A Comparison by SEM of Texture and Composition in Hematite and Chamosite Ooids from the Birmingham Ironstones of Alabama

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Petrography

A. PHANEROZOIC IRONSTONES are typically ooidal with ooids composed of Limonite, Hematite, or Chamosite/Berthierine.

BUT

1. Which of these minerals are primary precipitates and which formed by secondary replacement?
2. How are the ooids formed? By organic or inorganic processes; microbial metabolism or direct physico-chemical precipitation?
3. What was the origin of the iron; lateritic weathering on a terrestrial hinterland or mobilization from marine sediments?

The answers to these questions are critical to understanding the origin of ironstones

B. METHODOLOGY

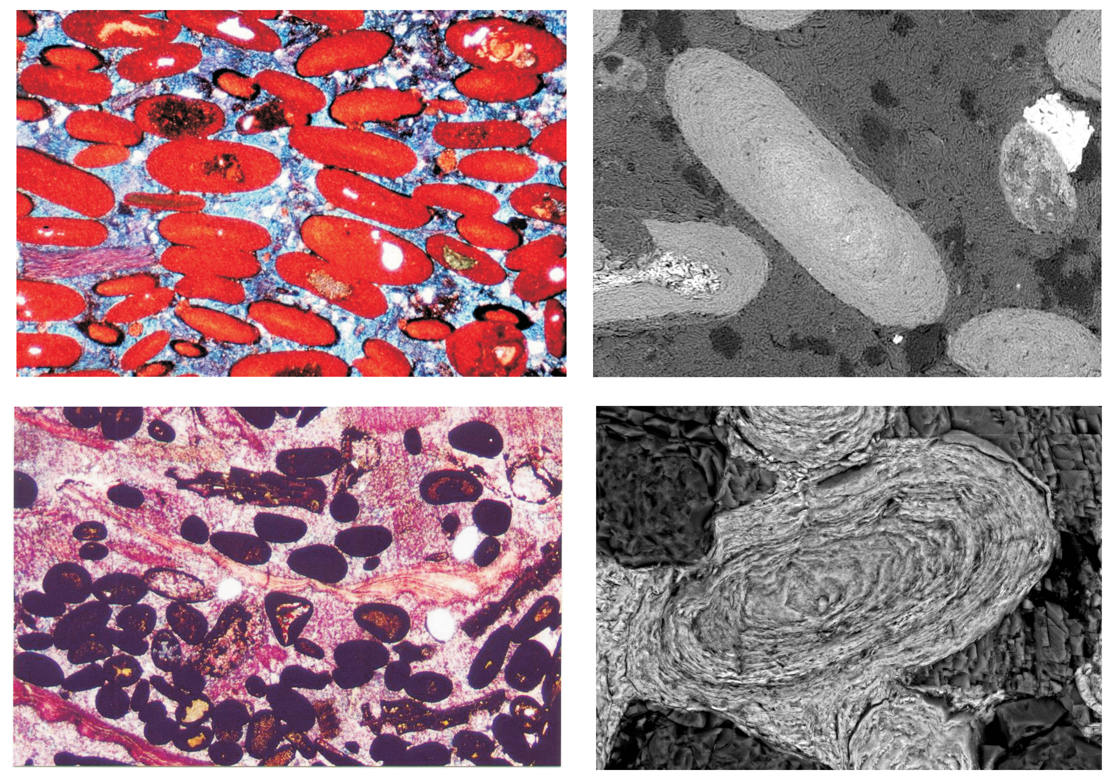
To help answer these questions ooids from localities of various ages (Ordovician, Silurian, Jurassic) were examined under light microscope (transmitted & reflected light) and by scanning electron microscope with ED spectrometer.

Chamosite Ooids

Consist of oriented and unoriented crystals arranged around various nucleii. The perfection of lamination observed by light microscope suggests the oriented chamosite is a primary precipitate. But chamosite is a ferrous iron aluminosilicate that is enigmatic in high energy, oxic facies.

Hematite Ooids

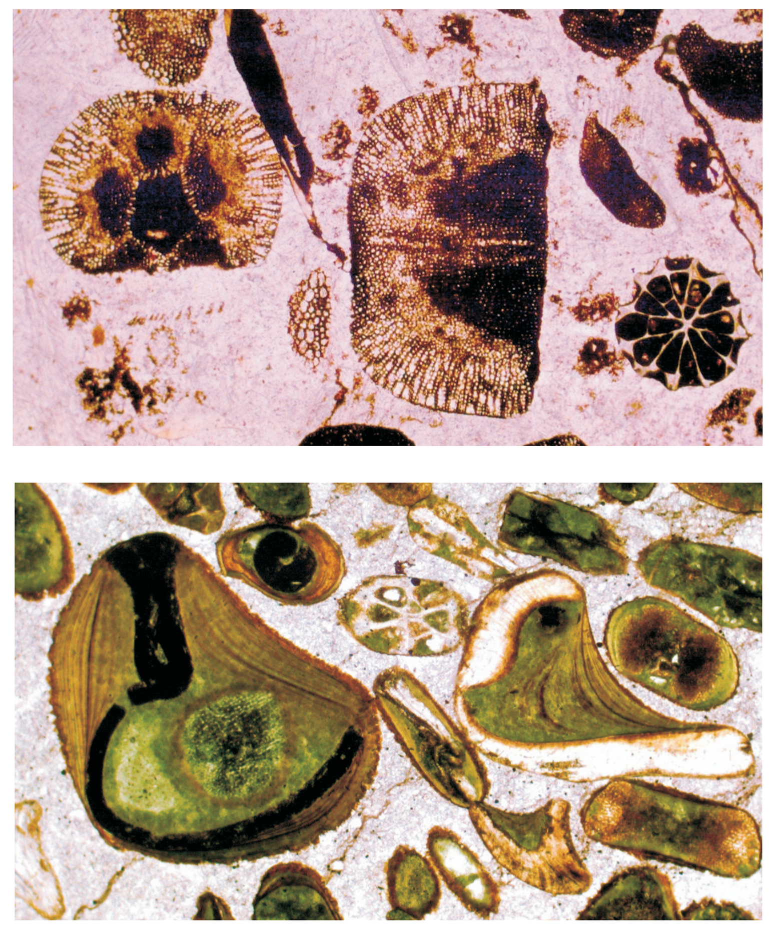
Appear almost structureless under light microscope but reveal delicate lamination under SEM. Is the hematite formed by oxidation of chamosite or was chamosite formed by reduction from iron oxide?



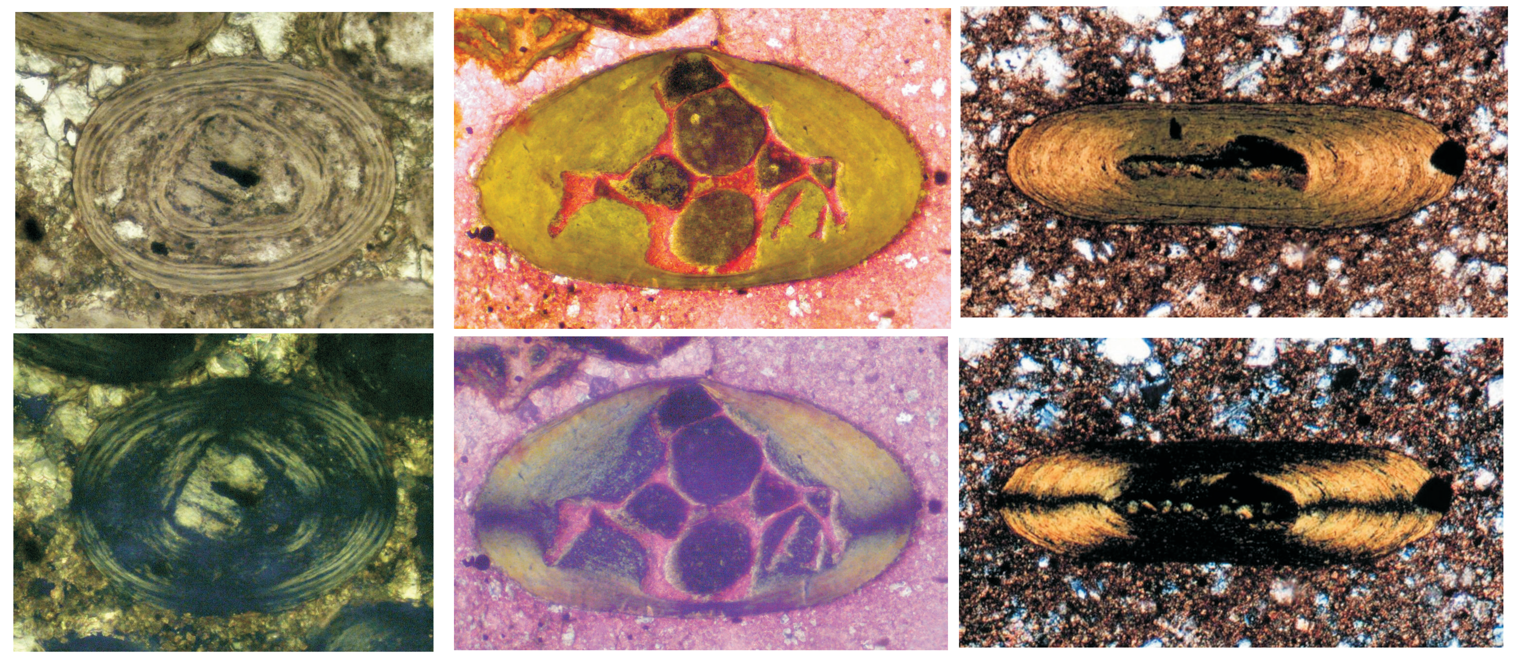
Flaxseed ooids from the Sequatchie Formation (top) and Red Mountain Formation (bottom). Internal fabric is obscured in thin sections but evident in back-scattered electron images. Thin sections are stained for identification of carbonates. Top left image transmitted & reflected light, bottom left transmitted light only. Ooids ~ 1mm diameter.

C. FLAXSEED SHAPE

Whereas modern aragonite ooids are subspherical as would be expected for grains formed by precipitation around rolling nuclei, ironstone ooids are typically discoidal or 'flaxseed' in shape. From an examination of lamination in the cortex this is an original growth form rather than the result of compaction. The similarity in shape between chamosite and hematite ooids from the same deposit suggests that one mineral may be a pseudomorph of the other. But which is the original?



Pelmatozoan debris with the stereome invaded by hematite; possibly as a consequence of microbial decay (top). Shell debris and pelmatozoans with coatings of ?stromatolitic chamosite (bottom). Red Mountain Fmn, Silurian, Alabama.



From left to right: Chamosite ooids from the Cleveland Ironstone (Early Jurassic, NE England), Red Mountain Fmn (Early Silurian, Alabama) and Sequatchie Fmn (Late Ordovician, NW Georgia). Note 'flaxseed' shape and Brewster cross under crossed polars. Nuclei include rounded chamosite crystals, fossil fragments and peloids. Ooids are ~ 1mm diameter. Calcite is stained pink in middle slide.

D. MICROBIAL ORIGIN

Several lines of evidence suggest that ironstone ooids may be microbial.

1. The peculiar discoidal shape is reminiscent of stromatolitic growth.

2. Thickened, stromatolitic laminae are common in the protection of shell debris.

3. The manner in which iron mineralization follows the stereome in pelmatozoan debris suggests early precipitation (before pore-filling by cement) perhaps by microbes within decaying soft tissue.

4. Stromatolitic chamosite has been reported from Jurassic ironstones.

5. Chamosite has been found associated with microbial consortia in the Amazon basin.

6. Iron bacteria living in transitional environments between aerobic and anaerobic are known to both oxidize and reduce iron during metabolism depending on whether electron donors or acceptors are required. Clay minerals with iron are used as electron acceptors during reduction.

Chemistry

Chamosite Ooids

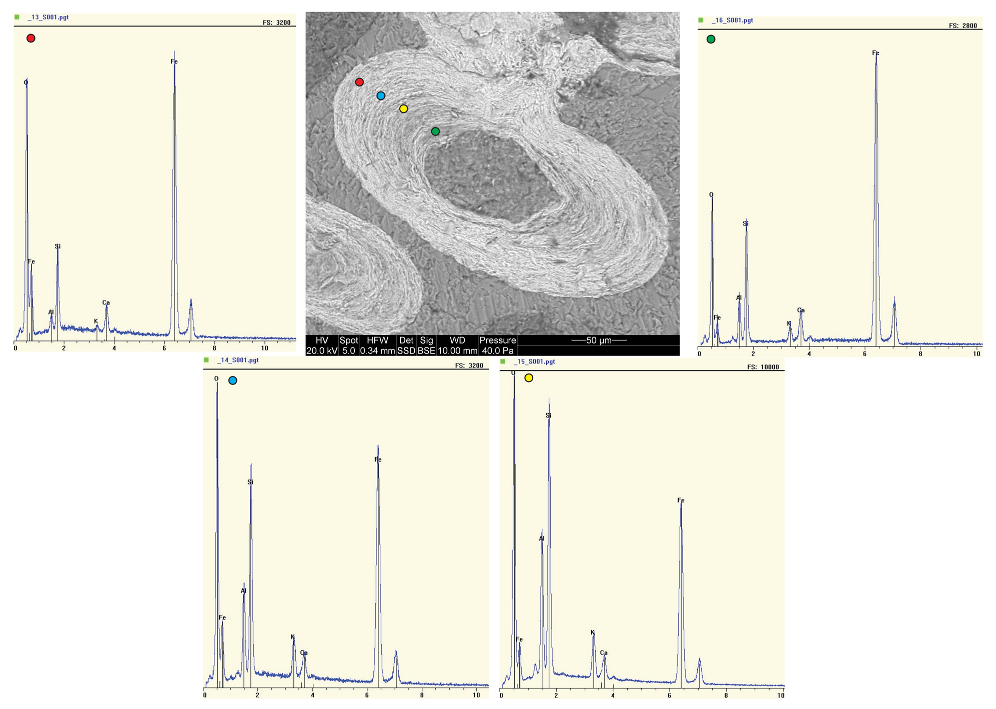
As expected from formula ($2SiO_2$ Al_2O_3 $3FeO$ aq.) chamosite ooids show cortices dominated by Fe, Al, and Si. Some fluorapatite is also present in ooids from the Red Mountain Formation

Hematite Ooids

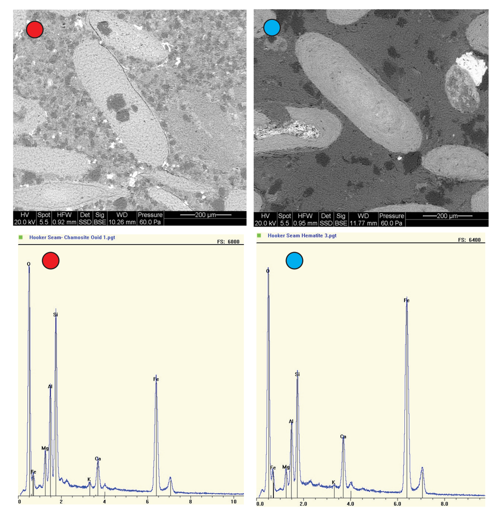
Hematite ooids from the Sequatchie Formation seem to have formed by replacement of chamosite and contain residual Si and Al.

Hematite ooids from the Red Mountain Formation consist of iron oxide contaminated with Si, Al, and K, probably illite. They are unlikely to have formed by the replacement of chamosite. The illite is more likely residual; inherited from the source area.

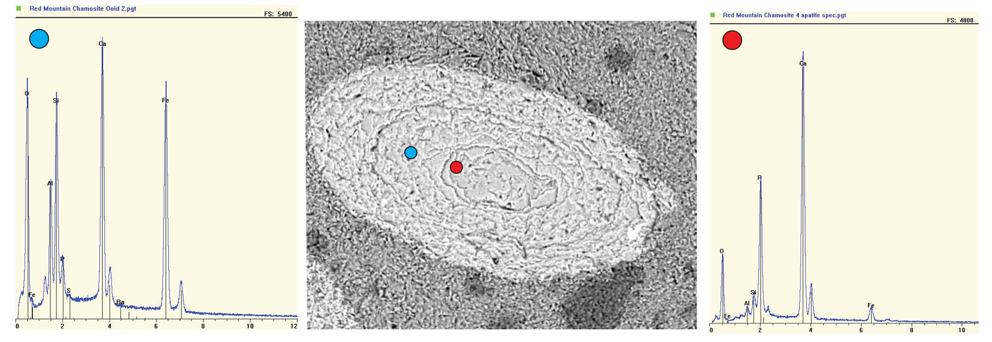
The presence of residual illite strongly suggests that iron was transported to the depositional environment in a colloidal complex with detrital clay, perhaps associated with bacterial consortia as in the modern Amazon basin.



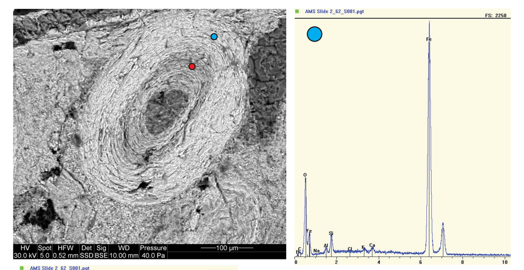
Chemical variation in the lamination of the cortex of a hematite ooid from the Irondale Seam, (Red Mountain Fmn. Alabama). Note changes in Fe relative to Si, Al & K. Ca peak may be result of calcite cement.

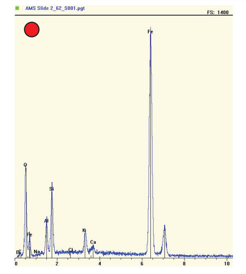


Comparison between chamosite & hematite ooids from the Hooker Seam (Sequatchie Formation, Upper Ordovician, northwest Georgia). Hematite is enriched in iron and depleted in silica and alumina when compared to chamosite. Hematite is formed by oxidation of chamosite.

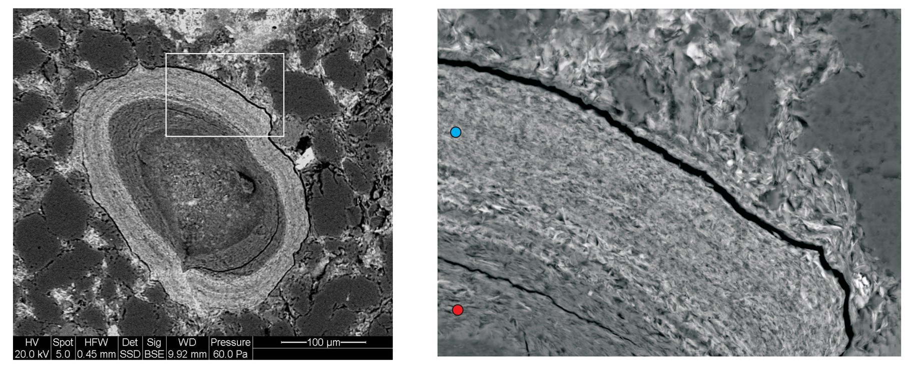


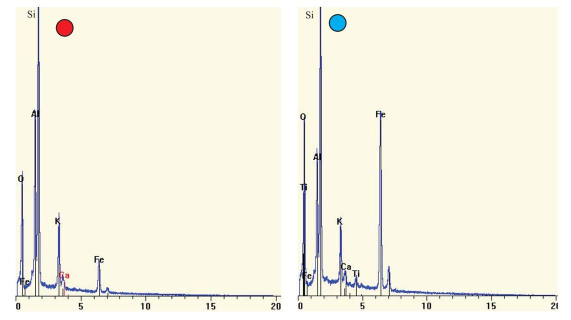
Ooid from Red Mountain Fmn (Silurian, Alabama) with cortex of chamosite & fluorapatite





Hematite ooid from the Irondale Seam (Silurian Red Mountain Fmn, Alabama) with residual illite (Si, Al, K) especially in the inner cortex





Hematite ooid from the Ida Seam (Silurian Red Mountain Fmn, Alabama) with residual illite (Si. Al, K) especially in the inner cortex.

Conclusions

1. Chamosite and hematite ooids from the Late Ordovician Sequatchie Formation are similar in form and chemistry except for a slight enrichment in iron relative to silica and alumina. The iron oxide was formed by the oxidation of chamosite on the sea floor.

2. Differences in chemistry between chamosite and hematite ooids from the Silurian Red Mountain Formation preclude replacement of one mineral by the other. Both may be original minerals.

3. The presence of illite as a residual mineral in hematite ooids from the Red Mountain Formation supports the hypothesis that iron was transported from the hinterland in combination with colloidal clays.

4. The conversion of clay minerals and iron oxihydroxide to chamosite or impure iron oxide was carried out during precipitation by microbes on the sea floor and led to the enrichment of iron and leaching of Si, Al and K.

5. The 'flaxseed ' shape of the ooids is a stromatolitic fabric and the particular iron mineral probably related to the metabolism of the microbes within the ooids.