

Lacustrine Carbonates and Evaporites – Facies Evolution and Diagenesis: Eocene Green River Formation, Piceance Creek Basin, Colorado*

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Search and Discovery Article #50424 (2011)

Posted July 18, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011.

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Abstract

The lacustrine carbonates of the Eocene Green River Formation crop out on the western margin of the Piceance Creek Basin, in Douglas Pass. Carbonates consist of littoral to sub-littoral facies: skeletal-oolitic-quartz grainstone, oolitic packstone or grainstone, skeletal grainstone, oolitic wackestone, intraclast rudstone, stromatolites, and thrombolites. Facies commonly form thin, 1-2 m thick, upward-deepening cycles that start with intraclast rudstone or oolitic grainstone followed by coarse-agglutinated stromatolites or thrombolites, and capped by fine-grained laminated stromatolites and shale.

The overall vertical succession of carbonate deposits correlate with lake evolutionary stages. The carbonate succession in the Douglas Pass area starts with skeletal-oolitic-quartz grainstone and skeletal grainstone deposits that occur in an initial Freshwater Lake Stage 1. Thrombolites capped by coarse-agglutinated stromatolites or fine-grained laminated stromatolite were deposited during the High Siliciclastic Input Stage 2. This Stage 1 to Stage 2 change also corresponds to a change in the lake waters to higher salinity. Nahcolite is precipitated in lake-center environments. Repeated deepening-upward cycles of thrombolites, coarse-agglutinated dendrolitic stromatolites, coarse-agglutinated stromatolites, and fine-grained laminated stromatolites occur in the Rapidly Fluctuating Lake Stage 3. During this lake stage, periodic hypersalinity existed in the lake, and halite was deposited in the lake center. Thin, and the richest oil shale units, occur interbedded with the halite beds. The uppermost part of the carbonate section is dominated by laminated stromatolites that correlate with an overall deepening of the lake, and the beginning of the Rising Lake Stage 4. The lake remains restricted during this period and Nahcolite is common. Nahcolite precipitation continues into the ensuing High Lake Stage 5, and is accompanied by widespread, organic-rich oil shale deposition (Mahogany Zone). Changes in Carbon and Oxygen stable isotope values reflect changes in lake chemistry and correspond well to Lake Stages.

The Green River Formation carbonates have undergone a complex diagenetic history including micritization, dissolution, neomorphism, siderite cementation, mechanical and chemical compaction, dolomite cementation, shallow burial dolomitization, fracturing, cementation (equant, block, and poikilotopic cements), late burial dolomitization, and dedolomitization.

Reference

Wright, V.P., and M.E. Tucker (eds.), 1991, Calcretes, *in* Reprint series of International Association of Sedimentologists, v. 2, Blackwell Scientific, Oxford, England.

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Conclusions

- Evaporites occupy a lake center position and are subaqueous in origin.
- Carbonates deposited in the littoral to sub-littoral zone of a fresh to saline lake.
- Overall vertical evolution of carbonates reflect evolutionary lake stages.
- Carbonate cycles show a predominantly deepening-upward succession in a rising lake level setting. *Ideal: intraclast rudstone or oolitic grainstone followed by coarse-agglutinated stromatolites or thrombolites, and capped by fine-grained laminated stromatolites and shale.*
- The $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values co-vary, and range from, -8 to +0.8 ‰ and -3 to +5 ‰, respectively. Major and minor trends show a good correlation with changing lake conditions thru time, from fresh to saline to a return to fresher conditions.

The Green River Formation

The world's largest known oil shale resources occur in:

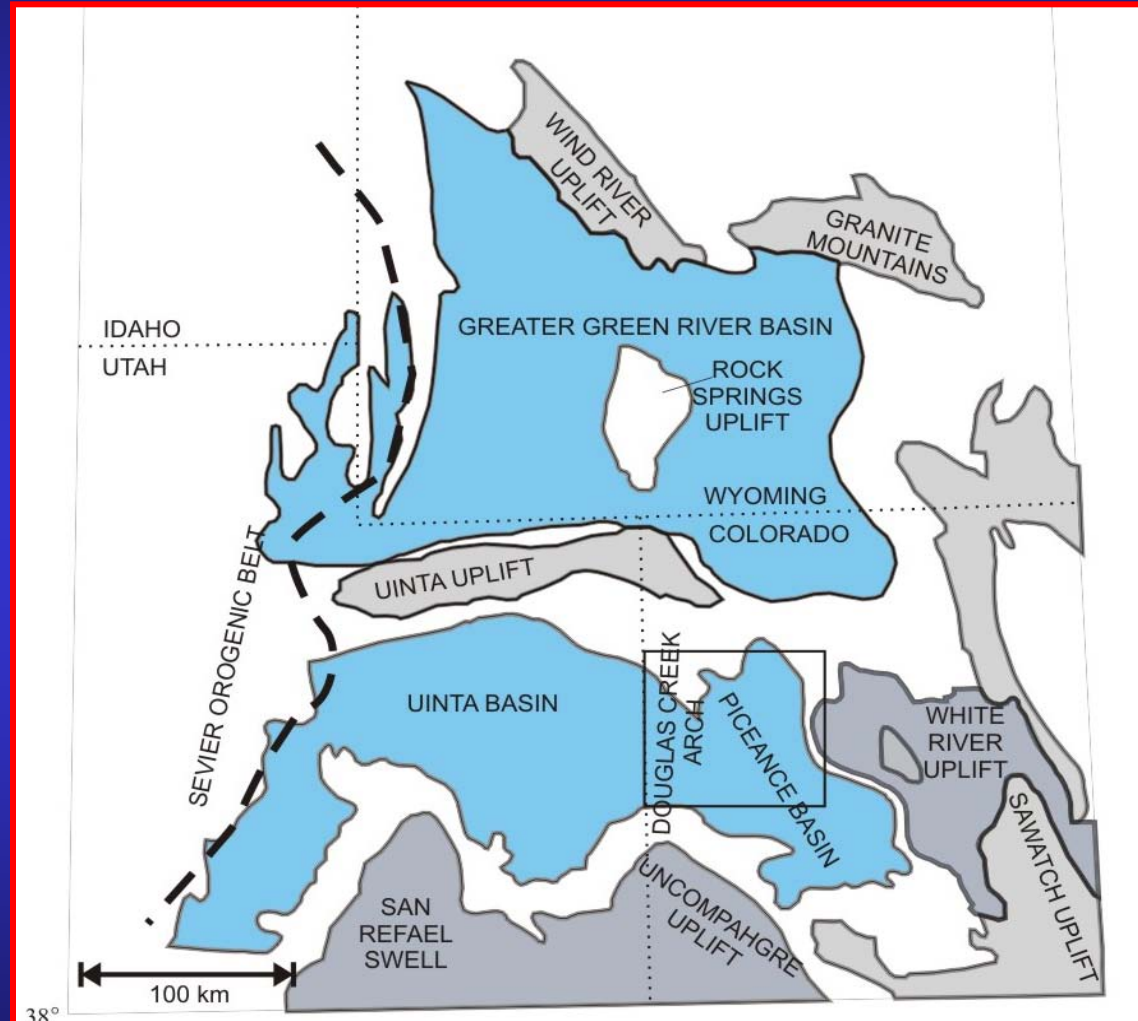
- Eocene lake sediments of Green River Formation
- Western Colorado and adjacent Utah and Wyoming

Piceance Basin largest fraction of reserves

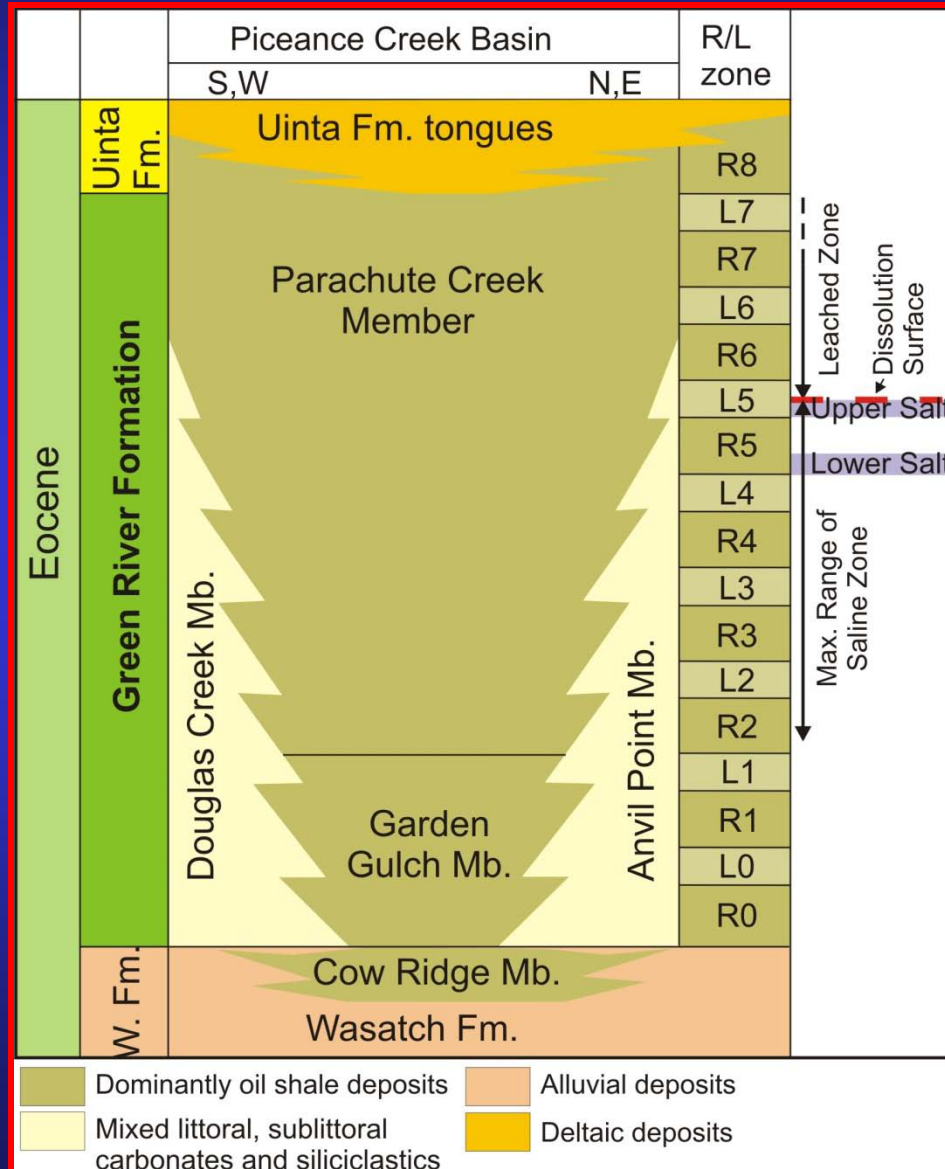
Each basin has a unique history

Major basins connected at times during history

All have periods of evaporite deposition



Piceance Creek Basin Stratigraphy



Study Area & Data

1. Cores - 6

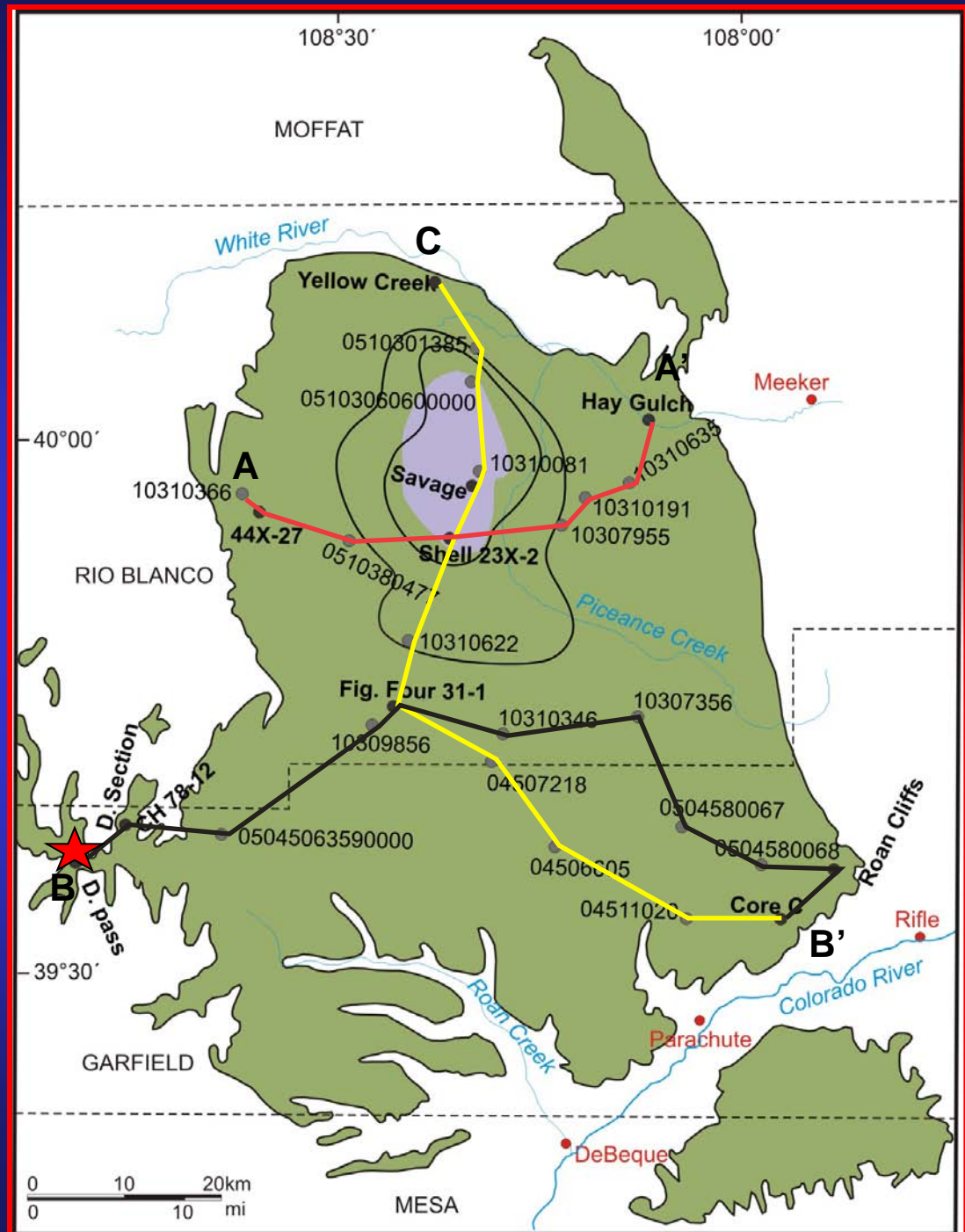
2. Outcrops - 5

Carbonate Outcrop
– Douglas Pass

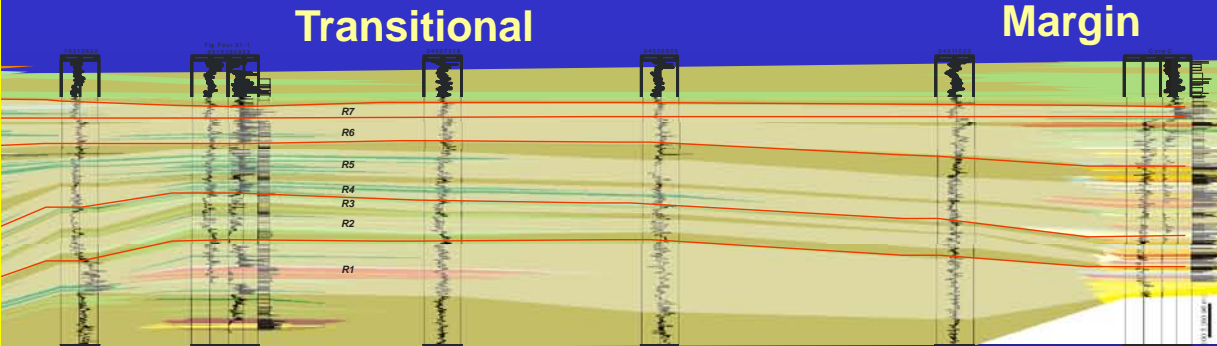
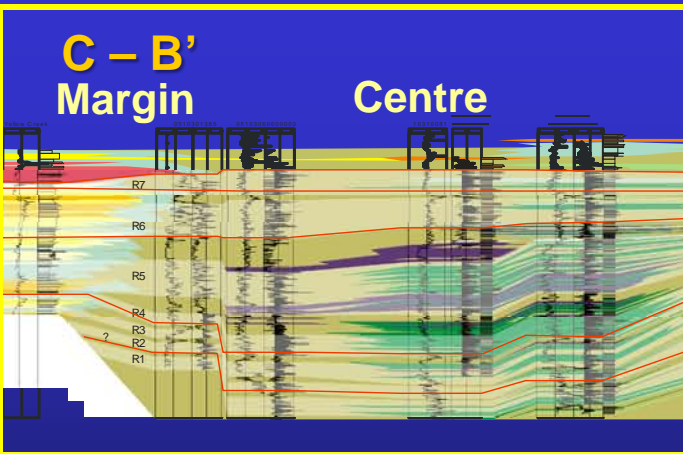
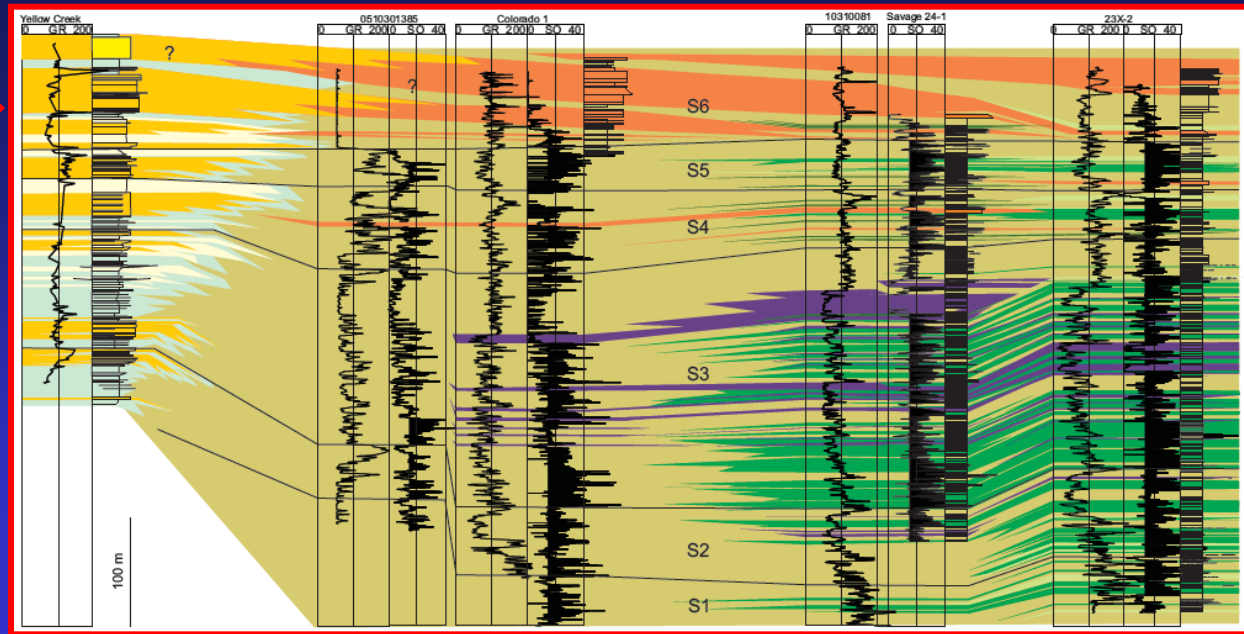
3. Wells

Gamma ray

Fisher Assay



Green River Stratigraphy



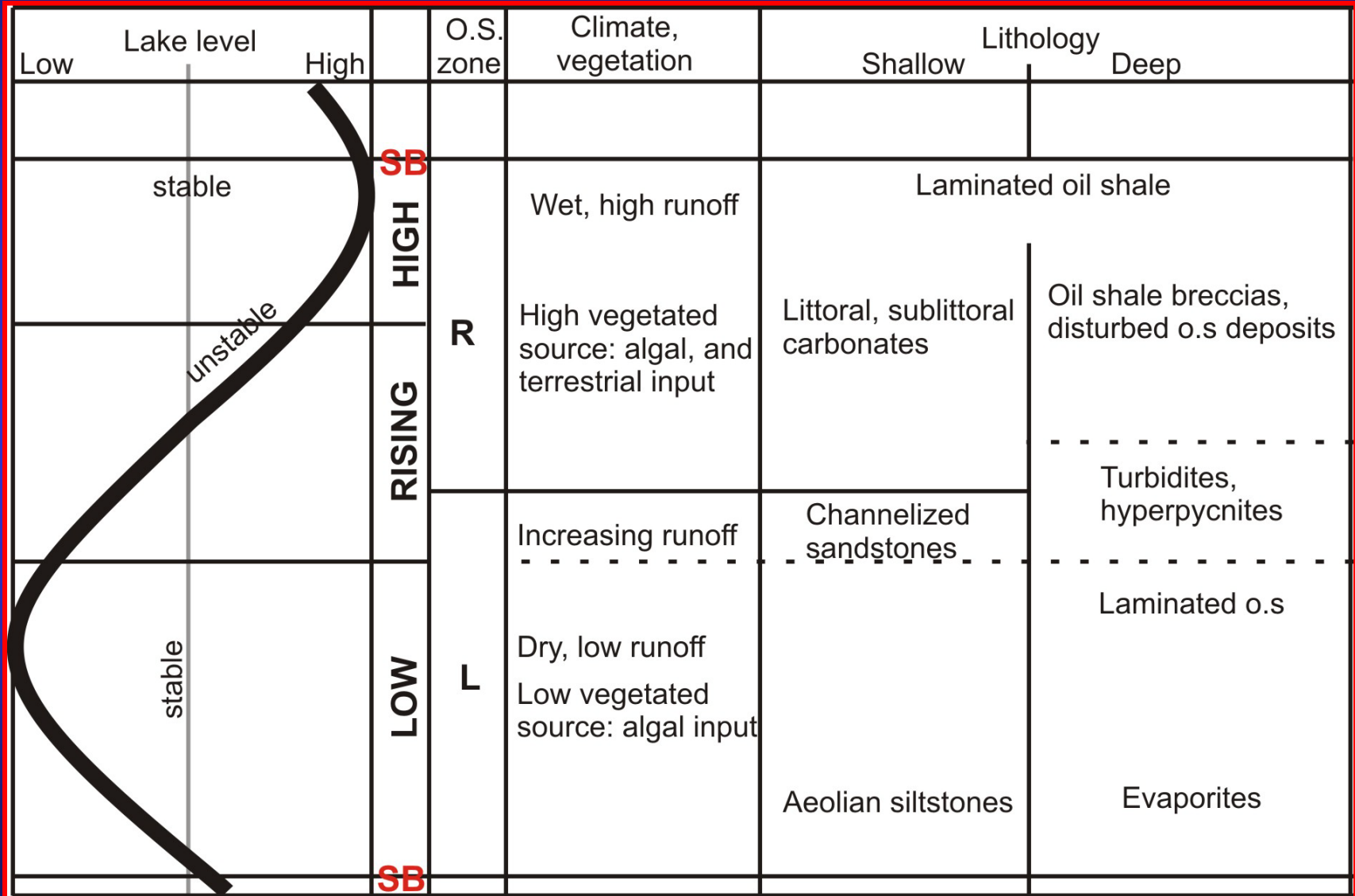
S-Stage

Fluvial deposits
Littoral siltstones, sandstones

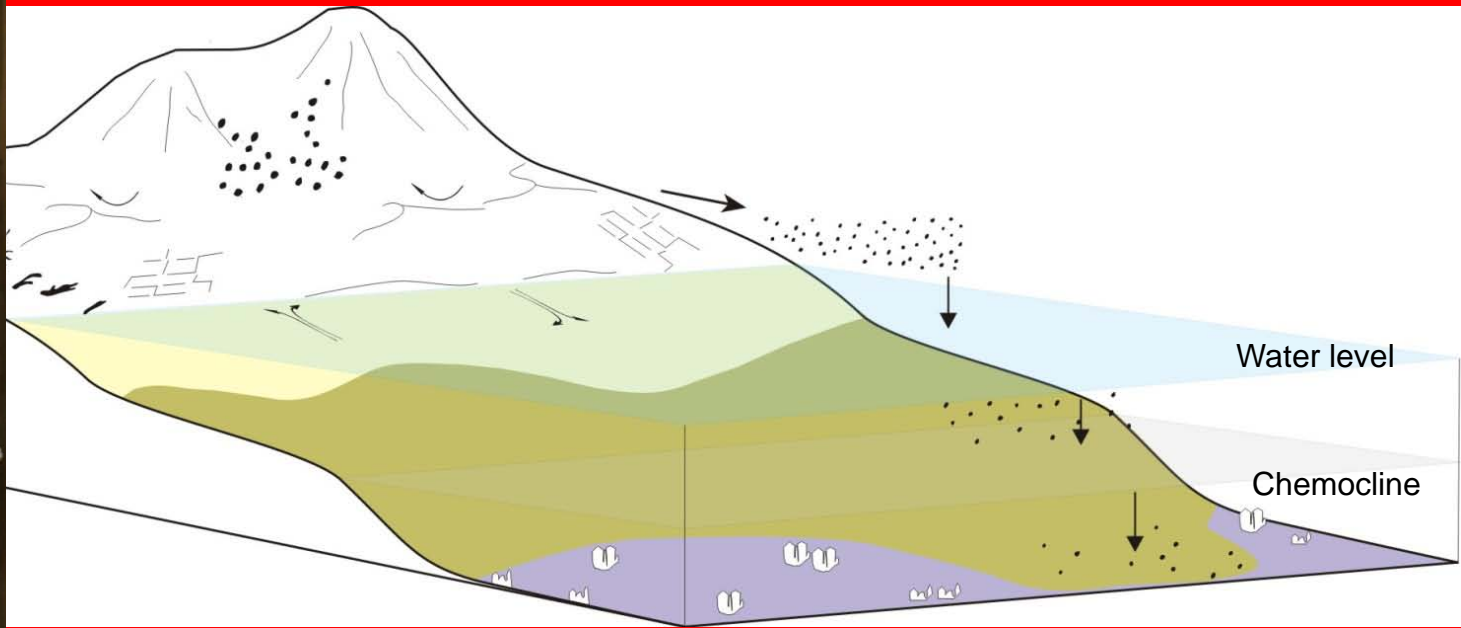
Shore sandstones
Delta deposits
Hyperpycnites, turbidities




Evaporites (halite, nahcolite)
Littoral oil shale
Laminated oil shale
Disturbed oil shale deposits
Oil shale breccia

Lake Cycle

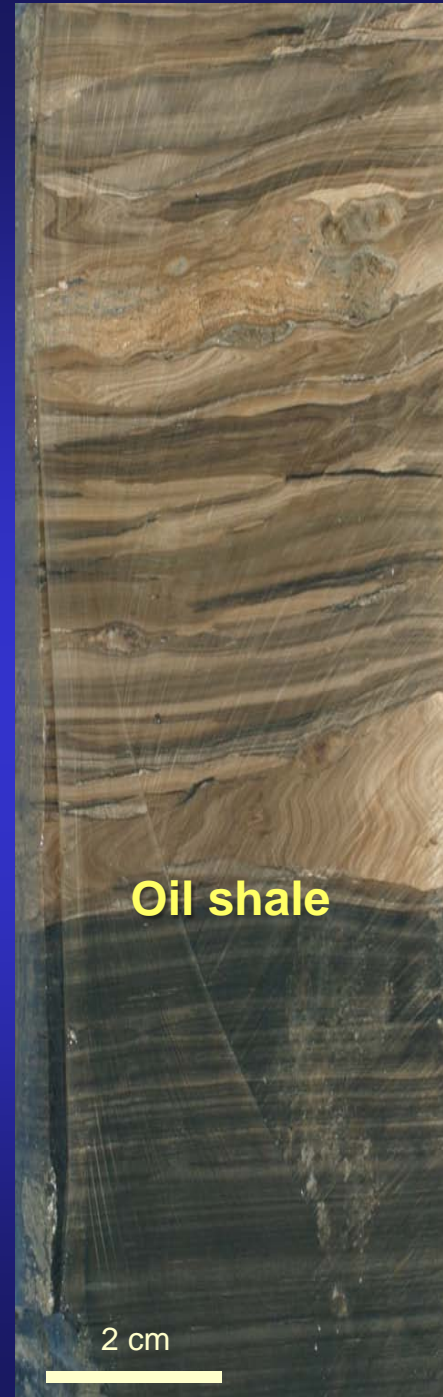


Low Lake Level

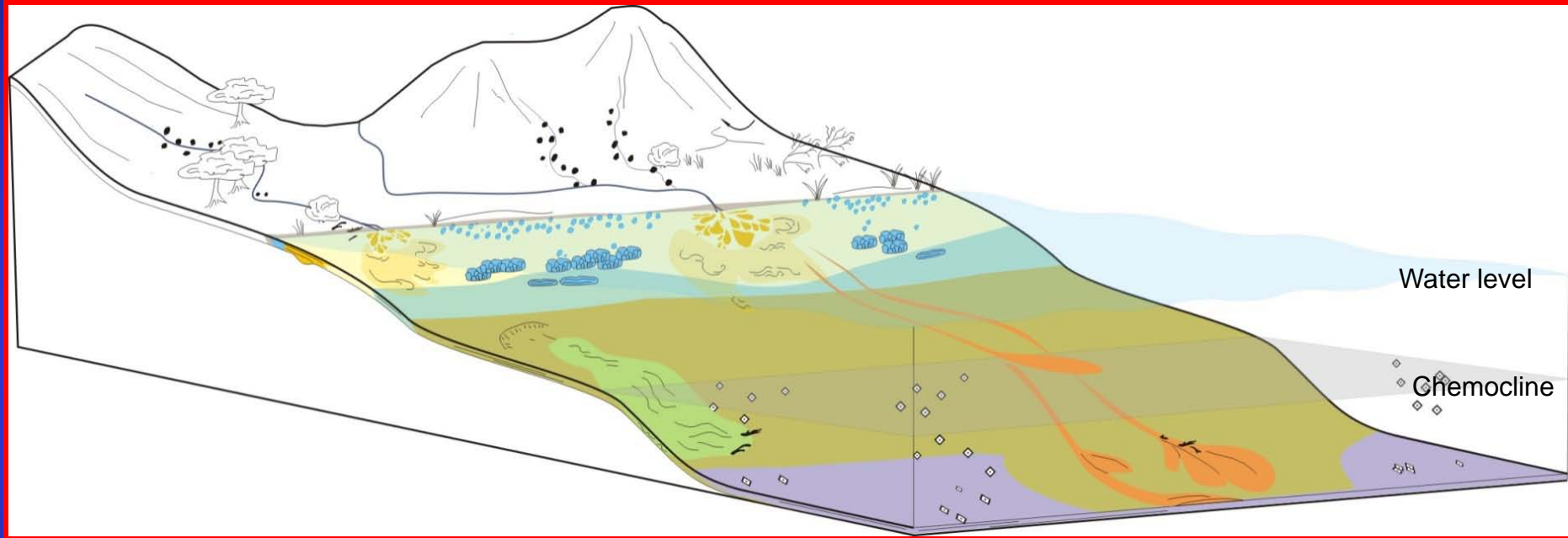


-  Littoral siltstones, sandstones
-  Evaporites (halite, nahcolite)
-  Laminated oil shale

Lake Center Deposits



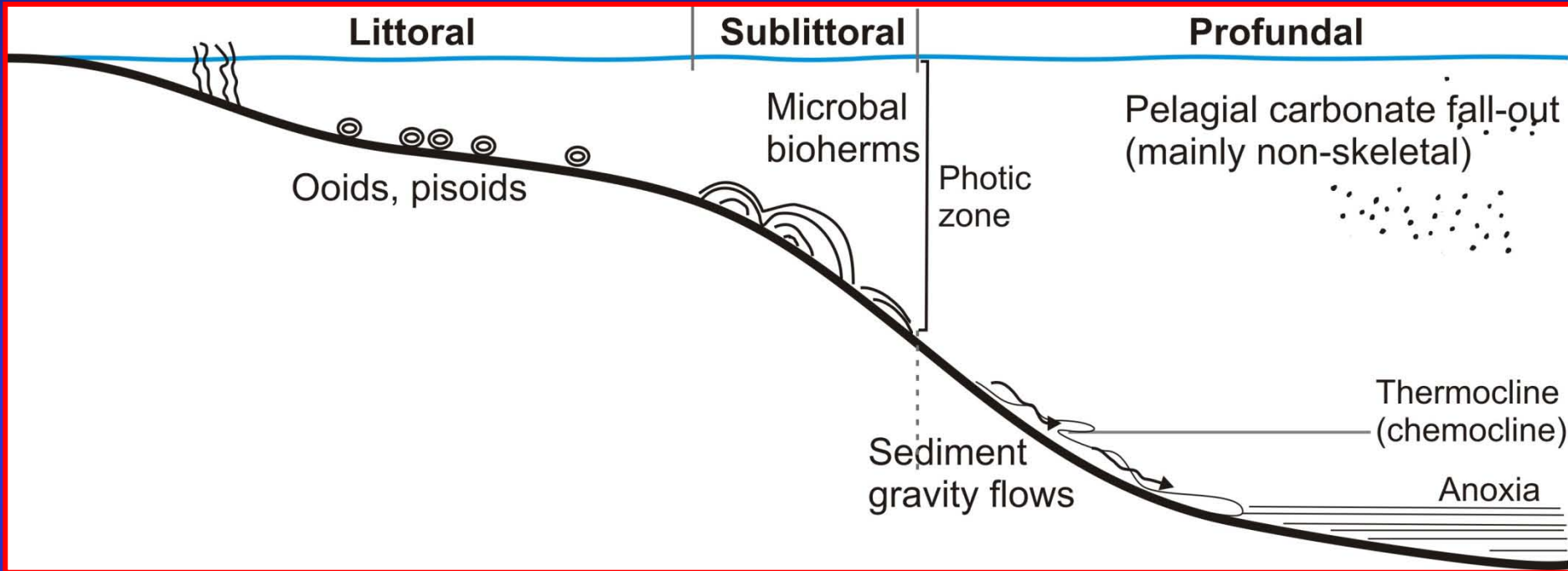
Rising lake



- Shore mudstones, siltstones
- Shore carbonates (stromatolites, carbonate grains)
- Littoral siltstones, sandstones
- Delta deposits
- Littoral oil shale

- Hyperpycnites, turbidities
- Laminated oil shale
- Disturbed oil shale deposits
- Evaporites (halite, nahcolite)

Carbonate Lake Environments



Modified after Wright, 1991

- Littoral, Sublittoral – carbonate grainstones, microbial carbonates, and siliciclastic shore deposits
- Profundal – laminated lake deposits

Carbonate & Evaporite Lithofacies Change Vertically with Evolving Lake Stages

1. Grainstones with abundance of mollusks and ostracods. Abundant fish.

S1: Fresh to Brackish Lake

2. First occurrence of stromatolites, thrombolites, & nahcolite.

S2: Restricted Lake

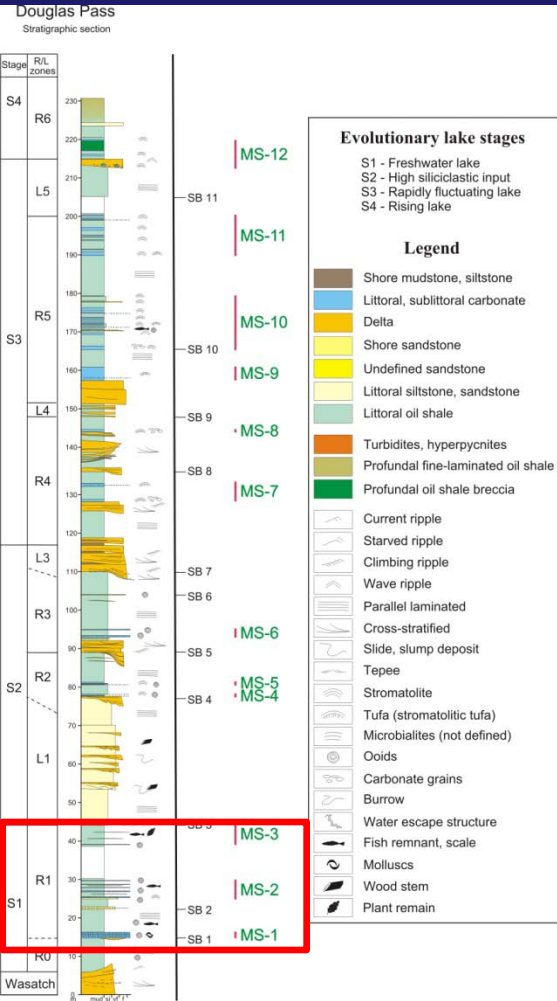
3. Repeated thin to thick, deepening upward cycles, & nahcolite/halite in lake center.

S3: Rapidly Fluctuating Lake

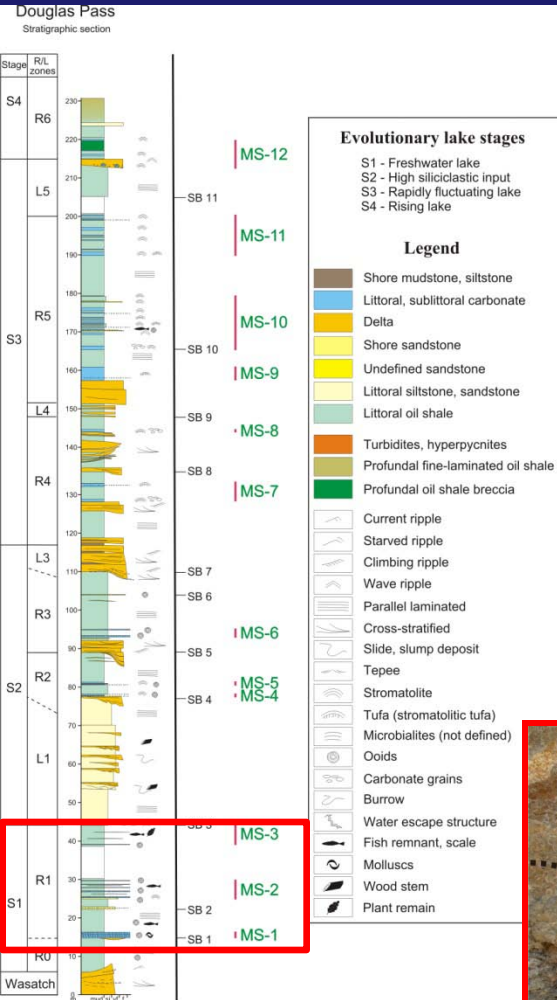
4. Dominant laminated stromatolites & return to nahcolite.

S4: Rising Lake

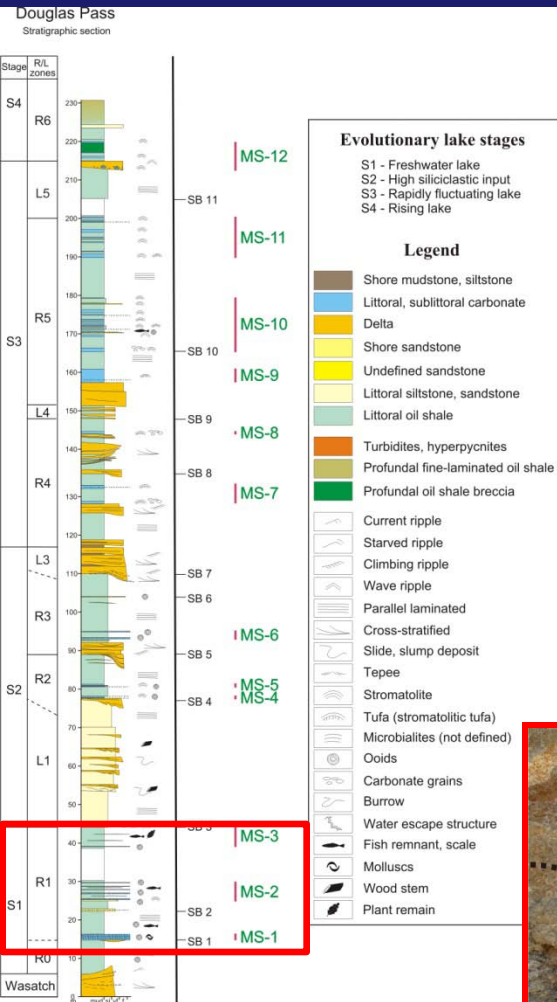
S1 – Fresh to Brackish Lake



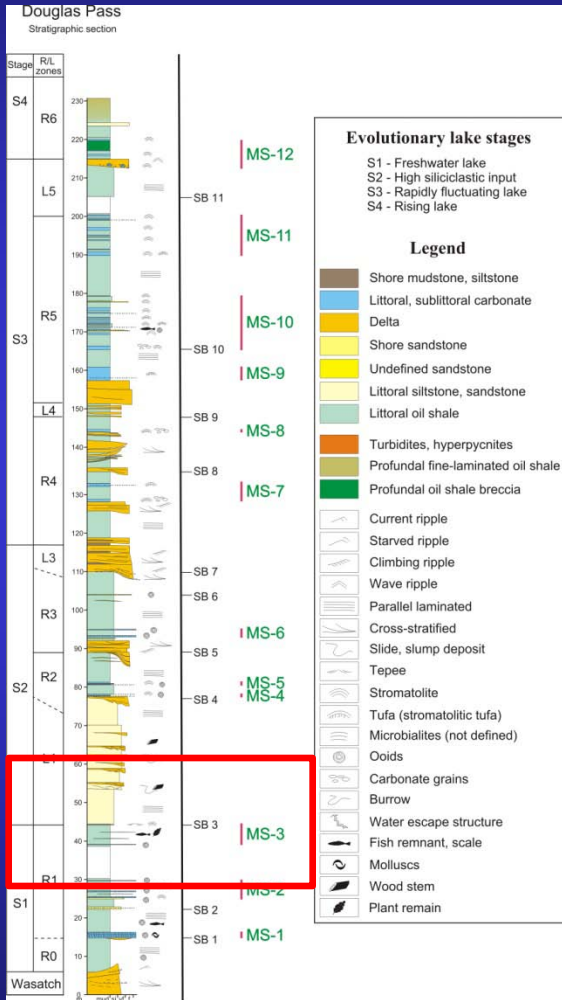
S1 – Fresh to Brackish Lake



S1 – Fresh to Brackish Lake

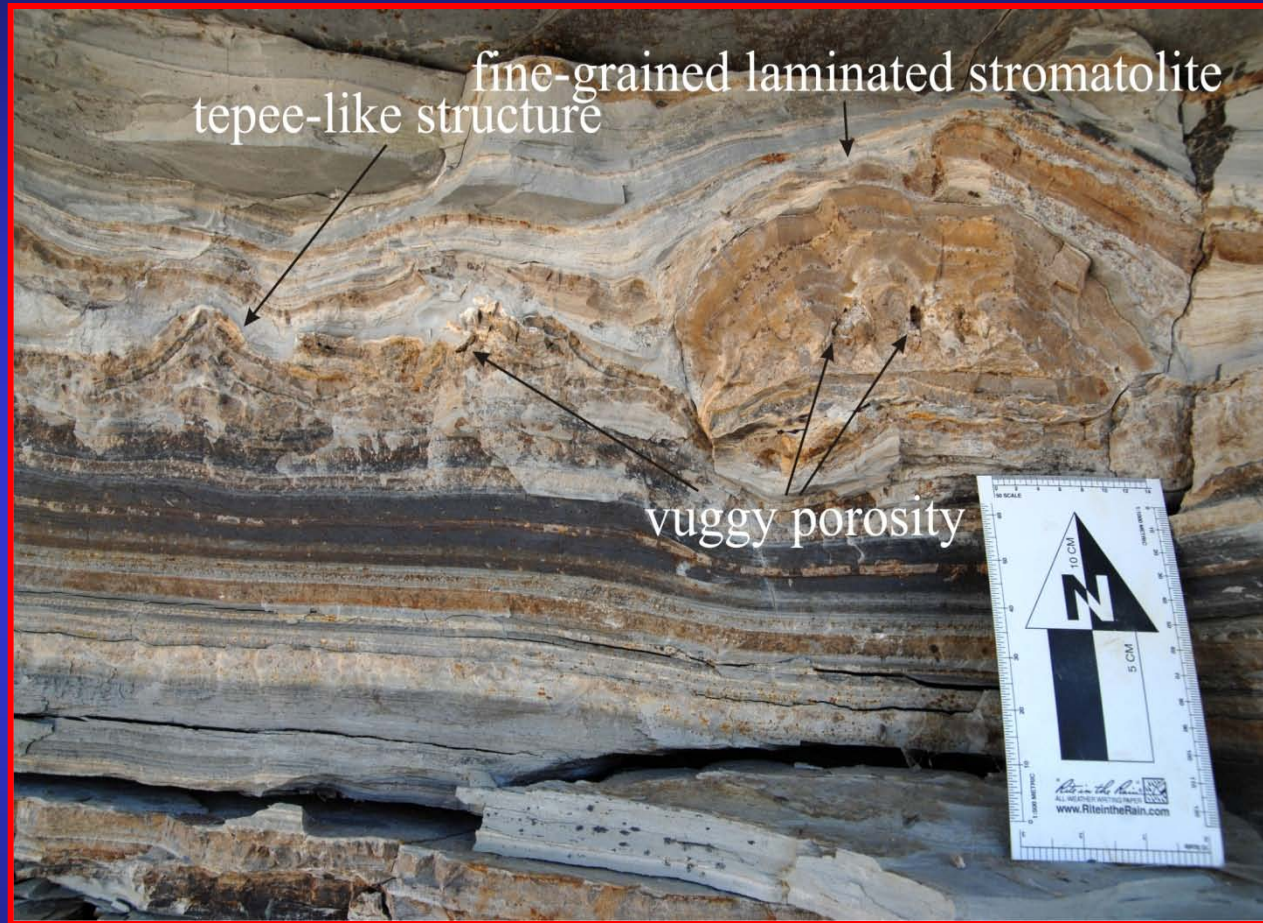
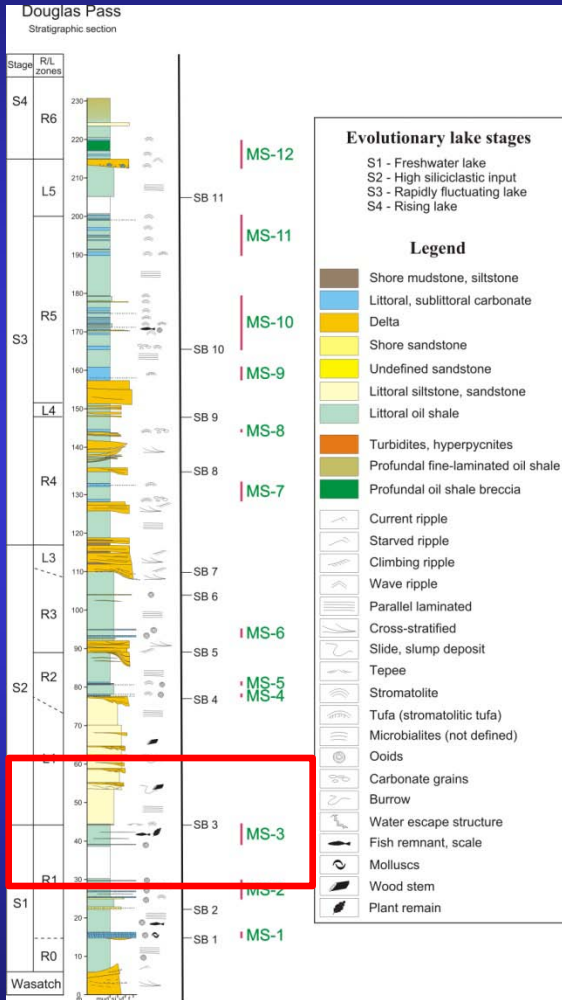


S2 – Restricted Lake



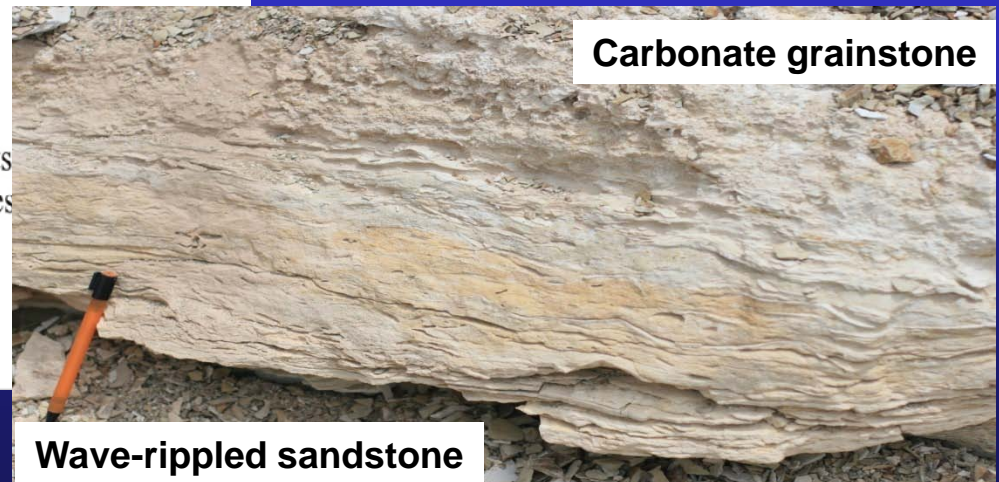
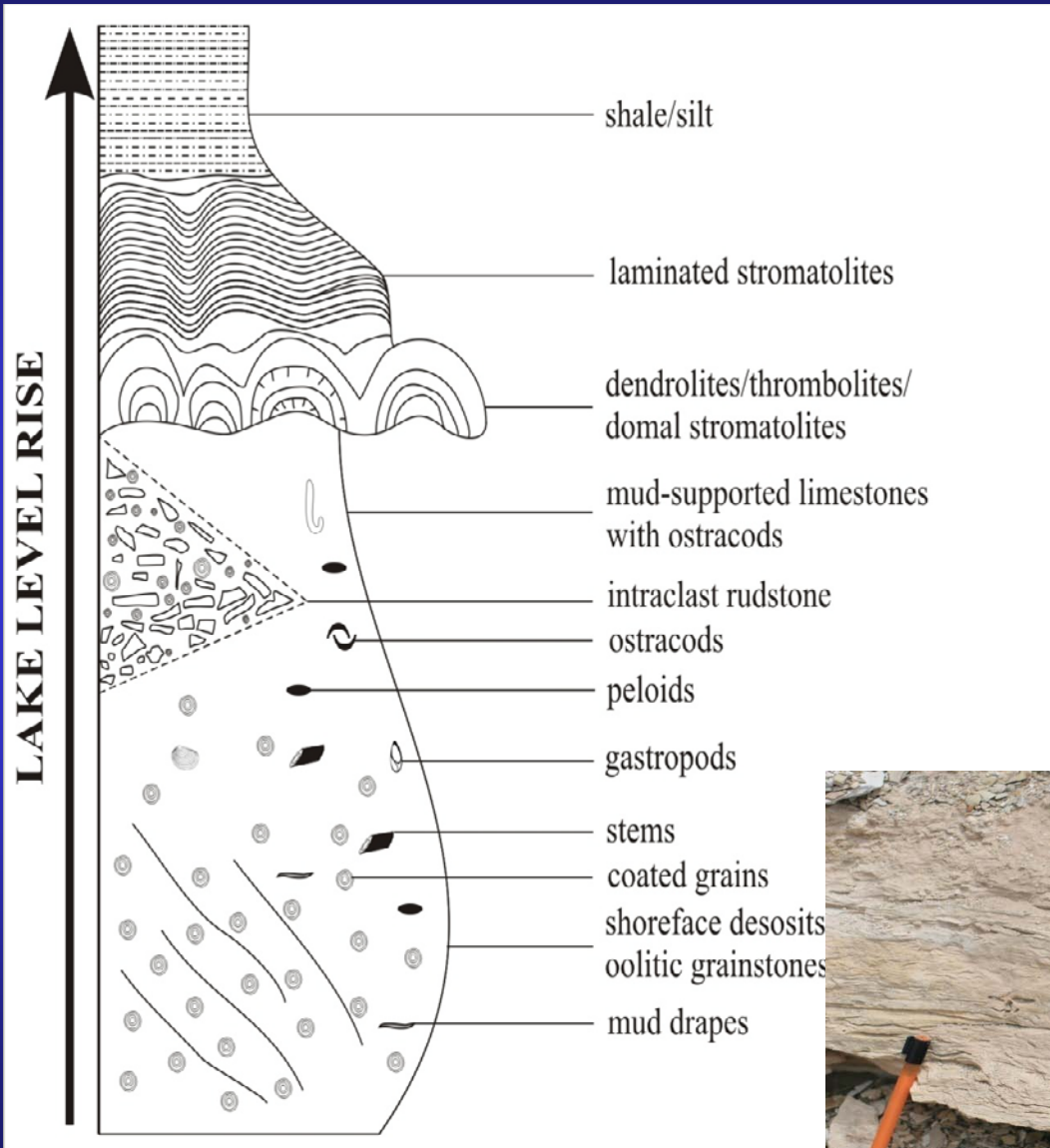
+ *Nahcolite*

S2 – Restricted Lake

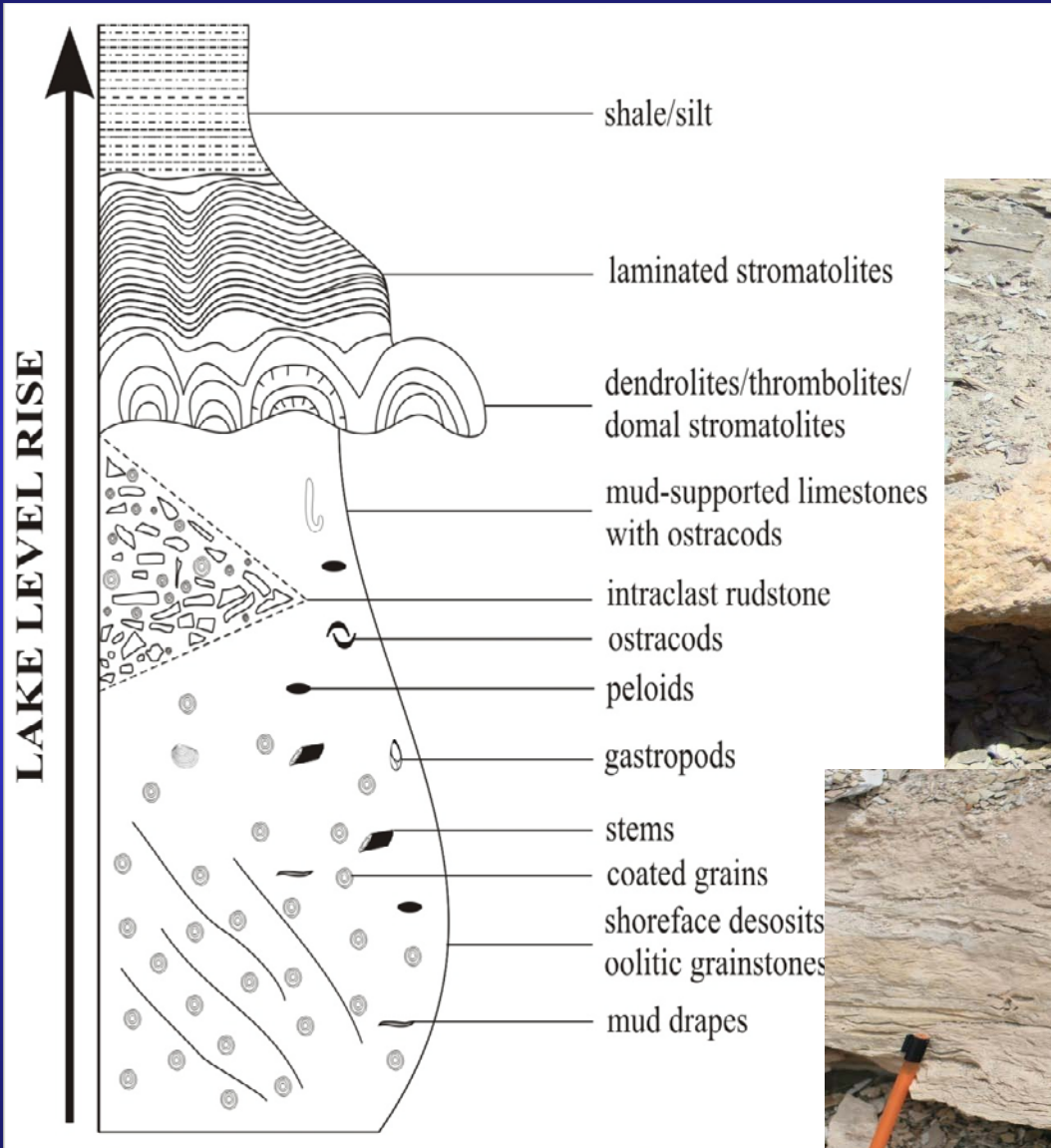


+ *Nahcolite*

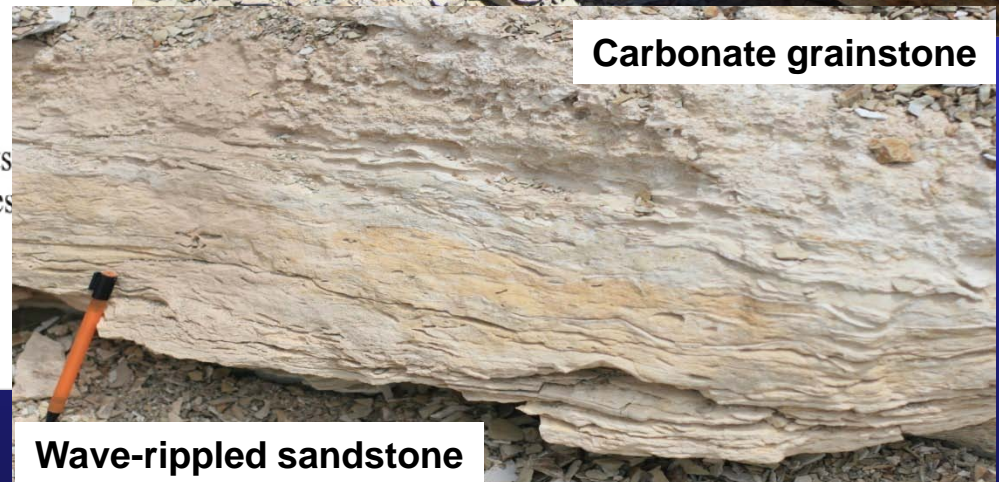
An idealized deepening-upward carbonate succession of Eocene Green River Formation.



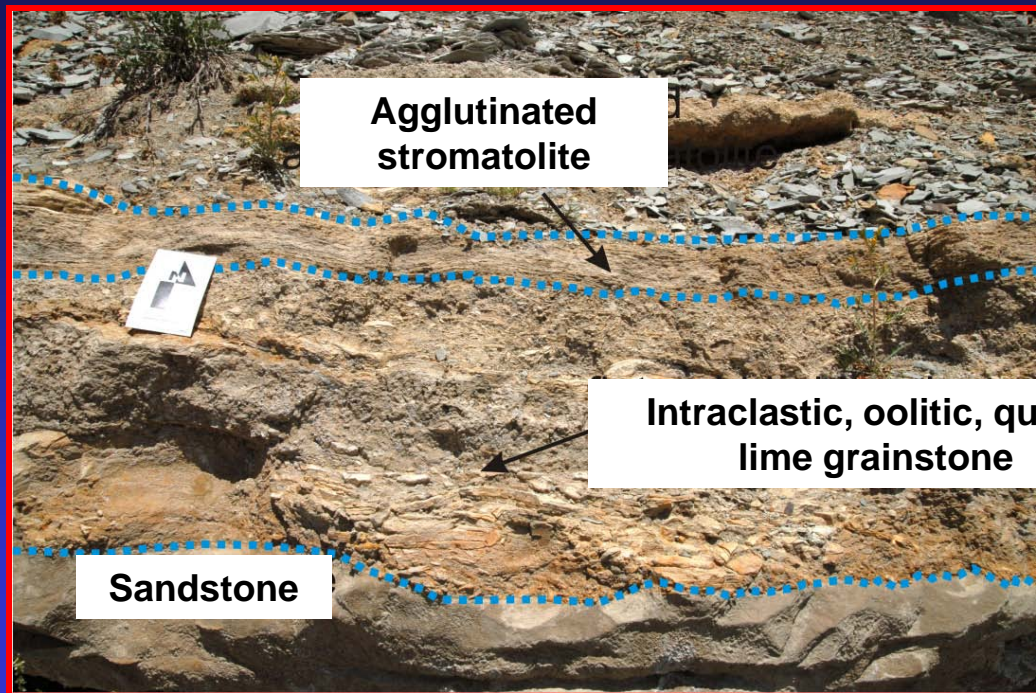
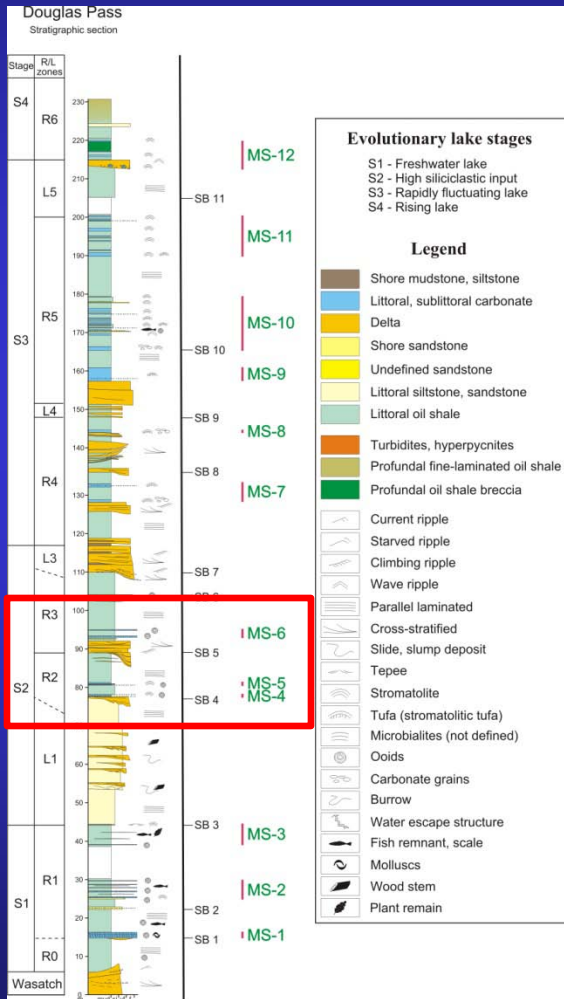
An idealized deepening-upward carbonate succession of Eocene Green River Formation.



Carbonate grainstone



Wave-rippled sandstone



Thrombolite + Laminated Stromatolite



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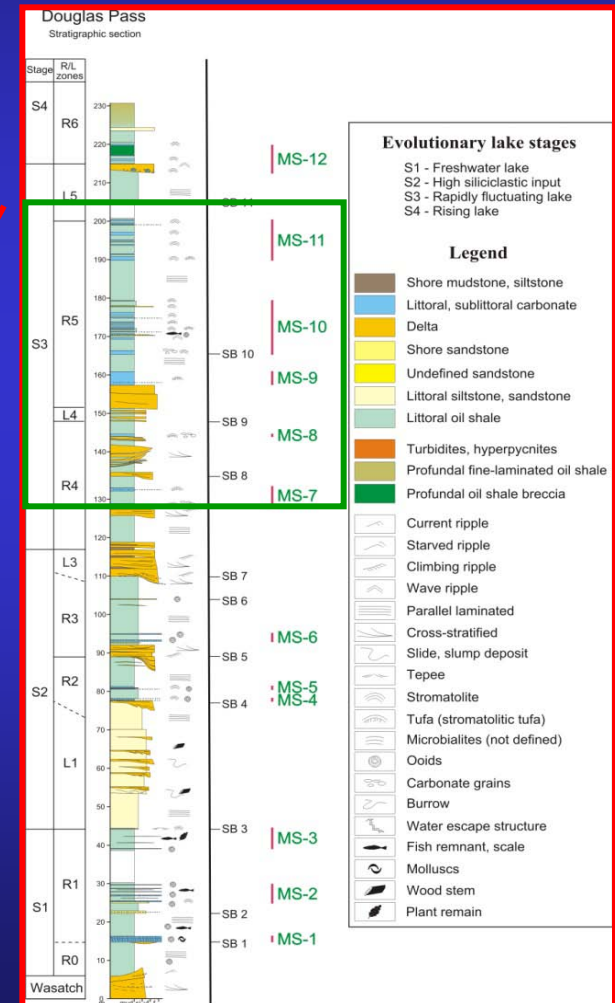
S2: Restricted Lake

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S3: Rapidly Fluctuating Lake

4. Dominant laminated stromatolites & return to nahcolite.

S4: Rising Lake



S3 – Highly Fluctuating Lake



+ *Nahcolite*
& *Halite*

S3 – Highly Fluctuating Lake



+ *Nahcolite*
& *Halite*





Thrombolite



Stromatolite Heads

Dendrolite



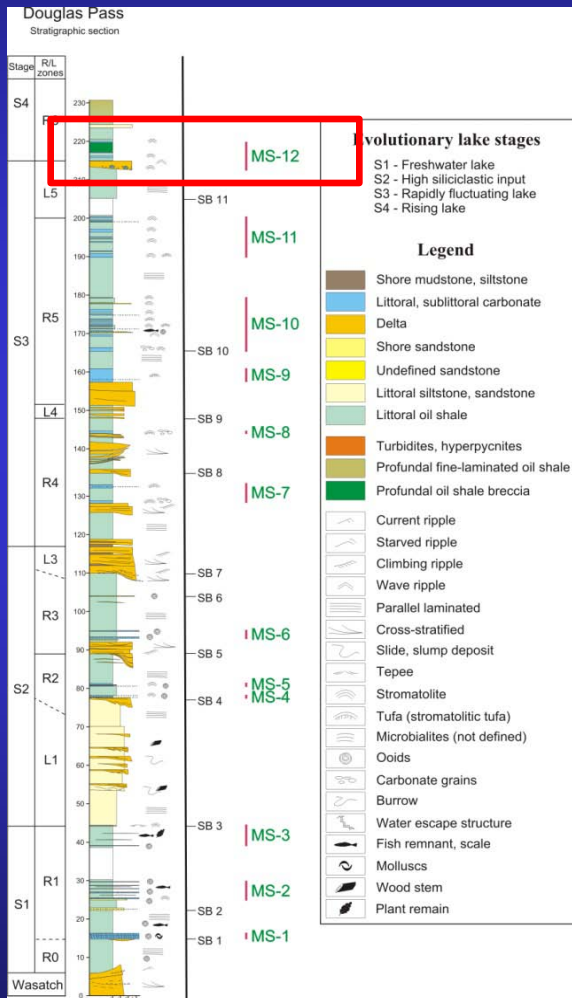
**Downward deflected
stromatolite**

S3 – Highly Fluctuating Lake

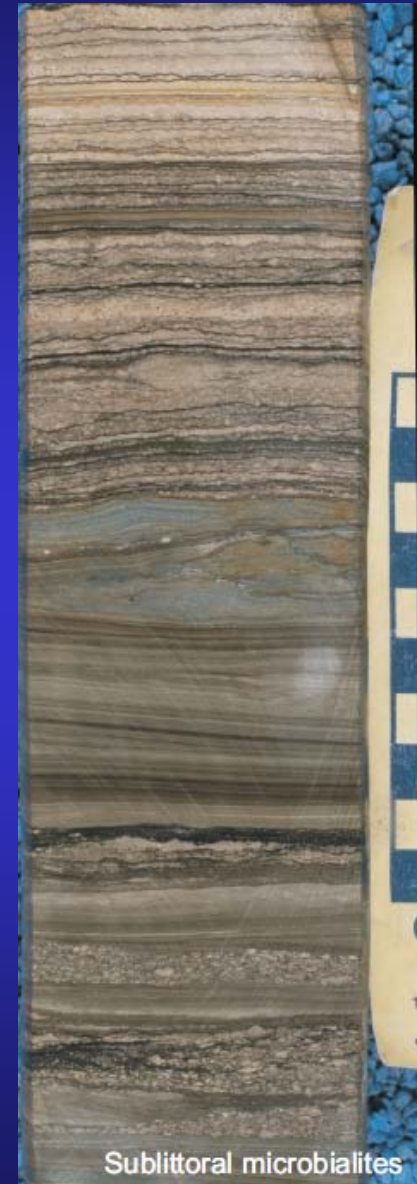
**Carbonate-
Claystone Cycles**



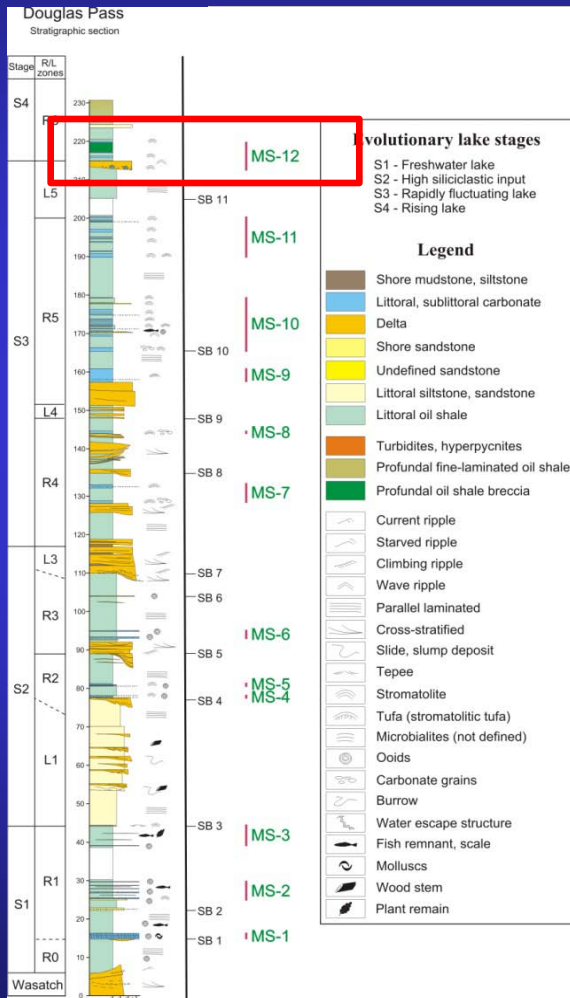
S4 – Rising Lake



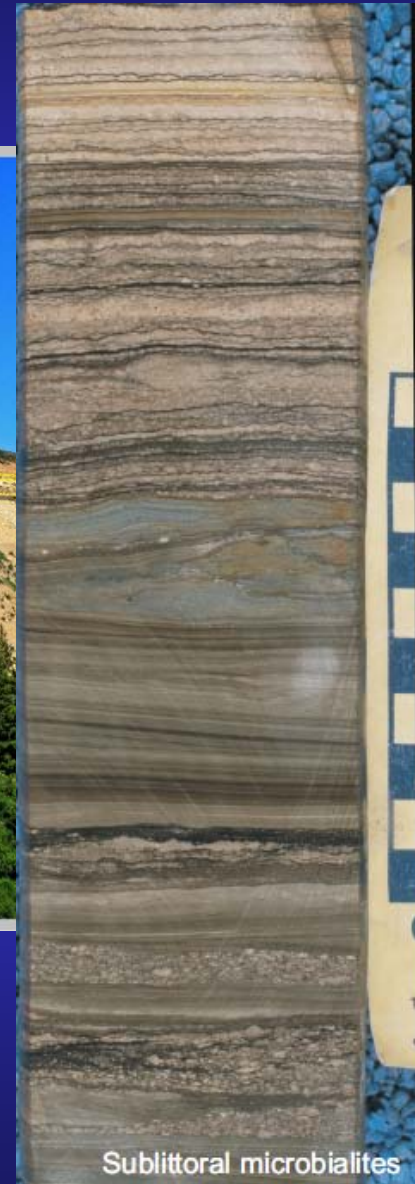
+ Nahcolite



S4 – Rising Lake



+ Nahcolite



Sublittoral microbialites

Diagenetic Paragenesis

Diagenesis

Timing

Early

Late

Micritization

Dissolution

Neomorphism

Siderite Cementation

Mechanical Compaction

Chemical Compaction

Dolomite Cementation

Fracturing

Early Burial Dolomitization

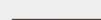
Cementation by Granular Cements

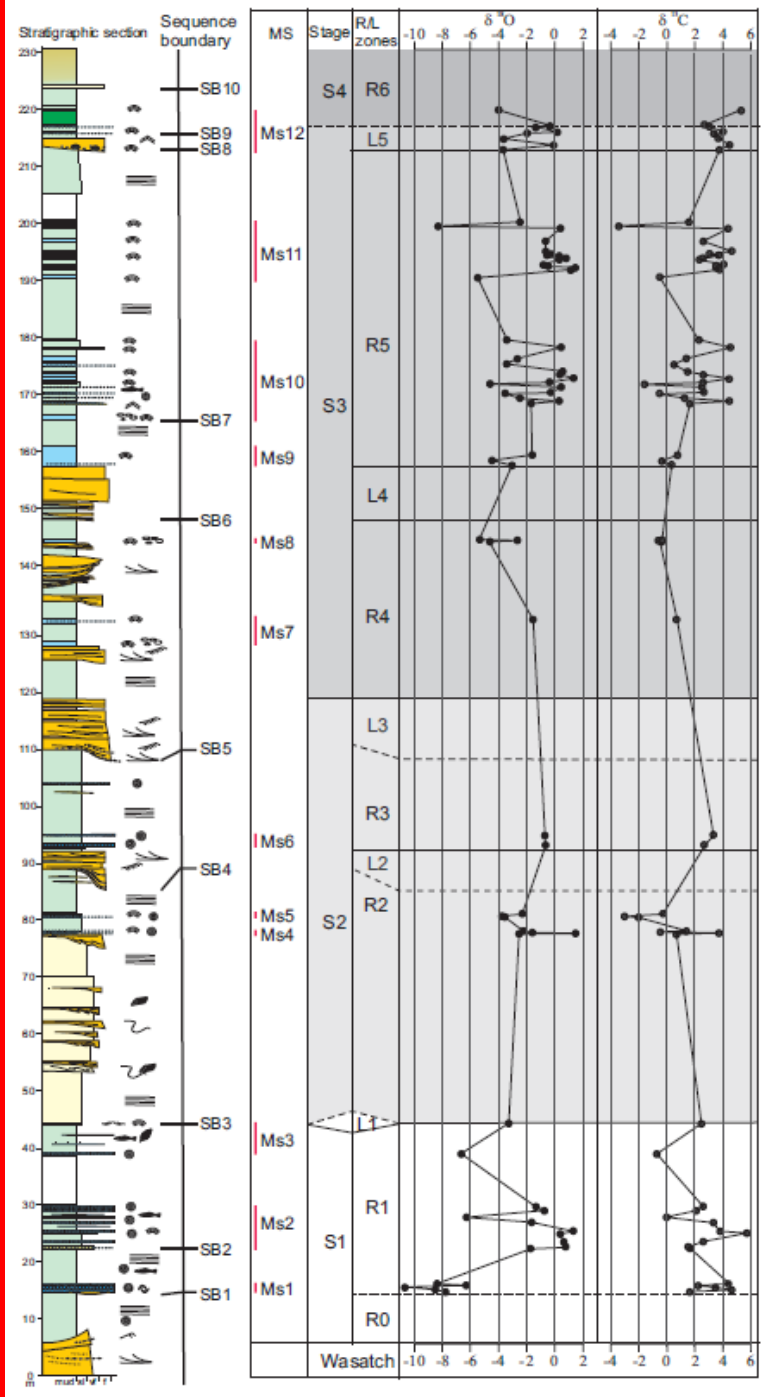
Cementation by Blocky Cements

Cementation by Poikilotopic Cement

Late Burial Dolomitization

Burial Dedolomitization



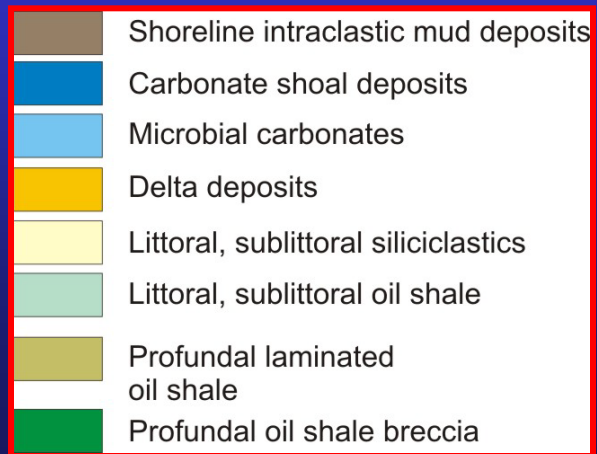


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