The Devonian Three Forks Formation:

Manitoba's Sinclair Field and Other Prospects

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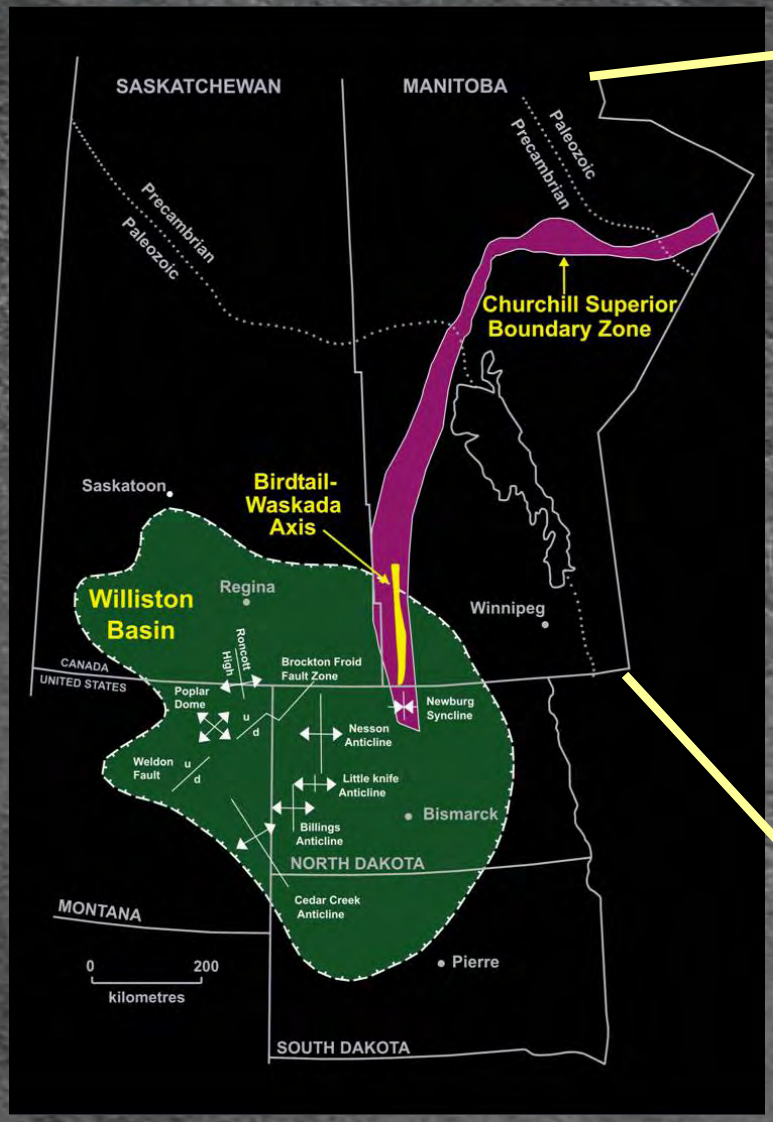
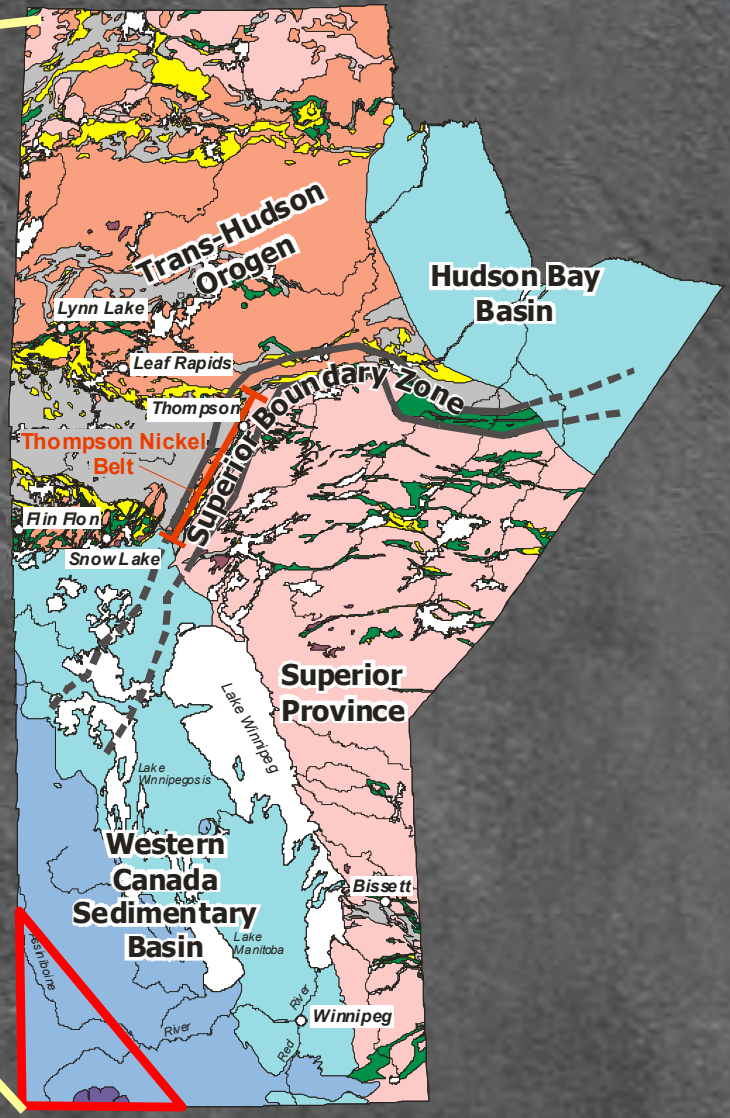
Manitoba

MANITOBA GEOLOGICAL SURVEY MGS 1928

Three Forks Study Area





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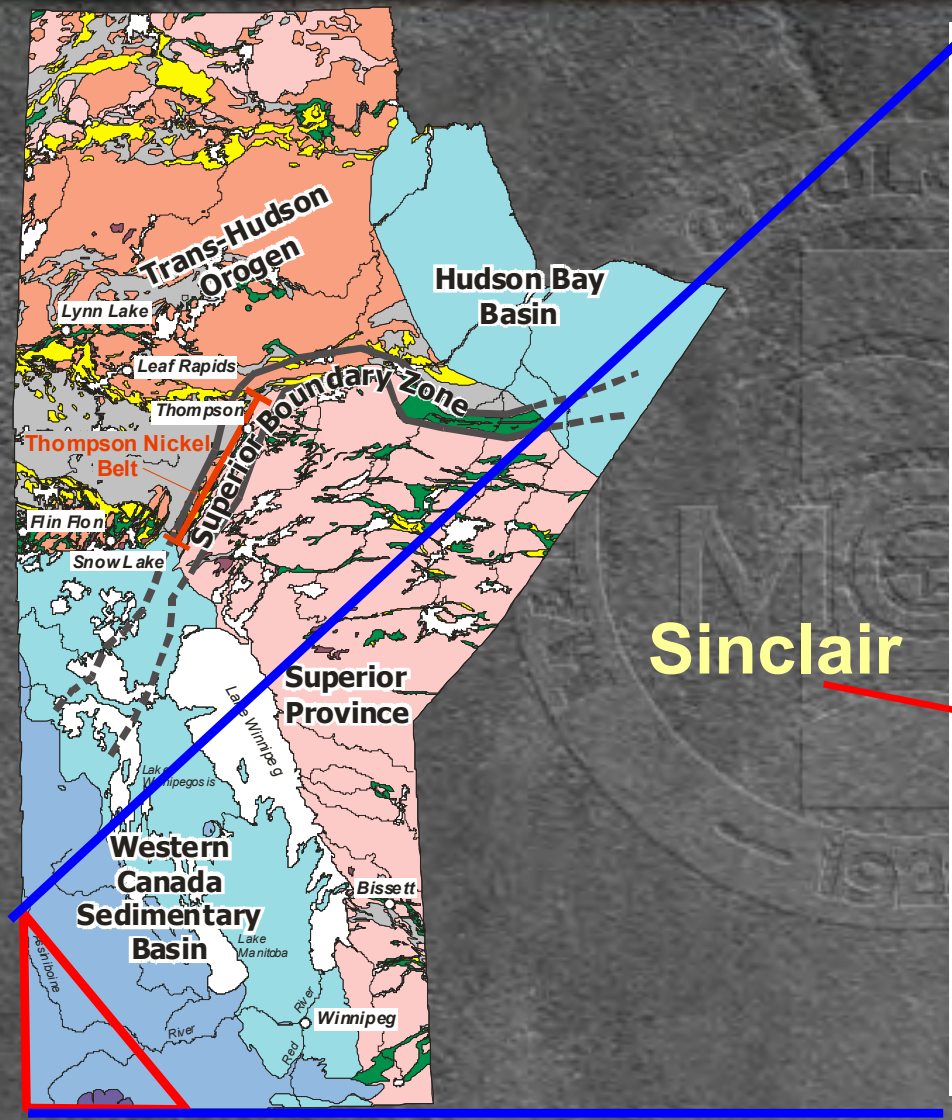
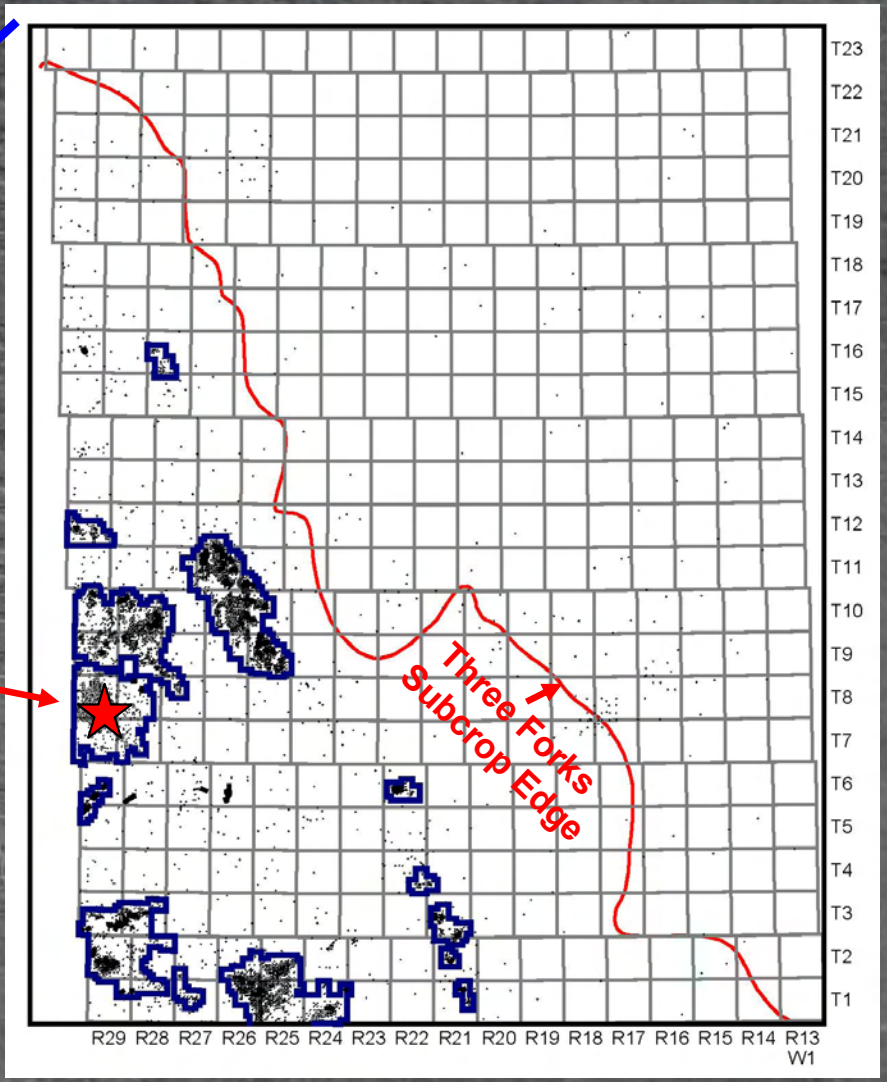


Sinclair



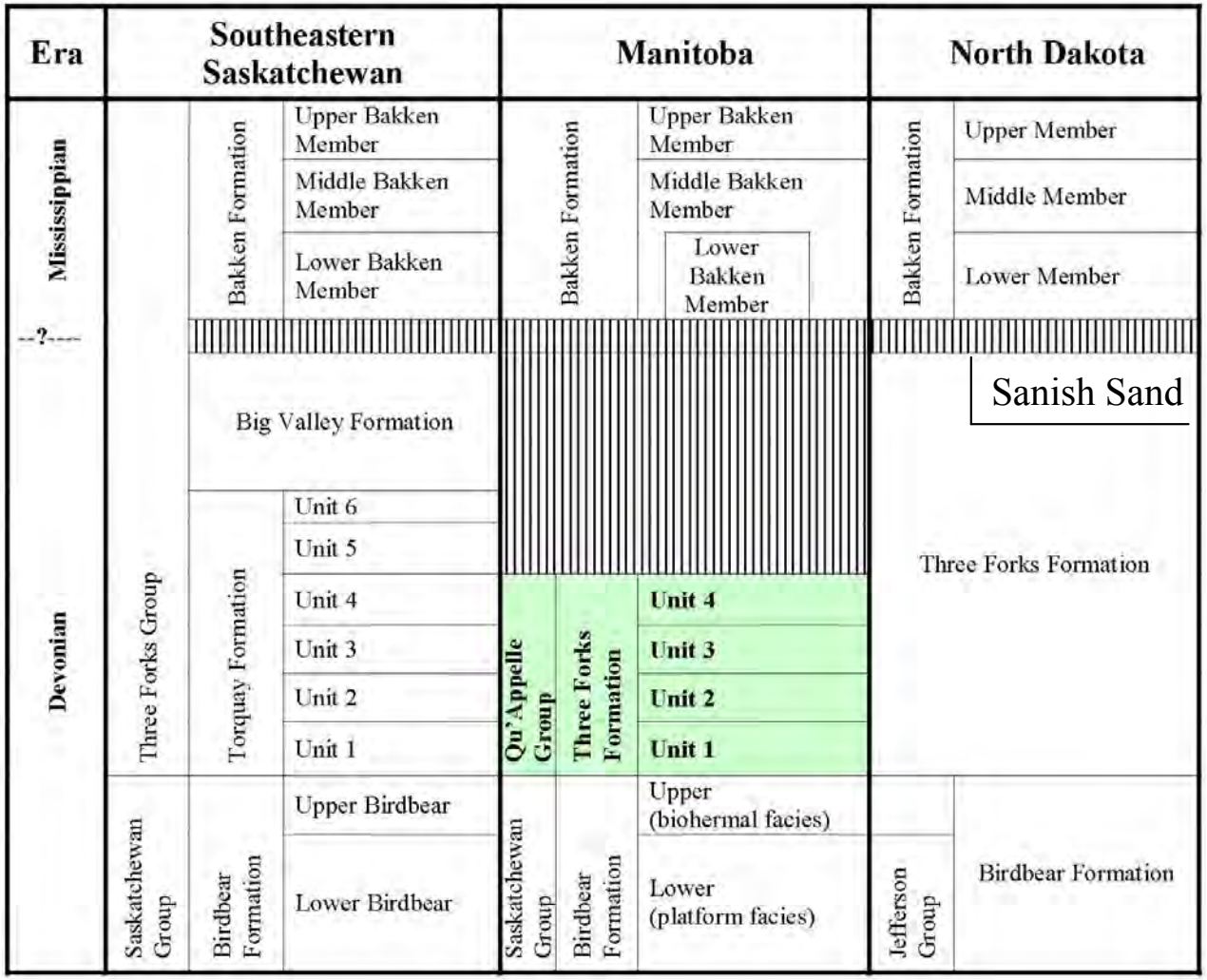
Sinclair Field

- Early exploration efforts → Dry wells
- Renewed exploration in 2003
- Field status by 2005
- Over 34 000 hectares in area
- Sinclair Unit No. 1 running since 2006, and will be expanding.
- > 880 wells drilled at Sinclair to date
- > 800 wells currently producing
- Proved and probable reserves: **40 Mbbl**

Three Forks Formation

- Cyclical transgressive-regressive sequence of argillaceous dolomites, brecciated, interbedded and interlaminated with silty dolomitic shales and claystones.
- Complex diagenetic and oxidation-reduction history.
- Produces at Sinclair, Daly and Kirkella Fields, and north of Pierson Field.
- Commingled with Middle Bakken.
- Subdivided into four units
  - Units subdivision equivalent to units in Christopher (1961).

Three Forks Stratigraphy



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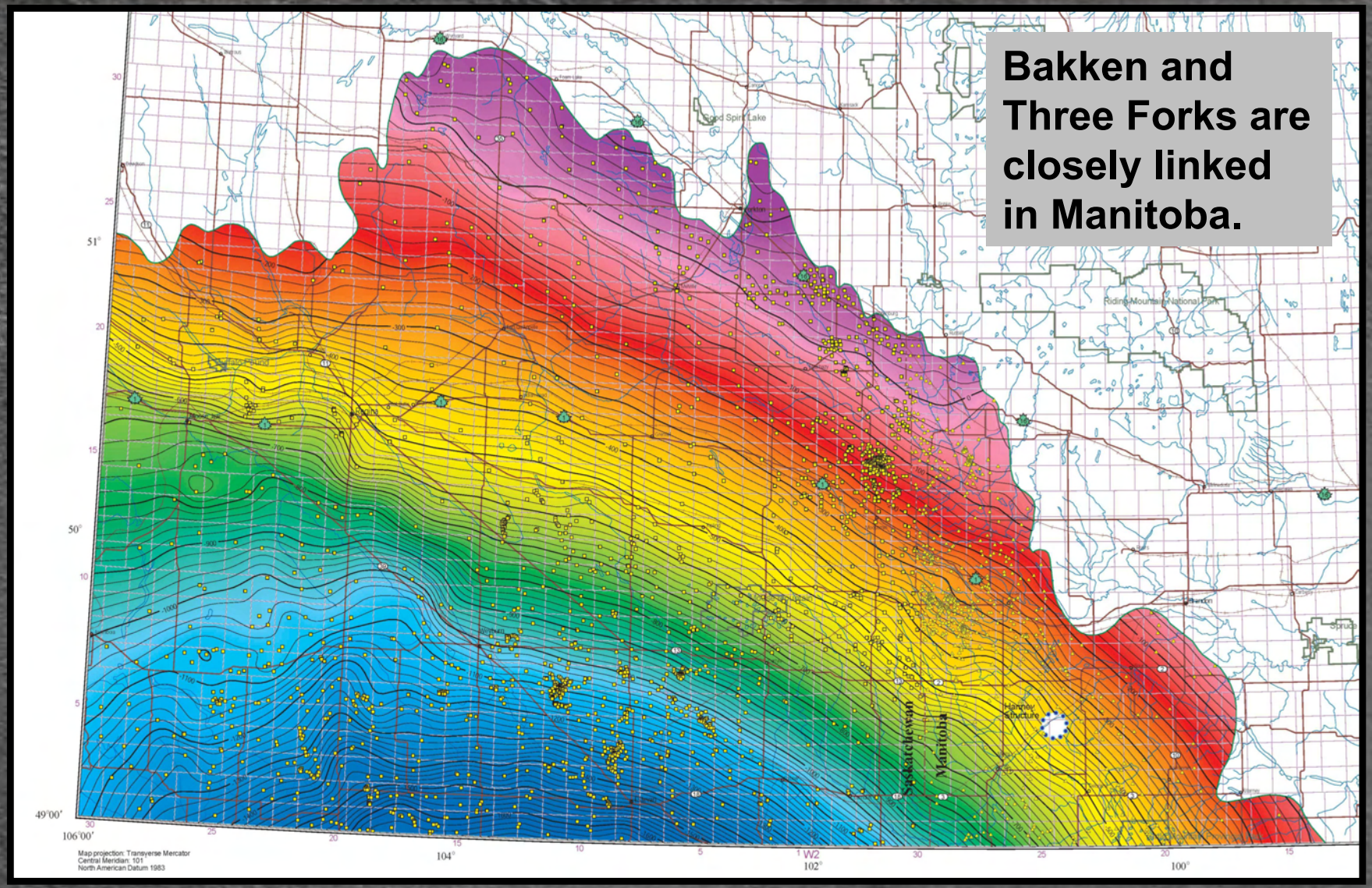
Bakken Structure

WILLISTON BASIN TGI



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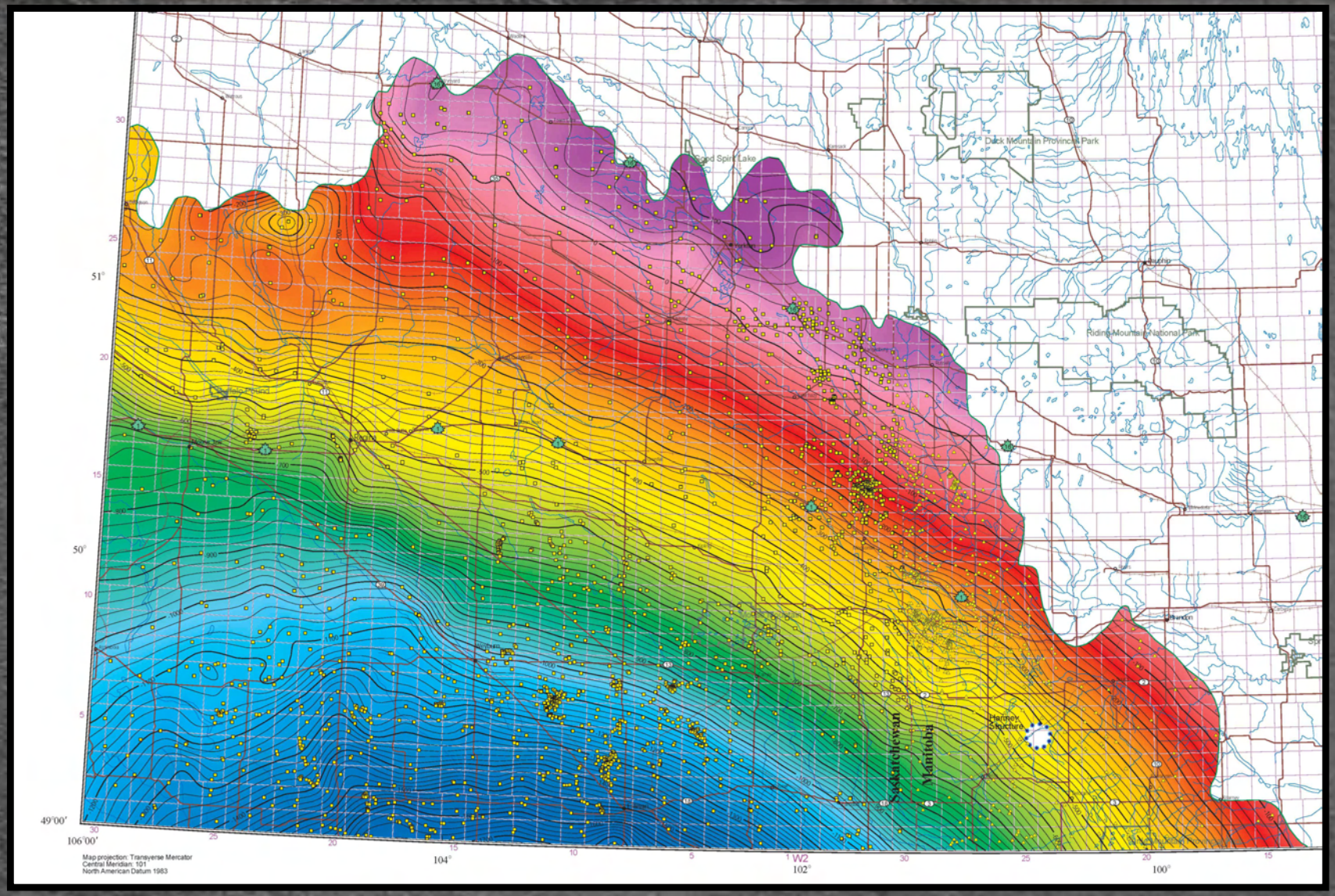
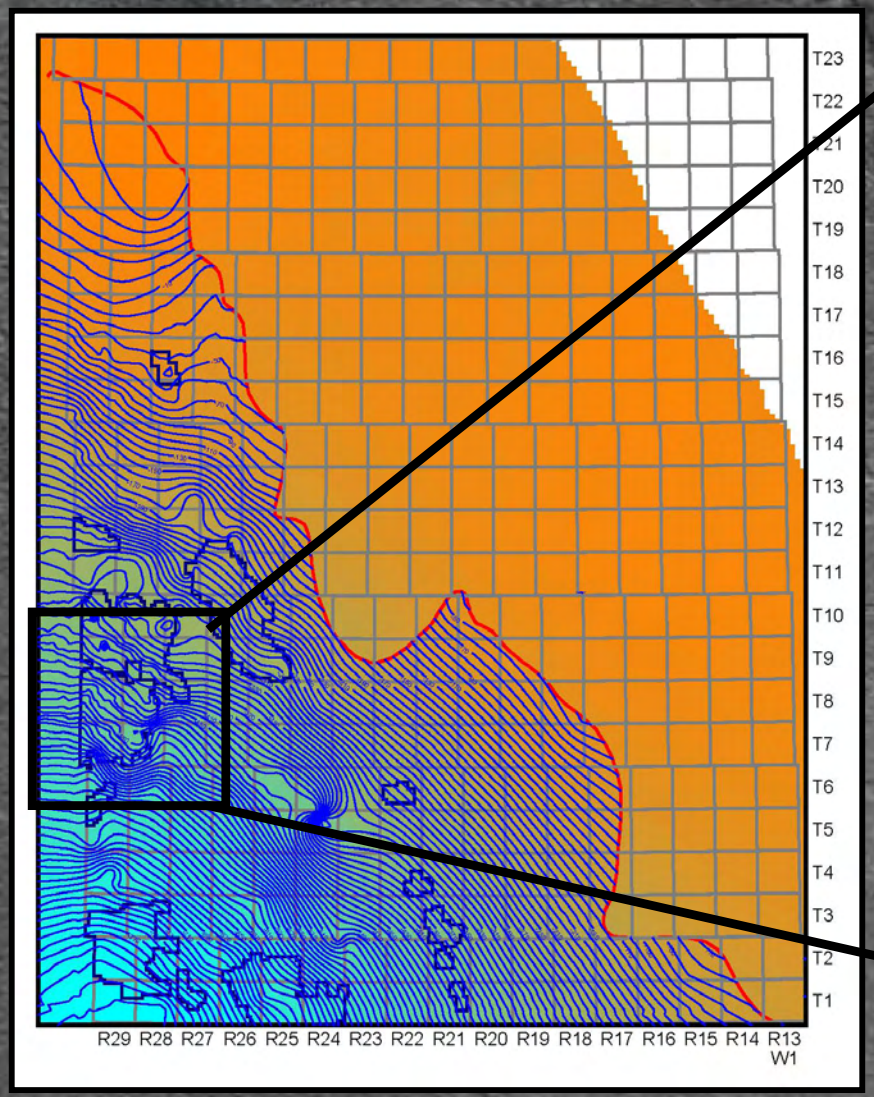
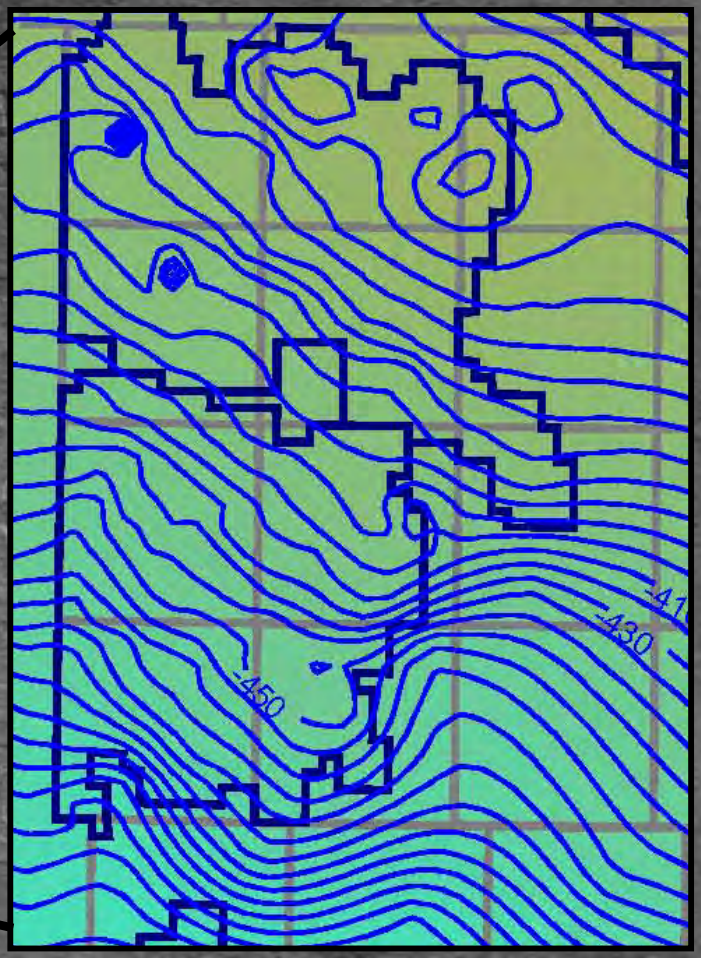
Three Forks Structure

WILLISTON BASIN TGI



Three Forks Structure





- Structural high in Sinclair
- Mappable from the top of the Prairie Evaporite to the top of Lodgepole Formation

Contour Interval = 10 m

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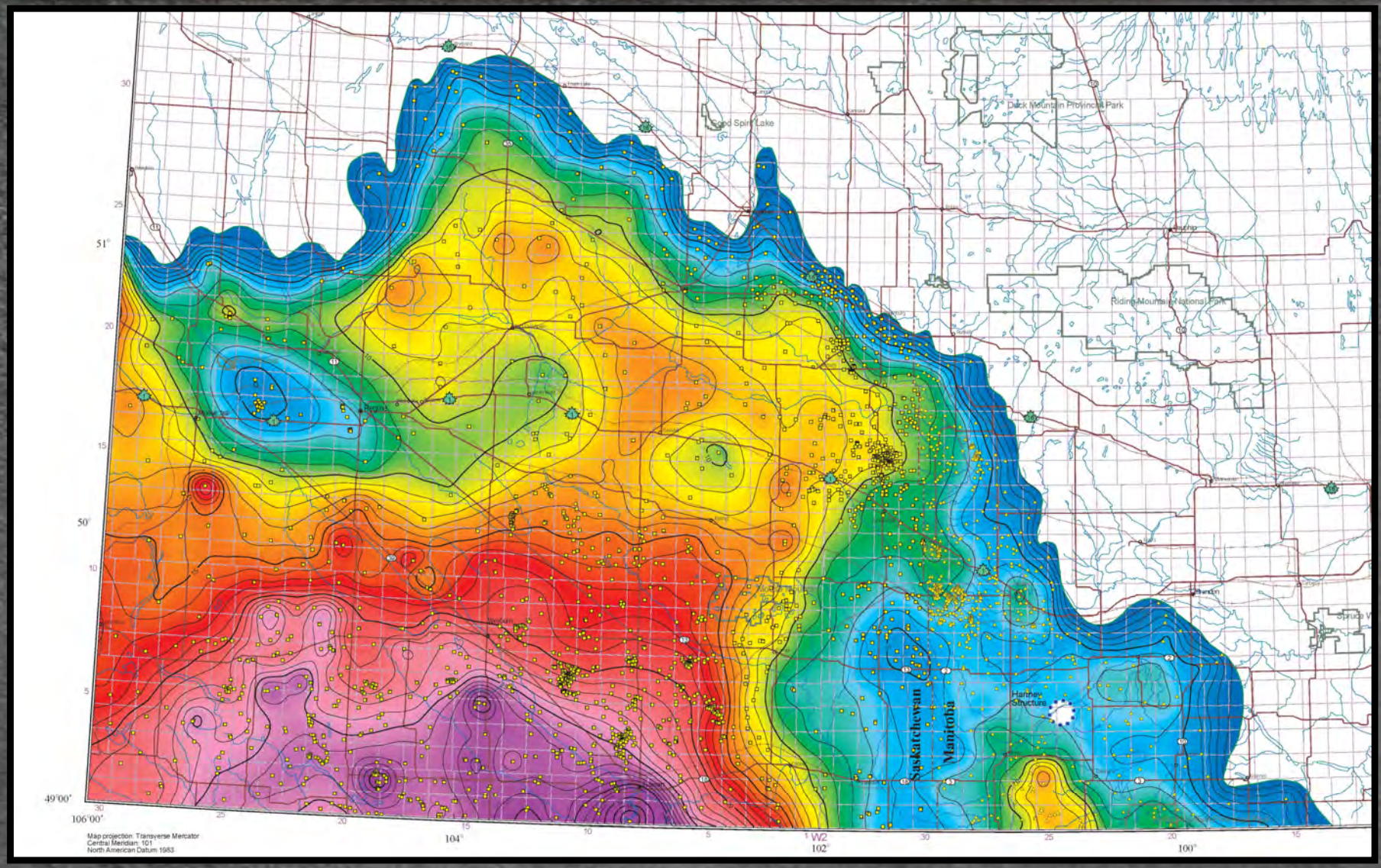
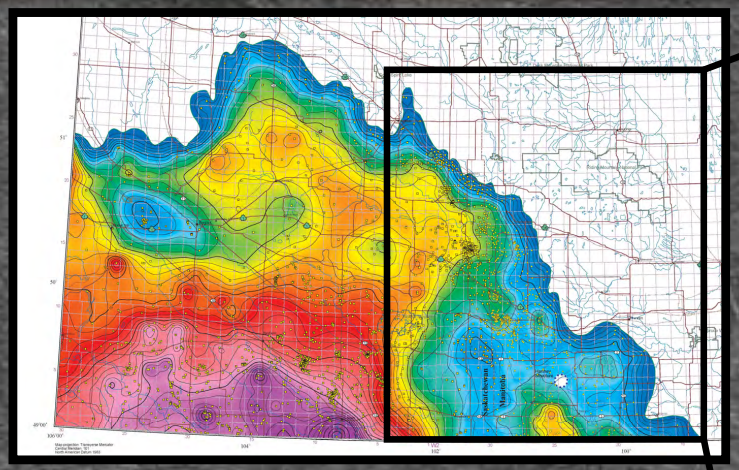
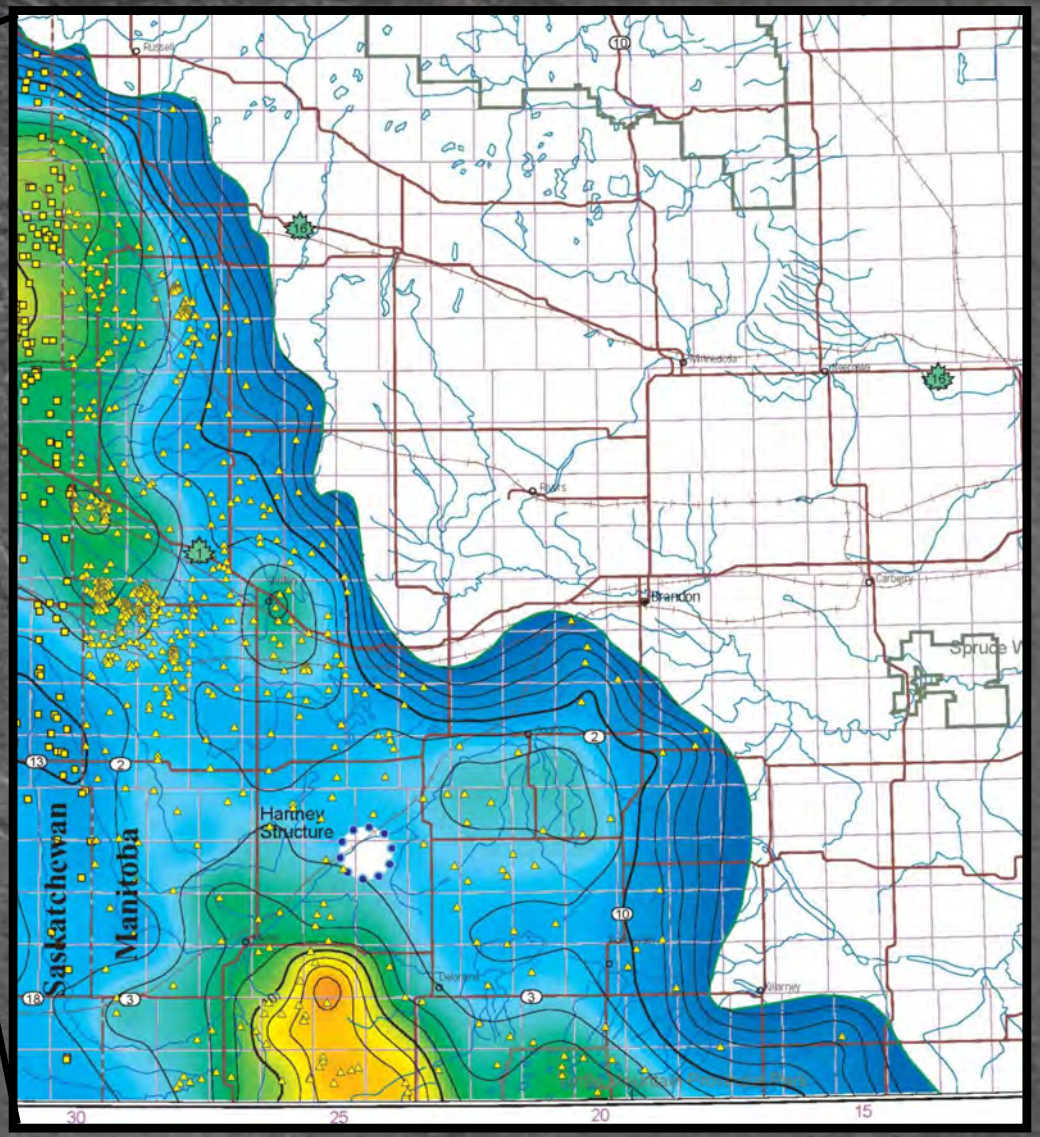
Bakken Isopach

WILLISTON BASIN TGI



Bakken Isopach





- Relatively thin in Manitoba (< 8 m)
- Localized thicks (Waskada Field)

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Three Forks Isopach

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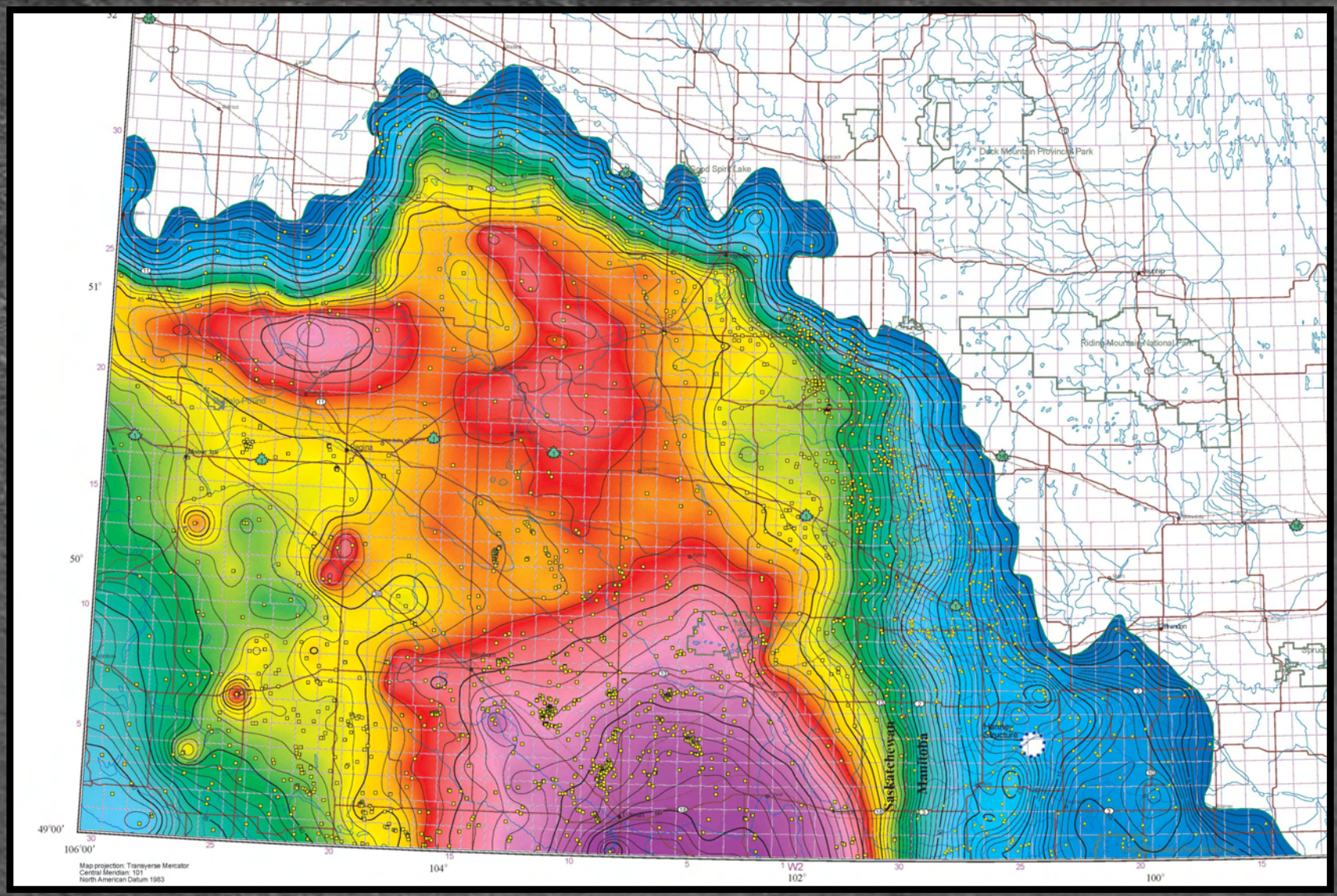
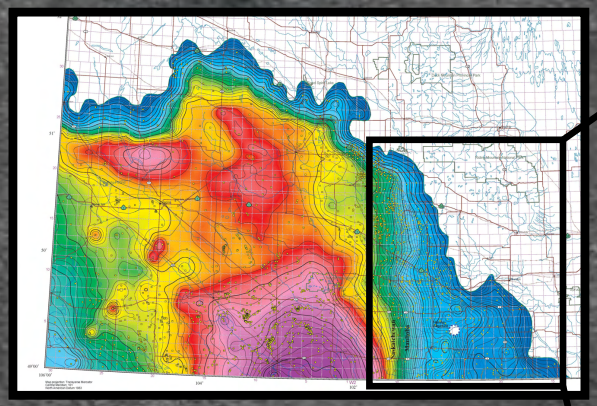
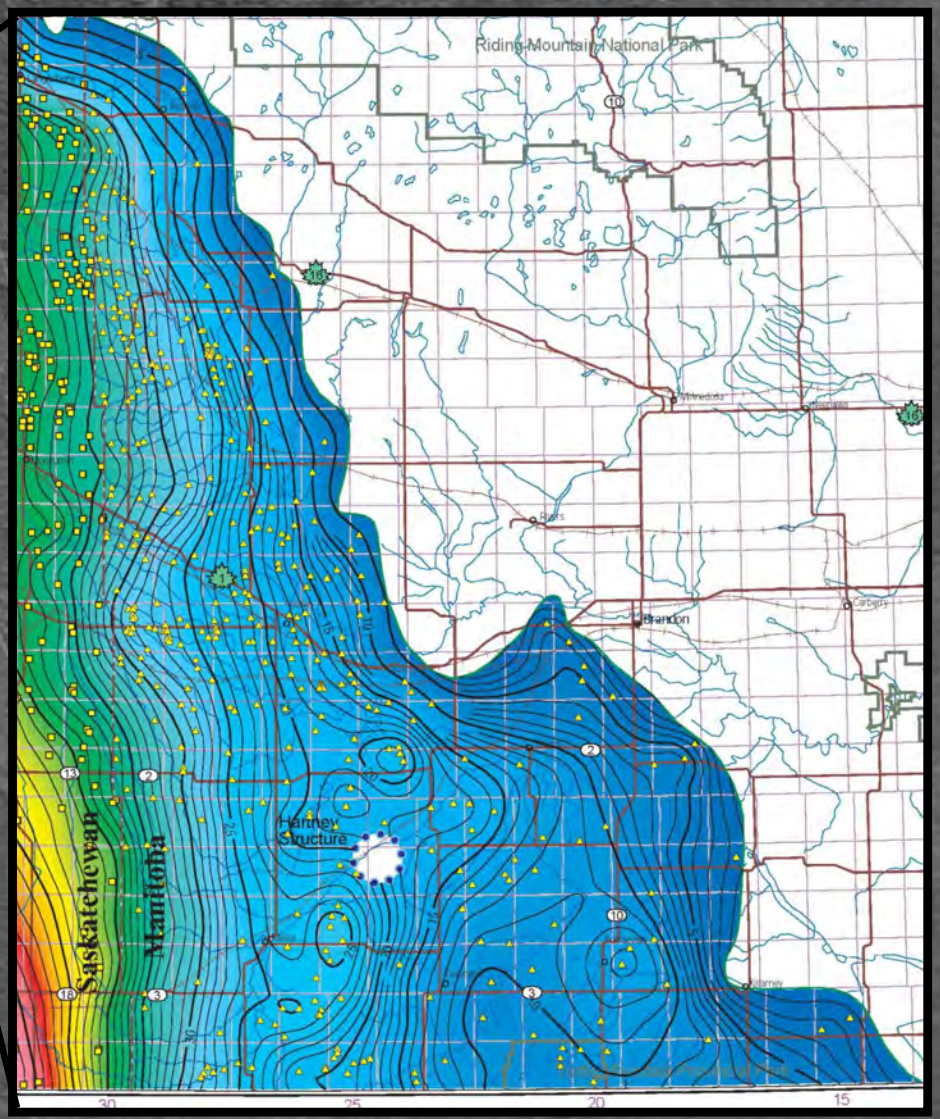


Three Forks Isopach

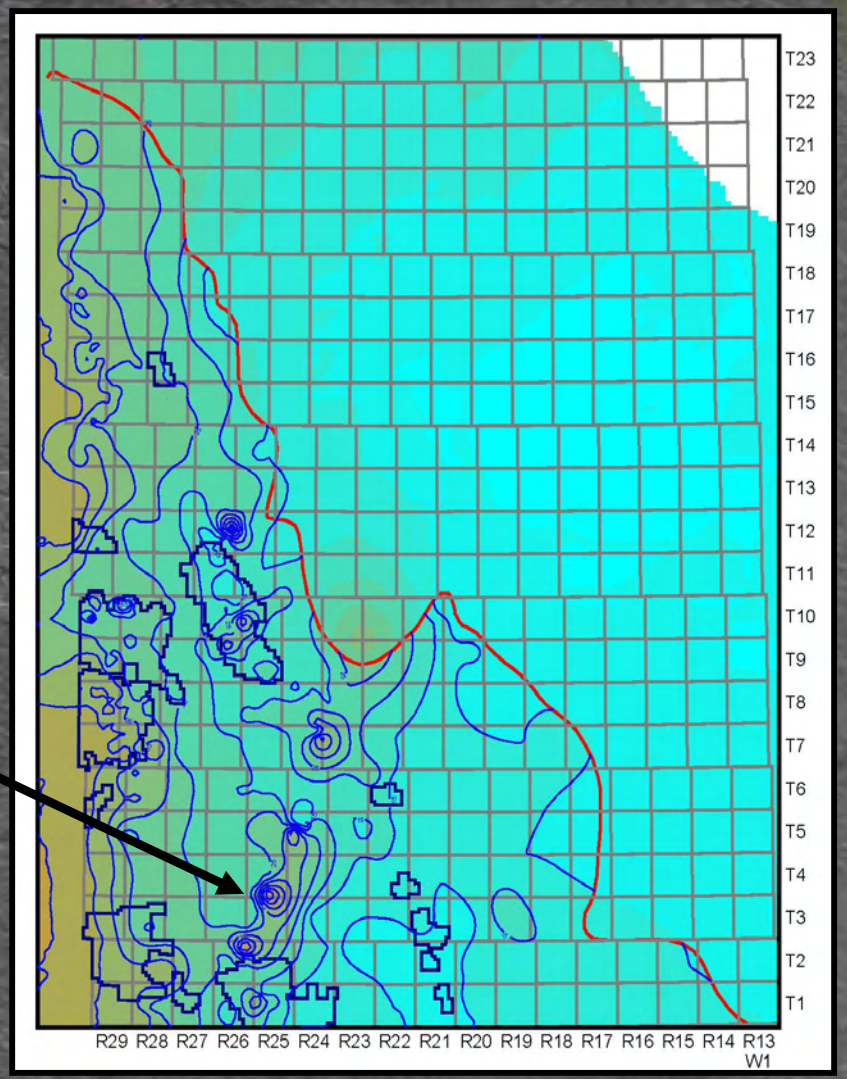


- Thin in Manitoba due to erosion
- Thickest in the west along the MB-SK border



Three Forks Isopach

- Thickest in the west along the MB-SK border
- Localized thickening in the east



Contour Interval = 5 m

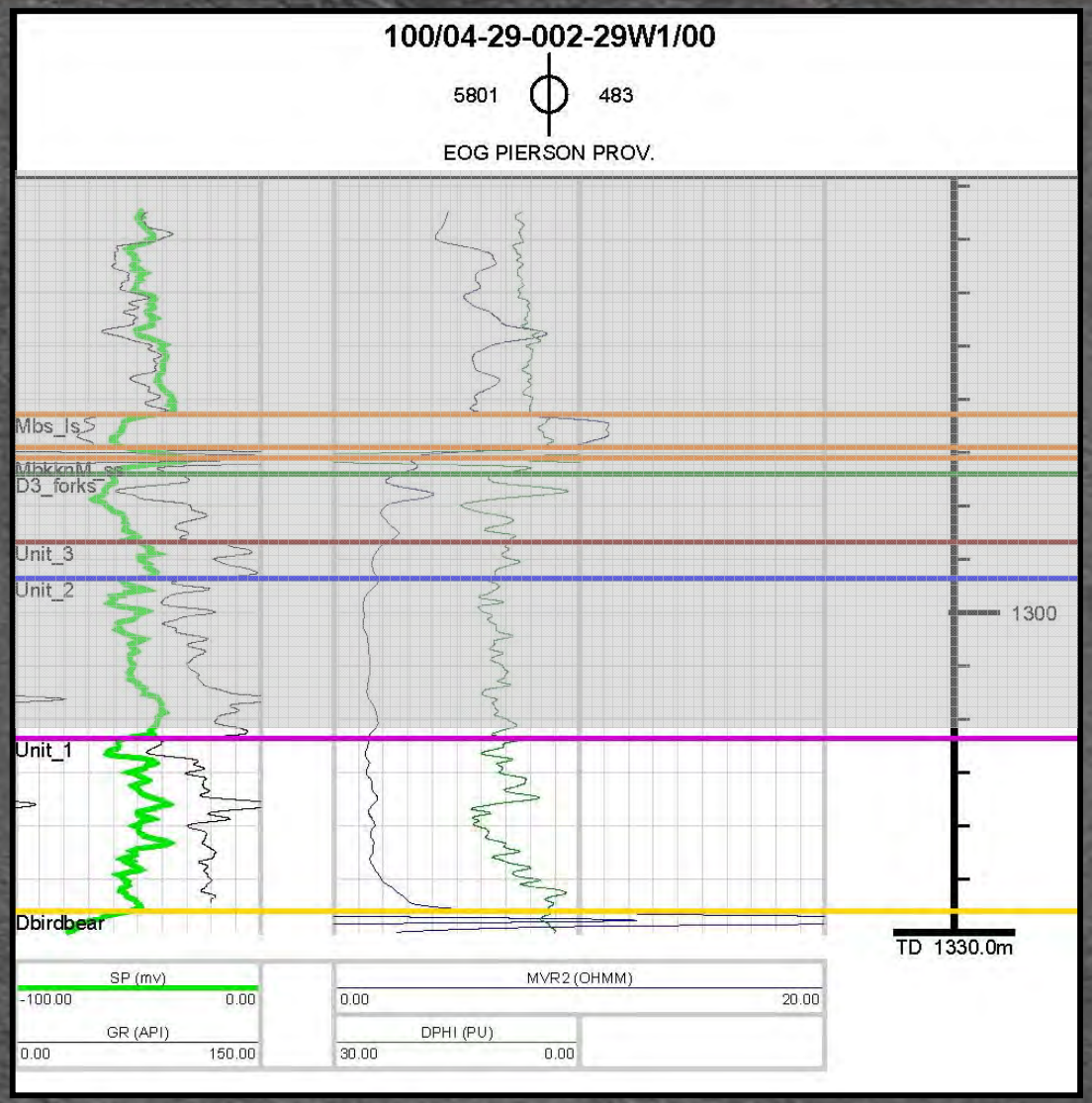
Three Forks – Unit 1

- Lowermost unit
- Highly oxidized with reduction halos
- Original fabric: Brecciated argillaceous dolomite with grey-green silty shale matrix.
- Highly fractured, unoxidized zone near top of unit; productive at 9-30-7-28W1.

9-22-8-28W1

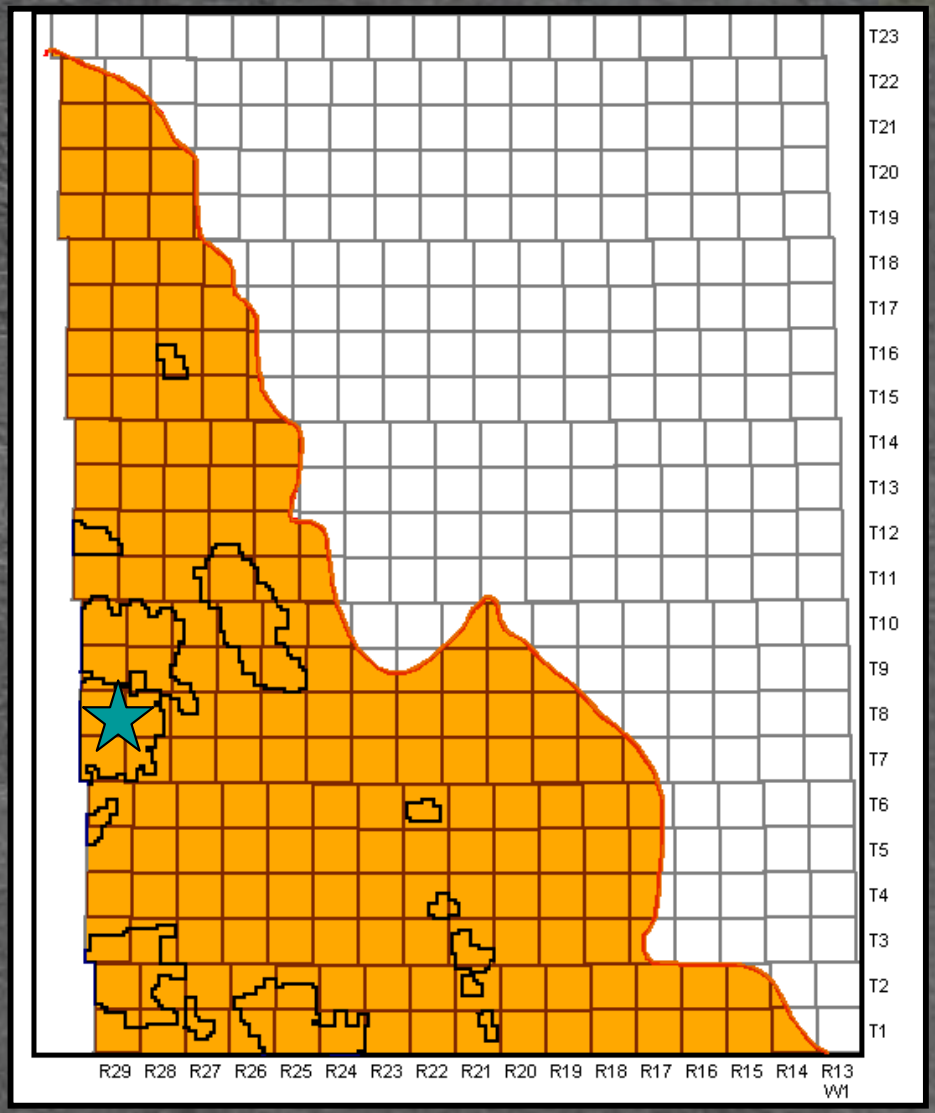
14-32-10-24W1

Reference Log – Unit 1



Three Forks – Unit 1

- Widespread distribution.
- Fairly constant isopach:
  - average = 16 m.
- Productive in a small isolated pool at Sinclair.
- Future reservoir potential is unknown.

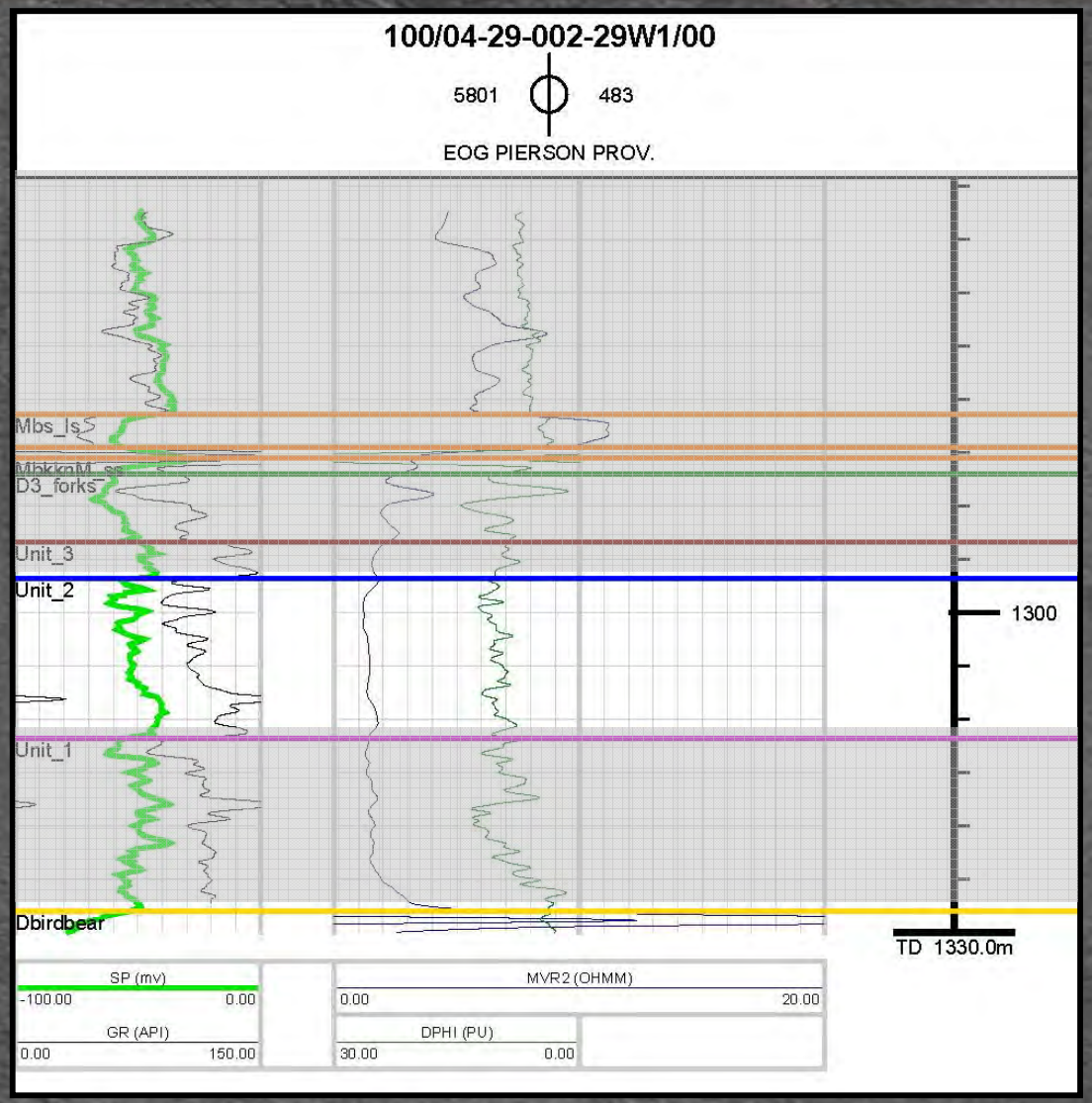


Three Forks – Unit 2

- Interbedded siltstone, shales and claystones.
- Massive and brecciated in places.
- Partially oxidized.
- Porosity decreases with depth.

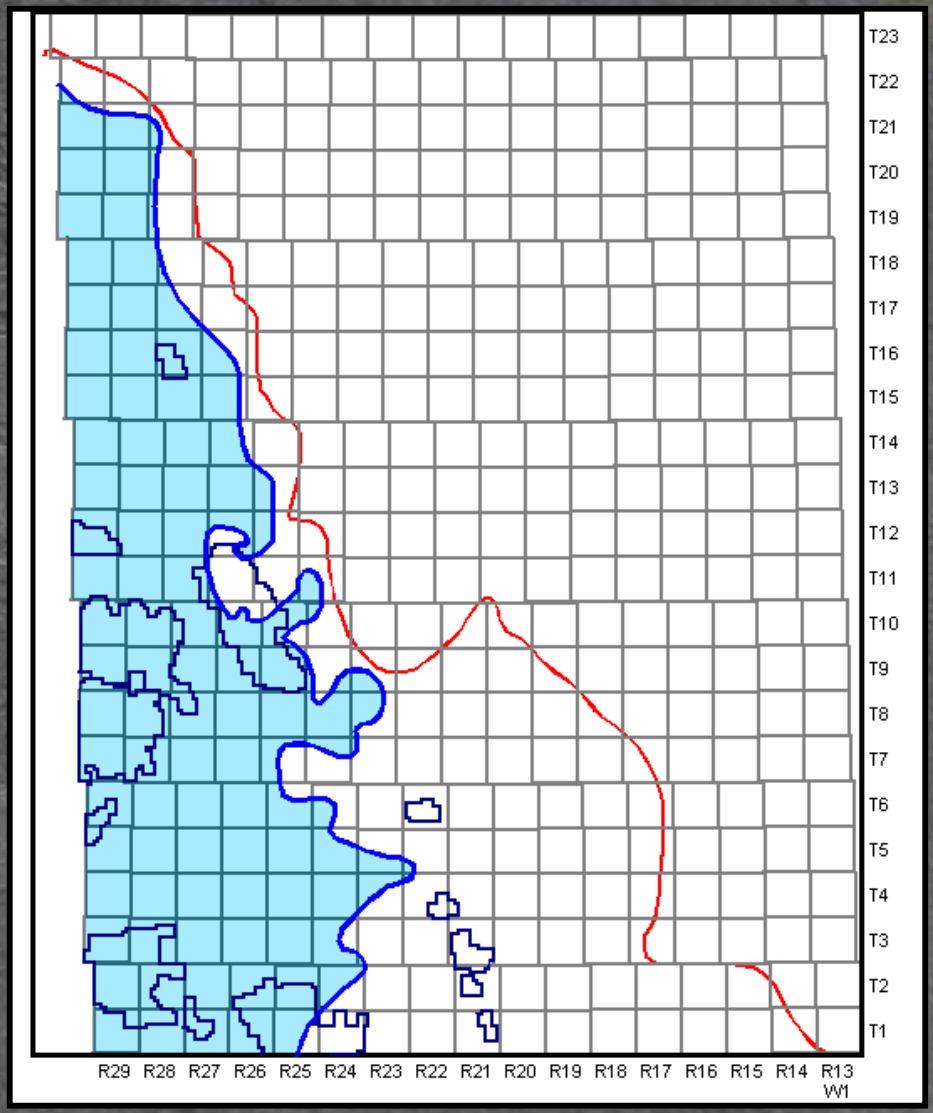
2-2-8-29W1

Reference Log – Unit 2



Three Forks – Unit 2

- Isopach: 1-19m
  - Uneroded: ~15 m
- Edge roughly follows the eastern boundary of the BWA & SBZ.
- Primary reservoir in Daly.
- Secondary reservoir unit in Sinclair (poor quality).
- Economically productive when Unit 4 is eroded.

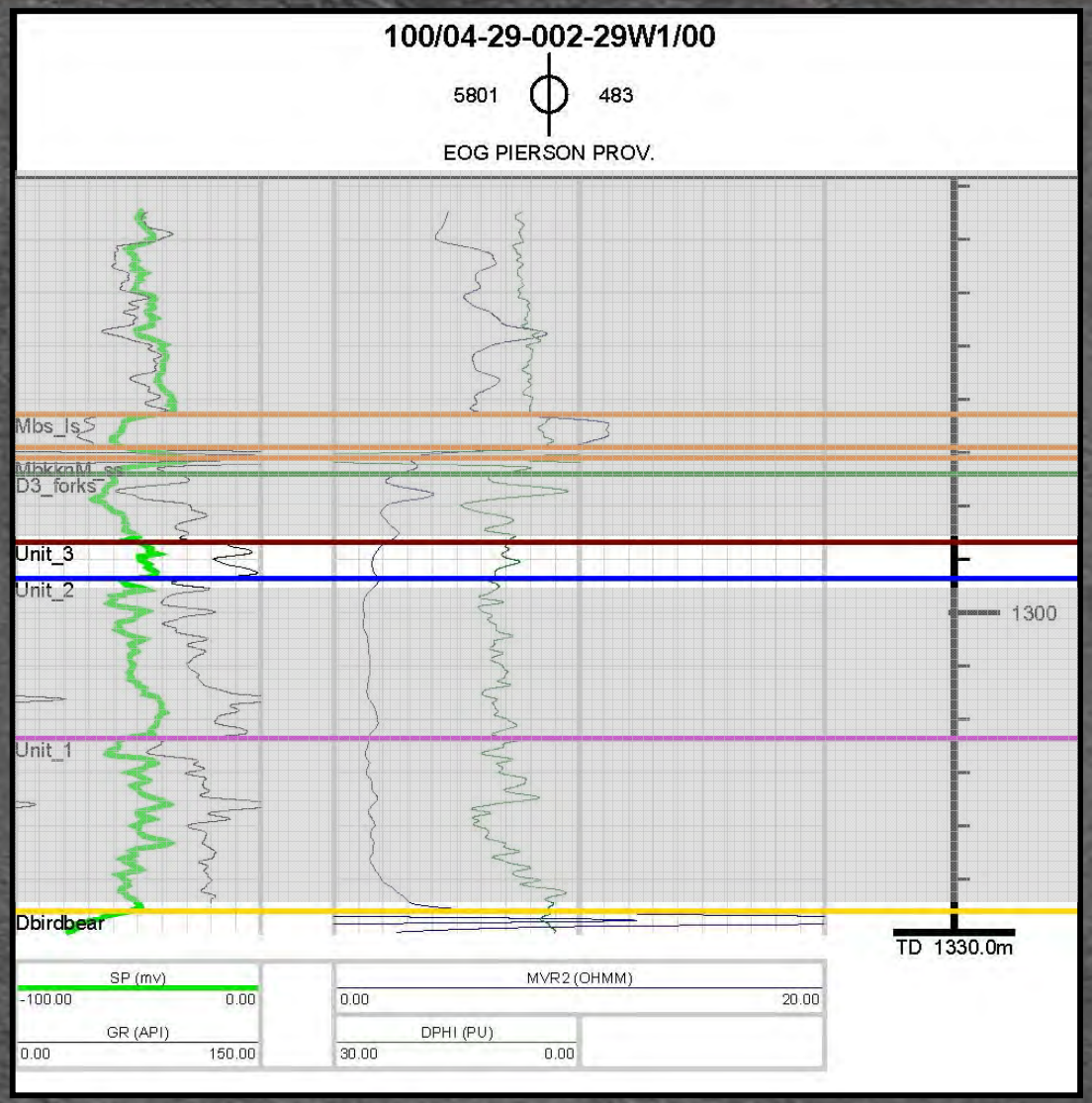


Three Forks – Unit 3

- Red-brown highly oxidized silty dolomitic shale.
- Rare reduced halos.
- Thinnest unit :
  - 3.5 m isopach.
- Generally a tight unit; poor reservoir, but productive when exposed at unconformity in Sinclair .

2-2-8-29W1

Reference Log – Unit 3



Lodgepole

Bakken

Unit 4

Unit 3

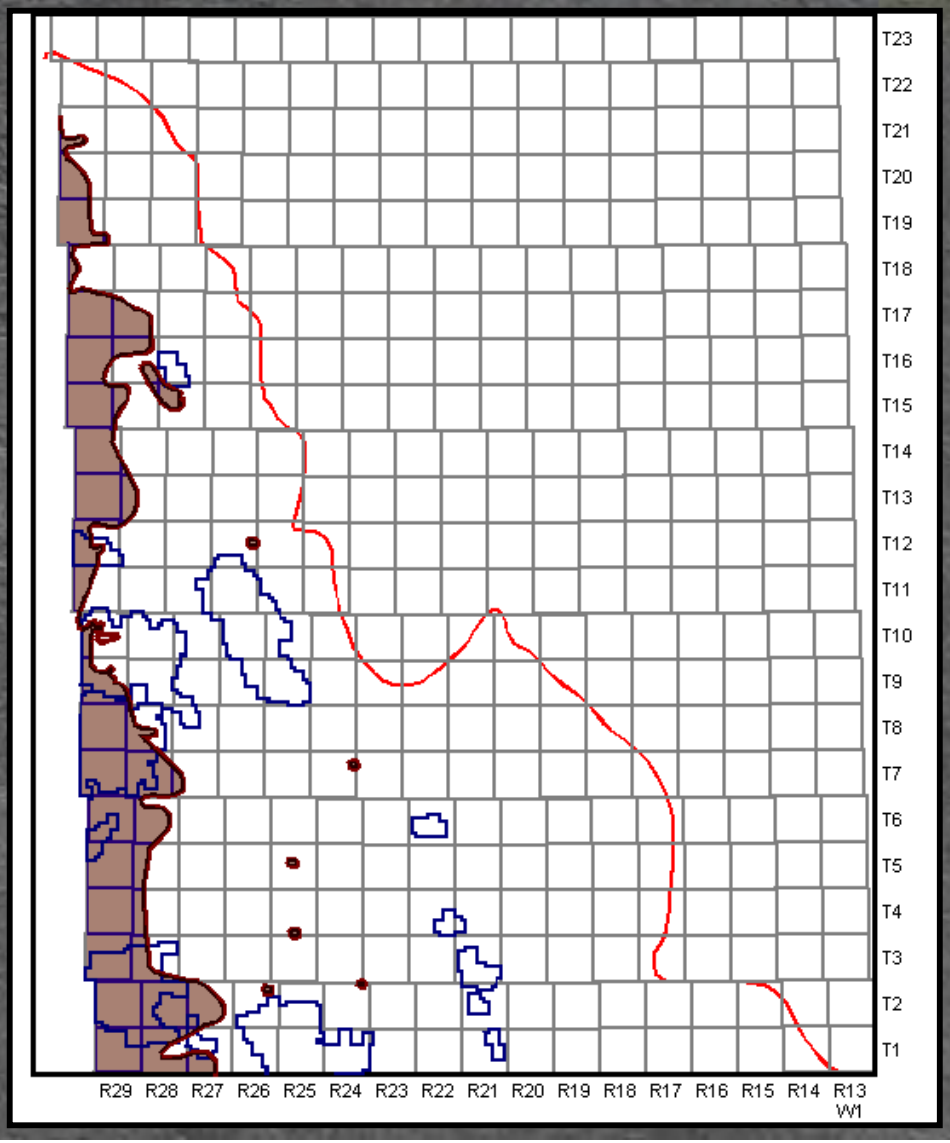
Unit 2

Unit 1

Birdbear

Three Forks – Unit 3

- Distribution follows Unit 4 closely
- More section preserved in isolated wells in the east



Three Forks – Unit 4

- Interbedded siltstone, argillaceous dolomites and silty dolomitic shale with thick subunits of distorted bedding and brecciated dolomitic siltstone.
- Primary, most productive reservoir unit (subunit 4c is best reservoir).

Subunit 4c:
Good reservoir

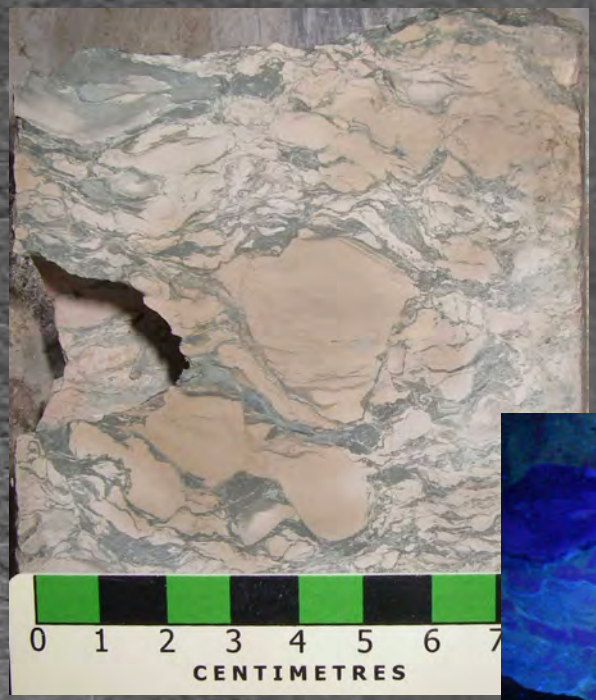
Subunit 4b:
Fair reservoir

2-2-8-29W1

Three Forks – Unit 4

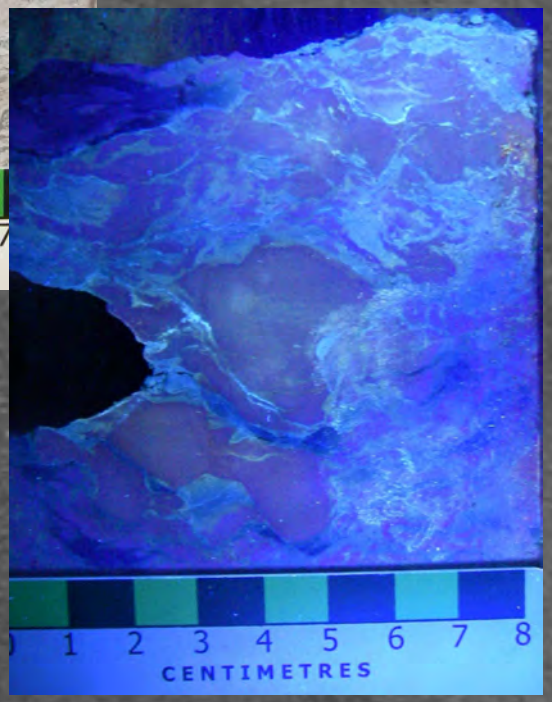
Good reservoir porosity and permeability.

Subunit 4c
4-29-8-29W1
Plain and UV light

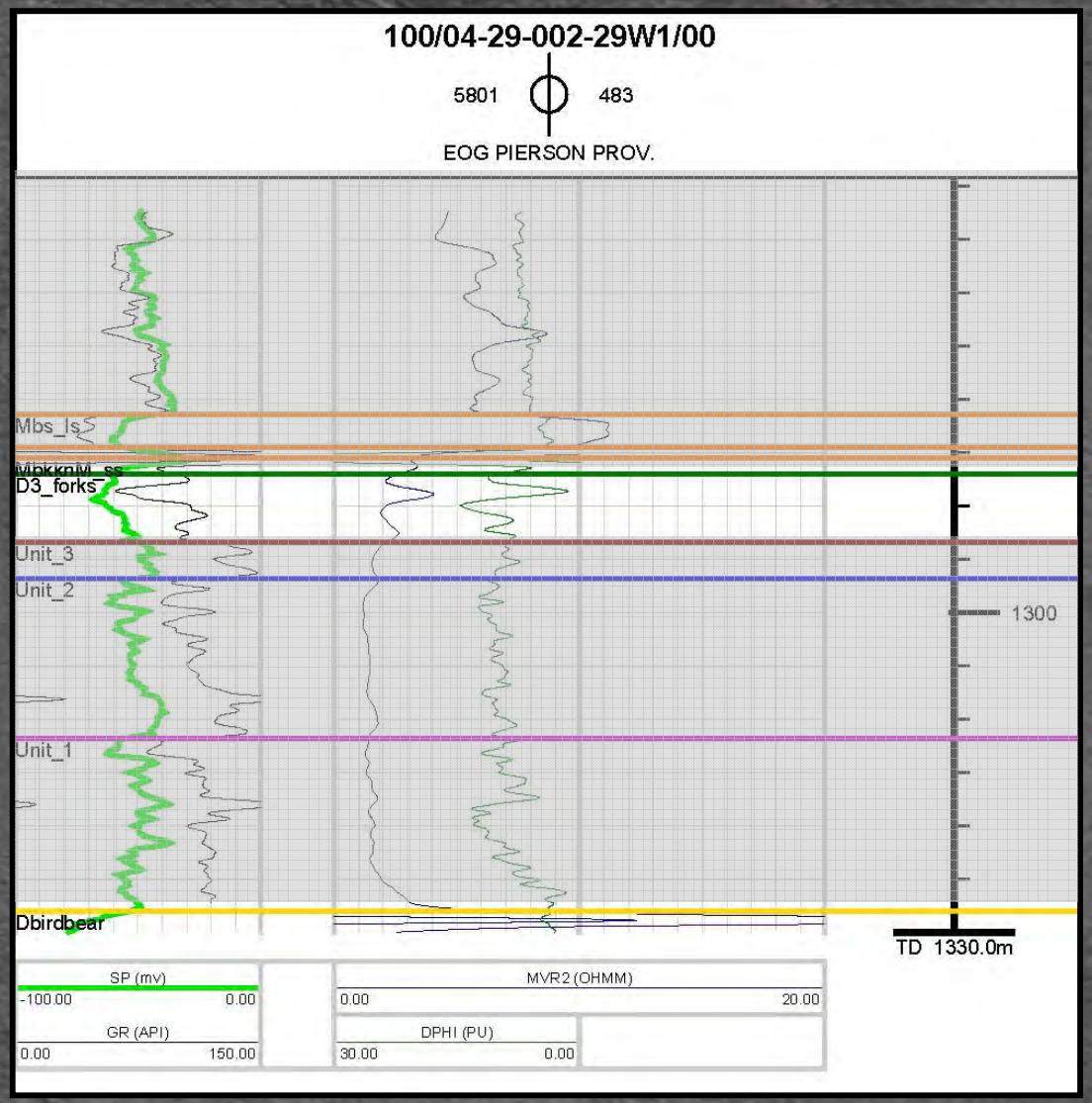


Subunit 4b
4-29-8-29W1
Plain and UV light

Fair reservoir porosity and permeability.



Reference Log – Unit 4



Lodgepole

Bakken

Unit 4

Unit 3

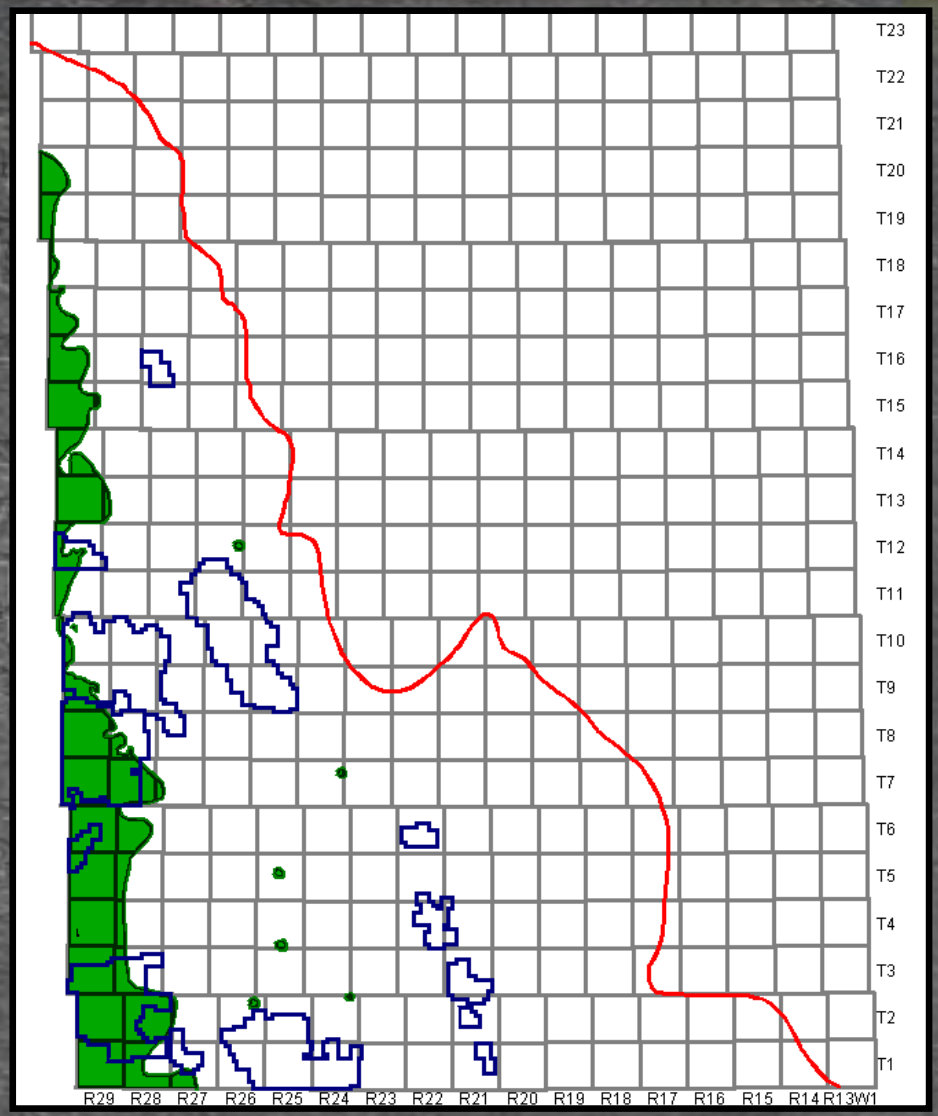
Unit 2

Unit 1

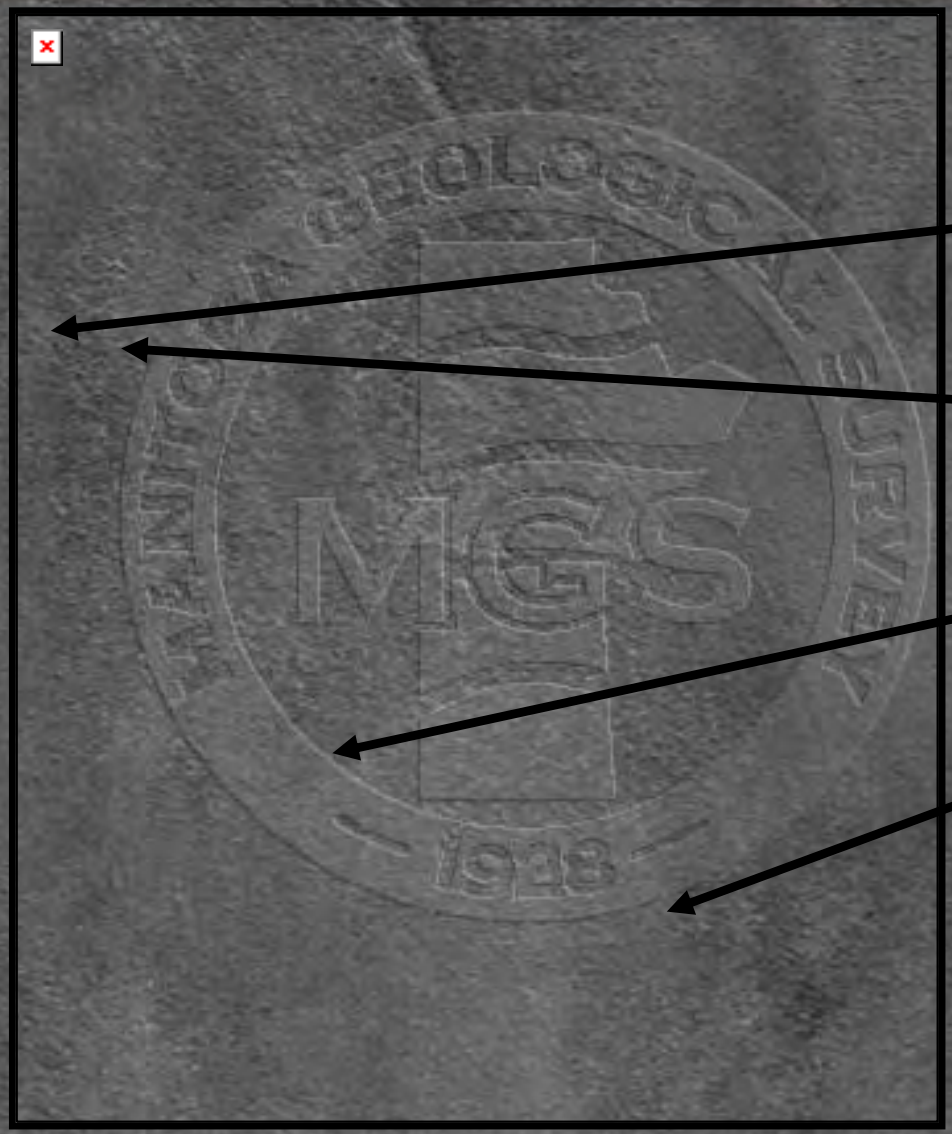
Birdbear

Three Forks – Unit 4

- Isopach: 1-14 m
  - average = 6 m
- Limited distribution
  - Restricted to the Ranges 29 & 28 W1
  - More section preserved in isolated wells in the east
- Primary reservoir at Sinclair
  - Also SW Daly and Kirkella
- Average core K = 4.3 mD
- Average core Ø = 16.5%
- Oil Saturation = 7.0-34.0 % (Karasinski, 2006)



Three Forks Unit Distribution



Unit 4 (green)

Unit 3 (purple)

Unit 2 (blue)

Unit 1 (red)

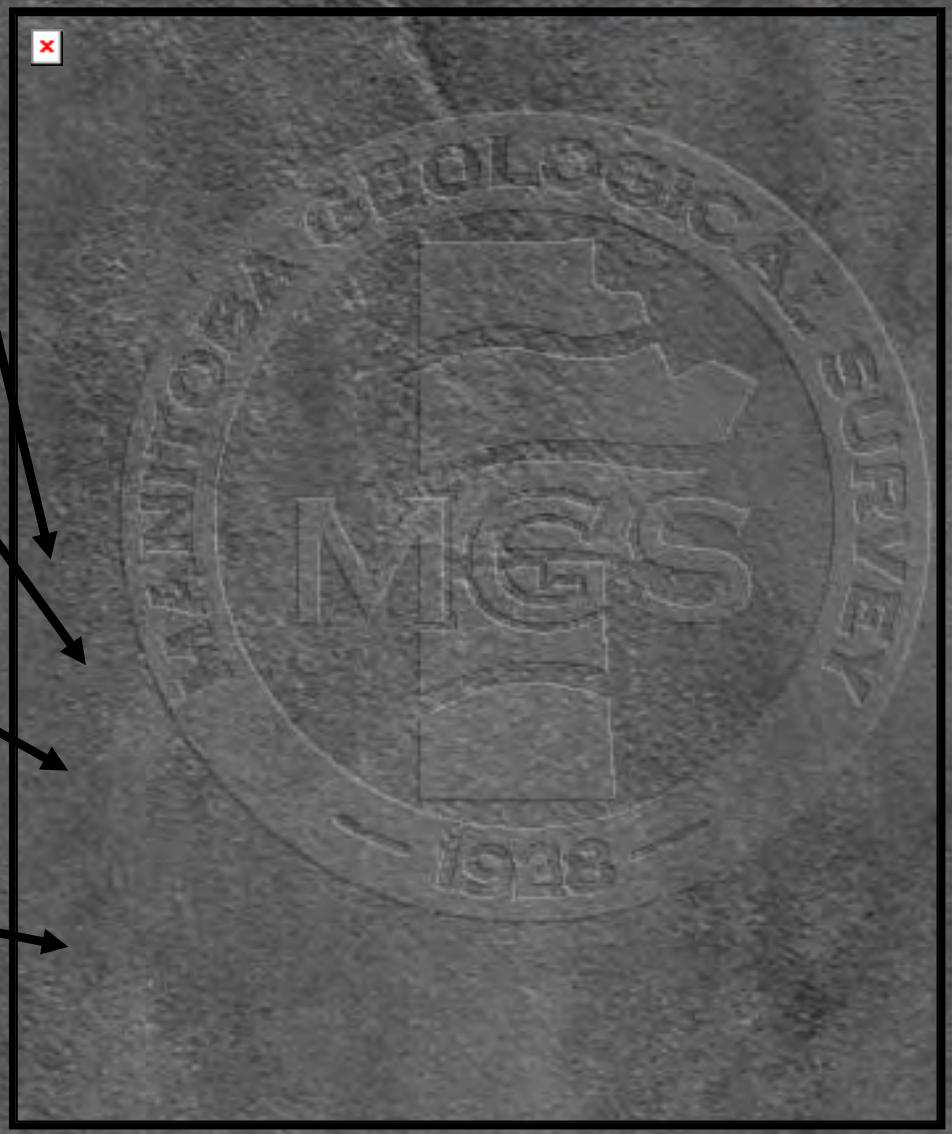
Three Forks Production

Kirkella Field
DIR 11-15-12-29W1:
146 bbl/day*

Daly Field
5-13-10-29W1:
65 bbl/day*

Sinclair Field
HZ 11-8-8-29W1:
115 bbl/day*

North of Pierson Field
HZ 5-8-4-29W1:
3 bbl/day*



Unit 4 (green)

Unit 3 (purple)

Unit 2 (blue)

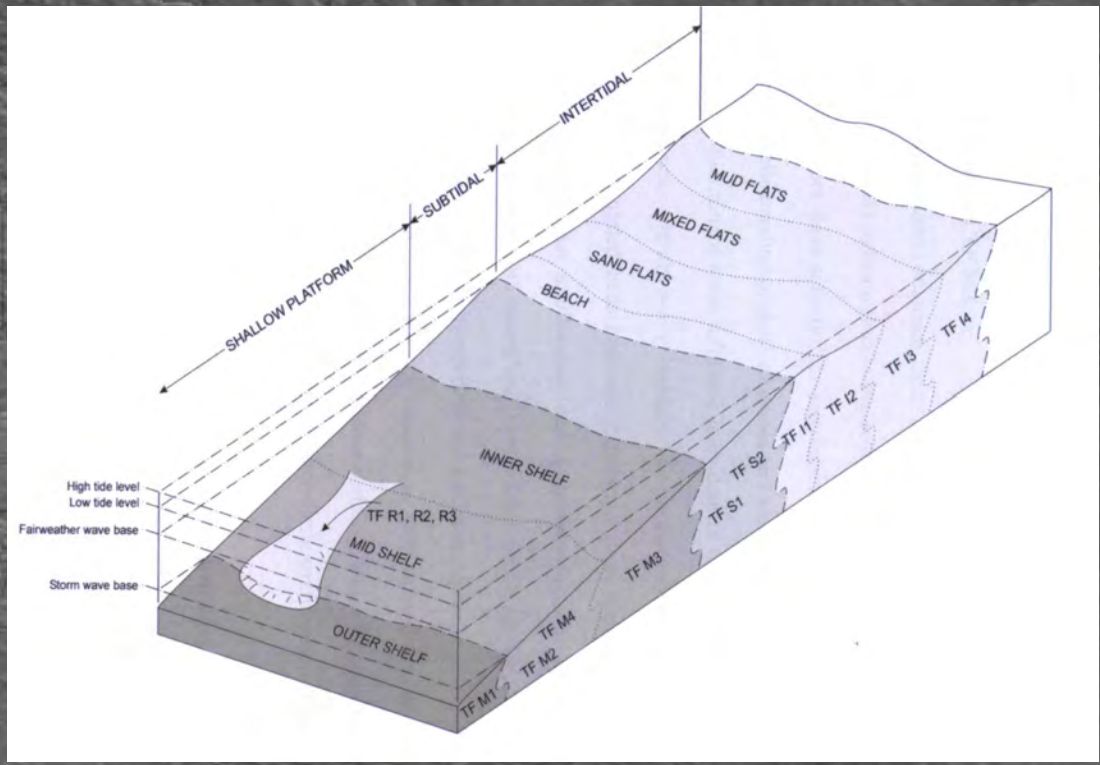
Unit 1 (red)

* First 12 months daily average oil

Depositional Environment

- "Deposited along a temperate, carbonate tidal flat that grades basinward towards an unrimmed carbonate platform." (Karasinski, 2006)

- Karasinski (2006)
  - Unrimmed platform facies
  - High-energy peritidal facies
  - Subaqueous debris flow facies

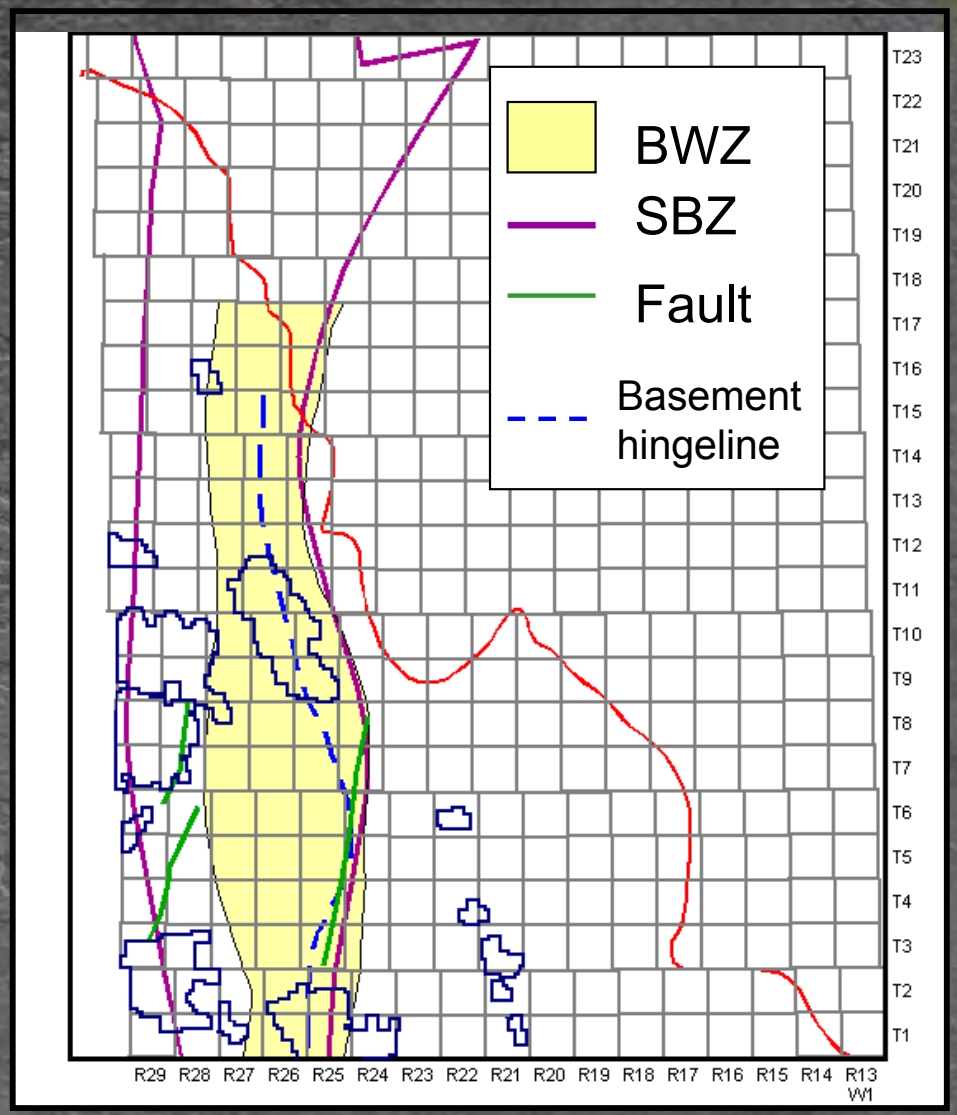


Diagenesis

- Karasinski (2006)
  - Complete dolomitization
    - Early stage: Upper Devonian & Mississippian seawater
    - Late stage: post-Middle Bakken shallow burial and diluted meteoric waters
  - Porosity
    - Fracture porosity
    - Vuggy porosity
    - Moldic porosity
  - Mineralization/cementation
    - Phosphates (early stage)
    - ***Pyrite*** (early and late stage)
      - » Reducing environment
    - Ferric minerals (hematite and Fe-sulphates; late stage)
      - » Oxidizing environment
    - Halite (late stage)
    - Authigenic silicates (quartz, K-feldpar, illite; late stage)
    - ***Anhydrite*** (latest stage)

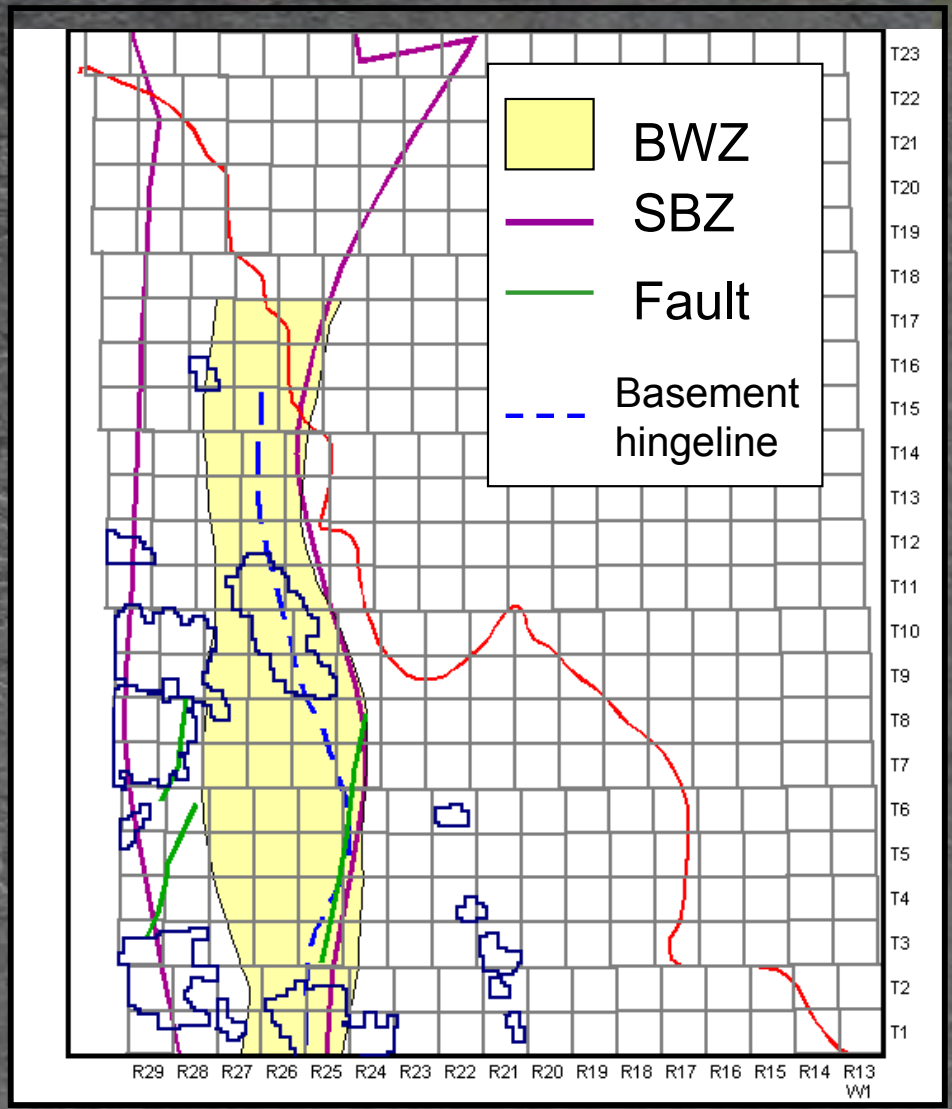
Tectonic Controls

- Birdtail-Waskada Zone (BWZ)
- Superior Boundary Zone (SBZ)
- Basement hingeline
- Faulting
  - Basement
  - Salt dissolution (Sinclair)



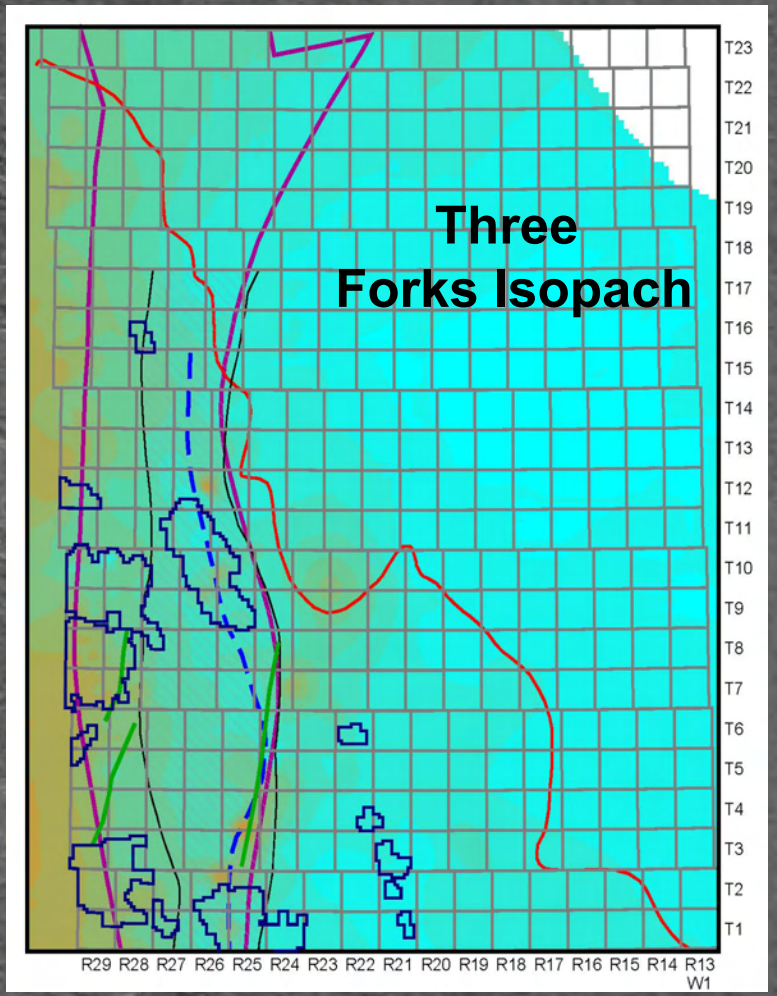
Tectonic Controls - Evidence

- Isopach variations and Unit 4 edge parallel to areas of proposed fautling.
- Rapid truncation of Unit 4 (up to 20 m offset)
- Unit 2 edge coincident with BWZ-SBZ eastern edge.
- Unit 2 isopach “plateau” over BWZ.
- Documented faults in seismic:
  - shallow Devonian faulting in west
  - deep basement-derived faulting in east



Tectonic Controls - Evidence

- Thickening coincident with tectonic elements
- Eastern anomalies likely basement driven
- Possible preservation of “Sanish”-like sand or anomalously thickened Middle Bakken in salt collapse structures.



Isopach Contour Interval = 5 m

Conclusions

- Sinclair is the newest oil field in Manitoba with excellent reserves
- Sinclair Field still growing
- Stratigraphic and structural/tectonic controls on reservoir and oil accumulations
- Largely unexplored and has excellent exploration potential
- Preliminary mapping shows areas of potential targets

Conclusions - Targets

Three Forks Exploration Targets