Life on the Inside

EVERETT L. SHOCK

School of Earth & Space Exploration and Department of Chemistry & Biochemistry, Arizona State University, Tempe, AZ 85287, USA; eshock@asu.edu

Using our example of Earth life as a guide, can we constrain Mars life? Life on Earth has chemotrophic origins, and phototrophy developed on a chemotrophic template. Subsurface ecosystems thrive without photosynthetic input. Plausibly, life emerges within the geochemistry of planetary interiors. Water, heat, chemical disequilibria, energy supplies, and nutrient fluxes are all present below planetary surfaces, and may still be present on Mars. Igneous processes release volatiles as melts drive volcanism. Quenching of volcanic gases establishes disequilibria during cooling. Hydrothermal circulation is stoked from below by volcanic input and from above by atmospheric exchange. Volcanically-derived energy sources permit reductive metabolisms: methanogenesis from CO_2 or CO, NH_3 from N_2, H_2S from SO_2, and O_2 reduction to H_2O. Hydrothermal extensions allow the addition of ferric iron reduction, sulfide oxidation, ferrous iron oxidation, methane oxidation, and sulfate reduction depending on temperature changes and mixing dynamics. Meanwhile, thermodynamic drives favor simultaneous organic synthesis from carbon oxides and H_2. Ranking potential energy supplies for autotrophy or heterotrophy is accomplished through theoretical models using petrologic constraints on volcanic gases, martian meteorite compositions, extents of hydrothermal reaction progress, and efficiency of atmospheric entrainment into groundwater. Results for subsurface habitats are recognizably Earth-like, with subtleties unique to the atmosphere and mantle of Mars. This framework needs tuning and tightening against firmer constraints, together with tests of emergent hypotheses. Ultimately, as the present is the key to the past, unlocking the possible biogeochemistries of Mars demands exploring the subsurface biosphere on Earth.