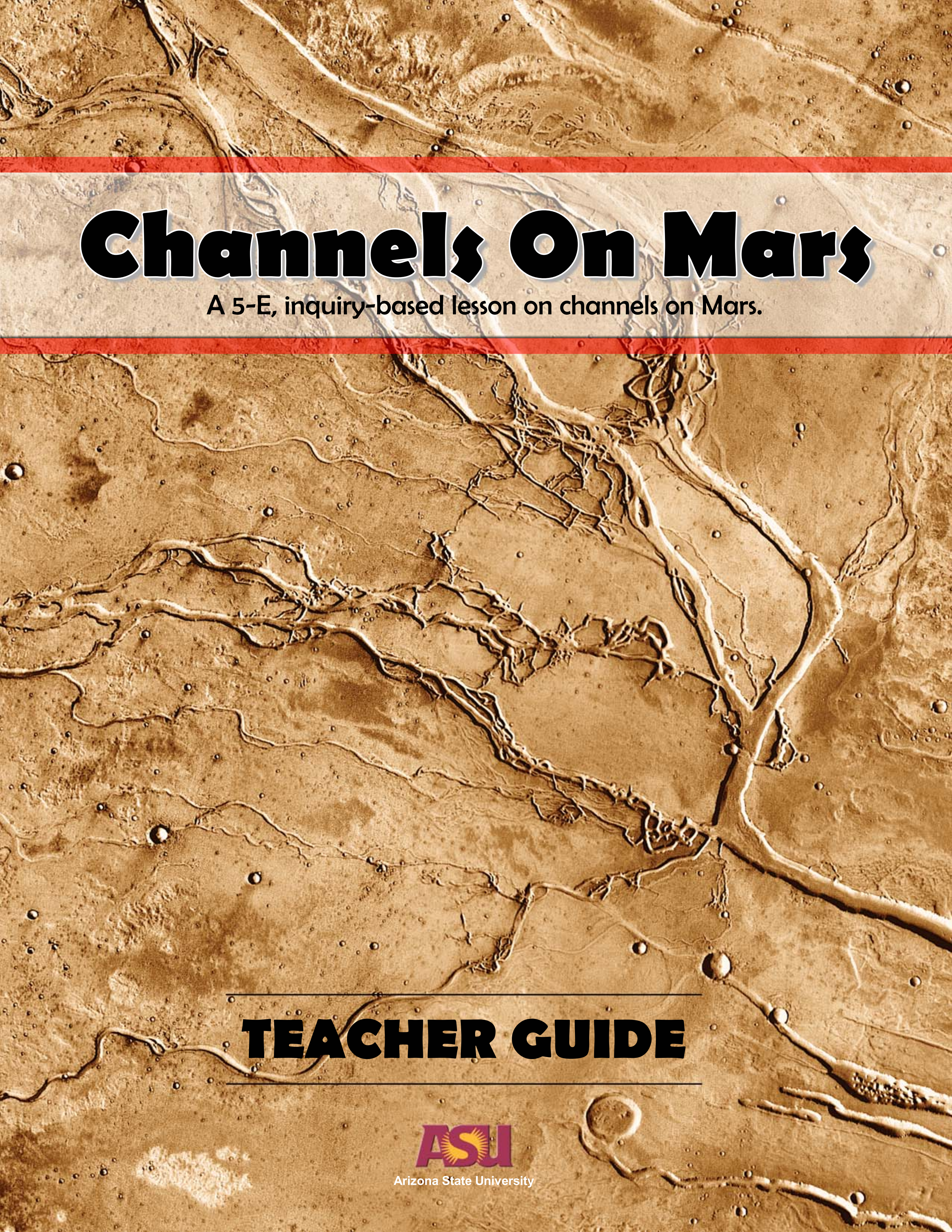

Channels On Mars

A 5-E, inquiry-based lesson on channels on Mars.

TEACHER GUIDE

Arizona State University

CHANNELS ON MARS

5-E Activity Module

Teacher's Guide

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Goal: This activity is designed to cultivate an interest in planetary investigations through an authentic exploration of geologic features with remote sensing images. This activity module uses inquiry-based learning techniques and uses the 5-E model of instruction.

Grade Level: 5 – 12

Time Requirements: 3 – 5 class periods

Objectives: Students will:

1. Identify different types of channels on Mars and interpret how they have formed.
2. Become familiar with remote sensing terminology associated with the *Mars Odyssey* satellite.
3. Use geologic relationships to determine the order of events that shaped an area.

Required Materials & Resources

- Computer lab for students to explore THEMIS website (http://themis.asu.edu)
- *Channels On Mars Teacher Guide*
- *Channels On Mars Student Guide*
- Students should have a working knowledge of rock-forming processes and the rock cycle

Other Useful Materials & Resources

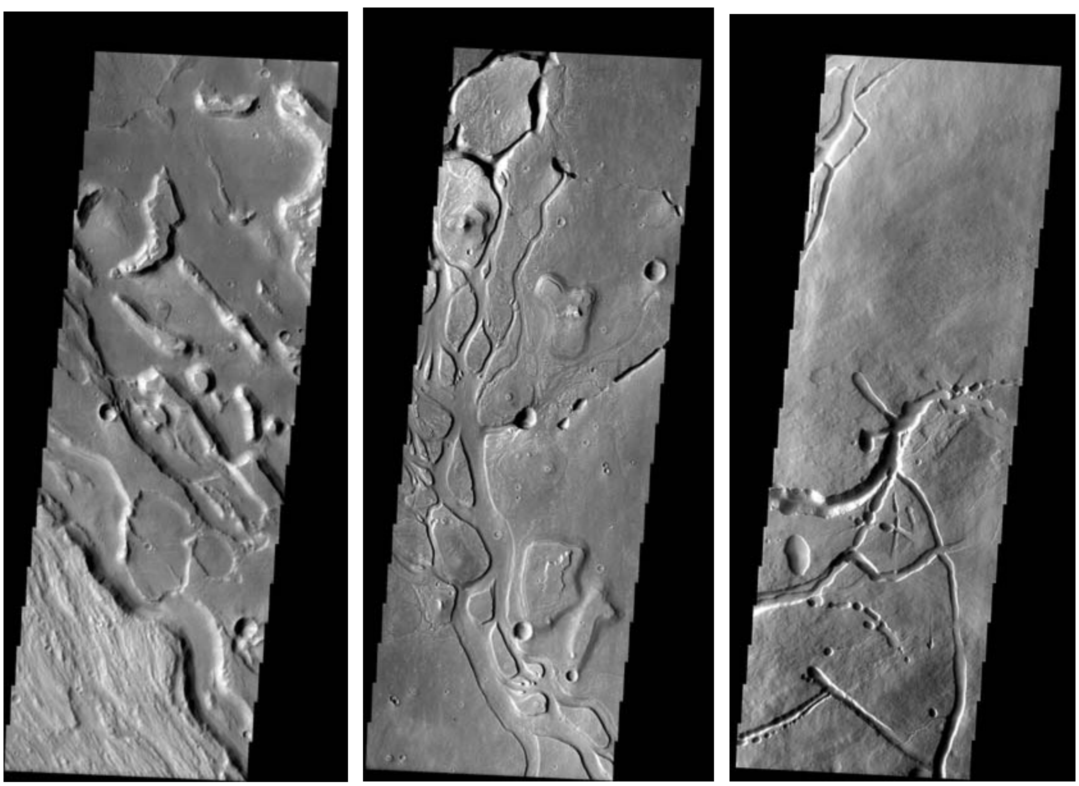
- PowerPoint presentation slides for use with students in the classroom (**NOTE**: Need to have a projector attached to your computer to use this resource).
- Feature Identification Charts (http://marsed.asu.edu/upload/FeatureIDChartsv2.pdf)

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

Introduction

This activity is designed to cultivate an interest in planetary investigations through an authentic exploration of geologic features with remote sensing images. Mars has been the subject of much human interest throughout the ages (Kieffer, et al., 1992). Recently there have been a number of successful missions to map and explore this fascinating planet. One such mission, the **2001 *Mars Odyssey*** (named after the movie *2001: A Space Odyssey*), has produced an amazing array of images that have been made available by Arizona State University's Mars Space Flight Facility at their website (http://themis.asu.edu). The site has a wealth of information about the mission itself and the Thermal Emission Imaging System (THEMIS) instrument that students can explore and learn about this new technology that is being used to map Mars. There are also background educational manuals that contain more detailed information written specifically for students about the history of Mars exploration, the different features and characteristics of Mars, the *Mars Odyssey* spacecraft, and THEMIS which can be downloaded (ASU Mars Education Program, 2002).



Selected channel images from THEMIS website (http://themis.asu.edu).

THEMIS stands for **Thermal Emission Imaging System** and is a type of camera onboard the *Mars Odyssey* spacecraft. It contains two independent multi-spectral imaging sub-systems: a 10-band **thermal infrared imager** (IR), and a 5-band **visible imager** (VIS) (Christensen, et al., 2004). The images that are taken by THEMIS have two different resolutions. The IR subsystem has a resolution of 100 meters per pixel in an image and the VIS subsystem has a resolution of ~17-19 meters per pixel. The VIS resolution of ~17-19 meters per pixel is a significant improvement in remote sensing and geologists are able to see more detail of the surface of Mars. While the IR imager has a less refined resolution, it gives us critical information about the heat stored by different geologic materials; simply put, different materials have different unique thermal signatures, like fingerprints or DNA.

This wealth of information has considerable value in determining not only the shape of geologic features, but also the specific rock types that are present, which makes it possible to construct a more accurate view of Mars' **geologic history**. Until we have actual rock samples from Mars to analyze for composition, texture, and age, we must rely on such innovative technology and research methods.

Geology of Channels on Mars

On Earth we are accustomed to seeing channels carved by water in streams and rivers. However, on modern-day Mars we don't observe water as a liquid on its surface. There is water on Mars in frozen form, in polar ice caps and as permafrost underground and a very small amount of water vapor in its atmosphere, but not enough to rain! Mars is a cold and frozen planet. Any water on its surface would quickly freeze and then rapidly volatilize into its atmosphere. This situation generates many questions about fundamental geologic cycles. How do Earth and Mars' water cycles differ? Did Mars ever have rivers and oceans? If so, when? and for how long? Mars has storms and weather, but what kind of atmosphere does it have and has the atmosphere changed over time?

The search for water was one of the main reasons for exploring Mars, as it is a critical component to life, as we know it on Earth. There are many fluvial features on Mars, braided stream channels, deltas, streamlined hills or islands, that have undeniably been formed by water, but the central question is about **time**. **When** did channels on Mars form (if they were formed by water)? One terrestrial example of this kind of mystery can be found in the **Channeled Scablands** of Washington State. An excellent resource is housed at http://www.pbs.org/wgbh/nova, along with a summary of a video, "Mystery of the Megaflood",

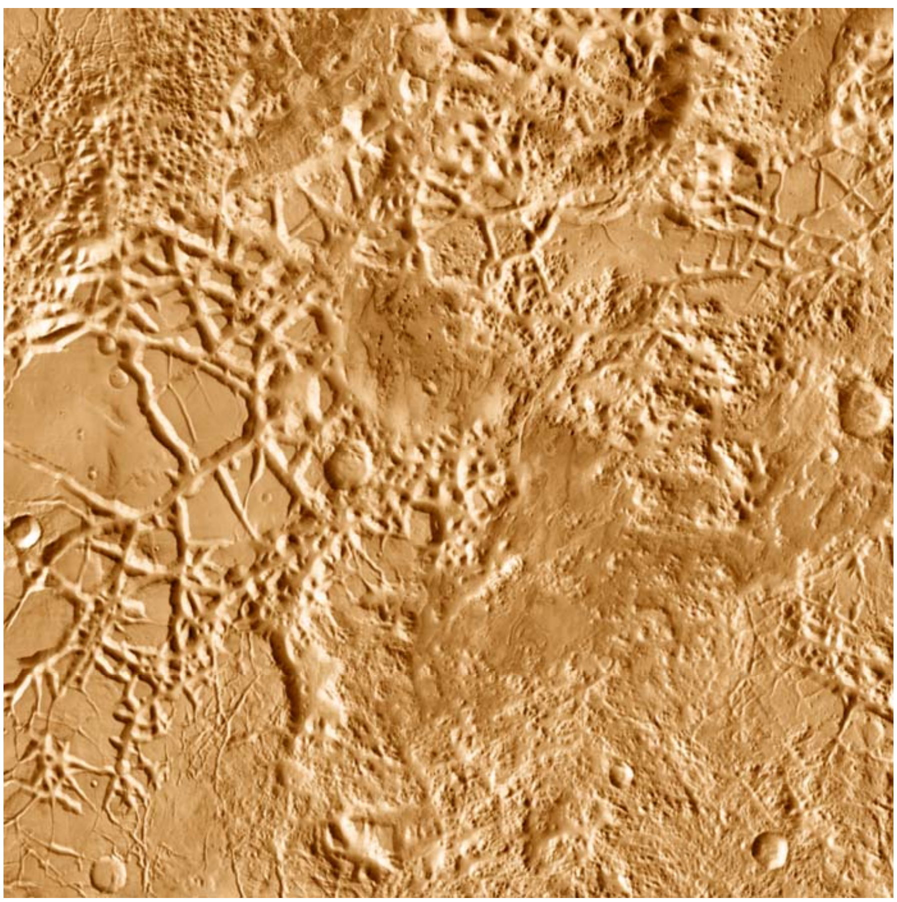
Ice Age Channeled Scablands, Washington State.
(http://www.pbs.org/wgbh/nova/megaflood/scab-nf.html)

that traces the scientific battle by geologist J. Harlen Bretz who determined that this area had undergone massive erosion by a catastrophic flood. Initially Bretz didn't have an identified source of water and the geologic community was very skeptical of his hypothesis. On Mars, scientists have outlined evidence for catastrophic floods. Liquid water has been suggested to have burst explosively from **groundwater aquifers**, which has disrupted surface rock layers creating chaotic terrain and carved out channels (Carr, 1979; Baker & Milton, 1974). These releases of water may be triggered by geothermal or volcanic activity (Plescia, 2003) and not just from the hydrostatic pressure from within the aquifer itself. But like the Channeled Scablands story, where water comes from on Mars is still a hot topic.

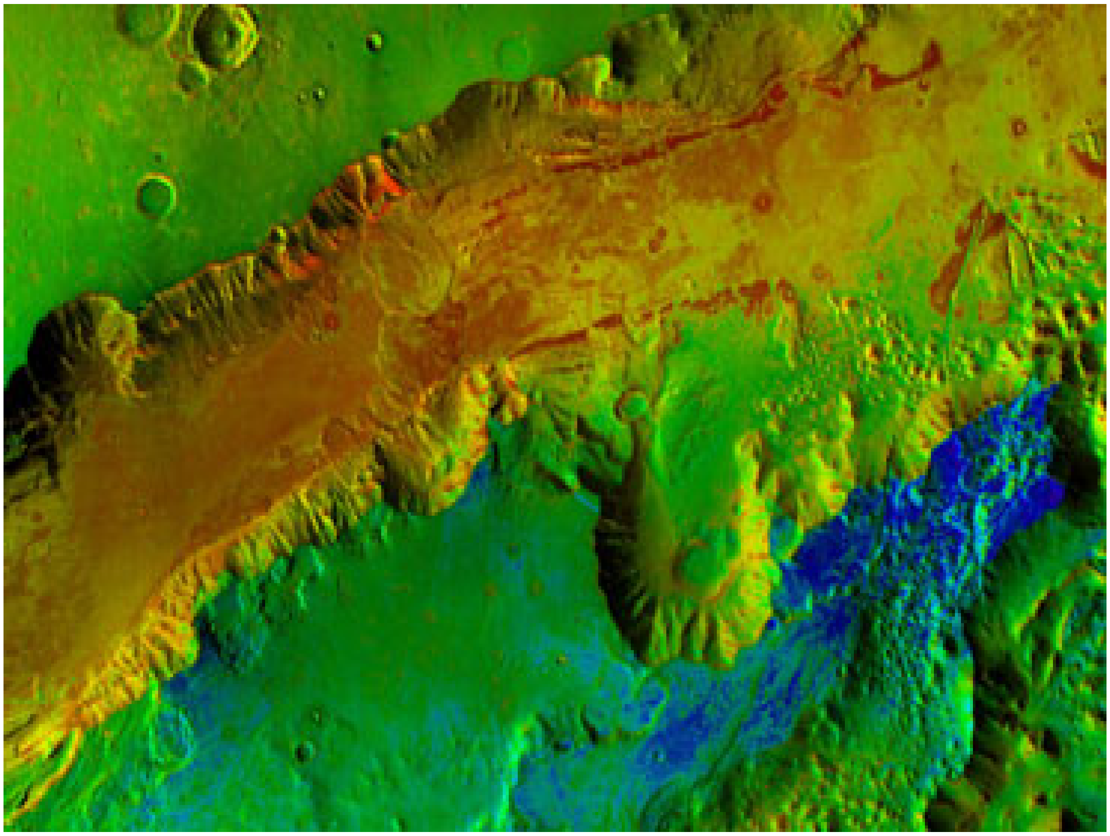
However, large quantities of water are not the only way that channels or valleys can form on Mars. **Tectonic forces** associated with past volcanism have created rift valleys (for example, the largest canyon on Mars, Valles Marineris) and grabens (smaller-scale features). **Volcanic activity** itself can carve channels on the surface. Lava flows sometimes mimic river deltas and can also create underground tubes that then collapse, leaving steep-sided, linear, channels and sinkhole-like features called "pitchains". **Mass wasting processes**, such as landslides and creep, driven by gravity modify existing channels and canyons. Ground water sapping can also produce rills, gullies, and channels. **Wind** scours the Martian surface and removes dust only to redeposit it elsewhere, filling in craters and channels and softening features. The PowerPoint presentation slides show examples of the various types of channels on Mars.

Channel Scablands (www.pnl.gov/cms/images/bsalt_flowers.jpg). This area is also composed of basalt, which is a very common igeous rock on Mars, so it makes an excellent analogue in many ways.

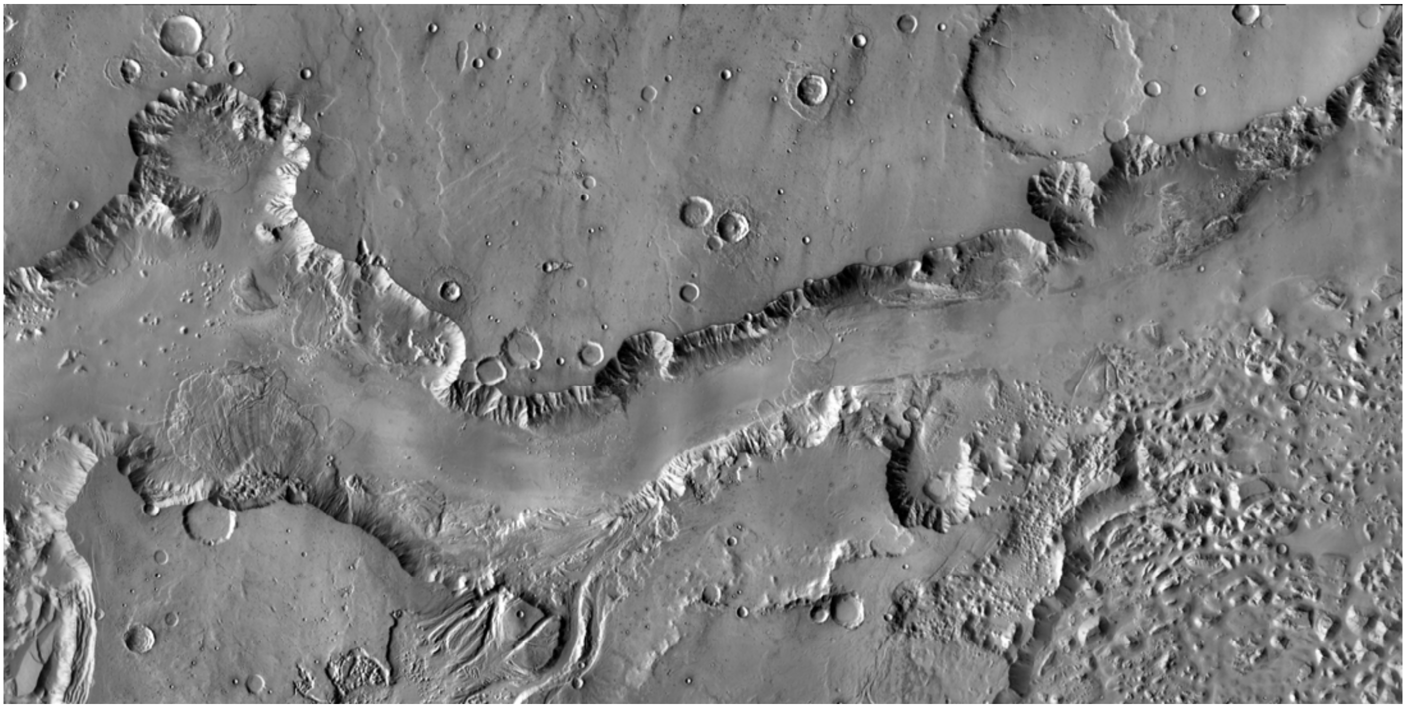
Martian outflow channel with chaotic terrain
(http://www.windows.ucar.edu/tour/link=/mars/images/mars_outflow_channel_jpg_image.html)



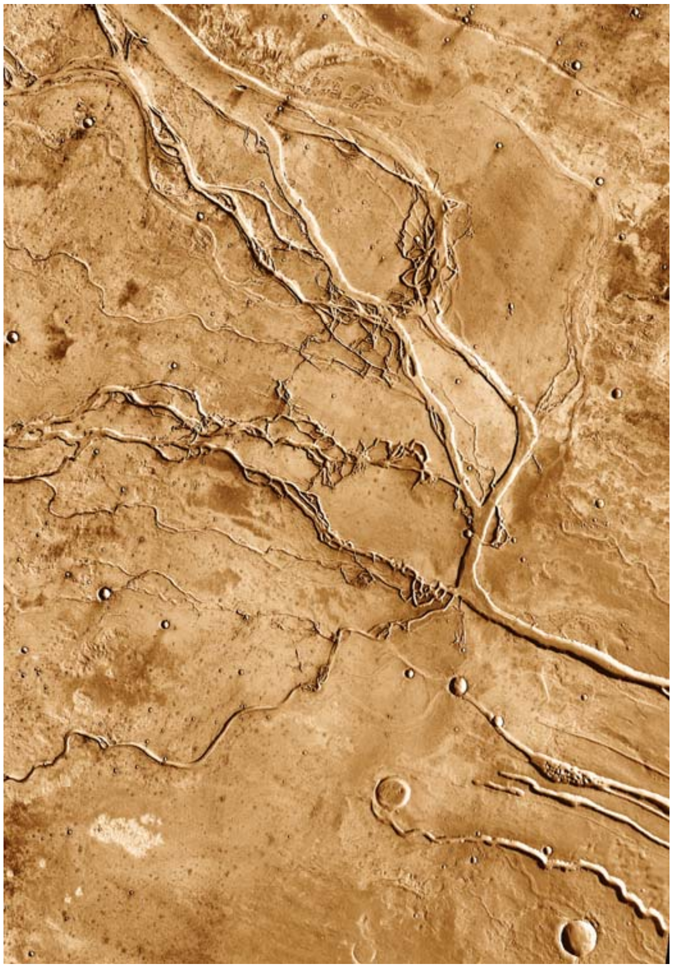
Additional image of Martian chaotic terrain
(http://themis.asu.edu/features/ianichaos)



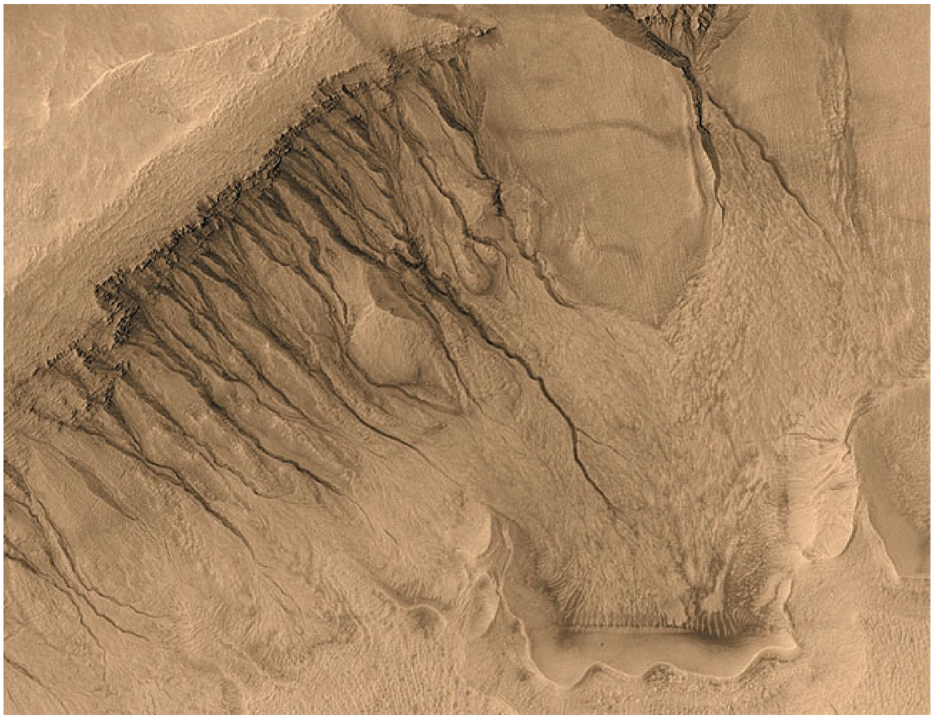
A section of Valles Marineris from the 2001 Mars Odyssey website
(http://mars.jpl.nasa.gov/odyssey)



Eastern Valles Marineris (Ganges Chasma) showing channels with craters, slope failure, chaotic terrain and wind erosion. (cropped image taken from infrared map of Mars available at http://www.google.com/mars/)



Water carved channels and collapsed lava tubes. (http://themis.asu.edu/features/granicusvalles)



Gully erosion and landslides, potentially by ground water sapping, in Newton Basin, Mars
(http://antwrp.gsfc.nasa.gov/apod/ap030205.html)

How Should Students Learn Science?

Learning through Inquiry

The National Research Council (2000) has identified five essential features of **classroom inquiry** for students (Carin, 2005):

1. Learners are engaged by scientific questions.
2. Learners give priority to evidence as they plan and conduct investigations.
3. Learners develop descriptions, explanations, and predictions using evidence.
4. Learners connect evidence and explanations to developing scientific knowledge.
5. Learners engage in critical discourse with others about procedures, evidence and explanations.

This activity module is designed to meet these criteria for inquiry-based learning and uses the 5-E model of instruction. It has also been designed with **three learning principles**, as outlined in *How Students Learn: Science in the Classroom* (NRC, 2005), in mind. These include: 1) engaging prior understandings, 2) the essential role of factual knowledge and conceptual frameworks in understanding, and 3) the importance of self-monitoring (NRC, 2005).

"Student learning experiences should have a stronger emphasis on inquiry-based learning, use of visualization technologies and understanding Earth as a system" (Barstow, 2002).

Accordingly, it is critical that you introduce this exploratory activity by **finding out what students know about channel formation and what that may mean in terms of the geologic history of Mars**. Their answers do not need to be correct at this point in time, it is simply an opportunity to access their ideas, acknowledge their questions and engage their curiosity. In the PowerPoint presentation you will find slides that will help guide this discussion with your students. Throughout the exploratory phase and activity with the THEMIS images you should ask students what they think the different geologic features mean and how they relate to each other (using the laws of cross-cutting relationships and superposition).

5-E Model of Instruction

This activity module is embedded within the **5-E model of instruction** (Carin, et al., 2005). The 5-E model was developed by the BSCS group (Biological Science Curriculum Study, 1989) and there are five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. It is a "second generation of the Learning Cycle…exploration, concept invention, and concept application" by Karplus & Their (1974). The 5-E model is a more structured version of guided discovery because there are specific concepts that teachers want students to know, activities are structured in a step-by-step fashion, and therefore more materials are prepared in advance. However, this is still considered to be inquiry-based learning due to the nature of the activities, the specific order that they occur, and how they are presented to students.

5-E Phase	General Description	Channels On Mars Activity
Engagement	Teachers engage students in questions and probe for prior knowledge and conceptions.	Prior knowledge activity: *What do we know about channels on Mars?*
Exploration	Students plan and conduct investigations to gather evidence.	Use of THEMIS website. Channel images with activity data collection sheets.
Explanation	Building on students' explorations and explanations, teachers formally present scientific terminology, concepts, and principles. Students, guided by the teacher, use new knowledge to construct scientific explanations and answer initial questions.	Presentations by students of their data gathering activities. Preliminary identification of geologic features seen in images.
Elaboration	Students apply new understandings to new problems.	Generate research questions based on exploration of Mars THEMIS images. Students select one of their images to investigate in greater depth. They will also research various channel-forming processes.
Evaluation	Teachers and students use formal and informal means to assess new knowledge, understandings, appreciations, and abilities.	Students create posters diagramming and explaining the geology of their selected image and summarizing the research that supports their interpretation.

Table 1. 5-E model of instruction with general description (Carin, et al., 2005) and application to *Channels On Mars* activity module.

Teaching of Module

Use the following procedure to teach the *Channels On Mars* 5-E Activity Module. The optional PowerPoint presentation can be used in the classroom as part of the *Engage* phase while the web-based student activity is the *Explore* phase. It takes time to look at images in-depth and you should allow for a few class periods for detailed mapping to occur. Educators at the ASU Mars Education Program have noticed that students tend not to mark features on images that they can't identify, but if encouraged they will mark interesting features with a question mark (Valderrama & Gootee, personal communication, 2005). This is an excellent way of broadening student's perspective and letting them know that science is about exploration and not knowing all the "right" answers.

1) Engage: Prior knowledge activity

How do channels form on Mars? How old are they?

1. Pair students with a partner and have them brainstorm on what they think they know about channels on Mars. This generally increases student participation and acknowledges their ideas. Have students fill out information in the first two columns of the KWL Prior Knowledge/Engagement Activity Chart in their student guide. Students can draw from their knowledge about how channels form in general, even on Earth. **Optional:** Use photographs of channels on the PowerPoint to spark students to think about what students think they know.

2. After students have finished their individual discussions, return their attention to the whole group. You can chart their responses on large chart paper (recommended so that you have a written, visible record during the module) so that everyone can hear students' ideas and questions.

What do we know about channels on Mars? (what they look like, how they are made, when were they formed?)	What questions do we have about channels on Mars?	What have we learned about channels on Mars?

3. You will leave the last column blank for now. As students learn new information to answer their questions and/or correct their misconceptions you can add these new (accurate) ideas to the chart)

2) Explore

Use of THEMIS website channel images with activity data collection sheets.

1. Students will need access to the internet in order to explore the THEMIS website.
2. Assign each pair of students 4 images from the website. You can circle these on your students' activity sheet, or if the website has added new images you can print out an updated image of the thumbnail images and give that to them with your assignments. The idea is that the entire class looks at as many images as possible.
3. Once students connect to http://themis.asu.edu they should follow the directions on their observation sheets. **NOTE: It is highly recommended that you use the website yourself beforehand to gain familiarity with its organization and features in order to help your students if they have difficulties navigating.**
4. Make sure that students are accessing enlarged views of the images as they will miss a great deal by simply looking at them as they are on the website.
    a. By clicking on the thumbnail image it will bring them to a page that has the THEMIS image, image information and corresponding context images.
    b. Students can (and should) read any information provided on the right hand side of the page.
    c. By clicking on the THEMIS image, students can view the entire image on the page.
    d. By clicking on the THEMIS image one more time, or by moving the mouse over the lower, right-hand corner a square button will appear allowing students to click to enlarge and see much greater detail of the features within the image. (Students will have to scroll around to look at it… and it will be much more interesting to look at!)
5. Alternatively, if students want to work off-line or print out an image (to use it later for their poster) they can select a JPG file (it's a smaller image file) and insert it into a *Microsoft Word* document. In *Microsoft Word* they can resize the image and also zoom in on it (up to 500%) to see the details.
6. Have students sketch what they see in the images on their data sheets. They should label features that they can't explain with a "?".

3) Explain

Presentations of assigned Mars images to whole class by students; preliminary identification of the geologic features they see in the images.

1. Student pairs can use chart paper or medium-sized white board to summarize their findings and post them at the front of the classroom to share with their classmates.
2. Alternatively, you can access the THEMIS website and have students chose one image to present to the class (ideally the one they found most interesting that they will do further study of and research pertinent information).
3. Help students with geologic vocabulary if they do not understand significant terms to use when discussing their image. You can even generate a class list of new words. This is helpful to English language learners, especially if you put a picture with the word.

4) Elaborate

Generate research questions based on exploration of Mars THEMIS images. Use research skills to learn more about geologic features of Mars.

1. Students select one of their original four images to investigate in greater depth.
2. Either assign for homework or as a class conduct research of various channel-forming processes on-line and/or in your school library.

5) Evaluate

Students create posters diagramming and explaining the geology of their selected image and summarizing the research that supports their interpretation.

NOTE: *Depending upon how you grade your students' work you may decide to convert the rubric score to a grade. You may wish to add or subtract from the rubric to meet the needs of all of your students.*

1. Give the students the product descriptor and scoring rubric for their poster assessment before they start the evaluation.
2. Once students have completed their research have a poster session (like "real" Mars scientists do!) so that all students can look at each other's work.
3. If you want students to give peer feedback you can give then Post-It notes to write on and leave with their classmates' posters or assign specific students to review specific posters.

Evaluation: Poster Session
Selected THEMIS image(s) with interpretation and supporting research.

Directions

1. Select one of your original four images to investigate in greater depth.
2. Print out a copy of your image (and other images if you wish) and label all features of interest. Include labels for features, such as craters, to show which feature was created first, i.e., which is older.

3. Along with your image information, include your research question and research you have done on the different geologic features that you are focusing on.

4. Reference all sources of information, including the THEMIS website.

Rubric for Poster Assessment

Exemplary	All information is complete, accurate and detailed. Selected THEMIS image(s): features have been thoroughly labeled. Correctly cited image information. Neatly presented and logically organized. No spelling or grammatical errors.
Meets Standards	All information is complete and accurate. Selected THEMIS image(s): most features have been labeled. Correctly cited image information. Neatly presented and generally organized. No spelling or grammatical errors.
Partially Meets Standards	Some information is missing; all others are complete and accurate. Selected THEMIS image(s): some features have been labeled. Partially cited image information. Generally organized, but not as neat as it could be. Few spelling and/or grammatical errors.
Redo	A lot of information is missing. Selected THEMIS image(s): few features have been labeled. No cited image information. Disorganized and sloppy. Multiple spelling and/or grammatical errors.

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