



**CSPG**  
**CORE CONFERENCE**  
IN CONJUNCTION WITH GEOCONVENTION 2017

18-19 MAY 2017 | AER CORE RESEARCH CENTRE | CALGARY, AB

Variability in Spirit River (Wilrich-Falher) reservoir facies associations in the Deep Basin: sequence stratigraphy, accommodation space, reservoir quality and chemostratigraphy

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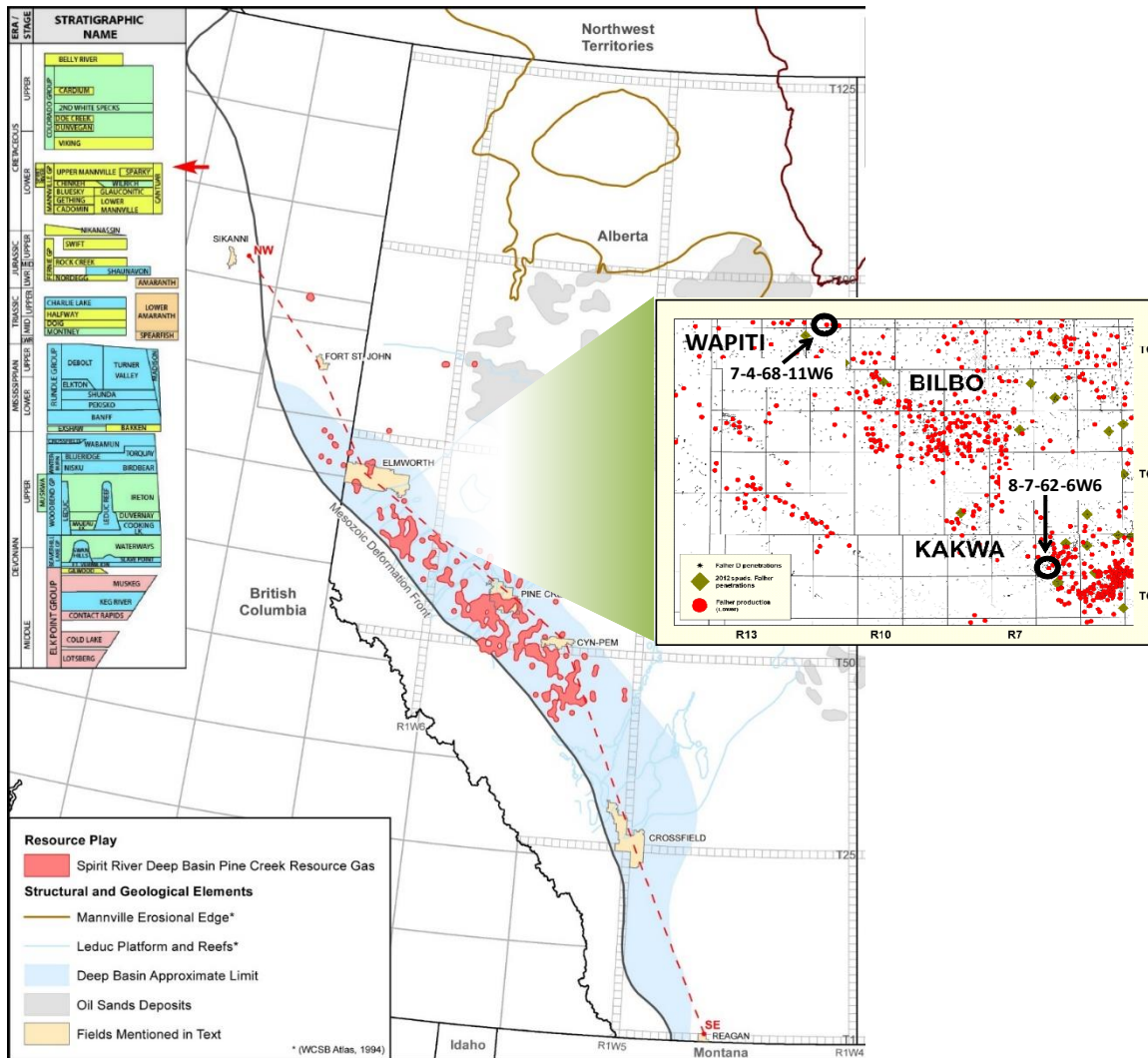


*Gemma Hildred*

*Chemostrat Inc.*



# Location Map



(Canadian Discovery)

# Outline

- Introduction and Purpose
- Economic Rationale for studying Wilrich – Lower Falher interval
- Conventional – Unconventional Continuum:
  - Conglomeratic vs. tight sandstone reservoir model
  - Reflective vs. Dissipative Shoreface model
- Asymmetric Wave-Dominated Delta model
- CANHUNTER ET AL ELMWORTH 7-4-68-11W6
- ECA KAKWA 8-7-62-6W6
- Summary and Conclusions

# Purpose of Core Display

- **Conventional – Unconventional Continuum:**

- Focus on conventional conglomerate vs. tight sandstone reservoir facies associations from the Spirit River Group strata in the Deep Basin of Alberta
- Core #1 is a highstand, conglomeratic, high accommodation, progradational reflective shoreface facies association from the Falher D in the Elmworth field (7-4-68-11W6)
- Core #2 is from the Lower Falher to Wilrich in the 8-7-62-6W6 well in the Kakwa area - a low accommodation, sandstone comprised of dissipative shoreface to wave dominated delta facies associations
- Differentiation between Wilrich and Falher in Spirit River Group
- “Sweet-spot” characterization

# Top 2016 Drilling Activity

## Last 12 Months Top 20 Monthly Gas Wells (Calendar Day Rate)

0 wells - Deep Basin – Overfilled Foreland Basin

19 wells - Deep Basin – Underfilled Foreland Basin – Spirit River Group

1 wells - Deep Basin - Pre-foreland Basin - Montney

Unique Well ID	Current Operator Name	Formation	Spud Date	On Prod	Field Name	Pool Name	TVD (m)	Peak Mthly boe/d	Cum. Oil & Cond. (bbl)	Cum. Gas (mcf)	% oil
102/01-22-049-19W5/00	Tourmaline Oil Corp	Knotikwn	1/25/2016	2016/02	MINEHEAD	U MANN UND	3,039	4,235	81	5,627,213	0%
100/08-14-059-02W6/00	Jupiter Rsrcs Inc	Kfalher	8/6/2015	2016/03	SMOKY	FALH UND	3,265	2,798	789	3,395,581	0%
100/09-14-059-02W6/00	Jupiter Rsrcs Inc	Kfalher	9/10/2015	2016/03	SMOKY	FALH UND	3,255	2,779	744	3,216,941	0%
102/12-30-058-01W6/00	Tourmaline Oil Corp	Kfalher	1/17/2016	2016/02	SMOKY	SPRT R UND	3,307	2,850	2,024	3,177,575	0%
100/04-29-061-06W6/00	Tourmaline Oil Corp	Kspirit_r	11/10/2015	2016/02	KAKWA	SPRT R UND	3,266	2,892	304	2,646,820	0%
100/03-19-044-09W5/00	Bellatrix Expl Ltd	Kfalher	7/17/2016	2016/03	WILLESDEN GREEN	COMMINGLED MFP9537	2,407	2,126	81	2,570,246	0%
102/13-34-067-04W6/00	Cdn Intl Oil Operating Co	TRmontney	1/2/2016	2016/03	ELMWORTH	MONTNEY III	2,369	2,930	136,058	2,438,497	25%
102/01-18-045-11W5/00	Westbrick Enrg Ltd	Kspirit_r	8/24/2015	2016/02	PEMBINA	SPRT R UND	2,603	1,716	16	2,418,265	0%
100/03-19-051-18W5/00	Tourmaline Oil Corp	Kwilrich	1/21/2016	2016/02	EDSON	SPRT R UND	2,799	1,802	129	2,275,875	0%
100/08-21-058-27W5/00	Tourmaline Oil Corp	Kspirit_r	12/11/2015	2016/02	LELAND	SPRT R UND	3,150	2,282	10,641	2,191,212	3%
100/15-33-061-05W6/00	Jupiter Rsrcs Inc	Kspirit_r	8/31/2015	2016/02	KAKWA	COMMINGLED POOL 005	2,960	2,029	82	2,188,230	0%
102/04-27-059-02W6/00	Jupiter Rsrcs Inc	Kfalher	4/12/2015	2015/09	RESTHAVEN	FALH UND	3,203	2,620	296	2,178,590	0%
100/10-06-060-01W6/00	Jupiter Rsrcs Inc	Kfalher	8/27/2015	2016/04	RESTHAVEN	FALH UND	3,074	2,693	1,565	2,120,728	0%
100/03-25-051-18W5/00	Tourmaline Oil Corp	Kwilrich	2/8/2016	2016/03	EDSON	TD UND	2,703	1,793	191	2,102,769	0%
103/15-29-054-24W5/00	Cdn Nat Rsrcs Ltd	Knotikwn	10/19/2014	2016/02	PEDLEY	TEMP COMMINGLED CODI	3,136	1,548	1,162	2,101,750	0%
100/04-29-058-27W5/00	Tourmaline Oil Corp	Kspirit_r	1/23/2016	2016/02	LELAND	SPRT R UND	3,144	2,475	6,283	2,092,468	2%
102/06-06-060-01W6/00	Jupiter Rsrcs Inc	Kfalher	8/21/2015	2016/05	RESTHAVEN	FALH UND	3,089	2,672	600	2,061,351	0%
102/16-15-049-19W5/00	Tourmaline Oil Corp	Kspirit_r	10/20/2016	2016/11	MINEHEAD	TD UND	3,048	5,879	7,226	2,056,165	2%
100/13-17-060-26W5/00	Tourmaline Oil Corp	Kfalher	10/10/2015	2016/02	LELAND	SPRT R UND	2,853	2,195	7,015	1,939,061	2%
100/06-29-061-06W6/00	Tourmaline Oil Corp	Kspirit_r	10/1/2015	2016/02	KAKWA	SPRT R UND	3,237	2,184	311	1,927,756	0%

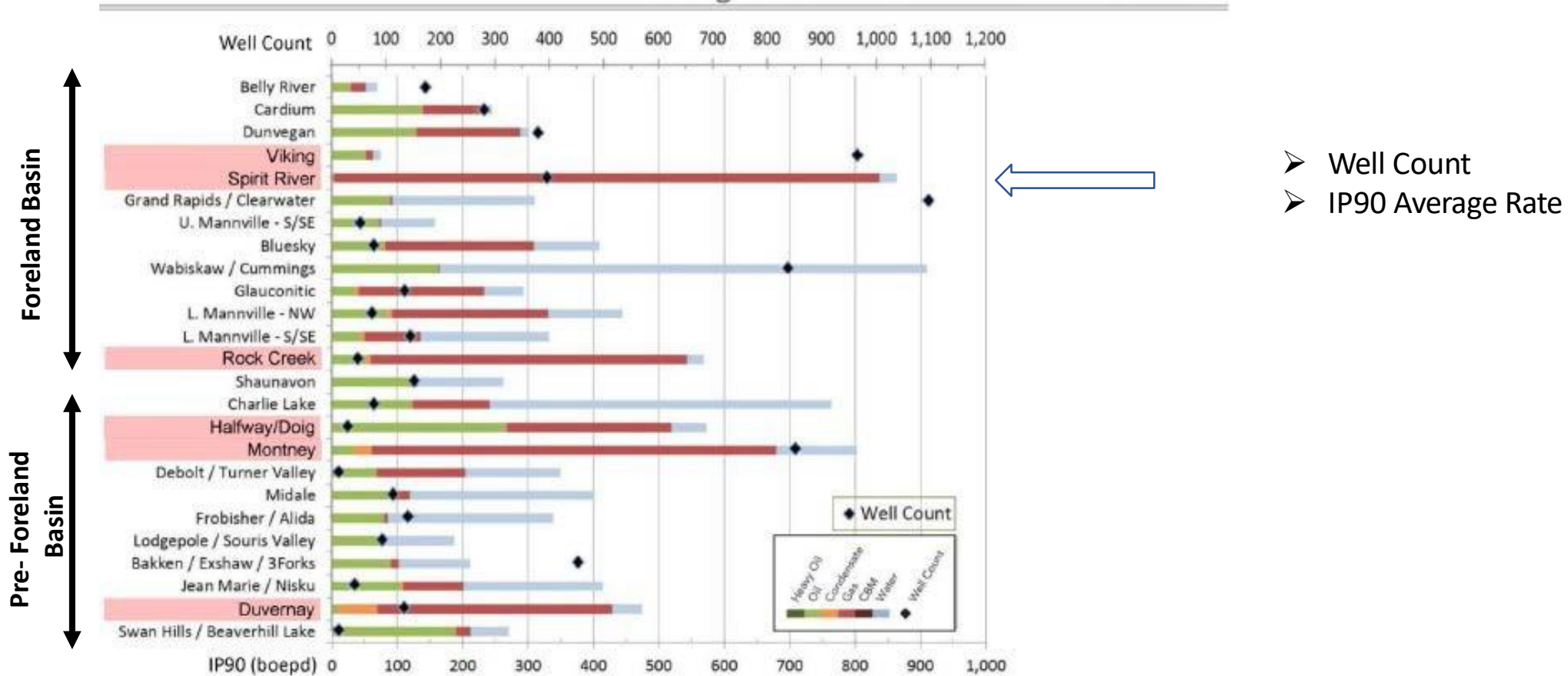
Kwan, van Bolhuis and Murphy, 2017



# Production and Well Count by Formation

## IP90 Average Rate – Wells on Stream in 2016

Production and Well Count by Formation  
IP90 Average Rate—Wells On-Stream in 2015

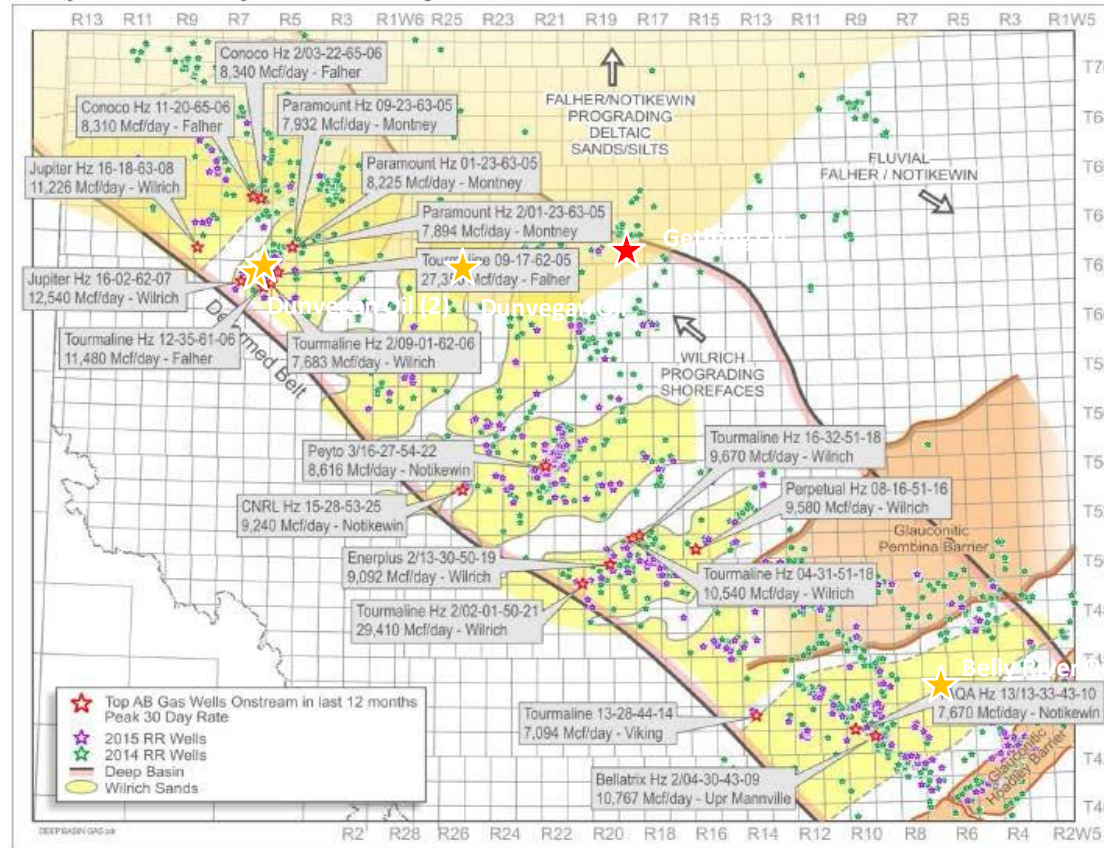


Fockler, 2016

# Top 2015 Drilling Activity

## Distribution of Top AB Gas Wells (*based on IP 30*)

Deep Basin – Top Well Activity in 2015



(1): Scotiabank Geoscout, September 2015



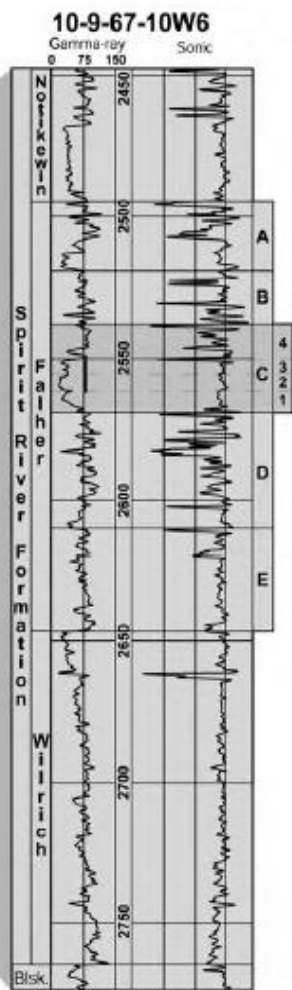
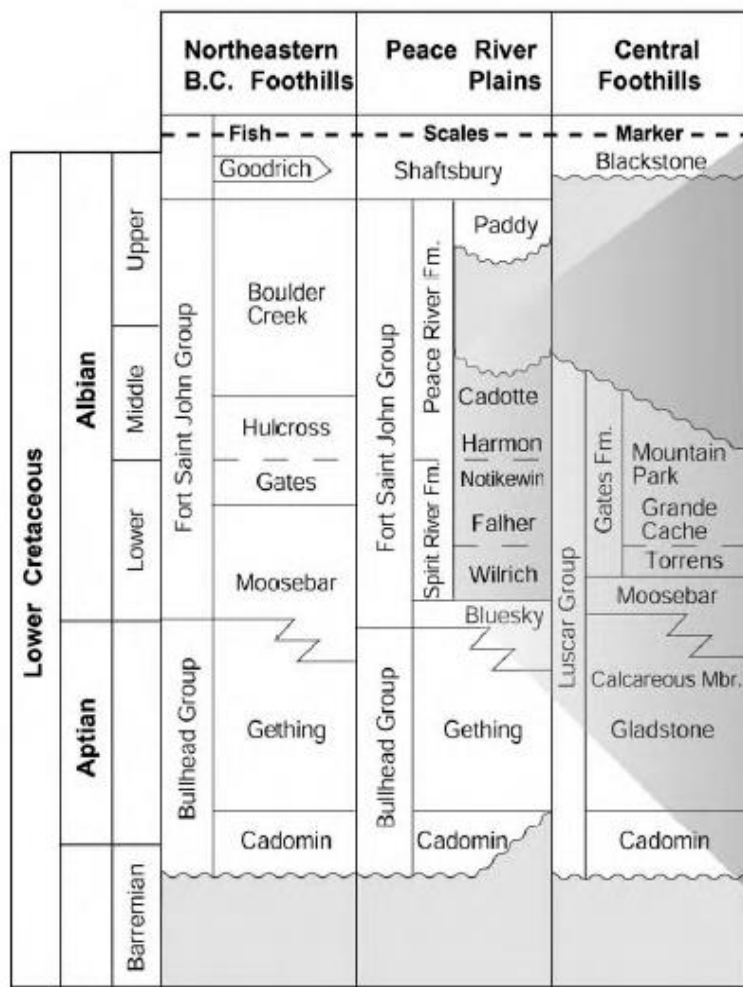
GLOBAL BANKING AND MARKETS

28

- Top 20/20 gas wells
- Spirit River Reservoir Trends (yellow)
- Underfilled FB

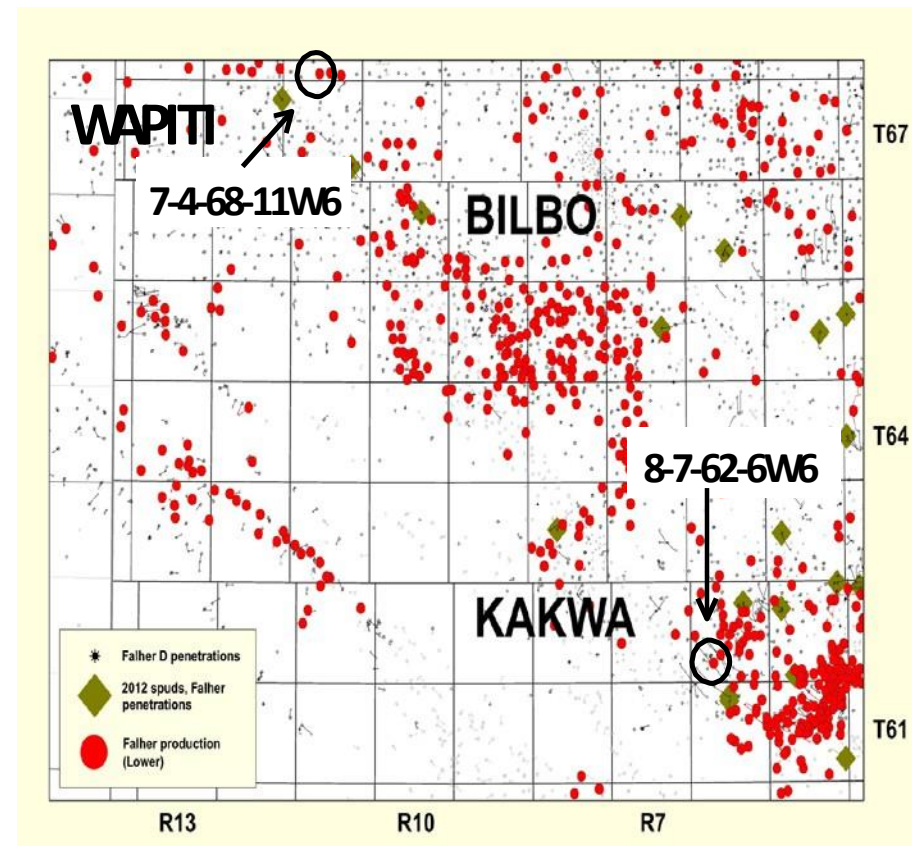


# Stratigraphy – Fort St. John – Spirit River Groups



7-4-68-11W6

8-7-62-6W6



# Conventional – Unconventional Continuum

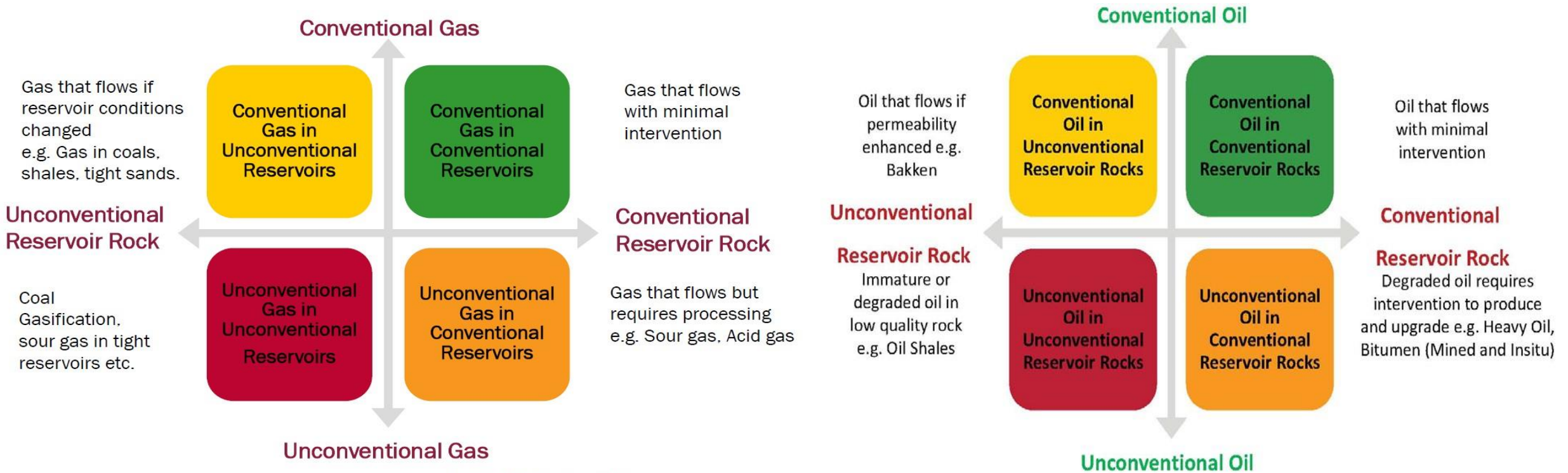


Image Source: AJM (Russum, 2010)

Source: R. Mann, AJM Petroleum Consultants, 2010



# Conventional – Unconventional Continuum - Gas

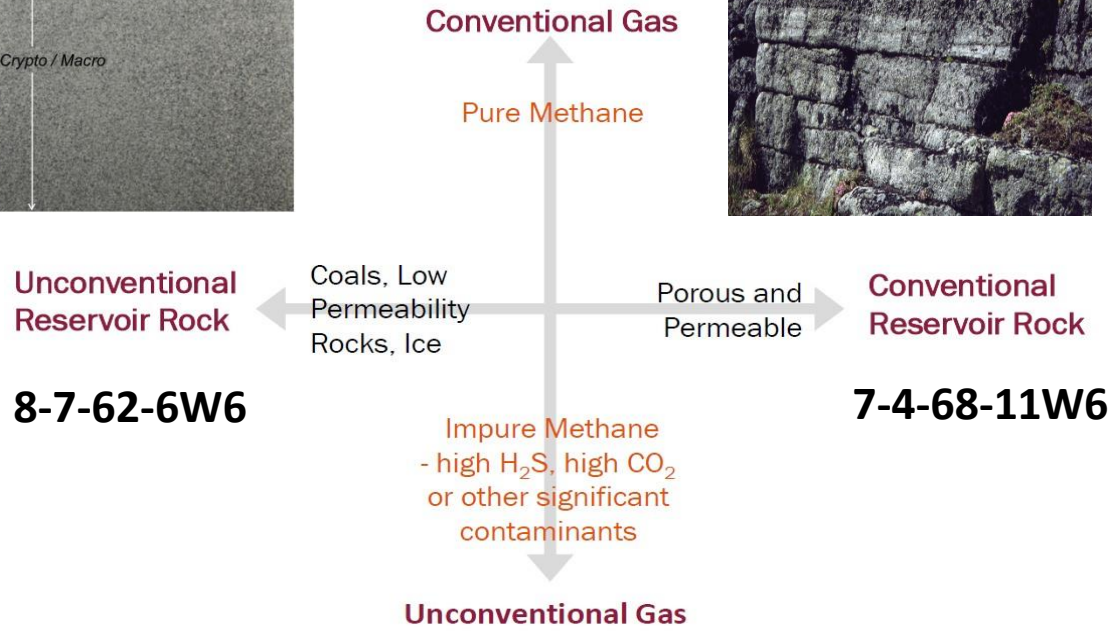
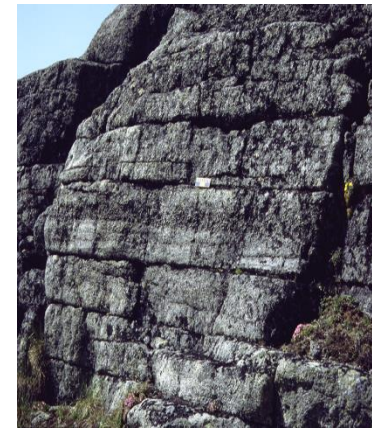
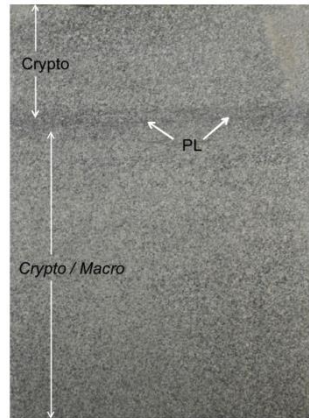
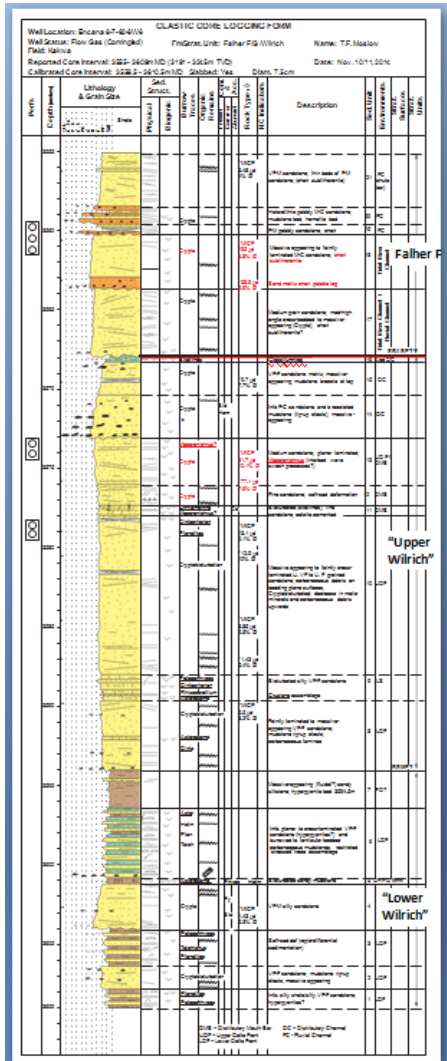
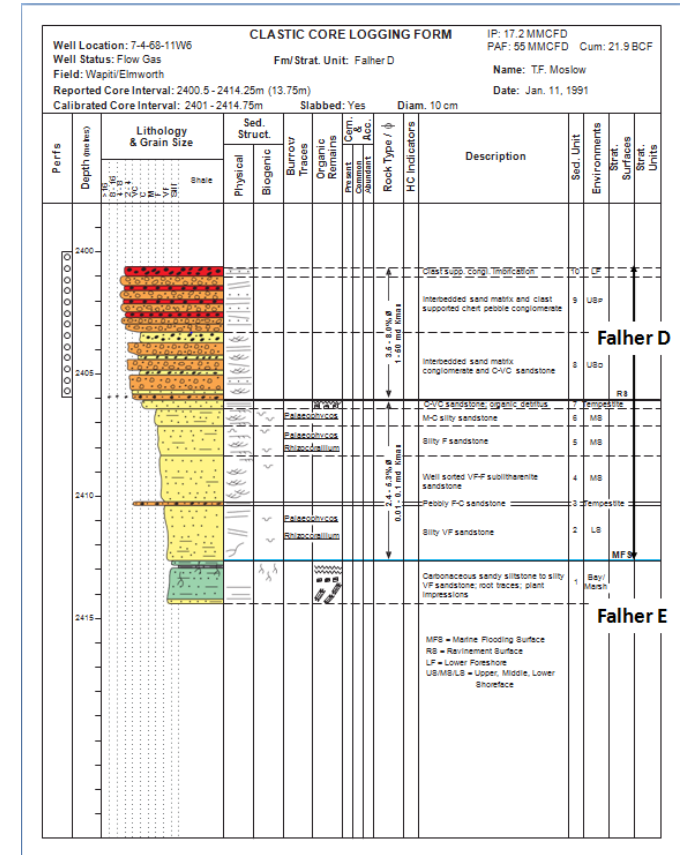


Image Source: AJM (Russum, 2010)

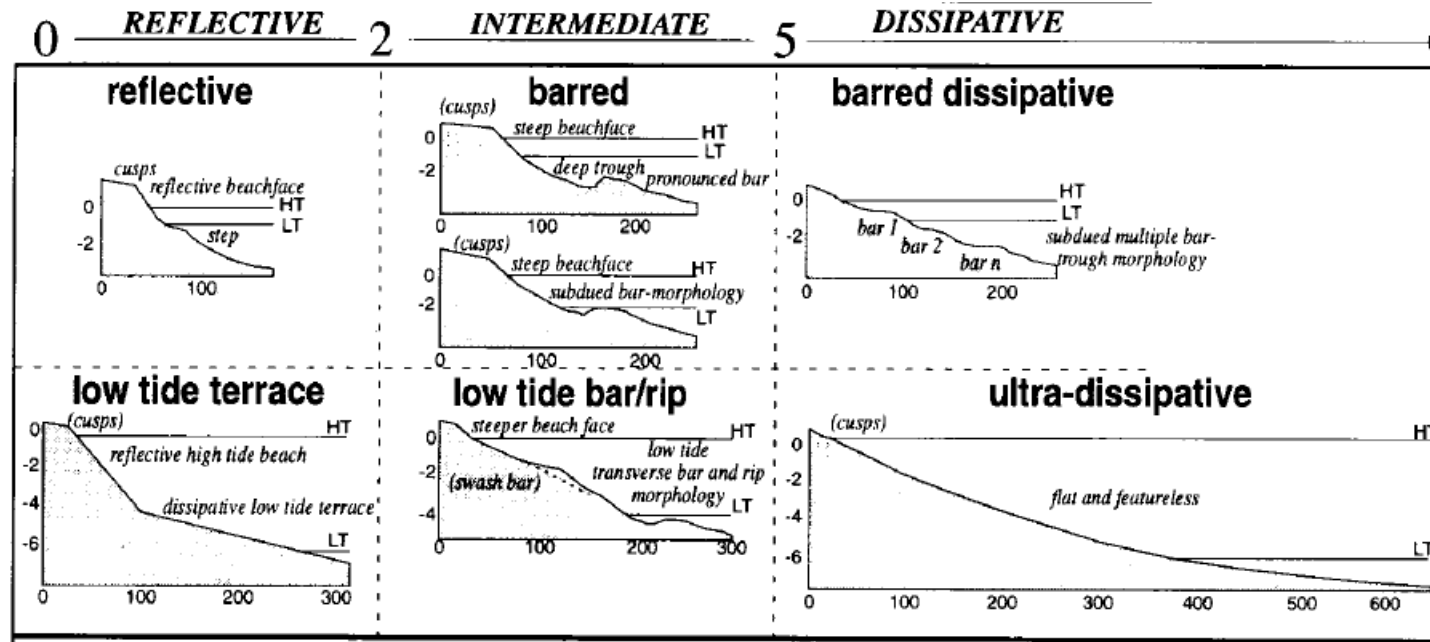
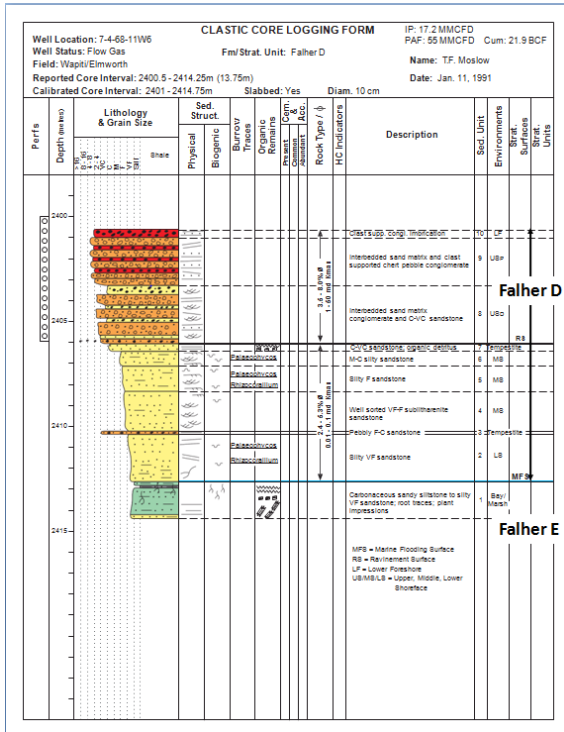


Source: R. Mann, AJM Petroleum Consultants, 2010

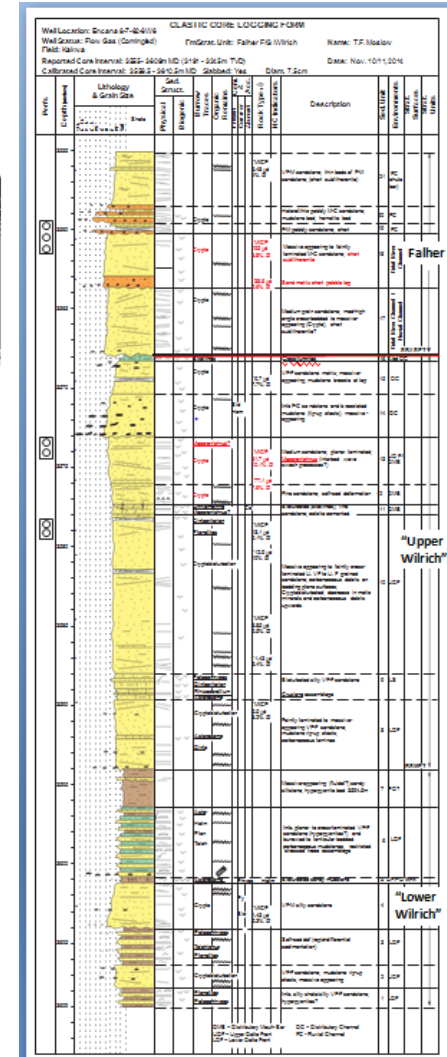
# Conventional – Unconventional Continuum - Gas

8-7-62-6W6

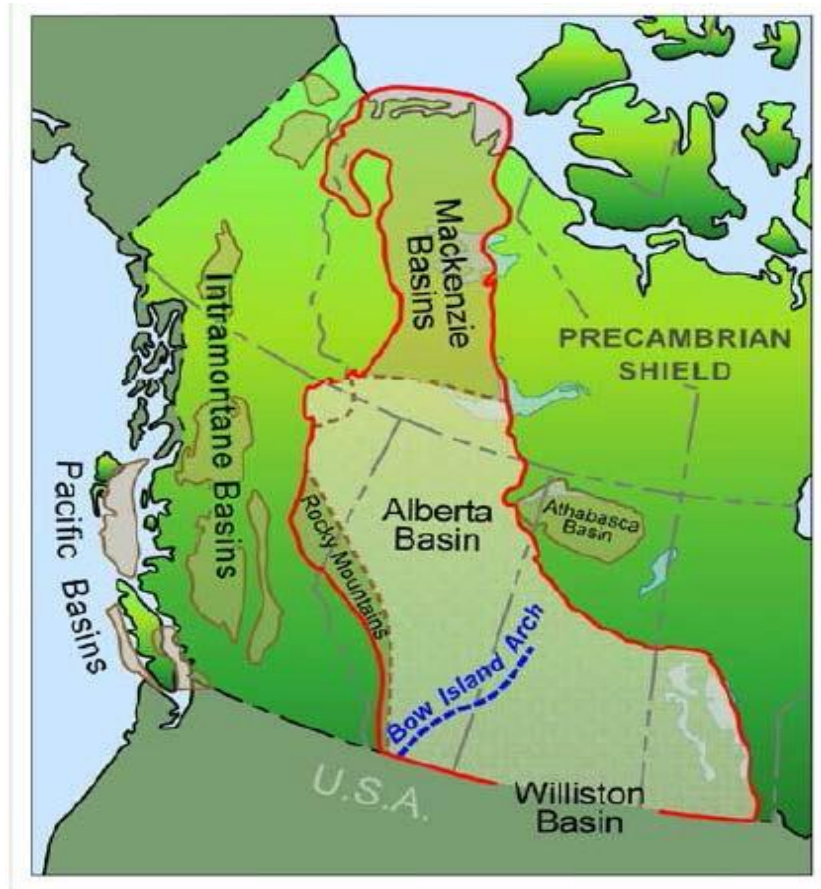
7-4-68-11W6



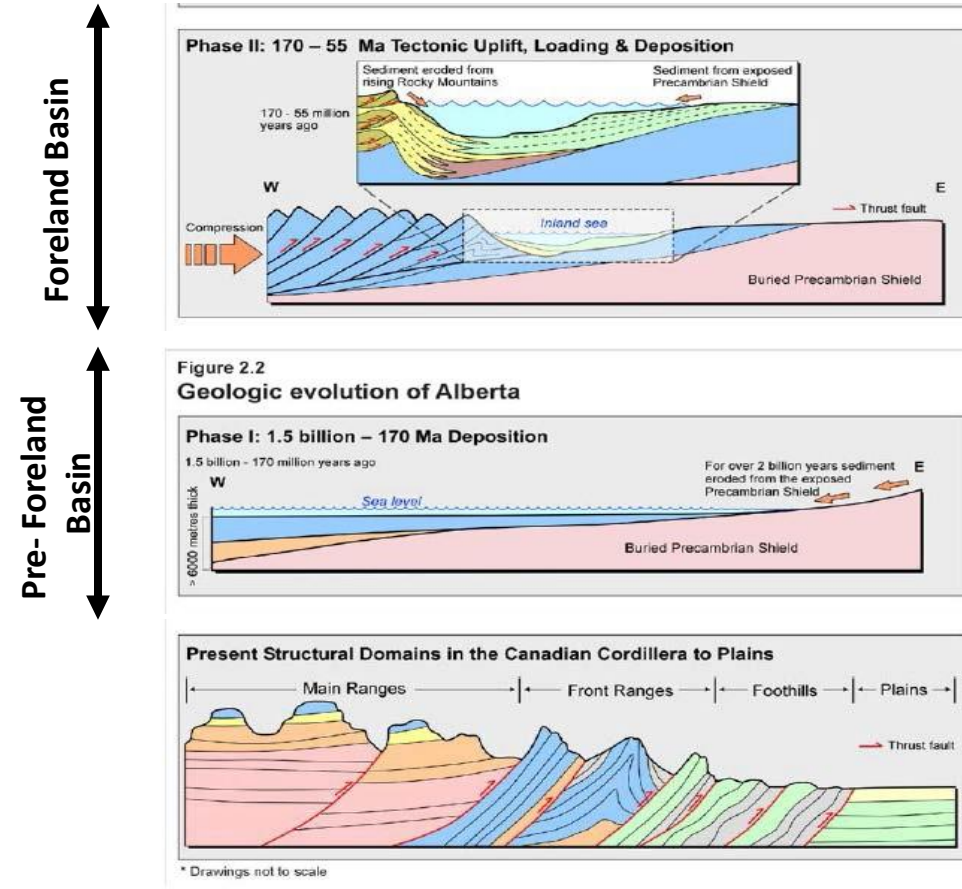
Short, 1996



# Western Canada Sedimentary Basin Tectonic Evolution



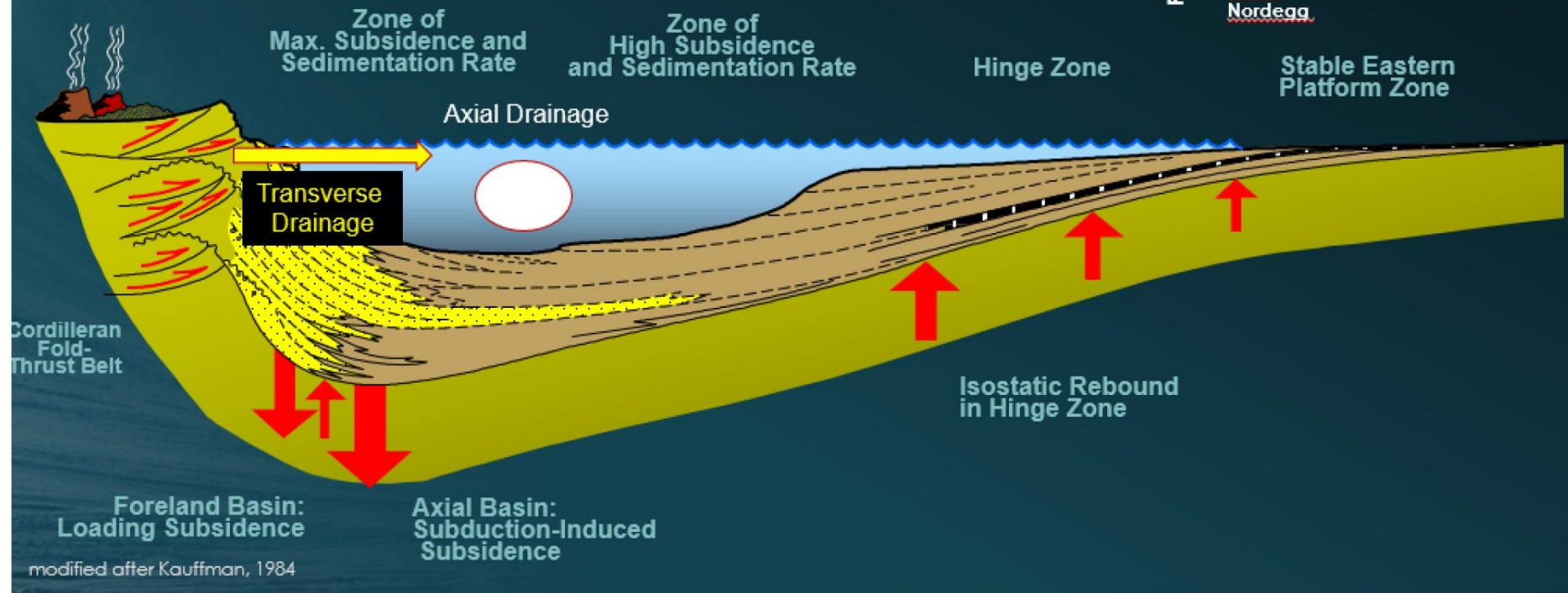
ERCB ST-98-2011



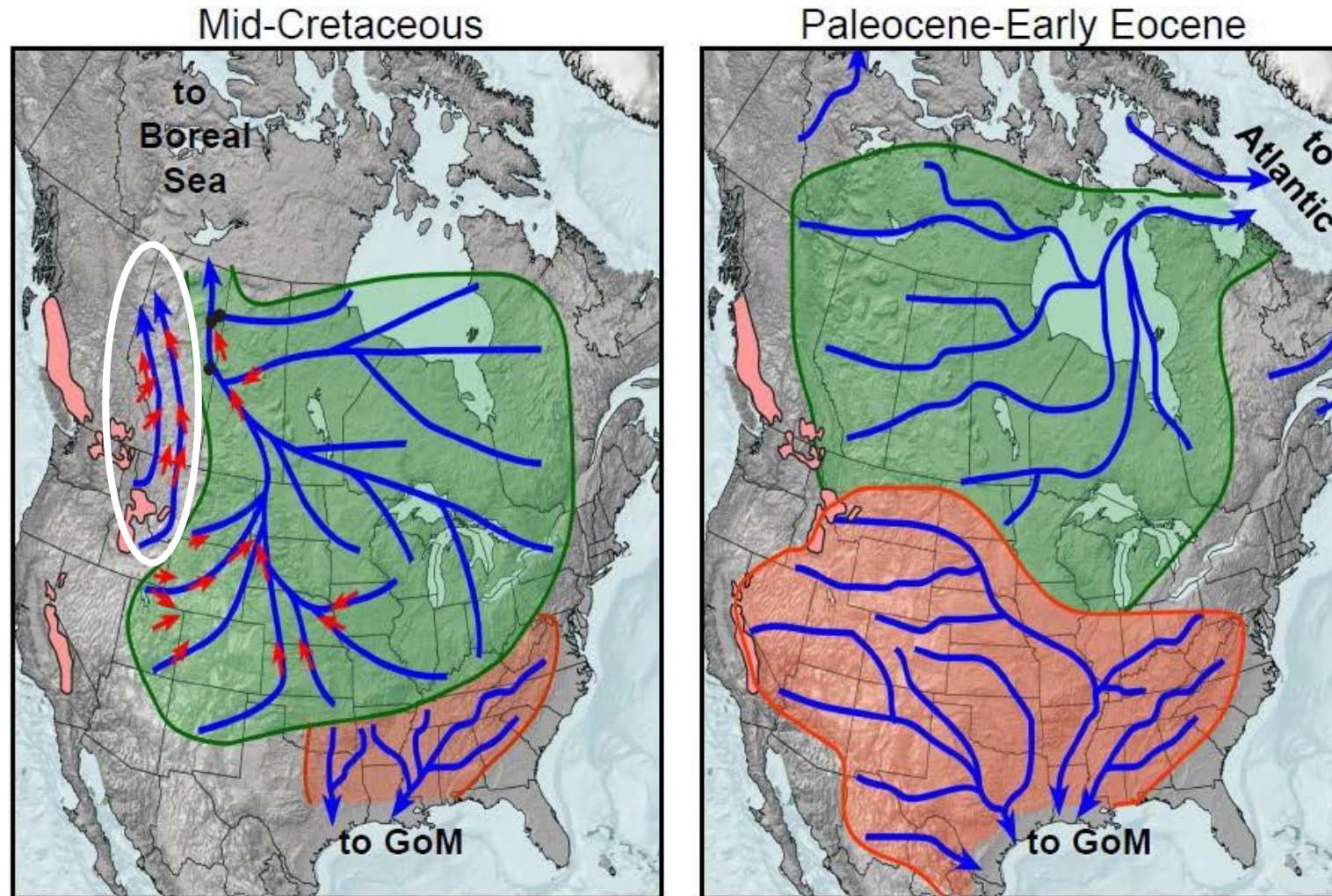
# Foreland Basin

## Axial Drainage vs. Transverse Drainage

### Underfilled FB vs. Overfilled FB

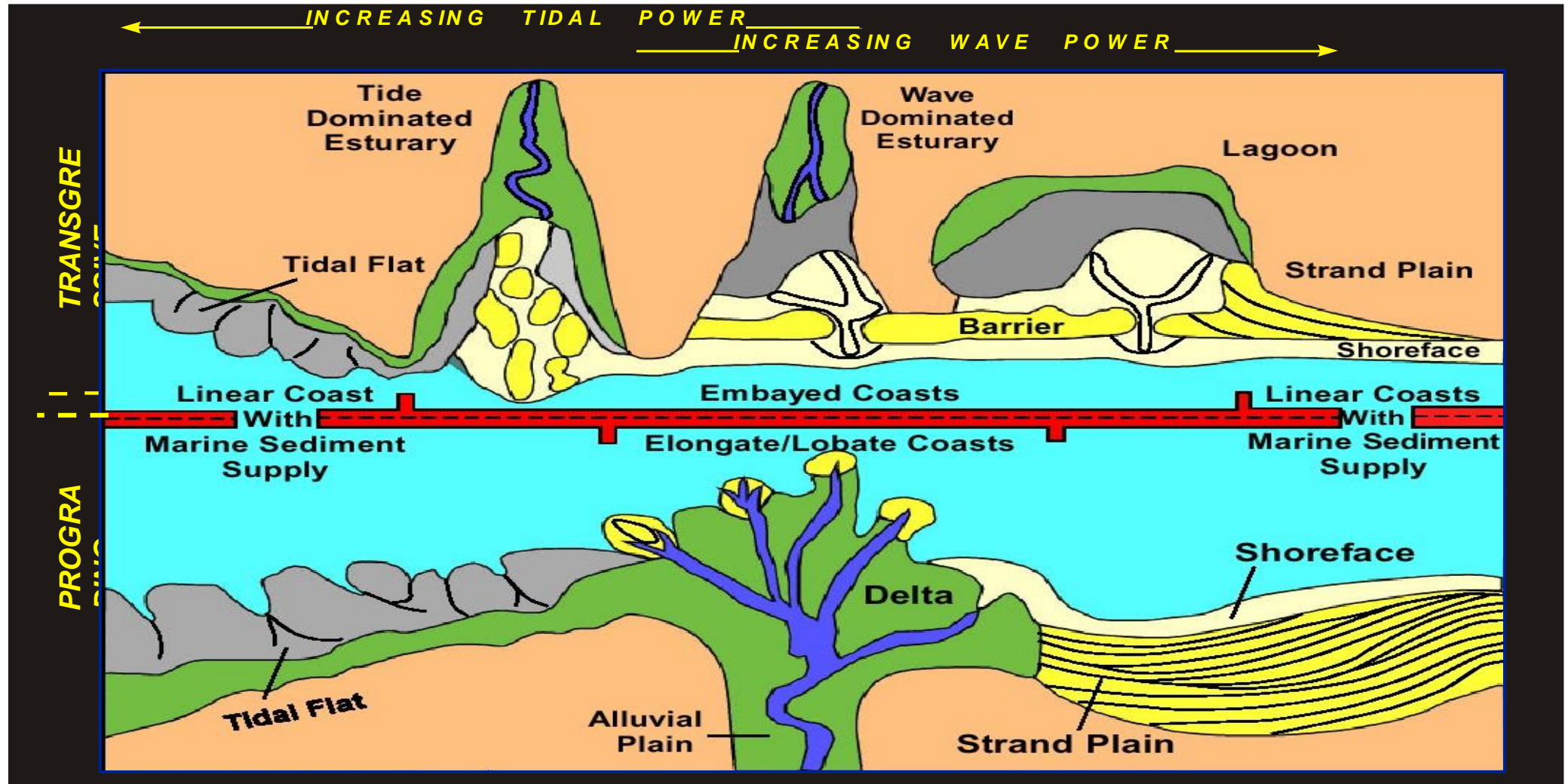


# Continental Scale - Paleodrainage Reorganization



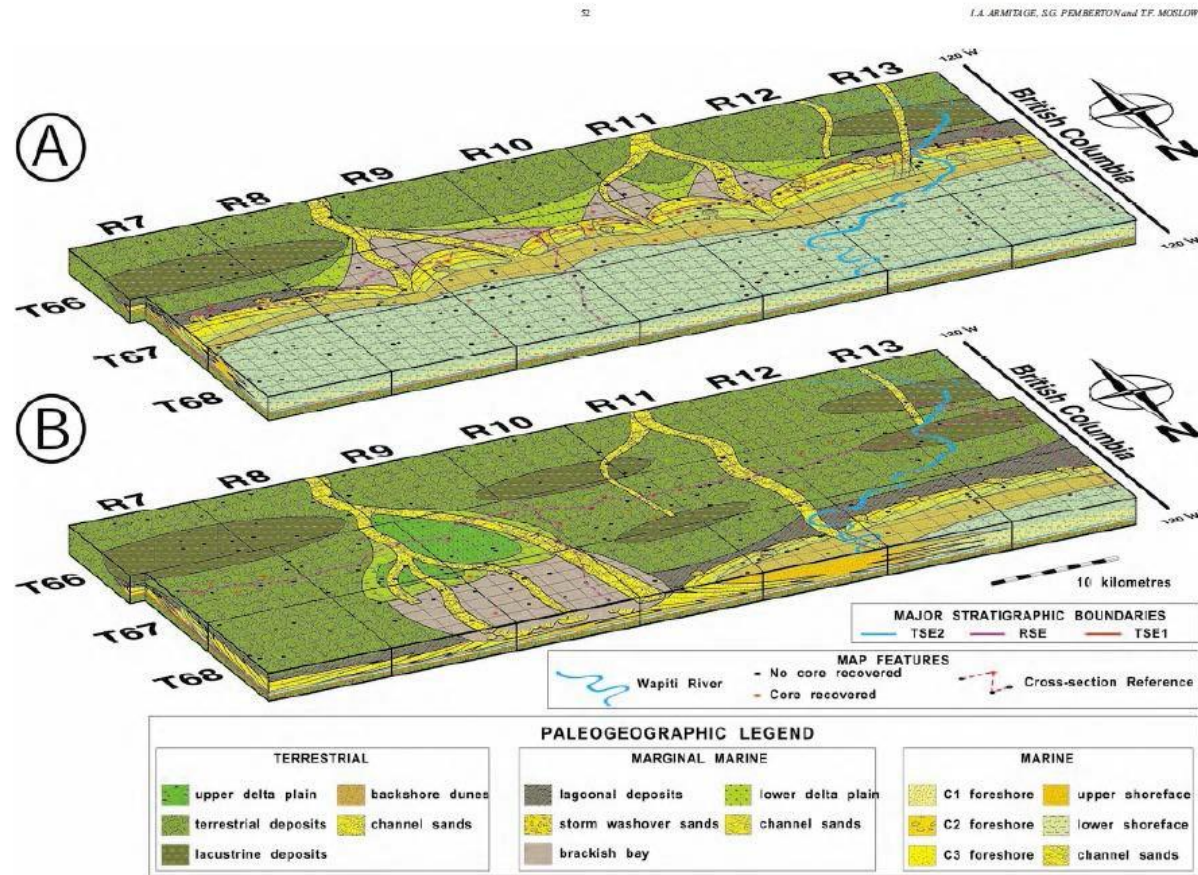
after Blum and Pecha(2014)

# Coastal Classification – along strike variation



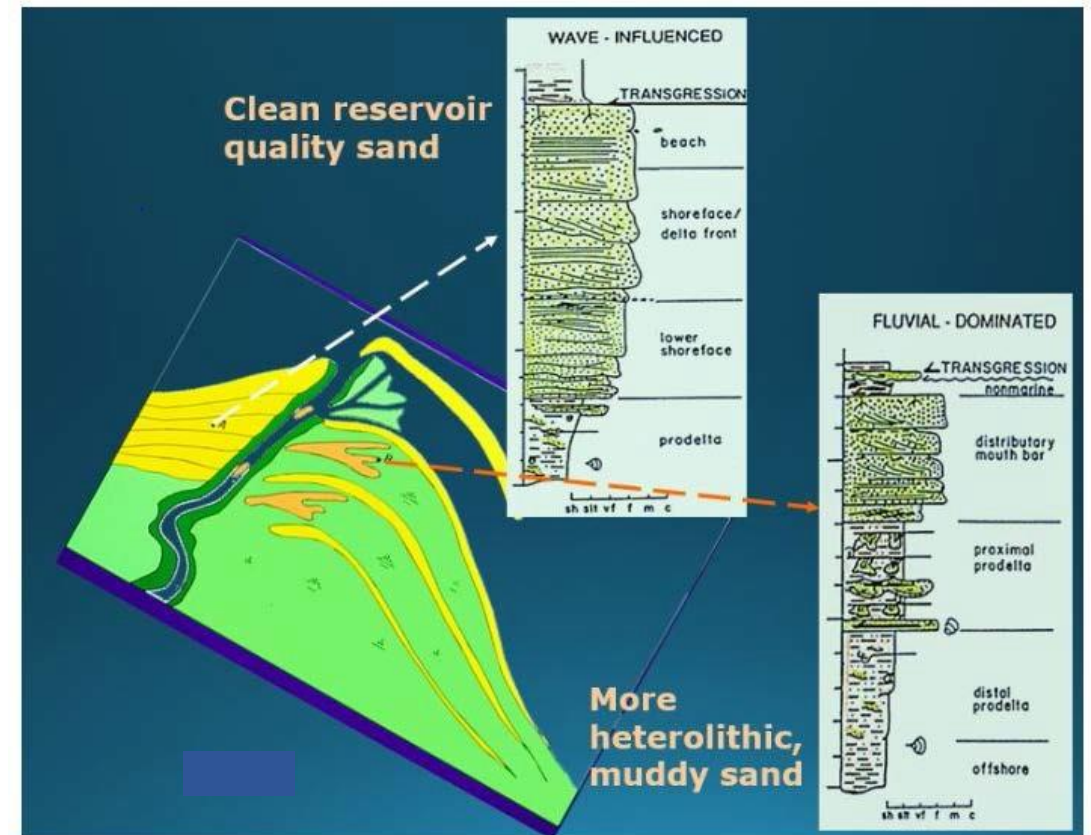
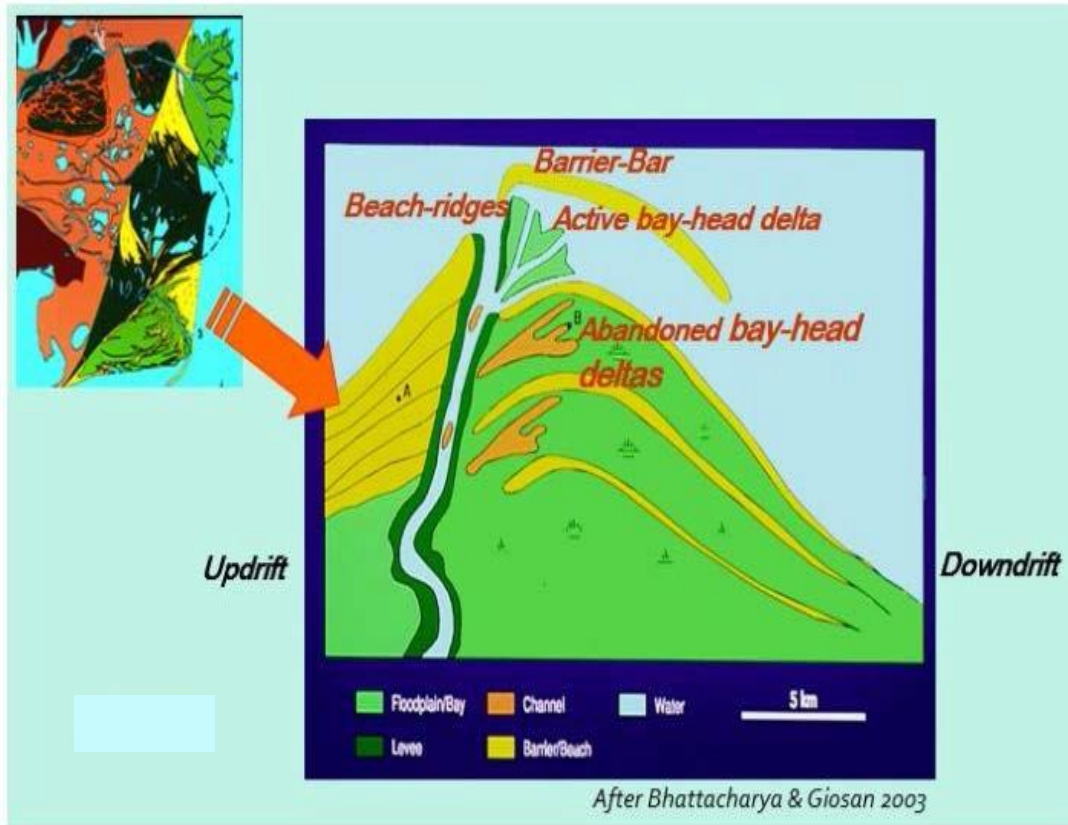
Boyd, Dalrymple and Zaitlin, 1992

# Shoreline Depositional Model of along strike variation for a wave dominated shoreline, deltas and associated facies



modified after Armitage, Pemberton and Moslow, 2004 for the Falher C

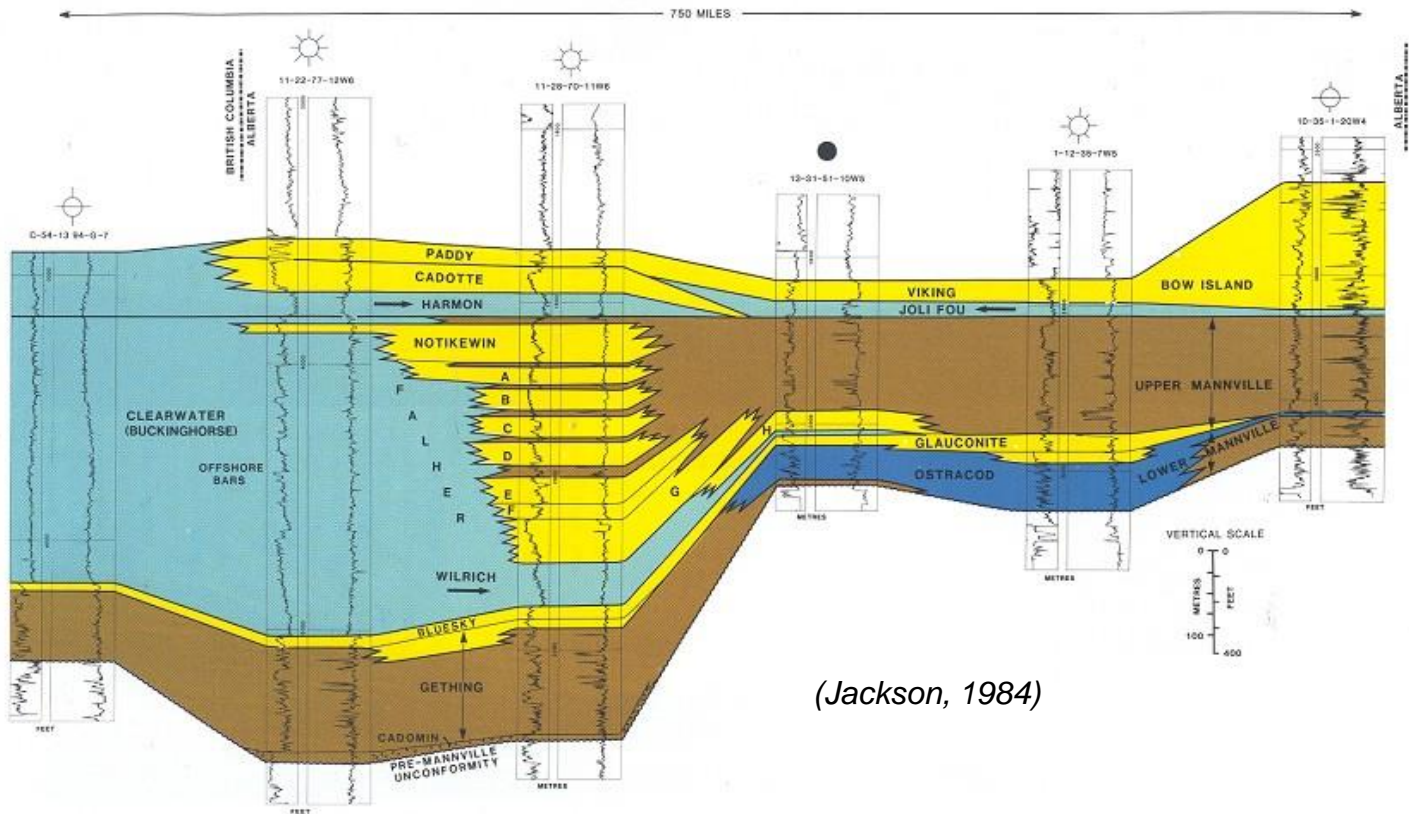
# Asymmetric Wave-Influenced Delta Model



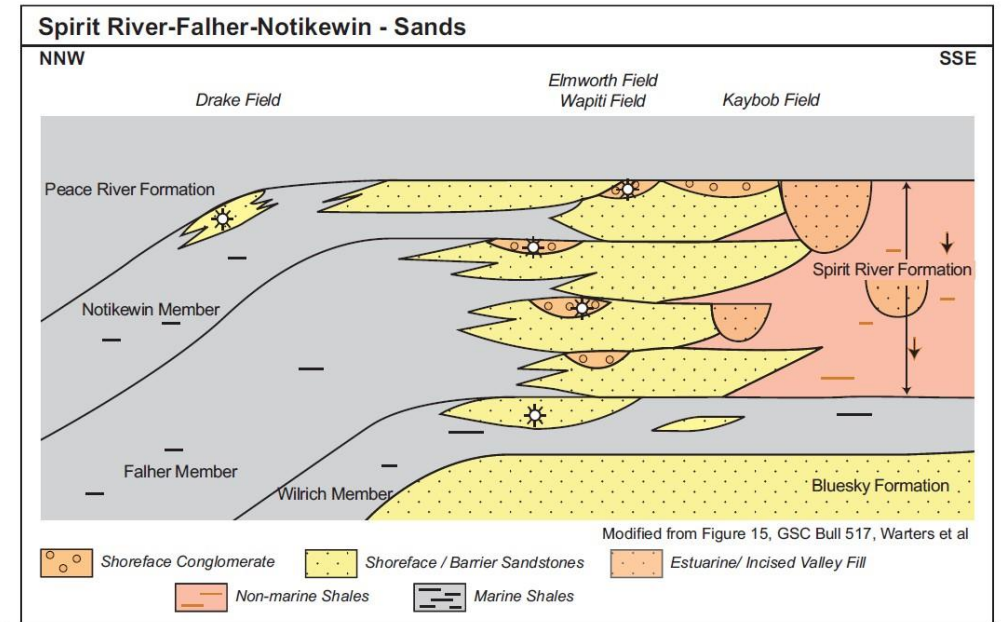
Junaid Sadeque, March, 2016



# Lower Cretaceous Depositional Cycles

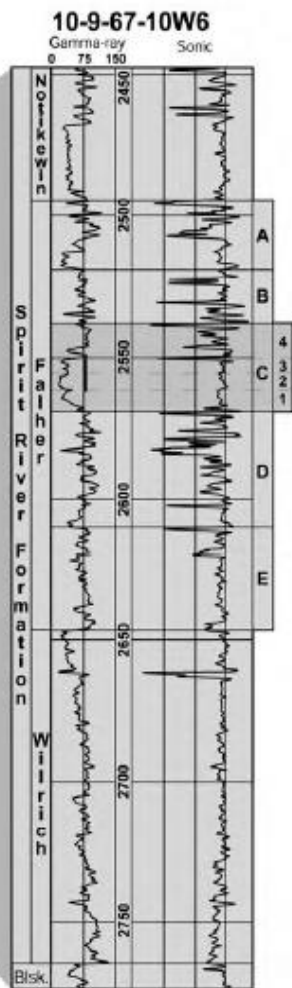
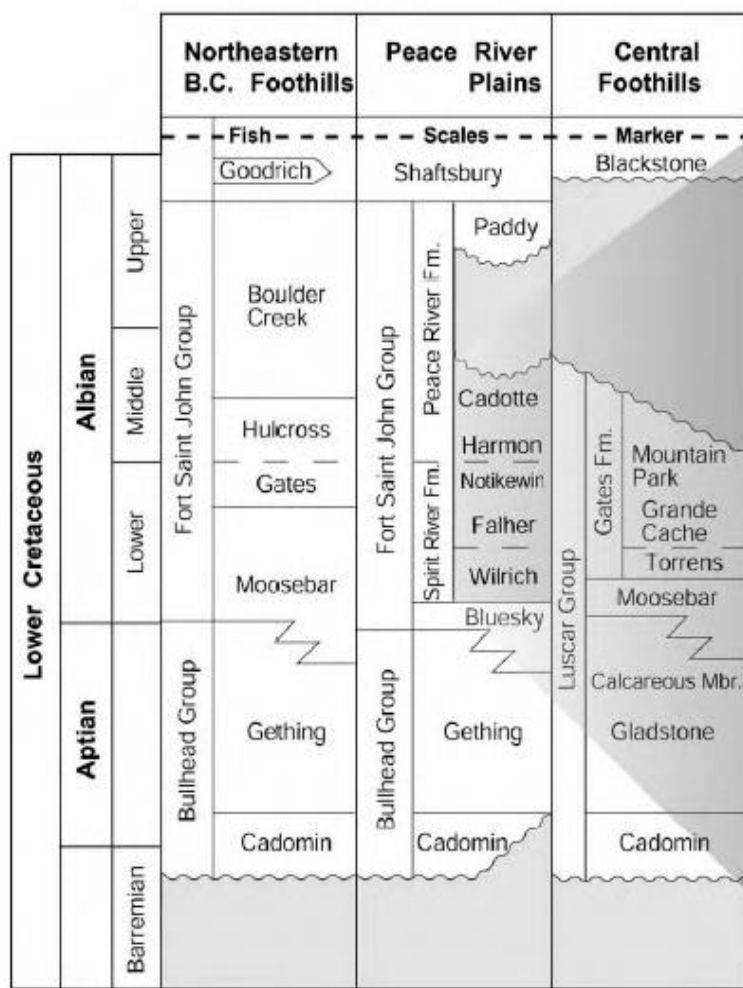


(Jackson, 1984)



CDD

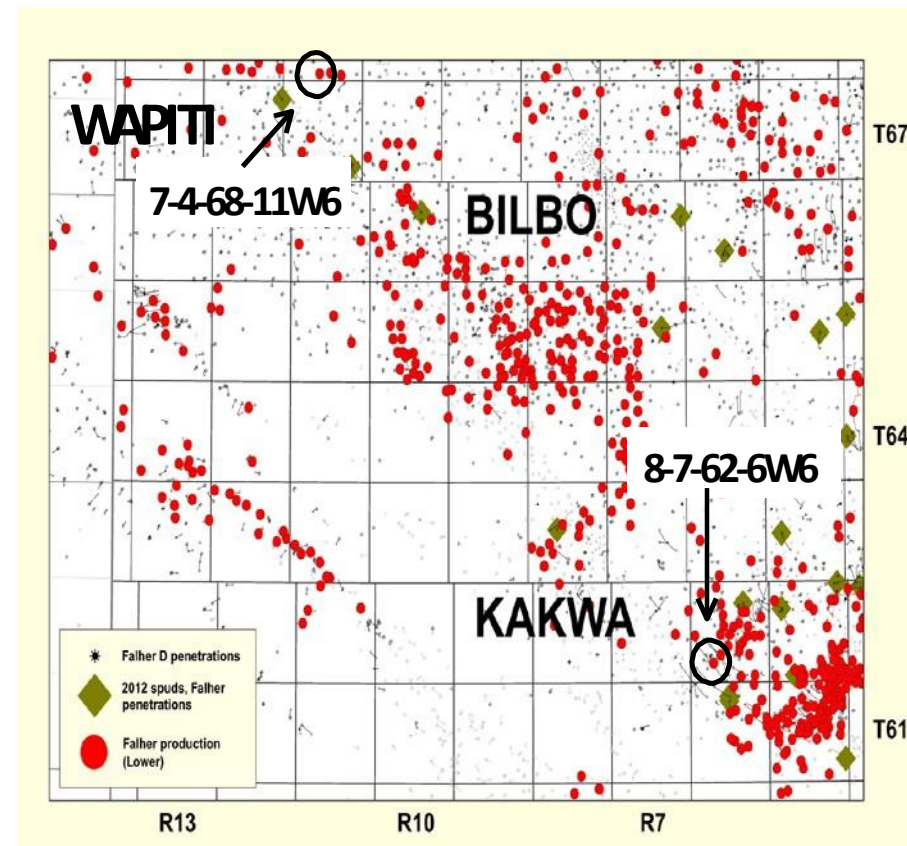
# Stratigraphy – Fort St. John – Spirit River Groups



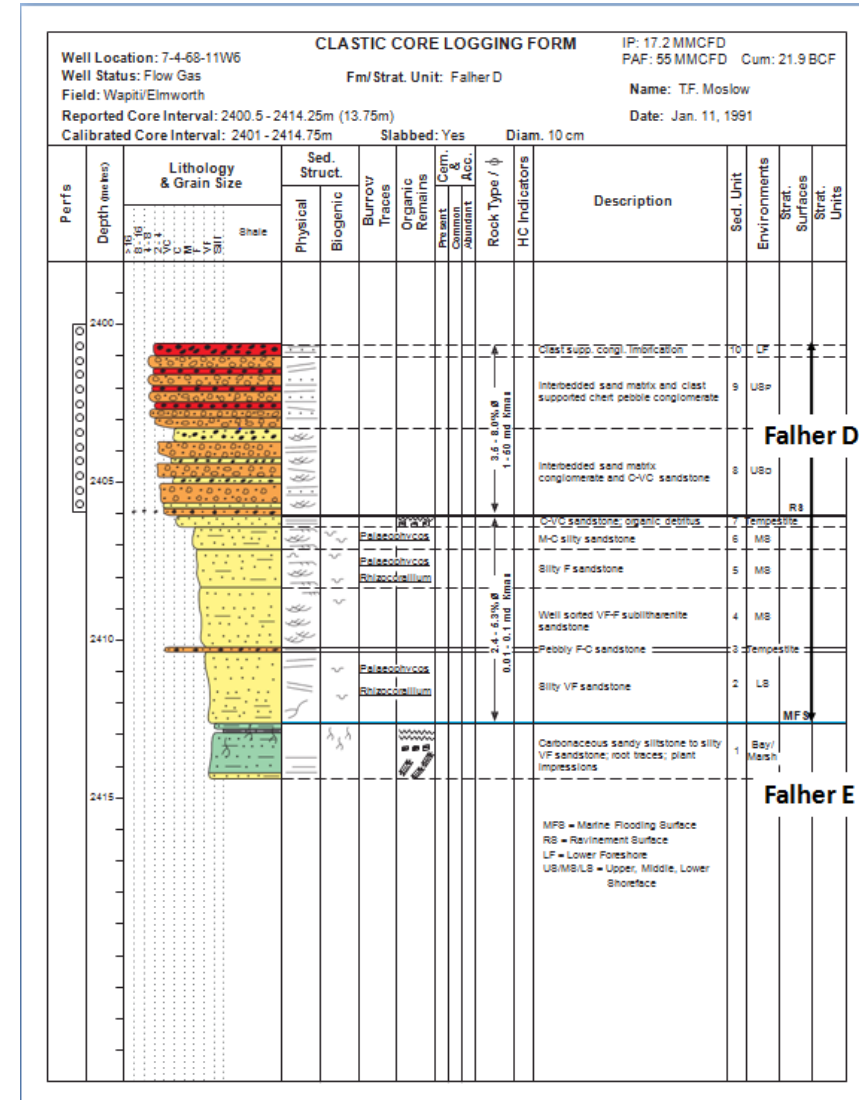
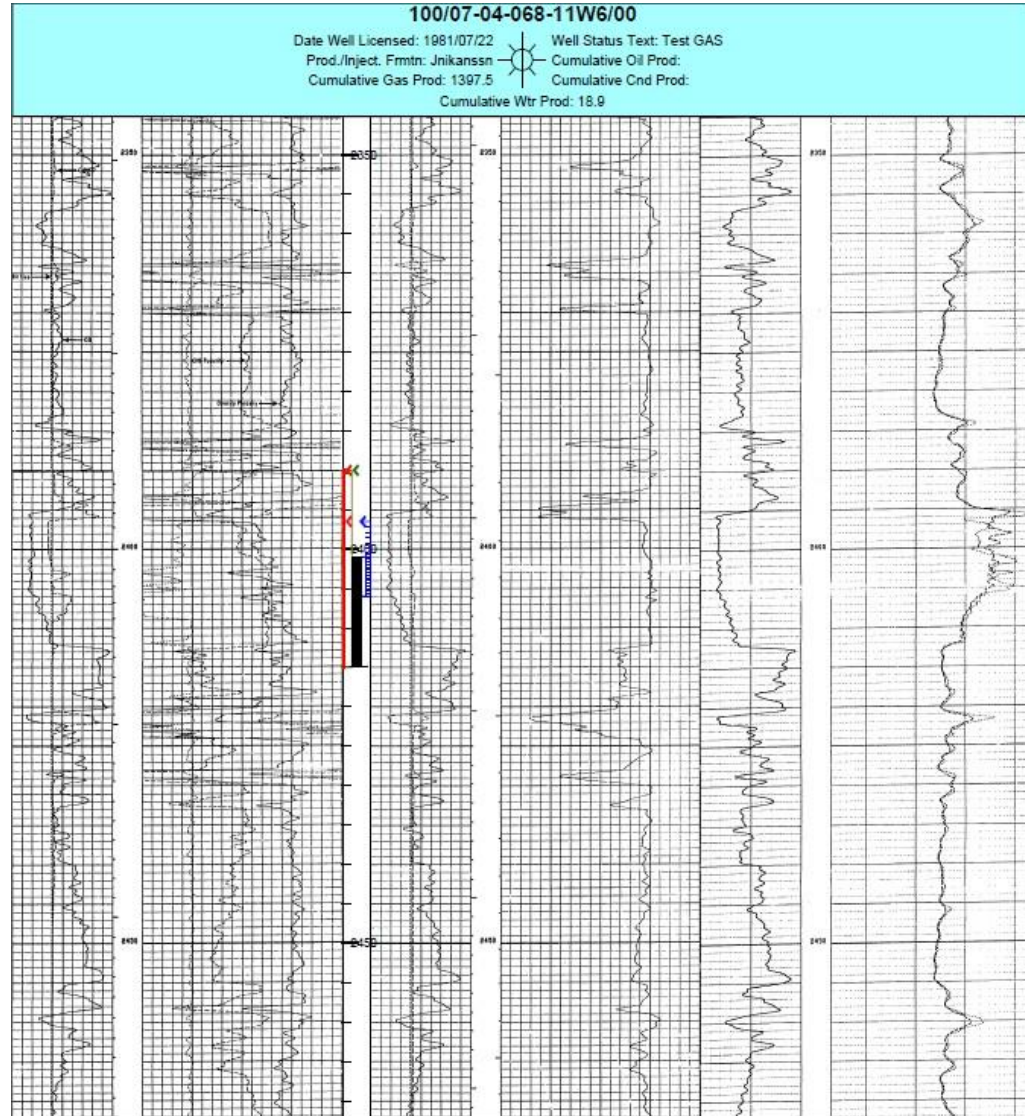
7-4-68-11W6



8-7-62-6W6

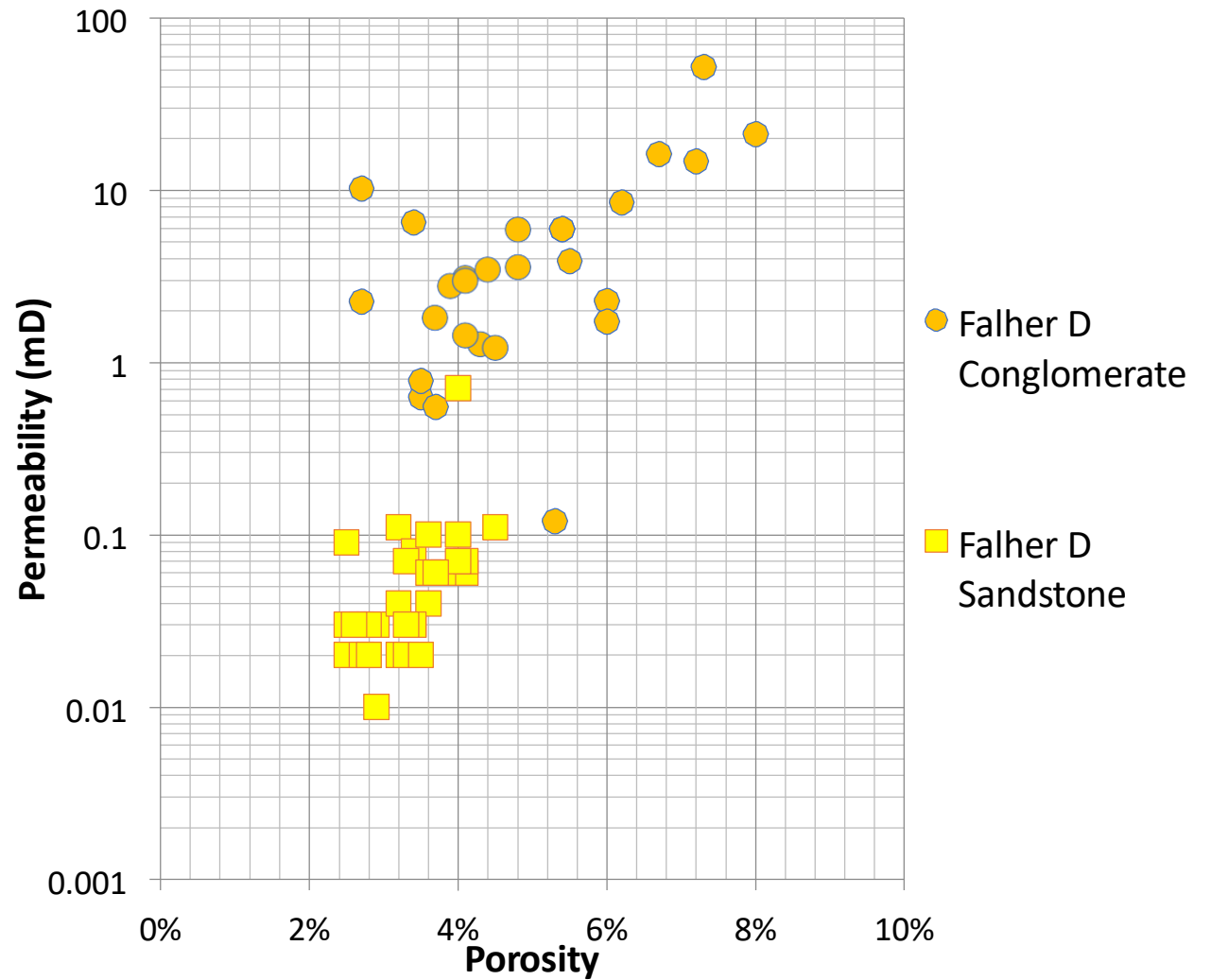
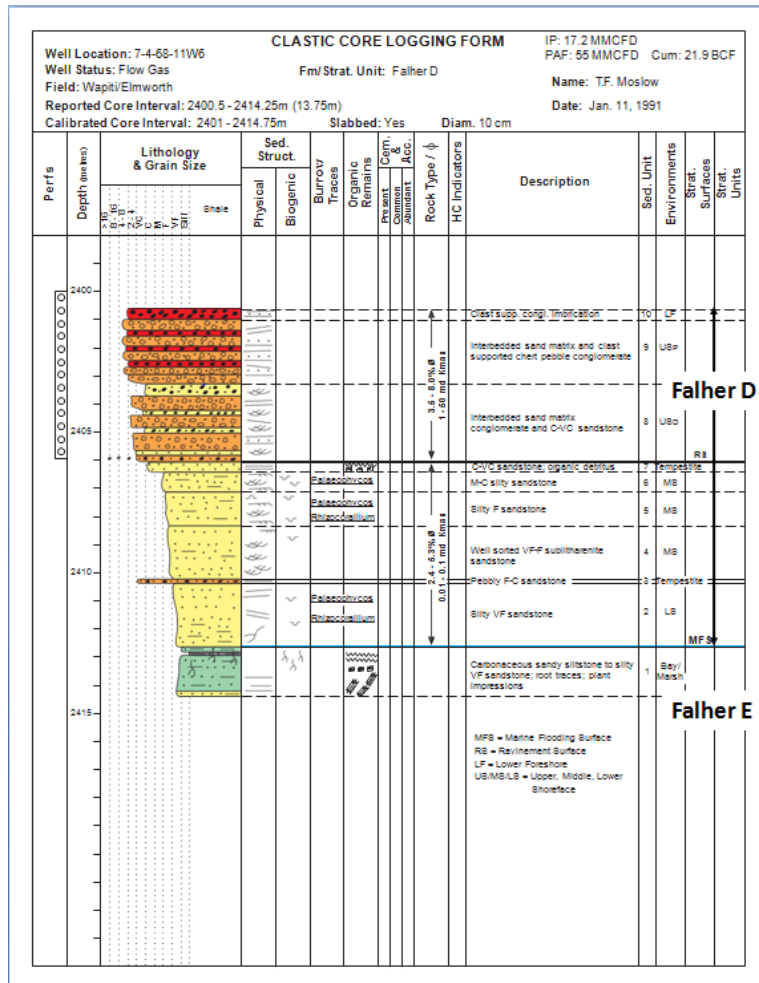


# CANHUNTER ET AL ELMWORTH 7-4-68-11W6



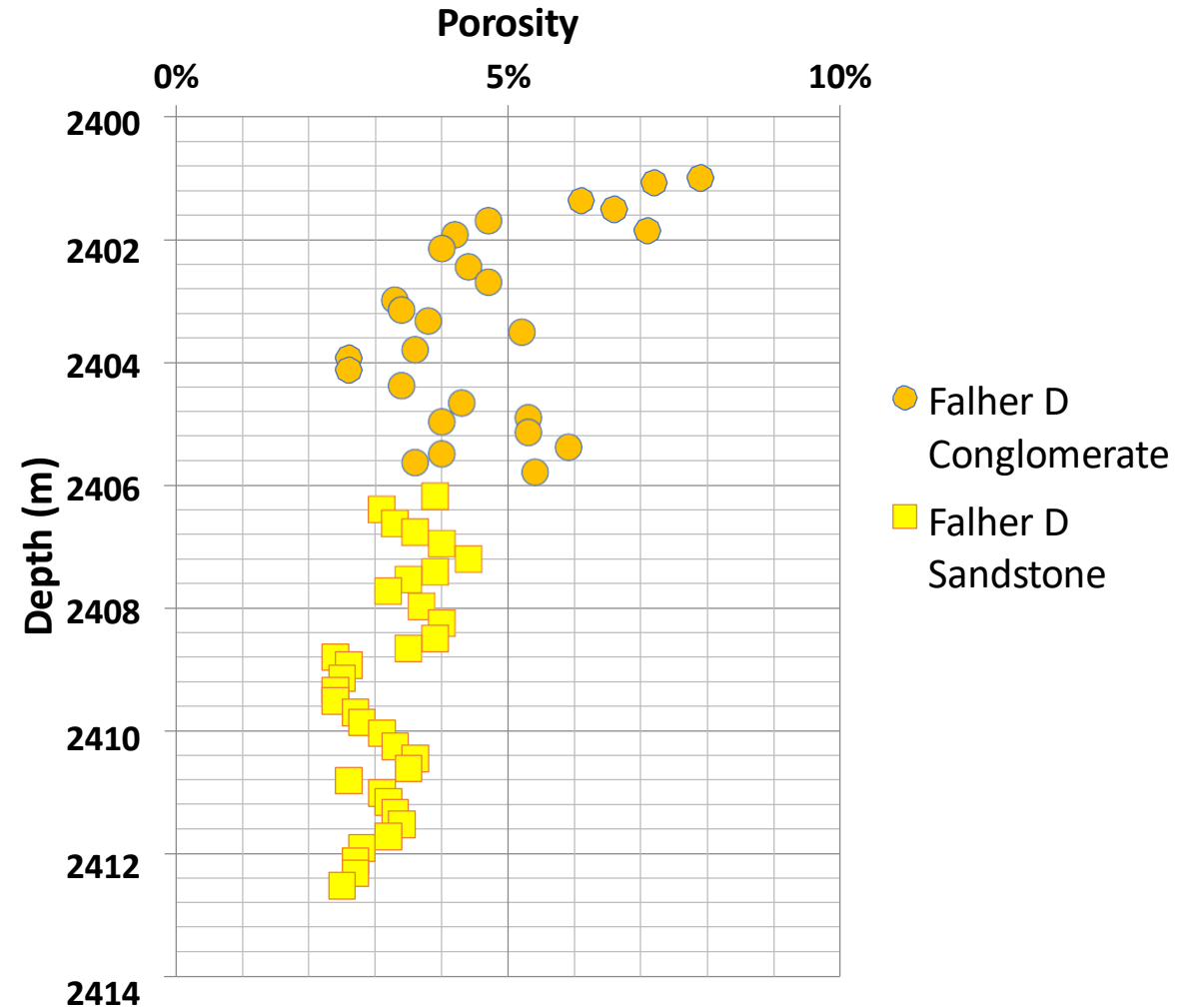
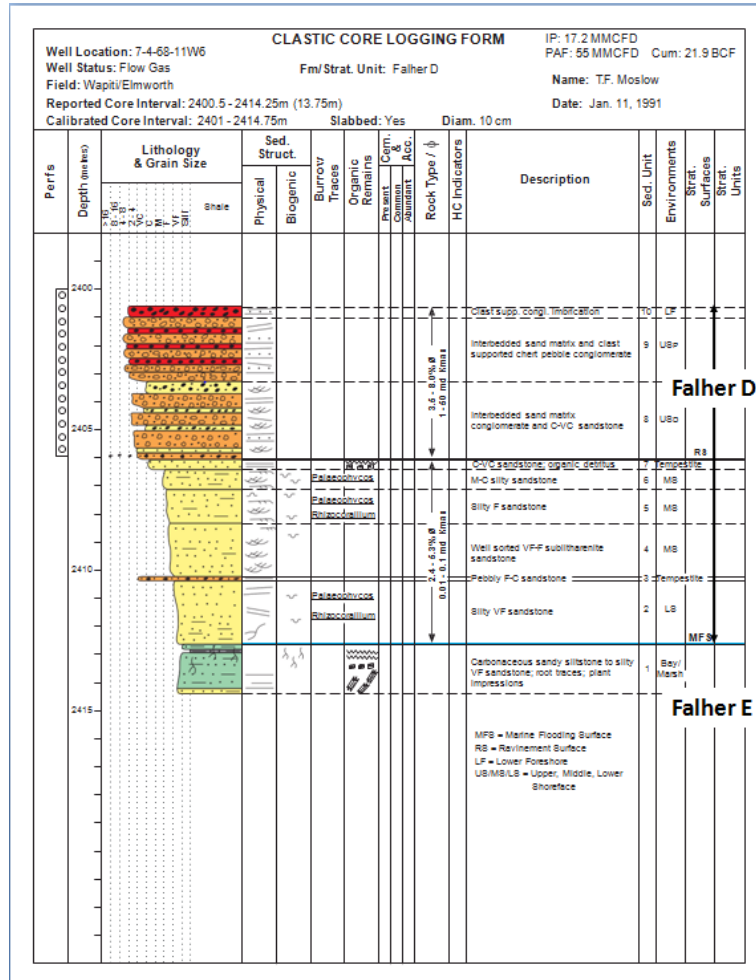
# CANHUNTER ET AL ELMWORTH 7-4-68-11W6

## Porosity (%) vs. Permeability (mD)



# CANHUNTER ET AL ELMWORTH 7-4-68-11W6

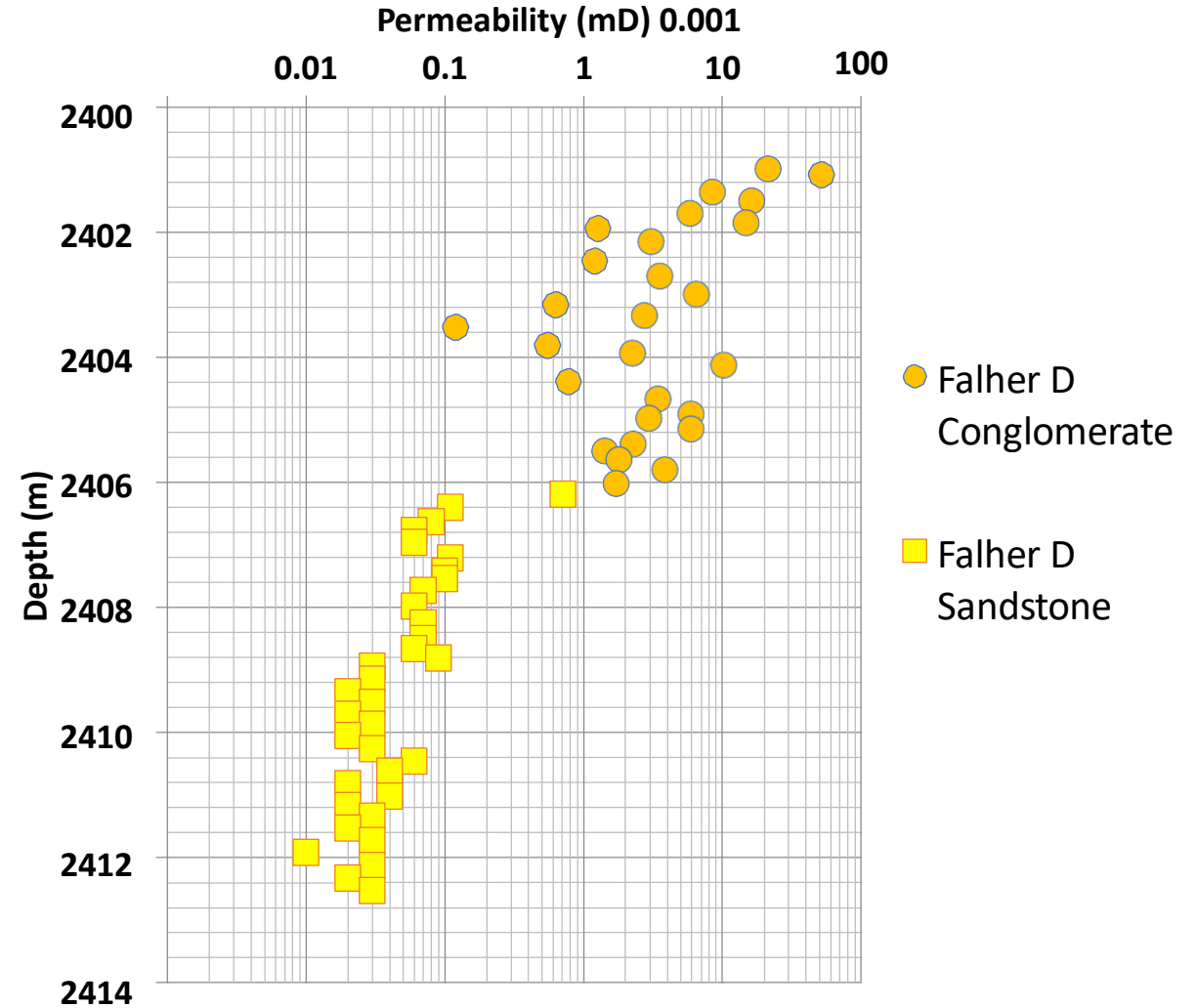
## Porosity (%) vs. Depth (m)



# CANHUNTER ET AL ELMWORTH 7-4-68-11W6

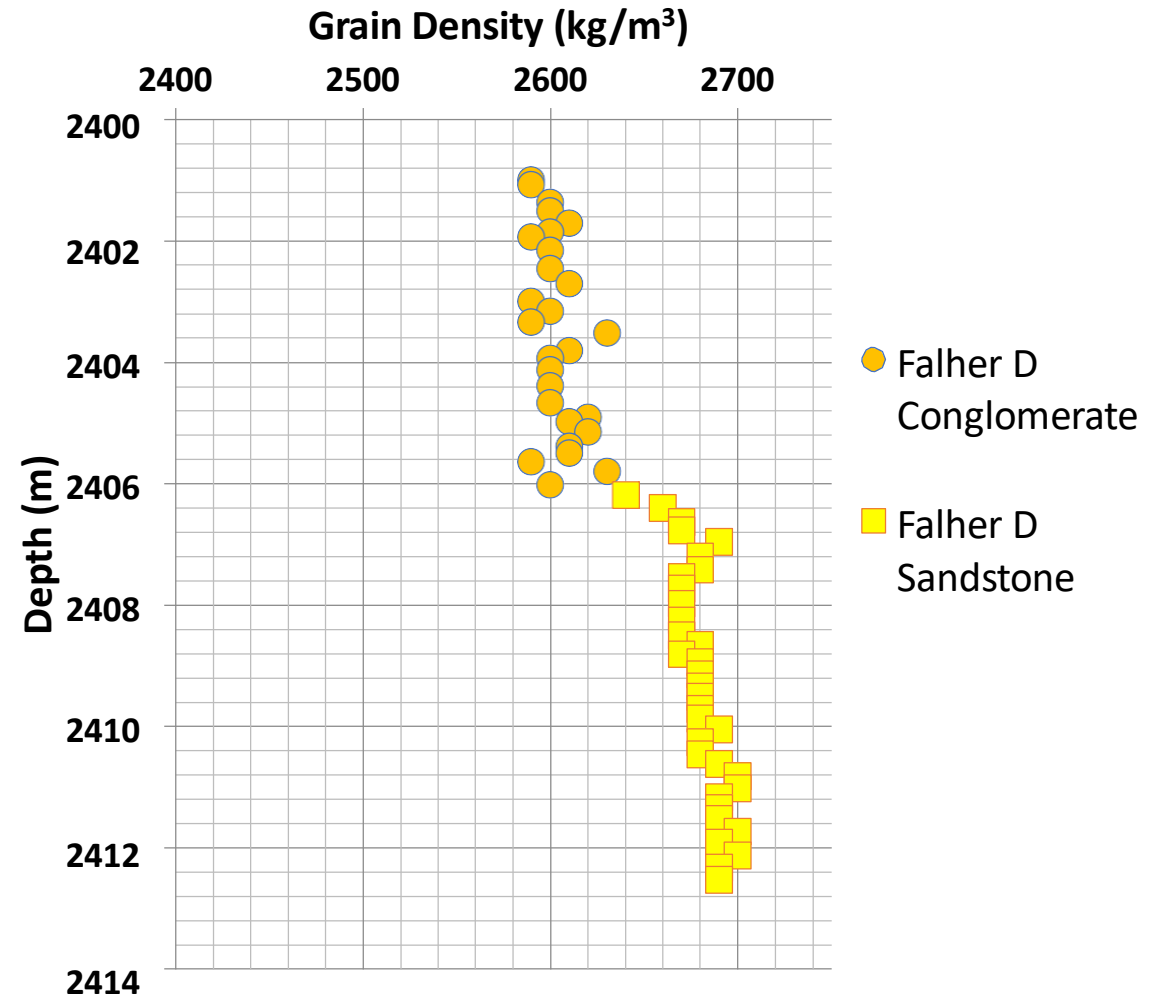
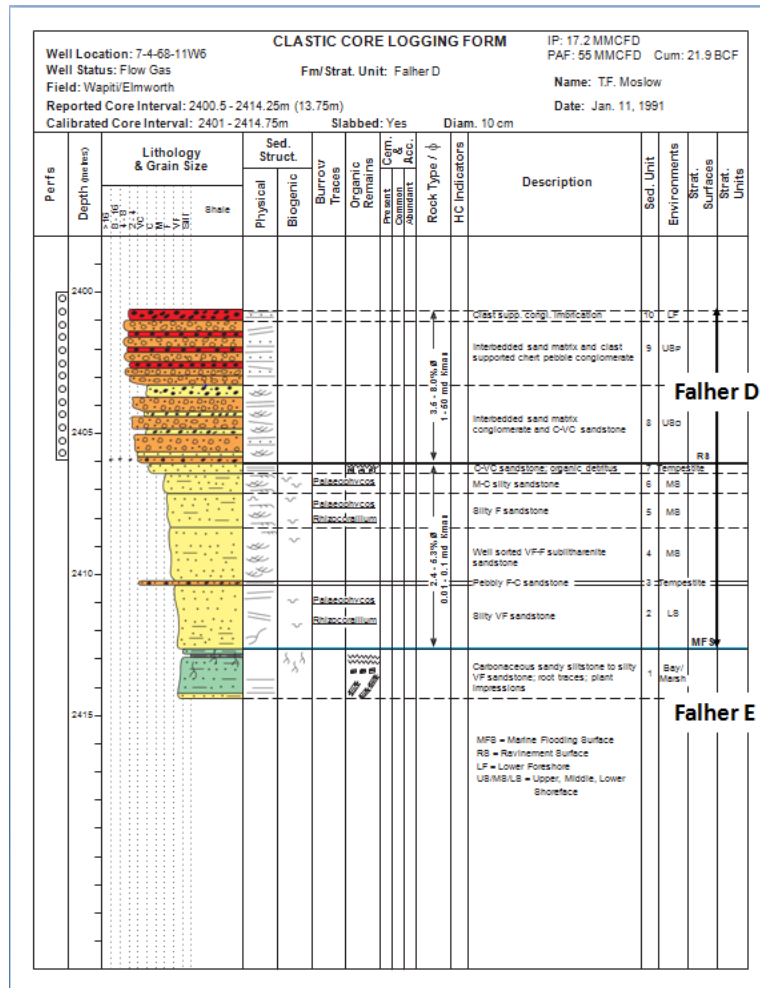
## Permeability (md) vs. Depth (m)

CLASTIC CORE LOGGING FORM														
Well Location: 7-4-68-11W6			Fm/Strat. Unit: Falher D			IP: 17.2 MMCFD PAF: 55 MMCFD Cum: 21.9 BCF								
Well Status: Flow Gas			Name: TF. Moslow			Date: Jan. 11, 1991								
Field: Wapiti/Elmworth			Reported Core Interval: 2400.5 - 2414.25m (13.75m)			Calibrated Core Interval: 2401 - 2414.75m								
Slabbed: Yes			Diam. 10 cm											
Perfs	Depth (meters)	Lithology & Grain Size	Sed. Struct.		Burrov Traces	Organic Remains	Cogn. & Abundant	Rock Type / $\phi$	HC Indicators	Description	Sed. Unit	Environments	Strat. Surfaces	Strat. Units
			Physical	Biogenic										
	2400	Shale												
	2401	Interbedded sand matrix and clay supported chert pebble conglomerate												
	2402	Interbedded sand matrix conglomerate and O/V-C sandstone												
	2403	M-C silty sandstone												
	2404	Silty F sandstone												
	2405	Well sorted VFF sublitharenite sandstone												
	2406	Pebbly F-C sandstone												
	2407	Silty VF sandstone												
	2408	Carbonaceous sandy siltstone to silty VF sandstone; root traces; plant impressions												
	2410													
	2412													
	2414													

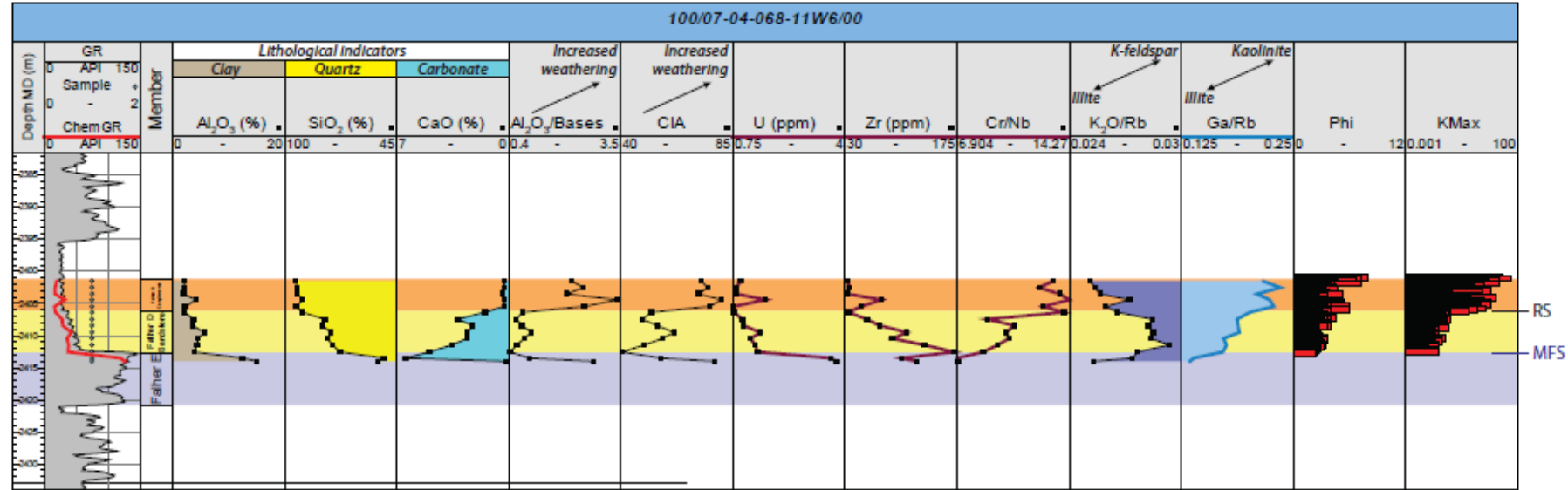
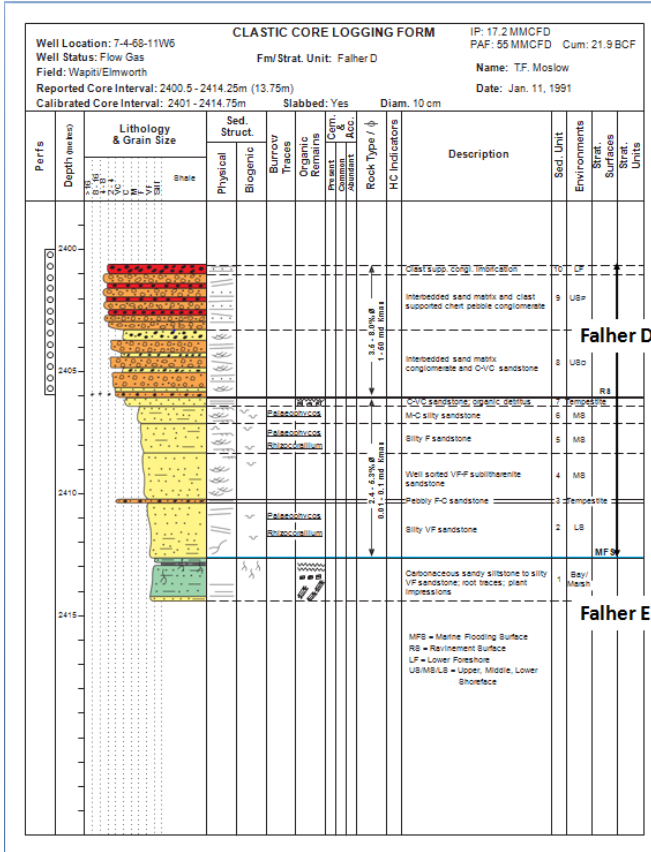


# CANHUNTER ET AL ELMWORTH 7-4-68-11W6

## Grain Density (kg/m<sup>3</sup>) vs. Depth (m)

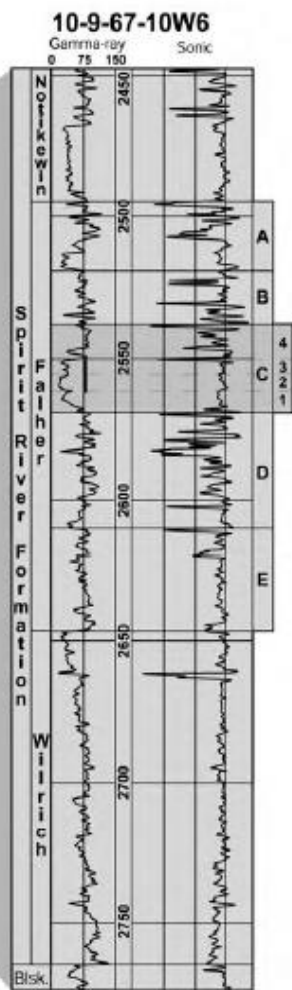
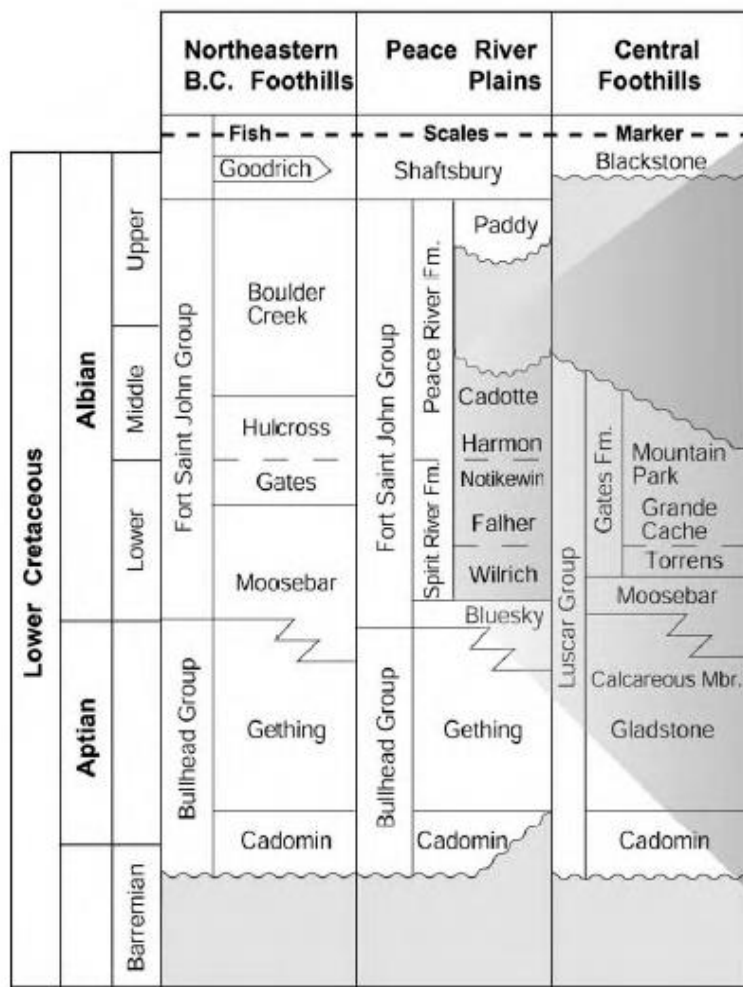


# CANHUNTER ET AL ELMWORTH 7-4-68-11W6





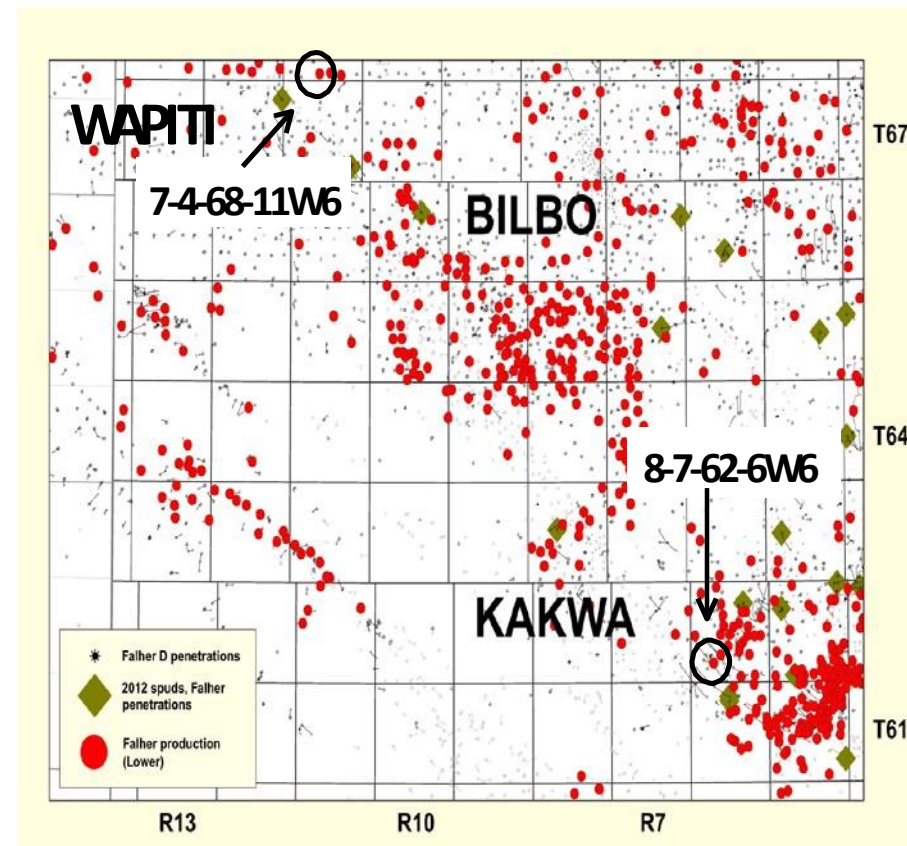
# Stratigraphy – Fort St. John – Spirit River Groups



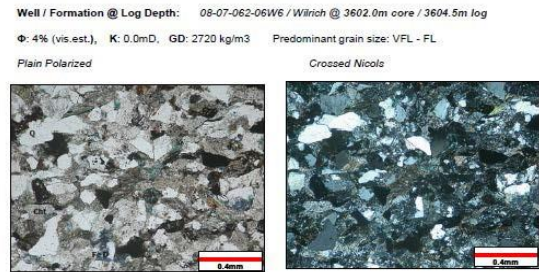
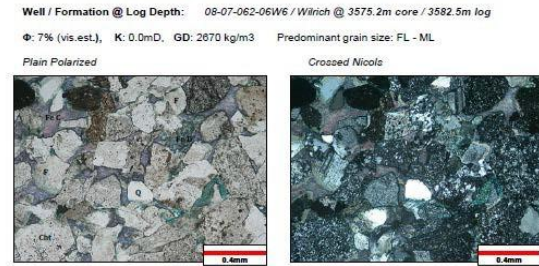
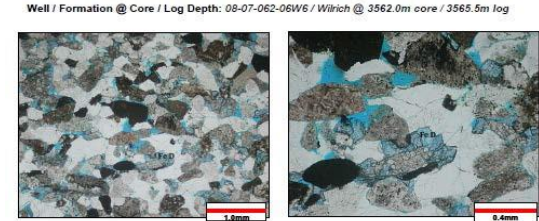
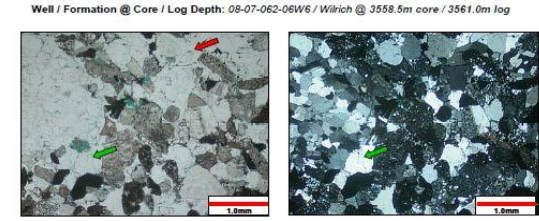
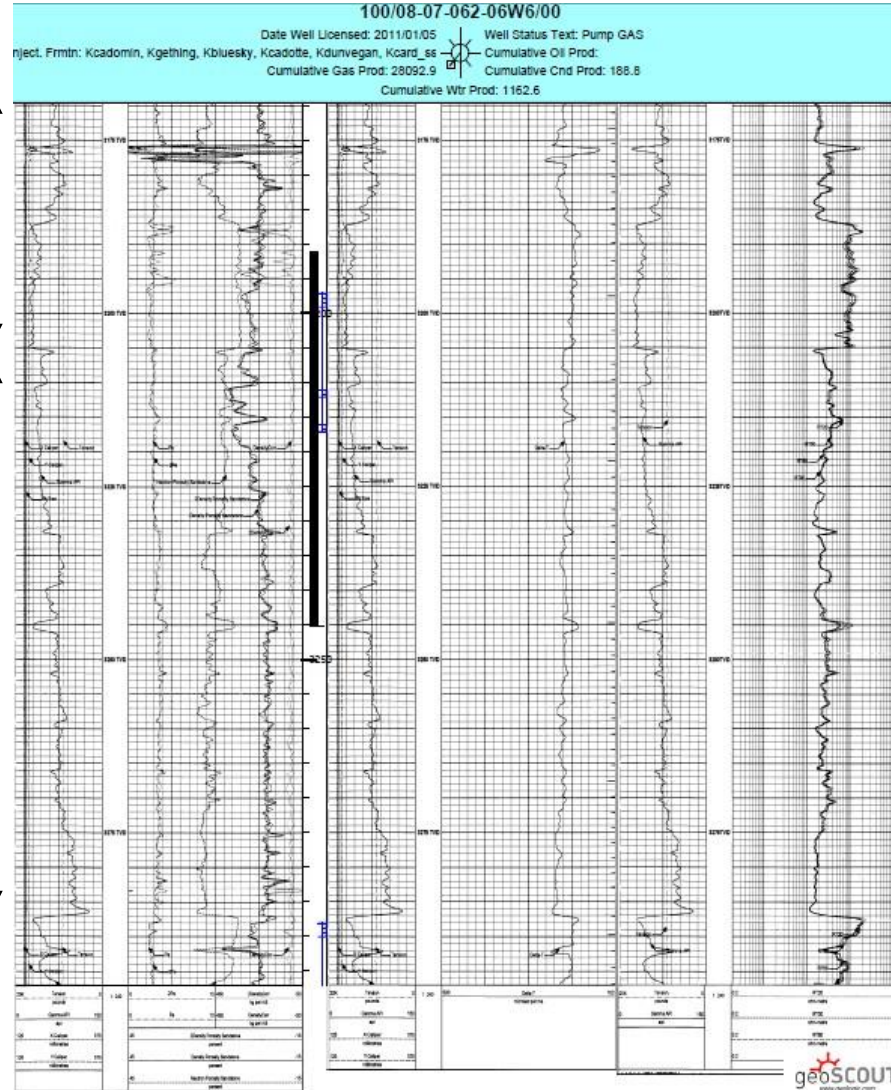
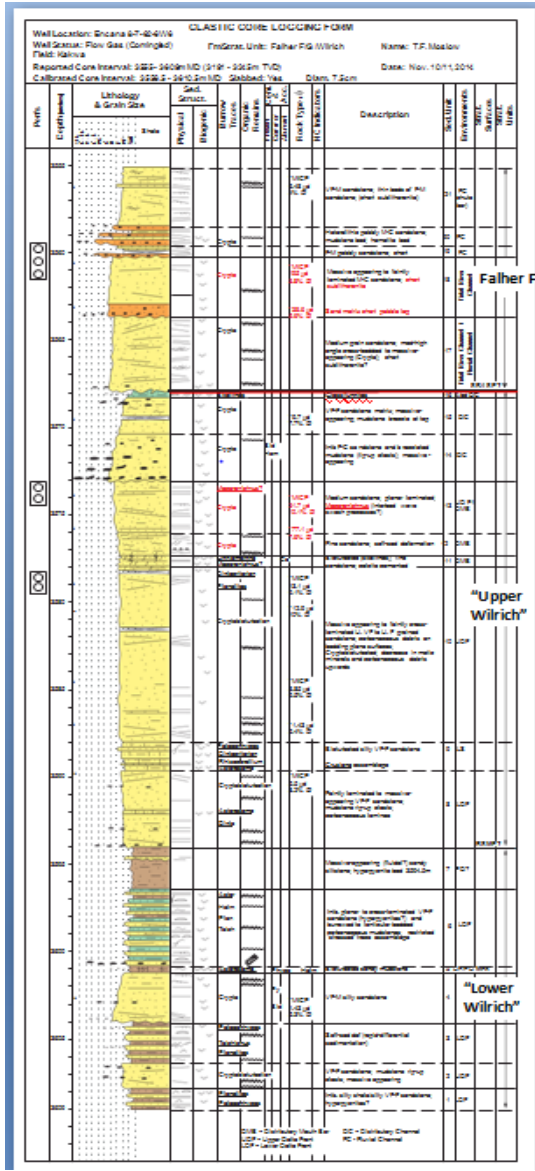
7-4-68-11W6



8-7-62-6W6



# ECA KAKWA 8-7-62-6W6



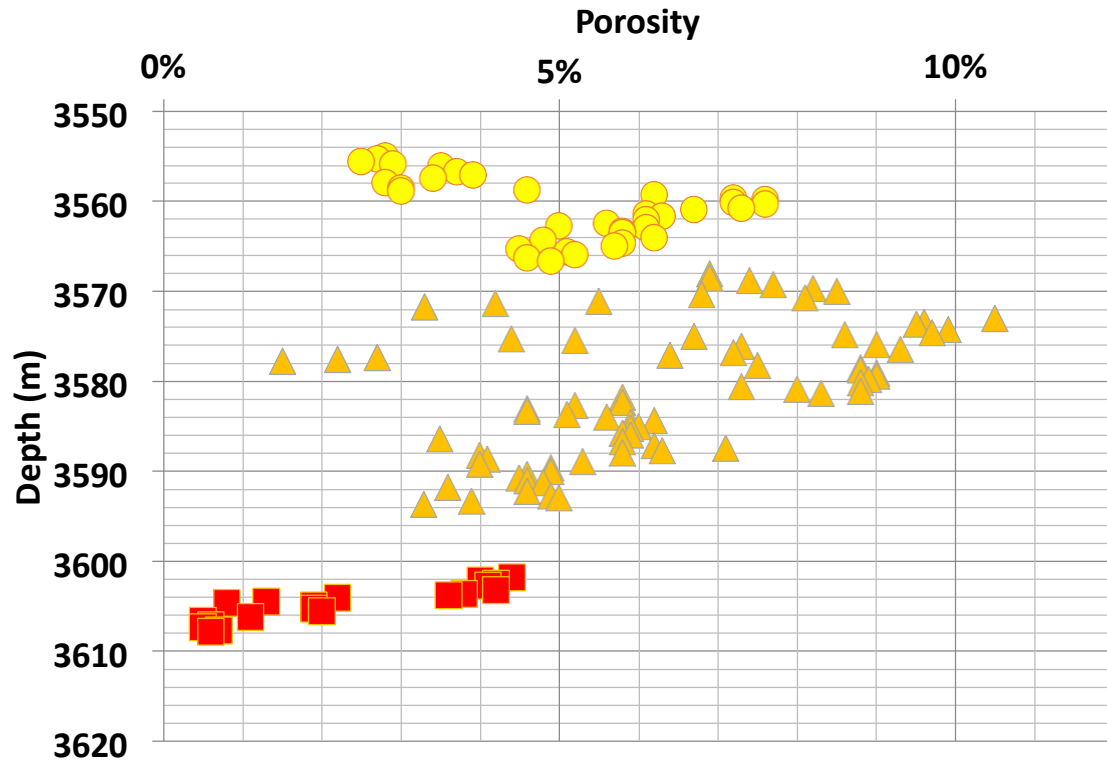
Falher

Wilrich

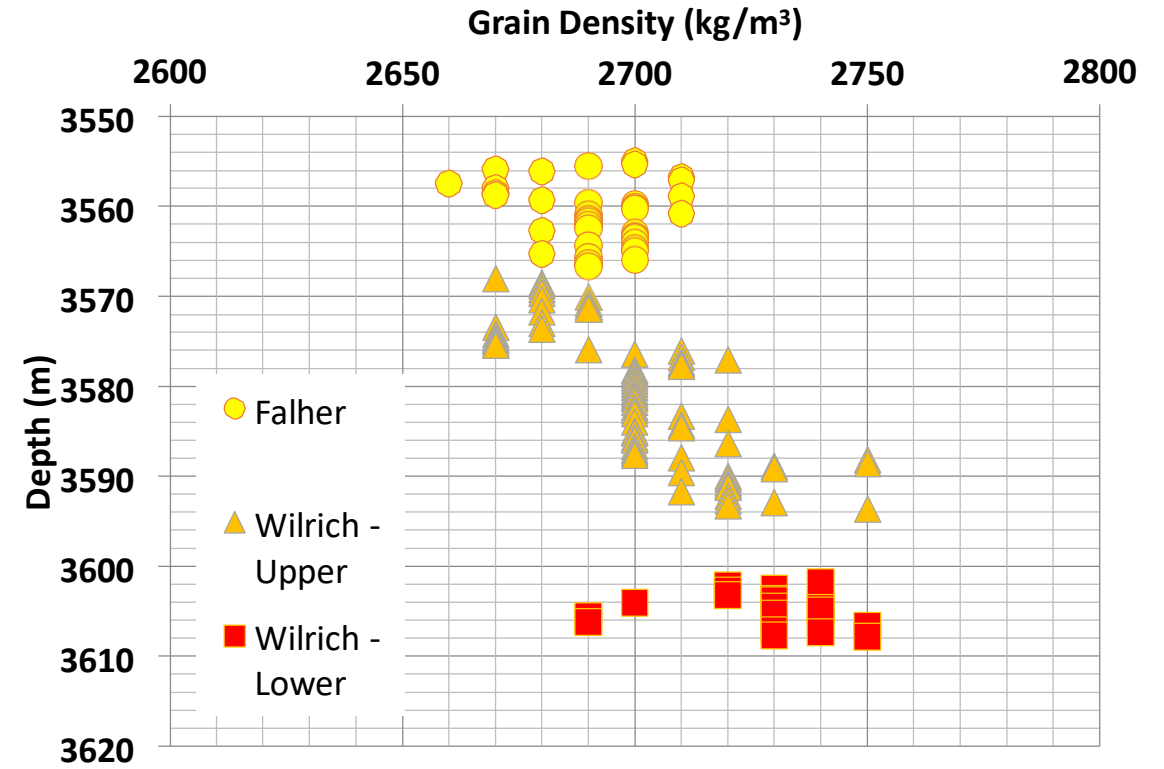
Falher

Wilrich

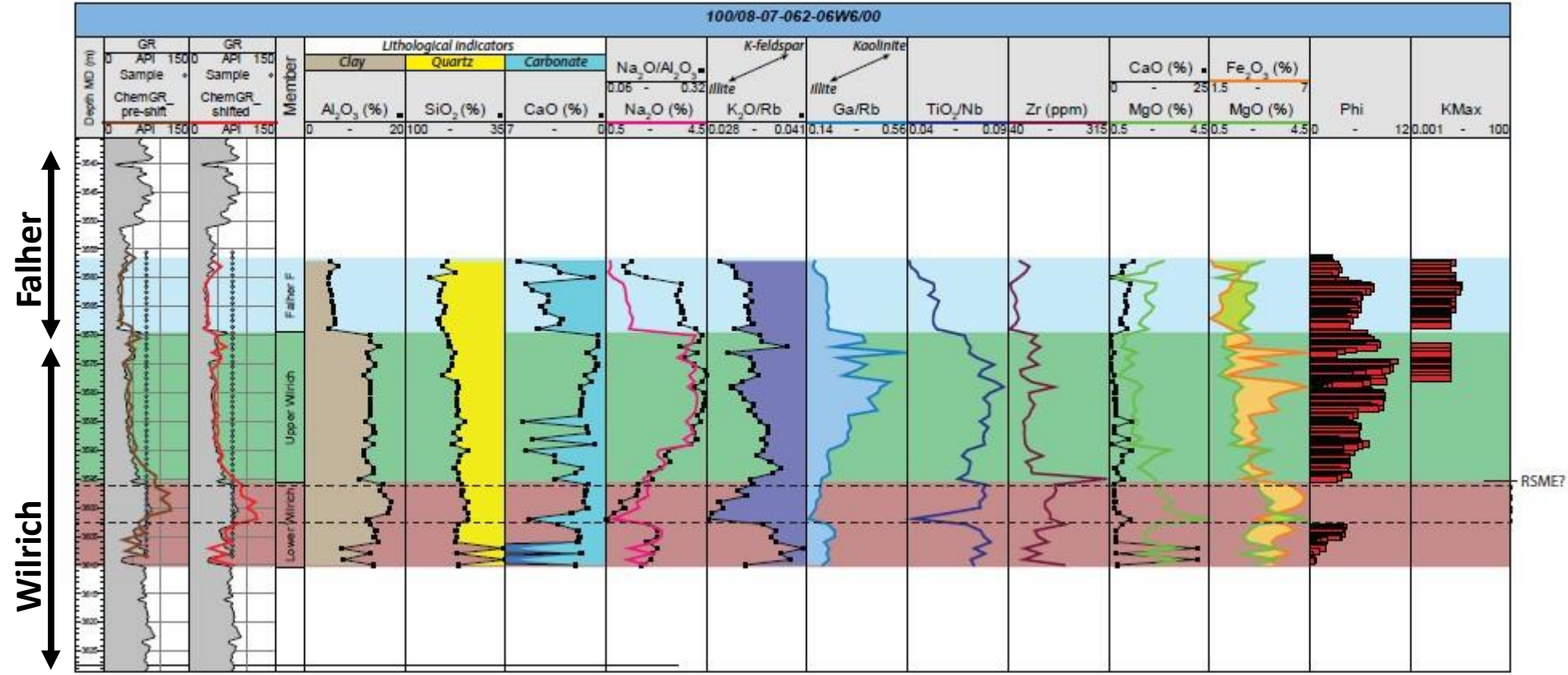
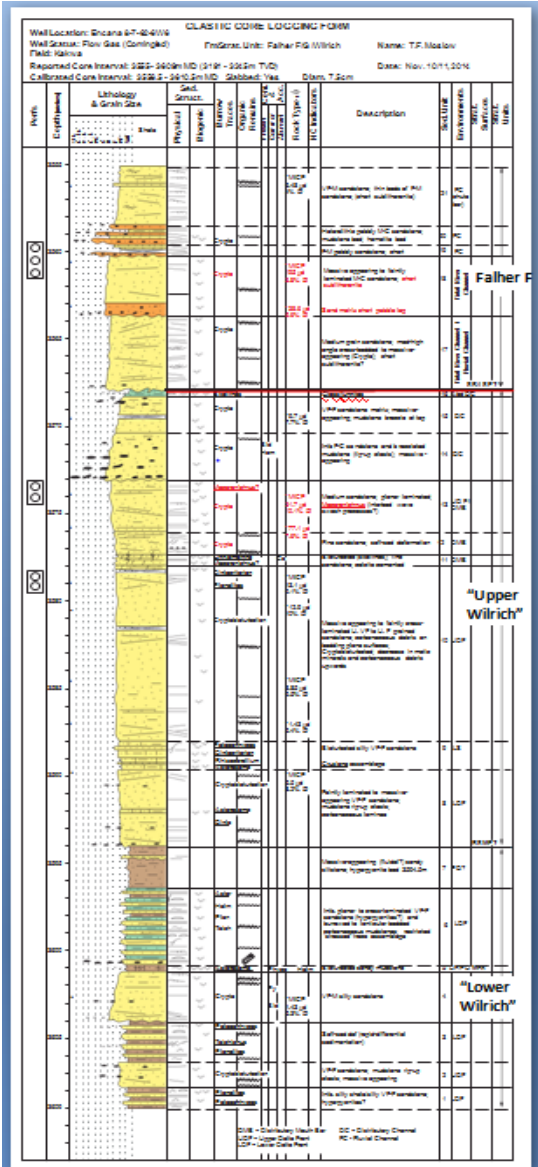
### ECA KAKWA 8-7-62-6W6 Porosity (%) vs. Depth (m)



### ECA KAKWA 8-7-62-6W6 Grain Density (kg/m<sup>3</sup>) vs. Depth (m)



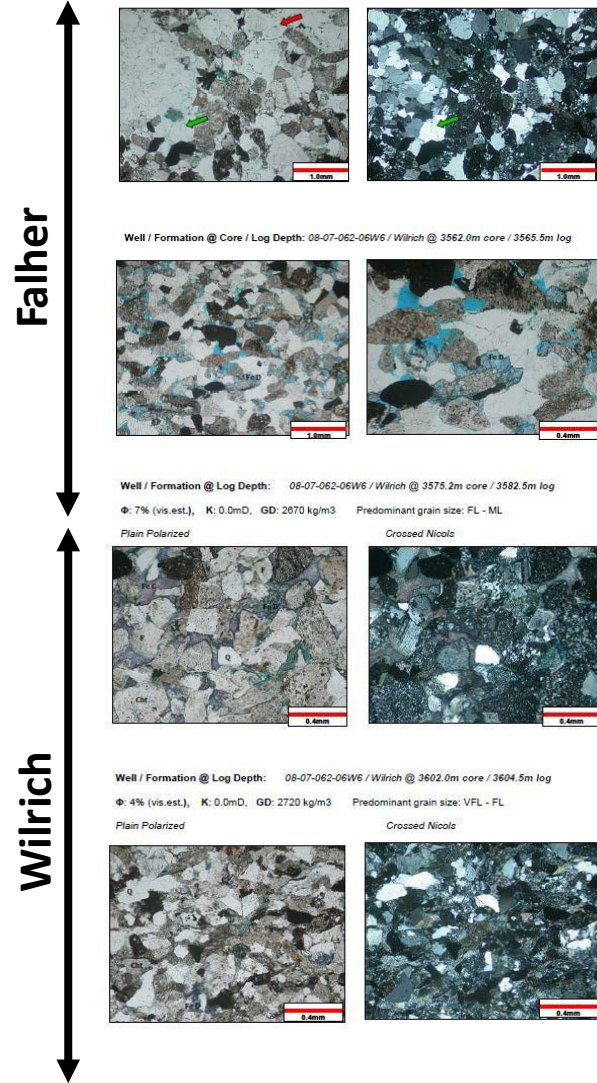
# ECA KAKWA 8-7-62-6W6



Falher  
 Wilrich

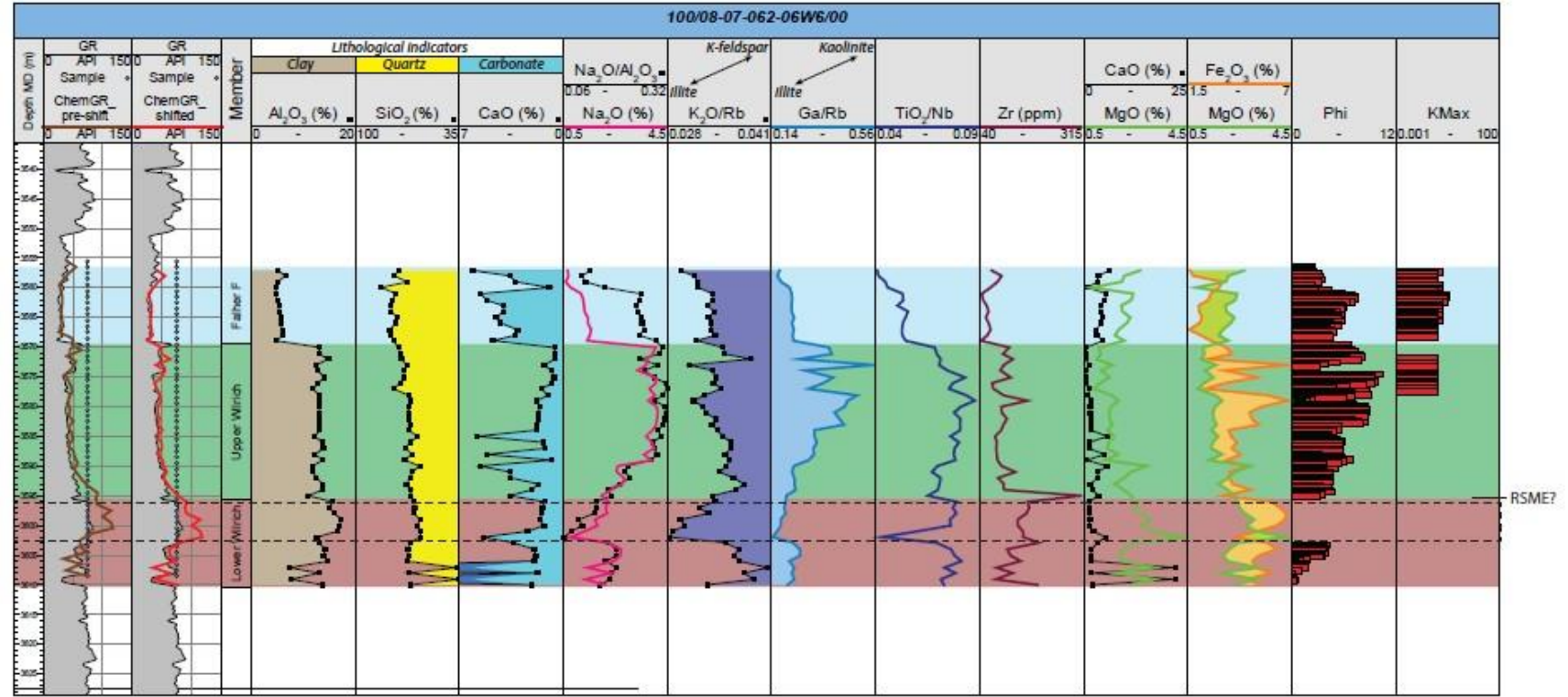


# ECA KAKWA 8-7-62-6W6

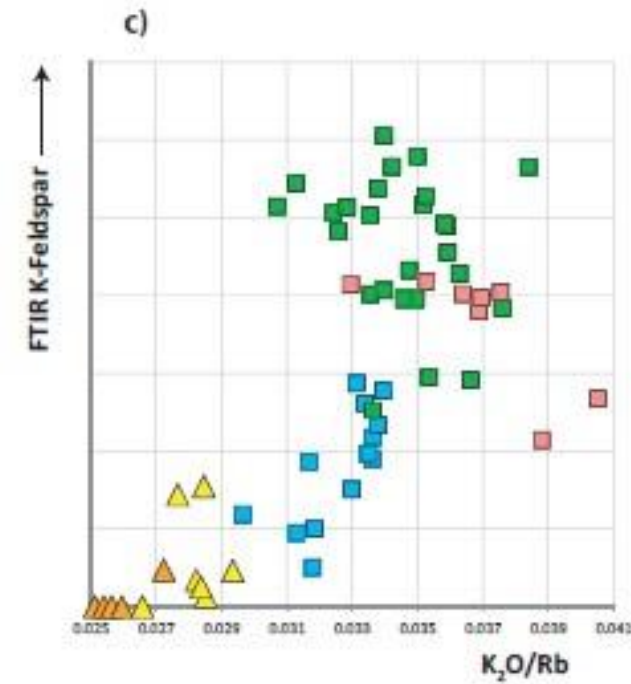
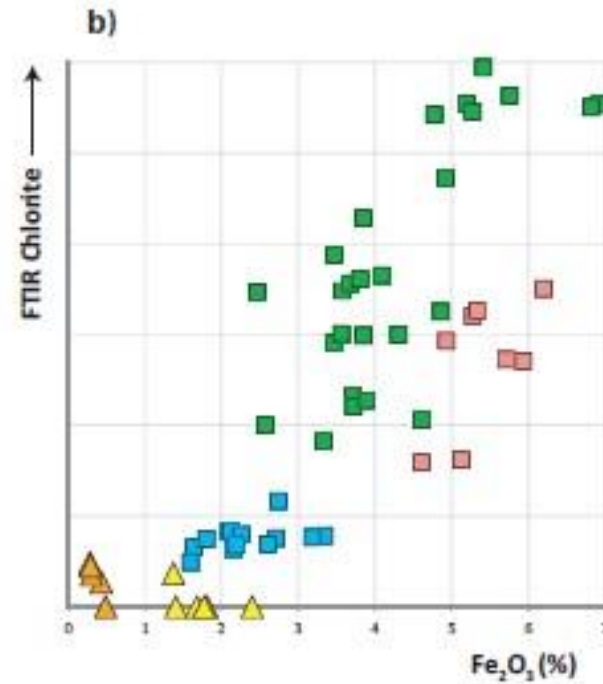
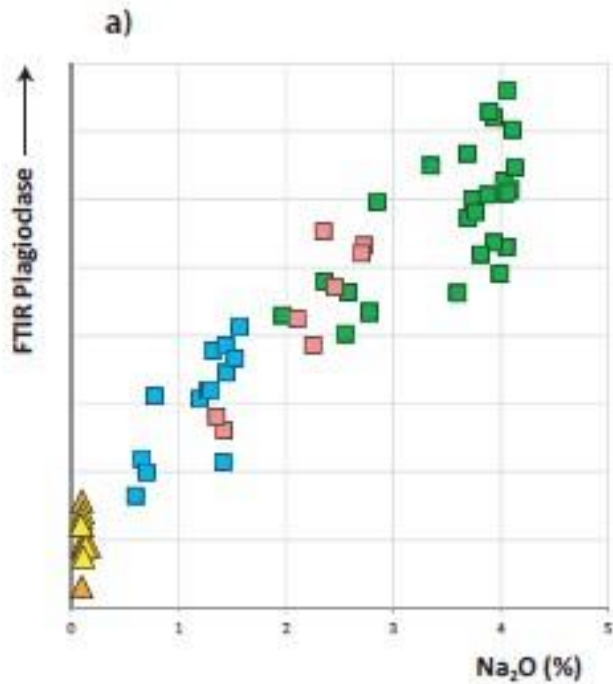


Falher

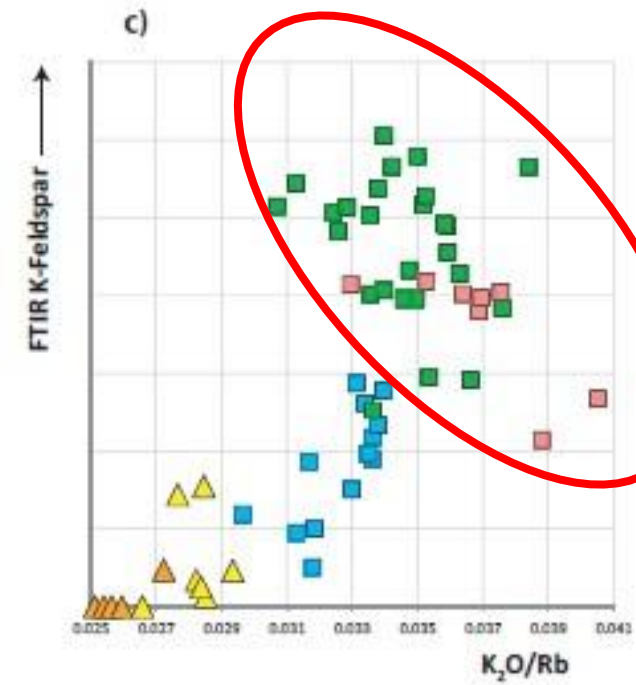
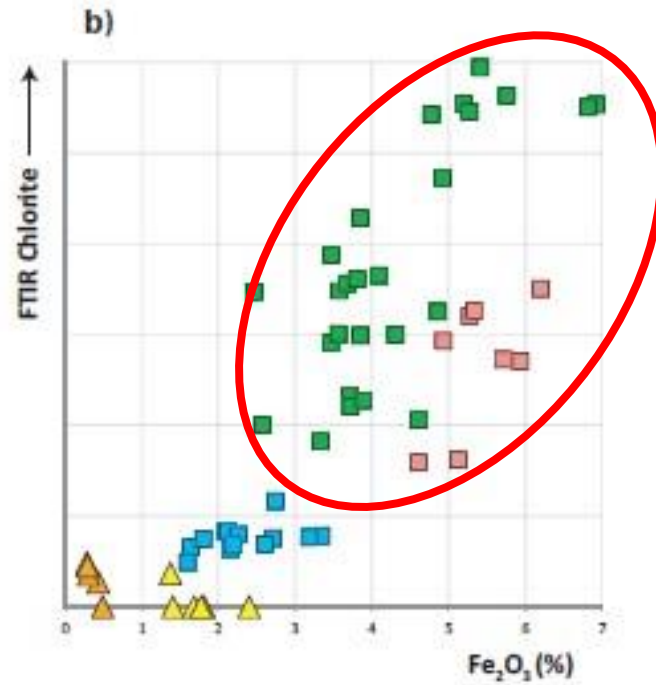
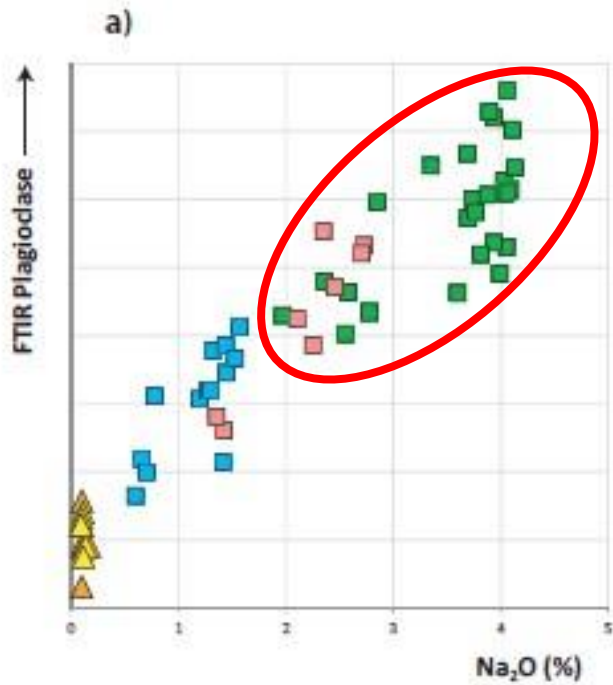
Wilrich



# Chemostrat Binary Diagrams

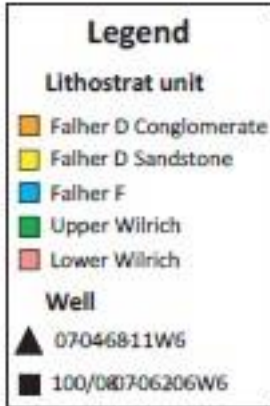
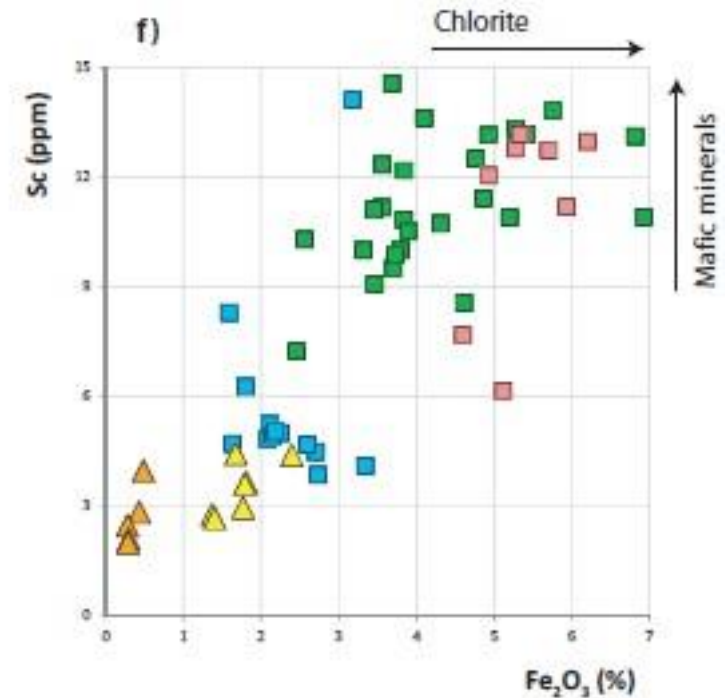
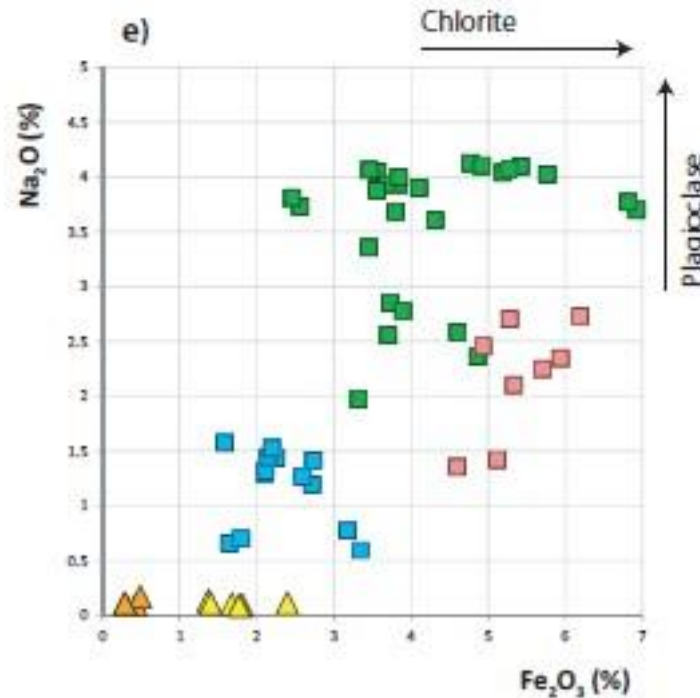
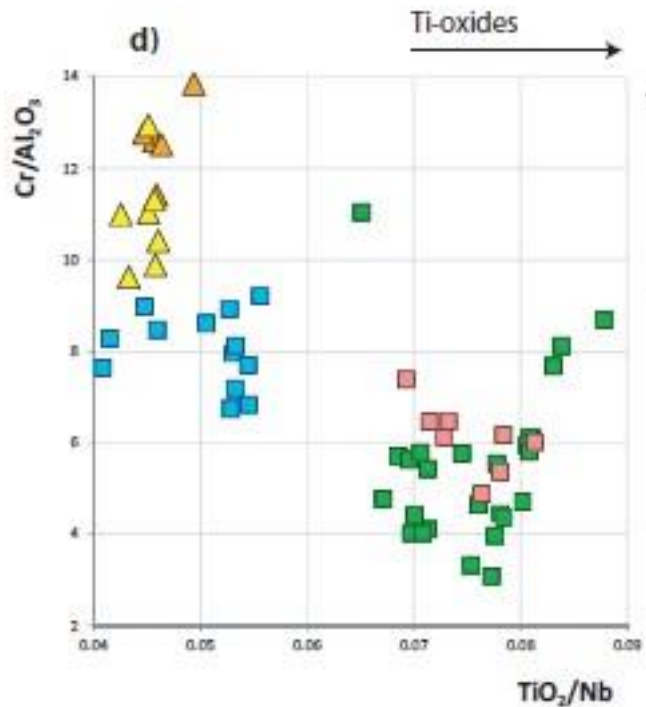


# Chemostrat Binary Diagrams



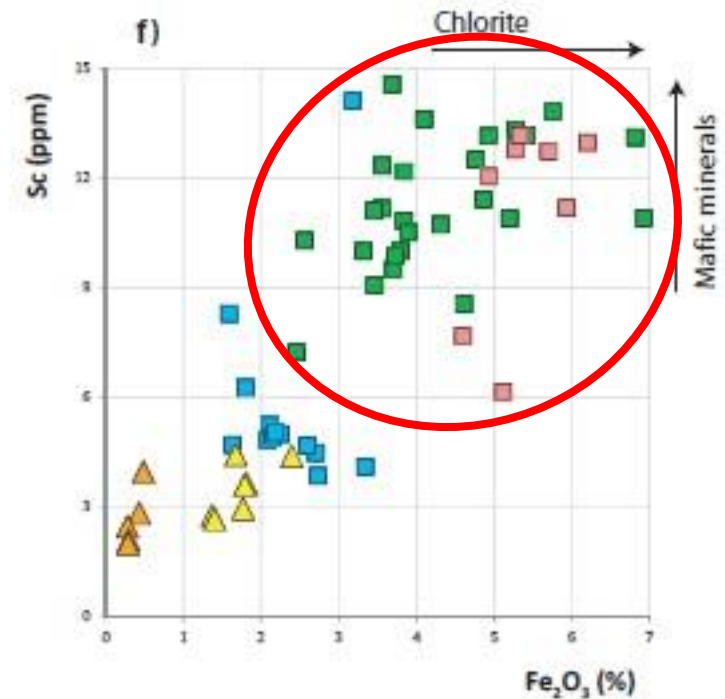
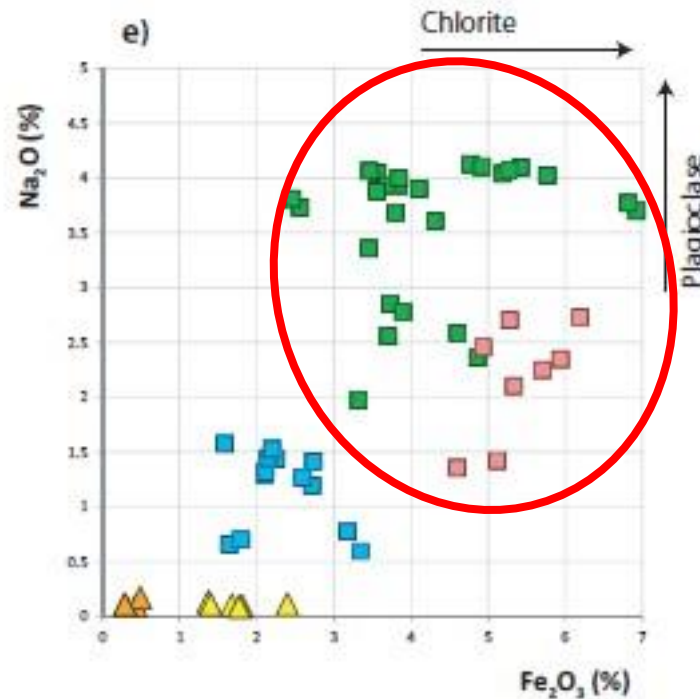
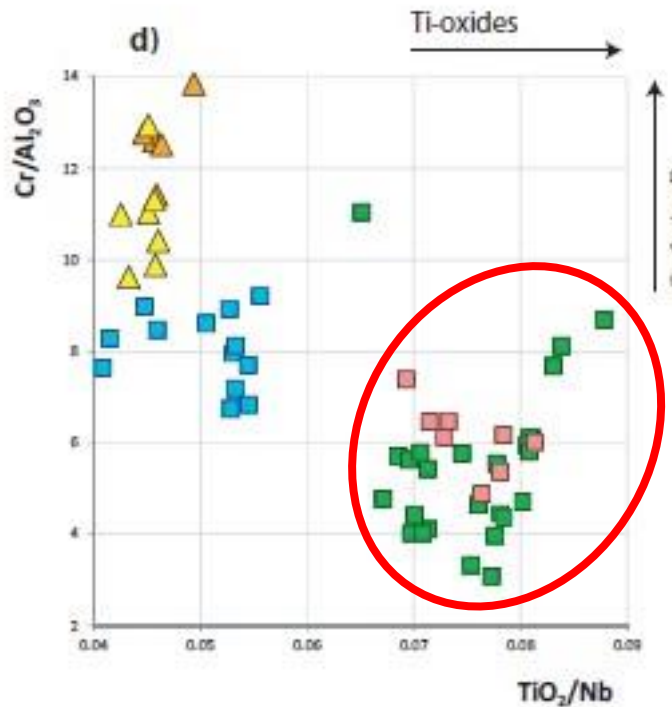
○ Wilrich

# Chemostrat Binary Diagrams





# Chemostrat Binary Diagrams

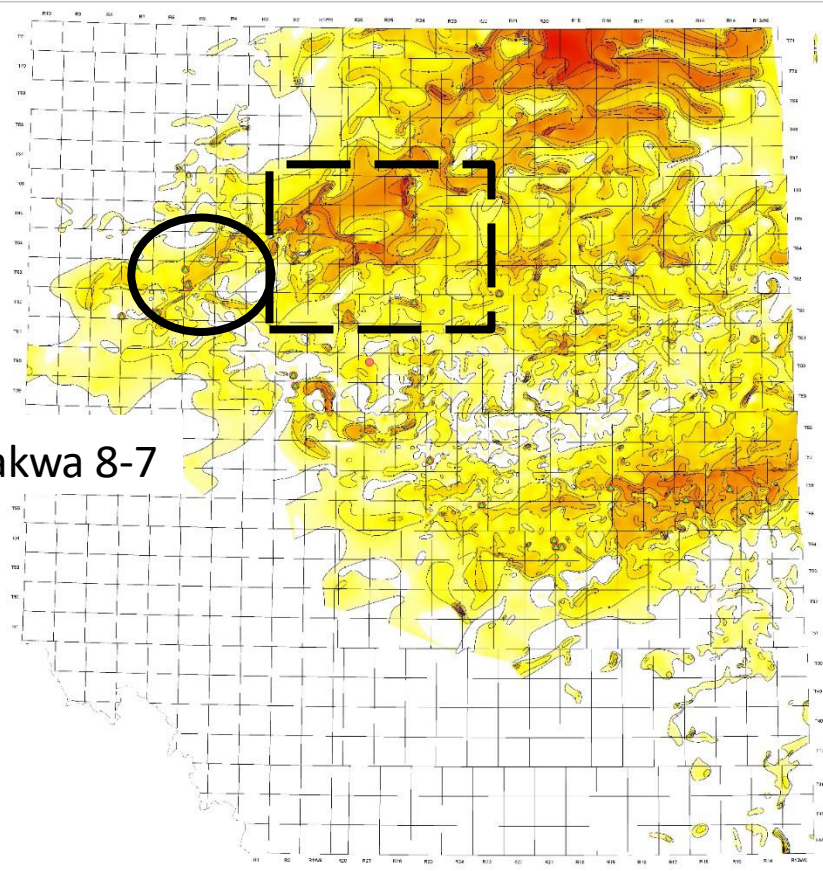
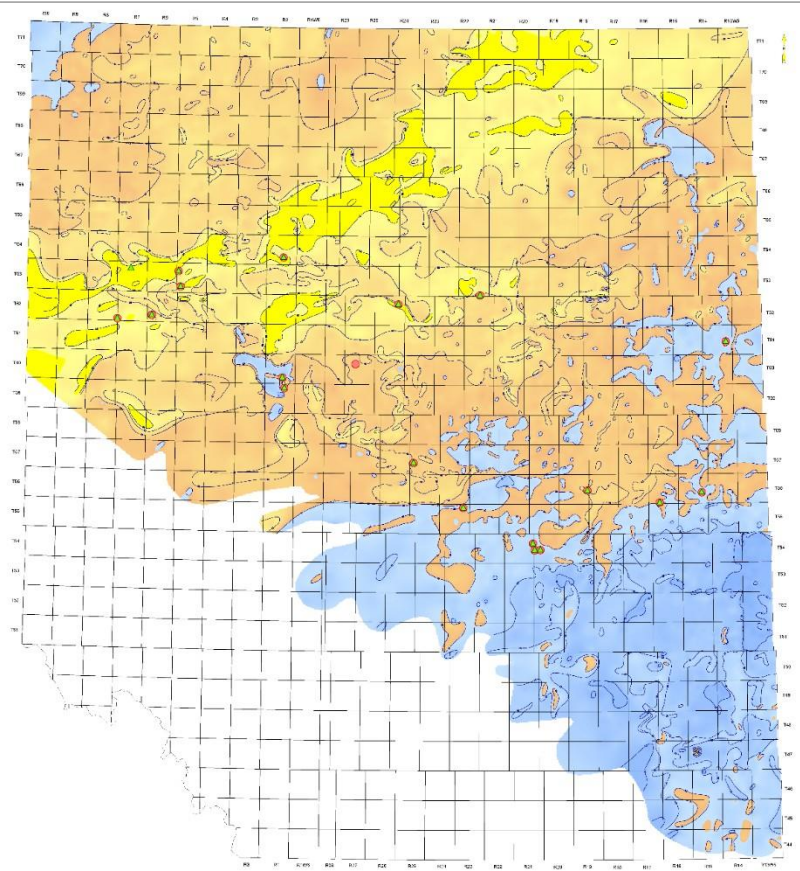


Wilrich

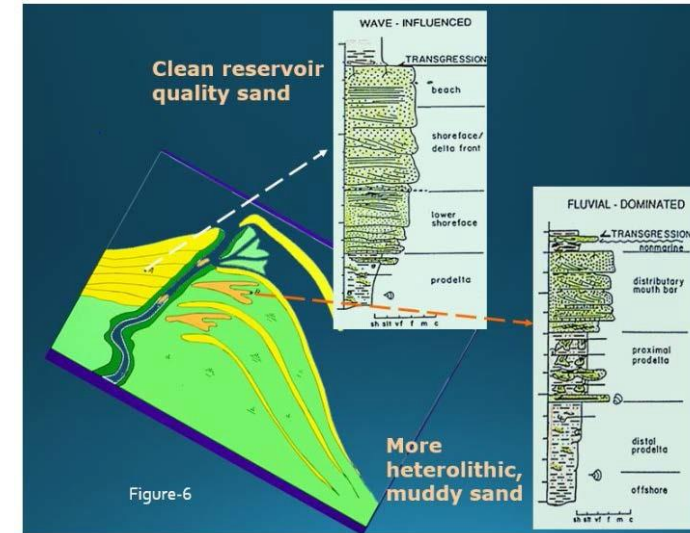
# Wilrich "A"

Wilrich "A" Gross Isopach

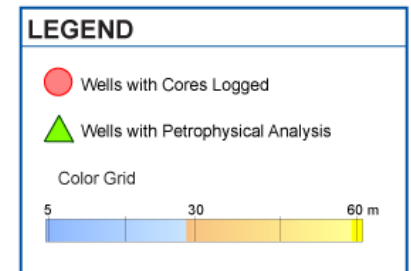
Wilrich "A" Net Clean Sandstone (6% Ø cutoff)



Kakwa 8-7



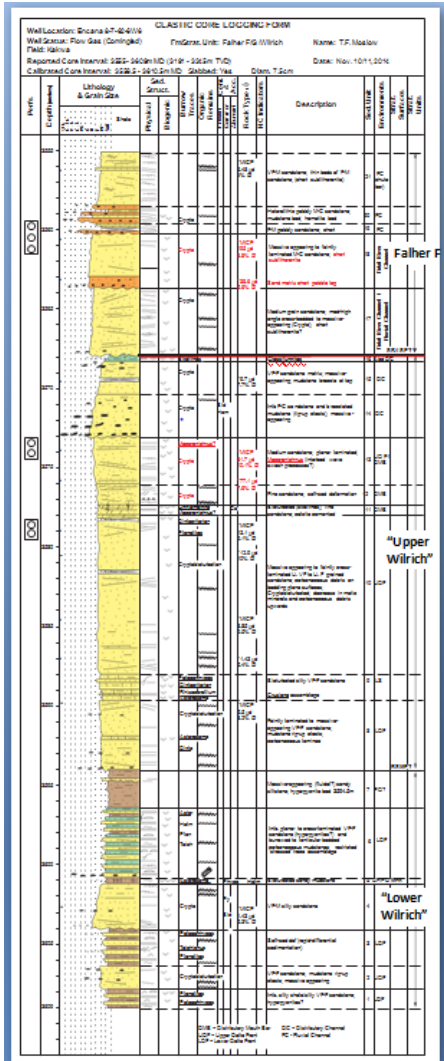
Junaid Sadeque, March, 2016



Maps Courtesy Brad Hayes, PRCL



# Conventional – Unconventional Continuum – Gas Summary and Conclusion



**8-7-62-6W6**

**Unconventional Reservoir Rock**

**Dissipative Shoreface – Assymmetric Delta**

**Conventional Gas**

Pure Methane

**7-4-68-11W6**

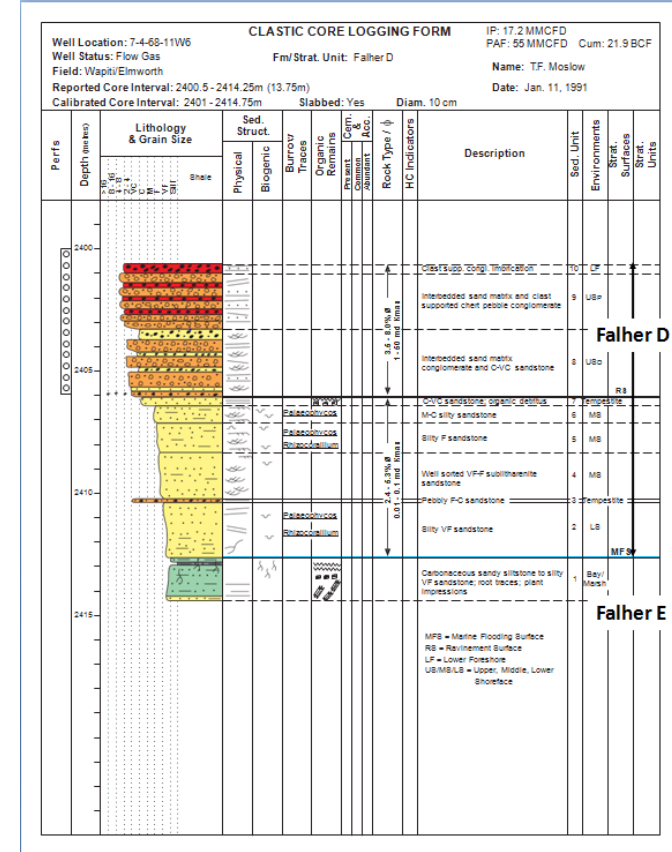
**Conventional Reservoir Rock**

Impure Methane - high H<sub>2</sub>S, high CO<sub>2</sub> or other significant contaminants

**Unconventional Gas**

Image Source: AJM (Russum, 2010)

Source: R. Mann, AJM Petroleum Consultants, 2010



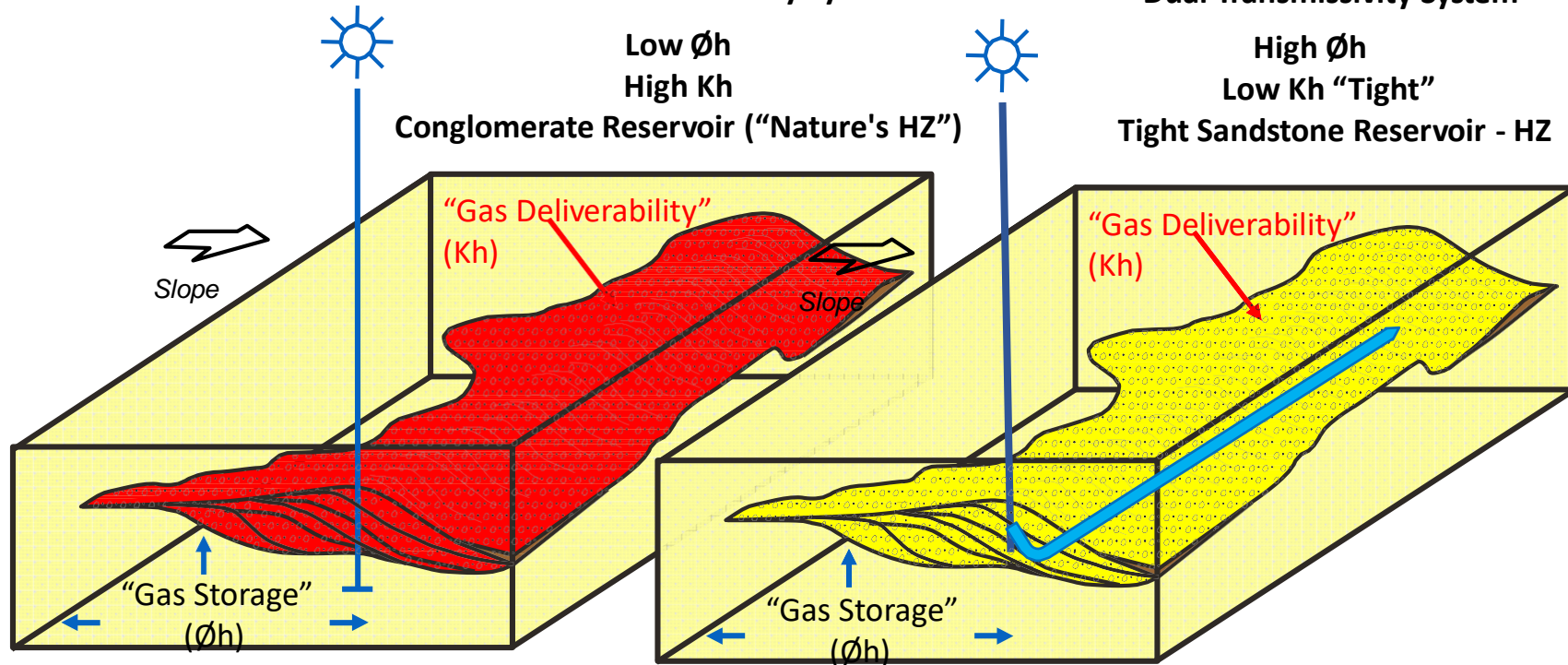
**Reflective Shoreface**

# Conventional – Unconventional Continuum – Gas Summary and Conclusion

**Conglomeratic (Falher)  
vs. Fine Grained  
Sandstone (Wilrich)  
Shoreface Reservoirs**

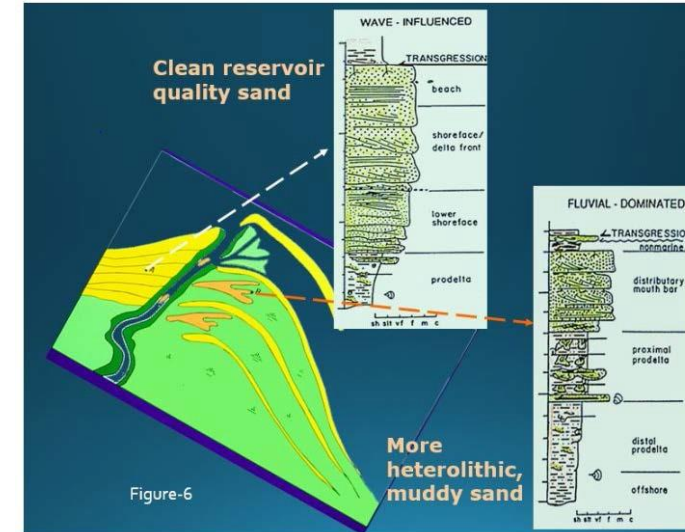
HPBCGA "Sweet Spots"  
act as a HZ well  
Dual Transmissivity System

HPBCGA "Sweet Spots"  
require a HZ well  
Dual Transmissivity System



Falher A thru D Reservoirs

Wilrich Reservoirs



# Summary and Conclusions

- A significant difference in mineralogy occurs between the chert-quartz dominated Core 1 and pebbly chert sublitharenite of Core 2.
- Chemostratigraphy was employed to characterize and differentiate between the individual “members” of the Spirit River Group.
- The greater chlorite abundance in the **Upper Wilrich** (formerly Falher G) corroborates the chlorite rims discussed by Moslow and Ala (2012) which improve the reservoir quality of the sandstones.
- Samples historically defined as Falher G show a stronger geochemical affinity to the Wilrich
- Cross plots of the results show different clusters produced by the sandstone samples of the Falher and Wilrich which points to distinct heavy minerals and other detrital mineral phases.
- These variations therefore can be used to understand subtle changes in provenance.
- The results of this study explain the contrasts between the mineralogy and provenance, reservoir quality, sedimentology and the stratigraphy of the Falher (A-E) and Wilrich in the Spirit River Group, and introduces the asymmetric delta model based on net clean sand mapping by member.

# Acknowledgements

- **Dr. Brad Hayes (Petrel Robertson Consulting Ltd.)**
  
- **Many Past Colleagues from:**
  - **Gulf**
  - **Esso/Exxon**
  - **PanCanadian/Encana**
  - **Suncor**
  - **Enerplus**
  - **BMO**
  - **NARP**
  - **EOG**
  - **Daylight/Midnight/Pace**

