Coal Seam Horizontal Drilling and Wellbore Design for Underground Coal Gasification

CCTR Advisory Panel

Indiana Center for
Coal Technology Research

March 5, 2009

Scientific Drilling

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CBM & Shale Gas Business Development

Mechanical Engineer w/ Scientific Drilling for 12 Years

Experience Coalbed Methane Planning & Drilling Operations in the Arkoma, San Juan, Black Warrior, North Louisiana, Appalachian, WCSB (Canada) & Alaska CBM Drilling Areas

Scientific Drilling

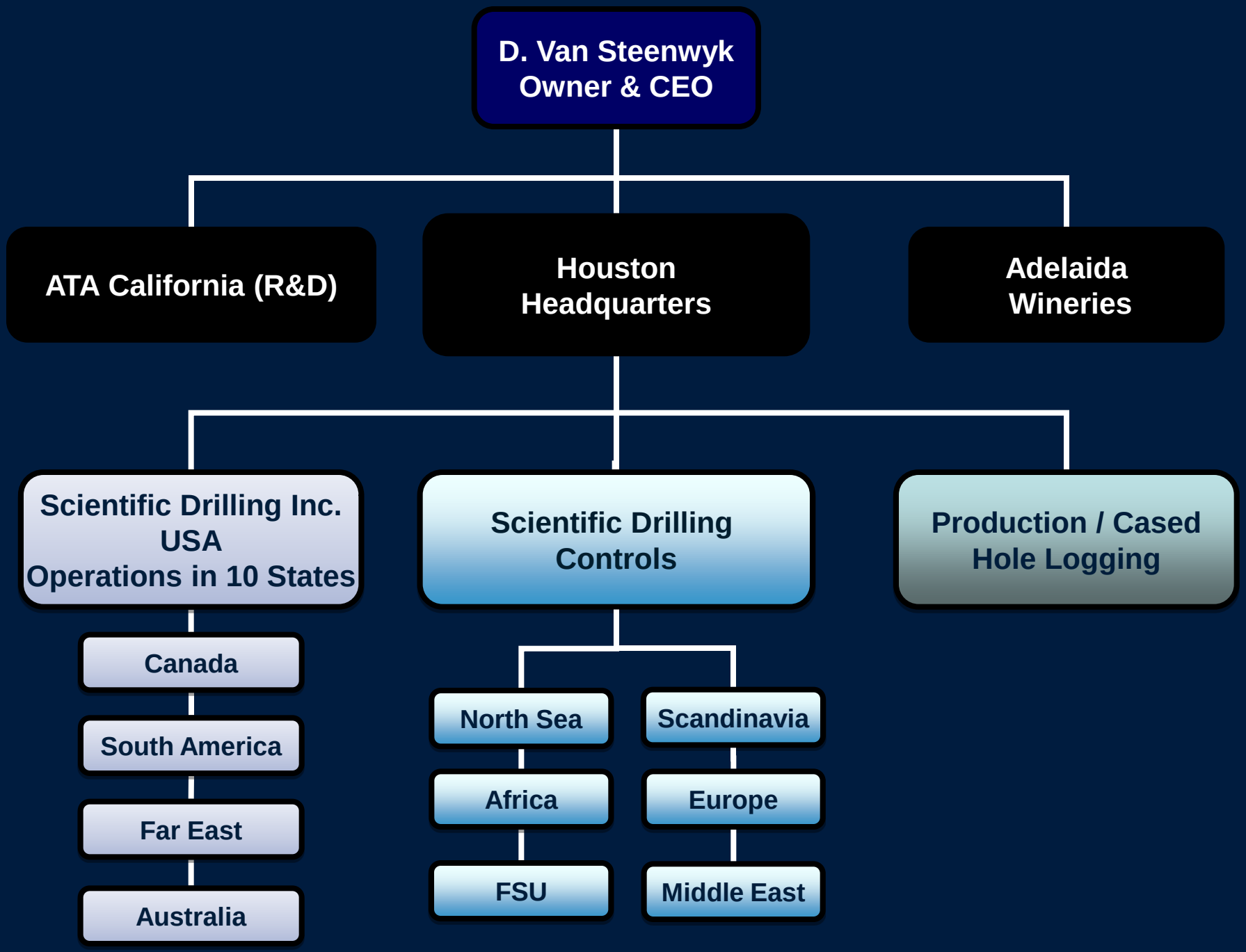
PRESENTATION OUTLINE

- SDI/SDC/ATA COMPANY INTRODUCTION
- COAL OVERVIEW
- UCG OVERVIEW
- WELL DESIGN OPTIONS
- INTERCEPT WELLS
- WELL DESIGN OPTIMIZATION CASE STUDY
- DIRECTIONAL DRILLING OVERVIEW
  - STEERING SYSTEMS
  - MEASUREMENT SYSTEMS
  - KEY ISSUES DRILLING IN COAL
  - LOGGING WHILE DRILLING SYSTEMS
- SUMMARY & RECOMMENDATIONS

WHO IS SCIENTIFIC DRILLING?

- Scientific is a Directional Drilling Service Provider that provides a very wide range of Wellbore Measurement & Navigation Systems
- Diversified into Directional Drilling, MWD, Ranging, Drill Motors and Production Logging
- Scientific is a company that custom builds all equipment, tools, sensors and instruments in-house

Company Structure



Company Structure

- Our research and development arm
- Aerospace industry background
- Military - Navigation Systems
- Tool and Sensor Manufacture
- Software Development
- Product testing & Employee training center

ATA – APPLIED TECHNOLOGIES ASSOCIATES

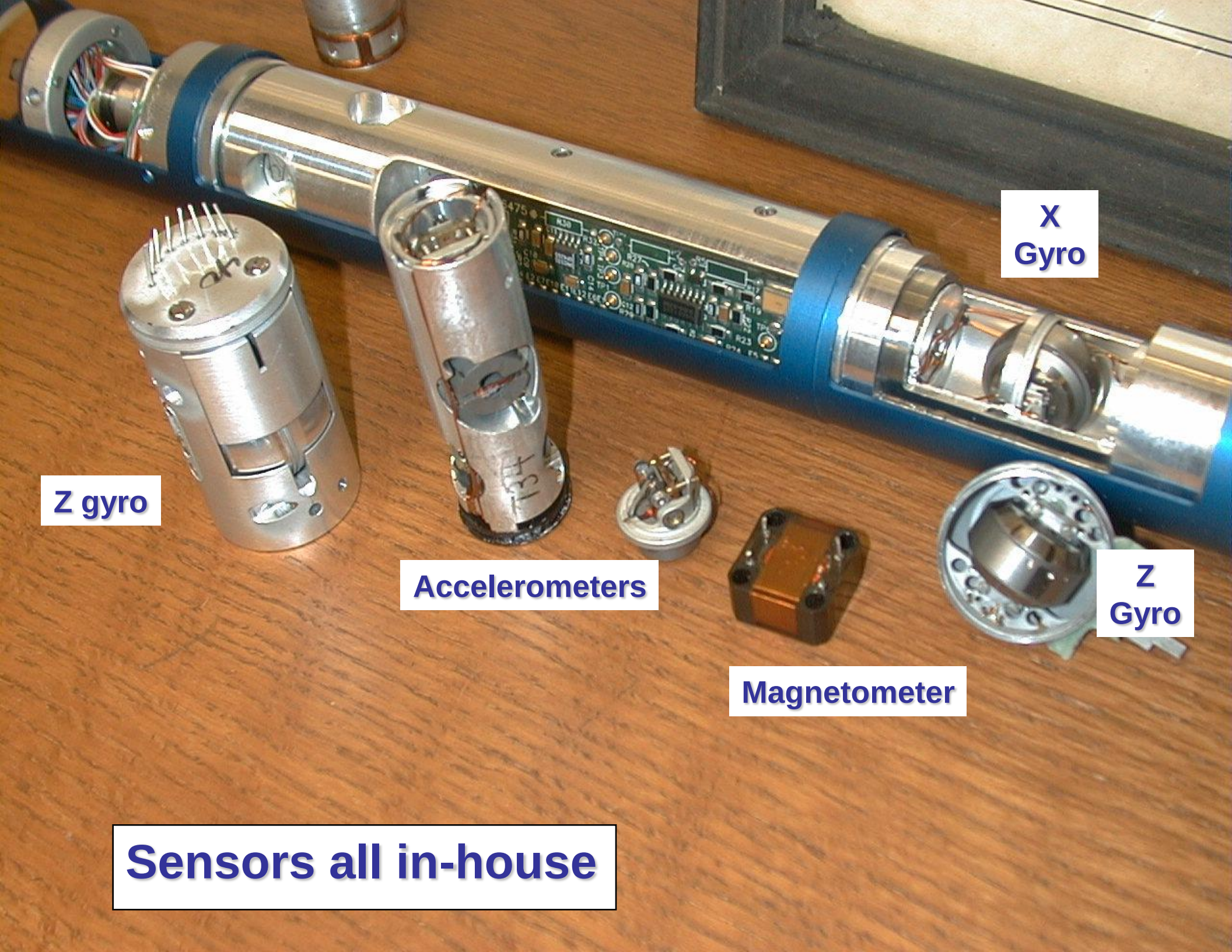
ATA FACILITY

Paso Robles, R&D Office

Magnetics Lab

Clean Room Manufacturing

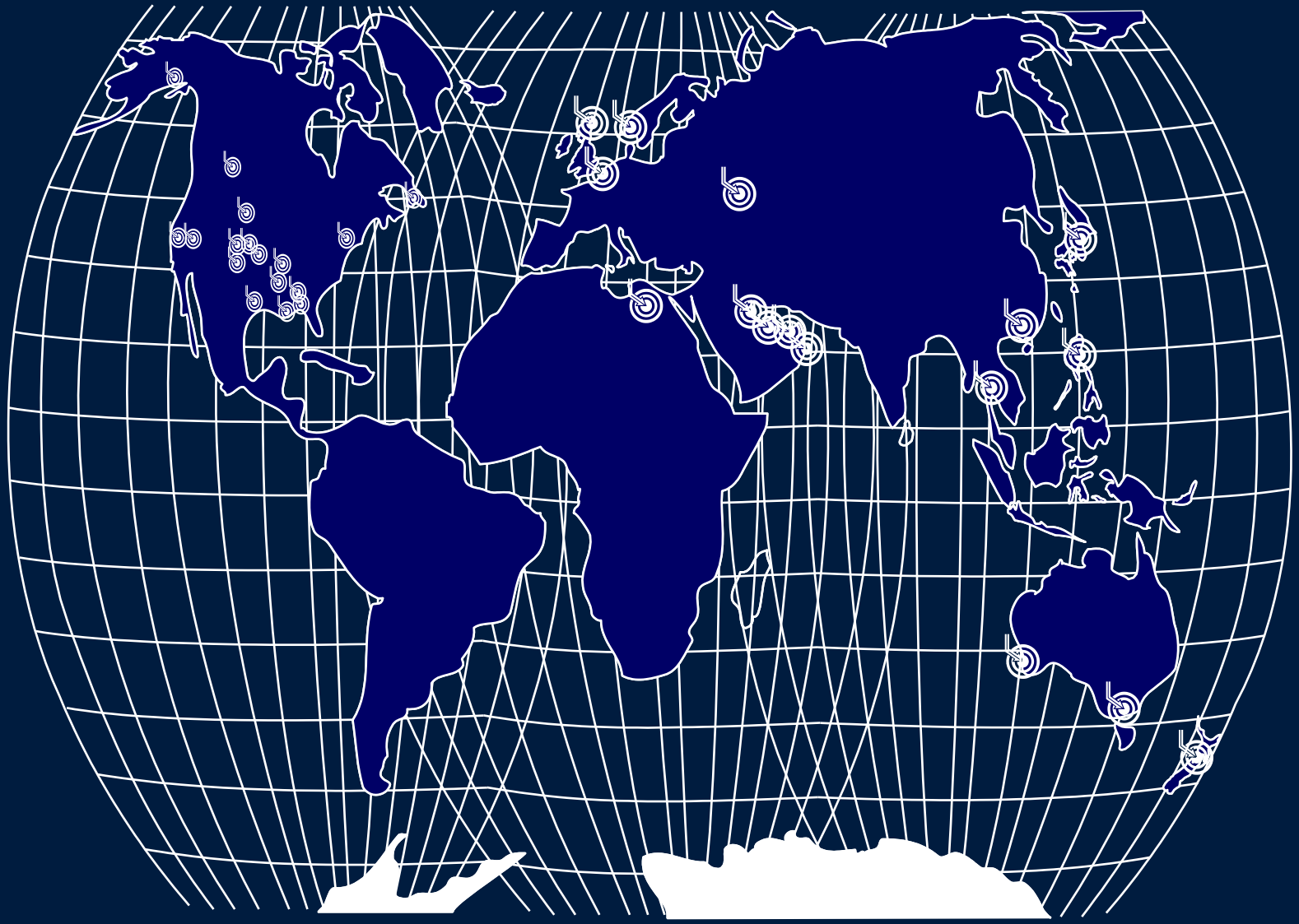
Gyro Lab



Sensors all in-house

WORLDWIDE OPERATIONS

Existing facilities



EXPERIENCE

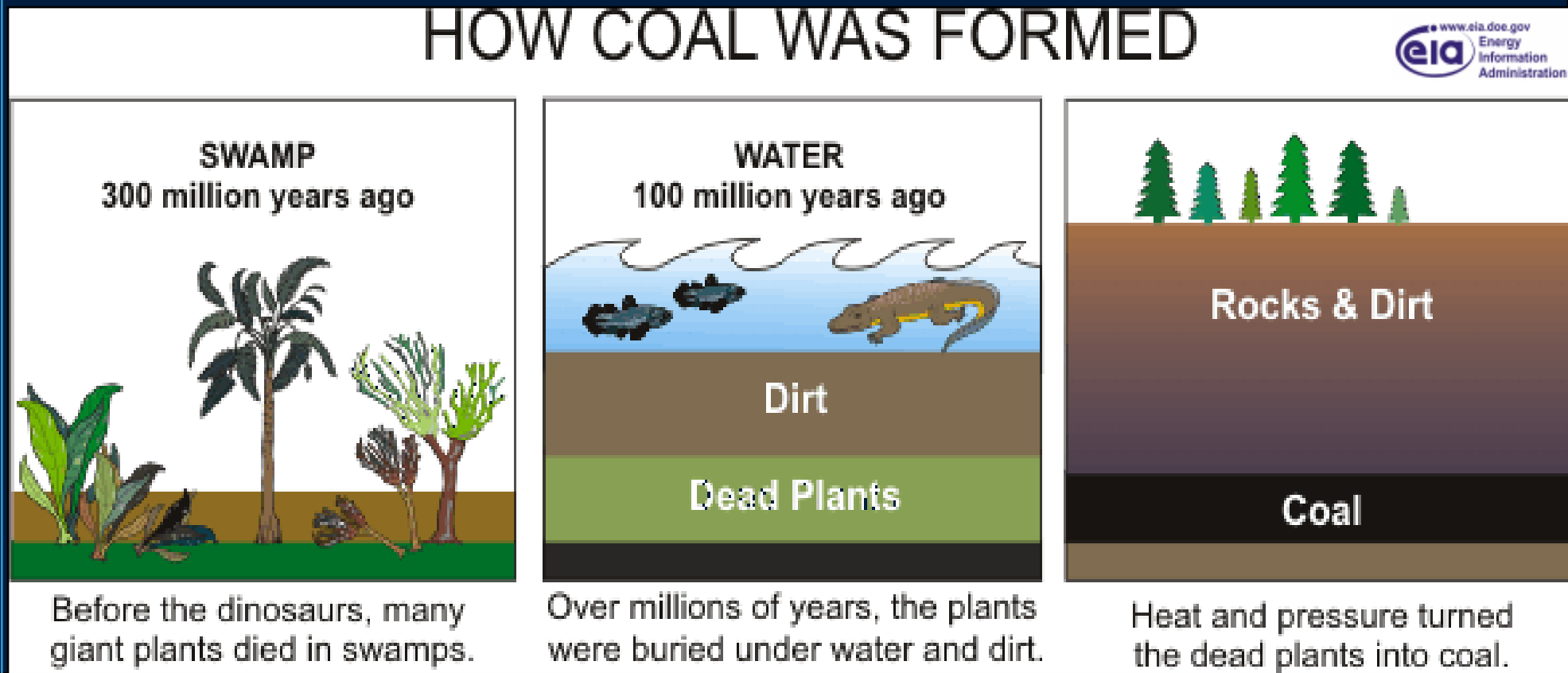
- Platform Drilling
- Deepwater Drilling
- Underbalanced
- Synthetic Muds
- Horizontal Drilling inc. underbalanced
- Reentries
- Bi-Center Bits / PDC Bits / Steerable Systems
- Casing Whipstock Sidetracks
- Coal Bed Methane Horizontal Drilling
- Shale Gas Horizontal Drilling
- Well control/intercept
- Geothermal wells

SDI HORIZONTAL EXPERIENCE

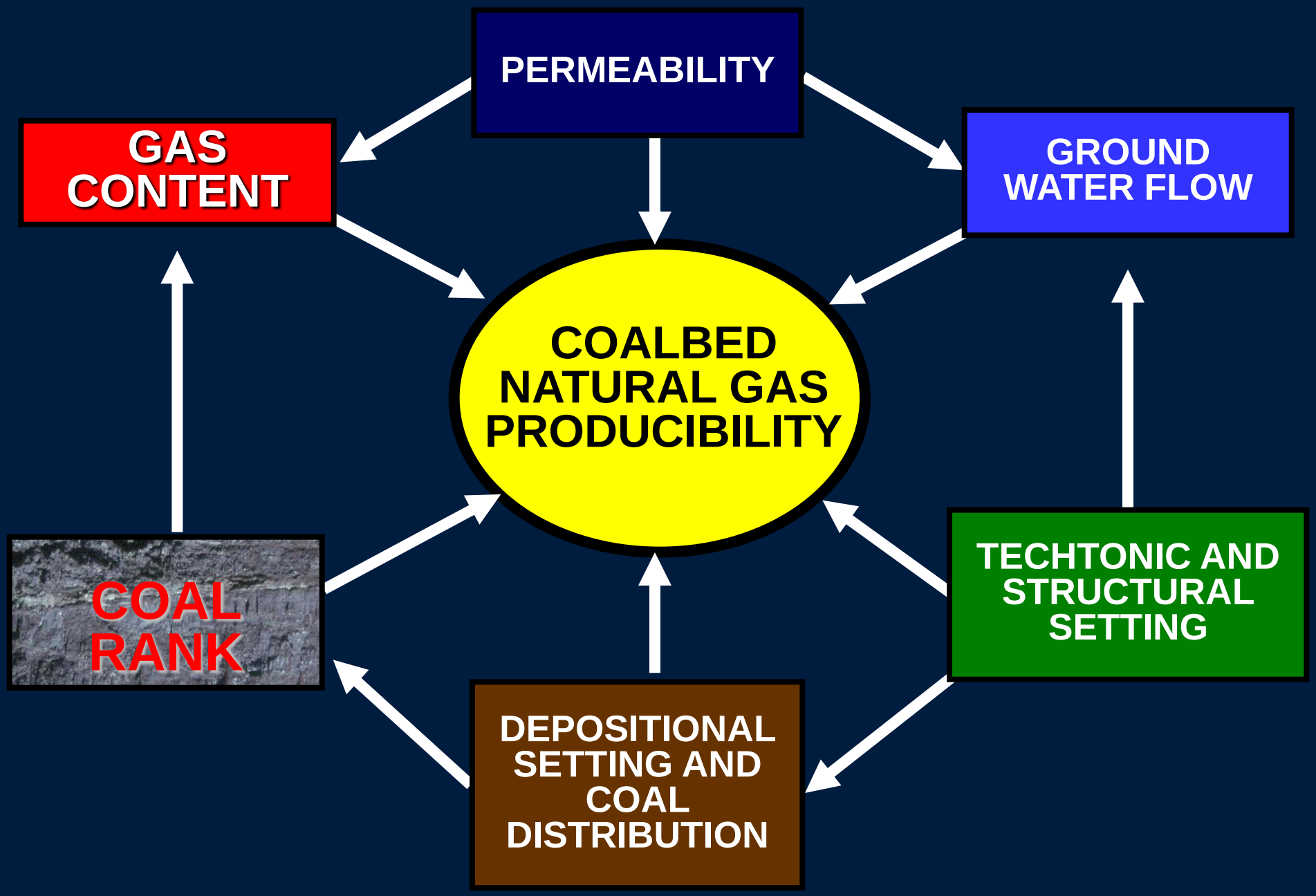
- Over 8,000 Onshore Wells North America in last decade
- >2,500 Horizontal Shale Gas projects (Barnett, Woodford, Caney….)
- >5,500 Coalbed Methane Horizontal Well Bores

COAL OVERVIEW

COAL IS UNIQUE:
SOURCE ROCK
&
RESERVOIR
95% PURE METHANE



Factors Critical to Coalbed Natural Gas Productivity

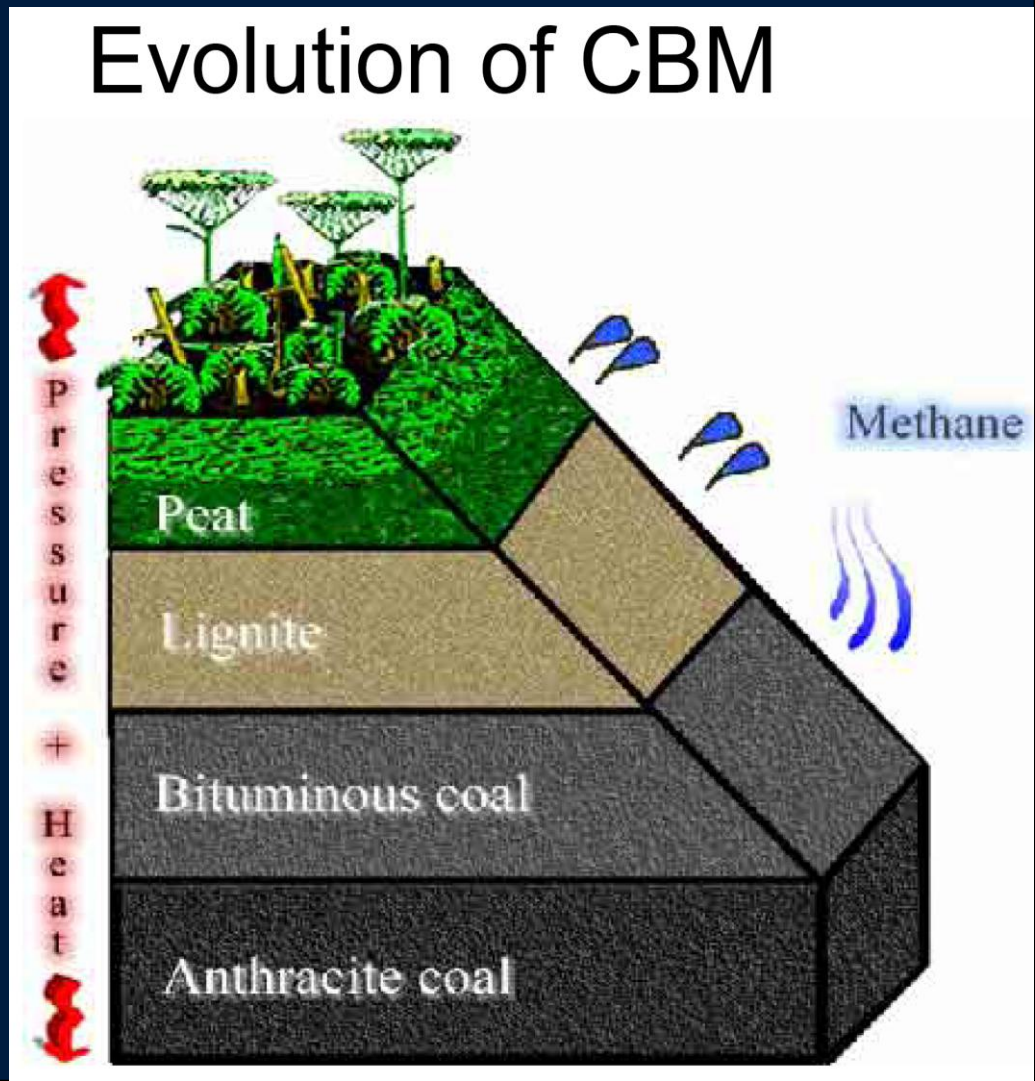


COAL GAS STORAGE

ABILITY FOR A COAL TO STORE GAS

IT IS A FUNCTION OF:

- RANK (GRADE)
  - LIGNITE
  - SUBBITUMINOUS
  - BITUMINOUS
  - ANTHRACITE
- PRESSURE
- TEMPERATURE



CBM – GAS CONTENT

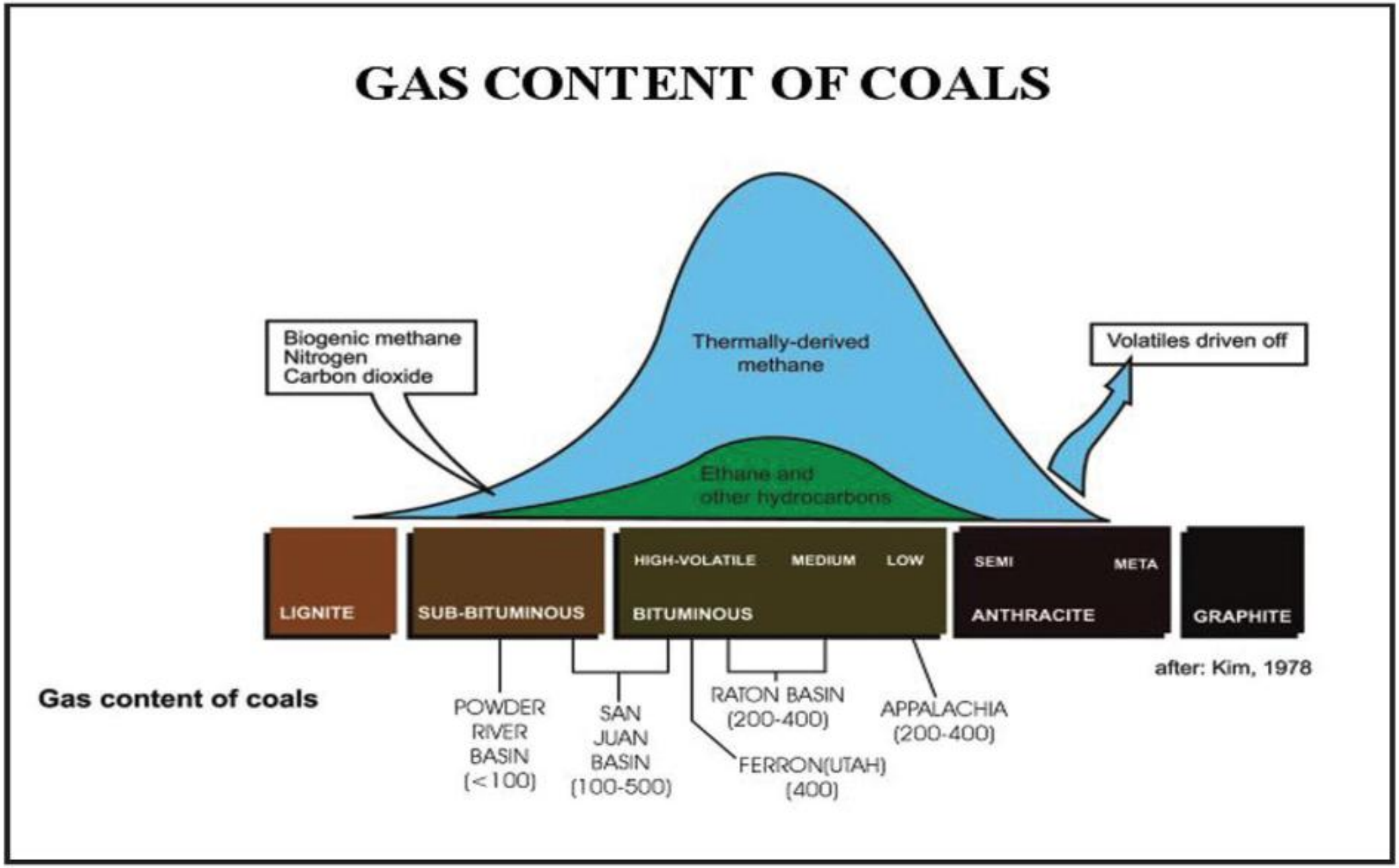
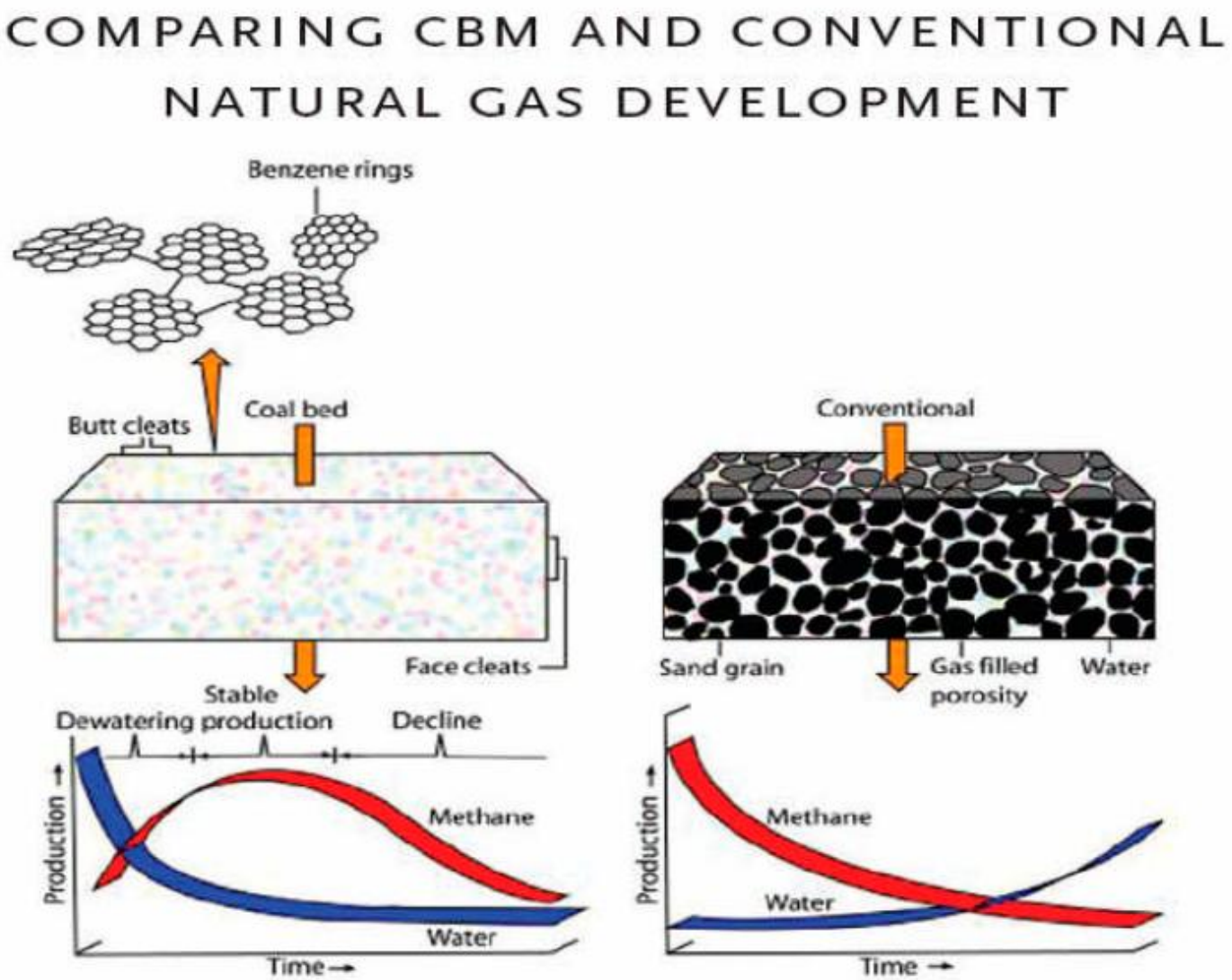


FIGURE 2 *Source: William T. Brown, NRLC coalbed methane conference, April 4–5, 2002.*

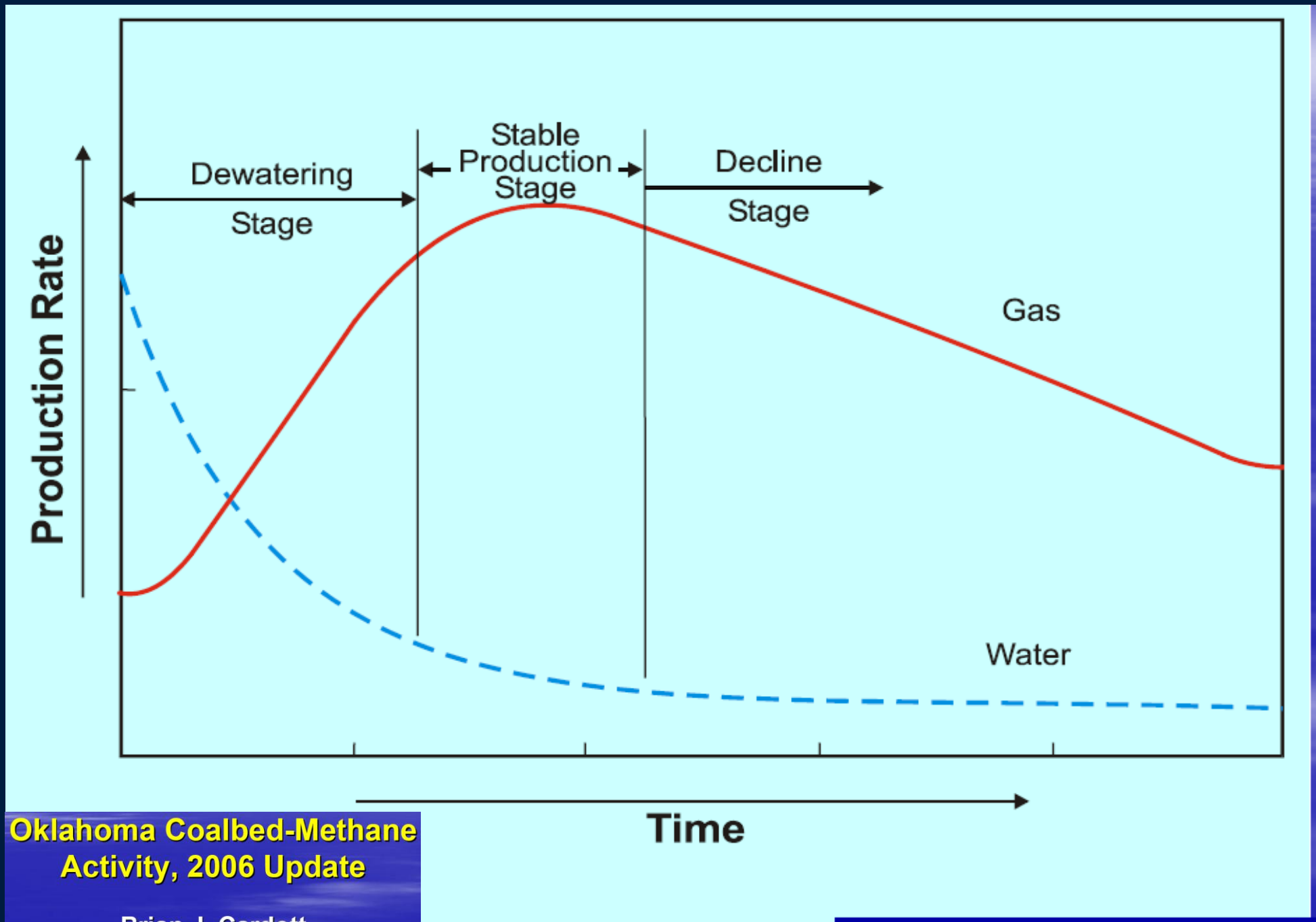

Photo Courtesy
of DBT Australia

WHY IS COALBED METHANE CONSIDERED UNCONVENTIONAL?

- **CONVENTIONAL COMPARED TO UNCONVENTIONAL**

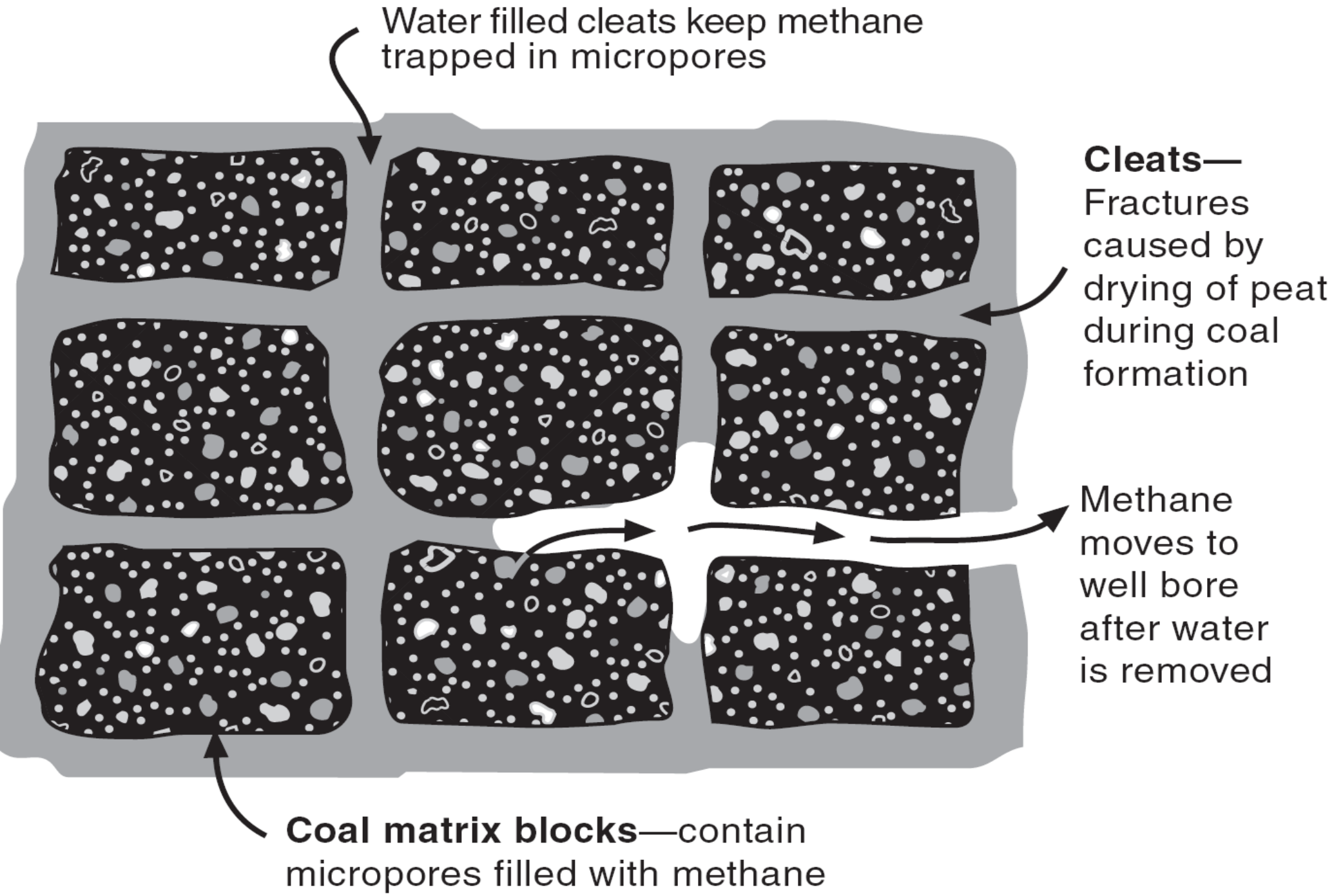


Theoretical decline curve for a CBM well

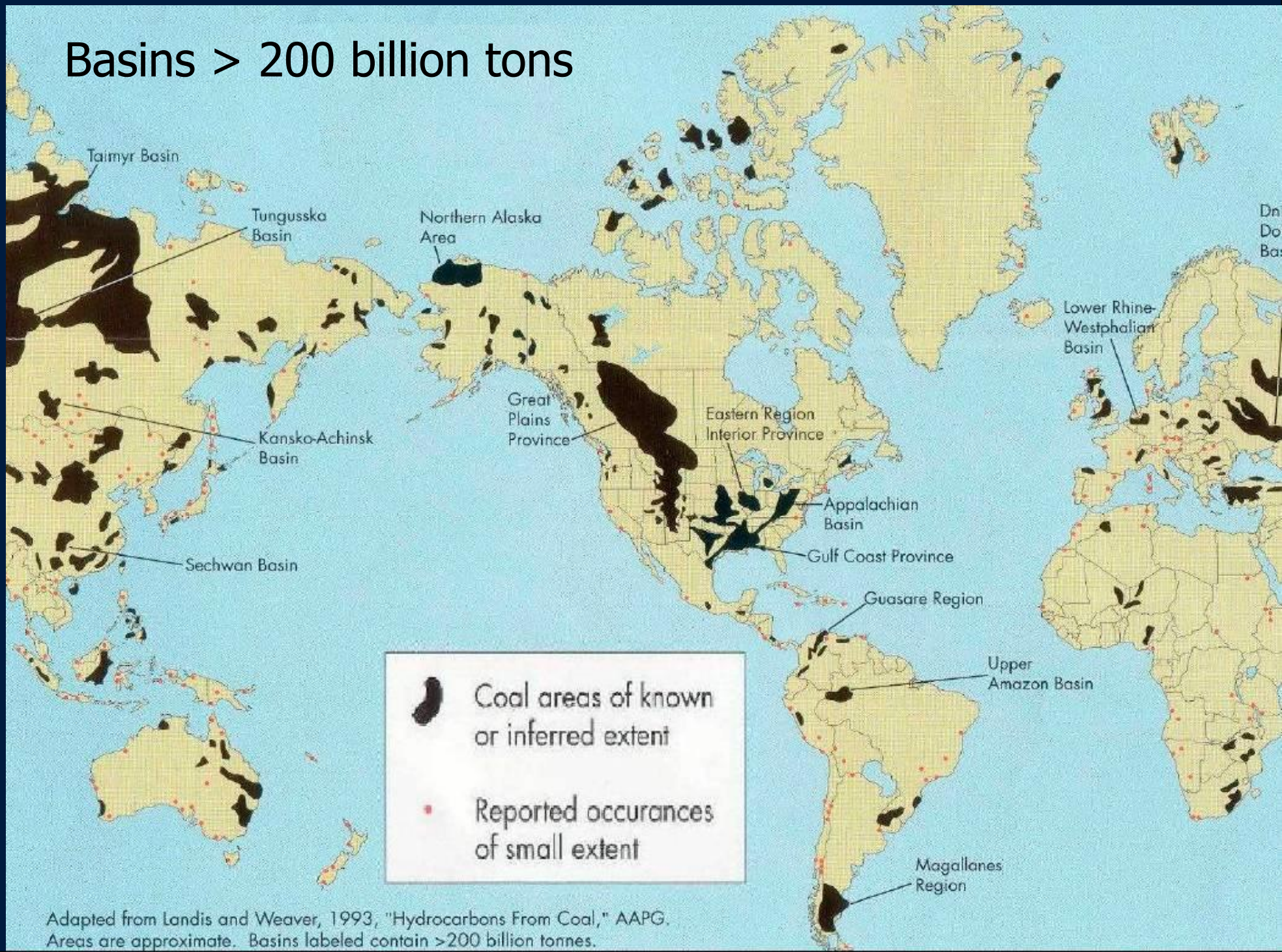


From Schraufnagel, 1993

METHANE PRODUCTION FROM COAL SEAMS



WORLD COAL DISTRIBUTION

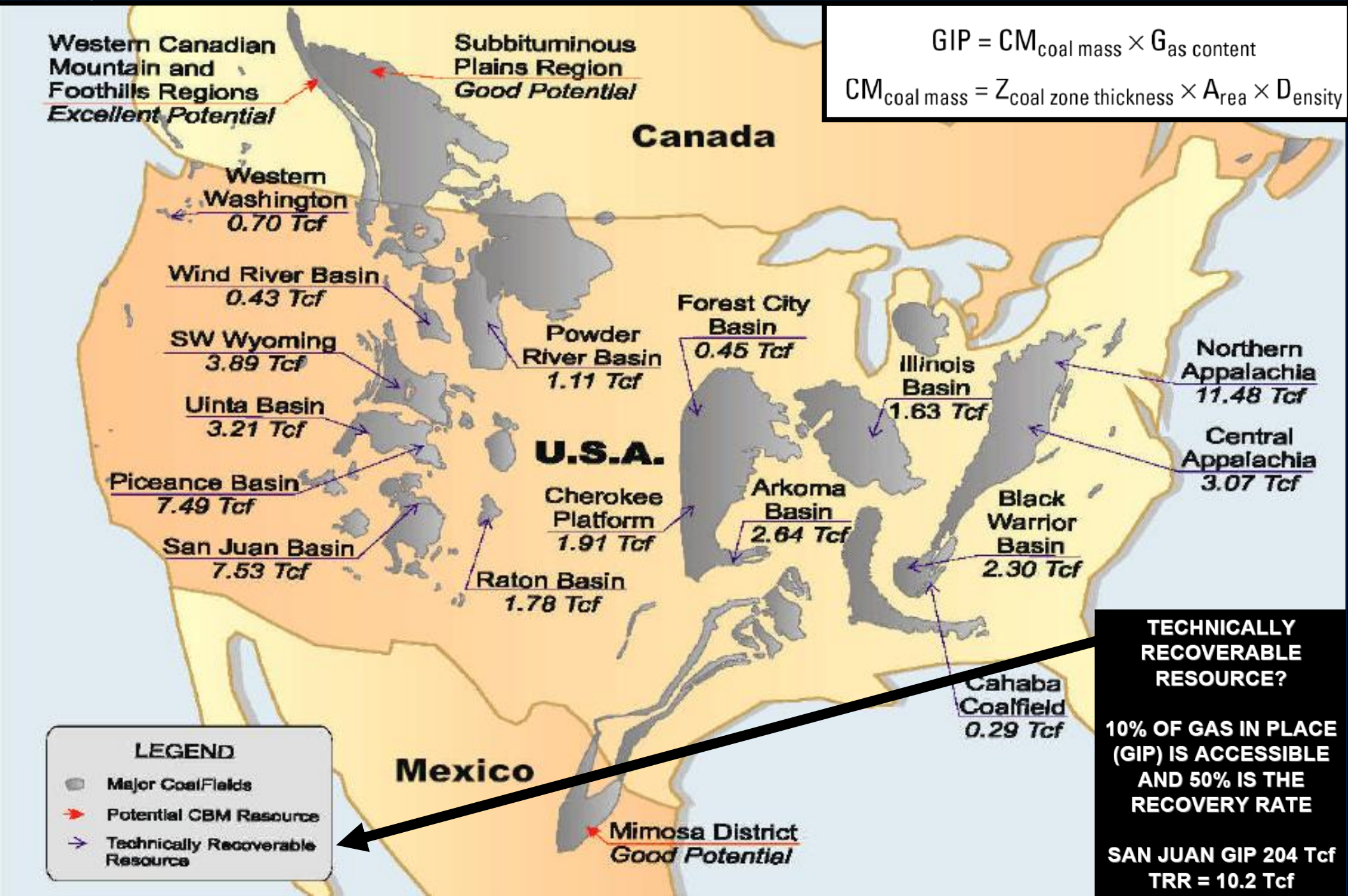


Adapted from Landis and Weaver, 1993, "Hydrocarbons From Coal," AAPG.
Areas are approximate. Basins labeled contain >200 billion tonnes.

TECHNICALLY RECOVERABLE COALBED METHANE GAS RESOURCES

$$GIP = CM_{coal\ mass} \times G_{as\ content}$$

$$CM_{coal\ mass} = Z_{coal\ zone\ thickness} \times A_{rea} \times D_{ensity}$$

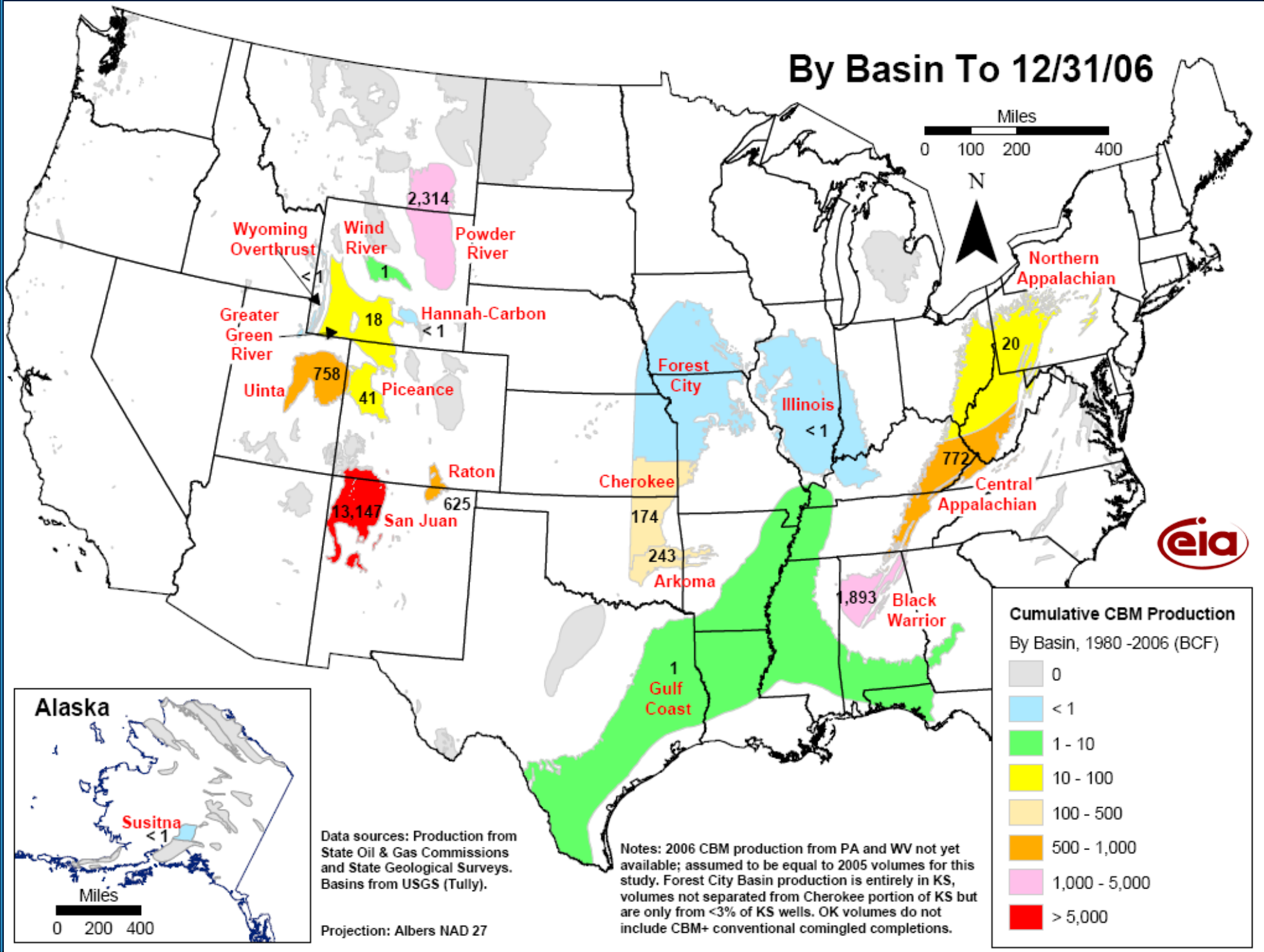


TECHNICALLY RECOVERABLE RESOURCE?

10% OF GAS IN PLACE (GIP) IS ACCESSIBLE AND 50% IS THE RECOVERY RATE

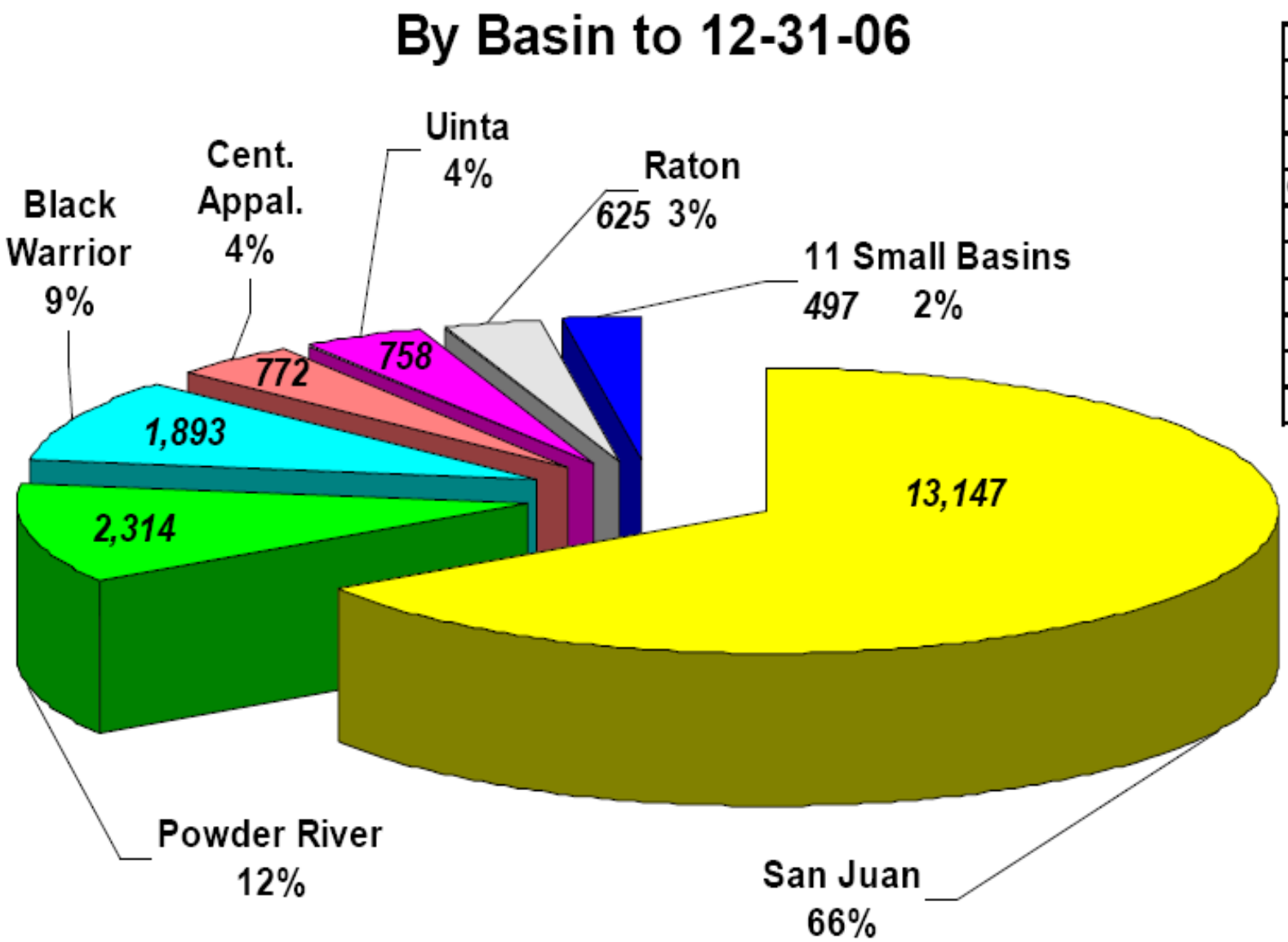
SAN JUAN GIP 204 Tcf
TRR = 10.2 Tcf

US CUMULATIVE PRODUCTION (BCF)



US CUMULATIVE PRODUCTION (BCF)

- AUSTRALIA 1996 -2005
- QUEENSLAND 166 BCF
- NSW 63 BCF
- TOTAL FOR AUSTRALIA – 266 BCF

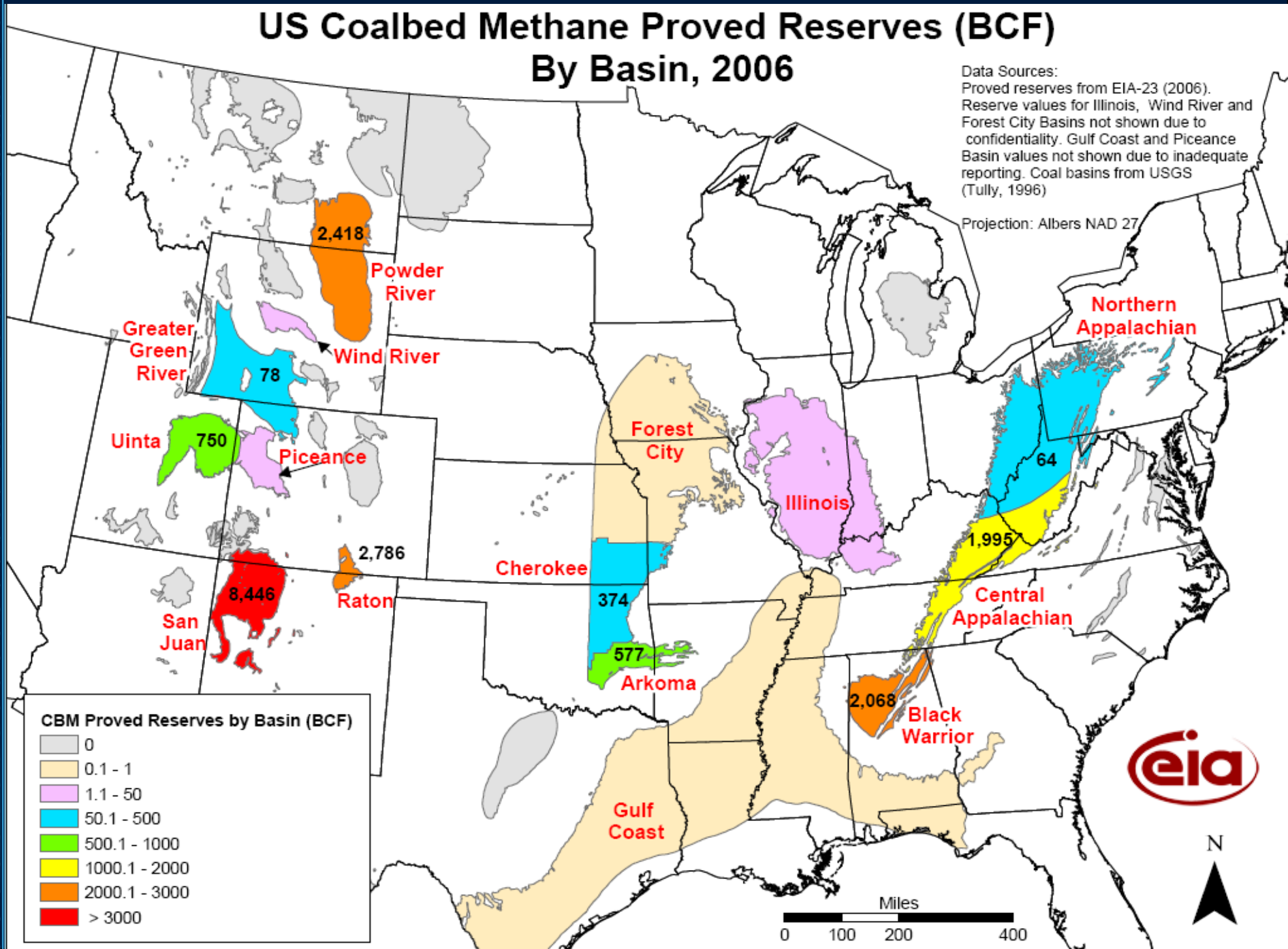


11 Small Basins

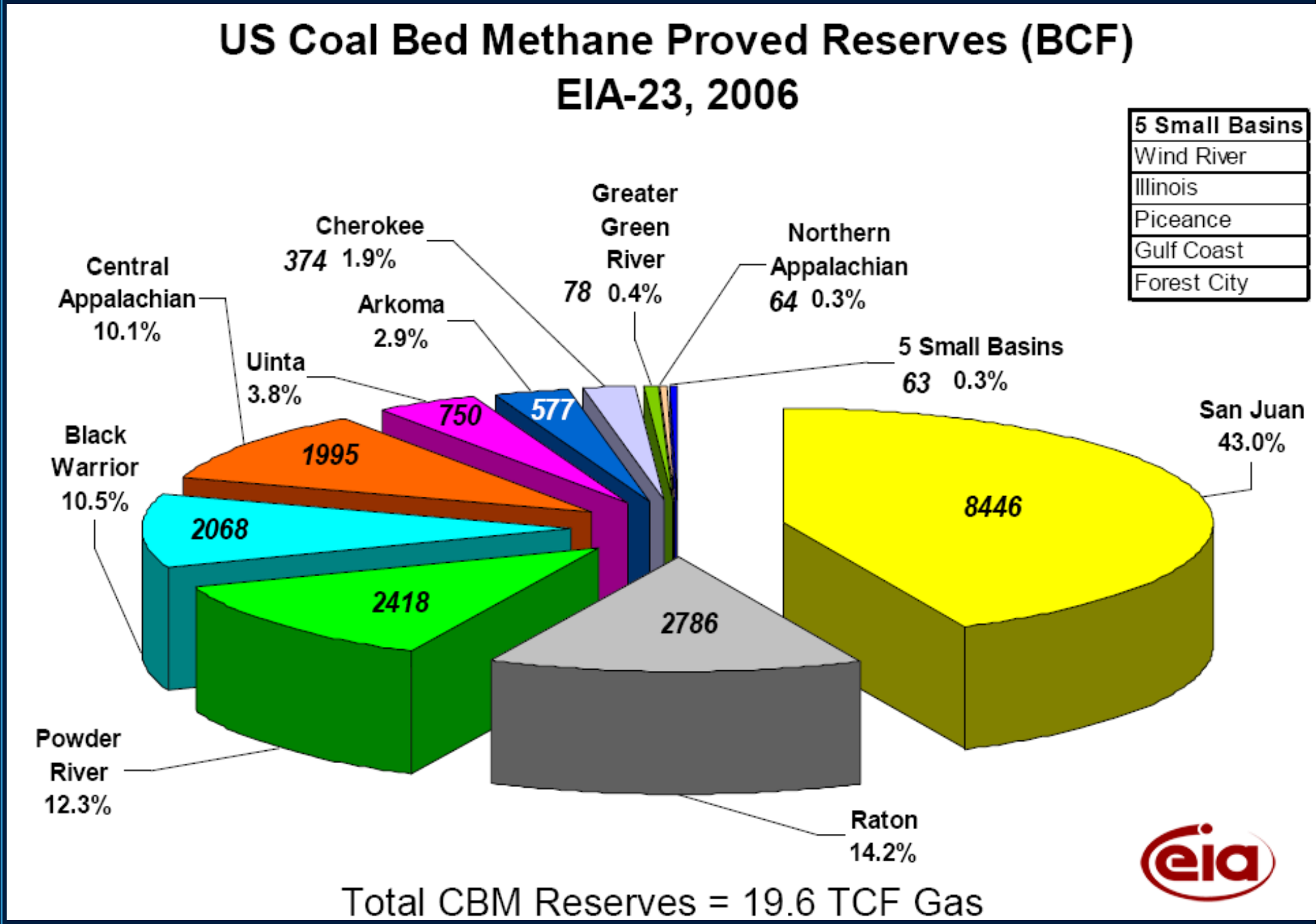
Arkoma	243
Cherokee	174
Piceance	41
N. Appalachian	20
Grtr Green River	18
Wind RIver	1
Gulf Coast	1
Hannah-Carbon	<1
WY Thrust Belt	<1
Alaska	<1
Illinois	<1

Total Cumulative CBM Production = 20,006 BCF Gas

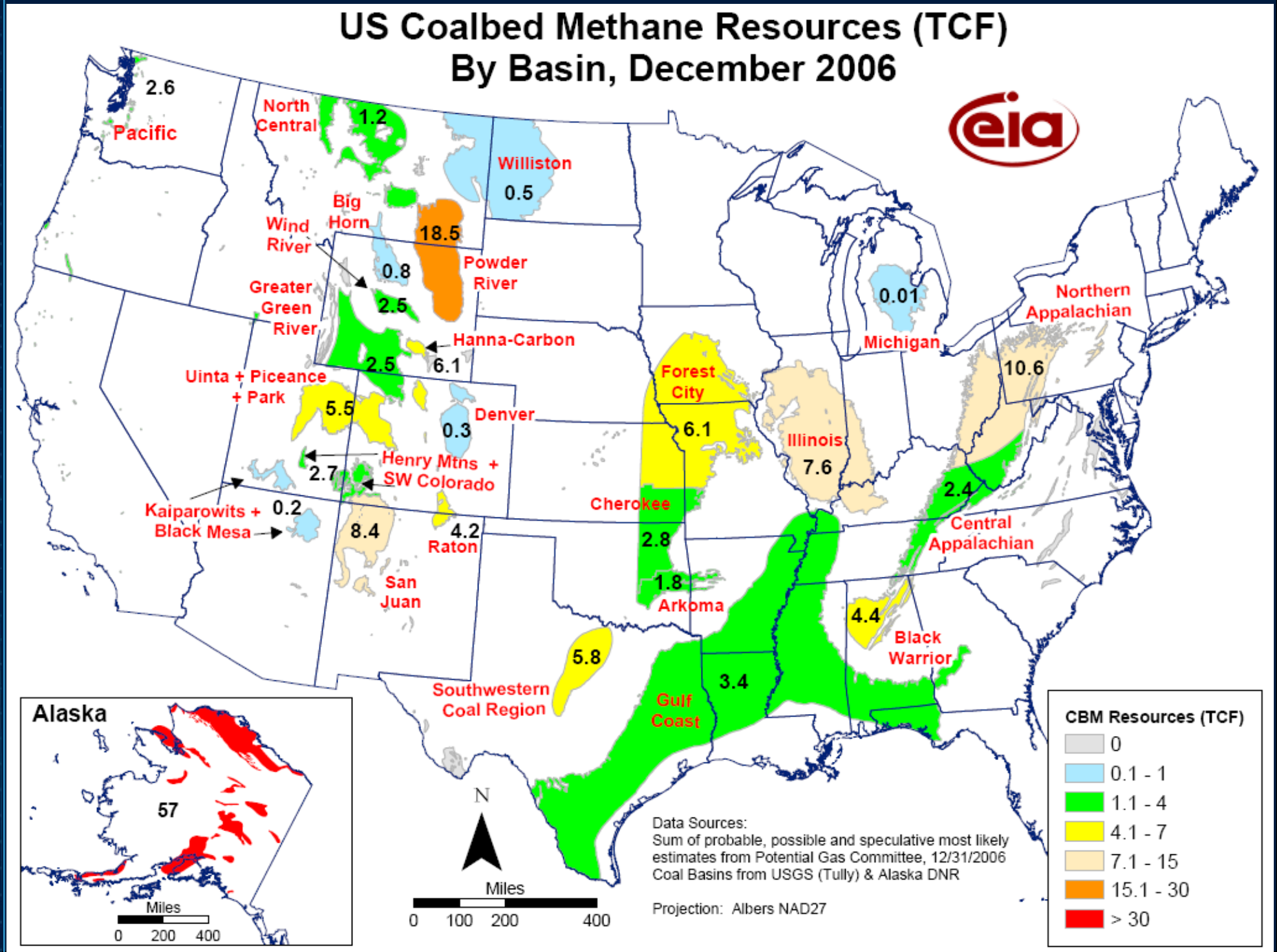
US COALBED METHANE PROVED RESERVES (BCF)



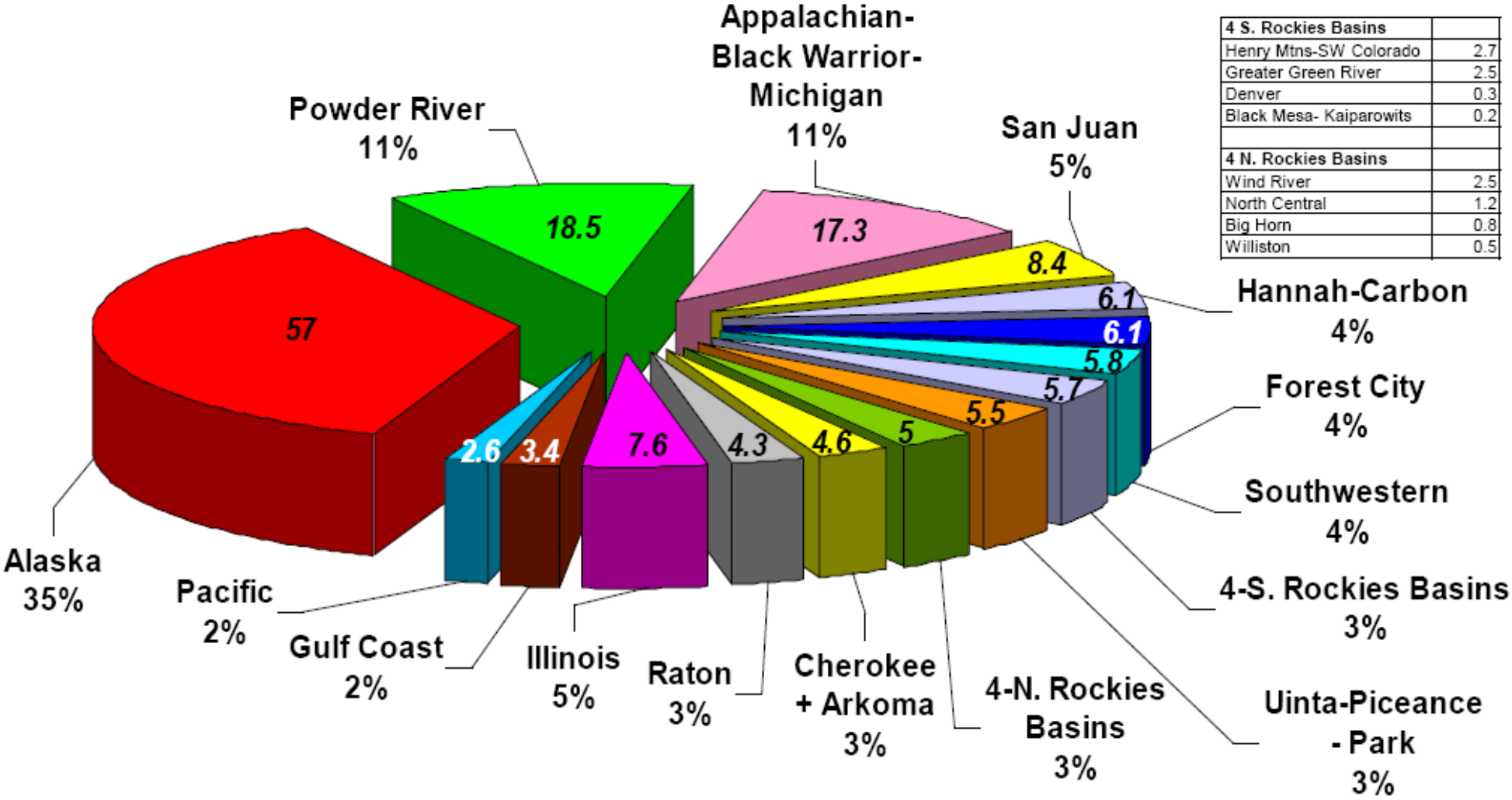
US COALBED METHANE PROVED RESERVES (BCF)



US COALBED METHANE RESOURCES (TCF)



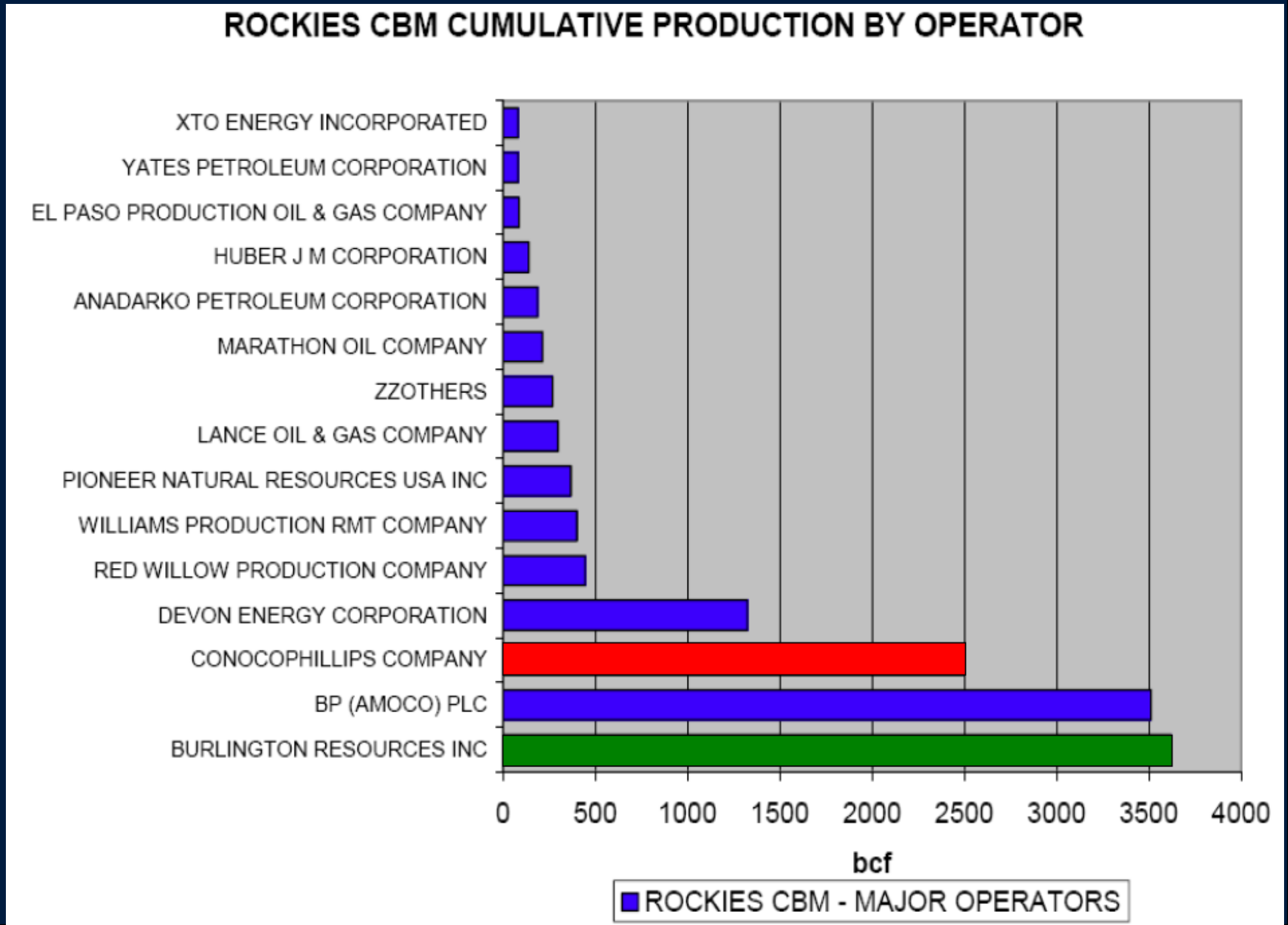
US COALBED METHANE RESOURCES (TCF)



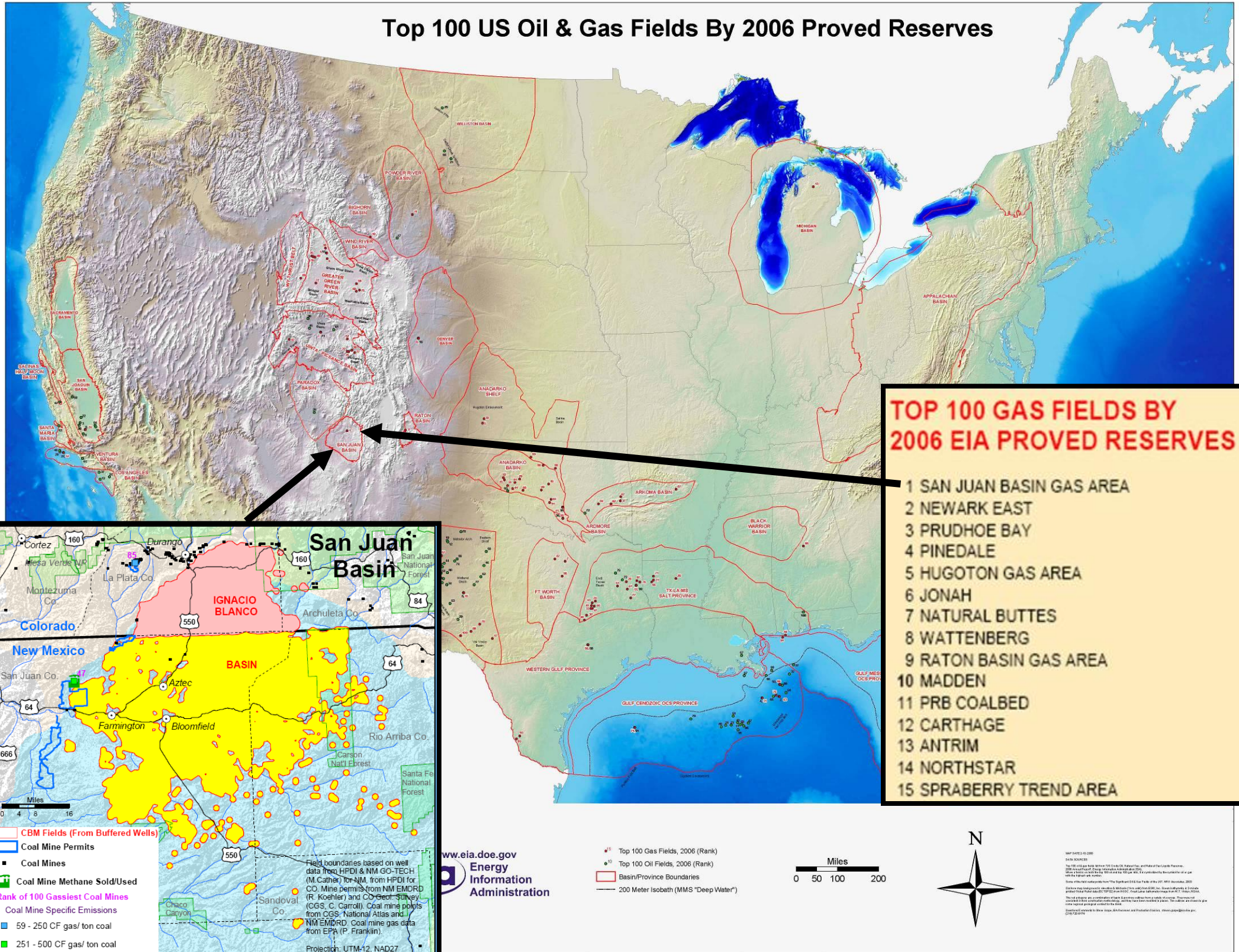
4 S. Rockies Basins	
Henry Mtns-SW Colorado	2.7
Greater Green River	2.5
Denver	0.3
Black Mesa- Kaiparowits	0.2
4 N. Rockies Basins	
Wind River	2.5
North Central	1.2
Big Horn	0.8
Williston	0.5

Total CBM Resources = 157.9 TCF Gas

LEADERS IN ROCKY MOUNTAIN CBM

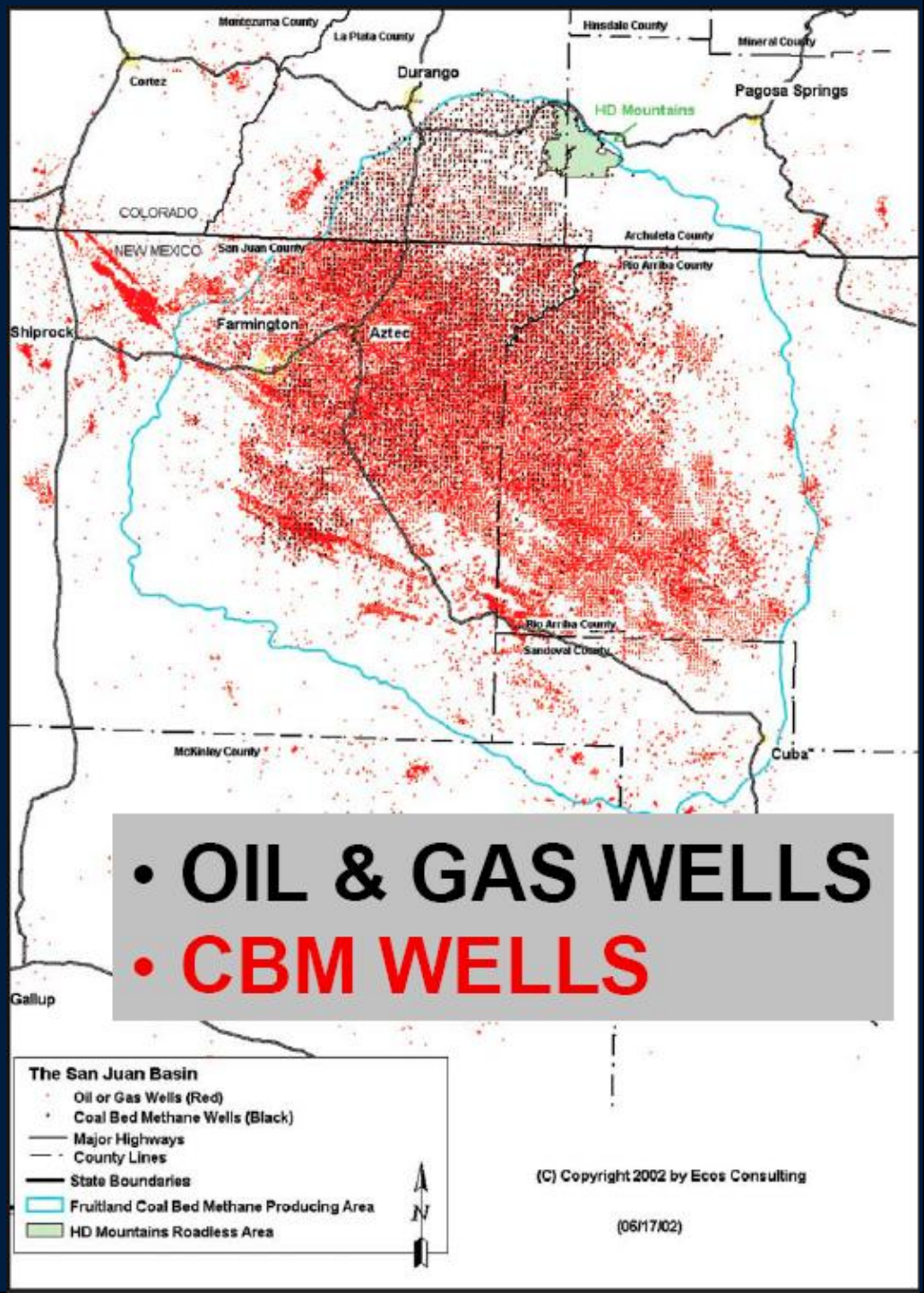


Top 100 US Oil & Gas Fields By 2006 Proved Reserves

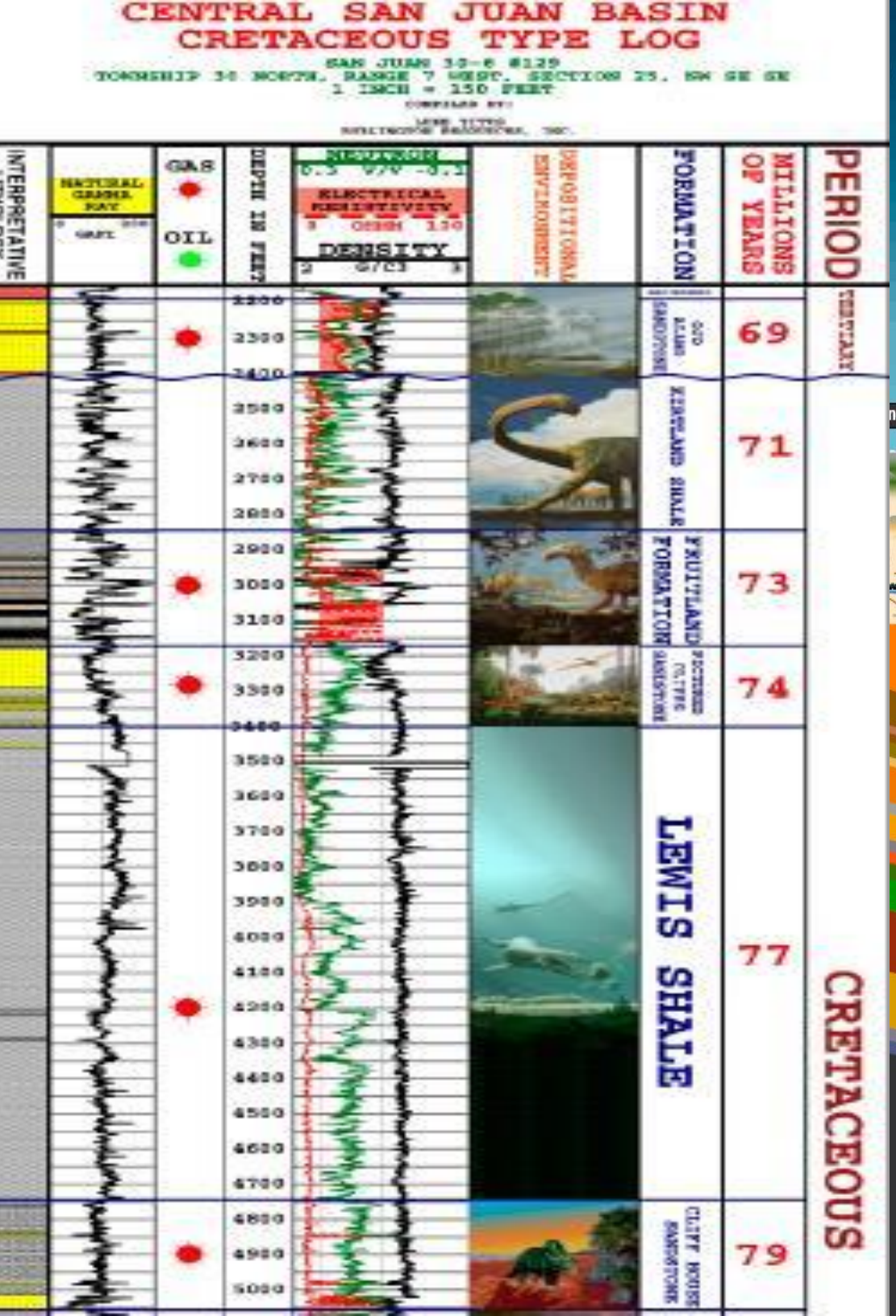


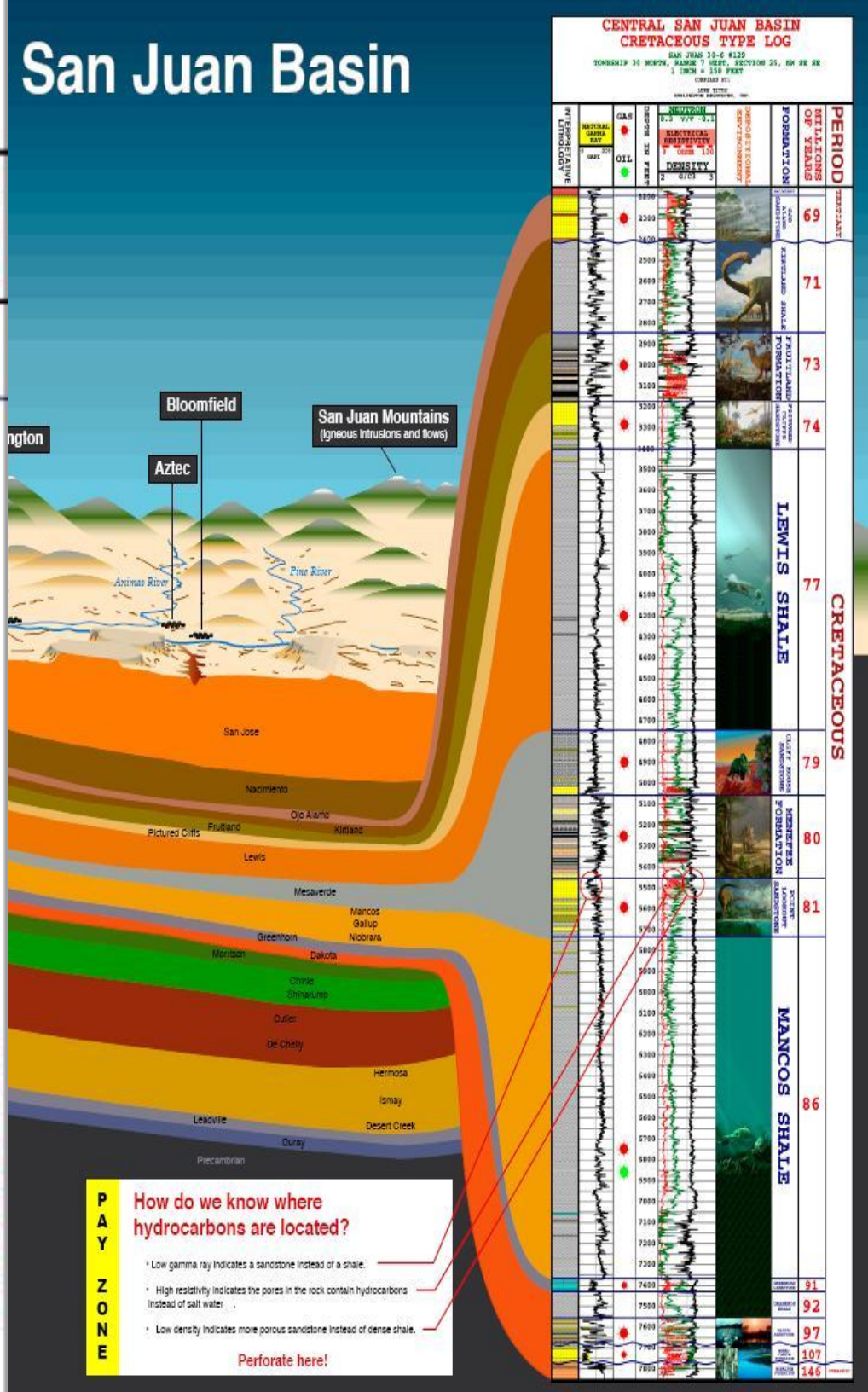
30,000 WELLS IN THE SAN JUAN

- FOCUS IS ON RECOVERY
- REDUCED WELL SPACING BELOW GROUND NOT AT SURFACE (PAD DRILLING)
- HORIZTONAL DRILLING
- CONSIDERABLE GAS STILL IN PLACE
- UCG POTENTIAL?



San Juan Basin





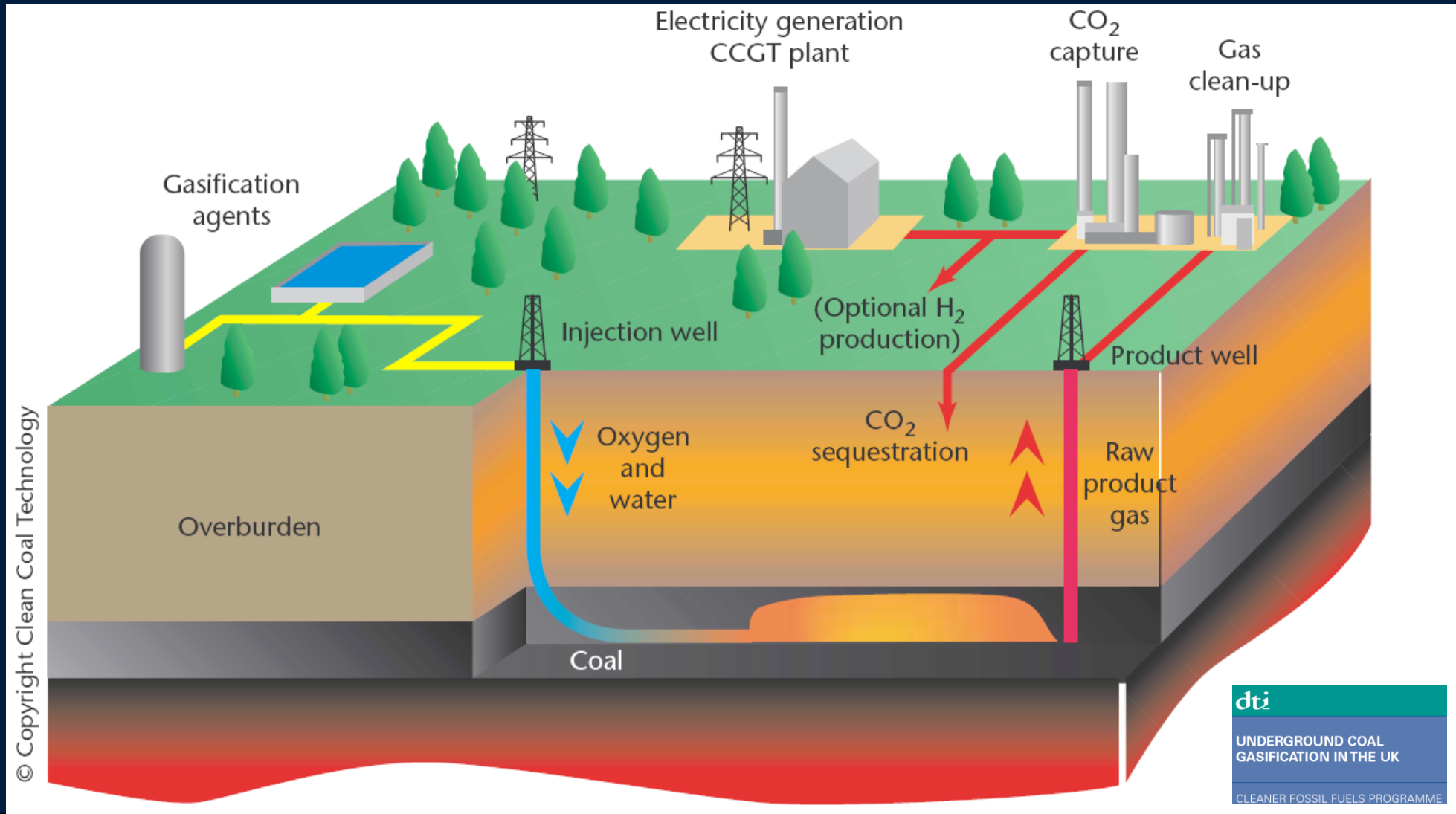
CBM BASIN COMPARISON

Coal Basin or Deposit	Coal Rank	Typical Depth (feet)	Typical Net Coal (feet)	Typical Gas Content (SCF/ton)	Typical Well Spacing (acres)	In-situ Density (g/cm^3)	Avg. Well Production (Mcfd)
Illinois	Hvb/c	500	17	100	80	1.35	40
San Juan	Hvb	2,500	70	430	320	1.54	2,000-5,000
Black Warrior	Mvb	3,000	25	350	80	1.4	100
Central Appalachian	Mvb	2,000	16	n/a	80	n/a	120
Piceance	Hvb	5,500	80	768	40	1.35	140
Powder River	Sb	1,000	75	30	40-80	1.34	100-750
Uinta	Hvb	3,400	24	400	160	1.54	690
Arkoma	Hvb	2,200	6	250	n/a	n/a	50
Raton	Hvb	2,200	25	400	160	1.50	300

UCG OVERVIEW

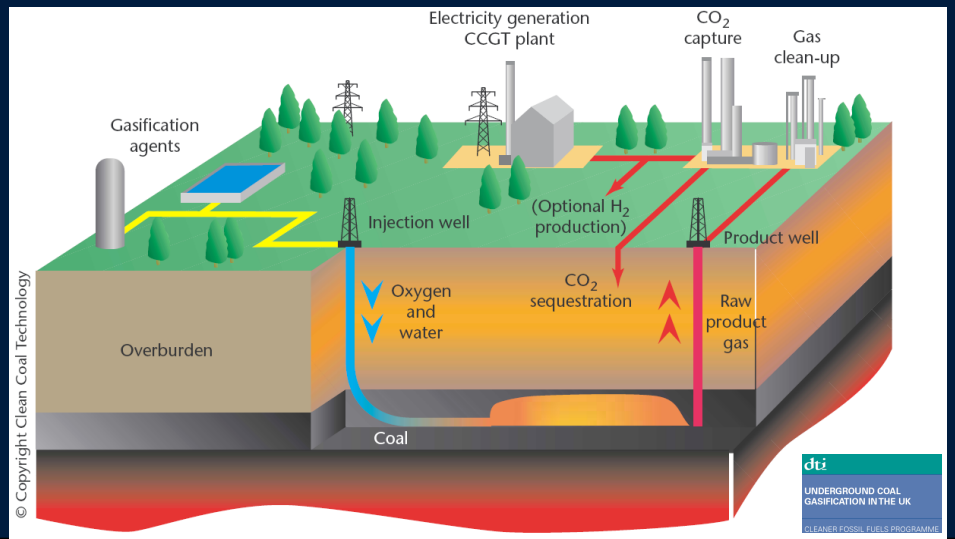
UNDERGROUND COAL GASIFICATION

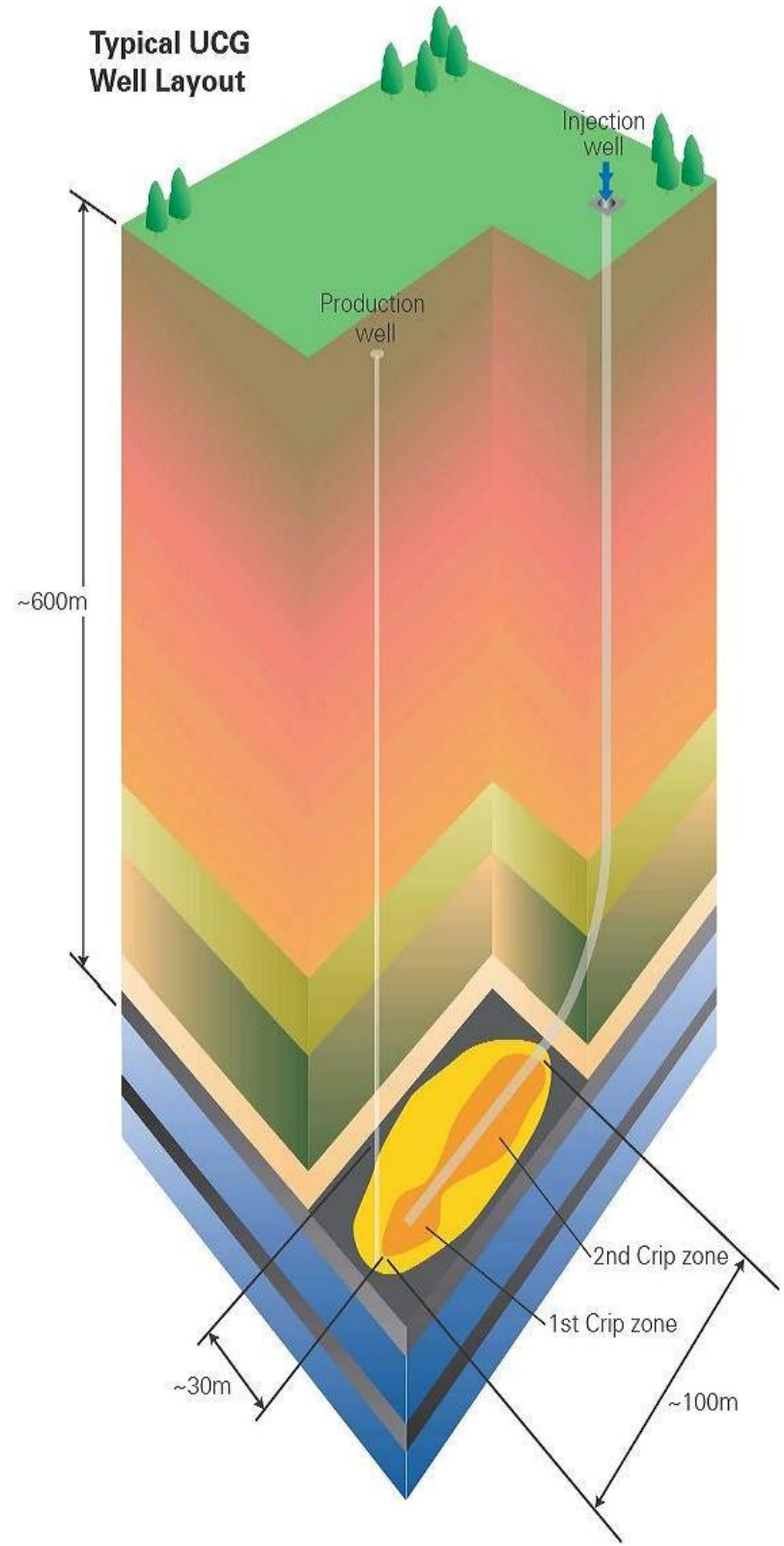
- **Oxygen & Water Injected Into Horizontal**
- **Vertical Well produces raw Syngas**



UNDERGROUND COAL GASIFICATION

- Underground Coal Gasification (UCG) is the *in situ* conversion of un-worked coal into a combustible product gas.
- The gas is suitable for industrial heating, power generation or hydrogen and natural gas production.





KEY FACTORS FOR ANY DRILLING PROGRAM

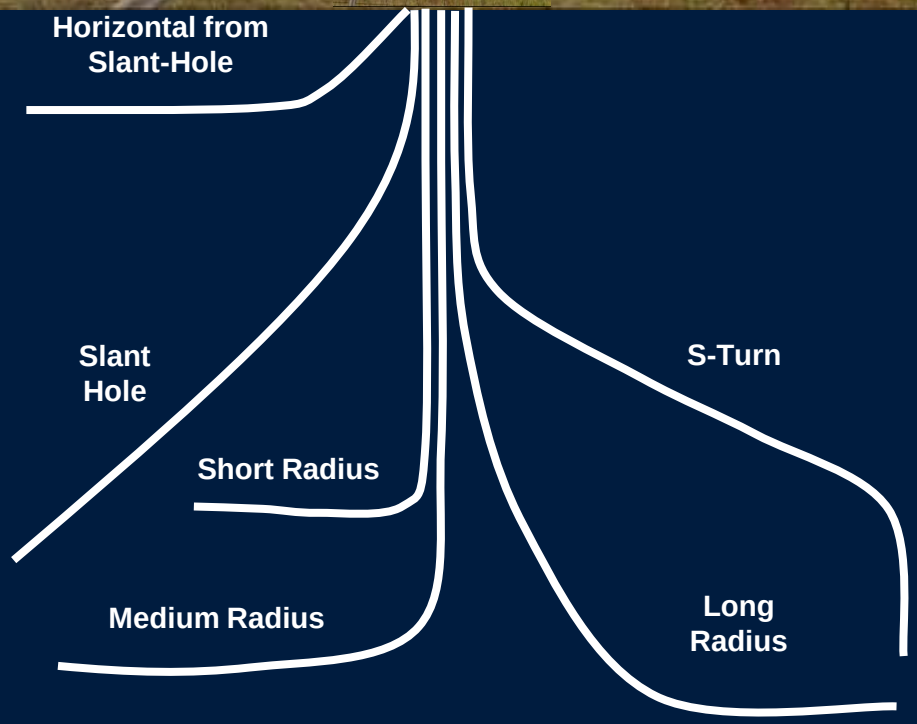
- SURFACE LOCATION RESTRICTIONS
- OFFSET WELLS (PROXIMITY & GEOLOGICAL CONTROL)
- COAL PROPERTIES – THICKNESS, DIP, PERM, ETC….
- ORIENTATION / DIRECTION OF CLEATS OR NATURAL FRACTURES
- PROXIMITY OF OTHER WATER-BEARING LITHOLOGIES

KEY FACTORS FOR ANY DRILLING PROGRAM

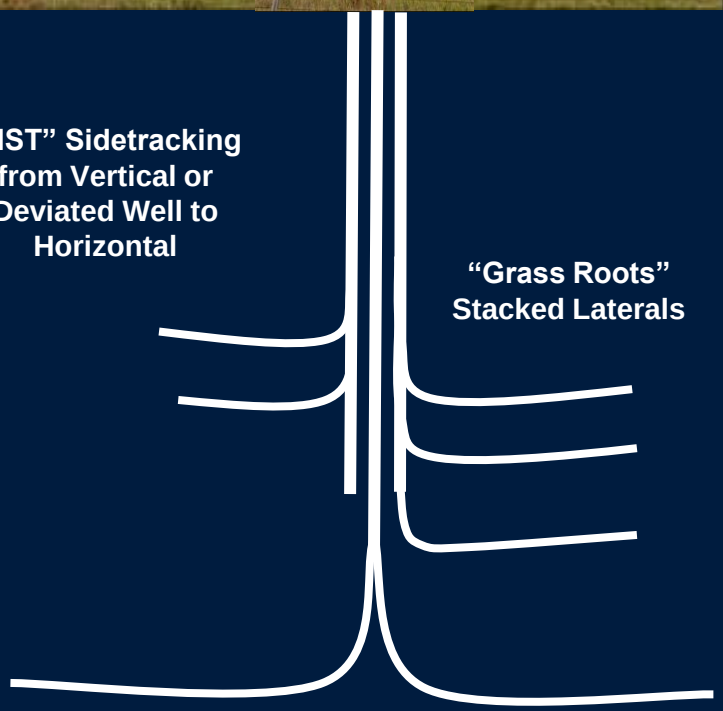
- STABILITY & QUALITY OF ROOF & FLOOR FORMATIONS
- WATER PRODUCTION & DISPOSAL REQUIREMENTS
- LEASE BOUNDARIES
- REGULATORY REQUIREMENTS – DRILL CUTTINGS, SAFETY, ROADS & INFASTRUCTURE, ETC…
- GAS PRICE (METHANE, HYDROGEN & CO_2)
- GATHERING & PIPELINE CAPACITY
- UCG TO ELECTRICITY – REQUIREMENTS FOR POWER GENERATION

WELL DESIGN CONSIDERATIONS & OPTIONS

DIRECTIONAL WELL PROFILES



Horizontal Wells



Opposing Horizontal Wells

MULTI-SEAM CBM WITH SUMP

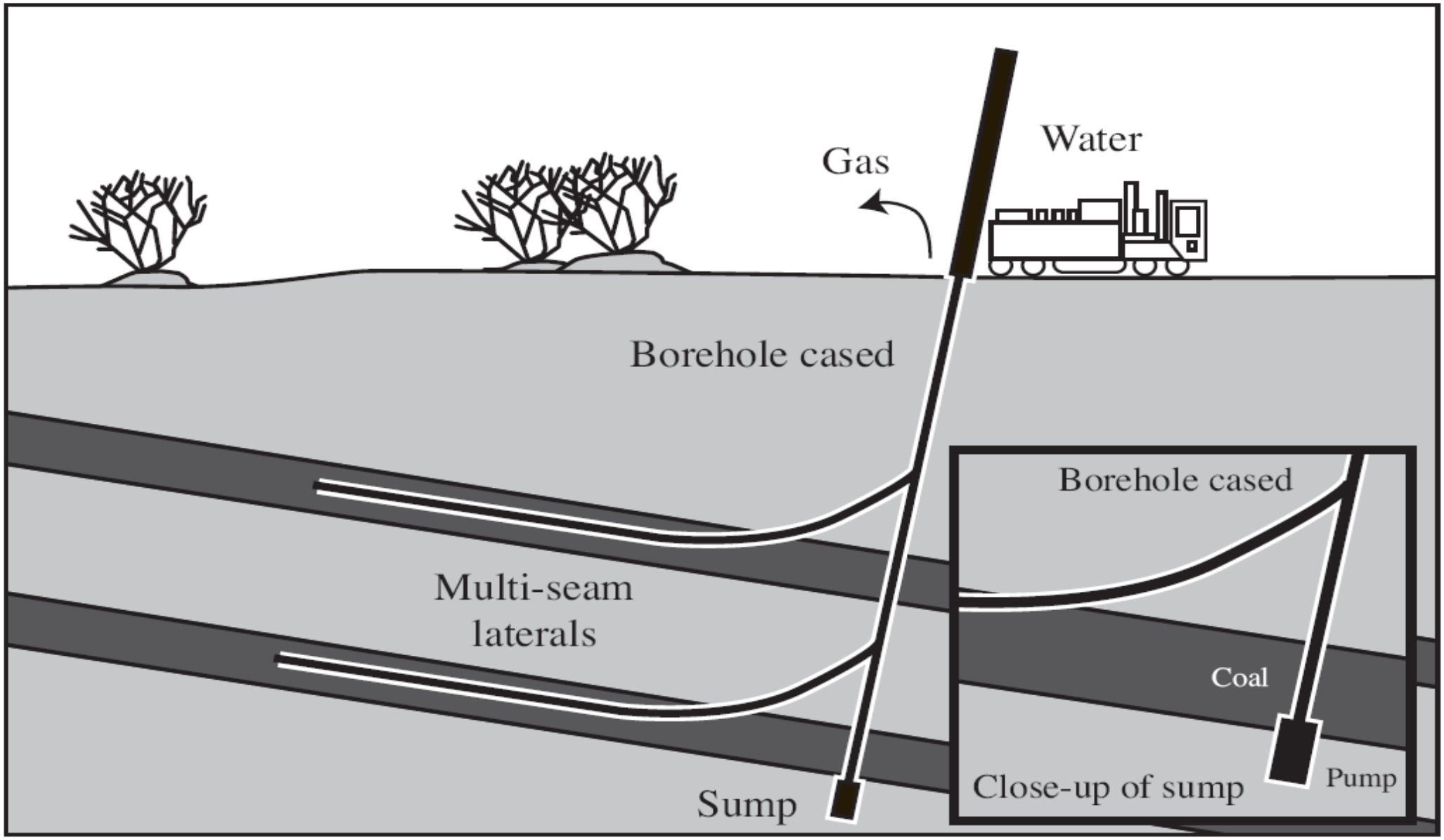
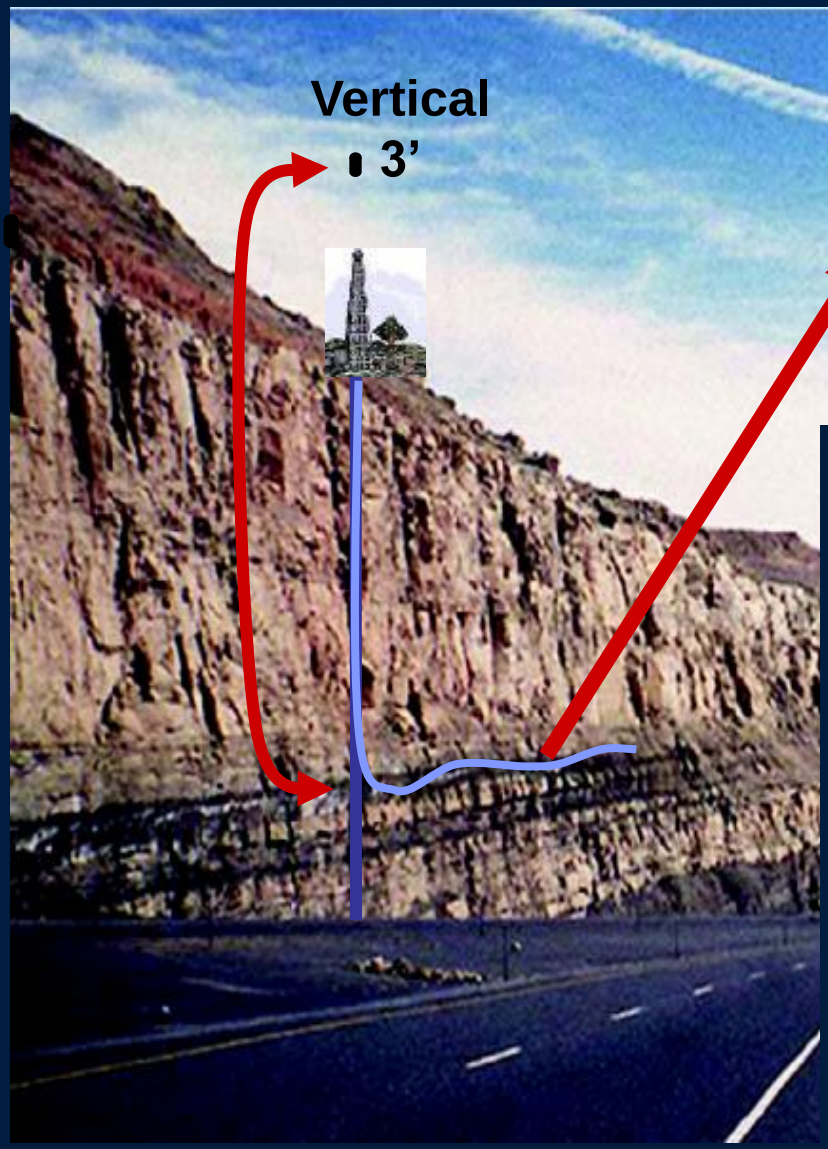


Figure 10 Multi-seam drilling for VCBM (Thompson et al)

VERTICAL vs. HORIZONTAL



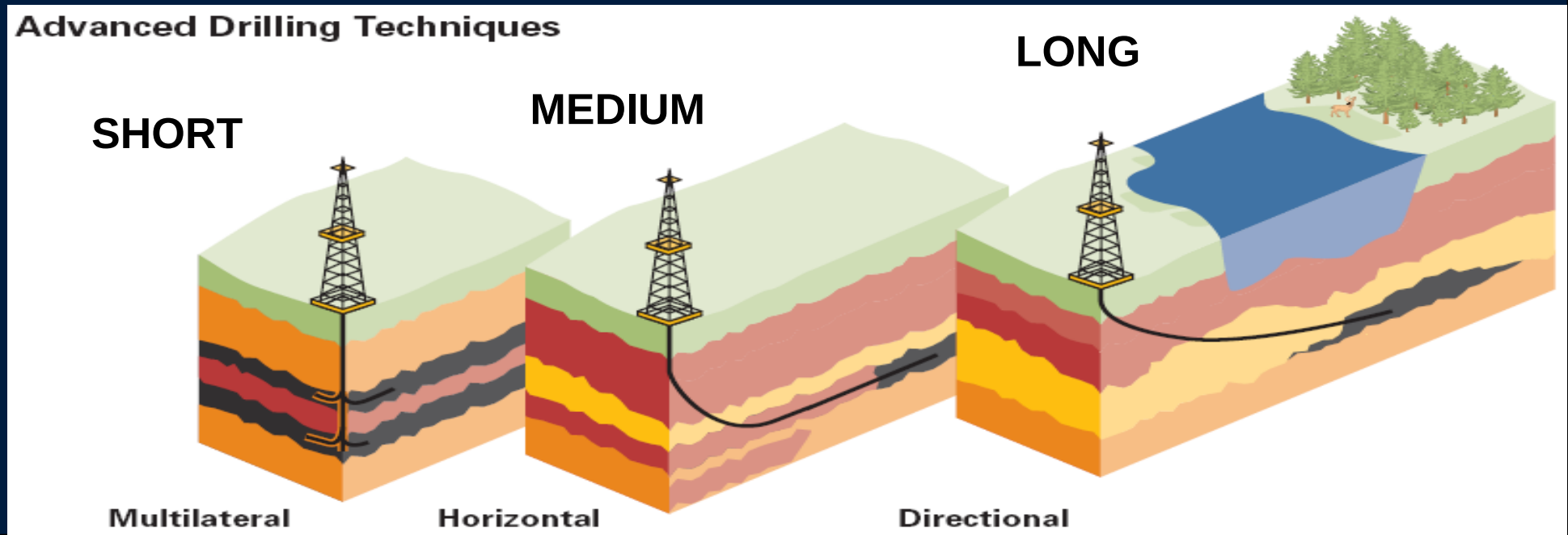
Horizontal – 3,000'+

- More footage of formation
- Increased cleat & fracture exposure
- Increased methane gas production!
- 4-10(x) Production
- 2(x) Total Well Cost

HORIZONTAL WELL TYPES

TYPES OF HORIZONTAL WELLS

- Categories of Horizontal Wells
  - LRH (LONG RADIUS)
  - MRH (MEDIUM RADIUS)
  - SHR (SHORT RADIUS)
- Horizontal classification in terms of build rates & type of wellbore
- Horizontal well design considerations

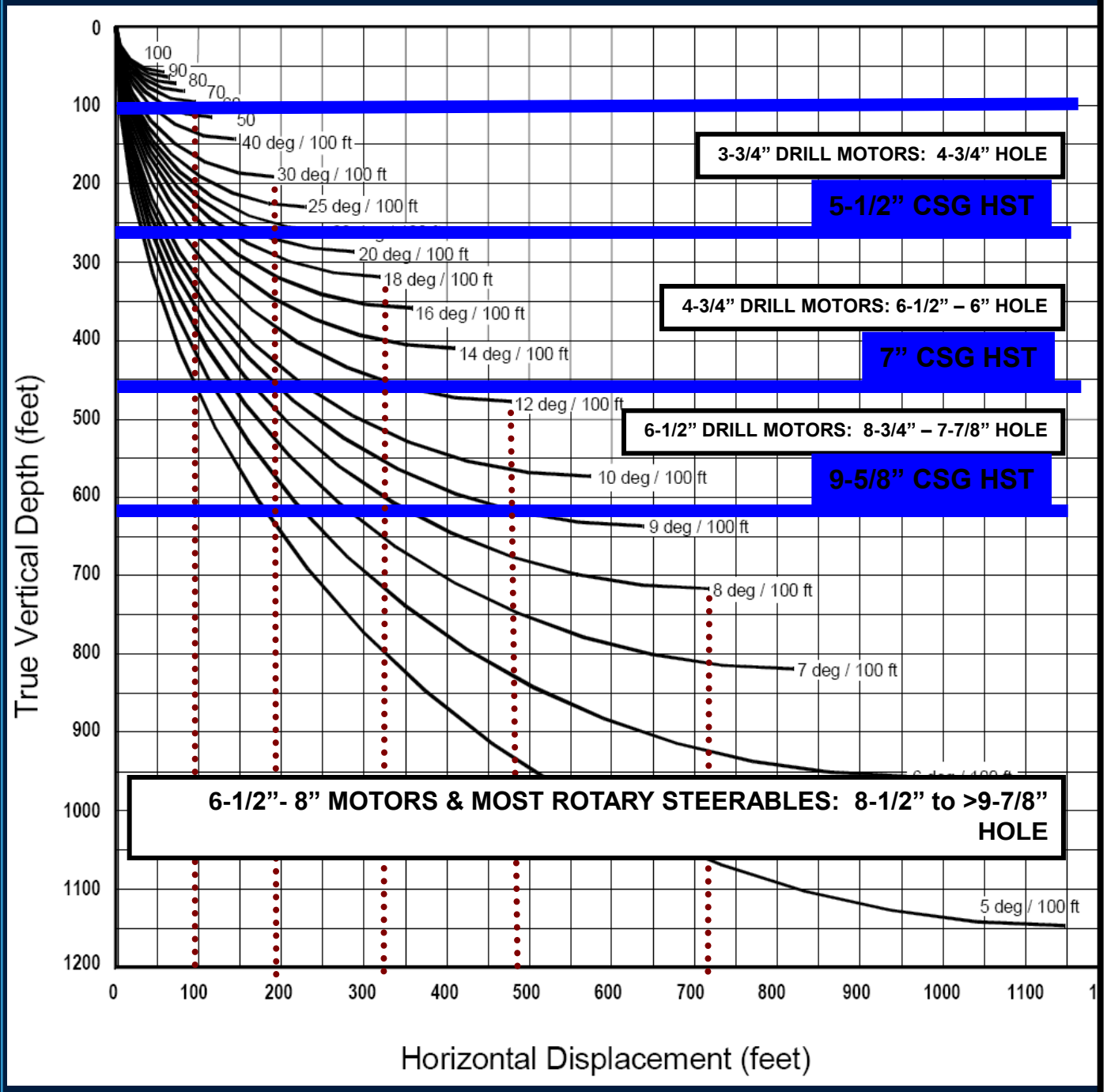


WHAT HOLE SIZE – INDUSTRY TRENDS

- TREND IS TO DRILL SMALLER CBM WELLBORES
- 4-3/4" FROM 5-1/2" RE-ENTRIES
- 4-3/4" GRASS ROOTS
- 4-3/4" IS BECOMING THE MOST COMMON, EXCEPT FOR ARKOMA
- GOOD WELLBORE STABILITY, SMALLER RIG, SMALLER FOOTPRINT, LESS IMPACT, HIGHER BUILD RATES, LESS $$$

Photo taken from:
CO_2 Sequestration Potential of Texas Low-Rank Coals
W. B. Ayers, Jr., D. A. McVay, J. L. Jensen, (Principal Investigators)

CURVE RADIUS



Build Rate °/100 ft.	Hole Radius ft.	Build Rate °/100 ft.	Hole Radius ft.
2	2865	66	87
4	1432	68	84
6	955	70	82
8	716	72	80
10	573	74	77
12	477	76	75
14	409	78	73
16	358	80	72
18	318	82	70
20	286	84	68
22	260	86	67
24	239	88	65
26	220	90	64
28	205	92	62
30	191	94	61
32	179	96	60
34	169	98	58
36	159	100	57
38	151	105	55
40	143	110	52
42	136	115	50
44	130	120	48
46	125	125	46
48	119	130	44
50	115	135	42
52	110	140	41
54	100	145	40
56	102	150	38
58	99	155	37
60	95	160	36
62	92	165	35
64	90	170	34

LATERAL BHA CONFIGURATIONS

Nominal Bit & Wellbore Diameter	PDM Diameter	MWD & LWD Tool Diameter	Lateral Push Drill Pipe	Drill Collars / Heavy Weight DP	Vertical Drillpipe	Horizontal Build Rate deg. / 100'	Horizontal Class Identifier
4-3/4"	**3-3/4"**	**3-1/2"**	2-7/8" 10.4# S-135 Premium 2-7/8" AOH Drillpipe	3-1/2" 26# Drill Collars	2-7/8" 10.4 # S-135 Premium AOH Pipe	20°/100' **30°/100'** 40°/100' 50°/100' 60°/100'	MRH20 **MRH30** MRH40 SHR50 SHR60
6-1/4"	**4-3/4"**	**4-3/4"**	3-1/2" 13.3# S-135 Premium NC38 Drill Pipe	3-1/2" 25# NC38 HWDP	3-1/2" 13.3# S-135 Premium NC38 Drill Pipe	6°/100' 12°/100' **20°/100'** 30°/100'	LRH6 MRH12 **MRH20** MRH30
8-1/2"	**6-1/2"**	**6-1/2"**	4-1/2" 14# S-135 Premium NC46 Drillpipe	4-1/2" 41# NC46 HWDP	4-1/2" 14# S-135 Premium NC46 Drillpipe	2°/100' 4°/100' 6°/100' **12°/100'** 16°/100'	LRH2 LRH4 LRH6 **MRH12** MRH16

INTERCEPT WELL DESIGNS

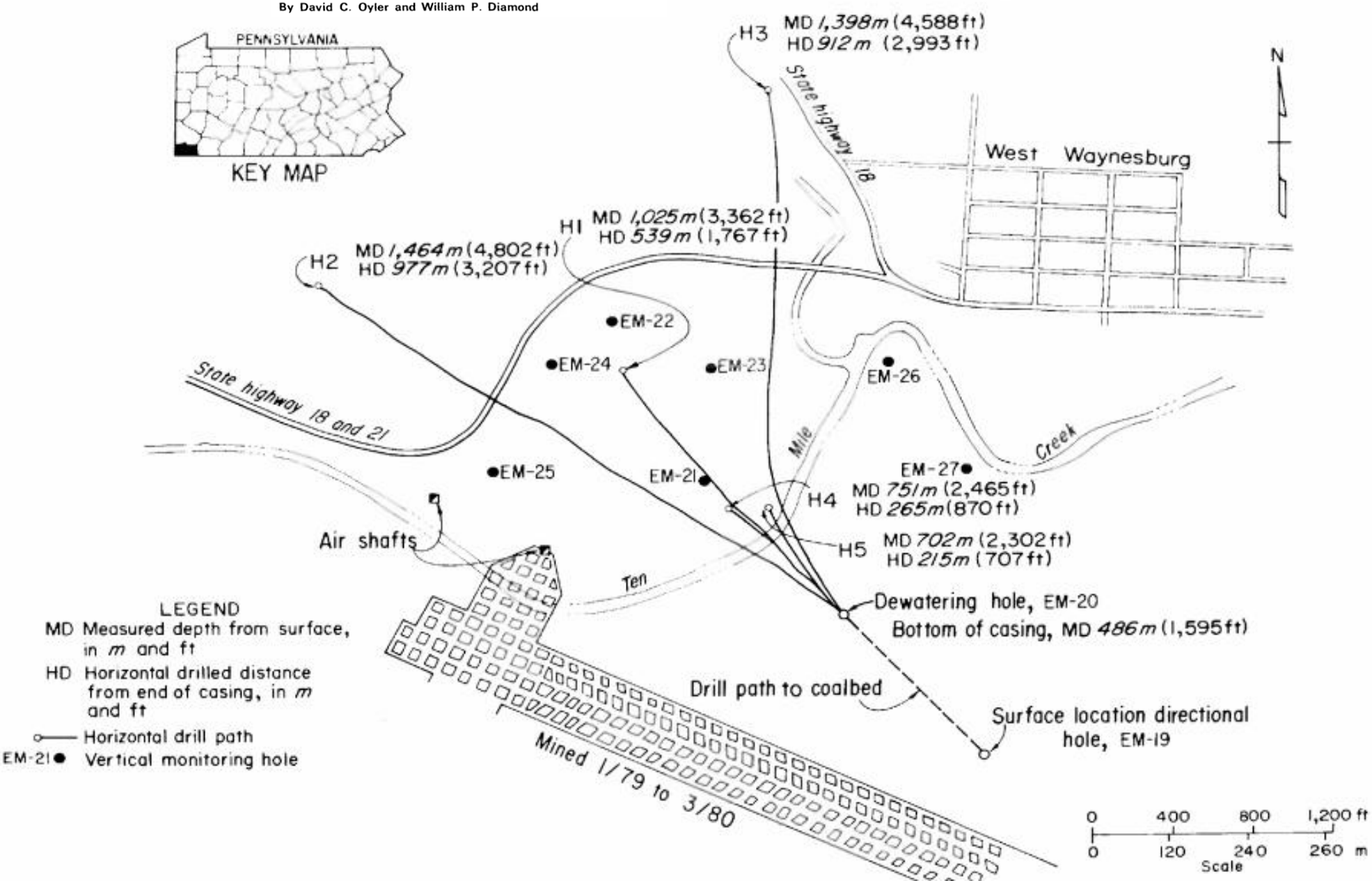
Prior Well Design

RI 8640

Drilling a Horizontal Coalbed Methane Drainage System From a Directional Surface Borehole

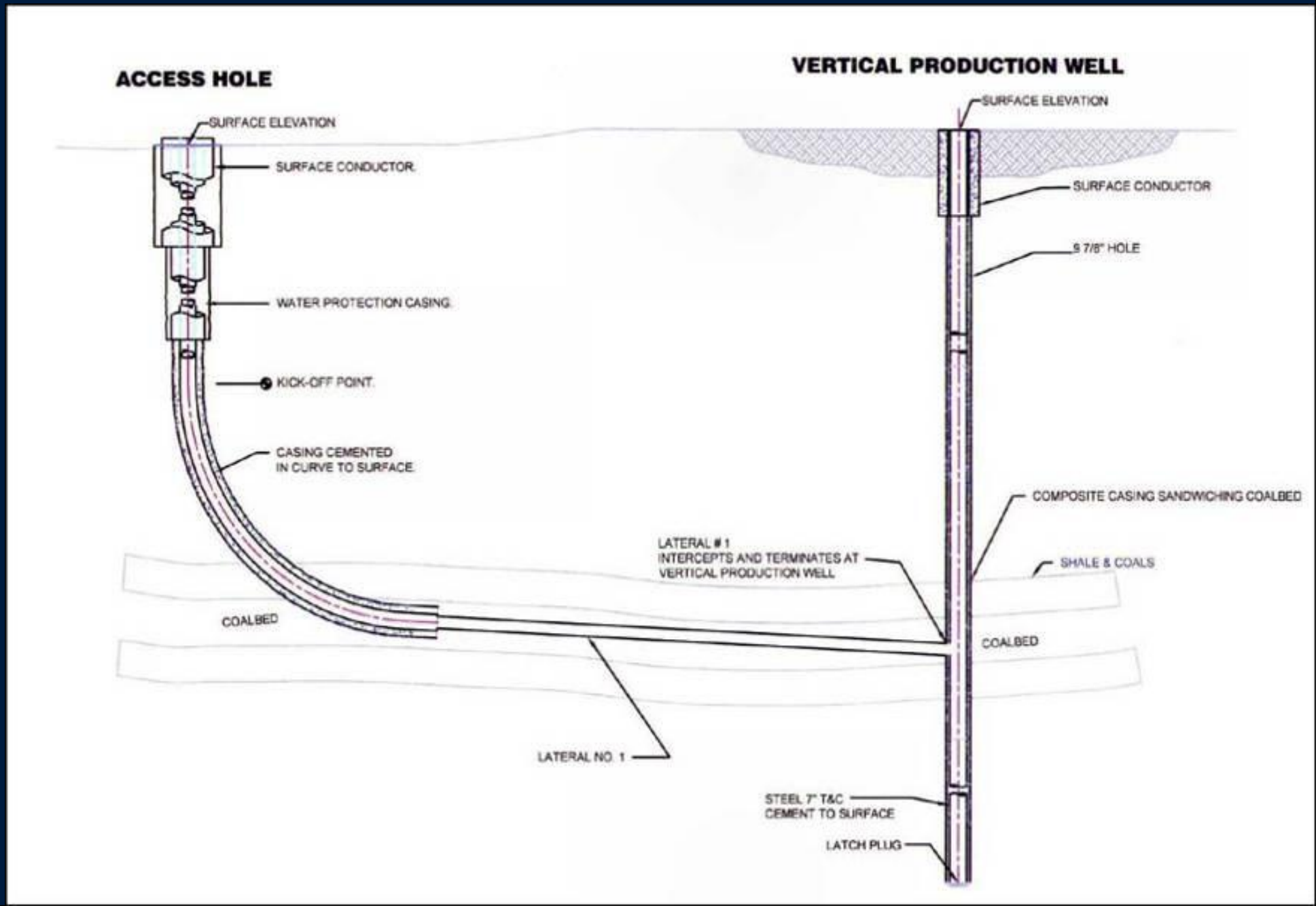
Bureau of Mines Report of Investigations/1982

By David C. Oyler and William P. Diamond



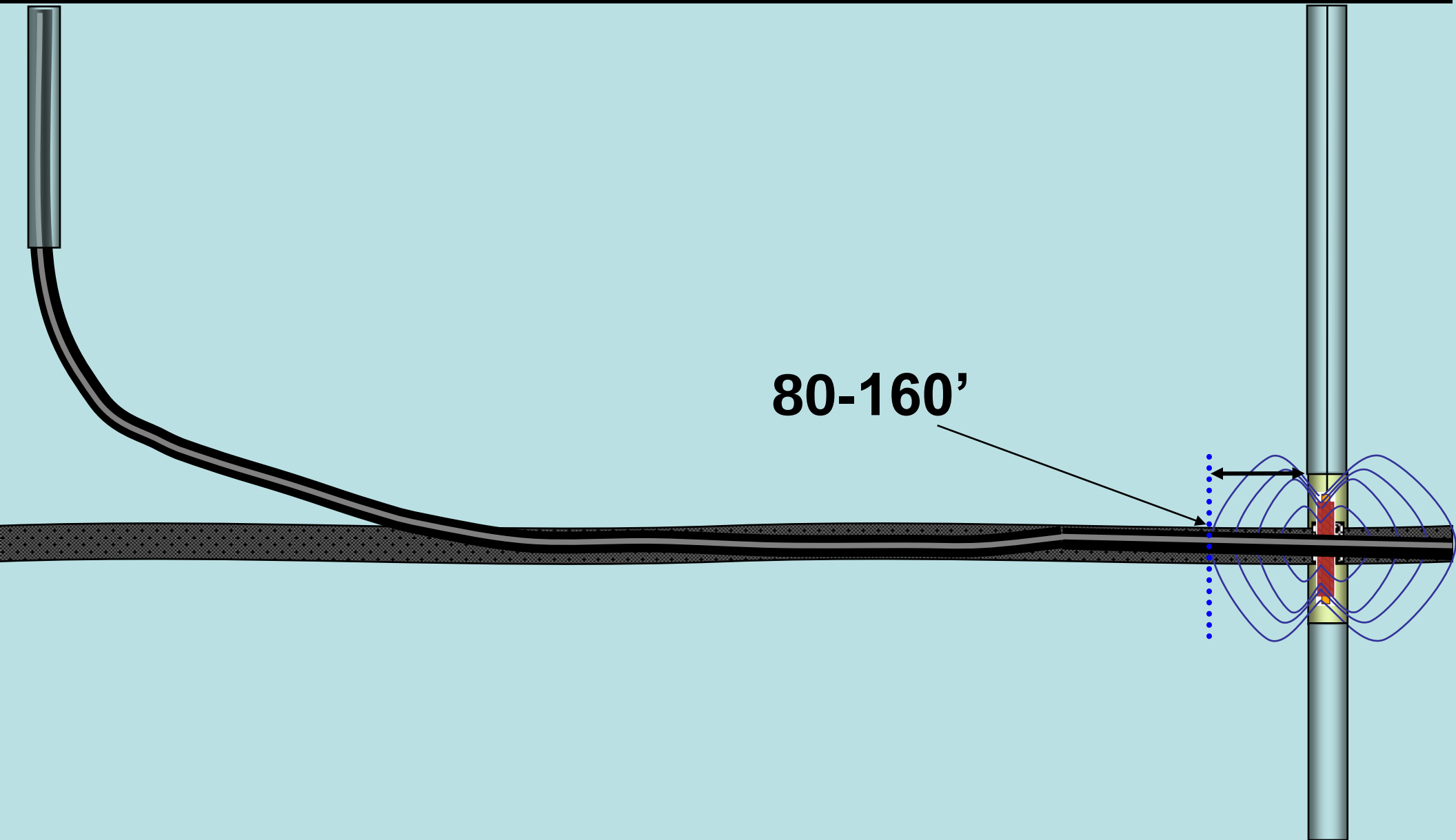
HORIZONTAL DOWNDIP INTERCEPT

- **DOWNDIP HORIZONTAL ACCESS TO VERTICAL PRODUCTION**



UCG-CSH END OF LATERAL INTERCEPT WITH THE MWD

CBM Horizontal to Vertical Intercept

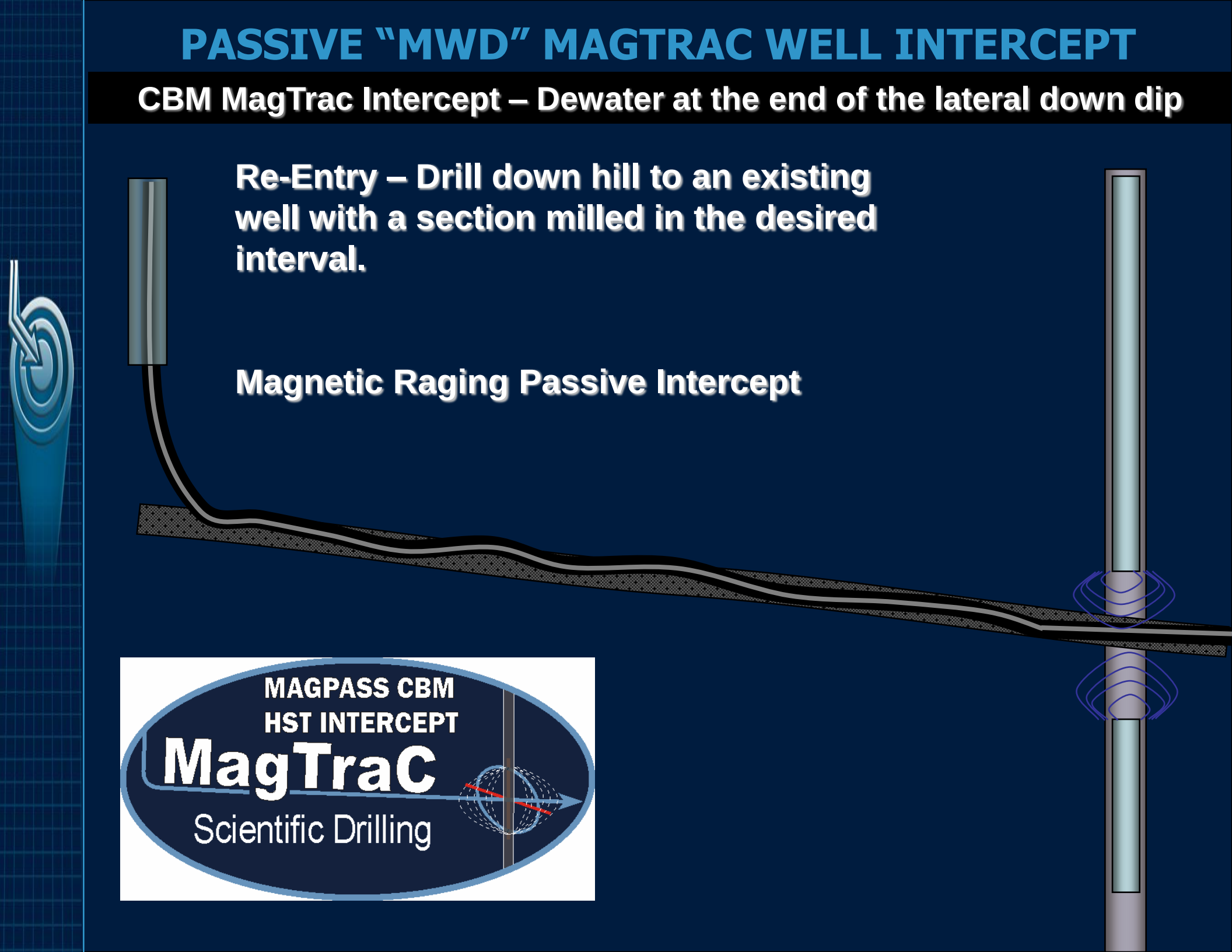


PASSIVE "MWD" MAGTRAC WELL INTERCEPT

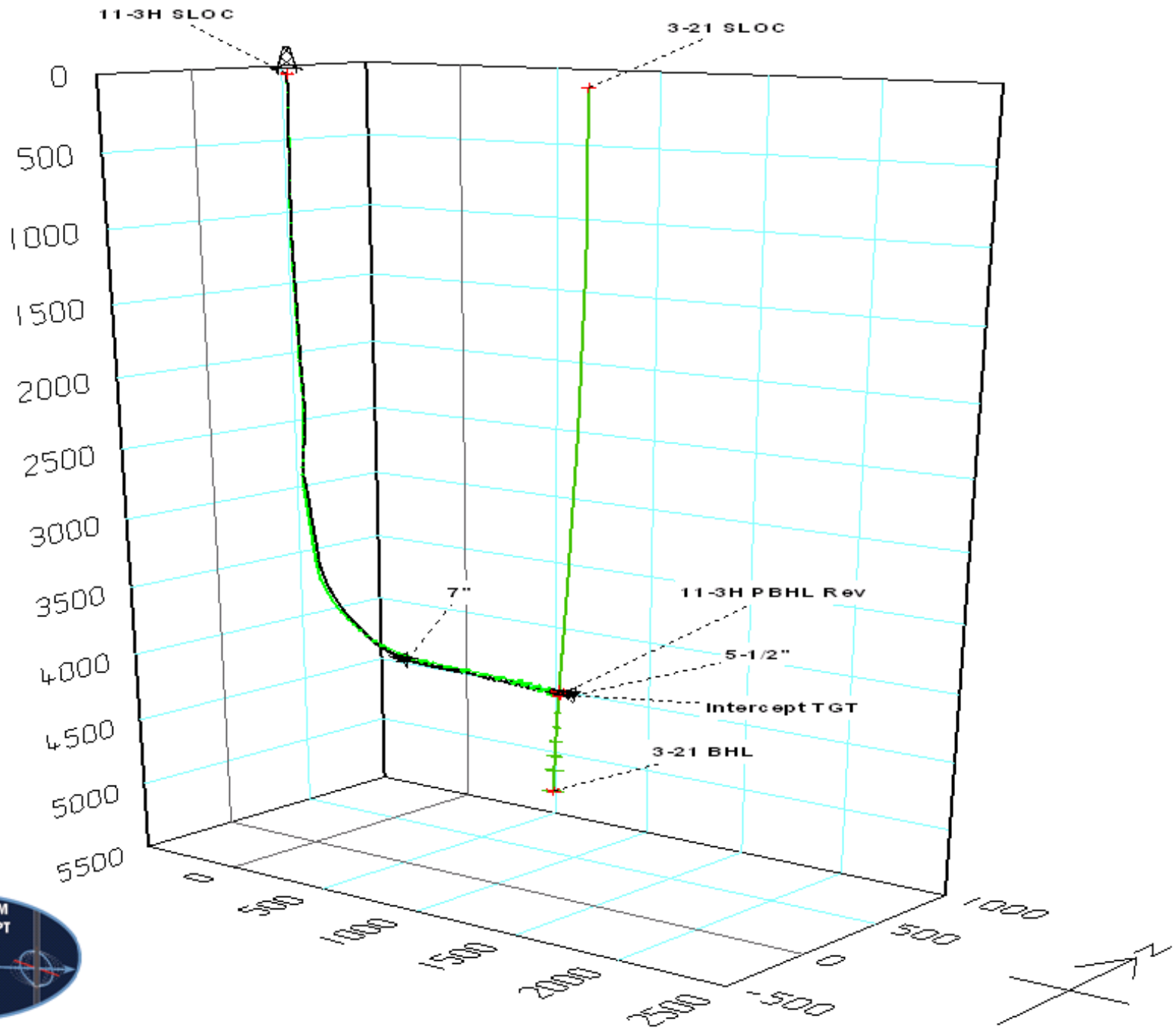
CBM MagTrac Intercept – Dewater at the end of the lateral down dip

Re-Entry – Drill down hill to an existing well with a section milled in the desired interval.

Magnetic Raging Passive Intercept



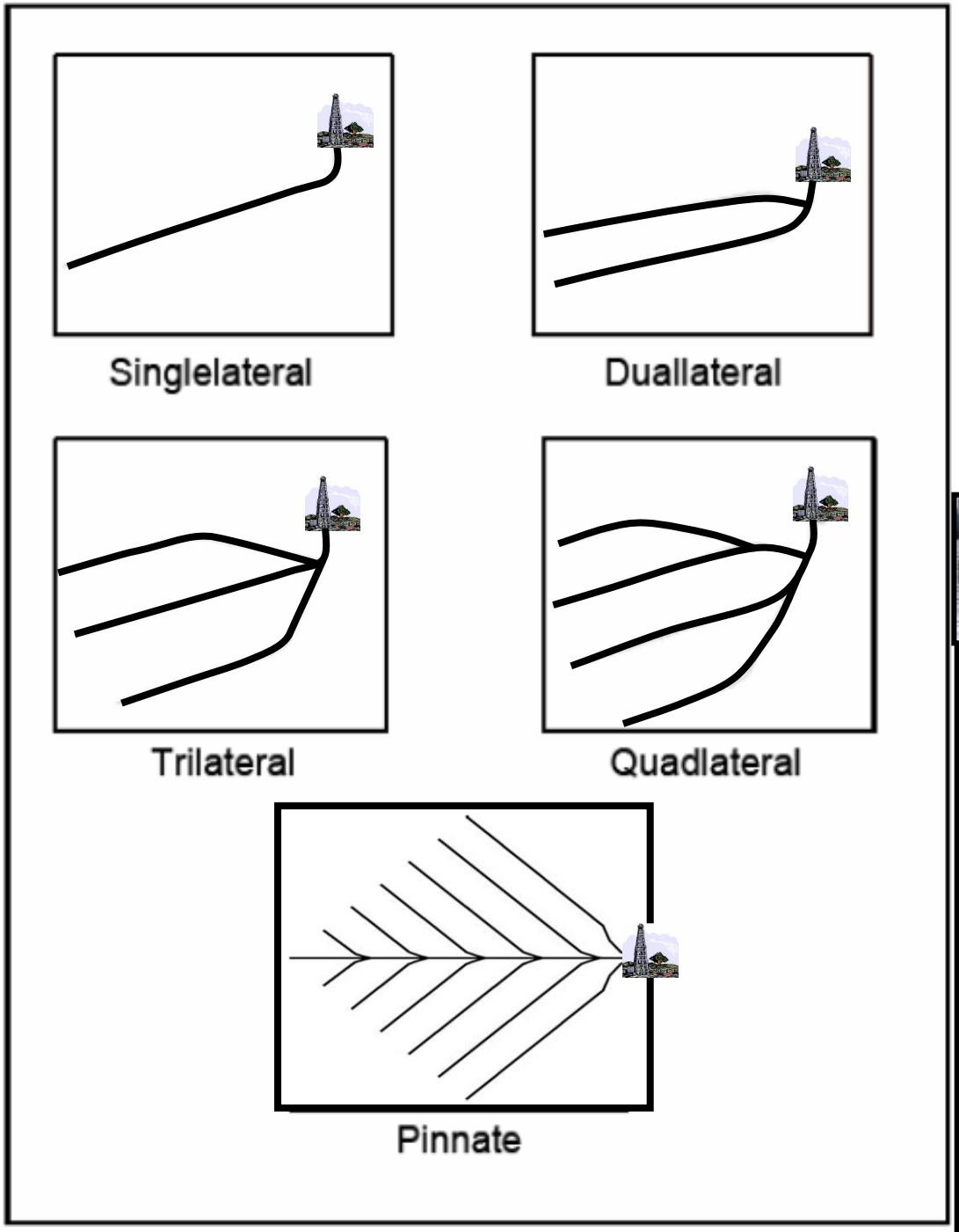
NORTH COLORADO CBM GRH INTERCEPT



MAGPASS CBM HST INTERCEPT
MagTraC
Scientific Drilling

WELL DESIGN OPTIMIZATION CASE STUDY

OPTIMAL WELL DESIGN?



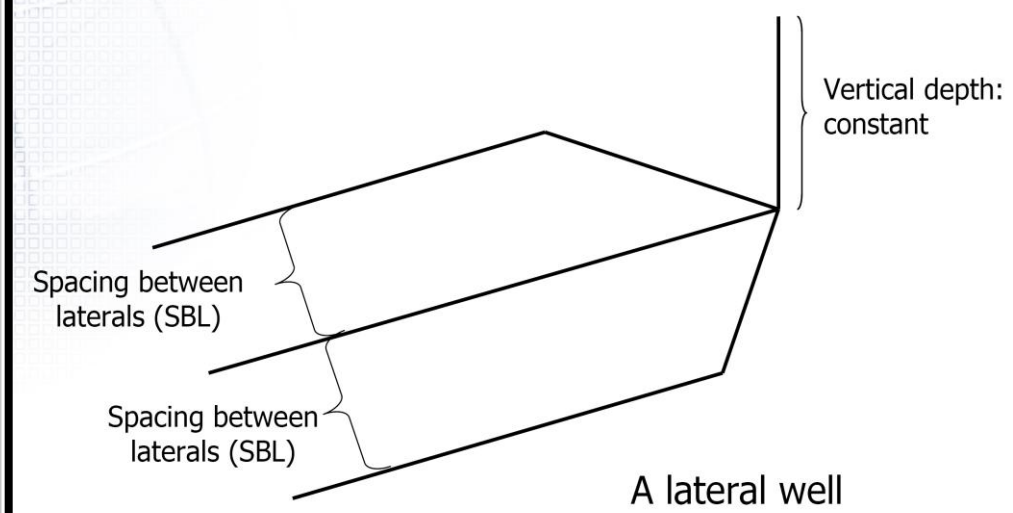
- **FIVE HORIZONTAL WELL PROFILES ANALYZED**

Nikola Maricic, Chevron
Shahab D. Mohaghegh, WVU
Emre Artun, WVU

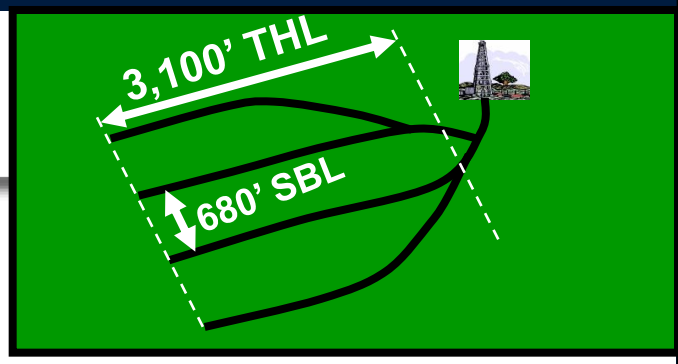
ATCE 2005
Dallas, Texas
SPE Paper # 96018

A Parametric Study on the Benefits of Drilling Multilateral and Horizontal Wells in Coalbed Methane Reservoirs

1. Total Horizontal Length (THL)
2. Spacing Between Laterals (SBL)



Conclusions



CBM recovery can significantly benefit from unconventional well configurations.

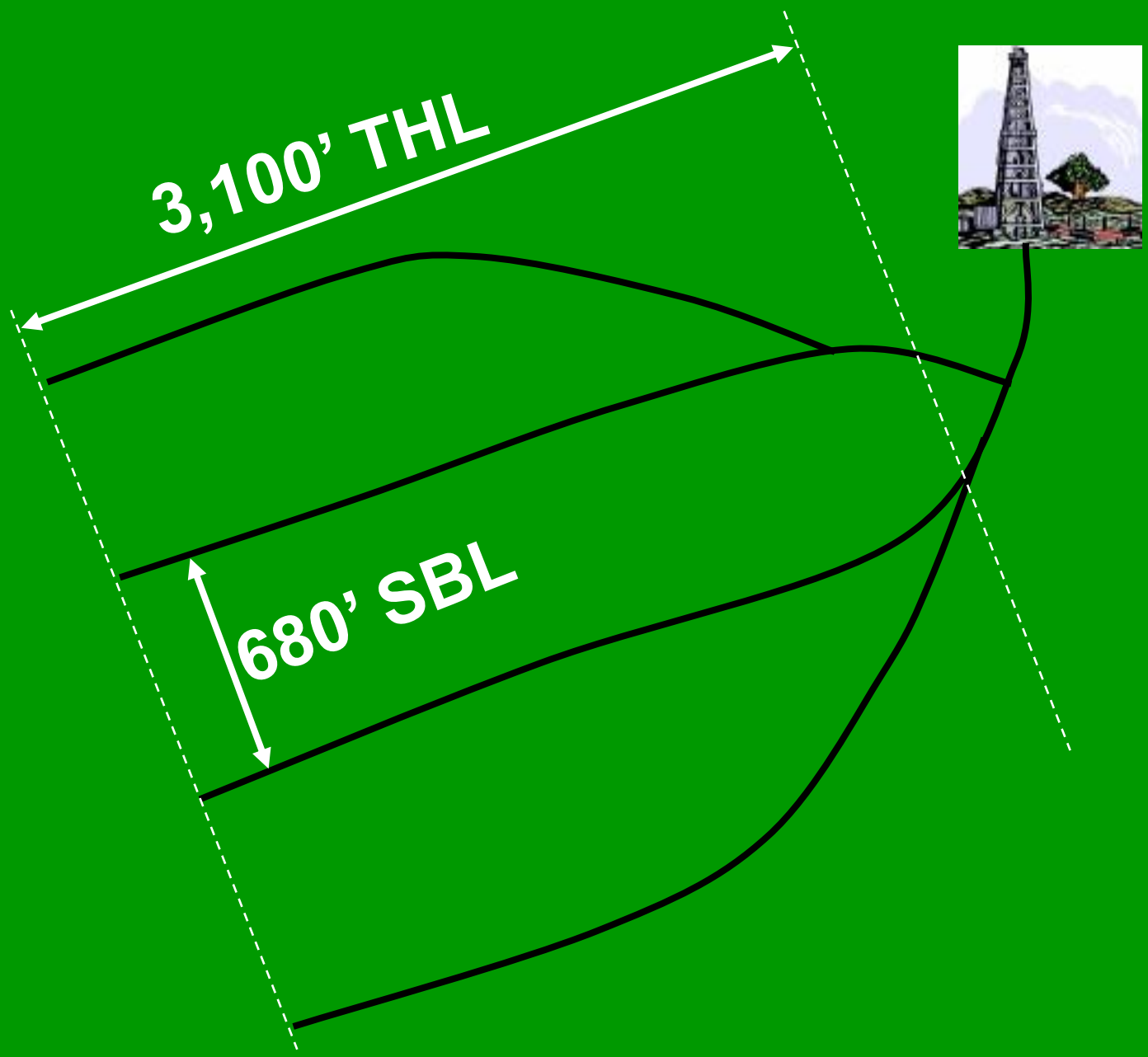
Considering a 320 acres of drainage area, the optimum configuration that the results of this study suggests is:

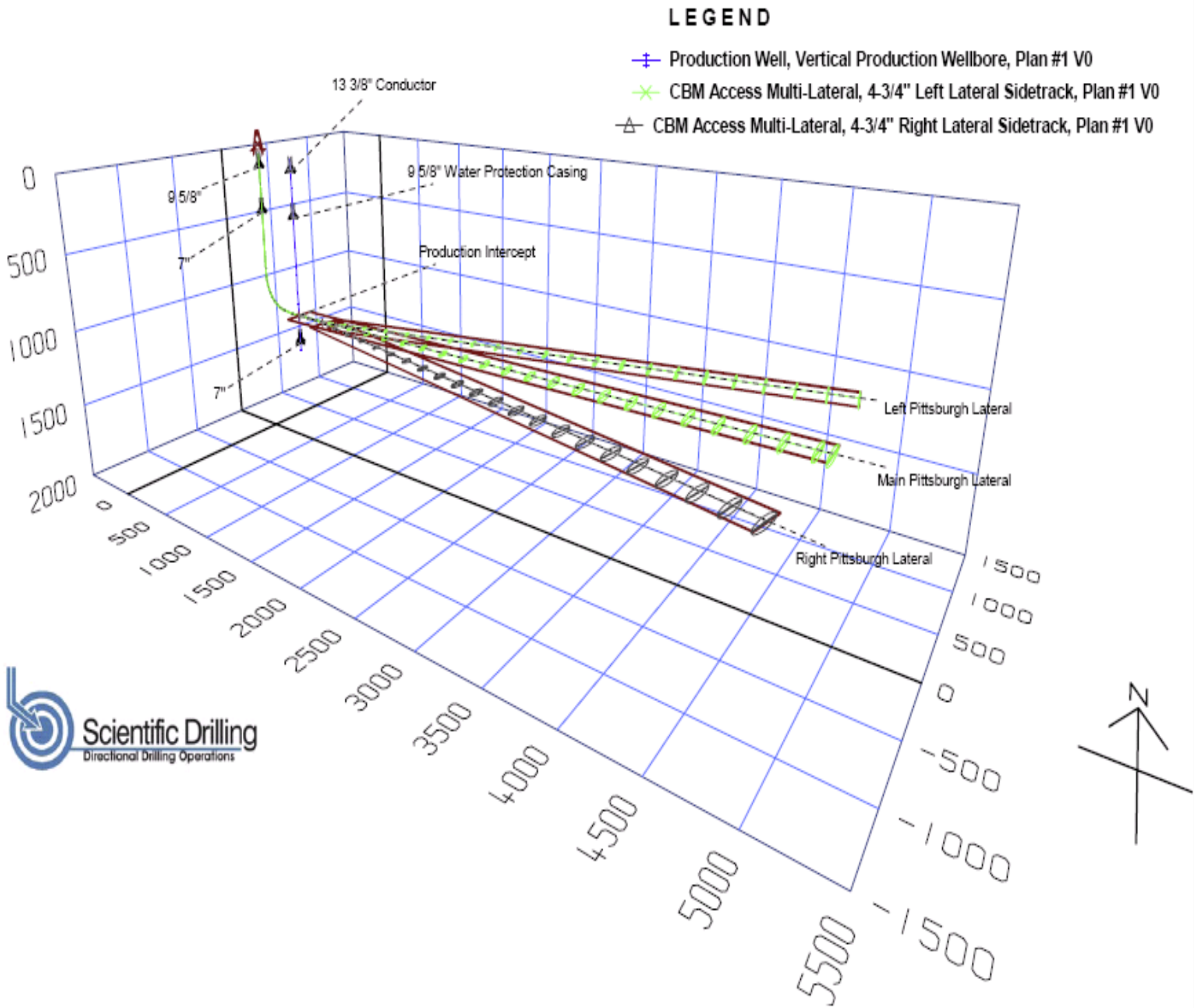
- Quadlateral well configuration:

  SBL = 680 ft, and THL = 3,100 ft.

Time constant has a significant effect on the first year production, although it does not have a considerable effect on overall recovery.

WELL DESIGN OPTIMIZATION




LEGEND
Production Well, Vertical Production Wellbore, Plan #1 V0
CBM Access Multi-Lateral, 4-3/4" Left Lateral Sidetrack, Plan #1 V0
CBM Access Multi-Lateral, 4-3/4" Right Lateral Sidetrack, Plan #1 V0
13 3/8" Conductor
9 5/8" Water Protection Casing
9 5/8"
7"
7"
Production Intercept
Left Pittsburgh Lateral
Main Pittsburgh Lateral
Right Pittsburgh Lateral
0
500
1000
1500
2000
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
1500
1000
500
0
-500
-1000
-1500
N
Scientific Drilling
Directional Drilling Operations

WEST VIRGINIA EXAMPLE

Field: MONONGALIA COUNTY, WV

Scientific Drilling
Directional Drilling Operations

TARGET DETAILS

Name	TVD	+N/-S	+E/-W	Northing	Easting	Shape
WEST TD	966.00	4880.60	-505.69	440440.68	1754162.34	Rectangle (3800x200)
CENTER TD	966.00	4564.57	1909.66	440101.22	1756574.50	Rectangle (3900x200)
SC13A INTERCEPT	966.00	428.52	145.19	435982.49	1754769.97	Circle (Radius: 1)
EAST TD	966.00	3369.88	3543.31	438890.73	1758196.48	Rectangle (3881x200)

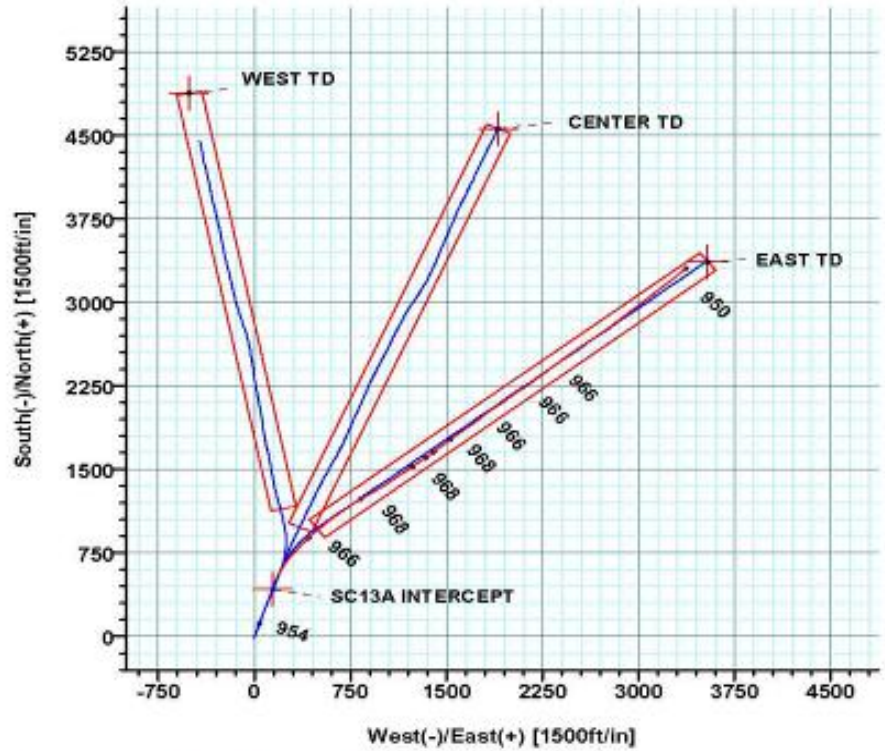
SITE DETAILS

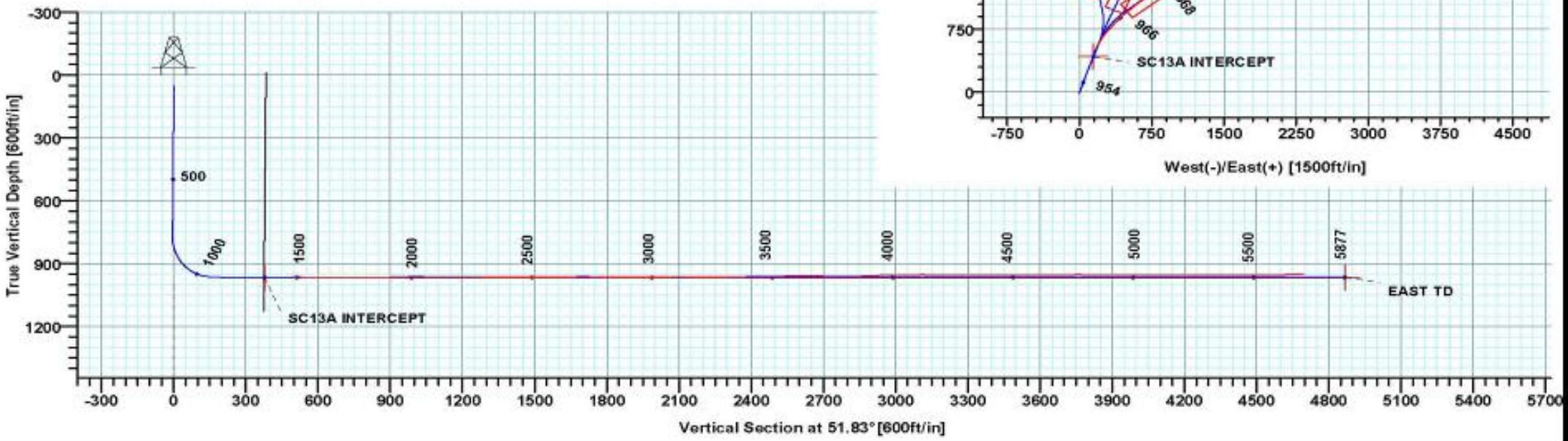
SC-13A WELL LOCATION
Monongalia County, WV

Site Centre Northing: 435,555.40
Easting: 1,754,620.63

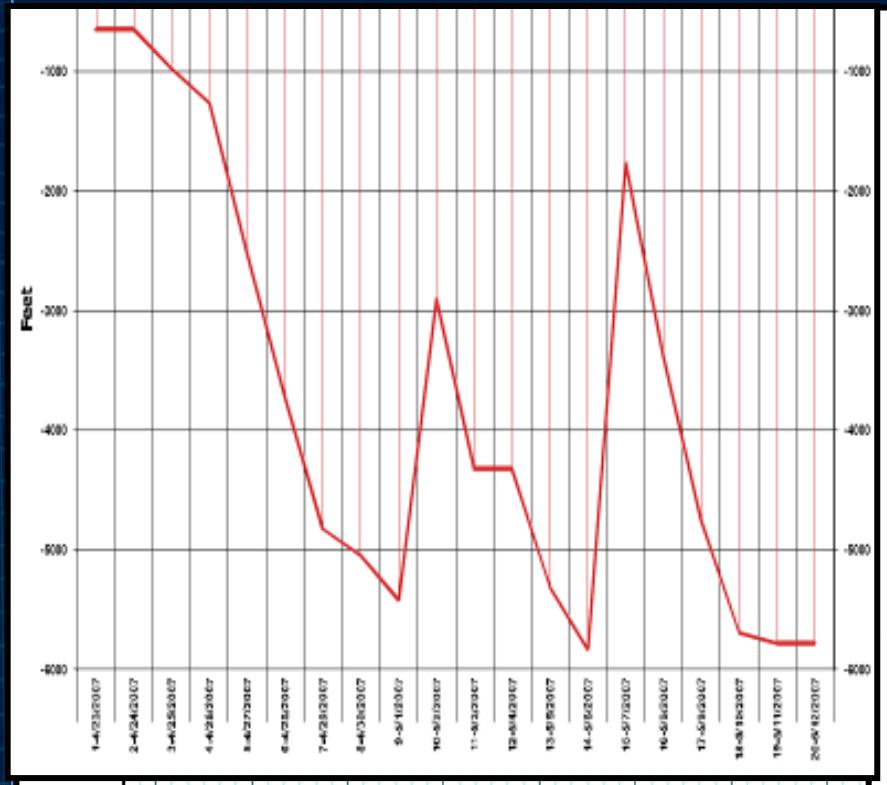
Ground Level: 1203.65
GL + 8 RKB: 1211.65
Convergence: -0.56

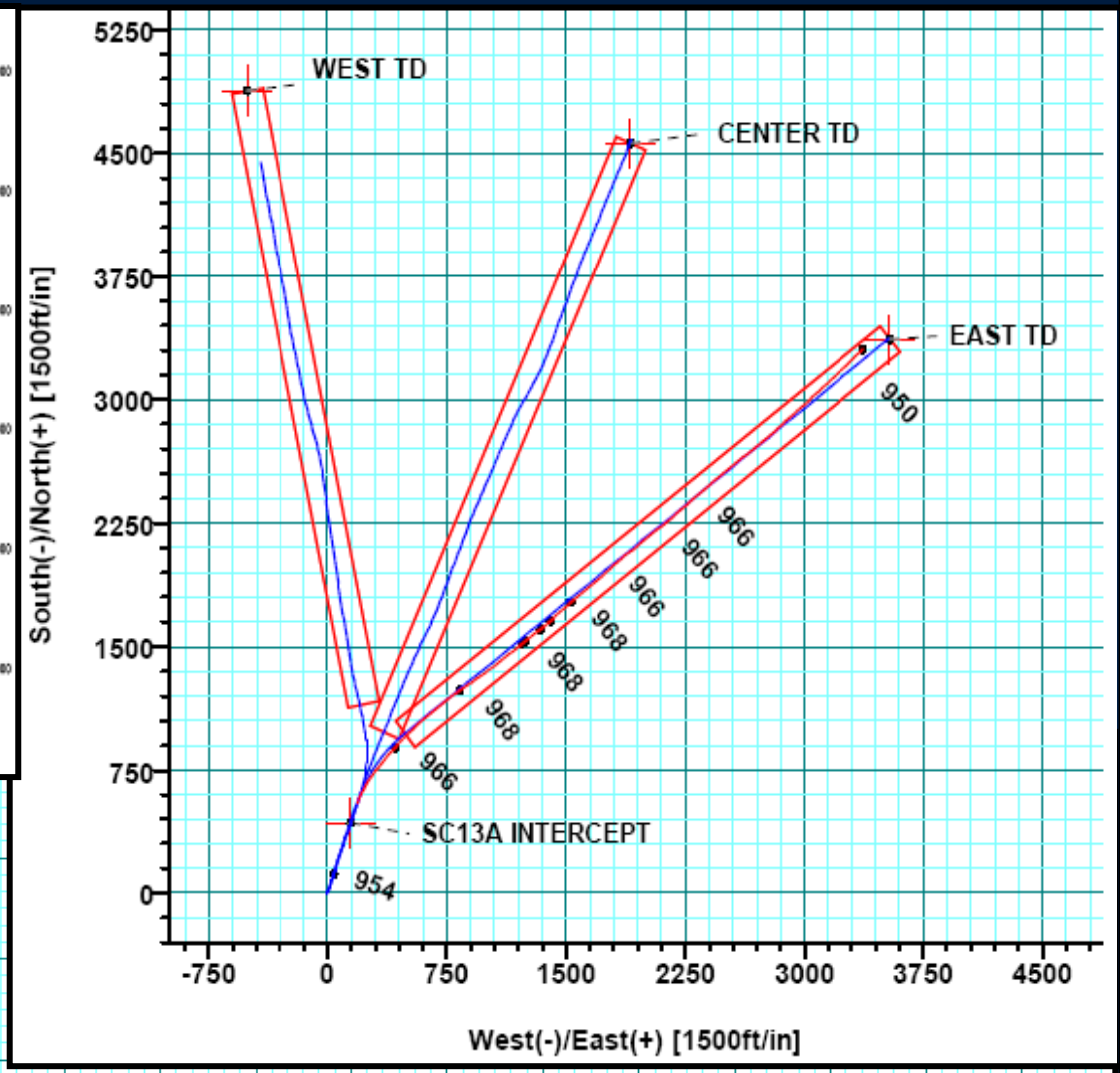
Plot Date: 4/23/2007
By: Carl Bakay
Scientific Drilling, Inc.
800-876-7302
carl.bakay@scientificdrilling.com

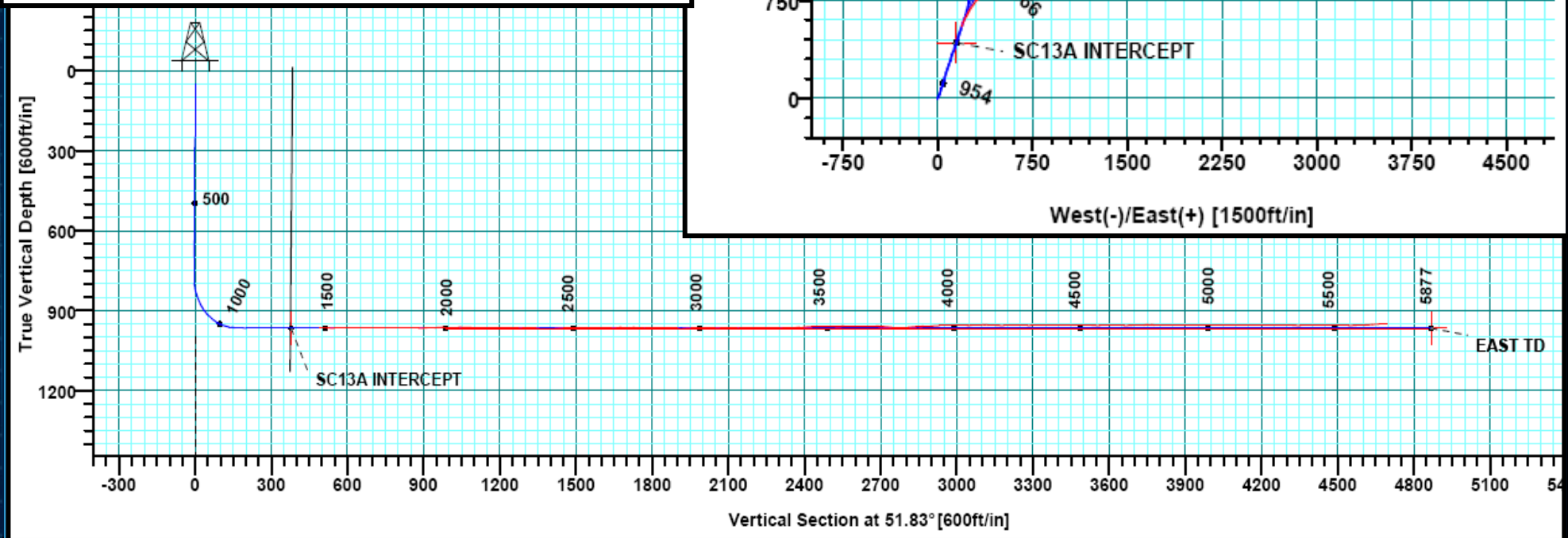




NORTHERN APPALACHIAN OPERATIONS







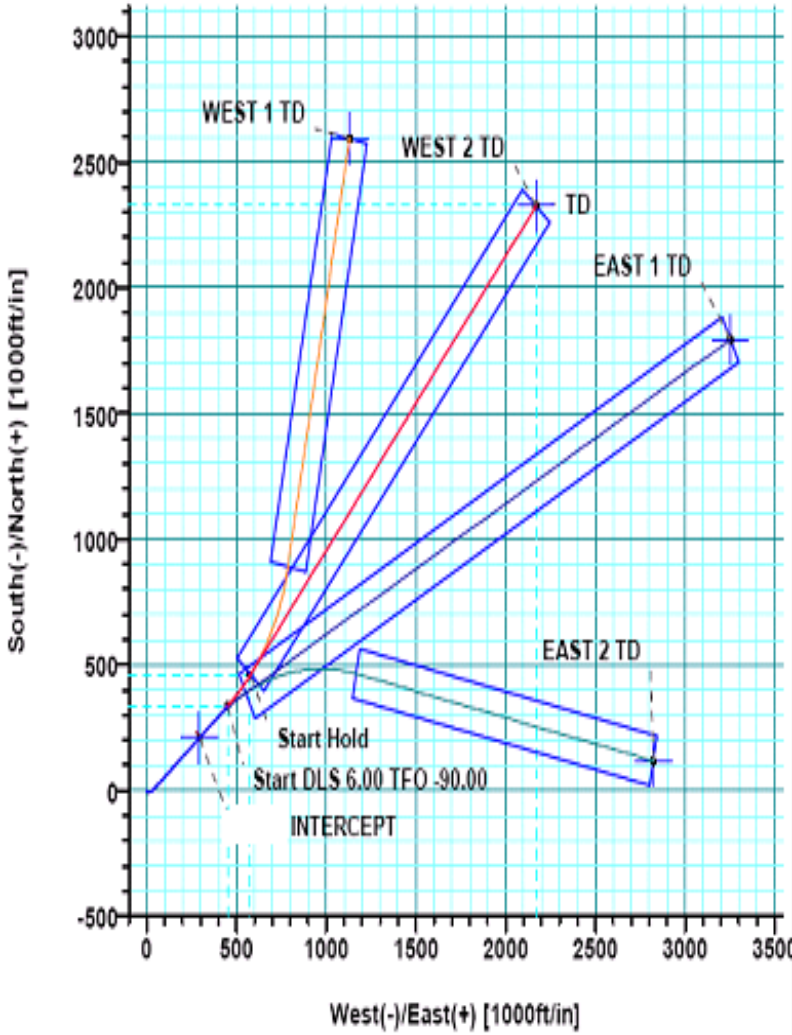
CBM - WELL DESIGN OPTIMIZATION

TARGET DETAILS

Name	TVD	+N/-S	+E/-W	Northing	Easting	Shape
EAST 1 TD	910.00	1794.94	3253.94			Rectangle (3044x200)
EAST 2 TD	910.00	118.94	2825.58			Rectangle (1693x200)
GH29 INTERCEPT	910.00	211.85	296.45			Circle (Radius: 1)
WEST 1 TD	910.00	2593.42	1131.45			Rectangle (1735x200)
WEST 2 TD	910.00	2327.17	2171.86			Rectangle (2452x200)

SECTION DETAILS

Sec	MD	Inc	Azi	TVD	+N/-S	+E/-W	DLeg	TFace	VSec	Target
1	1383.89	90.00	51.13	910.00	337.36	452.16	0.00	0.00	550.14	
2	1561.45	90.00	40.48	910.00	460.96	579.28	6.00	-90.00	726.68	
3	4014.82	90.00	40.48	910.00	2327.17	2171.86	0.00	0.00	3180.06	WEST 2 TD



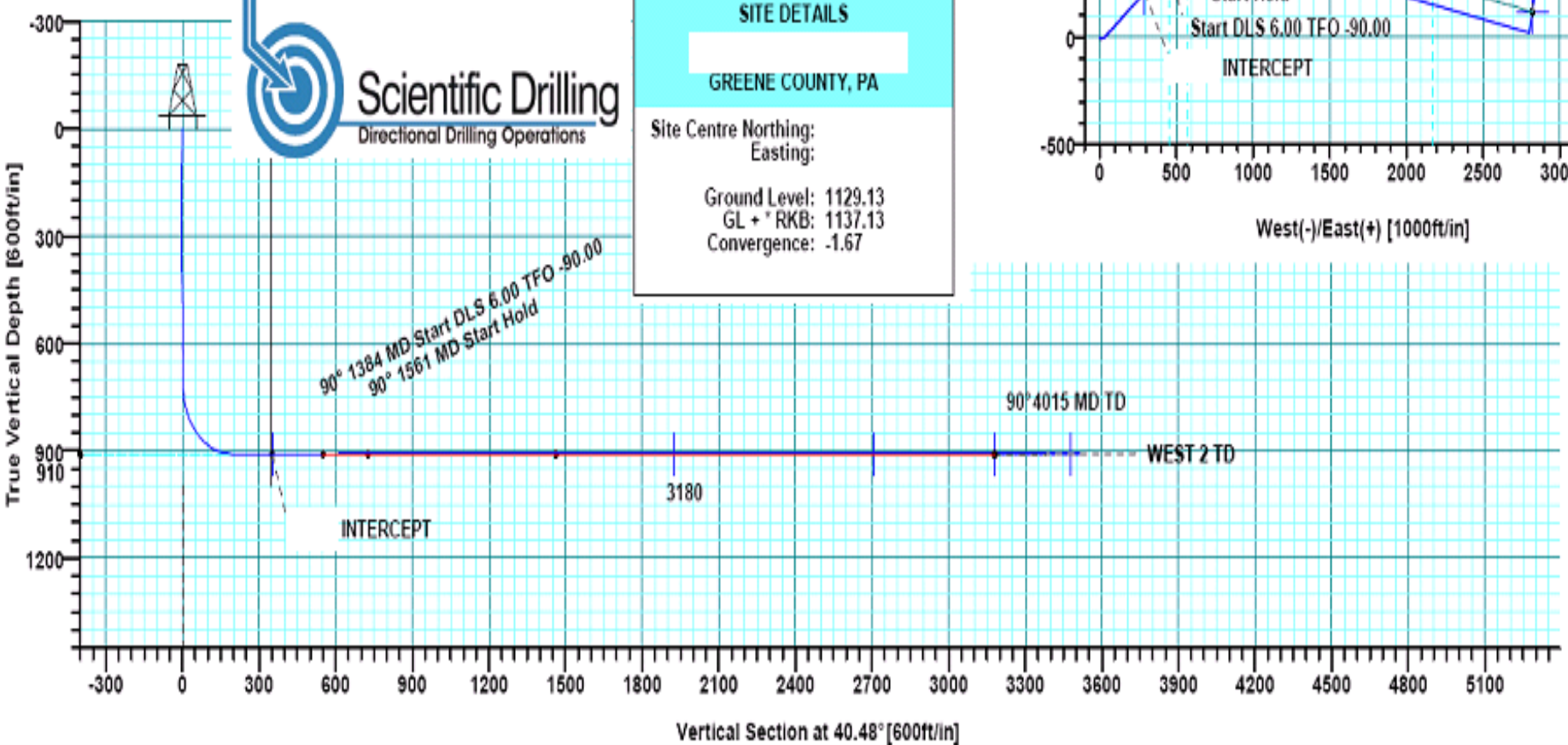
Scientific Drilling
Directional Drilling Operations

SITE DETAILS

GREENE COUNTY, PA

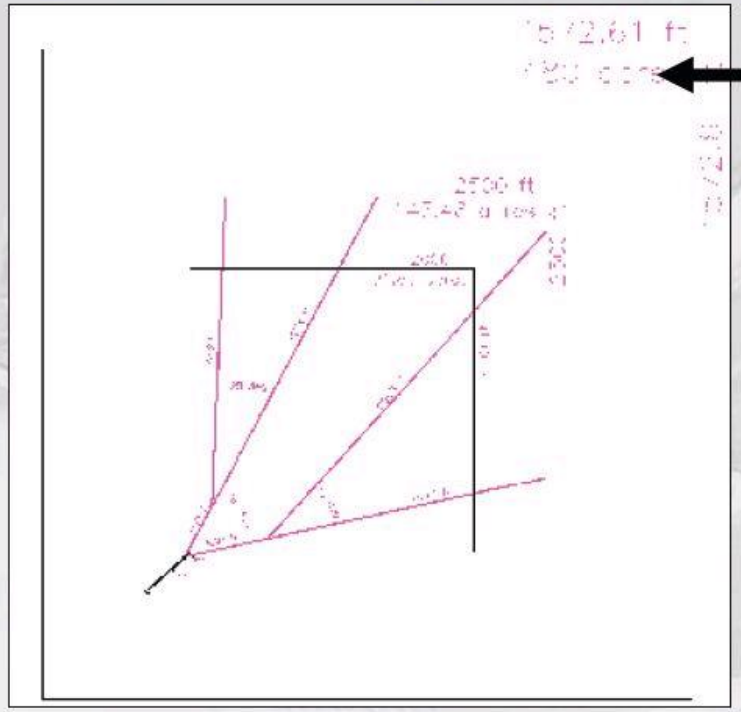
Site Centre Northing:
Easting:

Ground Level: 1129.13
GL + * RKB: 1137.13
Convergence: -1.67



Single Bit Cumulative Footage Drilling Records with Insert Bits

Mountaineer Operations (CBM)



CNX Gas reservoir engineers designed an asymmetric quad pattern in 2007.

- In 2007, drilling time was lowered from 21 days to 15 days with an improved well design
- In 2008, the use of near-bit gamma detectors could further lower drilling time from 15 to 12 days

Mountaineer Operations set three world records for horizontal drilling with a single drill bit (per Smith International).

COMPONENTS OF DIRECTIONAL STEERABLE SYSTEMS

DRILL STRING / BHA

DIRECTIONAL DRILLING EQUIPMENT

- Drill Bit
- Positive Displacement Drill Motor
- MWD System (MP or E-Field)
- Logging While Drilling Tool
- Non-Magnetic Collar
- Push Drill Pipe or Collars
- Heavy Weight Drill Pipe
- Drill Pipe from Surface

COALBED METHANE HORIZONTAL OPERATIONS - DRILL BIT SELECTION

Tri-Cone Bit

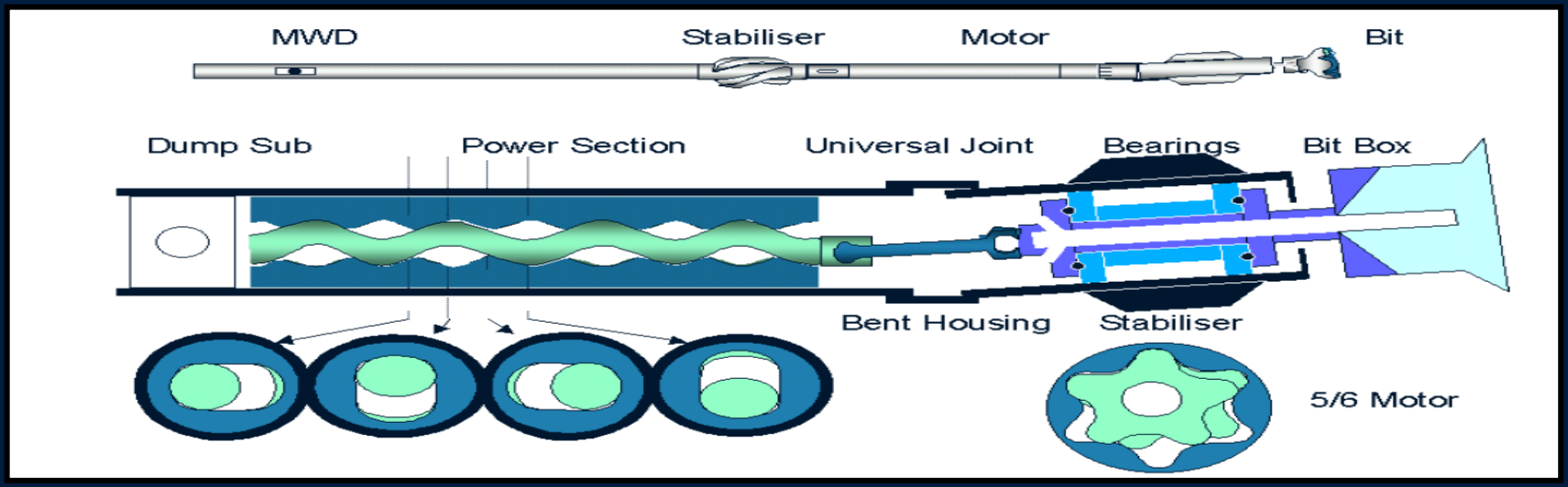
Tri-Cone and PDC Bits

PDC Bit

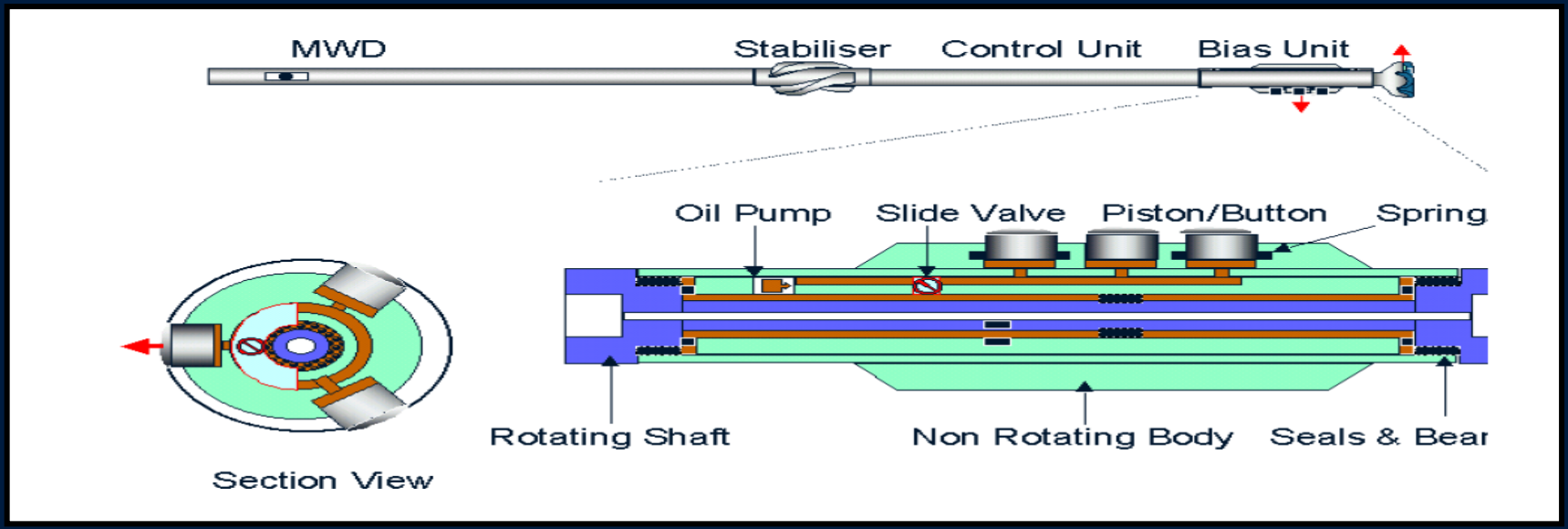
CURRENT DIRECTIONAL NAVIGATION DRILLING SYSTEMS

(DEFLECTION / STEERING)

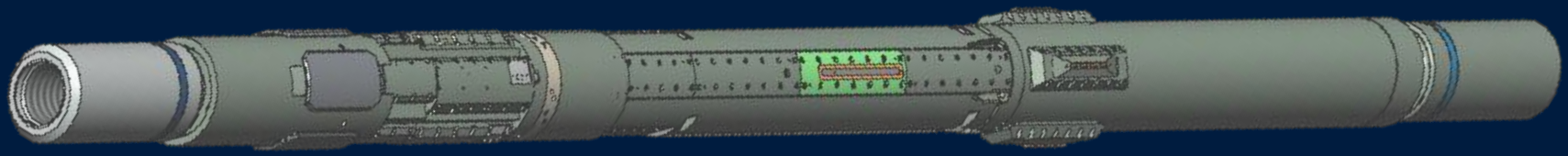
DIRECTIONAL DRILLING CURRENT SURVEY & DIRECTIONAL STEERING METHODS



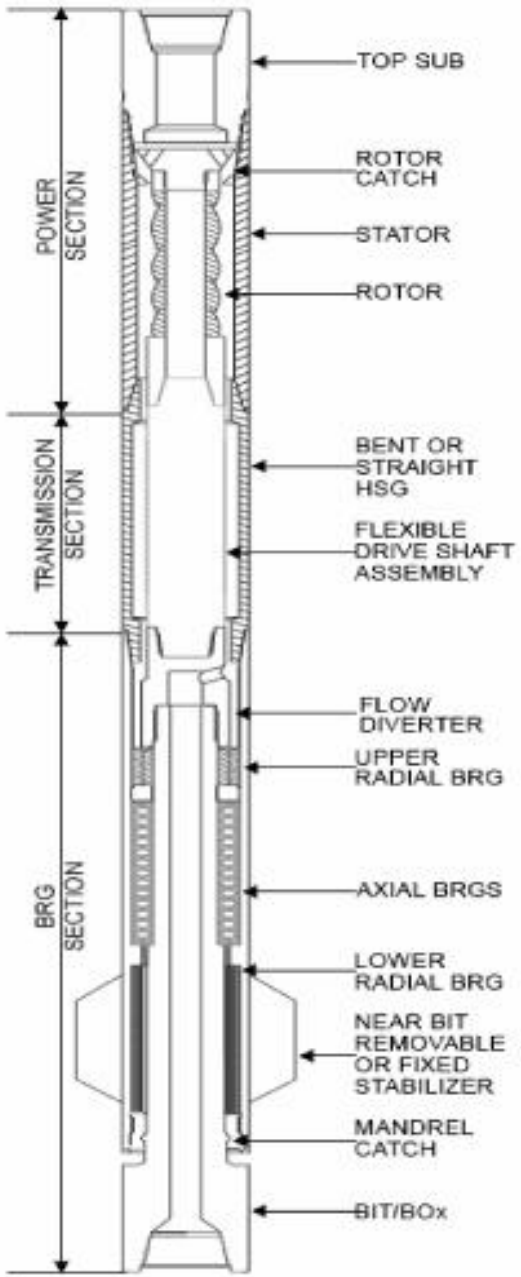
BENT HOUSING DRILL MOTOR



GENERIC HYBRID ROTARY STEERABLE



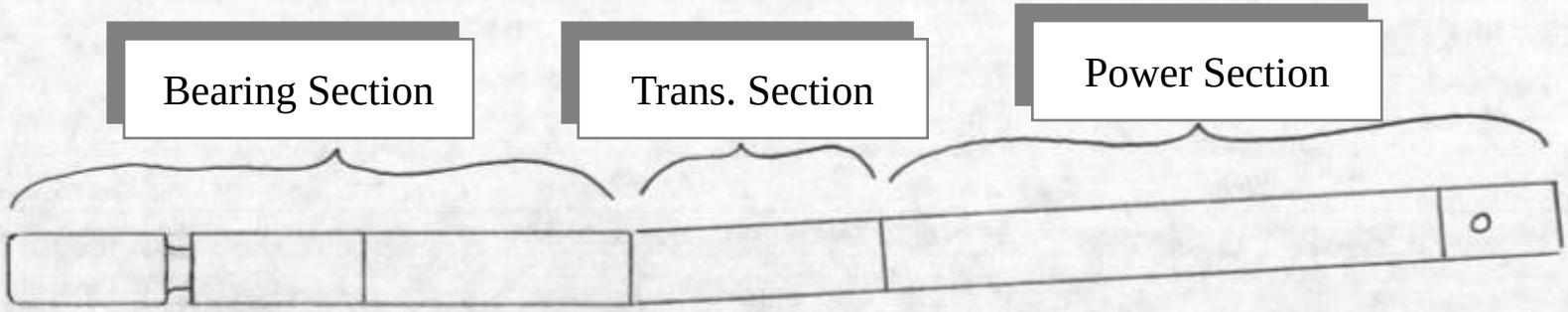
POSITIVE DISPLACEMENT MOTOR (BENT HOUSING)

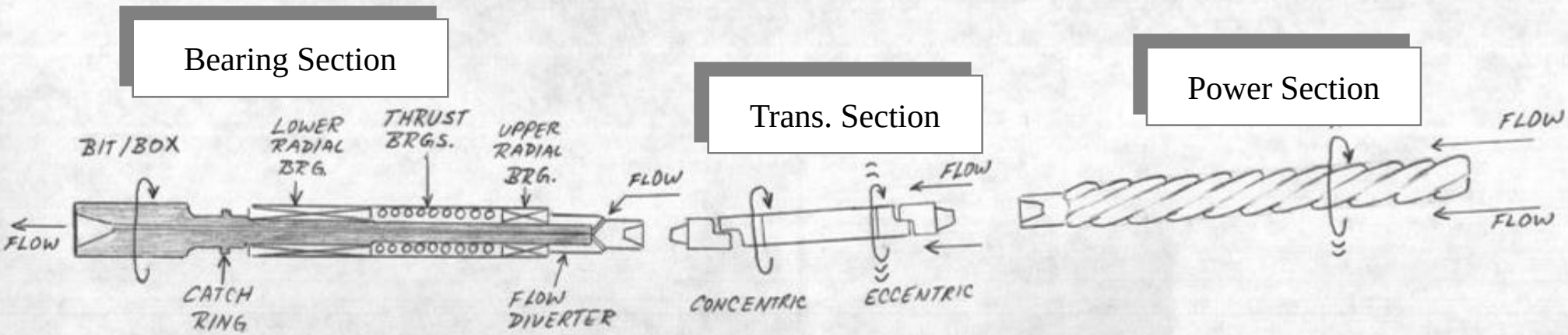


(Courtesy Scientific Drilling)

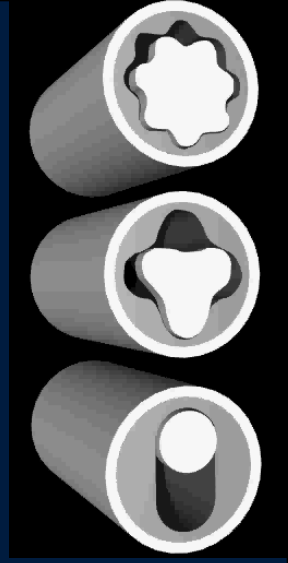
(Courtesy Robbins & Myers, Inc)

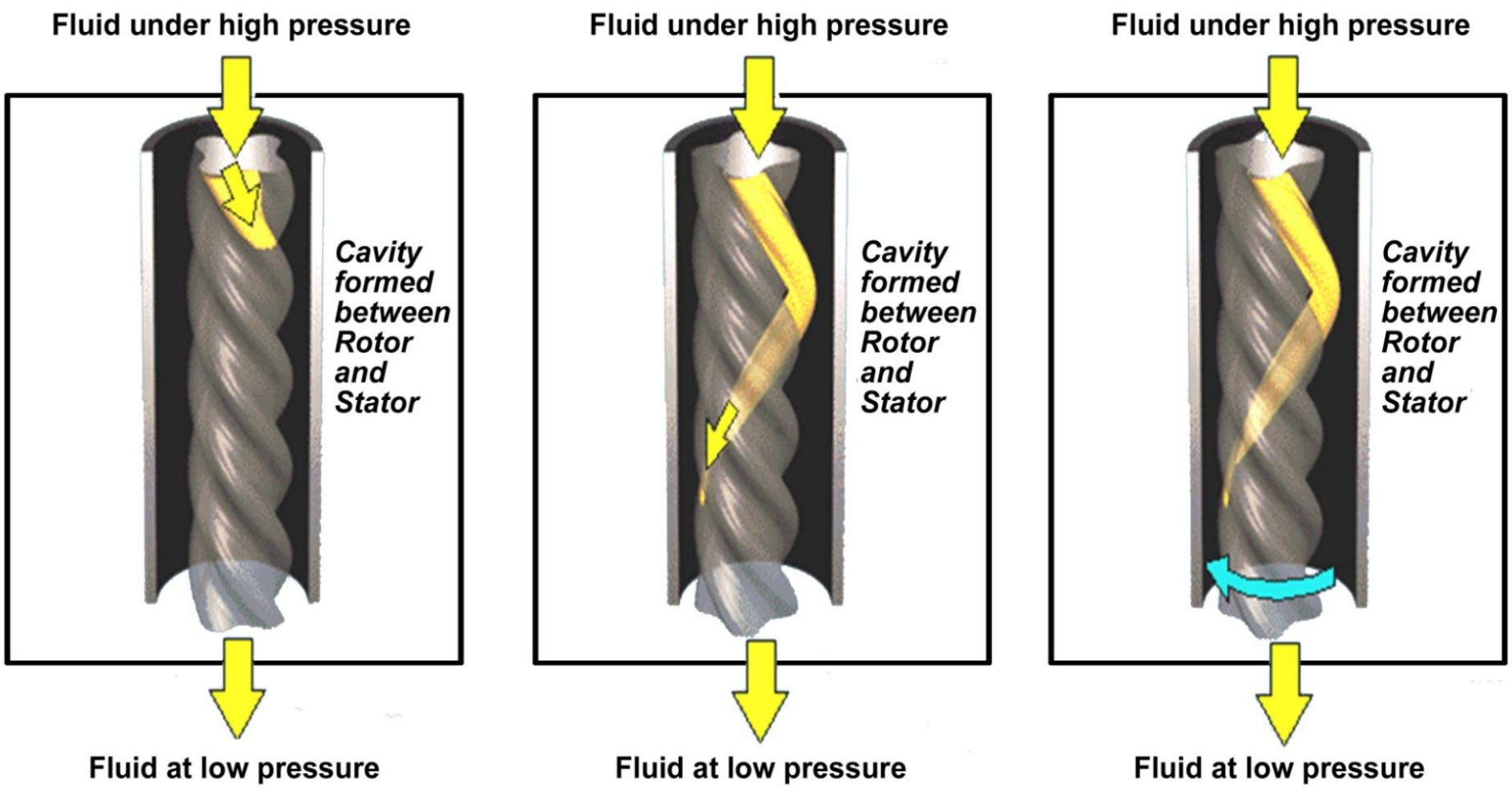
Drill Motor Components



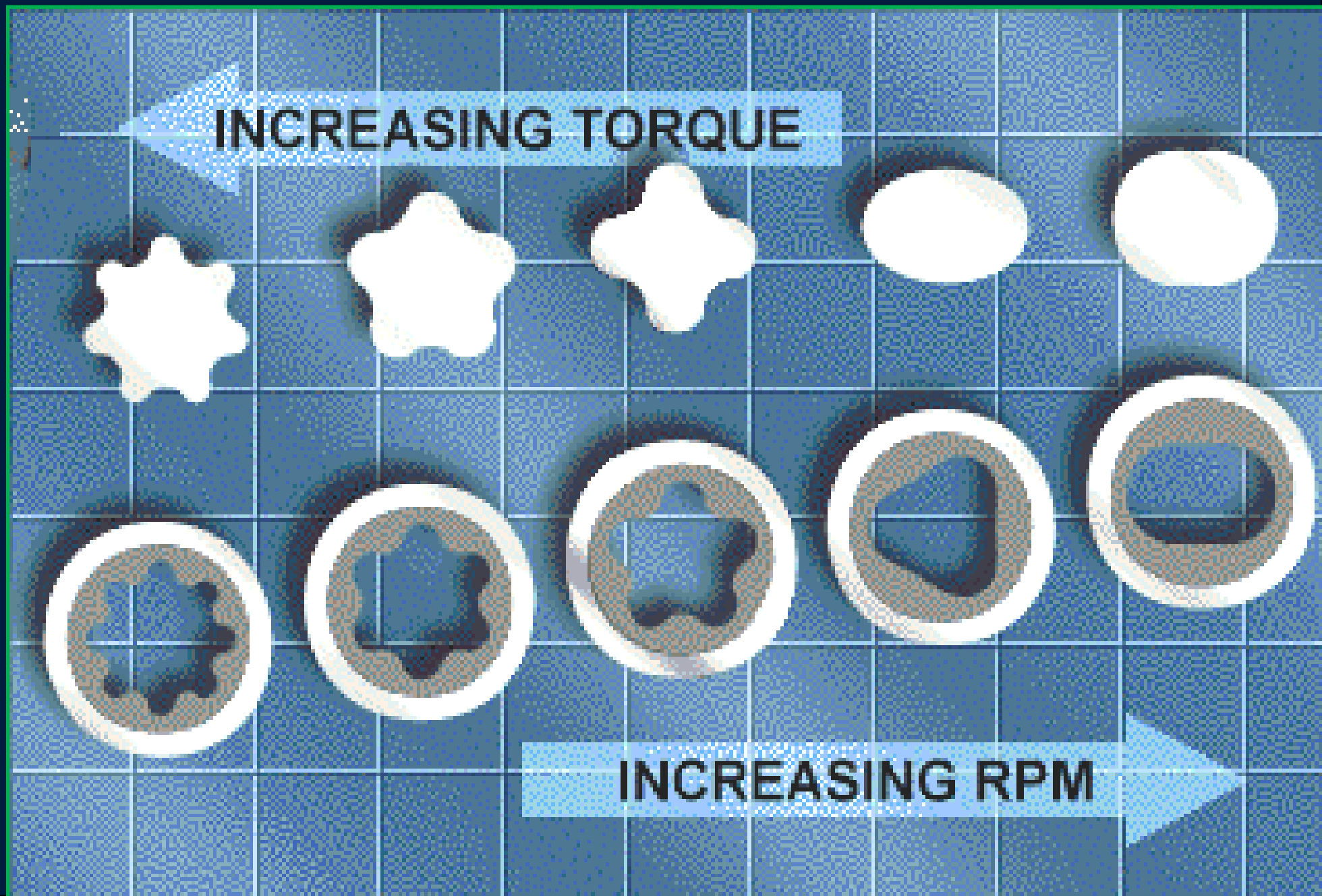


Methods of Deflection





Methods of Deflection



BUILD RATE PREDICTION

- HOLE SIZE
- FORMATION
- BIT TYPE
- FLOW RATE
- DIFFERENTIAL PRESSURE
- WEIGHT ON BIT
- BIT HYDRAULICS
- BEND SETTING
- BIT TO BEND DISTANCE
- STABILIZATION
- SLIDE PERCENTAGE (FOOTAGE SLIDING VS. ROTATING)

Predicted Build Rates - Degrees/100 ft (30 m)

Bend Setting	Slick			Single Stabilizer			Two Stabilizers		
	Hole Size			Hole Size			Hole Size		
Deg	8 1/2	8 3/4	9 7/8	8 1/2	8 3/4	9 7/8	8 1/2	8 3/4	9 7/8
0.39	1.3	1.3	1.2	1.5	1.5	1.5	1.7	1.7	1.7
0.78	2.7	2.5	2.5	3.7	3.7	3.7	4.2	4.2	4.2
1.15	5.1	4.5	3.7	5.8	5.8	5.7	6.5	6.5	6.5
1.50	7.4	6.8	4.8	7.8	7.7	7.6	8.7	8.7	8.7
1.83	9.6	9.0	6.4	9.6	9.6	9.4	10.8	10.8	10.8
2.12	11.5	10.9	8.3	11.5	11.2	11.0	12.6	12.6	12.6
2.38	13.2	12.6	9.9	13.2	12.7	12.5	14.3	14.3	14.2
2.60	14.6	14.0	11.4	14.6	14.0	13.7	15.7	15.7	15.6
2.77	15.8	15.1	12.4	15.8	15.1	14.6	16.7	16.7	16.7
2.89	16.5	15.9	13.2	16.5	15.9	15.3	17.5	17.5	17.4
2.97	17.1	16.4	13.7	17.1	16.4	15.7	18.0	18.0	18.0
3.00	17.3	16.6	13.9	17.3	16.6	15.9	18.2	18.2	18.1

Maximum Hole Curvature for Rotary Drilling Degrees/100 ft (30 m)

Bend Setting	Slick			Single Stabilizer			Two Stabilizers		
	Hole Size			Hole Size			Hole Size		
Deg	8 1/2	8 3/4	9 7/8	8 1/2	8 3/4	9 7/8	8 1/2	8 3/4	9 7/8
0.00	19	20	25	10	10	10	8	8	8
0.39	16	17	22	7	7	8	6	6	6
0.78	13	14	19	5	5	6	3	3	3
1.15	10	11	16	2	2	3	1	1	1
1.50	7	8	13	0	0	1			
1.83	5	6	11						
2.12	3	4	9						
2.38	1	2	7						
2.60		0	5						
2.77			4						
2.89			3						
2.97			2						
3.00			2						

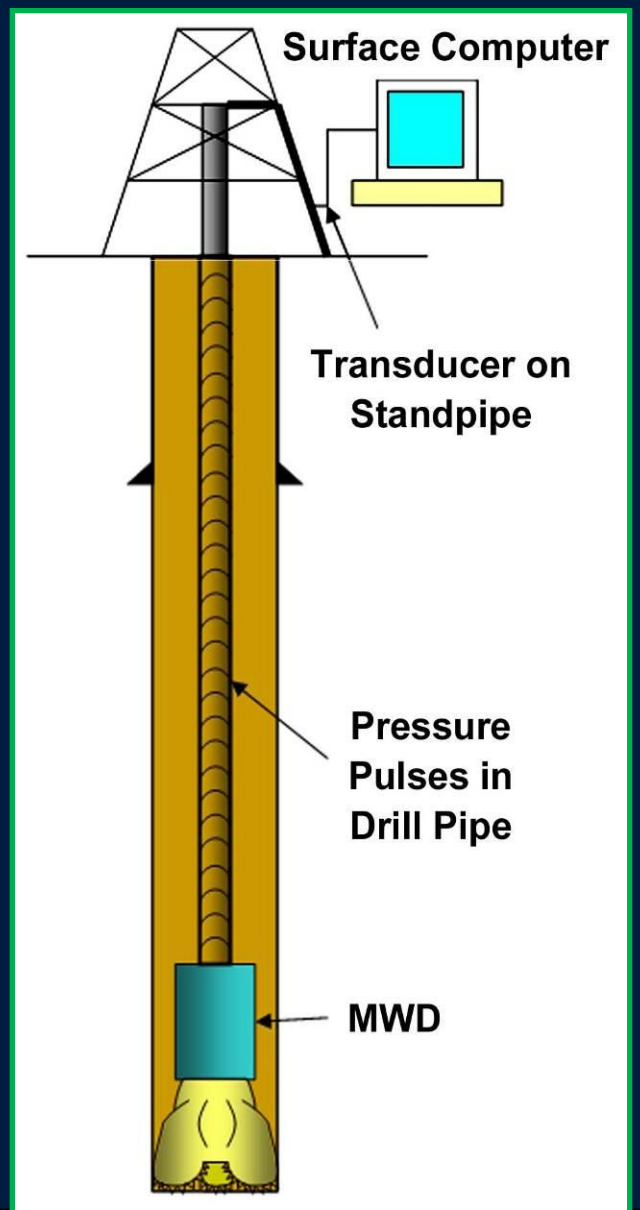
CURRENT DIRECTIONAL MEASUREMENT SYSTEMS

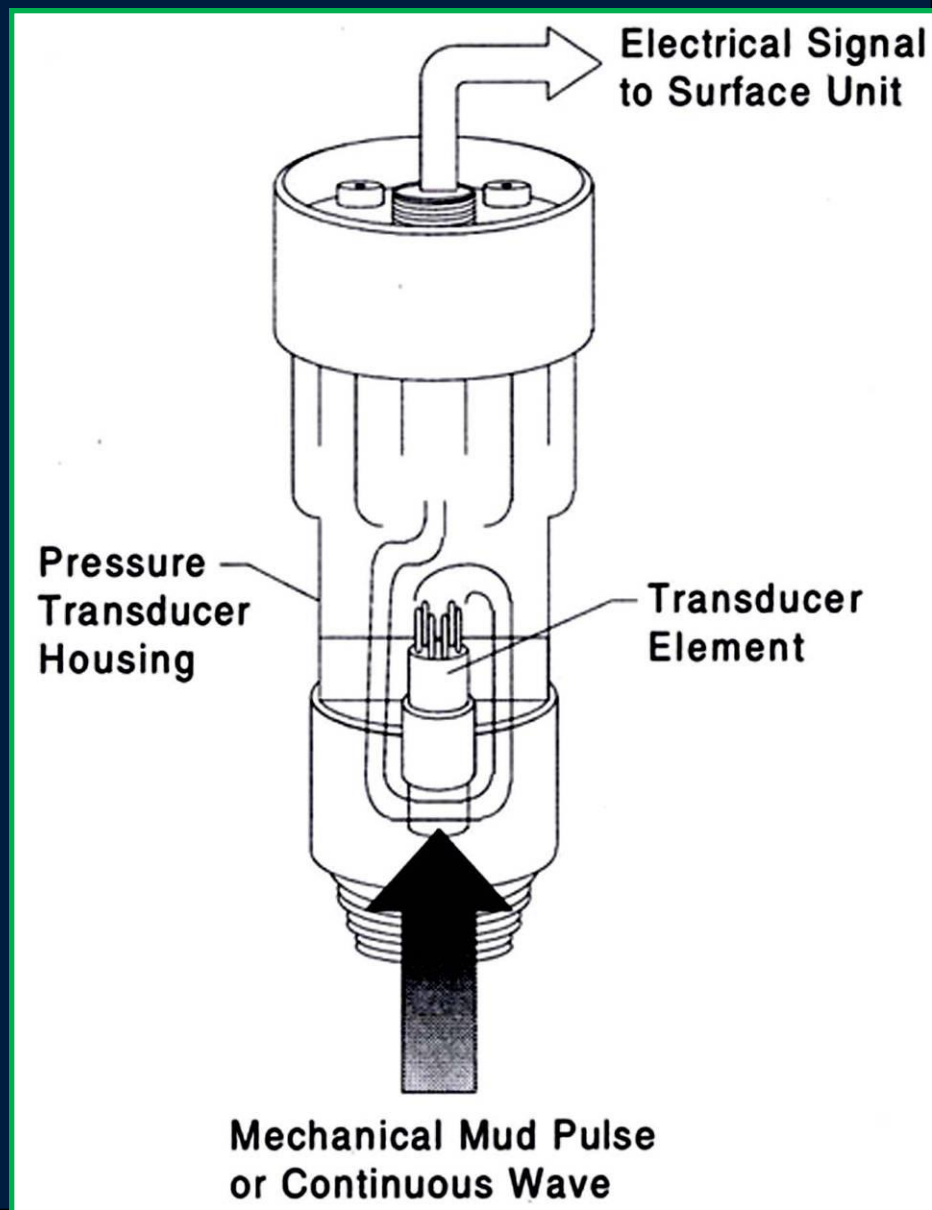
MWD – MEASUREMENT WHILE DRILLING

MEASUREMENT SYSTEMS (INC & AZ)

- WELLBORE NAVIGATION & MEASURMENT
  - WIRELINE STEERING & ORIENTATION SYSTEMS
    - CONVENTIONAL FILM BASED GYRO MULTI & SINGLE SHOT TOOLS
    - CONVENTIONAL FILM BASED MAGNETIC SINGLESHOT TOOLS
    - ELECTRONIC W/L STEERING TOOLS ("MWD ON WIRELINE")
    - NORTH SEEKING RATE GYROS
- MWD SYSTEMS
  - MUD-PULSED (POSITIVE OR NEGATIVE PULSE) MWD
  - E-FIELD (ELECTROMAGNETIC) MWD
  - gMWD (E-FIELD or MUD-PULSED)

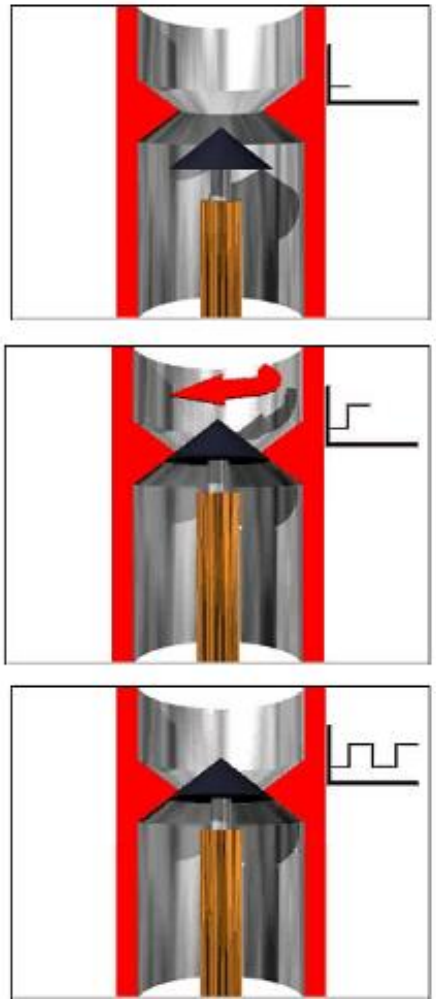
MWD Instruments



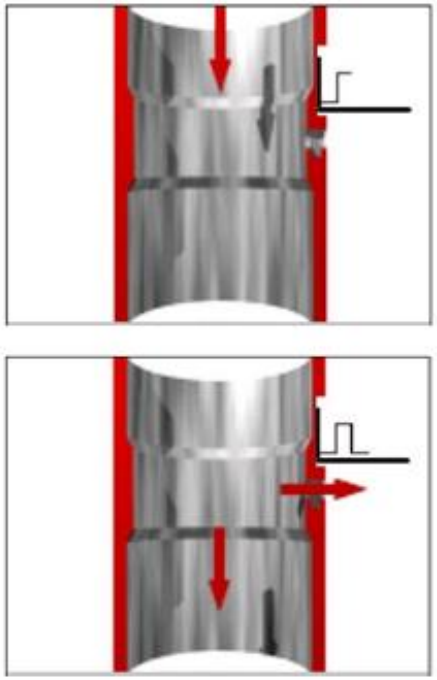


MWD FLUID PULSE DATA TRANSMISSION

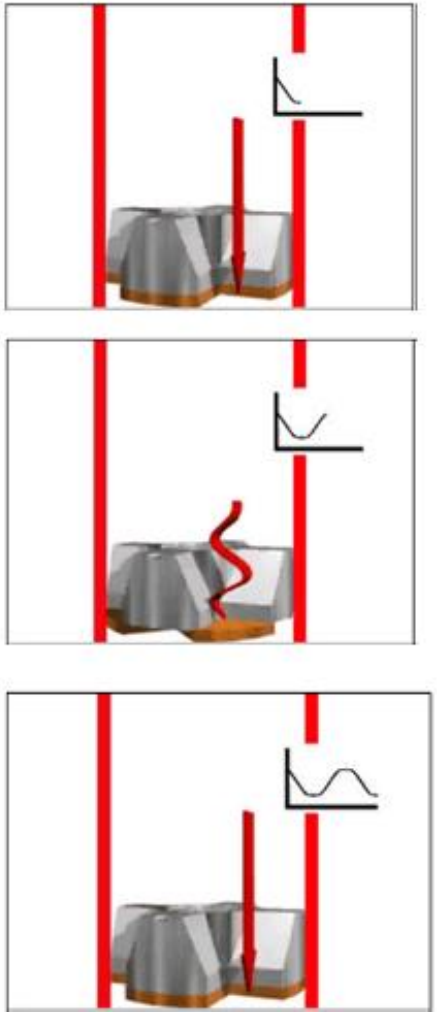
Positive Pulse Telemetry



Negative Pulse Telemetry



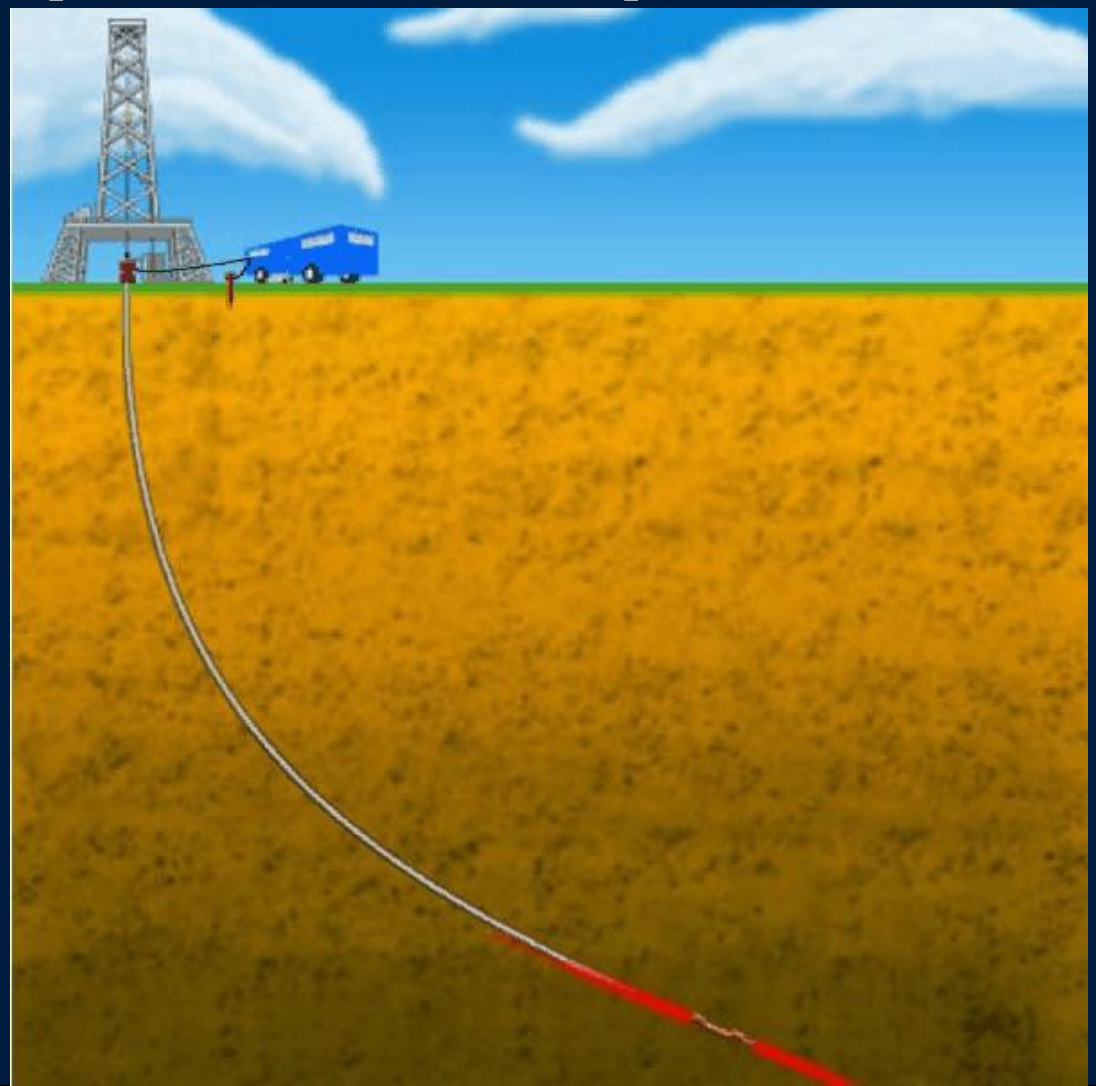
Continuous Wave Telemetry

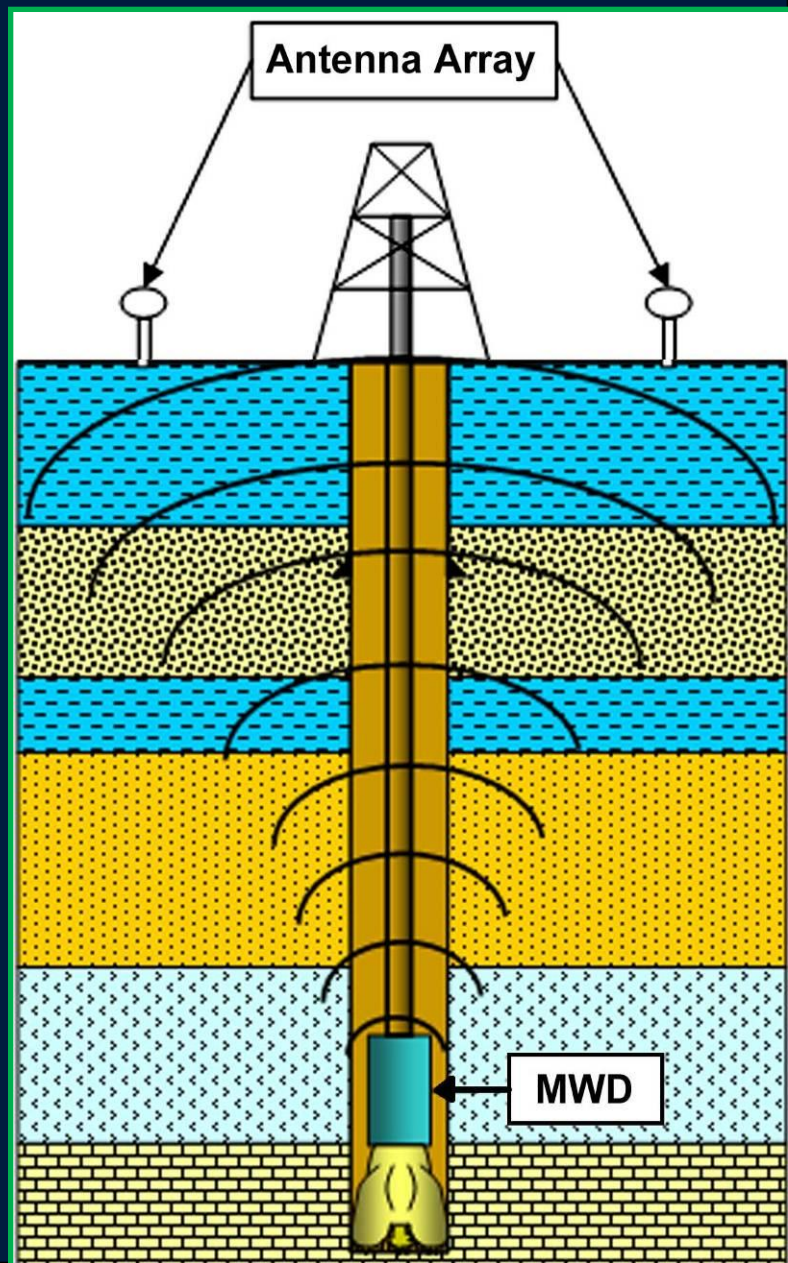


E-Field MWD Instruments

Electromagnetic MWD uses radio waves

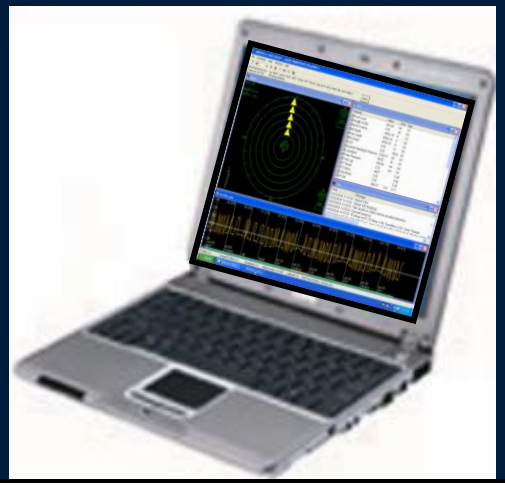
Works in compressible fluids (underbalanced)

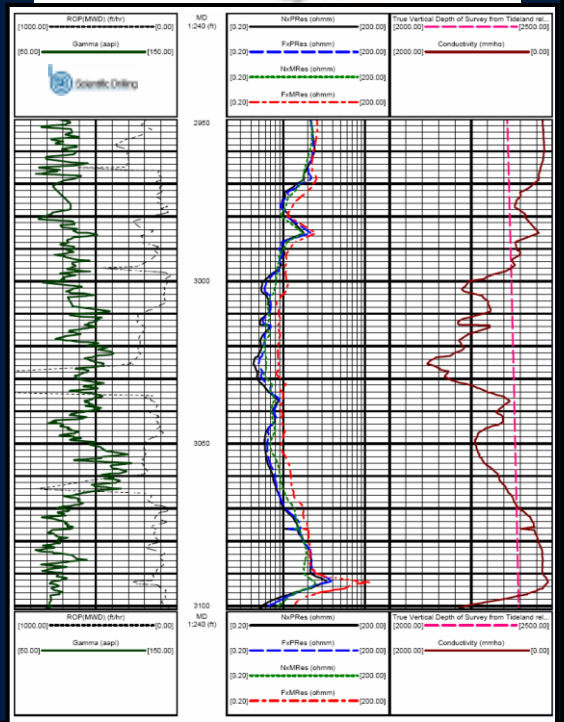


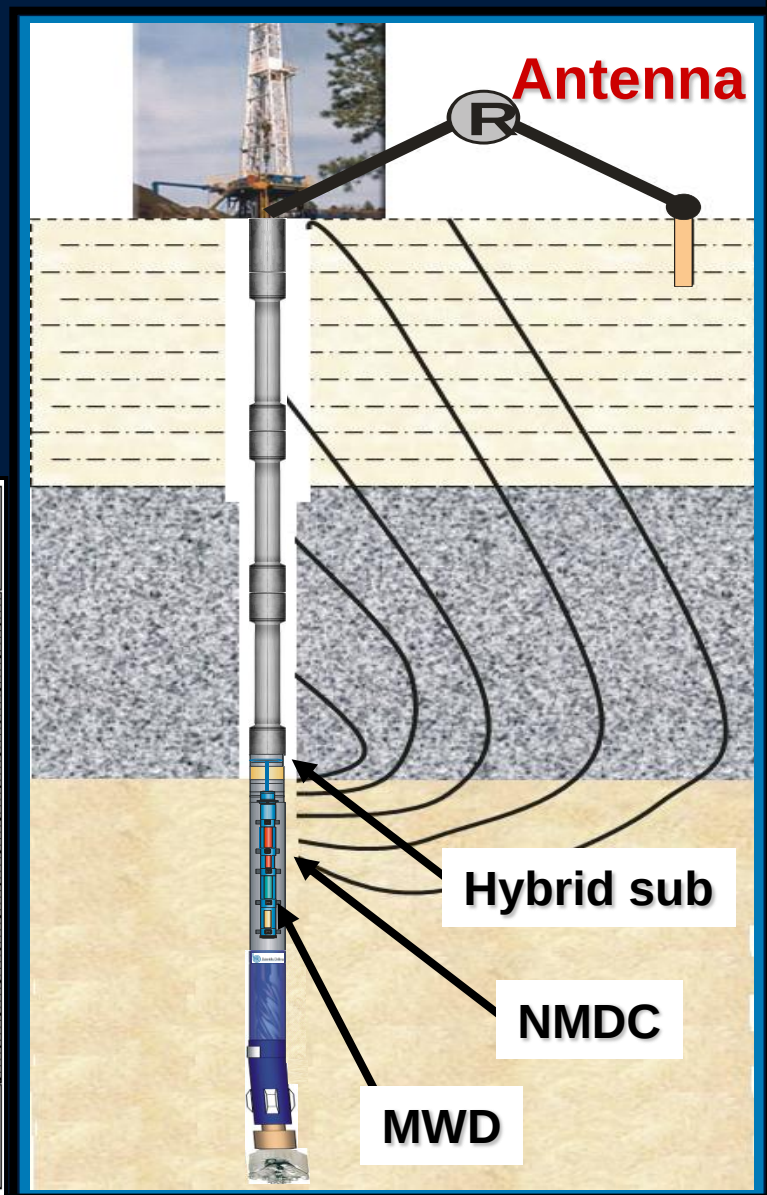


E-FIELD MEASUREMENT WHILE DRILLING

- **ELECTROMAGNETIC MWD ILLUSTRATION**



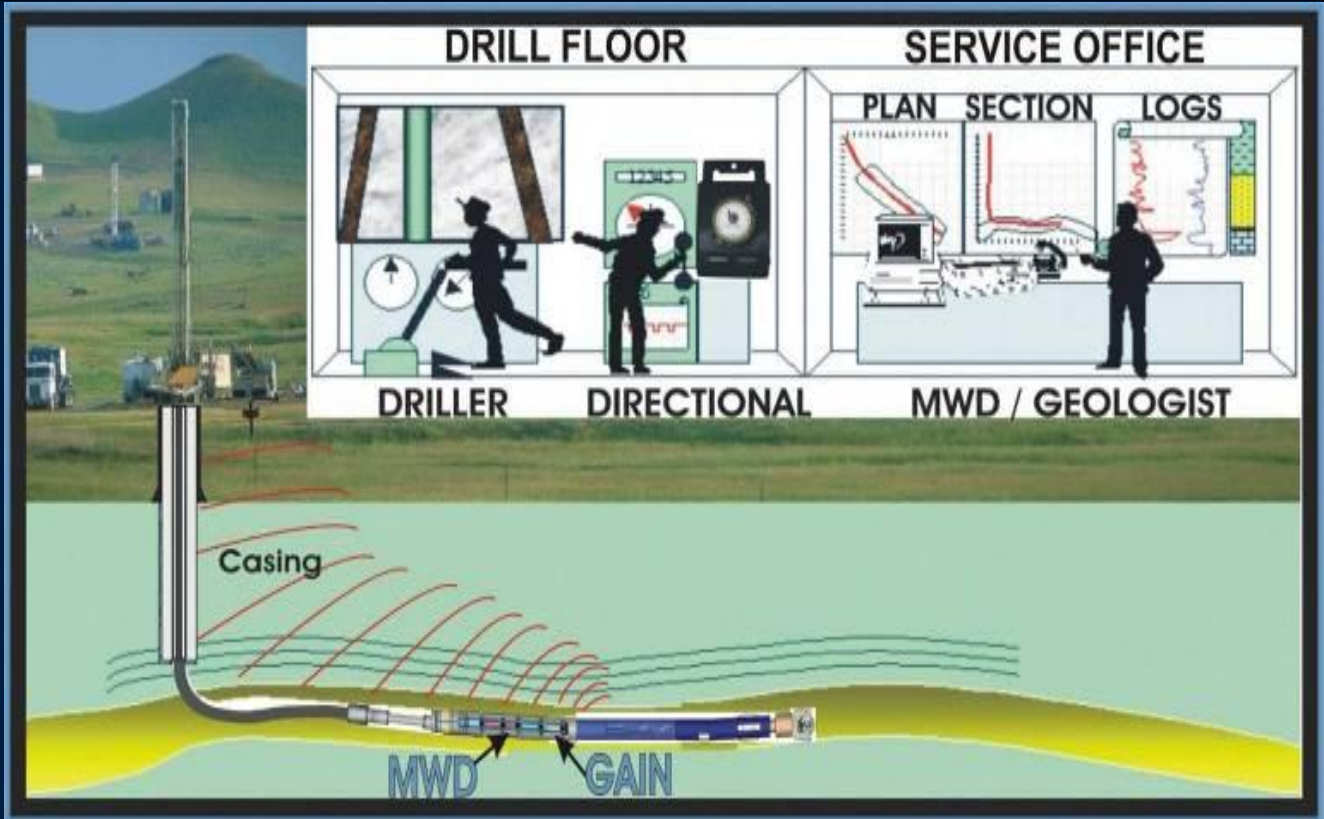




ELECTROMAGNETIC MWD FEATURES

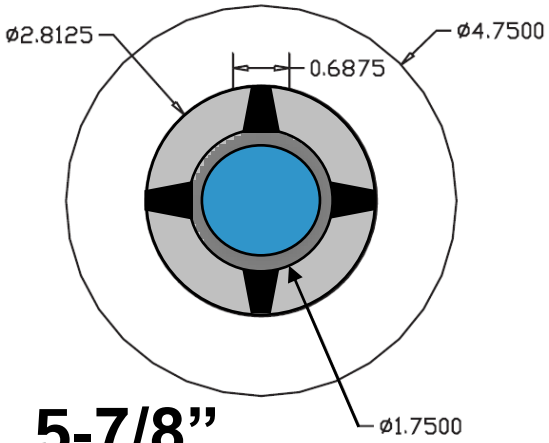
Features

- Inclination
- Azimuth
- Toolface (highside + magnetic)
- Vibration (peak, average & RMS)
- Gamma (optional)
- Focused Gamma (optional)
- GAIN (Gamma Inc)
- Pressure While Drilling (PWD)
- Annular-Pipe-Differential
- Long Wire
- Softride Collars (Air Drilling)
- Wi-Sci "Short Hop" communication to additional tools, i.e. Smart Motor, SRX, Bit Subs, etc…
- **NOW WITH KEEPER GYRO SERVICES**

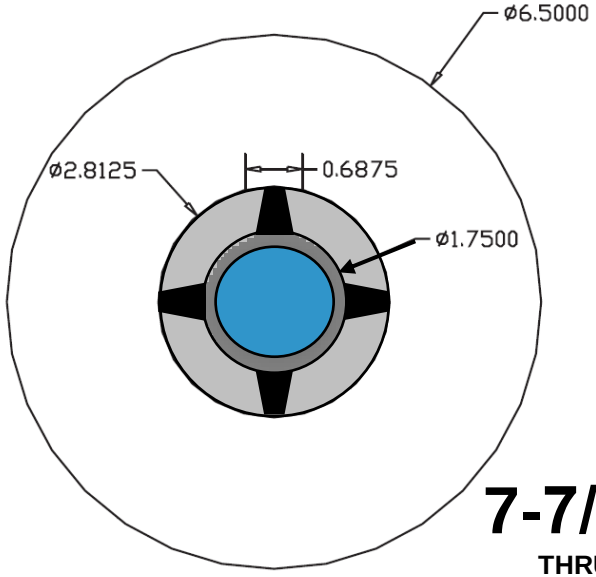


MP & E-Field MWD SYSTEMS
COLLAR AND HOLE SIZES

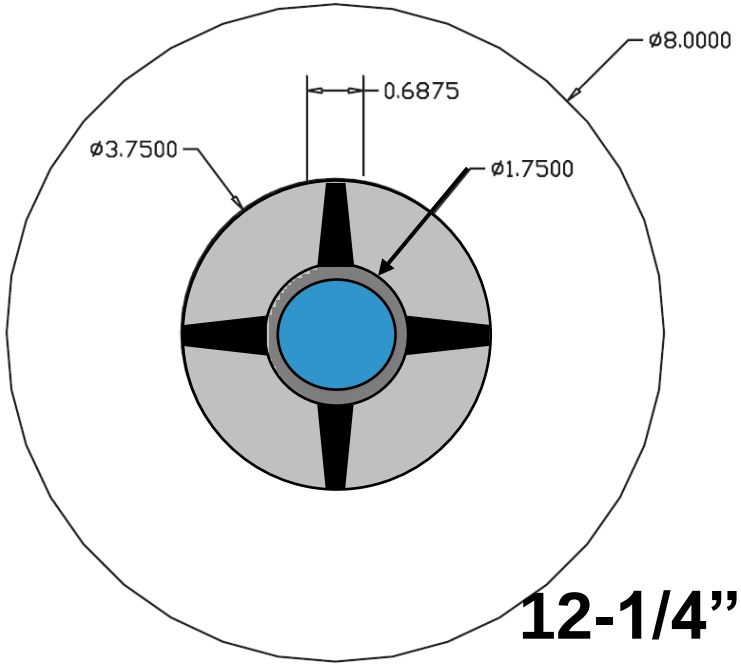
SDI - ONE SIZE MWD FOR ALL HOLE SIZES



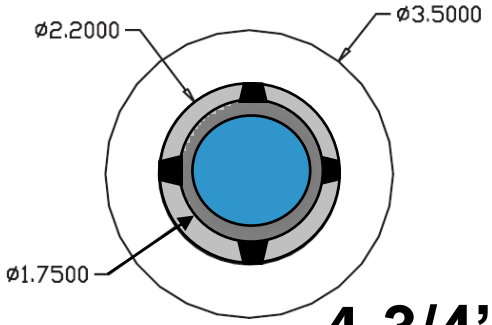
5-7/8”
THRU
7-7/8”



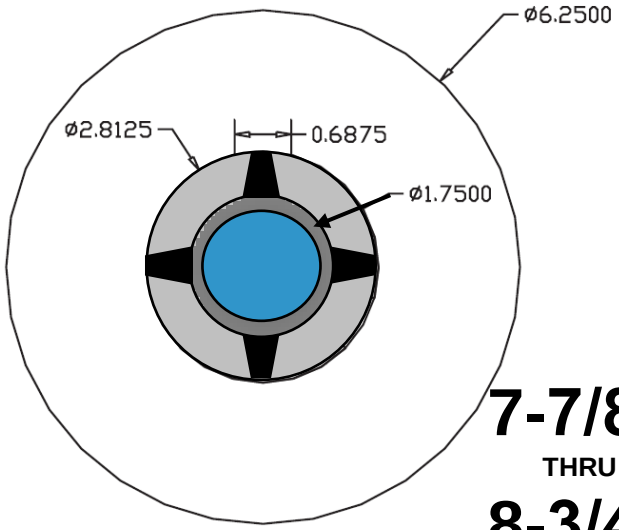
7-7/8”
THRU
9-7/8”



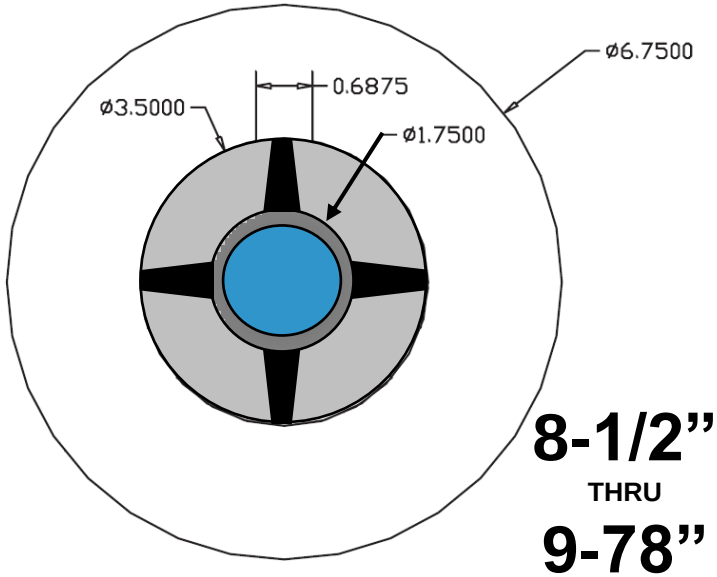
12-1/4”
or 9-7/8”



4-3/4”
THRU
5-7/8”



7-7/8”
THRU
8-3/4”

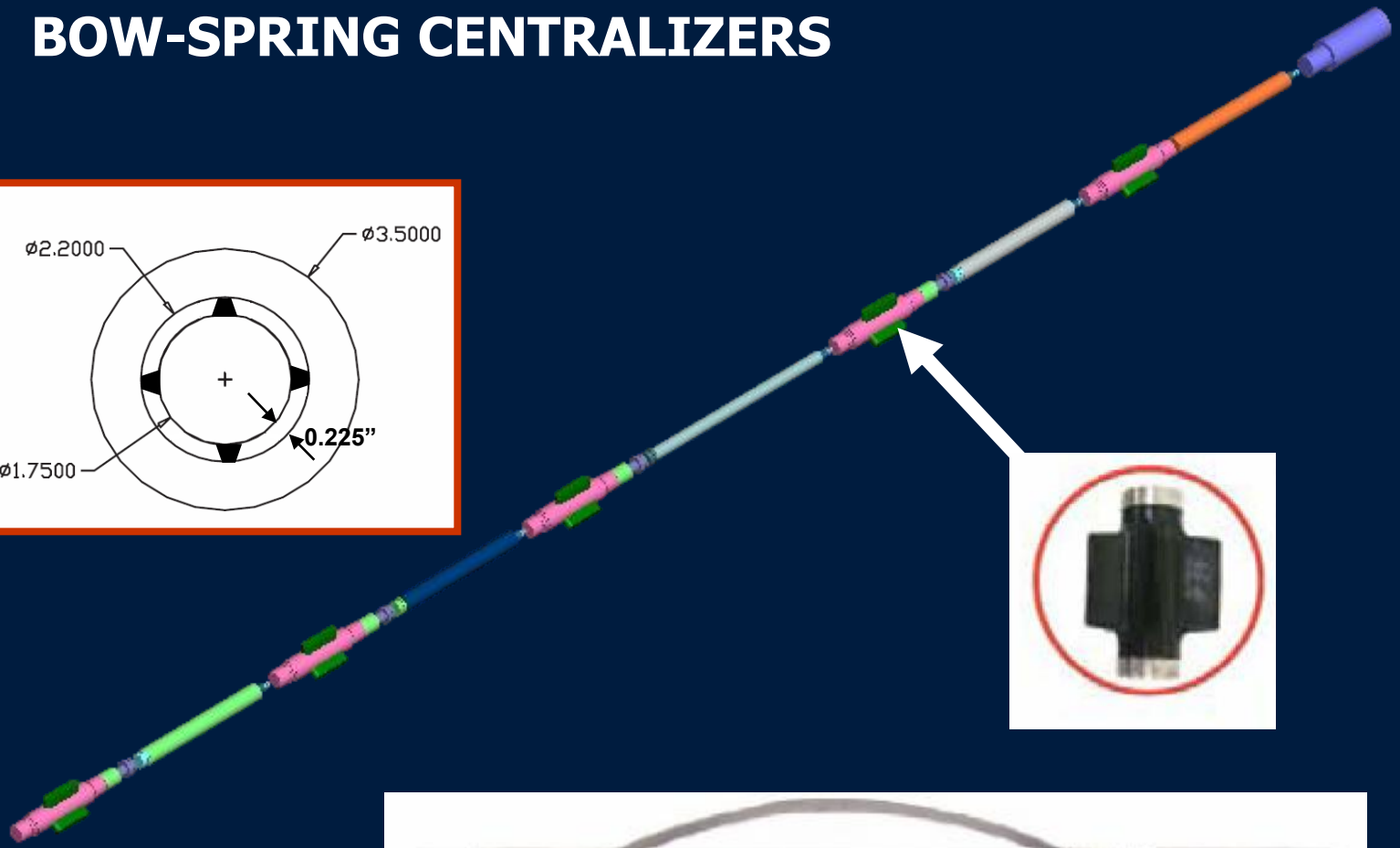


8-1/2”
THRU
9-78”

MWD – RETREIVABLE SYSTEMS

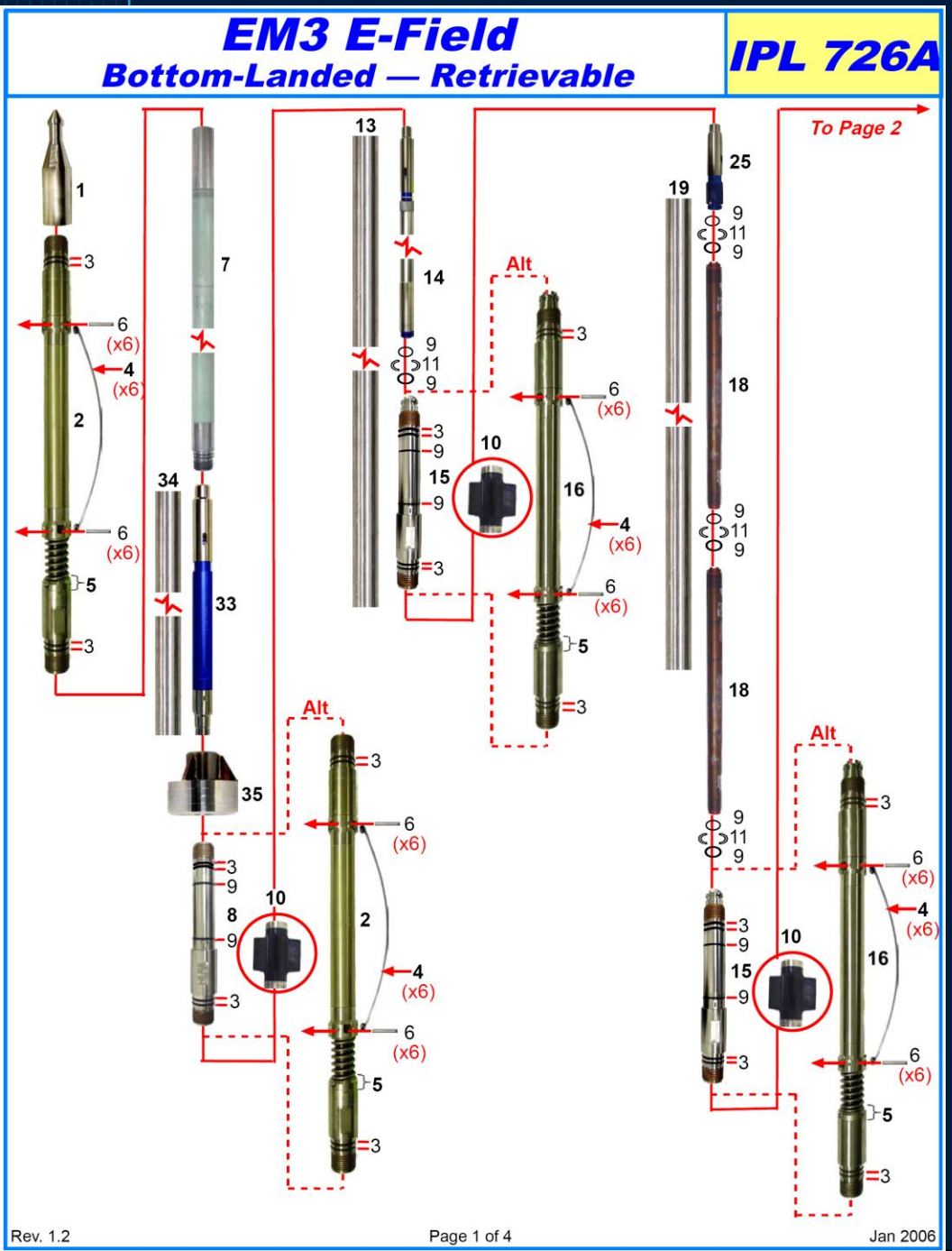
RETRIEVABLE OPTIONS

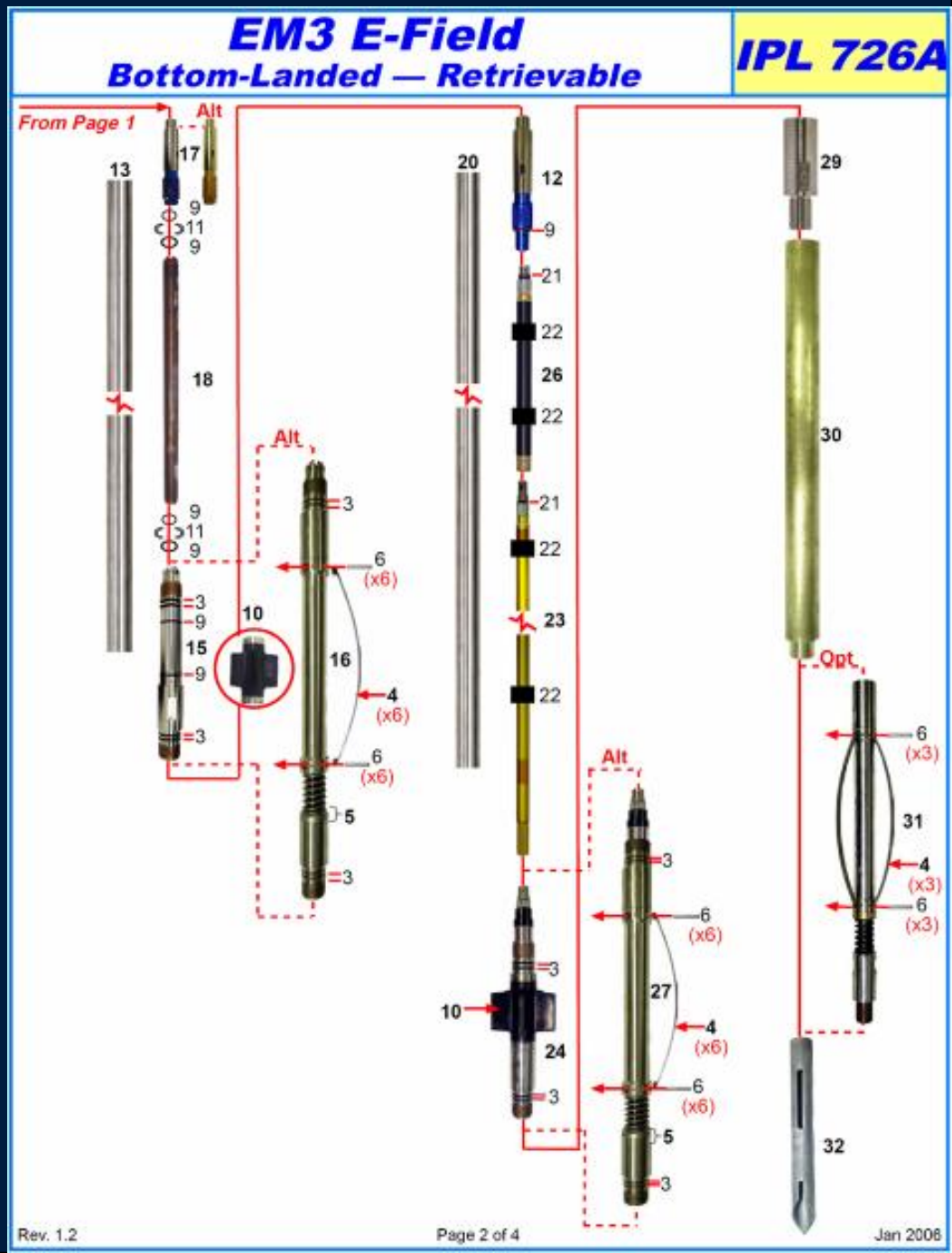
- **RUBBER FINNED CENTRALIZERS**
- **BOW-SPRING CENTRALIZERS**



MWD PROBE BEING PICKED UP

RETRIEVABLE E-FIELD MWD SYSTEM

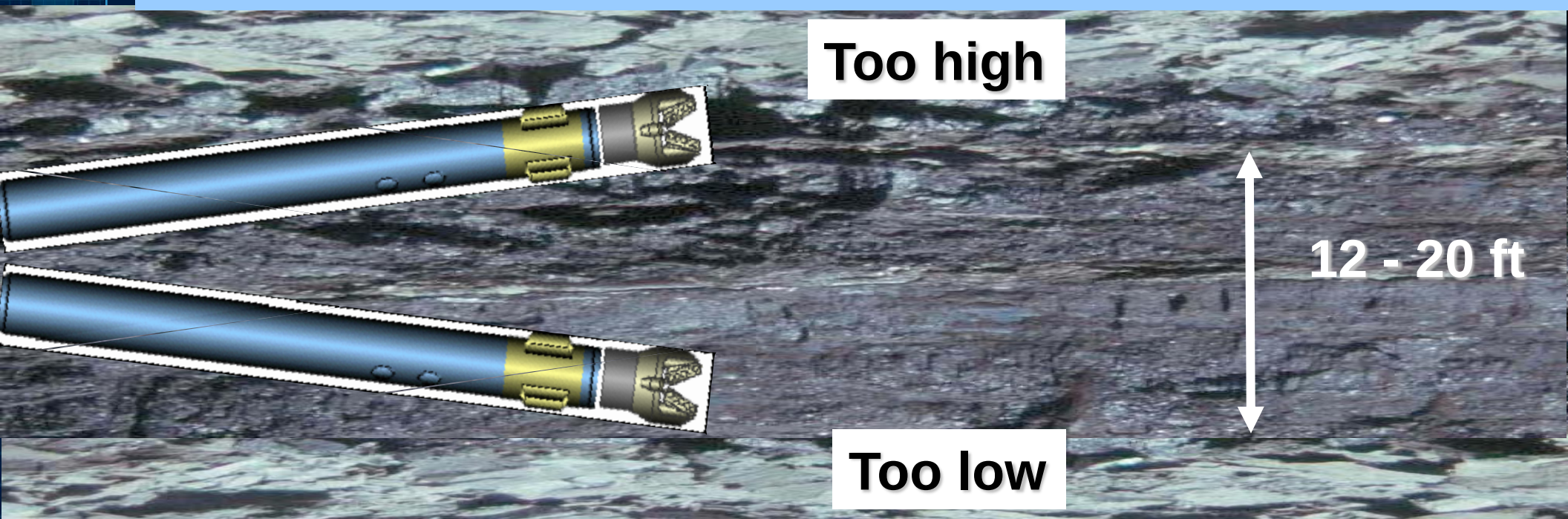




KEY ISSUES DRILLING IN COAL

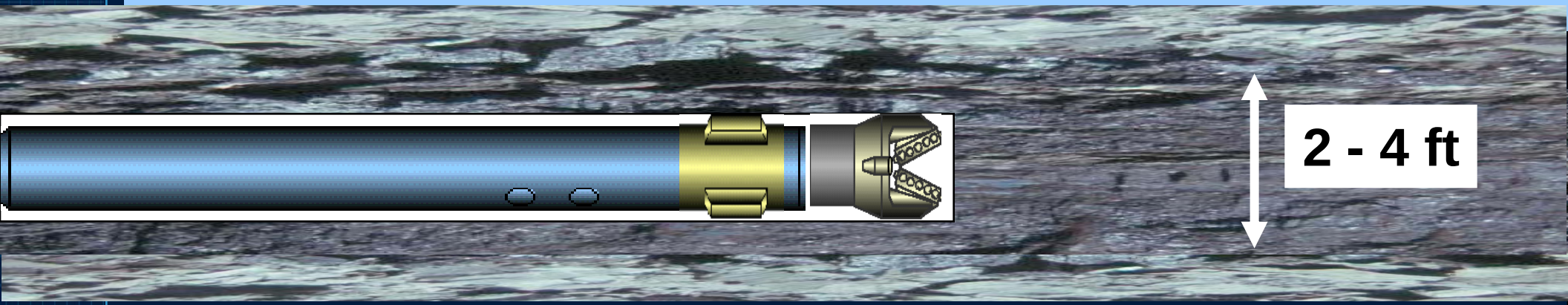
KEY ISSUES

Maintaining the BHA heading within the Target Zone – Thick Seams are sometimes More difficult to drill in zone because the BHA is prone to get out of plane with the formation



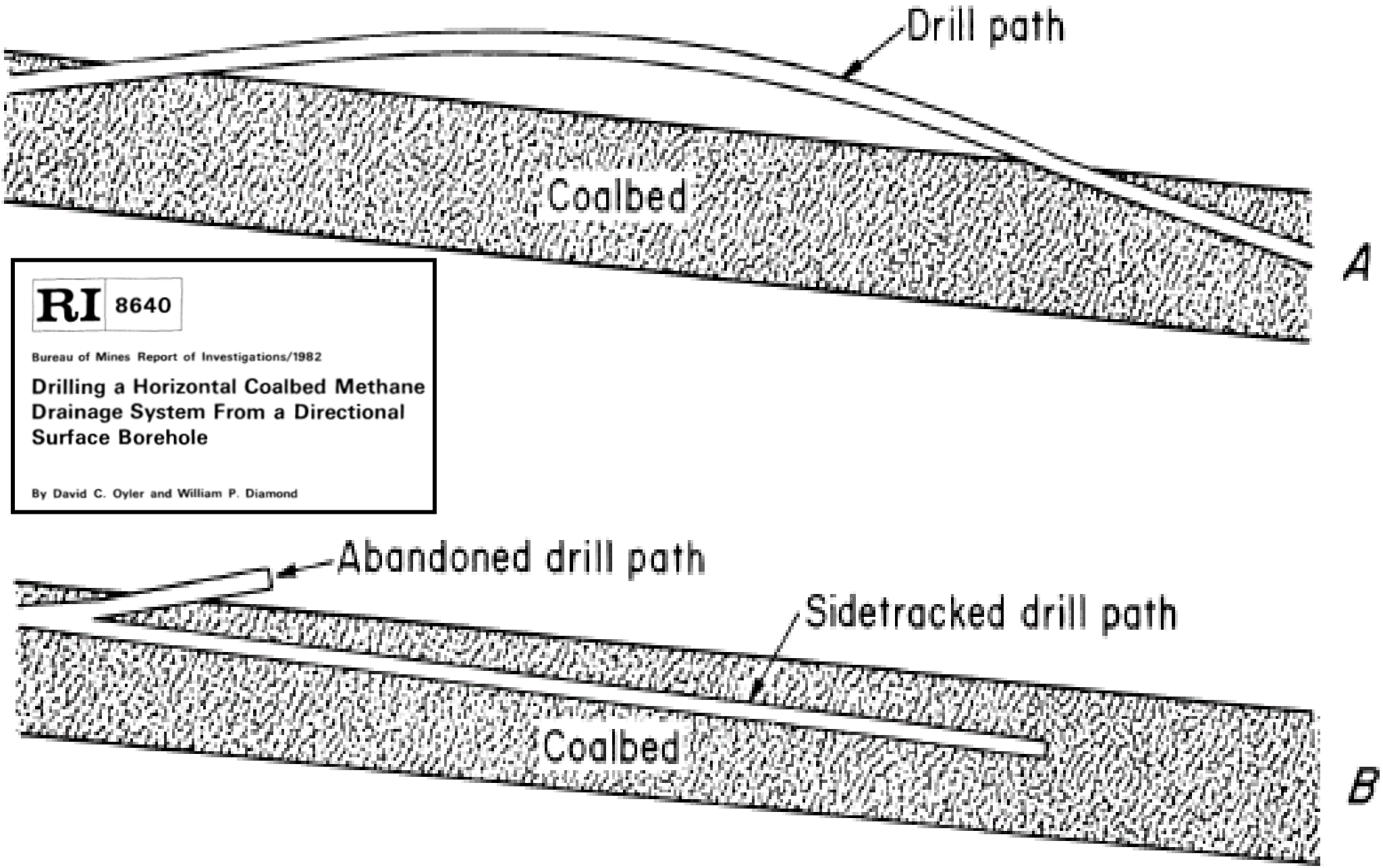
KEY ISSUES

Maintaining the BHA heading within the Target Zone – Thin Seams are sometimes Easier to drill in zone because the BHA Tends to deflect off the roof and floor of the coal seam and stay in plane with the formation



Maintaining the BHA heading within the Target Zone.

HORIZONTAL KEY DRILLING ISSUES



RI 8640

Bureau of Mines Report of Investigations/1982

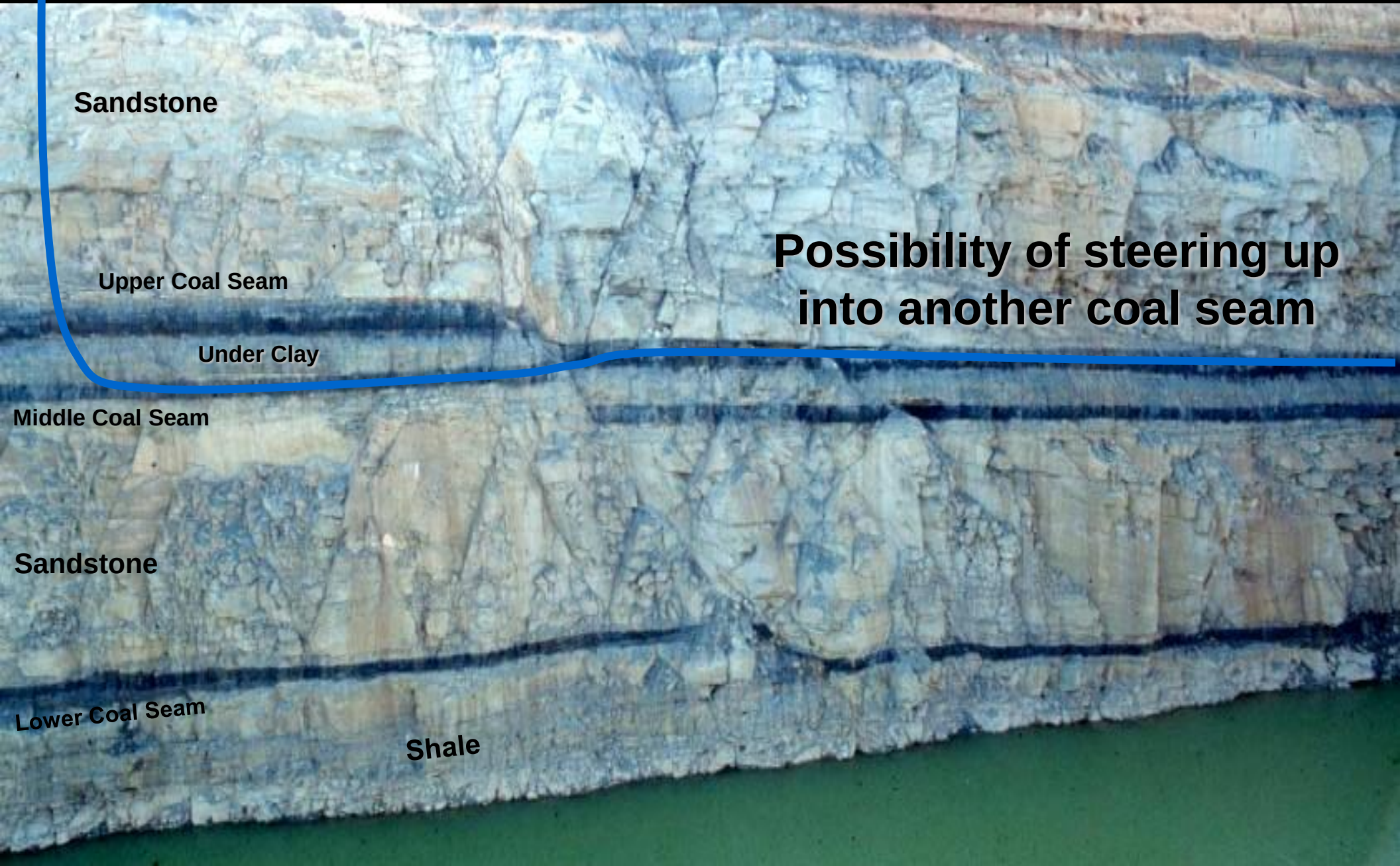
Drilling a Horizontal Coalbed Methane Drainage System From a Directional Surface Borehole

By David C. Oyler and William P. Diamond

FIGURE 19. - Two methods of following the coalbed. Method B is recommended.

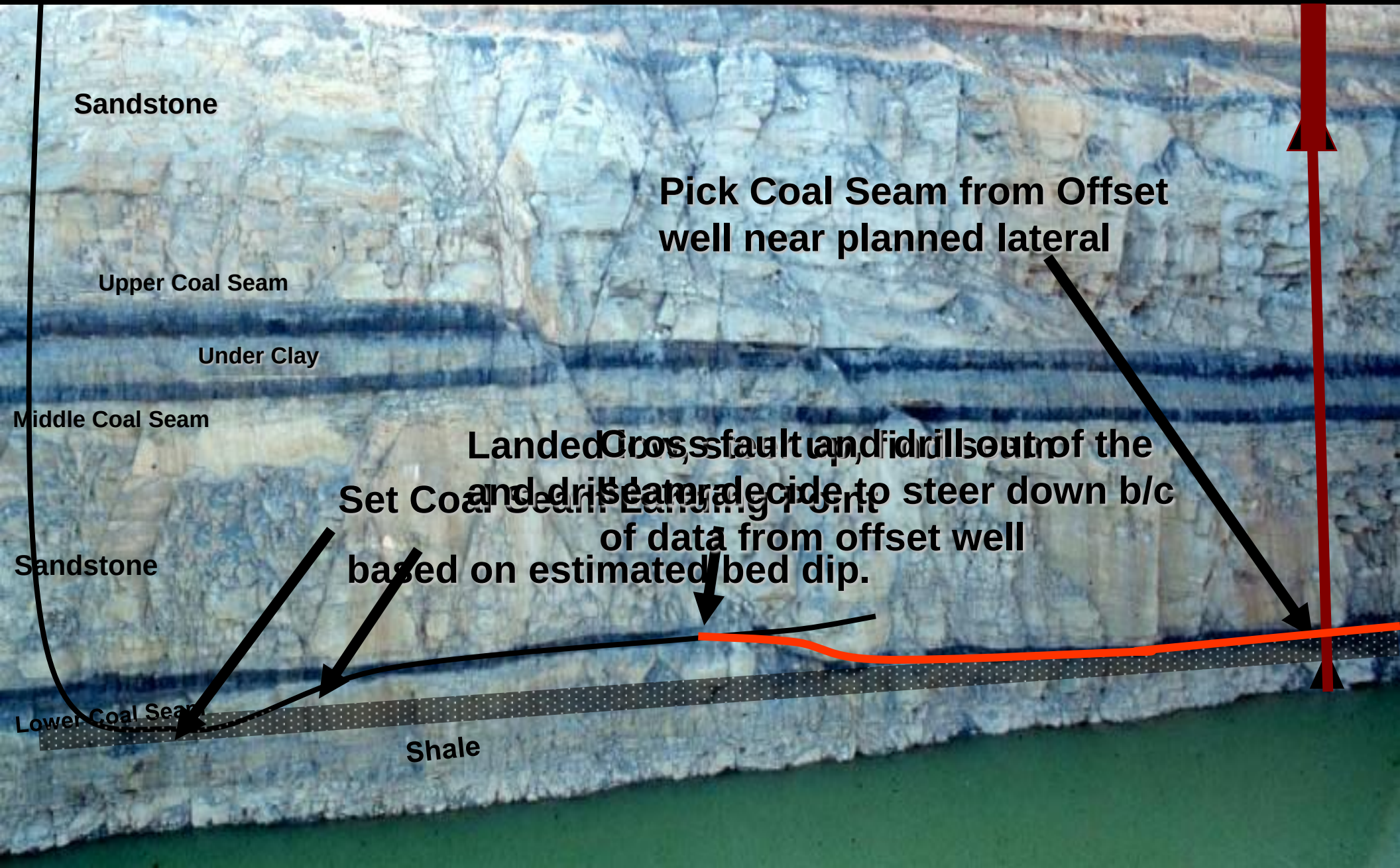
CSH KEY DRILLING ISSUES

FAULTING AND FRACTURING



CSH KEY DRILLING ISSUES

FAULTING AND FRACTURING



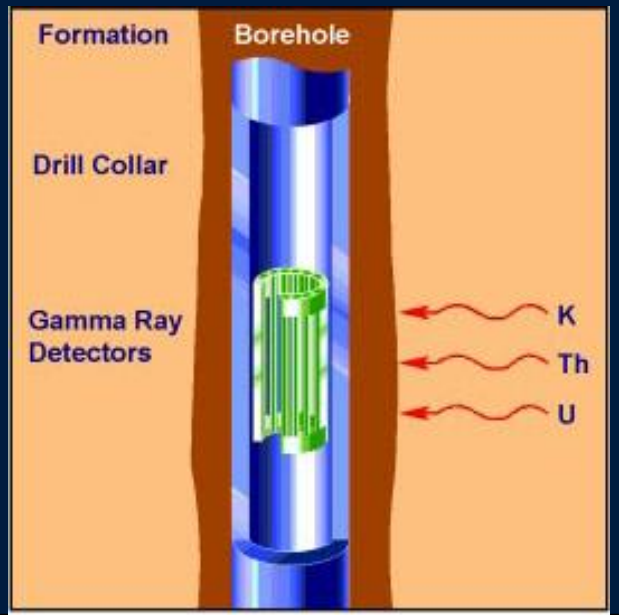
CURRENT COAL LATERAL LOGGING WHILE DRILLING TECHNOLOGY

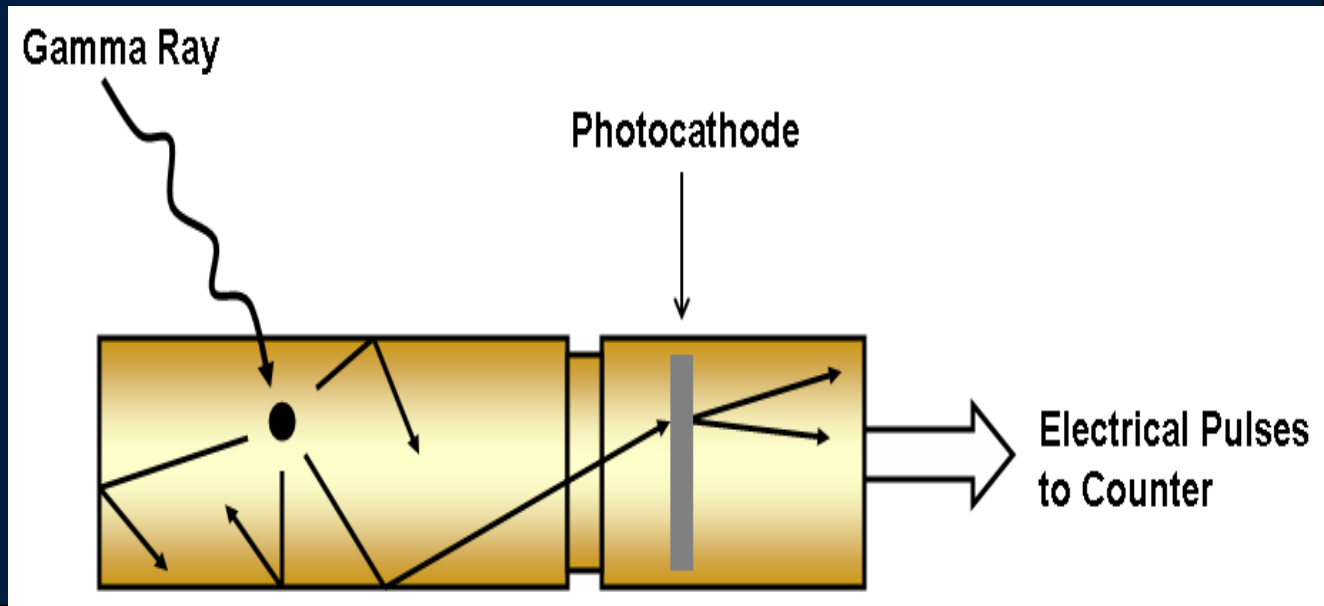
LWD – GAMMA RAY

RADIAL, FOCUSED (SHIELD)
NATURALLY FOCUSED (LWDM)

NATURAL GAMMA TOOLS

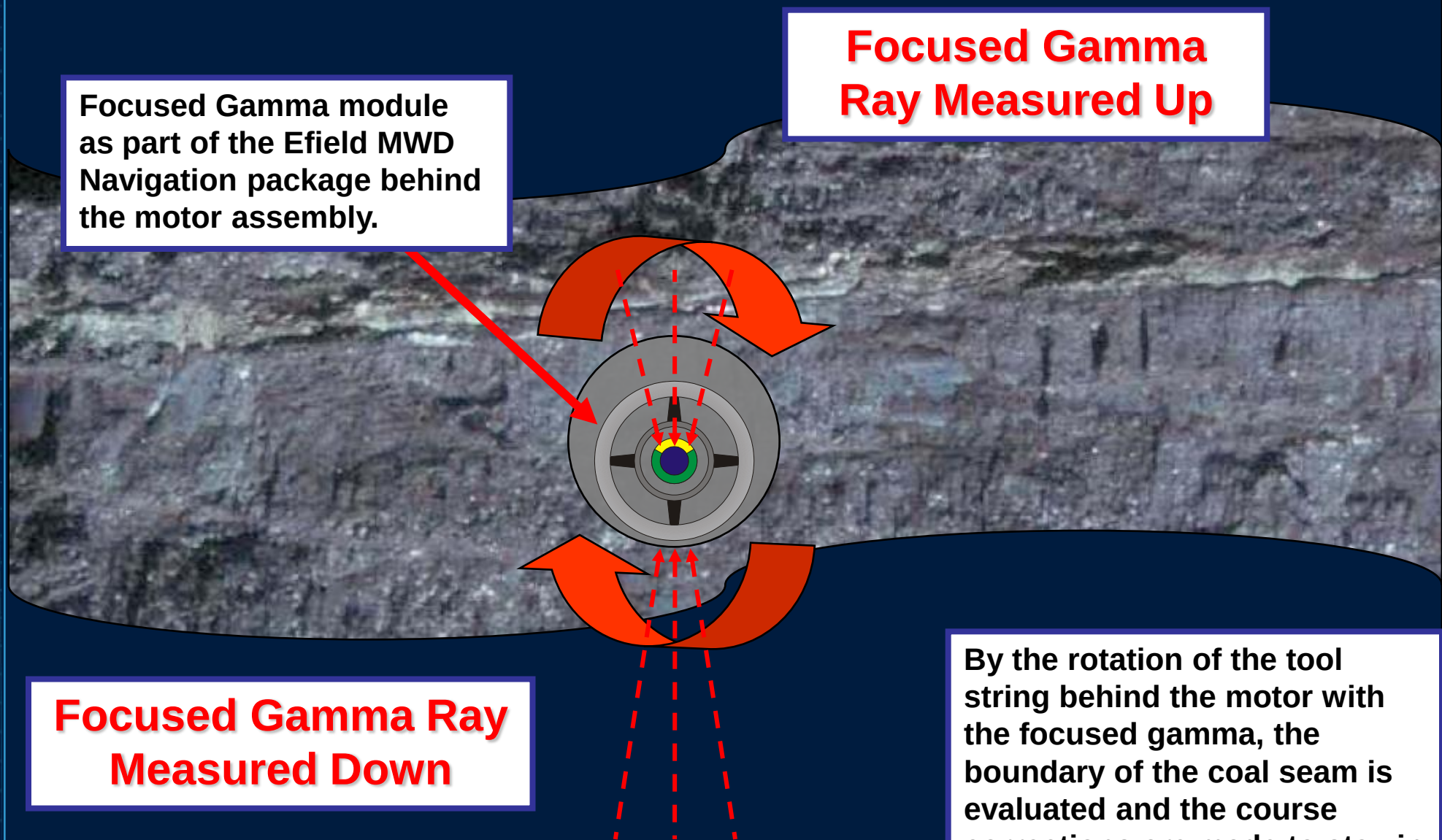
- The gamma tool measures naturally occurring radiation, rather than induced gamma rays from a source, such in the density tool.
- These natural gamma rays emanate from radioactive elements contained in sedimentary formations, mainly potassium (K), thorium (Th), and uranium (U).
- Potassium and thorium are closely associated with the presence of clay minerals in shale (illite, kaolinite, and montmorillonite), while uranium may be found in sands, shales, and certain carbonates
- The gamma tool provides an excellent indicator of the presence of shale





E-FIELD MWD EXTENDED FOCUS GAMMA RAY

Cross section view

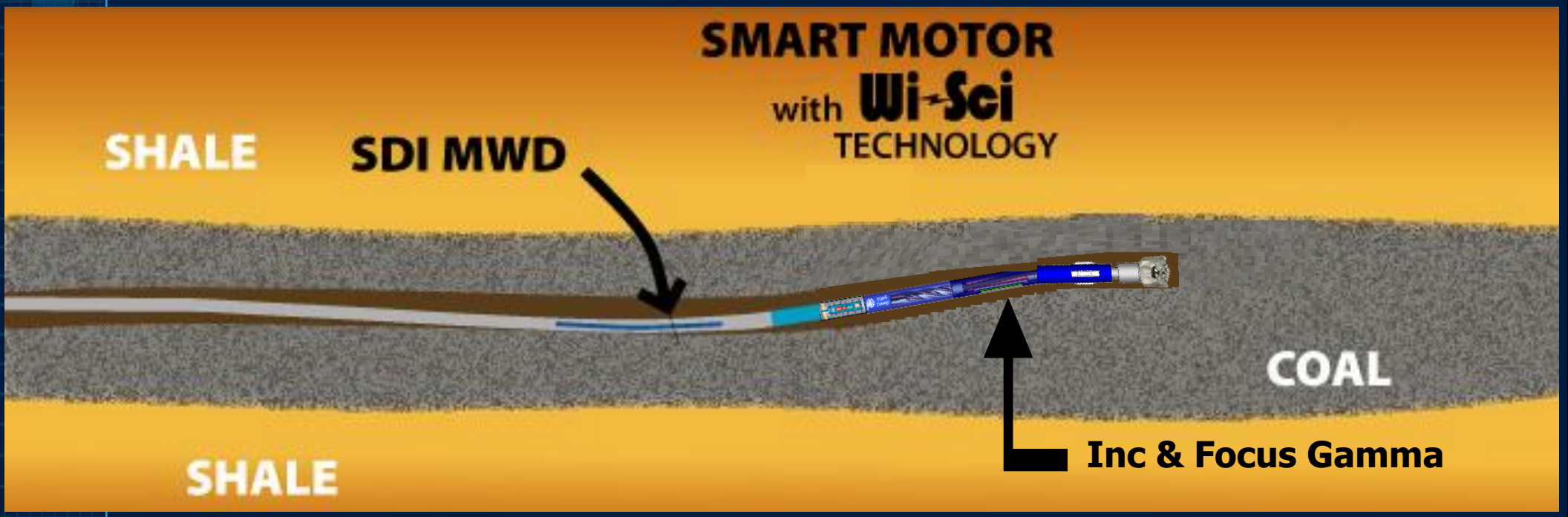


By the rotation of the tool string behind the motor with the focused gamma, the boundary of the coal seam is evaluated and the course corrections are made to stay in the zone.

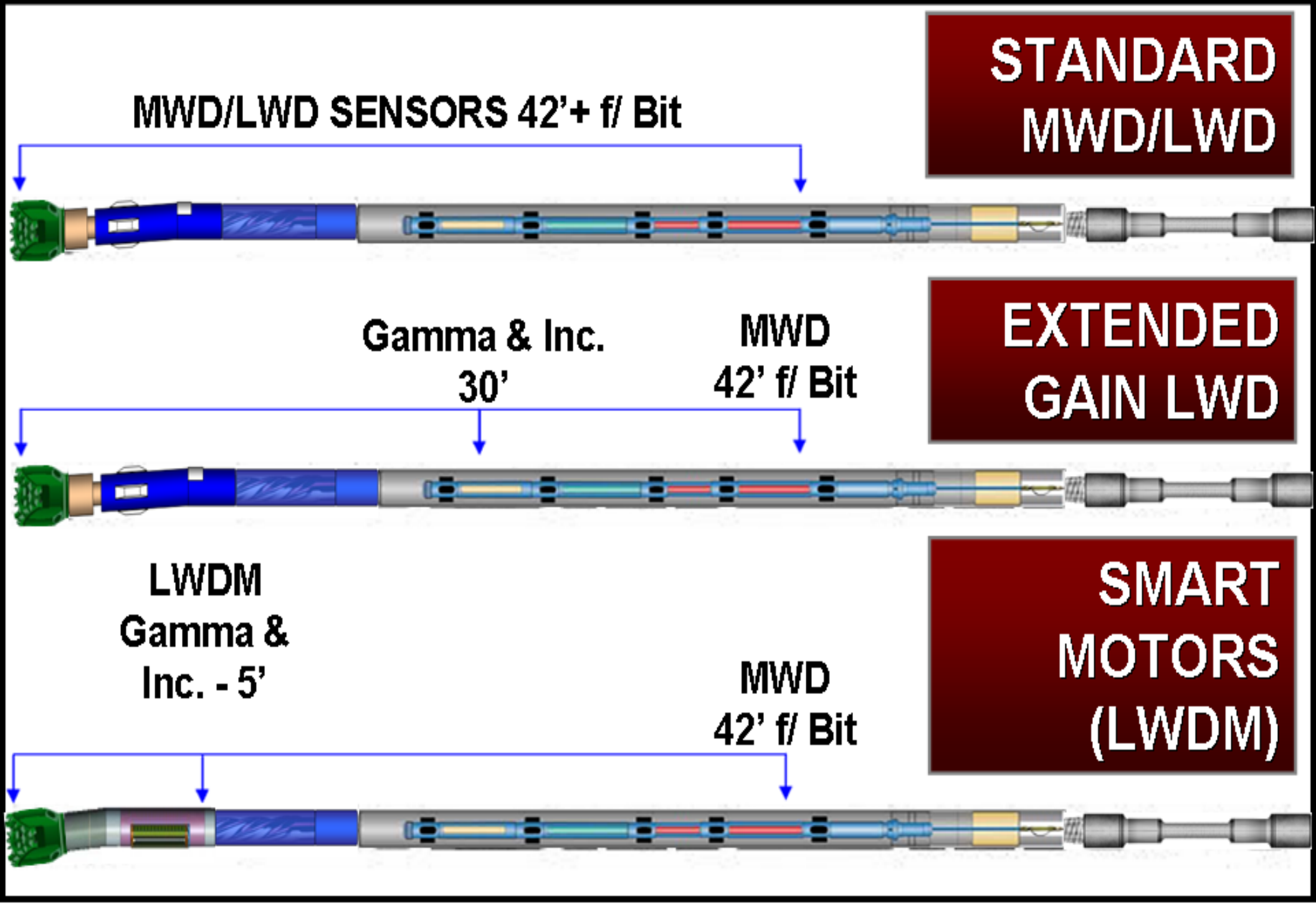
FOCUSED & ORIENTED GAMMA RAY

E-FIELD CSH LWD CONFIGURATION

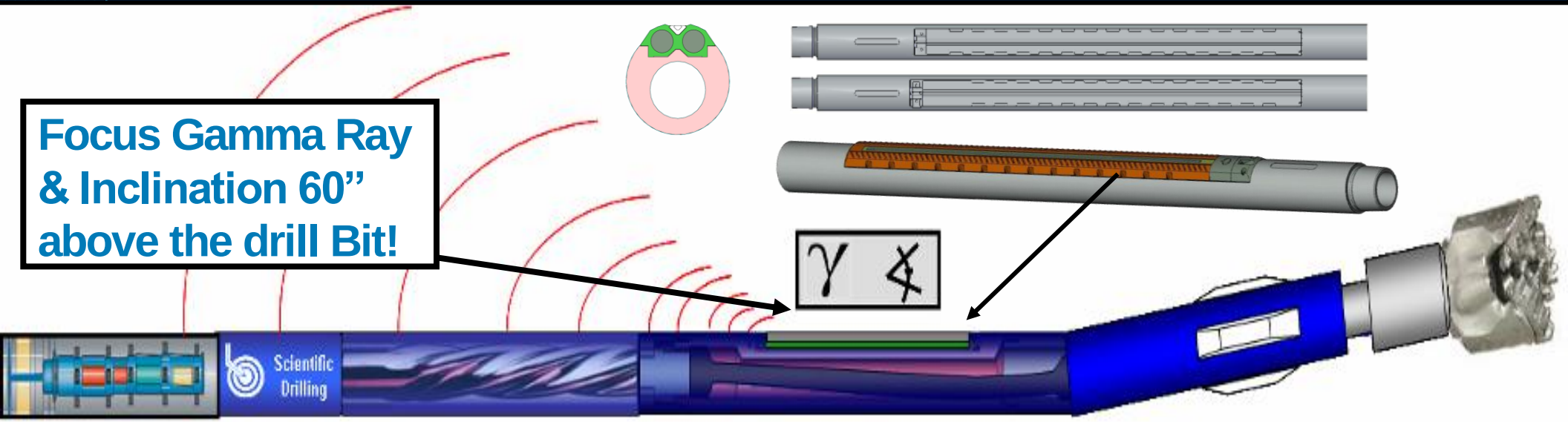
Wi-Sci Moves Sensors Closer to the Bit

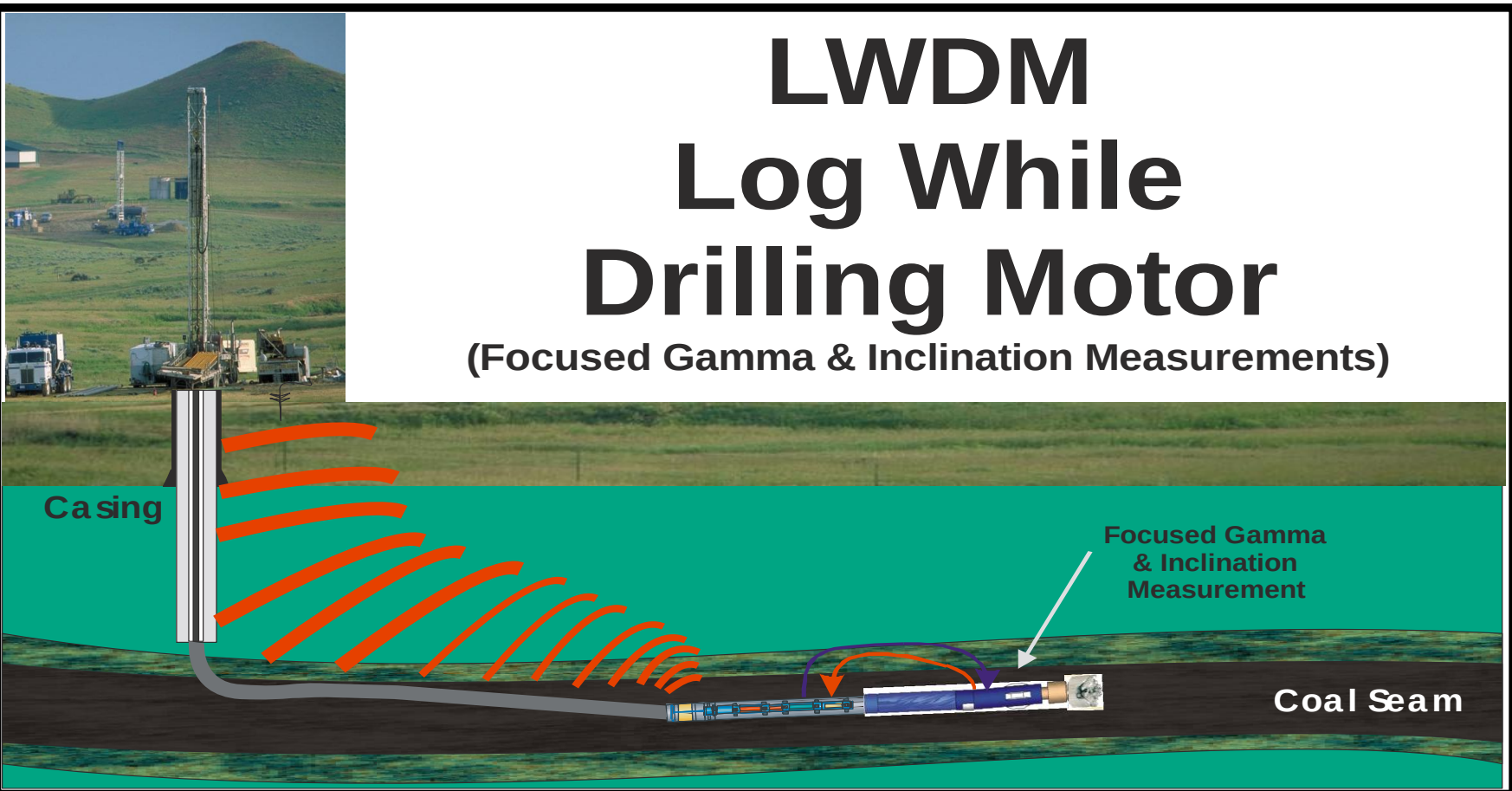


Reducing Bit to Sensor Distances

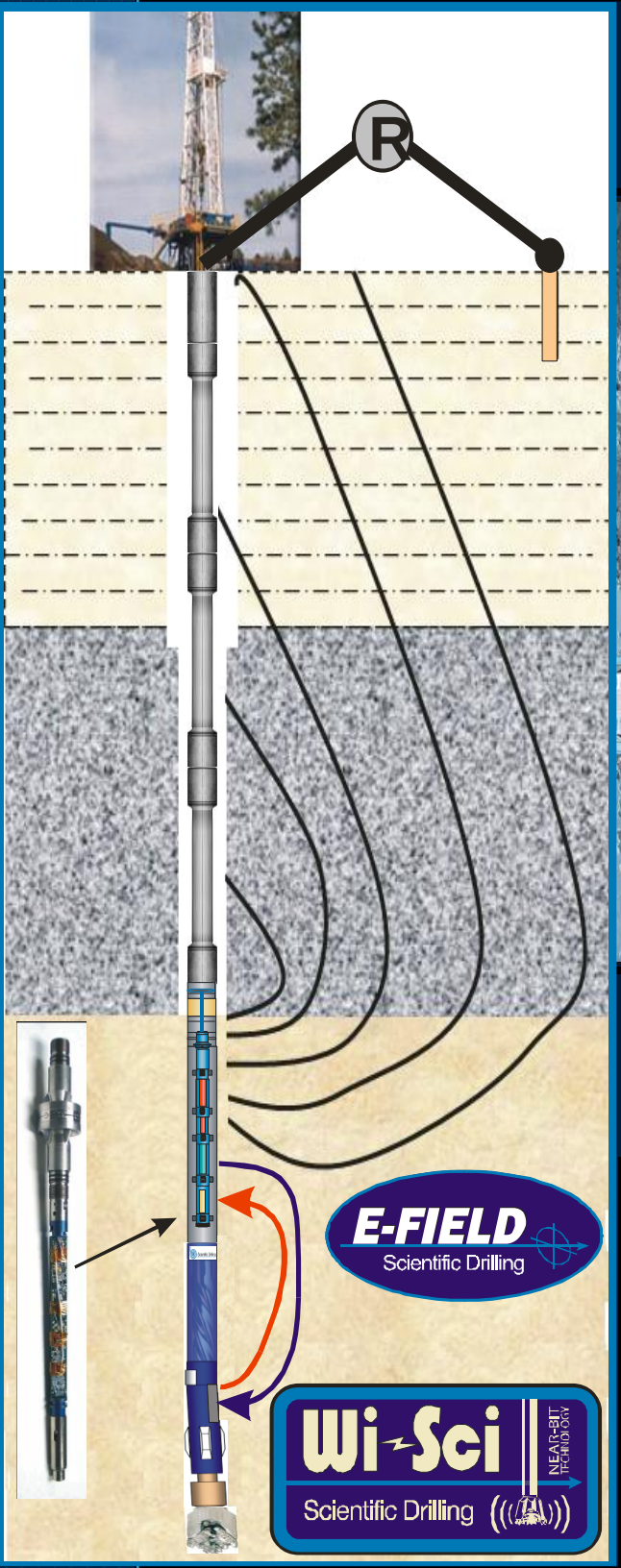


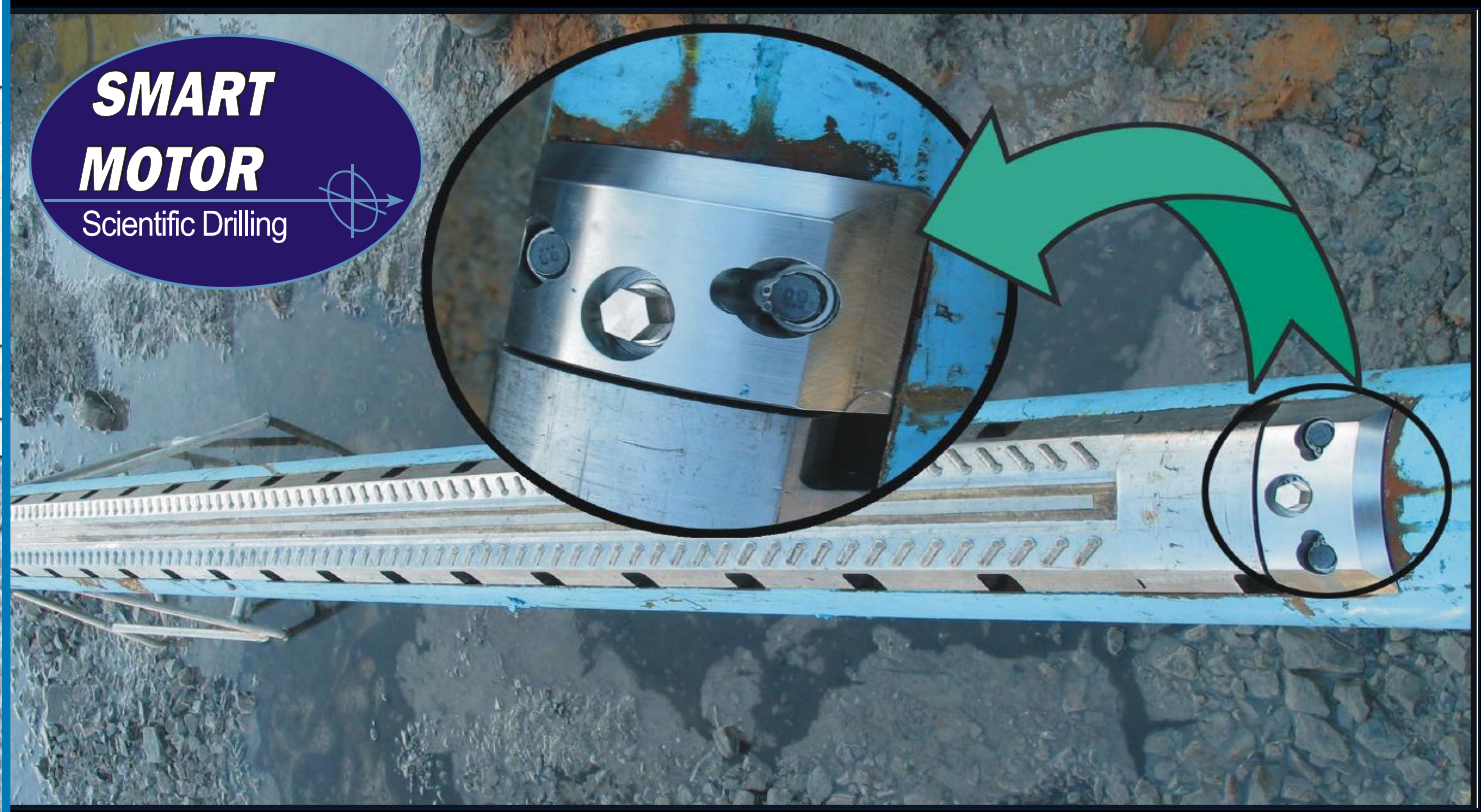
HORIZ. DIRECTIONAL DRILLING & GEOSTEERING LWD TOOLS

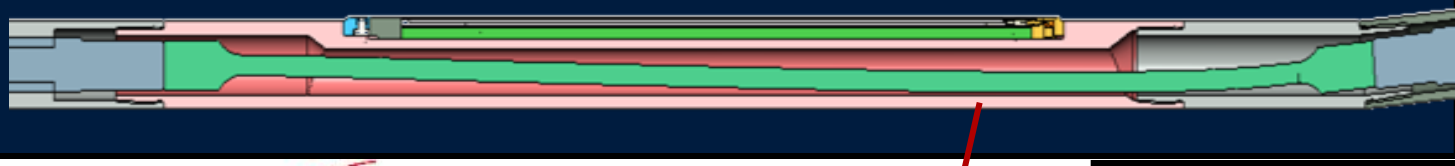


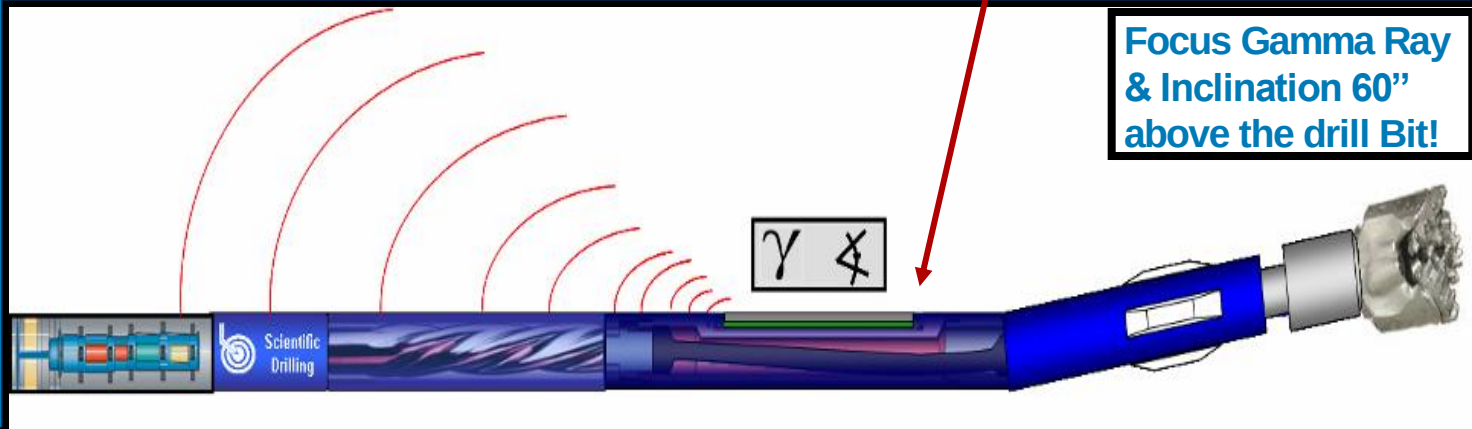


LWDM: SMART MOTOR II - DETAIL





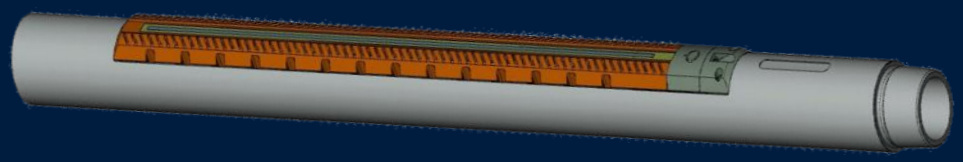




ELECTROMAGNETIC MWD –SHORT HOP

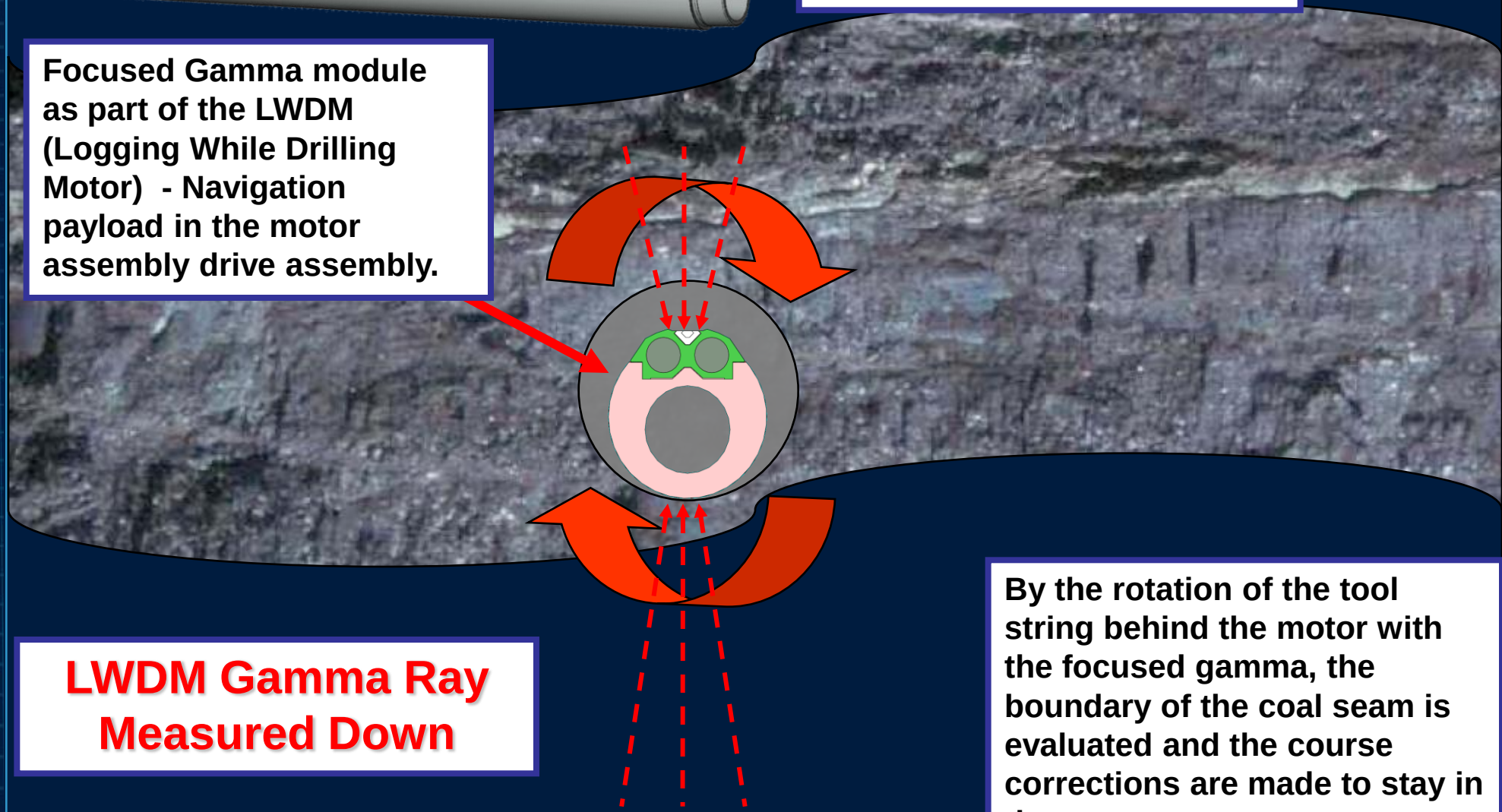
LWDM – SMART MOTOR W/ INC & FOCUS GAMMA RAY

Cross section view



LWDM Gamma Ray Measured Up

Focused Gamma module as part of the LWDM (Logging While Drilling Motor) - Navigation payload in the motor assembly drive assembly.



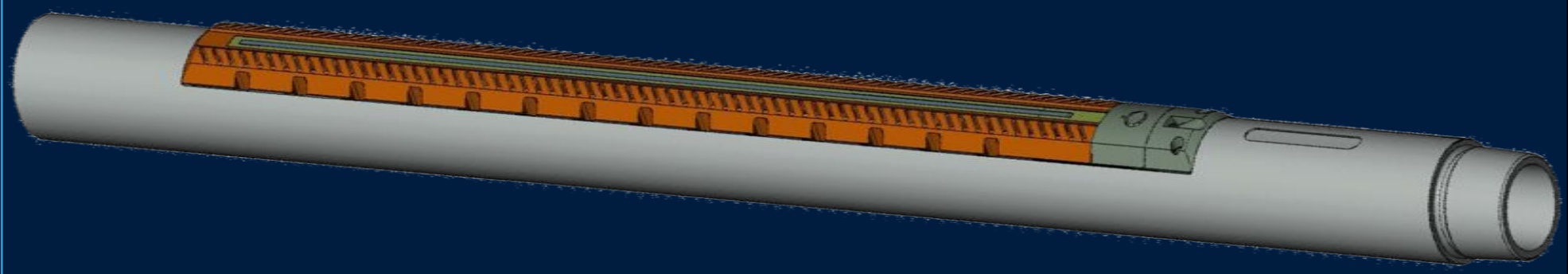
LWDM Gamma Ray Measured Down

By the rotation of the tool string behind the motor with the focused gamma, the boundary of the coal seam is evaluated and the course corrections are made to stay in the zone.

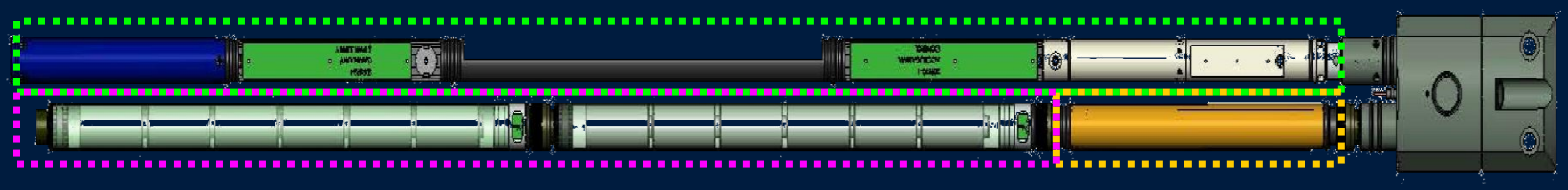
6/10/2008 2:45

LWDM SENSOR CONFIGURATION

- GAMMA RAY – NATURALLY FOCUSED / ORIENTED
- INCLINATION
- VIBRATION
- TEMPERATURE



Sensor Electronics

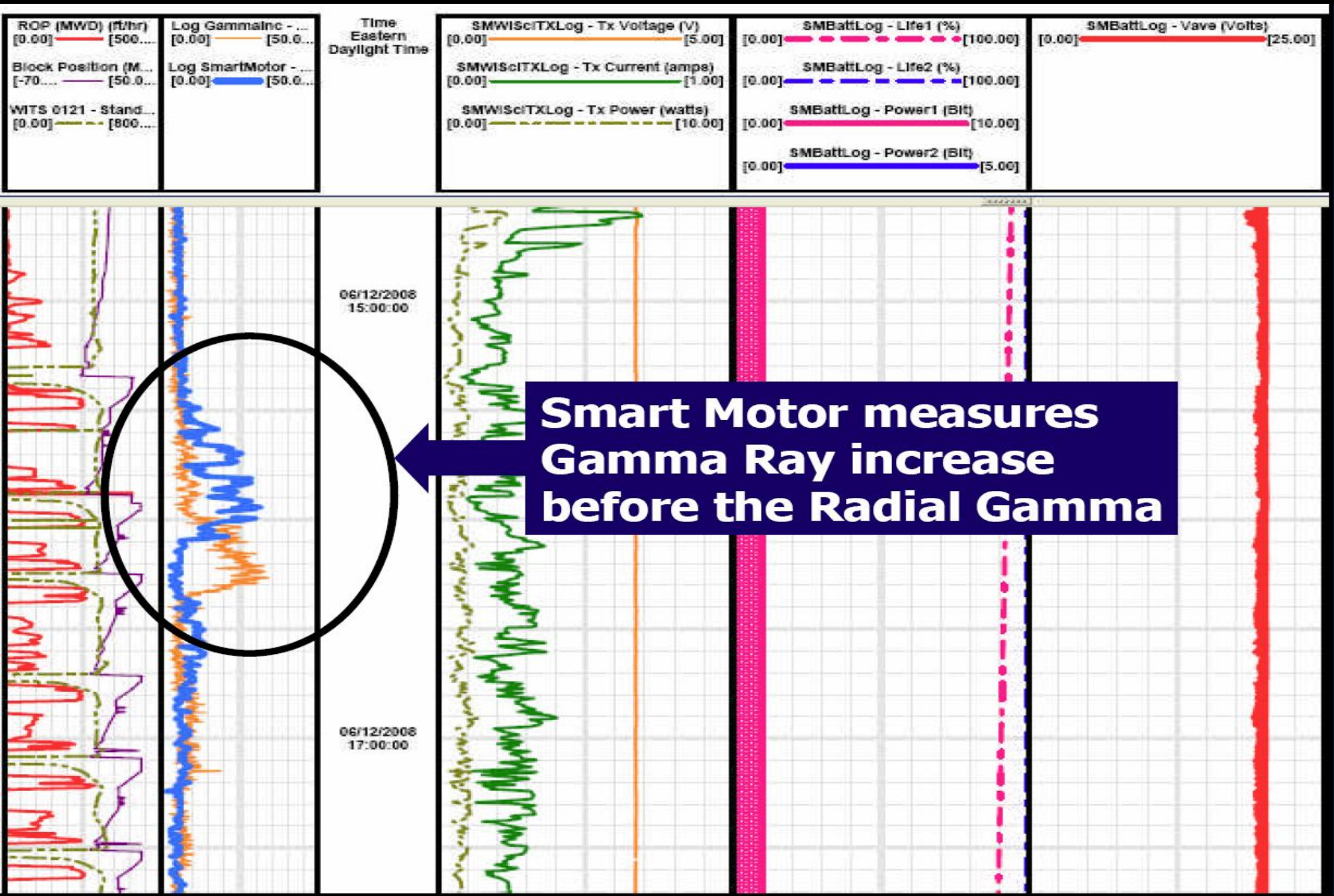


Stackable Smart Battery Packs

Smart Battery & Wi-Sci Telemetry Electronics

New Technology Development

MWD "Short Hop" data transmission & Motor Development for Slim Hole CBM



KEY CHALLENGE – DECIDE THE BEST APPROACH FOR THE SPECIFIC PROJECT

- WILL PROVEN CBM DRILLING TECHNIQUES APPLY TO UCG GAS WELL DESIGNS?
  - POSSIBLY
  - SOME TECHNOLOGY MAY WORK
  - USE SOUND DRILLING PRACTICES
  - EARLY ON, MINIMIZE YOUR RISK
- RECOMMENDATION
  - BE PREPARED TO TEST DIFFERENT DRILLING & COMPLETION TECHNIQUES TO FIND THE OPTIMAL SOLUTION
  - WHAT WORKS IN COLORADO OR OKLAHOMA CBM MAY NOT WORK IN ALL UCG APPLICATIONS
  - BE READY TO EXPERIMENT, MINIMIZE YOUR RISKS & WORK REALLY HARD TO ESTABLISH DESIGNS THAT WORK BEST FOR EACH LOCAL AREA
  - PLAN WELLS TO MAXIMIZE YOUR ACREAGE AND MINIMIZE IMPACT TO THE ENVIRONMENT

SUMMARY & RECOMMEDATIONS

- Use in UCG what has been successful in CBM Horizontal Drilling
- Have a Team Approach & Keep the Team Consistent
- Make a detailed plan but be flexible
- Maximize wellbore stability by drilling a smaller wellbore diameters
- Use the best “fit for purpose” drilling tools
- Promote the development of new tools and methods to help drill a higher percentage coal footage

GENERAL DISCUSSION & QUESTIONS