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What Is the Meaning of the Floods on Mars? Part I: Their Surprising Discovery

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Abstract

Uniformitarian scientists were surprised to discover channels on Mars like the Channeled Scablands of eastern Washington. Climate models indicate that large-scale Martian floods are impossible. This paper will describe what appear to be flood features on Mars. Three types of channels on Mars are described in this paper: valley networks, outflow channels, and gullies. Like the Solar System's other solid bodies that have not been resurfaced by debris and volcanism, Mars possesses numerous impact craters, some very large, which provide a framework for the planet's history. Secular uniformitarian scientists divide the geologic history of Mars into four main periods which span 4.5 billion years.

Key Words: Crater dating, glaciation, gullies, impacts, Mars, Mars floods, Mars magnetism, outflow channels, valley networks, Valles Marineris, volcanism

Introduction

Numerous satellites and ground probes of Mars have produced unexpected discoveries, including features that imply catastrophic floods. These surprises are not unusual; nearly every satellite and probe into the Solar System brings unexpected results that challenge their expectations and should challenge the uniformitarian paradigm (Psarris, 2009). Even their cherished 'big bang' hypothesis seems at risk (Psarris, 2012, 2016). This initial paper, and two subsequent papers, will explore evidence of floods on Mars and several other features that might have been concurrent with Earth's global Flood.

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The Great Surprise of Discovering Catastrophic Floods on Mars

Early satellites sent to Mars astonished scientists with abundant evidence of gigantic floods. Planetary scientist, Michael Carr (2012, p. 2194), exclaims:

> "Discovery of Mars' branching valley networks during the Mariner-9 mission in 1972 was a complete surprise because, by that time, we already knew that Mars had a very thin CO_2 atmosphere and that the surface was much too cold to permit streams of liquid water at the surface."

Catastrophic flood specialist, Victor Baker (2001), calls the floods on Mars another *outrageous hypothesis*, similar to that of J Harlen Bretz regarding the Lake Missoula flood (Bretz, 1923a, 1923b). So, uniformitarian scientists will concede large floods on Mars, with no surface liquid water, but reject the idea on a planet with over 70% surface-water coverage (Bates, 2005).

Mars' outflow channels are similar to the Channeled Scablands of eastern Washington, USA (Oard, 2004, 2014). Another type—narrower channels similar to terrestrial river valleys—are called valley networks (VNs). VNs are generally about 1 to 5 km wide, about 50 to 350 m deep, and up to 4000 km long (Howard et al., 2005). The multiple diverging and converging channels in the Channeled Scablands can be a few tens of km wide and up to 200 km long, cut into soft silt of the Palouse Formation and the hard Columbia River Basalts as displayed by the red areas of Figure 1. In the Channeled Scablands of eastern Washington, numerous streamlined hills were left as erosional remnants, as shown in Figure 2. In the outflow channels of Mars, shown in Figure 3 for Kasei Valles, teardrop shaped islands, similar to those shown in Figure 2, longitudinal striae in rock, cataracts, plucked zones, and inner channels occur, similar to those of the Lake Missoula flood (Carr, 2006, p. 114). A few of the Mars outflow channels indicate much larger flows: "Results indicate that paleodischarges may have been 10 to 100 times greater than the known largest prehistoric floods on Earth" (Komatsu and Baker, 1997, p. 4151). These obviously challenge uniformitarianism.

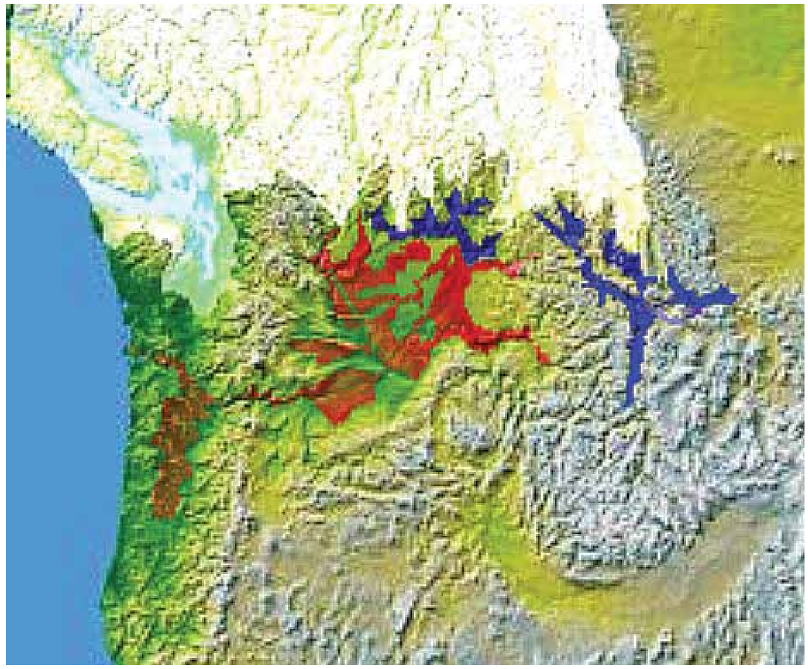

Figure 1. Path of the Lake Missoula flood (red) showing the extent of the southern Cordilleran Ice Sheet with glacial lakes Missoula and Columbia in blue (Matthew Trump, Wikipedia Commons CC-BY-SA-3.0 mitigated).

Climate Models Indicate Flooding on Mars Impossible

Flooding on Mars is difficult to explain when considering uniformitarian climate models for Mars, which predict very cold, dry conditions:

> "However, recent 3-dimensional climate models predict a cold and icy early Mars…, in which water is preferentially deposited in the highlands as snow and ice and MAT [mean annual temperature] is ~225 K, well below the melting point of water…." (Rosenberg et al., 2019, p. 379)

Floods on Mars imply a warm, wet climate. The conundrum is greater since the naturalistic origin model claims that solar luminosity was consistently reduced with time during most of Mars' history (Steakley et al., 2019), as shown by the graph in Figure 4. It would have been about 25% less than today at about

Figure 2. Streamlined silt hills from the Channeled Scablands just southwest of Palouse Falls.

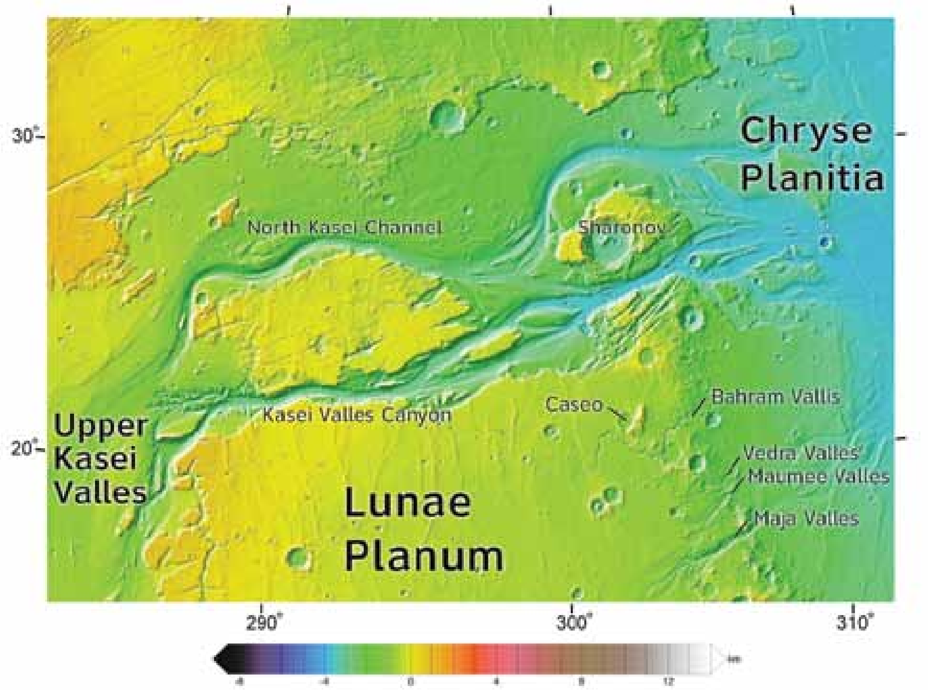

Figure 3. Kasei Valles on Mars (Aldaron, Wikipedia Commons CC-BY-SA-3.0). Note anastomosing path and teardrop-shaped erosional remnants.

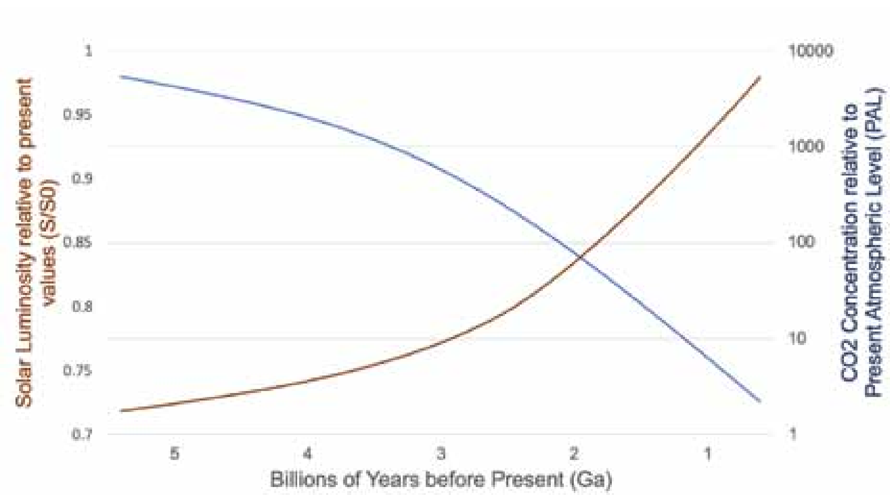

Figure 4. Historical decrease back in time in solar luminosity vs. CO_2 on Earth relative to the present due to the faint young Sun hypothesis (Gretashum, Wikipedia Commons CC-BY-SA-4.0). The values of solar luminosity on Earth also apply to Mars.

3.8 Ga (Wordsworth, 2016). It is already 43% less than Earth, due to distance. Early Mars would have had 1/3 the solar radiation Earth has today (Cang and Luo, 2019). So how did Mars have a warm, wet climate? Some think it never did (Carr and Head, 2003) while others continue looking for answers.

The faint young Sun hypothesis predicts Precambrian glaciation. Some periods of intermittent glaciation are inferred, but it is surprising that it was not one long period of global glaciation (Oard, 1997).

Researchers are struggling to come up with other potential mechanisms. One is high levels of greenhouse gases, but uniformitarians consider this unlikely, especially for "older" times:

> "Mars is presently so cold (average temperature of -60°C) that water freezes and ice subsequently sublimates. In fact, low solar luminosity would have kept Mars below freezing temperatures during its entire history regardless of how much green house [sic] gases such [sic] CO_2 were present. Despite the cold climate conditions, abundant geological, morphological, and sedimentological features indicate that liquid water flowed on Mars and in some cases accumulated in lakes." (Heydari et al., 2020, p. 12)

Numerous climate models have been developed. Researchers have learned that a CO_2 atmosphere is not warm enough (Wordsworth, 2016). Multiple bars of CO_2 cannot produce temperatures needed for liquid water (Wordsworth et al., 2013). Adding water vapor is not much help either. So, they claim higher hydrogen concentrations, an important greenhouse gas (Haberle et al., 2019), might cause warmer temperatures (Ramirez et al., 2014; Mangold, 2021), although its source has not been identified.

Perhaps the water came from volcanism (Navarro-Gonzáles et al., 2019). The Tharsis volcanism would have added up to 1.5 bars of CO_2 and 120 m Global Equivalent Layers (GEL) of water (Kamada et al., 2020). A GEL is a water layer covering Mars. However, it is unknown when Tharsis volcanism occurred—some say before flooding (Phillips et al., 2001) and some say after (Turbet et al., 2020).

The Planet Mars

Planetary scientists hope to solve the mystery flood features by accumulating more data on Mars. Figure 5 shows the general topographic features of Mars including the low altitude Northern Hemisphere with its higher ice cap, the Tharsis bulge showing the tall volcanoes, the higher and rougher Southern Hemisphere with its even higher polar ice sheet, and the deep Hellas (the blue area right) and Argyre impact craters (the green area left). All this information has been driven by the hype for Martian life (Carr, 2006). Despite a false alarm from what is believed to be a Martian meteorite in Antarctica, no life has been found (Sarfati, 1996, 2022). So, planetary scientists have been looking for the next best thing—water. Mars has plenty, but in a frozen state (Faulkner, 2009).

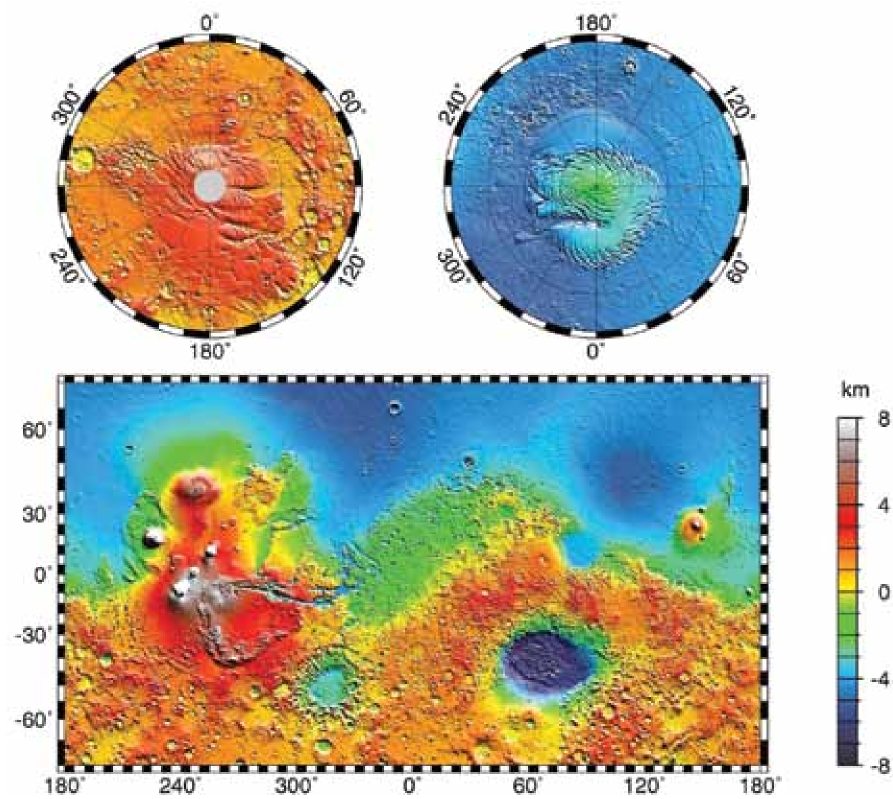

Figure 5. Map of Mars topography, including the north and south polar areas from the Mars Orbiter Laser Altimeter (MOLA) (NASA).

Mars Believed Formed from a Collapsing Dust and Gas Cloud

Uniformitarian cosmology assumes the Solar System formed from a collapsing nebula about 4.5 billion years ago. The Inner Solar System is rocky, while the outer planets are gas giants. There are numerous problems with that origin story (Chambers, 2004; Psarris, 2009; Sarfati, 2010). In it, dust and gas must first concentrate in the plane of the ecliptic (Chambers, 2004). Then dust must coagulate quickly into mountain-sized planetesimals, before particles are dispersed by solar radiation pressure, which formed first. Gravitational attraction and collisions developed planetesimals into planetary embryos, which collided to form the inner planets. Each step presents numerous problems.

It is believed that planetesimals impacted Mars early in its history—the Early Heavy Bombardment (EHB), of which there is little trace left (Oard, 2012). The EHB would have caused Mars' surface to be a "magma ocean," which is also believed to be the main reason why astronomers cannot detect much evidence for the EHB (Bottke and Norman, 2017).

As Mars cooled and the surface solidified, impact craters finally formed. Some astronomers place this at the end of the EHB; others call for a Late Heavy Bombardment (LHB). The LHB is controversial (Morbidelli et al., 2018; Brasser et al., 2020). Despite having no clear cause, proponents place it at about 4 Ga or even 3.9–3.5 Ga (Ćuk et al., 2010). Very few planetesimals should have existed then. After the LHB, impacts decreased dramatically.

Orbital Characteristics

Mars has a diameter of 3390 km, intermediate between Earth and the Moon. It possesses a core, mantle, and basaltic crust. It has an axial tilt of 25° at present but has supposedly ranged from 10° to 45° over the past 20 million years (Lasker et al., 2004). Mars, therefore, has seasons like Earth with warmer temperatures near the equator and cooler temperatures at higher latitudes and altitudes. Its orbit has a high eccentricity of 0.093, as compared to Earth's 0.017 (Carr, 2006). So, aphelion is 1.666 Astronomical Units (AUs), while perihelion is 1.495 AU. Mars has 28% of the Earth's surface area but has about twice the relief, ranging from 29.4 km at the top of Olympus Mons to the -8.2 km on the floor of the huge Hellas impact crater.

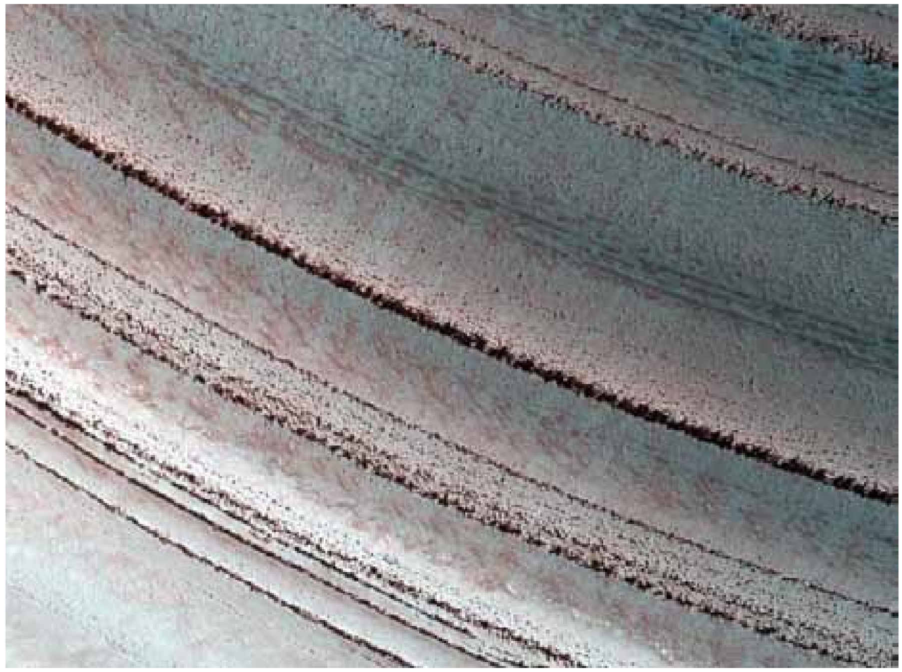

Figure 6. The Martian north polar layered deposits within the North Polar Ice Sheet from the Mars Reconnaissance Orbiter (NASA). The layers are assumed to record climate variations. The vertical scale of the light and dark bands is 10–80 m.

The Mysterious Crustal Dichotomy

Mars' crust ranges from 6 km to 102 km thick, averaging 45 km (Carr, 2006, p. 82). The Northern Hemisphere averages about 30 km, and the Southern Hemisphere, about 50 km. This is the "crustal dichotomy" that results in a topographic dichotomy as shown in Figure 5. The southern, well-cratered highlands are about 5 km higher than the northern lowlands. The slope of that boundary varies from a gentle, northward decline over 2500 km in northwest Arabia Terra to the same elevation drop within 250 km around the Isidis impact crater (Carr, 2006, p. 80).

The cause of the crustal dichotomy is much debated. Some believe the low Northern Hemisphere was formed by a giant impact (Andrews-Hanna et al., 2008; Citron, 2021) or several large ones (Manske et al., 2021). Others think it was caused by internal features, such as long-lived, single-plume mantle convection (Roberts, 2021). There are a variety of models. One evidence against the impact models is that the crust is not locally thinner beneath proposed Northern Hemisphere impacts, while it is locally thinner under Southern Hemisphere impacts, such as Hellas (Carr, 2006, pp. 82–83).

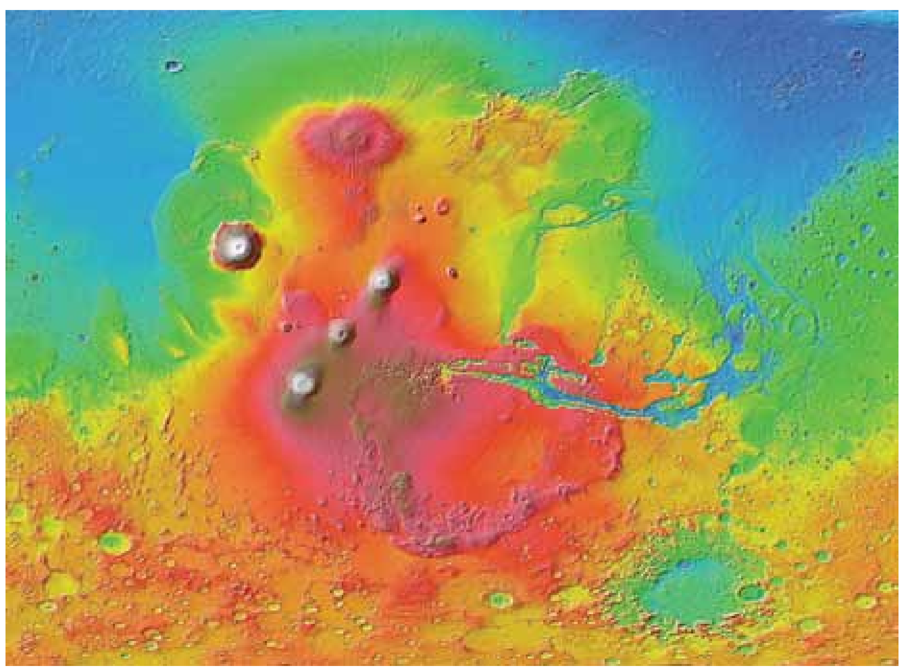

Figure 7. Mars Orbiter Laser Altimeter (MOLA) colorized topographic map of the western hemisphere of Mars, showing the Tharsis volcanic bulge, the Valles Marineris region, and the Kasei Valles. The Argyre impact basin is at lower right (NASA). Color code the same as on Figure 5.

The Extremely Thin Atmosphere

The atmospheric pressure of Mars ranges from 6.9 to 9 mbar (Carr, 2006), compared to Earth's ~1000 mbar. It is 96% carbon dioxide with a minor amount of water vapor. There are seasons with a low-to high-latitude temperature decrease and circulation, like Earth. The average surface temperature is 210°K (-113°F) but can range from 140°K (-240°F) at the poles to 300°K (81°F) during summer in the Southern Hemisphere (Carr, 2006). The diurnal range of temperature on Mars varies with latitude and season and is up to about 80°C (144°F) (Carr, 2006). The atmosphere can become very dusty and windy at times, and there are numerous sand or dust dunes on the surface. The atmospheric pressure must have been much higher during its floods.

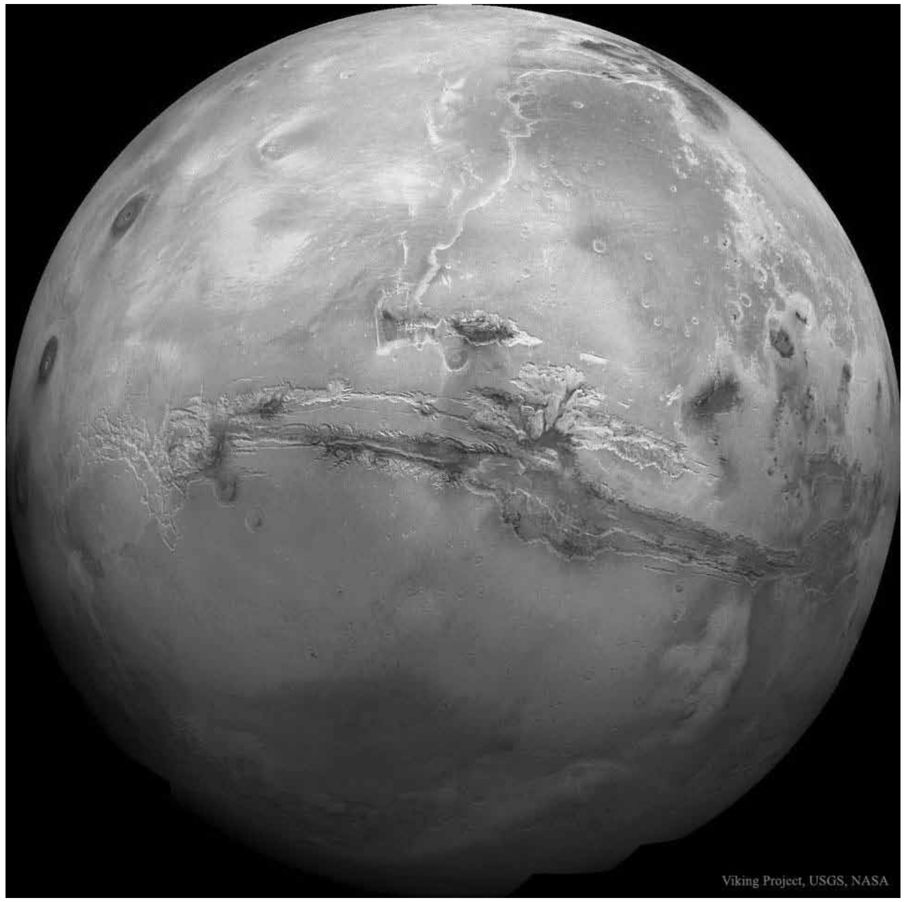

Figure 8. Valles Marineris: The Grand Canyon of Mars showing its massive length compared to the diameter of the planet (NASA). The elevation of the bottom of the canyon is about the same as the northern lowlands.

Ice on Mars—Another Great Surprise

Uniformitarians were also surprised by abundant evidence of frozen water at the mid-and high-latitudes. The mid-latitudes have glaciers (Gallagher et al., 2021). This ice is only stable because of a thin coating of dust, while it is unstable at all depths below the surface in the lower latitudes (Carr, 2006). Melted glaciers have created glacial landforms. Moreover, there are abundant periglacial features having polygonal surfaces and possibly pingos (Soare et al., 2021). Carr (2006) believes the glaciers formed at high obliquity in the past. Obliquity is the tilt of Mars' axis with the plain of the ecliptic. Since the VNs and outflow channels are believed by many to have been caused by floods, sometimes of enormous size, the precipitation must have been heavy, causing rapid glaciation.

Equally mysterious are the polar ice sheets. The northern ice sheet is about 1000 km across and 2 km thick (Lalich et al., 2019) and the southern is about the same area and 3–4 km thick (Byrne, 2009). These ice sheets consist of alternating layers of water ice and dust on a vertical scale of 10–80 m (Levard et al., 2007), as shown in Figure 6. The total volume of polar ice is estimated at ~3.5 x 10^6 km^3 (Arnold et al., 2019), comparable to the Greenland Ice Sheet. It is believed that the South Polar Ice Sheet was once twice as large (Arnold et al., 2019). These ice sheets have a surface coating of frozen CO_2 that insulates the ice. They are estimated to contain about 20 to 40 m GEL (Scheller et al., 2021). Because they lack impact craters, geologists think they are very young.

Enormous Volcanism

Mars shows evidence of massive volcanism. The amount of ejected volcanic material is estimated at 600 x 10^6 km^3; equivalent to a global layer of lava 4 km deep (Jakosky, 2021). Lava was concentrated in the Tharsis area, 5000 km across and 10 km high as shown on Figure 7 (Carr, 2006, p. 43) where several volcanic cones are found. Olympus Mons on the northwest part of the Tharsis bulge is 550 km (335 mi) across and 24 km (14.6 mi) above the surface, 2½ times the elevation of Mount Everest (Samec, 2013)! To the north, Alba Patera is 2000 km across but only a few km high. Another smaller area of volcanism occurs at Elysium Mons. Samec (2013) compares the total for volcanism in the Hawaiian-Emperor chain at 750,000 km^3 to that 4.5 times that volume for the five major volcanoes on Tharsis.

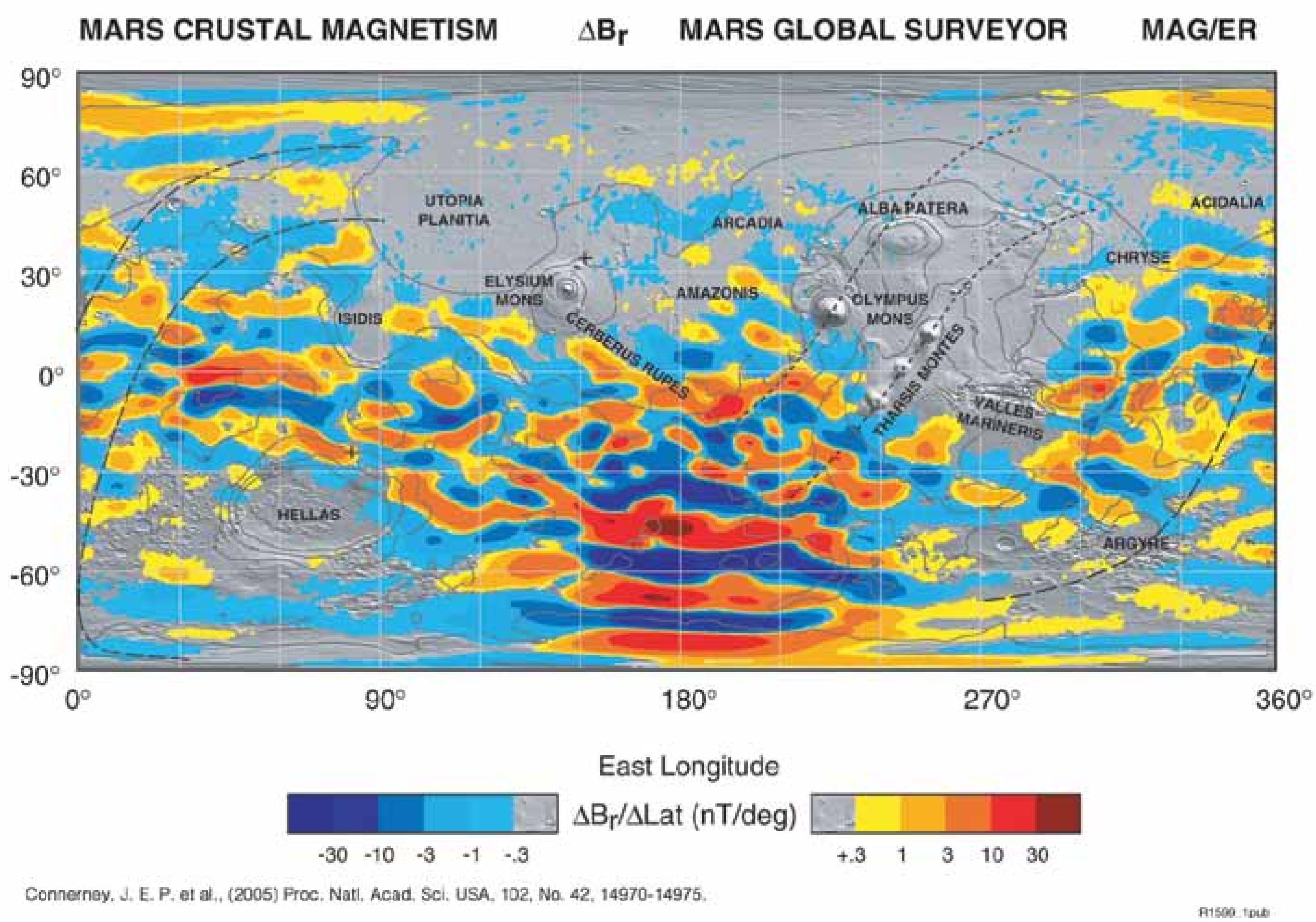

Figure 9. Map of Mars crustal magnetism (NASA). Note alternating positive and negative anomalies and areas of little or no magnetism.

The Amazing Valles Marineris

In the eastern portion of the Tharsis bulge is the great canyon system of the Valles Marineris, a linear, east-west trending canyon which is composed of multiple short canyons as shown in Figures 7 and 8. Valles Marineris is much larger than Grand Canyon, which is only 446 km long, up to 30 km wide, and over 1800 m deep. The Mars canyon starts on the eastern Tharsis bulge, first as intersecting canyons, called the Noctis Labyrinthus, and continues 4000 km east to the Chryse basin. It was earlier thought that Valles Marineris was the result of radial grabens rifting around the Tharsis bulge of which the Valles Marineris is the largest rift by far, but more recently researchers admit they do not know its origin (Andres-Hanna, 2012). The drop in elevation is from about 7000 m at the western end to less than 1000 m at the eastern end (Carr, 2006, p. 95). The depths of the individual canyons are around 6000 m, but the depth is over 10,000 m in western Coprates Chasma. Most individual canyons are around 150 km in width, but Melas Chasma is almost 300 km wide.

The Past Magnetic Field

Mars has no magnetic field today, but scientists discovered large, regional magnetism in the crust of Mars (McKenzie, 1999), indicating a magnetic field early in Martian history (Solomon et al., 2005). The strong remnant magnetic positive and negative anomalies are about 10 to 20 times stronger and much wider than oceanic magnetic anomalies on Earth (Figure 9) (Jurdy and Stefanick, 2008; Lillis et al., 2008). Some researchers have rejected a plate tectonics explanation (Kerr, 1999; Coles et al., 2019, p. 15). Anomalies are located mainly in the southern highlands with weak anomalies over portions of the northern lowlands, large volcanic areas, and the large impact craters (Coles et al., 2019, p. 15). The magnetic field was dead by the time of the large Utopia, Hellas, Isidis, and Argyre impacts. This was at about the time of the postulated Late Heavy Bombardment (Jurdy and Stefanick, 2009). Secular scientists assume the magnetism was caused by a "dynamo" that lasted for several hundred million years in early Mars history. But dynamos are unlikely (Humphreys and De Spain, 2016). The remnant magnetism is thought to reside in igneous dikes or dike swarms magnetized in the presence of a strong magnetic field early in Martian history (Carr, 2006, p. 78). The pattern of magnetism on the surface of Mars can give us a relative Biblical timescale for Mars history which will be discussed in Part III of this series.

Figure 10. The near side of the Moon showing the large impact basins filled with black basalt on a background of smaller highland craters (NASA/JPL/USGS).

Mars Impacts

Mars' surface has thousands of impact craters as shown in Figure 5. The number of impact craters greater than or equal to 5 km is about 42,000 (Barlow, 2010). Established sizes range up to Utopia Planitia's 3400 km in diameter. There were once questions about Utopia Planitia's origin, but it is now accepted as an impact (Brasser et al., 2020). The Hellas crater is 2400 km in diameter and about 8 km deep (Coles et al., 2019, pp. 28–29). These craters are among the largest in the Solar System and compare with the Aitken crater near the South Pole of the Moon, which is 2500 km. Other craters of note on Mars are Isidis at about 1500 km and Argyre about 900 km across. Several large basins in the northern lowlands have been considered impact craters, such as Acidalia Planitia at about 2800 km and Chryse Planitia at about 1700 km in diameter. Chryse Planitia was once rejected as an impact crater, but a re-evaluation suggests it is because it has a near-circular area and a near-circular positive Bouguer gravity anomaly about as strong as Utopia Planita but not the other three large impact basins (Pan et al., 2019). A Chryse impact would be about 1100 km and probably relaxed and filled with debris quickly. Many other impact craters over 1000 km have been suggested, but not proven (Vervelidou et al., 2017). Frey (2008) believes there are 21 impacts greater than 1000 km (Roberts et al., 2009). Table I lists the four largest accepted impact craters on Mars, their diameters, and the suggested size of the projectile.

Toon et al. (2010) show a graph of impactor size and resulting crater sizes. This is based on assumptions that impact velocity decreases away from the Sun. Average velocities for impacts on Mars would be 9 km/s. A crater 1000 km in diameter would be produced by a body 180 km in diameter. But lower velocities would not apply if the Solar System passed through an asteroid cloud.

Mars is often compared to the Moon in its cratering size-frequency distribution (Carr, 2006, p. 23). Thus, it is expected that the Earth should have been similarly bombarded, but to date, evidence has only confirmed about 200 impacts (Schmieder and Kring, 2020). This is a crucial problem for uniformitarians.

Mars' Southern Hemisphere contains numerous impact craters. Very few

Table I. The four largest impact craters on Mars and the assumed impactor size based on Toon et al. (2010)

Impact crater	Diameter of crater	Diameter of impactor
Utopia Planitia	3400 km	>500 km
Hellas	2400 km	~500 km
Isidis	1500 km	300 km
Argyre	900 km	160 km

are found in the Northern Hemisphere, but there is evidence of many buried impact craters, up to 130–470 km in diameter, in over 14% of the northern lowlands (Watters et al., 2006). There are probably many more yet undetected in the northern lowlands, based on the southern part of the planet (Carr, 2006, pp. 162–164).

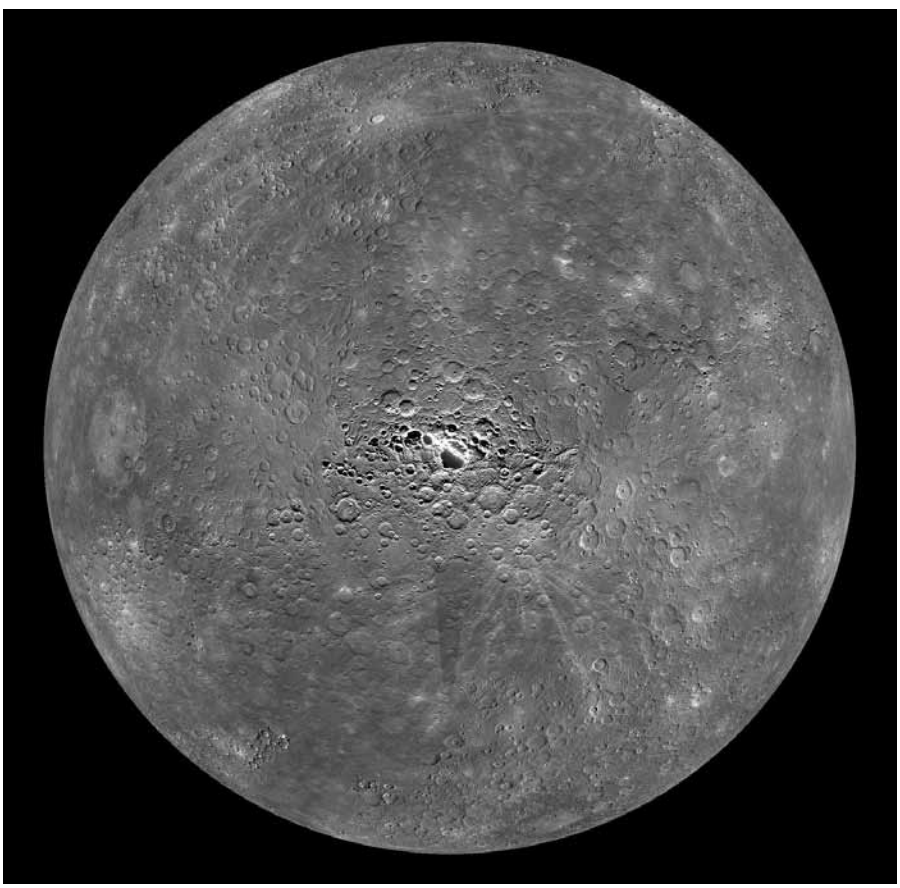

Figure 11. Mercury from the South Pole (NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington).

Whole Solar System Bombarded by Impactors

Cratering on Mars is similar to the surface of nearly all solid bodies of the Solar System as shown in Figures 10 through 14 which include images of four planetary moons and the planet Mercury:

> "Craters are ubiquitous across nearly every solid surface in the solar system, and they have long been used as a metric for assigning relative ages; If [sic] a surface has more craters of a given size per unit area, then it is older because crater accumulation is temporally cumulative." (Robbins, 2014, p. 188)

Thus, impact craters are the most significant landform in the whole Solar System:

> "Impact craters are the most distinctive landforms on solid planetary bodies other than the Earth. Almost every solid surface on every planet and satellite observed so far is cratered to some degree." (Carr, 2006, p. 23)

The only exceptions are locations where the older surface has been resurfaced or partially resurfaced by sediment, impact debris, and/or lava, such as Venus.

Impacts Violate the Uniformitarian Principle

It was argued up until the 1960s that Solar-System craters were volcanic caldera because of the strong belief in uniformitarianism, i.e., volcanic processes are observed today but large impacts are not. However, volcanoes, which also exist on many Solar-System bodies, including Mars, can be distinguished from impact craters:

> "Most calderas [on Mars] look very different from impact craters because they form by collapse rather than by excavation, and because they are commonly the result of multiple events rather than a single event." (Carr, 2006, p. 43)

Figure 12. Rhea, a moon of Saturn, sports an immense impact scar on its leading hemisphere as seen above center on the day-night dividing line (NASA/JPL/Space Science Institute).

Thus, secular scientists now believe that, over billions of years, large asteroid or comet impacts have swept the Solar System. The Earth, not being special, should also have been bombarded. This change is called neo-catastrophism, which recognizes a few, isolated major catastrophes on Earth, such as the Ice Age and the Lake Missoula flood, both of which once challenged uniformitarianism but were later incorporated into uniformitarianism and are now thought to be simply rare processes, rather than one-time events.

How Is the Surface of Mars Dated?

Scientists need a timescale for Mars to describe its history. How do secular scientists derive this for Mars and other planets? Since they cannot collect rocks for radiometric dating, they use a method called "crater dating." Superposition of craters provides a relative age: "Relative ages are determined from remote sensing mainly in two ways, from intersection relationships and from the number of superimposed impact craters" (Carr, 2006, pp. 14–15).

As stated by Carr, the second method is crater density. A well-cratered surface is considered old, and one with few craters is young. To tie this method to an absolute time scale, they use dates of Moon rocks compared to its cratering density and apply the derived dates to the Solar System (Robbins, 2014). Since Moon rocks were dated between 3 and 4 Ga, impacts are spread over billions of years. This assumes a constant flux from the asteroid belt after the Late Heavy Bombardment. They incorporate the distribution of asteroid orbits and size, and the gravity and target potential of Solar-System bodies (Michael and Neukum, 2010).

Moon rocks recovered from the Apollo and Luna missions gave dates of about 4 billion years for highland rocks and about 3.8 to 3.1 billion years for the mare basalts. Thus, researchers assume that the large impact basins on the near-side formed about 4 billion years ago, mainly during the LHB, but the basalt that filled the basins did not erupt until a billion years later! These dates make no sense, since we would expect that the basalt would fill the crater very soon after impact, since impacts fracture both the crust and mantle (Samec, 2008). Manske et al. (2021, p. 7) state that large impact craters should fill with basalt quickly:

> "It is expected that decompression melting contributes significantly to the total melt volume in large impacts, as more material from greater depths is stratigraphically uplifted with increasing impactor size."

The paradox grew when China recovered rocks from the northwest Procellarum mare (Chang'e-5 site) that were radiometrically dated at about 2 Ga (Che et al., 2021; Li et al., 2021). This was a maria area that was crater-dated at 3.2 to 1.2 Ga, suggesting problems with the method. An estimated 2000 km^3 of basalt lava erupted about that time. Some believe that the youngest mare basalt is about 1 Ga, indicating volcanism continued for 3 billion years (Qian et al., 2021)! Others have stretched the volcanism to 100 Ma (Braden et al., 2014). Why would these basalt eruptions last for over 3 billion years? What would cause a planet or moon to maintain its mantle heat that long? The Moon should have cooled early, ending volcanism after several hundred million years. Radioactive elements and water in the mantle do not solve the problem (Che et al., 2021; Hu et al., 2021).

Astronomers have divided Martian history into four major periods as shown in Table II (Bottke and Andrews-Hanna, 2017). The pre-Noachian is sometimes considered the early Noachian (Gulick, 2001), and the boundaries between the periods are a rough estimate. The EHB occurred during the pre-Noachian with

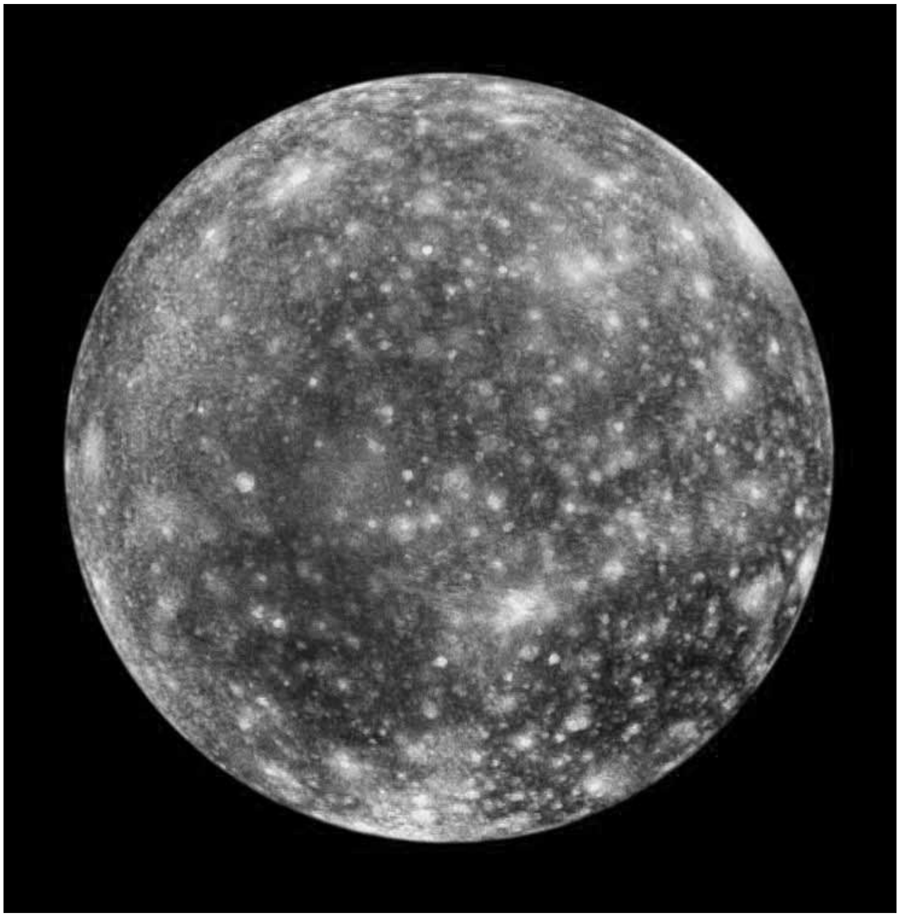

Figure 13. Callisto, a moon of Jupiter, showing numerous impacts (NASA/JPL/DLR).

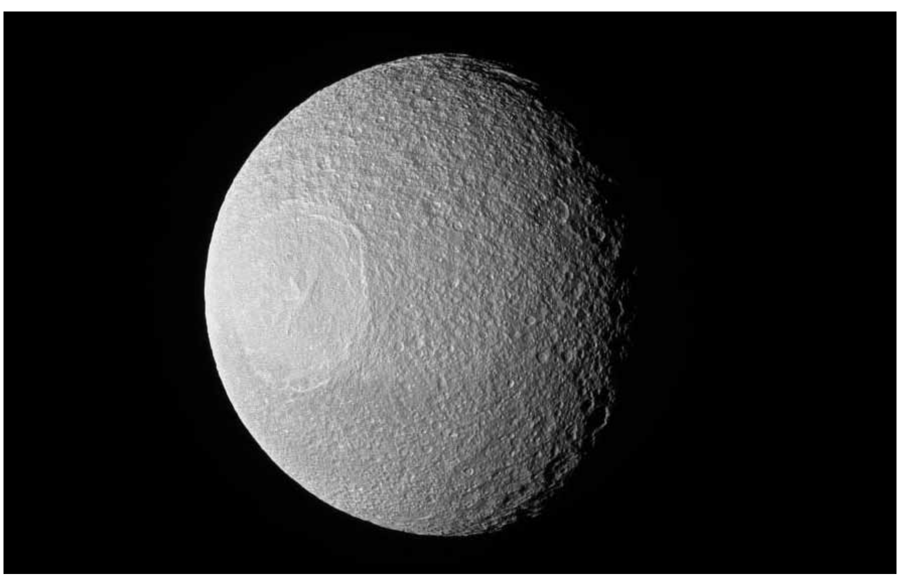

Figure 14. Tethys, an ice moon of Saturn, showing the large crater, Odysseus, on the left side (NASA/JPL-Caltech/Space Science Institute).

the LHB during the Noachian. Some of the numerous impact craters on Mars are believed to have struck during the Noachian, including those in Table I. The Hesperian is the period that refers to the oldest surfaces after the end of heavy bombardment. The Hesperian did have 67 impacts that produced craters 5 to 400 km in diameter.

Valley Networks

Valley networks (VNs) are narrow valleys observed on Mars, especially on the southern highlands, but they stretch latitudinally from 50°N to 65°S (Cassanelli and Head, 2019). The valleys are 50–350 m deep, 0.5–5 km wide, and 100–200 km long (Irwin et al., 2011). Individual valleys are up to 4000 km long (Howard et al., 2005). There are a small number of valleys that are significantly larger and deeper: ~10 km wide and >500 m deep (Irwin et al., 2011) or even 20 km wide (Hynek et al., 2010). However, it is a uniformitarian mystery why smaller valleys a few 100 m wide and narrower are absent (Carr and Malin, 2000). The origin of VNs has been debated since the 1970s (Gullick, 2001), because there are several puzzling aspects.

Many VNs start on local highs such as crater rims or central peaks, where groundwater seepage is unlikely, strongly suggesting precipitation (Fassett and Head, 2008). They then proceed down a steep slope and end in an enclosed basin or crater. For instance, Samara Vallis descends about 3000 m over 1700 km (Carr, 2006, p. 140). Some valley profiles in the Isidis crater region descend about 5000 m in 800 km (Howard et al., 2005).

There are thousands of VNs similar to those shown in Figure 15. Steakley et al. (2019) claim there are over 80,000 individual valleys, but they must be counting numerous short valleys. VNs can be either U-shaped or V-shaped (Gullick, 2001). Their upper reaches commonly are stubby with theaterheaded tributaries while the lower reaches are of low sinuosity, sometimes branching, and with broad flat floors, sometimes ending in an alluvial fan or delta. The ubiquitous wind on Mars has sometimes caused valley inversion on the downstream alluvial fans, in which the sides of a valley erode faster than the bottom, leaving the bottom of the channel as a ridge (Williams et al., 2009; Davis et al., 2019). VNs occur on most Martian volcanoes and are commonly denser and shallower, which implies precipitation (Hynek et al., 2010).

VNs are mostly dated late Noachian (Howard et al., 2005). Steakley et al. (2019) claim 90% formed in the Noachian, while Fassett and Head say only 70% are dated Noachian. Additionally, some VNs have been dated in the Hesperian and even as late as the Amazonian (Salvatore and Levy, 2021). This substantial variance is likely a contradiction to their crater dating scheme, since VNs should be carved close in time.

VN Occurrence, Sizes, Distribution, and Types

First, most VNs occur in the southern highlands along an east-west band at roughly 24°S latitude. When the Tharsis bulge formed, it shifted about 15–25° south by polar wandering to be near the equator, but on the opposite side of Mars the shift was about 15–25° north (Bouley et al., 2016), which is why the latitudinal range of VNs today is rather large. Why didn't VNs form at other locations, such as the northern lowlands?

Second, VNs often start full size with little to no width changes downstream (Irwin et al., 2011). They commonly flow northward down the crustal dichotomy into craters.

Third, VNs have a patchy distribution. They are found singly, or in clusters, but are absent over areas where they could be expected to exist (Gullick, 2001). For instance, there are few VNs found over the large Arabia Terra and between 30° to 60° S from the Argyre impact to the east of the Hellas impact (Bouley et al., 2016). Interestingly, drainage densities on Earth are 14 times those on Mars (Grand, 2000). VNs are believed to not conform to a warm, wet climate model with abundant precipitation (Gulick, 2001), as many researchers believe for early Mars.

Fourth, when compared to rivers on Earth, the drainage systems of Martian VNs are considered immature according to any measure (Carr, 2006, p. 143; Irwin et al., 2011; Craddock and Lorenz, 2017; Galofre et al., 2020). Geomorphically, VNs are mostly convex upward, the opposite of rivers on Earth (Irwin et al., 2011). They did not shape the topography, rather the current topography directed their paths (Irwin et al., 2011).

Were VNs Formed by Rain and Runoff?

Many researchers have suggested a groundwater origin for VNs in a cold, dry climate (Grand, 2000), but others believe they are due to precipitation and runoff (Hoke et al., 2010), especially since many VNs start at high elevations where groundwater is unlikely. In support of the origin by running water, fan-shaped deposits occur at the ends of some VNs. Some researchers have suggested a variety of mechanisms for the origins of the VNs:

> "Glaciation, mass wasting, faulting, and erosion by CO_2, wind, and lava have at times been invoked to

Figure 15. Channels near Warrego in Thaumasia. From the Mars 2001 Odyssey Thermal Emission Imaging System (THEMIS) (NASA/JPL/Arizona State University).

Table II. The four periods of Mars history.

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

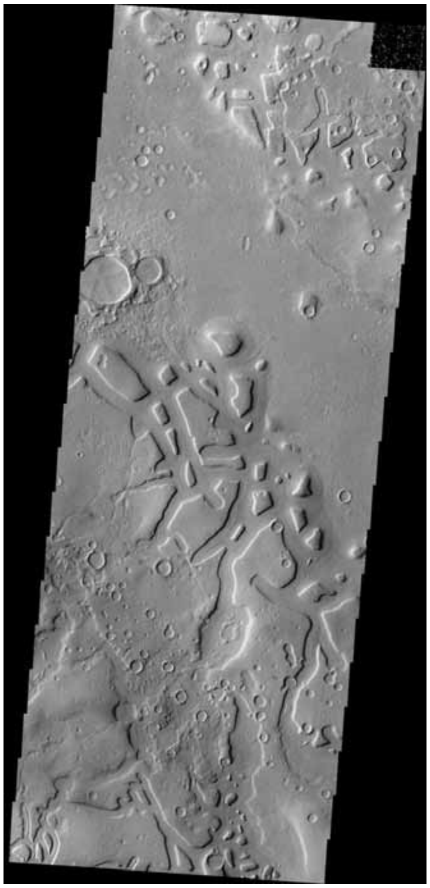

Figure 16. The region on the margin of Terra Sabaea showing several areas of chaos, as imaged by the Mars Odyssey spacecraft (NASA). Regions of mesas and channels are termed chaos.

> explain valley networks, but erosion by liquid water is now almost universally viewed as the primary cause." (Carr, 2006, p. 139)

Galofre et al. (2020) have claimed that some of the VNs formed from subglacial erosion when the area was glaciated. But precipitation is required for glaciation and there should be evidence of extensive glaciation in the southern highlands where most of the VNs are located. There is no evidence of glaciation to be found.

Most researchers believe VNs were eroded by running water, but there is controversy over the amount of running water and the climate conditions needed for their formation. Although some tributaries that start abruptly would support groundwater sapping, it is unlikely that groundwater discharges could erode the long VNs.

What Was the Climate Like?

VNs are assumed to form in a warm, wet climate during the long Noachian, but the young VNs present a conundrum for their origins (Carr and Malin, 2000). So, uniformitarian scientists claim the younger VNs formed in a brief warm, wet period.

The main resistance to an origin by water is the climate models indicate that it is very difficult to warm Mars. Some researchers believe there is something basically wrong with the climate simulations, since the evidence requires precipitation and warm conditions to have existed at one time. This is also supported by other evidence, such as degraded craters in the Noachian period but pristine craters in the Hesperian and Amazonian (Craddock and Lorenz, 2017). But this scale of degraded craters could be due to circular reasoning in that degraded craters are assumed to be old and pristine craters young.

Outflow Channels

Outflow channels, unlike VNs, are found outside the southern highlands (Carr, 2006, pp. 131–144), and commonly flow down the topographic dichotomy into the northern plains. Outflow channels are wider and show bedforms that VNs do not (Gullick, 2001).

Outflow channels vary in size. The largest, Kasei Valles, shown in Figures 3 and 7, is over 400 km across, over 2.5 km deep, and about 2000 km long (Carr, 2006, pp. 113–131), much larger than Grand Canyon. Kasei Valles has features like the Channeled Scablands, with three dry cataracts, 120 m high, such as Dry Falls, Washington, USA (Oard, 2004, 2014). Kasei Valles also has longitudinal scours and tear-drop shaped hills (Figure 3), common in the Channeled Scabland (Figure 2). Outflow channels *start full size* at the beginning, have little width change, and few tributaries. The majority of planetary geologists believe they were carved by huge floods, although some think such floods impossible. Researchers are divided on whether they formed from one large, or multiple smaller floods (Conway et al., 2011). Estimated flows range from 10^4 to 10^9 m^3/s, the latter for a single, large flood. These discharges compare to the Lake Missoula flood discharge of about 3 x 10^6 m^3/s. The amount of erosion of Kasei Valles is estimated to be 7 x 10^5 km^3, which at a 1:1 ratio of water to eroded sediments represents a water volume of 4.8 m Global Equivalent Layers (GEL) (Carr and Head, 2015).

The relatively rare outflow channels all terminate in the northern lowlands. They are most prominent around the Chryse basin, south of which lies the huge Valles Marineris. Several outflow channels start near the two largest volcanic provinces of Tharsis and Elysium (Roda et al., 2014). Because of the low atmospheric pressure, floods on Mars would flow faster, farther, and be more erosive (Conway et al., 2011). Some outflow channels are believed to have formed quickly, such as the channel from Aram Chaos into the Chryse basin, and some planetary scientists believe its formation took place in one flood over tens of days from a collapsed lake (Roda et al., 2014). Many outflow channels start at chaos regions, depressions that are about 4 km deep, 20–120 km wide (but up to 250 km wide) that contain a large number of undeformed tilted blocks, mesas and channels as shown in Figure 16 (Oard, 2017; Roda et al., 2017). Some chaotic terrain is up to 7 km deep (Meresse et al., 2008). It appears that, "The channels simply start at a hole in the ground, with no obvious catchment area" (Carr, 2006, p. 114). The origin of chaotic terrain is unknown (Meresse et al., 2008). Other outflow channels issue forth from rifts or grabens. The origin from chaos regions and grabens indicates a *groundwater* origin for the outflow channels, which is extremely perplexing.

There are many problems with explaining outflow channels having been cut by huge floods, including a source and indications that the water originated below the ground (Gallagher and Bahia, 2021; Leverington, 2021).

One major challenge is that most outflow channels are dated in the Hesperian, based on crater counting, when the climate was thought to be cold and dry (Carr and Malin, 2000). Planetary scientists also stretch a few outflow channels into the Amazonian based on crater counting (Salvatore and Levy, 2021). Cassanelli et al. (2015) even stretch some outflow channels back into the late Noachian. The dating of outflow channels from the late Noachian into the Amazonian requires underground reservoirs that need constant recharging by water over billions of years. Other researchers believe they formed mostly in the Amazonian, also based on crater dating (Rodriguez et al., 2015). This variable timing gives us some indication of the subjectivity of crater dating, since one would expect the outflow channels to be cut at about the same time. As a result, some think that the outflow channels formed during climate conditions similar to today on Mars (Carr, 2012), while others believe there were short periods of a warmer, wetter climate (Ramirez and Craddock, 2018).

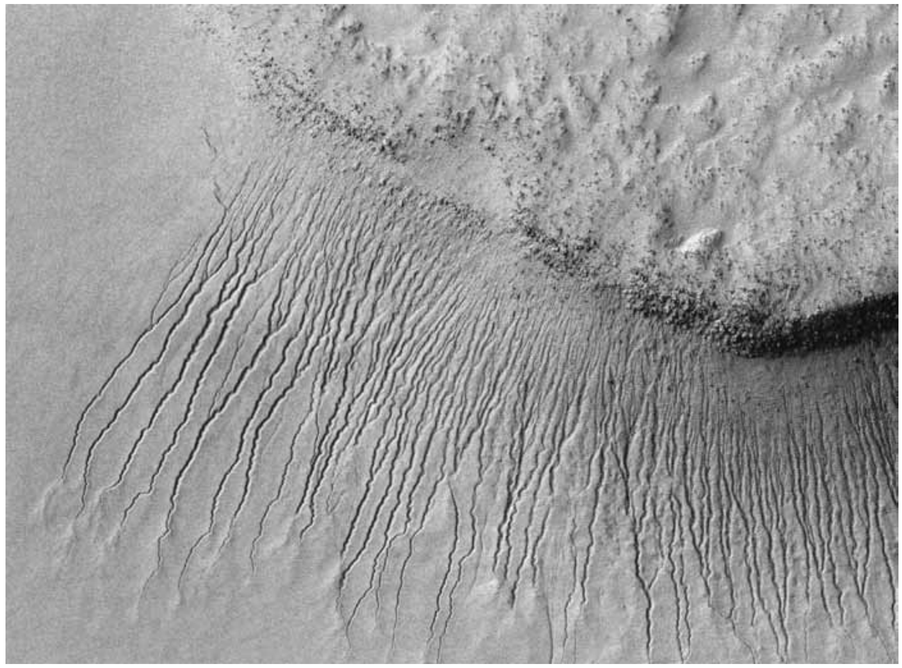

Figure 17. Mars Reconnaissance Orbiter showing many gullies on a scarp in the Hellas impact basin (NASA/JPL-Caltech/University of Arizona).

Gullies

Gullies are the third type of Mars channels. They generally start from an amphitheater-shaped erosion feature and travel down a steep slope. Gullies are representative of several other similar features thought to be evidence of recent liquid-water flow (Conway and Stillman, 2021). They are mostly meters to a few tens of meters wide and hundreds of meters long as shown in Figure 17. They are sometimes as long as 7 km (Bauley et al., 2016). Gullies are dated Late Amazonian, since there are very few, if any, impact craters on them. They have been observed forming today from orbiter images (Goldspiel and Squyres, 2011). They often start on the crests of central peaks, on isolated mesas, and the rims of craters. Because liquid water is not only unexpected on isolated high areas, and the climate is presently very cold and dry, these gullies present a problem for uniformitarian scientists. This implies the gullies must have formed when the ground was unfrozen, pointing once again to a warm, wet climate sometime within the late Amazonian; however, the late Amazonian was supposedly a time when Mars was cold and dry (Goldspiel and Squyres, 2011). Because of these difficulties, many researchers attribute the gullies and similar features to dry flows (Dundas, 2021), such as debris flows (De Hass et al., 2015).

Summary

As with the exploration of other bodies of our solar system, Mars has also produced numerous unexpected discoveries. The greatest are the large, apparently water-carved outflow channels and numerous, narrower valley networks. If outflow channels were carved by one flood, the required flow rate would have been up to 100 times the flow of the Lake Missoula flood on a planet with no liquid water. Climate models have only heightened the mystery, since they predict a cold, dry climate throughout Martian history.

In order to understand the cause of Mars flooding, I summarized the major features of the planet, including the mysterious crustal dichotomy with its low elevation and thin crust in most of the Northern Hemisphere as compared with high elevation and thick crust in the Southern Hemisphere, the evidence for an early magnetic field, evidence for precipitation including glaciers and ice sheets, the numerous impacts, and significant volcanism. The uniformitarian crater dates are very important to the secular beliefs of Mars history, and the geologic history of Mars has been divided into four major periods.

Valley networks show several unusual features. They are formed almost exclusively in the southern highlands; often start full-size and continue downgradient with little change in width; have a patchy distribution; exhibit immature drainage patterns; follow the surface topography; likely cut by water; and suggest a warm, wet climate. Outflow channels are just as mysterious in that they appear to have been caused by immense floods that initiate from underground, start full size at the beginning, have little width change, and possess few tributaries. Gullies are more recent small-scale erosional features that could indicate water erosion or erosion by dry mechanisms.

The likelihood of floods on Mars brings up a number of questions that will be answered in Parts II and III. It will be shown that these questions are difficult to answer within uniformitarian planetary science but can be explained within Biblical Earth history.

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