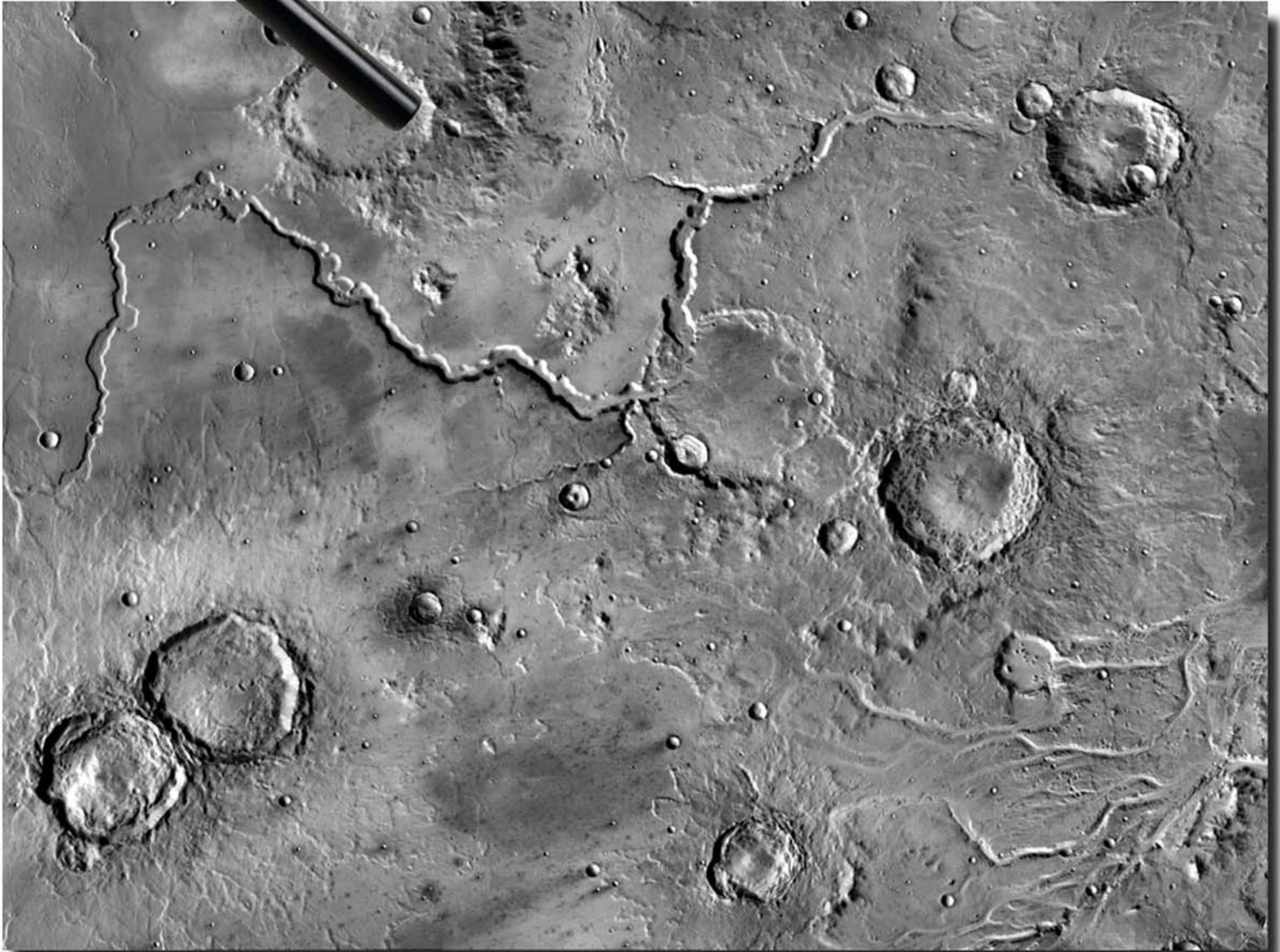




Mars Uncovered

Revealing the Geologic History Through Mapping



An inquiry-based, critical thinking lesson about interpreting the geologic history of regions on Mars

TEACHER GUIDE



Mars Uncovered

Revealing the Geologic History Through Mapping

Goal:

This activity will guide students through an inquiry-based, critical thinking approach to studying the surface of Mars in a similar way to what scientists do. This lesson will teach students to create a geologic map of part of Mars and use relative age dating techniques to analyze the information and interpret the geologic history of the region.

Grade Level: 5-12

Time Requirements: 2 - 3 class periods

Objectives:

Students will:

- Learn to classify craters
- Learn basic relative age dating principles
- Discuss and debate interpretations of observations
- Create a simple geologic feature map
- Analyze, interpret and write the geologic history of a region of Mars

Materials:

This activity has students working in pairs. Each pair should have:

- A Mars Uncovered Student Guide (or you can print and use the individual information sheets and Student Worksheets described from the Teacher Guide)
- Printed THEMIS Day IR Mosaic (1)
- Transparency paper (1)
- Set of red, green, black and blue erasable markers
- Paper clips (2)
- Magnifying glass (optional)

National Science Standards:

CONTENT STANDARD A: Science as Inquiry

CONTENT STANDARD D: Earth and Space Science

CONTENT STANDARD E: Science and Technology

CONTENT STANDARD G: History and Nature of Science

Teacher Overview and Introduction:

This activity has students work as planetary scientists do. They will map the geologic features in a region of Mars and make observations and interpretations of the region's geologic history.

The activity has a choice of three image mosaics that mainly display craters and channels in three regions on Mars. You may provide each pair of students with the same region or distribute two or three throughout your class. The image mosaics are made of daytime infrared images taken by the Thermal Emission Imaging System (THEMIS) on NASA's Mars Odyssey orbiter.

Using the relative age dating techniques provided in the lesson, students will learn to classify craters. They will also use two relative age dating principles in interpreting and writing the geologic history of a region on Mars.

THEMIS daytime infrared mosaics provide two kinds of information: surface temperatures and the morphology (shape) of surface features. For this activity students focus only on the morphology.

Students will go through a series of steps in order to:

- Make initial observations of a THEMIS daytime IR mosaic and create initial strategies to interpret the relative ages of features
- Classify craters
- Understand relative age dating principles
- Discuss and debate interpretations of observations
- Create a geologic feature map
- Answer questions that will assist them in interpreting and writing the geologic history of a region on Mars
- Evaluate their initial strategies and think about future investigations

Procedure:

This procedure description has been broken down into four parts in order to help structure the steps of this activity more clearly.

PART A: Initial Observations and Strategies

MATERIALS NEEDED: THEMIS Daytime IR Mosaic and Student Worksheet 1

1. Give each pair of students one THEMIS daytime IR mosaic and a Mars Uncovered Student Guide. There are three different regions of THEMIS Daytime IR image mosaics provided with this lesson. You can decide to have the entire class work with one of the regions of Mars or you can distribute the different image mosaics to different groups in the class. Have them focus only on the first page - *Student Worksheet 1*. (For this part of the activity do not allow students to read the information provided in the rest of the Student Guide.) Student Worksheet 1 asks students to think about strategies they would use to look at relative ages **before** they are formally introduced to commonly used scientific relative age dating techniques.
2. Give student pairs time to look at their image mosaic and answer the questions on *Worksheet 1*. **Discuss** with the class the answers to the questions, making sure they are aware of how the two main features shown in the images (craters and channels) are formed. This is important for them to be able to create the geologic history of their region later in this activity. You should also discuss with the class the strategies they used to determine which features are older or younger in their mosaic. As students discuss this – do not indicate if they are right or wrong. They can simply discuss their strategies and techniques. The subsequent parts of the lesson will allow them to judge for themselves if their strategies were valid or if there are actual scientific names for some of the strategies they used before they were even formally introduced to them.
3. If you wish, collect *Student Worksheet 1* after you have discussed it. This will deter students from changing any of the answers they may have written in as they continue with the other parts of the activity. If students have the entire Student Guide, they should not go back and change their answers.

PART B: Relative age dating techniques and mapping Mars

MATERIALS NEEDED: Background Information, Crater Classifications and Relative Age Dating Principles information sheets AND Student Worksheets 2 and 3 (although students can have all the worksheets)

1. Have students read the *Background Information*, *Crater Classifications* and *Relative Age Dating Principles* information sheets in order to introduce them to geologic principles and techniques that scientists commonly use to understand and interpret the geologic history of a particular region. Let students know that they will practice these techniques first and then apply them when asked to interpret the geologic history of the region on Mars they map.
2. Have students complete *Student Worksheets 2 and 3* and in small groups have them discuss and defend their answers with a group that is investigating the same region. After students have discussed their answers in small groups, ask them if they agreed on all of their answers. Hopefully the answer to this will be no. You will most likely have groups that have classified craters differently than other groups. Discuss with students that their interpretation of the classification of different craters may differ and that is acceptable. Emphasize that scientists often have different interpretations from one another as well. The key is that every scientist needs to be able to defend those interpretations with evidence and logical arguments. Let students know that they are experiencing what professional scientists experience as they interpret the geologic history of regions on Mars as well. Although students may not have changed their answers with this exercise, let them know that they can change their minds about an interpretation based on the argument provided by another group. (For most students and teachers, changing answers may be viewed as cheating. For this activity, it demonstrates a natural part of the process of science as scientists would experience it.)

PART C: Creating a feature map and interpreting the geologic history

MATERIALS NEEDED: THEMIS Daytime IR Mosaic and Student Worksheet 4, Student Worksheet 5, transparency paper, paper clips and magnifying glass (optional)

1. Distribute a piece of transparency paper, paper clips and magnifying glass (optional) to each pair of students. Discuss *Student Worksheet 4* in order to ensure they understand how to correctly create their feature map. Let students know that the paper clips are used to simply secure their THEMIS mosaic and transparency paper together. Demonstrate as necessary. The magnifying glass can be used to allow them to more closely view features in their mosaic.
2. Once students have successfully created their map, they should answer questions #1 through #5 on *Student Worksheet 5*. Before students write their interpretation of the geologic history of their region (question #7), have them discuss their answers to questions #1 through #5 with another group studying the same region. Students should defend their answers and try to convince the other group that their interpretation is the correct one. Students may or may not decide to change their answers, but they should indicate this in their answers to question #6. At this point student groups (or every individual – if you wish) should individually write their interpretation of the geologic history of the region they mapped.

THEMIS Daytime IR Mosaic Information:

Some points to keep in mind regarding these regions:

- Some of the features may be too small to map. Students do not need to map all the tiny craters in the image. They should use their judgment as to what features they should include on their maps.

- It is difficult to follow the exact 'path' of some of the channels seen in the image. Students should again use their judgment when mapping.
- Some areas have not been fully imaged by THEMIS and therefore data is missing in the mosaic. These areas are seen as vertical black lines. (See Tiu Valles and Shalbatana Vallis mosaics.)
- There is no absolute correct interpretation of the geologic history of any of the regions. Interpretations are valid as long as students can provide evidence and logical reasons for their interpretations.

Below are some brief descriptions and observations of the three regions:

Chryse Planitia: This image mosaic is centered at latitude 20°N and longitude 303°E. It covers an area of about 300 kilometers by 220 kilometers. If students carefully and closely map this region, they will notice many of the channels running over older craters. The most prominent channel in the northern part of the image is one of the younger features in the image. Most of the large craters are either severely modified or destroyed. Some of the large crater ejecta can still be seen, although it appears as though the channel runs over that ejecta, providing evidence (using the principle of superposition) that the channel is younger than those large modified craters. The smaller craters are the youngest of all the craters, but the interpretation of whether the small craters are younger or older than the channel is difficult to determine and open to interpretation.

Tiu Valles: This image mosaic is centered at latitude 10°N and longitude 338°E. It covers an area of about 300 kilometers by 240 kilometers. If students carefully and closely map this region, they will notice that most of the channel-like features are in the southern portion of the mosaic. There is a feature in the north eastern part of the image that seems to cut a large crater. It is difficult to determine whether this feature is a channel or some sort of fracture. When mapping the channels, student may have a difficult time deciding where the borders of the channels are. As scientists, they need to use their best judgment. There are many craters in this image that are overlapping, so determining their relative ages should be easy. Students will need to look at those craters relative ages compared to the channel and use the age dating principles they have learned (cross-cutting relationships and superposition) to determine if those craters are older or younger than the channel. The channel appears to be one of the younger features in this image. Many of the craters in this image are modified and most of their ejecta blankets are not easily noticed as they are very eroded. Students should map even eroded ejecta blankets as best they can. Most of the smaller craters in this image seem to be preserved, but there are some small craters that are destroyed.

Shalbatana Vallis: This image mosaic is centered at latitude 9.5°N and longitude 320°E. It covers an area of about 300 kilometers by 210 kilometers. This mosaic does have a few areas where data is missing, however it is still a good region to map. The area to the east of this region is most likely chaotic terrain, which has an association with water. For the purposes of this mapping exercise, students do not need this information – although it is interesting. They are focusing only on the craters and channels in the image. They should only map what they can see in the mosaic. For example, in the north western part of the mosaic, there is a beautiful channel but there is a large strip of data missing. They should only map what they can see and not draw in features that are not included in the image mosaic. Even with the missing data, they will still be able to map enough of the channels to see that they appear to be younger than most of the craters. For the channel that runs from approximately the center of the page towards the south western part of the image, there are a couple of craters in this area that if students map the eroded ejecta blankets, they will better be able to determine that those craters are younger than the channel. Like the other images, most of the larger craters appear to be older than the

smaller ones. In this image there are many tiny craters. Your students should again use their best judgment as to how many of those craters they should map.

3. **Writing a Geologic History:** When students write their interpretations of the geologic history of their region on Mars, there is no right or wrong way to do this. The information should be supported by the maps they create and the age dating principles they will learn with this activity. You may want to give them a leading sentence to start their geologic history or let them create their own. The sample starter sentence provide is: *In the _____ region of Mars there was a lot of geologic activity that modified the surface. First, what happened was.....*

PART D: Evaluation of initial strategies; future considerations

Materials Needed: Student Worksheets 1 and 6

1. After students have created their interpretation of the geologic history of their region, have them look back to *Student Worksheet 1*. Students should refer to this worksheet (*Student Worksheet 1*) to answer question #1 on *Student Worksheet 6*. They should also answer question #2 based on what they are curious about.
2. **Closure:** Have students read their interpretations of the geologic history of their regions on Mars, one region at a time (if you had groups working on different regions). Discuss with students how they probably all observed craters and channel features in their images, but that their interpretations and overall geologic history of a region may differ from one another. Re-emphasize that scientists can have different interpretations, as long as they can defend those interpretations with evidence and logical arguments. Reiterate to students that they are experiencing what professional scientists experience as they look at interpreting the geologic history of regions as well.

Assessment:

Students should be assessed on the answers they provide on each worksheet, but especially *Student Worksheet 5 and 6*. Answers to *Student Worksheet 5* should reflect critical thinking and reflect their feature map. Answers to *Student Worksheet 6* should also reflect critical thinking about the strategies they listed on *Student Worksheet 1* as well as their curiosity about craters and channels on Mars. Students should also be assessed on their ability to follow the instructions in the creation of their feature map and their ability to explain their classifications in a logical fashion.

Extensions:

- Have students create another map using a different THEMIS daytime IR mosaic and make comparisons between the two or three regions.
- Have students actually initiate an investigation to answer the questions they may have had regarding channels and or craters on Mars. Students could explore images available at <http://themis.asu.edu> or even using Google Mars (<http://www.google.com/mars/>) to conduct their investigation.
- If your student groups are really interested in formally conducting an investigation they can participate in the **Mars Student Imaging Project (MSIP)**. With this project students can actually formulate a specific question, put together a team proposal and actually propose to use the THEMIS camera to take a brand new image of Mars for their research. For more information, visit the MSIP Website (<http://msip.asu.edu>) or contact us at msip@asu.edu.

Acknowledgements:

This activity was modified from the Destination Mars Activity Packet, *Lesson Four - Mapping Mars: Geologic Sequence of Craters and River Channels*.



STUDENT WORKSHEET 1

Initial Observations and Strategies

SAMPLE ANSWERS

Look at the Thermal Emission Imaging System (THEMIS) Daytime Infrared (IR) image mosaic your teacher has given you. You will be investigating this image throughout this activity looking for clues about the geologic history of this region. Areas where no THEMIS data has been acquired yet are seen as vertical black lines on the image.

1. What is the name of your region on Mars: Region name is in upper left hand corner of image

3. What are the two geologic features seen in your image? Please explain how these features form.

A. Geologic Feature: Craters

Formation: *Craters are formed when a piece of 'space junk' enters the atmosphere and impacts a surface causing a hole in the ground (an impact crater).*

B. Geologic Feature: Channels

Formation: *Channels are formed when water flows across the surface. Channels on Mars show evidence where water flowed across the surface at one time.*

4. List two pairs of geologic features (two craters, or a crater and a channel) for which you can tell the relative ages (older/younger). Briefly describe where those features are on the image mosaic (NW part of image, center of image, etc.):

A. Two Features: Answers will vary Location: Answers will vary

Younger Feature: _____

Older Feature: _____

B. Two Features: _____ Location: _____

Younger Feature: _____

Older Feature: _____

4. Describe two methods (strategies) you used to determine which features are younger/older.

A. *Student answers will vary depending on image used. Students should list at least two strategies they used in their own words. There are no right or wrong answers.*

B.



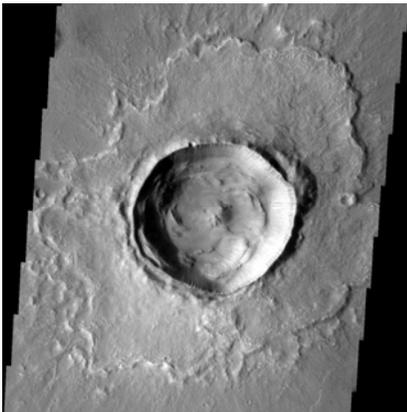
STUDENT WORKSHEET 2

Classifying Craters

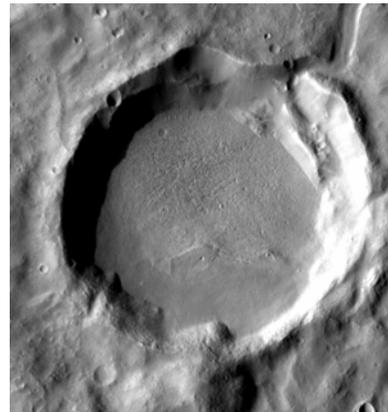
SAMPLE ANSWERS

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

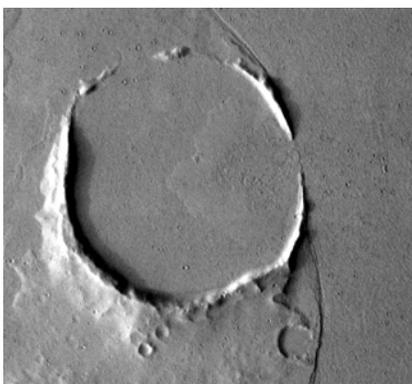
CRATER IMAGE	CRATER CLASSIFICATION: Preserved, Modified or Destroyed	REASONS
Crater A	<i>Preserved</i>	<i>Can see ejecta blanket clearly; has central peak; crater looks new</i>
Crater B	<i>Modified</i>	<i>Rims look eroded; very smooth floor</i>
Crater C	<i>Destroyed</i>	<i>Rims are broken; crater appears to be almost completely filled in</i>
Crater D	<i>Preserved</i>	<i>Can see ejecta blanket; rim looks nearly perfect; crater looks new</i>



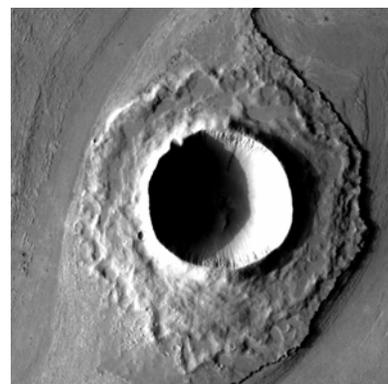
Crater A



Crater B



Crater C



Crater D

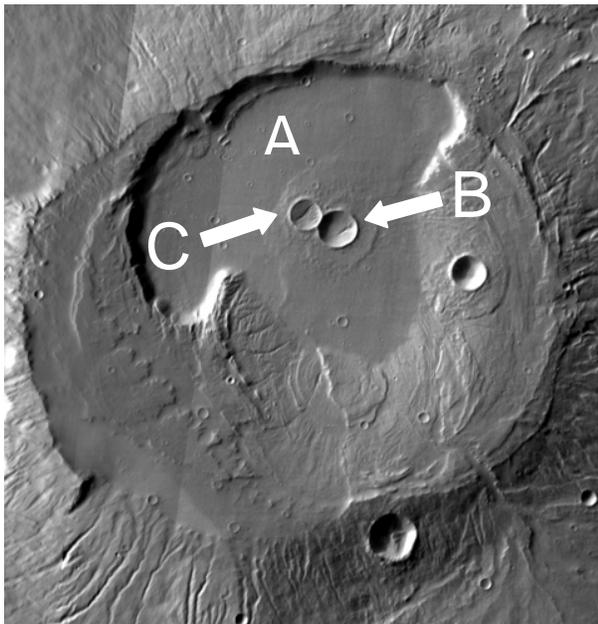


STUDENT WORKSHEET 3

Relative Age Dating Principles

SAMPLE ANSWERS

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



Oldest Crater: A

Younger Crater: B

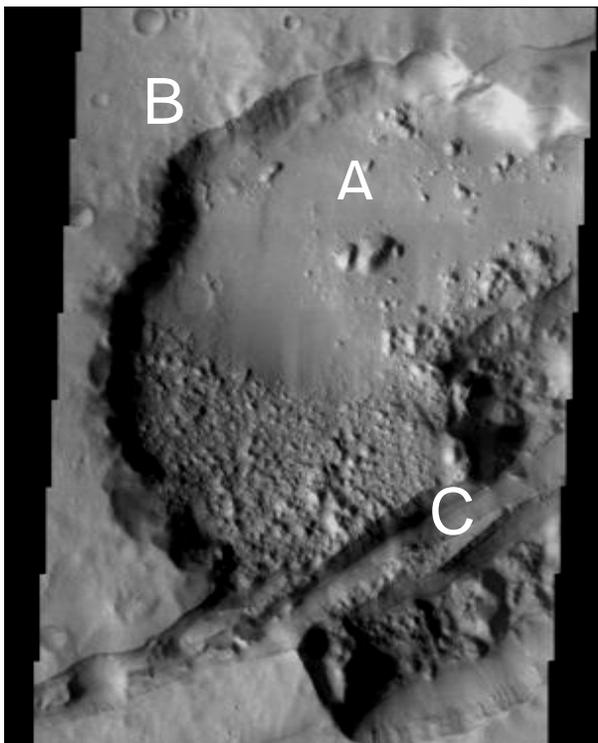
Youngest Crater: C

Please explain your answers:

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

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

 Principle of Superposition



Oldest Feature: B

Younger Feature: A

Youngest Feature: C

Please explain your answers:

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

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

 Cross Cutting Relationships and Superposition



STUDENT WORKSHEET 4

Interpreting the Geologic History

SAMPLE ANSWERS

Once you have made your feature map, you are now able to answer some questions and interpret the geologic history of your region. Be sure to name the age dating technique you used for each answer.

REGION NAME: _____

1. Which is older – the channel(s) (blue) or the destroyed (red) craters? How do you know?

Answers will vary but students should include which relative age dating technique they used.

2. Which is older – the channel(s) (blue) or the modified (green) craters? How do you know?

Answers will vary but students should include which relative age dating technique they used.

3. Which is older – the channel(s) (blue) or preserved (black) craters? How do you know?

Answers will vary but students should include which relative age dating technique they used.

4. Which are older – most large craters or smaller craters? How do you know? Why do you think this is?

Answers will vary. Students should include answers that include crater classifications. For the WHY part of this question, students may include answers such as: bigger craters may take longer to erode and smaller older craters have already completely eroded away; bigger craters may have been formed when larger pieces of space junk were floating around space and impacting the surface, etc.

5. Which features are oldest, youngest, and of medium age?

Answers will vary but students should include which relative age dating technique they used.



STUDENT WORKSHEET 5

Interpreting the Geologic History (cont'd)

6. Scientists don't always agree, but they try to convince each other with logical reasons for their interpretations. Discuss and defend your answers to questions #1 through #5 with another group that is studying the **same region**. Change any of your answers to questions #1 through #5 if you feel it is necessary. Fill out the table below after your discussion.

Answers will vary

Question #	Did you agree or disagree with the other groups answer	Did you change your answer (yes or no AND why) (Be specific and use 'geologic reasons')
1	<i>Agree or Disagree</i>	<i>Yes or No and students should provide their reasons using age dating techniques they discussed and used.</i>
2		
3		
4		
5		

7. Write your interpretation of the geologic history (the sequence of events that made this area look the way it does today.) of this region of Mars. You can use this sample starting sentence or create your own. Use additional paper as necessary.

In the _____ region of Mars, there was a lot of geologic activity that modified the surface. First, what happened was.....

Answers will vary but should reflect the answers to the above questions and their feature maps.



STUDENT WORKSHEET 6

Initial Strategies and Future Investigations

SAMPLE ANSWERS

1. Look back at question #4 from Student Worksheet I. List each of your initial strategies in the first column provided below. In column two, indicate if you feel it was a valid scientific strategy (method) to use. Use the knowledge you acquired after completing the lesson to make this decision. In the third column, state the common scientific name (if one exists) for the strategy you listed (crater classification or one of the relative age dating principles). If you feel your strategy is valid but there is no name for that strategy, create a name for that strategy that you feel is appropriate. If you feel the scientific strategy is not valid, leave the last column blank.

Initial Strategy Used	Valid Scientific Strategy (Yes or No)	Common Scientific Name (if applicable)
<i>Answers will vary.</i>	<i>Answers will vary – but should be a Yes or No.</i>	<i>Answers will vary – but strategies that have a common scientific name identified in lesson should be named as such.</i>
		<i>Students can get creative with the name they create if they feel they used a valid scientific strategy that was not described within the lesson.</i> <i>No name is necessary if they feel their initial strategy was not a good one to use.</i>

2. After creating, observing and interpreting your feature map, list at least two questions you have about craters or channels on Mars and how would you go about investigating each question?

Question about craters or channels on Mars	How would go about investigating your question?
1. <i>Questions will vary.</i>	<i>Investigation should involve looking at additional images of Mars.</i>
2.	



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<http://marsed.asu.edu>
<http://msip.asu.edu>