The Middle Montney - A Dirty Old Carbonate Formation with a Secret Past?*

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Abstract

In sedimentary research, the ultimate goal is to identify paleodepositional environments, levels of sediment compaction, and diagenetic history from the time of sediment deposition, through burial, until sampling. The Lower Triassic Montney Formation of the Western Canadian Sedimentary Basin is generally interpreted as a sequence of interbedded sand, siltstones and shales deposited in a shallow, clastic ramp setting that deepened to the west. Although geographically localized coquina units are recognized within the middle member, an overall siliciclastic depositional model is assumed. Here we present new evidence from the Middle Montney of British Columbia illustrating that the depositional model needs to be revised. Ubiquitous early diagenetic concretions containing abundant carbonate material and moderately abraded, likely monospecific, epifaunal bivalve shell fragments indicate a limited amount of sediment transport and reworking. These concretions contain minimal siliciclastic material; and in some, albite feldspars are completely absent. Based on observations of sediment drape, the Middle Montney Formation has lost ~35-65% of its initial sediment thickness (dissolution, compaction). We argue that the original Middle Montney sediment represented classical carbonate sediments (bioclastic carbonate muds) prior to burial and onset of diagenetic alteration. During burial, subsequent pore fluid migration and mineral alteration, calcite/aragonite and biogenic silica (>80% of original sediment composition) were transformed into dolomite, quartz, feldspar, and clay minerals. This mineral composition of the Middle Montney has led to incorrect classification as siliciclastic deposits. Rather than accumulation through depositional processes, high levels of compaction/dissolution and mineral neoformation during burial concentrated the organics, detrital minerals, and authigenic silicates and dolomite observed in the Middle Montney. These marked diagenetic alterations and

textural transformations are the result of burial diagenesis under the influence of hydrothermal fluids. This presentation dissects the Middle Montney Member in detail using petrographic, mineralogical and scanning electron microscopy evidence. A new depositional and diagenetic model of a Middle Montney carbonate-dominated shelf margin is also presented. This new model may have significant exploration implications as industry continues to search for new targets within the Montney Formation.

References Cited

Davies, Graham R., Thomas F. Moslow, and Mike D. Sherwin, 1997, The Lower Triassic Montney Formation, west-central Alberta: Bul. Canadian Petroleum Geology, v. 45/4, p. 474-505.

Wilson, Nick, J-P. Zonneveld, and Mike Orchard, 2012, Biostratigraphy of the Montney Formation: From the Alberta and British Columbia subsurface, to the Outcrop. AAPG Search and Discovery Article #50934 (2014). http://www.searchanddiscovery.com/documents/2014/50934wilson/ndx_wilson.pdf

AAPG Annual Convention & Exhibition 2016

with SEPM (Society for Sedimentary Geology) and Canadian Society of Petroleum Geologists (CSPG)

19–22 June 2016 (plus pre- and post-events) • BMO Centre at Stampede Park • Calgary, AB

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Canbriam

Outline & Acknowledgments

- **Introduction to the Montney Formation**
- **Overview of location**
- **Objective of presentation**
- **Date presentation**
- **Interpretation and conclusions**
- **Questions**

Thanks to:

Birchcliff (Bruce Palmer, Laura Ferguson, Dave Graham, Jon White)
Rock Metrics Americas LLC. (Jason Cruz, Bernard Lee, Jean-Yves Chatellier)

The Montney Formation- in the literature

BULLETIN OF CANADIAN PETROLEUM GEOLOGY, VOL. 45, NO. 4 (1997), 474-505

The Lower Triassic Montney Formation, west-central Alberta

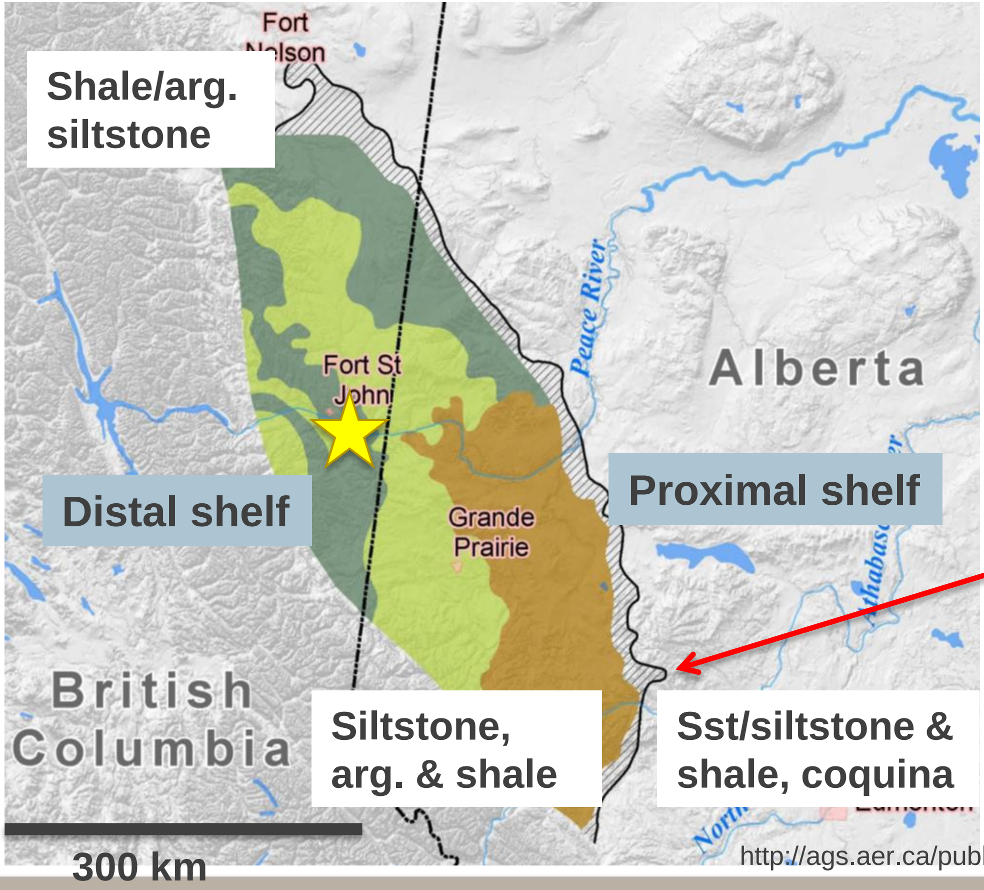
Graham R. Davies, Thomas F. Moslow, Mike D. Sherwin

The Lower Triassic Montney Formation was deposited in a west-facing, arcuate extensional basin, designated the Peace River Basin, on the northwestern margin of the Supercontinent Pangea, centred at about 30°N paleolatitude. At
least **seasonally arid climatic conditions, dominance of northeast trade winds, minimum fluvial influx, offshore coastal upwelling, and north to south longshore sediment transport affected Montney sedimentation**. Paleostructure, particularly highs over underlying Upper Devonian Leduc reefs and lows associated with graben trends in the Peace River area, strongly influenced Montney depositional and downslope mass-wasting processes.
A wide range of depositional environments in the Montney is recorded by facies ranging from mid to upper shoreface sandstones, to middle and lower shoreface HCS sandstones and coarse siltstones, to finely laminated lower shoreface sand and offshore siltstones, and to turbidites. **Dolomitized coquinal facies occur at seven stratigraphic horizons in the Montney**. Some coquinas are capped by karst breccias and coarse-grained aeolian deflation lag sand residues indicating subaerial exposure.

The Montney Formation- in the literature

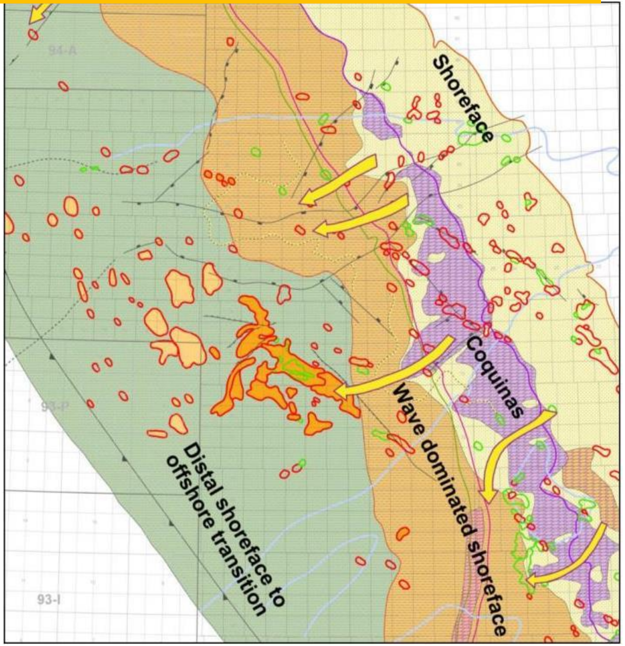
The Montney has been divided into 3 informal members that have been dated by palynology and compared with global Early Triassic sequences. The subdivisions are: … the Middle member, Coquinal Dolomite, of mixed Dienerian and Smithian ages;…
A **forced regressive wedge systems tract model** is adopted for deposition of the Coquinal Dolomite Middle member and for turbidites in the Valhalla-La Glace area of west-central Alberta. With this model, coquinas and turbidites accumulated during falling base level to lowstand, with a basal surface of forced regression at the base of the coquina and a sequence boundary at the top of the coquinal member. …
Very limited **grain size distribution in the Montney**, dominantly siltstone to very fine-grained sandstone, but often **very well sorted, is interpreted to reflect an aeolian influence on sediment source and transport**. **High detrital feldspar and detrital dolomite** in the Montney are consistent with (but not proof of) **aeolian source from an arid interior**, as is **high detrital mica** content in finer size grades. **Extensive and often pervasive dolomitization**, and early anhydrite cementation within the Montney, **are also consistent with an arid climatic imprint.**

The Montney Formation



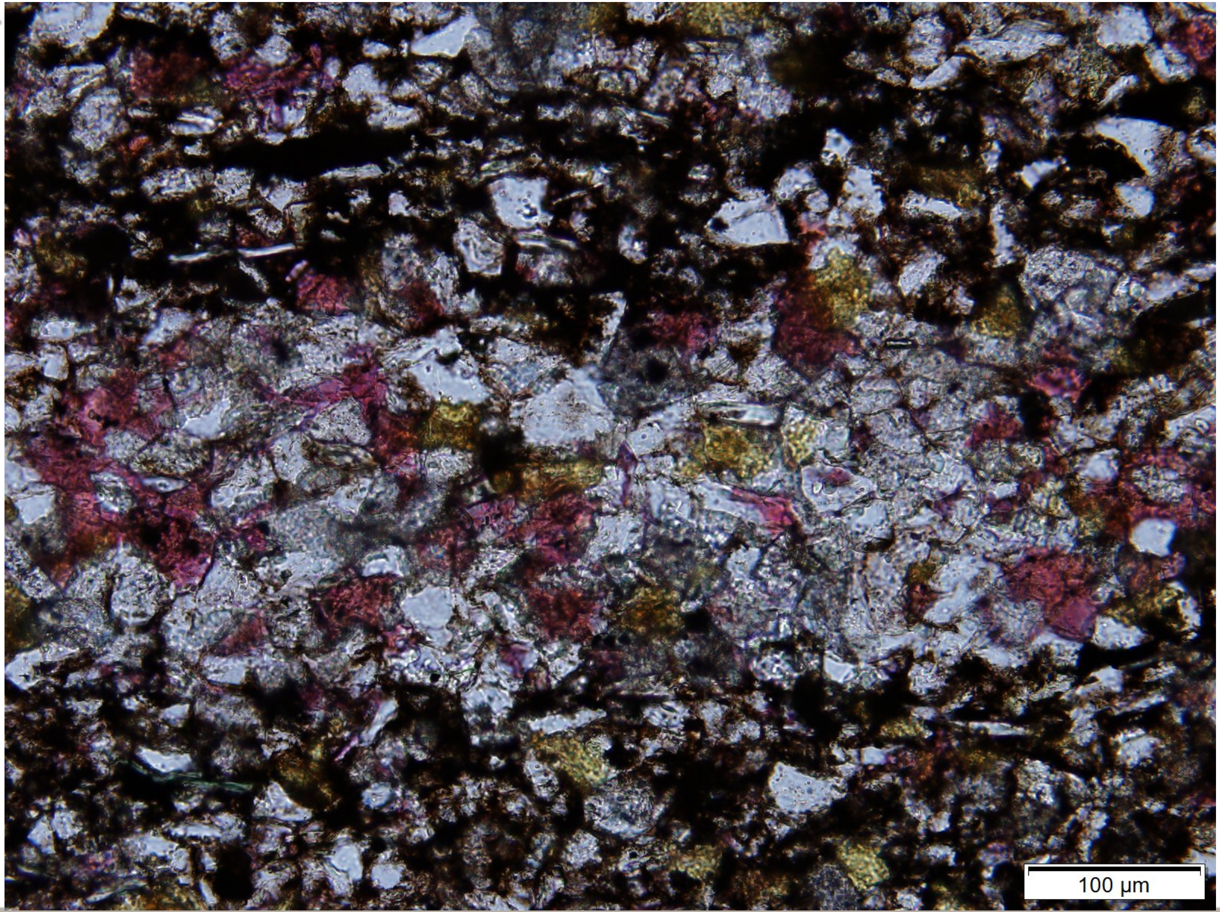
http://ags.aer.ca/publications/chapter-pdfs

Montney = mixed siliciclastic deposit, shore to offshore TCs, arid climate, detrital land influx



http://www.canadiandiscovery.com/

Characteristic Montney “dolomitic siltstone w shale”



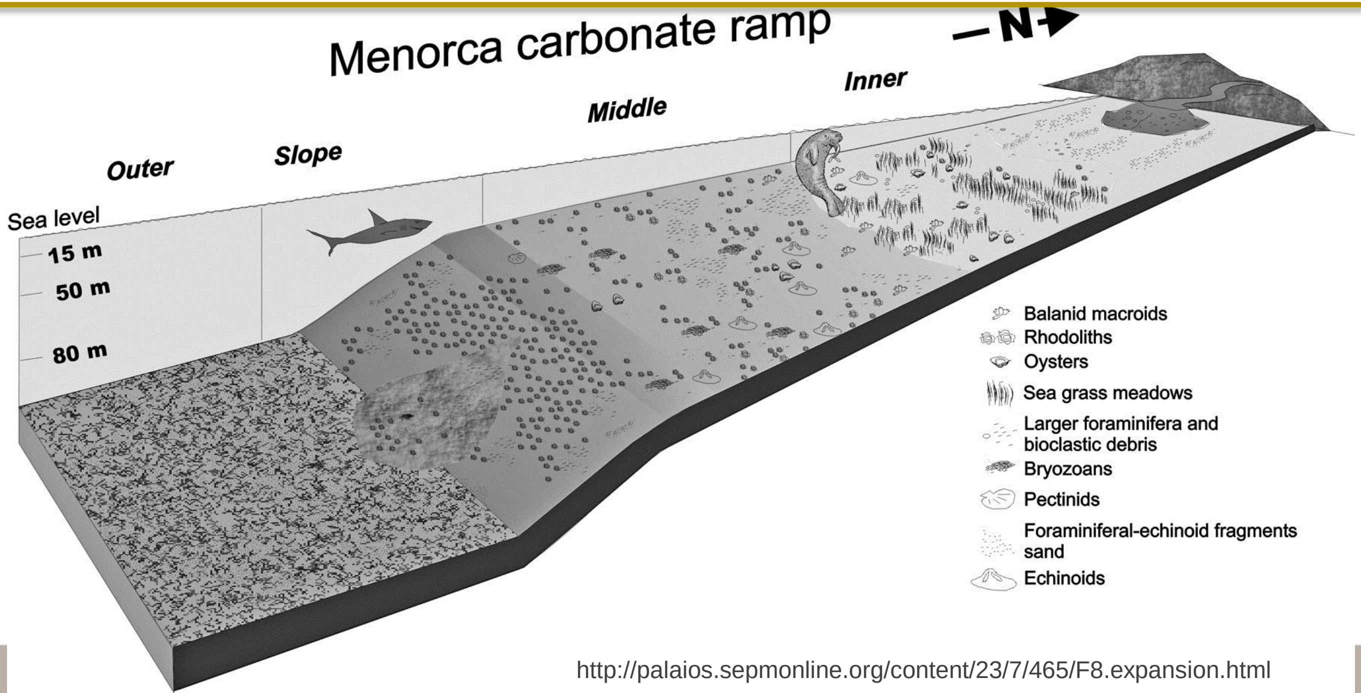
Fine-grained

Coarse-grained (dol, qz, cc, fsp, clays)

Detritus?

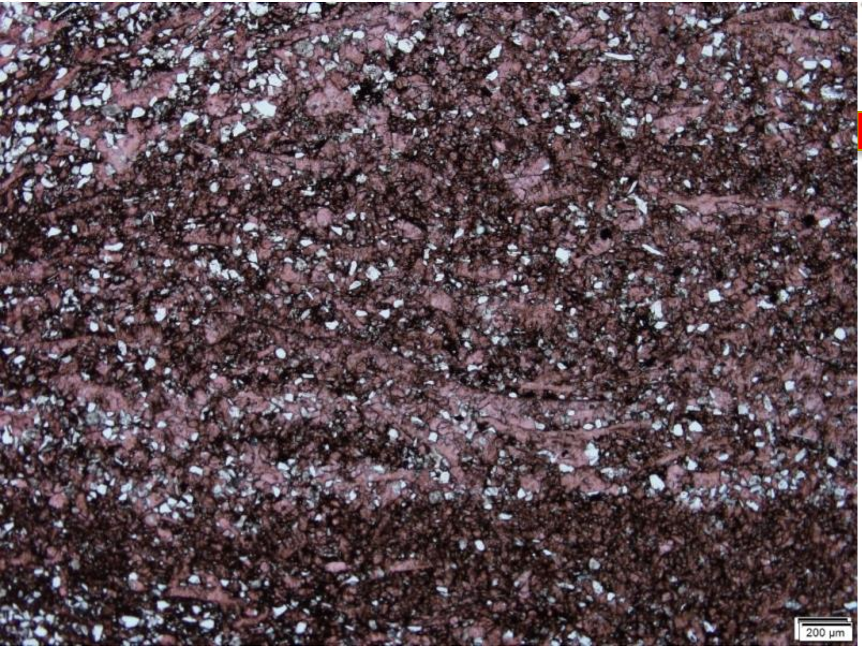
Fine-grained

Have you ever thought that the Middle Montney may represent a true carbonate ramp deposit?



http://palaios.sepmonline.org/content/23/7/465/F8.expansion.html

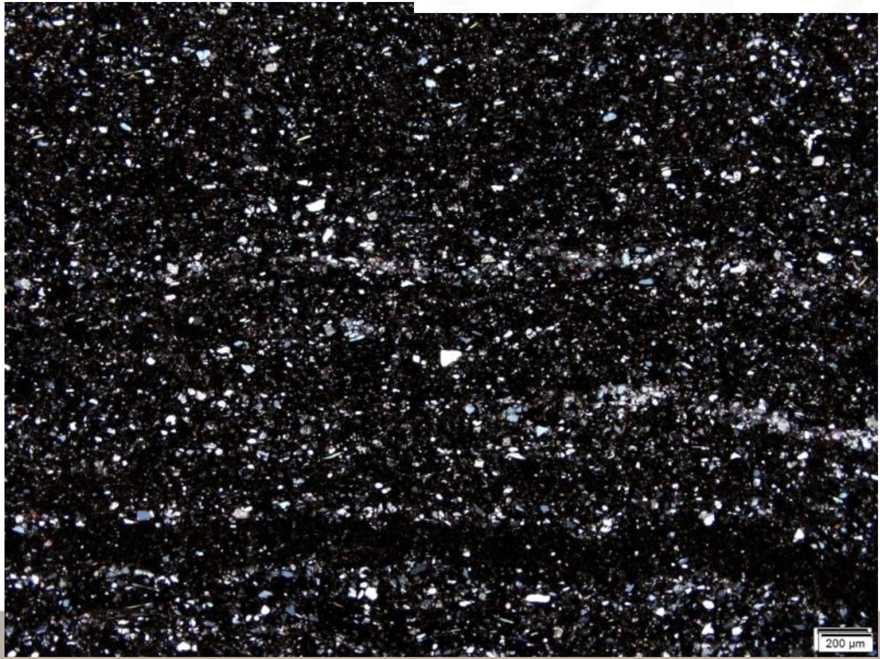
The "New" Montney: A formation that revolutionizes our view about Earth and geological dynamics!



Fluids, Temp, P, Time and ?

Carb. mud w. biogenic silica (250 Ma ago)

"Dolomitic Siltstone" (present)



Changing your view of the Middle (Lower?) Montney

Current view:

Rock type: Dolomitic siltstone & shales with occ. coquina

Composition: Detrital feldspar, mica, dolomite, quartz
diagenetic dolomite, some calcite

Depositional environment: arid climate => aeolian influx of feldspar, dolomite, mica. Shelf deposits, occ coquina biostromes, sediment long-shore transport and turbidite currents (off-shelf)

Siliciclastic (aeolian) shelf depositional setting

Hypothesis:

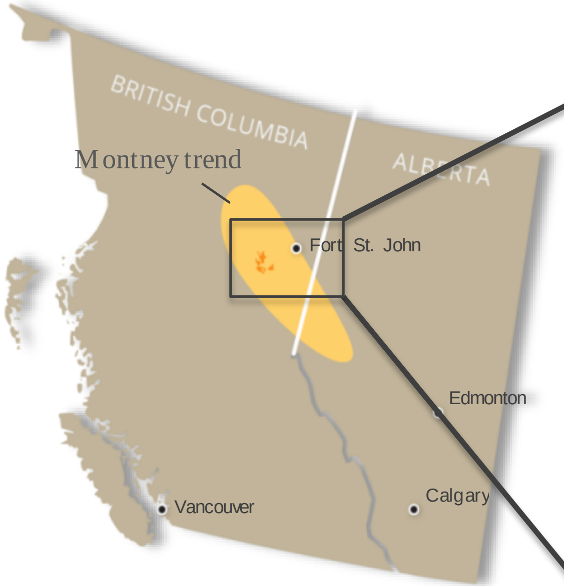
Rock type: Dolomitic “siltstone/shales” with occ. coquina

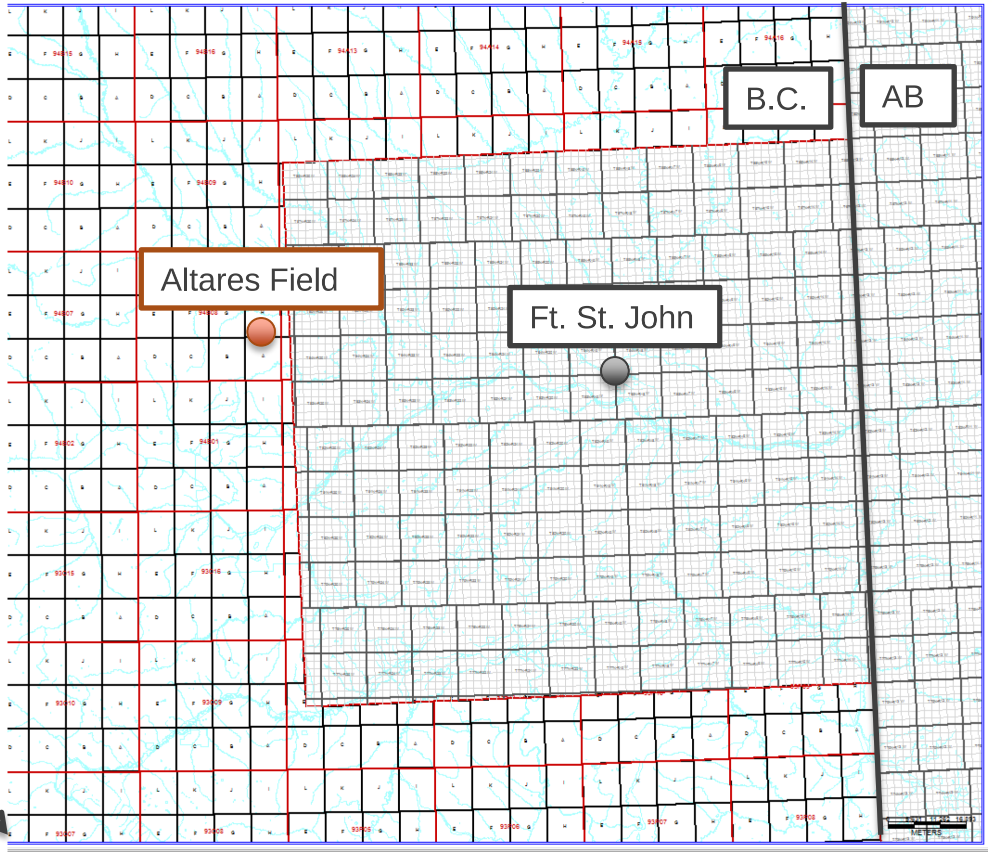
Composition: Few detrital feldspar, mica, quartz
Abundant diagenetic quartz, dolomite, feldspar

Depositional environment: arid climate with carbonate shelf. Carbonate muds (aragonite, calcite, low Mg-calcite) with contemporaneous siliceous ooze (radiolarian, dinoflagellates? and organics). Abd pectinoidal fauna (very limited species) with other critters (fish, ammonoids, etc). Bottom wave sorting and transport, shallow marine carbonate ramp.

Carbonate mud shelf with common biogenic silica influx

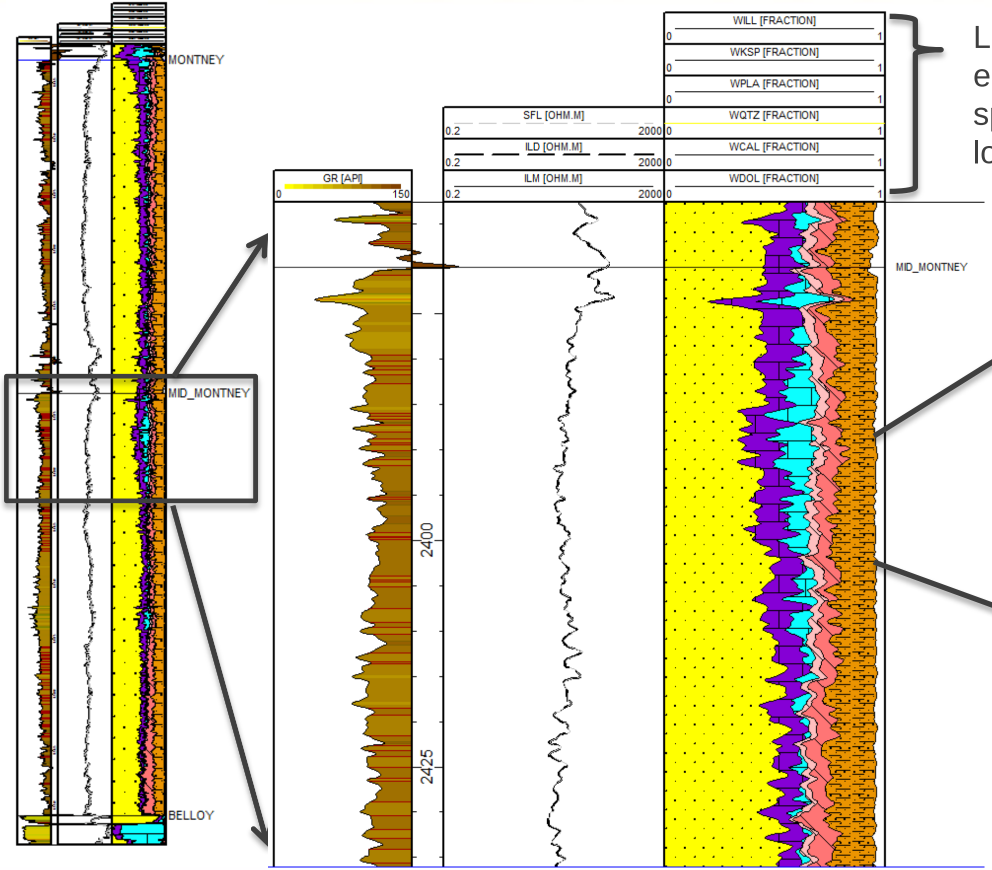
Sample site location



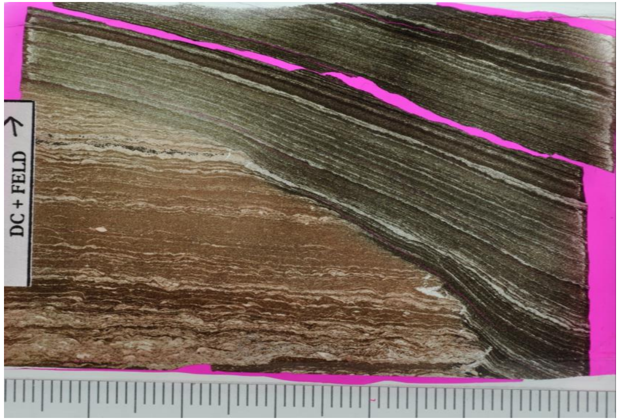


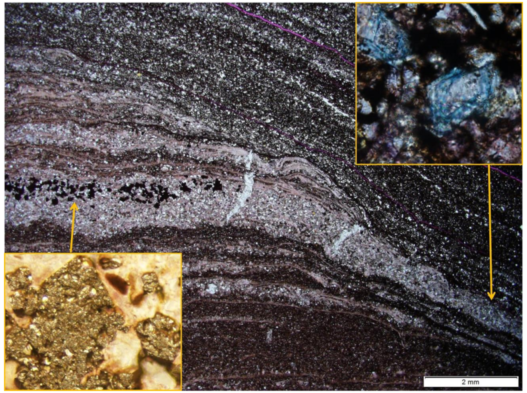
Disclaimer: only ONE well was investigated!

Routine core tests



Lithology from elemental spectroscopy logs





What was done for this study?

Middle Montney:

Concretions, calcitic beds and mudstones investigated for:

- “Compaction rate” (concretion – “mudstone”)
- Petrography
- Mineralogy
- Geochemistry
- Total acid solubility
- SEM

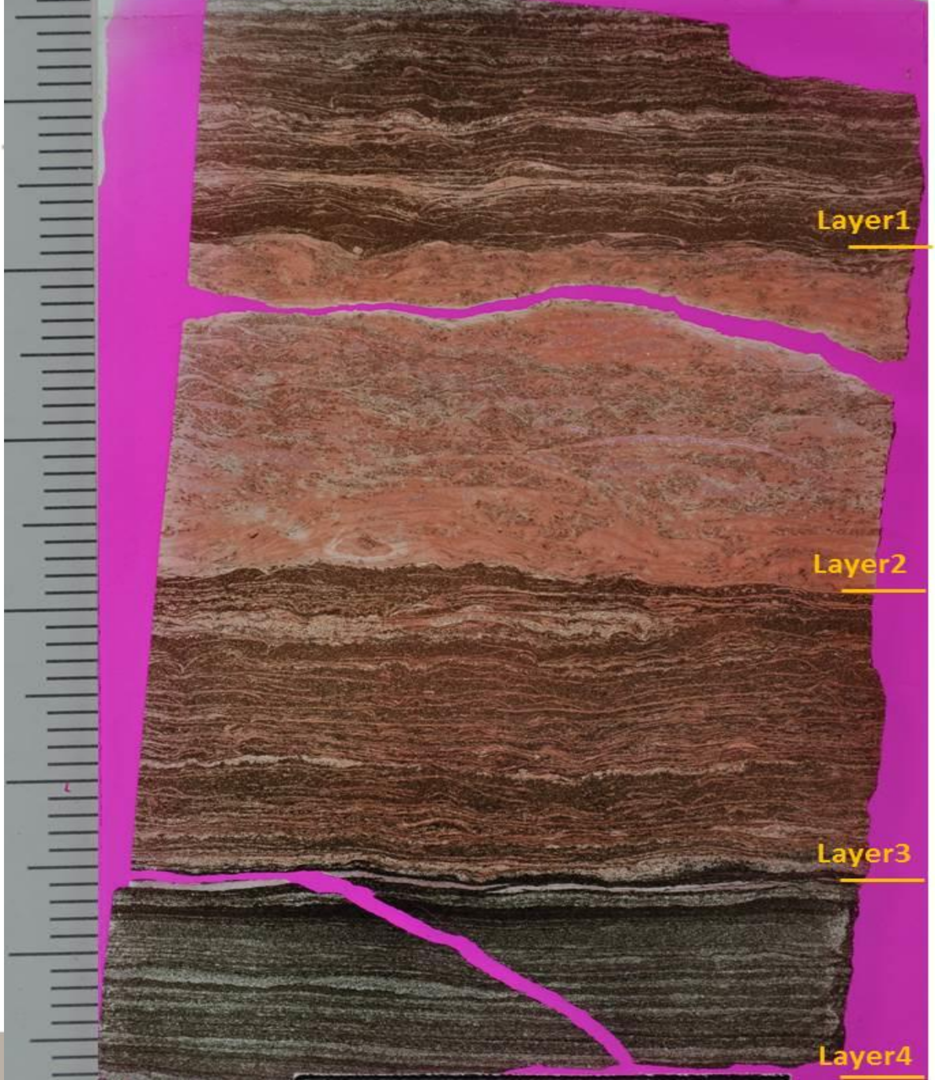
Mid Montney: “Siltstone” and bioclastic carbonate intervals (packstones)

Disarticulated bivalves

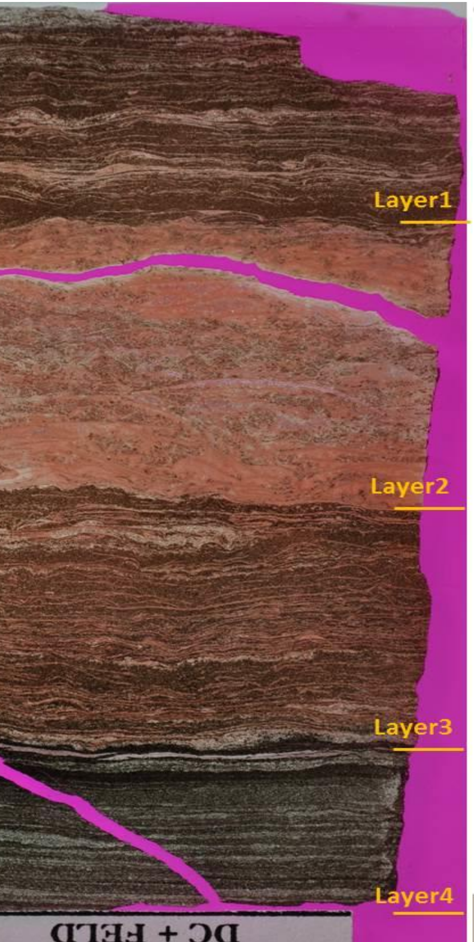
occc. articulated bivalves

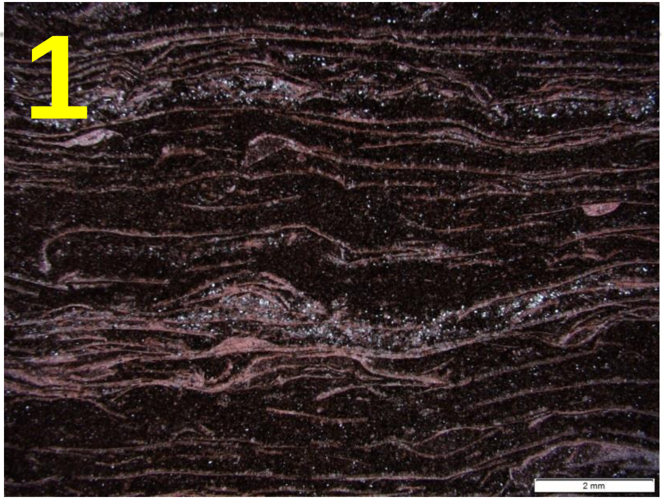
Bivalves almost always intact and parallel to bedding and concave down, i.e. ”sorted”

Disarticulated bivalves



Details

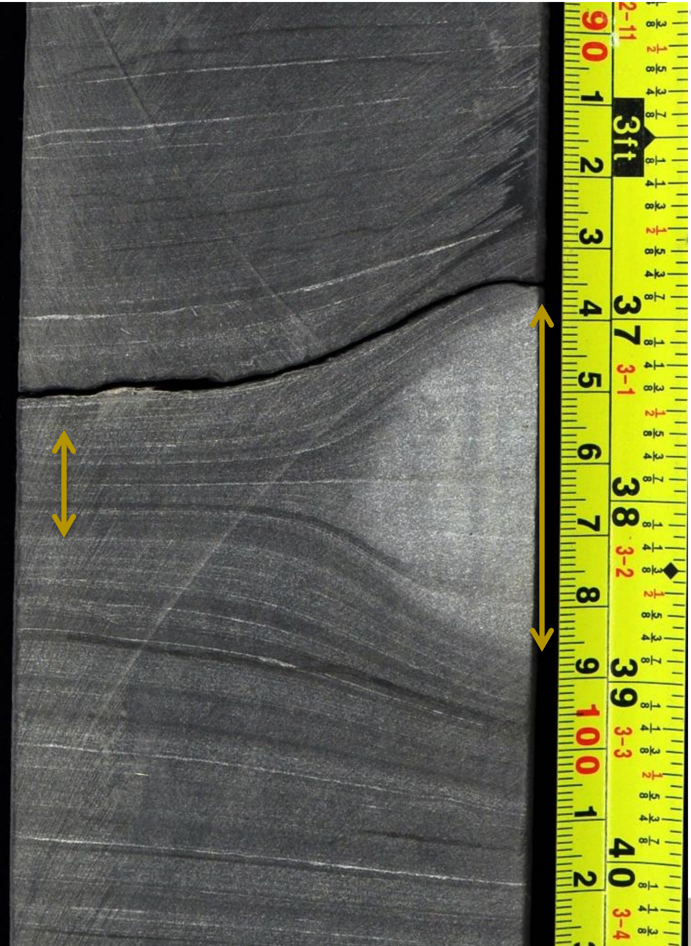


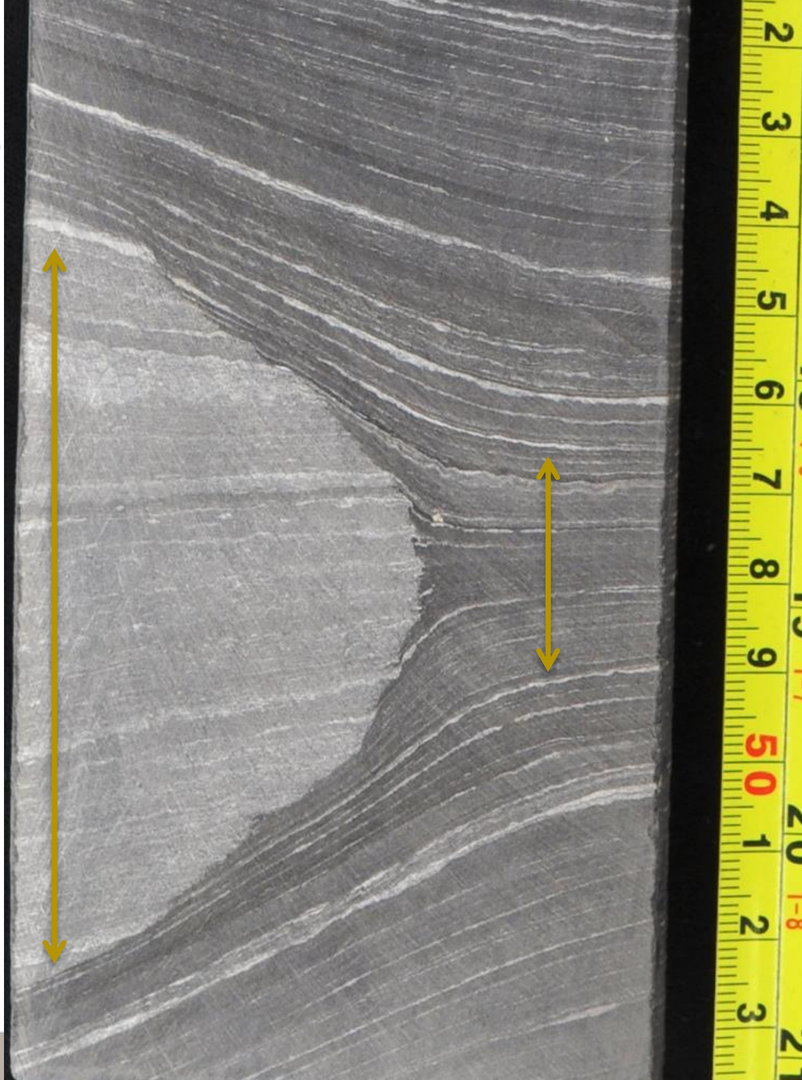


Bivalve packstone

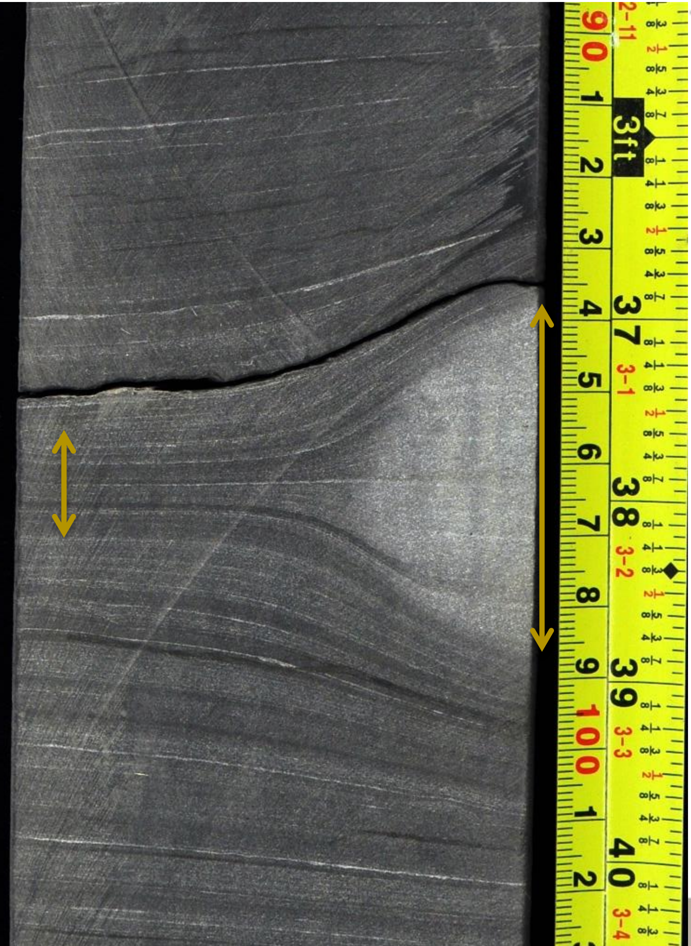
Laminated “siltstone”

Focus of this study: Concretions!





Analysis and results



2380.96: (6cm reduced to 2.4 cm)

Reduction is sediment thickness (from time of concretion fm)

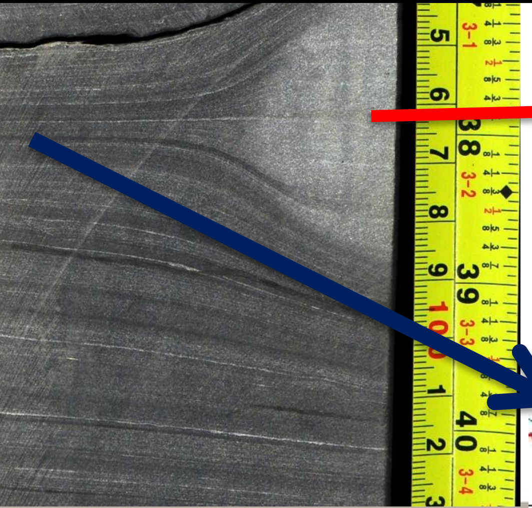
Loss: 60%

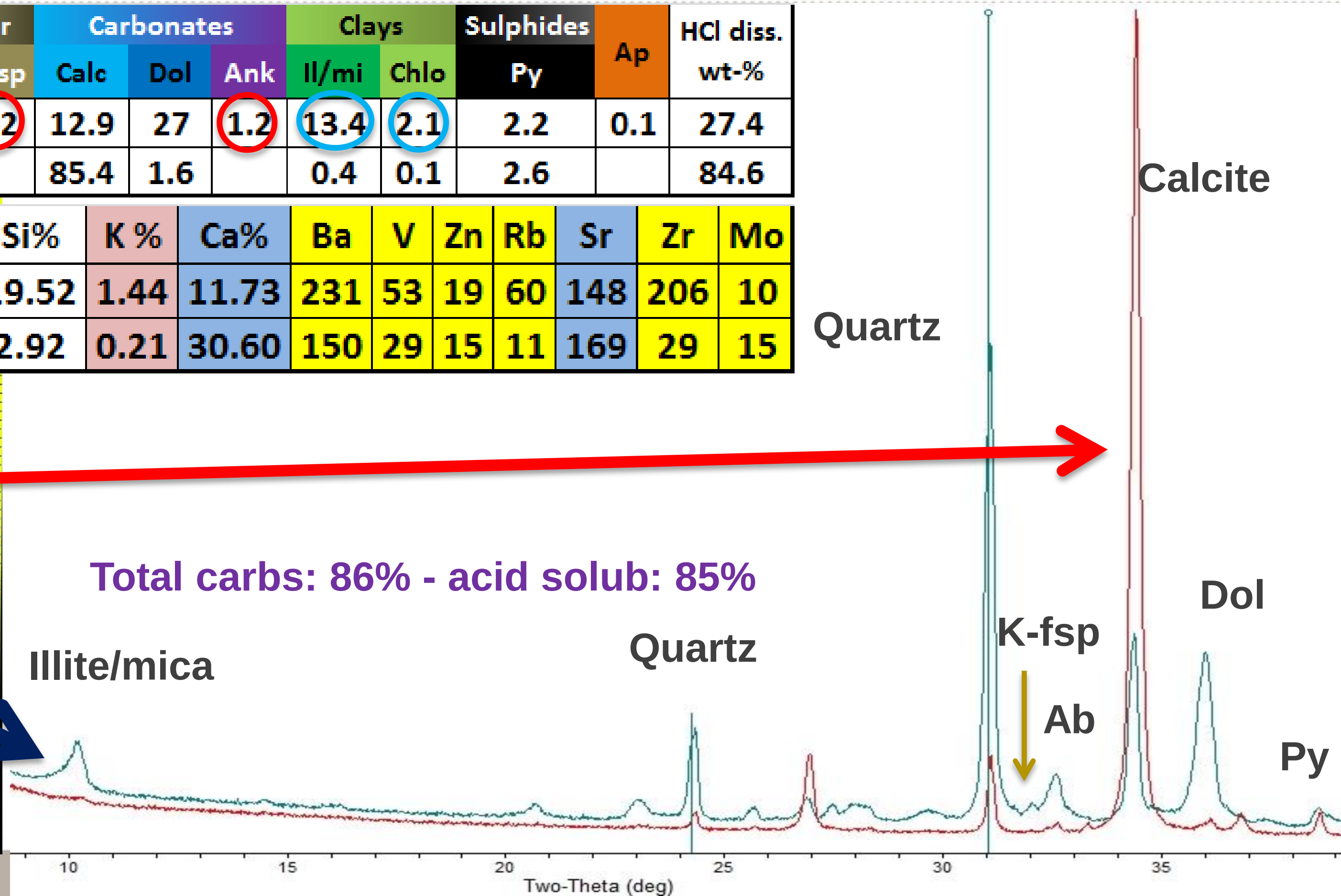
= Compaction + dissolution

XRD – XRF data – shale vs concretion

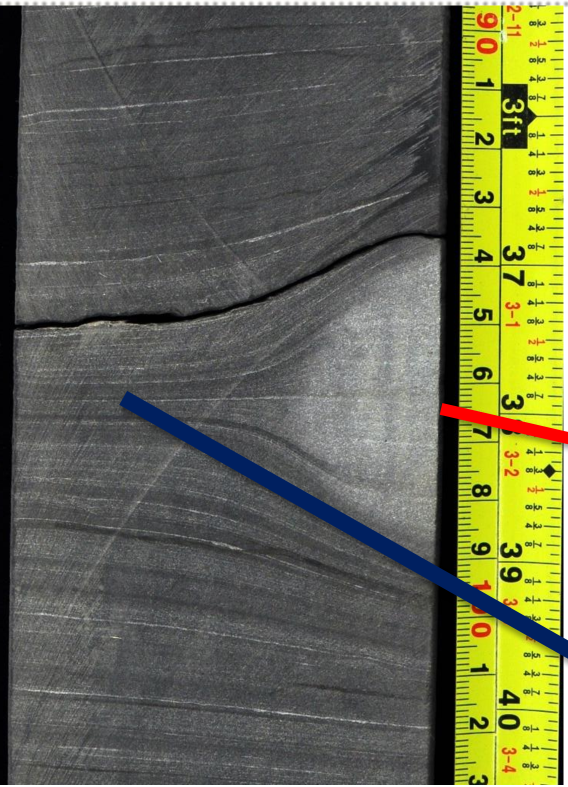
Sample ID	Depth in m	Qz	Feldspar		Carbonates			Clays		Sulphides	Ap	HCl diss. wt-%
			Ab	K-fsp	Calc	Dol	Ank	Il/mi	Chlo	Py		
"Shale"	2381	26.6	8.4	6.2	12.9	27	1.2	13.4	2.1	2.2	0.1	27.4
Concr	2381	5.7	3		85.4	1.6		0.4	0.1	2.6		84.6

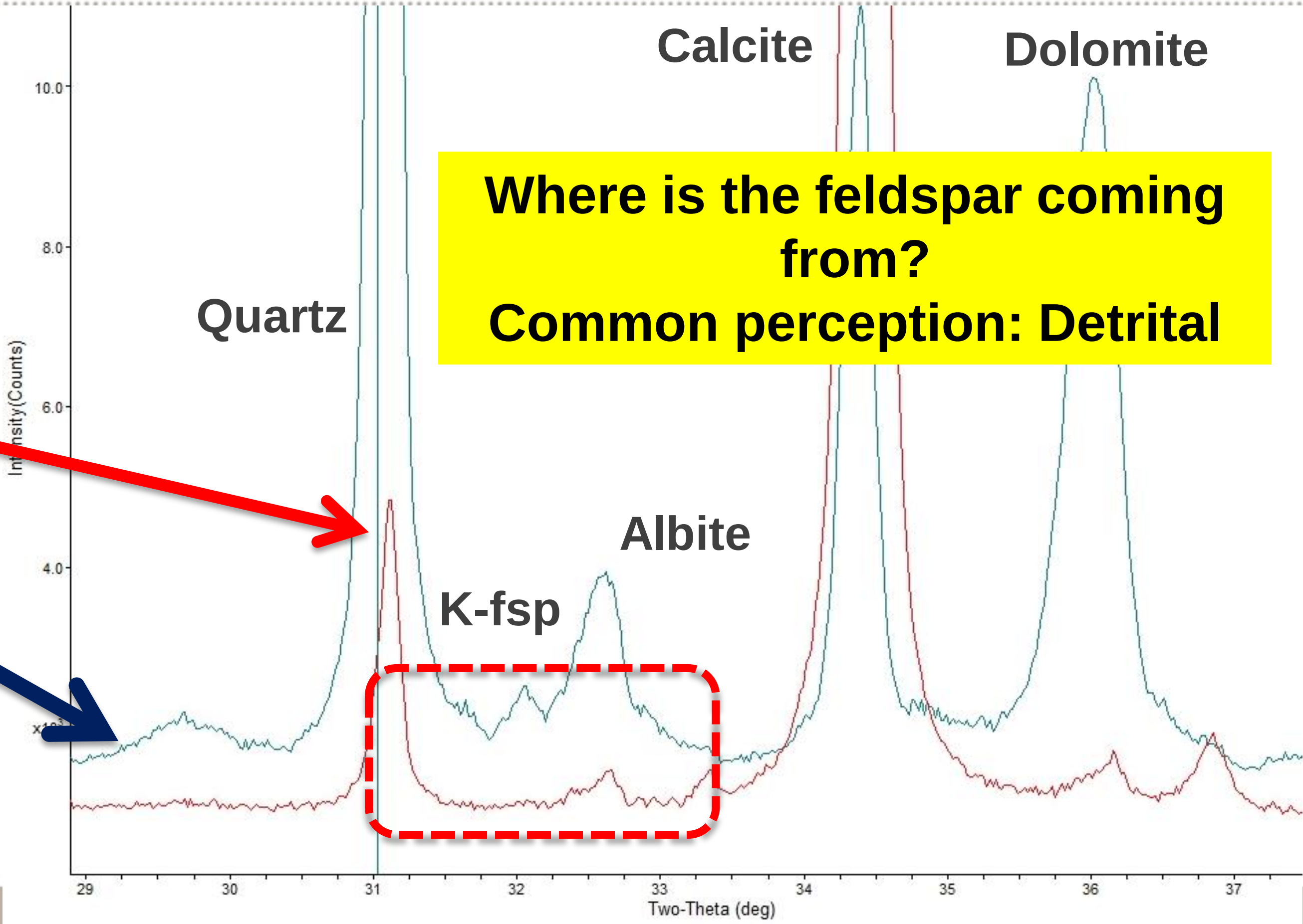
Sample ID	Na%	Mg%	Al%	Si%	K %	Ca%	Ba	V	Zn	Rb	Sr	Zr	Mo
"Shale"	0.62	2.90	2.72	19.52	1.44	11.73	231	53	19	60	148	206	10
Concr	0.20	nd	0.47	2.92	0.21	30.60	150	29	15	11	169	29	15





Where is the feldspar?

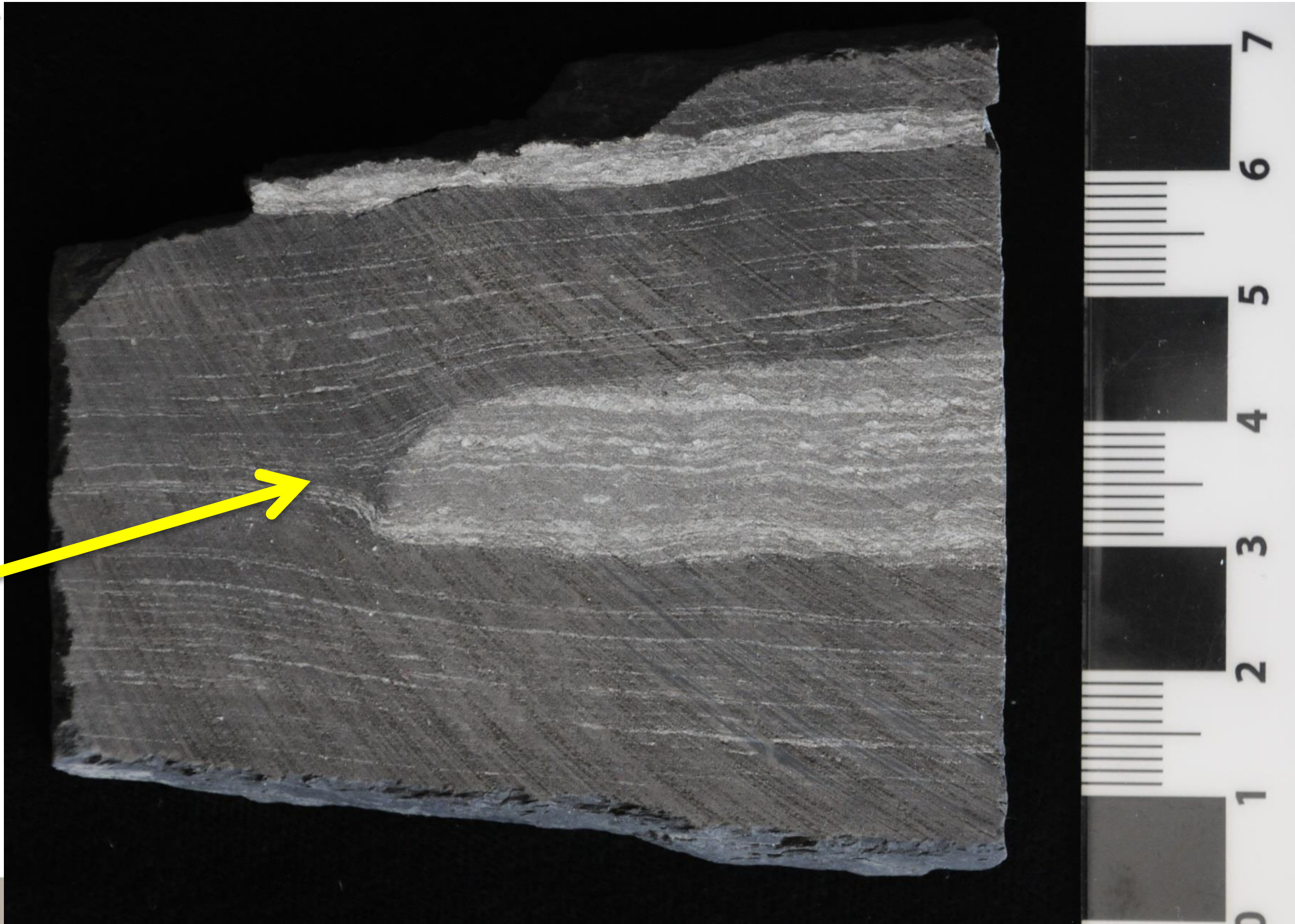




More (total 10 sections)

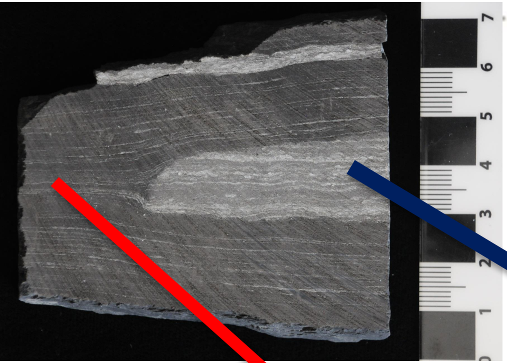
Reduction in sediment thickness (from time of concretion fm)

Loss: 41%



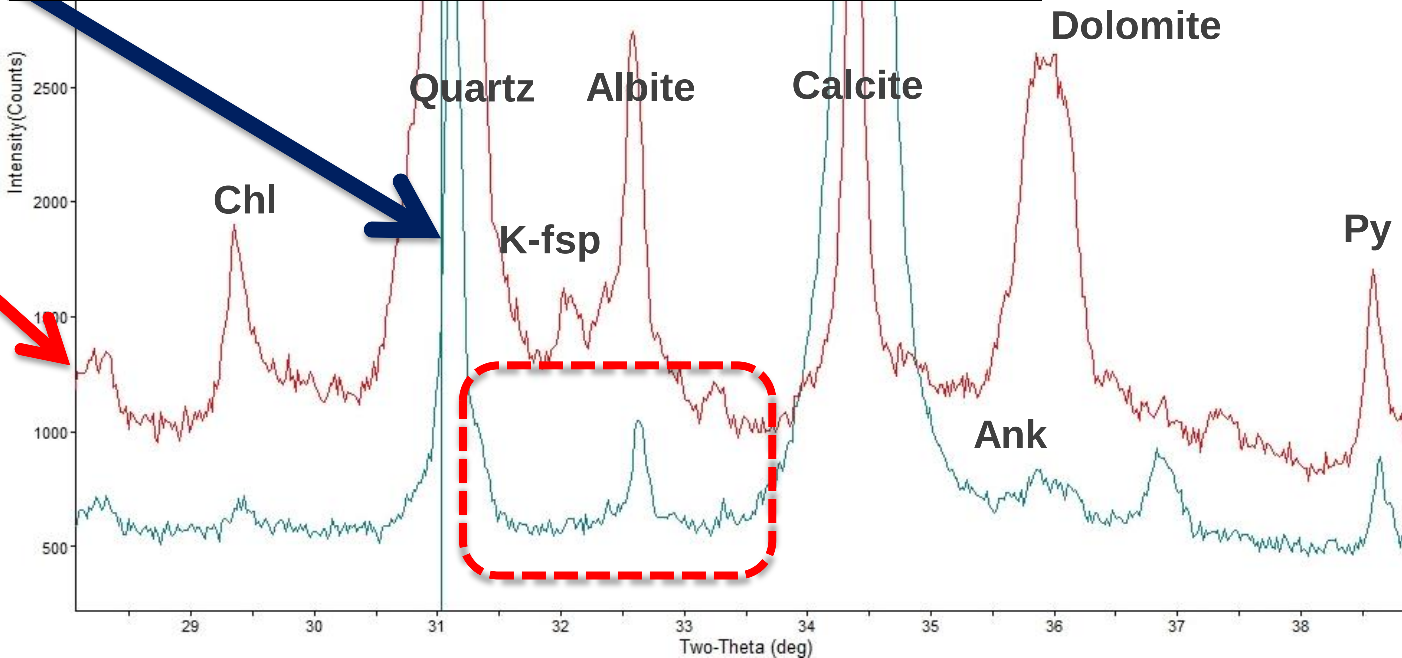
= Compaction + dissolution

XRD and XRF data – same picture!

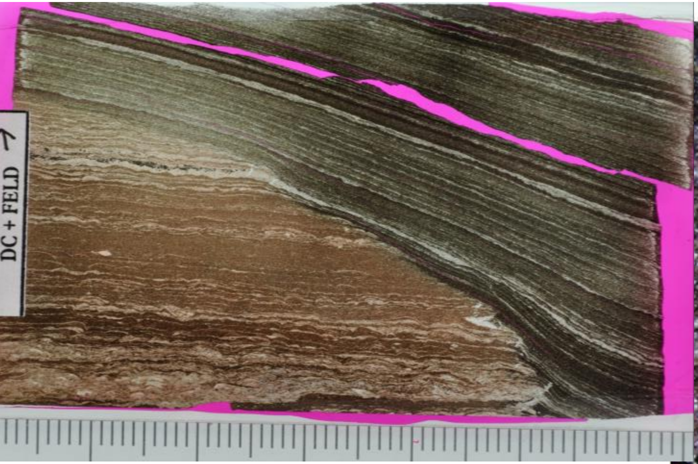


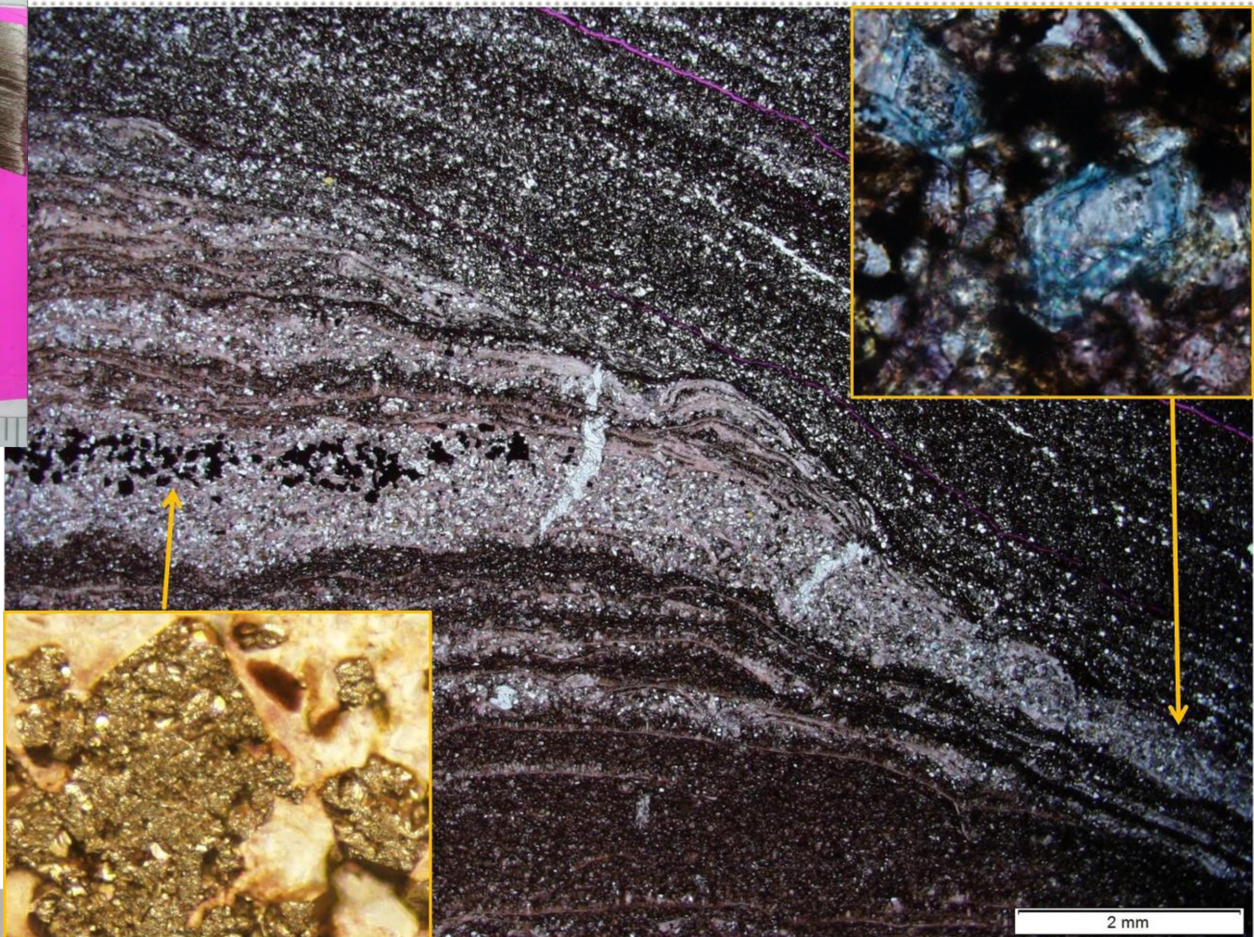
Sample ID	Depth in m	Qz	Feldspar		Carbonates			Clays		Sulphides	Ap	HCl diss. wt-%
			Ab	K-fsp	Calc	Dol	Ank	Il/mi	Chlo	Py		
"Shale"	2389	28.7	9.2	7.8	8.6	12.2	2.1	24.8	2.9	3.7		nd
Conc-1	2389	8.2	3.2		80.2	1.2	1.2	2.6	1.3	2.1		nd

Sample ID	Na%	Mg%	Al%	Si%	K %	Ca%	Ba	V	Zn	Rb	Sr	Zr	Mo
"Shale"	0.43	3.47	2.52	24.55	1.46	5.39	256	73	42	90	135	223	28
Conc-1	0.28	0.74	0.90	7.07	0.24	25.59	151	20	21	19	218	36	17



TS: mineral matter in concretion vs siltst (same “laminae”)

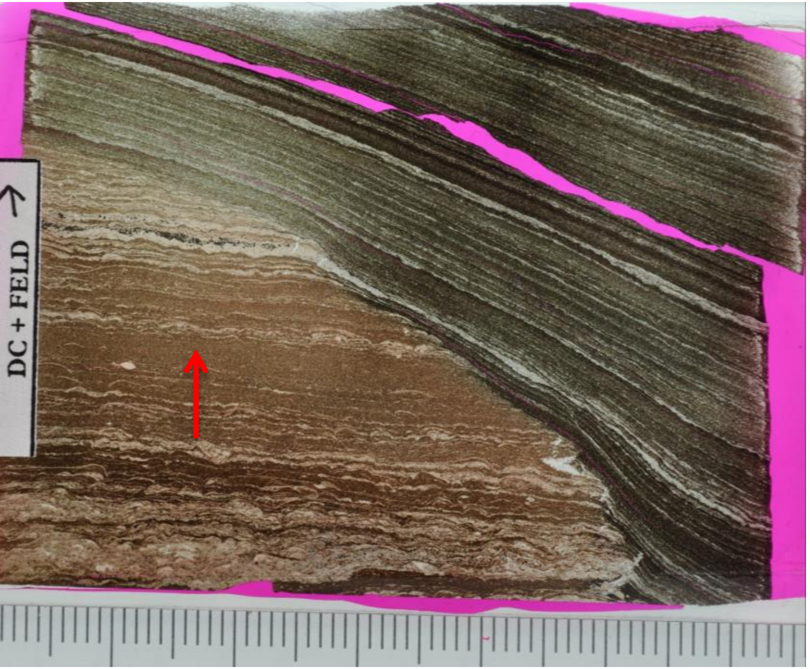


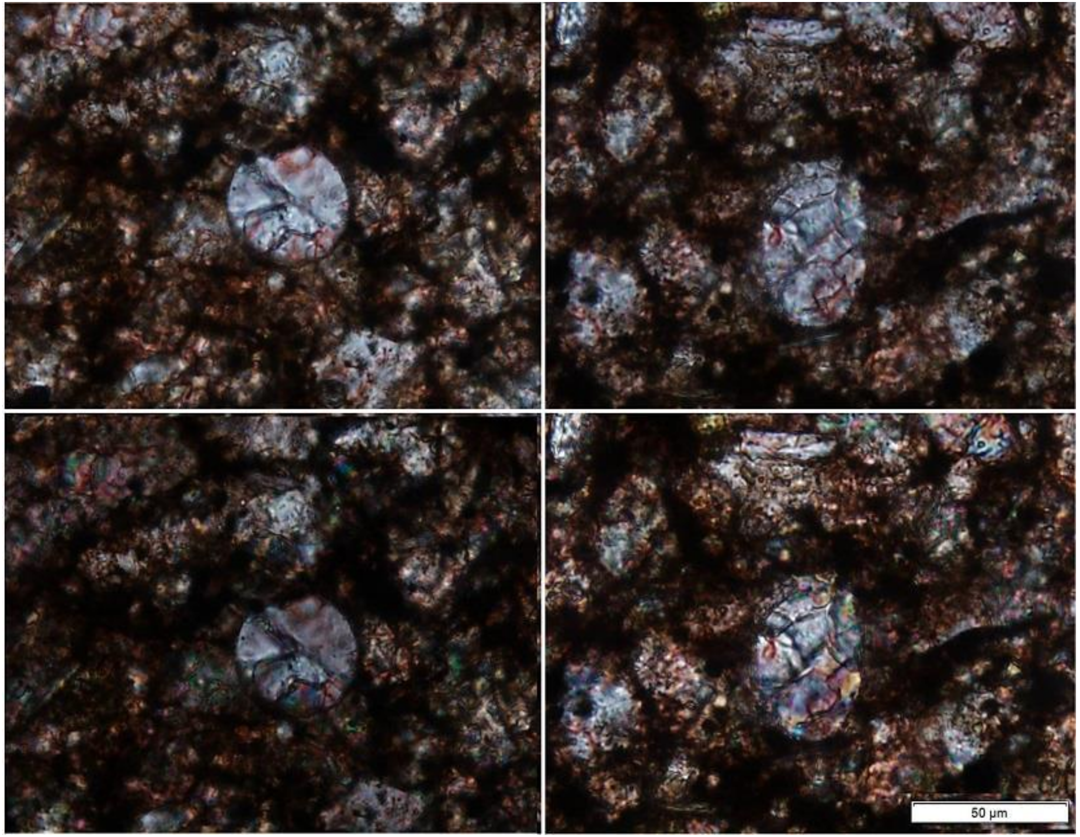


Concretion:
Calcite, pyrite

“Siltstone”:
Dolomite, Fe-dolomite,
Fe-calcite, minor pyrite

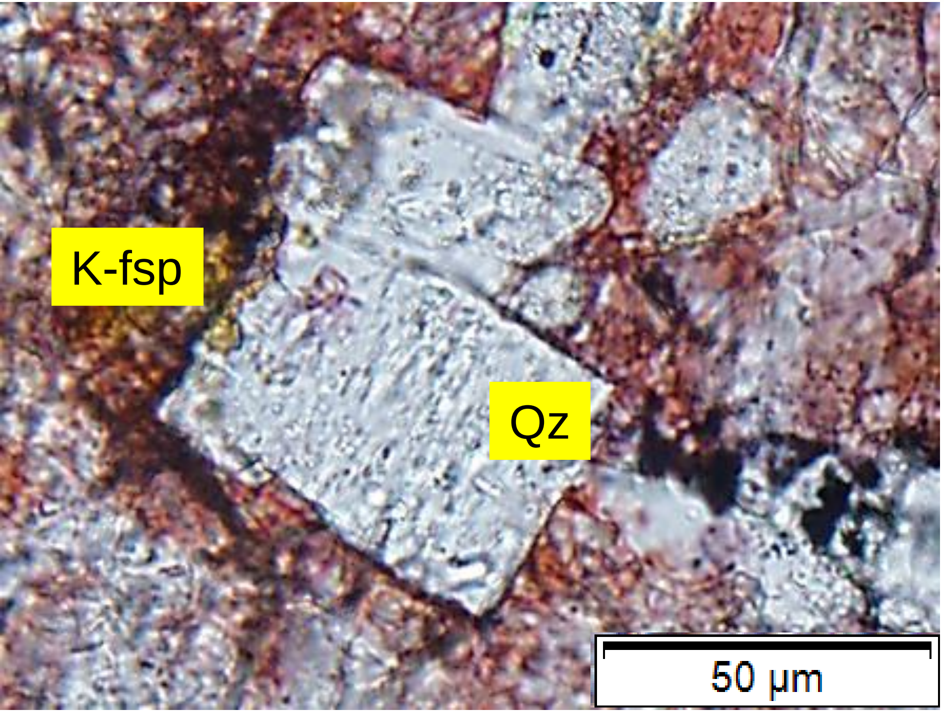
Microfossils- dinoflagellates? (Middle Montney)





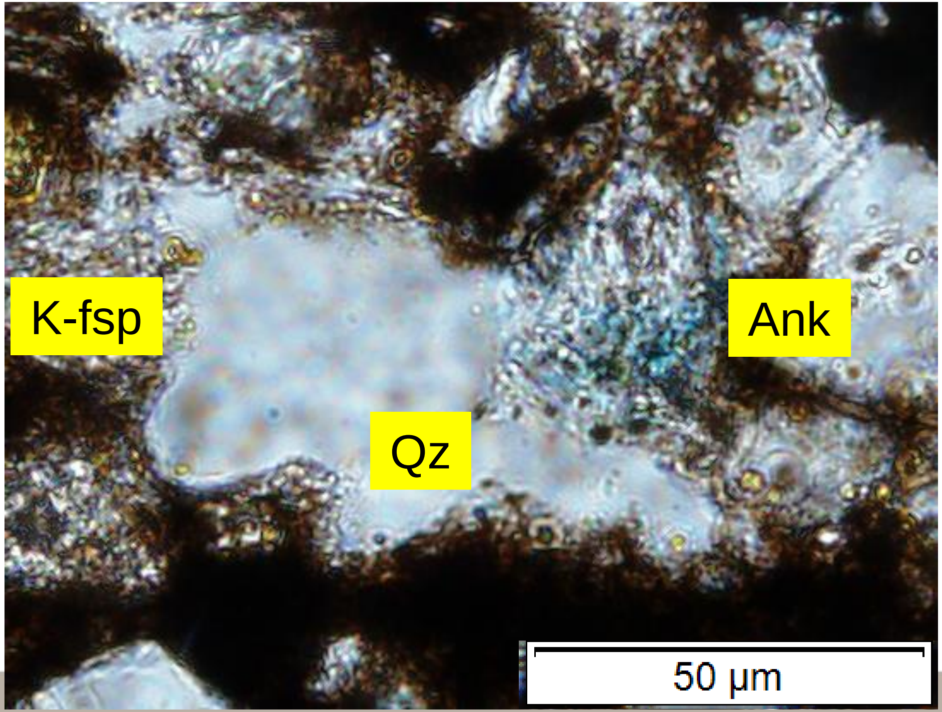
In concretions and calcite beds: Spherical and pseudo-spherical microfossils, recrystallized (dolomite, minor quartz, calcite)

Diagenetic quartz (from siliceous material!)

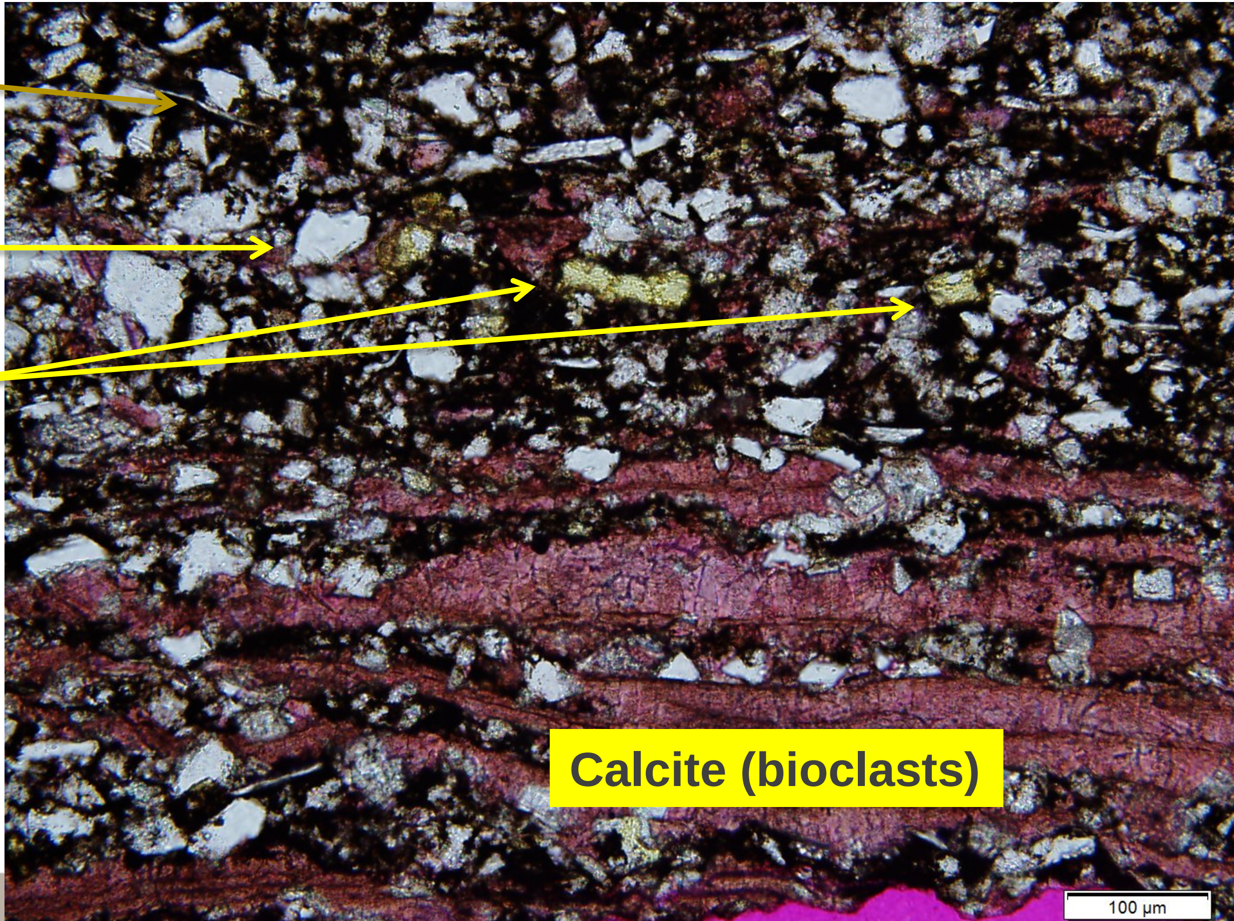


Pseudomorph (after dolomite)

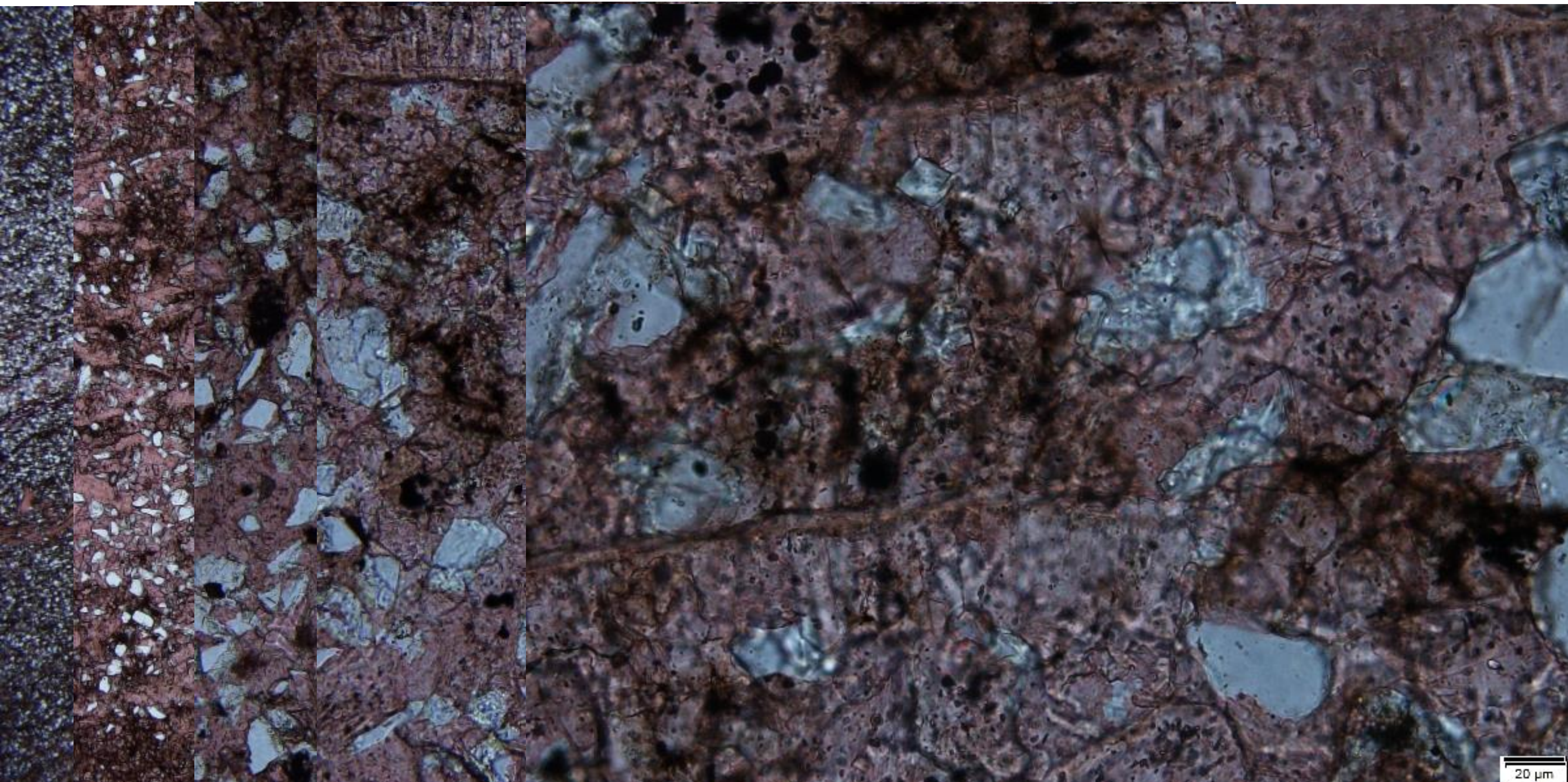
Amorphous with feldspar inclusions



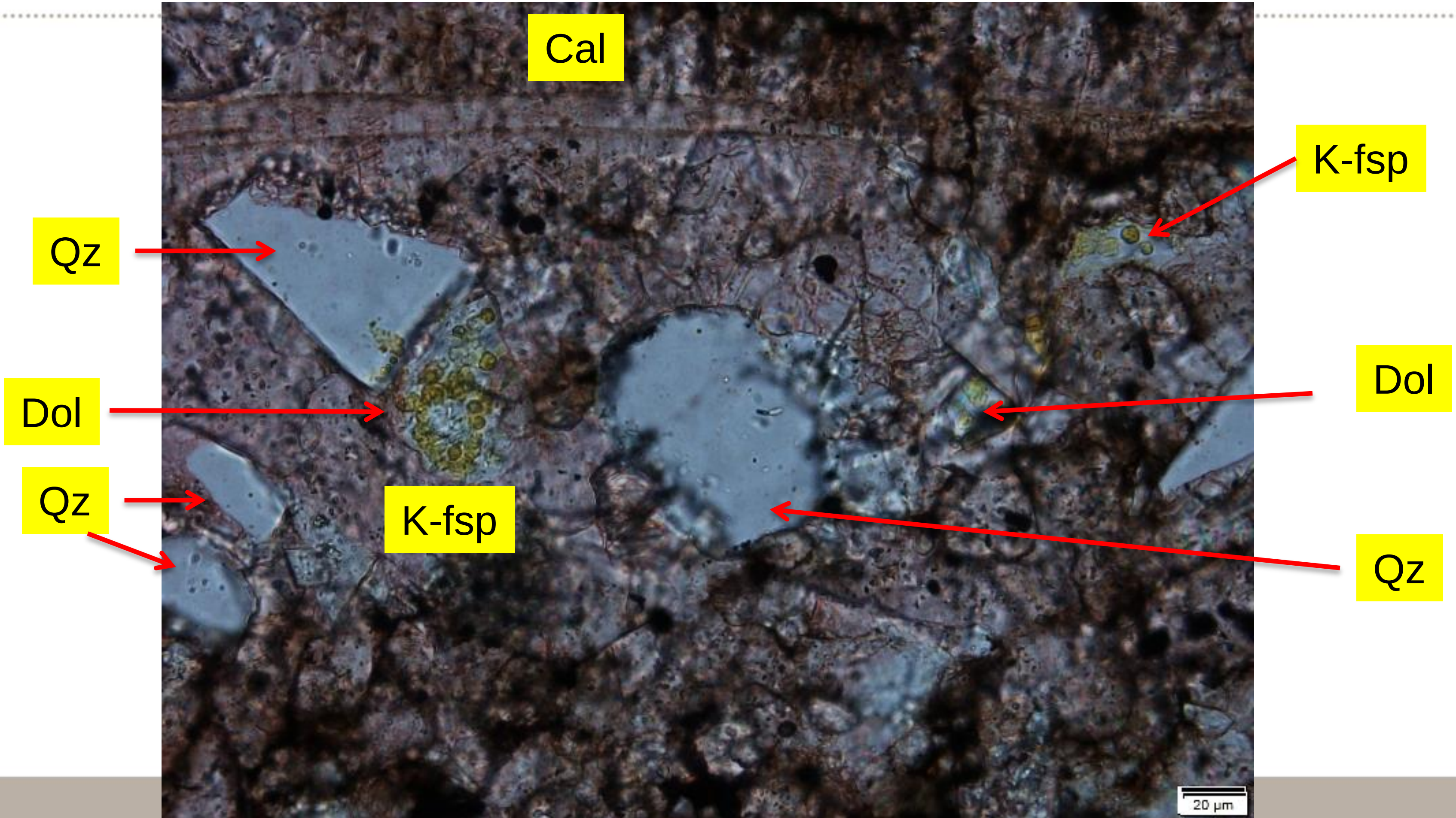
Neoformed minerals – calcite-”siltstone” transition zone



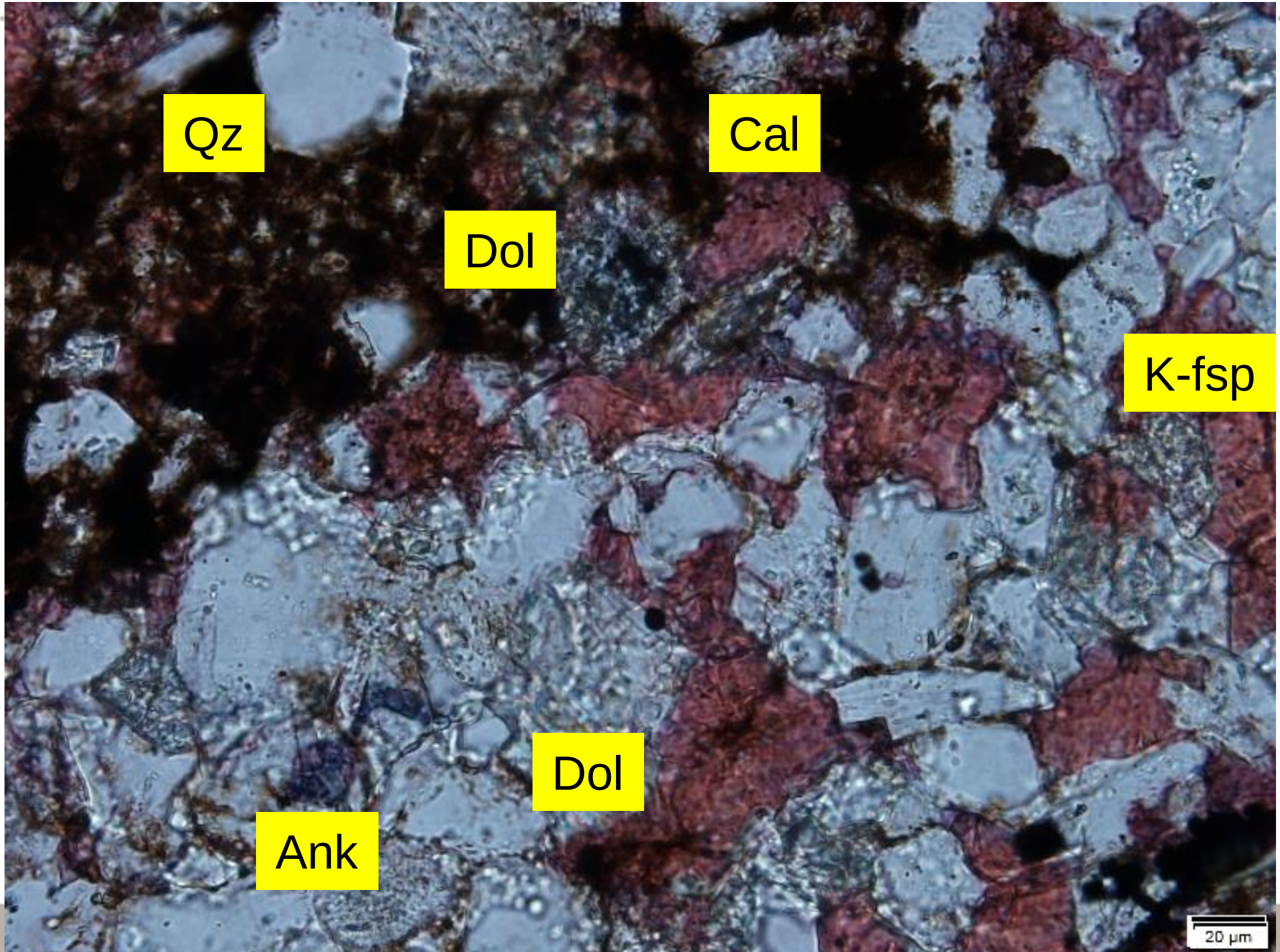
Lets look at the details



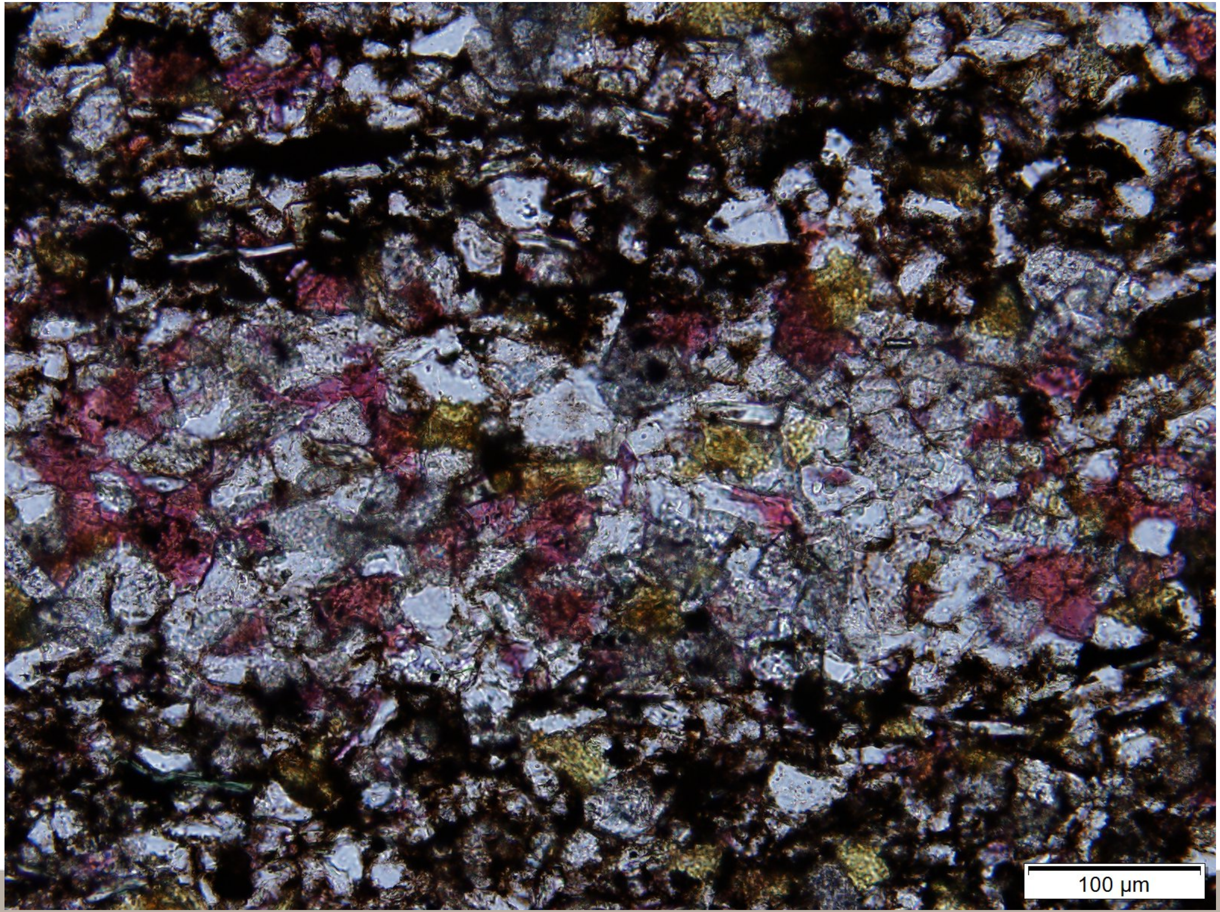
Packstone "siliciclastics"



Siltstone/shale "siliciclastics"



Do you still see all the land-derived detritus?



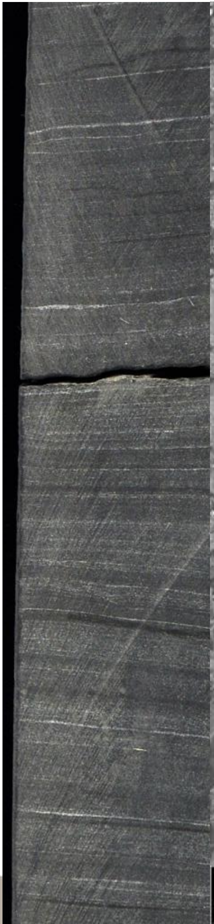
Fine-grained

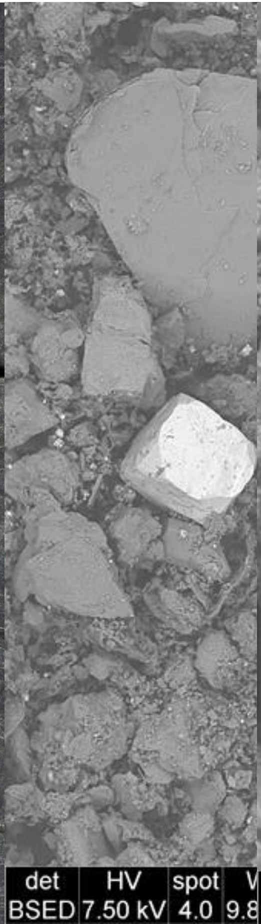
Coarse-grained (dol, qz, cc, fsp, clays)

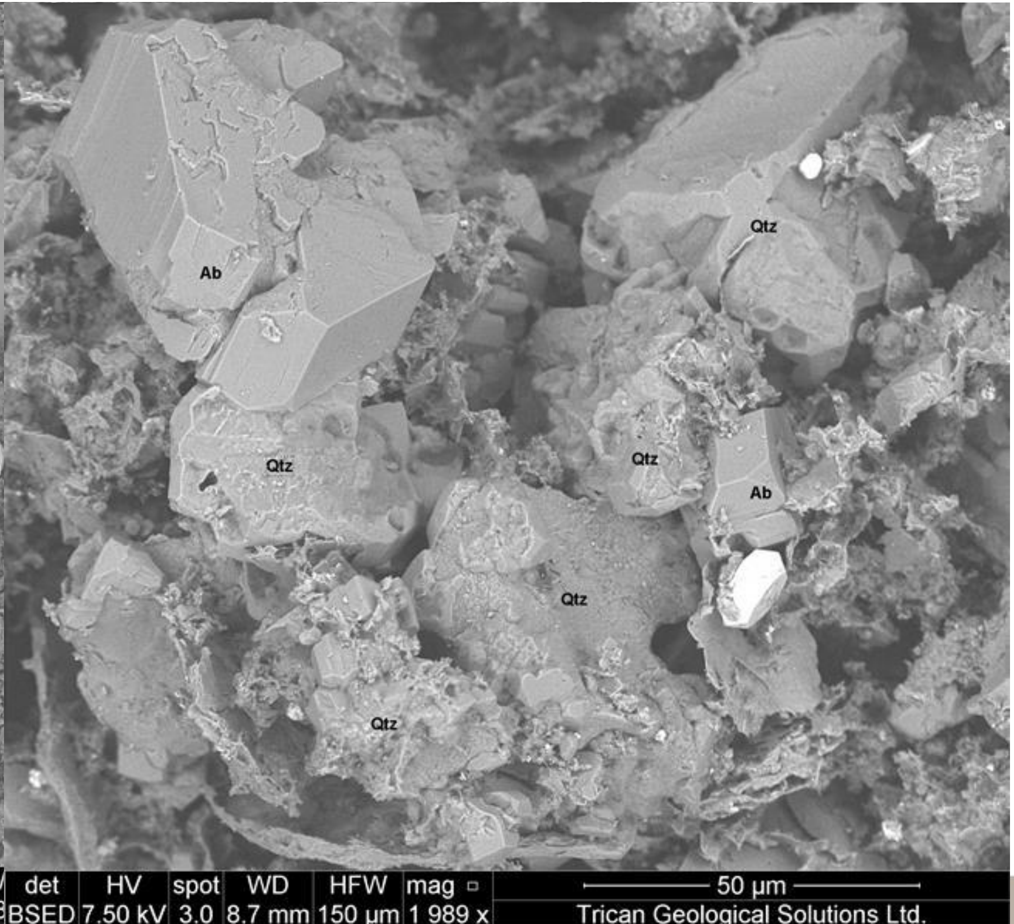
Detritus?

Fine-grained

Acidized concretions – some remains

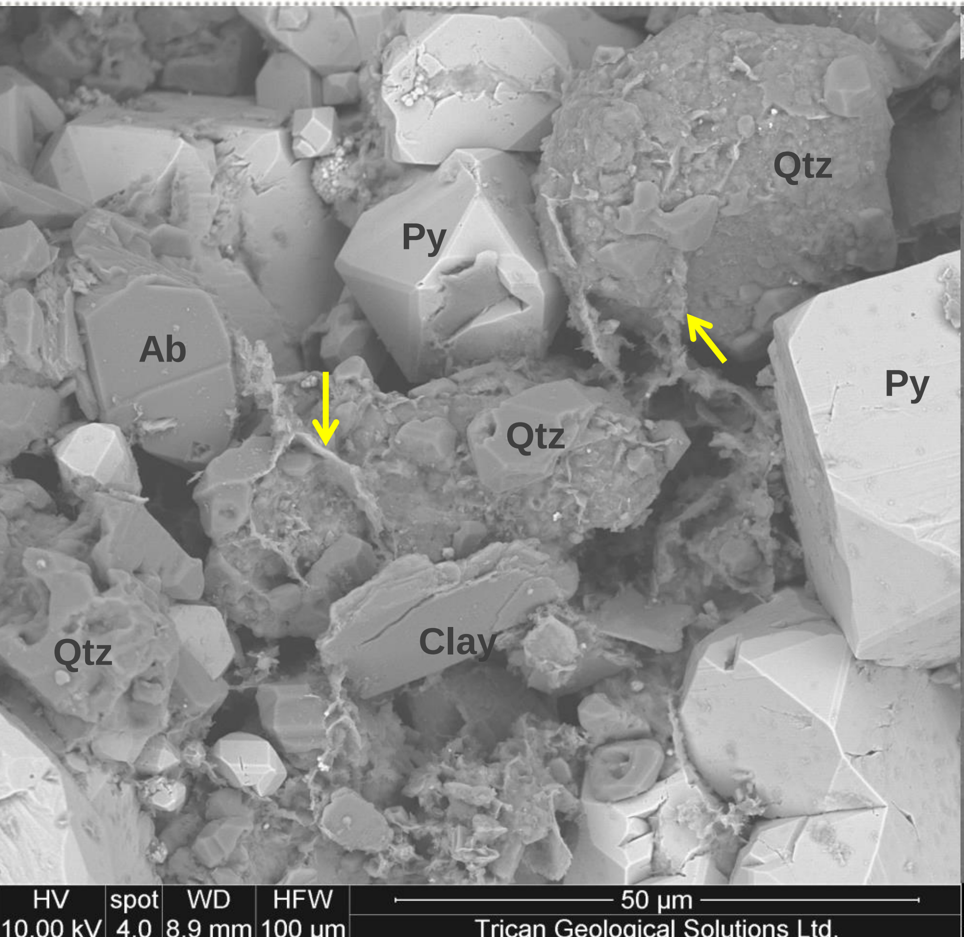


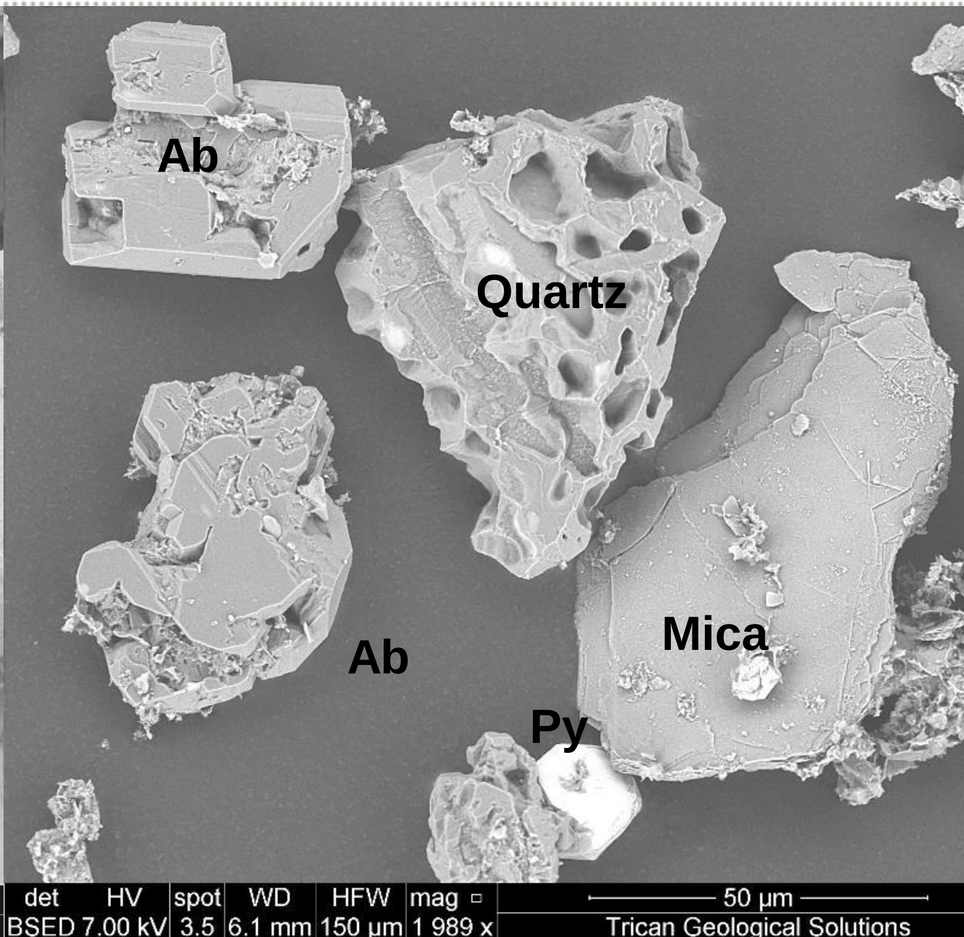


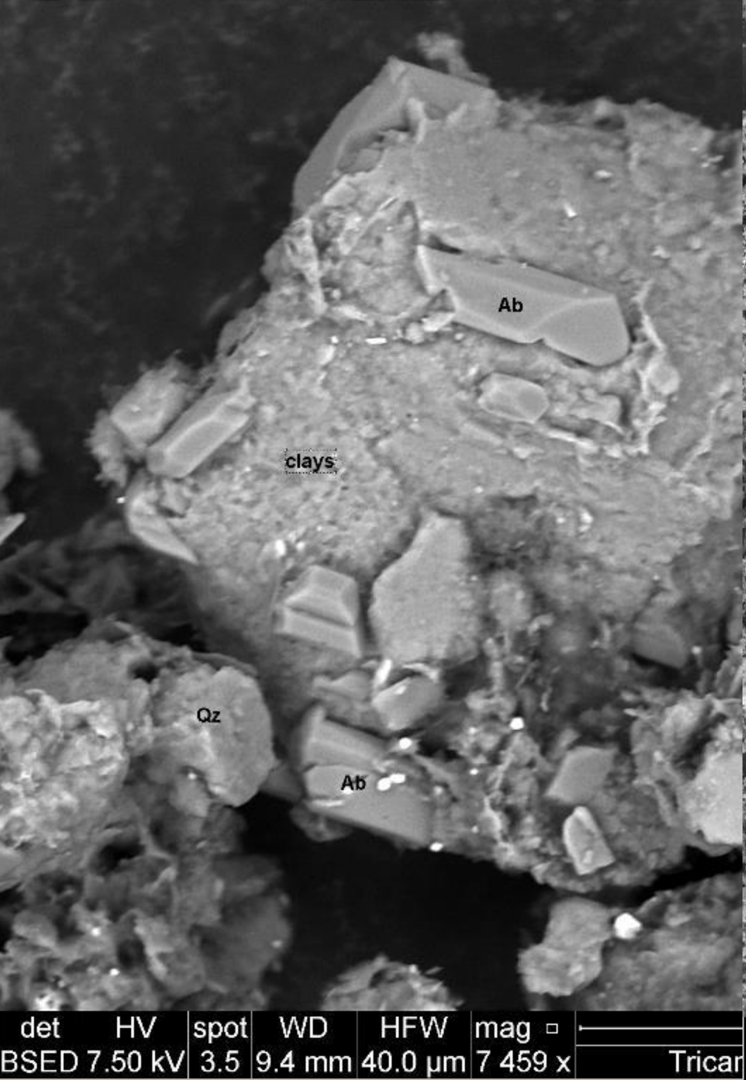
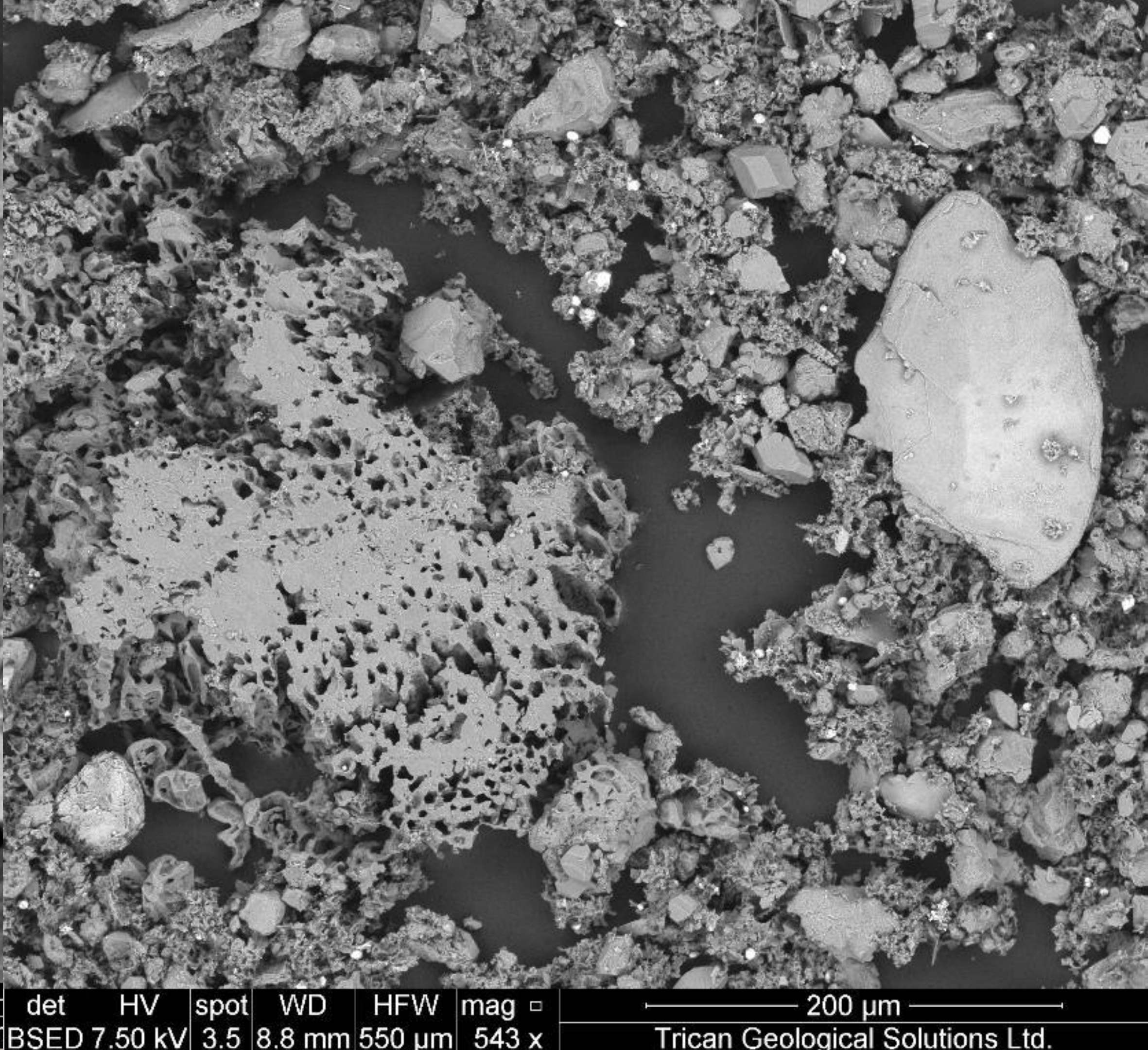


- Detrital mica
- Cubic and framboidal pyrite
- Amorphous and euhedral quartz
- Clay minerals
- Euhedral feldspar

More – neoformed minerals silt to vf sand size!

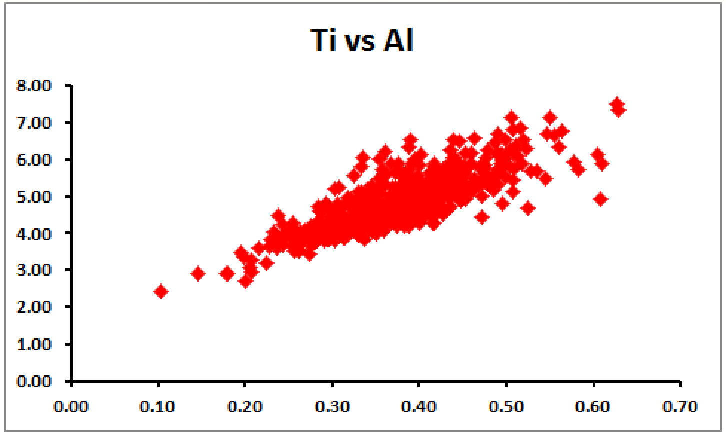


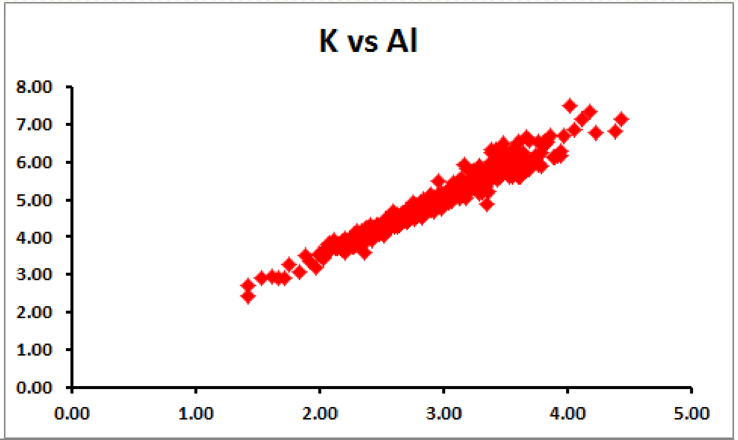


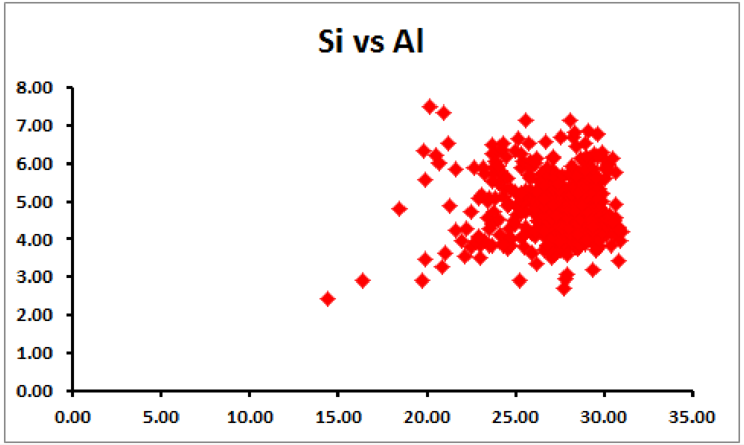

Ab
clays
Qz
Ab
det
HV
spot
WD
HFW
mag
BSED
7.50 kV
3.5
9.4 mm
40.0 µm
7 459 x

det
HV
spot
WD
HFW
mag
200 µm
BSED
7.50 kV
3.5
8.8 mm
550 µm
543 x
Trican Geological Solutions Ltd

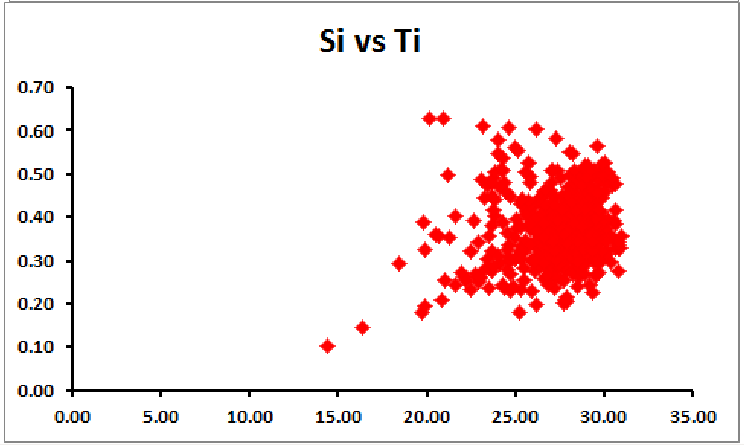
SEM shows only overgrowth! What about “real” evidence for “biogenetic” quartz?

XRF data indicate a poor correlation between Si and “typical” detrital indicators









What about original textures?

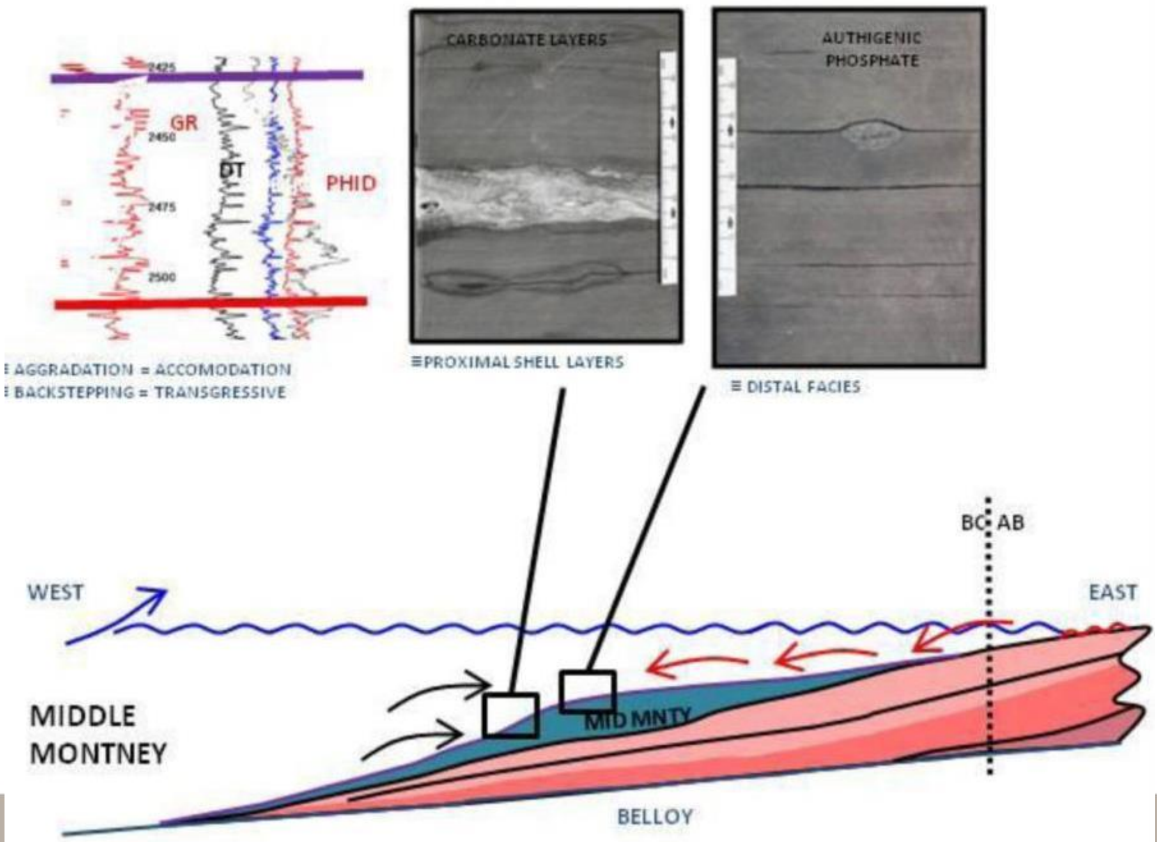
-bedding-parallel laminae
-cross-bedding
-convolute bedding
-concretion
-ripple

⇒ Active sediment deposition and bottom material movement – not chaotic – shells are rarely broken and concave down!

⇒ Some features possibly result of diagenetic processes!

Middle Montney – so far

Carbonate layers **Phosphate nodules**



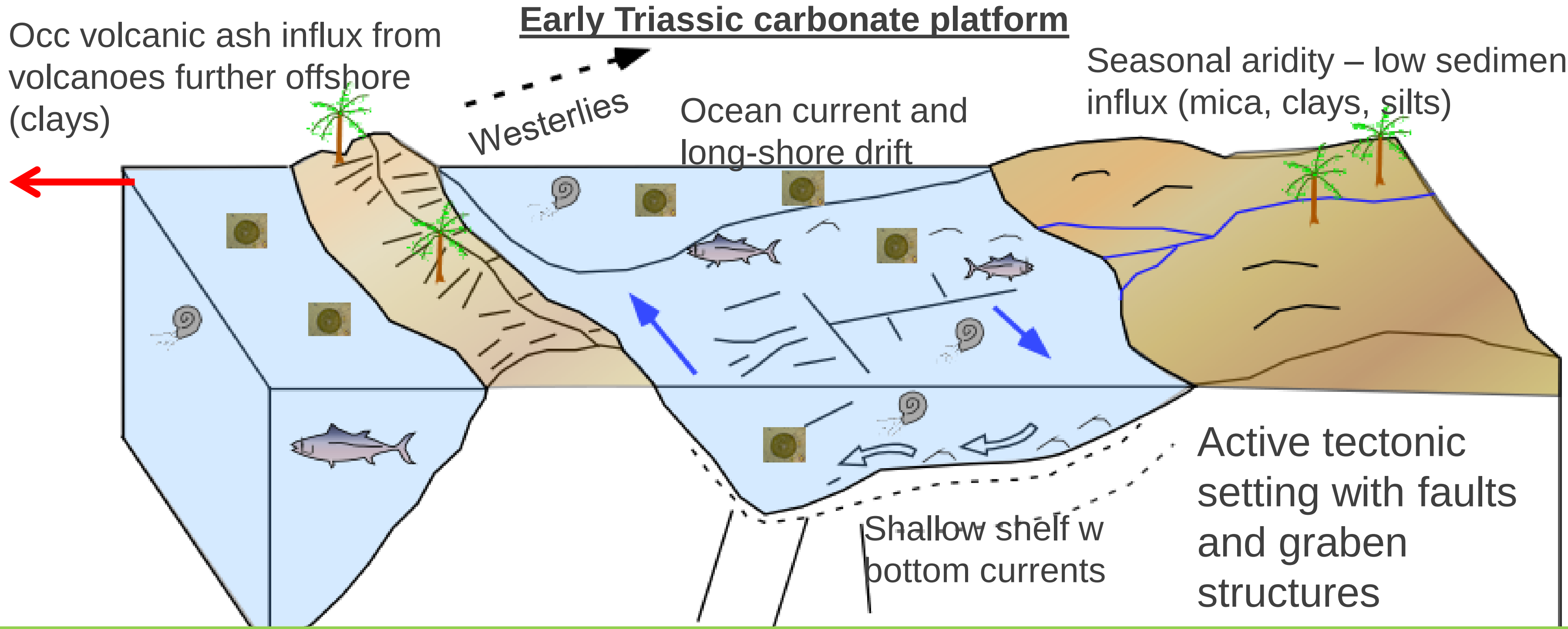
Wilson et al., 2012: **Biostratigraphy of the Montney Formation: From the Alberta and British Columbia subsurface, to the Outcrop.** Search and Discovery Article #50934 (2014)

Paleosetting Early Triassic

- Dry hinterland – little continuous sediment influx (aeolian and fluvial)
- Warm narrow ocean passage (back-arc setting due to subduction process)
- Shallow shelf with flourishing bivalve community (species diversity very limited!) – normal marine conditions with surface plankton (carb+siliceous)

https://www2.nau.edu/rcb7/namTr245.jpg

Middle Montney depositional setting



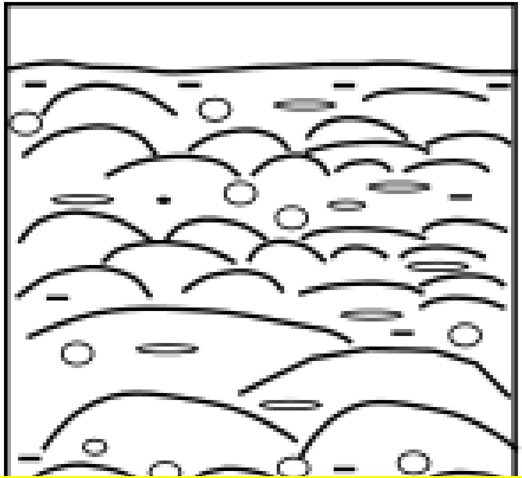
Normal marine conditions – aragonitic sea with siliceous and calcareous plankton
Abundant pectinoids in shallow carbonate mud system, common strong bottom water currents due to tidal and narrow/shallow seaway settings

Sediment Transformation- from carbonate mud to dolomitic "siltstones"

Deposition

Bioclasts, carb mud
Aragonite, Mg-calcite

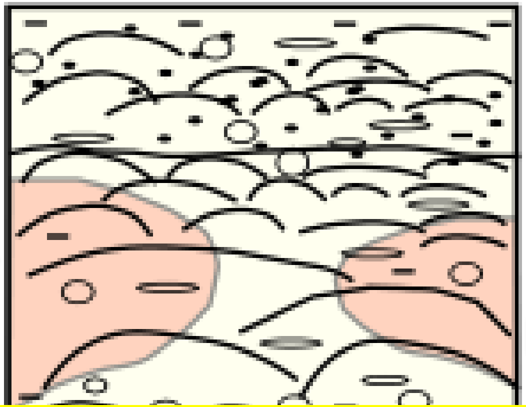
Detrital influx small except along shoreline: Mica, clays, qz, rare fdsp, dol,



Early Diagenesis

Pyrite fm
Opal-A -> Opal CT
Calcification (nodules)
Dolomitization

REDUCTION: Ca^{2+}, Sr^{2+}



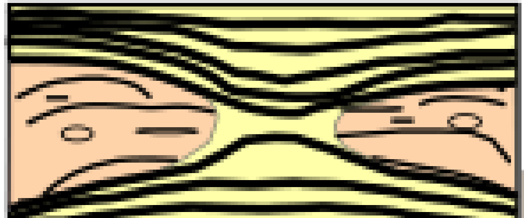
Progressive Diagenesis

Compaction & dewatering

Severe dolomitization, almost complete loss of calcite
Opal CT -> Chert/ quartz
Dissolution & neoform of clays, fdsp, qz

Massive calcium transformation (aragonite & calcite -> dolomite)

Heat and fluid flow elevated by active subduction, faults



100-180 m thick carbonate package (packed bimicrite-fossiliferous biomicrite) => 60 m dolomitic "siltstone"

Thanks for listening! Questions?