IRON (OXYHYDR)OXIDE BIOSIGNATURES IN THE BRUSHY BASIN MEMBER OF THE JURASSIC MORRISON FORMATION, COLORADO PLATEAU, USA: ANALOG FOR MARTIAN DIAGENETIC IRON.
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Introduction: Iron is the fourth most common element in the Earth's crust and an important part of understanding subsurface fluid/rock/ biota interactions. Mars contains abundant iron oxide concretions in the Burns formation at Meridiani Planum [e.g., 1, 2]. Any habitable rocky exoplanet will also likely have abundant iron. It is imperative to recognize unambiguous biosignatures in iron-bearing minerals, particularly iron (oxyhydr)oxides.

The purpose of this study is: 1. to document iron precipitation in ancient rocks and the relationship to biotic influences and, 2. to compare modern microbially precipitated iron oxides with ancient examples to elucidate on criteria for recognizing biosignatures in cements of ancient sedimentary rocks.

The upper part of the Brushy Basin Member of the Jurassic Morrison Formation (Jmb) has been interpreted as a large, ephemeral, alkaline saline lake system centered in the Four Corners region of the Colorado Plateau [3]. Copious input of volcanic ash combined with alkaline groundwater resulted in a unit composed of reactive, fine-grained sediments [3] (Fig.1).The Jurassic Morrison Formation caps the underlying Entrada Sandstone reservoir; the motivation for this study is to understand fluid/rock/biota interaction in the seal unit for potential CO_2 sequestration and iron cycling records the diagenetic biogeochemical cycles.

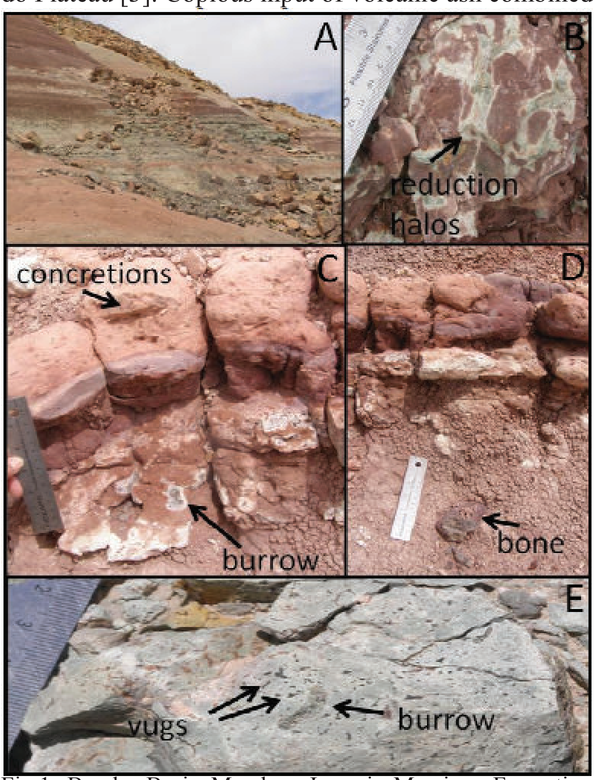

Fig.1. Brushy Basin Member, Jurassic Morrison Formation at (A.) Montezuma Creek, UT. exhibits: (B.) reduction halos around root traces, and (C.) concretions and burrows with reduction halos in red siltstone ledge. (D.) Ledge in C. also overlies fossilized bones. (E.) Bioturbated green siltstone is common.

Big Bubbling Spring (BB), Little Bubbling Spring (LB) and Crystal Geyser are modern CO_2-charged, saline cold springs and geysers that emanate from a fault system in southern Utah [4]. Iron-rich microbial mats surround the perennial springs [5] (Fig.2).

Methods/ Results: *Field:* A transect of Brushy Basin Member exposures were selected from the basinal center to the margins of Lake T'oo'dichi' deposits.

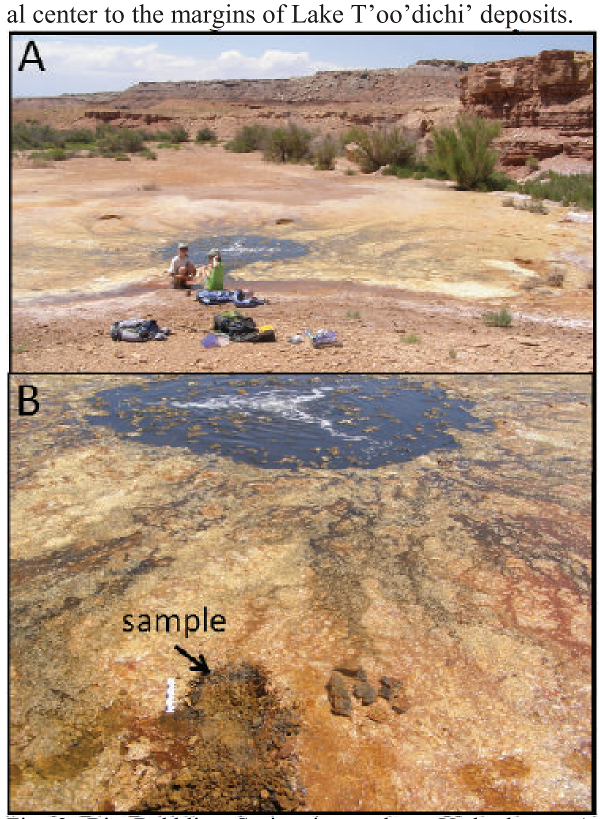

Fig. 2. Big Bubbling Spring in southern Utah shows: A. spring surrounded by iron (oxyhydr)oxide and aragonite precipitates, and B. detail of the microbial mat sample.

Abundant macroscopic biotic features include root traces/ vugs with reduction halos, burrows, and fossilized wood and bones (Fig.1). Vugs are assumed to be biotic in origin (e.g., root traces) because of reduction halos and sedimentary fabric similar to modern bioturbated sediments [6].

Samples were collected from iron-rich mats at BB and LB. Higher terraces of ancient travertines (< 400ka, [3]) are also present in the area. A sample from a 100ka ancient travertine was collected at Crystal Geyser (CG-AT).

X-ray Diffraction. Typical minerals identified in Jmb samples are: illite, smectite, hematite, goethite, quartz and feldspar. In the BB, LB and CG-AT samples, the minerals identified are aragonite, 6-line ferrihydrite and halite.

Petrology and Mineralogy. Petrographic microscopy and QEMSCAN (Quantitative Evaluation of Mineralogy using SCANning electron microscope) show that vugs in Jmb samples are filled with albite and/or calcite and commonly overprinted with euhedral chlorite (Fig. 3). Iron (oxyhydr)oxides in vugs are fine-grained and/or euhedral spheres along edges (Fig.3). Minor traces of organic carbon are detected in the iron (oxyhydr)oxide via QEMSCAN.

Laser Ablation Induced Coupled Mass Spectroscopy (LA-ICP-MS). Polished thin sections of Jmb (n=4), BB and LB (n=3) and CG-AT (n=1) samples were analyzed. Between one and four 1.7mm lines per sample were collected using a spot size of 9.7µm.

Principal Component Analysis (PCA) of results from the modern BB, LB and CG-AT samples show spatial correlation between carbon and iron as well as some trace elements such as manganese and arsenic. In ancient Jmb samples, carbon is strongly spatially correlated with sulfur and phosphorous, and sometimes with iron. In the Jmb sample with iron (oxyhydr)oxide spheres, the iron is strongly spatially correlated with carbon.

Discussion: Unusual crystal habits (acicular chlorite, iron (oxyhydr)oxide spheres) suggest biotic precipitation mechanisms and proxy morphological biosignatures. Comparison of known, modern microbially precipitated iron (oxyhydr)oxides with ancient putative examples via LA-ICP-MS shows that carbon and iron are typically strongly spatially correlated. Similar spatial correlations of elements (e.g., iron, carbon, arsenic, manganese) in modern and ancient examples suggest chemical biosignatures are present and preserved in Jurassic alkaline saline lake deposits.

Iron in ancient sedimentary rocks is significantly affected by biogeochemical diagenetic processes. This work provides "ground truth" in sediments with known biotic influence to show that trace element configurations combined with diagnostic crystal habits may function as a fingerprint for detection of biosignatures in ancient, oxidized iron-bearing cements. These techniques can be applied to Mars where biosignatures –if present - are likely more subtle.

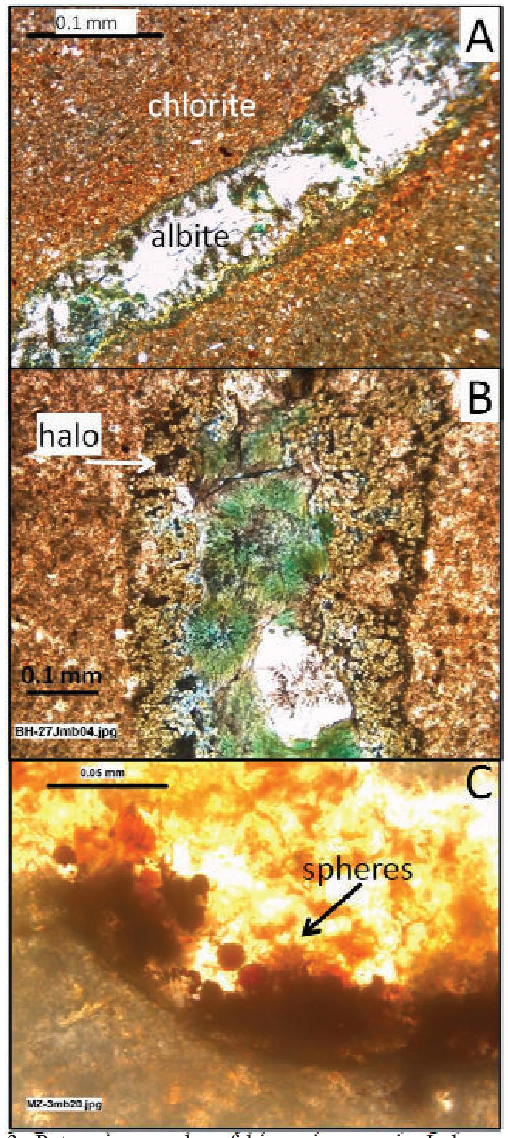

Fig. 3. Petromicrographs of biogenic vugs in Jmb samples show: (A.) chlorite and albite vug fill, (B.) reduction halo around acicular chlorite vug fill, and (C.) iron (oxyhydr)oxide spheres on edge of vug. Spheres contain traces of carbon detected via LA-ICP-MS and QEMSCAN (identified as organic carbon).

References: [1] Squyres, S. W. et al. (2005) EPSL, 240, 1-10. [2] Potter, S.L et al. (2011) EPSL, 301, 444-456. [3] Turner, C. E. and Fishman, N. S. (1999) GSA Bulletin, 103, 538-558. [4] Shipton, Z. K. et al. (2004) Geological Society Special Publications, 233, 43-58. [5] Burnside, N. M. (2010) PhD Thesis, University of Glasgow. [6] Aslan, A. and Autin, W.J. (1998) GSA Bulletin, 110, 433-449.

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