HABITABILITY OF TRANGRESSING MARS DUNES.

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Introduction: Static geological environments that do not replenish the building materials and energy needed by life can only support life as long as the original supply of resources has not been exhausted. Currently, most of the Martian surface is considered static, however, the drifting sands of Martian dunes are one environment where raw materials, such as water, nutrients, and possibly carbon are replenished and the chemical disequilibrium of oxidants and reductants can be maintained, creating a potentially habitable environment.

Sources of Carbon in Dunes: Organic matter is steadily supplied from space at a rate of about 5 nanograms of carbon per square meter per sol [1]. At the equator, the organic matter has a mean lifetime of about 300 years unless it is buried [2]. In areas where dust and sand bury organic matter, such as on the leeward side of transgressing dunes, the burial rate can be centimeters per year [3]. UV penetration and destruction of organic matter occurs only in the upper centimeter of the soil [4], so buried interplanetary carbon should be preserved in leeward sides of dunes. Carbon would also be supplied to the subsurface by fixation of CO_2 from the atmosphere if autotrophic metabolism existed in the dune. (There is no evidence that this is occurring on Mars.)

Source of Moisture in Dunes: The radiative cooling of the ground can cause the formation of frost early in the morning and the frost water also occurs below the surface of dunes. In the presence of salts, diurnal temperature cycles can force this water to migrate downward and form potentially habitable brine layers a few centimeters below the surface [5]. Both the mass spectrometer (SAM) [6] and the laser induced breakdown spectroscopy (LIBS) analyses [7] indicate that water substance is present in the upper few centimeters of Mars soil. Since the daytime soil temperatures exceed the melting point of frozen brines likely to be found on Mars, liquid water could be present at least briefly [5]. Salt candidates with eutectic temperatures below daytime ground temperatures at a depth of a few centimeters in a Gale Crater dune are calcium perchlorate and magnesium perchlorate. Magnesium, and calcium have been identified in the Rocknest dune by Mars Science Laboratory instruments and perchlorate may be present. $Mg(ClO_4)_2$ and $Ca(ClO_4)_2$ brines have eutectics of -71 to -77°C, respectively. This is lower than the lowest known temperatures of growth for terrestrial microorganisms of about -20°C, however, growth at lower temperatures may be possible as long as liquids are present.

Source of Reductants in Dunes: X-ray diffraction of sand indicates that the Rocknest dune in Gale Crater is composed primarily of igneous minerals (feldspar and the ferrous iron-bearing silicates, pyroxene, and olivine, [8]). Ferrous iron, in the presence of water, can be used as a reductant (electron donor) in microbial metabolism. Igneous minerals are the major source of iron in the terrestrial ocean crust and the energy from oxidation of this iron can support a significant part of the subseafloor biomass [9]. The presence of pyroxene and olivine indicates that the Gale Crater dunes can be a source of Fe^{2+}. In addition, as already mentioned, interplanetary dust can contribute organic carbon, another reductant, to the surface of the dune.

Source of Oxidants in Dunes: In addition to traces of oxygen, two oxidants have been potentially identified in Rocknest dune - ferric iron in hematite and perchlorate [6,8]. If these oxidants result from exposure of Fe^{2+} and Cl to atmospheric oxygen and ultraviolet radiation, then in a static dune an oxidized surface layer would be created and oxidants would be less abundant at depth. In a transgressing dune these oxidants, will be buried and when in contact with reduced chemicals in the presence of water could be used by microorganisms as a source of free energy. This renewable free energy can drive primary production of organic matter with carbon dioxide as the carbon source.

Source of Nutrients in Dunes: Additional major nutrients (N, P, S) and trace nutrients (Mg, Ca, K, Fe, etc.) required by microorganisms are, with the exception of N, readily available from the martian rocks and soils as determined by the alpha particle X-ray spectrometer (APXS) and LIBS. Reduced nitrogen production from N_2 can be catalyzed by iron oxides in the presence of UV radiation [10], and SAM measurements of high temperature evolved gases from the Rocknest soil suggest that a reduced nitrogen compound could be present in the soil. Although the presence of reduced nitrogen compounds in the Rocknest dune needs to be investigated further, there is experimental evidence that they can be produced abiotically [10].

Conclusions: Advancing martian dunes mix oxidants, reductants, water, nutrients, and possibly organic carbon in what could be considered bioreactors. Thus, martian dunes function as small scale analogues of the global geological cycles that are important in maintaining Earth's habitabiliy. On Mars, carbon can be cycled from the surface of the dune to its subsurface where it may come in contact with moisture and oxidants. Compounds oxidized at the surface of dunes by UV radiation and oxygen are buried on the lee side of dunes and mixed with reductants, carbon, and ephemeral brines. In addition, reduced compounds will be exposed at the surface on the windward side of dunes where they can be oxidized and complete the cycle. Other global cycles on Mars are likely to be driven by rising and sinking fluids in the subsurface [11]; however, transgressing dunes are a recyclable potential habitat readily accessible by the Mars Science Laboratory. Additional measurements by MSL such as detecting organic carbon and reduced nitrogen compounds would support the hypothesis that moving dunes are potential microbial habitats. The absence of these compounds would indicate that the today's dunes are unlikely to be habitable.

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