# Characterization of Microbialites in Bridger Bay, Antelope Island, Great Salt Lake, Utah


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## PUBLICATIONS

Chidsey, Thomas C., Vanden Berg, Michael D., and Eby, David E., 2015, Petrography and characterization of microbial carbonates and associated facies from modern Great Salt Lake and Uinta Basin's Eocene Green River Formation in Utah, USA. *in* Bosence, D.W.J., Gibbons, K.A., Le Heron, D.P., Morgan, W.A., Pritchard, T, and Vining, B.A. (eds.) Microbial Carbonates in Space and Time: Implications for Global Exploration and Production. Geological Society, London, Special Publications, 418.

Eby, David E., Chidsey, Thomas C., Vanden Berg, Michael D., and Laine, Michael D., 2012, Microbial carbonates from core and outcrop, Tertiary (Eocene) Green River Formation, Uinta Basin, Utah. AAPG annual meeting poster presentation, Long Beach, CA.



## ABSTRACT

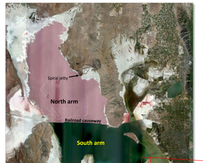
The shallow waters of Bridger Bay, on the northwestern tip of Antelope Island in the southern arm of hypersaline Great Salt Lake, support extensive microbial carbonate formation, especially in the north-northeast portion of the bay near Egg Island. Lake levels in the fall of 2014 were near 60-year lows (as low as 1278.1 m [4193.3 ft] AMSL, compared to the near-term historic average of about 1280 m [4200 ft]), giving unprecedented access to the microbial structures. Characterizing the microbialites of Bridger Bay, including facies delineation and aerial extent, can inform interpretations of similar deposits in the ancient rock record (e.g., Eocene Green River Formation), including potential petroleum reservoirs.

The goals of this project were to 1) characterize, in detail, the different types of microbial carbonates found in the bay, including thin, circular, domical microbialites; ring structures resulting from exposed collapsed domes; carbonate grains such as ooids and eroded pustular microbial growths; and large, thickly layered stromatolites; 2) delineate facies transitions from onshore to offshore, including exposed carbonate mud flats, remnants of older microbialite communities, ooid shoals, and offshore organic-rich mud; and 3) document the differences in the microbial communities from the sheltered waters of the bay (smaller, flat, superficial domal structures) and the windward side of the bay's northern spit (much larger, thickly layered stromatolites). The aforementioned characteristics were documented through routine field observations, petrographic analyses, and aerial photographs using a quadcopter mounted with a high-resolution video camera.

The dominant carbonate structures in Bridger Bay are domical microbialites, ranging in size from less than 0.5 m up to 2 m in diameter. The low-profile domical structures are composed of a partially lithified, mostly featureless (faintly laminated near the surface) outer crust about 10 to 20 cm thick, which covers unconsolidated ooids and mud. When submerged in the water, the outer surface of the structures is covered with unprecedented access to the microbial structures. Characterizing the microbialites of Bridger Bay, including facies delineation and aerial extent, can inform interpretations of similar deposits in the ancient rock record (e.g., Eocene Green River Formation), including potential petroleum reservoirs.

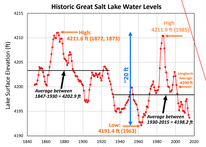
Several remnants of what are thought to be an older population of microbialites are also present near Bridger Bay at slightly higher elevations (1280-1283 m [4200-4210 ft]). Typically only the "roots" of these structures are preserved, but a few large, well-lithified, thickly layered stromatolites, up to 3 to 4 m in diameter, were found on the windward side of the spit of land connecting Antelope Island and Egg Island. These stromatolites are highly eroded but could have once been up to 4 m tall, possibly making them some of the largest stromatolites found in Great Salt Lake.


## BACKGROUND

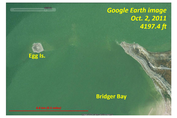



### General Characteristics of Great Salt Lake

- Remnant of Pleistocene Lake Bonneville
- 33rd largest lake in the world (largest fresh or saltwater lake in the United States after the Great Lakes)
- Averages 121 km (75 miles) long by 56 km (35 miles) wide
- Surface elevation: historical average (since 1847) ~1280 m (4200 ft) covering 4185 km$^2$ (1,034,000 acres)
- Lake level fluctuations: 0.3-0.6 m (1-2 ft) annually on average
- Maximum depth at average elevation (1280 m [4200 ft]): ~10 m (33 ft)
- Volume: 19 km$^3$ (15,390,000 acre-ft)
- Salinity: south arm = 5-22% (highly dependant on lake level and location), north arm = 24-26% (near salt-saturation point)
- Average chemical composition: chloride = 56%, sodium = 32%, sulfate = 7.0%, magnesium = 3.3%, potassium = 2.1%, calcium = 0.2%
- *Current conditions (June 2015): south arm = 14% - 1278.4 m (4194.3 ft), north arm = 25-26% - 1277.8 m (4192.4 ft), maximum water depth ~8.2 m (27 ft)*





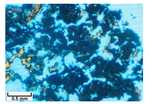




Microbialites ("bioherms") can be found throughout Great Salt Lake. This study focused on only one small area of the lake, the northern side of Bridger Bay, Antelope Island, to better understand spatial distributions and changing morphology of the microbialites with changing lake level (closeness to shore).

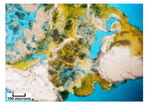
## PHOTOMICROGRAPHS

### Microbialite Examples from Bridger Bay, Antelope Island

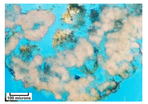
**Pustular microbialites - large number of discrete pustular microbial structures composed of very lightly lithified, clotted thrombolitic fabrics with moderate amounts of filamentous cells. The margins of some pustules display a honey-brown, highly organic crust. Detridal silicate and carbonate grains are incorporated into some pustules.**




Close-up view of a microbial pustule structure with honey-brown organic crust and filamentous cells bridging pores as well as incipient acicular cements. (Plane light)

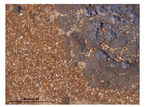



Small microbial pustule incorporating two silicate silt grains into honey-brown organic crust. (Plane light w/ white card technique)

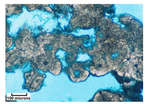



Heavily calcified "lumpy/bumpy" structures within a small microbial pustule. (Plane light w/ white card technique)

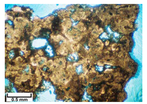
**Coarse lag containing large angular fragments of microbial boundstones.**




Flat microbialite (upper right) surrounded by coarse lag. The pustular grains are thought to be eroded remnants from the top of the microbialites, re-deposited in the surrounding lows via wave action.



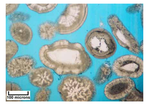

Overview of well-defined spherulitic structures within a microbial fabric. (Plane light)



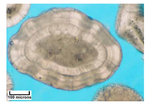

View of the internal lumpy texture of a well-lithified microbialite fragment. Note the internal primary constructional pores. (Plane light)

### Examples of Grains and Cements from Bridger Bay, Antelope Island

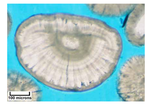
**Hypersaline ooids which display extensive radial recrystallization and cerebroid margins. Many ooids are broken across their cortex layers, and then are re-coated (regenerated ooids). Nuclei include quartz grains, well-rounded peloids (some with micro-pyrite), broken ooid fragments, chert grains, igneous (volcanic?) rock fragments, and microbialite fragments.**



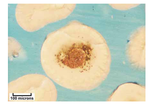

Ooids displaying various characteristics such as radial recrystallization, cerebroid margins, and regeneration. Note cerebroid ooid with quartz nucleus near the center of the image. (Plane light w/ white card technique)




Single large cerebroid ooid. (Plane light w/ white card technique)

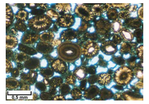



Single regenerated ooid with broken nucleus. (Plane light)

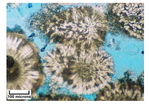



Single ooid with a brassy pyritic nucleus. (Plane light and reflected light)

**Moderately well-cemented oolitic clasts within a beachrock crust. Ooid nuclei include angular siliciclastic grains, rounded pellets, and occasional microbial fragments. Cements include micrite (precipitated from Great Salt Lake water either microbially or inorganically), isopachous microfibrous cement (from phreatic Salt Lake brines [inorganic]), acicular patchy cements of unknown origin, radially bladed cements that inherit that crystal orientation and morphology of the radial recrystallized bundles within certain ooids.**

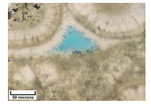



Overview of medium- to well-sorted oolitic sands showing abundance of interparticle micrite cement. (Plane light)



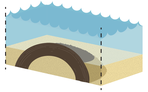

View of radially recrystallized ooids with rough grain margins and micrite cements. (Plane light)


Regenerated ooids and meniscus cements at grain contacts. (Plane light w/ white card technique)

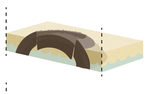



Ooid contacts with extensive acicular radial axial cements as well as micritic cements. (Plane light w/ white card technique)

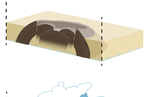
## ORIGIN OF THE MICROBIAL "RING"



Intact microbial mound, covered in green-brown algae, fully submerged in several centimeters of water. However, the domal structure is not solid like a typical stromatolite, but consists of a partially lithified outer shell, 5-15 cm (2-6 in) thick, with unconsolidated mud and ooids in the interior.

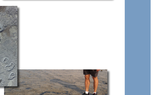



When the lake level drops, the microbialite becomes exposed. As the water table drops, the underlying mud and ooids compact, and the center of the microbialite collapses, leaving behind a raised outer ring. With prolonged exposure, the algae on the surface die and the microbialite is bleached white by the sun.

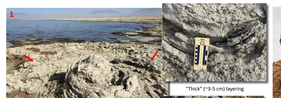



With prolonged exposure, the center collapsed portion of the microbialite continues to erode and disintegrate.


After the collapse and disintegration of the microbialite's interior, continued wave action washes out the broken material, leaving behind only the outer ring. If at some point the lake level rises, the eroded ring structure can be recolonized with algae.




## GIANTS - Windward side of northern Bridger Bay peninsula

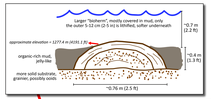

~5 m (16 ft) in diameter (outer ring, red arrows), highly eroded, older generation of microbialites?

Green River Formation giant stromatolite, Sand Wash Basin, NW Colorado - Similar??

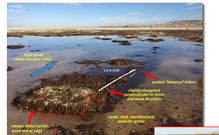

~2 m (6.5 ft) in diameter, center has collapsed, currently submerged and (October 31, 2014) colonized with algae.


## BRIDGER BAY PHOTO TRANSECT






Partially exposed "bioherms" with bleached tops (red arrow). Water level in this area must have dropped recently as living brown algae still exists on the sides of the exposed stuctures. Overtime, the entire exposed "bioherm" will bleach white.




Water line day of transect
Oct. 23, 2014
1278.1 m (4193.3 ft)



Only the outer several centimeters of the "bioherms" in Bridger Bay are lithified, with only faint layering.



The internal structure of the microbial "bioherms" is mostly amorphous, with only a hint of layering at the outer edge.



Often the submerged "bioherms" are covered with brine fly larval casings.



Rings are all that is left of exposed "bioherms" (see "Origin of the Microbial 'Ring'" section above)








Oolitic grainstone "beachrock"



Bedrock boulders are often coated with calcium carbonate, which could be microbial.







"Bioherms" begin to spread out, become "taller," roughly 12.2-25.9 cm (0.4-0.9 ft) above sediment, in about 0.3 m (1.0 ft) of water on day of transect, which places them at an elevation of about 1277.7 m (4192 ft).

Organic-rich mud starts to cover more solid ooid/bio-debris surface

Fully submerged "bioherms," more densely packed, greater relief on domal structures.

The dark brown "bioherms" are fully or nearly fully submerged in the water and covered with living algae. Some "bioherms" are partially exposed; the algae dies and the "bioherm" top bleaches white in the sun. The dark colored material between the domal structures is composed of "pustular" grains eroded from the top of the "bioherms". These dark brown grains were most likely eroded relatively recently and retain living algae. The lighter colored sediment between the "bioherms" is composed of ooids and bleached pustular grains, most likely older eroded remnants (see photos and photomicrographs above).

Ooid and carbonate mud "beach" with very few exposed "bioherms."

First microbial "bioherm" group - these "bioherms" have been exposed for a significant period of time; they are bleached, eroded, and only the outer rings of the domal structures remain.

Structures are aligned in groups parallel to the shoreline.

Ooid and carbonate mudstone "beach"

Ooid and carbonate mudstone "beach" with broken lithified ooid grainstone ("beachrock") increasing in abundance toward bedrock shoreline.