What Is the Meaning of the Floods on Mars?

Part II: Uniformitarian Origin Theories and Conundrums

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Abstract

Martian outflow channels and valley networks raise six questions and the first four are addressed in this part: 1) how were outflow channels and valley networks carved, likely from water?; 2) Were the channels and valley networks eroded by a few catastrophic floods or many small flows?; 3) What is the origin of the water: groundwater, rainfall and runoff, or both? If groundwater, how was it recharged?; and 4) What is the quantity of water needed for erosion; estimates varying from 3 m to 5000 m GEL. Ultimately, did water come from impacts, volcanism, or both?

Key Words: catastrophic floods, glaciation, Global Equivalent Layer (GEL), impacts, lava flows, Mars ocean, outflow channels, rover results, valley networks, volcanism

Introduction

Mars is a planet of contradictions. Planetary scientists were surprised to find evidence of water in the past, yet secular climate models indicate Mars was always cold and dry. Floods apparently produced both outflow channels and valley networks (VNs). Most VNs are in the southern highlands. They are generally about 1 to 5 km wide, about 50 to 350 m deep, and are up to 4000 km long (Howard et al., 2005). They exhibit interesting features. Some are of constant width. VNs have a patchy distribution, are immature, follow the surface topography, and show evidence of both overland water flow and groundwater sapping.

Outflow channels, much wider than VNs, show evidence of water erupting from the ground. The largest outflow channel is Kasei Valles, over 400 km across, over 2.5 km deep, and about 2000 km long (Carr, 2006, pp. 113–131). This outflow channel is much larger than Grand Canyon and suggests flooding up to 100 times the flow of the Lake Missoula megaflood on Earth.

Adding to the mystery, Mars exhibits subsurface ice in the middle and high latitudes and 2-to-4-km thick ice sheets at the poles. There has been significant volcanism, and Mars once had a powerful magnetic field, producing magnetic anomalies about 10 to 20 times the intensity of those on Earth. Like other solid bodies of the Solar System not resurfaced by impact debris and lava flows, Mars has numerous impact craters, some very large. Planetary scientists have great difficulty explaining these features, which suggests an alternative history may be more successful.

Six Major Questions

VNs and outflow channels raise six major questions (Carr and Malin, 2000, p. 366):

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> "(1) whether the channels and valleys were cut by water, ice, or some other fluid, and if they were cut by water, as seems likely, then (2) what [sic] the relative roles of catastrophic floods versus sustained but modest flow have been, (3) where the water came from (groundwater sapping vs surface runoff), (4) how much water was involved, (5) where the water went, and (6) what the channels and valleys imply for the planet's climate history."

Here, and in Part III, I will address these six questions from the Biblical, creationist worldview.

1) Were the Outflow Channels and VNs Carved by Lava, Ice Melt, or Water?

What processes created VNs and outflow channels? Water would be an obvious answer, but not on a uniformitarian Mars. Alternate uniformitarian mechanisms are runoff from ice melt and lava erosion. But there is little or no evidence for ice in equatorial latitudes, where VNs predominantly occur, except at high elevations such as the Tharsis region (Schon and Head, 2012). So, ice-melt is unlikely. The best-developed alternative is erosion by low-viscosity lava.

Were Outflow Channels Carved by Lava?

Leverington (2011, 2018, 2021) noted many problems with water erosion on Mars, especially the volume required, which he estimated at between 200 and 1400 m Global Equivalent Layer (GEL), the average water depth equalized over the entire globe. Others have suggested up to 5 km GEL (Luo et al., 2017). Since water for outflow channels originated below the ground, the porosities and permeabilities of Martian rocks are far from adequate to support such huge eruptions. They would also require large liquid reservoirs, but scientists believe at least several kilometers of the subsurface is frozen. Leverington also notes the outflow channels do not have expected properties. Water-related sediments, such as clays, sulfates, halides, and hydrated minerals, though widespread, are rare in outflow channels and VNs. Moreover, easily weathered minerals, such as olivine, are also common, arguing against widespread, long-lasting wet conditions.

Leverington advocates outflow channels being shaped by voluminous effusions of low-viscosity lava. He points to channels eroded by lava on the Moon, Mercury, Venus, and Earth. Large volumes of lava would be a natural and expected process of planetary geology. With turbulent flow, it would have rapidly eroded channels, essentially mimicking water. That would eliminate the conundrums presented by water erosion. Leverington claims that flowing lava can explain features associated with megafloods, such as the dry cataracts and streamlined erosional remnants of the Channeled Scablands.

But that theory has its own problems. The most basic aspects of lava flow and incision, such as mechanical and thermal processes, are not well understood (Leverington, 2021). Although lava flows are found in some outflow channels, they are mostly aggradational and not erosive (Dundas and Keszthelyi, 2014). Some outflow channels are thousands of km long and more than a km deep, requiring much lava. Kasei Valles would require over one million km^3 of lava. Such volumes are not evident at the channel mouths.

Outflow Channels and VNs Carved by Water

These problems suggest that the only reasonable answer to the first question is that liquid water eroded the VNs and outflow channels (Wordsworth, 2016).

Ubiquitous Evidence of Water

Recent satellite images are consistent with this answer which was proposed in the 1970s (Ramirez et al., 2014). Besides Channeled Scabland features, such as streamlined hills (Figure 1), there is evidence of paleolakes, alluvial fans, deltas (Figure 2), and layered sediments

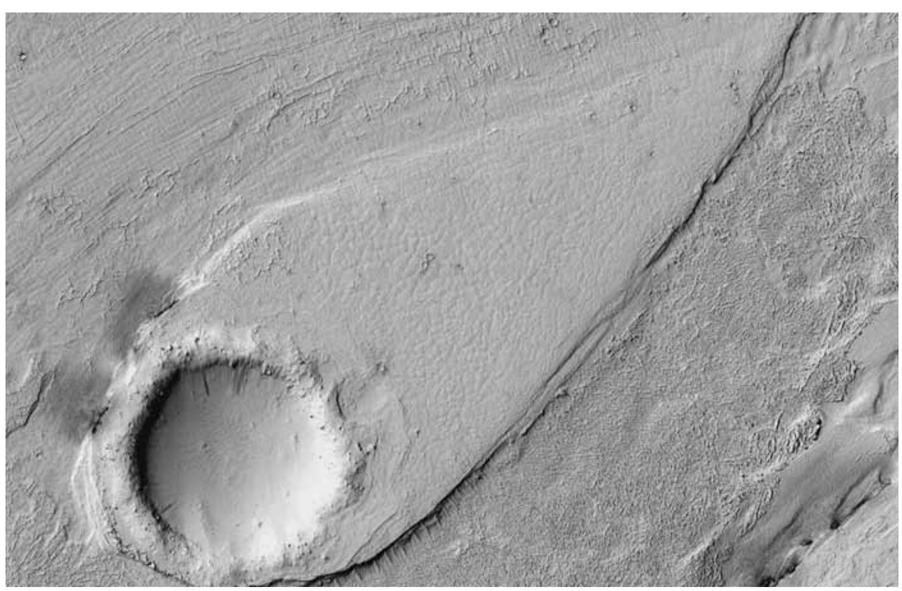

Figure 1. Streamlined form around an impact crater in Lethe Vallis outflow channel (NASA/JPL-Caltech/Univ. of Arizona).

(Figure 3) formed by precipitation and runoff (Davis et al., 2021). Strong evidence exists for hundreds of paleolakes; one in McLaughlin Crater was 500 m deep and contained 1500 km^3 of water (Michalski et al., 2019). A new global compilation of craters with alluvial fans and deltas on Mars indicate that there are 314 craters with 890 alluvial fans and 114 deltas, indicating widespread precipitation and runoff (Wilson et al., 2021). Turbet et al. (2020) state that the evidence for water on the planet is overwhelming: high erosion rates, sedimentary deposits, hydrated minerals, dry riverbeds, and lakes. Moreover, some crater rims and central uplifts have been eroded by water, with sedimentary deposits in the craters (Forsberg-Taylor et al., 2004). These features are dated as Noachian (Table I), probably because that period is believed to have been warm and wet.

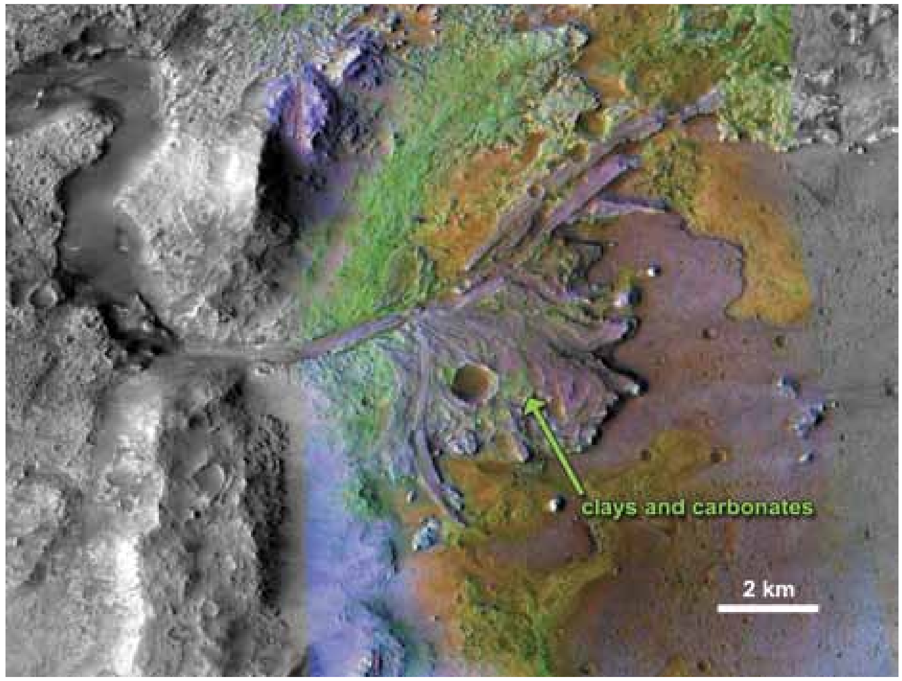

Figure 2. A fan delta in Jezero Crater, Mars, 48 km in diameter, where the Perseverance rover landed on February 18, 2021 (NASA/JPL-Caltech).

The awesome fan delta is a sedimentary deposit from Neretva Vallis. It was formed when a massive amount of water left the valley and spread into a lake in the crater. The image is from the High Resolution Imaging Experiment (HiRISE) camera aboard NASA's Mars Reconnaissance Orbiter that has a resolution as low as 0.25 m.

Clay minerals from water are common (Ramirez and Craddock, 2018). Some clays suggest temperatures of 298–323°C (Ramirez, 2017). Prehnite, a hydrated silicate, is found on Mars and requires temperatures of 200–400°C to form (Ehlmann and Edwards, 2014). It was likely excavated by impacts. Surface outcrops, dated to the Noachian, have chemically altered minerals (Haberle et al., 2019; Riu et al., 2022), but most of the surfaces have unweathered basalt with olivine, pyroxene, and feldspars (Jakosky and Mellon, 2004); all of which weather rapidly. The olivine enrichment at the surface likely was caused by impacts (Ehlmann and Edwards, 2014). Olivine is ubiquitous at craters greater than 10 km in diameter (Carter et al., 2010). How could many easily-weathered minerals have persisted in a warm, wet climate for tens of millions of years? Ehlmann and Edwards (2014, p. 306) conclude: "There remains numerous puzzles and key questions about the mineralogy of Mars that build upon the discoveries above."

Martian weathering profiles range from a few centimeters to 100 m thick (Bultel et al., 2019). A few areas, such as Syrtis Major have layered sulfates up to 600 m thick (Quinn and Ehlmann, 2019). These sulfates may be evaporites that contain water or were deposited during catastrophic chemical precipitation. The most abundant clay mineral is Mg/Fe smectite (Scheller et al., 2021), overlain by Al smectite, but sometimes that order is reversed (Carter et al., 2015; Buczkowski et al., 2020). This weathering profile was likely caused by acid rain resulting from the formation of sulfuric acid from SO_2 emitted by volcanoes (Loizeau et al., 2018; Bultel et al., 2019). Sediments with halide mineralogy are also abundant (Fernanders et al., 2022). Carr (2006, p. 113) summarizes the arguments for a liquid-water origin of outflow channels:

> "However, the close resemblance of the channels and valleys to terrestrial water-worn features, the abundant presence of water ice, the finding of evaporites in Meridiani Planum and elsewhere, and the difficulties with other erosive agents, make it almost certain that the principal erosive agent that cut most of the channels and valleys was liquid water."

Surface Rover Results Support Liquid Water Erosion

Surface rovers' data support water erosion on Mars. The Curiosity rover that

Figure 3. Perseverance image of layered sediments in Jezero Crater, Mars, on April 18, 2021 (NASA/JPL-Caltech/ASU/MSSS). The foreground flat-topped hill, informally named "Kodiak," is 2.2 km from the rover and 250 m wide. It exposes ancient, layered rocks indicating gradual deposition of sediments in a river delta, followed by floods.

Table I. The four periods of Mars' alleged uniformitarian history.

Period	Date (billion years = Ga)
Pre-Noachian	Before 4.1 Ga
Noachian	4.1 to 3.7 Ga
Hesperian	3.7 to 3.0 Ga
Amazonian	3.0 Ga to present

landed in Gale Crater on August 6, 2012 (Figure 4), especially has shown much evidence for flooding, for example fans and deltas (Palucis et al., 2014, 2016). Curiosity proved that what was thought to be a lava flow was actually sedimentary rock (Voosen, 2021). Curiosity also found evidence for a lake in the crater (Edgar et al., 2020; Fraeman, 2021). The rover also discovered a 5 km-tall mountain called Mt. Sharp (Aeolis Mons), composed of layered rock that is possibly fluvial or lacustrine in origin (Fraeman, 2021) with possibly a buried central peak (Grotzinger et al., 2015). Mt. Sharp and the crater rim have been fluvially incised (Williams et al., 2013). Minerals in the lower strata of Mt. Sharp indicate liquid water, and include phyllosilicates (clays), hydrated silica, sulfates, and iron oxides. Sandstones and conglomerates have also been observed forming a network of braided river channels originating on Gale's northern rim and flowing south. The Curiosity rover discovered gravel bars with evidence of minimum water flow of at least 10 m/sec (Heydari et al., 2020). Laminated mudstone has also been discovered.

The age of Gale Crater is said to vary from early Noachian to early Hesperian (Table I), depending upon the dating method used (Heydari et al., 2020), showing the uncertainty in crater counting ages. Voosen (2021, p. 871) states:

> "Any date [from radioactive dating on returned lava samples] will also help pin down the highly uncertain overall martian timeline, currently dated by counting the number of craters on a given terrain."

The new Perseverance rover landed in Jezero Crater on February 18, 2021, and has discovered water- and wind-eroded features, 40-meter-high cliffs of a river delta, and water locked up in minerals (Witze, 2021). This crater was once home to a lake with evidence of powerful flash floods and a delta (Anonymous, 2021).

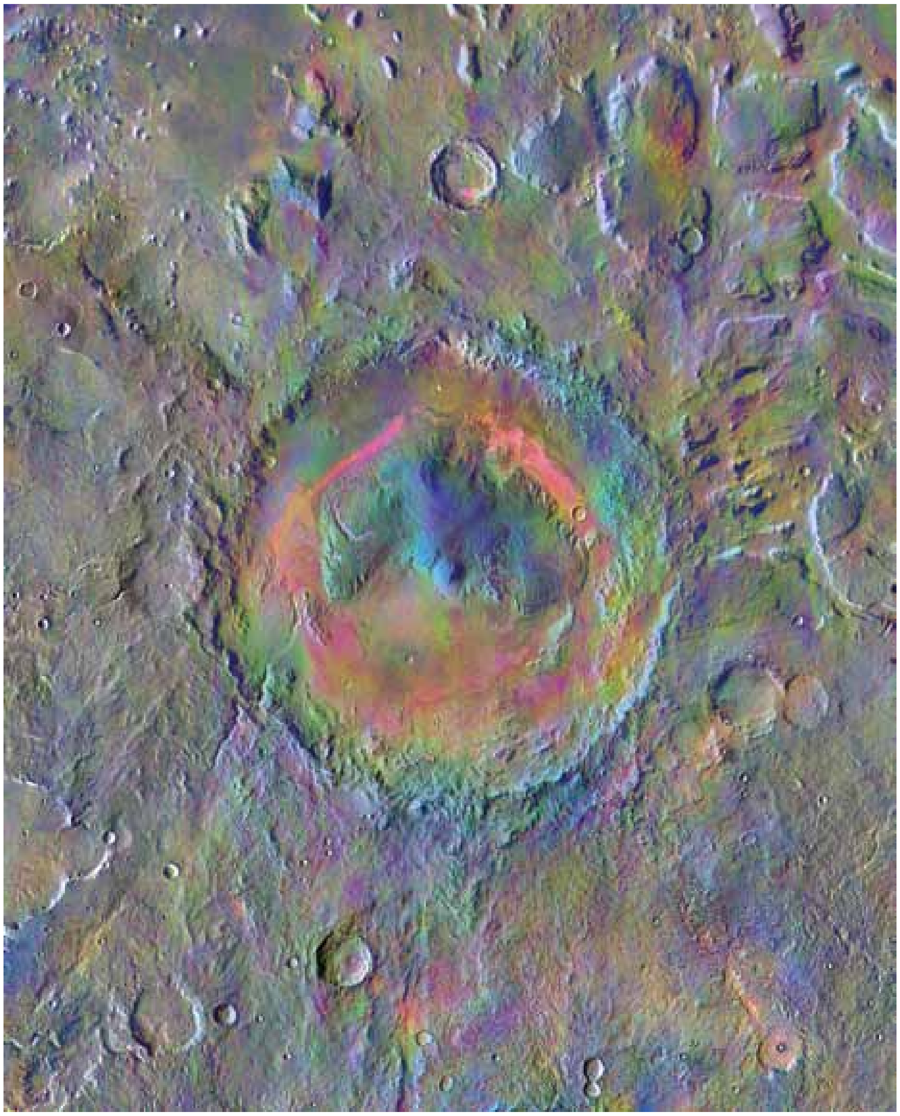

Figure 4. Gale Crater, 150 km in diameter, surface minerals, color coded, from THEMIS (NASA/JPL-Caltech/ASU). The high area at the top of the crater is Mt. Sharp. Windblown dust appears pale pink and olivine-rich basalt looks purple. The bright pink on Gale's floor appears due to a mix of basaltic sand and windblown dust. The blue at the summit of Gale's central mound, Mount Sharp, probably comes from local materials exposed there. The typical average Martian surface soil looks grayish-green.

Was There an Ocean in the Northern Lowlands?

Water erosion in a warm, wet climate would be aided if an ocean once covered the northern lowlands (Parker and Bills, 2021). Two shorelines have been suggested: the lower Deuteronilus level and the higher Arabia level (Sholes et al., 2021), but recent mapping has shown the putative shorelines vary laterally by hundreds of kilometers and vertically by up to 2.2 km! Some think that the warping of the shorelines occurred during true polar wandering caused by the Tharsis volcanic plateau (Citron et al., 2018). Some have claimed that a large bolide hit the ocean and caused tsunamis that spread southward, overran the shorelines, and backwashed northward into the "ocean" (Rodrigues et al., 2016). Others point to fans and deltas at the dichotomy boundary as evidence of an even higher shoreline (Fawdon et al., 2018), well above the two proposed shorelines (Rivera-Hernández and Palucis, 2019).

Many problems are associated with a northern ocean; some believe there is no evidence for it (Carter et al., 2010). It is true that water from outflow channels would end up in the northern lowlands, which it did, and if an ocean was formed it would quickly freeze and take hundreds of thousands of years to sublimate (Turbet et al., 2017).

2) Were the channels and valley networks eroded by a few catastrophic floods or many small flows?

The second question is: "How did water carve the VNs and outflow channels?" Was it by rare catastrophic flows or numerous, more modest floods (Carr, 2006, p. 135; Hargitai et al., 2017)? Scientists argue for both (Carr, 2006, p. 113; Goldspiel and Squyres, 2011). Evidence is accumulating that strongly favors catastrophic floods, which heightens questions of their origin.

A detailed analysis of the origin of VNs from breaches of over 200 paleolakes shows that some valleys formed by catastrophic lake breach (Goudge et al., 2018). Energy from an initial breach would erode the VNs quickly since discharge would be sufficiently high to maintain cobbles in suspension. Subsequent smaller floods, with much less erosive energy, would form lower terraces, which are hardly ever observed. The evidence for rare catastrophic floods forming VNs has reinforced the opinions of many researchers who have concluded that the origin of outflow channels was likewise catastrophic (Carr, 2006, p. 113).

The catastrophic origin of VNs is supported by the angle of tributaries that enter the main VNs, called *the branching angle*. Examining branching angles for main-stem rivers and streams across the United States, researchers determined that in more humid environments with more groundwater flow, angles of entrance tend to be higher. But in the dry southwestern United States, branching angles are more acute (Seybold et al., 2018). This result is independent of other variables. The tributaries of VNs on Mars branch at lower, acute angles, suggesting that Mars VNs were caused by brief catastrophic floods:

> "The correlation of branching angles with climatic controls supports the recent shift from groundwater-dominated theories for Martian channel formation … to more recent precipitation-based theories…. Our analysis suggests that Mars' channel networks were formed in an arid continental climate with sporadic heavy rainfall events large enough to create significant surface runoff." (Seybold et al., 2018, p. 3)

This suggests at least episodically warm temperatures during VN formation (Cang and Luo, 2019). Thus, VNs were apparently formed by catastrophic flows. This conclusion is reinforced by a large amount of recent research which also shows that most of the valleys were formed quickly by large surface flows of water (Mangold, 2012; Seybold et al., 2018).

3) What was the origin of the water: groundwater, rainfall and runoff, or both?

The third question is whether erosion was surface erosion from rain and runoff or by groundwater? A more basic question is where did the water come from in the first place?

VNs Formed by Groundwater?

Some researchers have suggested in the past that the outflow channels and VNs were carved by streams that originated from groundwater springs (Malin and Carr, 1999; Goldspiel and Squyres, 2000; Aharonson et al., 2002), possibly from a pressurized aquifer (Cassanelli and Head, 2019). Groundwater sapping is suggested for VNs having a box-canyon morphology (Howard, 2007).

VNs Formed by Rainfall?

Most planetary scientists have concluded VNs were eroded by rainfall and subsequent runoff. Evidence for precipitation is seen in small tributaries starting on divides (Fassett and Head, 2008). This is reinforced by the observation that some valleys start on volcanoes (Hynek et al., 2010), and some craters were eroded by rainfall (Craddock and Lorenz, 2017).

VNs Carved by Both Rainfall and Groundwater

Since there is evidence for a groundwater origin for some VNs, especially in their upper reach tributaries, some have suggested that VNs originated from *both* groundwater and surface precipitation (Shi et al., 2022). This does not weaken the case for rainfall, since it is needed to recharge aquifers.

Outflow Channels Did Form from Groundwater

However, outflow channels start from either grabens or below *chaos regions*, suggesting a groundwater origin (Meresse et al., 2008; Roda et al., 2017). Chaos regions generally consist of irregular groups of large blocks, some tens of kilometers across and hundred or more meters high. The tilted and flat-topped blocks form depressions hundreds to several thousand meters deep. However, groundwater alone is inadequate for the volumes of water released (Harrison and Grimm, 2008). One problem is the frozen ground; another is the low permeability of unfrozen ground. Large groundwater-sourced floods would require high permeability over a large area (Leverington, 2021); so, how are outflow channels to be explained? Part III of this series of papers will suggest a solution.

4) What is the quantity of water needed for erosion?

The fourth question, "What is the quantity of water needed for erosion?" must now be addressed, and there are many estimates, which vary widely. Planetary scientists do not know how much water was needed. Complicating factors include the existence of a northern ocean, whether floods were catastrophic or not, how much time it took for the carving of outflow channels and VNs, etc.

Estimates of the necessary volume of water range from 3 m to 5,000 m GEL, which indicates the great variety of opinions, models, and uncertainties (Rosenberg et al., 2019). Luo et al. (2017) are at the high end. On the other extreme, Palumbo and Head (2018) and Rosenberg and Head (2015) believe the amount of water needed was only 3 m to 100 m GEL. Carr and Malin (2000) estimated 50 m GEL to carve the VNs (Segura et al., 2002). Rosenberg et al. (2019) determined an intermediate estimate of 640 m GEL. Scheller et al. (2021) believe the amount of needed water for both the outflow channels and VNs ranged from 100 m to 1500 m GEL. The wide range of these estimates reveals that uniformitarian scientists do not know the answer to the fourth question.

The volume largely depends on the type of flooding, which has been determined to be catastrophic. The origin of Kasei Valles, the largest outflow channel, is a case in point. Estimated peak discharges range from 10^4 m^3/s to 10^9 m^3/s (Carr, 2006, p. 117), depending on the number of events. Although some have suggested Kasei Valles was formed by many floods, others have deduced that it was formed by one to a few very large floods (Bargrey and Wilson, 2011). Earlier, Robinson and Tanaka (1990) had concluded that Kasei Valles formed in one flood with discharge of 0.9 to 2.3 x 10^9 m^3/sec. The volumes are more problematic in light of evidence favoring groundwater eruption.

The time required to have cut the channels and valleys is also unknown. Some claim 100,000 to 10 million years to form the VNs by slow precipitation (Kamada et al., 2020). Rosenberg et al. (2019) suggest that eight specific VNs could have eroded in anywhere from 8 years to 592 years. So, the mechanism(s) and timing of valley networks, as well as outflow channels, depends upon many variables.

Since greater discharge generates rapid erosion, catastrophic floods indicate the VNs formed rapidly and that the lower estimates of GEL are more likely. Goudge et al. (2018, p. 9) conclude:

> "Instead, we conclude that the studied paleolake outlet canyons were primarily incised during *single episodes* of highly erosive lake overflow flooding. This conclusion is also physically intuitive, as the potential energy stored in the lake is available for incision prior to breaching vastly exceeds what can be generated by slower, post-breach outflow, which is inherently bounded by inflow rates and dampened by the storage capacity of the basin itself" (emphasis mine).

Such catastrophic, single-episode floods require less water and time. They also heighten the mystery of the origin of VNs and outflow channels for uniformitarians. Less time points to the alternative Biblical model with its short timescale, which will be presented in Part III.

The Problems with Impacts Causing the Mars Floods

These four questions lead one to ask what the ultimate source of the water was. At present, answers are very controversial, considering the present cold, dry climate and the main uniformitarian assumptions that it has always been so (Bauley et al., 2016).

One proposal is that impacts caused flooding by creating an ephemeral, warm, wet climate. Segura and colleagues were early advocates of this impact hypothesis (Segura et al., 2002, 2008, 2012; Toon et al., 2010). Heydari et al. (2020, p. 1) also suggest that the mechanism for flooding was a large impact:

> "The most likely mechanism that generated flood waters of this magnitude on a planet whose present-day average temperatures is - 60°C was the sudden heat produced by a large impact. The event vaporized frozen reservoirs of water and injected large amounts of CO_2 and CH_4 from their solid phases into the atmosphere. It temporarily interrupted a cold and dry climate and generated a warm and wet period."

Such an impact and its hot ejecta would no doubt melt much subsurface ice if it were present. There could also be some water in the impactors, especially if they were comets. Impacts would add dust/debris to the atmosphere, which would tend to cool it off by reflecting sunlight back to space. Much water vapor would be added to the atmosphere and warm the climate by the greenhouse effect. However, large impacts would add only a little CO_2 and CH_4 to the atmosphere, which some planetary scientists believe is needed for a warm, wet climate. Regardless, water vapor itself is about four times more efficient at trapping heat energy than CO_2, and it is probable that water vapor is all that is needed to cause a warm, wet climate.

Estimating water produced from a large impact is difficult (Segura et al., 2008). Segura and colleagues estimate that an impactor with a 250-km diameter could produce 50 m GEL of water, the amount some researchers claim is needed to form the valley networks (Carr and Malin, 2000).

Segura's 1-D model was much too simple (Steakley et al., 2019). Steakley et al. (2019) used more sophisticated 1-D and 3-D models with impactors up to 100 km and atmospheres up to 2 bars. One impact was insufficient to cause VN erosion by flooding (Steakely et al., 2019, p. 186): "Ultimately, the water and energy delivered by impacts in these scenarios do not result in sustained warm and wet climates." Although, impacts do not result in a sustained warm, wet climate, a transient warm, wet climate can occur with each impact and last for many years. Precipitation can be quite high the first year, ranging from tens of centimeters to several meters, but tail off rapidly after that with most precipitation as snow.

But Palumbo and Head (2018) indicate that a 100-km diameter impactor would produce only 1 m to 5 m GEL and a 250 km impactor only 10 m to 25 m GEL. Turbet et al. (2020) claim that one very large impact would add about 58 m GEL to the atmosphere with warming for several tens of years. Steakley et al. (2019) claim 640 m to 5000 m GEL is required and that the VNs needed 10^5 to 10^7 years to form. They believe one large impactor could not produce enough water and its effects would be too transient.

To further complicate the idea, Palumbo and Head (2018) claim that precipitation from impacts would be homogenous and inconsistent with the patchy location of VNs. They also do not believe the rainfall would be significant, which they predicted to be 2 m/yr. at the beginning and decrease rapidly. Furthermore, there would be tens of millions of years between impacts.

Turbet et al. (2020) also ran a variety of impact models but with impactors greater than 100 km, which would produce craters greater than 600 km. Some of the impactors would be 200 km to 500 km in diameter and produce craters 1000 km to 2500 km in diameter, assuming the impactor velocity was only 9 km/s. They obtained similar results as Steakley et al (2019) and discovered: (1) each very large impact causes only 0.1 to 1% of atmospheric erosion; (2) an impact-induced warm climate lasted several tens of years, which they believe is too little time, since VNs supposedly require about a million years to form; (3) about 2.6 m GEL per Earth year of water vapor formed with each large impact; (4) a large impact would cause a hot mantle and crust that would last for millions of years; (5) hot silicate vapor would fall on the surface first; (6) after a short time, hot, intense precipitation would occur. Hot water would erode VNs quicker (Palumbo and Head, 2018).

Turbet et al.'s (2020) scenario is considered unlikely. The hot, intense rain from each impact would last about 12 Martian years (one Martian year equals 1.88 Earth years). After 15 Martian years, the atmospheric temperature would drop below freezing, the event ending with snow. The effects of an impact last only 18 Martian years, and there would be no sustained warm, wet climate. The impact would produce 58 m GEL of precipitation, which is believed to be an order of magnitude too small. The 3-D atmospheric model produces a strong Hadley cell, similar to Earth, in which the atmosphere rises at the equator and sinks at 30° latitudes. So, heavy precipitation would occur near the equator and little precipitation at 30° latitude. The VNs are believed to be predominantly found at 30°S, which creates a problem as to their origin. There is heavy precipitation at high latitudes. Despite impacts not being able to produce a long-lasting warm, wet climate, they do produce an episodic warm, wet climate.

But due to the uniformitarian crater dating, the timing of impacts and VNs varies too much. It appears that the VNs occurred well after major impacting (Toon et al., 2010). Because the uniformitarian impacts are separated by long periods of time, each impact is thought insignificant.

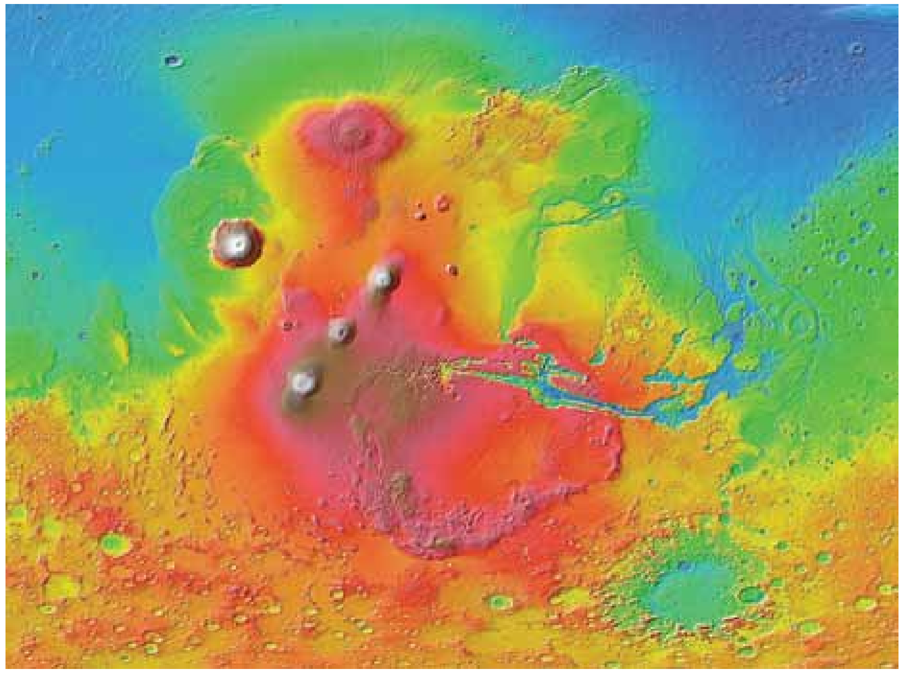

Figure 5. Mars Orbiter Laser Altimeter (MOLA) colorized topographic map of the western hemisphere of Mars, showing the Tharsis volcanic bulge with four distinctive volcanoes, the Valles Marineris region, and the Kasei Valles. The Argyre impact basin is at lower right (NASA). The red, brown, and white colors are high altitude, while the green and blue are lower altitude.

The Problems with Volcanism Causing the Floods

Volcanism, like the Tharsis volcanoes (Figure 5), could create a warmer, wetter Mars (Samec, 2013; Halevy and Head, 2014; Jakosky, 2021). Strong volcanism can cause warmth and precipitation (Cang and Luo, 2019) since volcanic emissions are about 90% water vapor (Samec, 2013). Scheller et al. (2021) estimated the amount of water from volcanism on Mars could range up to 120 m GEL. If the magma contained even one percent (1%) water vapor, water released to the atmosphere could reach 125 m GEL (Jakosky, 2021).

The 125 m GEL is a maximum since most water would be entrained in the magma. A more realistic number for water released from extruded lava is less than 15 m GEL; so it is thus unlikely that volcanism caused the floods. Secular scientists spread the volcanic eruptions over billions of years (Milbury et al., 2012; Broquet and Wieczorek, 2019), making each eruption insignificant.

The Tharsis Bulge is believed to have volcanic units of all ages (Johnson and Phillips, 2005), so the 1.5 bars of total CO_2 (Phillips et al., 2001) would be spread over billions of years. A little CO_2 can also be supplied by impacts (Navarro-Gonzáles et al., 2019). However, CO_2 is a minor gas and researchers have concluded other greenhouse gases are needed. Volcanoes also emit SO_2 that becomes sulfuric acid, which reflects sunlight back to space, probably negating any warming from CO_2.

Volcanoes give off ash and aerosols, especially SO_2, which will cool the planet by reflecting sunlight back to space, as observed after very large volcanic eruptions on Earth. The ash will fall out in a matter of weeks, but the aerosols would fall out much slower, on the order of years. Such cooling could negate any warming caused my minor gases, except for the water vapor, as described above.

Impacts May Have Triggered Volcanism

Some researchers suggest that impacts triggered volcanism, combining to produce a warm, wet climate. Toon et al. (2012) think the Hellas impact occurred before Tharsis volcanism. It was nearly antipodal to Hellas, suggesting it triggered Tharsis volcanism (Phillips et al., 2001; Faulkner, 2014). Otherwise, the cause of the Tharsis volcanism is unknown. It is believed that seismic energy from a major impact could cause fracturing and surface disruption on the planet opposite the impact, creating structural weaknesses in the area of the Tharsis bulge and its volcanic cones (Spencer, 1994). However, crater dating makes the timing uncertain. Some researchers date the main eruptions as Noachian (Fassett and Head, 2008), but others believe they were late because there are few craters on the Tharsis bulge (Carr, 2006; Bauley et al., 2016).

As an alternative theory, Reese et al. (2002) suggest that Tharsis was caused by an impact-induced thermal anomaly. This connection also suggests that impacts caused volcanism.

From a Biblical perspective, Samec (2013) believes that the volcanism was caused by accelerated radiometric decay during Creation and/or the Flood. This volcanism in turn caused the floods on Mars. Although he ignores impacts, Samec's hypothesis for the volcanism could be true during the time of the Genesis Flood.

Could Impacts and Volcanism Together Cause the Floods?

If impacts and volcanism occurred together, the combination might have created a warmer atmosphere with precipitation (Palumbo and Head, 2018; Steakley et al., 2019; Shi et al., 2022). Carr (2006, p. 130) states: "Most [large flood features] appear to have formed by eruptions of groundwater triggered by impacts, volcanic or tectonic events, or by catastrophic drainage of lakes." Rosenberg and Head (2015) believe that impacts and volcanism melted ground ice to produce VNs. If the flow through the valleys was only 4×10^4 m^3/s, it would take between a few centuries and 10,000 years to carve VNs (Rosenberg and Head, 2015). Deep time is a problem for uniformitarians, however. Spacing out impacts and eruptions over long ages would not allow for needed climate changes and flooding.

Glaciation

Impacting models show that the atmosphere would cool rapidly afterwards. The last stage of an impact would be snow (Segura et al., 2008), beginning at high latitudes and spreading toward middle latitudes. Along with the 2 km-to-4 km-thick polar ice sheets, ice could have also accumulated at mid-latitudes, based on various observed ice flow features. Ice is pervasive at the surface and in the subsurface from 35°N to 78°N (Ramsdale et al., 2019).

Was ice mostly in soil pores and ice lenses in the soil (Sizemore et al., 2015)? Evidence of clean ice occurs in the walls of new impact craters at mid-latitudes (Byrne et al., 2009; Dundas et al., 2014.). Ice has been observed to be at least 100 m thick at eight scarp locations in the mid-latitudes (Dundas et al., 2018). That which exists between 30° to 50° is unstable in the present climate, but does not sublimate, thanks to a thin covering of wind-blown sediment or regolithic debris as shown in Figure 6 (Hepburn et al., 2020). The origin of this clear ice is unknown, but it must have formed by snowfall in a much different climate (Mischna, 2018).

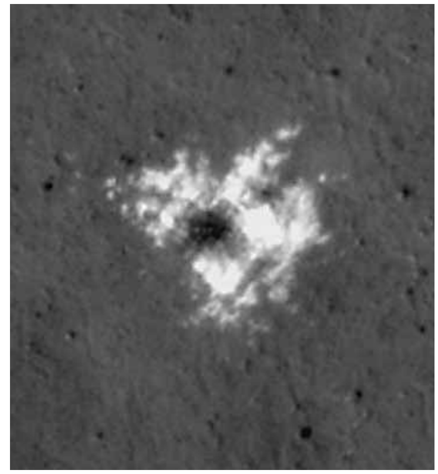

Figure 6. A fresh impact crater exposing water ice in the white area below the regolith (NASA/JPL-Caltech/University of Arizona).

The amount of ice in the subsurface has recently been established, which heightens the mystery of the origin of the snow. Based on a dielectric constant of the subsurface of 2 to 3, mid-latitude ice is probably 300 to 600 m thick (Campbell et al., 2021). Moreover, it is clean ice that resulted from snow and not thick, ice-rich regolith (Dundas et al., 2021).

The ice is dated as Amazonian (Table I) because of a lack of impact craters (Sinha and Ray, 2021), which places it well after impacts and volcanism. But there is a more logical association between glaciation and the formation of VNs and outflow channels. This suggests impacting occurred quickly, creating conditions for rapid flooding. It would also indicate that the crater dating system is flawed.

Given late Amazonian dates for mid- and high-latitude ice, including the polar ice sheets, planetary scientists have devised a theory that at high obliquity, ice is transferred from the polar ice sheets to the mid-latitudes and/or equatorial regions by sublimation over tens of thousands of years (Bramson et al., 2017). When the obliquity becomes low again, mid-latitude and/or equatorial ice sublimates and condenses on the polar ice sheets. But this does not explain the *origin* of the ice, estimated at 20 m–40 m GEL.

Numerous Periglacial Features

With so much subsurface ice at mid- and high-latitudes, there are widespread periglacial features (Sizemore et al., 2015). For instance, a polygonal-patterned surface is common in the northern lowlands as shown in Figure 7 (McEwen et al., 2007). It is likely that pingos also occur (Soare et al., 2021). Pingos are conical, ice-cored hills that form in permafrost and range in height on Earth from 3 m to 70 m and in diameter from 30 m to 1,000 m (Figure 8).

Summary

The floods of Mars bring up six major questions. Three of them were answered in this part: 1) the floods were the result of water; 2) the floods were catastrophic; and 3) both groundwater and rainfall runoff were the cause of VNs. The answer to Carr and Malin's (2000) third question: "What is the ultimate source of the water?" was left unanswered. The current suggestions are impacts and/or volcanism. The fourth question: the estimated amount of water varied considerably, from 3 m to 5000 m GEL, showing the wide range of assumptions and uncertainties. The uniformitarian scenarios are left with problems, opening the door for a Biblical explanation. One will be developed in Part III, which will also answer the remaining questions of Carr and Malin (2000).

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Figure 7. Polygonal patterned ground on the floor of a trough in the Southern Hemisphere of Mars from Mars Global Surveyor MGS Mars Orbiter Camera MOC (NASA/JPL/Malin Space Science Systems).

Figure 8. View from top of a pingo towards another pingo with the Arctic Ocean in the background, near Tuktoyaktu, Yukon Territory, Canada (Matti & Keti, Wikipedia Commons CC-BY-SA-4.0).

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