CHARACTERIZATION OF NAVAJO SANDSTONE CONCRETIONS: MARS COMPARISONS AND CRITERIA FOR DISTINGUISHING DIAGENETIC ORIGINS. Sally L. Potter and Marjorie A. Chan, University of Utah, Department of Geology and Geophysics, 115 S. 1460 E. Rm. 383-Sutton Building, Salt Lake City, UT. 84112-0111, sally.potter@utah.edu.

Introduction: Careful characterization of terrestrial concretions and Mars "blueberries" yields important criteria for distinguishing their diagenetic origin in comparison to other models for small, spherical forms.

The Jurassic Navajo Sandstone in the Grand Staircase Escalante National Monument (GSENM), southern Utah, contains many hydrous ferric oxide mineralization geometries (HFO phases including ferrihydrite, goethite, and hematite). Spheroidal concretions have been suggested as an analog for hematite concretions found at Meridiani Planum in the Burns formation [1, 2].

Calvin et al. [3] characterize Martian "blueberries" and their research provides a basis for our comparison to the Navajo Sandstone concretions.

Methods: Characterization of Navajo Sandstone concretions utilized field and laboratory strategies. In the field, concretion diameters were measured at their largest width with a digital caliper to differentiate size populations. Concretions that had weathered out and collected in topographic lows (n= 1400) were measured to 0.1 mm. In the laboratory, QEMSCAN, visible near infrared (VNIR) reflectance spectroscopy, and whole rock analysis are used to determine the mineral phases and adsorbed species present in the cements of the concretions.

Results and Discussion: Navajo Sandstone concretions have many similarities with Martian "blueberries" (Table 1) in the following characteristics: a fine-grained, homogenous host rock [2, 4]; spheroidal geometries; interior and exterior cement structures; HFO mineralogies (with some differences in mineral phases and crystal size); enrichment in Ni relative to the host rock; distinct size populations; *in situ* self-organized spacing and distributions within the host rock; and conjoined forms. The strength of the similarities from detailed characterizations all point to an origin of groundwater diagenesis in a porous and permeable eolian sandstone. Some notable differences exist in: 1) host rock composition; 2) more complex mineral phases in Utah concretions including the presence of silicates; 3) internal structure (more varied in Utah); and 4) HFO crystal size.

The notable differences and range of variability can be attributed to the more complex diagenetic history of the terrestrial examples. At least seven different mineralization and mobilization events are documented in the GSENM study area [5]. These distinct events are responsible for concretionary features such as internal structure, preferential cementation of host rock surrounding concretions, three phases of HFO cement, and different size populations [5, 6]. These features (from multiple chemical reaction fronts and events) are amplified in the following discussion and in Figure 1.

Host Rock Characteristics	Mars	Utah
Fine-grained, homogenous, eolian sedimentary host rock	X	X
Host rock covers >100,000 km^2 area	X	X
Host rock composition	sulfate, basaltic	quartz arenite
Concretion Characteristics		
Spheroidal geometry	X	X
Surficial, latitudinal ridges or furrows	X	X
Interior structure	solid	rind, layered, solid
Preferentially cemented host rock occasionally adhered to concretions	X	X
Cement mineralogy	hematite (goethite precursor)	hematite goethite ferrihydrite
Enriched in Ni relative to host rock	X	X
Radial crystal growth	X	rare
Poly-modal distribution	bimodal	trimodal
< 1mm dia	X	
1-2mm to 5mm dia	X	X
> 5mm dia		X
Two size ranges in single horizon	X	X
Self-organized spacing	X	X
Vertically distributed through 10's of meters of section	X	X
Three dimensional distribution throughout host rock	X	X
Occasionally doublets or triplets	X	X
Doublet population abundant in particular locale	X	X

Table 1. Comparison of characteristics of Burns formation concretions and Navajo Sandstone concretions. Mars data from Calvin et al. [9]. X= present

There are three end members of Utah concretions based on internal structure. 1. Rind concretions have a thin, well-cemented HFO rind surrounding an interior relatively depleted of cement. 2. Layered concretions have a rind and two or more well-cemented concentric layers throughout the concretion. 3. Solid concretions have uniform cementation throughout the concretion. Solid concretions can have variable amounts of HFO cement (~ 20% - 30%) and can be divided into two categories dependent on size: 1) larger solids are > 5mm in diameter, and 2) micro-concretions are < 5mm in diameter. Internal structure can vary between these three end members.

At Meridiani Planum, concretions tend to be uniformly cemented throughout the concretion, but some concentric zonation is also observed [3]. Although there are similarities in the interior structure between Mars and Utah (such as solid cementation and occasional concentric zonation in some Utah examples), Utah has likely had a much more complex and longer history of diagenetic groundwater which accounts for the greater variety in interior structure in Utah concretions.

The Martian spherules are predominately hematite formed via dehydration of goethite [7]. In contrast, the Utah concretions have a more complex mineralogy with at least three phases of HFO cement [5]. Both the Mars and Utah examples are enriched in Ni relative to the host rock [6, 8] which suggests that Ni is mobilized and precipitated along with the iron as an adsorbed species or possibly in solid solution.

The frequency plot of size distribution in Utah is trimodal with populations of approximately < 5mm, 5-12mm and 12mm-10cm. On Mars, the size distribution is bimodal, although a third, smaller and as yet undetectable size fraction may be present [3] (Figure 1). The presence of different size populations suggests the possibility of different mineralization events at Meridiani Planum as well.

Conclusion: Characterization of the Navajo Sandstone concretions establishes criteria for determining diagenetic origin. The many similarities between the Utah concretions and the Mars spherules suggest a concretionary genesis for the Mars examples. Other models (e.g. impact lapilli [8], hydrothermal alteration spherules [9], marine/ lacustrine ferromanganese nodules [3]) lack key characteristics of interior structure, preferentially adhered host rock, HFO mineralogy, polymodal size distribution, distribution throughout the stratigraphic section, self-organized spacing and presence of doublets and triplet forms. Although some differences exist (such as host rock composition and size), they do not preclude a diagenetic origin for the Mars concretions.

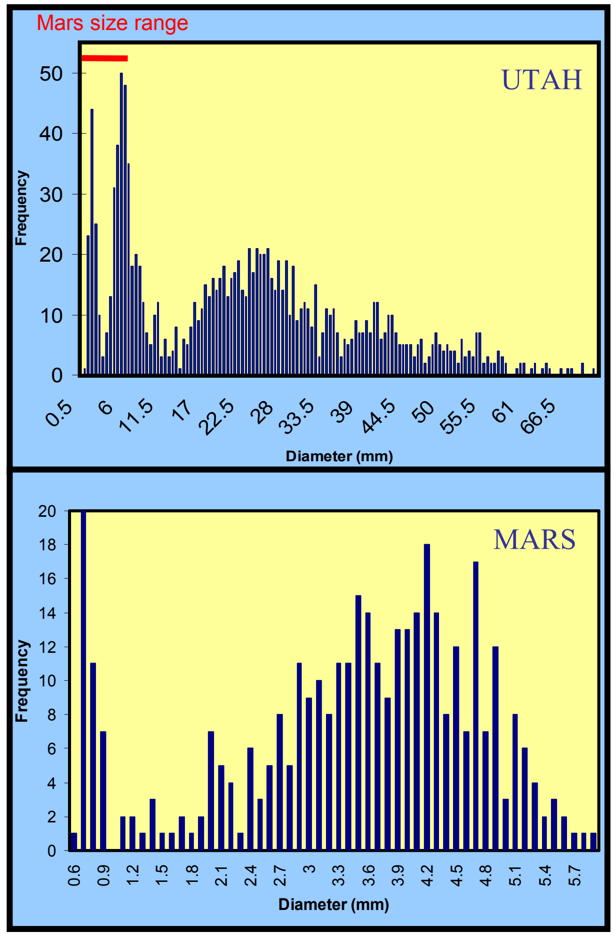

Figure 1. Comparison of size distribution in Utah (n=1300) and on Mars (n=378). Mars graph based on data from Calvin et al [9].

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