Lacustrine Carbonates – Beaches, Microbes, & Chemical Precipitates

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Green River Lake Waters: Brine Evolution and Chemical Divides

Green River Inflow Waters: Low temperature chemical weathering:
Minerals + dissolved atmospheric CO$_2$ produce ions Na, Ca, Mg, K, Cl
HCO$_3$, SO$_4$ which then form chemical sediments in closed basin lakes.

HCO$_3$ + CO$_3$ > Ca

CaCO$_3$ Precipitation, use up Ca, Mg; extra HCO$_3$ + CO$_3$
forms alkaline (pH 9-10) brines.

Precipitation of Na-carbonates,
i.e., nahcolite, trona, and halite

Accelerated chemical weathering with elevated
atmospheric CO$_2$ in the Eocene (Smith et al., 2008)
Carbonate Stable Isotopes Co-vary – A Closed System
Stratigraphy

- **Piceance basin (~54 to ~48 Ma)**
- **Uinta basin (~54 to ~44 Ma)**
- **Divided into:**
  - 1. Members, based on lithofacies
  - 2. Rich and lean zones (R/L), based on kerogen content

Modified after Self et al. 2010; Tänavsuu-Milkeviciene & Sarg 2012
Carbonate Lake Environments

Modified after Tucker & Wright, 1990
Uteland Butte shoreline grainstones

Oolitic & ostracod lime grainstones

Dolomitic intraclastic packstone
<table>
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<tr>
<th>FA</th>
<th>Image</th>
<th>Porosity + Mineral</th>
<th>Porosity</th>
<th>Mineral</th>
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<td>Green Siltstone (EVC 2-3)</td>
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<td>Bioclast Rudstone (EVC 3-17)</td>
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Brazil & West Africa
Bioclastic Bar Deposits

Comprise units >10m thick of grain supported, to densely packed molluscan calcudrites with thin (<5m) layers of bioclastic calcarenite and calctutite. No siliciclastic intercalations are present. This facies association forms thick deposits 20-550m thick.

These units are interpreted to result from the amalgamation of relatively thin (0.2-1m thick) cross bedded molluscan calcudrites deposited in shallow, high energy settings. They are mainly associated with steep sided palaeohighs and are believed to be the product of storms.

From Dolores de Carvalho M. et al. 2000 AAPG Studies in Geology 46, 245-256
Comprise <10m thick units of bioclastic calcarenites associated with thinner (<5m) layers of siltstone, shale and calcilutite. Calcarenites show low angle cross bedding and comprise abraded bivalve fragments and rare gastropod fragments together with micrite envelopes. This facies association is generally 50-150m thick.
Microbialites - Three Mile Canyon, Evacuation Creek

USGS: Johnson et al., 2010
Littoral Microbialite Deposits, Green River Fm., Three Mile Canyon
Depositional Cycles

Color Key
Orange: Intraclastic rudstone/grainstone
Yellow: Dendrolitic stromatolite
Gray: Thrombolite/columnar stromatolite
Red: Agglutinated stromatolite
Blue: Oolitic/peloidal gnst/pkst/wackest
Green: Spheroidal stromatolite
White: Fine-grained stromatolite
Depositional Architecture
Lower Mid-Littoral Setting
Stromatolite bioherm
Stromatolite Microtextures

A. f. g. stromatolite with alternating dolomite and calcite lamina
B. Columnar stromatolite with dolomitized outer coating
C. Dendrolite layer
D. Agglutinated stromatolite with alternating dolomite and calcite lamina
E. Agglutinated stromatolite with dolomite and calcite lamina
F. Agglutinated stromatolite with irregular laminations
Thrombolite Microtexture

A. Dolomitic thrombolite
B. Arborescent dolomitized thrombolite
C. Calcitic thrombolite with interstitial mud
D. Calcitic thrombolite
E. Partially dolomitized thrombolite clots
F. Fully dolomitized thrombolite
Intraparticle (after oogonia)

Enhanced fenestral

Dendrolitic framework

Interparticle

Interparticle & fracture

Vuggy framework

POROSITY
Fine-grained Laminated Stromatololites

Depositional environment - Lower sublittoral to upper profundal

Carbonate-Claystone Cycles
Fine-grained Laminated Stromatolites – Upper Profundal

Photomicrograph of fine-grained, laminated stromatolite
Brazil & West Africa
Stromatolite – Associated with Coarse Clastics; Mucua 1 well, Kwanza Basin, Angola
Lacustrine Microbial Carbonates, Toca Fm. Lower Cretaceous, offshore Angola

Microbial Boundstone displaying dendritic/clotted growth structures. Very sandy with matrix selective dolomitization.

Kambala Well A core: core is approx. 8.4 cm wide.
Profundal deposits
Profundal deposits

Continuity of profundal deposits

Soft-sediment-deformed deposits

Laminated oil shale

Oil shale breccia

61 cm

3 cm
Redox Conditions for Ferroan Dolomite

\[ a (\text{ankerite}) = 0.1; \]
\[ [\text{Fe(II) aq}] = 10^{-4} \]
Inorganic C conc. = $10^{-2.7}$
Grosz et al. (2006)
Geofluids 6, 137-153
Brazil & West Africa
Barra Velha Fm. carbonate components

Facies 1
Crystal shrubs –mm-cm-sized

Facies 2
Spherulites -mm-sized

Facies 3
Carbonate silt
Shrubs - Campos Basin

Spherulites with silica and silicate matrices
IN situ spherulites, with stevensite
Spherulites with dolomite threads and pseudo-fenestral porosity
Textural “model”

- Shrubs with fewer dolomite rhombs
- Spherulitic floatstone with pseudo-fenestral pores
- Floating dolomite and dolomite “bridges”
- Laminated calcimudstone with ostracodes, phosphatic debris and early silica nodules
- Shrubs nucleate off crystalline surfaces or detrital debris
- Spherulites in Mg-silicate matrix (former gel)

Reduced gel deposition allows nucleation and growth of shrubs in supersaturated solution

Rapid deposition of gels in hyper-alkaline waters limits carbonate growth

Reduced alkalinity-salinity phase
Lacustrine Carbonates – Beaches, Microbes, Springs, & Chemical Precipitates

It’s all about the CHEMISTRY – driven by climate, tectonics, & provenance (ions to the lake)!