THE NITROGEN CYCLE ON MARS

Rocco L. Mancinelli
Mail Stop 239-12
Solar System Exploration Branch
NASA Ames Research Center
Moffett Field, CA 94035

Abstract:

Nitrogen is an essential element for the evolution of life as we know it, because it is found in a variety of biologically important molecules. Therefore, N is an important element to study from an exobiological perspective. In particular, "fixed nitrogen" is the biologically useful form of nitrogen. Fixed nitrogen is generally defined as NH_3, NH_4^+, NO_x, or N that is chemically bound to either inorganic or organic molecules, and releasable by hydrolysis to NH_3 or NH_4^+. On Earth, the vast majority of nitrogen exists as N_2 in the atmosphere, and not in the fixed form. On early Mars the same situation probably existed. The partial pressure of N_2 on early Mars is thought to have been 18 mb, significantly less than that of early Earth. Dinitrogen can be fixed abiotically by several mechanisms. These mechanisms include thermal shock from meteoritic infall and lightning, which could produce NO at a rate of $\sim 10^{15}$ molecules J^{-1} in a primitive Martian atmosphere (1 bar total pressure; CO_2:N_2=33), as well as the interaction of light and sand containing TiO_2 which produces NH_3 that would be rapidly destroyed by photolysis and reaction with OH radicals. These mechanisms could have been operative on primitive Mars. Any NO produced under these conditions reacts with H forming HNO. In the Martian ocean HNO would react to form $N_2O_2^-$, $N_3O_3^-$, and their conjugate acids. These species would decay leaving a nitrogen pool in the oceans of NO_2^- and NO_3^-. In addition, there may have been organic nitrogen compounds available in the environment. These compounds then would have formed sediment, which may have been buried by volcanic lava to a depth at which gaseous products would be produced and released to the atmosphere. If this burial process did not occur, or was insufficient to produce enough heat and pressure, then any nitrogen that was fixed would remain buried on Mars, and not recycled. Would the relatively low abundance of nitrogen, compared to primitive Earth, have an impact on the origin and early evolution of a living system on Mars? Data gathered in our laboratory suggest that the low abundance of nitrogen alone may not significantly deter the origin and early evolution of a nitrogen utilizing organism. However, the conditions on current Mars with respect to nitrogen are quite different, and organisms may not be able to utilize all of the available nitrogen.