# Final Project Report

Title: Analysis of the Impacts of Geology and Fluvial Processes on the Development of Drainage Networks on the Tharsis Volcanic Region, Mars (Using Python and GIS)
Notice: Dr. Bryan Runck
Author: Alexander Danielson
Date: 12/21/2022

**Project Repository:** https://github.com/ardumn/GIS5571/tree/main/Project
**Google Drive Link:** https://drive.google.com/drive/folders/183B_oX5oOm6iMbK-FXO7rMHalzr-AU5n
**Time Spent:** 72+ hours (project editing/redefining, reading articles, presentation creation, and report writing/editing)

## Abstract

Mars is the next frontier in planetary expeditions and in geological breakthroughs in how it compares to other terrestrial planets. Especially geological quandaries such as Tharsis Mons volcanic region and Valles Marineris valley system, the most titanic features in the solar system. This study gives a baseline for how endogenic processes and drainage networks can have similar effects with each other with other secondary characteristics of geomorphology. Utilizing Mars Orbiter Laser Altimetry and Viking Rover/Satellite Data as the purview of data, lineaments digitized on Tharsis Mons and Valles Marineris from these said processes serve as the basis for how structural foundations of Mars also make up the foundations of Earth. Using GIS tools to process linear directional flow of lineaments, fluvial networks, and conduct a statistical analysis yields negative correlation and results, yet from literature, much can be gleaned on future work and analysis. Considerations that also were not factored into the project, but in the tentative model are more robust remote sensing analysis of mineralogy and hindrance of sedimentation in the flow of tributaries. Likewise, having different coordinate projections to suit the analysis of what geological impediment is under analysis (such as scarps, fault, garben) must be weighed heavily. To this extent, what is to be presented and learned from this is to implement 3D mapping protocols, automate mapping protocols for users to input their data with ease, and have a deep neural network to classify geological features with ease and effectively lessen the time needed in digitizing features.

## Problem Statement

The premise of this project is to assess the geological implications of fluvial networks on the surface of Mars and how drainage networks shape geomorphology. To this extent, the most astounding geological phenomena and quandaries arise in the Tharsis Mons Volcanic and Valles Marineris regions. These geological phenomena can extend to other physiographic features such as fractures, faults, lineaments (mainly in the extent of this project) grabens, yardangs, craters, strike-slips, horst, and so on from endogenic processes (volcanism, fractures, metamorphism). To see if there is significant evidence that the drainage networks are of geological significance, digitization in ArcGIS Pro and an ETL are utilized to gather MOLA/Viking imagery (already obtained from prior work) and CTX/HiRISE imagery to assess geological significance between fluvial processes is utilized.

To this extent, further analysis is applied to lineaments that represent subsurface phenomena and fracture/faults that form the surface from tectonic activity from when the Tharsis Mons and Valles Marineris regions originated in past historical geological periods. Shears and geometric transformations that are applied to the imagery and how the imagery is displayed can alter digitization and geoprocessing output. Factors of spectral resolution, changes in physiographic features, and data/statistical discrepancies, hinder the accuracy and flexibility of digitization features. To enhance and provide flexibility for users who want to input their data and classify geological features, an automated script is provided, and a convolutional neural network tool, which is discussed in the conclusion for how is advantageous in efficiency and mitigating digitization efforts.

| # | Requirement | Defined As | (Spatial) Data | Attribute Data | Dataset | Preparation |
|---|---|---|---|---|---|---|
| 1 | MOLA (Mars Orbiter Laser Altimeter) | Shaded relief derived from altimetry Mars data. | Raster | Bands | Mars | None, Spectral resolution accounted for in Verification/ Discussion as “Automatic delineation techniques subsequently updated by manual digitization … was successfully employed in mapping out the fluvial channels in the Antoniadi watershed, NW Syrtis “ (Rangarajan, et. al pg. 1546) |
| 2 | Viking Satellite Imagery | Viking Color Mosaic sharped with MDIM 1.0. | Raster | Bands | Mars | None, (Rangarajan, et. al pg. 1546) |
| 3 | CTX (Context Camera) (ETL) | CTX (Context Camera) makes observations simultaneously with high-resolution images collected by HiRISE and data collected by the mineral-finding CRISM spectrometer. | Raster | Pixels/Cells | CTX | ETL created to extract data from website, carried over and used as cursory analysis in better depicting geological anomalies at finer scale. |
| 4 | HiRISE (High Resolution Imaging Experiment) (ETL) | The High Resolution Imaging Experiment is known as HIRISE. The big and powerful HIRISE camera takes pictures that | Raster | Pixels/Cells | HiRISE | ETL created to extract data from website, carried over |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | cover vast areas of Martian terrain while being able to see features as small as a kitchen table. | | | | and used as cursory analysis in better depicting geological anomalies at a finer scale. |
| 5 | Digitization of Lineaments | Lineaments are define as: A mappable linear surface features which differ distinctly from the patterns of adjacent features and presumably reflect subsurface phenomena. Digitized on MOLA and Viking imagery to delineate and fine configuration in drainage networks. | Vector | Polyline | N/A | (Rangarajan, et. al pg. 1546) |
| 6 | Drainage Network | A drainage network includes all the stream channels that drain toward a reference point. The network is bounded by a topographically defined drainage divide; precipitation falling on the far side of the divide flows down the slope into an adjacent drainage network. | Vector/Raster | Polyline/Pixels/Cells | N/A | Raster to Vector, (Rangarajan, et. al pg. 1546) |
| 7 | Fishnet/Grid/ *Split* (testing) | Creates a fishnet of rectangular cells. The output can be polyline or polygon features. | Vector Tool | Polygon | N/A | Bisection of Lineaments and Assessment of LDMs |
| 8 | Linear Directional Mean (LDM) | Linear directional mean can be used to analyze the main direction of the line object. The general linear feature usually points in one direction, where the position from the starting point points to the destination. | Vector Tool | Polyline | N/A | Develop Stream Network from MOLA/Viking Imagery and Lineaments |
| 9 | Ordinary Least Squares/Generalized Linear Regression | Performs global Ordinary Least Squares (OLS) linear regression to generate predictions or to model a dependent | Statistical Tool | Discrete Data | N/A | Develop Stream Network. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | variable in terms of its relationships to a set of explanatory variables. AND generate predictions or model a dependent variable in terms of its relationship to a set of explanatory variables. | | | | |

Table 1. Prerequisites that are implemented into this project i.e., MOLA/Viking imagery, digitization, and CTX/HiRISE ETL, then geoprocessing tools utilized.

## Input Data

In comparing all the spectral resolutions of each satellite and the imagery, the VIKING satellite would be irrevocably the most reliable and consistent in physiographic monology and spectral construct (despite the technology from the 1970s) being comparable to Landsat at 30m resolution. As it is the most reputable/renowned for digital processing and overall good general reference for viewing a small scale or the general world of Mars itself. "Despite the better spatial resolution of stereo-derived DTMs (Kim and Mueller,2009), MOLA data coverage is still more complete and consistent, making it ideal for regional mapping. Integration of both kinds of datasets through data fusion seems to be a promising technique (Liet et. al.,2010)" (Vaz, pg. 1211).

CTX/HiRISE imagery are extracted from modern satellites of the 21st century (such as the Opportunity and Curiosity) and can have 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 since the lack of geo-composite TIFF data from the HiRISE map viewer and the narrow swaths of land that are captured by the telescope/camera of the CTX, they aren't advantageous in this analysis. Likewise, "The resolution and quality of the stereo DTMs can change according to acquisition conditions and even with the stereo-matching algorithms used (Heipke et al.,2007). (Vaz, pg. 1211). One of the arising concerns with raster data and regarding integrity in this development is how spatial limitations can impact the quality assurance of the stream extraction and processing of lineaments continuity. As MOLA/VIKING imagery is reliable, it does have its faults in processing, as Vaz states: "MOLA data gaps could break lineament continuity leading to an over-segmentation of the lineaments… This over-segmentation is less evident for EW scarps due to the NS preferential orientation of the MOLA tracks. Those problems are specific to MOLA data and better quality DTMs should not present this kind of problem." (Vaz, pg. 1213).

| # | Title | Purpose in Analysis | Link to Source |
|---|---|---|---|
| 1 | Mars Orbiter Laser Altimeter (MOLA) | Back-up general spectral imagery for delineating lineaments and yardangs in the Martian surface. | MARS Global Data Sets |
| 2 | Viking Merged Color Mosaic | Back-up general spectral imagery for delineating lineaments and yardangs in the Martian surface. | MARS Global Data Sets |
| 3 | Context Camera (CTX) | Higher-resolution imagery will be attempted to be utilized for the project to decipher lineaments and yardangs. (No spatial referenced information available) Proposed for further analysis in the future project in Advanced Remote Sensing for machine learning and creating generated labels and discriminating physiographic features. (Reflected upon in "Discussion/Conclusion") | HiRISE Map Viewer |

| | | | |
|---|---|---|---|
| 4 | HiRISE (High-Resolution Imaging Experiment) (ETL) | Higher-resolution imagery which will be attempted to be utilized for the project to decipher lineaments and yardangs. (No spatial referenced information available) Proposed for further analysis in the future project in Advanced Remote Sensing for machine learning and creating generated labels and discriminating physiographic features. (Reflected upon in “Discussion/Conclusion”) | HiRISE Map Viewer |
| 5 | Mars Streams | Used for Stream Extraction and processing from rasters. | N/A |

Table 2. Enumeration of each data that’s utilized throughout the project and highlighted throughout the report.

## Methods

The following data flow diagrams depict; **1)** the initial phases and ideation with planned phases of implementing extraction of CTX swaths of imagery from the HiRISE Map Viewer, for further delineating sub-strata geological with digital processing that was performed on MOLA/VIKING Imagery in Figure 1. After revising the parameters and reviewing the literature of digitizing lineaments, yardangs physiographical underpinnings have the same structure and geological processes as lineaments so were omitted in this study. Likewise, mineralogy characteristics are omitted (but are highlighted in the Discussion for fluvial sedimentation ramifications) and were generating a cost surface from governed Slope, Hillshade, and Aspect rasters. These could potentially be weighted to see which lineaments and fluvial networks are most conducive in showing configuration to geological phenomena and structure (which is ultimately a suitability analysis carried out for this project).

**2)** Figure 2. The data flow diagram *is the actual basis for this study and the other data flow diagrams that follow* and simply show the initial procedures without estimating a cost surface as well aforementioned parameters above. Then establishing a simple drainage network from the Mars Elevation Data from MOLA/Viking data. Which is in Figure 3. A fishnet is created to analyze each portion of lineament and drainage network polylines for which the linear mean directional line tool can convey directional flow based on the geometrical direction of every line from Aspect, Slope and Hillshade digitized. These are then joined by their IDs using a tabular join and grouped. **3)** Statistical analysis in figure 4 of stream bias and perform ordinary least squares and generalized linear regression for validity for lineaments and drainage network, based on the factors of each suitability analysis performed.

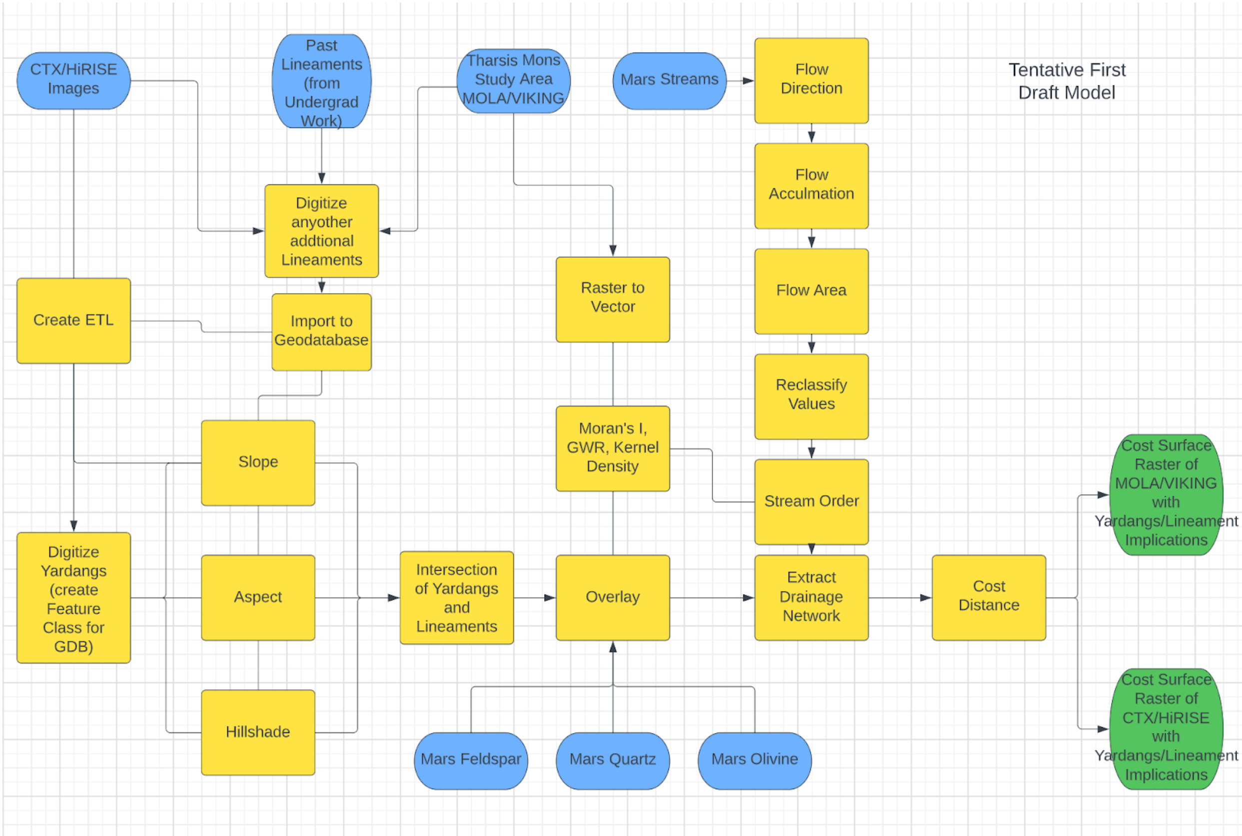



Figure 1. The original Data flow model was initially intended to produce a cost surface model for each suitable lineament analysis and was no longer implemented but included for first ideation and rationale.

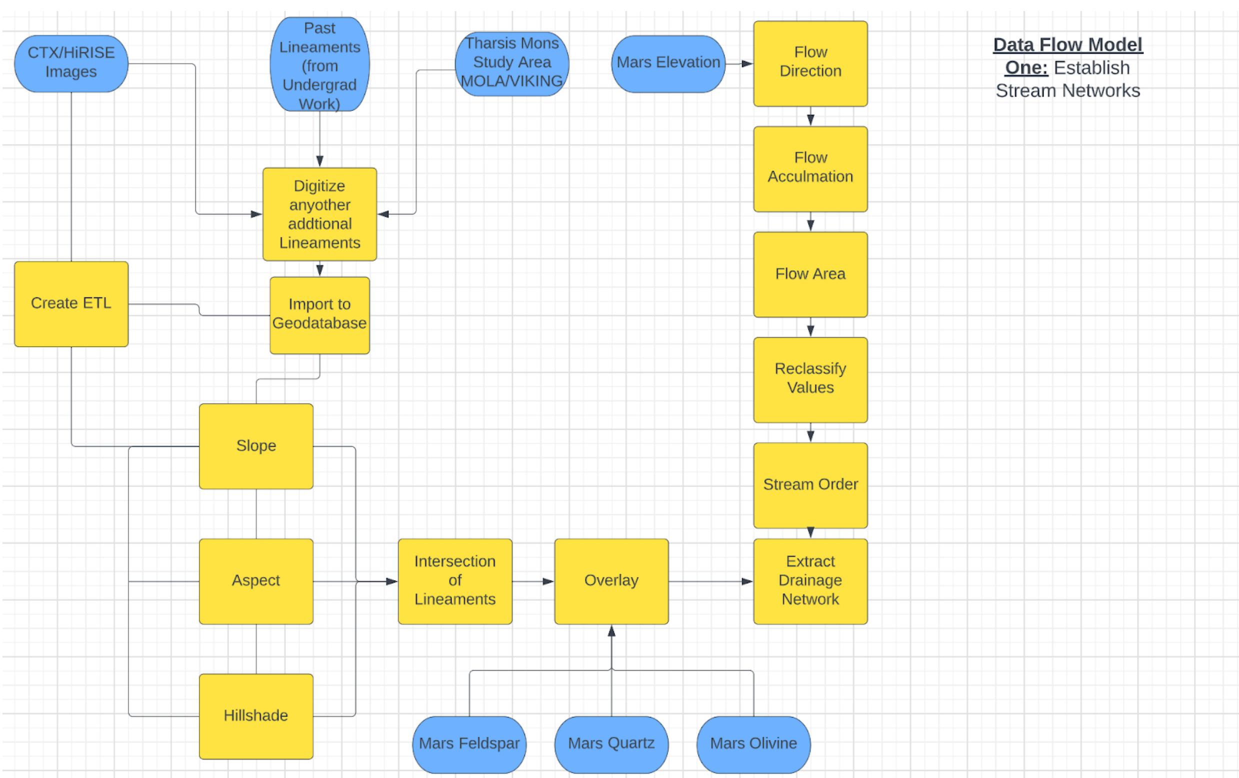


Figure 2. Phase one of three in project development; developing drainage networks for the Tharsis Mars region and delineating lineaments from each raster product. (*mineralogy not implemented but discussed in results verification)*

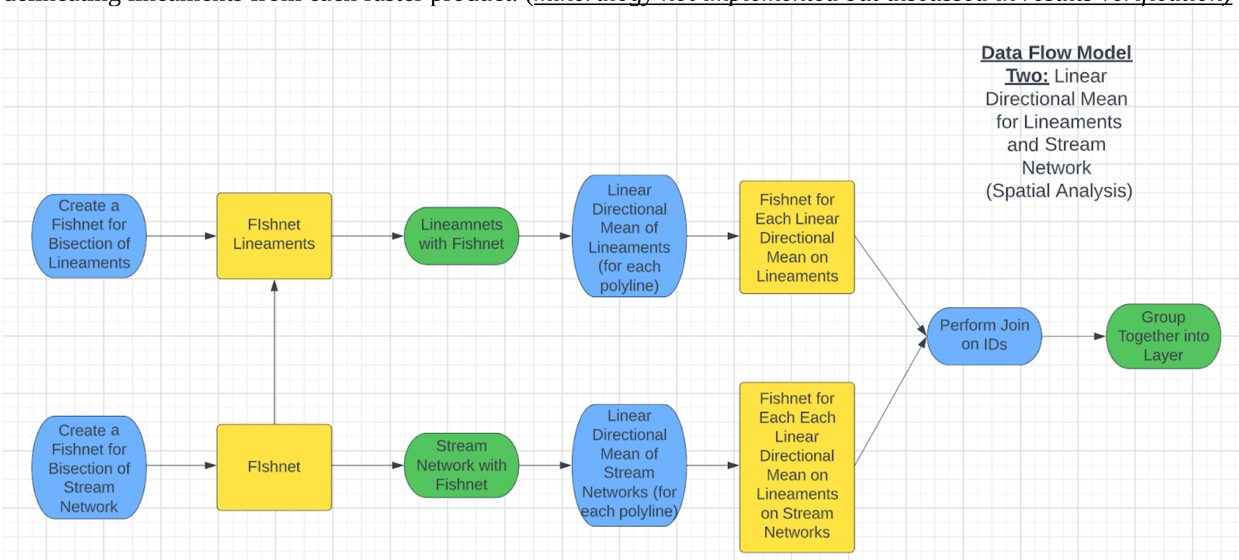



Figure 3. Phase two of three in project development; envelop lineament and drainage network features into fishnet and each feature's directional mean flow is calculated and joined by IDs and grouped.

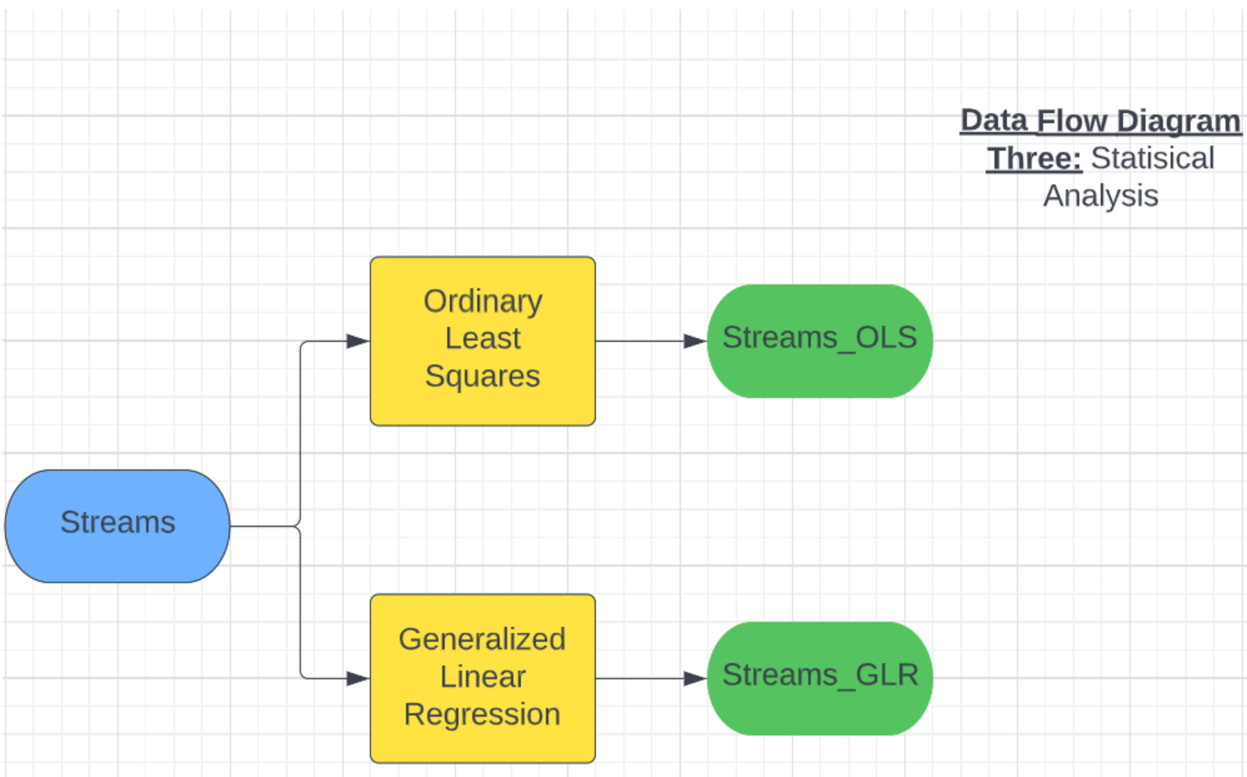


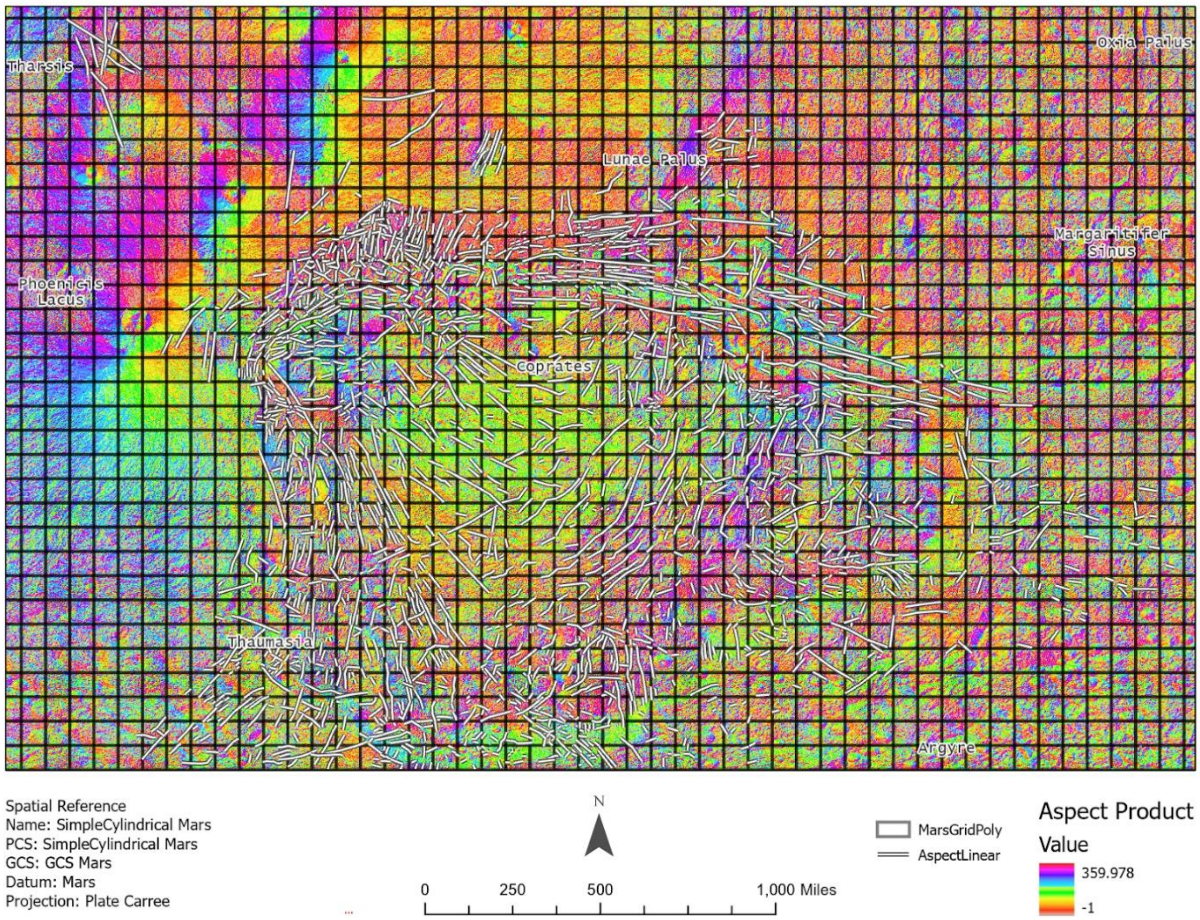

Figure 4. Phase Three of Three in project development; Stream analysis and assessment for geometric configuration and statistical science if stream data is reputable for analysis along with raster suitability.

## Results

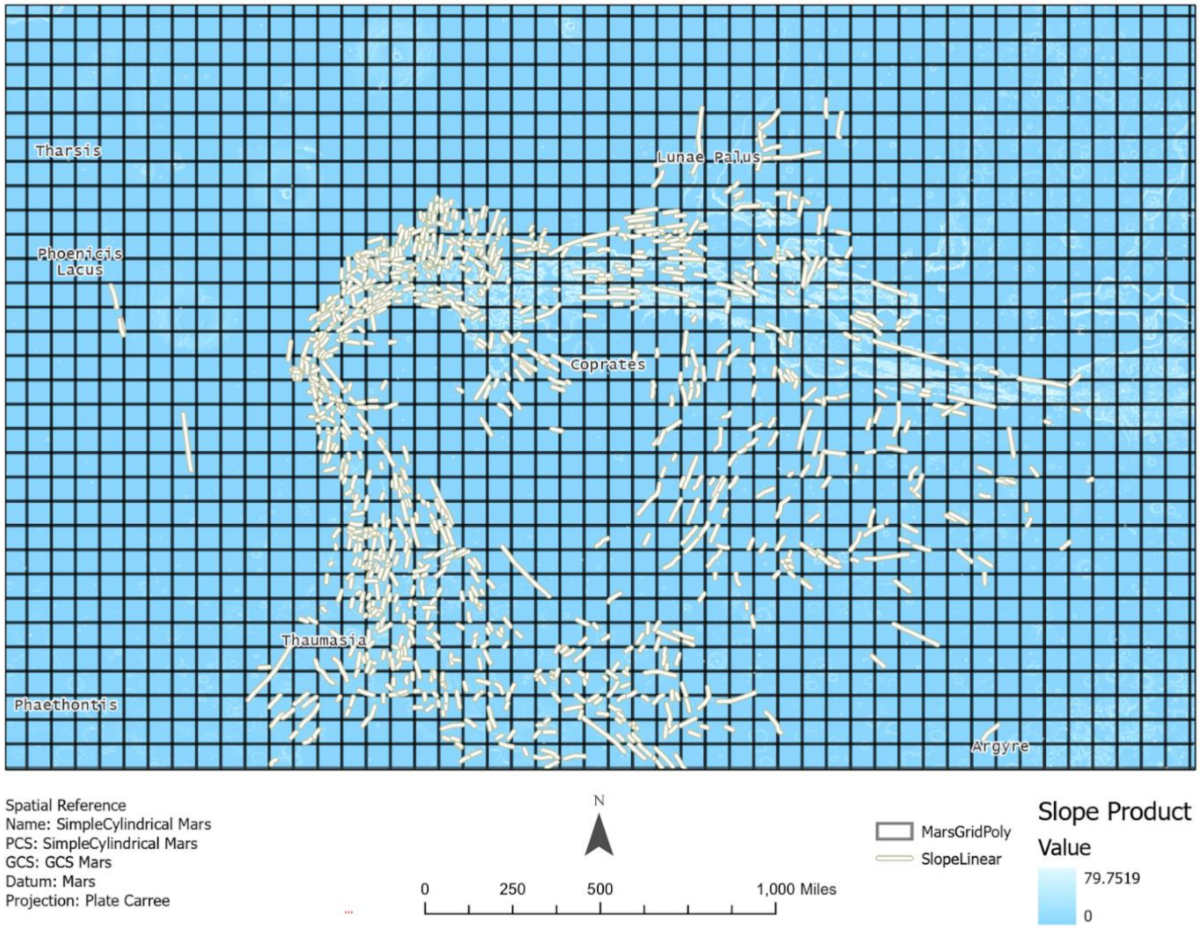
The results depicted in each of the following maps serve as a general baseline for the mapping of lineaments and how they can compare to other physiographic regions and geological phenomena of Mars. Most studies use lineaments as an indicator for underlying geological activities and subsurface analysis.  Some also involve quantitative analysis of said lineaments and assess scarps, garben situations, and fault line dynamics, with volumetric considerations, densities, and inertia. (Vaz, pg.1212-1215). These results are mostly considered those of faults and fractures that equate to lineaments caused by divergent plate boundaries rifting apart during the Noachian and Hesperian geological periods of Mars with the consideration of drainage networks obtained in the present Amazonian period.

The considerations of each of the three suitability maps which measure if the lineaments are aligned with the configuration of drainage basins qualitatively are weighed equally, instead of one being superior to the other.  As mentioned in the Input Data section, reliance on MOLA alone was not in the best interest, the use of Aspect, Slope, and Hillshade is utilized to extract breadth from MOLA to find linear faults/fractures and gain much from data as possible. Each of these is then merged and superimposed to contrast over their linear directional mean flow and the streams, which unfortunately show no conclusive result.  Although, the geometry of the LDM was not aligned with the stream network, (see Figure 5.) and statistical analysis of each LDM for lineaments show negative correlations. Given the results, much can still be justified and verified from other sources on analytical and future steps forward.

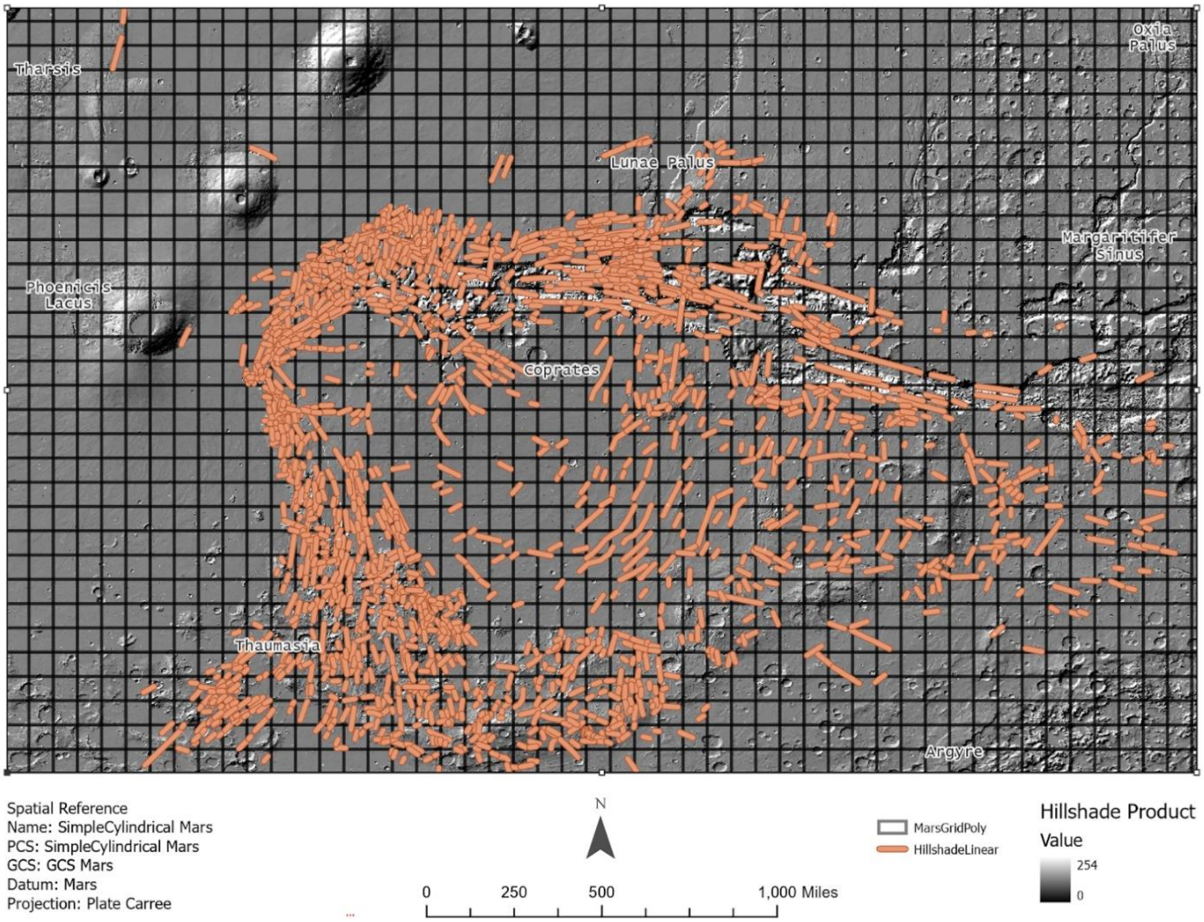
"The use of altimetry data for mapping geomorphologic structures allows a morphometric characterization that imagery alone cannot provide and also has the advantage of avoiding possible biases related with illumination conditions." (David Alegre Vaz, pg. 1211).  CTX/HiRISE is more purposeful and practical for quantitative analysis of that of deeper and more complex subsurface geomorphological phenomena and that of yardangs, strike-flip faults, synclines vs. anticlines, etc. which will be discussed in the following "Results Verifications" and relating to the various geological complexities and historical considerations and principle of uniformitarianism (what happens now is reflected from the past).



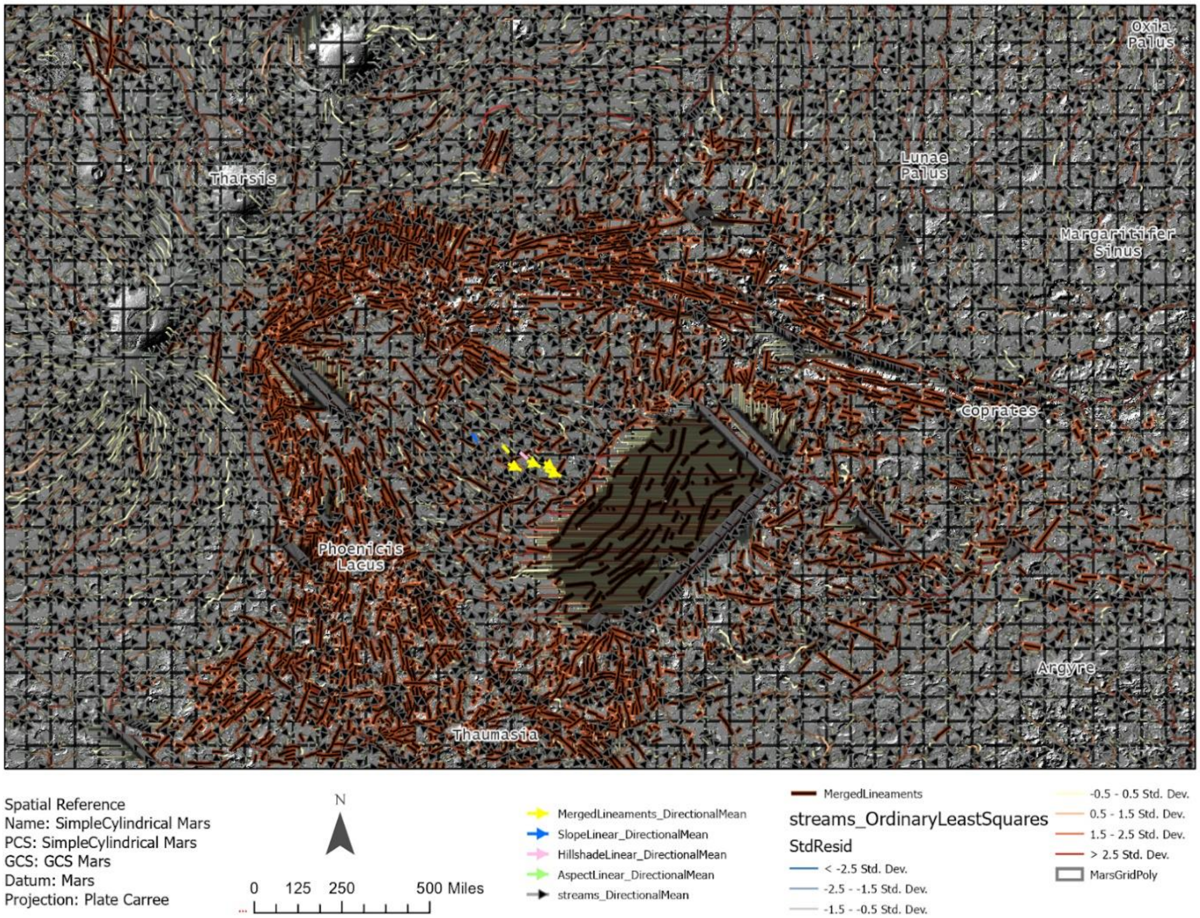

Map 1. Aspect map with each compass direction aligned with lineaments to find suitable drainage networks that configure to the Tharsis Mons/Valles Marines region of Mars.




Map 1. Slope map with each steepness of direction aligned with lineaments to find suitable drainage networks that configure to the Tharsis Mons/Valles Marines region of Mars.




Map 3. Hillshade map with each shaded relief aligned with lineaments to find suitable drainage networks that configure to the Tharsis Mons/Valles Marines region of Mars.




Map 4. Merged Lineaments (Slope, Aspect, and Hillshade) superimposed on Linear Direction Means from each and merged lineaments. Including LDM for stream networks based on OLS. Lack of data assumes no correlation in stream networks and lineaments configuration in the geology of Tharsis Mons/Valles Marineris regions.

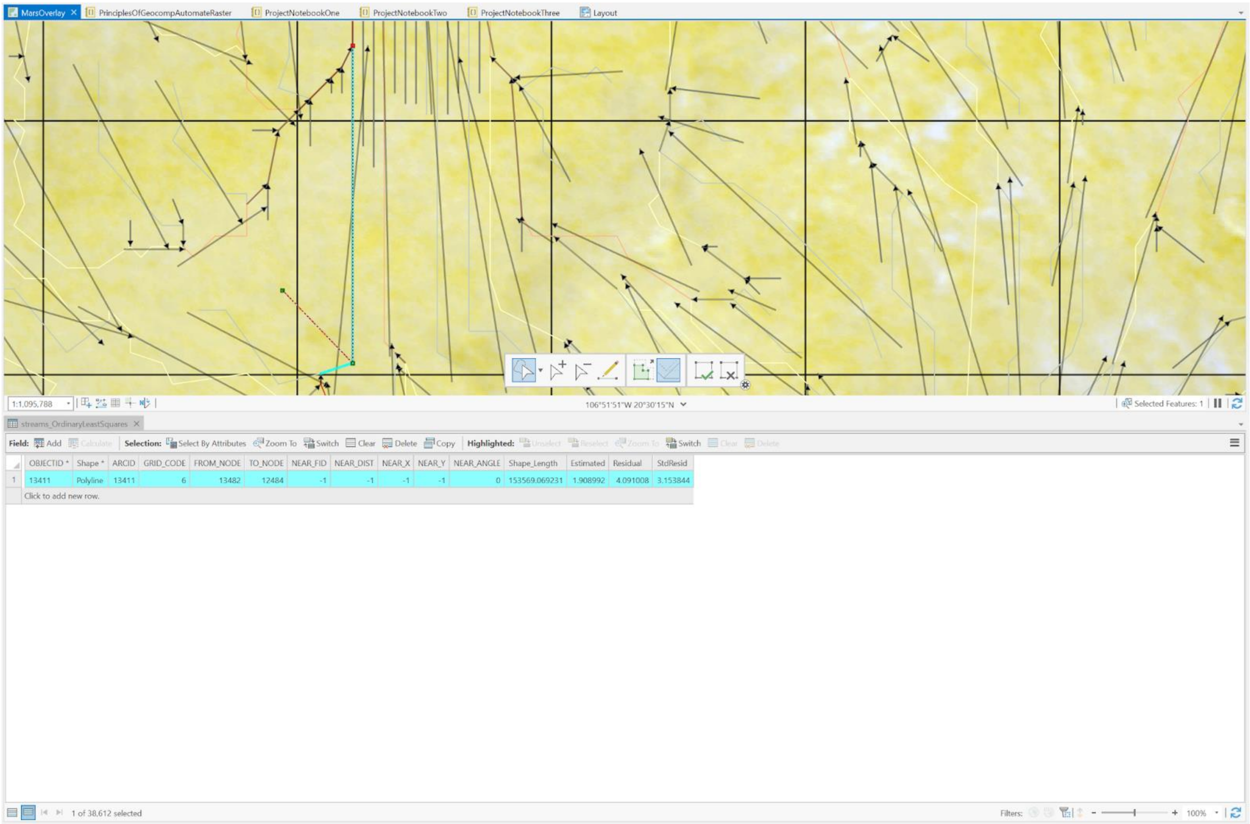
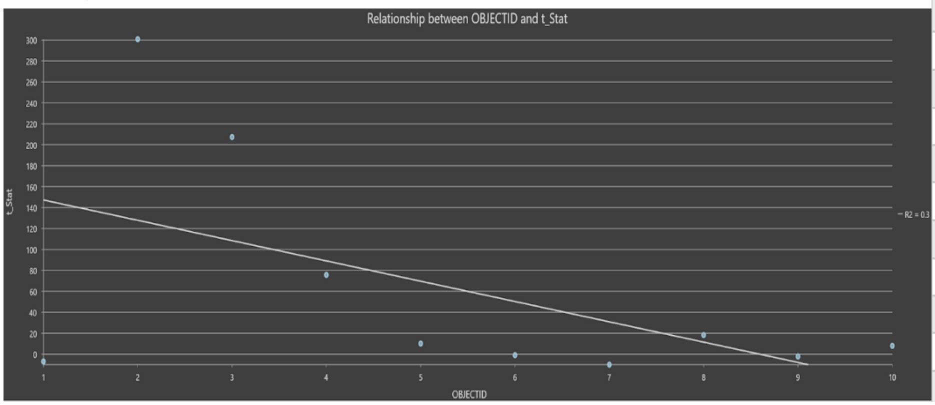


Figure 5. Deconstruction of Stream Network shapefile and comparison to LDM to see discontinuity in geometric ordering and direction.




| StdError | t_Stat | Prob |
|---|---|---|
| 0.600155 | -0.884158 | 0.376617 |
| 0.172131 | -2.233281 | 0.025536 |
| 0.344286 | -6.966137 | 0 |
| 1.349866 | 8.024522 | 0 |
| 0.001963 | 300.746255 | 0 |
| 0.001957 | 207.312049 | 0 |
| 0.000007 | 75.735142 | 0 |
| 0.002766 | 10.117482 | 0 |
| 0.000001 | -9.980591 | 0 |
| 0.000002 | 18.270764 | 0 |

Figure 6. The scatterplot of Linear Directional Means for each Lineament in Map 4 shows the negative correlation of results and low probable cause that there is the correlation of drainage network similarities.

## Results Verification

Based on the "Results" section, despite there being no definitive evidence in the scope of this project, much can be gleaned and surmised for the next phases of this project's potential. Evidence from literature and the geological historical periods can provide insight into the negative correlation and analysis from this baseline project. This can also serve as a precursor to many other projects, such as network analysis, steam and geomorphological analysis, site, and suitability analysis, and so on. Other potential add-ons were negated or cut off from this project (as depicted in the original data flow diagram) that did not make it into the final project and are touched on here:

1.Yardangs and projection considerations: When considering the multifaceted nature of geomorphology and biophysical processes of a different planet there also comes considerations of projections used and how to correctly map the features on the ground. Throughout this project, an Equidistant Cylindrical project was utilized to have no area, distances, or shape comprised within the area of Tharsis Mons/Valles Marineris regions, "To ensure precise measurements and avoid map-projection induced distortions, map projections of Mollweide equal-area projection and Mercator projection" (Liu, J et. al, pg. 2-3)". Yardangs were considered to have the same configuration and structure as that of lineaments, but can be shaped from exogenic (aeolian, erosion, transportation) influences from long valley shapes to boxes and curvilinear forms. It is imperative that when digitizing lineaments that they aren't confused for another geological feature, or confine.

2. Mineralogy considerations for drainage flows: Yardangs represent more current Amazonian geological phenomena and that of the lineaments. As the Tharsis Mons/Valles Marineris regions were created billions of years ago during intense metamorphism and volcanism that altered the landscape and shaped the Tharsis Mons volcanos and Valles Marineris valley channel. The desolate carbon-dense atmosphere of Mars today wasn't like what it was, as it had a warmer humid stomper allowing geothermal processes and glaciation of ice caps to form and carve out the sinuous valleys and channels from magma formation and groundwater discharge (Irwin, et al. pg. 430-433). Including greenhouse gases allowing a water cycle to be sustainable for the planet and creating different drainage networks and physiographic systems.

3.Remote Sensing with Multi-Spectral Imagery: In applying this to GIS with a reputable DEM, any hydrological system can be obtained, the predicament though is deciphering what impacts of the tributary system and the order of the streams. The sediments and minerals that were depicted in the tentative model (feldspar, quartz, olivine) can shed light further on the compositional structure of definite geology that is making up the planet of Mars. As in the study conducted by Rangarajan, et. al, they further used remote sensing in deducing that magma and lava may not be the sole factors of shaping one region of Mars (Syrtis Major). Using OMEGA, HiRISE, CRISM, and MOLA imagery, profile of mineral obedience and influence in sedimentation and composition: "The role of water in carving out channels in this region was further supported by associated mineralogical evidence of hydrated minerals like Fe/Mg phyllosilicates, Al phyllosilicates and zeolites in a crater in the region from CRISM TRDR observations. A representative pixel spectrum extracted from these CRISM-derived spectral summary products showed absorptions at 1.4 and 1.9 lm, attributed to the presence of structural H2O and a 2.30–2.32 lm absorption due to the presence of Fe/Mg, which showed a very good spectral match with CRISM spectral repository for commonly found Fe/Mg phyllosilicates on Mars." (Rangarajan, et. al pg. 1546)

## Discussion and Conclusion

In synopsis, this project serves as a baseline for conducting lineament analysis and drainage network extraction of DEMs and investigating linear directional means based on the flow of said features. Based on the literature and overall project there are many considerations to be factored into delving into another whole planet and the intricacies of how it originated, shaped, and is processed today. Having resources of spectral imagery from space rovers and satellites paves the way for innovation and discovering more about the planetary systems beyond that of Earth (and not just Earth). This project has provided additional supplemental materials that had to be quelled due to time limitations and from negative correlations from the results gathered. To provide more alternatives in assisting potential users in classifying and automating geological features and honing on phenomena on Mars (whether it be Tharsis Mons or Valles Marineris) it to have more qualitative analysis and conduct through quantitative analysis of their choosing.

From the literature presented and learned additional resources have been supplemented:

Figure 7. Provides insights into using three-dimensional modeling techniques and the actual dimensionality of the two-dimensional rasters and seeing the actual formation of the Tharsis Mons Shield Volcanos and ridges and valleys of Valles Marineris. Though this model presented is an overview of what can be done, we can get a better understanding of the flow patterns and catchment basins for watershed assessment and fine-scaled geology if we were to use the CTX/HiRISE imagery in this scenario ((Rangarajan, et. al pg. 1548). Delineating the finer-detailed imagery and having inter-dimensionality between raster datasets would prove advantageous for qualitative analysis

and modeling to compare even the environment of Mars to that of Earth and ascertain current-day differences and comparisons without historical geological intricateness.

Figure 8. Is a script that is purposed towards inputting spatially referenced Mars features and streamlining them to the surface. This allows users to automatically input their features with said Aspect, Slope, and Hillshade suitability analysis and compare gemological features with what they have to assess. This leads to the following Figure 9., which is a Deep Neural network that takes a folder of a plethora of various photos from Mars of differing features and classifies them and labels what they are. Using parallel computing, pooling, and flattening techniques, both these scripts combine can suit users to find and outline an area of interest on Mars they would want to delve into and then begin suitability analysis, on and use remote sensing to find changes or comparison of geological quandaries to that of Earth.

Based on these avenues and potentials, the next phase of this project would be to further assess different quantities of features that can be assessed and propose the study in a different light or more thorough analysis of lineaments and their faults and fracture implications instead of comparison with drainage network correlations. The brevity of this project and superficial analysis was enough to bring insight into how two confounding variables can potentially be similar and function together, and just because they aren't the same here, doesn't mean that it can be the same elsewhere from past events (uniformitarianism) given the literature analysis and discontinuous data that was mapped from this project.

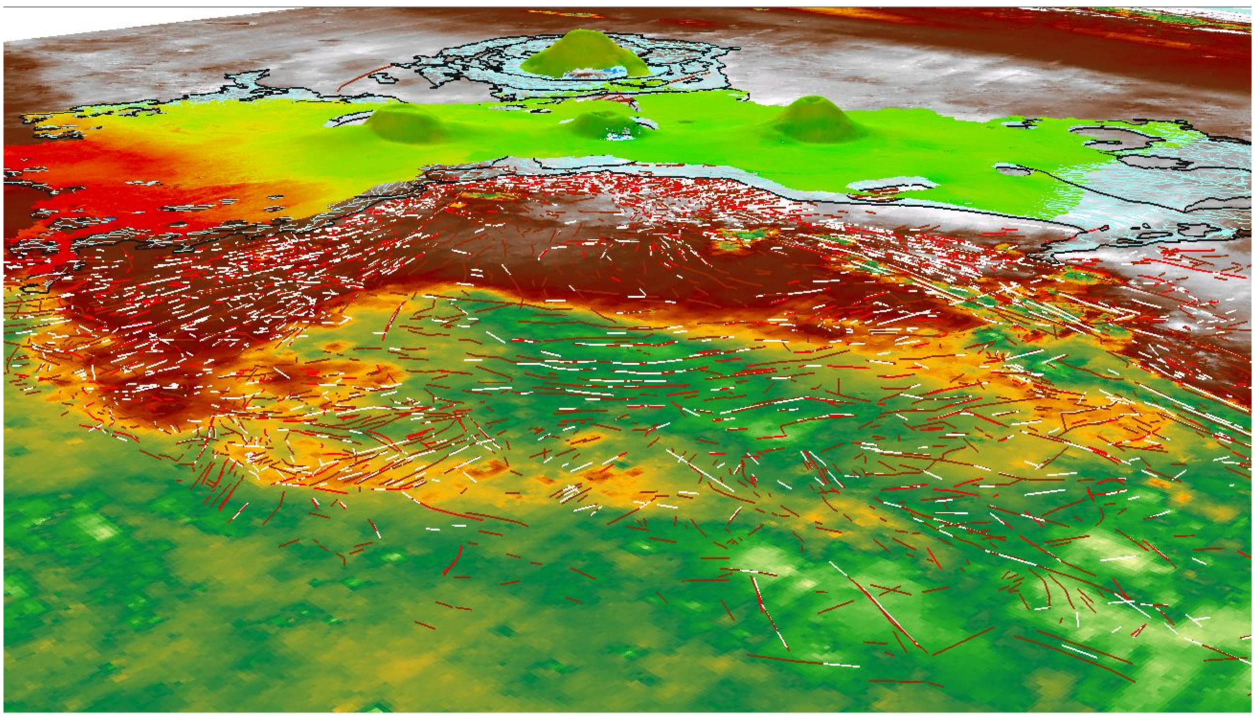
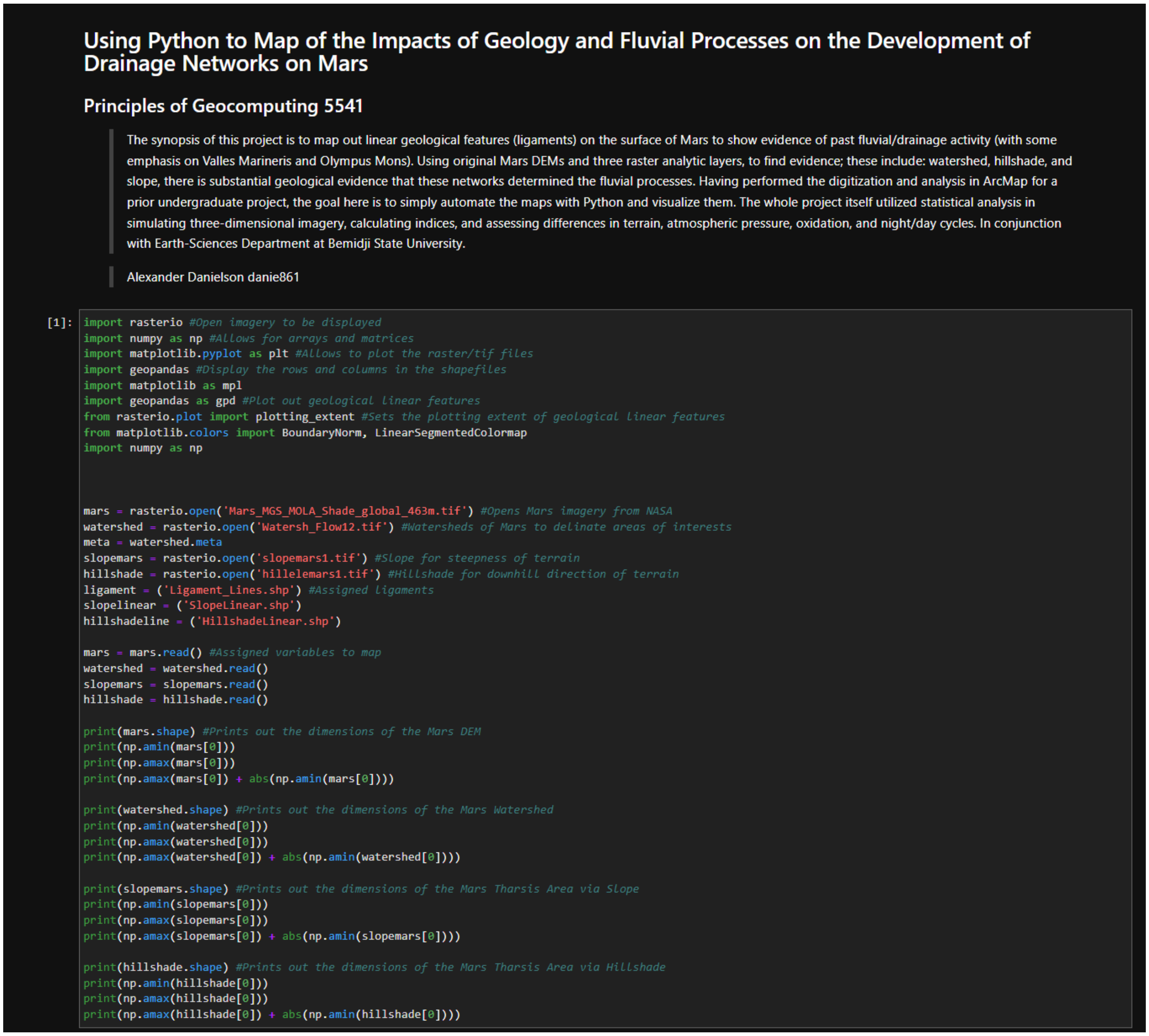


Figure 7. 3D Rendering of Tharsis Mons/Valles Marineris regions with the ordering of Stream networks and ancillary lineaments in ArcScene adjusting Base Heights and stretching of feature layers.



## Using Python to Map of the Impacts of Geology and Fluvial Processes on the Development of Drainage Networks on Mars

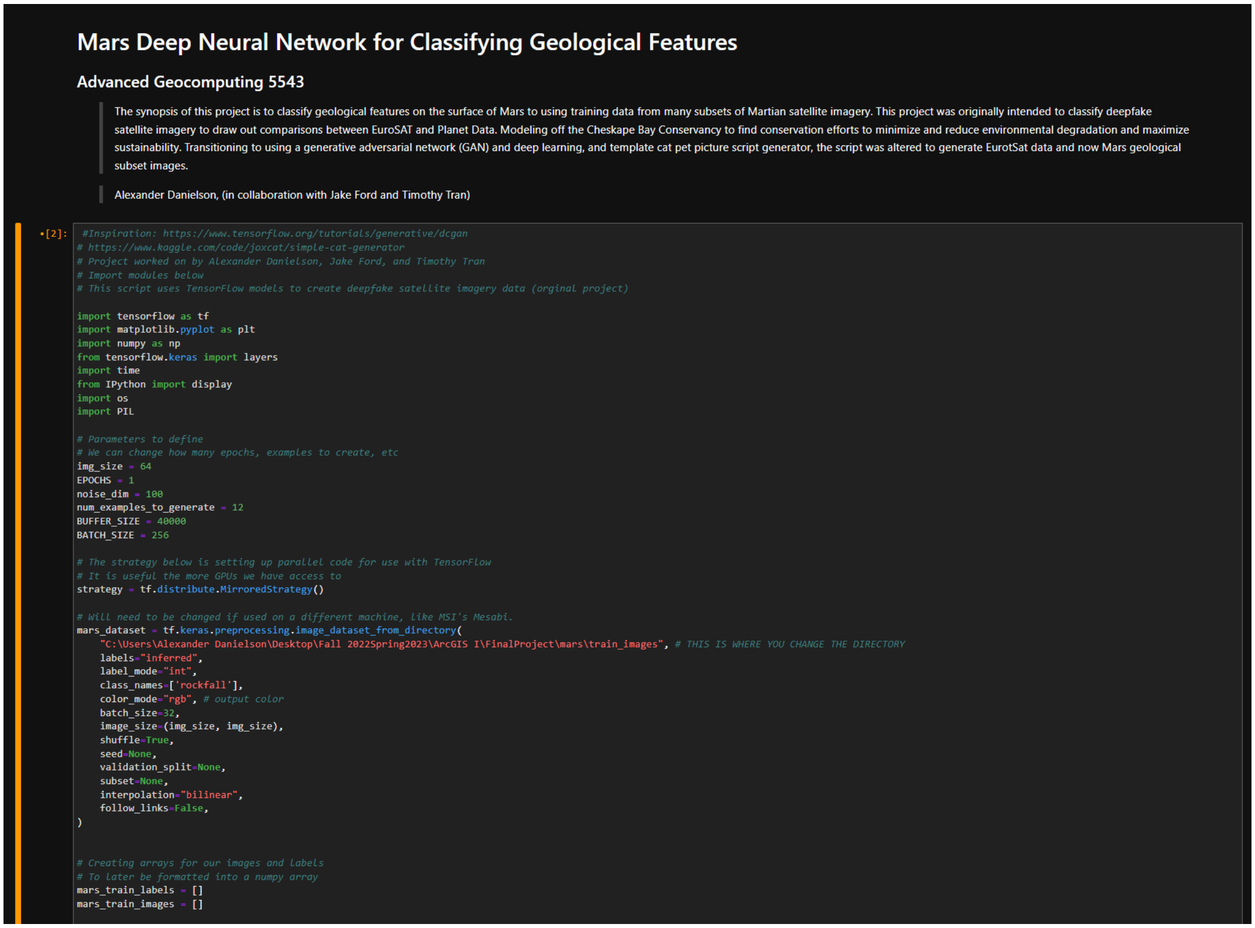
### Principles of Geocomputing 5541

> The synopsis of this project is to map out linear geological features (ligaments) on the surface of Mars to show evidence of past fluvial/drainage activity (with some emphasis on Valles Marineris and Olympus Mons). Using original Mars DEMs and three raster analytic layers, to find evidence; these include: watershed, hillshade, and slope, there is substantial geological evidence that these networks determined the fluvial processes. Having performed the digitization and analysis in ArcMap for a prior undergraduate project, the goal here is to simply automate the maps with Python and visualize them. The whole project itself utilized statistical analysis in simulating three-dimensional imagery, calculating indices, and assessing differences in terrain, atmospheric pressure, oxidation, and night/day cycles. In conjunction with Earth-Sciences Department at Bemidji State University.

> Alexander Danielson danie861

[1]:
```
import rasterio #Open imagery to be displayed
import numpy as np #Allows for arrays and matrices
import matplotlib.pyplot as plt #Allows to plot the raster/tif files
import geopandas #Display the rows and columns in the shapefiles
import matplotlib as mpl
import geopandas as gpd #Plot out geological linear features
from rasterio.plot import plotting_extent #Sets the plotting extent of geological linear features
from matplotlib.colors import BoundaryNorm, LinearSegmentedColormap
import numpy as np



mars = rasterio.open('Mars_MGS_MOLA_Shade_global_463m.tif') #Opens Mars imagery from NASA
watershed = rasterio.open('Watersh_Flow12.tif') #Watersheds of Mars to delinate areas of interests
meta = watershed.meta
slopemars = rasterio.open('slopemars1.tif') #Slope for steepness of terrain
hillshade = rasterio.open('hillelemars1.tif') #Hillshade for downhill direction of terrain
ligament = ('Ligament_Lines.shp') #Assigned ligaments
slopelinear = ('SlopeLinear.shp')
hillshadeline = ('HillshadeLinear.shp')

mars = mars.read() #Assigned variables to map
watershed = watershed.read()
slopemars = slopemars.read()
hillshade = hillshade.read()

print(mars.shape) #Prints out the dimensions of the Mars DEM
print(np.amin(mars[0]))
print(np.amax(mars[0]))
print(np.amax(mars[0]) + abs(np.amin(mars[0])))

print(watershed.shape) #Prints out the dimensions of the Mars Watershed
print(np.amin(watershed[0]))
print(np.amax(watershed[0]))
print(np.amax(watershed[0]) + abs(np.amin(watershed[0])))

print(slopemars.shape) #Prints out the dimensions of the Mars Tharsis Area via Slope
print(np.amin(slopemars[0]))
print(np.amax(slopemars[0]))
print(np.amax(slopemars[0]) + abs(np.amin(slopemars[0])))

print(hillshade.shape) #Prints out the dimensions of the Mars Tharsis Area via Hillshade
print(np.amin(hillshade[0]))
print(np.amax(hillshade[0]))
print(np.amax(hillshade[0]) + abs(np.amin(hillshade[0])))
```

Figure 8. Automated Script pseudocode utilized for inputting geomorphological Mars data to superimpose and automate the data, instead of mapping in ArcGIS.



Mars Deep Neural Network for Classifying Geological Features

Advanced Geocomputing 5543

> The synopsis of this project is to classify geological features on the surface of Mars to using training data from many subsets of Martian satellite imagery. This project was originally intended to classify deepfake satellite imagery to draw out comparisons between EuroSAT and Planet Data. Modeling off the Cheskape Bay Conservancy to find conservation efforts to minimize and reduce environmental degradation and maximize sustainability. Transitioning to using a generative adversarial network (GAN) and deep learning, and template cat pet picture script generator, the script was altered to generate EurotSat data and now Mars geological subset images.

> Alexander Danielson, (in collaboration with Jake Ford and Timothy Tran)

•[2]:
```
#Inspiration: https://www.tensorflow.org/tutorials/generative/dcgan
# https://www.kaggle.com/code/joxcat/simple-cat-generator
# Project worked on by Alexander Danielson, Jake Ford, and Timothy Tran
# Import modules below
# This script uses TensorFlow models to create deepfake satellite imagery data (orginal project)

import tensorflow as tf
import matplotlib.pyplot as plt
import numpy as np
from tensorflow.keras import layers
import time
from IPython import display
import os
import PIL

# Parameters to define
# We can change how many epochs, examples to create, etc
img_size = 64
EPOCHS = 1
noise_dim = 100
num_examples_to_generate = 12
BUFFER_SIZE = 40000
BATCH_SIZE = 256

# The strategy below is setting up parallel code for use with TensorFlow
# It is useful the more GPUs we have access to
strategy = tf.distribute.MirroredStrategy()

# Will need to be changed if used on a different machine, like MSI's Mesabi.
mars_dataset = tf.keras.preprocessing.image_dataset_from_directory(
    "C:\Users\Alexander Danielson\Desktop\Fall 2022Spring2023\ArcGIS I\FinalProject\mars\train_images", # THIS IS WHERE YOU CHANGE THE DIRECTORY
    labels="inferred",
    label_mode="int",
    class_names=['rockfall'],
    color_mode="rgb", # output color
    batch_size=32,
    image_size=(img_size, img_size),
    shuffle=True,
    seed=None,
    validation_split=None,
    subset=None,
    interpolation="bilinear",
    follow_links=False,
)


# Creating arrays for our images and labels
# To later be formatted into a numpy array
mars_train_labels = []
mars_train_images = []
```

Figure 9. Deep Neural Network pseudocode for generating Mars geological features (faults, scarps, carters, etc.) and to assist in classifying the features efficiently and reduce time in locating features.

## References


Alegre Vaz, D. (2011). Analysis of a Thaumasia Planum rift through automatic mapping and strain characterization of normal faults. Planetary and Space Science, 59(11–12), 1210–1221. https://doi.org/10.1016/j.pss.2010.07.008

How Linear Directional Mean works—ArcGIS pro. (n.d.). Arcgis.com. Retrieved December 19, 2022, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-how-linear-directional-mean-spatial-statistics-w.htm

Irwin, R. P., III, Howard, A. D., & Craddock, R. A. (2008). Fluvial Valley Networks on Mars. In River Confluences, Tributaries and the Fluvial Network (pp. 419–451). John Wiley & Sons, Ltd.

Kiri L.Wagstaff You Lu,1 Alice Stanboli,1 Kevin Grimes,1 Thamme Gowda,1,2 Jordan Padams. (n.d.). Deep Mars: CNN Classification of Mars Imagery for the PDS Imaging Atlas. The Thirtieth AAAI Conference on Innovative Applications of Artificial Intelligence (IAAI-18).

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

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

Sauer, T. J., Alexander, R. B., Brahana, J. V., & Smith, R. A. (2001). The importance and role of watersheds in the transport of nitrogen. In Nitrogen in the Environment: Sources, Problems and Management (pp. 147–181). Elsevier.

Stepinski, T. F., Marinova, M. M., McGovern, P. J., & Clifford, S. M. (2002). Fractal analysis of drainage basins on Mars: FRACTAL ANALYSIS OF DRAINAGE BASINS ON MARS. Geophysical Research Letters, 29(8), 30-1-30–34. https://doi.org/10.1029/2002gl014666

Wikipedia contributors. (2022, November 29). Rock cycle. Wikipedia, The Free Encyclopedia. https://en.wikipedia.org/w/index.php?title=Rock_cycle&oldid=1124521537

## Self-score

Fill out this rubric for yourself and include it in your lab report. The same rubric will be used to generate a grade in proportion to the points assigned in the syllabus to the assignment.

| 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 | **20** |
| **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 | **25** |
| **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 | **18** |
| | | 100 | **91** |