Understanding Mars's Past Fluvial Geomorphology through Comparative Planetology

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Abstract

There is no question in the distant past, Mars was a planet teeming with liquid water, and the planet may have been hospitable enough to support life. The evidence of this past water is written all over Mar's dusty surface. The geomorphological features signal past fluvial activity. Using comparative planetology, such features can be compared to similar phenomena on Earth in order to draw conclusions regarding Mars' fluvial past and future.

Keywords: GES, Mars, planetology, Earth, fluvial, geomorphology, geography

Humans are among the most curious creatures on planet Earth. We have explored our home planet from almost every point imaginable, and it is no surprise many people have turned to the skies as a source of new and exciting information. As humans search for other life in our solar system, galaxy, and beyond, we are increasingly surprised by the data coming back from some of our closest celestial neighbors, such as Mars. It is becoming increasingly clear it may not be necessary to go so far from home to locate "extraterrestrial life"—it may be right in our own backyard. Water is intricately connected with life as we know it, and as we search for signs of other life we are often very pleased to find sources of liquid water, as there exists a strong possibility that life lurks nearby. Scientists have been able to examine the surface features on Mars and retrace the historical steps of ancient water sources as they carved their paths across the planet. There is no question in the distant past, Mars was a planet teeming with liquid water, and may have been hospitable enough to support life. The question we now face is this— does any liquid water remain on Mars? If so, is it possible we may be able to locate life forms beneath the planet's inhospitable surface?

In NOVA's *Ultimate Mars Challenge,* it claims there are three essential "ingredients" necessary to promote and support life (carbon based life forms) present on Earth: liquid water, an energy source (such as volcanic sources or solar energy) and organic compounds.[1] When scientists send rovers to Mars, they select the areas having the most promise of past liquid water, based on observations of water features on Earth. Examples of these paleo-hydrological features include deep canyons having been carved by water or areas with high concentrations of course grained hematite, usually formed in areas with a large concentration of water.[2] Of the three components allowing for life, the most constant on Mars is an energy source. Solar energy is abundant on Mars— not only is the Martian atmosphere 100 times thinner than ours on Earth, but there is no magnetosphere to protect the planet from the solar wind. Though this provides more energy to the planet, it narrows the varieties of life able to exist on the surface comfortably. Because Mars has such a constant energy source, the stage is set for life to emerge. Water would be the next best indicator of past or present life. Liquid water is also the condition used to determine the landing location of rovers. But in this search for life through water, what type of evidence are the rovers trying to find?

[1] Shinefield, Jill, & Willumsen, Gail, "Ultimate Mars Challenge," Documentary, Web.
[2] Grocott, Paul, "Voyage to the Sea of Mars," *Catalyst*, Documentary, Web.

The ultimate goal of the Mars missions is to search for any signs of past or present life on the planet. By only searching in places with evidence of past water features, our chances of finding life increase. Unlike the fossils we search for on Earth, the evidence we are searching for on Mars is in the form of organic compounds left behind in the Martian soil.[3] Therefore, the places where there was water and a constant energy source are the most likely to provide evidence of past life in the form of organic compounds.

How do scientists determine whether a given location on Mars was a significant water feature millions of years ago? One of the most effective ways is the process of examining the surface for evidence of paleo-hydrological features. Scientists use the features on Earth as a template for the study of Mars. This is possible because of the incredible similarities between the two planets, such as the rock and soil making up both Earth and Mars. Many landforms on Mars were likely formed in the same ways as their counterparts on Earth. For example, sapping features on Earth such as theater headed valleys appear in the canyons of Mars; it is likely the same process created the Martian features. These features suggest the likelihood of fluvial systems operating on a grand scale at some point in the past mirroring those on Earth today.

Though today Mars seems to be a vast expanse of cold, dry desert, it was not always so desolate. Mars is home to the largest volcano in our solar system: Olympus Mons.[4] Rising to 15 miles above the surface of the planet, this once-active feature contributed to the landscape and the environment, creating lava flows and leaving basalt scattered across the Martian surface. The Martian surface of the past was much warmer than it is today, and was likely much more wet. Research suggests Mars used to be a "paradise" planet with large bodies of water, as well as a hydrothermally active planet with several massive volcanoes.[5] Scientists are still trying to understand the changes that transformed an almost Earth-like planet into the rocky, barren "wasteland" it, is today. The current atmosphere is so thin, liquid water existing at or above the surface would freeze and evaporate at the same time. The only liquid water at the surface consists of two polar ice caps, of not pure water, but are mixed with carbon dioxide and other chemicals preventing the freezing-evaporation result.[6] However, it is possible liquid water exists just below the surface and is therefore "safe" from this fate. Mars is seemingly devoid of surface water, but landforms shaped by past fluvial systems may

[3] Shinefield and Willumsen.

[4] Long, Tony, "Mars: The Red Planet," *The Universe*, Documentary, Web.

[5] Long.

[6] "Astrobiology," *The Universe*, Documentary, Web.

give scientists a clue as to the fate of the past Martian seas and maybe even clues on the location of Mars' water today.

In the search for evidence of life through water on Mars, one of the obvious choices for exploration via rover was the Valles Marineris canyon system, Fig. 1 and 2. This massive feature is the biggest canyon system in the solar system, reaching from the equivalent of "the distance from California to New York" with "steep walls nearly as high as Mt. Everest".[7] The canyon was originally thought to have been created entirely by tectonic activity, formed as the crust cooled and cracked above an abnormality in the mantle.[8]

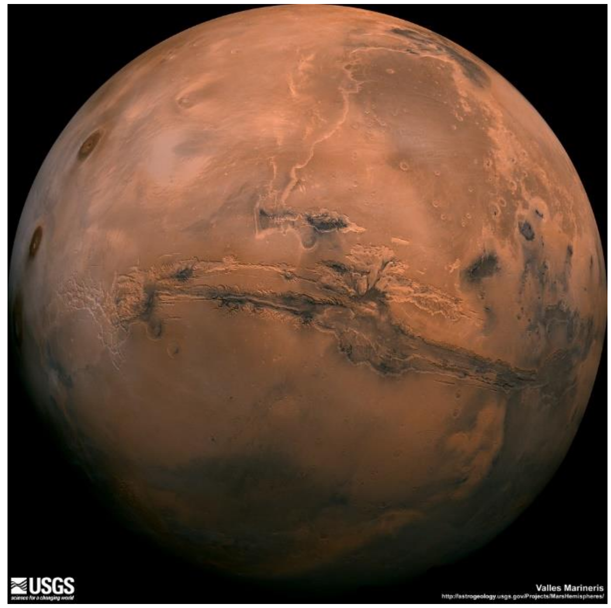


Figure 1 View of the Valles Marineris. [9]

In recent years, scientists have taken a closer look at the Valles Marineris and have determing there were several processes at work helping to create the immense system seen today, water not being the least of these. The most common explanatory processes for the formation of the Valles Marineris include subsidence, faulting, and other disruption, such as landslides, volcanism, and fluvial erosion. The outflow channels extending out of the Valles Marineris canyons have a more watery history, with explanations ranging from "wind, rivers of liquid carbon dioxide, and lava flows to "aqueous floods, carbon dioxide charged

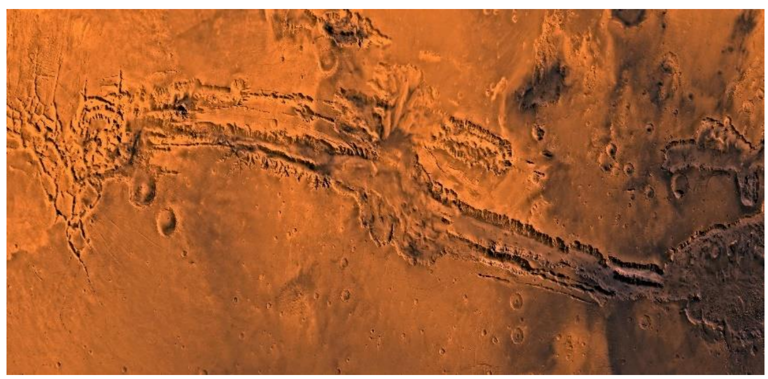


Figure 2 View of the Valles Marineris canyon system on Mars. There has been much debate in the scientific community regarding the processes which shaped the canyons and their outflow channels.

[7] NASA Jet Propulsion Laboratory, "Years of Observing Combined into Best-Yet Look at Mars Canyon." Last modified March 13, 2006. http://www.jpl.nasa.gov/news/news.php?release=2006-035.

[8] USRA Lunar and Planetary Institute, "Explore Mars Inside and Out: About Mars." Last modified October 19, 2009. http://www.lpi.usra.edu/education/explore/mars/background/.

avalanches, and glaciers".[9] The most obvious sign of past water is visible when "zooming in" to the Valles Marineris, where forms resembling dendritic drainage patterns can be seen. The southern hemisphere of Mars contains what scientists have identified as eroding floodplains, river valleys, and fluvial channels.[10] It is also full of the evidence of past stream drainages that flowed in dendritic patterns, as can be seen in Image 606A56 from the Viking Orbiter.

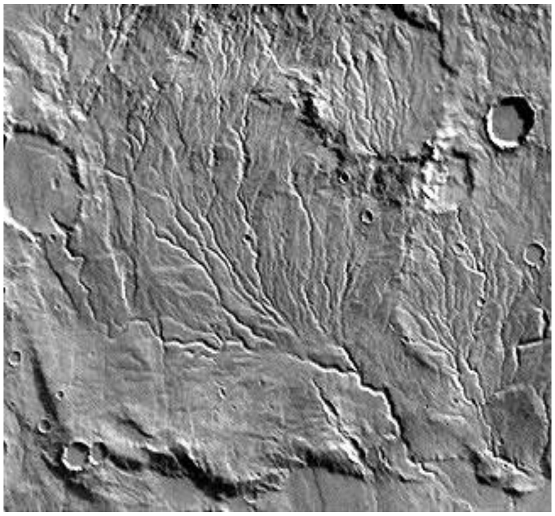


Figure 3 Possible dendritic stream drainage patterns in the southern hemisphere of Mars.

Another contributing factor aiding in the selection of the Valles Marineris is the abundant presence of course-grained hematite.[11] On Earth, this material forms in large bodies of water— through comparative planetology scientists have determined the Valles Marineris is a good place to begin the search for signs of organic compounds (and by extension, life on Mars) because of the conclusive evidence we have pointing to a past abundance of water there. Rovers continue to gather data that may provide more conclusive evidence regarding the role of water in the shaping of the Valles Marineris.

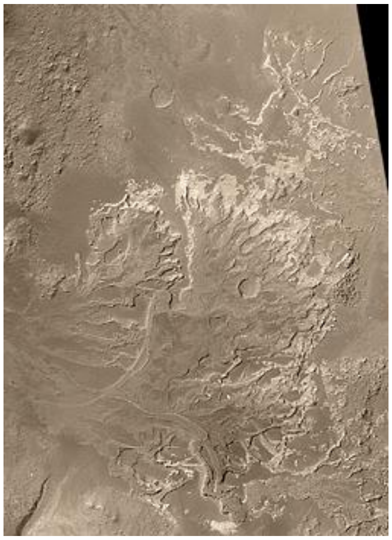


Figure 4 Possible ripple marks left behind when water covered the bottom of Eagle Crater on Mars. See footnote 14.

Evidence of past water flow exists elsewhere on Mars. In Eagle Crater[12] (Fig. 4), there has been evidence of what resembles Earth's ripple marks from shallow seas, as well as dried up deltas resembling the Mississippi River Delta (Fig 5).[13] These examples are intriguing, but rare. A much more common hydrological landform on Mars are

[9] Neil Coleman, and Victor Baker, "Surface morphology and origin of outflow channels in the Valles Marineris region," Chap. 9 in Megaflooding on Earth and Mars, ed. Devon Burr, Paul Carling, Victor Baker (New York: Cambridge University Press, 2009).

[10] BBC., "River Channels Suggest water existed on Mars,"*Learning Zone Broadband: Class Clips*, Documentary, Web.

[11] (Grocott, April 28 2005)

[12] (Short November 01, 2005)

[13] ("Explore Mars Inside and Out: About Mars" October 19, 2009)

craters, that may have formed crater-lakes, such as Gusev Crater[14] (Fig. 6) at some point in the distant past.

Figure 5 Image of what appears to be a dried up river delta on Mars. See footnote 16.

Martian outflow channels are unmistakably signs of past water, and closely resemble the stream channels existing today on Earth. As previously mentioned, these channels may have formed during repeated Martian megafloods, when massive craters in the surface became so full of liquid water they spilled over, carving channels in the surrounding rock.[15] Likely more common in the Martian water cycle were underwater source regions, where water flowed from beneath the surface and flowed over the land. Another hypothesis regarding source regions for these channel flows is the possibility of ice-capped lakes, that permitted the trapped liquid water from evaporating, causing it to seep through the soil and carve passages elsewhere.[16] Most of the hydrological landforms we find on Mars are attributed to the Noachian period[17], this seems to be the most likely period for active precipitation and flooding so far. This is just another piece of the Martian hydrological puzzle scientists are just beginning to understand in recent years.

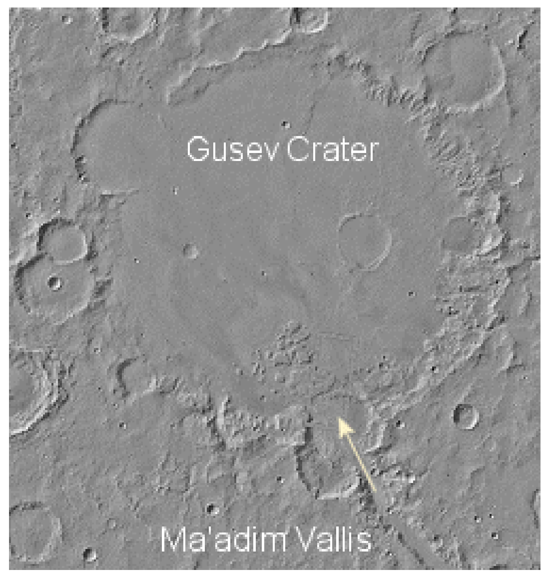


Figure 6 Gusev Crater, a possible crater-lake long dried up. The arrow shows the possible entrance path of water into the crater. See footnote 17.

Perhaps even more intriguing than the abundance of evidence for paleo-hydrological landforms on Mars is the possibility of an active water cycle working on the Martian landscape today. NASA scientists have recently observed a phenomenon bringing the rise of many questions about the possibility of liquid water below the surface of Mars, possibly even enough to sustain life. The Mars

14 ("Science News: Destination Gusev Crater")

15 Lionel Wilson, Alistair Bargery, and Devon Baker, "Dynamics of fluid flow in Martian outflow channels," chap. 16 in *Megaflooding on Earth and Mars*, ed. Devon Burr, Paul Carling, Victor Baker (New York: Cambridge University Press, 2009).

16 (Wilson et al. 2009)

17 Devon Burr, "Paleoflood-generating mechanisms on Earth, Mars, and Titan," *Global and Planetary Change*, no. 70 (2010): 5-13.

Reconnaissance Orbiter captured images of what appears to be dark streaks on the inner mouth of a crater (Fig. 7)[18]. These dark streaks appear in the spring, and disappear later in the season. It is believed these streaks are evidence of saltwater just beneath the surface, which appear as the weather warms up and soon evaporate off.[19] If these streaks are evidence of subsurface water, how much liquid water could scientists expect to find? Measurements have been taken which reveal how much water may be just beneath the surface. The map of water concentration in the upper surface (Fig.8) shows the concentrations of water just below the surface (in the upper sub-surface). Whether this water is habitable remains unclear; this may lead researchers to discoveries of past microbial life. This intriguing phenomenon encourages further testing and research to be completed.

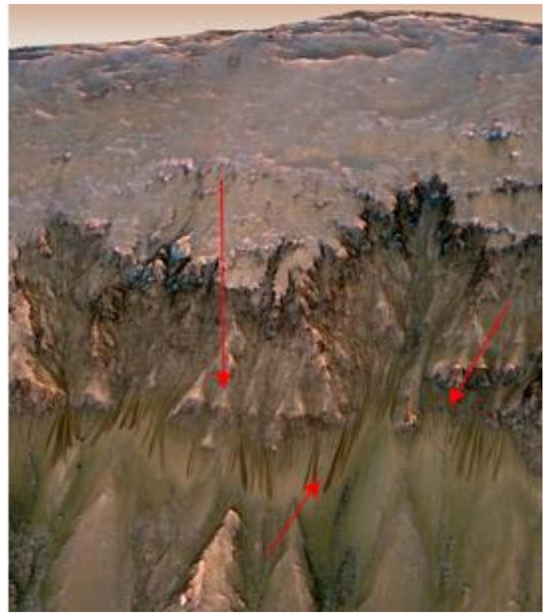
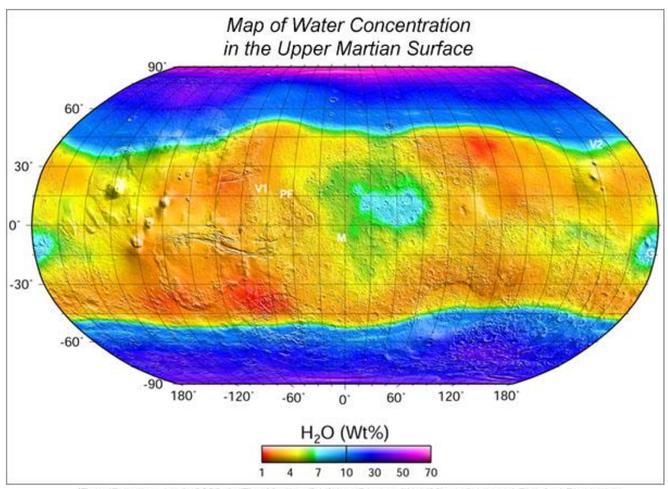


Figure 7 Seasonally occurring dark streak marks on the surface of Mars (indicated by red arrows) may be indicators of the presence of sub surface water.



(From Boynton, *et al.*, 2008, in *The Martian Surface: Composition, Mineralogy, and Physical Properties*, (J. F. Bell, ed.), p. 105-124, Cambridge University Press.)

Figure 8 This map shows water concentration in the upper surface of Mars. The bright blue reveals an abundance of water.

The Red Planet has been considered a "dead" planet for years. Its dry, dusty surface and frigid temperatures, along with the incredibly thin atmosphere and lack of a magnetic field make Mars seem quite inhospitable to us. However, at some point in the past Mars may have looked much friendlier. Scientists have evidence that Mars may have been a land of immense seas and massive volcanoes long ago, and may have even supported basic life. The energy source was there, and as we have learned there was an abundance of

[18] (Chow December 10, 2013)
[19] (Chow 2013)

liquid water. The search for organic compounds will prove whether Mars ever sustained life. For now, scientists will continue to search out locations on Mars having geomorphological markers indicative of water, based on those observed on Earth. The search for water- and for life- continues on our celestial neighbor, Mars.

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