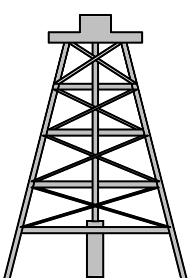
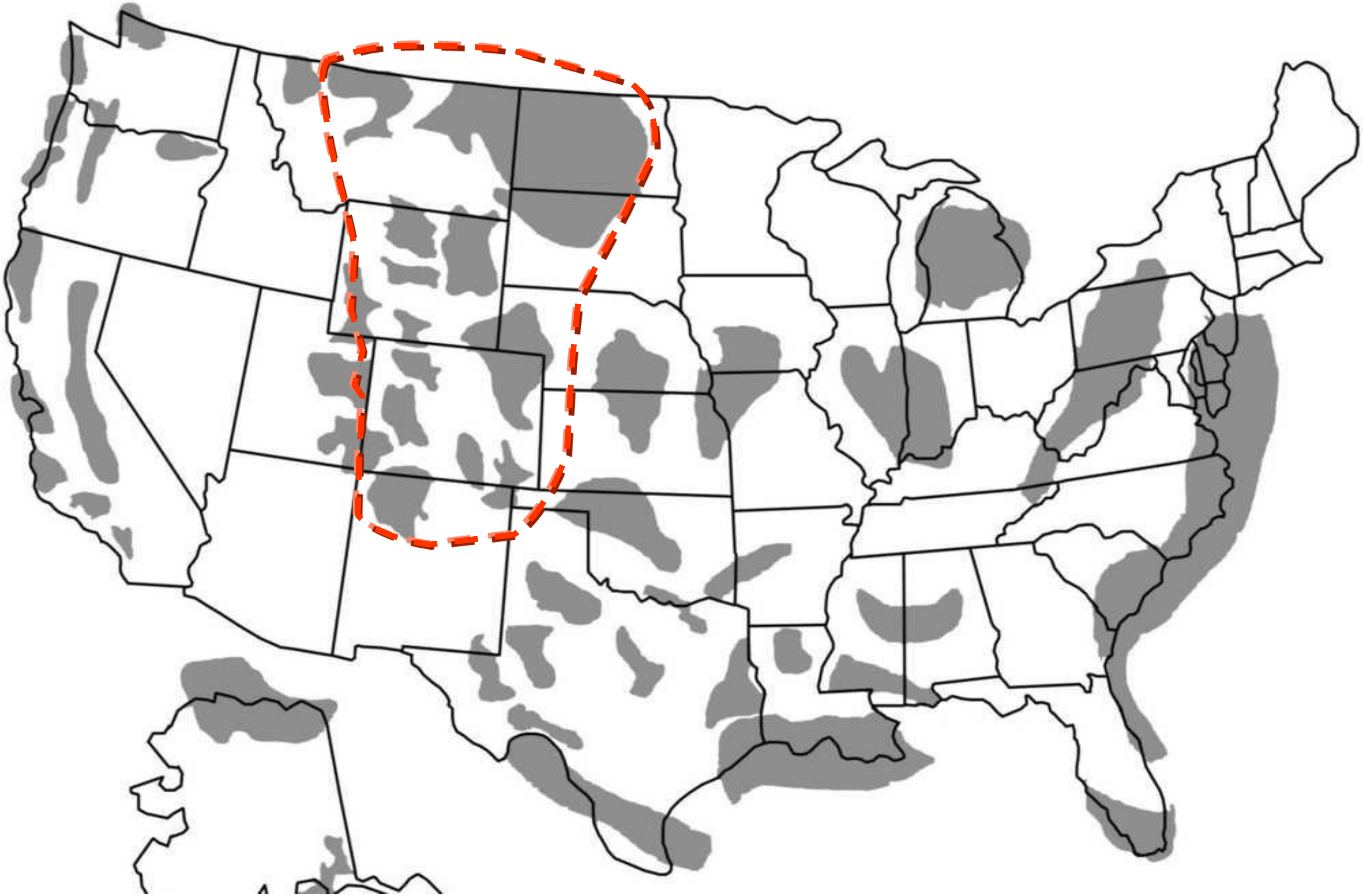
The Niobrara Petroleum System, A Tight Oil/Gas Resource Play



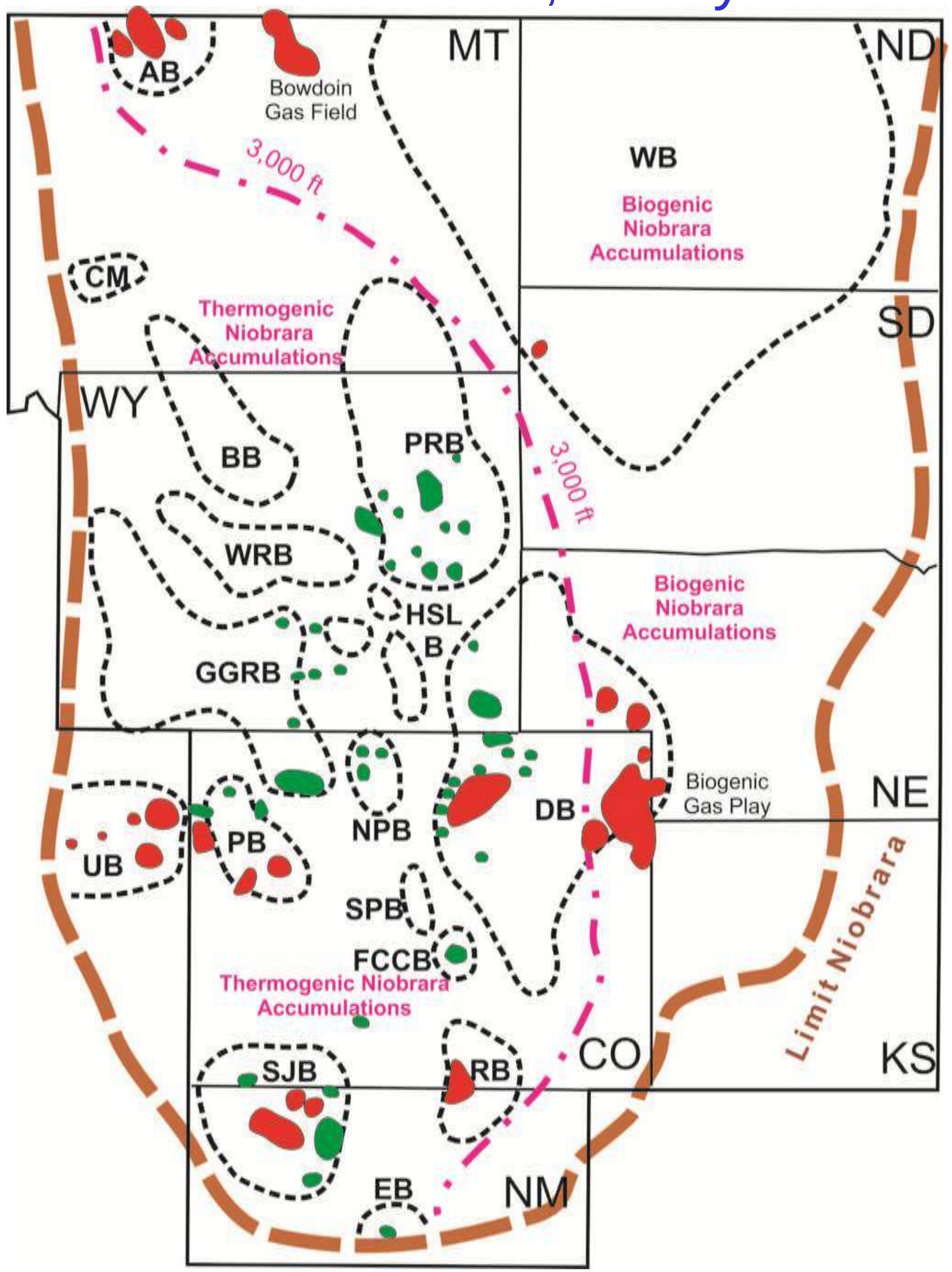
Stephen A. Sonnenberg

Colorado School of Mines

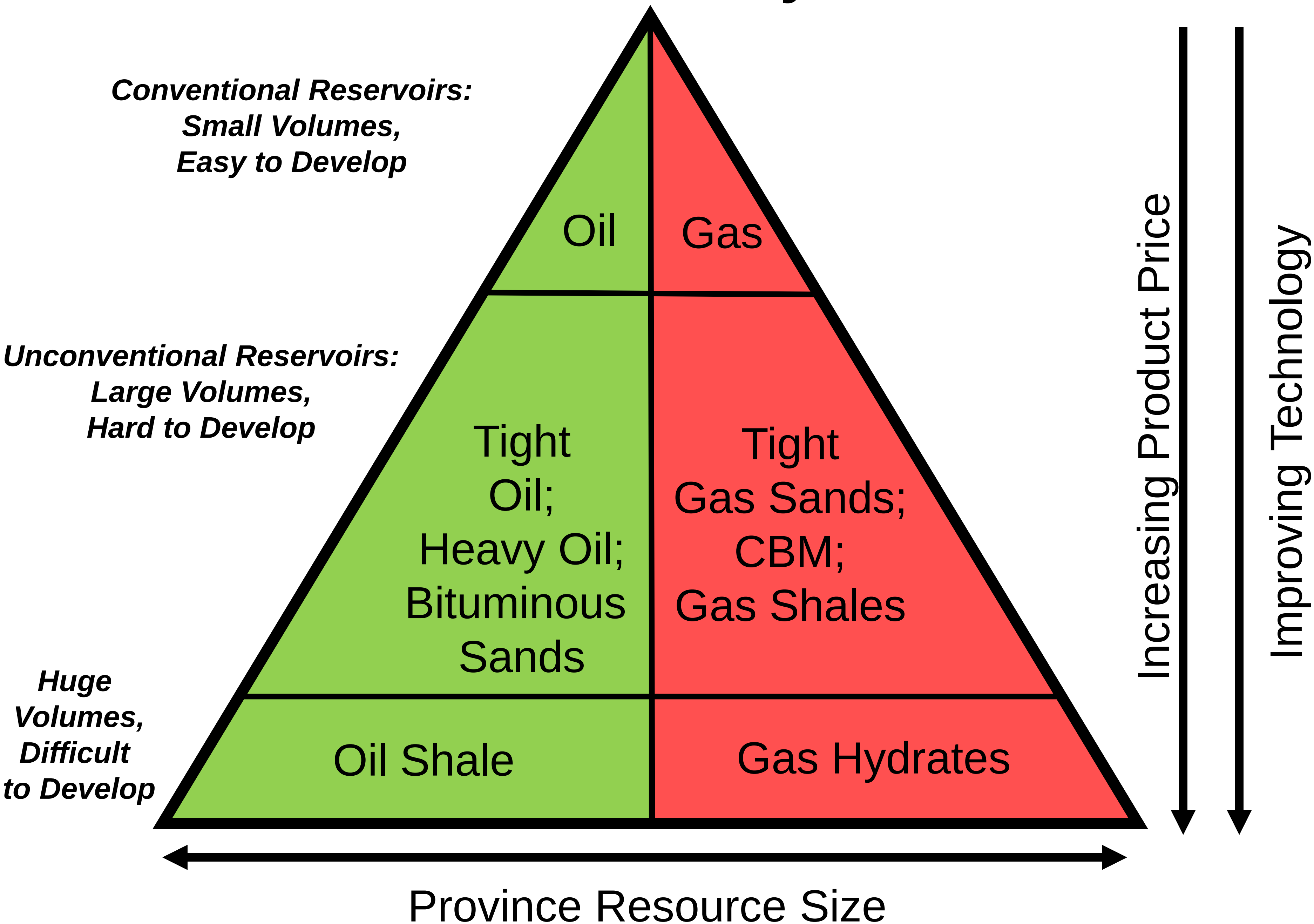
The Niobrara-Mancos Oil & Gas Play, Rocky Mountain Region



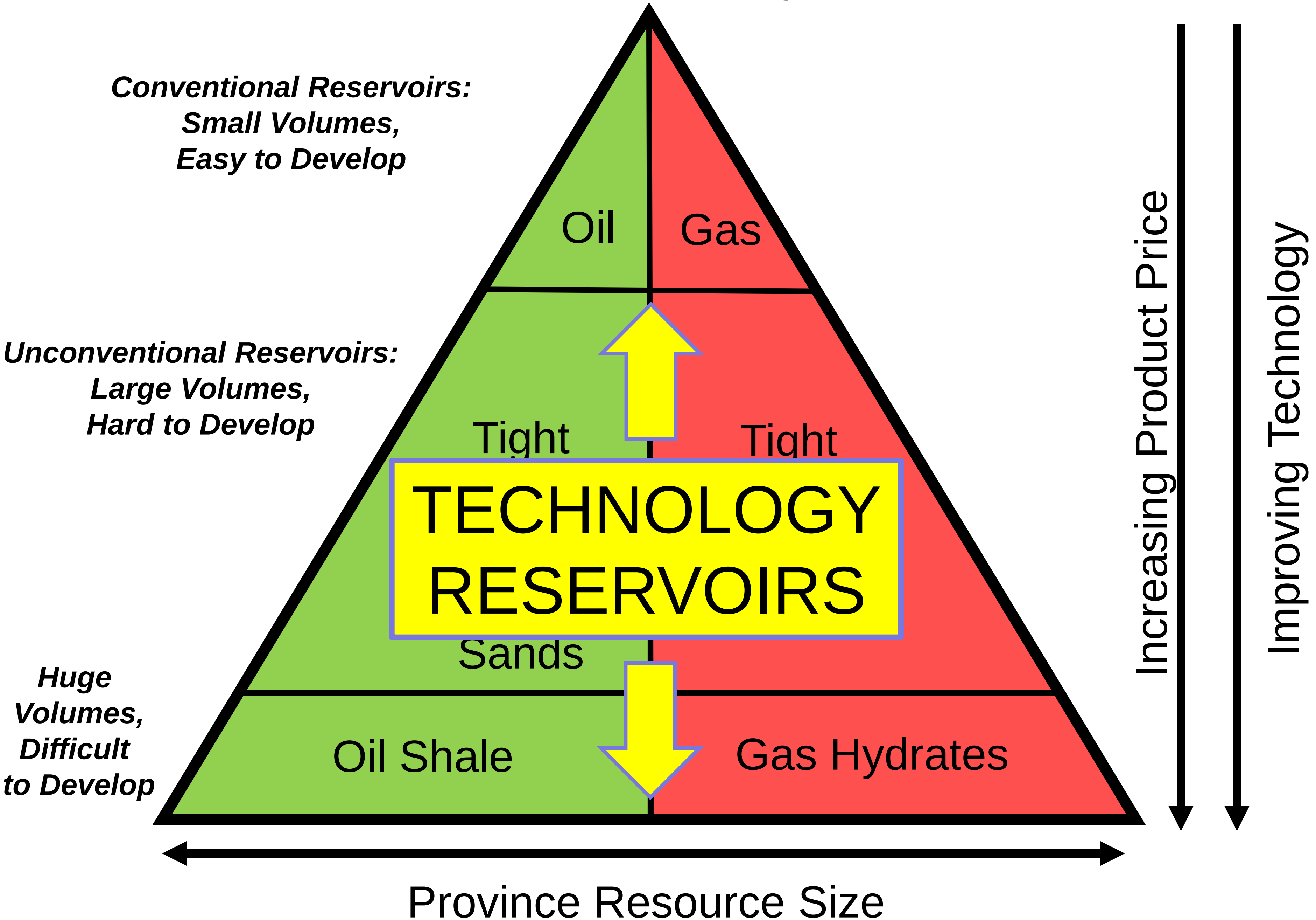
Niobrara and Mancos Production, Rocky Mountain Region



The Resource Pyramid



The Resource Pyramid



Unconventional, Continuous Tight Oil Accumulations

- Pervasive petroleum saturation
- Mature source rocks
- Abnormally pressured
- Generally lacks down-dip water
- Up-dip water saturation
- Low porosity and permeability reservoirs
- Fields have diffuse boundaries
- Enhanced by fracturing

Factors Related to Tight Oil Production

- **Source beds**
- **Mature source rocks form continuous oil column (*pervasive saturation*)**
- **Reservoir - favorable facies and diagenetic history (*matrix permeability*)**
- **Favorable history of fracture development: folds, faults, solution of evaporites, high fluid pressures, regional stress field (*fracture permeability*)**
- **Mechanical stratigraphy**

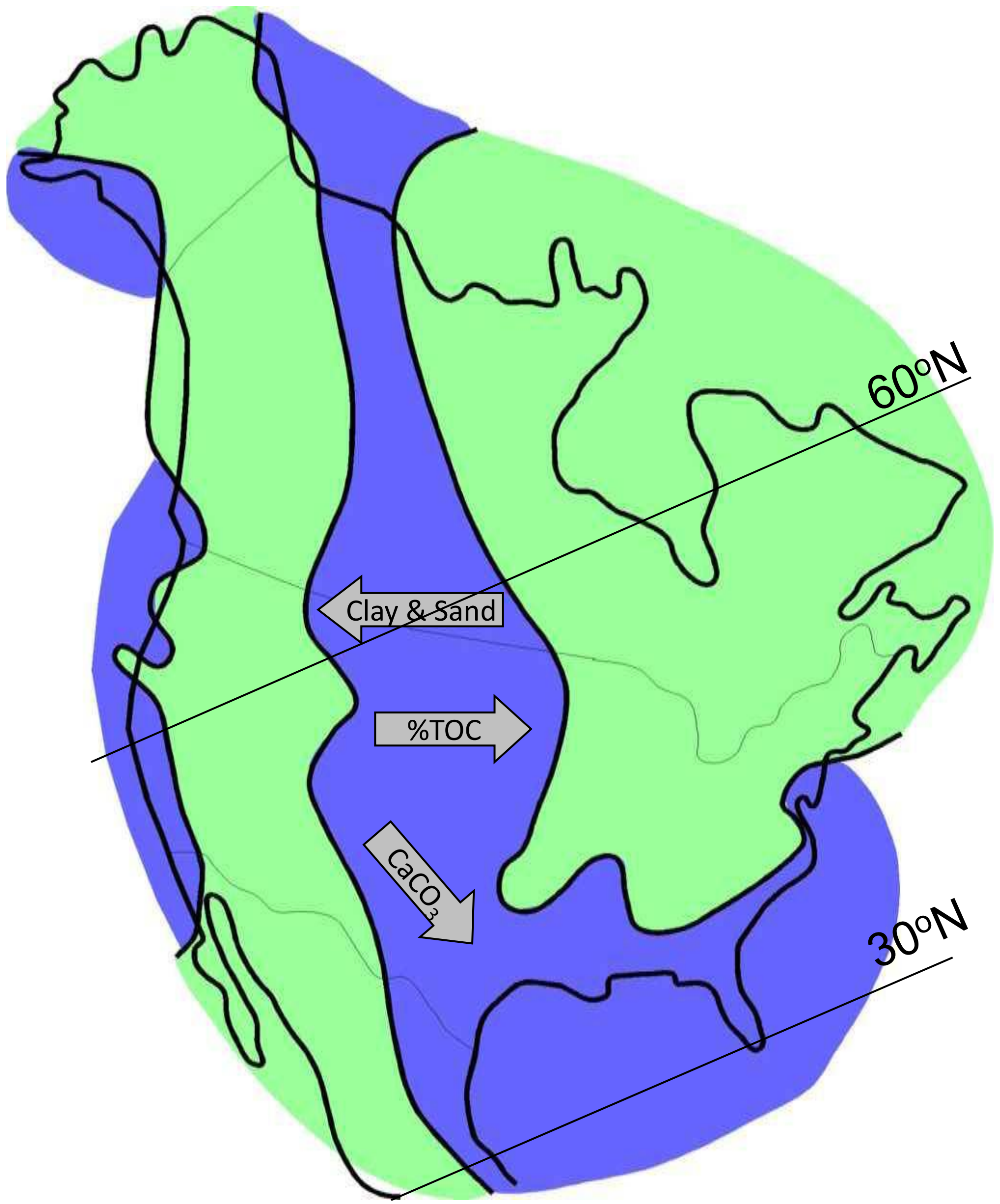
Western Interior Cretaceous Basin

Late Cretaceous

85Ma

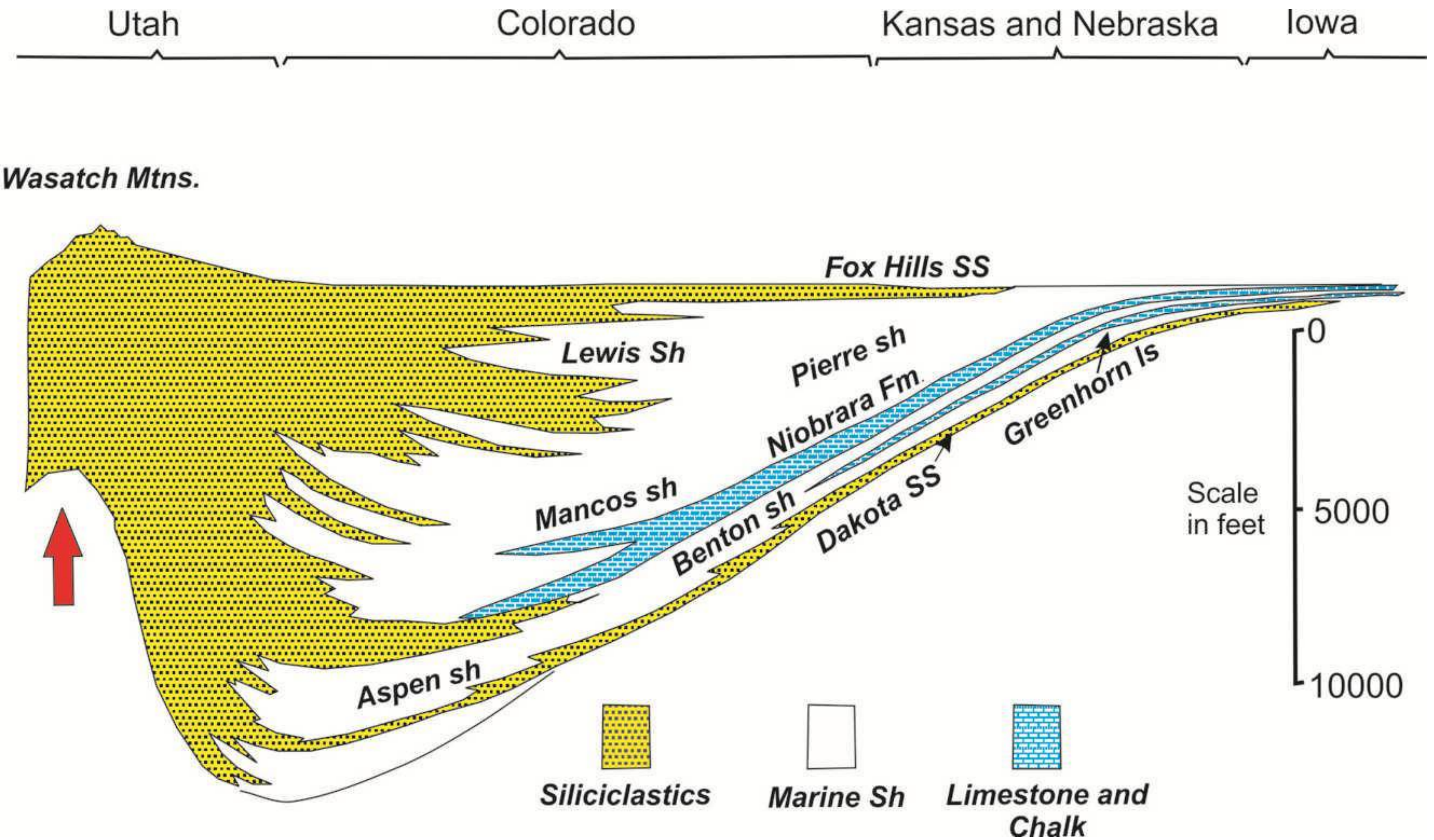
http://jan.ucc.nau.edu/~rcb7/namK85.jpg

WIC Seaway, Niobrara Time



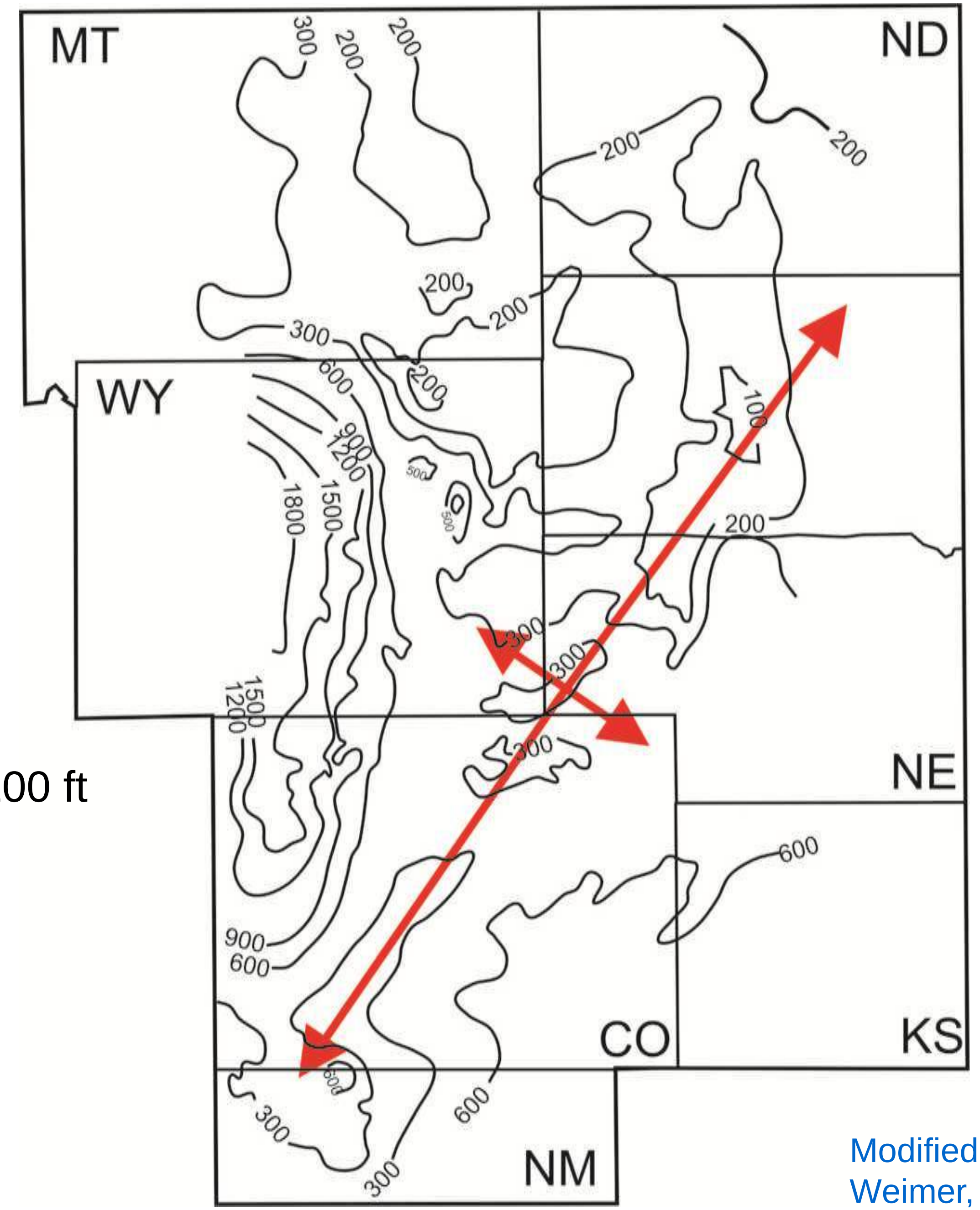
Modified from Longman et al., 1998

Cretaceous Cross Section, Western Interior Basin



Modified from Kauffman, 1977

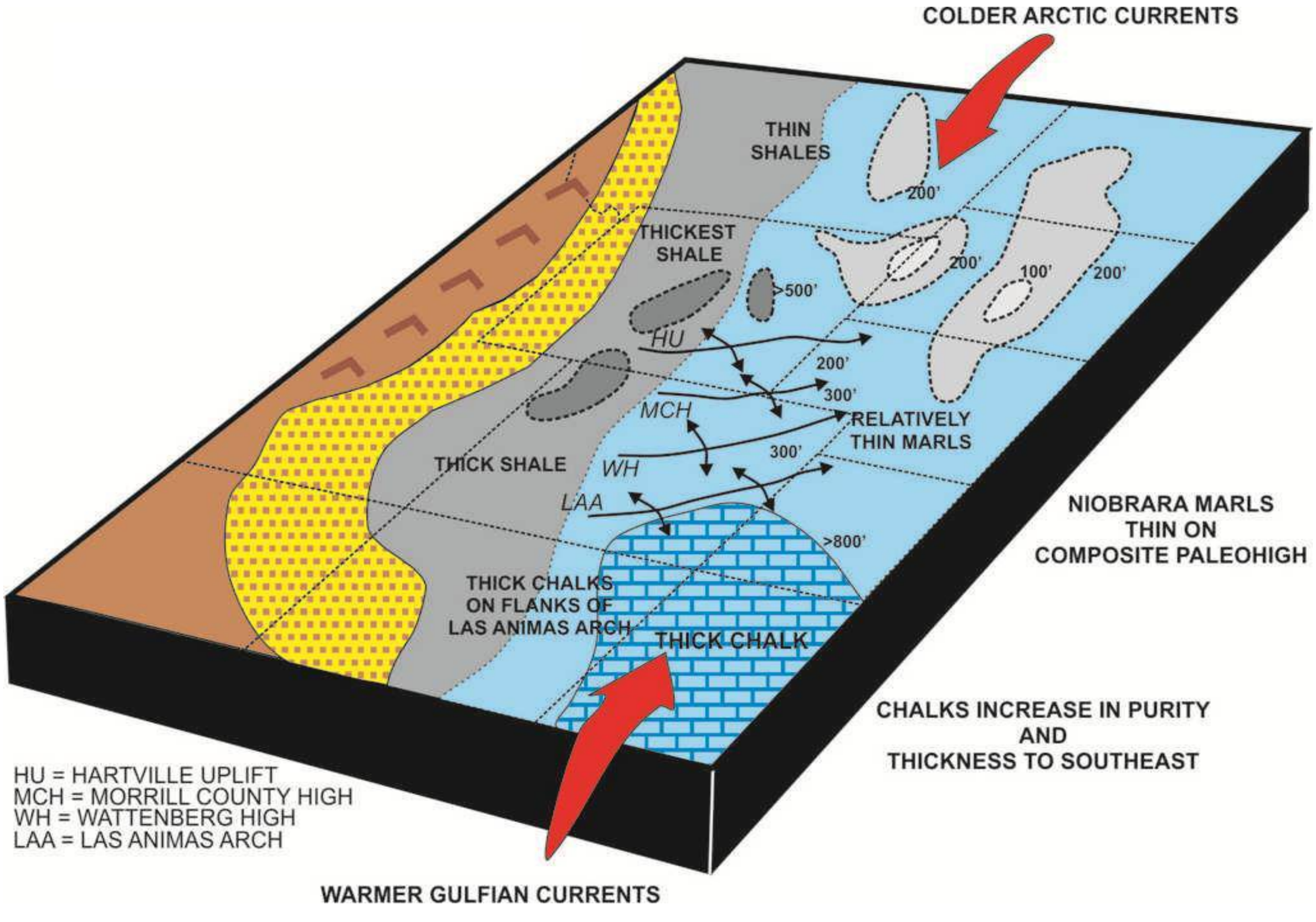
Isopach Niobrara – Location of Transcontinental Arch



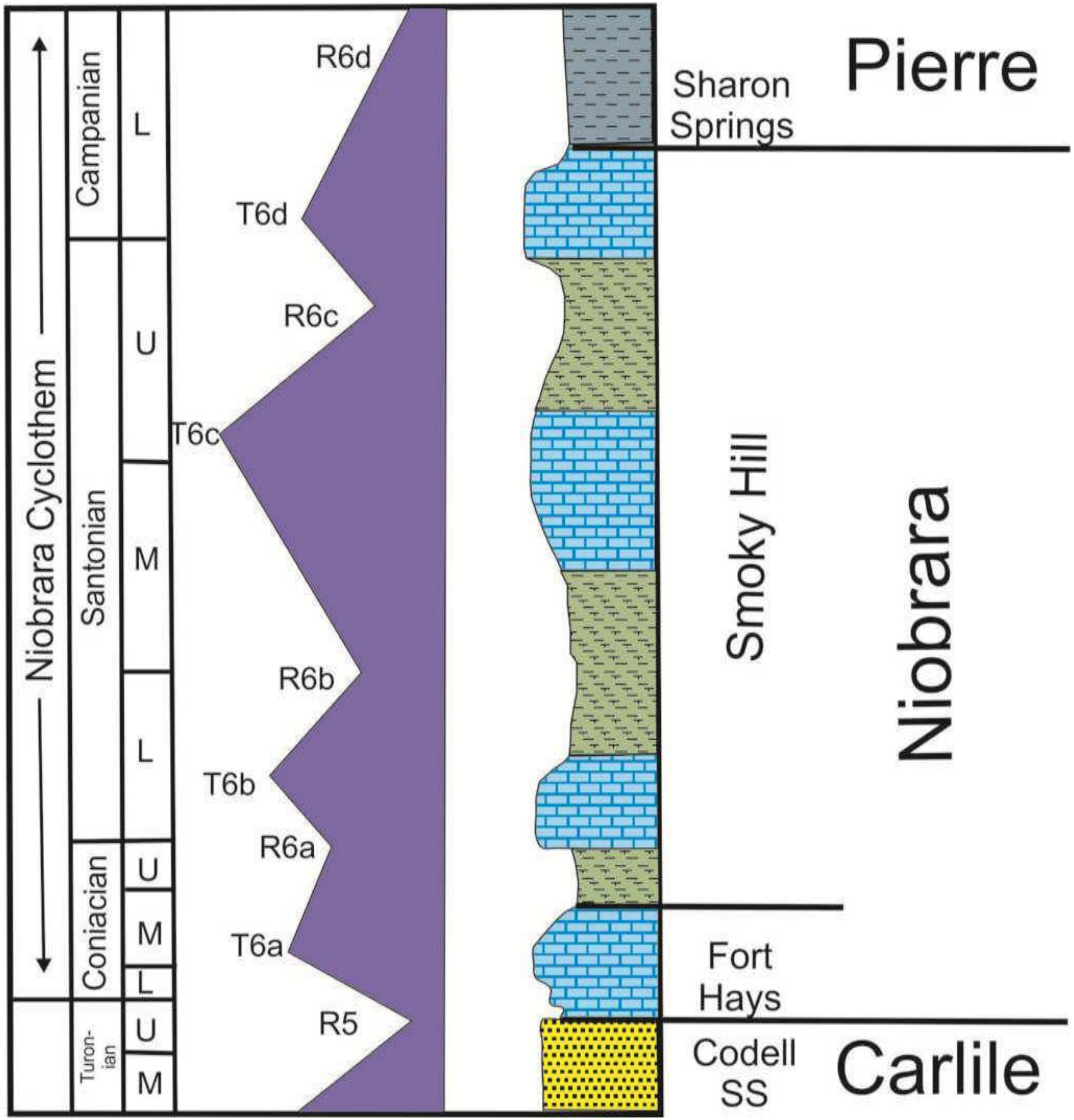
CI: 100 ft

Modified from Longman et al., 1998; Weimer, 1978

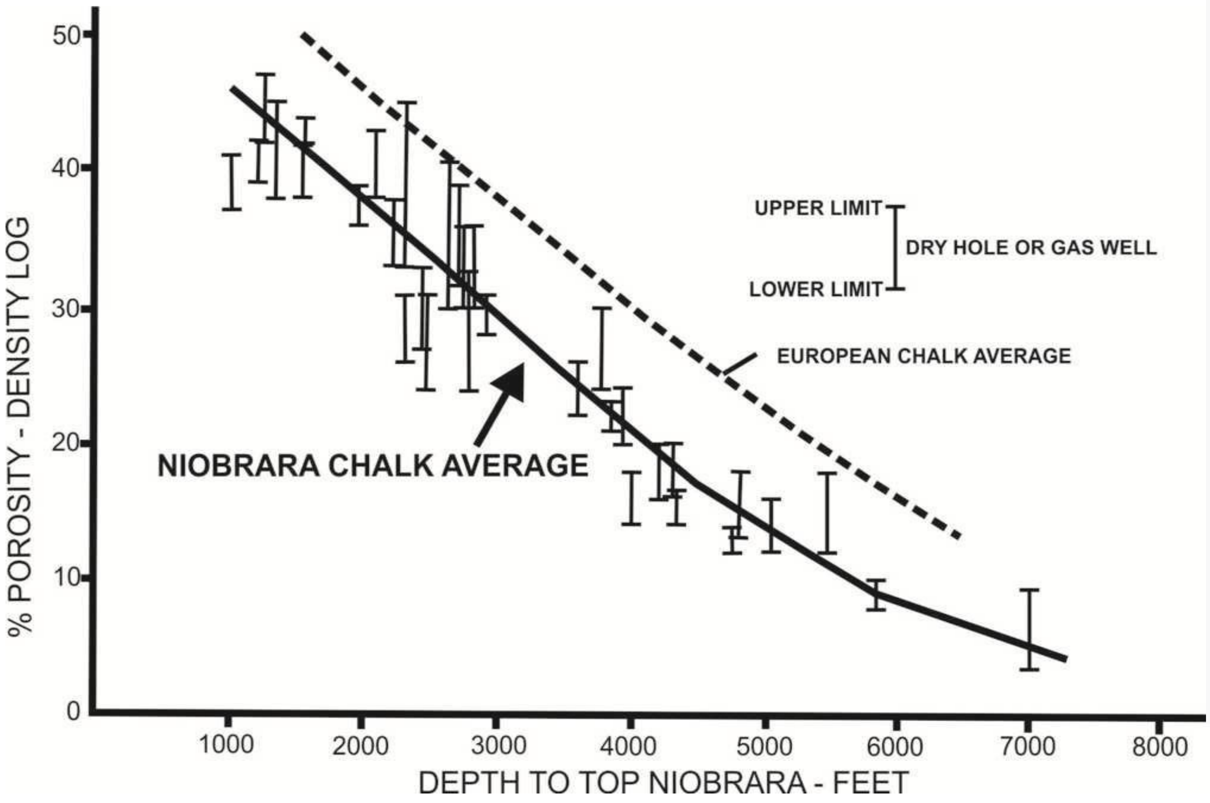
Niobrara Depositional Trends



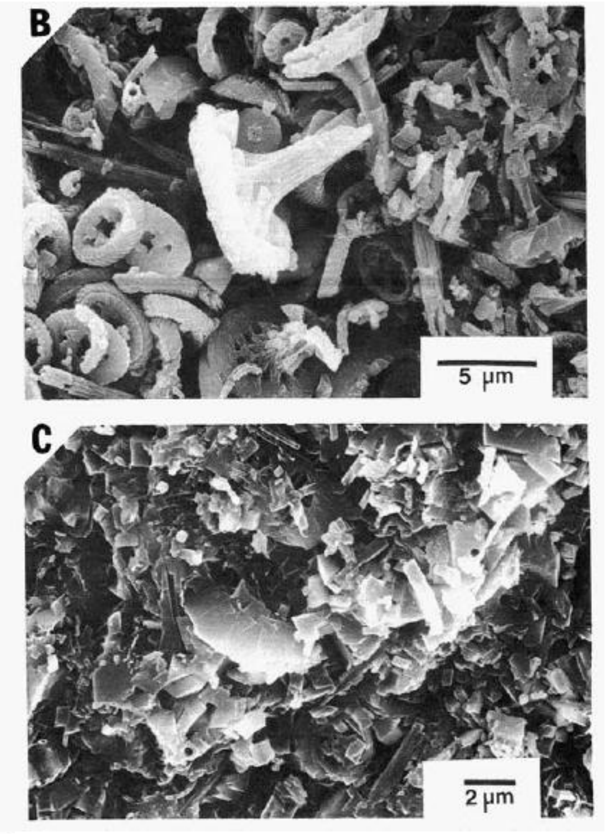
Modified from Longman et al., 1998



Modified from Longman et al., 1998, after Barlow, 1986



2000 ft



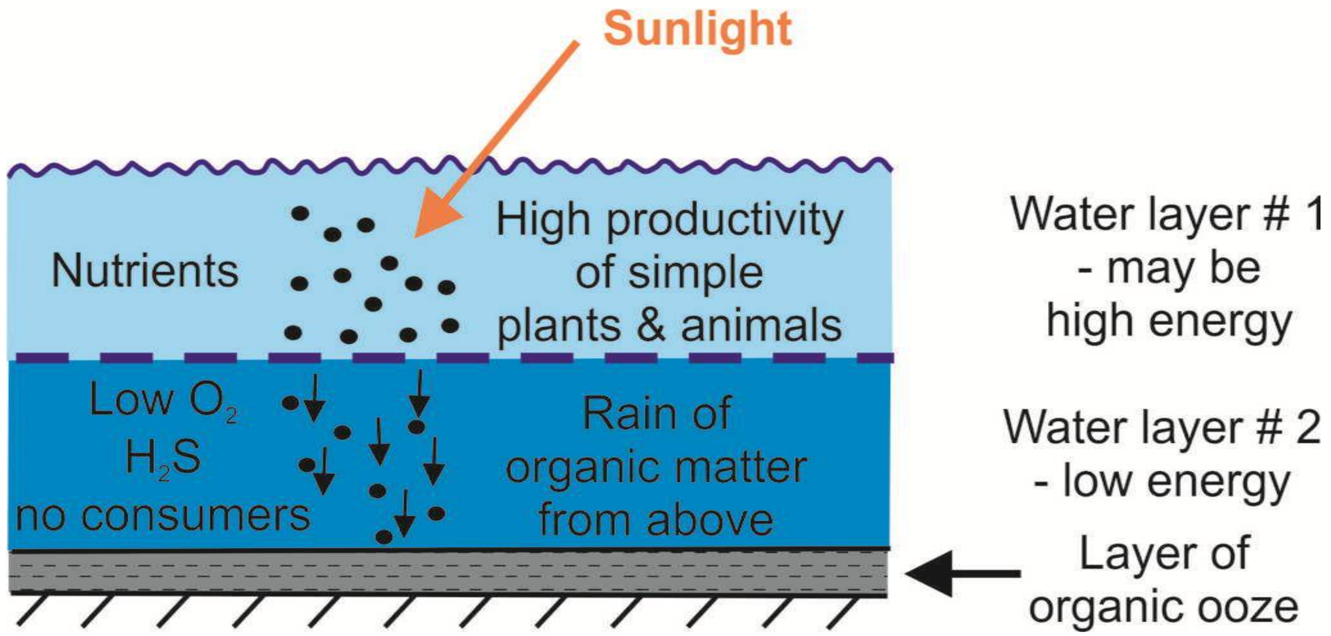
5600 ft

Modified from Lockridge and Pollastro, 1988

Requirements of Source Rock Deposition

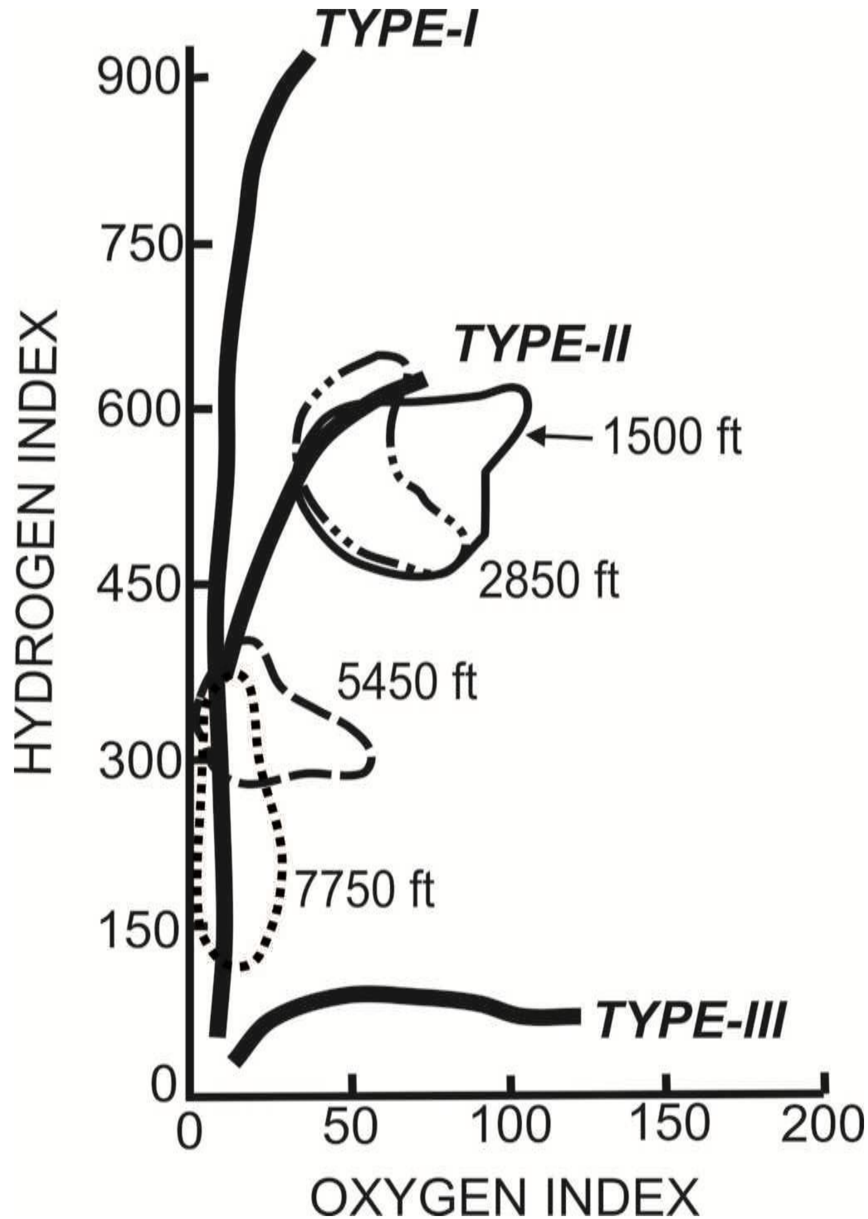
- High organic productivity
  - Sunlight
  - Nutrients
  - Absence of poisons (H_2S)
- Low destruction rate of organic material
  - Absence of O_2 and biologic consumers
- Lack of dilution by other constituents
  - i.e., Shale, sandstone, etc.

Oil Source Rocks
Sapropelic Deposition

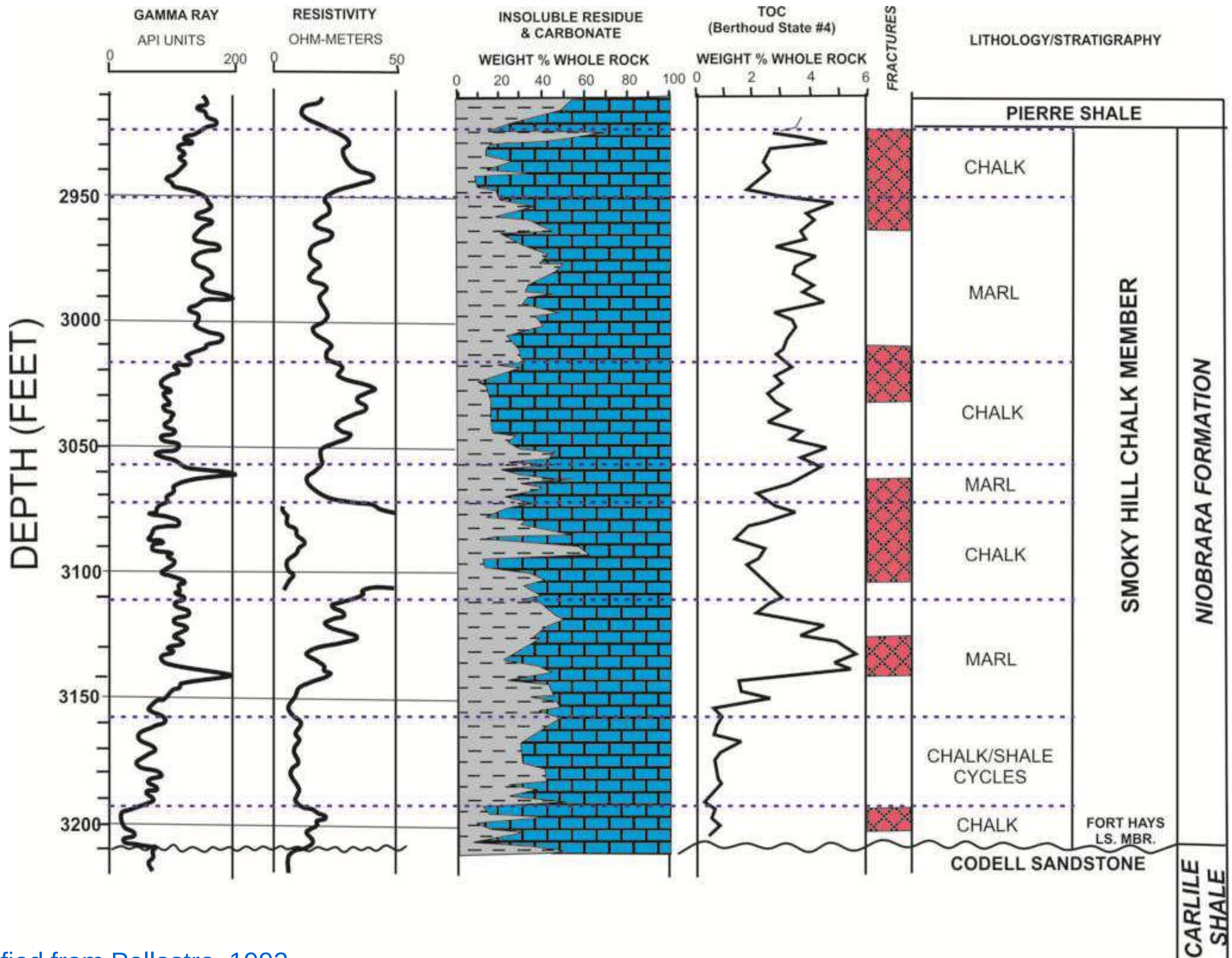


- **Stratified water column**
- **~ Depth of 150 ft (below photic zone and wave action)**
- **Heavy rain of organic material (predominantly marine phytoplankton)**

Modified from Meissner et al., 1984; Webster, 1984

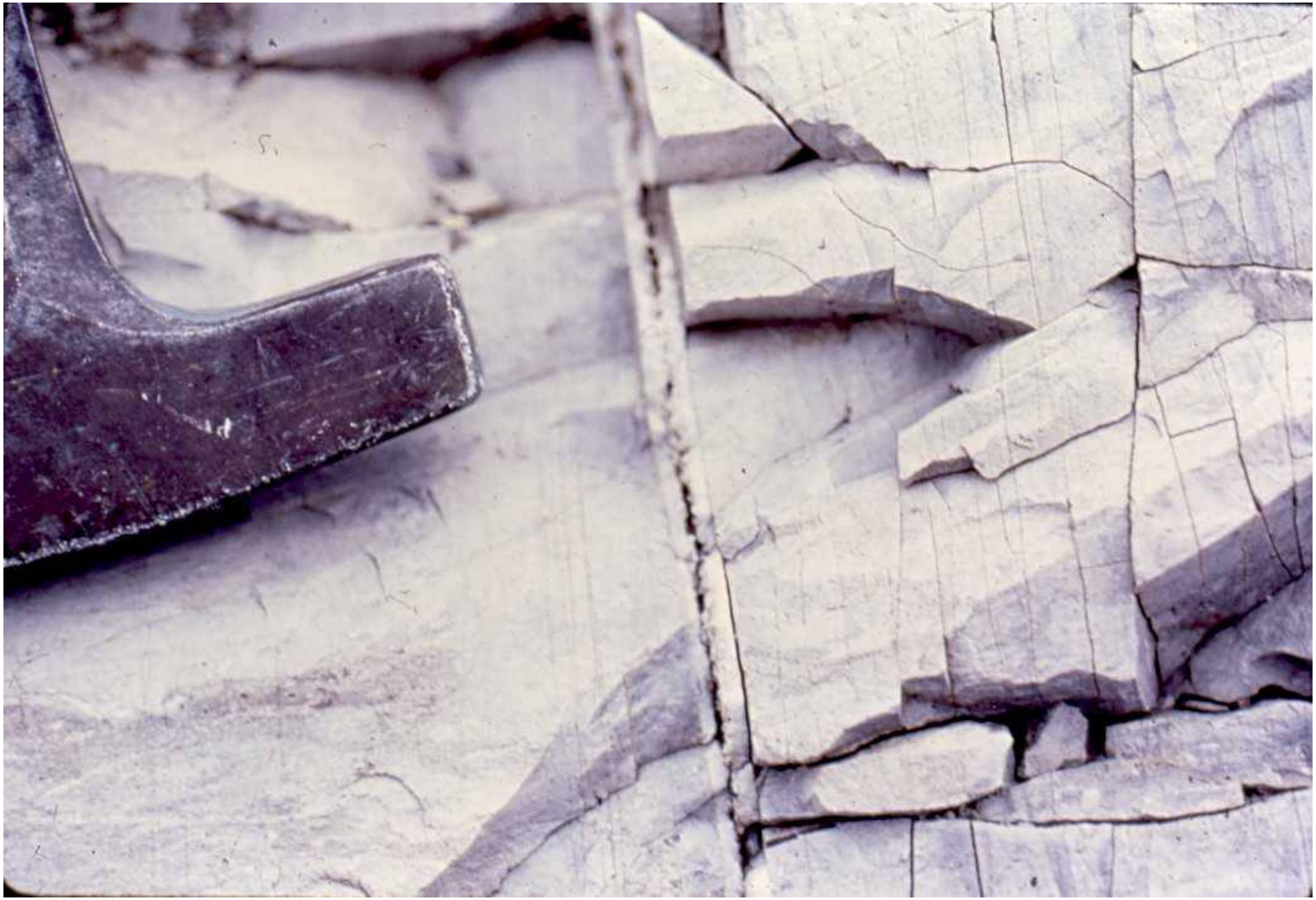


Modified from Sonnenberg and Weimer, 1993



Modified from Pollastro, 1992

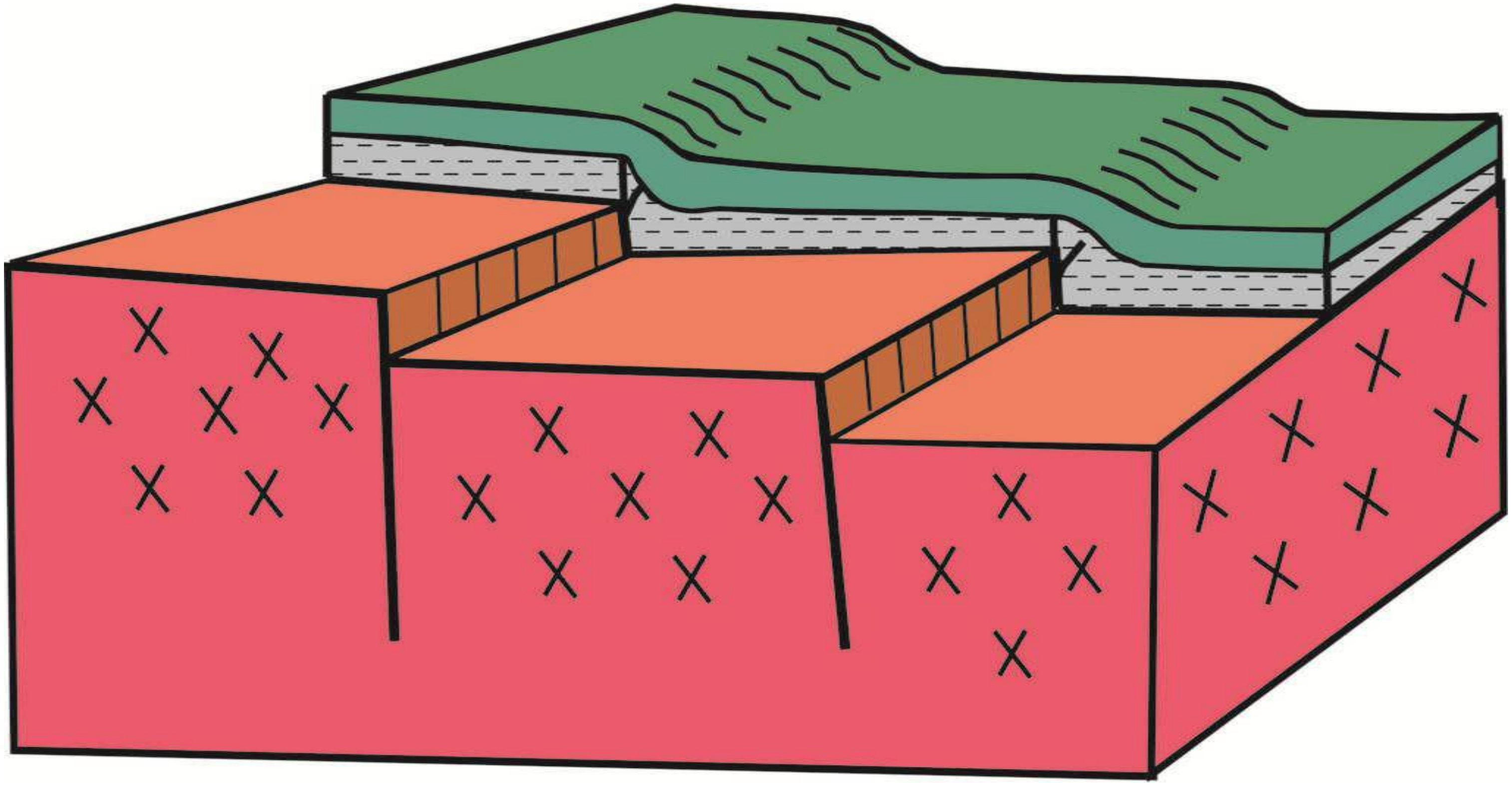
Niobrara Fractures



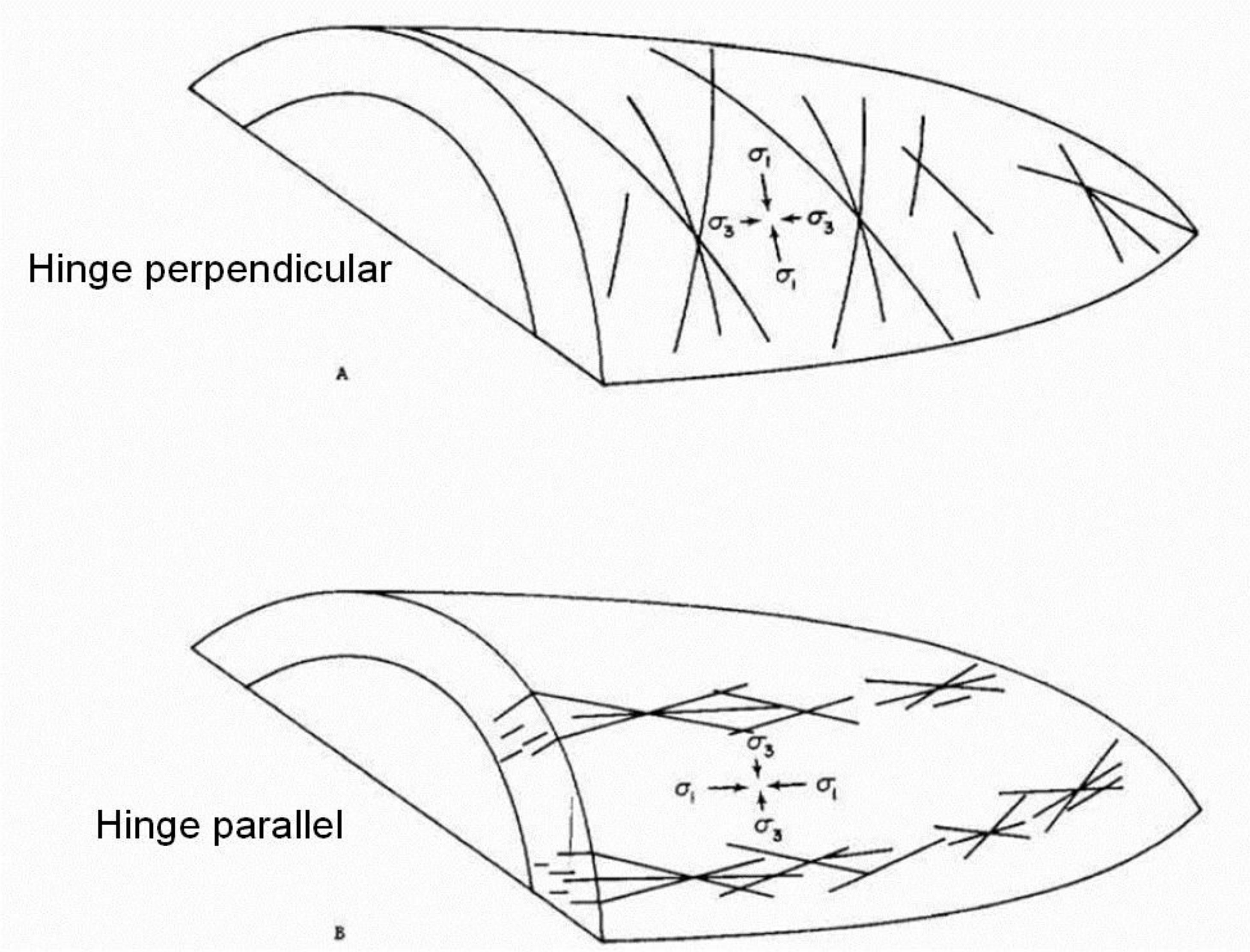
Origin of Fractures

- Folding and Faulting
  - Tectonic, diapiric, slumping
  - Wrench faults
- Geologic History of Fractures
  - Recurrent movement on basement shear zones
- Solution of Evaporites
- High Fluid Pressure
  - Maturation of source rocks
- Compaction and Dewatering
- Regional Stress Field
- Regional Epeirogenic Uplift

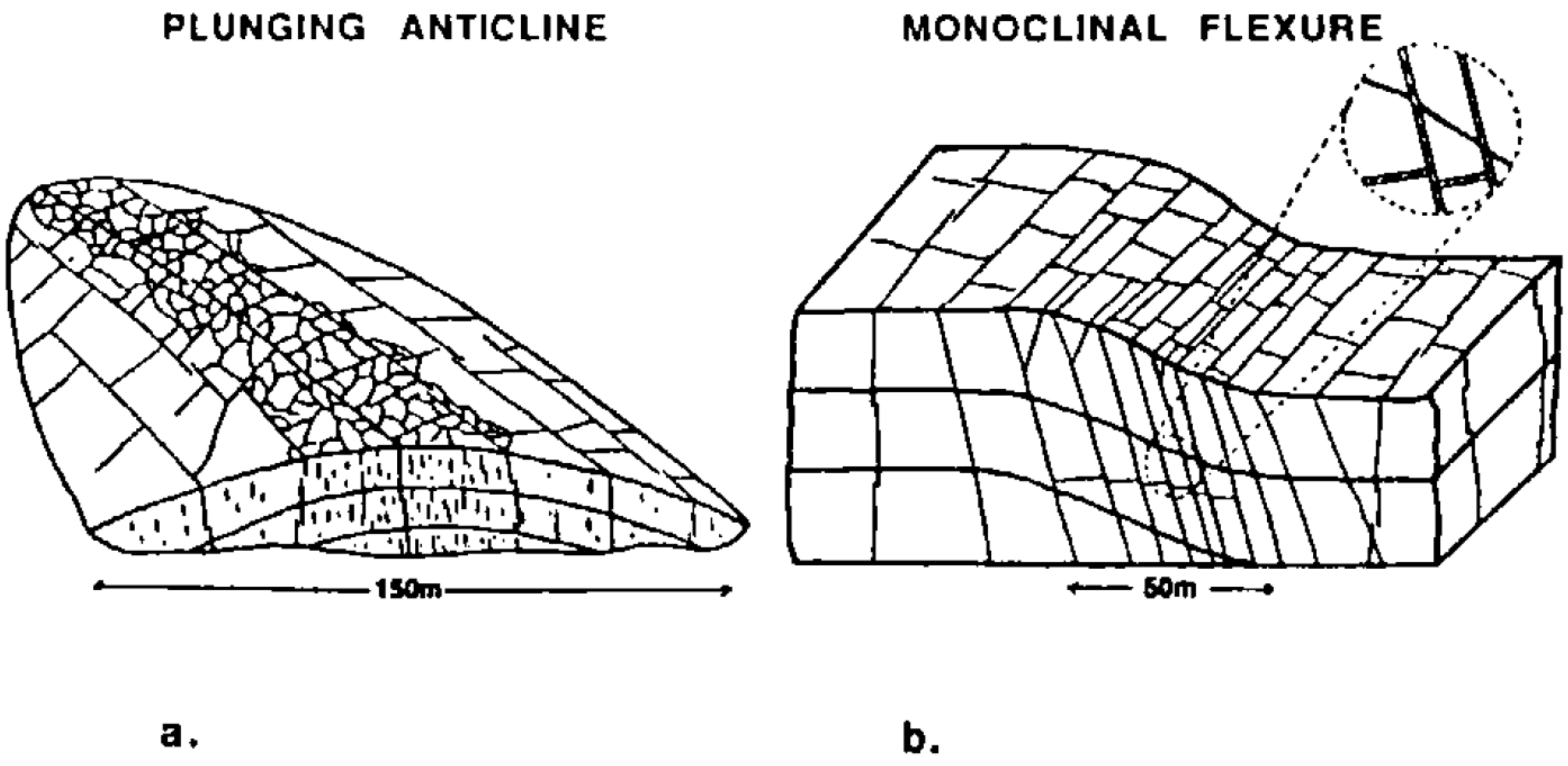
Force Folds, Faults, and Fractures



Fractures Related To Folds



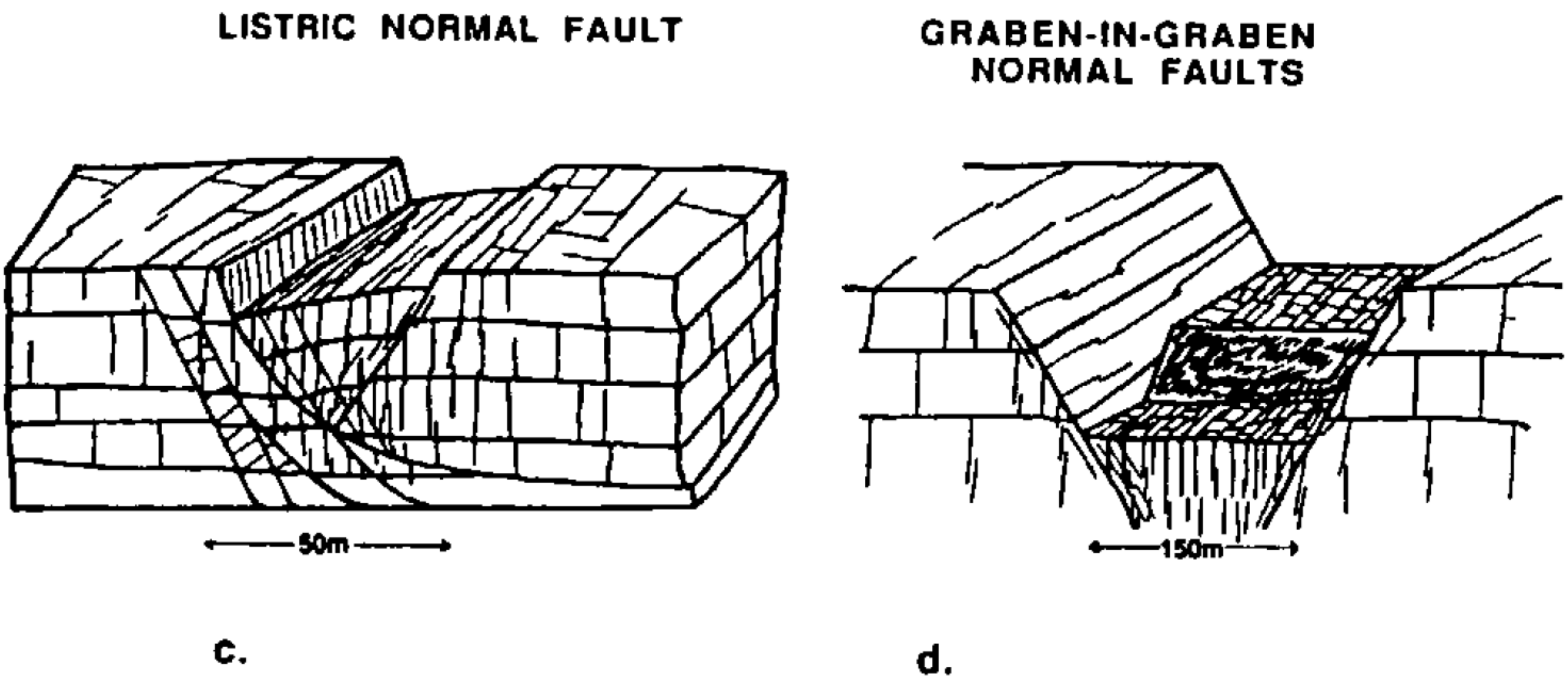
Structures and Associated Fractures



From Austin Chalk Outcrops

Friedman et al., 1992

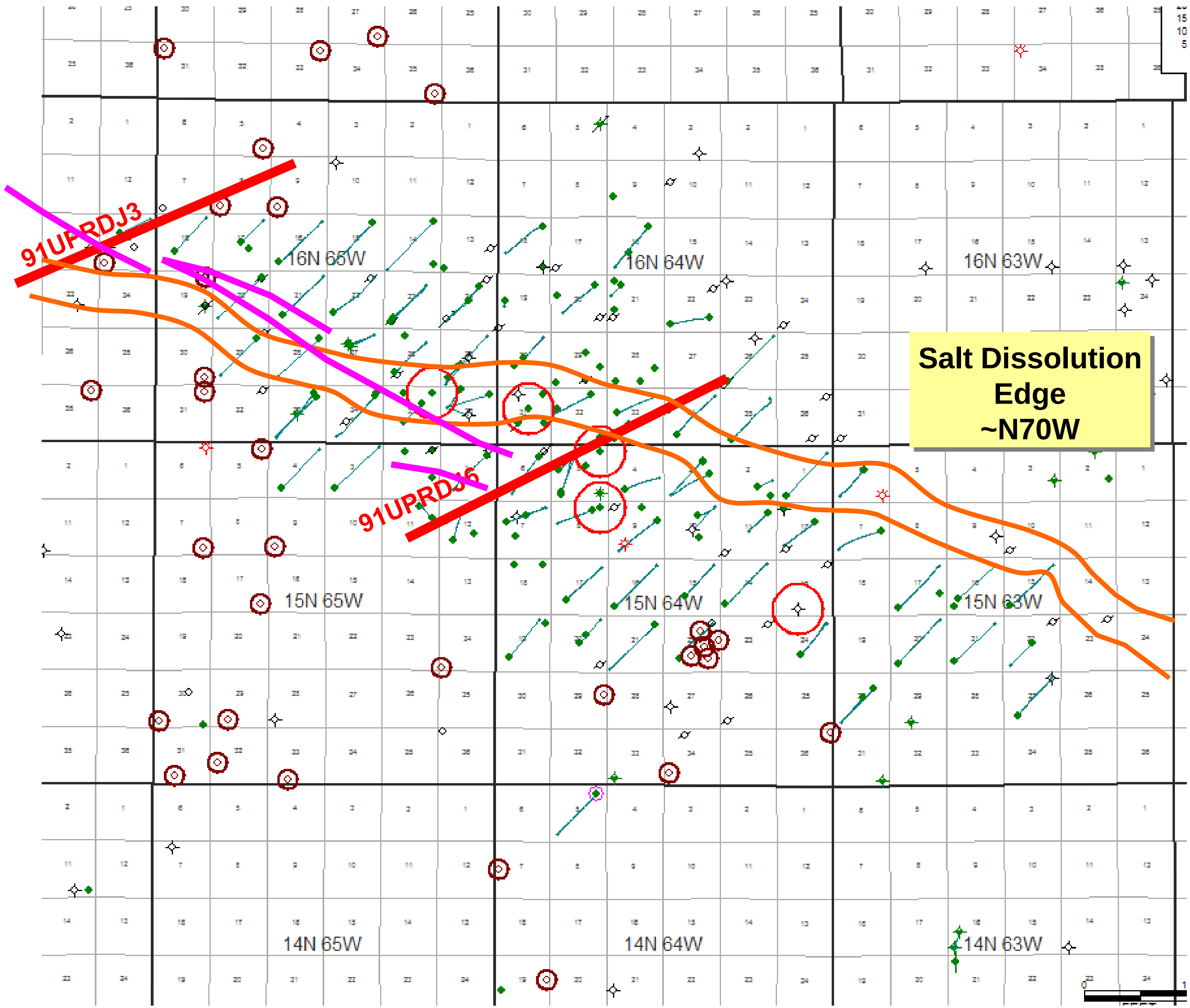
Structures and Associated Fractures



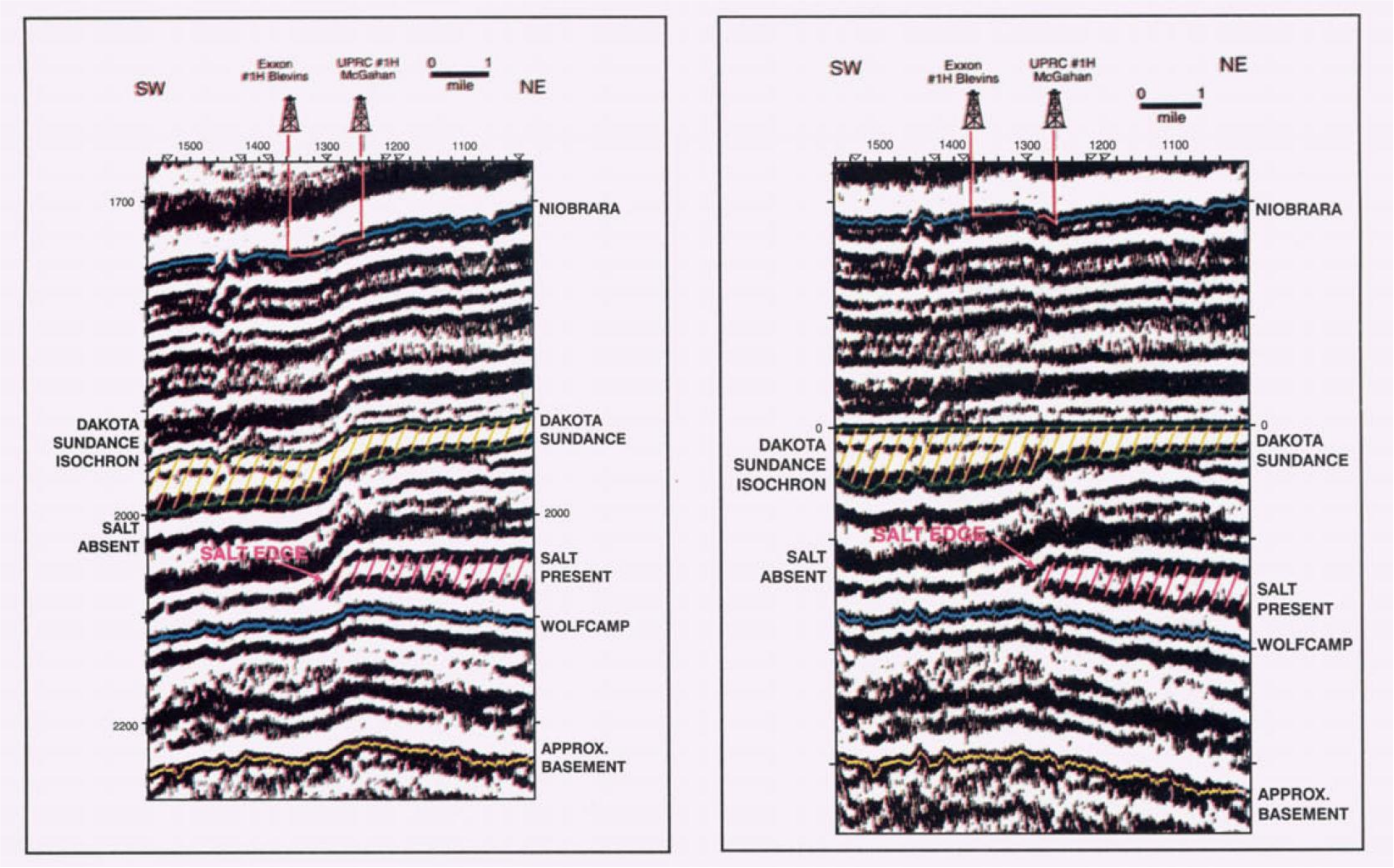
From Austin Chalk Outcrops

Friedman et al., 1992

Silo Field Cores And Seismic

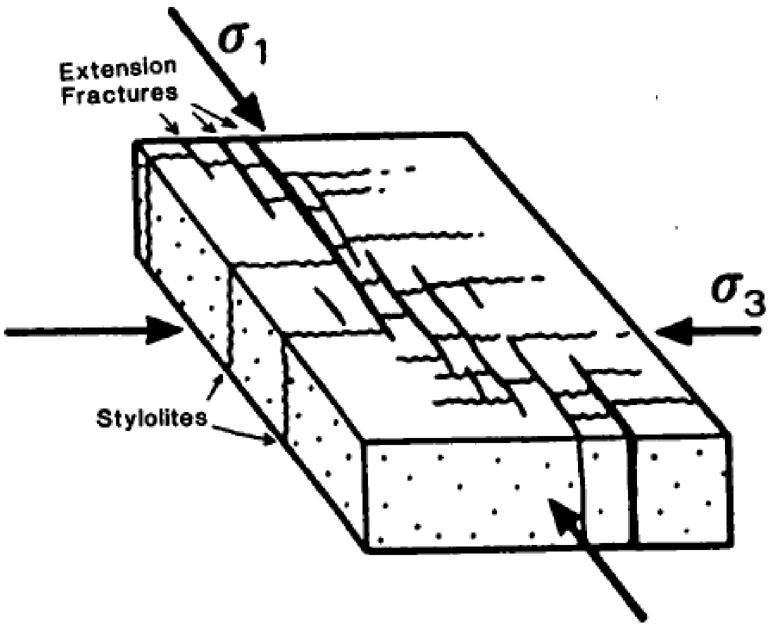


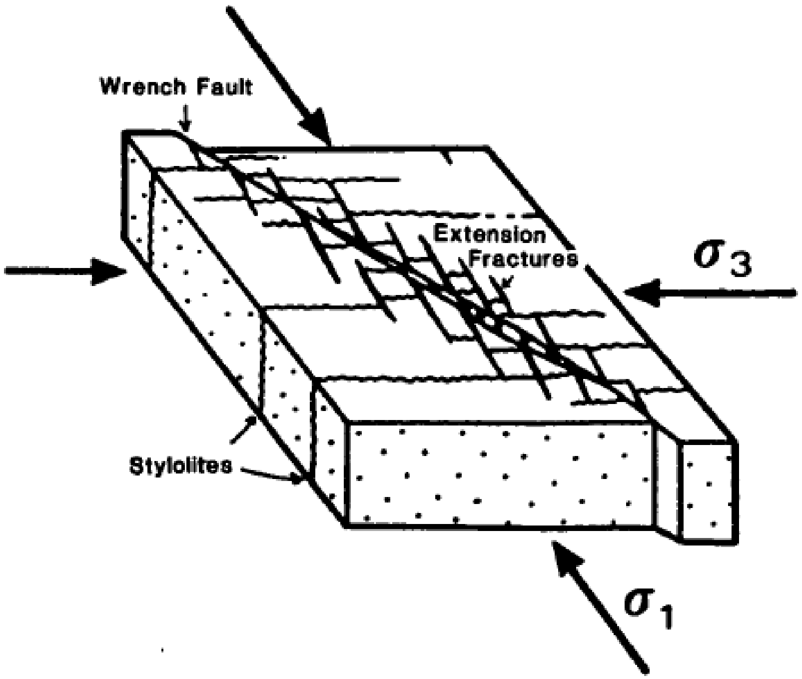
Faults and Salt Edge



Svoboda, 1995

Extension Fractures and Wrench Faults

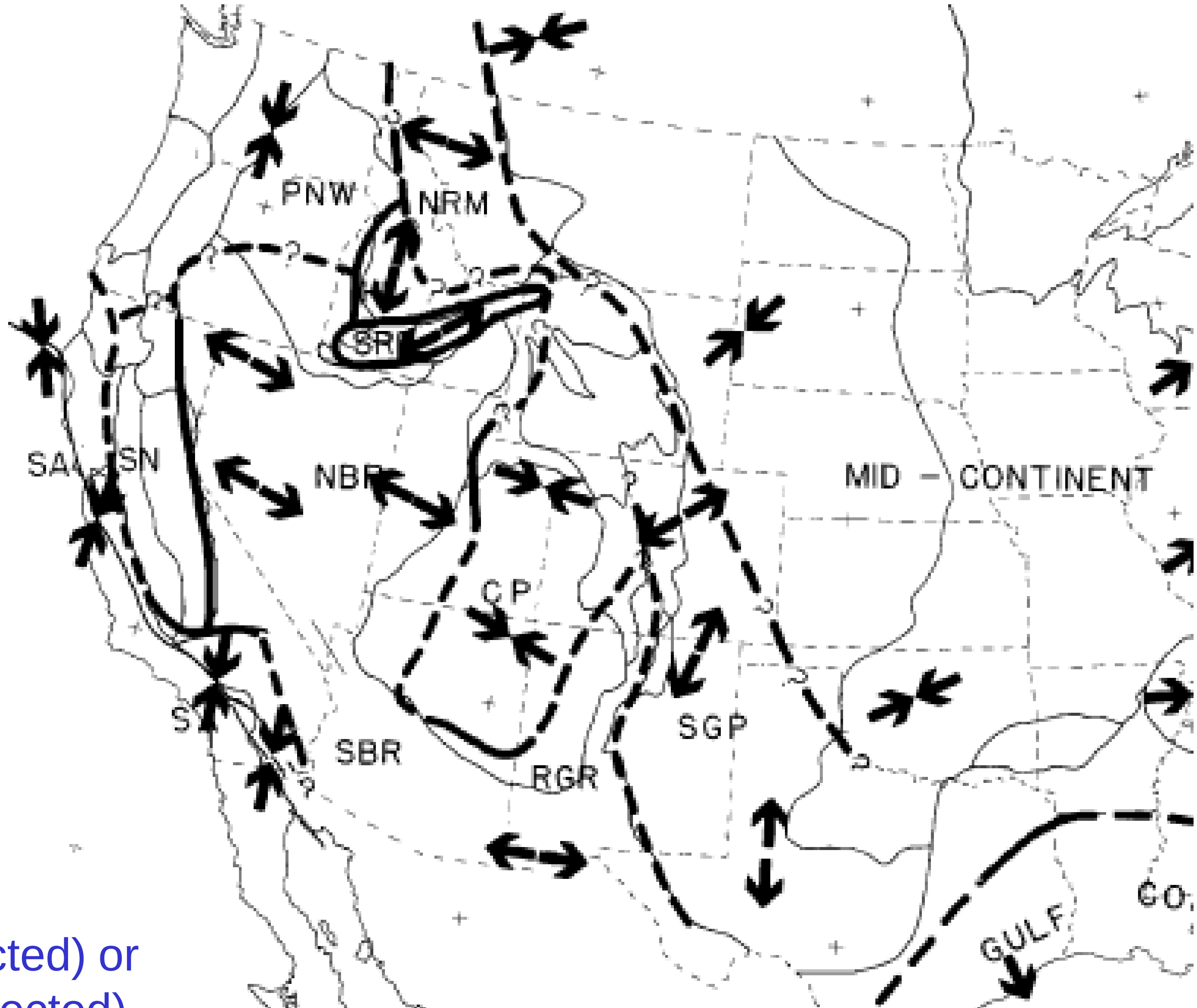




Shmax

Sonnenberg and Weimer, 1993

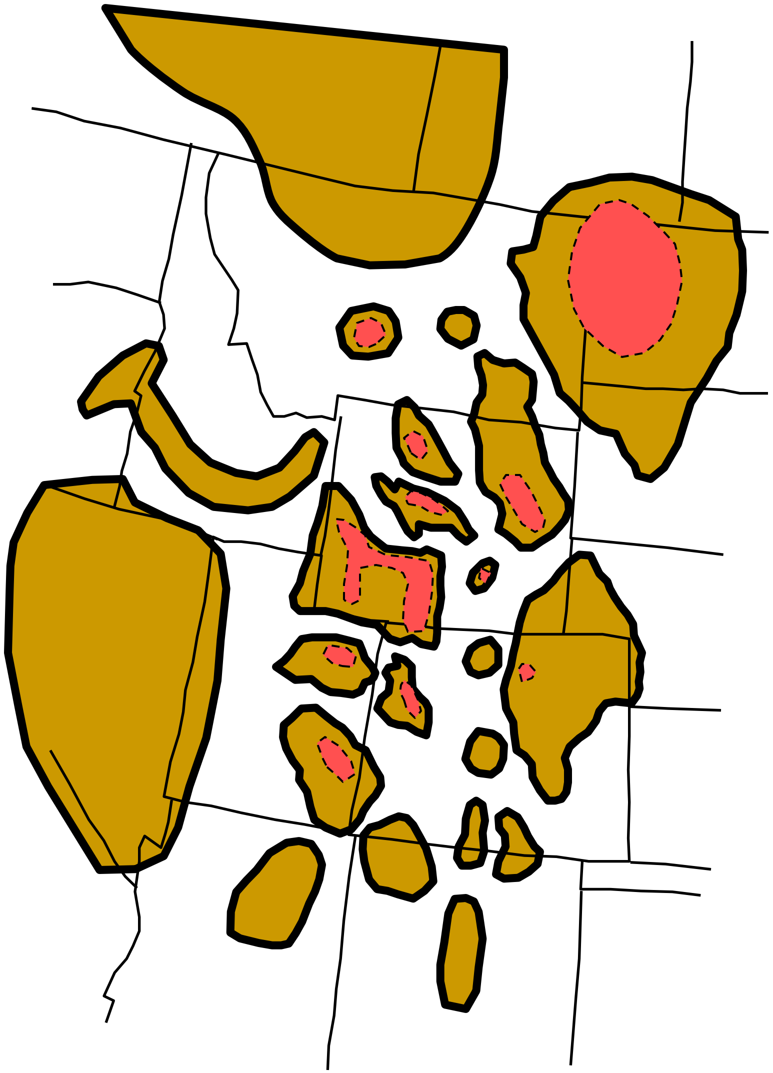
Regional Horizontal Stress Orientation

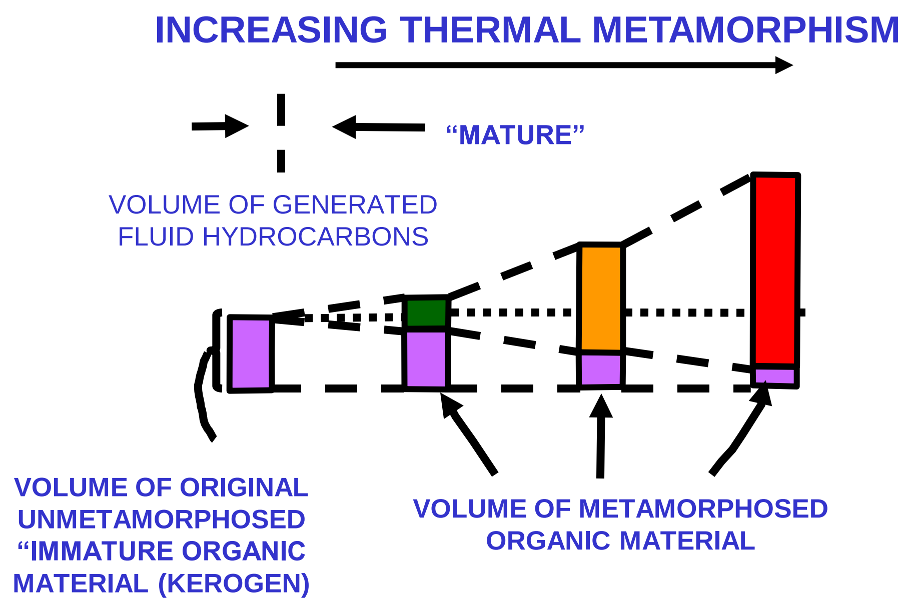


Generalized stress map, western US. Arrows represent direction of either least (outward directed) or greatest (inward directed) principal horizontal stress.

Modified from Zoback and Zoback, 1980

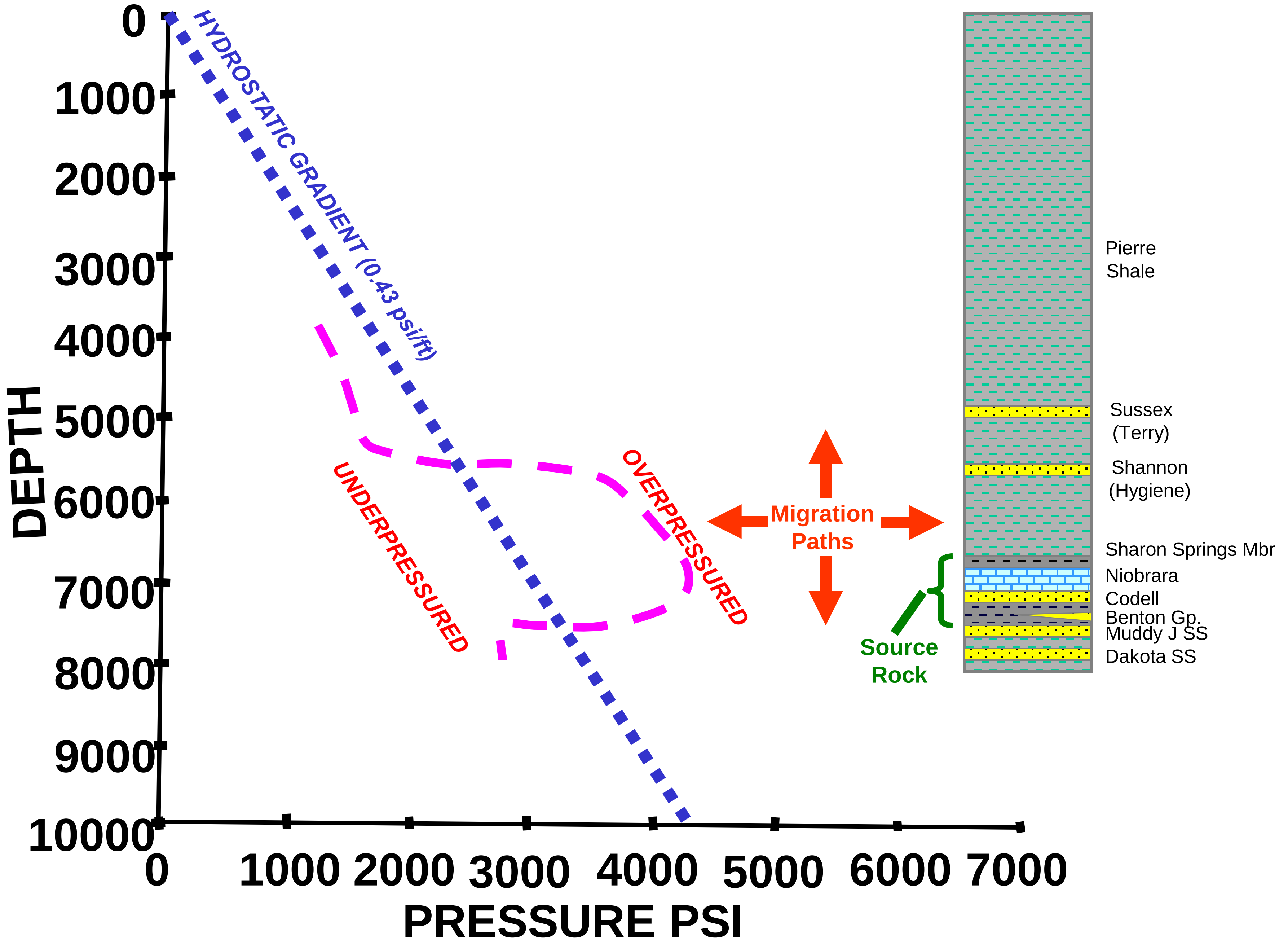
Overpressuring in Rockies Basins





ASSUMES GENERATED HYDROCARBONS ARE RETAINED IN SYSTEM & CONVERT TO STABLE SPECIES

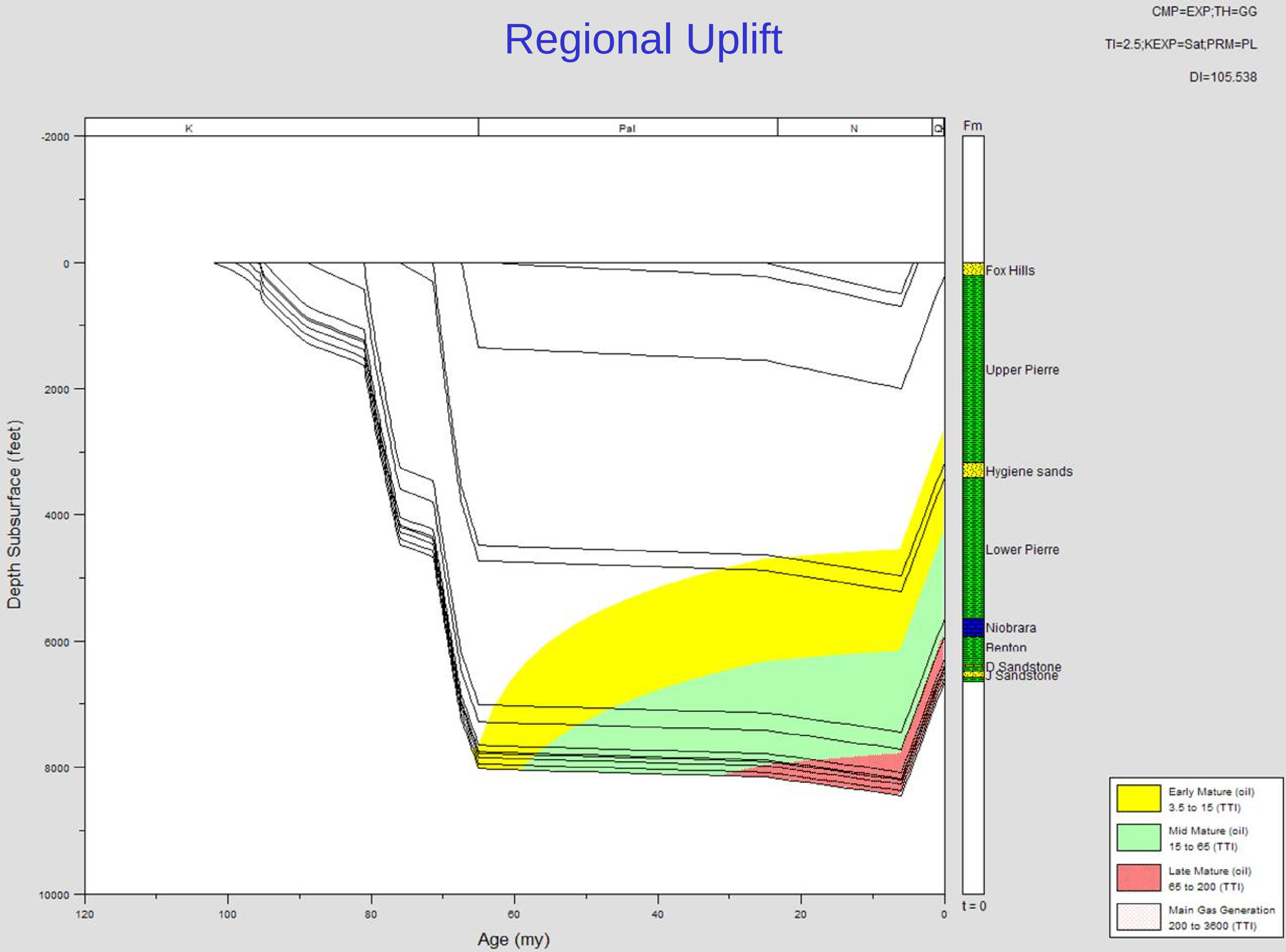
Modified from Spencer, 1987 and Meissner, 1980

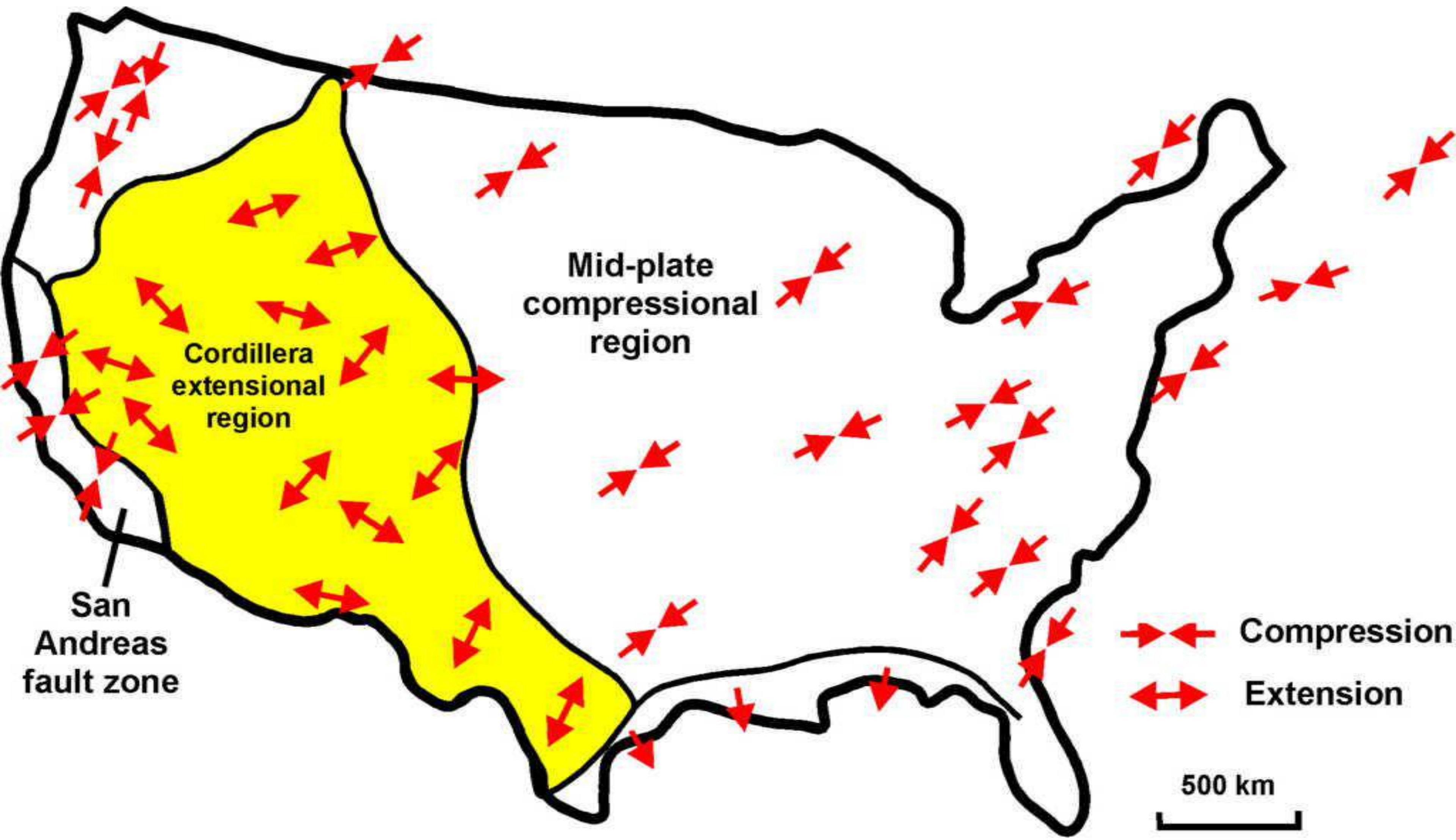


0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
DEPTH
HYDROSTATIC GRADIENT (0.43 psi/ft)
UNDERPRESSURED
OVERPRESSURED
Migration
Paths
Source
Rock
Pierre
Shale
Sussex
(Terry)
Shannon
(Hygiene)
Sharon Springs Mbr
Niobrara
Codell
Benton Gp.
Muddy J SS
Dakota SS
0
1000
2000
3000
4000
5000
6000
7000
PRESSURE PSI

Weimer, 1995

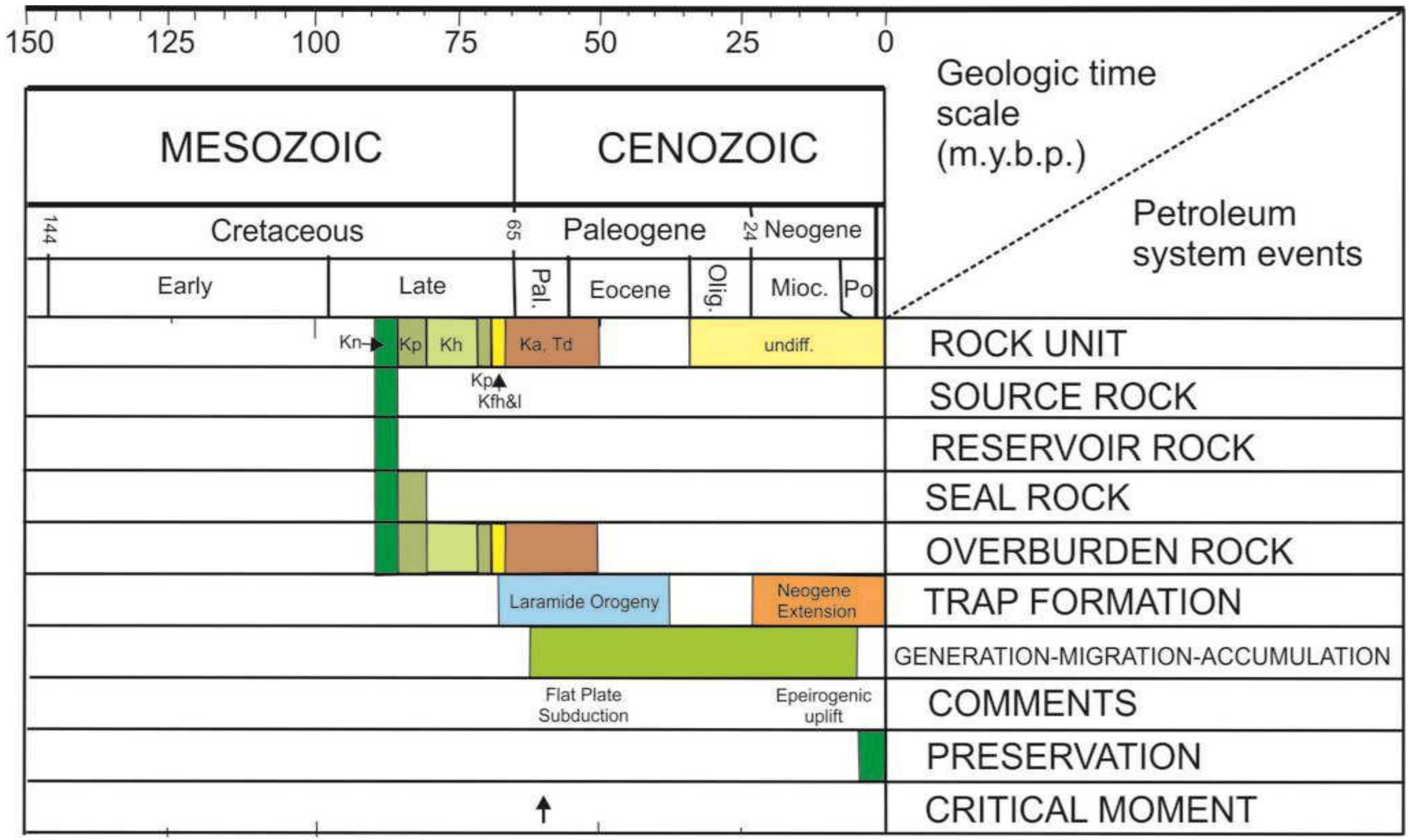
Regional Uplift





http://science.jrank.org/pages/48171/stress-field-Earth.html

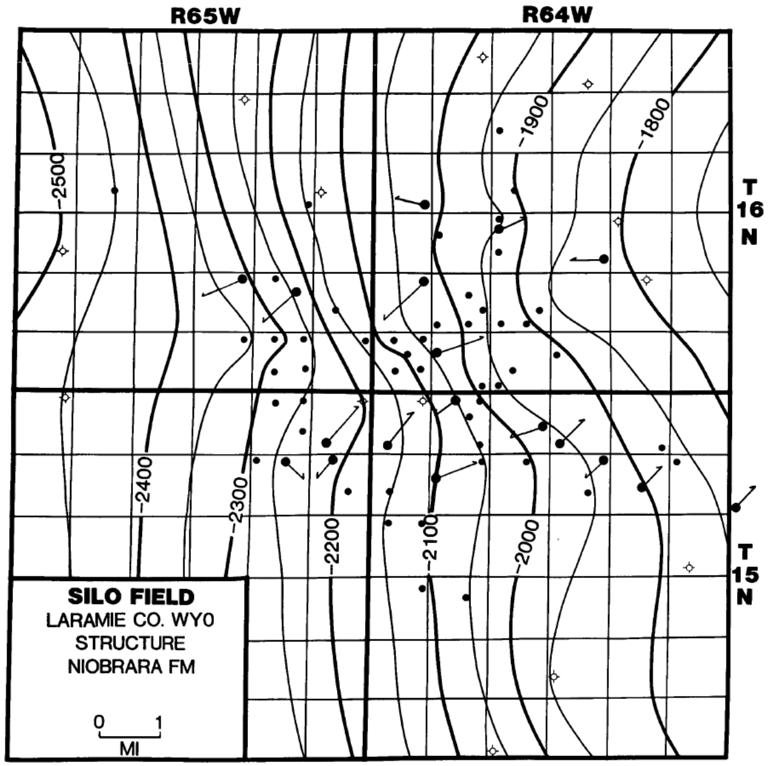
Niobrara Petroleum System Events Chart

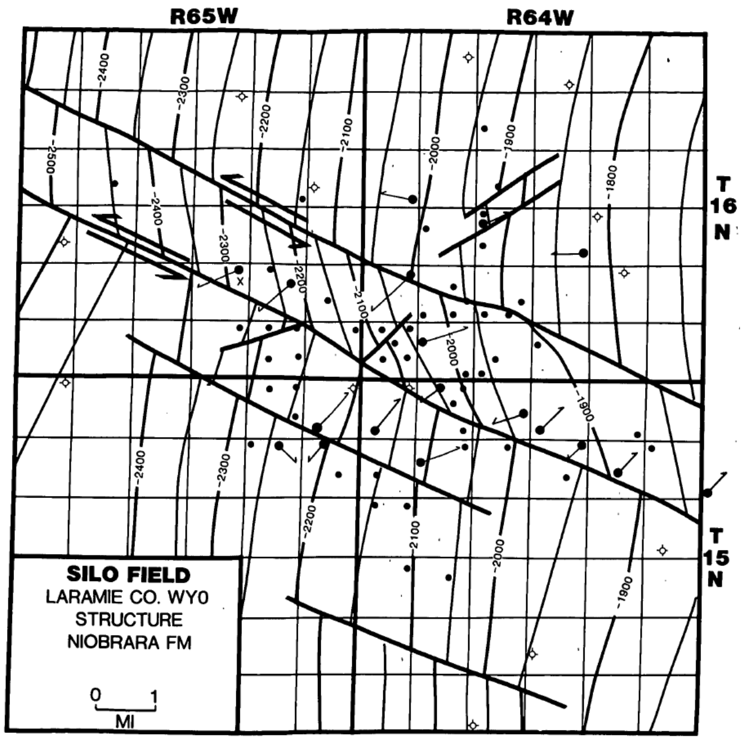


Technology for Source Bed Plays

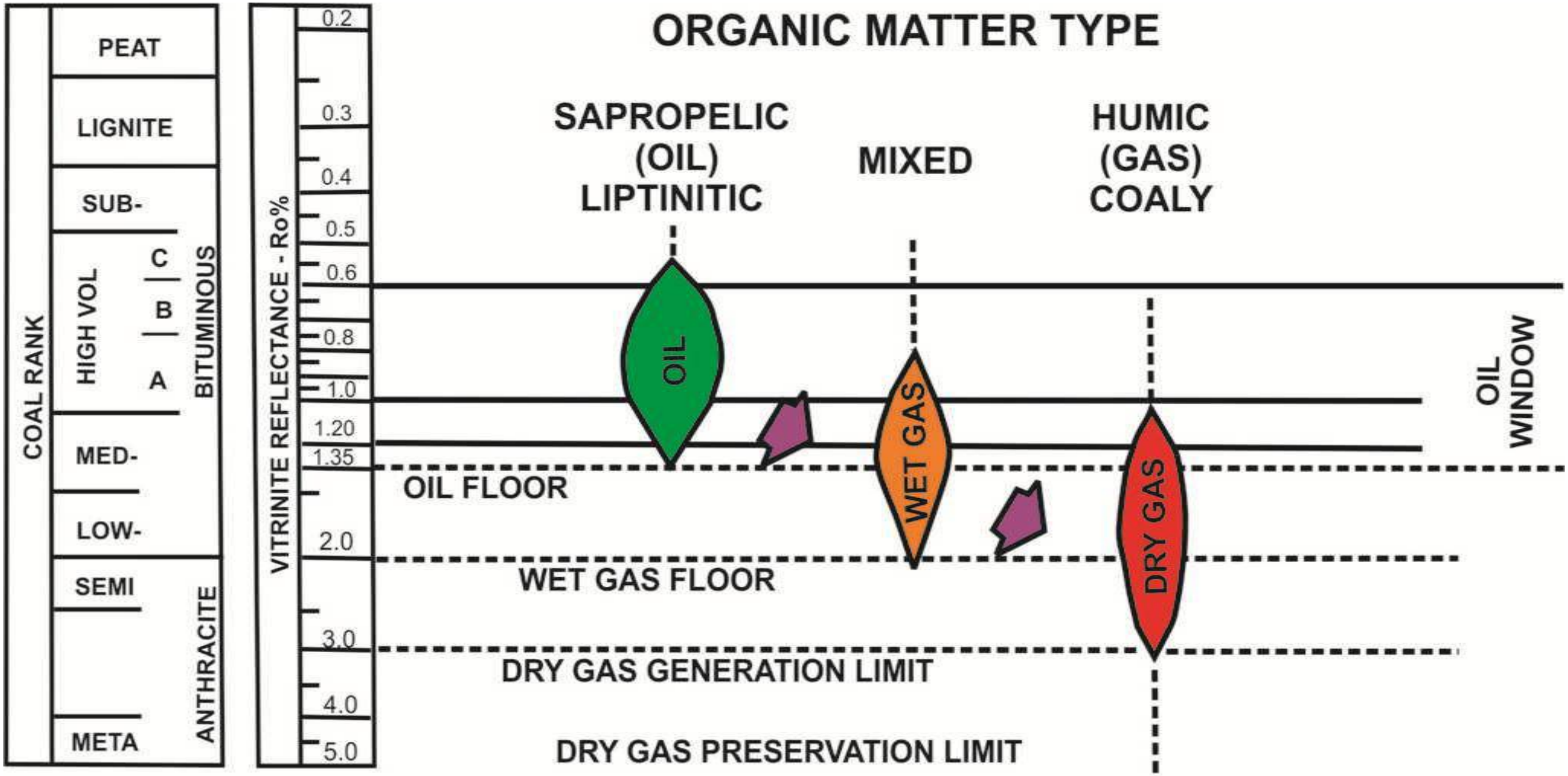
- Source rock evaluation
- Normal surface and subsurface mapping (i.e., the fundamentals)
- Resistivity mapping (e.g., logs)
- Lineament discrimination (local, regional)
- 3-D, 3-C Seismic Imaging
- Borehole fracture mapping (FMS etc.)
- Surface geochemistry (microseeps)
- Horizontal drilling
- Microseismic
- Multistage hydraulic-fracture stimulation

Structure Top Niobrara



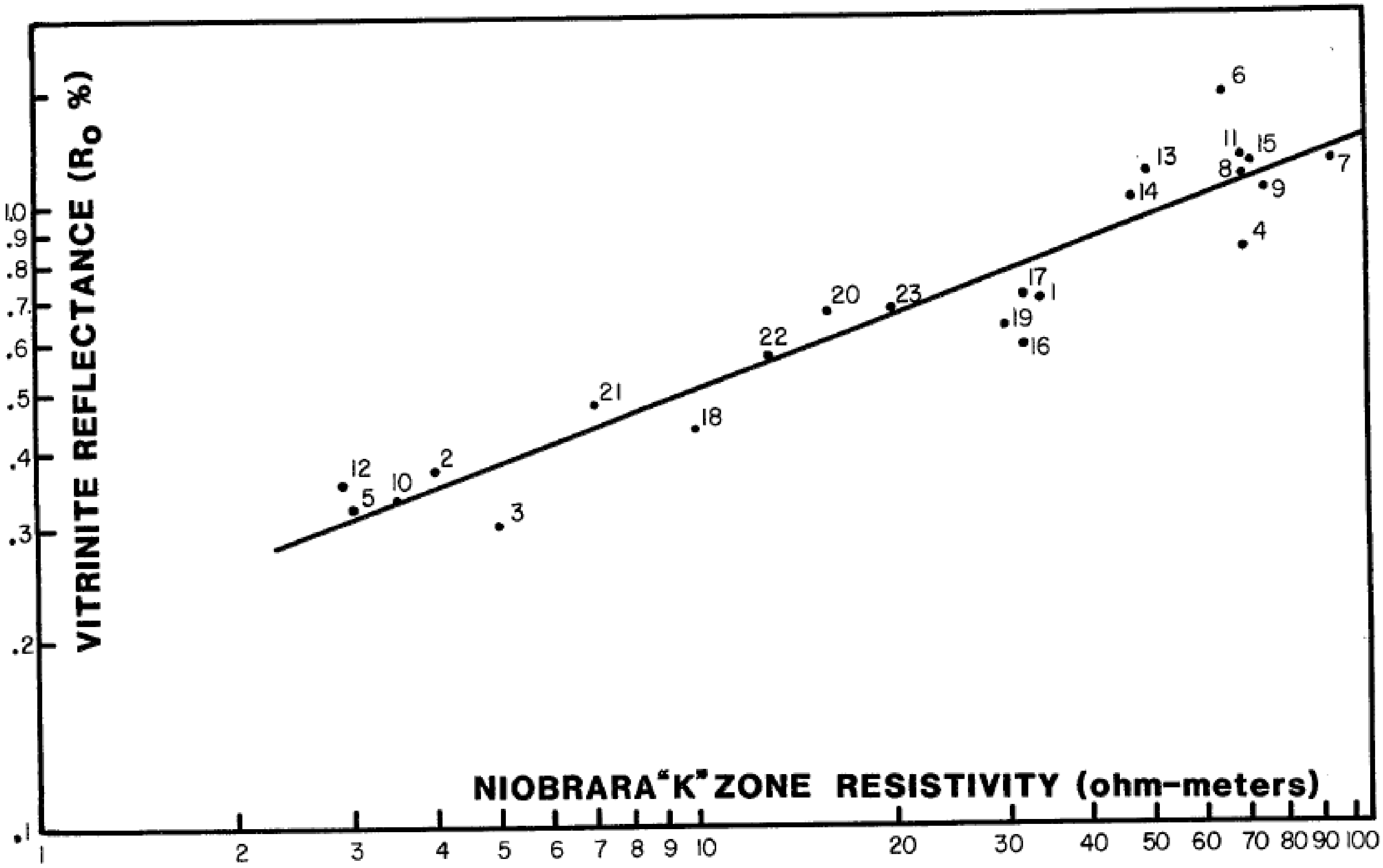


Sonnenberg and Weimer, 1993



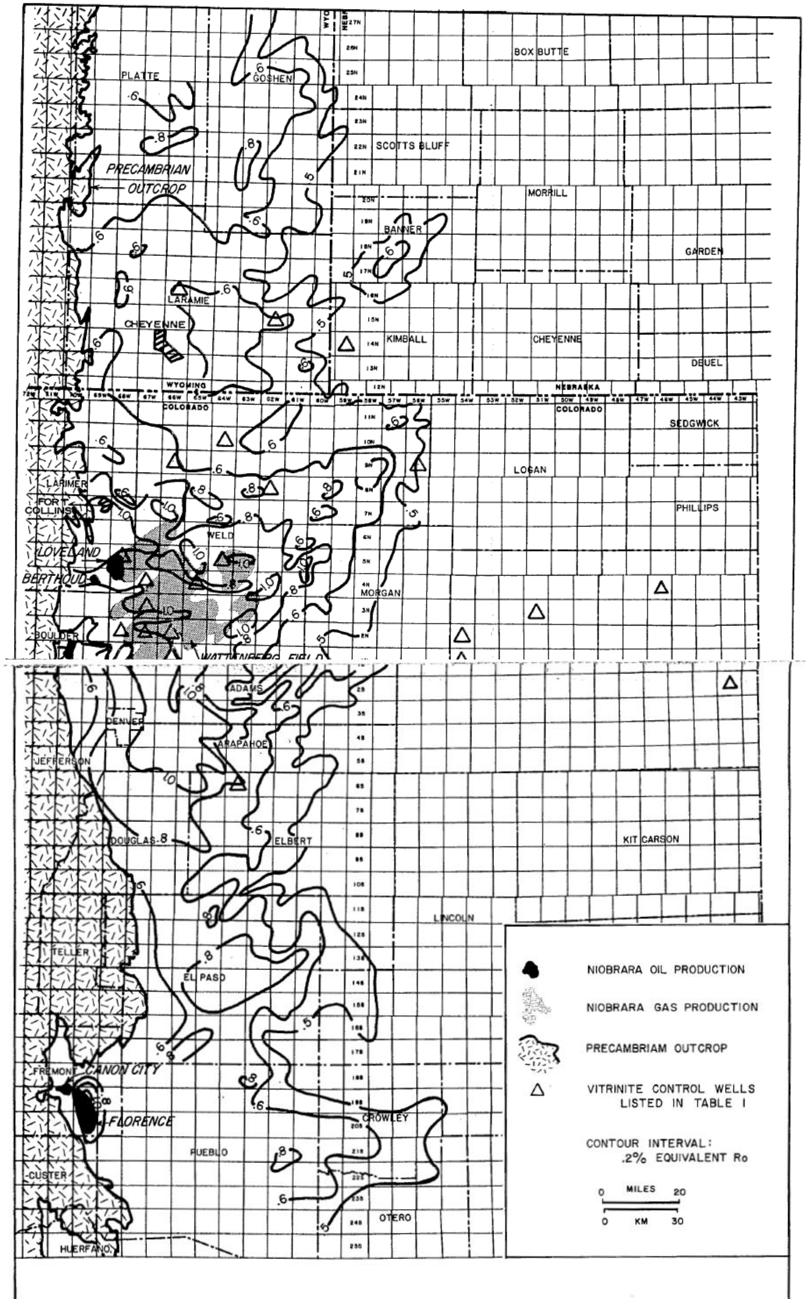
Modified from Dow, 1977

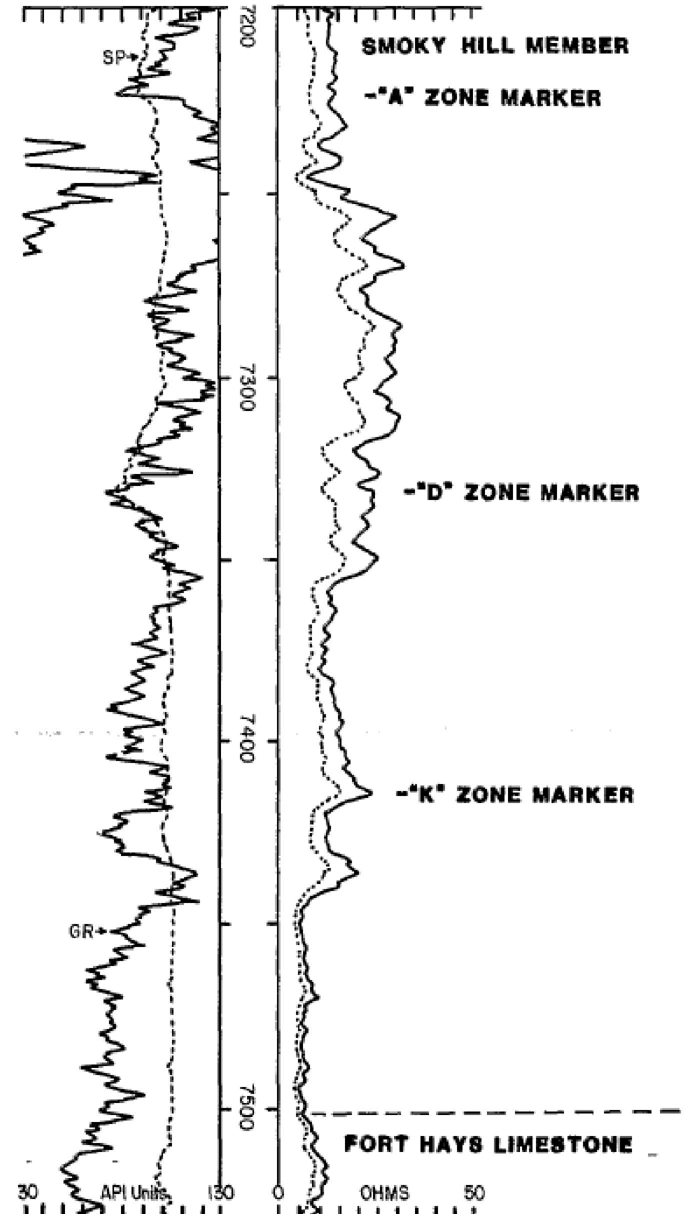
Niobrara vitrinite reflectance versus “K” zone resistivity, Denver Basin



Smagala et al., 1984

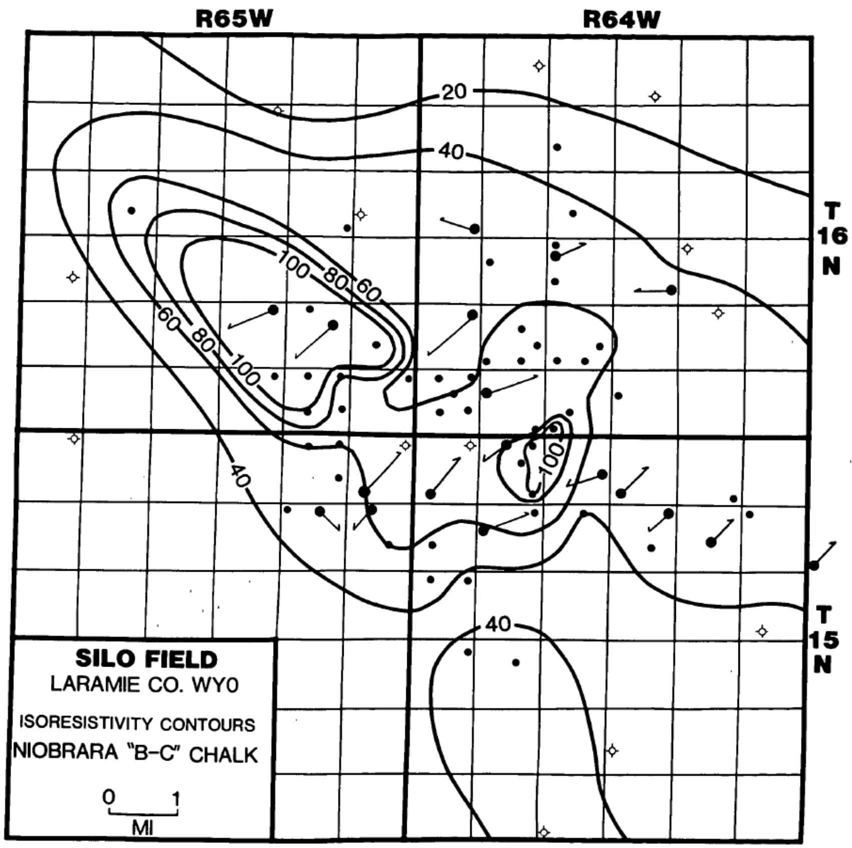
Niobrara Source Rock Maturity-Denver Basin

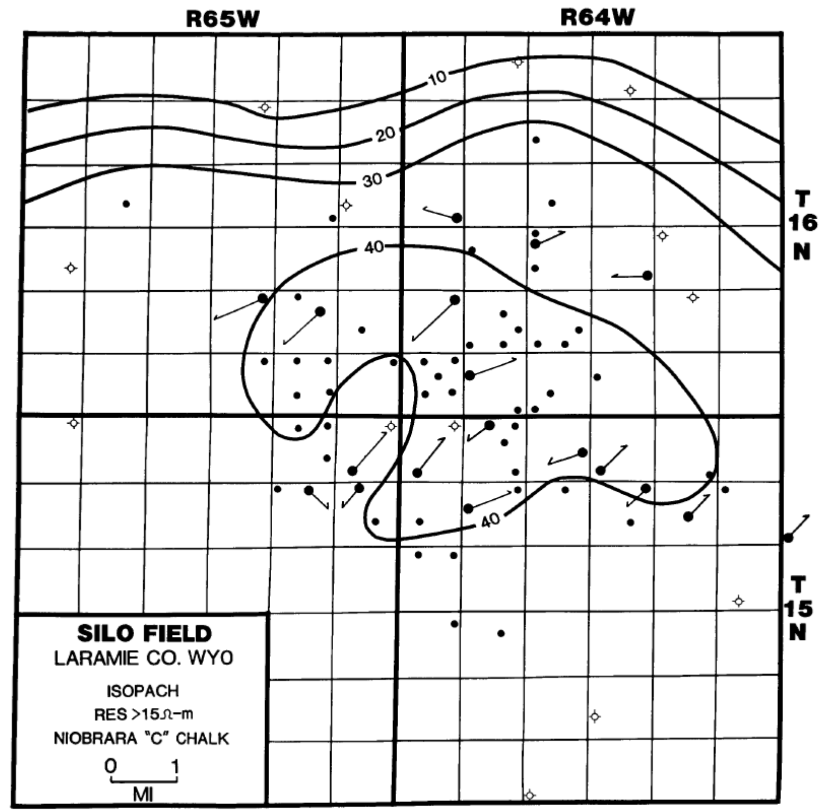




Smagala et al., 1984

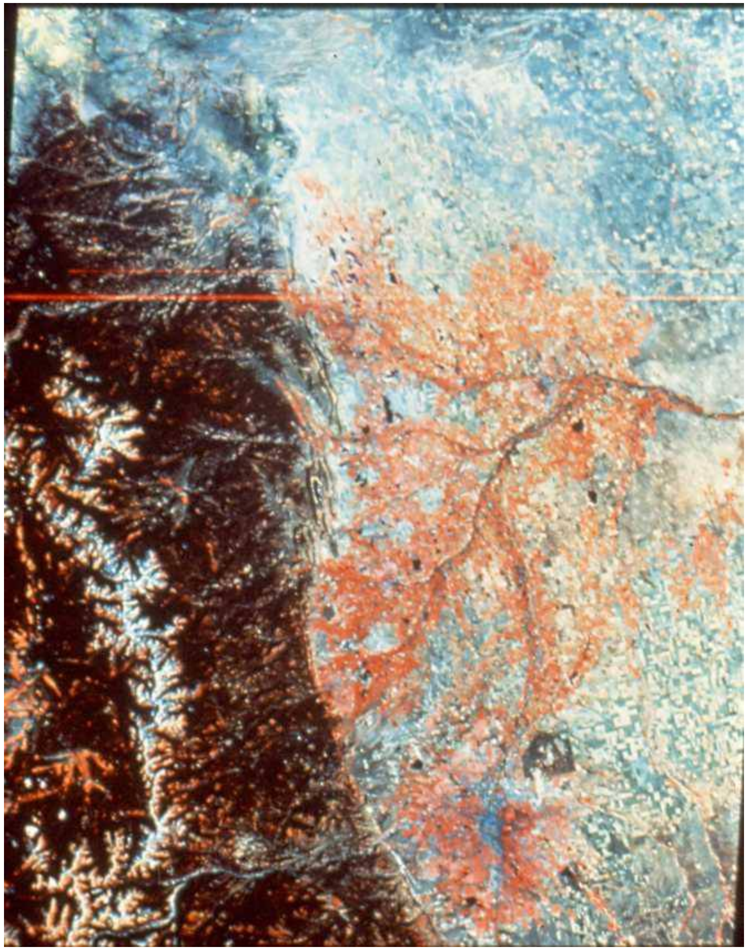
Resistivity Mapping and Accumulation

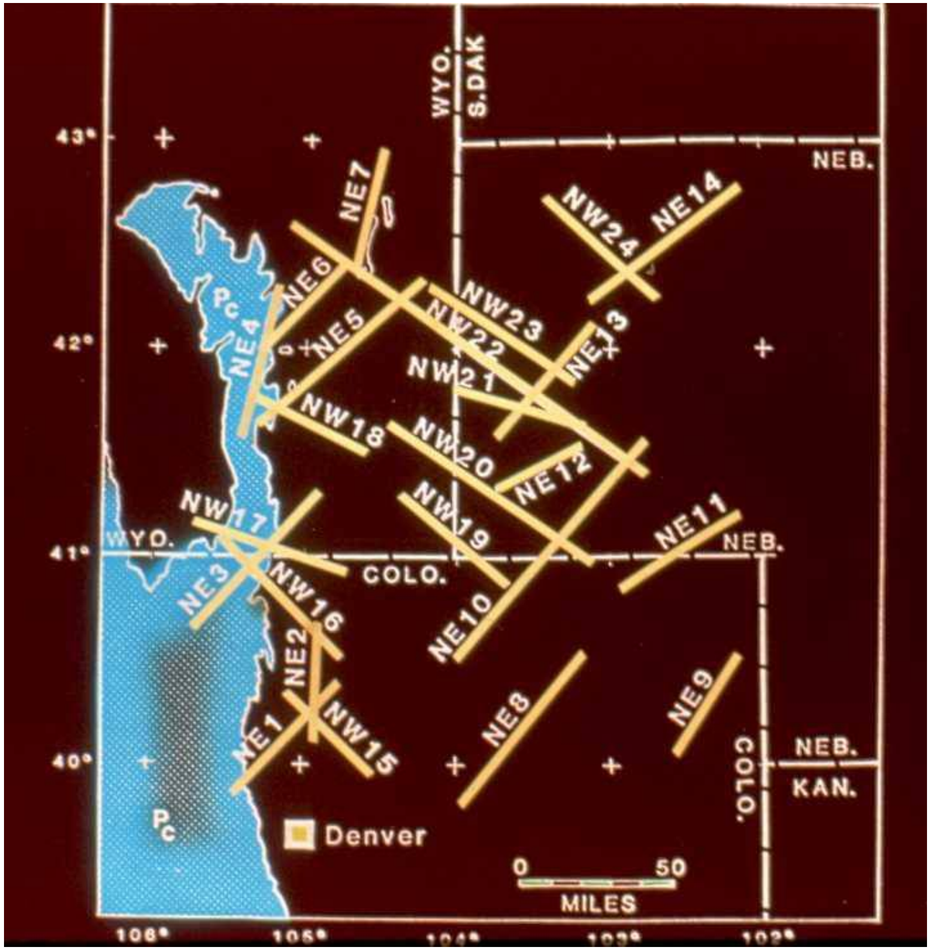




Sonnenberg and Weimer, 1993

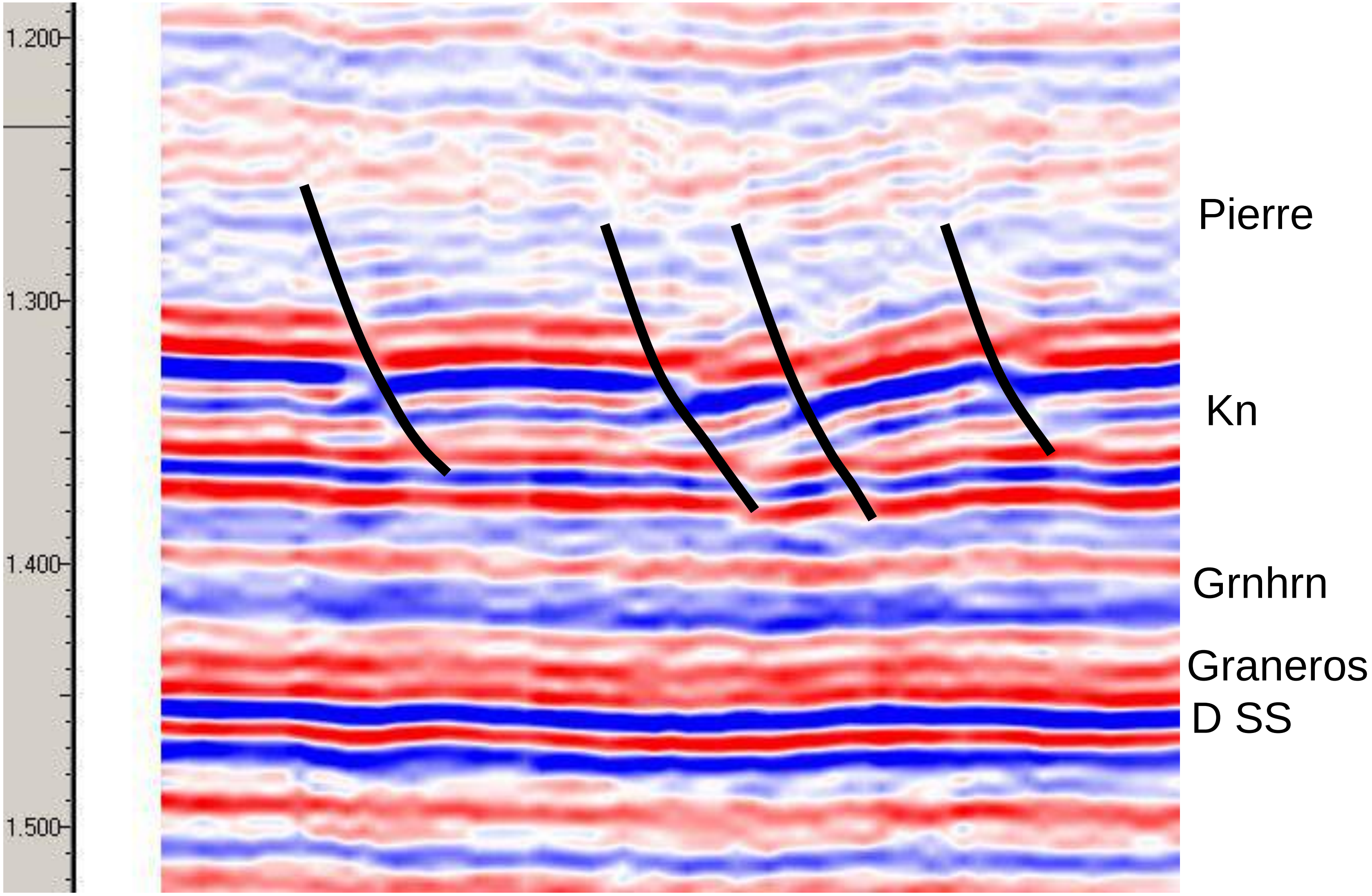
Lineament Analysis

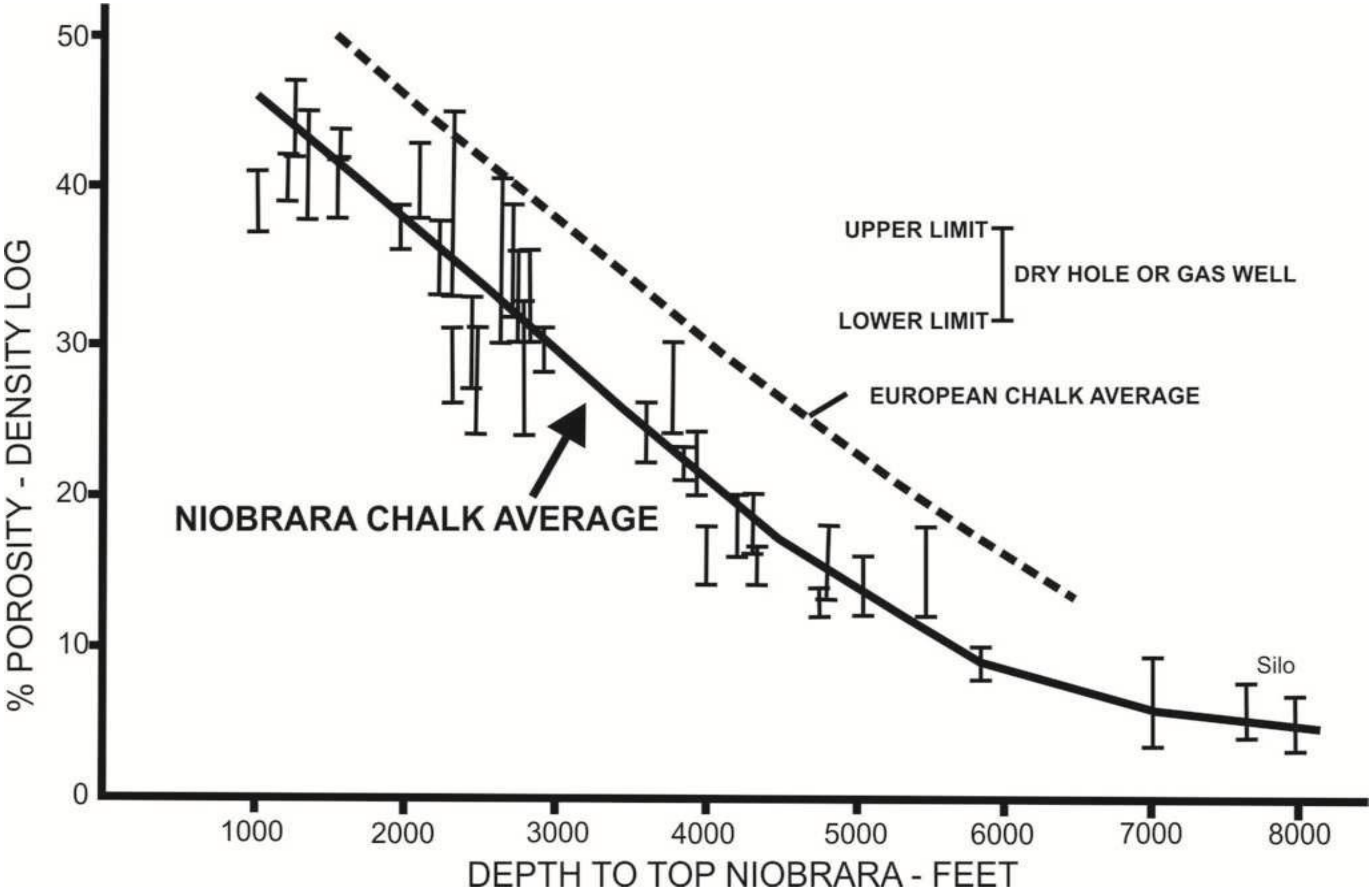




S. Perry, ca 1985

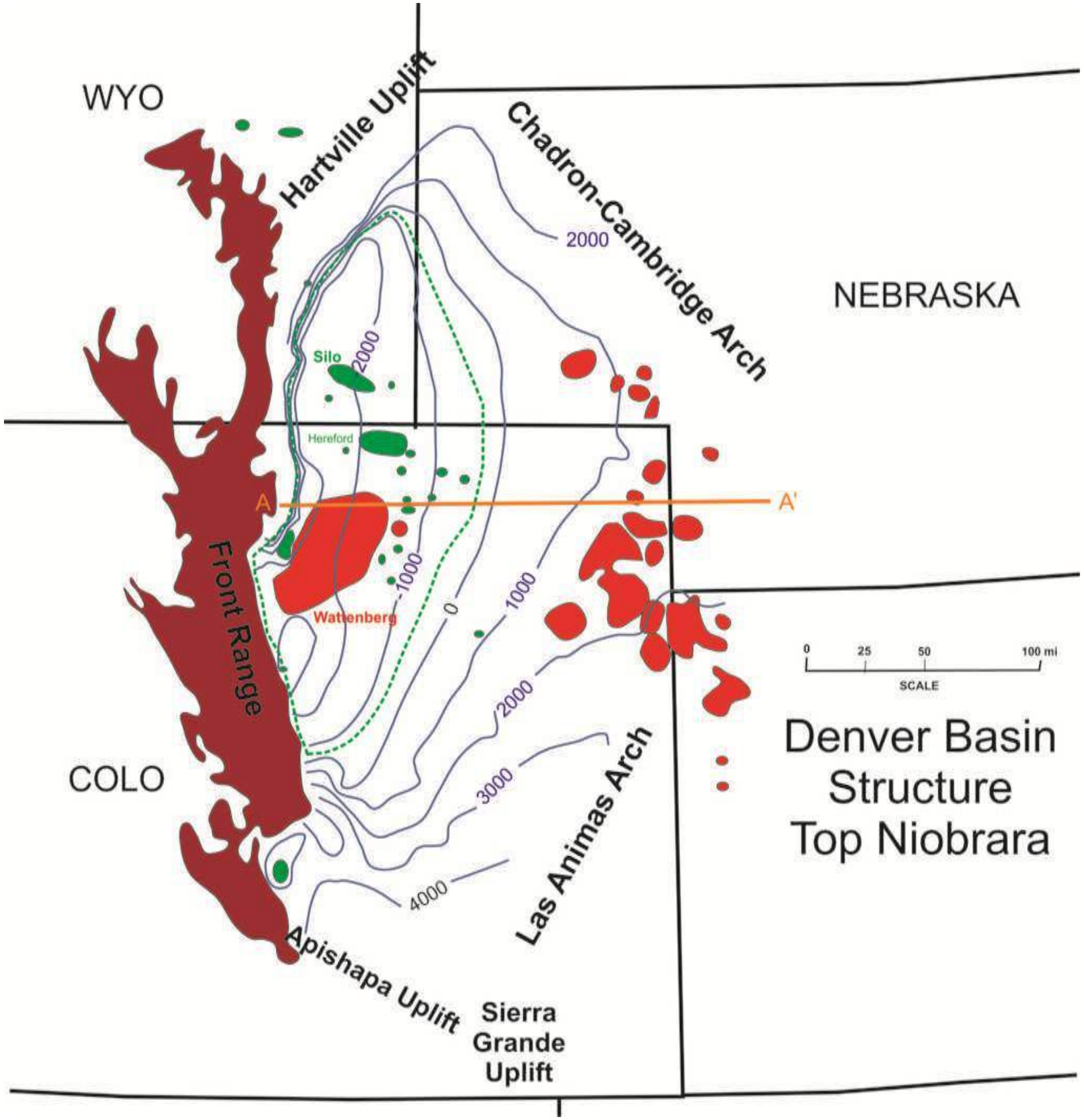
3-D Seismic

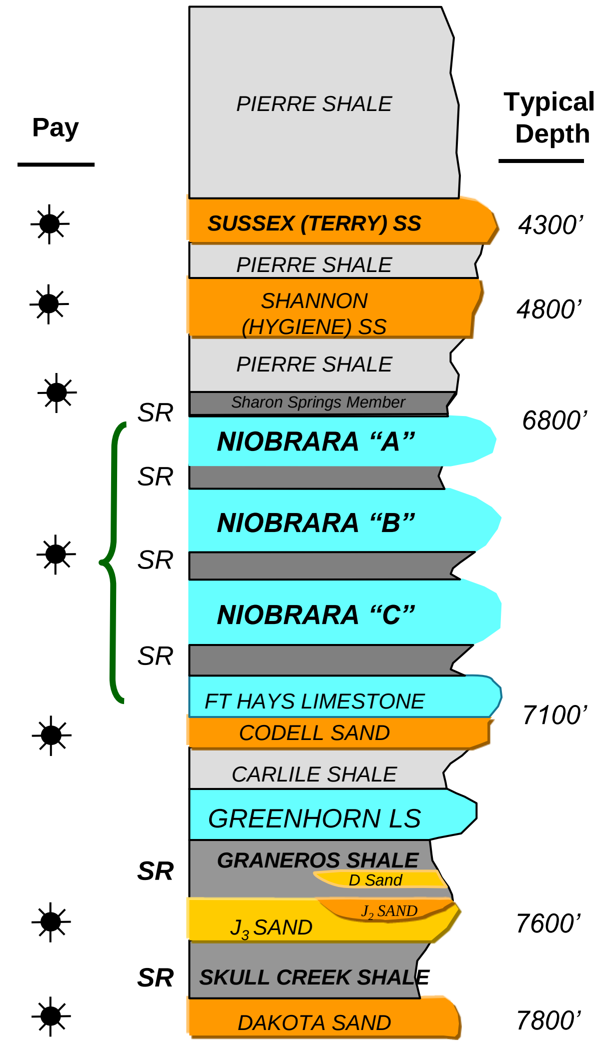


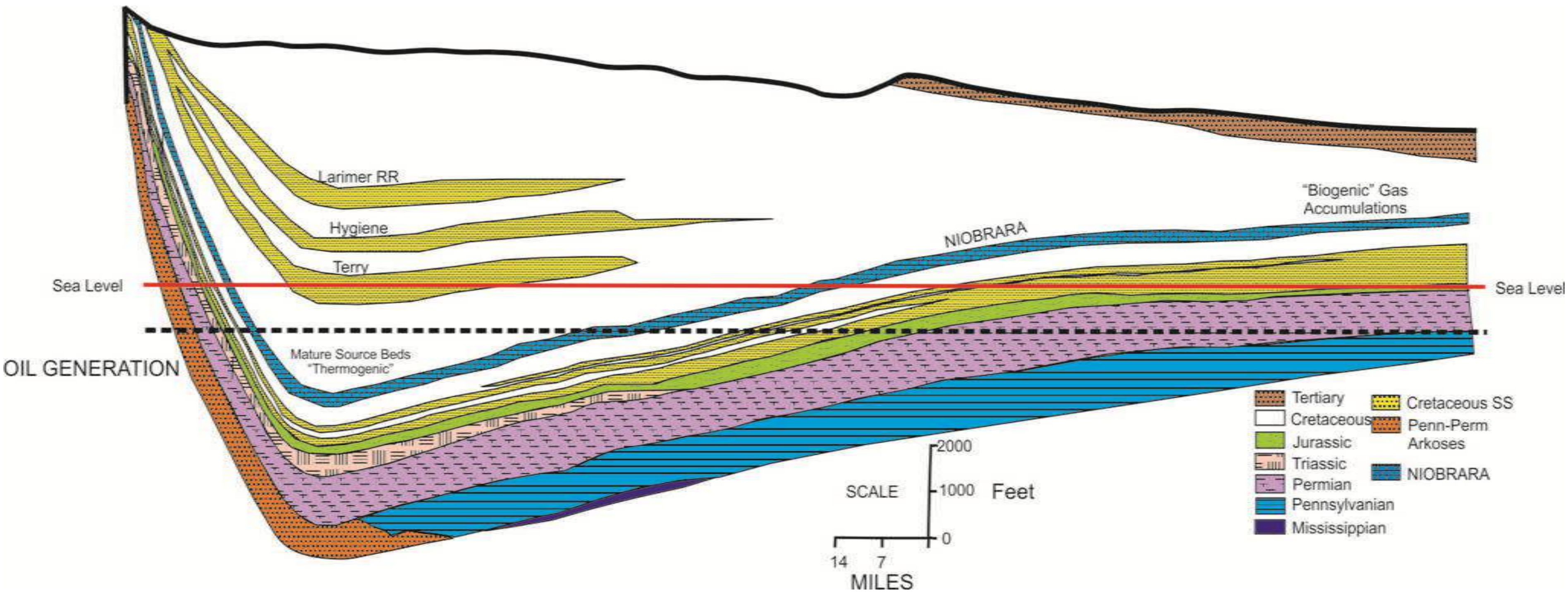


Modified from Lockridge and Pollastro, 1988

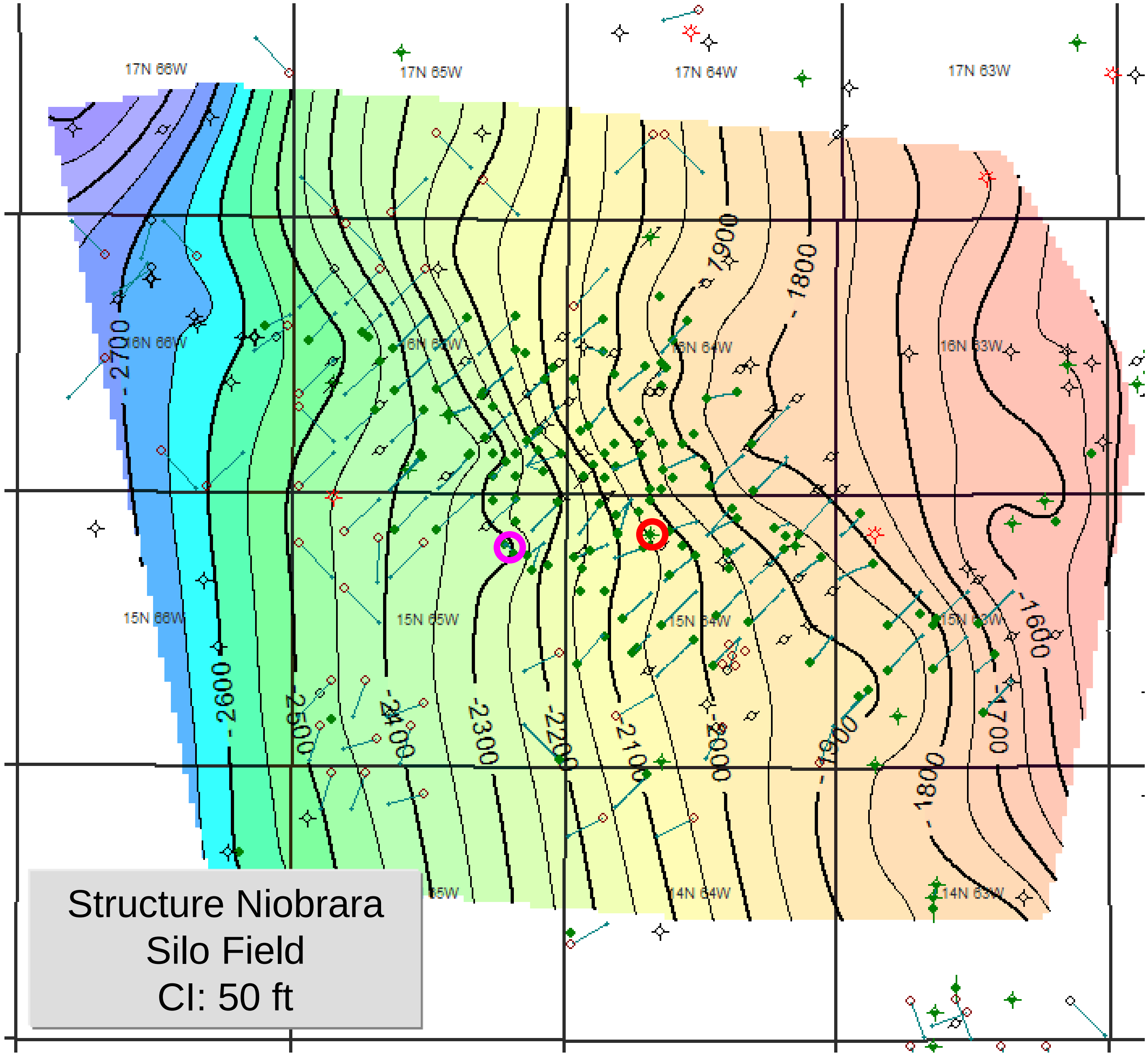
Niobrara Petroleum System - Denver Basin
Shallow Biogenic Gas
Deep Thermogenic Oil and Gas







Larimer RR
Hygiene
Terry
"Biogenic" Gas
Accumulations
NIOBRARA
Sea Level
Sea Level
OIL GENERATION
Mature Source Beds
"Thermogenic"
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Pennsylvanian
Mississippian
Cretaceous SS
Penn-Perm
Arkoses
NIOBRARA
SCALE
2000
1000
0
Feet
14
7
MILES



SILO FIELD

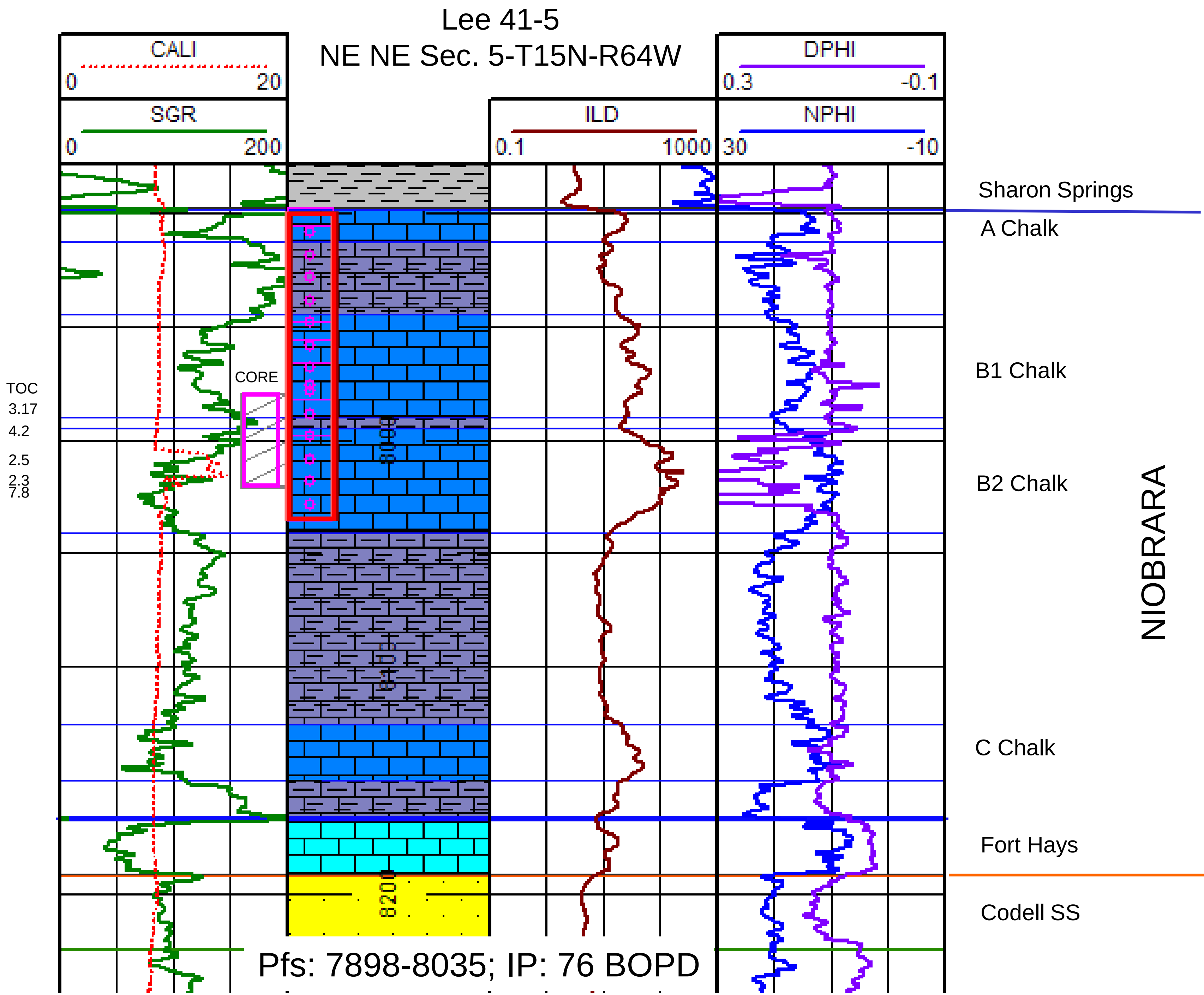
Niobrara Fm.

Discovery:

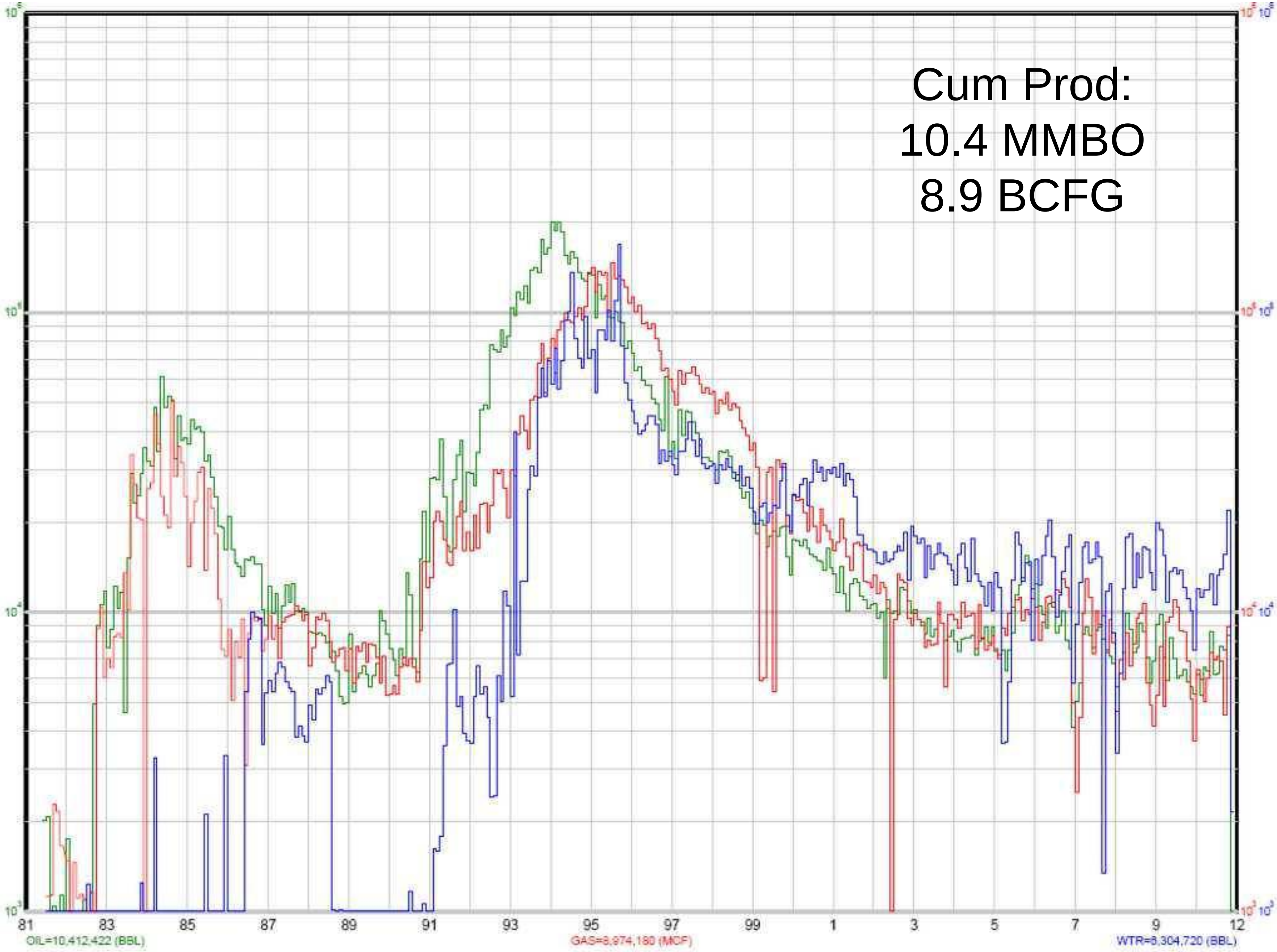
1981
Amoco Champlin 300 1
SE SE Sec 5, T15N, R64W
Ft Hays completion
78 BOPD

1990
First horizontal:
Warren # 1
Sec. 11, T15N, R65W
600 BOPD

Veridical Depths:
7100 to 8800 ft



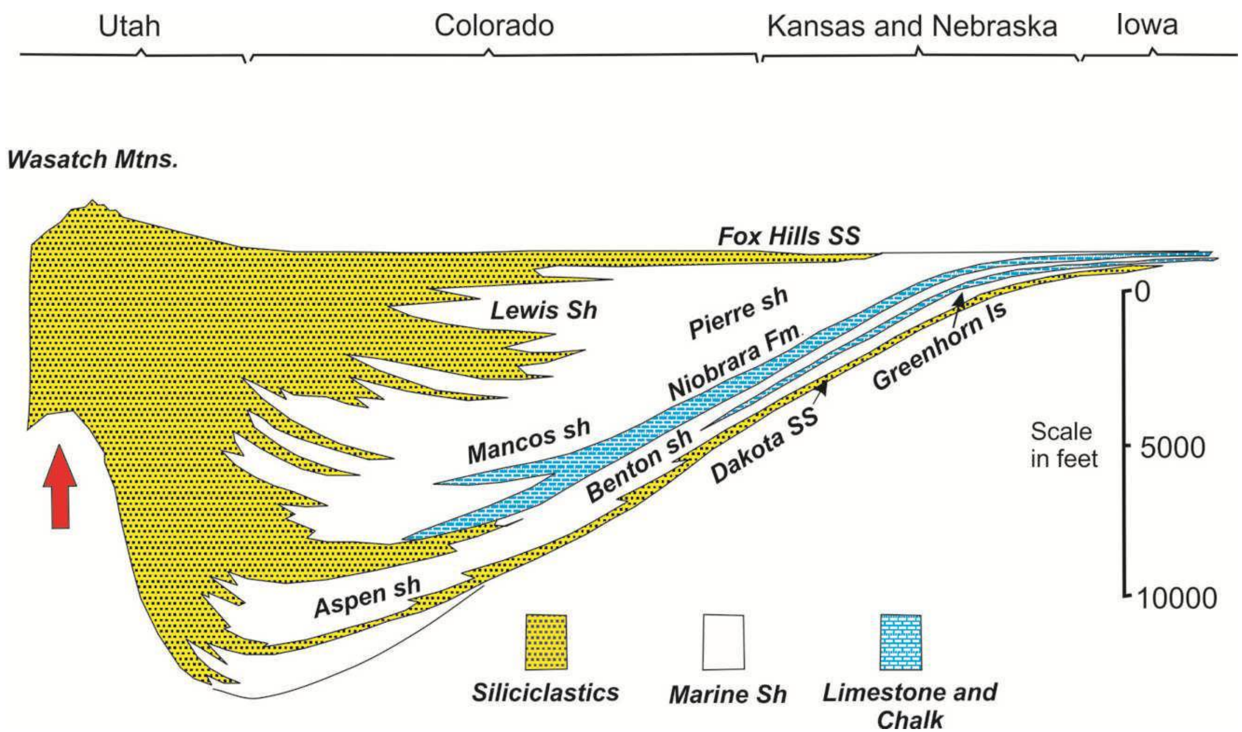
Lee 41-5
NE NE Sec. 5-T15N-R64W
CALI
0
20
SGR
0
200
ILD
0.1
1000
DPHI
0.3
-0.1
NPHI
30
-10
Sharon Springs
A Chalk
B1 Chalk
B2 Chalk
C Chalk
Fort Hays
Codell SS
NIOBRARA
CORE
TOC
3.17
4.2
2.5
2.3
7.8
8000
8100
8200
Pfs: 7898-8035; IP: 76 BOPD


Cum Prod:
10.4 MMBO
8.9 BCFG
81
83
85
87
89
91
93
95
97
99
1
3
5
7
9
12
OIL=10,412,422 (BBL)
GAS=8,974,180 (MCF)
WTR=8,304,720 (BBL)

Summary

- Unconventional tight oil resource plays are ‘changing the game’
- Niobrara Petroleum System present in most Rockies basins
- It all starts with good to excellent source beds
- Source beds mature over large areal extent
- Natural fracturing enhances tight reservoirs
- Horizontal drilling and fracture stimulation technology important in tight oil plays

Colorado School of Mines Niobrara Consortium



For Information, Contact:

Steve Sonnenberg
ssonnenb@mines.edu

Q&A With Steve Sonnenberg

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Please give us your feedback and suggestions

CLICK HERE

(A new browser window will open)