**Using Lava Flows & Volcanic Structures on Mars to Introduce the Concept of Relative Dating in Introductory Courses**

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**Type of Exercise:** In-Class Activity or Laboratory Exercise.

**Overarching Goals:** To enable students: (1) to develop the skills necessary to engage in relative dating and interpretation of the geologic history of an area here on Earth and other planetary bodies; (2) to develop the skills necessary to solve complex problems in a deliberate and systematic manner, so they can make the transition to interpreting geologic history from geologic cross sections.

**Description:** Geology is historical. The rocks at any one place are rarely if ever the same age. Interpreting Earth's history is a two-step process: first, interpreting each individual rock, and second, interpreting the sequence of deformational events through which the rocks have formed. Doing this requires that the students apply all the skills and knowledge they have learned about rocks and geologic process by integrating them with new skills. A student's initial challenge in interpreting cross-sections and determining the relative ages of rocks is to visualize the existing rock sequence into distinctive units that can be associated with geologic process and specific events. Thus, this exercise focus on guiding the students to observe important, basic concepts used in relative dating on a one-dimensional setting by using images from the Thermal Emission Imaging System (THEMIS) onboard the Mars Odyssey mission. The three images presented here were acquired in the visible mode of THEMIS. Copies of the images should be supplied to the students. Other options for presenting the images would be to display a large version of the images on the walls (appropriate for a small classroom), or to display a digital version of the images using a power point slide or overhead (appropriate for larger classrooms).

**Instructions:** To compare bodies of rocks in the same region and come out with a sequence of events that led to the formation of these rocks, geologists use a few simple rules of observation that help determining the relative ages of the rocks. In order to do this, geologists depend highly on two-dimensional, vertical diagrams called cross sections. Before you begin to interpret these diagrams however, we will practice understanding relative dating using images from the volcanic region of Tharsis on Mars. Mars is only about one-half the size of Earth and yet has several volcanoes that surpass the scale of the largest volcanoes on our planet. The Tharsis region resembles a dome 4,000 kilometers across and up to 10 kilometers in height. During the course of this exercise, please remember that these images represent a top view of the surface of Mars. Work together in groups of two or three. It helps to learn by discussing and debating how interpretations should be made.

The first image, V05473003, shows lava flowing west from Arsia Mons located in the Tharsis volcanic complex.

- Can you easily determine the sequence of volcanic events (which came first, which came last) that led to the deposition of the lava flows seen on this image?
- What information from the image let you to this sequence?
- What techniques will help you learn more about the ages of the lava flows on the image?

►*Give the students time to analyze the image, then discuss their results and introduce the principles of horizontality and superposition.*

Relative dating can not only be applied to lava flows on Mars, it can be used with any geologic product such as the wind deposits seen on image V05598003 (dark parabolas behind impact craters). This image is located south west of the Tharsis region and wind has played a great part in modifying the surface producing distinctive windstreaks.

- On a piece of paper, write a description of the sequence that tells the history of this area on Mars.
- Do you think it would be easier to map surfaces here on Earth? Why or why not? Explain.

►*Again, give the students time to analyze the image, then discuss their results and introduce the principles of horizontality and superposition. Also, take some time to discuss some of the similarities and differences of geologic process (i.e. erosion and transportation) between our planet and Mars.*

At this point it is time for you to practice relative dating of features on Mars on your own. Image V05896013, located south of Alba Patera another of the volcanoes located within the Tharsis Region, is a great resource to comprehend the principle of cross-cutting relations.

- Using the concepts you just learned about, determine the relative ages and write a description of the sequence that tells the history of the features labeled A to F. Keep in mind the mode of origin of the various structures and always start with the question: what came first?

►*Due to the complexity of this image, it could be used as a follow up assignment, but you have to make sure that you explain the concepts of impact cratering, pit chains, and graben formation beforehand or include some literature. From oldest to youngest the main geologic events occurred as follows: Lava flows were deposited (D); a N-S trending graben (C) is developed; large impact crater (A) is formed; more N-S trending grabens form (F) cutting the ejecta blanket of large crater; a third episode of graben formation (E); and, a pit chain trending WE (B) forms cutting across both the ejecta blanket and the top to bottom trending graben.*

*Note: The images from this exercise could also be used to examine, describe and compare geologic processes on Mars and Earth.*

**The Next Step:** Now that you have analyzed the individual components of these images, you can begin to put all the information together in two-dimensions by using cross-sectional views the way a geologist would.

►*Instructor should do this exercise on a transparency together with the students.*

- Go back to our first image (V05473003) and using coloring pencils map the extension and contacts of Arsia Mons' lava flows.

- How do you think the topography would look if you take a topographic profile from north to south along the middle of the image? Assume that each lava flow is a couple of meters thick. Use a piece of paper (as you learned during the topographic map laboratory exercise) to create your representative profile.
- Project the contacts between the lava flows from the profile down onto the cross section.
- Sketch the lava flows below the surface to create your cross section.
- Which relative dating principle(s) did you use for the creation of your cross section?
- Have you seen similar vertical views of rocks before?

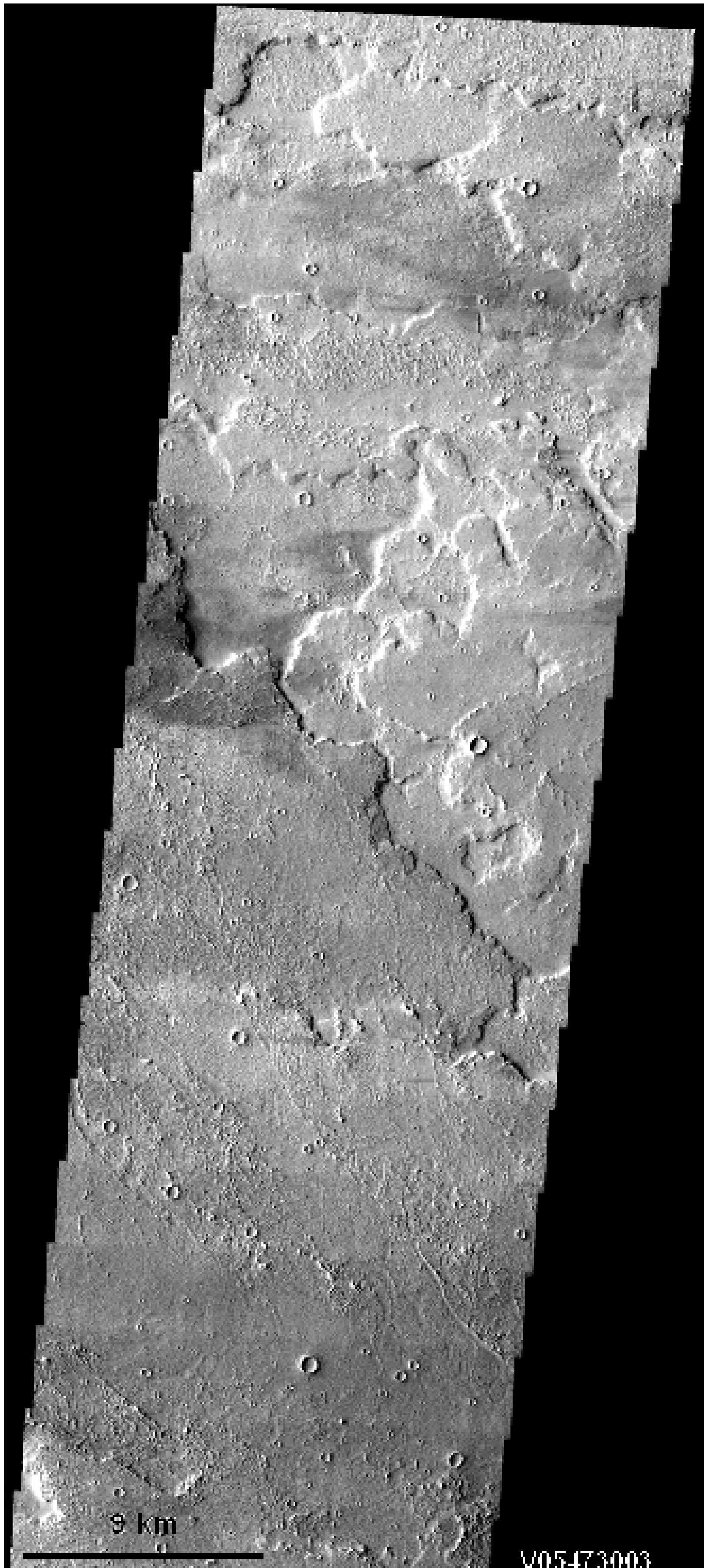
►*The answer here is yes and probably the most common example are road cuts, but students could require some help remembering this every day example. This is a good point to make your students think about road cuts as cross sections and windows to the past geologic history. Cliffs, road cuts, and non-vegetated landscapes allow us glimpses into geology which is often hidden from view. Cliffs and road cuts are "side views" or "geologic cross-sections" of the topography which show the relative positions of various rock layers and structures at a given spot.*
►*Other principles of relative dating (i.e. unconformities) and more examples of cross-cutting using faults and dikes should be explained with cross sections from Earth.*

**Principles of Relative Dating Used on this Exercise:**
*Principle of Uniformitarianism:* “The present is the key to the past”. Physical process that we observe in operation today also operated in the past at comparable rates.

*Principle of Superposition:* In any undisturbed sedimentary sequence, the oldest rock is at the bottom and the youngest is at the top.

*Principle of Lateral Continuity:* Sedimentary rock layers and lava flows extend laterally (i.e. they are continuous in sheets) in all directions until they thin to their termination (pinch out) or reach the edges of an obstacle.

*Principle of Cross-Cutting:* Any feature (fault, fracture, igneous intrusion, etc.) that cuts across another rock(s) must be younger than the rock it cuts.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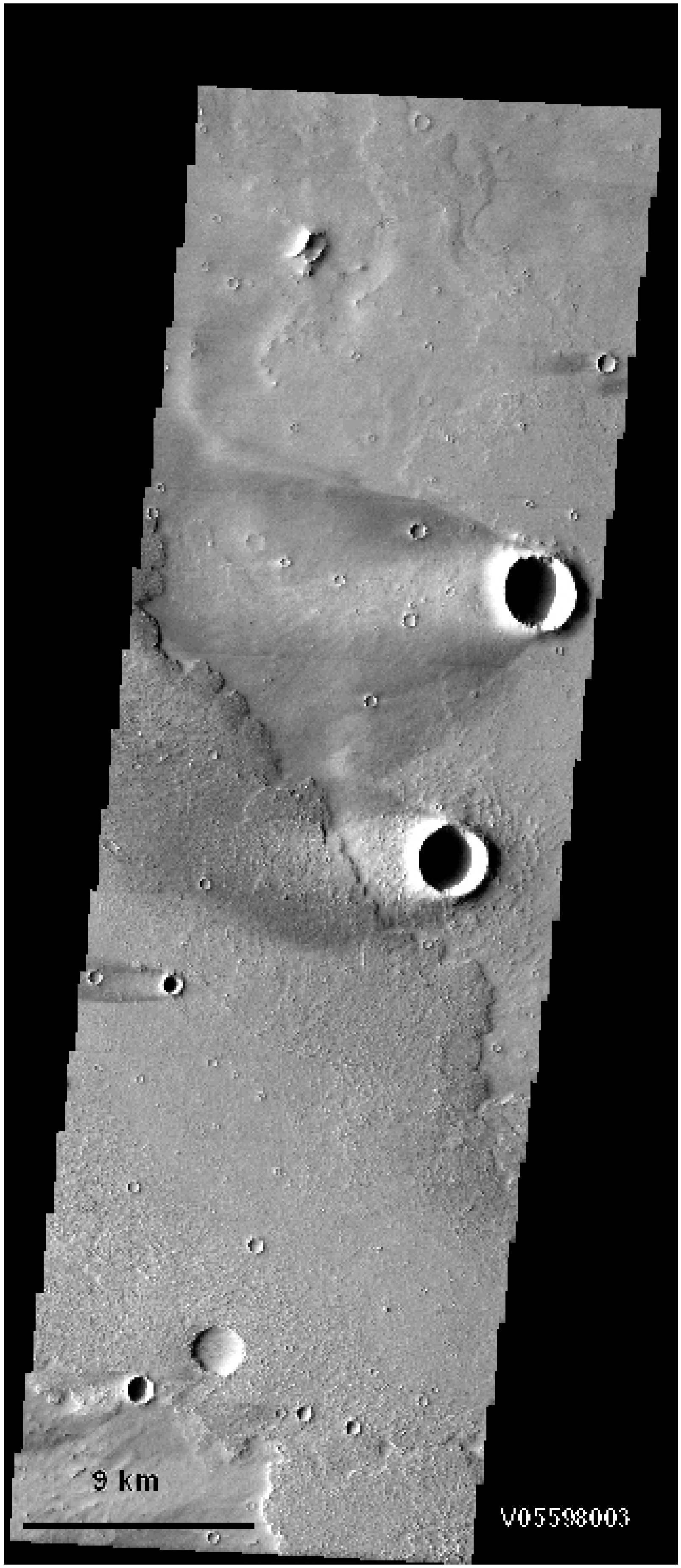
V05473003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A
F
B
F
E
D
C
9 km
V05896013