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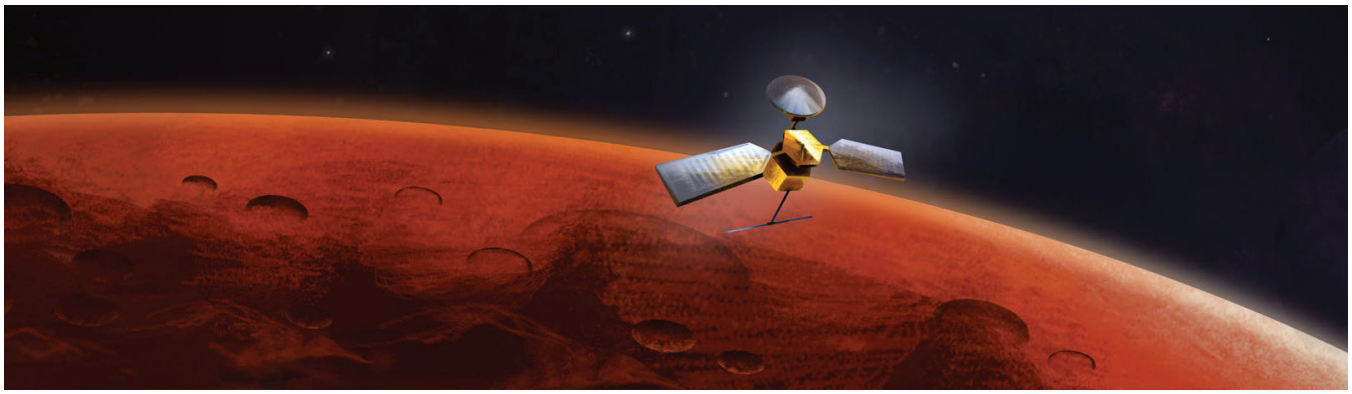

Geology on Mars

Investigation Notebook with Article Compilation

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Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

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Geology on Mars

Investigation Notebook

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Chapter 3: Analyzing New Evidence

Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____ Date: _____

Geology on Mars
Unit Overview

How can we search for evidence that other planets were once habitable? This is the question that you and your classmates will take on in your role as student planetary geologists. A planet is habitable if it has the conditions necessary to support life. Liquid water is one of those conditions; it is essential for life to exist. In your search, you will focus on our neighboring planet, Mars. You will examine a particular landform on the surface of Mars to investigate whether it was formed by flowing water or flowing lava. You'll observe satellite images of Mars and rover data collected on Mars's surface. You will also get evidence from models and compare Mars images to images of landforms formed by flowing water and flowing lava on Earth's surface.

Name: _____ Date: _____

Chapter 1: Comparing Earth and Rocky Planets
Chapter Overview

Could life exist on Mars? One essential requirement for life is water. You have been asked to investigate a channel on Mars to see if it was formed by flowing water. You will begin by comparing landforms on Mars with landforms on Earth.

Name: _____ Date: _____

Lesson 1.1: Comparing Rocky Planets

Today you will take on the role of a student planetary geologist working for the Universal Space Agency. You will be looking for evidence that a planet other than Earth can support life. You will use the same data and practices that planetary geologists use to explore Earth, Mercury, Venus, and Mars, and you'll get to study each of these planets in detail. This will help you form your own ideas about where in our solar system future space missions might find evidence of life. Welcome to outer space!

Unit Question

- How can we search for evidence that other planets were once habitable?

Vocabulary

- habitable
- rocky planet
- system

Name: _____ Date: _____

Comparing Rocky Planets

Working with a partner, use the Comparing Rocky Planets Cards to gather evidence about which planet is most similar to Earth.

1. Which sphere are you and your partner studying? (check one)

☐ atmosphere ☐ biosphere ☐ geosphere ☐ hydrosphere

2. Record your notes about your sphere for each planet.

Mercury:

_____

_____

_____

_____

Venus:

_____

_____

_____

_____

Earth:

_____

_____

_____

_____

Mars:

_____

_____

_____

_____

Name: _____ Date: _____

Comparing Rocky Planets (continued)

3. Answer the following questions for your sphere, using evidence from the Comparing Rocky Planets Cards.

For the sphere you studied, which rocky planet is most similar to Earth? _____

Why?

_____

_____

_____

_____

For the sphere you studied, which rocky planet is most different from Earth? _____

Why?

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Signs of Habitability on Mars

1. This unit focuses on Mars. List one or two ideas or questions you have about Mars.

_____

_____

_____

_____

2. Scientists are looking for signs that Mars could have been habitable in the past. Think of the things that a planet needs to be habitable. With these things in mind, what signs of habitability would you look for on Mars?

_____

_____

_____

_____

3. Why would you look for the signs of habitability that you listed above?

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reading "Scale in the Solar System"

Read and annotate the "Scale in the Solar System" article. Then, answer the questions below.

1. What is the biggest object in our solar system, and how many Earths could fit inside it?

_____

_____

_____

_____

2. Humans have been on the Moon, so why haven't humans visited any other planets in the solar system?

_____

_____

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Lesson 1.2: Observing the Surfaces of Mars and Earth

You have been asked to help search for evidence that Mars might have been habitable in the past. You'll begin by exploring an interactive map of Mars's surface that is based on 50 years of data from satellites, rovers, and landers. You will also study aerial images that show landforms formed by flowing water and flowing lava on Earth to help identify whether landforms on Mars might have been formed by the liquid water that is necessary for a place to be habitable.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 1 Question

- What geologic process could have formed the channel on Mars?

Key Concepts

- Earth, Mars, and other rocky planets can be thought of as systems. These systems are made up of interacting spheres that can include the geosphere, atmosphere, hydrosphere, and biosphere.

Vocabulary

- channel
- geologic process
- landform

Digital Tools

- NASA's Mars Trek

Name: _____ Date: _____

Warm-Up

In a moment, you will watch a video made by other students about the Earth system. A system is a set of interacting parts forming a complex whole.

What systems can you think of? List one or two examples of things that you think might be systems.

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Observing the Surface of Earth

1. With your partner, closely examine each of the landforms on the Geologic Processes Cards.
2. In the middle column of the table below, describe the shape of the landforms formed by each geologic process.
3. In the last column, record any other interesting observations or questions you have about the landforms.

Word Bank

straight	wide	branching	triangular
curved	narrow	merging	square
gnarled	spread out	loopy	circular

Geologic process	**Describe the shape of the landforms formed by this geologic process.**	**Record other observations or questions about the landforms formed by this geologic process.**
Flowing water		
Flowing lava		

Name: _____ Date: _____

Lesson 1.3: Investigating a Mystery Object on Mars

What is the mysterious object found on Mars? That is the question scientists tried to answer after an image from a rover on Mars showed a mysterious object that looked like a jelly donut. Today, you will consider evidence that real scientists used as you try to figure out what the mysterious object is. To help you with this, you will also learn about how scientists engage in argumentation to find convincing answers to science questions.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 1 Question

- What geologic process could have formed the channel on Mars?

Key Concepts

- Earth, Mars, and other rocky planets can be thought of as systems. These systems are made up of interacting spheres that can include the geosphere, atmosphere, hydrosphere, and biosphere.
- When landforms on different rocky planets look similar, it is evidence that they may have been formed by the same geologic process.

Vocabulary

- claim
- evidence
- geologic process
- landform
- reasoning
- rocky planet
- system

Name: _____ Date: _____

Warm-Up

Read the story about Claire and the puddle, and then answer the questions that follow.

> Claire is a middle school student. On her way to school one day, she saw a puddle in the road. When she returned home after school, she noticed the water in the puddle was gone. What happened to the water in the puddle?

1. What ideas do you have about what happened to the puddle?

_____

_____

_____

_____

2. What information would you need to collect in order to be more confident about what happened to the puddle?

_____

_____

_____

_____

Name: _____ Date: _____

Jelly Donut Evidence Card Sort

1. Sit next to your partner. Place the question and two claims at the top of the desk between you, as shown below.
2. Read the information on each evidence card.
3. Discuss each piece of evidence with your partner.
4. Place the evidence under the claim you think it supports.

Question

What is this object that the *Opportunity* rover photographed on the surface of Mars?

Claim 1

The object is a rock that was moved to that spot.

Claim 2

The object is fungus that grew in that spot.

Evidence

Evidence

Evidence

Evidence

Evidence

Name: _____ Date: _____

Homework: Reflecting on How Planetary Geologists Get Evidence

In your role as a student planetary geologist, you have been helping the Universal Space Agency figure out what geologic process formed the channel on Mars. Answer the questions below and refer to the image of the channel on Mars on page 17.

Landform Formed by Flowing Water	Landform Formed by Flowing Lava
	

1. Above are two images of landforms on Earth. Select one of the images above that you think is evidence that can support an answer to the question *What geologic process could have formed the channel on Mars?* What do you think the answer to this question is, and how does the image you selected support that answer to this question?

_____

_____

_____

_____

_____

2. Based on what you know now, do you think the channel on Mars was formed by flowing water or flowing lava? (check one)

   ☐ flowing water

   ☐ flowing lava

   ☐ unsure

Name: _____ Date: _____

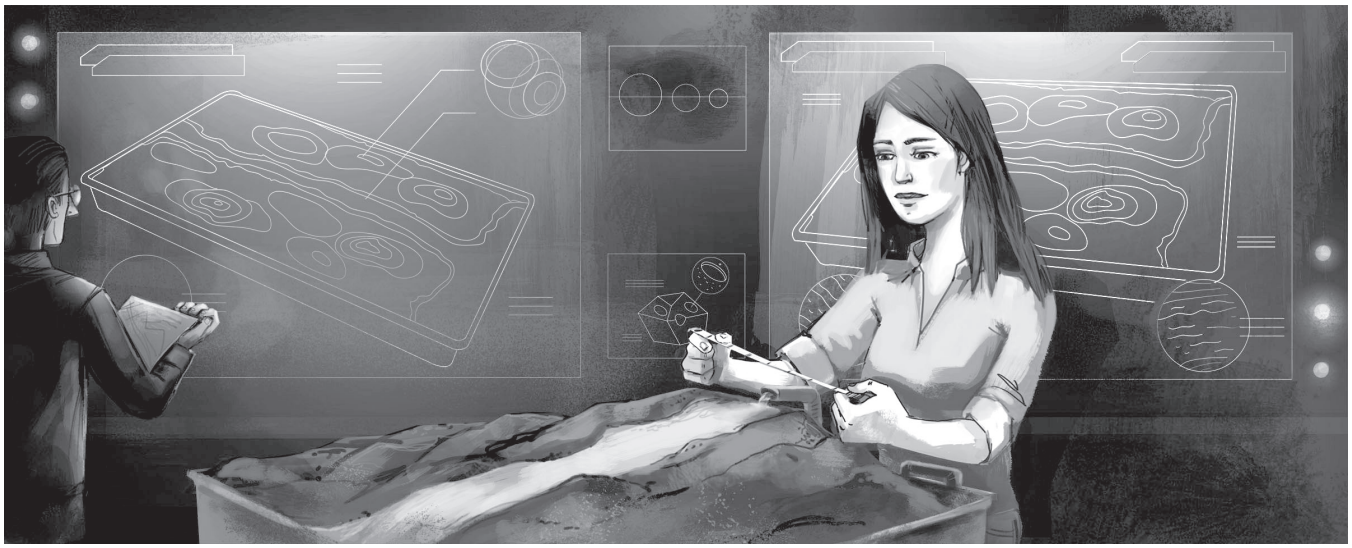
Homework: Reflecting on How Planetary Geologists Get Evidence
(continued)

Channel on Mars

Name: _____ Date: _____

Chapter 2: Using Models as Evidence
Chapter Overview

How can you study a planet that is too far away for you to directly observe? In this chapter, you will learn about models and how scientists use them to gather evidence about things that are otherwise difficult to study.



Name: _____ Date: _____

Lesson 2.1: "Investigating Landforms on Venus"

How do scientists gather evidence about things they cannot directly observe, such as planets that are far away? Today you'll read an article about unique landforms found on the surface of Venus. You'll find out how scientist Taras Gerya used a computer model to figure out what geologic process on Venus formed those landforms. You will practice reading like a scientist: carefully and actively, making sure that you understand the text and images. You will record your questions and ideas as you read, and you'll have a chance to discuss your thoughts about the article with others.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 2 Question

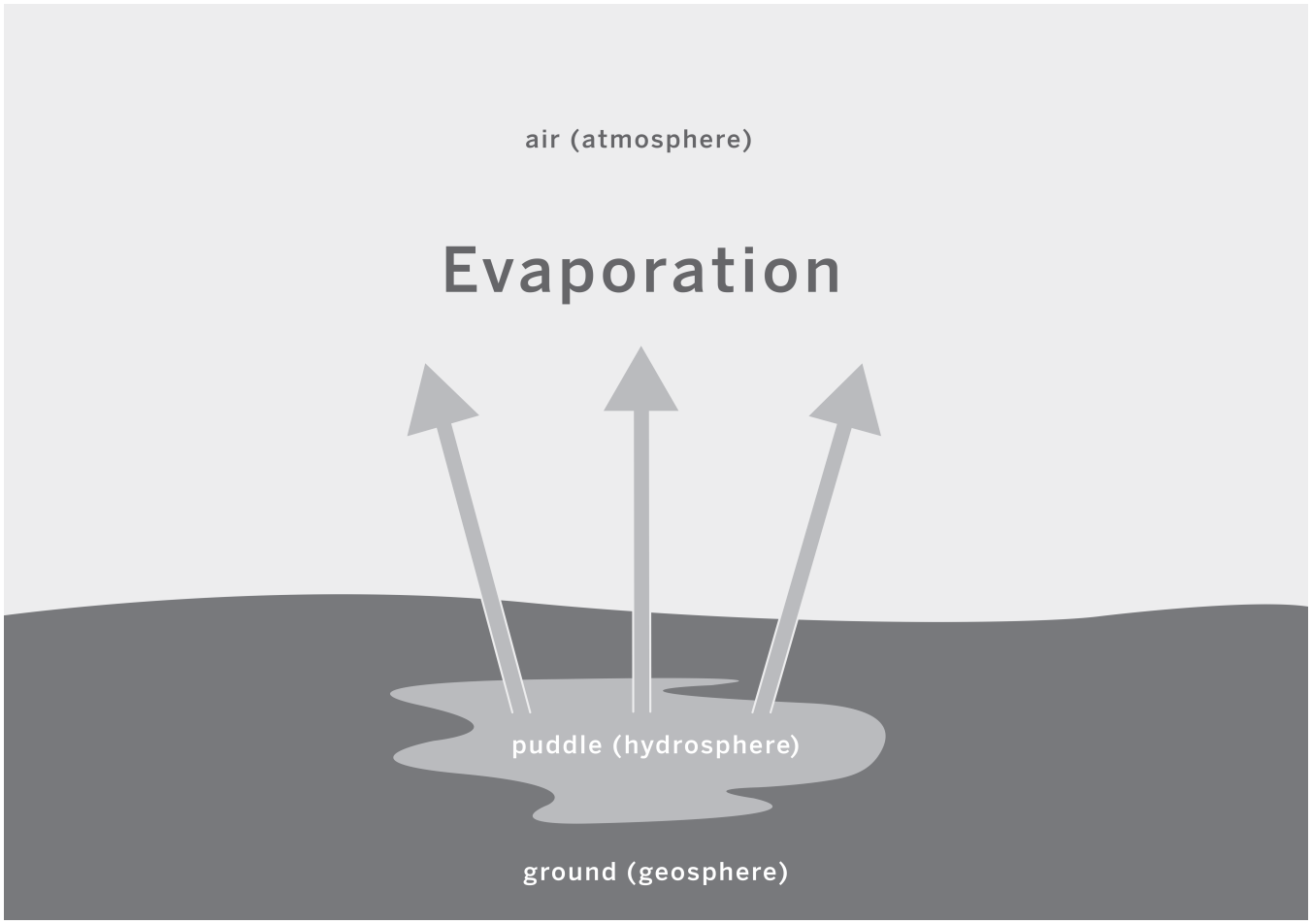
- How can we gather more evidence about whether lava or water formed the channel on Mars?

Vocabulary

- geologic process
- landform
- model

Name: _____ Date: _____

Warm-Up



Claire made the diagram above to show how the puddle she saw on the way to school disappeared by the end of the day. She wanted to show her idea that heat from the sun caused the water to evaporate into the air. However, Claire's diagram is incomplete.

Think about what's missing. What would you add to the diagram to better show Claire's idea?

_____

_____

_____

_____

Name: _____ Date: _____

Introducing Active Reading

that are incredibly powerful, and you can't see them, and they're everywhere," says Lynch. "And they dictate, in my book, pretty much everything that goes on on this planet."

They are so tiny, but so important!

Today, at the University of California, San Francisco, Lynch works with many different types of scientists to study the human microbiome and how it affects the body as a system—which requires building bridges between different areas of science. To study the interactions between microorganisms and the body as a whole, scientists have to think and learn about topics outside of their usual areas of study. "In that way, we're kind of like our own little microbiome," she says. "Everybody brings different knowledge and skills to the table."

The crosscutting concept of Systems

How long have scientists studied microbiome?

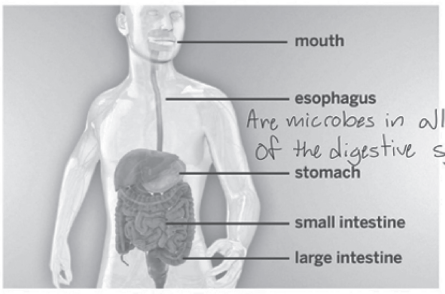
The study of the human microbiome is still in its early stages: scientists are trying to find out and describe the basics of how the microbiome works. Someday, scientists hope to understand exactly what happens during each interaction—and that could open up whole new fields of study.

Interactions seem really important. What does that mean?

What are the challenges?

Studying the human microbiome has its challenges, but Lynch says she loves learning new things—and she encourages young people to find something they love, too. "Go after something that you really enjoy, something that isn't a chore," she says. "I've ended up where I am because I've always gone after things that interest me. I eat, breathe, and sleep this stuff, and I love it."

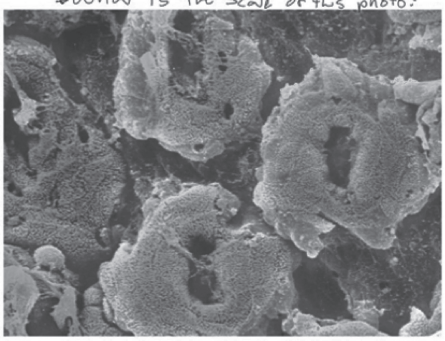
gross



Are microbes in all parts of the digestive system?

Many of the microbes Dr. Susan Lynch studies are found in the human digestive system.

What is the scale of this photo?



This photo, taken with a microscope, shows the wall of a gut infected with ulcerative colitis, a digestive problem that may be caused by the interaction between microorganisms. Lynch's work may someday help heal people with this condition. (Colors were added to the photo to make it easier to see.)

BIG IDEA:

The microbiome interacts with and affects lots of things even though it's not visible

Discussion Questions

- What do you notice about this student's annotations?
- How do you know that she was thinking carefully while reading and trying to understand the article?

Name: _____ Date: _____

Reading "Investigating Landforms on Venus"

1. Read and annotate the article "Investigating Landforms on Venus."
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Recording Initial Ideas About the Chapter 2 Question

Chapter 2 Question: *How can we gather more evidence about whether lava or water formed the channel on Mars?*

One challenge in studying the channel on Mars is that Mars is too far away for scientists to directly observe what happens there.

Based on what you learned about Gerya in the article you read today, how can scientists study Mars if they can't directly observe what is happening there?

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.2: Modeling a Geologic Process

In the previous lesson, you read about a computer model of Venus. Today, you will return to the "Investigating Landforms on Venus" article to deepen your understanding of how Taras Gerya's model helped explain a geologic process that happened on Venus. You will then use a physical model to gather evidence about what formed the channel on Mars.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 2 Question

- How can we gather more evidence about whether lava or water formed the channel on Mars?

Vocabulary

- evidence
- geologic process
- landform
- model

Name: _____ Date: _____

Warm-Up

1. Which question would a scientist be most likely to use a model to answer? (check one)

   ☐ How was this lake formed?

   ☐ What is the temperature of this lake?

   ☐ What is a rock at the bottom of this lake made of?

2. Why might a scientist use a model to answer the question you selected?

_____

_____

_____

_____

Name: _____ Date: _____

Second Read of "Investigating Landforms on Venus"

Gerya and his team wanted to answer the question *What formed the novae on Venus?* Their idea was that the higher surface temperature and thinner crust of Venus caused the novae to form.

- Reread the final three paragraphs of the "Investigating Landforms on Venus" article.
- Then, highlight or add annotations to parts of the text that relate to the questions next to the article.
- Using your annotations, answer the questions below.

How were the novae on Venus similar to the landforms in Gerya's computer model?

_____

_____

_____

_____

How did the results of Gerya's model provide evidence for what formed the novae on Venus?

_____

_____

_____

_____

Name: _____ Date: _____

Stream Table Observations: Do Landforms Remain?

Stream Table Observations

1. During the Flowing Water Model demonstration, observe the stream table while water is flowing through it. What do you notice? Record your observations on the lines below. You can use the Word Bank to help you describe what you see.

Word Bank

straight	wide	branching	triangular
curved	narrow	merging	square
gnarled	spread out	loopy	circular

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

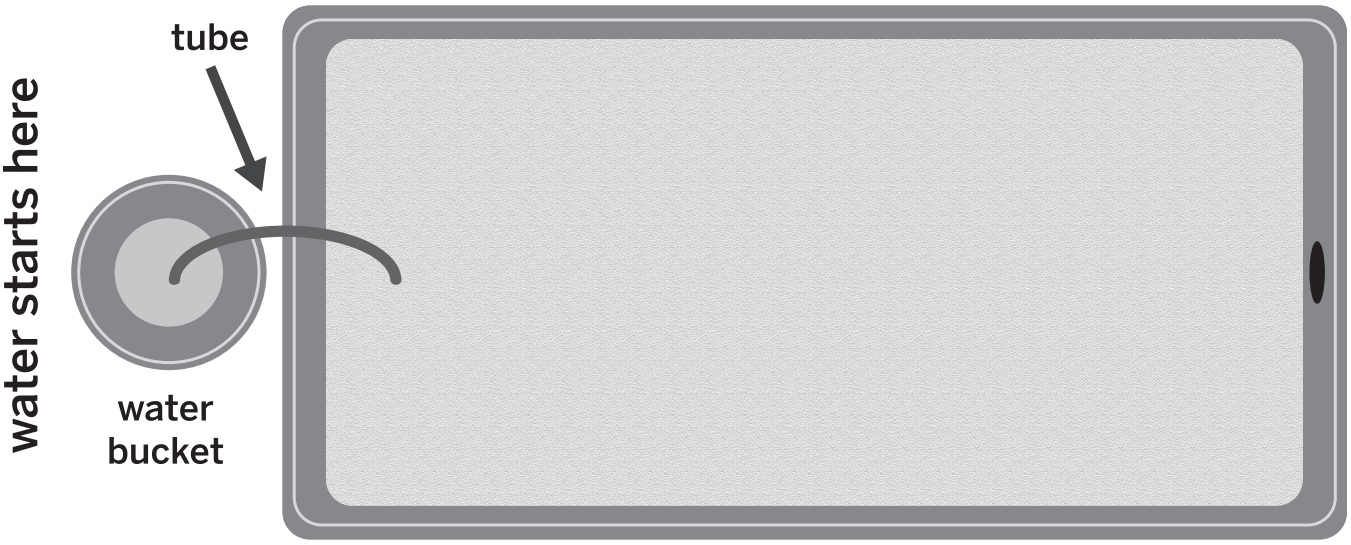
Name: _____ Date: _____

Stream Table Observations: Do Landforms Remain? (continued)

Landform Observations

2. In the stream table diagram below, draw what you see in the stream table once the water has stopped flowing through it. Make sure to draw any landforms that the flowing water formed. Remember, you are looking at the stream table from above (bird's-eye view).

Stream Table After Water Has Stopped Flowing



3. Record your observations about the landform(s) that the flowing water formed.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Reflecting on the Flowing Water Model

In this lesson, you used a scientific model to learn more about the geologic process of flowing water.

1. How was the Flowing Water Model similar to flowing water on Earth?

_____

_____

_____

_____

2. How was the Flowing Water Model different than flowing water on Earth?

_____

_____

_____

_____

3. How would you change the Flowing Water Model to make it more like the actual geologic process on Earth?

_____

_____

_____

_____

Name: _____ Date: _____

Lesson 2.3: Gathering Additional Evidence from Models

Today you will get to test some of your ideas about how flowing water forms a channel by setting up the Flowing Water Model to specifically test an idea your class comes up with! You'll then watch a video of a Flowing Lava Model. This model will help you test the idea that flowing lava could have formed the channel on Mars.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 2 Question

- How can we gather more evidence about whether lava or water formed the channel on Mars?

Key Concepts

- Scientists can use models to test their ideas and get evidence about processes in the natural world that are difficult to observe.
- Landforms can provide evidence about the past because they remain after the geologic processes that formed them stop happening.
- Models represent the natural processes being investigated in important ways, but they are not exactly the same.

Vocabulary

- claim
- evidence
- geologic process
- landform
- model
- system

Name: _____ Date: _____

Warm-Up

Marta observed a flowing stream in a sandy area. She developed a claim that water flowing over sand will create a curved and winding channel.

1. How can she test this idea in the Flowing Water Model?

_____

_____

_____

_____

2. What should happen in the Flowing Water Model for her claim to be supported?

_____

_____

_____

_____

Name: _____ Date: _____

Stream Table Observations: Testing an Idea

1. The scientific idea we are testing is _____

_____

_____

2. Describe how the two stream tables are set up in order to test this idea.

_____

_____

_____

3. During the Flowing Water Model demonstration, observe *one* stream table while water is flowing through it. What do you notice? Record your observations on the lines below. You can use the Word Bank to help you describe what you see.

Word Bank

straight	wide	branching	triangular
curved	narrow	merging	square
gnarled	spread out	loopy	circular

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

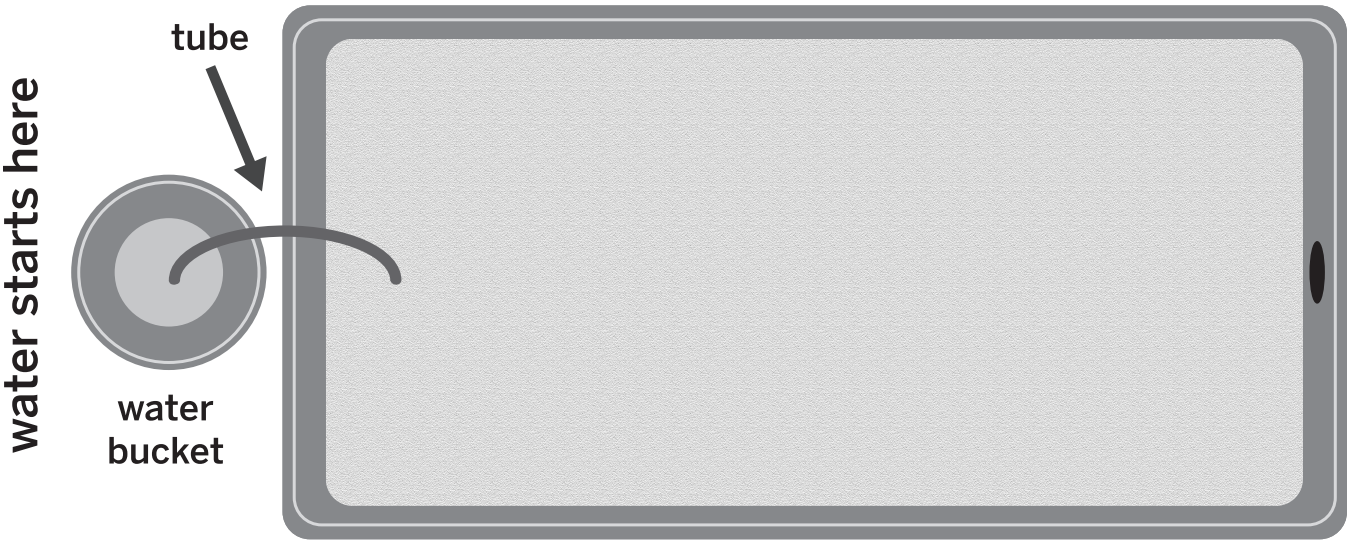
Name: _____ Date: _____

Stream Table Observations: Testing an Idea (continued)

Landform Observations

4. In the stream table diagram below, draw what you see in *the same* stream table you observed once the water has stopped flowing through it. Make sure to draw any landforms that the flowing water formed. Remember, you are looking at the stream table from above (bird's-eye view).

Stream Table After Water Has Stopped Flowing



5. Record your observations about the landform(s) that the flowing water formed.

_____

_____

_____

_____

6. Did the Flowing Water Model support the idea we tested?

The scientific idea we tested is (**supported** / **not supported**) based on the Flowing Water Model.

I think this because . . .

_____

_____

_____

_____

Name: _____ Date: _____

Observing a Flowing Lava Model

1. Record your observations about the landforms that remain after the wax has stopped flowing.

_____

_____

_____

_____

2. Based on your observations, do you think lava could have formed the channel on Mars? Why or why not?

_____

_____

_____

_____

Name: _____ Date: _____

Homework: Thinking About Modeling Flowing Lava

In this lesson, you observed a scientific model to learn more about the geologic process of flowing lava. Think about how the Flowing Lava Model was similar to and different than real flowing lava and the landforms it forms on Earth.

1. How was the Flowing Lava Model similar to flowing lava on Earth?

_____

_____

_____

_____

2. How was the Flowing Lava Model different than flowing lava on Earth?

_____

_____

_____

_____

3. How would you change the Flowing Lava Model to make it more like the actual geologic process on Earth?

_____

_____

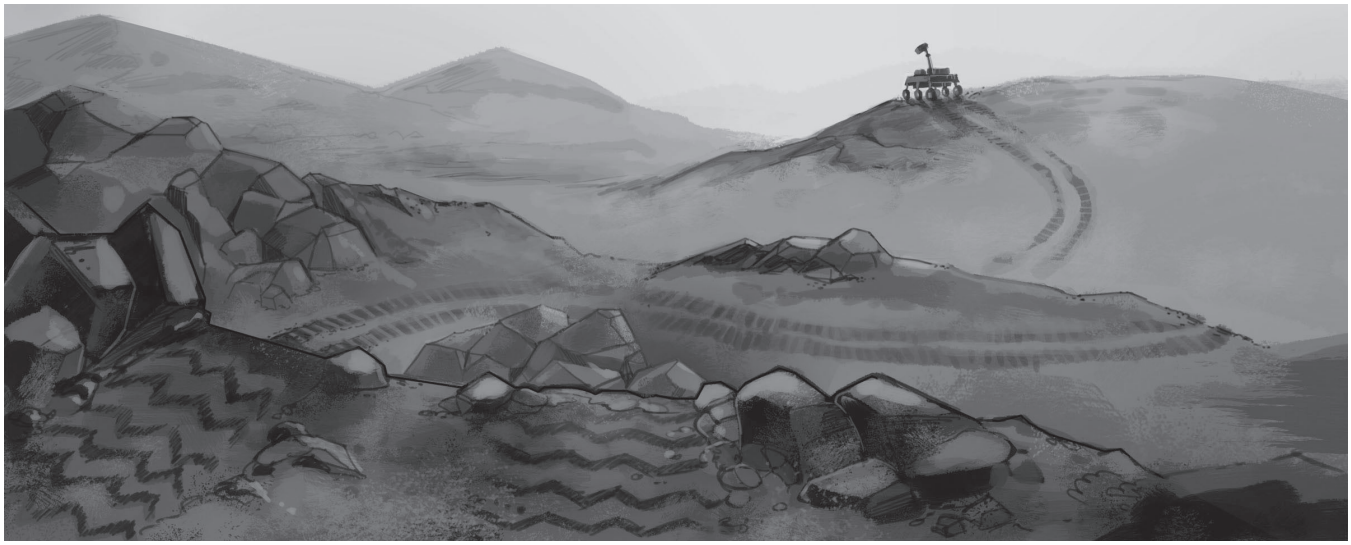
_____

_____

Name: _____ Date: _____

Chapter 3: Analyzing New Evidence
Chapter Overview

You have received new evidence from NASA about the channel on Mars. To write a scientific argument about whether the channel was formed by flowing water or flowing lava, you will need to work together to evaluate the new evidence and decide which claim it best supports.



Name: _____ Date: _____

Lesson 3.1: Evaluating New Information from Mars

In this lesson, you'll continue your search for evidence that will help you decide what geologic process formed the channel on Mars and whether the channel is evidence that Mars once had the liquid water necessary for life. After you consider how convincing the evidence you have so far is, you will examine new evidence collected by NASA spacecraft orbiting Mars. How can the new evidence help you think about whether flowing lava or flowing water formed the channel on Mars?

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 3 Question

- How can we decide which geologic process formed the channel on Mars?

Key Concepts

- When landforms on different rocky planets look similar, it is evidence that they may have been formed by the same geologic process.
- Scientists can use models to test their ideas and get evidence about processes in the natural world that are difficult to observe.
- Landforms can provide evidence about the past because they remain after the geologic processes that formed them stop happening.

Vocabulary

- claim
- evidence
- geologic process
- landform
- model
- reasoning

Name: _____ Date: _____

Warm-Up

Our Scientific Question

What geologic process could have formed the channel on Mars?

We have been thinking about two claims that are possible explanations for how the channel on Mars was formed. We have considered evidence from images, as well as from the Flowing Water Model and the Flowing Lava Model. As you answer the questions below, refer to the image of the channel on Mars on page 17.

1. Select the claim you think is best supported by the evidence you have seen so far. (check one)

   ☐ **Claim 1:** Flowing water formed the channel on Mars.

   ☐ **Claim 2:** Flowing lava formed the channel on Mars.

2. Why do you think the claim you selected is best supported by the evidence?

_____

_____

_____

_____

_____

Name: _____ Date: _____

New Information About the Channel on Mars

Comparing Triangle-Shaped Landforms on Mars and Earth

Channel on Mars

1. What did you learn about the channel on Mars from the new NASA data? After you look at the new evidence card about Mars, describe the new information you learned.

_____

_____

_____

_____

Channel on Earth Formed by Flowing Water

2. What did you learn from the background information about this type of channel? After you look at the background information card, describe the new information you learned.

_____

_____

_____

_____

Channel on Earth Formed by Flowing Lava

3. What did you learn from the background information about this type of channel? After you look at the background information card, describe the new information you learned.

_____

_____

_____

_____

Name: _____ Date: _____

New Information About the Channel on Mars (continued)

4. Which claim does the evidence about the triangle-shaped landform near the channel on Mars best support? (check one)

   ☐ **Claim 1:** Flowing water formed the channel on Mars.

   ☐ **Claim 2:** Flowing lava formed the channel on Mars.

   ☐ both claims

5. Explain how the evidence supports the claim you selected.

_____

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Name: _____ Date: _____

Lesson 3.2: Evaluating Claims About the Channel on Mars

You have looked at evidence that was collected by satellites orbiting Mars, as well as evidence from scientific models and from images of Earth. Today, you'll get to look at evidence that the *Curiosity* rover collected on the surface of Mars! You will also investigate rock samples from Earth that may help you understand more about the channel on Mars.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 3 Question

- How can we decide which geologic process formed the channel on Mars?

Key Concepts

- When landforms on different rocky planets look similar, it is evidence that they may have been formed by the same geologic process.
- Scientists can use models to test their ideas and get evidence about processes in the natural world that are difficult to observe.
- Landforms can provide evidence about the past because they remain after the geologic processes that formed them stop happening.

Vocabulary

- claim
- evidence
- geologic process
- habitable
- landform
- model
- reasoning

Name: _____ Date: _____

Warm-Up

The information we have about the channel on Mars has mostly come from satellite images and scientific models. However, rovers and landers developed by NASA have made it possible to collect information directly from the surface of Mars.

Think about the channel on Mars. (You can refer to the image of the channel on page 17.) What information would you want to collect from the surface of Mars to help you determine whether the channel was formed by flowing lava or flowing water?

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Name: _____ Date: _____

Evaluating New Rock Information

1. Read and analyze Background Information: Rock Types Card.
2. Observe the basalt and conglomerate rock samples with your hand lens.
3. Read and analyze Channel on Mars Evidence Card F.
4. Discuss and answer the questions below.

Channel on Mars

1. What did you learn about the channel on Mars from the new NASA data about the rock *Curiosity* found?

_____

_____

_____

_____

Channel on Earth Formed by Flowing Water

2. What did you learn from the background information about rock types?

_____

_____

_____

_____

Channel on Earth Formed by Flowing Lava

3. What did you learn from the background information about rock types?

_____

_____

_____

_____

Name: _____ Date: _____

Evaluating New Rock Information (continued)

4. Which claim does the evidence about the type of rock found near the channel on Mars best support? (check one)

   ☐ Flowing water formed the channel on Mars.

   ☐ Flowing lava formed the channel on Mars.

   ☐ Both claims.

5. Explain how the evidence supports the claim you selected.

_____

_____

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Name: _____ Date: _____

Recording Your Completed Evidence Gradient

1. On the Channel on Mars Evidence Gradient below, write "Card A" in the same location you placed that card on your student sheet.
2. Repeat this process for Cards B–F.

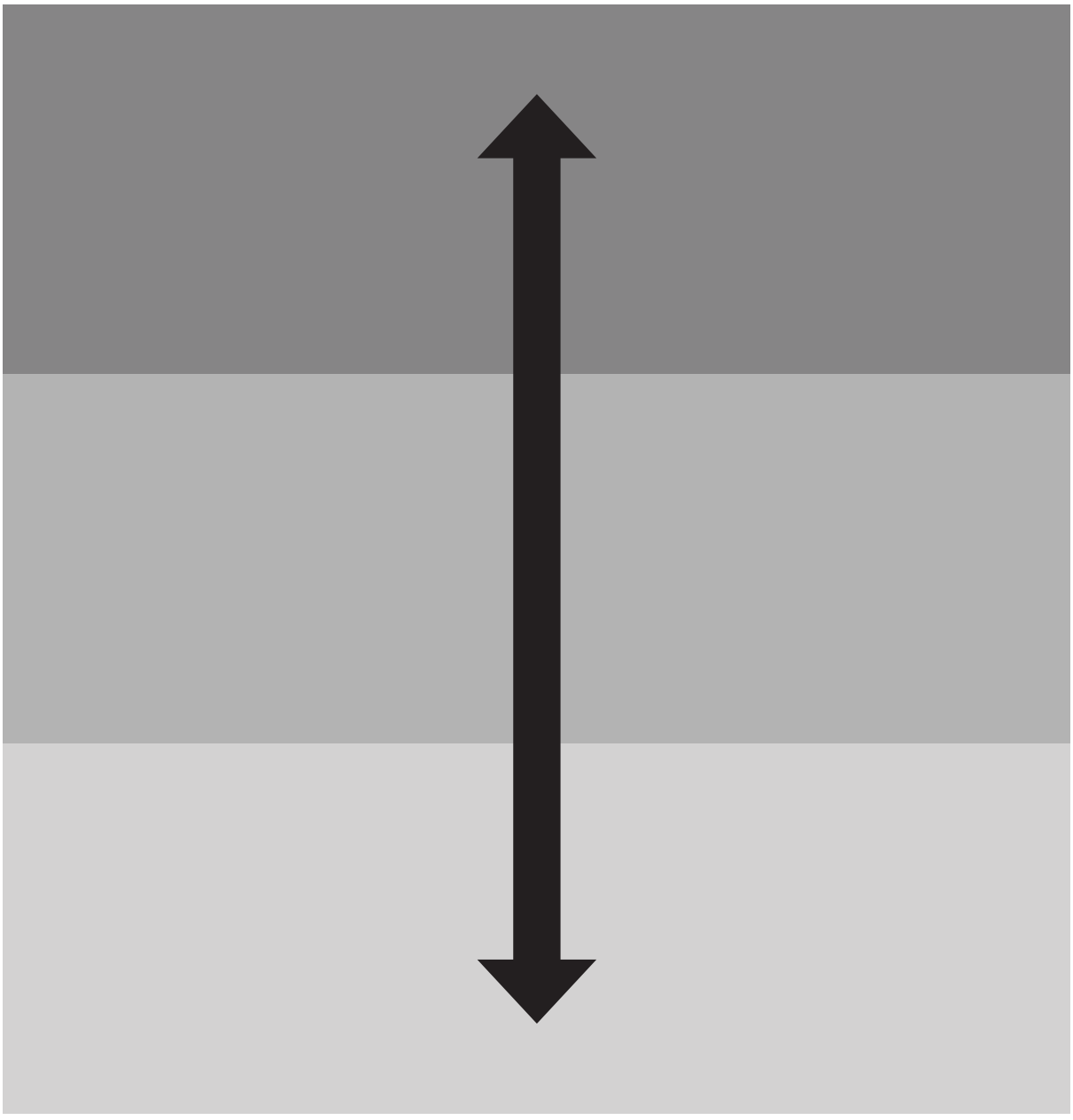
Channel on Mars Evidence Gradient

Claim 1

Flowing water formed the channel on Mars.

Claim 2

Flowing lava formed the channel on Mars.



Name: _____ Date: _____

Homework: Could Mars Have Been Habitable?

We learned about two of the characteristics that make Earth habitable:

- liquid water
- an energy source (such as the sun)

In this lesson, you considered all the evidence about the channel on Mars.

Based on what you've learned about this channel, do you think space agencies should continue to explore Mars for evidence of past habitability? Why or why not? Explain your thinking.

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Name: _____ Date: _____

You can use this page to record notes or create drawings.

Name: _____ Date: _____

Lesson 3.3: Reasoning About Evidence from Mars

Today you will use a tool called the Reasoning Tool to help you develop a convincing argument about what formed the channel on Mars. This work will prepare you to write a scientific argument for the Universal Space Agency. Your argument will help the Agency decide whether the channel provides evidence that there was once liquid water in this location on Mars. Liquid water is one of the conditions necessary for habitability.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 3 Question

- How can we decide which geologic process formed the channel on Mars?

Key Concepts

- When landforms on different rocky planets look similar, it is evidence that they may have been formed by the same geologic process.
- Scientists can use models to test their ideas and get evidence about processes in the natural world that are difficult to observe.
- Landforms can provide evidence about the past because they remain after the geologic processes that formed them stop happening.

Vocabulary

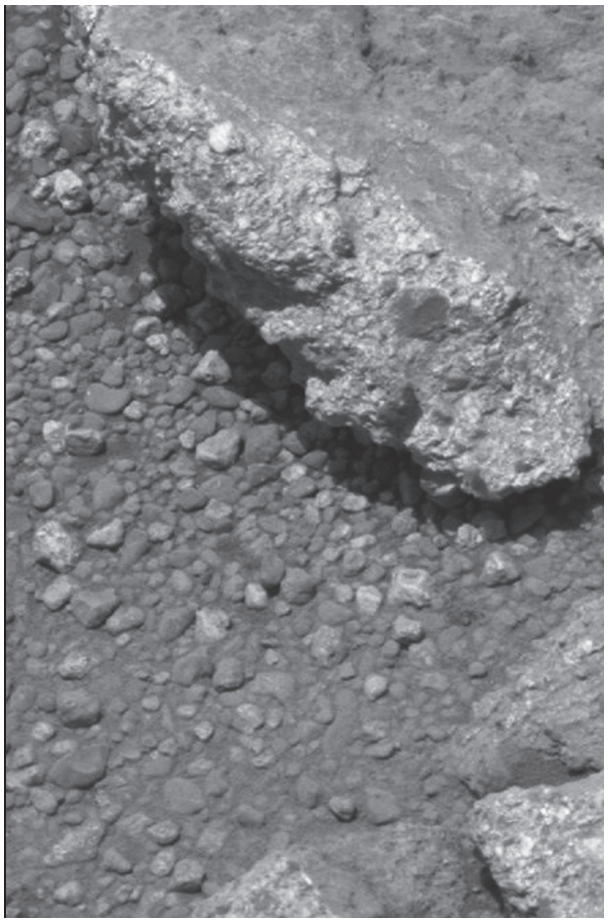
- channel
- claim
- evidence
- geologic process
- habitable
- landform
- model
- reasoning
- rocky planet
- system

Name: _____ Date: _____

Warm-Up

Curiosity's image of rock near the base of the channel on Mars was an exciting discovery for NASA. It changed many scientists' thinking about the possibility of water on Mars and of its habitability.

How did this piece of evidence change your thinking about the channel on Mars? Explain your ideas below.



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Name: _____ Date: _____

Reasoning About Evidence from Mars

1. Review the left column, which contains evidence that was gathered in previous lessons.
2. Work with a partner to complete the middle column of the Reasoning Tool by recording your reasoning about how the evidence connects to or supports the claim listed in the right column.
3. In the last row at the bottom of the Reasoning Tool, include one more piece of evidence.
4. When your teacher instructs you to do so, find a new partner and explain at least one piece of evidence and the reasoning about that evidence to your new partner.

Question: *What geologic process could have formed the channel on Mars?*

Claim: Flowing water formed the channel on Mars.

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Evidence Card A: Geologic Process: Flowing Water In satellite and aerial images, channels formed by water on Earth have a curved, branching shape similar to the shape of the channel on Mars.		Flowing water formed the channel on Mars.
Evidence Card C: Flowing Water Model In the Flowing Water Model, a channel remained in the sand after the water stopped flowing.		Flowing water formed the channel on Mars.

Name: _____ Date: _____

Reasoning About Evidence from Mars (continued)

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
Evidence Card F: Image of Rock Near the Triangle-Shaped Landform The same type of rock (made of pebbles and other cemented sediment) is found near the base of the channel on Mars and near channels on Earth that are formed by flowing water.		Flowing water formed the channel on Mars.

Name: _____ Date: _____

Lesson 3.4: Writing an Argument About the Channel on Mars

Today you will write a scientific argument to support your claim about which geologic process formed the channel on Mars, just like scientists do at the end of their investigations. After you write your argument, you will hear from planetary geologist Dr. Lauren Edgar again. She will share some of the exciting evidence that the rover *Curiosity* has gathered on Mars.

Unit Question

- How can we search for evidence that other planets were once habitable?

Chapter 3 Question

- How can we decide which geologic process formed the channel on Mars?

Key Concepts

- When landforms on different rocky planets look similar, it is evidence that they may have been formed by the same geologic process.
- Scientists can use models to test their ideas and get evidence about processes in the natural world that are difficult to observe.
- Landforms can provide evidence about the past because they remain after the geologic processes that formed them stop happening.
- Evidence can support or go against a claim.
- A convincing argument is supported by evidence and the process of reasoning.

Vocabulary

- claim
- evidence
- geologic process
- habitable
- landform
- model
- reasoning

Name: _____ Date: _____

Warm-Up

Read both arguments about the puddle. Pay attention to what makes one argument more convincing than the other. Then, answer the questions below the two arguments.

Argument 1	Argument 2
The water in the puddle that Claire observed evaporated. The highest temperature was 32°C (90°F). Since the puddle was there in the morning and gone later that day, it must have evaporated.	The water in the puddle that Claire observed evaporated. Since the highest temperature was 32°C (90°F), we know that it was a warm day. When water gets hot, it can change from liquid to gas. This is called evaporation. I think the water became so warm that it became water vapor (gas), and that is why the puddle was gone by the afternoon.

1. Which argument is more convincing? (check one)

   ☐ Argument 1

   ☐ Argument 2

2. Why is the argument you selected more convincing?

_____

_____

_____

_____

_____

Name: _____ Date: _____

Writing a Scientific Argument About the Channel on Mars

What geologic process could have formed the channel on Mars?

- Use your Reasoning Tool from Lesson 3.3 (pages 50–51) to help you write an argument to answer this question.
- Refer to Components of a Written Scientific Argument and the Word Bank below, as needed.
- Be convincing; show the audience how your claim is clearly supported by the evidence.

Word Bank

landform	model	rocky planet	reasoning
geologic process	conglomerate rock	claim	evidence

Name: _____ Date: _____

Homework: Reading "The Future of Mars Exploration"

Find out what the next steps are in the search for evidence of habitability on Mars! Read and annotate the "The Future of Mars Exploration" article and then answer the question below.

Would you be interested in being one of the first humans to explore Mars? Why or why not?

_____

_____

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Reading "Canals on Mars?"

Scientists have been studying Mars for hundreds of years! To learn more about the ideas that scientists used to have about Mars, read and annotate the "Canals on Mars?" article and then answer the questions below.

Why did some people think that there was evidence of intelligent life on Mars?

_____

_____

_____

How was this idea refuted?

_____

_____

_____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Geology on Mars Glossary

atmosphere: the mixture of gases surrounding a planet

atmósfera: la mezcla de gases que rodea a un planeta

biosphere: all the living things on a planet

biosfera: todos los seres vivientes en un planeta

channel: a long, narrow groove that forms where water, lava, or other liquid flows

canal: una ranura larga y estrecha que se forma donde el agua, la lava u otro líquido fluye

claim: a proposed answer to a question about the natural world

afirmación: una respuesta propuesta a una pregunta sobre el mundo natural

compare: to notice how two or more things are alike or different

comparar: notar en qué son iguales o diferentes dos o más cosas

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

geologic process: an event or series of events that causes changes in the geosphere, such as flowing water or flowing lava

proceso geológico: un evento o serie de eventos que causa cambios en la geosfera, como agua o lava que fluye

geosphere: the solid part of a rocky planet

geosfera: la parte sólida de un planeta rocoso

habitable: having the conditions necessary to support life

habitable: que tiene las condiciones necesarias para sostener la vida

hydrosphere: all the liquid water and solid water (ice) on a planet

hidrosfera: toda el agua líquida y el agua sólida (hielo) en un planeta

landform: a feature that forms on the surface of a planet, such as a mountain, channel, or sand dune

accidente geográfico: un rasgo que se forma sobre la superficie de un planeta, como una montaña, un canal o una duna de arena

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

planetary geologist: a scientist who studies the geospheres of planets in our solar system

geólogo/a de planetas: un/a científico/a que estudia las geosferas de los planetas en nuestro sistema solar

reasoning: the process of making clear how your evidence supports your claim

razonamiento: el proceso de aclarar cómo tu evidencia respalda tu afirmación

rocky planet: any planet with a solid surface, such as Earth or Mars

planeta rocoso: cualquier planeta con una superficie sólida, como la Tierra o Marte

scientific argument: a claim supported by evidence

argumento científico: una afirmación respaldada por evidencia

system: a set of interacting parts forming a complex whole

sistema: un conjunto de partes que interactúan formando un todo complejo

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Geology on Mars

Article Compilation

Table of Contents

Scale in the Solar System

In 1969, millions of people watched as humans visited the Moon for the first time. Since then, many astronauts have visited the area of space that's just outside Earth's atmosphere. We've even built the International Space Station, which circles Earth and allows astronauts to live and do research in space! We have also explored more distant areas of the solar system using probes—spacecraft without people on board. However, humans have never set foot anywhere else in the solar system. Technology that helps humans travel and survive in space has improved since that first trip to the Moon—so why haven't we traveled to any other planets? The answer lies in size and distance. Compared to the rest of our solar system, Earth is just a tiny dot surrounded by a whole lot of empty space.

Objects in the Solar System Come in Different Sizes

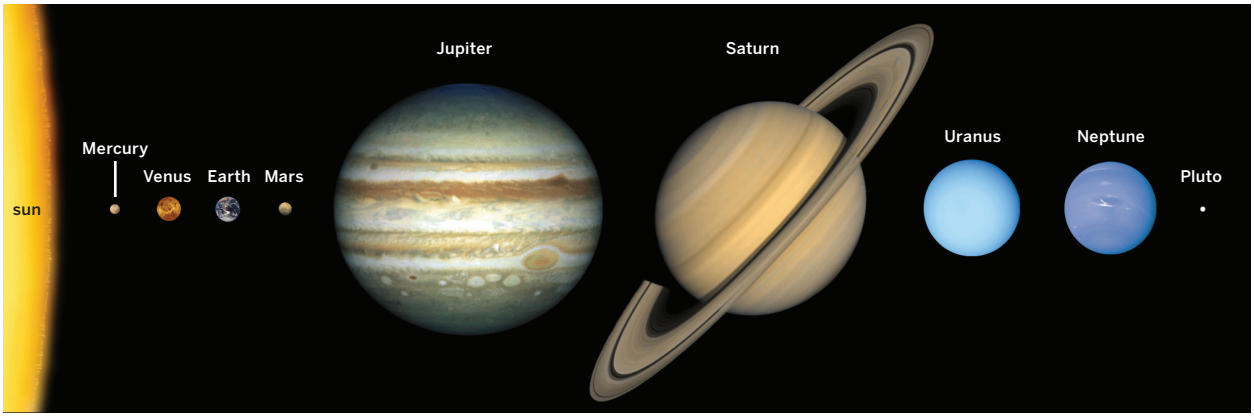
Earth is just one object in the group of objects we call our solar system. Our solar system includes the sun, the planets that move around the sun, and the moons that move around the planets. Some of the objects in our solar system, like the sun and the planet Jupiter, are so big that they're hard to imagine. Others aren't very big at all: some moons are only 3 or 4 kilometers all the way around!

The sun is by far the biggest object in our solar system: it's so big that about 1.3 million Earths could fit inside it! If the sun were the size of a basketball, Earth would be the size of a grain of rice and Mercury would be the size of a pinhead. Even planets that are much bigger than Earth, like Jupiter and Saturn, would only be about the size of table-tennis balls.

In the night sky we can see objects in our solar system, like planets, and objects outside our solar system, like stars.

There are eight planets in our solar system, and they vary widely in size. Planets close to the sun are smaller, while planets far from the sun tend to be larger. In comparison with the rest of the planets, Earth is near the middle: it's the third planet in distance from the sun and the fifth-largest planet in size. The smallest planet in our solar system is Mercury—if Earth were hollow, about 18 Mercurys would fit inside. The largest planet in our solar system is Jupiter. It's so big that more than 1,000 Earths could fit inside!

Many of the planets in our solar system have moons—objects that travel around planets. Earth has one Moon, which you sometimes see in the night sky and during the day as well. If Earth were hollow, about 49 Moons would fit inside. Mars has two moons, and Jupiter and Saturn have many more than that: Jupiter has at least 63 moons and Saturn has 62, but scientists are still identifying more. Most moons aren't very big, but even moons vary a lot in size. Ganymede, a moon of Jupiter, is the largest moon in our solar system. It's larger than the planet Mercury!



The planets in our solar system come in a variety of sizes, but they are all much smaller than the sun. To show the sizes of the planets accurately, this illustration shows them much closer together than they really are.

Different Planets Are Different Distances from the Sun

The objects in our solar system don't just vary in size; each is also a different distance from the sun. The closest planet to the sun is Mercury; it's about 57 million kilometers from the sun. That may seem pretty far, but it's nothing considering how big the solar system is and how far away some of the other planets are. The farthest planet from the sun is Neptune—it's 4.5 *billion* kilometers from the sun. The distance of each planet from the sun makes a big difference in its climate and whether it can support life. Planets that are close to the sun, like Mercury and Venus, get a lot of energy from the sun and are too hot to be habitable. Planets that are very far from the sun, like Uranus and Neptune, get much less energy from the sun and are much too cold to be habitable. On these planets, water exists only as ice. Earth is about 149 million kilometers from the sun, which is good news for living things. Earth can support life partly because it has liquid water—and it has liquid water because it's just the right distance from the sun.

Since all the planets in the solar system (including Earth) are always moving around the sun, the distances between them are always changing. When scientists send spacecraft out to explore other planets, they must think about where each planet will be at a certain time and when it will be easiest to reach. Even when our closest neighbor planets are as close to Earth as they can get, they're still very far away: Earth's neighbor planet Mars is so far away that it would take 6 months to get there by rocket. Other planets are much farther from Earth than Mars is—a spacecraft launched from Earth would take about 12 years to reach Neptune!

With all this empty space around us, it's no wonder humans haven't traveled very far from Earth. Sending people into space and bringing them back safely is complicated: scientists must take into account the amount of fuel needed to stay in space for months or years at a time, the weight of all the food and equipment astronauts need for a long trip, the way the human body might react to conditions on other planets, and lots of other important information. Still, many people are working on solving these problems in hopes of sending humans to other planets someday. The National Aeronautics and Space Administration (NASA) currently estimates that humans may make it to Mars around the year 2030.

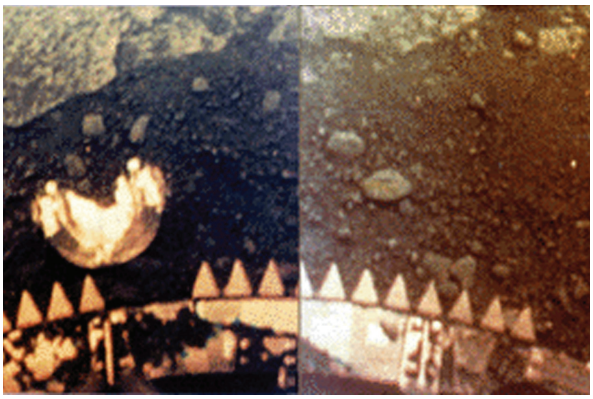
Investigating Landforms on Venus

Imagine traveling in a spaceship toward the surface of the planet Venus. At first, everything is hidden by thick clouds, but as you get closer, you can see the rocky surface below. As you fly over the surface, you notice strange landforms scattered around. They are raised domes with cracks reaching outward in all directions. These are called novae (NO-vay).

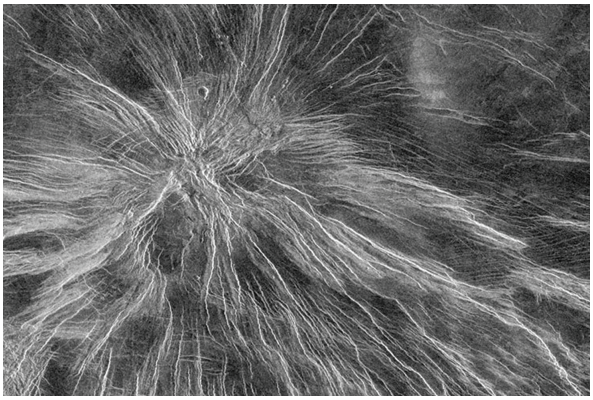
Why do we see novae on Venus but not on Earth? Planetary geologist Taras Gerya (TAR-as GARE-ya) wondered whether two important differences between the two planets might help answer that question. First, Venus's atmosphere is much thicker than Earth's. Its thick atmosphere traps heat from the sun, making Venus much hotter than Earth. The average surface temperature of Earth is a comfortable 14°C (57°F), while the average surface temperature of Venus is a scorching 462°C (864°F)! Second, Gerya thought that possible differences between the geospheres of Earth and Venus might affect how novae are formed. He didn't know for sure, but he thought that the top rock layer on Venus might be thinner than the top layer of Earth's crust. A thinner crust might allow melted rock called magma to move toward the surface more easily, pushing the surface upward to form the novae.

Gerya wanted to test his ideas about how novae form on Venus. But how? Venus is millions of kilometers from Earth, and the novae there were formed millions of years ago. To test his ideas, Gerya made a computer model of Venus.

Models can help scientists like Gerya get evidence about things that are difficult or



This photo, taken by a spacecraft called *Venera*, shows the rocky surface of Venus. The triangles in the photo are part of the spacecraft.



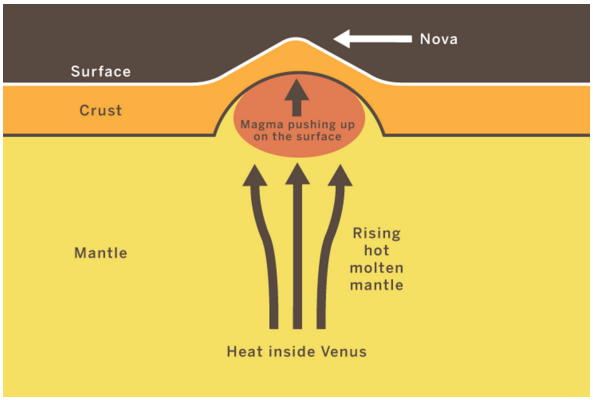
Novae are dome-shaped landforms on Venus. They are easy to see from above because they have cracks reaching out from their centers in all directions. The word novae is the plural form of the word *nova*.

Geologist Taras Gerya built a computer model to test whether the high temperature of Venus's surface and the planet's thin crust make it possible for novae to form there.

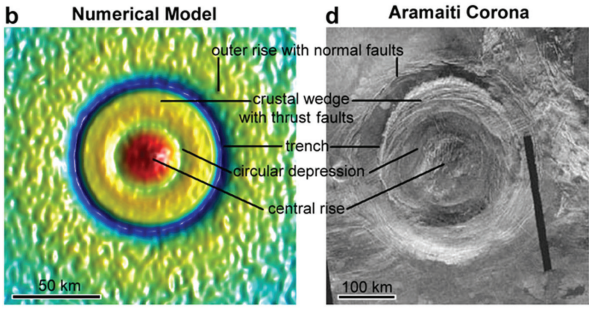
impossible to observe, like the creation of landforms on Venus. Some models are made of physical materials and others run on computers, like Gerya's Venus model. When Gerya made his computer model, he made it represent Venus in ways that would let him test his ideas. For example, he made the surface temperature of the Venus model much hotter than the surface temperature of Earth. He also made the top rock layer in his model much thinner than the top layer of Earth's crust. Gerya programmed his model to show what would happen on Venus over time with this combination of a high surface temperature and a thin rock layer. If features like novae formed in his model, he would have evidence that he was right about how novae on Venus were formed.

When Gerya ran the model, it showed melted rock rising up from underground, pushing the surface upward and creating raised domes with cracks reaching out in all directions.

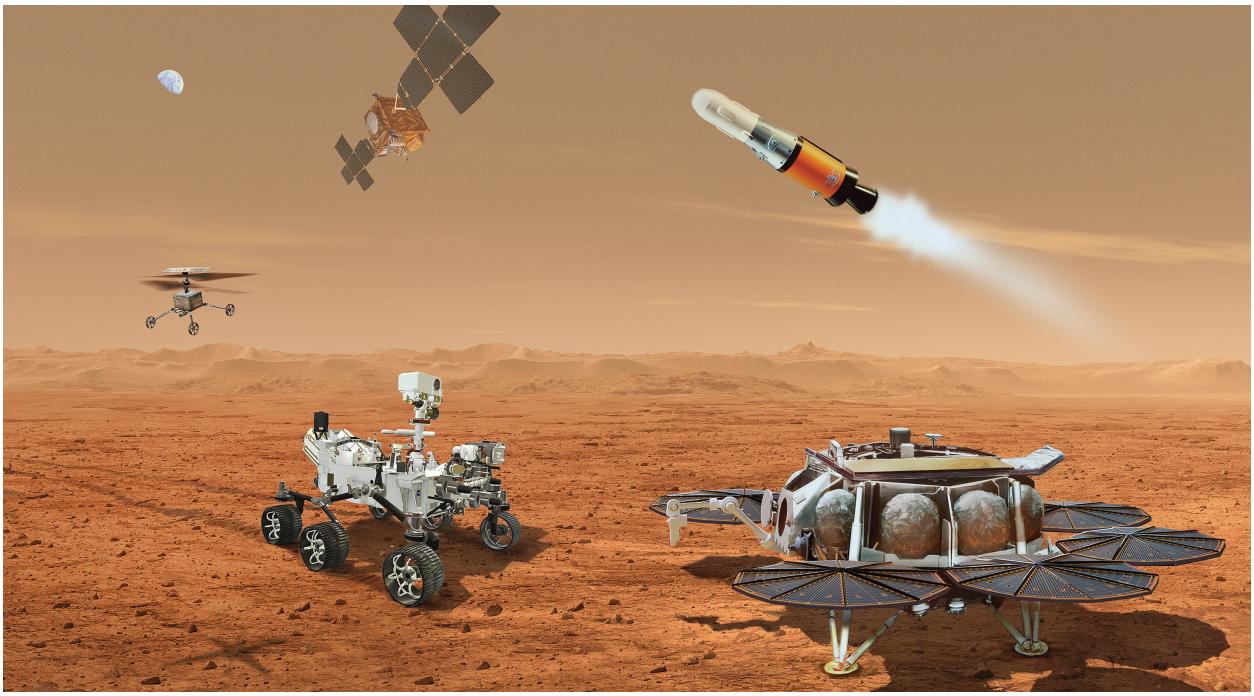
When he compared the domes that formed in the computer model with the domes on the surface of Venus, he found that the domes in the computer model were the same size and shape as the novae that have been observed on the surface of Venus. Because the model results matched the real features on Venus, Gerya was more confident that the ideas represented in his model were accurate.



When Gerya ran his model, it showed melted rock rising up from the mantle, pushing the surface up and creating raised domes with cracks spreading in all directions.



The domes formed in Gerya's computer model (left) were the same size and shape as the novae found on the real planet Venus (right)



This illustration shows plans for a future mission to bring samples of Martian rocks and soil back to Earth.

The Future of Mars Exploration

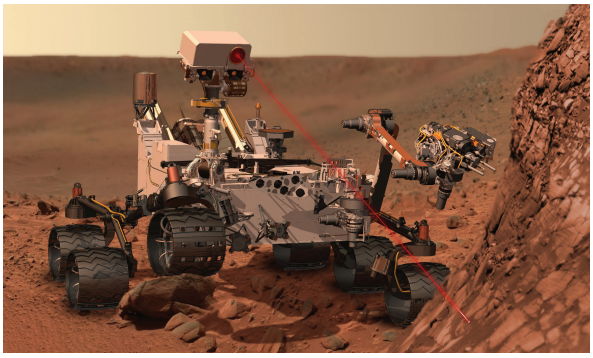
To search for clues about the history of Mars, scientists use small robots called rovers. Exploring the surface of Mars over the course of about 40 years, rovers have found evidence that the red planet was once an active place: Mars once had active volcanoes, meteorites crashing on the surface, and floods of water rushing over the land. Many surface features have shown that Mars was watery long ago, and that it stayed that way long enough that it could have supported the development of life.

Now, scientists are using rovers to seek evidence of past life on Mars. "All of the ingredients are there to make the cake of life," says geobiologist Amy Williams. "We just

The surface of Mars is covered with rocky landforms, including hills and cliffs.

need to see if it was ever baked." Rovers are investigating the surface of Mars and sending back photos and data. The rovers have also been collecting samples of Martian rocks and soil. Scientists are planning missions to bring these rocks and soil back to Earth. In future missions, rovers will load samples into a small rocket that will blast into orbit around Mars, then another spacecraft can pick the rocket up and carry its load of samples to Earth. By analyzing Martian rocks and soil in detail, scientists hope to determine whether life ever existed on Mars.

So far, no human explorers have visited Mars. However, data from rover missions may help scientists and engineers figure out how to get human astronauts to Mars someday and how to keep those astronauts safe as they explore the red planet. Using rovers, scientists and engineers investigate the challenges that human explorers might face on Mars. They also investigate resources on Mars that human explorers might be able to use. For example, scientists are studying ways to collect carbon dioxide from the atmosphere on Mars. Carbon dioxide could be used to produce oxygen for explorers to breathe and rocket fuel to help them return to Earth. By learning more about the geosphere and atmosphere of Mars, scientists will find out whether the resources necessary to support human life and provide transportation are available on Mars. If they are, Mars may become the first planet other than Earth that humans ever visit!



An artist made this illustration of a rover scanning a rock on Mars. Rovers help scientists gather information.

This rover took a picture of itself on the surface of Mars.

There are no canals on the surface of Mars, but there are natural landforms like mountains and dry riverbeds.

Canals on Mars?

In 1877, the Italian astronomer Giovanni Schiaparelli looked through a telescope and saw straight lines running in all directions across the surface of Mars. He thought the lines were canals. A canal is a channel or river that has been built intentionally rather than formed by natural processes. Schiaparelli's idea caught on and astronomers around the world began observing and studying the lines, giving them names and making maps of how they were arranged. Some people thought the canals were proof of intelligent life on Mars and were being used to bring water to crops on Martian farms.

Within a few years of Schiaparelli's discovery, the quality of telescope lenses improved and scientists learned the truth: there are no canals on Mars. The lines Schiaparelli and others saw were an optical illusion caused by early telescope lenses on Earth and dusty conditions on Mars. In the years since Schiaparelli made his claim, humans have developed telescopes and cameras that produce very clear images of the surface of Mars. We've even sent spacecraft to Mars! All the information gathered by these spacecraft confirms that the surface of Mars is empty and frozen, with no canals, farms, or living organisms that we've found so far.

Today, it may sound strange to think of people believing there were canals on Mars. But at the time, the idea didn't sound so odd. Many scientists looked through their telescopes and saw the lines Schiaparelli had seen. Also, canals were on many people's minds: several large canals were built on Earth during the late 1800s to help ships get from one place to another. It made sense to many people that there might be canals on other planets, too.

We know now that there are no canals on Mars, but we also know that there are landforms, like volcanoes and seabeds, that formed there naturally through geologic processes and other natural processes. In fact, there are dry riverbeds on Mars that aren't so different from canals, but they weren't built by an alien civilization—and Schiaparelli's telescope wasn't strong enough to show them. Evidence shows that natural processes like wind, formation of volcanoes, and flowing water have shaped the landscape of Mars. Though there are no canals on Mars, landforms there still have plenty to teach us about the history of our neighbor planet.

Geology on Mars

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