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[AV]Case Study of a Large Conventional Oil Pool Discovery in a Mature Basin: The Upper Mannville of the Western Canada Sedimentary Basin*

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Abstract

The Western Canada Sedimentary Basin has a complex depositional and structural history and hosts many hydrocarbon deposits in numerous horizons and play types. The Basin has been explored and exploited for over a century and has over 600,000 wellbore penetrations. Some of the producing horizons have been exploited more than others, with the Albian aged Upper Mannville (UM) zone being one of the least exploited units. In the southern portion of the basin, the UM was dominantly deposited in a coastal plain environment, making it difficult to map and predict due to the inconsistent and unpredictable log-based marker horizons. In addition, the reservoirs have subtle log characteristics due to the lithic nature of the sands. This talk will provide some background on how the pool of interest was discovered and the technical details of the pool itself.

The Altura Energy Inc. (ATU) discovery well was drilled in July 2016 with the drilling of the horizontal well 13-15-48-26W4 located 20 miles southwest of Edmonton, Alberta in the Leduc-Woodbend (LWB) Field. This field was the site of the first large commercial oil pool discovery (Frasnian aged Leduc Formation) in the Basin by Imperial Oil in 1947 and heralded the birth of the modern oil and gas industry in Western Canada. Hundreds of wells were drilled in the field in the 1940s and 1950s and by 2016 there were approximately 2400 wells in the field. The 13-15 well was drilled to a depth of 1350 m TVD based on the

geological mapping of many of these old wells with almost 900 of them penetrating the UM sand, all with missed pay indications. In the LWB area, the UM transitions from a channelized coastal plain environment into a marginal marine environment to the north. This provides the perfect setup to trap hydrocarbons updip against the sand pinchout edge. In this area, the sand body maps as a large wave dominated delta system roughly 200 square miles in size. This oil pool has remained undetected for so long because of a combination of subtle log characteristics, poor correlation relationships for mapping purposes and a relatively inactive area for competitors. The key to successfully exploiting this zone is the implementation of horizontal drilling and multistage hydraulic fracturing.

Key reservoir details will be presented and discussed but most notable is that the pool is approximately 1100 million barrels OOIP, making it one of the largest conventional oil pool discoveries in the Western Canadian Sedimentary Basin in the last 20 years. ATU has tied up just over sixty sections of land in the pool through Crown land sales and freehold leasing. Development has occurred methodically, with four horizontal wells drilled to date. Drilling has been successfully accomplished with the use of existing well control to pick both bottom hole locations and landing depths. Seismic usage has been ineffective as the sand is too thin to resolve. Horizontal wellbore lengths vary from 1 to 1.5 miles and the wells are hydraulic fractured with 20 tonnes of sand per stage and 30-45 stages per well. Individual well performance with be shown and initial indications show optimal pool development of 4 to 8 wells per section which will provide many future locations for the company.

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Leckie, D.A., and D.G. Smith, 1992, Regional setting, evolution, and depositional cycles of the Western Canada Foreland Basin: Chapter 1, AAPG Memoir 55, p. 9-46.

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Case Study of a Large Conventional Oil Pool Discovery in a Mature Basin: the Upper Mannville of the Western Canada Sedimentary Basin

Rob Pinckston
Altura Energy Inc

Talk Outline

altura ENERGY INC.

PART 1:

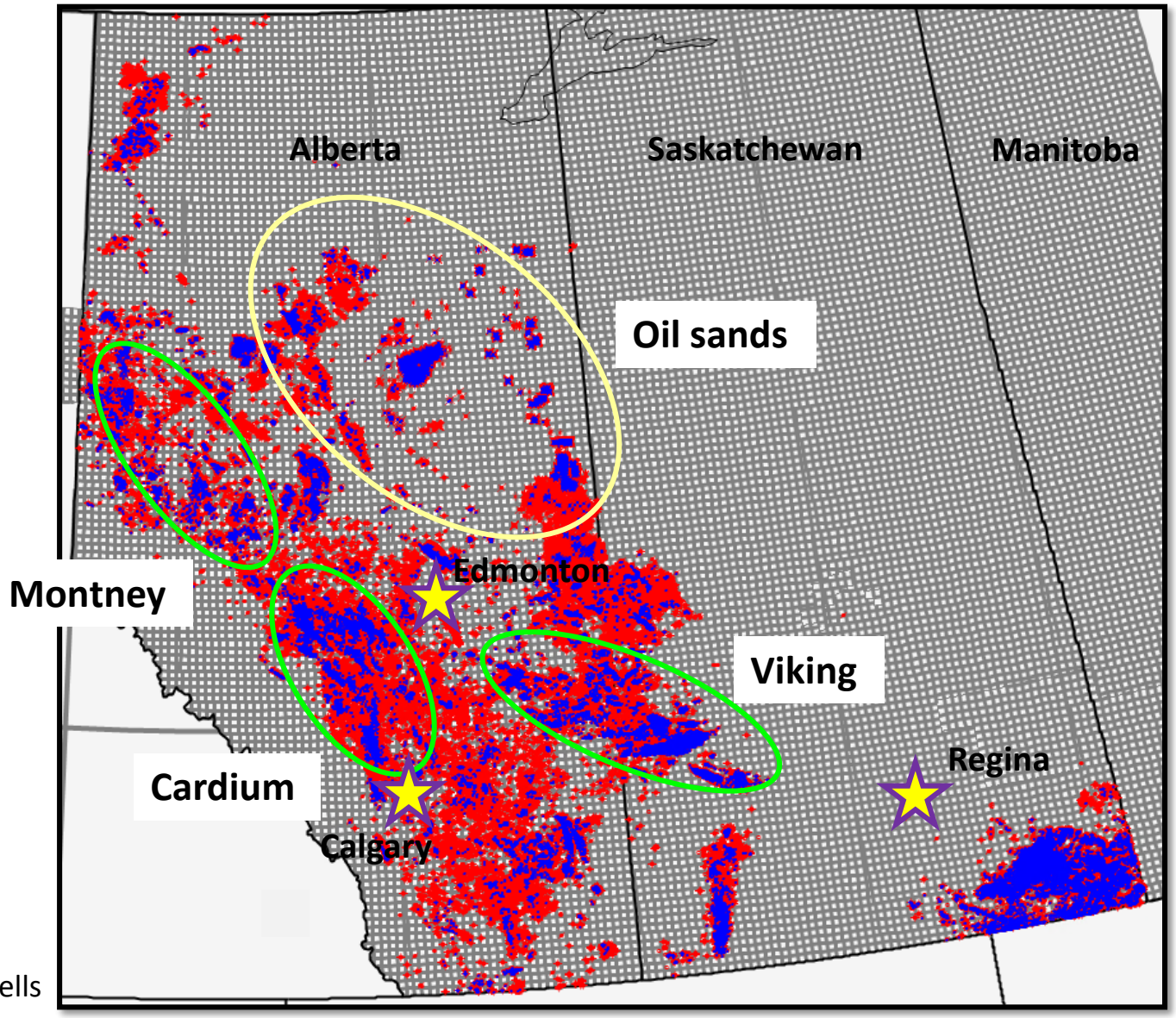
- Introduction to the Western Canada Sedimentary Basin (WCSB) including the Upper Mannville regional picture
- Overview of Leduc-Woodbend (LWB) area
- Discuss largest conventional oil pool discoveries in the basin
- Why was this pool undiscovered for so long?

PART 2:

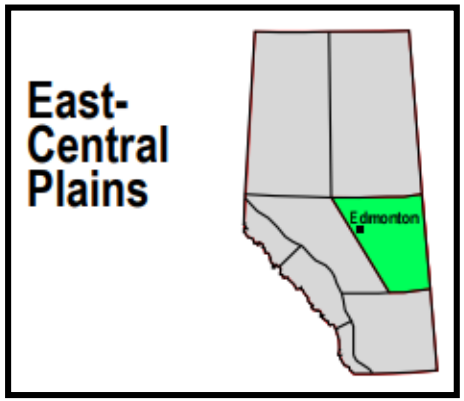
- Pool parameters and key characteristics
- Pool exploitation process
  - Drilling and Completion practices
  - Production results
  - Economics
  - Development plan
- Conclusions

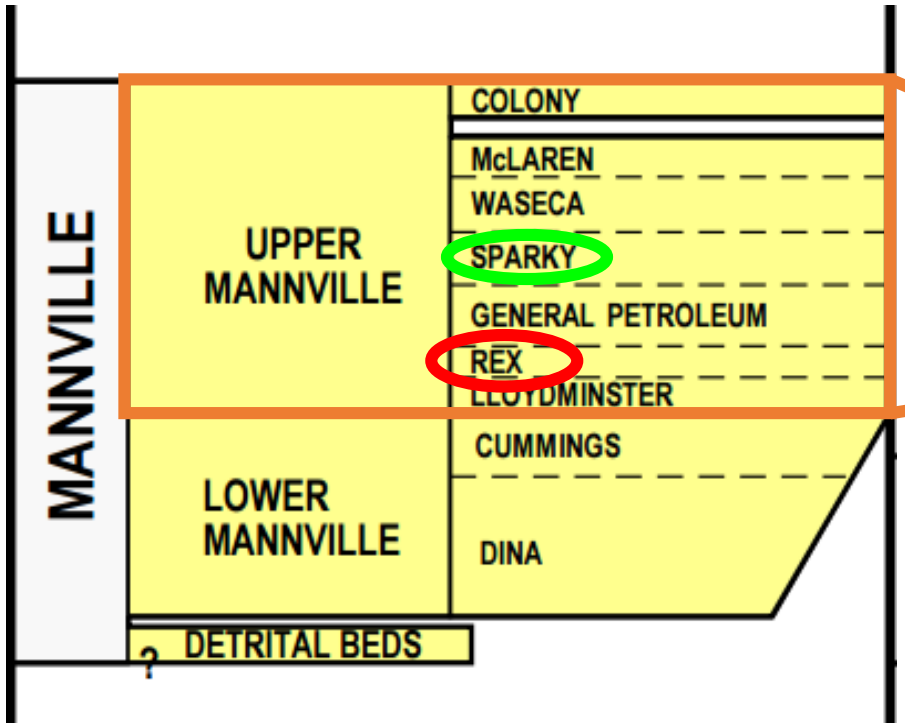
WCSB Distribution of Oil Pools

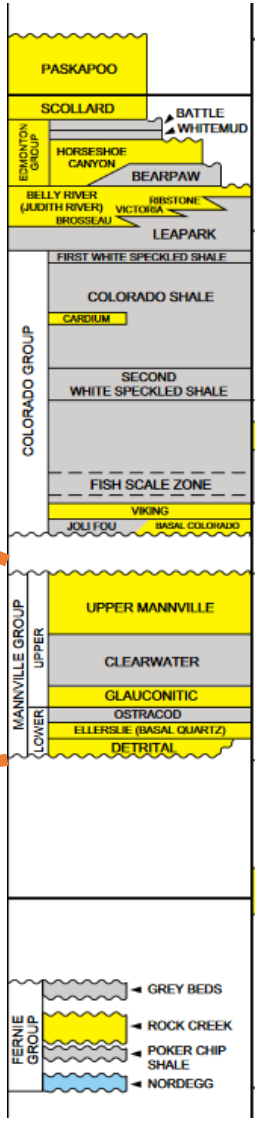
- 172Bn bbls or 10% of world's total proved oil reserves (3rd largest)
- 4.2MM bbls/d production (6th largest)
- Greater than 600k wells

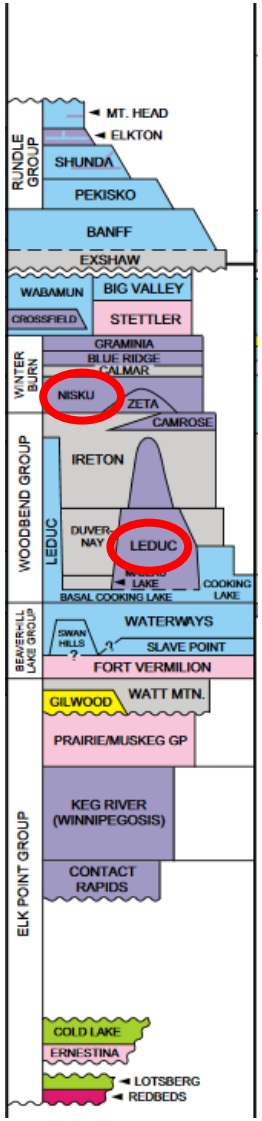


WCSB Stratigraphic Column





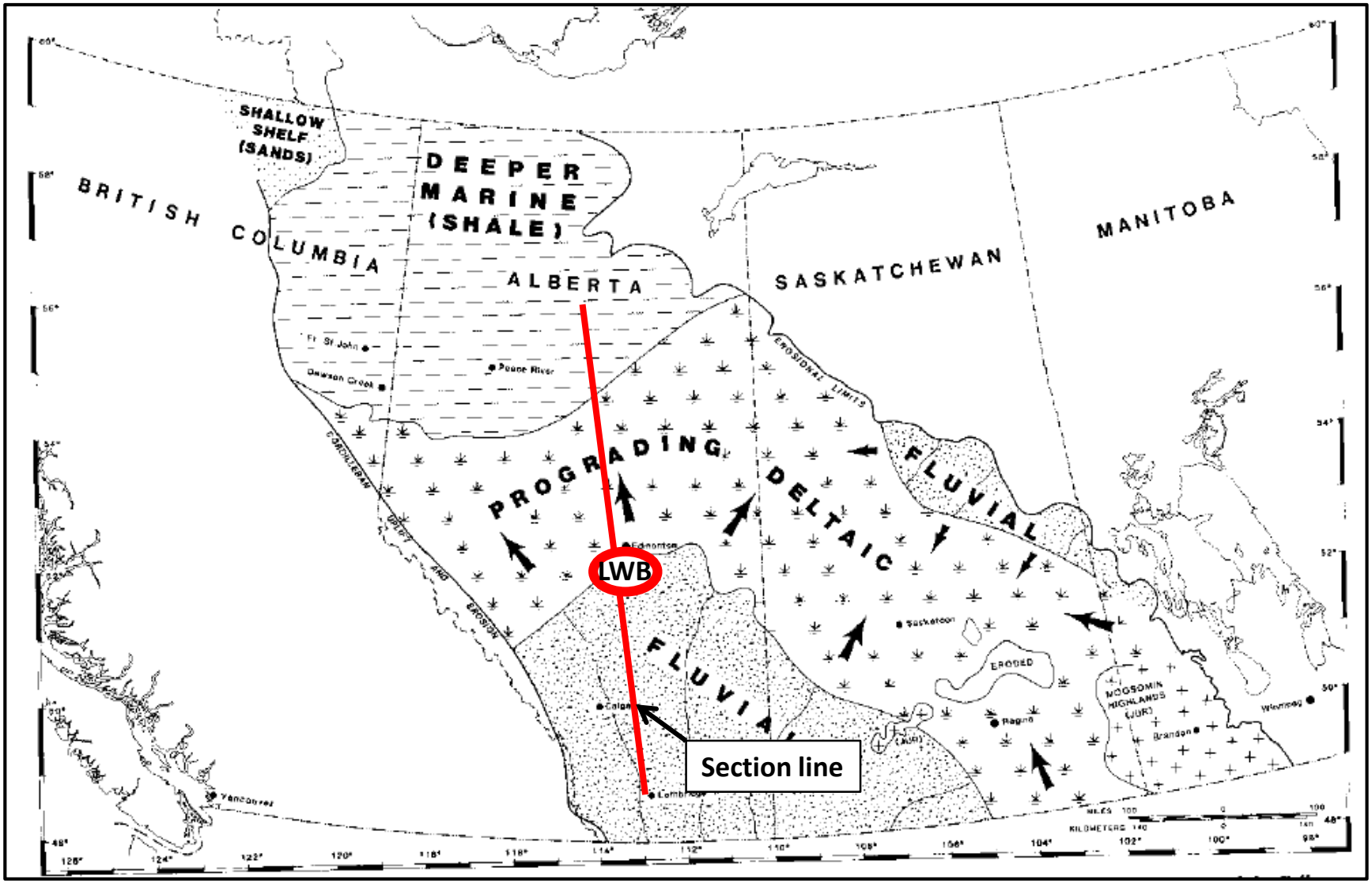




Upper Mannville
Key Characteristics

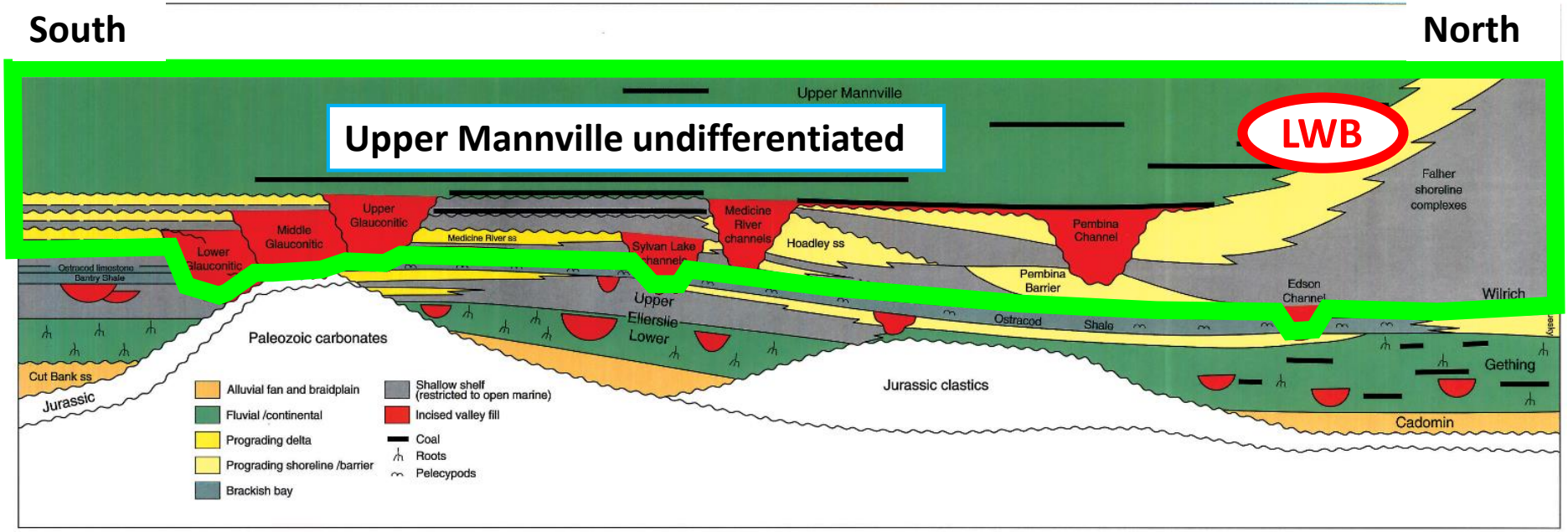
- Full spectrum of depositional environments:
  - Coastal plain to deltaic and marginal marine to fully marine
- Progradation northward across the foreland basin
- Extensive coastal plain deposits in the south to fully marine shales in the north
- Climate was warm and humid with extensive coal deposits to the south
- Sediment load derived from volcanic and tectonic events to the west in the ancestral Canadian and American Rockies
- Sands typically immature and lithic containing volcanic and feldspathic components; complex mineralogy with moderate to abundant amount of clays and cements

Upper Mannville Paleogeography



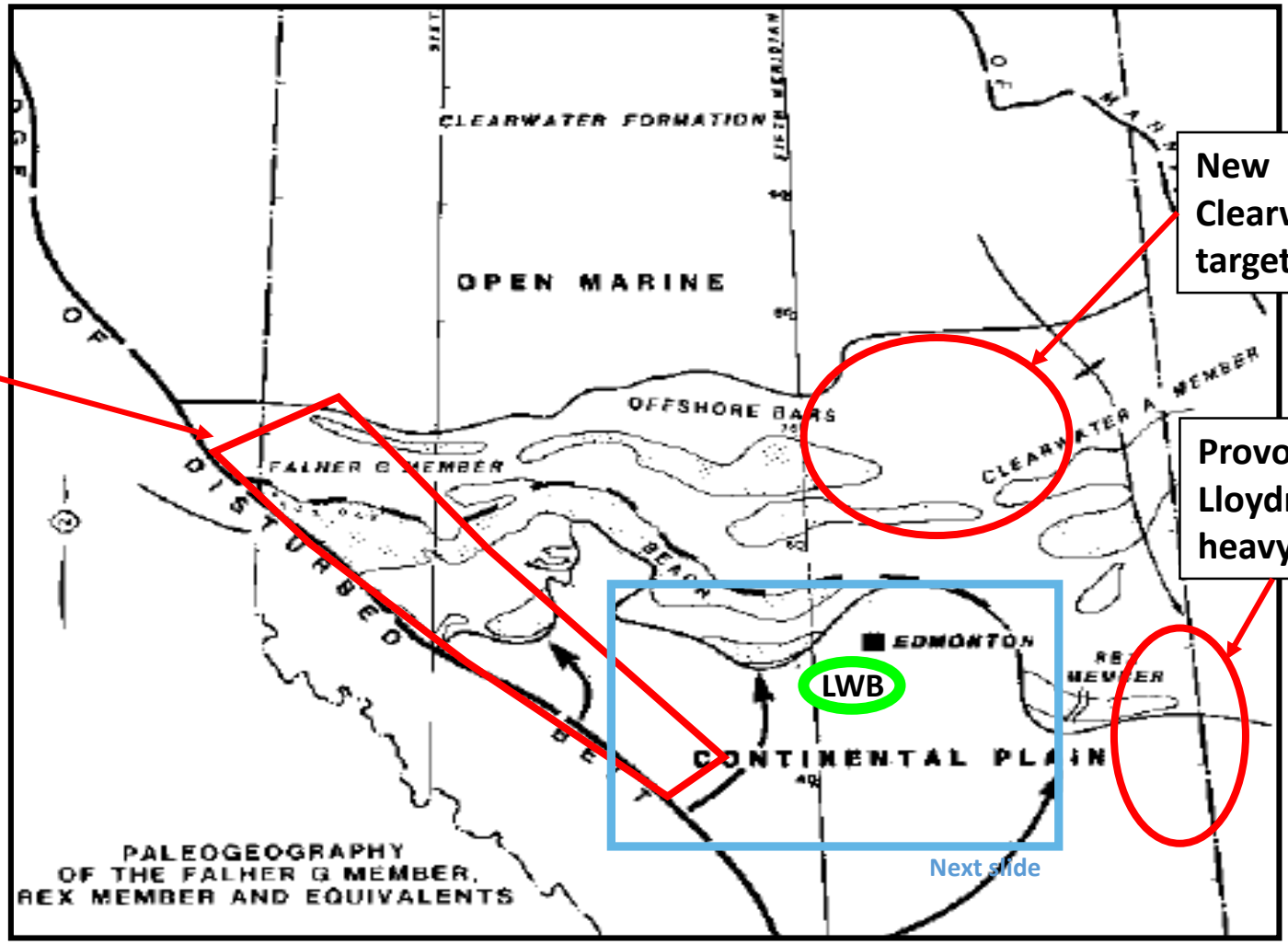
From Leckie and Smith, AAPG Mem 55

Upper Mannville
Regional Cross Section



From the Geological Atlas of the WCSB

Falher, Rex & Clearwater members Paleogeography



Spirit River (Falher) deep basin gas fairway

New Clearwater oil targets

Provost-Lloydminster heavy oil belt

From Masters, AAPG Mem 38

Central Alberta Upper Mannville Overview

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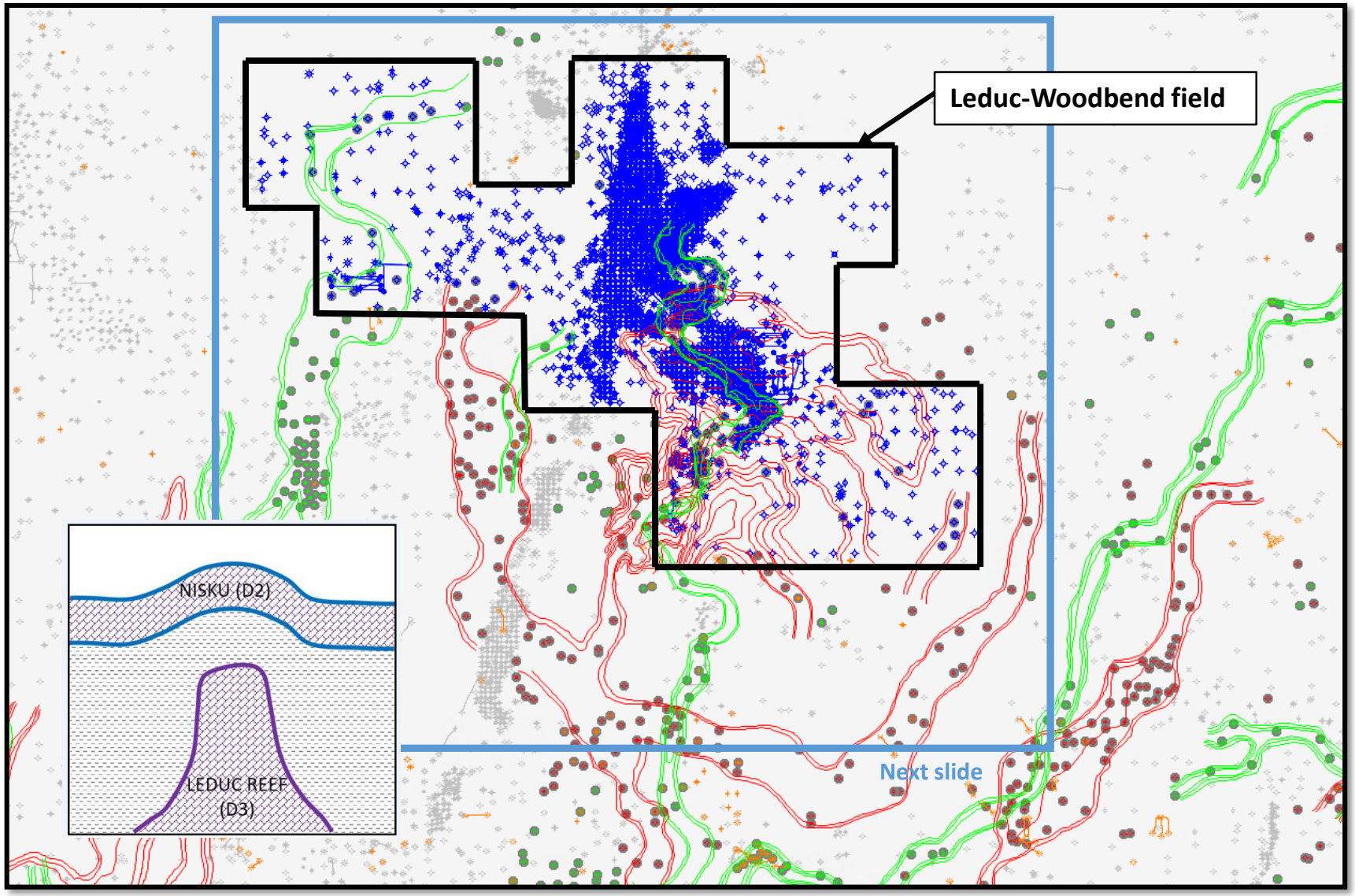
Leduc-Woodbend Field



Well Control prior to 1947

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Well Control Today

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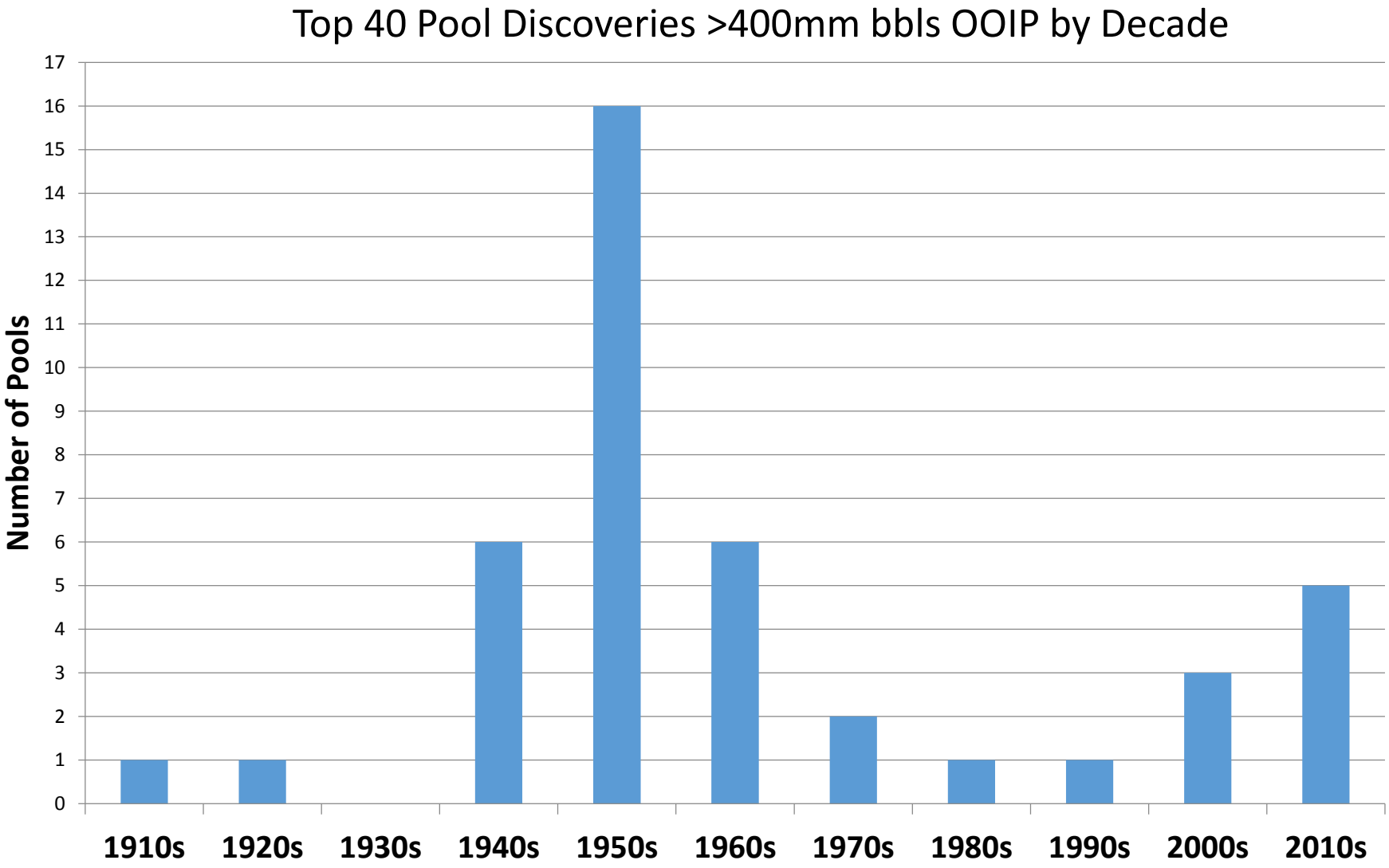
Top 20 Conventional Oil Pool Discoveries

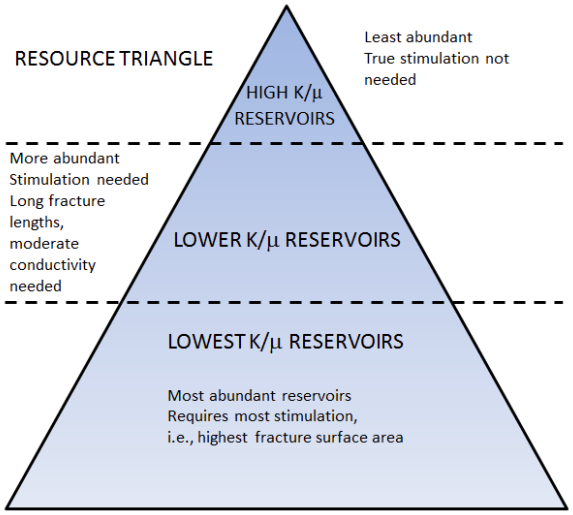
Overall Rank	Area	Pool Name	Twp-Rge	Province	Formation	Disc Date (vt/hz)	OOIP (mmbbls)	notes
1	Pembina		46-50,6-11W5	Alberta	Cardium	1953	7421	halo
2	Viewfield		6-11,5-11W2	SK	Bakken	1981/2004	4600	technology
3	Marten Hills		73-76,24W4-3W5	Alberta	Clearwater	2009/2011	3000?	technology
4	Swan Hills	BHL A&B	66-70,8-11W5	Alberta	BHL	1957	2895	halo
5	Weyburn/Midale	various units	5-6,10-14W2	SK	Midale	1954	2061	halo
6	Provost	Hamilton Lake etc	34-36, 7-12W4	Alberta	Viking	1946	1661	halo
7	Turner Valley	Rundle	18-21,2-3W5	Alberta	TV	1916	1325	
8	Redwater	D-3	56-58,20-22W4	Alberta	Leduc	1948	1302	
9	Sinclair		7-10, 28-30W1	MB	Torquay	?/2004	1300	technology
10	Leduc-Woodbend		48-50,24-26W4	Alberta	U Mann	2014/2016	1160	technology
11	Willesden Green	Cardium A	39-44, 4-9W5	Alberta	Cardium	1954	1094	halo
12	Swan Hills South	BHL A&B	65-66,9-11W5	Alberta	BHL	1959	1084	
13	Twining	Rundle A	30-33, 24-25W4	Alberta	Pekisko	1952	935	
14	Nipisi	Gilwood A	78-81,7-9W5	Alberta	Gilwood	1965	909	
15	Mitsue	Gilwood A	69-74, 3-6W5	Alberta	Gilwood	1964	818	
16	Judy Creek	BHL	63-64,10-11W5	Alberta	BHL	1959	817	
17	Morgan	Lloyd A	52-4W4	Alberta	Lloydminster	1962	811	
18	Bonnie Glen	Leduc A	46-47,27-28W4	Alberta	Leduc	1952	787	
19	Cecil/Mulligan		80-83, 8W6	Alberta	U Charlie Lake	1983/2013	700	technology
20	Ferrier	Cardium G etc	38-42,7-9W5	Alberta	Cardium	1961	649	halo

WCSB Pool Discovery History



Oil Resource Triangle

- The term ‘discovery’ has been blurred because of technology
- Were the ‘discoveries’ of the 2000s and 2010s truly discoveries?
  - Most pools had uneconomic vertical producers
  - In some cases it’s not clear if the first vertical producers actually targeted the zone
  - The first horizontal well within each of those pools were typically the first commercial/economic success
- Resource triangle shows that the most recent pool discoveries exist further down on the triangle



High Perm, pre 2000s pools (darcies)

Bitumen

Low Perm, 2000s & 2010s pools (millidarcies)

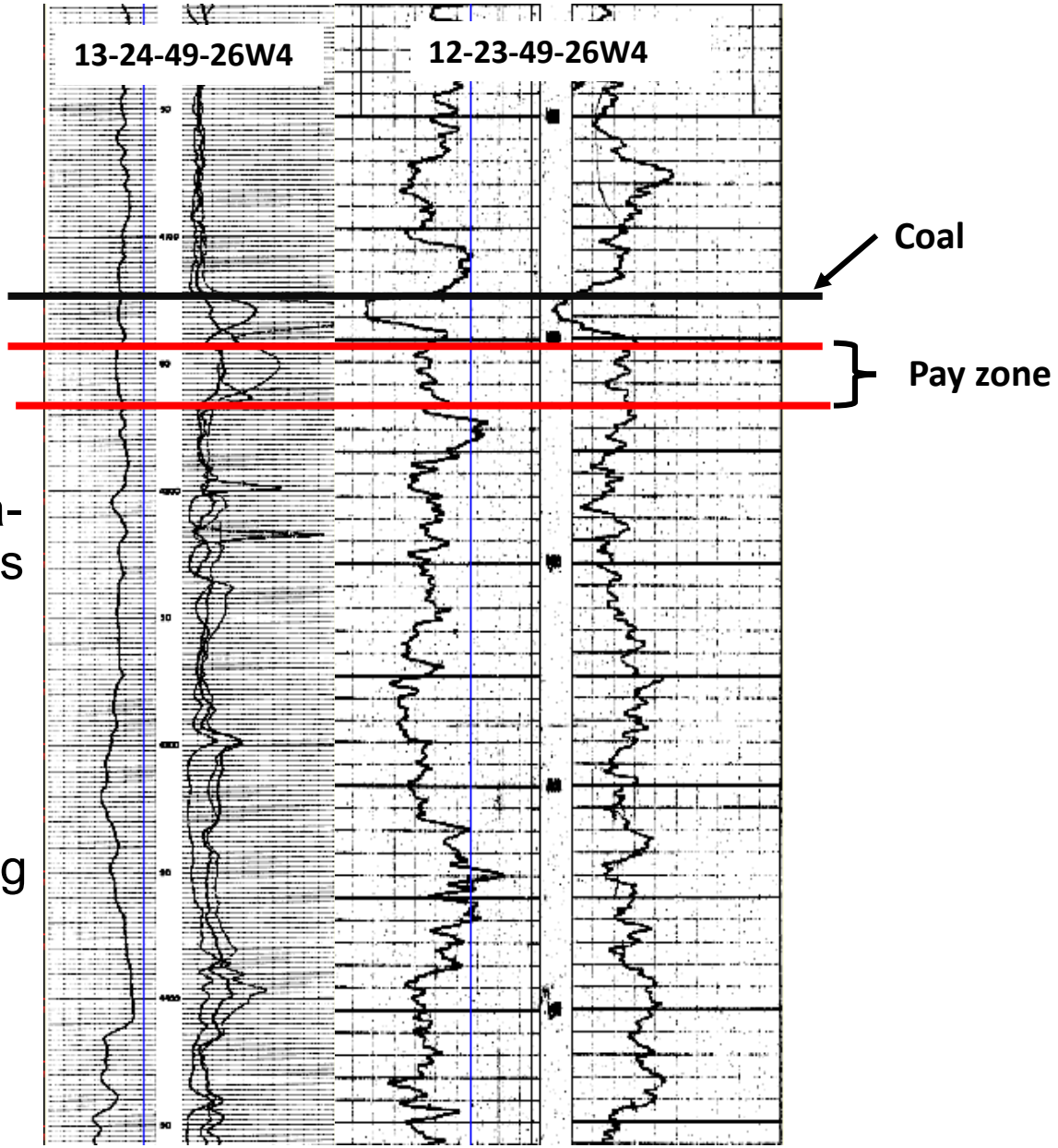
Oil Shale, Source beds (micro/nanodarcies)

How did the LWB oil pool remain undiscovered for so long?

1. Poor quality logs
   - very little quantitative information available from Electric logs and Gamma-Neutron logs
   - poor logs makes for a relatively quiet area with very few competitors
2. Difficult correlation relationships (coastal plain sequence)
3. Subtle log characteristics
4. Lack of production or drill stem test shows due to tight nature of rock

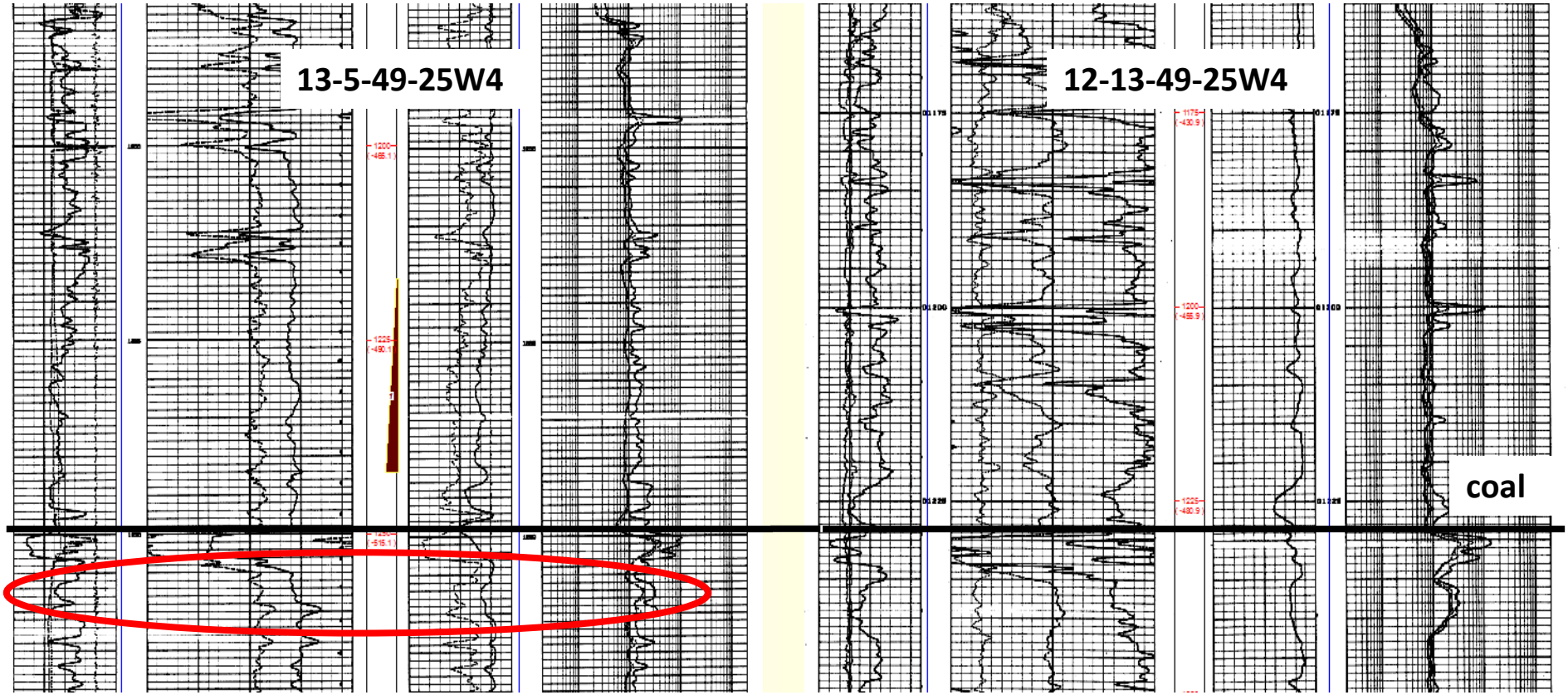
Poor Logs

- Most wells in the area drilled prior to 1960 (eg 13-24 & 12-23)
- Electric logs and Gamma-Neutron logs the only logs run in the 1940s and 1950s
- Many geologists today uncomfortable interpreting or even bother looking at pre 1960s logs



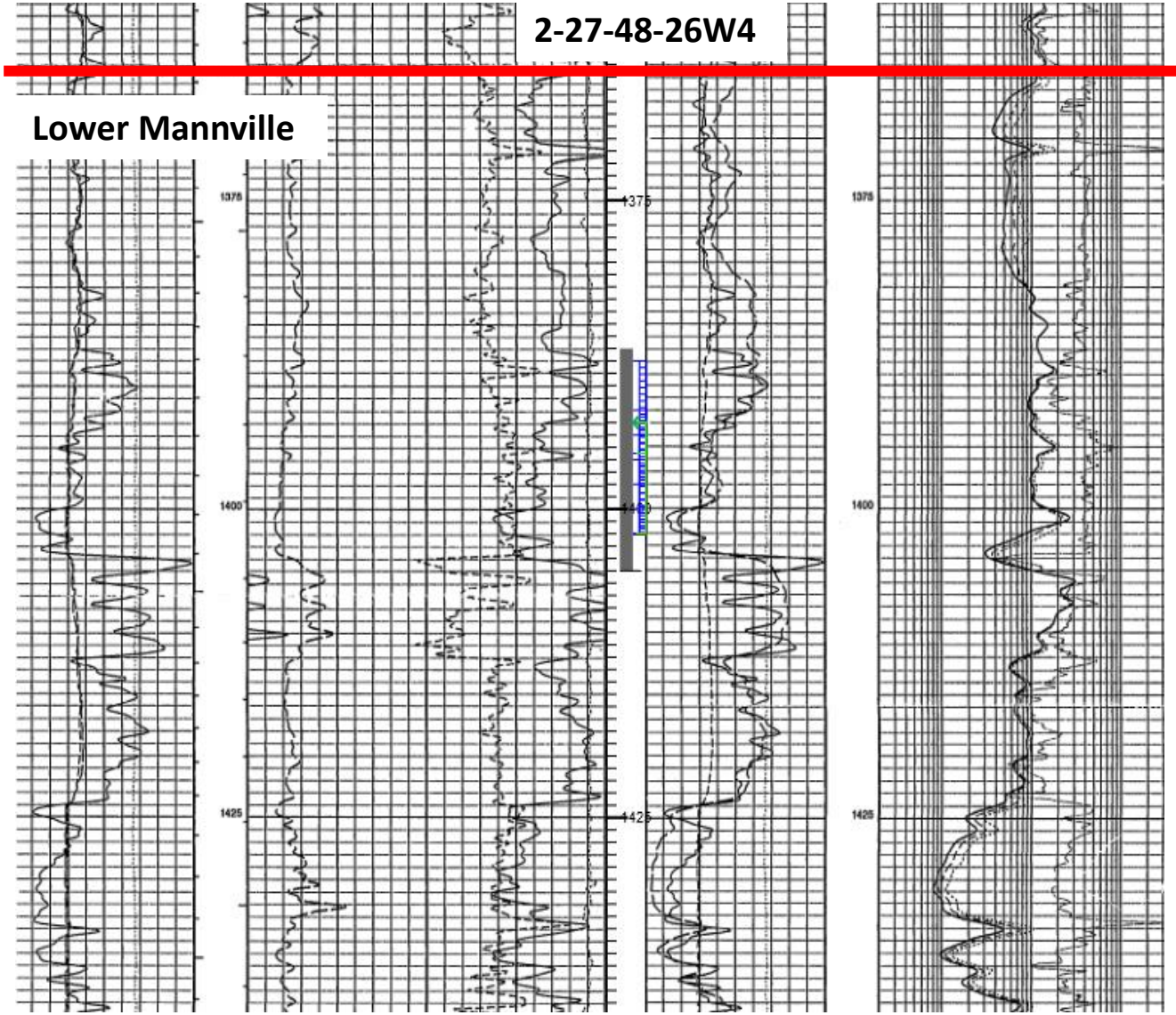
Correlation Challenges

- Being a Coastal Plain environment there are no recognizable shale markers or flooding surfaces
- Thick coals are the only correlatable units but only in limited areas
- Two examples below are four miles apart:



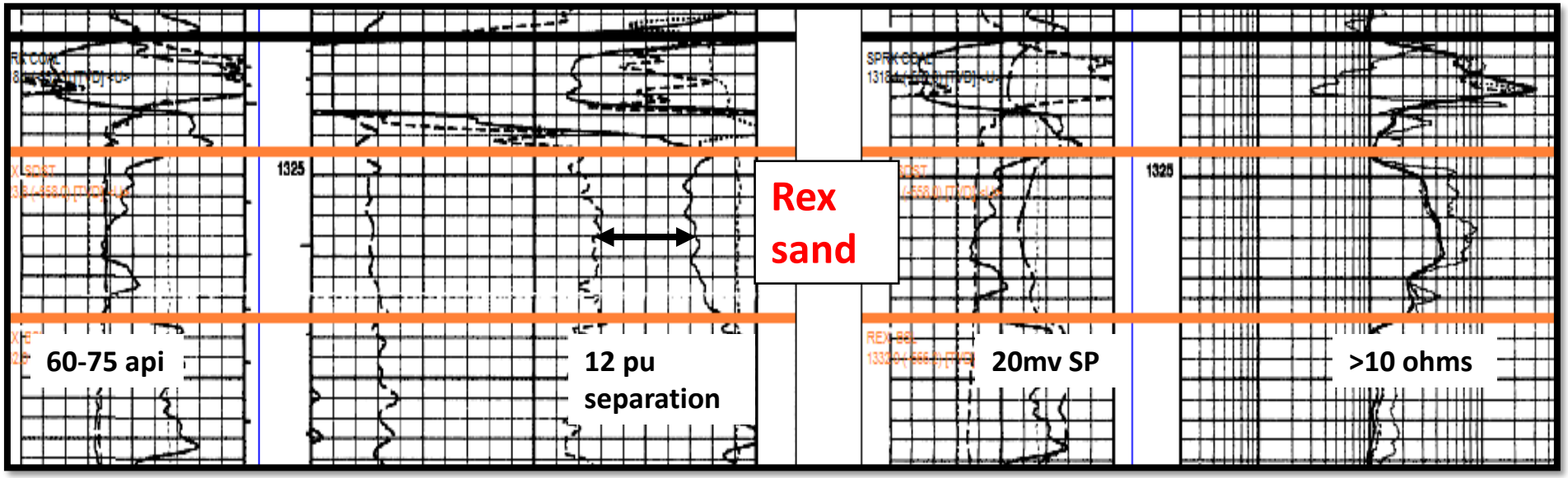
Subtle Log Characteristics

- After initial Devonian targets drilled a second phase of drilling from 1970s to the 2000s
- Clean, high perm Lower Mannville sands were the main target of drilling during second phase
- Lower perm Upper Mannville targets were again ignored because of their subtle log characteristics



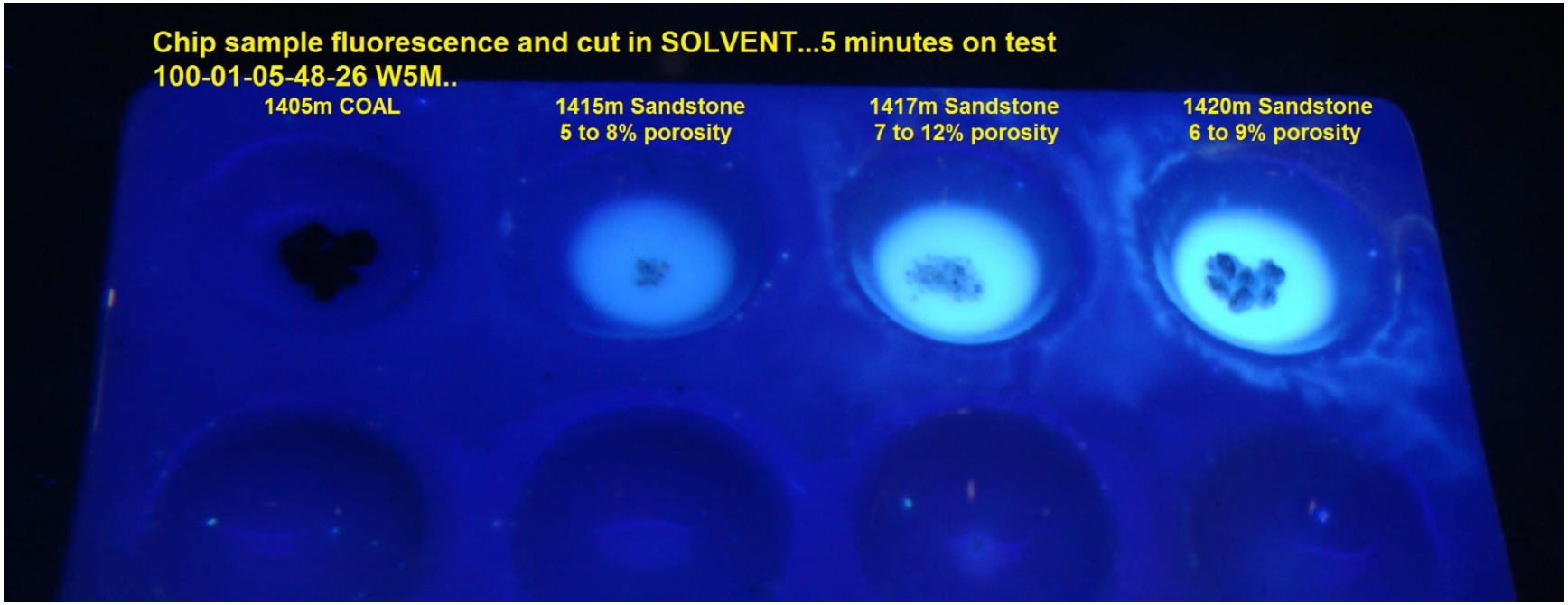
Subtle Log Characteristics

- Neutron-Density separation
- Low to moderate resistivity pay zones
- High gamma readings in sands
- Poor SP development due to low permeability



Lack of Production or Shows

- Prior to 2016, only 3 vertical wells out of almost 900 had production within the pool; 1 gas well and 2 oil wells with all three producing non commercial quantities of hydrocarbons
- All 3 wells originally targeted deeper zones and were recompleted in the Upper Mannville
- The only hint of oil productivity was chip sample analysis with fluorescence being key



PART 2:
LWB Rex member oil pool

POOL PARAMETERS

Depth:	4200-4600ft
Porosity:	9-15%
Permeability:	unknown but likely 1-10mD (no core in pool)
Areal size:	approximately 200 sections
Average net pay:	20ft, range 6-40ft
Water saturation:	30-50%
OOIP:	1.0-1.2Bn bbls
Oil quality:	17 API, 100-200cP, 2.8%S
Pressure:	1600 psi or about 0.37 psi/ft
Oil column:	400ft with no known gas cap
GOR:	varies from 200-1000 scf/bbl
Drive:	solution gas
Depositional environment:	delta/distributary channels

LWB Net Pay Pool Outline

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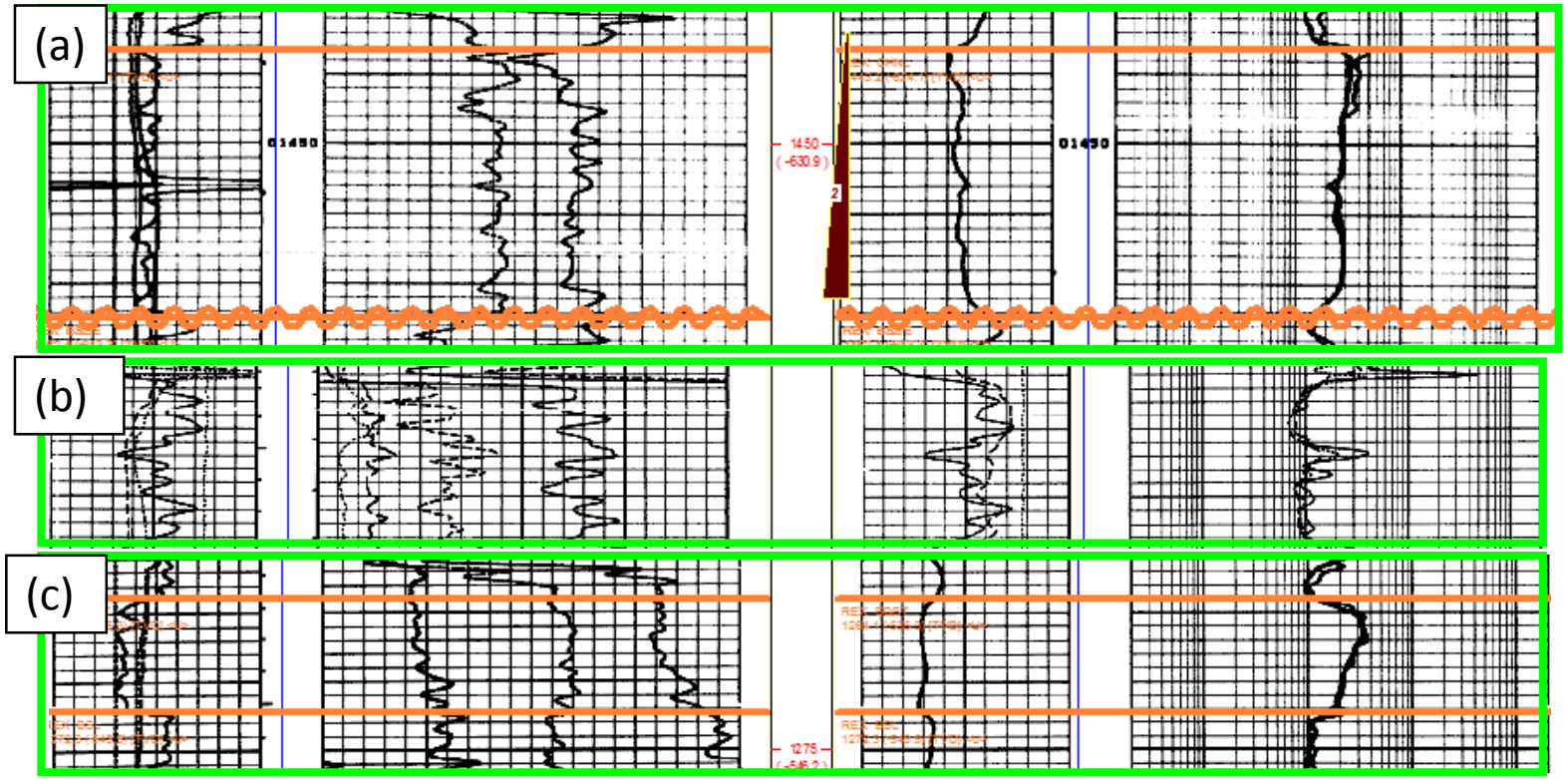
Rex member Facies Type Logs

a) **Channel facies**: medium-coarse grained sands, typically 50-80ft thick, 0.5-1.5mile wide; vary from straight to highly sinuous

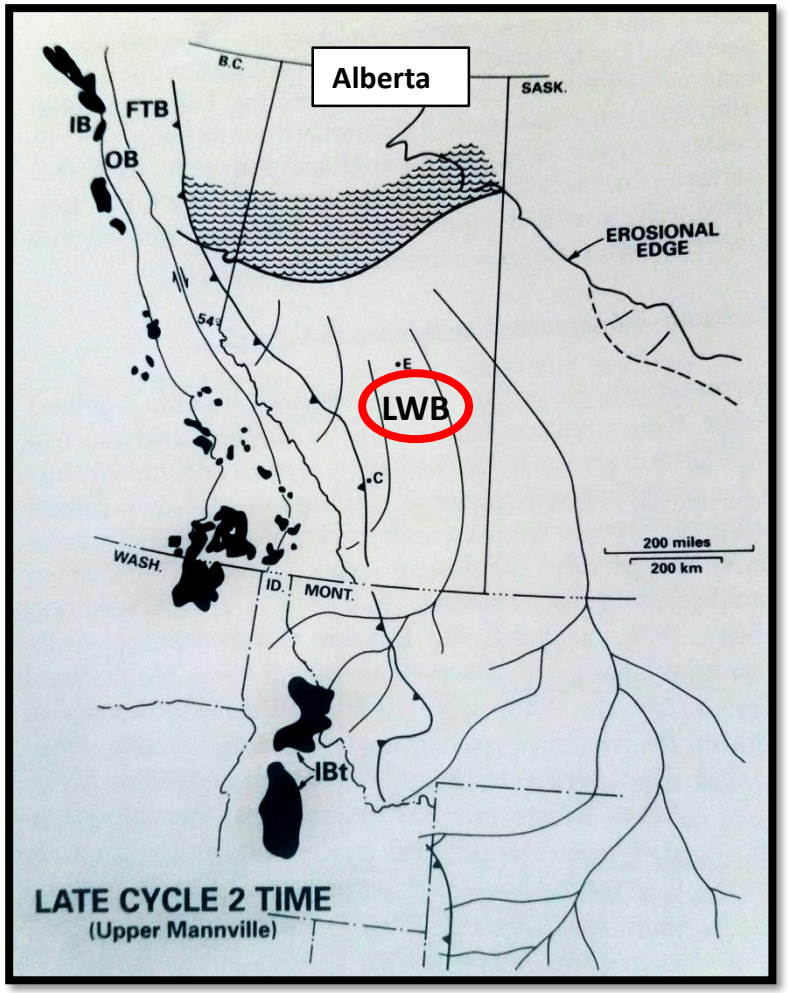
b) **Non channel facies:** silt to fine grained sands interbedded with non-marine shales and thin coals

c) **Delta facies**: fine-medium grained sands; widespread when present



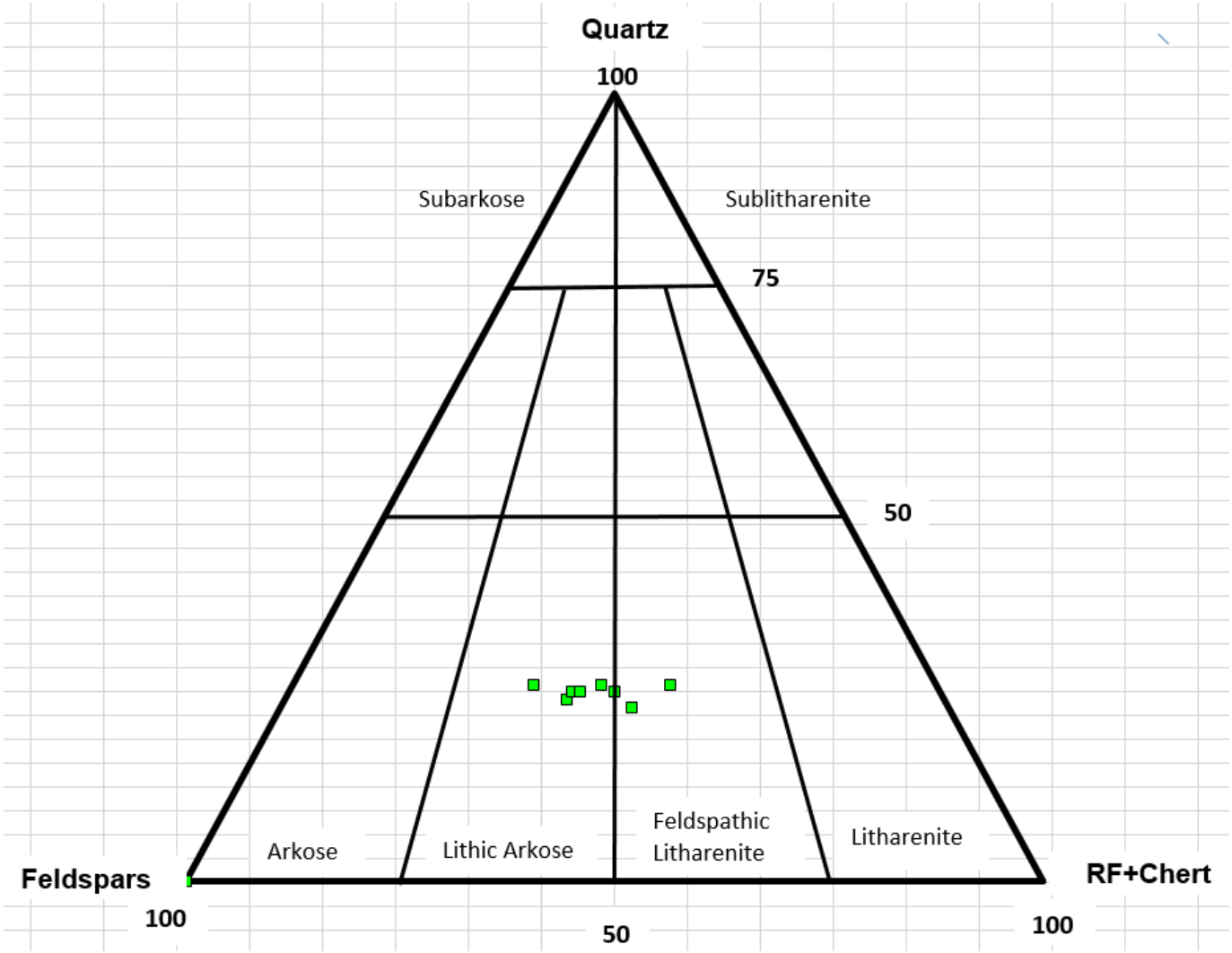
Provenance

- part of the volcano-feldspathic lithofacies within the Upper Mannville
- Texturally immature; likely plutonic or volcanic sources from the south and west; derived from a magmatic arc terrane in Idaho, Washington and BC
- Abundant feldspar and lithic rock fragments; existence of feldspar is important as it controls porosity type
- High percentage of lithic grains severely compacts or alters the framework grains which contributes to poorer permeability



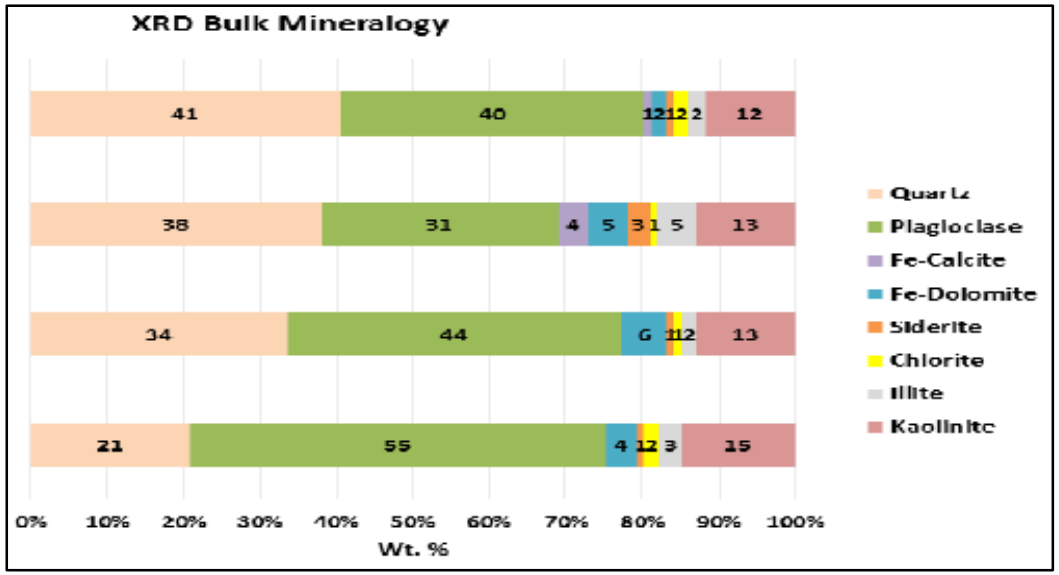
From Potocki and Hutcheon, AAPG Mem 55

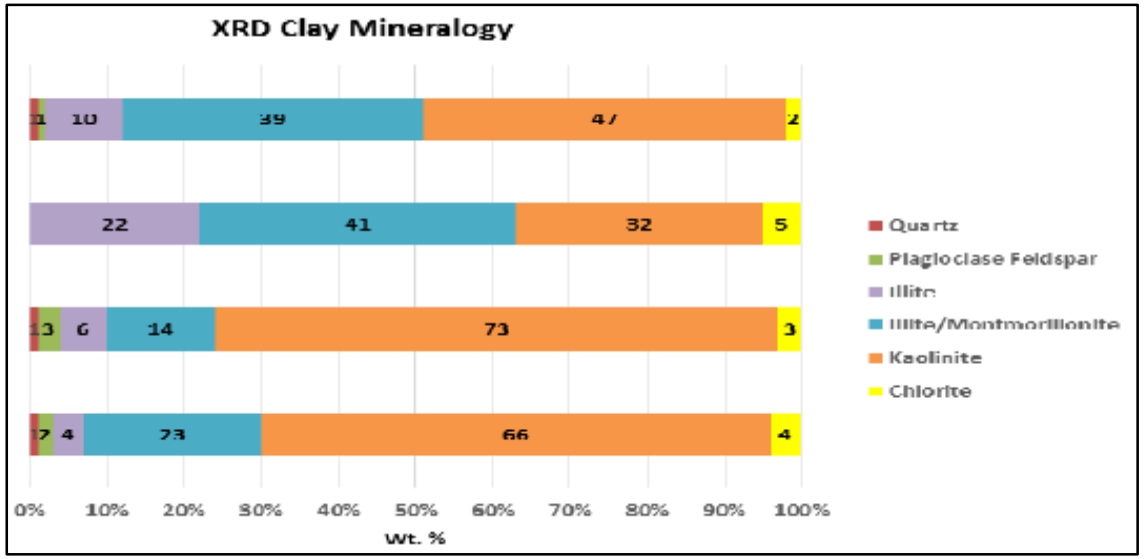
Rock-type Ternary Diagram



Mineralogy data from XRD

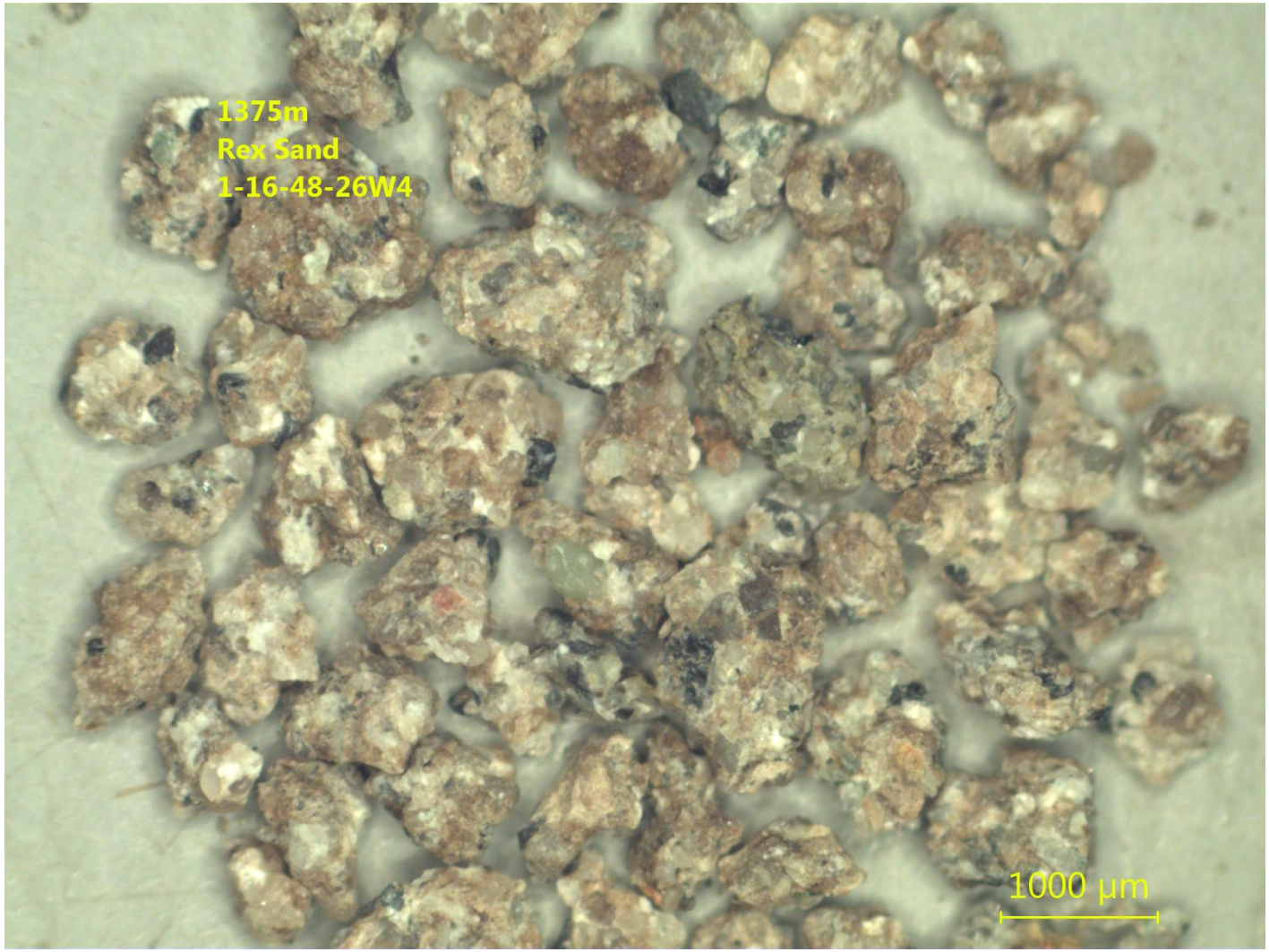
- Bulk mineralogy dominated by plagioclase and quartz
- Clay content varies from 15-40%
- composed mainly of kaolinite, illite and mixed layer illite/ montmorillonite



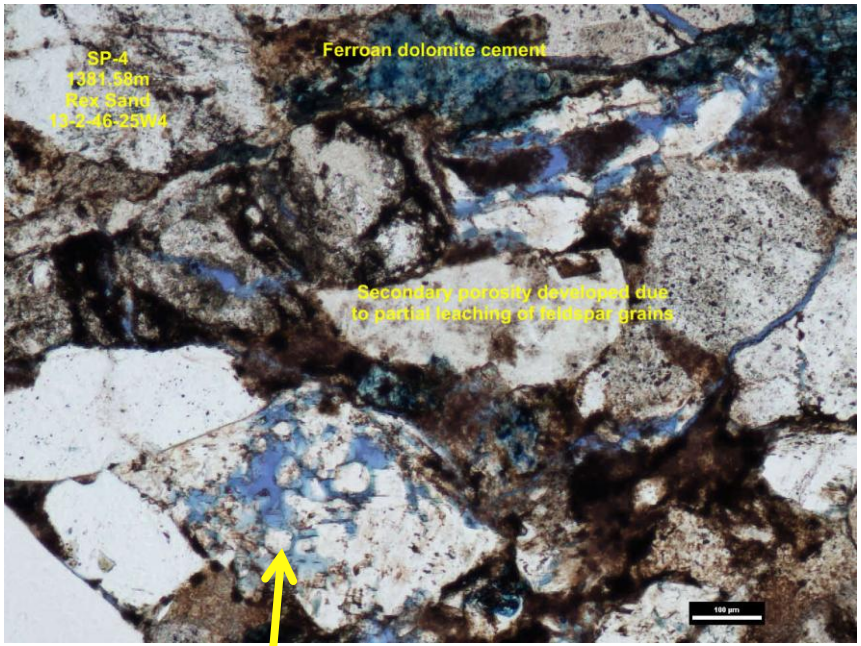


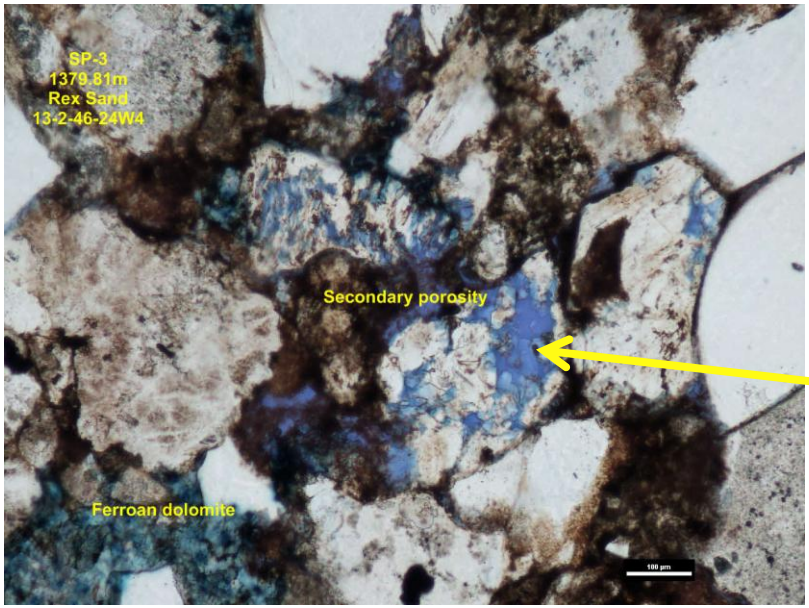
Data from ProGeo Labs

Chip Sample Overview



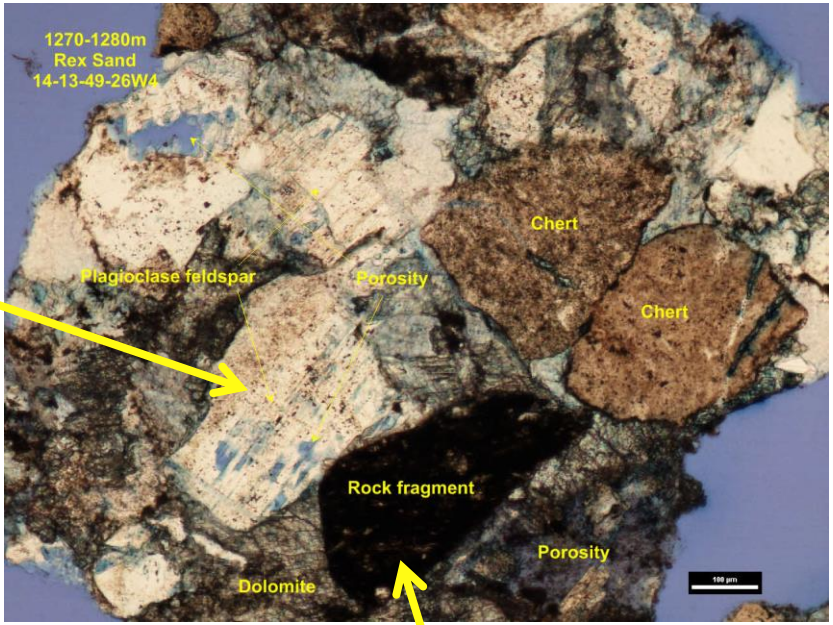
Petrography – porosity examples

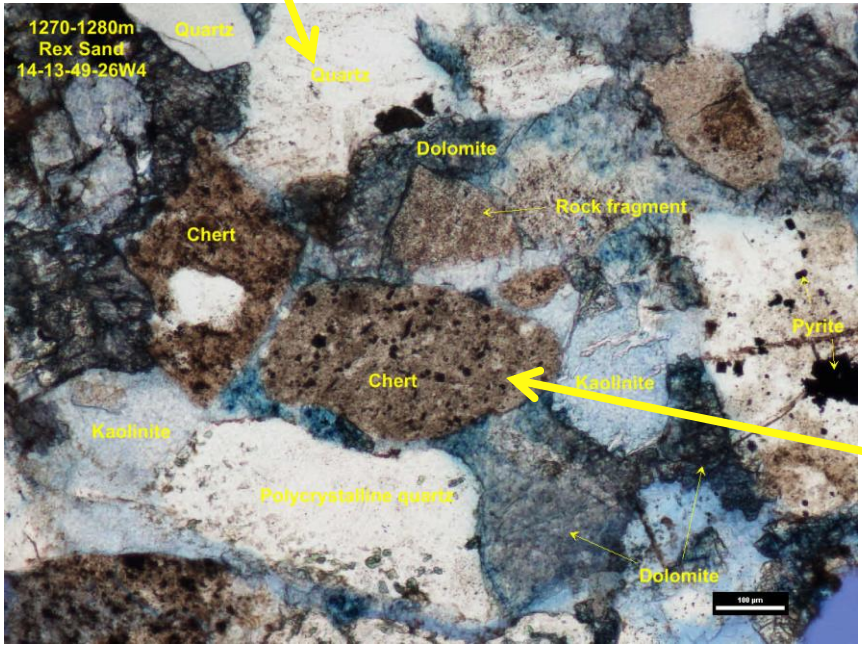




Intragranular porosity

Petrography – grain type examples





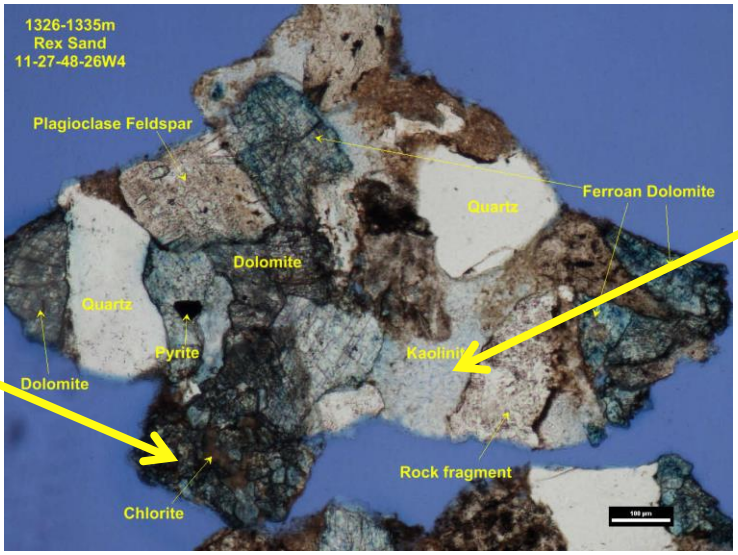
Plagioclase feldspar

Quartz

Rock fragment

Chert

Petrography – cement examples

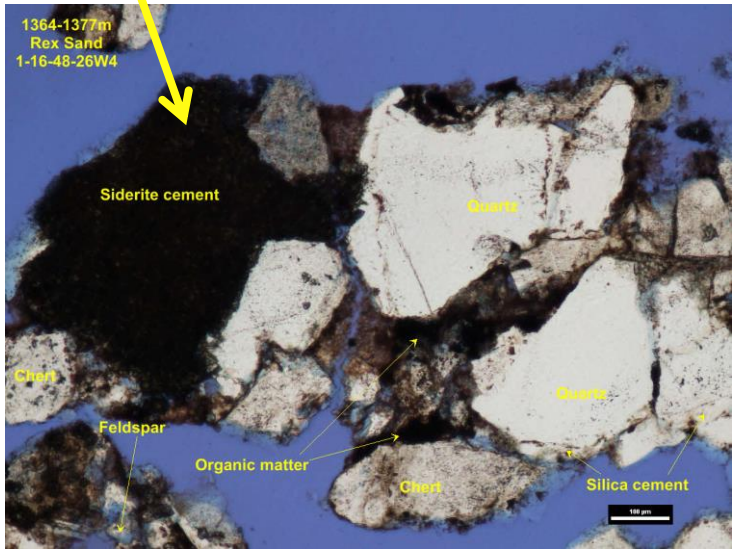


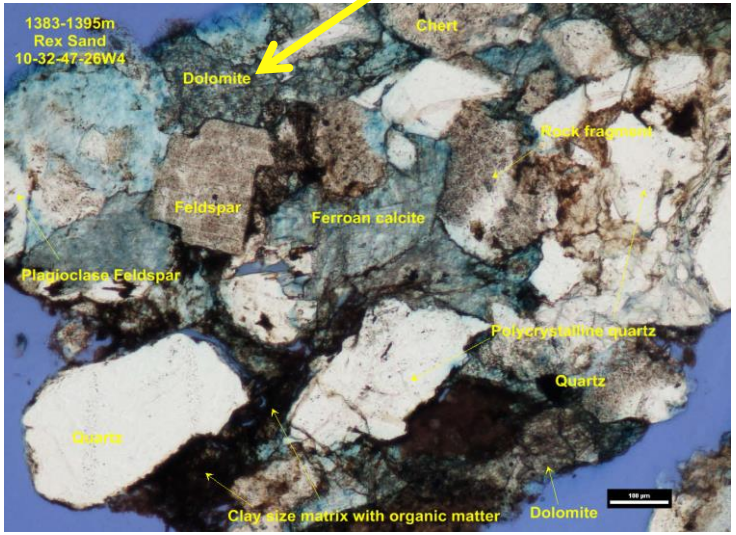
Kaolinite

Chlorite

Siderite

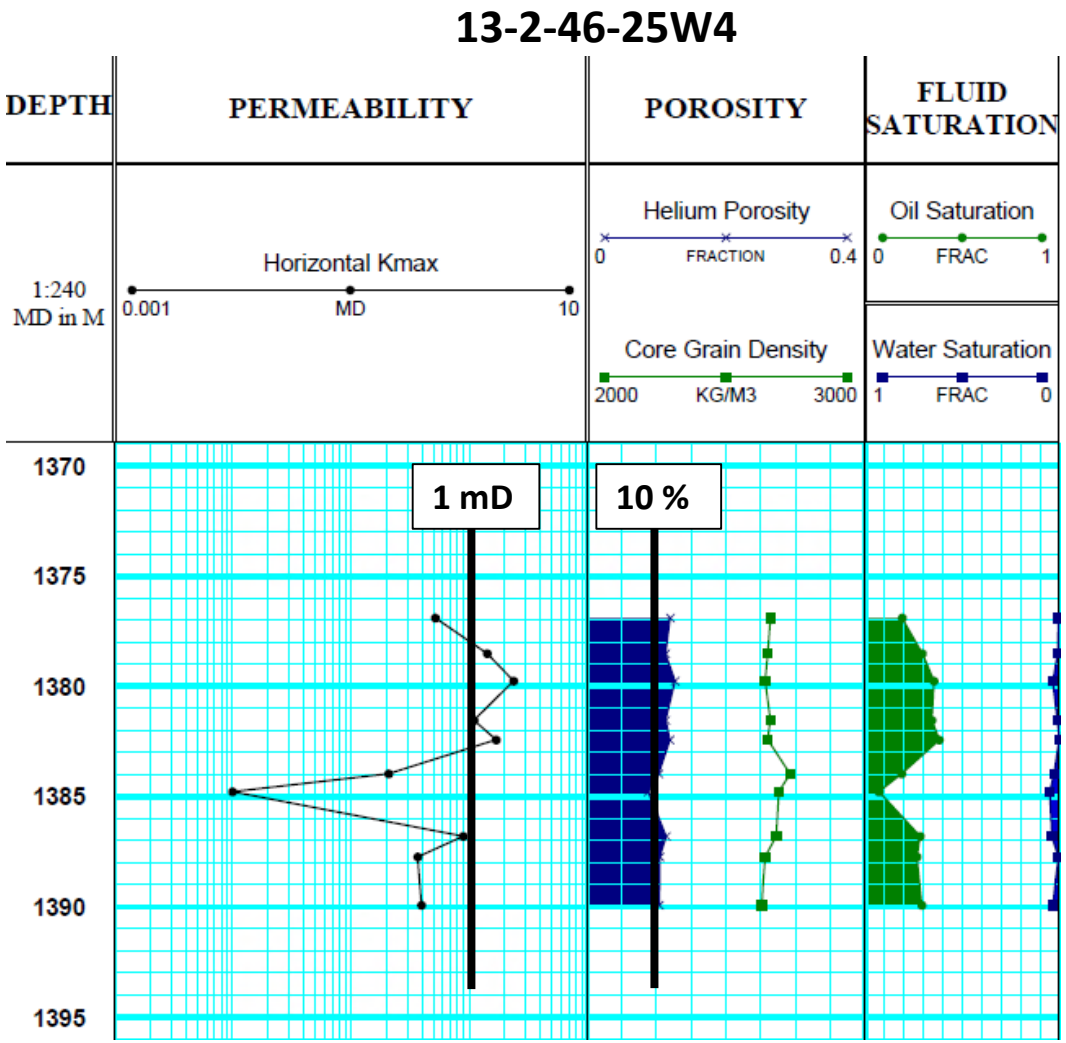
Dolomite



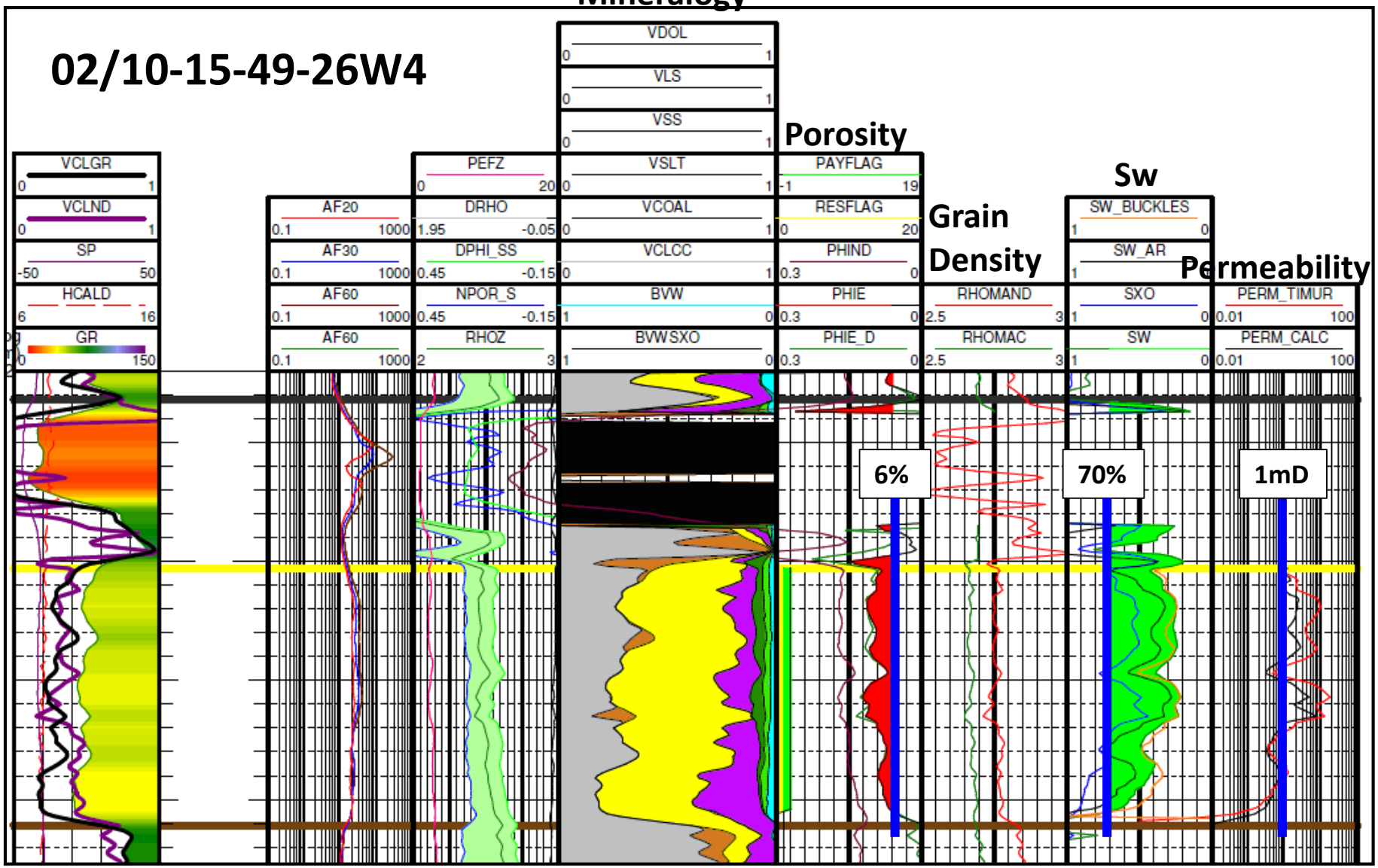


Core Data

- The only core in the area is from a distributary channel (13-2) about 15 miles south of the pool
- Volcano-feldspathic sands quickly decrease in porosity with depth due to lithic material; results in lower permeability in Rex sand vs Lower Mannville sands at LWB

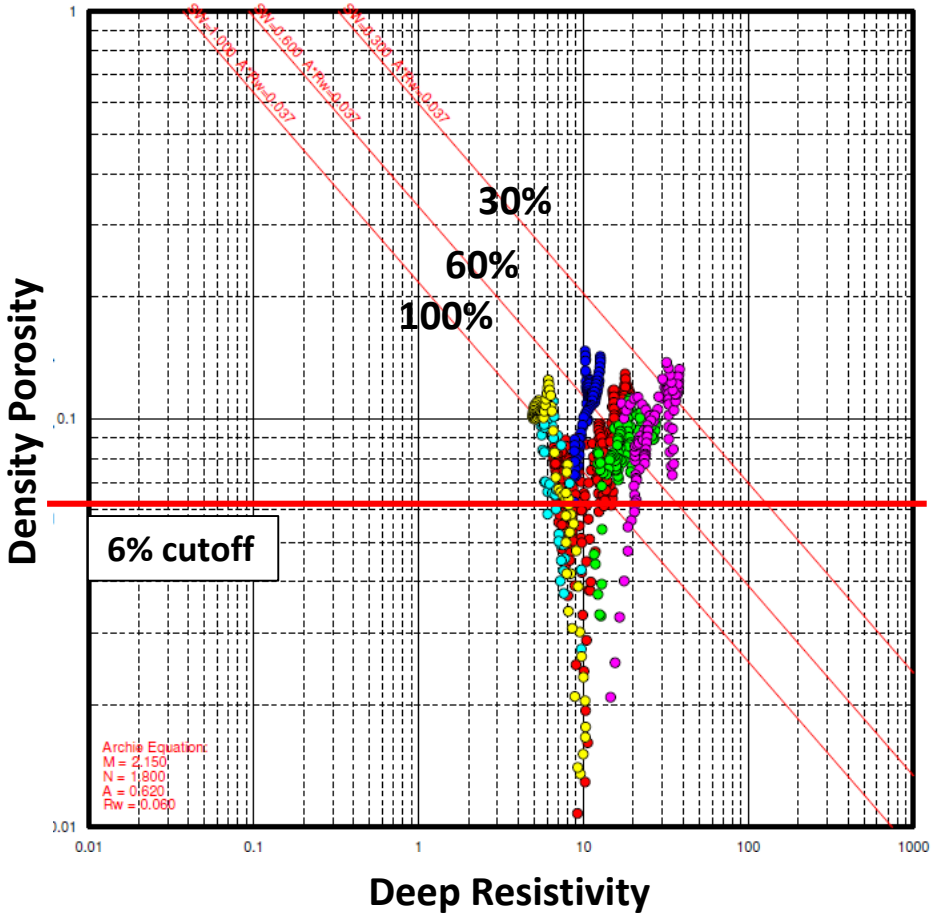


Petrophysical Data

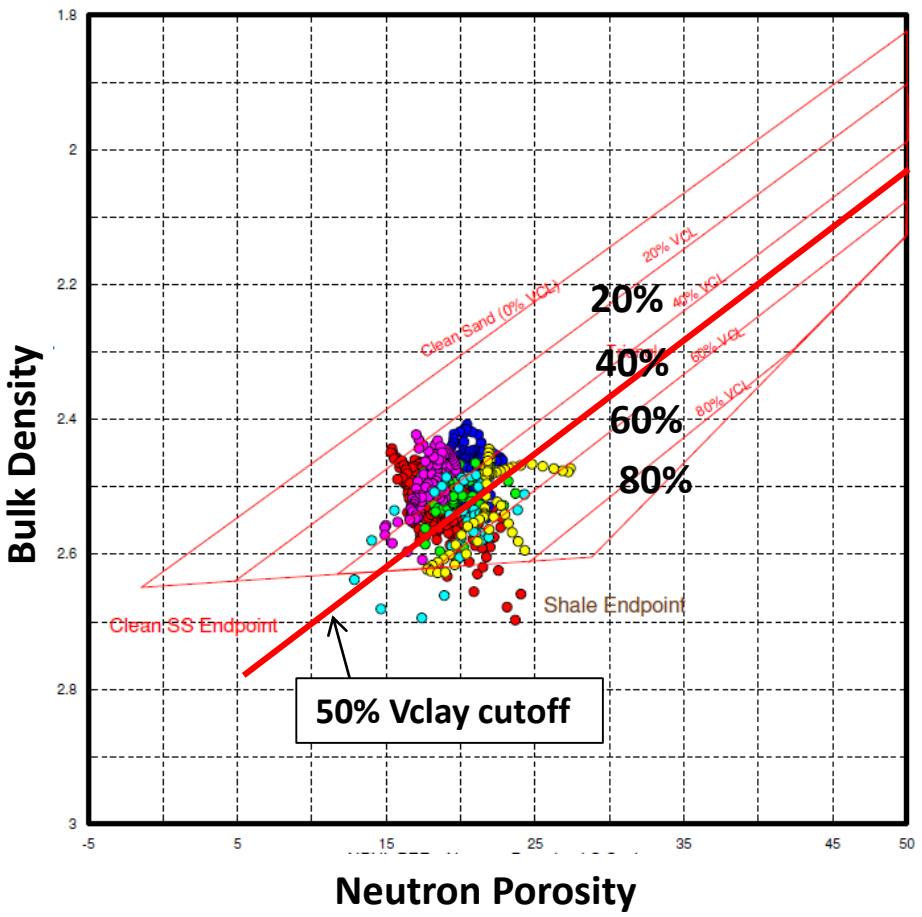


Log Data Cross Plots

Pickett Plot



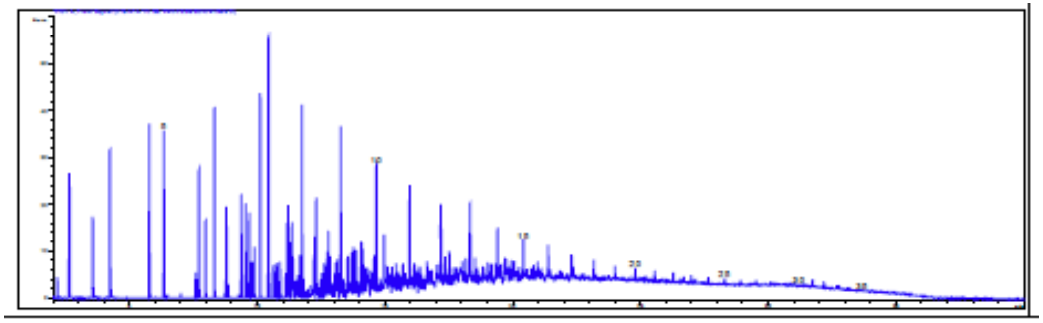
Neutron-Density Cross Plot

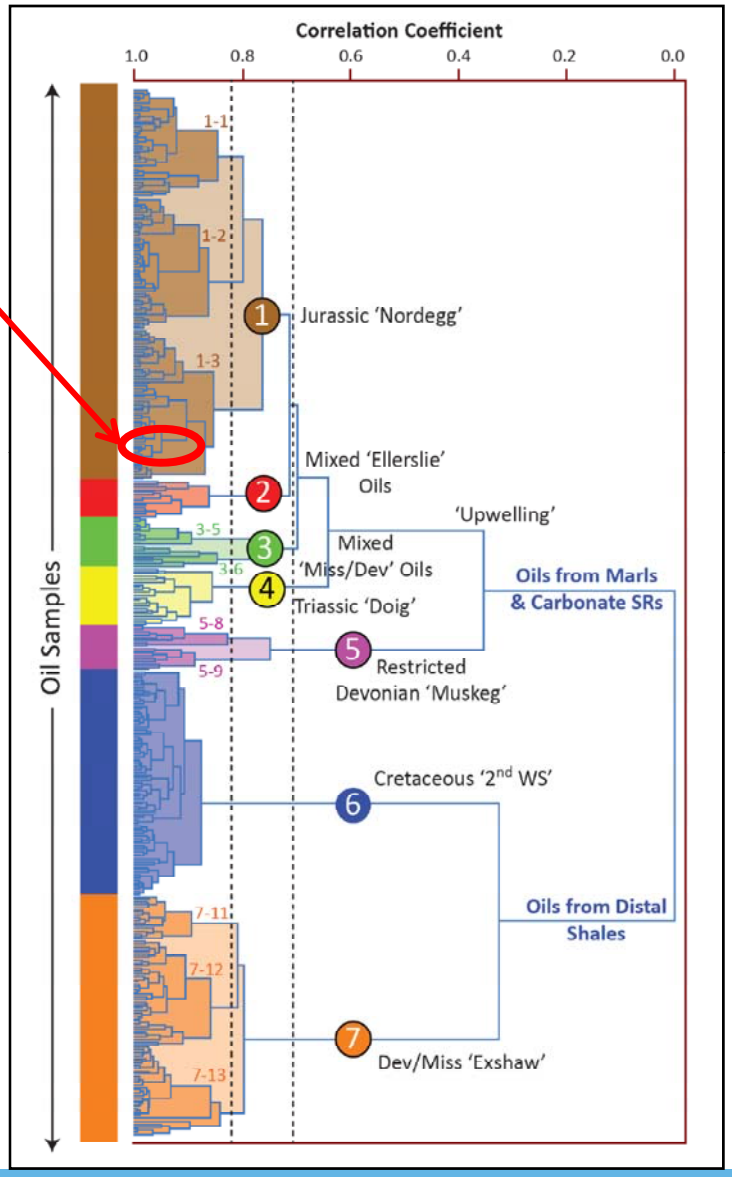


Oil Quality Data

- Moderate degree of biodegration, 16-17 API, 100-200cP, 2.8%sulphur
- Likely from a Nordegg carbonate source as shown by family 1 on plot
- Nordegg oils tend to be low API due to lower thermal maturities near their subcrop edge (approximately 5 Twps to the west) and high sulphur oils due to the sulphur-rich kerogen
- Moderate amounts of light ends which suggests some mixing with other oils; likely from Exshaw

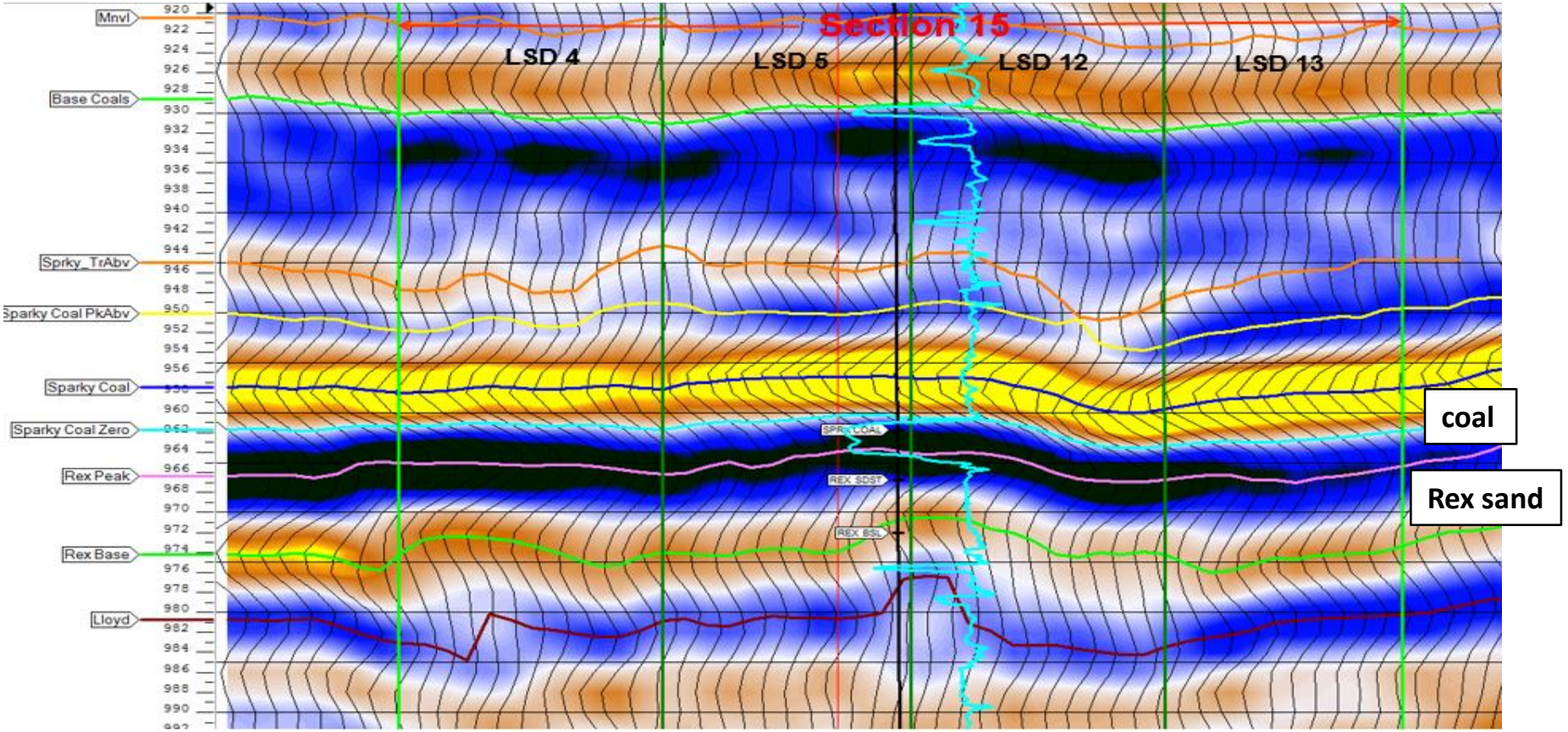
Data from Geomark Research



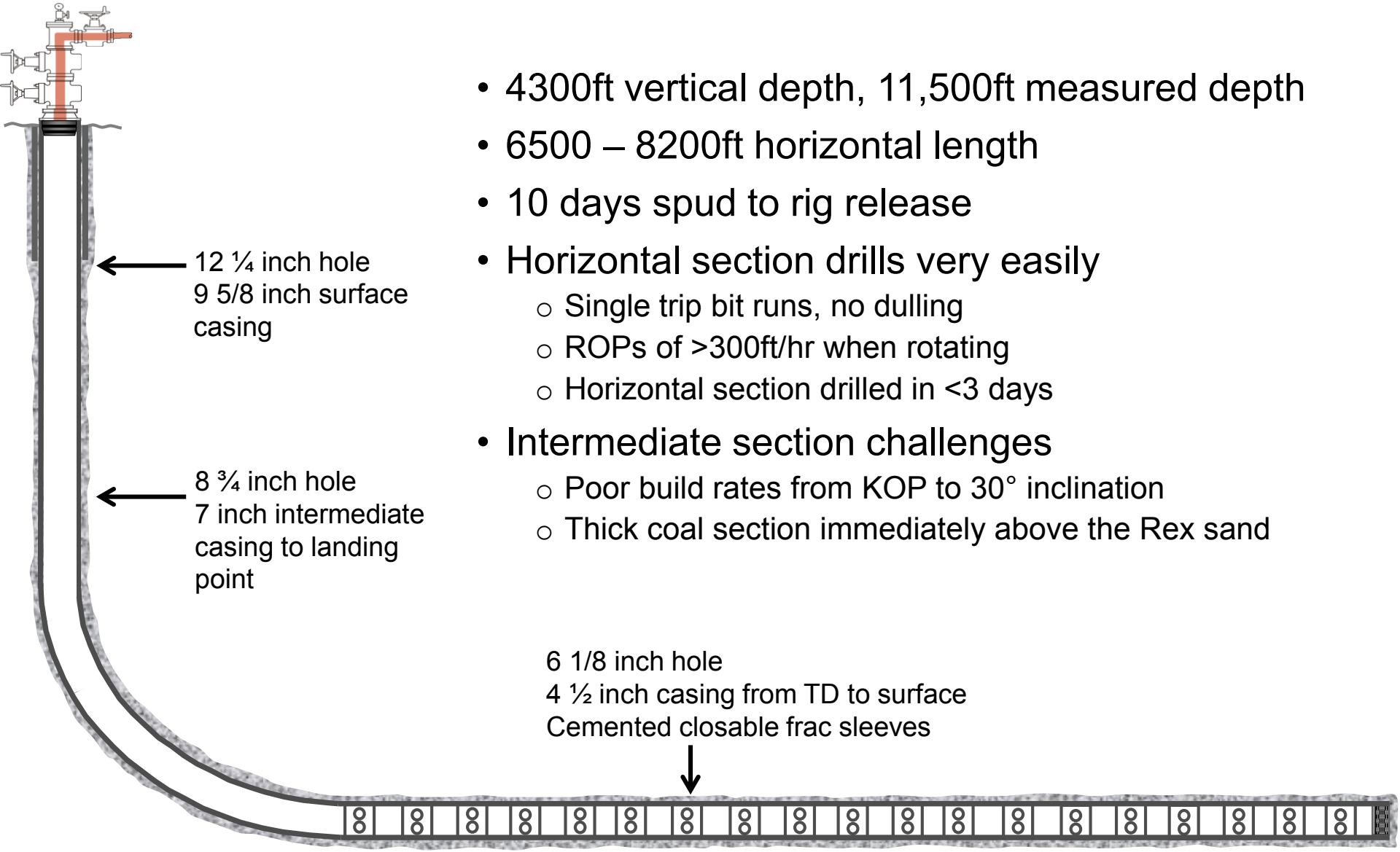


Seismic Data

- Reservoir is too thin to be resolved but used for structural control when drilling
- In areas of poor well control, have used a Rex isochron to identify thicks

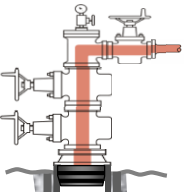


Drilling Well Construction



- 4300ft vertical depth, 11,500ft measured depth
- 6500 – 8200ft horizontal length
- 10 days spud to rig release
- Horizontal section drills very easily
  - Single trip bit runs, no dulling
  - ROPs of >300ft/hr when rotating
  - Horizontal section drilled in <3 days
- Intermediate section challenges
  - Poor build rates from KOP to 30° inclination
  - Thick coal section immediately above the Rex sand

Completions



- Cemented frac sleeves, open – frac – close sequence. All sleeves re-opened after the last frac is complete
- 150ft sleeve spacing, evaluating reducing to 100ft sleeve spacing
- Frac is pumped down the annulus of 2 3/8 inch coiled tubing and the 4 ½ inch production casing
- 16/30 natural sand
- 33,000 lbs per interval on the last well, previously 44,000 lbs per interval
- Fluid system is a crosslinked borate to achieve high proppant concentration at low pump rate

Production and Facilities

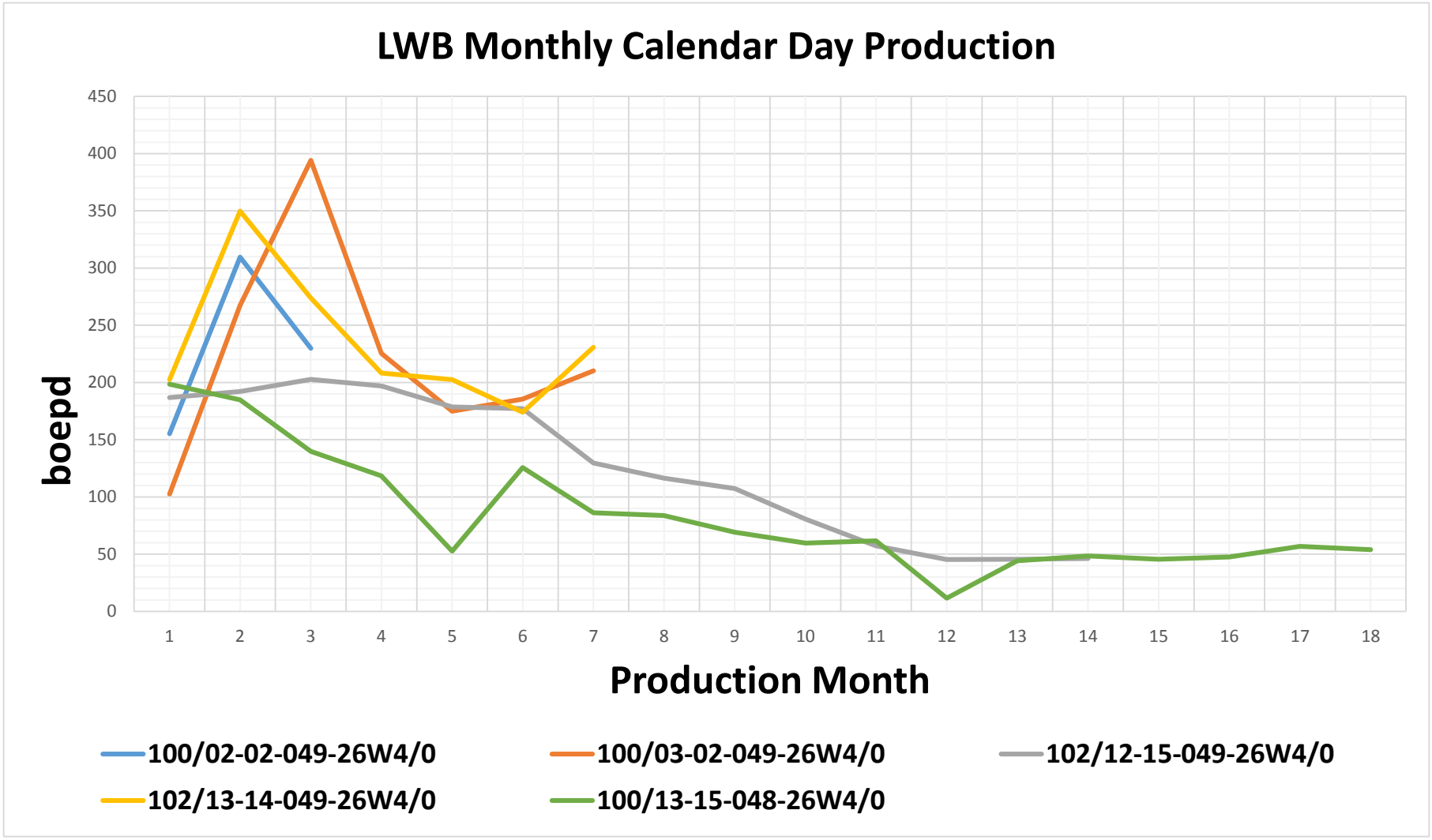
- Have evaluated a variety of artificial lift systems
  - Jet pump
  - Insert pump with pump jack
  - Electric Submersible Pumps (ESP)
  - Progressive Cavity Pumps (PCP)
- Prefer PCP's due to wide production operating range, ability to handle solids and ease of operating in a viscous oil environment
- Constructing a multi-well battery in 2018/2019 capable of handling approximately 6000bfpd (3000bopd)
  - Clean oil hauled to sales points
  - Water removed and disposed into Viking and Ellerslie formations
  - Solution gas processed at a downstream gas plant

Field Operations

13-15-48-26W4
fracing operation

13-15-48-26W4 wellsite

Production Plot



Economics and Inventory of Locations

- Robust economics on both freehold and crown lands
- Inventory of about 200 1mile equivalent wells based on 4 wells/section
- Depending on pace of development that translates into 10-15 years of drilling inventory

LWB 1.5 Mile Crown Hz MSF Type Curve AB MRF Economics		
Price Forecast	**McDaniel Q2 2018**	**$US65/bbl WTI Flat**
DCET Capital	$2,650,000	
1st Month IP	270 boepd	
1st Year Average	165 boepd	
EUR (2P)	250 Mboe	
NPV10BT	$2.9MM	$2.9MM
Payout (yrs)	**1.4**	**1.3**
IRR	**75%**	**82%**
F&D	$10.65/boe	
Operating Cost	$10.00/boe	
Operating Netback	$33.50/boe	$35.50/boe
Recycle Ratio	**3.1**	**3.3**
Liquids Weighting	80%	
Breakeven Oil Price (2)	WTI US$ 42.55/bbl	

Pool Development Plan

Proprietary Slide Removed

Conclusions

- Upper Mannville a significant hydrocarbon target in the WCSB
  - A common conventional oil and gas producer with multiple pools
  - Contains 9 of the top 40 conventional oil pool discoveries
- A relatively immature, bypassed target
  - Difficult to map and interpret based on subtle log response
  - Poorly understood; no regional industry trend maps or cross sections available
  - New ideas applied to abundant old data
- Multi-stage frac horizontal wells have allowed economic rates of production from this low permeability zone
  - This technology has led to large oil and gas pool discoveries and extensions
  - In the deep basin producers are realizing massive productivity gains within the gas window
- Discovery of the LWB Rex oil pool in a mature basin is an example of combined hard work, skill and luck

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