Estimating timescales for liquid water on Mars using sulfates in Meridiani Planum through terrestrial analogues in the Hawaiian Islands

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Introduction:

- Sulfate minerals are common on the Martian surface and suggest past water activity
- Current estimates place liquid water activity on Mars ending ~3 billion years ago in Hesperian Period
- Competing models exist for sulfate origin in literature, these models address individual sulfate sources but are incomplete regarding hydrological processes and timescales of Martian water activity

Goals:

- Determine whether aqueous sulfate transported through equatorial valley networks was primary sulfate source for layered sulfate-rich terrains of Meridiani Planum on Mars and to better understand the timescale of this process

- Using two terrestrial analogues from the Hawaiian Islands, Kauai (5.1 million years old), and Island of Hawaii (0-400,000 years old) we can quantify aqueous sulfate transport and estimate the timescale of this process
- Hawaiian islands were chosen as they are of basaltic composition and show high sulfur emission rates similar to Mars
- Both islands differ in porosity and modern volcanic emission with Kauai being much older and volcanically inactive compared to the newly formed more porous basaltic bedrock of currently active Island of Hawaii

Methods:

- Sulfate quantity and size of watershed area in Meridiani Planum were estimated using previously published data[1]
- Water chemistry and discharge data were obtained from an online USGS repository for the islands of Hawaii and Kauai
- SO_4 Flux was calculated for surface water and groundwater measurements using the following equations:

SO_4 Flux = SO_4 (mg/L) * Discharge (L/s)

- To calculate the total SO_4 Flux, two equations were performed depending on the island, these equations exist with G_w as groundwater and S_w signifying surface water

Kauai **Hawaii**

$$G_w = \frac{.15 * S_w}{.85} \qquad G_w = \frac{.85 * S_w}{.15}$$

Where G_w as is groundwater and S_w signifying surface water

- Digital elevation maps (DEMs) of Hawaii and Kauai were downloaded from the USGS National Map repository and the coordinates for surface and groundwater sites were plotted on the DEMs
- Using the hydrology spatial analyst tools in ArcGIS, the sizes of watersheds were calculated
- Using the line of best fit on the graphs of SO_4 Flux relative to Watershed Size in Hawaii, we calculated the SO_4 Flux and timescales of water activity for the Meridiani Planum on Mars

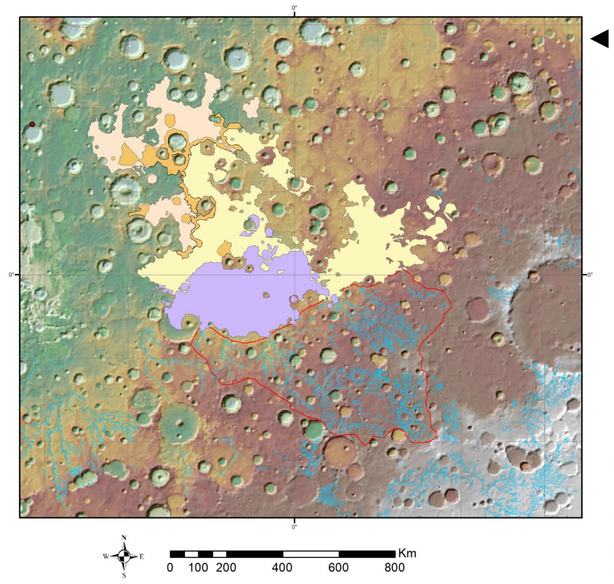
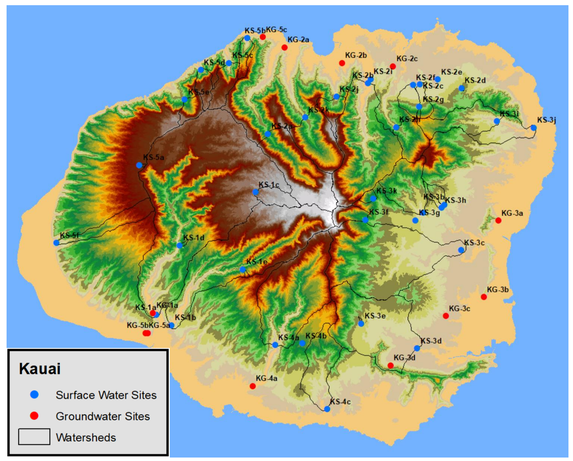


Figure 1: Regional map showing Meridiani Planum (MP) and its watershed on Mars. This low-lying region near equatorial Mars shows strong evidence for flowing water through valleys that led to layered sulfate deposits. Figure adopted from [1]

Figures 2 & 3: Maps of Kauai and Island of Hawaii with USGS surface and groundwater sites and watersheds.



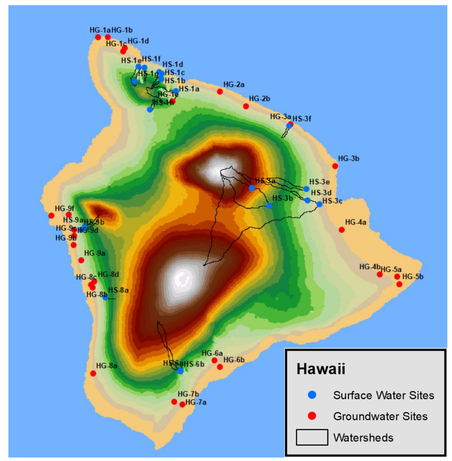


Figure 6: Simplified model adopted from [2] showing water sources in Meridiani Planum. Local geology provides evidence for multiple water sources. Karst topography in the region suggests water flowed at the surface, while lower sulfate-rich unit from acidic groundwater that permeated upwards to the Martian surface.

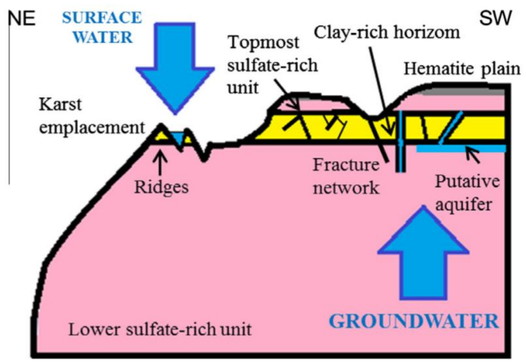
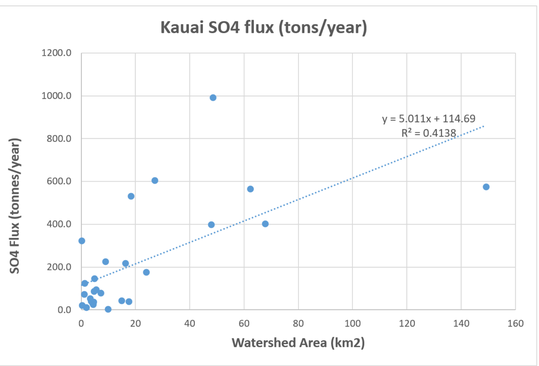
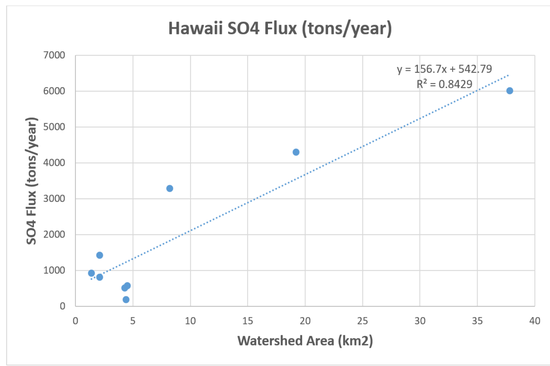


Figure 7: [5] Image taken by the Opportunity rover in Meridiani Planum region. Strange rounded rock, Wopmay, may have been formed from flowing water on Mars. Courtesy of NASA.





▲ **Figures 4 & 5:** Using the watershed areas from figures 2 and 3, we plotted the area in km^2 against the total calculated SO_4 Flux for each surface water site on both islands. By applying a line of best fit to each graph, a model for the Martian water timescales could be created for both analogues. Kauai and Hawaii offer good comparisons to the Martian surface as they share the same basaltic rock composition. By plugging in the calculated watershed size and SO_4 volume for Meridiani Planum from figure 1, an estimated timescale can be predicted for the history of liquid water on Mars.

Results/Future Work:

Preliminary results using Kauai as analog suggest a timescale of 3.22 x 10^7 years for water activity in Meridiani Planum, while Hawaii suggests a timescale of 1.03 x 10^6 years. These results count as continuous water flow and do not take in the possibility of intermittent flows. Current estimates for the total timescale of Martian water flows place intermittent flows of 10^5 – 10^7 years over a timespan of 10^8 years which occurred ~3 billion years ago [3]. While these are rough preliminary estimates with few samples, these early results provide a reasonable timeframe for these flows to occur. These results are promising as the values received from these models are fairly congruent to other estimations, strengthening the validity of previous methods. In the future, more data will be collected to improve the accuracy of these models. Also, Iceland will be used as analogue for Mars due to its basaltic terrain. Observing the difference in age estimates between a warm-wet climate (Hawaii) and a cold-icy climate (Iceland), will be a crucial step in understanding the history of liquid water on Mars.

Citations:

[1] Brian Hynek, University of Colorado, Boulder
[2] Flahaut J. et al. (2015) *Icarus*, *248*, 269-88
[3] Hoke M. et al. (2011) *Earth and Planetary Science Letters, 312,* 1-12
[4] Szynkiewicz A. et al. (2014) *Earth and Planetary Science Letters, 393,* 14-25
[5] NASA Opportunity Rover
[6] USGS National Map

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