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Iron concretions in the Cretaceous Dakota Formation

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I. Introduction

The Cretaceous Dakota Formation contains abundant iron oxide concretions. The precursors to the iron concretions are siderite ($FeCO_3$) nodules that formed in a reducing floodplain environment. A variety of concretion morphologies formed when the precursor siderite nodules were dissolved by oxidizing groundwater in a paleoaquifer. Iron-oxidizing bacteria are able to oxidize aqueous Fe(II) to Fe(III) oxy-hydroxide at microaerophilic and neutrophilic conditions. This study investigated these concretions to determine if there was a microbial element in their formation and to characterize the concretion morphologies present in the Dakota. This is important for complete paleoenvironment interpretations and astrobiology pursuits.

II. Study Area

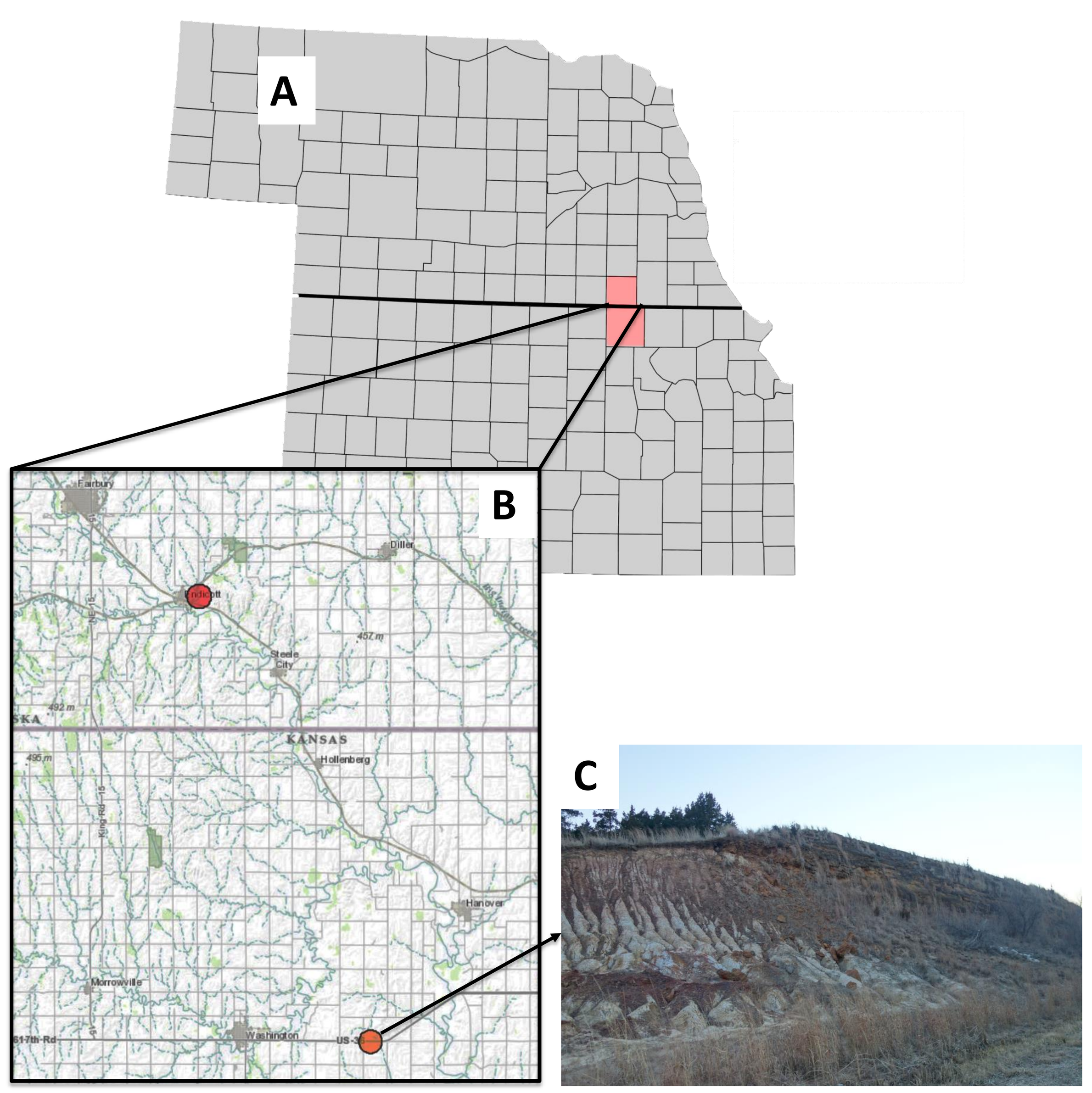


Fig. 1. Iron concretions were gathered from road cuts. Additional concretions had previously been collected from a train cut outside of Mahoney State Park (Loope et al., 2012). (A) Map of Nebraska and Kansas, with Jefferson (NE) and Washington (KS) counties highlighted in red. (B) Enlarged view of the counties with outcrop areas marked in red. (C) A picture of the outcrop along highway 36.

III. Iron Concretion Morphologies

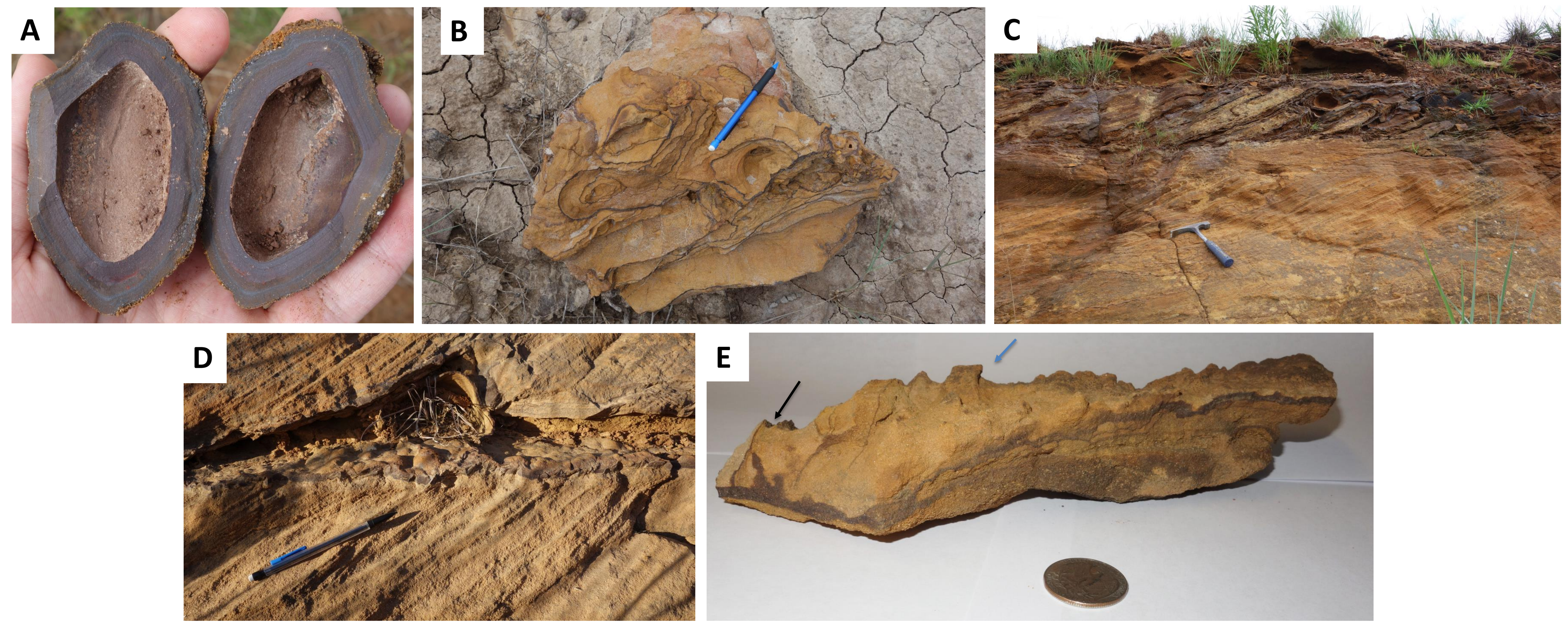


Fig. 2. (A) Rounded rattlestone that was split open, internal fine grained material has been removed. (B) “Wonderstone” patterning, with bands of iron oxide interspersed with iron oxide staining. (C) Convoluted diagenetic iron oxides, note large pipe shaped concretion in top center and crossbedding in the center. (D) Pipe and columnar concretions. (E) Sample showing iron banding, parallel fractures filled with iron oxide (black arrow), and columnar concretions (blue arrow).

IV. Under the microscope

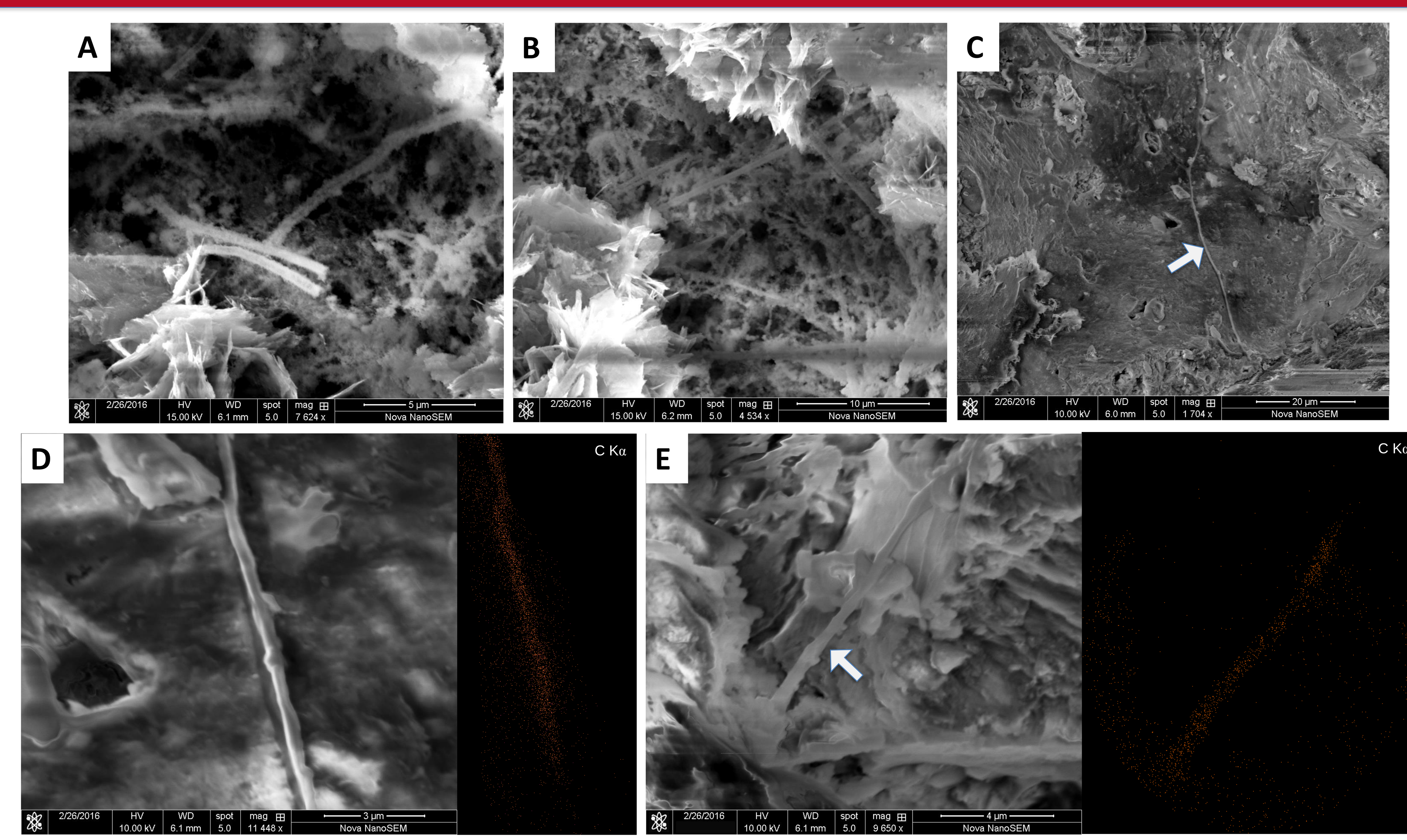


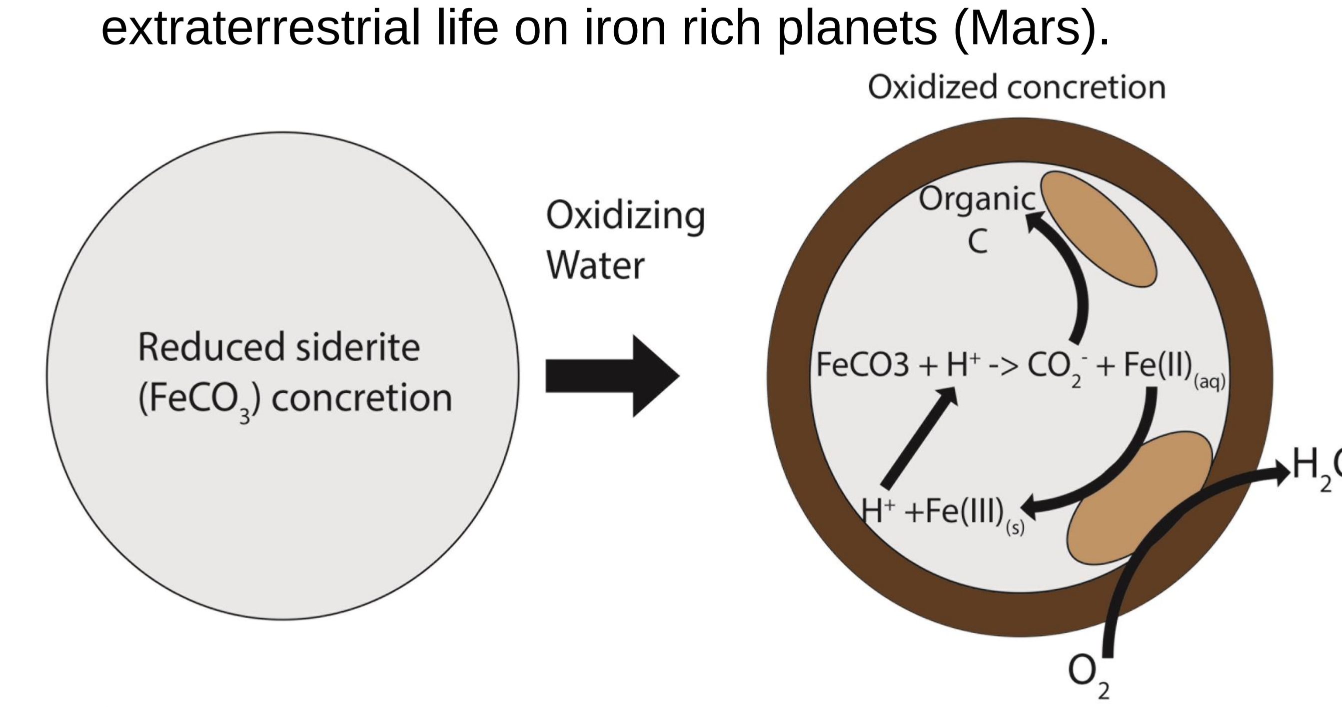
Fig. 3. (A) Sheath structures that are interpreted as biogenic iron oxides, similar to modern *Leptothrix sp.* sheaths. (B) Abundant sheaths in a dense biofilm arrangement (C) Arrow points to a filamentous structure (D) Close-up and carbon map of the filament from C. Note that the carbon signal is more intense on the stalk compared to the surrounding material. (E) Another stalk structure (arrow) with its associated carbon map showing a more intense signal on the stalk. Stalk also has small iron oxide protrusions along its length, similar to that in D.

V. Methods

Samples were washed with distilled water, methanol, and acetone. They were then dried in an oven to remove water. Intergranular spaces in the concretions were observed using a FEI Nova NanoSEM and suspect microbial structures were analyzed using electron dispersive spectroscopy (EDS) to identify the element composition.

VI. Discussion

Wonderstone and columnar iron-oxide concretions were identified, in addition to the rounded rattlestone concretions that were previously identified in the Dakota (Loope et al., 2012). Similar concretions in the Navajo and Shinarump have been show to contain iron-oxidizing biosignatures (Weber et al., 2012; Kettler et al., 2015).The filament structures found in this study are similar to those identified in those studies in both morphology and carbon intensity on the stalks. Abundant sheaths that are comparable to modern *Leptothrix sp.* were also identified. These biosignatures are the first to be reported in the Dakota concretions. Below is the current model of concretion formation in the Navajo (after Weber et al. 2012). This can now be extended to the Dakota concretions. Since these concretions can be associated with microbes, they make good targets in the search for extraterrestrial life on iron rich planets (Mars).



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