A MODEL FOR CHEMICAL EVOLUTION OF LIFE ON MARS, V. R. Oberbeck, NASA Ames Research Center, Moffett Field CA 94035, J. R. Marshall, Arizona State University, Tempe AZ 85287, D. E. Schwartz, SETI Institute, Mountain View, CA 94043

Geological and atmospheric models of Mars strongly suggest the presence of liquid water and a significant atmosphere prior to 3.8 Gyr. Early conditions favorable for life on Mars may have been similar to those on Earth at the time when life began on this planet. It has recently been recognized that the path of prebiotic chemistry (and of life itself) on the early Earth was probably interrupted, or at best retarded, by giant impacts[1]. The time between such impacts (just before the oldest evidence of life on Earth, 3.8 Gyr ago) has been used to estimate the maximum time required to originate life[2,3]. When the same calculations are applied to Mars, it appears that the time windows available for the development of life are longer than those for Earth[3]. Consequently, conditions on Mars conceivably could have been more favorable to life than were those on early Earth. Thus, Mars remains the most likely extraterrestrial setting for the origin of life. However, no specific model for *prebiotic* chemical evolution has yet been developed for Mars.

We now consider the geologic environment during Noachian time in order to develop a realistic model for the planetary processes that could have been involved in the chemical evolution of life on Mars. During the first 800 My of the Solar System, the terrestrial planets accreted planetesimals and experienced an exponential decay of impacting objects. Based on knowledge of the lunar uplands[4], impacting objects produced a thick megaregolith of crushed silicate minerals. Volatiles from comets were also delivered in sufficient quantities to produce terrestrial oceans similar in size to those present today and water, of exogenous origin, 10 m to 100 m in depth may have been retained on Mars[5] very early in its history. Because certain classes of meteorites contain clay minerals believed to have been formed in hydrated regoliths on planetary surfaces[6], we believe that it is likely that clay minerals existed in the ancient megaregoliths of both Mars and Earth. The existence of valley networks formed by sapping in the ancient cratered terrain suggests that surface water had a very limited distribution during the Noachian period. Intermittent precipitation fed subsurface aquifers which in turn fed springs at the heads of sapping channels formed by intermittent flowing water[7]. We believe that the geologic and meteorologic conditions during this period on Mars were at least as favorable (and perhaps more so) for the origination of life as they were on Earth.

We propose the following model for chemical evolution of life on Mars. Important prebiotic organic reactants were supplied by comets, IDPs, carbonaceous chondrites, and photochemical reactions.These compounds would have included amino acids, such as those recently discovered in clays at the KT boundary[8]. Monomers in the atmosphere were scavenged by precipitation or brought to the surface by sedimentation. During the time when reactants where incorporated in rain drops, some were polymerized to produce more complex prebiotic materials.

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Seepage of these materials into the megaregolith then provided an ideal environment for the attachment of such monomers and polymers to clay particles. Percolation/filtration processes and fluctuating groundwater levels permitted dehydration of monomers and redistribution of reaction-product polymers. Fluctuations in water content are known to promote the formation of macromolecules[9]. Over a long period of time, the megaregolith acted as a large chemical processing column to form organic polymers of increasing complexity.

The next stage of biochemical organization, the formation of cell-like structures, occurred in the bottoms of sapping channels and lakes fed by sapping channels. Groundwater percolating through the megaregolith emerged as springs at the amphitheater heads of the channels. These were abundant on the surface of the ancient cratered terrain. Complex polymers emerging with the groundwater developed cellular organization on the level of coacervate droplets in this environment, and this permitted some interchange of biochemical compounds with the environment. Solar energy was available as an energy source to drive further chemical organization. Eventually, life may have originated in concentrated aqueous solutions at the bottoms of sapping channels and lakes in a way similar to that proposed for the terrestrial oceans.

Such a model for the chemical evolution of life on Mars compares favorably with the existing model for the origin of life on Earth. For this planet, life is believed to have originated in the primordial soup of organic compounds in the ocean. Monomers were produced in, or supplied to, the atmosphere in the manner referred to above and ultimately settled into the ocean. On Earth, the concentration of monomers in the oceanic "soup" would have taken longer than the time required to concentrate monomers in the megaregolith of Mars. In addition, movement of groundwater through the megaregolith would have provided more efficient absorption of monomers on clay particles. Thus, chemical evolution of life may have proceeded more rapidly on Mars.

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