

A Comparison of Coalbed Methane Drilling Practices in the Southern Shanxi Province, China, through Advanced Reservoir Modeling

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Overview

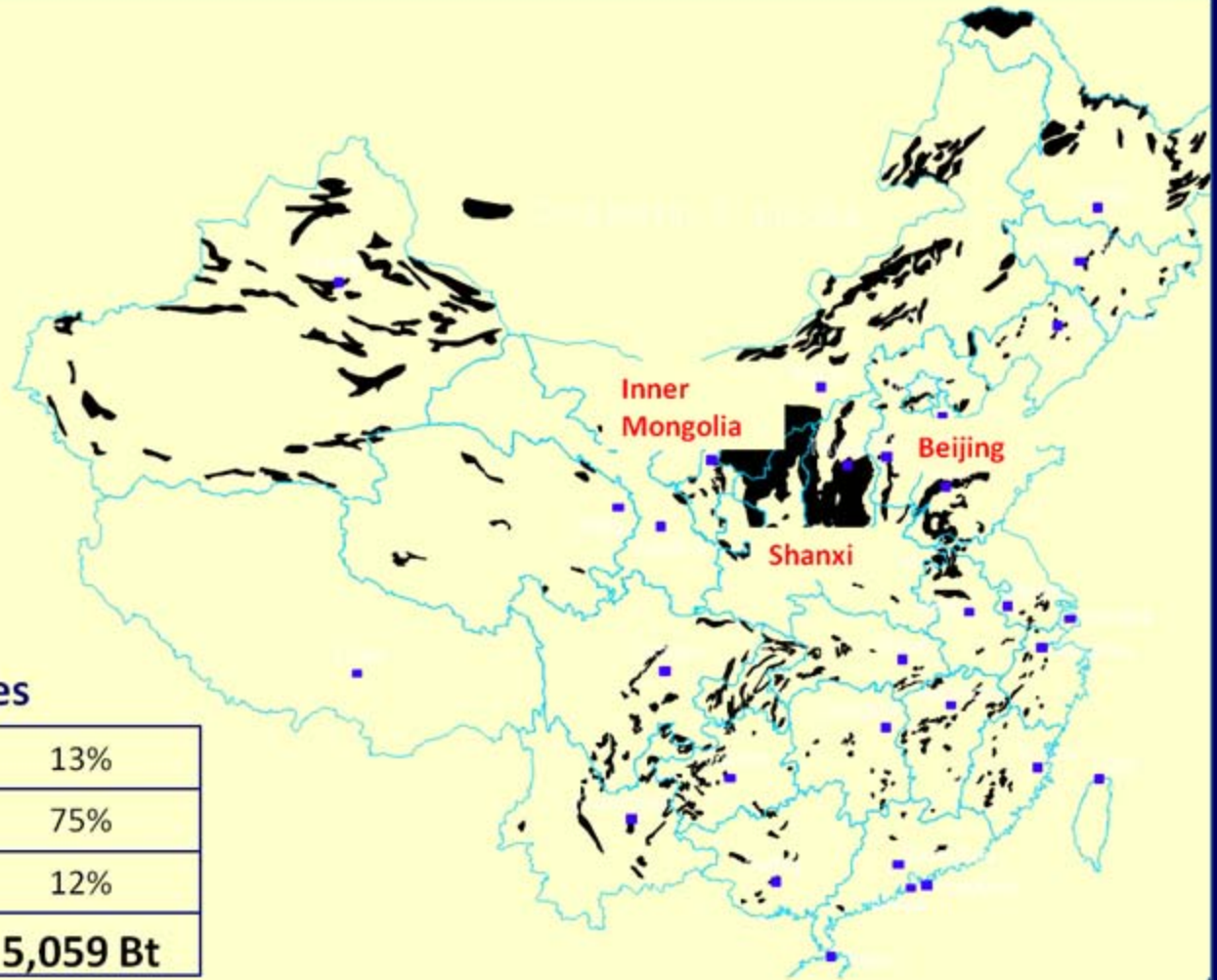
- EPA Methane to Markets Project
- Current status of CBM production in China
- CBM potential in China
- Basic CBM modeling parameters and assumptions
- Inputs for modeled CBM reservoir
- Results

EPA Methane to Markets Project

Best Practices for Mine Degasification

- **Marshall Miller and Associates** - Detailed Feasibility Study Template and Reserve Analysis for CBM Field in Southern Shanxi Province, China
- **Virginia Tech** - Modeling Simulations, Comparisons of Various Degasification Practices

Coal Basins and Resources in China



China's Coal Reserves

Brown Coal	658 Bt	13%
Bituminous	3,794 Bt	75%
Anthracite	607 Bt	12%
Total Reserve	5,059 Bt	

Source: Overview of China's Coal Resources – 1996 (Bt: Billion Tonnes)

China Coal Statistics

- Energy consumption satisfied by coal
- ~30,000 existing coal mines (fully mechanized to hand-loading). Some estimates are >50,000 mines
- Reported employment >6 million
- Average miner produces ~325 tonnes/year
- Coal production
 - 2003: 1.7 billion tonnes
 - 2004: 2.0 billion tonnes
 - 2005: 2.2 billion tonnes
 - 2006: 2.3 billion tonnes
 - 2009: 2.6 billion tonnes

China Coal Statistics

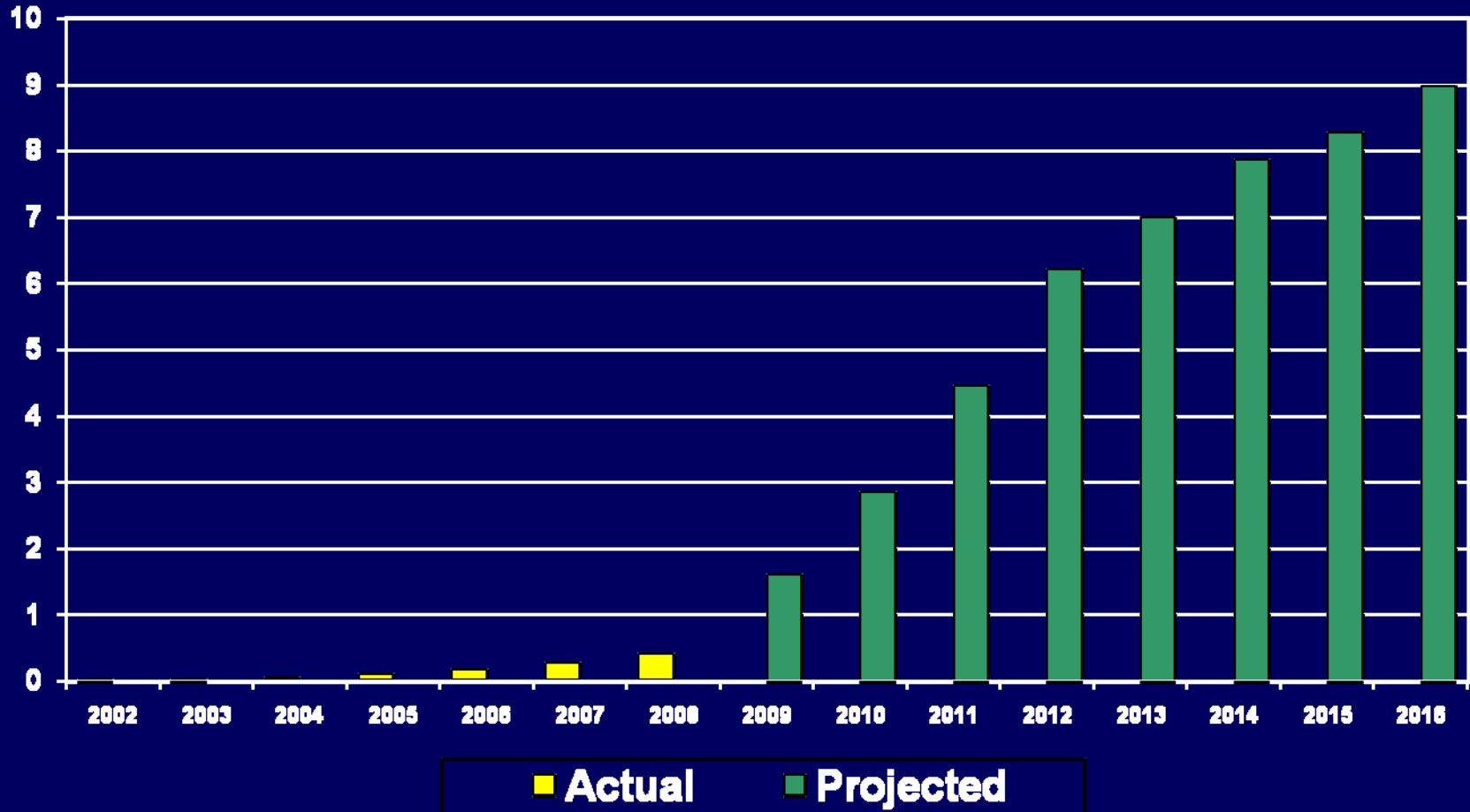
- Official reported fatalities in
 - 2003 = 6,700
 - 2004 = 6,000
 - 2005 = 5,500
 - 2006 = 4,700
 - 2007 = 3,800
- Reportedly China can safely produce 1.2 billion tonnes/year
- Remaining 0.8 billion tonnes generated from small, unregulated mines and overproduction at large, undercapitalized mines

China Coal Statistics

- Majority of Chinese mining accidents related to methane explosions
 - Reported ~30% to 40% of deaths from CH₄ explosions
- Low permeability and high rank coals
- **~ 1/3 of Chinese mines develop coal with gas contents exceeding 300 ft³ /tonne**
- Chinese need western degas technology
 - In-mine drainage
 - Surface drilling (both vertical and slant)

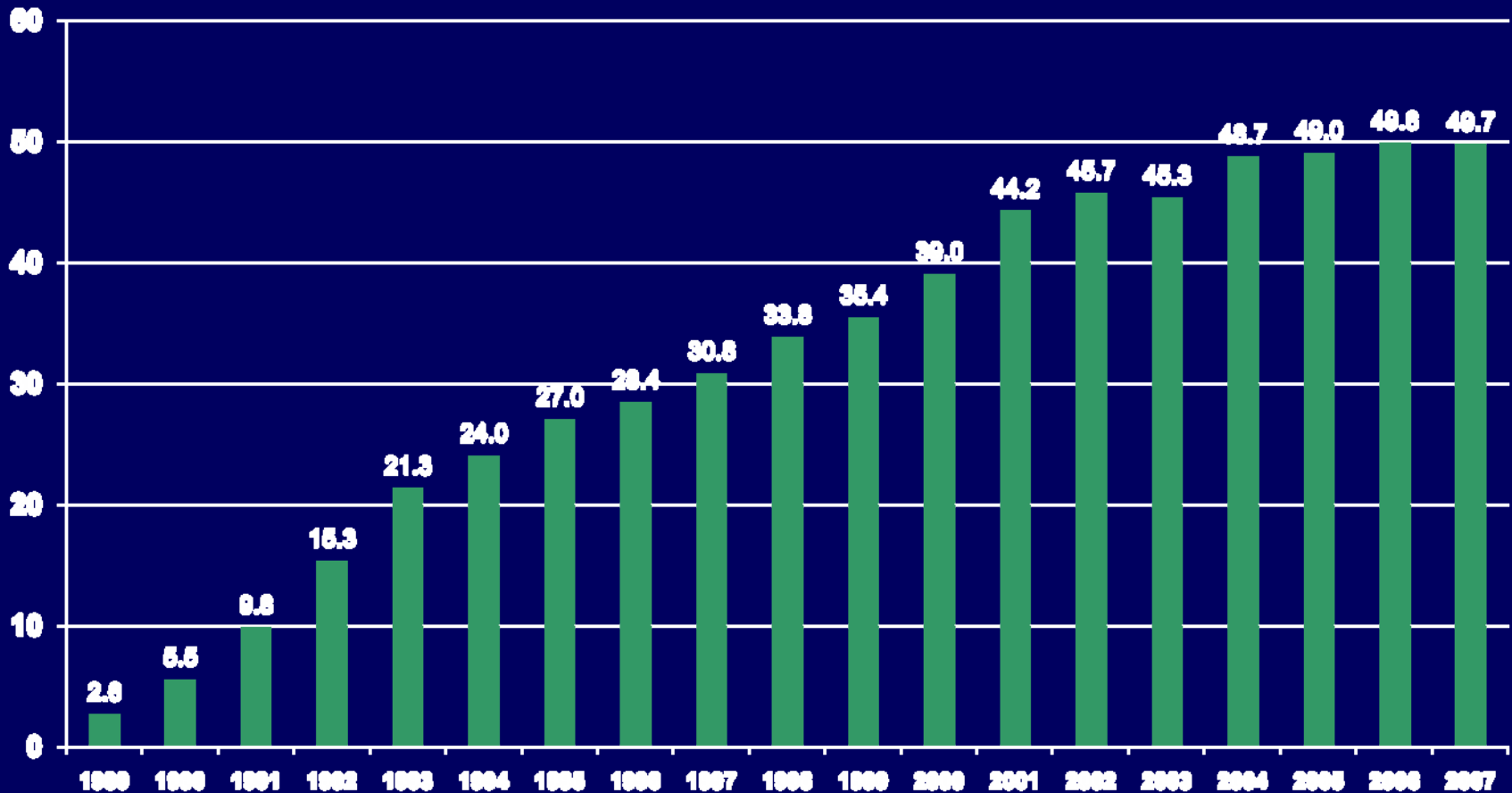
China's Coalbed Methane Production

Billion cubic meters



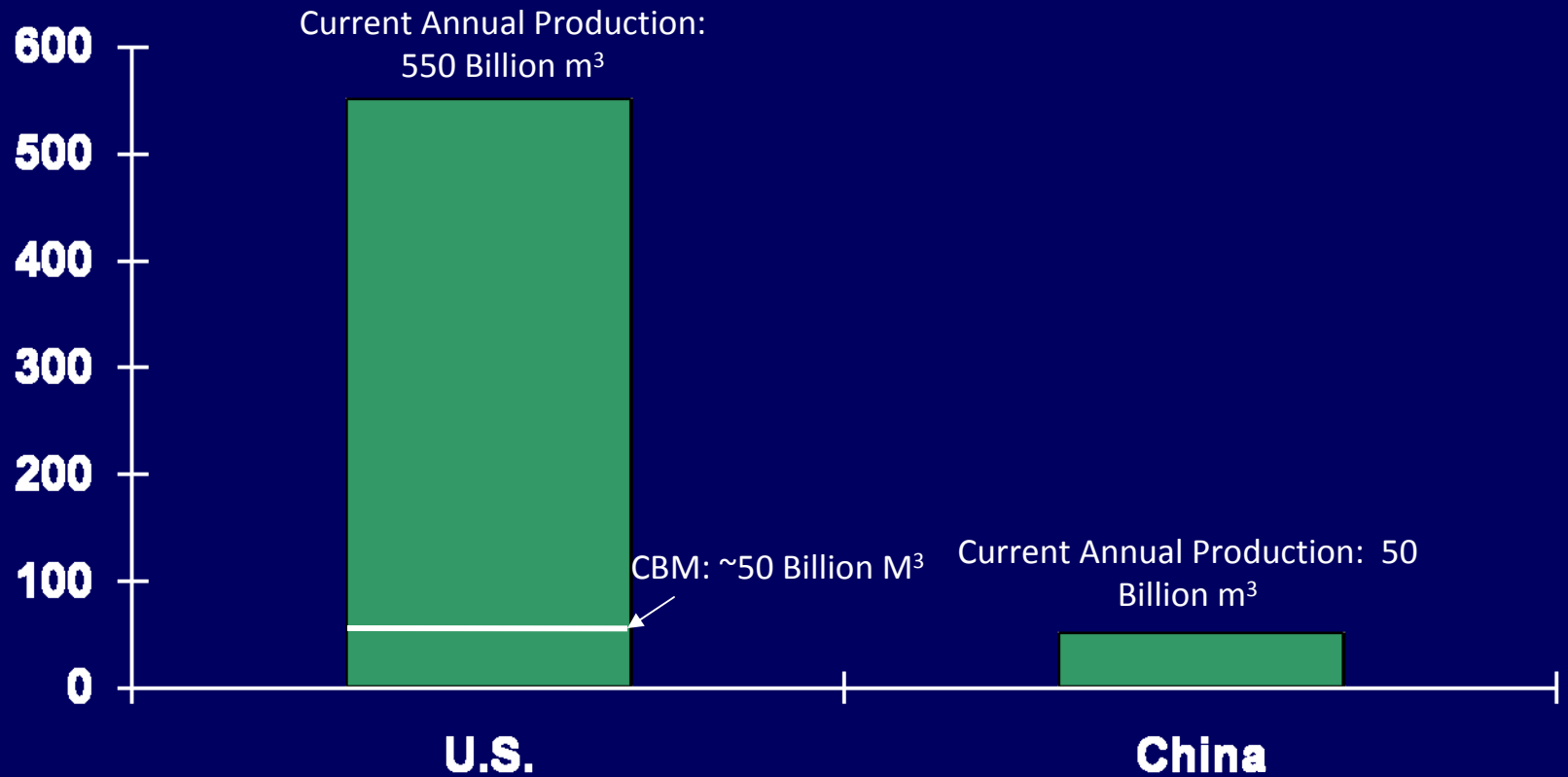
U.S. Coalbed Methane Production 1989 - 2007

Billion cubic meters

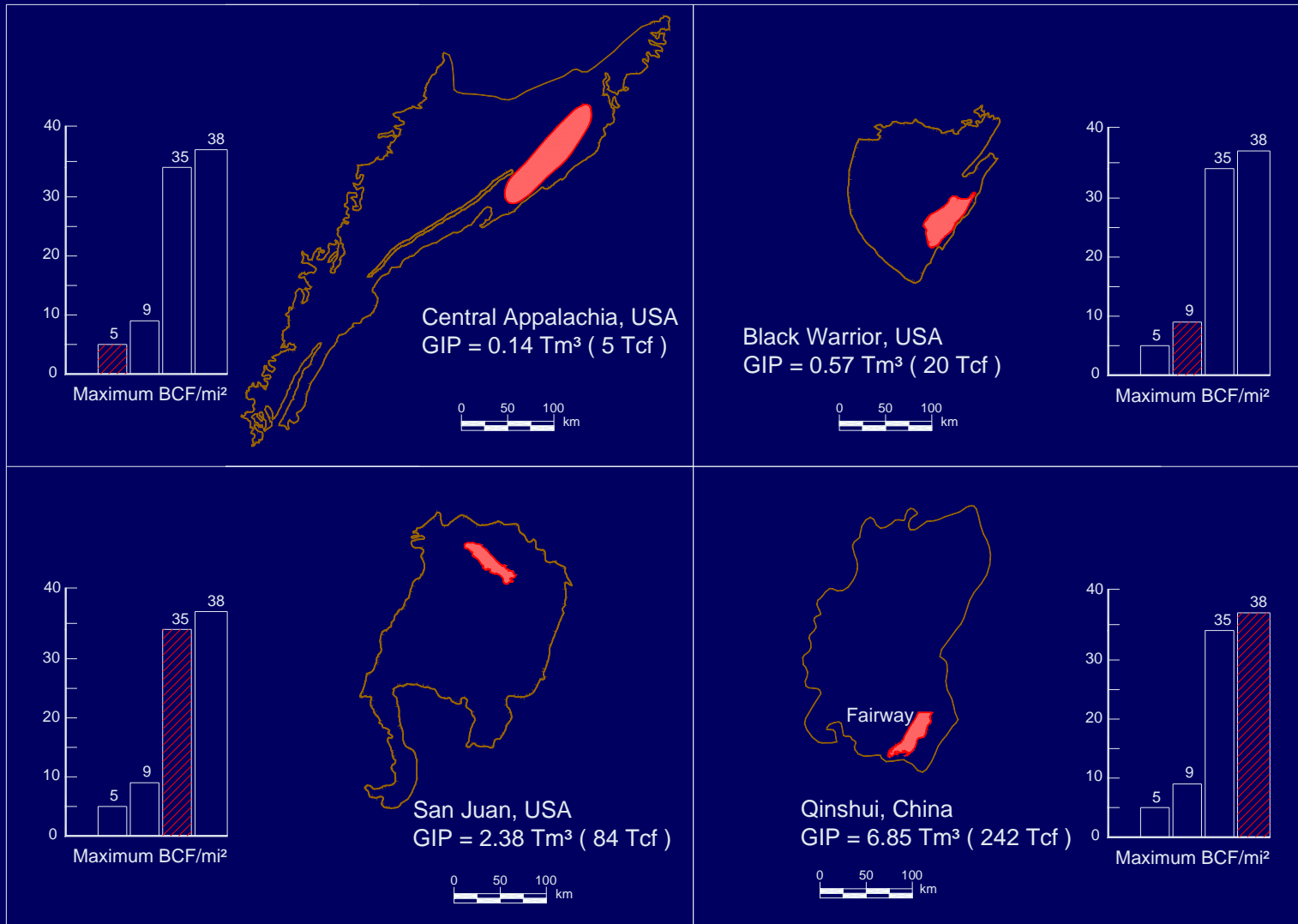


Source: E.I.A., Office of Oil and Gas • Annual Report

Natural Gas Production: US vs. China



Comparison of 4 CBM Basins: Central Appalachian Basin, Black Warrior Basin, and San Juan Basin (U.S.A.), and Qinshui (China)



Cleat Development Comparison

Typical Anthracite (U.S.)



Note: Absence of Cleats

Jincheng No. 3 Seam



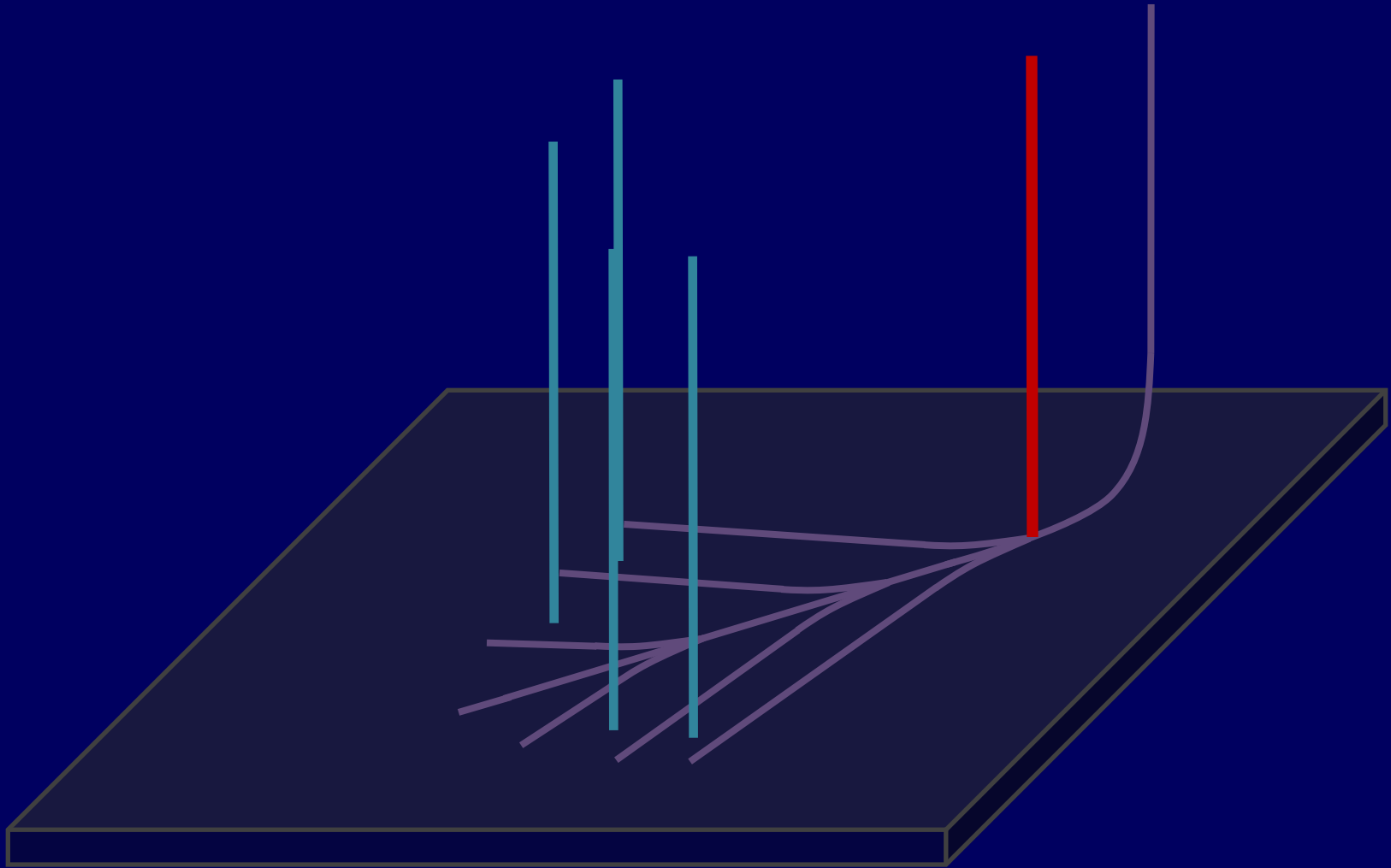
Note: Favorable Cleat Development



MLD Well Drilling



Modeled Wellbore Orientations



Modeling Governing Equations

- Langmuir Isotherm Relationship

$$V(p) = \frac{V_L P}{P_L + P}$$

- Fick's Law of Diffusion

$$q_m = \frac{V_m}{\tau} [V - V(p)]$$

- Darcy's Law

$$q_s = \frac{-k}{\mu} \text{grad}(P)$$

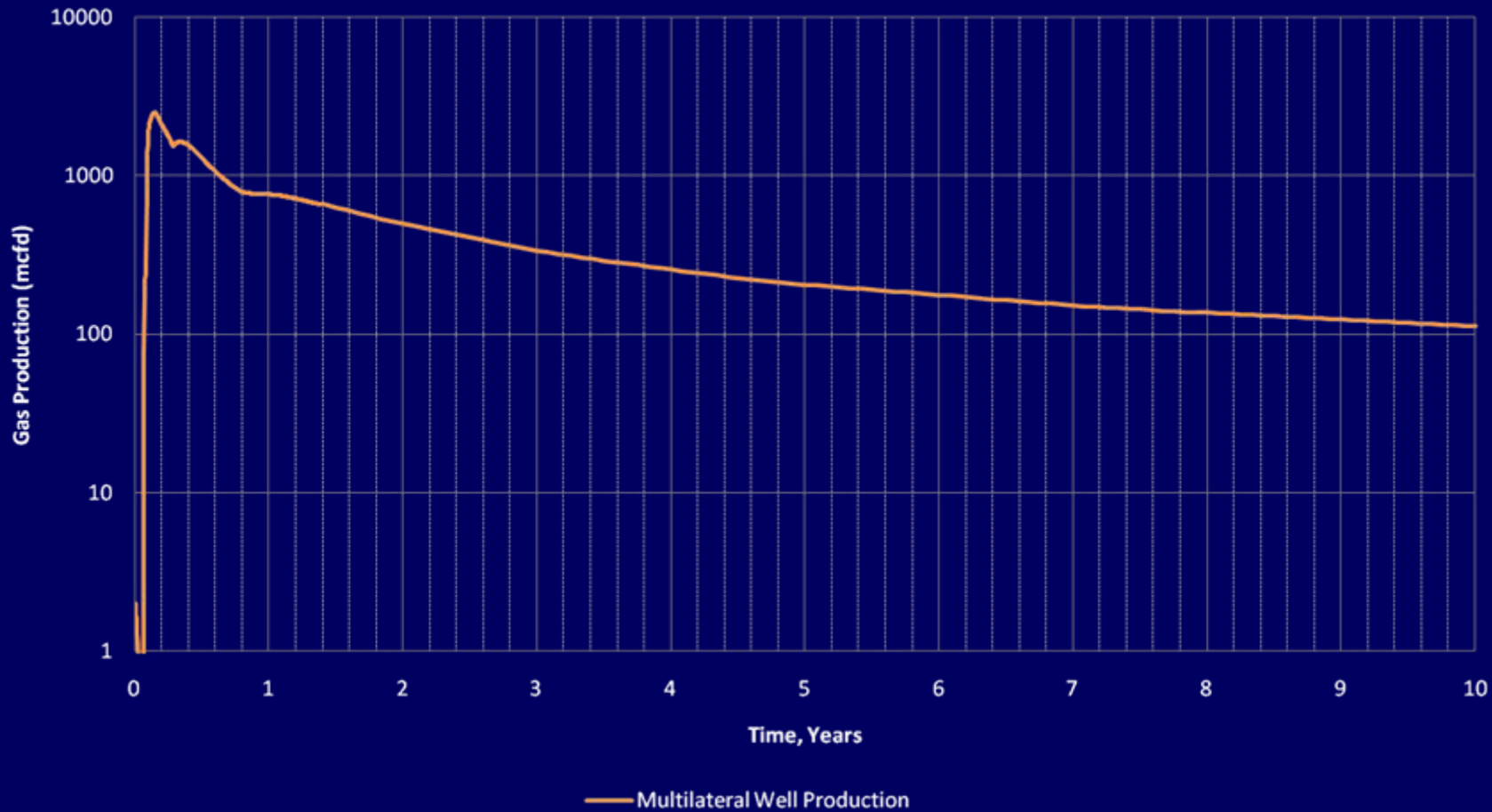
Modeling Inputs

Input Parameter	Value
Initial Water Saturation	100%
Initial Reservoir Pressure	550 psi
Initial Gas Content	500 cubic feet per ton
Cleat Porosity	3%
Cleat Spacing	2 inches
X Direction Permeability	3 md
Y Direction Permeability	1 md
Z Direction Permeability	3 md
Langmuir Pressure	290 psi
Langmuir Volume	1000 cubic feet per ton

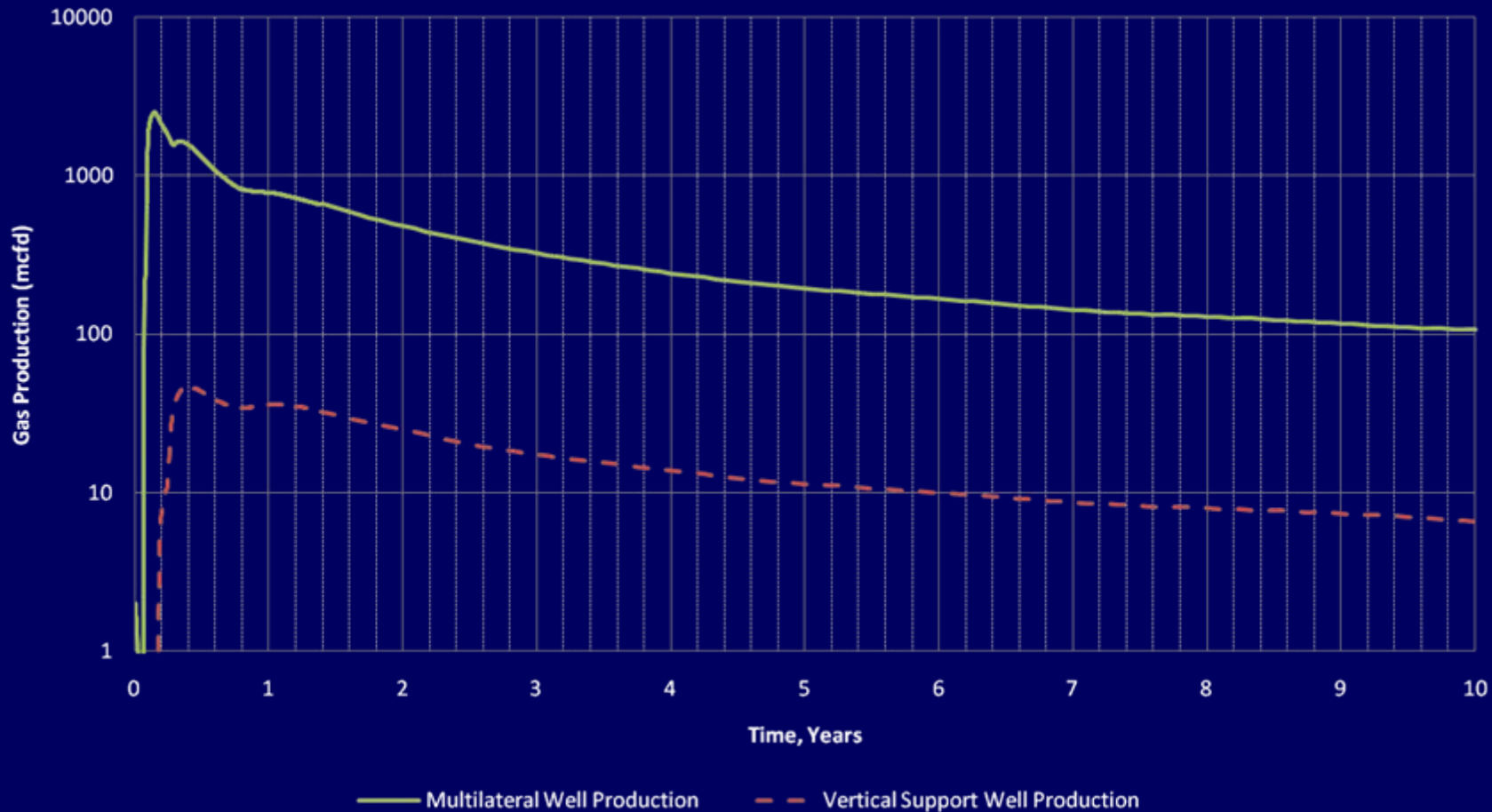
Modeling Calibration

- Assumes all wells (vertical and multilateral) can produce 250 barrels of water per day
- Once operating pressures reach atmospheric pressure, water production is reduced to maintain atmospheric operating pressure
- Skin Factors
 - Vertical Fracture Wells: -3.0
 - Multilateral Horizontal: +0.5

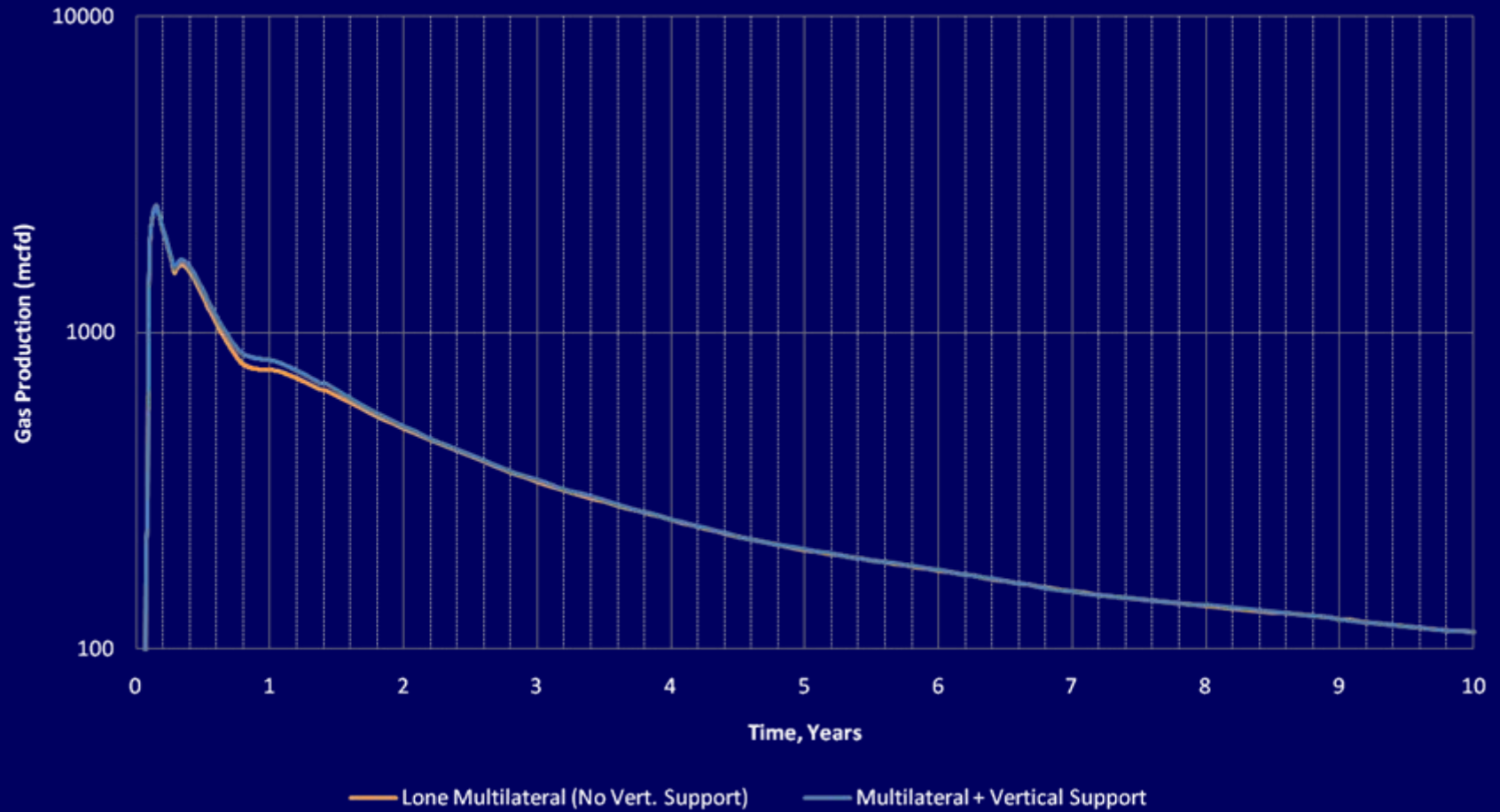
Daily Total Production Comparison - MLD Without Vertical Support



Daily Total Production Comparison – System of MLD and Vertical Support



Daily Total Production Comparison

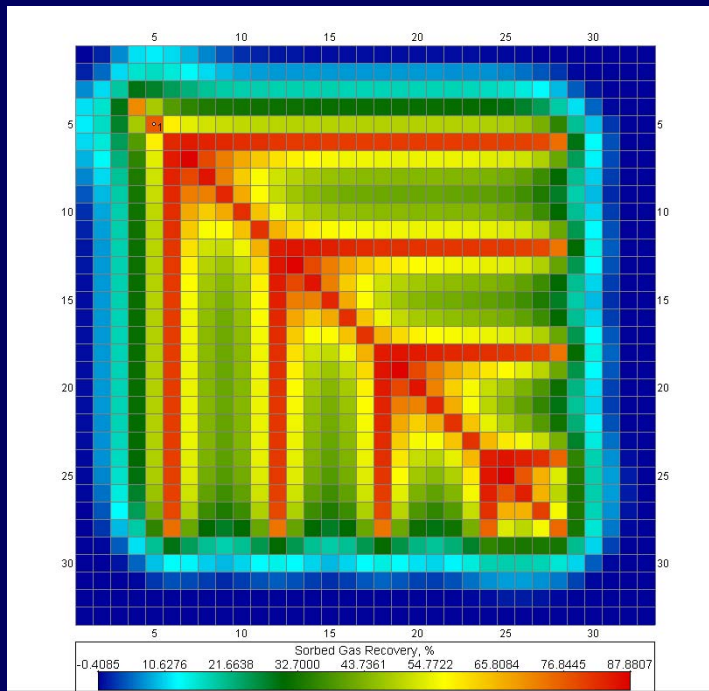


Analysis of Vertical Support Wells

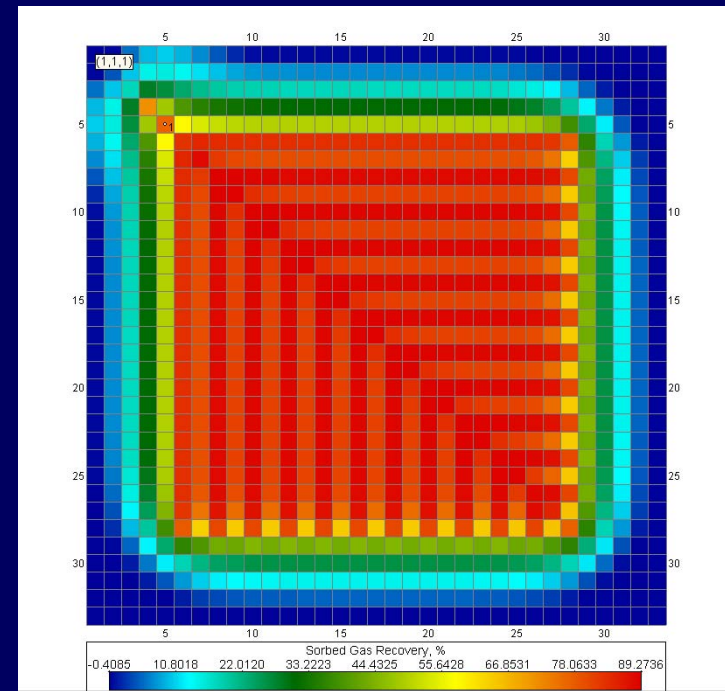
- Multilateral Wells Produce Large Volumes of Gas Without the Use of Vertical Support Wells
 - MLD Peak Rate—2.4 MMcfd
 - Vertical Peak Rate—50 Mcfd
- Vertical Support Wells Provide Negligible Additional CBM Production
 - Gas Drained by Vertical Support Wells is Easily Drained by MLD
- Economically, the Capital Expenditures from Vertical Support Wells Could be Better Used to Drill More Densely Spaced Multilateral Wells and/or Additional MLD Wells

Comparison of Recovery (2.0 md)

2.0 md, 600-ft spacing, 3
years

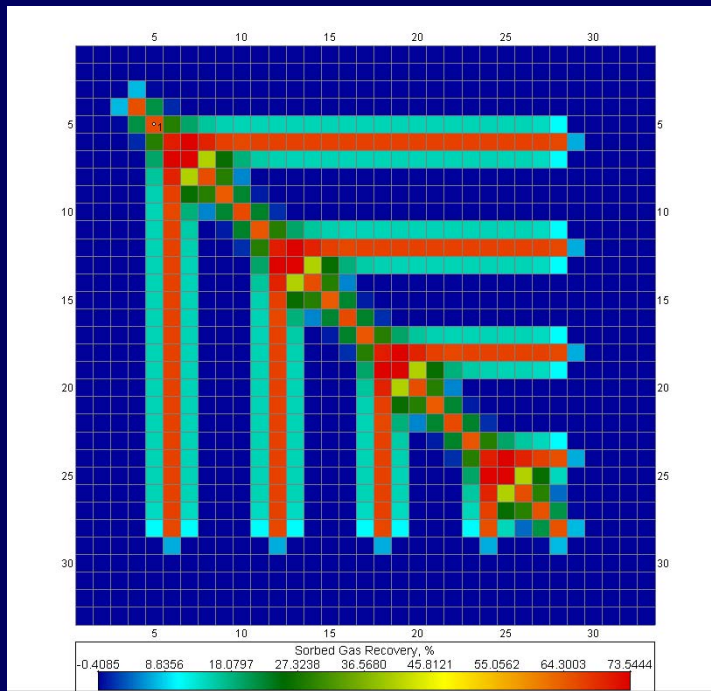


2.0 md, 200-ft spacing, 3
years

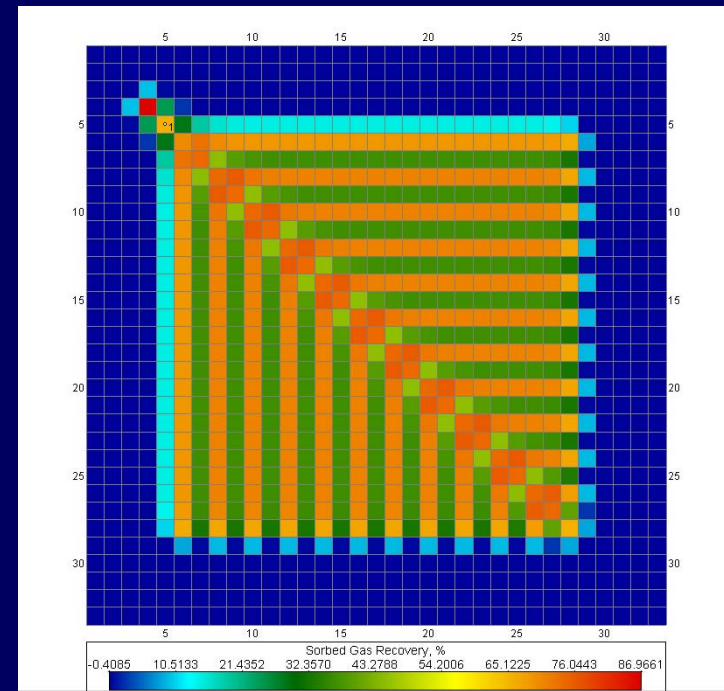


Comparison of Recovery (0.2 md)

0.2 md, 600-ft spacing, 3
years



0.2 md, 200-ft spacing, 3
years



Conclusions

- Vertical Support Wells Do Not Provide Sufficient Additional Production Compared to Closely Spaced Laterals
- Closely Spaced Laterals are Crucial for Optimal Recovery When Degasification Time is Short and/or Reservoir Permeability is Low
- Required Capital to Drill Additional Laterals is Low Relative to Other Capital
- In Gassy Reservoirs, Effective Pre-Mining Degasification Lowers Carbon Footprint and Improves Mine Safety

Acknowledgements

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