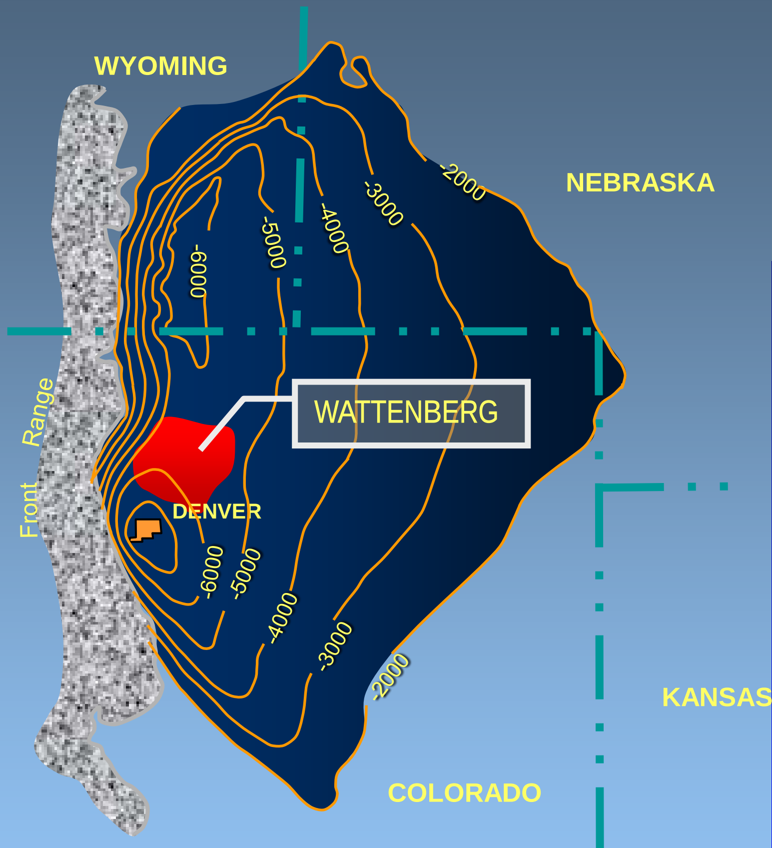
COGCC Hearing Wattenberg Horizontal Rule Making

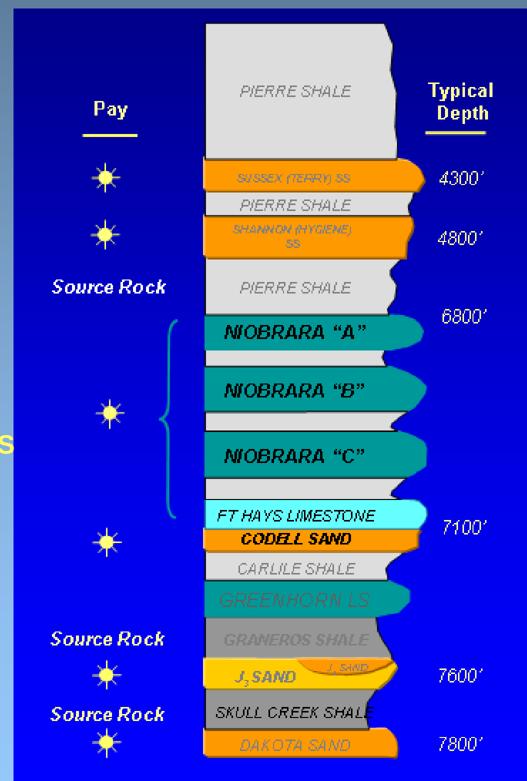
Aug. 8 & 9, 2011

Outline

- General Wattenberg Field information
- Structure/thermal anomaly/pressure envelope
- Major Cretaceous Reservoirs
- Compartmentalization
- Permeability
- Summary

Wattenberg Field – DJ Basin



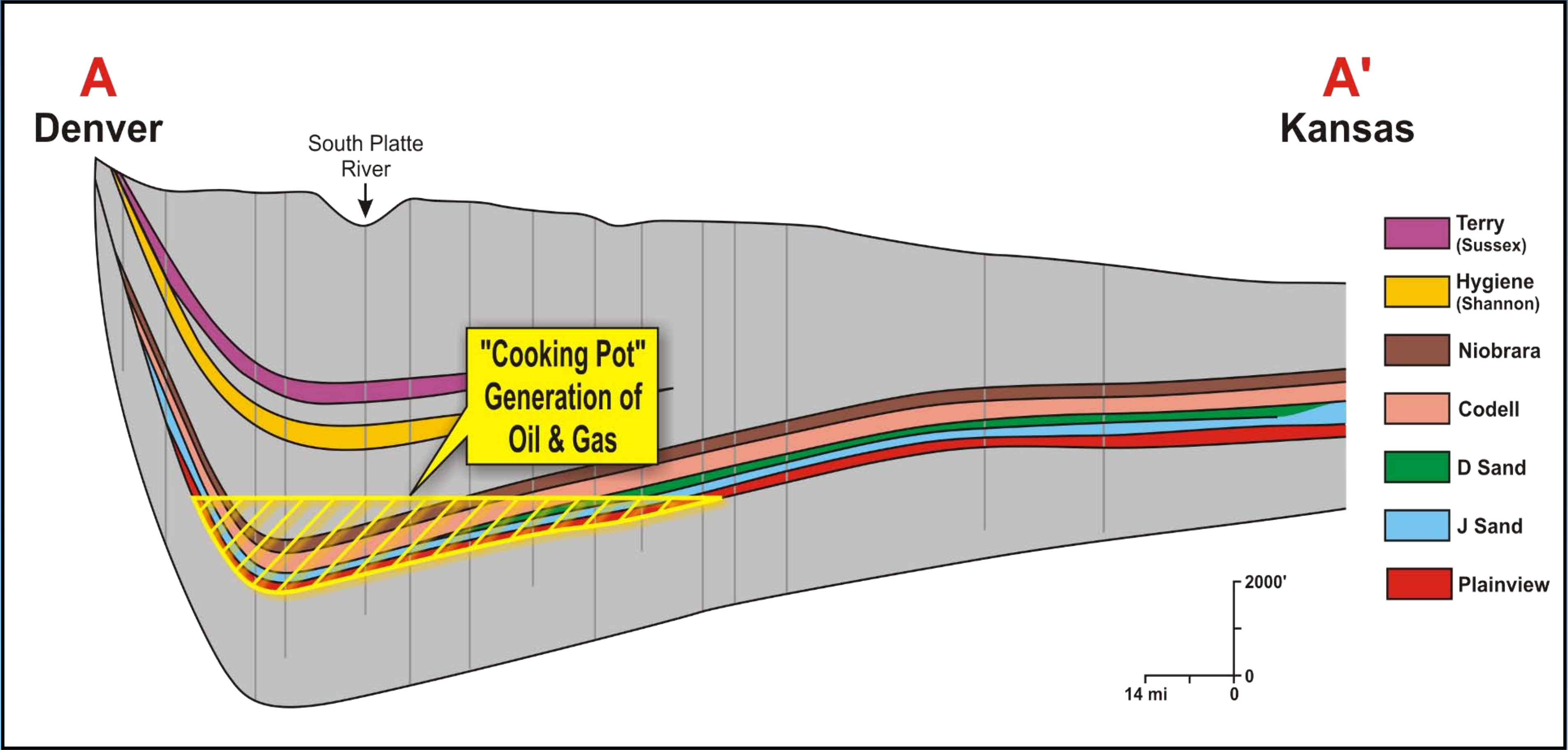


- Discovered 1970
- 1750 mi^2
- **8th Largest US Gas Field**
- Over 18,000 Producing Wells
- CUM **4.9** TCFE
  - 45% > last 6 yrs
  - New Drills >> 700/yr
- J Sand & Codell/Niobrara Reservoirs (Sussex, Shannon, Parkman, Dakota Overlap)

Structural Cross Section of the Denver Basin

West

East

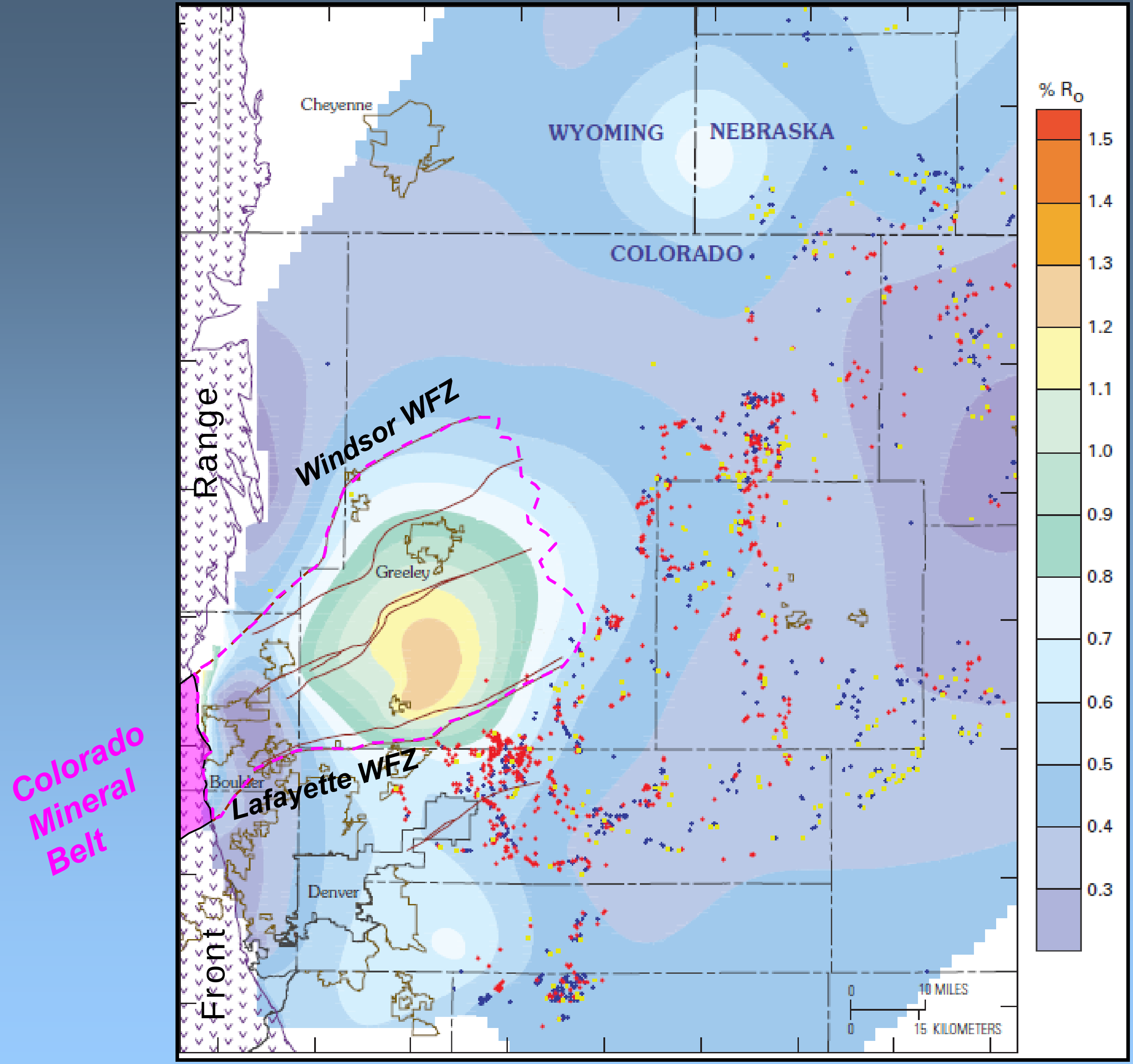


V.E. ~ 37:1

Structural cross section of the Denver Basin showing main reservoir packages and hydrocarbon generation area

Weimer, 1996

Wattenberg Thermal Anomaly

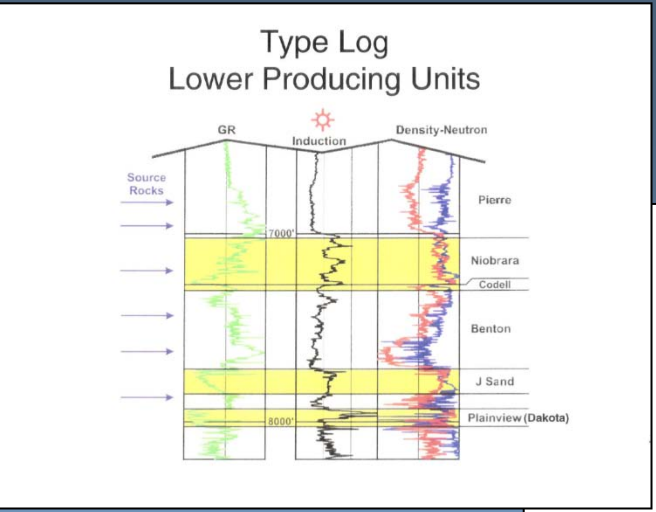


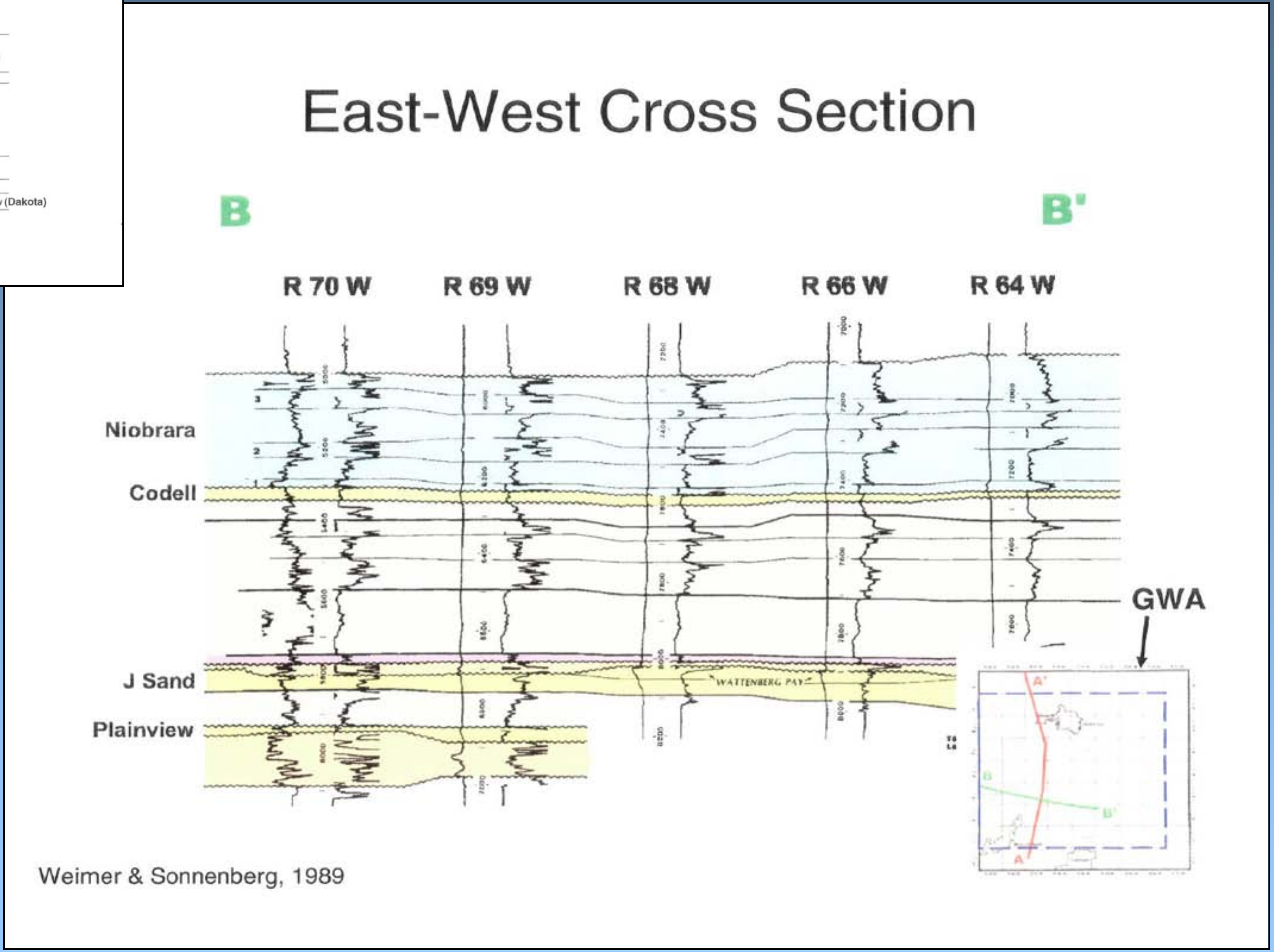
Thermal anomaly over the Wattenberg area as demonstated by vitirnite reflectance data.

- **Colorado Mineral Belt bounded by & projects through Windsor & Lafayette WFZs**
- **Coincidence of Wattenberg Thermal Anomaly within same mega-block**
- **Overpressure envelope coincident with Thermal Anomaly from ~ 5500-7500'**

After Higley & Cox, 2005

Lower Cretaceous Reservoirs

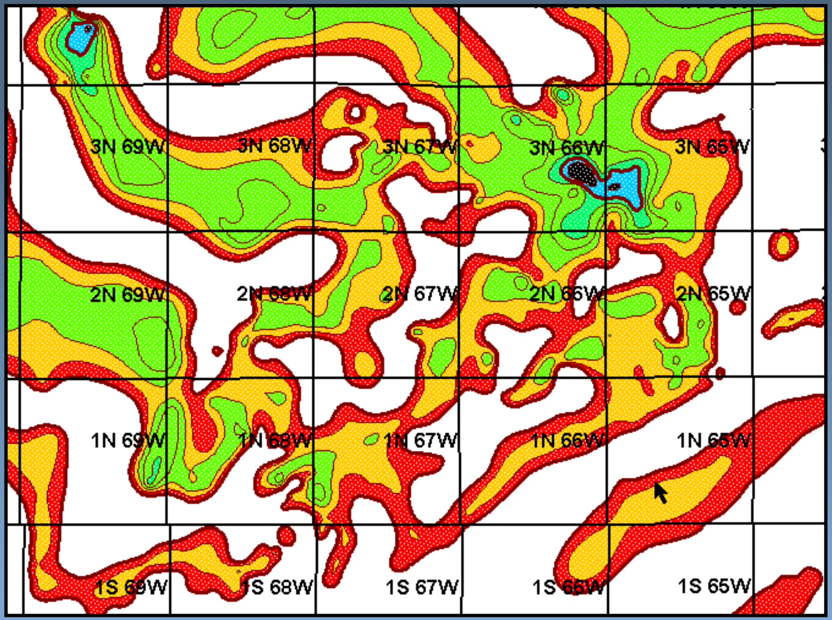




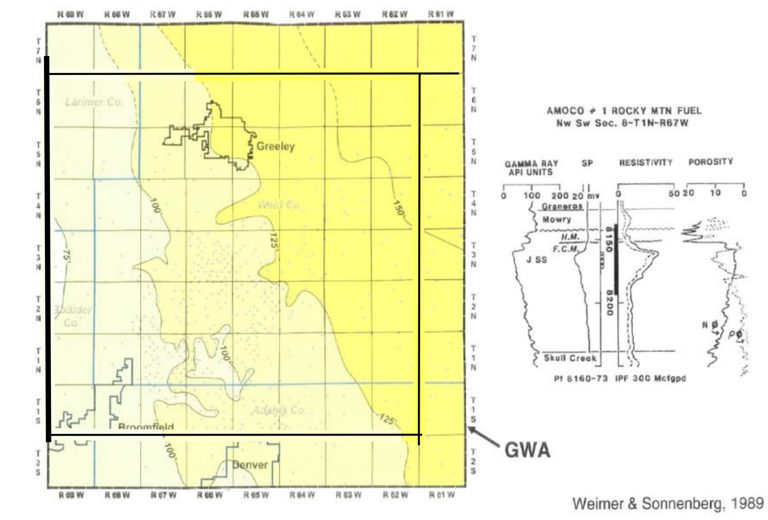
Presented at Rule 318Ae Hearing, 2005

Isopachs of Lower Cretaceous Reservoirs

Isopach of Dakota Sand

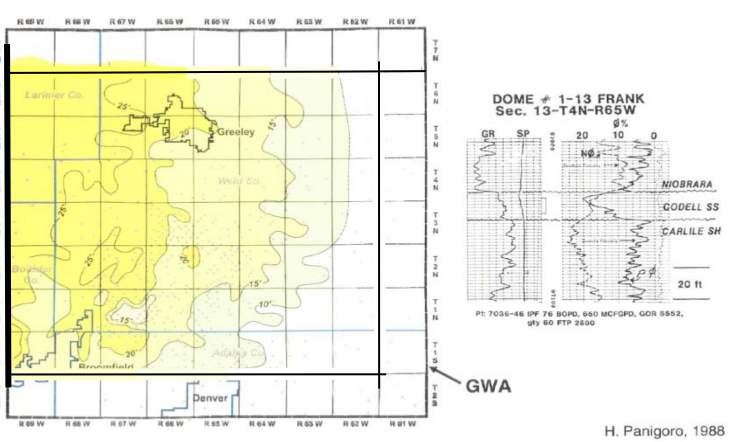


Isopach Map of J Sand



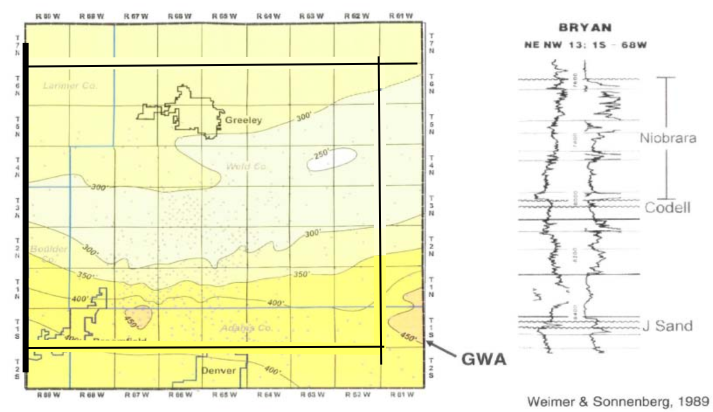
Weimer & Sonnenberg, 1989

Codell Sand



H. Panigoro, 1988

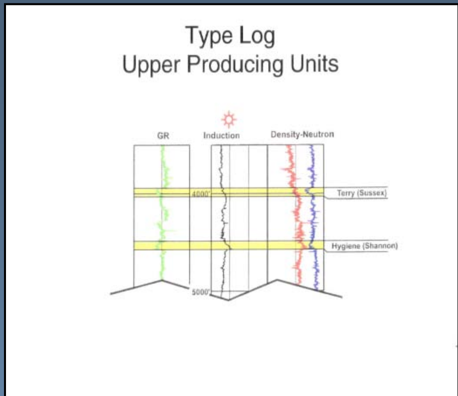
Niobrara Isopach Map



Weimer & Sonnenberg, 1989

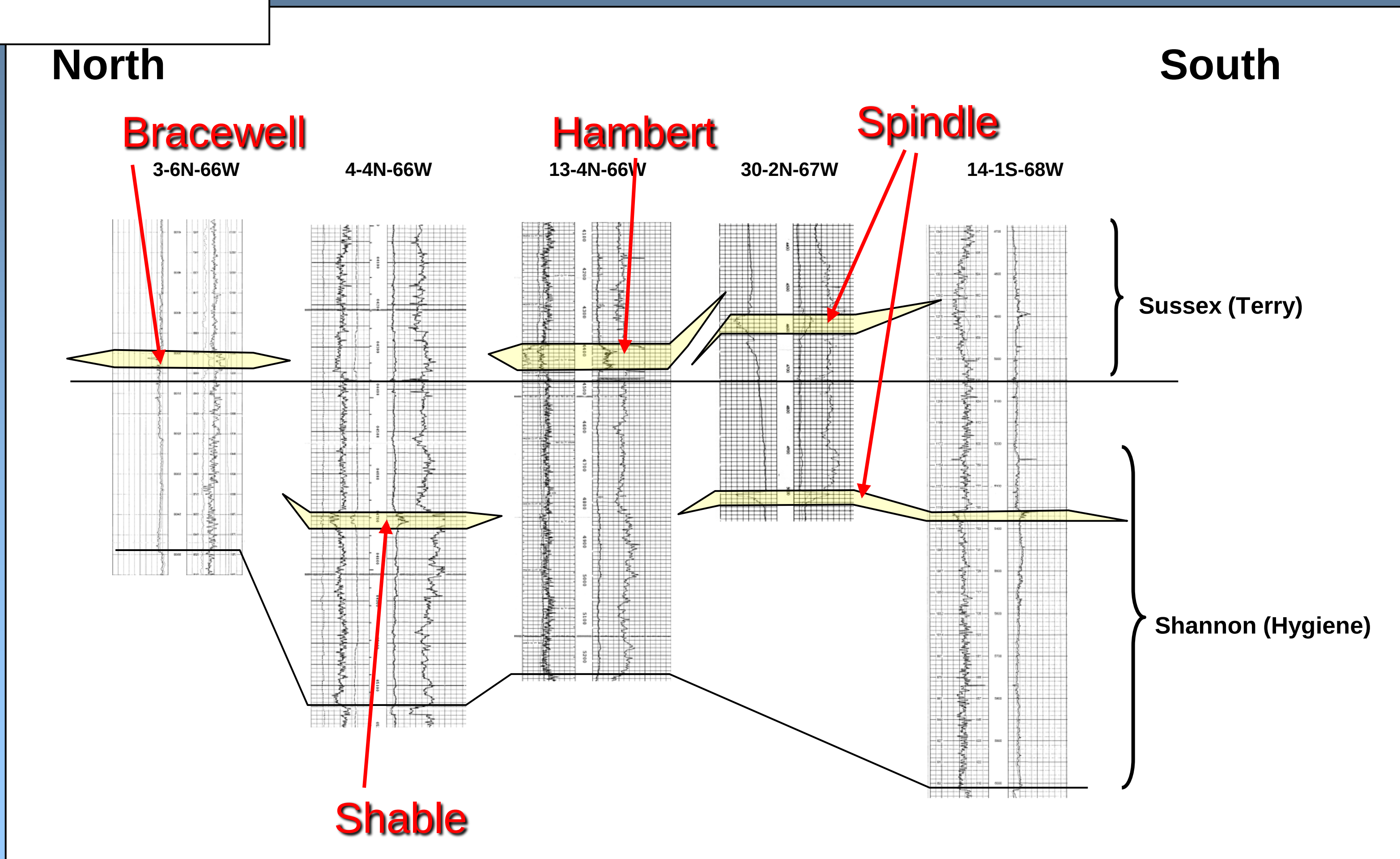
C.I. 10'; 25'; 50'

After Ladd, 2001; Weimer & Sonnenberg, 1989

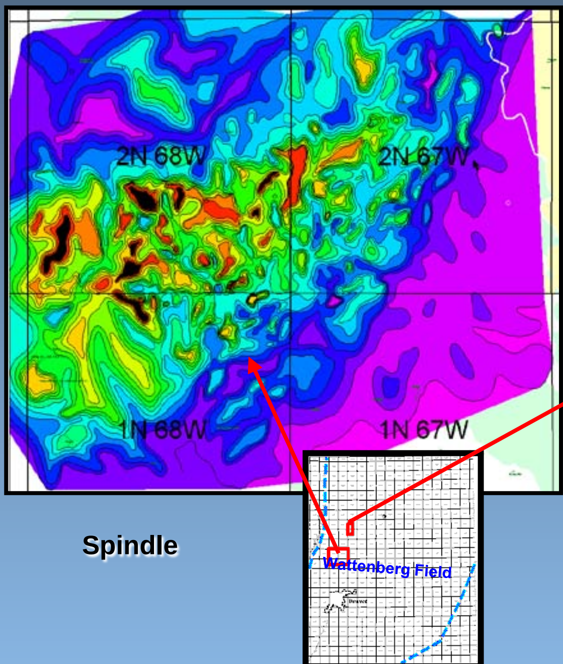


Upper Cretaceous Reservoirs

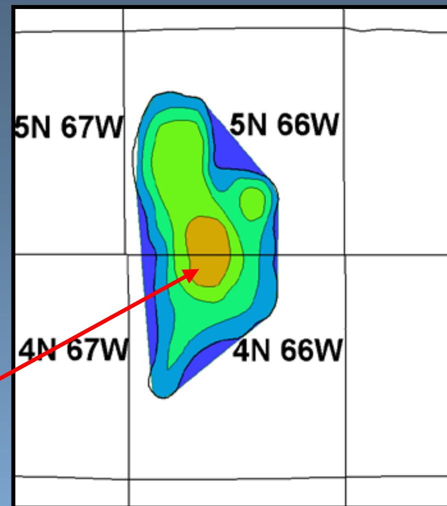
Presented at Rule 318Ae Hearing, 2005



Shannon & Sussex (Upper Cretaceous) Isopachs-Spindle, Shable & Hambert Fields/Areas



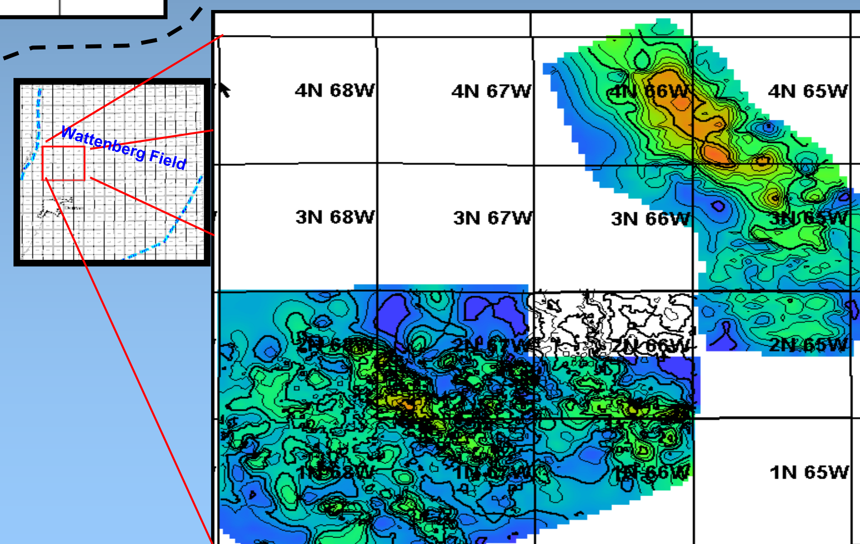
Spindle



Shable

Sussex

Hambert



Spindle

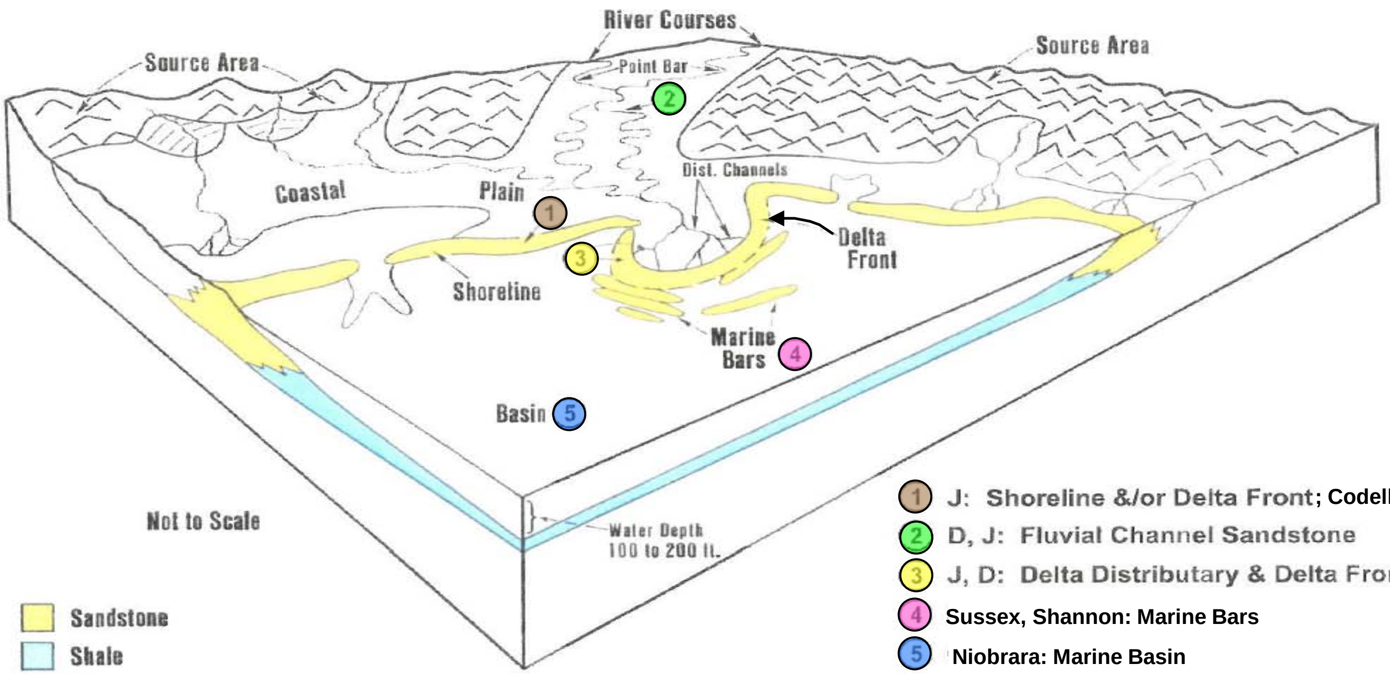
Shannon

C.I. = 5'

Compartments…. Limitations to drainage

Environments of Deposition
Reservoir Compartments

(Mega-Scale)



1 J: Shoreline &/or Delta Front; **Codell: Distal Shoreline**

2 D, J: Fluvial Channel Sandstone

3 J, D: Delta Distributary & Delta Front

4 **Sussex, Shannon: Marine Bars**

5 **Niobrara: Marine Basin**

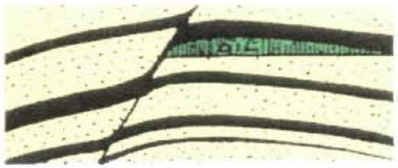
After Weimer, Land, & Porter, 1985

Presented at Rule 318Ae Hearing, 2005

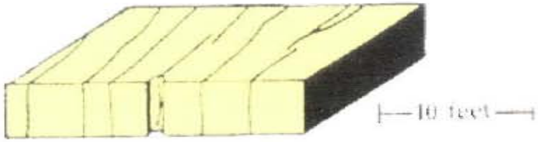
Types of Compartmentalization

Most Common Types

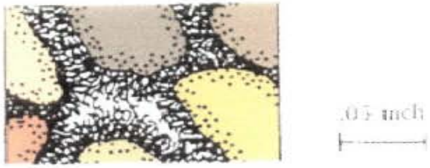
Sealing Fault
Semi-sealing Fault
Non-sealing Fault



Fracturing-Tight
-Open

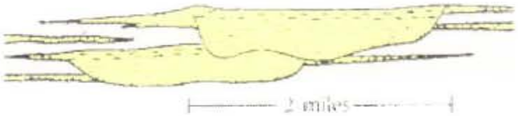


Microscopic Heterogeneity
Textural Types, Diagenesis

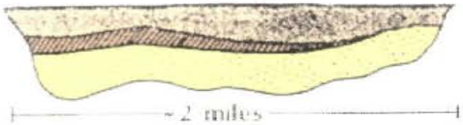


Less Common Types

Boundaries Genetic Units



Permeability Zonation Within Genetic Units

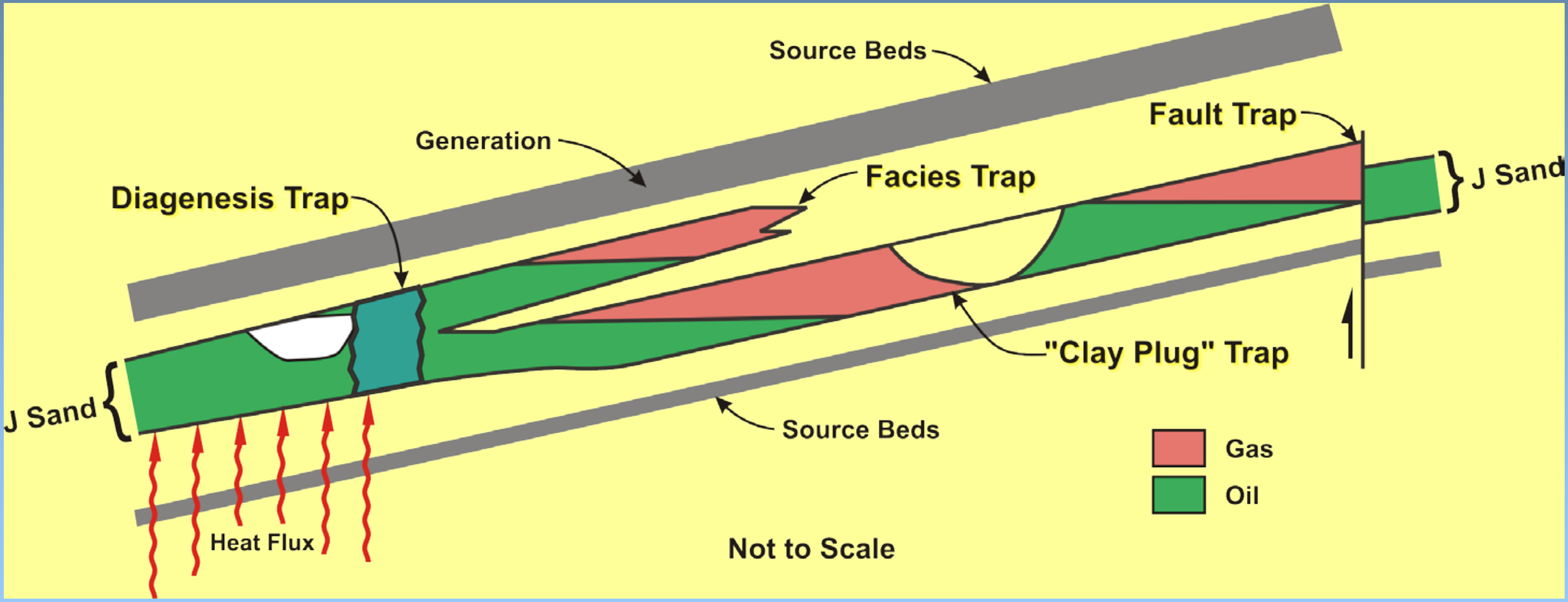


After Weber, 1988

Presented at Rule 318Ae Hearing, 2005

General Compartmentalization Factors for J Sandstone

Diagrammatic Cross Section

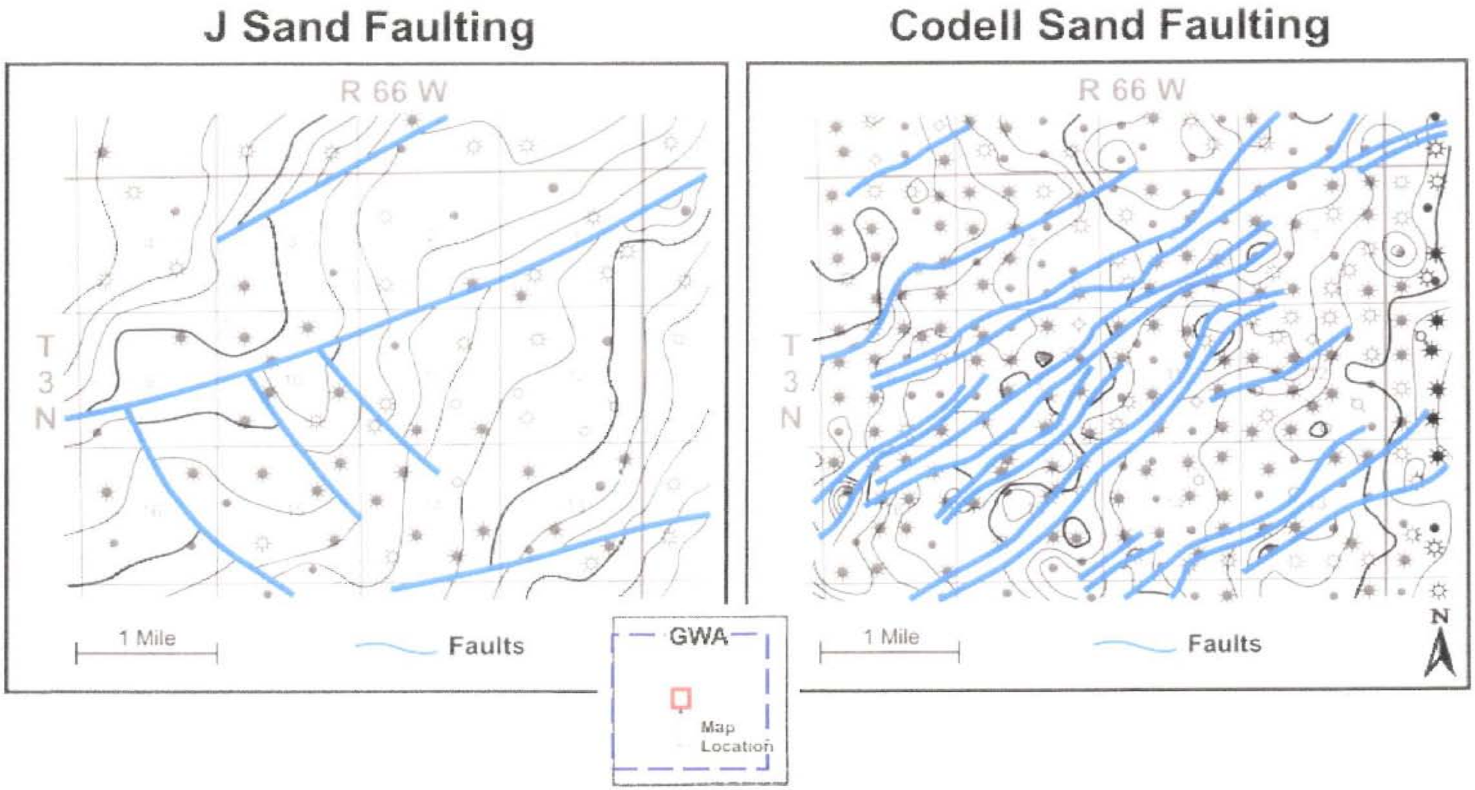


** 1 Horizontal well intersects multiple compartments; 1 vertical well intersects one compartment

Presented at Rule 318Ae Hearing, 2005

Weimer et al, 1998

Codell Faulting Density is Greater than J Sand

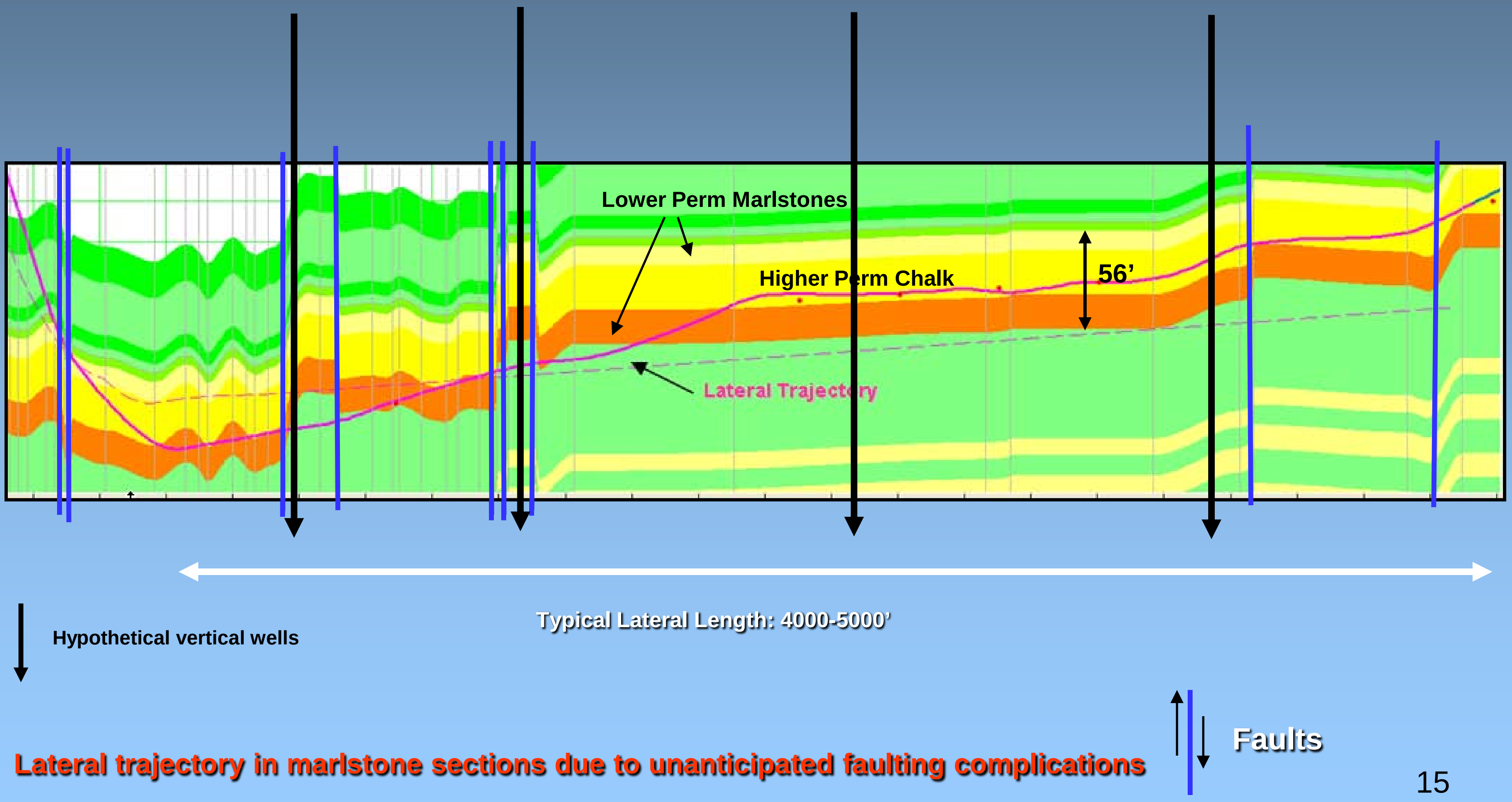


Ladd, 2001

***Niobrara fault density is demonstrably higher**

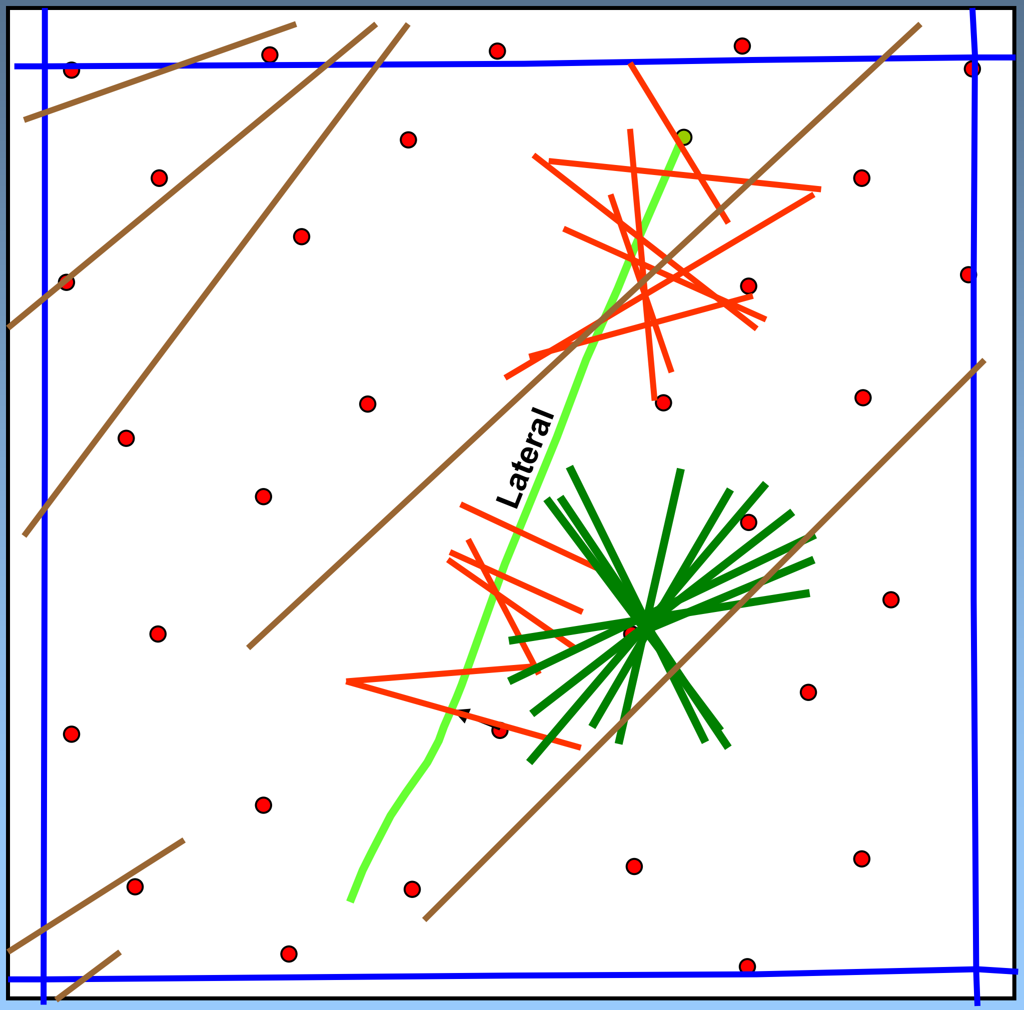
Presented at Rule 318Ae Hearing, 2005

Example Geological Cross Section of Niobrara Horizontal well



Lateral trajectory in marlstone sections due to unanticipated faulting complications

Structural Complexity (faulting)
Map View



Faults

Well-control based

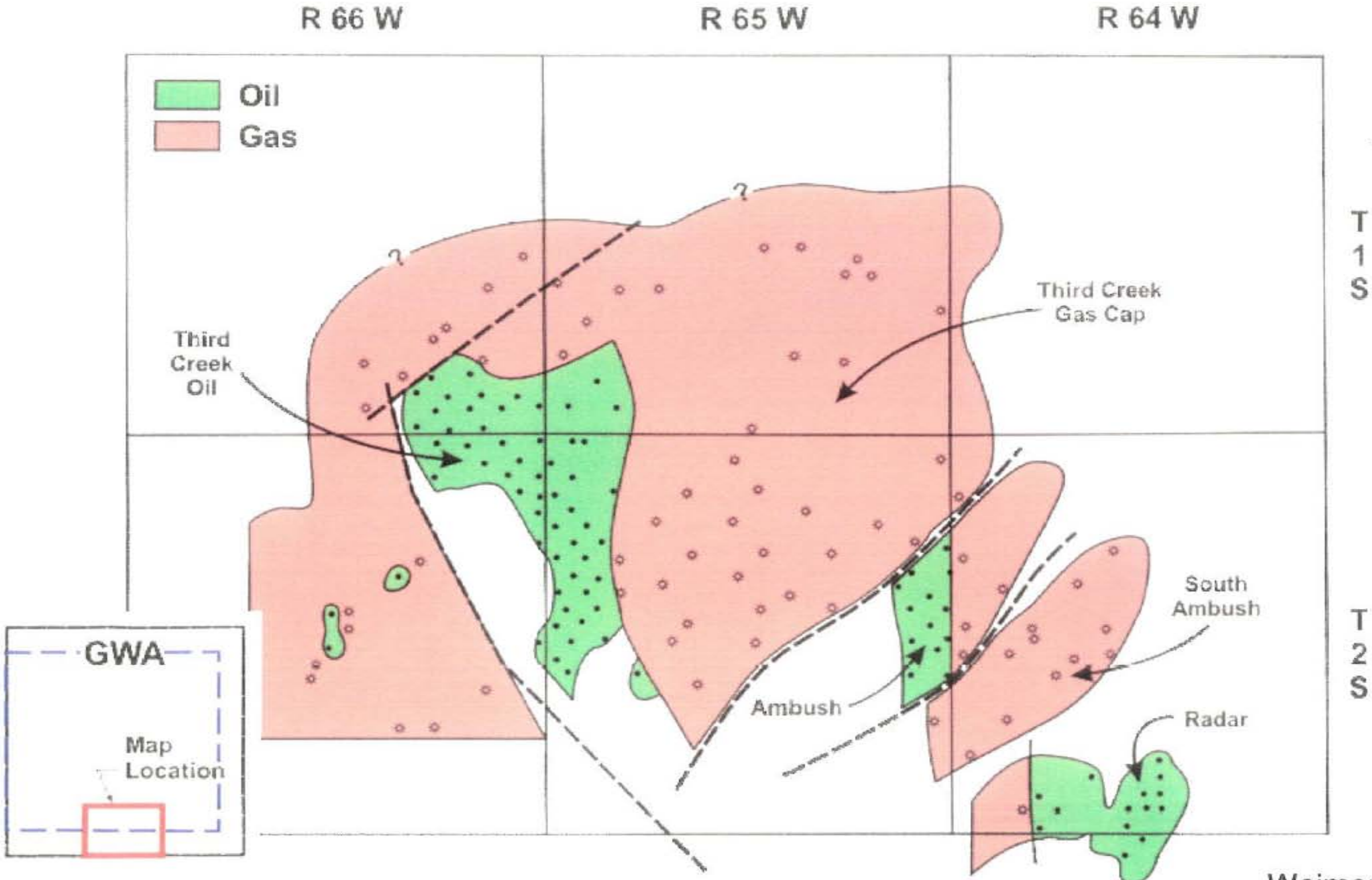
FMI Control (vert)

FMI Control (HZ)

Faults create barriers to fluids & pressure in Cretaceous reservoirs

Reservoir Compartments

DIA Example (South GWA)



Weimer et al, 1998

Presented at Rule 318Ae Hearing, 2005

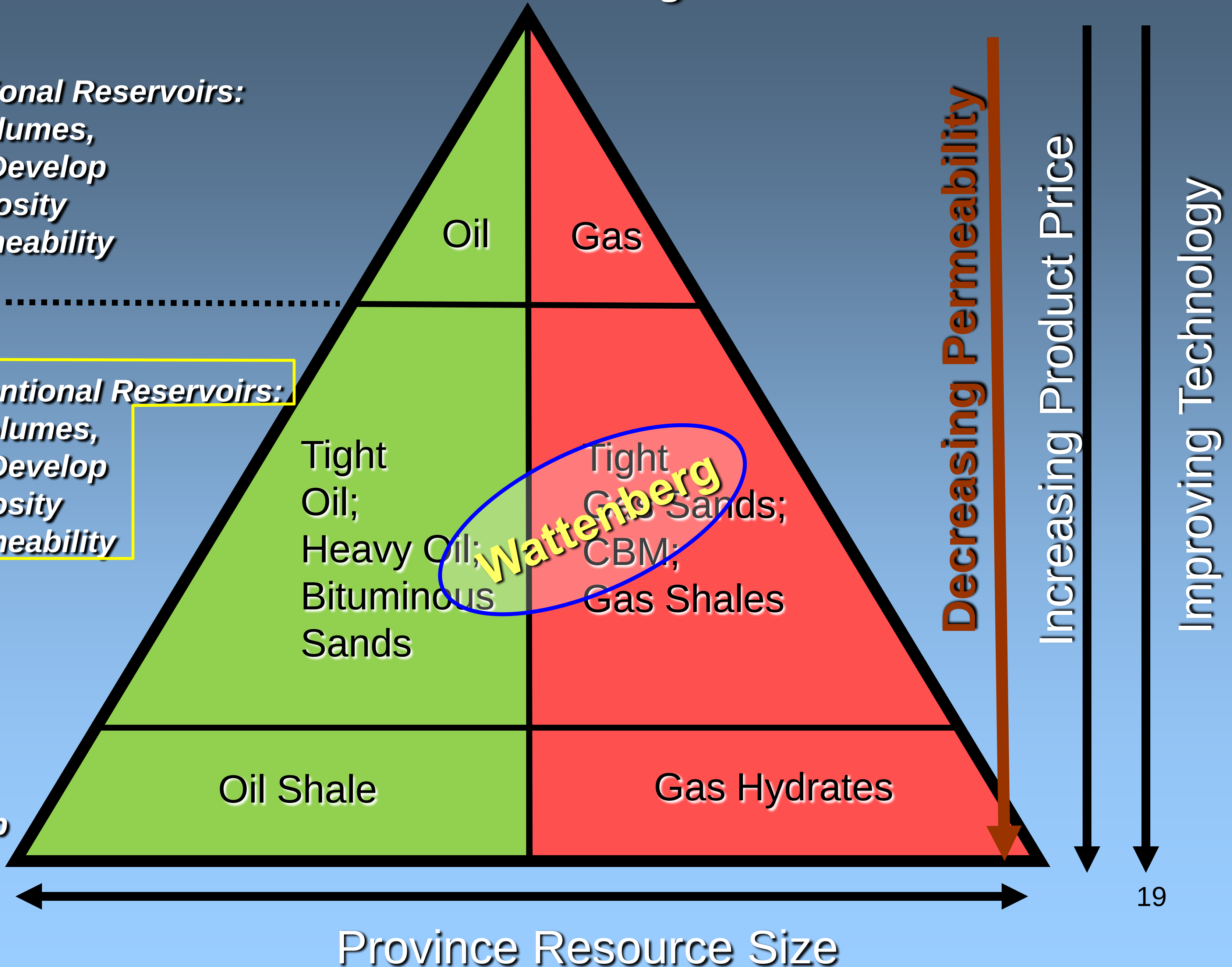
Permeability…a main key

The Resource Pyramid

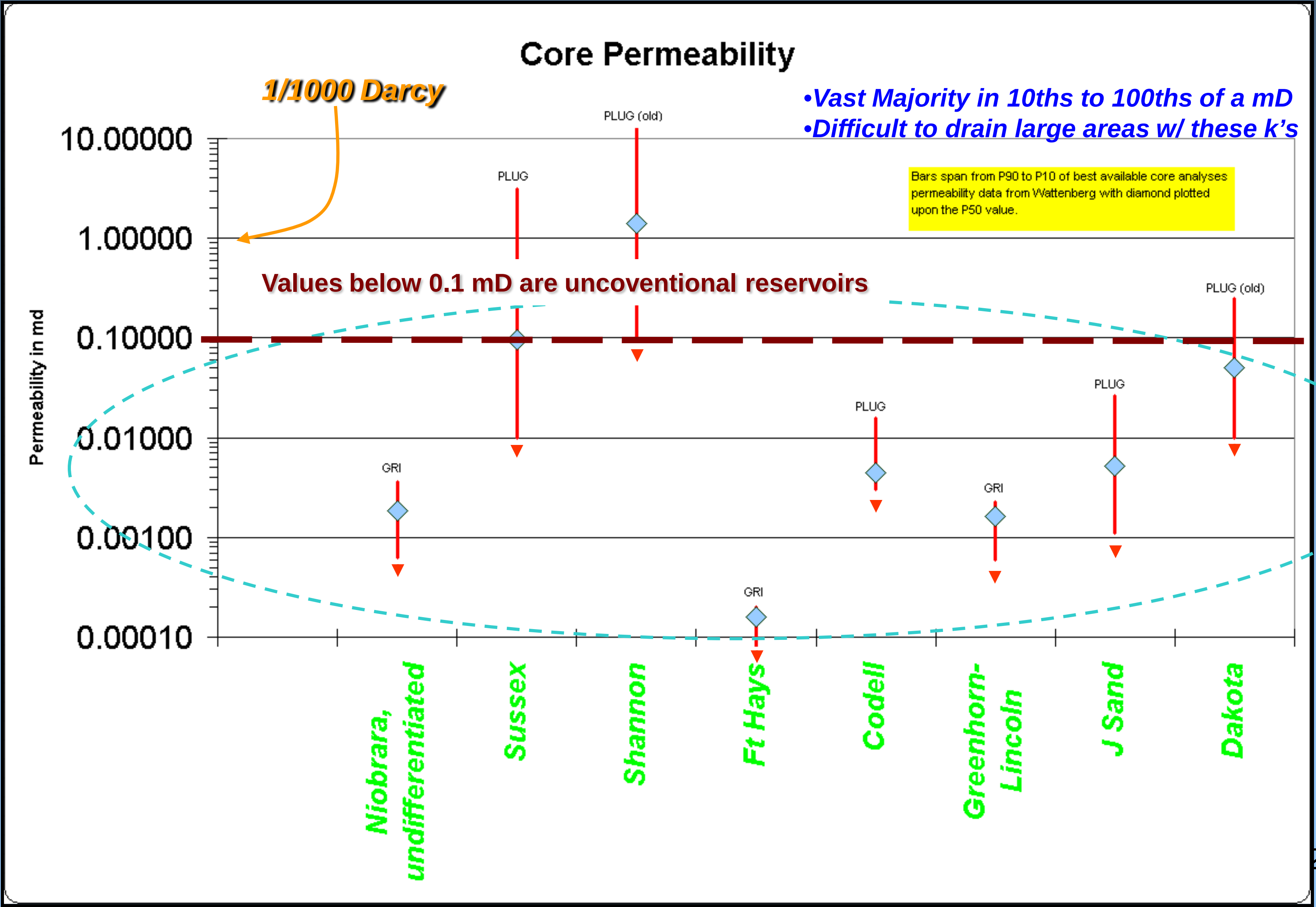
Conventional Reservoirs:
Small Volumes,
Easy to Develop
High porosity
and permeability

Unconventional Reservoirs:
Large Volumes,
Hard to Develop
Low porosity
and permeability

Huge
Volumes,
Difficult
to Develop



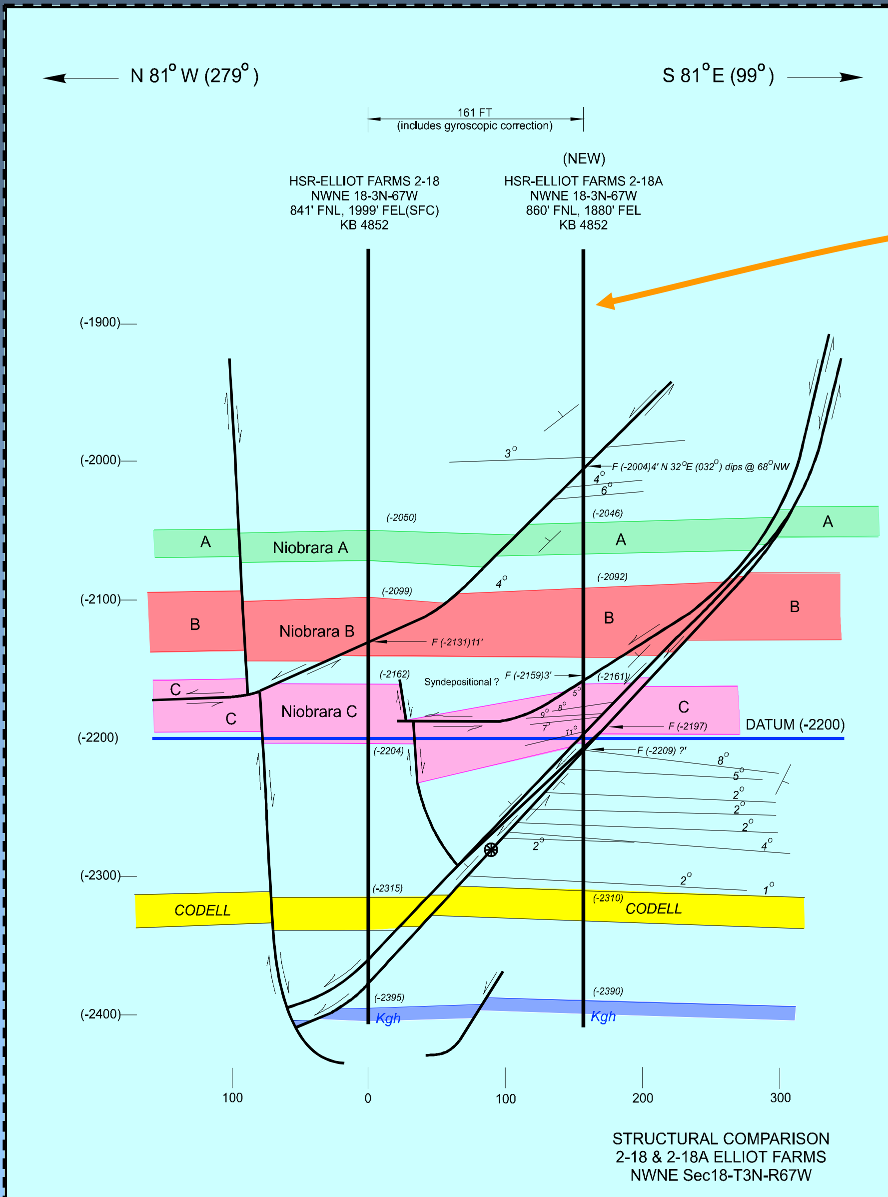
Core Permeabilities for Wattenberg Cretaceous Reservoirs



Summary

- Cretaceous reservoirs cover most of the Wattenberg Field area
- Wattenberg's unique conditions create multiple productive zones within the Cretaceous series of reservoirs
- Barriers to flow are controlled by:
  - very low permeabilities
  - stratigraphic compartmentalization
  - structural compartmentalization
- Low permeability and compartmentalization evidence has been previously testified & accepted in the 318Ae hearing (2005)

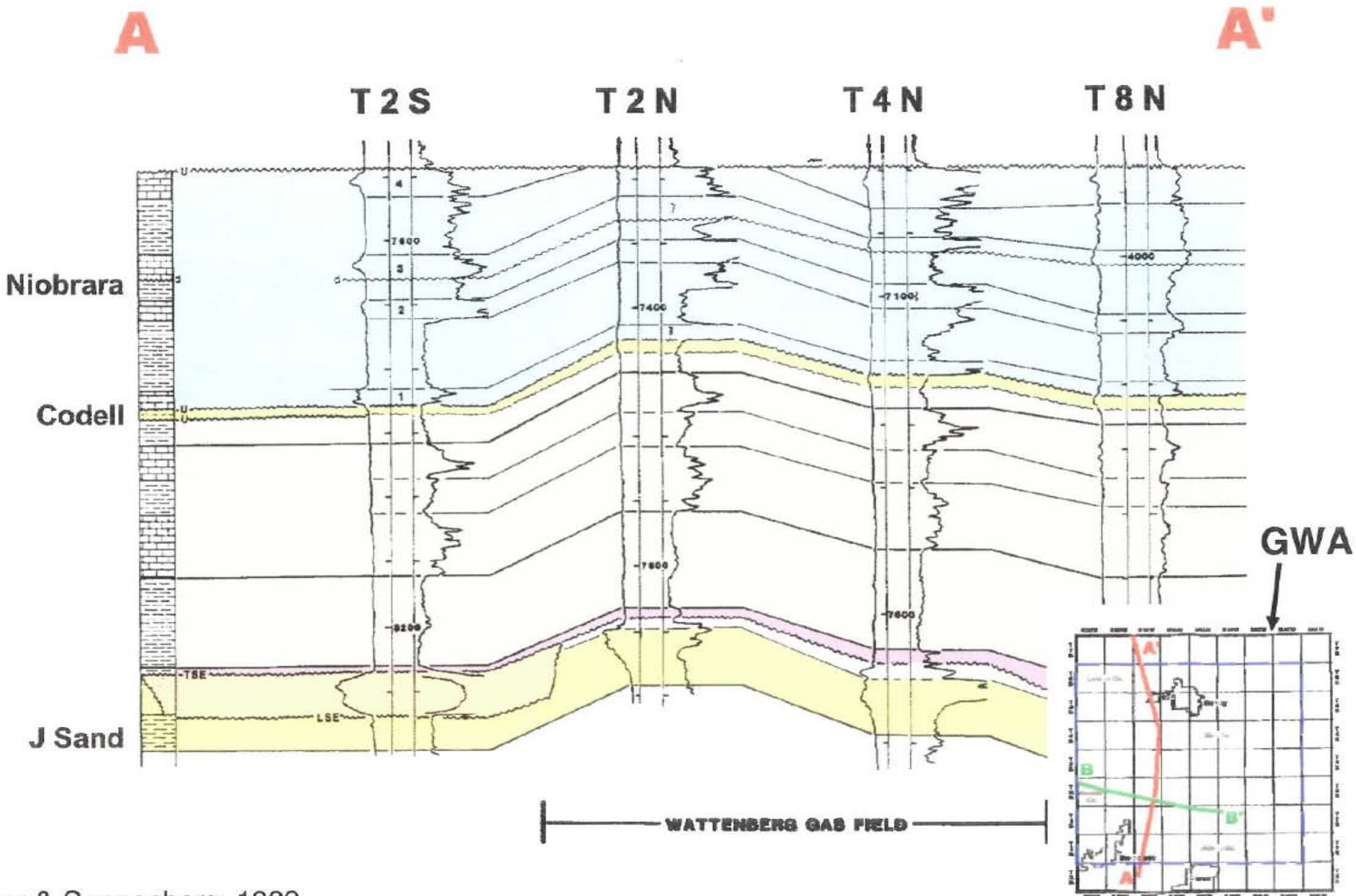
Codell/Niobrara –Structural complexity causes compartmentalization



- **2-18 A** drilled & compl 3.25 years later
- Should have seen reduced pressure next to historic offset producer
- Virgin pressure w/in 160' of offset
- Faults = effective seals

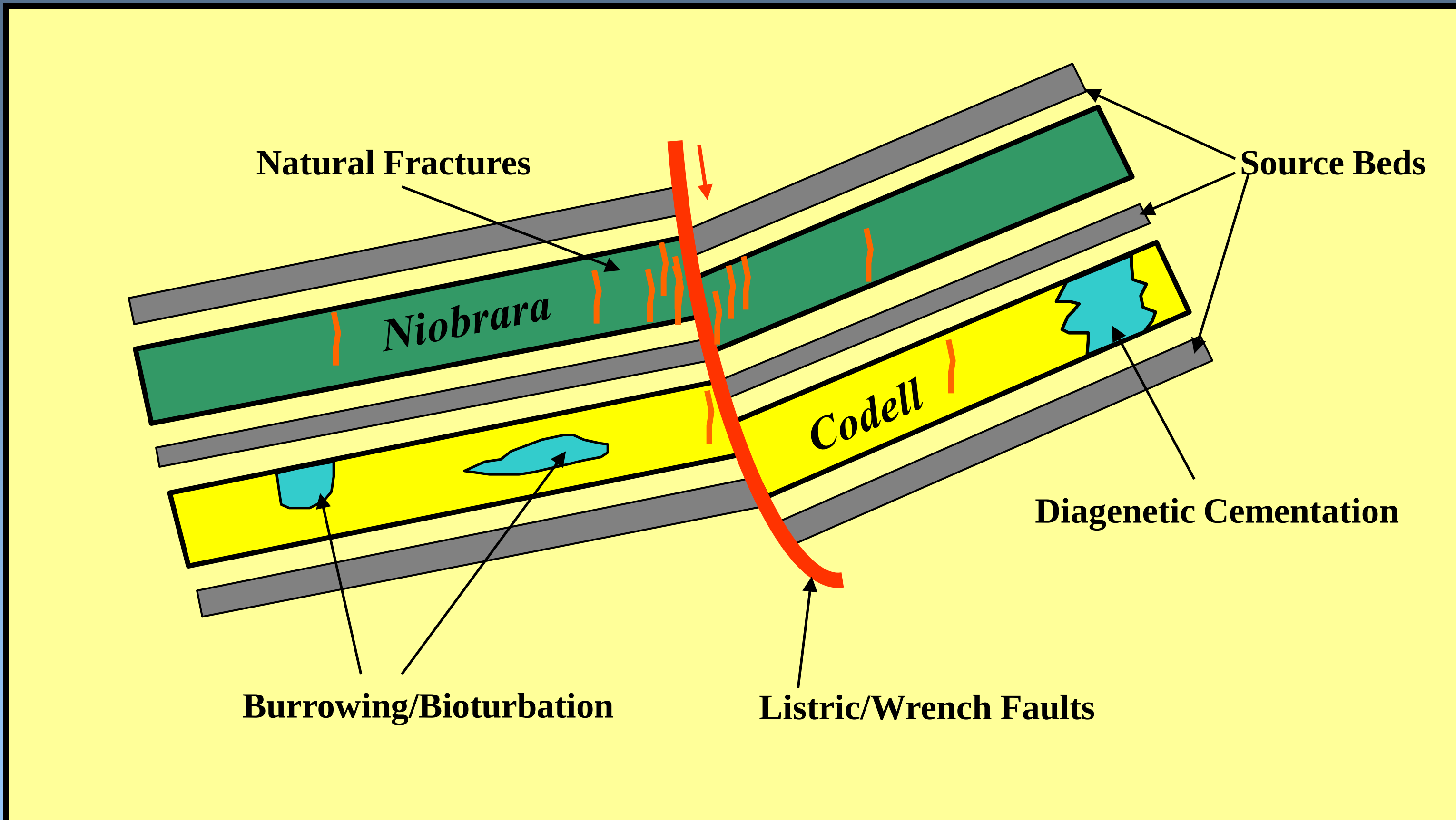
Birmingham, 1998

North-South Cross Section



Weimer & Sonnenberg, 1989

Codell/Niobrara Reservoir Compartmentalization/Permeability Factors



Not to Scale

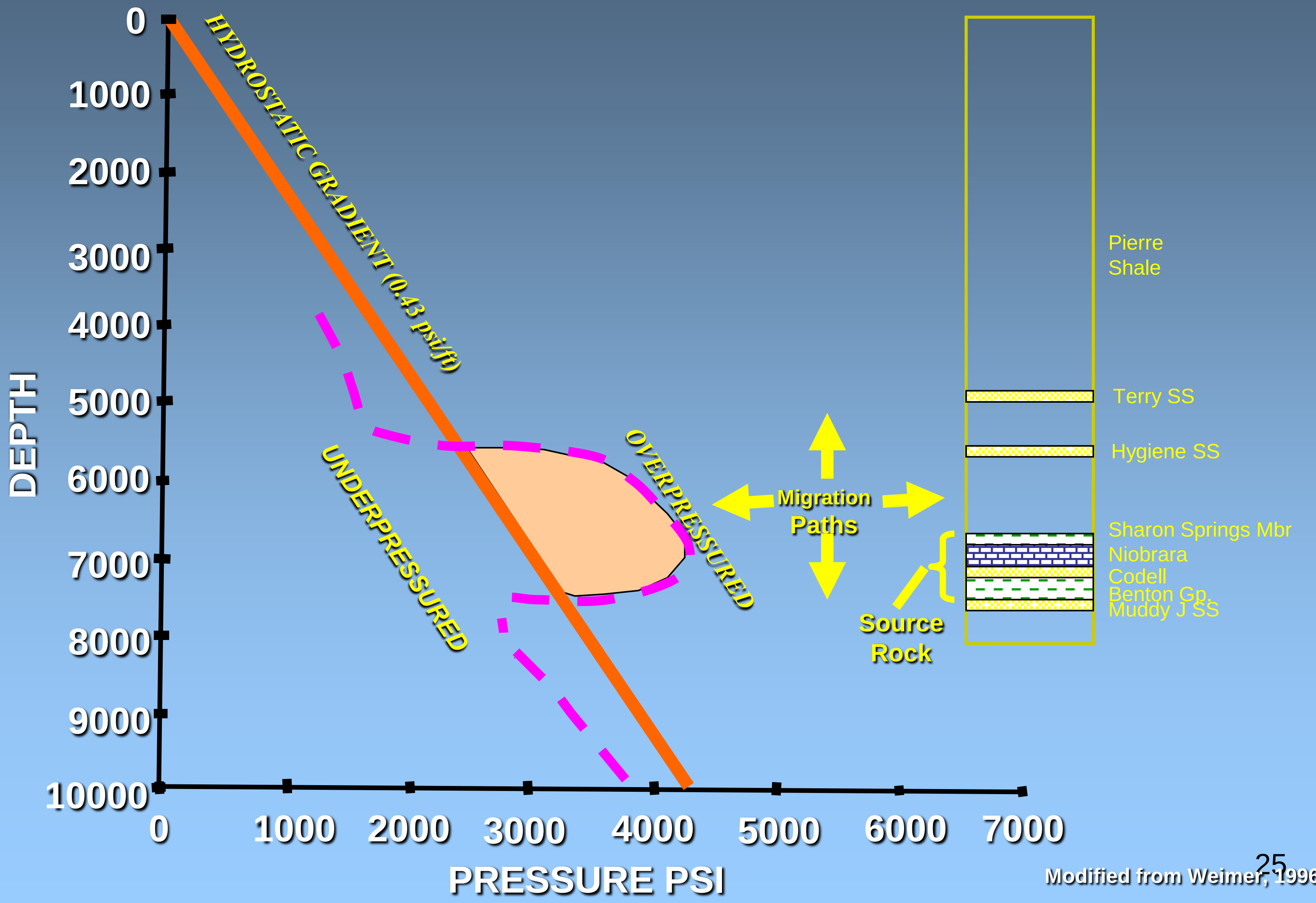
Compartmentalization and permeability factors affecting the Niobrara/Codell section

Factors related to structure

Factors related to biologic activity/diagenesis

Birmingham et al, 2001

Pressure/Depth Plot
Wattenberg Field



Modified from Weimer, 1996

Cretaceous Pressure/Depth Plot for the Wattenberg Field. Intermediate depth ranges contain overpressured envelope, helping fuel hydrocarbon migratory paths