Build-and-Fill Stratigraphic Sequences in Carbonates*

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Abstract

Build-and-fill sequences are a particular class of carbonate sequences formed during a full cycle of sea-level rise and fall and are characterized by the following: thin (typically 10's of m thick) compared to amplitude of sea-level change; drape paleotopography; maintain similar thickness throughout wide geographic areas; have a complex internal architecture of building and filling relief. Build-and-fill sequences occur in icehouse, greenhouse, and transitional systems throughout the geologic record. Less-than-optimal carbonate production is the primary control that leads to underfilled accommodation. The build-and-fill zone typically occurs in middle portions of ramps, and interior lagoons of rimmed platforms located at intermediate positions between sea-level highstand and lowstand position. Relatively gentle substrate slopes are a common theme in build-and-fill examples; they result in rapid lateral migration of areas of shallow-water production when combined with relatively high rates of sea-level rise and fall, and may promote underfilled accommodation. The predominant constructional building phase occurs during transgressions (e.g. coral reefs, microbial buildups, algal facies, and grainstone facies). The filling phase (commonly packstones/grainstones; siliciclastics in mixed systems) predominates during forced regressions, likely as a result of limited accommodation. Topography-draping deeper water facies, hiatal surfaces, and hardgrounds can form during maximum flooding. During sea-level fall, deposition may result in building constructional relief as well, but these geobodies are typically more tabular (biostromal) than those formed during rises, stillstands, or minor rises during an overall fall. Where shallow-water conditions intersect complex topography, currents may be focused, depositing grainy carbonate and siliciclastic facies in lows. If energies are too high along topographic highs, boundstone, wackestone, and packstone facies may accumulate in adjacent topographic lows where current energies are weaker. Examples from the Pleistocene, Pliocene, Miocene, Cretaceous, Triassic, Jurassic, Permian, Pennsylvanian, Mississippian Devonian, and Proterozoic illustrate build-and-fill sequences from various settings and systems. Examples include reservoir systems, such as the Upper Jurassic Arab D, Pennsylvanian Midcontinent and Paradox Basin, and Miocene-Pliocene in Indonesia.

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Build-and-Fill Stratigraphic Sequences in Carbonates

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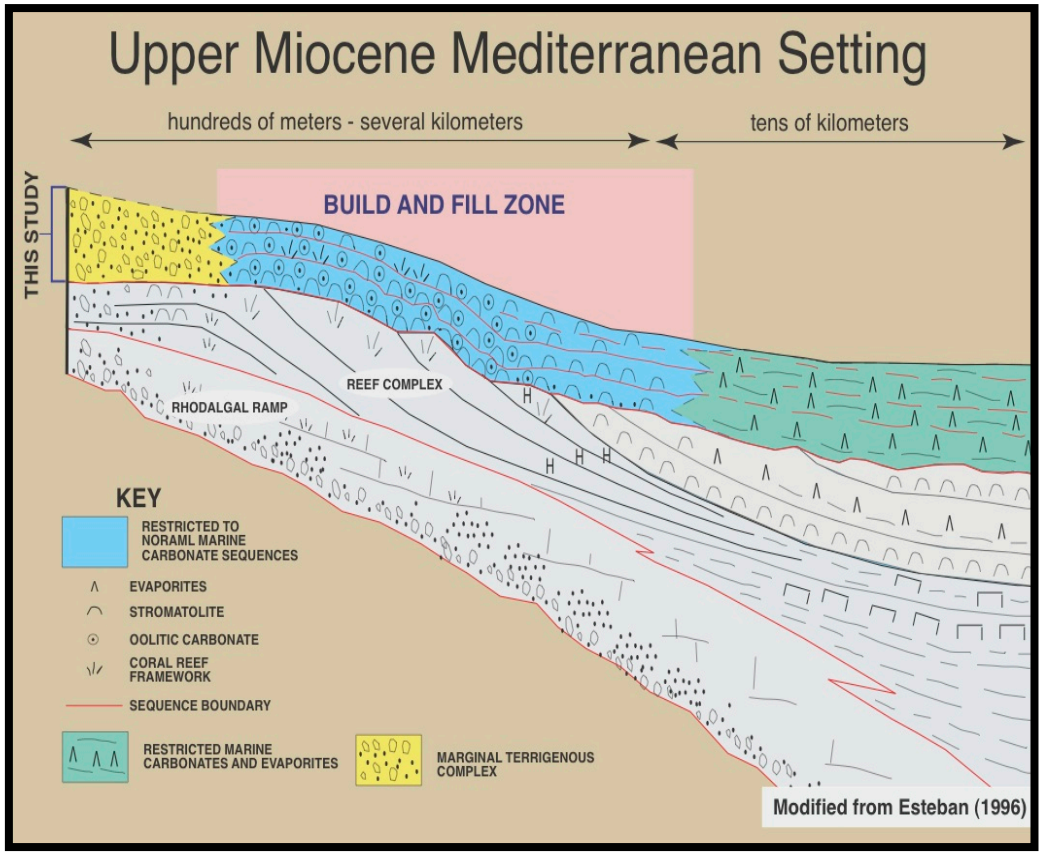
Kansas Interdisciplinary Carbonates Consortium

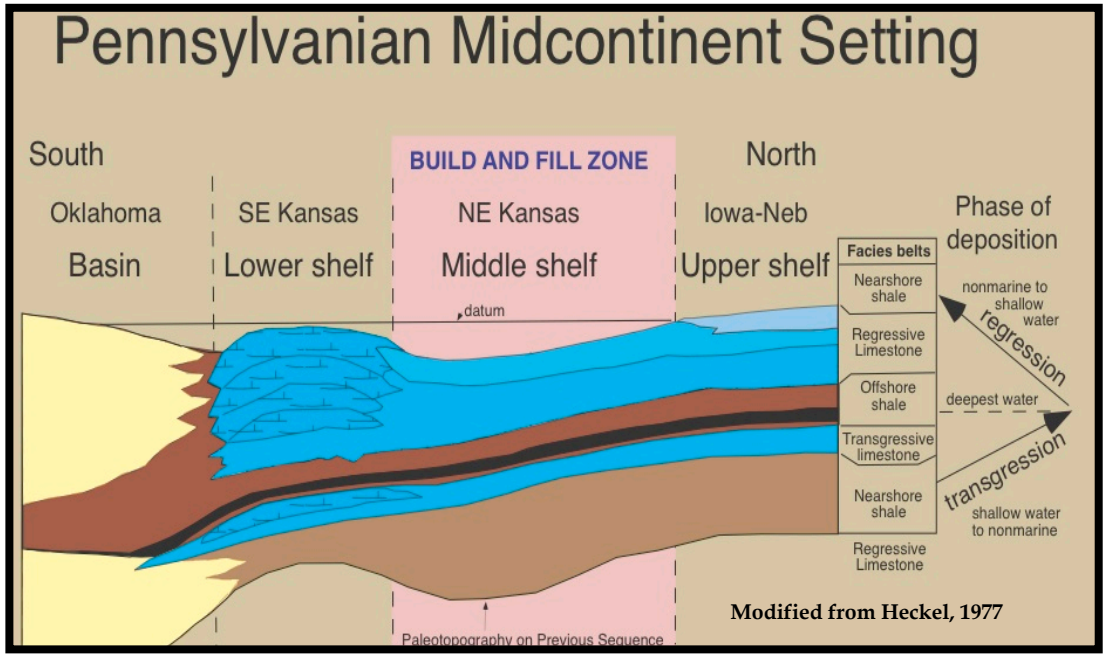
Build-and-fill sequences are characterized by the following:

- *An entire sequence deposited during a cycle of sea-level rise and fall; typically capped by surface of subaerial exposure*
- *Sequence typically laterally extensive and of relatively even thickness as an entire unit*
- *Sequence tends to drape paleotopgraphy as an entire unit*
- *Sequence is thin compared to amplitude of sea-level change (underfilled accommodation)*
- *Sequence has complex internal architecture of build-and-fill*

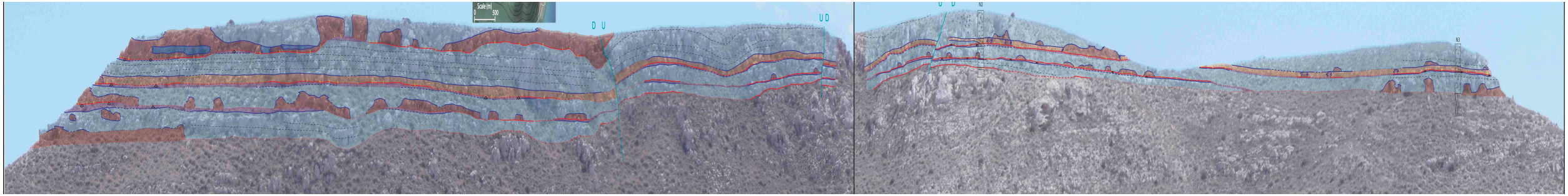
What Do Miocene-Pennsylvanian Settings Have In Common?

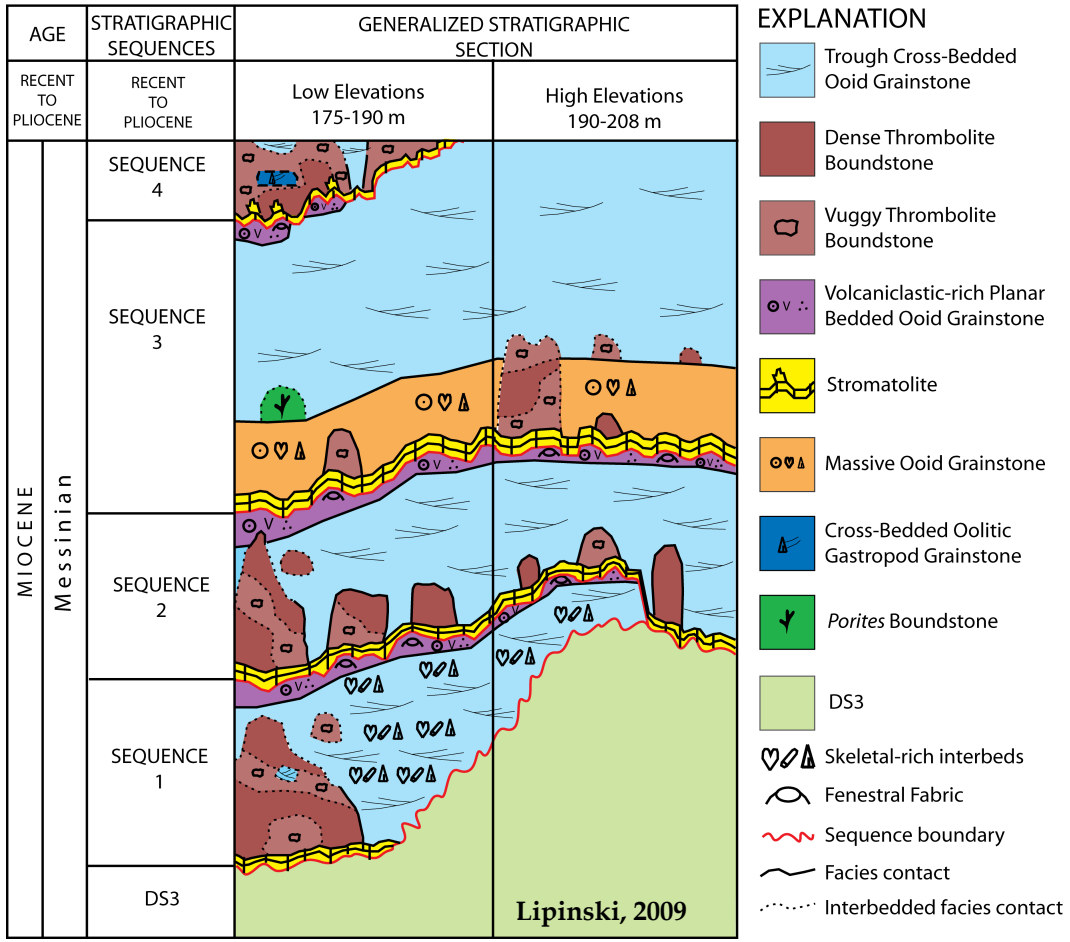
- Ice-house systems – high frequency, high amplitude sea-level fluctuations
- Non-optimal carbonate productivity
  - Miocene - Restricted basin during/after “Messinian Salinity Crisis”
  - Pennsylvanian - Semi-enclosed basin; restricted ocean connection; upwelling
- Build-&-fill zone is in mid-ramp setting, between SL turn around points



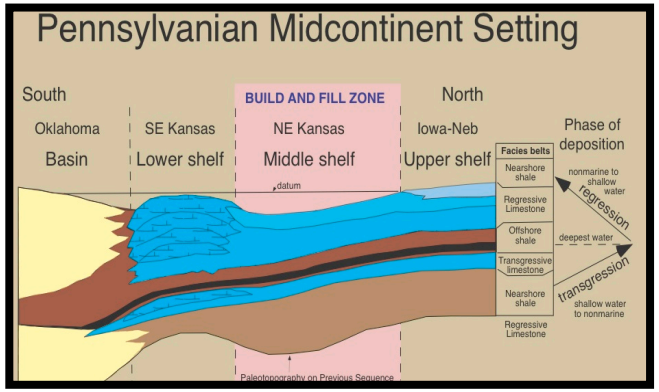


Upper Miocene, SE Spain



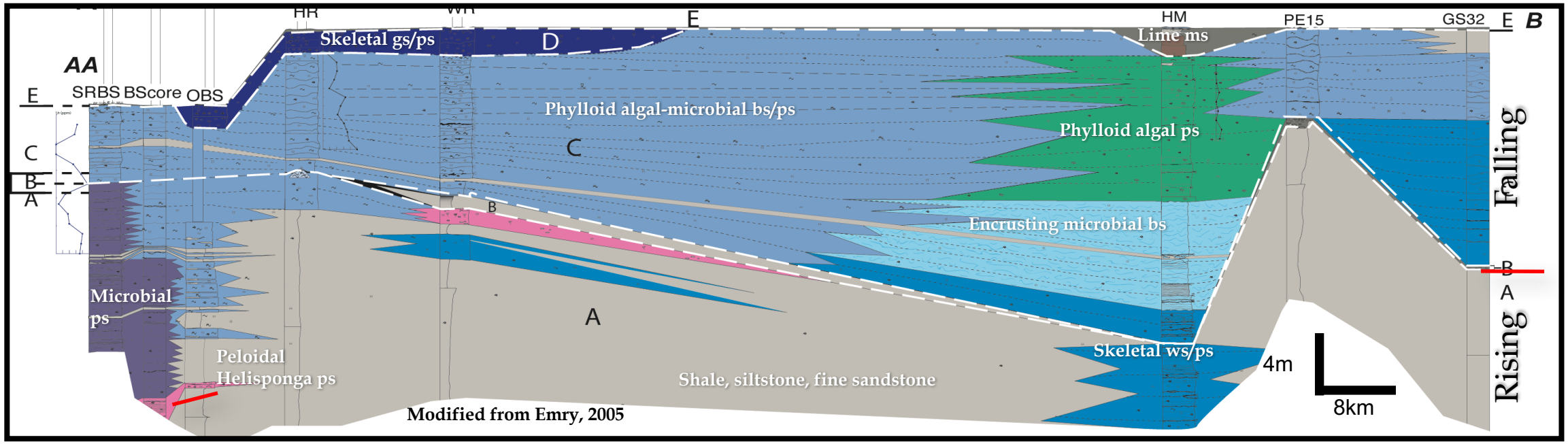


- 4 topography draping microbialite-oolitic sequences maintaining relatively equal thickness
- 32-43 m sea-level amplitudes (min); sequences 1.7–12.8 m thick
  - Underfilled accommodation
- Topographic building phase predominant during rises
- Topographic filling phase predominant during falls



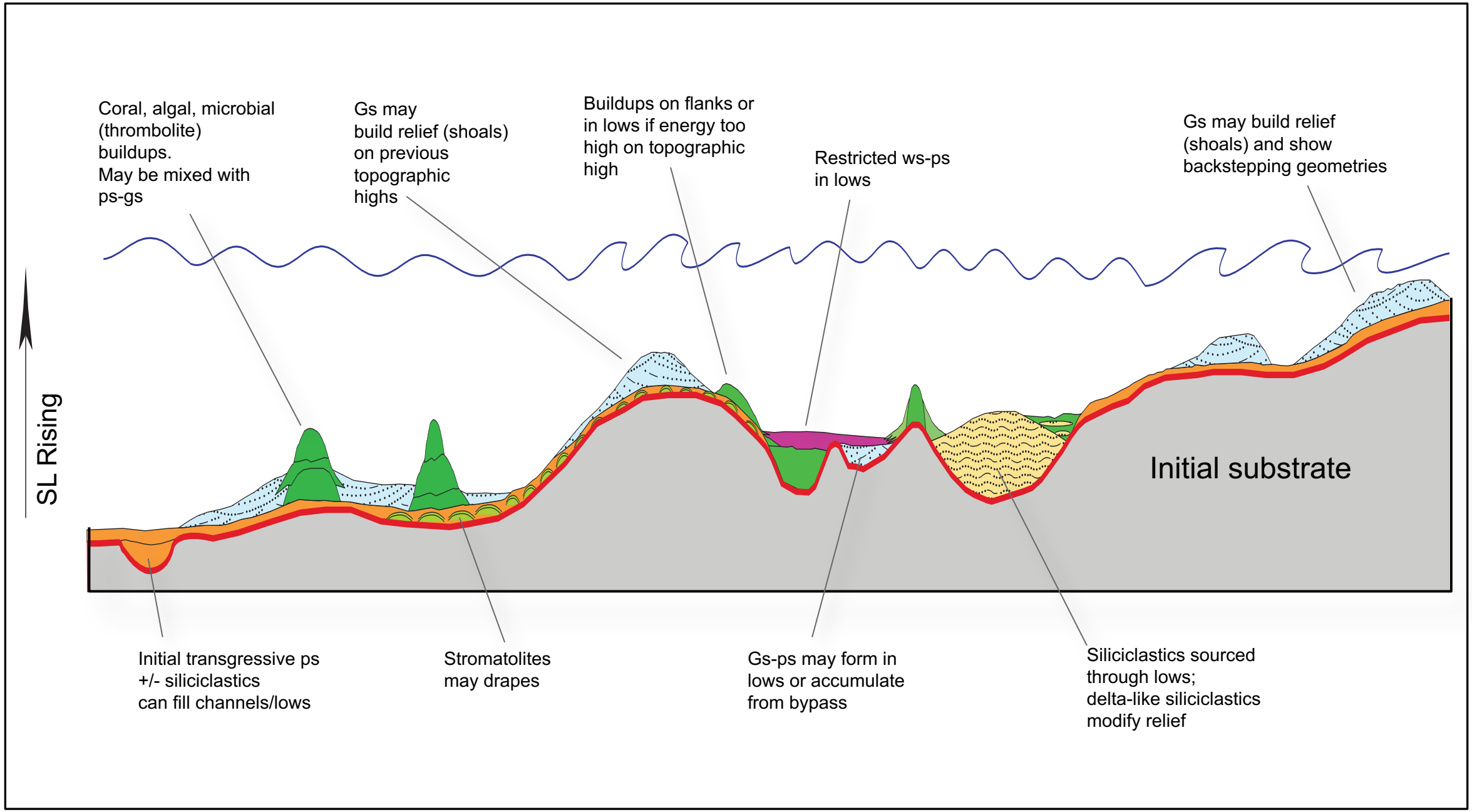
U. Pennsylvanian, Kansas – Mid Ramp

- Laterally extensive, equal thickness sequence
- Thin (~24 m thick) compared to sea-level fluctuation amplitude - unfilled accommodation

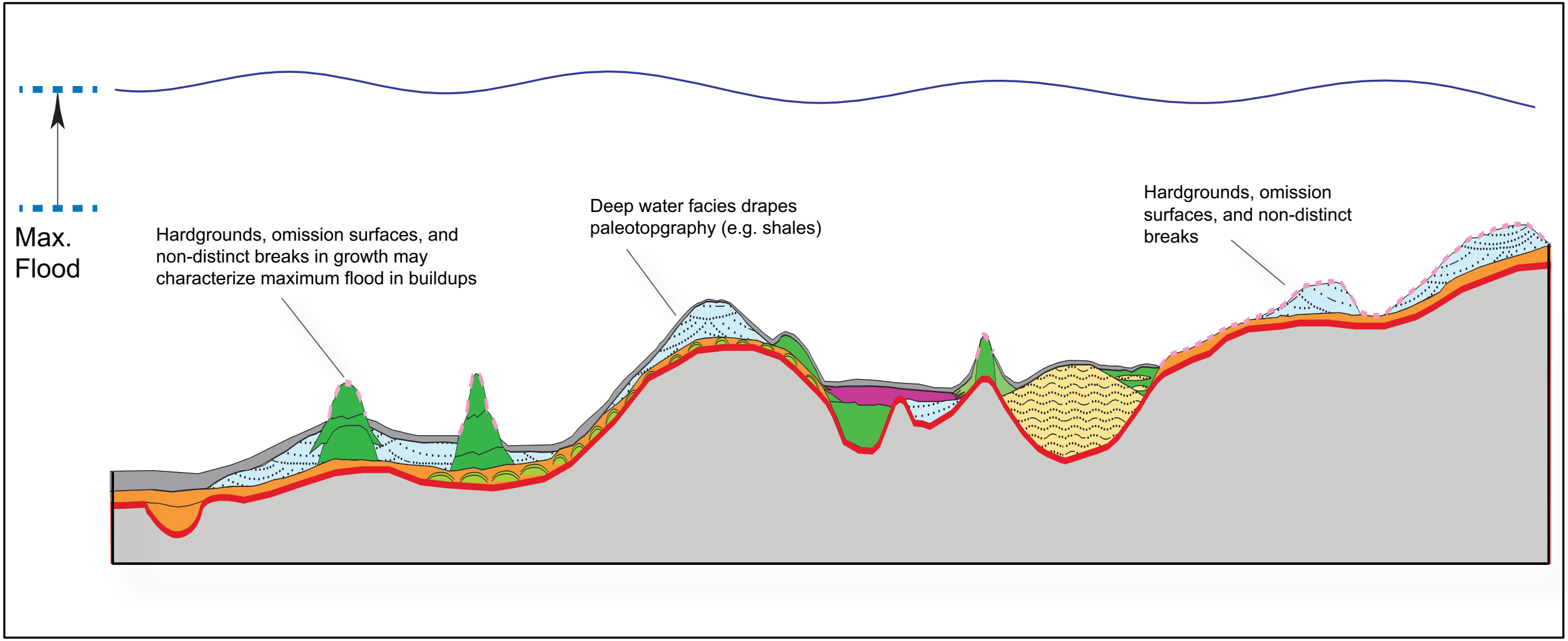


- Facies build relief during sea-level low and rise
- Microbial boundstone fills low during falling sea level
- Phylloid algal-microbial facies facies fill and subdue paleotopography during fall (don't form mounds)

Preliminary Build-and-Fill Model



Preliminary Build-and-Fill Model



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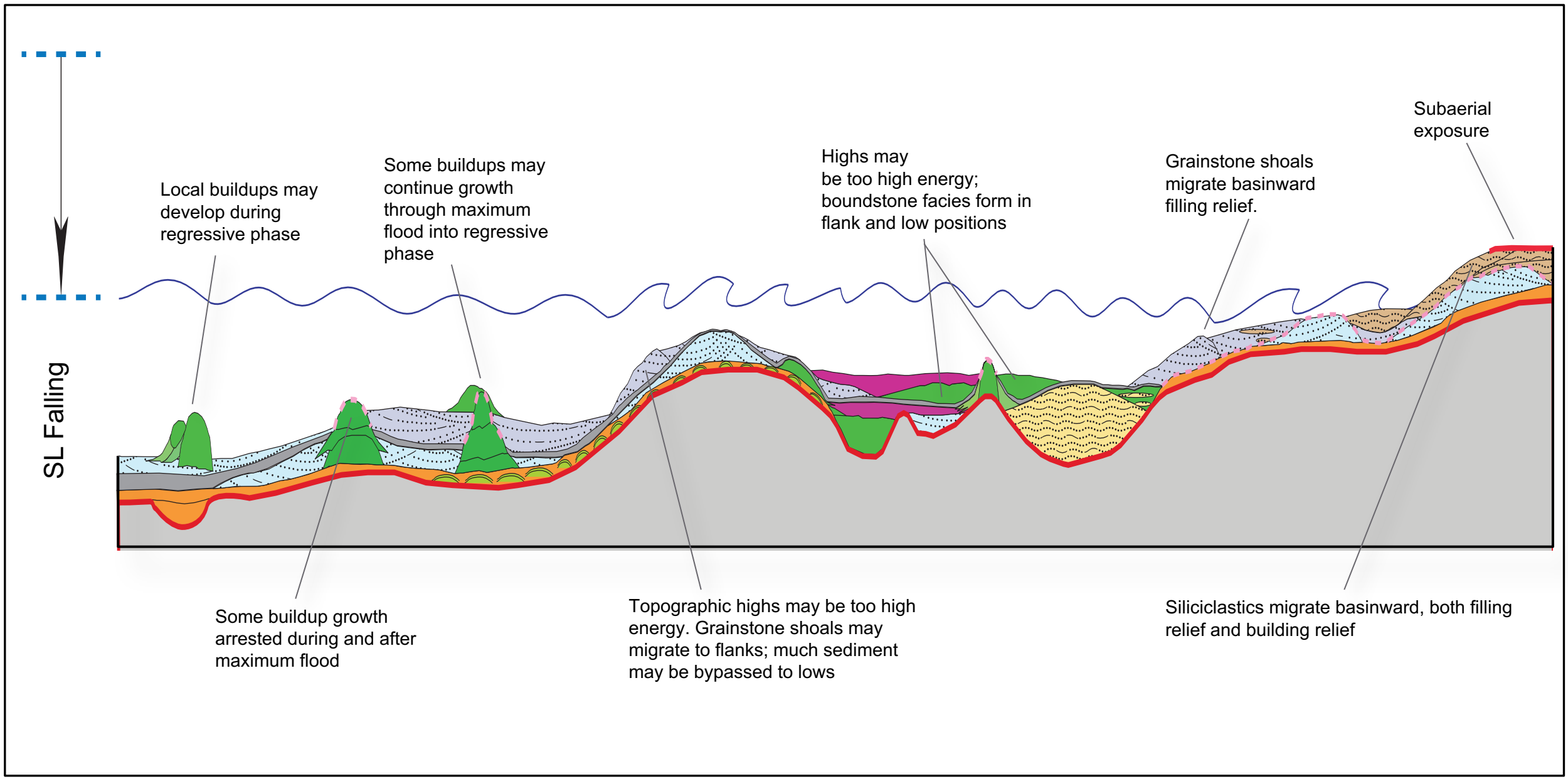

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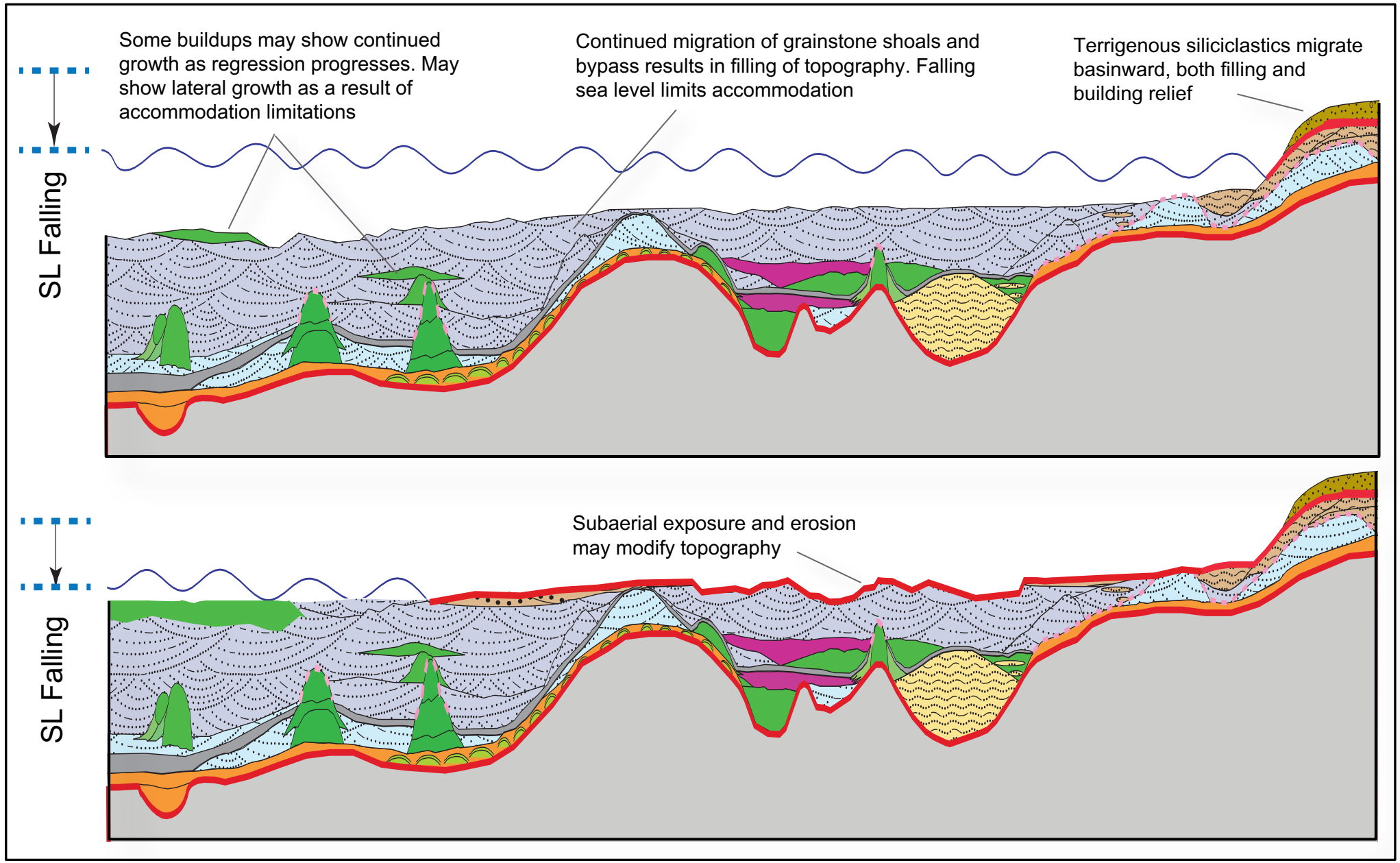

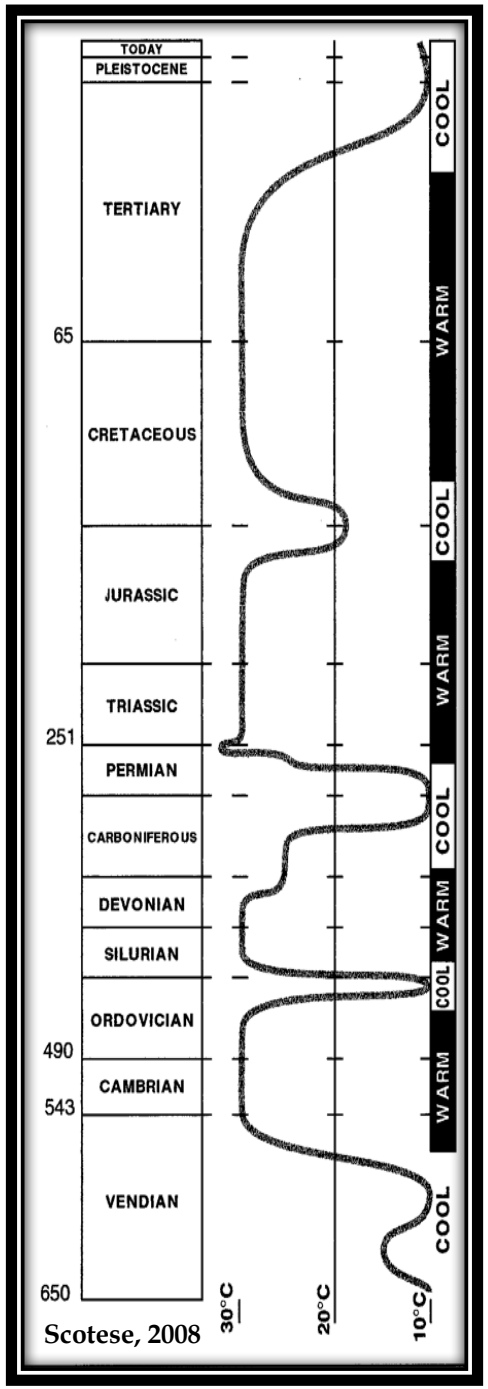

L. Pleistocene
Ramp – S. Italy
Shelf - Greece
Lagoon - Jamaica

L. Pliocene
Estuary - Australia

L. Miocene
Ramps – SE Spain
Delta shelf - Indonesia

M. Miocene
Lagoon - Turkey
Delta shelf - Borneo

L. Cretaceous
Platforms - Oman
Ramps – N. Spain
Ramp – Mexico

L. Jurassic
Ramp - Argentina
Ramp – S. Spain
Ramp – Saudi Arabia
(Arab D)
Ramp – SW Germany
Lagoons – NW Germany
Delta shelf – Nova Scotia
Ramp – Portugal
Ramp – NE Spain

M. Jurassic
Ramp – Morocco
Ramp – N. Switzerland

E. Jurassic
Ramp - Morocco
Platform – S. Spain

E. Triassic
Ramp – Turkey

Permian
Ramp -
New Mexico

Pennsylvanian
Ramp – Spitzbergen
Delta shelf – NW Spain
Ramp - NW Spain
Lagoon – NW Spain
Ramp – Kansas
Ramp/shelf – S. Utah

L. Mississippian
Ramp – Illinois
Ramp – Algeria

E. Mississippian
Lagoon – Sask., Canada

L. Devonian
Ramp – NW Terr., Canada

M. Devonian
Ramp – Morocco

E. Devonian
Ramp – NW Spain
Ramp – Morocco

L. Silurian
Ramp – Morocco

L. Cambrian
Platform – N Wyoming,
S. Montana

L. Proterozoic
Ramp – Namibia
Ramp – NW Canada

Ongoing Study & Documentation

- 50+ examples
- Found throughout rock record
- Icehouse, transitional, greenhouse climates
- Ramps, rimmed platform lagoons, deltaic systems

Summary of Examples To Date

- Build-&-fill sequences form in icehouse and greenhouse systems
  - Middle ramp and rimmed platform interiors (lagoons)
  - 4^{th}, 5^{th} order sequences common
- Less-than-optimal carbonate production leading to unfilled accommodation is primary control
  - Local to regional restriction, increased nutrients, cool-water conditions
  - Microbialites important in many examples
- Build-&-fill sequences form in intermediate locations between sea-level hightstand and lowstand position (build-&-fill zone)
  - Gentle substrate slopes are a common theme
  - Relatively high rate of sea-level change may promote underfilled accommodation
- Constructional building phase - predominant during transgression
  - Thrombolites/stromatolites, corals, stromatoporoids, sponges, red and green algae, mud mounds, grainstone shoals
- Fill phase - predominant during regression; commonly grainy carbonates and siliciclastics; may build relief in topographic lows
- Facies that commonly form on highs (boundstone, grainstone) may accumulate in topographic lows if energies too strong on highs