Upgrading a Landforms Analysis Activity for an Introductory Planetary Science Course Using MGS/Mars Odyssey Imagery resources and *Google Earth/Mars*

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Background and Context

"GLY 4045: Moons, Planets and Meteors - an Introduction to Planetary Science" is a 3 credit hour, upper-level undergraduate general education "exit" offering which I developed and taught at the University of South Florida every Spring and Summer term between 1996 to 2003. The audience for this course included both non-science and science majors, along with significant numbers of students from our College of Education.

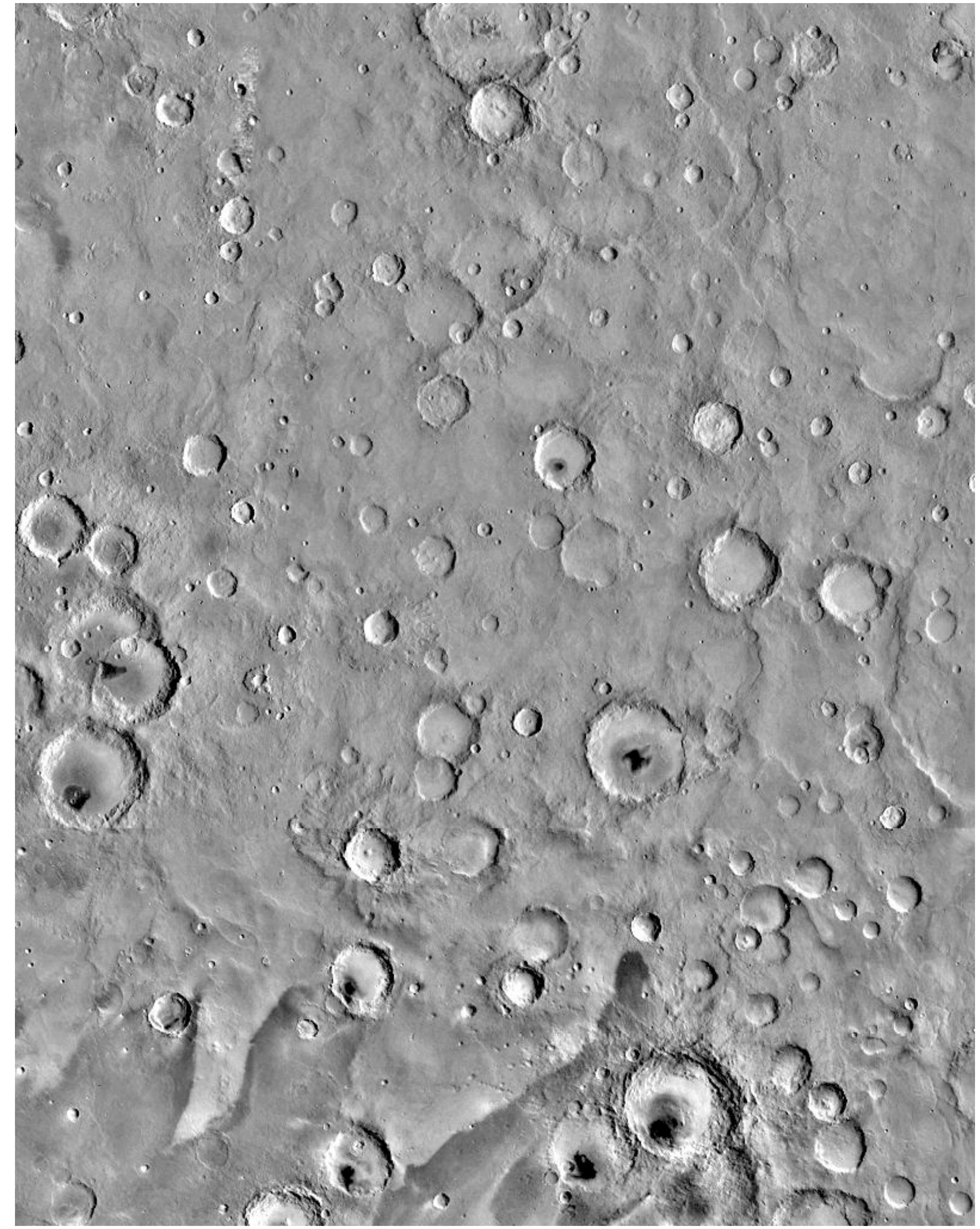
The course was originally conceived as an interactive lecture/discussion offering for audiences of 20-25 students. However, rapid growth in the popularity of the course, combined with requests that it be offered on all four of the USF campuses (Tampa, St. Petersburg, Lakeland and Sarasota), led to its transformation into a live-audience distance learning class: up to four course sections of ~20 students connected to one another via videoconferencing technologies, with me leading each session from one (rotating) site, aided by teaching assistants at other sites.

Use of Internet-based information resources, especially the extensive Web imagery databases available through NASA and NASA-related sites, has always been a critical component of this course, and its use in the classroom was facilitated by the transition to distance-learning technologies. Online resources were used as the basis for traditional homework exercises, and for out-of-class assignments preparing for hands-on classroom activities.

Future plans for the course involve taking advantage of current courseware technologies to move it in the direction of a predominantly online offering, with periodic on-campus discussion/recitation sessions. Thus, the ability to create learning activities that both engage and challenge students will be critical to the future effectiveness of this course.

Landform Identification Activities

A primary instructional objective of GLY 4045 is to have students develop an understanding and appreciation of the scientific method as it is applied in the earth and planetary sciences, and an important goal of the course is to demystify science - to show students, through class activities, that much of what a scientist does is straightforward, provided one has access to the necessary data. In this regard activities involving the recognition of landforms from planetary surface images are particularly effective, as students can quickly begin to identify and catalog different kinds of surface features and use these to constrain land surface ages (via crater densities), the igneous and tectonic histories of planets (by identifying volcanic landforms), and the nature of planetary surface environments through time (i.e, the presence of aeolian or hydrologic features, and their apparent ages). A recurring theme in the course is one of planetary comparisons - how are features on the Moon/Mars/Venus similar or different from those on Earth, and what may this mean re: their histories?



Highly cratered Martian Terrane (Viking image data from Mars Clickable Map -
http://pdsmaps.wr.usgs.gov/PDS/public/explorer/html/marslvls.htm

Doing Planetary Geology! Surficial Features of Mars and Other Worlds, and What They Mean

Discovering the geologic history of a planet that you've never visited (generally, the situation we're in) means that all you really get to work with are pictures – images of the surfaces of planets, which we obtain via **direct photography or video**, as in the case of the Mars Pathfinder and Global Surveyor missions, or by **radar mapping (essentially bouncing radio waves off the surface, and determining elevation based on travel times),** which the Magellan probe did on Venus, where the thick atmosphere and cloud cover prevented direct visual imaging of the land surface (on Earth we use **Sonar (a sound wave source)** to map the seafloor in much the same way that Magellan mapped Venus!). The US Geological Survey and NASA both maintain extensive libraries of images of the surfaces of the terrestrial planets and the Jovian moons, which researchers and the simply curious can access, examine, and even download for their own use.

But, once you have pictures of another planet, how do you tell what is going on? What geologists do is compare what they see to features we find on the Earth, and apply the **Principle of Uniformitarianism** – if a certain geologic process produces a certain land feature on the Earth, then a generally similar process probably produces that feature on other planets as well! If the feature doesn"t occur on the Earth, then they have to "work without a net" and try and infer how the feature might have formed based on related features that they do recognize. Sometimes, the feature resembles something seen on the Moon (from where we have a little first-hand field information!), and we can work a lunar analogy, based on our understanding of Lunar processes.

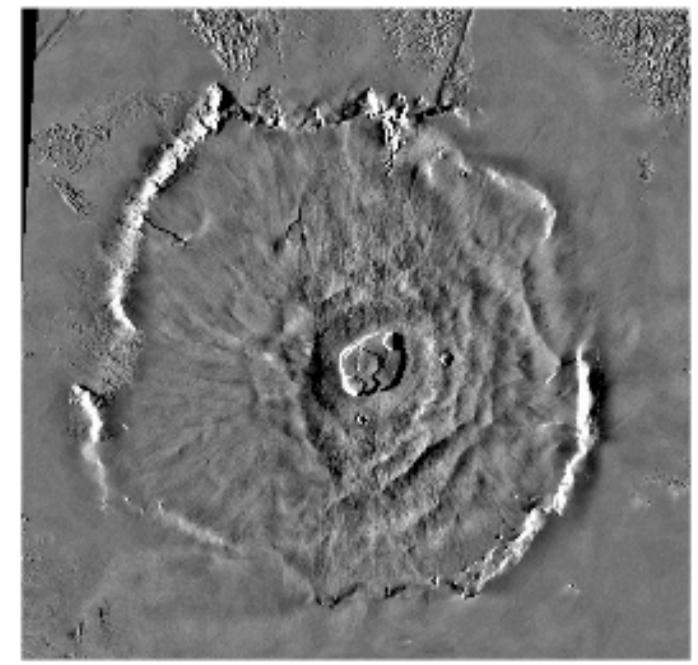
Types of Surface Features: We can break the surface features we see on planets down into four general categories:

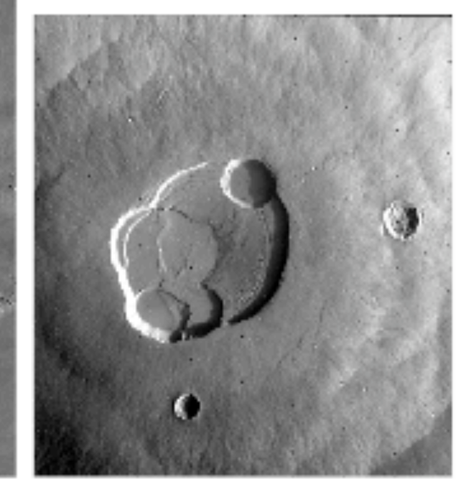
- **Volcanic** (related to igneous processes, and lava flows at the surface)
- **Fluvial/Sedimentary** (related to the movement of water or to weathering and sedimentary processes at the surface)
- **Tectonic** (related to internal geologic processes which move and deform the crust of planets.)
- **Impact** (craters from asteroids and meteors – happens to all worlds)

- **Volcanic Features** tell us that the planet has/had a molten, active interior like the Earth:
- **Fluvial/Sedimentary Features** point to the presence of water (IMPORTANT!) and Earth-like surficial processes;
- **Tectonic Features,** like volcanoes, suggest a melted, active interior, but take it further – the interior must be hot enough to flow, so that **Convection** within the planet can move and deform the crust, which means it is very much like Earth, indeed!

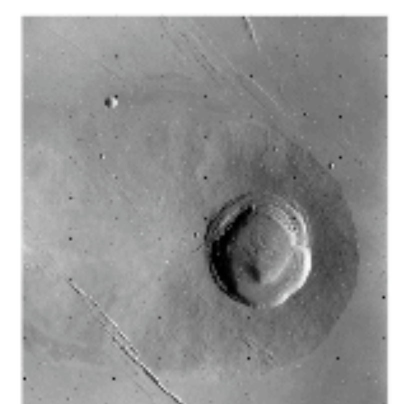
Volcanic features come in a variety of forms:

Shield Volcanoes: Large, broad volcanoes, not unlike Mauna Loa volcano in Hawaii. Olympus Mons (below), the biggest of these, is on Mars. All Shield volcanoes have some sort of Summit Caldera – a collapse crater that once contained a lava lake. A close-up of the caldera is to the right, showing the difference between a volcanic collapse crater and Impact Craters (on the flanks, with raised rims). Note that the edges of Olympus Mons almost look like canyons – what is happening is that the crust beneath this huge (32 km tall!) volcano is sagging, and the edges of the volcanic pile are collapsing via landslides, making cliffs.



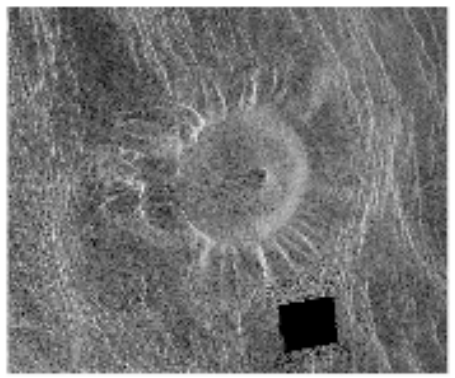


Other Volcanoes:



Pateras: Smaller, steeper edifices, but similar to shields

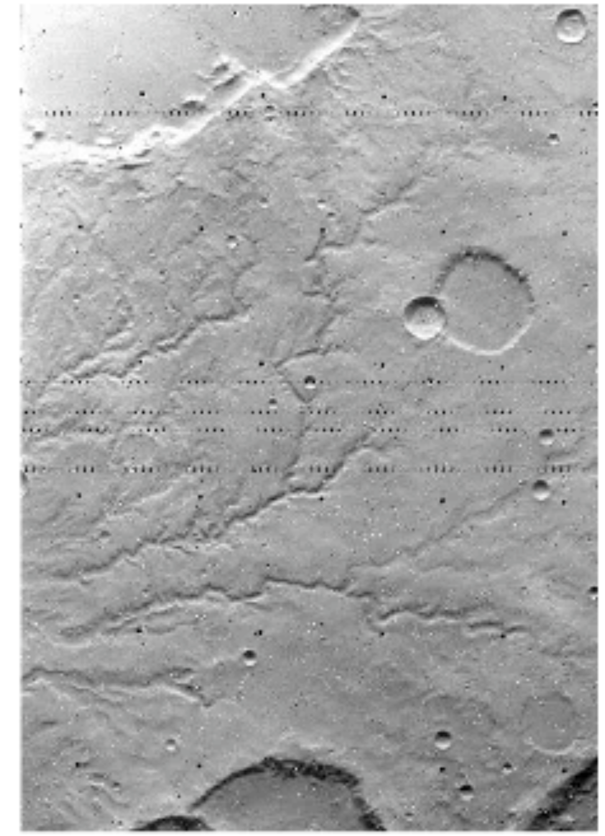
"Pancake" domes. Broad, flat edifices. The erupting lavas must be thick and viscous to make them.

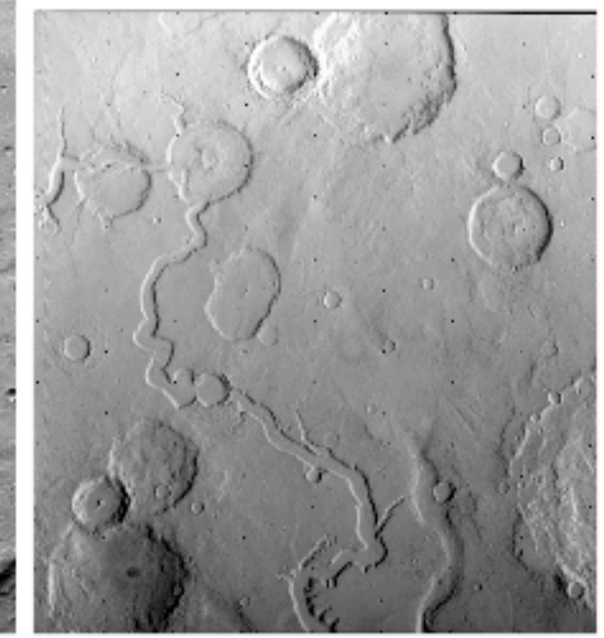


"Ticks" : Domes with radiating fractures due to subsidence of the crust beneath them.

"Strato-volcanoes" (Image is Sapas Mons from Venus). These are taller, and always show a radiating pattern of lava flows away from the summit.

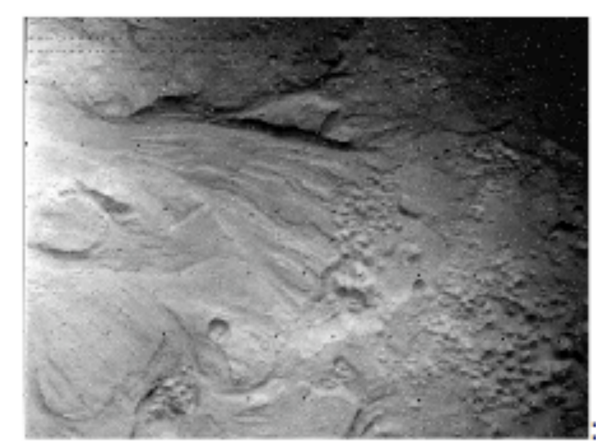
Fluvial and Sedimentary features can relate to water flow, or to land subsidence:





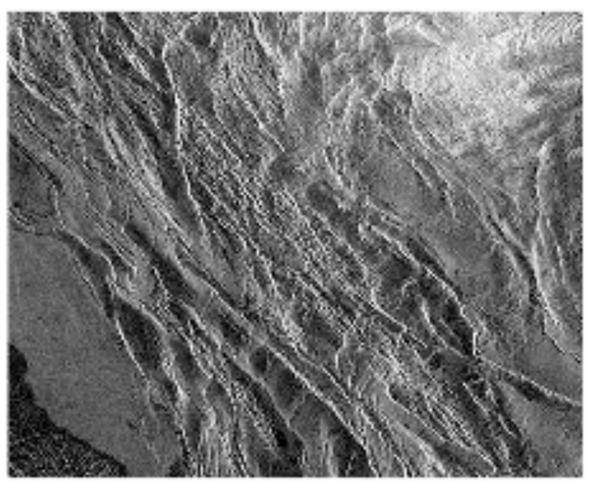
Fluvial Features can be **dendritic drainage patterns** (above, left) or **meandering channels** (above, right) – both of them indicate flowing water at the surface at some time in the past.

Catastrophic water flows (as in sudden floods) produce **Chaos Terrains** (below). We encounter these terrains on Earth in places like Antarctica, where sudden melting glaciers can release large quantities of water.

:

Subsidence Features are related largely to gravity, though the presence of water may facilitate them. **Slumping** (seen above, as higher ground breaks up and slides into valleys on Mars) is perhaps the most obvious in imagery.

Tectonic Features are generally linear and suggest a crumpling of the crust. Basically, these are mountains on other worlds!



An image of tectonized crust from Venus, part of the Venusian highlands.

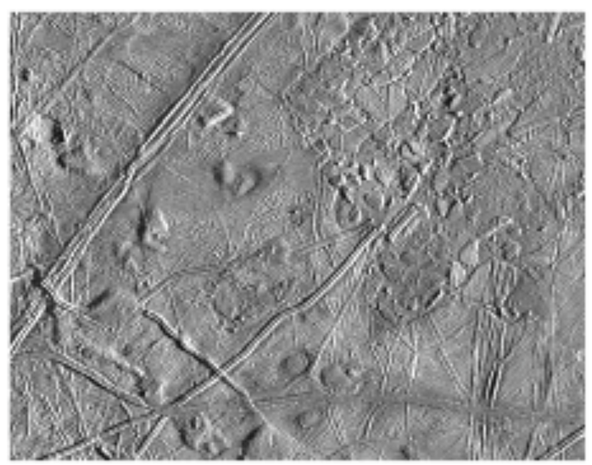
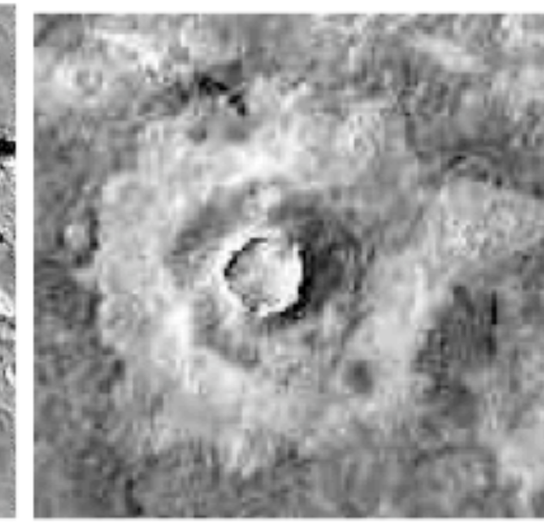


Image from Jovian moon Europa Europa's surface is essentially ice, so The ridges represent colliding ice sheets pushed together by convecting water below.

Craters are impact structures. **Simple craters** are small and have rounded bottoms, while **Complex Craters** are larger and show a raised central peak (below, left). If there is water in the crust, the Debris field around the crater will have a distinctive "splash-like" appearance (below, right). Contrast these with volcanic calderas above.



Please work in groups (as our materials are limited) but write your own individual answers!

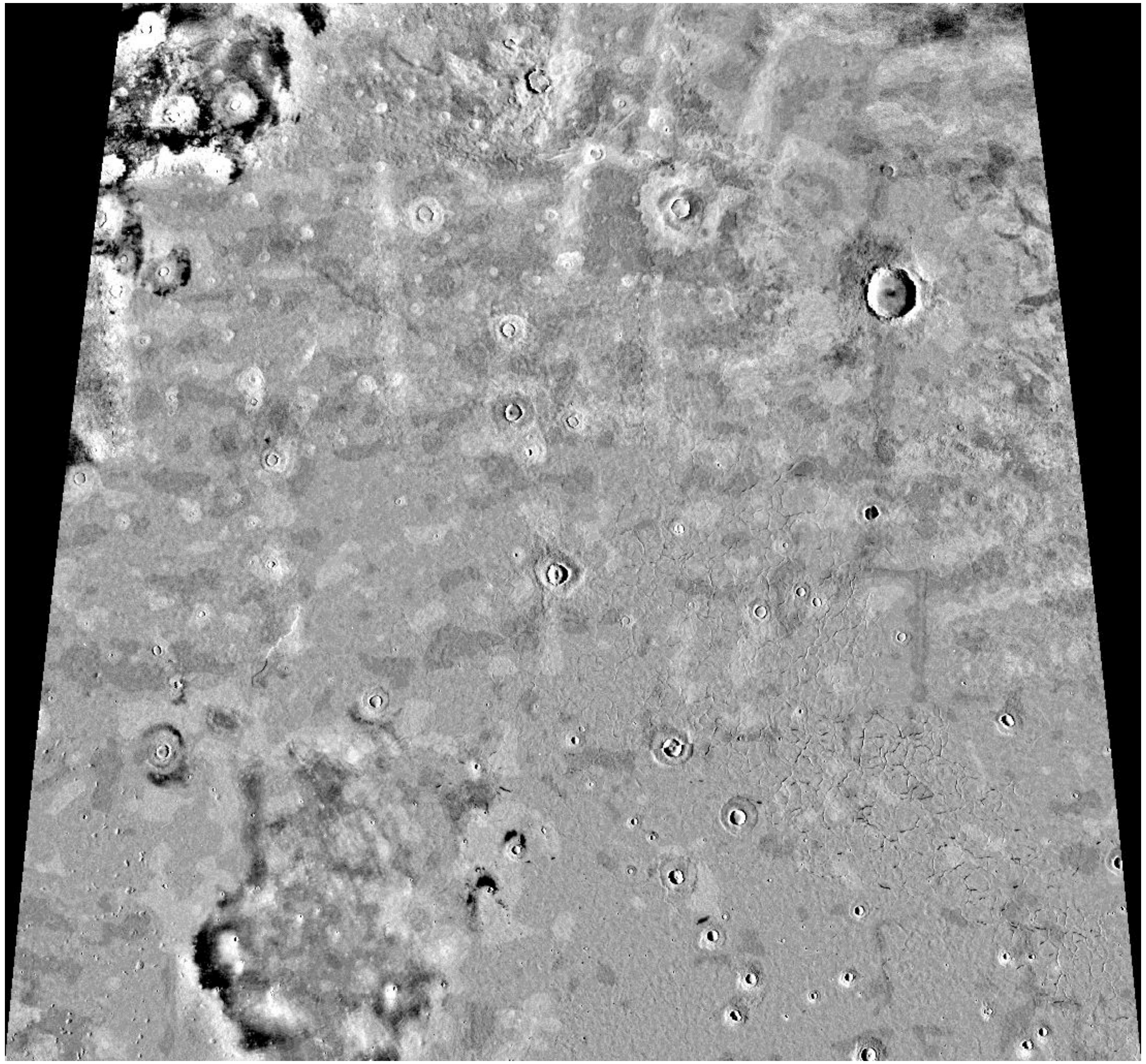
1) You have been provided with a set of black-and white pictures of Mars. Look at these pictures carefully, and make a record of the Volcanic, Fluvial/Sedimentary, and Tectonic features that you see. Use the images above as a guide for your looking (Note: don't try to name everything, but if it looks similar to the features shown above, jot that down. You may have a variety of features of different origins in each picture).

2) Now, compare notes with your classmates, and draw up a general list of Mars landforms and their relative abundances (assume that your pictures are a representative sample of the planet's surface!) What classes of features occur, and which are more common?

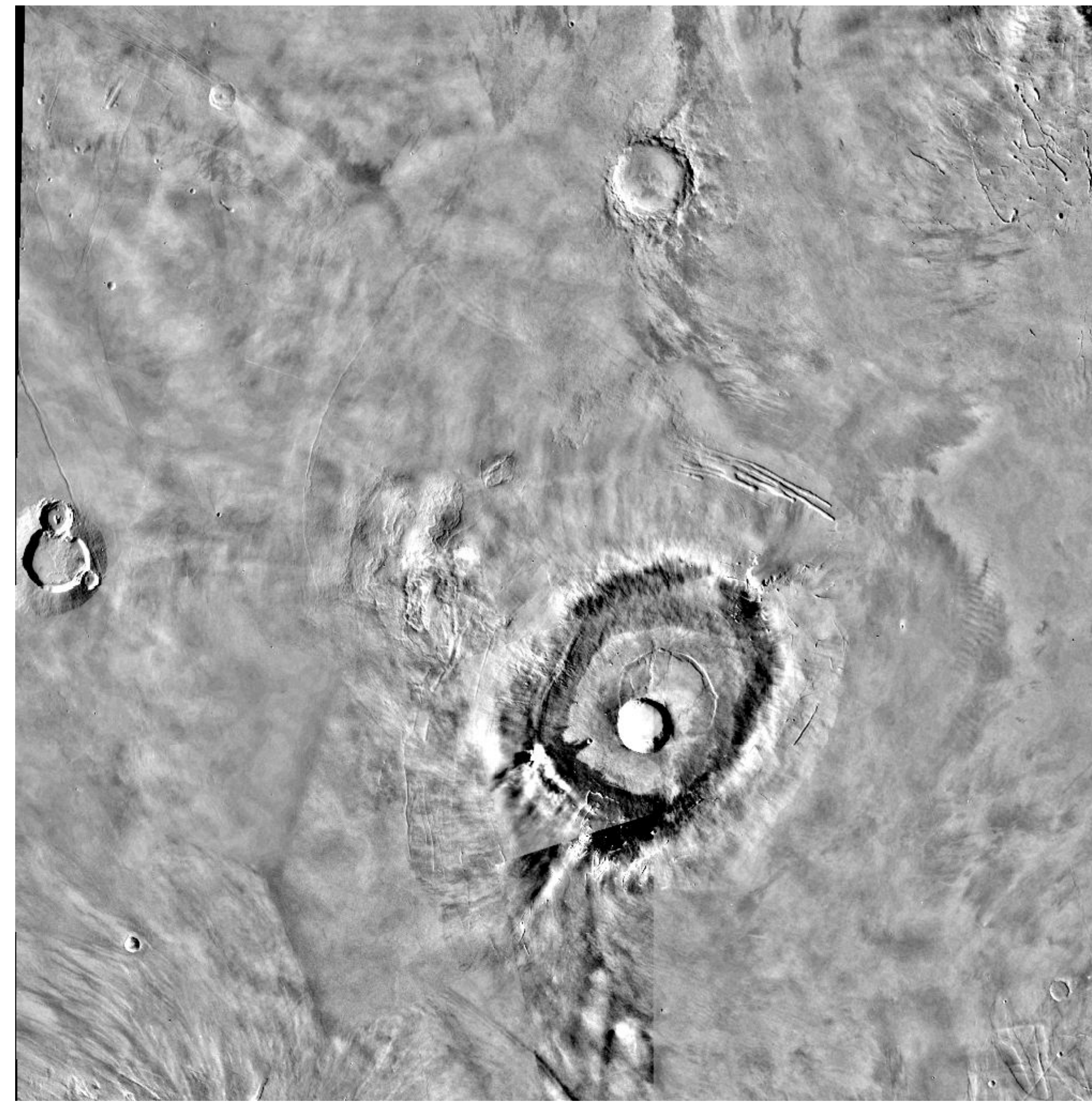
3) Now, from your own knowledge, compare Mars to the Earth. Of the classes of features listed here, which ones do we find on Earth? Are there features on Earth that don't occur on Mars, or vica versa?

4) What could the differences you found in Question 3 mean about the comparative geological histories of Earth and Mars?

Examples of Images



“Splash” cratering in the Martian Northern Lowlands. Viking image from Mars Clickable Map (http://pdsmaps.wr.usgs.gov/PDS/public/explorer/html/marslvls.htm)



Tharsis Mons and nearby features. Viking image from Mars Clickable Map

Limitations and Challenges

In GLY 4045 we conducted two classroom landforms activities involving Mars, using imagery collected during the Viking missions drawn from the Mars Clickable Map, and like sources. (http://pdsmaps.wr.usgs.gov/PDS/public/explorer/html/marslvls.htm)

In the first I provided ten representative images of the surfaces of Mars, the Moon, and Venus, all scaled similarly, and had students assess the relative ages of these planets' surfaces based on crater densities. The second activity, which included an out of class preparatory assignment and in-class work, focused entirely on Mars: students were to seek images of the Martian surface on their own via NASA and other sources and bring them to class to compare with sets of images I provided, and to document the different classes of geologic features (volcanic, sedimentary or tectonic) they observed.

While the first activity generally worked well, the second, Mars-focused exercise was more challenging. Students consistently had difficulties obtaining images of reasonable scale and resolution, in large part because the available image resources were not particularly user-friendly. A second difficulty related to getting students familiarized with what a volcano or a fault might look like from far above a planet. A big obstacle here (for me and the students) was a lack of reasonably scaled and accessible images of the Earth's land surface, to provide a basis for comparison.

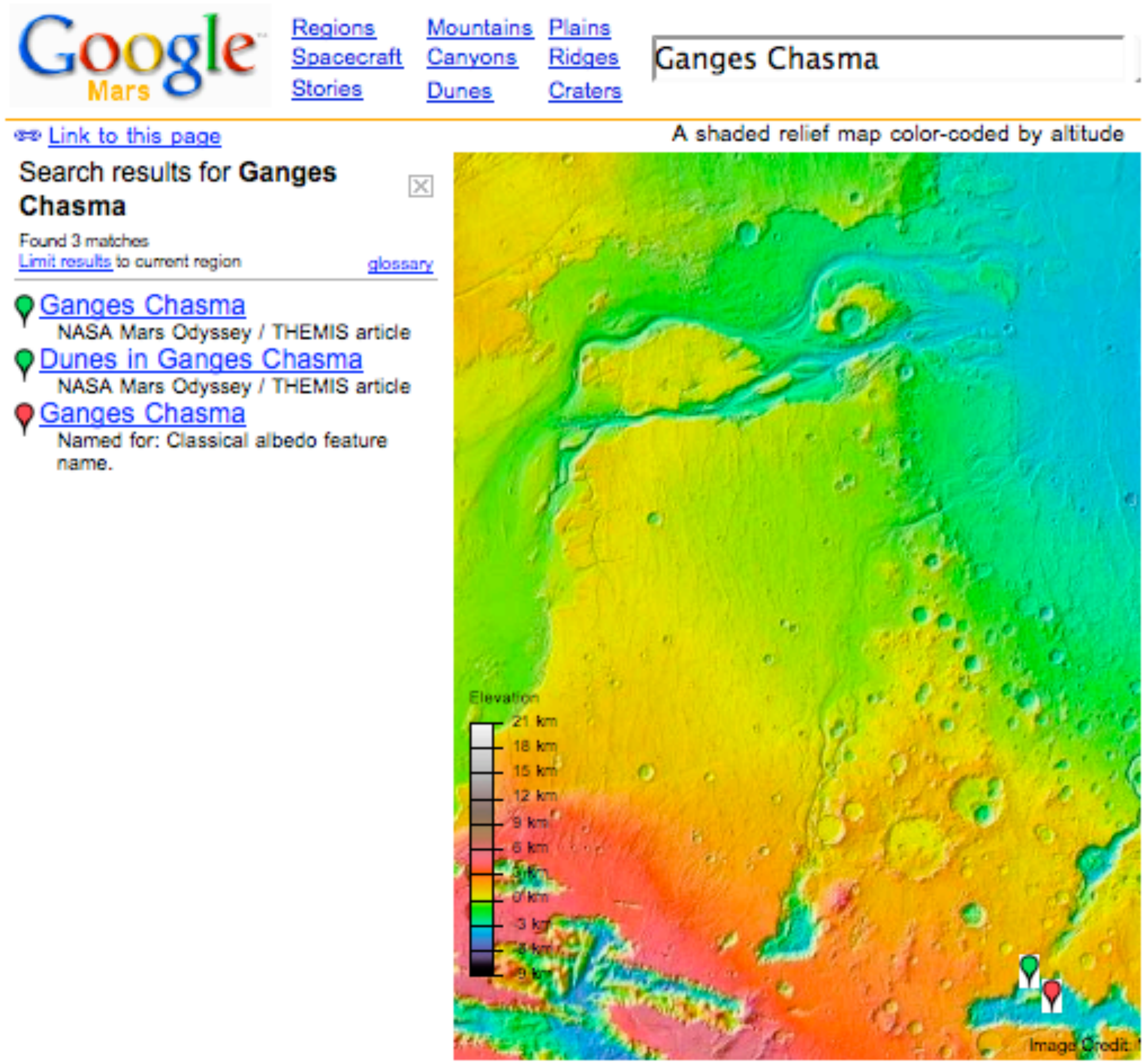
New Resources: THEMIS, JMARS, and Google Earth/Mars

The success of the MGS, Mars Odyssey and MER missions has not only made available a wealth of public domain image data for the surface of Mars, but it has led to the development of a number of powerful image compilation and search tools. The JMARS public portal, developed by ASU, permits one to examine particular map data types from all Mars missions (through Mars Global Surveyor) for a region, or to overlay them to identify unique features. As well, one can easily choose from a range of image scales to examine a large region of the planet, or to focus in on very small features. The THEMIS data portal allows one to look at the high resolution image strips collected by THEMIS overlain on a MOLA or MOC image base for context.

Google, Inc. has developed two new and easy-to-use products: Google Earth (based on composite high-altitude image resources for Earth) and Google Mars (based on the compiled image resources for Mars primarily from Mars Odyssey). Both of these systems are very easily searchable and scaleable, permitting users to look at large scale features, and/or rapidly focus in on smaller scale landforms.

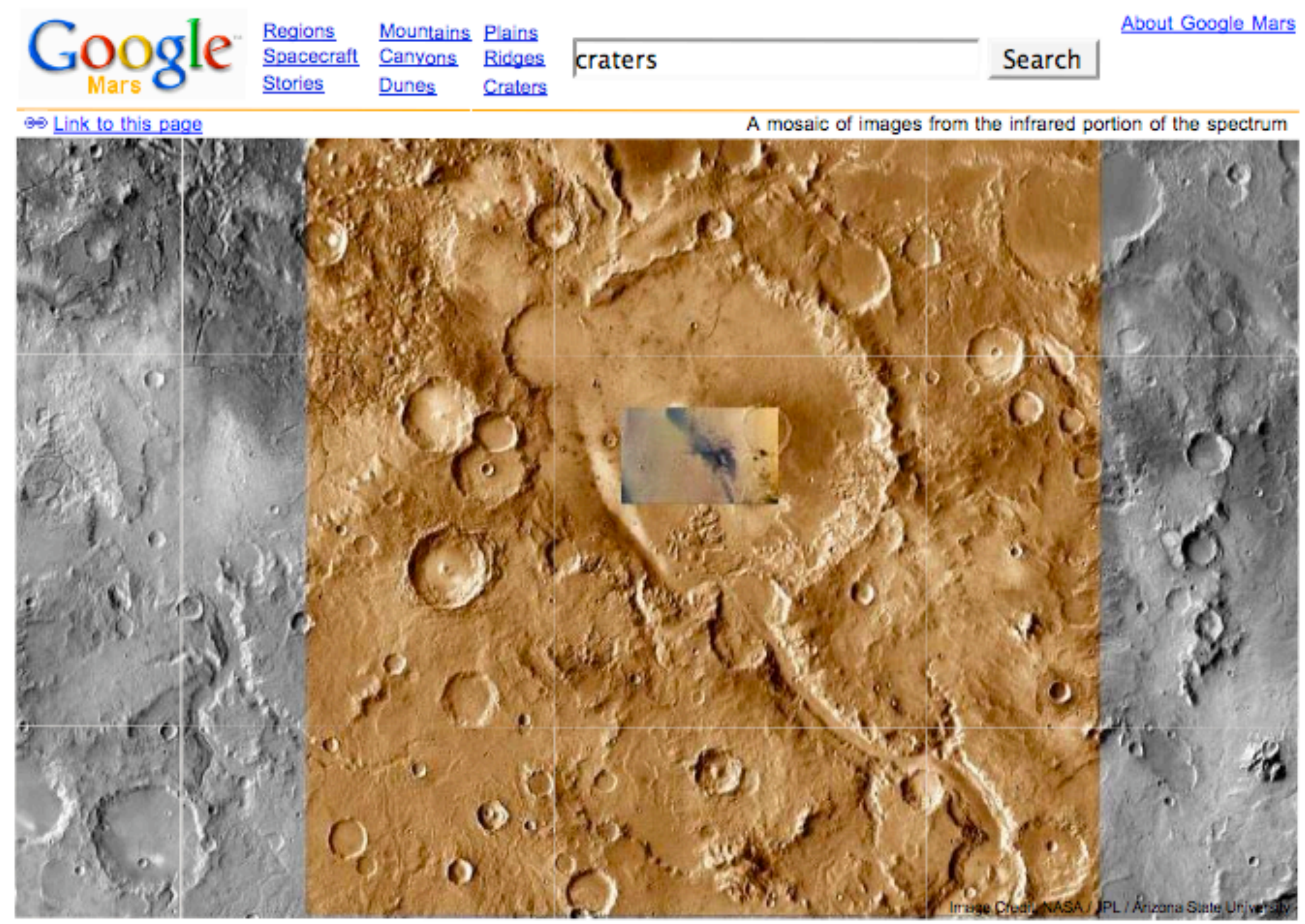
The availability of these new, readily searchable and scaleable geospatial resources permits the development of image analysis activities that are both more in-depth and more investigative in character.

Google Mars

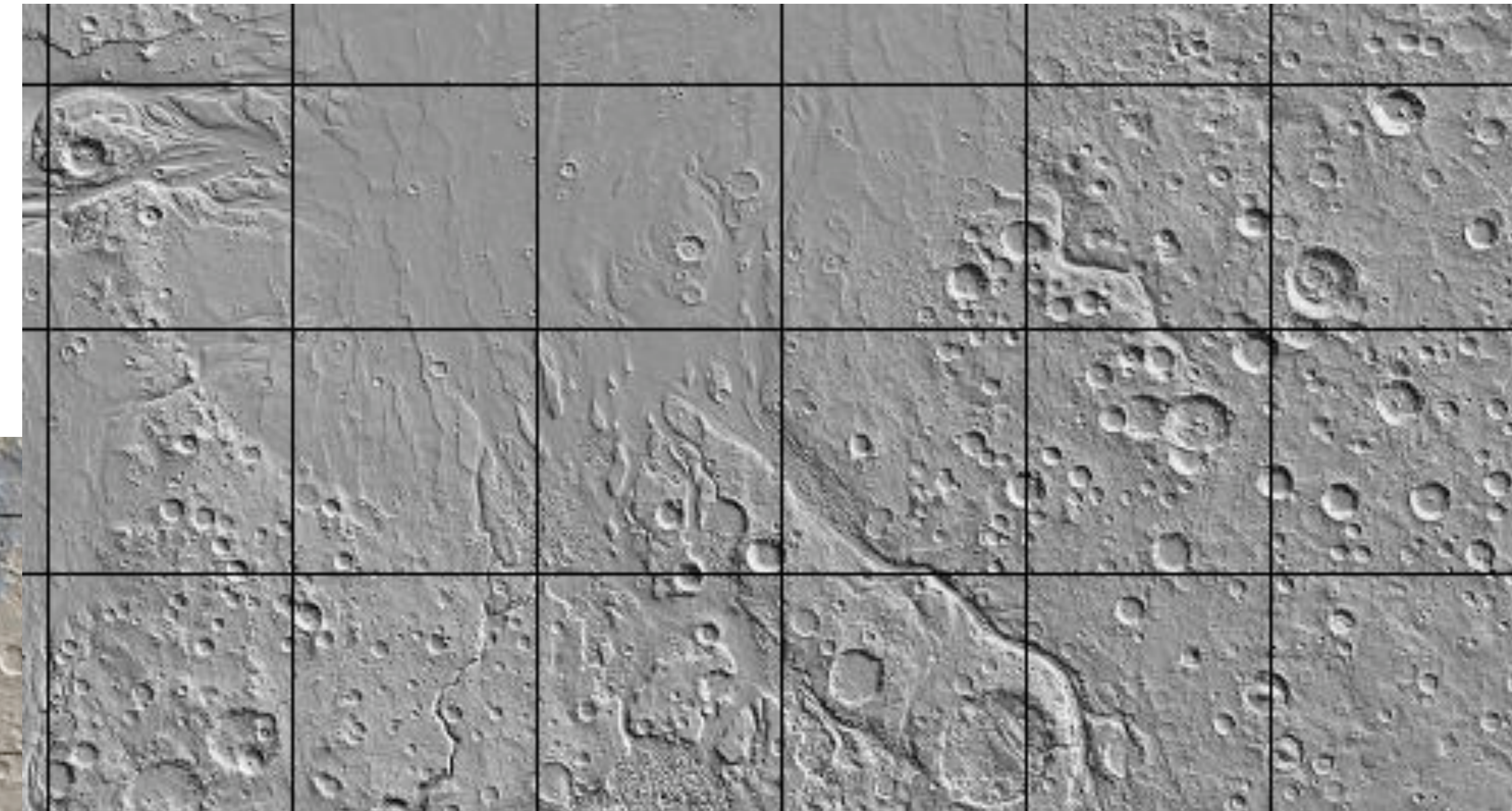


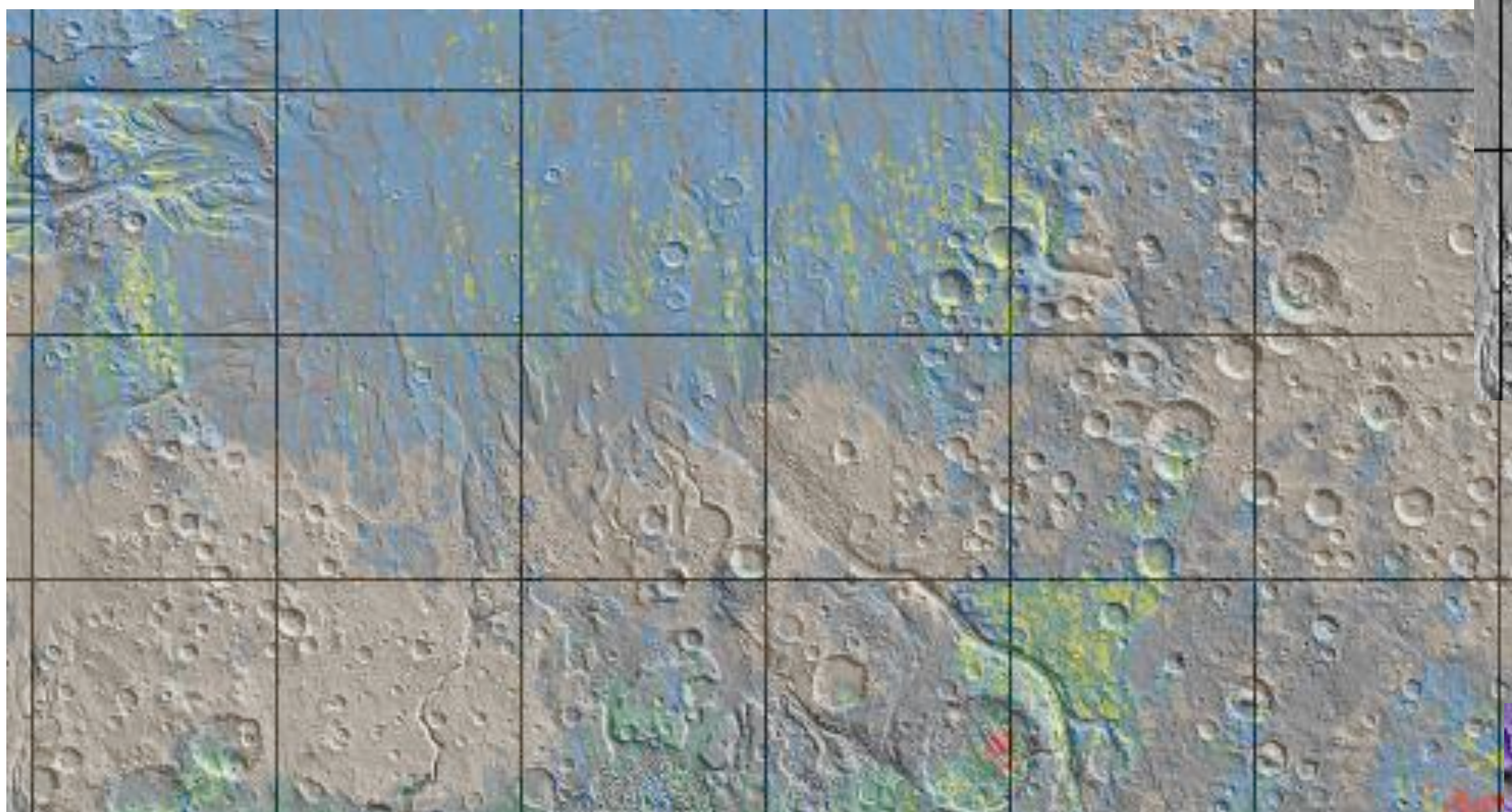
Drainages north of Ganges Chasma, MOLA altimetry data, color-coded

Gusev Crater and environs, False-color MGS infrared imagery (overlain on MOC photography?)



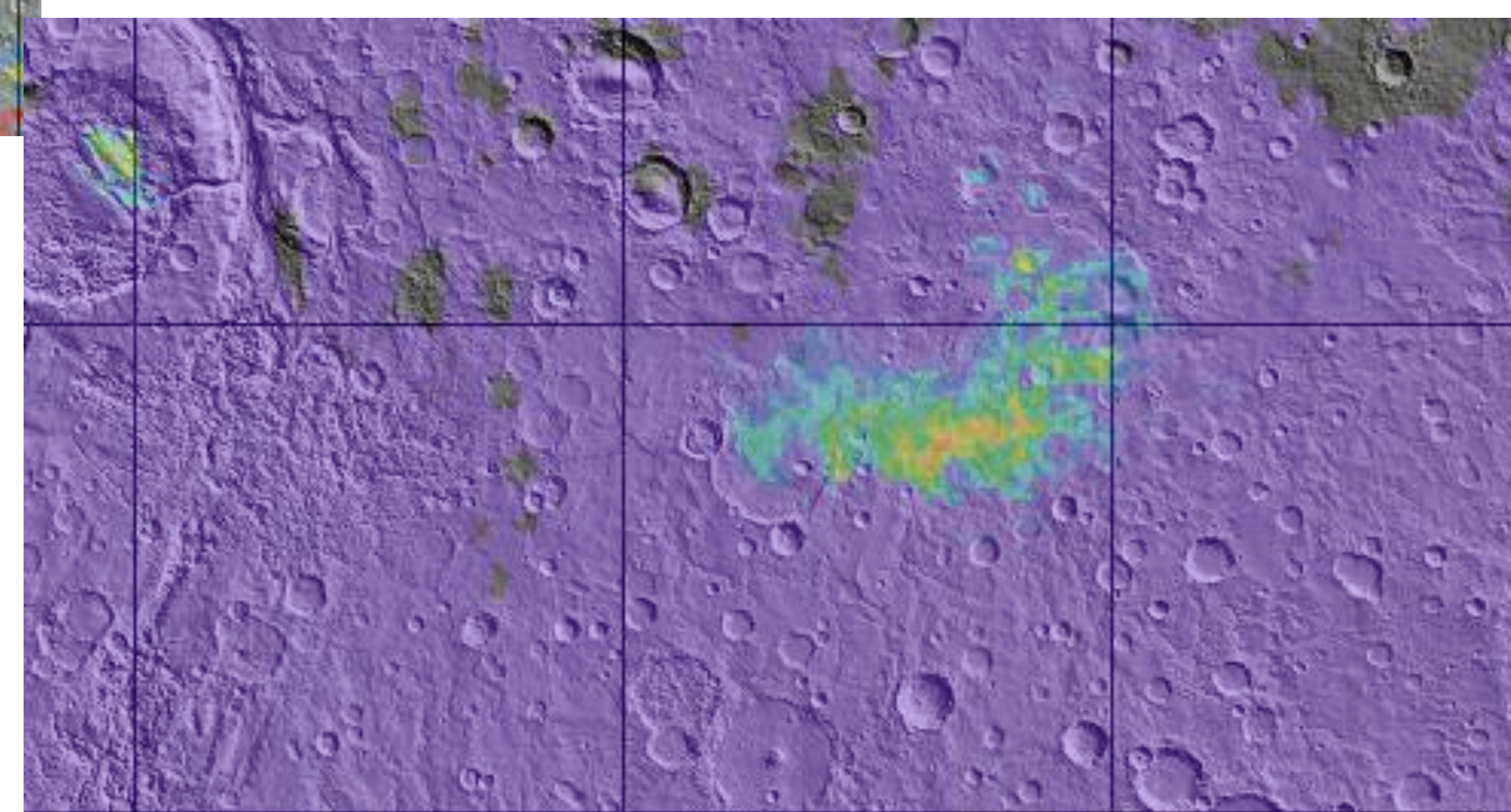
a) MOLA graphical elevation and lat/long of area centered on 16.625N lat, 330 E long.





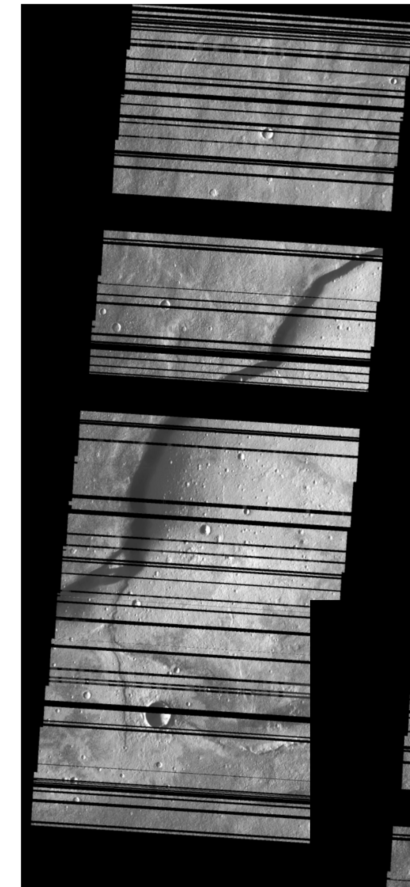
b) Geologic color overlay on a)

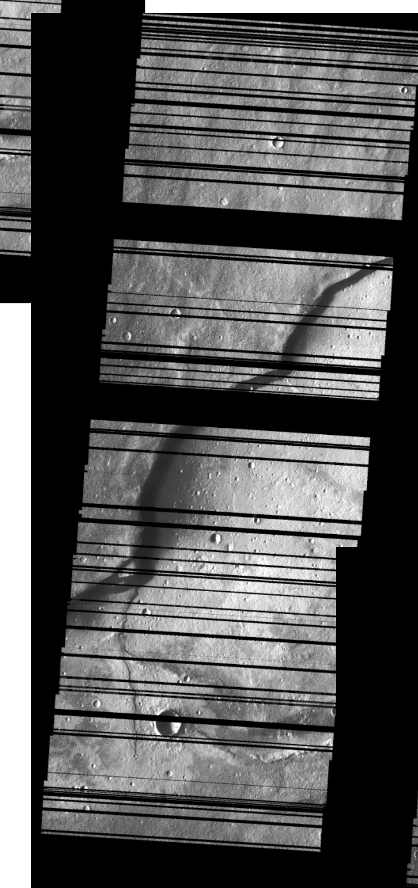
c) 16x overlay of MOLA elevation and hematite abundance for Meridiani Planum region

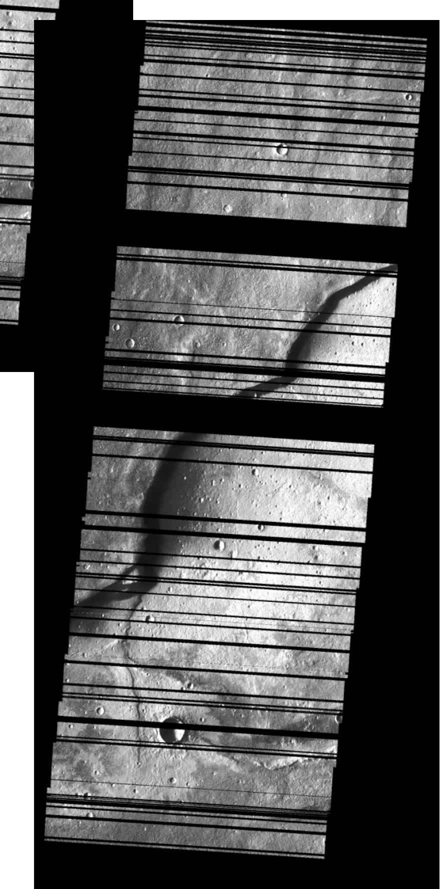


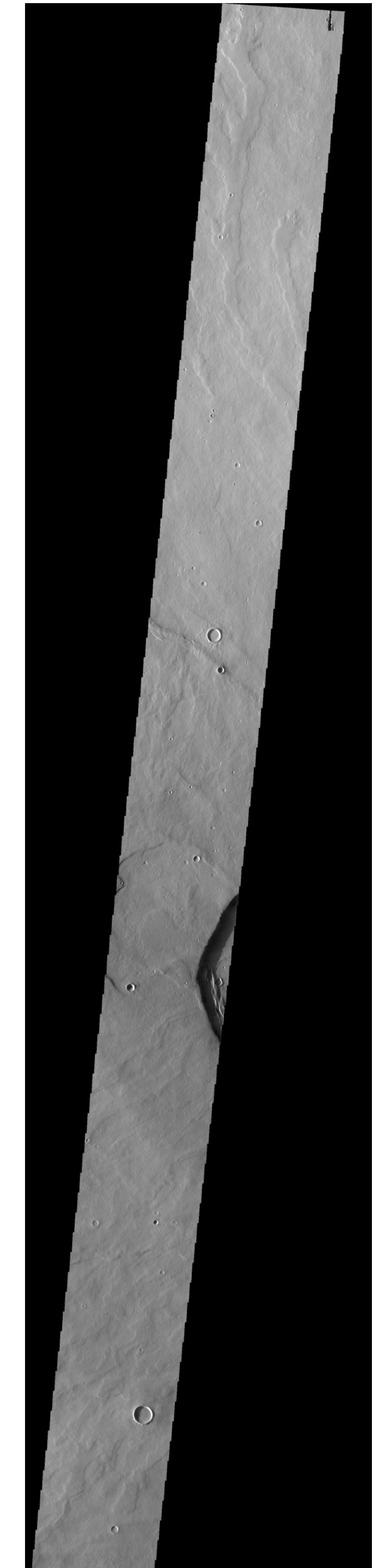
JMARS

www.themis.asu.edu





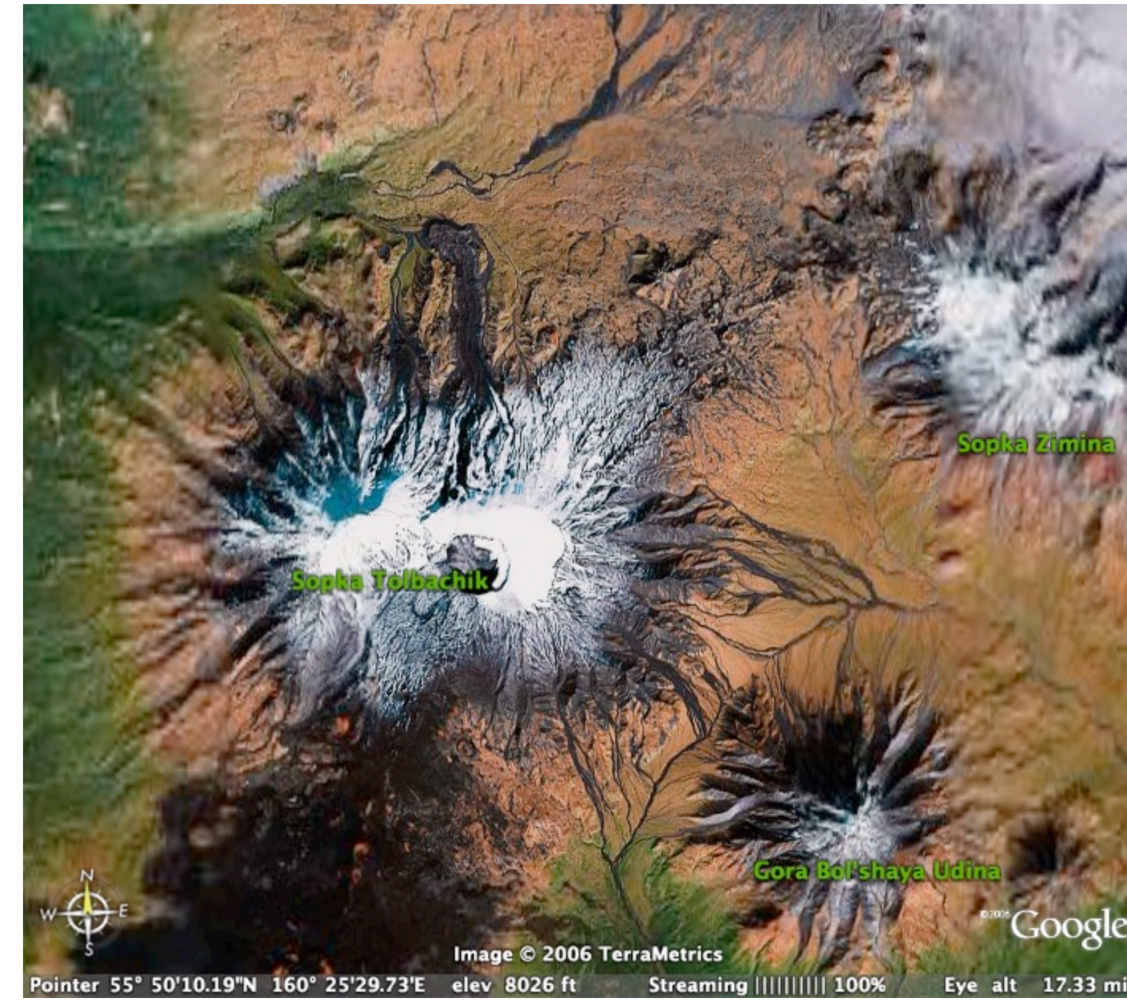


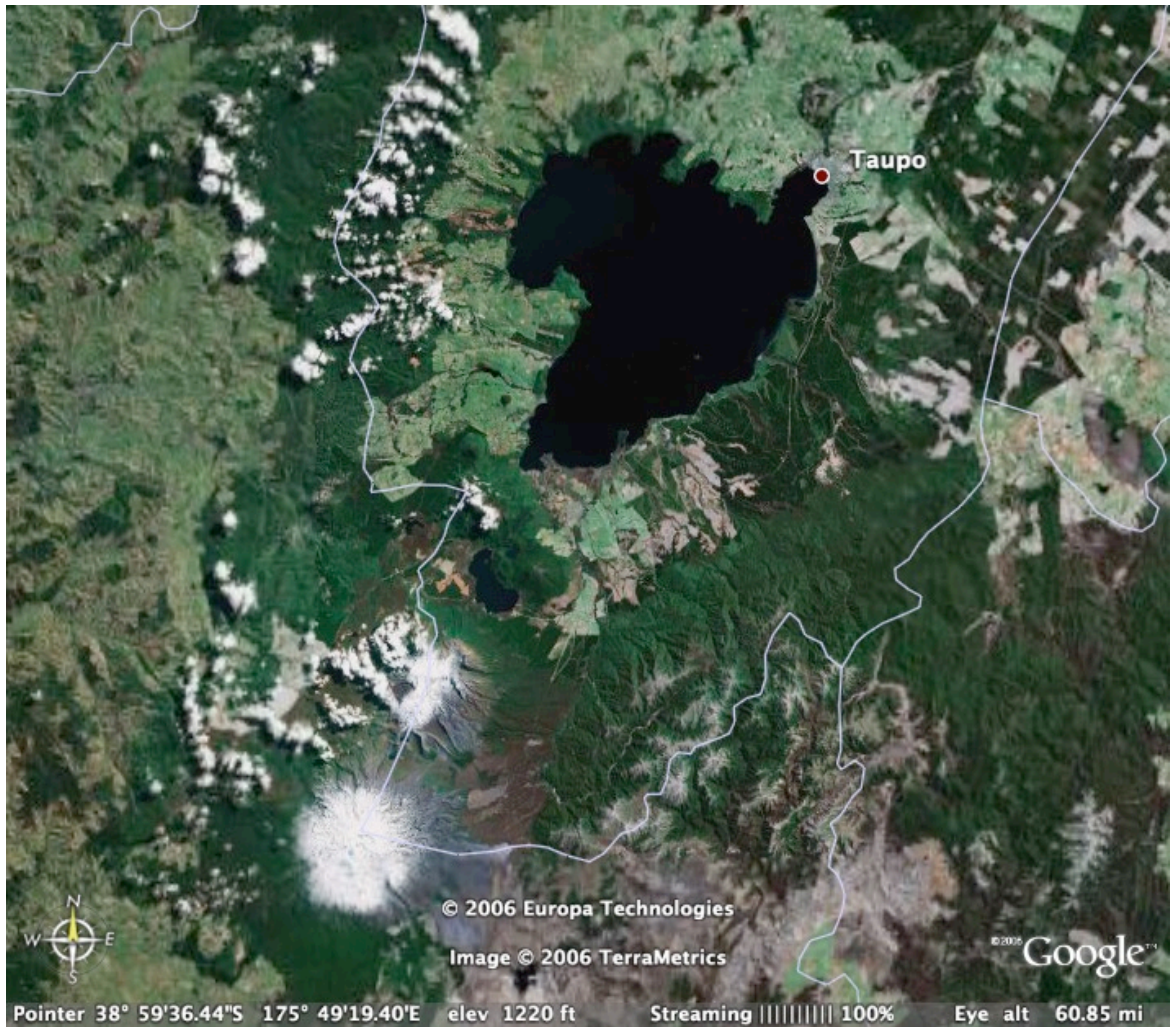


Themis image strips across the summit of Alba Patera, showing both lava flow and subsidence (caldera collapse?) features.

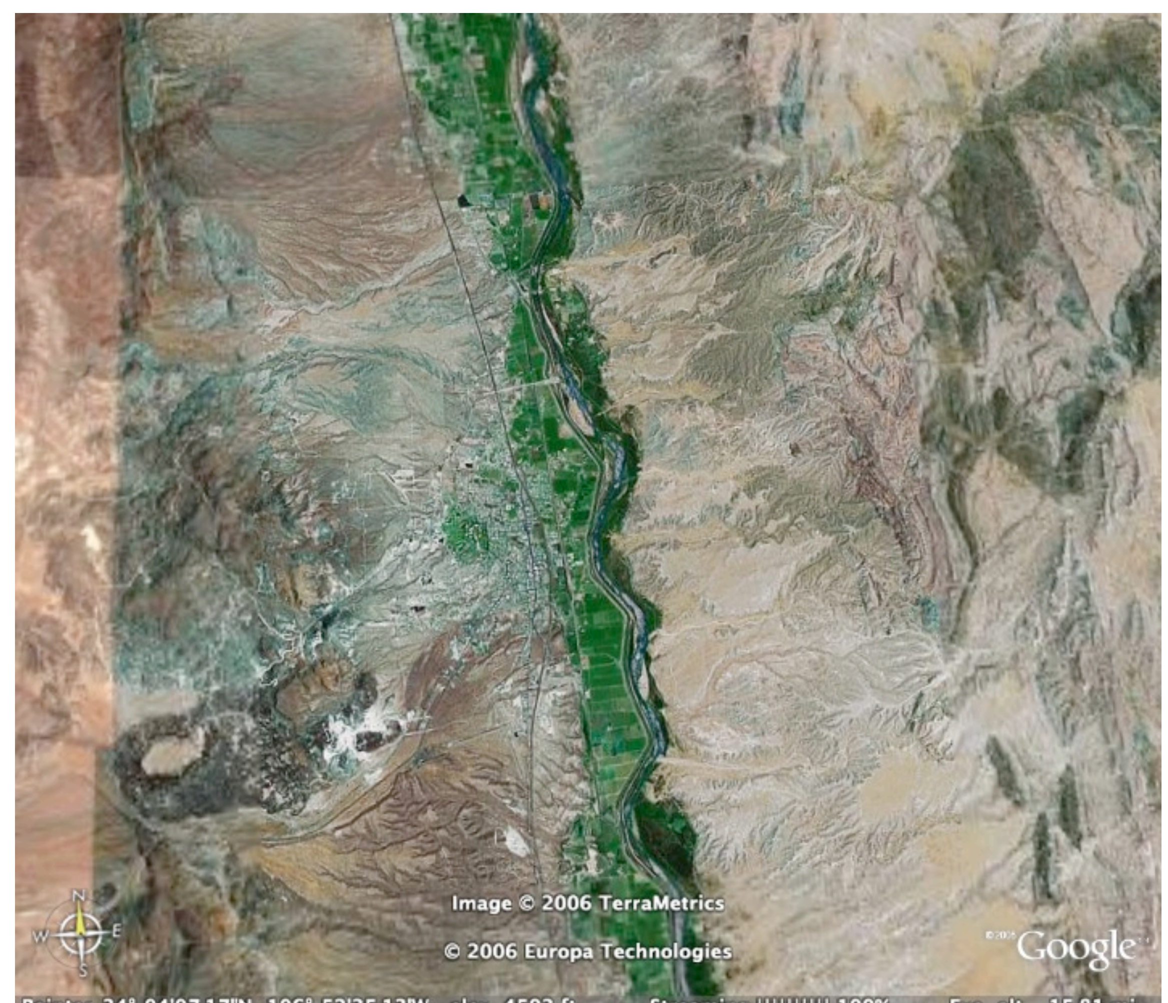
Google Earth

Tolbachik volcano, and nearby stratocones, Kamchatka peninsula





Lake Taupo, and the volcanoes of Tongariro National Park, New Zealand



Rio Grande basin near Socorro, New Mexico, showing the nearby Cenozoic igneous complex (to the right)

Volcanic Edifices on the Earth and on Mars.

Requirements:
Register and upload Google Earth onto your computer (it's both PC and Mac compatible now!)
Google Mars (http://www.google.com/mars/)
Mars Odyssey Mission Themis webpages (http://themis.asu.edu)
The objectives of this activity are:
a) To familiarize you with the geospatial data resources available for examining the features of Earth and Mars.
b) To ascertain (to a first order) the variety of volcanic structures and features on each planet, as a means of making inferences about the nature of their volcanic activity.

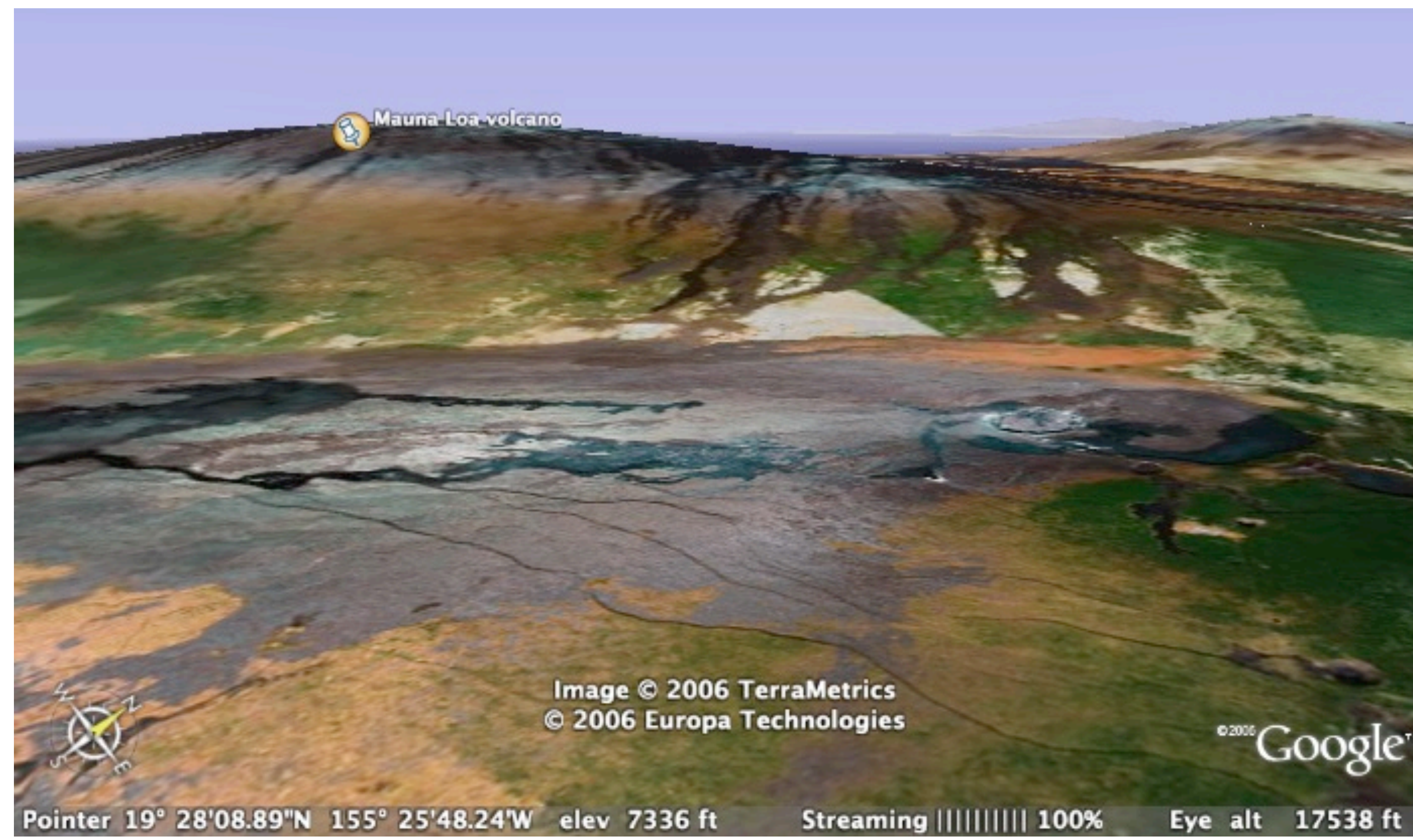
A) Using Google Earth, search for Mauna Loa Volcano, an example of a **Shield Volcano**. Scale the image so that you can not only see Mauna Loa, but the other major mountains on the island of Hawaii.
1) What features of the volcano can you identify? [A: lava flows emanating from summit and rift zones, large summit caldera, smaller volcanic vents along rift zones]
2) What are the other mountains on Hawaii island called, what are they, and how are they related to Mauna Loa? [A: Haleakala, Mauna Kea +/- Kohala and Kilauea. All are active or dormant volcanoes, based on presence of lava flows and volcanic vents. Mauna Loa appears to be burying some of the other mountains, and is the biggest of them by far.]
3) How is Mauna Loa built? The shape of a shield volcano is often described as a "warrior's shield laid on the ground." Is this an accurate description of Mauna Loa's shape? Of the shape of the other volcanic mountains on the island? Take a look at this using the Adjust Tilt bar. [A: not really – there is a linearity to Mauna Loa's structure related to rift zone eruptions – if it's like a shield, it's a tall, narrow one. Kilauea and Haleakala show a similar linear structure of vents and eruptives – Mauna Kea is more circular in its dimensions].
4) What is the overall slope gradient of Mauna Loa? You can figure this out by reading the elevation from the summit (using the hand cursor – the land elevation reads along the bottom of the page for the spot where the cursor lies) and dividing by the distance (in feet) to the sea (using the Measure tool, trace a line from the summit to the sea in any direction where Mauna Loa lavas flow directly to the sea, and read the answer in feet. The slope grade is the change in elevation/distance*100%). [A: about a 7% gradient, like a highway in the mountains]

OK – now that you have some basics on Earth, lets take a look at Mars:

B) Using Google Mars, call up the Digital Elevation colored relief map of the planet. Also, check out the Infrared and Visible imagery.

Example of an, inquiry-based image analysis exercise:

The activity presented here is a very basic example of the kinds of exercises that might be effective in a course such as GLY 4045. It is designed to work either as a homework activity followed by class discussion, or as a purely Web-based exercise, with virtual feedback.



1) Are there any features that look like Shield Volcanoes? If so, identify them. [A: There are four for sure, and several smaller ones that may be ID'ed.]
2) What is your rationale for identifying these as Shield Volcanoes – what properties or features are you using? [A: something about flat-bottomed calderas, and an obvious volcanic edifice]
3) What distinguishes a Volcanic Caldera from a large Impact Crater, when looking at Mars? [A: no rebound peak in center, no roughened area marking a debris field, and/or no "splash" features of crater ejecta.]
4) Do the large Shield Volcanoes on Mars look like Mauna Loa? How are they similar or different, and why, do you think? [Both have relatively low slopes, but the Martian ones have no linear features (rift zones, or chains of secondary craters). Tectonics of Martian volcanism, whatever they are, don't lead to linear fracturing of the crust.]
5) How do Lava flows compare on Mars and Earth? Using the Themis web resource, select some multispectral image strips from across the larger Tharsis volcanoes, examining them for flow features. Compare your observations with the lava flows visible on Mauna Loa and Kilauea on Hawaii.

C) OK – back to Google Earth. Seek out **Umnak Island in the Aleutians**, and look at its volcanic features aerially, and in the profile view. Umnak consists of two parts, one of which includes the Stratovolcano Mt. Vsveidof (and the eroded stratovolcano Mt. Recheshnoi), and the other includes the Okmok Caldera, a large volcanic collapse crater.

1) How do Stratovolcanoes differ from Shield Volcanoes? [A: much steeper slopes, conical shapes, small summit craters]
2) Are there any volcanoes on Mars which might be called Stratovolcanoes? (take a look!) [Hopefully they say no!]
3) Describe the salient features of the Okmok Caldera – its topographic profile, the presence of smaller secondary cones, its shape. Based on these features, are there any volcanic edifices on Mars which show similarities to Okmok volcano? [low profile, secondary cones in crater, circular; Maybe Alba Patera and other such paterae on Mars?]