Alberta Hydrocarbon-Bearing Shales and Siltstones

Steve Lyster and Dean Rokosh

Alberta Geological Survey

February 11, 2014

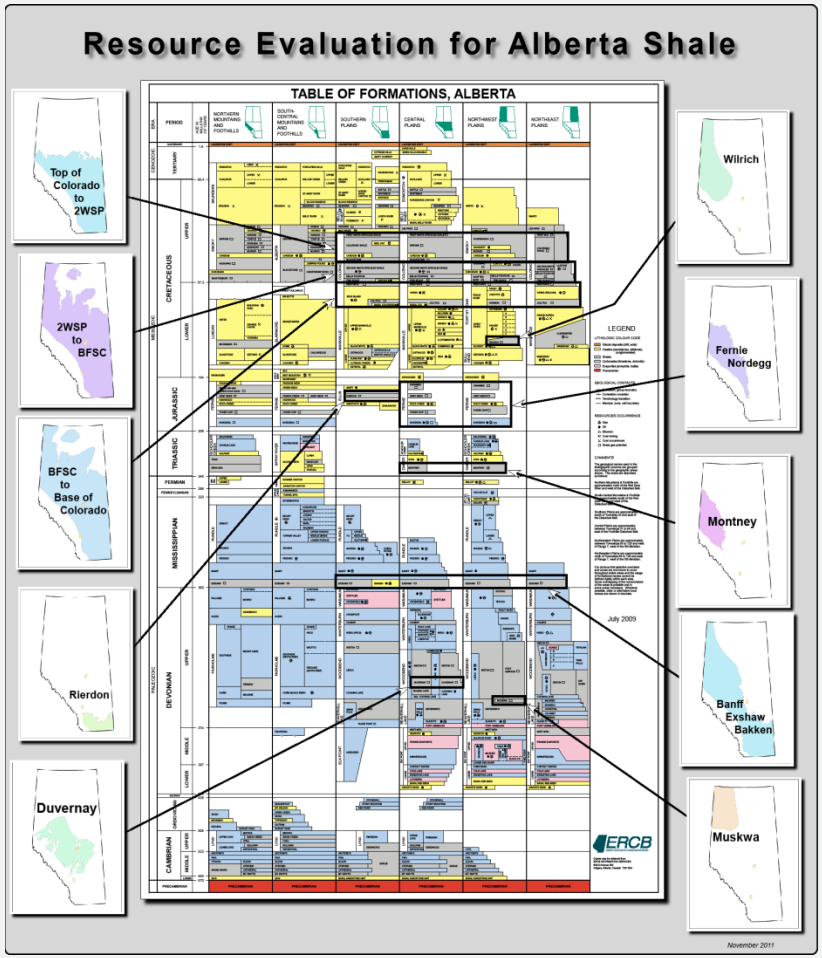
Outline

- Alberta Shale Project
- Data Collection
- Resource Evaluation Methodology
- Porosity and Grain Density
- Assessed Shales and Siltstones
- Discussion

Alberta Shale Project

- Shale is a hot topic in the industry
- Land sales are significant (>$3B in 2011)
- Drilling (jobs, regulation)
- Conventional production is declining
- Environmental issues (water, fracking)
- Need to know the “size of the prize”

Alberta Shale Project



- Duvernay
- Muskwa
- Montney / Doig Siltstone
- Banff / Exshaw / Bakken
- Fernie / Nordegg
- Wilrich
- Rierdon
- Colorado

What is a shale-hosted unconventional hydrocarbon ?

- Shale gas typically refers to hydrocarbons both sourced and trapped within a source rock, either by adsorption onto organic matter or trapped as free gas in very low permeability/porosity shale.

- The hydrocarbon can be oil, gas or NGL depending on:
  1. the type of organic matter in the shale, and
  2. the thermal maturity of the organic matter

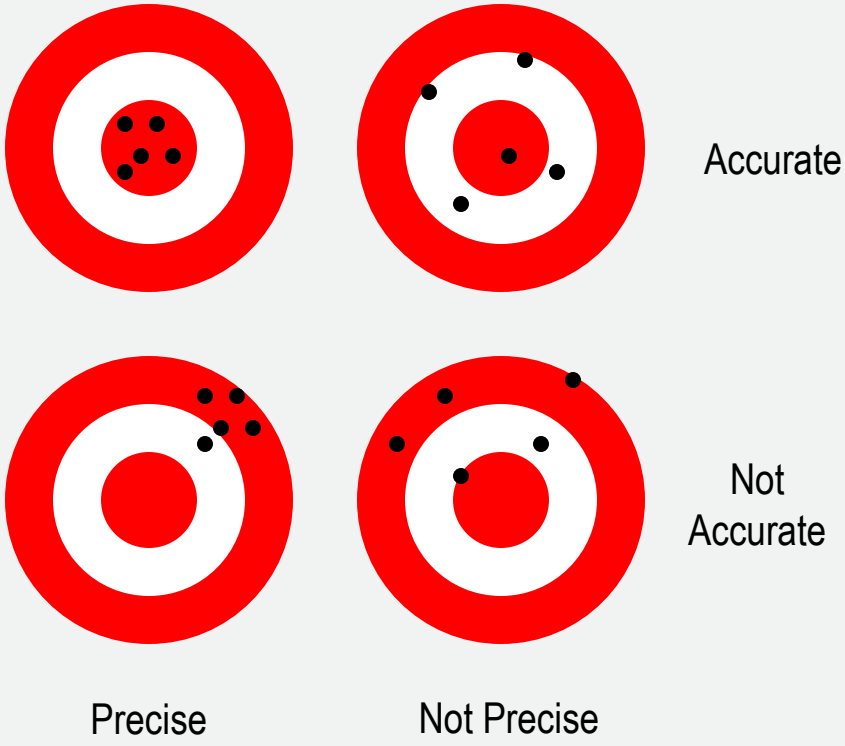
- The tight nature of the rock requires stimulation to open up conduits so hydrocarbon can move from the rock to the wellbore

Data Collection

- In an ideal setting, we collect core, sample immediately for gas content, also get fresh samples for analysis.

Data in Unconventional Reservoirs

- Standard tests weren't made for shale / siltstone
- Results may be questionable
- Have to account for uncertainty

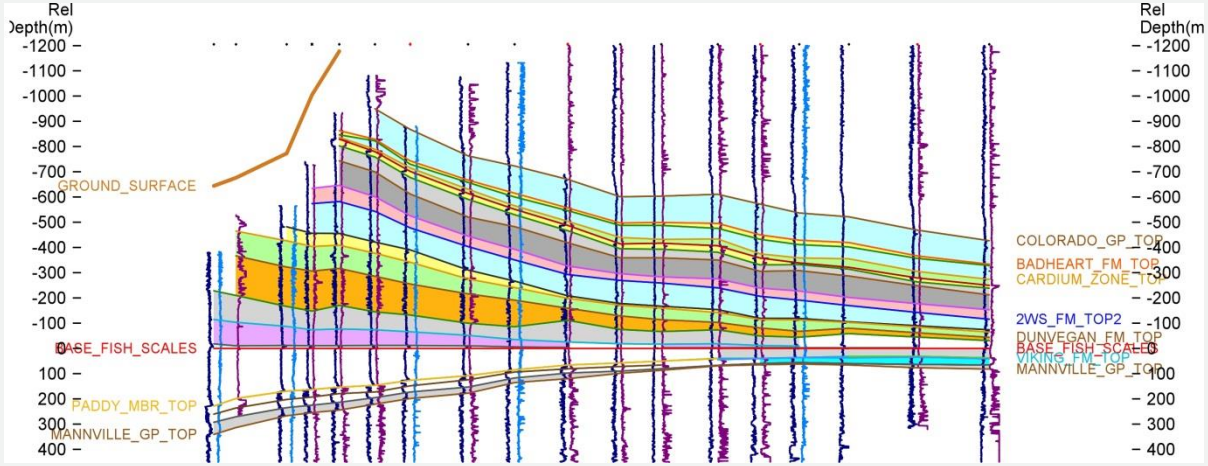


Data Sources

- Geological picks and interpretation
- Sample core from CRC
- Geophysical log analysis
- Reservoir data from IHS Accumap
- Published reports, releases

Geological Picks

- Shale resources exist in a geological framework
- Expert interpretations and picks build the skeleton of this framework
- We need to be sure we're talking about the same thing



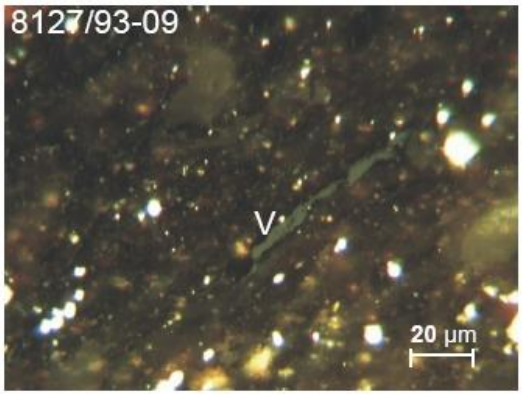
Credit: Dongqing Chen

Core Samples

- Little has been done to study shales in the past
- Samples had to be taken and tests run
- The Core Research Centre proved invaluable

Core Testing

- Thin sections
- Adsorption isotherms
- RockEval and TOC
- XRD for grain density
- Dean Stark
- Pycnometry



Methane Adsorption Isotherm

Alberta Geological Survey	**Well: 100/08-30-082-02W6/00**
Sample: 8046	**Depth: 1994.45 m**
Raw Basis	**TOC = 1.66%**

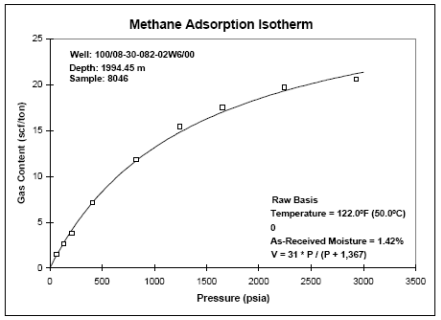
Sample Weight = 233.36 g
Particle Size = < 12 Mesh
Temperature = 122.0°F (50.0°C)
As-Received Moisture = 1.42%

Methane Adsorption

Pressure (psia)	Pressure (MPa)	Gas Content (Raw Basis) (scf/ton)	Gas Content (Raw Basis) (scc/gm)
64	0.44	1.5	0.05
135	0.93	2.7	0.08
212	1.46	3.8	0.12
411	2.83	7.2	0.22
829	5.72	11.8	0.37
1,247	8.60	15.4	0.48
1,654	11.40	17.4	0.54
2,244	15.47	19.7	0.61
2,936	20.24	20.6	0.64

Langmuir Coefficients V = 31.1 * P / (P + 1,366.7)

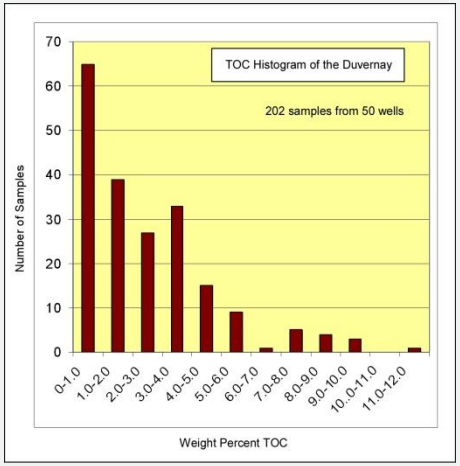
PL (psia)	PL (MPa)	VL (Raw Basis) (scf/ton)	VL (Raw Basis) (scc/gm)
1,366.7	9.42	31.1	1.0

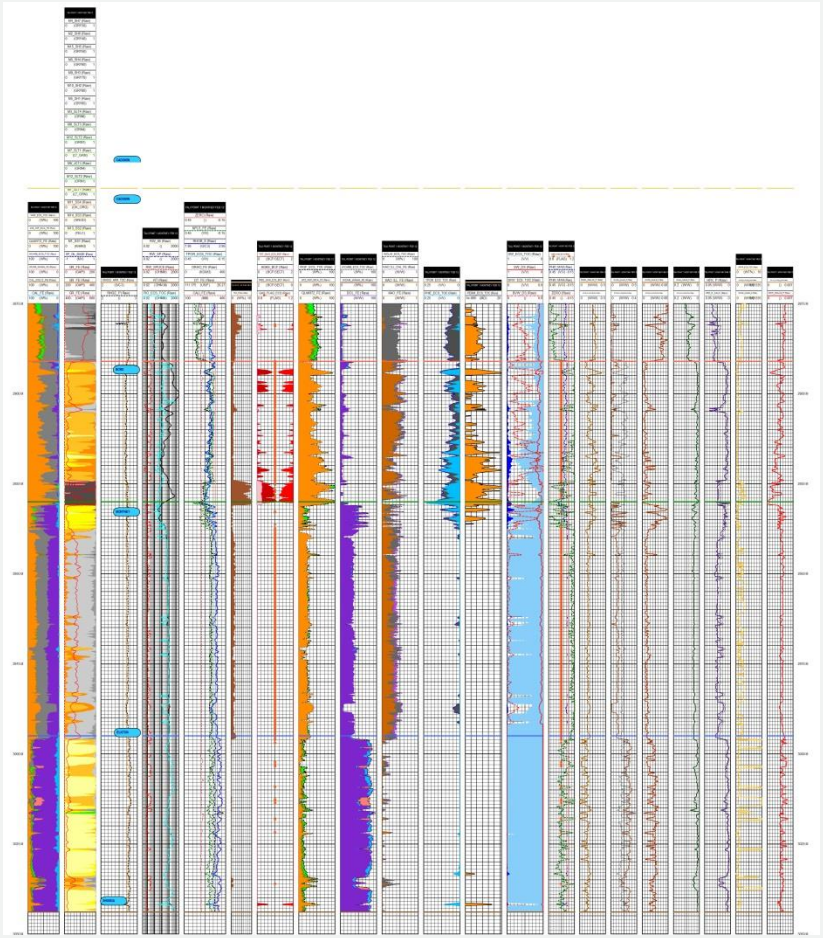


Schlumberger

Geophysical Log Analysis

- Once the framework is built, fill in properties
  - Net Shale
  - Porosity
  - Total Organic Carbon
- Calibrate to core samples





Credit: Bob Everett

Reservoir Data

- Reservoir conditions have an effect on storage
- Gas is compressed at depth
- Oil also affected, mainly by dissolved gas
- Data is from early test wells or conventional reserves

Field/Strike		Field	Pool	Gas in Place	Recovery Factor	Producible	Initial Reserves	Net Cum. Prodn	Remaining Reserves	Initial Soln Reserves	Area	Average Pay Thickness		Porosity	Gas Saturation	Initial Pressure	Temp	Compressibility	Raw Gas Relative Density	M3/M3	Gas-Water Interface	Gas-Oil Interface	Mean Formation Depth	Analysis Code	Discovery Year	Discovery Well	Formation Top	Formation Base	kB	Zone BaseType
GRS		Field and Pool Codes		Raw Gas			Marketable Gas			Solution Gas	Reservoir Parameters												Other Pool Information							
ALBRIGHT	MONTNEY B	400	524002	61	0.75	46	41		41		64	9.2	589	0.07	0.75	21740	83	0.878	0.67	10.384			2549.1	VO	2005	12-27-071-09W6	2541	2557.2	770.1	PB
ANTE CREEK	MONTNEY G	550	524007	251	0.75	188	179	81	98		513	4.1	2103	0.134	0.8	17140	67	0.835	0.67	18.405			1918.5	PD	2003	13-30-066-24W5	1923.6	1932.7	735.2	PB
ANTE CREEK NORTH	MONTNEY A	560	524001	275	0.75	206	185	103	82		573	2.74	1570	0.128	0.8	16640	67	0.813	0.7	17.53		-1125.5	1894.6	VO	2001	06-07-067-23W5	1896.5	1902	788.6	PB
ANTE CREEK NORTH	MONTNEY D	560	524004							2									0.72					2001	01-01-068-24W5				
BEATON	MONTNEY C	1070	524003	12	0.75	9	9	6	3		64	2	128	0.18	0.65	7150	34	0.857	0.64	9.042			893.5	VO	2000	12-22-087-02W6	892	895	697.1	PB
BEATON	MONTNEY E	1070	524005							6									0.66					2007	01-01-089-02W6				
BELLOY	MONTNEY A	1130	524001	534	0.8	427	406	348	58		1957	1.55	3033	0.139	0.6	8290	40	0.862	0.63	7.287		-493.5	1069.8	PD	1969	11-18-078-01W6	1068.9	1070.7	580.9	PB
BELLOY	MONTNEY D	1130	524004	25	0.8	20	19	13	6		64	2.6	166	0.18	0.7	10780	40	0.834	0.61	14.797			1075.3	VO	1997	08-33-078-02W6	1073	1077.5	567.7	PB
BELLOY	MONTNEY F	1130	524006	111	0.75	83	79	65	14		128	9.95	1274	0.13	0.6	10340	40	0.838	0.62	8.744			1067.6	VO	1995	06-22-078-01W6	1060	1075	576	PB
BELLOY	MONTNEY G	1130	524007	22	0.8	18	17	8	9		128	2.2	282	0.12	0.55	10690	40	0.834	0.62	7.686			1070.1	VO	1997	12-02-079-02W6	1068.3	1070.5	567	PB
BELLOY	MONTNEY H	1130	524008	49	0.85	42	40	14	26							10300	53	0.866	0.61				1459.5	PE	2000	08-33-078-02W6	1457	1462	570.1	ZB
BELLOY	MONTNEY K	1130	524011	8	0.75	6	5	5			10	4.5	45	0.18	0.85	9980	38	0.84	0.61	16.622			1015.7	CP	1987	08-19-078-25W5	1013.5	1018	574.5	PB
BELLOY	MONTNEY L	1130	524012	3	0.75	2	2	2			16	1	16	0.18	0.85	9950	39	0.851	0.61	16.305	-428.6		1001.1	CP	2001	13-29-078-25W5	1000.2	1002	573.4	GW
BELLOY	MONTNEY M	1130	524013	36	0.75	27	26	15	11		227	1.7	386	0.15	0.6	9790	43	0.852	0.61	9.307			1145.4	PD	2001	06-22-078-01W6	1144.5	1146.2	575.9	PB
BERWYN	MONTNEY D	10060	524004	15	0.75	11	10	9	1		85	1.6	136	0.18	0.7	7910	31	0.866	0.59	10.766			853.7	PD	2006	06-16-082-24W5	852.9	854.5	588.9	PB
BERWYN	MONTNEY E	10060	524005	14	0.75	11	10		10		64	2	128	0.18	0.7	7990	31	0.865	0.59	10.888			865	VO	2006	06-16-082-24W5	863.5	866.5	588.9	PB
BLUEBERRY	MONTNEY A	1470	524001	117	0.75	88	84	84			248	3.63	900	0.18	0.6	11270	48	0.832	0.64	12.96			1198.1	PD	1994	08-16-082-07W6	1192.2	1197	647.6	PB
BLUEBERRY	MONTNEY B	1470	524002	144	0.75	108	103	100	3		93	11	1023	0.18	0.6	11930	46	0.818	0.65	14.042			1254	PD	1997	08-16-082-07W6	1225	1283	647.4	PB
BLUEBERRY	MONTNEY C	1470	524003	13	0.75	10	9	9			356	1.3	463	0.06	0.5	9100	46	0.845	0.65	2.88			1228.3	CP	1973	11-16-082-07W6	1227.7	1229	653.2	PB

Reserves and reservoir data report

Published Information

Encana buys rights in hunt for liquid gas

Rebecca Penty, Calgary Herald; Postmedia News
Published: Friday, June 17 2011

Encana Corp. took part in Alberta's record land sale recently to target a new gas opportunity potentially as liquids-rich as the hottest current play in the U.S., executive vicepresident Mike Graham says.

The continent's second-largest producer of natural gas participated in the $842-million rights sale on June 1, Graham admitted, not revealing how much Encana spent or how much land it bought up.

He said the firm is trying to prove the potential of liquids-rich gas in the Duvernay formation in the Rimbey area, about 60 kilometres northwest of Red Deer.

"We're excited about results from the Duvernay," Graham said this week, noting Encana will drill three wells in the shale this year.

Graham, the president of Encana's Canadian operations, made public admission Encana was in on the bidding for oil and gas licences, a highly secretive process in which companies have to submit offers on their behalf.

Alberta oil and gas companies paid an average of $3,100 per hectare June 1 for leases or licences on 271,000 hectares -the largest sale record for the province.

Research analysts at boutique investment-banking firm Peters and Co. estimated in a note that majority of money spent -$750 million -was on deep rights likely targeting the Duvernay shale a significant portion of acquired Crown acreage is interspersed with freehold title lands, with Enc the dominant owner.

Encana owns just over 76,000 hectares of land underlain by the Duvernay, Graham said, noting competitors have been producing more than five million cubic feet of gas a day from the shale, with 50 to 200 barrels of liquids per mcf of gas.

He compared the Duvernay to the Eagle Ford shale in south Texas that has firms paying top dollar for land and competing for busy contractors to get drilling and completion work done.

Murphy Oil Corp. senior vice-president and chief financial officer Kevin Fitzgerald, who heard Graham's presentation, said the Eagle Ford play is "very hot" south of t

"The Eagle Ford is the big new play, the big current play, dov whose company paid $1,800 an acre there in 2009 -compar

The Duvernay focus is part of Encana's shift away from dry g prices closer to those of oil, which has been hovering aroun

Graham said he doesn't expect natural gas prices to move r another couple of years.

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Yoho Adds To Duvernay Acreage As Alberta Takes In $19.48 Million At Land Sale

BY RICHARD MACEDO - DEC. 5, 2013

Alberta pulled in $19.48 million at Wednesday's sale, which

The nearest Duvernay producer is Celtic's June 2012 horizontal outpost well at 01-25-59-19W5, which has produced 473 mmcf of gas with 5,371 bbls of condensate since September 2012.

average price of $300.07, which are all behind the pace set in 2012. Last year to the same point, industry had paid $1.05 billion for 2.89 million hectares at an average of $363.10.

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Changes To Completions Could Boost Duvernay Results, Conference Told

BY ELSIE ROSS - SEPT. 16, 2013 – VIEW ISSUE

The prize in the Duvernay is 100 to 120 bcf per section of gas in place with liquids rich gas of 100 to 160 bbls per mmcf (65 per cent condensate), with expected average well recoveries of approximately one million boe.

Trilogy Boosts Production During Challenging Quarter

AUG. 8, 2013 – VIEW ISSUE

Trilogy Energy Corp.'s average second quarter 2013 production improved eight per cent over second-quarter 2012 to 37,209 boe per day, thanks to success in the Montney oil and gas plays of the Kaybob area where it was focused, and despite

NewTechnology magazine

Duvernay shale development

Trilogy budgeted $75 million to manage its Duvernay land expiries in 2013 through the drilling of five or six net wells. This year, the company has drilled and completed two wells in the Tony Creek area; both wells are on production and yielding 250 to 300 bbls per mmcf of 50-degree API oil/condensate.

But the company was also faced with unanticipated plant issues, weather-related delays and operational issues during the second quarter.

Northern Gateway Pledges Ongoing Work To Address Concerns Following JRP Approval

CANADIAN WELL LOGGING SOCIETY

Shale Gas Petrophysics – Montney and Muskwa, are they Barnett Look-Alikes?

John Nieto, Robert Bercha and Jim Chan, (CANBRIAM Energy Inc, Calgary)

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This paper was prepare Logging Symposium hel

Maps, figures and equat authors. Canbriam Ene responsible for any loss, resulting from the use of

TOC. Net pay, porosity and TOC maps are presented in the paper. Further, we show that although both are prolific gas producing formations, only one, the Muskwa, can truly be called a rid shale, and silt- Muskwa, rinsically coarser, gard, the nding of

Parameter	Barnett	Muskwa	Montney
Depth, ft	6500 -8500	6000 - 9000	5000 - 6500
Gross Thickness ft	200 - 300	60 - 220	820 - 1300
Net Thickness ft	50 - 100	30 - 160	100 - 275*
Bottom Hole Temperature °F	200	150 - 190	131 - 170
TOC %	4.50%	2.5% - 4.5%	2.0% - 4.5%
Total Porosity %	4% - 5%	3% - 8%	3% - 10%*
Gas Filled Porosity %	2.50%	1% - 4.5%	2.0% - 7%
Water Filled Porosity %	1.90%	1.0% - 2.0%	1% - 3%
Kh md-ft	0.01-2	0.15-1	6 - 16.5
Gas content, scf/ton	105 - 115	10-60	16-48
Adsorbed Gas, %	20	60-85	15
Reservoir Pressure, psi	3,000-4,000	2200-2900	2600 - 3300
Pressure Gradient, psi	0.43-0.44	0.35	0.52-0.63
Well Costs, $1000	1,000	2500-3000	2,200
Completion Costs, $1000	1,250 - 750	1000-3000	2,250
Well spacing, Acres	55-160	80-320	640 - 160
Gas-in-Place, Bcf /Section	30-40	60 - 100**	6 - 60*
Historic Production area basis for data	Wise Co., Texas	N.E.B.C; Canada	Swan, Dawson BC, Canada

Source: GTI report 8365, Montgomery et. al. 2005

* Upper Montney Only

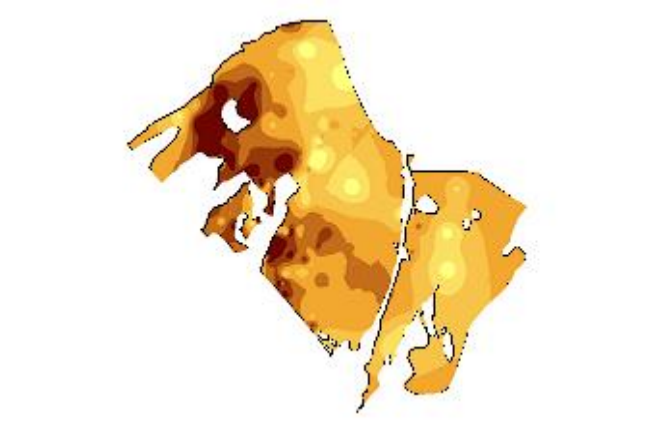
Figure 31. Summary Table of published Barnett, Muskwa and Montney Reservoir Properties.

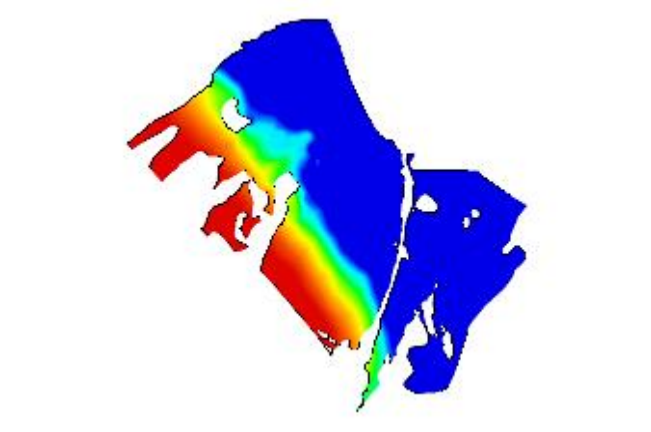
Evaluation Methodology

1. Map variables that have sufficient density
2. Calculate dependent variables
3. Determine other variables
4. Calculate resources
5. Simulate all variables

Mapping Primary Variables

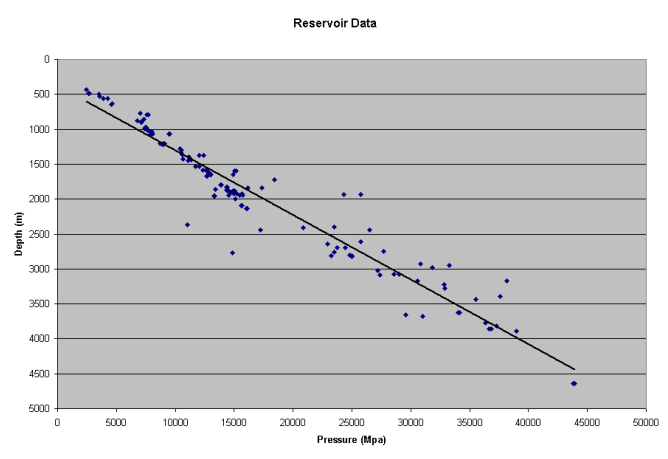
- Variables that have enough data should be mapped spatially
  - Depth
  - Gross thickness
  - Net thickness (or N:G)
  - Porosity
  - TOC
  - Vitrinite relfectance
  - Hydrogen index

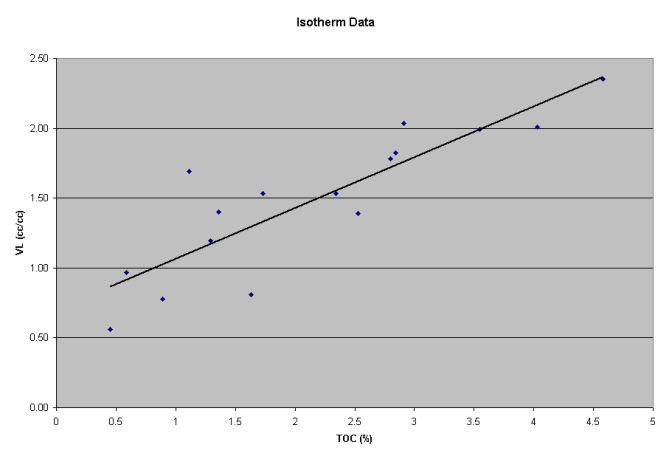




Calculating Dependent Variables

- Some variables are sampled too sparsely to map spatially
- BUT: They are dependent on other variables





Other Variables

- Some data are too sparse to map or use bivariate relationships
- Depends on data, logs, time constraints

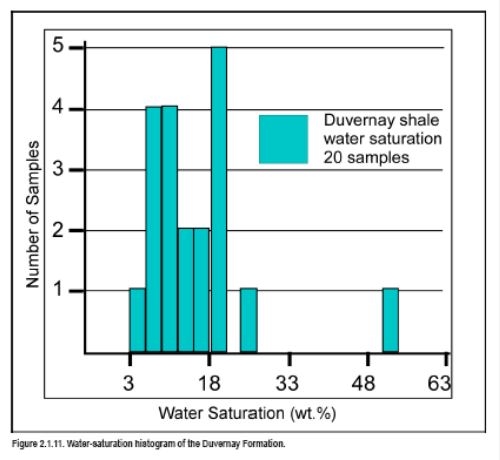
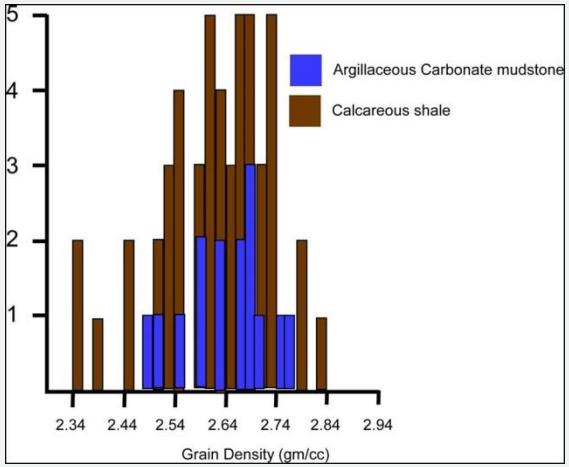
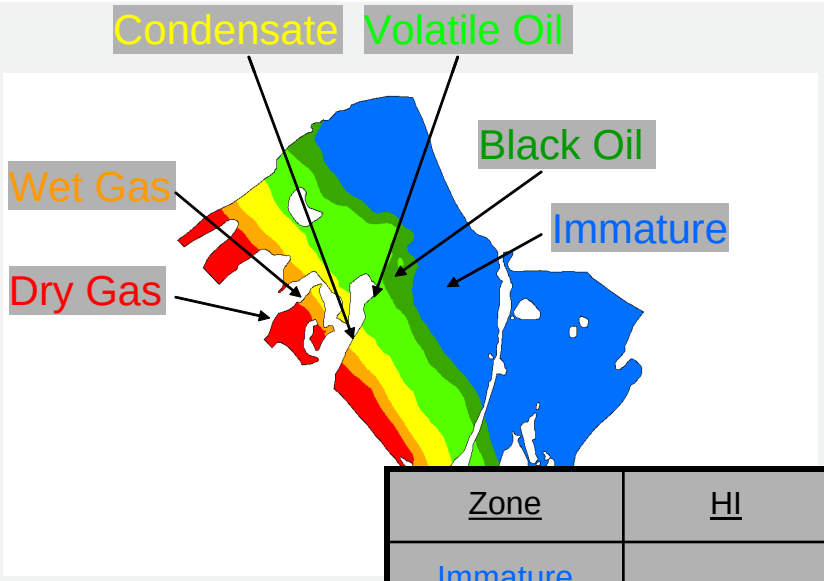


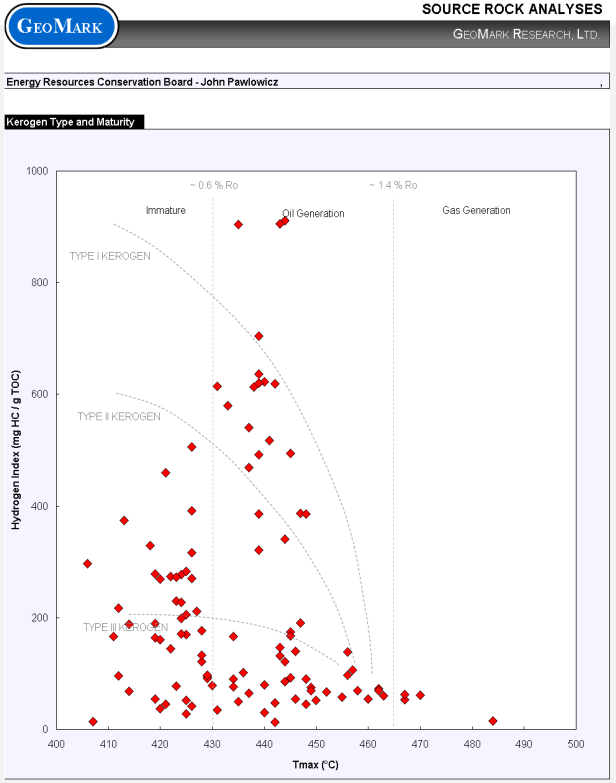
Figure 2.1.11. Water-saturation histogram of the Duvernay Formation.



Fluid Zones



Zone	HI	Ro	GOR
Immature		< 0.8	
Black Oil	350 +	> 0.8	0-310
Volatile Oil	200 – 350	> 0.85	310-570
Condensate	100 – 200	>1.0	570-10000
Wet Gas	60 – 100	> 1.2	
Dry Gas	< 60	> 1.35	



Resource Calculations

- With all the necessary parameters, calculate the resources in place:

$$GIP_{free} = AREA \cdot NET \cdot PHI \cdot SG \cdot \frac{PRES}{101} \cdot \frac{288}{TEMP} \cdot \frac{1}{ZI}$$

$$GIP_{ads} = AREA \cdot NET \cdot \frac{VL}{(PRES + PL)}$$

$$GIP_{tot} = GIP_{free} + GIP_{ads}$$

$$NGLIP = GIP \cdot CGR$$

$$OIP = AREA \cdot NET \cdot PHI \cdot SO \cdot \frac{1}{BOI}$$

Simulation and Uncertainty

$$OIP = AREA \cdot NET \cdot PHI \cdot SO \cdot \frac{1}{BOI}$$

Why Uncertainty?

- Duvernay shale play:

$$60000 km^2 \times 16 m \approx 960 km^3$$

$$960 km^3 \times 2.55 t / m^3 \approx 2.5 Tt$$

- Total samples taken:

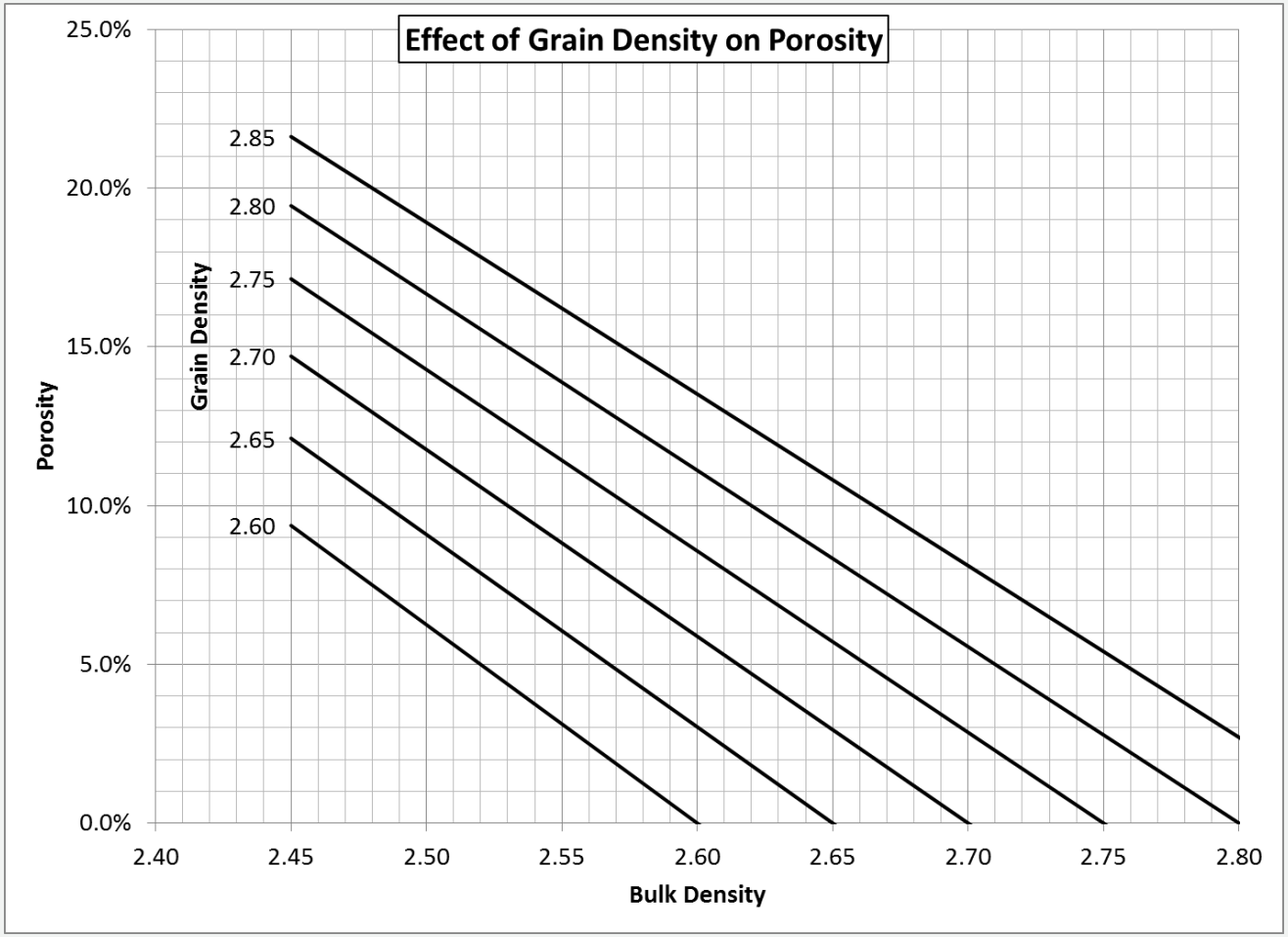
$$16 kg / 2.5 Tt \approx 0.000000000000064\%$$

$$\approx 0.0000064\, ppb$$

Grain Density and Porosity

- Porosity is a major driving factor in hydrocarbons-in-place
- Density log analysis is a standard tool for calculating porosity
- Shales and siltstones do not follow normal log scales
- Small variations in grain density make a huge difference at low porosity

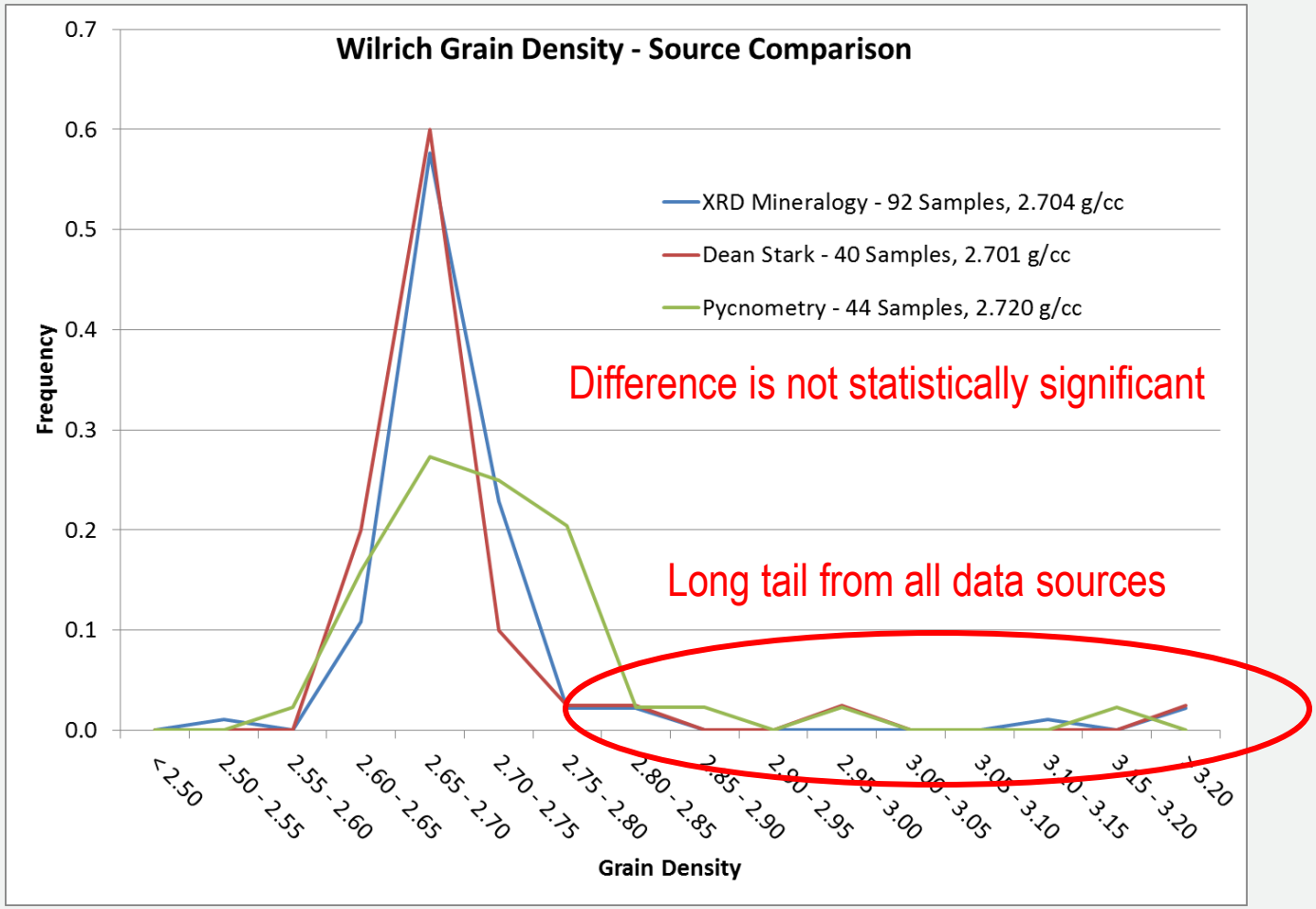
Grain Density and Porosity



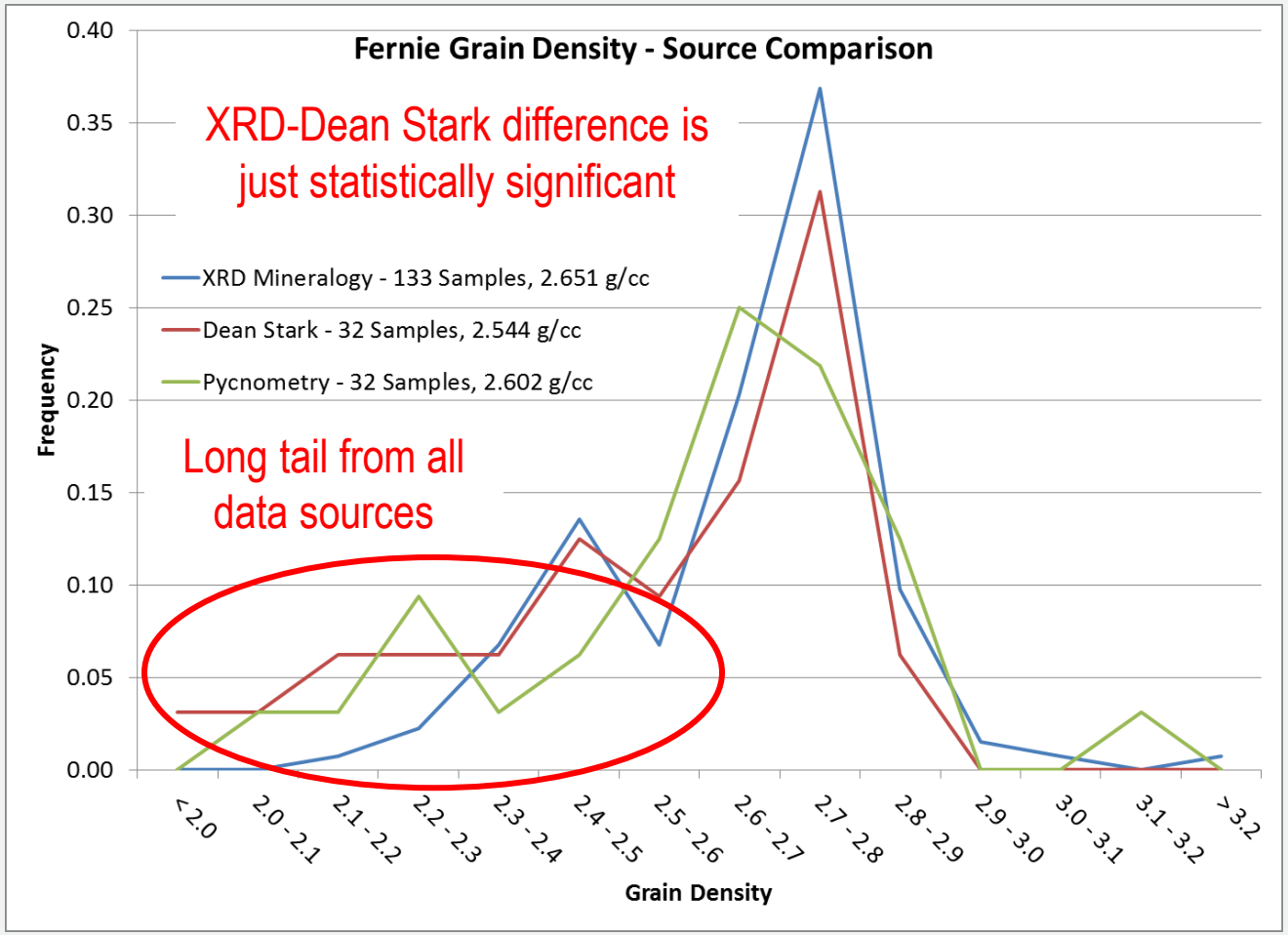
Sources of Grain Density

1. Calculated from XRD Mineralogy
   - Use density of constituents
   - Have to include TOC as a mineral
2. Helium Pycnometry
   - Crush sample, measure pressure difference
3. Dean Stark Analysis
   - Includes GRI and pycnometry
   - Meant for saturations

Source Comparison



Source Comparison

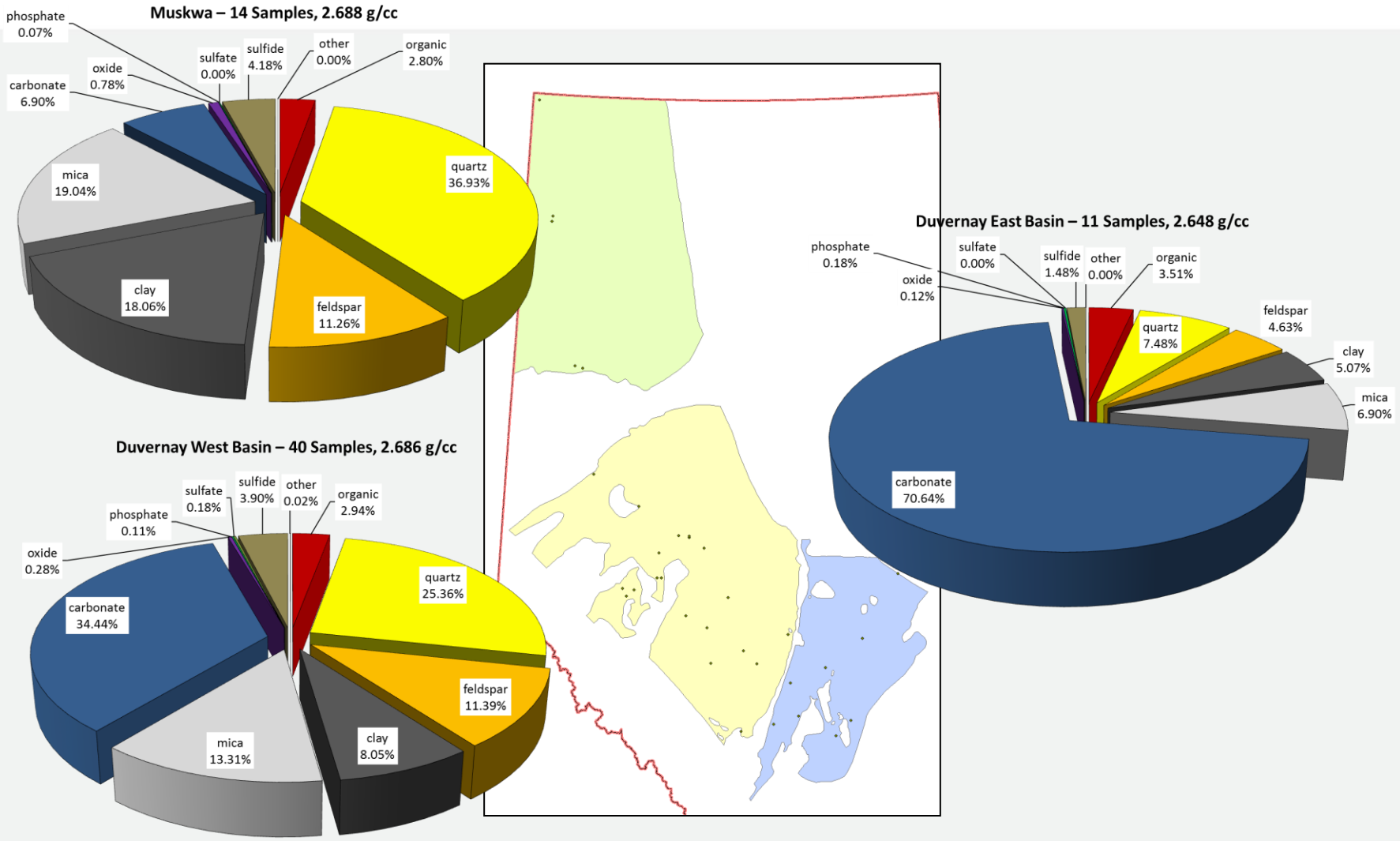


Grain Density from Mineralogy

1. Add kerogen to the minerals
2. Renormalize to 100%: $$W_i' = \frac{W_i}{\sum_{i=1}^{n+1} W_i}$$
3. Convert to volume percent: $$V_i = \frac{W_i' / \rho_i}{\sum_{j=1}^{n+1} W_j' / \rho_j}$$
4. Calculate volume-weighted average grain density: $$\rho_g = \sum_{i=1}^{n+1} V_i \cdot \rho_i$$

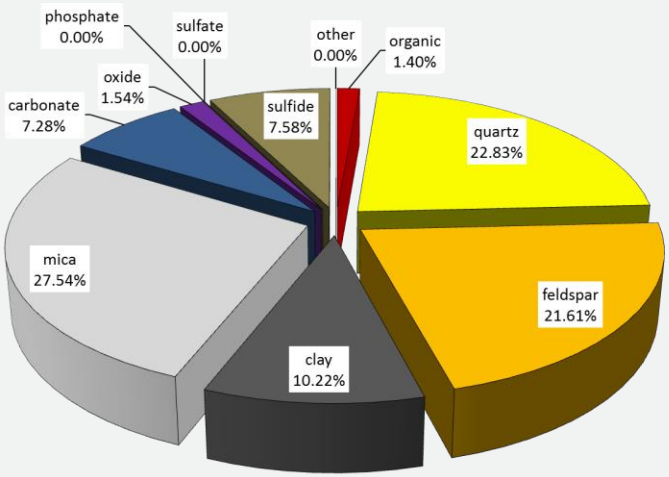
or shortcut: $$\rho_g = \sum_{i=1}^{n+1} \frac{W_i'}{\sum_{j=1}^{n+1} W_i' / \rho_i}$$

Duvernay/Muskwa Mineralogy

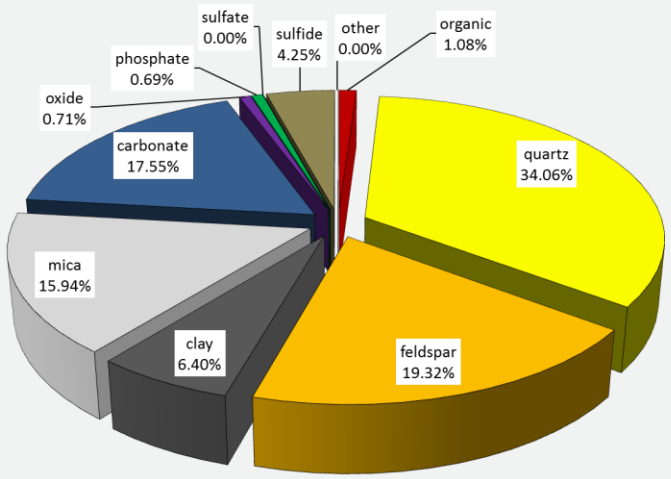


Montney Mineralogy

Montney Shale – 3 Samples, 2.779 g/cc

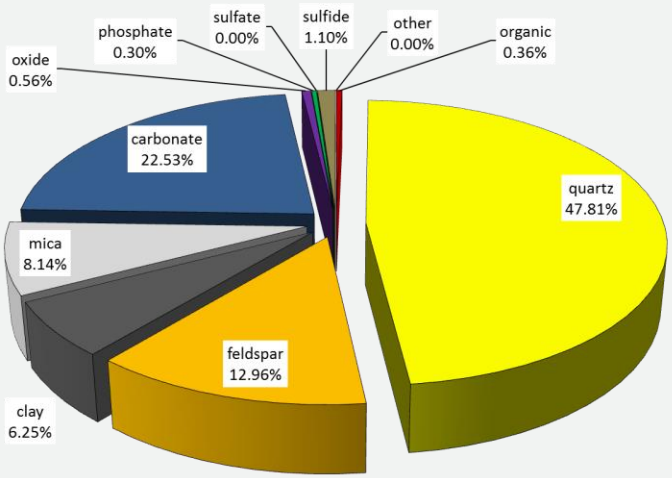


Montney Siltstone – 34 Samples, 2.748 g/cc

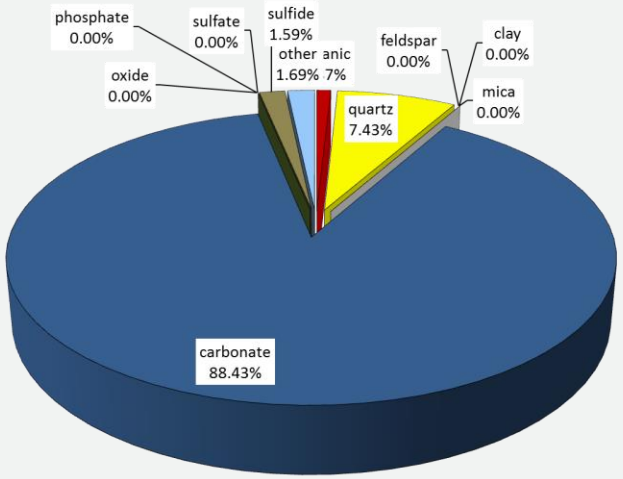


Montney Mineralogy

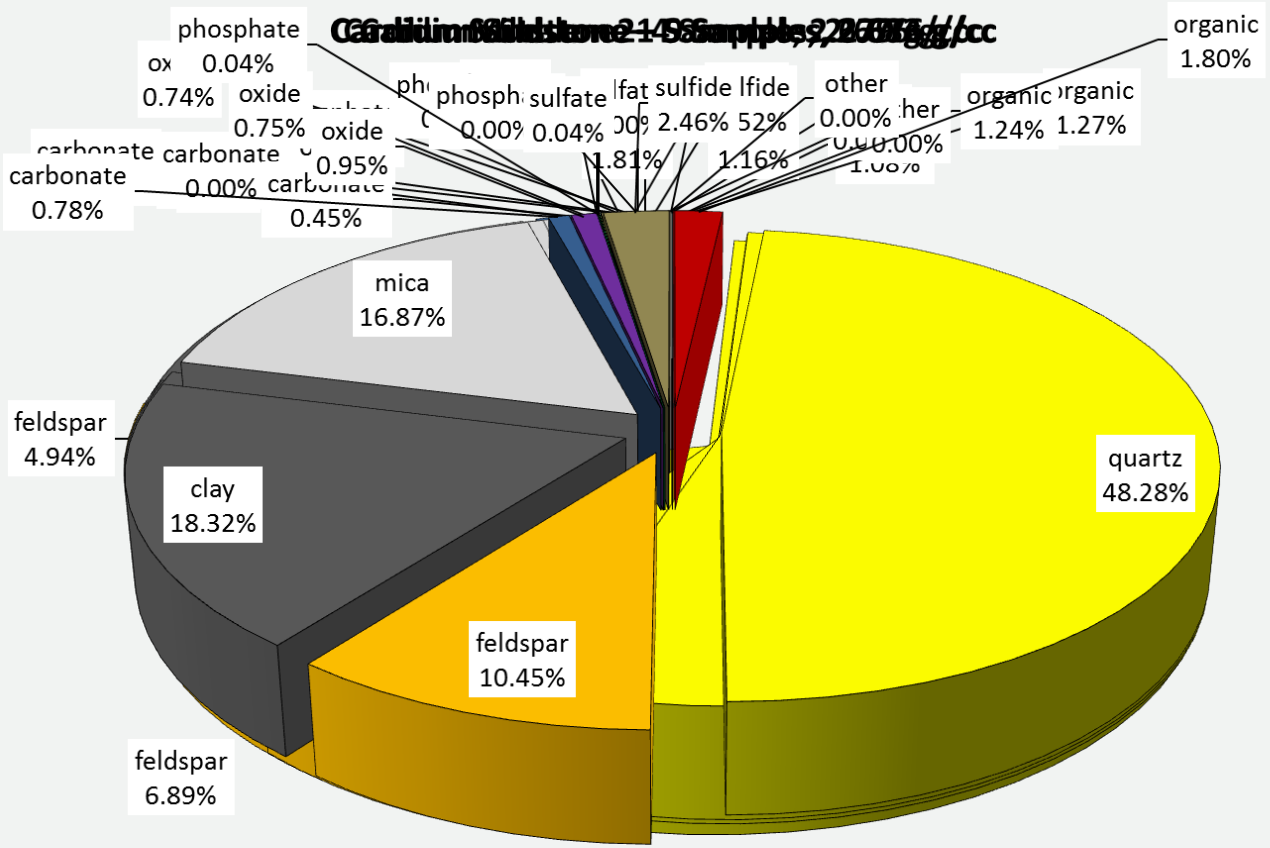
Montney Sandstone – 3 Samples, 2.722 g/cc



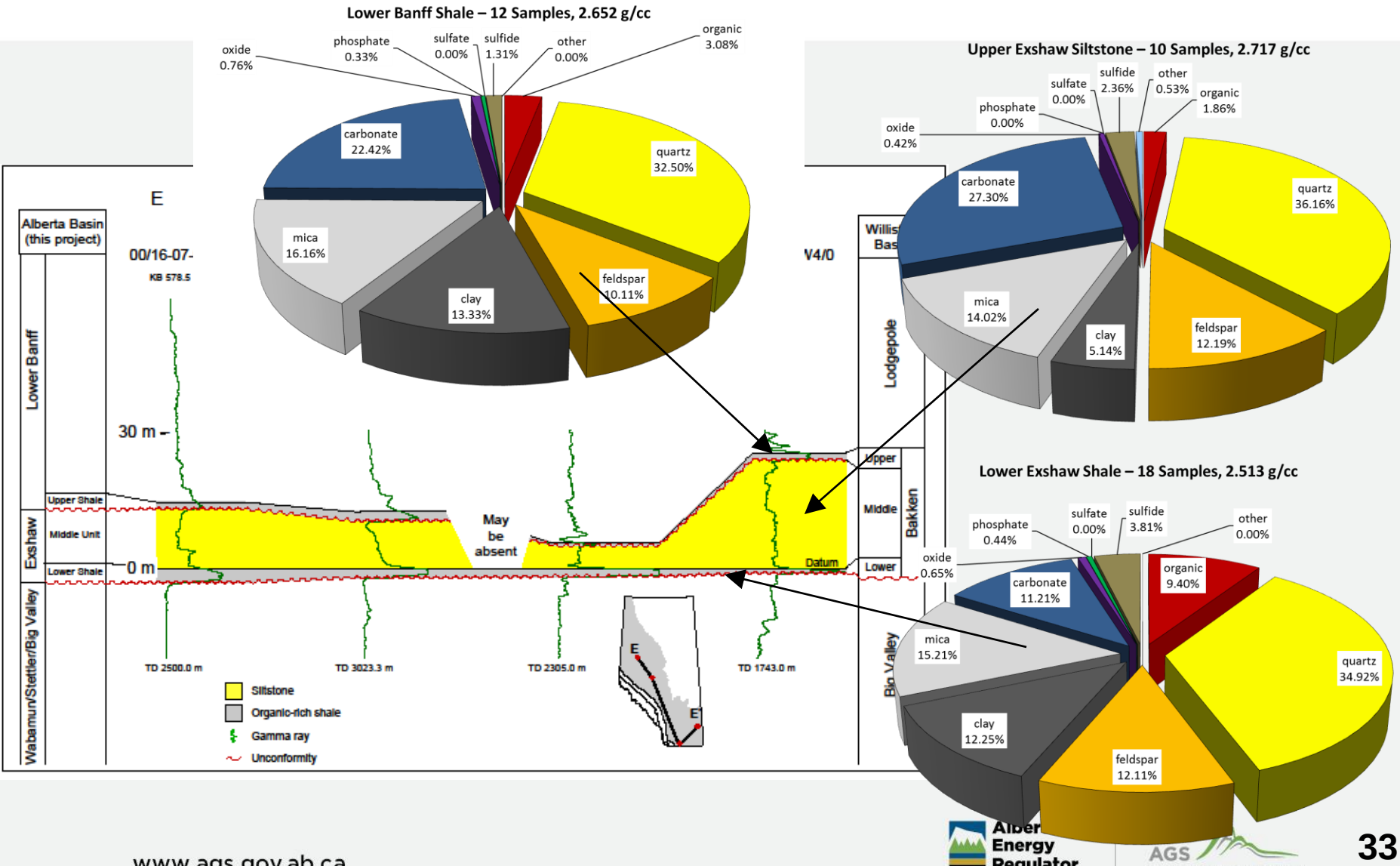
Montney Coquina – 1 Sample, 2.831 g/cc



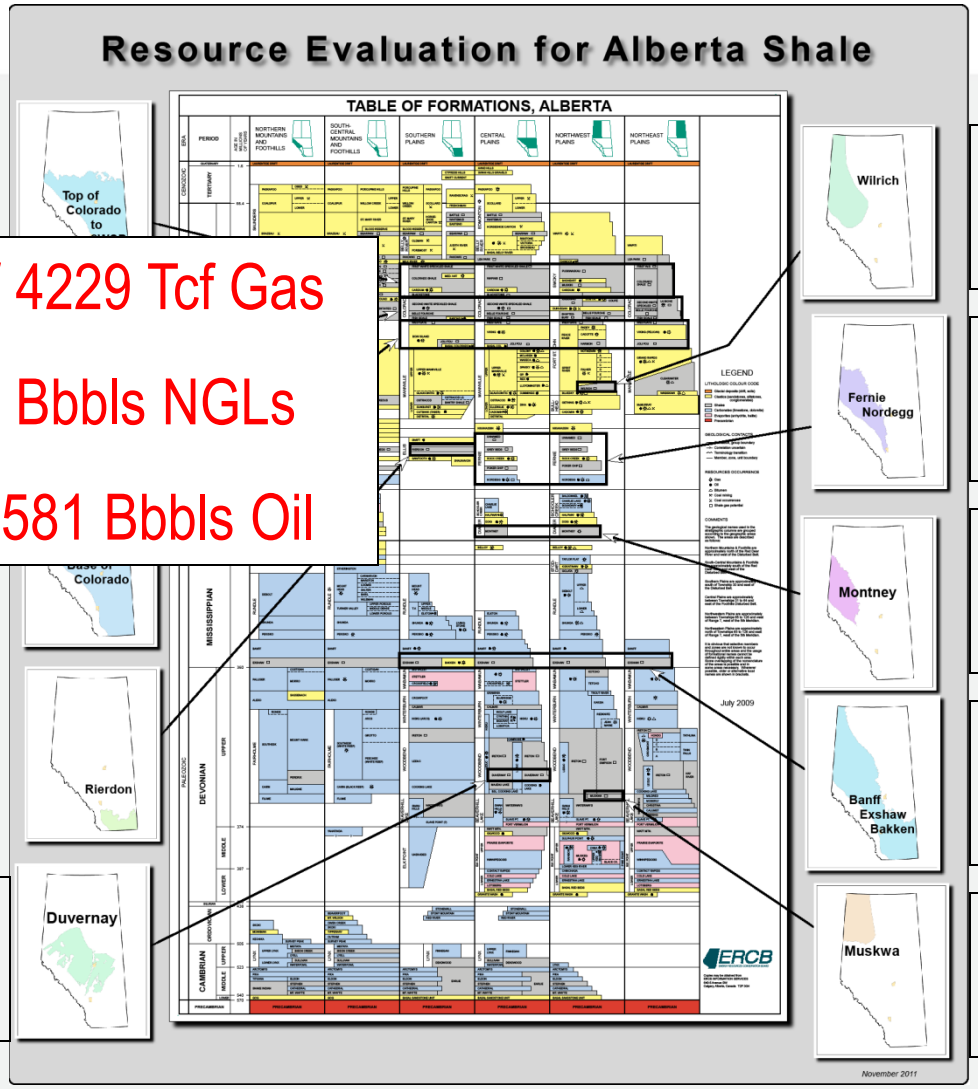
Cardium Mineralogy



Lower Banff / Exshaw Mineralogy



Shale Resources: Released



2835 / 3424 / 4229 Tcf Gas

41 / 58.6 / 88 Bbbls NGLs

353 / 423.6 / 581 Bbbls Oil

353 / 443 / 540 Tcf Gas
7.5 / 11.3 / 16.3 Bbbls NGLs
44.1 / 61.7 / 82.9 Bbbls Oil

115 / 246 / 568 Tcf Gas
0.689 / 2.1 / 4.45 Bbbls NGLs
20.2 / 47.9 / 172.3 Bbbls Oil

70 / 148 / 281 Tcf Gas
0.487 / 2.1 / 3.5 Bbbls NGLs
19.9 / 47.9 / 66.4 Bbbls Oil

1630 / 2133 / 2828 Tcf Gas
11.7 / 28.9 / 54.4 Bbbls NGLs
78.6 / 136.3 / 220.5 Bbbls Oil

16 / 35 / 70 Tcf Gas
0.034 / 1.4 / 0.217 Bbbls NGLs
9.0 / 37.8 / 44.9 Bbbls Oil

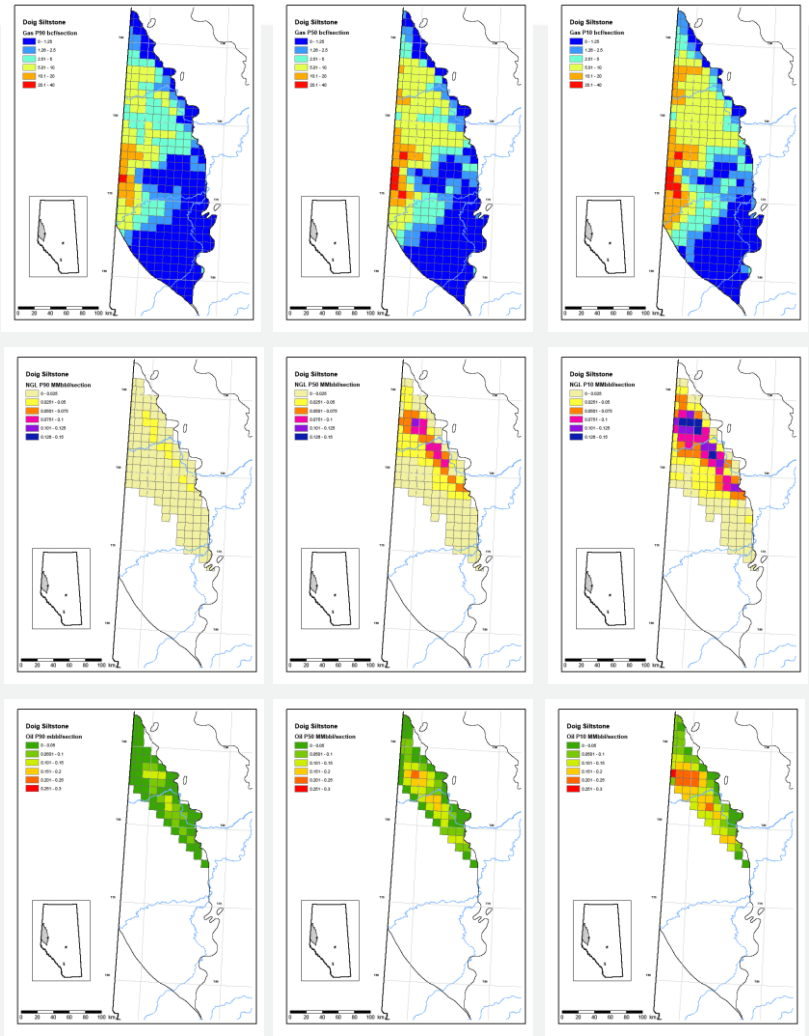
289 / 419 / 527 Tcf Gas
6.0 / 14.8 / 16.3 Bbbls NGLs
74.8 / 115.1 / 159.9 Bbbls Oil

Shale Resources: Doig Siltstone

- Equivalent to BC Upper Montney
- Recent NEB report:

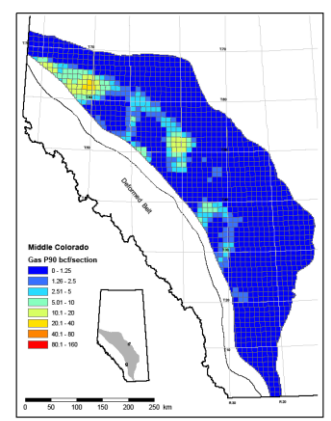
1699 / 2309 / 2947 Tcf Gas
12.0 / 30.6 / 56.2 Bbbls NGLs
79.6 / 138.7 / 222.6 Bbbls Oil

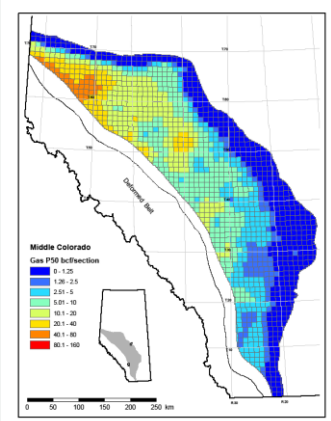
- Combined Montney and Doig Siltstone

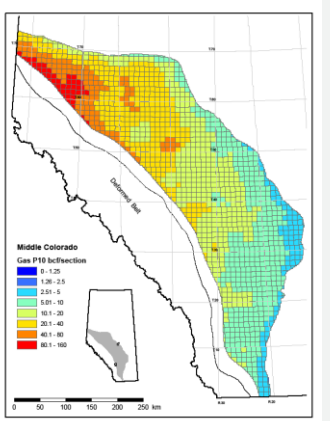


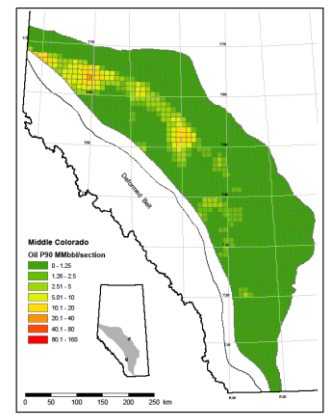
Shale Resources: M Colorado

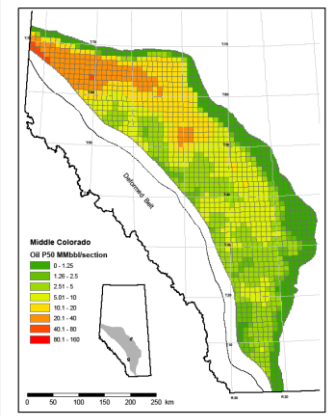
- Top of 2WS to BFSZ
- Includes 2WS interval
- Extensive and thick
- High clay minerals

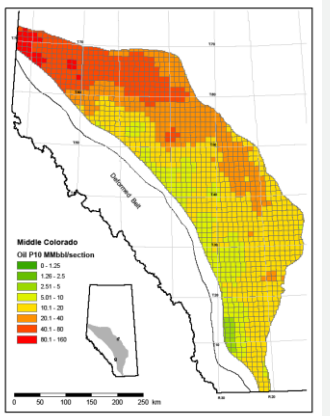






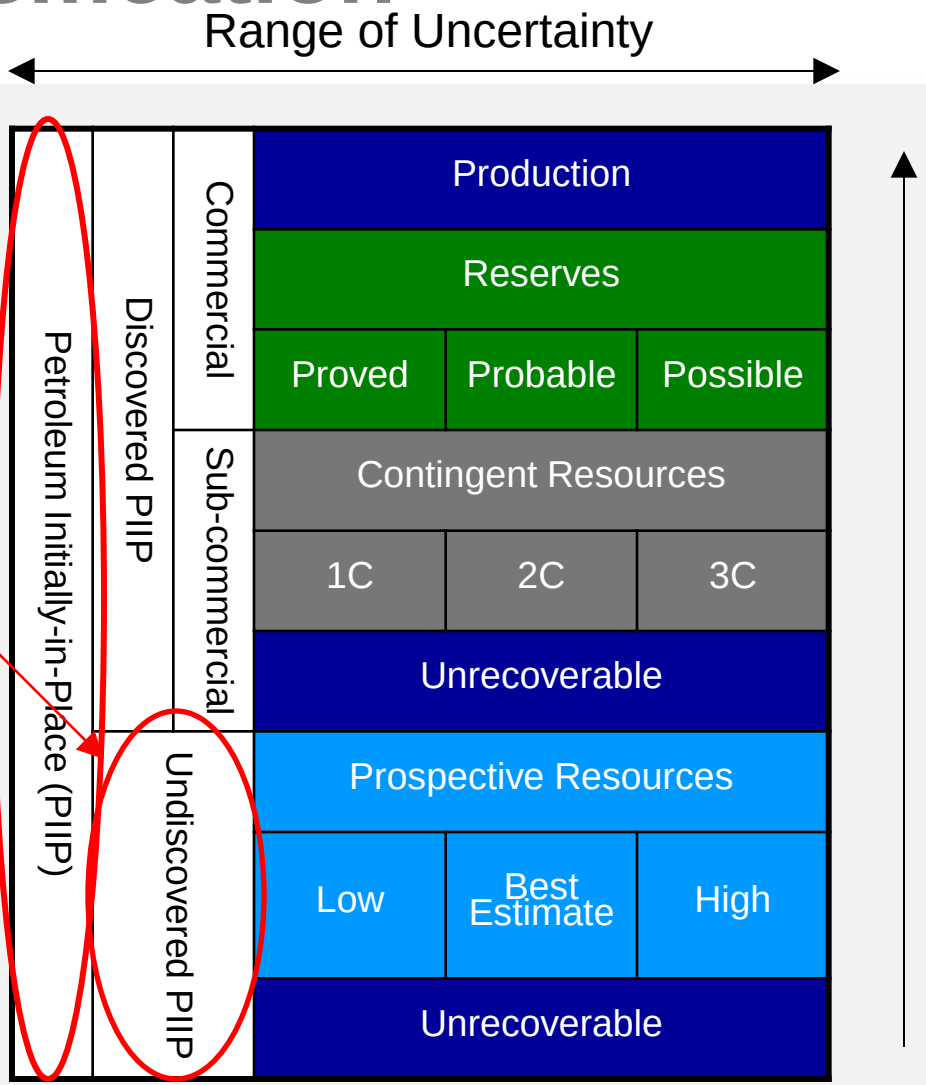






Resource Classification

- Currently, we only look at PIIP
  - For new plays, this is all undiscovered PIIP
- May tackle commerciality in the future
  - Frackability
  - Local hot spots
  - Well performance



Challenges and Issues

- Shales haven’t been studied in the past
- Shales are “homogeneously heterogeneous”
- Data and core is limited
- Log analysis requires new approaches
- Traditional assumptions don’t hold
- Every shale is different

Comments

- Uncertainty is key: identify and quantify
- Reality check: is everything reasonable?
  - “Tomato test”
- Grain density is a major consideration
  - Affects log porosity significantly

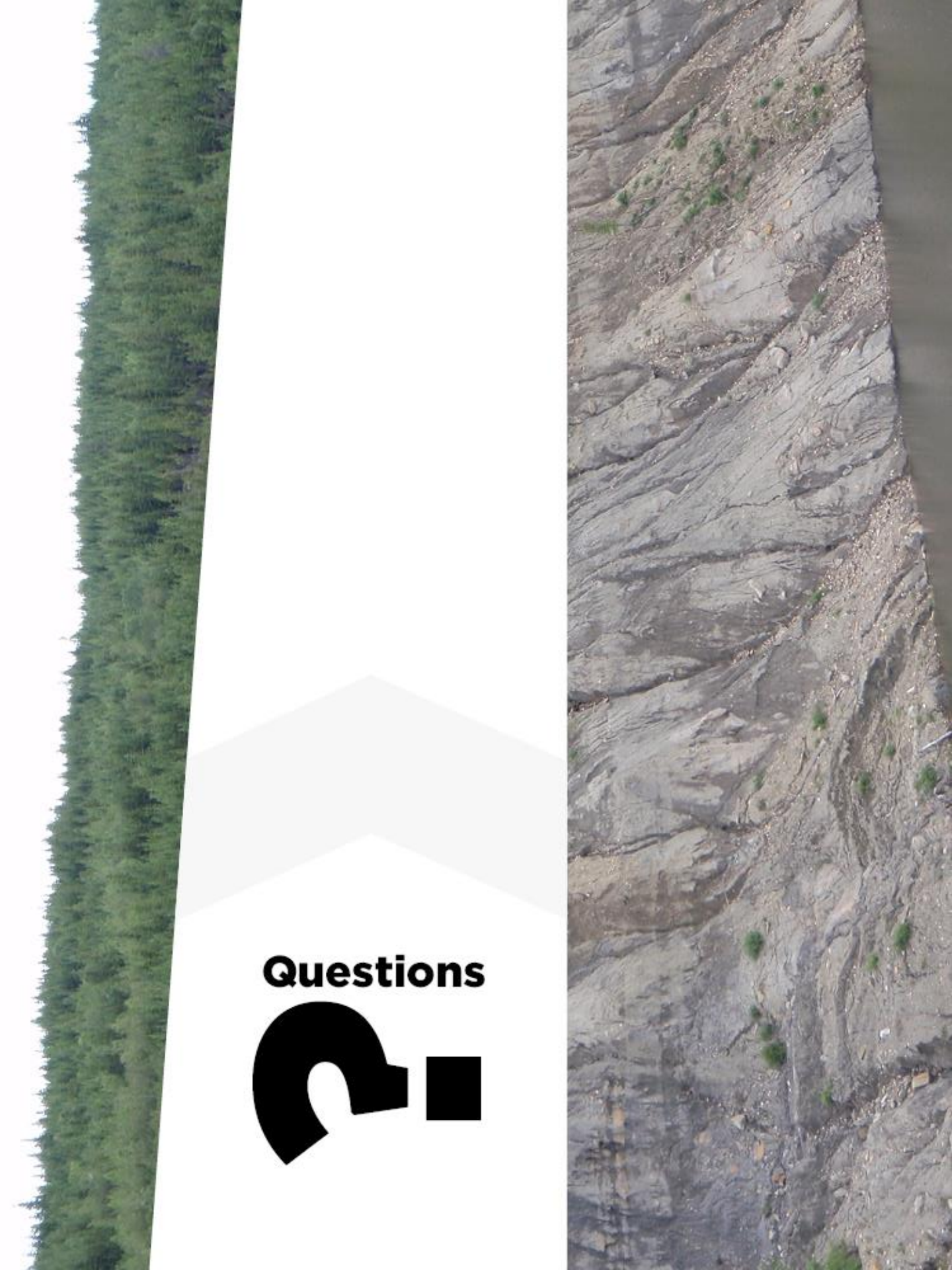
Next Steps

- Evaluate more formations
- Move towards technically recoverable
  - Prospective resources, contingent resources, marketable hydrocarbons, etc.
- Refine analyses and zoom in
  - Divide formations into plays
  - Subdivide stratigraphic intervals

Publications

http://ags.gov.ab.ca/publications/pubs.aspx?tkey=shale%20gas

AGS Website -> Activities -> Shale Gas -> Shale Gas Publications


Questions

Thank you