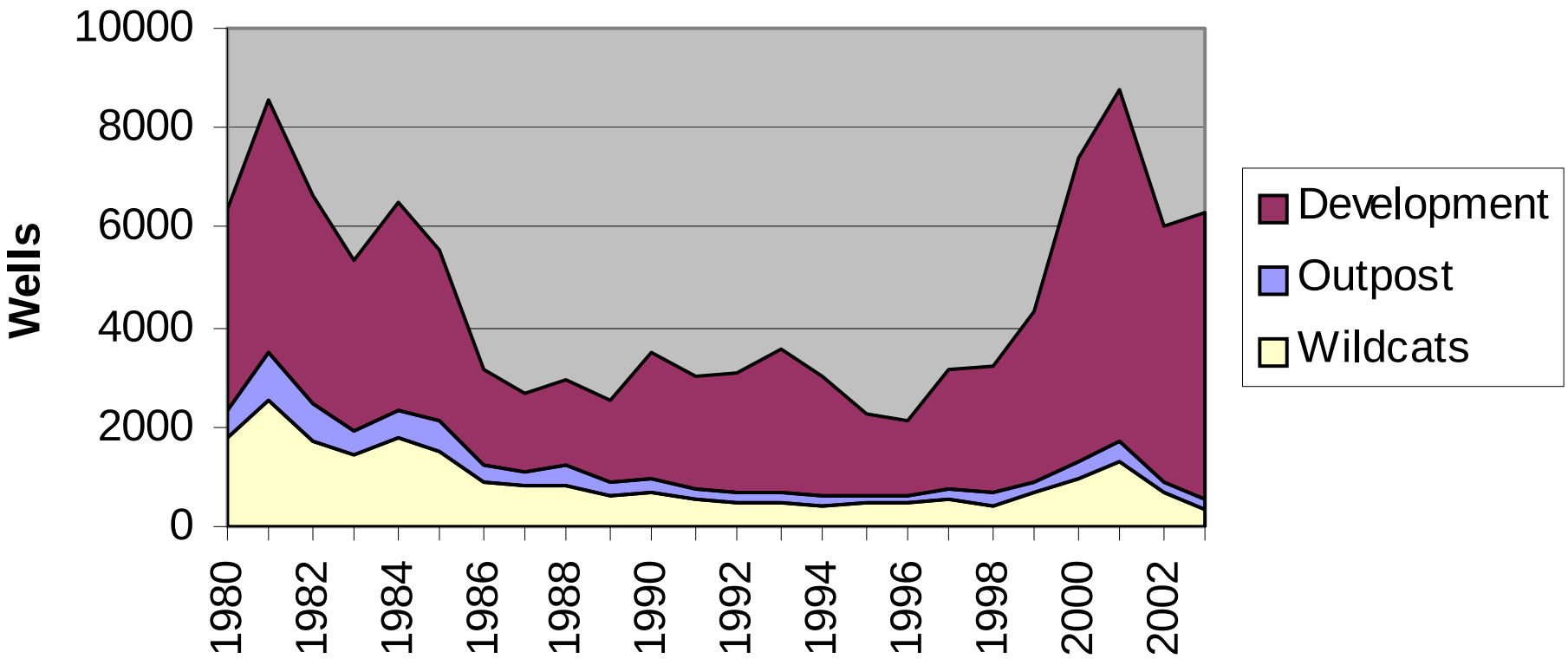
# RPSEA R&D Topics
# Tight Gas, CBM, Shale Gas

S. A. Sonnenberg

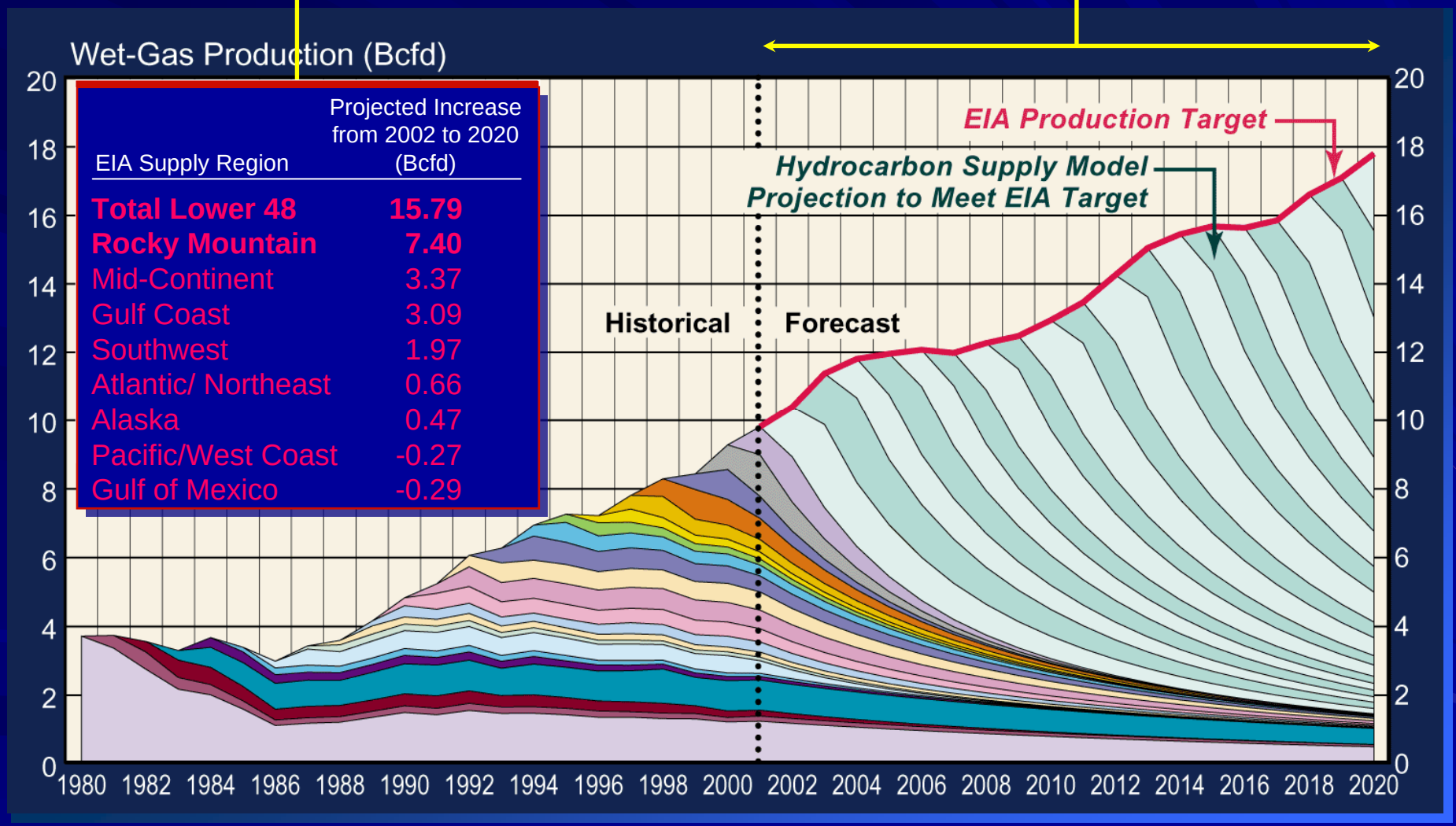
November 14, 2006

**“The future just ain’t what it used to be.”**
**--W.C. Fields**

# Rockies Development, Exploratory Wells



# Rocky Mountains Production Forecast




Source: Potential Gas Committee (2003). Data from EIA, Petroleum Information/Dwights LLC (©2002) and D.L. Pierce.

# Unconventional resources in the Greater Green River Basin will drive Rockies growth

| *The Plays* | | |
|---|---|---|
| Play | Type | Potential bcf (USGS P50) |
| Wasatch-Green River | CBM | 58 |
| Mesaverde | CBM | 257 |
| Fort Union | CBM | 964 |
| Lance | CBM | 152 |
| Frontier-Adaville-Evanston | CBM | 323 |
| Lewis Shale | Shale Gas | 13,133 |
| Lance (Jonah-Pinedale) | Tight Gas | 40,000 |
| Mesaverde | Tight Gas | 25,527 |
| Hilliard-Baxter-Mancos | Tight Gas | 10,542 |
| Lance (Other) | Tight Gas | 20,378 |

***Announcements & Plans***

- The **Pinedale field** has estimated gas in place reserves of 40 tcf with Jonah holding an estimated 13.8 tcf. **Ultra Petroleum** estimates that 10-acre drilling across the entire field will allow access to an incremental **15 tcf** of gas.
- It is estimated **Jonah** holds approx. 13.8 tcf with around **8 tcf** recoverable.
- **Anadarko** has stated their **CBM** exploration program on their Land Grant acreage offers a resource potential of around **8 tcf**.
- **Questar** has indicated their acreage in the Vermillion Basin provides around **3-4 tcf** of resource potential.

**Wood Mackenzie, 2006**

# Unconventional resources in the Uinta-Piceance Basin will drive Rockies growth

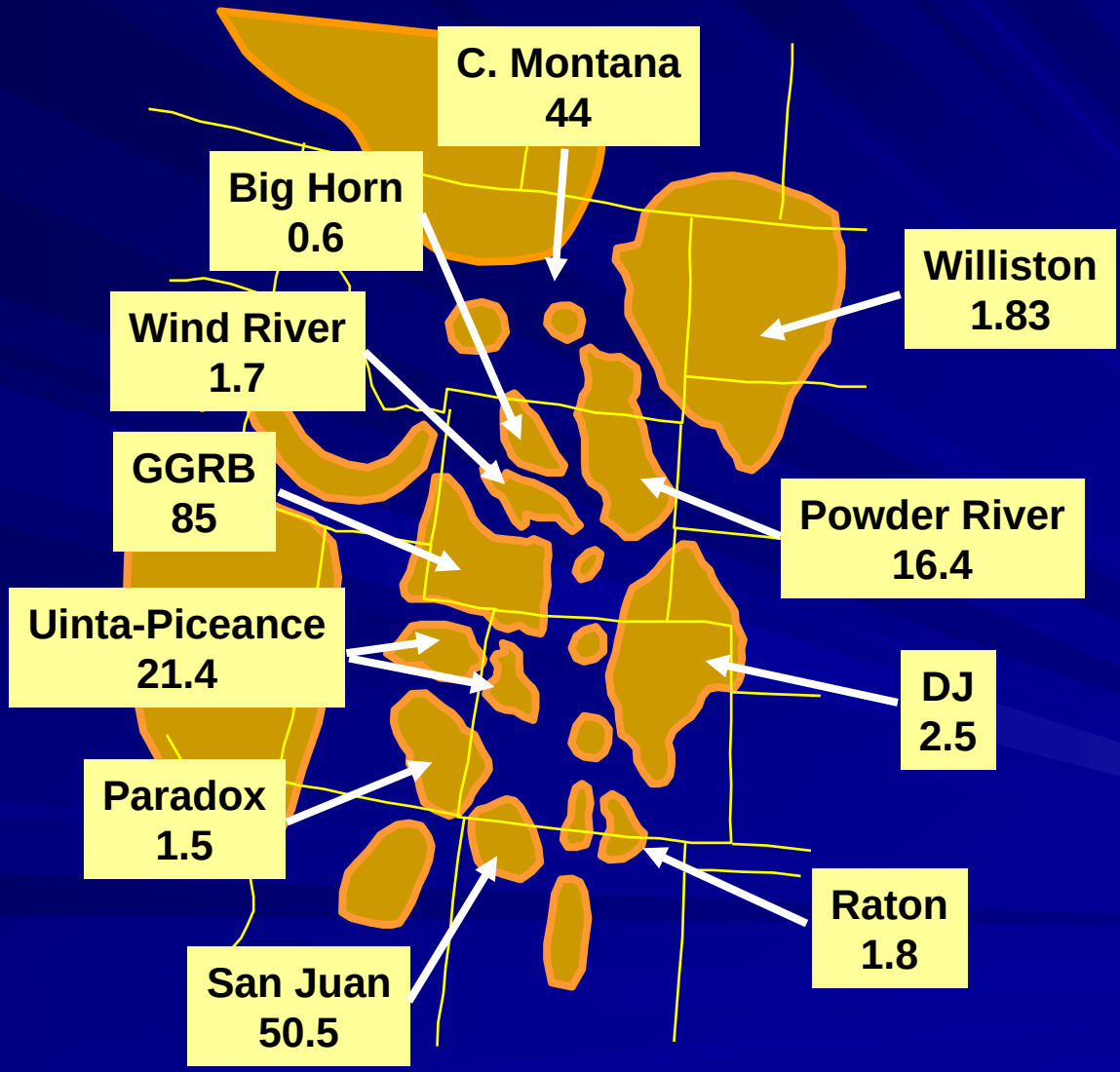
| *The Plays* | | |
|---|---|---|
| Play | Type | Potential bcf (USGS P50) |
| Williams Fork | Tight Gas | 11,691 |
| Ferron | Tight Gas | 52 |
| Mancos-Mowry TPS | Tight Gas | 6,171 |

***Announcements & Plans***

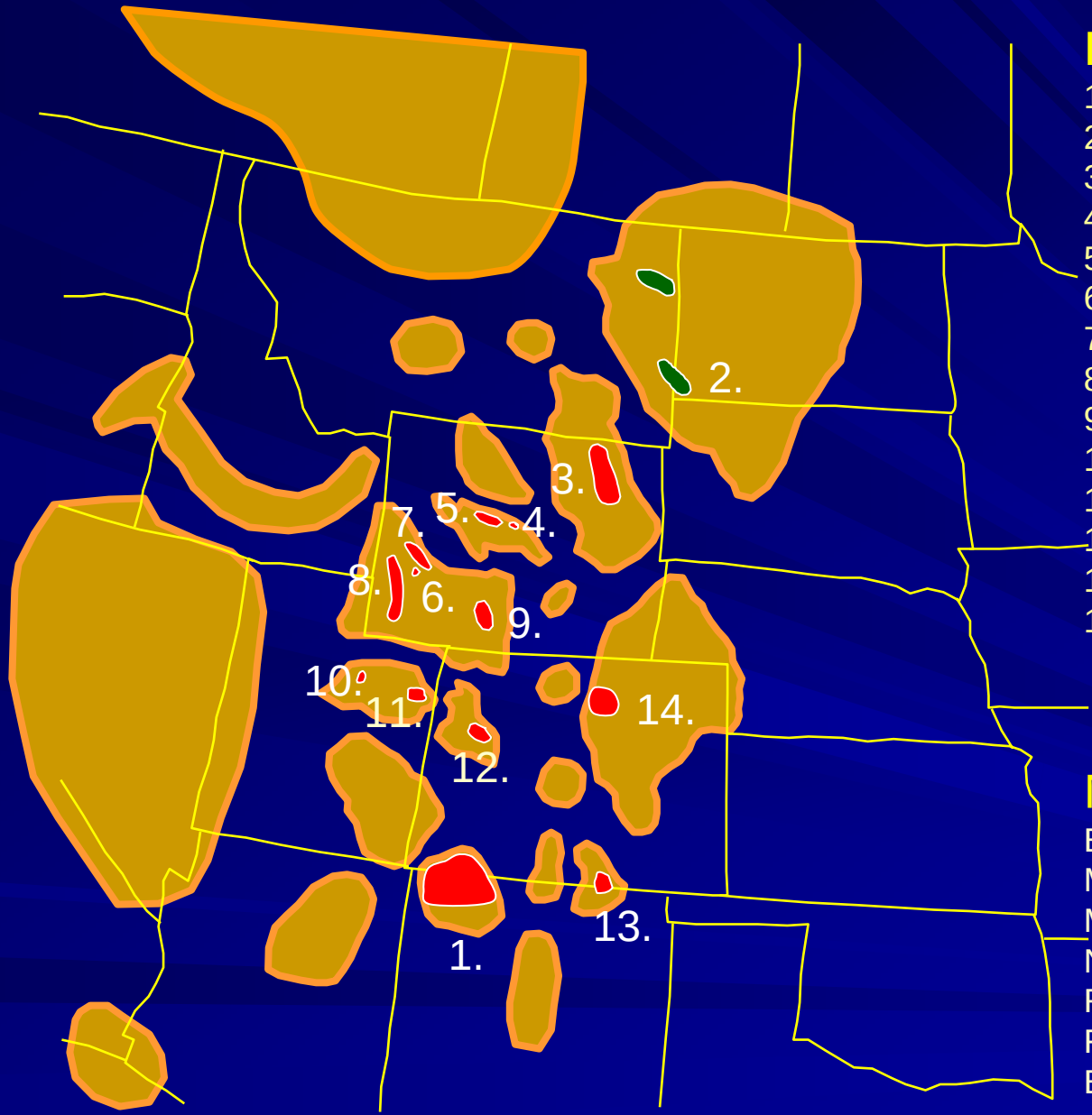
- **EnCana** estimates that the resource opportunity amounts to **100 tcf**. They also identified their unbooked resource potential in the Piceance Basin to be 11.9 tcf.
- **ExxonMobil** is putting together a development plan for the area east of Piceance Creek which is reported to have **35 tcfe** of recoverable reserves.
- **Williams** estimates net potential reserves to be in the order of **8 tcf** from their Piceance Valley and Piceance Highlands projects.
- In January 2006, **Kerr-McGee** revised its resources estimate in the Uinta Basin. The company has identified **4.7 tcfe** unbooked potential reserves in the region around the Natural Buttes field in Utah.

**Wood Mackenzie, 2006**

# Remaining Gas Potential (TCFG)




*USGS 1995, 2001*




## Resource Plays (70s – P)

1. San Juan CBM (c 1977)
2. Cedar Hills Field CBM (c 1981)
3. Powder River CBM (c 1981)
4. Cave Gulch TG(1995)
5. Madden TG (c 1974)
6. Pine Dale Anticline TG (c 1975)
7. Jonah Field TG (1975)
8. Moxa – LaBarge TG (c 1957)
9. Wamsutter Arch TG (c 1958)
10. Drunkard's Wash CBM (c 1987)
11. Natural Buttes TG (1955)
12. Rulison Area TG (1958)
13. Raton Basin CBM (c 1989)
14. Wattenberg TG (1970)

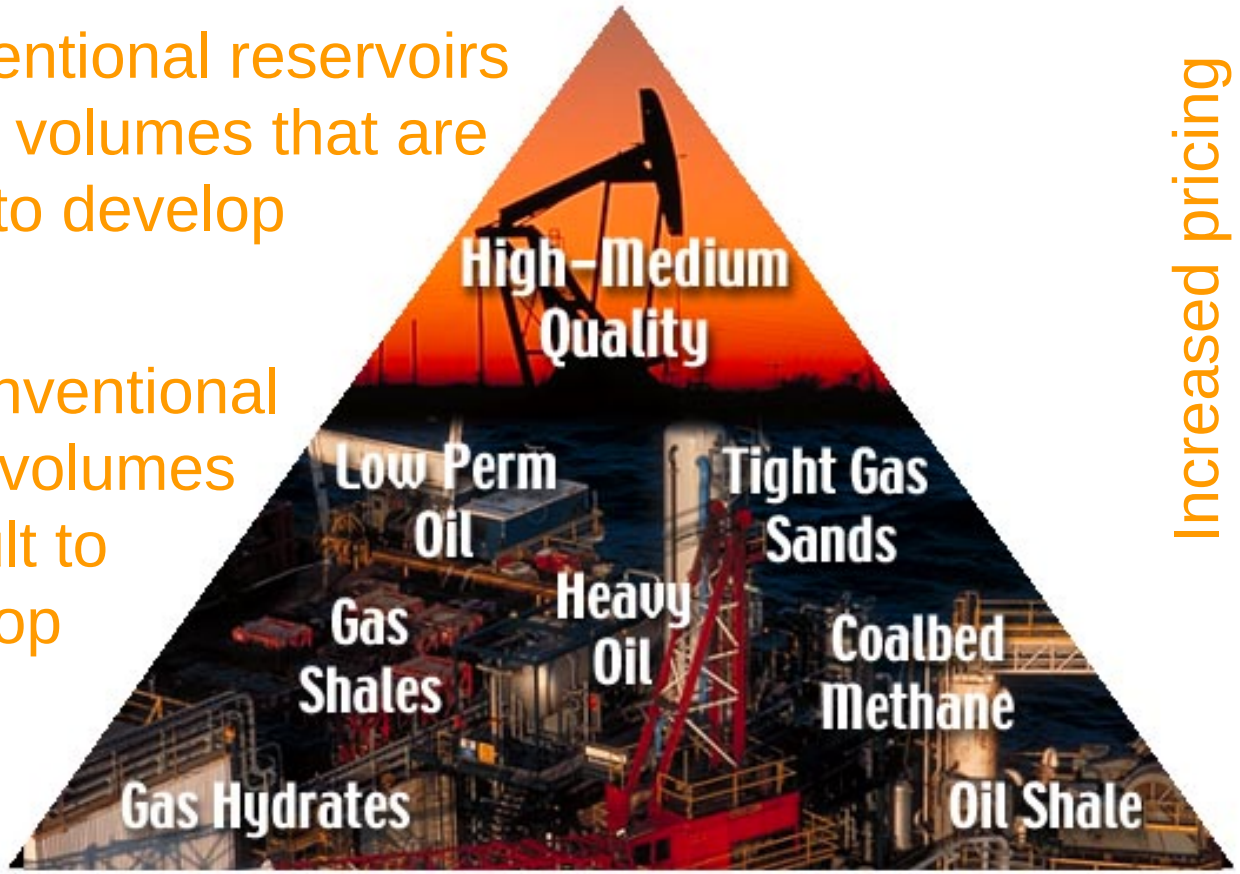
## New Resource Plays

Bakken FM.- Richland Co., MT
MV-W, Piceance Basin
MV-W, Mancos, Uinta Basin
Niobrara Fm., DJB, PRB
Rock Springs, GGRB
Fort Union, WRB
Baxter/Hilliard, GGRB

# Conventional & Unconventional Reservoirs & The Resource Triangle

Conventional reservoirs
Small volumes that are easy to develop

Unconventional large volumes difficult to develop



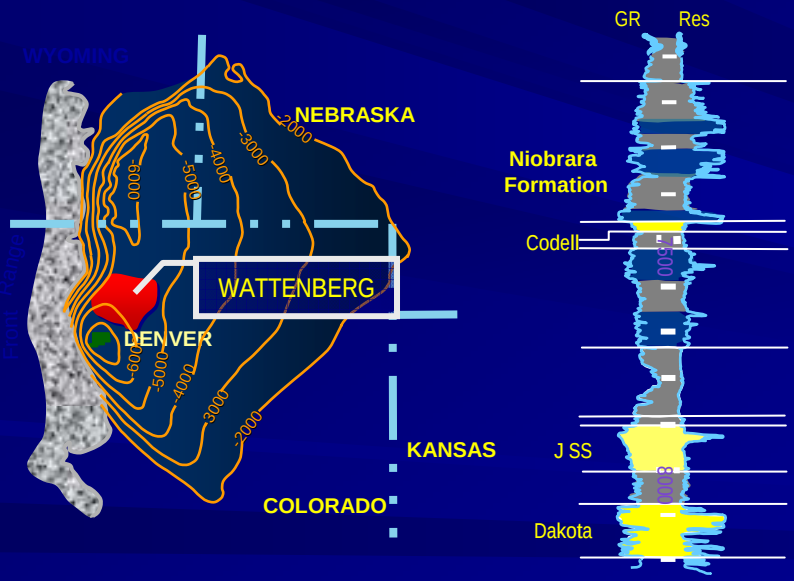

Holditch, 2005

# “Resource Play” Characteristics

- Large resource known in place
  - Predictable & Repeatable
  - Large areal or vertical extent
  - Lower steady-state decline rate vs. conventional
  - Large-scale developments
  - Assembly line approach
- Technology application
  - Unlocks reserves
  - Drives down costs
- Operations control
  - Cost control
  - Development pace

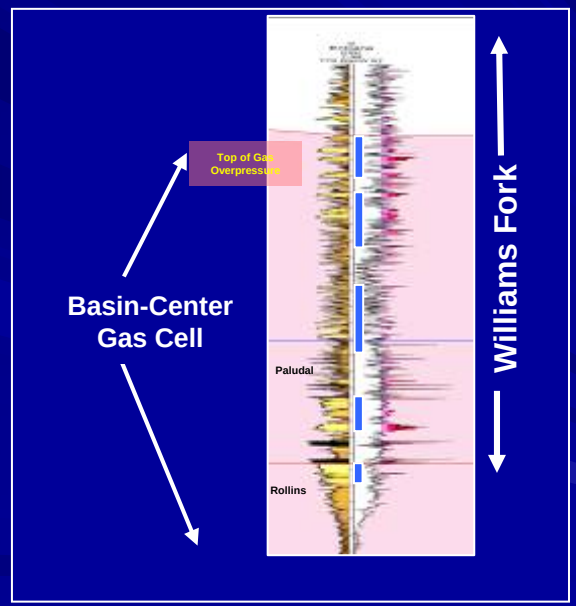
# Resource Plays–Large, Predictable, Repeatable

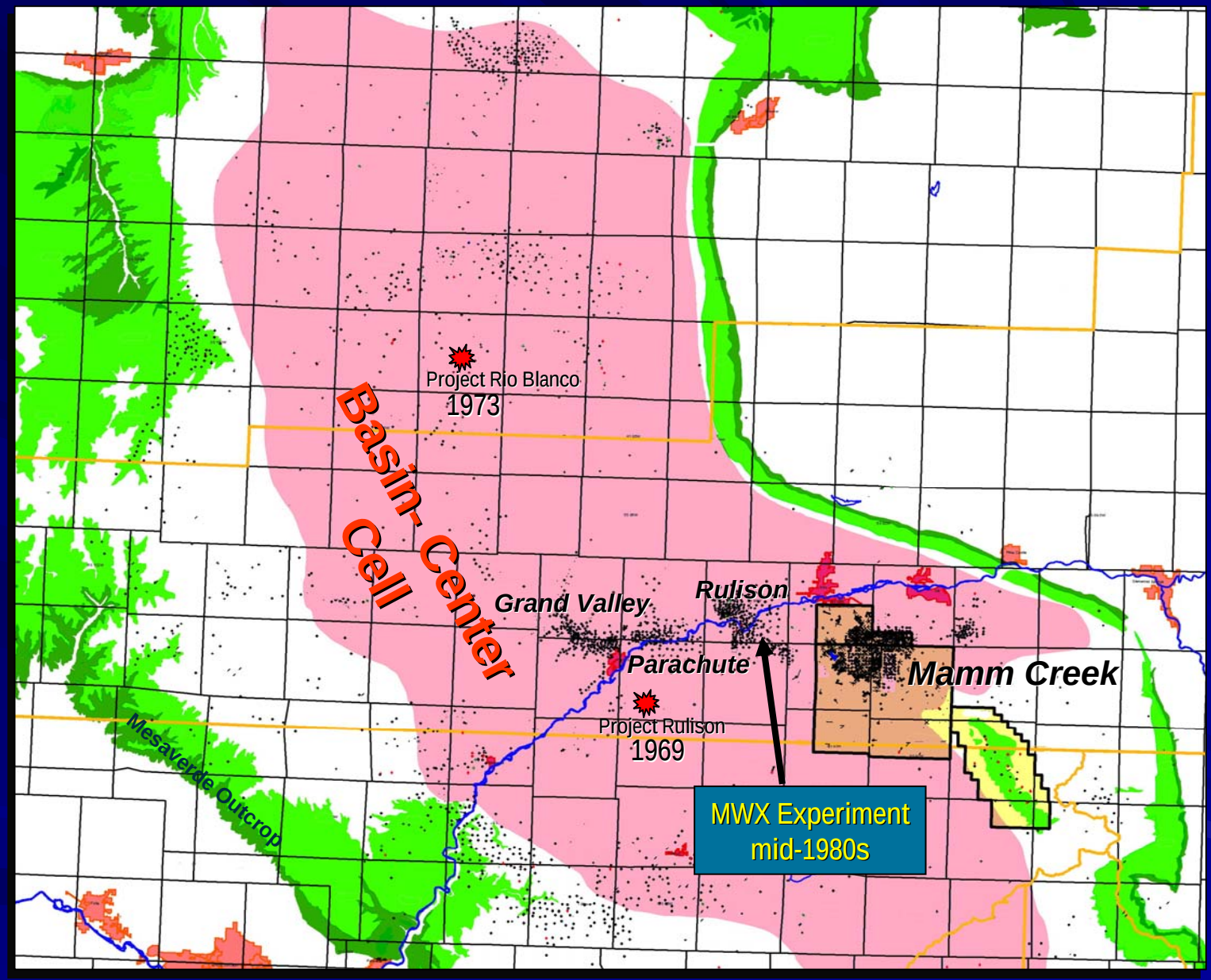
## Large Areal Extent
## Wattenberg Gas Field




## Large Vertical Extent

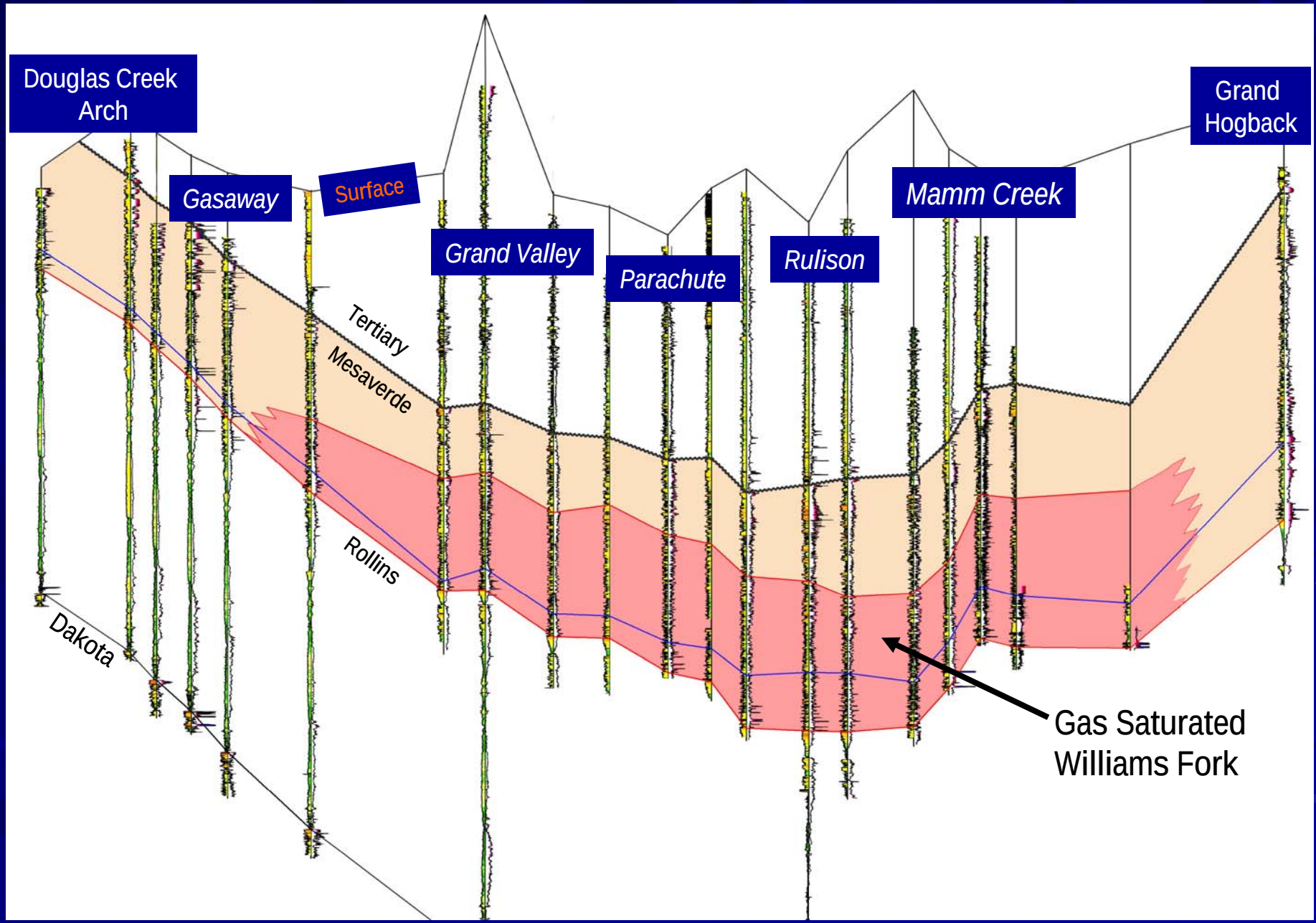
### Mamm Creek, Piceance Basin






# Extent of Gas-Saturated Mesaverde

Uhl, 2003

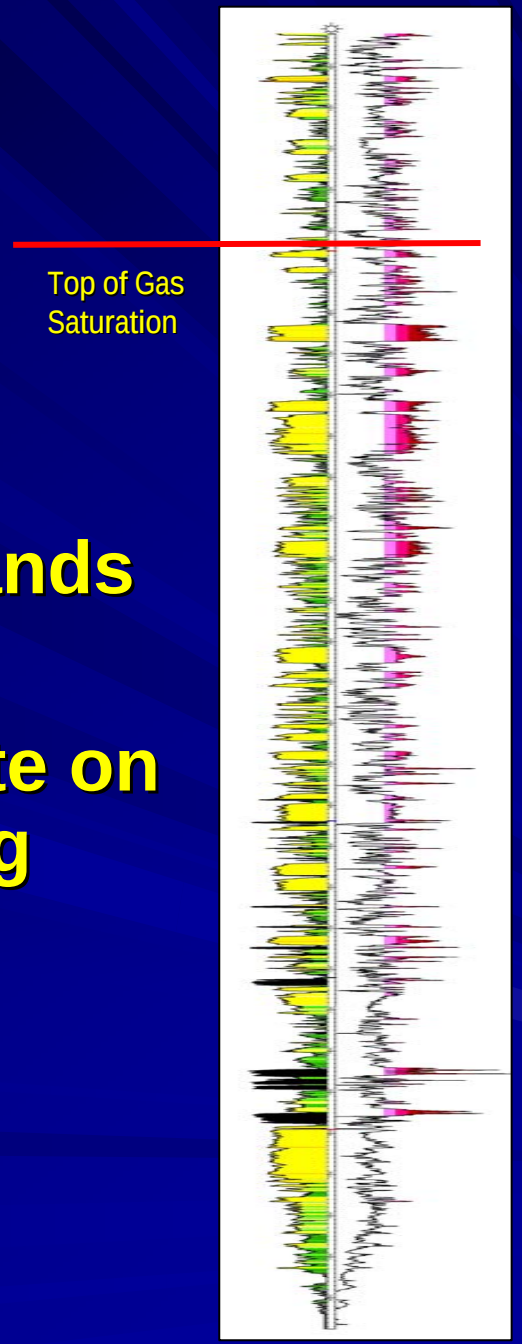



# East-West Structural X-Section

Uhl, 2003

# Williams Fork Sands

- **Numerous**
- **“Tight Gas” Sands**
- **Rarely Correlate on 40 acre spacing**




Uhl, 2003

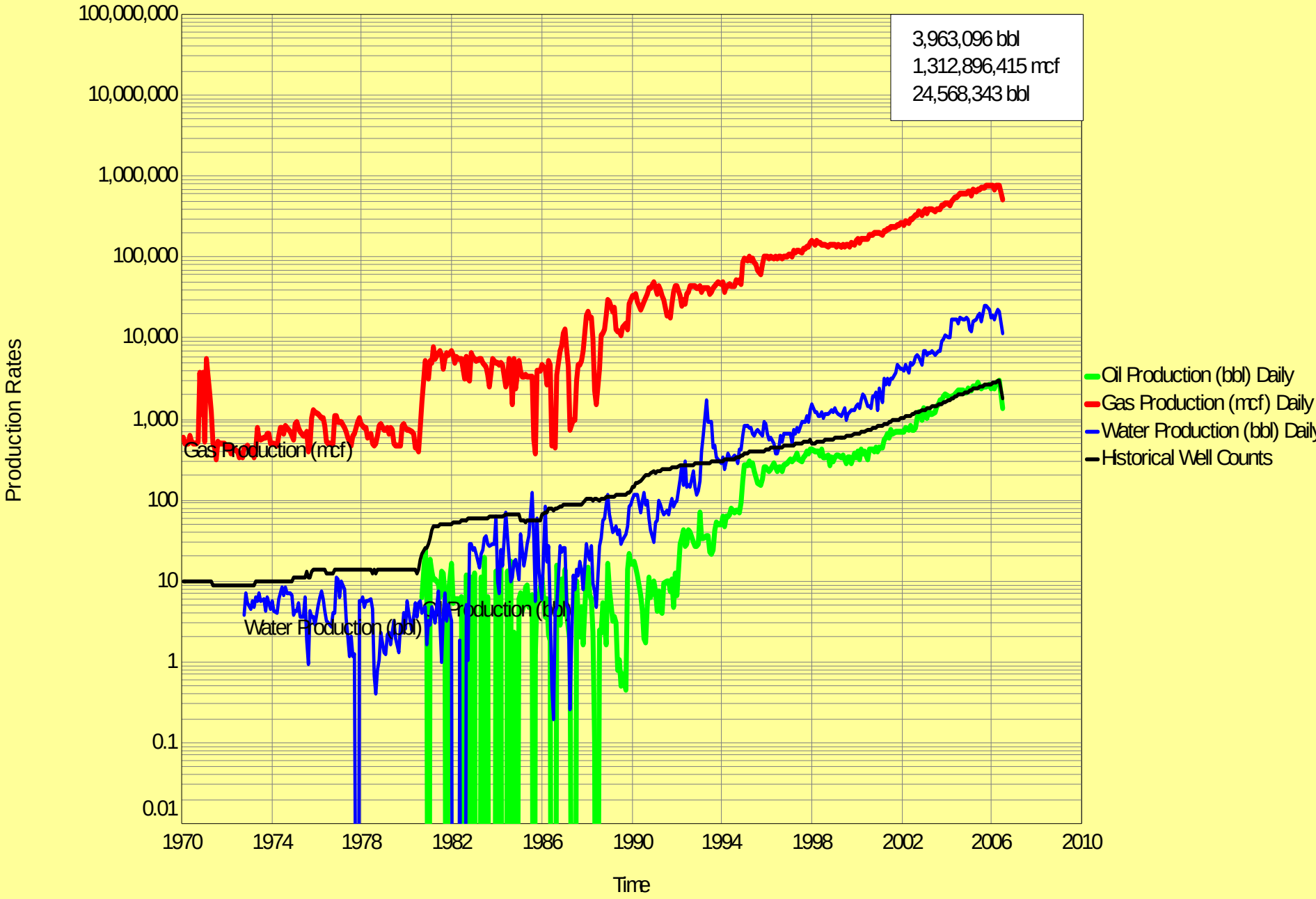
# Williams Fork - Reservoir Parameters

- Gas from overpressured fluvial SS
- Porosity: 8-16%
- Permeability: 0.01 - 0.25 md
- Water Saturation: ~35%
- Depths: 5,000 - 9,000 ft
- Individual SS: 20-60 ft  thick
- Net Pay-Max: 1,000 ft; Ave: 400 ft
- GIP: 50 - 120 Bcf / section

# Keys to Development

- Gas Price
- Technology
  - Pay identification
  - Frac designs
  - Bits & mud motors
  - Pad drilling
- Pipeline infrastructure

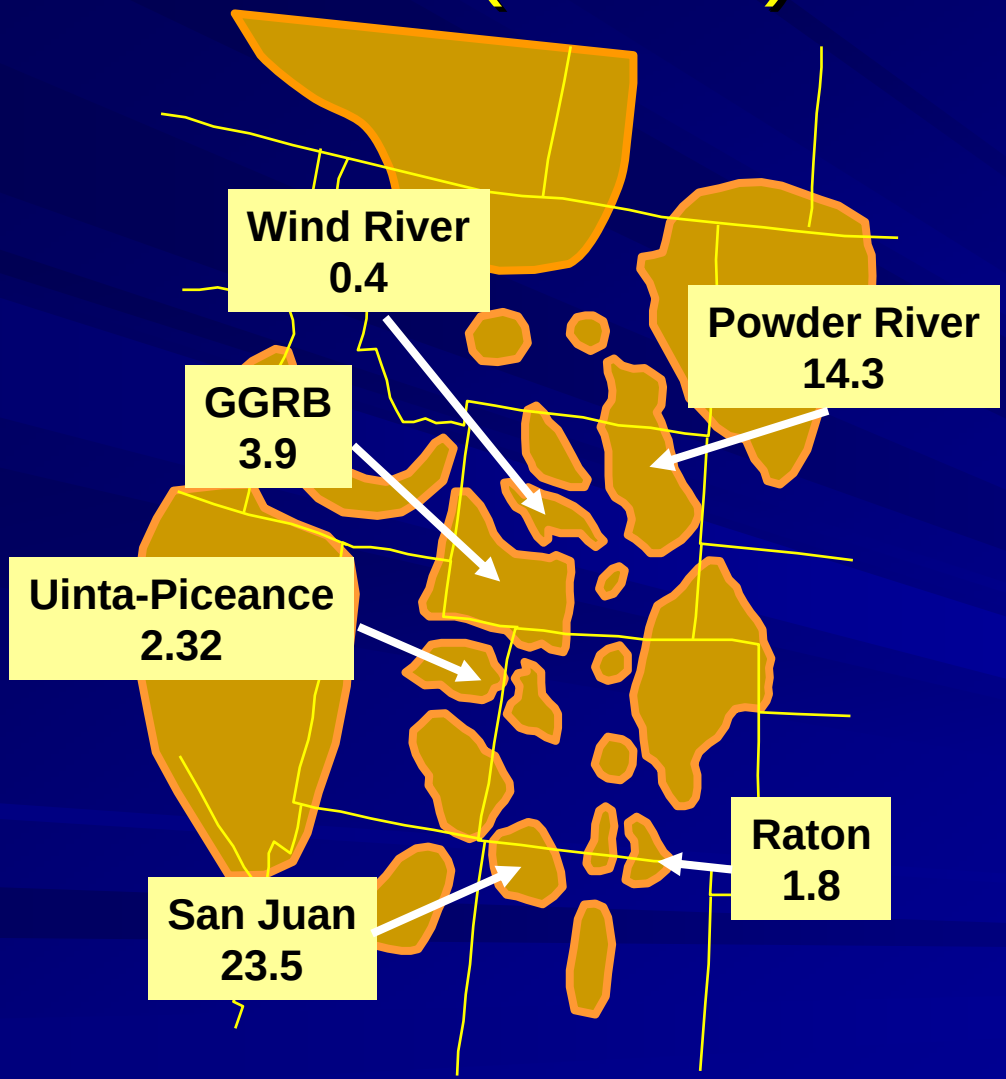
# Piceance Basin Rulison Trend



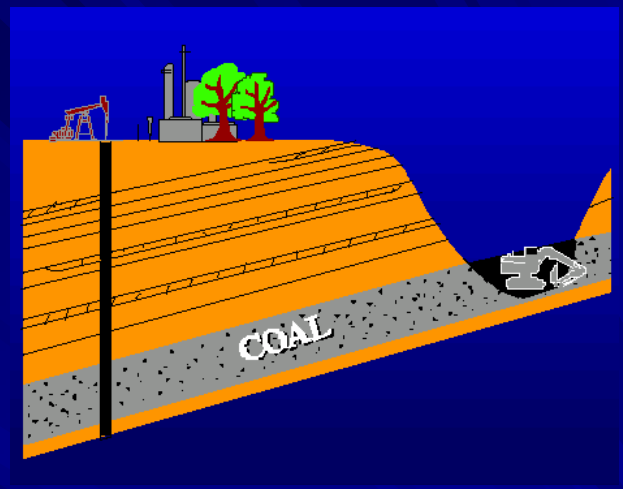
# Tight Gas Issues

- Identifying potential future resource plays
- Sweet spots—controls and identification
  - Faults & fractures
  - Matrix versus reservoir permeability (microfractures)
- Reservoir heterogeneity
- Optimum spacing studies, reservoir simulation, etc.
- Drainage areas: radial or elliptical?
- Petrophysics—pay identification
  - LRLC pays
  - HR pays in fresh water intervals
- Rock Properties—better frac designs, etc.
- Completions & stimulations
  - Frac technology: gel, slick, hybrids; proppant; energized; etc.
  - Frac mapping, etc.
- Refracs—what makes a good candidate?
- High $H_2O$ gas pays
- Deep reservoirs—porosity, perm., etc.

# Rockies CBM Resource (TCFG)



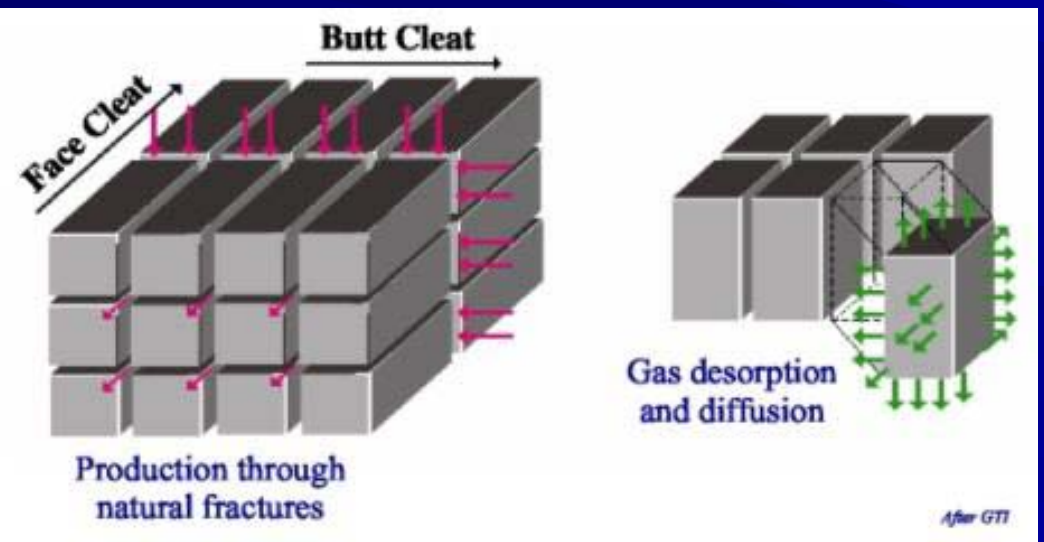

Estimates from USGS, 1995 & 2001

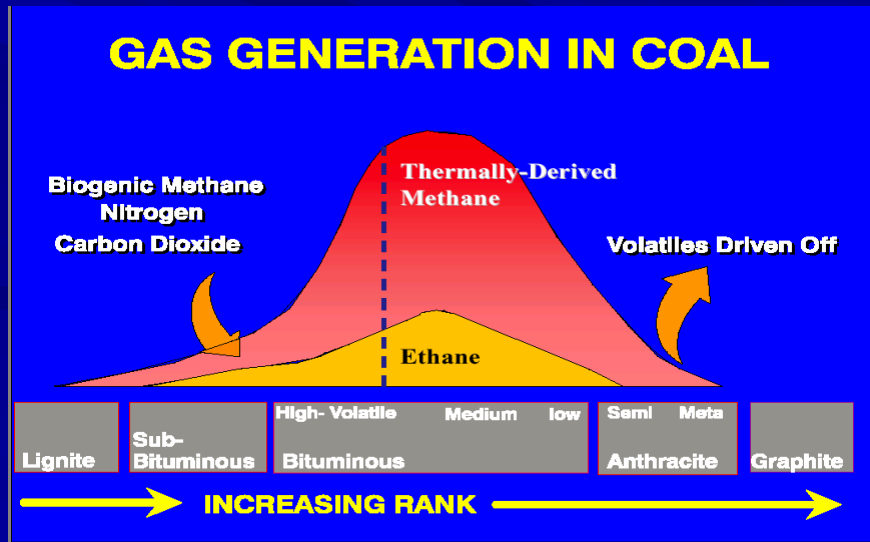



- 500 to 6,000 ft present-day depth
- Widespread, commonly basin wide accumulations
- Majority of U.S. assessed CBM in Rockies
- Coal seam thickness, heterogeneity, depth, composition, seals, gas content, gas composition, permeability, pressure regime, structural setting and hydrology are important factors

# CBM Issues

- Update CBM potential in Rockies
- Advanced drilling and completion technology
- Produced water management
- Efficient recovery schemes: e.g., spacing
- $CO_2$ storage and enhanced gas recovery
- Deep CBM



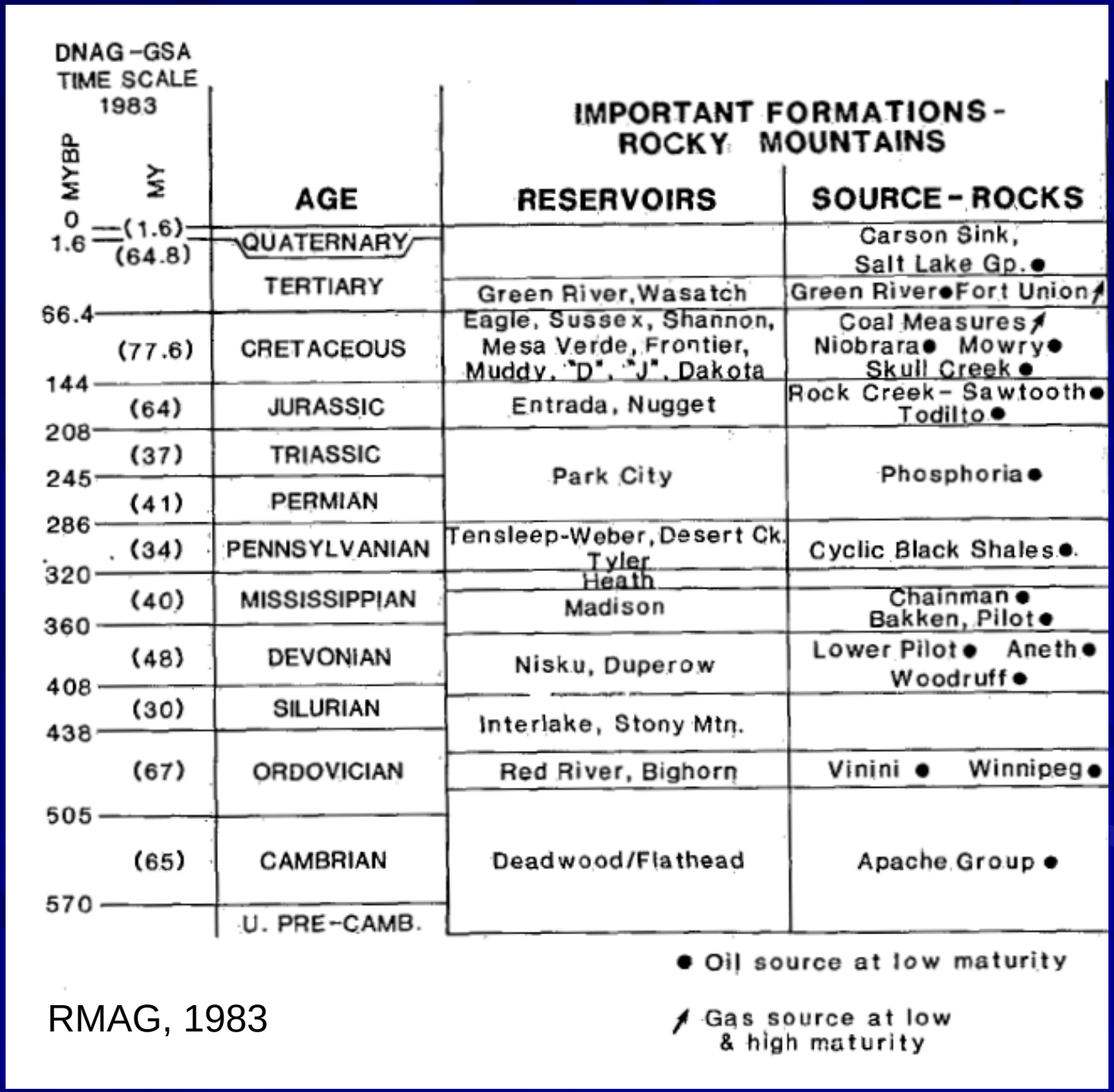
# Shale Gas Plays

Some shale factors to assess:

- Organic richness (TOC)
- Thermal maturity
- Natural fractures
- Kerogen type
- Product yields at maturity
- Gas contents
- Lithological and mineralogical variations
- Adsorbed gas, gas in fractures & pores
- Thickness

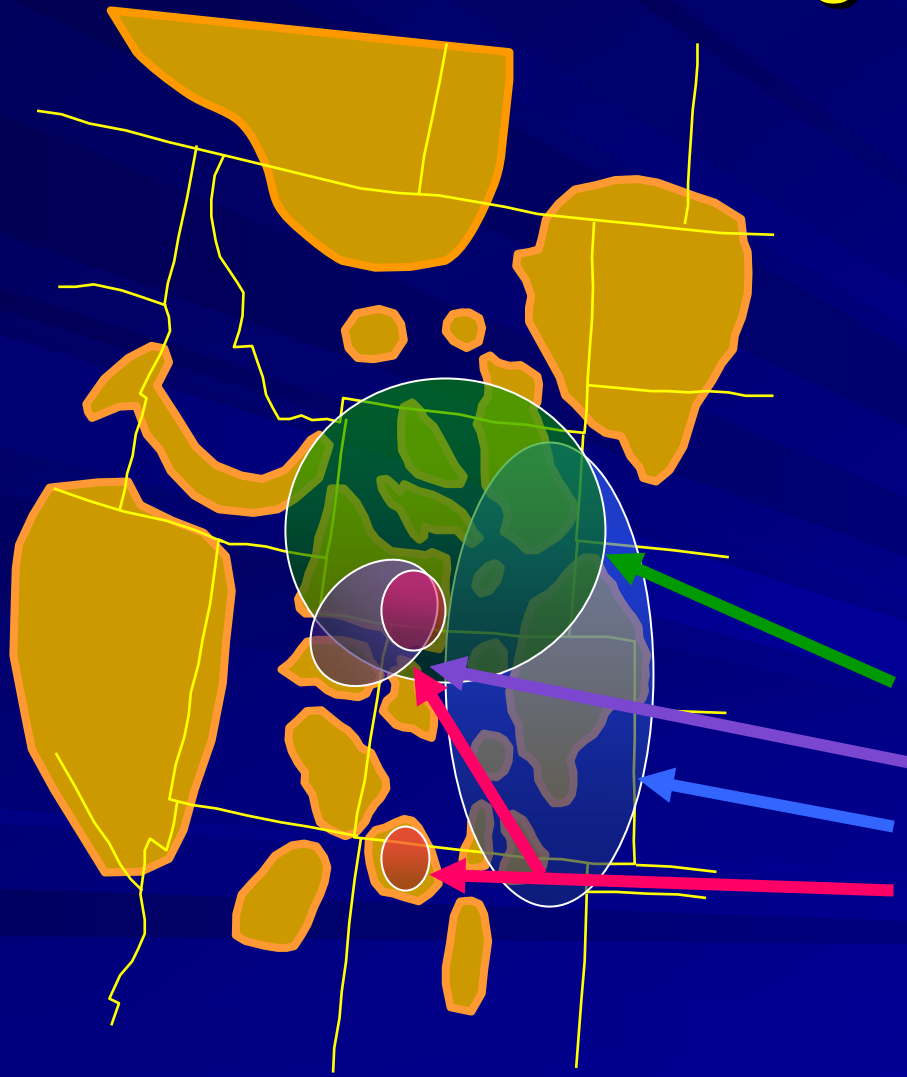
US Shale Gas Plays
Depth: 200 - 8500 ft
Thickness: 160 - 2000 ft
TOC: 1 - 25%
%Ro: 0.4 - 1.88
Gas Content: 1 – 350

- Plays need to be assessed, critical factors researched
- Horizontal drilling, fracture stimulation, natural fractures keys to date


DNAG-GSA
TIME SCALE
1983
MYBP
MY
AGE
IMPORTANT FORMATIONS -
ROCKY MOUNTAINS
RESERVOIRS
SOURCE-ROCKS
0
(1.6)
1.6
(64.8)
QUATERNARY
TERTIARY
Carson Sink,
Salt Lake Gp.●
Green River, Wasatch
Green River● Fort Union
66.4
(77.6)
CRETACEOUS
Eagle, Sussex, Shannon,
Mesa Verde, Frontier,
Muddy, "D", "J", Dakota
Coal Measures
Niobrara● Mowry●
Skull Creek●
144
(64)
JURASSIC
Entrada, Nugget
Rock Creek- Sawtooth●
Todilto●
208
(37)
TRIASSIC
245
(41)
PERMIAN
Park City
Phosphoria●
286
(34)
PENNSYLVANIAN
Tensleep-Weber, Desert Ck.
Tyler
Cyclic Black Shales●
320
(40)
MISSISSIPPIAN
Heath
Madison
Chainman●
Bakken, Pilot●
360
(48)
DEVONIAN
Nisku, Duperow
Lower Pilot● Aneth●
Woodruff●
408
(30)
SILURIAN
438
Interlake, Stony Mtn.
(67)
ORDOVICIAN
Red River, Bighorn
Vinini● Winnipeg●
505
(65)
CAMBRIAN
Deadwood/Flathead
Apache Group●
570
U. PRE-CAMB.
● Oil source at low maturity
Gas source at low
& high maturity

RMAG, 1983

# Rockies Shale Gas Resources
# Some of the evolving Cretaceous plays



Rocky Mountain Basins

- Mowry
- Mancos/Hilliard/Baxter
- Niobrara
- Lewis

# Abundant Tight Gas, CBM, and Gas Shale Resources!
## What could slow development?

- Challenges to growth:
  - Availability of rigs
  - Regulatory processes
  - Lack of human capital
  - Technology improvements

- How industry and government are taking action:
  - Rig construction, new commercial approaches, adjusting capital budgets
  - Permitting and staffing
  - Education and training
  - Funding research and development

**Modified from Wood Mackenzie, 2006**

**“The future just ain’t what it used to be.”**

**But the future is bright!**

The Rockies have “Plenty of Gas Left in the Tank!”

Tight Gas, CBM, Gas Shale