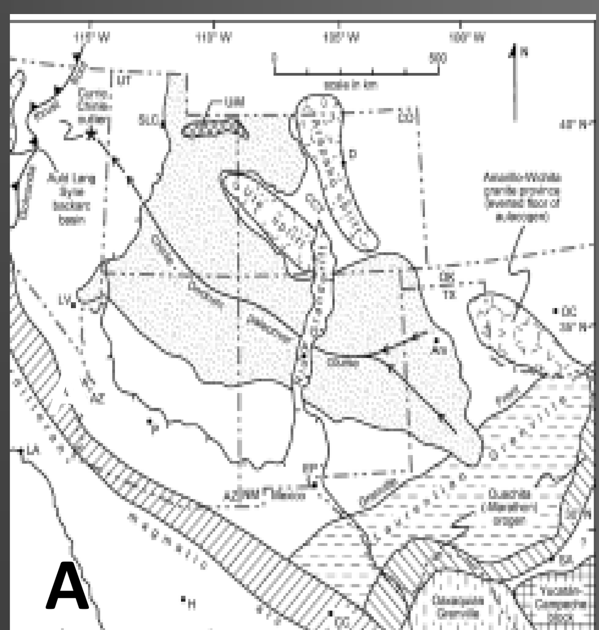
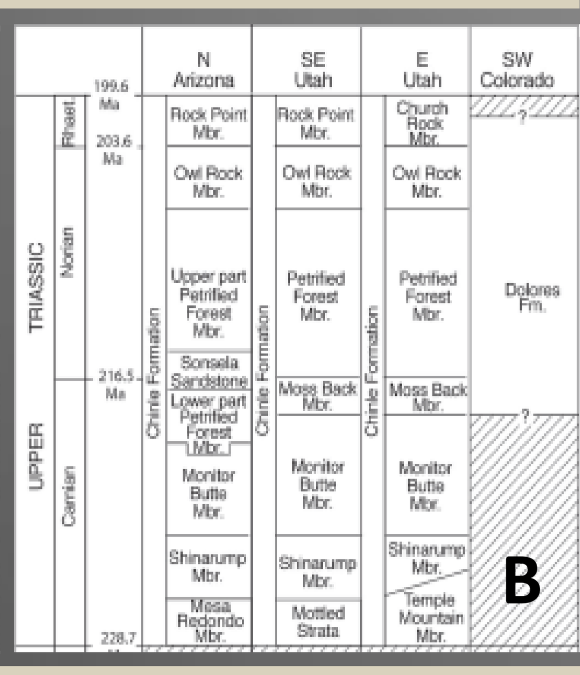
PALEOENVIRONMENTAL IMPLICATIONS OF IRON DIAGENSIS IN THE TRIASSIC SHINARUMP MEMBER OF THE CHINLE FORMATION

Burgess, D.T., Loope, D.B., Kettler, R.M., Department of Earth and Atmospheric Sciences ,University of Nebraska-Lincoln

Abstract

The Shinarump Member of the Chinle Formation in southwestern Utah and northwestern Arizona contains several types of iron accumulations, ranging from 1 cm to 50 cm in diameter, and composed of iron oxide, siderite, and pyrite. Iron oxide is present in different depositional facies, but is most common in channel sandstone bodies as dispersed, rhombic pseudomorphs and as small, discoidal concretions within intraformational conglomerates. Large discoidal, septarian concretions occur in thinly laminated mudstone overbank facies. Several different lines of evidence from the concretions and surrounding sediments indicate that the ferrous carbonate mineral siderite was the precursor mineral for current iron oxide cements. Early diagenetic siderite characteristically forms in conditions that are consistently water-logged, organic-rich and methanic (like those found in present-day swamps and peat bogs). It is typically difficult to find preserved siderite because it quickly dissolves in oxygenated pore waters. We have found little preserved siderite, but physical evidence such as rhomb-shaped iron oxide pseudomorphs indicate its previous distribution. Accumulation of iron oxide in rinds around NNW-SSE trending joints indicate siderite was oxidized long after the Triassic and more likely during Basin and Range deformation (Miocene to Recent). Rattle stones are intraformational clasts that comprise iron-poor, mudstone centers surrounded by iron-oxide cemented rinds. Iron oxide pebbles, are also found in intraformational conglomerates. In thin-section, these pebbles resemble iron-cemented concretions and commonly have sharp edges, suggesting they reworked early oxidized concretions. Septarian concretions display varying fracture networks, iron oxide cement, and calcite fracture fills. Rattle stones, iron oxide pebbles, and septarian in the Shinarump provide valuable clues about over bank deposits and floodplain hydrology. All had precursors composed of early diagenetic siderite. Some were oxidized at shallow depth, during the Triassic (iron-oxide pebbles and septarian concretions), and others (rattle stones and dispersed cements were oxidized long after lithification).



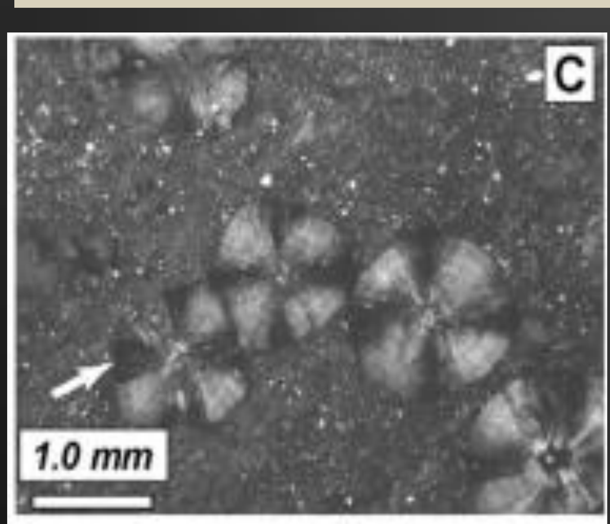


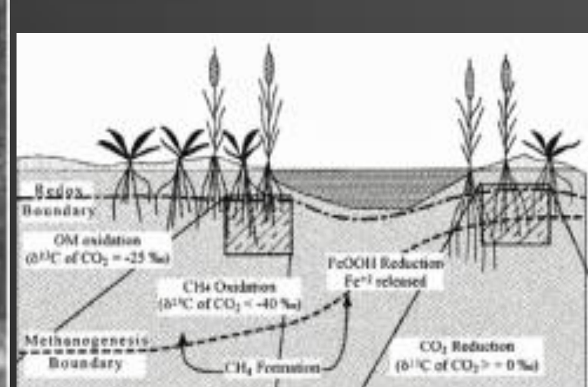
Geological & Paleoclimate Settings

The Shinarump was deposited in a backarc basin on the supercontinent Pangea at ~5-15^{o} latitude north of the equator (Dubiel 2011). The Chinle Basin extended from the craton to the western edge of the continent (figure A) (Dickinson & Gehrels 2008). The fluvial Shinarump Member is the lowest member of the Chinle Formation, overlying the Tr-3 Unconformity, which separates the Chinle & Moenkopi Formations(figure B). Commonly the Shinarump is found as a resistant cliff-forming bed that has a general grain size decrease to the northwest portions of the basin. Grains are often composed of coarse sand and pebble conglomerates with extrafromational clasts

Paleoclimate conditions during Chinle deposition were mostly controlled by the Pangaean supercontinent. The equal distribution of land across the equator and large amount of land exposed on the Pangaean supercontinent led to maximizing of the monsoonal climate. Warm temperatures have been agreed upon by many researchers , but precipitation has been debated on (Dubiel1991). The general consensus drawn by (Dubiel 1991) is that there was a heavy amount of precipitation varying seasonally. This resulted in a consistently high ground water table.

Siderite is commonly found in depositional environments that are reducing , ever-wet, and methanogenic in nature (figure D) (Ludvigson 1998, Unfar2005). These early diagenetic iron minerals are unstable in oxygenated conditions. Iron oxide concretions have been identified as remnants of altered early & late diagenetic minerals like siderite by (Loope et al. 2012,2010) Pedogenic siderite precipitation in flood plain environments like that of the Mississippi River are precipitated in distinct spherical masses (figure C) (Ludvigson 1998).





Below: The figure shows localities Little Creek Mountain (upper asterisk) & Lost Spring Mountain (lower asterisk).

Right: A map of the state of Utah identifying the study area, outlined in black, in the lower left hand corner

Lower: The picture shows the Shinarump Cliffs Locality near Kanab, Utah.

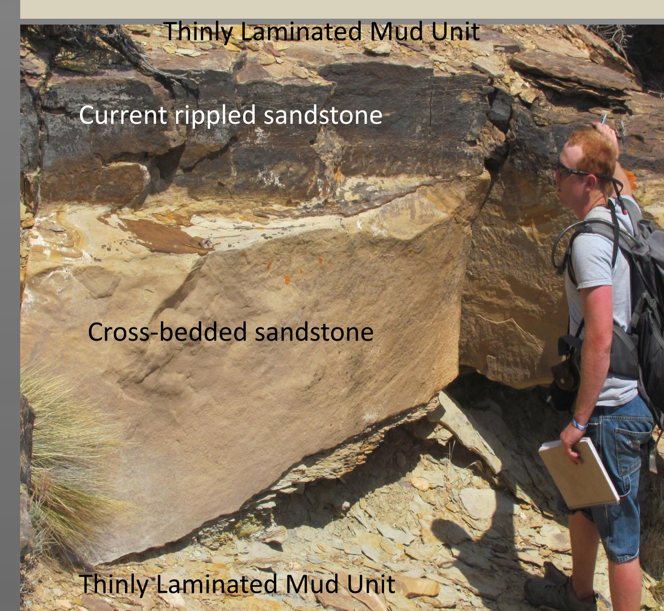
Field Evidence

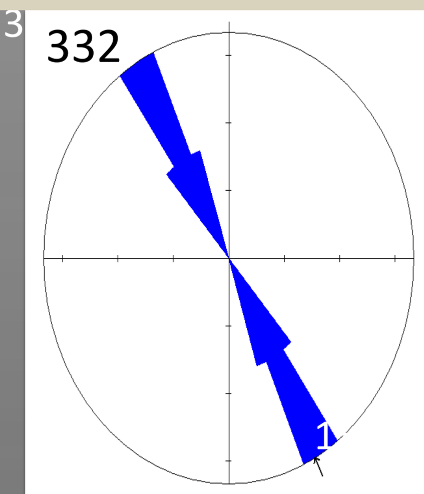
Lag Deposits

Upper Left: An outcrop of reworked iron oxide clasts, which likely originated from larger iron oxide concretions, that were oxidized in the late Triassic.

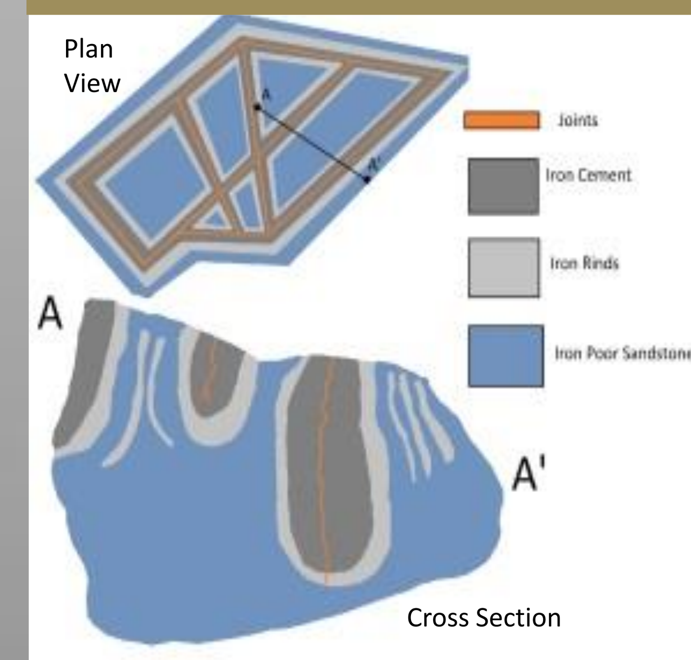
Upper Right: Large concretions have fracture orientations (lower right)(N=6), that are consistent with Basin and Range joints. Joints in the concretions controlled iron oxide precipitation, indicating oxidation post -dates fractures.

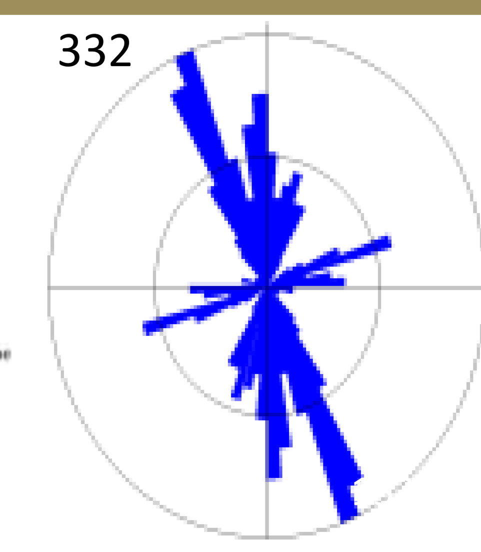
Lower Left: Sharply based erosional surface that is overlain by a fining-up sequence. Intraformational conglomerates typically lie on sharply based erosional contacts.





Current Ripple Sandstone

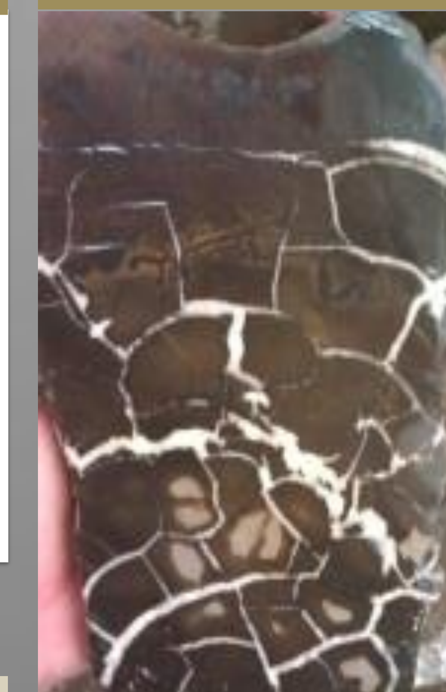




Above: Diagrams present the physical aspects of boxwork concretions. Plan view (above) and cross section (below),and their orientations (right)(N=175).

Below: Current rippled sandstone is iron oxide cemented, preserving three dimensional shape of current ripples . Iron oxide cement is concentrated in thick rinds that line each side of the joints present in the block.

Thinly laminated Mudstone



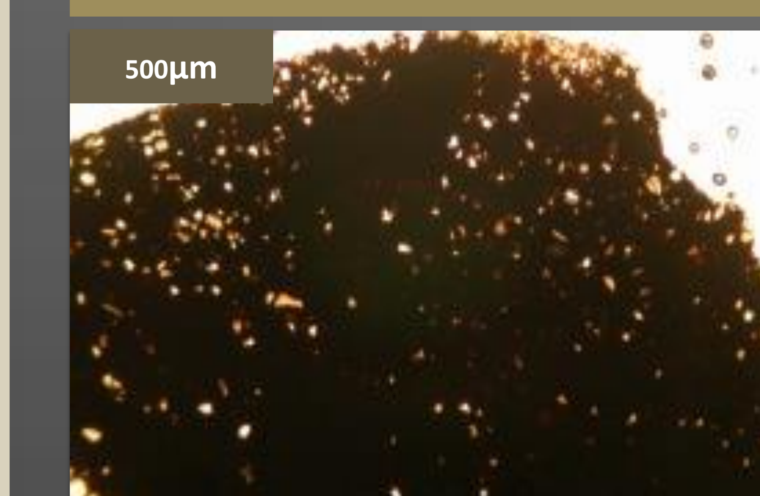
Top Left: A plan view slab cut through a tabular concretions (top right) displaying the fracture network and fracture filling.

Top Right: A tabular concretion is found in a thinly laminated mudstone showing evidence of early diagenetic iron minerals. Concretions can be as large as 45 cm in width and 6 cm in thickness, and display varying fracture networks.

Lower Left: A cross section cut through a large septarian concretion, lower right, Fe or Mn dendrites and carbonate fracture fills are common.

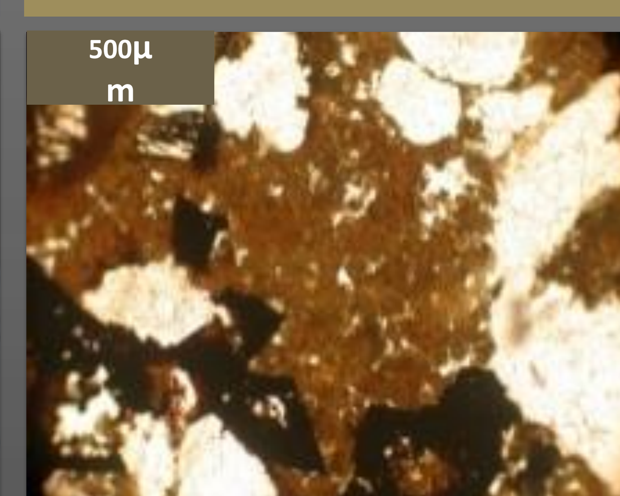
Petrographic Evidence

Lost spring Mountain –LSM-16



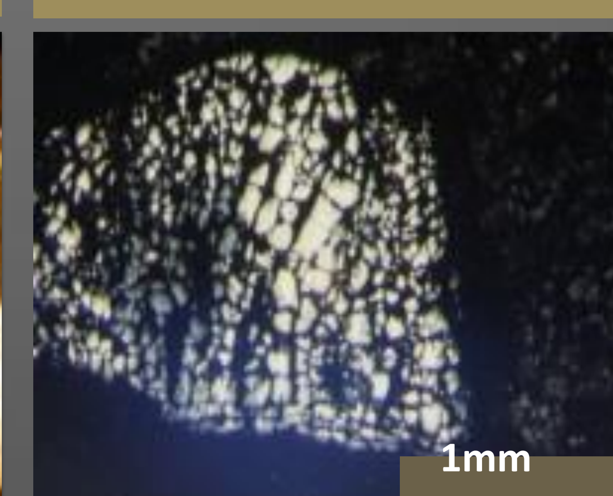
LSM-16: Rind of an iron oxide concretion preserves evidence of previously existing pedogenic siderite spheres. 3D spherical shapes are formed when the outward growth of siderite pushes aside silt and clay sized quartz grains during outward growth.

Shinarump Cliffs- SC-NF-01



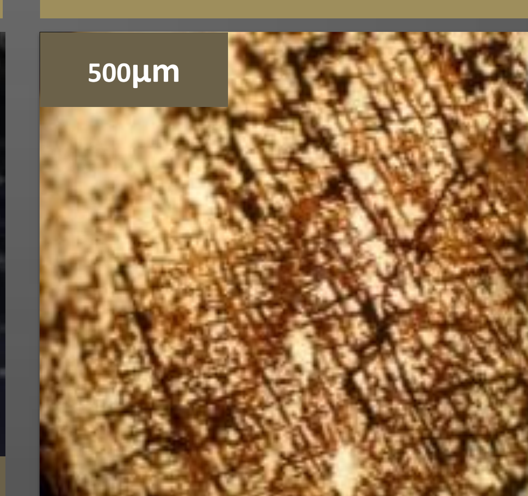
SC-NF-01: Photomicrographs of siderite & opaque iron oxide cement. Siderite is readily oxidized in the presence of O_2.

Little Creek Mountain LC-1-1

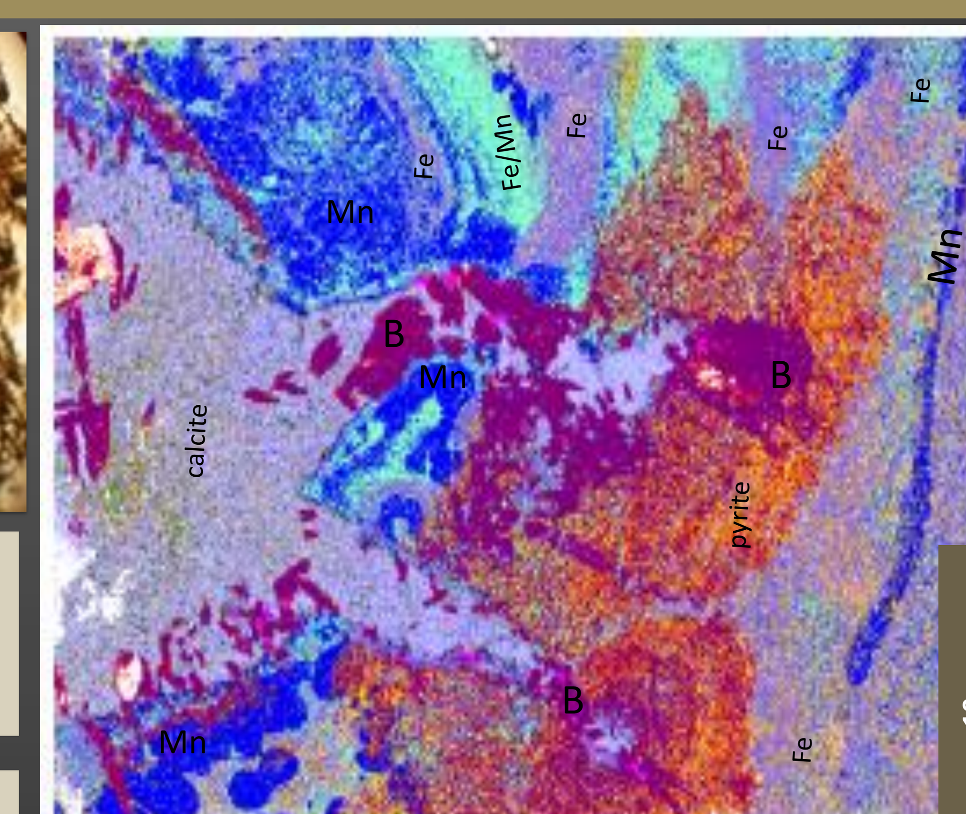


LC-1-1: Reflected light micrograph of pyrite from a septarian concretion shows signs of oxidation in the darker portion of the pyrite crystal.

Little Creek Mountain-LCM-SC-01



LCM-SC-01: Photomicrograph of iron oxide in a cross-hatch pattern, that is commonly associated with Fe/Mn carbonate minerals.



Upper Right: Microprobe scan depicting changing mineralogy across the thin section.

The legend is to the right giving area percent per mineral.

Mineral Name	Area%
Calcite_AMRC	10.27
Ca/Mg Carbonate	0.02
Fe Carbonate (Siderite)	20.93
Fe/Mn Carbonate	12.43
Mn/Fe Carbonate	12.91
Silicates	8.36
Barite	19.08
Phosphates	0.23
Ti Minerals	3.91
Pyrite	3.07
Fe-ox/hydro-silicate	3.23
Fe Phase	1.33
Mn Phase	2.97
other minerals	1.16
Others	0.10

Conclusions

1. Early diagenetic siderite was precipitated within both the channel, and the floodplain facies of the Shinarump Member of the Chinle Formation. This indicates continuously water-saturated and reducing groundwater conditions consistent with previous conclusions made by (Dubiel 1991) of paleoclimate during Shinarump deposition.
2. Some siderite concretions from intraformational conglomerates could have been oxidized within the flood plain facies during the deposition due to a drop in the water table.
3. Siderite in the channel sandstones was oxidized after the start of Basin and Range deformation of the western edge of Colorado Plateau. Post-Miocene
4. Septarian concretions , commonly developing in less than a few meters of burial, are composed of siderite, pyrite, Mn/Fe carbonate, and barite.

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