How to Make the Most Out of Your First Trip to Mars

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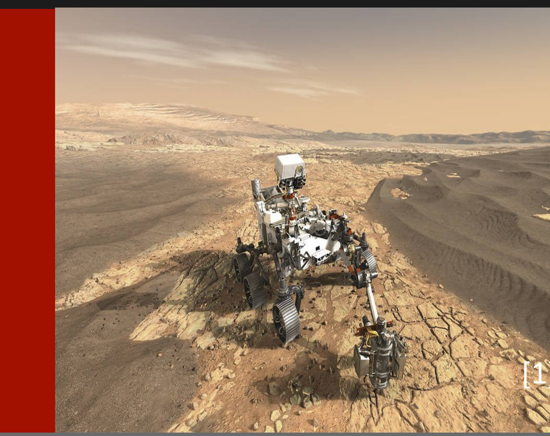

Introduction

With manned missions to Mars becoming a reality in the coming decades, determining ideal sites is increasingly important.

Potential scientific goals of such missions:

1.) Understand the geology of Mars and gain insights into the early solar system

2.) Locate liquid water or ice and do detailed chemical analysis

3.) Find conclusive evidence for the presence of life

The safety of the astronauts and potential Martian life is of the highest priority and minimizing the risks of sandstorms and biological cross contamination is of utmost importance to future missions.

Methodology

Atmospheric Model: I wrote a computer model in Python for the Martian atmosphere to determine pressure and temperature as a function of altitude and season on the Martian surface. The equations below are the main equations of my model.

$$P(h) = 8.686 \exp\left(\frac{-h + 4000}{10800}\right) \quad [4]$$

$$T_{LR} = \left(\sqrt[4]{L_{\odot}(1-\alpha)/(4\sigma)} - 4.4\frac{h}{1000}\right) * (Cos(\phi)Cos(\delta) + Sin(\phi)Sin(\delta))$$

This model, coupled with a DEM from MOLA (Mars Orbital Laser Altimeter)[5], allowed me to make temperature and pressure maps of the Martian surface for noon during the late Martian spring (Figures 1 and 2). With these two maps I was able to make binary rasters and find locations that lie above the triple point of water (6.11567 mBars and 0.01°C) which is where liquid water could be stable on the Martian Surface for at least part of the year. To minimize distortion my analysis only considered areas between 60N and 60S on the Martian surface.

Weighted Overlay Analysis: The second part of my project involved a weighted overlay analysis in which I considered both the scientific goals and environmental hazards that a potential mission might face.

Scientific Goals: To achieve the outlined scientific goals, I wanted to find a location that is near or on top of volcanic units (11%), impact units (11%), ice/water rich units (11%), or geological units that are a mix of these (11%)[3] and that are within my potential water-bearing regions (18%) and near fluvial features (11%). I also considered the potential value to a mission of being able to locate and recover one of the rovers or landers previously sent to Mars (5%).

Environmental Hazards: The two biggest hazards that can be controlled by location on the Martian surface are sandstorms and biological cross contamination with Martian lifeforms. To minimize these hazards I wanted a location far away from known sand dune regions (11%) and that isn't within fluvial features (11%)[2,3].

The result of my analysis is the above site suitability map which shows the best sites in red (Figure 6)

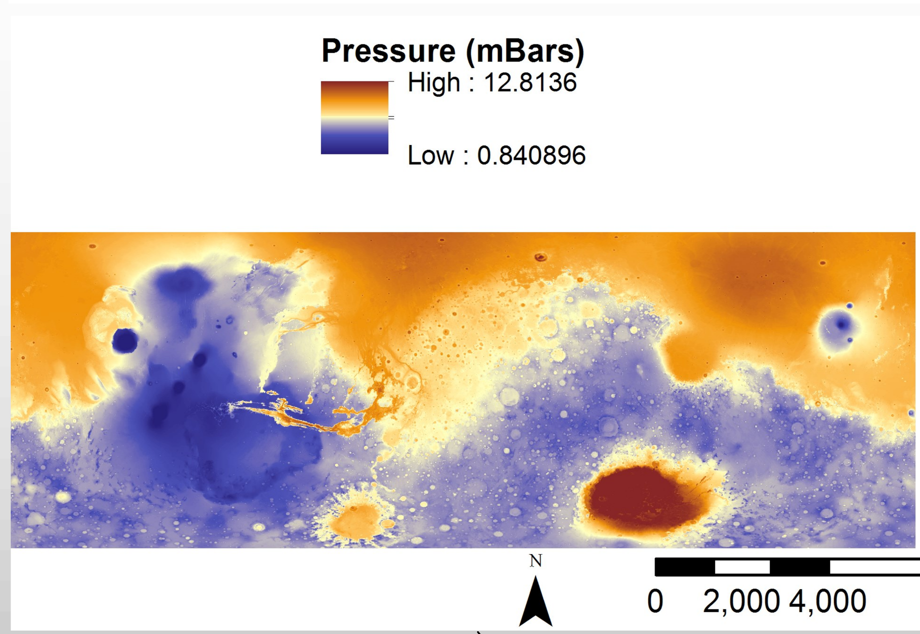

Figure 1: Pressure Map for the Martian Spring made using the modified methodology of Lobitz et. al 2000.

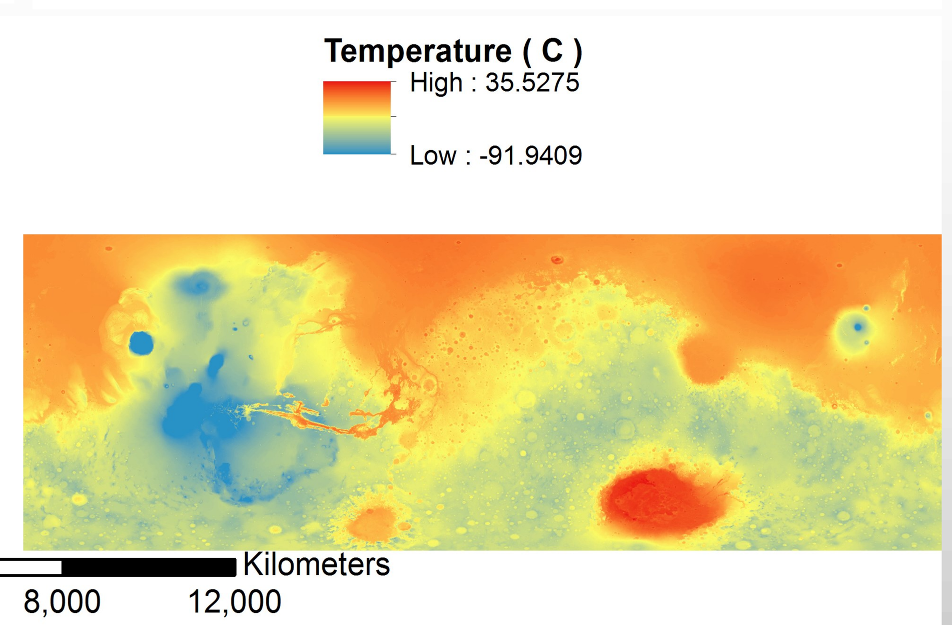

Figure 2: Temperature map for Martian Spring made from the temperature model for the Martian surface.

Site Suitability Map

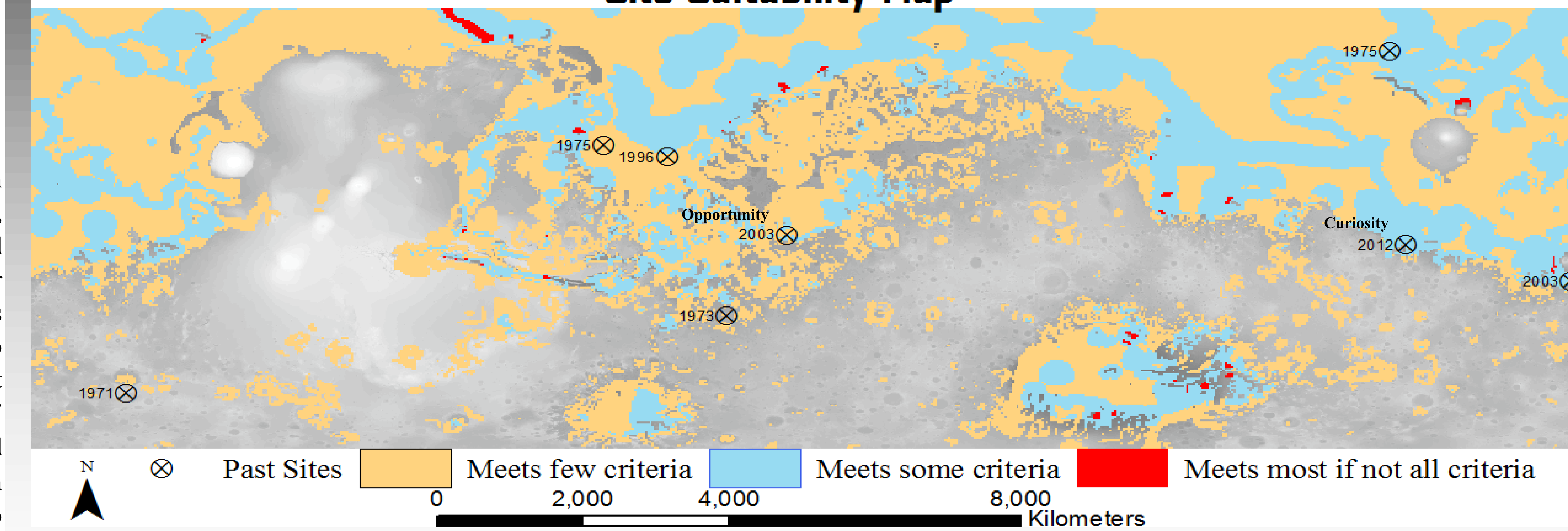

Figure 6: Output map of the weighted overlay analysis detailing locations based upon my suitability criteria. Included on this map are previous NASA, RSA, and ESA missions that landed on Mars. After 1973 all missions were within areas I identified as being suitable for manned missions

Results

Unsurprisingly the Northern Hemisphere, which contains most of the Martian Ice, holds the majority of the regions which meet my criteria. As a quality check I added the locations of previous Mars missions to see if they fell within my regions. Besides the early Mars 2 and 6 landers which had significantly less data, all craft fell within regions I highlighted.

Conclusions

While my model and methodology yielded good results by comparison with Lobitz et. al 2000 and previous missions, improved physical models, and higher resolution data could produce better, more detailed maps, and thanks to Jake Benner for his help with this project.

Sources

[1]Greicius, Tony. “Mars Exploration Image Gallery.” *NASA*, NASA, 13 Mar. 2015, www.nasa.gov/mission_pages/mars/images/index.html.

[2]Hayward, R.K., Mullins, K.F., Fenton, L.K., Hare, T.M., Titus, T.N., Bourke, M.C., Colaprete, A., and Christensen, P.R., 2007 Mars Global Digital Dune Database: MC2 - MC29: U.S. Geological Survey Open-File Report 2007-1158. [http://pubs.usgs.gov/of/2007/1158/].

[3]Hynek, B. M., M.R.T. Hoke, and M. Beach (2010) Updated Global Map of Martian Valley Networks and Implications for Climate and Hydrologic Processes, Journal of Geophysical Research, 115, E09008, doi:10.1029/2009JE003548.

[4]Lobitz, B., et al. “Use of Spacecraft Data to Derive Regions on Mars Where Liquid Water Would Be Stable.” *Proceedings of the National Academy of Sciences*, vol. 98, no. 5, 27 Jan. 2000, pp. 2132–2137., doi:10.1073/pnas.031581098.

[5]P. Withers, J.R. Murphy, MER1/MER2-M-IMU-5-EDL-DERIVE-V1.0, NASA Planetary Data System 2009.

Potential Regions with Water

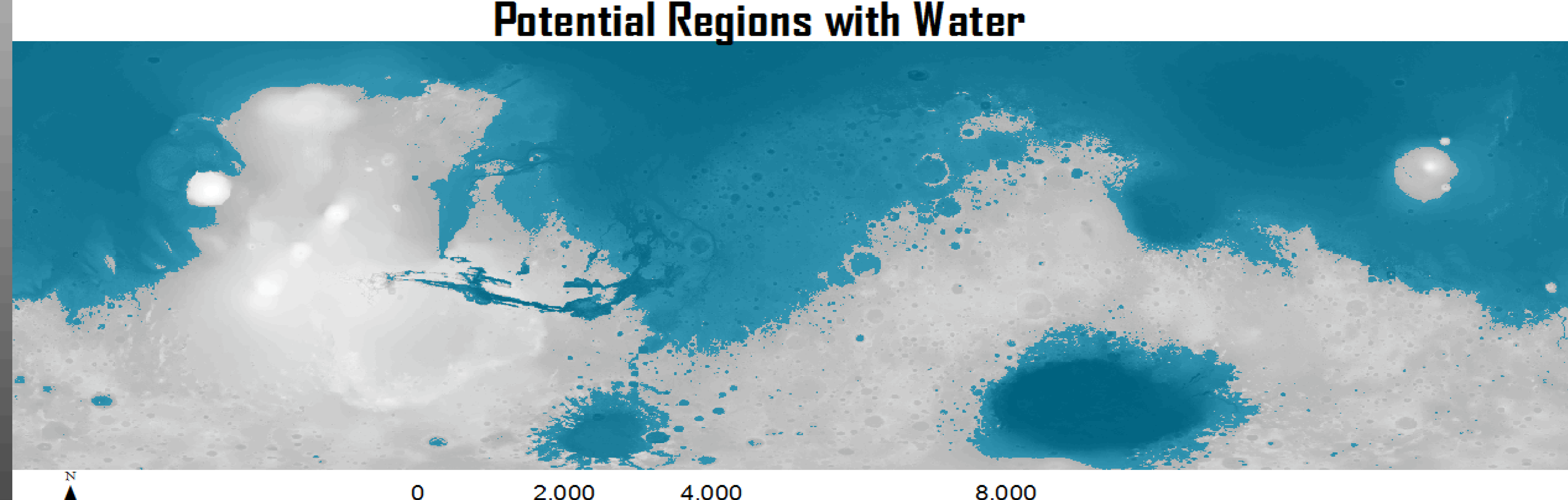

Figure 3: Map of areas where liquid water could potentially exist during the Martian spring. This map was made through the combination of the pressure (Figure 1) and temperature (Figure 2) maps. The areas highlighted in blue are those that are above and to the left of the triple point of water (6.11657 mBar and 0.01° C). See Methodology section for details on the creation of this map

Environmental Hazards

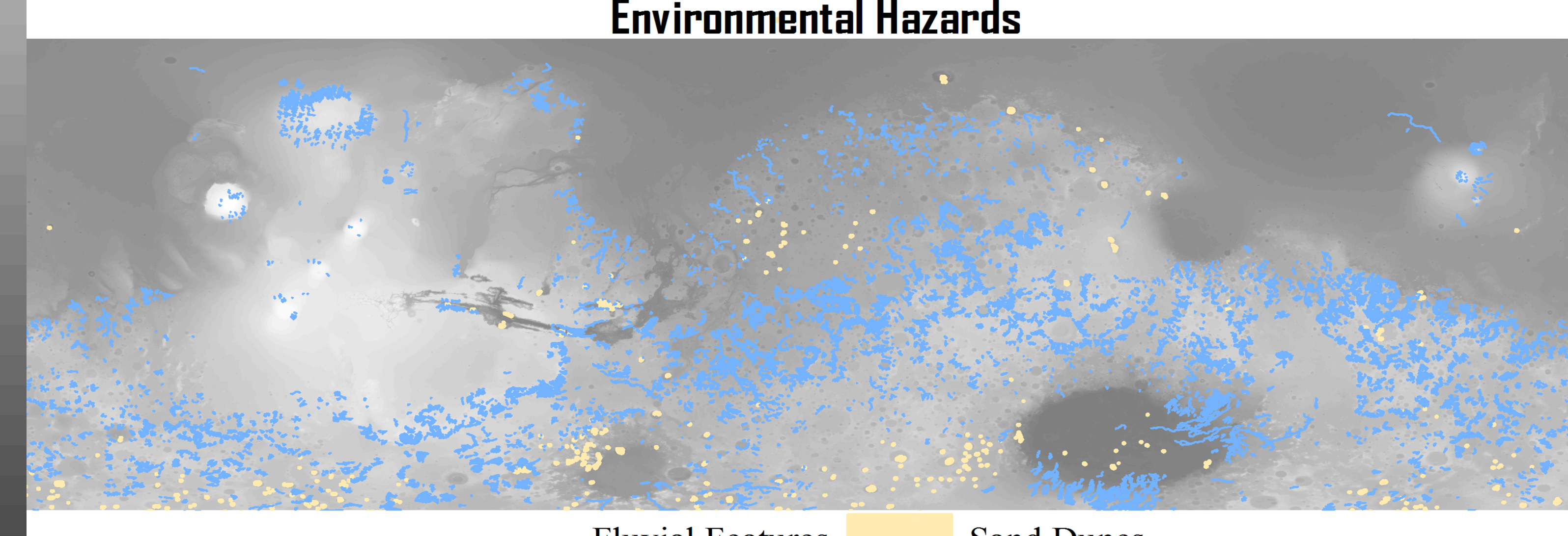

Figure 4: Surficial Features on Mars that must be avoided to prevent harm to the astronauts, equipment, and possible life that exists on Mars

Geologic Units of interest

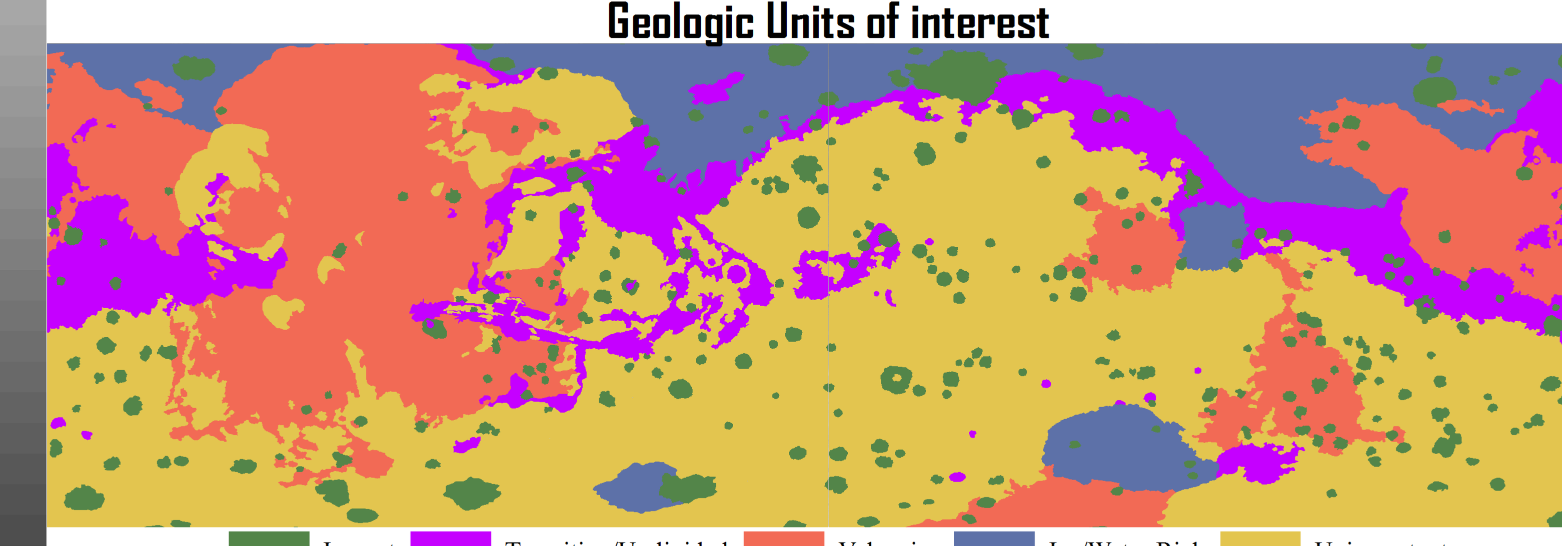

Figure 5: Categorized map of the geological units of Mars. Focuses on Impact, Volcanic, and potentially Ice/Water rich units. Transition and Undivided units are included in analysis but are weighted less.