Diagenetic Fabrics in Stromatolites and Coated Grains in the Precambrian Copper Harbor Conglomerate

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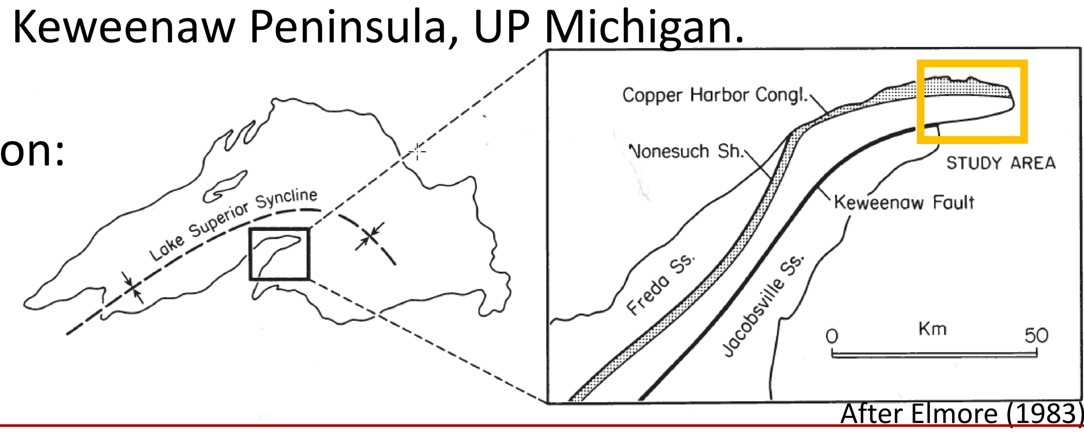
INTRODUCTION / BACKGOUND

The Copper Harbor Conglomerate (CHC) is Precambrian in age, 1.1Ga. Has been interpreted as non-marine in origin and composed of sandstones, conglomerates, and basaltic lava flows; with stromatolitic beds found in the upper portion of the unit. The CHC is overlain by the Nonesuch Shale and Freda Sandstone, and the stromatolites are located in the northern tip of the Keweenaw Peninsula, UP Michigan.

Three areas of diagenetic alteration:
1. Ooids
2. Stromatolites
3. Fractures/Brecciation



After Elmore (1983)

COATED GRAINS / OOIDS

Volcanic rock fragments and quartz grains serve as the nucleus for alternating laminae of calcite and clinochlore, a magnesium rich chlorite (Fig 1).

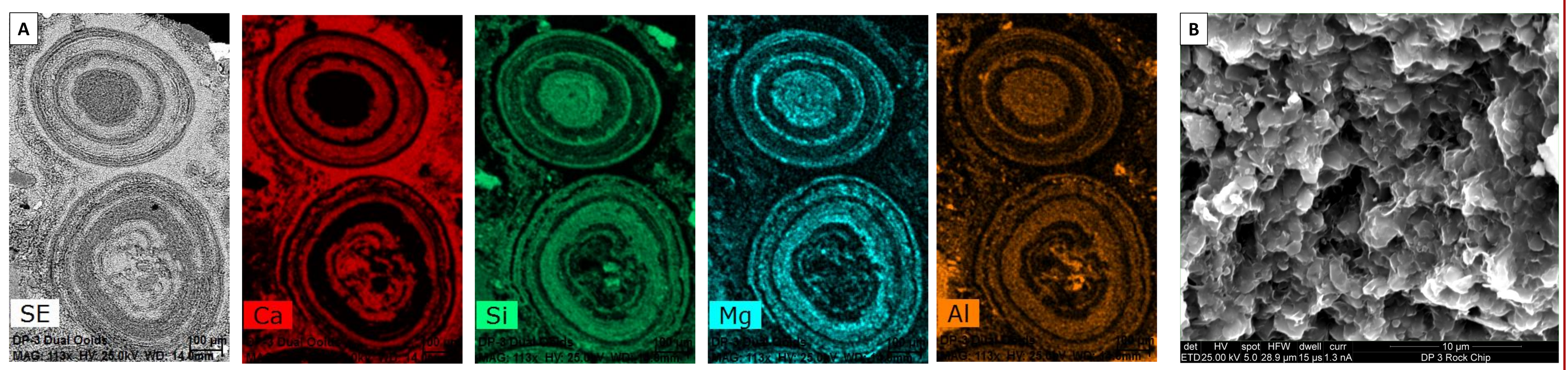


Fig. 1: A) SEM energy dispersive spectroscopy (EDS) analysis of the ooid laminae highlighting the alternating layers of calcite and clinochlore. B) Secondary electron image of the clinochlore structure.

Two fabrics present within ooids (Fig. 2):
1. Radial calcite -> Primary origin
2. Blocky calcite spar -> Secondary origin

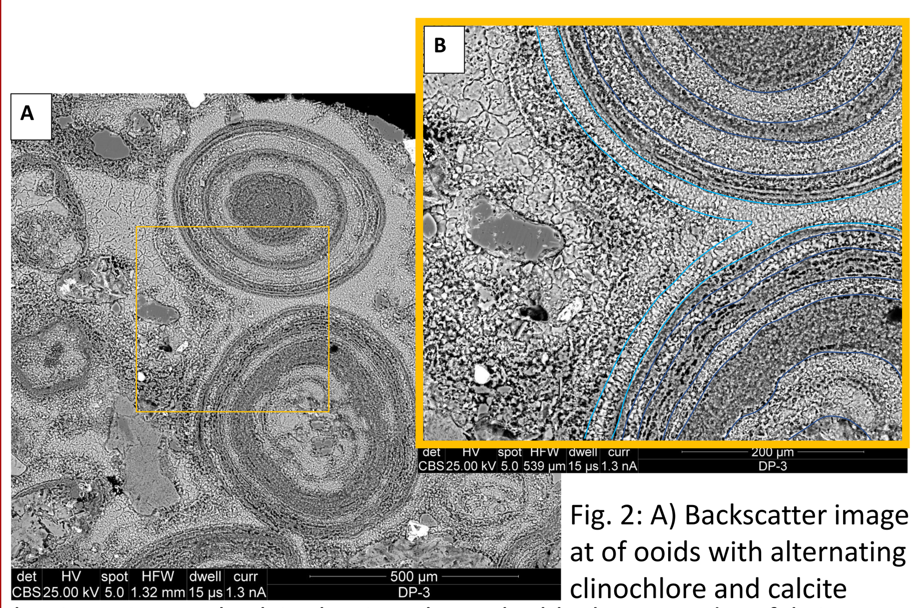


Fig. 2: A) Backscatter image at of ooids with alternating clinochlore and calcite laminae. Internal calcite laminae have the blocky, secondary fabric and the external laminae is the primary radial fabric. B) Close up backscatter image of the ooid laminae. Dark blue outlining the internal blocky calcite, light blue outlining the radial fabric of the external laminae.

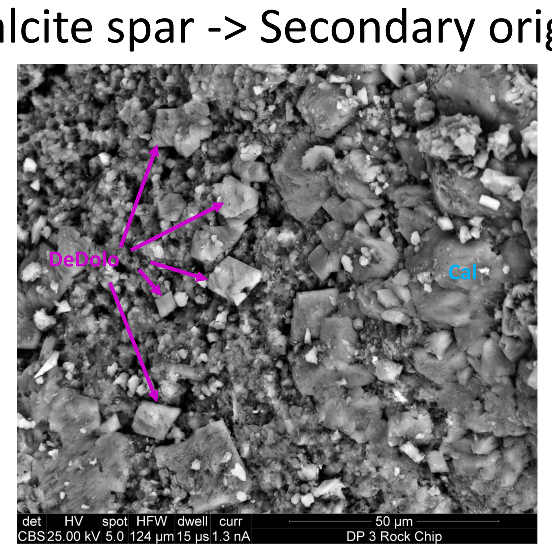


Fig. 3: Dedolomite altered from early dolomite suggests the lake water had elevated magnesium relative to calcium.

Primary and secondary (diagenetic) calcite fabrics are present as blocky calcite in the internal laminae, and radial calcite in the exterior laminae primarily. High-Mg calcite is likely the original material for the blocky calcite, it was later replaced by Low-Mg calcite. High-Mg calcite was determined to the be original material due presence of dolomite rhombs in the stromatolites (Fig. 3) and lack of strontium.

Petrographic analysis suggests the coated grain growth may be mediated by algal processes or other microbial processes (Fig. 4). Fedorchuk et. al. (2016) suggest a partial biogenic origin for the stromatolites trapping the coated grains.

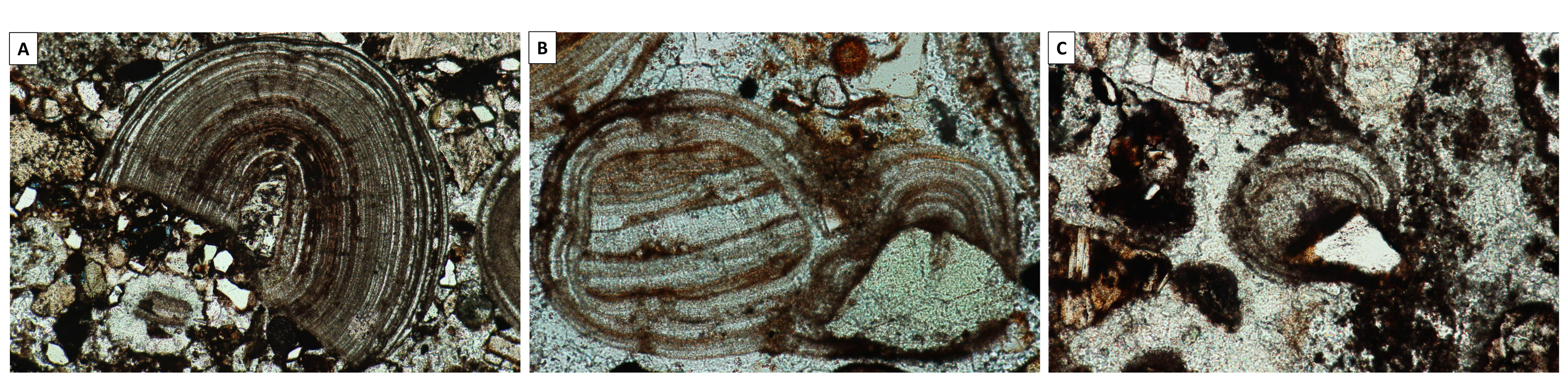


Fig. 4: Thin section photomicrographs of coated grains whose laminae appear to be growing from rock fragments (A) and individual grains (B&C). Edges do not appear jagged indicating laminae were broken prior to lithification but rather formed in the present configuration.

STROMATOLITES

Fig. 5: Stromatolites at different scales A) Dan's Point CHC outcrop in Copper Harbor, MI, the stromatolite bed Is outlined in yellow. B) Close up of the individual stromatolite defined by the yellow box in (A). C) Axio Scan of a stromatolite in thin section.

The CHC stromatolites are in the upper portion of the section, underlain and overlain by sandstones and conglomerates. Individual stromatolites show irregular bleaching, vugs filled with calcite, and 1-10mm crosscutting fractures (Fig. 5A-C).

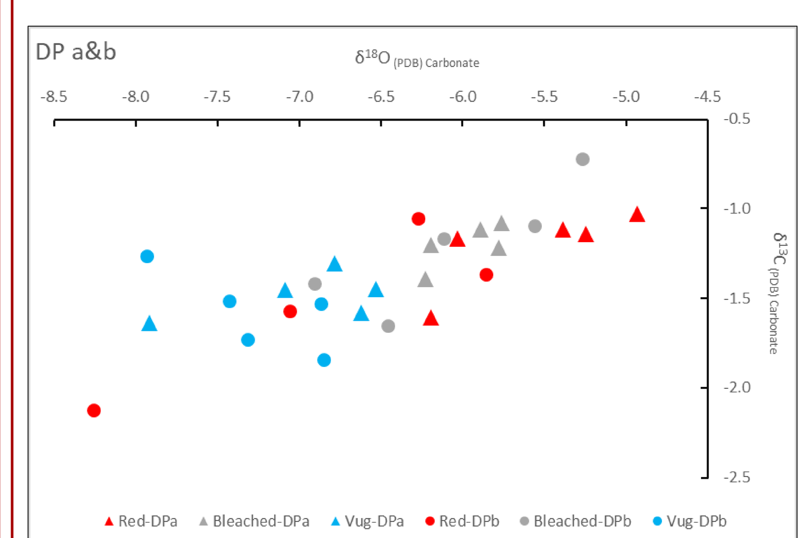


Fig. 6 : Carbon and Oxygen isotopes. Samples were collected from the reddened laminae, bleached laminae, and vugs.

Carbon and oxygen isotope analysis were run for two stromatolites (30 samples). The vug samples appear to be depleted in $\delta^{18}O$ relative to the reddened and bleached samples, which plot similarly to each other (Fig. 6).

Stromatolite laminae contain authigenic minerals: albite, dedolomite, chlorite, cuprite, native copper, titanium oxide, and quartz. The albite, chlorite (Fig. 7A&B) and dedolomite (Fig. 3) formed early, while the quartz, titanium oxide, cuprite, and native copper formed late (Fig. 7B-D).

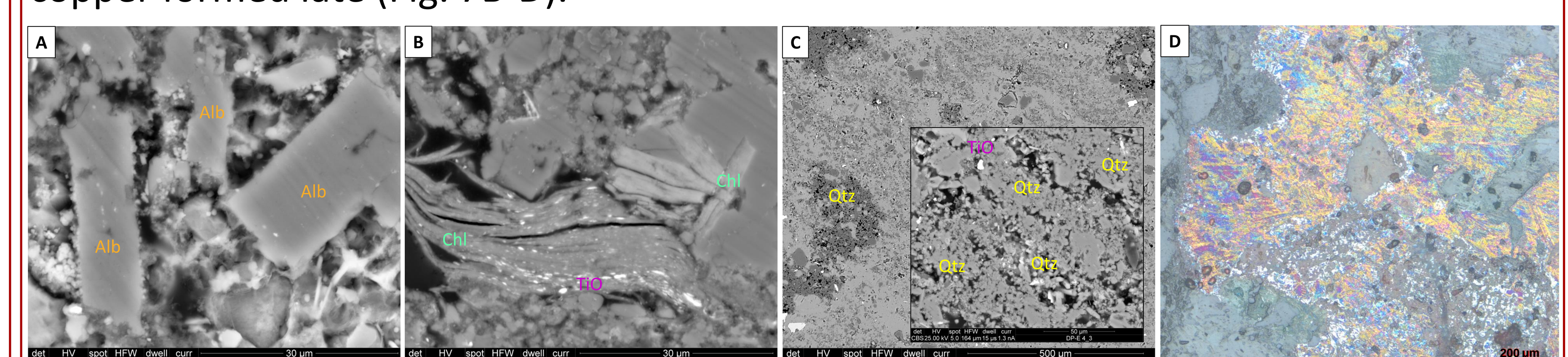


Fig. 7 : A-C) SEM images of authigenic mineral phases within the stromatolites. D) Reflected light photomicrograph of cuprite.

FRACTURES / BRECCIATION

Three sets of fractures were identified in the field; as well as irregular bleaching in sandstones, stromatolites, and the brecciated interval (Fig. 8).

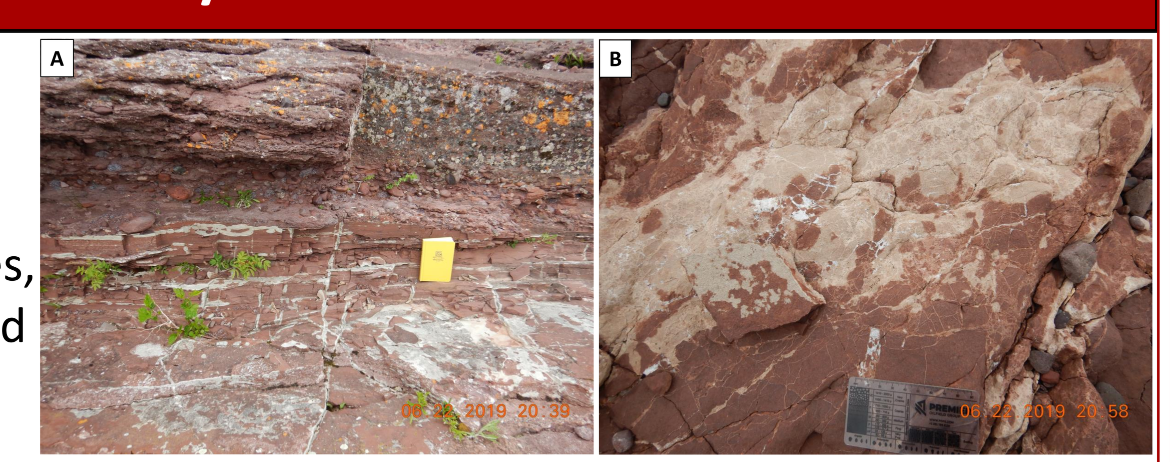


Fig. 8: A) Bleaching pattern in the underlying sandstone. B) Overlying brecciation with sporadic bleaching and fracture fill.

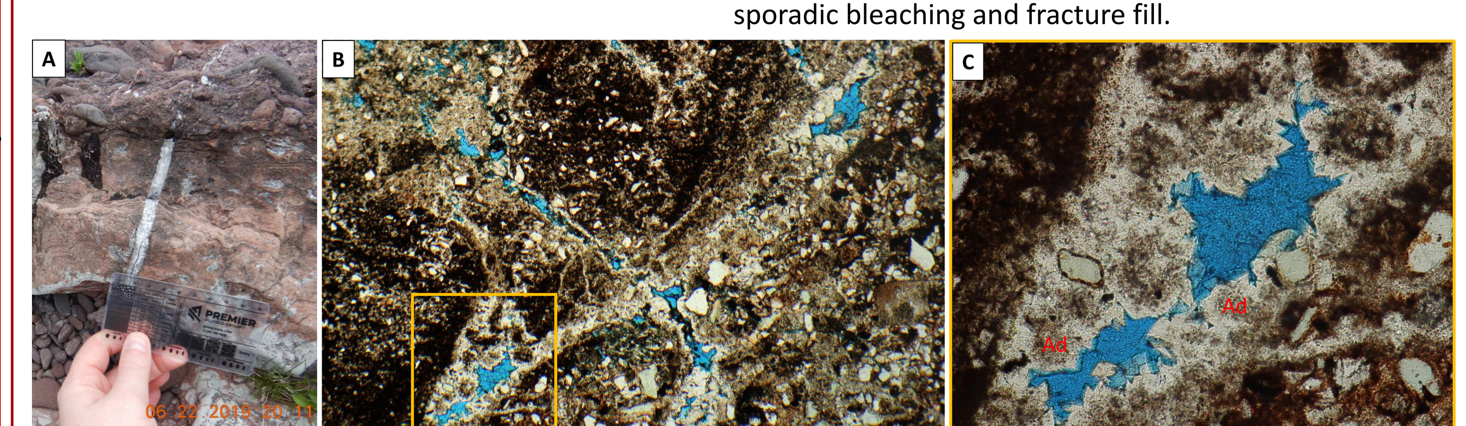
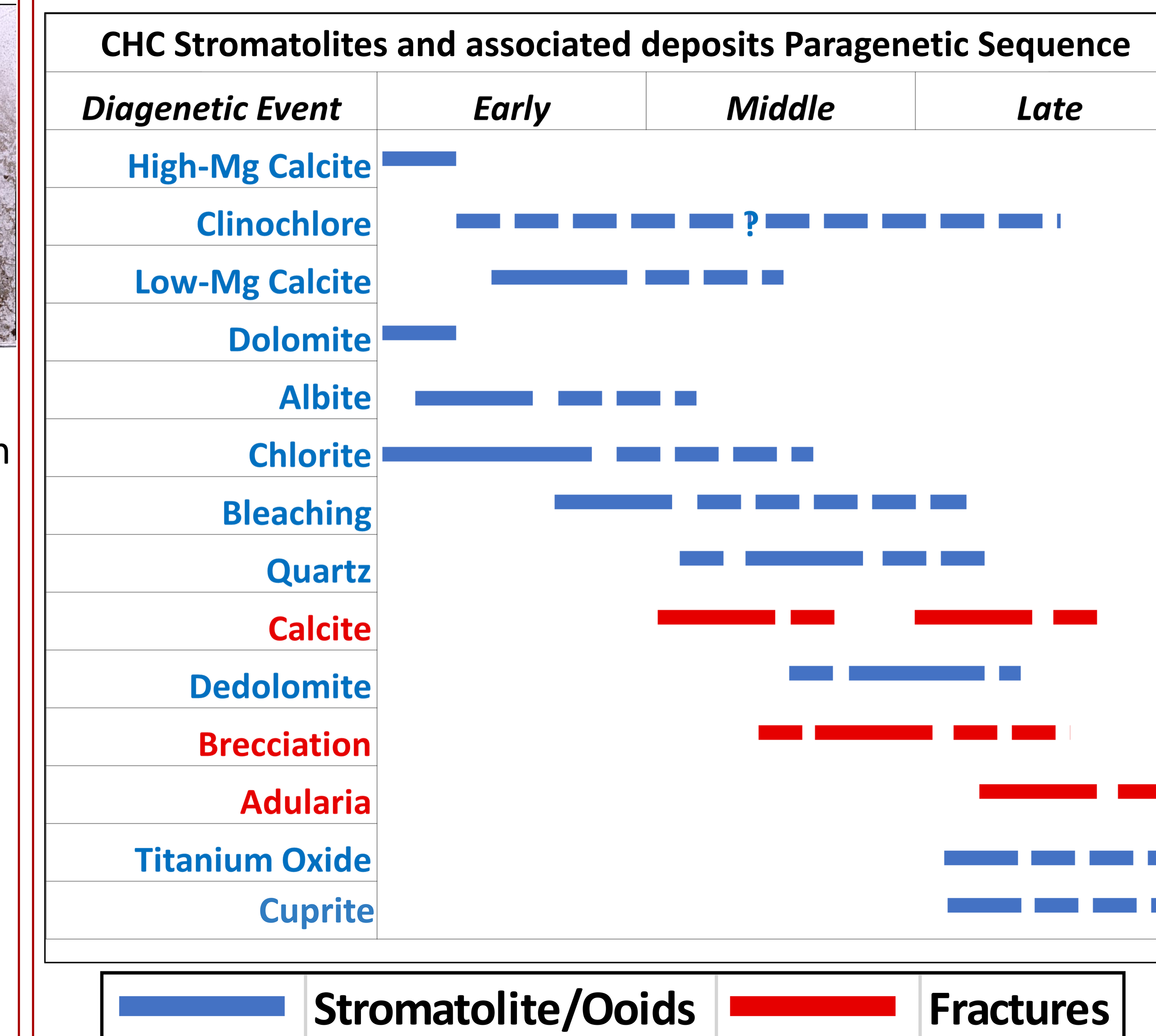


Fig. 9: A) Millimeter width fracture with dual-mineral fill crosscutting the stromatolite bed. B) Thin section photomicrograph of fractures filled with adularia (rhombic potassium feldspar) from the brecciated zone. C) Close up of adularia (Ad).

The fractures cutting the stromatolites are predominately calcite for small fractures (<1mm), and multi-mineralic in larger fractures (>1mm). In the overlying brecciated zone fracture fill is comprised of two main phases, calcite and adularia (Fig. 9).

PARAGENESIS



IMPLICATIONS

- Dual calcite fabrics within the ooids suggest rapid changes in the Ca:Mg in the water chemistry; ex. blocky calcite replaced High-Mg calcite in the ooids.
- Clinochlore is associated with burial diagenesis/ low-grade metamorphism; original mineralogy is unknown.
- The variety of authigenic mineral phases within the stromatolites indicates the system is complex.
- Bleaching is often associated with calcite fractures, suggesting fluid flow is the dominate driver for the bleaching pattern, however not every calcite event is associated with bleaching.
- Adularia is indicative of hydrothermal alteration.
- Presence of copper minerals, cuprite and native copper, is consistent with the CHC serving as a conduit for copper-bearing fluids that migrated into the lower Nonesuch.

ACKNOWLEDGEMENTS / REFERENCES

I would like to extend my thanks to Dr. Andy Elwood-Madden and Dr. Lindsey Hunt for their help in identification of the clinochlore.

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