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Extreme halophiles and carbon monoxide: looking through a window at Earth's past and towards a future on Mars

King, Gary M.
Department of Biological Sciences, Louisiana State University, Baton Rouge, LA 70803

Carbon monoxide occurs throughout the cosmos, and is ubiquitous on Earth, where various terrestrial Bacteria have long been known to use it as a carbon and energy source. CO-oxidizing bacteria are particularly active in soils, and play an important role in tropospheric CO regulation, which in turn plays a major role in the regulation of the tropospheric oxidative state. However, in spite of their importance, much about the evolutionary history and diversity of CO oxidizers remains unknown. The recent discovery of CO-oxidizing extremely halophilic Euryarchaea offers new insights about both. Although molybdenum dependence, a requirement for O_2 and previous phylogenetic inferences have all supported a relatively late evolution for "aerobic" CO oxidation, new analyses based on CO dehydrogenase gene sequences from haloarchaea support an origin prior to the Bacteria-Archaea split, long before the "Great Oxidation Event" (GOE). These observations are consistent with phylogenetic analyses of genes involved in Mo-cofactor synthesis, and findings by others that Mo-nitrogenase was likely active > 3 Gya. Initial cultivation efforts have also revealed CO-oxidizing haloarchaea in five genera and the three major sub-groups of extreme halophiles. These observations suggest that CO oxidizer diversity is likely substantially greater than previously imagined, with a distribution among the Archaea that might parallel that known for Bacteria. Finally, extremely halophilic CO oxidizers provide a new perspective on extraterrestrial life in general and Mars in particular. Models of Mars' early atmosphere indicate that CO could have occurred at very high concentrations; at present concentrations exceed 800 ppm, well above those on Earth, even correcting for pressure differences. At such high concentrations, CO represents one of the most abundant energy sources available for near-surface regolith. Nonetheless, use of CO in regolith would require tolerance of very low water potentials and high salt concentrations. Assays with isolates and a variety of saline brines, sediments and soils show that extreme halophiles use CO in solutions of saturated NaCl (5.4 M) and at water potentials as low as -118 MPa. The latter are consistent with conditions inferred for recurrent slope lineae on Mars.