Prospectus First Draft for Final Report

Title: *Inspecting Mars Geomorphology with Implications of Yardangs/Lineaments and Mineralogy in Fluvial Networks using GIS and Python*
Notice: Dr. Bryan Runck
Author: Alexander Danielson
Date: 11/09/2022

Project Repository: *https://github.com/ardumn/GIS5571/tree/main/Project*
Google Drive Link: *N/A*
Time Spent: 8 hours

Abstract

The basis of this project is to find geological implications derived from lineaments of linear surface features and yardangs from elongated eroded gullies and hull-shaped abrasions or wind-arced shapes. From these findings, the deterministic analysis applied from drainage and fluvial processes will confirm if these are geologically significant or implicate the geomorphology of Mars and how they are related to that of Earth qualitatively. Including how mineralogy impacts streams on a hydrological level. The data used will be from many years of Mars missions that orbited around the red planet from Viking, Mars Global Surveyor, and to that Context Camera and HiRISE, and CRISM. Each of these has variable spatial resolutions and vast parts of the electromagnetic spectrum to depict geological features and phenomena. The systematic plan will derive a computational framework and develop a fluvial model from the digitization of lineaments and yardangs, the result from abrasions, erosion, and wind inflicting on the landscape and altering/bending topological features. The expectations are to ultimately see if the extra variable of yardangs and lineaments can influence geomorphology and have a significant influence and will use extra quantitative methods to see so as well.

Problem Statement

The main idea is to build on lineament lines of geological origin from prior work and confirm if they are of geological origin in the Tharsis Mons region in addition to yardangs and mineralogy for deeper and wider research implications. This region is highlighted the cause of the active plume and subduction that occurred during past historical geological periods (Danielson, slide 7) Added variables to be included in the project are 1. Yardangs, like that of lineaments, are eroded linear geological lines that are eroded by wind through abrasions and have parallel troughs/ridges which depict the direction of it is going. Yardangs are predominantly concentrated around the Tharsis region and transitional region in northern lowland and southern highland and enclosed volcanos (Near Olympus Mons) (Liu J, et al. pg. 5). 2. Deeper Fluvial influence/modeling, create a model like that from the previous study, except factoring in mineralogy and how it influences hydrological sinuosity along yardangs effect on subsurface phenomena and lineaments with slope, aspect, and hillshade. 3. Find evidence that geology (faulting and fractures) influences the yardangs and lineaments of Mars and juxtaposed them to Earth with an overlay of suitability and sensitivity analysis. (All to be processed with ArcGIS Pro and Arcpy (side-by-side, fluvial modeling and tabulating Juypter Notebooks of three image products for study area)

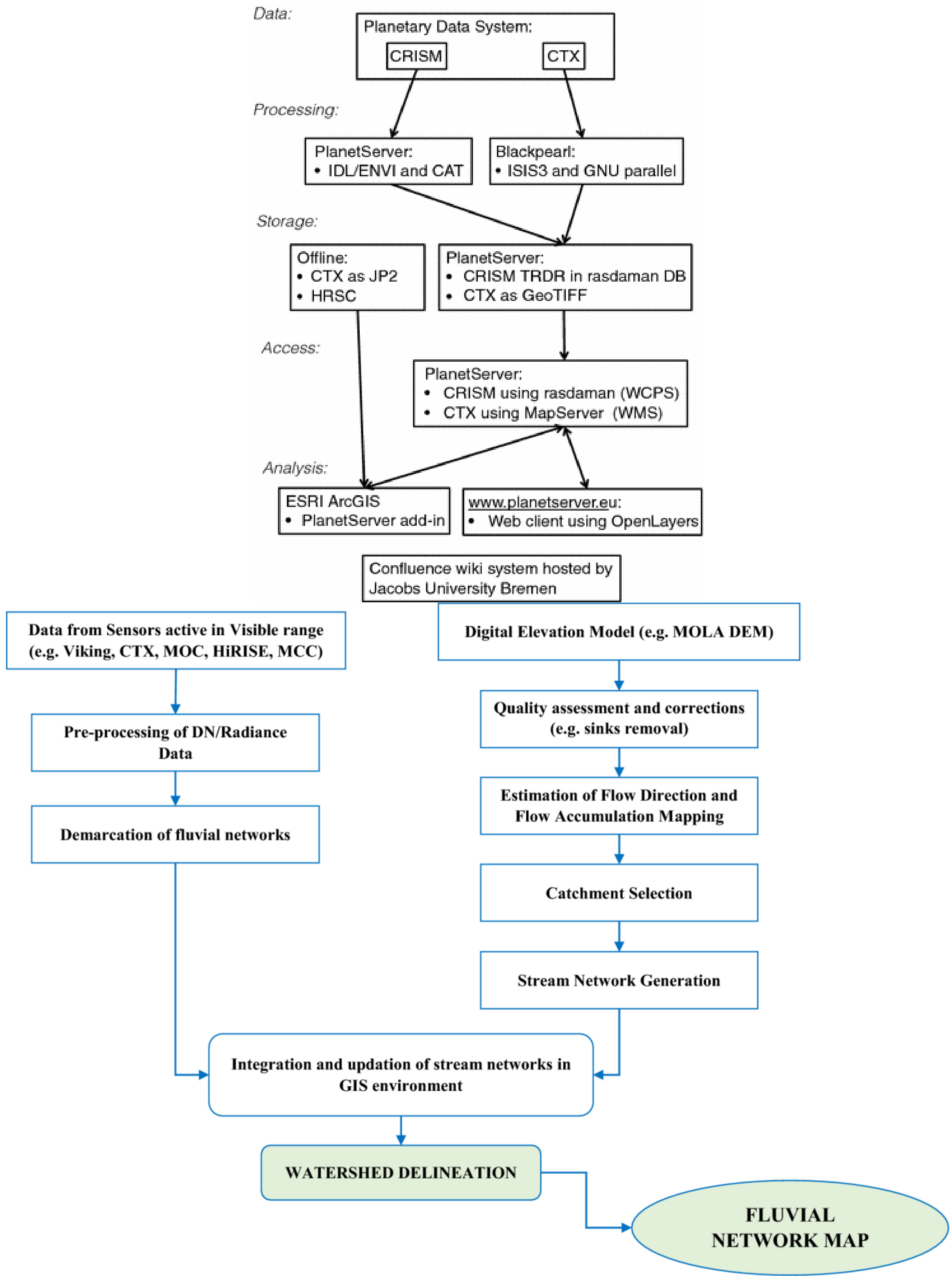

Figure 1 + 2. (Oosthoek and Rossi) A rough conceptual context map/model for the workflow of the project (with different semantics implemented based on problem statement). (Rangarajan, et. al) A conceptual model depicting steps taken for the supposed model of drainage networks and fluvial processes. Inspiration for the project carried into the methodology and reviewed for literature.

#	Requirement	Defined As	(Spatial) Data	Attribute Data	Dataset	Preparation
1	Mars Orbiter Laser Altimeter (MOLA) instrument dataset (apart of Mars Global Surveyor)	Shaded relief derived from altimetry.	Raster/Imagery	Pixel/Cells	Mars	None/Geoprocessing for Yardings and justifications for fluvial processes in geological evidence in that of Earth
2	Viking Merged Color Mosaic	Viking Color Mosaic sharped with MDIM 1.0.	Raster/Imagery	Pixel/Cells	Mars	None/Geoprocessing for Yardings and justifications for fluvial processes in geological evidence in that of Earth
3	Mars Orbiter Laser Altimeter (MOLA) Minerals: Feldspar, Quartz, Olivine	Each unique for specific mineral showing concertation	Raster/Imagery	Pixel/Cells	Mars	None/Geoprocessing for Yardings and justifications for fluvial processes in geological evidence in that of Earth
4	Context Camera (CTX)*	CTX (Context Camera) makes observations simultaneously with high-resolution images collected by HiRISE and data collected by the mineral-finding CRISM spectrometer.	Raster/Imagery	Pixel/Cells	NASA	Lengthy process of acquiring/pre-processing data and must be mosaiced together (see Github reference. HiRISE data comes in JP2 format, so must be converted to GeoTIFF in programming cycle.
5	CRISM (Compact Reconnaissance Imaging Spectrometer for Mars)*	To study active surface processes and landscape evolution.	Raster/Imagery	Pixel/Cells	NASA	Same processes as those of CTXs, must be performed for CRISM imagery.

Table 1. List of Mars Data sources that serve as a precursor to setting up a model for processing 1. ArcGIS Pro and ArcPy: with comparison of CTX and CRISM image datasets for analysis of possible Yardang sites and imagery (if not deciphered from MOLA imagery). 2. Fluvial construction: Using the same tools from ArcGIS Pro and ArcPy to make a Fluvial model and possibly simulate the factors of wind, abrasion, and erosion for Yardangs (or separate one). 3. Juypter Notebooks: Use three imagery tools (slope, aspect, and hillshade) to be created and digitize Yardangs and lineaments in Tharsis regions.
**CTX and CRISM have no georeferenced imagery (no TIFFS) but will still be used for comparison and analysis.*

Input Data

In comparing all the spectral resolutions of each satellite, the VIKING would be the poorest and inadequate but is still reputable and a good general reference for viewing a small scale or the general world of Mars itself. Viking paved the way for higher spectral, radiometric, and magnet telescopes, and satellite technology such as the Mars Orbiter Laser, which lasted almost a decade in space, and will be used as the main dataset in this study if CTX and CRISM cannot be pre-processed effectively. MOLA prior also could read a wide gamut of electromagnetic spectrums such as infrared/gamma from THEMIS (Thermal Emission Imaging System) and TES (Thermal Emission Spectrometer. These aren't necessarily needed for the analysis because the lineaments and yardangs are decipherable in the visible spectrum, and the other geoprocessing products are adequate to able to see them as well. CTX and CRISM products are more modern satellite and higher resolution data products up to almost six pixels per inch or 1 meter and would be more effective in deciphering those less prominent or microscopic features. *(Although* *sources presented are not geo rectified, but can still be assessed for comparison of extreme details for certain features, abrasions, gullies, mounds, etc. In this case, creating Areas of interest (AOIs from Liu J et al.s study to assess certain areas of interest could be a placeholder for CTX and CRISM imagery).*

#	Title	Purpose in Analysis	Link to Source
1	Mars Orbiter Laser Altimeter (MOLA) dataset	Back-up general spectral imagery for deciphering lineaments and yardangs in the Martian surface.	MARS Global Data Sets
2	Viking Merged Color Mosaic	Back-up general spectral imagery for deciphering lineaments and yardangs in the Martian surface.	MARS Global Data Sets
3	Context Camera (CTX)	Higher-resolution imagery which will be attempted to be utilized for the project to decipher lineaments and yardangs.	https://ode.rsl.wustl.edu/mars/
4	CRISM (Compact Reconnaissance Imaging Spectrometer for Mars)	Higher-resolution imagery which will be attempted to be utilized for the project to decipher lineaments and yardangs. (with different application and processes used)	http://crism-map.jhuapl.edu/
5	Mars Streams	Used for Stream Extraction and processing.	N/A

Table 2. Data listing as each data source builds on each other from previous satellite launches to Mars from NASA missions from the Mars Global Surveyor to Mars Orbiter Mission. From technological innovations to resolution enhancement in each iteration of telescopes, sensors and gamut of sending and receiving data.

Methods

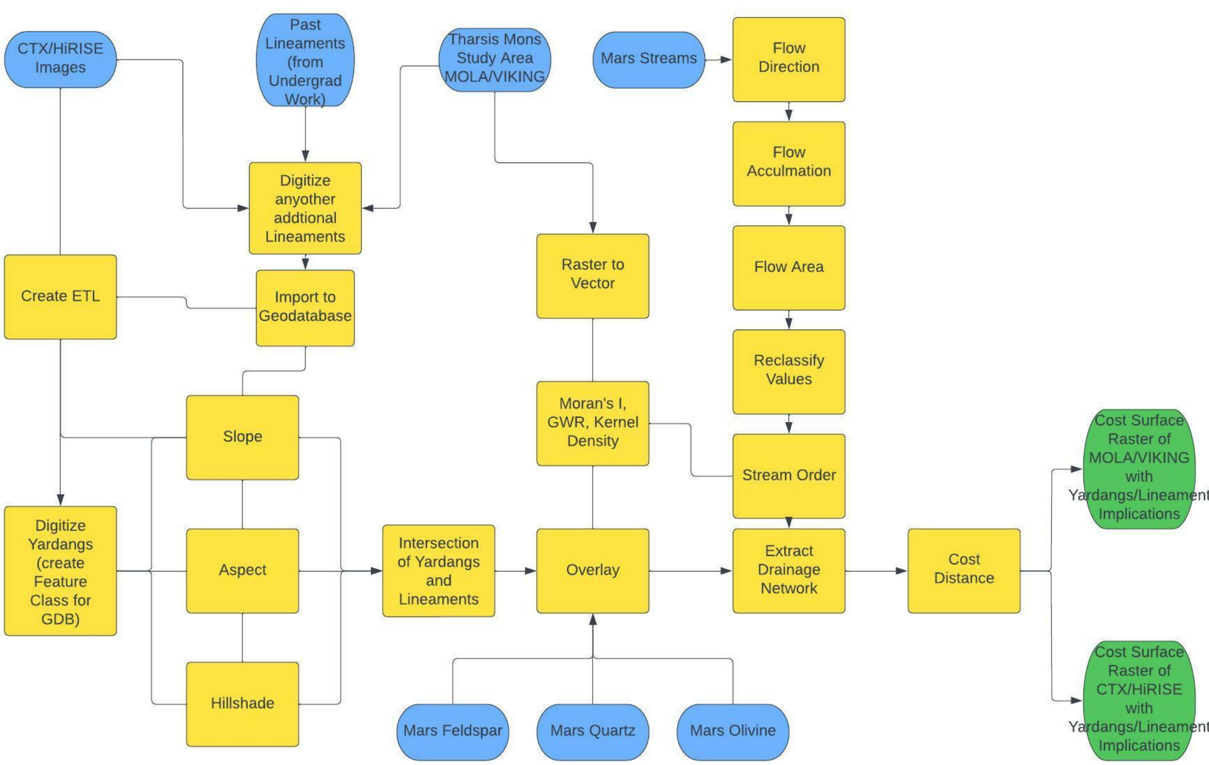

Figure 2. Data flow model used for enumeration of imagery and ETL to display, manual digitization of each suitable analysis done and then perform cost analysis.

1. Create an ETL for each CTX/HIRISE and CRISM image of interest and digitized Lineament/Yardang
2. Create initial study boundary that has supplemental lineaments and yardangs for comparison and or CTX/CRISM AOI (Tharsis Volcanic area already good pre-defined area based on recent study).
3. Replicate data flow steps using ArcGIS Pro, ArcPy, and Jupyter Notebooks for geological influences and conformation.
4. Plot data from MarsProject_AD Script from Principles of Geocomputing for view-by-view exploratory analysis of geological features of Earth and Mars.
5. Rerun model for Sensitivity analysis of Overlay and Cost Surface.

Necessary Modules Needed to Import Data and Setting ArcGIS Environment (Working Directory)

```
In [4]: import arcpy # Useful and productive way to perform geographic data analysis, data conversion, data management,
        import os # Provides a portable way of using operating system dependent functionality
        import io # Using different input/output systems
        import requests # Allows you to send HTTP requests
```

```
In [5]: arcpy.env.workspace # Parameterizes the workspace for data to be outputted with ArcPy
Out[5]: 'C:\\Users\\Alexander Danielson\\Desktop\\Fall 2022Spring2023\\ArcGIS I\\FinalProject\\FinalProject\\Default.gdb'
```

```
In [6]: Working_Directory = r'C:\Users\Alexander Danielson\Desktop\Fall 2022Spring2023\ArcGIS I\FinalProject\FinalProject' # Assigning directory.
```

ETL For CTX/HiRISE Swaths of Interested Geology

Extraction of CTX/HiRISE Images

First CTX Image

```
In [13]: CTX_DataPageI = r'http://viewer.mars.asu.edu/planetview/inst/ctx/B19_017188_1768_XN_03S097W#P=B19_017188_1768_XN_03S097W&T=2'
         # Assign variable to data page for first CTX raster in data comparison analysis.
```

```
In [14]: CTX_Image_I = r'http://pds-imaging.jpl.nasa.gov/data/mro/mars_reconnaissance_orbiter/ctx/mrox_1069/data/B19_017188_1768_XN_03S097W.IMG'
         # Assign variable to TIFF file for download.
```

```
In [17]: CTX_OBJI = requests.post(CTX_Image_I)
         CTX_OBJI
         # Sending a post request to TIFF file download and getting a valid reponse back.
Out[17]: <Response [200]>
```

```
In [18]: PATHCTXIMAGEI = os.path.join(Working_Directory, 'CTXMarsImageI.IMG')
         PATHCTXIMAGEI
         # Creating output file name for first CTX raster (where the file will be saved) assigned as a variable.
Out[18]: 'C:\\Users\\Alexander Danielson\\Desktop\\Fall 2022Spring2023\\ArcGIS I\\FinalProject\\FinalProject\\CTXMarsImageI.IMG'
```

```
In [19]: with open(PATHCTXIMAGEI, 'wb')as f:
             f.write(CTX_OBJI.content)
         # Writing (. content of) Response from Post Request to Disk/Directory.
```

Second CTX Image

```
In [20]: CTX_DataPageII = r'http://viewer.mars.asu.edu/planetview/inst/ctx/B06_011914_1620_XI_18S110W#P=B06_011914_1620_XI_18S110W&T=2'
         # Assign variable to data page for first CTX raster in data comparison analysis.
```

```
In [22]: CTX_Image_II = r'http://pds-imaging.jpl.nasa.gov/data/mro/mars_reconnaissance_orbiter/ctx/mrox_0759/data/B06_011914_1620_XI_18S110W.IMG'
         # Assign variable to TIFF file for download.
```

Figure 3. Half of the Pseudo code for the first steps in extracting imagery for digitizing lineaments and yardangs on CTX/HiRISE imagery.

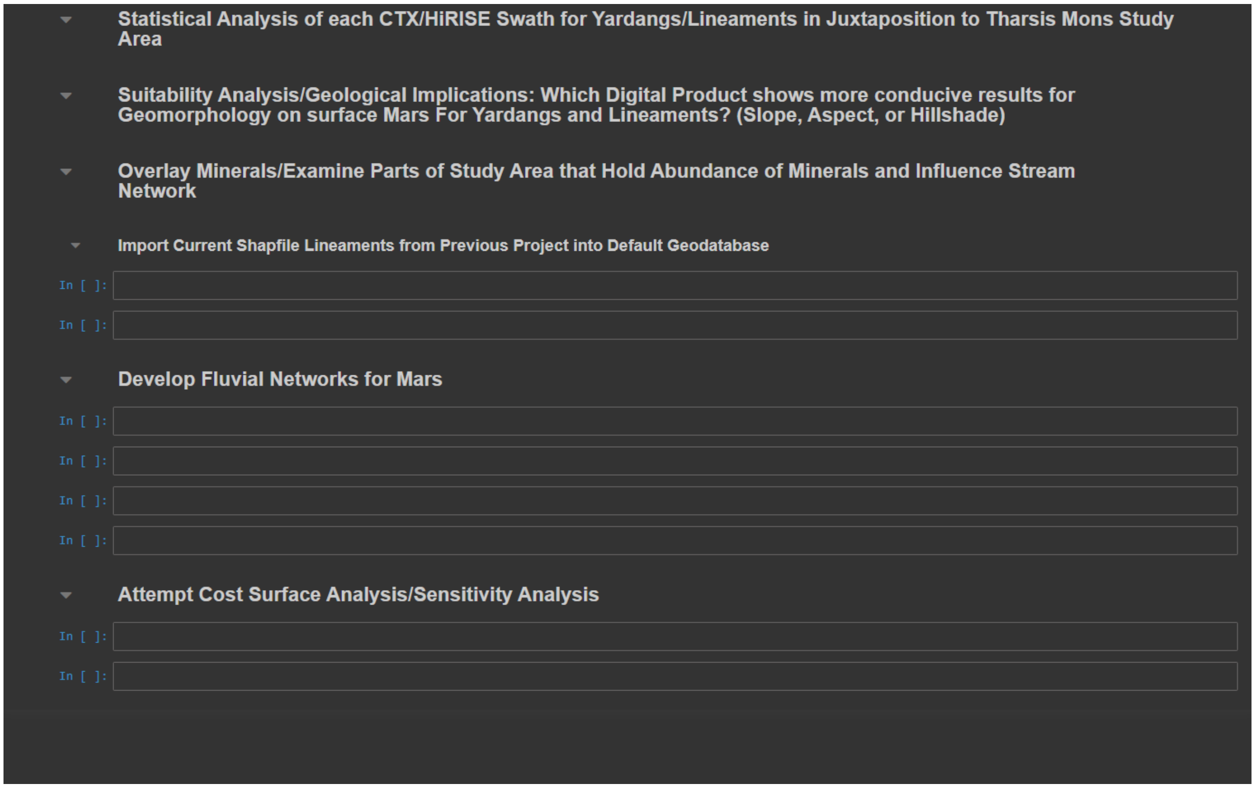

Figure 4. Last half of the Pseudo code for preliminary code will distill analysis of CTX, suitability analysis, and overlay mineralogy for fluvial networks, including cost surface (to be broken into more notebooks).

Results

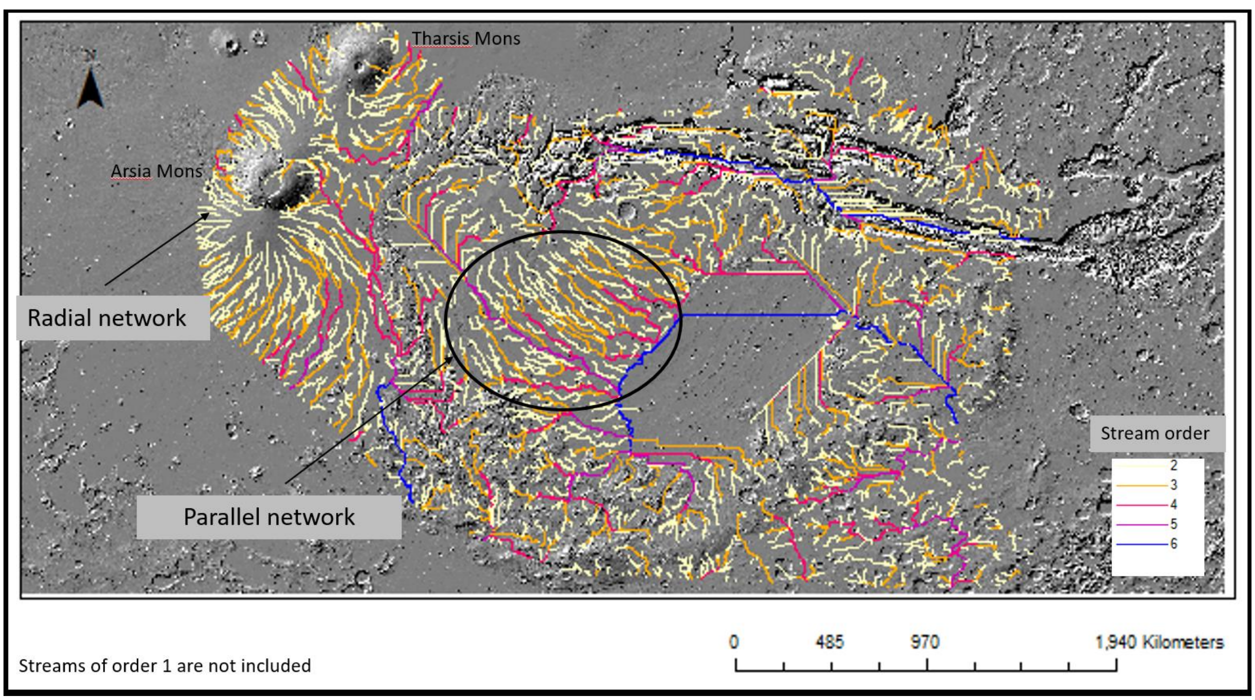

Figure 5. (Danielson, et. al) Drainage networks and stream orders are used for outlining flow direction, accumulation, and area and then being reclassified. Sinuosity of streams (how they bend relative to the valley) factors into how geology influenced the landscape.

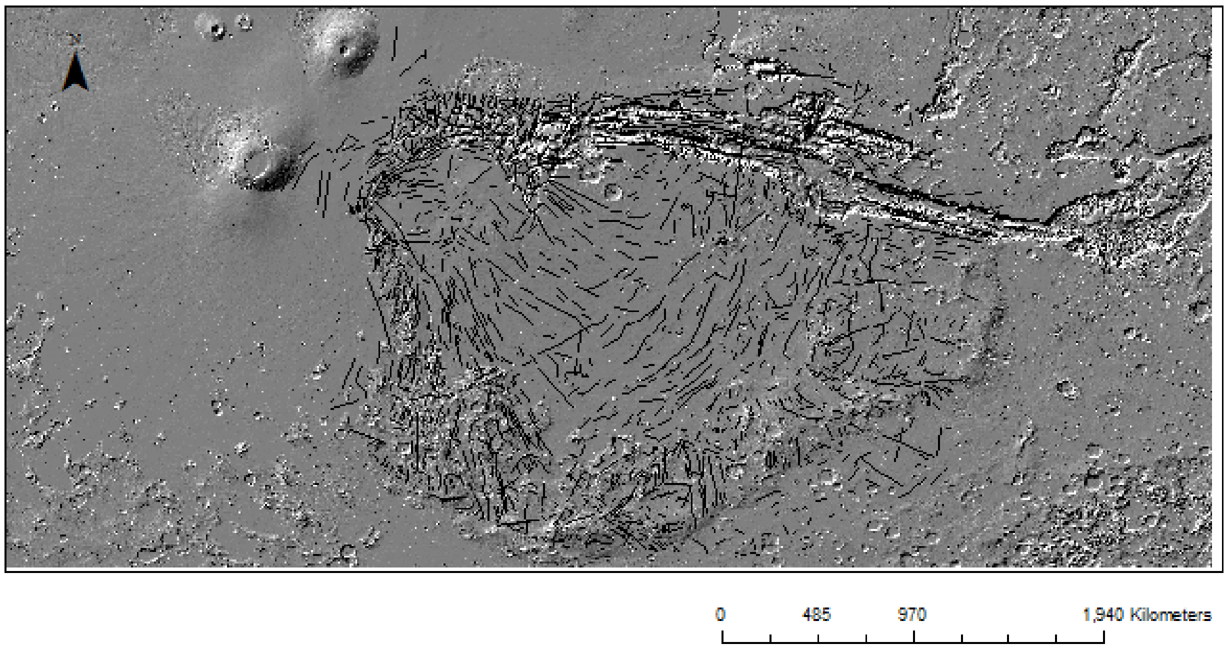

Figure 6. (Danielson, et. al) Slope and Aspect lineaments digitized on the surface of Mars (shown on MOLA imagery).

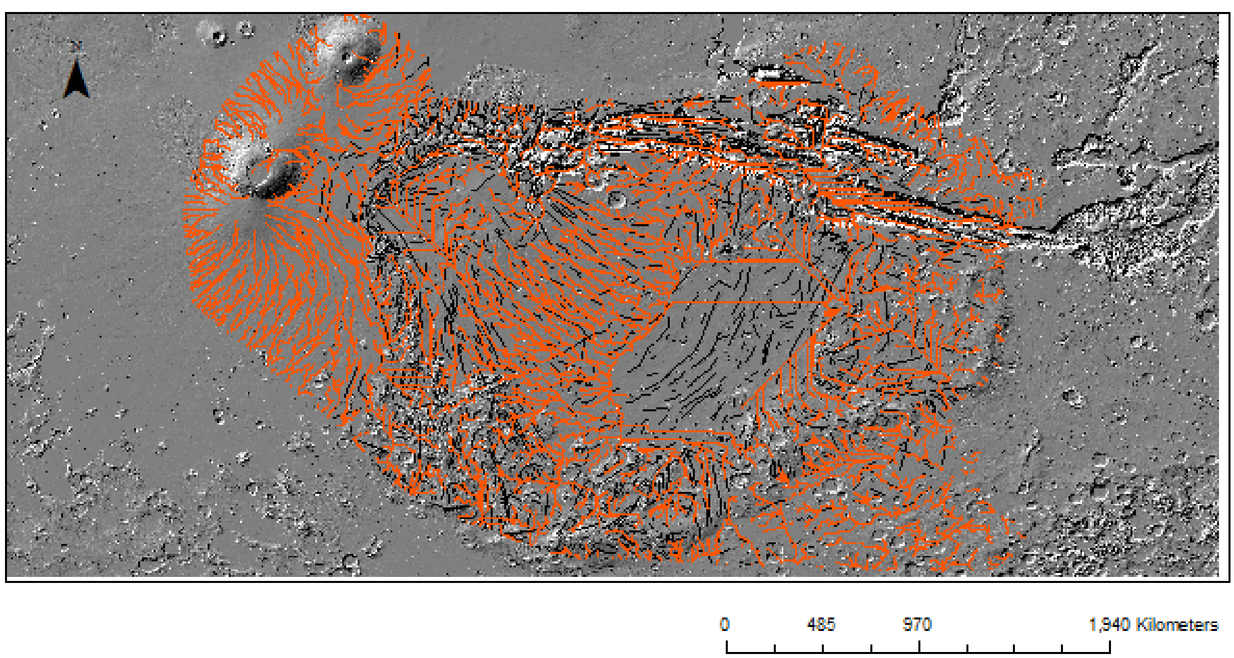

Figure 7. (Danielson, et. al) Hillshade Lineaments digitized on the surface of Mars (shown on MOLA imagery)

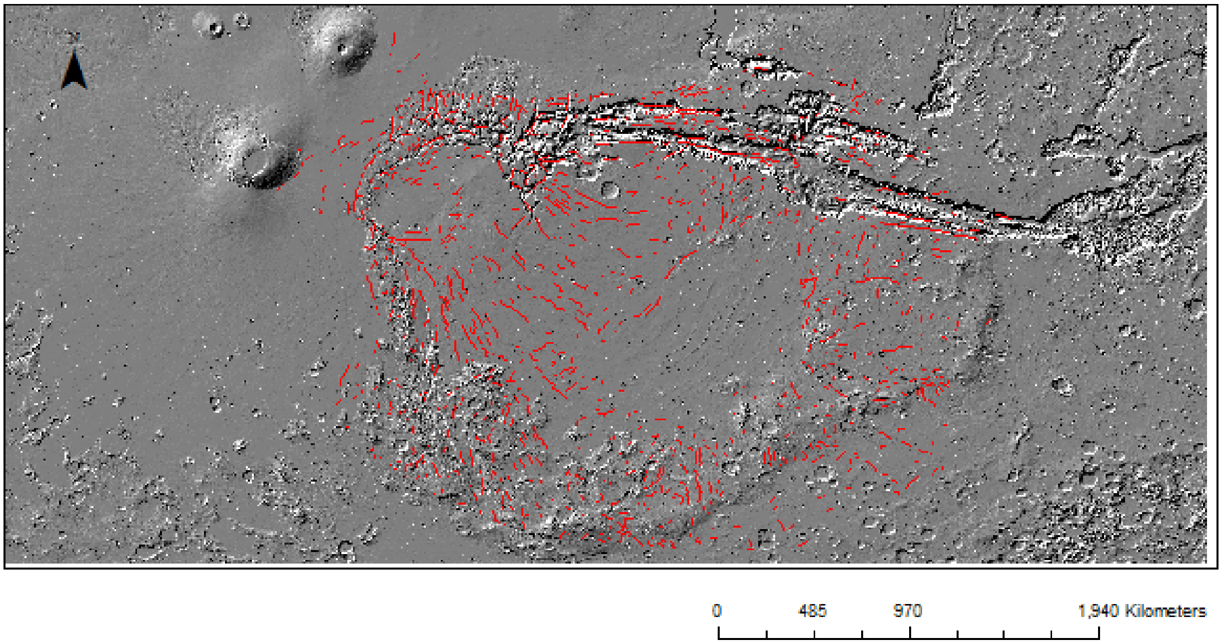

Figure 8. (Danielson, et. al) Intersection tool used for all lineaments and drainage networks to conclude there was no substantial evidence of geological implications in the fluvial processes on Mars or drainage.

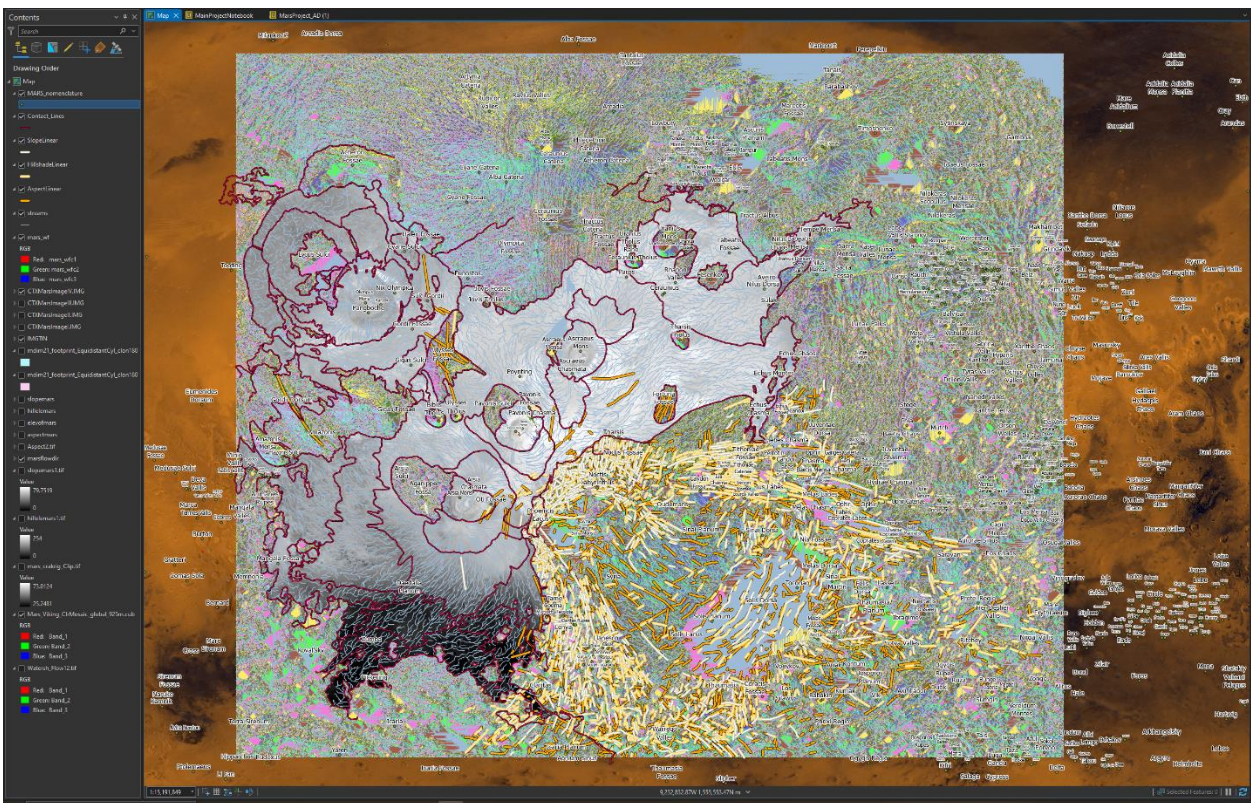

Figure 9. Outputs of overlaying lineaments in ArcGIS Pro along with Flow Direction raster and watersheds delineated from Flow Area and Martian nomenclature.

Results Verification

The results depicted serve as a precursor for the lineaments and how they can compare to yardangs as another factor in configuring the geological implications of Mars and to that of Earth. Yardangs are configured to the surface by different structural elements, but most yardangs are linear which is assumed that they are equal in some way to lineaments. Also, the fluvial and drainage networks are implicating the fact that water once was on Mars and has similar biophysical and geomorphological processes to that of Earth if looking at the historical past. Including the inertia and magnetosphere the wind, abrasion, and erosion were paramount in shaping the faults, valleys, gullies, and faults of Mars.

In comparison to that of Earth which has more layers of atmosphere and a stronger magnetosphere, Mar's lithosphere is comprehensive to that of Earth and contains the same crust, magma core, and intermediate nickel and iron mantle. The mineralogical properties of feldspar, quartz, and olivine, and mica (not in imagery analysis) are the most abundant in terms of sedimentation and metamorphism in geological implications. These layers will prove prudent for developing a cursory and explanatory insight into fluvial implications of how geology factored into shaping Mars.

Other qualitative and deterministic analyses to be assessed with computational frameworks to be factored in are using matplotlib to compare each analysis together and automate all features to mitigate hassles for future users. Quantitative analysis can be used to some extent with the stream orders and comparison of yardang/lineaments (i.e spatial autocorrelation, GWR, and kernel density). with each digital imagery product overlayed with the stream network. Likewise, the possibility of the mineralogy to be implemented holistically or independently of each other for the ETL and each stream network.

Possible deep learning or machine learning could be implemented, but time management and budgeting needs to be factored into what can be achieved and what AOIs should be delved into for digitization.

Discussion and Conclusion

In synopsis, if these operations and parameters prove successful, then a streamlined and computational framework with a robust planetary geological analysis would be advantageous for many agencies. What needs to be done is to see if there can be an actual finding and geological significance with configurations of yardangs in conformity with lineaments as they shape the drainage and fluvial processes on Mars.

A comprehensive overview of the geomorphological processes of Earth to Mars are quelled by diurnal days, axial tilt, and magnetosphere. But are similar in geological composition, climatic and geological past with evidence of hydrological history and sediments from glaciation and faulting/igneous intrusions (Rangarnjan, et. al). "Well-developed fluvial patterns have been identified in the Syrtis Major volcanic construct which is similar to the channels formed by glacial surges on Earth. The spectroscopic studies reveal the signature of hydroxylated and hydrated minerals in NW Syrtis which could be a step towards finding traces of water on Martian surfaces." (Rangarnjan, et. al).

Since yardangs form in approximately narrow corridors of soft bedrock, evidence can point to drainage and fluvial processes which these can house feldspar, quartz, olivine, and other sedimentary rocks in rivers which configured geological processes and shapes in forming rivers/outcroppings along the yardangs. Along with the conformity in features to can be utilized in resources on Earth or for space exploration for future experiments and expeditions.

References

Danielson, Alexander, Rios-Sanchez, Miriam, Analysis of the Impacts of Geology and Fluvial Processes on the Development of Drainage Networks on the Tharsis Volcanic Region, Mars. Center for Environmental, Economic, Earth, and Space Studies. Bemidji State University, Presentation (April 5th, 2017).

Liu, J., Di, K., Gou, S., Yue, Z., Liu, B., Xiao, J., & Liu, Z. (2020). Mapping and spatial statistical analysis of Mars Yardangs. *Planetary and Space Science*, *192*(105035), 105035. https://doi.org/10.1016/j.pss.2020.105035

Mars Global Data Sets. (n.d.). Asu.edu. Retrieved September 25, 2022, from http://www.mars.asu.edu/data/

Oosthoek, J. H. P., Rossi, A. P., & Unnithan, V. (2015). Towards collaborative exploration and analysis of big data from mars: A noachis Terra case study. In *Towards an Interdisciplinary Approach in Earth System Science* (pp. 241–251). Springer International Publishing.

Rangarajan, V. G., Bharti, R., Mondal, S. K., Pradhan, C., & Dutta, S. (2018). Remote sensing for martian studies: Inferences from syrtis major. Journal of the Indian Society of Remote Sensing, 46(9), 1537–1551. https://doi.org/10.1007/s12524-018-0826-7

The HiRISE Project at the University of Arizona's Lunar, & Lab, P. (n.d.). HiRISE DTMs. Uahirise.org. Retrieved September 28, 2022, from https://www.uahirise.org/hiwish/maps/dtms.jsp

(N.d.). Jhuapl.edu. Retrieved September 28, 2022, from http://crism-map.jhuapl.edu/

https://github.com/USGS-Astrogeology/ISIS3/wiki/Working_with_Mars_Reconnaissance_Orbiter_CTX_Data#Projecting-the-Image-

Self-score

Category	**Description**	**Points Possible**	**Score**
Structural Elements	All elements of a lab report are included **(2 points each)**: Title, Notice: Dr. Bryan Runck, Author, Project Repository, Date, Abstract, Problem Statement, Input Data w/ tables, Methods w/ Data, Flow Diagrams, Results, Results Verification, Discussion and Conclusion, References in common format, Self-score	28	**28**
Clarity of Content	Each element above is executed at a professional level so that someone can understand the goal, data, methods, results, and their validity and implications in a 5 minute reading at a cursory-level, and in a 30 minute meeting at a deep level **(12 points)**. There is a clear connection from data to results to discussion and conclusion **(12 points)**.	24	**21**
Reproducibility	Results are completely reproducible by someone with basic GIS training. There is no ambiguity in data flow or rationale for data operations. Every step is documented and justified.	28	**28**
Verification	Results are correct in that they have been verified in comparison to some standard. The standard is clearly stated **(10 points)**, the method of comparison is clearly stated **(5 points)**, and the result of verification is clearly stated **(5 points)**.	20	**19**
		100	**96**