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

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Search and Discovery Article #10905 (2017)**
Posted January 23, 2017

*Adapted from oral presentation given at AAPG Annual Convention & Exhibition, Calgary, Alberta, Canada, June 19-22, 2016
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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


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).
The Middle Montney – a dirty old carbonate formation with a secret past?

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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 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

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

Shale/arg. siltstone
Distal shelf
Siltstone, arg. & shale
Proximal shelf
Sst/siltstone & shale, coquina

http://www.canadiandiscovery.com/
http://ags.aer.ca/publications/chapter-pdfs
Characteristic Montney “dolomitic siltstone w shale”

Fine-grained

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

Fine-grained

Detritus?
This talk will change your view of the Montney!

Have you ever thought that the Middle Montney may represent a true carbonate ramp deposit?
The “New” Montney: A formation that revolutionizes our view about Earth and geological dynamics!

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

“Dolomitic Siltstone” (present)

Fluids, Temp, P, Time and ?
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)

**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.

**Siliciclastic (aeolian) shelf depositional setting**

**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
occ. articulated bivalves

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

Disarticulated bivalves
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

**Total carbs: 86% - acid solub: 85%**

<table>
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<th>Sample ID</th>
<th>Na%</th>
<th>Mg%</th>
<th>Al%</th>
<th>Si%</th>
<th>K%</th>
<th>Ca%</th>
<th>Ba</th>
<th>V</th>
<th>Zn</th>
<th>Rb</th>
<th>Sr</th>
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<td>30.60</td>
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<td>15</td>
<td>11</td>
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<td>29</td>
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**Quartz Illite/mica**

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<th>Sample ID</th>
<th>Qz</th>
<th>Feldspar</th>
<th>Carbonates</th>
<th>Clays</th>
<th>Sulphides</th>
<th>HCl diss. wt-%</th>
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<td>8.4 Ab</td>
<td>12.9 Calc</td>
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<td>3 Ab</td>
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</table>

**Calcite**

**Quartz**

**Dol**

**Py**

**K-fsp**

**Ab**

**Illite/mica**
Where is the feldspar?

Common perception: Detrital
Reduction in sediment thickness (from time of concretion fm)

Loss: 41%

= Compaction + dissolution
XRD and XRF data – same picture!
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

- Mica (detrital)
- Quartz
- K-feldspar
- Calcite (bioclasts)
Let's look at the details
Packstone “siliciclastics”
Siltstone/shale “siliciclastics”

- Qz
- Cal
- Dol
- K-fsp
- Ank

Legend:
- Qz: Quartz
- Cal: Calcium
- Dol: Dolomite
- K-fsp: Potassium feldspar
- Ank: Ankerite

Scale: 20 μm
Do you still see all the land-derived detritus?

Fine-grained

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

Fine-grained

Detritus?
Acidized concretions – some remains

- Detrital mica
- Cubic and frambooidal pyrite
- Amorphous and euhedral quartz
- Clay minerals
- Euhedral feldspar
More – neoformed minerals silt to vf sand size!
Various samples! Not cherry picked!

Trican Geological Solutions
– 621-37th Ave NE | Calgary | AB | T2E 2M1 | 403.250.5582 | www.trican.ca

2392.85m
Qtz
Qtz
Qtz
Qtz & Clay
Ab
Ab
Clay

Ab
clays
Gz
Ab
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
- convoluted 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)
Middle Montney depositional setting

Occ volcanic ash influx from volcanoes further offshore (clays)

Early Triassic carbonate platform

Westerlies
Ocean current and long-shore drift
Seasonal aridity – low sediment influx (mica, clays, silts)

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

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

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

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?