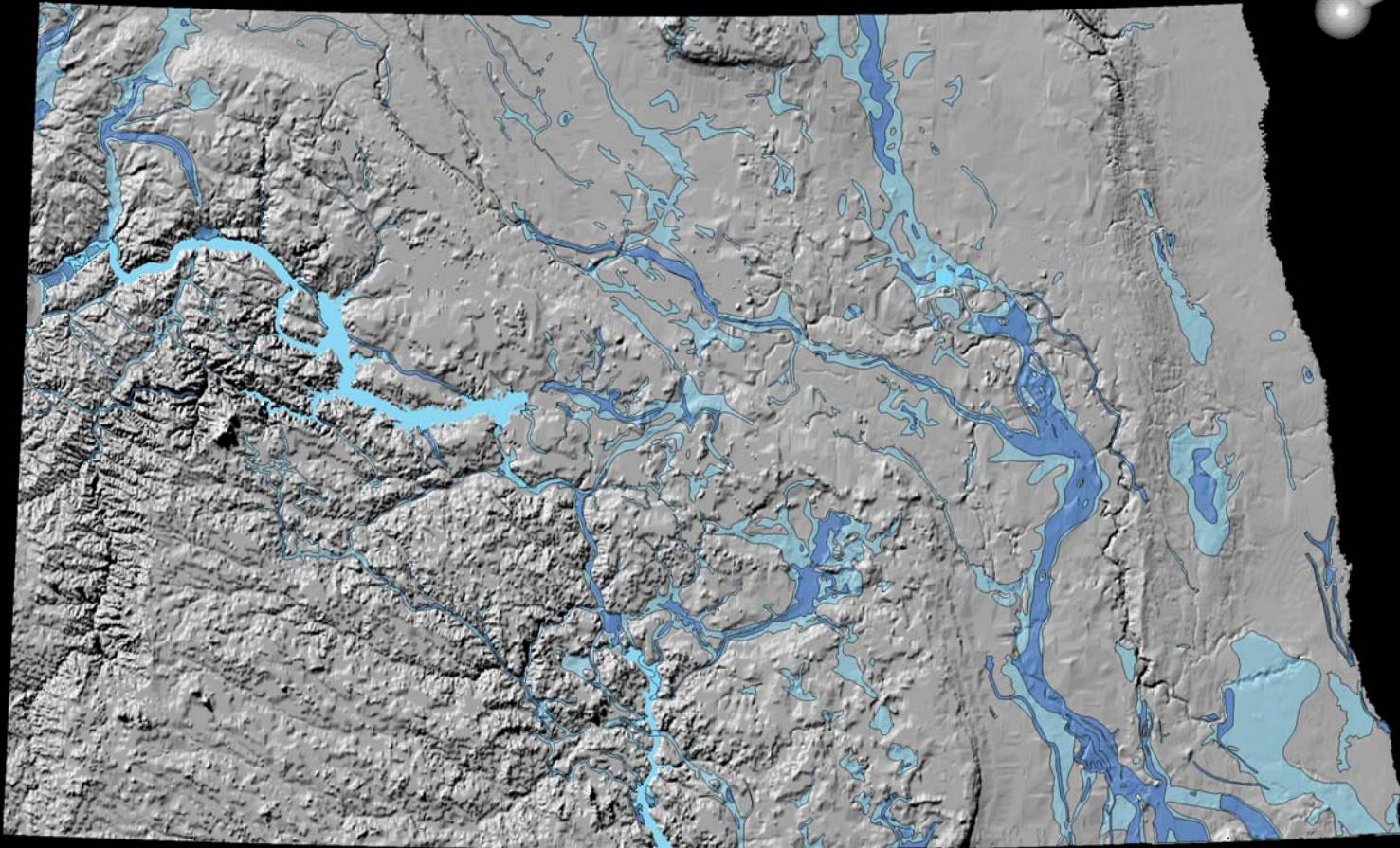
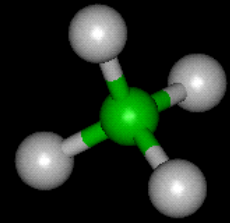
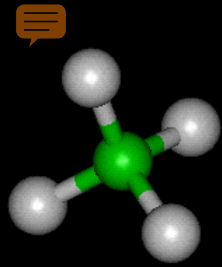


# *Methane Occurrence in Glacial Buried-Valley Aquifer Systems in North Dakota*



([www.nd.gov/gis](http://www.nd.gov/gis))

Surficial Aquifers in North Dakota

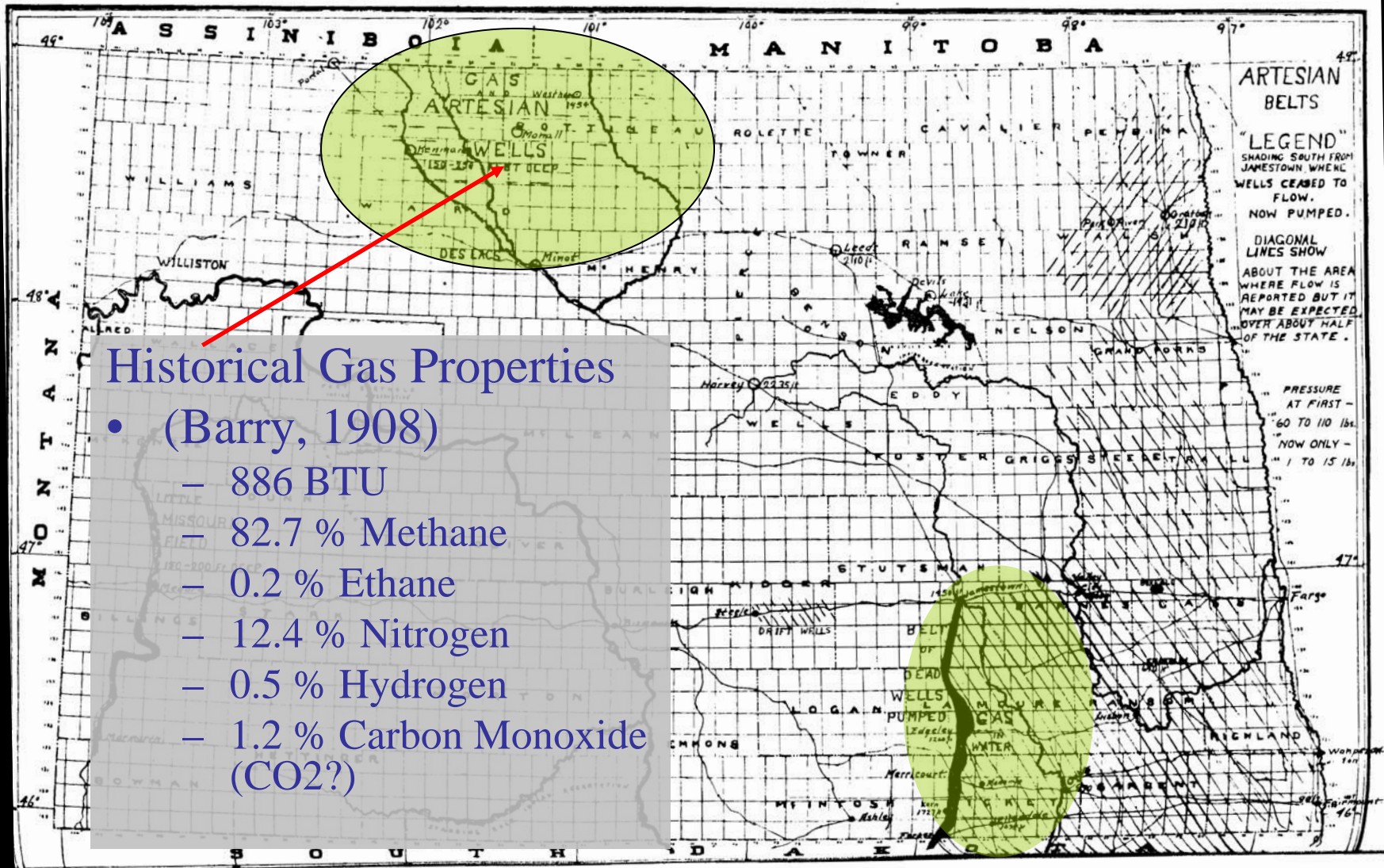


*Fred J. Anderson, Geologist*  
North Dakota Geological Survey

*Geological Investigations No. 87*



# Areas of Historical Shallow Natural Gas Occurrence



## Historical Gas Properties

- (Barry, 1908)
  - 886 BTU
  - 82.7 % Methane
  - 0.2 % Ethane
  - 12.4 % Nitrogen
  - 0.5 % Hydrogen
  - 1.2 % Carbon Monoxide (CO<sub>2</sub>?)

Modified from Hard, 1920

# Investigation Overview

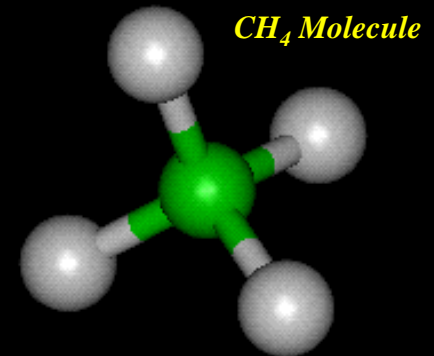
- Reconnaissance style well field screening program for shallow natural gas ( $\text{CH}_4$ ) occurrence.
- Focused on observation and livestock supply wells.
- Utilizing portable flame-ionization detector (FID) instrumentation.
- Measuring FID response as  $\text{CH}_4$  in air at the well.



*NDGS summer undergraduate (NDSU) field technician Mr. Brian Hall field screening a shallow ground-water observation well south of Fargo, N.D. in Cass County.*

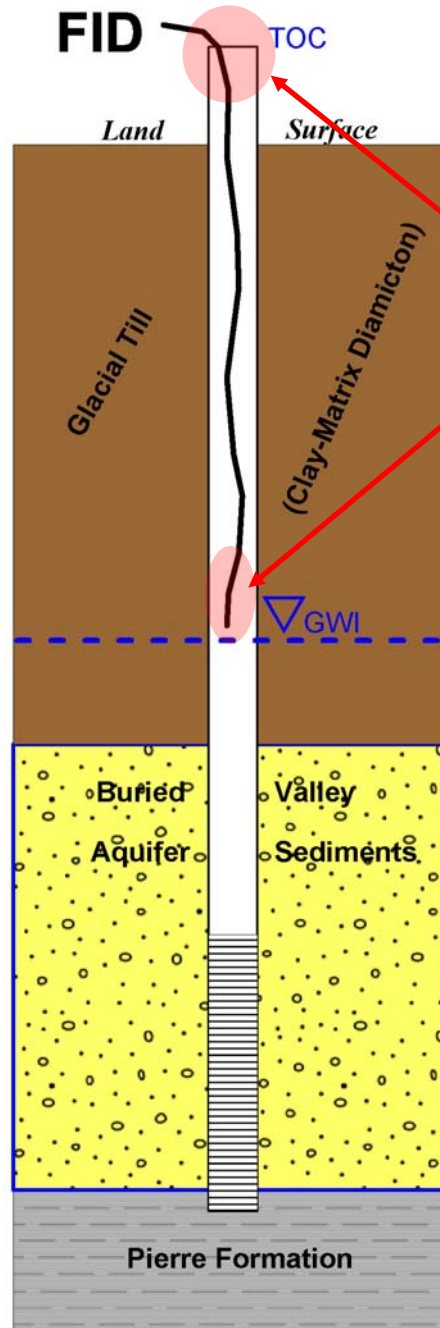


*PhotoVac® MicroFID*



# *CH<sub>4</sub> Detection at the Well*

- CH<sub>4</sub> in the well most often detected at or above the GWI.
- Less commonly detected at the TOC.
- Wells screened in buried-valley aquifers containing detrital lignites overlying Cretaceous shale bedrock.



**FID Instrument response collected at the well TOC and GWI.**

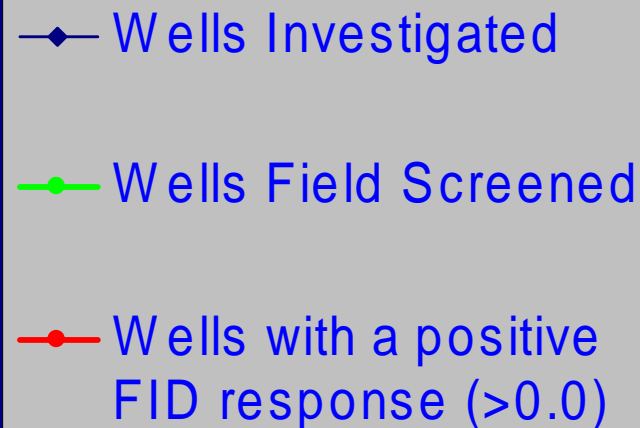
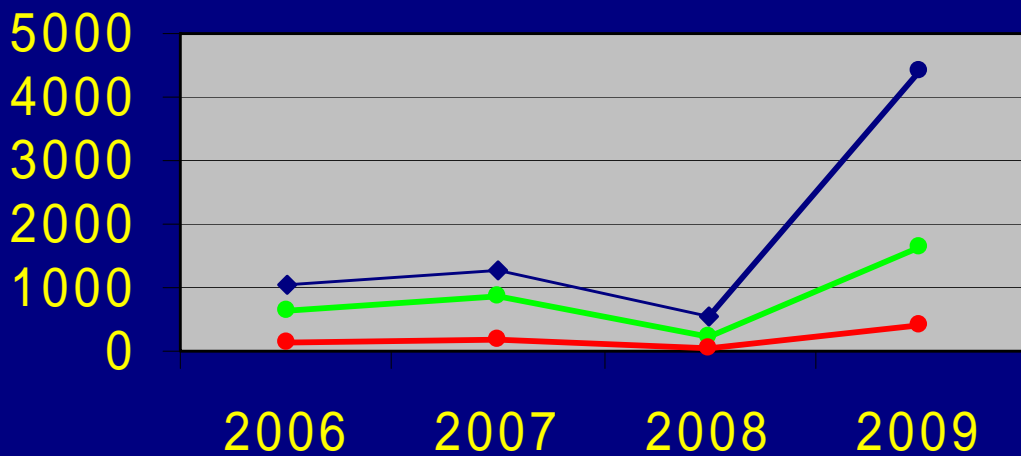
**Typical Observation Well Construction**

# Number of Wells Field Screened to Date

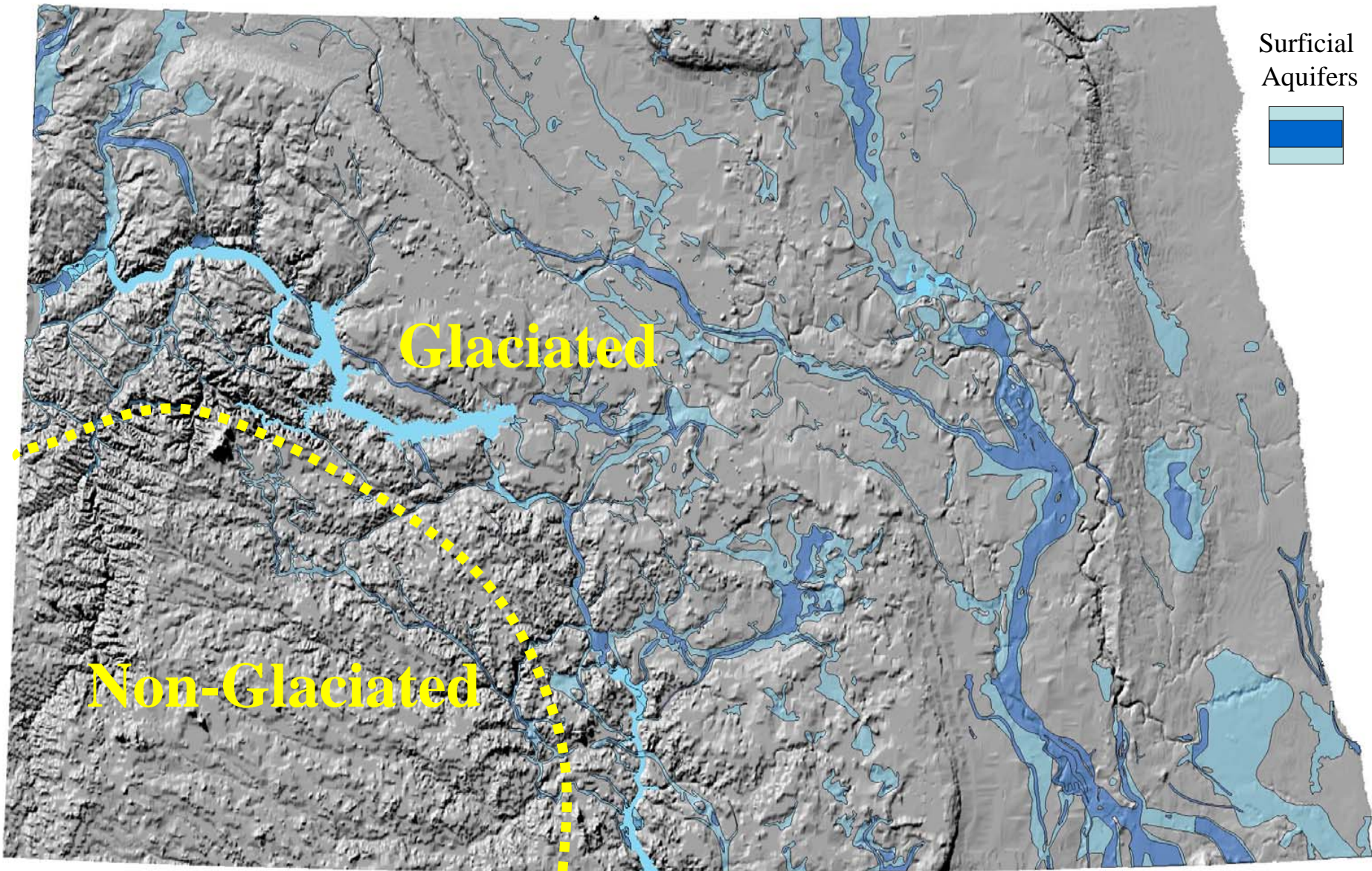
## North Dakota Shallow Gas FID Field Screening Summary\*

### Number of Wells Investigated Summary

Year	Counties Covered	Wells Investigated	Wells Field Screened	% Field Screened	Wells with a positive FID response (>0.0)	% Positive FID response (>0.0)	Wells with no FID response (0.0)
2009	25	4,413	1,635	37%	389	24%	1,246
2008	3	539	209	39%	23	11%	186
2007	8	1282	859	67%	177	21%	682
2006	7	1066	658	62%	126	19%	532
Total	43	7,300	3,361	46%	715	21%	2,646

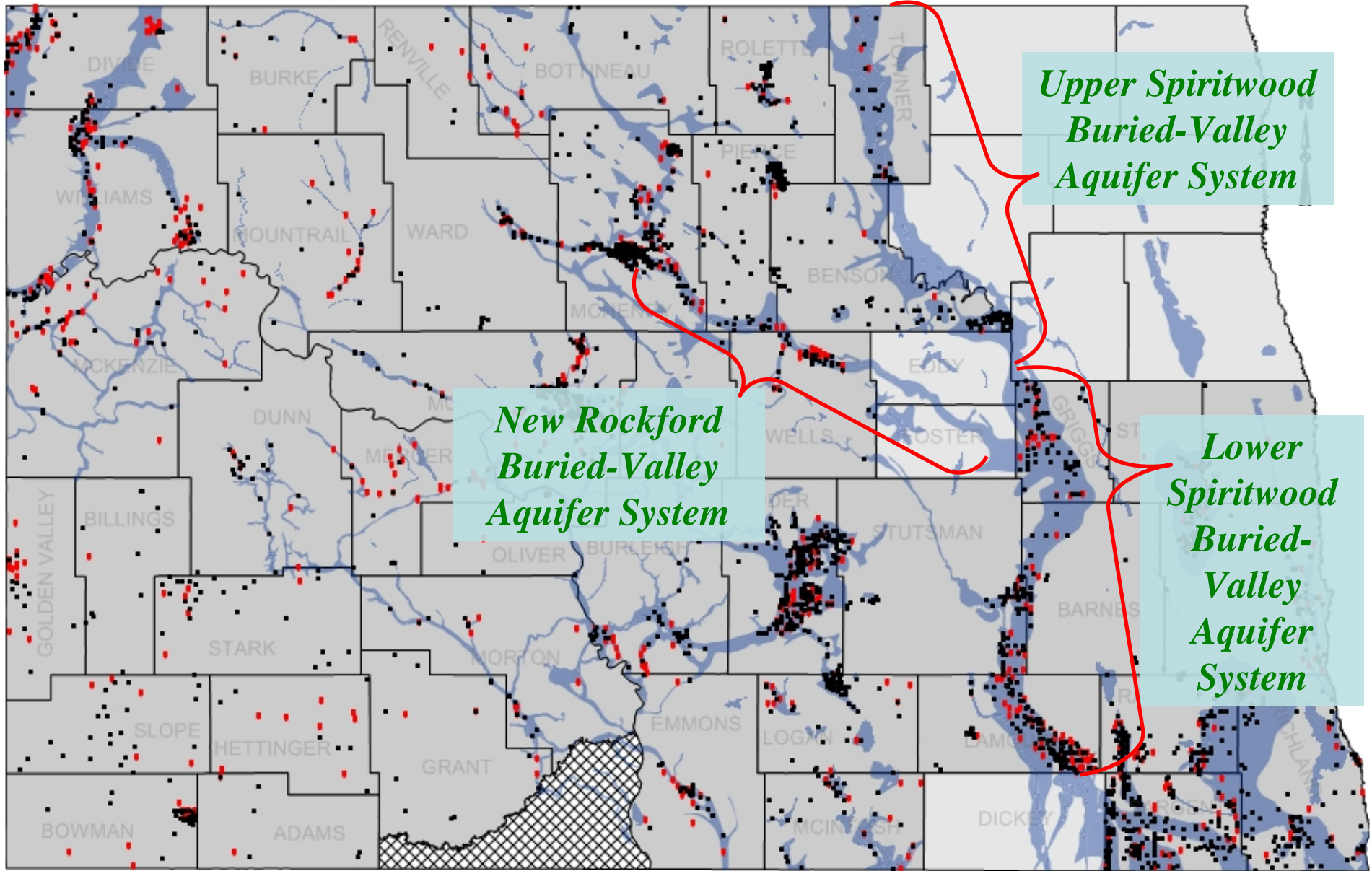


# *Surficial Aquifers in North Dakota*

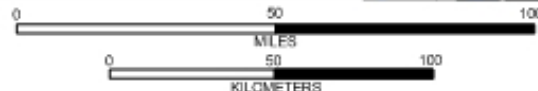


(NDSWC, 2009)

# Areal Distribution of Methane Occurrences in Aquifers



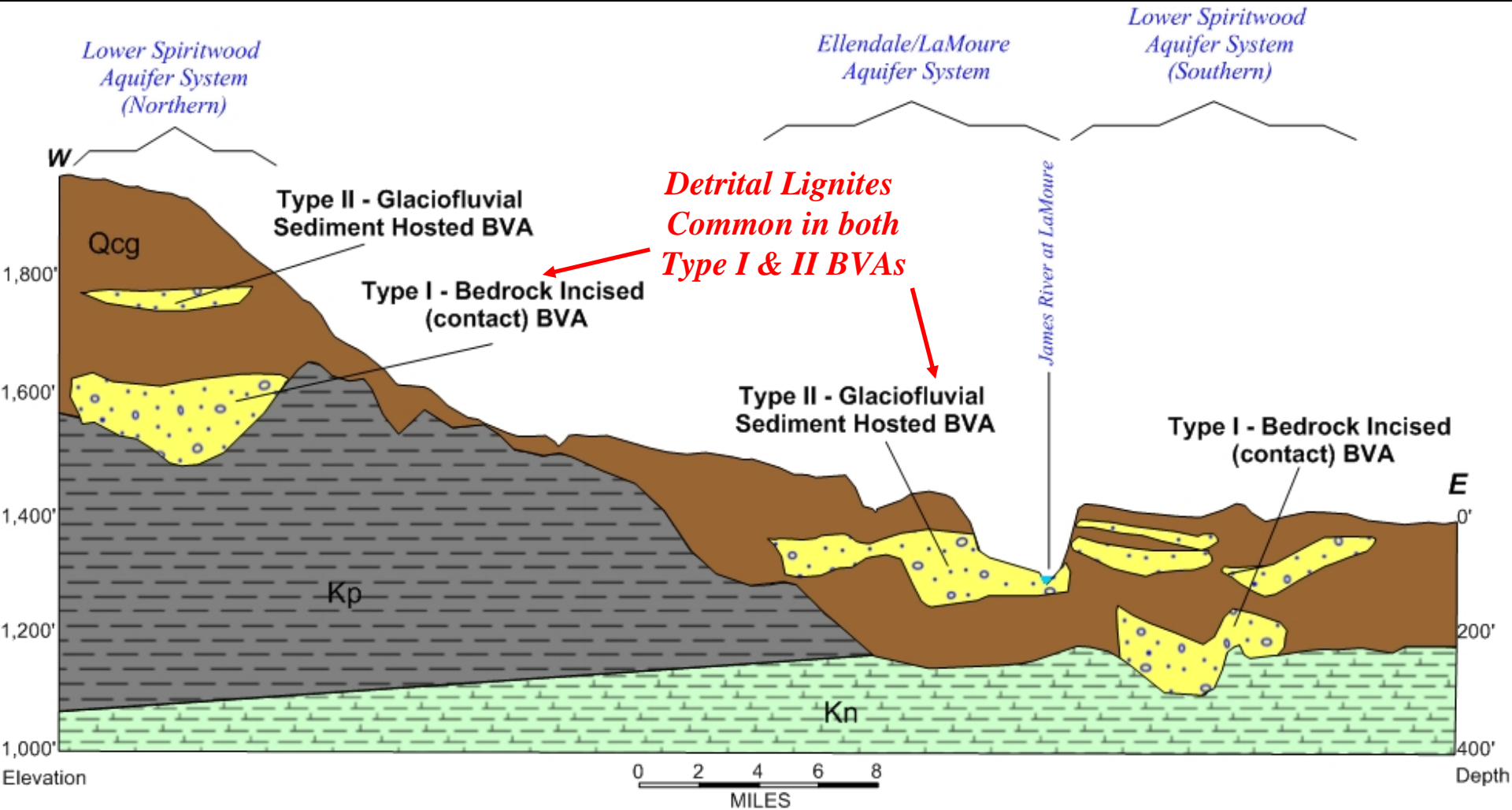
● [CH<sub>4</sub>] Occurrence



● No [CH<sub>4</sub>] Detected (Kehew & Boettger, 1986)

# Types of Glacial Buried-Valley Aquifers

(as related to CH<sub>4</sub> occurrence)

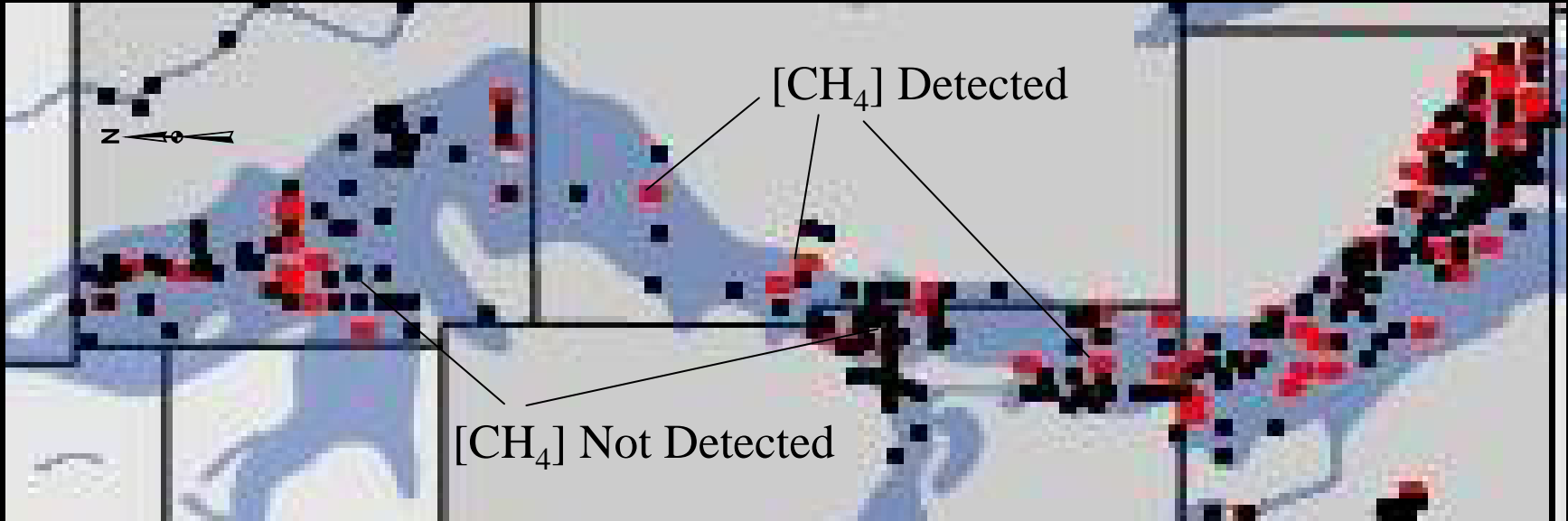


Generalized/Conceptual Geohydrologic Section

(Modified after Armstrong, 1979)



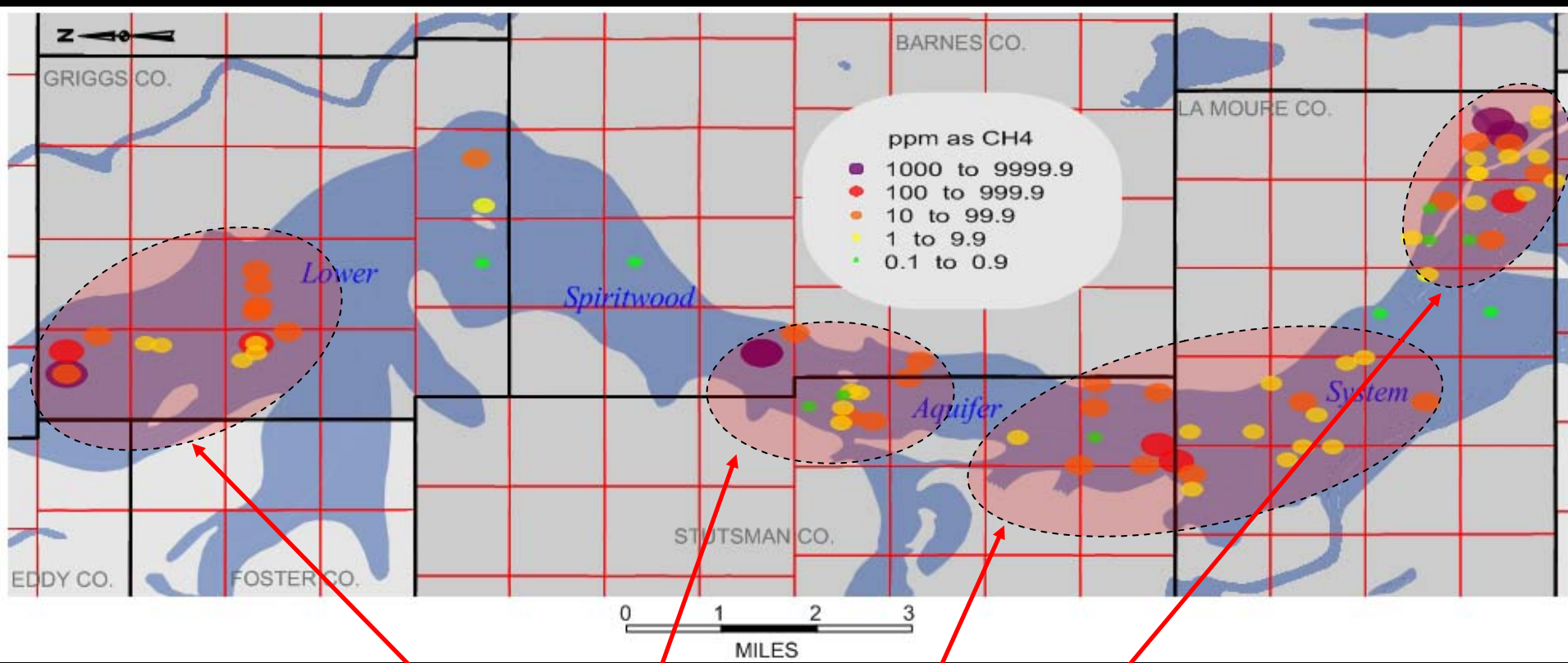
# Lower Spiritwood Aquifer System in Southeastern North Dakota



County	Wells Tested	CH <sub>4</sub> Occurrences*	CH <sub>4</sub> High (ppm)	CH <sub>4</sub> Low (ppm)	CH <sub>4</sub> Mean (ppm)
Griggs	94	18	2,063	0.3	183
Barnes	28	5	2,897	0.3	1,092
Stutsman	107	17	182	0.4	29
LaMoure	195	41	3,712	0.4	151
<b>Totals/Means</b>	<b>424</b>	<b>81</b>	<b>2,213</b>	<b>0.35</b>	<b>364</b>

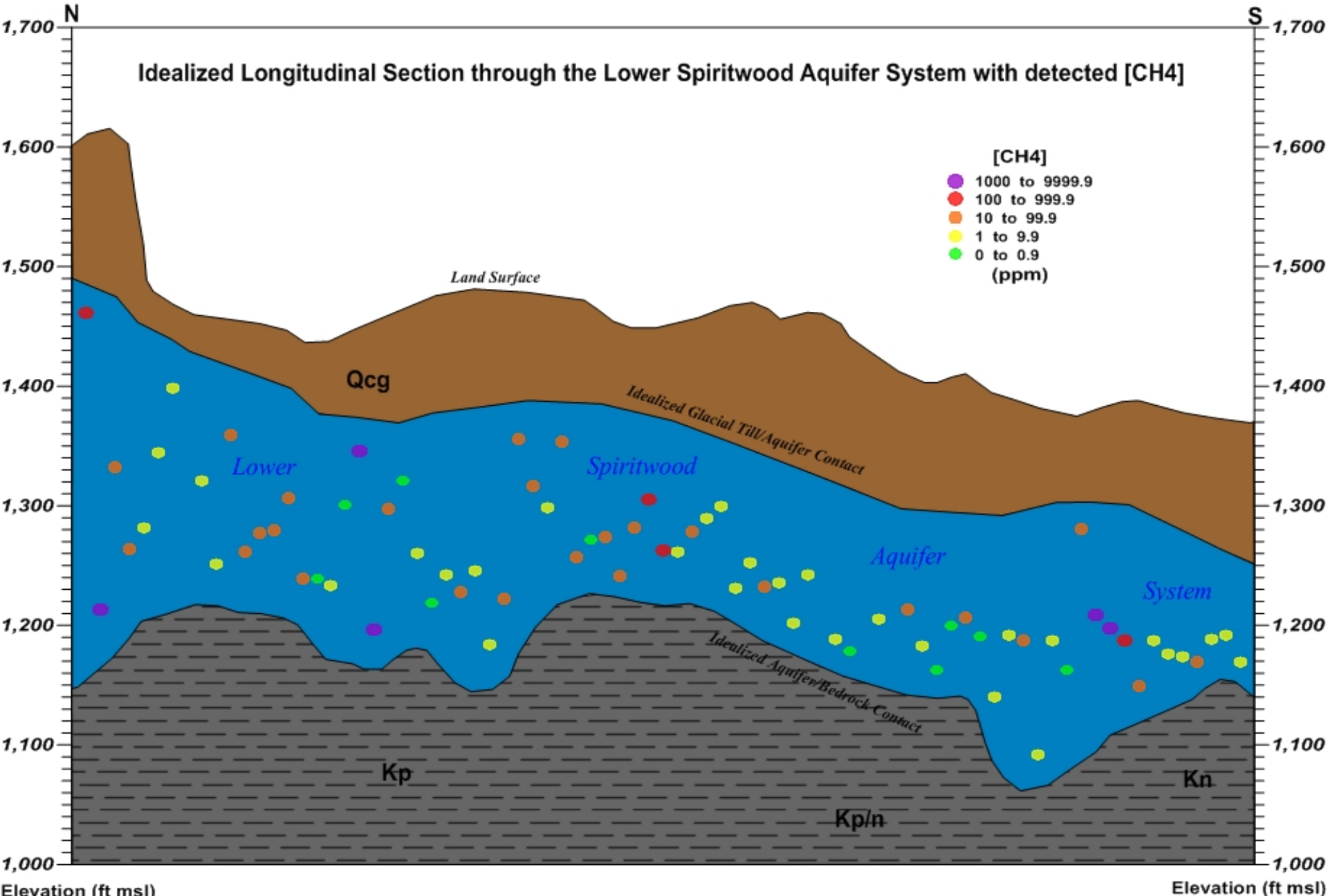
\* CH<sub>4</sub> Occurrences found within the lower Spiritwood Aquifer.

# *CH<sub>4</sub> Occurrence in the Lower Spiritwood Aquifer*

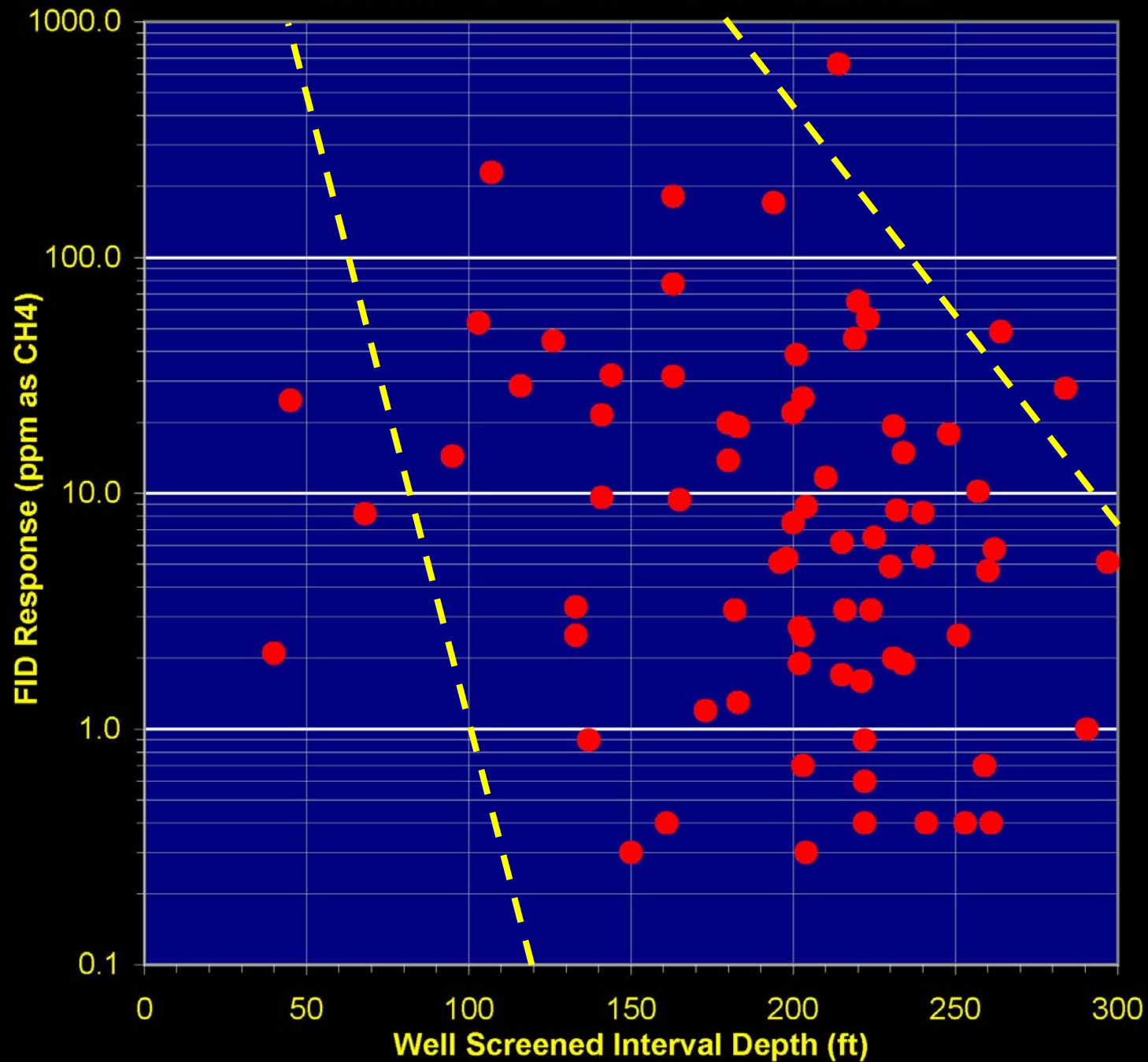


Four zones of relatively higher CH<sub>4</sub> concentration appear in four separate regions of the aquifer system

# Detected CH<sub>4</sub> Distribution Lower Spiritwood Aquifer

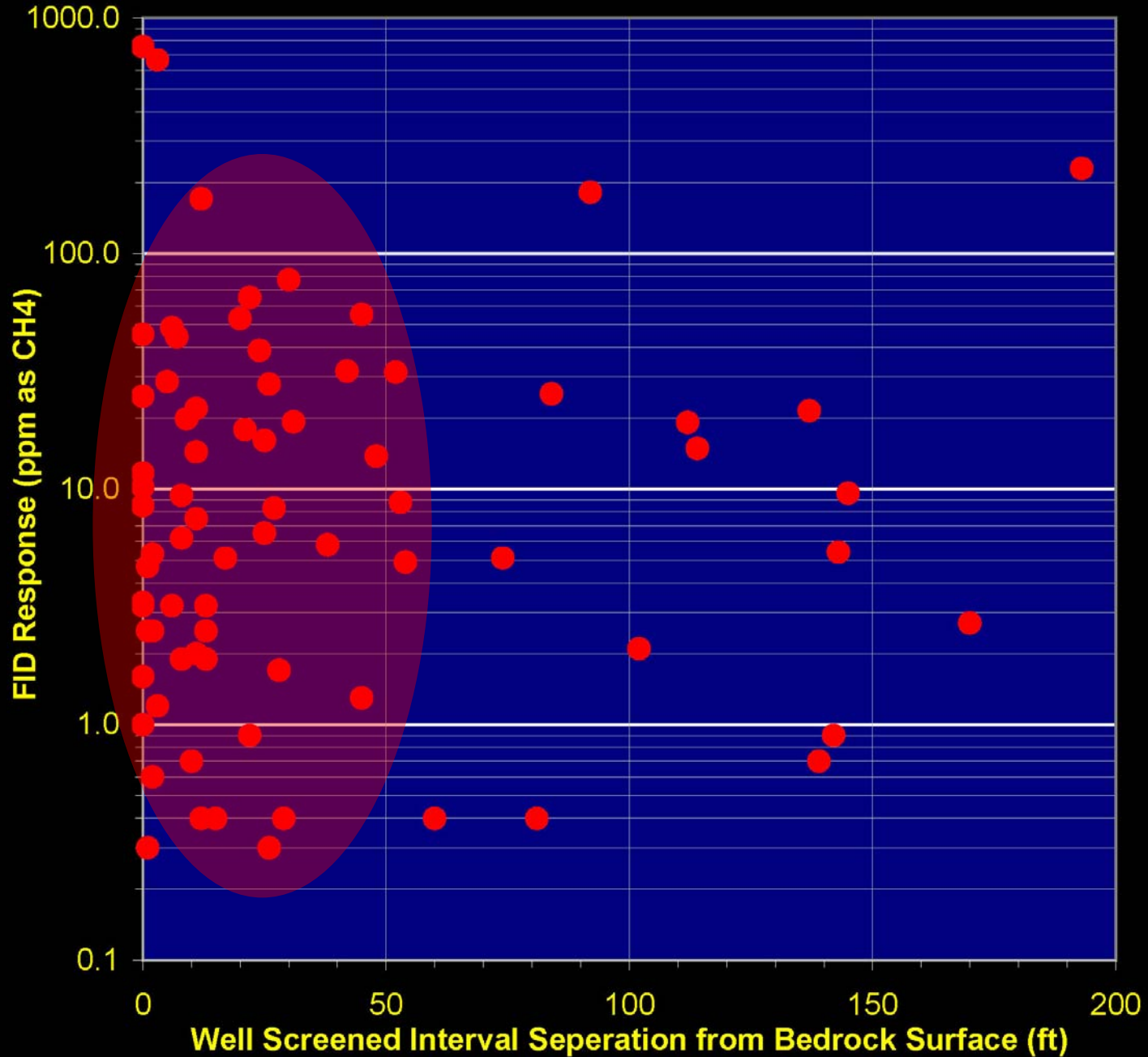


Depth of Screened Interval vs. [ CH<sub>4</sub> ]



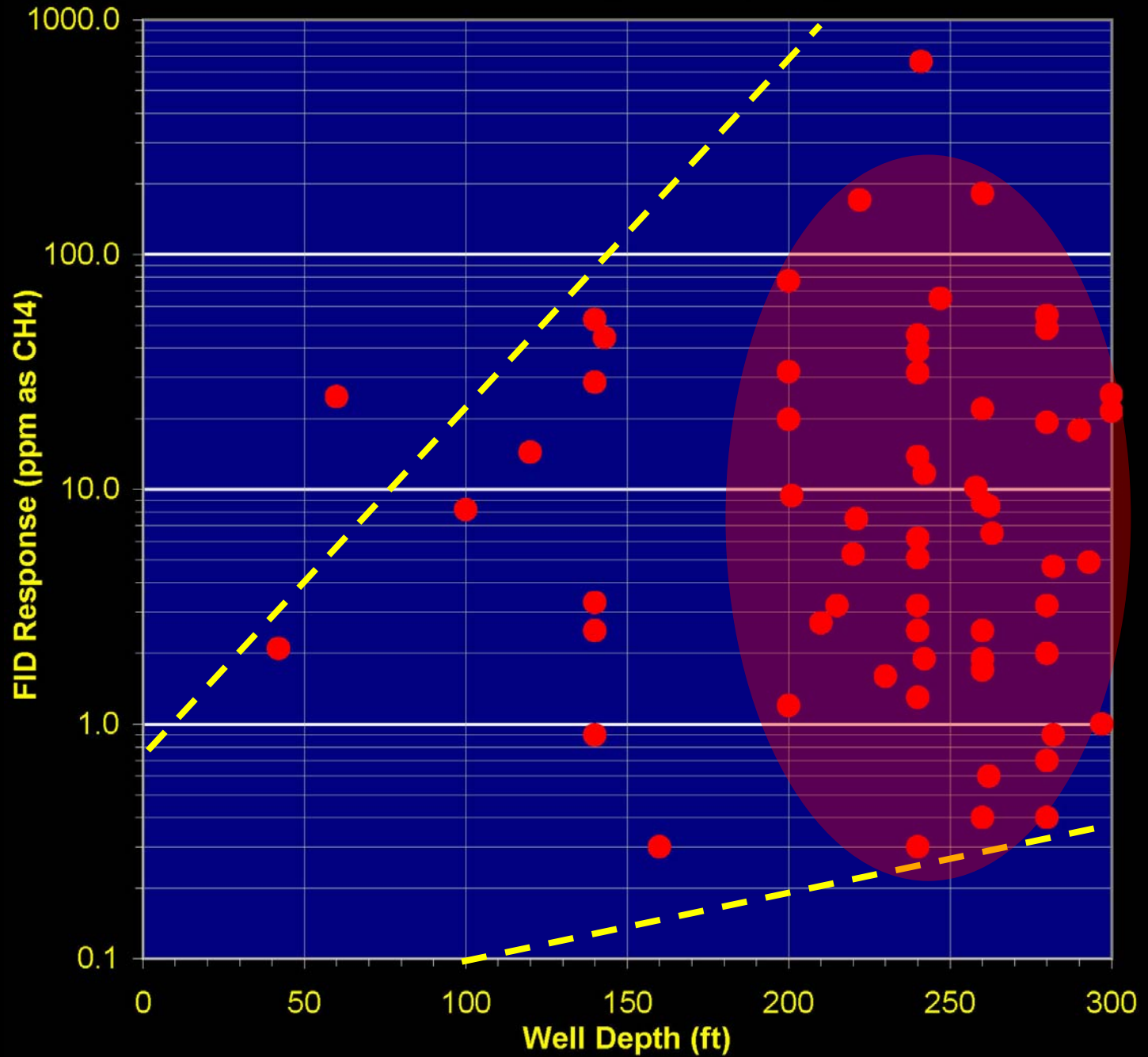


# Seperation of Screened Interval from Pierre Shale Bedrock Surface vs. [CH<sub>4</sub>]



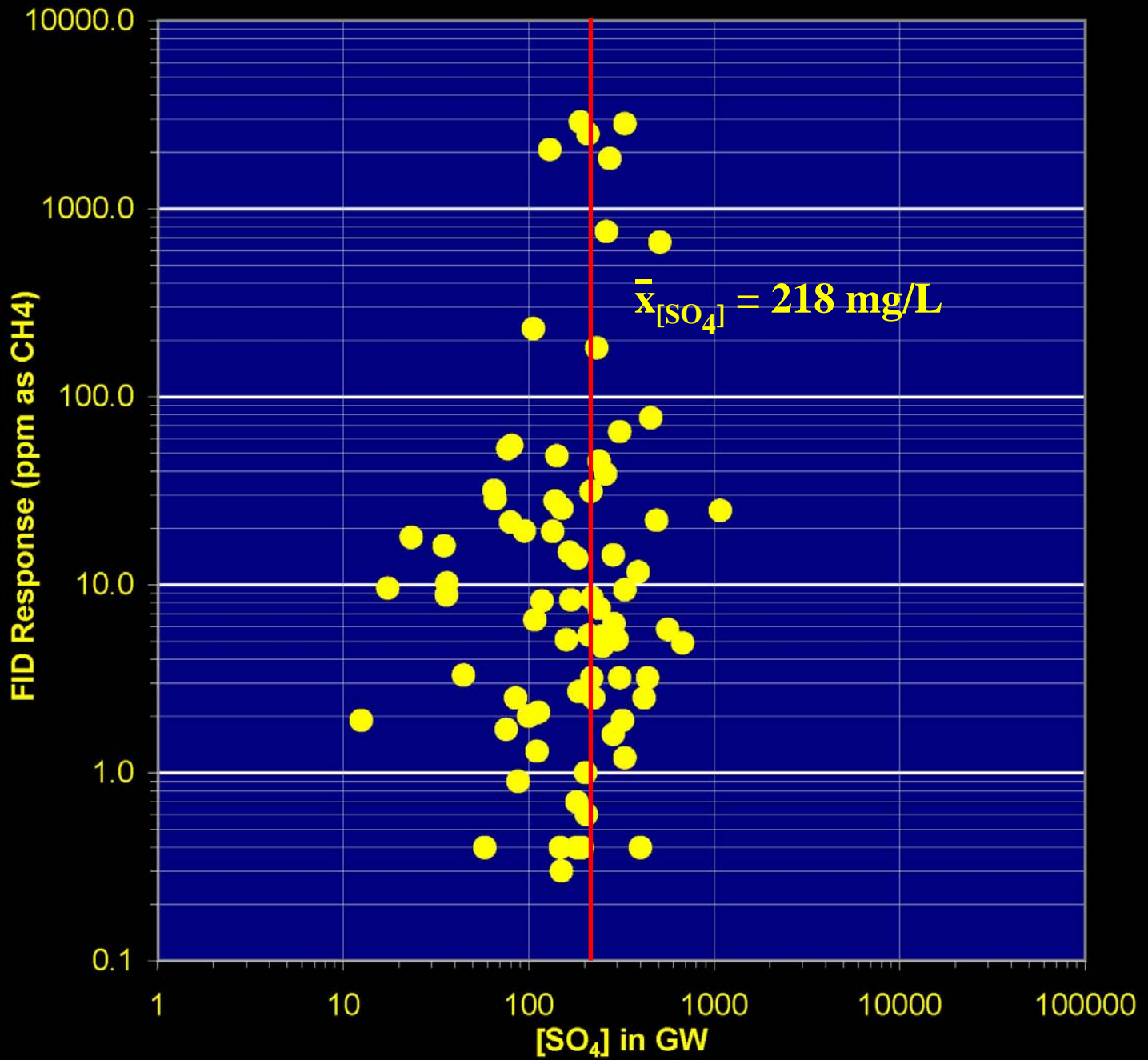


### Total Well Depth vs. [ CH<sub>4</sub> ]



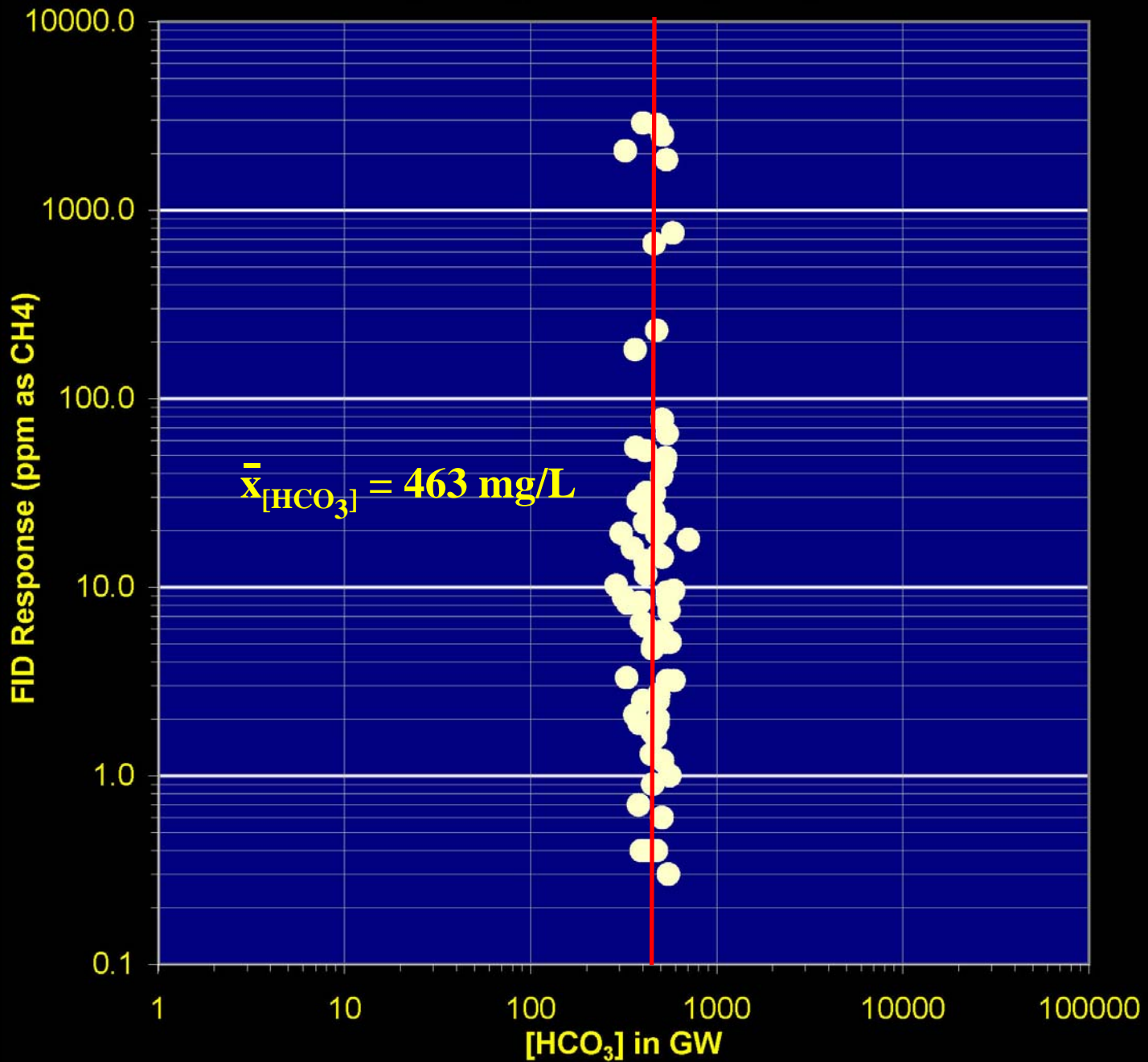


# [SO<sub>4</sub>] in GW vs. [CH<sub>4</sub>]





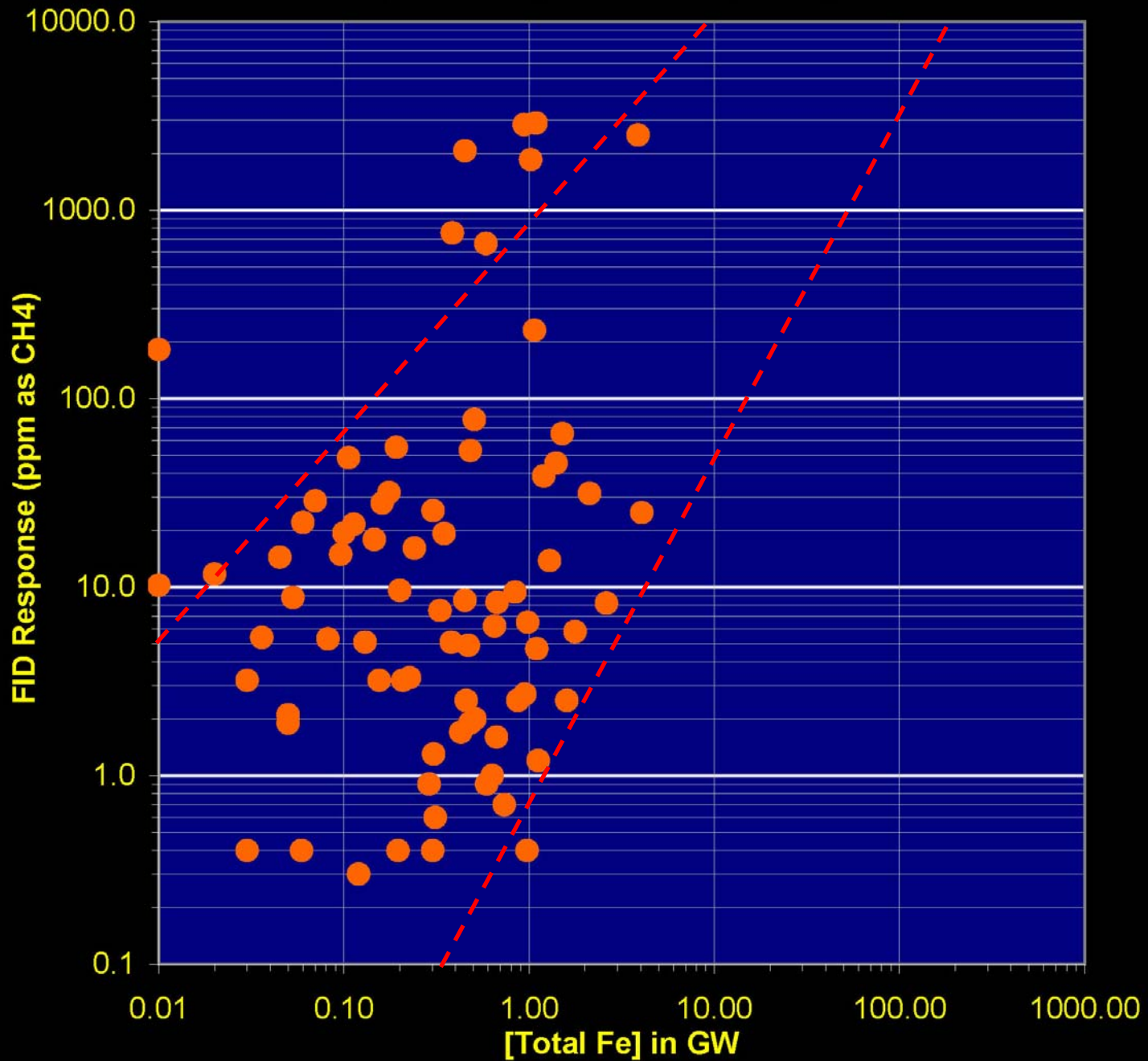
# [HCO<sub>3</sub>] in GW vs. [CH<sub>4</sub>]







# [Total Fe] in GW vs. [CH<sub>4</sub>]

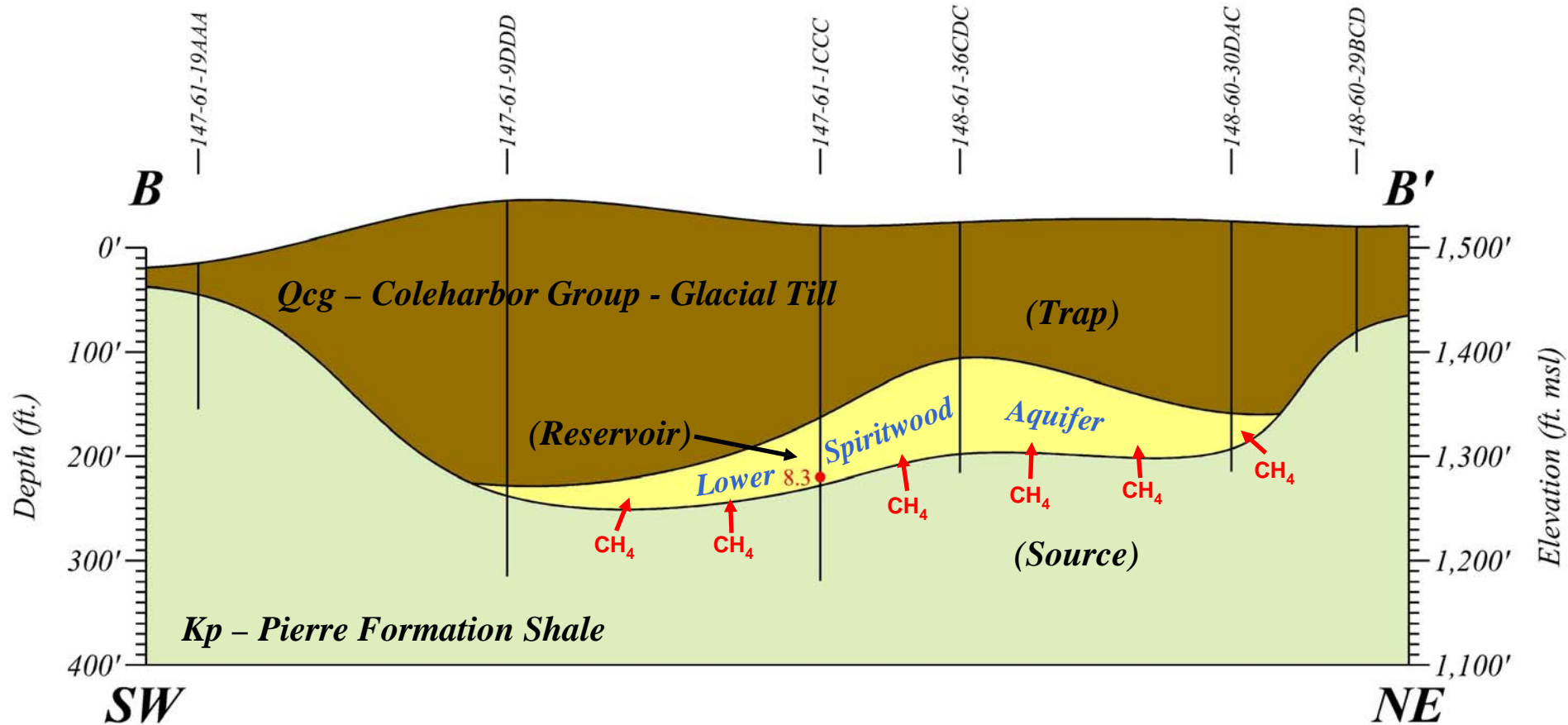


# Ground-Water Methanogenic Indicator Summary

Constituent	Methanogenic Range <sup>1</sup>	Mean	Std. Dev.	Range	Min	Max	n
FID [CH <sub>4</sub> ] (ppm)	--	186	66	2,897	0.3	2,897	81
[SO <sub>4</sub> ] (mg/L)	< 500	218	168	1,068	12	1,080	76
[HCO <sub>3</sub> ] (mg/L)	400 - 1000	463	78	416	289	705	76
[Fe] Total (mg/L)	?	0.62	0.76	4.05	0.01	4.06	76

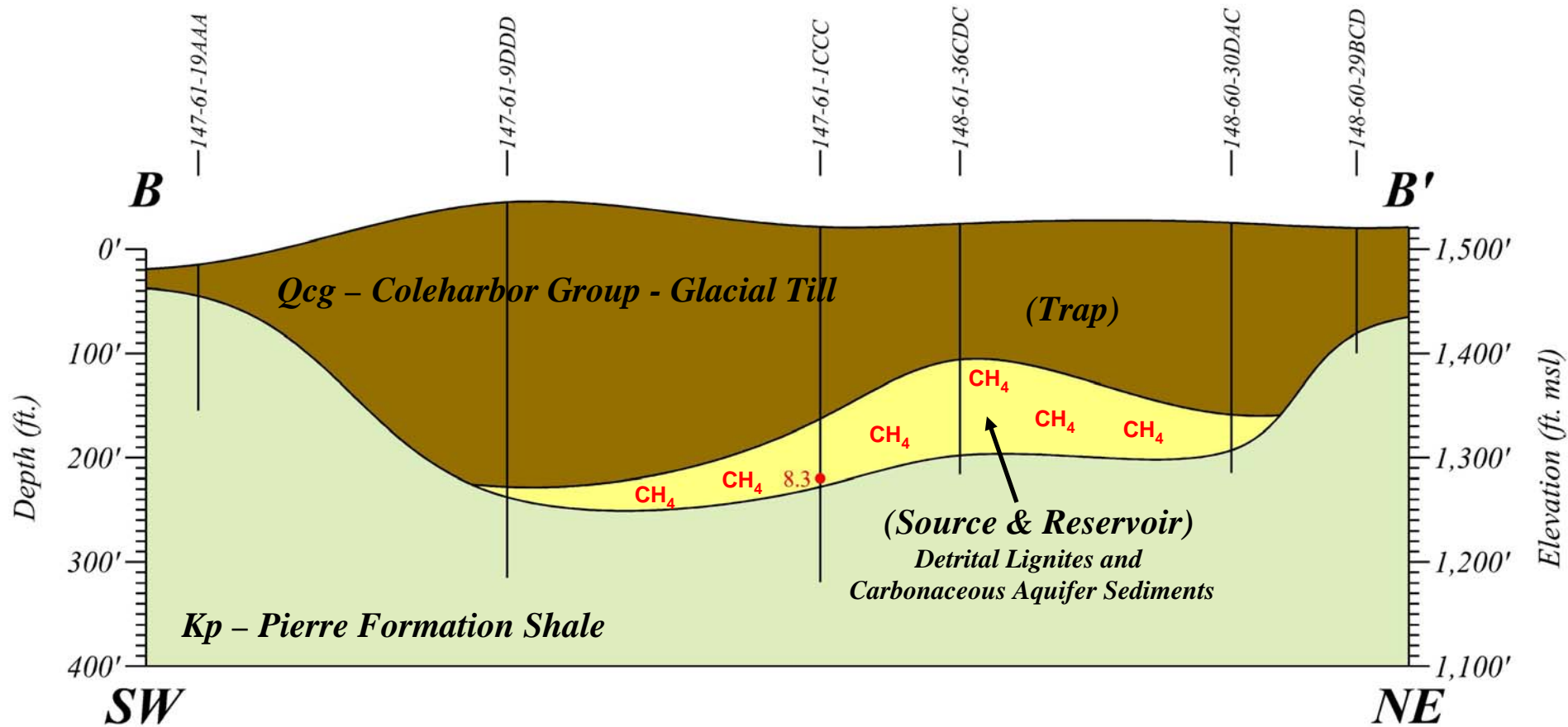
<sup>1</sup>Shurr, 2006

# Buried Valley Aquifer as a "Petroleum System" (Late-Generation Biogenic Gas)



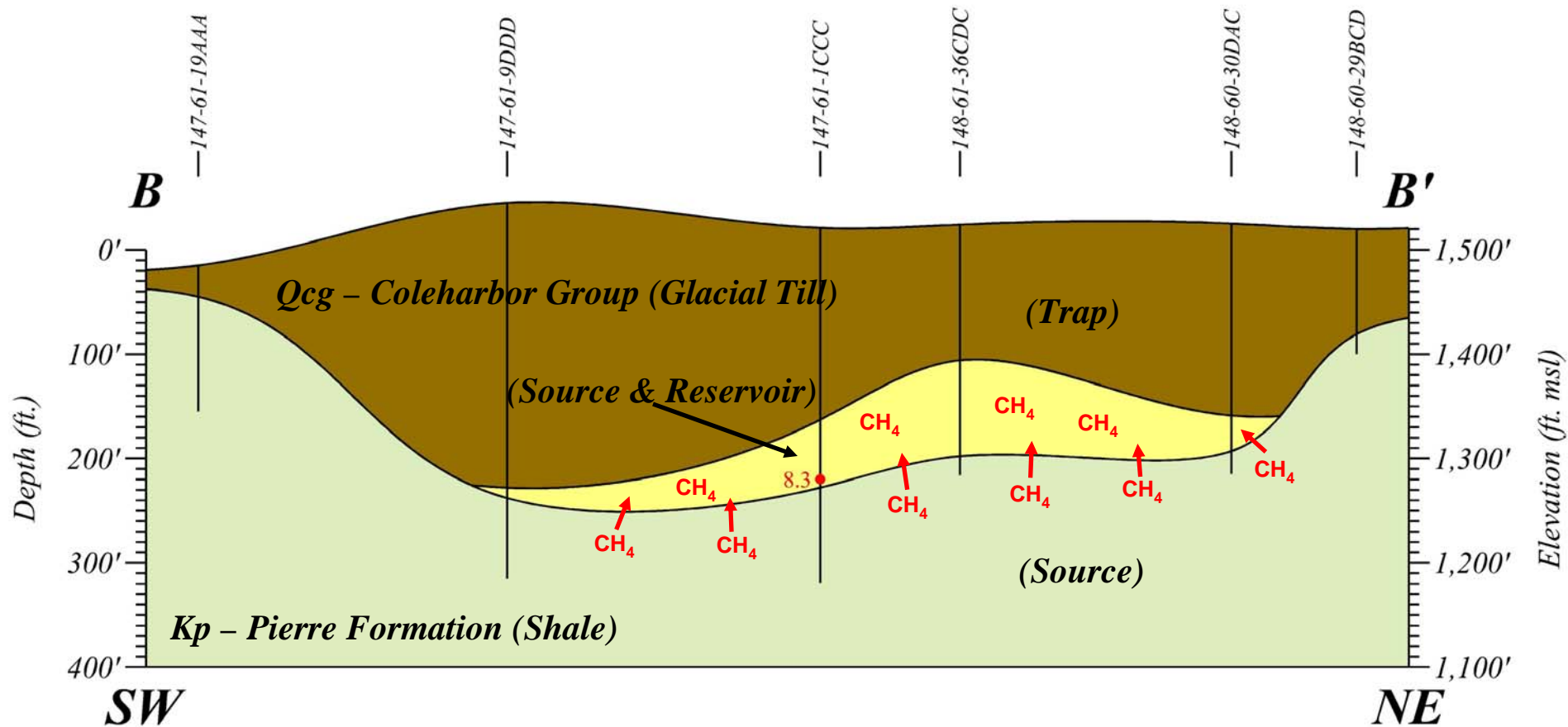
Possible Sourcing - I: Bedrock Shale Source

# Buried Valley Aquifer as a "Petroleum System" (Late-Generation Biogenic Gas)



Possible Sourcing - II: Aquifer as Source & Reservoir

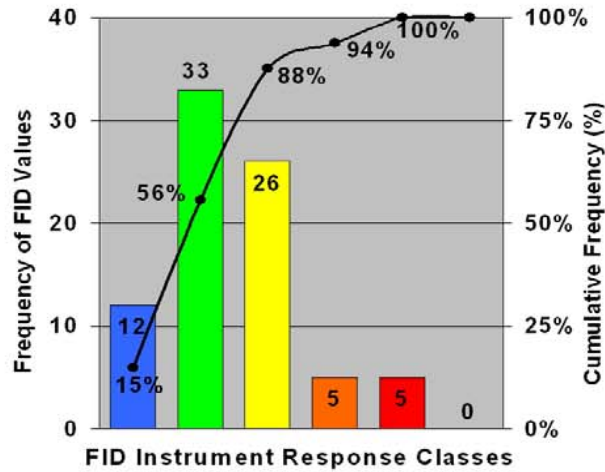
# Buried Valley Aquifer as a "Petroleum System" (Late-Generation Biogenic Gas)



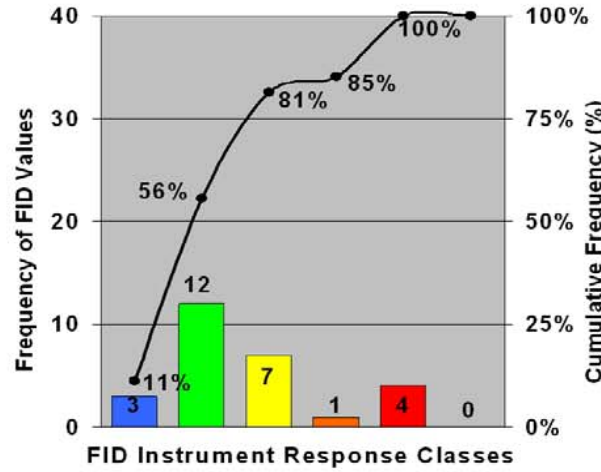
Possible Sourcing - III: Bedrock & Aquifer

# Potential CH<sub>4</sub> Sourcing – Lower Spiritwood Aquifer System

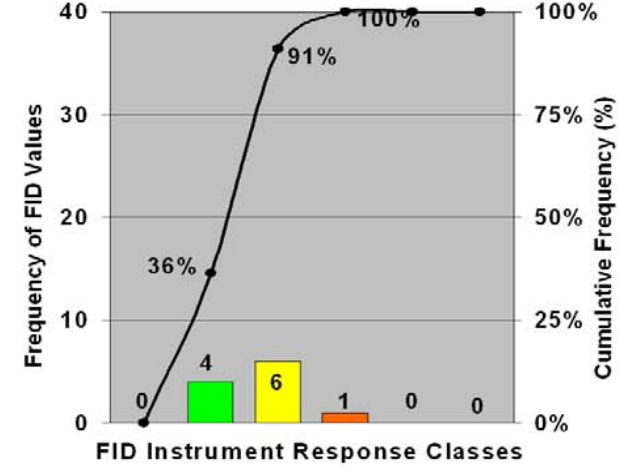
## All FID Results



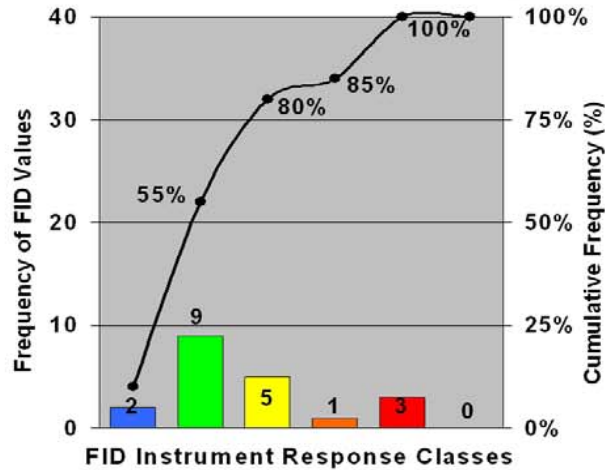
## Bedrock Sourced



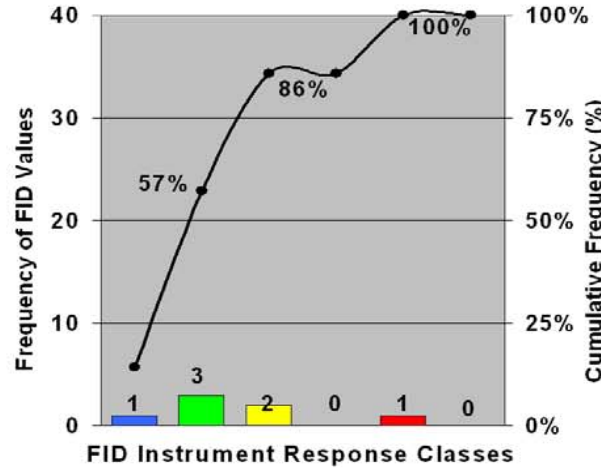
## Detrital Lignites



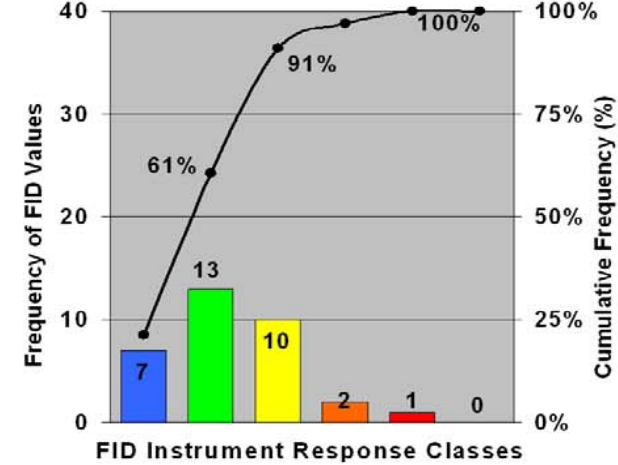
## Bedrock Sourced - Kp



## Bedrock Sourced - Kn



## Bedrock & Detrital Lignites



FID Instrument Response Classes [ppm as CH<sub>4</sub>]



# *Characteristics of Glacial Buried-Valley Aquifers in North Dakota (Lower-Spiritwood Aquifer System)*

- Relatively shallow, commonly 0'~300' in depth (91m).
- Aquifer sediments dominantly coarse sands and gravels.
- Vary from unconfined (shallow to surface) to confined (deeper with clay aquitard) conditions within the aquifer system.
- Deeper portions of the aquifer are commonly in unconformable contact with underlying Cretaceous shale bedrock of the Pierre and/or Niobrara Formations (shale-calcareous shale).
- Detrital lignites most common in the upper portions, but not ubiquitous throughout the aquifer (based on descriptions in lithologic logs).
- Favorable methanogenic geochemical conditions are present.
- Portions of the aquifer have reservoir-style lithologic architecture (i.e. trap, reservoir, and source).
- CH<sub>4</sub> occurrence appears more abundant in the lower portions of the aquifer but tends towards higher concentrations in the shallower depths of the aquifer.
- CH<sub>4</sub> generation could be related to both the presence of detrital lignites in the aquifer or from carbonaceous shales in contact with the aquifer.
- Detected [CH<sub>4</sub>] is generally less than 100 ppm.



## *Conclusions:*

1. CH<sub>4</sub> occurs in glacial buried-valley aquifers in North Dakota and is being generated from the presence of a detrital lignite substrate in a Type II BVA, *and* from a shallow carbonaceous bedrock source-with an influence from the presence of detrital lignites, in a Type I BVA.
2. [SO<sub>4</sub>] and [HCO<sub>3</sub>] ground-water geochemistry associated with detected methane concentrations in the Lower Spiritwood Aquifer System are within the ranges shown to be favorable for methanogenesis.





# *Questions for Future Research*

- 1) Is  $\text{CH}_4$  being generated within the aquifer or is it being trapped within the aquifer, having migrated from a deeper source, or both?
- 2) What is the timing of  $\text{CH}_4$  generation and distribution of  $\text{CH}_4$  within the aquifer/reservoir?
- 3) Can  $\text{CH}_4$  production be sustained for beneficial use with produced groundwaters?
- 4) Could this system be anthropogenically stimulated (microbially) and maintained in order to produce economic quantities of  $\text{CH}_4$ ?



# *Acknowledgements*

- *Elroy Kadrmas (GIS)*
  - *N.D. Geological Survey*
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  - *N.D. Geological Survey*
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  - *N.D. State Water Commission*
- *Brian Hall*
  - *North Dakota State University*

# NORTH DAKOTA GEOLOGICAL SURVEY

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and Geological Survey Division Main Offices

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