

GENETIC MODELS OF IRON OXIDE CONCRETIONS ON EARTH AND MARS. Marjorie A. Chan¹, Sally L. Potter¹, Erich U. Petersen¹, and Brenda B. Bowen² ¹University of Utah, Department of Geology and Geophysics, 115 S. 1460 E. Rm. 383 FASB, Salt Lake City, UT 84112-0102, marjorie.chan@utah.edu, ²Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907.

Introduction: Terrestrial studies of iron oxide concretions have been encouraged by the Mars Exploration Rover (MER) Opportunity discovery of similar “blueberries” in the Burns formation [1,2,3]. Although decades ago concretions were viewed simply as geologic “curiosities”, it is now clear that the presence of concretions has important implications for groundwater movement and chemistry, diagenesis, host rock properties, and iron cycling through time.

The exact origin of iron oxide concretions and genetic models of how they form are not simple. There are many factors to consider including the nature of the open (vs. closed) system, supply of reactants, composition of the water(s), temperature, pH, water-rock interactions, diffusive rates, nucleation kinetics, biomediation, and fluctuating water table or reaction fronts. Jurassic Navajo Sandstone examples show a wide range of varieties, shapes and sizes indicating multiple diagenetic precipitation and mobilization events [4]. Cretaceous sandstone examples from the Western Interior associated with coal forming environments show pyrite precursors that typically alter to the iron oxide mineralogies [5]. Modern concretion examples form in extreme acid and saline syndepositional to early diagenetic conditions over short time scales of hundreds of years [6]. Laboratory bench tests cannot replicate the natural diagenetic settings, but they can simulate concretion-like nucleates with strong chemical solutions [7]. Mars is likely unique in its own particular setting of the sulfate and basaltic sandstone and extreme chemical solutions (by Earth standards). Thus, there are multiple genetic models that can arrive at a final end product of iron oxide concretions. These studies collectively can provide a better understanding of the subtleties and details of water-rock interactions on Earth and Mars.

Discussion: The common occurrence of terrestrial concretions in a wide range of mineralogies (carbonates, iron sulfides, and iron oxides) suggest that concretion formation is a common geologic process in near surface, porous sediments and sedimentary rocks, and thus it is not surprising that similar concretions were discovered in sedimentary deposits of Mars. There can be multiple chemical pathways and successive transitions from initial different iron-rich mineralogies, ending at metastable goethite or stable hematite end products.

Iron oxide concretions typically lack a nucleus, yet some cement textures show a component of inward growth (similar to a geode). Nucleation centers that produce smaller spheroids are far more abundant and commonly aggregate and coalesce to make larger forms. Kinetic factors and iron supply in addition to permeability/tortuosity paths likely affects the concretion mineralogy and geometry or spacing. Both terrestrial occurrences and the Mars examples with its extreme chemical settings suggest that concretion formation can span a wide range of temperature (diagenetic to even hydrothermal) and chemical conditions.

Areas for continued concretion research lie in several approaches. Eventually, if appropriate standards can be obtained, it should be possible to analyze iron isotopes *in situ* to look at subtle changes or gradients in cementation. Any modeling of the concretions is difficult because there are so many assumptions. However, sensitivity tests for different parameters in model equations can help show the magnitude of influence of those factors. Ancient concretions typically lack datable material to pinpoint the timing of diagenetic events, and the record that remains may represent a preservational bias. However, more detailed studies of the chemistry and textural and mineral relationships may help elucidate the relative timing and perhaps even the role of biomediation.

Summary: Concretions are significant records of groundwater flow through porous sedimentary deposits. It is likely that the “simple”, solid, spheroidal Mars “blueberries” formed relatively quickly with abundant iron supply by diffusive mass transfer. Terrestrial examples record a longer and more complex diagenesis than Mars, perhaps because Earth has been a water planet for more of its history.

References: [1] Chan, M.A. et al. (2004) *Nature*, 429, 731-734. [2] Chan, M.A. et al. (2005) *GSA Today*, 15, 4-10. [3] Calvin, W. et al. (2008) *JGR* 113, E12. [4] Chan et al. 2000: *AAPG Bull* 84, 1281-1310. [5] Roberts and Chan, 2010 in press, *Utah Geol. Assoc.* [6] Bowen, B. B. et al. (2008) *EPSL*, 268, 52-63. [7] Barge, L. M. et al. (2008), *LPS XXXIX Abstract* # 1414.

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