Early Mars: A warm wet niche for Life. Everett K. Gibson[1], David S. McKay[1], Kathie L. Thomas-Keprta[2], and Simon J. Clemett[2]. [1]KR Astromaterials Research Office, NASA Johnson Space Center, Houston, TX 77058 and [2]ESCG, NASA Johnson Space Center, Houston, TX 77058. (everett.k.gibson@nasa.gov)

Exploration of Mars has begun to unveil the history of the planet. Combinations of remote sensing, *in situ* compositional measurements and photographic observations have shown Mars had a dynamic and active geologic evolution. Mars' geologic evolution had conditions that were suitable for supporting life. A habitable planet must have water, carbon and energy sources along with a dynamic geologic past. Mars meets all of these requirements.

The first 600 Ma of Martian history were ripe for life to develop because of the abundance of: (i) Water-as shown by carved canyons and oceans or lakes with the early presence of near surface water shown by precipitated carbonates in ALH84001, well-dated at ~3.9 Ga, (ii) Energy from the original accretional processes, a molten core which generated a strong magnetic field leaving a permanent record in the early crust, active volcanism continuing throughout Martian history, and continuing impact processes, (iii) Carbon, water and a likely thicker atmosphere from extensive volcanic outgassing (i.e. H_20, CO_2, CH_4, CO, O_2, N_2, H_2S, SO_2, etc.) and (iv) crustal tectonics as revealed by faulting and possible plate movement reflected by the magnetic patterns in the crust [1]. The question arises: "Why would life not develop from these favorable conditions on Mars in its first 600 Ma?" During this period, environmental near-surface conditions on Mars were more favorable to life than at any later time. Standing bodies of water, precipitation and flowing surface water, and possibly abundant hydrothermal energy would favor the formation of early life. (Even if life developed elsewhere on Earth, Venus, or on other bodies-it was transported to Mars where surface conditions were suitable for life to evolve).

The commonly stated requirement that life would need hundreds of millions of year to get started is only an assumption; we know of no evidence that requires such a long interval for the development of life, if the proper habitable conditions are meet. Perhaps it could start in a very short interval during the first tens of millions of years after crustal formation. Even with impact-driven extinction events, such a short start-up time would allow life to restart multiple times until it persevered. If panspermia is considered, life could be introduced as soon as liquid surface water was present and could instantly thrive and spread.

Magnetic fields were present on early Mars and began to dissipate after ~500 to 600 Ma [1]. Magnetic fields protected Mars' surface from UV irradiation and allowed organic components to survive. An early primordial soup existing on Earth, Mars may have fostered and produced the required ingredients for the development of life. Synthesis of organic compounds by hydrothermal Fischer-Tropsch reactions may have been typical in the volcanically active upper crust. Random cometary impacts on the surface would have enhanced these ingredients. Extensive bombardment of the inner solar system and the Martian crust around 3.9 Ga supplied additional volatiles and energy for chemical evolution to proceed. Impacts put extreme stress on any living system present and only the most adaptable survived. While stressful, early bombardment on Mars may have been less destructive to life compared to on Earth because of the lower gravitational attraction of Mars. A very early start would allow time for organisms to evolve and occupy subsurface habitable niches where they might be protected from even a major 3.9 Ga bombardment event. Because of the likely warmth and abundance of water on Mars (Noachian period), it is likely that evolutionary development could have occurred rapidly. With thinning of the atmosphere and changes in temperature, decline of the magnetic field, and increasing intensity of cosmic rays and UV irradiation getting to the surface, causing mutations in organisms near the surface after 3.9 Ga and during the Hesperian period in Mars history, perhaps only the hardy subsurface organisms survived. As the surface conditions became more harsh, organisms would have to adapt to the subsurface water and carbon reservoirs and would likely have become chemically dependent for their energy; electron donor and acceptor systems (i.e. Fe-rich minerals etc. driven by chemical disequilibria associated with the geologic processes).

During the post 3 Ga period of the Amazonian period, Mars underwent fewer impacts, the UV irradiation on the surface was sufficient to destroy organic molecules and organisms. The "Cold and Dry" Late Mars period extended back at least 3 Ga from the present. Energies required for organisms to survive and for Mars to be habitable were from geologic processes associated with subsurface aquifers and thermal energies associated with volcanism. Energies associated with late-stage polar caps, volcanism, and abundance of carbon species such as the frozen CO_2 polar cap would offer opportunities for organisms to find niches for habitats to survive to the present-provided they escaped radiation by staying beneath the surface or developing a natural sunscreen production mechanism. Periodic episodes of wetter, warmer climate caused by obliquity changes may have enabled organisms to emerge into surface water and soils, only to retreat or hibernate when the dry, cold conditions returned.

All samples available from Mars for study are subsurface samples. SNC meteorites come from 0.05 to 0.5 km beneath the Martian surface. From the 53+ Martian meteorites available, there are no sedimentary rocks. The presence of abundant surface sedimentary rock formations is inferred from various remote data. Evidence of pre-terrestrial aqueous alteration products and indigenous reduced carbon species have been identified within the least terrestrially altered Martian meteorites. The oldest Martian sample of the early crust is ALH84001 (crystallization age of 4.5 Ga) and contains 3.9 Ga. carbonates as well as reduced carbon phases [2]. Carbonates have now been identified by remote sensing (CRISM) in Nili Fossae region [3]. Identification of carbonate-bedding and clays suggests the presence of hydrothermal fluids and near-surface water [3]. McKay et al.,[4] and Gibson et al.[5] have suggested that the morphological features, along with reduced carbon components are remnants of earlier biogenic processes. Thomas-Keprta et al. [6, 7] have strengthened the arguments about biogenic processes occurring by their detailed studies of magnetites within ALH84001 carbonates. Oxygen isotopic compositions for ALH84001 carbonates suggest fluids temperatures in the 80^{o}C range [8]. These temperatures were suitable to support a host of organisms. The work of [6,7] clearly shows a population of magnetites within the carbonates define a robust biosignature and cannot simply be end-products of thermal decomposition of iron-bearing carbonates. This latter hypothesis, cited for years to argue against the ALH84001 evidence for early life, is simply no longer credible as a source for much of the magnetite within ALH84001 carbonates. With this being the case, it strongly supports the idea that microorganisms similar to magnetotactic bacteria were present on Mars at 3.9 Ga because their magnetite by-products are found in 3.9 Ga carbonates. The presence of bacteria on Mars at 3.9 Ga implies that life had already been around for a while, possibly several hundred million years. With formation of the magnetites at the period of time when the planet was undergoing heavy impact bombardment, and changing from a "Warm and Wet Early Mars" to the transitional Hesperian period between 3.8 Ga to 3 Ga, organisms were stressed and trying to survive. Removal of the protective early magnetic field after 3.9 Ga, added to the stress of the organisms near the surface because of the destructive power of the solar flare events, cosmic rays, and increased UV resulting from a thinning atmosphere. Habitats beneath the Martian surface within the aquifers offered the required niches to survive. Terrestrial organisms do everything they can to survive. Slowing down their metabolic processes and going dormant are clearly a survival mode option.

The subsurface of Mars could be a site where microbial activity would have found a hospitable niche. Identification of carbonate-bedding and clays suggests the presence of fluids or near-surface waters in the Nili Fossae region [3]. Groundwaters have been seen to be active with fluid releases observed on crater and canyon walls [9] and observations from the MARSIS onboard Mars Express and MRO observations. Despite the surface of Mars being "cold and dry", abundant subsurface water is present. This water increases habitat survivability on Mars. Interpretations that there may be biosignatures of Martian microbial life [3,4,6,7] would be consistent with the concept that such life evolved early on Mars and then found amenable ecological niches below the surface.

During the first 600 Ma, Mars could have had conditions favorable for rapid evolutionary and development of life, and this life escaped extinction during the heavy bombardment. In this case, Mars had a good 600 Ma start on the Earth and may have developed relatively complex organisms much earlier. Development and evolution of life on Mars may have slowed after 3.9 Ga because of the reduction of magnetic field protection, thinning atmosphere, and harsher surface conditions. With the ability of impacts to remove samples from planetary surfaces, perhaps some of this early-developed Martian biota were removed and traveled to Earth. The arrival of these organisms would have jumped-started life on Earth anytime after 3.9 Ga by seeding the Earth with microbes which were developed during the first 600 Ma of Martian history, a time period when life on Earth was simply not possible. Earth then became a much more hospitable place for life to develop and flourish, and pulled way ahead of Mars. On Mars, even with the early start, the harsh conditions kept life from evolving beyond a relatively simple stage, although it has certainly had enough time for complex development, and Martian life may be more complex than is commonly assumed.

In our view, life is probably present beneath the surface on Mars today, possibly associated with aqueous water reservoirs, ice-rich areas near the poles, and equatorial frozen lakes and outwash features. Suitable sites are present on Mars and we must use the right tools to positively identify the signatures of life. Until the proper suite of analytical instruments are on the Martian surface, the Martian meteorites are our only hope for unraveling the signatures of life on Mars.

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