A Tight Carbonate Reservoir in the Mississippian Pekisko Formation: The Role of Pervasive Microvuggy Porosity*

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Abstract

The Lower Mississippian (Tournaisian) Pekisko Formation in the Hawk Hills area of northern Alberta is a 25 to 40 m thick carbonate ramp succession which hosts a large, medium to heavy-gravity oil resource that is presently being evaluated. The formation has been subdivided into three informal units: the lower carbonate, middle shaly, and upper carbonate. The units are composed of three lithofacies associations: (1) basinal – characterized by argillaceous lime mudstones and crinoid wackestones; (2) outer ramp – consisting of crinoid-brachiopod wackestones and packstones; and (3) middle to inner ramp – composed of peloidal-skeletal packstones to grainstones. The Pekisko Formation has been significantly affected by marine, burial, and meteoric diagenesis. Marine diagenesis was typified by significant micritization and microboring of allochems, as well as limited radial-fibrous calcite cementation. Burial diagenesis was dominated by neomorphism of the matrix and allochems, dissolution of gastropods and other allochems, significant syntaxial and coarse mosaic calcite cementation, minor dolomitization, and limited quartz and gypsum cementation. Late meteoric diagenesis included dedolomitization and precipitation of chert and fluorite. Partial dissolution of the matrix, interpreted to have occurred during late burial to meteoric diagenesis, resulted in significant, pervasive microvuggy porosity in packstones. This style of porosity development has not been commonly observed in Mississippian strata.

Oil-saturated reservoir packages, 0.1 to 13.1 m thick, are dominantly composed of mid-inner ramp lithofacies, with thin intervals of outer ramp facies. These packages are typified by 10-20% microvuggy porosity. Permeability is typically low, ranging from 0.5 to 20 mD on average, but is up to 420 mD locally. The Pekisko Formation in the Hawk Hills area is commonly considered an unconformity-related play, but this study demonstrates that the development of microvuggy porosity is not restricted to the subcrop area, and extends down-dip into the subsurface. Although there are development issues to be addressed, the Pekisko Formation in the Hawk Hills area is an excellent reservoir, with significant potential for future exploitation.

References Cited

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http://geology.gsapubs.org

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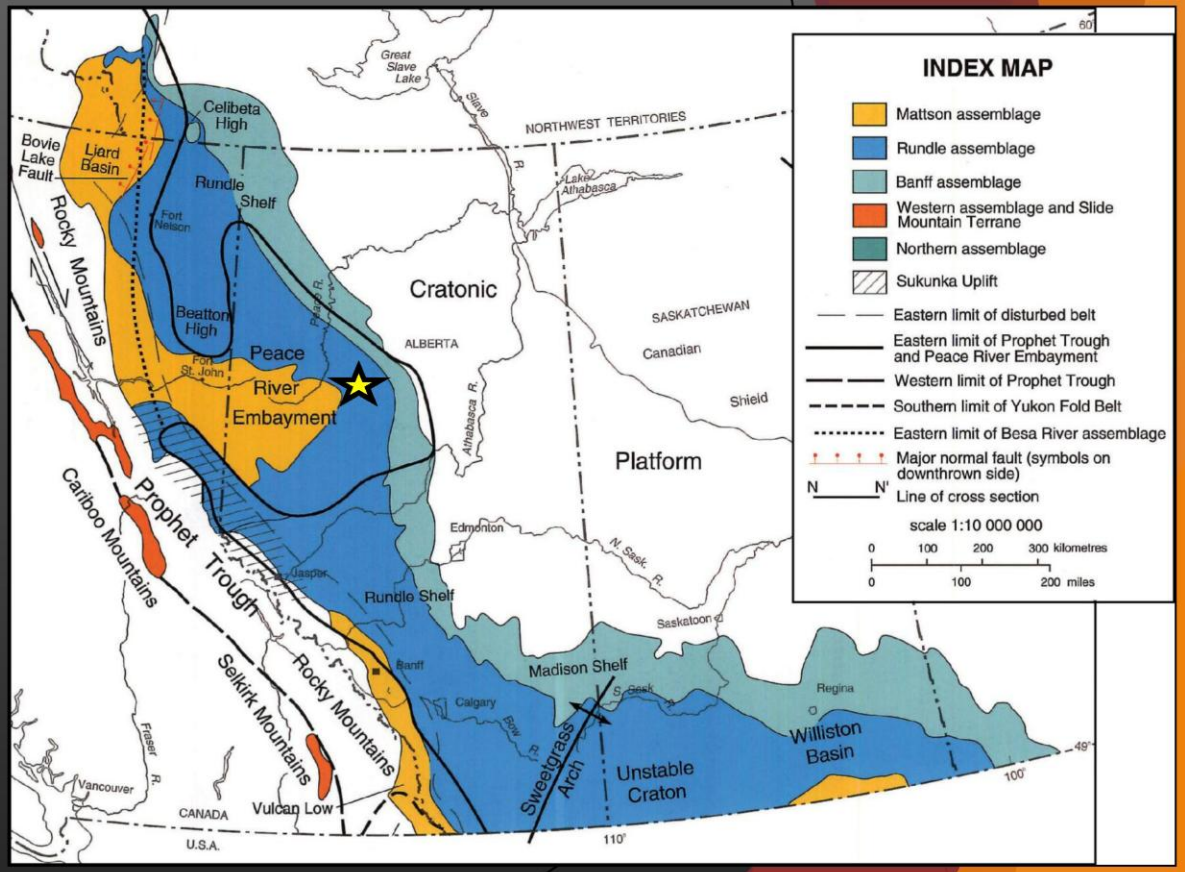
Introduction: Why Are We Interested?

- Carbonate rocks with cool-water characteristics
- Wide areal extent: southern Alberta to the southernmost N.W.T.
- Significant oil and gas reservoir rock
- Development challenges:
  - Relatively tight reservoir
  - Medium to heavy gravity oil

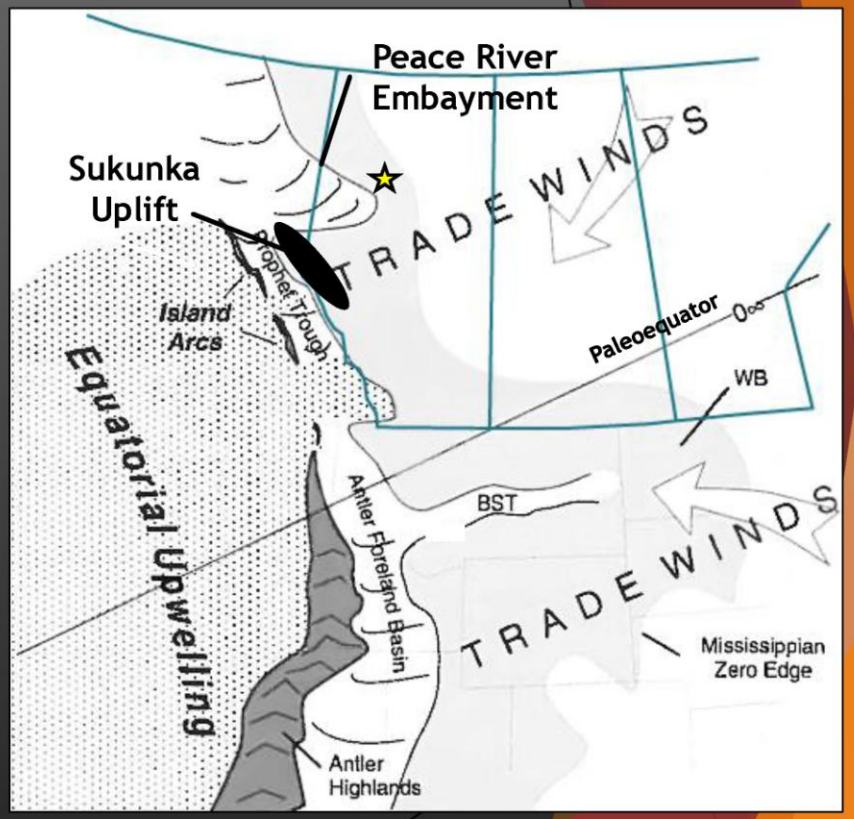


Modified from Richards *et al.* (1994)

Presenter's notes:
Relatively understudied interval
Mississippian carbonate
Dominated by crinoids and peloids

Geologic Setting

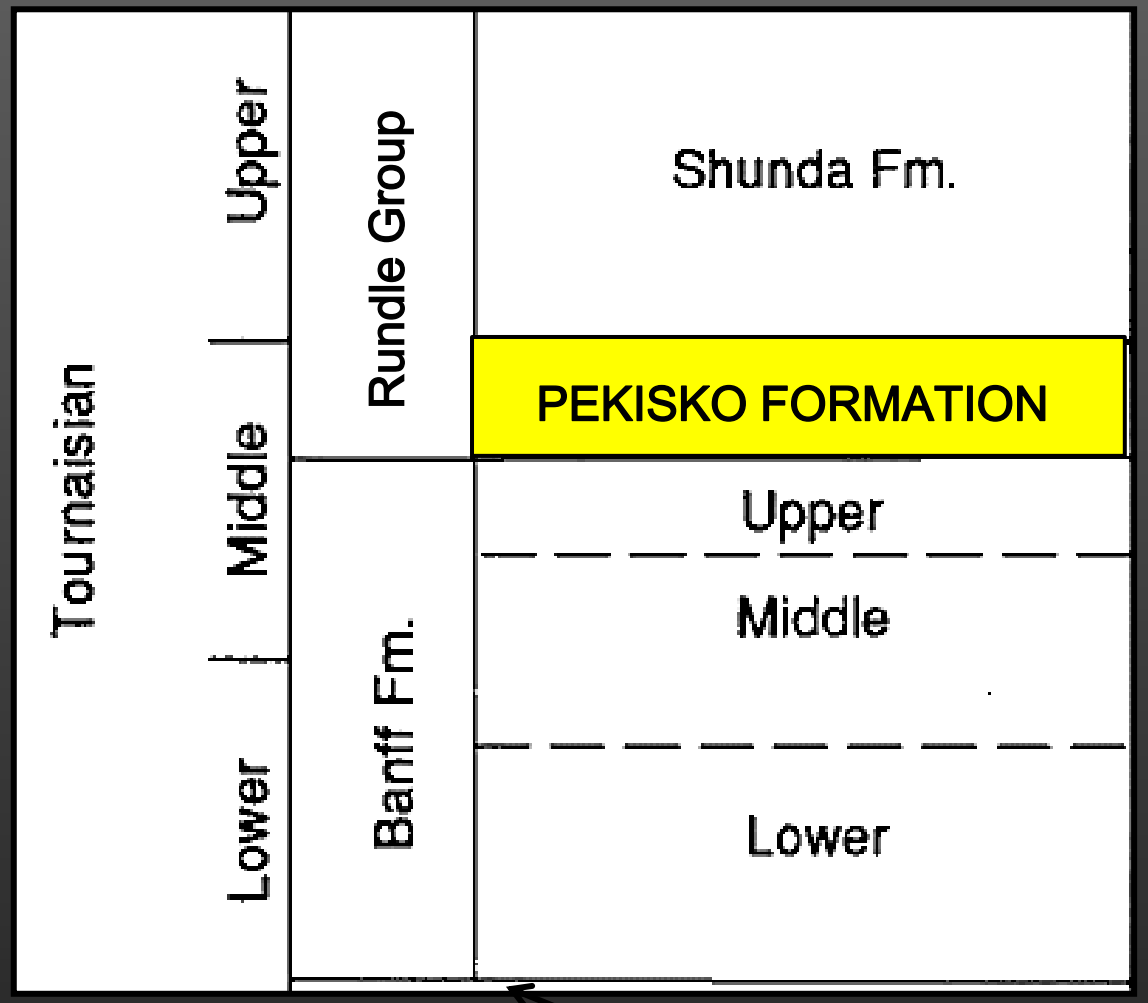
- Western margin of ancestral North America
- Several tectonically-influenced basins present
- Equatorial: 10°S-30°N
- Offshore-directed trade winds
- Shallow marine, carbonate ramps
- Stratified water column



Modified from Brandley and Krause (1997)

Presenter's notes:
Formed during continental accretion
Western margin of down-warped and down-faulted ancestral North American Plate
Subduction resulted in island arcs, plutonic belts, and associated foreland basins
Other structural components formed due to reactivation of Precambrian faults and the formation of new faults along the continental margin
Subduction resulted in island arcs, plutonic belts, and associated foreland basins
Other structural components formed due to reactivation of Precambrian faults and the formation of new faults along the continental margin
Comment on importance of PRE
Most of Alberta was covered by a shallow, epicontinental sea

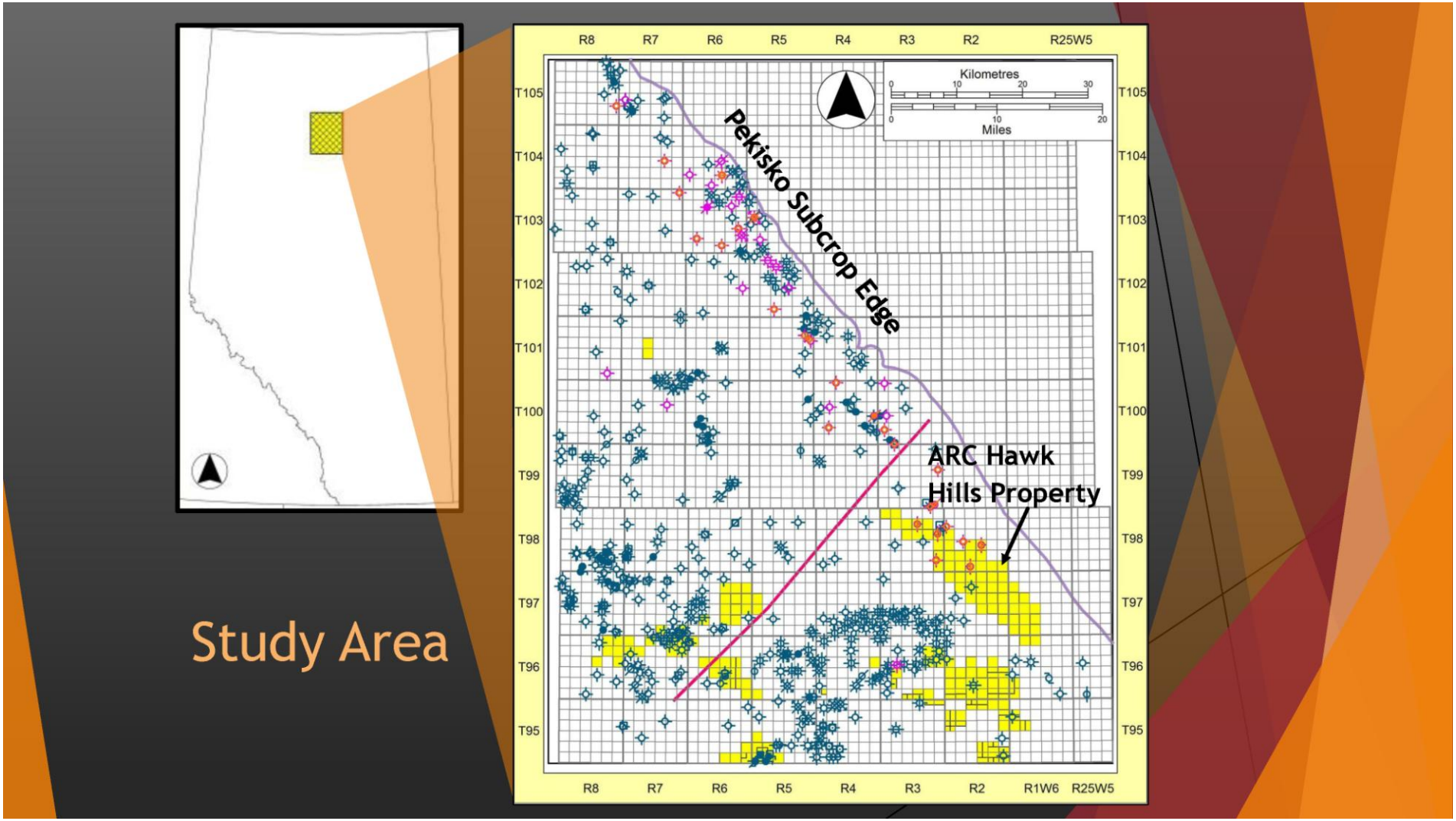
Lower Mississippian Stratigraphy



Modified from O'Connell (1990)

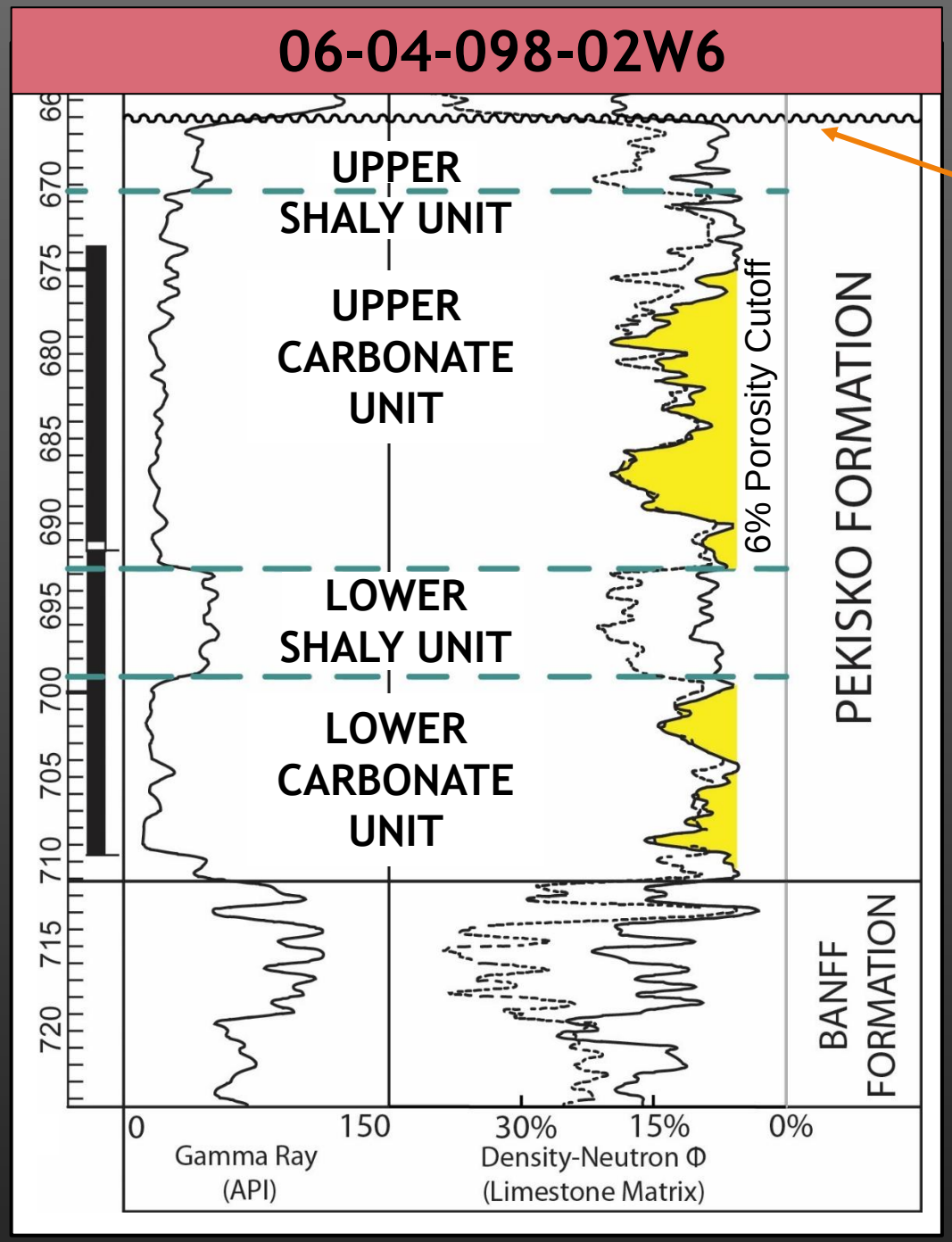
Pekisko Formation:

- 30-80 m thick
- Base of the Rundle Group
- Base of 3rd-order transgressive-regressive sequence (with the Shunda Formation)



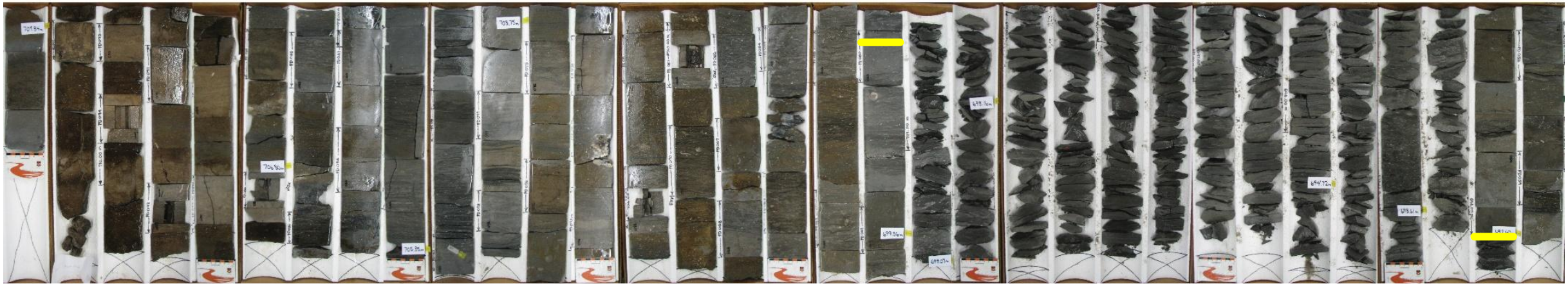
Presenter's notes: 508 wells intersect the Pekisko Formation in the region, and are marked in blue; 43 of these wells also have core of the Pekisko Formation, and are marked in purple. Of these, 24 were logged for the purposes of this project. The cores were selected to represent the formation both laterally, throughout the study area, and vertically, in order to observe the stratigraphy as fully as possible. A total of 158 samples were taken to be made into thin sections.

Pekisko Stratigraphy



Composite Core Photo: O6-04-098-02W6

Upper Carbonate

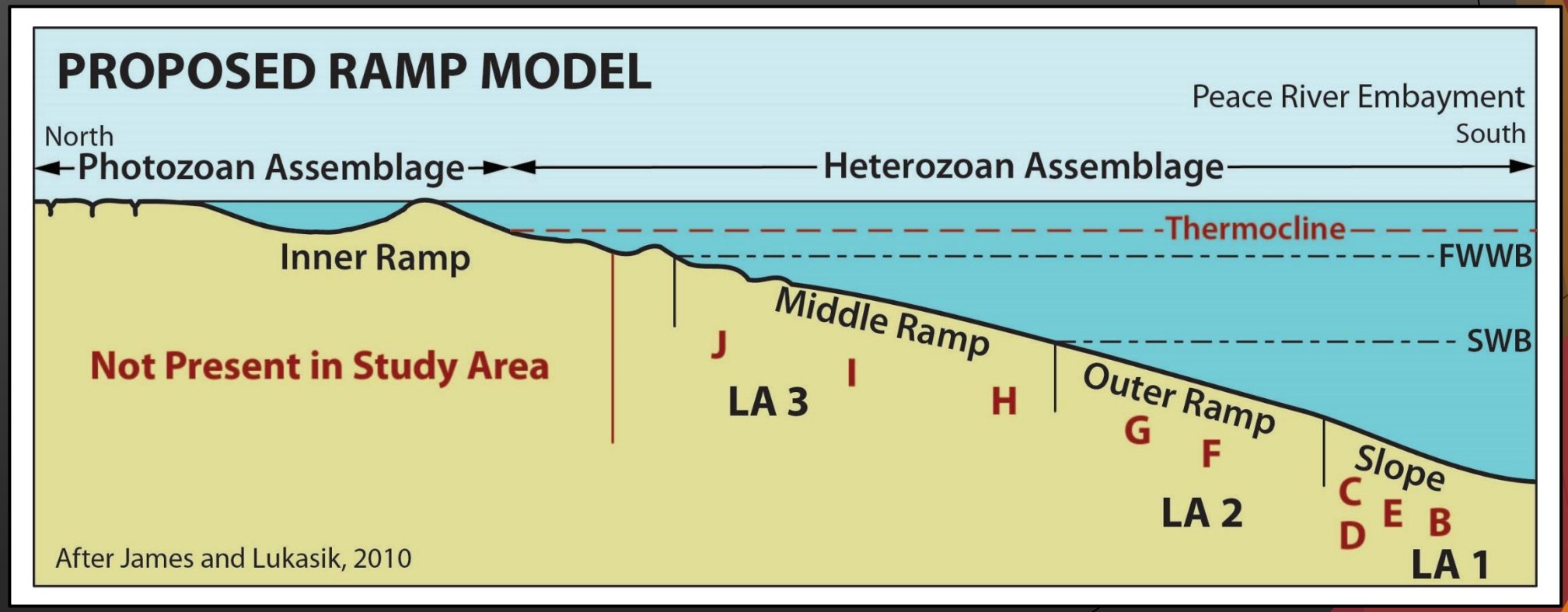


Lower Carbonate

Middle Shaly

Lithofacies Associations:

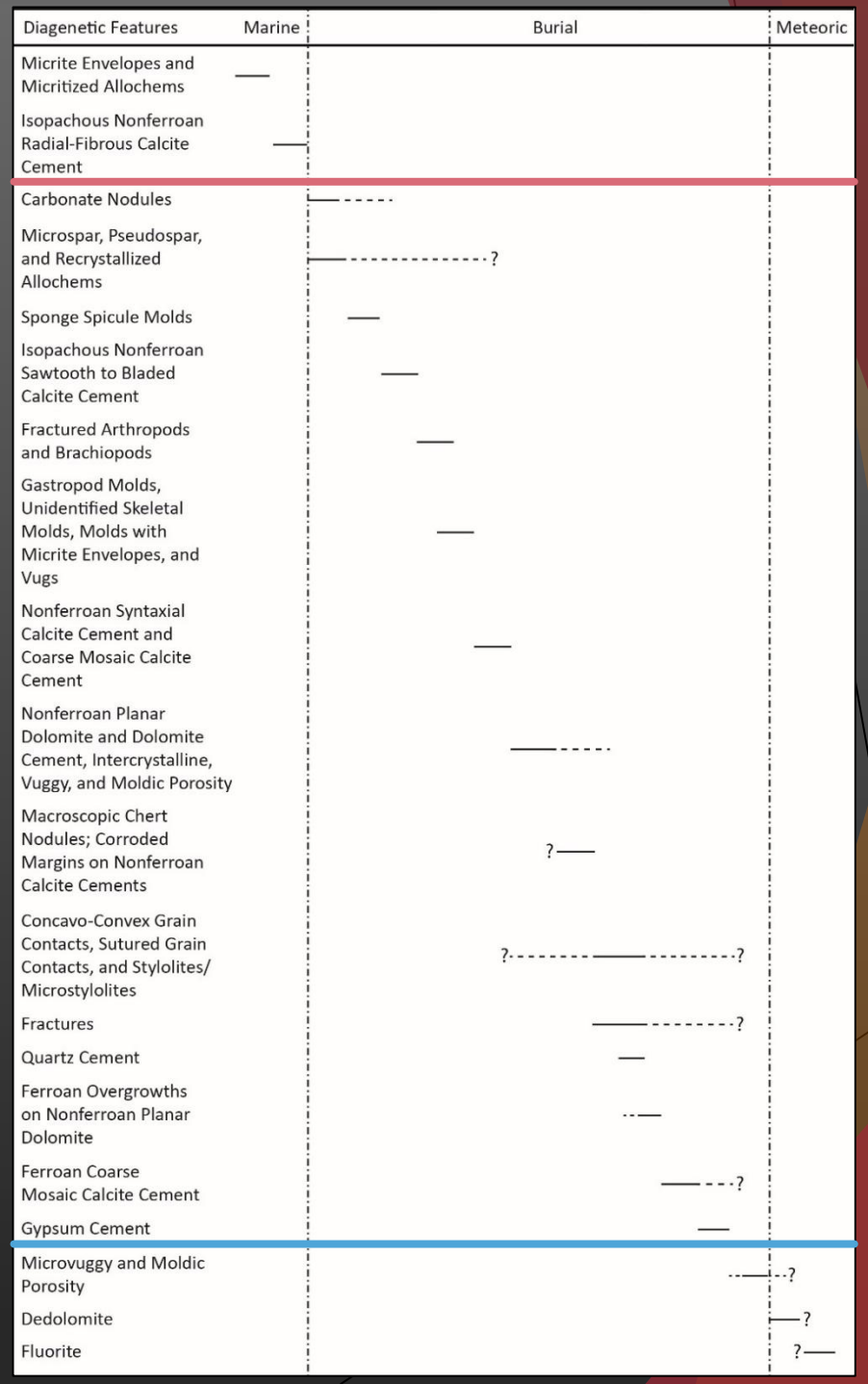
- Three lithofacies associations:
  - LA 1 – Outer Ramp - Slope
  - LA 2 – Outer Ramp
  - LA 3 – Middle Ramp



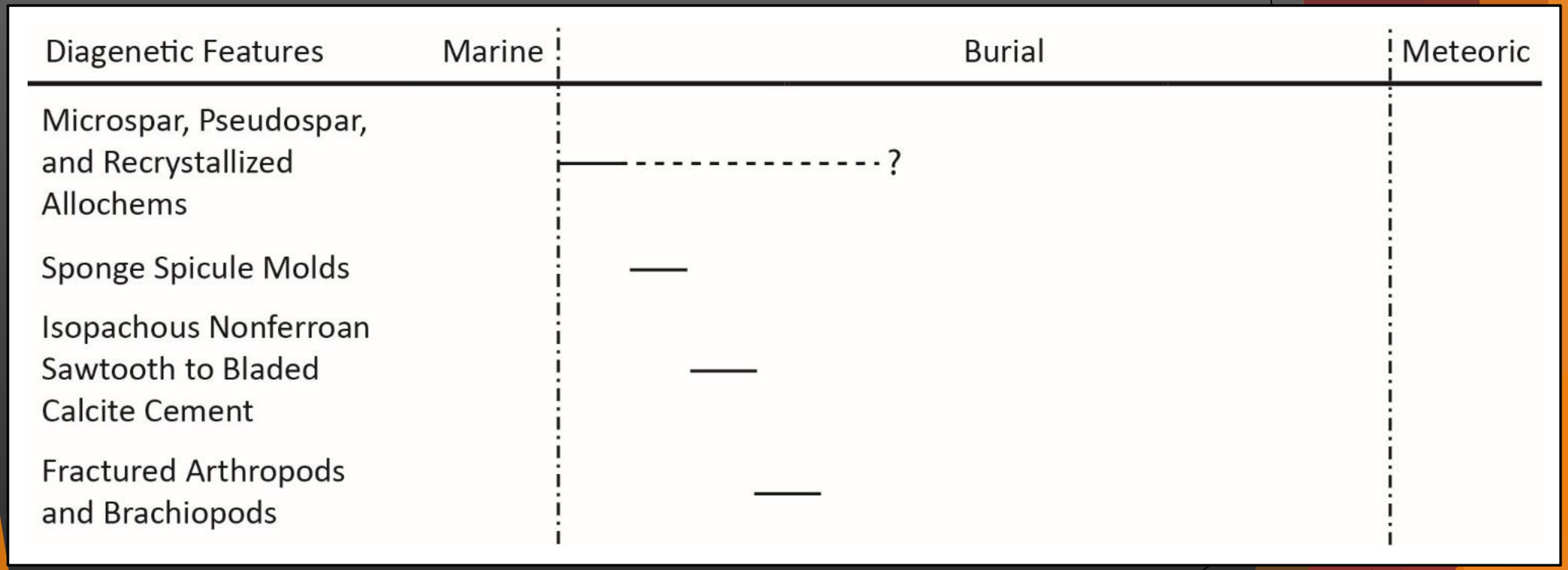
Diagenetic Sequence

1. Very few early marine diagenetic features
2. No early meteoric diagenesis
3. Large variety of burial diagenetic features
4. Few late meteoric diagenetic features

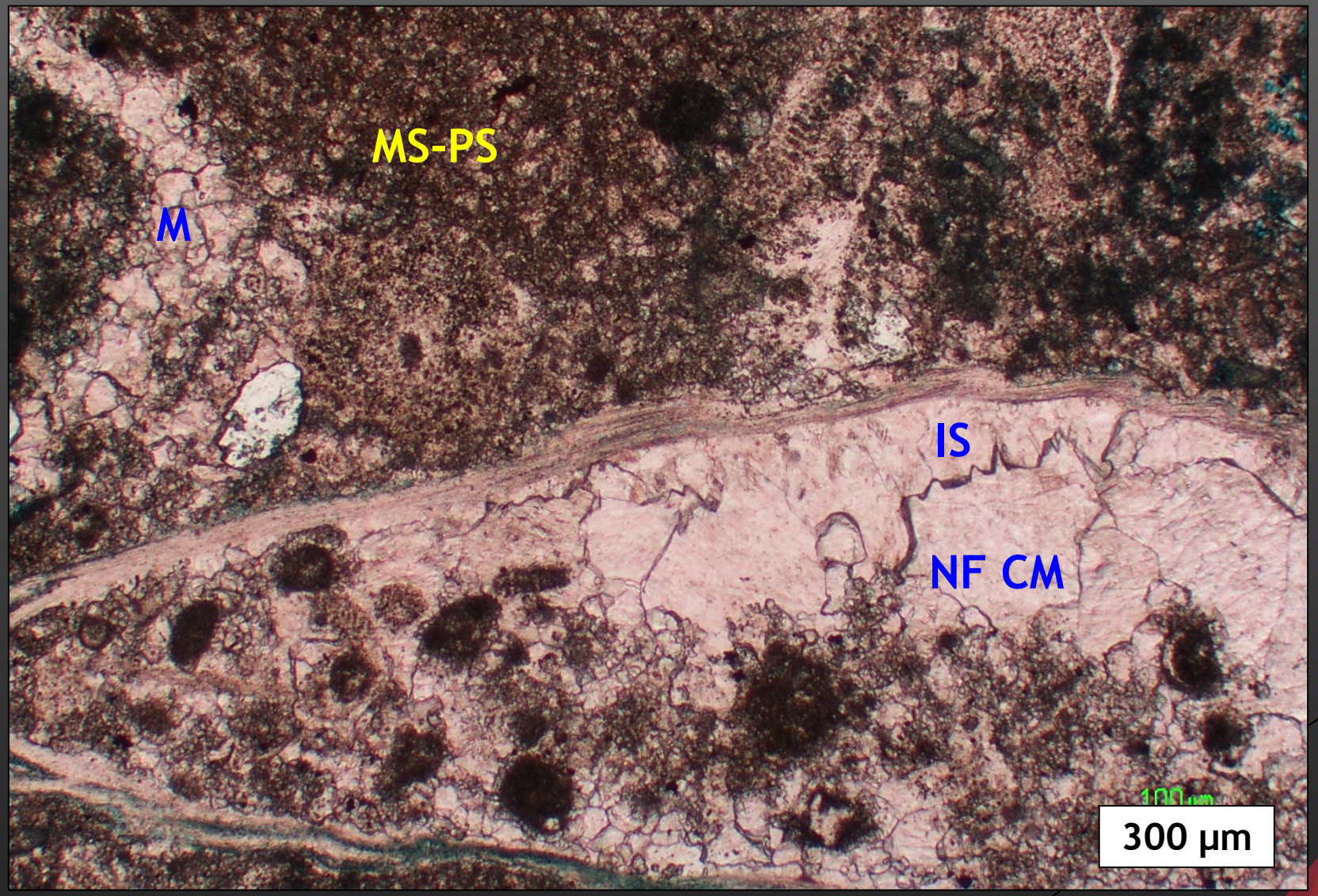
Interpretation based on petrography, isotope analysis, trace element analysis



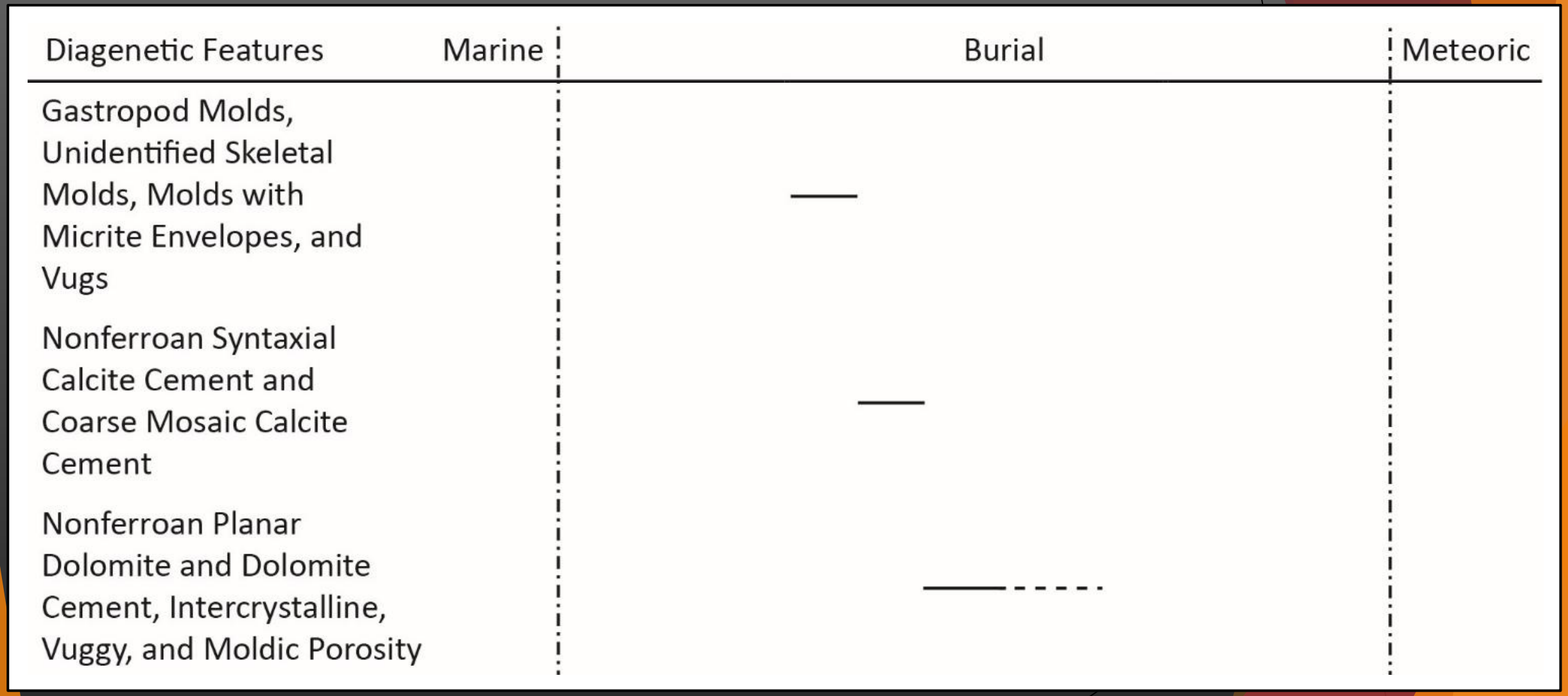
Burial Diagenesis (1)



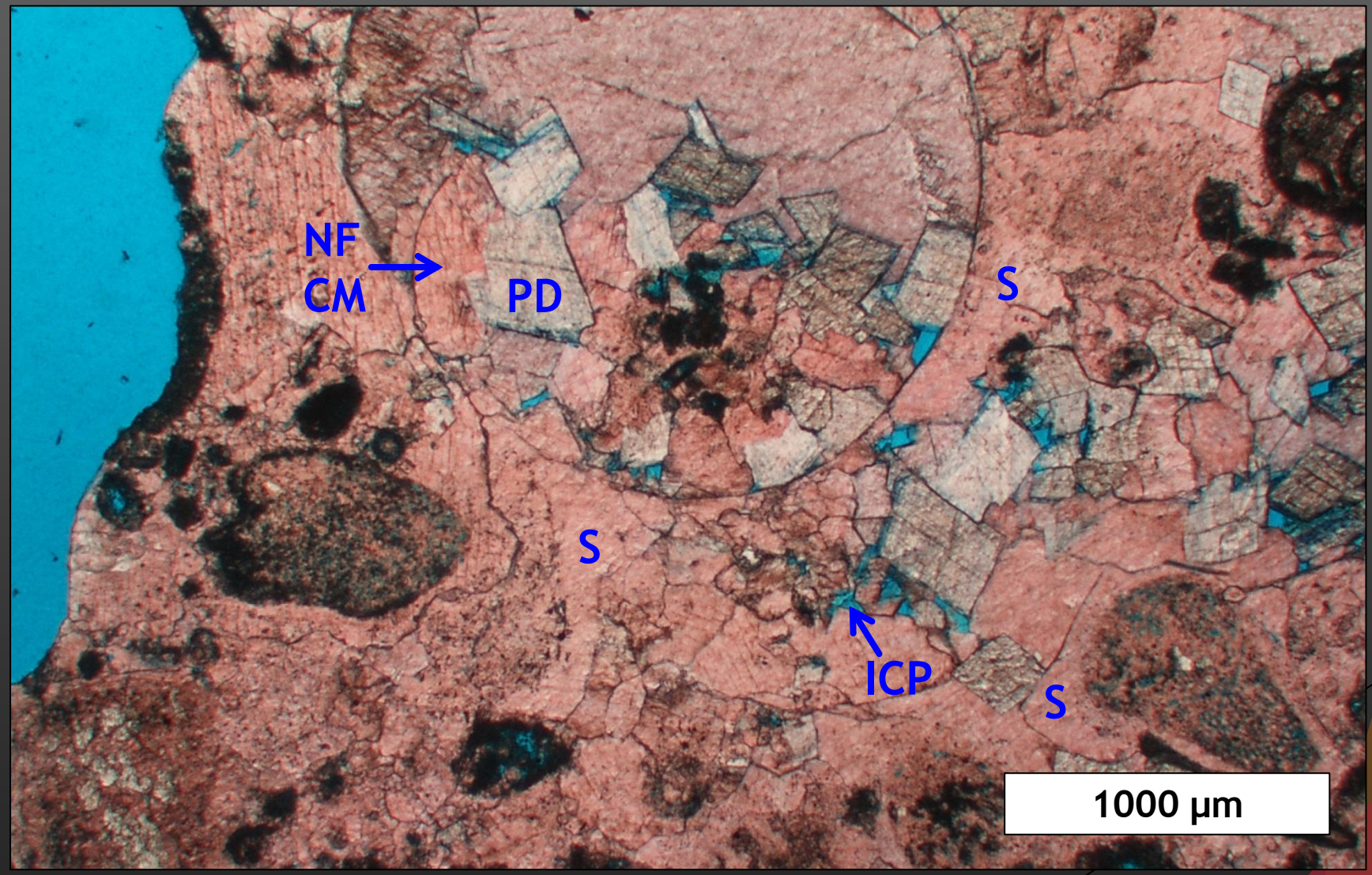
Burial Features: Calcite Cements and Neomorphosed Matrix



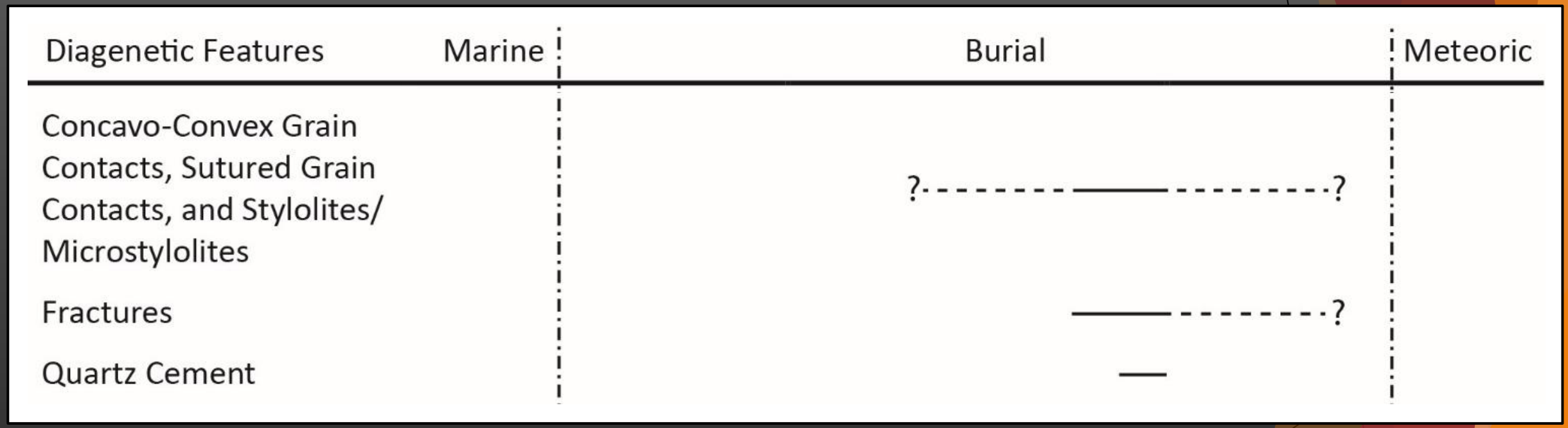
Burial Diagenesis (2)



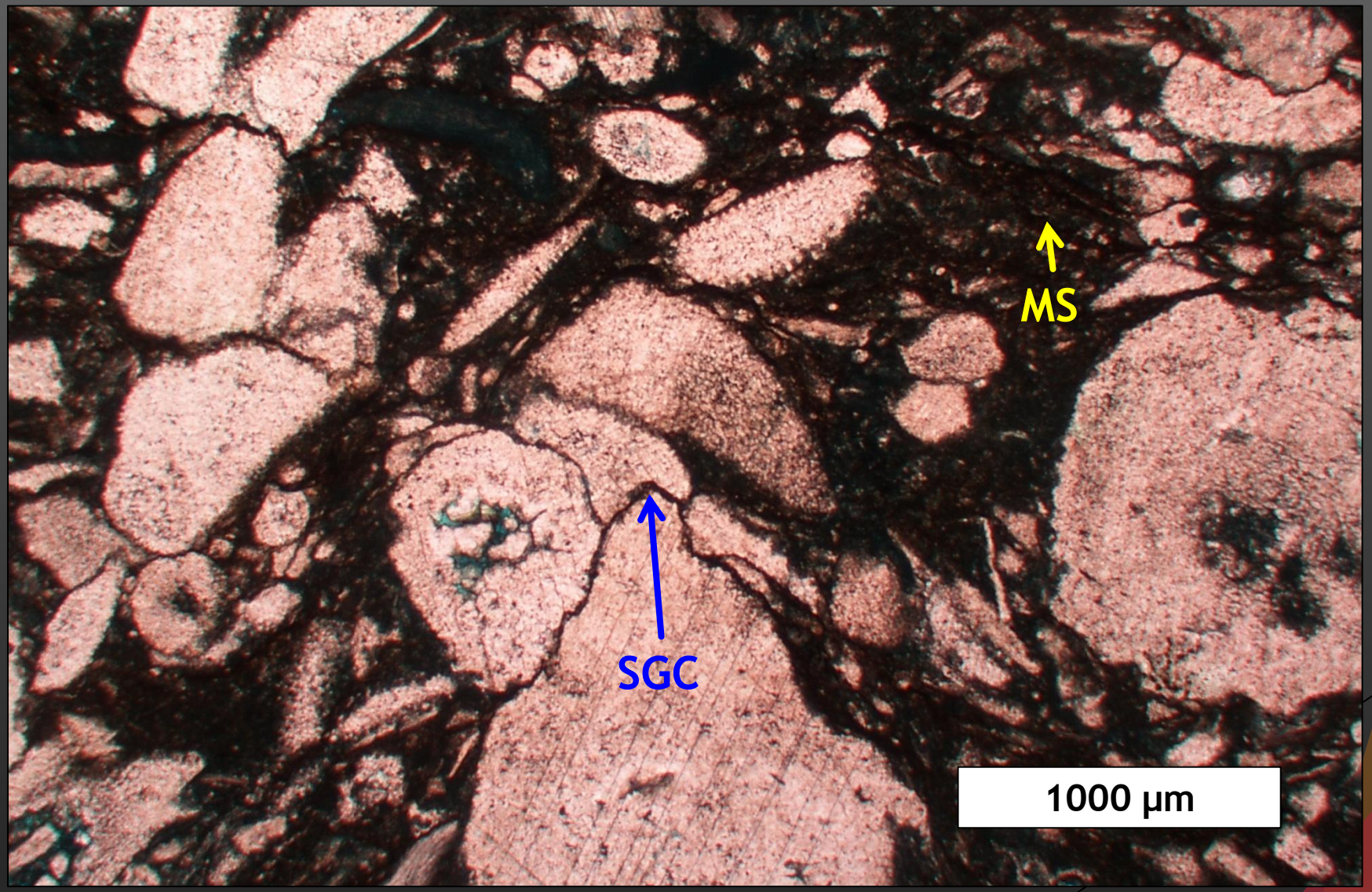
Burial Features: Filled Molds, Calcite Cements, Planar Dolomite



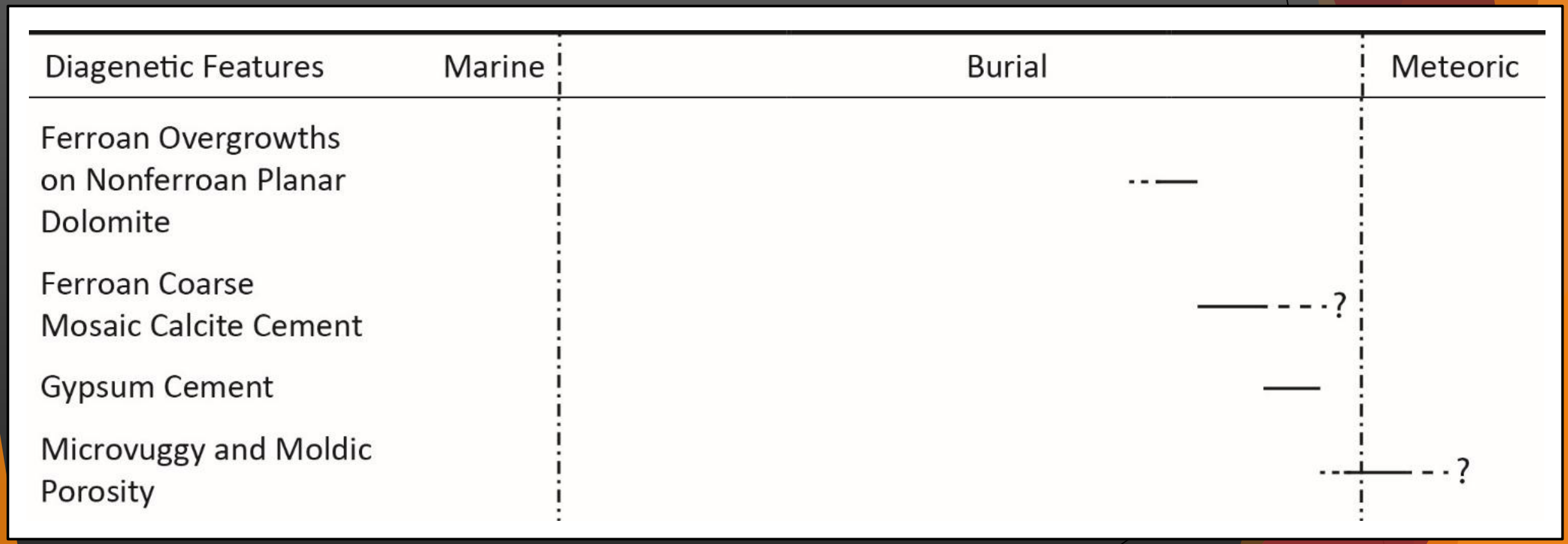
Burial Diagenesis (3)



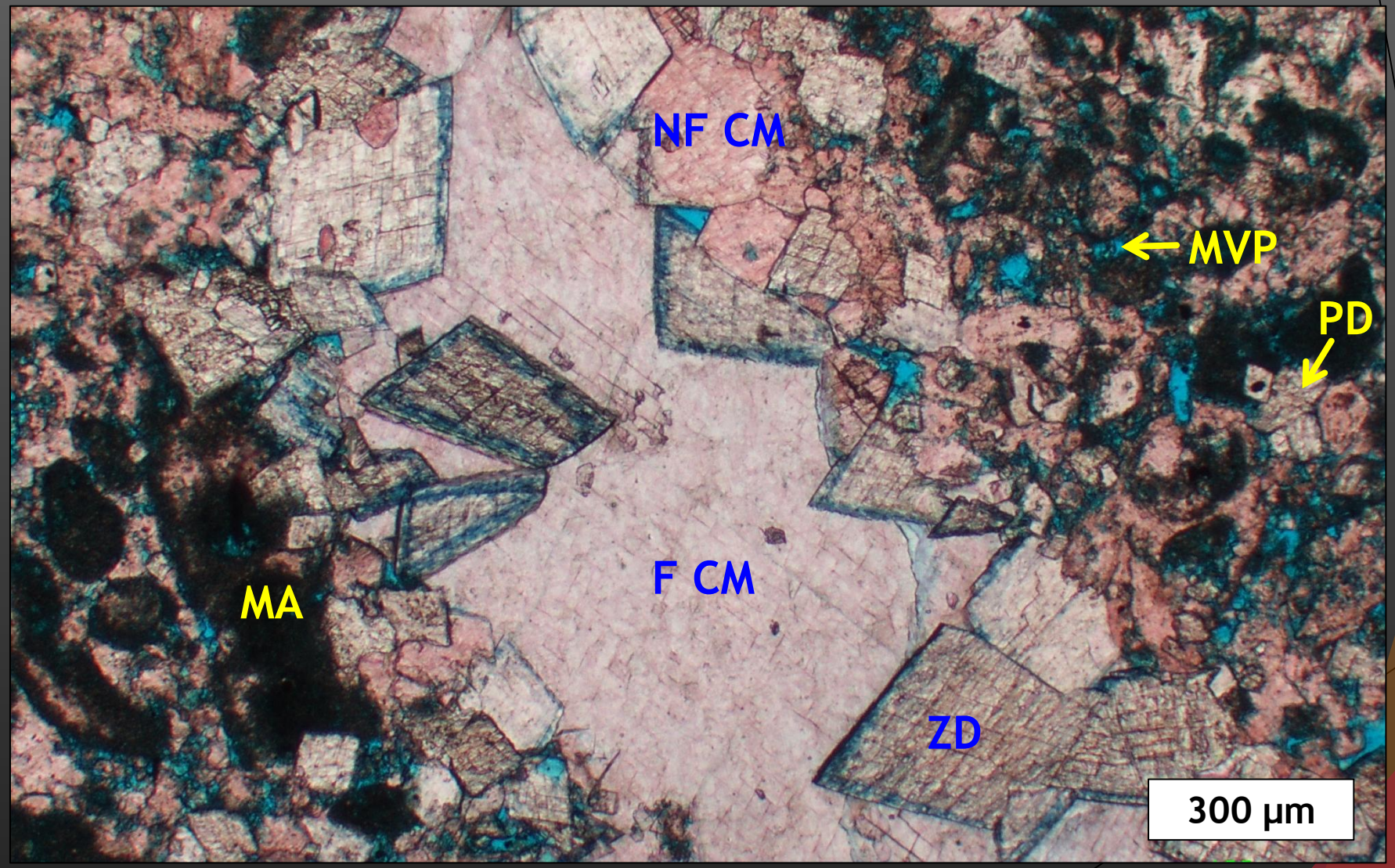
Burial Features: Microstylolites and Sutured Seams



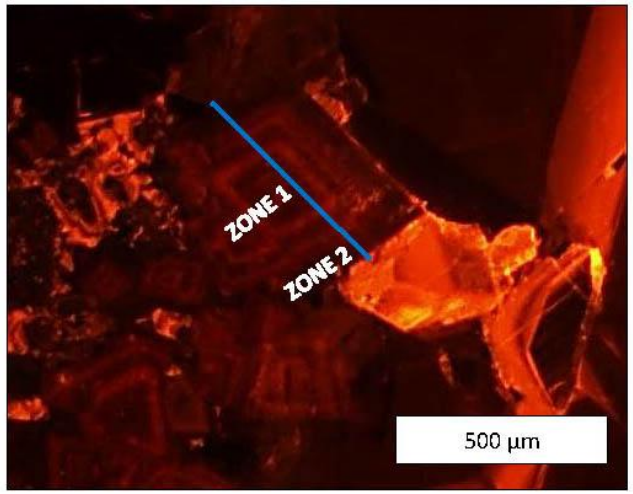
Burial Diagenesis (4)

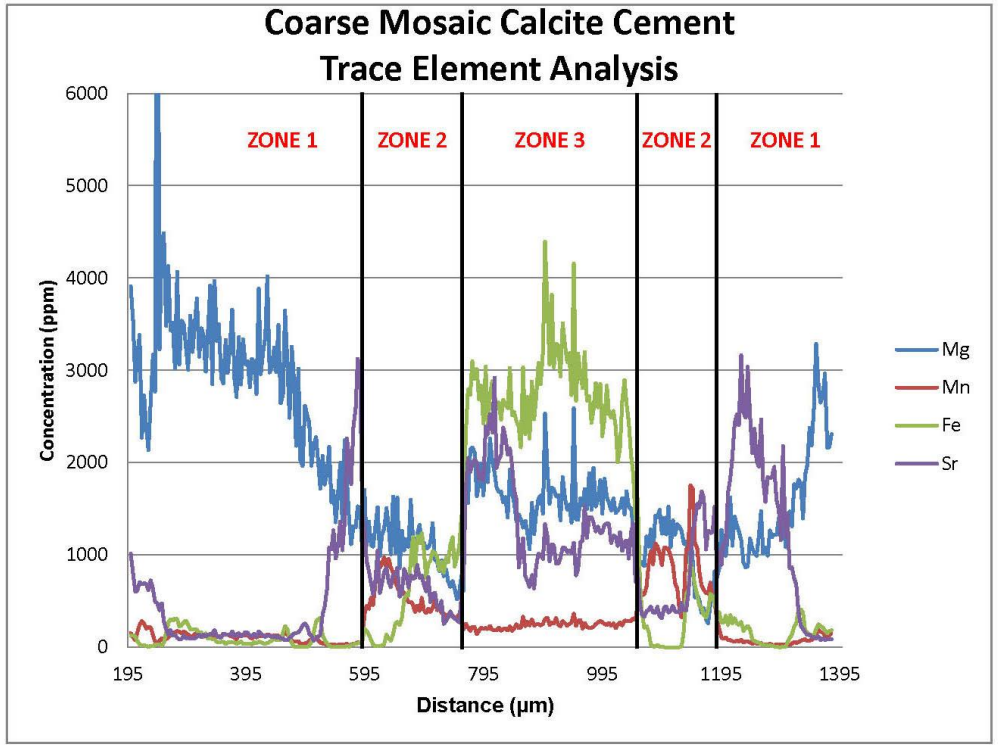


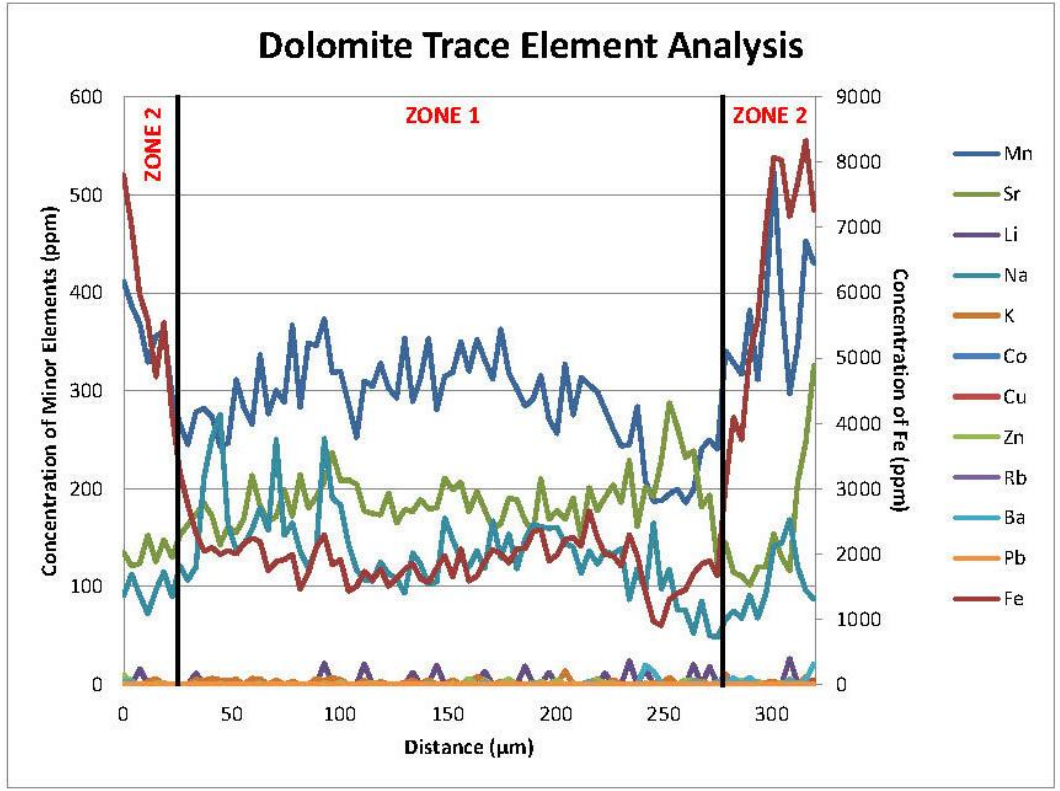
Burial Features: Zoned Dolomite and Calcite Cements



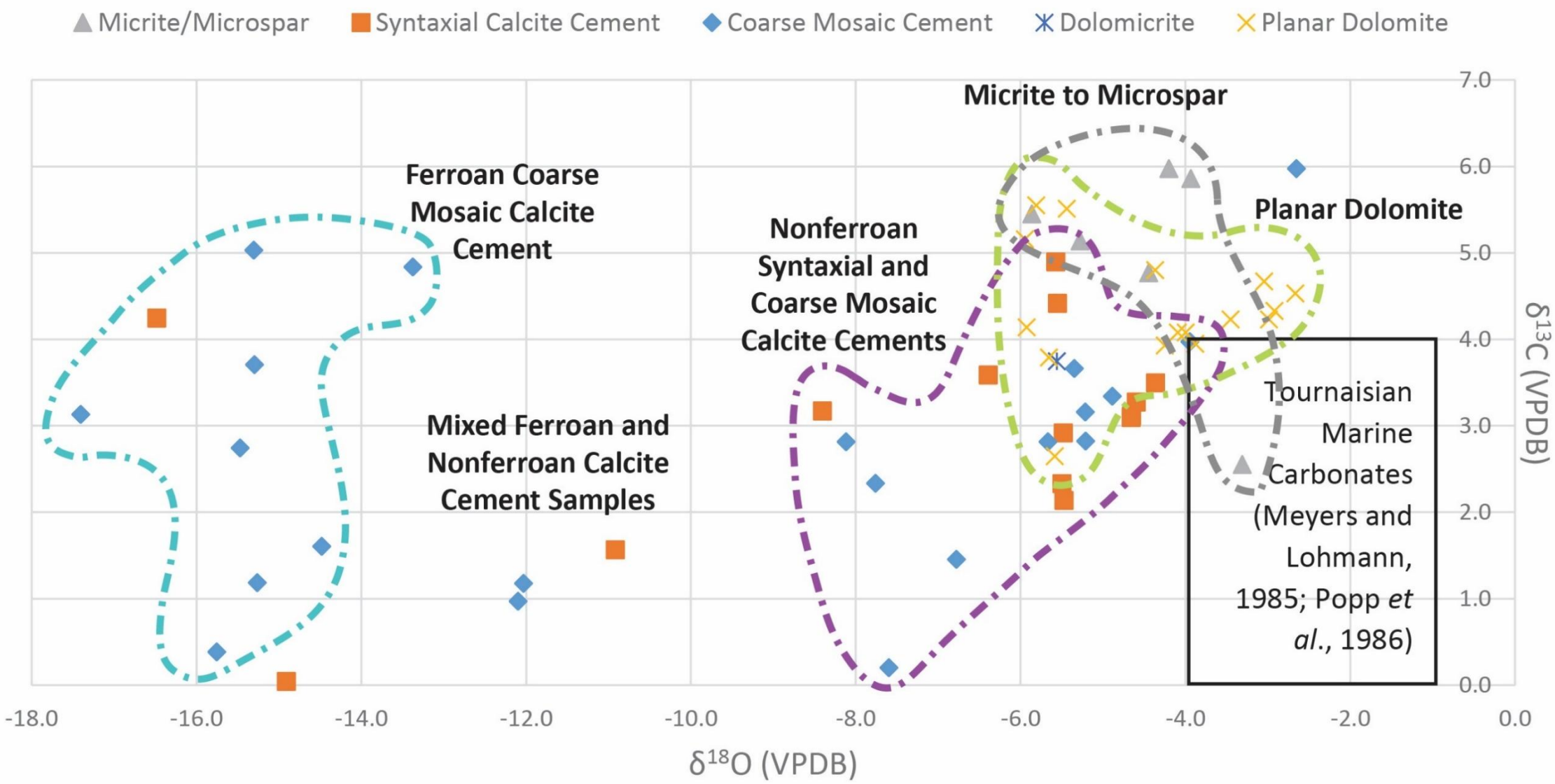

200 µm
ZONE 1
ZONE 2
ZONE 3
ZONE 2
ZONE 1


ZONE 1
ZONE 2
500 µm

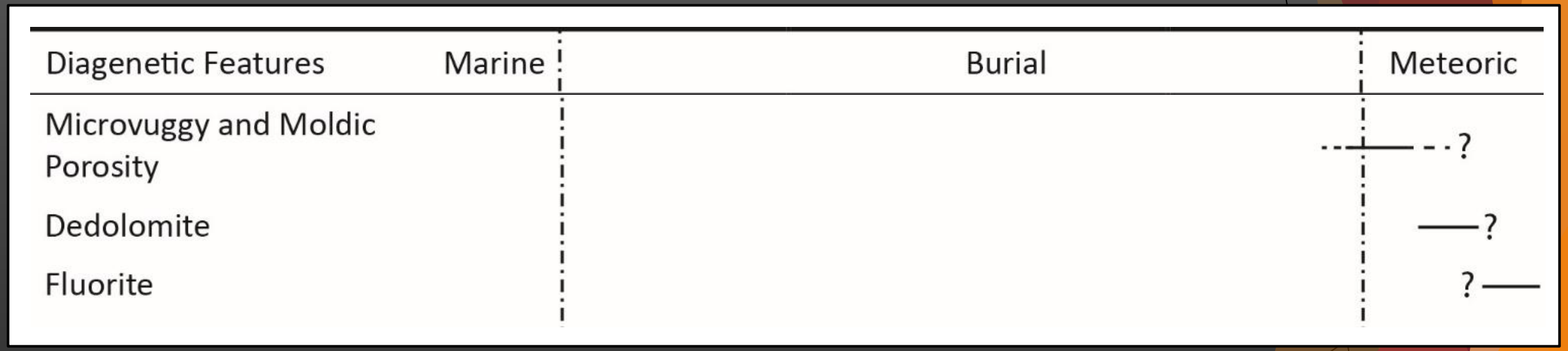

Coarse Mosaic Calcite Cement
Trace Element Analysis
ZONE 1
ZONE 2
ZONE 3
ZONE 2
ZONE 1
Concentration (ppm)
Distance (µm)
Mg
Mn
Fe
Sr


Dolomite Trace Element Analysis
ZONE 2
ZONE 1
ZONE 2
Concentration of Minor Elements (ppm)
Concentration of Fe (ppm)
Distance (µm)
Mn
Sr
Li
Na
K
Co
Cu
Zn
Rb
Ba
Pb
Fe

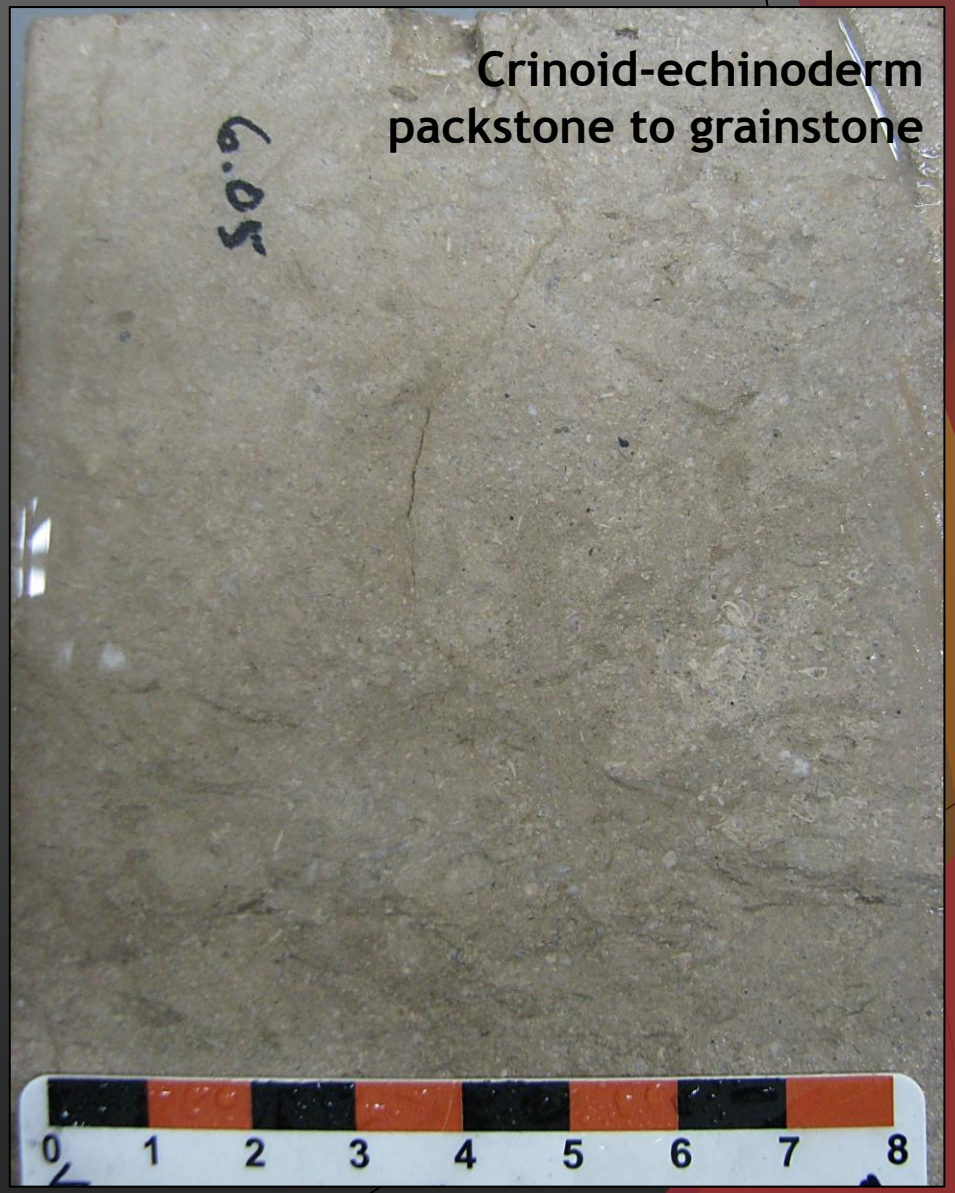
C-O ISOTOPE ANALYSIS



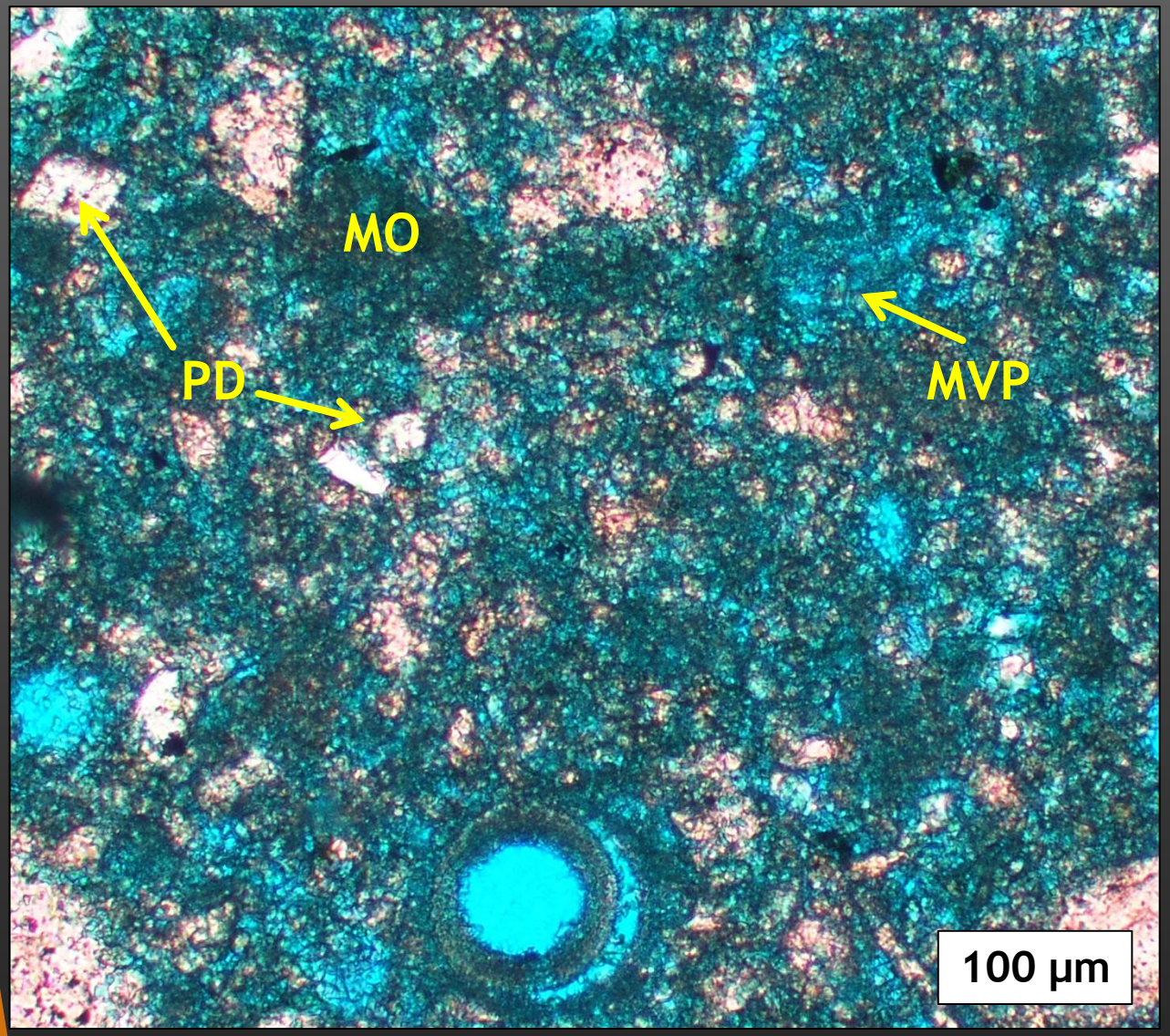
Burial to Meteoric Diagenesis

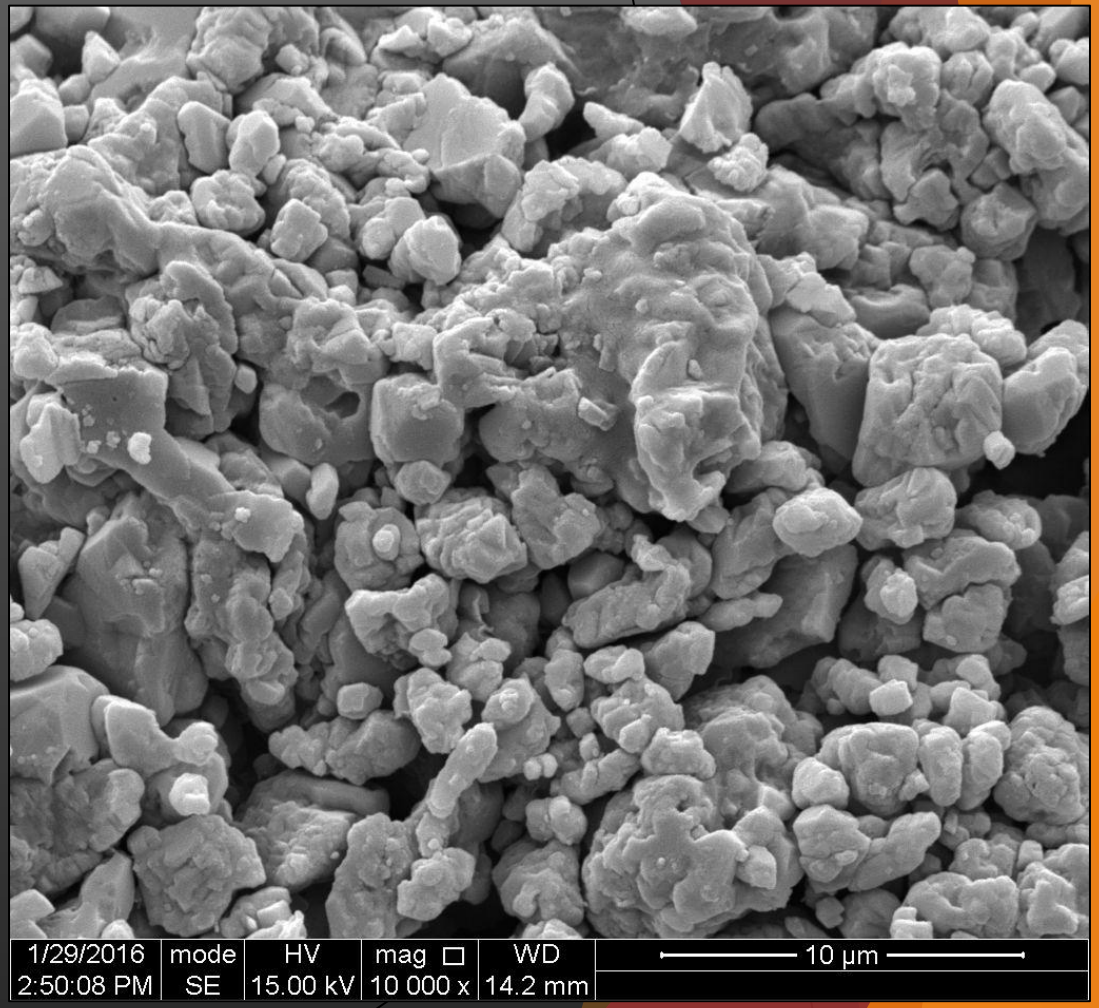


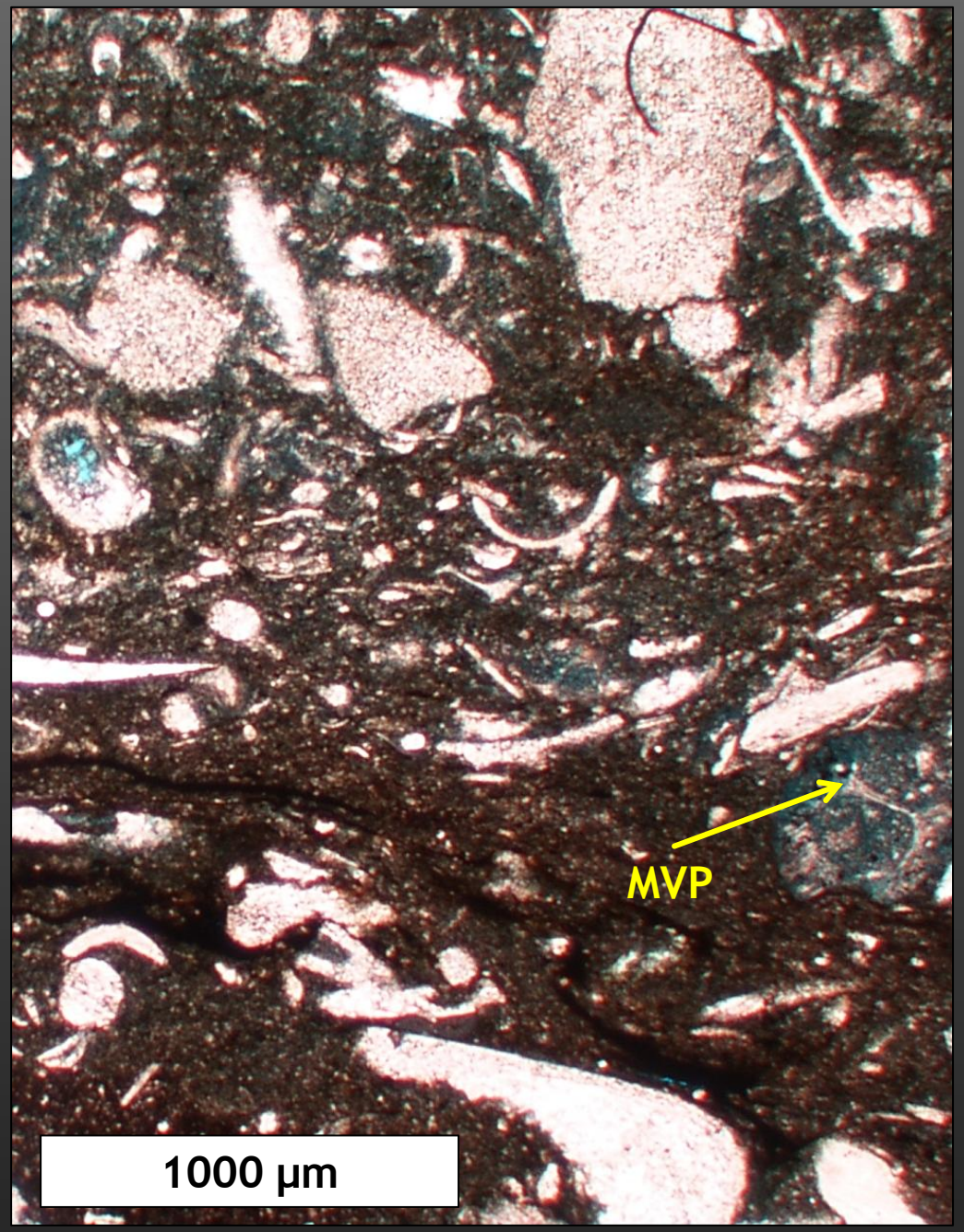
Packstones with Pervasive Microvuggy Porosity

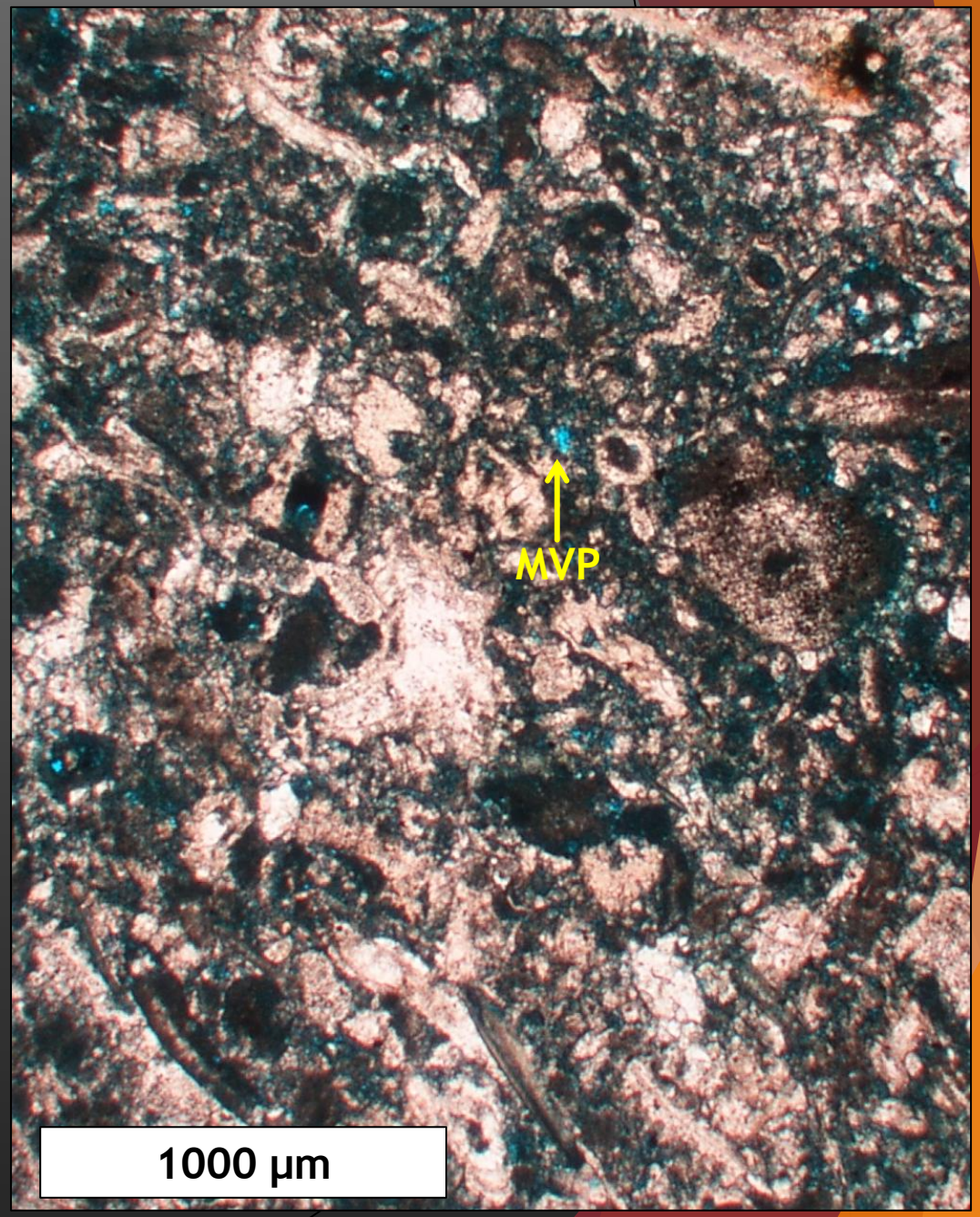


Burial Features: Microvuggy Porosity



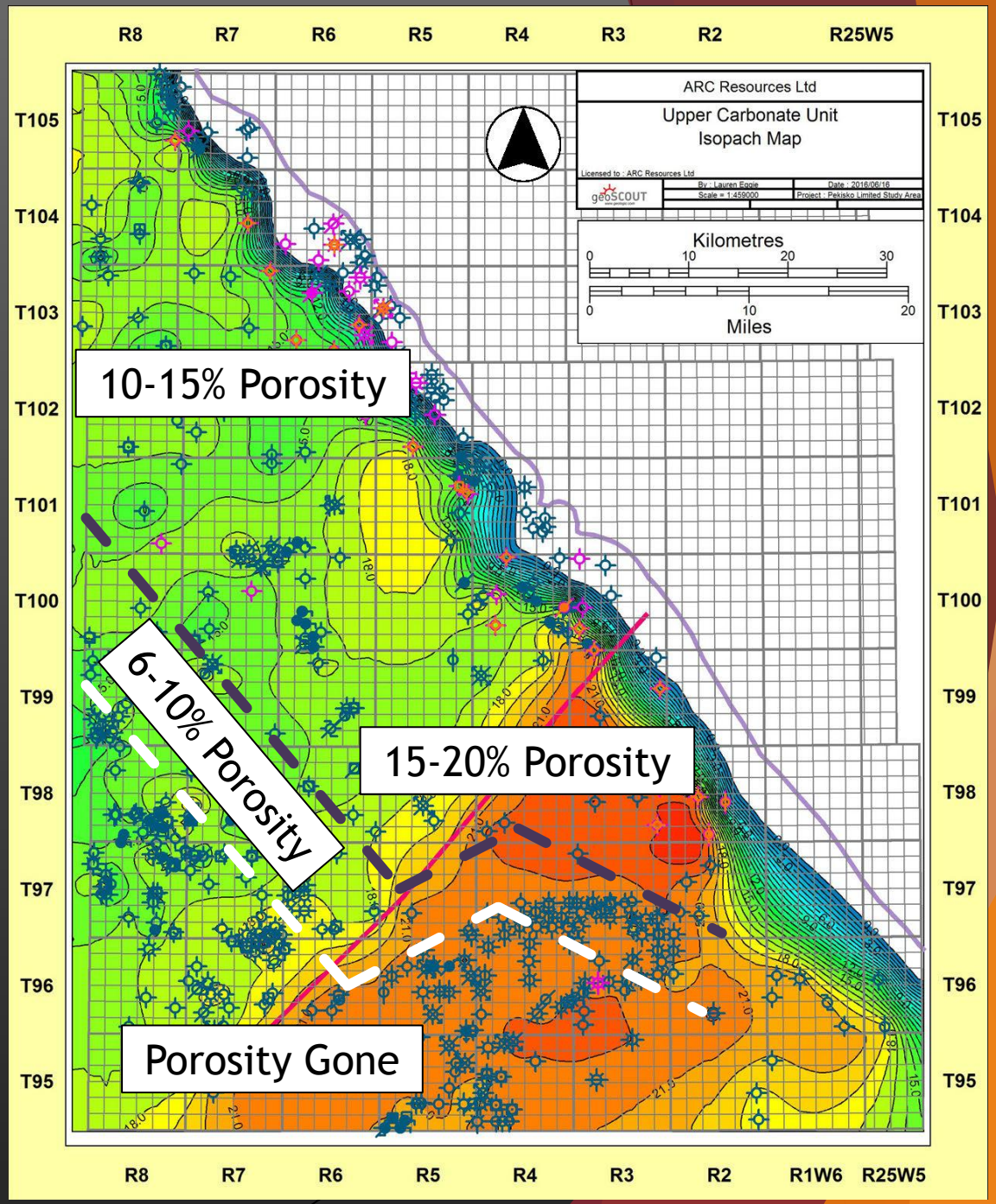



MVP
1000 µm


MVP
1000 µm

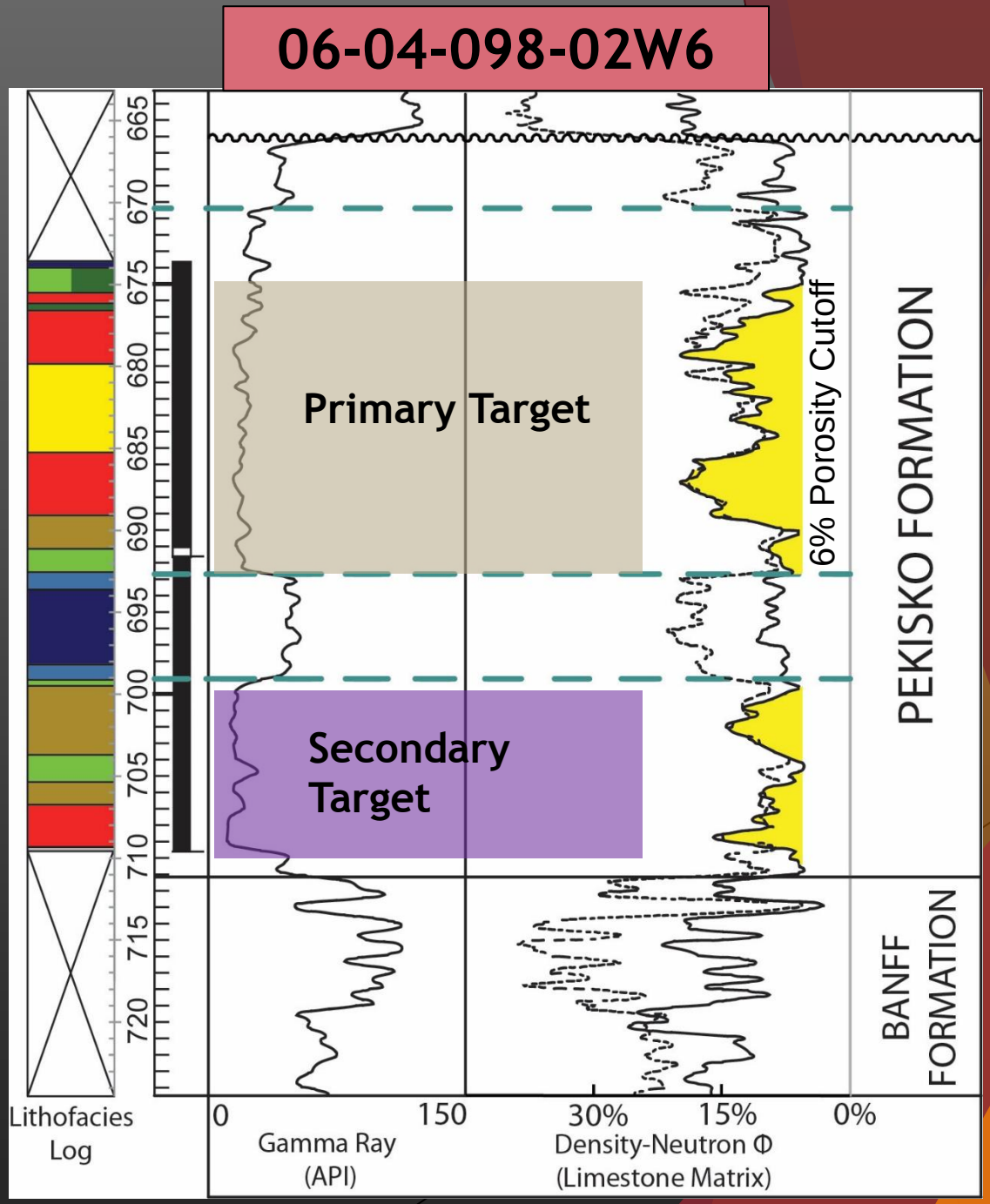
Microvuggy Porosity Formation Mechanisms

- Three potential processes:
  1. Subaerial exposure during formation of the post-Mississippian unconformity
  2. Burial compaction of shales
  3. Tectonic forcing/tectonic activity



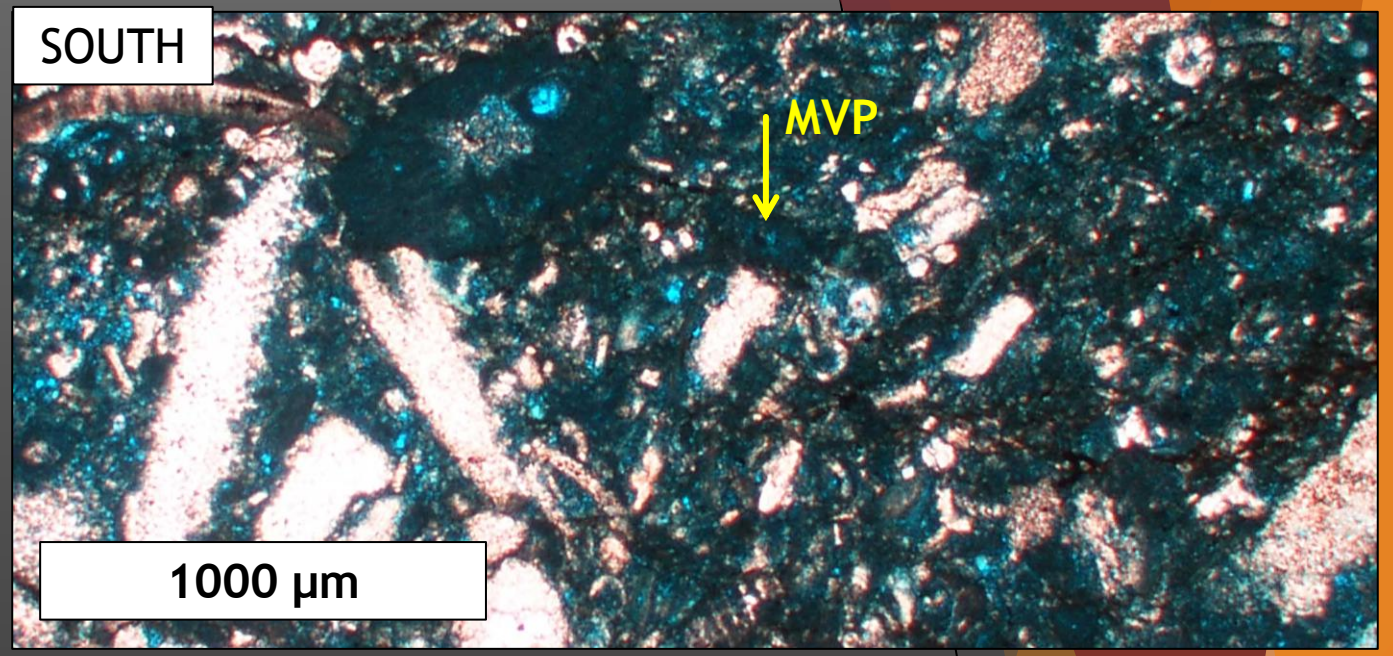
Reservoir Intervals

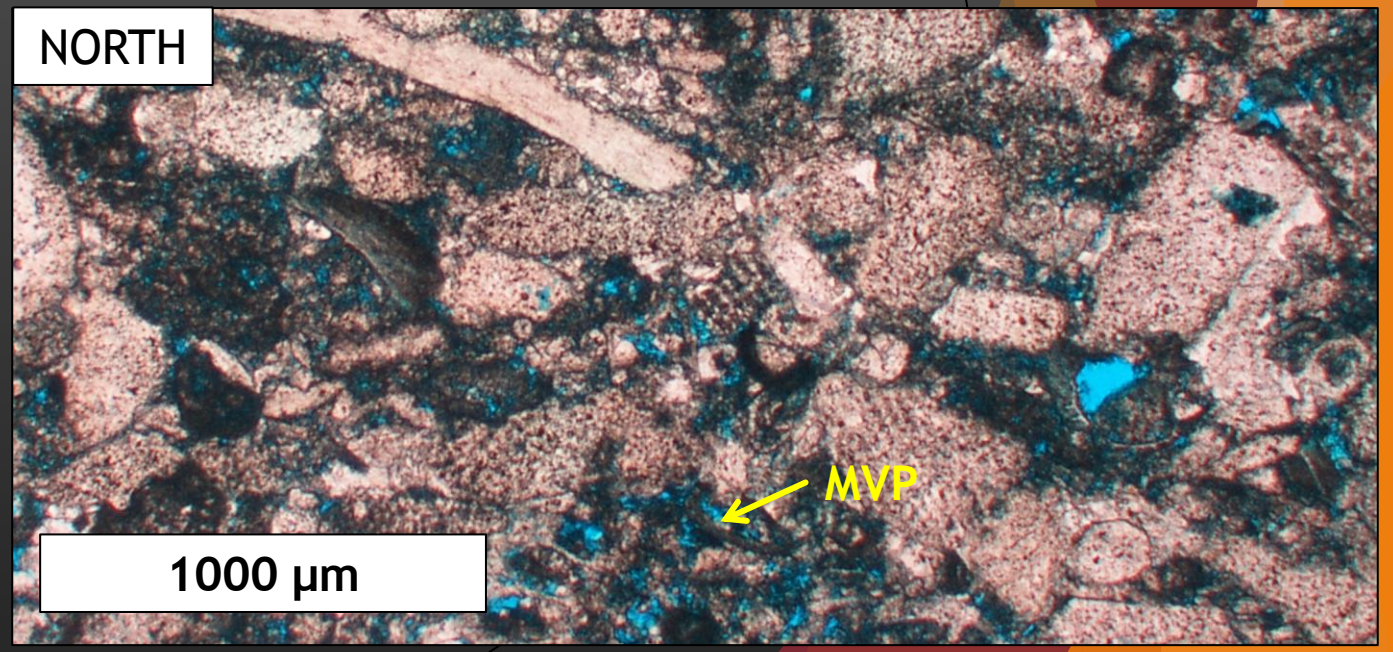
- Primary target: upper carbonate unit
- Pay intervals: 0.9 – 13.1 m thick; fully oil saturated
- Laterally continuous and typically vertically homogenous
- Middle shaly unit: major permeability barrier



Reservoir Characteristics

Parameter	Value
Porosity (visual estimates)	**South:10-20%** North: 7-15%
Porosity (GeoSCOUT)	**South: 9.4-20.5%** North: 5-17.7%
Permeability (GeoSCOUT)	**South: 0.52-420 mD** North: 0.1-2.8 mD
Oil Gravity	22° API
Estimated Resource	**30 million bbl/section**
Hawk Hills TOTAL:	**1.8 billion bbl OOIP**





Conclusions

- Diagenetic features include early marine, burial, and late meteoric features (*majority: burial*)
- Dolomitization and calcite cementation took place relatively early; most primary and early secondary porosity is occluded
- Dominant reservoir porosity is the pervasive microvuggy porosity
  - Likely related to uplift and subaerial unconformity formation
- Significant oil-in-place and oil saturated reservoir packages up to 13 m thick
  - Dominantly microvuggy porosity, partial moldic porosity, and minor interparticle porosity

Presenter's notes: This is a really interesting project both scientifically and economically, and with completion of the second part of my project, I hope to better characterize the reservoir and to understand the controls on platform development and the implications this may have for interpretations of Mississippian ramps in northern Alberta.

Thank You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