Fundamental Units of Heterozoan Carbonates: Sedimentologic and Reservoir Properties of Shoaling- and Fining-Upward Cycles*

Tony Pugliano[1], Robert Goldstein[1], and Evan Franseen[1]

Search and Discovery Article #41687 (2015)**
Posted October 5, 2015

*Adapted from oral presentation given at AAPG 2015 Annual Convention and Exhibition, Denver, Colorado, May 31 – June 3, 2015

[1]Kansas Interdisciplinary Carbonate Consortium, University of Kansas, Lawrence, KS, USA (tonympugliano@gmail.com)

Abstract

Hydrocarbon-bearing reservoirs in heterozoan carbonate deposits currently lack necessary predictive reservoir-analog models. Neogene complexes of the Cabo de Gata region of SE Spain provide ideal outcrops of heterozoan carbonates preserved as fining-upward cycles and fining-up-depositional-dip progradational clinothems. This pattern differs significantly from the coarsening-upward shoaling cycles of photozoan carbonates, suggesting the fundamental differences of heterozoan and photozoan carbonate reservoir architecture. Study of multiple outcrops of Miocene and Pliocene carbonates shows there are four fundamental cycle types. The cycles are documented using vertical and time-equivalent, lateral stratigraphic sections to provide a 3-D representation of facies. Each cycle contains coarse rhodolith and bivalve-rich gravel facies at the base, representing in situ production in deeper water. These facies systematically fine upward into sand-sized bioclastic facies that result from wave abrasion in shallower water, indicating a shoaling-upward origin for each cycle. Petrographic and petrophysical analyses allow for the quantification of sedimentologic variables and their control on reservoir character, as well as evaluation of geologic controls on reservoir-analog properties. Analyses include grain size and sorting, origin of sediment supply, grain constituents, abrasion parameters, mineralogy, and diagenesis as they relate to and are controlled by the shoaling- and fining-upward cycle. Preliminary porosity analyses demonstrate that the basal and cycle-capping facies contain the highest porosity at 26–29%, whereas medially deposited coarse-grained facies contain 13–19% porosity, and with burial, may act as potential baffles to fluid flow. The main controls on porosity distribution appear to be grain sorting and the abundance of coralline algae. Analysis of the extent of diagenetic alteration correlates to grain size, and therefore enhances variation in reservoir quality throughout cycles. We propose that the shoaling- and fining-upward cycle could be used as a fundamental object-based unit for construction of subsurface geomodels in heterozoan reservoirs. Property modeling in Petrel will be used to develop 3-D reservoir-analog models for application. These results provide a vital reservoir unit and data applicable to recent discoveries in offshore Vietnam and Perla Field, Gulf of Venezuela, as well as application to future discoveries of heterozoan reservoirs.

References Cited

Instituto Geolo´ Gico Y Minero De Espana, 1981, Mapa Geolo´ gico de Espana: Servicio de Publicaciones, Ministerio de Industria, Spain.

Toomey, N.L., R.H. Goldstein, and E.K. Franseen, 2003, Paleotopographic Controls on Carbonate Facies during an Interval of Warming Climate: Miocene, Cerro de Ricardillo, SE Spain: 2003 AAPG Annual Convention, Official Program, v. 12, p. A171.

Fundamental Units of Heterozoan Carbonates: Sedimentologic and Reservoir Properties of Shoaling- and Fining-Upward Cycles

Tony Pugliano, Robert Goldstein, Evan Franseen

Kansas Interdisciplinary Carbonates Consortium (KICC)

University of Kansas, Department of Geology

KICC

Kansas Interdisciplinary Carbonates Consortium

Significance

- Heterozoan carbonates are widely distributed, but poorly understood.
- Heterozoan carbonates form predictable depositional patterns distinct from photozoan carbonates.
- Currently reservoir-analog models are lacking, and there are few geologic models.
- This research provides the following results:
  - Stratigraphic architecture
  - Quantification of sedimentologic variables
  - Petrophysical values and their controls
  - Reservoir-analog models

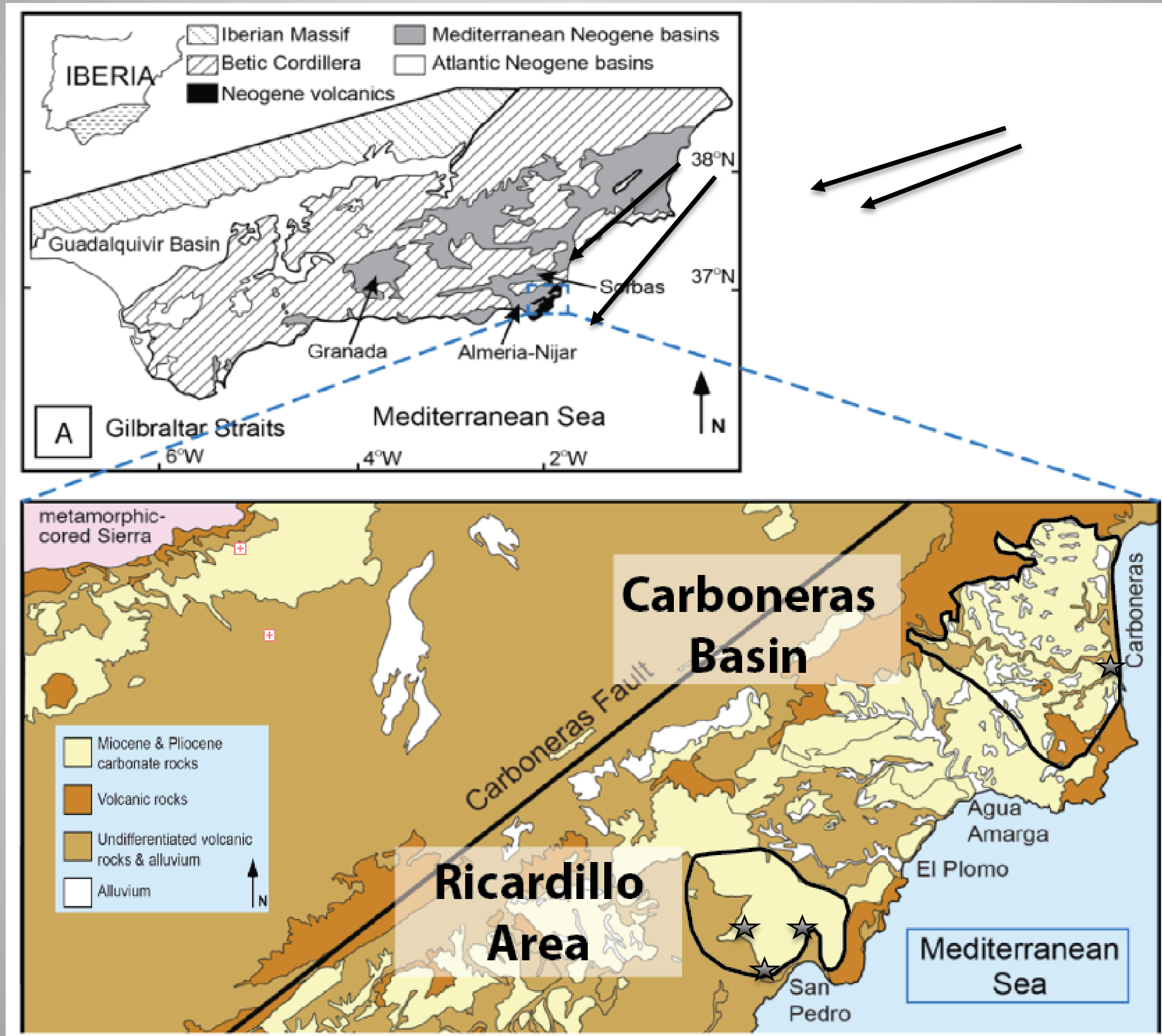
Key Findings

- Distinctive depositional patterns representing transgressive-regressive cycles.
- Depositional trends are governed vertically by grain size and laterally by grain constituents and grain size.
- Heterozoan carbonates are potentially highly economic conventional hydrocarbon reservoirs.
- Outcrop analog permeability values average 100s of millidarcies and ~35% porosity.
- Petrophysical values are governed by predictable patterns of grain size, grain constituents, and diagenesis.

Overview of Heterozoan Carbonates

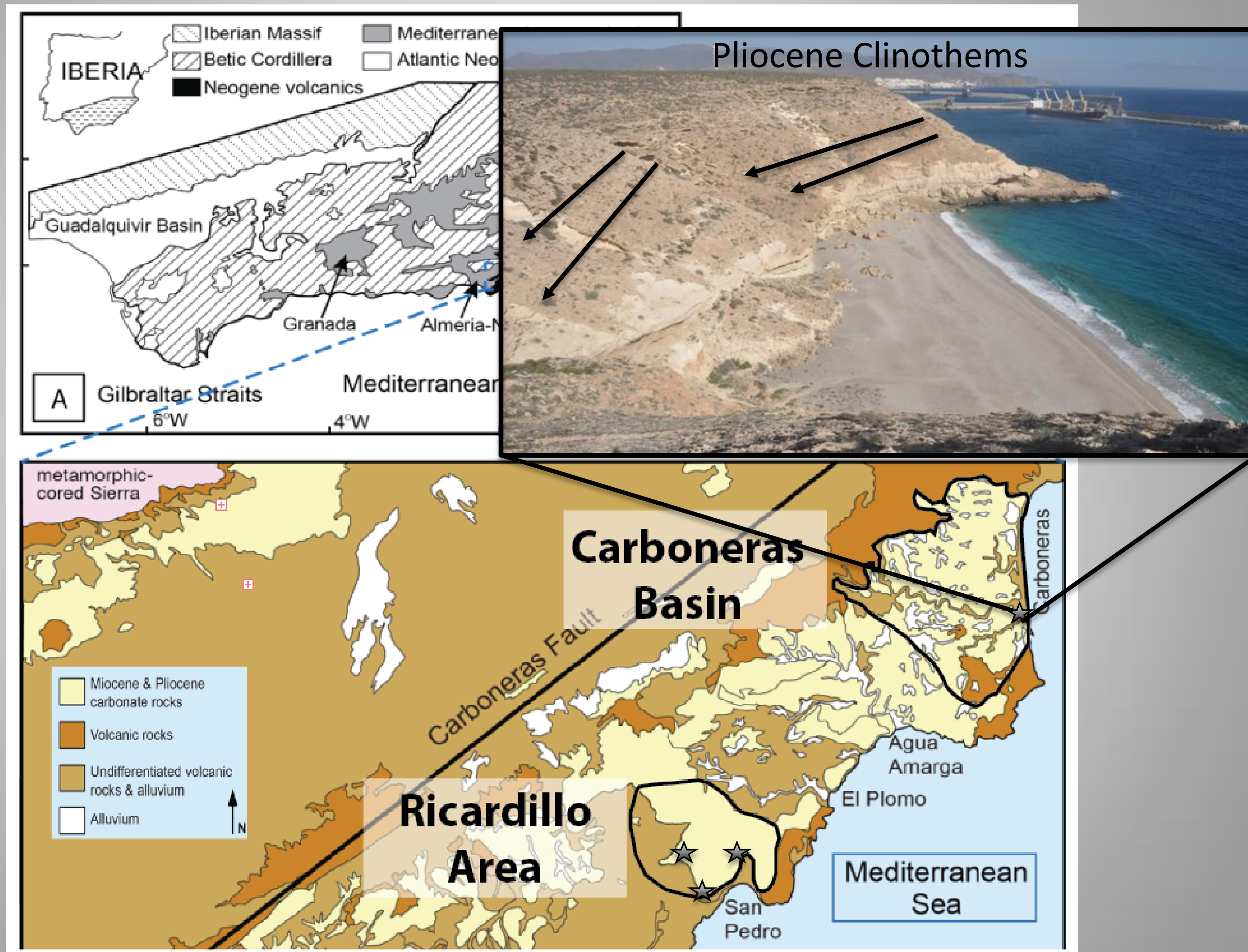
- Heterotrophic filter feeders and coralline algae
- Nutrient dependent
- High energy
- Primarily calcite
- High abrasion and bioerosion

Geologic Setting



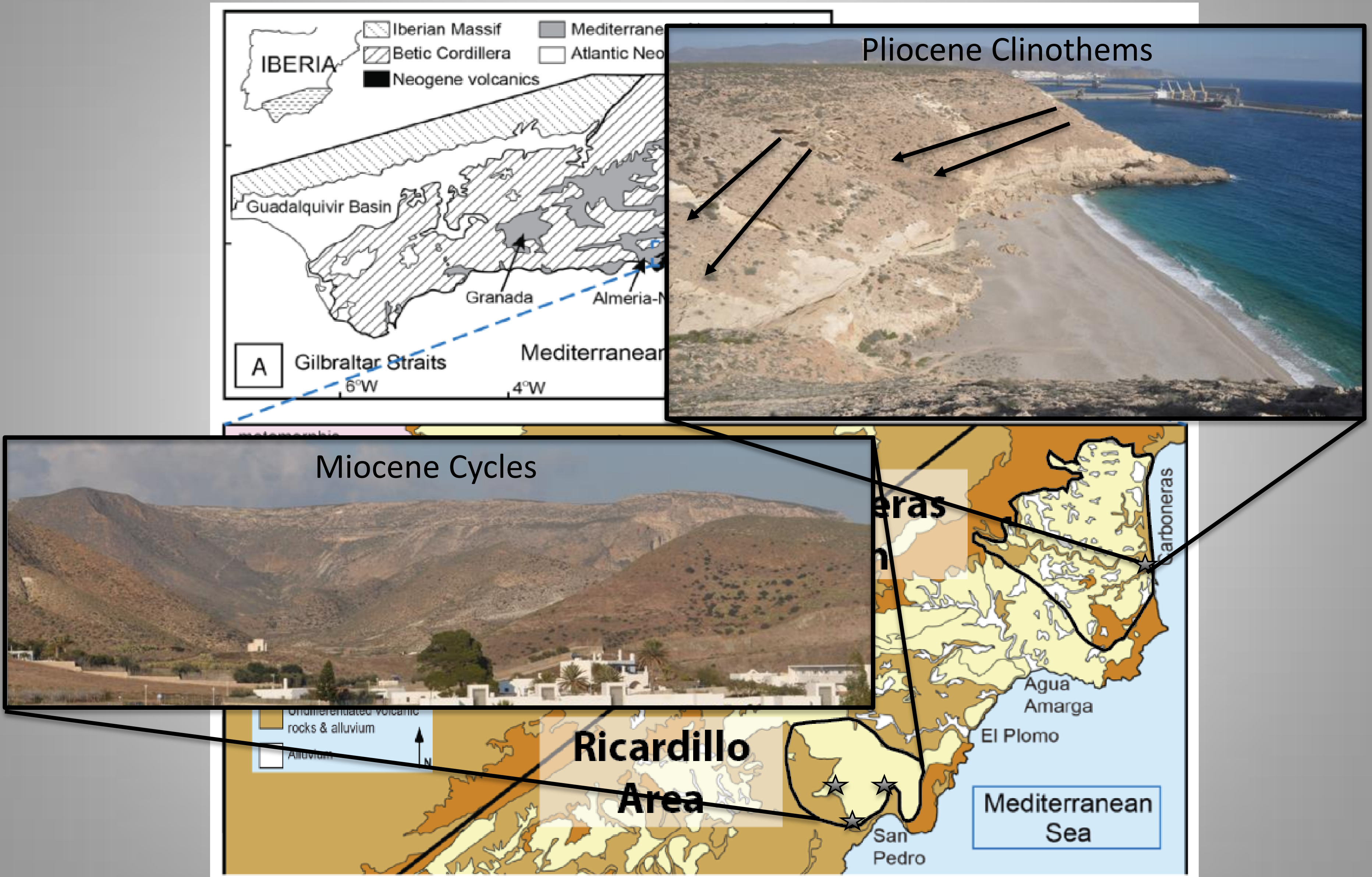
Modified from Instituto Geologico y Minero de Espana (1981).

Geologic Setting



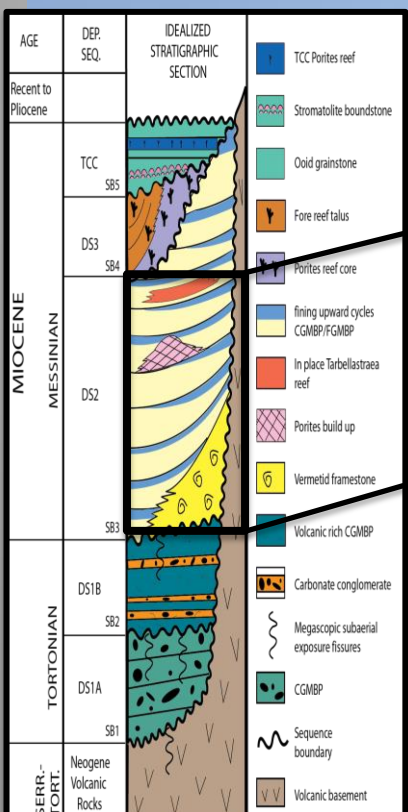
Modified from Instituto Geologico y Minero de Espana (1981).

Geologic Setting



Modified from Instituto Geologico y Minero de Espana (1981).

Transgressive-Regressive Cycles: Ricardillo Area-Miocene



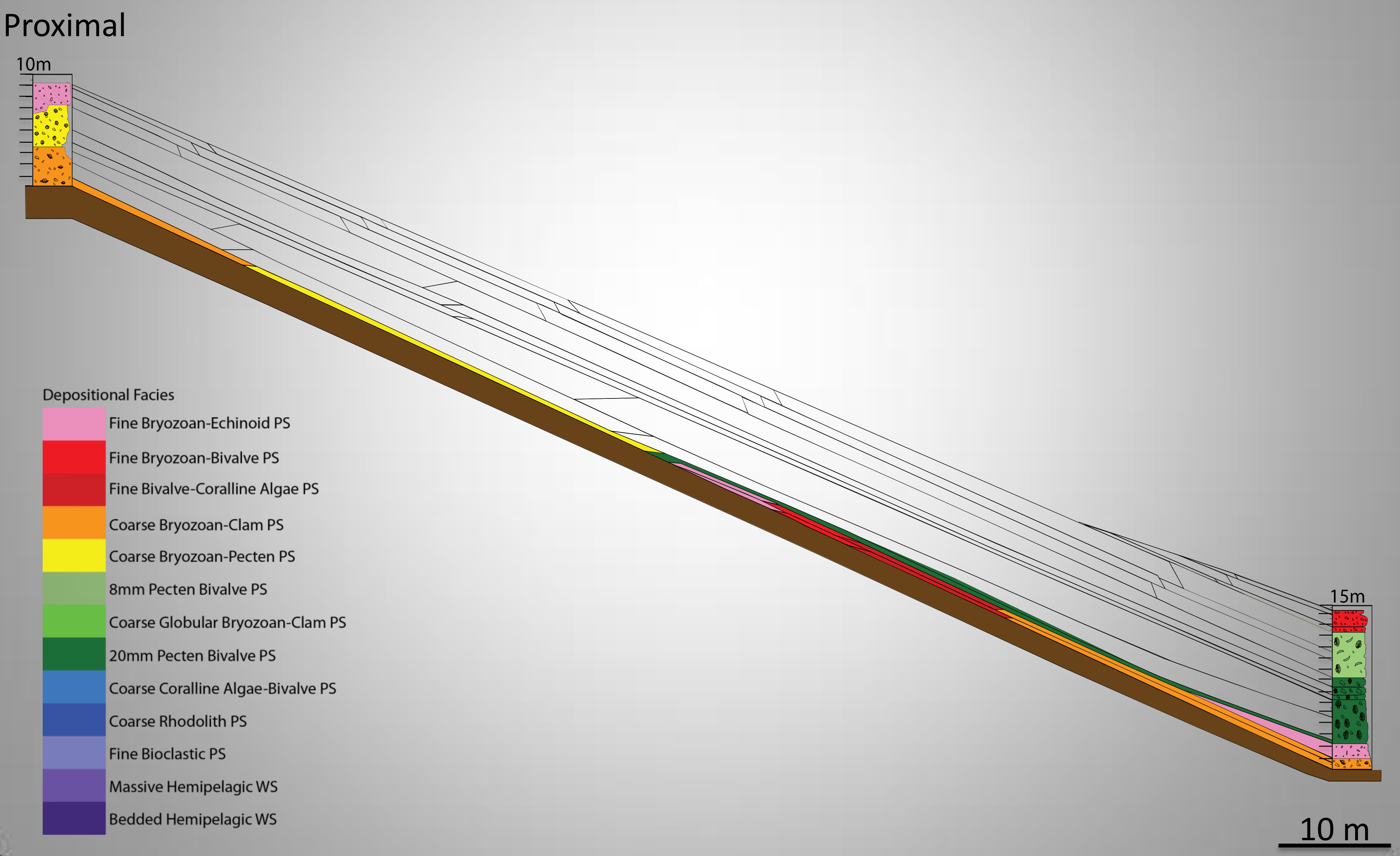
Toomey et al. 2003

Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles

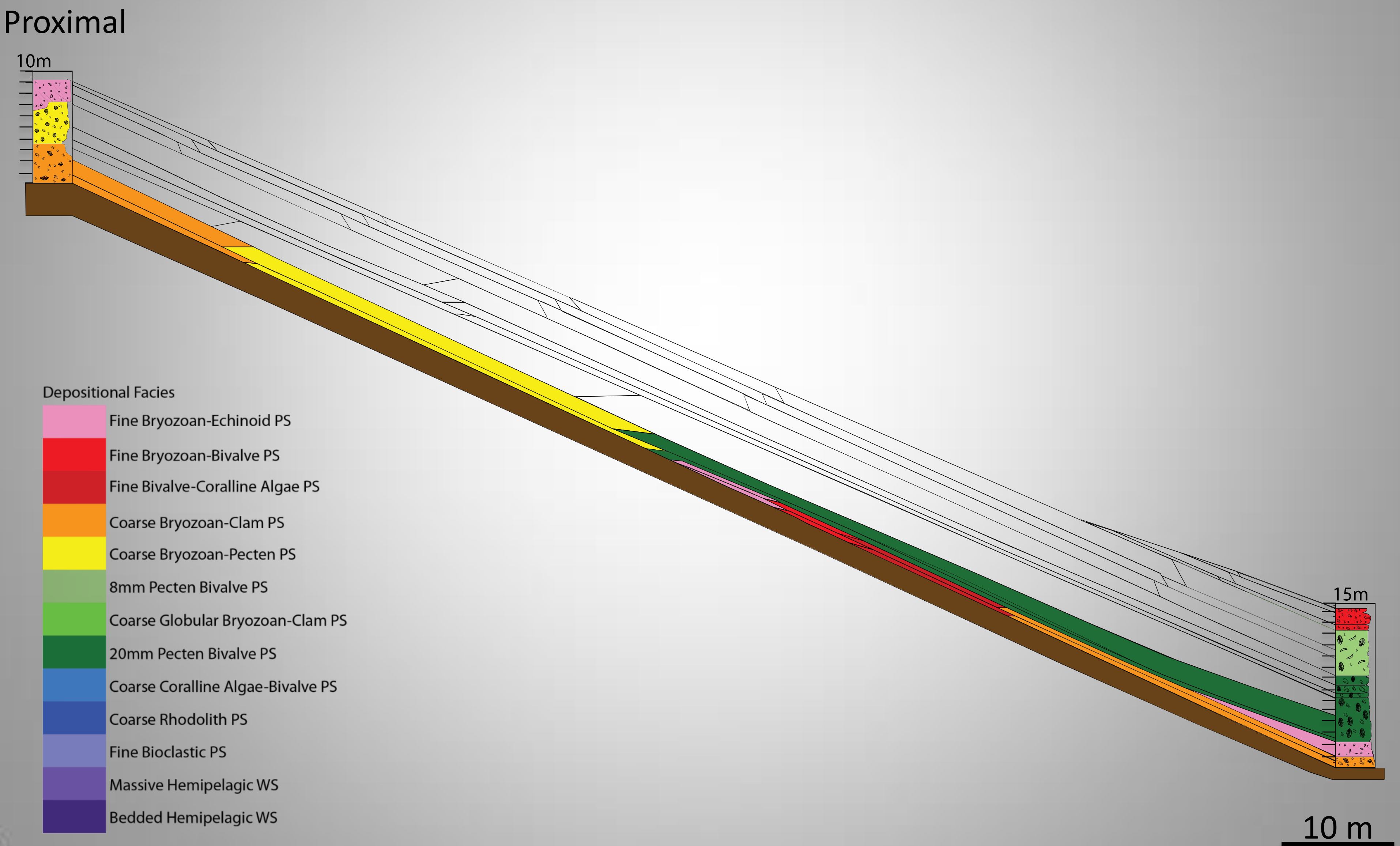
Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles



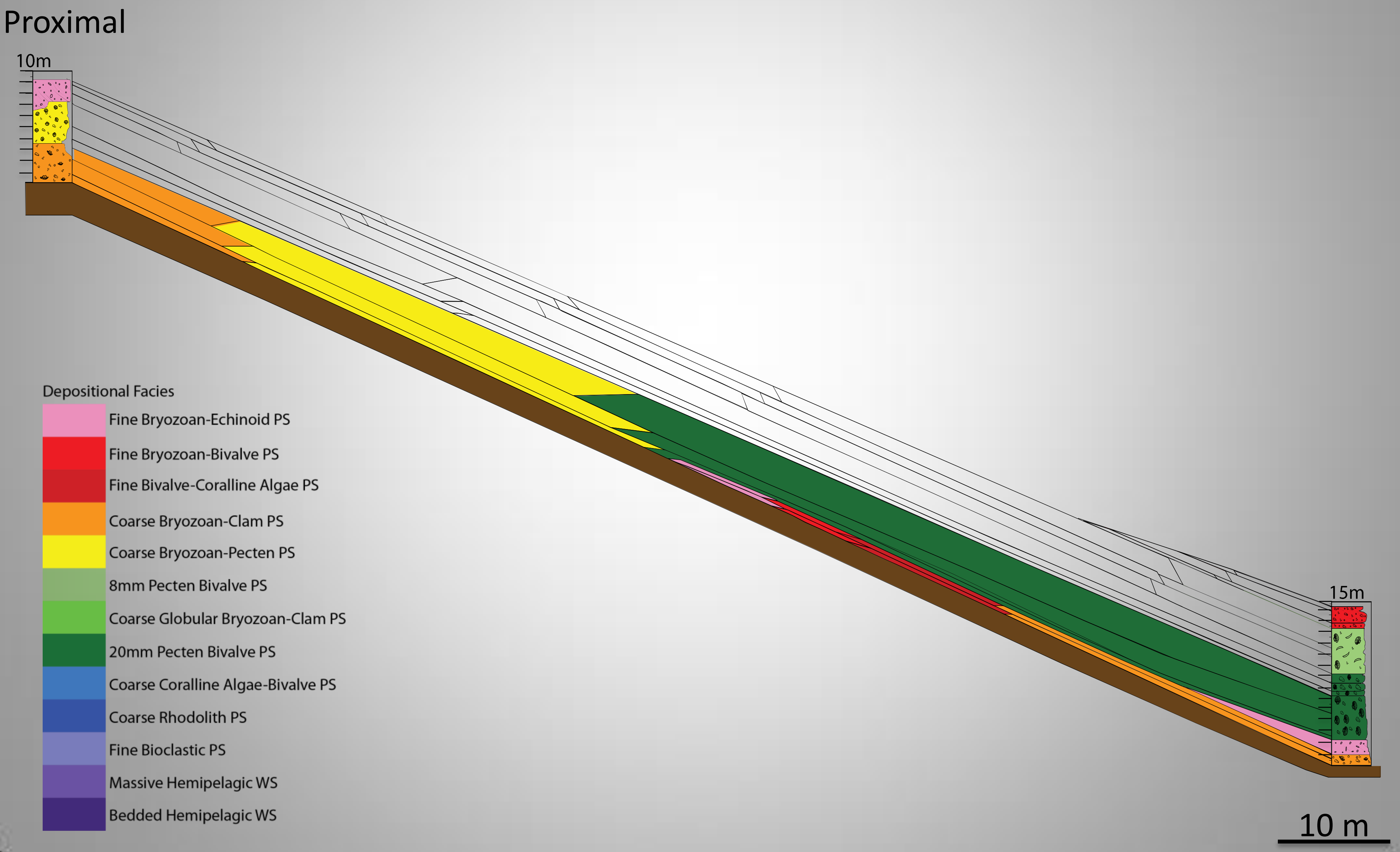
Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles



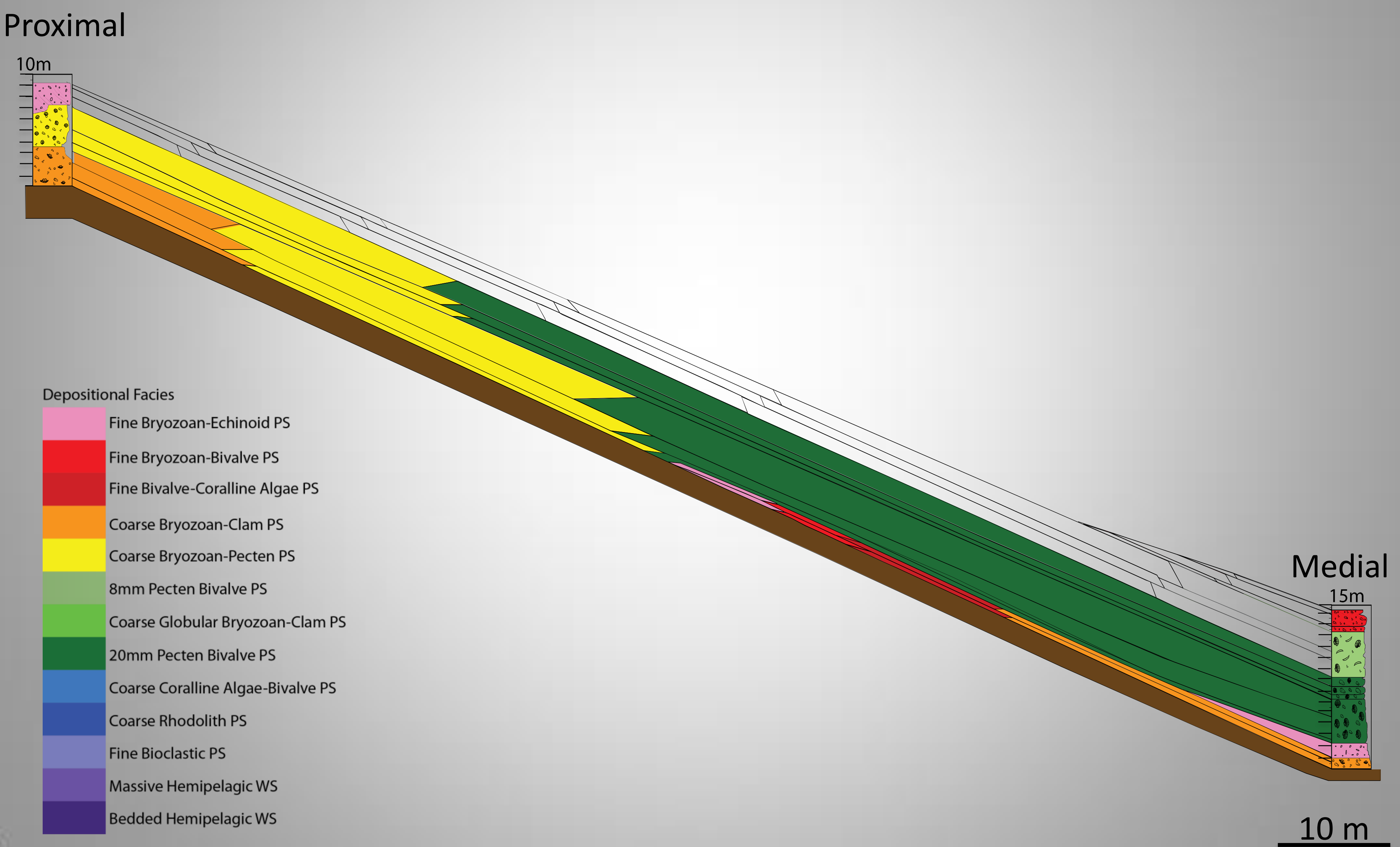
Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles



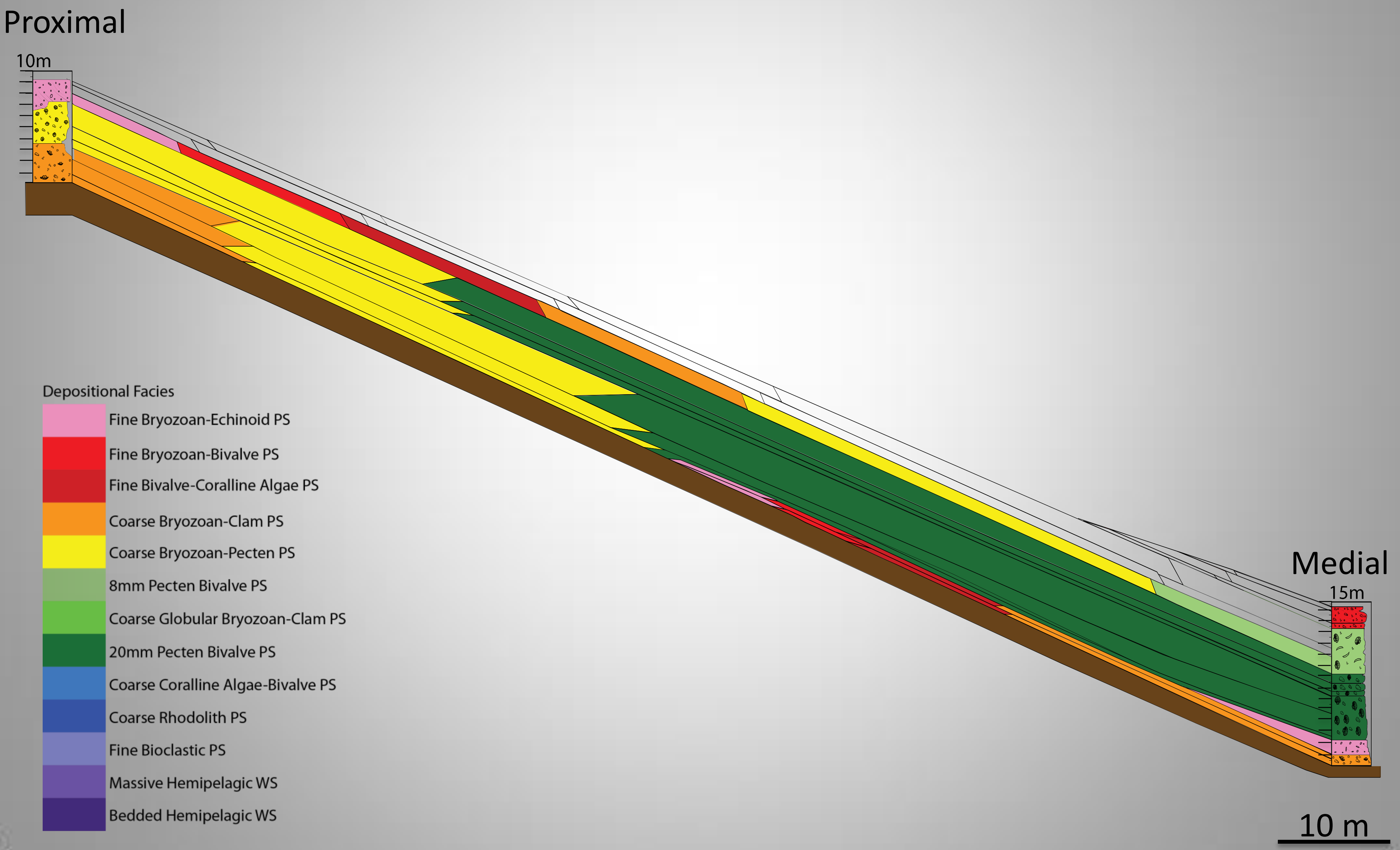
Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles



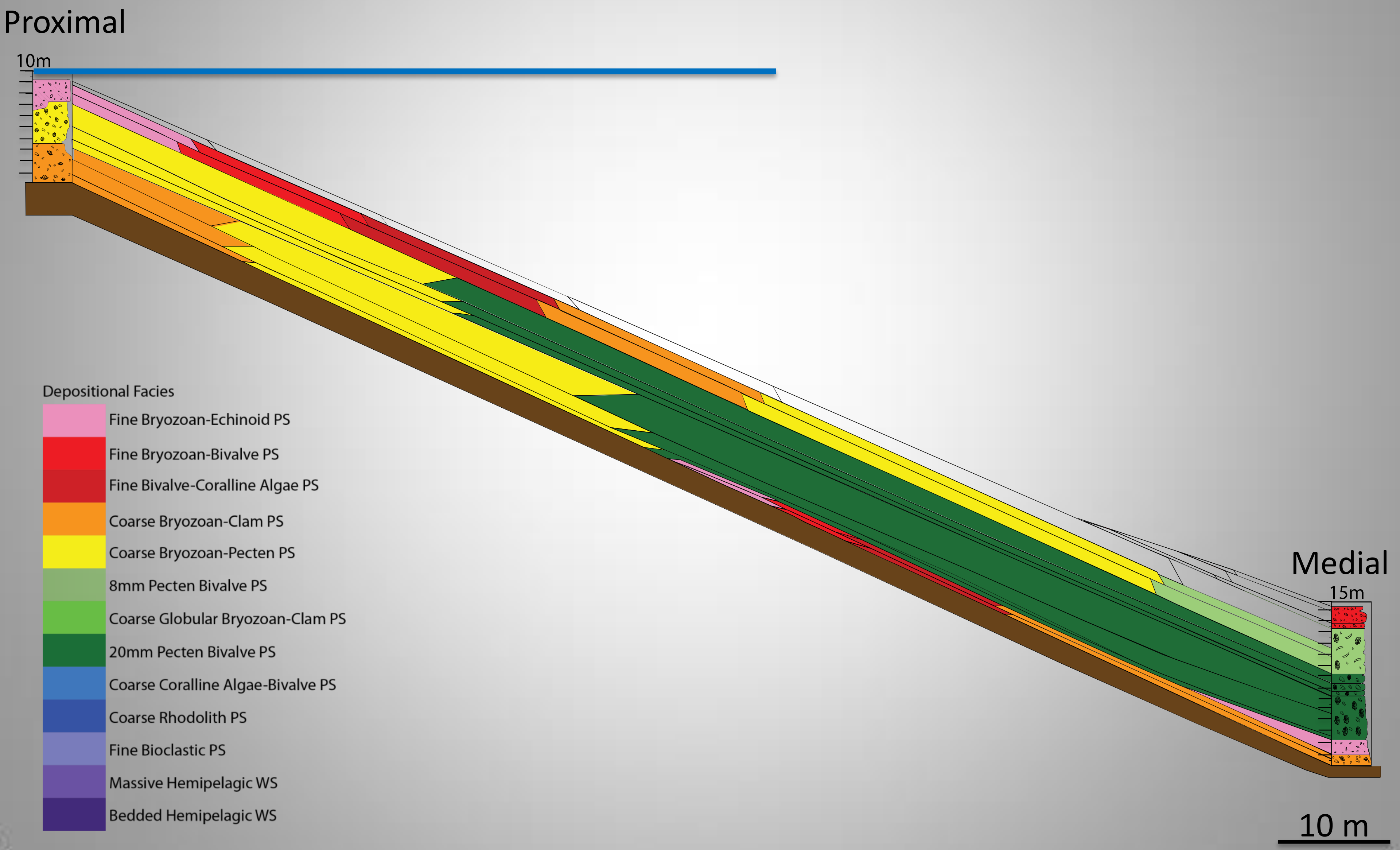
Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles



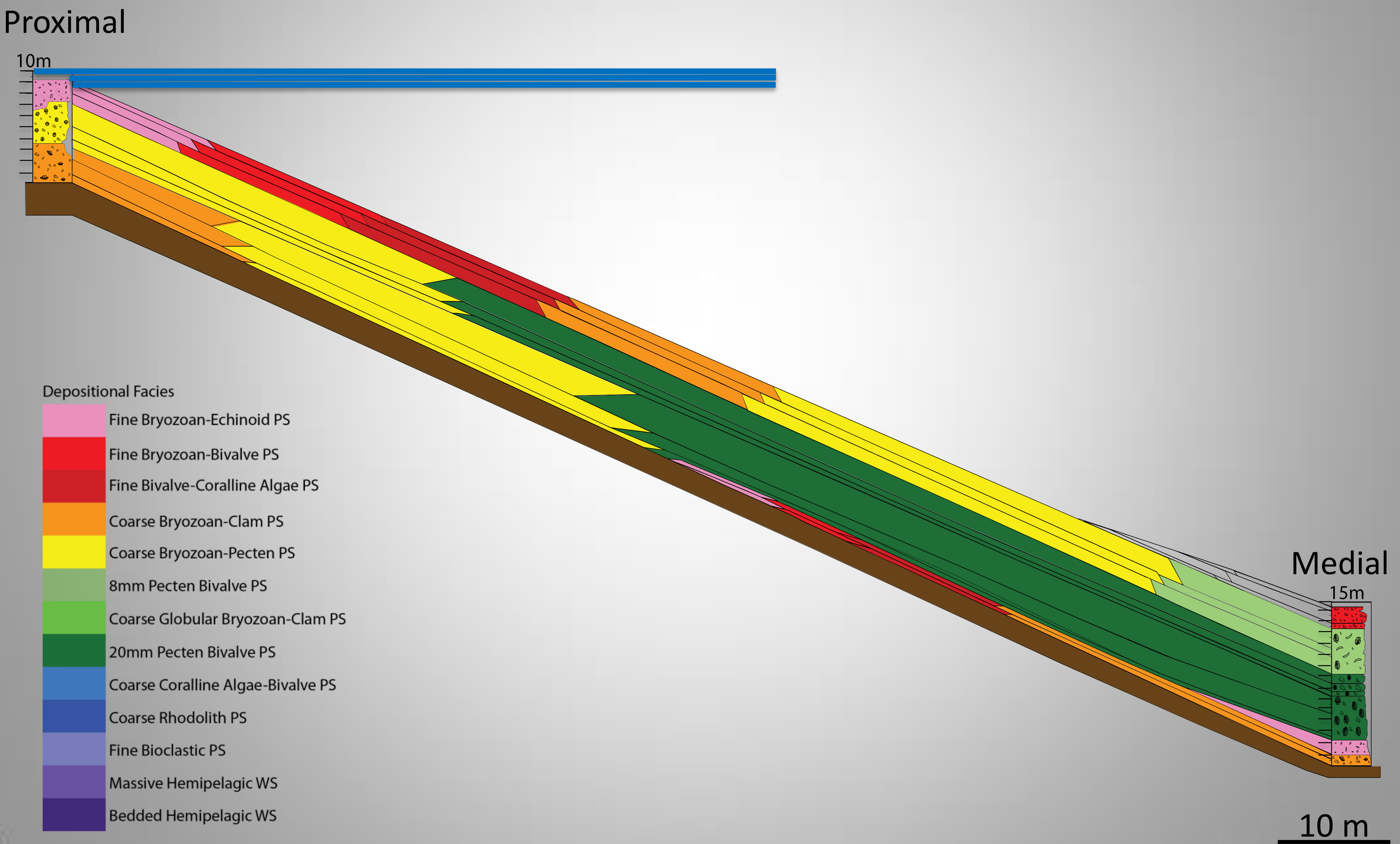
Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles



Stratigraphic Architecture

Building Blocks of Transgressive-Regressive Cycles

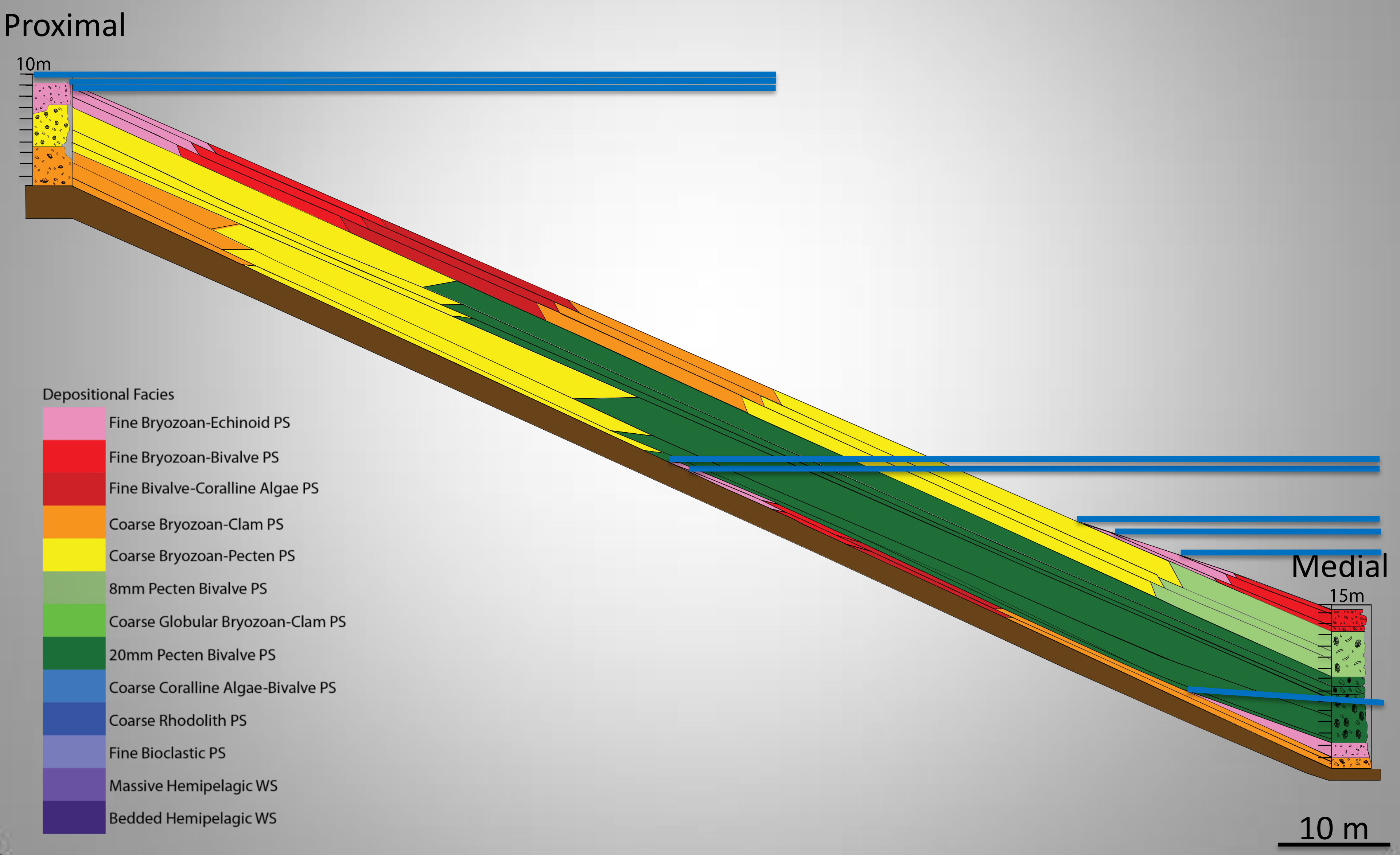


Stratigraphic Architecture

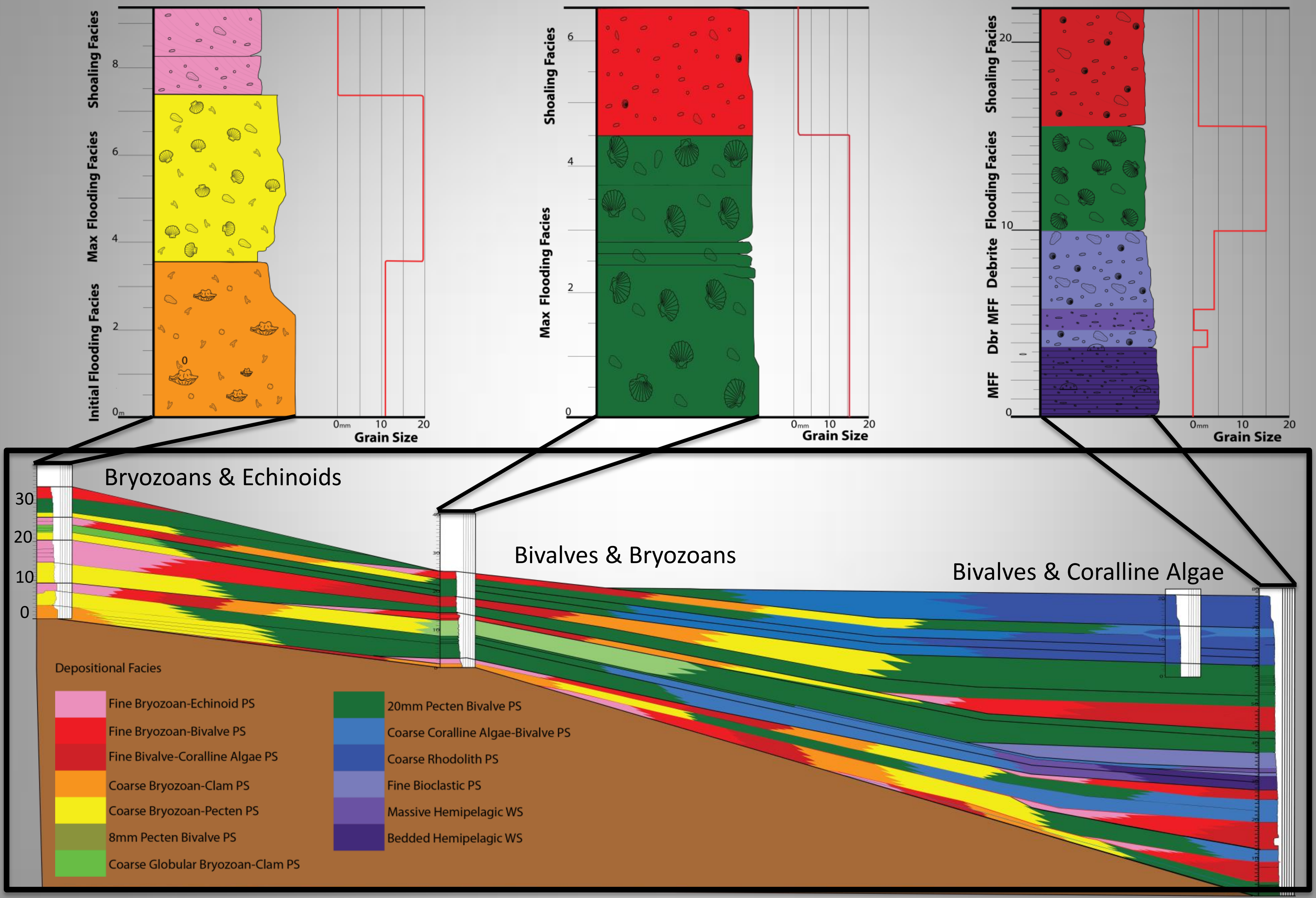
Building Blocks of Transgressive-Regressive Cycles

Stratigraphic Architecture

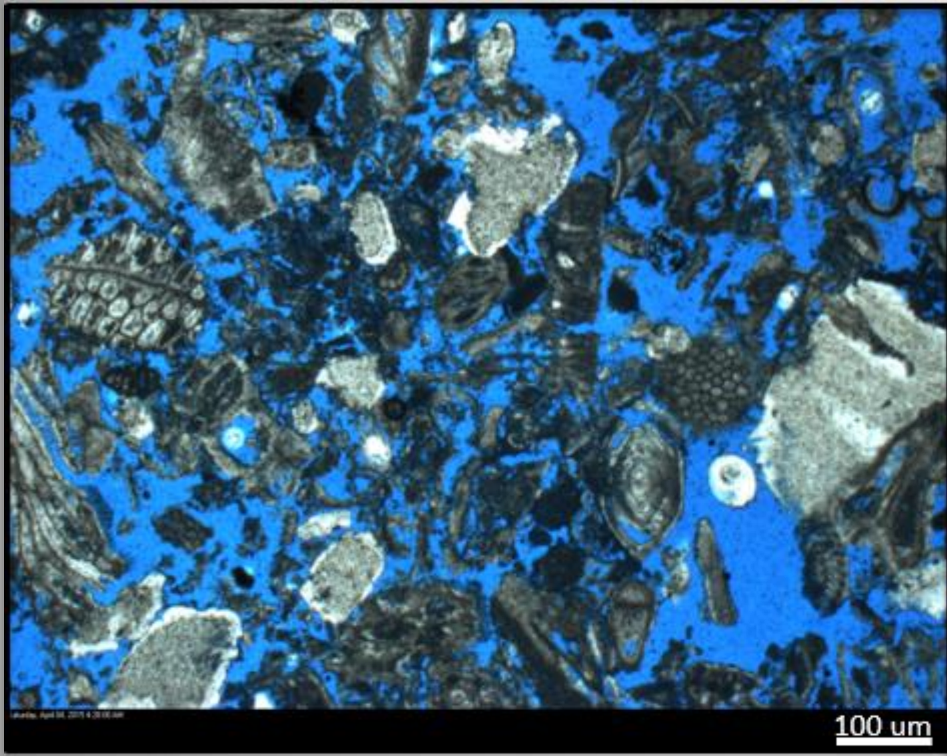
Building Blocks of Transgressive-Regressive Cycles

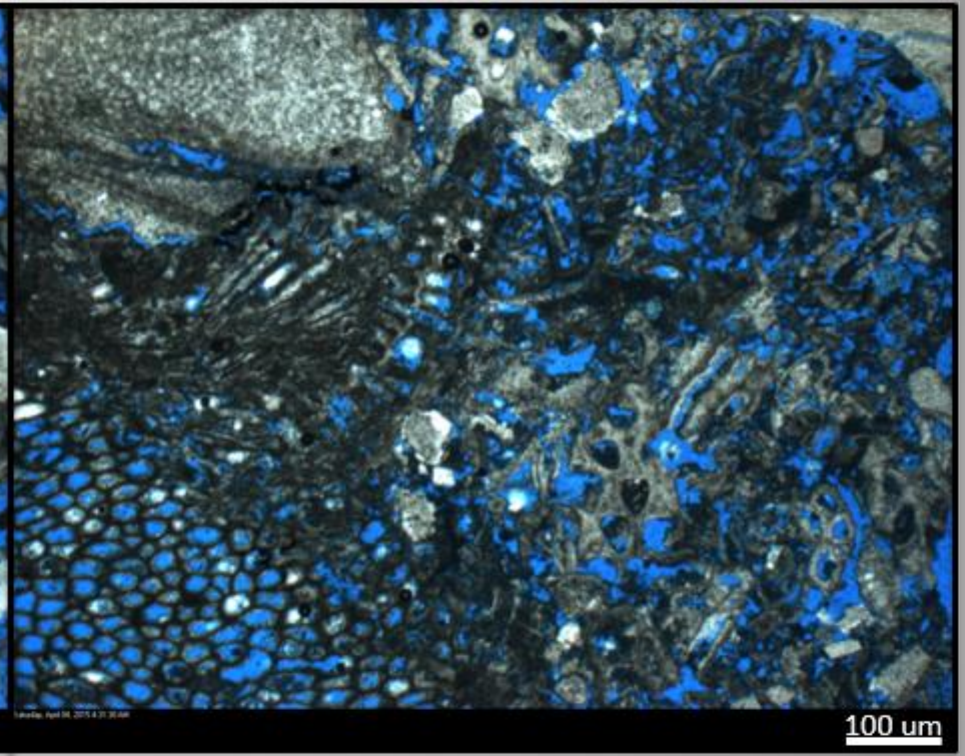


Miocene Cross Section



Textures of Cycles





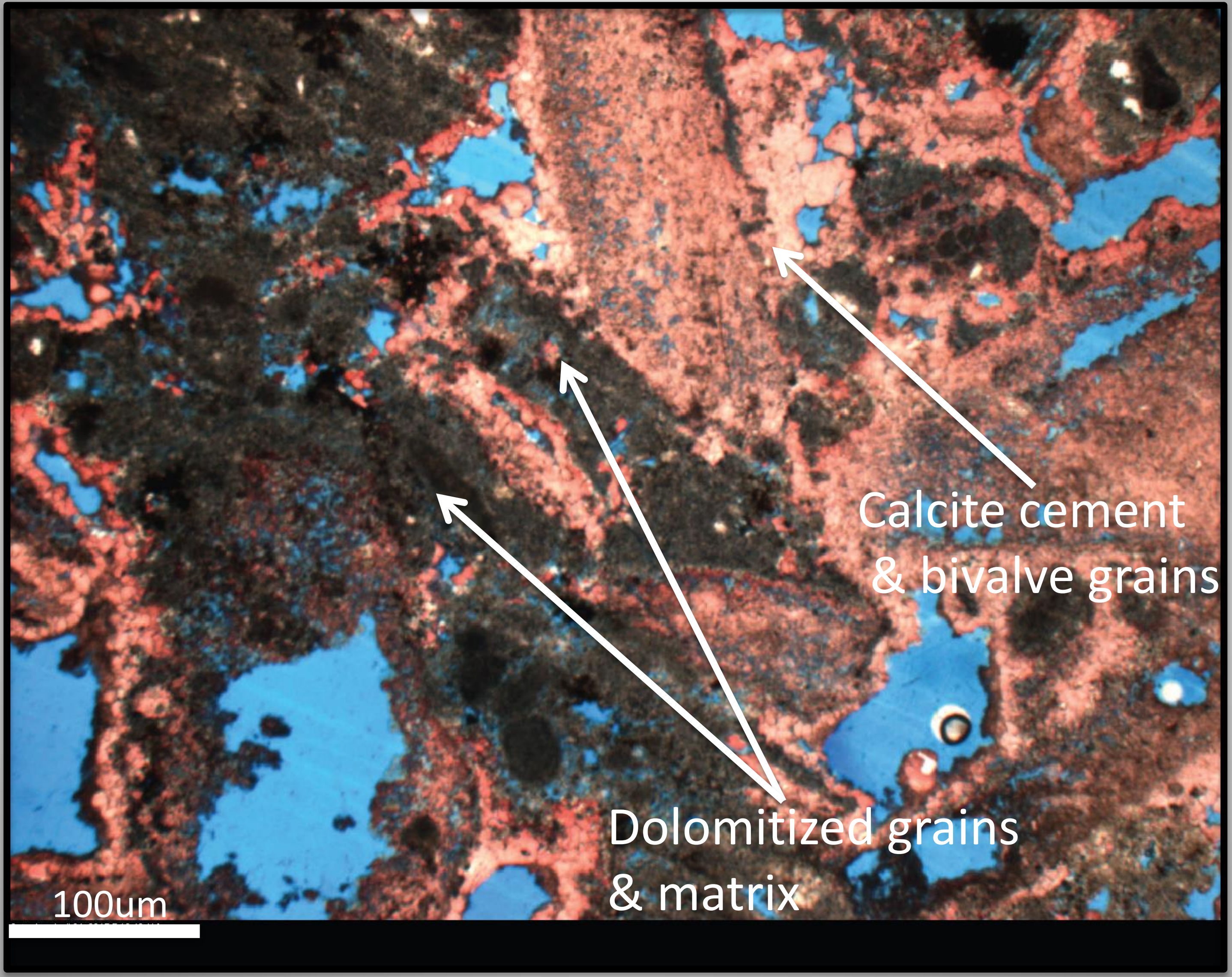
<u>Fine-grained Bryozoan-Echinoid Packstone</u>

- Abraded grains
- Average grain size ~2mm
- Moderately well sorted
- Diverse grain constituents
- Higher energy environment
- Fine shoaling facies deposited at/near wave base ~30m.

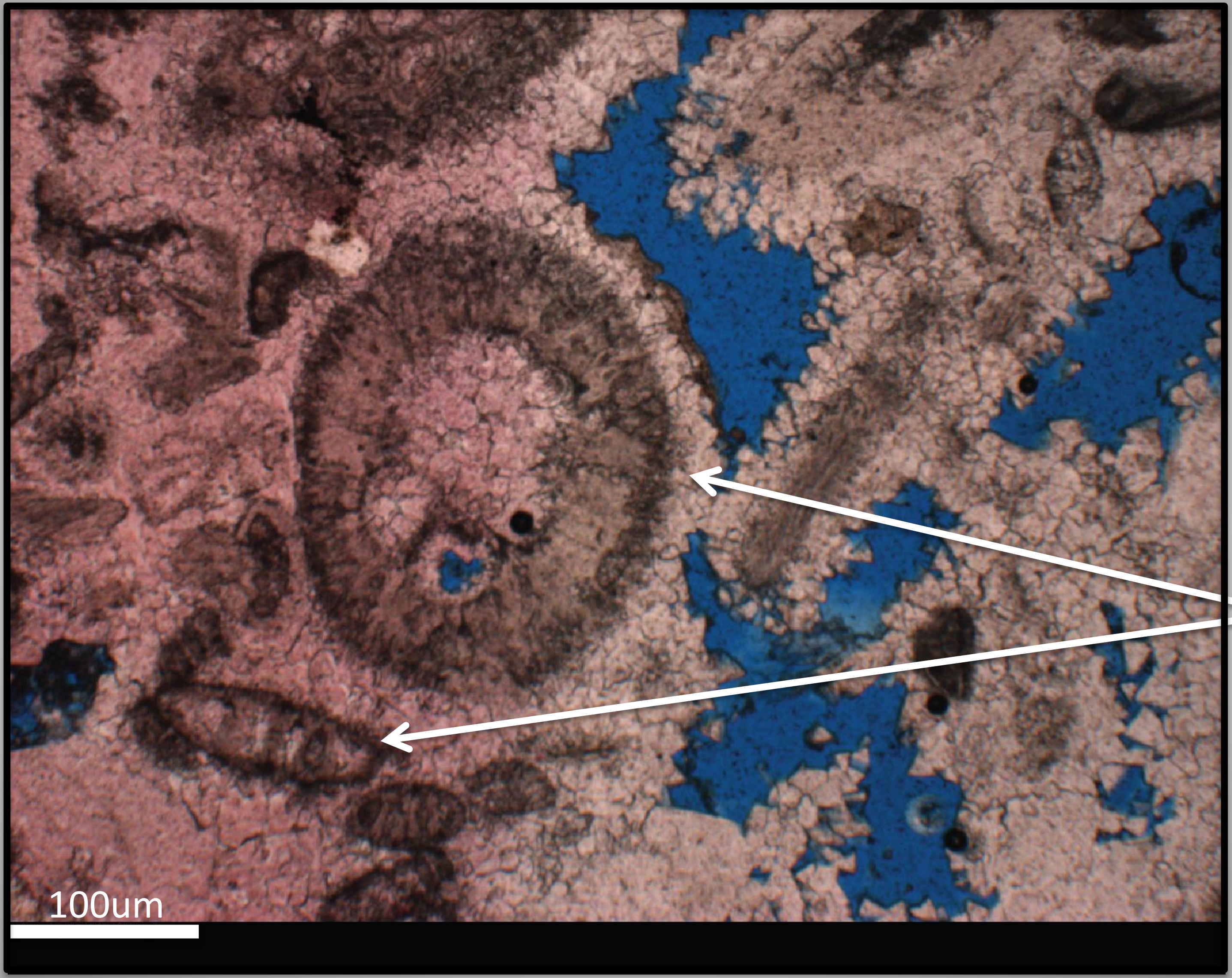
<u>Coarse-Grained Bryozoan-Bivalve Packstone</u>

- Whole globular bryozoans and unabraded bivalves
- Average grain size ~15mm
- Poorly-moderately sorted
- Relatively homogenous constituents
- Coarse facies (>45m) represent a mixture of *in situ* and transported deposition.

Diagenetic Facies

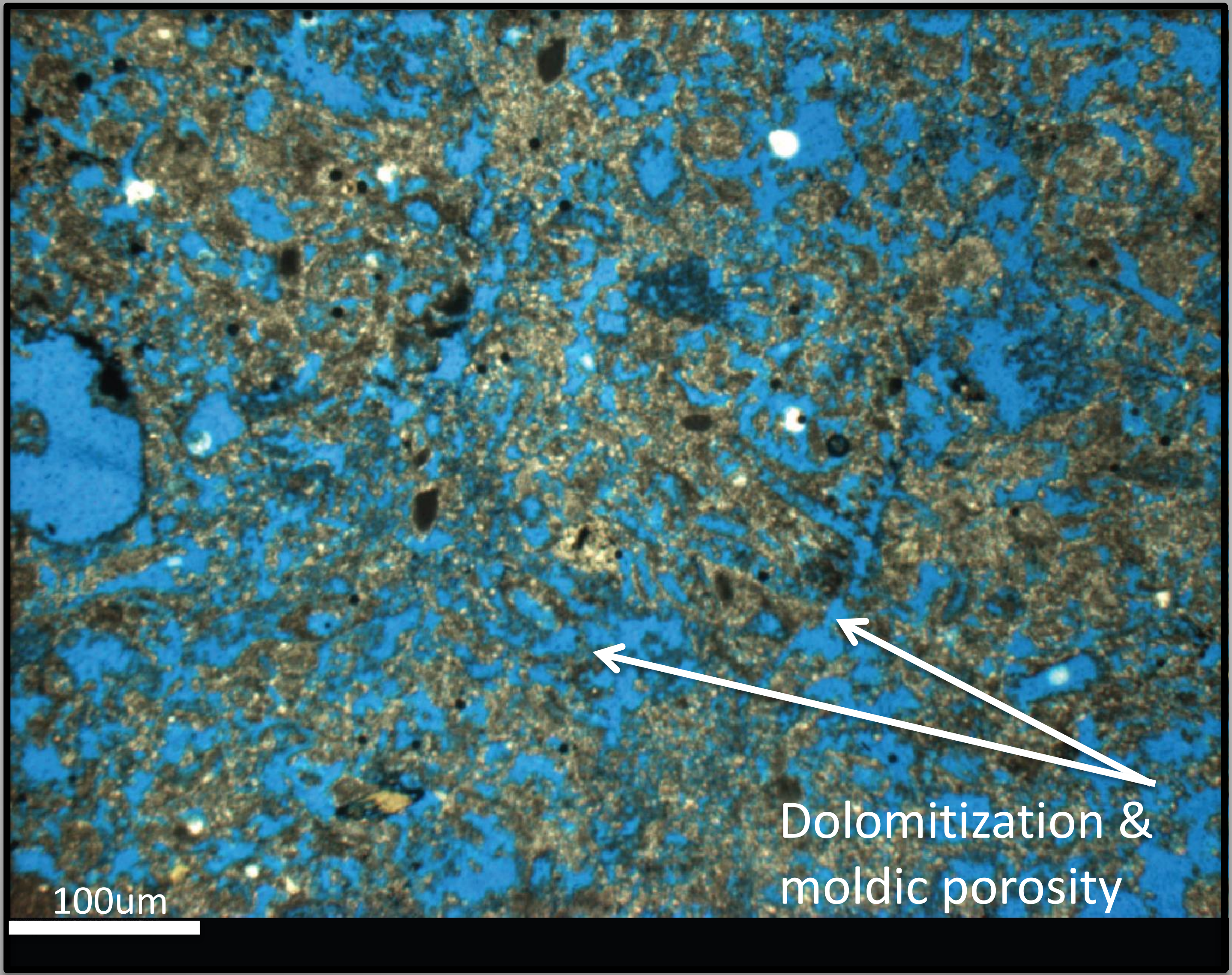


Diagenetic Facies



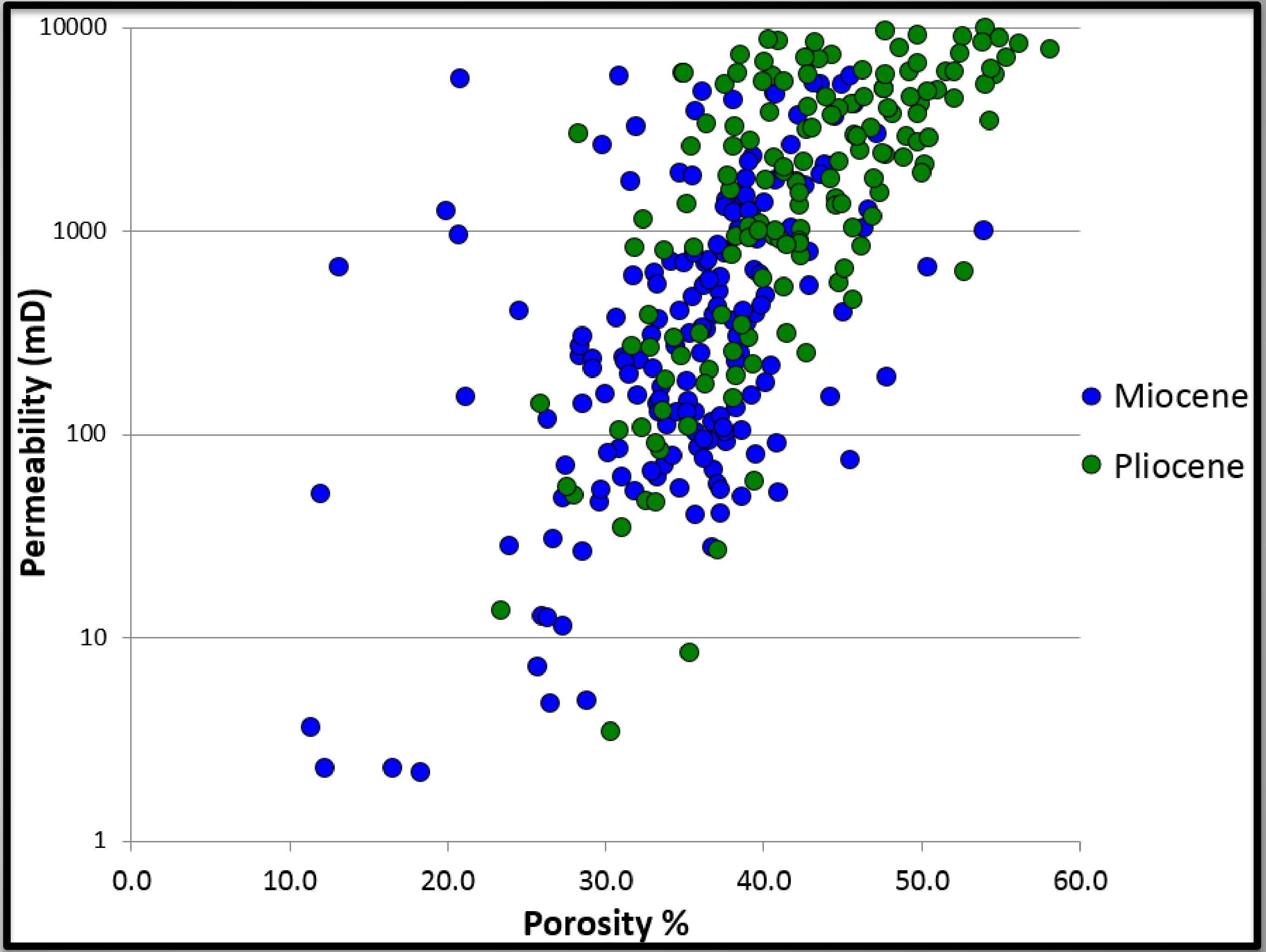
Calcite cement & grains

Diagenetic Facies

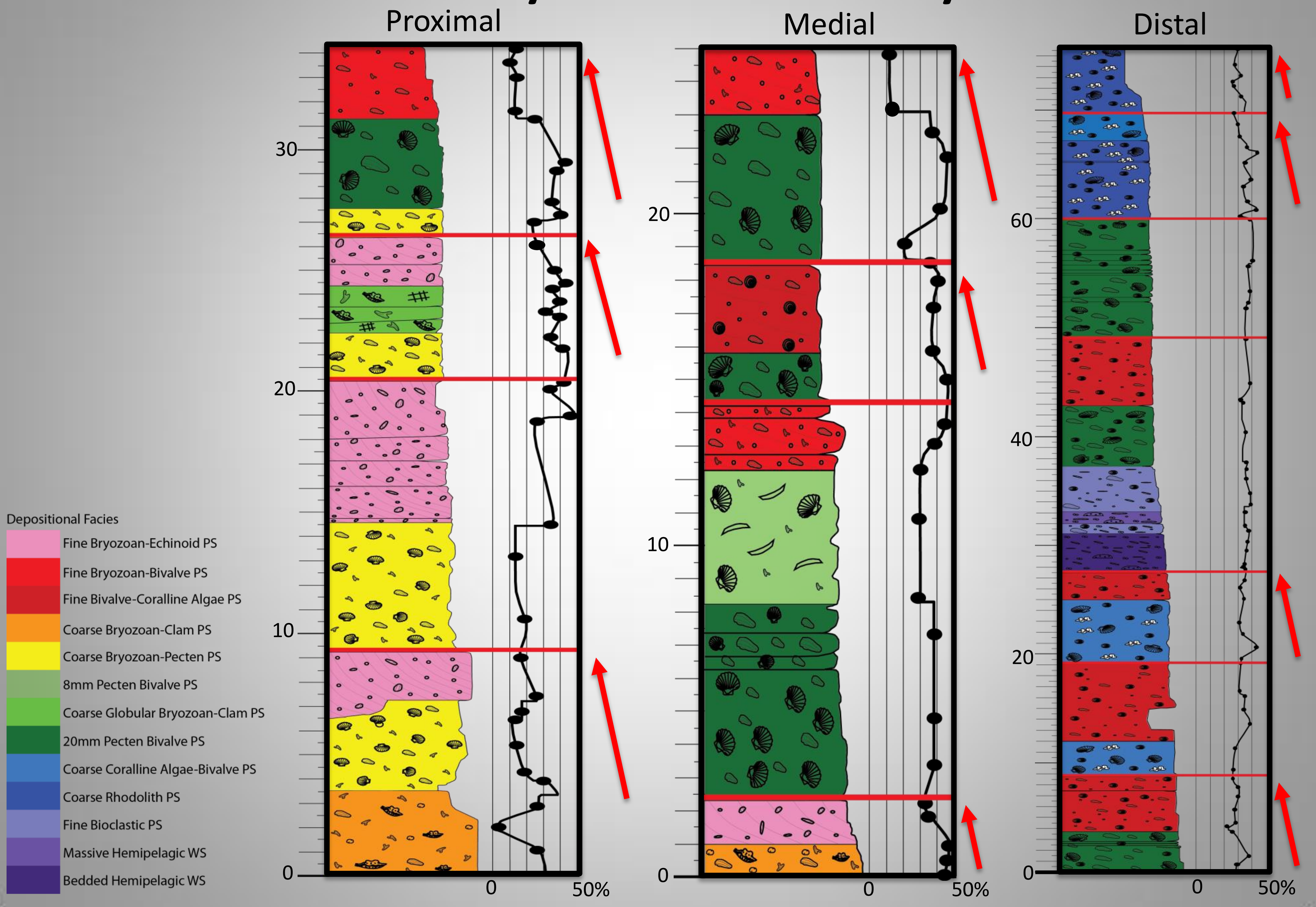


Petrophysical Dataset

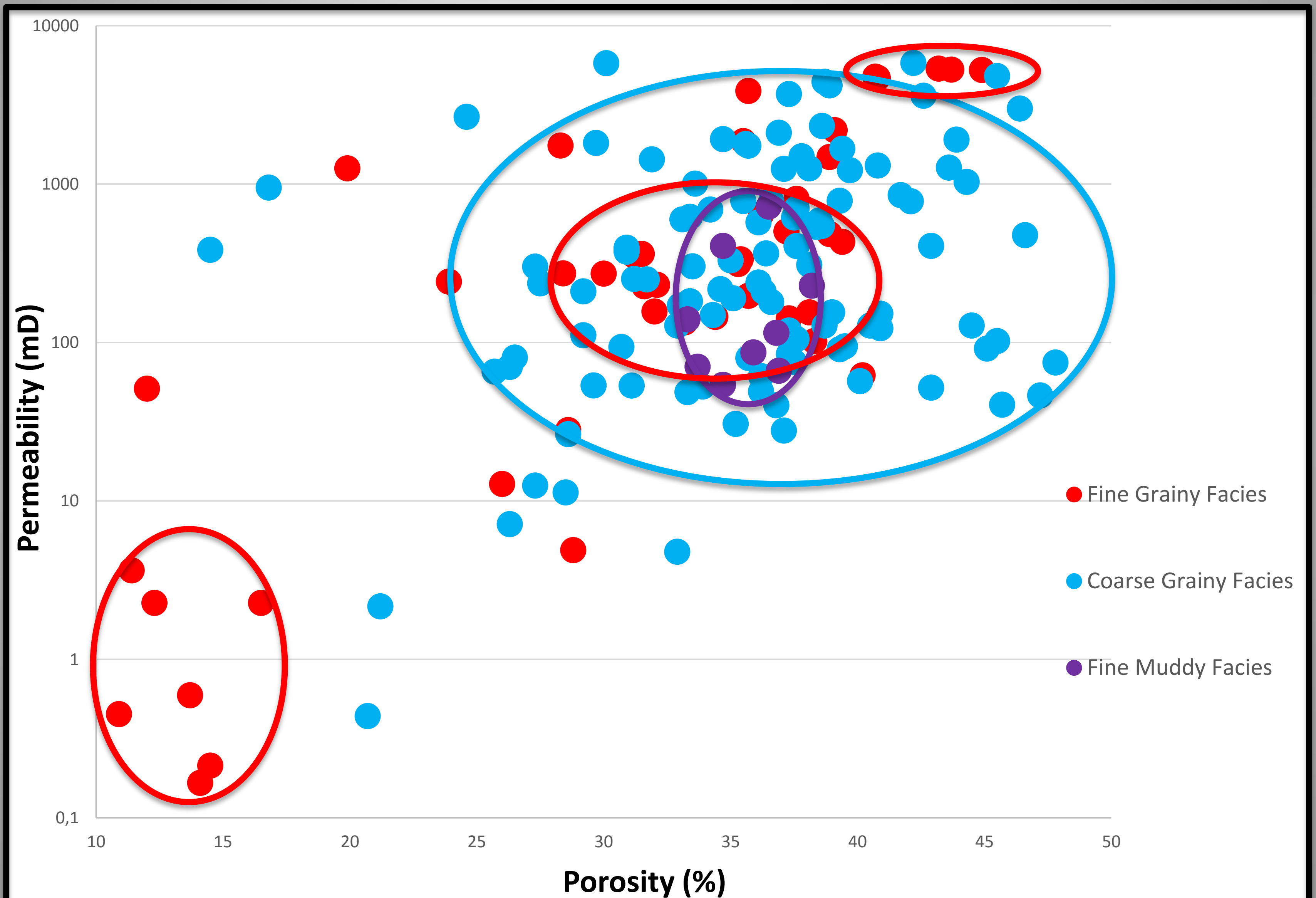
- 361 samples
  - 179 Miocene
  - 182 Pliocene
- Diagenetic Control
  - Miocene average
    - 422-621 mD
    - 32-33%
  - Pliocene average
    - 3,370-4243 mD
    - 42-46%
- Deviation from the normalized trend increases as diagenetic alteration increases.



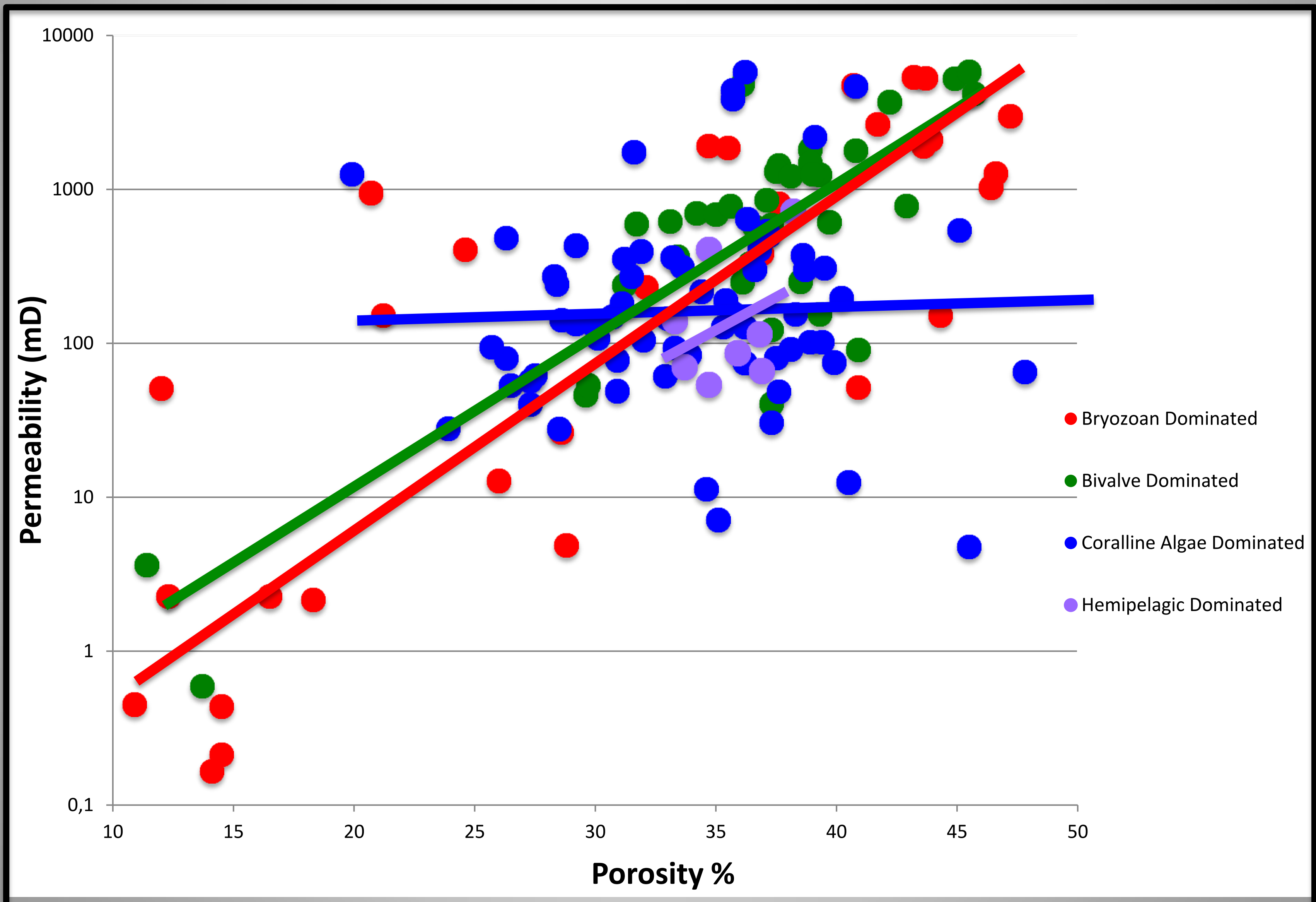
Porosity Trends in Cycles



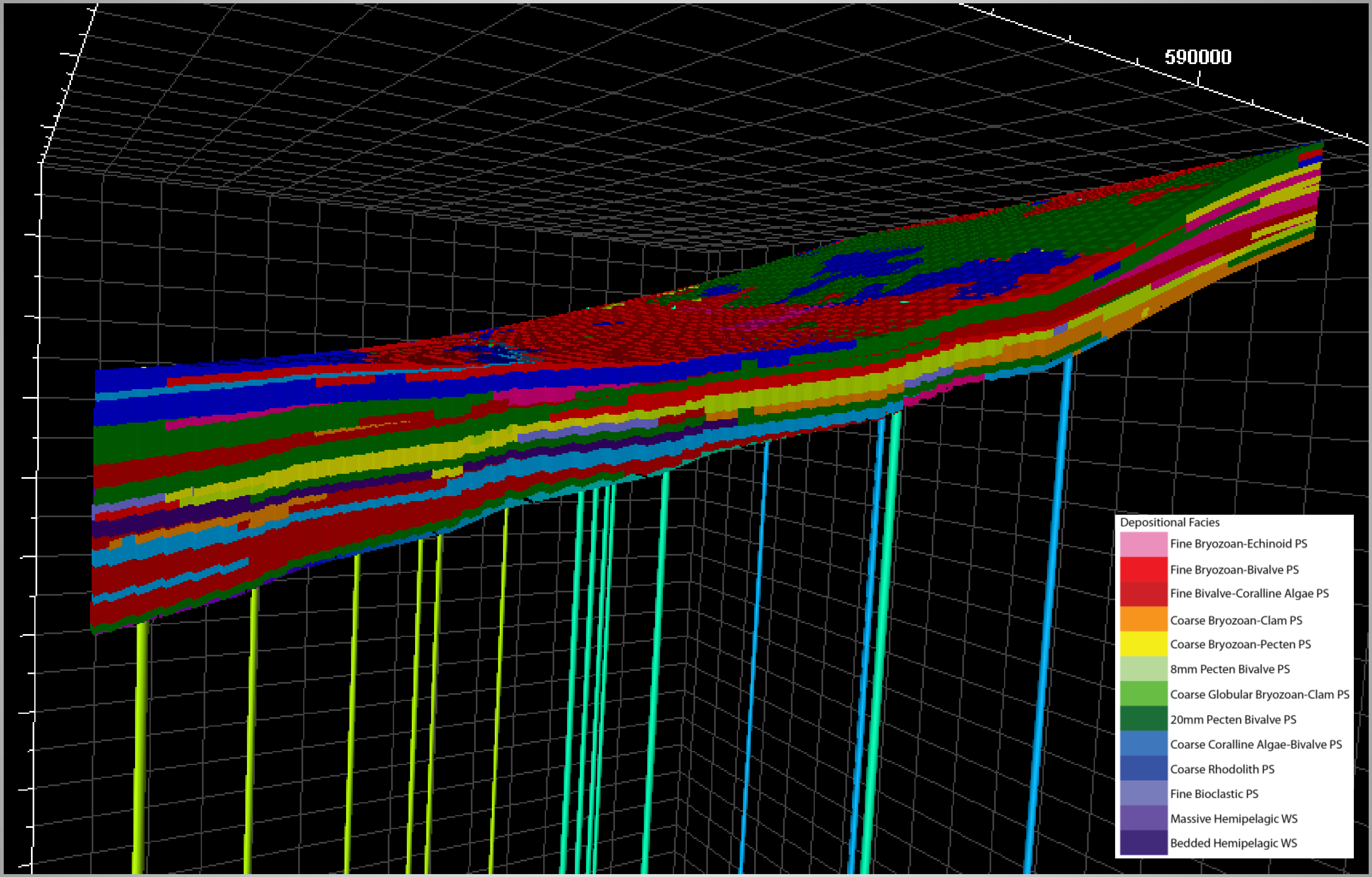
Grain Size and Petrophysics



Grain Constituents and Petrophysics

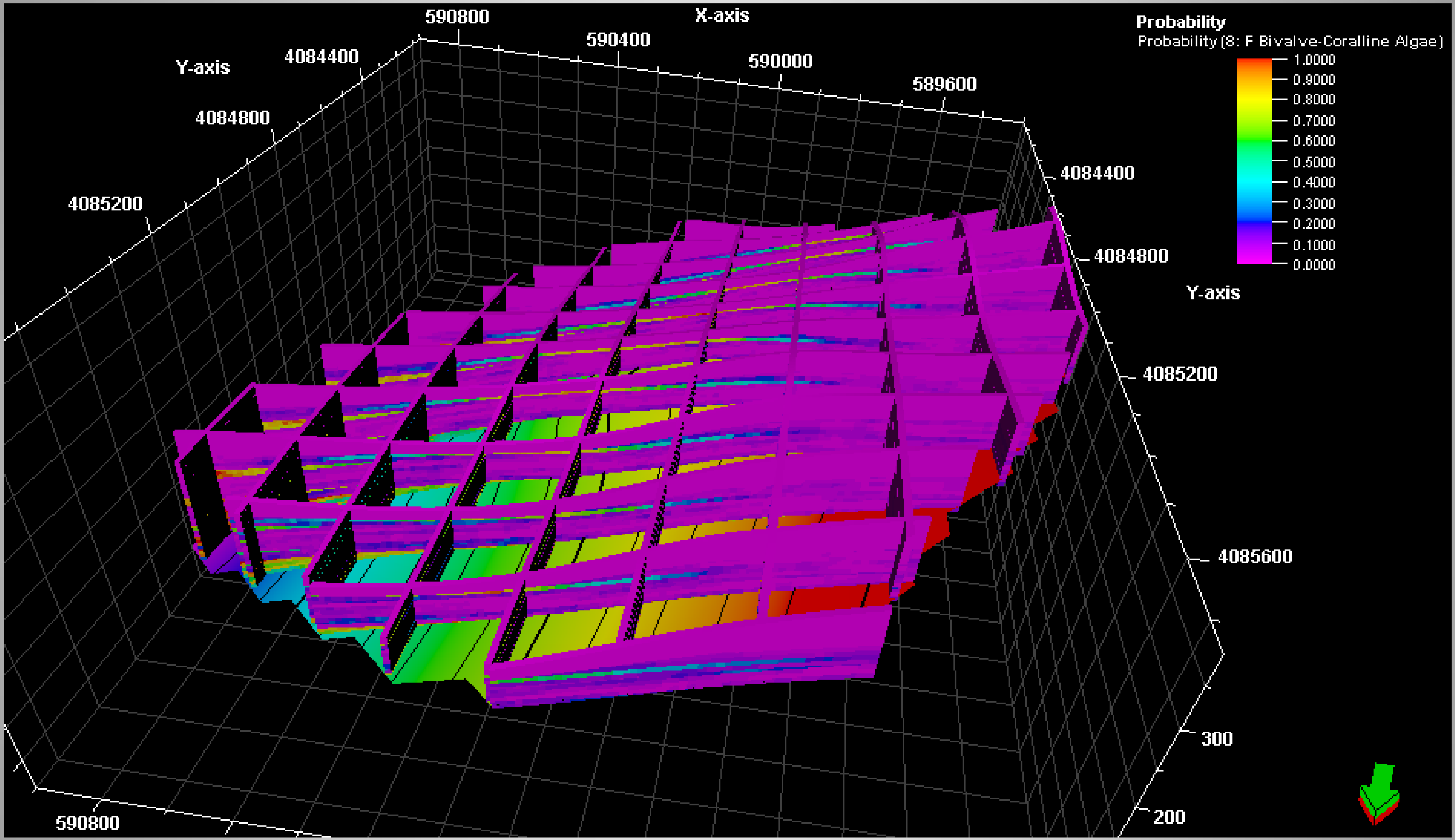


Petrel Facies Model



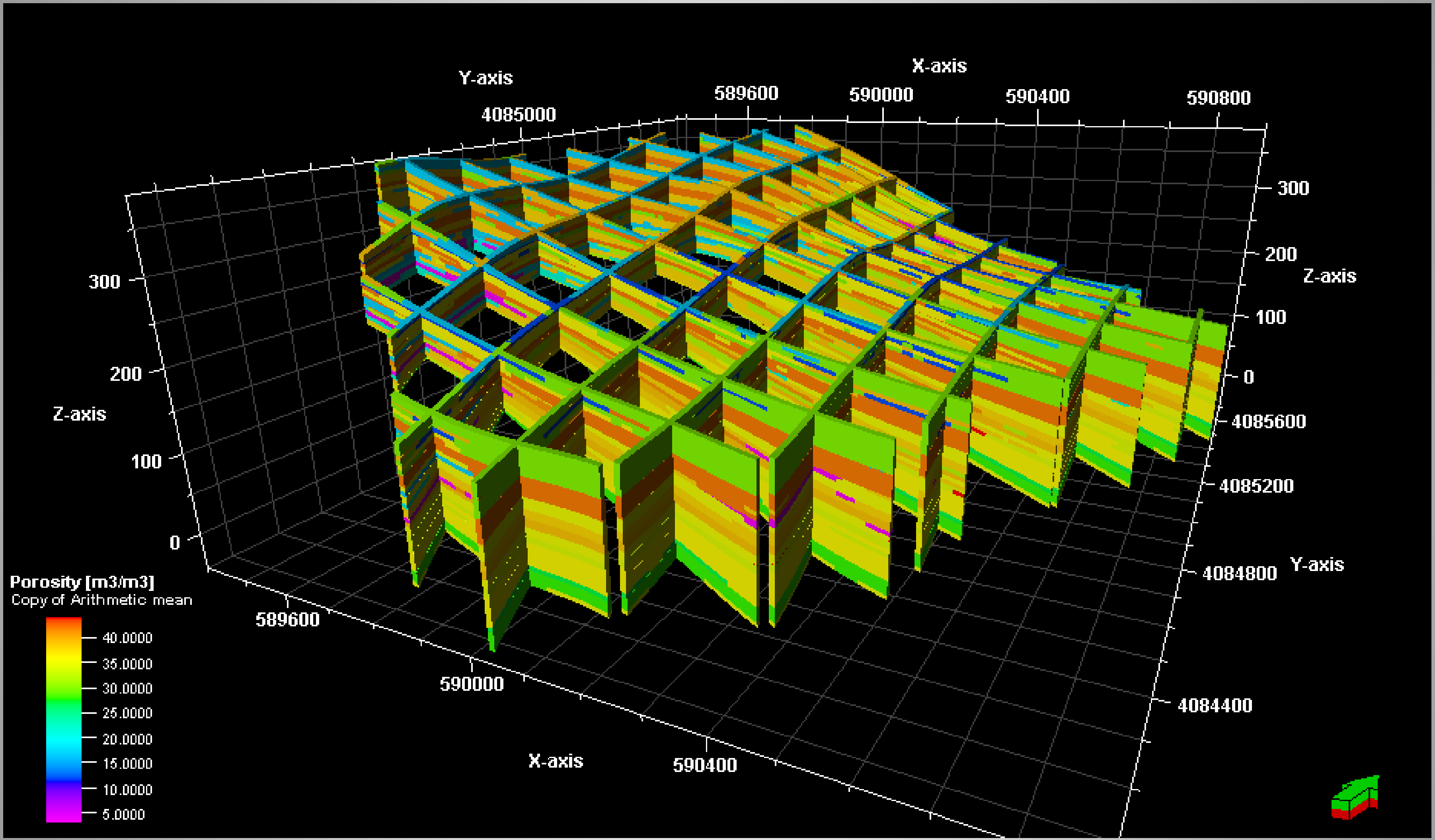
- 16 pseudosections based on outcrop
- Paleotopography
- Additional pseudosections and further confined zones are required to achieve more geologically sound results.

Predictive Facies Modeling



- Predictive example of one facies
- 33 realizations used for distribution

Porosity Distribution Model



- 33 realizations used to create arithmetic mean to distribute porosity values through facies model.

Summary

- Transgressive-regressive cycles in heterozoan carbonates form cycles composed of predictable coarsening- and fining-upward grainy facies.
- Predictable depositional trends are governed vertically by grain size and laterally by grain size and grain constituents.
- Heterozoan carbonates have potential to form highly economic hydrocarbon reservoirs.
- Petrophysical values are governed by grain size, grain constituents, and diagenesis.

Acknowledgements

1926 SEPM
Society for Sedimentary Geology

American Association of Petroleum Geologists
AAPG
1917

Kansas Geological Survey
University of Kansas

devon

KICC
Kansas Interdisciplinary Carbonates Consortium

KU
Department of Geology
College of Liberal Arts & Sciences