Lab 6: Martian Chronology
Crater Counting

A PDF of the lab report must be uploaded to Gradescope by 10 am on Tuesday, March 22, 2022 – this is after spring break (see submission instructions on Brightspace, and check Brightspace for due date updates).

Setup

Back on your lab computer, navigate to your home directory from the icon on the Desktop, and create a working directory for the lab called lab06 in your EAPS577 folder. *Remember to keep an eye on your free space in your home directory* – you can always move old lab files to OneDrive, or delete the original image files that are easy to re-download.

Download all of the files for the lab from this folder into your working directory (remember that unzipping is much faster in the downloads folder before you move the files): https://www.dropbox.com/sh/tasrdcang0vfj5h/AAD443rLkZejML8VLdjk3nRUa?dl=0

There are two key documents for this lab - this document gives instructions for the lab, but make sure to also fill out the lab report. You should open and edit this file and write your answers in all the indicated areas.

Lab Goals

In this lab, you'll estimate model ages for resurfacing in three specific regions on Mars in order to gain experience with counting craters and constructing crater chronologies. You'll also get an intro to JMARS , an example of Geographic Information System (GIS) software, which you could use for the your class project.

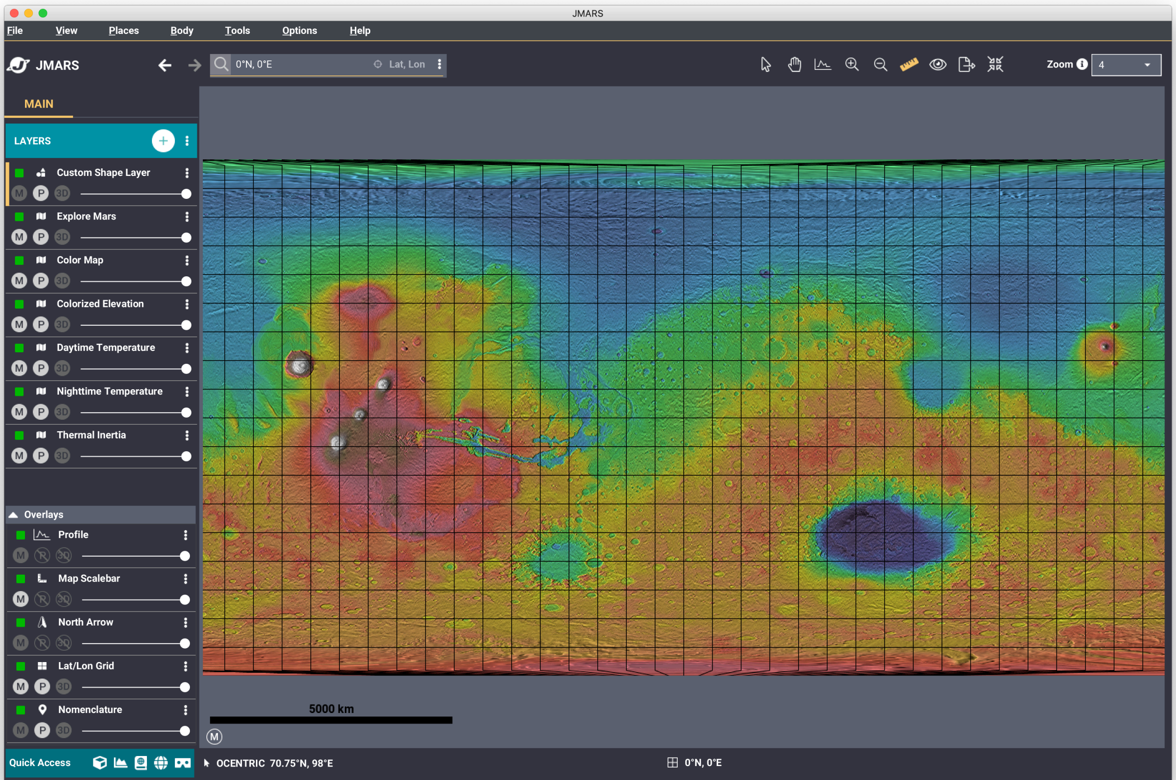
Background

On planetary surfaces, quantitative age dating is estimated using crater densities. This approach has many potential pitfalls, as we discussed in class, but it's still the best we have. For Mars, this is extra tough because the chronology is translated from the Moon, with some very large assumptions. On Mars, we have exactly one date with which to test these results – Mars Science Laboratory dated sediment assumed to be sourced from within the Gale Crater ejecta blanket or rim to 4.21 +/- 0.35 billion years – not very accurate! Gale Crater is assumed to be Late Noachian in age based on crater densities, which typically is assumed to end sometime between 3.74-3.5 billion years ago (note the discrepancy…). With all this in mind, let's do the best job we can at estimating ages for some typical surfaces on Mars.

JMARS introduction

For a few labs in this course, you'll be working with JMARS (Java Mission-planning and Analysis for Remote Sensing). It is an open source and free geospatial information system (GIS) developed by ASU's Mars Space Flight Facility to provide mission planning and data-analysis tools to NASA scientists, instrument team members, students of all ages and the general public. JMARS provides online viewing and analysis of all NASA and many other satellite datasets. JMARS was originally developed for Mars, but now supports data from most solar system bodies (including Earth). You can download JMARS onto your personal computer (http://jmars.mars.asu.edu) if you would like to work on this lab at home.

Open JMARS: JMARS has been installed on the lab computers, but you could also do this part of the lab on your own computer. On the lab computers, open JMARS by searching for it in the Windows search bar. Make sure that the Body is set to Mars.



<u>The JMARS interface</u>

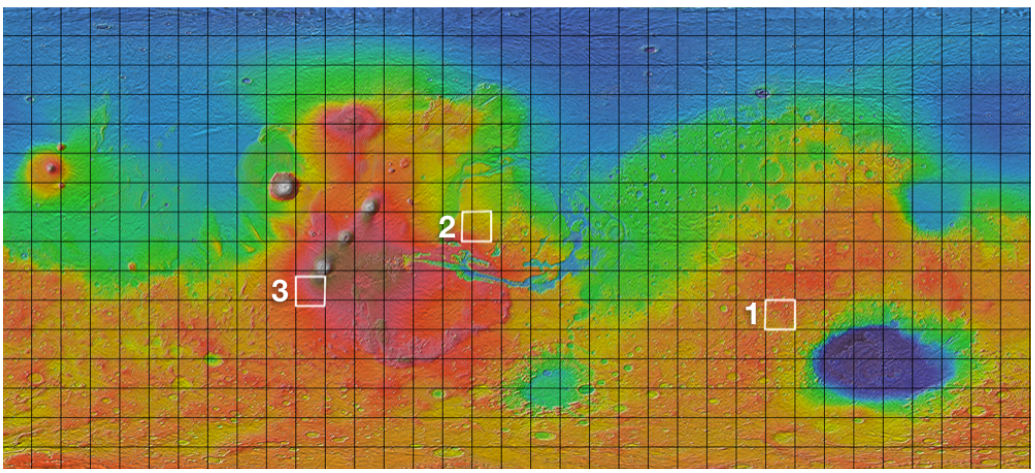
Familiarize yourself with the JMARS layout, as shown above. The right panel shows the map view. Initially, you should see a low resolution basemap (Clementine UVVIS) with a latitude/longitude grid and crater names labeled (Nomenclature). These are all separate layers that you can turn on and off in the left panel by clicking the "M" button on the layer. (The "P" button turns them on and off in the regional panner view, which you can turn on from the view menu). You can change the opacity of a layer by moving the circle along the bar below the layer name. The order of the layer list corresponds to how the layers are stacked in the scene. Try dragging the layers up and down in the main layer tab to change the order that they're displayed in on the map view.

The toolbar above the map view has several options for how you can interact with the map. The selection mode (the arrow) allows you to select and deselect data products. The pan mode (hand) allows you to drag the map around for easy navigation. The zoom modes allow you to zoom in and out on specific locations, and the ruler allows you to measure distances on the surface (left click and hold to draw a line, and the measurement is shown in the info bar on the bottom). In any mode, you can right-click inside of the map view to bring up a simple navigation menu. You can also select the zoom level from the menu in the upper right corner.

Step 1: Add datasets

Load images: Add new layer -> Search for MOLA color over THEMIS Day. This is a global daytime infrared mosaic (great at showing texture! Remember why?) colorized using elevation, where blue is low and red is high. This is similar to the default map but higher resolution.

Load the counting areas: Add new layer -> Scroll down to custom shape layer. Double click on the shape layer, and make sure that you're on the adjustments tab. File -> Open -> navigate to your lab folder and select counting_areas.csv. Zoom out so that you can see where all three boxes are, and then zoom in on area 1 as labeled below. Zoom to 128 ppd (as shown in the upper right), and stay at this ppd while you count craters for consistency.



Take a look at the area: Describe the geology of the boxed area to the best of your ability. Do you see evidence for modification of craters here (infill, erosion, ghost craters, tectonic disruption, etc.)? Do you see any evidence for a change in age of the surface across the area, and if so, how can you tell? [Q1a-c]

Step 2: Count craters

Load the crater counting tool layer: Add new layer -> Scroll down to Crater Counting.

Count craters! Make sure you have the arrow tool selected, and hover over your area at 128ppd resolution. The arrow should be surrounded by a circle that says "100 km". This is the default starting size for craters. Scroll with the mouse wheel to change the crater size. Find a crater in the scene that is approximately that size and adjust the size of the circle to match. Click to place the crater. Repeat this for *all craters 30 km and larger in the scene, that have at least 50% of their area inside of the box*. If you make a mistake, you can right click to remove the last crater. You can also change the mode to select, which allows you to move and resize existing craters.

Change the increment size: For smaller craters, we want to be a little more precise. Double click on the crater counting layer, and select the Settings tab at the bottom. You can change the default starting crater size and the increment by which the crater size changes. Change this to 100 m (each tick of a mouse wheel is 10x this). *Now place circles for all craters larger than 8 km in the scene.* For the next two areas, we'll go down to 4 km, but there are enough craters here than 8 km is fine. Feel free to go back and adjust previous craters. Once you think you're done, make sure to doublecheck that you didn't miss any craters – you normally will miss a few that won't be obvious until everything else is selected.

Save your data: On the craters tab, select the Export CSV button, and save the file to your working directory as area1.csv (you can load this again later into JMARS if needed). Then click the Export Craterstats button and save the file to your working directory as area1.diam.

Paste a screenshot of your counted area with the craters on it into your report. [Q1d]

Step 3: Determine the crater rention age

Now we'll use the crater diameter data that you've collected to determine some ages. You have two options for this step: (A) Use the craterstats tool, (B) Use a spreadsheet and plot the results manually. Choose your own adventure below!

→ OPTION A: Use the craterstats tool

This is a tool written in IDL that can take the JMARS output and plot it for you. This is a nice way to go as the plot will be much more accurate than in option B, but sometimes the software (or IDL) are a little tricky. Note that this requires the use of the IDL virtual machine (should come installed with IDL), and that this cannot be run using the Citrix remote software.

Install craterstats 2: Download the zip file and unzip it to your working directory. You can download from either the dropbox folder for the lab:
https://www.dropbox.com/s/wumnl2b83bbdjq1/craterstats2.zip?dl=0
Or the Craterstats website:
http://hrscview.fu-berlin.de/mex4/software/craterstats2/craterstats2.zip

The original website is here:
https://www.geo.fu-berlin.de/en/geol/fachrichtungen/planet/software/index.html

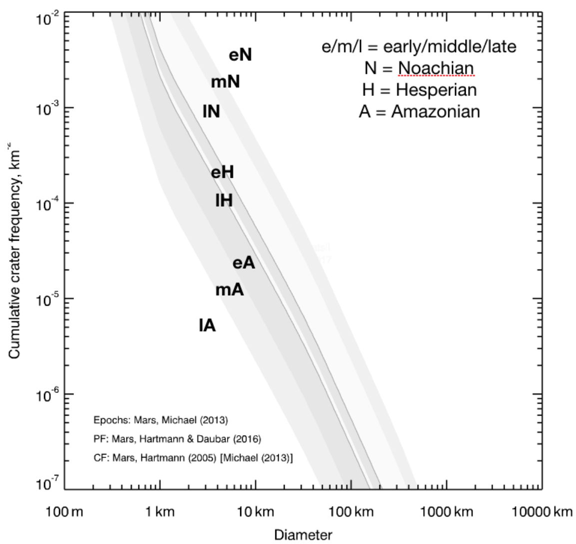
Open craterstats2: In the file explorer, navigate to the folder where you installed craterstats, and then double click on ***craterstats2.sav***. It should open in IDL. If you run this program on your own Mac or Linux computer, you'll need to open it at the terminal command line – see the readme.txt file in the folder for instructions.

Set up the software: In the upper middle, change the Body menu to Mars and the Chronology System to Mars, Hartmann & Daubar (2016). In the box at the lower left, click the Browse button, change the filter to *.diam, and open up your area1.diam file. The data should appear on the plot.

Clean up the plot: Change the symbols to be a filled in shape with a distinct color. In the middle of the interface, hit the Rescale button to zoom in. You can turn off the randomness and mu notation buttons on the far left to clean up the plot.

Try to fit your data: If you hover over the plot, the readout on the bottom will provide info on that location, including the age that would be inferred for a data point at that location. Use this to make a quick estimate for your data. Then, enter this number in billions of years in the Isochrons box in the middle, and select the button to the right to turn on this isochron. A line of the production function for that age will appear on the plot. Adjust to number as needed to best fit your data. Should you be trying to fit all of the points, or do some matter more than others?

A better way to look at the ages is to try to determine the min and max ages that fit the data. Note that you can put more than one age in the isochron field, if you separate them with a comma. Check these ages against Mars eras by changing the Epochs field to Mars, Michael (2013), where the shaded areas correspond to the eras shown at right.

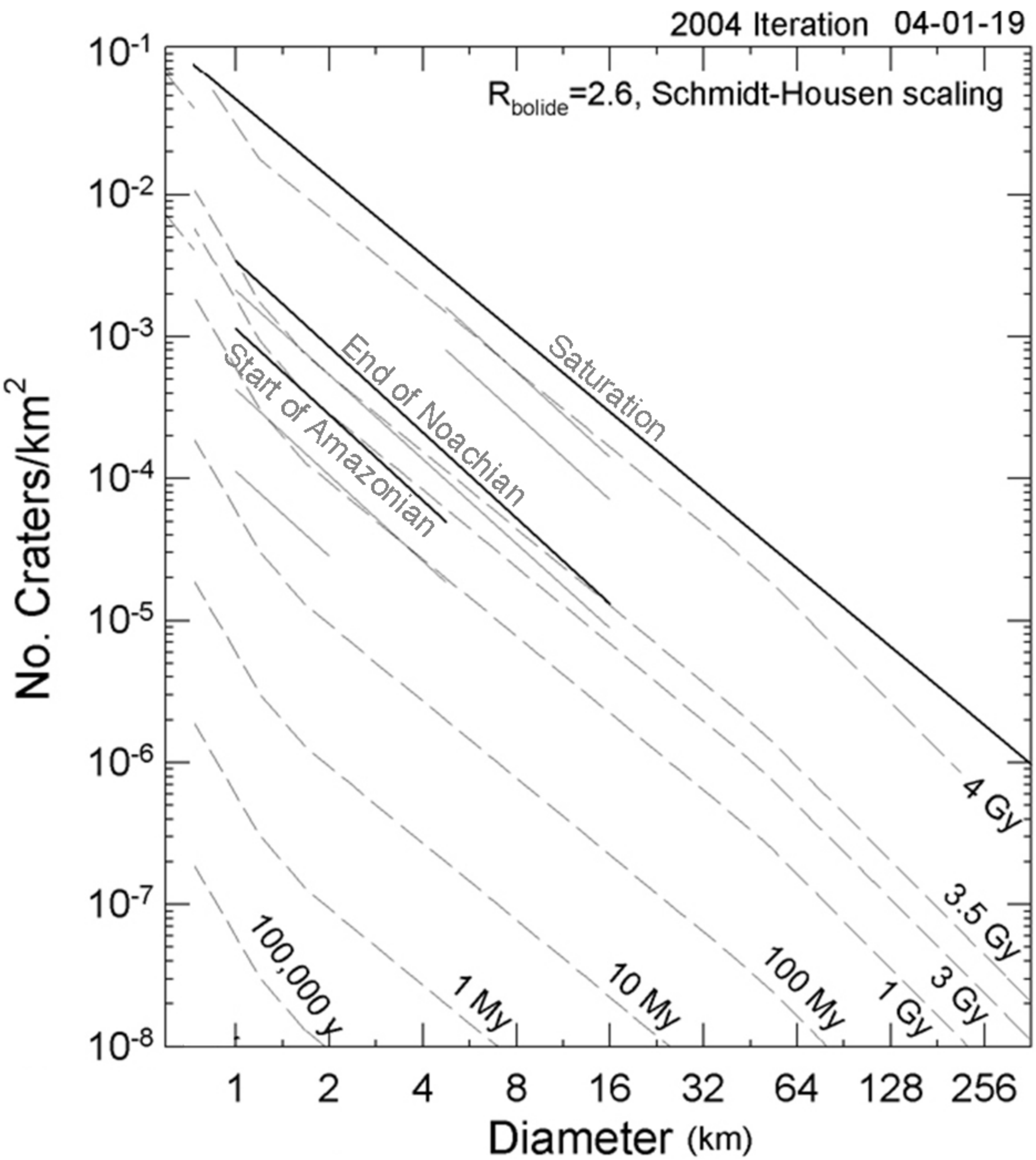


→ OPTION B: Use a spreadsheet and manually plot to determine ages
I've provided a simple spreadsheet that you can load your crater data into and that will bin your crater sizes for you (crater_bins_hartmann.xslx), after which you can create the plot yourself.

Copy the data: Open this spreadsheet in Excel or Google Spreadsheet along with your crater CSV file from JMARS. Copy your crater data and paste it into the crater bins sheet. This sheet should automatically calculate crater density in "Number of craters/km^2", with crater sizes binned as in the plot below.

Make the plot: Take the numbers in the "Average for plotting (km)" and "TOTAL/sq km" rows and plot them on the plot below (I did this by copying and pasting the image onto a slide and adding points for my data). Take a moment to remember how to plot on a log scale: $3\text{x}10^{-5}$ is the second tick mark *above* 10^{-5}. This plot is based on the Hartmann (2004) chronology functions for Mars, and is also available as an image in the dropbox folder.

Find the age: Now try to fit a line to your points, with approximately the same slope as the dashed age lines (isochrons) that are on the plot. The data from the largest craters is the most reliable, so if your data doesn't make one obvious trend, bias your line toward those points. Then use the position of the line relative to the isochrons to estimate the age. Can you get a better answer if you bracket the data using two lines? This will give you a range of plausible ages.



→Adventure complete, back to the report.

Paste a screenshot of your plot produced using either method, including your best fit lines, into your lab report. [Q2a]

What best fit age did you determine for the surface? What range of ages would be plausible for your data? That is, for each surface, what are the oldest and youngest ages that fit your data? Be quantitative (i.e. ± 1 billion years). What geologic epoch does your age estimate assign to this data? [Q2b-e]

Evaluate your fit: Is there any evidence for surface modification/resurfacing in the shape of the trend? What do you believe was your greatest source(s) of error for the uncertainties in the ages? Things to think about: Did you observe any really degraded craters, and did you end up including them in your count? Were you able to accurately count down to ~8 km? Please be as specific and as quantitative as possible. [Please note that the following are not adequate explanations: human error, bad eyesight, classmates talking, etc.] [Q3]

Do it again: Repeat this analysis for the other two boxes, and answer the same questions for each (don't worry, the other two have far fewer craters). Don't forget to clear out your crater counts in JMARS each time after you save them. *Note: for areas 2 and 3, you should extend your crater counts down to 4 km diameter.* [Q4 through Q9]

Wrap up: Which of the areas you examined gave you the least precise date and why? Use the plot of crater frequency versus age of the surface below to explain your answer. Imagine you get to choose one surface with a specific crater density to try to quantify the ages more precisely using radiometric age dating. Again using the plot, which era would be most useful to sample to pin down the ages and why? [Q10]