# Assessment of Organic Petrology Methodology and Characterization of Primary and Secondary Dispersed Organic Matter in Liquid-Rich Shales: Using optical microscopy methodologies*

**L. D. Stasiuk[1], Amr El-Ezhary[1], Michelle Asgar-Deen[2], Volker Dieckmann[3], Rob Robinson[2], and Gary Green[2]**

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[1]Shell Canada, Calgary-SIEP (Lavern.Stasiuk@shell.com)
[2]Shell Canada, Calgary
[3]SIEP, Houston, TX

## Abstract

Traditionally, organic petrology (OP) method is defined as an optical-based, reflected white and fluorescent light, microscopic characterization-classification-quantification, and measurement of % reflectance in oil (%Ro) and VIS of individual primary (kerogen) and secondary (e.g., bitumens, oils, solid hydrocarbons, pyrobitumens) organic matter, referred to as macerals. Combined, primary and secondary organic matter, make up total weight percent of organic carbon in sedimentary rocks, including liquid-rich shale (LRS). Perfecting the sample preparation of fine-grained rocks is not achieved in many labs, thus negatively impacting analytical data and interpretations. Ideally LRS samples for OP maceral analyses should be whole rocks, very gently crushed and or sized such that random, parallel, and perpendicular to bedding, and or microfractures are represented, and impregnated with new, very low viscosity, epoxy, under vacuum conditions. Use of solid, bored, acrylic rods and epoxy are an ideal combination for superior preparation of LRS samples, thus ensuring integrity and retention of all microtextural elements and organic (e.g., friable 'solid bitumens') and mineral (e.g., clays) matter that are otherwise prone to plucking during the grinding and polishing process, resulting in poor quality data, poor interpretations.

Commonly, the assessment of microscopic organic matter is inadequate because of lack of versatility in classifications and under-recognition of secondary organic matter in LRS. A new, maceral classification for primary and secondary dispersed organic matter in sedimentary rocks, adopted by the International Committee for Coal and Organic Petrology (I.C.C.P) in 2013, will improve consistency in nomenclature between commercial labs, if explicitly requested by clients. In order to adequately evaluate original kerogen type, organic facies, and paleodepositional settings of LRS, based on data collected following the I.C.C.P. (2013 ) classification of dispersed organic matter (DOM), higher levels of macerals classification identification (e.g., maceral type, maceral variety, maceral sub-variety (Table below) needs to be augmented with inorganic microfossil components. Examples are  provided from ahe WCSB.

Secondary organic matter likely constitutes more of the TOC in LRS than has previously been recognized by OP; that is, there are higher amounts of solid hydrocarbon and pyrobitumens derived from kerogen to bitumen to oil conversion and from oil to gas and oil to condensate cracking. This has implications for assessing original petroleum potential of an LRS, and potential, for linking OM-related nano-porosity to individual secondary maceral types using combined OP and FIBSEM types of analyses

| Maceral Group | Maceral | Maceral type | Maceral Variety | Maceral Sub-variety |
|---|---|---|---|---|
| **Liptinite** | Alginite | Telalginite | Botryococcus | Tenui-Botryococcus; Large diameter/length colonies, Usually >50 micron, cell walls are highly thickened |
| | | | | Crassi-Botryococcus; Small diameter/length colonies, Usually 5 - < 50 microns, cell walls are thins |

## Selected References


Bharati, S., R.L. Patience, S.R. Larter, G. Standen, and I.J. Poplett, 1995, Elucidation of the Alum shale kerogen structure using a multi-disciplinary approach: Organic Geochemistry, v. 23/11-12, p. 1043-1058.

McCartney, K., 1993. Silicoflagellates. *in* J.H. Lipps, ed., Fossil Prokaryotes and Protists: Wiley-Blackwell, Malden, MA, p. 143–154.

Senftle, J.T., J.I-L, Brown, and S.R. Latter, 1987, Refinement of organic petrographic methods for kerogen characterization: International Journal of Coal Geology, v. 7, p. 105-117.

Stasiuk, L.D., 1999. Microscopic studies of sedimentary organic matter: key to understanding organic-rich strata, with Paleozoic examples from Western Canada: Geoscience Canada, v. 26, p. 149-172.

Stasiuk, L.D., and L.R. Snowdon, 1997, Fluorescence microscopy of synthetic and natural hydrocarbon fluid inclusions: crude oil chemistry, density and application to petroleum migration: Applied Organic Geochemistry, v. 12, p. 229-241.

Stasiuk, L.D., B.D. Kybett, and S.L. Bend, 1993, Reflected light microscopy and micro-FTIR of Upper Ordovician *Gloeocapsomorpha prisca* alginite in relation to paleoenvironment and petroleum generation, Saskatchewan, Canada: Organic Geochemistry, v. 20, p. 707-719.

Suárez-Ruiz, I., D Flores, J.G. Mendonça Filho, and P.C. Hackley, 2012, Review and update of the applications of organic petrology: Part 1, Geological applications: International Journal of Coal Geology, v. 99, p. 54-112.

Thompson, C.L., and H. Dembicki, 1986, Optical characteristics of amorphous kerogens and the hydrocarbon-generating potential of source rocks: International Journal of Coal Geology, v. 6, p. 229-249.

Wiebe, N.S., N. Chow,and L.D. Stasiuk, 2013, Origin of source rocks in the Middle Devonian Keg River Formation, Rainbow and Zama sub-basins, Alberta: Sedimentological and organic petrological evidence: Bulletin of Canadian Petroleum Geology, v. 61/2, p. 187-210.

Young, Jeremy R., and J.H. Lipps, 1997, Taxonomy and taxonomic appendices in Marine Micropaleontology: Marine Micropaleontology, v. 29/3, p. 173-174.

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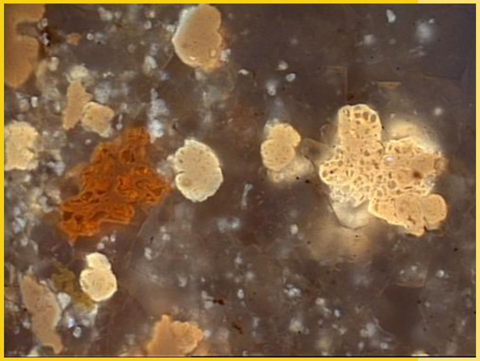
Using optical microscopy methodologies



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[1] Shell Canada-SIEP, Calgary; [2]Shell Canada, Calgary; [3]SIEP, Houston

# 1.0 Introduction to Organic Petrology  What is It ?

‘Organic Petrology is a branch of the Earth Science that studies fossil organic matter in sedimentary sequences including coal and the dispersed organic matter in rocks (DOM)’

‘Organic petrology is usually expressed by two fundamental parameters: the nature and proportions of the organic constituents, and by the rank or maturity of these organic components. ‘

(Modified from Suárez-Ruiz et al., 2012)

Largely based on optical microscopic methods

# 1.0 INTRODUCTION TO ORGANIC PETROLOGY (OP)

Analysis of polished whole rock samples, using reflected white and fluorescent light, optical microscopy. OP can address questions such as:

(i) What was the primary biological matter contributing to the kerogen (e.g., algae, spores, woody matter, bacteria); organic facies or paleodepositional setting, and control on original kerogen type/petroleum potential?

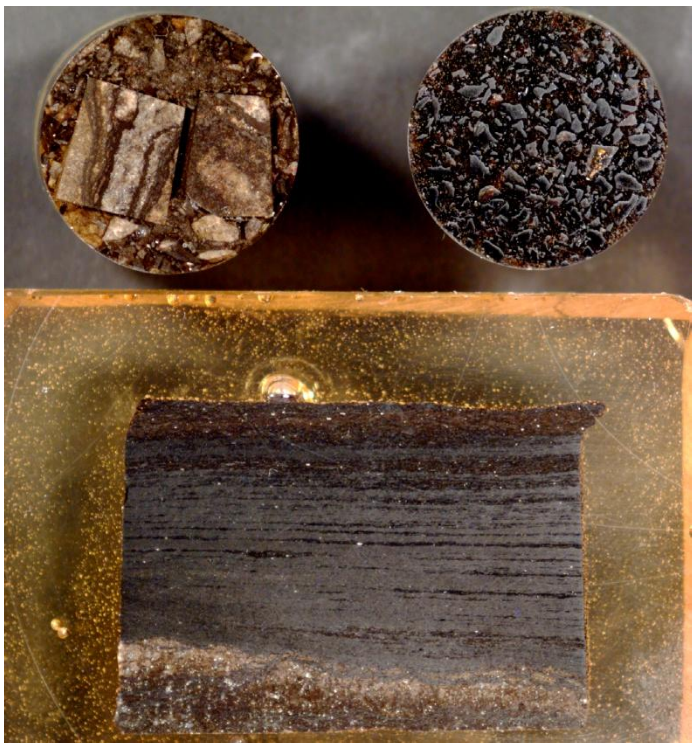
(ii) What are the secondary products in the Organic Matter asemblage (oils, bitumens , solid hydrocarbons, pyrobitumens)

(iii) What is the level of thermal maturity of the kerogen and secondary products (e.g., solid bitumens, oil inclusions), immature-, early oil-, light liquids-, condensate-, dry gas-windows

# 1.0 SAMPLE PREPARATION & INSTRUMENTATION

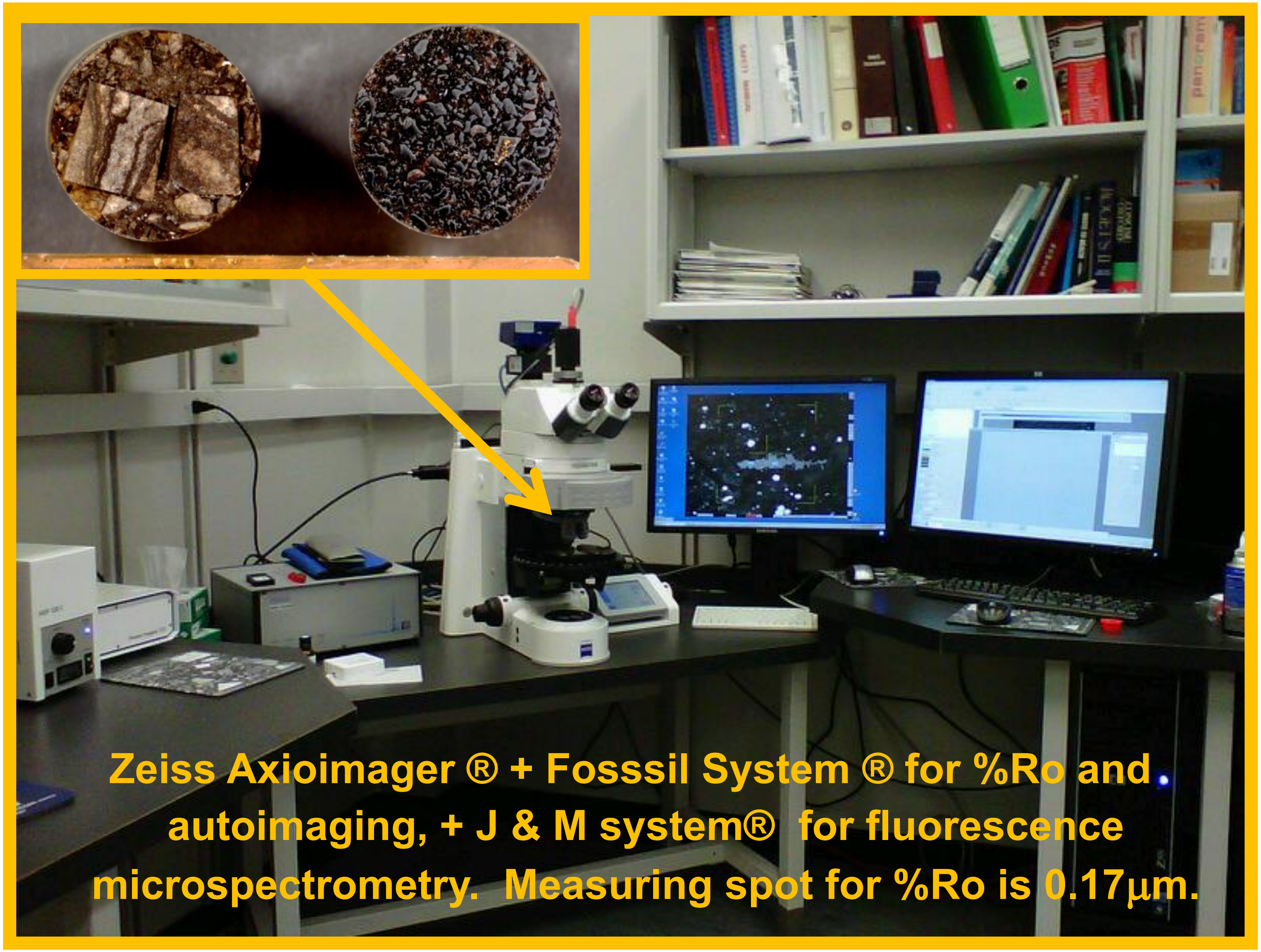
**Sample preparation for microscopy:**

**Reflected light white and fluorescent light microscopy:**

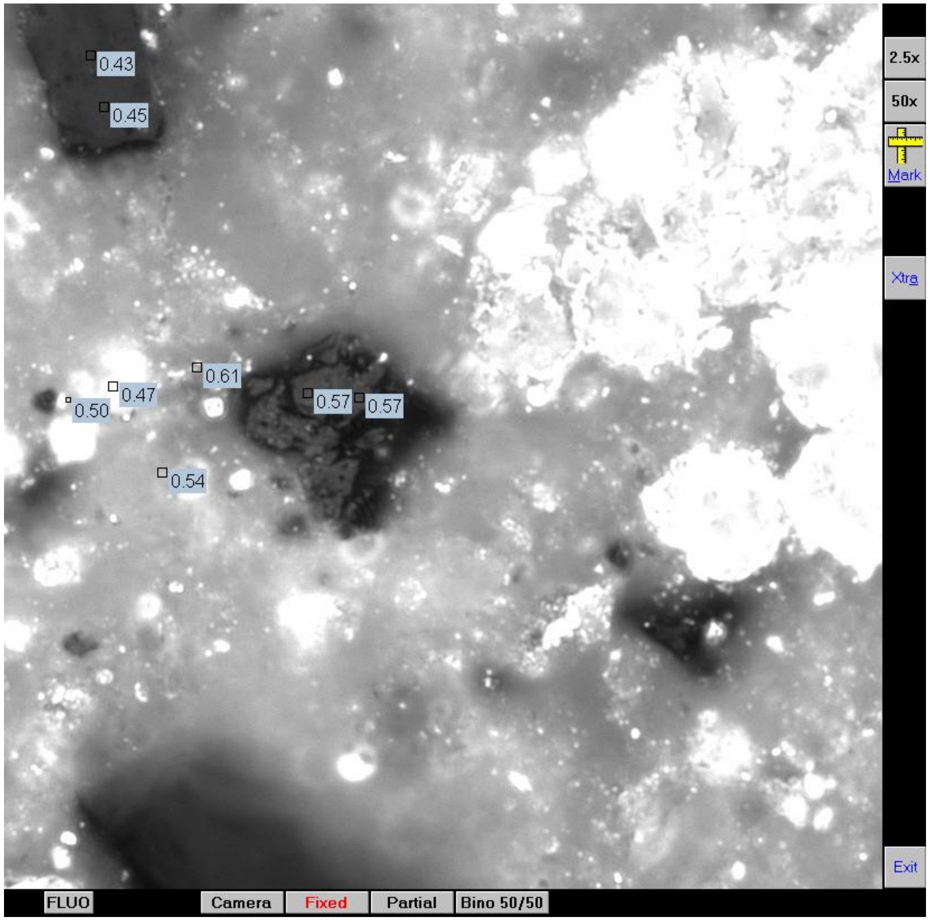


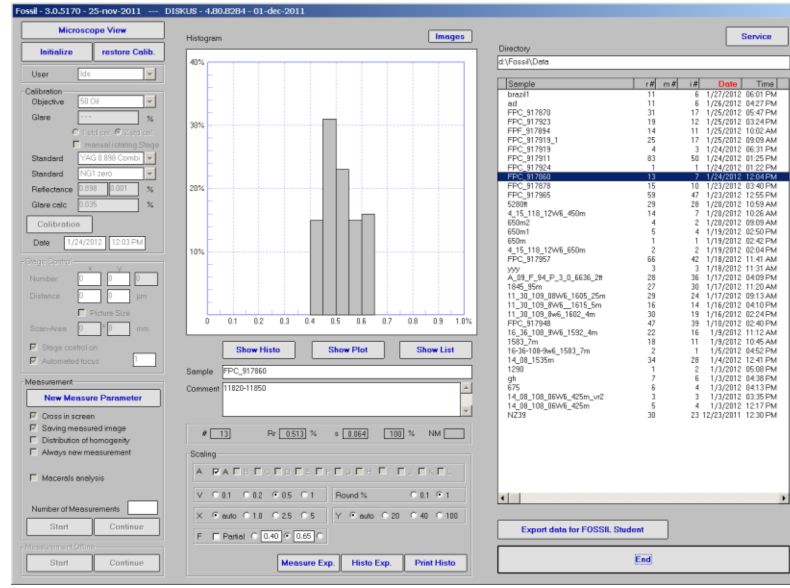

January 2012

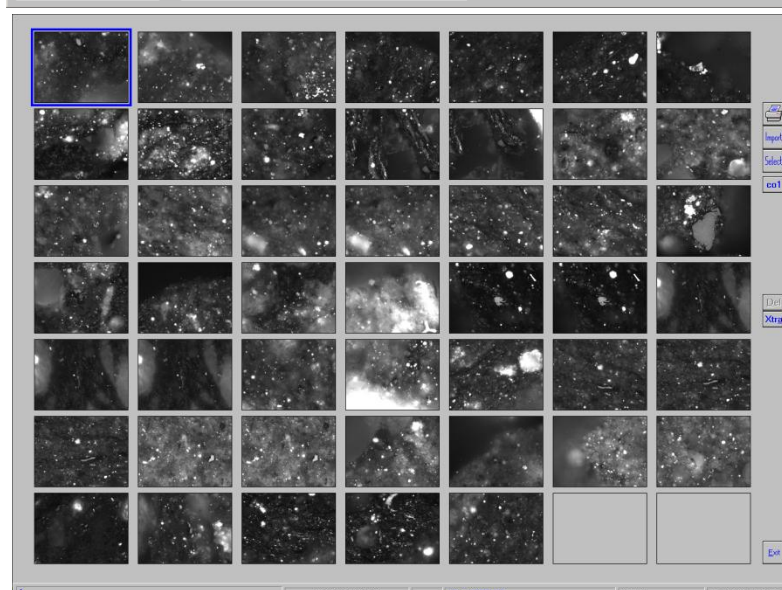
# 1.0 OPTICAL MICROSCOPY: REFLECTED WHITE & FLUORESCENT LIGHT



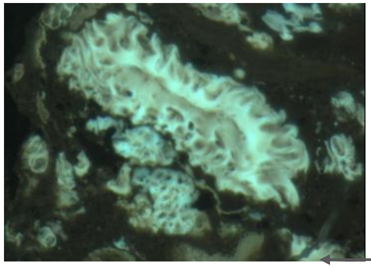
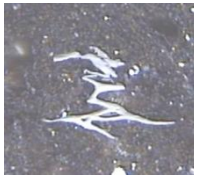
# 1.0 VITRINITE %RO: ZEISS ® AND FOSSIL SYSTEM ® EXPANDED CAPABILITIES FOR %RO MEASUREMENTS FOR THERMAL MATURITY ASSESSMENT; DIAMETER 0.17UM X 0.17 UM, WITH A RECORD OF ALL MEASUREMENTS



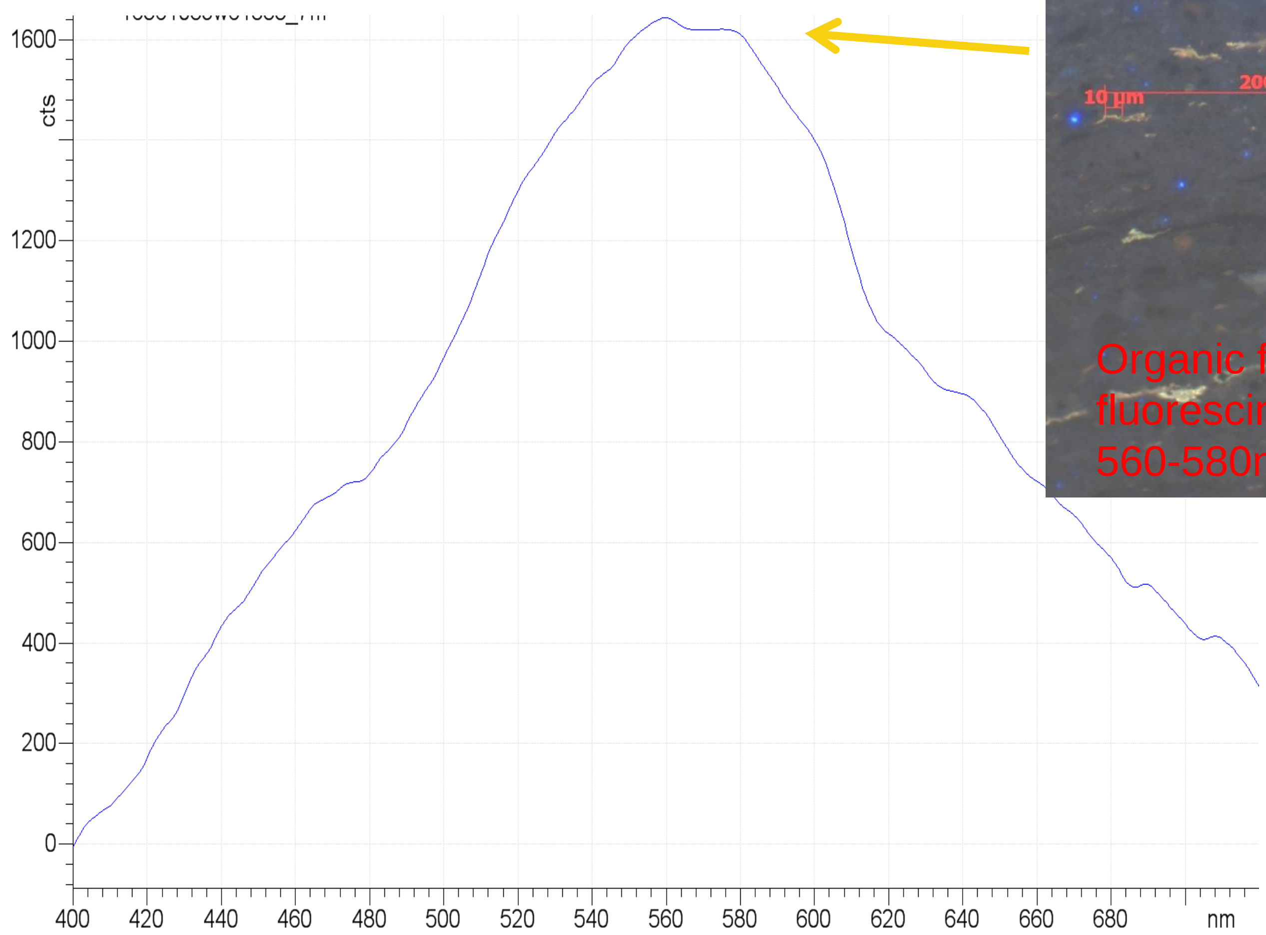



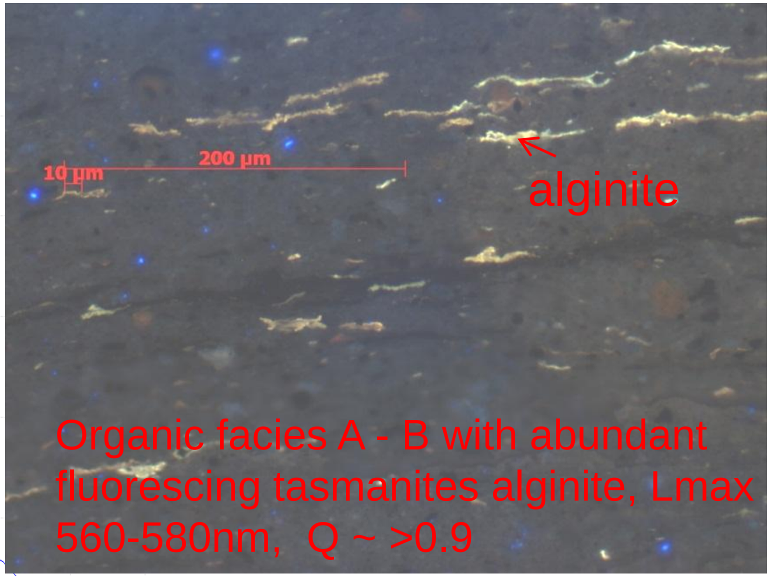



# 1.0 Organic Matter Classification using optical Microscopy

| Maceral Group | Maceral examples | Precursor biological matter |
|---|---|---|
| **Vitrinite**  | telovitrinite | **cell walls of wood (and other lignin etc.) Derivatives** |
| **Liptinite/Exinite**   | Sporinite | **terrestrial plant spores, pollen** |
| | resinite<br>cutinite | **higher and lower waxy plant leaves, cuticles,** |
| | Chlorophyllinite<br>Resinite | **chlorophyll**<br>**plant resins** |
| | Alginites,<br>Dinoflagellates,<br>Acritarchs | marine and freshwater algae, benthic or planktonic |
| **Inertinite**  | fusinite<br>semi-fusinite | **wood-derived charcoal; oxidized organic matter floral faunal-bacterial,** |

# 1.0 METHODOLOGY: J AND M VIS MICROFLUORESCENCE SPECTRA FOR PRASINOPHYTE ALGINITE IN MUSKWA FM, ~ > 0.70 - < 0.80 V%RO EQUIV.

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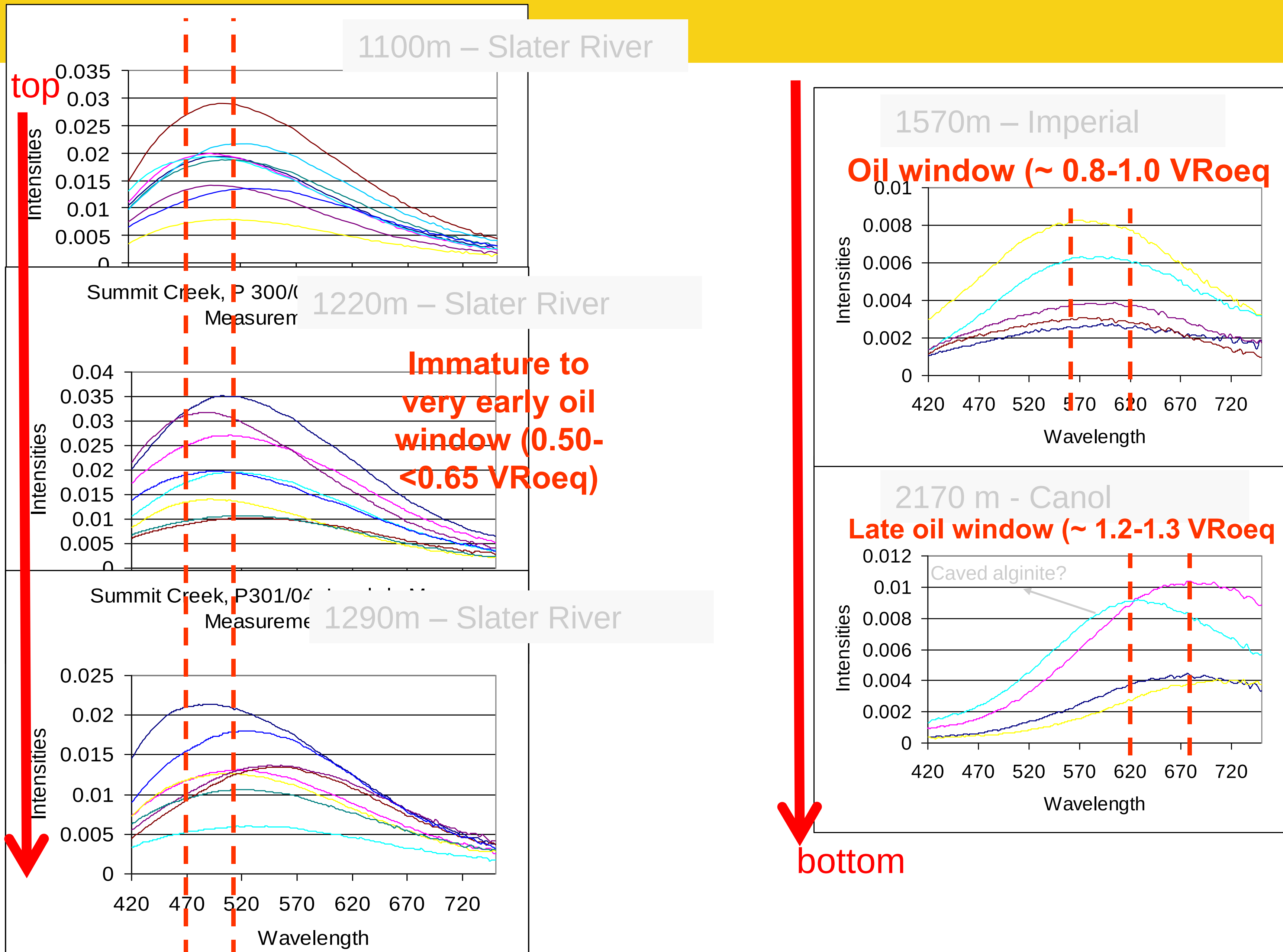
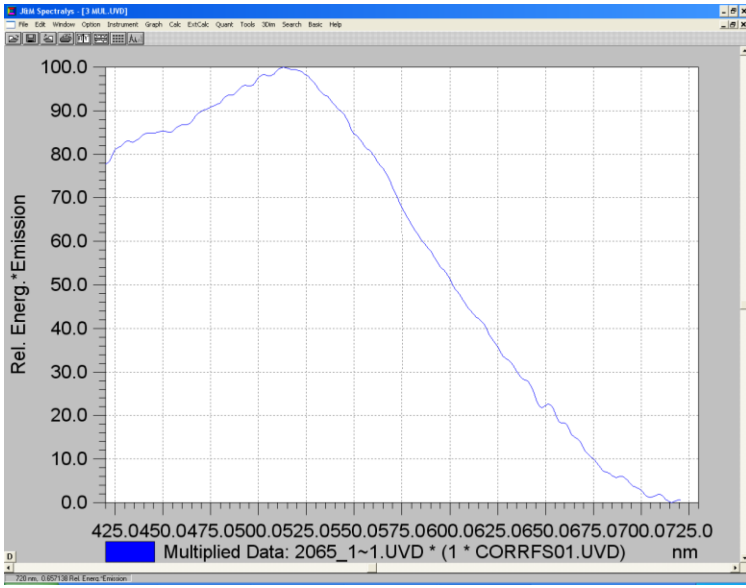
# VIS FLUORESCENCE OF *TASMANITES* SHOWING RED SHIFT WITH INCREASING DEPTH V%RO FROM CRETACEOUS TO DEVONIAN , MATURATION SERIES AT B-45,



# 1.0 VIS flourescence microspectrometry of petroleum inclusions and API gravity.



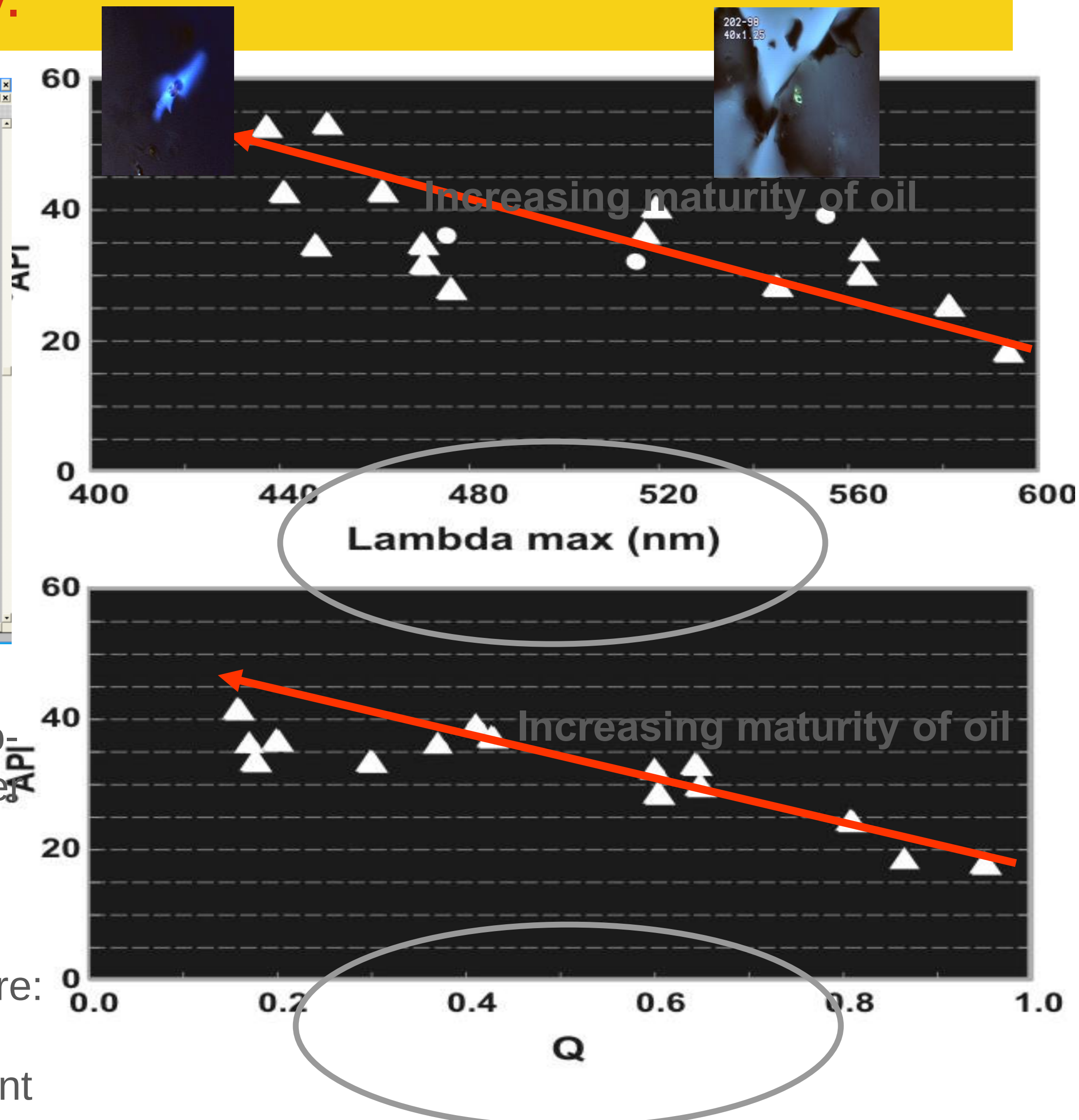
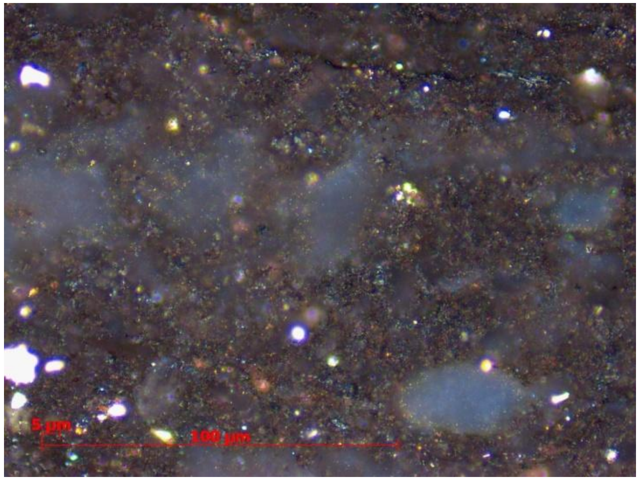



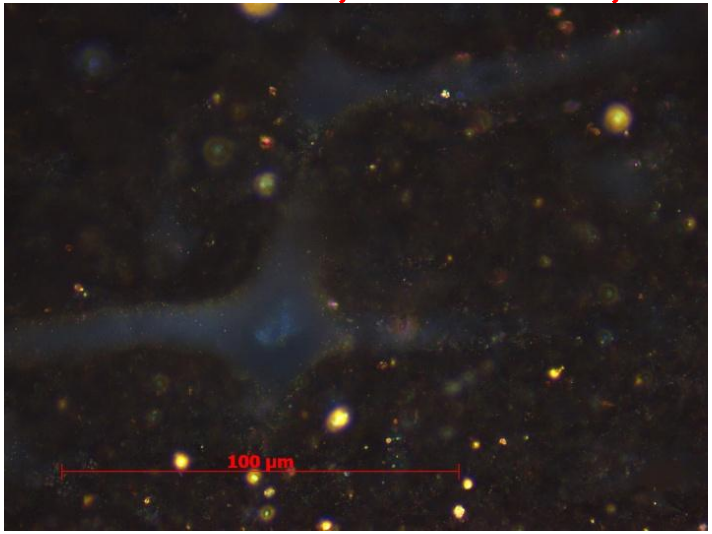

Figure 2. Relationship between gravity of crude oil (API) and fluorescence parameters, Lmax and Q (from Stasiuk and Snowdon, 1997).

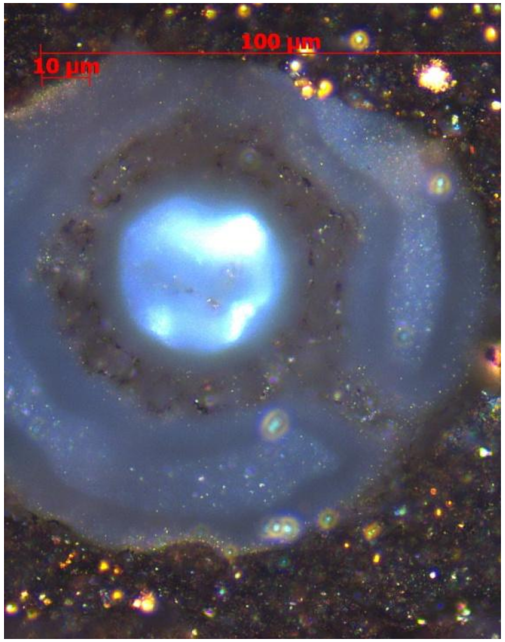
Crude oils: Application of fluorescence microscopy and VIS fluorescence micro-spectrometry to the study of oil character (e.g., API estimate) migration using petroleum inclusions

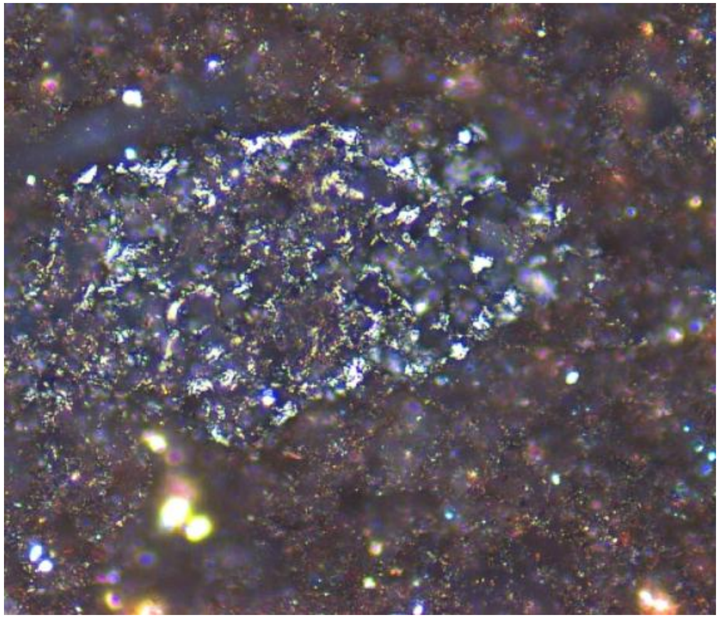
Fluorescence colors (parameters used are: Lambda maximum = Wavelength of maximum emission and Q = Int650 nm/Int 500nm)

# 1.0 METHODOLOGY: REFLECTED WHITE LIGHT MICROSCOPY OF POLISHED WHOLE ROCK PARALLEL TO BEDDING VIEW, BIOGENIC SILICA, ORGANIC FACIES D, UPPER DEVONIAN, MUSKWA, V%R 1.0



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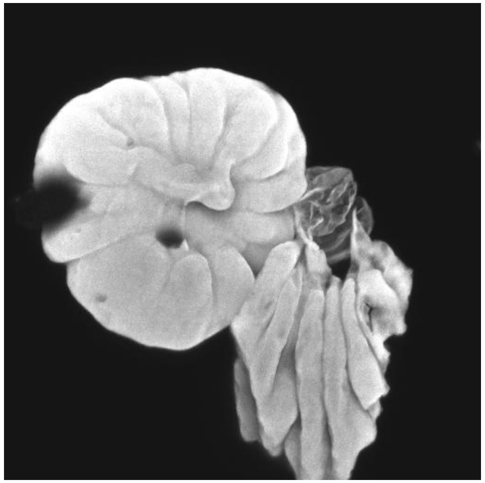
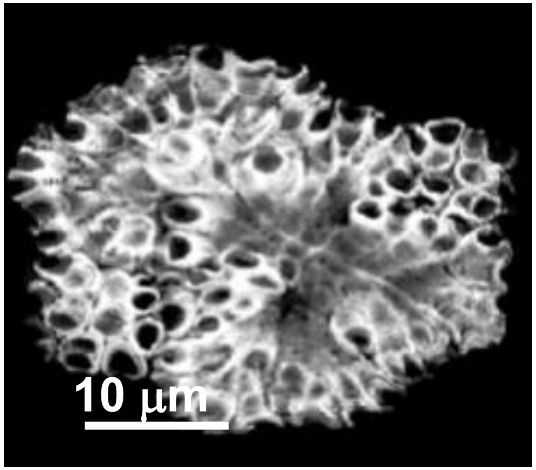
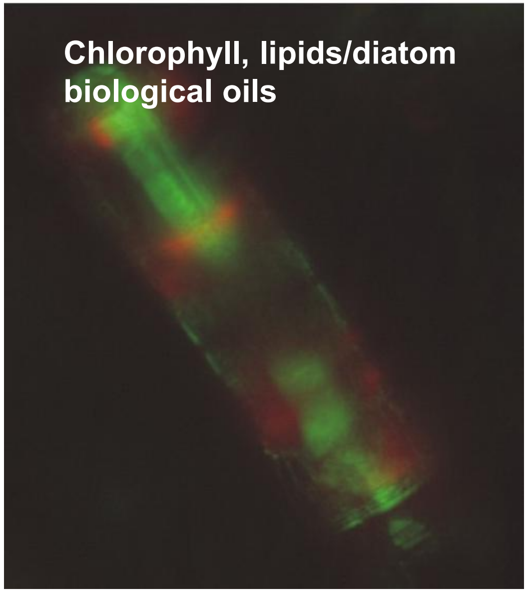
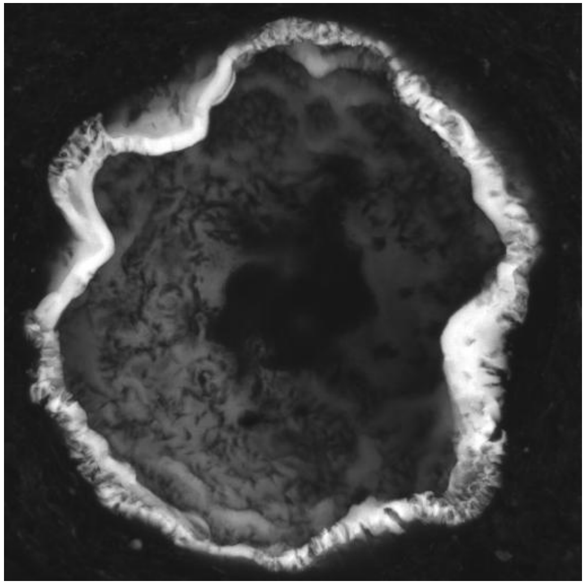
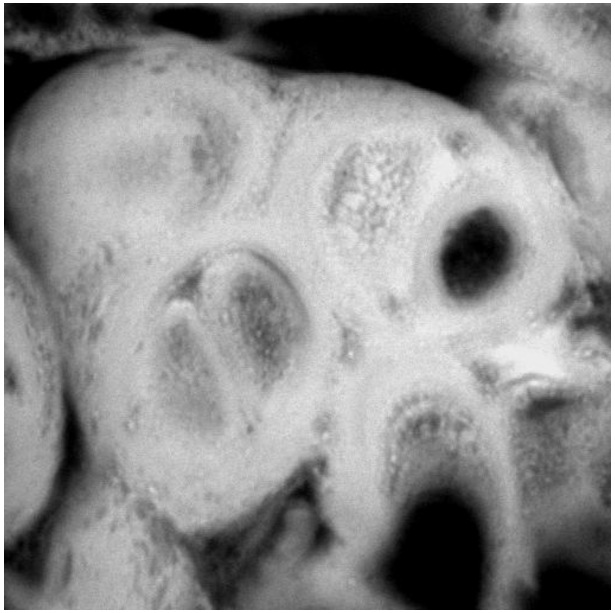
# 1.0 METHODOLOGY : CONFOCAL LASER SCANNING FLUORESCENCE MICROSCOPY



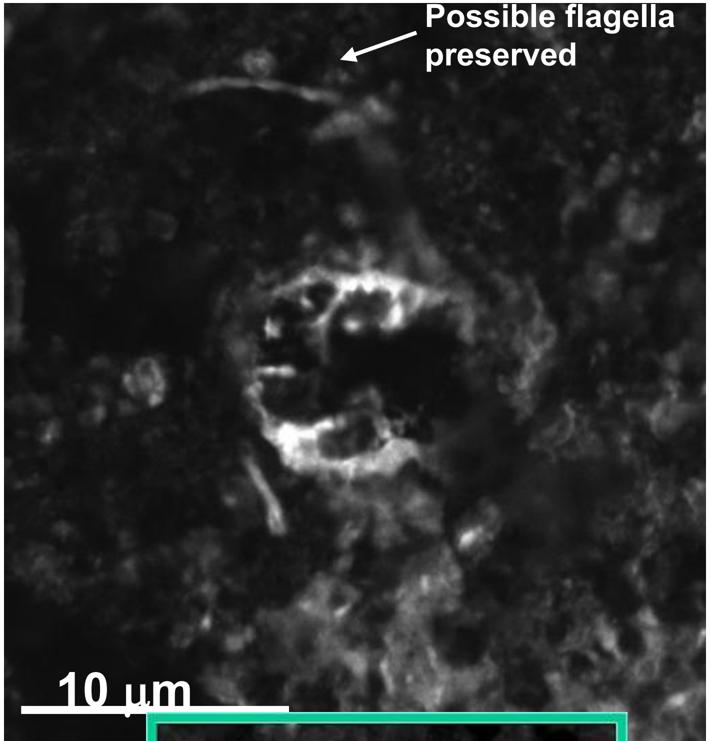


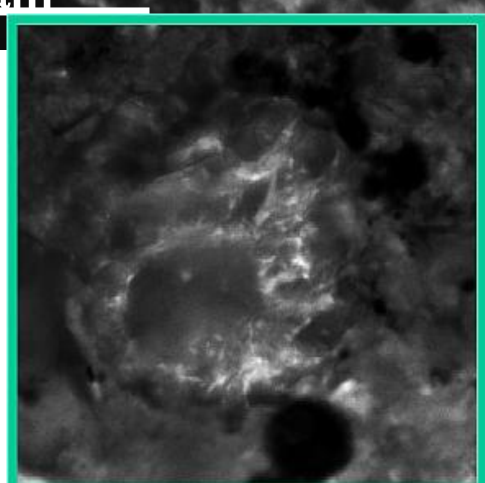



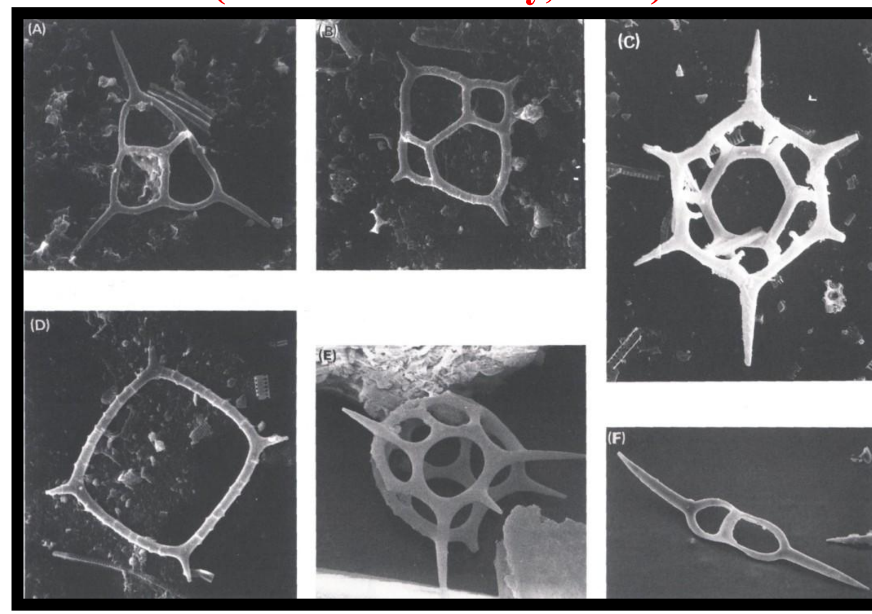


# 1.0 METHODOLOGY: CONFOCAL LASER SCANNING FLUORESCENCE MICROSCOPY, PROTEROZOIC BIOGENIC SILICA PROBABLY RADIOLARIA-SILICOFLAGELLATE SKELETONS: INFRA-CAMBRIAN,~ 650 MA



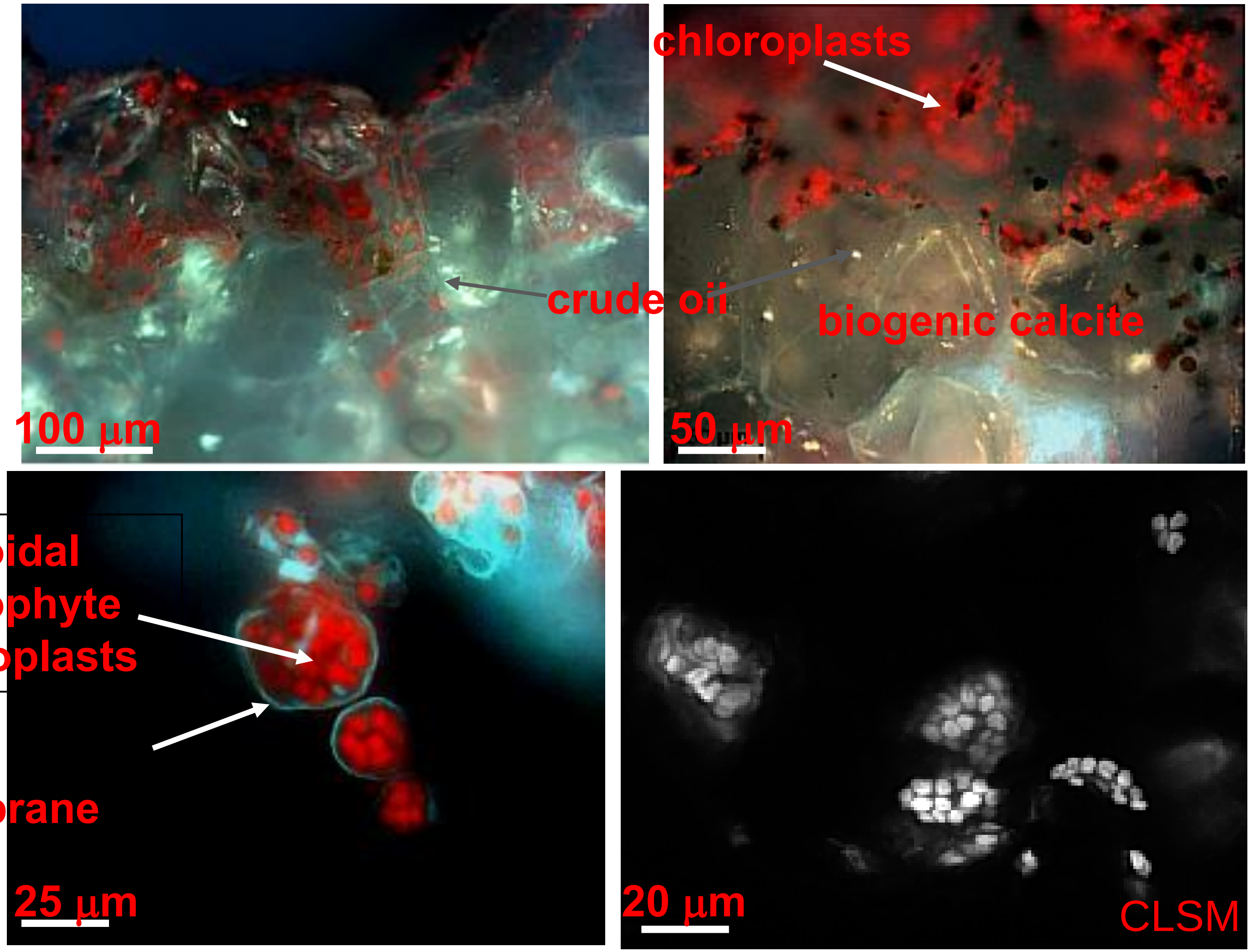



**SEM images of Recent silicoflagellates (From McCartney, 1993)**




- Age range in literature : 'first appear in Early Cretaceous'

# Outcrop cyanobacterial 'mat' from desert in 4 corners area, SW USA– related to oil seep at surface (Recent and ancient organic matter)



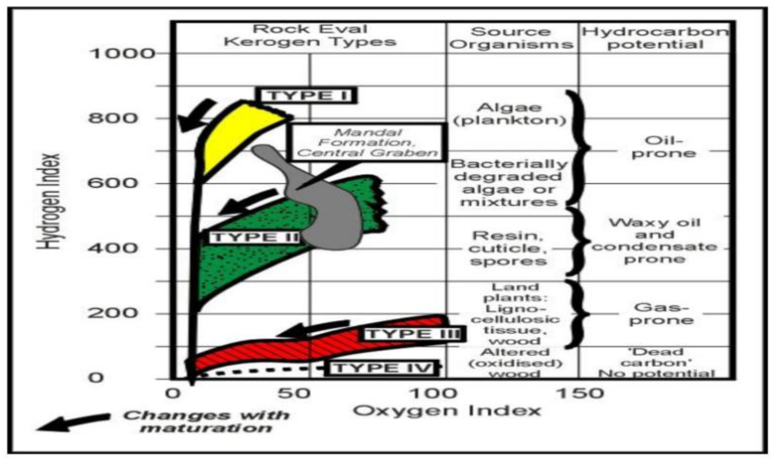
# 2.0

## Optical Microscopic Classification of Organic Matter

# 2.0 TSOP and ICCP Classification of Dispersed Organic Matter (macerals) in sedimentary rocks and isolated organic matter[1]

| MACERAL GROUP | MACERAL[3] |
|---|---|
| **Vitrinite** | Telinite |
| (Type III kerogen) | Collotelinite |
| | Vitrodetrinite |
| | Collodetrinite |
| | Gelinite |
| | Corpogelinite |
| **Liptinite** | Alginite |
| (Type I to II kerogen) | Bituminite (Amorphinite)[4] |
| | Liptodetrinite |
| | Sporinite |
| | Cutinite |
| | Suberinite |
| | Resinite |
| | Chlorophyllinite |
| **Inertinite** | Fusinite |
| (Type IV kerogen) | Semifusinite |
| | Funginite |
| | Secretinite |
| | Macrinite |
| | Micrinite |
| | Inertodetrinite |

| MACERAL GROUP | MACERAL[3] |
|---|---|
| **Zooclasts** | Scolecodont |
| (Type III to II kerogen) | Graptolite |
| | Chitinozoa |
| | Foram lining |
| **Secondary Products** | (Migra)bitumen |
| | Oil |
| | Pyrobitumen |




Presenter's notes: Footnotes—1. Outcrop, core, side-wall core, well cuttings samples at moderate thermal maturity (within the oil window 0.5 to 1.3% Ro); 2. Sample processed with HCl and HF acids. 3. Using transmitted light and kerogen concentrates, it may not be possible to subdivide the vitrinite group into macerals; therefore vitrinite must be used. This may also apply to macerals within the inertinite group. 4. Bituminite is a defined ICCP maceral term, variety amorphinite is more commonly applied to this type of DOM and and can be further expanded upon using the following recommendations: (i) fluorescing (fluoramorphinite) and non-fluorescing (hebamorphinite) amorphinite (Sentfle et al., 1987) or (ii) Types A, B, C, D (Thompson and Dembicki, 1986). May 22/02

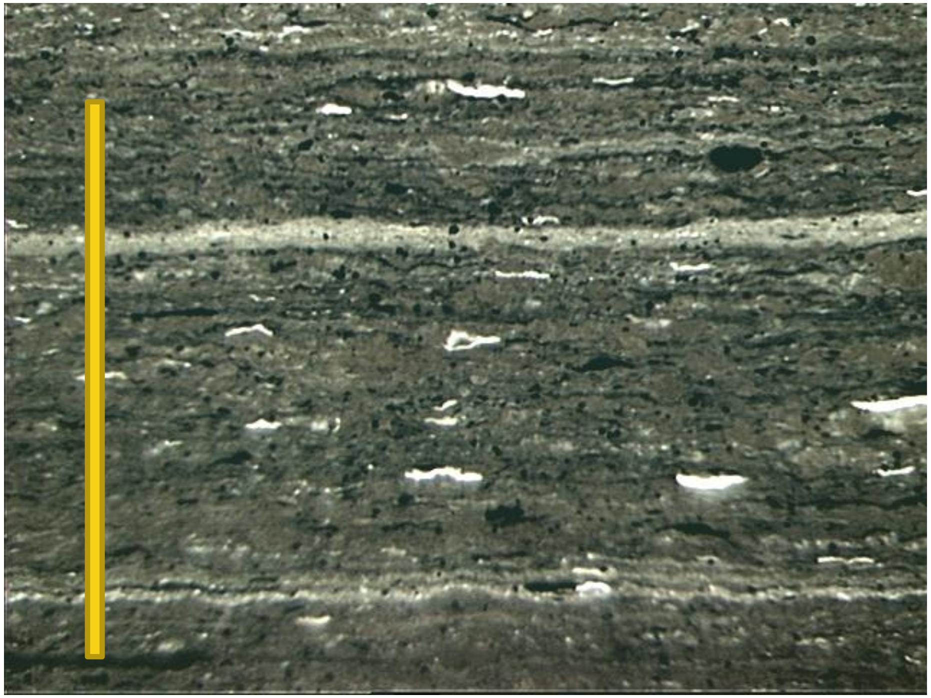
# 2.0 CLASSIFICATION EXPANSION OF ALGINITE MACERAL FOR ORGANIC FACIES

| Maceral Group | Maceral | Maceral type | Maceral Variety | Maceral Sub-variety |
|---|---|---|---|---|
| Liptinite | Alginite | Telalginite | Botryococcus | Tenui-Botryococcus; Large diameter/length colonies, Usually >50 micron, cell walls are highly thickened |
| | | | | Crassi-Botryococcus; Small diameter/length colonies, Usually 5 - < 50 microns, cell walls are thins, |
| | | | Tasmanites | Large diameter/length, usually > 75 microns, thick walled, cyst - like |
| | | | | Small diameter/length thin usually 5 microns - < 50 microns |
| | | | Leiosphaeridia | Large diameter/length, usually > 75 microns, thick walled, cyst - like |
| | | | | Small diameter/length thin usually 5 microns - < 50 microns |
| | | | Pila | |
| | | | Reinschia | |
| | | | Gloeocapsa | Large diameter/length colonies, Usually >50 micron, cell walls are highly thickened; forms stromatolites/ algal mats |
| | | | | Small diameter/length colonies, Usually 5 - < 50 microns, cell walls are thins, |
| | | | Pediastrum | |
| | | | Acritarchs | Acanthomorphic-like |
| | | | | Veryachium -like |
| | | | | Michysridium - like |
| | | | Dinoflagellates | theca ; non resting cells |
| | | | | chorate cysts |
| | | Lamalginite | Filamentous | |

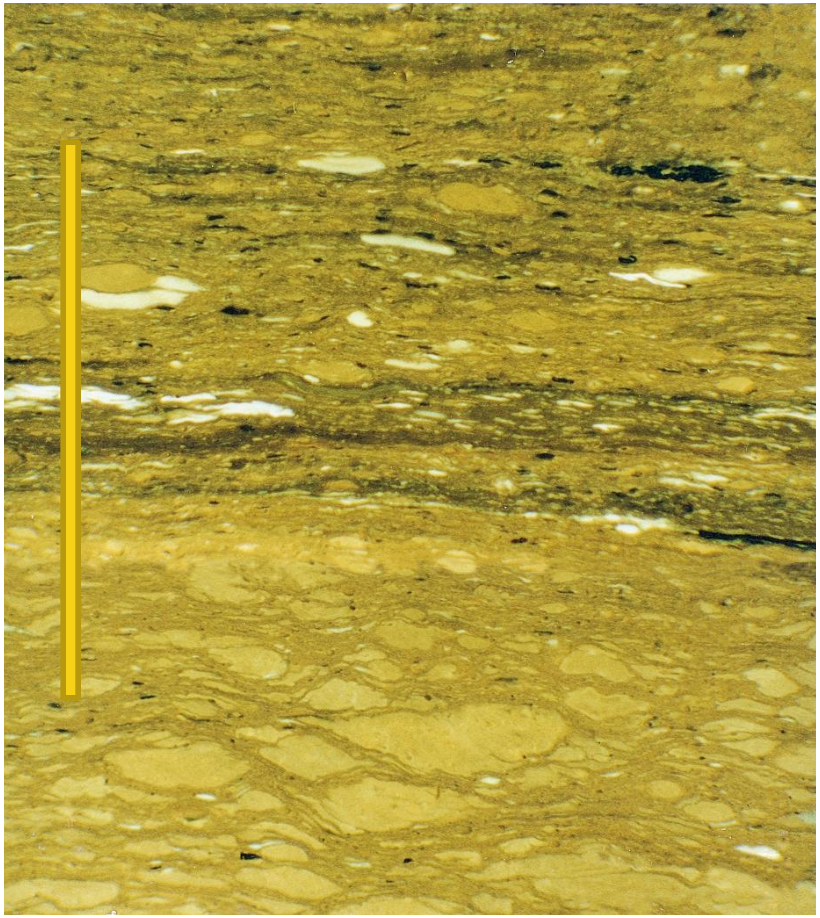
# 2.0 CLASSIFICATION EXPANSION OF MICROFOSSIL AND ZOOCLAST ‘MACERAL GROUP’ FOR ORGANIC FACIES INTERPRETATION

| Maceral Group | Maceral | Maceral type |
|---|---|---|
| **Non-organic Microfossils** | biogenic siliceous microfossils | radiolaria |
| | | Diatoms, silicoflagellates; chrysophytes |
| | | tentaculites |
| | Pyritized microfossils | algal filaments and cells |
| | | forams |
| | | wood |
| | phosphatic microfossils | conodonts |
| | | pellets |
| | | bone |
| | calcareous micro- and nanoplankton fossils | Coccoliths, calcareous nanoplankton, |
| | | microforams |
| | | cricoconarids |
| **Zooclasts** | Graptolite | telagraptolite |
| | | collograptolite |
| | Chitinozoa | |
| | Scolecodont | |

# 2.0 THE DISTRIBUTION OF ORGANIC MATTER TYPE, QUALITY, QUANTITY, AND INORGANIC MICROFOSSILS (E.G., BIOGENIC SILICA) CAN VARY SIGNIFICANTLY VERTICALLY AND LATERALLY IN LRS



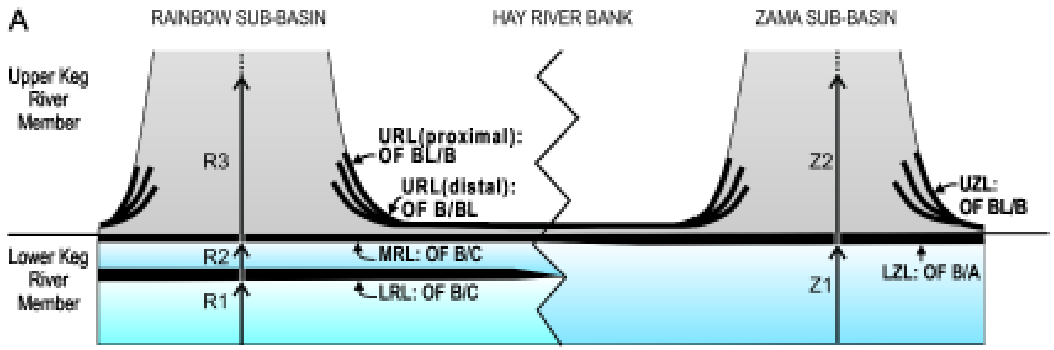
UV excitation, polished whole rock, perpendicular to bedding



Blue light excitation, polished whole rock, perpendicular to bedding

# 2.0 THE DISTRIBUTION OF ORGANIC MATTER TYPE, QUALITY, QUANTITY, AND INORGANIC MICROFOSSILS CAN VARY SIGNIFICANTLY VERTICALLY AND LATERALLY IN LRS

A



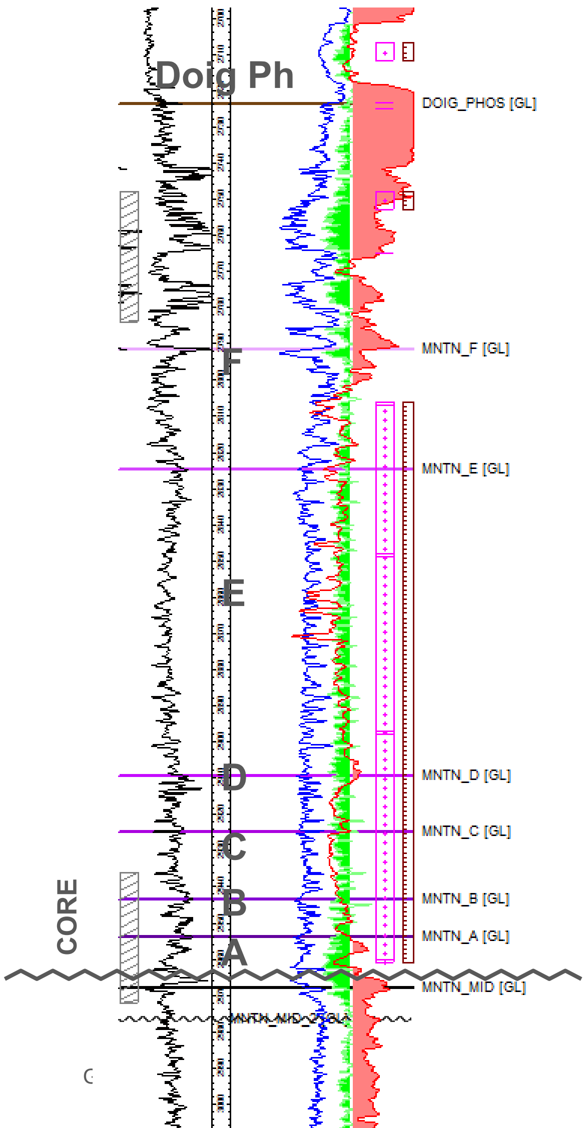

B

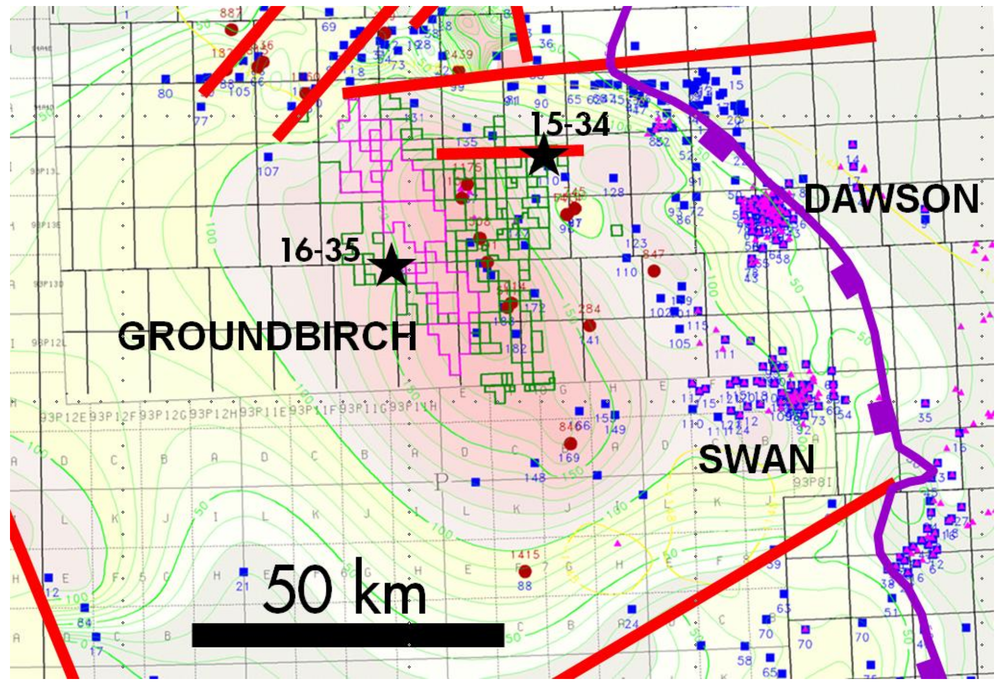
| Controls | Rainbow Sub-basin: Lower Laminite (LRL) | Middle Laminite (MRL) | Upper Laminite (URL) (Distal Foreslope) | Upper Laminite (URL) (Proximal Foreslope) | Zama Sub-basin: Lower Laminite (LZL) | Upper Laminite (UZL) |
|---|---|---|---|---|---|---|
| Preservation (anoxia) | Primary | Primary | Primary | Secondary | Primary | Secondary |
| Productivity | --- | --- | Secondary | Primary | --- | Primary |
| Sedimentation rate | Minor | Minor | Minor | Clastic dilution | Minor | Clastic dilution |
| Supply of terrestrial organic matter | --- | --- | --- | --- | --- | --- |

Figure 11. A) Schematic diagram illustrating the proposed correlation between the Rainbow and Zama sub-basins. Decametre-scale cycles are labeled R1, R2 and R3 in the Rainbow Sub-basin, and Z1 and Z2 in the Zama Sub-basin. LRL = lower Rainbow laminite, MRL = middle Rainbow laminite, URL = upper Rainbow laminite, LZL = lower Zama laminite, UZL = upper Zama laminite. OF = organic facies. B) Summary of interpreted controls on organic matter accumulation and preservation in the Rainbow and Zama sub-basins. Refer to text for details.

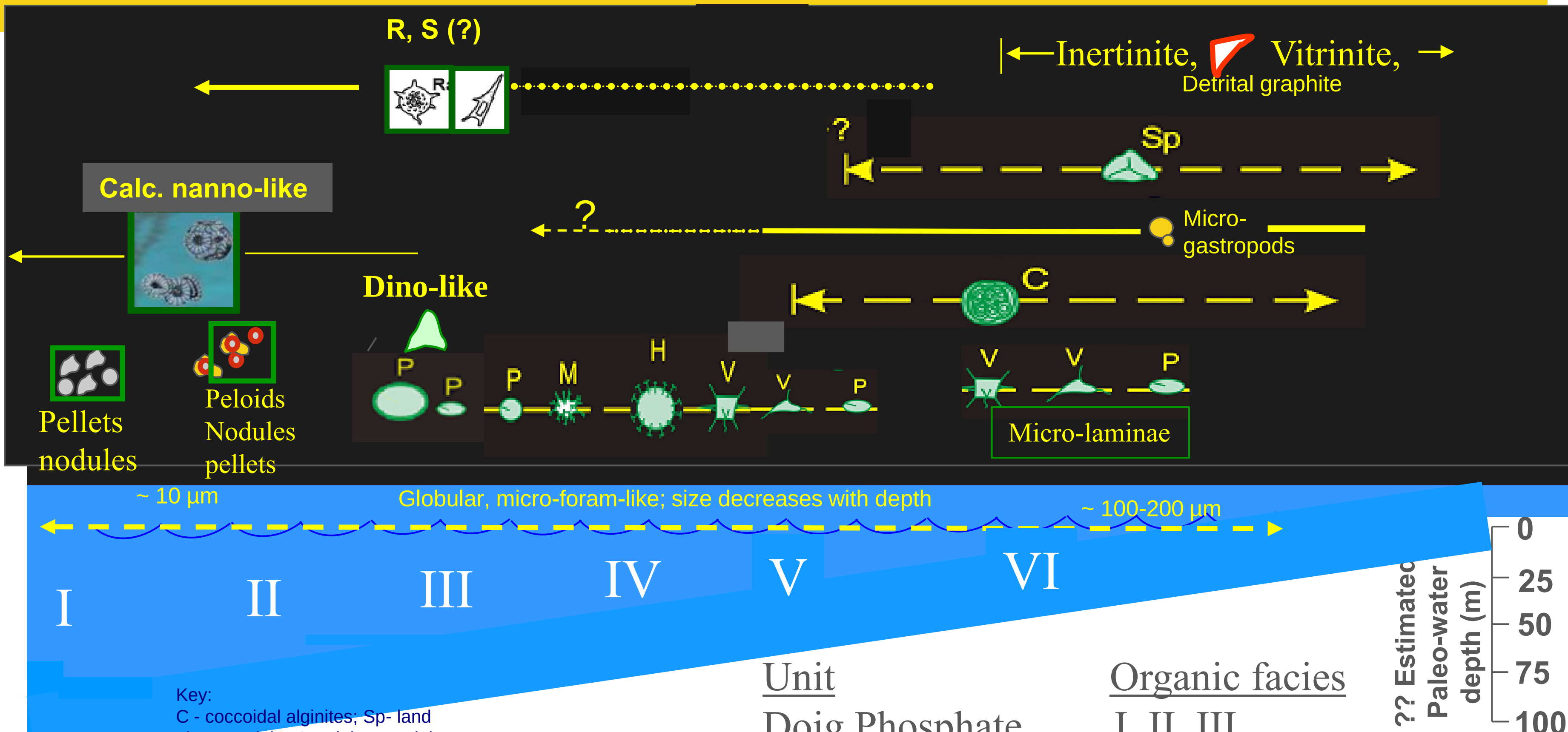
Wiebe et al., 2013

# 3.0 WCSB ORGANIC FACIES MODELS: UPPER TRIASSIC, DOIG & UPPER MONTNEY FMS; GROUNDBIRCH & SUNSET SHALE GAS ASSETS, CANADA



# 3.0 WCSB ORGANIC FACIES MODELS: UPPER TRIASSIC, DOIG & UPPER MONTNEY FMS; GROUNDBIRCH GAS & SUNSET LRS ASSETS, CANADA




Key:
C - coccoidal alginites; Sp- land plant sporinite; Inertinite – mainly herbaceous derived, some woody; Dino-like - dinoflagellate like
P - prasinophytes, unicellular alginites; M, V, H - Michystridium, Verachium, Hystricosphaeridium acritarchs; RS - radiolarian-like siliceous microfossils; Calcareous nannoplankton in biofacies I includes coccoliths.

| Unit | Organic facies |
|---|---|
| Doig Phosphate | I, II, III |
| U Montney E | II-III |
| U Montney D | IV |
| U Montney C | V-IV (outer IV) |
| U Montney B | V (inner IV) |
| U Montney A | VI (V) |

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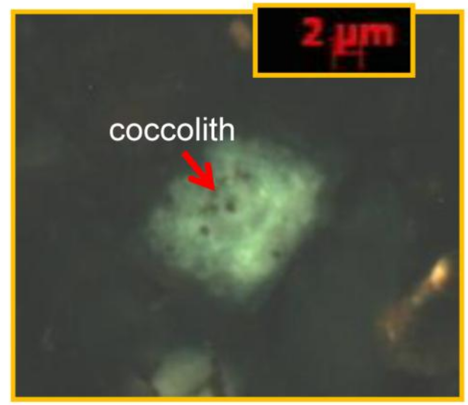
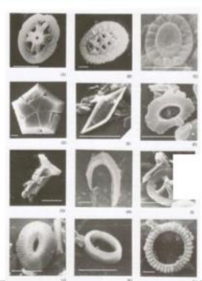
10’s to 100’s km

## 3.0 WCSB ORGANIC FACIES MODELS: UPPER TRIASSIC DOIG PHOSPHATE SUNSET LRS ASSETS, CANADA; SIGNIFICANT CALCAREOUS NANNO-PLANKTON, COCCOLITHS,






Blue light excitation, polished whole rock, oil immersion objectives



SEM calcareous nannoplankton (from Lipps, 1997)

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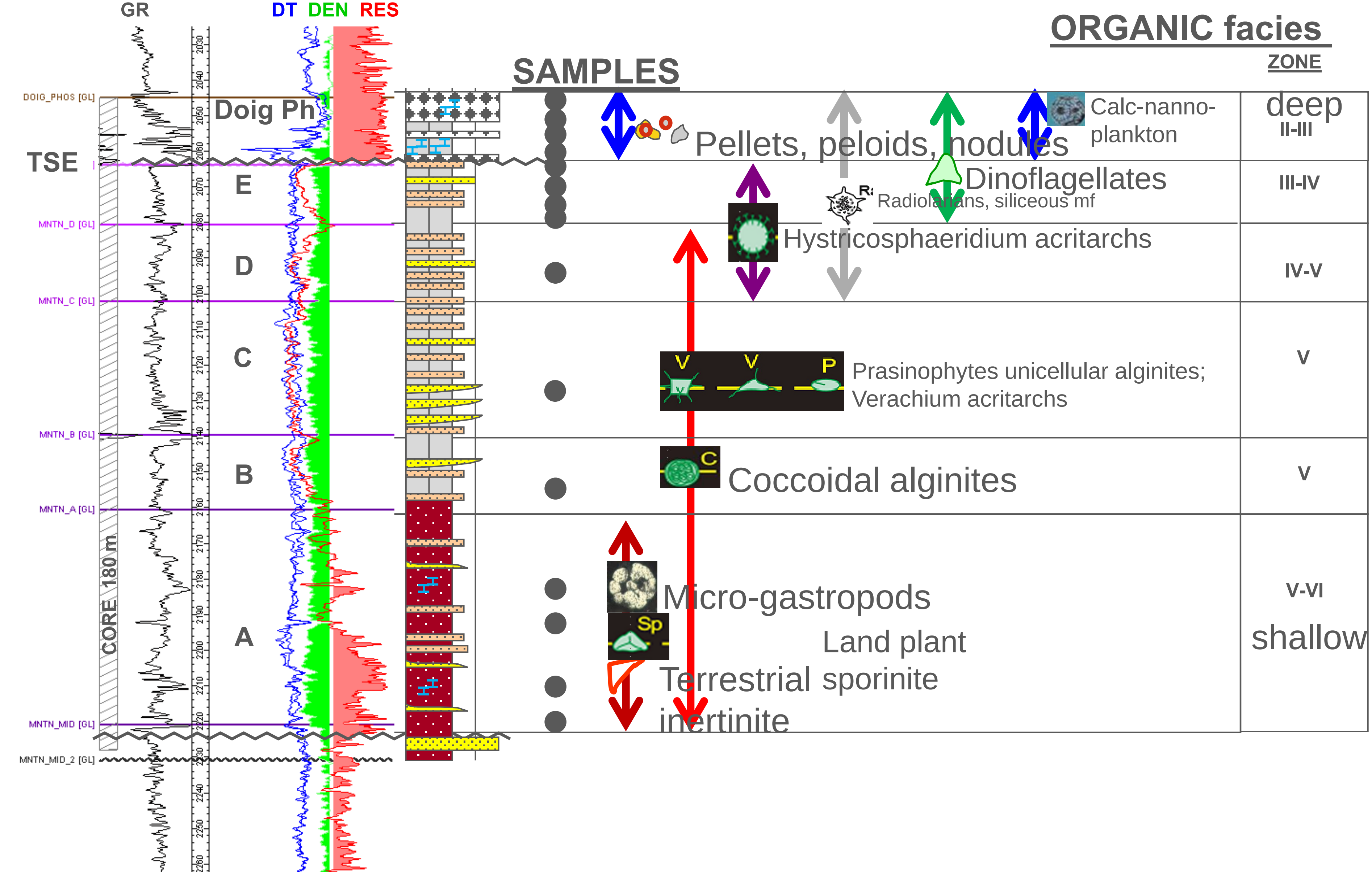
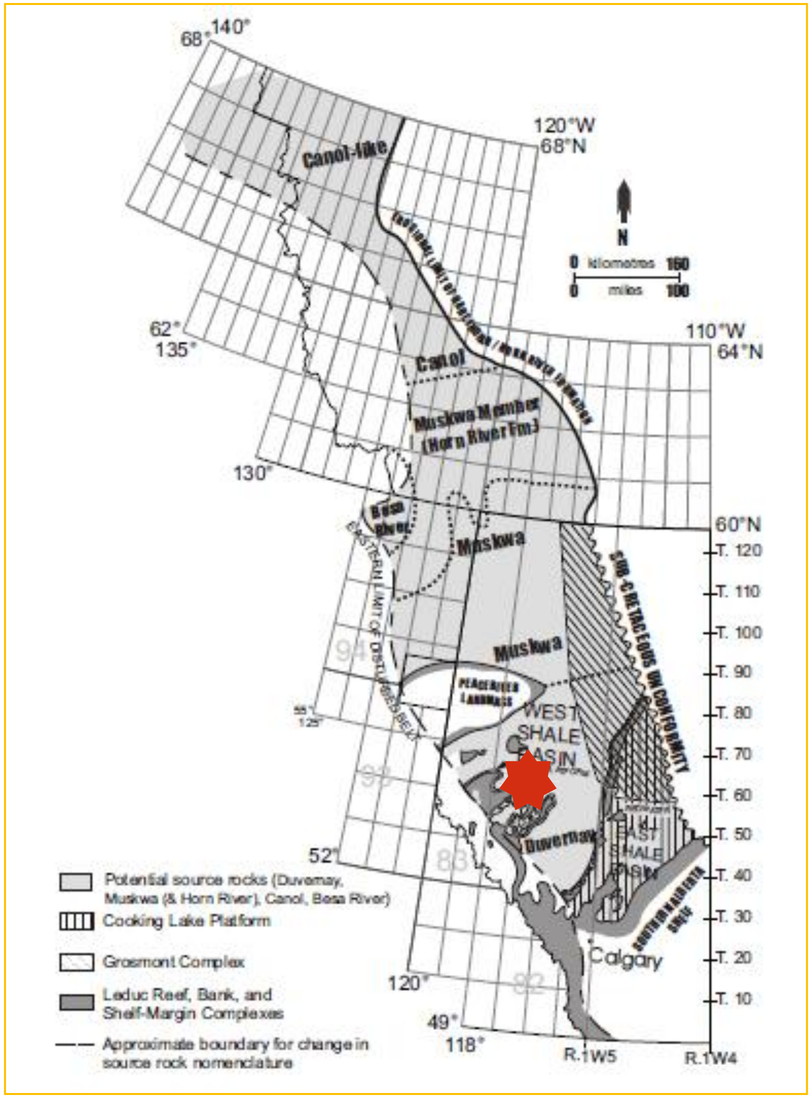
Presenter's notes: What are calcareous nannoplankton? The calcareous nannoplankton are unicellular photosynthetic protists, members of the group Haptophyta. They may take on many different shapes, but all have shells composed of tiny, calcium carbonate plates called "coccoliths." These tiny plankton are found mostly in tropical marine environments and are important primary producers. After the organisms die, their coccoliths accumulate on the bottom of the ocean, forming calcareous oozes that can harden into chalks and other fine-grained limestones. Fossils of calcareous nannoplankton have been found in limestones and chalks since the Jurassic.

# 3.0 WCSB ORGANIC FACIES MODELS : UPPER TRIASSIC DOIG AND UPPER MONTNEY, SUNSET LRS ASSETS, CORE 180 M



# 3.0 WCSB ORGANIC FACIES MODELS: UPPER DEVONIAN DUVERNAY FORMATION – LRS PLAY IN WCSB




SCAN Kaybob well, Fox Creek Play area

# 3.0 WCSB ORGANIC FACIES MODELS: UPPER DEVONIAN DUVERNAY FORMATION SHALES

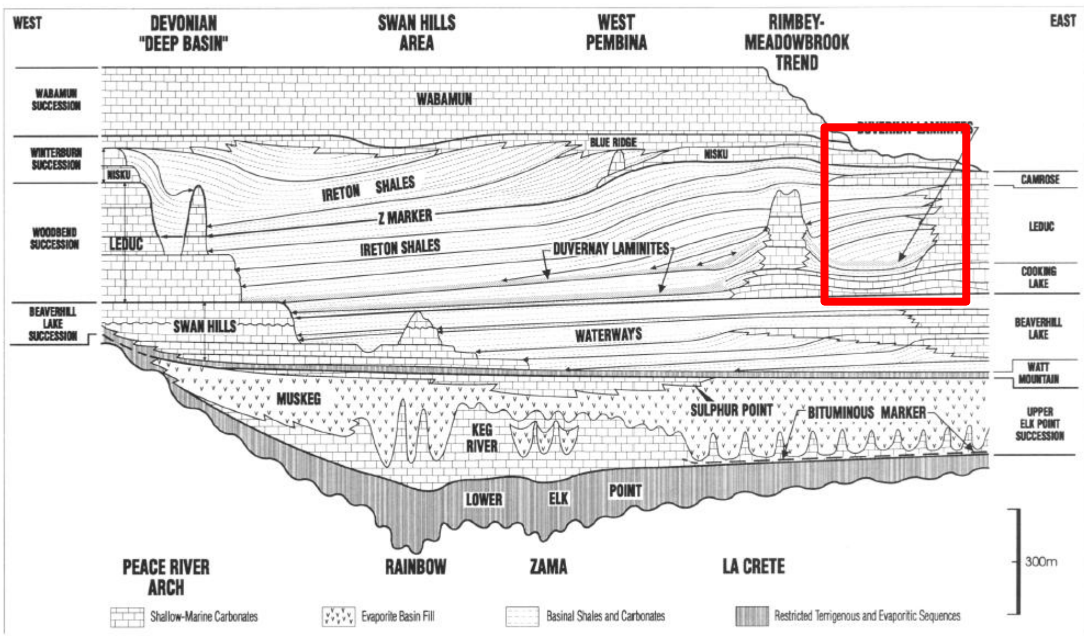



**Fig. 2.** Composite schematic cross-section across the Alberta Basin illustrating the cyclicity of Devonian successions and the distribution of major facies. The portion of the cross-section above the base of the Watt Mountain Formation is from central Alberta and corresponds to the geographic locations listed above the section. The lower portion of the cross-section, below the Watt Mountain Formation, is from northern Alberta and corresponds to the geographic locations listed below the sections. The bituminous marker is part of the Upper Elk Point succession and the Duvernay laminites are part of the Woodbend succession.

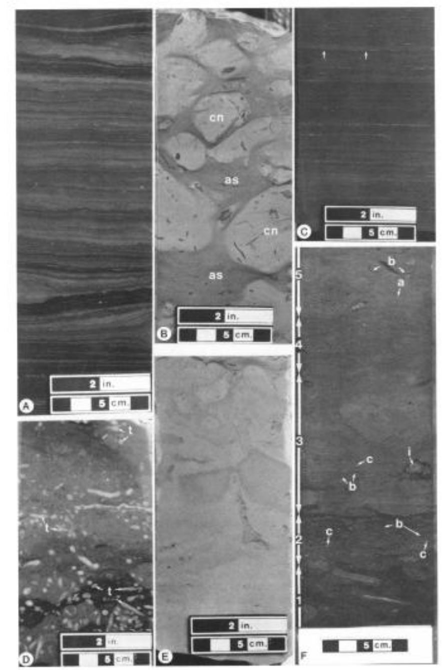


**Fig. 9.** Core photographs illustrating Lower and Middle Leduc reef and coeval Duvernay basin facies. (**A**) Basinal laminite with alternating dark organic and light sediment laminae and lenses. Sediment laminae consist of peloidal lime grainstones and packstones and have variable thicknesses, mainly ranging from less than 0.25 mm to 3.0 mm. Similar laminites have TOCs that range between 5.8 and 6.8%. Lower Leduc succession, 10-27-57-21W4, 1205.6 m. (**B**) Extensively bioturbated, irregular nodular lime mudstone with wispy argillaceous seams (as) between the more carbonate-rich nodules (n). Nodular lime mudstone like this sample have TOC less than 0.4%. ML1B subcycle, 10-27-57-21W4, 1168.2 m. (**C**) Nonbioturbated, organic-rich basinal laminite with alternating organic and sediment laminae. Sediment laminae are very thin (< 0.25 mm), in some places discontinuous, and consist of peloidal and skeletal packstones. A scour surface (arrows) with very minor relief underlies one sediment lamina. Laminites similar to this sample have TOC between 6 and 9%. ML3 cycle, 10-27-57-21W4, 1153.9 m. (**D**) *Thamnopora* coral (t) rudstone to floatstone with a peloidal packstone matrix. Dark-coloured organic and argillaceous matter occur as concentrations along horsetail stylolites. This branching coral limestone is part of an *in situ* deep-water reef succession, deposited in a foreslope setting. ML4 cycle, 5-36-56-21W4, 1082.0 m (3550 ft). (**E**) Peloidal lime grainstone deposited as part of a proximal foreslope sand apron. Colour variations reflect the degree of cementation. Dark areas are extensively cemented and have minor porosity, whereas lighter areas are less extensively cemented and have good interparticle porosity. ML4 cycle, 5-36-56-21W4, 1079.0 m (3540 ft). (**F**) Bioturbated skeletal-peloidal packstones containing fragmented crinoids (c), brachiopods (b), very small *Amphipora* (a) and cylindrical idiostromid stromatoporoids (i). This sample consists of five depositional units, described and numerically labelled in ascending order: (1) a lower organic-rich unit with some fossil fragments apparently derived by biological reworking from the overlying unit; (2) a moderately organic-rich and coarser skeletal-peloidal packstone; (3) an organic-lean skeletal-peloidal packstone; (4) a moderately organic-rich interval with some fossil fragments; and (5) an organic-lean and coarser skeletal-peloidal packstone. These skeletal-peloidal packstones are a distal foreslope sand accumulation. TOC of these deposits ranges from 0.5% to nearly 5.0% but most commonly is less than 2.0%. ML4 cycle, 10-27-57-21W4, 1149.4 m.

# 3.0 WCSB ORGANIC FACIES MODELS: UPPER DEVONIAN DUVERNAY FORMATION AT RIMBEY LEDUC REEFS

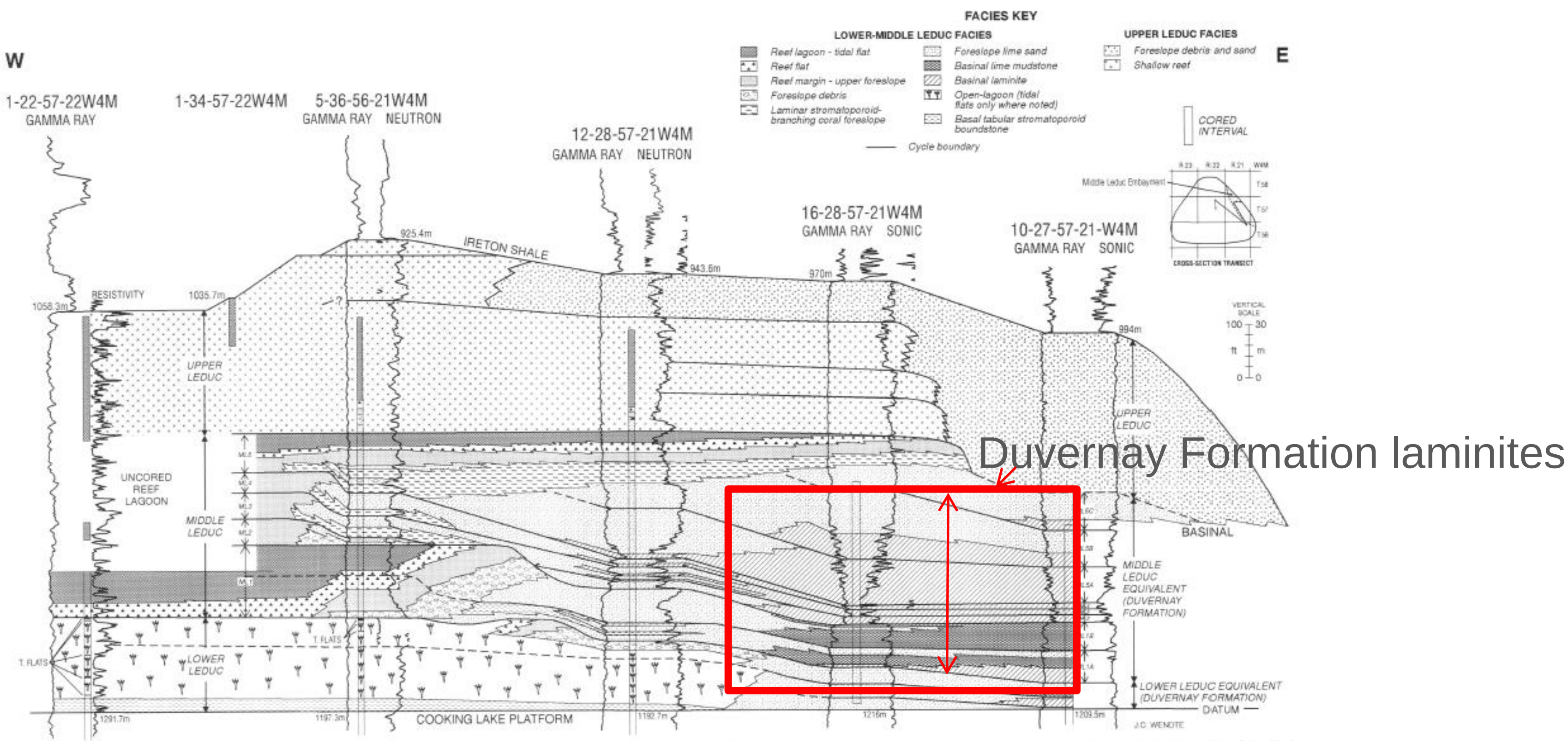
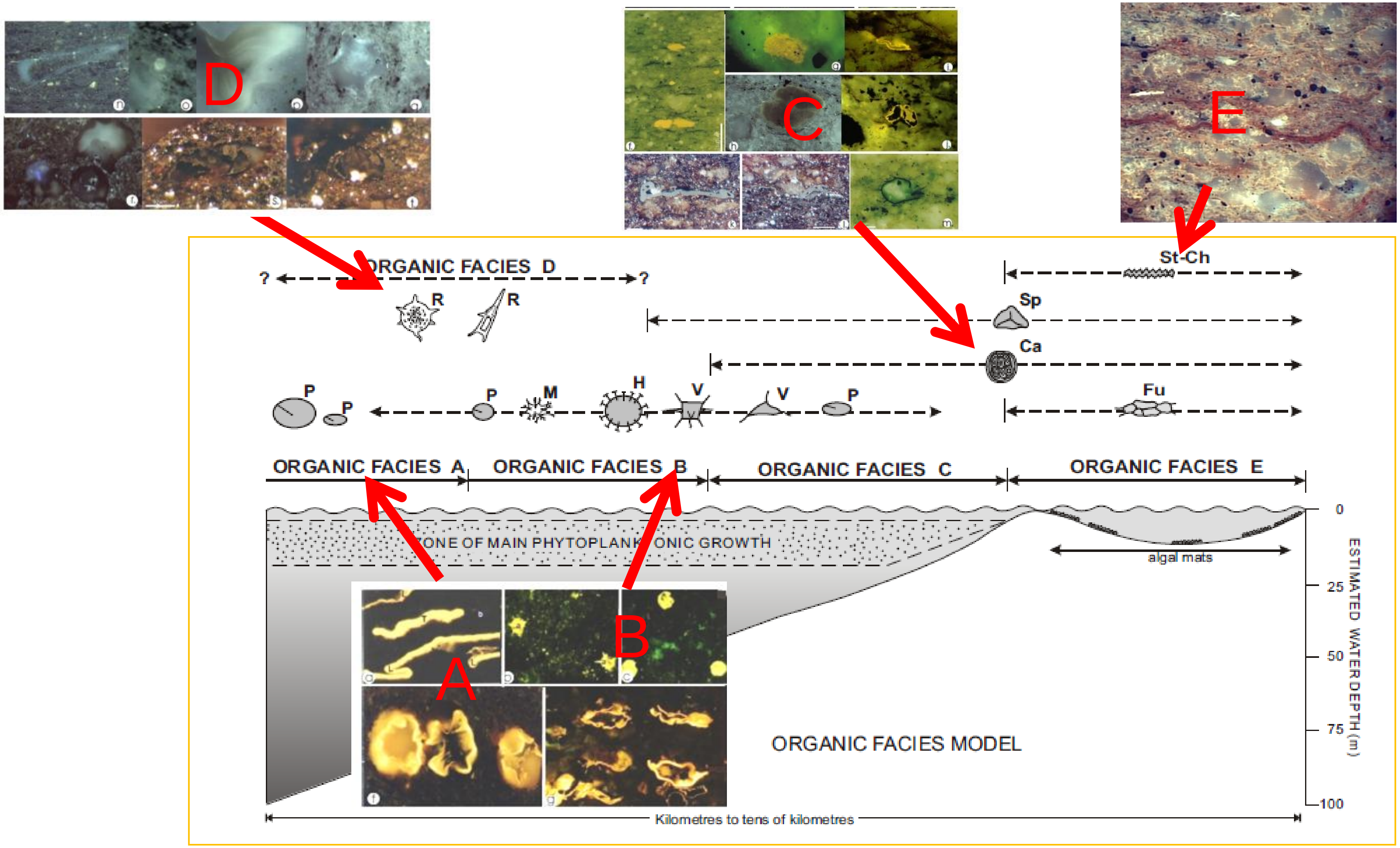
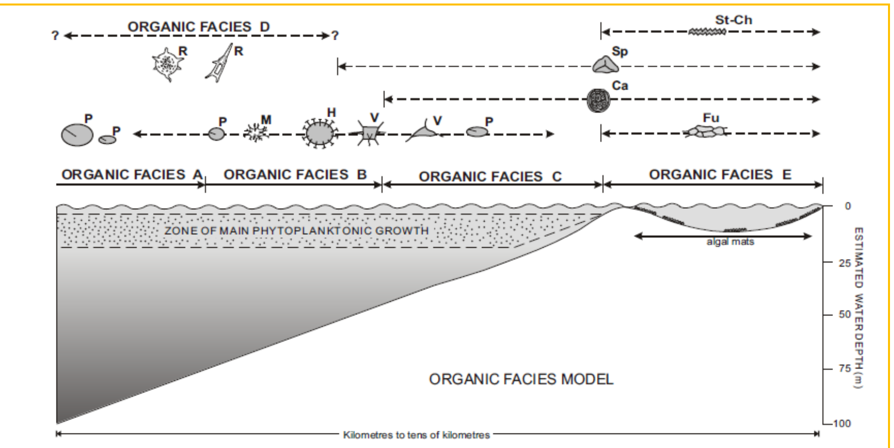



Fig. 7. Stratigraphic cross-section along the northeastern margin of the Redwater Leduc reef complex showing the correlation of depositional cycles and the general distribution of depositional facies. A more detailed distribution of facies from the 10-27-57-21W4 well is illustrated in Figure 10.

# 3.0 WCSB Organic Facies Model for Devonian shales, based on macerals and siliceous microfossil assemblage



# 3.0 WCSB ORGANIC FACIES: UPPER DEVONIAN DUVERNAY FORMATION – LRS; VERTICAL VARIATION IN ORGANIC FACIES AT RIMBEY LEDUC REEFS




OF and TOC's are related to fore-stepping and back-stepping of reef, water depth

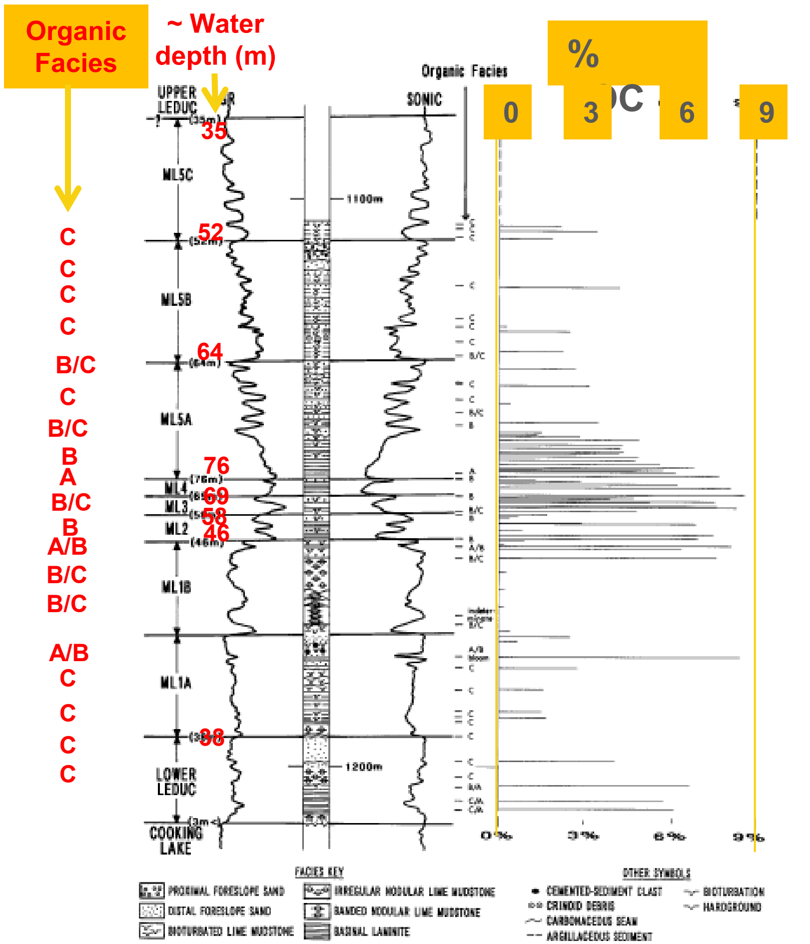
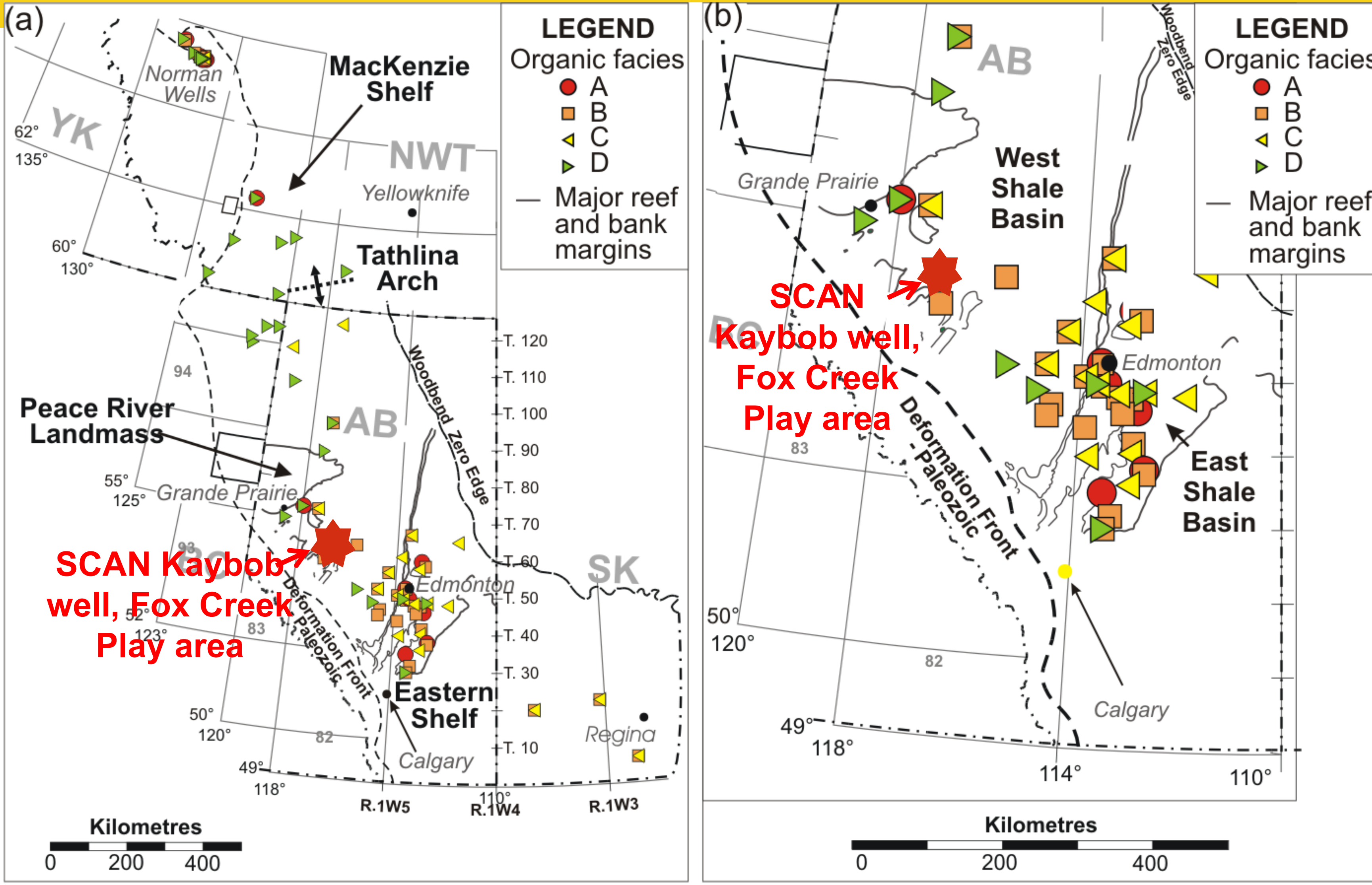
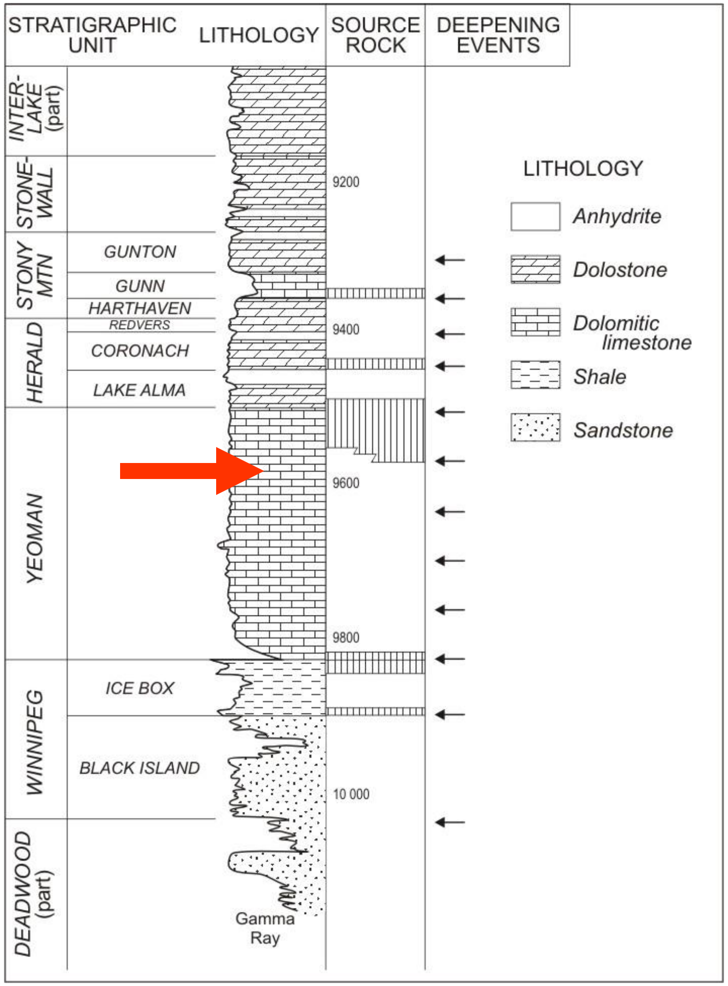


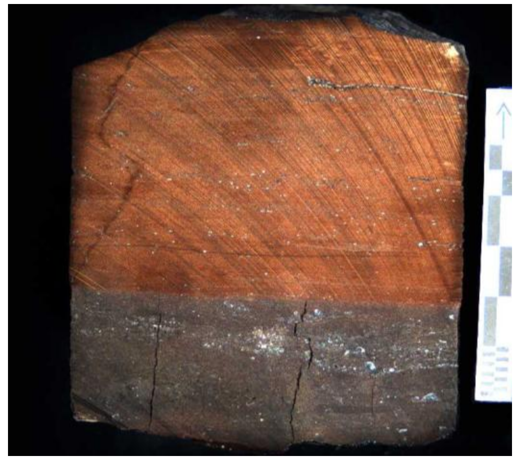

Fig. 10. Lithologic-wireline log section of Duvernay strata in the 10-27-57-21W4 well showing the depositional cycles and facies, the gamma-ray and sonic-log signatures, organic facies and TOC. Proximal foreslope sands are peloidal lime grainstones, whereas distal foreslope sands are peloidal and skeletal lime packstones. The numbers in parentheses refer to the estimated water depths at the top of the major depositional cycles.

# 3.0 WCSB ORGANIC FACIES; DUVERNAY FORMATION REGIONAL VARIATION IN ORGANIC FACIES

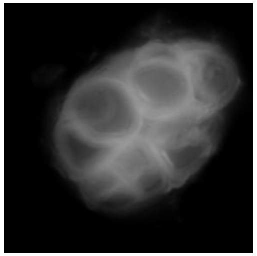


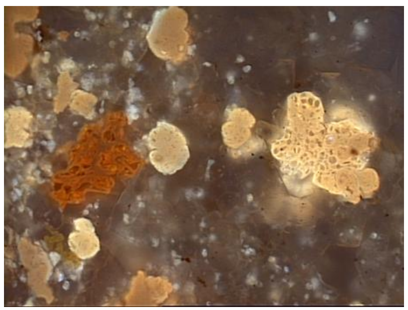
# 3.0 ORGANIC FACIES IN MARINE PETROLEUM SOURCE ROCKS, UPPER ORDOVICIAN, WILLISTON BASIN: SUBTIDAL LIME MUDSTONES, VERY HIGH TOC'S, TYPE I AND II KEROGEN

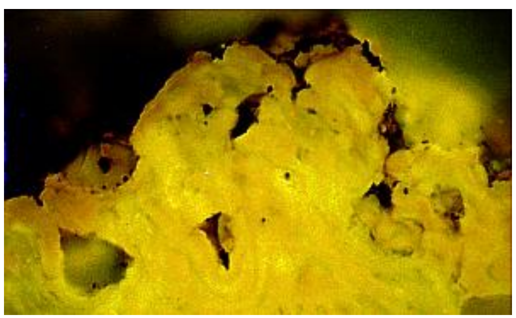


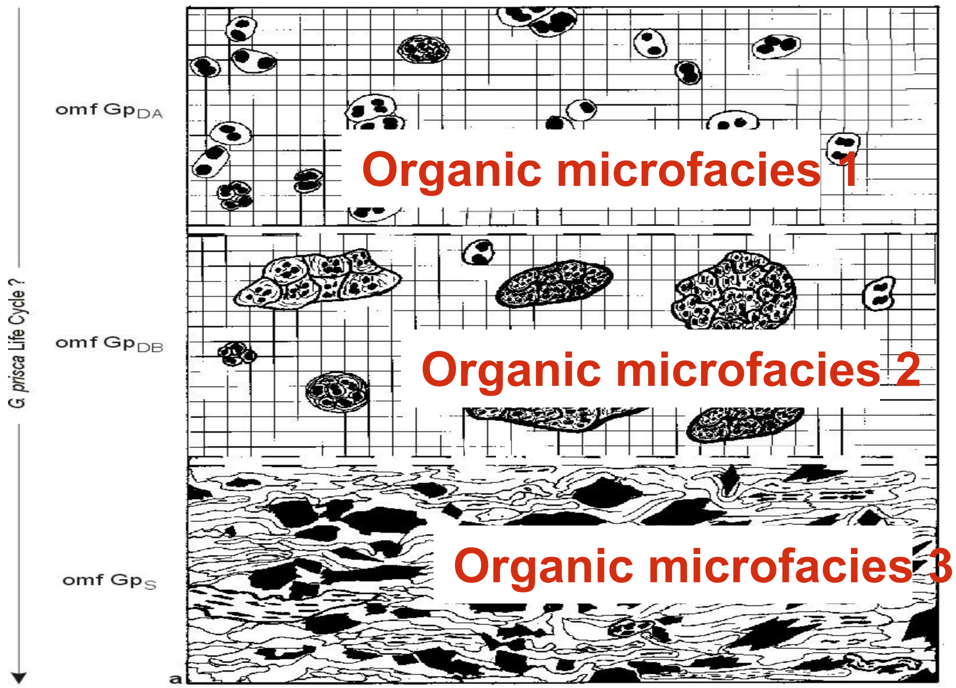



# 3.0 Paleodepositional Model for *G. prisca* alginite in Upper Ordovician lime mudstones, Type I and II kerogen





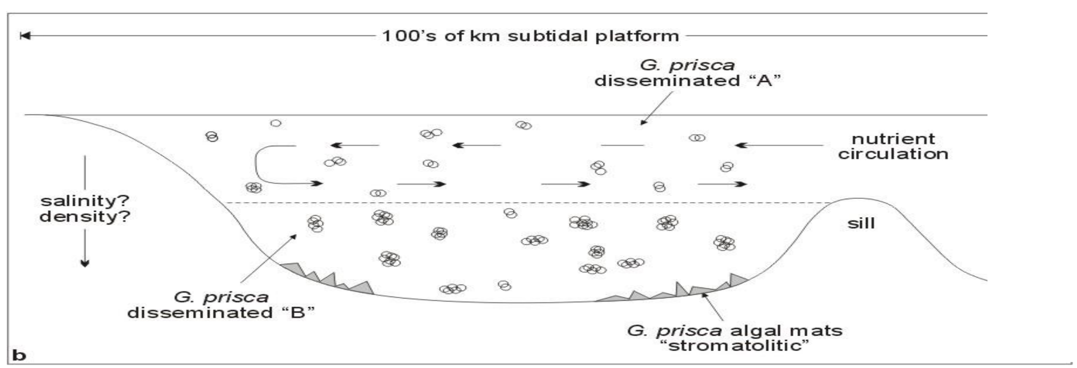




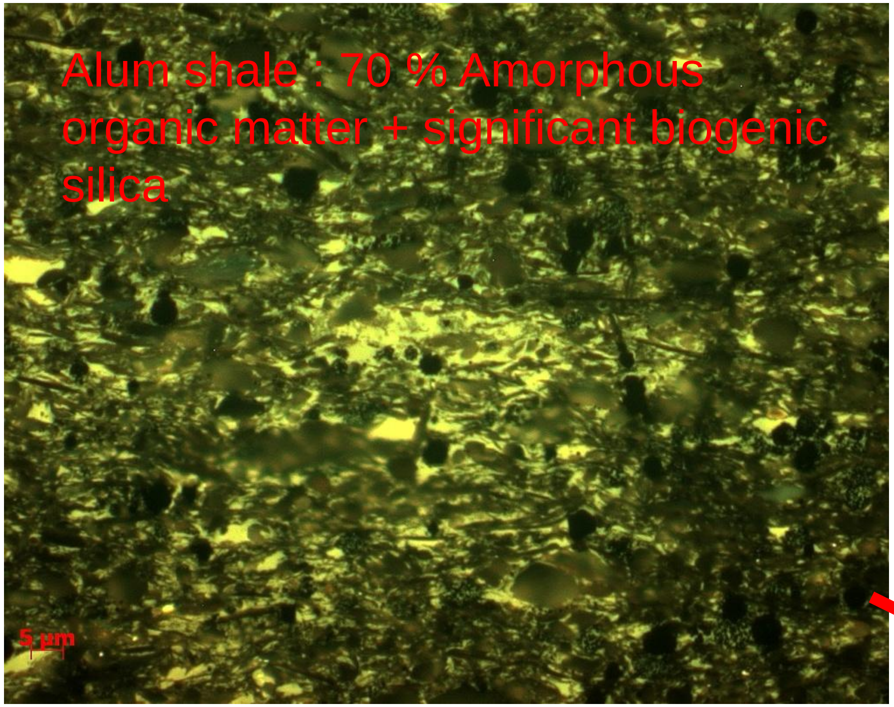

Initial growth – non-motile

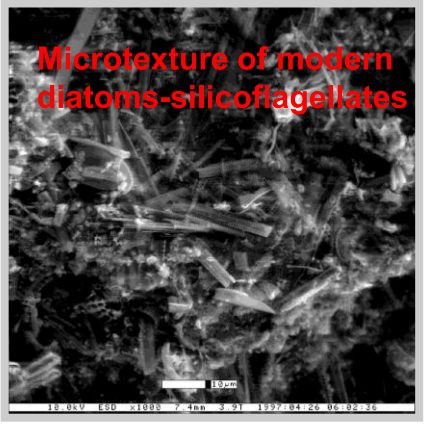
Sheath development – palmella stage

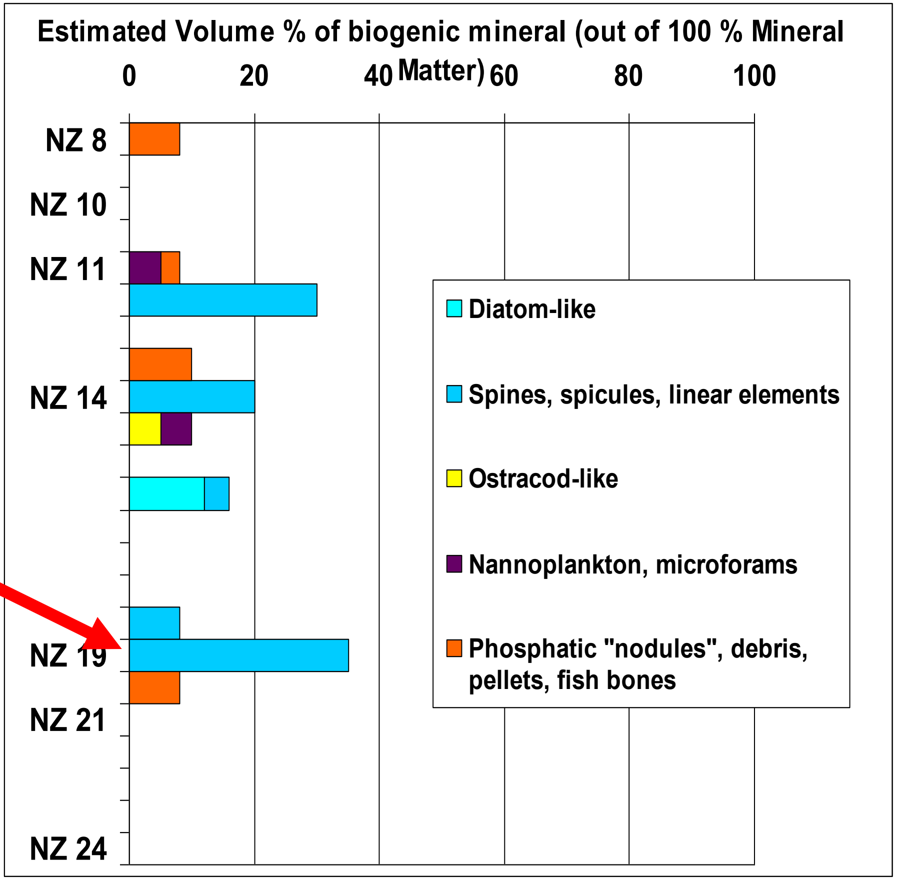
Stromatolite stage



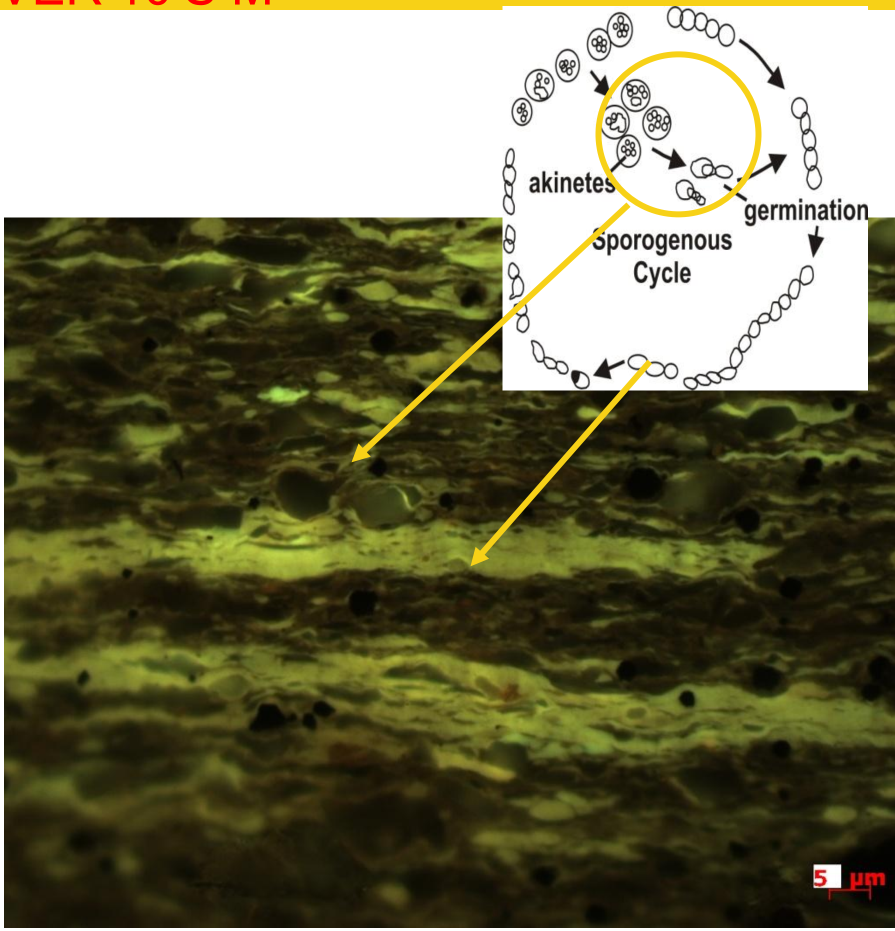
# 3.0 VERTICAL VARIATIONS IN INORGANIC MICROFOSSIL, BIOGENIC SILICA , IN CAMBRIAN ALUM SHALE, SWEDEN, OVER 10'S M

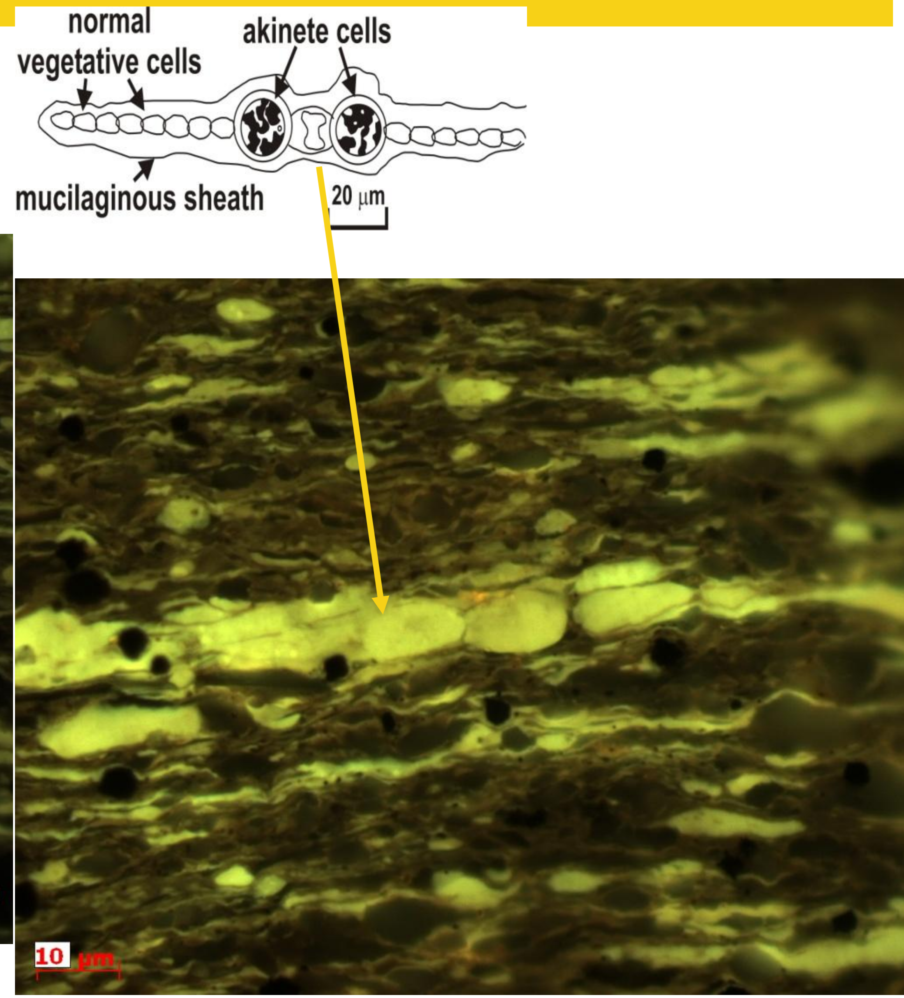


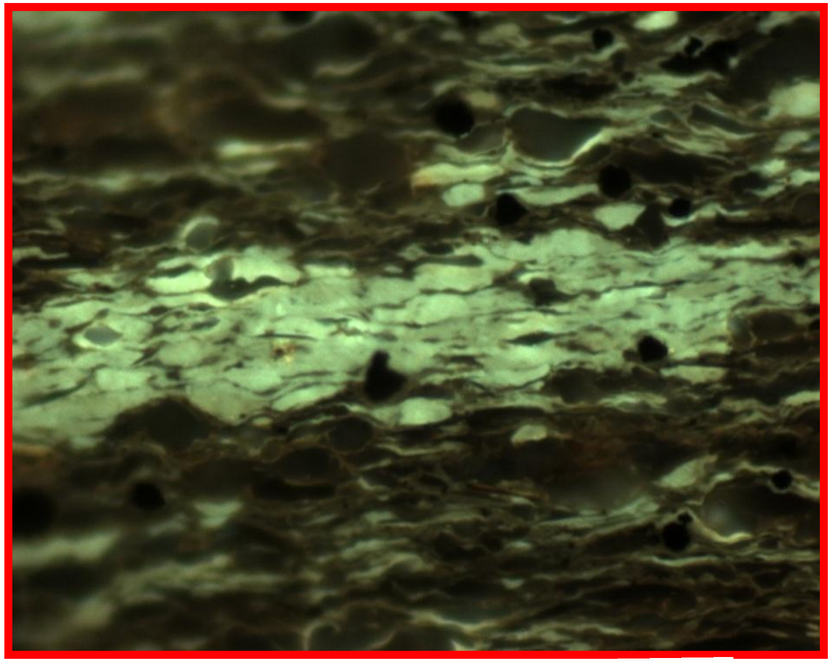
# 3.0 VERTICAL VARIATIONS IN HC POTENTIAL AND TYPE CONTROLLED BY DOM CONTENT – ALGINITE TYPE, IN CAMBRIAN ALUM SHALE, SWEDEN, OVER 10'S M

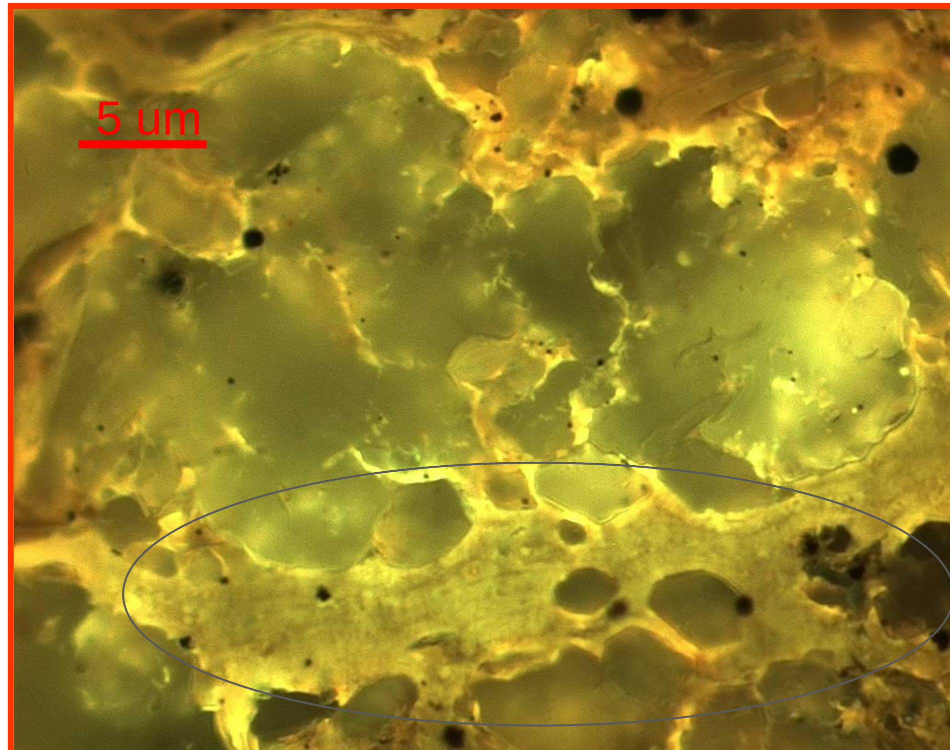



High amount filamentous alginite (blue-green "algae"/ cyanobacteria in vegetative state with akinete cell-heterocysts ,~ tannins) with small prasinophytes + amorphous organic matter

# 3.0 VERTICAL VARIATIONS IN HC POTENTIAL AND TYPE CONTROLLED BY DOM CONTENT – ALGINITE TYPE, IN CAMBRIAN ALUM SHALE, SWEDEN, OVER 10'S M, CAMBRIAN ALUM SHALE SWEDEN





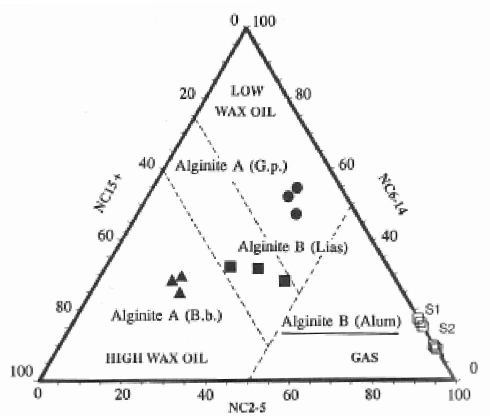



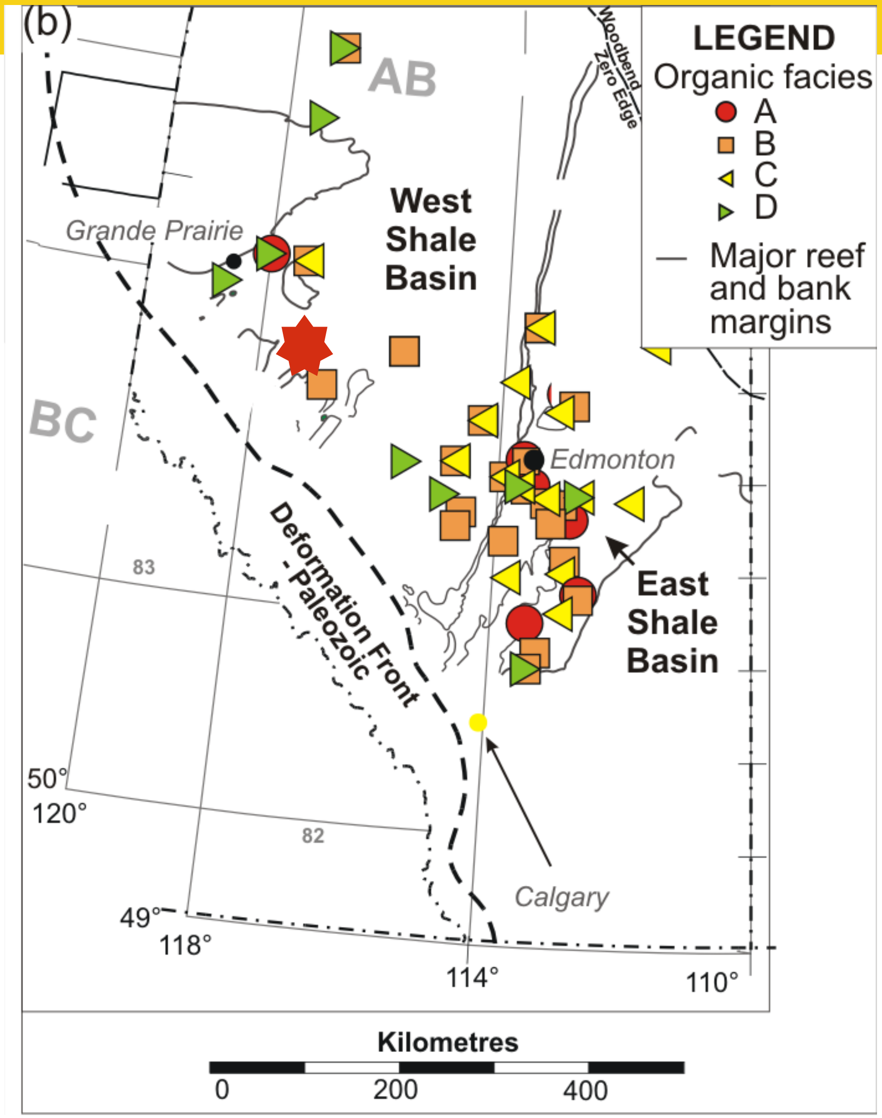

*Figure 9. Distribution of normal paraffins in the products released and residues of artificially matured Alum Shale kerogen, as compared to other alginites.*

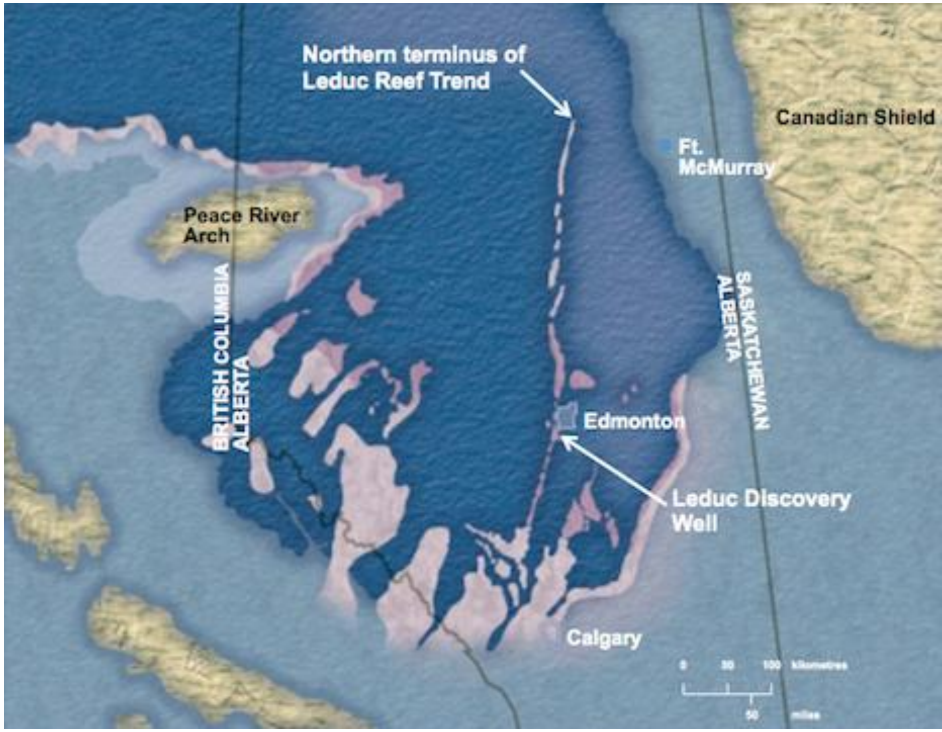
From Baharti and Larter, 1995

Alum shale OF with filamentous alginite (blue-green "algae"/ cyanobacteria in vegetative state with akinete cell-heterocysts, ~ tannins), with small prasinophytes + amorphous organic matter

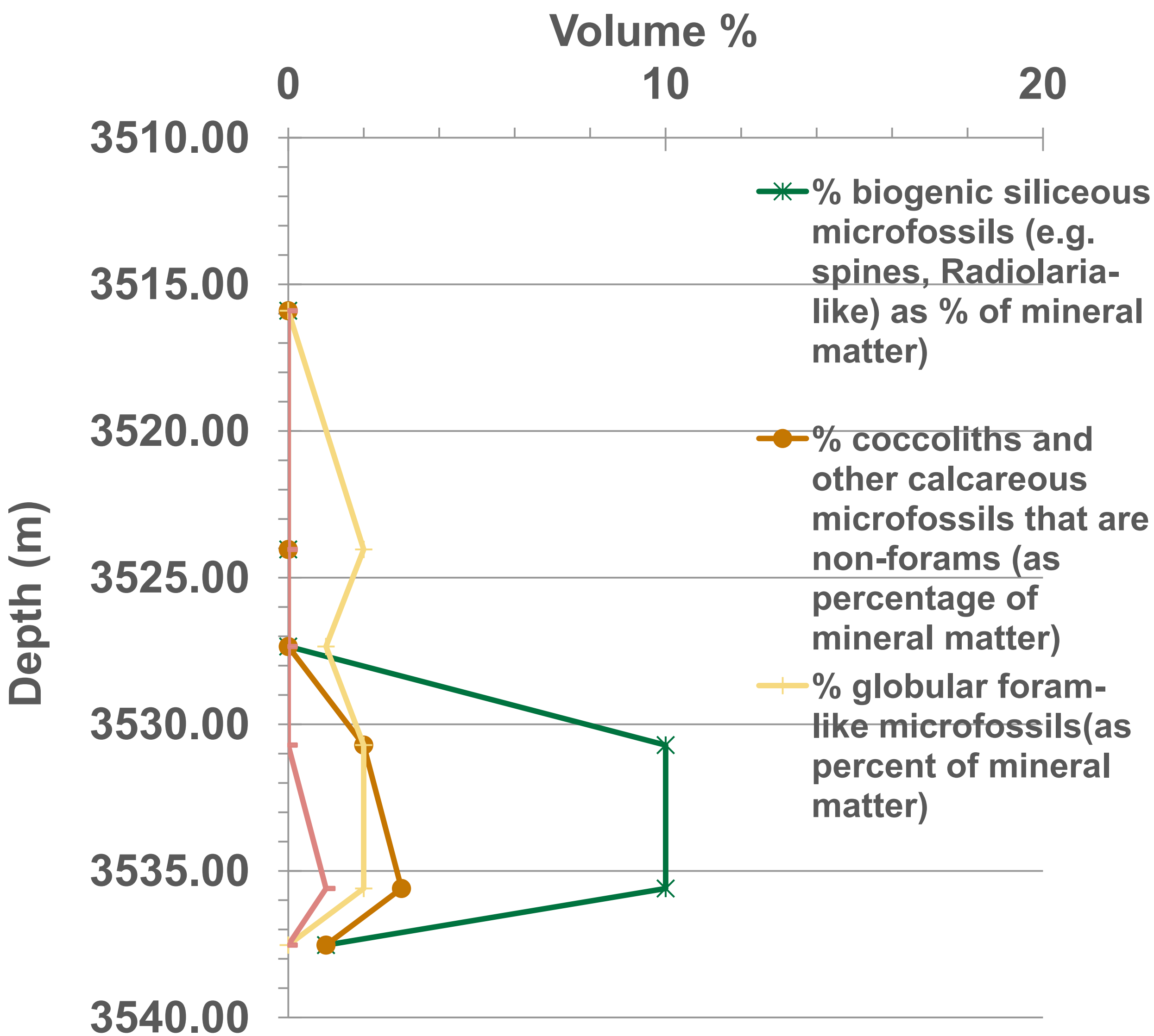
# Appendix: Additional Slides

# ORGANIC FACIES IN DUVERNAY SCAN KAYBOB WELL, FOX CREEK PLAY AREA



# E.G., VERTICAL CHANGES IN SILICEOUS AND CALCAREOUS MICROFOSSILS – IN LRS USED IN PART TO DEFINE ORGANIC FACIES , PALEOZOIC.

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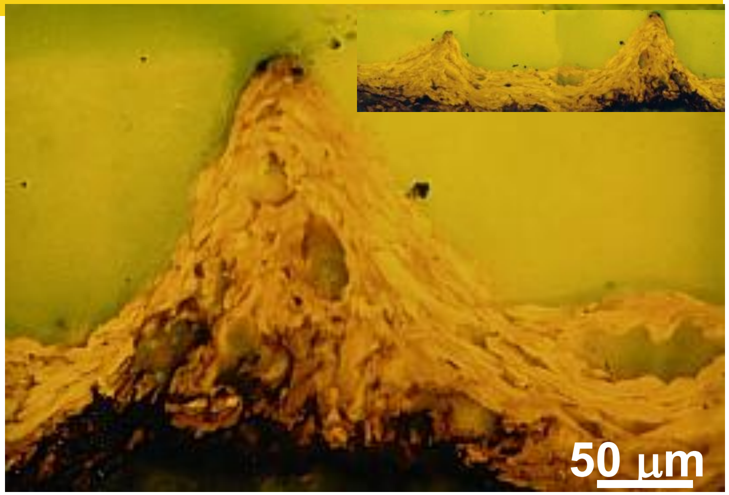
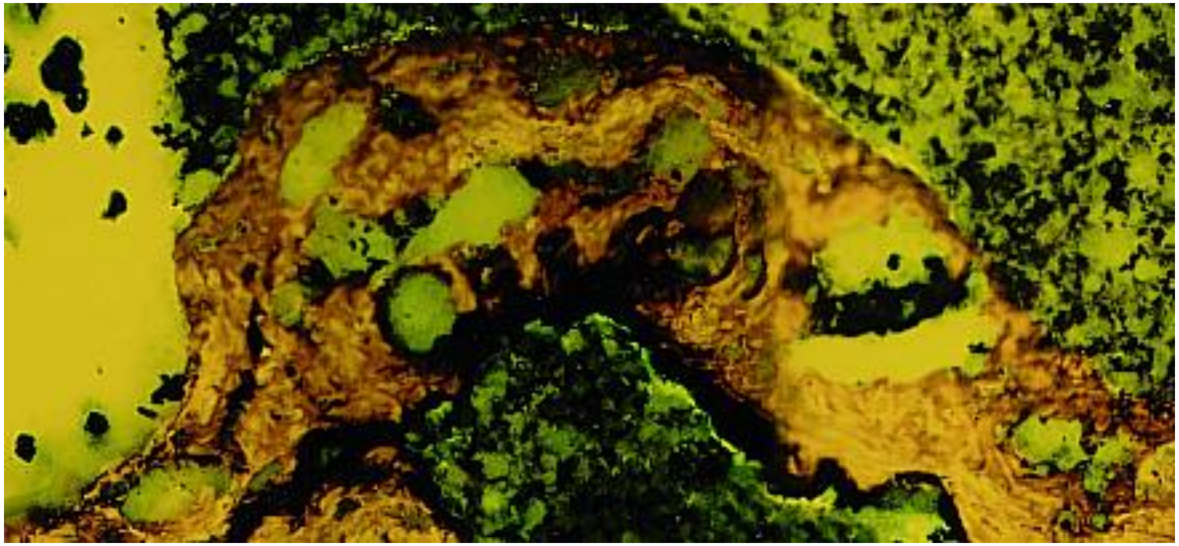
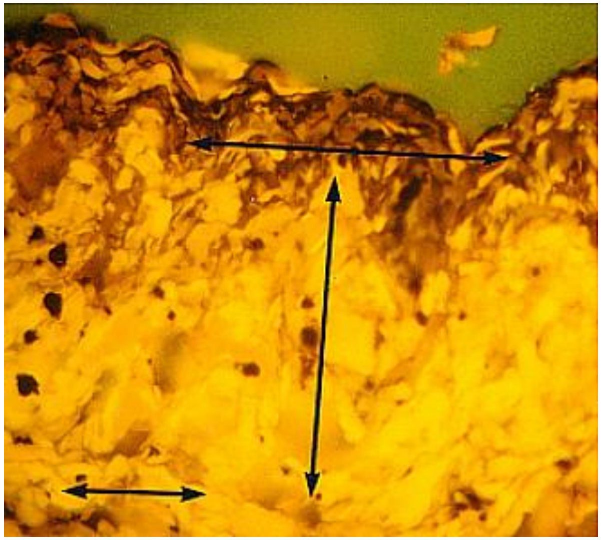
# 4.0 Stromatolite micro-textures, *G. prisca* alginite in Upper Ordovician lime mudstones

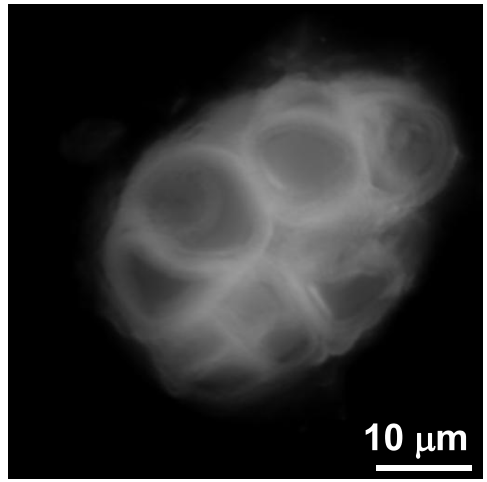


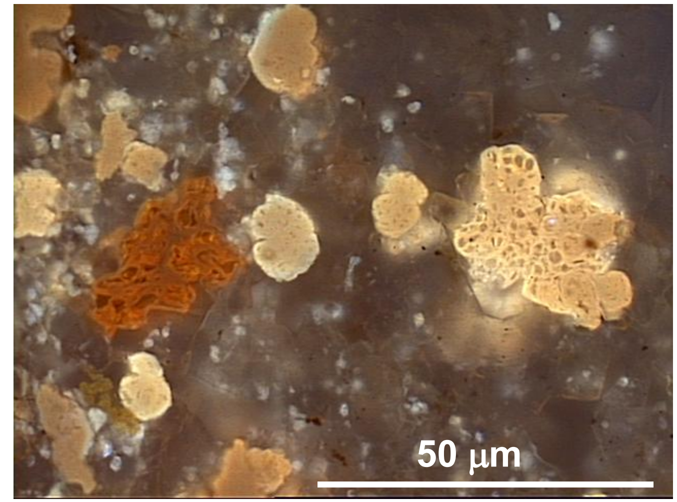



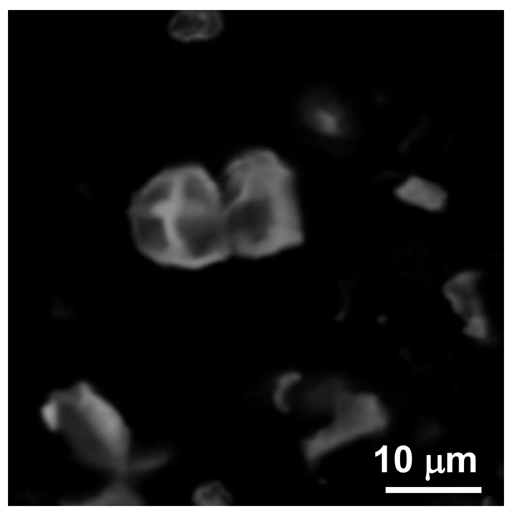


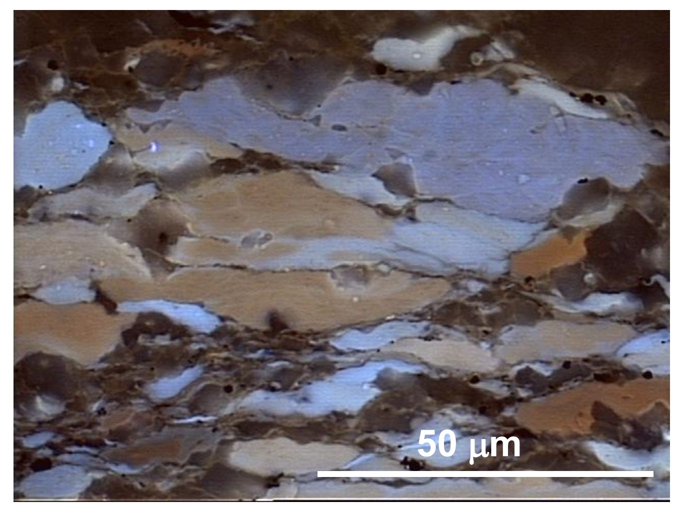
**(Stasiuk et al , 1993, *Org. Geochem;* 1999, *Geoscience Canada)***

Vertical variations in organic microfacies & HC potential in Upper Ordovician, marine petroleum source rocks, Williston basin, Saskachewan. Subtidal, lime mudstones with average to very high TOC's, Type I & II kerogen, comprising microlaminated, disseminated coccoidal alginite w/ spiny acritarchs, and layered coccoidal alginite,


**(Stasiuk et al , 1993, *Org. Geochem;* 1999, *Geoscience Canada)***

# 3.0 WCSB ORGANIC FACIES MODELS UPPER TRIASSIC UPPER MONTNEY TO DOIG ORGANIC FACIES : LRS - SHALE GAS ASSETS