Sulfur cycling at Meridiani, Mars

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Unlike Earth's carbon cycle, Mars' history has been dominated by a sulfur cycle. This has likely had a large impact on geophysical (core composition), geological (sulfur soures-to-sinks), and even climatic conditions (potentially warming the planet). Sulfur enrichment is evident in the Mars meteorites (enrichment up to ~22 wt%), global martian soil (2.5 wt%), global dust (2.7 wt%), and bedrocks investigated by rovers (>30 wt% in cases) (King and McClennan, 2010). It is thought that Mars accreted sulfur-rich, and through extensive volcanism it outgassed significant sulfur to the surface-atmosphere. Thus, sulfur is perhaps the key element for understanding the geochemical evolution of Mars.

One of the largest concentrations of sulfur-rich bedrocks occurs in Meridiani Planum; the site of the Opportunity rover investigations. These bedrocks are thought to have been subjected to acid-sulfate weathering that resulted in sulfate cemented sandstones (e.g., Squyres et al., 2004). However, the source of the sediments and sulfur for these acidic groundwater fluids remains unclear.

Here, we test the hypothesis that the upstream valley networks could have supplied the sediment and/or sulfur required to result in the extensive (4×10^5 km^2) deposits of sulfate-rich bedrocks, with a volume of ~1×10^5 km^3. Recent geological mapping by Hynek and di Achille (2017) has provided broader context for the local in situ rover observations and extended them over a large area. These fluvial systems appear to have been active before, and also during, the incipient emplacement of the sulfate-rich bedrocks. This provides a potential source of mobilized sulfur to accumulate in the Meridiani region. Sediment transport modeling by Hoke et al. (2011) detailed the volume of material removed, and the timescales to form the valleys.

We find that the valleys could have provided ~1-2% of the sediments and sulfur required to explain the contemporary observations. Further, the highland watersheds do not display a strong surface enrichment in sulfur, leading to a maximum estimate. Thus, an additional source of sulfur is necessary to explain the enrichment in the bedrocks, which might have been from high SO_4 concentration in a global groundwater system or volcanogenic acid weathering in dust/ice deposits (Michalski and Niles, 2012).