Cyclic Sedimentation Patterns of the Mississippian-Devonian Bakken Formation, North Dakota*

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Abstract

The Devonian-Mississippian age Bakken Formation records at least two episodes of rising sea level. The vertical and lateral lithofacies left by both transgressive events suggest a pattern of cyclical sedimentation that coincides with the transition between shallow tidal dominated carbonates of the Upper Devonian Three Forks Formation and the open marine platform to platform slope carbonates of the Lower Mississippian Lodgepole Formation. The basal deposits of both transgressions contain thin discontinuous nearshore or beach sandstones that grade upward into the organic-rich, oxygen-stratified hemipelagic muds that make the two Bakken shales world class source rocks.

The initial transgression is represented by basal sandstone that unconformably overlies the Three Forks Formation and is informally referred to as the "Sanish Sand". The basal sandstones typically grade upward into a regionally extensive siltstone that is usually found in depositional lows along the basin margin. Farther into the basin the Three Forks grades directly into the organic-rich portion of the lower Bakken with no obvious unconformity. Maximum transgression culminated with the deposition of the lower Bakken shale.

The lower portion of the middle member consists of carbonate-siliciclastic rocks that coarsen upward from sediments dominated by mud-sized material through a thinly bedded or laminated algal section and into a very fine- to fine-grained sandstone that forms a conspicuous "clean gamma-ray" bench within the middle Bakken that is referred to as Lithofacies 3 in North Dakota. The vertical distribution of facies within the middle Bakken below Lithofacies 3 (L3) is consistent with a gradual fall in sea level, with L3 marking the lowstand of this regressive period.

A repeat of the initial transgressive sequence is observed in the rocks overlying L3. A series of finely laminated algal-bearing siltstones grade upward into silty lime mudstones that are ultimately capped by the upper Bakken shale as the Bakken seas reach their maximum transgression.

The coincidence of localized “thinning” trends in all three members of the Bakken Formation suggests that local structural features were active during deposition of the Bakken Formation. These features allow for the preservation of the rock sequence previously discussed. These active structural features, in association with Prairie Salt tectonics, also increase the potential to develop a good reservoir.

Selected References

Berwick, B., 2008, Depositional Environment, Mineralogy, and Sequence Stratigraphy of the Late Devonian Sanish Member (Upper Three Forks Formation), Williston Basin, North Dakota: Colorado School of Mines M.S. Thesis, 263 p.

North Dakota Geological Survey, 1954, Stratigraphy of the Williston Basin: North Dakota Geological Survey, Bismarck, North Dakota.

Sandberg, C.A., and C.R. Hammond, 1958, Devonian System in Williston Basin and Central Montana: AAPG Bulletin, v. 42, p. 2293-2334.

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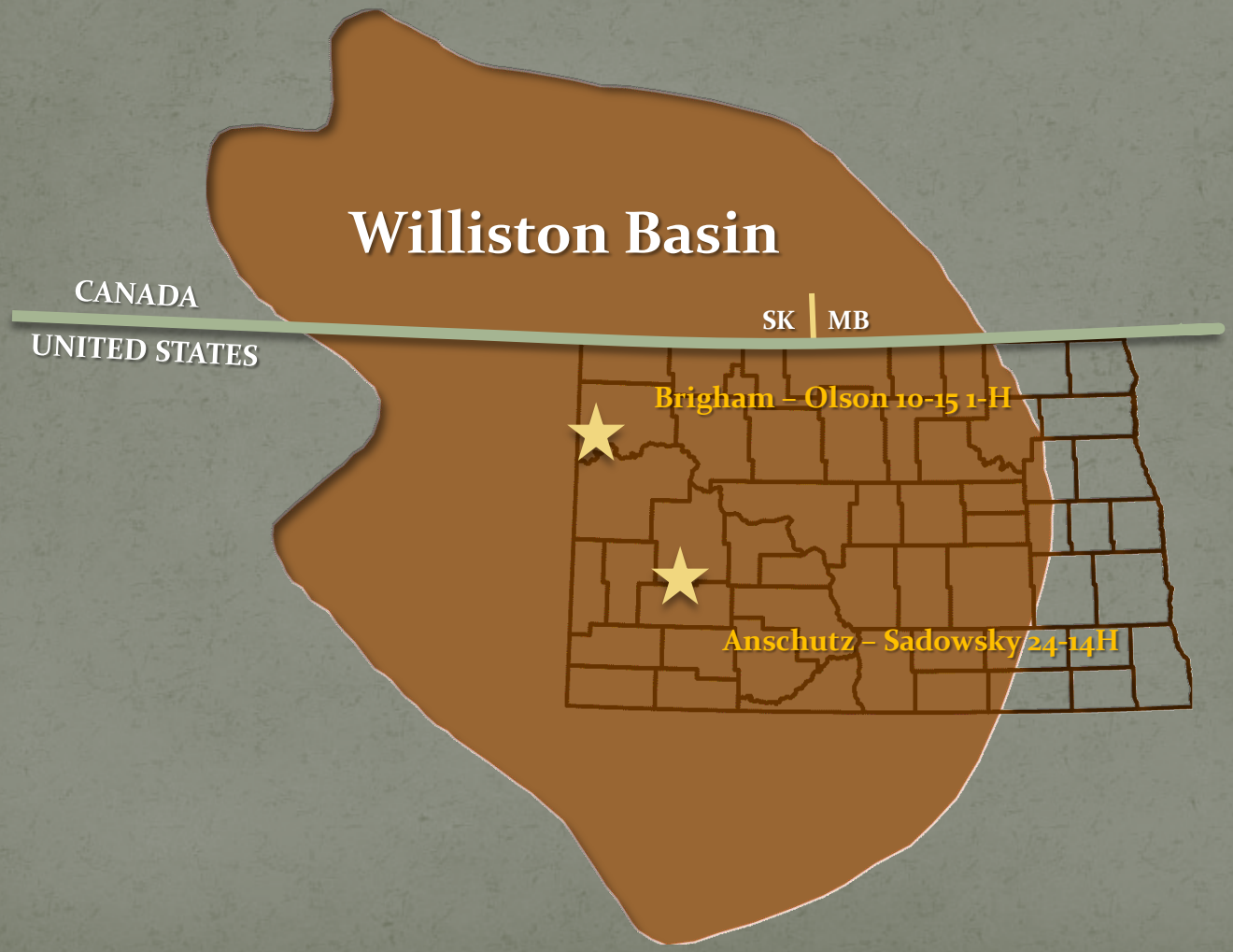
Location Map



Objectives

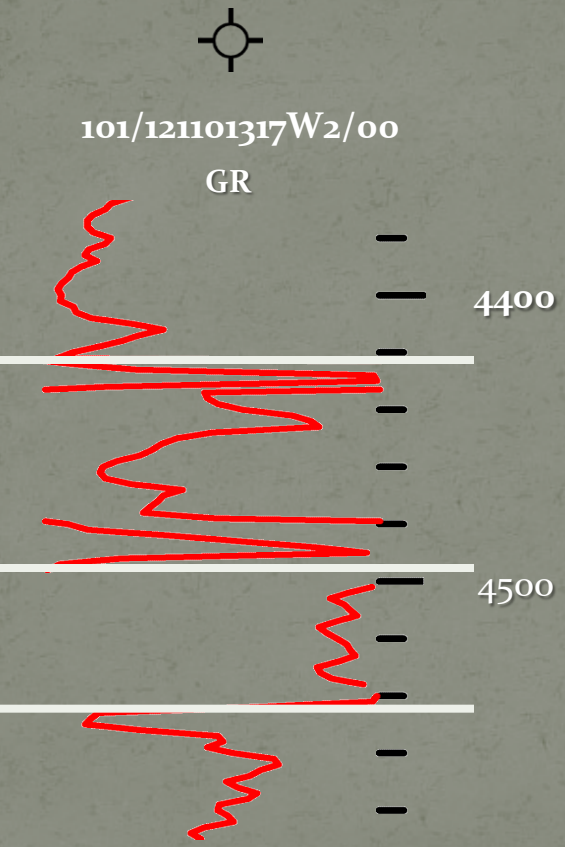
- Nomenclature
  - Existing
  - Problems
- Examine the characteristics of the rock section
  - Specifically lower Bakken shale to Three Forks
- Geologic setting
- Possible mechanisms for the preservation
- Preliminary conclusions

North Dakota Geological Society 1954	Sandberg and Hammond 1958	Christopher 1966	Berwick 2008
North Dakota	Williston Basin	Saskatchewan	North Dakota
Lodgepole Formation	Lodgepole Formation	Lodgepole Formation	Lodgepole Formation
Bakken Formation	Bakken Formation	Bakken Formation	Bakken Formation
		Big Valley Formation	
"Sanish Sand"	"Sanish Sand"		Sanish Member
Three Forks Formation	Three Forks Formation	Torquay Formation	Three Forks Formation

Saskatchewan Sequence

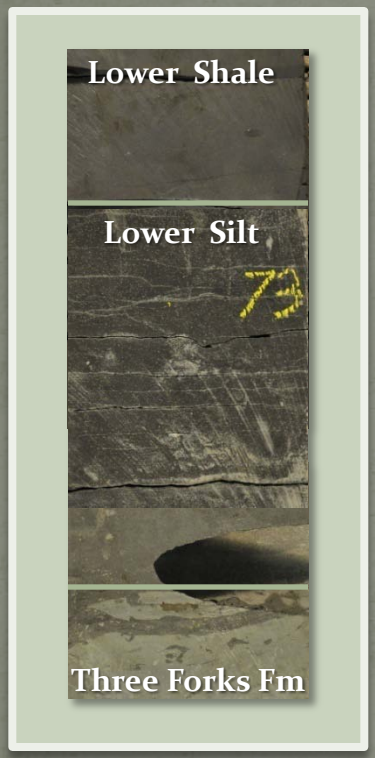
Christopher
1966

Saskatchewan

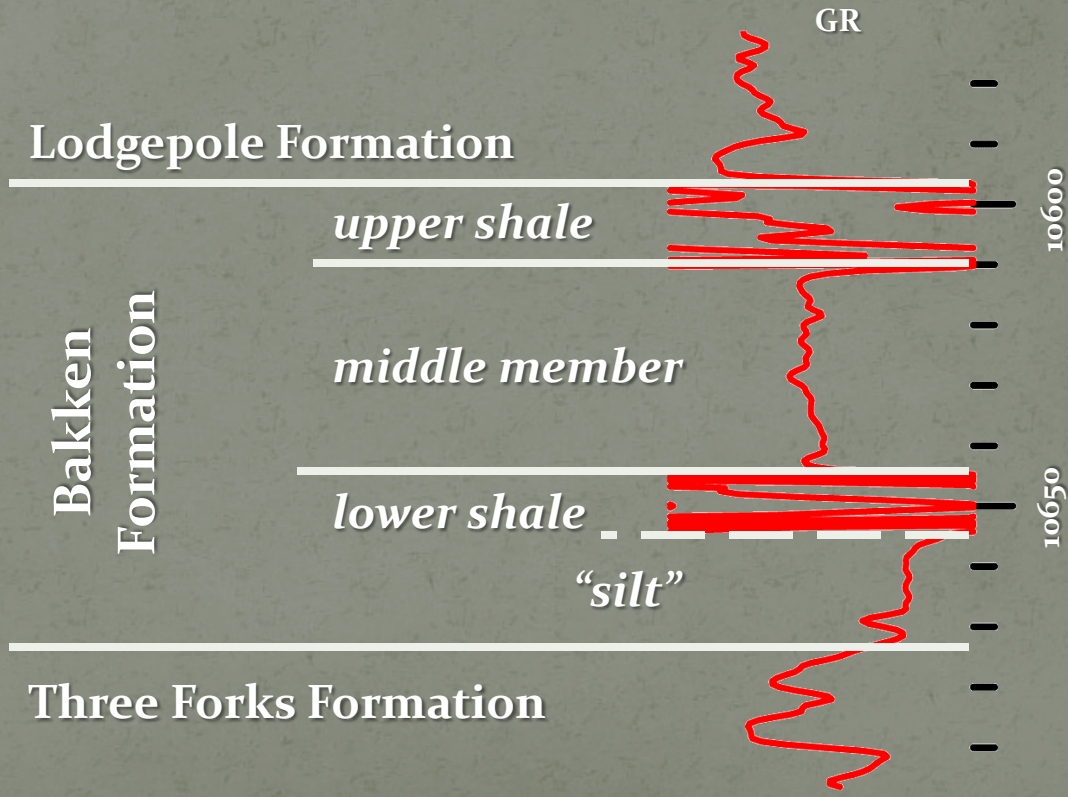


	Lithology
Bakken Formation	Two black shales separated by a sequence of laminated sands, oolitic calcarenites, a massive siltstones.
Big Valley Formation	Consists of a sea-green to dark grey black to black, pyritic, non-calcareous silty shale to earthy mudstone
Torquay Formation	Tan dolomite interbedded with green shale.

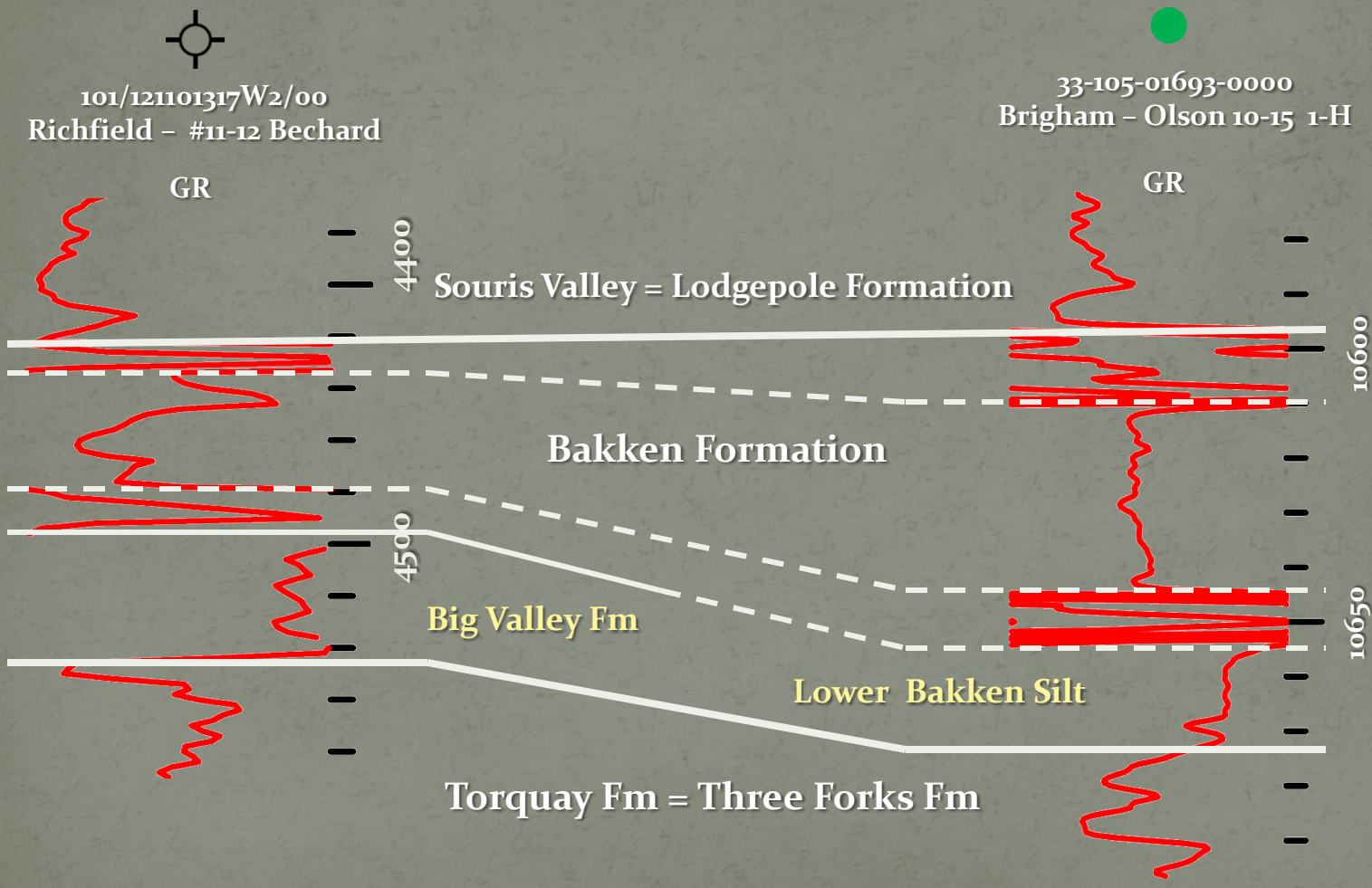
North Dakota – Lower Bakken Silt



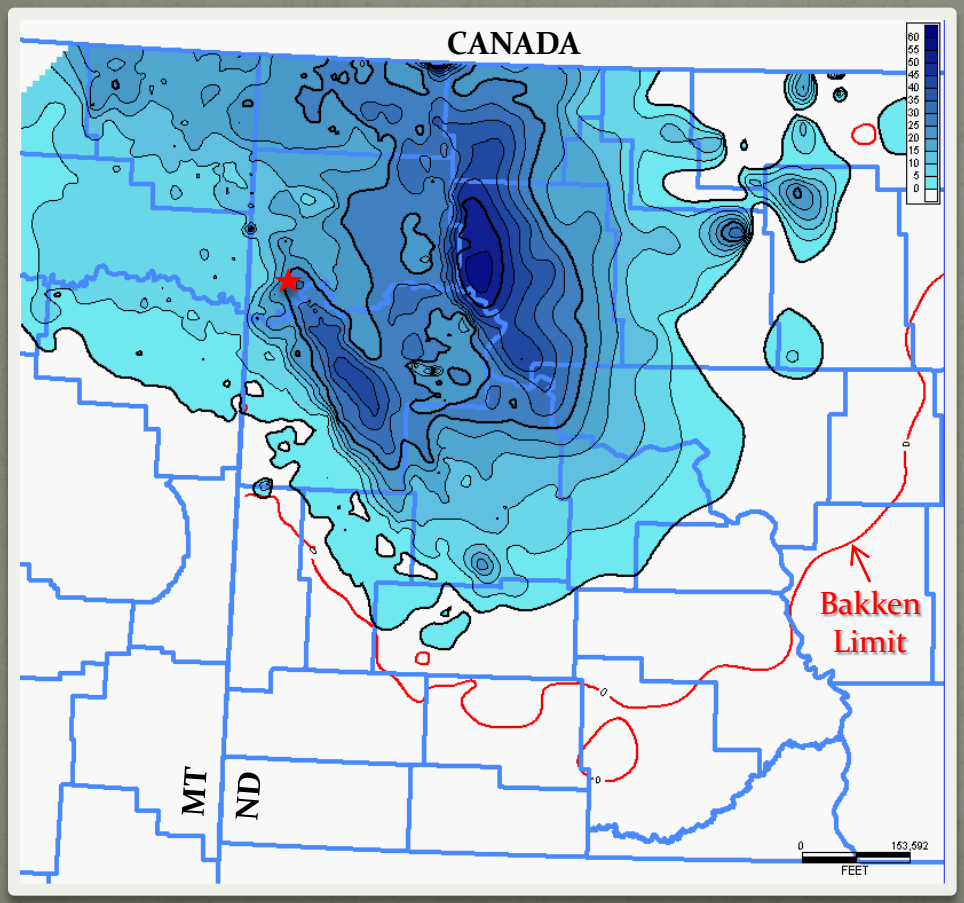
33-105-01693-0000
Brigham – Olson 10-15 1-H

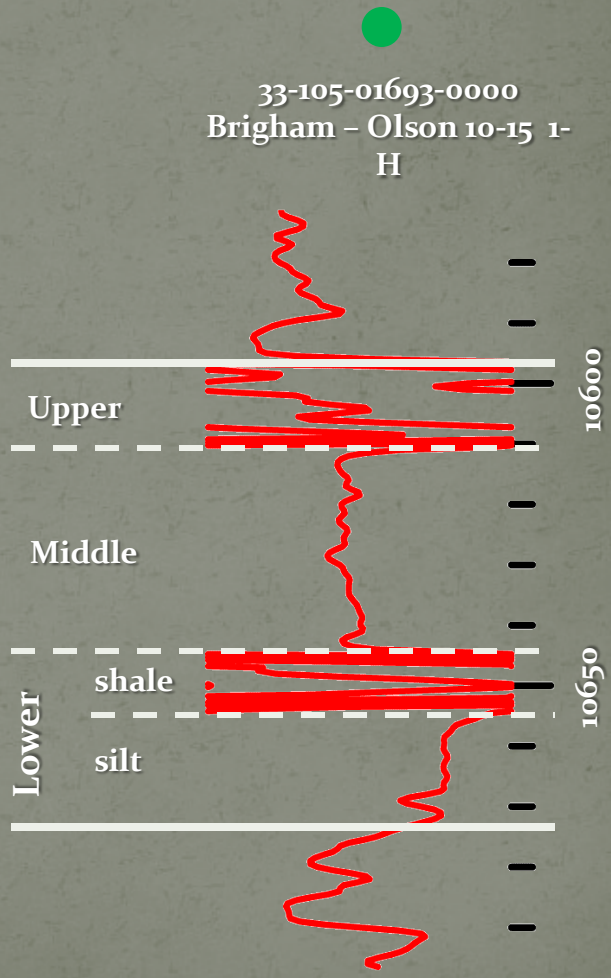


SK – ND Correlations

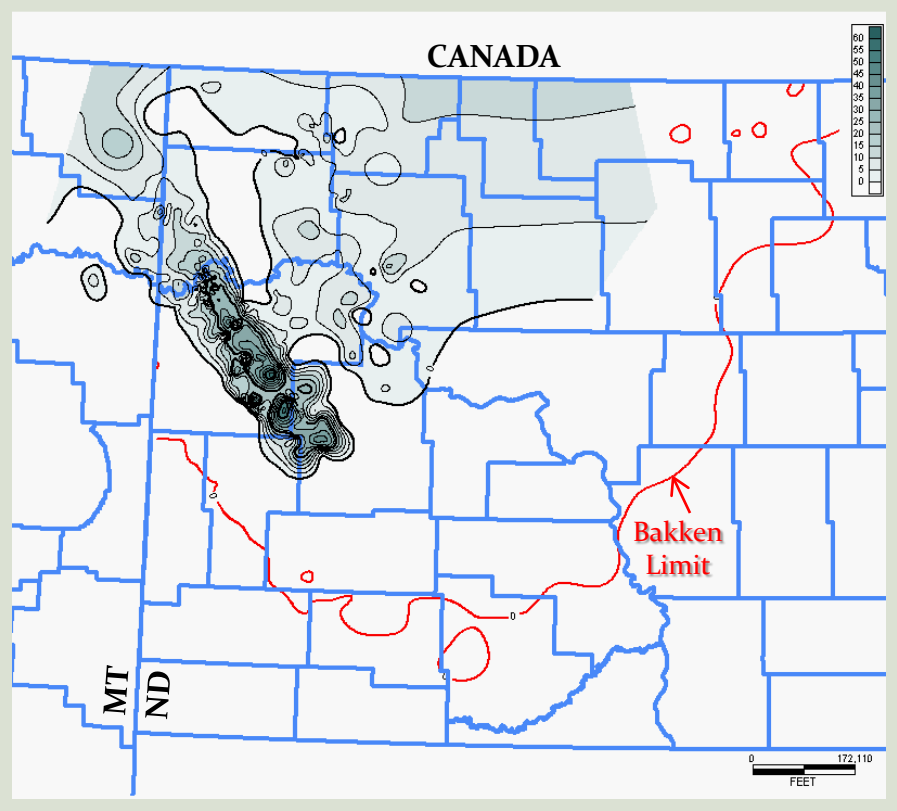


Isopach of the Lower Bakken Shale



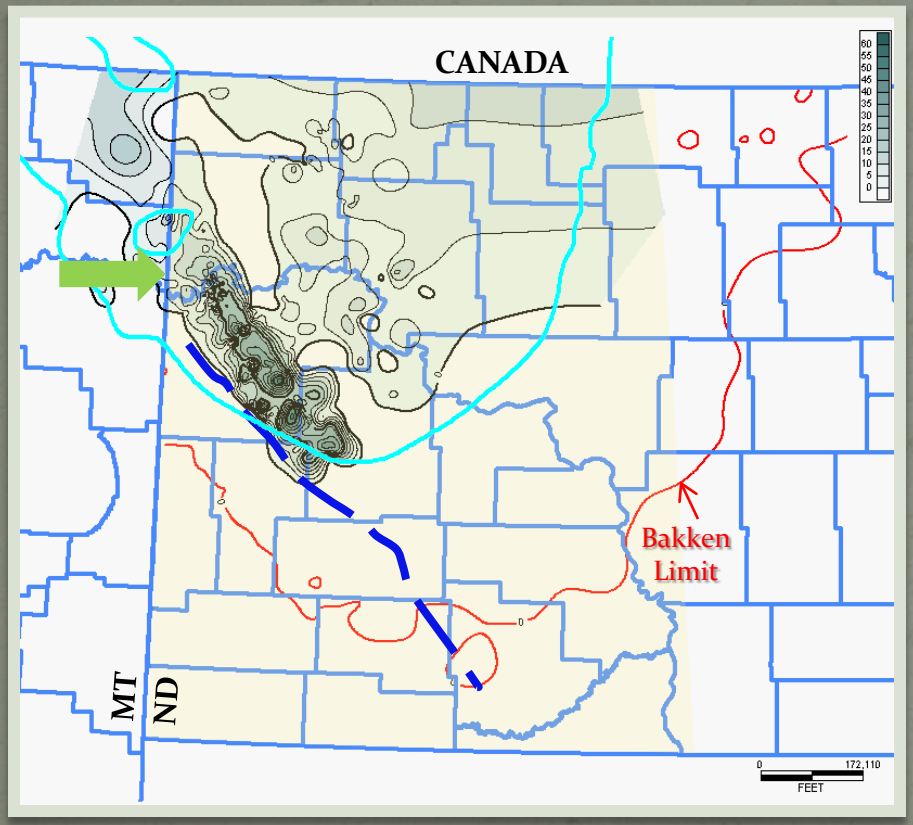


Isopach of the Lower Bakken Silt



- Less organic-rich
- Greater silt/carbonate component
- Maximum thickness 58 ft.
- Linear trough-like feature

Isopach of the Lower Bakken Silt



Possible Interpretations
For Depositional Pattern

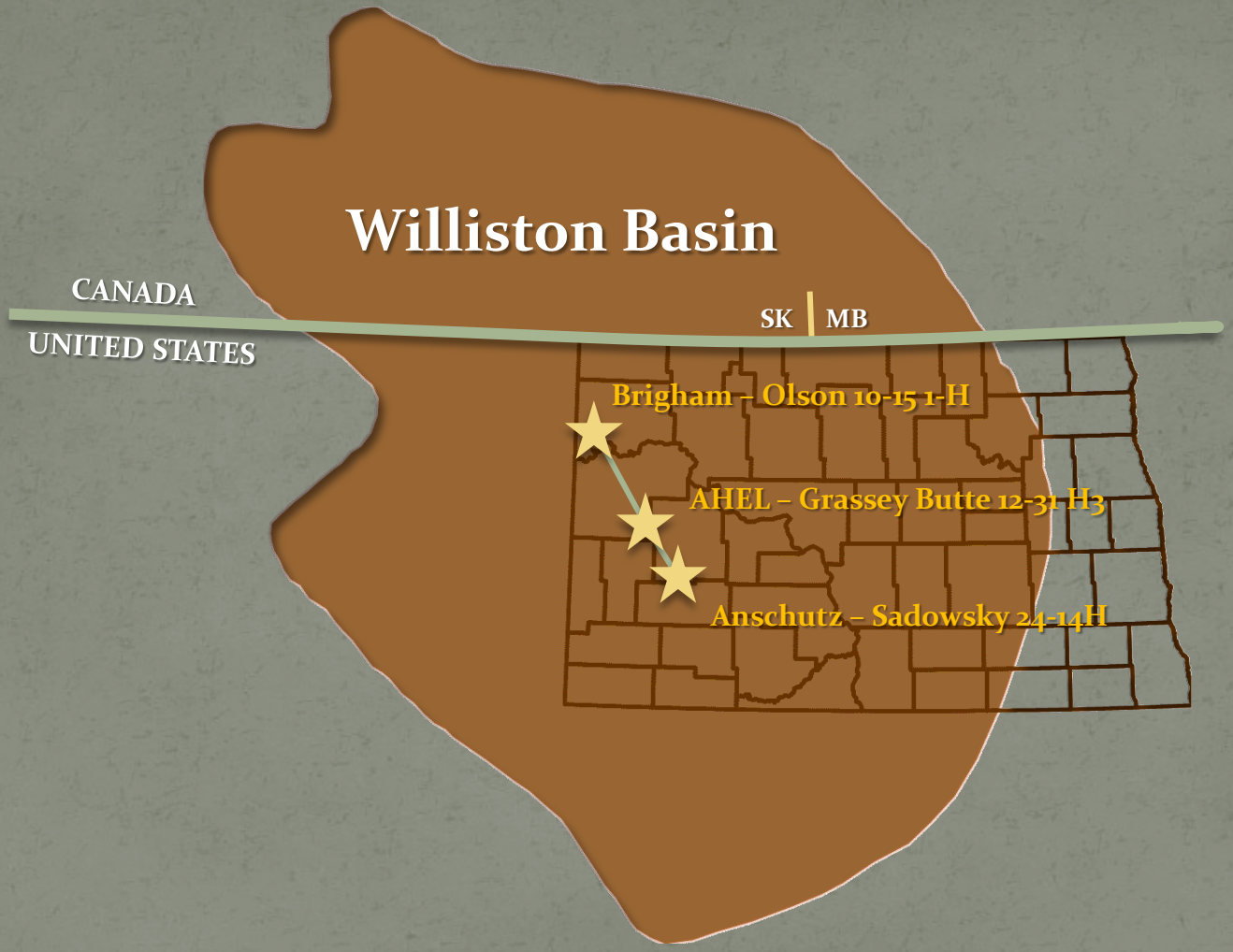
Faulting

- **Heart River**
- Central Montana Trough
- Trans-Hudson Orogenic Belt
  - N-S Basement Faults

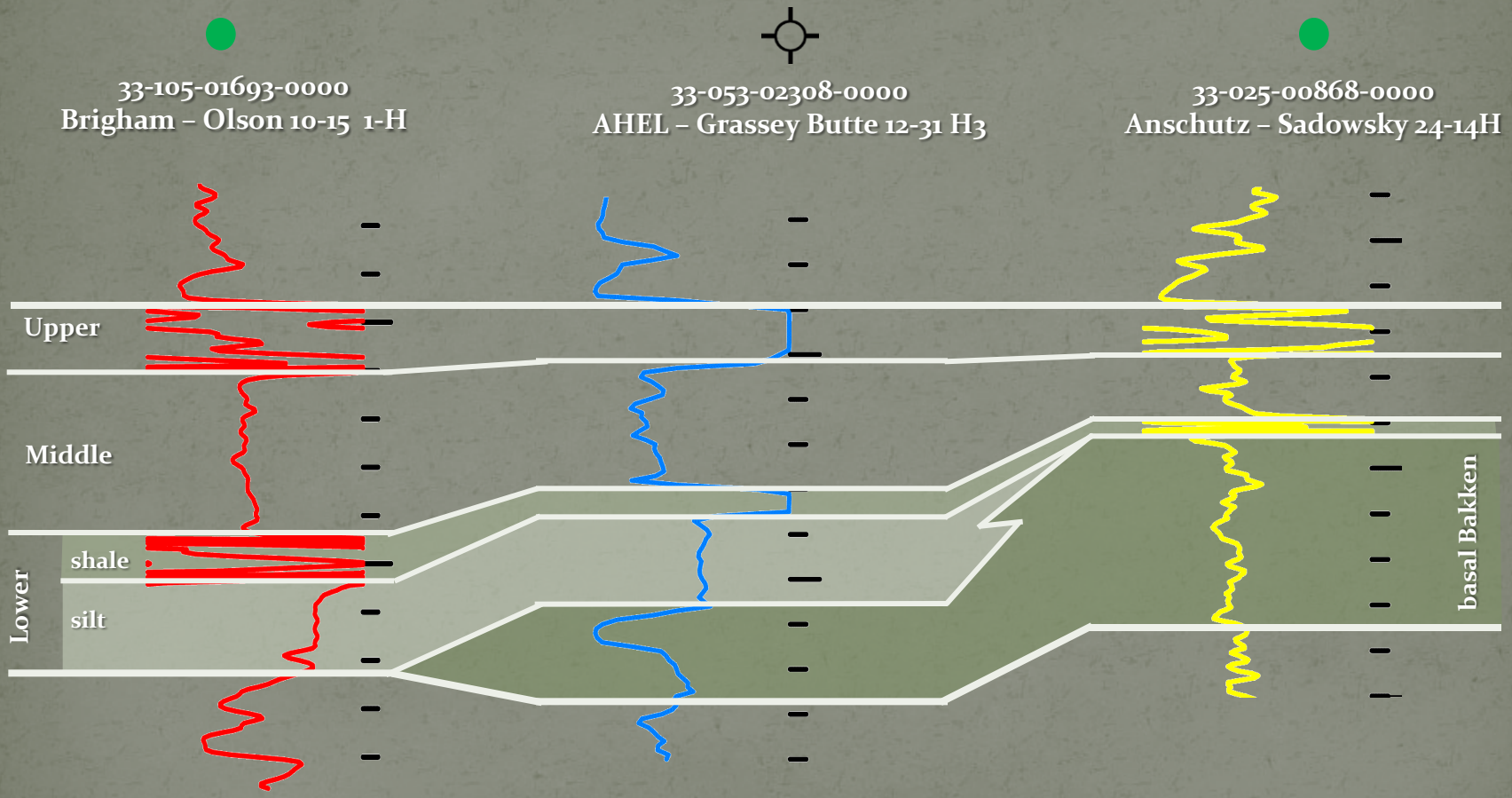
Dissolution of Salt

- Devonian Prairie Salt
  - Hummingbird Trough

Combination of Both

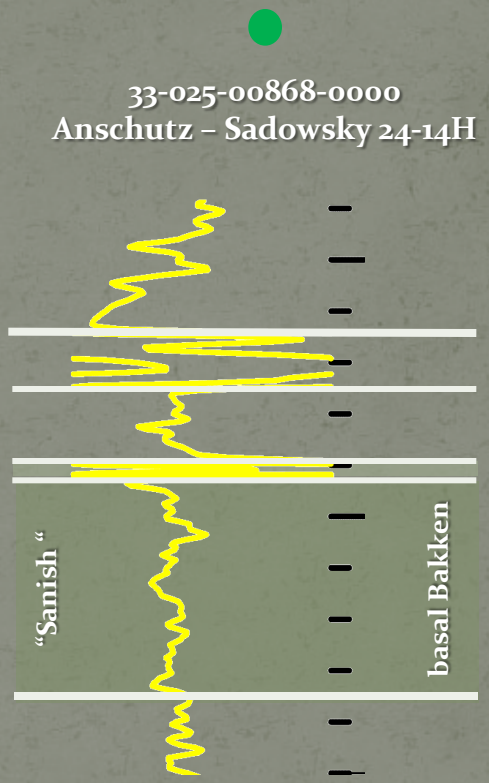

Williston Basin
CANADA
UNITED STATES
SK
MB
Brigham – Olson 10-15 1-H
AHEL – Grassey Butte 12-31 H3
Anschutz – Sadowsky 24-14H

NW – SE Cross-Section



Basal Bakken Beds

North Dakota Geological Society 1954	Berwick 2008
North Dakota	North Dakota
Bakken Formation	Bakken Formation
"Sanish Sand"	
Three Forks Formation	Three Forks Formation
	Sanish Member



“Sanish”

Refers to:

ND Historical Society *Ed Murphy*

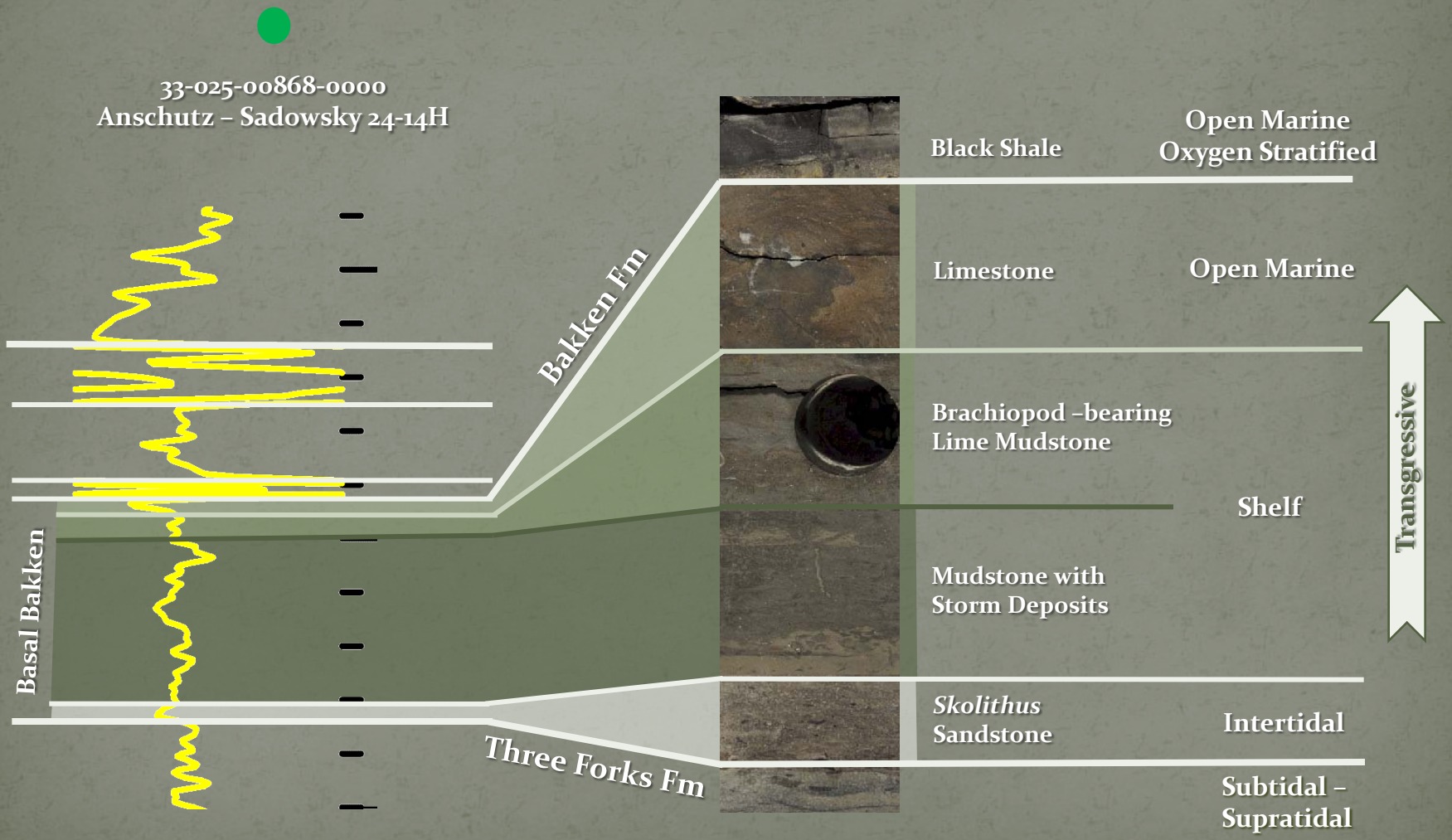
- A former town that “vanished” under Lake Sakakawea

"Sanish"

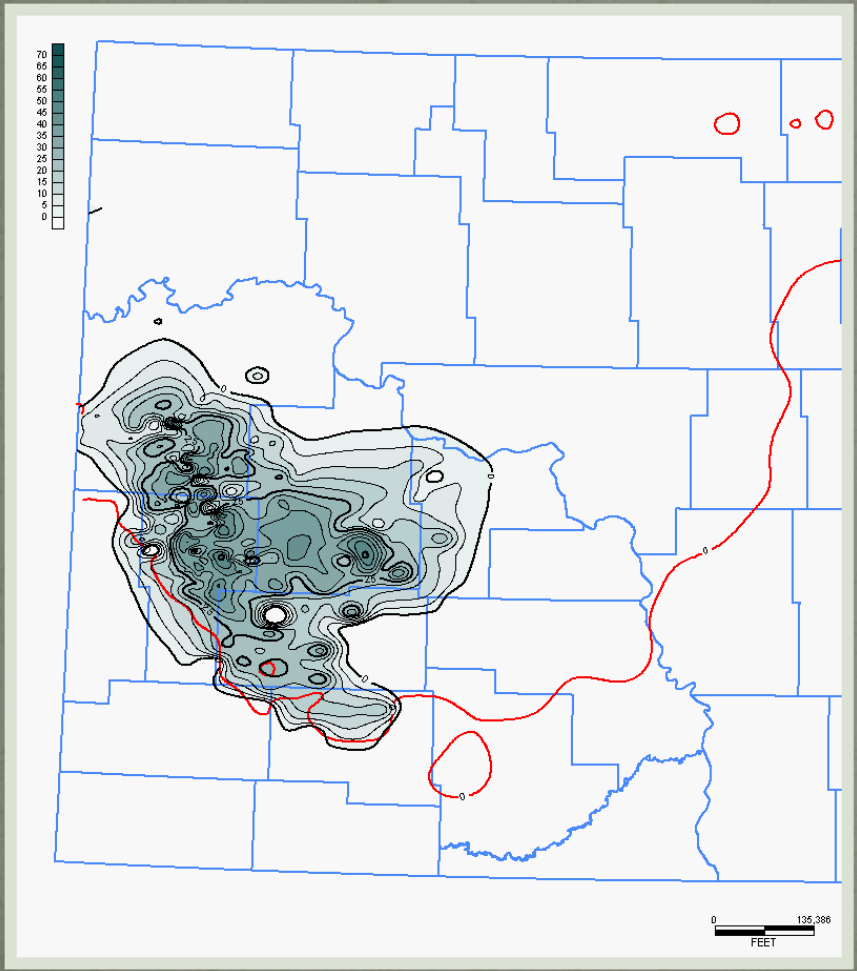
Refers to:

- Informal sandstone bed described in the 50s along the Antelope Anticline
  - Regulatory "Pool" name
- Mountrail County oil field (that produces from the Bakken)
- The uppermost section of the Three Forks Formation

Basal Bakken Beds

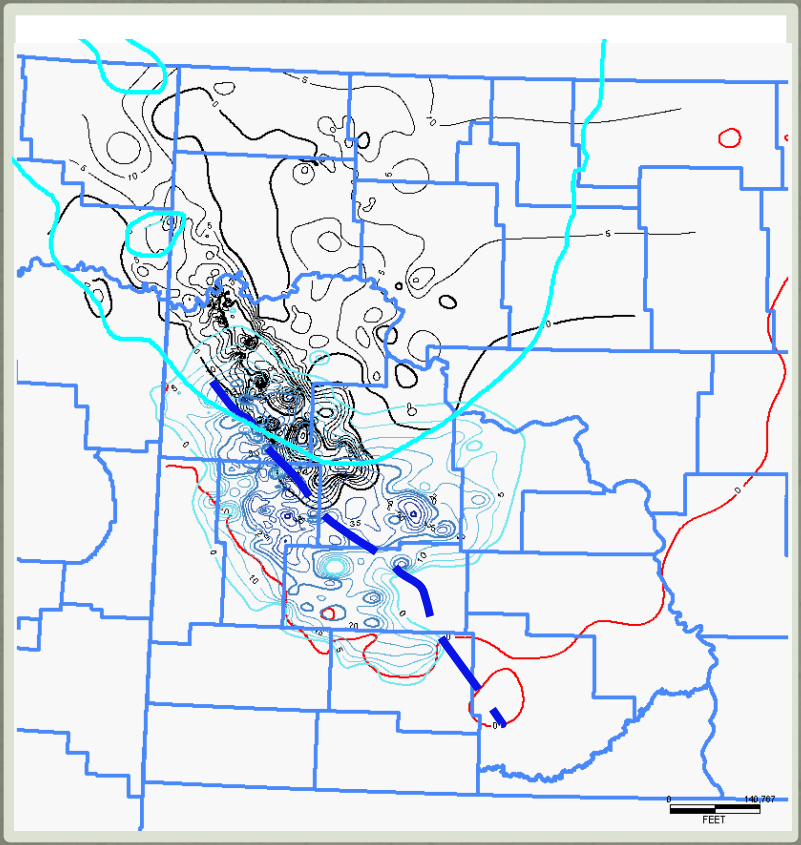


Isopach of Basal Bakken Beds



- Mixed siliciclastics/carbonates
- Maximum thickness - 52 ft
- Unconformable - Three Forks Formation
- Restricted to the southwest
- Linear trend

Basal Bakken Beds – Lower Bakken Silt



Strong correlation to faulting and salt dissolution

Strong NW-SE fabric?

Bakken Bed Comparison

33-061-00490-0000
Amerada-Hess – Sara Barstad 6-44H

Upper Black Shale

Lithofacies L5
Brachiopod –bearing
Lime Mudstone

Lithofacies L4
Mudstone with
Storm Deposits

Lithofacies L3
Sandstone

Upper Middle Bakken

33-025-00868-0000
Anschutz – Sadowsky 24-14H

Bakken Fm

Lower
Black Shale

Open Marine
Oxygen Stratified

Limestone

Open Marine

Basal Bakken Beds

Brachiopod –bearing
Lime Mudstone

Shelf

Mudstone with
Storm Deposits

Skolithus
Sandstone

Intertidal

Subtidal –
Supratidal

Three Forks Fm

Transgressive

Summary

- Basal Bakken represents an additional section of rocks below the lower shale
  - Usually unconformable above and below
  - Transgressive
  - Slight variations in lithologies occur due to local structure
- the usage of the term "Sanish" should be dropped (and perhaps it should "vanish" like the "town")
  - Regulatory impact
- Repeat of two depositional cycles involving the same vertical and lateral facies, with the first incompletely preserved due to local tectonics