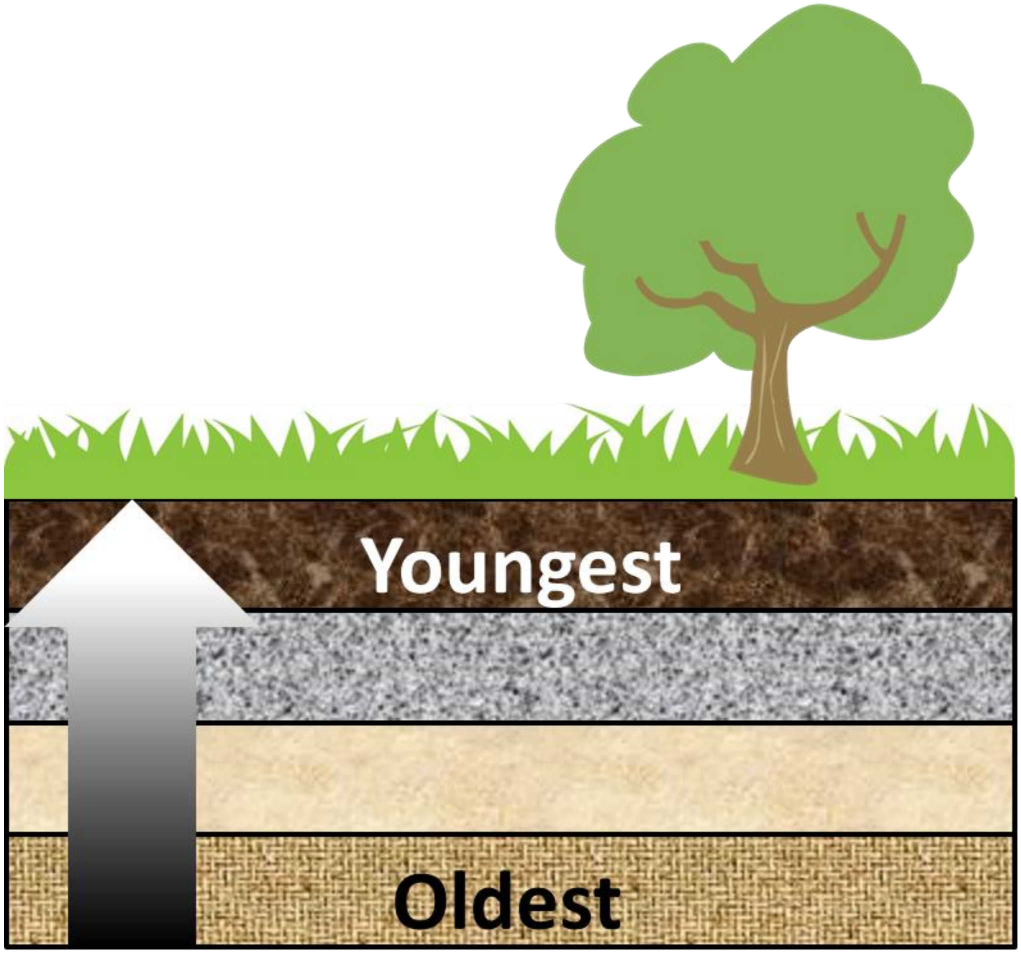
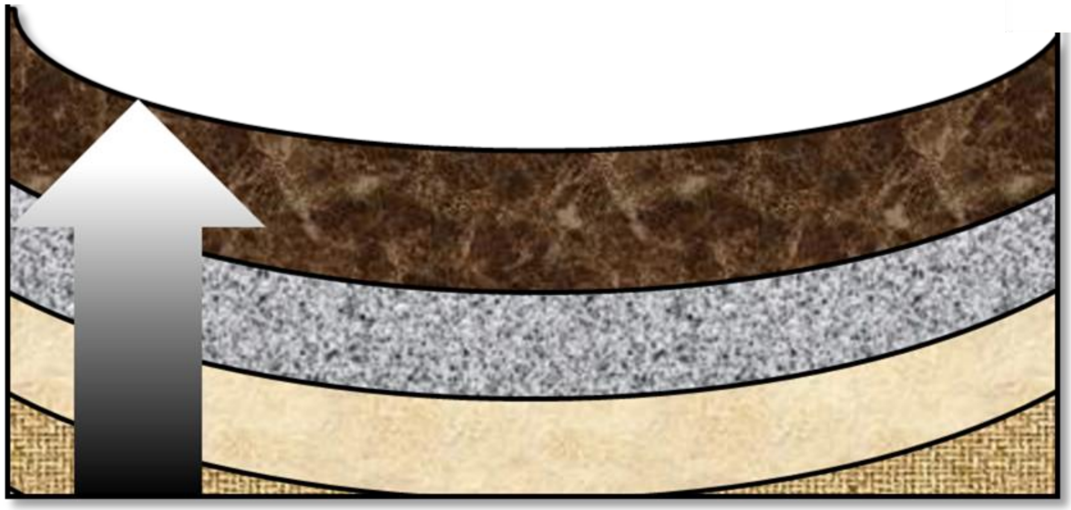
2.2 Stratigraphy- the past, present, and future of a surface and Geological Cross Sections

Geological events need to be put in a time perspective, so that you can reveal the history of a surface. Stratigraphy is the study of the time sequence of geological events on a planetary body, by dating the happened events relative to each other (e.g. first, second, third). Relative dating gives no information about absolute surface ages, so we still do not know when exactly events occurred. To create a relative timescale three main principles need to be kept in mind:

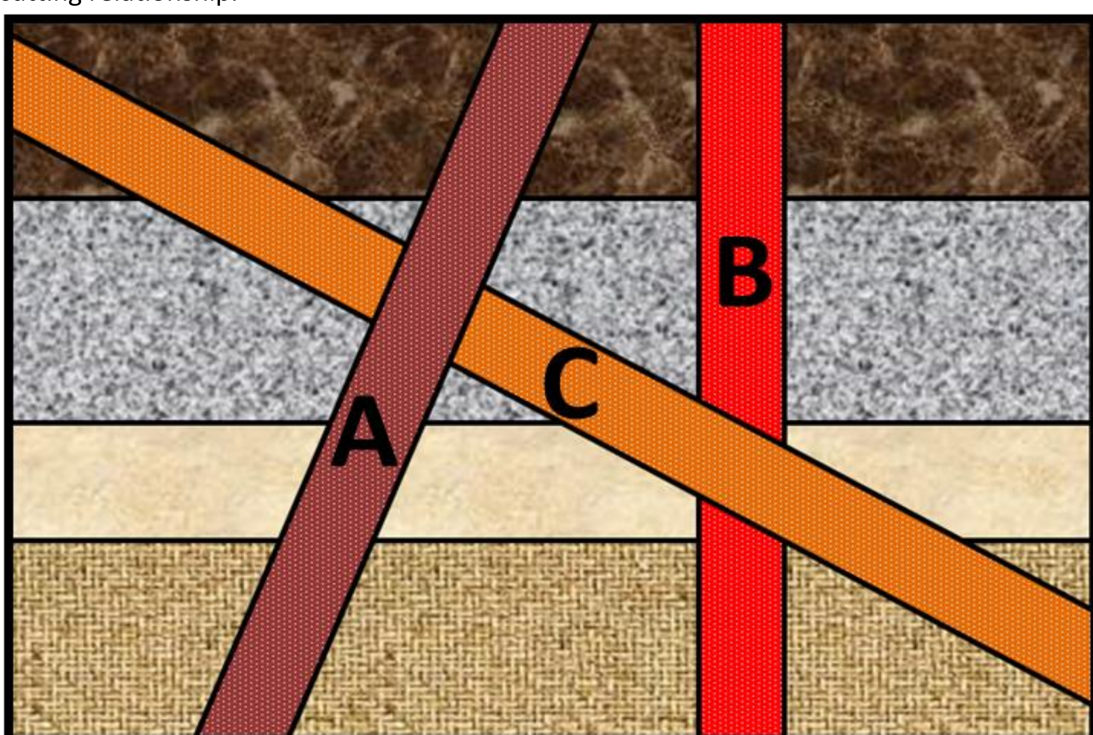
1. Law of Superposition
   This law is the most basic principle for relative dating and was defined in 1669 by Nicolaus Steno. He stated that each layer of material is older than the layer above it and younger than the layer below. It is understandable that in order to form a new layer, there was an older one, where it was deposited on. This rule applies for all materials deposited on the surface (e.g. volcanic lava, ashes, fluvial deposits).



2. Principle of Original Horizontality
   Steno also noticed that layers are usually deposited horizontally. If flat/horizontal layers are found, it means they have not been disturbed by any geological process. In contrary, if the layers are folded or inclined in any angle they were moved or bend into this position by geological processes.



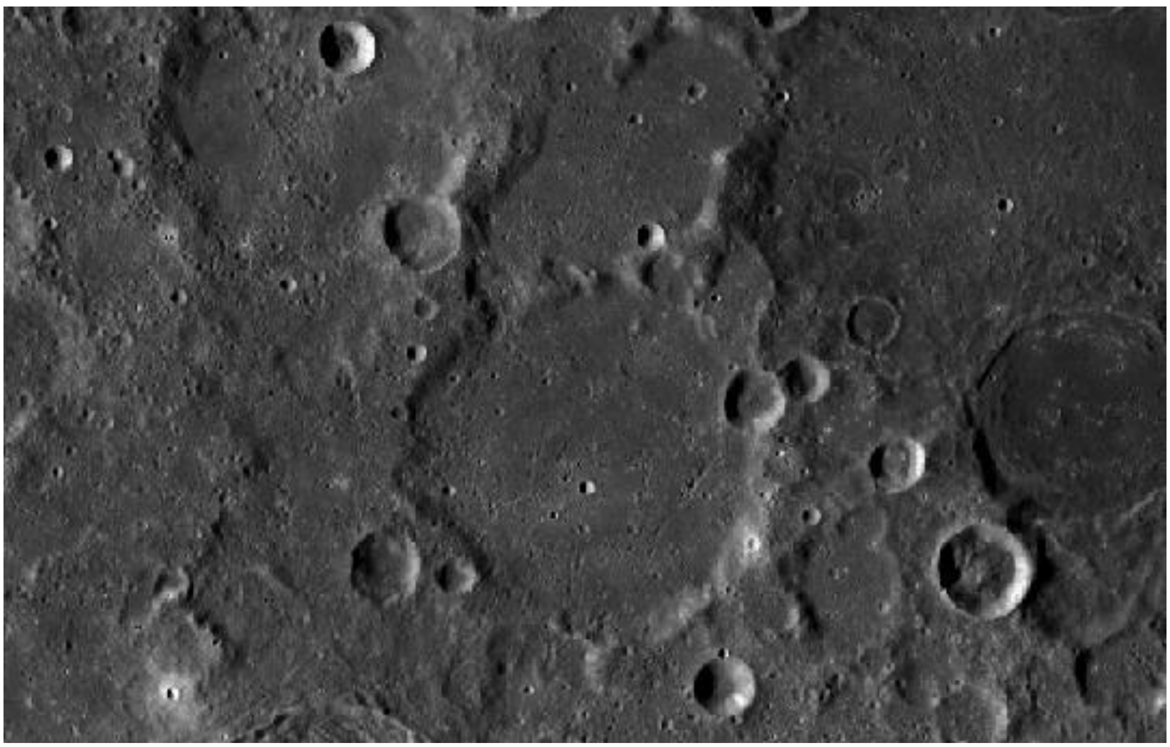
3. Principle of Cross-Cutting Relationships
   A disrupted layer is always older than the cause of disruption. When a fault or magma intrusion has cut through layers, we can assume that the affected layers are older than the faulting or intrusion event. The following image will provide an example for this principle. A, B, and C are dikes that disrupt the horizontally deposited layers. The youngest unit in this image is A, because it is not disrupted by any other unit. C is only disrupted by A, which makes it the second youngest unit. B is the oldest dike but younger than the horizontal units. This is a simple example for cross-cutting relationship.



Layers without disruption are called conformable. Due to active geologic processes in history of a planetary body, most of the layers are disrupted and show unconformities. They represent periods of erosion of material and no deposition of layers. Therefore, they can indicate large geological events that happened in the past. There are three types of unconformities: angular unconformities (layers are tilted to each other), disconformities (parallel units with erosion marks), and nonconformities (layers border randomly).

In planetary science we do not have the information about layers in the subsurface. We can only assume how layers or units continue in the subsurface. We are still using relative dating, but based on features on the surface and not below. The law of superposition is the most applicable one for remote sensing.

The illumination in remote sensing images can help identify landforms such as depressions (e.g. craters) or uplifts (e.g. mountains). We can also see how deep and distinct surface features are. Smoother surfaces will have fewer shadows. In the image shown below you can see that compared to old craters fresh appearing craters are also deeper and have steeper rims. To perform calculations based on shadow length, the solar incidence angle must be known for the image.



Geological cross sections are an important tool used by geologists on Earth. They visualize the subsurface and make it easier to understand the stratigraphic order of deposited units. To fully understand geological profiles a general knowledge of terrain profiles is necessary (see guide 2.2 for further information).

On Earth, subsurface information are obtained by outcrops, drillings, or radar measurements. Outcrops are natural or manmade excavations of surface material (e.g. an open pit mine). They allow us to observe the original layering and thickness of different surface units in that particular location. A reliable method to get information about the subsurface is drilling. The drilling core shows exactly how much and which materials are deposited in that particular position. Several drillings are needed to create a geologic profile.

Radar measurements are often used in resource search, e.g. oil or gas. A radar measurement by itself indicates different layers in the subsurface, the borders of those layers is visible. However, the material composition is not identifiable by radar measurements alone. Drilling needs to supplement the radar measurements. Radar measurements are less local than the other methods. Combination of all methods will lead to the best outcome for the geological profile.

Drilling and radar measurements are not available for planetary bodies. This fact does not stop us from drawing geological profiles, as they can provide important information about the stratigraphy and geological processes. A geological mapping is the first step to a profile or cross section of an area. In the mapping areas consisting of the same surface materials are the same unit. The crater counting and relative age analysis also help to identify the deposition order, which is also important for obtaining the geological cross section.

Before starting a cross section the following questions should be addressed:

- What is the scale of the map?
- What kind of landscape are you looking at?
- What is the contour interval?
- What do colors and symbols represent?

Task:

1. Use the three laws of relative dating to recreate the history of the diagram shown. Explain the layering sequence in a relative timescale (A to O) with your own words. Start with the first event that happened.
2. Perform a relative dating of the area of your mapping done in 2.1.
    a. Fill in the table below and explain with your own words the sequence of processes that happened in the area.
    b. Discuss advantages and disadvantages of relative dating in remote sensing.
    c. Which instrument and map did you use for this task?
    d. What is the resolution of the data you are using?
    e. From which direction is the sun coming?
3. Folding of geological units. Important for the geological cross sections are also folding and dipping of surface units. Based on the already learned principles of super position you are aware that older units are deposited below younger units.
    a. Draw a geological cross section of the shown units with yellow being the oldest one and blue the youngest. Describe what feature it has to be based on the deposition sequence.
    b. Draw a geological cross section of the shown units with blue being the oldest one and yellow the youngest. How is it different from the previous one?
4. Combination of drilling, geological maps, and topography.
    a. Describe the general topography of the shown map (height, size, direction, slope, shape, …). Name and describe the surface features that are present?
    b. Mark the highest and lowest point of the map.
    c. Draw the geological cross section and topographic profile of AB, CD, and EF. Take the drilling results into account for AB. They show how thick single geological units were. Yellow units are the oldest and blue the youngest.
5. Draw a cross section of your mapping done on the Moon and discuss the results.

Hints: Faults fracture the units and move regions up or down relative to another one. Dikes are volcanic intrusions. Sill can be a result of these intrusions. The magma is deposited between existing layers if the magma cannot rise through the overlaying unit. Batholith is a magmatic body that rises upwards.

Download:
Guide 2.2 Cross sections, Task 1 Image, Task 3 Image, Task 4 Image