MIXING AND RE-SOLUTION PROCESSES AFFECTING EVAPORITE MINERAL DISTRIBUTIONS ON EARTH AND MARS. J. K. Crowley[1], J. S. Kargel[2], G. M. Marion[3], S. J. Hook[4], N. T. Bridges[4], A. J. Brown[5] and C. R. de Souza Filho[6]
[1] U. S. Geological Survey, MS 954, Reston, VA 20192, jcrowley@usgs.gov
[2] University of Arizona, Tucson, AZ, jkargel1054@earthlink.net
3 Desert Research Institute, NV, giles.marion@dri.edu
4 Jet Propulsion Laboratory, CA, simon.j.hook@jpl.nasa.gov, nathan.t.bridges@jpl.nasa.gov
5 Ames Research Center, CA, abrown@arc.nasa.gov
6 U. of Campinas, S.P., Brasil, beto@ige.unicamp.br

Introduction: Near-surface groundwaters that freeze or evaporate produce saline mineral assemblages that are generally related to the initial dissolved solute compositions [1]. Such assemblages formed by the fractional crystallization of evaporating brines are composed mainly of phases that represent major chemical divides, and these assemblages can be readily predicted by chemical modeling [2], [3]. Here we highlight several additional processes that can markedly increase evaporite assemblage complexity on Earth and likely also on Mars. Temporal oscillations in these processes can produce evaporite laminations and beds.

Dilute Inflow Additions to Brine: During the course of groundwater evolution certain solutes are typically depleted. A classic terrestrial example is potassium, which is removed from groundwaters by clay mineral adsorption. Even major solutes such as calcium may be depleted via the action of chemical divides. However, playa-margin springs and ephemeral streams provide inflow sources of dilute, unevolved waters that may discharge directly into more concentrated brines. A similar source function may be served on Mars by permafrost melting during warm climatic shifts or by impact heating or hydrothermal activity. These sources "short-circuit" the normal course of brine evolution and produce mineral assemblages containing "unexpected" solute components.

Volcanic Exhalative and Hydrothermal Additions to Brine: In terrestrial playa settings, and hypothetically also on Mars, some springs have water sources and solute compositions that are very different from typical basinal groundwaters. For example, spring waters enriched in borate produce distinctive evaporite mineral assemblages and at the same time signal the existence of deeper circulating, perhaps hydrothermal, water sources.

Zone Refining: Another way that unusual brine compositions are produced is by passage of concentrated brines through thick sequences of evaporitic materials; already saturated major mineral species remain stable, but minor and trace species are progressively leached and fractionated into the brine until they too, saturate. Salts enriched in K, Rb, Sr, Br, I, B, and other elements can be produced this way. On Mars, where rainfall washing and re-solution of precipitated salts has been minimal or absent through much of geologic time, zone refining in subsurface saline groundwater/evaporite systems or in surficial duricrusts may have produced long-lasting deposits of exotic salt compositions.

Re-cycling of Evaporite Crusts: Partial re-solution of evaporite crusts-- a process that includes zone refining but includes other processes, too-- also can lead to increased mineral diversity. For example, Mg is present in many terrestrial salt crusts as highly soluble chloride phases that are easily leached and redistributed. However, in sulfate-rich brines, perhaps akin to those on Mars, Mg is more resistant under some circumstances. On Mars, we expect that incongruent dissolution-- peritectic melting of hydrates with partial dehydration of residual salts-- is apt to be even more important than on Earth, because the higher hydration states are expected to be more common. In fact, crustal re-cycling outcomes are complexly dependent on parent brine compositions.

Redox and pH Cycling: Special types of geochemical divides are represented by the buffering of pH and redox state by major mineral or dissolved species. When acid/base or reductant/oxidant titration occurs, buffers eventually can be overwhelmed and brine equilibria can suddenly shift, additional species can be solubilized or precipitated out of solution, and mineral stability completely altered. This type of behavior can occur in response to oscillations in brine sources and brine mixing, episodes of igneous rock emplacement in the catchment basin, volcanic exhalative activity, erosional exhumation and weathering of different rock types, or shifts in atmospheric composition.

Terrestrial acid evaporite mineral deposits are one of several Mars-analog environments being studied by the authors in the field and through chemical modeling.

References:

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