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MINERALOGICAL SINKS FOR BIOGENIC ELEMENTS ON MARS

J. L. Gooding
Planetary Science Branch
NASA Johnson Space Center
Houston, TX 77058

ND185000

INTRODUCTION. The efficacy of biochemical reactions on Mars should depend not only on concentrations of the biogenic elements[1] H, C, N, O, and S but also on the forms (compounds and water-soluble ions) that are available to those elements. It is possible that mineralogical reactions could act to lock biogenic elements into relatively inaccessible inorganic forms or, alternatively, to shelter sensitive organic compounds from chemically hostile environments. Recognition of these competing pathways is essential in planning sampling missions and *in situ* experiments directed toward assessing the biological potential of Mars.

SINKS THROUGH CHEMICAL WEATHERING. The four principal types of chemical weathering expected for Mars are oxidation, hydration, carbonation, and solution.[2] *Oxidation* irreversibly (with respect to reverse reactions under most natural conditions) locks oxygen into oxides and silicates. In general, the oxidant can be molecular oxygen, water, or carbon dioxide. *Hydration* refers strictly to reaction of molecular water to form hydrated oxides, silicates or salts whereas *carbonation* consists of reactions involving carbon dioxide to form carbonate minerals. Given suitable volumes of liquid water, *solution* proceeds by either congruently or incongruently dissolving pre-existing minerals to form various simple or complex ions, ultimately with precipitation of new phases.

SINKS THROUGH SORPTION AND ION EXCHANGE. In contrast with chemical weathering reactions, sorption and ion-exchange reactions can sequester biogenic chemical species (and their antagonists) through contact with independently formed mineral substrates. The major available sorbents are Fe-, Mn-, or Al-oxyhydroxide minerals (and their gel equivalents), layer-structured silicates ("clay" minerals), and zeolites. Ferric oxyhydroxides sorb Mn and foster disproportionation reactions among Mn-oxides, producing strongly oxidizing surface layers[3] that might be destructive to organic compounds. Phyllosilicates and zeolites exhibit preferential sorption of organic compounds that can include either preservation or catalyzed decomposition of those compounds.[4] Sorbed species can be released by later exchange reactions.

EXAMPLES OF MECHANISMS AND RATES: ANTARCTIC METEORITE WEATHERING. Many of the sinks that are likely to be available on Mars currently operate in analogous fashion in the glacial and periglacial weathering environments that affect meteorites found in Antarctica. Under mostly sub-freezing conditions and in the presence of only limited quantities of liquid water, mafic-igneous meteorites have experienced incipient clay-mineral formation in less than 1 million years.[5] Both the clay mineraloids and associated ferric rust have sorbed large concentrations of carbon, sulfur, potassium, boron, and water through essentially nonbiological processes. Weathered basaltic achondrites, in particular, might be useful test cases for assessing the behavior of biogenic elements under ostensibly abiotic, Mars-analogous conditions.

SEARCH STRATEGY FOR MARS. Sampling and analysis of Martian materials for exobiology should not be restricted to carbonate-bearing units but should extend to units that contain clay mineral(oid)s and zeolites—if such materials exist on Mars. Aluminosilicate sorbents are the most likely phases to have trapped and preserved organic compounds. If ferric-oxide-related oxidants are important on Mars, then units containing the least rust might be relatively more hospitable to organic compounds than would common, rusty surface fines.

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