

**Alberta  
Energy  
Regulator**



**AGS**  
ALBERTA GEOLOGICAL SURVEY

# Distribution and origin of lithium-enriched formation waters in Alberta

G. Lopez, J. Weiss and R. Huff

March 28, 2018



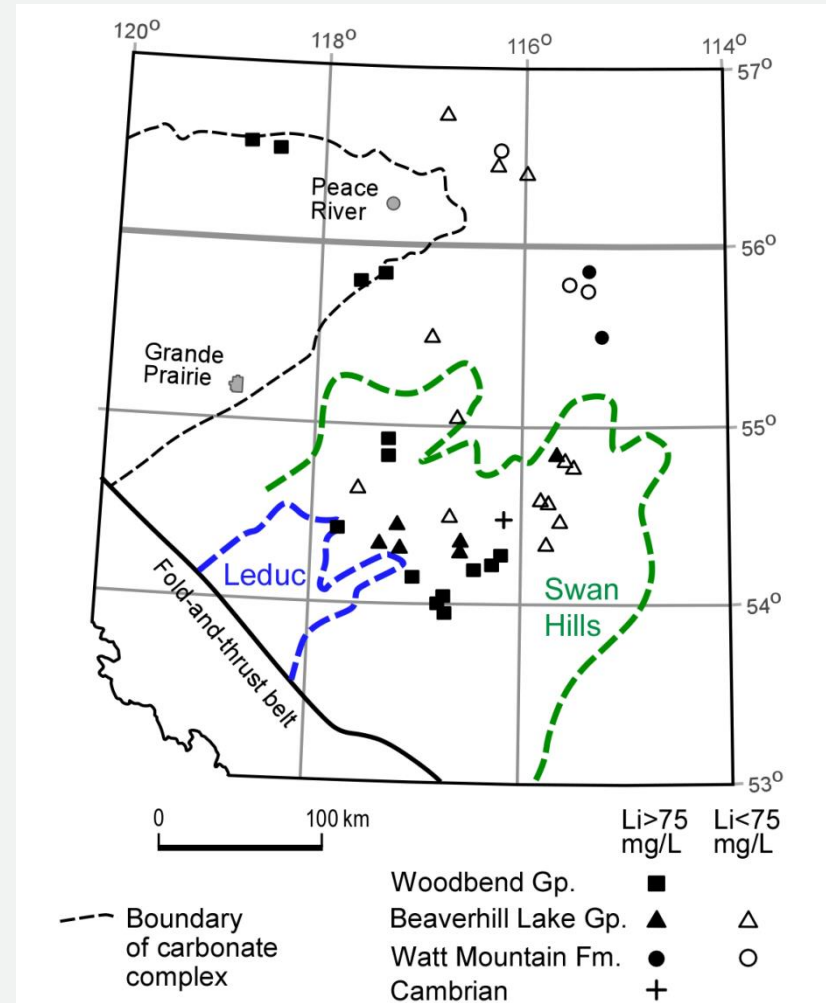
# Outline

- 》 AGS history on lithium-rich formation waters
- 》 Lithium in Alberta Interactive Minerals Map
- 》 Distribution of lithium-enriched formation waters
- 》 Characteristics of lithium-enriched formation waters
- 》 Origin of lithium-rich formation waters (Huff, 2016)

# AGS history on Li-enriched formation waters

## » Hitchon (1993-95):

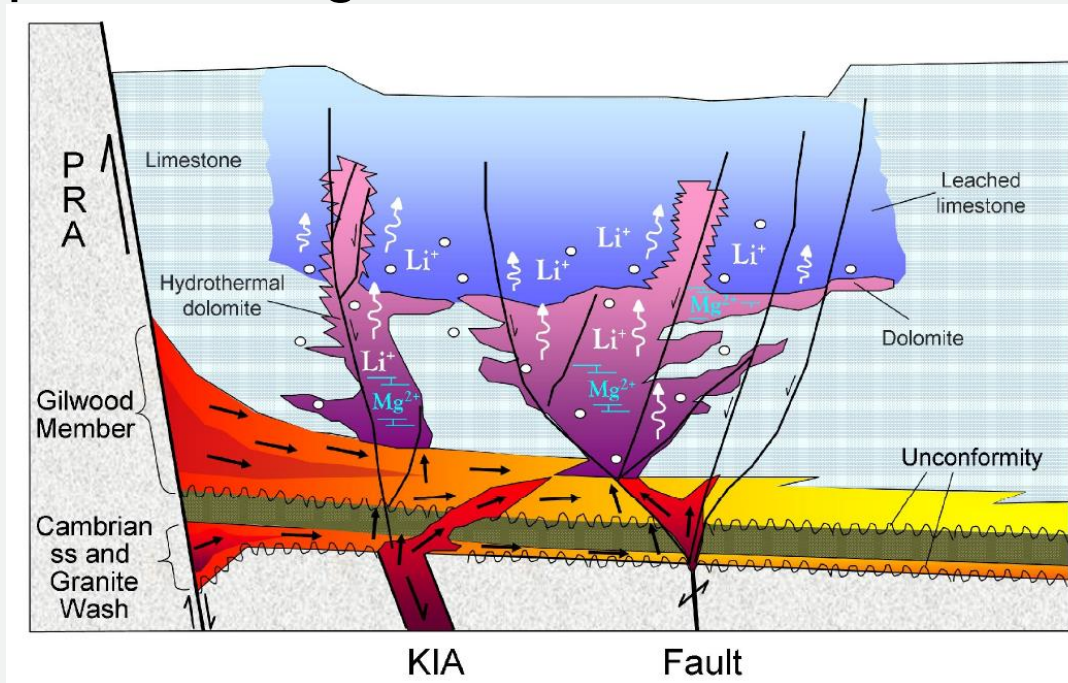
- Search elements of potential economic interest
- 130,000 analyses of formation waters (708 for Li)
- Li up to 140 mg/L in Devonian formation waters in west-central AB



# AGS history on Li-enriched formation waters

» Eccles et al. (2010, 2011):

- 1,511 analyses
- Li up to 140 mg/L in Devonian formation waters



From Eccles & Berhane, 2011

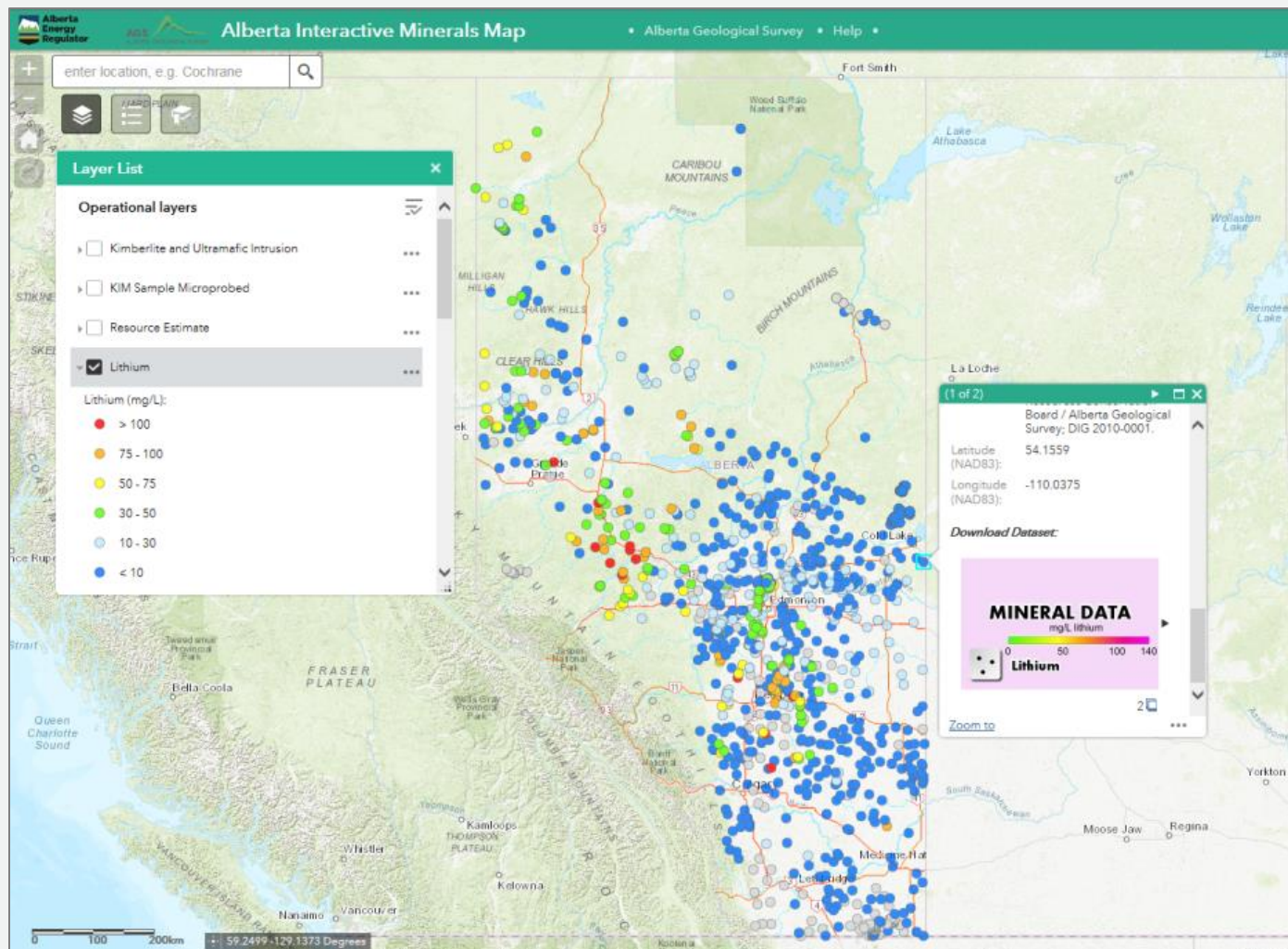


# AGS history on Li-enriched oilfield brines

- » Huff (2011, 2012, 2016, report in progress):
- Saline aquifer project Edmonton-Red Deer
  - Lithium in Devonian carbonate formation waters
  - Sampling in west-central AB in 2016



# Alberta Interactive Minerals Map



# Alberta Interactive Minerals Map: lithium hits

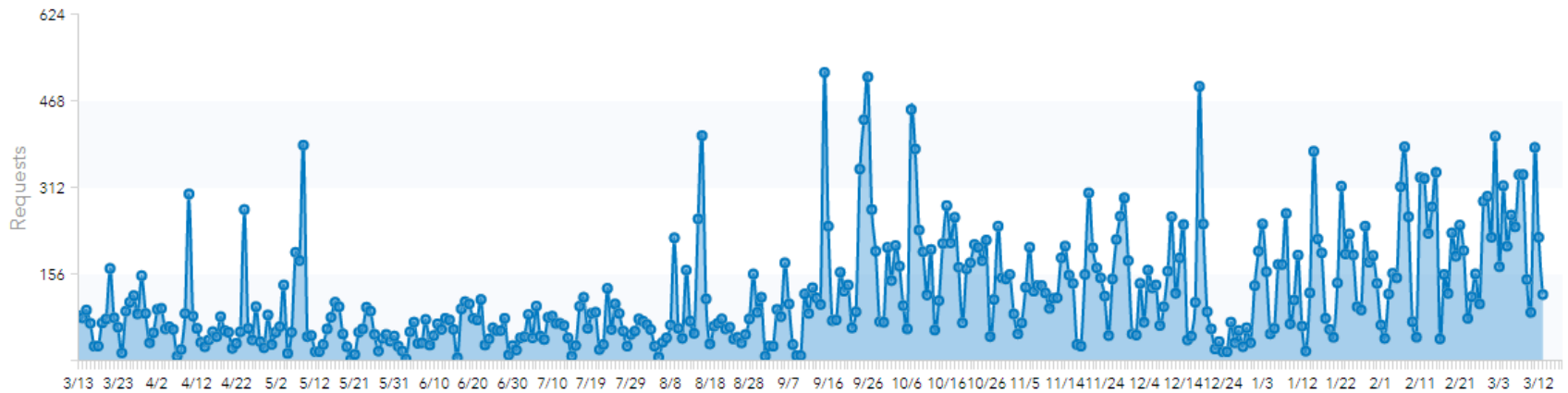
Requests this Period

44,031

Avg Requests Per Day

120.63

Usage Time Series



2017

2018



# Sample location and sources

Total of 1,683 samples with lithium analysis

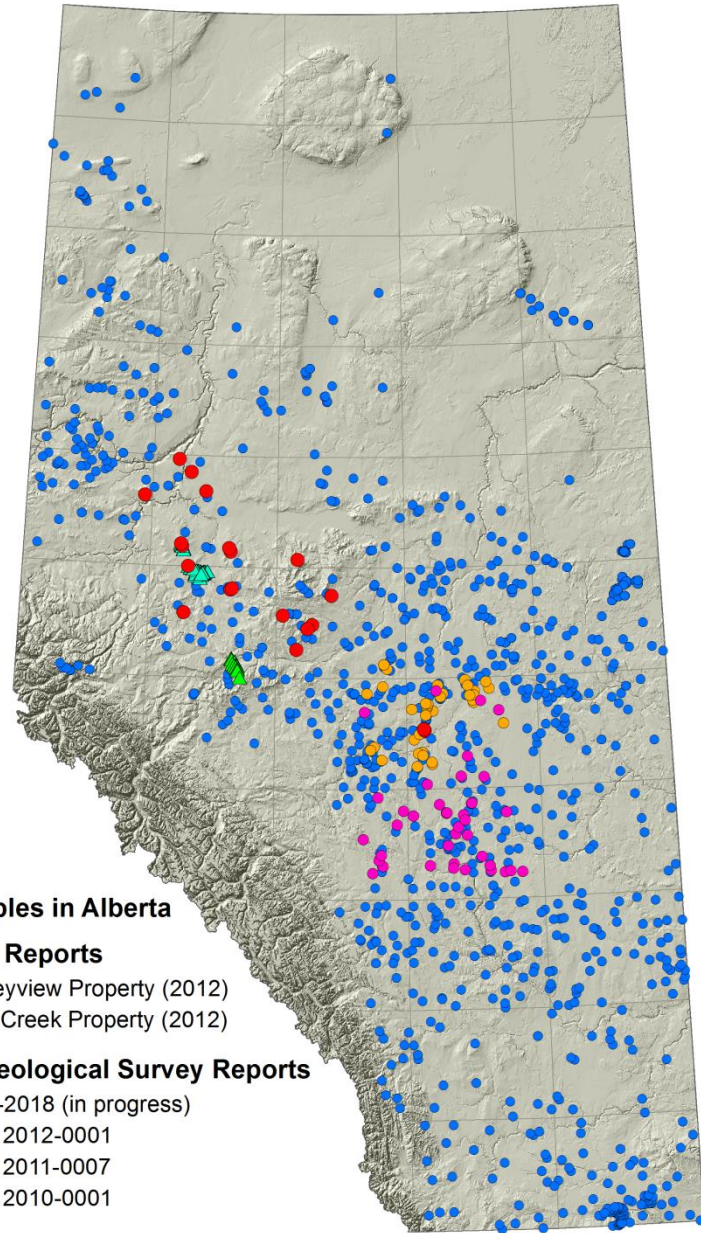
## Brine Samples in Alberta

### Technical Reports

- ▲ Valleyview Property (2012)
- ▲ Fox Creek Property (2012)

### Alberta Geological Survey Reports

- DIG-2018 (in progress)
- DIG 2012-0001
- DIG 2011-0007
- DIG 2010-0001





# Distribution of Li-enriched samples

172  $\geq$  50 mg/L

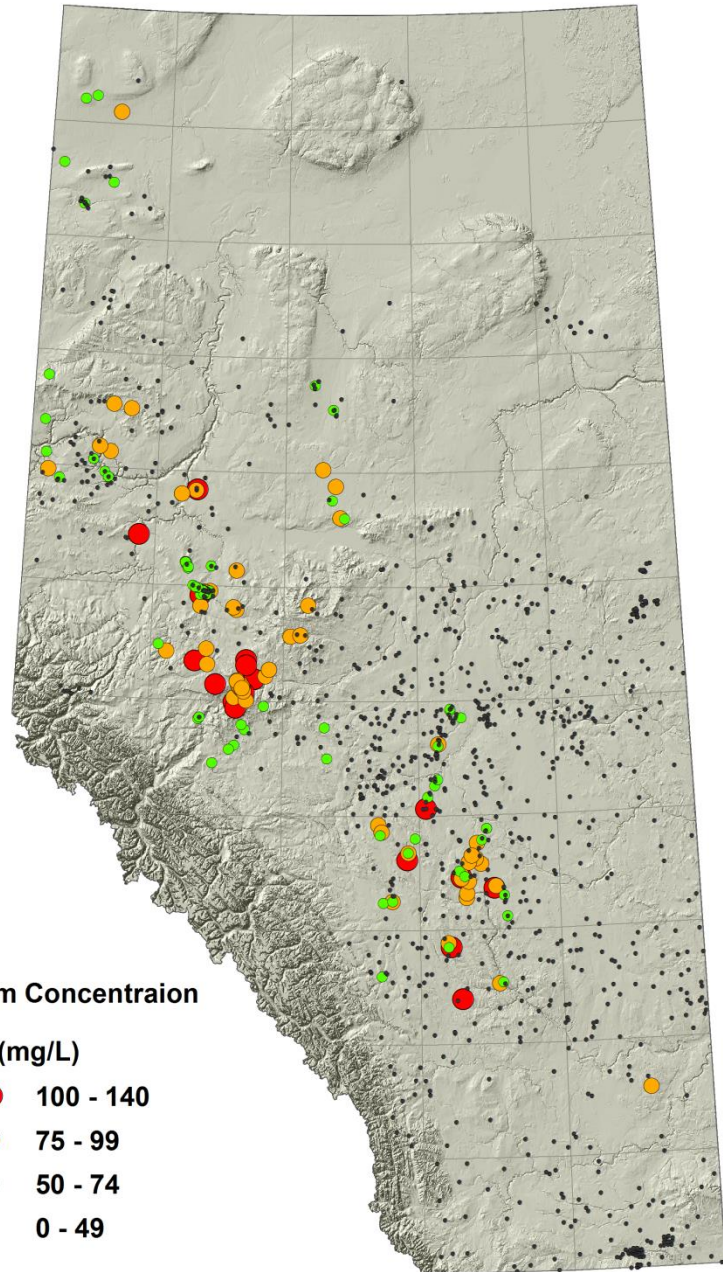
74  $\geq$  75 mg/L

17  $\geq$  100 mg/L

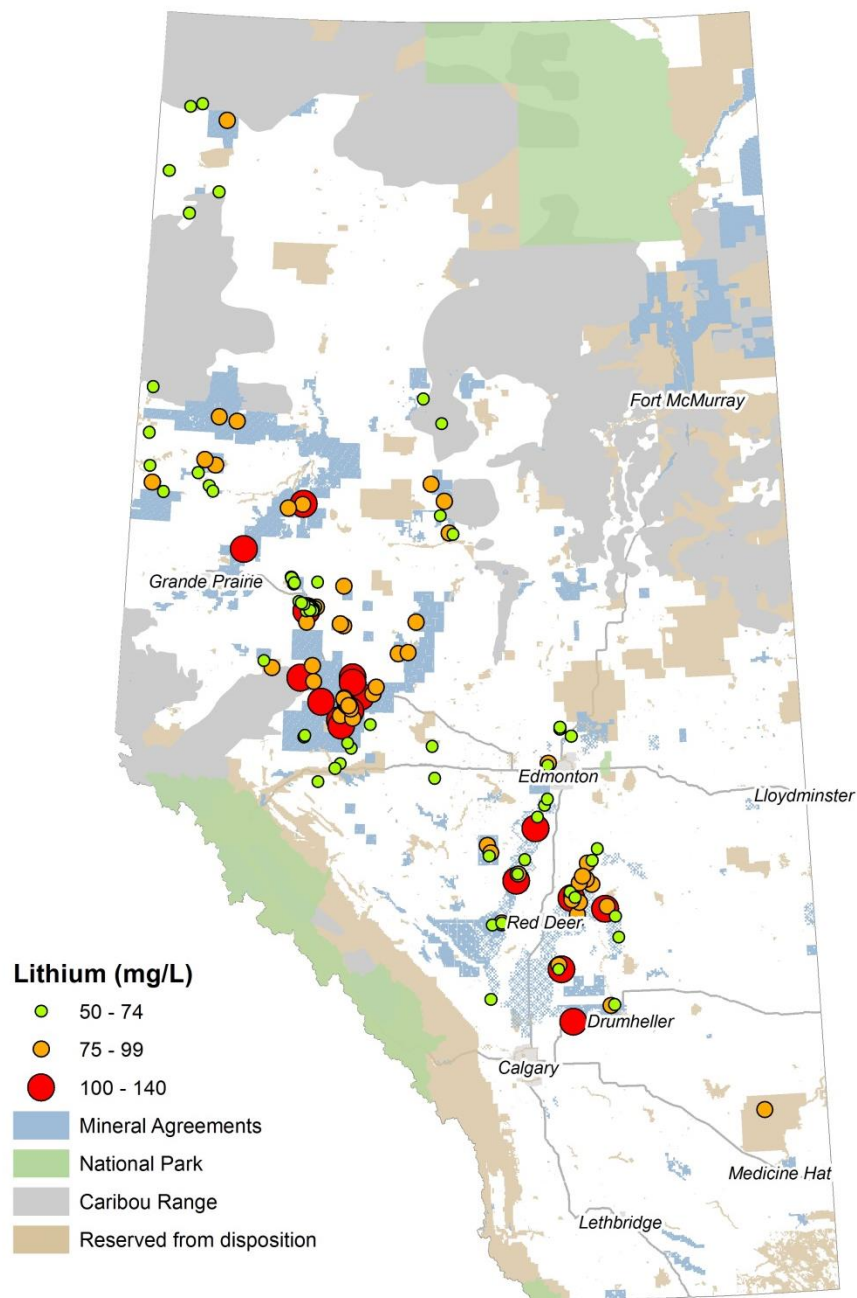
## Lithium Concentration

Li (mg/L)

- 100 - 140
- 75 - 99
- 50 - 74
- 0 - 49

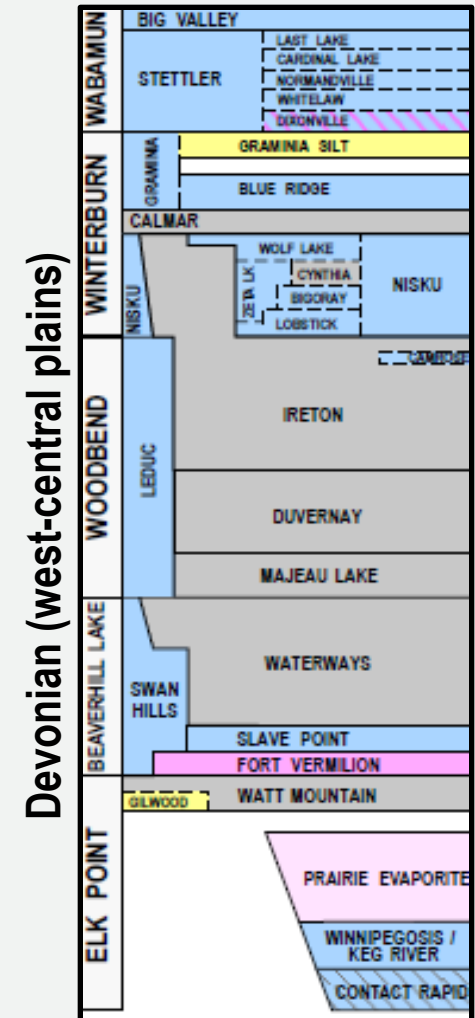


# Distribution of Li-enriched samples



# Distribution of lithium-enriched formation waters

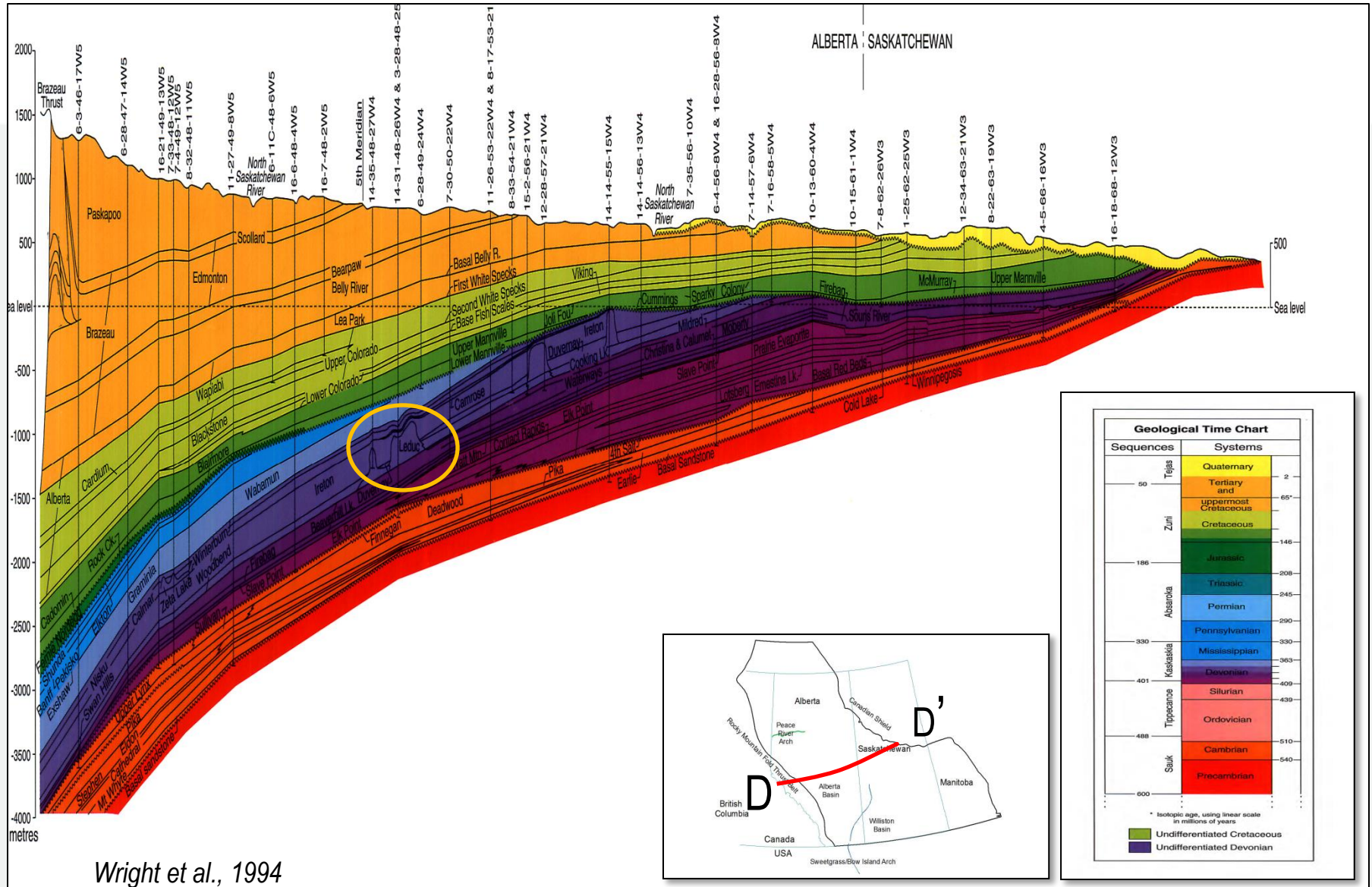
- »  $\text{Li} \geq 100 \text{ mg/L}$ : Devonian carbonate formation waters of the **Swan Hills, Leduc and Nisku Fms.**
- »  $\text{Li} \geq 50 \text{ mg/L}$ :
  - Cambrian, Triassic, Devonian, and Carboniferous-Mississippian units
  - Two samples in Jurassic and Cretaceous units.





D

D'

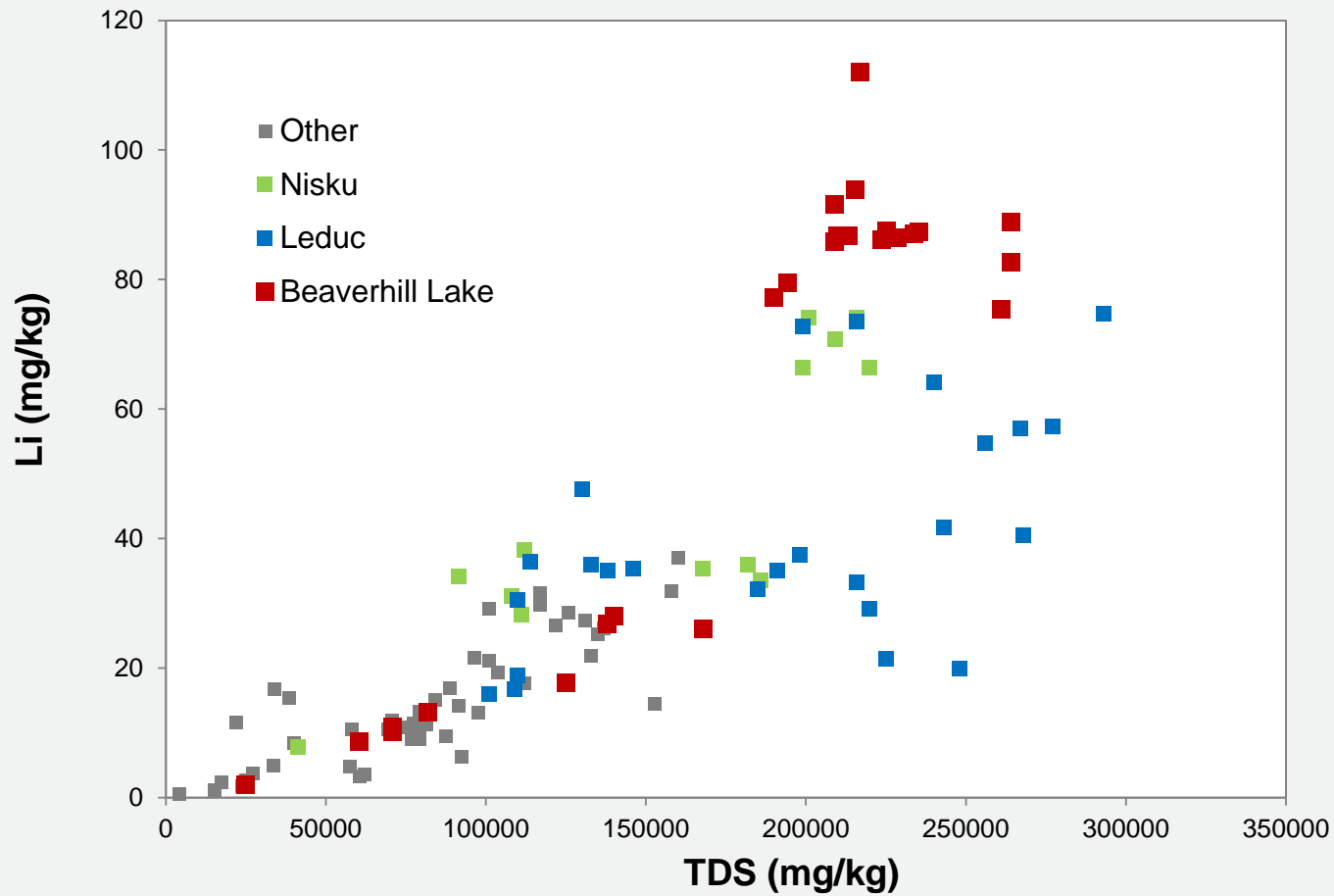


Wright et al., 1994

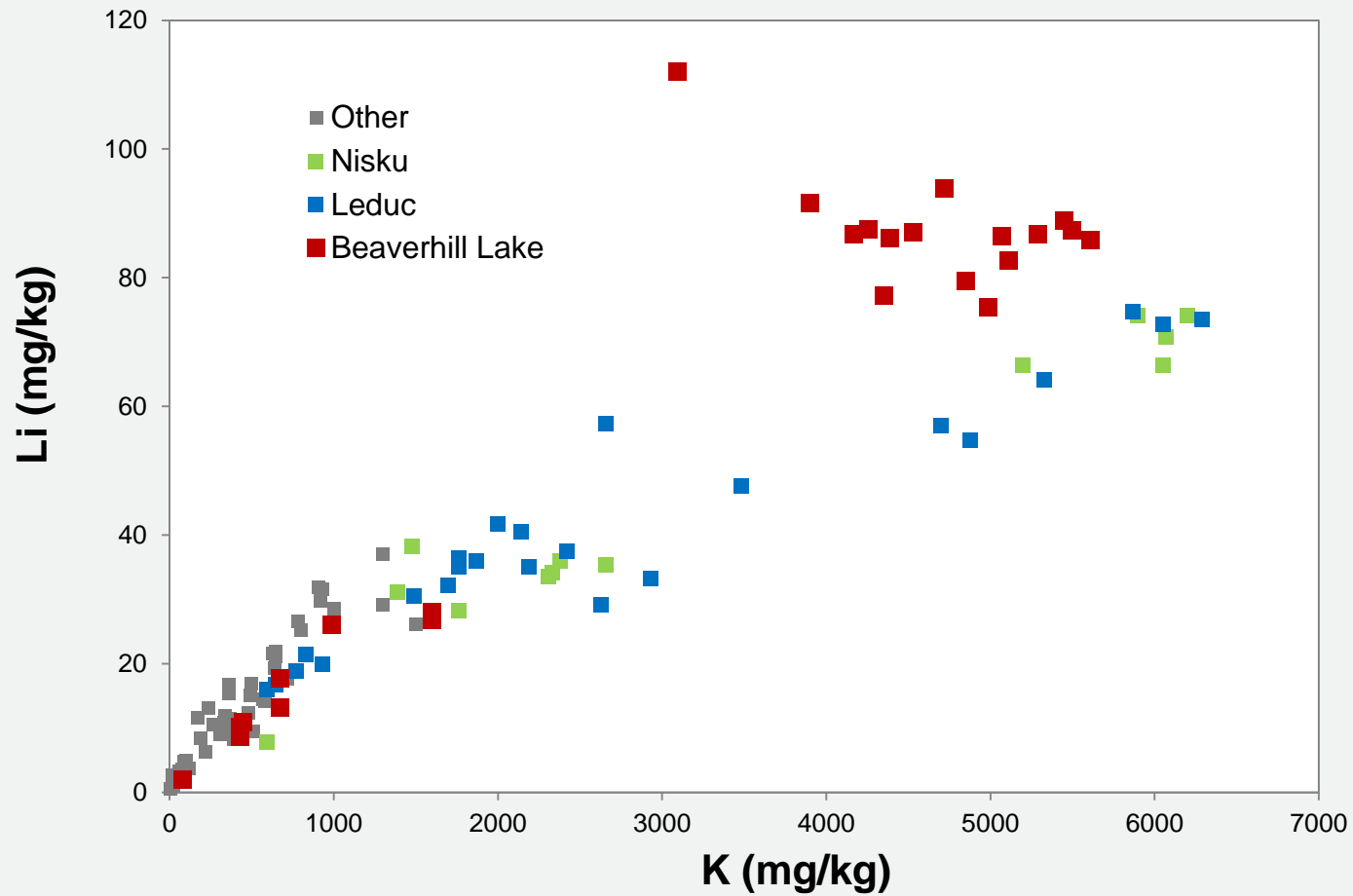
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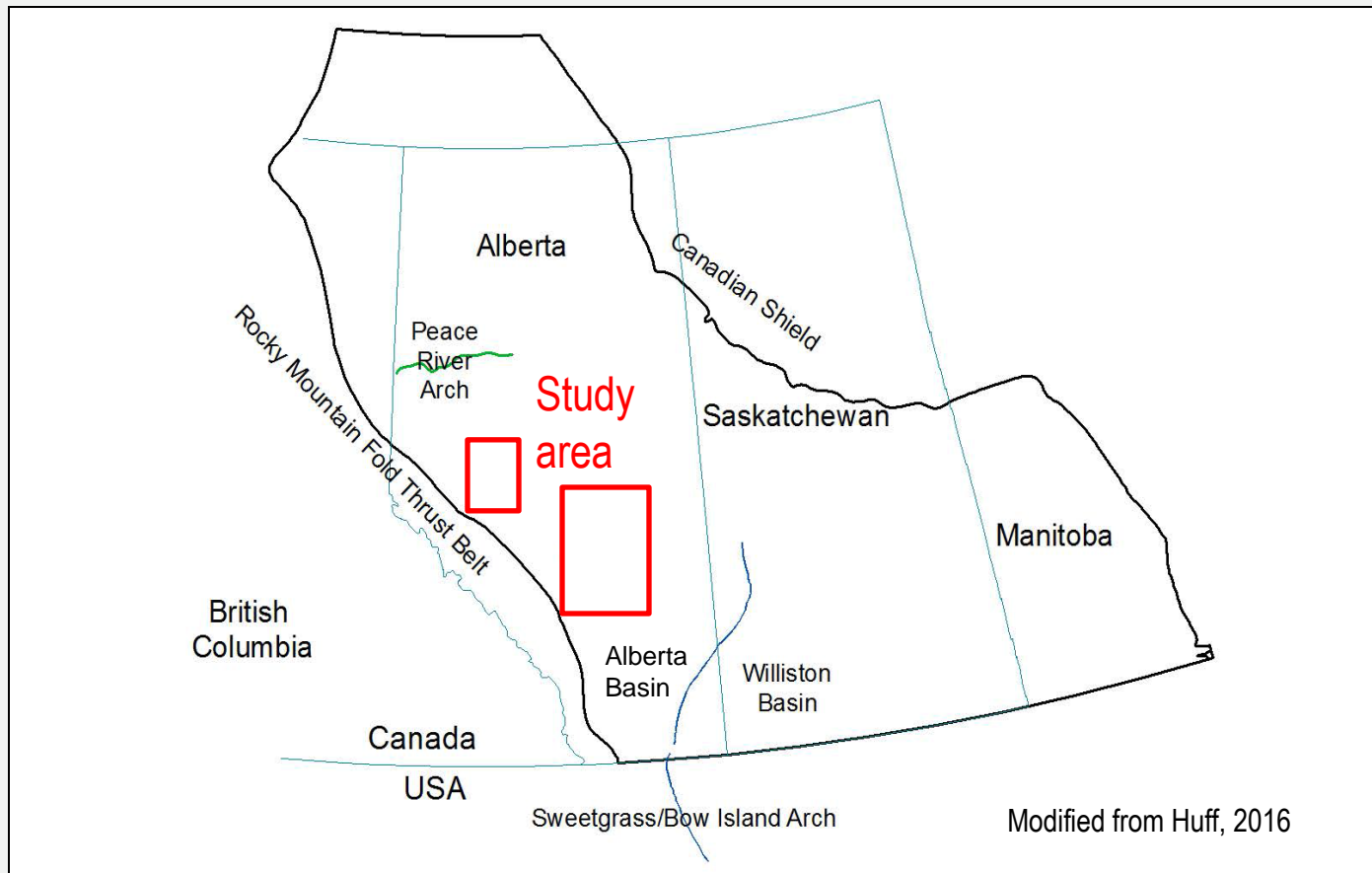
# Li vs TDS



# Li vs K

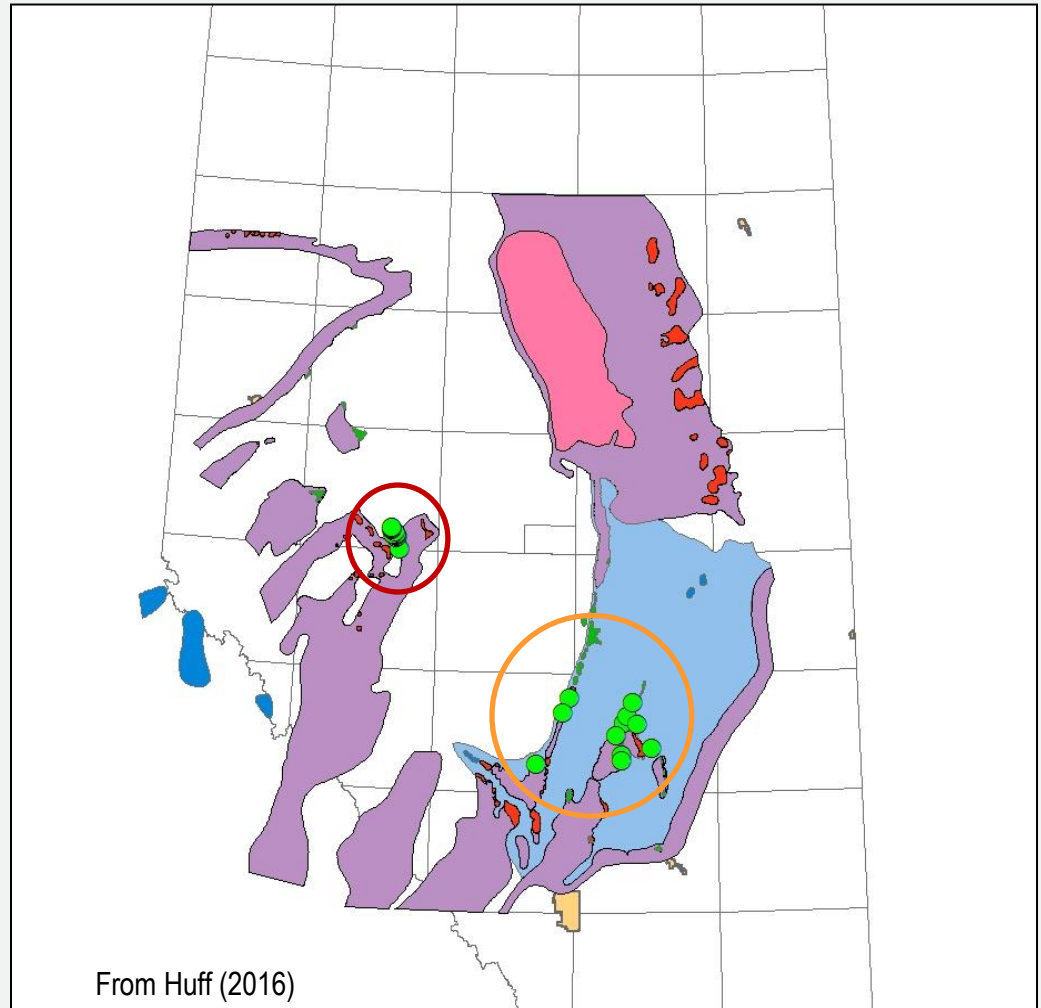


# Origin of Li-enriched oilfield brines in Devonian carbonates



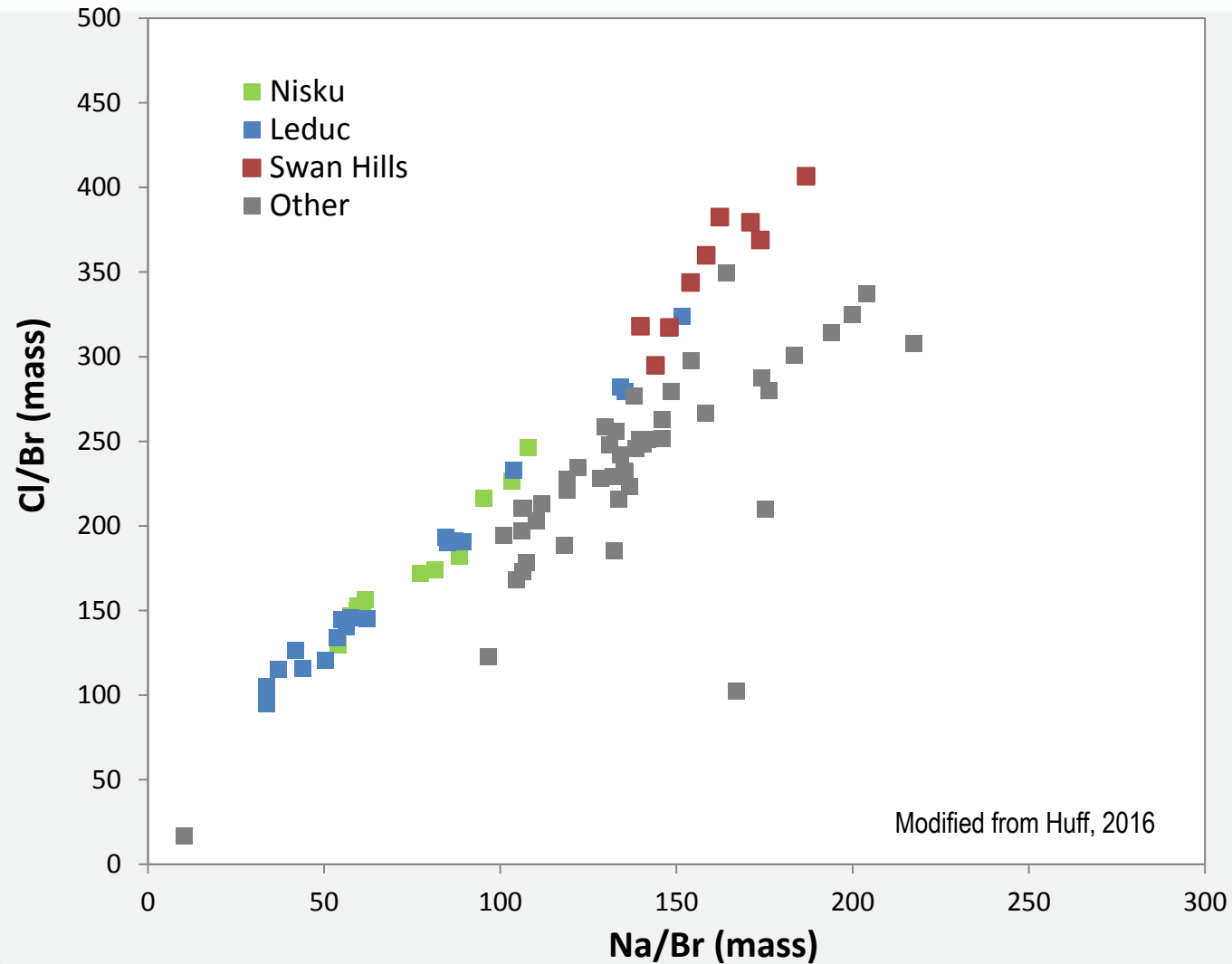
# Origin of Li-enriched ( $\geq 50$ mg/L) oilfield brines in Devonian carbonate

- Samples from Carbonates
- Evaporites
- Dolomitized Carbonates
- Non-Dolomitized Carbonates
- Gas Pools
- Oil Pools
- Eccles and Berhane (2011)  
AGS OFR 2011-10
- Huff et al. (2011, 2012)  
AGS DIG 2011-07  
AGS DIG 2012-01

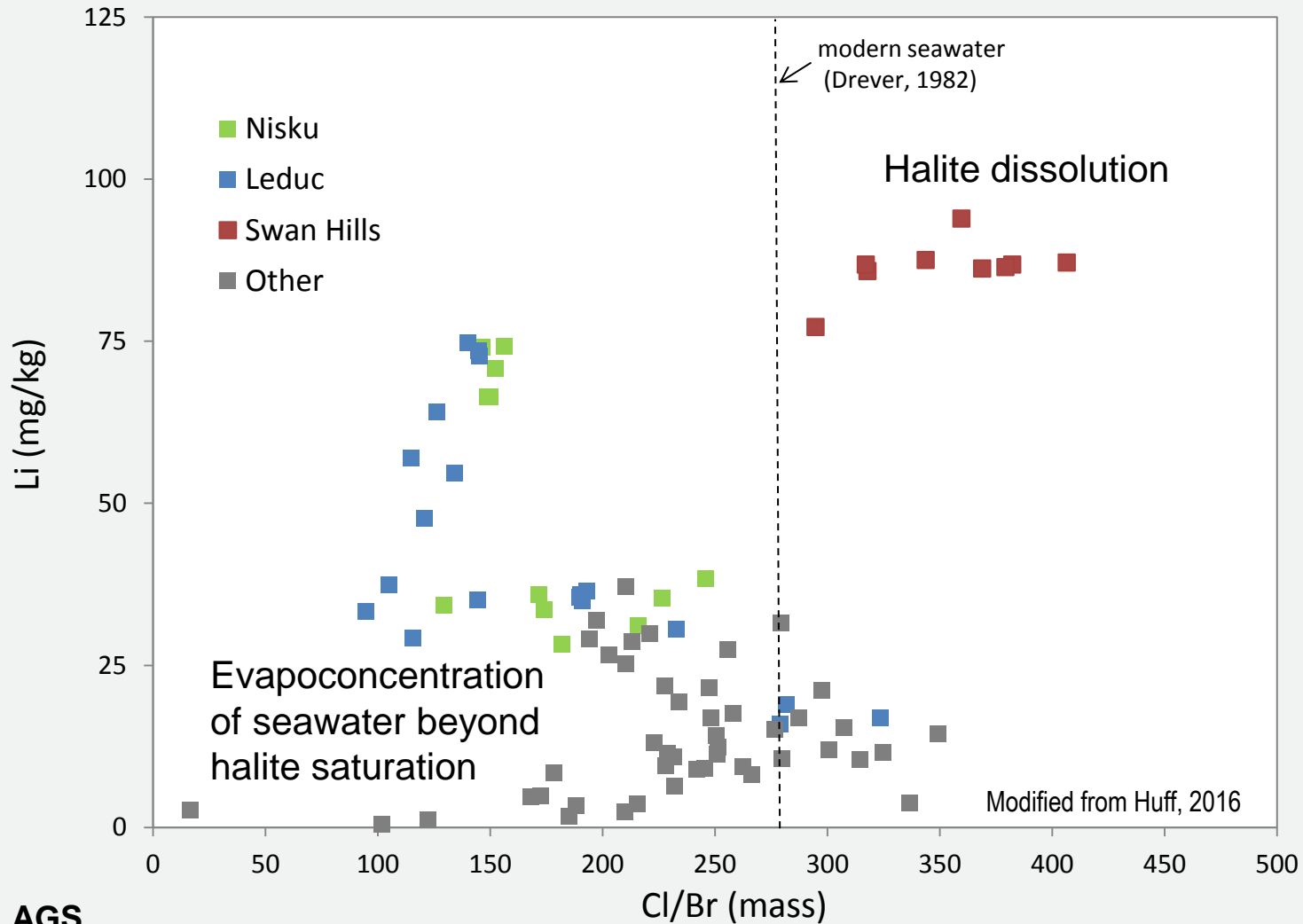




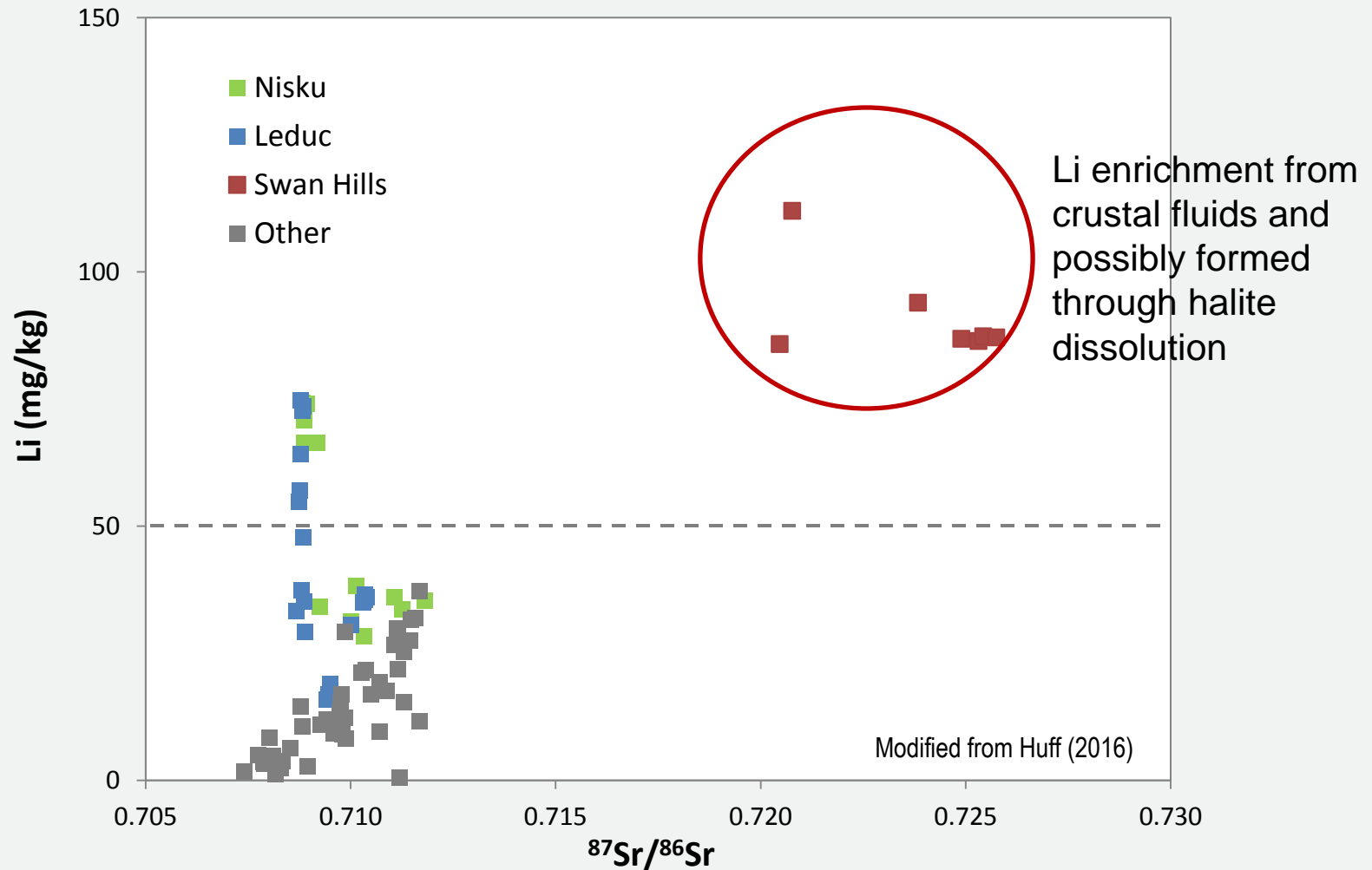
# Na-Cl-Br systematics



# Li vs Cl/Br



# Origins of Li-enriched oilfield brines in Devonian carbonates of south-central AB



# Problem: how to explain Li enrichment in Leduc and Nisku

» Leduc and Nisku brines show:

- No  $^{87}\text{Sr}/^{86}\text{Sr}$  evidence of Li derived from silicates
- Oxygen and hydrogen isotope ratios are characteristic of evaporation
- Cl/Br ratios indicate a degree (but not enough) evapoconcentration

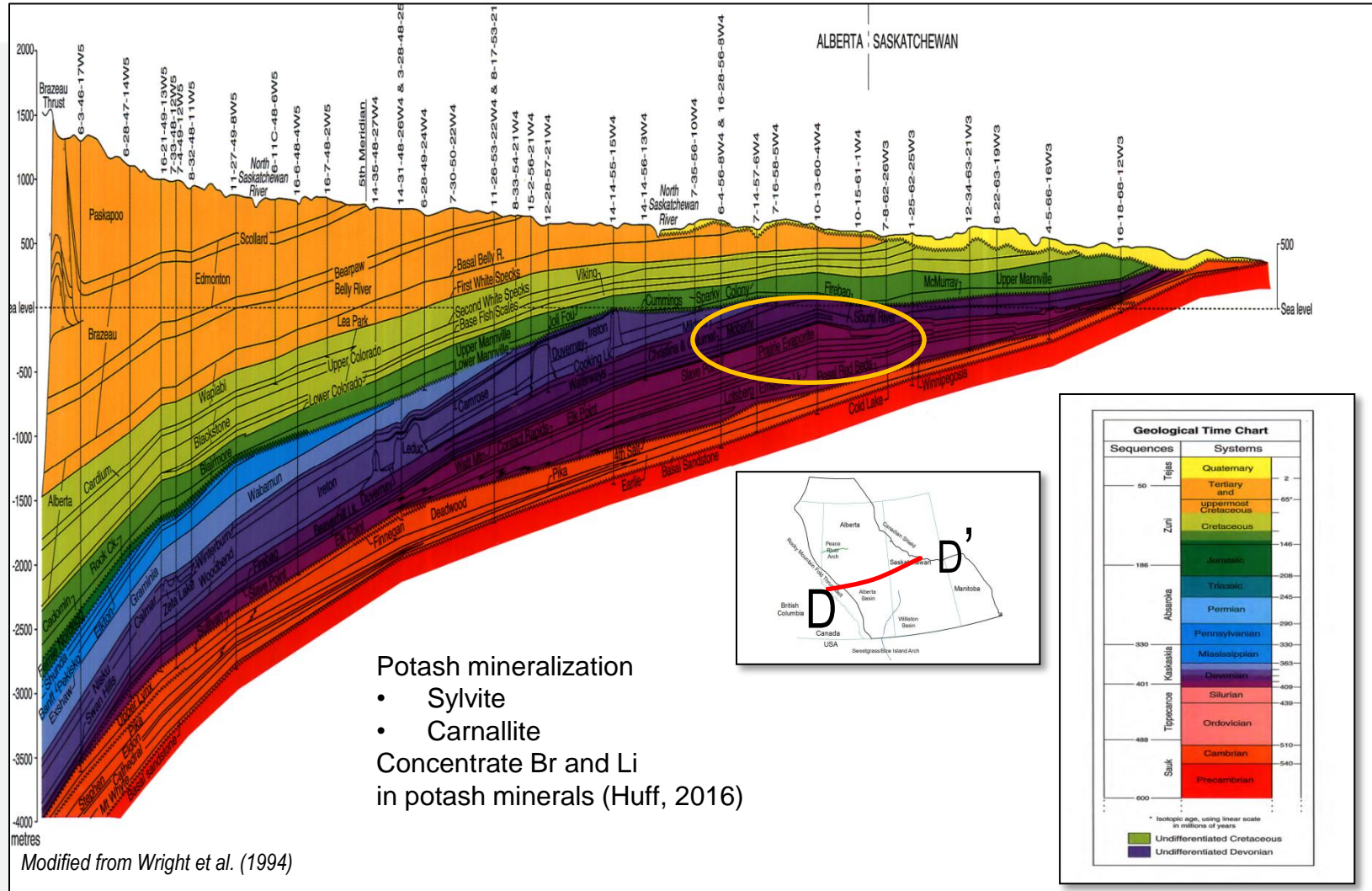
From Huff, 2016



# Step 1 – Concentrate Br and Li

D

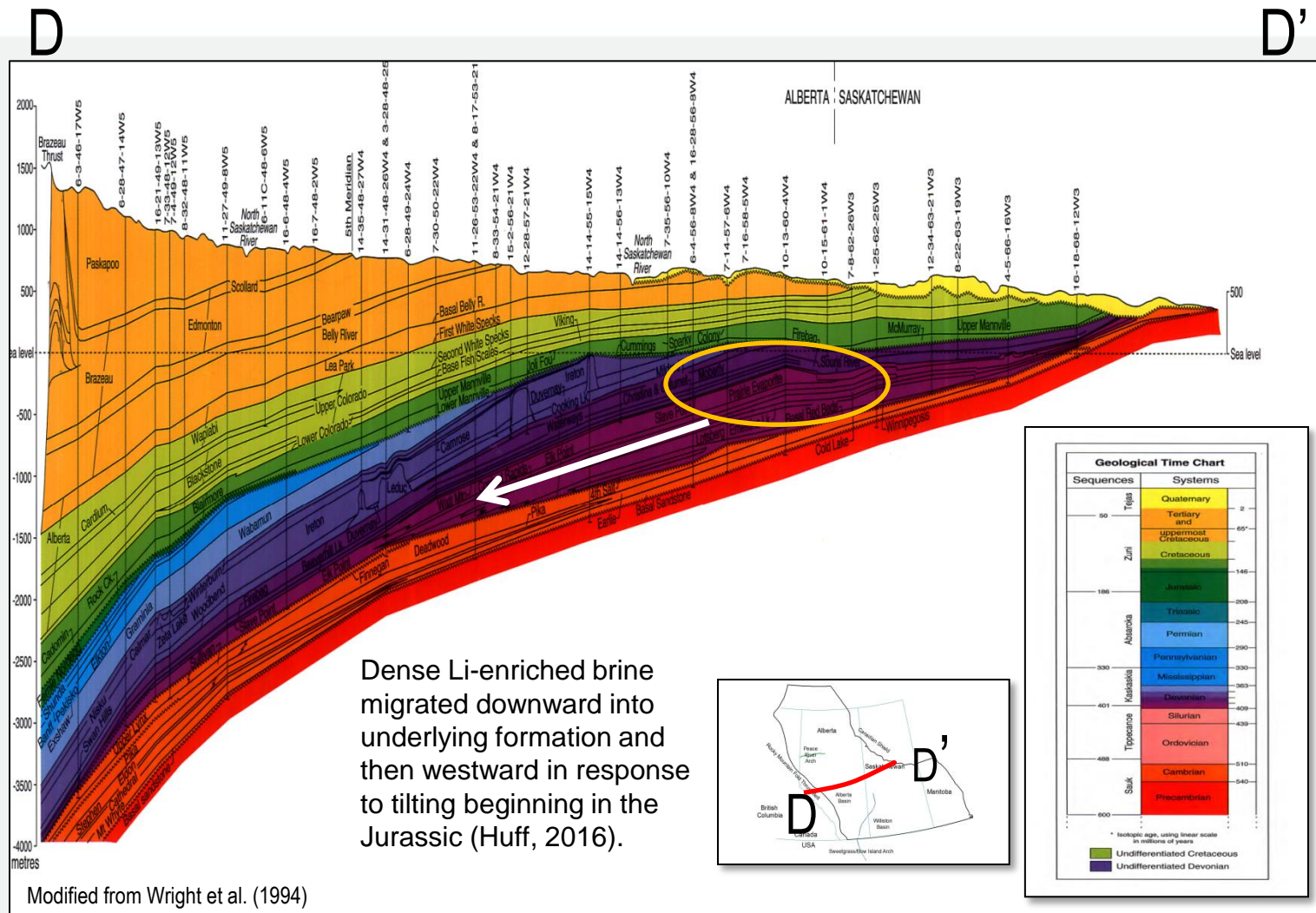
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## Step 2 – Remobilize late-stage evaporites into evaporated middle Devonian seawater

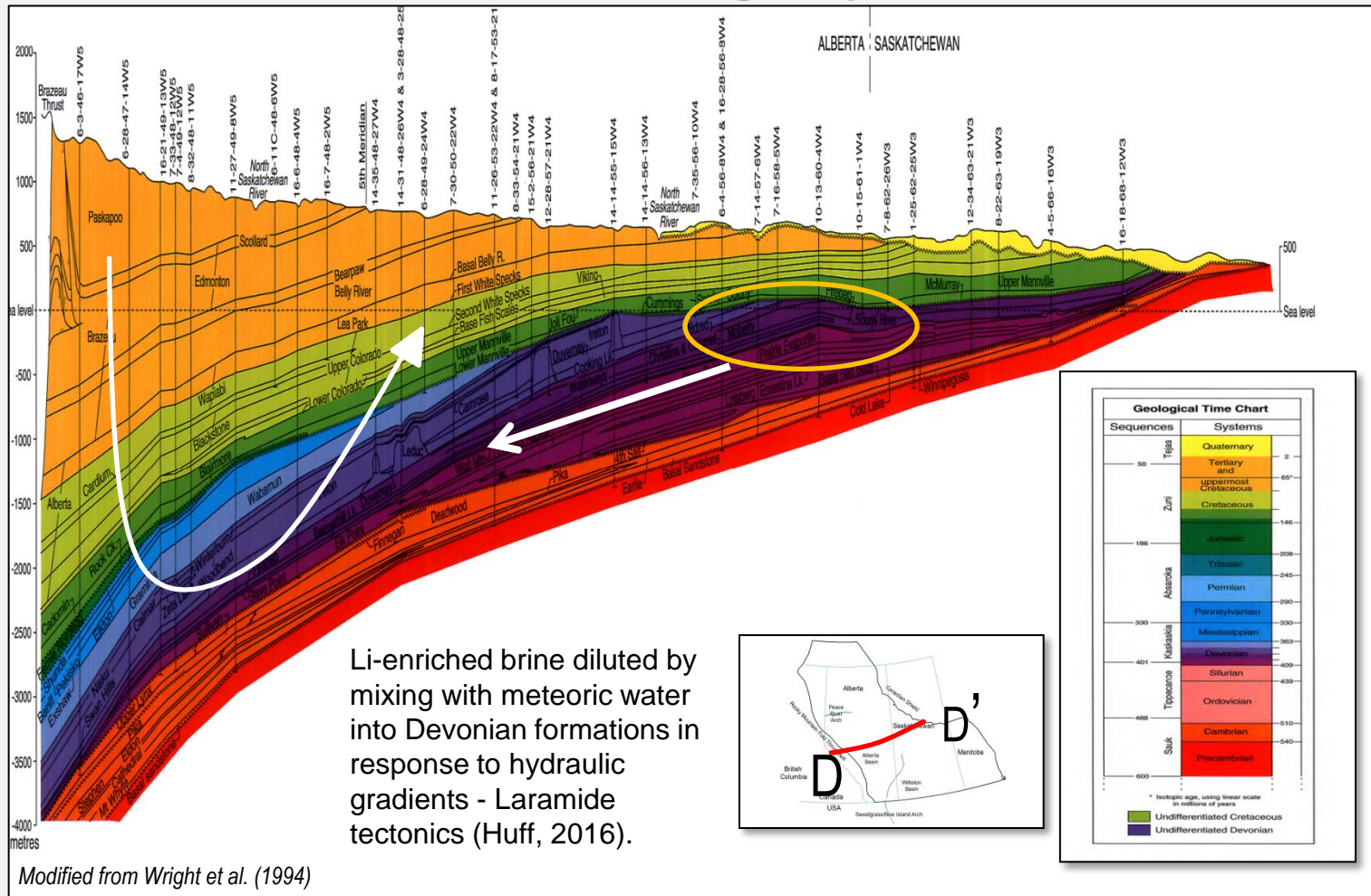
- » Remobilizing brine under-saturated with regard to potash minerals
  - Storm events?
  
- » Collect the Li and Br enriched brines in underlying permeable carbonate (Winnipegosis/Contact Rapids)

# Step 3 – Tip the carbonates westward and allow the dense Li-enriched brines flow west





# Step 4 – Establish deep penetration of meteoric water due to topography caused by Laramide Orogeny



# Summary

- »  $\text{Li} \geq 100 \text{ mg/L}$ : Devonian carbonate formation waters of the **Swan Hills, Leduc and Nisku**.
- » Two brines with distinct chemistry/evolution histories (Huff, 2016):
  - Swan Hills Formation brines: **dissolution of halite** and mixing **basement-derived fluids**.
  - Nisku and Leduc formations brines: **preferential dissolution of lithium-enriched late-stage evaporite minerals**, likely from the middle Devonian Prairie Evaporite, into **evapoconcentrated late Devonian seawater**.





# Questions?

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**Thank you!**