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CHANGING PERCEPTIONS OF COALBED METHANE RESERVOIRS

Presented by:

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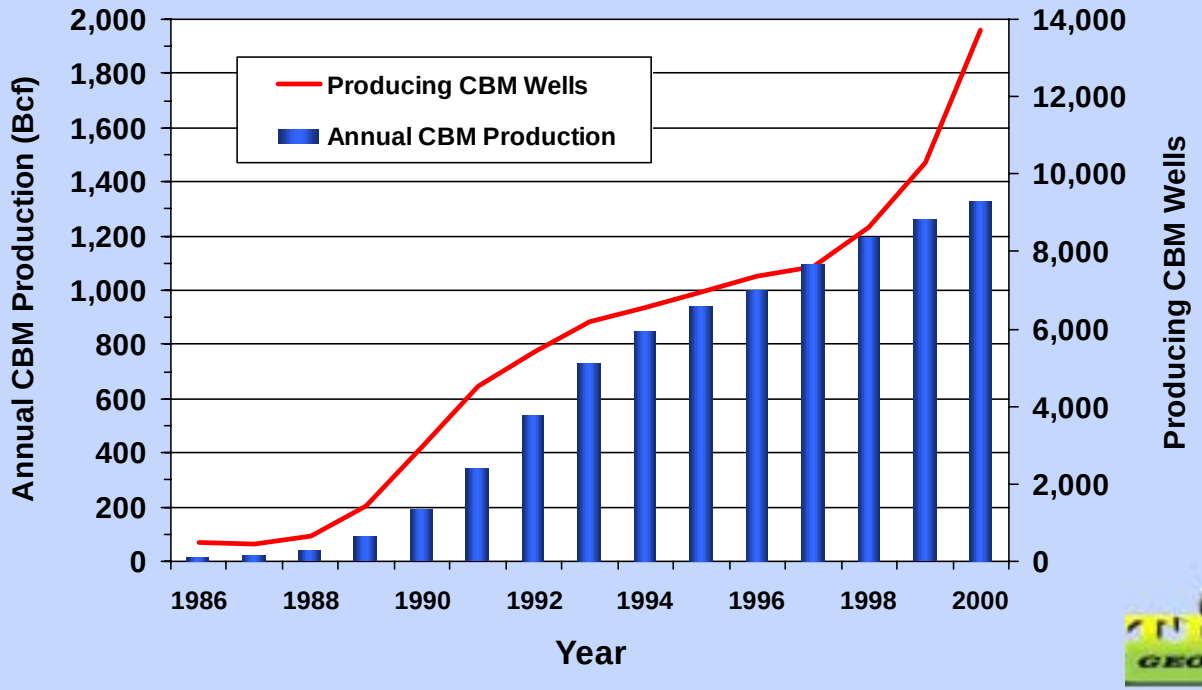
U.S. Coalbed Gas Production

- **Important Natural Gas Resource**
  - **Current Coalbed Gas production represents 7% of annual U.S. natural gas production**
  - **Over 13,000 producing coalbed methane wells in 12 states**



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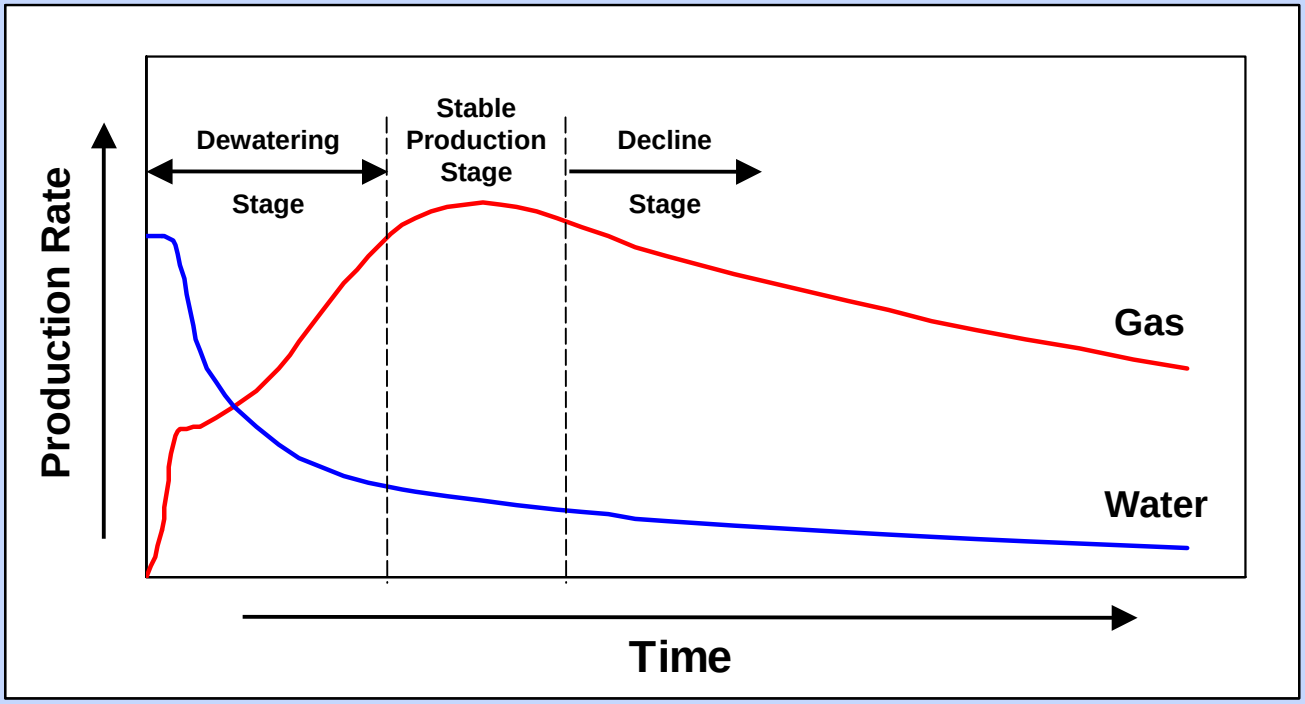
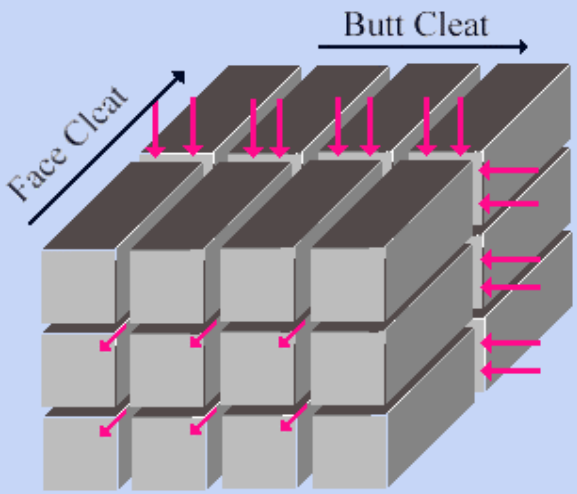
Coalbed Reservoir Gas Production Characteristics

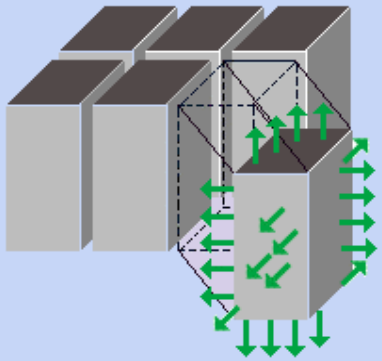


- Water production volume progressively declines with time. (Minimize well shut in time.)
- Development & in-fill wells often exhibit higher initial gas-water ratios.
- Maintain low bottom hole pressure to maximize gas production rates & recovery factors.

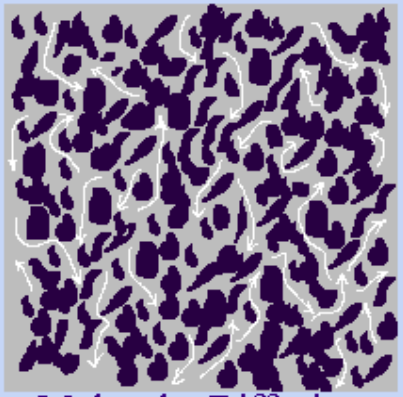
Gas Transport Mechanisms



1 Fluid production from Natural Fracture



2 Gas Desorption from Coal Surface



3 Molecular Diffusion Through the Coal Matrix

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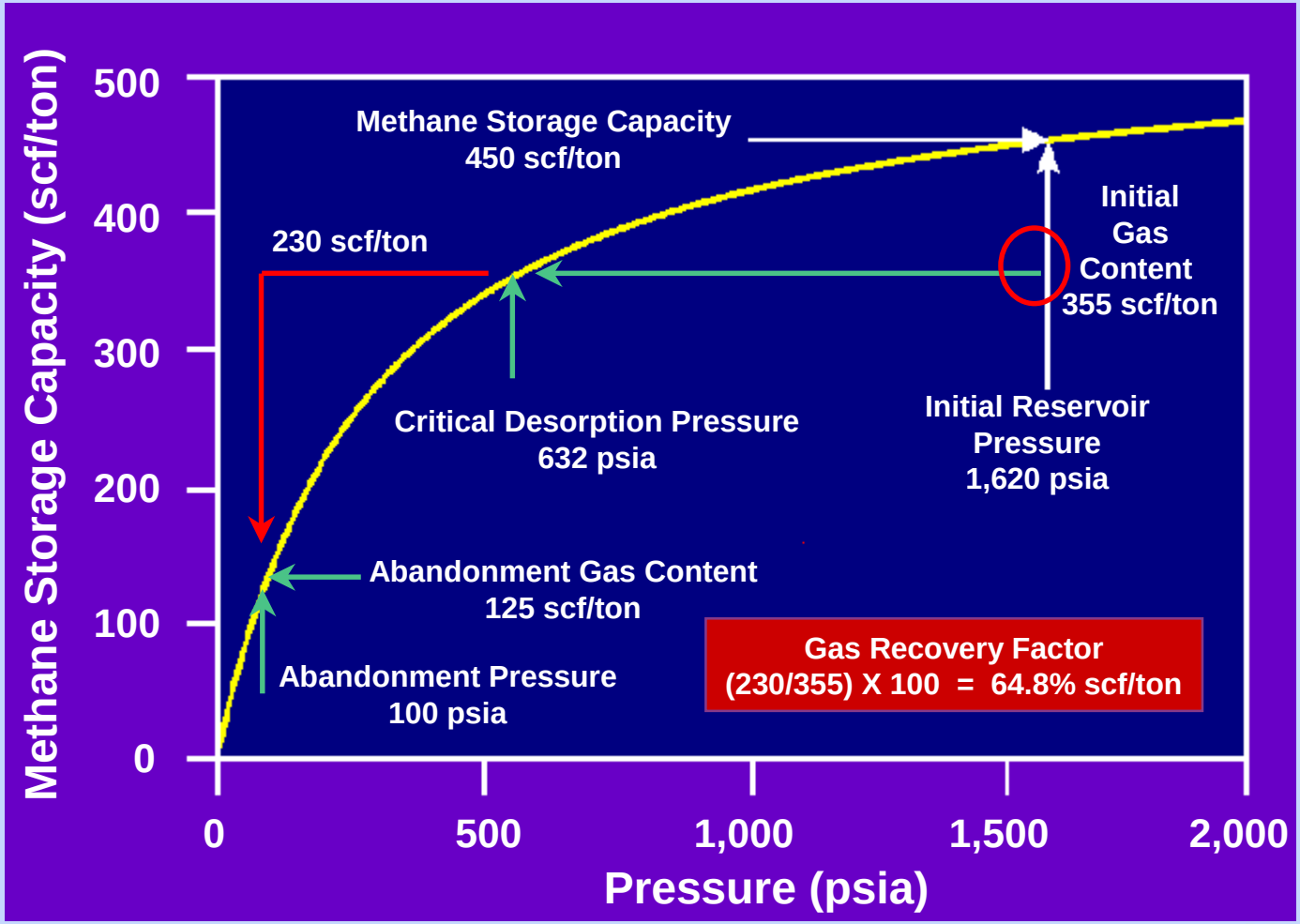
Typical Methane Isotherm



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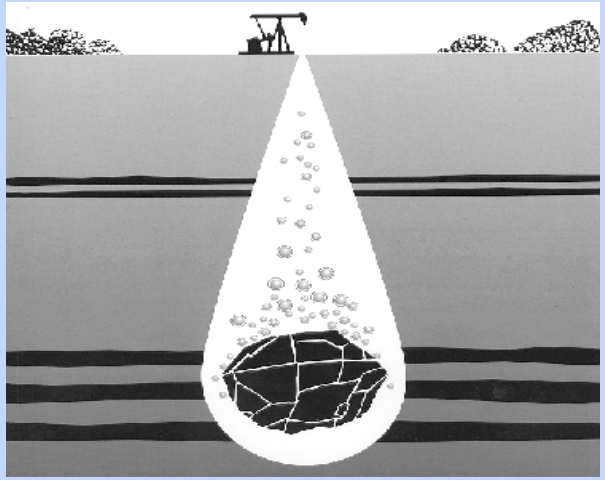
Presentation Overview

- Early Coalbed Gas Industry Drivers
- Resource Base Perceptions
- Play Area & Gas Production Economics Perceptions
- Gas-In-Place Perception
- Recovery Factor Perception
- Play Area Perception
- Future Coalbed Gas Advances
- 2-5 Year Outlook for CBM



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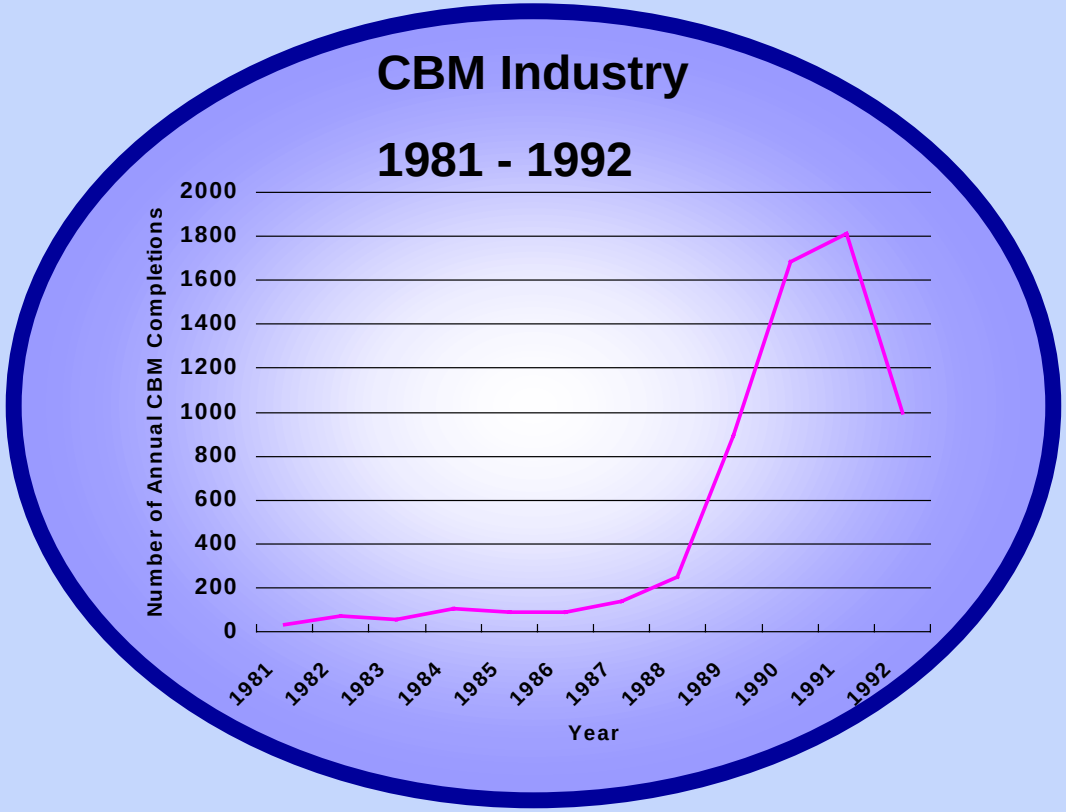
Early Coalbed Gas Industry Drivers

- Coal Mine Safety
- Energy Policy
- Oil & Gas Industry Technology
- Targeted Research & Development



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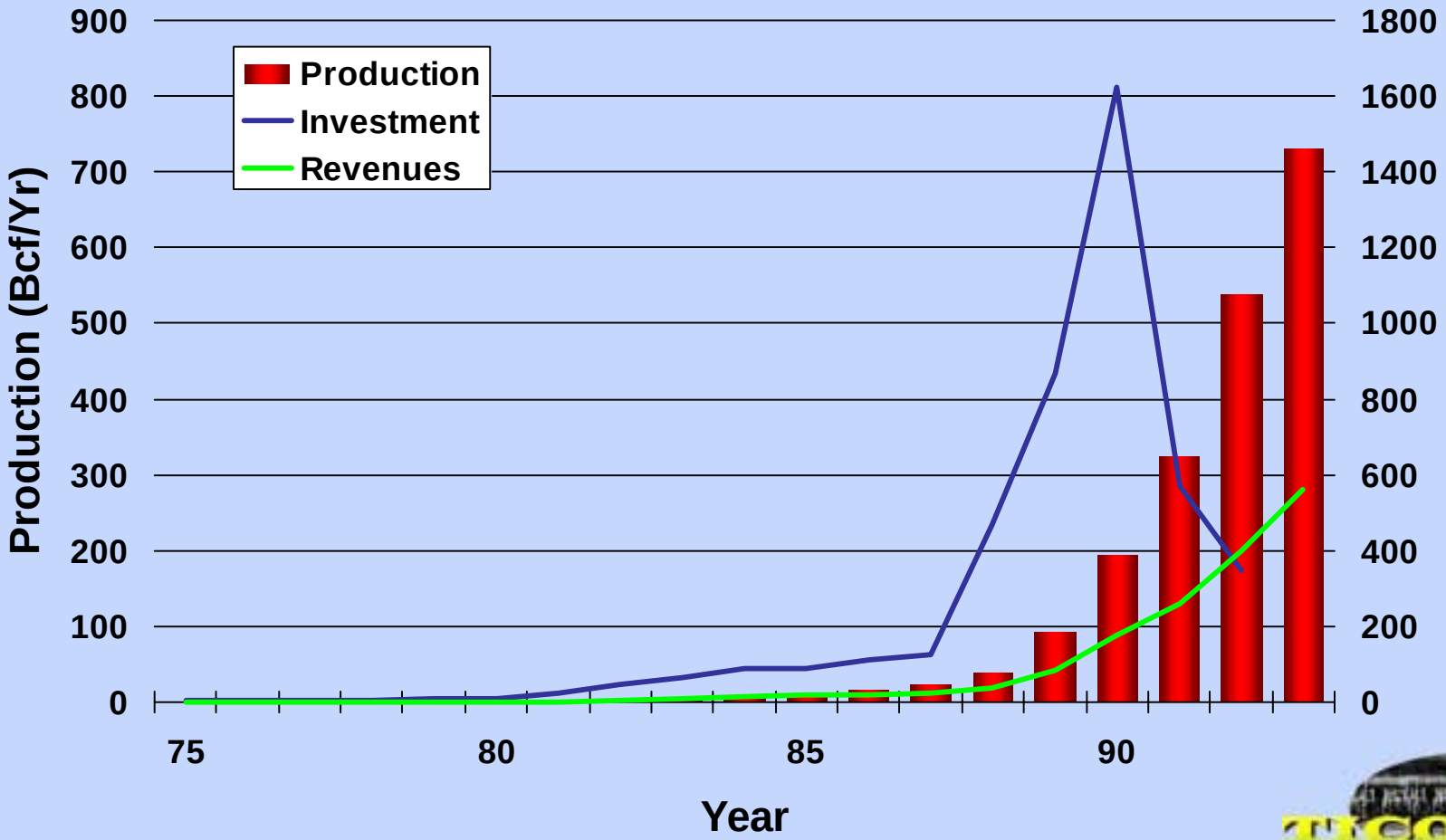
U.S. Coalbed Gas Industry Investment and Revenues



Source: SPE 28581 *"A Decade of Success: Coalbed Methane,"* Schraufnagel, Hill, and McBane

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Key Technology Advances In Coalbed Gas

- Understanding of Fundamental Production Mechanisms
- Improved Procedures for Isotherm and Gas Content Determination
- New Improved Well Testing to measure permeability
- Stimulation & Completion Practices to maximize deliverability / reduce costs
- Coalbed Specific Reservoir Simulators for property evaluation and projections

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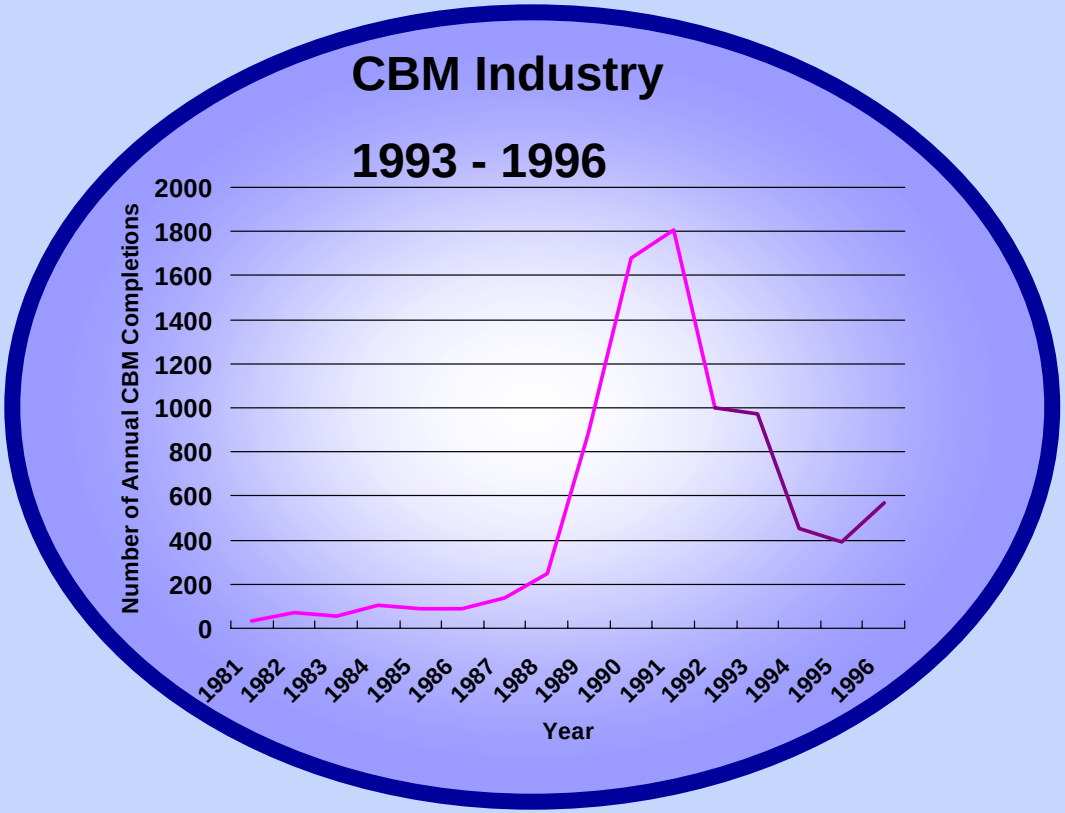
Post Tax Credit CBM Industry Drivers

- Natural Gas Prices
- Uneconomic Perceptions
- Off Shore Resource Focus
- Industry Consolidation



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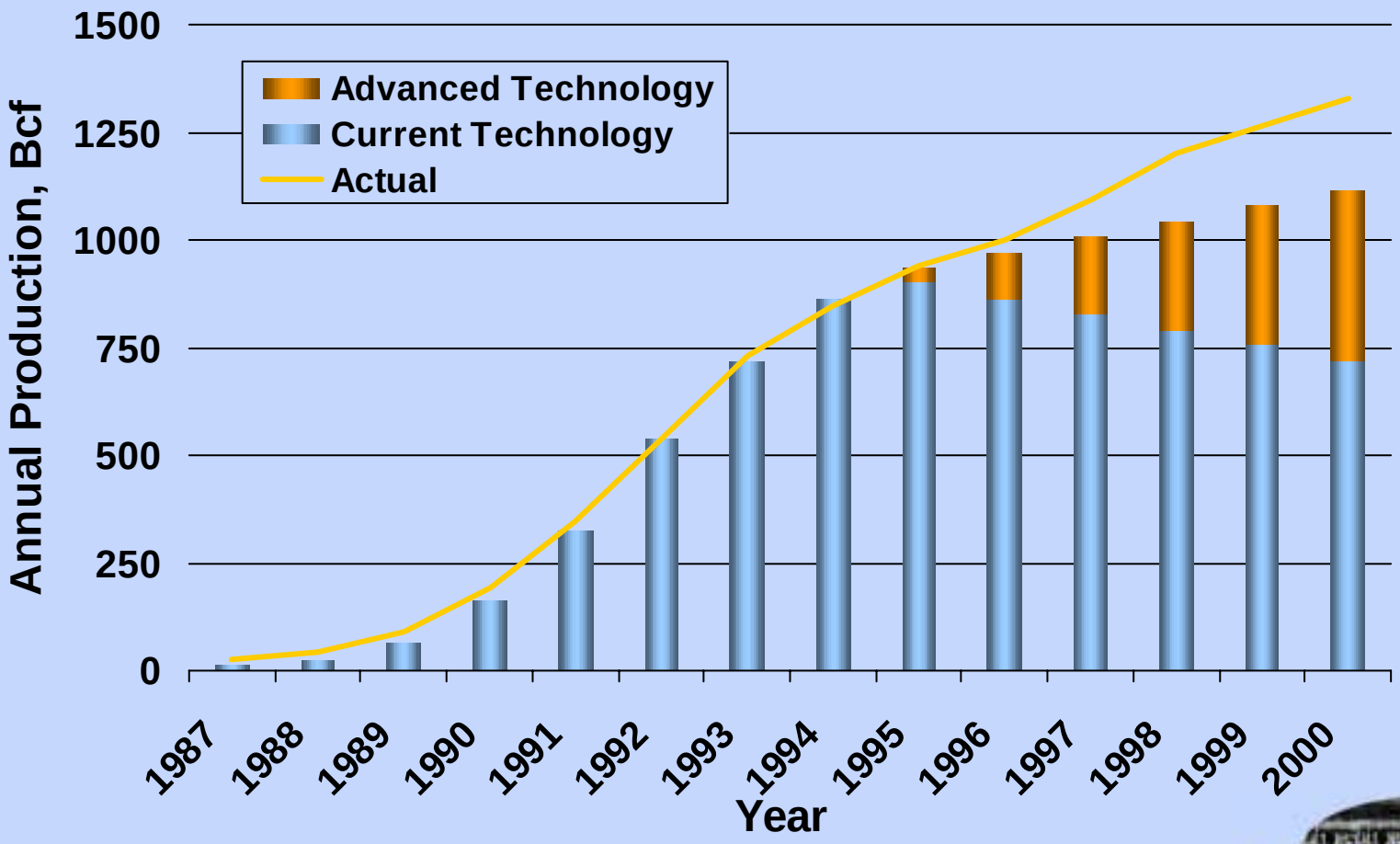
1993 Projection of Future U.S. CBM Production



Source: GRI

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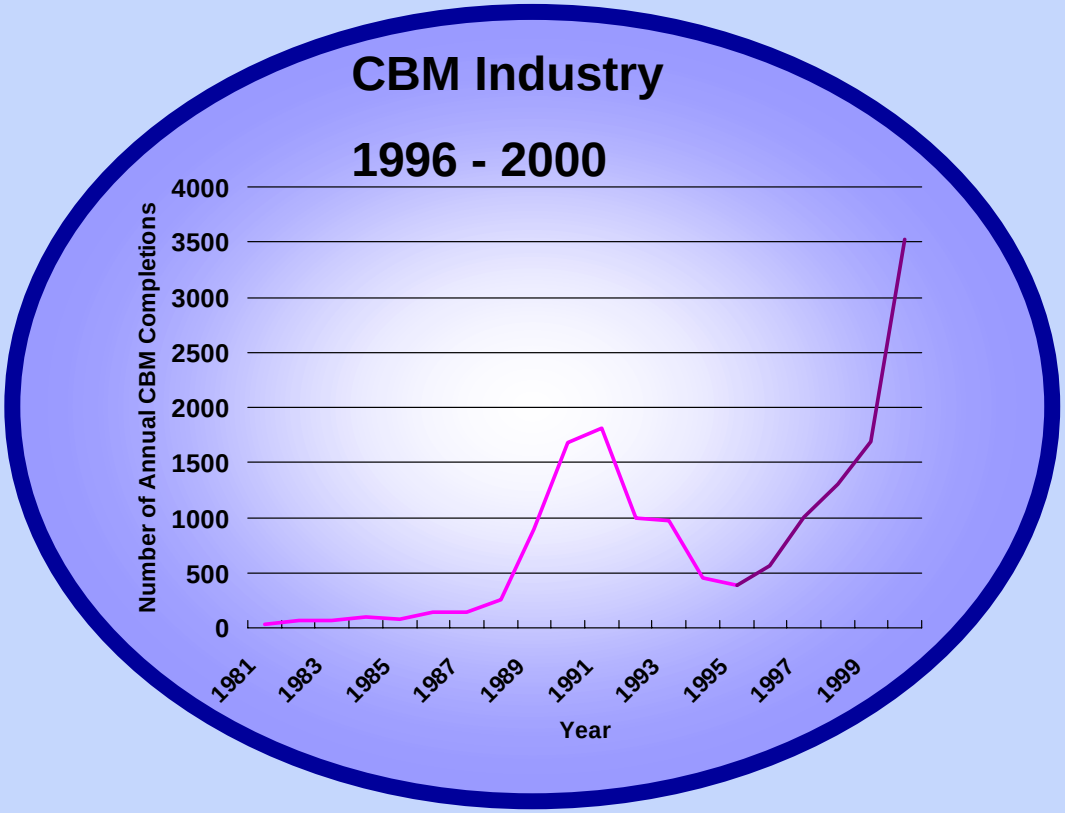
Second Expansion Period

CBM Technology

New Basins

Play Specific Focus

Economics



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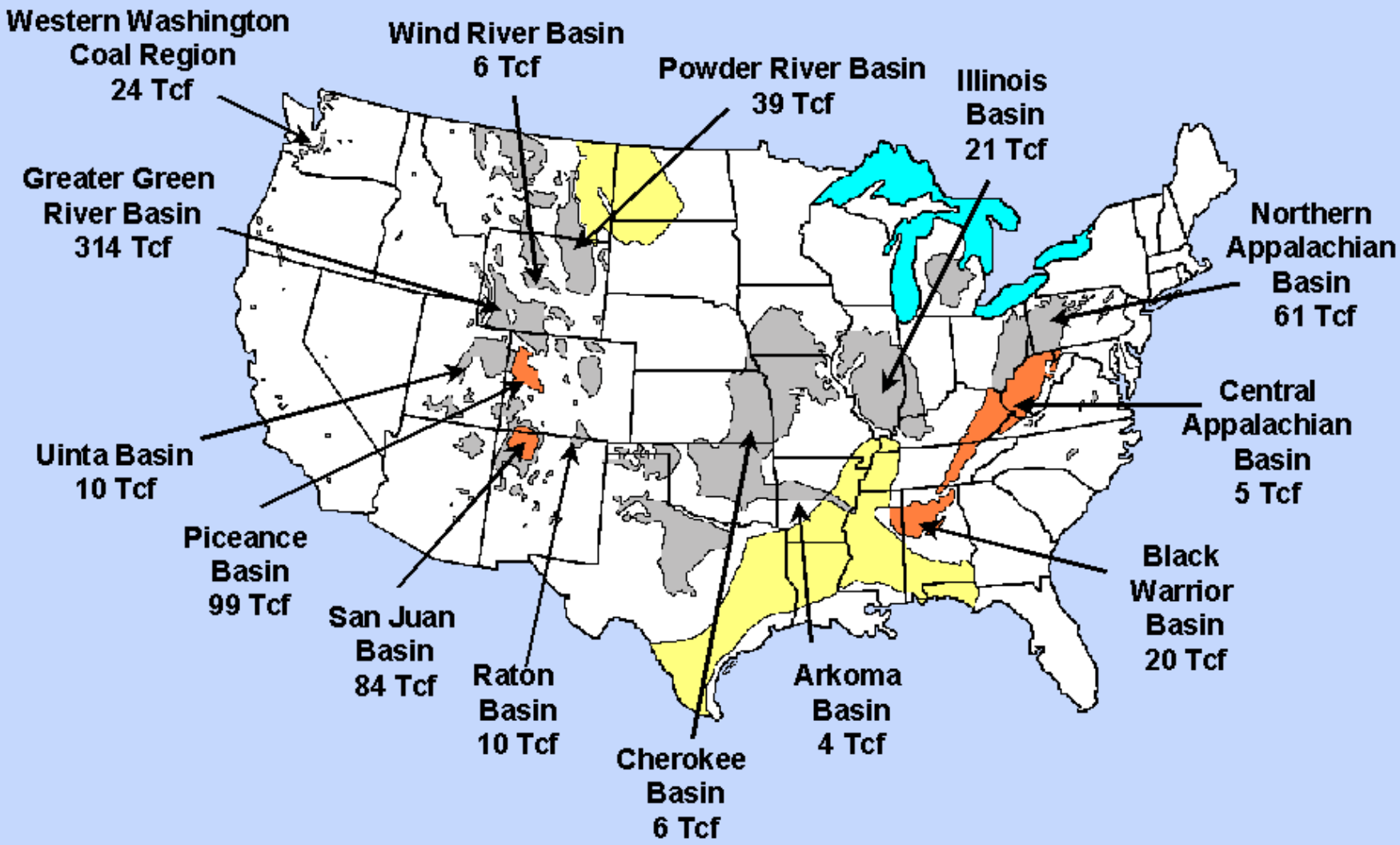
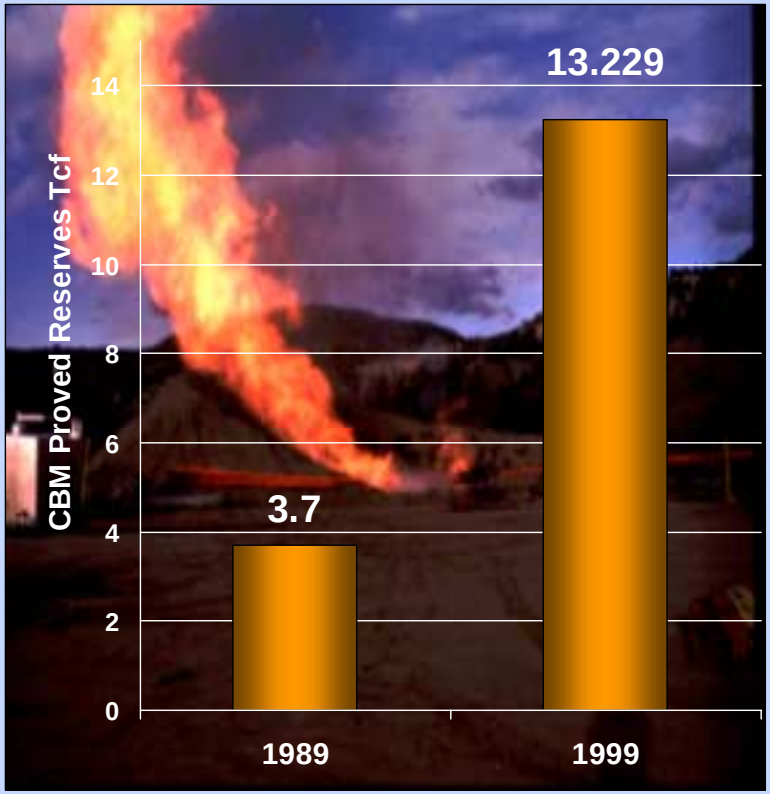
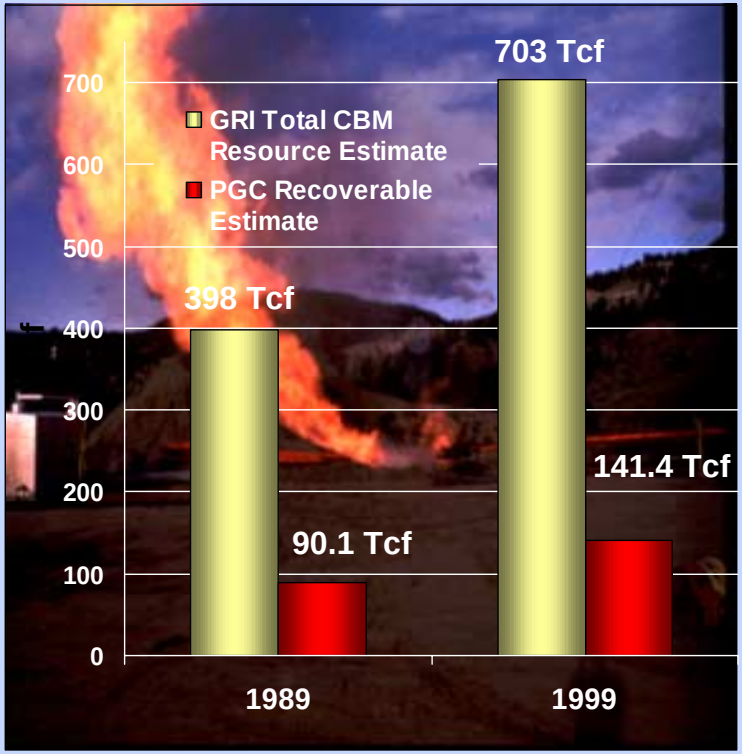
U.S. Lower-48 Coalbed Gas Resources



Sources: EIA, PGC, GRI, State Agencies, and Other Public Information Sources

U.S. Lower-48 Coalbed Gas Resources





Sources: EIA, PGC, GRI, State Agencies, and Other Public Information Sources

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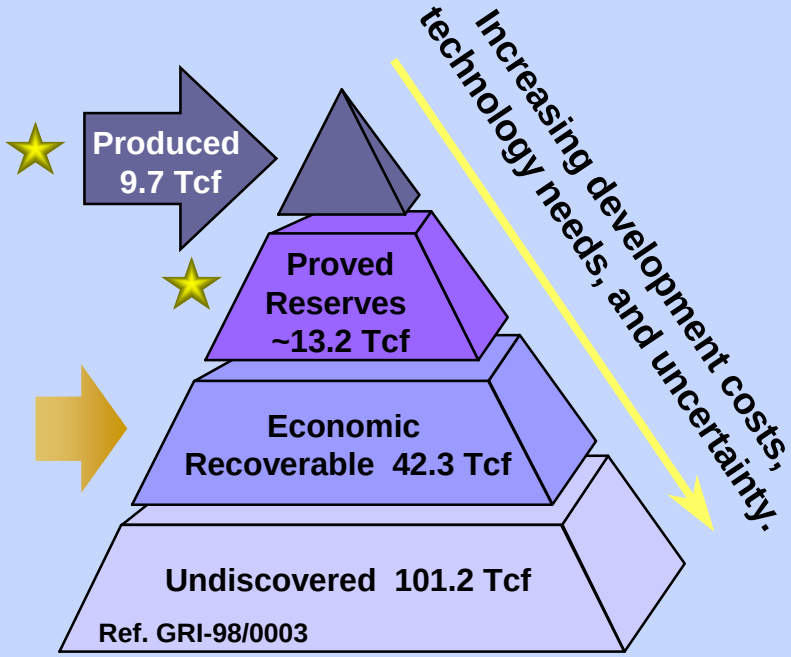
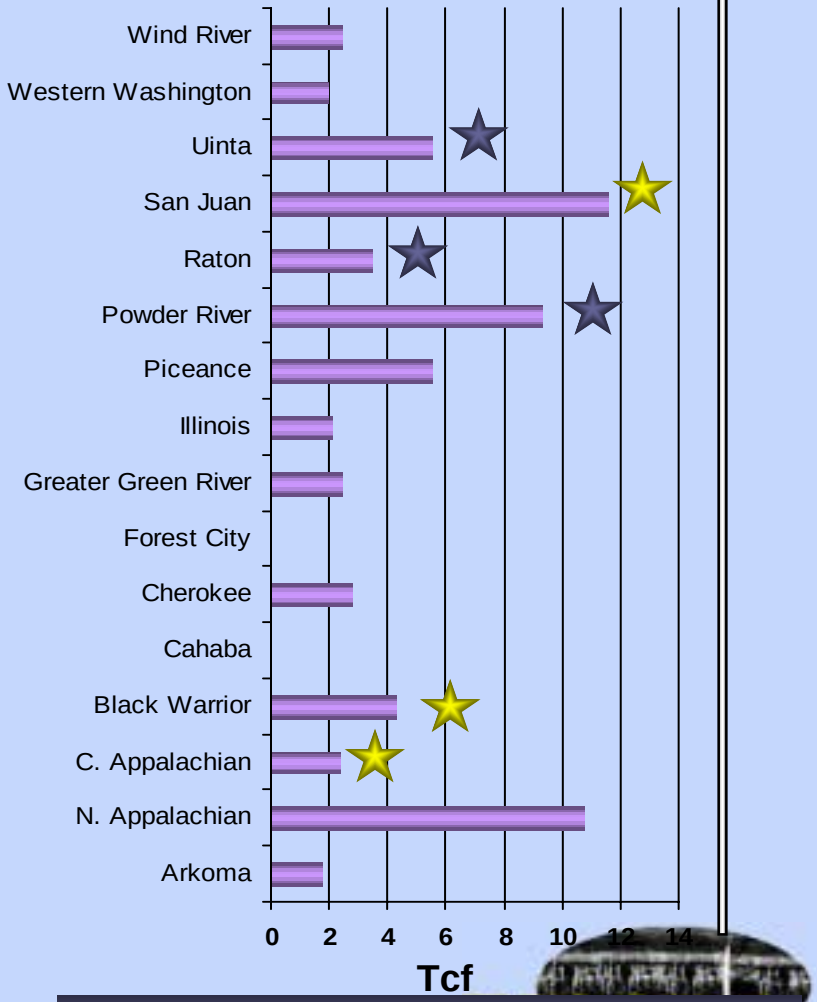
U.S. Lower-48 Coalbed Gas Resources

166.4 Tcf Total Producible Coalbed Methane Resource Base



U.S. Lower-48 CBM Resource Pyramid



Economic Recoverable CBM Resources

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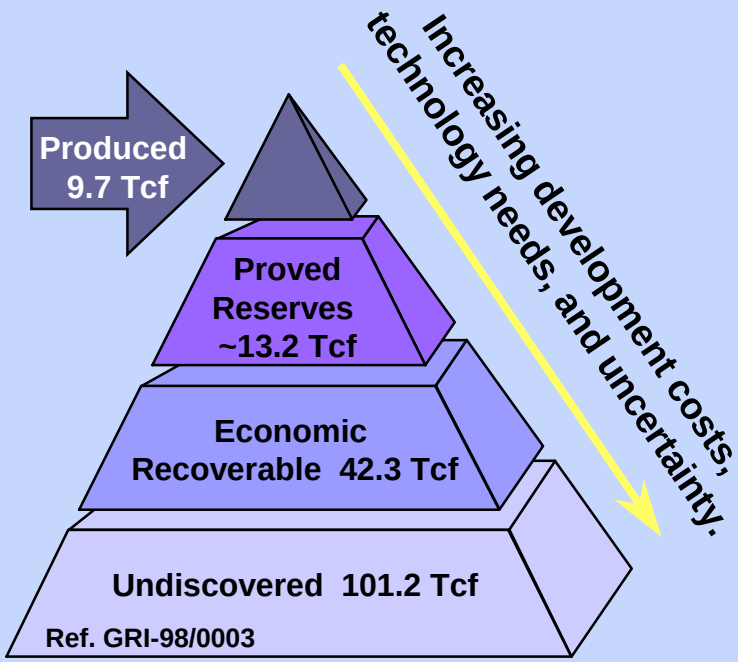
U.S. Lower-48 Coalbed Gas Resources

166.4 Tcf Total Producible Coalbed Methane Resource Base



U.S. Lower-48 CBM Resource Pyramid

Factor Influencing Change

1. New Information from Exploration and Recent Commercial Successes
2. Use of More Accurate Gas Content Analysis Methods
3. Greater Abundance and Spatial Coverage of Gas Content Data for the Rocky Mountain Region Basins

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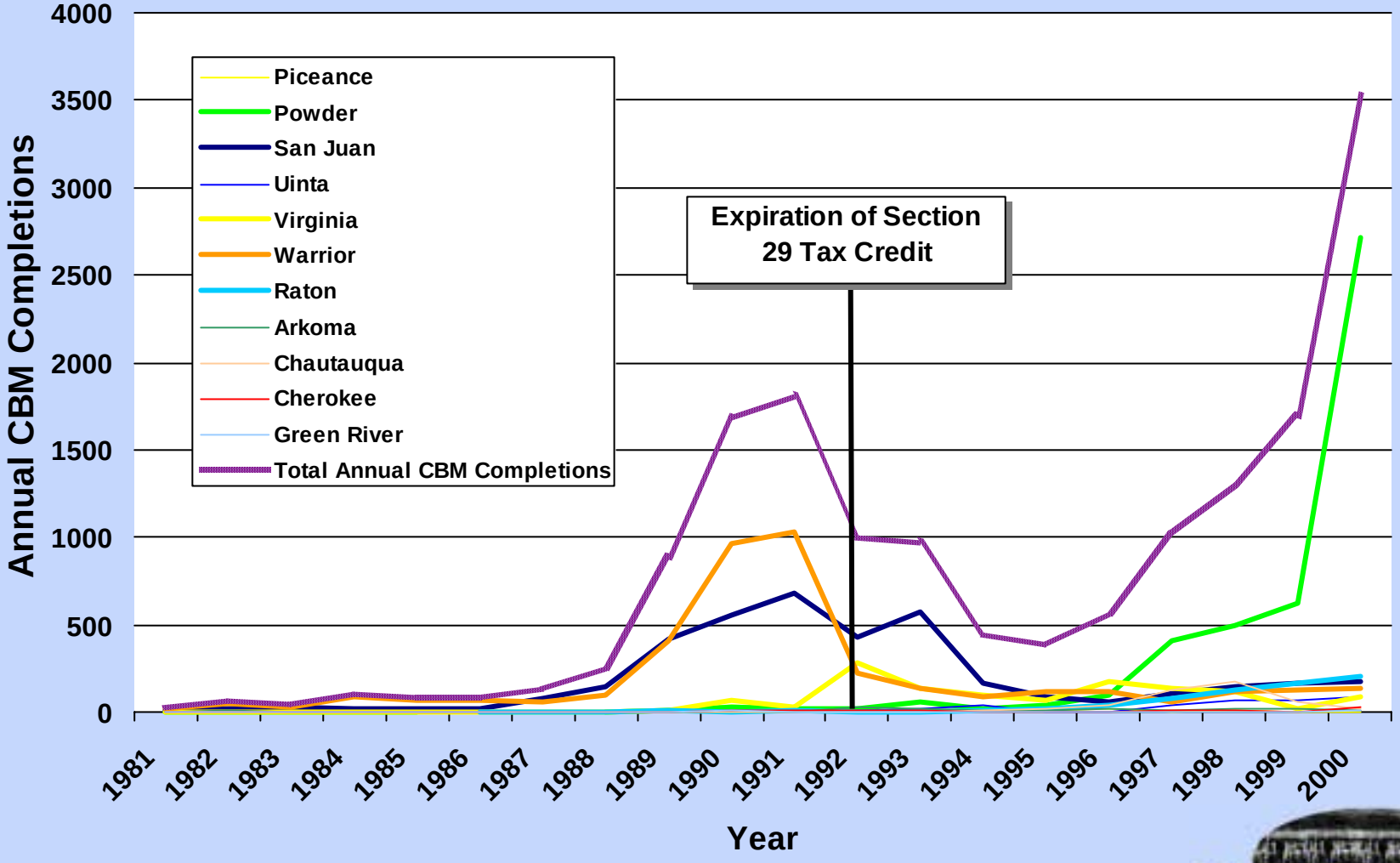
U.S. Annual Coalbed Gas Completions



Source: GTI Unconventional Natural Gas Resource Database 2nd Edition, GTI-01/0136

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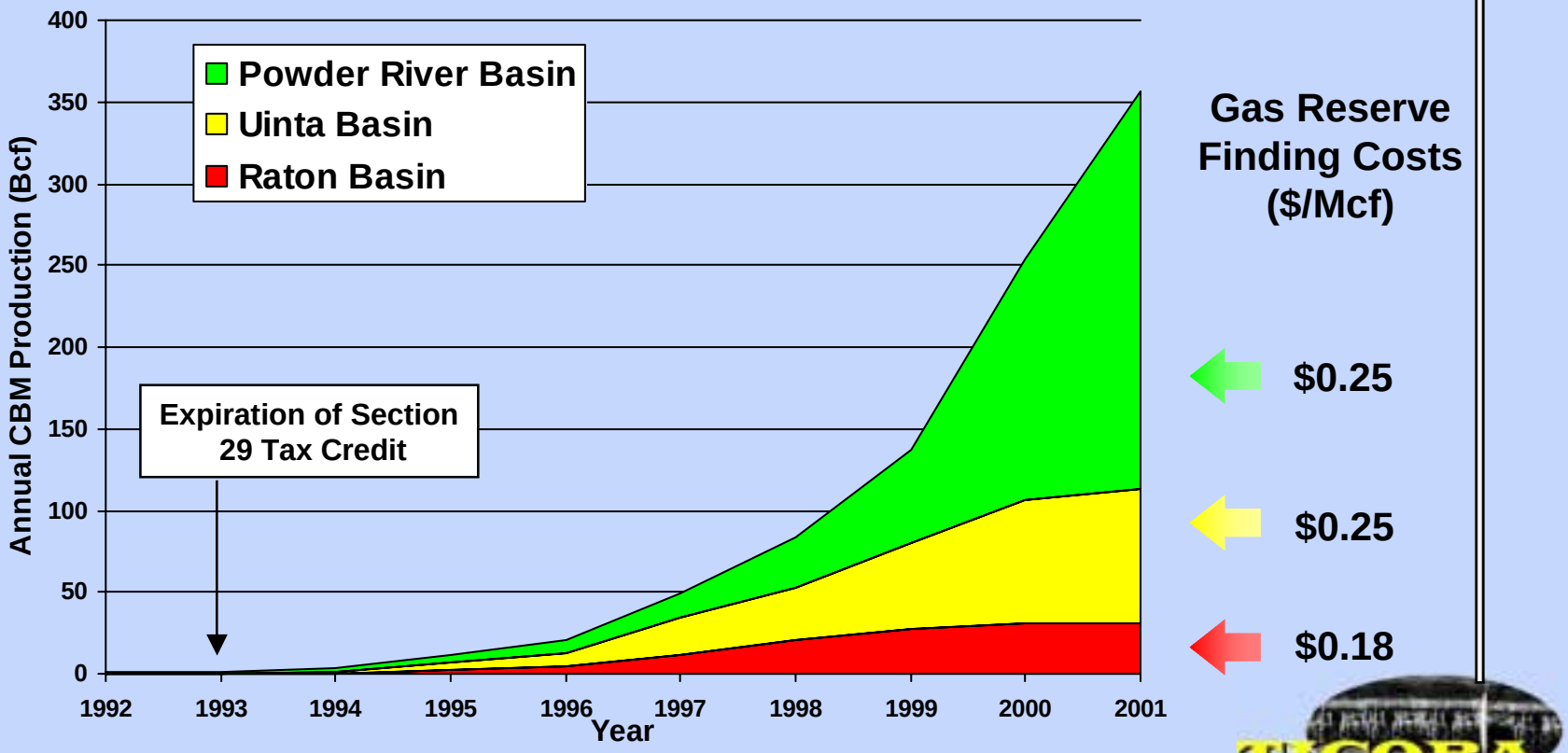
Recent Industry Coalbed Activity

- New CBM Plays No Longer Driven By Section 29 Tax Credit
- Finding Costs are Very Attractive



Sources: GTI, State Agencies, and Other Public Information Sources

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Characteristics of Newest U.S. Rocky Mountain Region Coalbed Gas Plays

	Powder	Raton	Uinta
Drilling	Air - Water	Air - Percussion	Air - Percussion
Completion	Openhole Underream Water Frac	Cased Hole Perforate/Multi-stage N_2 Foam/Sand	Cased Hole Perforate/Multi-stage X-Link/Sand
Water Disposal	Surface Disch. Electric Water Pump	Surf. Disch./Evaporate/ Deep Inject Progressive Cavity Pump	Evaporate/Deep Inject Conv. Rod Pump
Well Spacing	80 acres	160 acres	160 acres
Avg. Well Cost	$100,000	$360,000	$375,000
Average Reserves	0.4 Bcf	1.8 Bcf	1.5 BCF
Average Finding Costs ($/Mcf)	0.25	0.18	0.25

Sources: GTI, State Agencies, and Other Public Information Sources

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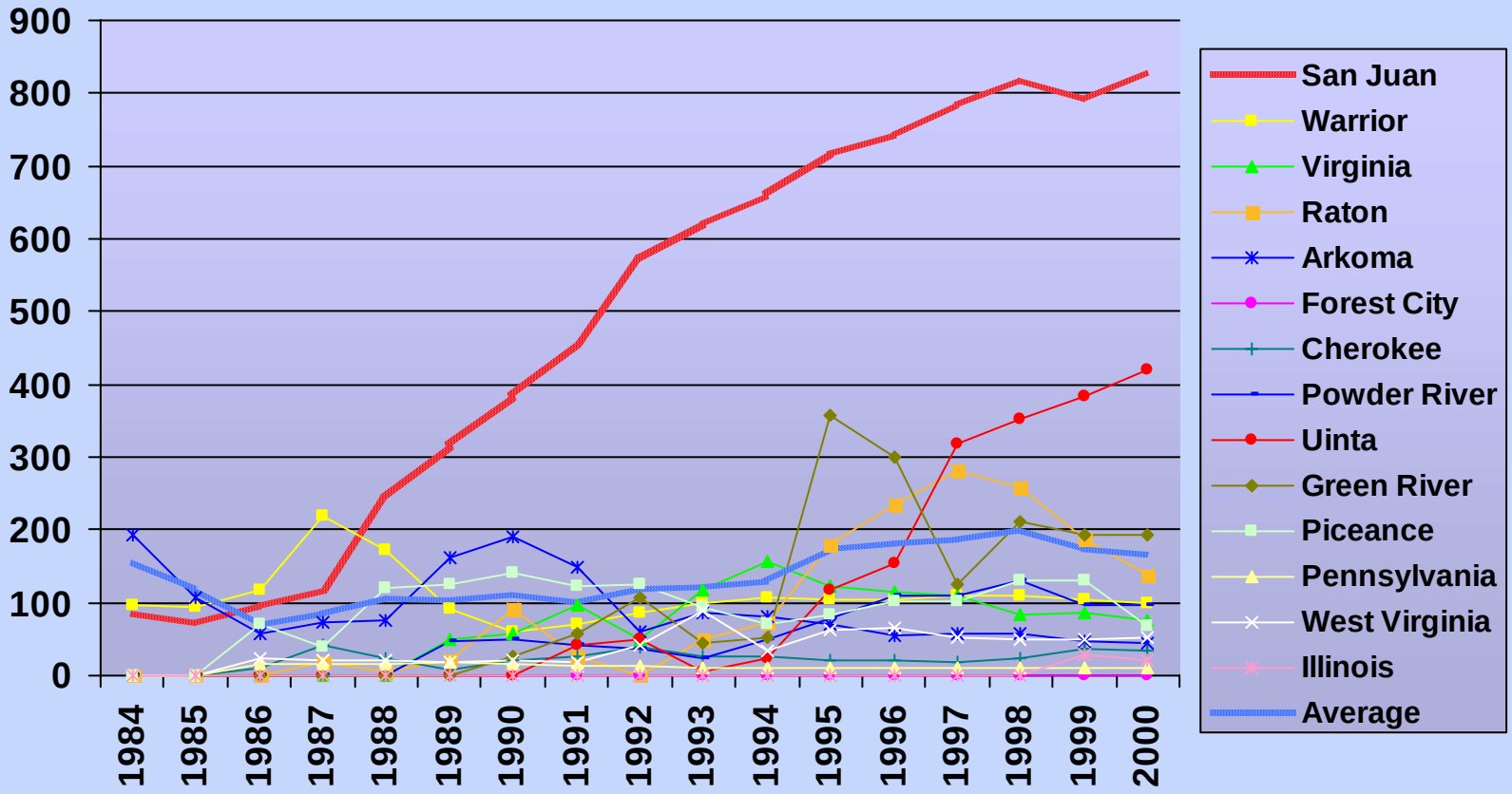
U.S. Average Daily Coalbed Gas Production (Mcfd)



Source: GTI Unconventional Natural Gas Resource Database 2nd Edition, GTI-01/0136

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Initial Coalbed Reservoir Gas-In-Place Perception

- **In Many Established Coalbed Gas Plays, Cumulative Gas Production Volumes Have Exceeded the Initial GIP Volumes**
- **GIP is One of the Key Reservoir Parameters that Influences Production and Producible Reserves**
  - **Values are Method Dependent**
  - **Existing GIP Data May be Inaccurate**

Basin/Field	Initial GIP Estimate	Cumulative Production	δ GIP (%)
Black Warrior Basin Oak Grove Field (23 Wells)	1.55 Bcf	3.2 Bcf (10 Years)	206 %
San Juan Basin Cedar Hill Field (Cahn Well)	2.5 Bcf	2.4 Bcf (~10 Years)	96 %
Powder River Basin Marquiss Field (Lynde Trust 4-23 Well)	0.84 Bcf	1.130 Bcf (8/01/01)	135 %
Uinta Basin Drunkard's Wash (Utah #35-1-9 Well)	3.2 Bcf	5.04 Bcf (12/01/01)	158 %

Ref. GRI-97/0263

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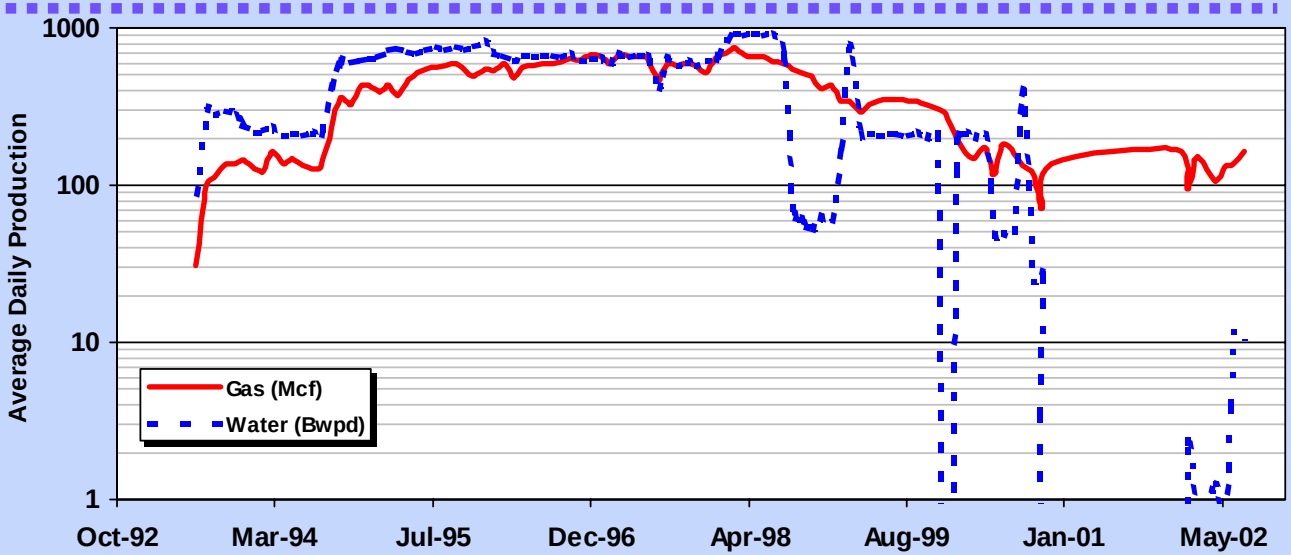
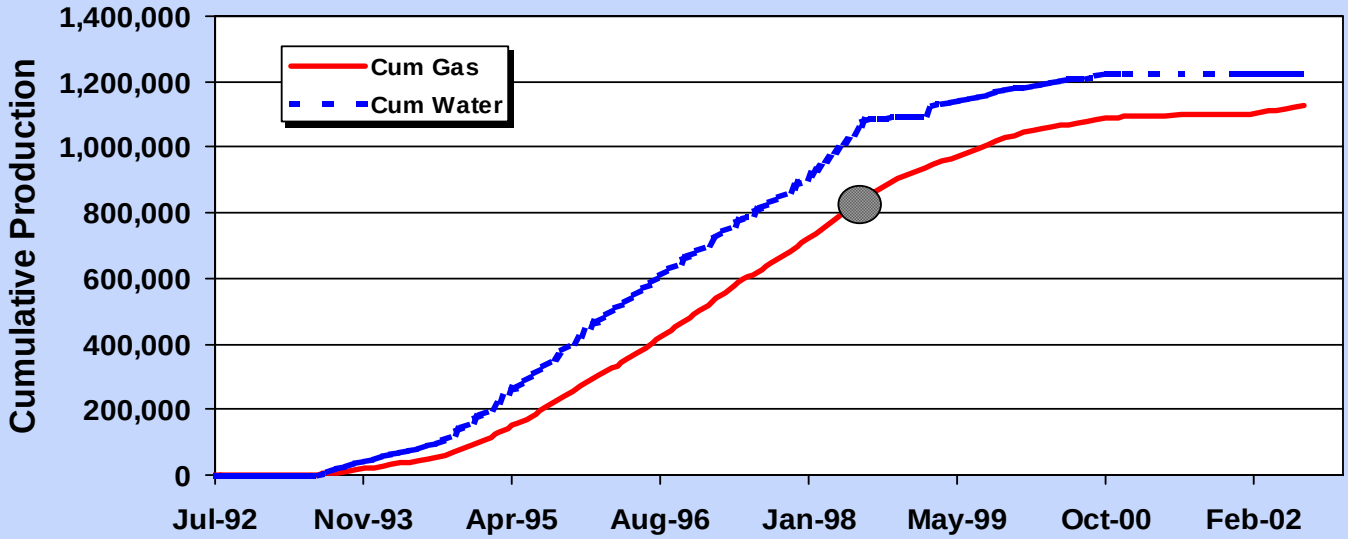
Lynde Trust 4-23 Well, Powder River Basin





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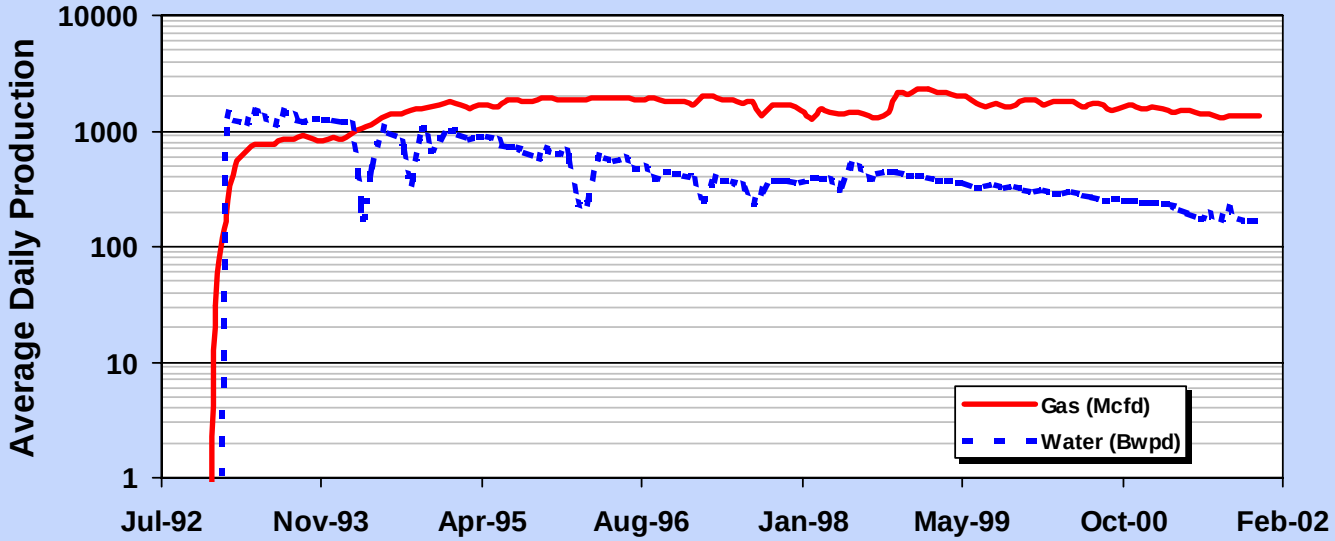
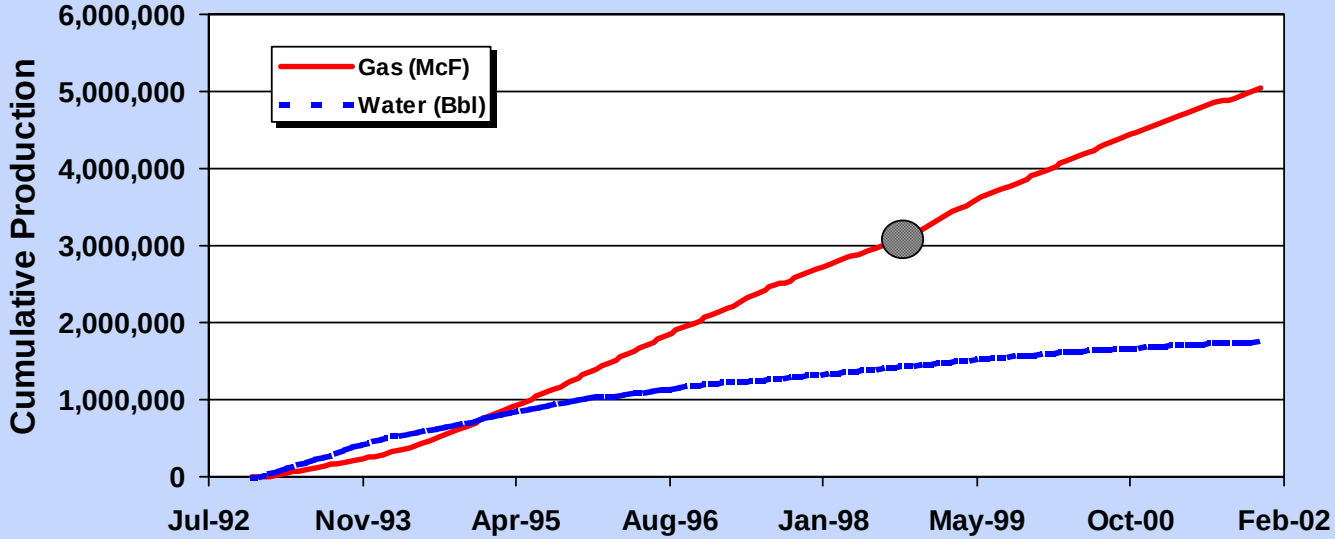
Utah 35-1-9 Well, Uinta Basin





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Data Uncertainties For Coalbed Gas Resource And Reservoir Gas-In-Place Values

$$GIP = Ah\bar{\rho}_c\bar{G}_c$$

UNCERTAINTY	DRAINAGE AREA	THICKNESS	IN-SITU DENSITY	IN-SITU GAS CONTENT
HIGH				
MEDIUM				
LOW				

- Commonly Used Methods
- Very High Sampling Density
- Best Practice Methods

Ref. GRI-97/0263

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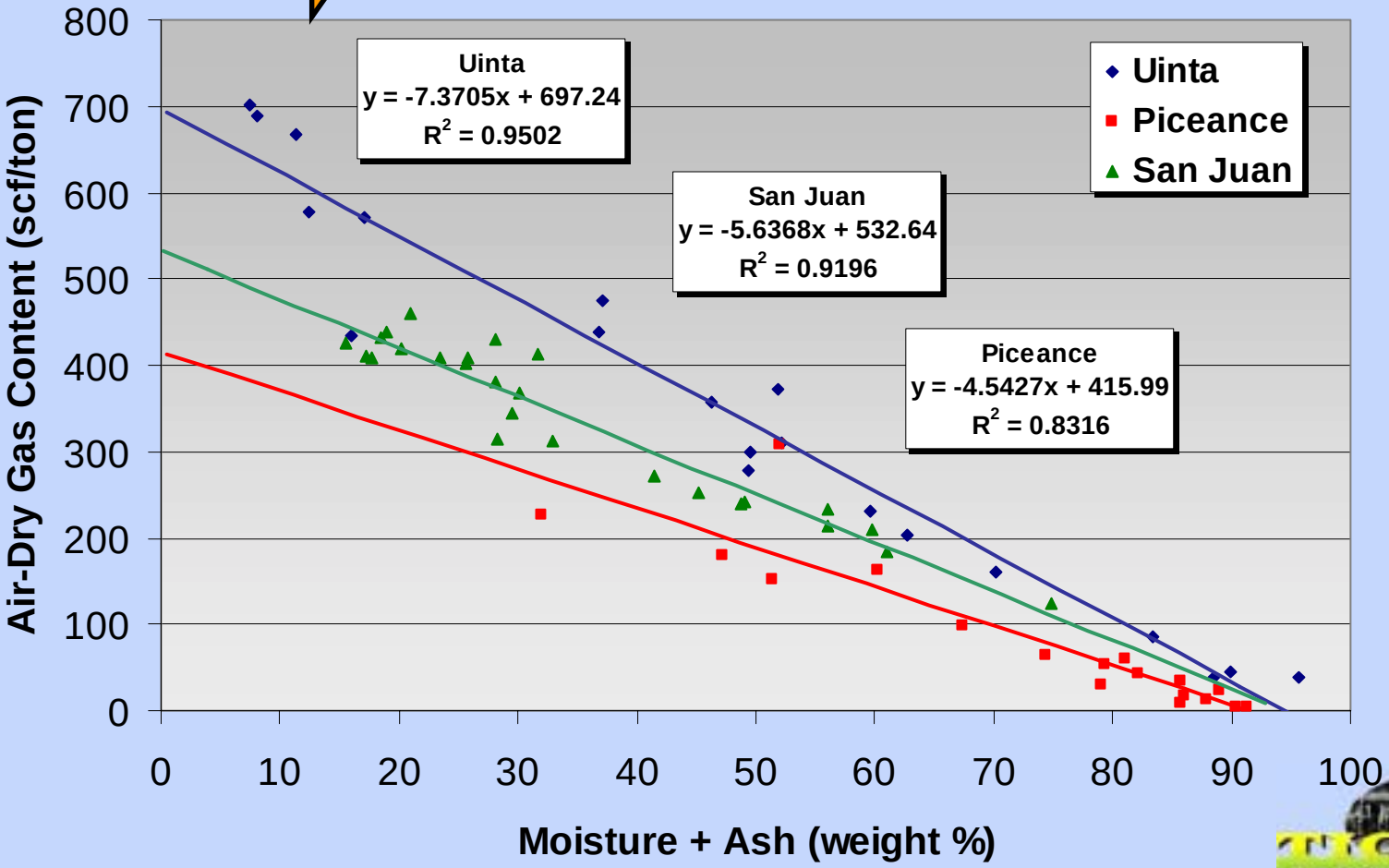
Coalbed Reservoir Gross Thickness Error

Rule-of-thumb upper density limit: 1.75 g/cm^3



Sources: GRI-97/0263, Lamarre and Pratt, *Rocky Mountain Geologist*, April 2002.

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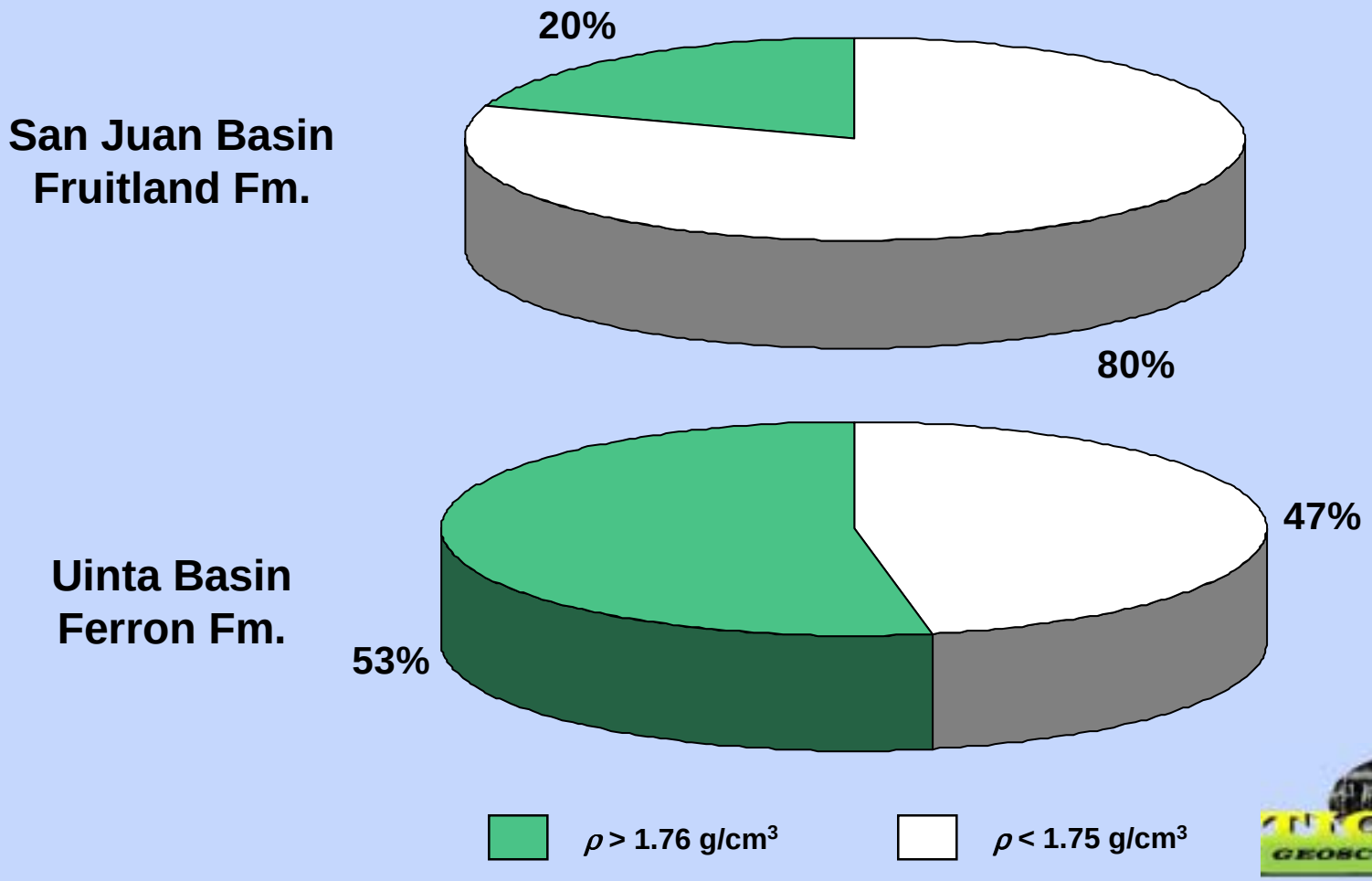
Coalbed Reservoir Gas-In-Place Distribution



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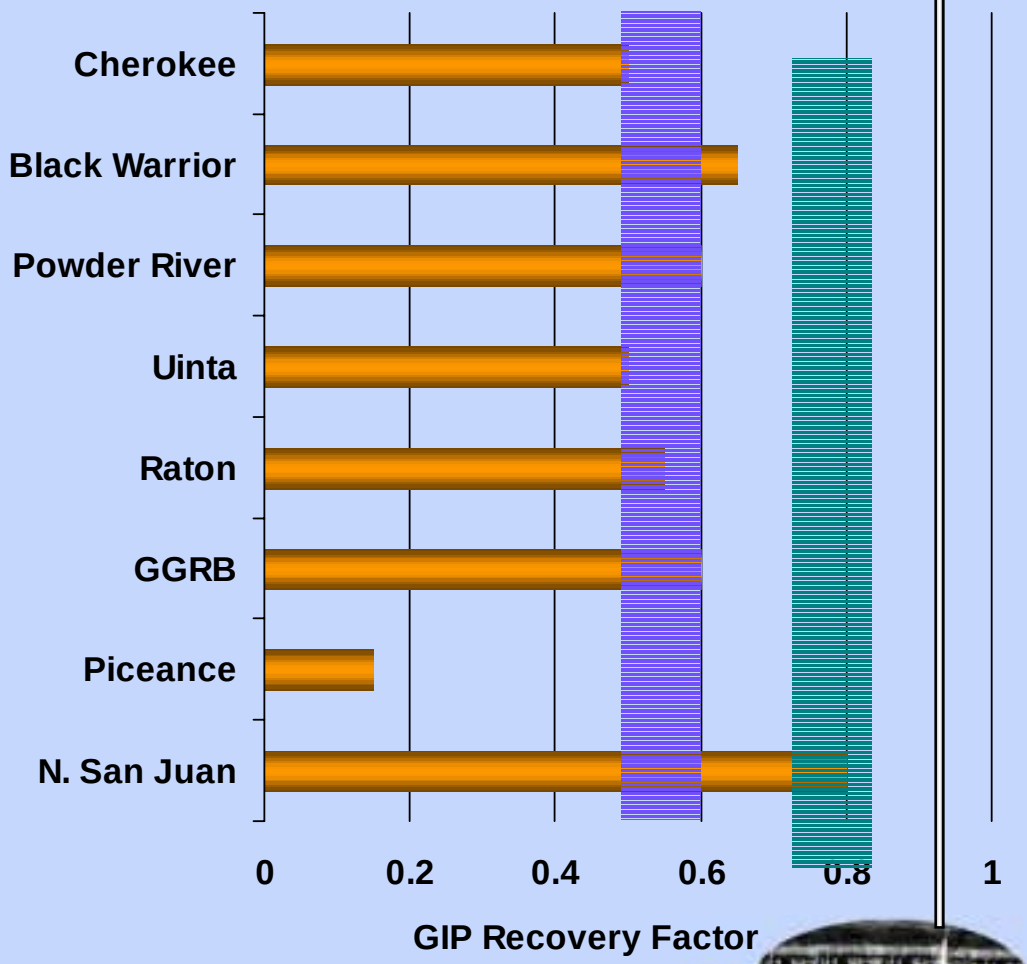
Coalbed Gas Reservoir Recovery Factor Perceptions

- Typical Recovery Factor Averages 50% to 60% with Conventional Technology
- New Enhanced CBM Recovery Technology
  - Injection of Nitrogen or Carbon Dioxide
  - Promotes the Desorption of Methane
  - Potential for Six-Fold Increase in Production Rate and Two-Fold Increase in Reserves



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Play Area Perceptions - Coalbed Gas Producibility Model

- **Based on Comprehensive Geologic and Hydrologic Studies of the San Juan, Greater Green River, and Piceance Basins.**
- **Exceptionally High Productivity is Governed by:**
  - **Thick, Laterally Continuous Coals of High Thermal Maturity**
  - **Adequate Permeability**
  - **Basinward Flow of Ground Water Through Coals of High Rank and Gas Content Orthogonally Toward No-Flow Boundaries (regional hingelines, fault systems, facies changes, and/or, discharge areas)**
  - **Generation of Secondary Biogenic Gases**
  - **Conventional Trapping Along Those Boundaries to Provide Additional Gas Beyond that Generated During Coalification**

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Coalbed Gas Producibility Model

The interplay of these critical geologic and hydrologic controls determines coalbed methane producibility

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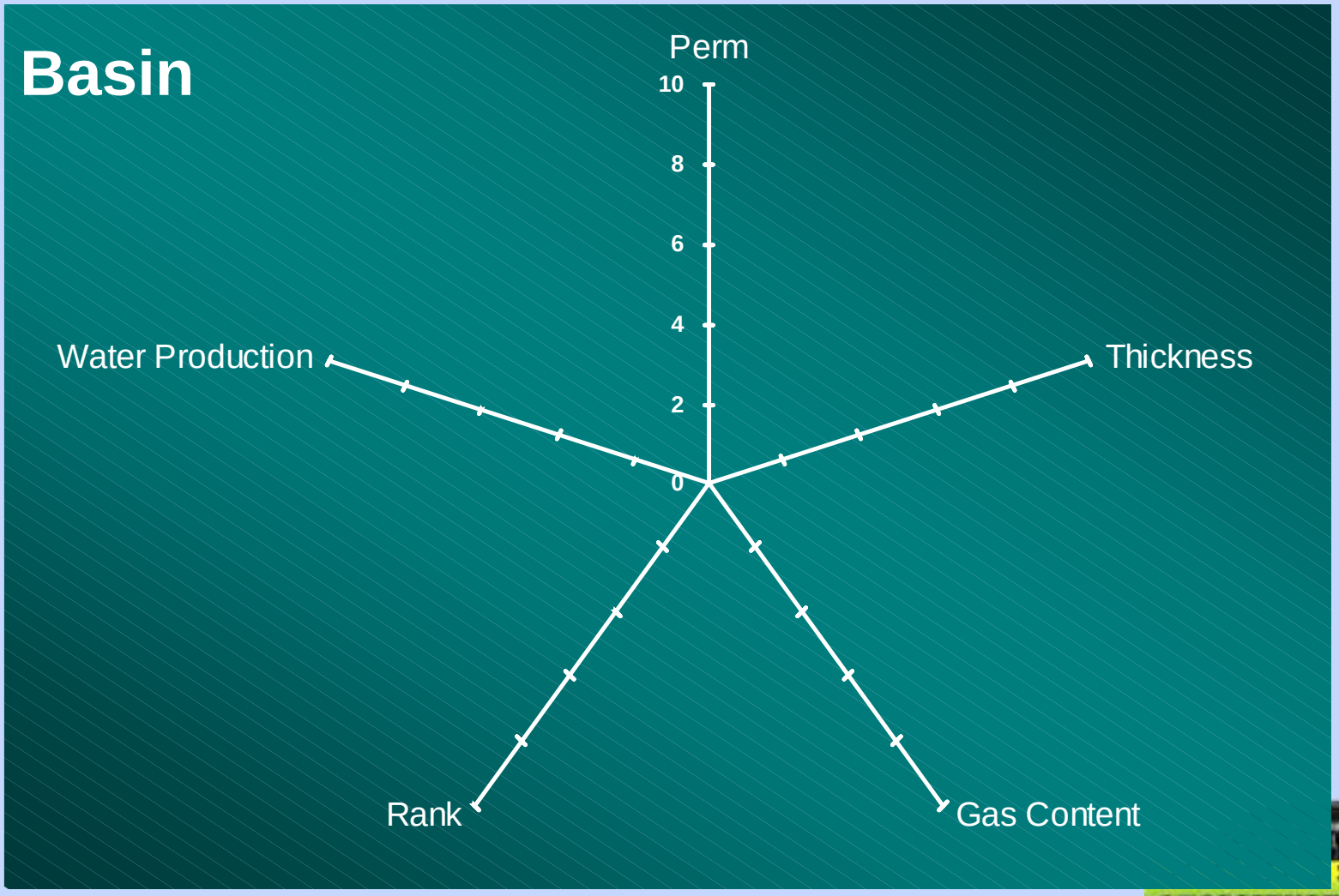
Basin Property Comparisons



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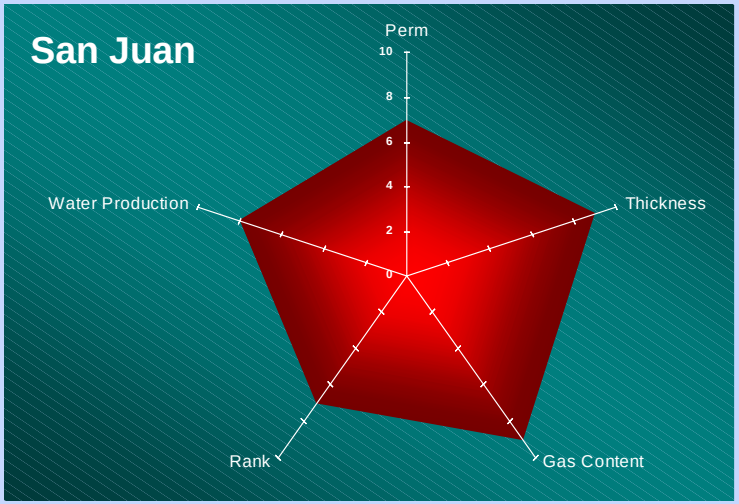
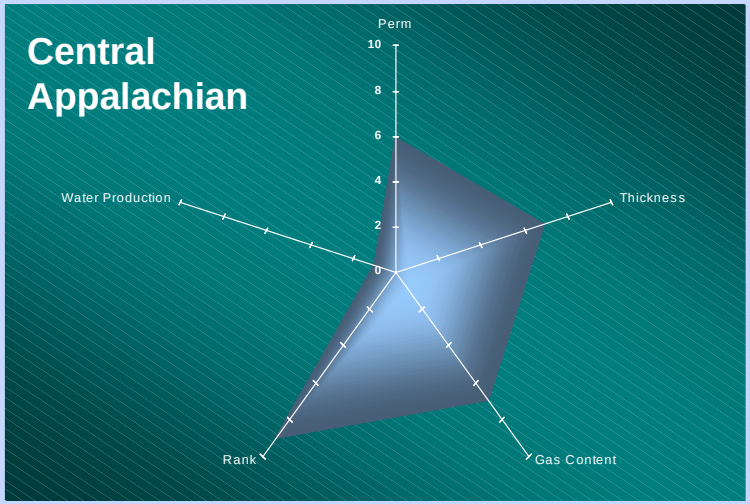
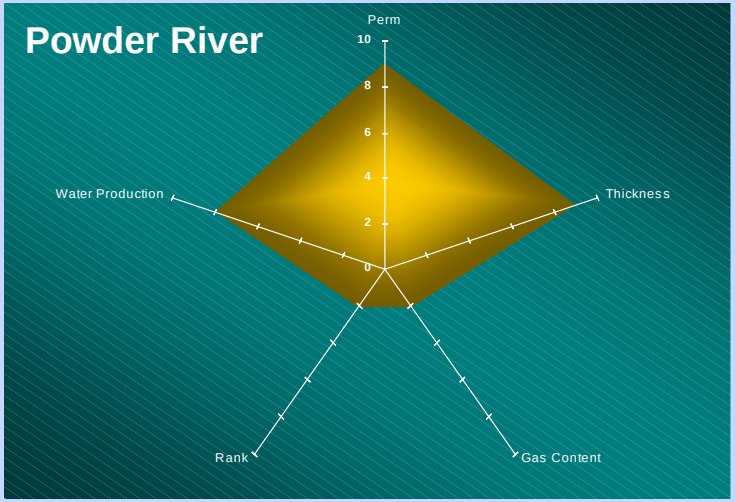
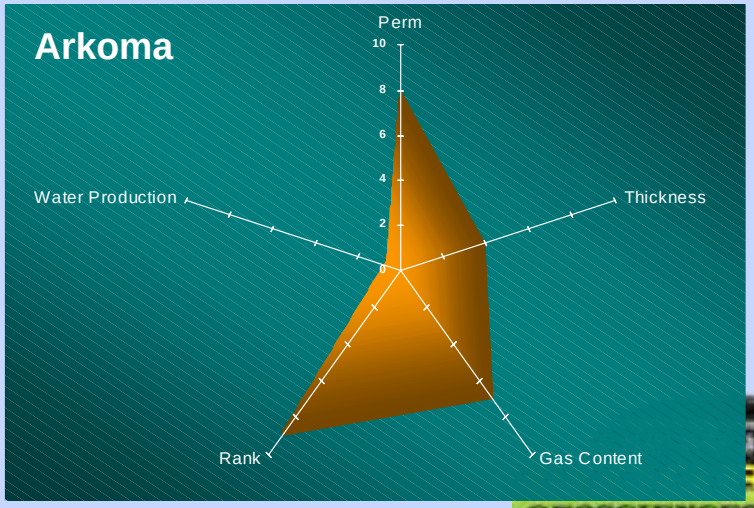
Basin Property Comparisons









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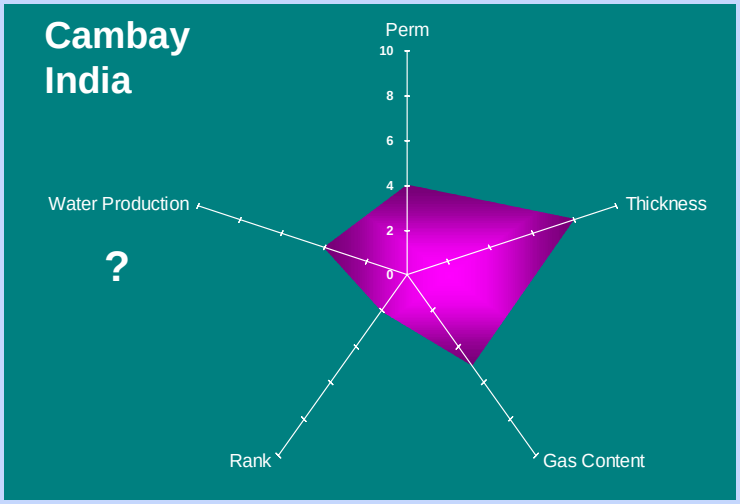
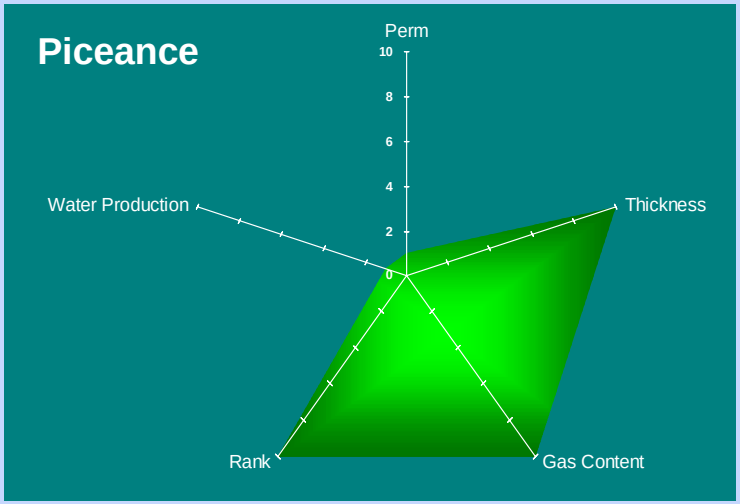
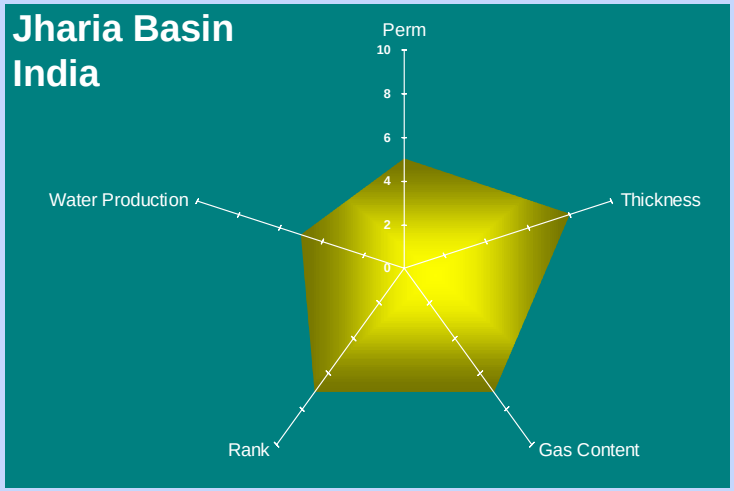
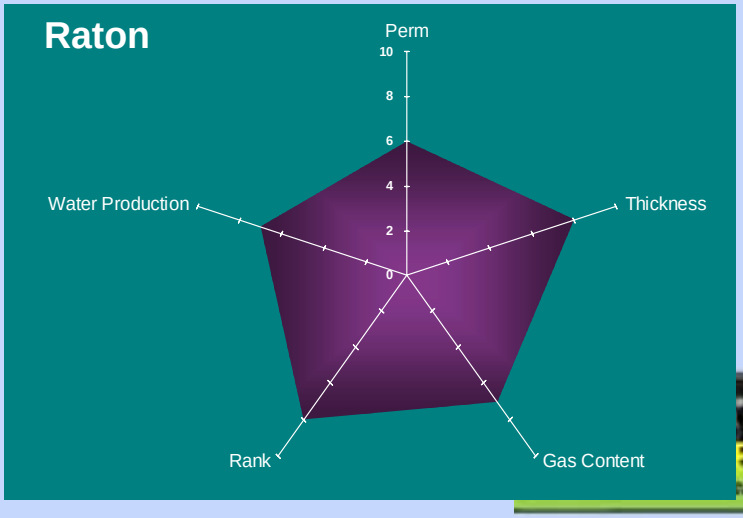
Basin Property Comparisons









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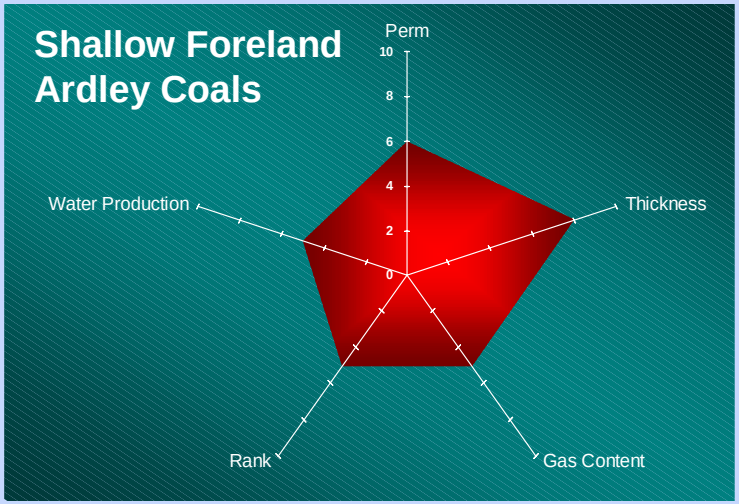
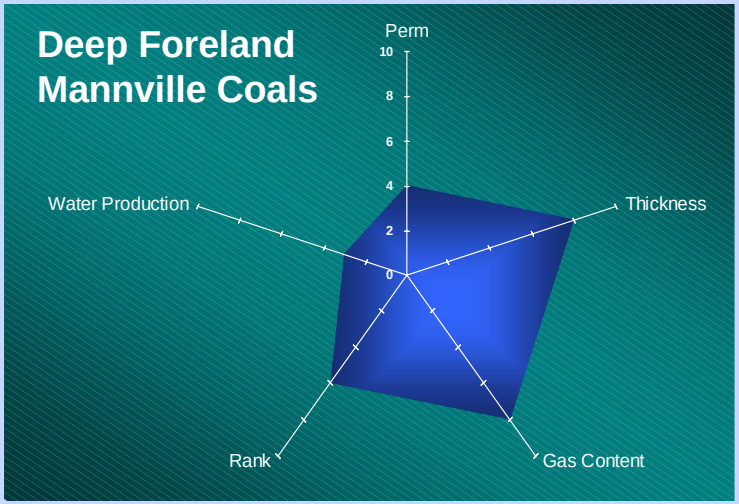
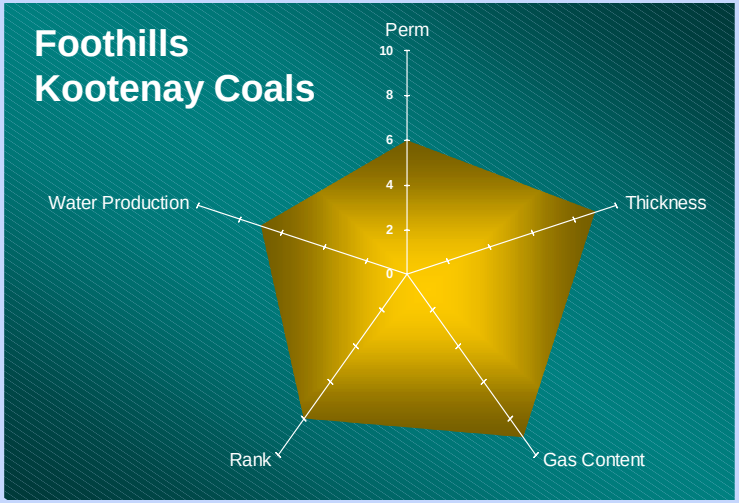
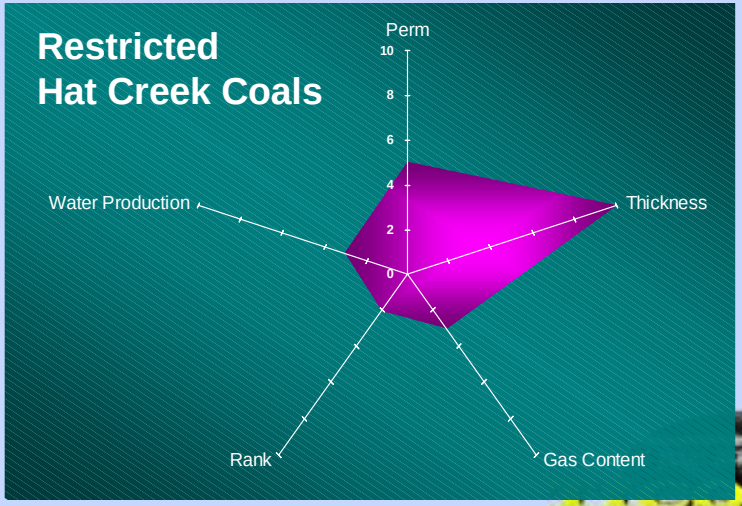
Play Type Comparison - Canada









After Dawson et al, 2000, and Sloan et al, 2001

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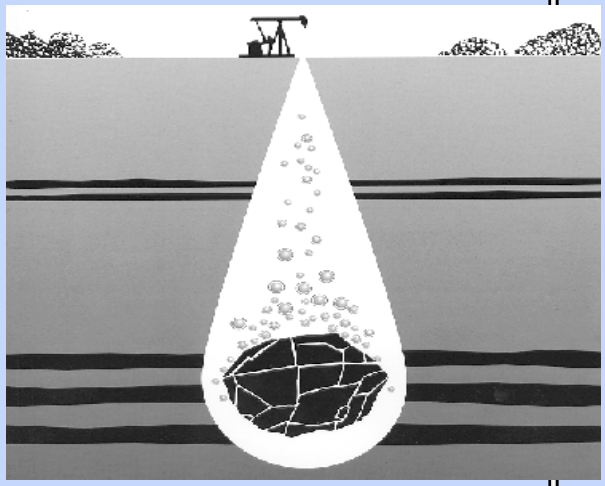
Next Major Coalbed Gas Advances

- **Extending the Producibility Model**
  - **New Areas/Basins (New Data)**
  - **Lower Maturity**
  - **Deep Coals**
  - **Infield Development**
- **New Players**
  - **Challenging Conventional Wisdom**
  - **International**
- **Environmental Drivers**
  - **Global Warming**
    - **Carbon Sequestration**
    - **Enhanced Coalbed Methane Recovery**
  - **Produced Water Management**



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Coalbed Gas: 2 – 5 Year Outlook

- **Continued Exploration in Frontier Plays**
  - **Greater Green River Basin** **Wind River**
  - **Illinois Basin** **Gulf Coast**
  - **Menefee – San Juan Basin**
- **Growth In Mid-Continent Basins**
- **Extensive Infield Development in the San Juan Basin (outside the fairway)**
- **Commercial Production Begins in Canada**
- **Progress in Enhanced Coalbed Methane Recovery and CO_2 Sequestration**
  - **Science First**
  - **Financial Incentive Second**

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