MINERALOGICAL CHARACTERIZATION OF NAVAJO SANDSTONE IRON OXIDE CONCRETIONS USING QEMSCAN AND REFLECTANCE SPECTROSCOPY; ANALOGUE FOR MARTIAN DIAGENETIC PROCESSES. S.L. Potter, M.A. Chan and E.U Petersen, University of Utah, Department of Geology and Geophysics, 135S. 1460E., RM719 Salt Lake City, UT 84112-0111, sally.potter@earth.utah.edu.

Introduction: The Jurassic Navajo Sandstone, widely exposed throughout southern Utah, contains a variety of spheroidal iron oxide concretions due to its porous and permeable nature [1]. Established geochemical fluid flow models provide a starting point for detailed mineralogical characterization [1,2,3,4] of the iron oxide concretions. Evaluation of the concretions with QEMSCAN (a scanning electron microscope with four energy dispersive X-ray detectors and a microanalyser) and Vnir (visible to near infrared) reflectance spectroscopy are used to detect mineralogical changes and chemical gradients across concretions. Mineralogic and chemical changes can help determine whether concretions form from an evolved fluid, or perhaps in discrete multiple events. These data provide a terrestrial analogue for understanding diagenetic processes and formation of Martian "blueberries" in the Burns formation.

Methods: Polished thin sections were made from five Navajo Sandstone iron oxide concretions and these were carbon coated for the QEMSCAN. Mineralogical maps of the entire thin sections were made at a 10µm spacing. Detailed images of rind and interior areas on each sample were compiled at 1µm spacing. A Species Identification Program (SIP) was compiled.

For Vnir reflectance spectroscopy, 23 iron oxide concretions were cut in half. The fiber optic cable was placed ~0.9 cm from the sample in order to obtain a 3mm field of view. Measurements were taken along a transect through the center of the concretion. These data were graphed and compared with standards from the USGS Spectral Library 06.

Results: Average modal mineralogies from QEMSCAN data for rind, interior and host rock cements are shown in Figure 1 (n=4 for interior and rind, n=1 for host rock). Average porosity of depleted interior area is 29.13% and average porosity of cemented rind area is 1.84%. Porosity of the host rock sample is 23.78%. Hydrous ferric oxide (HFO) cements are present in two forms: a flat, tabular texture (labeled "HFO") visible with petrographic microscopy and a frothy texture (labeled "HFO texture") visible with scanning electron microscopy (SEM) (Figure 2).

Minor amounts (~0.2%) of different manganese-bearing oxides are present on the inside edges of the rinds and exhibit a paragenetic relationship to the HFOs (Figure 3).

Spectroscopy analysis, although not as detailed as QEMSCAN, can also differentiate between phases of HFO. Three HFO phases are observed via spectroscopy in the concretions: ferrihydrite ($Fe_5O_3(OH)_9$), goethite ($\alpha FeO(OH)$), and hematite (Fe_2O_3). This analysis shows that cement in the rinds are predominately ferrihydrite. The interior cement is mostly sparse patches of kaolinite. HFO in the interior is identified as goethite or hematite. Layered concretions have more

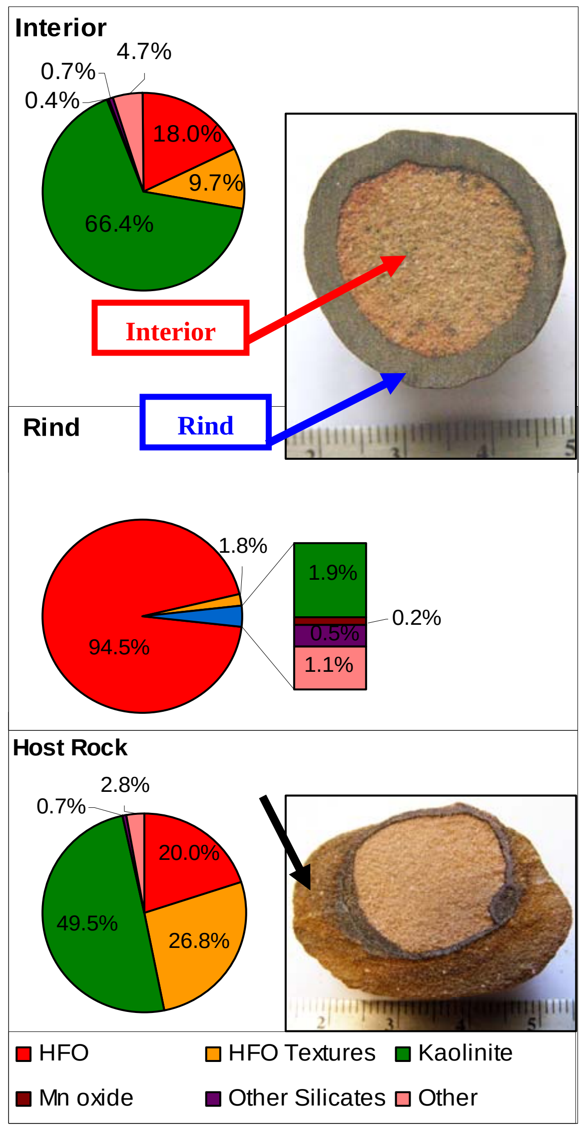

Figure 1. QEMSCAN modal mineralogies of cements normalized to 100%. Scale in photos is mm.

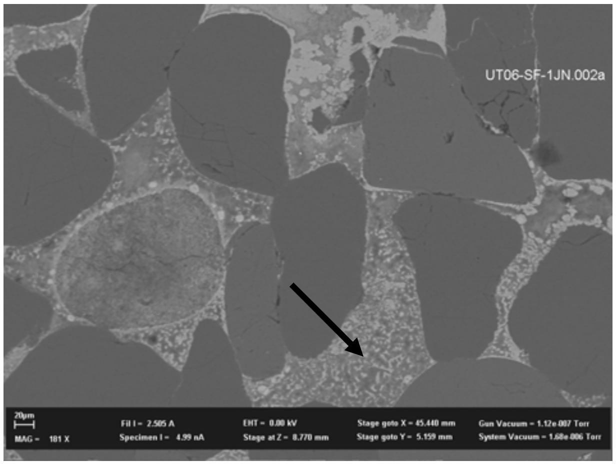

Figure 2. SEM image of concretion rind showing two generations of HFO cement. Arrow denotes frothy texture of HFO. Note rim cement around sand grains followed by pore-filling frothy texture cement.

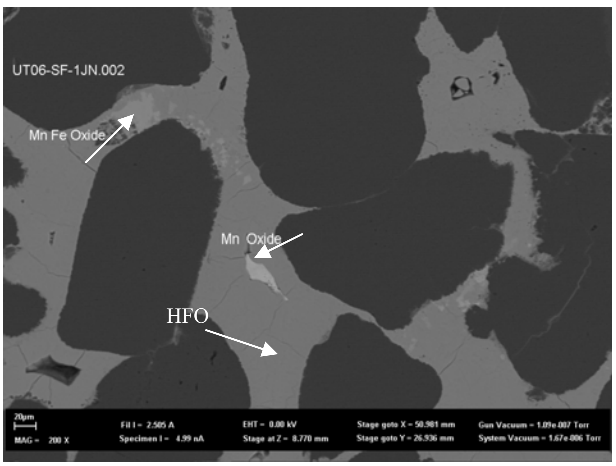

Figure 3. SEM image of concretion rind. Manganese oxide cement occurs as late stage pore fill. Other cement is HFO. Manganese oxide is brighter than HFO due to barium content.

ferrihydrite or goethite cements than hematite in the interiors. Where host rock was analyzed, the HFO tends to be more hematitic.

Discussion: Previous field work has established that at least seven different iron mobilization and mineralization events have occurred in Grand Staircase/ Escalante National Monument [5]. Mineralogical characterization establishes that these events have affected the internal structure of concretions at this same locality.

Different textures of HFOs exhibiting sequential relations indicate different precipitation phases. The manganese oxides are a late stage pore filling following the HFO. Under oxidizing conditions required for the precipitation of HFO, manganese oxides precipitate at a slightly higher pH than HFO [6]. This chemical gradient implies the presence of a changing pH in the interior of concretions.

Vnir spectroscopy results also suggest there has been an evolution of HFO phases. The concretions have interiors dominated by kaolinite and relatively depleted in HFO which is typically the hematitic phase. In contrast, the rinds are typically ferrihydrite and the interiors near the rinds tend to be goethite. Because amorphous iron oxide gel dehydrates to hematite over time [7], the rinds may contain younger cements than the interiors. When the concretions have layered interiors, the layers are ferrihydrite as well as the rinds. The presence of multiple phases of HFO is further evidence for multiple mineralization events.

Concretions can originally precipitate as amorphous $Fe(OH)_3$ gel that ages to more stable phases. Subsequent mineralization events have added different phases of cement to the rinds and in some cases interiors, as fluid diffused inward. The variations in internal structure in the concretions are due to later stage mineralization events.

The hematite "blueberries" on Mars may have a similar evolution of cements although they have a much simpler diagenetic history of diffusion. The Utah example suggests the possibility of precursor mineral phases to hematite in the Burns formation at Meridiani Planum [8].

This work is important not only for understanding diagenetic processes in the Burns formation, but for assessing new equipment to include in payloads for future Mars rover missions as well as testing investigative techniques to use in the event of sample return.

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