Mud volcanism on Mars: Investigating Possible Surface Liquid Water Activity on Mars using Evidence from Terrestrial Mud Volcano Analogues

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Abstract:

Mars has long been considered a dead world with no liquid water on or near its surface. It is a cold, dry and frigid world. The old adage of 'follow the water' makes us think that if any life ever existed on Mars, it would be fossilized in dry lake beds, frozen in time for millions, even billions of years.

Mareekh Dynamics team is studying the dark streaks on the slopes of Martian landscapes found in satellite imagery. While theorized as possibly being dry sand avalanches, we find stark resemblance of many of these streaks to the mudflows emanating from the vents in the mud volcano fields in Balochistan province of Pakistan. These mudflows composed of brine mixed with fine clay, ooze out with methane pressure and flow downhill on the surface until eventually drying out.

Could the same mechanism be going on, on the surface of Mars? Mars seems dry, yet it locks oceans worth of water just underneath its surface in the form of permafrost. While it is not known if Mars has any current volcanic activity below its crust, there is evidence suggesting existence of areas with fairly recent volcanism. We believe it is possible that the trapped heat and pressure from intermittent underground volcanic activity and gravitational forces may be causing occasional melting of water in the permafrost, which, combined with fine Martian regolith, volcanic ash, and possibly methane, may be bursting out occasionally to the surface appearing as dark streaks before drying out. This may be analogous to the mud volcanic activity in Balochistan and other places on Earth. If this is true, it will not only be an exciting discovery of the existence of liquid water on Mars on or near its surface, but also increase the prospects of finding life on the red planet.

1. Introduction

Mars. Dry, desolate, dead. Secrets of its wet past frozen and locked away forever.

Or are we wrong?

More exploratory missions have been sent to Mars than any other planet. But Mars won't give up its secrets so easily. The very question of if there is liquid water on Mars will likely lead us to the answer of the ultimate question humanity asks…are we alone?

At present times, the very thin atmosphere of Mars, low surface gravity and very cold temperatures almost guarantee liquid water cannot exist for any period of time. However, few meters beneath its surface, is an altogether different story. Ocean's worth of ice locked away in a seemingly geologically dead world. But everywhere you look on Mars, the landscape tells a tale of a very dynamic, wet world where rivers flowed and liquid water existed in vast open water bodies. Nearly the entire surface of

Mars is riddled with dry rivers, channels and gullies, depression that were once lakes, and landscape carved by flowing water that existed for hundreds of millions of years before drying out or being locked into its current frozen form in ice caps, sub-surface glaciers, and vast areas of permafrost.

Liquid water existed for a substantial period of time in the era when Earth, with its very similar surface conditions, gave birth to life. There is no reason not to believe that life may have originated and thrived on Mars too. At present, the Martian surface is exposed to high energy radiation from the Sun and from deep space with almost no protection. Any fossilized remains of microbes would have been completely obliterated by this onslaught of radiation. To search for life on Mars that may have originated as parallel and independent to life on Earth, we just have to look in the right direction, i.e., follow the water…liquid water.

2. But where is it?

The dried water flow channels on Mars are mere relics of its long dead wet past.

At Mareekh Dynamics, we are seeking the possibility of present-day liquid water on Mars and gathering evidence for it.

Search for liquid water on Mars is nothing new, and scientists have been looking for it for decades. So far, no direct or convincing evidence of liquid water on Mars has been found. The probes and rovers that landed on Mars have found evidence of past liquid water activity from a few million years ago, including discovery of minerals that are formed only under open liquid water bodies over a long period of time. Instruments on board orbital satellites (MOC, HiRISE) have found water channels and gullies with tell-tale evidence of flows, some fairly recent, as evident from the lack of impact craters and relatively fresh and intact landscape erosion patterns in certain locations. Some features of particular interest are the dark streaks and narrow debris flow gullies over slopes of craters, hills, depressions and sand dunes. While most of these have been described as aeolian or dry-mass wasting processes and dust avalanches (Sullivan et al. 2001)[1], Ferris et al (2002)[2] argue that many of these dark streaks may have formed as a result of fluvial processes or liquid flow. Though no presence of active liquid water on the surface has been found yet, these dark streaks could hold the key for the discovery of liquid water on the surface. Another feature studied through orbital cameras photographs on Mars are the deep gullies over the edges of sand dunes with more or less uniform length, width and depth. Some researchers (Mangold N., Costard F., Nov 2002)[3] have argued that these slopes are new and the only explanation for their presence is possible periodic active and brief liquid water flow.

No single model of the possibility of brief liquid water flows as a possible cause of these dark streaks and formation of gullies is agreed upon. It ranges from brief brine flows or small-scale ice melting in loose dust blankets and broken rocks, to dry landslides (Anderson P.S. 2021)[4].

We believe that the dark streaks and gullies on slopes on Martian surface are not formed due to a single mechanism, but these streaks belong to different categories based on their processes of formation. While some streaks on steeper slopes with straight radiations are likely to be due to dry sand or dust avalanches exposing darker material underneath, many of these streaks are visibly different in their pattern and the gradient of slopes. Some streaks stretch over gentle slopes with 10 degrees or less gradient, over much greater distances than can be explained by the dry material avalanches or aeolian processes, that would require slopes in excess of 30 degrees for such a dry flow to occur (Mangold N., Costard F., Nov 2002)[3]. Several fluvial mechanisms have been proposed as a likely explanation for such dark streaks and gullies, including spring discharges, hydrothermal systems, and hypersaline aquifers (Ferris et al 2002)[2]. Though convincing, no single fluvial mechanism seems to explain the formation of these dark streaks and narrow deep gullies.

We would like to support the idea of mudflows from mud-volcanoes as a likely explanation of these. In addition, we would like to propose that these mudflows are currently active, emanating from live mud-volcanoes or gas hydrates on the surface of Mars. We also propose that the giant volcanoes such as Olympus Mons, Tharsis trio, Elysium Mons and numerous other tholi could actually be active mud volcanoes. We can use mud volcanoes on Earth as terrestrial analogues to our proposed idea of active mud volcanism on Mars, and will try to explain the characteristics of the dark streaks and gullies on Mars through their similarities to the appearance and nature of active mud flows of mud volcanoes in Hingol and Lasbela region in Balochistan province of Pakistan.

3. What are mud volcanoes?

Mud volcanoes belong to the classification of sedimentary volcanoes to differentiate these from igneous volcanoes. These mud volcanoes are either located next to the subduction zones on the continental plates or in proximity to oil and gas reserves. These spew mud of varying consistency, mostly driven by gas pressure such as methane or as a result of geothermal processes.

Figure 1. A close-up view of a mud volcano vent and mudflow.
(Picture credit: Muhammad Mehdi Hussain)

4. Hingol and Lasbela mud volcano region

Figure 2. Mud volcanoes in Hingol and Lasbela region reach heights over 700m and can be several kilometers across.
(Picture: Mt Mehdi mud volcano, elevation 430m.
Credit: M Akbar Hussain)

In the southern part of Pakistan in the province of Balochistan, located above the subduction zone of Indian and Eurasian continental plate, lies the Hingol and Lasbela mud volcano region, spanning over 12,000 square kilometers. This arid area is home to over 130 individual mud volcanoes or mud vents, spewing cool mud and discharging methane bubbles in the process, shaping the entire area into a geologic wonderland. This area is a geologists' and explorers' paradise. Little was known about these mud volcanoes except for the trio of relatively accessible Chandragup volcanoes due to their religious importance. Further inland, many times bigger mud volcanoes remained uncatalogued and uncharted until serious expeditions by local enthusiasts to explore, catalogue and conduct scientific study were carried out in 2014. Over few years prior to these expeditions, we used Google Earth to identify and log the coordinates of the individual mud vents, their altitudes and access routes through eroded badlands. This identification of individual mud volcanoes was done through closely studying and understanding the morphological appearances of their mudflow patterns. The locations of the mud vents were pinpointed by identifying and following the fresh mud flows using their appearances, gradients and lengths from satellite images on Google Earth. This data was later utilized to carry out expeditions to explore and reach these vents by navigating through extremely inaccessible routes on foot. The nature of mud flows, their rates of extrusion, consistency, and venting of gases were closely studied.

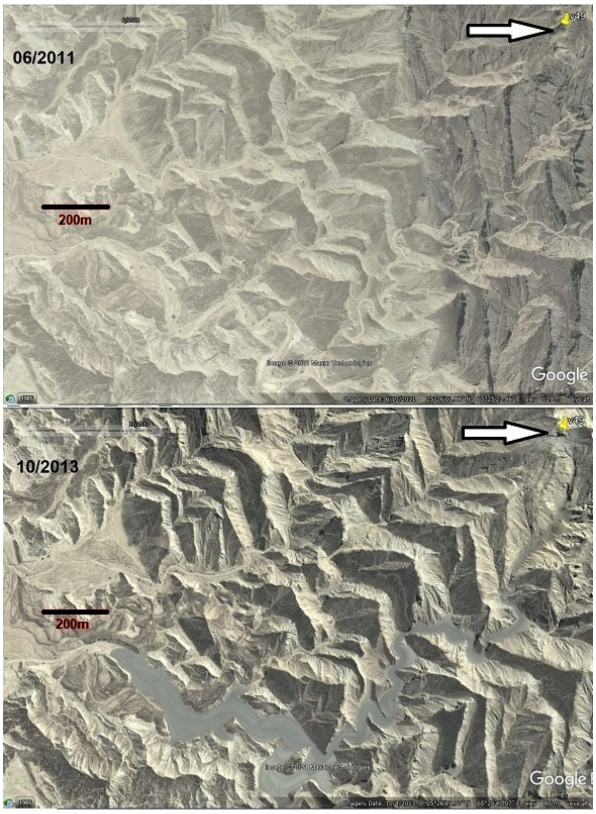


Figure 3. Flash mudflow from V49 (arrow) in Mehdi's catalogue of mud volcanoes in Hingol and Lasbela region, as seen on Google Earth

Figure 4. Rugged and treacherous signature landscape of Hingol and Lasbela mud volcano field makes it extremely inaccessible.
(Picture credit: Muhammad Mehdi Hussain)

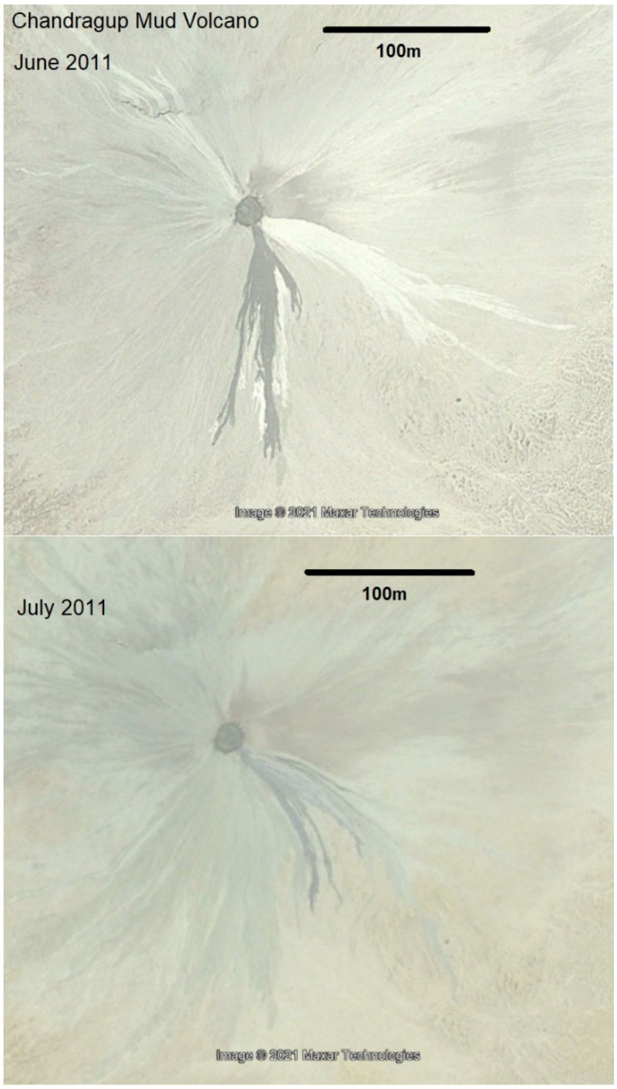


Figure 5. Changes in mudflow pattern of Chandragup mud volcano (Hingol) with time.
(Image source: Google Earth)

5. Possible mudflows on Mars

One of the lead explorers Muhammad Mehdi Hussain started to note the similarities of these fresh mudflows in Hingol and Lasbela to the dark streaks on Mars in their appearance, flow patterns, gradients and lengths. This led us to conduct close inspection of these dark streaks in high resolution images from MOC and HiRISE satellites imagery of Mars. The similarities only deepened.

There are certain features on satellite imagery suggesting that ancient mudflows on Mars may be disguised as lava flows.

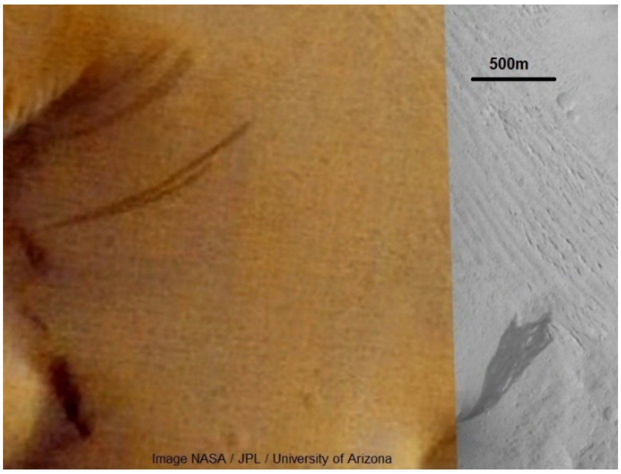


Figure 6. Dark streaks in the Lycus Sulcus; an aeolian landscape north west of the Olympus Mons. The higher resolution pictures serve as a useful tool for the identification of similar dark streaks in lower resolution images. Lycus Sulcus has a large number of dark streaks over its slopes. Many streaks are over a kilometer in length.
Image source: Google Earth. NASA / JPL / University of Arizona

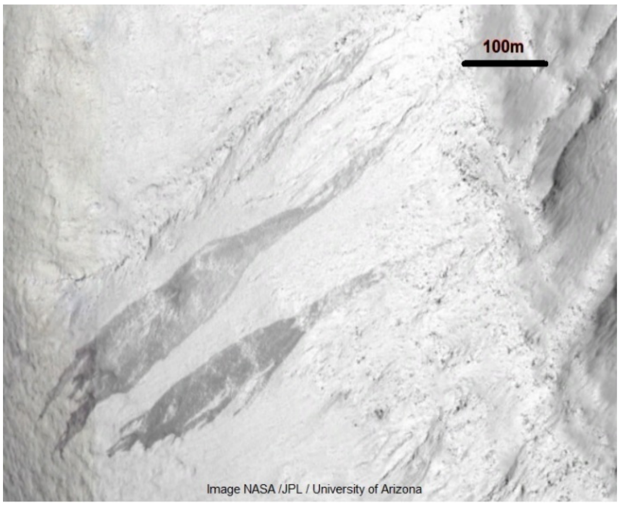
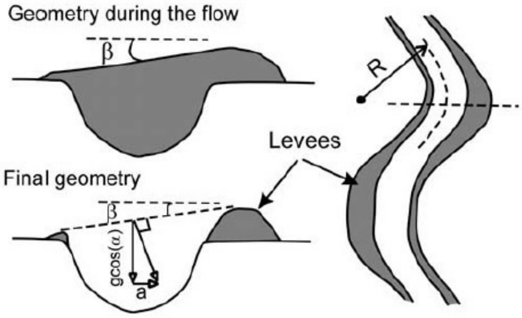


Figure 7. Dark streaks over the southern flank of Olympus Mons at an elevation of approximately 2560m. Such dark streaks could be due to brine flow through the porous soil or low viscosity mud oozing from vents similar to terrestrial mud volcanoes in Hingol and Lasbela region.
(Image source: Google Earth. NASA / JPL / University of Arizona)

N. Mangold and F. Costard[3] have argued that many gullies and flow patterns on Mars can only be explained by liquid flows. These include gullies and flow channels at low slopes of 10 degrees or less, formations of sinuosities, interconnected branching channels, and symmetric lateral deposits or levees[3]. However, no direct evidence of current active liquid water, brine, or debris flow is evident in satellite imagery signifying present or recent intermittent fluvial activity.



Schematic view of levees inside bends. (right)
Seen from top. (left) In cross section. The flow is tilted inside the bend and the levees are asymmetric (adapted from *Johnson and Rodine* [1984]).

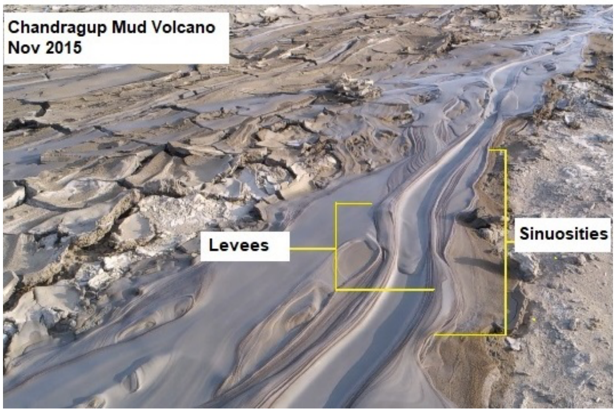


Figure 8. Levees and sinuosities in mudflows from mud volcano in Hingol are similar to the flow channels on Mars
(Diagram: Mangold N., Costard F., Nov 2002
Picture credit: Muhammad Akbar Hussain)

Our findings from the mud volcano fields of Pakistan show presence of all the above features in active and ongoing mudflows from the mud volcanoes, including interconnecting channels, levee formation, and sinuosities. These channels may look like dormant and dry channels in satellite imagery of Earth. We believe that the similar dark streaks and gullies on Mars which look dormant in Martian orbital camera images may actually be active mudflows on the surface of Mars.

Another important feature of the mud volcanoes in Hingol and Lasbela is methane bubbling. It is likely that methane deposits under pressure trapped between sedimentary layers is the main driving force behind the very existence of the mud volcanoes. Another source powering these mud volcanoes could be geothermal at the boundary of Indian and Eurasian plates traversing through Pakistan.

Figure 9. Close-up of a mud vent with methane bubbles. (Picture credit: Muhammad Mehdi Hussain)

6. Mechanism of possible fluid flows on Mars

Flow channels and dark streaks on Mars don't have any particular geographical distribution to volcanic terrain or any suspected geothermal source. It seems like the flow channels on Mars may have an entirely different mechanism such as ground water being in liquid from due to pressure from the rocks above it and coming out of slopes (Malin and Edgett 2000)[5]. This doesn't seem to explain certain flow patterns in several areas suspected of being mudflows. Small mounds present on the surface of Mars in several locations signify that mud volcanism could have been an important source of changing the Martian landscape and may still be active today.

We think that narrow flow patterns and dark streaks on the surface of Mars could be due to ongoing active mud volcano activity. While other explanations of their formation such as liquid water from the melting of ice or brine with its ability to withstand freezing and evaporating at lower temperatures and pressures (Mangold 2002 and Ferris 2002)[2,3], suspected mudflows cannot be solely explained by these superficial environmental factors. If these dark streaks are indeed proven to be active, ongoing mudflows, and the gullies with levees and sinuosities as being the result of frequent mudflows, this opens up a whole arena of possibilities including existence of liquid water on the surface of Mars, active geothermal activity and the possibility of biological processes at work deep within the sediments of Martian crust.

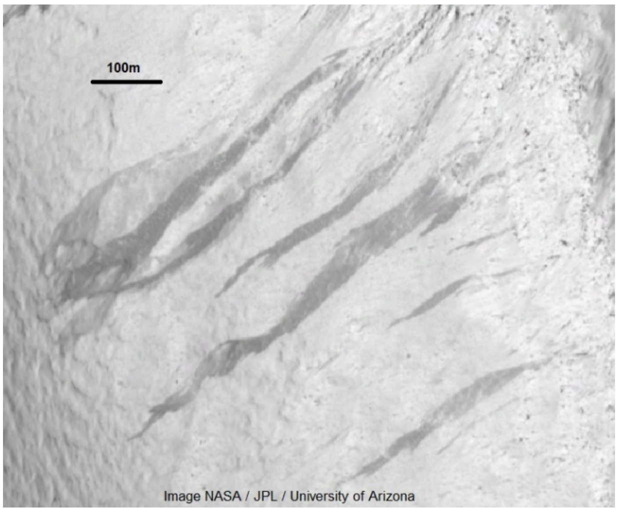


Figure 10. Southern flanks of Olympus Mons. Individual dark streaks can be of varying albedo, suggesting their formation at different times. If formed due to fluid activity such as brine or mudflow, variations in albedo may indicate differences in soil moisture content due to evaporation. Note that the albedo of an individual streak remains nearly uniform throughout its length, possibly due to its formation in a single, brief flow event. (Image source: Google Earth. NASA / JPL / University of Arizona)

7. Why we feel the possibility of active mudflows on Mars is exciting?

7.1. An interesting find

Such a discovery will reiterate the importance of similarities between Terrestrial and Martian geology. This will help us understand and develop technologies for future human habitation and use of resources for the new colonies. Such flows will become sources of minerals and extractable substrates obviating some need for mining or drilling. This would be vital for a budding human settlement on Mars with scarce resources and manpower.

7.2. Solving the conundrum of liquid water on Mars

Active mudflows would not only mean presence of surface or near-surface liquid water, but also the possibility of existence of huge reservoirs of water. Such flows mean the reservoirs would be replete with chemicals and substrates deemed necessary for life.

7.3. Solving the methane mystery of Mars

Missions such as Curiosity have detected methane in Martian atmosphere that fluctuates from 0.5ppb (parts per billion) to surges up to 20ppb (Wall M. 2021)[8]. While the source of this methane, or whether its origin being biological or geological is not known, or the reason for its fluctuation, the mud vents on Earth are known to bubble off methane which is possibly driving the entire process. If the mud volcanism on Mars is driven by methane pressure too, causing episodic mud venting events, this could help explain the fluctuating methane levels on Mars.

Figure 11. Methane bubbling off from vent of a mud volcano in Hingol
(Picture credit: Muhammad Akbar Hussain)

7.3. Search for life

Near-surface liquid water with substrates will help in the search for life. Probes can be made to land close to the sources of these mudflows, and rovers can inspect the mudflow vents and flexible probes can extract samples from deep inside the source to search for the evidence of life. Chinese Zhurong probe and rover landed in such a mud volcano rich field in Utopia Planitia with numerous mounds believed to be dormant mud volcanoes. Such sites may have fossilized remains or chemical signatures of past life. But extracting samples from 'active' mud flows may be the ultimate game changer in the search of present-day life on Mars.

7.4. Sample return missions

Miniaturization of space technology, from the advent of cubesats to the development of technology for the manufacture of fuel literally from thin air, means that sample return missions can be envisioned in near future. We believe that the sources of dark streaks, and fresh gullies and channels can be a vantage point for landing of probes and rovers, and sample return missions, in order to conduct detailed study of the Martian samples brought to Earth for the search of past or present-day life.

Figure 12. Mud-volcano fields of Hingol and Lasbela region are virtually lifeless with no visual trace of any macroscopic life. These mud fields can serve as a good analogue for testing and calibrating science instruments on-board probes and rovers destined for search of life on Mars.
(Picture credit: Muhammad Mehdi Hussain)

7.5. Future robotic missions

Mud flows at Hingol and Lasbela can be studied to develop parameters and calibrate instruments for such missions.

The pristine and unaltered landscape in the extremely arid mud volcano region of Hingol and Lasbela can serve as a useful testing ground for the future Martian probes and rovers and for calibrating instruments for the search of past or present life on Mars. These mud vents and surrounding landscapes shaped by aeolian and fluvial processes are virtually lifeless and closely mimic sterile Martian landscape; possibly the reason behind apparent similarity of the mudflows to the dark streaks, gullies and channels on Mars.

8. Could the large volcanoes on Mars be huge mud volcanoes instead?

The entire surface of Mars is littered with dead or dormant volcanoes. The largest group is the Olympus Mons and the Tharsis Trio. Believed to be basaltic lava volcanoes, these volcanoes are dead, or dormant at best, with no evidence of ongoing or recent basaltic lava activities. The surrounding areas (aureoles) have numerous lava flows resulting from ancient eruptions. Along the flanks of these large volcanoes, we see dark streaks which we suspect have fluid origin.

We think that while Olympus Mons and other large volcanoes of the Tharsis Trio are dormant basaltic volcanoes, these may still be currently active as mud volcanoes, discharging mud driven by gas pressure, gravitational forces and now weakened geothermal forces not strong enough to drive the igneous volcanic activity. This may be contributing to the shaping of landscapes of these volcanoes and surrounding areas. These include areas such as Medusae Fossae; a heavily wind eroded landscape composed of fine, and loosely cemented particles. Fine particles cemented in this manner and being highly prone to erosion, whether water or wind, is a known characteristic of the solidified mud landscape around the mud volcanoes in Hingol and Lasbela region. These are different from sand dunes in which the particles are not physically attached to each other. The cementing process of dried mud landscape due to water and chemicals in the mud leads to complex eroded shapes and patterns when subject to erosion. The heavily wind eroded aeolian landscape of Medusae Fossae has a plethora of dark streaks almost uniformly distributed throughout the slopes as apparent in the high-resolution satellite imagery. Many of these streaks are over a kilometer in length along low angle slopes, winding their way around the obstacles. These are likely due to liquid flows rather than dry avalanches as discussed above (Mangold N., Costard F., Nov 2002)[3].

The Olympus Mons itself has dark streaks along its peripheries emanating from the cliff faces, scattered along nearly the entire length of its escarpment. Surprisingly, no such dark streaks are visible over the inner slopes of the caldera of Olympus Mons (18,000-20,000 meters altitude). However, this is not the case with Pavonis or Arsia Mons of the Tharsis group. The Caldera of Arsia Mons at an altitude of 16,000 to 17,000 meters, is rich in similar dark streaks. Another interesting feature of these dark streaks in the caldera of Arsia Mons is that they stretch out over 10 kilometers over extremely gentle slopes towards the centre of the caldera. Over the outer slopes of Arsia Mons, these dark streaks can stretch over 50 kilometers or more and are very numerous and crowded together.

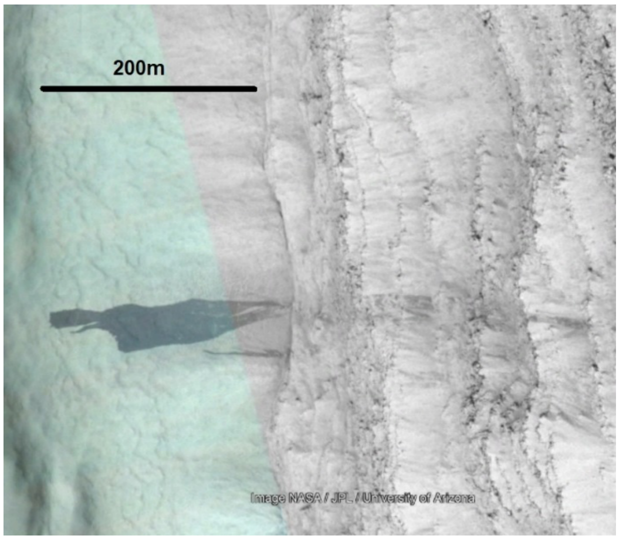


Figure 13. Dark streaks of different ages over the slopes of a collapsed canyon on the western flanks of Arsia Mons. Such flow patterns are strong indicators of fluid activity, possibly episodic active mudflows. (Image source: NASA / JPL / University of Arizona)

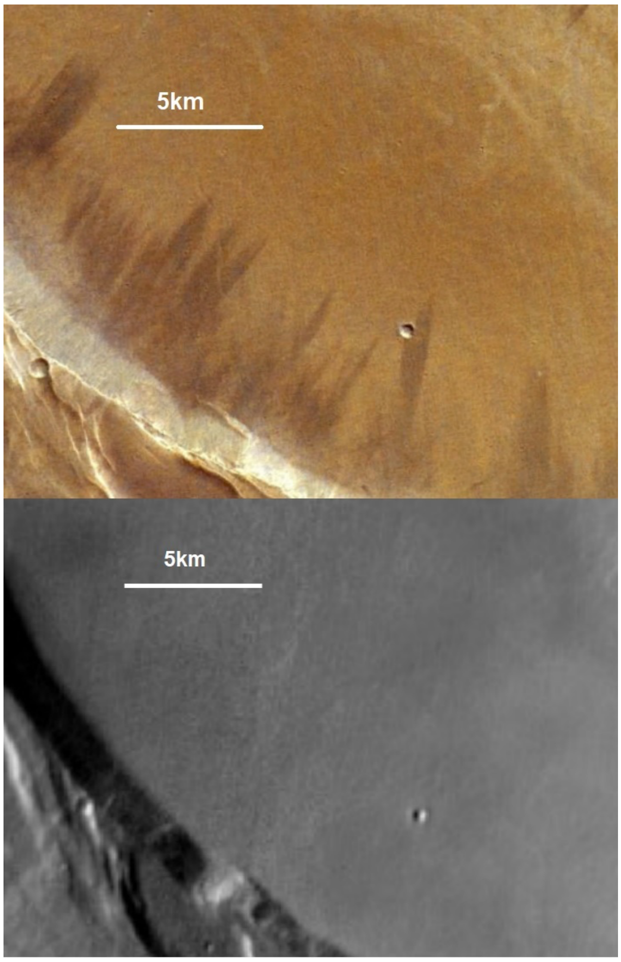


Figure 14. The presence of dark streaks radiating inwards from the slopes of Arsia Mons caldera in the top image and their apparent absence in the bottom image could be due to difference in resolution and contrast enhancement, but this may also indicate episodic flow of

low viscosity mud or brine.
(Image sources: NASA / JPL-Caltech / Arizona State University and ESA / DLR / FU Berlin)

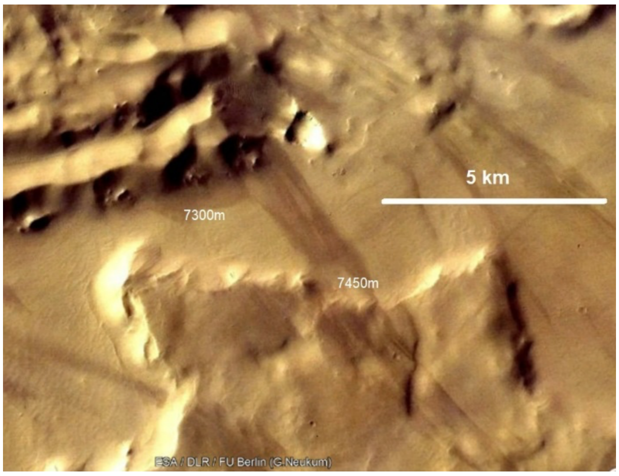


Figure 15. Dark streaks on the north-western flanks of the Arsia Mons over a gentle slope pf <5 degrees gradient. Note the percolation pattern of the deposit indicating possible fluid flow. Many of these dark streaks are over 50km in length over the slopes of Arsia Mons. (Image source: Google Earth. ESA / DLR / FU Berlin)

We believe that these dark streaks are liquid water activity in the form of mudflows in Arsia and Olympus Mons. The reason for their absence in the caldera of Olympus Mons could be due to the limit of height these mudflows can be pushed against gravity. It is possible that Arsia Mons summit and caldera are just below this threshold in present times. Perhaps during the ancient past when Mars was geologically more active, forces acting on these mud flows were strong enough to push the mud to the heights topped at 22,000 meters forming the summit of the Olympus Mons. However, this may not be happening anymore. While the mud activity is perhaps still going on, the current geological processes may be able to push it to enough altitude that it is able to ooze out of the edges of escarpment along the periphery of Olympus Mons.

Based on these observations, we believe that perhaps giant volcanoes on Mars including Olympus Mons and the Tharsis group are giant mud volcanoes instead of basaltic lava volcanoes, at least in the present times. The reason for these to grow to such enormous sizes is likely due to lack of plate tectonics on Mars, and these volcanoes gathering mass in the same very location they were born billions of years ago. In contrast, the mud volcano field of Hingol and Lasbela being only a few tens of millions of years old, formed against much higher gravity, and subject to much more erosive forces, still managed to reach heights of over 700 meters as a result of constant ooze of mud.

9. Could there still be mud venting activity at present?

9.1. Evidence of past mudflows

Many flow patterns from several volcanoes with their smooth and undulating lobular patterns look nothing like basaltic lava flows. Dr Petr Brož of Czech Academy of Sciences[7] conducted mudflow experiments in vacuum chamber simulating Martian temperature and pressures noted that not only the mudflows pattern is different under Martian conditions (low temperature and pressure) as compared to the Earth-like simulated conditions, these mudflows under Martian simulated conditions assume lobular and undulating forms, similar to many flow patterns seen around small to large volcanoes on Mars, raising the possibility of past mudflows.

9.2. Dark streaks on Mars and mudflow patterns on Earth

We have noted that features such as the dark streaks on the slopes of many volcanoes and other elevations on Mars have a stark resemblance to the active mudflows on Earth. Assuming that these flow patterns, especially those over very gentle slopes and extending several hundred meters to several kilometers are active liquid flows of aqueous origin, these could be thin mud of very low viscosity similar to the mudflows of Hingol and Lasbela.

9.3. A possible shift from igneous to mud volcanism

There are no active volcanoes on Mars. Most are either dead or dormant. Believed to be igneous volcanoes that spewed lava in the distant past, there is no evidence of currently active volcanic processes on Mars. This is at least true for the igneous volcanism. However, the sedimentary volcanism, or mud volcanism, is a constant, slow process and is nearly impossible to be detected in single snapshots from orbital satellites. It is possible that the geothermal processes that drove the igneous volcanism on Mars may still be active, though too weak to bring the basaltic lava activity to the surface, but still active enough to drive mud volcanism through mixing and churning of subsurface water with fine volcanic ash to create extremely low viscosity mud which through heat and pressure, is making it to the surface over the slopes as dark streaks or narrow gullies that we see in current images. This process could be periodic in low Martian atmospheric temperature and pressure, due to freezing and sealing of the vents after each mud or fluid extrusion event (Ferris 2002)[2], until fresh mud breaks through and flows again. Long dead as igneous volcanoes with basaltic lava flows, we think that many Martian volcanoes may now be active as mud volcanoes constantly shaping the Martian landscape.

9.4. Morphological similarities

Near-circular pancake shape of Martian volcanoes including Olympus Mons, the Tharsis Trio, Elysium Mons or several smaller tholi are in stark resemblance in their appearance to the mud volcanoes on Earth including the Hingol and Lasbela group of volcanoes or those in Azerbaijan. Their calderas are circular depressed structures likely due to depletion of either magma or mud chambers, resulting in the collapse of the overlying roof. This is also similar to the calderas of mud volcanoes in the above-named region on Earth. However, the structures on Mars are on a much more massive scale, possibly due to far less erosion on Mars, lack of plate tectonics, lesser gravity, and their formation over several billion years in comparison to the terrestrial mud volcanoes. This leads us to believe that these giant volcanoes on Mars could be entirely mud volcanoes with mud venting out due to geothermal processes driven by basaltic lava chambers deep within the Martian crust and this process may still be going on.

10. Current understanding of mud volcanism on Mars

Mud volcanism on Mars is a relatively new but not entirely an alien concept among scientific circles keen to unravel mysteries of Mars. In addition to the work of Ferris et al[2], Mangold[3] and Anderson[4] among others proposing recent or intermittent ongoing aqueous flow activity either in the form of seepage or free flow of brine, extensive studies have been conducted by many researchers in proposing mudflows from mud volcanoes as possible explanation for many flow patterns on Mars. Dr Petr Brož's work is very significant in visualization of mud flows in a simulated Martian environment[7]. Oehler D.Z. and Allen C.C. (2010)[9] have studied thousands of circular mounds in Acidalia Planitia which stand out different from their surrounding plains in their albedo and chemical composition, and have suggested mud volcanism to explain their attributes in a Martian context. Komatsu et al (2014)[10] have emphasized the astrobiological implications of mud volcanism on Mars. While referring to the mounds in Acidalia Planitia, Utopia Planitia. Isidis Planitia, Arabia Terra and Chryse Planitia as possible mud volcanoes, Komatsu et al have suggested such landscapes as vantage points for search for life, for if life ever existed on Mars, it would have likely survived in the deeper layers of mud, and mud flows, past or present, would have pumped its evidence (fossils or chemical signatures) to the surface that can be studied. Dr Baldwin E. (2009)[11] has also supported this idea of exploration of these mounds for their astrobiological potential.

Most of these studies acknowledge the existence of mud volcanism on Mars, especially in the regions of Acidalia Planitia and surrounding plains. Whether there is any evidence of active mud volcanism on Mars, or whether the rapidly morphing dark streaks with their stark resemblance to the active mud flows on Earth in their appearance and characteristics, could actually be active mud flows, is not directly addressed. We suggest combining ongoing aqueous activity hypothesis behind the formation of narrow gullies dark streaks, and the existence of mounds as mud volcanoes, to suggest that there is at present, active mud volcanism going on, on Mars. We also propose that mud volcanism may not be limited to the isolated mounds in low plains but the giant volcanoes such as Olympus Mons and Tharsis Trio may be active mud volcanoes at present times.

11. Conclusion

Study of mud-volcanism and active mud-flows on Mars may help us understand the mud volcanism on Earth itself as many mud volcanoes and gas hydrates are obscure due to vegetation or obliterated due to erosion and human activities.

Our findings are purely observational, based on the study of high-resolution satellite imagery of Martian surface, our expeditions and observation of the dynamics of mud volcanoes on Earth, and on the work of other researchers in understanding the nature of dark streaks and flow channels as possible present day liquid water activity on the surface of Mars. We take it further in suggesting that this liquid water activity could, in fact, be an ongoing mud volcanic activity on Mars. This may lead to further research into understanding of the mechanism of the formation of dark streaks and flow patterns especially those over the slopes and flanks of the volcanoes on Mars. If proven to be true, this may help us understand the Martian methane problem, existence of liquid water on the surface of Mars, and also lead us to study the sources of mudflows and help us discover clues of ancient or even present-day life on the red planet.

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