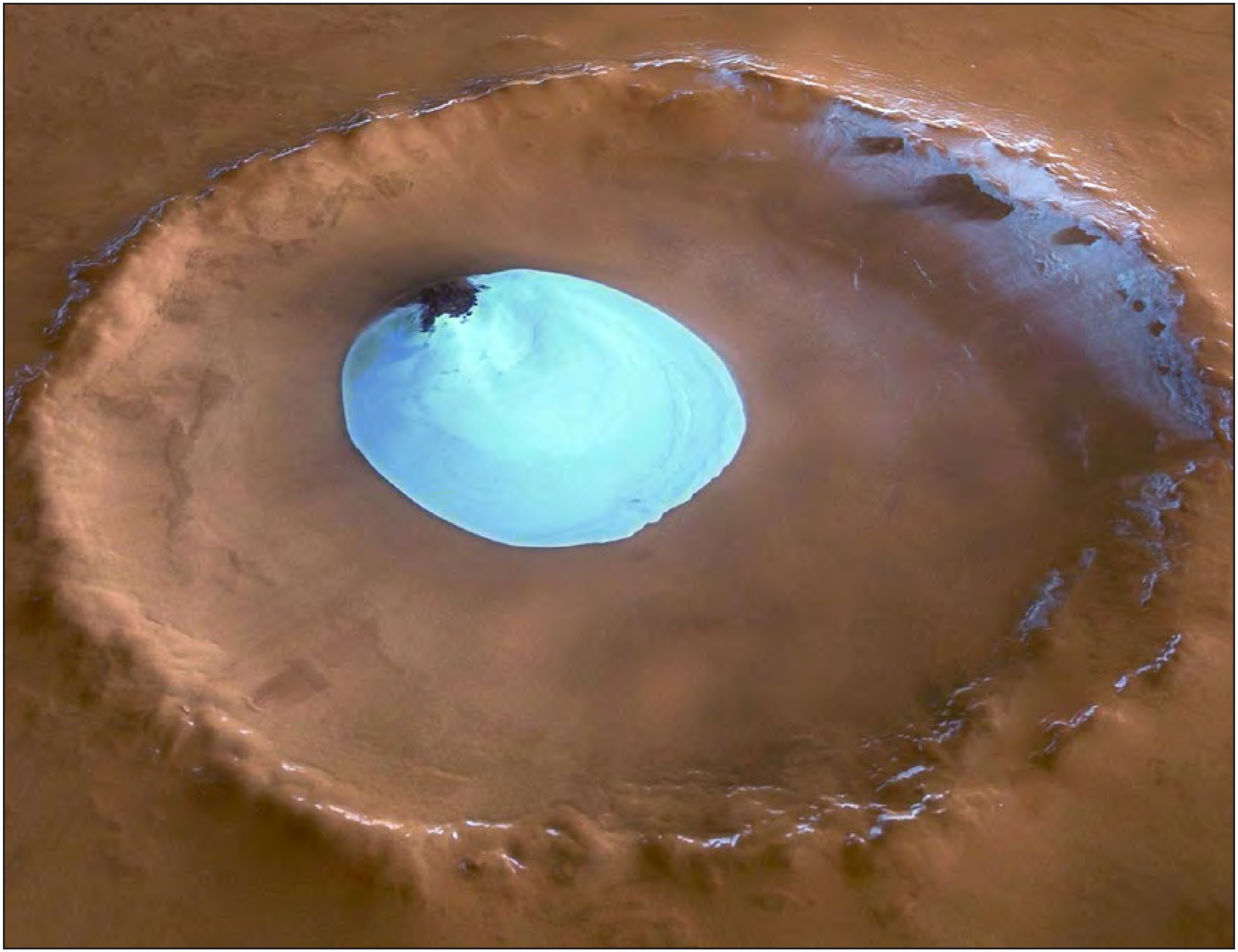
The view is toward the north-northeast. The distance between the two parallel tracks is about 3.3 feet (1 meter). This sol's drive brought Opportunity's cumulative driving distance to 24.01 miles (38.64 kilometers).
November 12, 2013. (NASA/JPL-Caltech)

Activity 2

6003

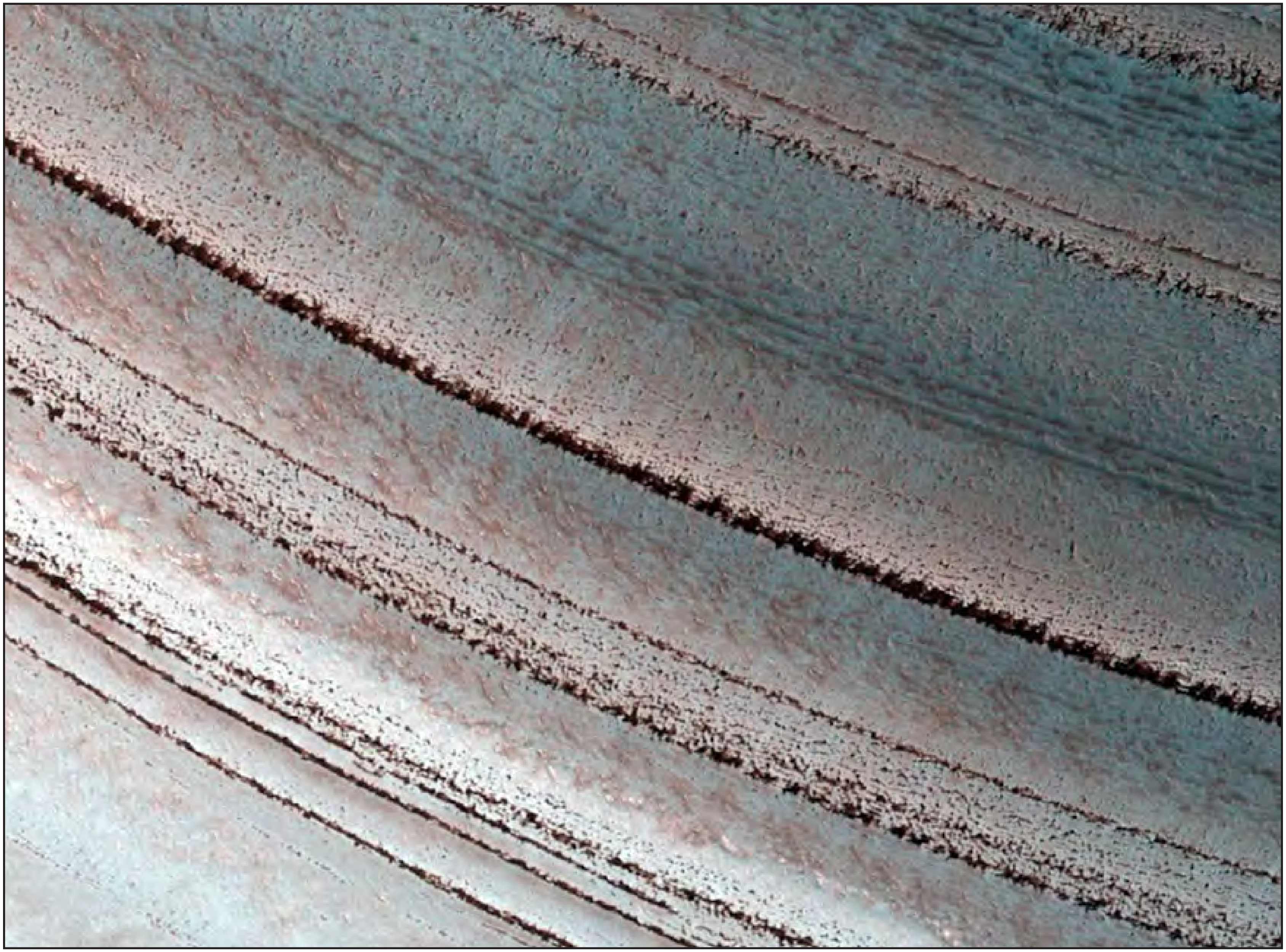
Mars Crater Ice

The European Space Agency's (ESA's) Mars Express obtained this view of an unnamed impact crater located on Vastitas Borealis, a broad plain that covers much of Mars's far northern latitudes. The circular patch of bright material located at the center of the crater is residual water ice. The colors are very close to natural, but the vertical relief of the topography is exaggerated three times. This patch of ice is present all year round, remaining after frozen carbon dioxide overlaying it disappears during the Martian summer. February 2, 2005. (ESA/DLR/ Freie Universitat Berlin/G. Neukum)



Activity 2
6004

Icy Layers and Climate Fluctuations Near the Martian North Pole. *In the Martian north polar region, layered deposits are an ice sheet, much like the Greenland ice sheet on the Earth. Just as with the ice sheet in Greenland, this Martian ice sheet contains many layers that record variations in the Martian climate. Sometimes icy layers can be ablated away during warm climates. Later the ice sheet can be buried by new ice layers and grow in size again. It's likely that many of these cycles have occurred over the ice sheet's history. March 11, 2010. (NASA/JPL-Caltech/University of Arizona)*

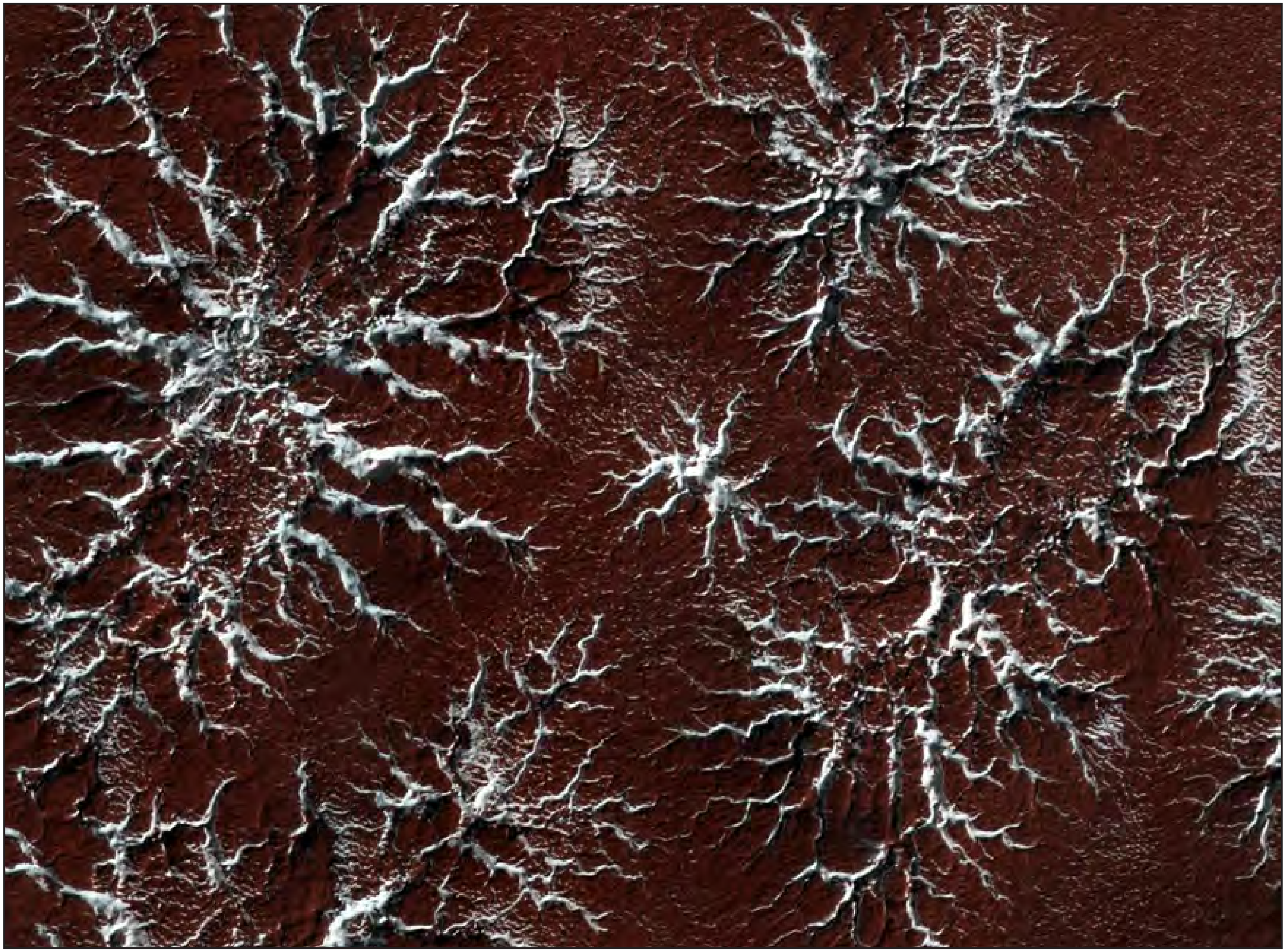


Activity 2

6005

Dry Ice Gone Wild

On Mars, the seasonal polar caps are composed of dry ice (carbon dioxide). In the springtime, as the sun shines on the ice, it turns from solid to gas and causes erosion of the surface. "Spiders," "caterpillars," or "starbursts," can be colloquial words for what is actually called "araneiform" terrain. This particular example shows eroded channels filled with bright ice, in contrast to the muted red of the underlying ground. In the summer, the ice will disappear into the atmosphere, which leaves just the channels carved in the surface. This type of erosion does not take place anywhere naturally on earth because our climate is too warm. January 12, 2011. (NASA/JPL-Caltech/University of Arizona)

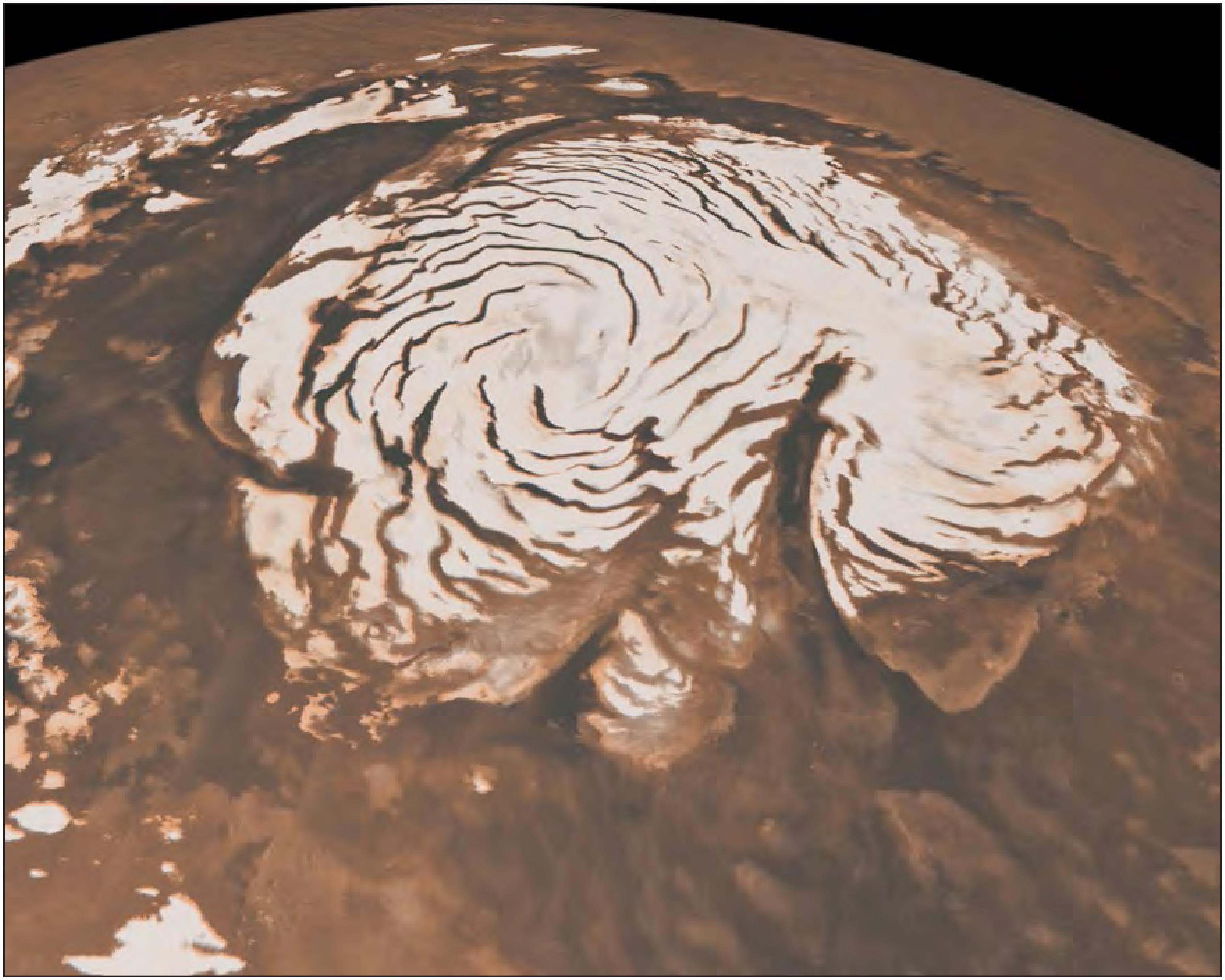


Activity 2

6006

Polar Region of Mars

This image, combining data from two instruments aboard NASA's Mars Global Surveyor, depicts an orbital view of the north polar region of Mars. The ice-rich polar cap (the quasi-circular white area at center) is approximately 1,000 kilometers (621 miles) across. The white cap is riven with dark, spiral-shaped bands. These are deep troughs that are in shadow. They do not reflect sunlight as well or have more internal layers exposed. To the right of center, a large canyon, Chasma Boreale, almost bisects the ice cap. Chasma Boreale is about the length of the Grand Canyon and up to 2 kilometers (1.2 miles) deep. May 26, 2010. (NASA/JPL-Caltech/MSSS)

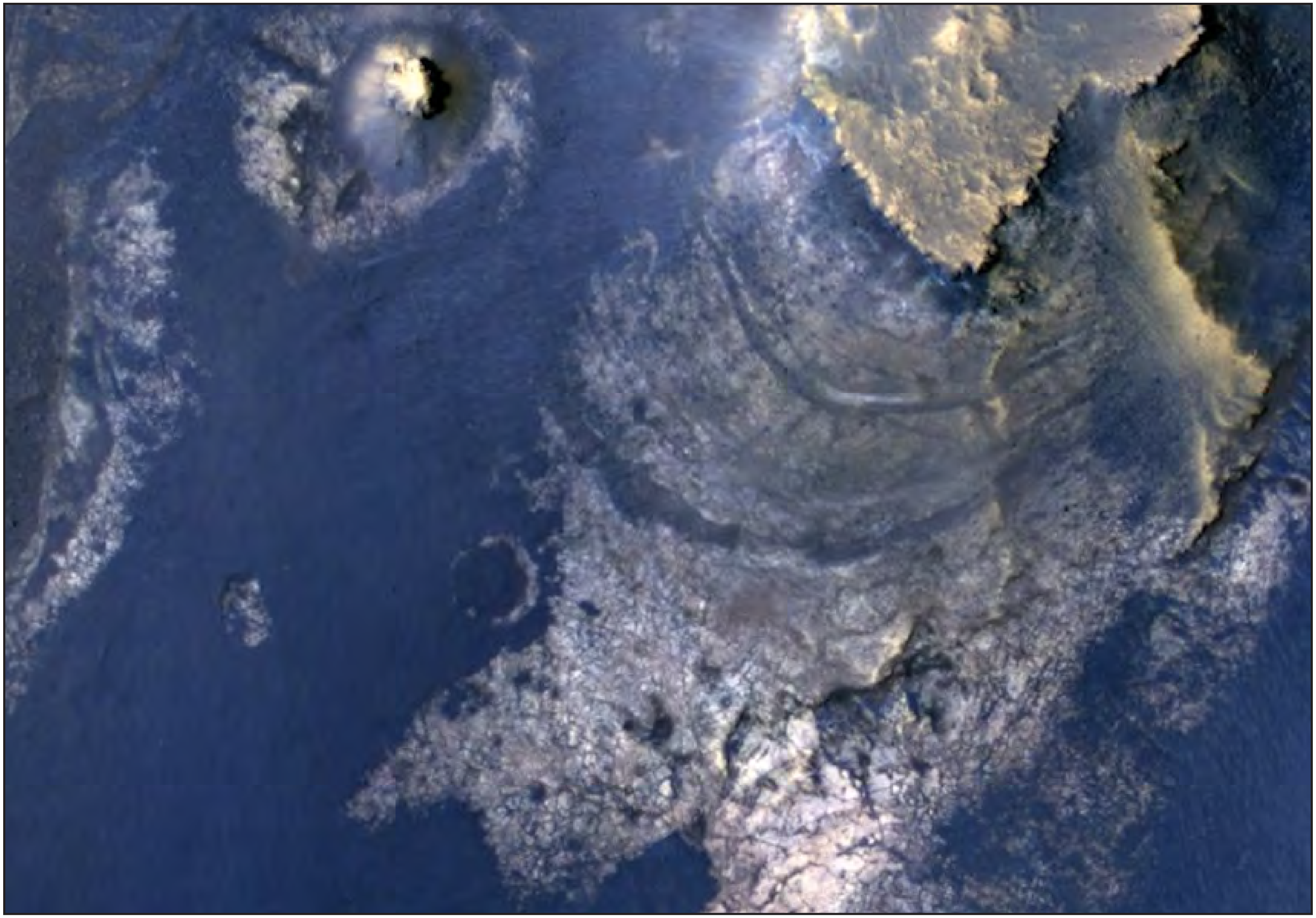


Activity 2

6007

McLaughlin Crater Image Clues

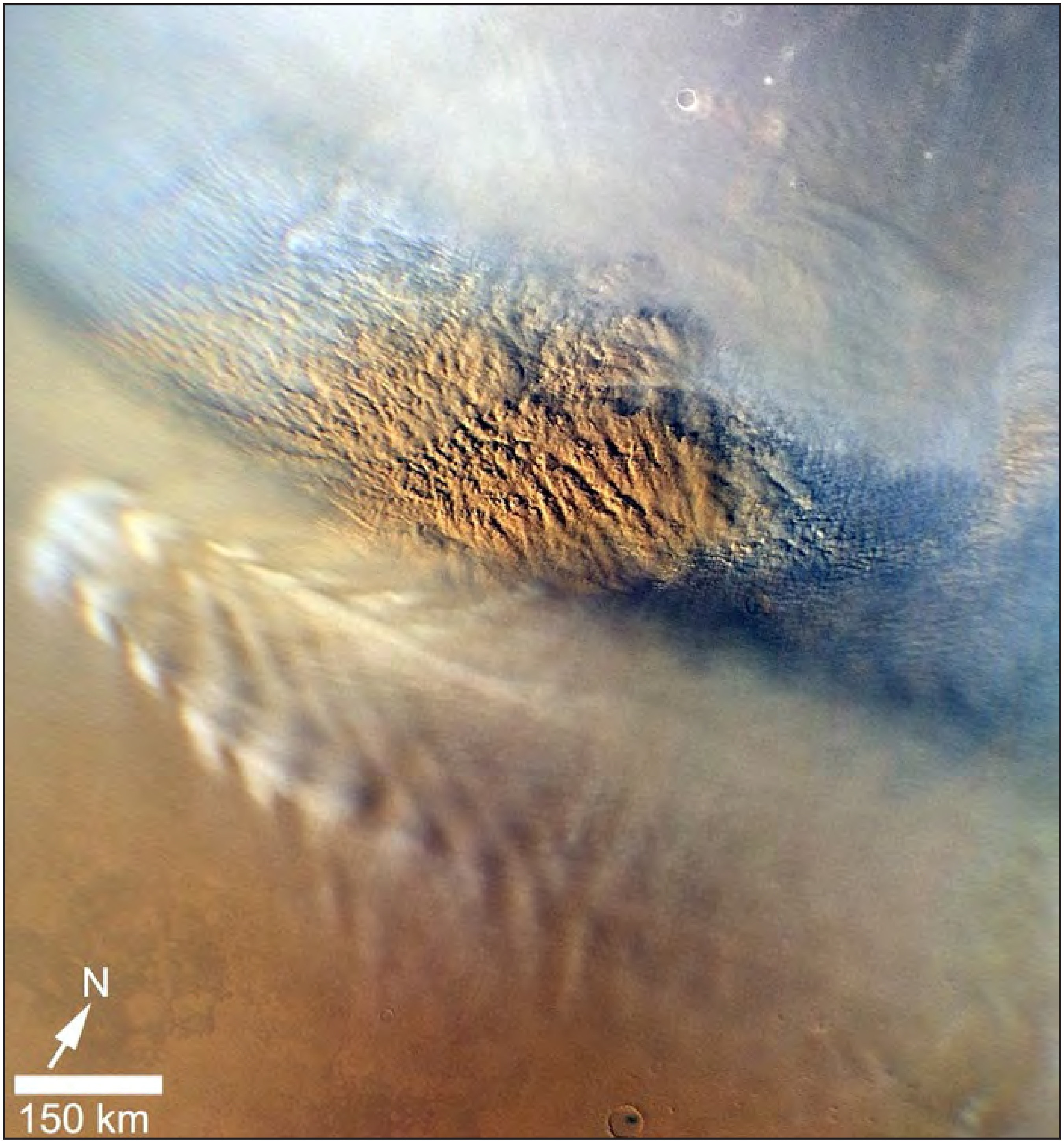
This view of layered rocks on the floor of McLaughlin Crater shows sedimentary rocks that contain spectroscopic evidence for minerals formed through interaction with water. The High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter recorded the image. A combination of clues suggests this 1.4-mile-deep (2.2-kilometer-deep) crater once held a lake fed by groundwater. Part of the evidence is identification of clay and carbonate minerals within layers visible near the center of this image. The scene covers an area about one-third of a mile (about 550 meters) across. North is up. January 20, 2013. (NASA/JPL-Caltech/University of Arizona)



Activity 2 - 6008

Barchan Dunes on the Move

Sand dunes such as those seen in this image have been observed to creep slowly across the surface of Mars through the action of the wind. These are a particular type of dune called a "barchan," which forms when the wind blows in one direction (here, east to west) for long periods. Barchan dunes are common on Mars and in the desert regions of the Earth. These barchan dunes are located on the western rim of the Hellas impact basin, in the Southern Hemisphere of Mars. This area is covered by extensive deposits of layered rocks that were initially deposited as loose sediments and, over time, formed these rock layers. Portions of these layered rocks were subsequently eroded away, and the remaining layers now form numerous flat-topped hills called "mesas." Careful comparison of repeat images can reveal the speed and manner by which dunes move across the Martian surface. This information can be used to study the current atmosphere of Mars, the age and mobility of sand deposits on the planet's surface. November 4, 2013. (NASA/JPL-Caltech/University of Arizona)



Activity 2 - **6009** - **Martian Dust Storm**

This image is centered on Utopia Planitia, along the north seasonal polar cap edge in late northern winter. Scientists were looking at similar small storms that form near the south seasonal polar cap edge. The dust storm pictured here was short-lived, lasting less than 24 hours. The image also shows the seasonal north polar cap (at top of figure) and gravity-wave water ice clouds coming off of Mie crater, just south of the storm. Gravity-wave clouds, also called lee-wave clouds, are clouds that result from changes in atmospheric pressure, temperature, and height because of vertical displacement, such as when wind blows over a mountain or crater wall. The projection of the image is polar stereographic and the image has a resolution of about 0.6 miles (1 kilometer) per pixel. November 7, 2007. (NASA/JPL-Caltech/MSSS)

Activity 2 - 6010

A Moment Frozen in Time

This small panorama of the western sky was obtained using Pancam's 750-nanometer, 530-nanometer and 430-nanometer color filters. This filter combination allows false color images to be generated that are similar to what a human would see, but with the colors slightly exaggerated. The terrain in the foreground is the rock outcrop "Jibsheet". The floor of Gusev crater is visible in the distance, and the Sun is setting behind the wall of Gusev some 80 km (50 miles) in the distance. This example captures some important scientific information. Specifically, sunset and twilight images are occasionally acquired by the science team to determine how high into the atmosphere the Martian dust extends, and to look for dust or ice clouds. Similar long twilights or extra-colorful sunrises and sunsets sometimes occur on Earth when tiny dust grains that are erupted from powerful volcanoes scatter light high in the atmosphere. May 19th, 2005. (NASA/JPL-Caltech/Texas A&M/Cornell University)

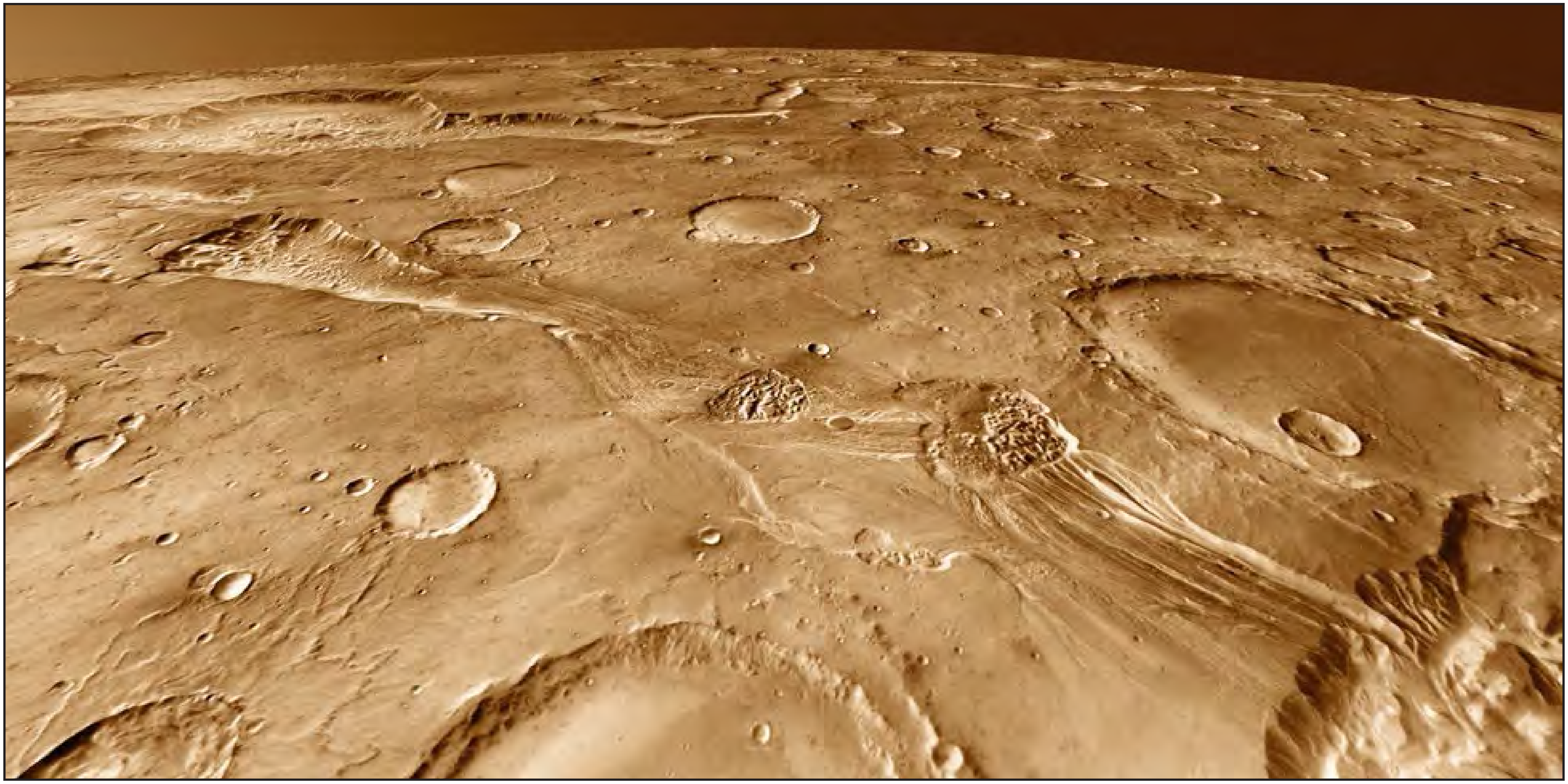
Activity 2 - **6011** - ***Destination, Mount Sharp Terrain***

A chapter of the layered geological history of Mars is laid bare in this postcard from NASA's Curiosity rover. The image shows the base of Mount Sharp, the rover's eventual science destination. This image is a portion of a larger image taken by Curiosity's 100-millimeter Mast Camera on Aug. 23, 2012. Scientists enhanced the color in one version to show the Martian scene under the lighting conditions we have on Earth, which helps in analyzing the terrain. For scale, an annotated version of the figure highlights a dark rock that is approximately the same size as Curiosity. The pointy mound in the center of the image, looming above the rover-sized rock, is about 1,000 feet (300 meters) across and 300 feet (100 meters) high. August 23, 2012. (NASA/JPL-Caltech/MSSS)

Activity 2

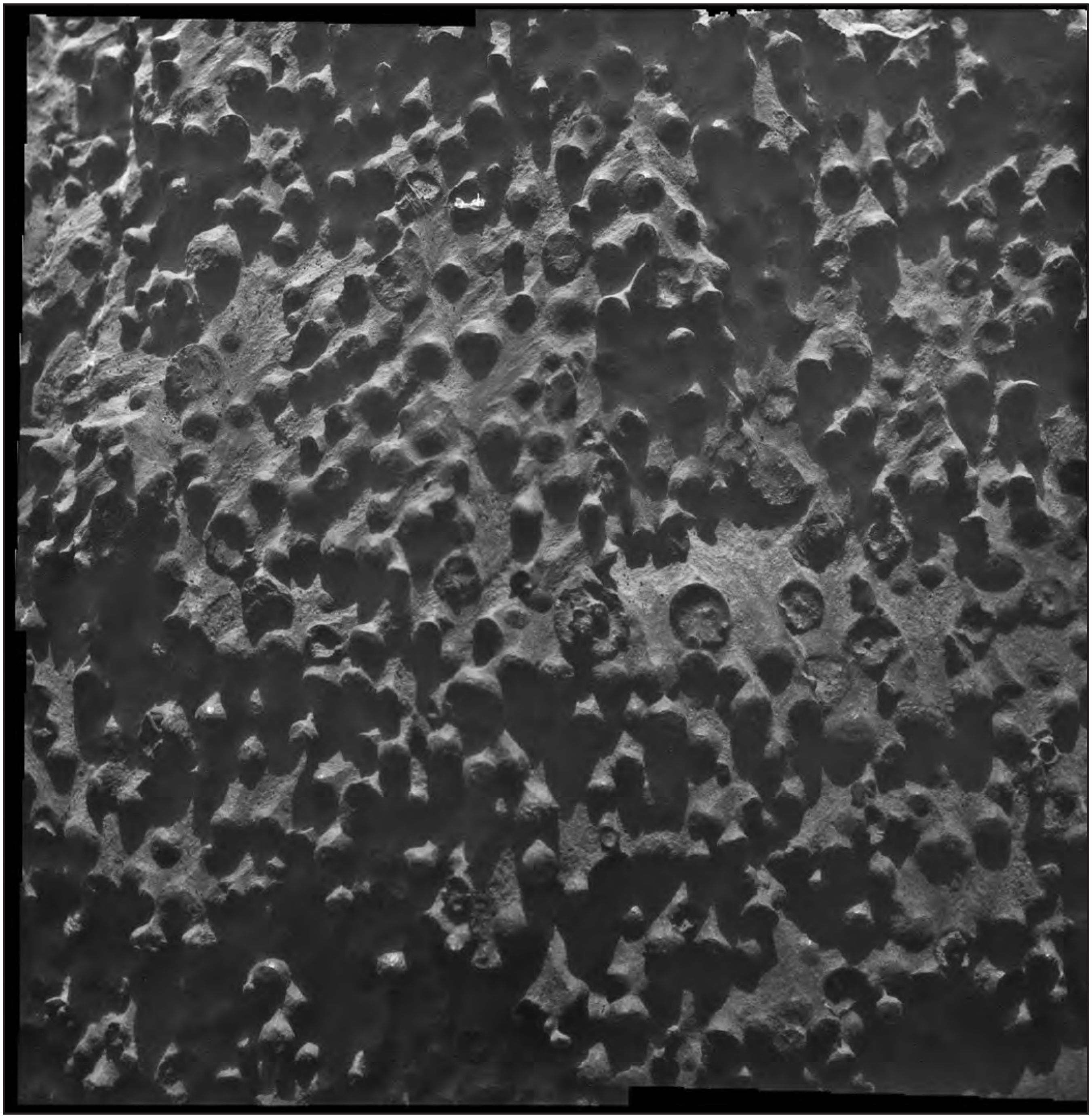
6012 - *Carbonate-Containing Martian Rocks*

In 2005, NASA confirmed that an outcrop called "Comanche" contains a mineral. This indicates that a past environment was wet and non-acidic, possibly favorable to life. The rover's Moessbauer spectrometer, miniature thermal emission spectrometer, and alpha particle X-ray spectrometer each examined targets on Comanche. On June 3, 2010, scientists, using data from all three spectrometers, reported that about one-fourth of the composition is magnesium iron carbonate. That concentration is 10 times higher than any previously identified carbonate in a Martian rock. Carbonates originate in wet, near-neutral conditions but dissolve in acid. Comanche is the dark reddish mound above the center of the view. December 11, 2005. (NASA/JPL-Caltech/Cornell University)



Activity 2 - **6013** - ***Short, Fast Run***

Around 200 kilometers long, Ravi Vallis was born in a flood of water from Aromatum Chaos (left). The racing waters sliced a pathway across Xanthe Terra, spawned at least two small chaos regions in the channel (center), and then hurtled over the plateau edge to disappear into another chaos region (right foreground). In the distance at left lies Orson Welles Crater and the meandering path of Shalbatana Vallis, a much longer outflow channel perhaps related hydrologically to Ravi. This view looks northwest from an altitude of about 120 kilometers (75 miles); vertical exaggeration 1.5x. Date unknown. (NASA/JPL/Arizona State University, R. Luk)

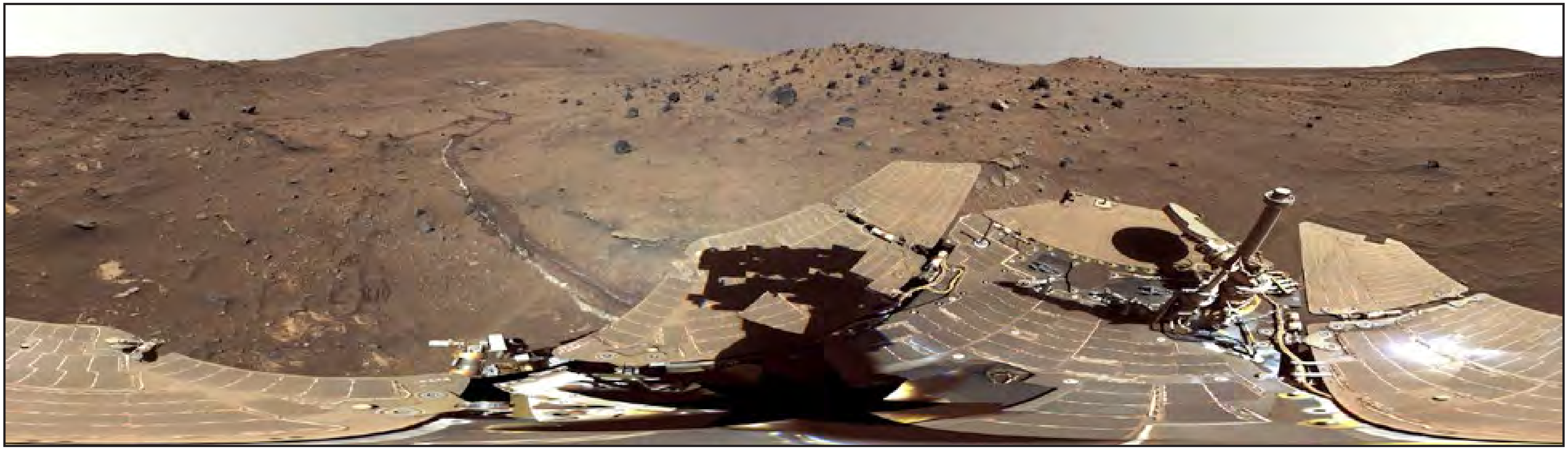


Activity 2 - **6014** - ***Blueberry Spherules***

Small spherical objects fill the field that combines four images from the Microscopic Imager on Mars Exploration Rover, Opportunity. The view covers an area about 2.4 inches across, at an outcrop called "Kirkwood" on the western rim of Endeavour Crater. The individual spherules are about one-eighth inch in diameter. Opportunity discovered spherules at its landing site more than eight years earlier, nicknaming them "blueberries." They provide evidence about long-ago wet environmental conditions on Mars because researchers, using Opportunity's science instruments, identified them as concretions rich in the mineral hematite deposited by water saturating the bedrock. The spherules at Kirkwood do not have the iron-rich composition of the blueberries. September 6, 2012. (NASA/JPL-Caltech/Cornell University/USGS/Modesto Junior College)

Activity 2 - **6015** - ***Iron Meteorite***

NASA's Mars Exploration Rover Opportunity found an iron meteorite on Mars: the first meteorite of any type ever identified on another planet. The pitted, basketball-size object is mostly made of iron and nickel. Readings from spectrometers on the rover determined its composition. This composite combines images taken through the panoramic camera's 600-nanometer (red), 530-nanometer (green), and 480-nanometer (blue) filters. January 6, 2005. (NASA/JPL/Cornell University)



Activity 2 - **6016** - ***Spirit Mars Rover in McMurdo Panorama***

This 360-degree view, called the "McMurdo" panorama, comes from the Panoramic Camera on Mars Exploration Rover Spirit. Many dark, porous-textured volcanic rocks can be seen around the rover, including Low Ridge. Two rocks to the right of center are thought to be meteorites. On the right, "Husband Hill" on the horizon, the rippled "El Dorado" sand dune near the base of that hill, and lighter-toned "Home Plate" below the dunes provide context for Spirit's travels from mid-2005 to early 2006. Left of center, tracks and a trench dug by Spirit's right-front wheel, which could no longer rotate, exposed bright underlying material. This material is evidence of sulfur-rich salty minerals in the subsurface, providing clues about the watery past of this part of Gusev Crater. October 5, 2006. (NASA/JPL-Caltech/Cornell University/Arizona State University)

Activity 2

6017 - ***Link to a Watery Past***

In this image from the Curiosity rover, a rock outcrop, called "Link," pops out from a Martian surface that is elsewhere blanketed by reddish-brown dust. The fractured Link outcrop has blocks of exposed, clean surfaces. Rounded gravel fragments, or clasts, up to a couple inches in size are in a matrix of white material. Many gravel-sized rocks have eroded out of the outcrop onto the surface, particularly in the left portion of the frame. The outcrop characteristics are consistent with a sedimentary conglomerate, or a rock that was formed by the deposition of water and is composed of many smaller rounded rocks cemented together. Water transport is the only process capable of producing the rounded shape of clasts of this size. September 2, 2012. (NASA/JPLCaltech/MSSS)

Activity 2 - **6018** - ***Remnants of Ancient Streambed on Mars***

Curiosity rover found evidence for an ancient, flowing stream including the Mars rock outcrop pictured here, which has been named "Hottah" after a Lake in Canada. It may look like a broken sidewalk, but this geological feature is actually exposed bedrock made up of smaller fragments cemented together, or sedimentary conglomerate. Scientists theorize that the bedrock was disrupted in the past, giving it the titled angle, most likely via impacts from meteorites. The key evidence for the ancient stream comes from the size and rounded shape of the gravel in and around the bedrock. Some of the clasts are round in shape, leading the science team to conclude they were transported by a vigorous flow of water; the grains are too large to have been moved by wind. September 14, 2012. (NASA/JPL-Caltech/MSSS)

Activity 2 - **6019** - ***Matijevic Hill***

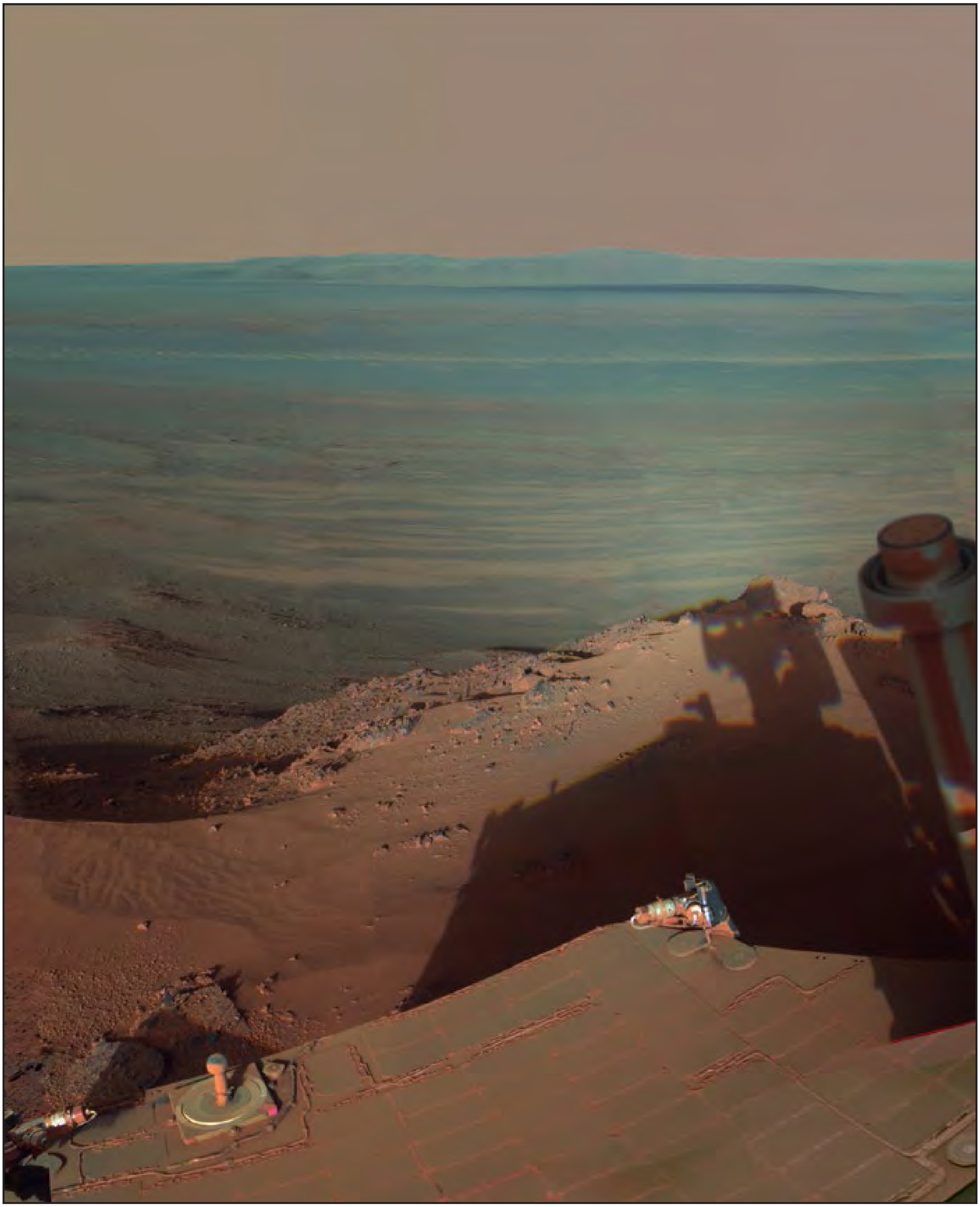
Rock fins up to about 1 foot tall dominate this scene from the Panoramic Camera (Pancam) on NASA's Mars Exploration Rover Opportunity. The component images were taken during the 3,058th Martian day, or sol, of Opportunity's work on Mars (Aug. 23, 2012). The view spans an area of terrain about 30 feet (9 meters) wide. This outcrop is within an area informally named Matijevic Hill. Orbital investigation has identified a possibility of clay minerals in this area. It is presented in false color to make some differences between materials easier to see. August 23, 2012. (NASA/JPL-Caltech/Cornell University/Arizona State University)

Activity 2 - **6020** - ***First Use of Mars Rover Curiosity's Dust Removal Tool***

This image from the Mars Hand Lens Imager (MAHLI) on NASA's Mars rover Curiosity shows the patch of rock cleaned by the first use of the rover's Dust Removal Tool (DRT). The tool is a motorized, wire-bristle brush on the turret at the end of the rover's arm. Its first use was on the 150th Martian day, or sol, of the mission (Jan. 6, 2013). MAHLI took this image from a distance of about 10 inches (25 centimeters) after the brushing was completed on this rock target called "Ekwir_1." The patch of the rock from which dust has been brushed away is about 1.85 inches by 2.44 inches (47 millimeters by 62 millimeters). January 6, 2013. (NASA/JPL-Caltech/MSSS)

Activity 2 - **6021** - ***Whitewater Lake Rock Viewed by Opportunity***

A rind that appears bluish in this false-color view covers portions of the surface of a rock called "Whitewater Lake" in the top half of the view from Mars Rover Opportunity. Whitewater Lake is in the Matijevic Hill portion of the Cape York segment of the rim of Endeavour Crater. Whitewater Lake is the large flat rock in the top half of the image. From left to right it is about 30 inches across. The dark blue nubby rock to the lower left is Kirkwood, which bears non-hematite spherules. The rocks to the lower right look like breccias: a type of rock containing jumbled fragments cemented together. September 6, 2012. (NASA/JPL-Caltech/Cornell University/Arizona State University)

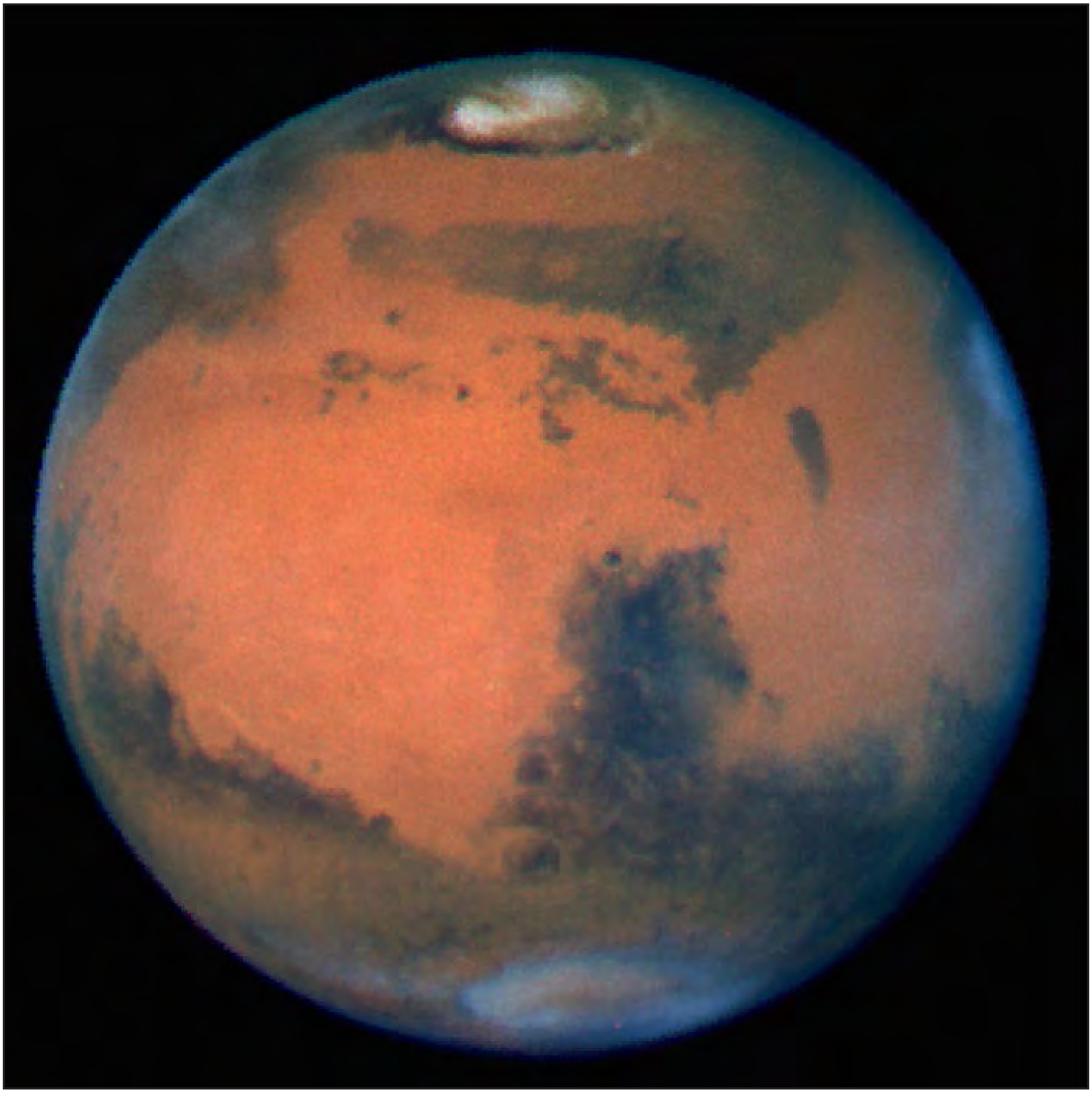


Activity 2 - **6022** - ***Late Afternoon Shadows at Endeavour Crater on Mars***

Mars Rover Opportunity catches its own late-afternoon shadow in this view eastward across Endeavour Crater on Mars. The rover used the Panoramic Camera to record images taken through different filters and combined into this mosaic view. The crater spans 14 miles in diameter, or about the same area as the city of Seattle. This is more than 20 times wider than Victoria Crater, the largest impact crater that Opportunity had previously examined. The interior basin of Endeavour is in the upper half of this view. The view is presented in false color to make some differences between materials easier to see, such as the dark sandy ripples and dunes on the crater's distant floor. March 9, 2012. (NASA/JPL-Caltech/Cornell University/Arizona State University)

Activity 2 - **6023** - ***Spirit Lander and Bonneville Crater in Color***

This image, taken on Jan. 29, 2012, provided the first image from orbit to show Spirit's lander platform in color. The view covers an area about 2,000 feet wide, dominated by Bonneveille Crater. North is up. A bright spot on the northern edge of Bonneville Crater is a remnant of Spirit's heat shield. Spirit spent most of its six-year working life in a range of hills about two miles east of its landing site. (NASA/JPL-Caltech/University of Arizona)



Activity 2 - **6029**- ***Hubble's Sharpest View of Mars***

This stunning portrait of Mars was taken just before Mars opposition, when the red planet made one of its closest passes to the Earth (about 60 million miles). The Martian north pole is at the top. This view of Mars was taken on the last day of Martian spring in the northern hemisphere. The annual north polar carbon dioxide frost (dry ice) cap is rapidly sublimating (evaporating from solid to gas), revealing the much smaller permanent water ice cap, along with a few nearby detached regions of surface frost. The receding polar cap also reveals the dark, circular sea of sand dunes that surrounds the north pole (Olympia Planitia). Other prominent features in this hemisphere include Syrtis Major Planitia, the large dark feature seen just below the center of the disk. The giant impact basin Hellas (near the bottom of the disk) is shrouded in bright water ice clouds. March 10, 1997. (David Crisp and the WFPC2 Science Team/Jet Propulsion Laboratory/California Institute of Technology)

Activity 2 - **6030** - ***Blue Marble***

Much of the information contained in this image came from a single remote-sensing device-NASA's Moderate Resolution Imaging Spectroradiometer, or MODIS. Flying more than 700 km above the Earth onboard the Terrasatellite, MODIS provides an integrated tool for observing a variety of terrestrial, oceanic, and atmospheric features of the Earth. The land and coastal ocean portions of these images are based on surface observations collected from June through September 2001 and combined, or composited, every eight days to compensate for clouds that might block the sensor's view of the surface on any single day. 2001. (NASA Goddard Space Flight Center)

Activity 2 - **6031** - ***Tenoumer Crater, Mauritania***

Deep in the Sahara Desert lies a crater. It is 1.9 kilometers wide, with a rim 100 meters high. Modern geologists long debated what caused this crater, some favoring a volcano. Closer examination revealed that the crater's hardened "lava" was actually rock that had melted from a meteorite impact. The crater's outline is unmistakable, yet it doesn't necessarily look like a crater; the light and shadows make it look like someone pressed a giant cookie cutter into the rock. The sunlight shines from the southeast (lower right), and the bright arc along the northwestern part of the crater is where crater walls slope up to the rim. Around the perimeter, the relatively steep walls cast dark shadows. Although it resides in ancient rock, Tenoumer is geologically young, ranging in age between roughly 10,000 and 30,000 years old.

January 24, 2008. (NASA image created by Jesse Allen, using data provided courtesy of NASA/GSFC/METI/ERSDAC/JAROS, and United States/Japan ASTER Science Team)

Activity 2
6032 - *Death Valley*
Detail view of heavily eroded ridges at the famous Zabriskie Point, Death Valley National Park, California. 2014. (iStock)

Activity 2 - **6034** - ***Sand Hills***
Big stones in Sand Hills of Samaria, Israel. 2012. (iStock)

Activity 2
6035 - ***Desert Canyon***
The Perazim canyon. Judean Desert nature reserve, Israel. 2009. (iStock)

Activity 2 - **6036** - ***Playa***
Racetrack Playa is a seasonally dry lake (a playa), located in the northern part of the Panamint Mountains in Death Valley National Park, California. 2009. (iStock)

Activity 2
6037 - *River Valley*
Rocks and gravel are heavy substances, and thus are not generally moved by wind. They can be easily displaced by the flow of water, however. 2012. Kali Gandaki river valley with Himalayan mountains in the background. (iStock)

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