Calcite Cements in a Fluvial Cycle, Hartford Basin, Connecticut

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Introduction:

We have undertaken a petrographic examination of rocks from a fluvial sequence of the Triassic New Haven Arkose in the Hartford Basin, Connecticut (Figure 1) to understand the relationship between the calcite that cements channel sand deposits and the calcite that forms anastomosing horizontal layers that have been considered caliches in the underlying mudstone deposits (Wang et al., 1998). Based on the field relationships a second reasonable hypothesis is that the cements in the sandstones and mudstones are the result of the same fluid because the sandstone is leached drab and well cemented with calcite and the top of the underlying overbank deposit has a network of near horizontal veins that are gleyed and in many cases areas have calcite precipitation. Petrographic study reveals many similarities between the calcites in the sandstone and underlying mudstone and our conclusion is that the calcites form at the same time and therefore the calcite in the mudstone is not a soil-formed caliche but is more like the groundwater calcretes described by Pimental et al. (1996).

Geological Setting:

The Hartford Basin in Connecticut (Figure 1) is one of the Triassic Basins that lines the eastern margin of North America. The caliches within the Hartford Basin are mainly in fluvial sequences of the New Haven Arkose. The New Haven Arkose consists of 2000 meters of sandstone and red mudstone that make up the lower portion of the approximately 4000 meter thick clastic fill of the basin (Wang et al. 1998).

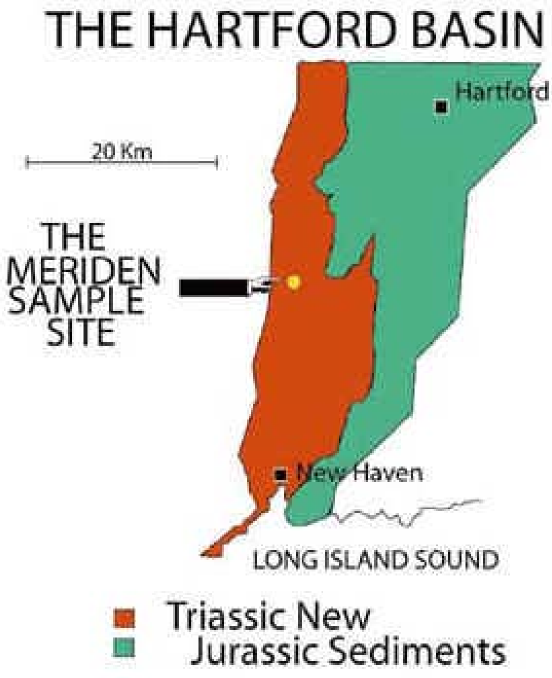

Figure 1: Map of the Hartford Basin, Connecticut, USA, showing the location of a studied section of the New Haven Arkose.

Petrographic Techniques:

Thin sections were examined under plane light and incidental light to investigate the variety of cement fabrics. Additionally we examined the thin sections with cathodoluminescence (CL), a technique commonly used for the study of diagenesis of carbonates because trace elements such as Fe and Mn quench and excite luminescence in a sample. Often CL shows generations of calcite that could not have been easily recognized with standard petrographic examination. Additionally, since the mobility of Fe and Mn is controlled by the redox state of the fluid (Meyers, 1974) the CL technique allows a qualitative evaluation of the redox changes at the time that the calcite was precipitated.

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Discussion:

Our focus is a detailed study of two of the multiple cycles of a section near Meridan, Connecticut (Figure 1; Figure 2; Figure 3) to try and understand how generations of calcite that Wang et al. (1998) recognize from the overbank claystones relate to the calcite that cements the overlying channel sand deposits. Further we look at differences in the calcite cement generations in the sandstone from bottom to top of the cycle to better understand the cementation history of the sandstone. The base of the overlying channel sand deposit is highly cemented with calcite (Figure 2; Figure 3).

Figure 2: Photo of one cycle from the Meriden section showing an overbank claystone on the bottom with an overlying channel sandstone deposit. Vertical structures we interpret as tap roots penetrate the channel sandstone and stand out due to the gleying of the rock around these features. Cherri is 5’ 6” and is pointing to vertical tap roots. The base of the sandstone is gleyed and cemented with calcite.

Figure 3**:** Field shot of the Meriden section showing calcite cemented base of the overlying channel sandstone deposit that appears drab in color. Below is the overbank deposit that exhibits bleaching associated with sheet cracks. Note, similar textures are not observed at the *bases* of overbank deposits.

Calcite cements in the overbank deposits have a pervasive horizontal orientation and are associated with gleying of the surrounding rock (Figure 3; Figure 4). These features are considered sheet cracks by Wang et al. (1998). Sheet cracks are planar cracks attributed to shrinkage of sediment due to dewatering. They are commonly parallel to the bedding and in the New Haven Arkose they are filled with calcite. The gleyed areas are not all filled with calcite but since they have a similar geometry to areas that are filled with calcite we interpret that the fluid responsible for this diagenesis was reducing (so Fe is leached) and supersaturated with respect to calcite. Our petrographic examination of the overbank cements shows a dull-luminescent micritic calcite occurring as first generation (Figure 5B.), similar to that observed by Wang et al. (1998). The second generation is the non-luminescing sparry calcite and the third generation is the brightly luminescing calcite (Figure 5C and 5D). These generations were also recognized by Wang et al. (1998) and the micrite (1^{st}) generation is 212 ± 2 Ma based on U-Pb dating. Both of the first two generations of calcite have broken apart grains (Figure 5A) and separated mudstone layers by as much as a centimeter (Figure 6A).

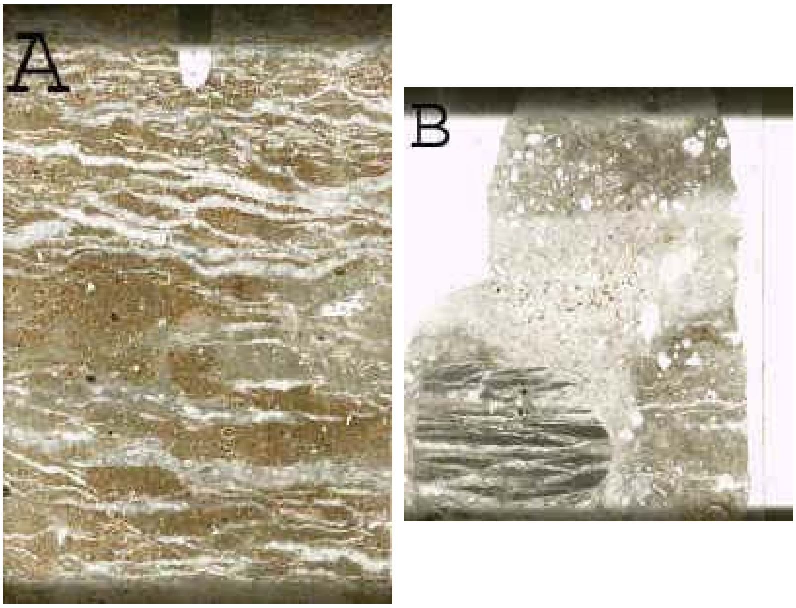


Figure 4: A) A red mudstone with a horizontal fabric created by gleyed veins that are often filled with calcite. B) is a drab channel sandstone with a brecciated metamorphic rock fragment. Many other grains are shattered in this manner and all of the grains show a floating texture requiring displacive calcite growth. Note blocky calcite cuts across veining in the host rock and the metamorphic rock fragment.

Thin section examination of sandstone samples from the bottom of the channel deposit shows sandstone grains floating in calcite cement. The top of the sandstone is grain supported although it is also well cemented with calcite. The types of cements recognized in the base of the channel deposit are micritic calcite, blocky calcite (sparry), and a fluid inclusion rich calcite. The micrite and blocky calcite generations break apart grains and have grains floating in them (Figure 6A; and Figure 6E). This geometry requires that the calcite grew displacively and this seems to require early formation because this type of calcite growth is not expected with much overburden. A layered brightly luminescent calcite is the first generation of cement (Figure 6C and 6D), although it is not always seen prior to the precipitation of prismatic calcite. Prismatic calcite (blade like) cement is the second generation in the sandstone and it formed perpendicular to the grain surface (Figure 6G and 6H). We interpret this prismatic calcite as forming in the phreatic zone analogous to the model of Rossinsky et al (1992). Although the prismatic calcite appears as a pervasive coating on sand grains (Figure 6A), not all veins of calcite exhibit this prismatic calcite (Figure 6G and 6H). Neither of these first two generations of calcite are not recognized in the overbank deposits. Micritic calcite follows prismatic calcite and is the third generation of calcite. This micritic calcite may be equivalent to Wang et al.'s (1998) first generation cement. The forth generation of calcite is a blocky calcite that has a variety of crystal sizes 140 microns to 340 microns (Figure 6I and 6K) and is zoned in CL (Figure 6J and 6L). This forth generation of calcite clearly cuts the horizontal veins defined by generations one and two (Figure 4B). A fifth generation of calcite is fluid inclusion rich and is brightly luminescent (Figure 7A and 7B). We also see fluid inclusion rich calcite in the center of large crystals (Figure 6L) followed by an oscillatory-zoned calcite generation. The fluid inclusion rich calcite has blotchy luminescence and may be the product of alteration of an earlier generation. This fluid inclusion rich calcite appears to line cavities in the rock and is not observed within the overbank deposits.

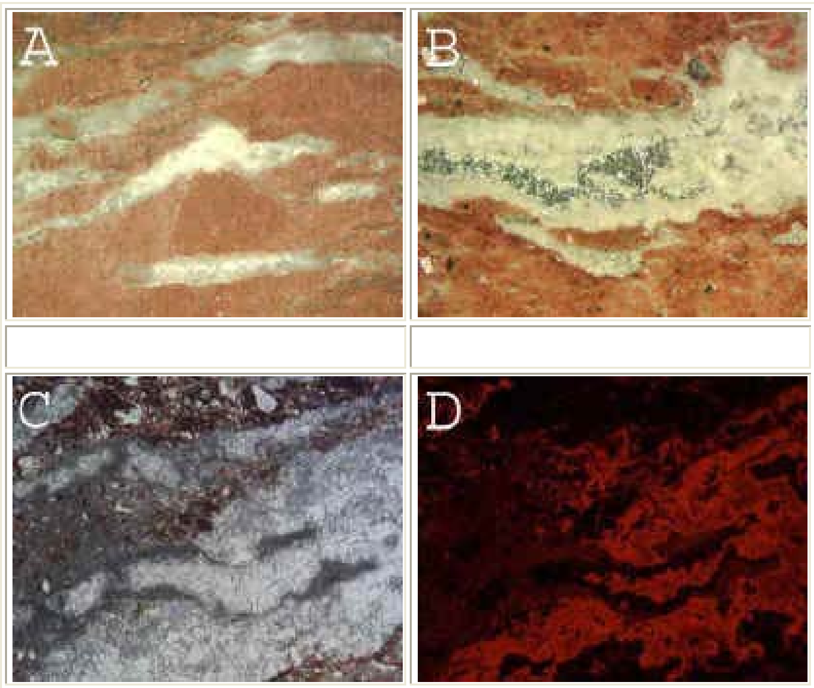


Figure 5: **A)** Photomicrograph of a clast from the overbank deposit that is broken in situ and separated by calcite. Scale is 2cm across. **B**) Blackcard image of overbank deposit using black card technique. White micritic calcite as first generation calcite followed by the clear blocky calcite as second generation. Scale is 2cm. **C)** Plane light photomicrograph of mudstone deposit exhibiting three generations of calcite. The first is micritic calcite, the second is non-luminescing calcite and the third is blocky calcite. The center of the quadrant also exhibits alveolar textures. Scale is 0.6mm wide. **D)** Catholuminescence of the same area as C showing three generations of calcite. The first appears to be dull-luminescing micrite calcite. The second generation is a non-

luminescing sparry calcite that is followed by the third generation of brightly luminescing calcite. Scale is 0.6mm wide.

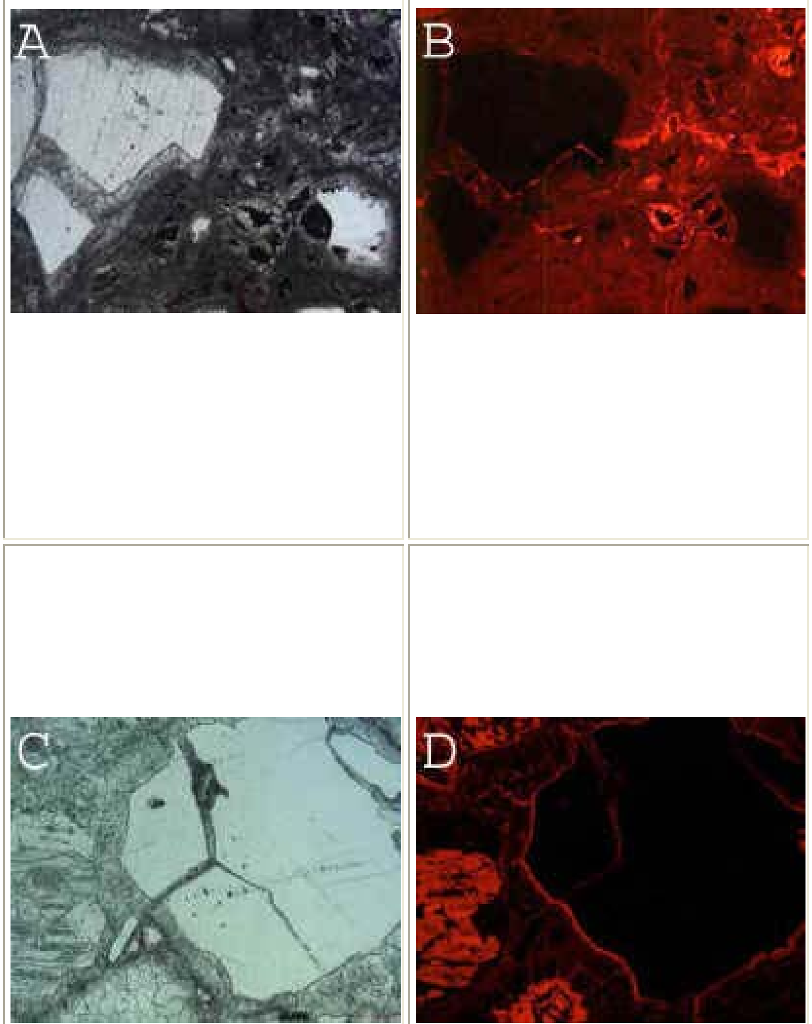
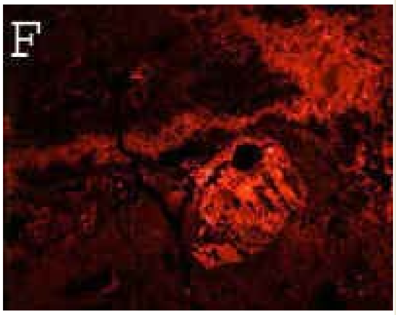


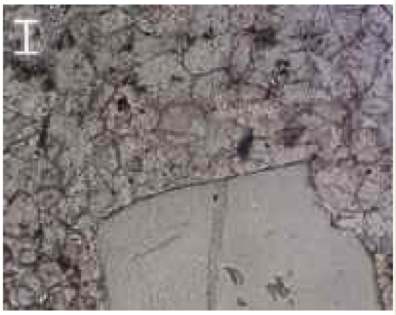
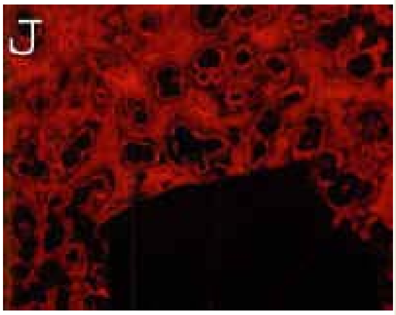
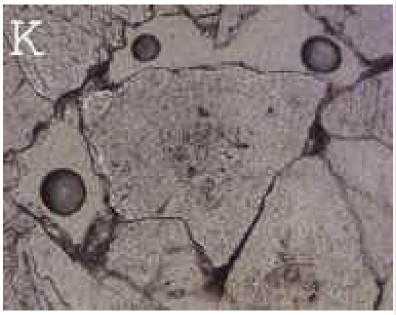
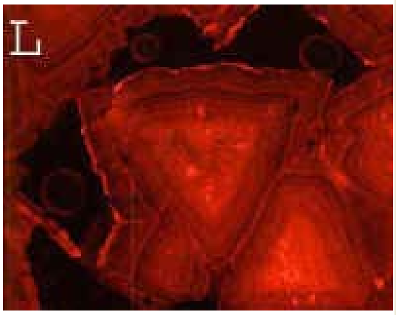
Figure 6:
A) Plane light photomicrograph of a broken quartz grain coated by prismatic calcite. This and other small grains are floating in micritic calcite**.**
B) Catholuminescence of same area as A. There is a bright rim of calcite on the quartz grain that is not easily seen in plane light, followed by the non-luminescing bladed calcite, followed by dull-luminescent micritic calcite, followed by bright-luminescent blocky calcite.

C) Plane light photomicrograph of channel sand showing a broken grain coated by prismatic calcite. Note altered feldspar grain to the left.
D) Catholuminescence of the same area as C showing a brightly luminescent calcite (first generation) that lines the contour of the quartz grain as in B. On the left is a feldspar grain that has been replaced by bright luminescent calcite.



E) Plane light photomicrograph showing micrite calcite along with blocky calcite occurring in the overlying channel sand deposit. Sand grains are floating among these two generations of calcite.
F) CL of E that exhibits dull- luminescent micritic calcite followed by bright-luminescent blocky calcite. Note grain replaced by bright luminescing calcite near center.

G) Photomicrograph using the black card technique of Folk (1987) showing three generations of calcite in the channel sand deposit. Prismatic calcite occurs as first generation in a few veins present in the metamorphic rock fragment. The second generation is micritic calcite and this is followed by blocky calcite.
H) Magnified (0.3cm or 3mm) image of G that shows prismatic calcite occurring as first generation calcite. Notice that in figure G, not all calcite veins display prismatic calcite as occurring first, however, both photomicrographs show micrite occurring as

		second generation followed by blocky calcite as the third generation.
		**I)** PL of overlying channel sand deposits with quartz grain floating in calcite deposits that are of the order of 140microns. **J)** CL of the same area as I showing oscillatory zoning of calcite deposits. The centers of zoned calcite crystals do not exhibit any luminescence as in the centers of bigger calcite crystals such as Figure K and L.
		**K)** PL of photomicrograph of larger calcite crystals of the order of 340 microns within the overlying channel sand deposits. **L)** CL of the same area as K showing oscillatory zoning. This calcite is cored by fluid inclusion rich bright luminescing calcite. More study is needed to determine the timing relationships of this generation of calcite. It could be the result of later alteration. However, we tentatively relate it to the fluid inclusion rich calcite that lines veins in Figure 7A and 7B. Scale for all images is 0.6mm.

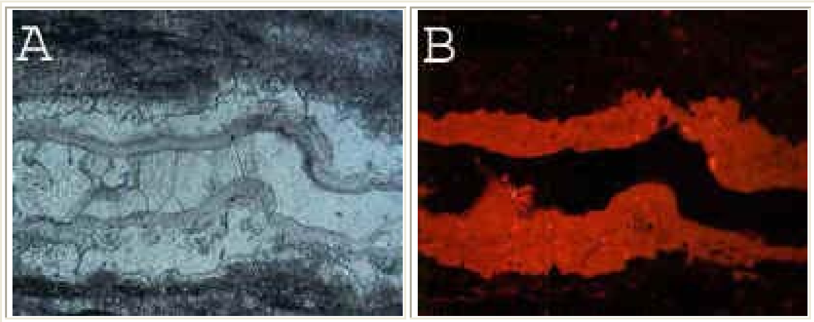


Figure 7: A) PL photomicrograph showing a vein like fluid inclusion rich calcite as occurring after deposition of blocky calcite. **B)** CL of A showing the first generation of calcite to be blocky and non-luminescent. This is followed by a brightly luminescent calcite with zoning followed by a fluid inclusion rich calcite that is also followed by a zoned brightly luminescing calcite. Scale is 0.6mm wide.

Our observations have led to the interpretation that the channel sands were permeable layers that water could percolate through. The passage of water through the underlying mudstone layer was slowed due to its lower permeability, thereby creating a perched water table. Calcite cements display displacive fabrics such as floating grains and grains that are broken and filled with calcite at the base of the sandstone layers and the top of the underlying overbank deposit. However, near the top of the sandstone layer, the grains are in contact and the cement appears to be solely one generation of brightly luminescing calcite. We tenatively interpret this as equivalent to the third generation of calcite recognized by Wang et al. (1998) in the mudstone. If so, this calcite may be as young as 81 ± 11 Ma (Wang et al., 1998). Although our study reveals all of the three generations of calcite recognized by Wang et al. (1998) in the mudstone, we see at least 5 additional generations of calcite at the base of the overlying sandstone. Like Pimentel et al. (1996) our field observations show color-mottling (gleyed areas) occurring within the fluvial sequence of the New Haven Arkose. Such features are interpreted as the products of shallow reducing groundwater rather than true soil formation (Pimentel et al., 1996). Supporting this interpretation is the pervasive bladed calcite that coats grains interpreted by Rossinsky et al. (1992) as a phreatic fabric.

References:

Folk R. L. (1959) Pratical petrographic classification of limestones. Bull. Am. Ass. Petro. Geol., 43, p.1-38.

Meyers W. J. (1974) Carbonate cement stratigraphy of the Lake Valley formation (Mississippian) Sacramento Mountains, New Mexico. Journal of Sedimentary Research, 44, p. 837-861.

Olsen, P. E. (1997,) Stratigraphic record of the early Mesozoic breakup of Pangea in the Laurasia Gondwana rift system: Annual Review of Earth and planetary Sciences, 25, p. 337-401.

Pimentel N.L. (1996) Distinguishing early groundwater alteration effects from pedogenesis in ancient alluvial basins: examples from the Palaeogene of southern Portugal. Sedimentary Geology, 105, p.1-10.

Rossinsky V. Wanless, H.R. Swart, P.K. (1992) Penetrative calcretes and their stratigraphic implications. Geology, 20, p. 331-334.

Wang Z. S., Rasbury, E.T., Hanson, G.N., and Meyers, W.J., (1998) Using the U-Pb system of calcretes to date the time of sedimentation of clastic sedimentary rocks. Geochimica Et Cosmochimica Acta, 62 (16), 2823-2835.