[PS]Predicting Lacustrine Microbialite Distribution and Facies Associations: The Eocene Green River Formation Analogue*

Paul Buchheim[1] and Stanley M. Awramik[2]

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[1]Earth and Biological Sciences, Loma Linda University, Loma Linda, CA (pbuchheim@llu.edu)
[2]Earth Science, University of California, Santa Barbara, CA

Abstract

The Green River Formation contains one of the richest records of microbialites known from lacustrine systems. The microbialites include stromatolites, oncoids, thrombolites, caddisfly-microbialites, and tufa-microbialite structures.

Four basic facies associations containing microbialites are recognized in the Green River Formation: Type I Biostrome, Type II Bioherm, Type III Oncolite, and Type IV Tufa-microbialite. A fifth facies association without microbialites (Type V Barren) is useful for comparison.

The Type I Biostrome facies association is composed of dolomicrite, ooids, and flat-pebble conglomerate, followed in turn by stromatolite biostromes and oil shale. This association was deposited in balanced-fill lakes and on low-gradient lake bottoms.

The Type II Bioherm facies association is composed a succession of oolite and grainstone, large stromatolite bioherms, wackestone, and carbonate mudstones. Microbialites represent aggradational stacking and are restricted to localized build-ups in a near-shore, littoral setting. This association was deposited in overfilled lakes or balanced-fill lakes with stable shorelines.

The Type III Oncolite facies association is composed of conglomerate followed by oncoids. This facies interfingers with fanconglomerate facies in steep, near-shore settings, where lake margin alluvial fans were transgressed. This association was associated with island margins or basin sills, and was deposited on higher gradient lake bottoms during overfilled-lake phases.

The Type IV Tufa-microbialite facies association is composed of localized intraclastic conglomerate succeeded by porous microbialites that are mostly columnar in shape. They may be associated with spring-inflow features. This association was deposited in overfilled to balanced-fill lakes.

The Type V Barren facies association is composed of grainstone/flat-pebble conglomerate, dolomicritic oil shale, and evaporites, but lacks microbialites. It was deposited in underfilled lakes that were saline-alkaline and deficient in calcium. The Green River Formation microbialite facies association types and their relationship to lake types provides an excellent analogue for understanding and hence predicting microbialite distribution and facies associations when exploring for hydrocarbons in deeply buried lacustrine formations.

Predicting Lacustrine Microbialite Distribution and Facies Associations: The Eocene Green River Formation Analogue

H. Paul Buchheim[1] and Stanley M. Awramik[2]

1. Department of Earth and Biological Sciences, Loma Linda University, Loma Linda , CA, United States
2. Department of Earth Science, University of California, Santa Barbara, CA, United States

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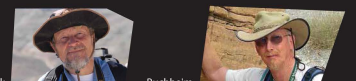


Awramik

Buchheim

Introduction

The Green River Formation contains what may be the richest and most diverse microbialites of any lacustrine deposit

A complete range of lake types from underfilled to overfilled are present allowing comparison of lake types to facies and their microbialites.

How do microbialite forms and facies associations change with various settings?

Can we make predictions about lateral facies changes within microbialite lithofacies in the lake?

Ultimately, can we make predictions about lake types, microbialite basinal distribution, and spatial facies variations?

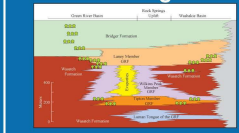
A typical microbialite biostrome (stromatolite) that forms laterally extensive beds that can be traced 50+ km.

Thick biohermal build-ups form isolated reef-like structures over 30 meters thick in the NW Green River Basin.

Eocene Green River Lake System

Thick lacustrine sequences were deposited in a system of extensive Eocene lakes, containing the richest and most diverse microbialites of any lacustrine deposit (after Bradley, 1964 & MacGinnitie, 1969).

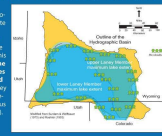
Stratigraphic Occurrence Through Time



The green mushroom shaped icons depict the location of microbialites stratigraphically in the various members of the Green River Formation (Wyoming) and associated fluvial-lacustrine formations (After Roehler, 1992).

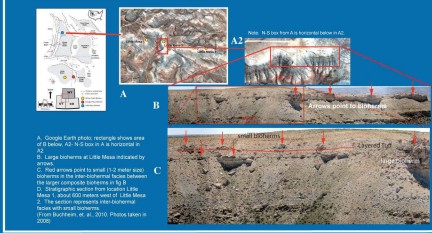
Spatial Distribution

Microbialites grew in shallow, high-energy littoral zones of Lake Gosiute and clearly define the margins during various time periods. The figure provides examples of this distribution pattern. **The "band" of stromatolites is over 20 km wide and 60 km long** during Laney Member time and represents a time synchronous unit (Shultz et. al., 2007).

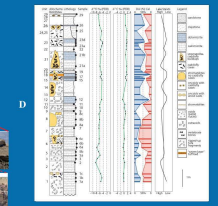


Facies Relationships

BIOHERM DISTRIBUTION AT LITTLE MESA



A. Google Earth photo, rectangle shows area of B below. A2- N-S box in A is horizontal in A2.
B. Large bioherms at Little Mesa indicated by arrows.
C. Red arrows point to small (1-2 meter size) bioherms in the inter-bioherm facies between the larger composite bioherms in fig B
D. Stratigraphic section from location Little Mesa 1, about 600 meters west of Little Mesa
1. The section represents inter-bioherm facies with small bioherms.
(From Buchheim, et. al., 2010. Photos taken in 2008)

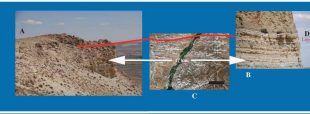


Detailed stratigraphic section and other data from the Little Mesa 1 location showing the relationships among lithology, stable isotopes, mineralogy, allochems, fossils, and inferred lake stands (from Leggitt, 2005).

LAKE MARGIN BASINWARD CORRELATION

Bioherm facies grade basinward into Wilkins Peak Member oil shales. Bioherm growth and burial occurred in response to renewed expansion of Lake Gosiute during late Wilkins Peak and early Laney time. The bioherms are succeeded basinward by kerogenous mudstones (Buchheim, et. al., 2010). In the Uinta Basin of Utah similar Green River Formation bioherms form at least one hydrocarbon reservoir (Osmond, 2000).

A. Little Mesa Bioherm
B. Equivalent profundal facies 17 km to the east at Chapel Canyon where oil shale replaces the upper half of the bioherm facies that is present at Little Mesa.
C. Google Map showing the locations of the localities discussed above.
D. Close up of the Layered Tuff at the Chapel Canyon location. Outcrop view is about 15 meters thick.



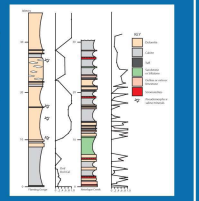
Biostrome Distribution

A

B

Microbialites occur as laterally extensive stromatolitic biostromes in shallow water facies of most members of the Green River Formation. Figures A , B, and C illustrate several types, including very porous tufa-like textures (A) and typically well laminated domical forms (B, C) . These may occur as a tufa/ceous association with oolite and flat-pebble conglomerate at the base succeeded by stromatolitic oil shale, and mud-cracked dolomite. The stromatolites are coincident with flooding surfaces of parasequences. Figure D compares a profundal section (Flaming Gorge) with a littoral section (Antelope Creek). No stromatolites occur in the deep water profundal facies. From Buchheim and Surdam, 1979.

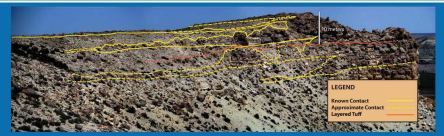
C



D

Types & Distribution

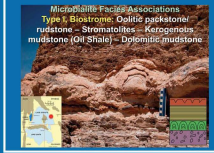
Bioherm Lateral Facies Relationships



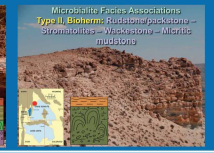
Individual microbialite units coalesce into a 30 meter-thick bioherm. Note the yellow contact lines outline individual units. The microbialites interfinger with wackestone toward the left side of the photo. From Buchheim et. al., 2010.

Microbialite Facies Associations

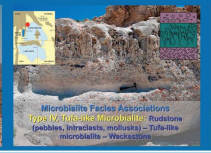
TYPE I



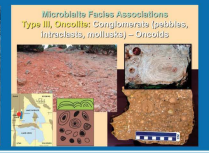
TYPE II



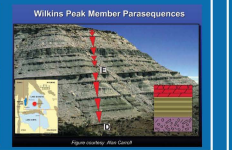
TYPE III



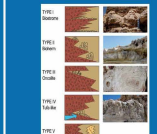
TYPE IV



TYPE V

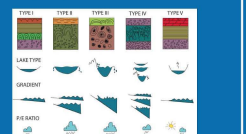


Microbialite Stratigraphic Relations



A

Figure A illustrates the large scale stratigraphic relationships of the five basic microbialite facies types. The In all cases microbialites are associated with major flooding surfaces and form the basal unit of a transgressive sequence. Type I microbialites grow during rapid lake expansive on low topographic gradients. The 10 meter thick bioherms of Type II form when the lake is over-filled and thus are aggradational. Oncolite beds of Type III form on steep gradients or sills. The tufa-like microbialites of Type IV appear to be highly influenced by spring inflow. No microbialites are found associated with the hypersaline facies of Type V.



B

Figure B shows the relationship of the facies types to lake type, bottom gradient, and precipitation-evaporation ratio (P/E). If we know the lake type (under-filled, balanced-fill, or overfilled), we can make some predications about the potential for the formation of thick biohermal sequences, assuming steady subsidence and accommodation space. If it is concluded that the lake was underfilled, the potential for microbialite growth is severely limited. Abundant ground water in the form of sub-lacustrine springs can have a significant influence on the type of microbialite growth, such as the tufa-like microbialites of Type IV. Conversely, if we know the microbialite facies type from a limited perspective, such as a core, we can predict the lake-type (overfilled, etc.)

Conclusions

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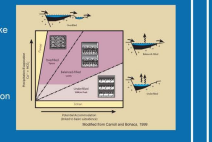

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Future oil deposits in the making: microbialites forming lithified deposits in a modern fresh water spring!