Lab 12: Topography from the Earth to the Moon

You are only required to complete EITHER Lab 12 or 13 to receive full points – the other one is extra credit. Whatever you choose to do, the lab(s) must be turned into Gradescope by Friday May 6 at 5pm (no extensions possible).

Part 1: Topographic eye candy in ENVI

In the first part of the lab, you'll be using a DEM derived from ASTER stereo imagery (aka photogrammetry) and comparing to the ASTER color data. You'll gain experience working with DEM's in ENVI and in geologic interpretation using DEMs and color data. All data for the lab can be found on Brightspace.

First we'll take a few minutes to practice loading and processing topographic data in ENVI. From ENVI, load ***final_turkana_aster_vnir_subset*** *and* ***final_turkana_aster_DEM***. Load the VNIR image as an RGB (order: 3/2/1=RGB) and the DEM as a greyscale image, and link the displays. The VNIR image bands are near-IR/Red/Green, so red indicates vegetation and bare rocks/soils are green to brown. This is the Turkana region of Kenya, within the East African Rift (*you can enter these coordinates into Google maps/Earth for context: 1.925743, 36.485341*). Rifting causes down dropping of long blocks of crust to form valleys (grabens), and the extension and thinning of the crust also makes rift zones volcanically active.

Take a look at the DEM and determine where the low parts of the scene are. If you're not sure, use the cursor location/value tool to look at the data values (units are in meters). Compare this to the VNIR image - what geologic/geographic features are associated with the low parts of the scene? *Hint: Play around with different stretches if the area of interest is washed out in the VNIR image.* [Q1]

We can use the DEM to create other topographic products. We'll create a shaded relief map and a slope map. From the ***main ENVI tool bar***, go to ***Topographic → Topographic Modeling***. In the ***Topo Model Input DEM*** pop-up window, select the final_turkana_aster_DEM and click ***OK***. In the ***Topo Model Parameters*** window, under ***Select Topographic Measures to Compute***, select ***Shaded Relief***. Enter an elevation and azimuth for the simulated sun (illumination direction) – try 30 and 30 if you're not sure. Save the image as ***turkana_relief.img*** and click ***OK***. Repeat the process above to create a slope map. Load both maps as greyscale into new displays, and link the displays again.

Use the relief map to identify and investigate volcanic features to the north of the lake. Do you see evidence for a caldera collapse? How can you tell? [Q2a]

Use the X/Y profile tool on the DEM to generate a profile across the caldera and paste an image of the profile in your report. Assuming that the resolution is 30 meters/pixel, use the profile tool to determine the depth and width of the caldera (sample/line = row/column, which are one pixel wide). [Q2b/c]

Use the slope map to identify the typical slopes of the following features: (a) the large alluvial fan complex (bajada) along the left side of the valley, and (b) the sides of the volcanic cone to the upper right of the lake. [Q3]

ENVI has some nice tools for "draping" images over DEM's to produce a 3D image. From the ***main ENVI tool bar,*** go to ***Topographic → 3D Surface View***. In the ***3D Surface View*** pop-up window, select the display number that contains your VNIR image, then click ***OK***. Then, in the pop-up ***Associated DEM Input File*** window, select your DEM (final_turkana_aster_DEM), then click ***OK***. In the pop-up ***3D SurfaceView Input Parameters*** window, select ***"Full"*** under ***DEM Resolution***, and click ***OK***.

A new window will pop-up with your color image draped over the DEM. You can change the perspective by left-clicking and dragging the scene. You can also go to **Options→Surface Controls**, to see more options for zooming, translating (panning), and rotating the scene. You can also click on the corner of the window, and drag it outwards to make the window bigger. Finally, you can modify the vertical exaggeration of the scene – right now, the vertical distance is exaggerated 5x compared to the horizontal distance, to emphasize topography.

Use the 3D view to determine the order of geologic events in the scene, including rifting, volcanism (multiple episodes?), and fluvial incision. Describe how you can tell which came first, and use screenshots or saved images from the 3D view to support your arguments [Q4].

Part 2: Lunar Crater Morphometry with LOLA in JMARS

In this part of the lab, you will gain experience with JMARS, with crater morphology, as well as with acquiring and analyzing topographic profiles. You'll be using the Lunar Reconnaissance Orbiter (LRO) Wide Angle Camera Mosaic (100 m/pixel resolution) as a basemap to identify craters, and a Digital Elevation Model derived from LRO Lunar Orbiter Laser Altimeter (LOLA) data (1024 pixel/degree resolution).

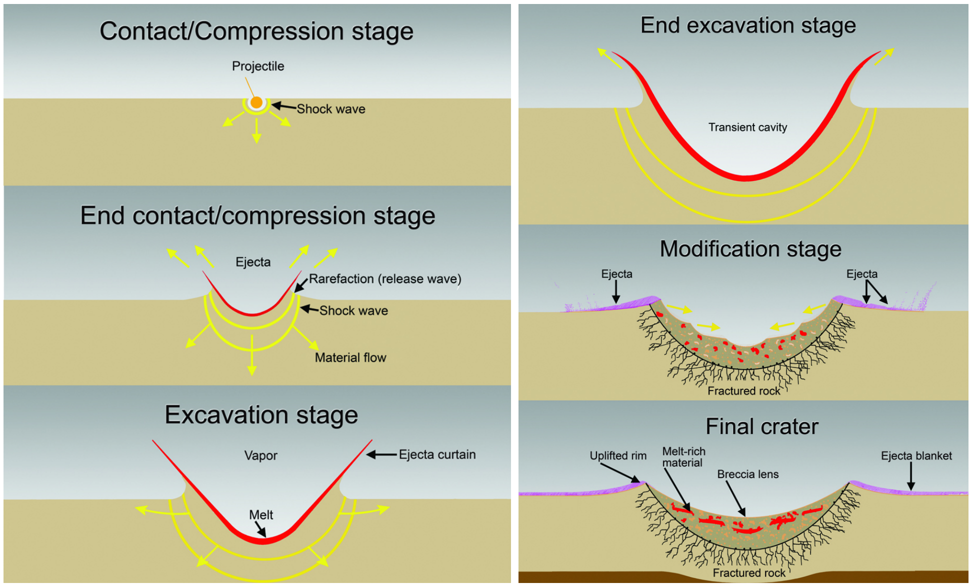

Figure 1: *Formation of a small bowl-shaped simple crater, from initial impact to final crater.*

Impact craters come in a variety of shapes and sizes on all planets. Figure 1 shows the impact cratering process for a simple crater. The simple rule is that the greater the impact energy, the larger the crater. However, the resultant crater will take on a very specific morphology that is dependent on the energy of the impact. As the impact energy increases, the target surface responds in different ways, particularly during the modification stage. Figure 2 shows the impact cratering process for a much larger complex crater – note the differences compared to Figure 1. In this part of the lab, you will use image and LOLA data to examine how craters vary in morphology (general physical characteristics) and morphometry (measurable physical characteristics) and how this variation is dependent on the energy of impact.

Open JMARS, and change the body to the Moon under ***Body* → *Luna.*** The interface should now look like Figure 3 below.

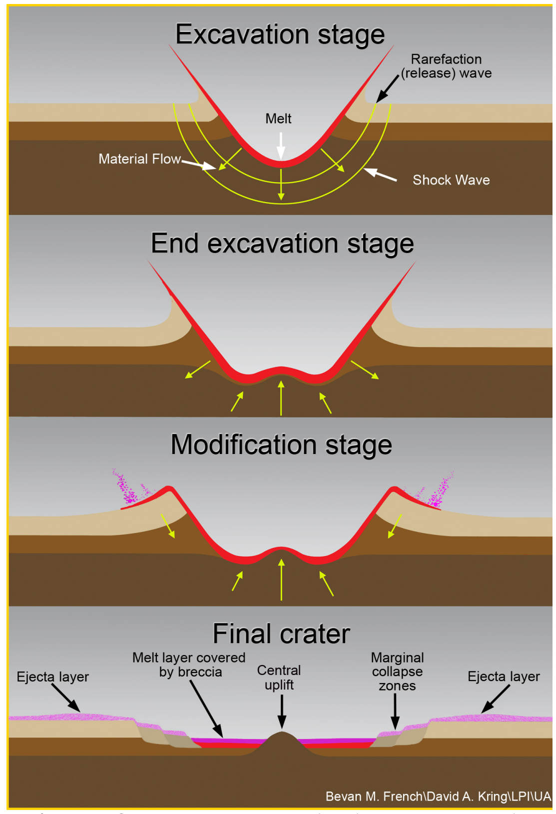

***Figure 2:** Formation of a larger complex crater, from initial impact to final crater.*

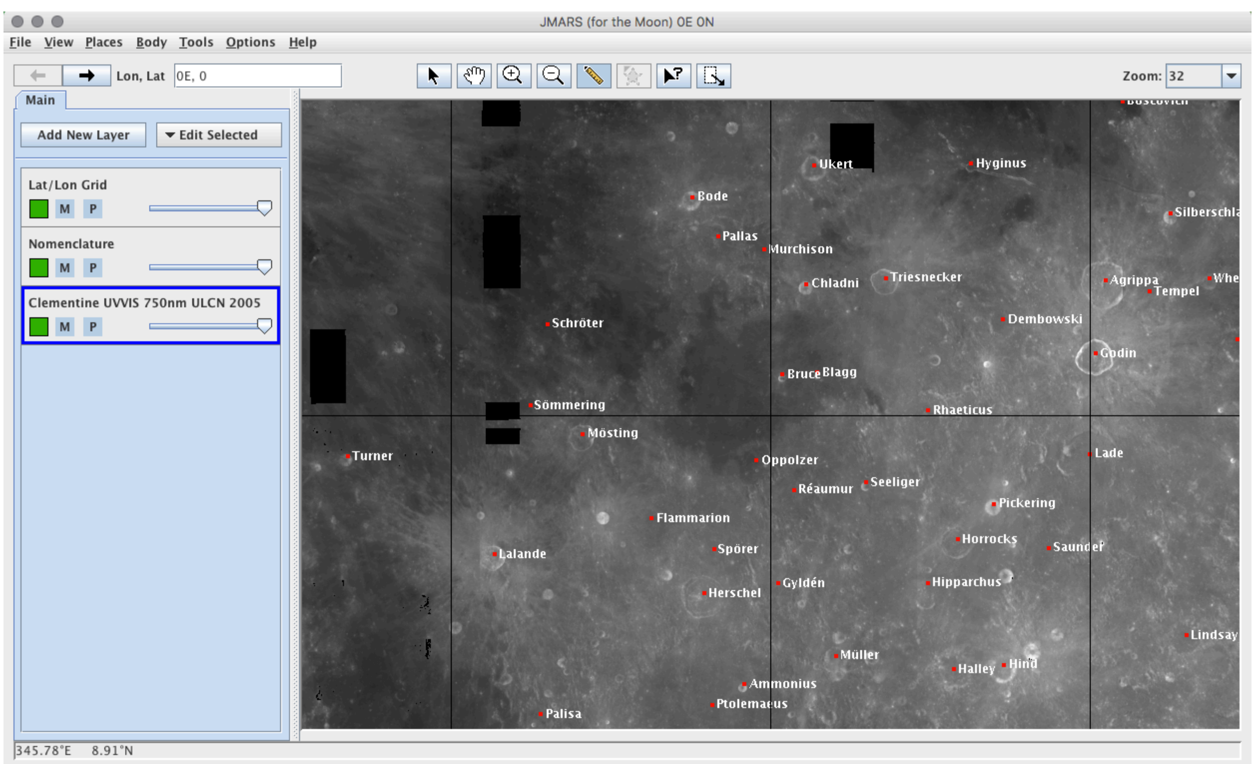

***Figure 3:** Default JMARS interface for the Moon.*

Add datasets

Add a scalebar: click Add New Layer in the main layer tab, and click Map Scalebar. If the layer is selected, the scalebar can be repositioned by dragging it around the scene. You can change the size and color of the scalebar by double clicking on the layer.

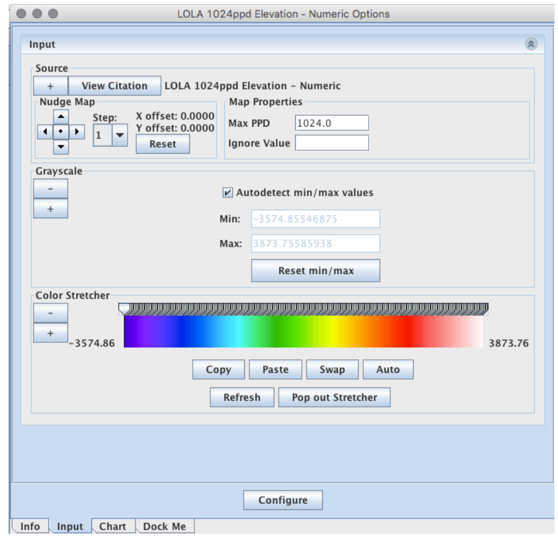

Figure 4: *Layer details window, showing default stretch values applied to LOLA DEM, and color stretcher with the TES daily color map.*

Add the DEM: Click Add New Layer, then select Topography from the top menu. In the panel below, click on Elevation to expand the list, and select LOLA 1024ppd Elevation. This layer is numeric, as opposed imagery, meaning that it has physical data associated with it. Double click the elevation layer, then select the input tab, as shown in Figure 4. The default stretch values are shown in meters of elevation above the global average. You can add a color stretch by clicking the + button under greyscale, right clicking the color bar, selecting Built In Colors, and choosing one of the color schemes (I like the TES daily color map). You can make the DEM partially transparent over the basemap for extra coolness.

Add a higher resolution image mosaic: click Add New Layer, then select Imagery from the first drop down menu. In the second menu, select Equatorial, then click LROC-WAC Equatorial Mosaic. Drag the layer so that the grid, labels, and scalebar are still on top. Compare this new basemap to the Clementine map. To make a fancy map, make the LROC mosaic ~50% transparent and layer it on top of the LOLA DEM. You can see that this combination provides a lot more information and depth (ha) than either map alone.

Crater Map Views

Use the ruler tool to find a relatively fresh crater that is 5 to 10 km in diameter in this region. In this context, "fresh" means that the crater has crisp features (look for a clear rim and an ejecta blanket with rays), and hasn't been significantly modified by mare infill, other impacts, etc. You'll return to each crater to take a profile in a moment.

Paste an LROC WAC image into your lab report of an example **fresh** crater that is 5 to 10 km in diameter. Don't forget to include an appropriate scale bar. Include the lat/lon coordinates of the crater (shown in the bottom left corner when the mouse is over the crater). [Q5a]

Paste an LROC WAC image into your lab report of an example **fresh** crater that is > 20 km in diameter. Don't forget to include an appropriate scale bar. Include the lat/lon coordinates of the crater. [Q6a]

Topographic Profiles

To extract a topographic profile from the DEM, select the LOLA layer, then the cursor tool. To draw a topographic profile, start the profile by clicking on one side of the crater beyond the rim, then double click on the other side beyond the rim to complete the profile. The profile should extend well past the rim and pass through the center of the crater. To view the profile, double click the LOLA layer and select the chart layer.

Paste the topographic profile of your crater that is 5 to 10 km in diameter in your lab report (you can screenshot the chart or right click and "save as"). What is the height of the rim and depth of the floor above the surrounding terrain? How wide is your crater? [Q5b]

Paste the topographic profile of your crater that is >20 km in diameter. What is the height of the rim and depth of the floor above the surrounding terrain? How wide is your crater? Can you constrain the depth of the ejecta blanket (make sure you have a long enough profile to see this and don't confuse the ejecta with the rim) [Q6b]

What major morphologic differences do you notice between these two craters (both map view and profile view)? Make sure to discuss the rim, continuous ejecta blanket, and any interior structures. [Q7]

Crater Morphometry Survey

"Morphometry" refers to the quantitative analysis of form, a concept that encompasses size and shape. In this part, you'll conduct a survey of crater depths and diameters in this portion of the Moon. This crater population has already been selected for you. Copy everything in the craters folder from the dropbox "craters" folder into your working directory. To open this data in JMARS, click Add New Layer, and click Custom Shape Layer. Double click on the shape layer, open the File menu in the new window, and select Load File. Navigate to your directory, select Craters.shp, and select "GeoTools ESRI .shp file provider" as the file type. The craters for your survey will now be shown as red circles on the map, in the central equatorial region 0-30°E and 0-30°N. In the shape file layer window, you can left click on a line of the table to highlight a circle, or right click it to center on the feature.

Measure both the depth (compared to the surrounding terrain) and diameter (rim to rim) of the craters highlighted by the craters.shp file. Plot the data as points in a scatter plot of diameter on the x-axis and depth on the y-axis and paste it into your lab report (don't forget to label your axes). [Q8] ***This can get a bit tedious, so you can collaborate with a group of up to 3 other students to complete this task – I suggest making a collaborative google spreadsheet to record the data and then plotting the results together. <u>Please include the names of the students you worked with in your report.</u>***

The data will have some scatter, but what is the general trend in the depth to diameter data? Note that there is a significant break in slope in the trend, what is the approximate diameter range where you see this? What is the typical depth:diameter ratio for lunar craters below the break? Hypothesize why this break in the slope occurs – what might be limiting the depth of impact craters above a certain size? (its ok if you don't know the answers here, just think of possible reasons). What factors might be responsible for the scatter in the data? [Q9]