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Atmospheric Mass Loss on Mars and the Consequences for the Cydonian Hypothesis and Early Martian-Life Forms

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Abstract — This work investigates atmospheric escape processes on Mars and their consequences for possible early Martian lifeforms and the Cydonia hypothesis. The results show that while future Mars missions may find archeobacteriological fossils, no evidence of skeletal lifeforms is expected.

Introduction

In July 1976 NASA's Viking spacecraft acquired a strange image in the Cydonia region in the northern hemisphere of Mars, which appeared to be a human face staring straight up into space from the Martian surface. DiPietro and Molenaar, two engineers at the Goddard Space Flight Center rediscovered the image several years later. They found a second image of this feature that had been acquired in slightly different lighting conditions. Digital image enhancements of this second image revealed a bisymmetrical object having features suggestive of eyes, a nose and a mouth (Carlotto, 1988, 1991). In a subsequent investigation, other nearby objects which seemed to be related with the face were found. These features are polyhedral objects southwest of the face.

Due the controversial nature of the subject, these results were published independently of the planetary scientific community. Carlotto (1991) applied fractal analysis on these features. The results of this examination support the hypothesis that the face in Cydonia is artificial (Carlotto, 1991; McDaniel, 1993). Brandenburg *et* al. (1989, 1991) suggested that the planet Mars was once the home of an "indigenous" race of intelligent humanoid beings which constructed a humanoid face (or faces) in the Cydonia region, pyramids and other strange Martian surface features. They suggested that the motivation for the construction of large faces and pyramids was similar to the God-King worship of ancient Egypt, since the objects look similar in appearance and psychology to ourselves. The Cydonian Hypothesis works with the principle of mediocrity and requires a long-lived Earth-like biosphere (at least 3-4 billion years), to allow the formation and evolution of such a culture. The principle of mediocrity states that humankind is nothing special and that both our sun and solar system are average bodies in the Galaxy. The Cydonian Hypothesis also requires the death of the planetary atmosphere, since Mars is presently hostile to Earth-like life. For the evolution of lifeforms similar to those found on Earth we need to find evidence of liquid water. With the exception of Earth, liquid water appears to be uncommon on the inner planets; only Mars shows evidence of possible ancient water flows. The evolution of the now thin atmosphere of about 6 mbar is thought to have proceeded by some combination of escape to space and surface absorption. This work, therefore, has the aim of investigating using present knowledge of atmospheric escape, climatological and geological studies, to see if Mars might once have had a long-lived Earth-like biosphere.

The Martian Atmosphere

The atmosphere of Mars is very thin (the average surface pressure is about 6 mbar) and essentially composed of carbon-dioxide, CO_2 (95%), nitrogen, N (2.5%) and argon, Ar (2%). Oxygen, 0 , and water, H_2O, vapor are not very abundant. The abundance of argon and the isotopic ratios (D/H, $^{14}N/^{15}N$) show that the planet's total gas loss during its history was much higher than the mass of the current atmosphere. The stratifications observed around the polar caps demonstrate the existence of medium-term climatic variations. It is important to establish whether, at some point in history, Mars could have had conditions that would favor the appearance of life, such as substantial quantities of water in liquid form on the surface and a thick atmosphere that would protect the planet from ionizing radiation.

The geomorphology on Mars shows the probable existence, at least in the past, of important quantities of water on the surface or in the surface layers of Mars. There are outflow channels with large-scale fluvial features which appear to have been caused by catastrophic flooding events (eg. Baker, 1982) associated with the rapid drainage of underground ice reservoirs (Carr, 1979). The channel networks observed in the ancient formations in the southern hemisphere have similarities with fluvial systems on Earth and lead one to think that flowing water (or mud) were responsible. In contrast to the outflow channels, the channel networks could not form under current atmospheric pressure conditions. Some of the channels have complex dendritic networks leading into the main channel and are suggestive of formation by rainfall (Masursky et ul., 1987). These networks are commonly found in the ancient crater terrain in the southern hemisphere, the oldest Martian terrain, and are rarely found on the younger northern plains. This suggests that the networks are old, and they are believed to have formed about 3.5-3.8 billion years ago (Carr, 1986).

The current atmosphere is very dry and the reservoir made up by the polar caps could only supply about ten meters of water on average over the Martian surface. However, 200 m would be required to explain the observed shapes. A part of the water was lost to space and the other part must be stocked in a reservoir that could be permafrost (permanently frozen soil composed of a mixture of ice and rock) kilometers thick in the subpolar regions. Current surface temperatures are too low for allowing such flows. Therefore, an increase in the main atmospheric constituent CO_2 is necessary, given the extent of the greenhouse effect that would be needed to exceed 0 °C and at least an atmospheric pressure of about 1 bar.

Atmospheric Mass Loss

The amount of water and carbonate that has escaped to space in the past must be determined by modelling the atmospheric loss processes backward in time. Atmospheric escape occur when atoms or ions move upward with velocities greater than the escape velocity to an atmospheric level where the collision probability between the atmospheric constituents is low (*i.e.* the critical level or exobase). Because of the weak gravitational acceleration, a possible small intrinsic magnetic field, and the small size of the planet, many atmospheric loss mechanisms work on Mars (*e.g.* Lammer and Bauer, 1991, 1992; Luhmann et al., 1992; Kass and Yung, 1995). Several important constituents, namely H, H_2, N, O, C, CO, O, and CO_2 are known to undergo thermal and non-thermal escape mechanisms. If we calculate the atmospheric loss rates back in time we get a much denser atmosphere in the past (at least 1 bar). The calculated oxygen loss is equivalent to a planet-wide 50-80 m depth ocean of liquid water (global surface depth) (Luhmann et *al.*, 1992; Kass and Yung, 1995). New calculations by the author and colleagues (Lammer et al., 1996) of Martian H and O escape rates cast serious doubt on the assumption that as much as 80 m of water has been lost to space. Reconsideration of extreme ultraviolet (EUV) fluxes on water dissociation in the ancient atmosphere of Mars lead to much lower escape rates and imply the loss to space of an equivalent depth of less than 7m (The new results were presented at the European Geophysical Society meeting in The Hague, Netherlands, 6-10 May 1996).

However, these loss rates of volatiles due to atmospheric escape are insufficient to deplete the initial endowment of water and other volatiles. Therefore, most of the volatiles may still be on the planet in surface reservoirs. The current knowledge about the amount of CO_2 that was available for forming and maintaining a dense CO_2 atmosphere and for sustaining a wet, warm climate in the early history of Mars is not well constrained. The estimations of outgassed CO_2 for Mars are in the range from 1-10 bars (Pollack et al., 1987). CO_2 partial pressures of 0.75 to 5 bars are needed in the early Martian atmosphere to raise the surface temperature to the melting point of water ice. The critical unknown in the possibility of the origin of life on Mars is how long clement conditions prevailed after the first occurrence of liquid water on the Martian surface. Mars would have lost its dense CO_2 atmosphere as it was transformed into carbonate rocks (*e.g.*, Pollack, 1987), increasingly absorbed by regolith as the temperatures became cooler (*e.g.*, Zent et al., 1987), or reacted with surface materials (Huguenin, 1976). The formation of carbonate rocks would have proceeded on Mars as long as liquid water was present and ceased once the pressure dropped so low that liquid water could no longer exist (Kahn, 1985).

The time scale for decreasing atmospheric CO, from 1 bar to its present value by carbonate formation is estimated to be 10^7–10^9 years, including volcanism (*e.g.* Pollack et *al.,* 1987). In the absence of recycling, the lifetime of such an early dense atmosphere would have been very short. On an active planet like Earth, subduction of ocean sediments at plate boundaries followed by decomposition of carbonates in the mantle is the primary mechanism for completing the long-term geochemical CO_2 cycle. Mars does not have sufficient heat flow at present to cause the global scale recycling of volatiles incorporated into crustal rocks, nor is there any sign that Mars has, or ever had, crustal dynamics akin to plate tectonics. Space-missions found no hot-spot volcanos, like the Hawaiian islands on Earth, which are the result of crustal dynamics. Mars' large shield volcanos like Mons Olympus are consistent with a one-plate planet (Solomon, 1978). The geological evidence for stable liquid water and the atmospheric models developed to explain this stability, suggest that the conditions on Earth and Mars may have been similar during the first hundred million years and perhaps for as long as one billion years (McKay et *al.,* 1989).

Subsequent planetary evolution led to very different histories for the two planets. Current understanding of planetary evolution would suggest that the main cause of the unfavorable conditions for higher developed Martian lifeforms was the incorporation of CO, into carbonate sediments. The accumulation of carbonates was a direct and inevitable result of Mars' small size and hence its inability to support and retain sufficient heat flow to power plate tectonic activity and thereby recycle the atmospheric constituents in a long-term geochemical cycle. Life appears to have been widespread on Earth and existed in ecological communities 3.5 billion years ago (Schopf and Packer, 1987). The time interval for the origin of life on Earth is between 4 and 3.5 billion years ago (Schopf, 1983). If liquid water was indeed on the Martian surface at the termination of the late accretition phase, some 3.8 billion years ago, there must have been a warm atmosphere of approximately 1 bar CO_2. During and after this time, there was extensive crustal and volcanic activity. However, habitats suitable for the origin and survival of life may have existed for hundreds of millions of years up to one billion years. The period of most interest is between 4.5 and 3.5 billion years ago. During this time, life arose on Earth and reached a degree of biological sophistication. Since Mars is not covered with an active biota today, it seems probable that if there was life during an earlier period it is now extinct (McKay and Stoker, 1989).

Murray et ***al.*** (1973) discovered that the eccentricity of the Martian orbit varied with two superimposed periods of about 95,000 and 2 million years. The resulting periodic insolation variations on Mars could perhaps be a trigger of catastrophic floods (Baker and Milton, 1974) and meteorological variations, but not a source for the formation of a Martian biosphere. The timescales for these variations are also too short for the evolution of higher developed lifeforms. If somehow life has survived to present times, then it has not fully adapted to current conditions on Mars and exists only in restricted habitats. However, these results have "bad consequences" for the Cydonian Hypothesis.

Discussion

The time-range for an Earth-like biosphere on Mars was too short for the evolution of intelligent humanoid life forms. The accumulation of CO, in surface material and the very strong atmospheric escape are direct and inevitable results of Mars' small size and hence its inability to support and retain sufficient heat flow to power plate tectonic activity and thereby recycle the atmospheric constituents in a long-term geochemical cycle. Therefore, future Mars missions will probably find archeobacteriological fossils, but no skeletal remains of a Martian lifeform. The results and conclusions above clearly eliminate the evolution of more highly developed Martian lifeforms and thus the Cydonia Hypothesis of Brandenburg *et al.* (1989, 1991). Therefore, such statements as *apparently some* 150 *million years ago the Martians were living comfortably on Mars* (Stark, 1993) are not supportable by the evidence, since our analysis indicates that Mars must have been the same dead planet 150 million years ago as today. Claims that the Phobos 2 spacecraft filmed a shadow on the Martian surface of a cylindrical UFO are also impossible (Sitchin, 1991). The long, elongated "UFO" was nothing more than a shadow cast by the Martian moon Phobos under special circumstances (Murray *et al.*, 1991; Birdsall, 1993). Horizontal white lines on some pictures before or near the moon Phobos are also not UFO-light-tracks. They represent locations of the KRFM ground tracks from the TV-imaging experiment VSK-Fregat on the Phobos 2 spacecraft (Avanesov *et al.*, 1991) or picture failures.

We must consider alternate hypotheses for the origin of these unusual surface features. Brandenburg *et al.* (1989, 1991) proposed two other alternatives for their origin. One such alternative is the Null Hypothesis, which represents the consensus of the scientific community. If this hypothesis is true, then the objects discussed are the result of random geological and erosional forces.

However, three-dimensional analysis of the Face revealed that the facial features remain present when the object is viewed from radically different perspectives (Carlotto, 1988, 1991). Such is not the case for familiar terrestrial analogs. Carlotto (1991) used fractal analysis to support the hypothesis that the face in the Cydonia region is artificial. Fractal Analysis is based on the finding that natural terrain tends to follow the rules of fractal mathematical, while the Martian surface features do not follow these rules. These facts and the close proximity of other unusual objects give "small likelihoods" for a second and a third alternative hypothesis. The so called Prior Colonization Hypothesis suggests that these Objects owe their appearance to a culture that was not indigenous to Mars. This hypothesis requires no long-lived Earth-like biosphere nor its subsequent death. Such a civilization would possess capabilities for interstellar/interdimensional travel and the colonization of other planets. An earthly hypothesis is the Previous Technical Civilization Hypothesis, which suggests that in the prehistory of our race, a previous technical civilization had developed, gone to Mars and left the surface features as a message to the future (Hoagland, 1992).

It is the author's belief that the Viking data are not of sufficient resolution to permit the identification of possible mechanisms of the origin for these objects, although some results to date suggest that they may not be natural. Clearly these mysterious objects deserve further scrutiny by the forthcoming Mars missions. If one of these mission finds that the face on Mars, the pyramids and the other strange structures are indeed artificial, then the "unlikely" Prior Colonization or Previous Technical Civilization hypotheses would provide a possible answer.

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