Geography 441/541

The Geography of Mars

November 17, 2022

Dr. Rodrigue

Lab 10

– Crater Counting with Software –

CraterTools for ArcMap 10.8.2 and CraterStats2

This lab has the following objectives:

- to familiarize you with **crater-counting and mapping software** available to the public.
- To demonstrate the workflow and the many options available for how to display your results
- to have you map craters using the CraterTools(v2.1) (CT) plugin package for ArcMap 10.8 within your choice of geologic units already mapped in the Bathys Planum region, southwest of Claritas Fossae.
- To have you import the generated crater maps into CraterStats2 (CS2) for analysis and display.
- to have you perform a randomness analysis on your mapped data using the built-in feature in CS2
- To familiarize you with several Size-Frequency-Display (SFD) chart options and to provide an opportunity to experiment with each display configuration before picking a favorite.
- to (re)introduce you to the great Stuart Robbins' crater database, but with a visual component this time!
- To show how geologic mapping of Mars at 1:1Million scale can be done.

The setup:

For this lab, you don't need to download anything. Everything has been set up for you to be able to launch ArcMap, do some minor adjustments to data layers, and start mapping craters, but let's go over some things before we dig in.

We will be using three software applications in this lab today:

1. **ArcMap 10.8.2 -** already installed on your computer
    a. **CraterTools(v2.1)** - plugin for ArcMap -- just double-click on the **"CraterTools.esriAddIn"** which is in the "software" folder of your **"Lab 10 Geog of Mars 2022** (on your desktop)**\Software\"**

2. **CraterStats 2 –** Just double-click on the **"craterstats2.sav"** to launch the application. You will then tell it where your data is located.

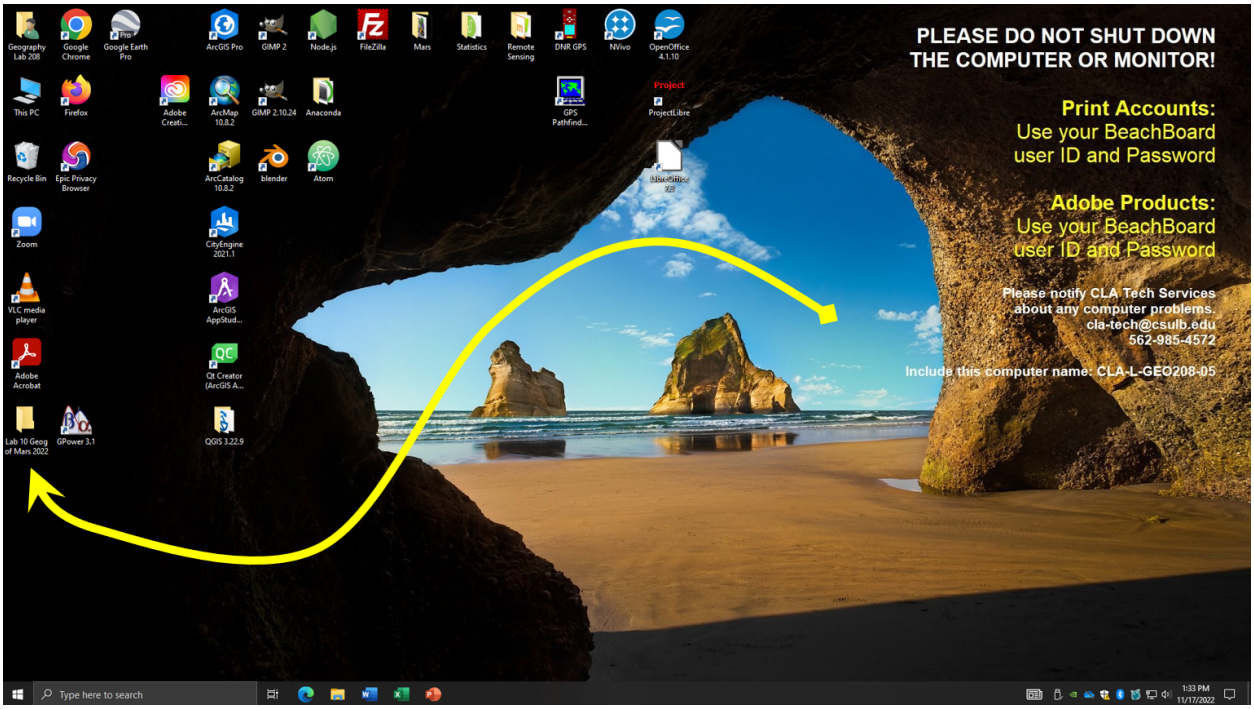
Both of these applications are available for anyone to download from the Free University of Berlin's web page for planetary and remote sensing: https://www.geo.fu-berlin.de/en/geol/fachrichtungen/planet/software/_content/software/index.html

Further readings about these applications and their underlying science can also be found here.

Setting up ArcMap 10.8.2 for crater counting

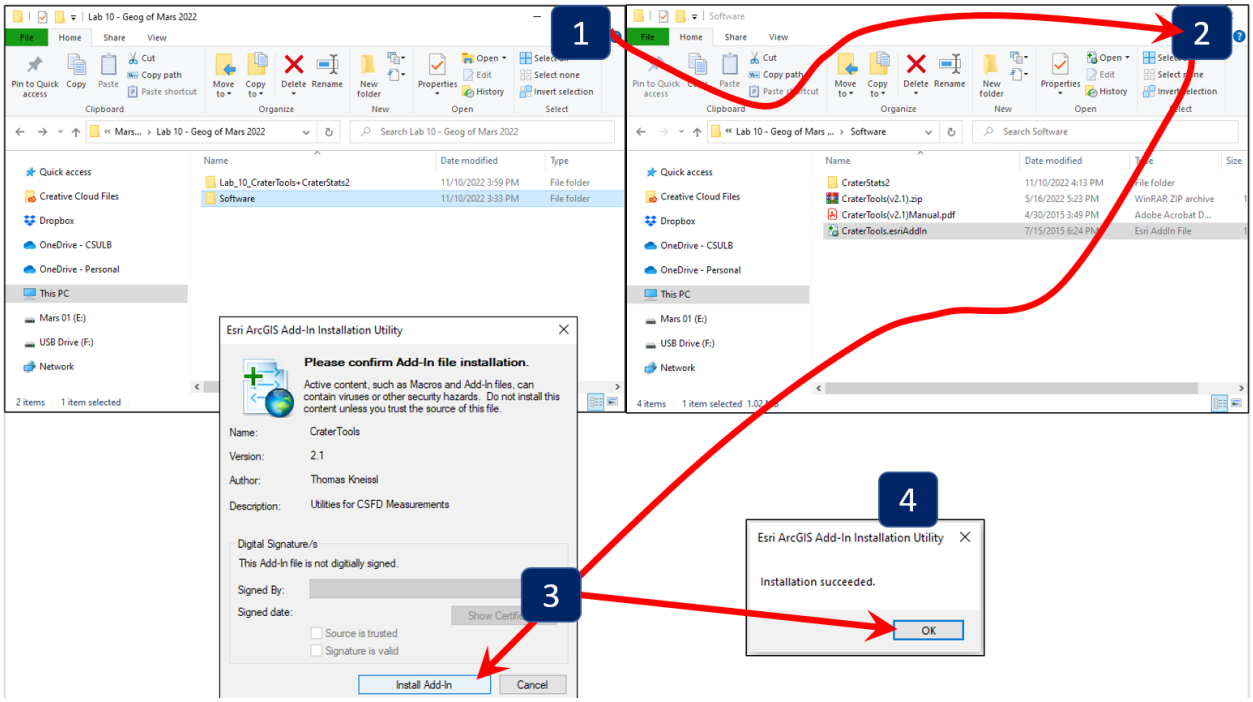
Open: **"Lab 10 Geog of Mars 2022"** folder on your computer's desktop.

a. **This will be your main working folder. Remember it where it is!**



To install the CraterTools(v2.1) tool for ArcMap 10.8.2…

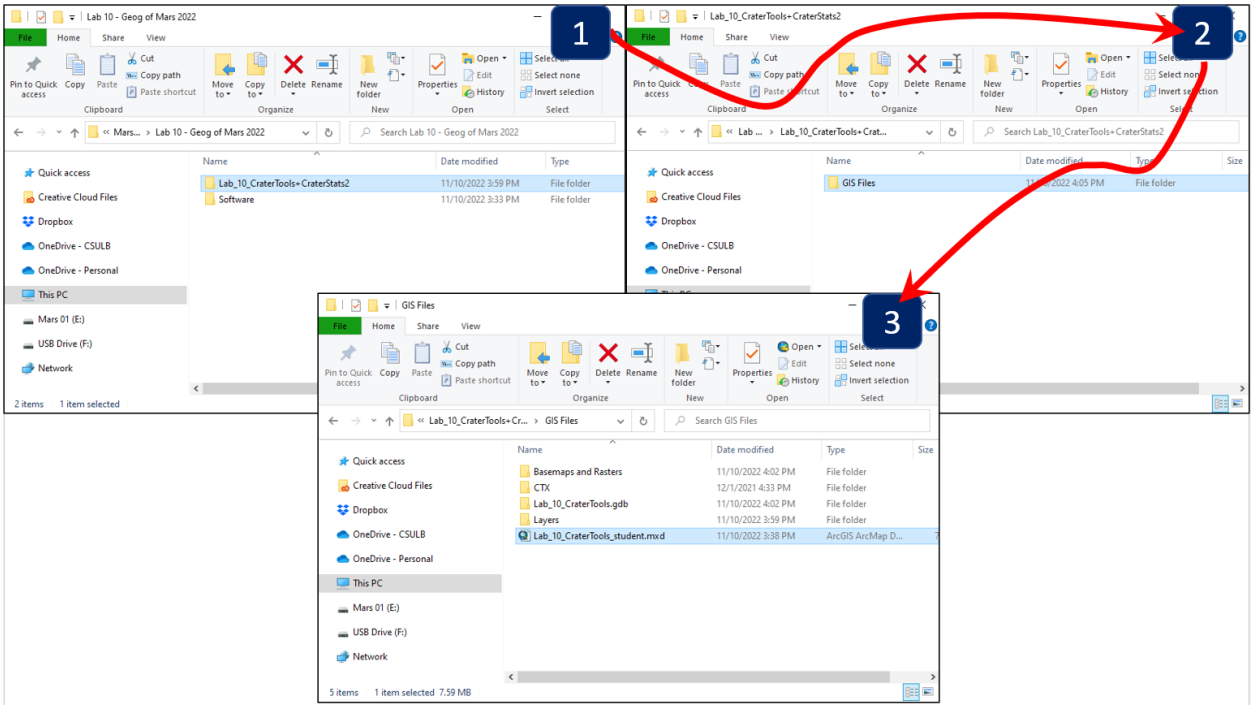
1. Open: the **"Software"** folder.
2. Find the plugin for ArcMap -- just double-click on the **"CraterTools.esriAddIn"** to open the installation dialog box.
3. Single-click: **"Install Add-in"** and then…
4. Single-click the **"OK"** button once the installation process completes.



Now it's time to open the map project and take a look at what we have to work with!

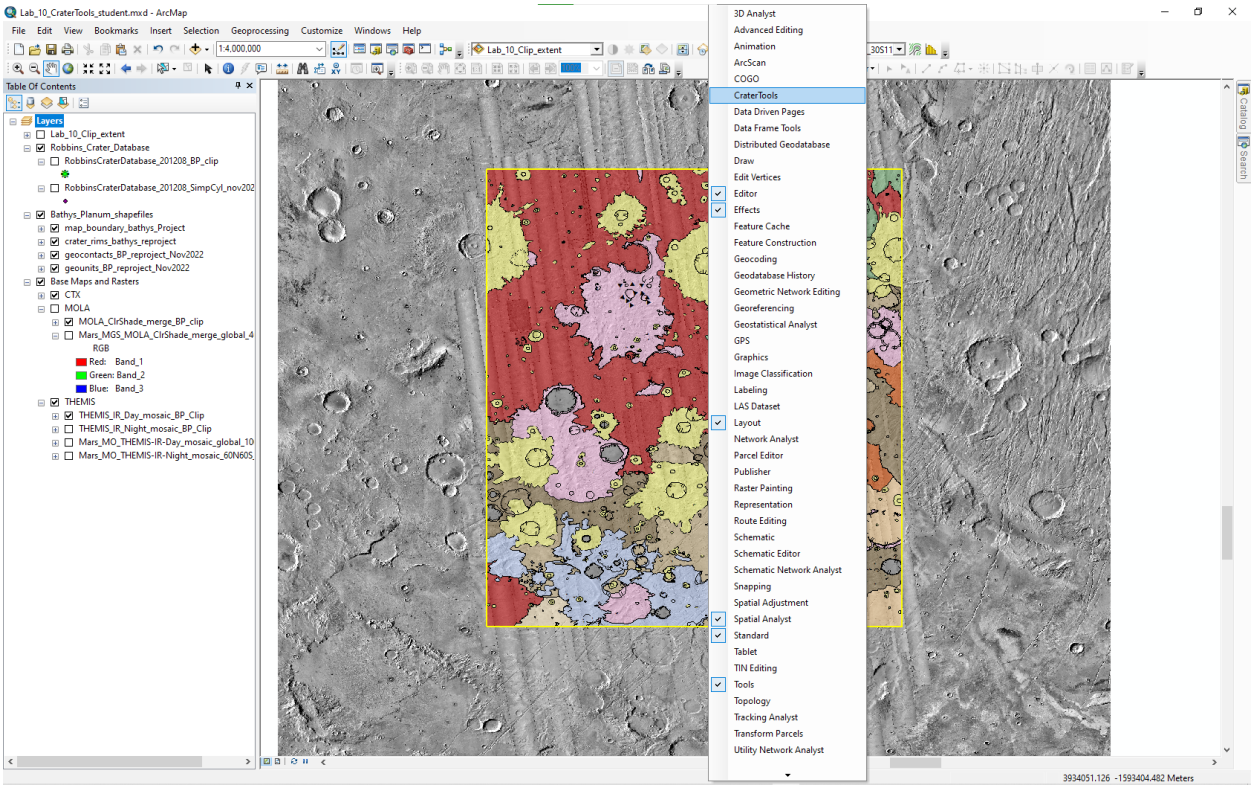
Go back to the computer's desktop and open: **"Lab 10 Geog of Mars 2022"** folder on your computer's desktop.

1. Open: the **"Lab_10_CraterTools+CraterStats2" → "GIS Files"** folder and double-click on the **"Lab_10_CraterTools_student.mxd"**
    a. This will open the map project in ArcMap 10.8.2
    b. This might take a while to load.

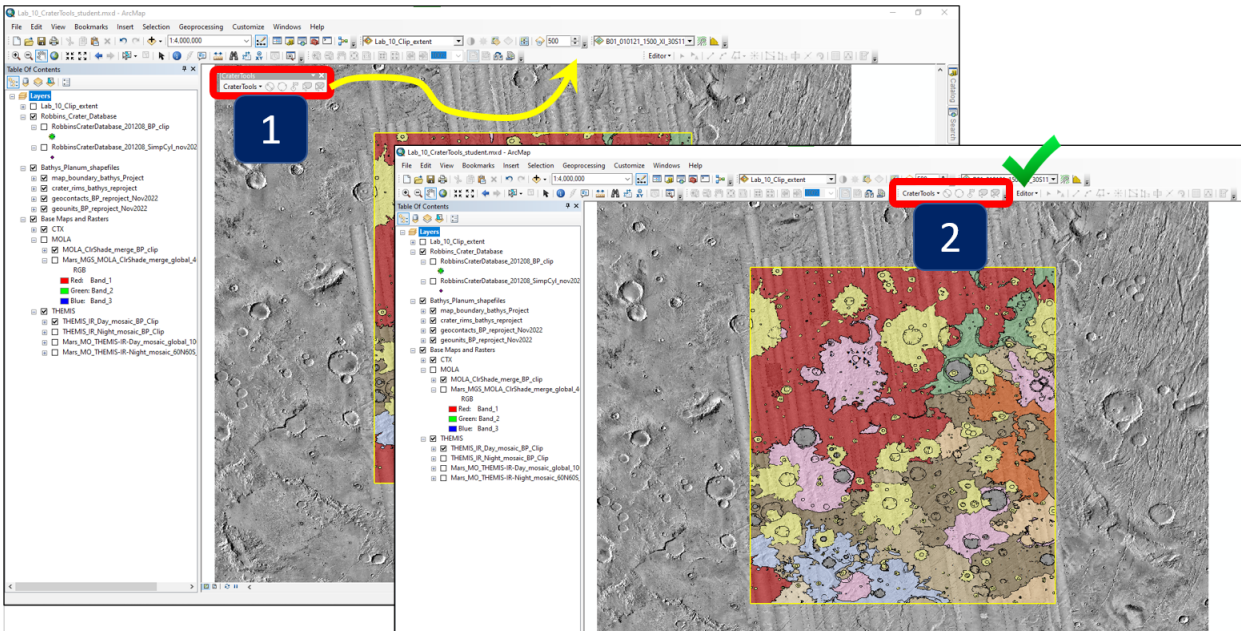


Once the map is all loaded in…

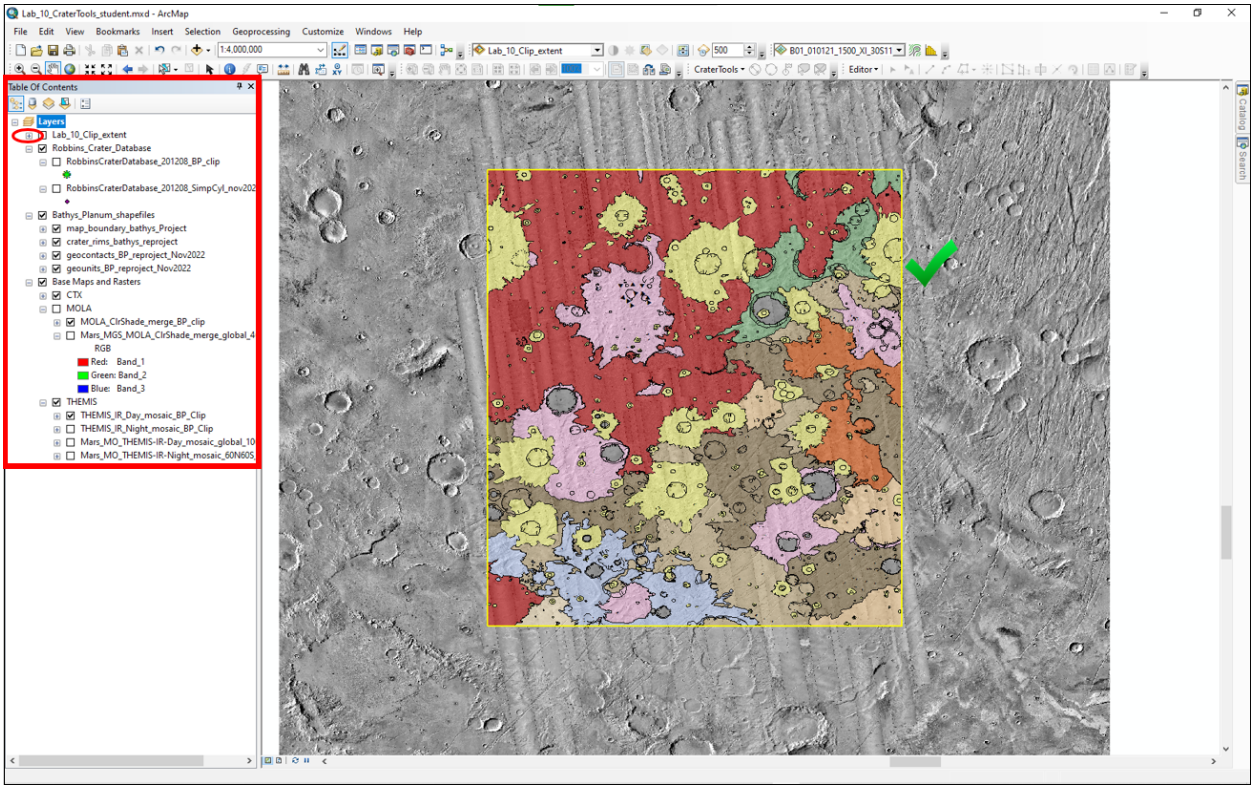
2. **Move your cursor to the top toolbar and hover over a blank spot and then right-click.**
3. Select **"CraterTools"** from the menu that pops up.



4. Now you have the **CraterTools toolbar** ready to go! Feel free to drag this to anywhere on the screen or you can even "dock" it to the toolbar at the top by dragging it to where you want.



5. Now go through each of the **layers** in the **table of contents** and click the little to expand their categories….



a. Let me know <u>if</u> you see any *red exclamation marks*  in front of any of the **layer** names. This should not happen, but if it does…

b. I will show you how to fix this – You just need to click the red exclamation mark and tell it where the file got moved to.

c. All layers in this map are within the Lab10 folder somewhere.

d. Fixing broken CTX images will be the biggest task since I have them separated into folders according to location.

6. Once all the red exclamation marks are fixed (<u>if necessary</u>) you are ready to start crater counting!

NOTE: Several of the layers I've included here are not strictly necessary for the crater counting process. I have them in here, partially as a showcase for some of the works Dr. Rodrigue has referenced during this course to get you some more up-close exposure to these data products. The extraneous-but-interesting layers include:

1. MOLA colored hillshade
2. THEMIS IR Night mosaic
3. My "crater_rims_bathys_reproject" layer which maps crater rim crests as they currently exist, and this layer doesn't necessarily correspond well to the kind of mapping you will be doing.
4. CTX – This is not strictly necessary for what we are doing, but I wanted to include it to show how much of a difference it makes for understanding what you are looking at.

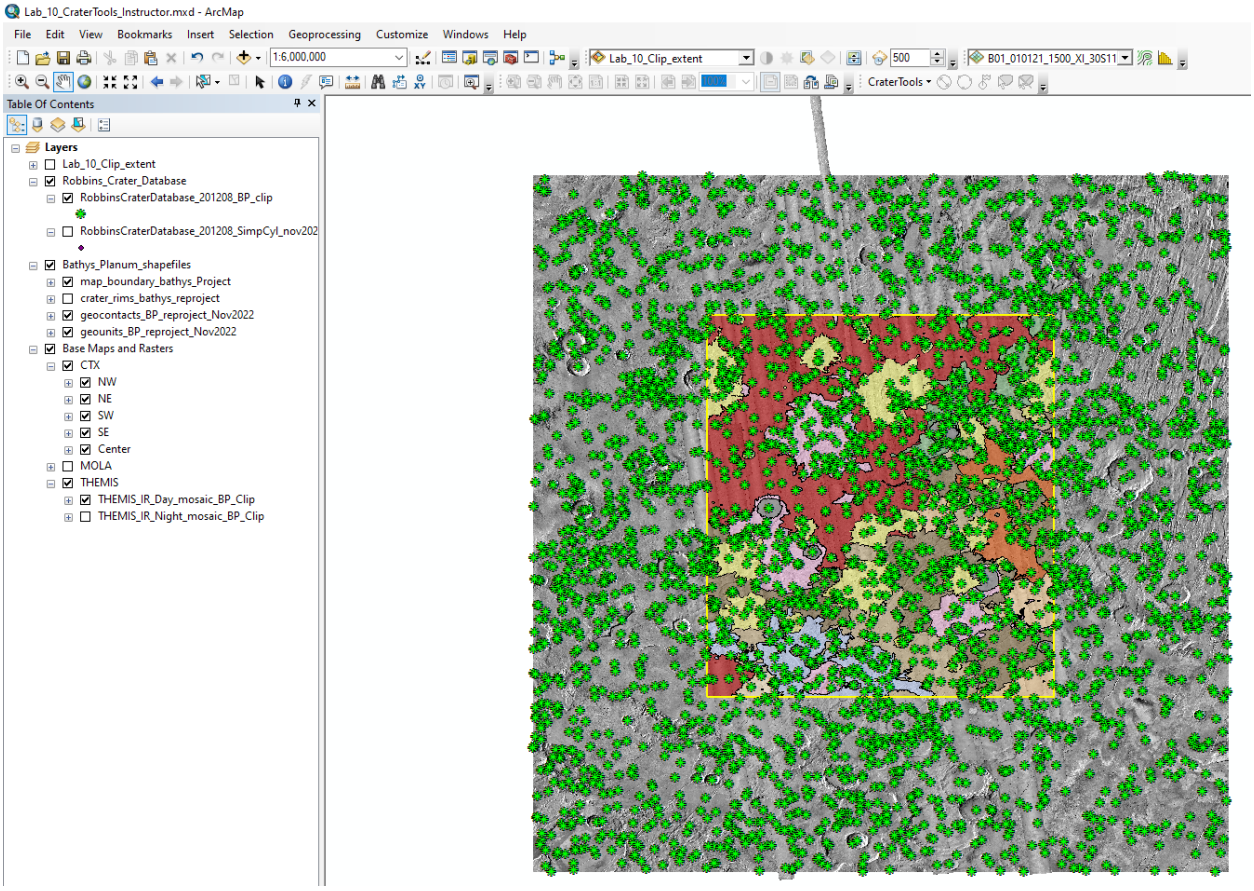
While you map craters, I recommend you **<u>turn off</u> <u>all</u>** layers (uncheck the box) **<u>except</u>**:

(So, **keep these <u>ON</u>**)

1. "Robbins_Crater_Database"
2. "RobbinsCraterDatabase_201208_BP_clip" → You may want to switch this on/off as you go.
3. "Bathys_Planum_shapefiles"
4. "map_boundary_bathys_Project"
5. "geocontacts_BP_reproject_Nov2022"
6. "geounits_BP_reproject_Nov2022" → You may want to switch this on/off as you go.
7. "Base Maps and Rasters"
8. All CTX layers → Also somewhat optional.

9. “THEMIS”

10. “THEMIS_IR_Day_mosaic_BP_Clip”



Now let’s get into CraterTools!

Understanding the CraterTools(v2.1) toolbar interface

CraterTools was developed by Thomas Kneissl (Kneissl et al. 2011; Kneissl et al., 2014; Kneissl et al., 2015) to streamline the painstakingly tedious process of mapping and counting craters within a region.

I have included the user manual “CraterTools(v2.1)Manual.pdf” for CraterTools in the “Software” folder in the Lab10 folder on your desktop. I have embedded sections of this rather straightforward document to help us understand how to use CraterTools(v2.1), but please also have the full manual open for your own reference if you wish.

I also found this **YouTube video showing all of the necessary steps** we will be following…

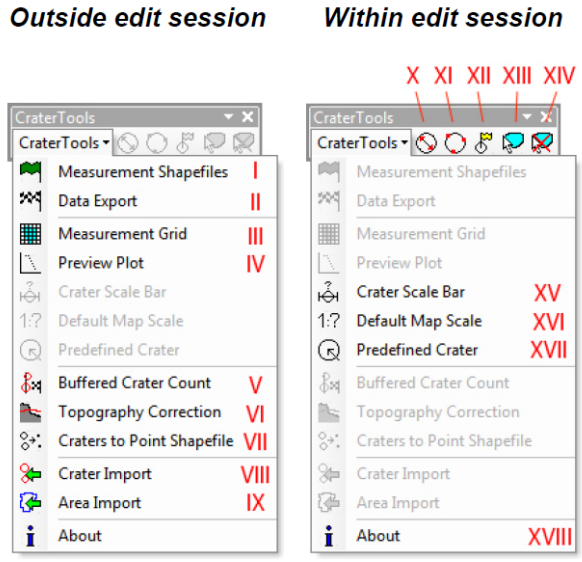
- so if you get lost, try referring here.
- There is no voiceover, but the workflow can still be easily followed.

- Note that the user in the video does not have a pre-defined unit-area to start with like we do.
- This video also has the benefit of showing a good crater mapping technique:
    - click on the rim of the crater and then click on the rim directly opposite of the first point.
- https://www.youtube.com/watch?v=yI6NHB9hlHY

The CraterTools(v2.1) Toolbar:

Yes the below image shows quite a lot of information. You don't need to take this in all at once.

The buttons we will be using are I, II, X, and maybe XI through XIV.



I Generate two shapefiles with CraterTools format.
II Export measurement data to SCC/DIAM file.
III Generate custom grid for systematic CSFD measurements.
IV Preview SFD plot of crater measurement.
V Perform buffered crater count analysis.
VI Correction of topography-related crater and area distortions.
VII Generate point shapefile with crater centers.
VIII Import craters from Diam/Scc file.
IX Import areas from Scc file.
X Digitize crater by two opposing points on crater rim.
XI Digitize crater by any three points on the crater rim.
XII Mark selected craters. They can optionally be excluded in the export/analyses processes.
XIII Make all AREA layers selectable.
XIV Make all AREA layers unselectable.
XV Define crater scale bar that can be shown at the cursor position.
XVI Set the default map scale.
XVII Generate crater with predefined diameter.
XVIII About CraterTools.

Mapping craters using the CraterTools (v2.1) plugin for the old ArcMap

GIS software is also particularly great for easily finding the area and other measurements for irregularly shaped regions. I have also included a shapefile of Robbins' crater database (introduced in the previous crater counting lab) to help you locate relevant craters (1 km in diameter and up). Unfortunately, this plugin has yet to be updated to work in ArcGIS Pro, so for now we have to fall back to the old ArcMap 10.8.2 (aka "Desktop").

While it is not necessary to map the geology of a region before crater mapping/counting, if you have already made one (like my -unpublished- map of Bathys Planum), the geologic units also conveniently serve as well-defined unit-areas. However, you might notice there is a problem with the way I mapped my units (particularly the crater-ejecta) and mapping craters considered to be impacted into any given unit. This will require some extra steps to mitigate, but it's possible to deal with this issue.

Thankfully CraterTools is designed to handle this contingency. Fixing this will involve re-designating crater ejecta polygons (yellow) to be the same color as its host unit (brown, green, orange, etc…). We will go over how to do this when it's time.

IMPORTANT → When we start mapping, **you will have a choice of which geologic unit for which you wish to count craters.**

A. I strongly recommend you **DON'T pick the red unit!** - It's too big and has far too many tiny yellow polygons to redesignate for one lab session.

B. Also, please **DON'T pick the tiny beige colored unit** in the southwest corner of the map (between the blue and red units). - This unit is far too small (within the mapped region) for crater counts on this scale.

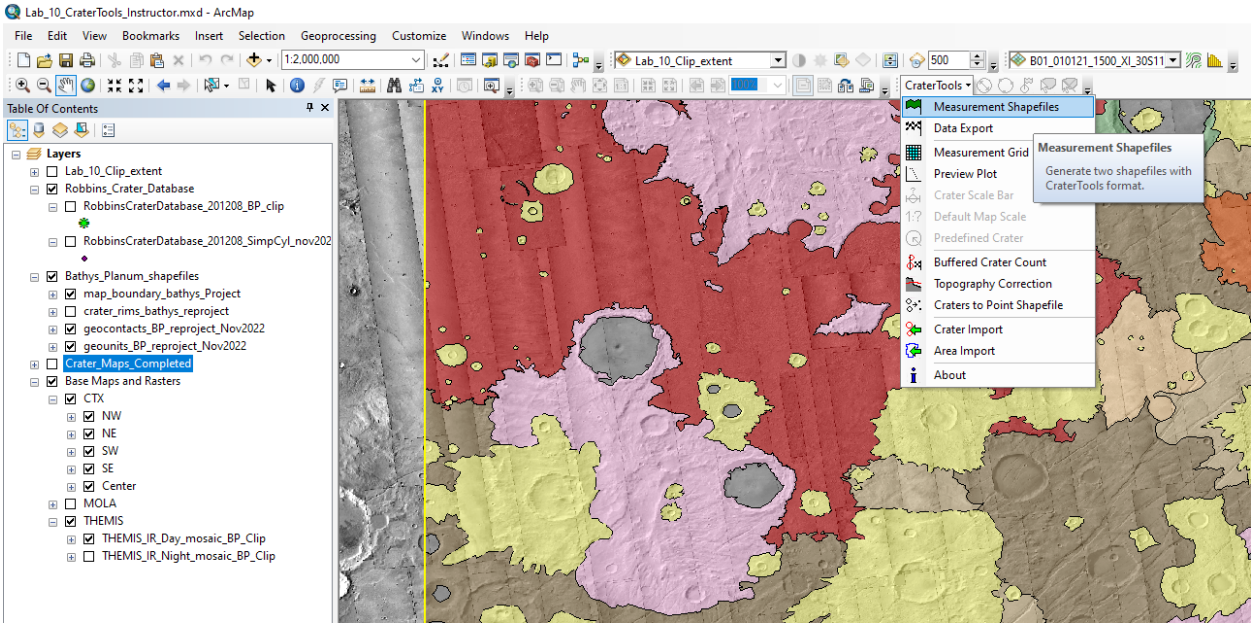
C. The yellow unit is not really the same kind of unit as the others and should not be treated as such. **No crater counting for Yellow, please**.

D. **Everything else is fair game.**

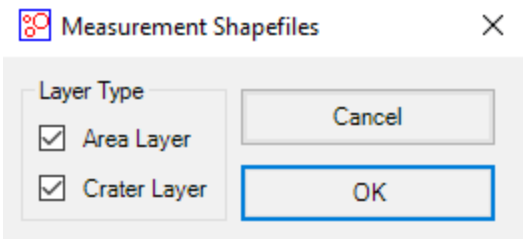
Using CraterTools(v2.1)

Now we are ready to begin mapping craters!

1. The first thing to do is to click the **"CraterTools"** dropdown menu button and select **"Measurement Shapefiles."**

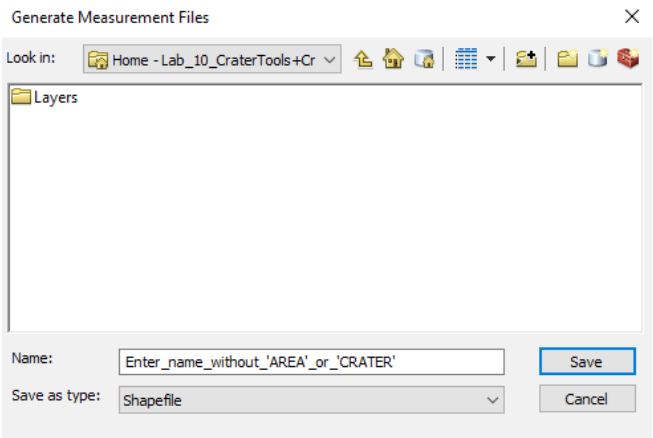


2. A dialog box will pop up asking if you want to create layers for either Area, Craters, or both.



➢ **Keep both checked and click OK.**

3. Now a new dialog box pops up that looks like this: **DON'T click Save yet!.**



This is asking where you want CraterTools to put the AREA and CRATER shapefiles the app generates as you map. **DON'T click Save yet!.**

4. Navigate to where you are inside the **"Lab_10_CraterTools+CraterStats2" → "GIS Files"** folder.

5. Single-click the folder icon with a little yellow star  to **create a new folder**. Rename this folder as **"BP_cc_shapefiles." DON'T click Save yet!.**

    a. **This is where all of your new map shapefiles will go.**

    b. **NOTE: If this folder already exists → Delete it first and then make a new one! (Or use the folder and just delete the contents before you map anything to avoid any conflicts with your new map files and any old ones left over from previous projects)**

6. Now go back to your "Generate Measurement Files" **dialog box** and make sure it is set to this new folder **(BP_cc_shapefiles)** before you do the next thing. **DON'T click Save yet!.**

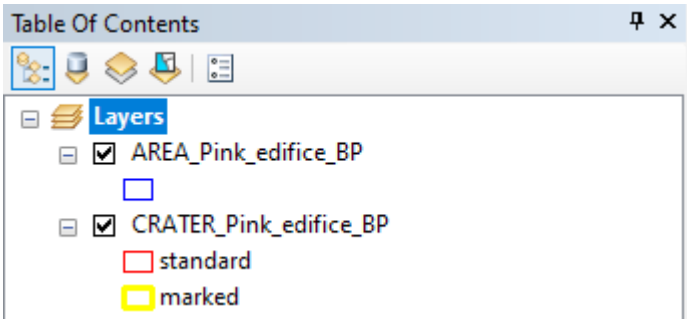
Before you click Save, you must **enter a general name** for the new files to be generated**.** I suggest **"[YourChosenUnitColor]_[highlands or plains]_BP."**

CraterTools will **automatically** add the appropriate prefix (AREA vs CRATER).

- This is why it says **"Enter_name_without_'AREA'_or_'CRATER'."**
- Doing so will conflict with CraterTool's naming system and break your map files.

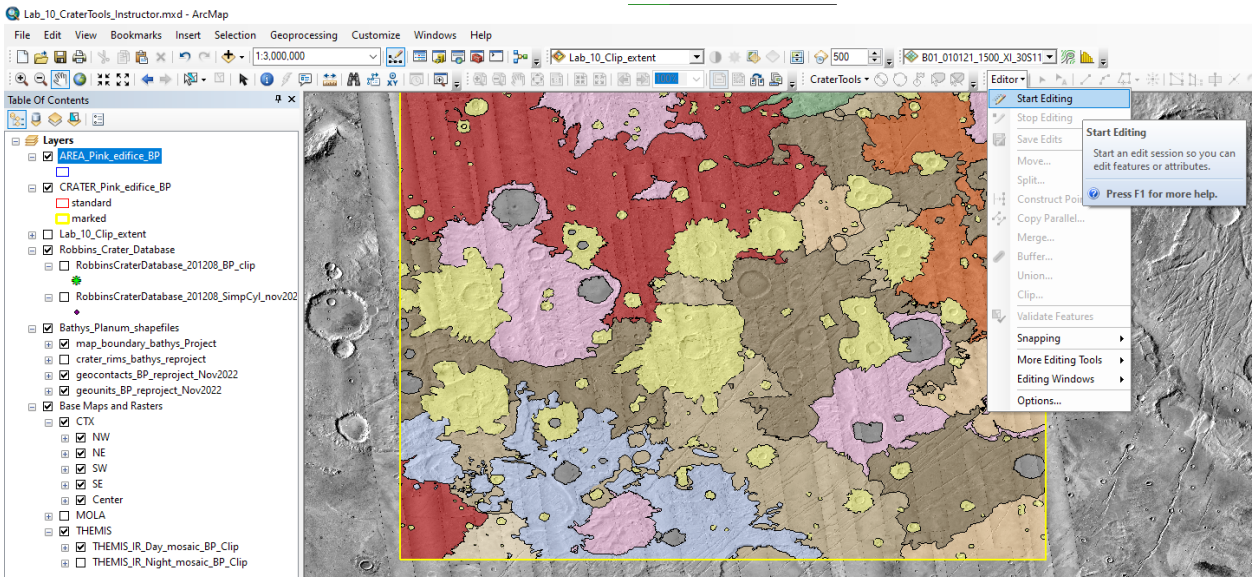
Now click Save!

7. Notice, now you have two new layers in your Table Of Contents:

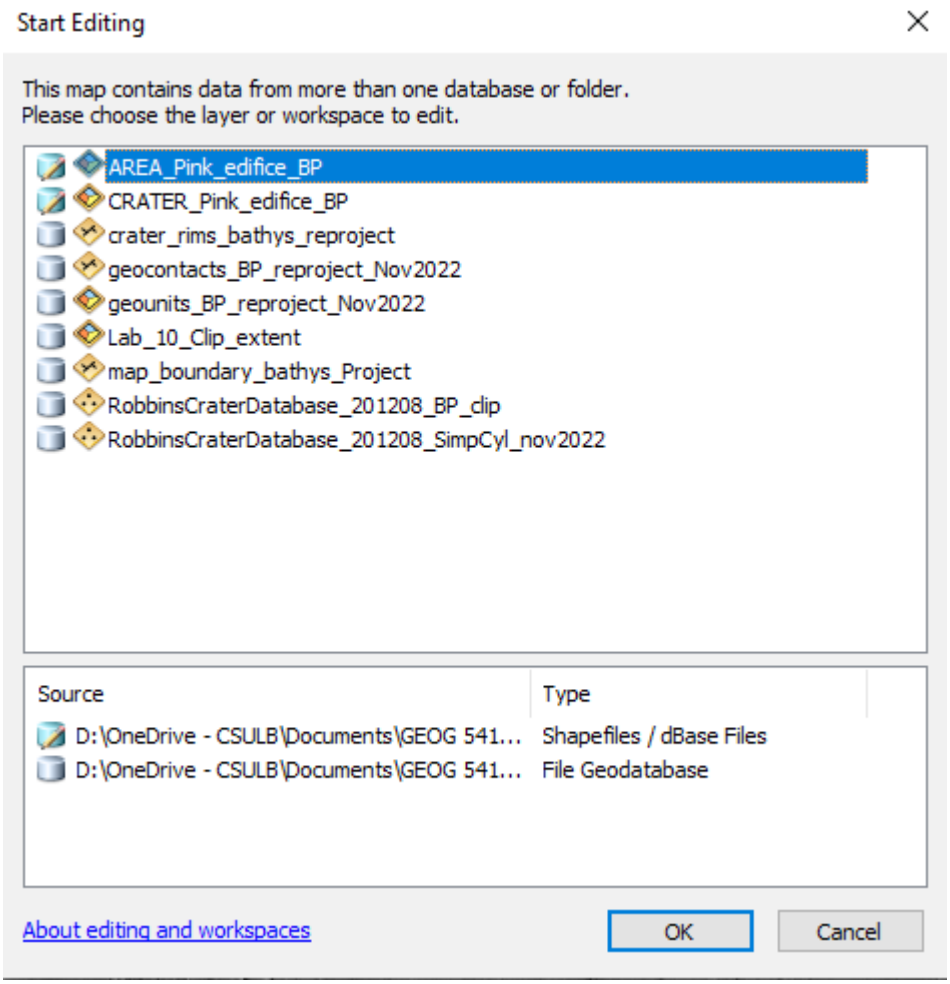


8. Move your cursor to the top menu bar and look for the **"Editor"** button. Press it and then select **"Start Editing."**

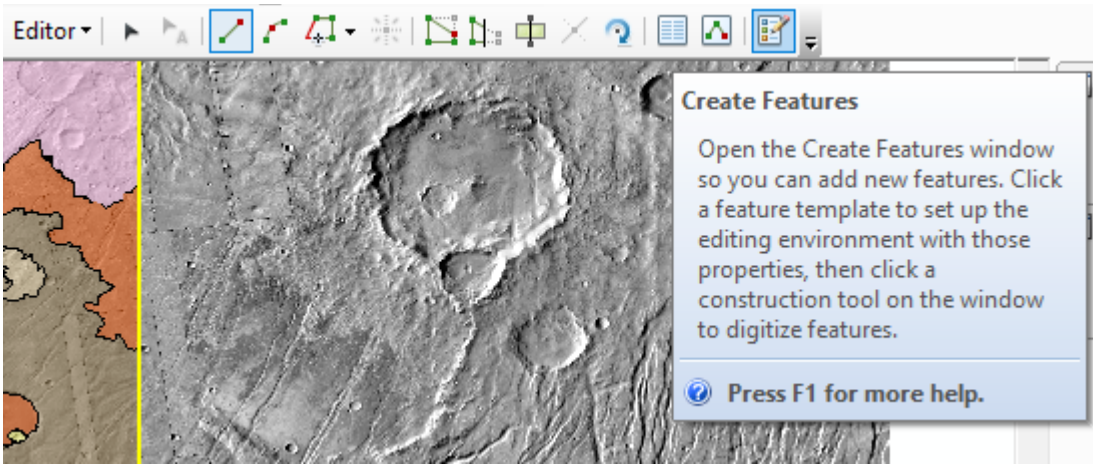
Note: If you can't find this button, do the same thing as when you added the CraterTools toolbar → right click on an empty spot and select the **"editor"** option in the menu that pops up.



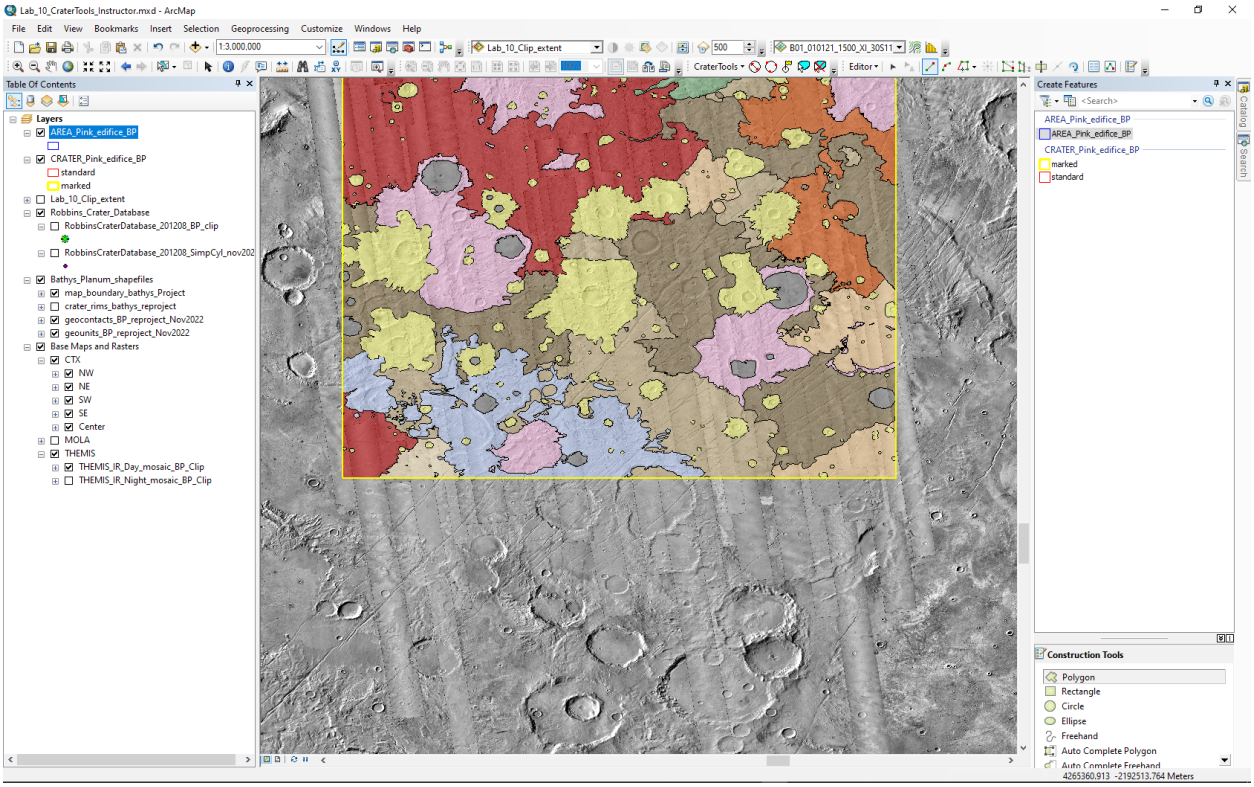
9. Note if you see this dialog when you click **"start editing"** just select **"AREA_..."** layer in the list and click OK.



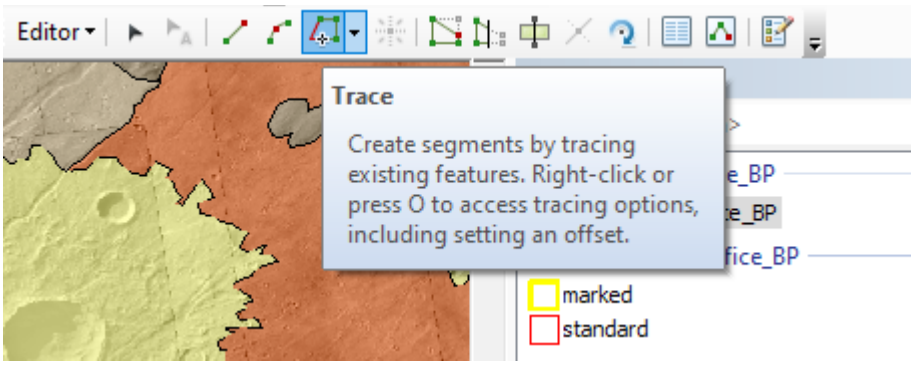
10. **Note:** you **<u>may</u>** have to click the **"create Features"** button in the **"Editor toolbar"** before the next step (see below screenshot).



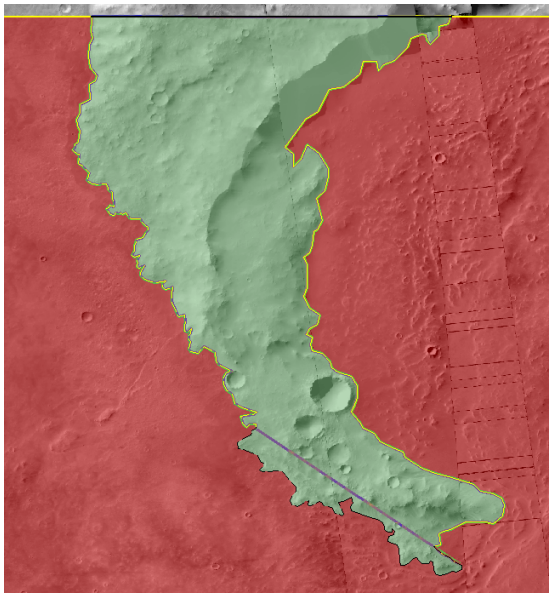
11. Now the **“Create Features”** panel opens up on the right. Click the blue **“AREA_...”** layer in this panel and be sure the same layer is highlighted (a.k.a. selected) in the table of contents panel on the left of the window (see screenshot below).



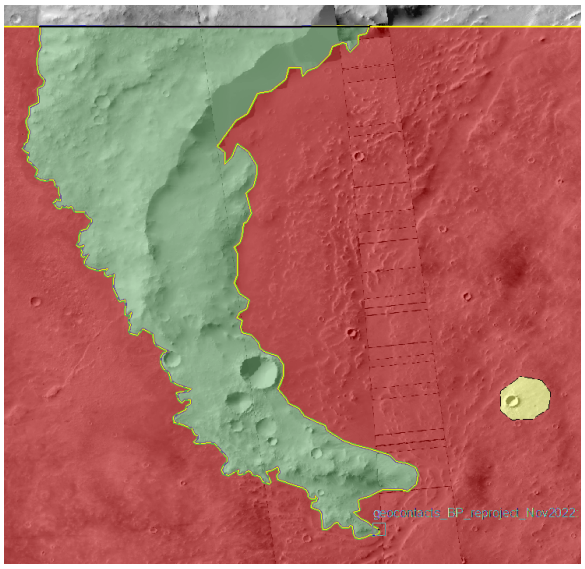
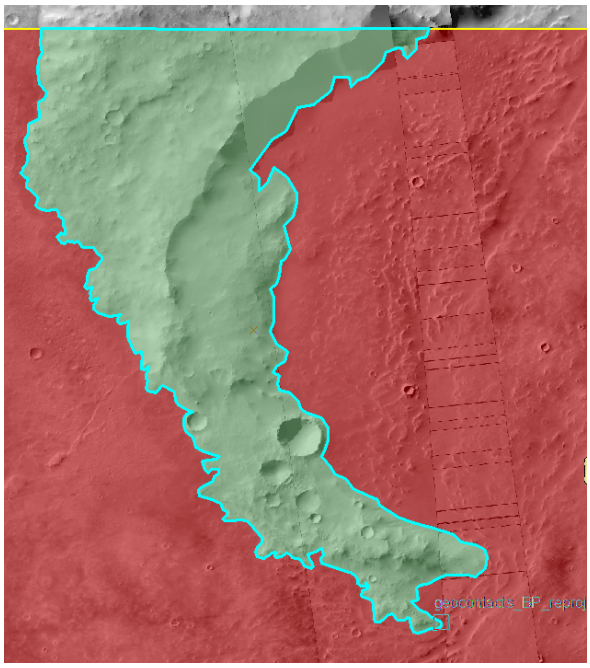
12. This is where we will deviate from the YouTube video… because we already have our unit areas mapped out (as geologic terrain units), we will click the **“Trace”** button in the **“Editor menu”** while we have the **blue AREA rectangle selected** in the **Create Features panel** (see below screenshot).



13. Now click any spot along the contact line of your unit and then drag the mouse around the edge of the unit polygon. It can be a little tricky, but you want to trace the entire outline of the unit. Double-click to accept when you get the cursor back to its original spot and the edge of the polygon is now yellow.

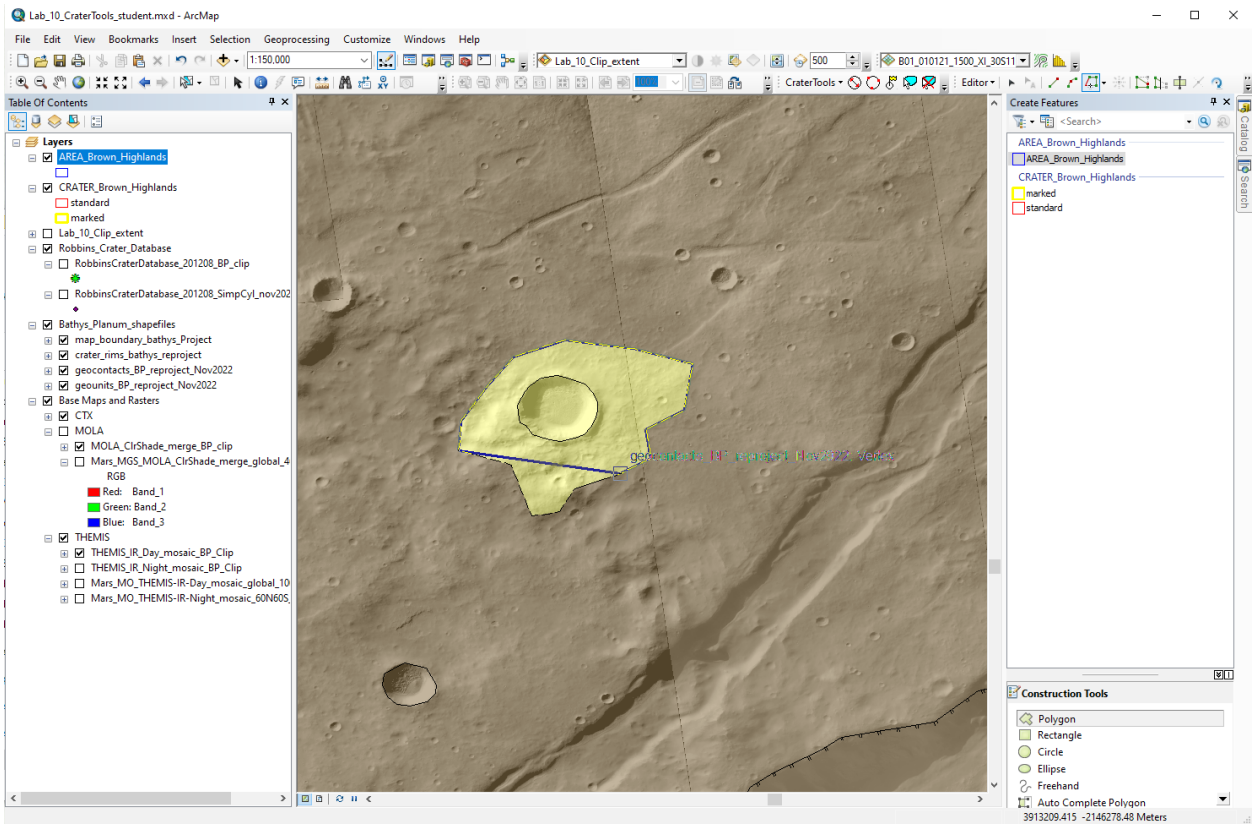


1.

2. 
3. 

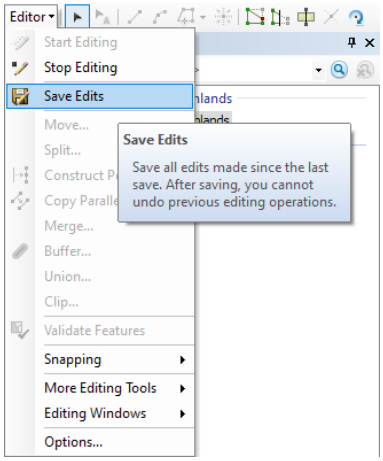
14. **Repeat this procedure for EVERY polygon of your chosen color!**
15. Once you have those areas marked, **you're not done! Now you must also add ALL of the crater ejecta polygons that fall within your unit!**

    NOTE 1: It's best to **turn OFF the crater rims layer** while you do this so they don't get confused for extra unit polygons.

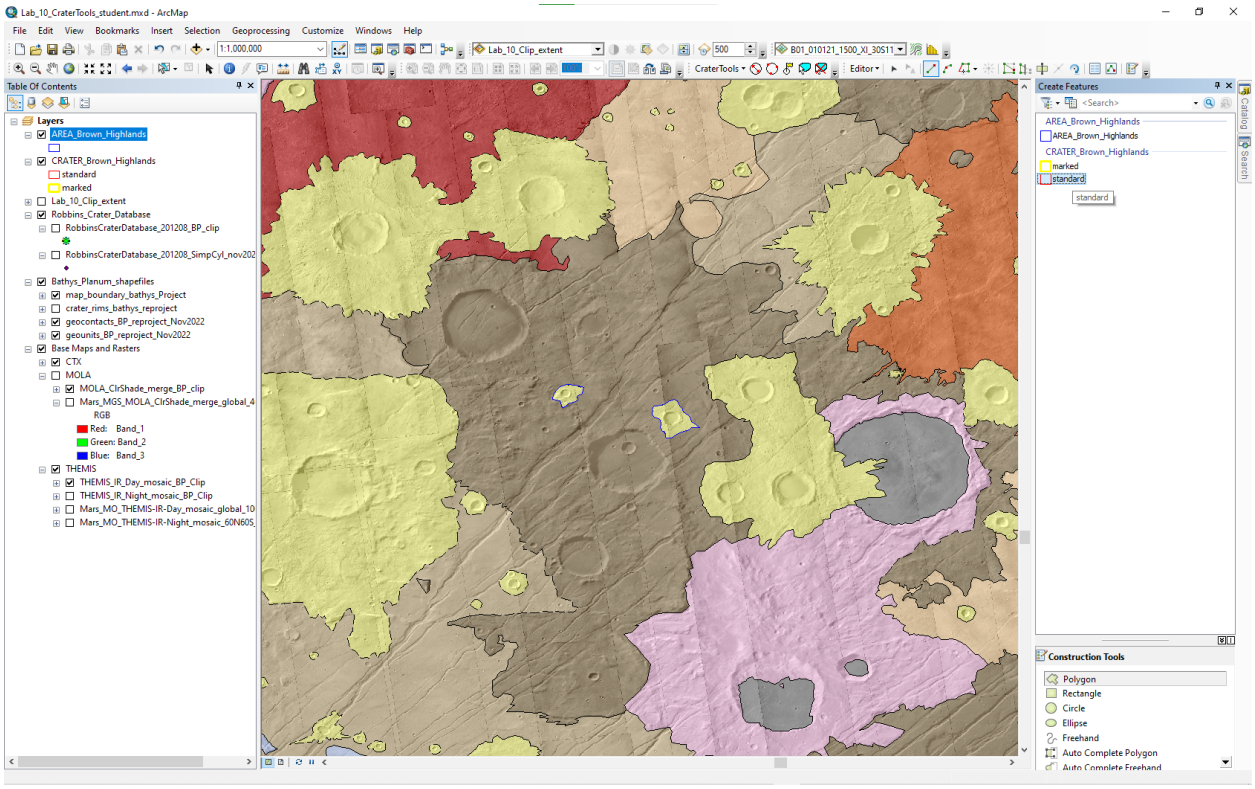


Some of them can get pretty subjective, especially if they are straddling geologic units. Use your best judgement for which ejecta polygons to include.

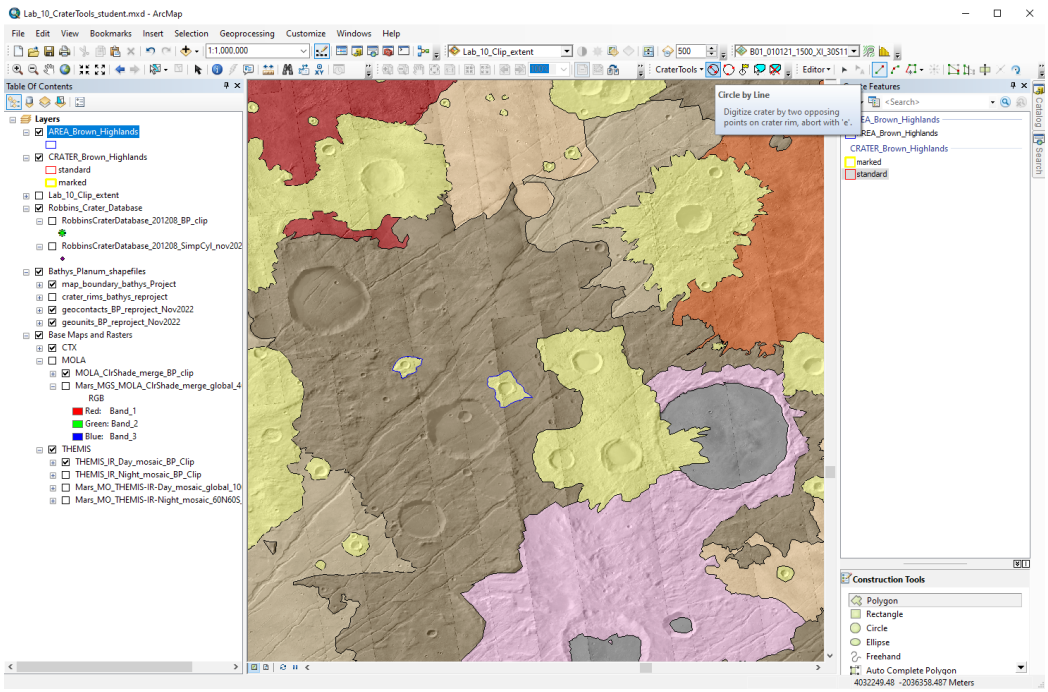
NOTE 2: **SAVE YOUR EDITS OFTEN!** → Do this from the **"Editor"** toolbar menu.



16. After you have traced the inside of **all polygons** for your unit area it's time to **save your edits** and then ***switch your editing tool*** from the AREA polygon to the CRATER polygon. To do this, click to select the **red rectangle** labeled **"standard"** under the **"Create Features"** panel on the right.



17. Now click the **"Circle by Line"** tool in the **CraterTools toolbar**. This is your crater mapping tool!

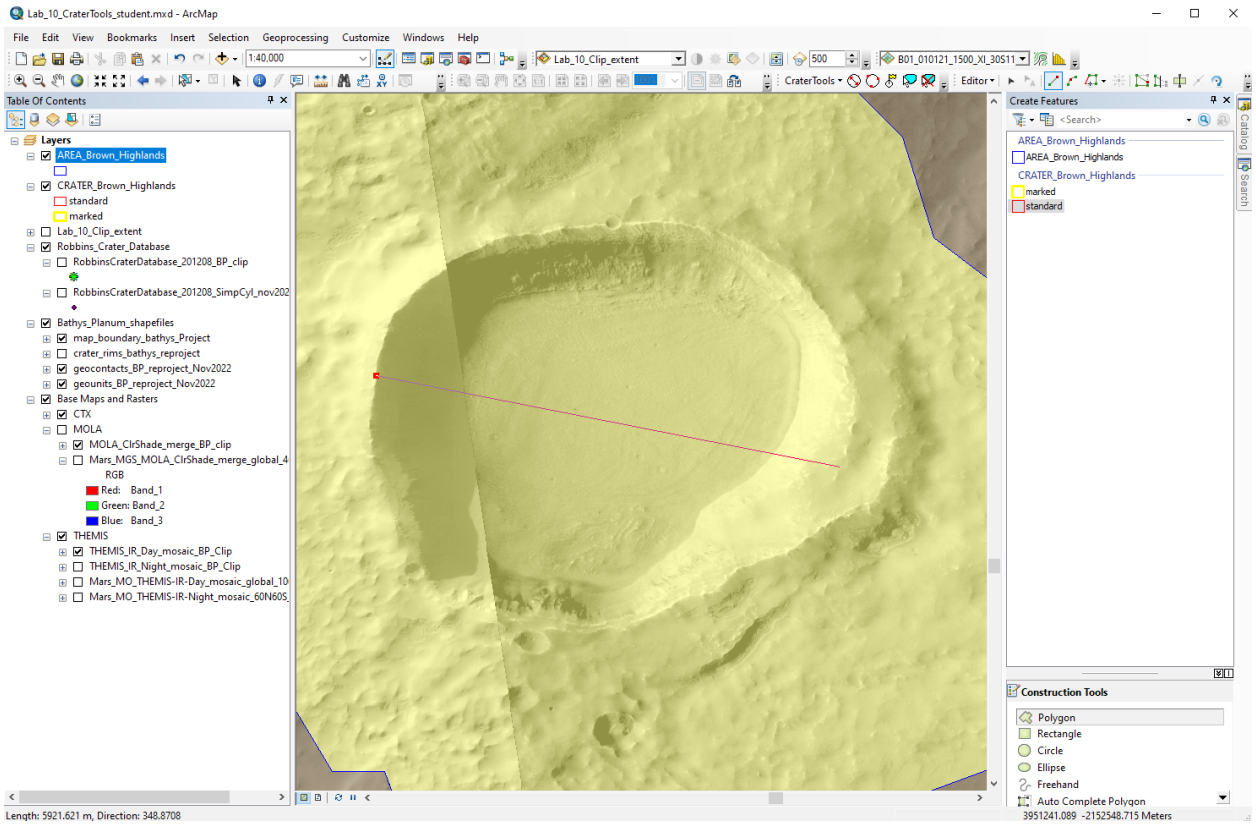


18. Now click anywhere along the **crest** of a crater rim and then **double-click** the point along the rim **exactly opposite** to your first position to set the polygon. The crater is now mapped!

    NOTE 1: There is also the “Circle by Points” tool, but I have had less reliable results from this. You may experiment with it as you wish.

    NOTE 2:

1.


Lab_10_CraterTools_student.mxd - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
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Layers
AREA_Brown_Highlands
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Bathys_Planum_shapefiles
map_boundary_bathys_Project
crater_rims_bathys_reproject
geocontacts_BP_reproject_Nov2022
geounits_BP_reproject_Nov2022
Base Maps and Rasters
CTX
MOLA
MOLA_ClrShade_merge_BP_clip
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
THEMIS
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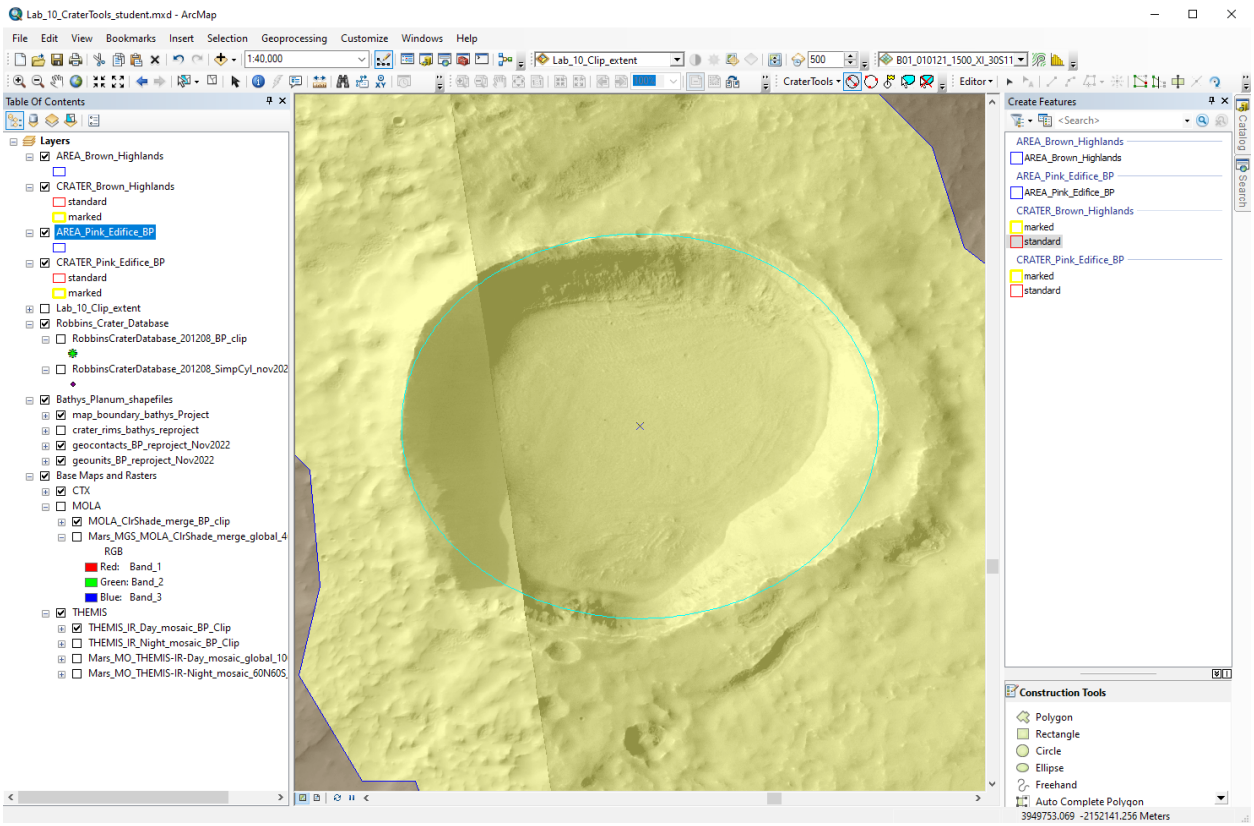
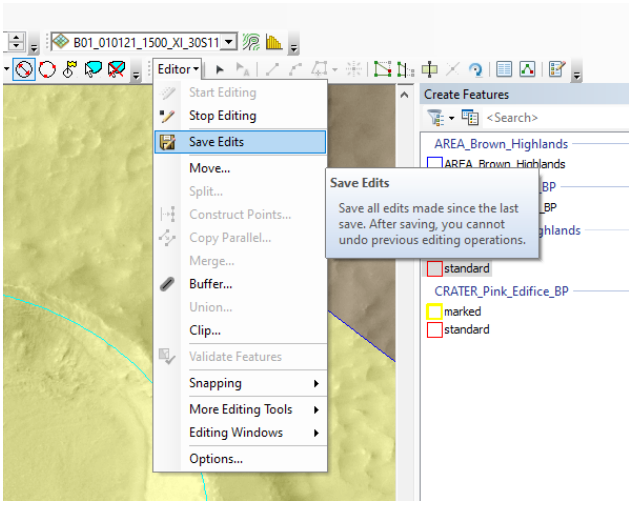
THEMIS_IR_Night_mosaic_BP_Clip
Create Features
AREA_Brown_Highlands
CRATER_Brown_Highlands
marked
standard
Construction Tools
Polygon
Rectangle
Circle
Ellipse
Freehand
Auto Complete Polygon
Length: 5921.621 m, Direction: 348.8708
3951241.089 -2152548.715 Meters

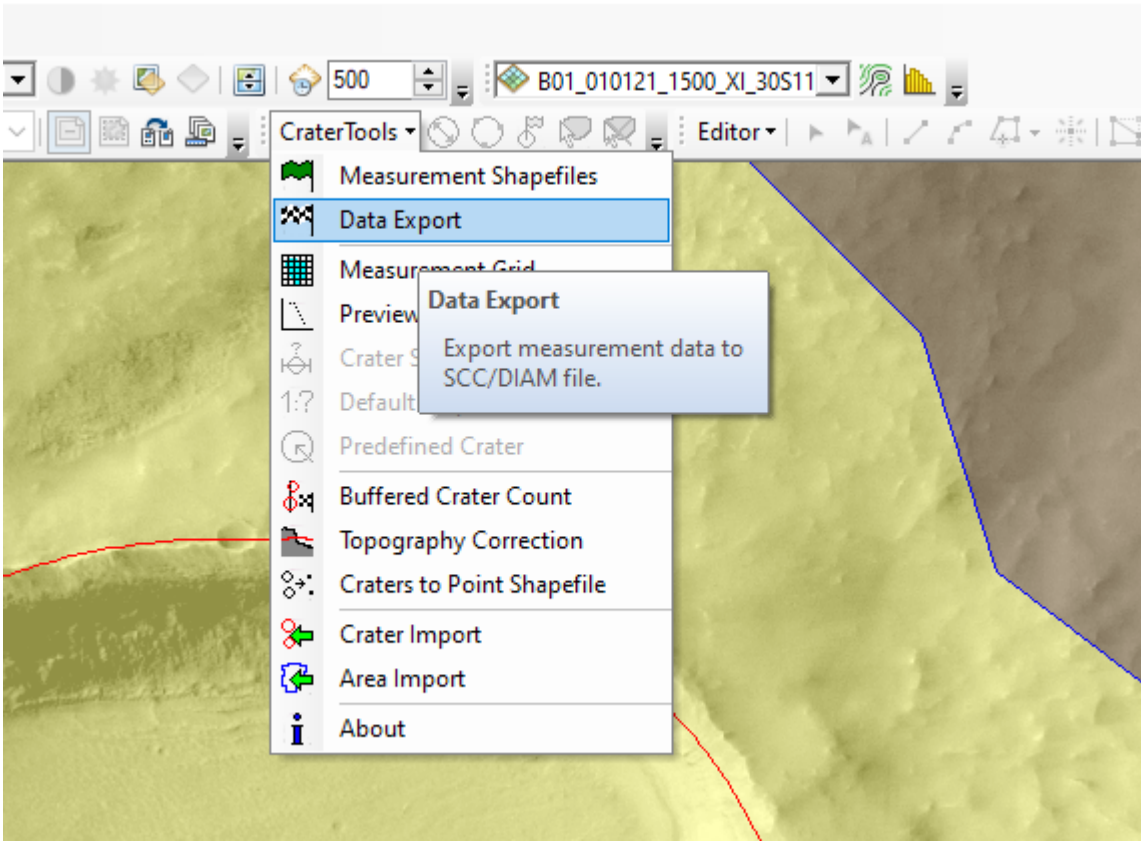
2.



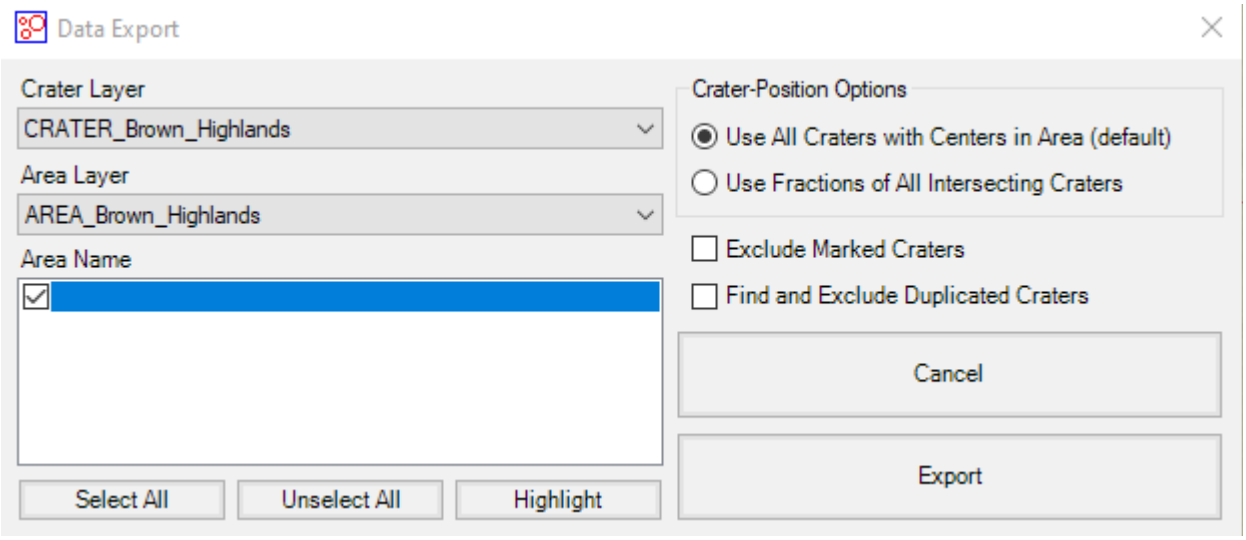
19. Once you have all your craters (1 kilometer diameter and up – use Robbin's database layer to help you find these!) mapped, go up to your **"Editor"** toolbar and click the dropdown menu and **"Save Edits"** then **"Stop Editing."**



20. Now it's time to export your data!
    a. Go to the **CraterTools toolbar** and click the **dropdown menu**.
    b. Click **Data Export** option:



21. The Data Export dialog box opens (See screenshot below). As in the screenshot below, set your **Crater Layer** and **Area Layer** as the two shapefiles you just mapped. **Make sure the check box under Area Name is checked. Now click Export.**



22. A window will pop up asking you **where you would like to save the exported data**.
    a. Create a new folder within your **"GIS Files"** folder and name it **"BP_scc_files."**
    b. Make sure your save prompt is set to put your files into this folder and then **click OK**.

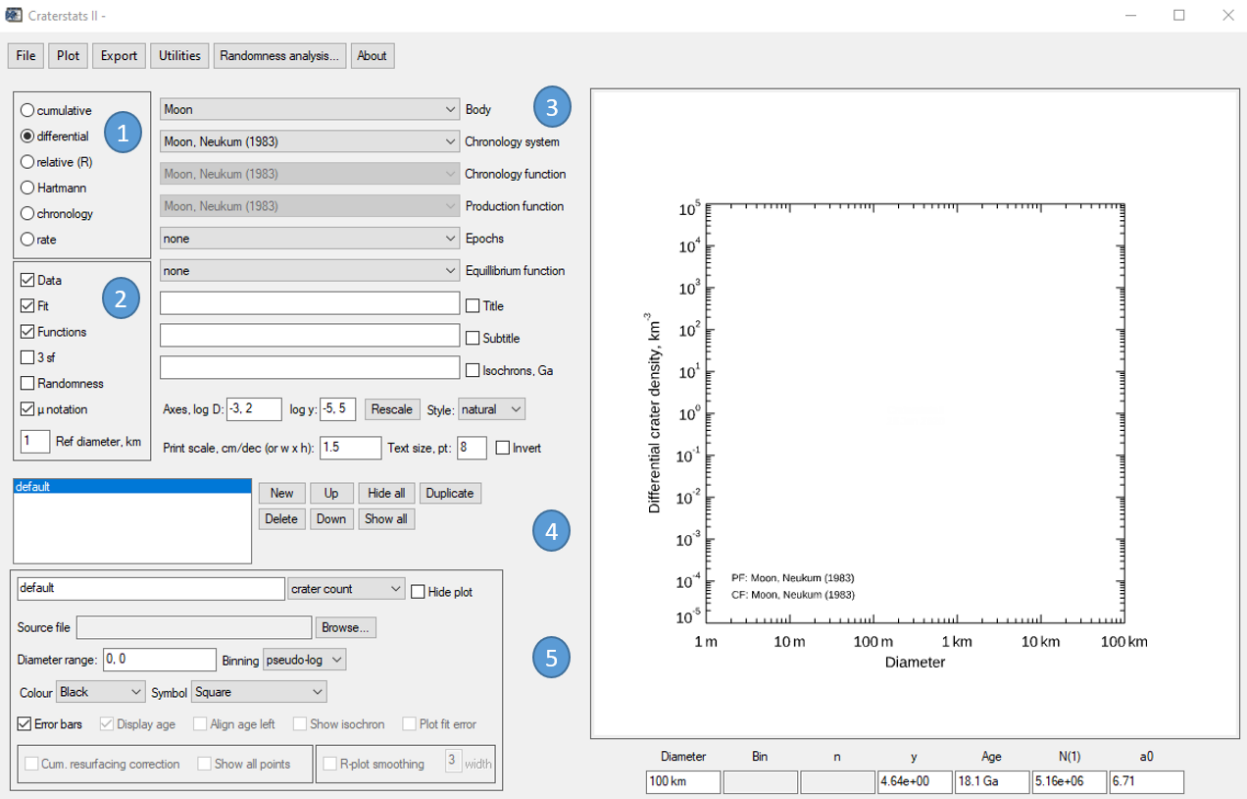
23. We are now done with CraterTools and ArcMap! Now we can switch to CraterStats2 and find out the age of your geologic unit!

CraterStats 2

How to Open and Use CraterStats

CraterStats is a tool that creates the size-frequency diagrams associated with the mapped area, and then maps them to isochrons (like what we did in the previous crater counting lab with Dr. Rodrigue's spreadsheet) to return a modeled crater retention age (how old we are modeling the surface of this unit). You will import data just exported from ArcMap/CraterTools in the above section of this lab. These are in the format of ".scc" files.

1. To open CraterStats, navigate to your **"Lab_10_CraterTools+CraterStats2" →"Software"** folder. You are looking for the **craterstats2.sav** file. Double-click on it when you find it. Craterstats will boot in IDL as we used with the previous elevation profile lab. The following window will open up. This is CraterStats 2.



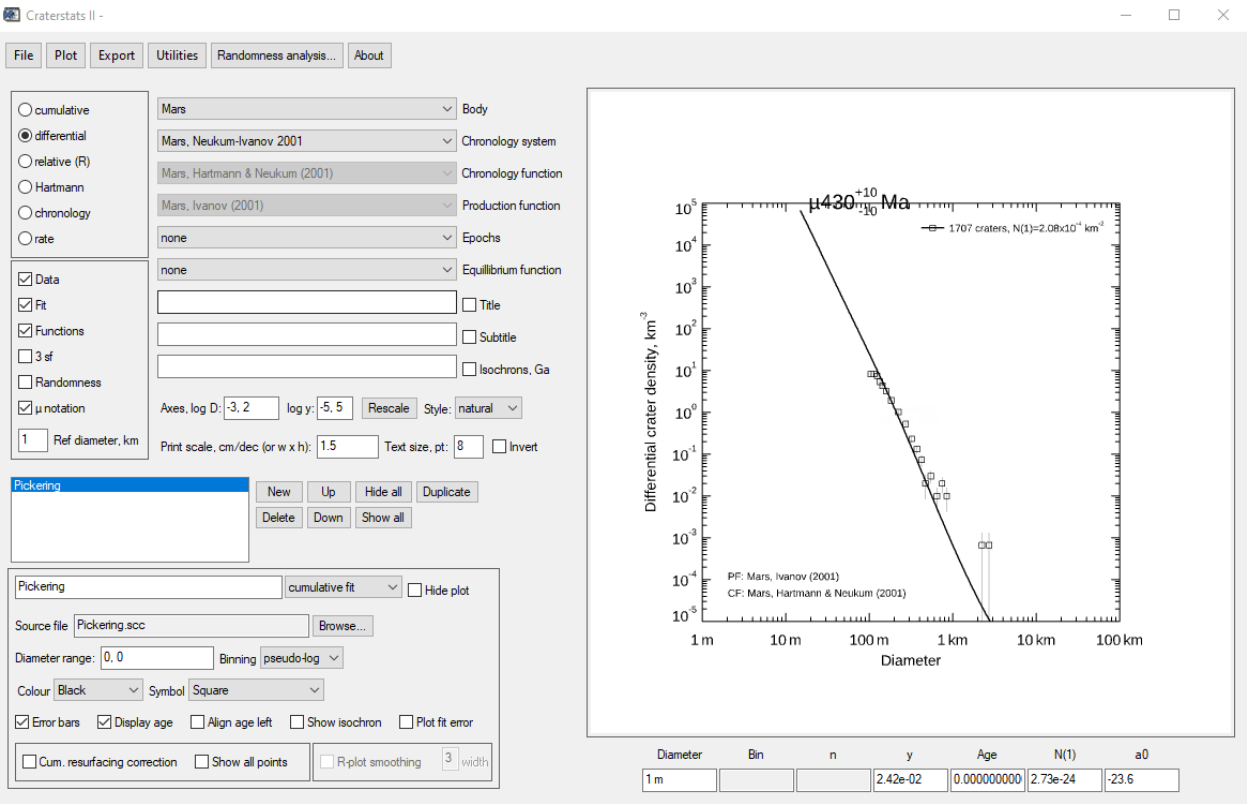
2. Towards the bottom of the screen **(Area 5)**, click **Browse**. Upload your .scc file from where you exported it to after using CraterTools.

3. Change the **Body** (towards the top of the window) **(Area 3)** into **Mars**.

4. In the lower box **(Area 5)**, select the tab that reads **"Crater Count"** and select some other option from the dropdown menu (experiment a bit). The options in this menu will fit a line to the data in the size-frequency diagram at the right side of the screen. A number will also appear on the graph illustrating the age of the isochron to which the data is best fit.

5. In the bottom box **(Area 5)**, change the binning from the default **"pseudo-log"** to the other options and see what happens. *What mathematically changes when you perform this operation?*

The bin area value changes



6. You can change the ***production function*** in the top-left window **(Area 1).** Switch (experiment) between the **cumulative**, **Hartmann**, and **differential** options. *Although each of these graphs contain the same information, they are differently represented in each case. Why is that so?*

They are represented differently because the mathematical function changes

7. In the toolbar at the top, select **Export >> Image** and save your file as a **PNG**. **Submit this file**.
8. In the toolbar at the top, select **File >> Save** and save your **instance of CraterStats as a .PLT file**. **Submit this file**.

Deliverables:

1. A copy of your exported map data from CraterTools
2. Your .png screenshot of your CraterStats2
3. Your .PLT instance file for CraterStats2

4. A copy of these instructions with your responses to the above two questions in their designated boxes.

Extra information:

Recall from the first crater counting lab…

Interpreting your isochron charts

Ideally, all your dots would line up like obedient little ducklings in a line paralleling one of those isochrons. In the real world, you'll see your dots wandering away here and there, especially on the right side (you get crazy **small-sample effects and high uncertainties** among the largest craters).

Something else going on has to do with the lack of homogeneity in your five-degree study areas. These largish study areas typically include **multiple surface units of different ages**. You might have an old highland terrain full of large craters but there may have been newer resurfacing in some areas, such as when a fresh lava flow covers part of the older terrain, a newer hydrological process eroded one surface and deposited materials on another, a landslide fell in an old canyon, or whatever. You can use this spreadsheet on smaller units (if you remember to adjust everything in Cells V105 forward), but that imports another problem. As your study area shrinks, your cell frequency counts do, too, and that can result in small sample effects and high uncertainties! Danged if you do and danged if you don't! But crater-counting is IT for constraining, at least loosely, surface ages until some day samples of Mars "stuff" can be brought back to Earth and radiometrically dated and all the crater counts recalibrated with actual martian data.

So, to interpret your crater counts, focus only on the left side of the distribution, the larger counts in smaller size bins. It's safest to **focus on the range from about 1 km up to maybe 16 km** (about the length of that thick, short isochron marking the transition from the Noachian to the Hesperian a bit before 3.5 billion years ago. Focussing just on that, about how old is the bulk of your study area? Compare the nearest isochrons in the vicinity of your small-diameter bin counts to constrain the age range in your study area.

What your graph shows is the famous **magnitude-frequency** curve seen in many natural (and sociogenic) hazards, such as flooding, earthquakes, volcanic eruptions, industrial toxic release accidents. And this includes the hazard of extraterrestrial bolides hitting Earth, too!