Concepts Used for Conducting CMM Resource Assessment in Frontier Areas

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August 30 – 31, 2010

Methane to Markets Partnership – Mongolia

CMM Project Development Workshop

Ulaanbaatar, Mongolia

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Presentation Outline

- Defining Terms: CMM Resources and Reserves
- Understanding the Occurrence of Gaseous Hydrocarbons in Coal
- Example CBM/CMM Resource Study: Texas Gulf Coast
- Hypothetical Resource Estimate for Mongolia Coal Deposit

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Defining Terms: CMM Resources and Reserves

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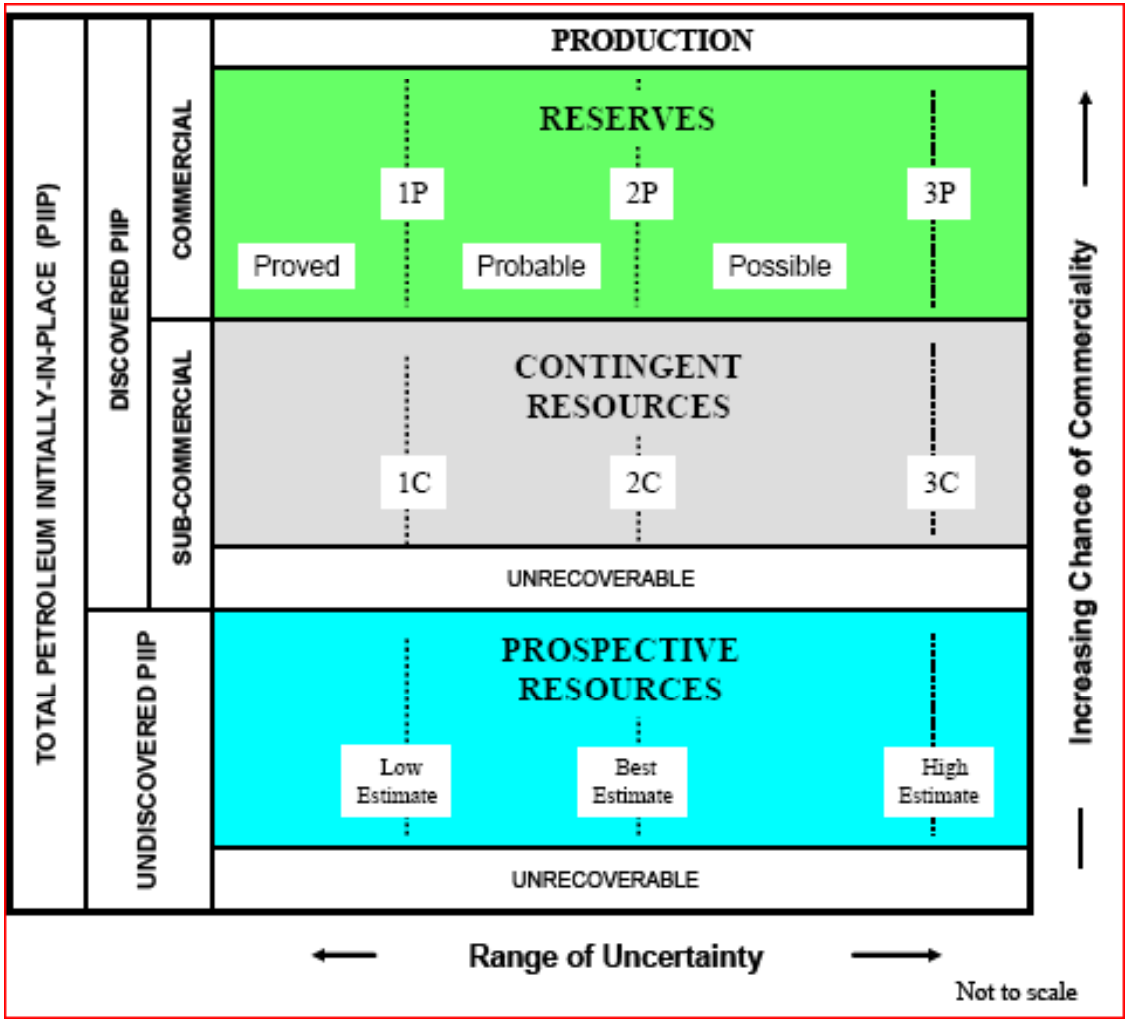
The Petroleum Resources Management System



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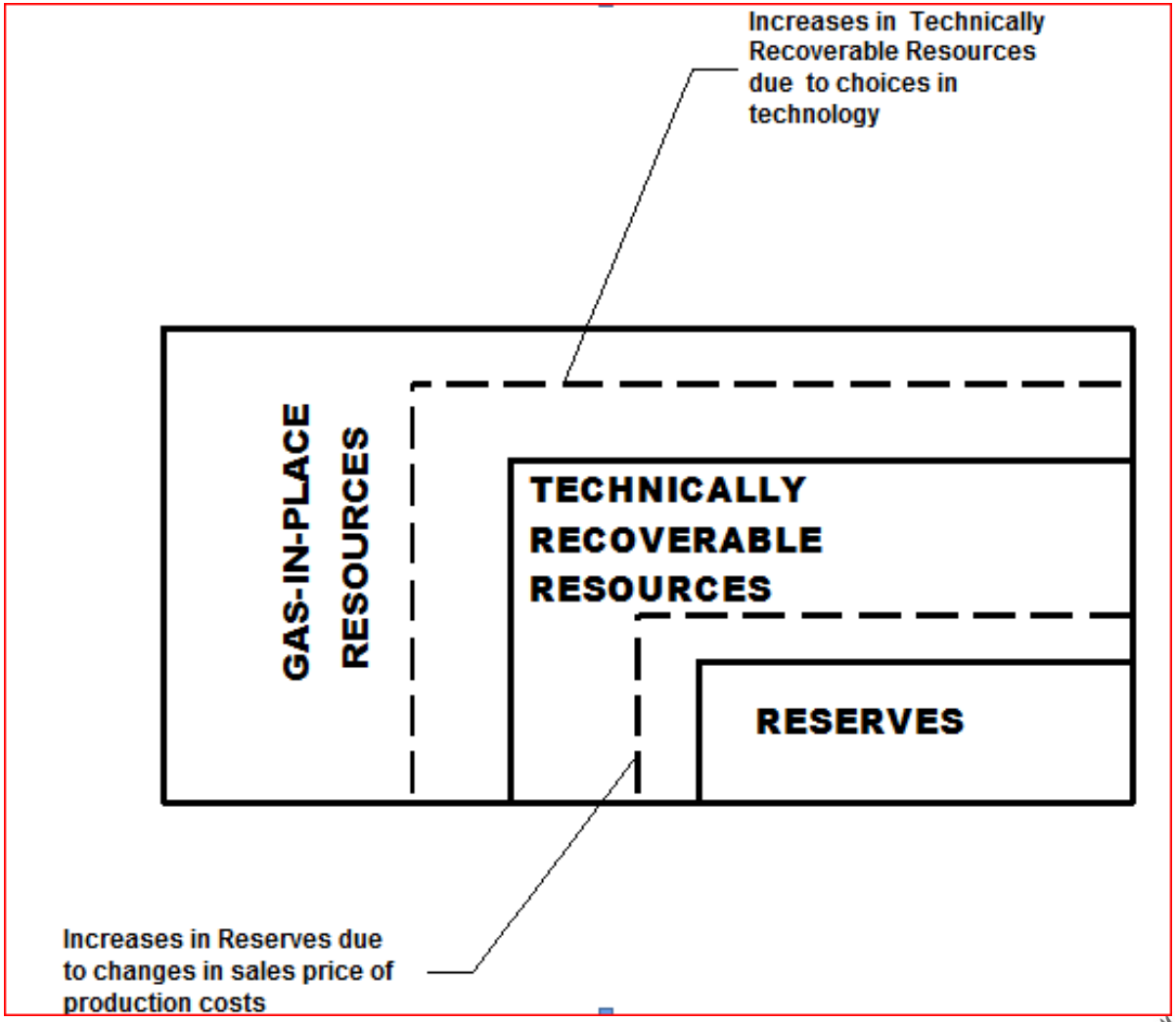
Converting Resources to Reserves



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Keys to Understanding Occurrence of Gaseous Hydrocarbons in Coal

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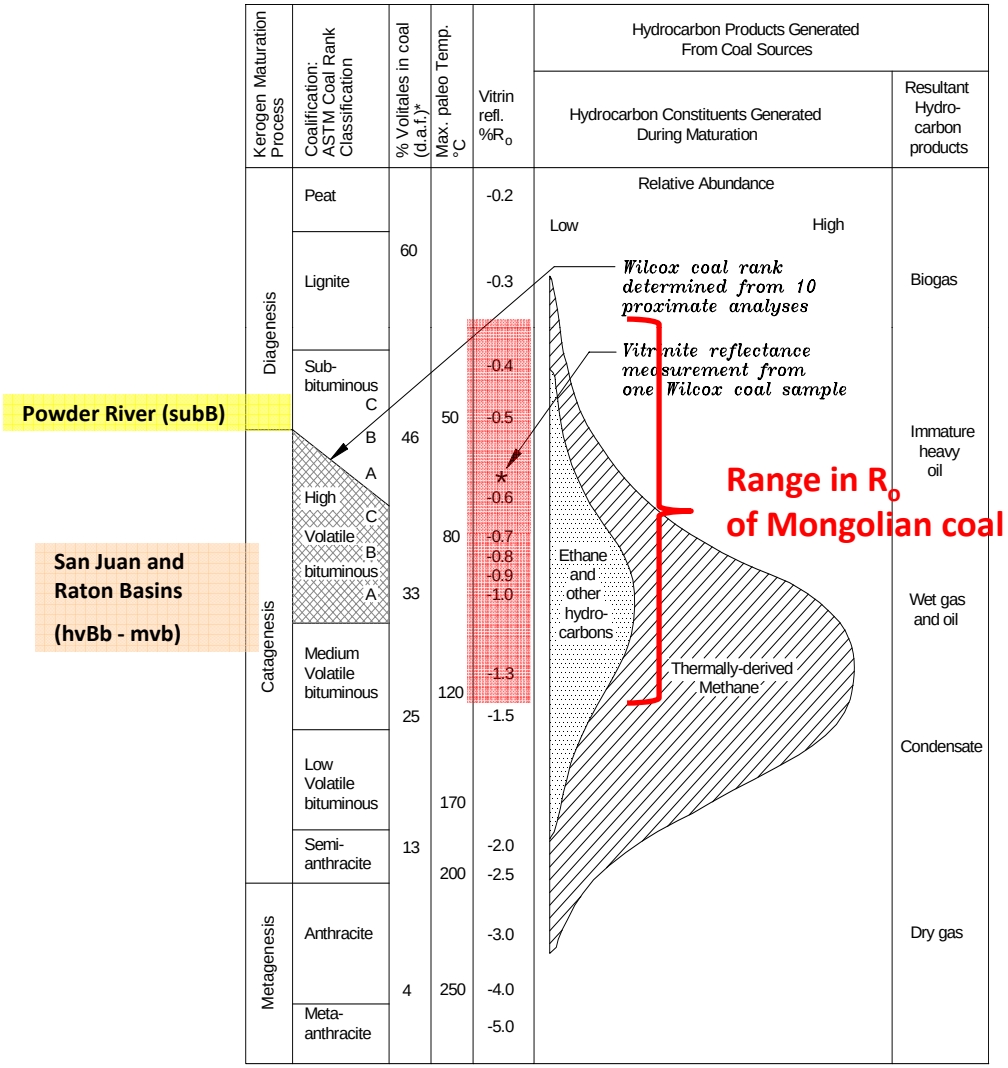
Coal Rank and Hydrocarbon Generation



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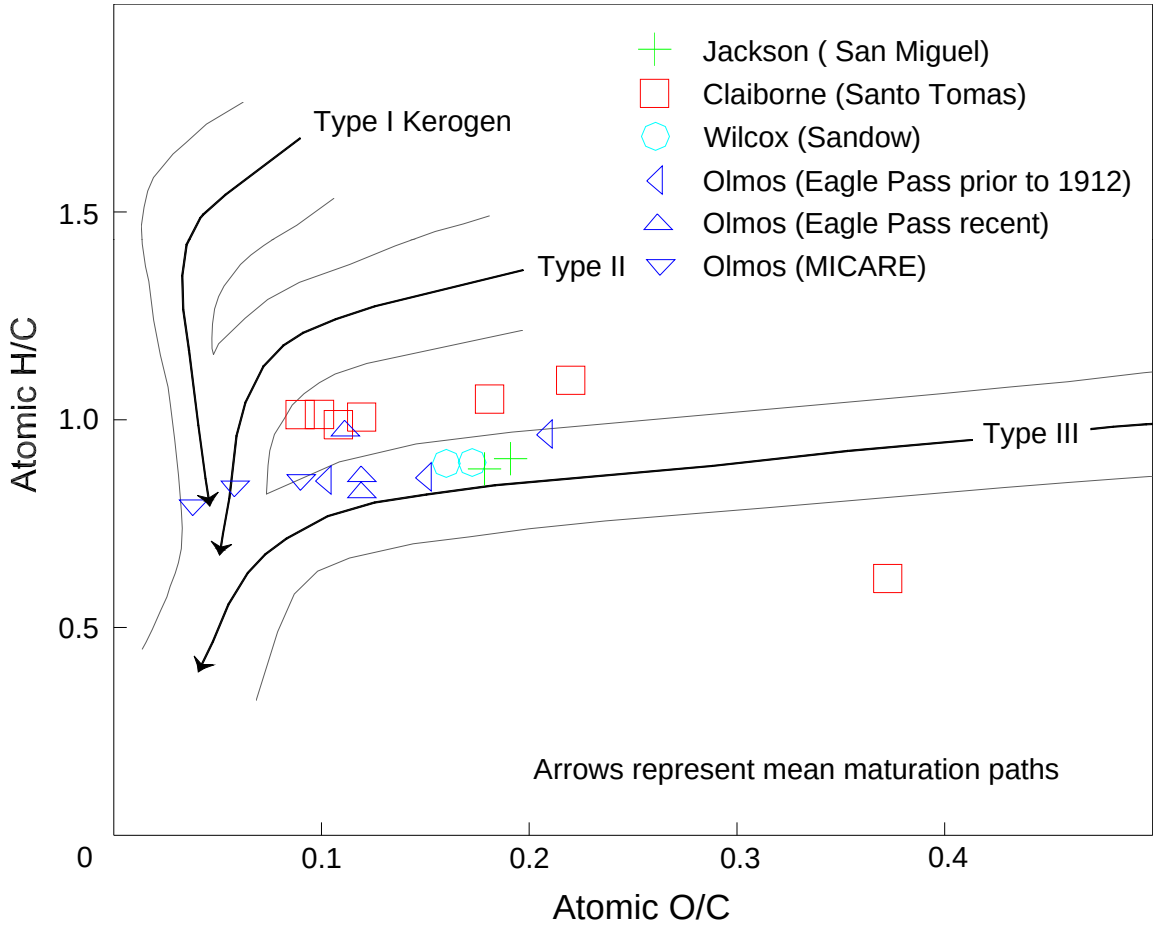
Van Krevelen-type diagram for various coal types of south Texas and vicinity



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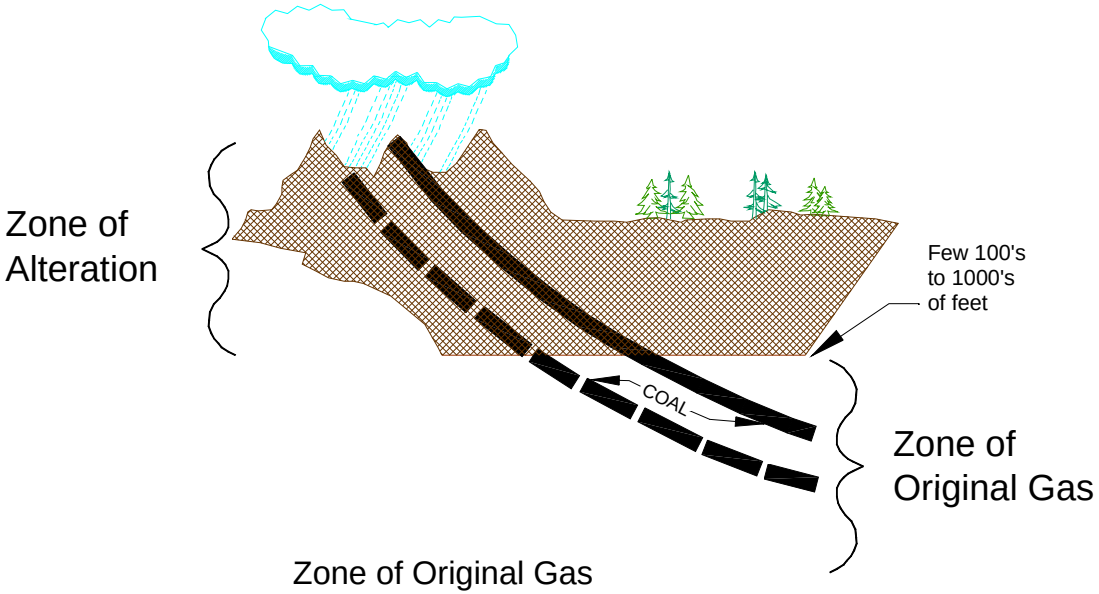
Model of Methane Occurrence and Enrichment in Coal

Zone of Alteration

- Dry gas with isotopically light methane
- Gas composition controlled by (1) mixing of biogenic methane and/or (2) oxidation of heavy gases
- Located in margins and shallow central parts of basins.



Zone of Original Gas

- Wetter gas with isotopically heavier methane
- Gas composition controlled by rank and composition of associated coal
- Located in deep and central parts of basins

After Rice, 1993

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Comparison of CBM Producing Basins in USA to Coal Basins in Mongolia

	San Juan	Raton	Powder River	Tavan-tolgoi	Nariin-sukhait	Nuurstk-hotgor
Coal Rank	hvBb-mvb	hvBb-mvb	subB	hvBb-mvB	hvBb	hvBb-c
Gas Content m^3/tonne	3-14	6-14	<3	?	?	?
Max. Coal Thk.	8-14m	<3.5m	30-50m	1-73m	1-54m	1-38m
Cum. Coal Thk.	13-20m	13-22m	75-105m	?	?	?
Sorption Time	>52 days	>8 days	>7 days	?	?	?
Depth of Completion	~800m	~650m	~150m	?	?	?

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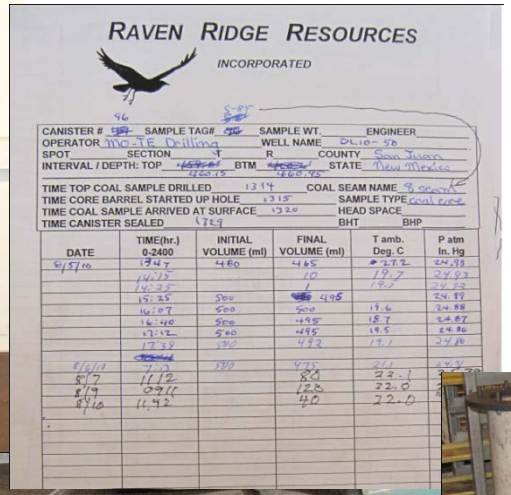
Desorption Testing



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CANISTER # 96 SAMPLE TAG# S-85 SAMPLE WT. ENGINEER
OPERATOR Nance Drilling WELL NAME DL10-62
SPOT SECTION T R COUNTY San Juan
INTERVAL / DEPTH: TOP 460.15 BTM 460.92 STATE New Mexico
TIME TOP COAL SAMPLE DRILLED 1314 COAL SEAM NAME B seam
TIME CORE BARREL STARTED UP HOLE 1315 SAMPLE TYPE coal core
TIME COAL SAMPLE ARRIVED AT SURFACE 1320 HEAD SPACE
TIME CANISTER SEALED 1329 BHT BHP

DATE	TIME(hr.) 0-2400	INITIAL VOLUME (ml)	FINAL VOLUME (ml)	T amb. Deg. C	P atm In. Hg
8/5/10	1314	480	465	27.2	24.98
	14:15		10	19.7	24.93
	14:23			19.7	24.93
	15:25	500	495		24.89
	16:07	500	500	19.6	24.88
	16:40	500	495	18.7	24.87
	17:12	500	495	19.5	24.86
	17:29	330	492	19.1	24.19
8/6/10	11:13	320	475	21.1	24.24
8/7	1112		84	22.1	
8/9	0911		128	22.0	
8/10	11:42		40	22.0	

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Example Desorption Report

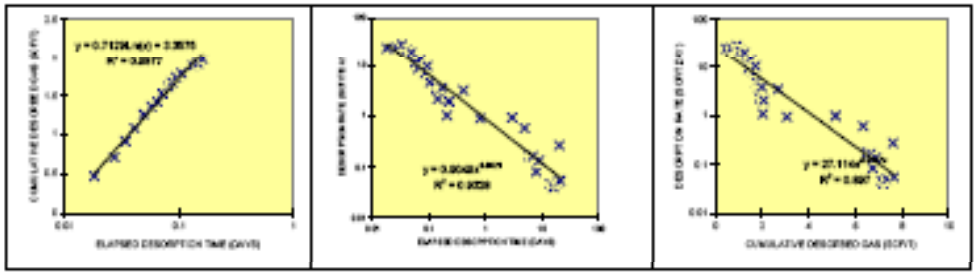
COAL GAS CONTENT	SMITH AND WILLIAMS METHOD (STP)	DECLINE CURVE METHOD (STP)
LOST GAS:	0.8 SCF/T	0.5 SCF/T
VOLUME CORRECTION:	1.105	1.057
RESIDUAL GAS (raw):	11.5 SCF/T	11.5 SCF/T
RESIDUAL GAS (%):	58.3%	59.2%
DESORBED GAS (raw):	8.2 SCF/T	7.9 SCF/T
TOTAL GAS (raw):	19.7 SCF/T	19.4 SCF/T
	0.62 cc/g	0.61 cc/g
RESIDUAL GAS (DAF):	14.0 SCF/T	14.0 SCF/T
DESORBED GAS (DAF):	10.0 SCF/T	9.7 SCF/T
TOTAL GAS (DAF):	24.0 SCF/T	23.7 SCF/T
	0.75 cc/g	0.74 cc/g

RAW MEASURED DATA	
TOTAL RESIDUAL GAS (STP):	625.0 cc
TOTAL DESORBED GAS:	408.0 cc
RAW SAMPLE WEIGHT:	1740.0 g
DAF SAMPLE WEIGHT:	1429.8 g
RAW SURFACE CONDITIONS:	19.0 CF/T
	0.59 cc/g
RAW STP CONDITIONS:	19.7 SCF/T
	0.62 cc/g
CANISTER HEAD SPACE:	1060 cc

TIME COAL SEAM PENETRATED:	8 : 50	17-Sep-08
TIME COAL ARRIVED AT SURFACE:	9 : 04	17-Sep-08
TIME CANISTER SEALED:	9 : 16	17-Sep-08

PROXIMATE ANALYSIS	
% MOISTURE:	5.15
% ASH:	12.68
% VOLATILE:	35.84
% FIXED CARBON:	46.33
TOTAL %:	100.00
HEAT VALUE (BTU/lb):	11532
% SULFUR:	0.65
APP. SPECIFIC GRAVITY:	

Td:	14.00 minutes
Ts:	26.00 minutes
T25%:	207.67 minutes
SURFACE TIME RATIO:	0.46
LOST TIME RATIO:	0.13



T25% = time from seam penetration to the time when 25% of the measured volume has desorbed

Td = time from seam penetration to sample surfacing

Ts = time from seam penetration to container sealing

COMMENTS:

SURFACE TIME RATIO = (Ts - Td)/Ts

LOST TIME RATIO = Ts/T25%

STP = 15 degrees C and 29.92 in. Hg

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Example Adsorption Report

Sample Weight = 104.43 g
Particle Size = < 20 Mesh
Temperature = 78.8°F (26.0°C)

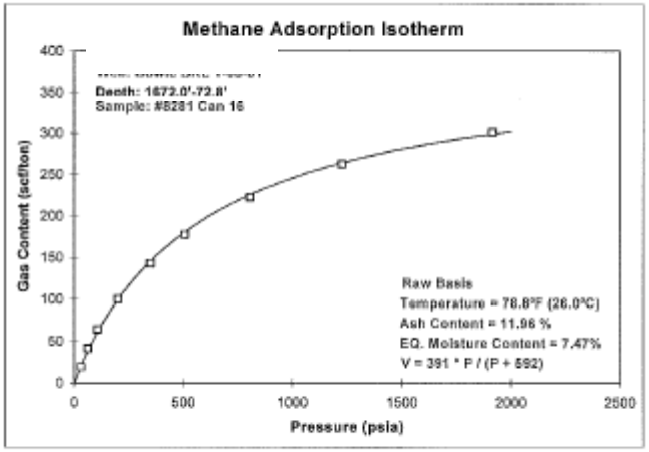
Ash Content = 11.96 %
EQ. Moisture Content = 7.47%

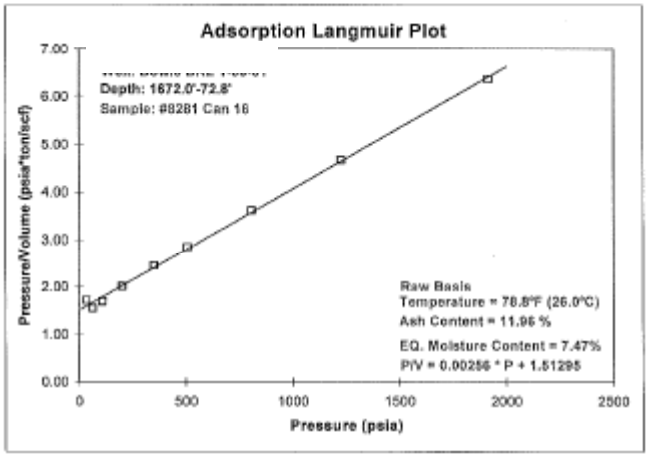
Methane Adsorption

Pressure		Gas Content (Raw Basis)	
(psia)	(MPa)	(scf/ton)	(scc/gm)
33	0.23	19.2	0.60
64	0.44	41.1	1.28
108	0.74	63.8	1.99
202	1.39	100.4	3.13
350	2.41	142.9	4.46
507	3.50	177.5	5.54
807	5.56	222.6	6.95
1,226	8.45	262.4	8.19
1,916	13.21	301.0	9.40

Langmuir Coefficients **V = 391.1 * P / (P + 591.7)**

PL		VL (Raw Basis)	
(psia)	(MPa)	(scf/ton)	(scc/gm)
591.7	4.08	391.1	12.2





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Adsorption Laboratory

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Data Required for CMM/CBM Resource Study:

Data-type and associated uncertainty

- Coal thickness data- continuous, variable with gaps caused by sparse data -- often modeled which may obscure uncertainty
- Coal Quality data- variability related to geologic setting and sampling density
- Depth and area of occurrence- function of geologic setting and sampling density
- Variation in data density- required for evaluation of resource class -- subjective to some extent
- Sorption data- desorbed gas content can be highly variable determined by coal type and geologic setting, may be necessary to model gas potential based on adsorption isotherm

CMM Resource Assessment Approaches

- Usually a volumetric calculation:
  - multiply mass of coal (tonnes) by gas content (cubic meters of methane per ton of coal) = volume of gas in place (equivalent to PIIP)
- Two accepted approaches to calculate estimate:
  - Use low, high, and mid range single values for all parameters; result is a resource estimate ranging from low to high forecasts
  - Stochastic estimate using probability functions developed for each parameter yielding a probabilistic forecast of resources

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Example CBM/CMM Resource Study: Texas Gulf Coast

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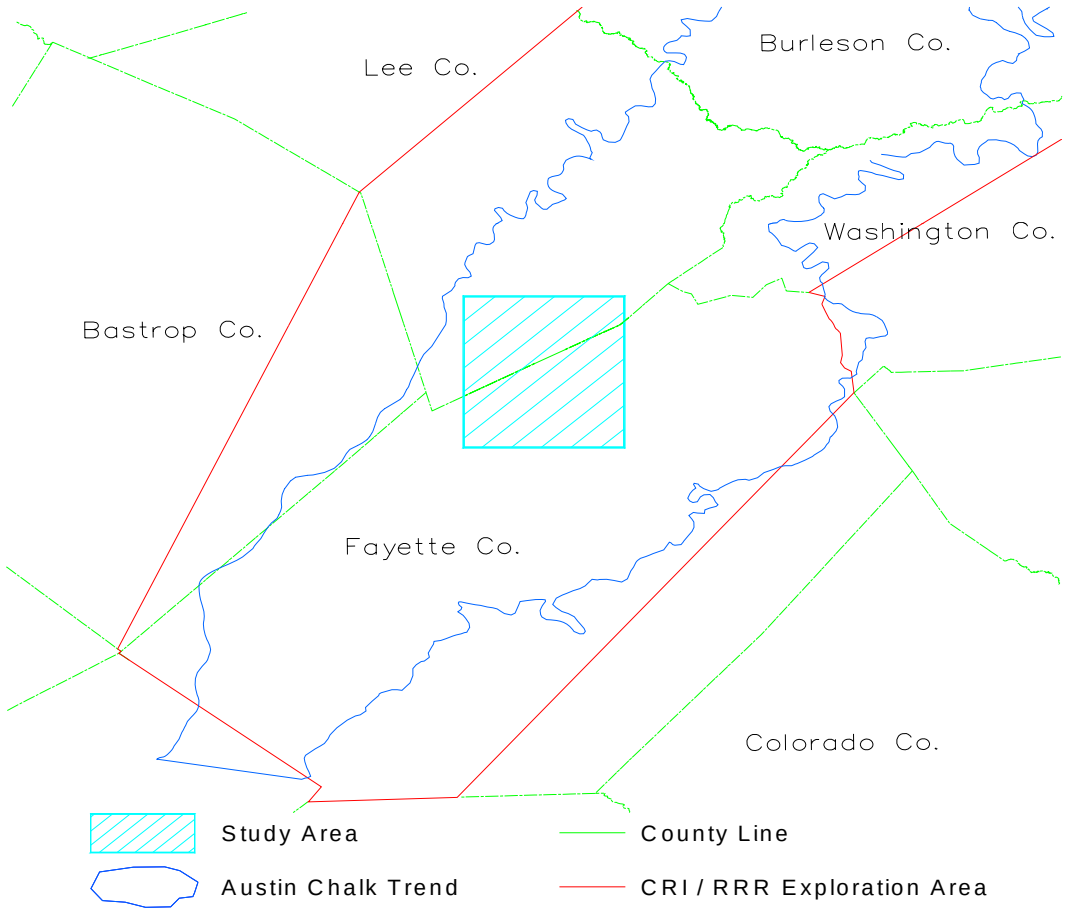
Location of Initial Study Area



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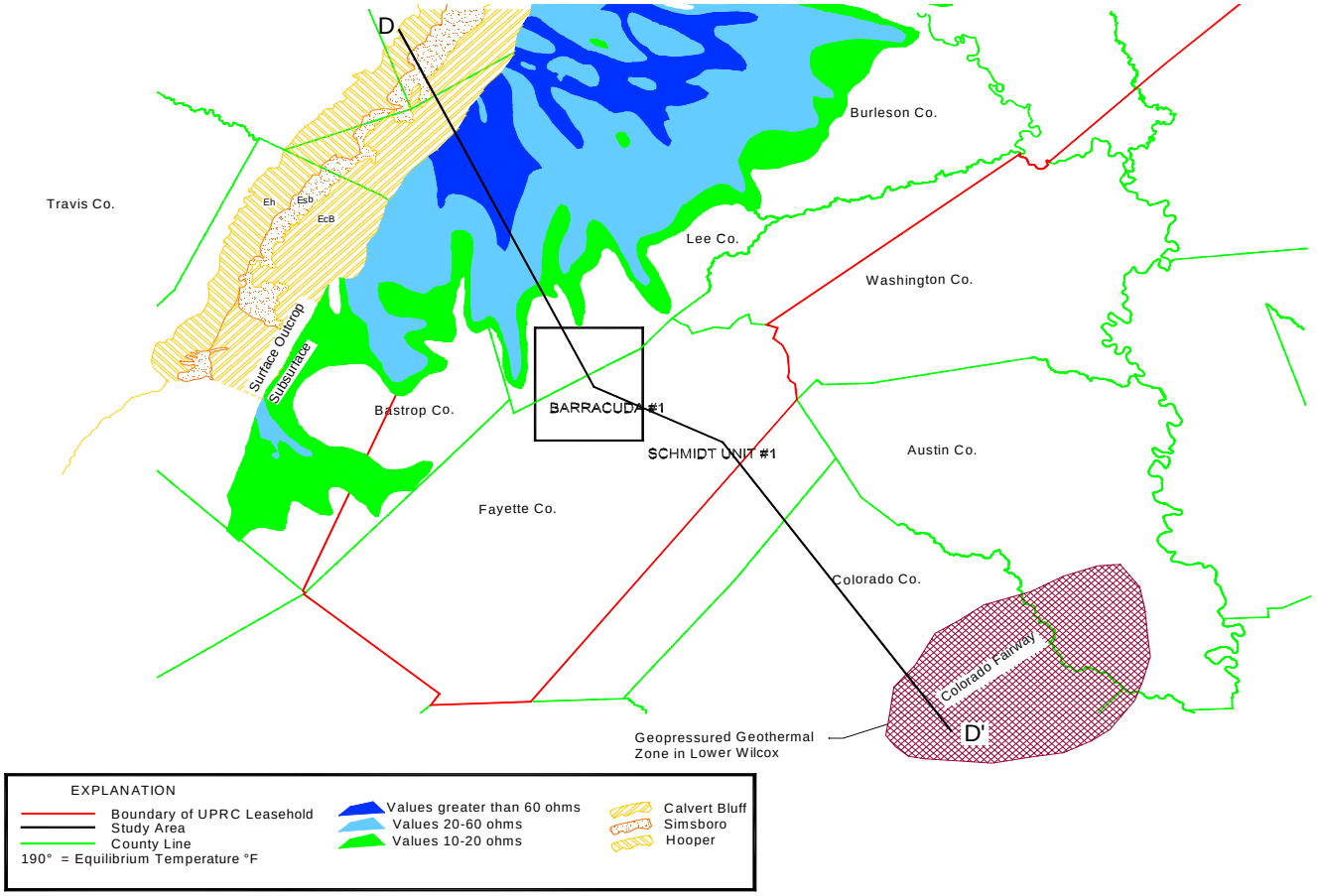
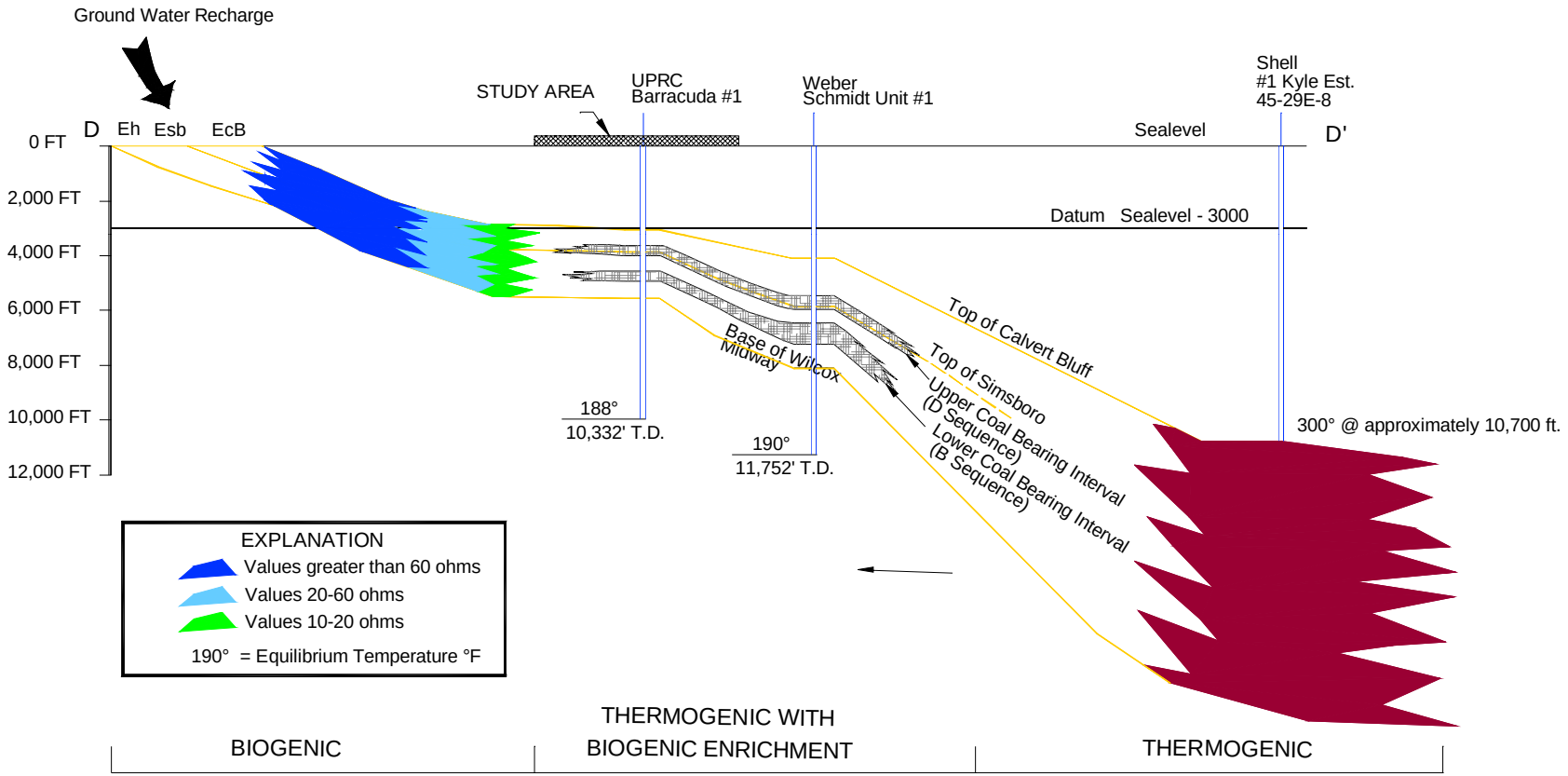
Model for Methane Generation in Upper Texas Gulf Coast Wilcox Coals



Model for Methane Generation in Upper Texas Gulf Coast



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Comparison of CBM Producing Basins

	San Juan	Raton	Powder River	Upper Texas Gulf Coast
Coal Rank	hvBb-mvb	hvBb-mvb	subB	subB-hvAb
Gas Content scm/ton	3-16	6-16	< 4	3-15
Max. Coal Thk.	7-12 m.	< 3 m.	30-46 m.	6-12 m.
Cum. Coal Thk.	12-18 m.	12-21m.	75-106 m.	3-33 m.*
Sorption Time	>52 days	>8 days	>7 days	<10 days*
Depth of Completion	~787 m.	~650 m.	~150 m.	~750 – 1800 m.

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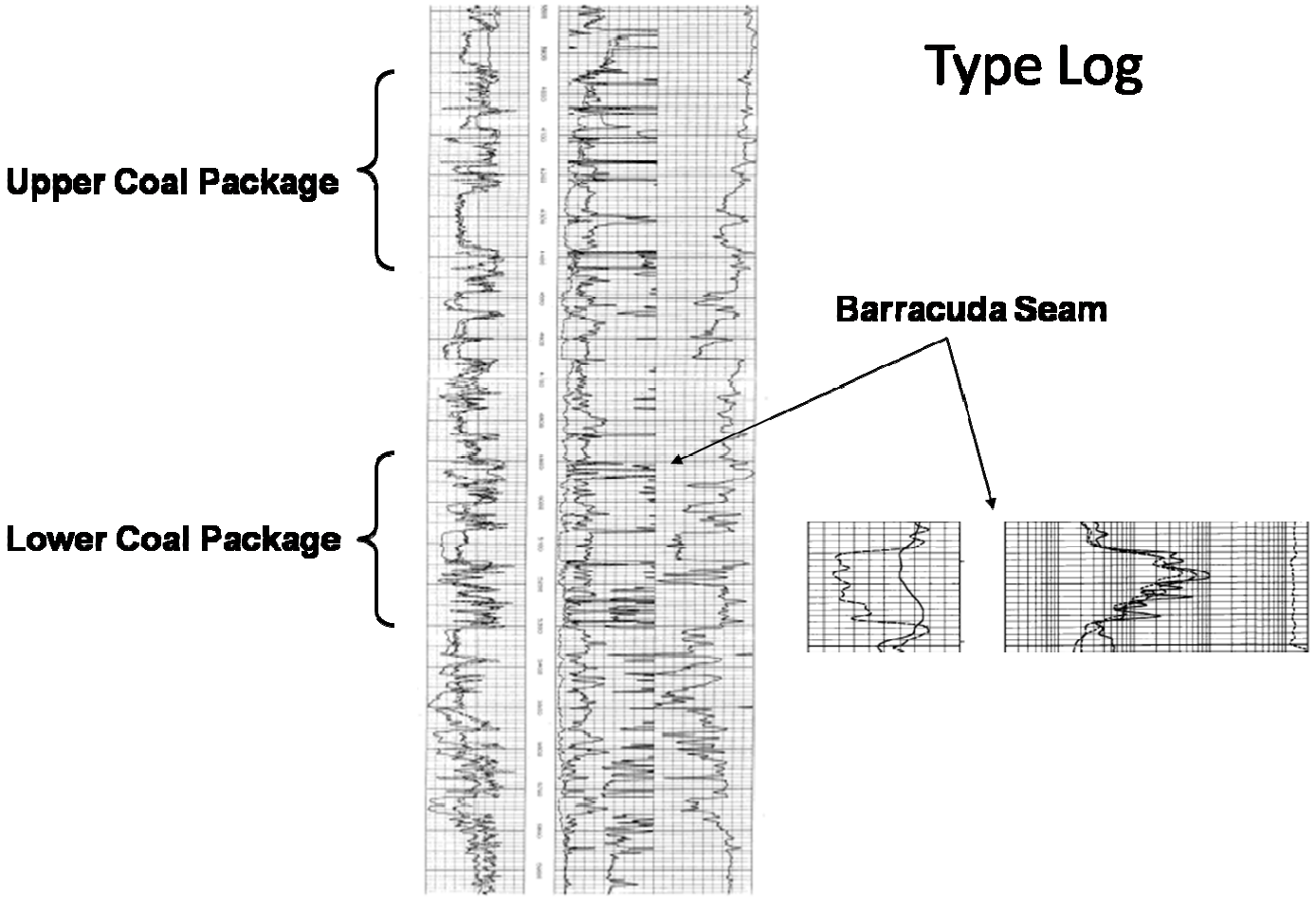
Type Log Showing Primary Objective



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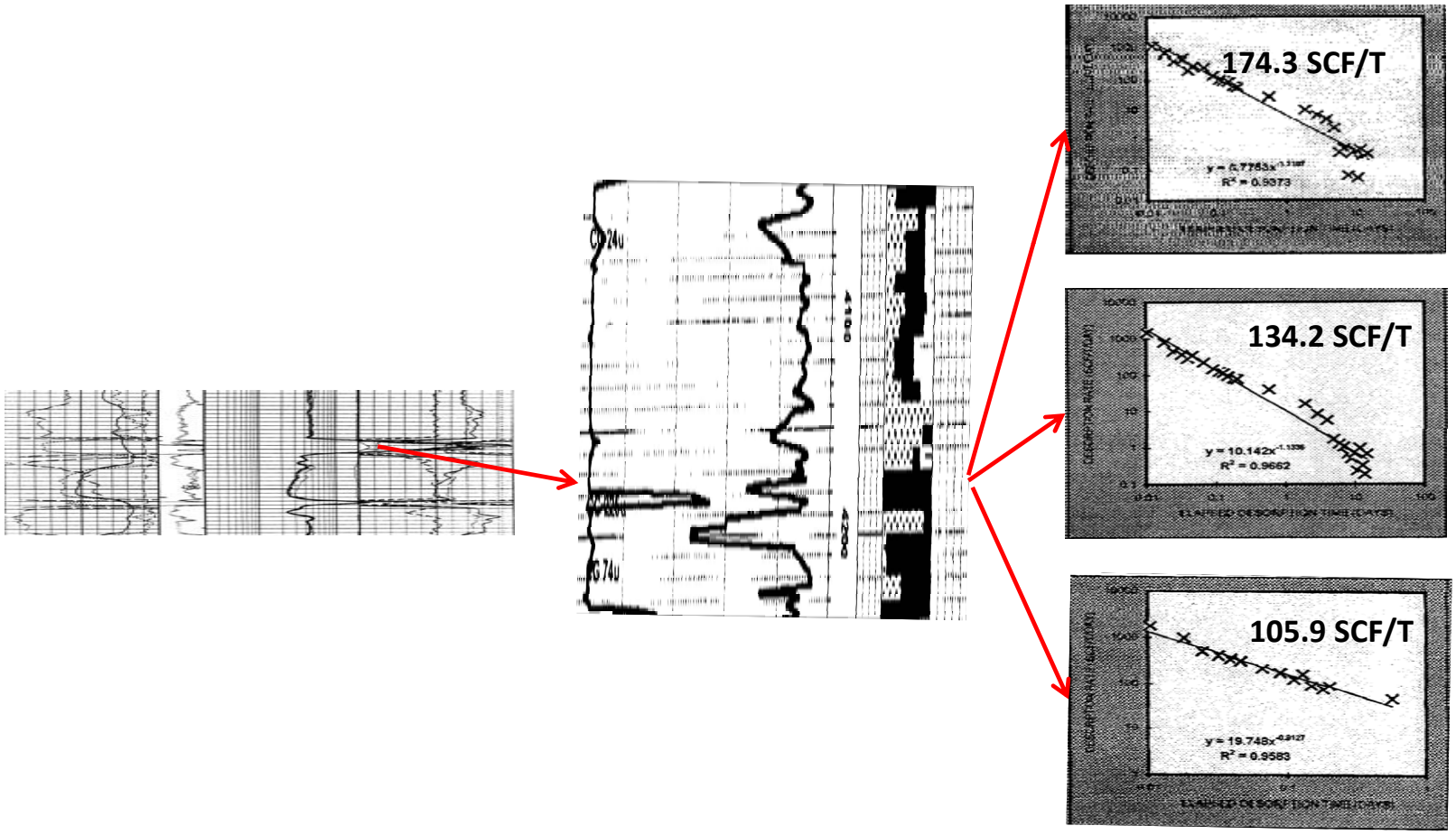
Gas Content Variation Within A Single Coal Seam



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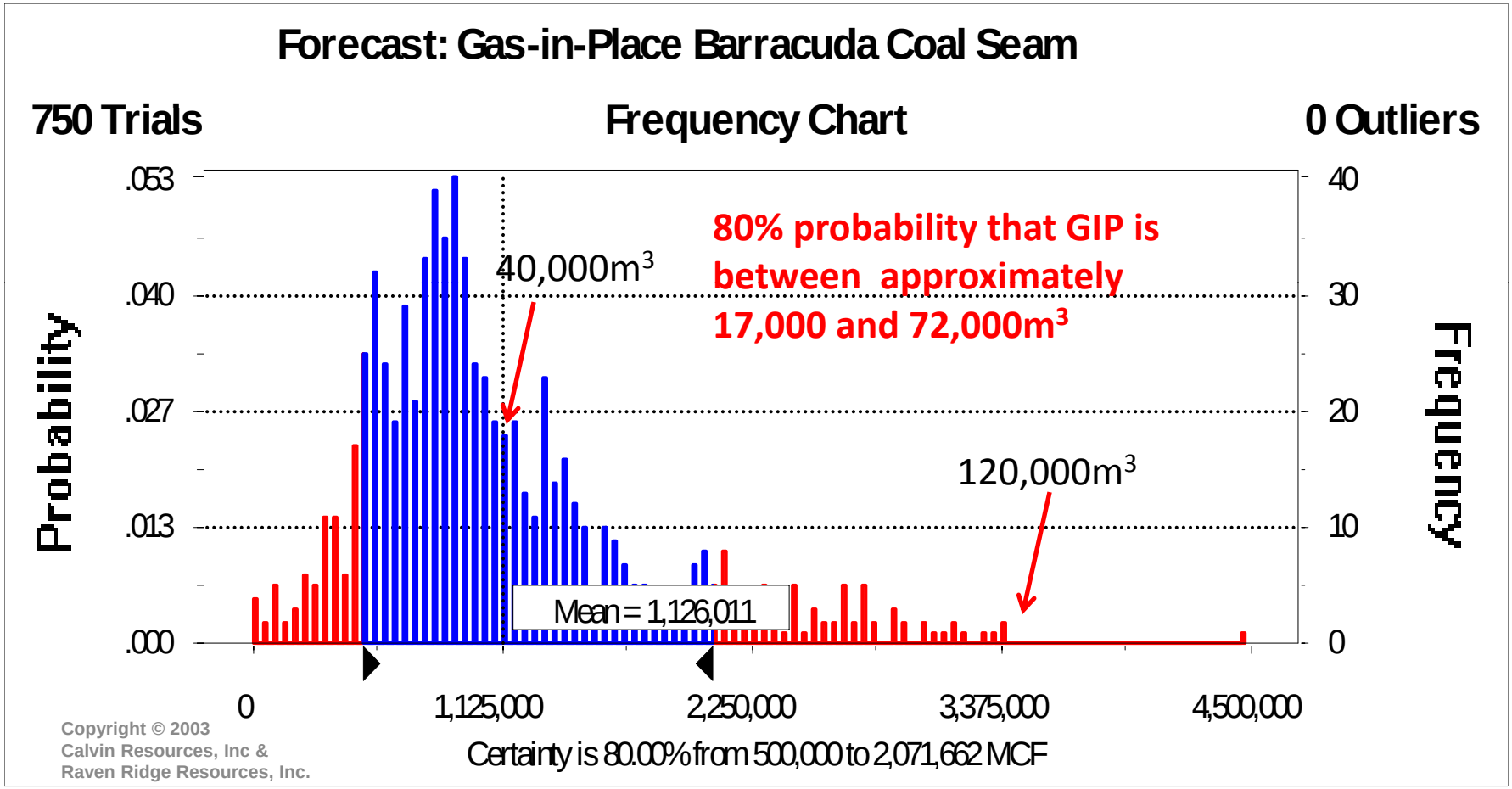
Resource Model:Barracuda Seam



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CBM Resource Model for Barracuda Coal Seam and Cumulative Coal Thickness

- Developed Probability Frequency Distributions Based on Available Data for:
  - Gas Content of Coals (conservative)
  - Specific Gravity of Coal
  - Coal Thickness
- Assumed 64 hectare well spacing
- Forecasted Frequency of Occurrence of EUR's of Proposed Wells by Size Class

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Summary of Barracuda CBM Resource Base

- 28,283 Acres Mapped (11,466 hectares)
- Avg. Coal Thickness 15.3 Ft (4.6m)
- Avg. Gas Content 214.6 scf/ton (6.7 m^3/ton)
- Maximum Gas Content of 470 scf/ton (14.7 m^3/ton)
- 80% Probability of 0.5 to 2 BCF Gas in Place Per 160 Ac. Unit (14.16Mm^3 to 56.63Mm^3 per 64 hectares)
- Avg. Gas In Place 1,143,548 MCF Per 160 Ac. Unit (32.38 Mm^3 per 64 hectares)

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Hypothetical Resource Estimate for Mongolia Coal Deposit

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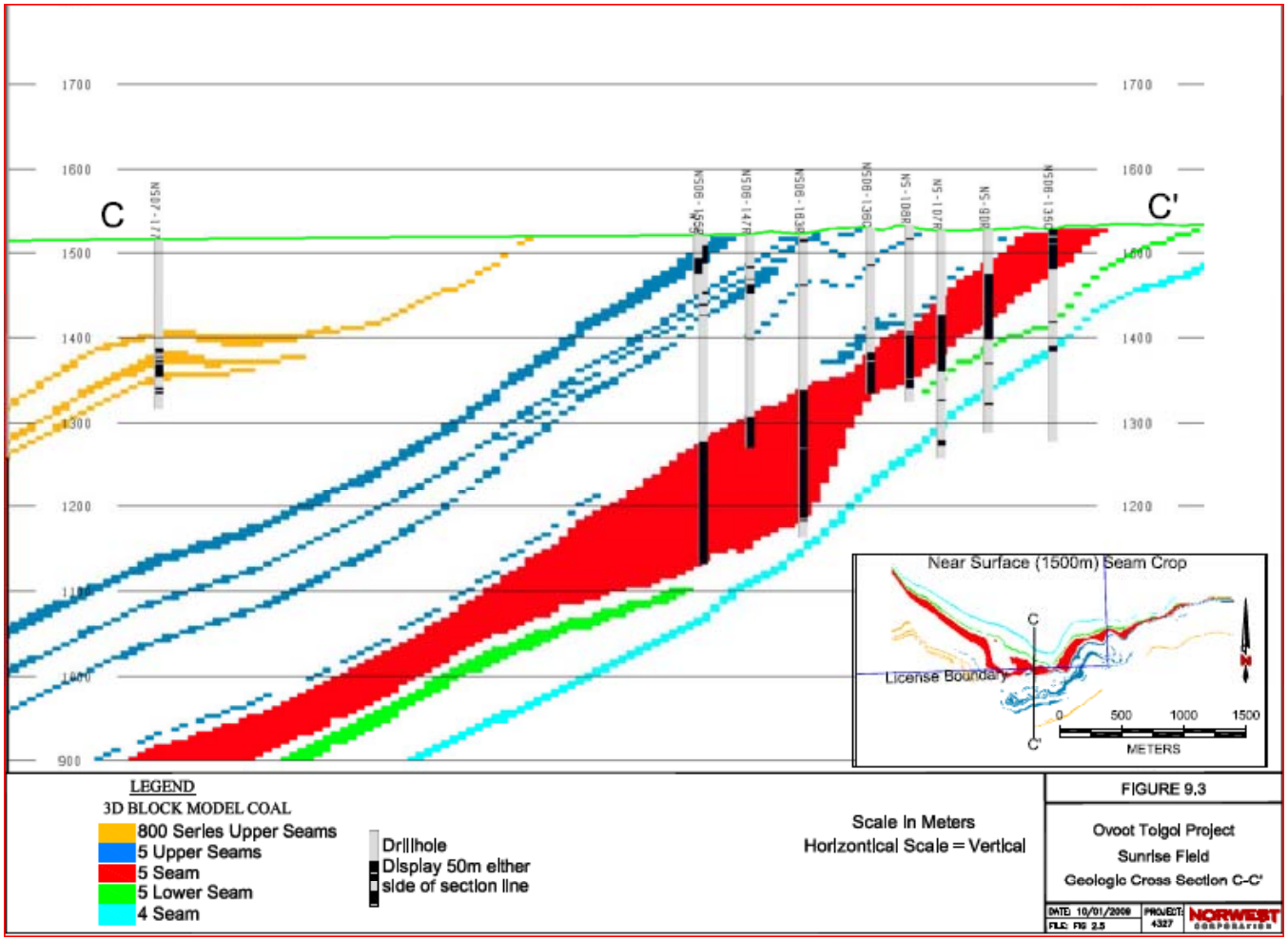
Cross-section through part of Ovoot Tolgoi hvB-hvA Coal Deposit



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Thickness of Seams Ocurring in Ovoot Tolgoi Deposit

Property	Series	No Seams	Minimum Thickness* (m)	Maximum Thickness* (m)	Mean Thickness* (m)
Sunrise Field	Upper Seams	11	0.6	74	10
	5 Main	1	0.9	157	53
	5 Lower	1	0.6	100	16
	4 Main	1	1.0	30	8
Sunset Field	Upper Seams	60	0.6	31	7
	5 Main & Lower	2	0.6	142	39

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In- Place Coal Resources Delineated by 430 Boreholes Drilled from 2006 through 2009

Area	Type	Resource Limits Depth (m)	ASTM Group	In-Place Resources (Million Tonnes)		
				Measured	Indicated	Inferred
Sunrise Field	Surface	Surface to 250m	hvB to hvA	53.8	15.7	4.9
Sunset Field	Surface	Surface to 250m	hvB to hvA	82.1	19.4	8.1
Sub-Total				**135.9**	**35.1**	**13.0**
Sunrise Field	Underground	250m to 600m	hvB to hvA	11.2	5.2	11.2
Sunset Field	Underground	250m to 600m	mhB to hvA	34.6	27.8	9.3
Sub-Total				**45.8**	**33.0**	**20.5**
Total				**181.7**	**68.1**	**33.5**

Resources estimated using cross-section method

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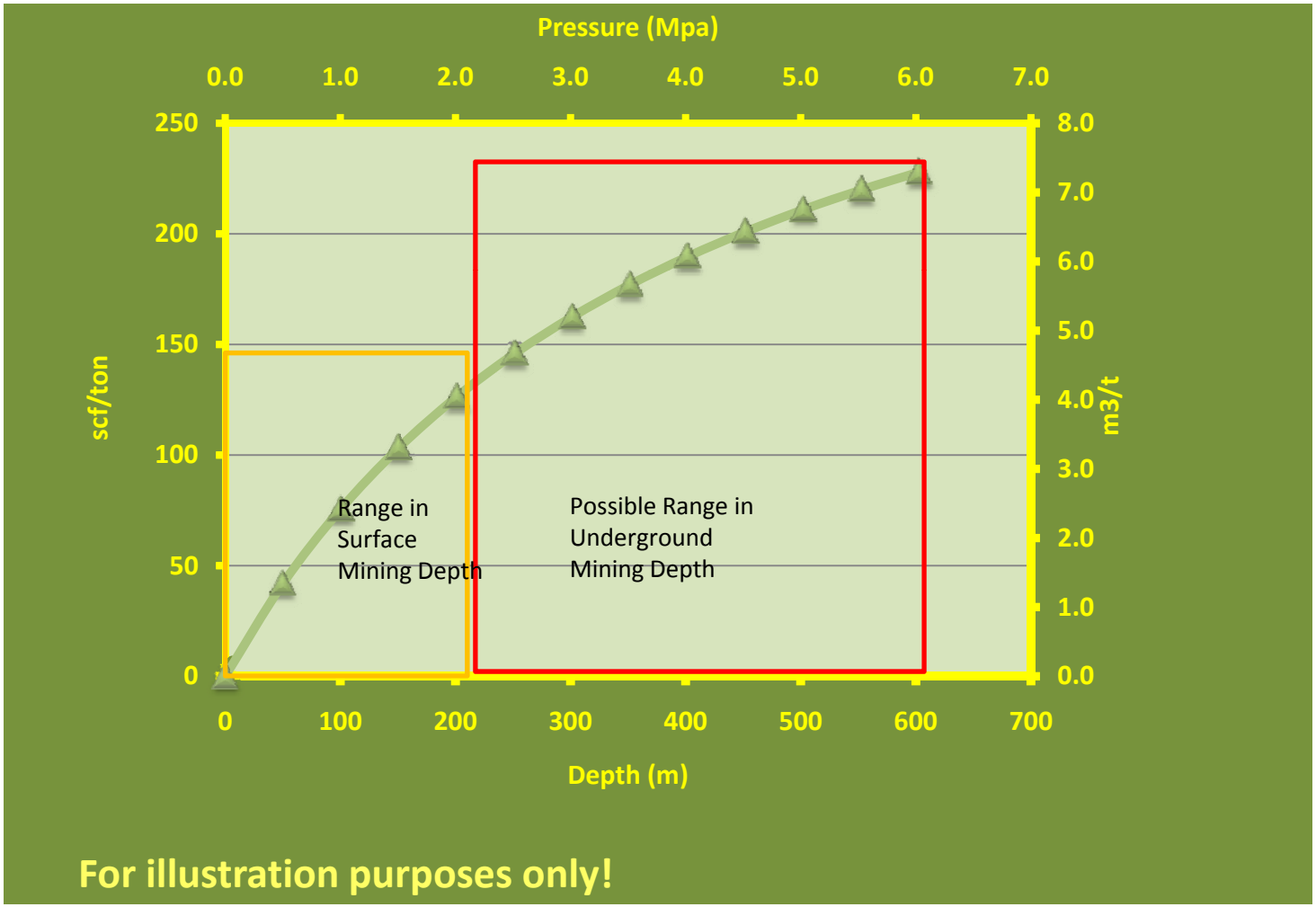
Hypothetical Isotherm for hvB-hvA Coal Rank



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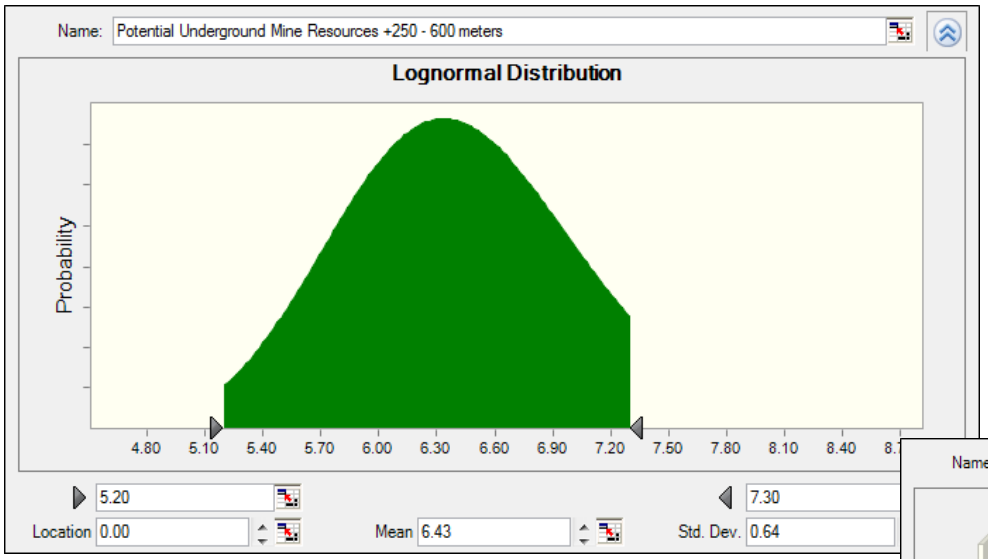
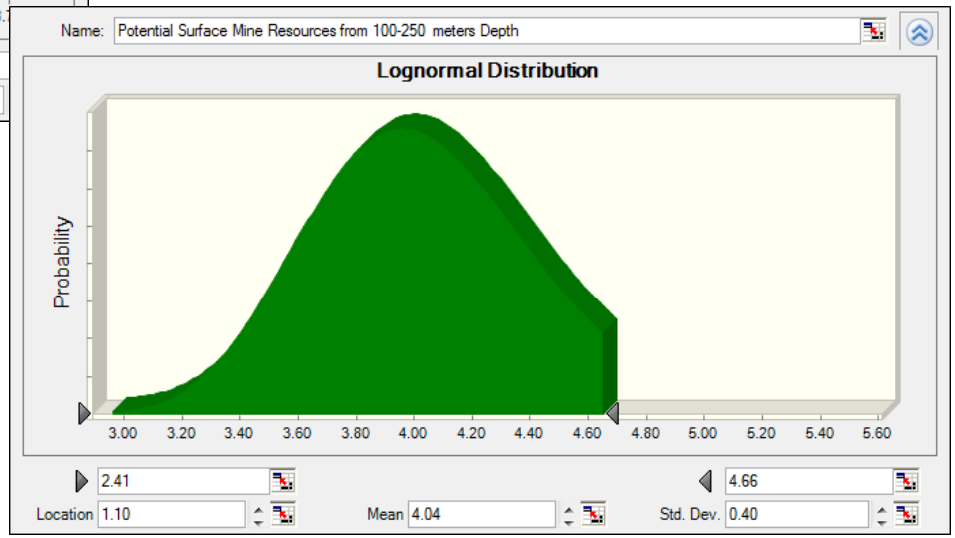
Hypothetical Gas Content Probability Distributions for Ovoot Tolgoi Coal Resources





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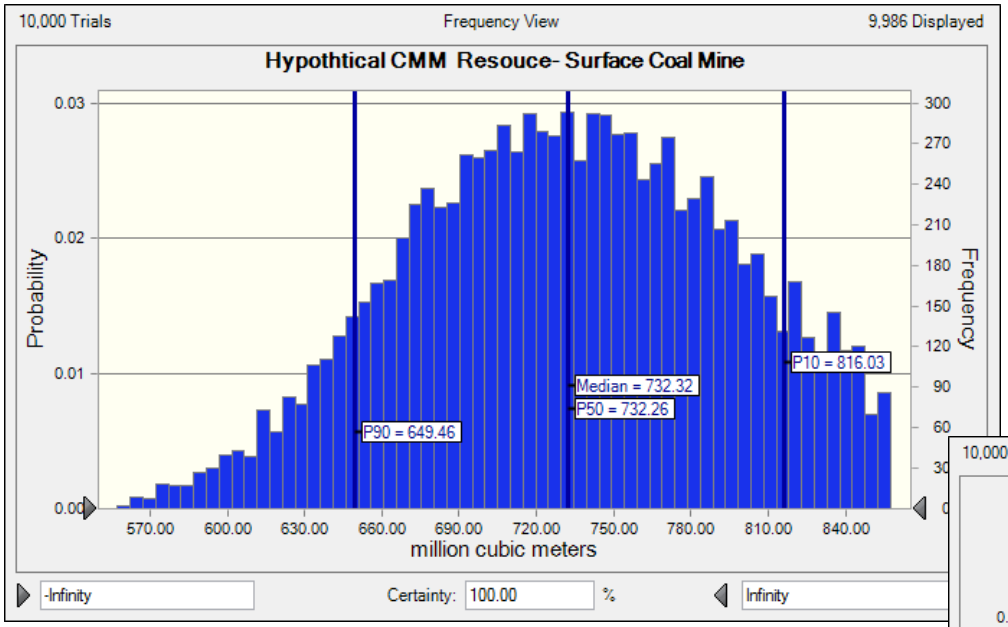
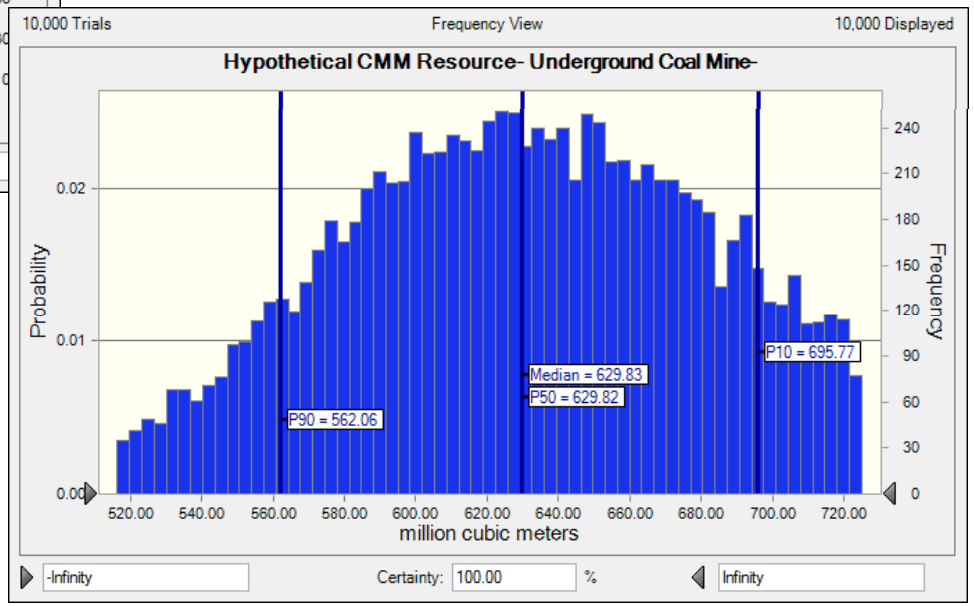
Hypothetical CMM Resources of Ovoot Tolgoi Coal Deposit



Potential Surface Coal Mine CMM Resource Estimate (million cubic meters)		
P_{90}	P_{50}	P_{10}
649	732	816



Potential Underground Coal Mine CMM Resource Estimate (million cubic meters)		
P_{90}	P_{50}	P_{10}
562	630	696

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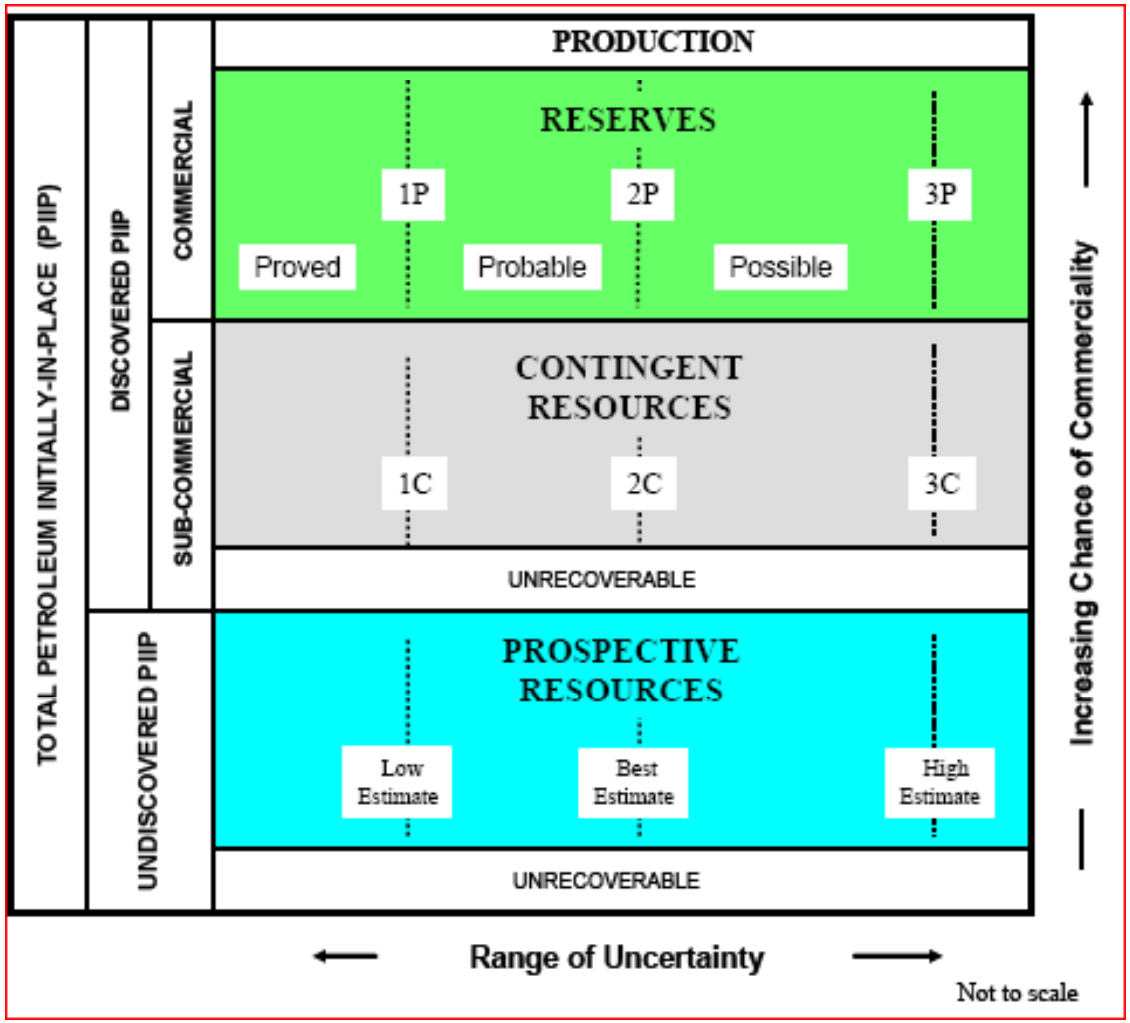
The Petroleum Resources Management System (review)



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Thanks!

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