Reservoir Architectures in Non-Marine Carbonates*

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Abstract

Research on non-marine carbonates, especially in terms of developing concepts and models applicable to subsurface data sets, is at a very early stage. Recent discoveries in such carbonates in the South Atlantic expose all too clearly our lack of understanding. Unlike marine carbonates, which show strong stratigraphic age dependency in terms of facies architecture and composition, non-marine carbonates do reveal consistent patterns in facies and pore-scale architecture through time. However, variety is related to specific hydrological conditions in terms of the catchment geology and its effect on water chemistry, nature of solute supply (for example spring fed systems) and on the unique physical aspects of many carbonate lakes such as their limited fetch (and shallow wave base) and stratification controls. As an update to earlier models for lacustrine carbonates (Platt & Wright 1991), a re-assessment of the controls on carbonate facies, from seismic to genetic flow unit scale, will be presented, including microbialites.

Selected References

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Meister, P., O. Johnson, F. Corsetti, and K.H. Nealson, 2011, Magnesium Inhibition controls Spherical Carbonate Precipitation in Ultrabasic Springwater (Cedars, California) and Culture Experiments: Advances in Stromatolite Geobiology, Lecture Notes in Earth Sciences, v. 131/2011, p. 101-121.

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Reservoir architecture in non-marine carbonates

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13 April 2011

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SUMMARY

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•Our current facies models for lacustrine carbonates are limiting our ability to decipher and predict facies

•Microbialites are a major feature of lacustrine carbonate deposystems but we need to use the term carefully

•There are different distributions to “microbialites” in modern lakes....and large buildups are associated with vent/spring fed chemistries

•Unlike marine carbonates where stratigraphic age is a critical consideration in understanding the composition and architecture of reservoirs, in non-marine systems drainage basin geology and hydrology are the key controls. **In rift systems especially we need to consider the influence of volcanic sources on the chemistry, location and diagenesis of “microbialites”**

Themes

- Facies models for lacustrine carbonates – Platt & Wright 1991 ...out of date
- Retrospective on those models
- Microbialite ...or not?
- Lacustrine hydrocarbons ...rift systems so where do "microbialites" develop in rift lakes?
- Hydrology – rifts and volcanics

Platt & Wright 1991 Simple facies models

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- **Bench**
  - High energy
  - Low energy
- **Ramp**
  - High energy
  - Low energy

Critical antecedant topography – Toca 2

Constructional like carbonate shelves?

Little refinement

Arid end – Great Salt Lake, Late Triassic of UK

Side-lined into palustrine model – vegetated, and discharge wetlands

Models are simplistic - only really related to more humid hardwater lakes, did not incorporate bioherm development, or consider other lake chemistries

Lacustrine Facies Models (Platt & Wright 1991)

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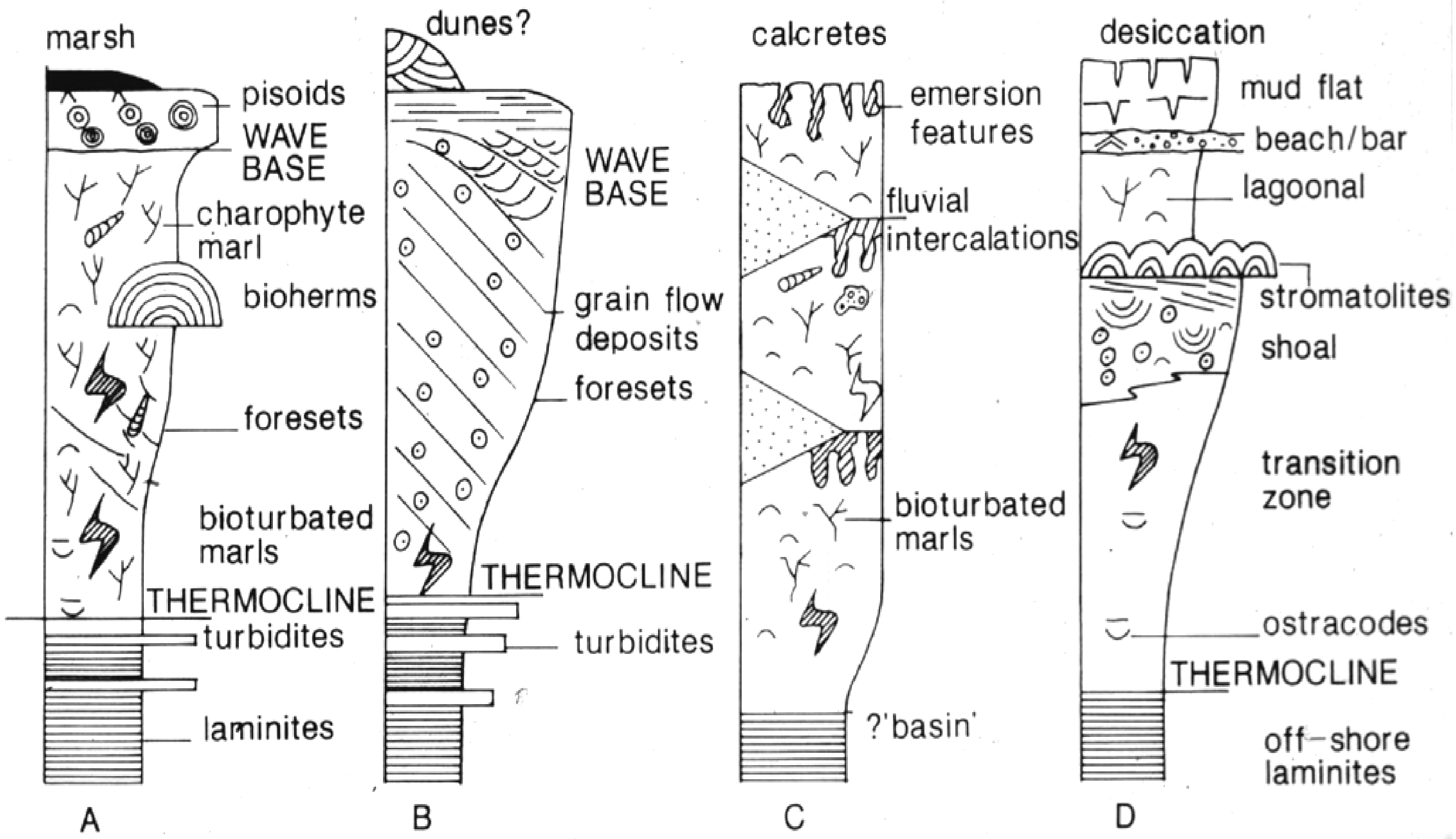
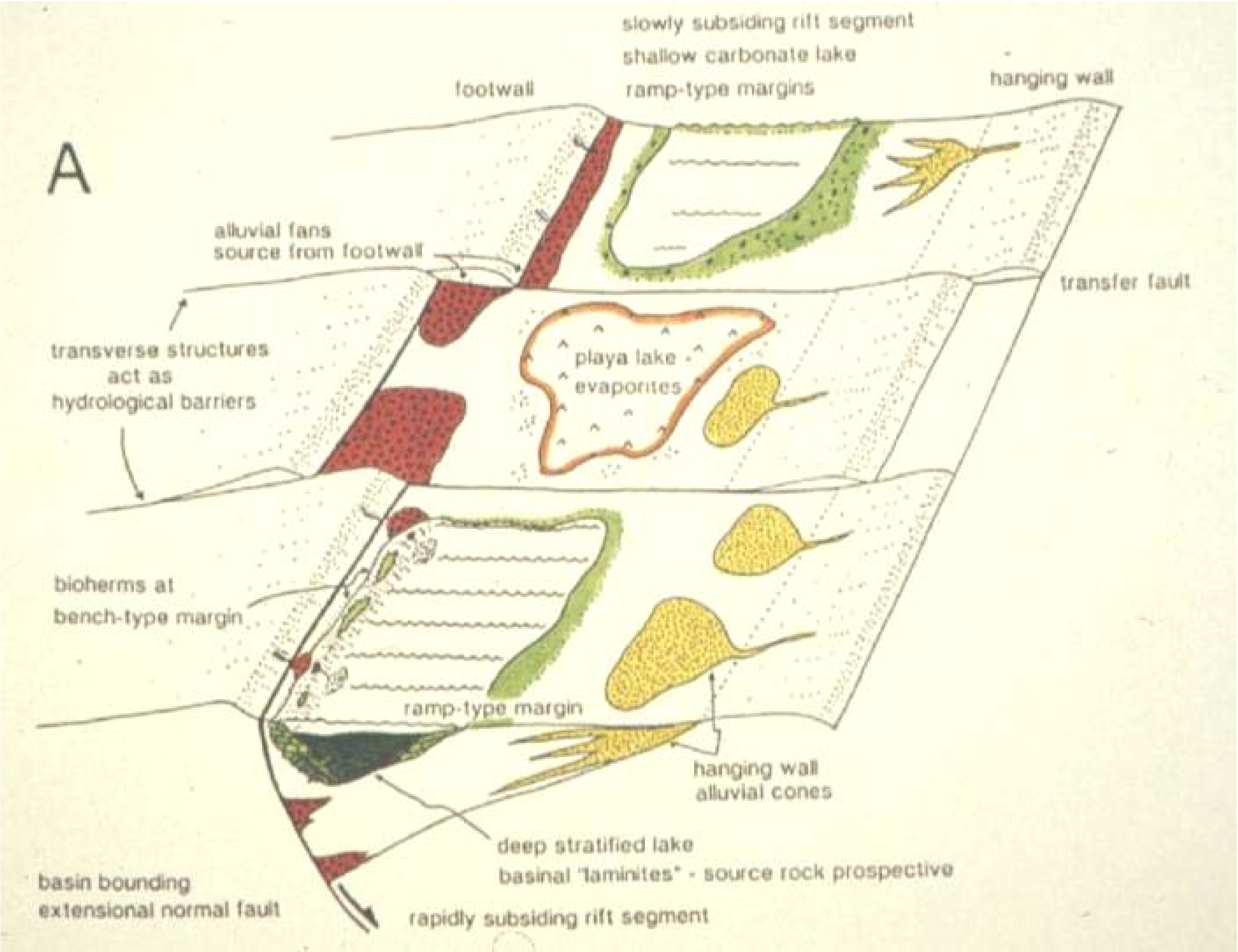
Bench | Ramp

Low (wave) energy | high (wave) energy | low (wave) energy | high (wave) energy



Lacustrine Facies Models - distribution in extensional basins (Platt & Wright 1991)



Toca 2 – Barremian, Congo Basin

Bench with rim

Lowstand stage, subaerial exposure, lithification of rim

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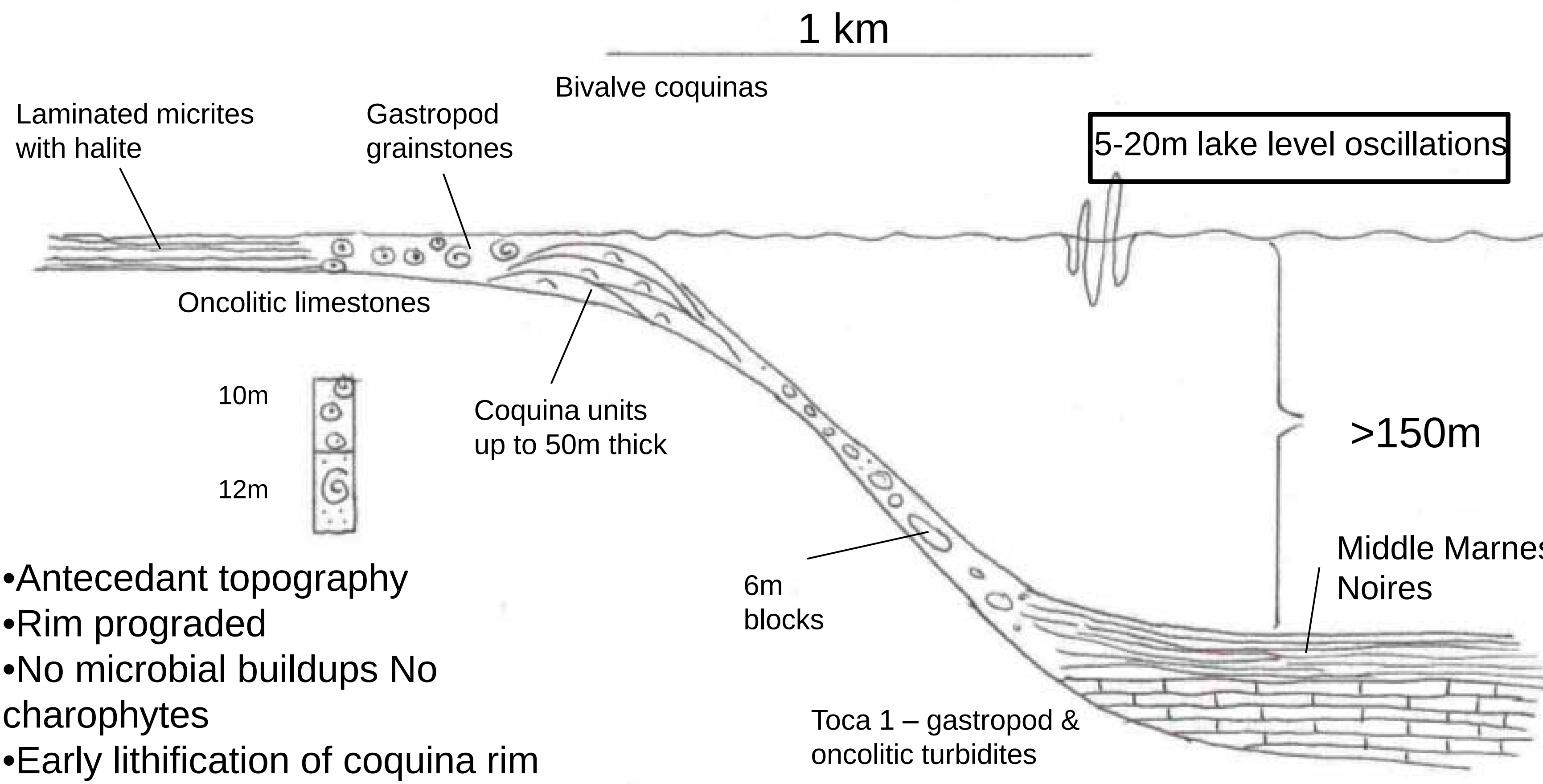

- Antecedant topography
- Rim prograded
- No microbial buildups No charophytes
- Early lithification of coquina rim

Based on papers by Harris & co-workers

Microbialites – everyone is interested....BUT are what appear to be microbialites really microbial?

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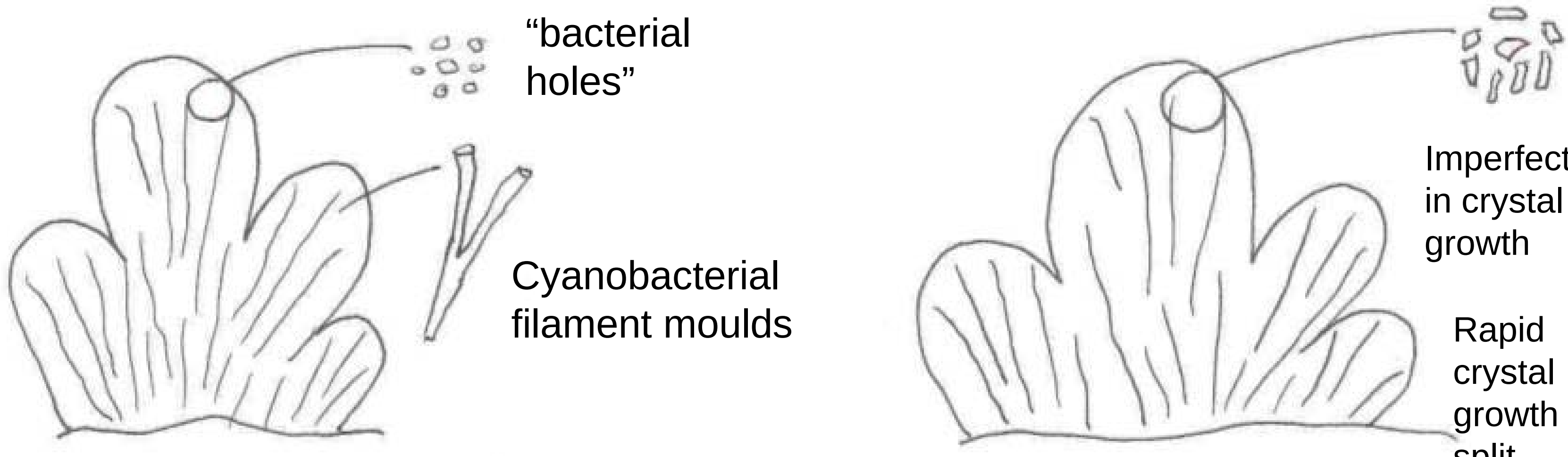
Biotic - - - - - - - - - - - - - - - - Abiotic



"bacterial holes"

Cyanobacterial filament moulds

Imperfections in crystal growth

Rapid crystal growth – split crystals

Crystal shrubs - common growth form

Calcite shrubs – a common features of many non-marine carbonate buildups

Shrubs from Campos Basin

Quaternary Italian travertine

What produces microbial-looking carbonates in a rift setting?

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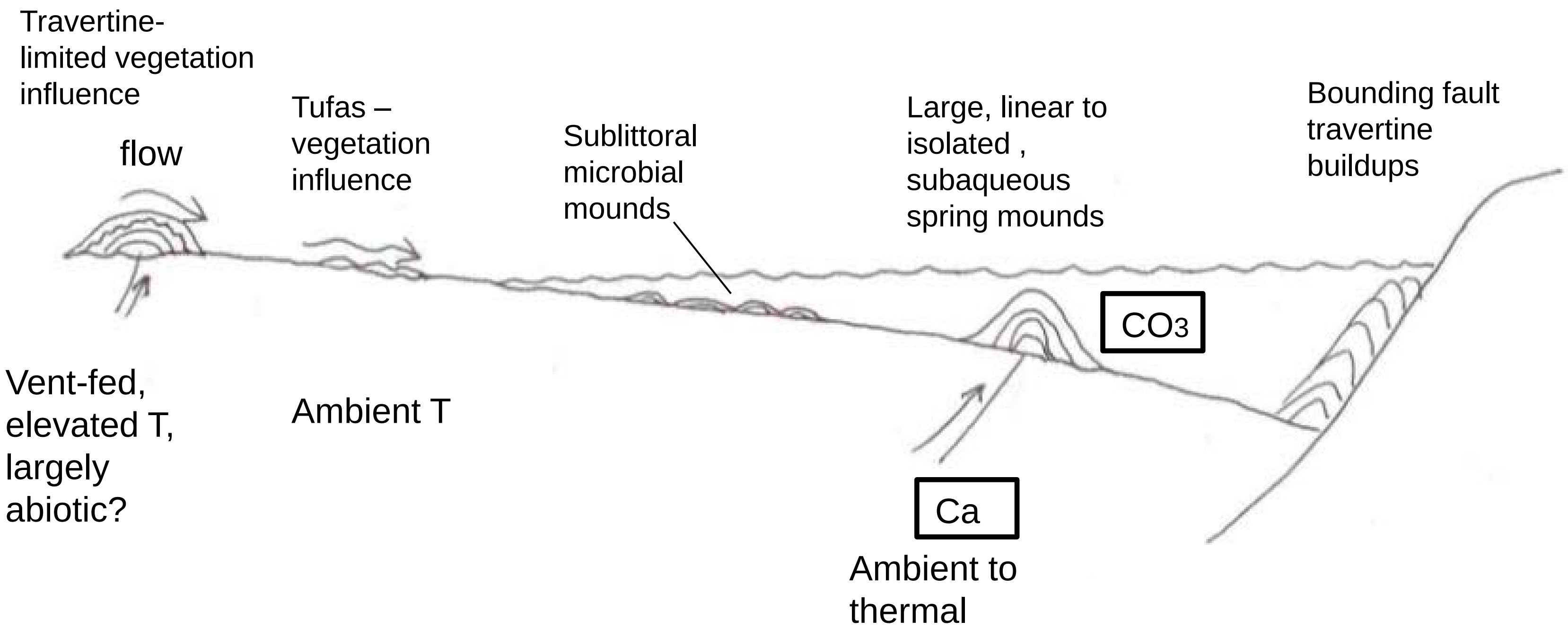
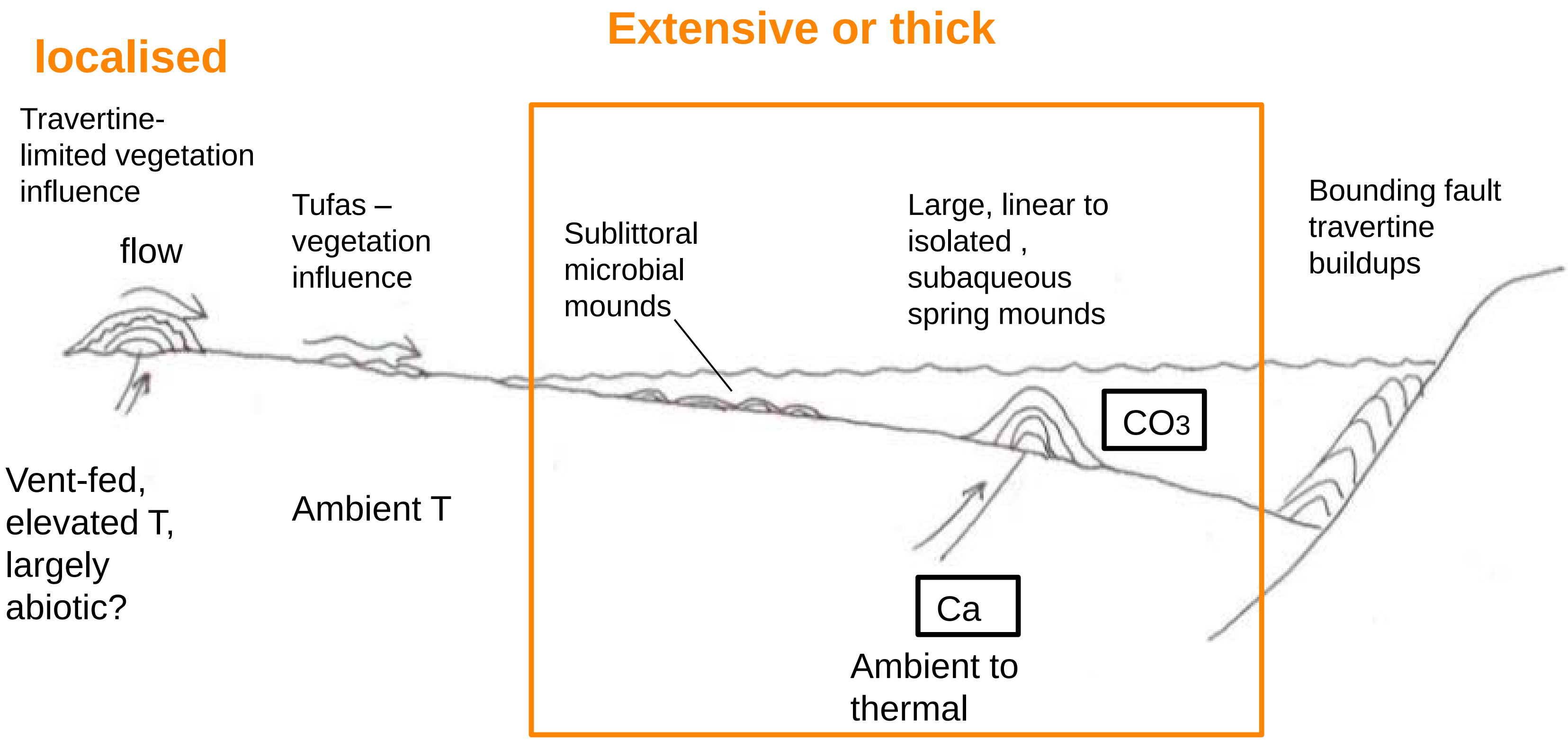


What produces microbial-looking carbonates in a rift setting?



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Microbial-like buildups in lacustrine rift settings

Several models to choose from, from fresh to saline to alkaline–

•Shallow lake with dispersed "microbialites – Great Salt Lake

•Depth controlled belts in deeper lake – Lake Tanganyika…

•Spring fed (thermal or non-thermal) –subaqueous in lacustrine settings such as Mono Lake and Pyramid Lake.

Each has specific geometries and architectures

MODERN RIFT SYSTEMS WITH "MICROBIALITES"

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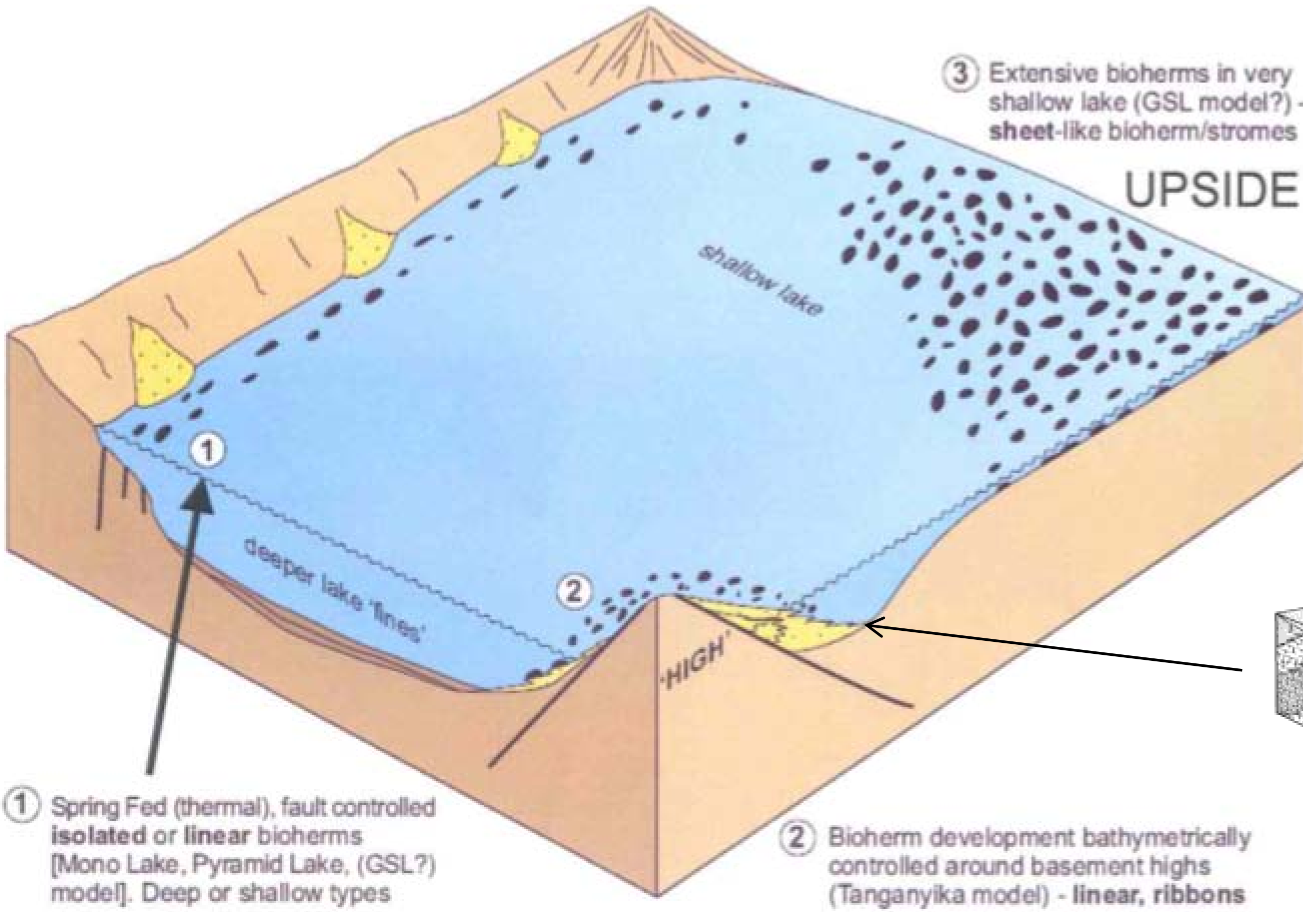

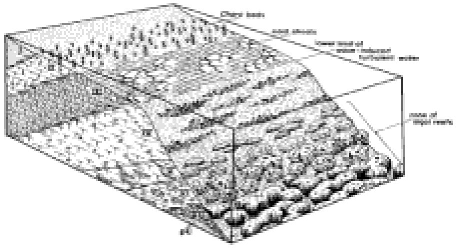

LAKE TANGANYIKA

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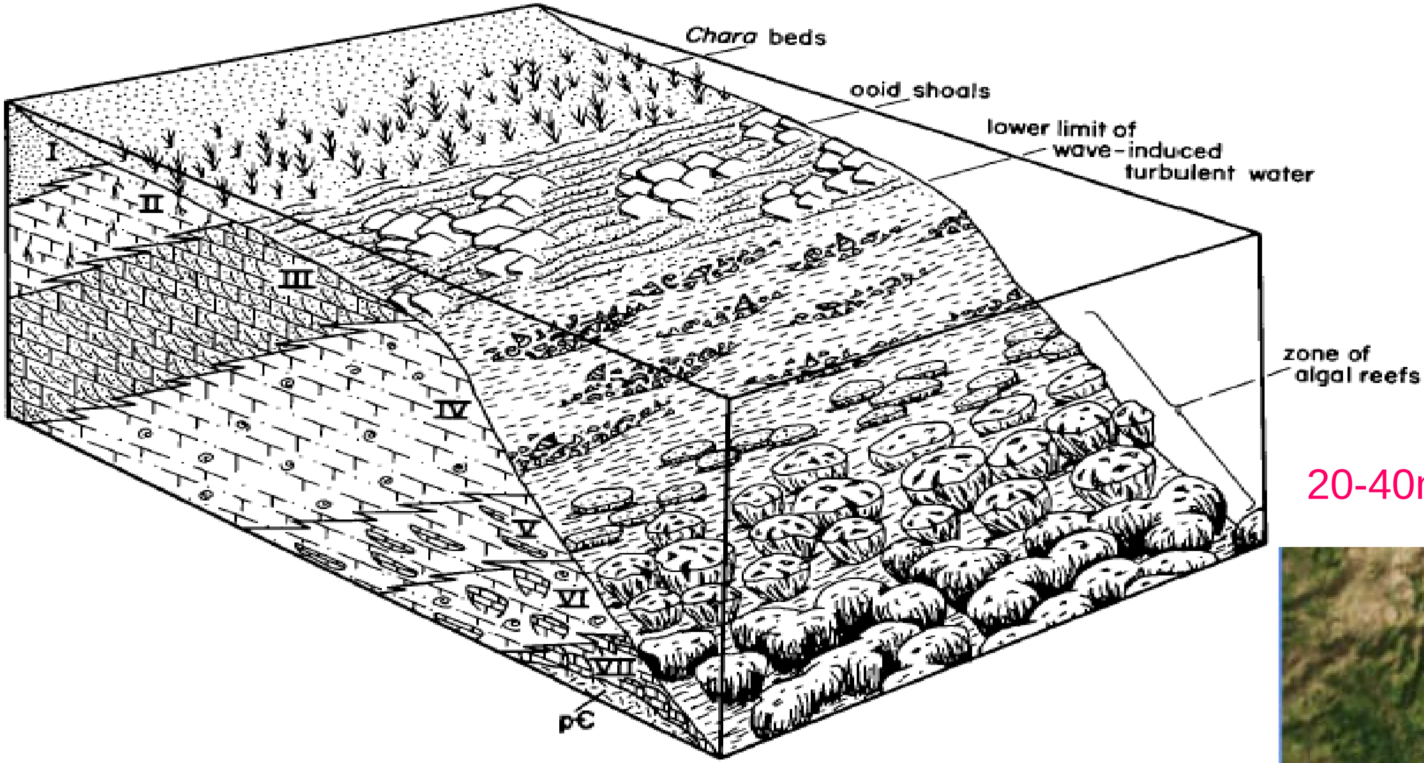
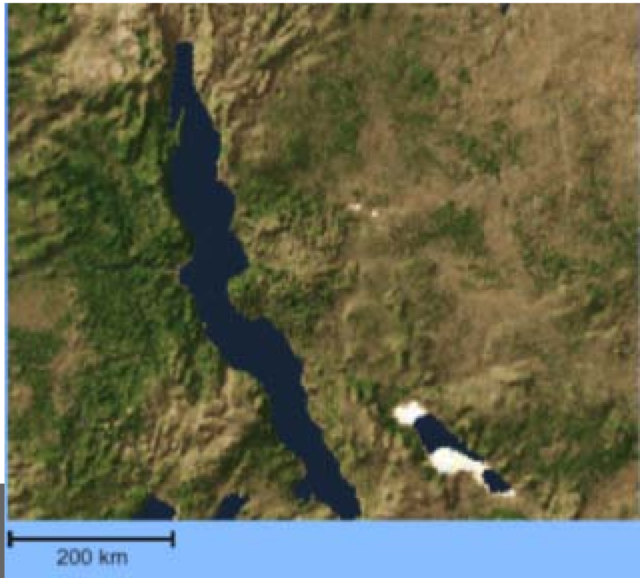
Depth-related microbial facies belts



20-40m water depth



From Cohen & Thouin 1987, Geology, 15, 414-418

PYRAMID LAKE – THE NEEDLES

Spring fed buildups - up to 105m high, 2 kms long along faults, thermal

MONO LAKE

subaqueous buildups in a volcanic alkaline lake in USA…..spring (thermal) controlled “microbial” metre-scale features, also associated with Mg-silica

POSSIBLE MODELS

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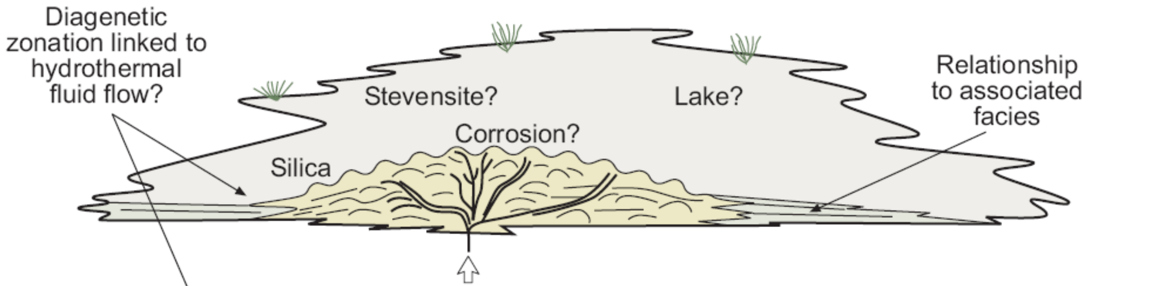
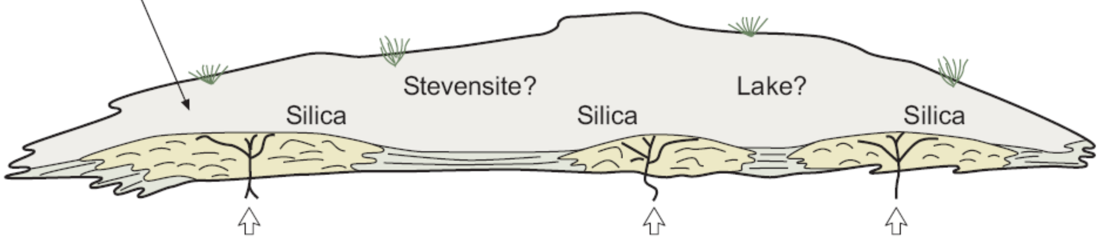
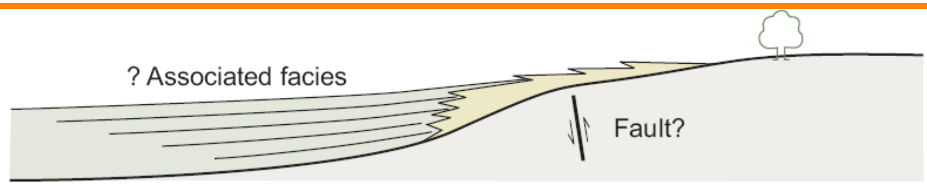


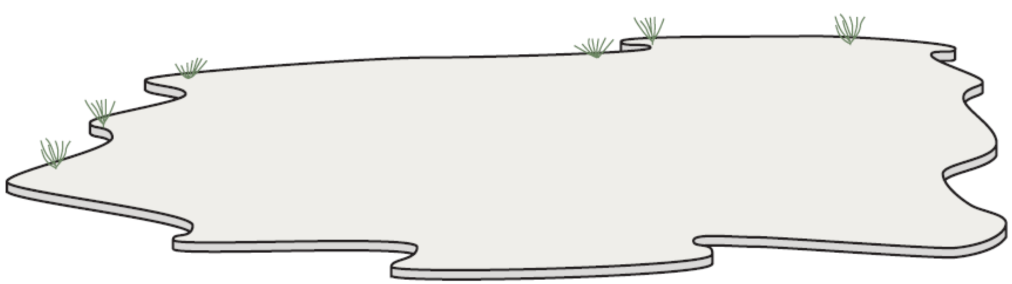
① HYDROTHERMAL SPRING/VENT MODEL
Size, thickness, geometry, architecture, spacing



② LINEAR SPRING/VENT MODEL
Size, thickness, geometry, architecture, spacing



③ TOPOGRAPHICALLY CONTROLLED ACCUMULATIONS
Size, thickness, geometry, architecture, spacing



④ SHEETS?
Broadly like GSL - extensive facies sheets

Gross geometries of microbial carbonates

In rift systems volcanics are a major feature – what effect do they have on lake carbonates?

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SOLUTE CHEMISTRY OF RIFT LAKES DRAINING VOLCANICS

" calcite, tri-octahedral smectite, analcime (& Na bicarbonates & carbonates) etc…form in lakes where volcanic terrains predominate."

Stevensite - Ca, Mg, Na, K, Fe, & Li silicate…over 30% Mg

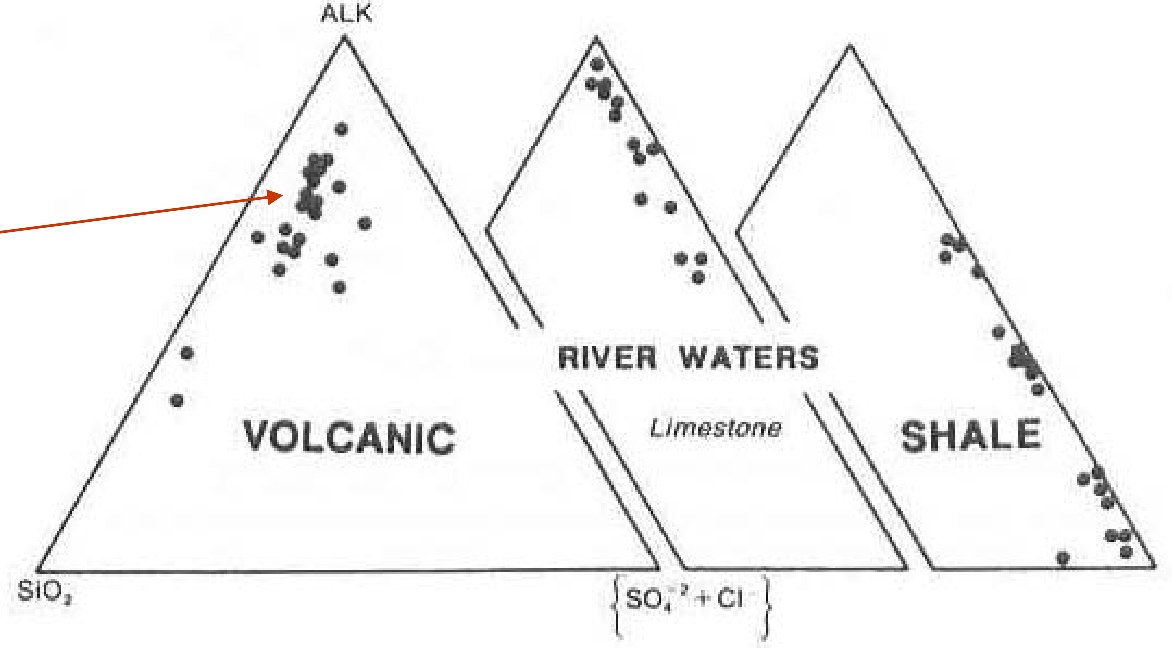

Fig. 1. Water chemistry of rivers draining exclusively volcanic (left), limestone (center), or shale (right) terrains normalized to the molar concentrations of dissolved SiO_2^o, HCO_3^-, and $[SO_4^{-2} + Cl^-]$.

Cerling T E 1994 Global Geological Record of Lake Basins Vol 1, page 29

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So what?

Rift setting volcanic fed -lakes typically are highly alkaline, have limited chemistry dominated by Mg, Ca and silica in solution....prone to rapid precipitation by degassing, and mixing of alkaline waters and cation-rich inflows

High dissolved silica is likely to “drop out” during lowered pH pluvial phases.

Rapid precipitation creates textures like crystal shrubs, abiotically, and high Mg and SiO_2 activity is associated with the growth of spherulitic calcites (Garcia-Ruiz, J M 2000, Beck & Andreassen 2010; Meister et al. 2011).

High pH and Mg and SiO_2 favour stevensite precipitation...a tri-octahedral smectite likely metastable under burial conditions - possibly releasing SiO_2, Ca & Mg (dolomite) and Fe.

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