

COULD MARTIAN STRAWBERRIES BE? — PREBIOTIC CHEMICAL EVOLUTION ON AN EARLY WET MARS

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Introduction: Pre-biotic chemical evolution presupposes successive generations of increasingly complex organic molecules combinatorially synthesized from previous generations. Not so obvious is how this combinatorial chemistry occurred; or how the overall process of chemical self-organization was functionally supported at each stage of its occurrence on an earlier, much wetter Mars. Yet just as the biochemistry of contemporary organisms can be viewed as a ‘fossil’ record of biogenesis, so the geochemical physics of the contemporary Earth and Mars is an indicator of the self-organizing dynamic processes underlying prebiotic chemistry. Independent of chemical details, the universalities of chemical physics strongly suggest that past Martian weather cycles offered functional support for organic chemical self-organization, the assumed predecessor to an independent “origin” of life. The key element is the existence of an air-water interface at a variety of physical scales and whose global issues with respect to an early Mars are discussed in the author’s accompanying paper: (*Do Martian Blueberries have Pits? — Artifacts of An Early Wet Mars*).

Artifacts of past Martian water cycles fall into two basic categories: inorganic and organic. Inorganic signals of Martian water tables of the past include terrain morphologies such as cross-bedding and the chemical indicators of hydrated minerals such as serpentine and hematite. Found by the twin rovers, Spirit and Opportunity, on the current Mars these are the geological equivalents of a smoking gun. Coupled to the gamma-spectroscopy measurements of Odyssey these inorganic findings tantalize our imaginations with thoughts of complex hydrological cycles on a Mars past that could run the gamut from intermittent high-velocity water flows to free-standing seas.

Lacking the sophisticated infrared spectroscopy needed for more subtle organic analysis, organic (abiotic) artifacts are in shorter supply. Yet the universalities of chemical physics (i.e. the Rayleigh-Taylor instability metastabilized by polar organics) offer considerable insights into the intimate details of possible Martian hydrology cycles in its past.

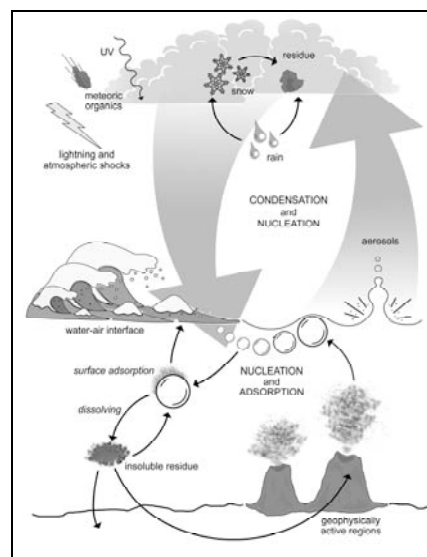


Figure 1: Early Martian Hydrology Cycle?

A Planetary-Scale Chemical Engineering System: Even short time-scale surface water (lakes, seas, or intermittent turbulent flows) can initiate the cycle outlined in Figure 1. The capstone element is the air-water interface. One can, in the abstract, usefully look at bubbles and aerosols as complements: one is a meta-stabilized fluctuation of air in water, the other of water in air. Whether floating under water, bobbing on the sea, or drifting in the atmosphere of today’s earth or early Mars it is the adsorption of amphiphiles that drives these phenomena by decreasing the local surface energy and hence metastabilizing the micro-environment and its structure.

In analogy to the terrestrial, a single stage of this cycle can include bubble formation, the consequent adsorption of surface active materials, bubble dissolution, and the non-equilibrium energetics of bubble bursting. Organic materials and selected metals, as well as clay particles are preferentially adsorbed onto the surface of the bubble. This stabilizes the bubble leading to a highly concentrated resultant particulate, as the now organically ‘dirty’ bubble dissolves or bursts. A dissolving bubble yields an *organic rich residue* which can then nucleate other bubble formation, or be adsorbed in turn by other bubbles. The bursting of bubbles injects into the atmosphere particulate matter also rich in organics and

minerals. Besides organic molecules, which can be concentrated a million-fold, these processes can yield 10,000-fold enhancements in many essential inorganics such as phosphates. These injected materials are then coupled to aerosol formation and the subsequent nucleation of atmospheric condensation; leading to the further heterogeneous chemistry and non-equilibrium physics associated with rain and snow.

System Level Drivers of Chemical Evolution: The Bubble-Aerosol-Droplet cycle's amplifying characteristics includes the fact that these processes are:

- *First-order ('had-to-have-been' physico-chemical phenomena)*
- *Robust (highly efficient & rapid processes)*
- *Diverse (parallel exploration of many different chemical routes and mechanisms)*
- *Selective (for the good stuff!)*
- *Semi-closed (able to retain useful materials in the total system)*

The semi-closed nature of the cycle results in a global chemical engineering system functionally capable of supporting chemical evolution. Most importantly, at the System Level it seems capable of amplifying the probabilities of stochastic self-organization of the Molecular Level.

Molecular Level Drivers of Chemical Evolution: At the molecular level the race between the self-organization of increasingly complex organic structure and its dissipation due to entropy is helped by the following functional operations:

- *Selective Concentration of the desired organics and metal ions needed as reactants*
- *Stabilization and Coordination of these reactants*
- *Controlled Energy and 'Directed' Synthesis*
- *Cycle Continuity (where the products become in turn the reactants for the next stage of the cycle)*
- *All must occur in Plausible and Likely Geophysical/chemical Environments.*

Throughout this supercycle coupled hydration-dehydration cycles are much in abundance.

This is of potentially unique importance to self-organizing polymerization reactions, for essentially all biopolymers are formed through linkages derived from a dehydration reaction. Additionally, these conditions promote the existence of temporary 'membrane-like phase boundaries, which may well have played an essential role in the transition from organic chemistry to biochemistry.

Universality: Remarkably, this complex supercycle is a process that requires *only* the disturbance of a water-air interface metastabilized by simple amphiphilic compounds (from carbonaceous chondrites, for example, or comets). The rest follows from the fundamentals of chemical physics, being relatively independent of specific chemistry.

In proposing the functional cycle presented above we necessarily play the game of minimalist prebiotics, making the simplest strong-principle-based assumptions on the early planets. As an example, one can with even greater confidence assume the existence of bubbles on the early earth and Mars, than say the widespread availability of a particular montmorillonite clay. Because the existence of these bubbles, cavities, and droplets are such common phenomena in nature, their relevance to chemical evolution is likely critical: whether on the early earth and Mars or elsewhere in the outer solar system (Titan and Europa).

More exhaustive treatments of the self-organizing processes are found in the references; especially [1], [5], and [6]. Further discussion of the bubble-aerosol-droplet cycle in the more global context of an early Mars will be found in the author's accompanying paper at this conference, "*Do Martian Blueberries Have Pits? — Artifacts of An Early Wet Mars.*"

References: [1] Lerman, L. and Teng, J. (2004) *Origins: Genesis, Evolution, and Biodiversity of Life* (ed. J. Seckbach) [2] Lerman, L. (2002a,b) *Origins of Life* 32, p. 419, 538 [3] Lerman, L. (1996) *Origins of Life* 26, p. 369 [4] Lerman, L. (1994) *Origins of Life* 24, p. 111, 138 [5] Chang, S. (1993) *The Chemistry of Life's Origins* (ed. J.M. Greenberg) [6] Lerman, L. (1992) *The Role of the Air-Water Interface in Prebiotic Chemistry* Thesis, Stanford University

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