[PS]Giant Microbialites from the Green River Formation, Laney Member, Sand Wash Basin, Colorado*

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Abstract

The discovery of oil in large microbial carbonate reservoirs in the lacustrine Cretaceous pre-salt of Brazil and Angola has generated great interest in microbialites, lacustrine carbonates, and lacustrine systems in general. Recent and ancient analogs have been sought in order to develop models for the pre-salt to facilitate exploration; however, all analogs known to date lack one or more features reported from the pre-salt. The Eocene Green River Formation of Wyoming, Utah, and Colorado may be the best overall analog. The lacustrine system covered 77,000+ km^2, is over 2,000 m thick, contains stevensite, has numerous subaqueous spring buildups, is rich in microbialites (many with shrubs), and has large microbialite bioherms. Giant microbialites from the Laney Member in the Sand Wash Basin, Colorado, provide a new example of these large lacustrine microbialites. The microbialites occur as individual and amalgamated structures in an ooid-dominated unit covering an area of ~2 km^2. Some amalgamated structures exceed 5 m in height and 10s of meters in width. Many of the microbialites encrusted logs. Individual and amalgamated microbialites are complex, consisting of cm-thick, successive layers of boundstone, cm-wide columns, shrubs, cm-size laterally linked domical stromatolites, and planar laminated stromatolites. Shrubs, planar laminated stromatolites, and domical stromatolites are often silicified. A number of these microbialites occur as individual columns, 4+ m wide and up to 5.5 m tall, with laminae and layers continuous from base to top indicating a 5.5 m of synoptic relief (sticking up above the lake floor). These are among the greatest synoptic relief lacustrine microbialites known. Like the large bioherms at Little Mesa (Wilkins Peak Member), these large Laney Member microbialites grew in a nearshore environment several kilometers from nearby mountains, were associated with nearby faults, possibly formed on somewhat steeper gradients than more common Green River microbialite biostromes, and likely were supplied with calcium-rich waters from rivers and/or springs in the area.

Giant Microbialites from the Green River Formation, Laney Member, Sand Wash Basin, Colorado

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2. The Green River Formation

The Eocene Green River Formation is the most extensively studied lacustrine system in the world. It crops out in Wyoming, Colorado, and Utah, and was deposited in three lakes (Lakes Gosiute and Uinta, and Fossil Lake), which were infrequently connected. The lakes system had a combined hydrographic basin of 349,000 km^2 (Dyni, 1981). Lake Gosiute at its maximum extent covered 40,150 km^2 (Bradley and Eugster, 1969). The formation was deposited over a 5 m.y. interval, from 53.5 Ma to 48.5 Ma, during which the Early Eocene Climatic Optimum occurred (Smith et al., 2003).

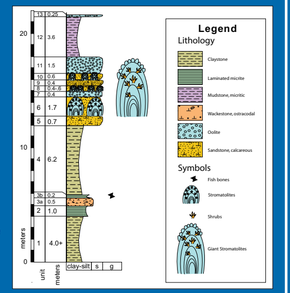
The Green River Formation consists of over 2000 m of lacustrine and alluvial sediments that were deposited in lake systems that ranged from overfilled, to balanced-filled, to underfilled. Two principle basins were involved, the Greater Green River Basin and the Uinta-Piceance Creek Basin. These basins are made up of smaller, subbasins. The Greater Green River Basin contains the Bridger, Great Divide, Washakie, and Sand Wash subbasins.

The stromatolites described here occur in the Sand Wash Basin, in the Laney Member.

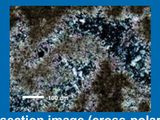
Green River Lakes

4. Measured Section of Giant Microbialite-Bearing Succession

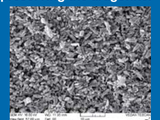
Fine sediments such as calcareous claystone and laminated mudstone dominate the lower part of the section. These grade vertically into calcareous sandstone, oolite, and coated ostracods associated with microbialites ranging from 0.4 to 5.5 m high and up to 7 m wide. Finally oolite and coated sand grains bury the microbialites. We interpret this sequence as shallowing upward. The microbialites grew in shallow, near-shore depositional system that probably ranged from 1-6 meters deep (indicated by the synoptic relief of the largest microbialites). Abundant coated quartz grains, coated ostracods, and oolite also indicate a near-shore environment that experienced frequent storm and wave activity. Spring-water input along a fault provided abundant calcium, enhancing microbialite growth.



6. Aragonite



Thin section image (cross-polarized light) of shrubs. Acicular aragonite cements coating shrubs. Silica filled voids preserving the aragonite.



SEM of aragonite from laminated mudstones 4 km north (basinward) of main outcrop.

1. Abstract

The discovery of oil in large microbial carbonate reservoirs in the lacustrine Cretaceous pre-salt of Brazil and Angola has generated great interest in microbialites, lacustrine carbonates, and lacustrine systems in general. Recent and ancient analogs have been sought in order to develop models for the pre-salt to facilitate exploration; however, all analogs known to date lack one or more features reported from the pre-salt.

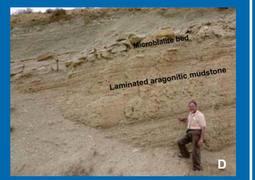
The Eocene Green River Formation of Wyoming, Utah, and Colorado may be the best overall analog. The lacustrine system covered 77,000+ km^2, is over 2000 m thick, contains stevensite, has numerous subaqueous spring buildups, is rich in microbialites (many with shrubs), and has large microbialite bioherms.

Giant microbialites from the Laney Member in the Sand Wash Basin, Colorado, provide a new example of these large lacustrine microbialites. The microbialites occur as individual and amalgamated structures in an ooid-dominated unit covering an area of ~2 km^2. Some amalgamated structures exceed 5 m in height and 10s of meters in width. Many of the microbialites encrusted logs. Individual and amalgamated microbialites are complex, consisting of cm-thick, successive layers of boundstone, cm-wide columns, shrubs, cm-size laterally linked domical stromatolites, and planar laminated stromatolites. Shrubs, planar laminated stromatolites, and domical stromatolites are often silicified. A number of these microbialites occur as individual columns, 7+ m wide and up to 5.5 m tall, with laminae and layers continuous from base to top indicating 5.5 m of synoptic relief (sticking up above the lake floor). These are among the greatest synoptic relief lacustrine microbialites known.

Like the large bioherms at Little Mesa (Wilkins Peak Member), these large Laney Member microbialites grew in a nearshore environment several kilometers from nearby mountains, were associated with nearby faults, possibly formed on somewhat steeper gradients than more common Green River microbialite biostromes, and likely were supplied with calcium-rich waters from rivers and/or springs in the area.

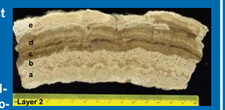
3. Giant and Associated Microbialites

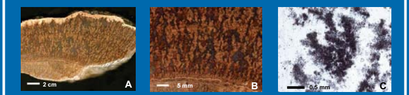
The Eocene Green River Formation contains what may be the richest and most diverse record of lacustrine stromatolites known (Awramik and Buchheim, 2012). Among the most spectacular are the giant stromatolites from the Laney Member in Sand Wash Basin. Some individuals are over 5.5 m tall and 7 m across. Associated with these giants are a whole array of smaller stromatolites (A, B, D). Many encrust logs (A, B). Layers contain different microbialites (C). The succession is traced basinward 4 km north, where it thins (D).



5. Microbialite Structure

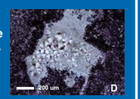
Giant microbialites consist of stacked layers, centimeters thick, of different stromatolites and boundstone. Layers can be traced from base to top of the microbialite. Layer 1 is composed of columnar stromatolites. Layer 2 directly overlies Layer 1 and consists of (a) columnar-layered stromatolites that grade into (b) shrubs, then (c) linked domes, back to (d) shrubs, and capped by (e) broader domes; c, d, and part of e are silicified.





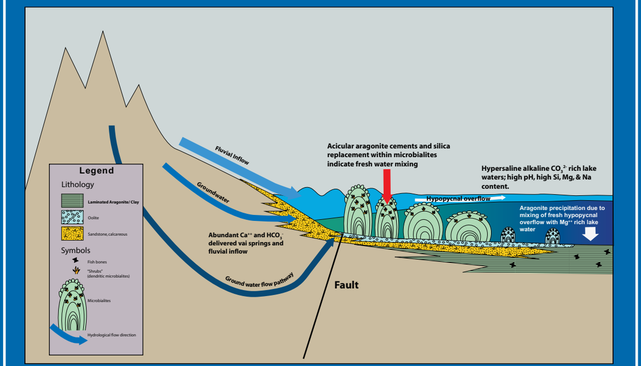
Layer composed of silicified shrubs. A. Slab with shrubs. B. Enlargement showing <1mm shrubs that grow into mm-scale shrubs. C. Photomicrograph showing peloidal nature of shrubs. Plain light.

D. Photomicrograph (cross-polarized light) of silica cement filling void between shrubs. Note the Maltese crosses.



7. Model Diagram for Giant Microbialites

Microbial growth is enhanced by hydrologic input via springs and fluvial water sources enriched in calcium carbonate. Hypersaline-alkaline (pH>9), HCO_3-rich lake waters are enriched with Si, Mg, and Na. Carbonates rapidly precipitate during mixing of inflow waters with ambient lake waters. Silica is precipitated as cements and replaces carbonates. Acicular aragonite cements precipitated within the microbialites along with silica. Aragonite is precipitated as whitings during mixing of hypopycnal overflow with the saline-alkaline lake water. This process has been documented in the Green River Formation (Buchheim and Surdam, 1981) and Searles Lake (Smith, 2009). Shrubs, components of the microbialites, probably grew in response to the abundant availability of calcium bicarbonate within the system.



8. Conclusions

1. Largest individual microbialites known from lacustrine environments. At least 5.5 m tall. Some 7 m in diameter.
2. Giant size likely the result of hydrologic input of Ca-rich water, and a delicate balance among subsidence, lake level, and microbial accretion.
3. Hypersaline-alkaline (pH>9), HCO_3-rich, lake water enriched with Si, Mg, and Na.
4. Acicular aragonite and silica cements are a consequence of mixing Ca-rich input waters with high Si, Mg, HCO_3^- pore and lake waters.

9. References

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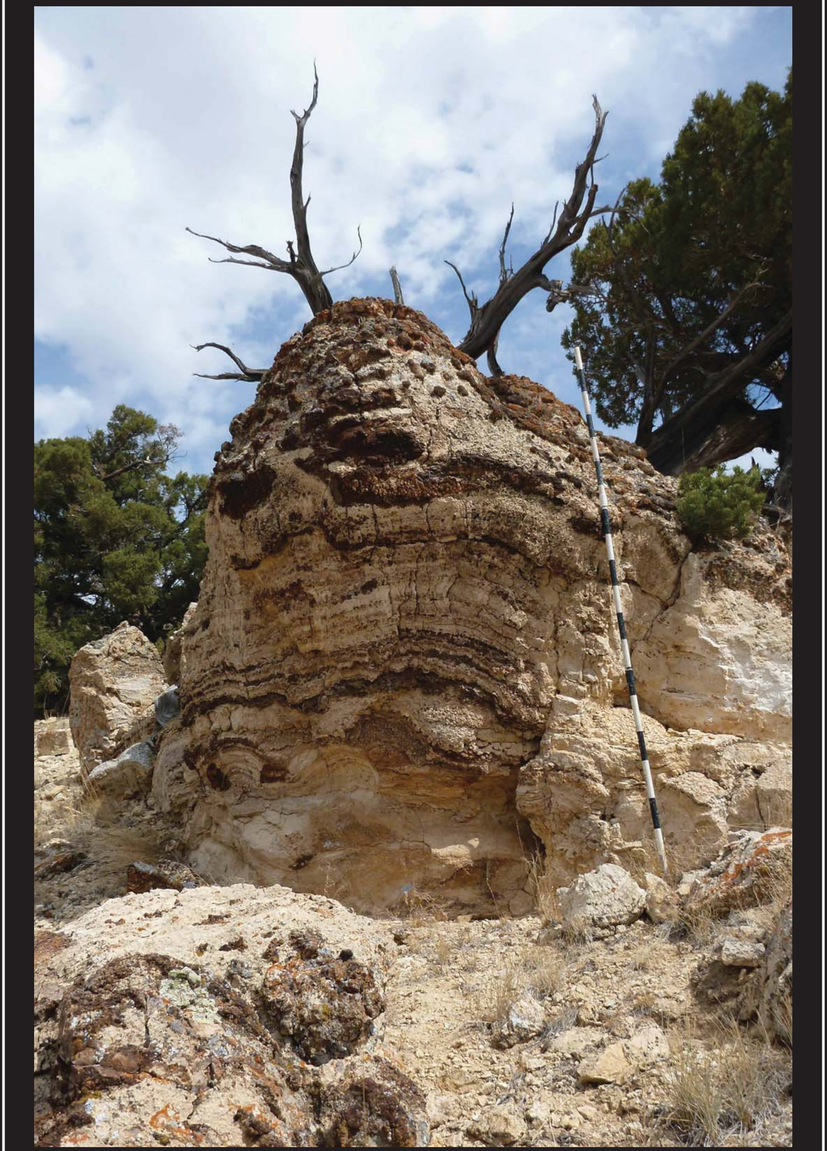
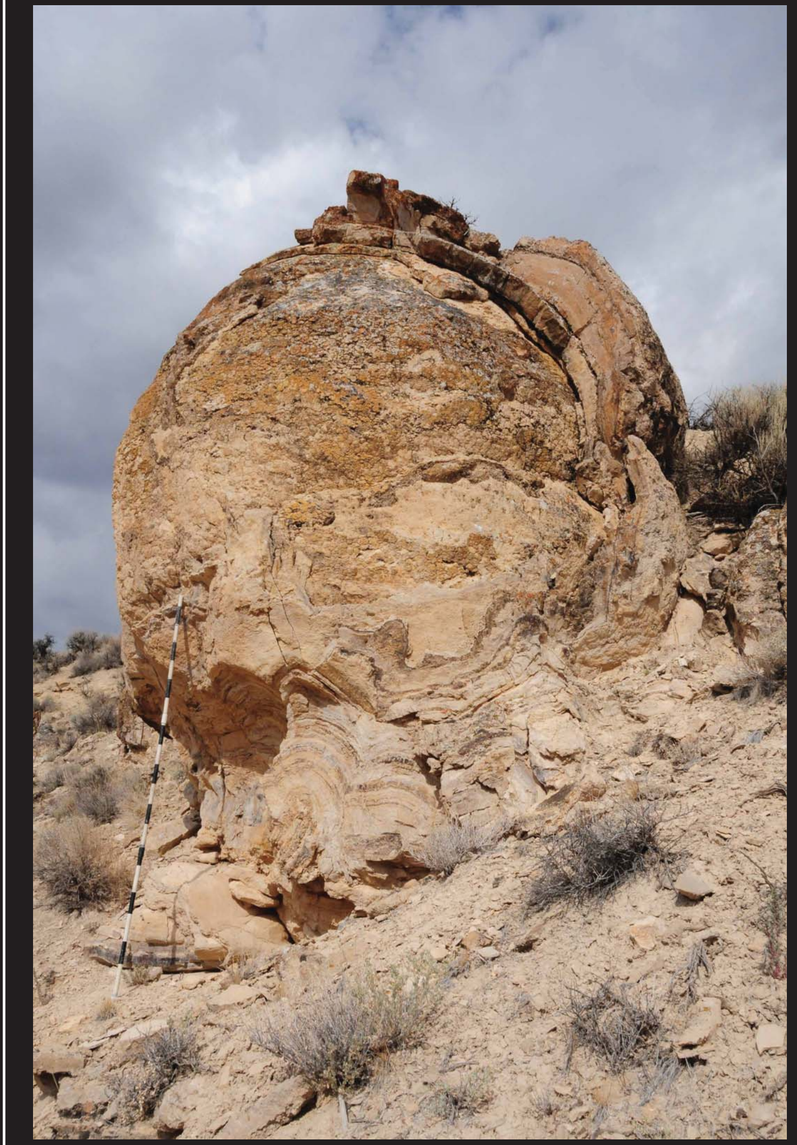


GIANT MICROBIALITES

These giant microbialites (stromatolites) had a synoptic relief (depositional surface) as much as 5.5 meters (image above). These are the largest "pure" (non-tufa) stromatolites of any lacustrine examples known. Jacob's staff is 2 meters.



GIANT MICROBIALITES The giant microbialites have an unusual mesostructure. Layers, a few cm thick, can be traced from base to top, and layers are composed of shrubs, laterally linked stromatolites, small columnar stromatolites, even ooids. Jacob's staff is 2m.