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

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

Conventional Reservoirs:
Small Volumes,
Easy to Develop

Unconventional Reservoirs:
Large Volumes,
Hard to Develop

Increasing Product Price
Improving Technology

Province Resource Size

- Oil Shale
- Oil Sands; Heavy Oil; Bituminous Sands
- Tight Gas Sands; CBM; Gas Shales
- Gas Hydrates

Oil
Gas
Oil Shale
Gas Hydrates
Tight Gas Sands; CBM; Gas Shales
Tight Oil; Heavy Oil; Bituminous Sands
Oil
Gas

Conventional Reservoirs: Small Volumes, Easy to Develop
Unconventional Reservoirs: Large Volumes, Hard to Develop

Huge Volumes, Difficult to Develop

The Resource Pyramid

Increasing Product Price
Improving Technology

Province Resource Size

TECHNOLOGY RESERVOIRS
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
Isopach Niobrara – Location of Transcontinental Arch

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

CI: 100 ft
Modified from Longman et al., 1998, after Barlow, 1986
Requirements of Source Rock Deposition

• High organic productivity
  ➢ Sunlight
  ➢ Nutrients
  ➢ Absence of poisons (H₂S)

• Low destruction rate of organic material
  ➢ Absence of O₂ 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 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

[Diagram showing geological features]
Fractures Related To Folds

Hinge perpendicular

Hinge parallel
Structures and Associated Fractures

PLUNGING ANTICLINE

MONOCLINAL FLEXURE

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

Salt Dissolution Edge ~N70W
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

INCREASING THERMAL METAMORPHISM

“MATURE”

VOLUME OF GENERATED FLUID HYDROCARBONS

VOLUME OF ORIGINAL UNMETAMORPHOSED “IMMATURE ORGANIC MATERIAL (KEROGEN)”

VOLUME OF METAMORPHOSED ORGANIC MATERIAL

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

Modified from Spencer, 1987 and Meissner, 1980
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
Niobrara vitrinite reflectance versus “K” zone resistivity, Denver Basin

Smagala et al., 1984
Resistivity Mapping and Accumulation

Sonnenberg and Weimer, 1993
Lineament Analysis

S. Perry, ca 1985
3-D Seismic

Pierre
Kn
Grnhrn
Graneros
D SS
Modified from Lockridge and Pollastro, 1988
Niobrara Petroleum System - Denver Basin
Shallow Biogenic Gas
Deep Thermogenic Oil and Gas

Typical Depth

Pay

PIERRE SHALE
SUSSEX (TERRY) SS
4300'
SHANNON (HYGIENE) SS
4800'
PIERRE SHALE
SR
6800'
NIOBRA "A"
SR
6800'
NIOBRA "B"
SR
NIOBRA "C"
SR
FT HAYS LIMESTONE
7100'
CODELL SAND
7600'
CARLILE SHALE
7600'
GREENHORN LS
7800'
GRANEROS SHALE
SR
D Sand
7800'
J Base SAND
J O F Sand
7600'
SKULL CREEK SHALE
SR
DAKOTA SAND
7800'

Denver Basin Structure
Top Niobrara
Structure Niobrara
Silo Field
CI: 50 ft

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
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

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