Lab 6: Introduction to Photogeologic mapping

Purpose

Over the past several weeks we have been looking at how the four main types of geologic processes (volcanism, tectonism, gradation, and impact cratering) affect planetary bodies. This week we will be putting it all together by mapping areas on the surface of Mars. I've picked Mars since it's the only body where all of these processes can be readily studied (most bodies have no fluvial gradation, Earth has few impact craters, etc…Titan potentially has all of these processes, but data is very limited). Next week you can pick your own planetary surface to map.

A note on next week's lab: I will put together a collection of datasets for a variety of planetary bodies. If there is somewhere in particular you are interested in let me know and I will try to include it. Obtaining and projecting data can be a bit complicated, so be sure to give me plenty of notice (i.e. by 2/27).

Introduction

A geologic map is a graphic portrayal of the distribution and sequence of rock types, structural features such as folds and faults, and other geologic information. Such a map allows geologists to represent observations in a form that can be understood by others and links the observations made at different localities into a unified form. It allows one to understand many observations in a comprehensive form.

Step1: Identification of Units and Mode of Formation

The **unit** is the basic component of geologic maps. By definition, it is a three-dimensional body of rock of essentially uniform composition formed during some specified interval of time and that is large enough to be shown on a conventional map. Thus, the making of geologic maps involves subdividing surface and near-surface rocks into different units according to their type and age. On Earth, geologic mapping involves a combination of field work, laboratory studies, and analyses of aerial photographs. In planetary geology, geologic mapping is done primarily by remote sensing methods—commonly interpretation of photographs. Field work is rather costly and not always possible. Mapping units are identified on photographs from **morphology** (the shape of the landforms), **albedo** characteristics (the range of "tone" from light to dark), **color**, **state of surface preservation** (degree of erosion), and other properties. Once units are identified, interpretations of how the unit was formed are made. In planetary geologic mapping the observation and interpretation parts of a unit description are separated (see figure 7.1).

Step 2: Stratigraphic Relation among Units

After identifying the units and interpreting their mode of formation, the next task in preparing a photogeologic map is to determine the stratigraphic (age) relation among all the units. Stratigraphic relations are determined using: (a) the **Principle of Superposition,** (b) the law of cross-cutting relations, (c) embayment, and (d) impact crater distributions. The Principle of Superposition states that rock units are laid down one on top of the other, with the oldest (first formed) on the bottom and the youngest on the top. The law of cross-cutting relations states that for a rock unit to be modified (impacted, faulted, eroded, etc.) it must first exist as a unit. In other words, for a rock unit that is faulted, the rock is older than the faulting event. Embayment states that a unit "flooding into" (embaying) another unit must be younger. On planetary surfaces, impact crater frequency is also used in determining stratigraphic relations. In general, older units show more craters, larger craters, and more degraded (eroded) craters than younger units.

Step 3: Stratigraphic Column and Geologic History

Once the stratigraphic relations have been determined, the units are listed on the map in order from oldest (at the bottom) to youngest (at the top). This is called the stratigraphic column. The final task, and the primary objective in preparing the photogeologic map, is to derive a general geologic history of the region being mapped. The geologic history synthesizes, in written format, the events that formed the surface seen in the photo -- including interpretation of the processes in the formation of rock units and events that have modified the units -- and is presented in chronological order from oldest to youngest.

There is a sample geologic map and stratigraphic column on page 4, including its unit descriptions and stratigraphic column. The relative ages were determined in the following manner: The cratered terrain has more (and larger) craters than the smooth plains unit -- indicating that the cratered terrain unit is older. In addition, fault 1 cuts across the cratered terrain, but does not continue across the smooth plains. Faulting occurred after the formation of the cratered terrain and prior to the formation of the smooth plains -- indicating that the smooth plains unit is younger than the cratered terrain and fault 1. The crater and its ejecta unit occurs on top of the smooth plains unit, and thus is younger. Finally, fault 2 cuts across all the units, including the crater and its ejecta unit, and is thus the youngest event in the region. The geologic history that could be derived from this map would be similar to the following:

> "This region was cratered and then faulted by tectonic activity. After the tectonic activity, a plains unit was emplaced. Cratering continued after the emplacement of the smooth plains unit, as seen by the craters superposed on the smooth plains and the large, young crater mapped as its own unit. Finally, there has been a continuation (or reactivation) of tectonic activity, indicated by the major fault which postdates the young crater."

Procedure

Exercise 1: Mapping of the Moon

1. Create a new folder which you will be saving all of your work to.
2. Open ArcCatalog on your computer and using the file tree on the left side of the screen, locate the folder you created.
3. Right click on your folder name. Go to "New" and choose "Shapefile."
4. Use "Geological_units" as a *name* and choose "polygon" as a *feature type*. Don't worry about the projection for this lab. Click "OK."
5. Repeat the step 3 and 4 and create a new "polyline" shapefile named "Structural_features."
6. Open ArcMap on your computer. Add the two layers you just created above by either clicking on the *yellow triangle with + sign* or by going to "File" and then "add data". Also add the image data, *moon1.tiff*, provided for this lab. You can ignore any warnings you get about projections. This image is about 300 km across and is centered at 4° S, 58° W.
7. Click on the "Editor tool" and from the drop menu, choose "start editing."
8. Using the Geologic Features as your target layer, mark 4 corners in order (either clockwise or counter clockwise direction). Double click on the last one to finish the figure. You should have created a square that is the same size as your image. Choose "no color" for the fill so that you can see the image.
9. Click "cut polygon features" (rectangle with a line through it). Split the square into two regions (mare and highlands) by tracing the contact between the rough highlands and the smooth plains. Make sure to start from and end at outside of the square.
10. Map all the craters by using the "circle" construction tool.

11. Note the long, semi-linear feature near the NE of the image. Can you tell if this is a ridge or a valley? Trace this feature on your map.
12. Note the crack-like features in the crater and to the west of the crater at the SW of the image. These are likely graben caused by tectonic activity. Because this is a linear feature, we will use lines to represent this feature. Change the target layer to “Structural_features” and trace this feature on your map.
13. Save your edits and stop editing. Open the “attribute table” by right clicking on the layer name (*i.e.* Geological_units) and then “open attribute table”. Click on the options and then “add field.” This allows you to add more columns to the table. Type “Processes” as a name and choose “text” as a type with precision of 10. Create another column with the name “unit_type” with precision of 15.
14. Start editing again and fill in the table. For processes, choose one of the four geologic processes (volcanism, tectonism, gradation, impact cratering) responsible for the formation of the feature and label what it is (e.g. crater, highland, mare, fault, etc.) under unit_type. Save and stop editing when the table is complete.
15. Change the color of the features according to their unit_type. You can do this by going to the properties and then click on the “symbology” tab. Click on “categories” and then on “unique values”. Change the “value field” to unit_type and click on “add all values.”

Answer the questions below before moving on to Exercise 2.

1. What is the age relation between the highlands and the smooth plains? (are the smooth plains older or younger than the highlands?) What observations did you use to decide?

2. What is the age relation between the graben and the highlands?

3. What is the relation between the graben and the crater?

4. What is the age relation between the ridge/valley and the smooth plains?

5. Place the geologic units and structural features identified above in their correct sequence in a stratigraphic chart (see the figure on the previous page for an example). List the oldest at the bottom and the youngest at the top.

Exercise 2a: Mapping of Mars

There are two images included of the Memnonia quadrangle, a daytime infrared mosaic from the THEMIS instrument onboard Mars Odyssey (*memnonia-quadrangle-16.tif*), and topography from the Mars Orbital Laser Altimeter onboard the Mars Global Surveyor (*memnonia-quadrangle-16-shade.jpg*). Examine the photomosaic in detail and identify the geologic units based on surface morphology (hilly, flat, etc.), albedo (light, dark), crater density, and other appropriate characteristics. There are at least 4 major geologic units in the region. Draw preliminary contacts around the units. Label the units by name, or letters symbols within each unit. Areas of a unit need not be laterally continuous on the surface. Tabulate the units in the table and describe their main characteristics. Names are of your choice, such as “mountain unit,” “smooth plains”. You should map at least:

- 4 geological units (highland, lava flow, river channel, smooth plains, etc)
- 20 craters
- 4 linear cracks
- 1 channel

Exercise 2b: Regional Geologic History

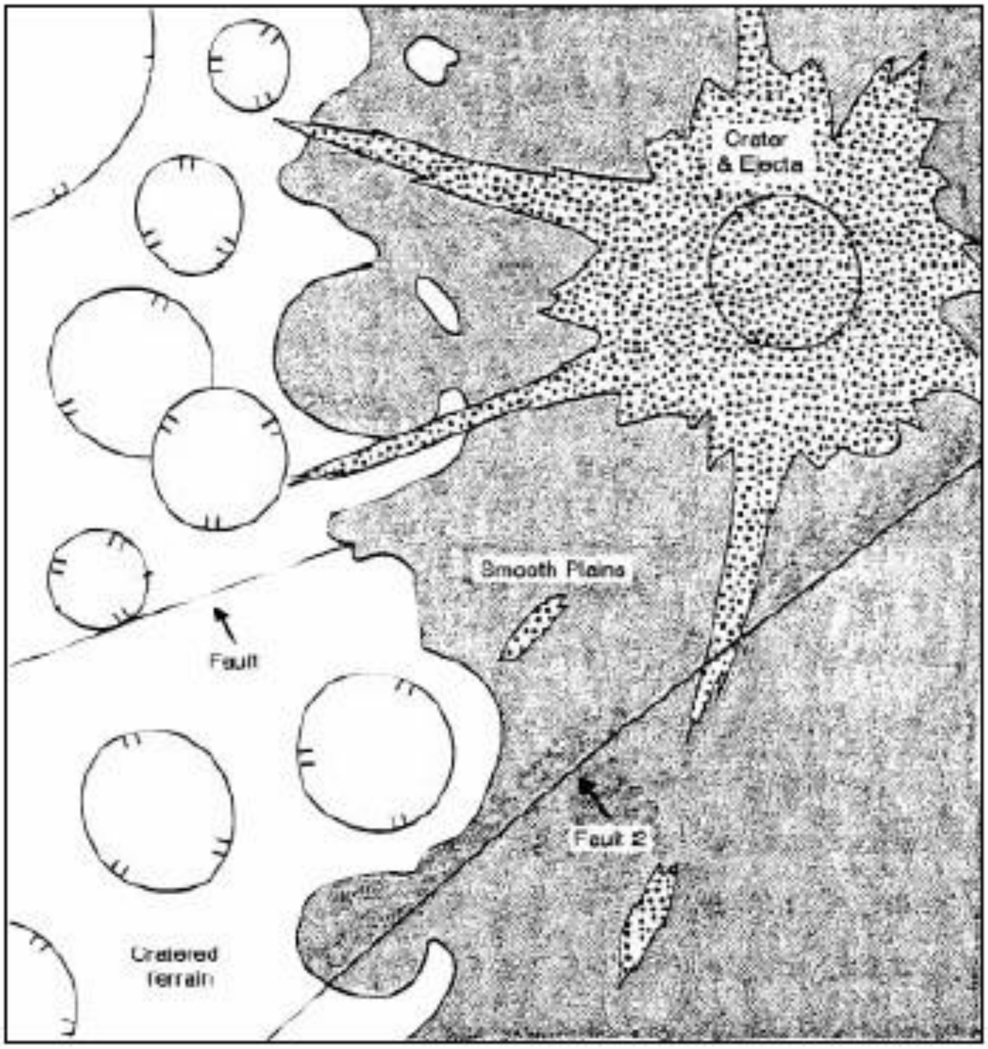
Based on your observations, determine the stratigraphy of your units (the relative order of units from youngest to oldest). List the units in the column "Geologic Unit" in Figure 7.3 in order from youngest at the top to oldest at the bottom. Place structural information in the column "Structural Events." Using the stratigraphic relations and interpretations based on your examination of the photomosaic, derive a geologic history for the Memnonia region. Include this with your abstract for this week.

Exercise 3: Making a Map

All maps must have a title, scale, north arrow, legend, and map information (author, date, data source). To put these in a map using the ArcMap is simple: click on the "View" menu and chose "Layout view". You can choose the orientation from portrait to landscape just like you do with word documents. Click "insert" to add these to your map.

Export the map as a jpeg by clicking File>Export map. Export as a jpeg and name it in the format "[your name]_lab6.jpg, and upload it to Collab.

Mapping Example:



Stratographic Column

	Geologic Unit	Structural Event
Youngest ↑	Crater and Ejecta	Fault 2
	Smooth Plains	
Oldest	Crater Terrain	Fault 1

Unit Descriptions

Unit Name	Observation	Interpretation
Crater and Ejecta	rough, blocky surface, high albedo, surrounds and includes crater	crater and ejecta formed by impact
Smooth Plains	smooth plains, few craters, low albedo, lobate (rounded) margins	volcanic flow
Crater Terrain	rugged, heavily cratered plains, high albedo	old unit, possibly of volcanic origin, has had extensive cratering