The Shale Gas Boom and Bust

Outline

- Introduction
- Shales and Claystones
- Conventional Petroleum Systems
- How to Drill a Well
- Unconventional Petroleum Systems
- Three Shale Gas Basins
- Comments on Diverse Problems: Water, Resource Assessments, Joint Ventures, Gas Prices, Booms and Busts
- Conclusions

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Dave White, Chris Cornelius, Dennis Carlton, Bill Zagorski

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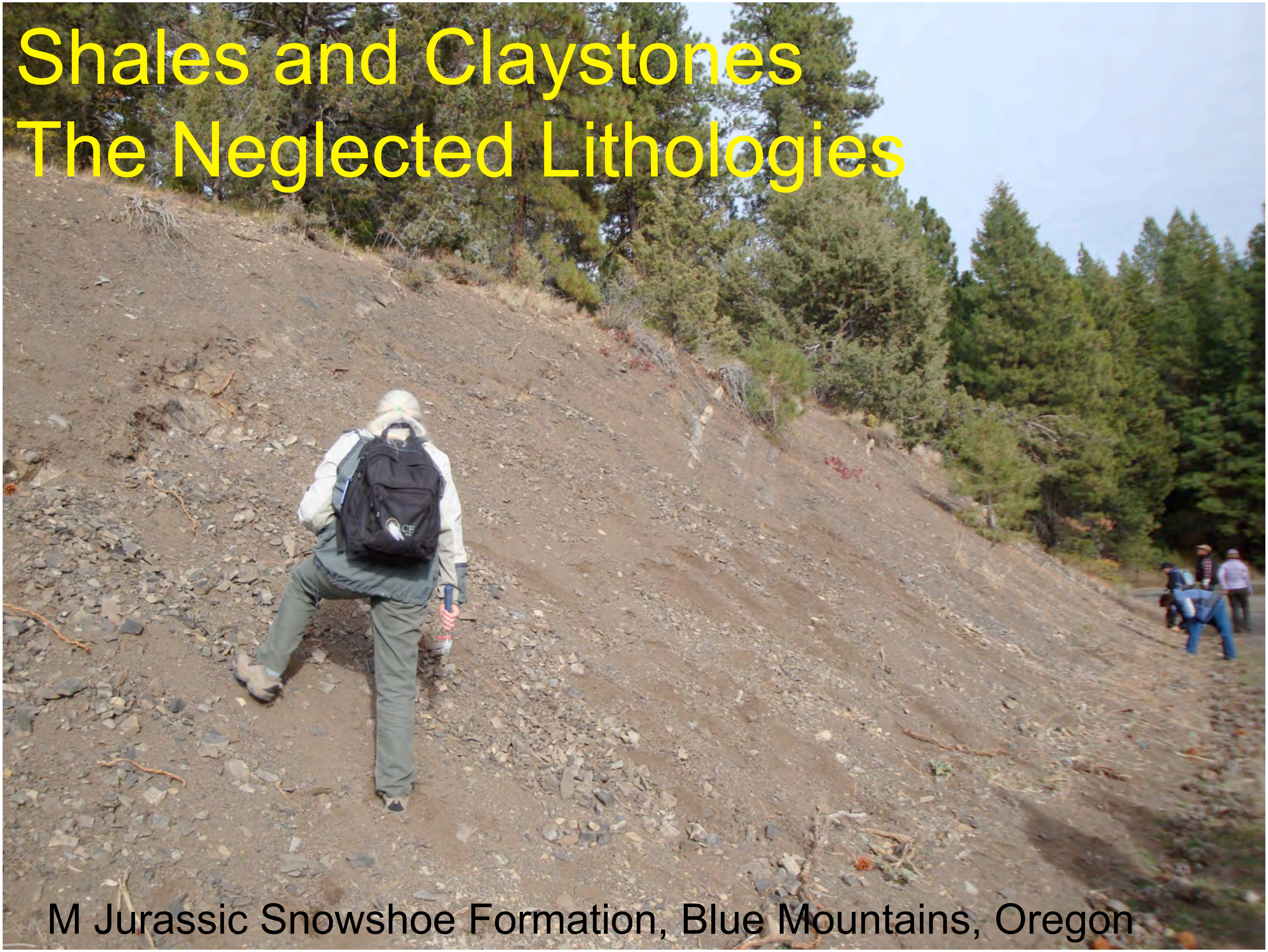
Grain Diameter: millimeters	microns	phi	Wentworth Size Class		
				Boulder	Gravel
256		-8.0			
				Cobble	Gravel
64		-6.0			
				Pebble	Gravel
4.0	4000	-2.0			
				Granule	Gravel
2.0	2000	-1.0			
			vcU	Very coarse sand	Sand
1.41	1410	-0.5			
			vcL	Very coarse sand	Sand
1.0	1000	0.0			
			cU	Coarse sand	Sand
.71	710	0.5			
			cL	Coarse sand	Sand
0.5	500	1.0			
			mU	Medium sand	Sand
0.35	350	1.5			
			mL	Medium sand	Sand
0.25	250	2.0			
			fU	Fine sand	Sand
0.177	177	2.5			
			fL	Fine sand	Sand
0.125	125	3.0			
			vfU	Very fine sand	Sand
0.088	88	3.5			
			vfL	Very fine sand	Sand
0.0625	62.5	4.0			
				Silt	Mud
0.002	2.0	9.0			
				Clay	Mud

http://jsedres.sepmonline.org/content/82/6/364/F1.large.jpg

Shales and Claystones
The Neglected Lithologies



M Jurassic Snowshoe Formation, Blue Mountains, Oregon


Upper Cretaceous Hunters Cove Formation,
Cape Sebastian, Oregon

Paunsagut Plateau, Southwest Utah

Eastern Grand Canyon, Arizona

Claystones are deposited in quiet water environments

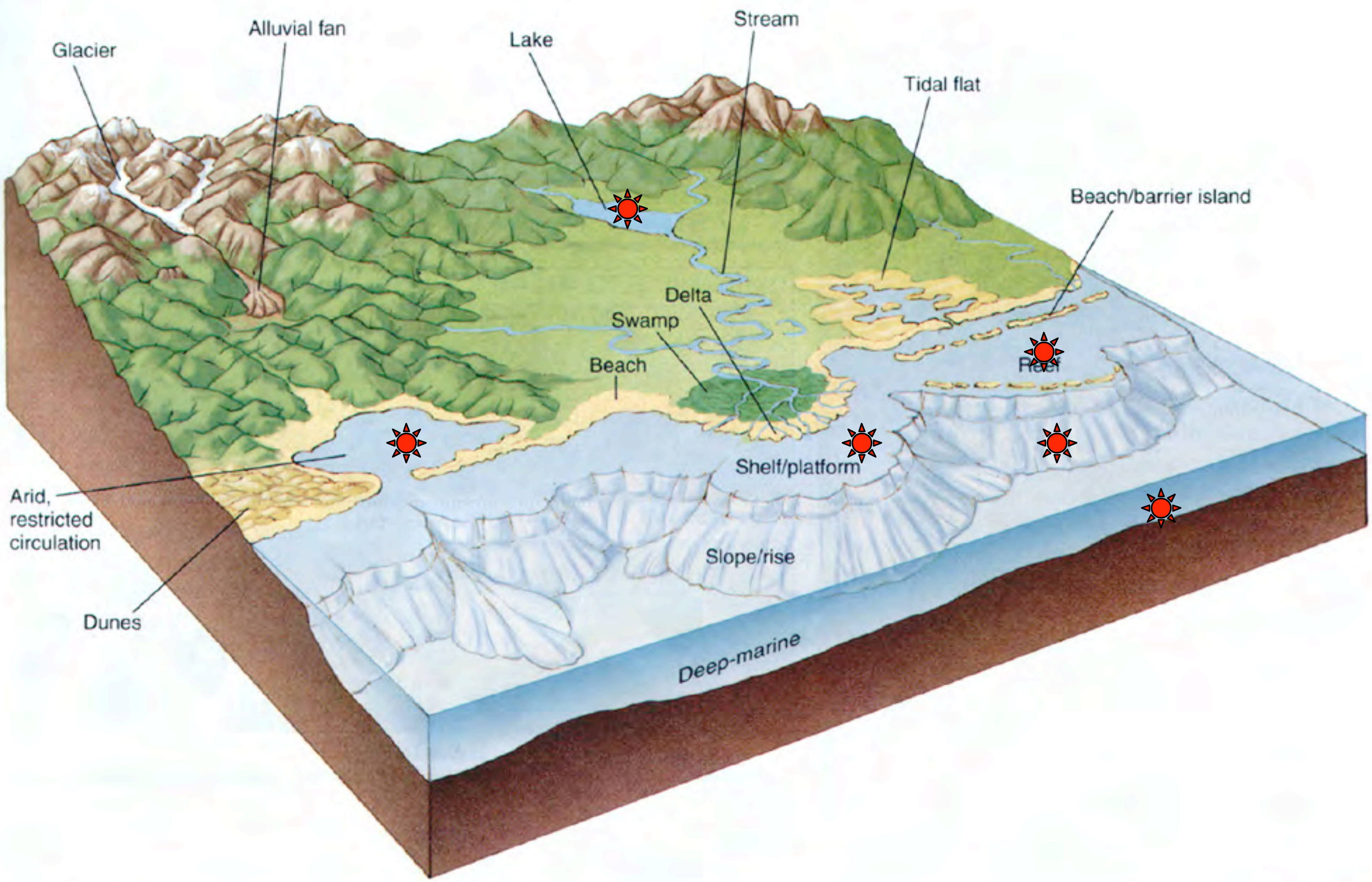
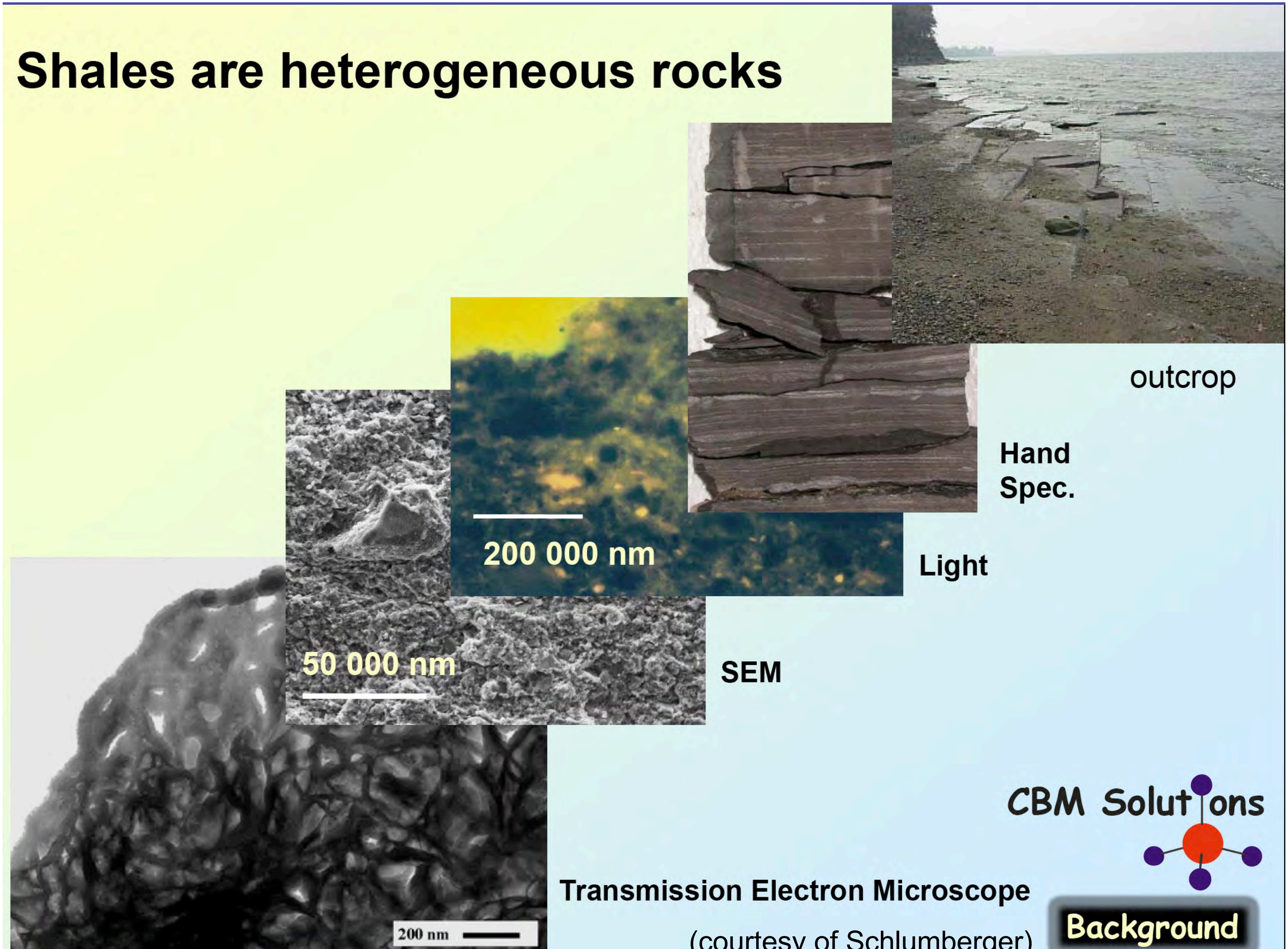


FIGURE 4.2
Typical sedimentary depositional environments.
(Adapted from Jones, 2001: Laboratory Manual for Physical Geology, 3rd edition.)

http://www.eas.purdue.edu/mesozoic/lab_03/Sedi_Environments.jpg

Shales are heterogeneous rocks



(courtesy of Schlumberger)

CBM Solutions

Background

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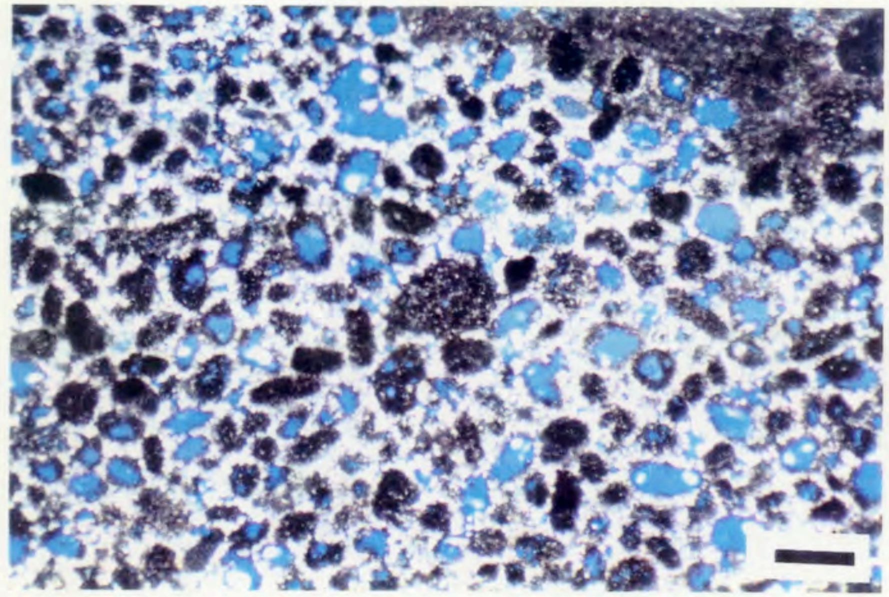
Conventional Petroleum Systems

- Reservoir Rock
- Seal Rock
- Structure or Trap
- Source Rock
- Maturation of Source Rock
- Migration of Oil and Gas

Reservoir:
Porosity
Without
Permeability

Reservoir:
Porosity
With
Permeability



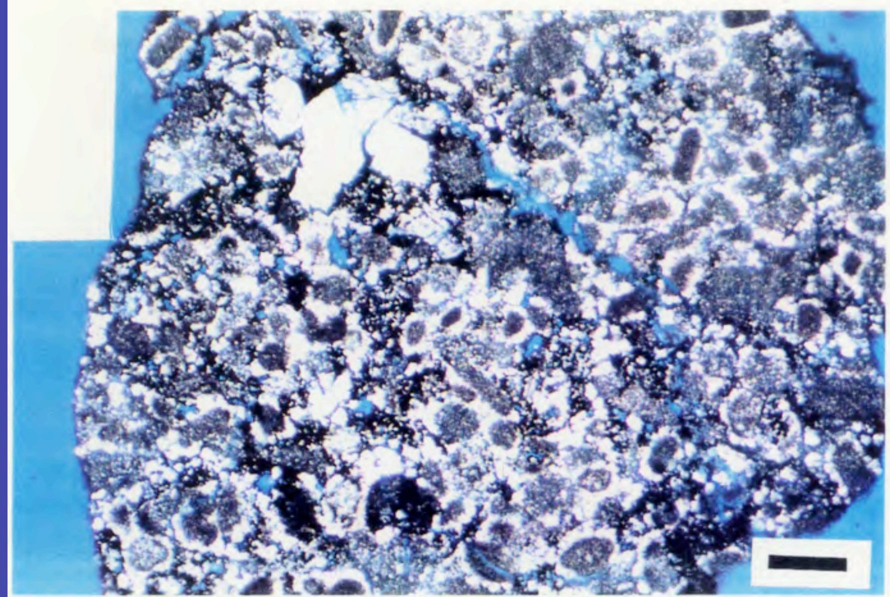


Figure 8. Photomicrographs of dolomite facies, #1 Linden. A. thin section photomicrograph from core, 4406.8 m; B. thin section photomicrograph from cuttings, 4409.5 m. Blue voids indicate porosity. Scale bars = 500 μ.

Structure

Reservoirs-Seals-Source Rocks

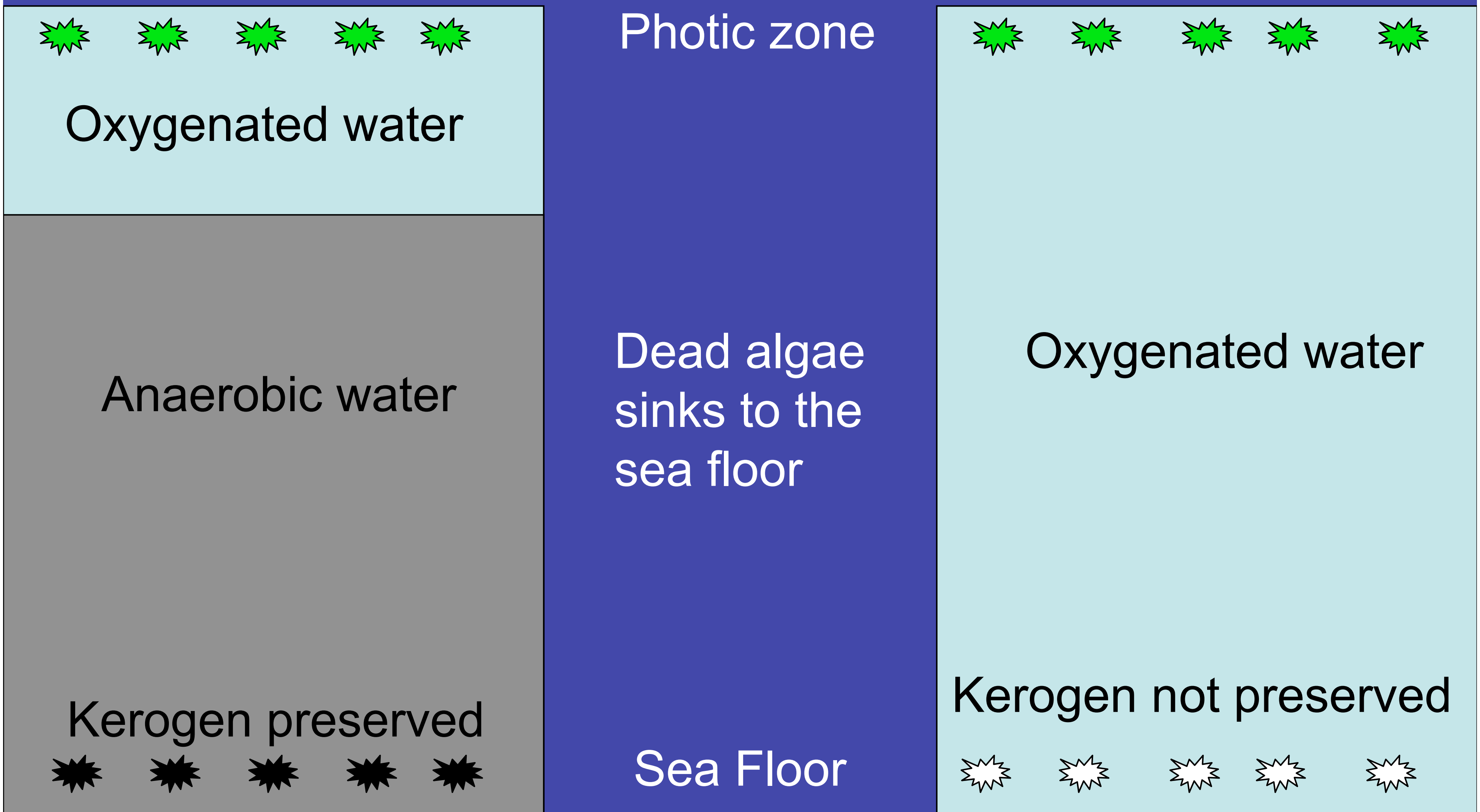
Seep = Migration

Source rock: Kerogen supports the walls of algae.
With burial, kerogen breaks down to yield oil and gas.

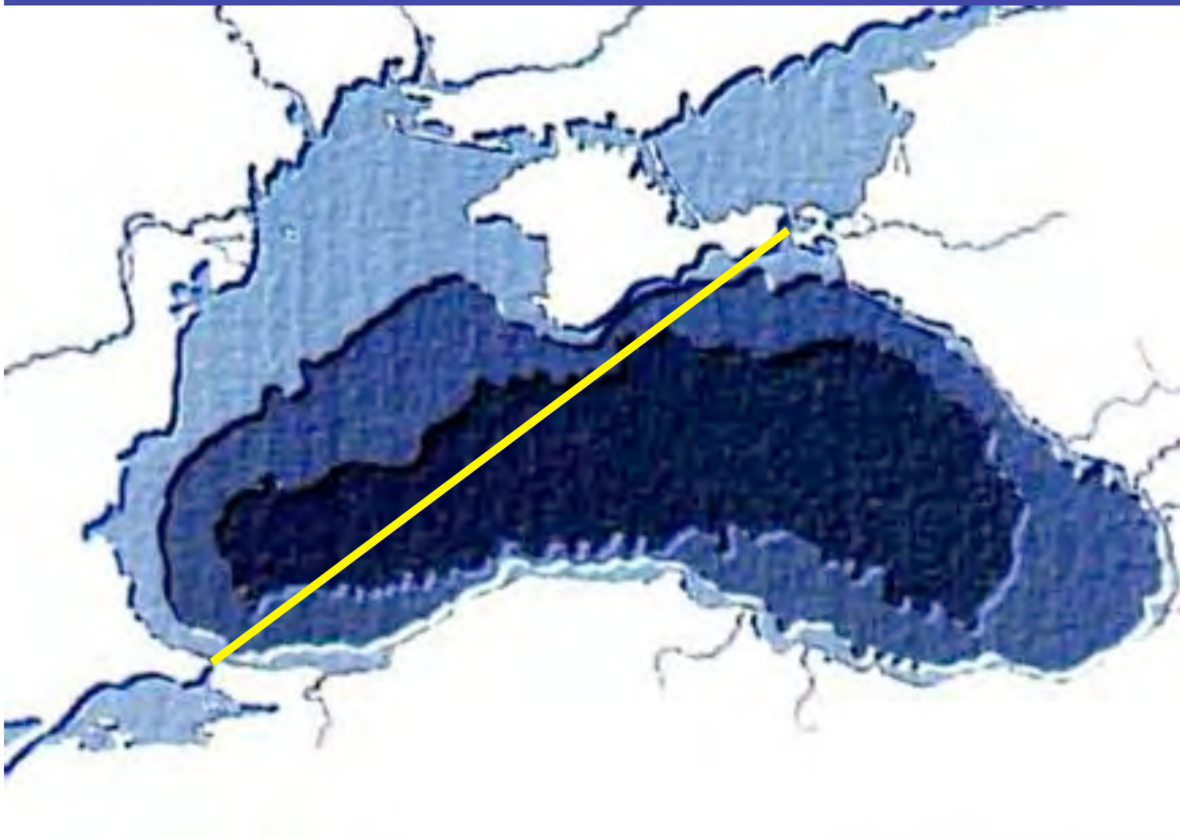
Seaweed *enteromorpha sp*

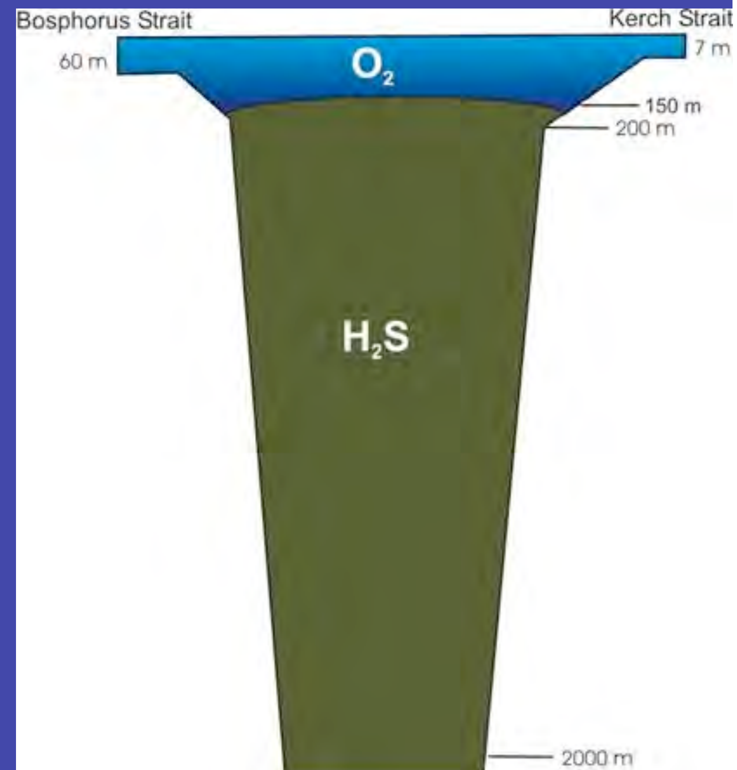
http://www.sciencephoto.com/media/16469/enlarge

Source rock: Algae sink to the sea floor after death. Kerogen preservation depends on anoxic conditions on the basin floor



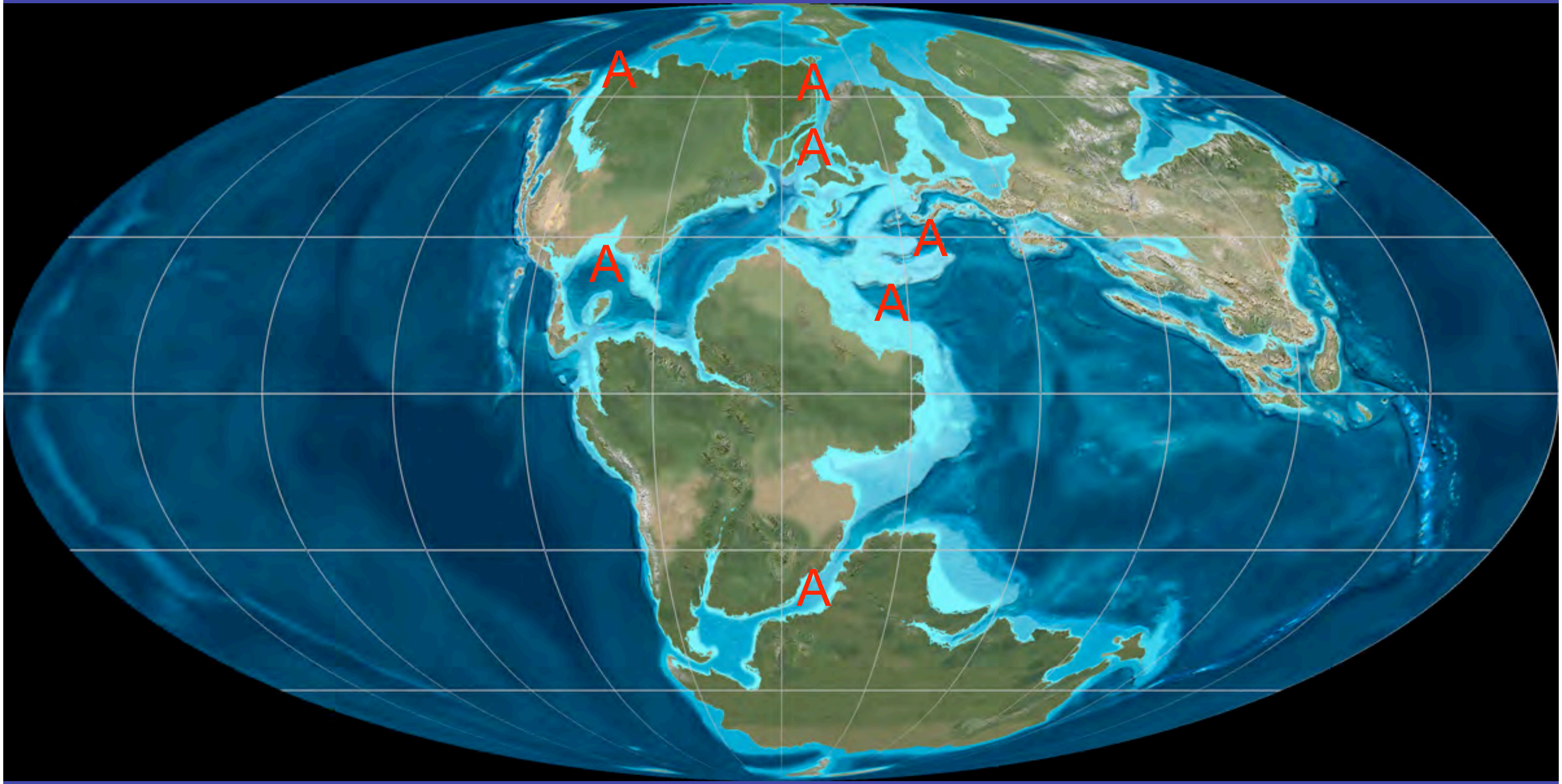
Black Sea: Model for Anoxic Basins Where Kerogen is Preserved





http://www.blacksea-commission.org/_publ-SOE2002-eng.asp#_Toc39914629

Late Jurassic Paleogeography



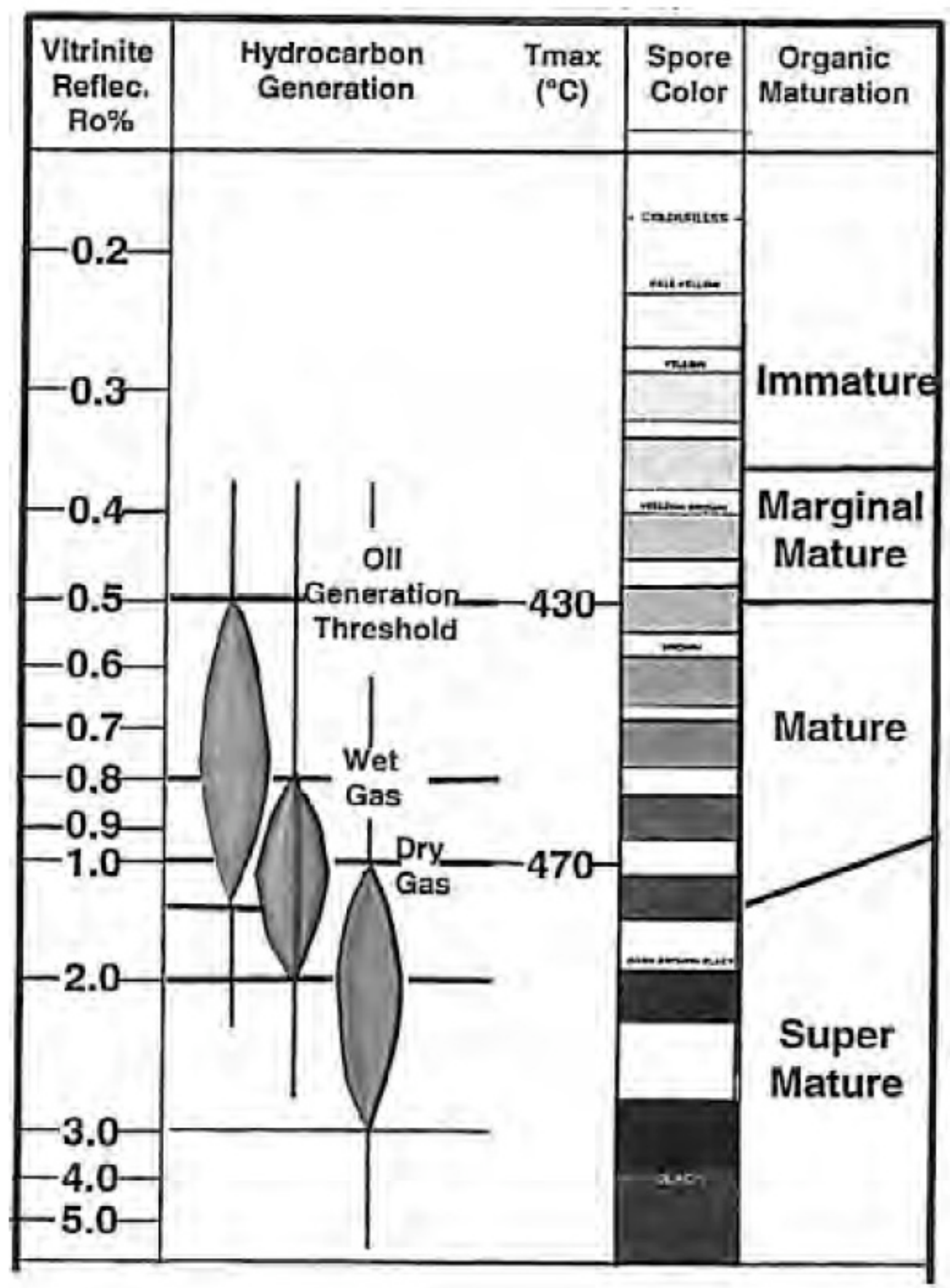
A = Basins with anoxic deposition

http://cpgeosystems.com/150moll.jpg, Copyright Ron Blakely

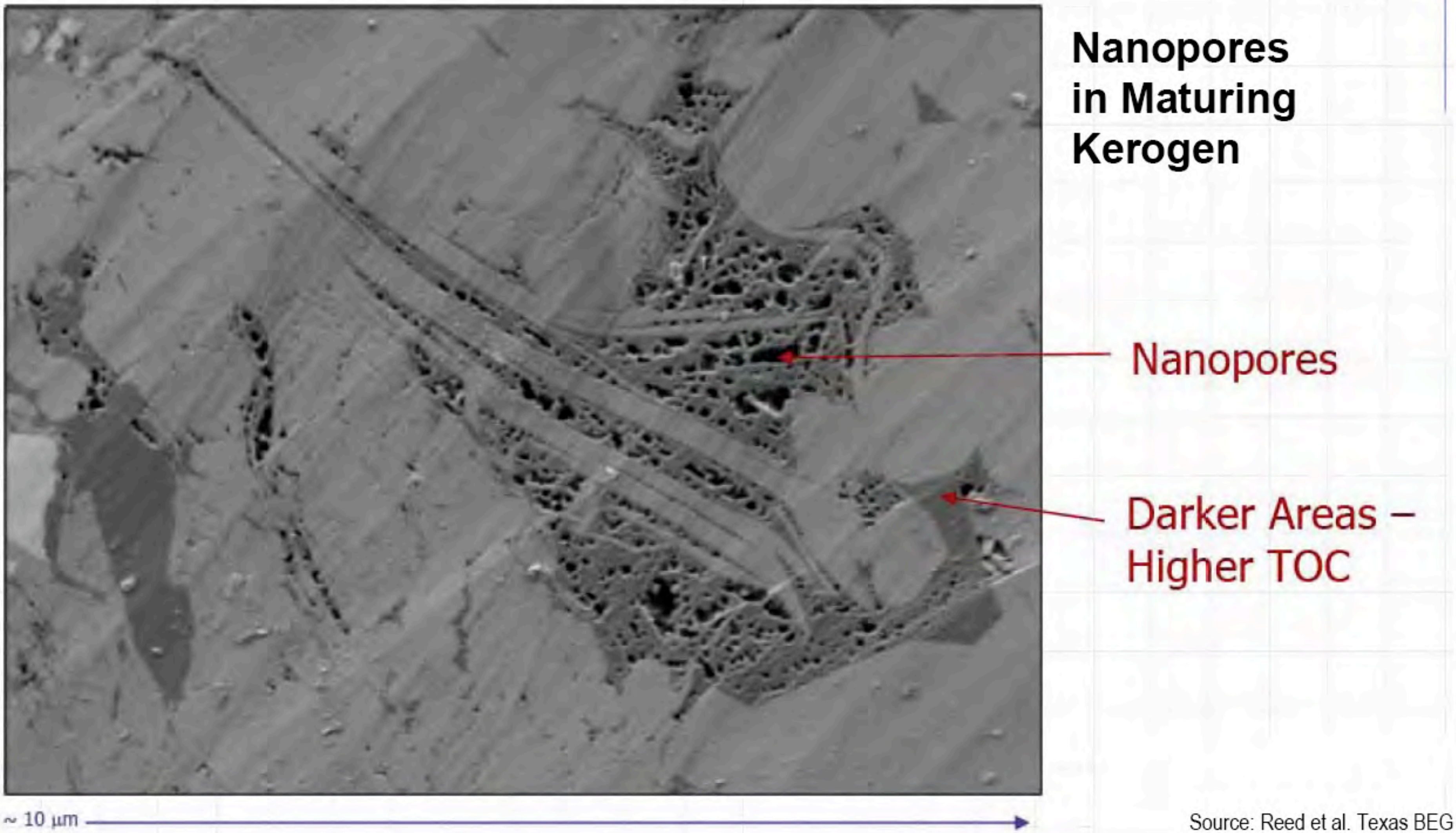
Burial of kerogen results in heating, which causes it to break down yielding oil, gas, and ultimately carbon.

The depth of each of these events depends on the local geothermal gradient and the composition of the kerogen.

Figure 2-6. Thermal Maturation Scale

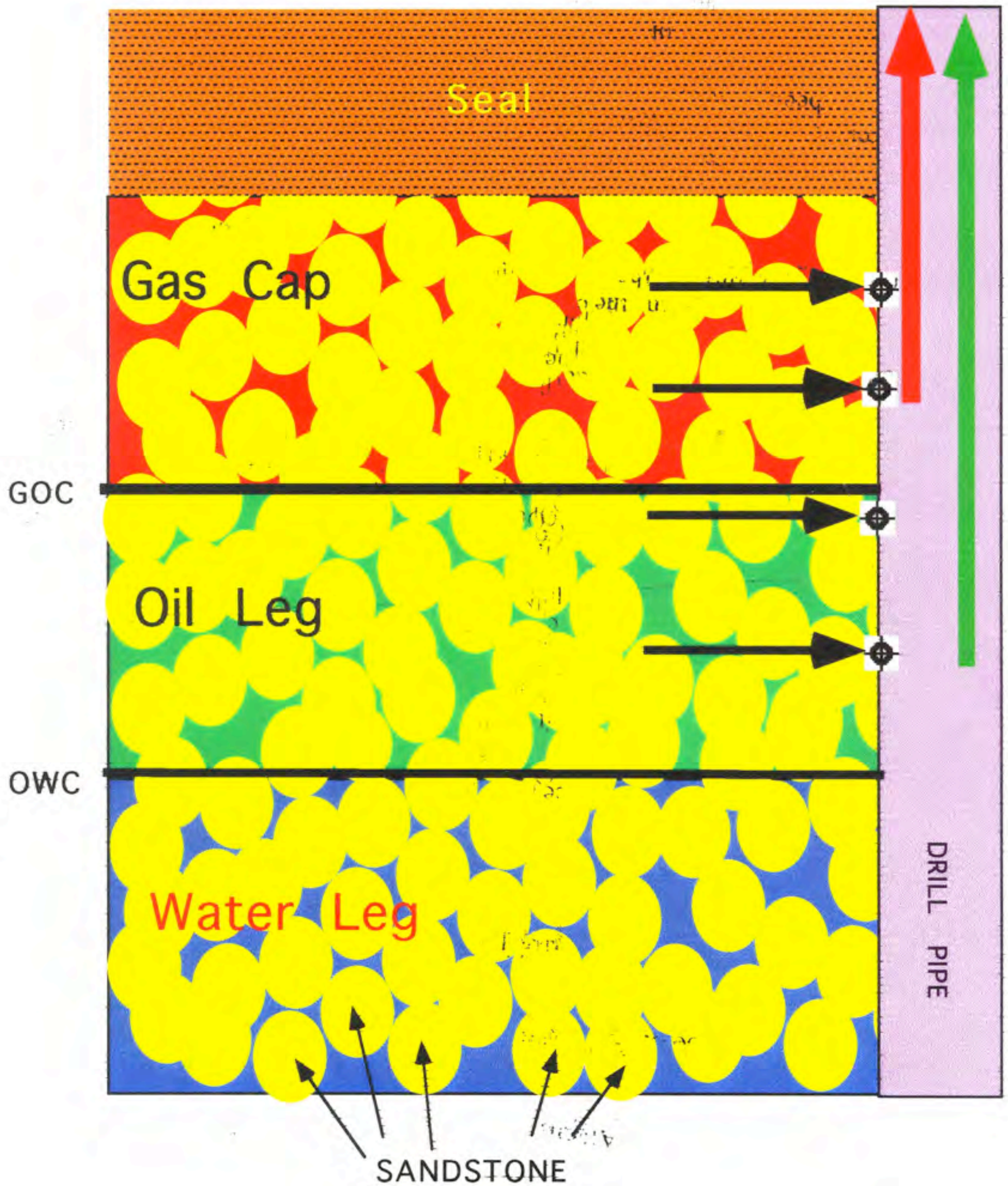


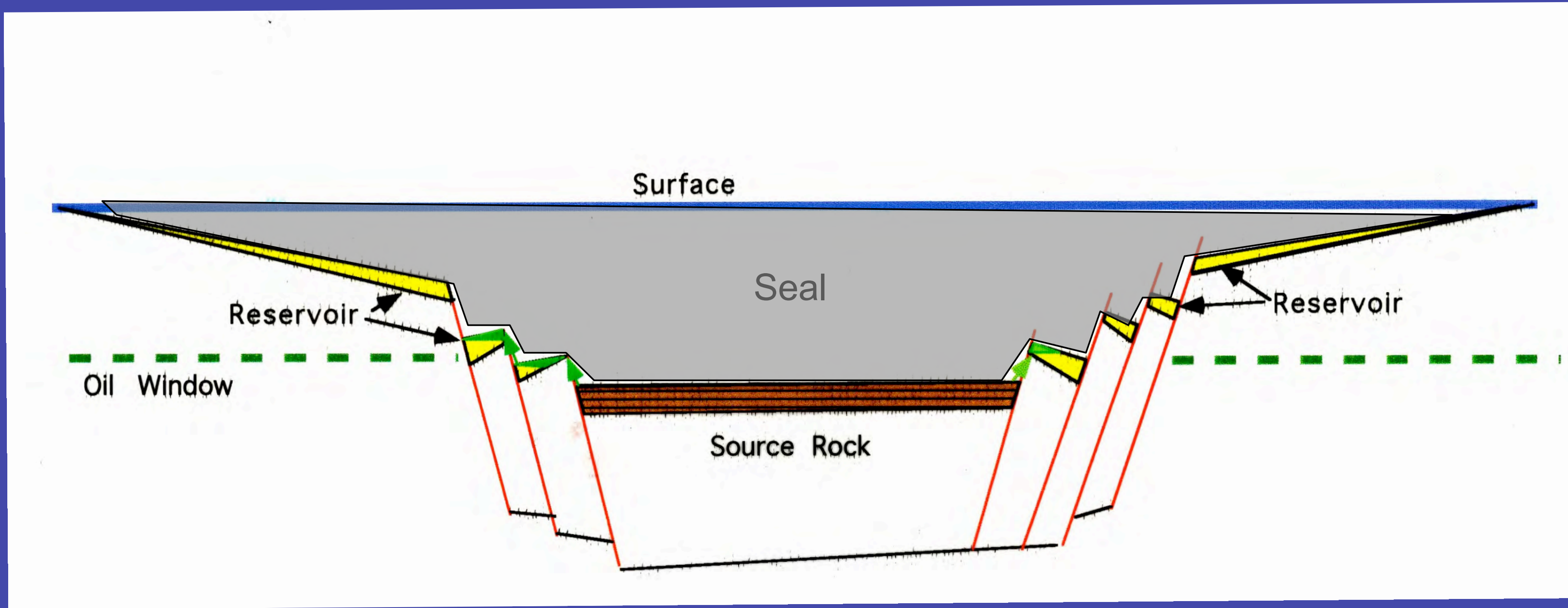
Thermal maturation of kerogen also generates nano-porosity



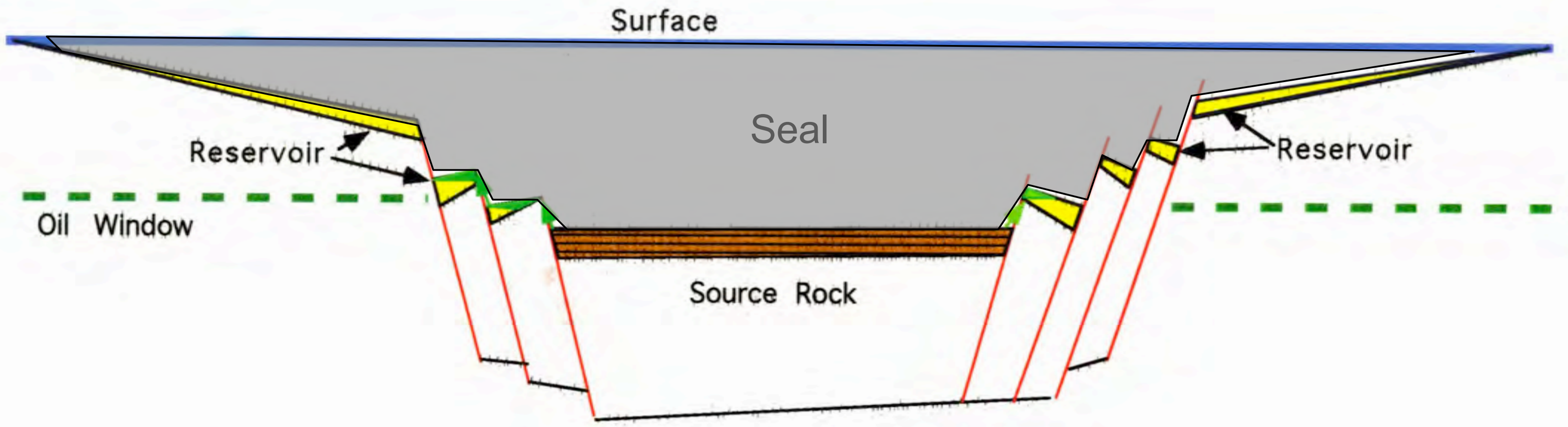
Source: Reed et al. Texas BEG

GAS AND OIL RESERVOIR

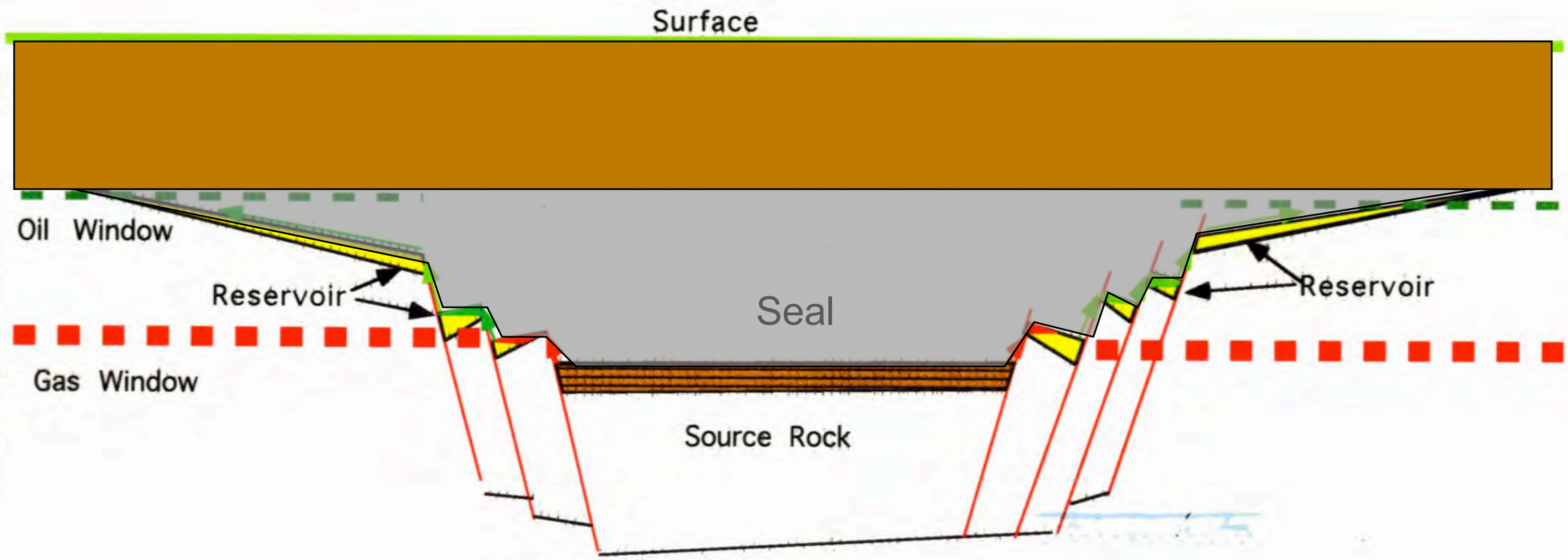



Surface
Seal
Reservoir
Reservoir
Oil Window
Source Rock

Time 1


Surface
Seal
Reservoir
Reservoir
Oil Window
Source Rock

Time 2


Surface
Oil Window
Reservoir
Seal
Reservoir
Gas Window
Source Rock

Conventional petroleum systems require a well orchestrated subsurface sequence

- Reservoir Rock
- Seal Rock
- Structure or Trap
- Source Rock
- Maturation of Source Rock
- Migration of oil and gas

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How to drill a well

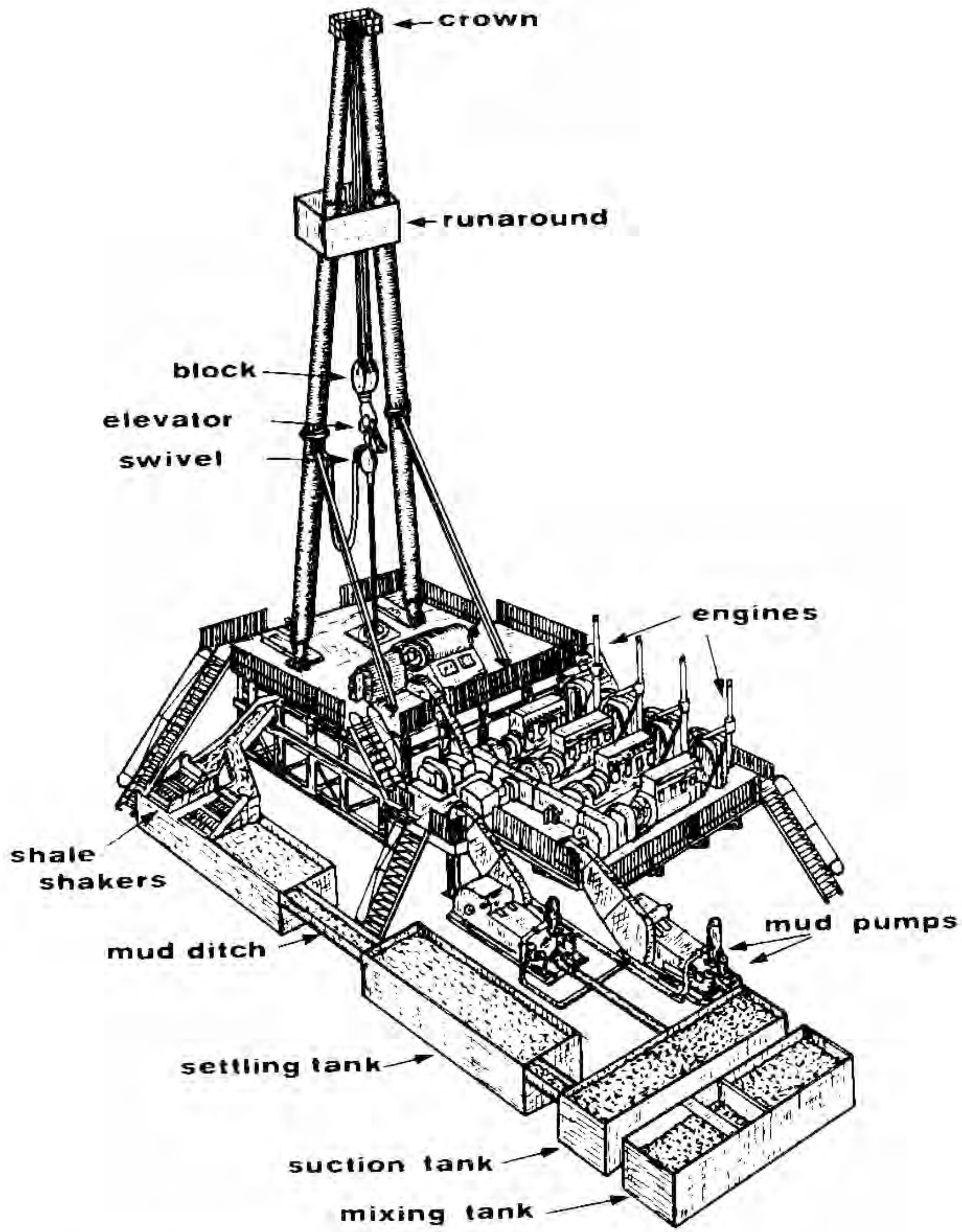


Fig. 43 Schematical picture of a typical rotary rig.

Brockmann (1971)

Brockmann (1971)

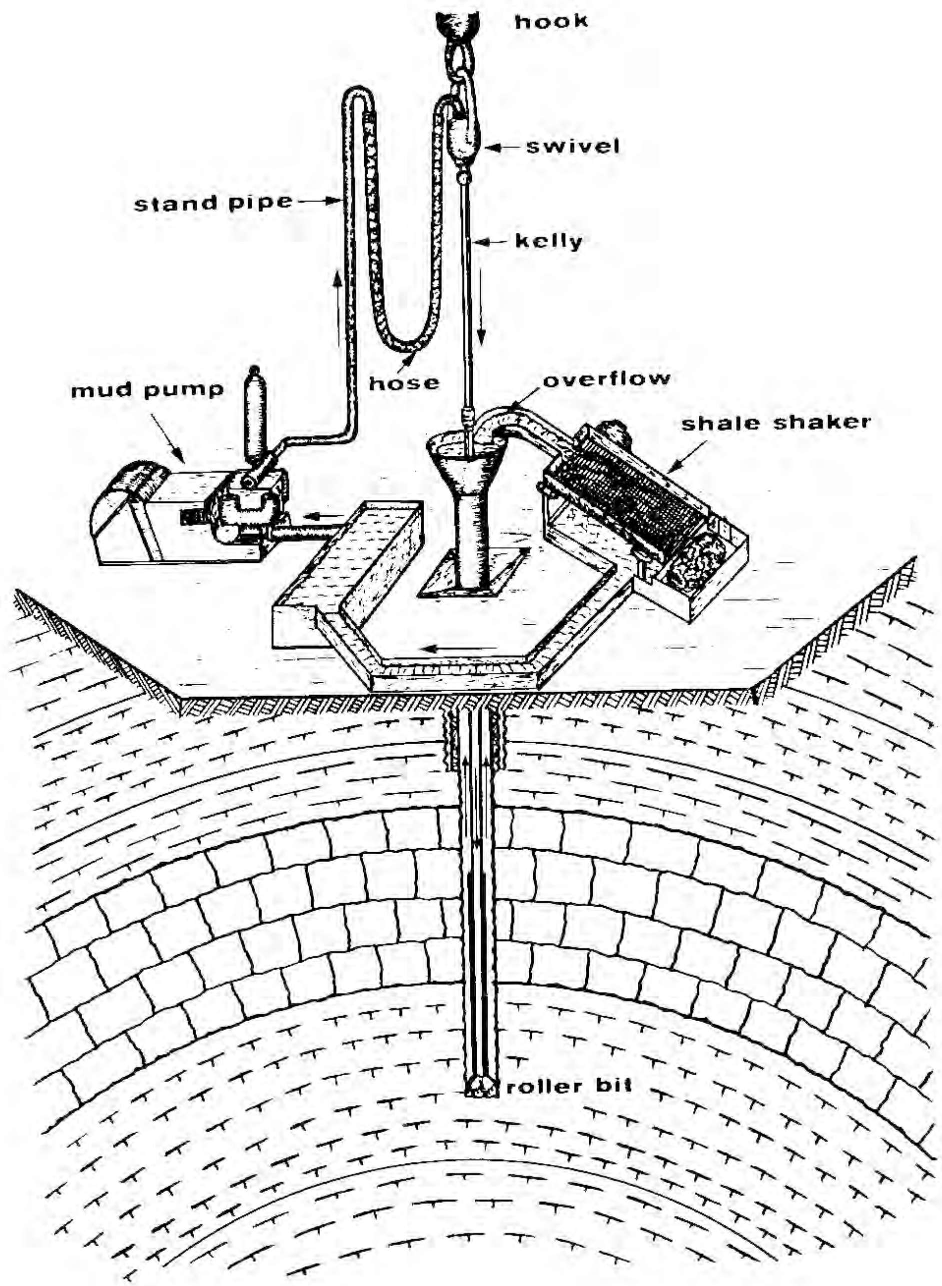
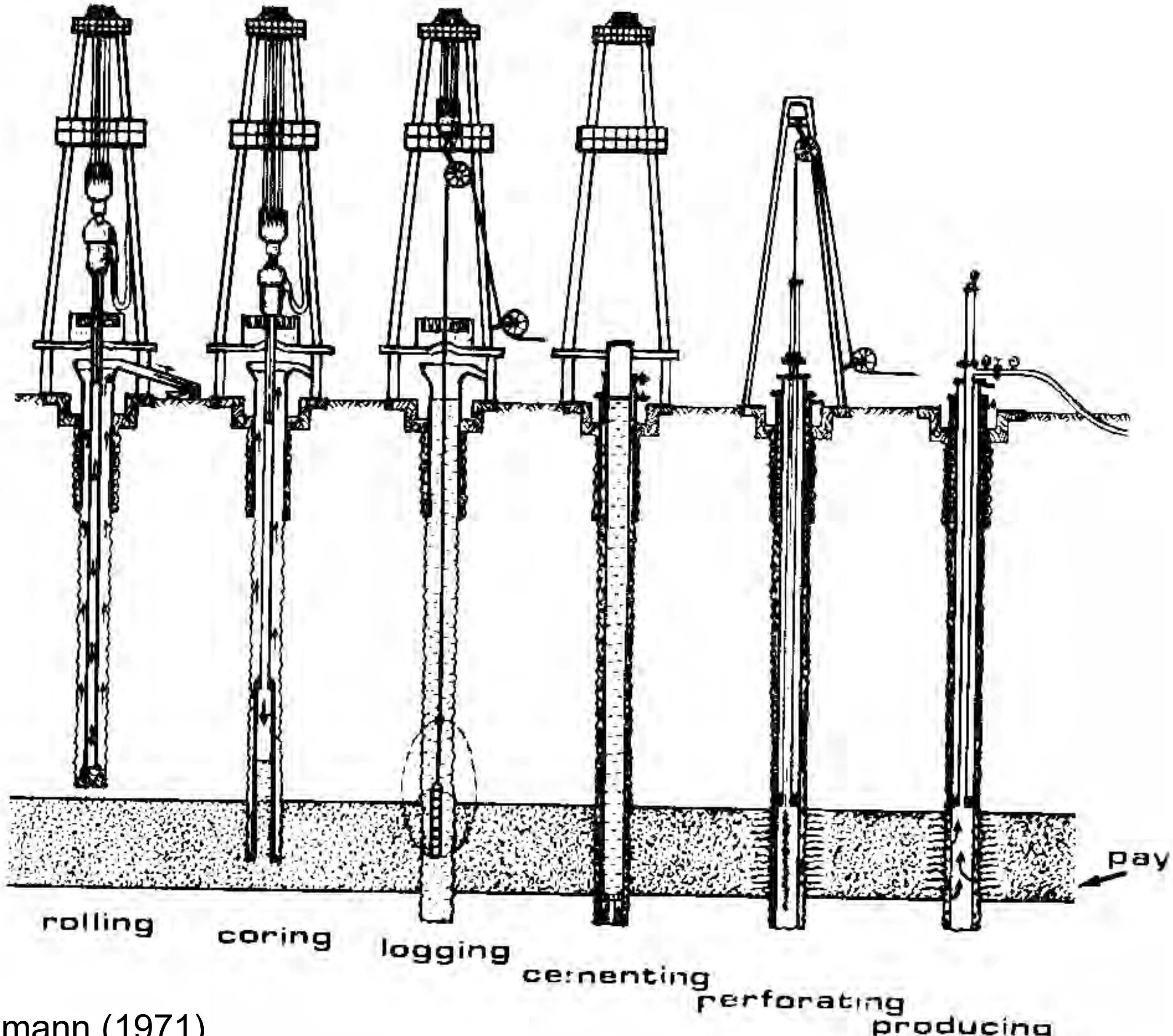


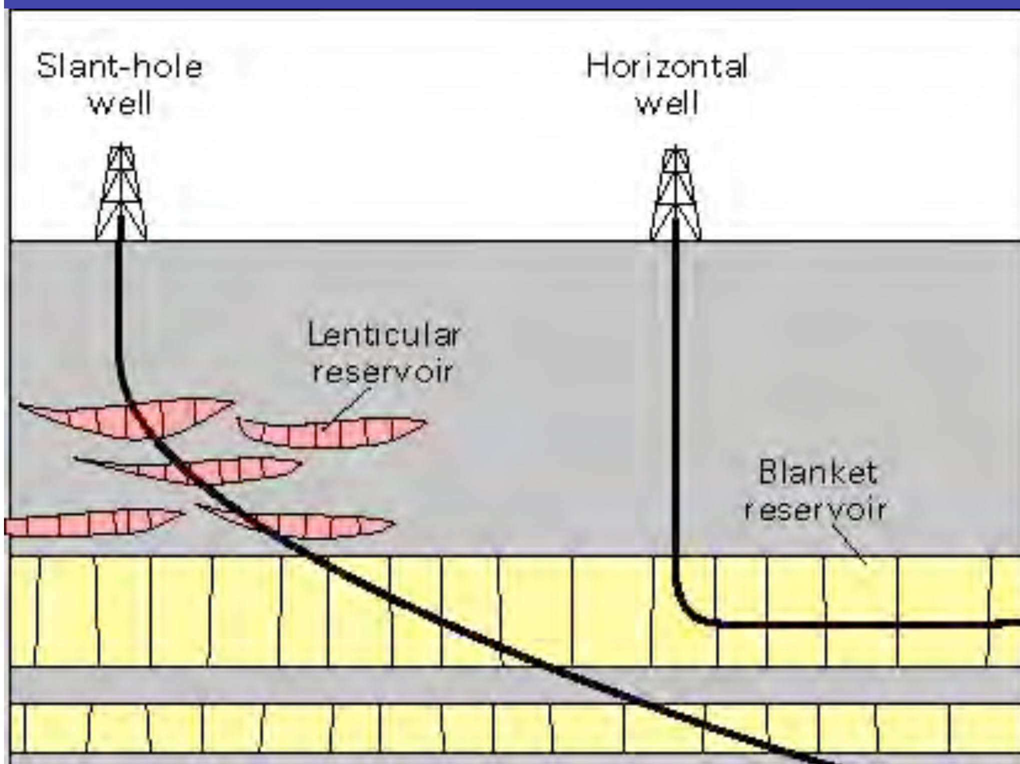
Fig. 50 Schematical flow diagram of the drilling mud system.

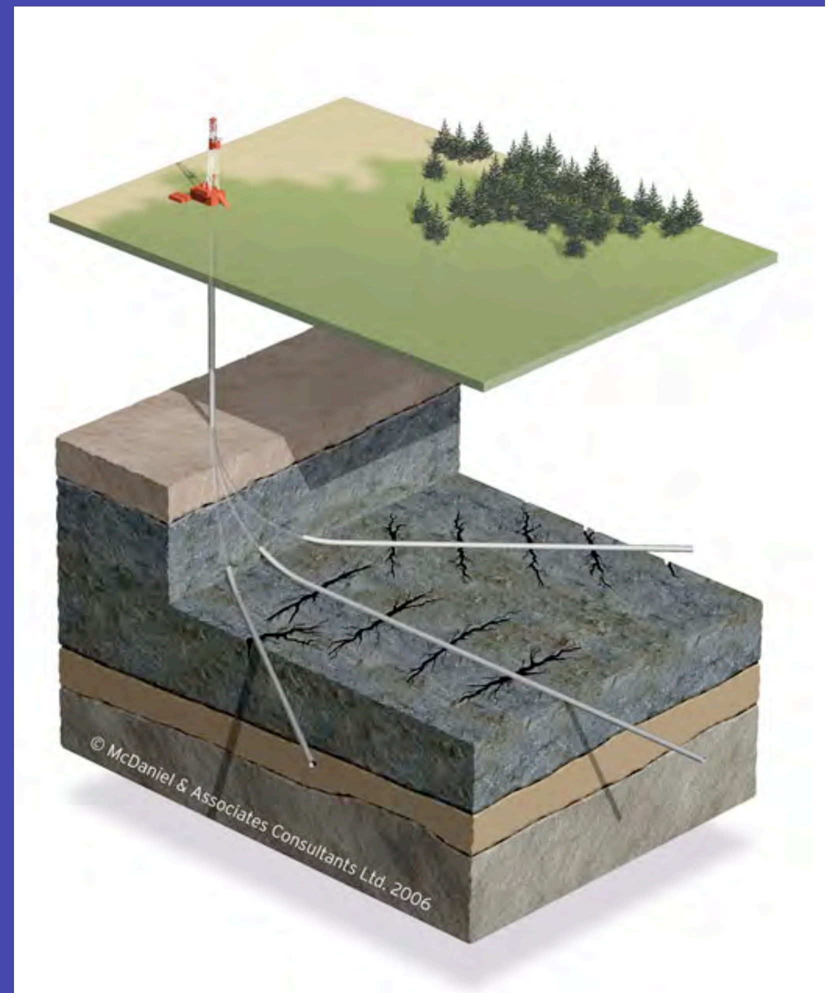


Brockmann (1971)

Deviated Wells

- First developed to reach offshore locations
- Subsequently used to reach multiple reservoirs
- Recently, horizontal wells used to increase reservoir pay





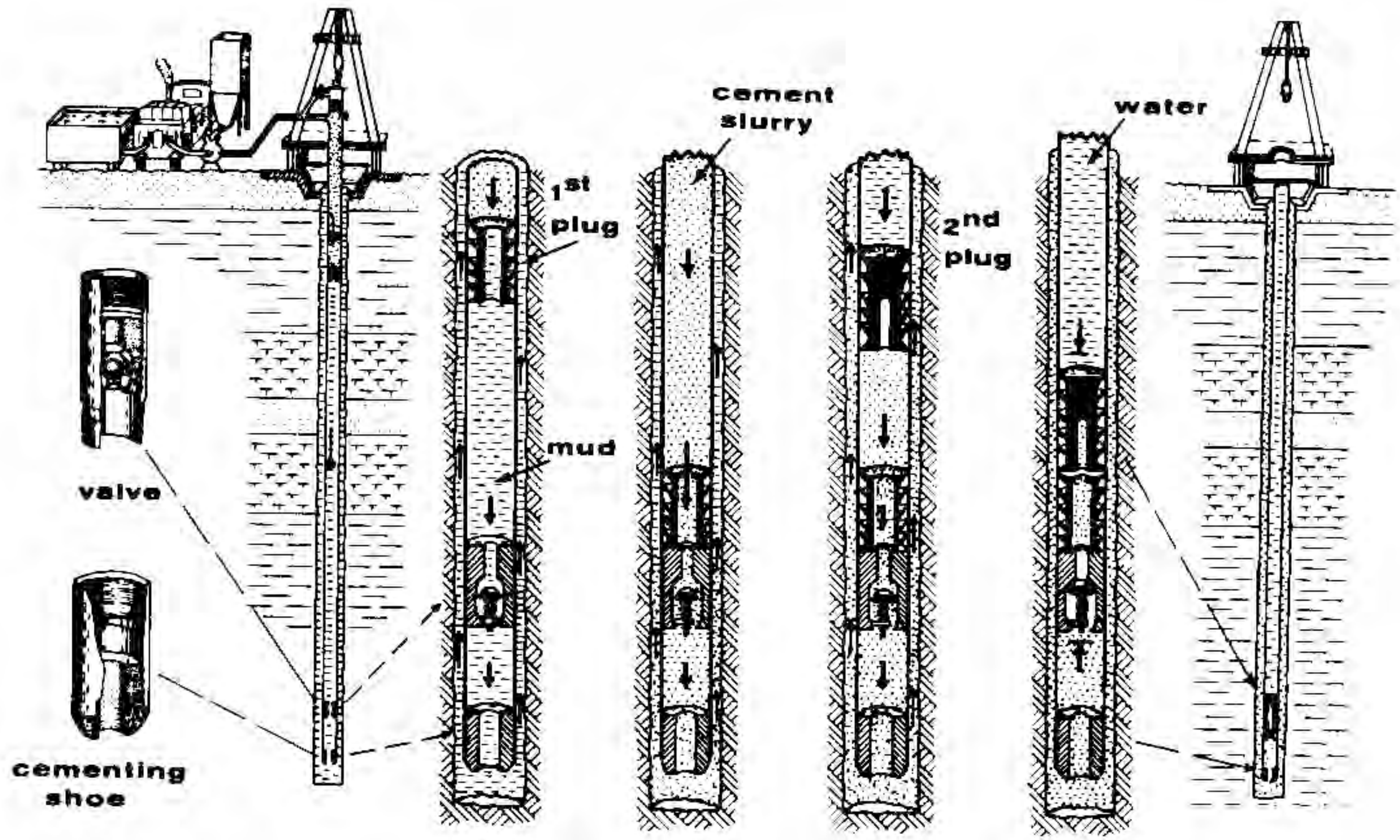


Fig. 107 The procedure of cementing a string of casing. The cement slurry is pumped in after the first plug. As soon as this plug arrives at the cementing valve, a rupture disk on its surface is broken by the pumping pressure and the cement slurry begins to fill the space between the casing and the formation. The second plug is run in after the slurry. It is pumped down with water. Cementing is finished, when both plugs have arrived above the valve.

Brockmann (1971)

Two procedures assure the integrity of casing:

Cement Bond Log (CBL)

Positive and Negative Pressure Test

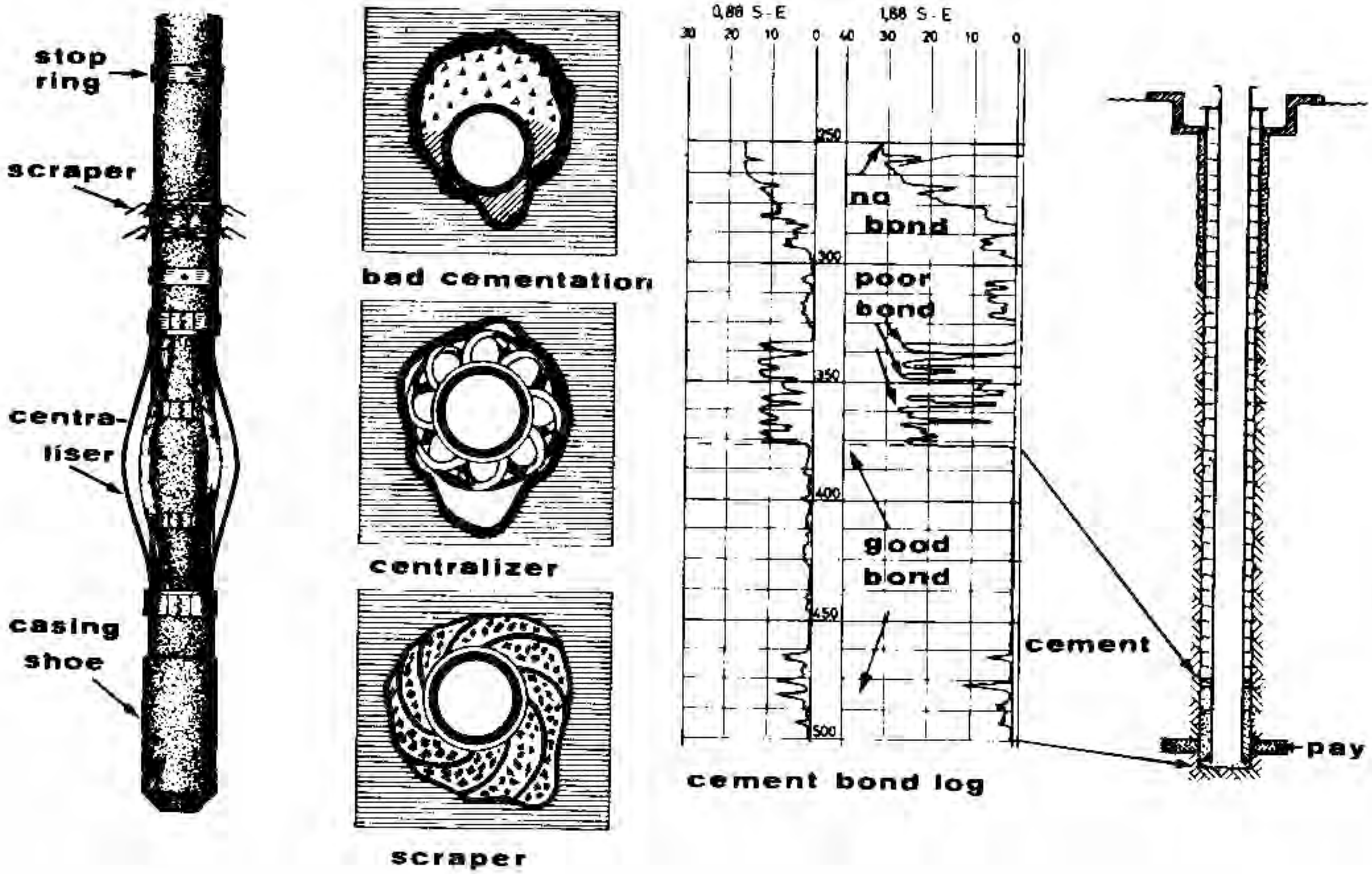
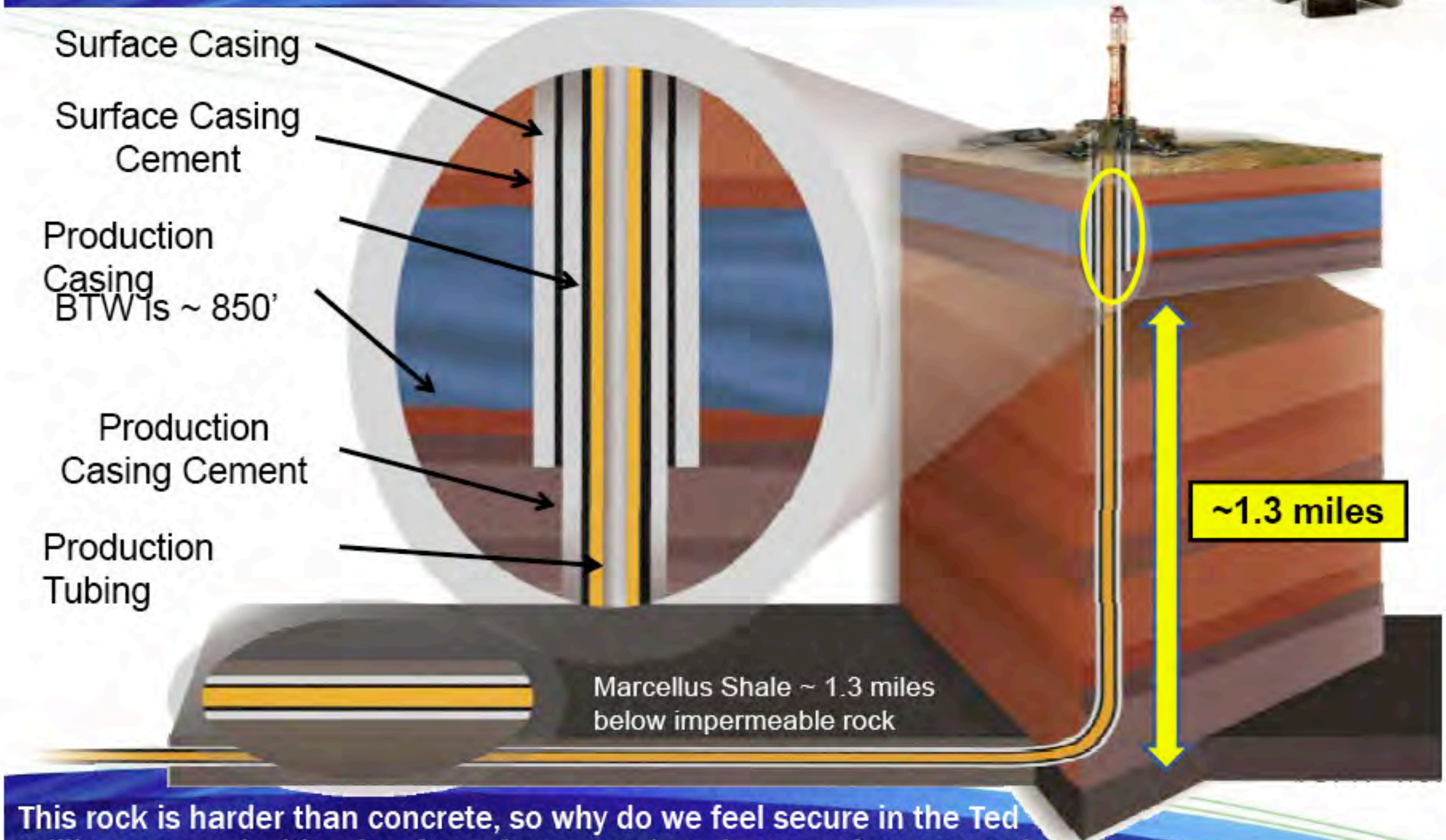


Fig. 108 How to get better cementing. Centralizers keep the casing in the center of the hole. Scrapers cleen the walls of the bore hole. The cement bound log (CBL) shows the quality of the cementation.

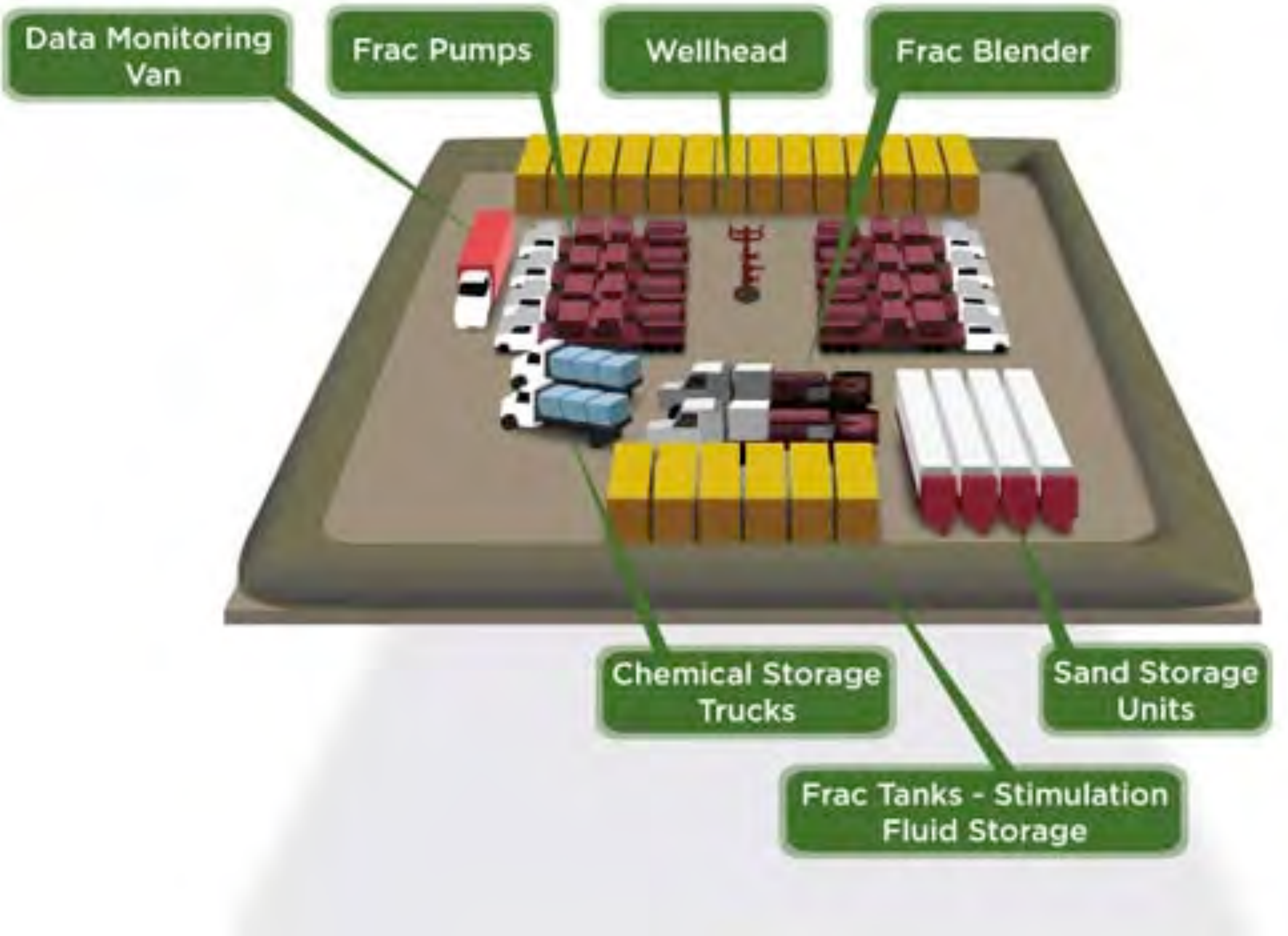
Brockmann (1971

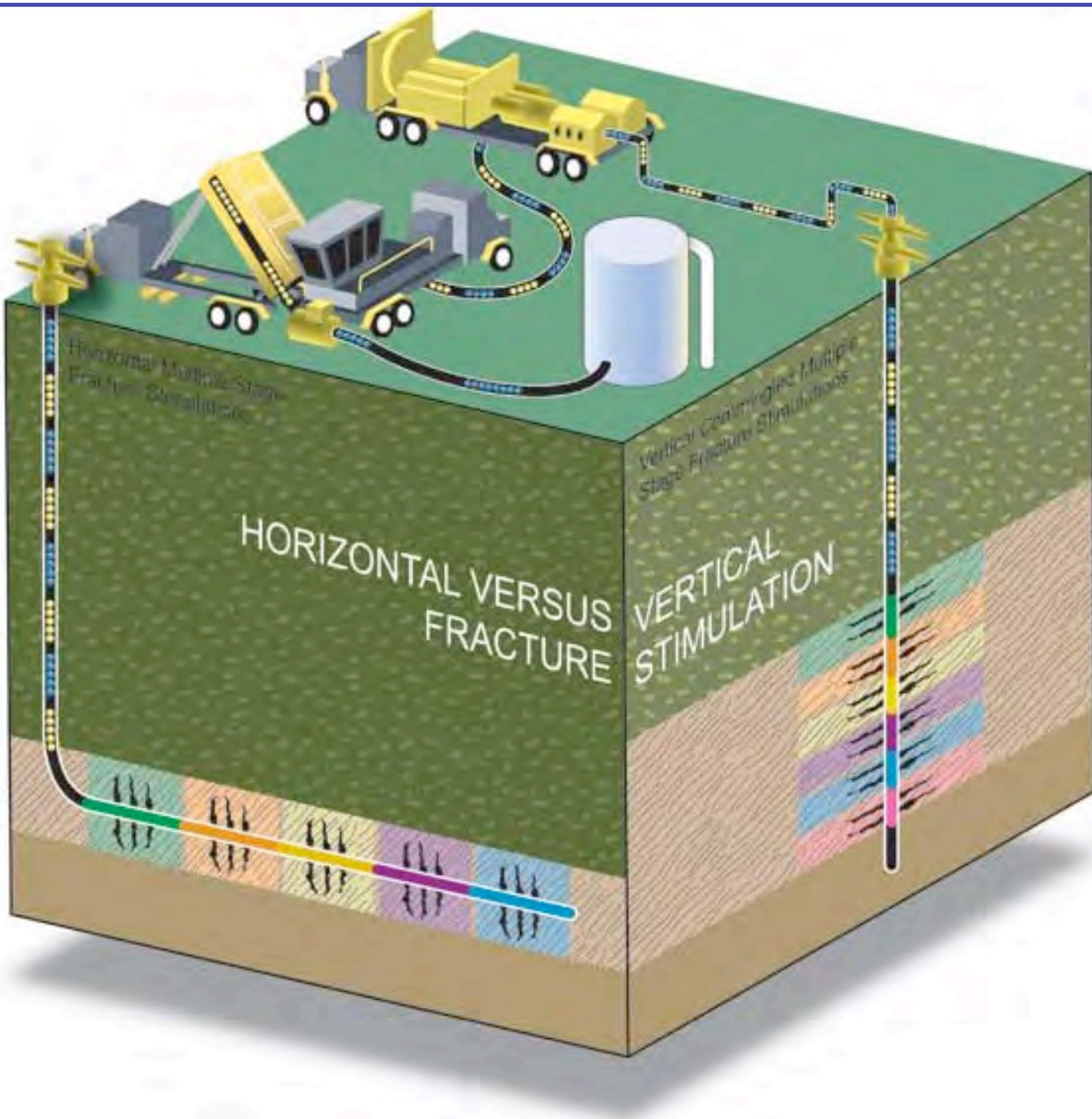
Fracture Stimulation and Gas Production Are Completely Isolated From Fresh Water



This rock is harder than concrete, so why do we feel secure in the Ted Williams Tunnel with a few feet of concrete keeping us safe vs. 8,000' of concrete-like rock separating frac fluids from the surface?

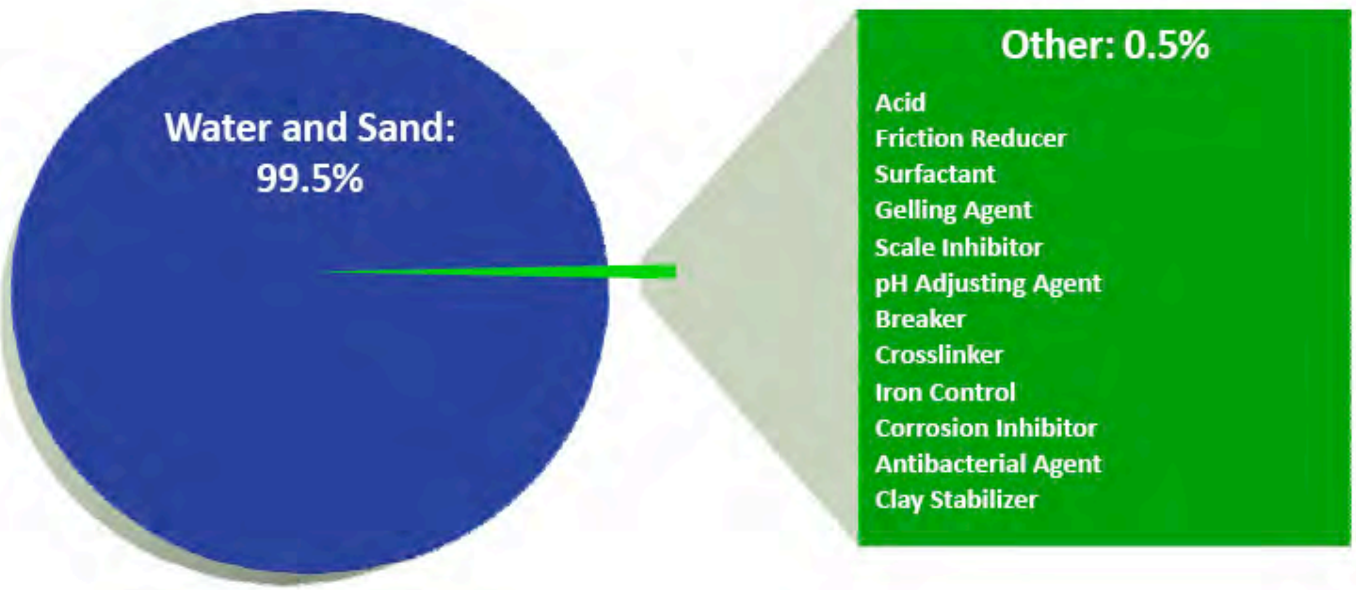
Chesapeake O&G


Data Monitoring Van
Frac Pumps
Wellhead
Frac Blender
Chemical Storage Trucks
Sand Storage Units
Frac Tanks - Stimulation Fluid Storage


HORIZONTAL VERSUS VERTICAL FRACTURE STIMULATION
Horizontal Multiple Stage Fracture Stimulations
Vertical Commingled Multiple Stage Fracture Stimulations

Composition of the Fracture Stimulation Mix – Dispelling the Myths, Presenting the Facts

Empowering Energy



For all the facts, please visit www.hydraulicfracturing.com

Components of Frac Fluid – The Facts

Empowering Energy

Product Category	Main Ingredient	Purpose	Other Common Uses
Water	99.5% Water & Sand	Expand fracture and deliver sand	Landscaping, manufacturing
Sand (Proppant)		Allows the fractures to remain open so the gas can escape	Drinking water filtration, play sand, concrete and brick mortar
Other	~ 0.5%		
Gel	Guar gum or Hydroexyethyl cellulose	Thickens the water in order to suspend the sand	Cosmetics, baked goods, ice cream, toothpaste, sauces, and salad dressings
Friction Reducer	Petroleum distillate	"Slicks" the water to minimize friction	Used in cosmetics including hair, make-up, nail and skin products
Acid	Hydrochloric acid or muriatic acid	Helps dissolve minerals and initiate cracks in the rock	Swimming pool chemical and cleaner
Anti-Bacterial Agents	Glutaraldehyde	Eliminates bacteria in the water that produces corrosive by-products	Disinfectant; sterilizer for medical and dental equipment
Scale inhibitor	Ethylene glycol	Prevents scale deposits in the pipe	Used in household cleansers, de-icer, paints, and caulk
Breaker	Ammonium Persulfate	Allows a delayed break down the gel	Used in hair coloring, as a disinfectant, and in the manufacture of common household plastics
Corrosion inhibitor	n,n-dimethyl formamide	Prevents the corrosion of the pipe	Used in pharmaceuticals, acrylic fibers and plastics
Crosslinker	Borate Salts	Maintains fluid viscosity as temperature increases	Used in laundry detergents, hand soaps and cosmetics
Iron Control	Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice ~7% citric acid
Clay Stabilizer	Potassium Chloride	Creates a brine carrier fluid	Used in low-sodium table salt substitute, medicines, and IV fluids
pH adjusting agent	Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Used in laundry detergents, soap, water softener and dish washer detergents
Surfactant	Isopropanol	Used to increase the viscosity of the fracture fluid	Used in glass cleaner, multi-surface cleansers, antiperspirant, deodorants and hair-color

Drilling Techniques:

Early vertical wells perfected casing and testing

Early non-vertical wells perfected directional drilling

Hydraulic fracturing first used in vertical wells
- -tight sandstones
- -coal bed methane wells
- -early shale gas wells

Fluids used in hydraulic fracturing
- increase volume with length of well
- components have specific operational roles
- return to surface with dissolved minerals
- represent a major disposal-recycling problem

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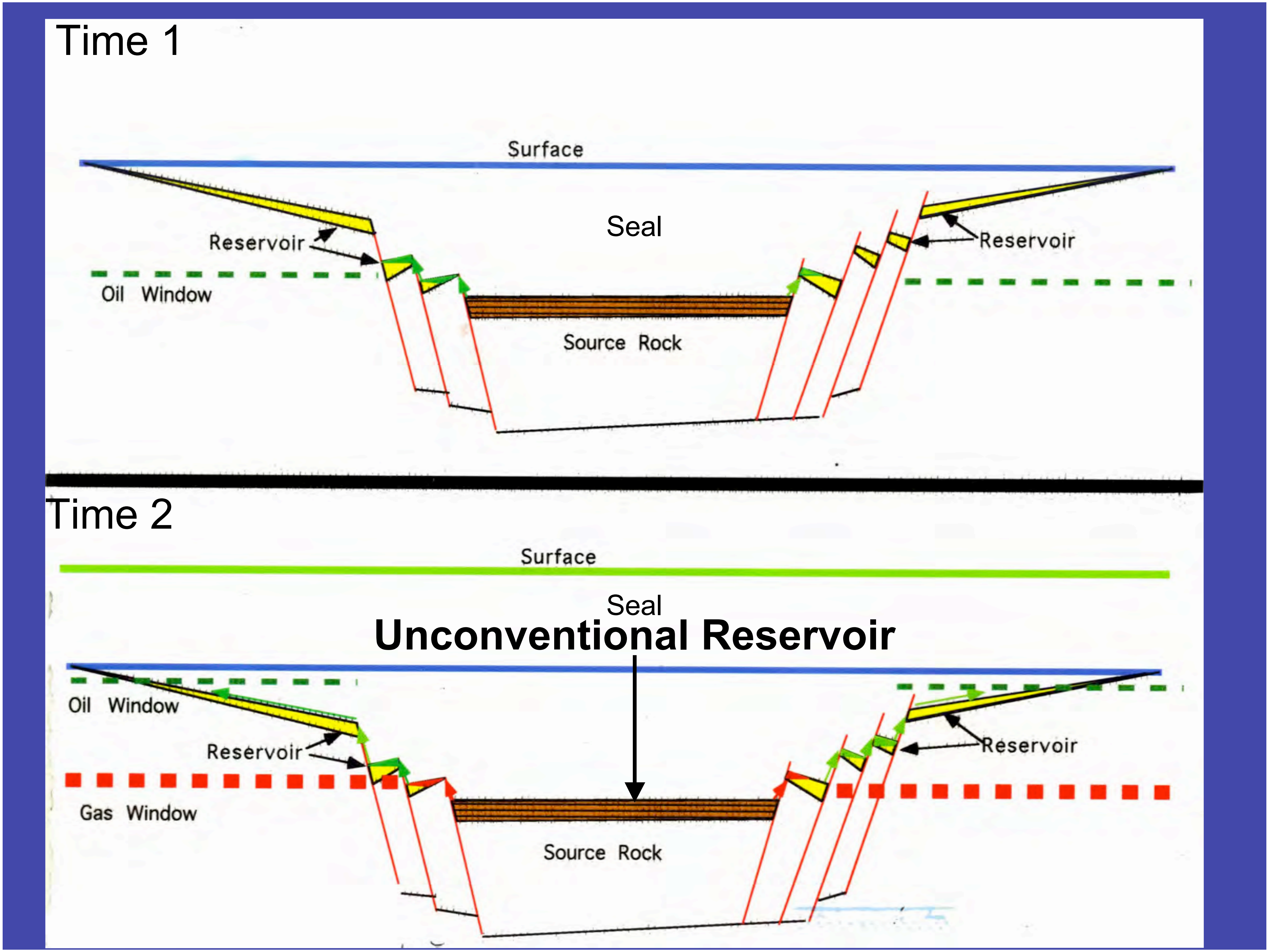
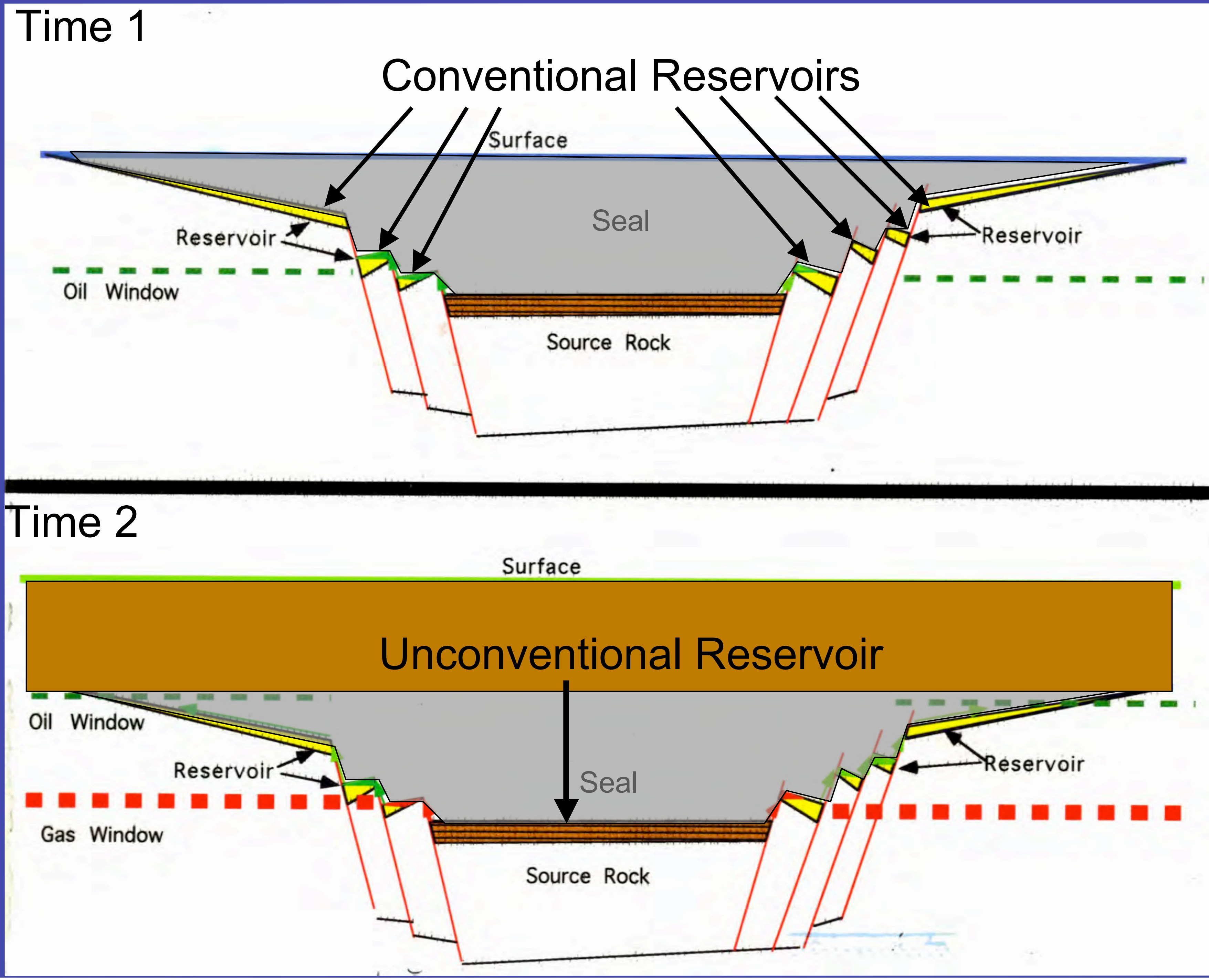
Unconventional petroleum systems are less demanding

- ~~Reservoir Rock~~
- ~~Seal Rock~~
- ~~Structure~~ or Trap
- Source Rock
- Maturation of Source Rock
- ~~Migration of oil and gas~~


Time 1
Surface
Seal
Reservoir
Reservoir
Oil Window
Source Rock
Time 2
Surface
Seal
Unconventional Reservoir
Oil Window
Reservoir
Reservoir
Gas Window
Source Rock

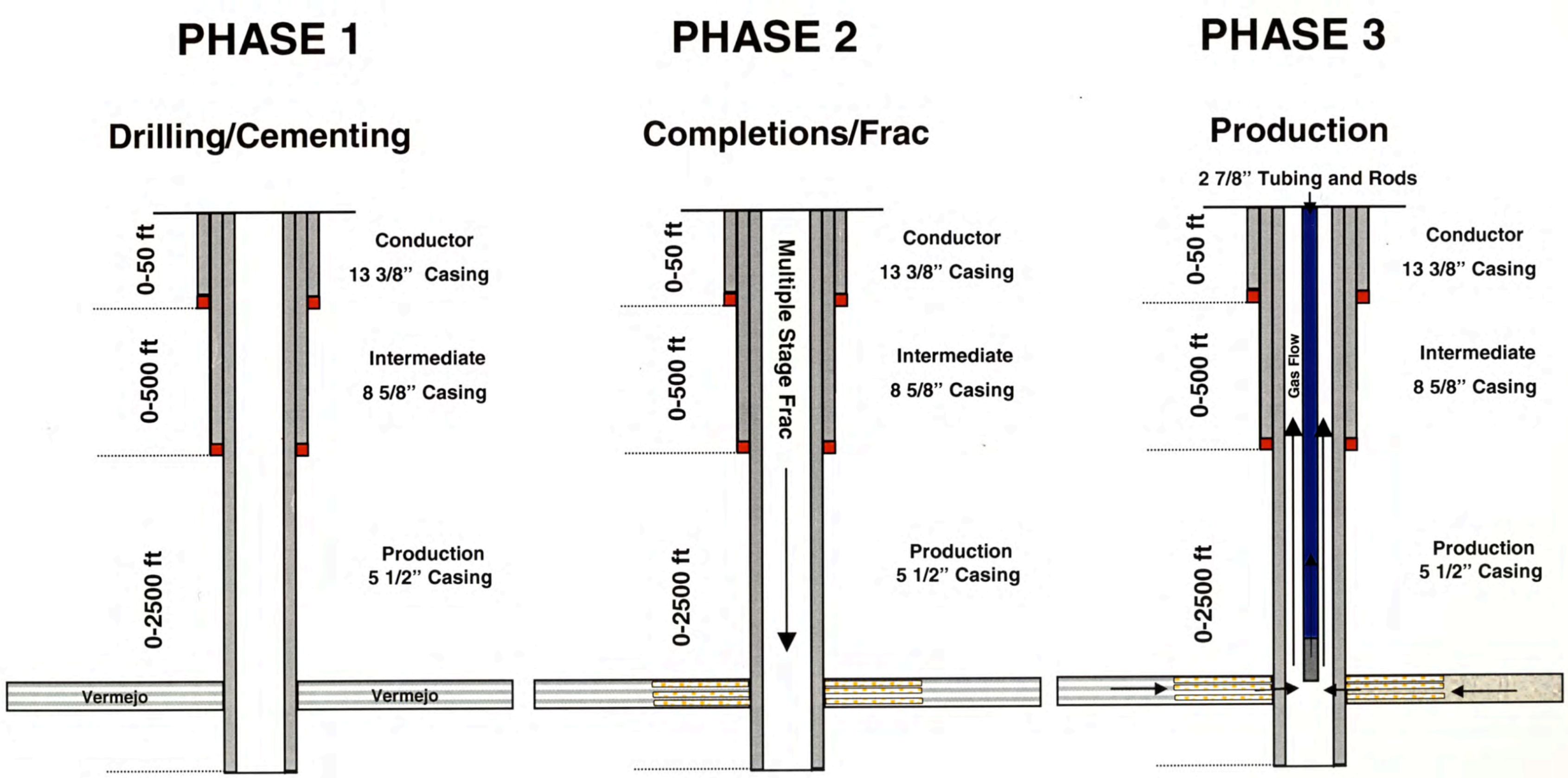


Time 1
Conventional Reservoirs
Surface
Seal
Reservoir
Reservoir
Oil Window
Source Rock
Time 2
Surface
Unconventional Reservoir
Oil Window
Reservoir
Seal
Reservoir
Gas Window
Source Rock

Coal Bed Methane Hydraulic Fracture Operation

Operations Cycle

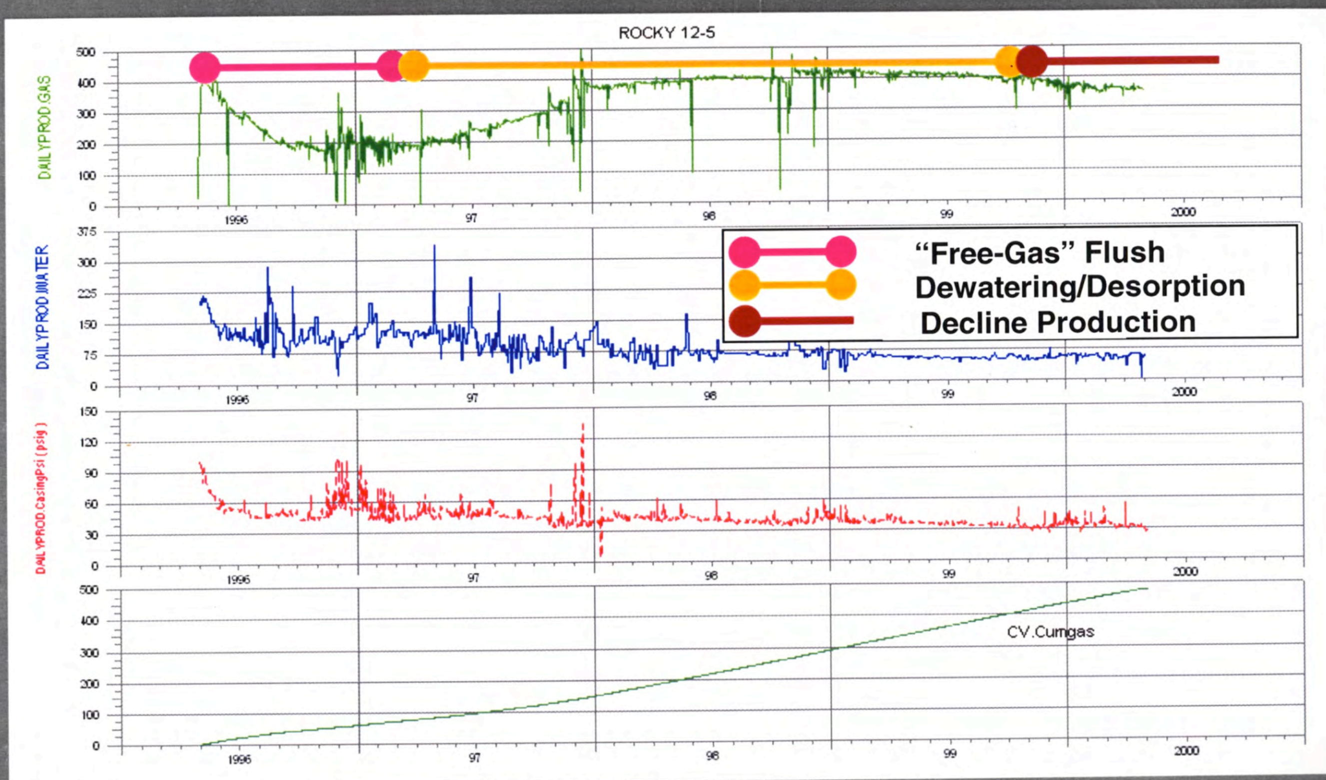
AAPG



EVERGREEN
EVERGREEN RESOURCES, INC.

Production Profiles - Vermejo Coals

AAPG



Typical Raton Basin Vermejo Coal Production Profile

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Estimated Reserves

AAPG

	Vermejo Coal	Raton Coals
Net Coal	30 ft	40 ft
Storage	350 scf/ton	200 scf/ton
Drainage Area	160 +/- acres	160 +/- acres
Coal Volume	1850 ton/acre ft	1850 ton/acre ft
GIP per well	3.1 BCFG	2.35 BCFG
Recovery Factor (est)	60%	40%
Recoverable	1.8 BCF	1.0 BCF

	Reserve Potential
Spanish Peaks Field	1.15 TCFG
Raton/Saddlebag Field	0.5 TCFG
Unnamed (Sangre De Cristo)	0.5 TCFG
Long Canyon Field	0.15 TCFG
Ultimate Reserve Potential	2.3 TCFG

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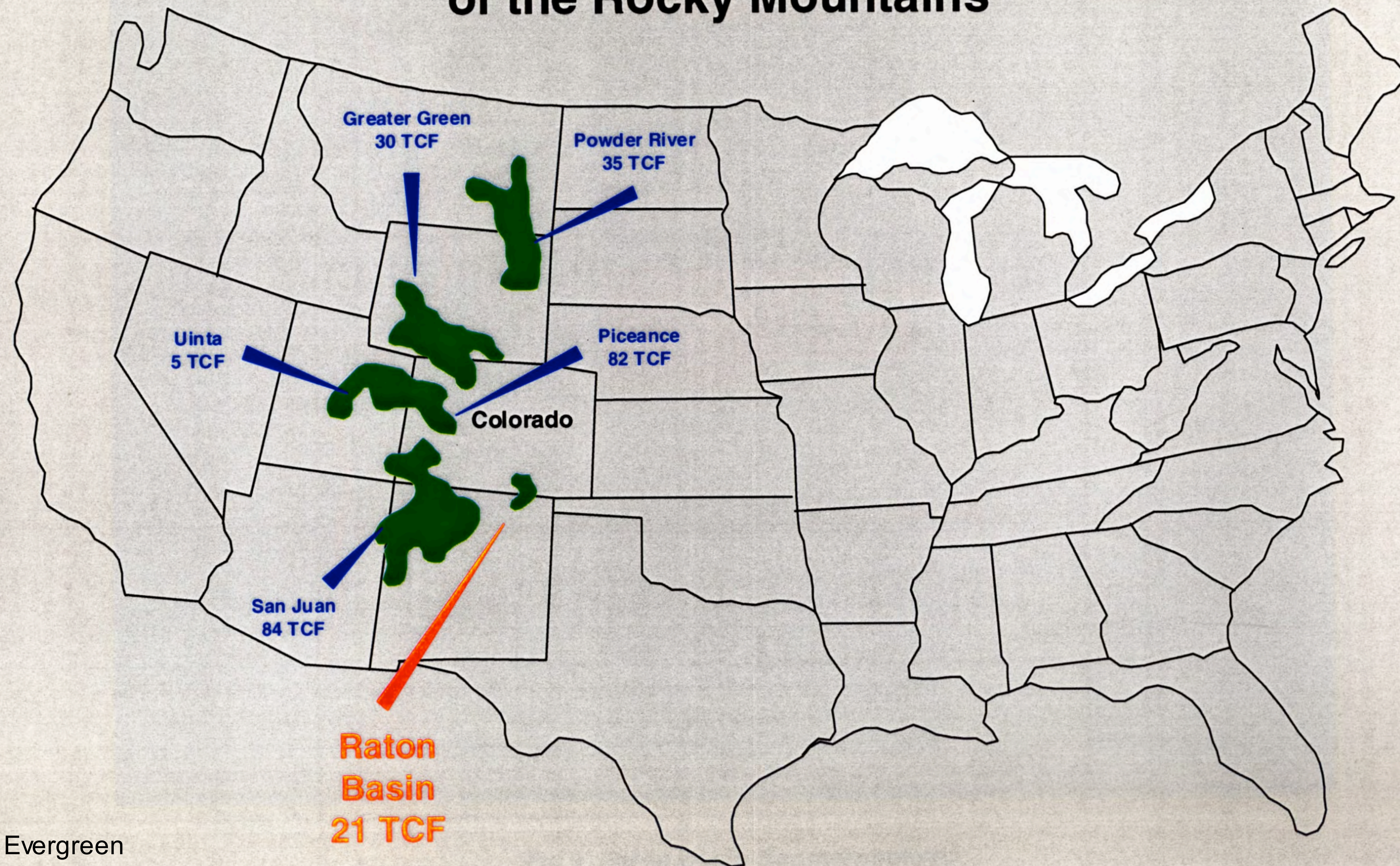
Principal Coalbed Methane Basins of the Rocky Mountains



Evergreen

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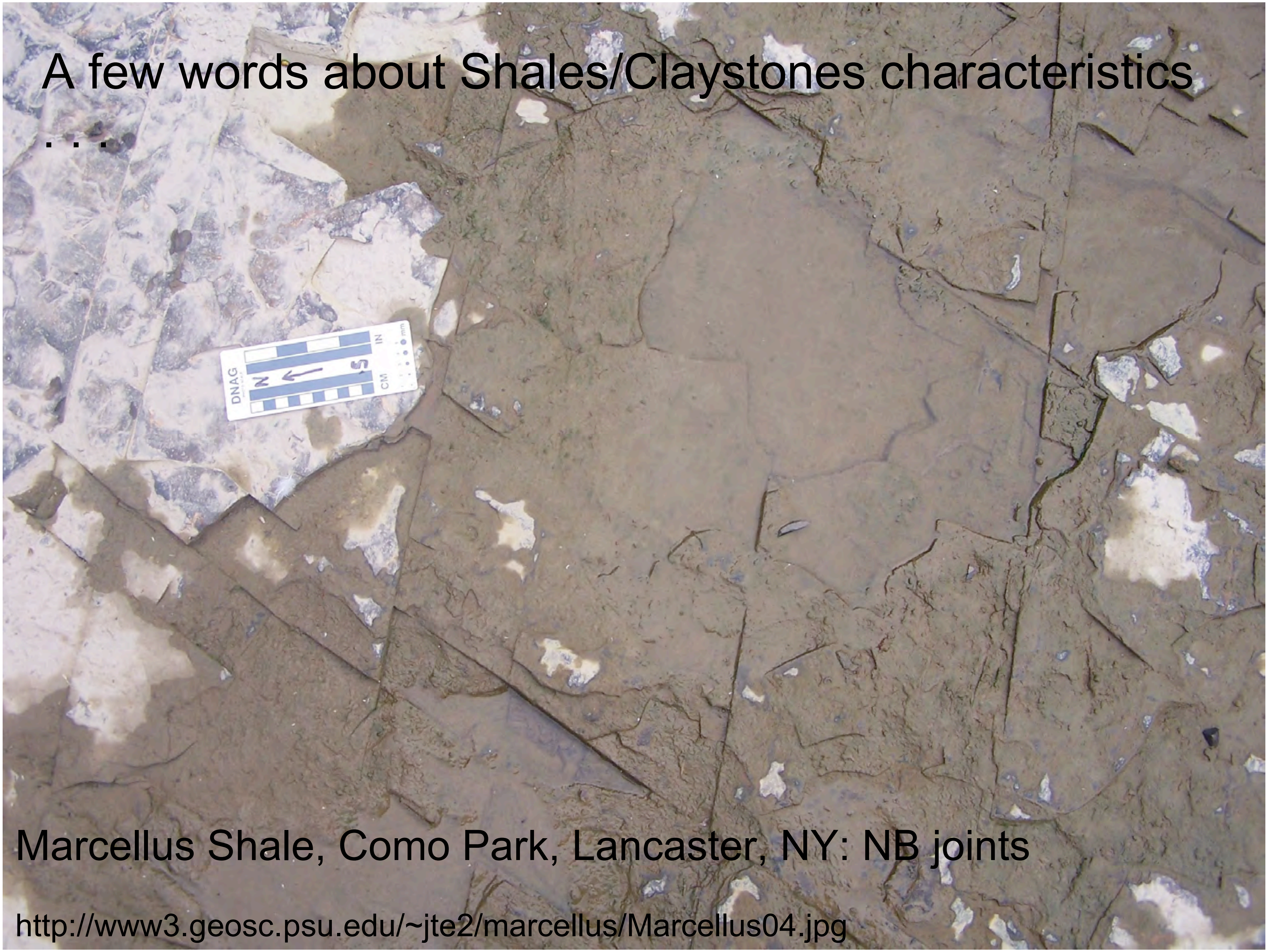
A few words about Shales/Claystones characteristics . . .



Marcellus Shale, Como Park, Lancaster, NY: NB joints

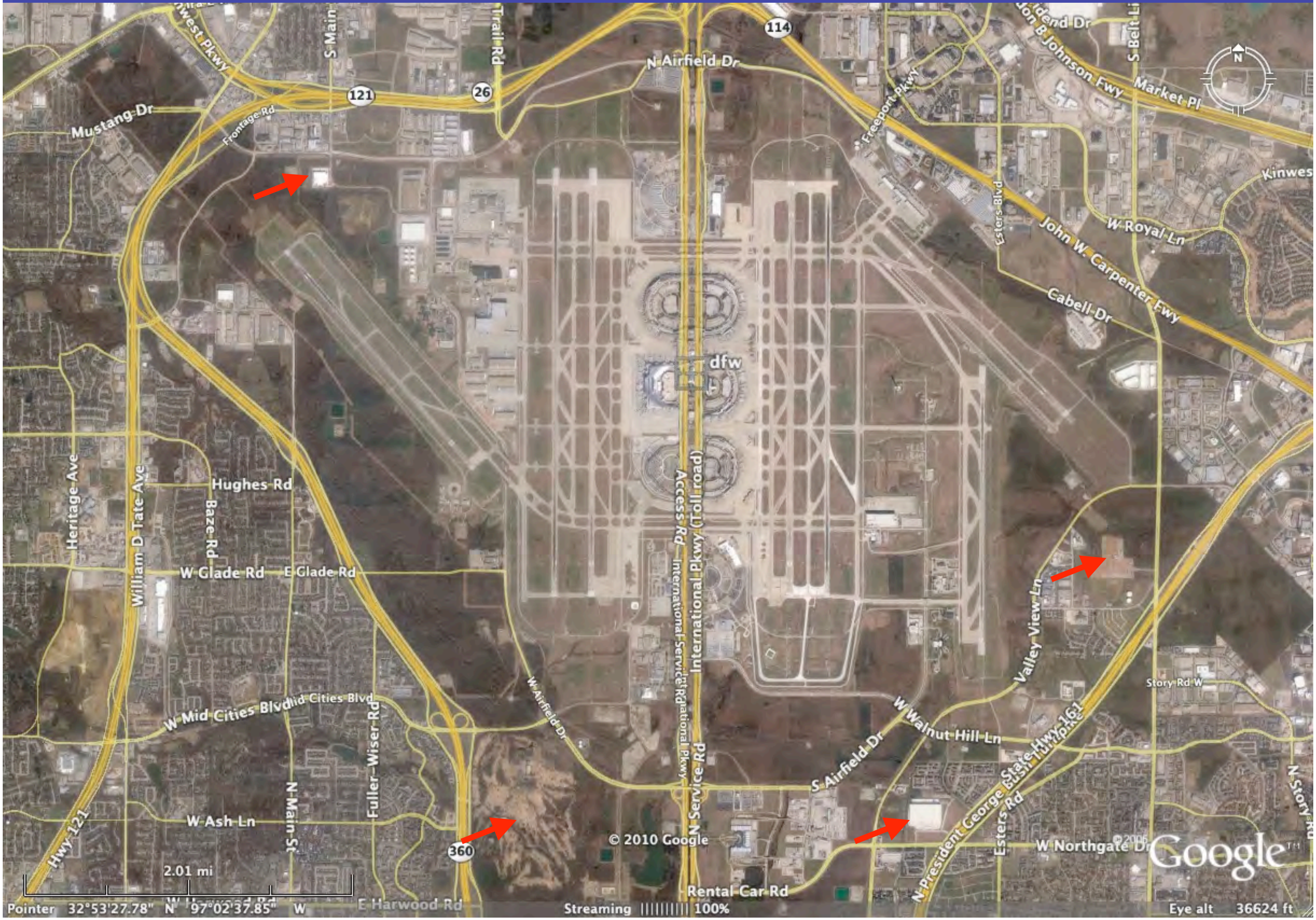
http://www3.geosc.psu.edu/~jte2/marcellus/Marcellus04.jpg

Shale gas: not just any shale will do

- Brittle lithologies are required
  - Silica-rich lithologies are preferred
  - Clay-rich lithologies are problematic
- Kerogen-rich lithologies are required
- Burial to the gas window (Ro = 1.0%) is required

Shale Gas I: Barnett Shale, Dallas-Fort Worth, Texas

Dallas Fort Worth International Airport



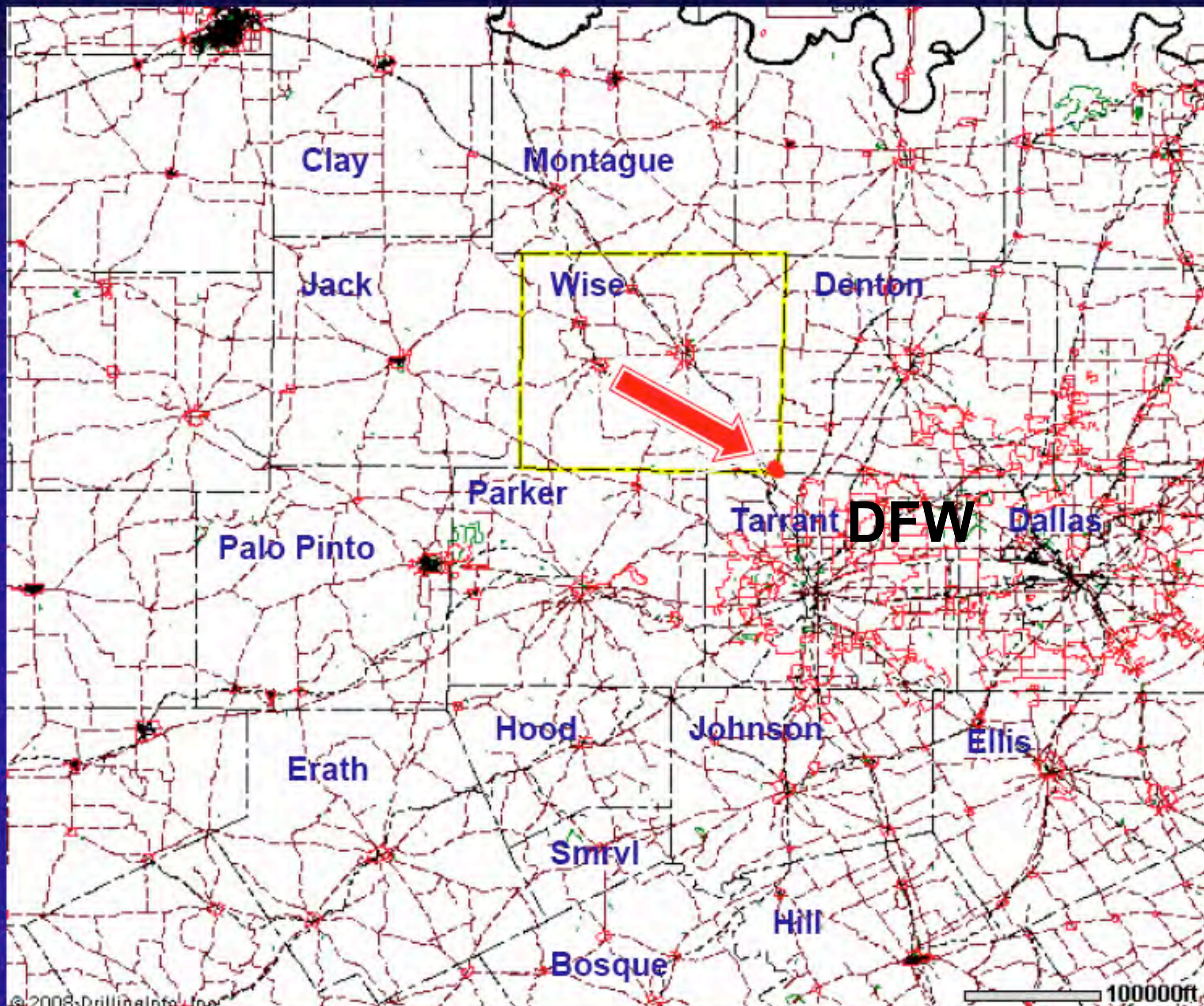

NW Runway
Google


Southeast Side of Airport
Google


West Side of Airport
Google


South Side of Airport
Google

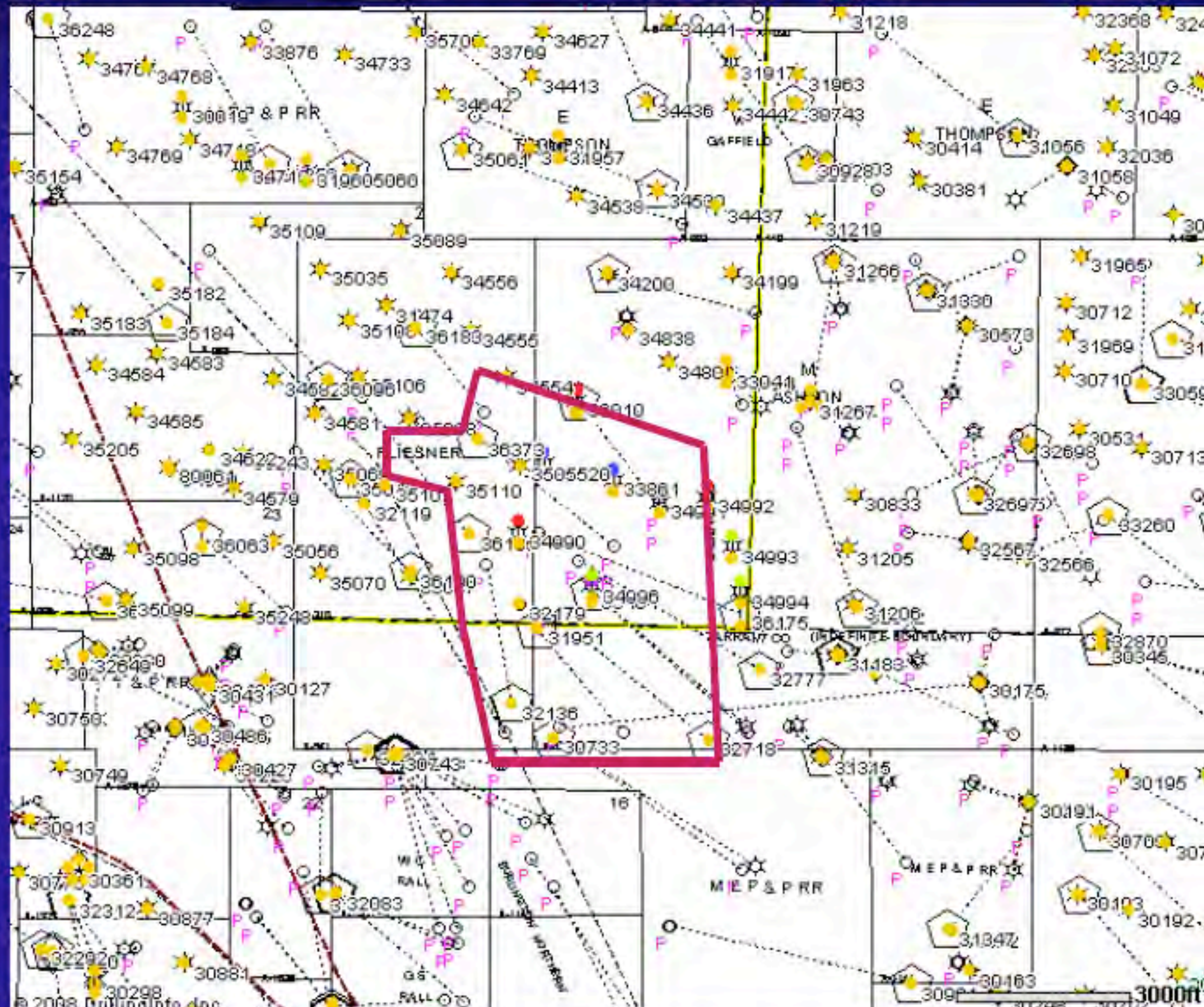
Birthplace of the Barnett – CW Slay



Mathews 2008

Devon: C.W. Slay Unit

- 12 wells on 704 ac
- 9 vert, 3 Hrz + 4 Drlg
- Cum Prod = 11.5 Bcf
- Feb 08 = 7.2 MMcfd
- EUR_V = 1.9 Bcf/well
- EUR_H = 4.0 Bcf/well
- PDPs = 30 Bcf
- 4 add'l horiz wells
  Est'd Rsvs = 16 Bcf
- Total EUR = 46 Bcf
- Avg Spacing = 44 ac
- 41.8 Bcf per SqMi
- ~ 28% R_f 150 B/SqMi

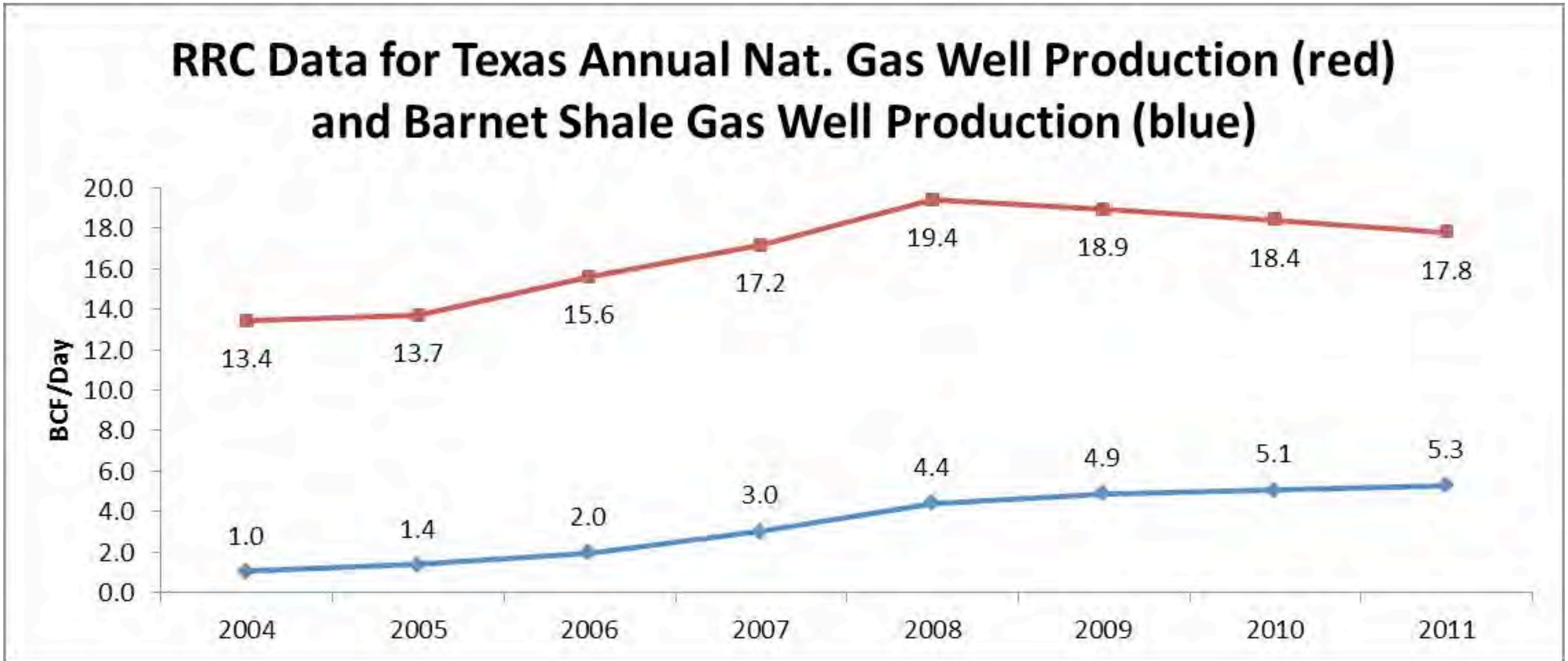


Mathews 2008

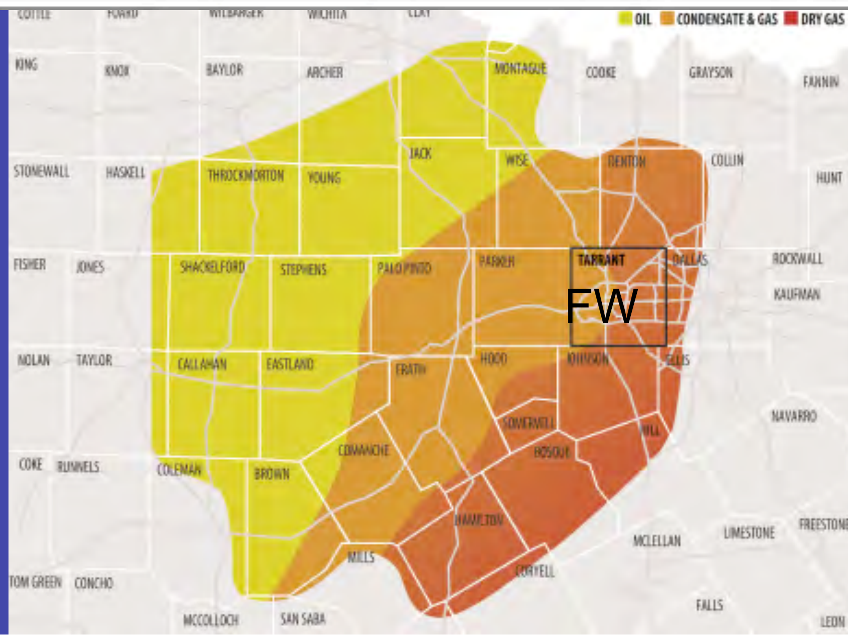
Technological Milestones

- Early 1900's: Shale gas becomes productive. N_2 foam fracs
- 1983: Mitchell drills 1st Barnett Shale well: C.W. Slay No. 1
- 80-90s: Evolution of X-linked gel technology in vertical wells
- 1991: 1st Horizontal Barnett well MEC: T.P. Sims "B" 1H
  Identified fracture azimuth – Max Principal stress
- 1996: Intro of slick water fracs (SWF) & Microseismic
- 1998: SW refracs of original gel fracs
- 2002: Horizontal laterals with multi-stage SWFs
- 2004: 3D seismic tool to avoid karsts and faulting
- 2005: Shift focus to increasing recovery factor
- 2007: Multi-well pads and cluster drilling

Mathews 2008

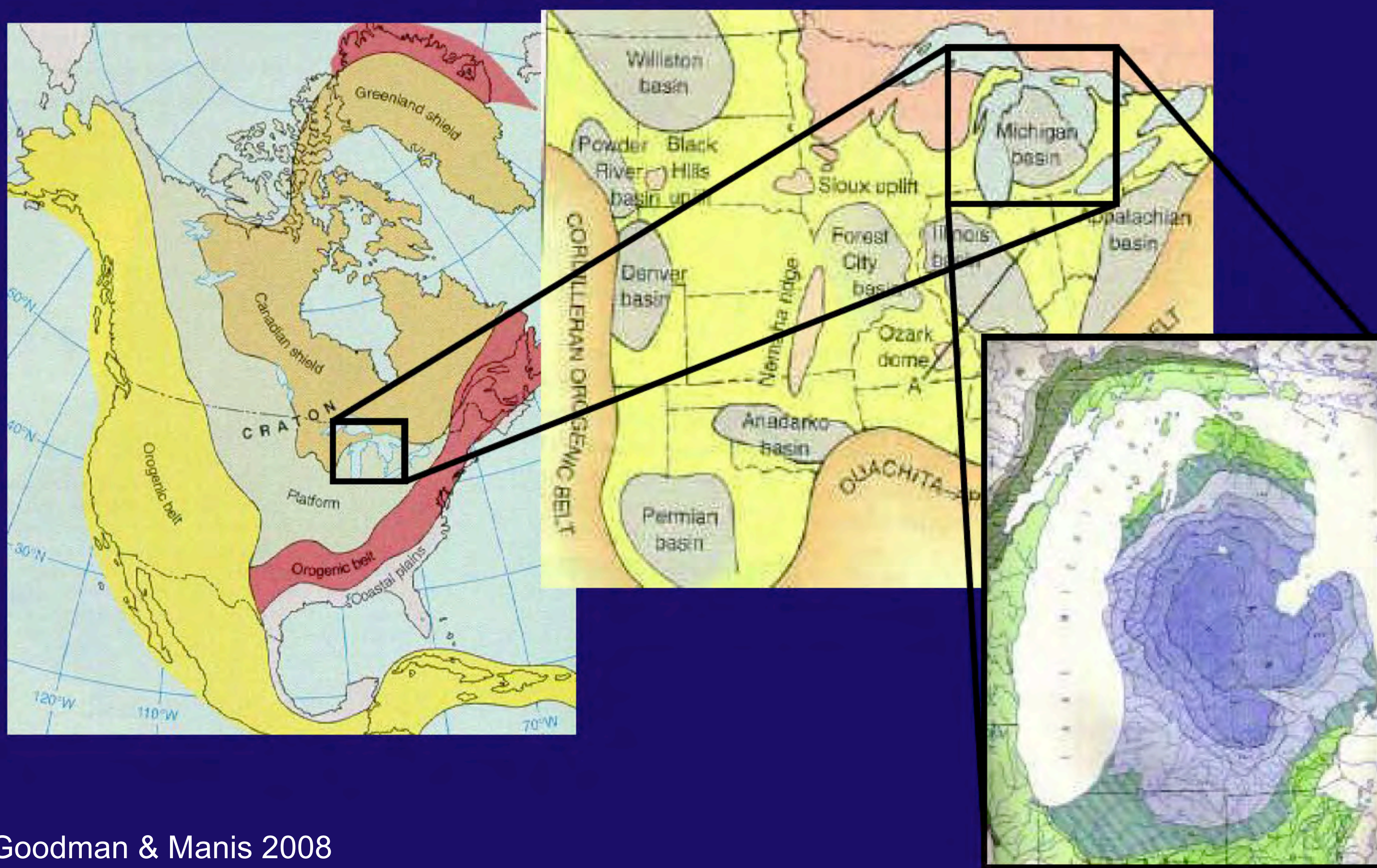


Barnett Play Area



Shale Gas II: Antrim Play, Michigan Basin, Michigan

Geologic Setting of the Michigan Basin



Goodman & Manis 2008

Michigan Oil & Gas Plays

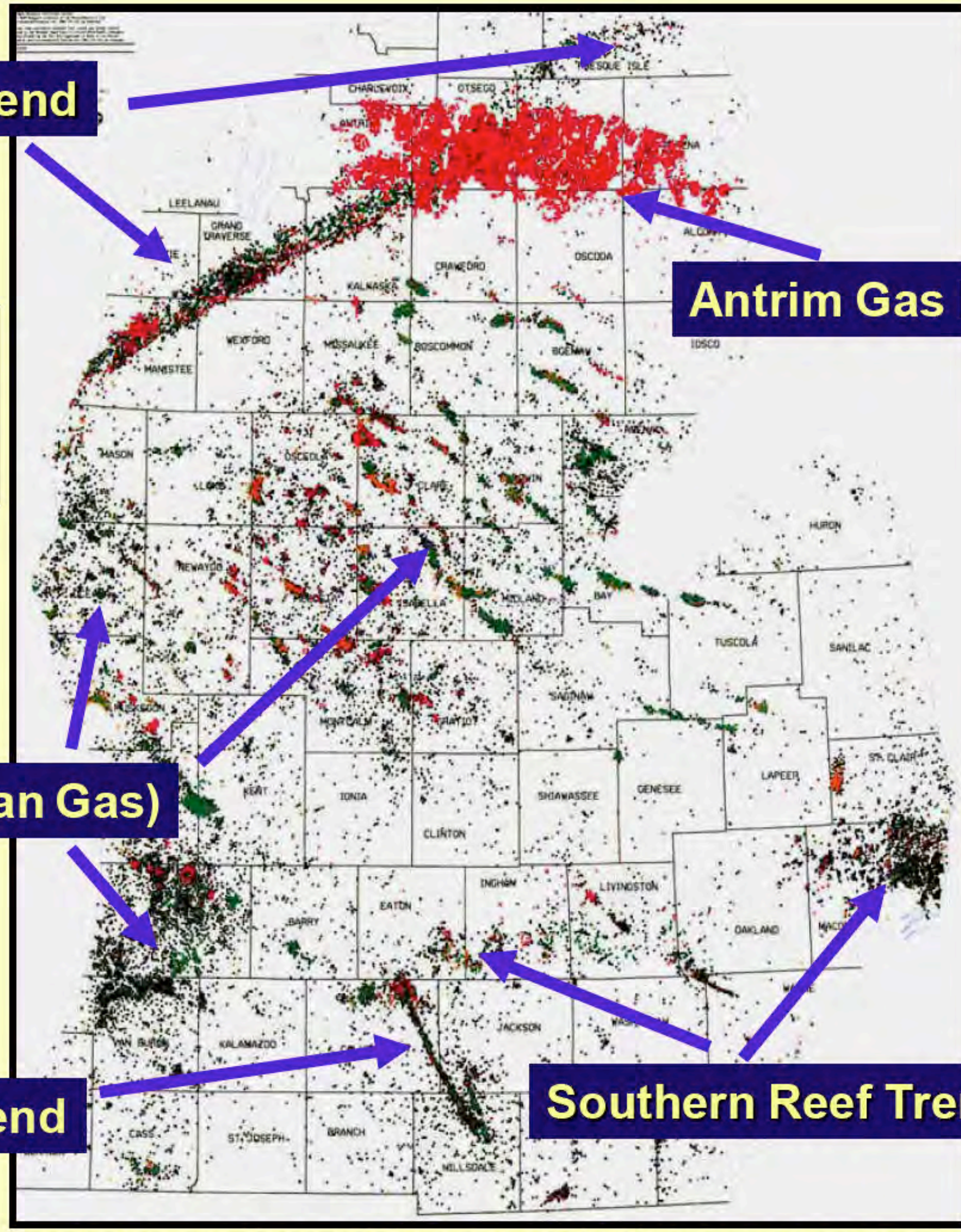
Northern Reef Trend

Antrim Gas Play

Devonian Oil (Ordovician Gas)

Albion-Scipio Trend

Southern Reef Trend



MICHIGAN'S LOWER PENINSULA O&G PROD.

Goodman & Manis 2008

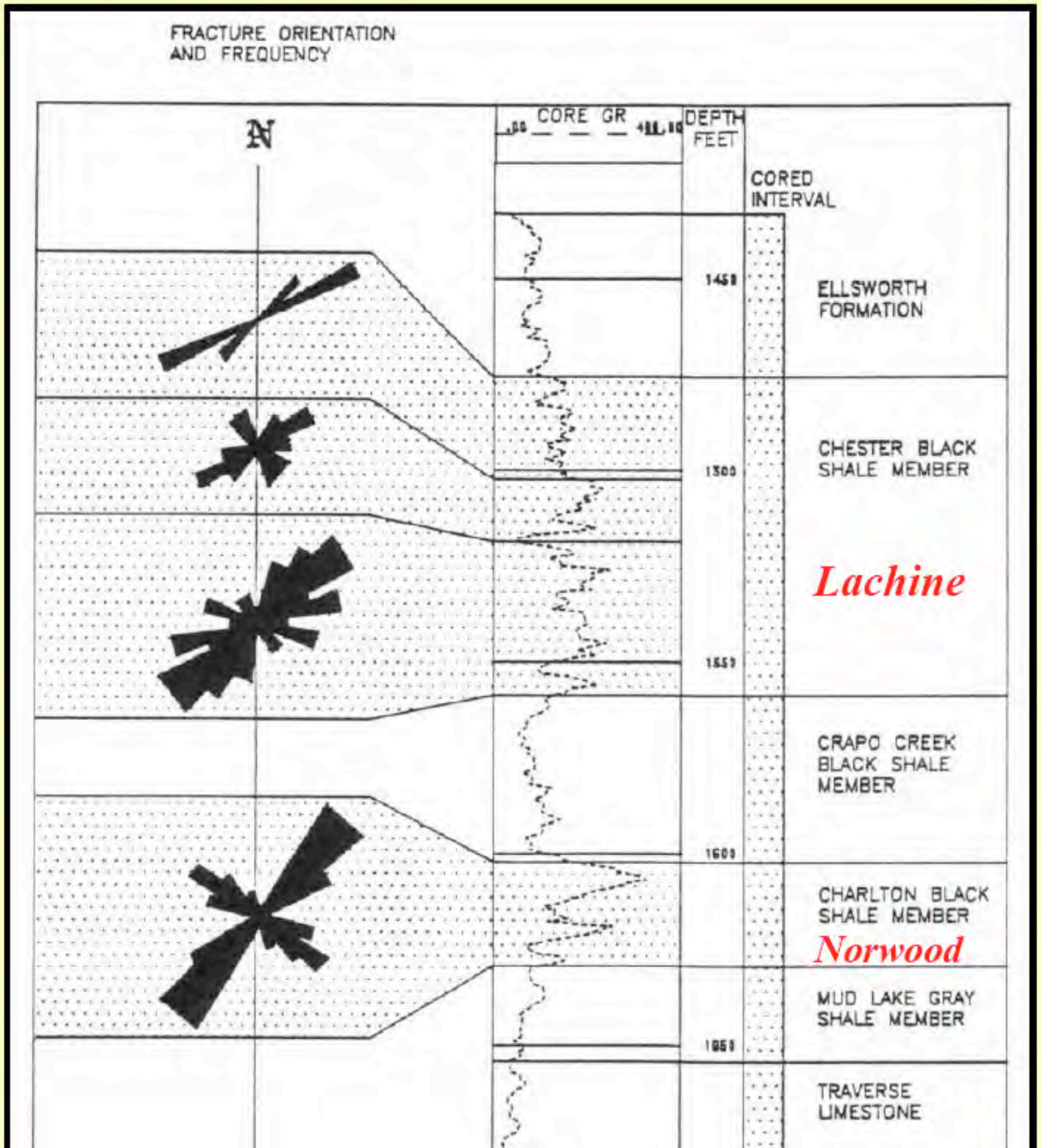
Lachine Member

High TOC's and Significant High Angle Fracturing

Goodman & Manis 2008

Fracture Orientations

Welch-St. Chester #18 Core, South Chester Twp., Otsego County (from Dellapenna, 1991)



Goodman & Manis 2008

Roots of the Antrim Shale Play in Northern Michigan (Pt. 2)

Goodman & Manis 2008

- 1986: Non-Convent. Fuels Tax Incentive + Underutilized Niag. Infrastructure + CPF Concept Trigger Modern Antrim Play

- 1992: Expiry of NCF Credit-Eligible Wells on 12/31/92 Triggers Antrim Drilling Peak (1189 Compl. Wells)

- 1995: Antrim Uniform Spacing Plans (USP) Allow Greater Oper. Discretion in Placing Wells in Projects. 80-Ac. Spacing.

Typical Antrim Project

Central Production Facility (compressor, disposal)

Several wells (avg. 13)

~$350K per well (w/ facility)

Peak water in 5 mo. (110 BWPD)

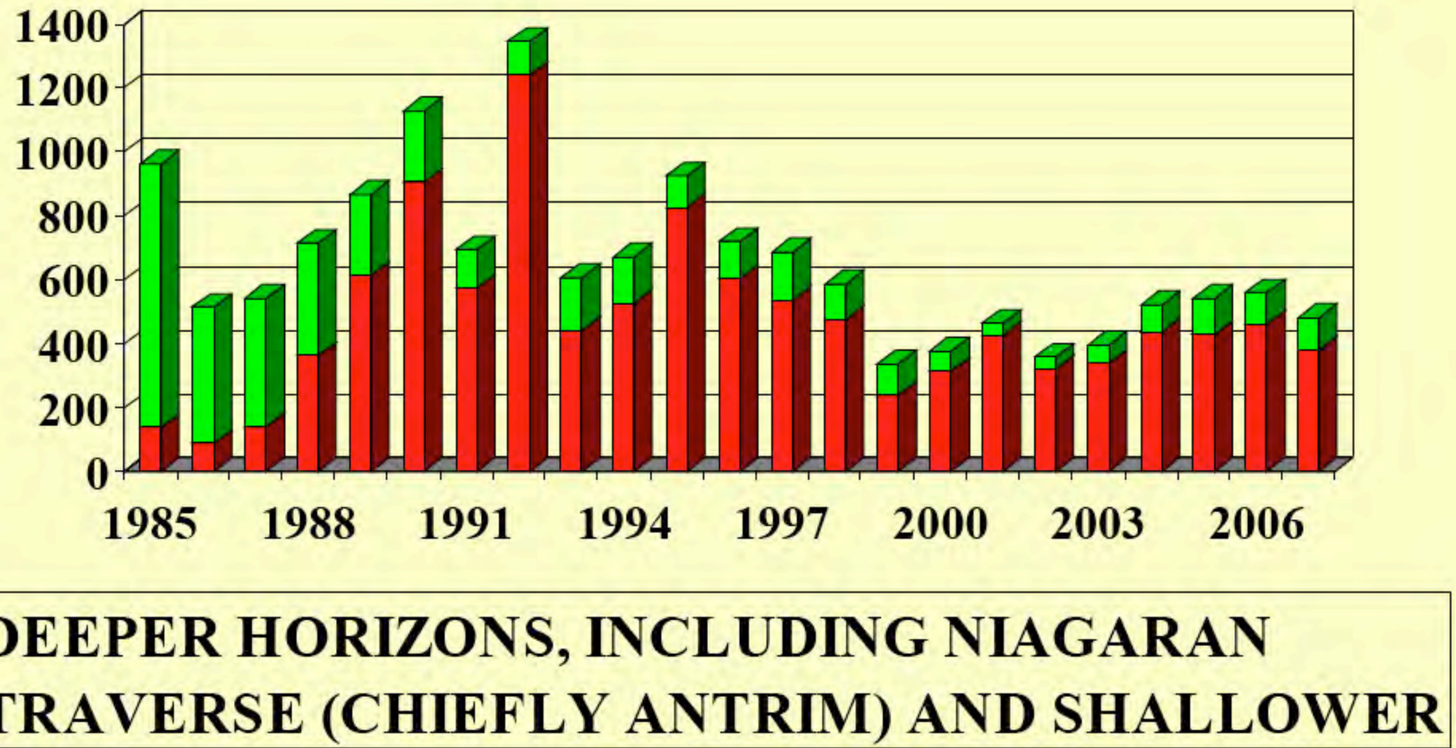
Peak gas in 20 mo. (125 MCFD)

Well Spacing (40-160 Acres)

EUR of ~500 MMCF per 80 acres

Goodman & Manis 2008

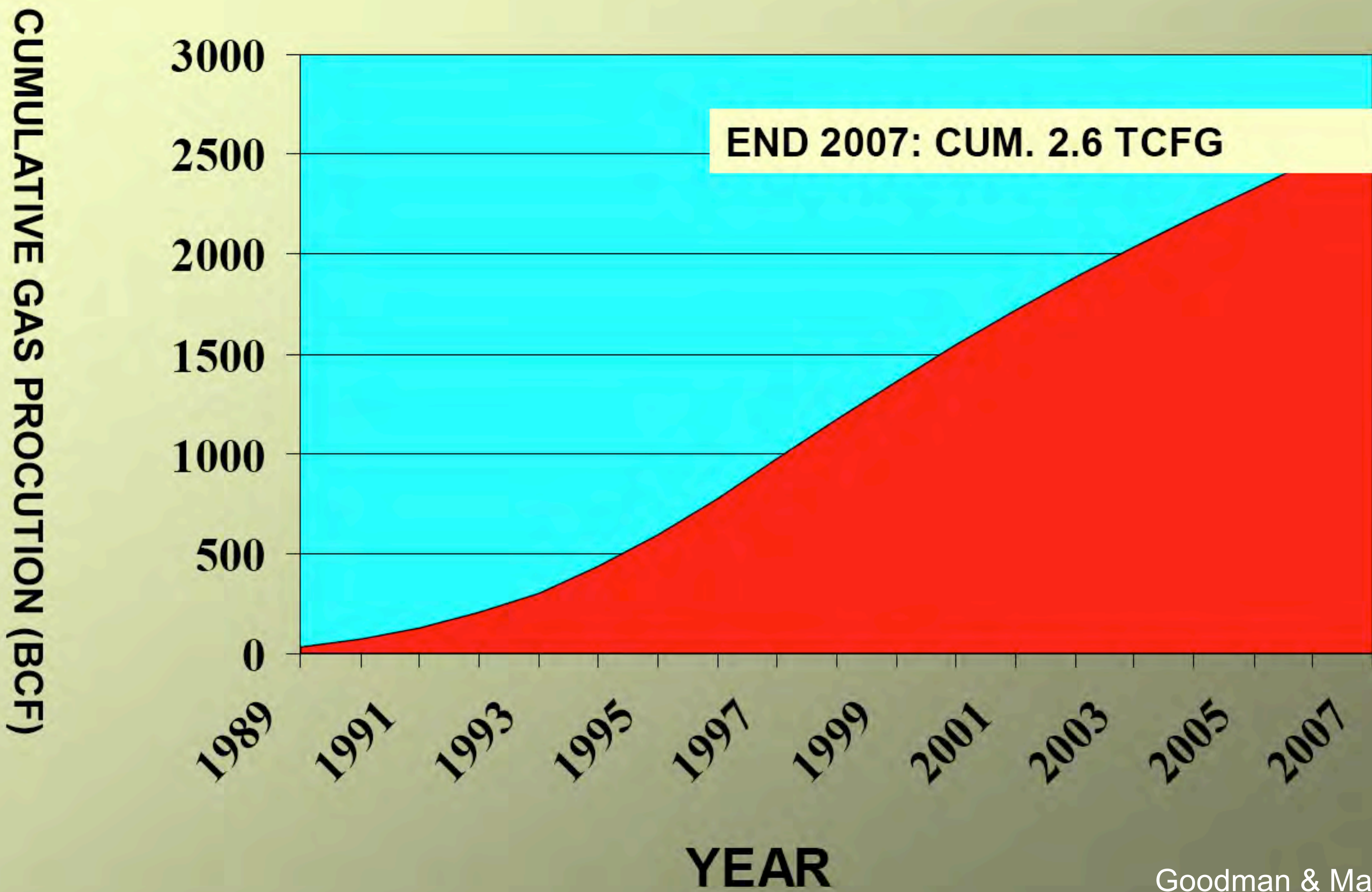
WELLS DRILLED BY TARGET DEPTH, 1985-2007



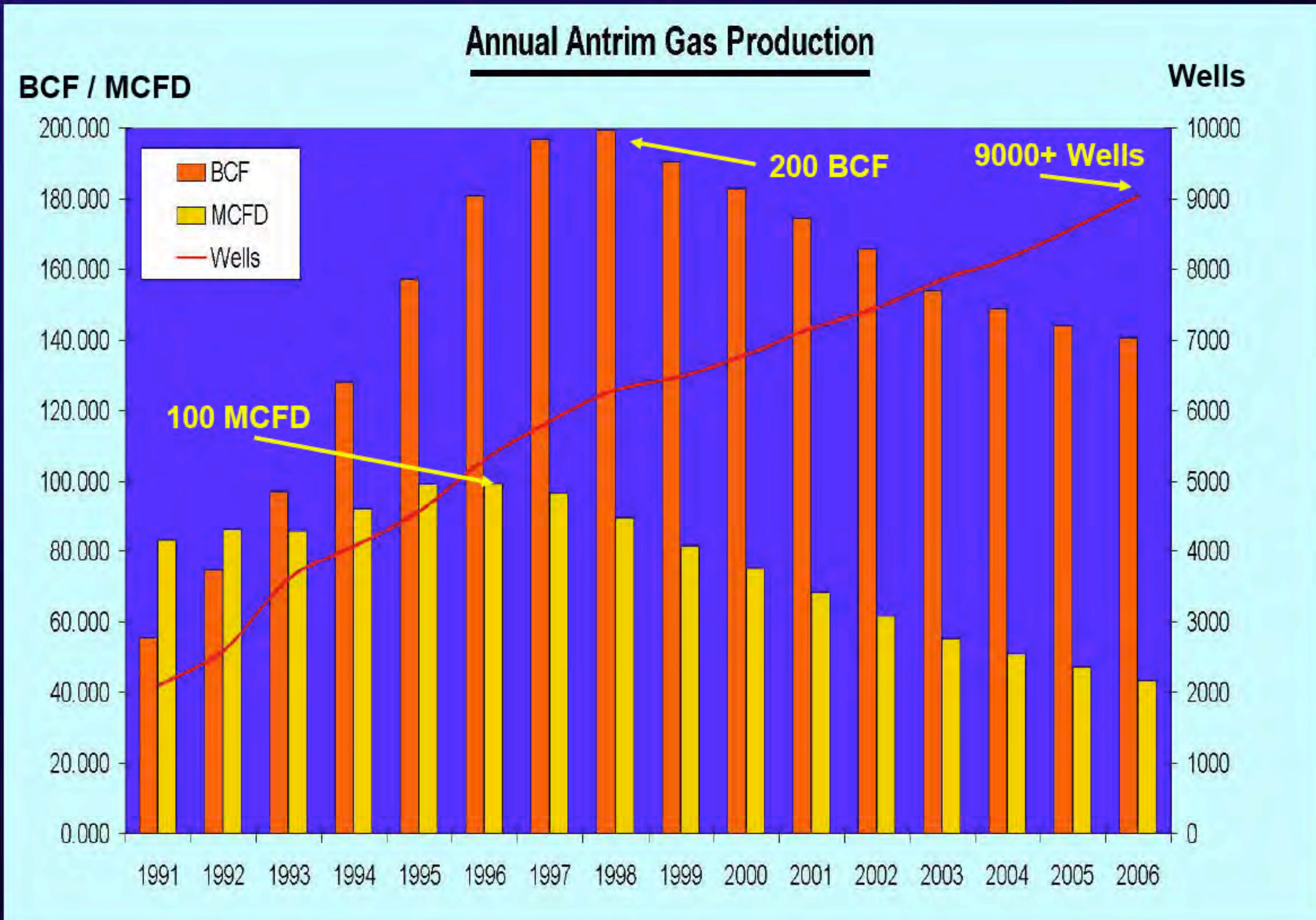
Goodman & Manis 2008

CUMULATIVE MICHIGAN ANTRIM PRODUCTION

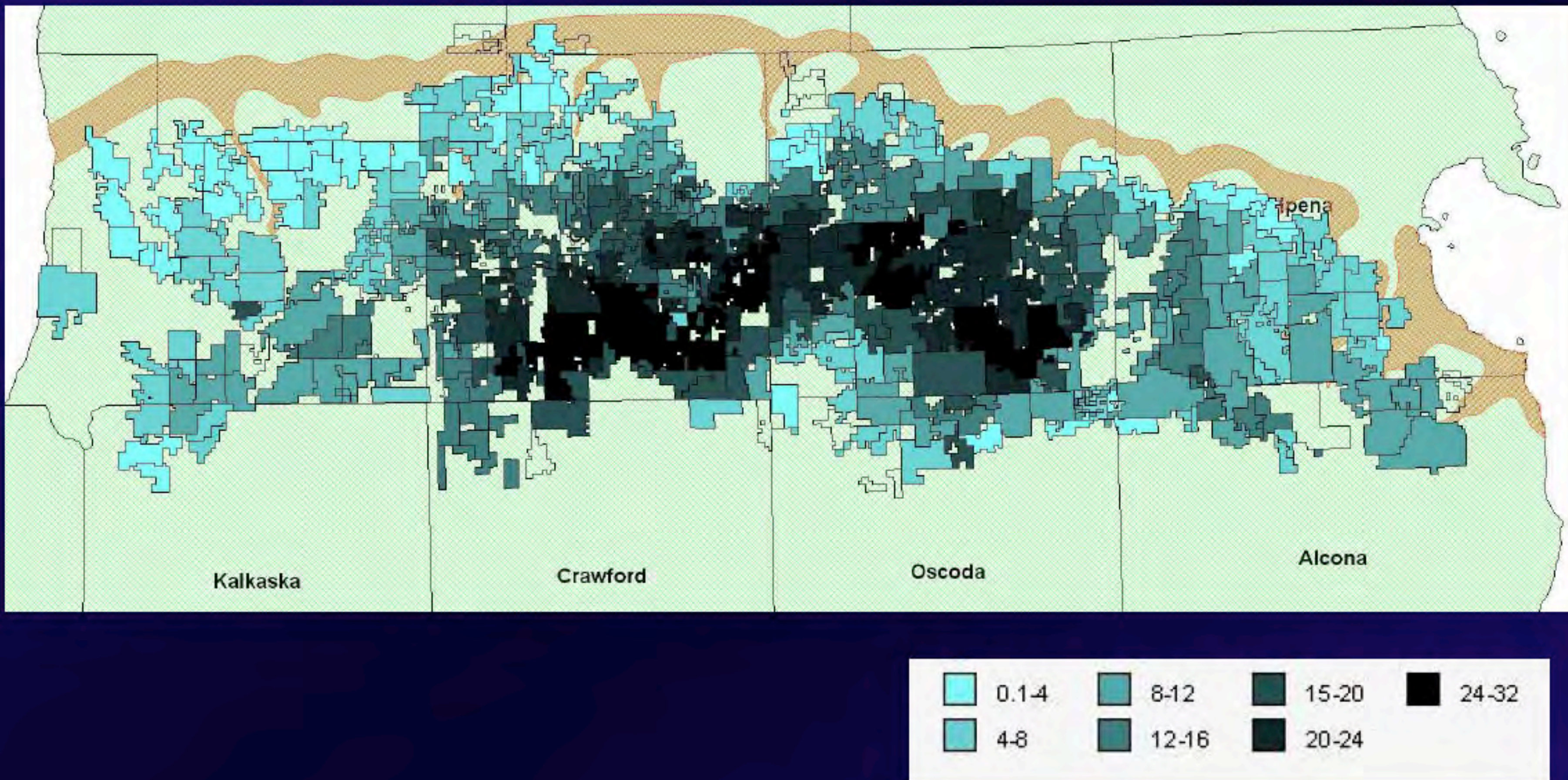
1989-2007



Goodman & Manis 2008



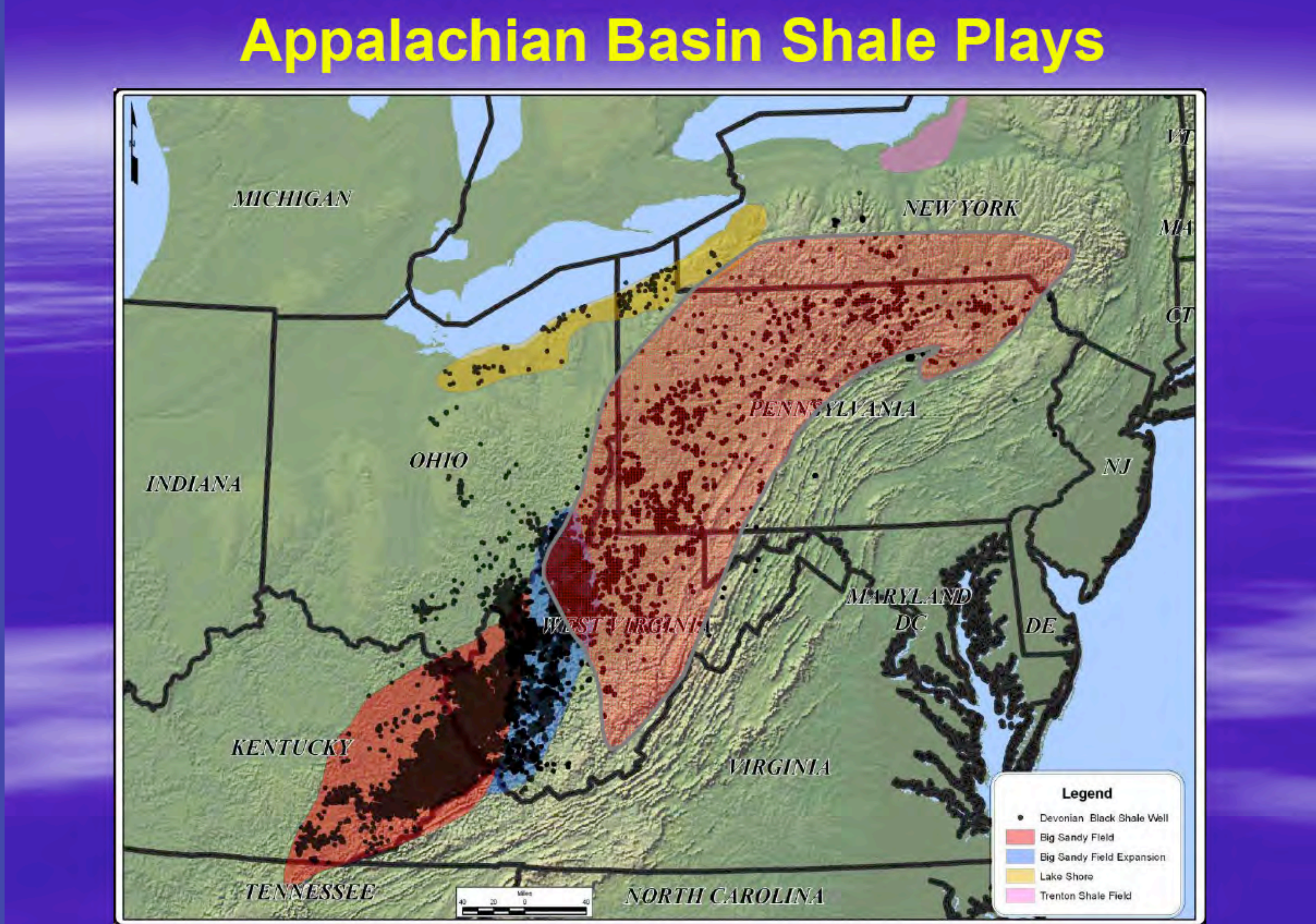
Goodman & Manis 2008



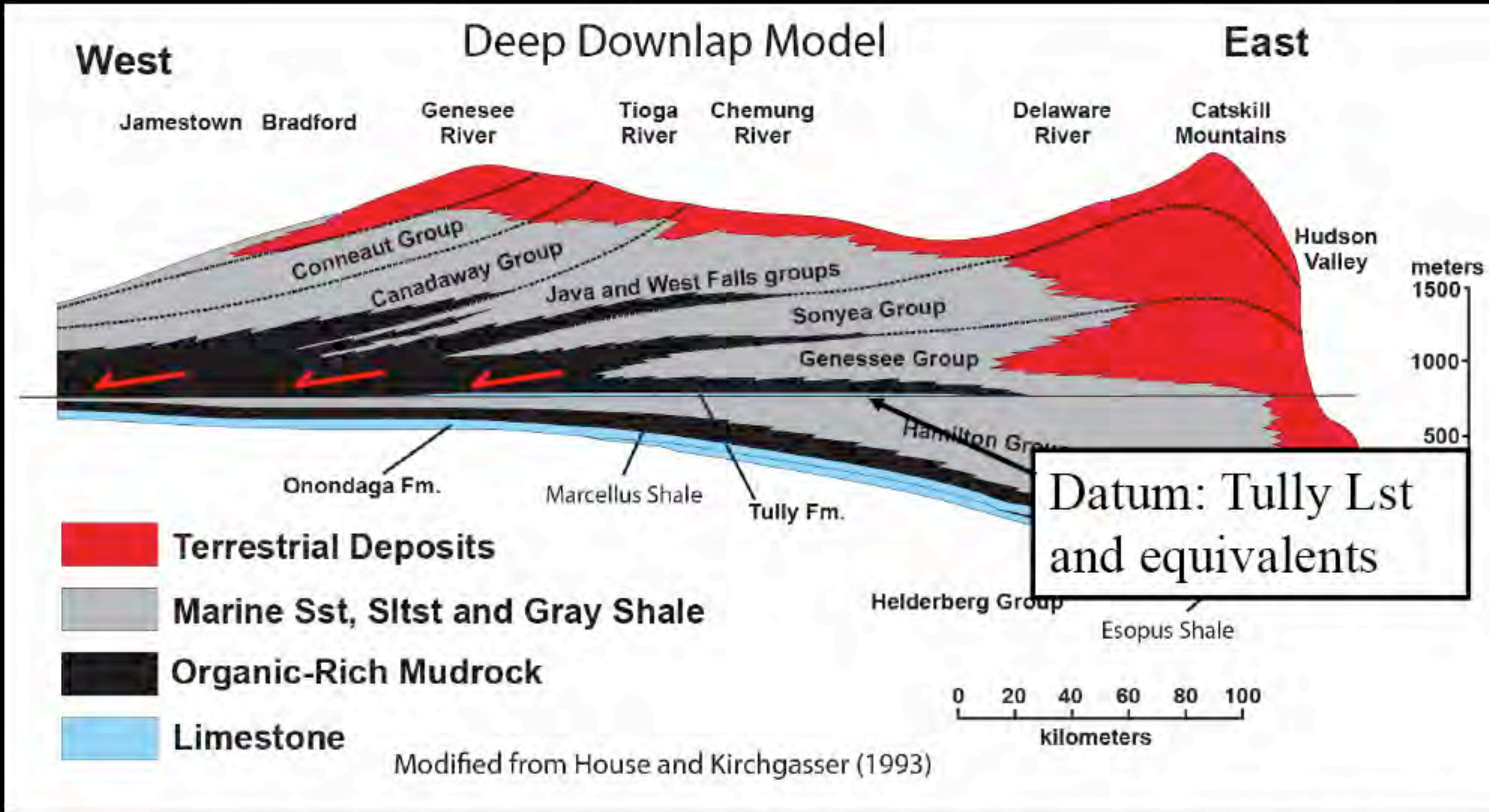
CO_2 Percentage: 2008

Goodman & Manis 2008

Shale Gas III: Marcellus Shale, Appalachian Foreland



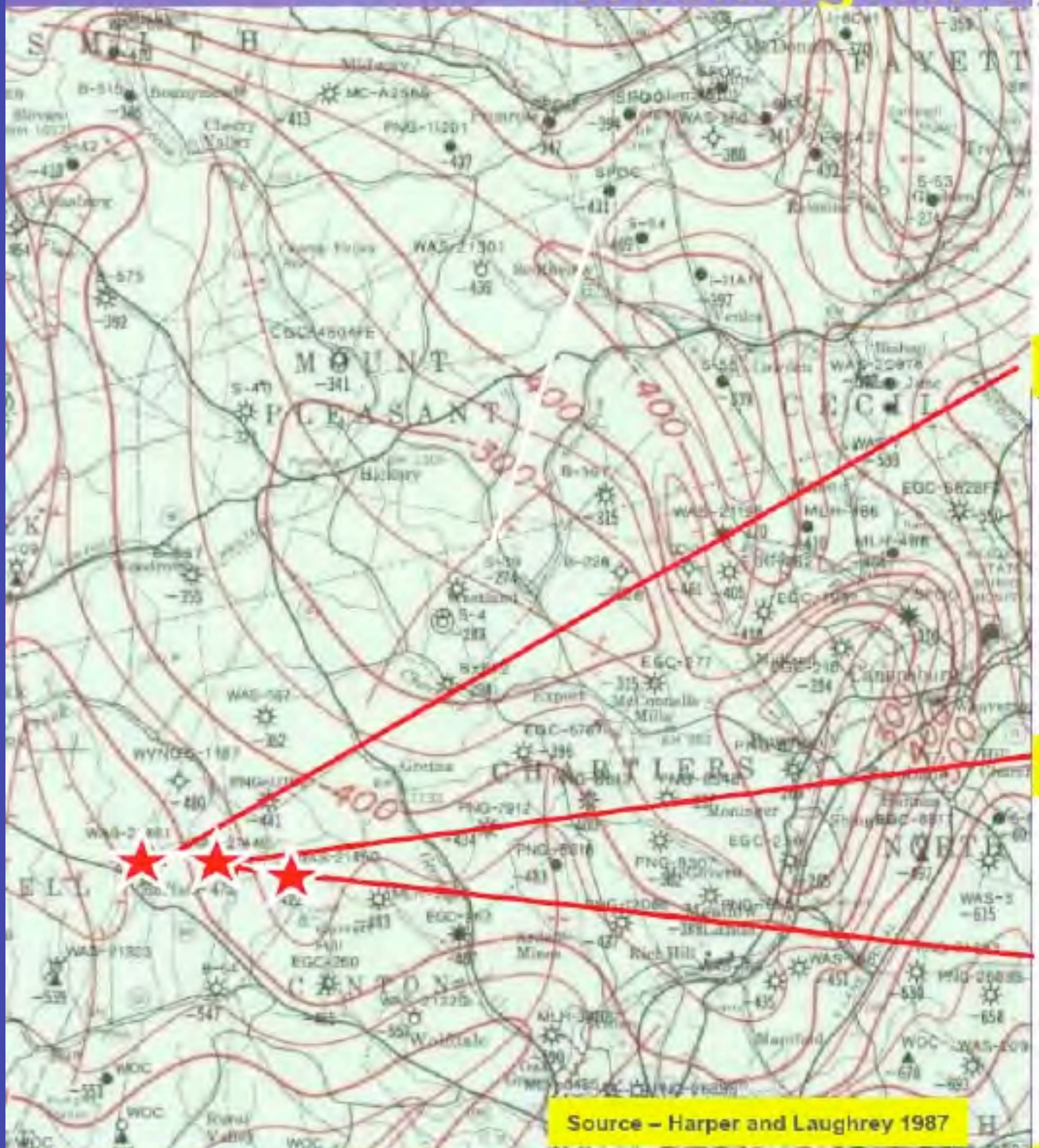
Zagorski 2010



A commonly applied model for the Devonian organic-rich shales in NY is that they were deposited in deep permanently anoxic water (>>100 m) at the toe of the slope and that they downlap on underlying shallow water carbonates onto a drowning unconformity – similar models have been proposed for the Utica

Zagorski 2010

1982 - 1983 Marcellus Completions
Washington Co., PA



Source – Harper and Laughrey 1987

PERFORATION RECORD 20 shots — STIMULATION RECORD

DATE	INTERVAL PERFORATED FROM	TO	DATE 12-10-82	INTERVAL TREATED	AMOUNT FLUID	AMOUNT SAND	INJECTION RATE
12-10-82	6627'	6603'	straight nitrogen	54'	450,000scf	none	30,000 scf

NATURAL OPEN FLOW: none — NATURAL ROCK PRESSURE: 3000

AFTER TREATMENT OPEN FLOW: 15 mcf — AFTER TREATMENT ROCK PRESSURE: 4000 — 48 HRS.

REMARKS: We believe the Marcellus shale fines have caused problems in this well. We will be doing a CO2/water frac on the same

Unsuccessful N2 frac

PERFORATION RECORD 20 shots — STIMULATION RECORD

DATE	INTERVAL PERFORATED FROM	TO	DATE 2-11-83	INTERVAL TREATED	AMOUNT FLUID	AMOUNT SAND	INJECTION RATE
2-11-83	6593'	6698'	CO 2/water frac	105'	65,778gl	48,000	12.8 BPM

NATURAL OPEN FLOW: none — NATURAL ROCK PRESSURE: none

AFTER TREATMENT OPEN FLOW: 400 mcf — AFTER TREATMENT ROCK PRESSURE: 2700 # — 168HR

REMARKS: no oil or fluid has been shown yet. Well is not in line to date.

Unsuccessful CO2 frac

STIMULATION RECORD

DATE	INTERVAL PERFORATED FROM	TO	DATE 6/2/83	INTERVAL TREATED	AMOUNT FLUID	AMOUNT SAND	INJECTION RATE
6/2/83	6588	6683 (20 shots)	35% CO 2 Water Frac	Marcellus Shale	50,400 gl	40,000#	30 BPM
6/2/83	6056	6428 (30 shots)	Same	Devonian Shale	50,600 gl	40,000#	20 BPM

NATURAL OPEN FLOW: 5 MCF — NATURAL ROCK PRESSURE: 100#

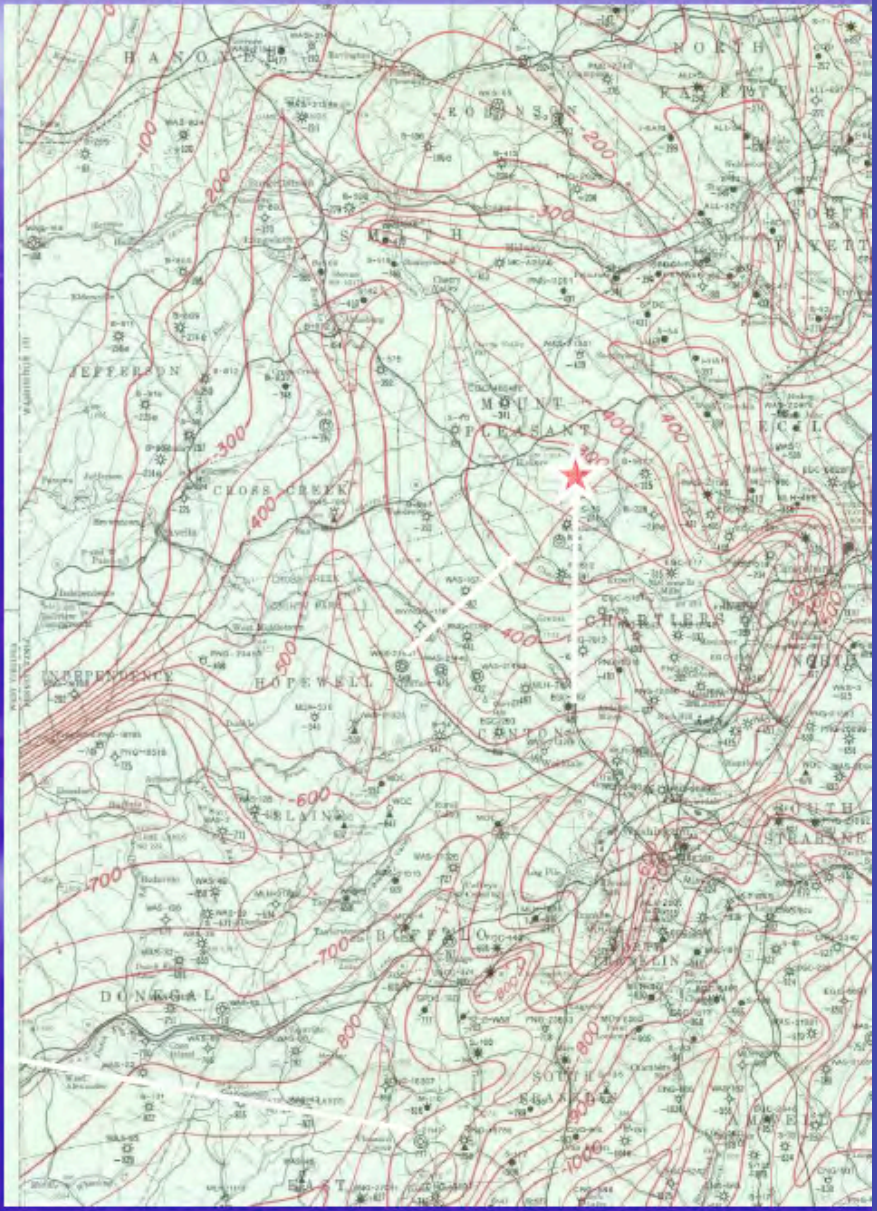
AFTER TREATMENT OPEN FLOW: 70 MCF — AFTER TREATMENT ROCK PRESSURE: 1000#

REMARKS: Set electric bridge plug at 6722 with one sack of cal seal on top of plug per Walter Cooper's (State Inspector) recommendation on plugging off the

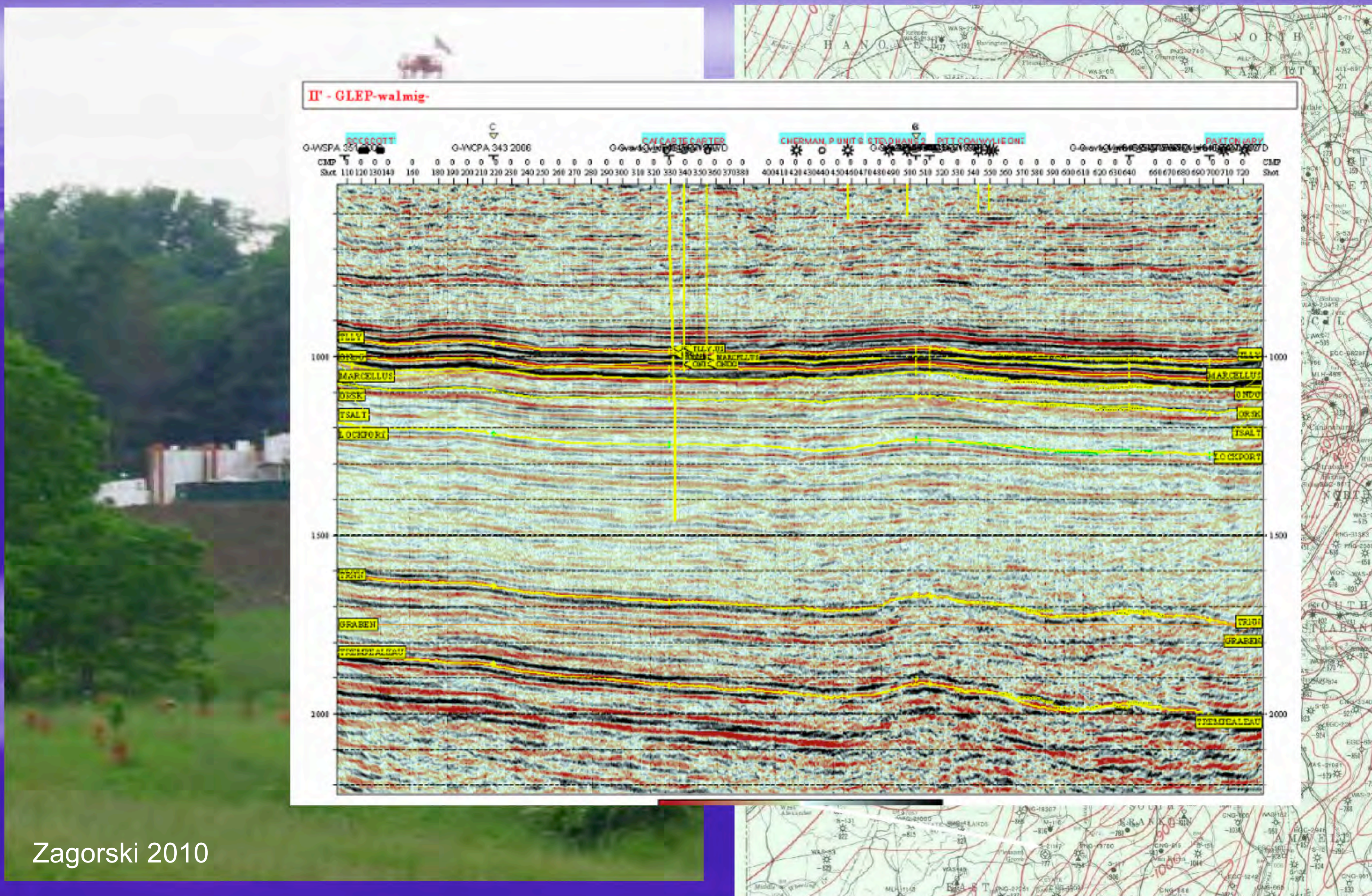
Low volume water/gel frac

Zagorski 2010

2004 - Modern Marcellus Discovery – Renz Unit #1



2004 - Modern Marcellus Discovery – Renz Unit #1



Zagorski 2010

Marcellus GIP, Porosity and Permeability

GIP – 85 BCF/mi2

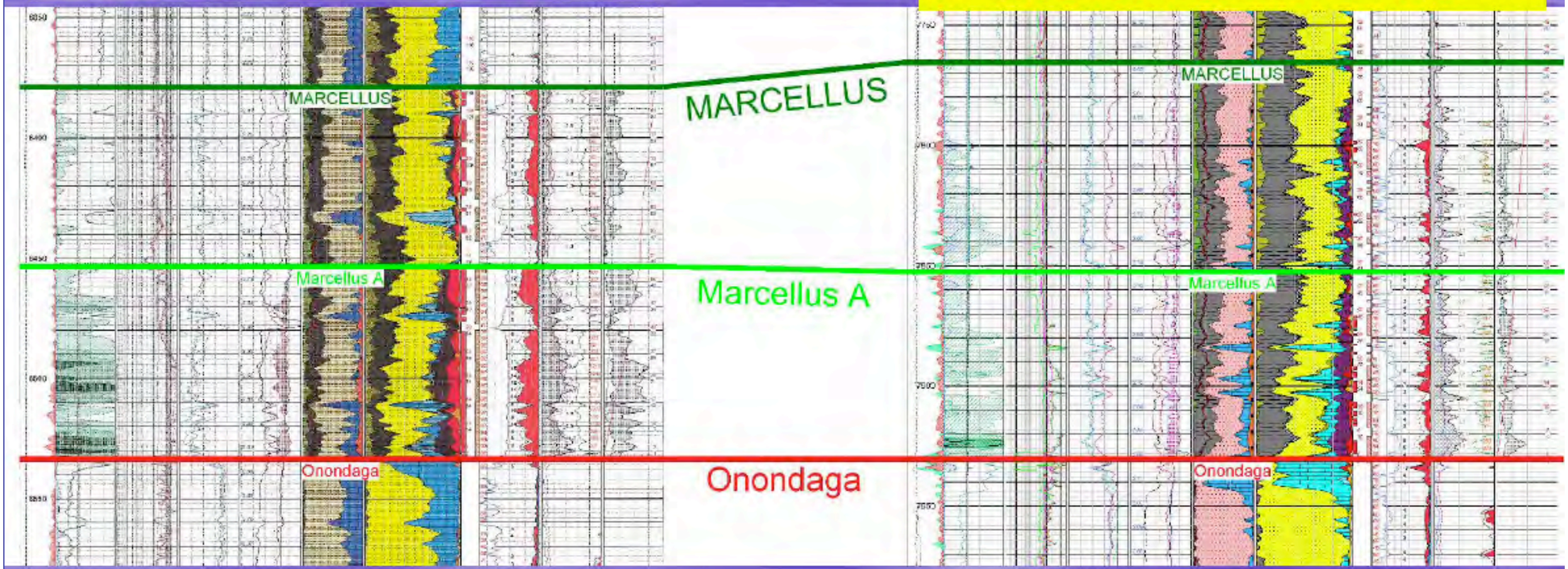
AVG PERM – 598 Nd

AVG EFFECTIVE POROSITY – 8.2%

GIP 57 BCF/mi2

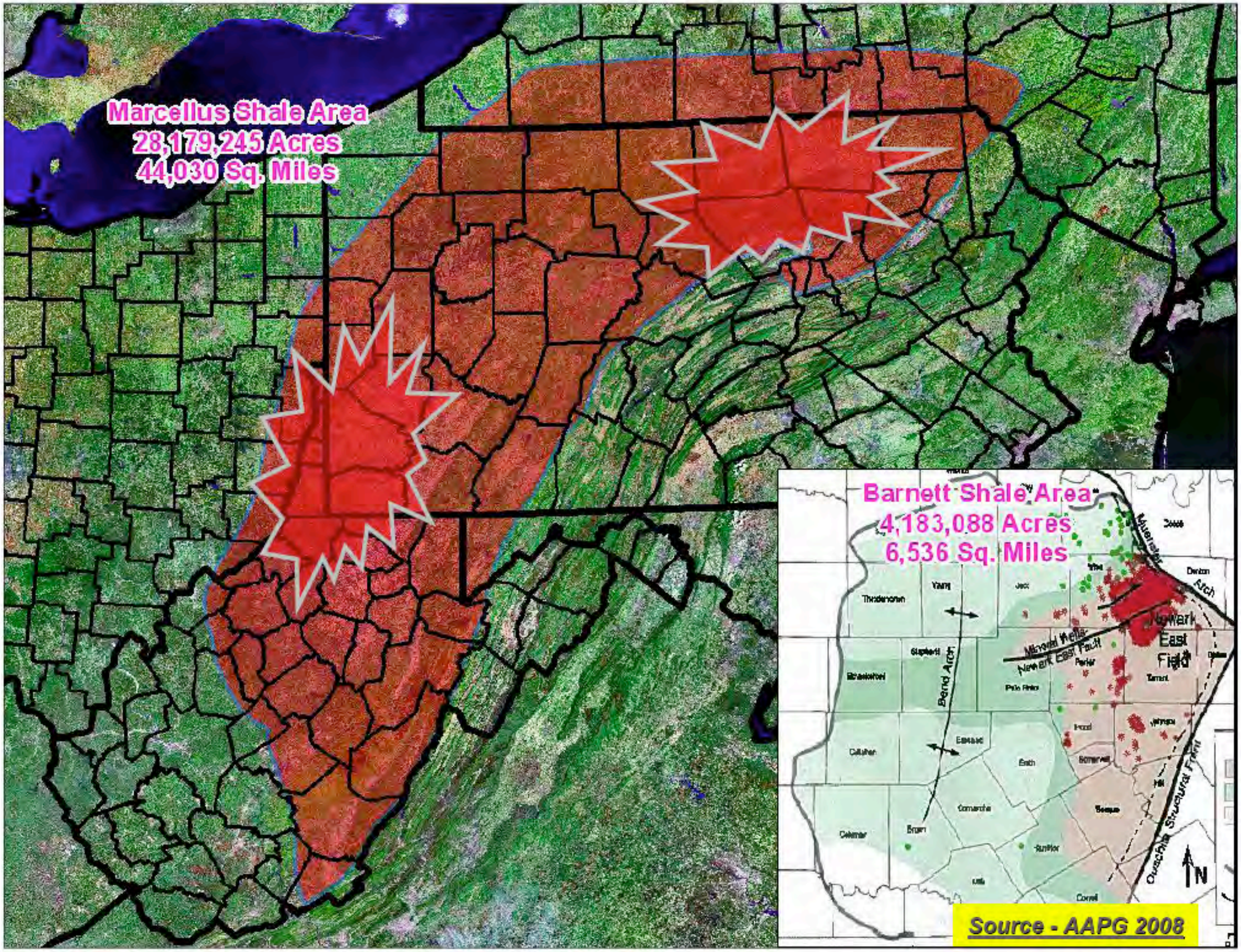
AVG PERM – 247.16 Nd

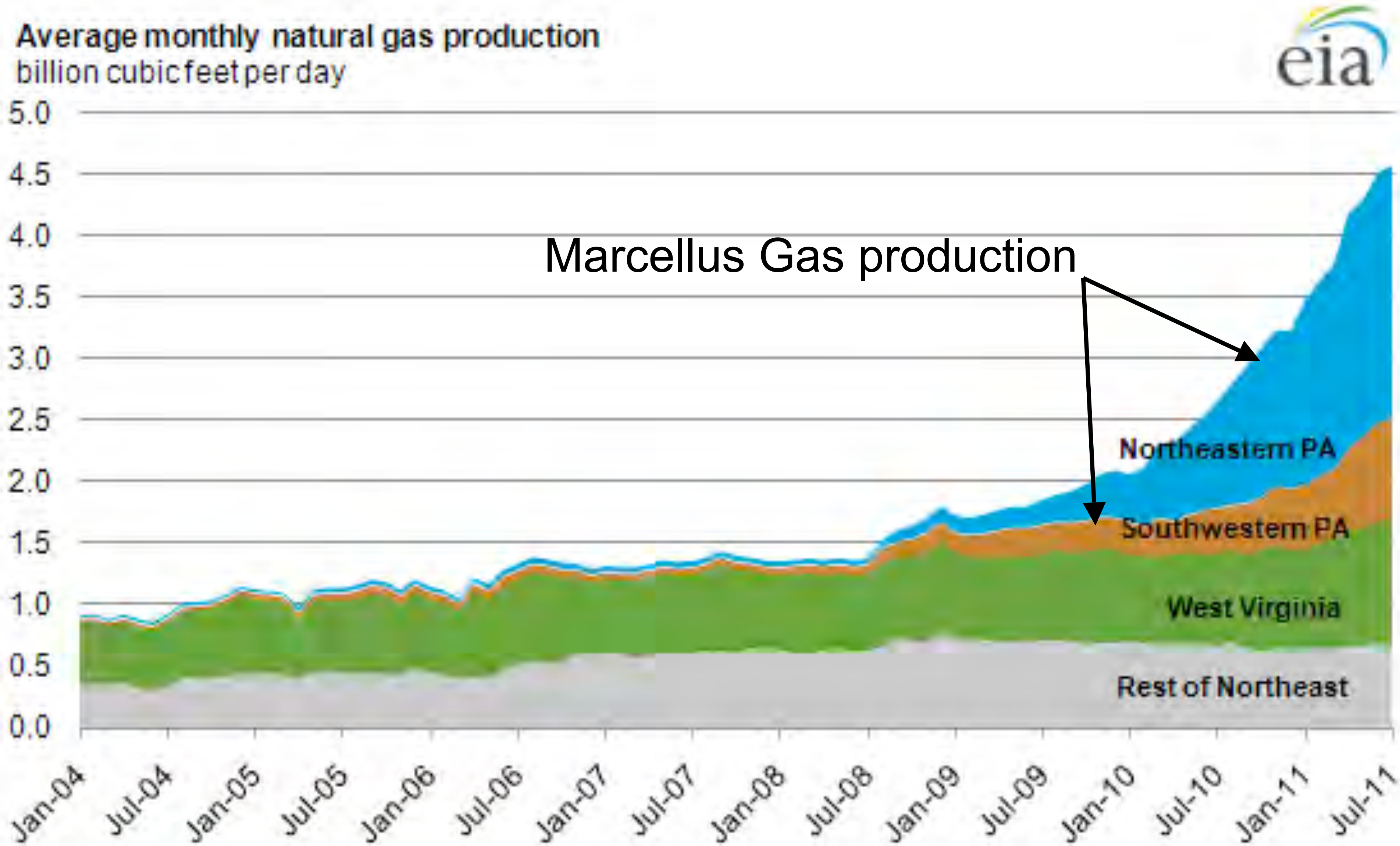
AVG EFFECTIVE POROSITY – 5.02



Zagorski 2010

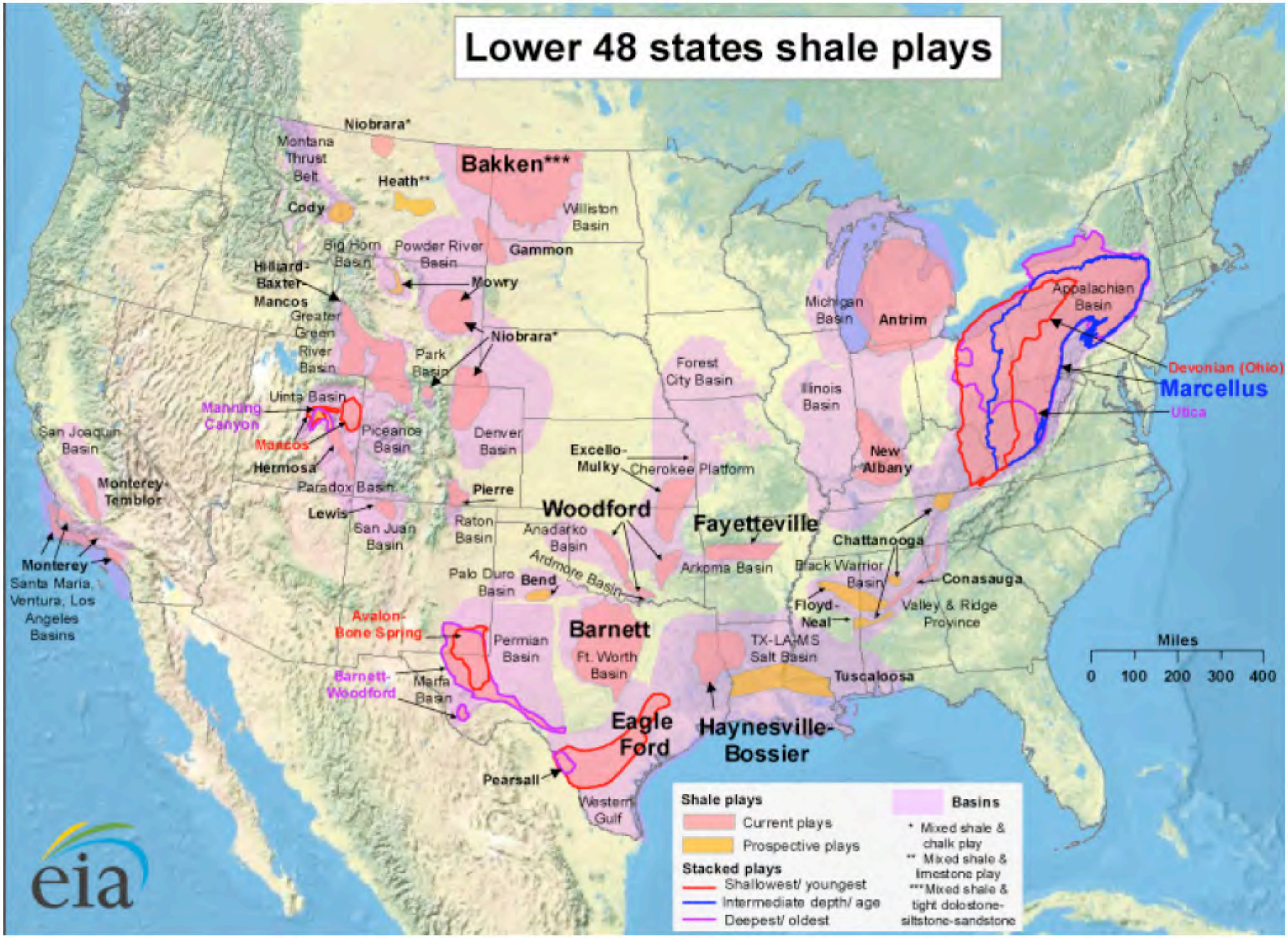
Marcellus Resource Potential




Average monthly natural gas production
billion cubic feet per day
eia
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Marcellus Gas production
Northeastern PA
Southwestern PA
West Virginia
Rest of Northeast
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11

Lower 48 Plays

Figure 1. Map of U.S. shale gas and shale oil plays (as of May 9, 2011)



Source U.S. Energy Information Administration based on data from various published studies.
Upeate: May 9, 2011

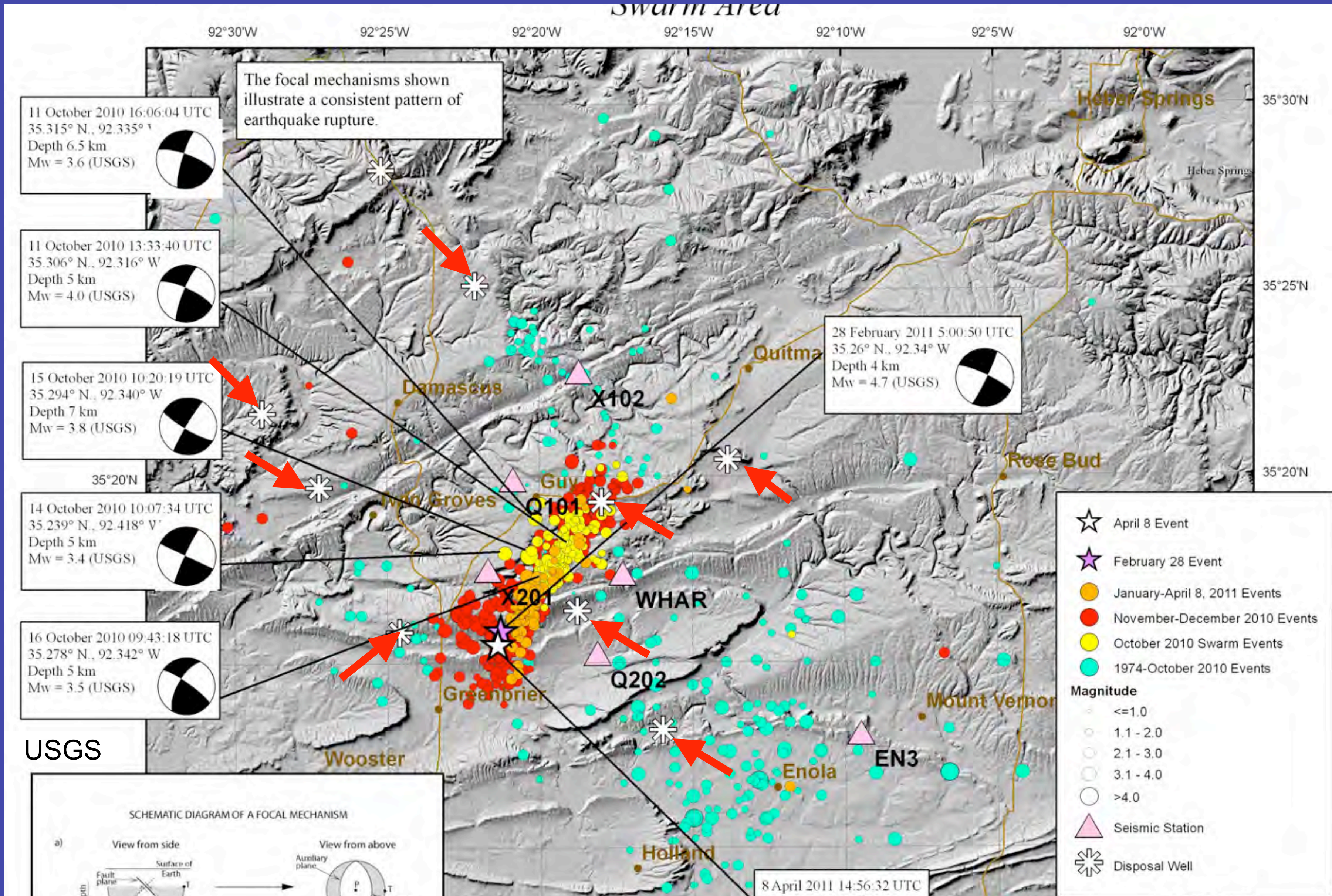
- Introduction
- Shales and Claystones
- Conventional Petroleum Systems
- How to Drill a Well
- Unconventional Petroleum Systems
- Three Shale Gas Basins
- Comments on Diverse Problems: Water, Resource Assessments, Joint Ventures, Gas Prices, Booms and Busts
- Conclusions

What's wrong with this picture?

http://upload.wikimedia.org/wikipedia/commons/1/1c/RoseTestGardenPortland.jpg

TRAFFIC Problems: many large trucks on rural roads not necessarily designed for the volumes or weight

SEISMIC Problems: earthquakes primarily due to waste water injection (Jim Helwig, personal communication)

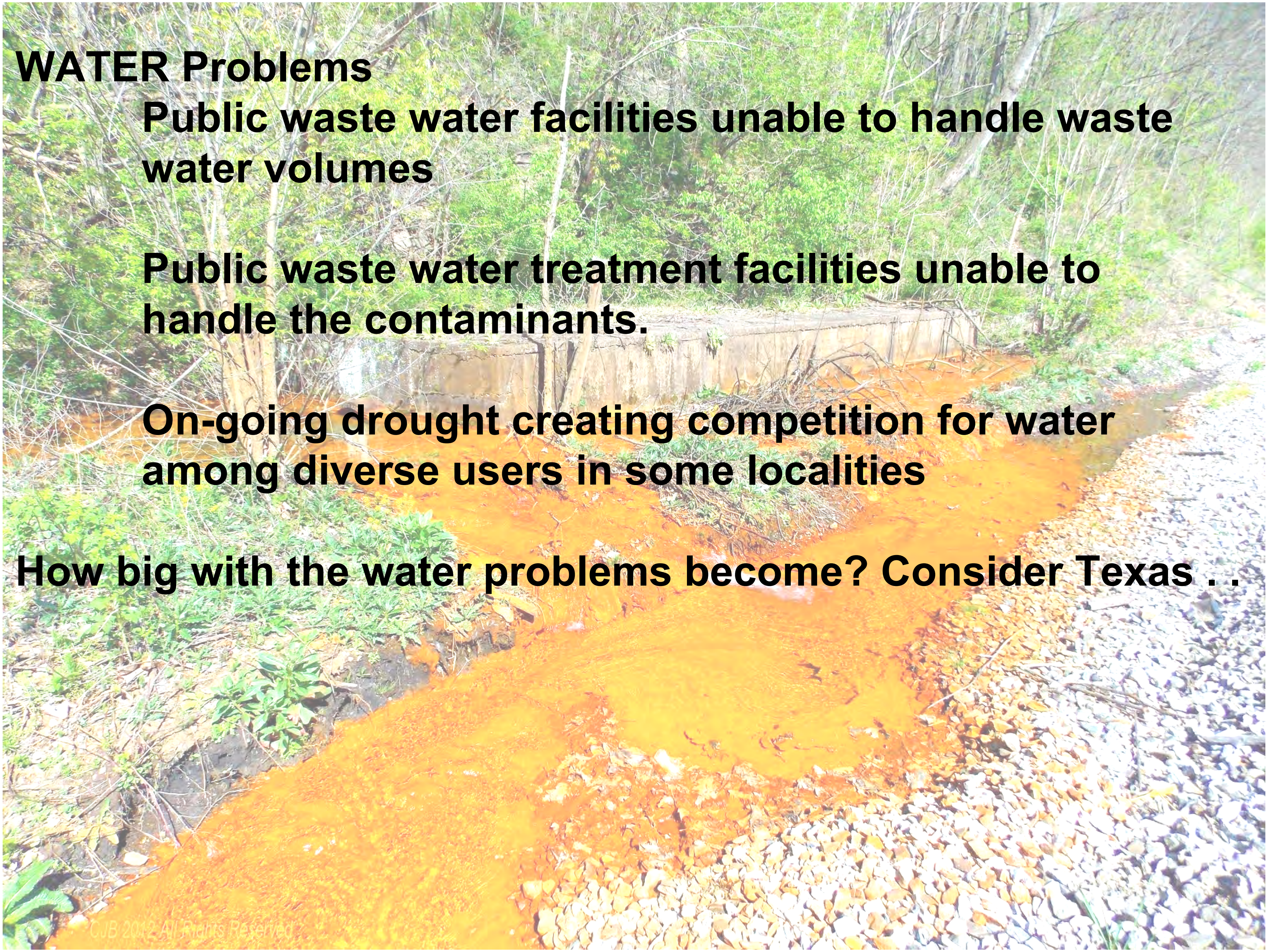


Water Problems

Acid mine drainage

Bradford, Pa

http://www.flickr.com/photos/cjb19772009/6953797418/



WATER Problems

Public waste water facilities unable to handle waste water volumes

Public waste water treatment facilities unable to handle the contaminants.

On-going drought creating competition for water among diverse users in some localities

How big with the water problems become? Consider Texas . .

Texas Shale Gas Plays

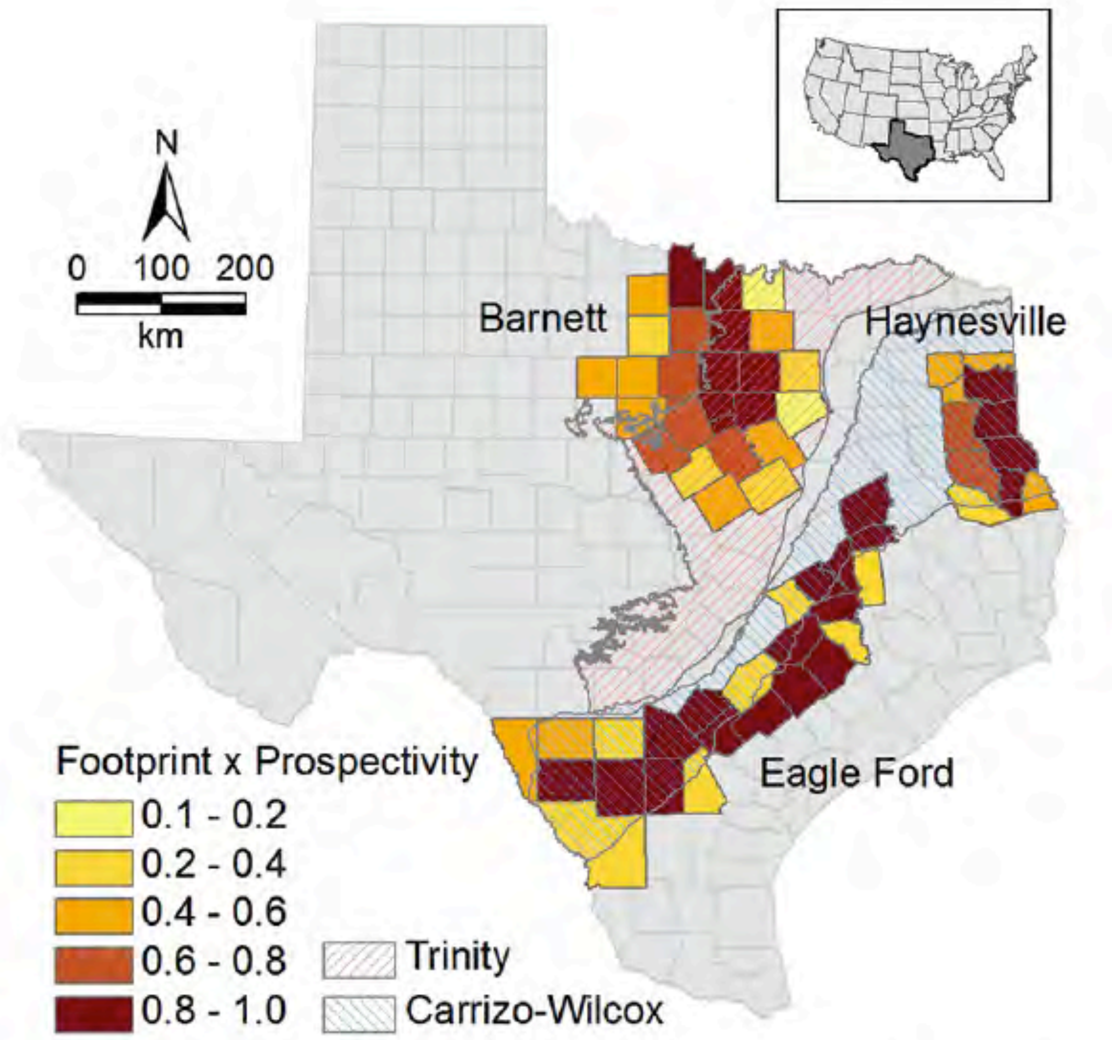
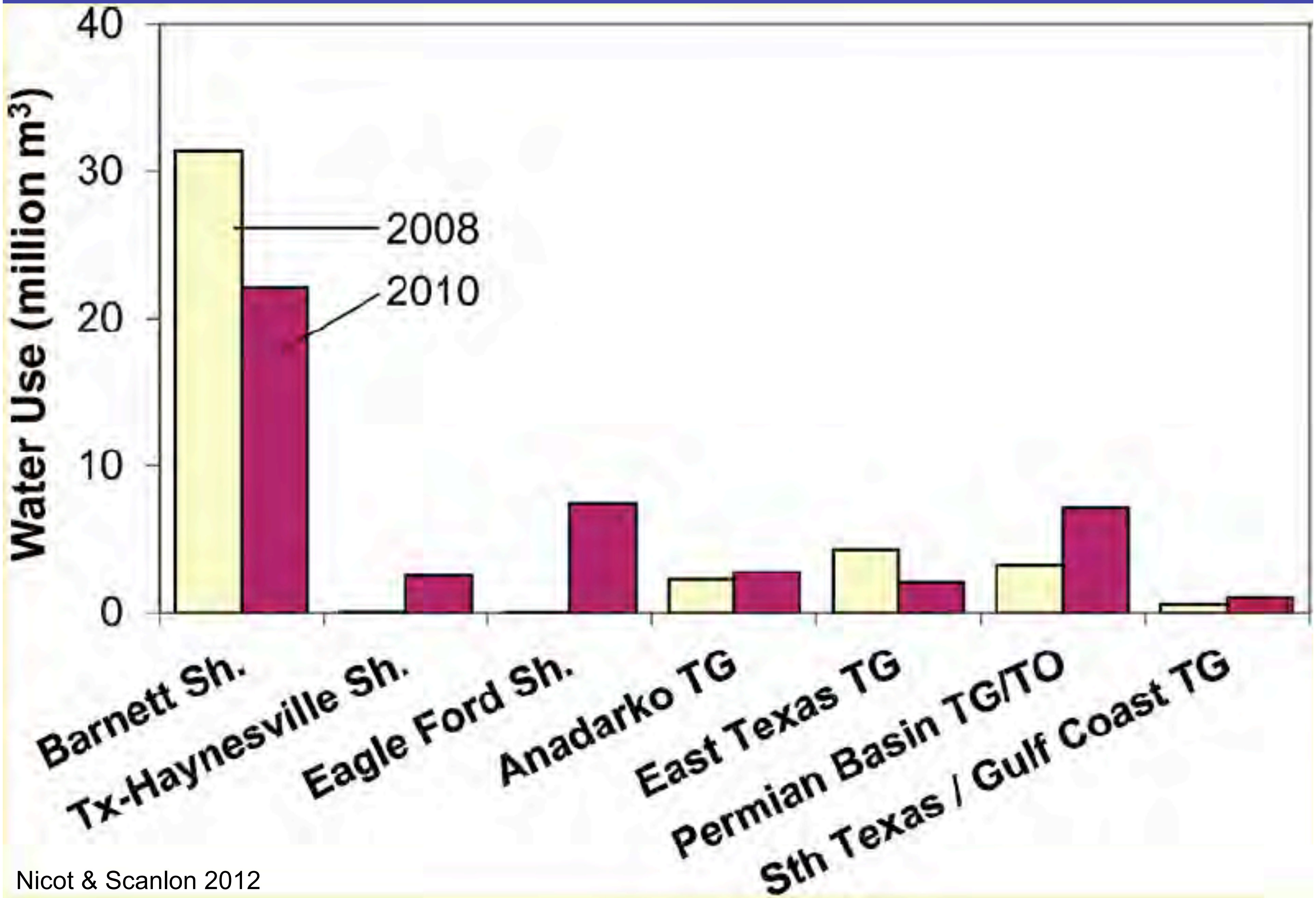


Figure 1. Location of major shale-gas plays in Texas. Colors represent the product of fraction of county area within play footprint (number >0 and ≤1) and prospectivity (number >0 and ≤1). Core counties in

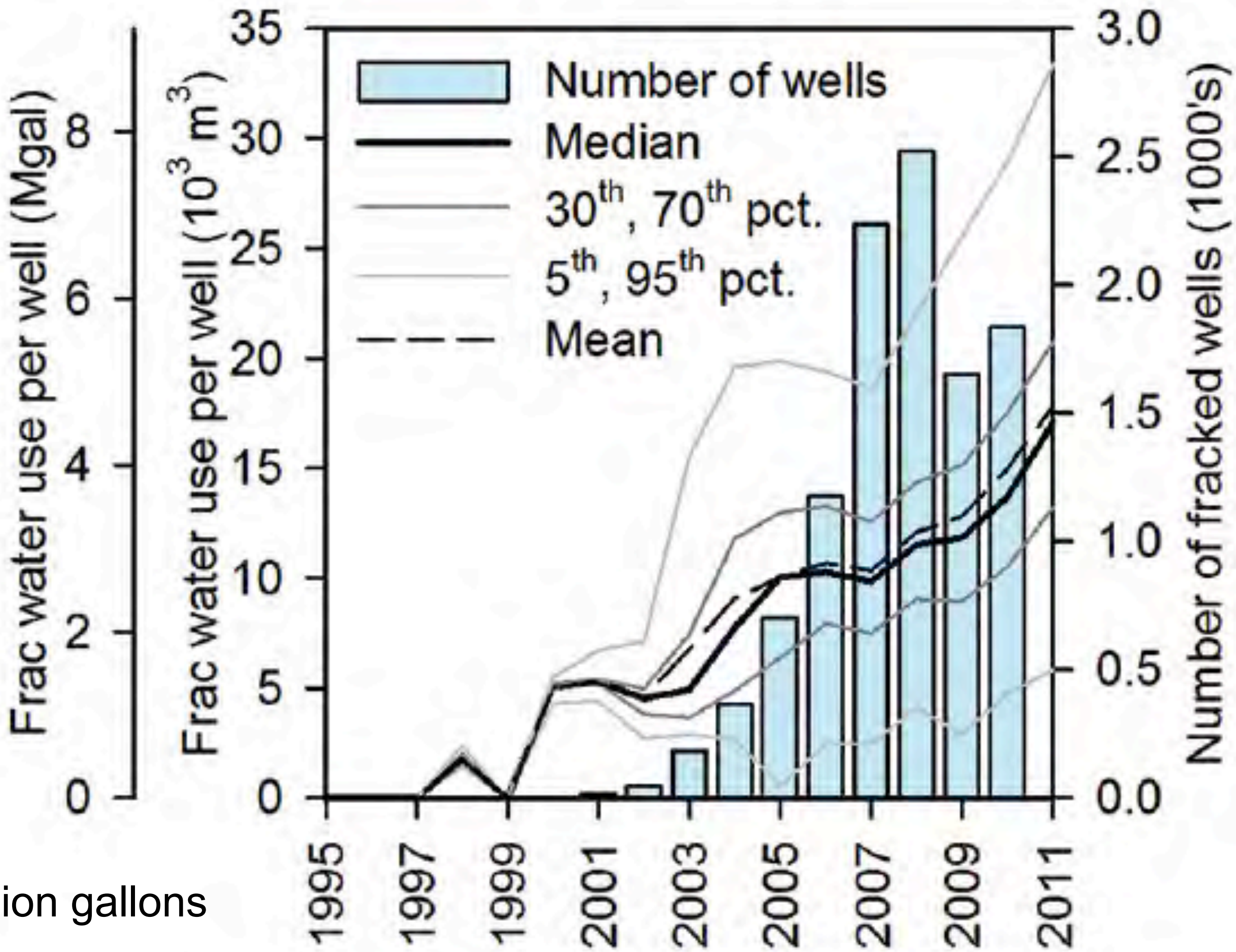
Nicot & Scanlon 2012

Water in Texas shale gas completions



Nicot & Scanlon 2012

Barnett Shale Wells and Water Use



Mgal = million gallons

Figure 3. Time evolution of Barnett Shale well count and water use per well percentiles.

Nicot & Scanlon 2012

Forecast of Texas Shale Well Water Use

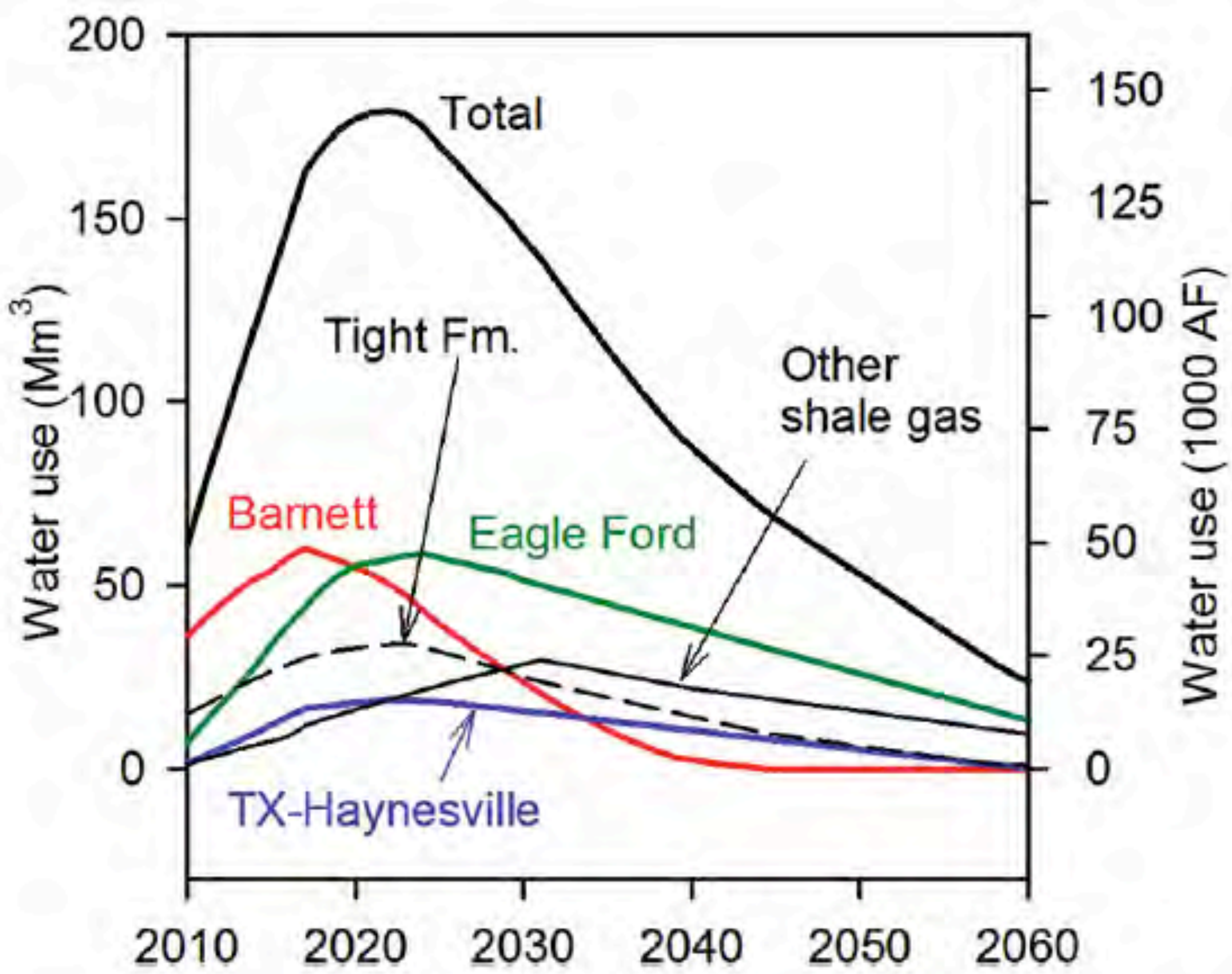
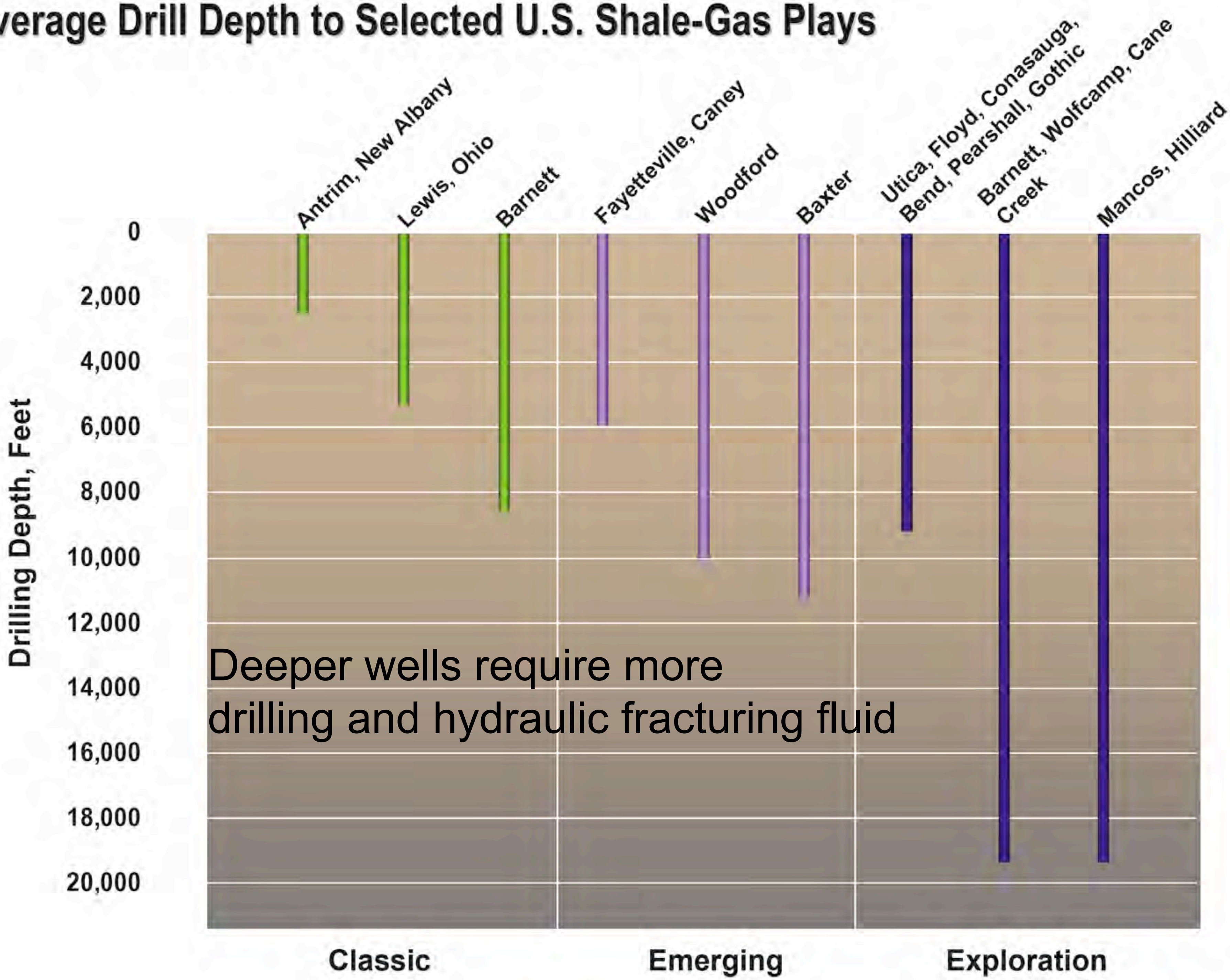


Figure 4. Time evolution in Texas of fracking net water use distributed among the Barnett, Tx-Haynesville, Eagle Ford, and other shale-gas plays to which water-use fracturing of more traditional tight formations is added.

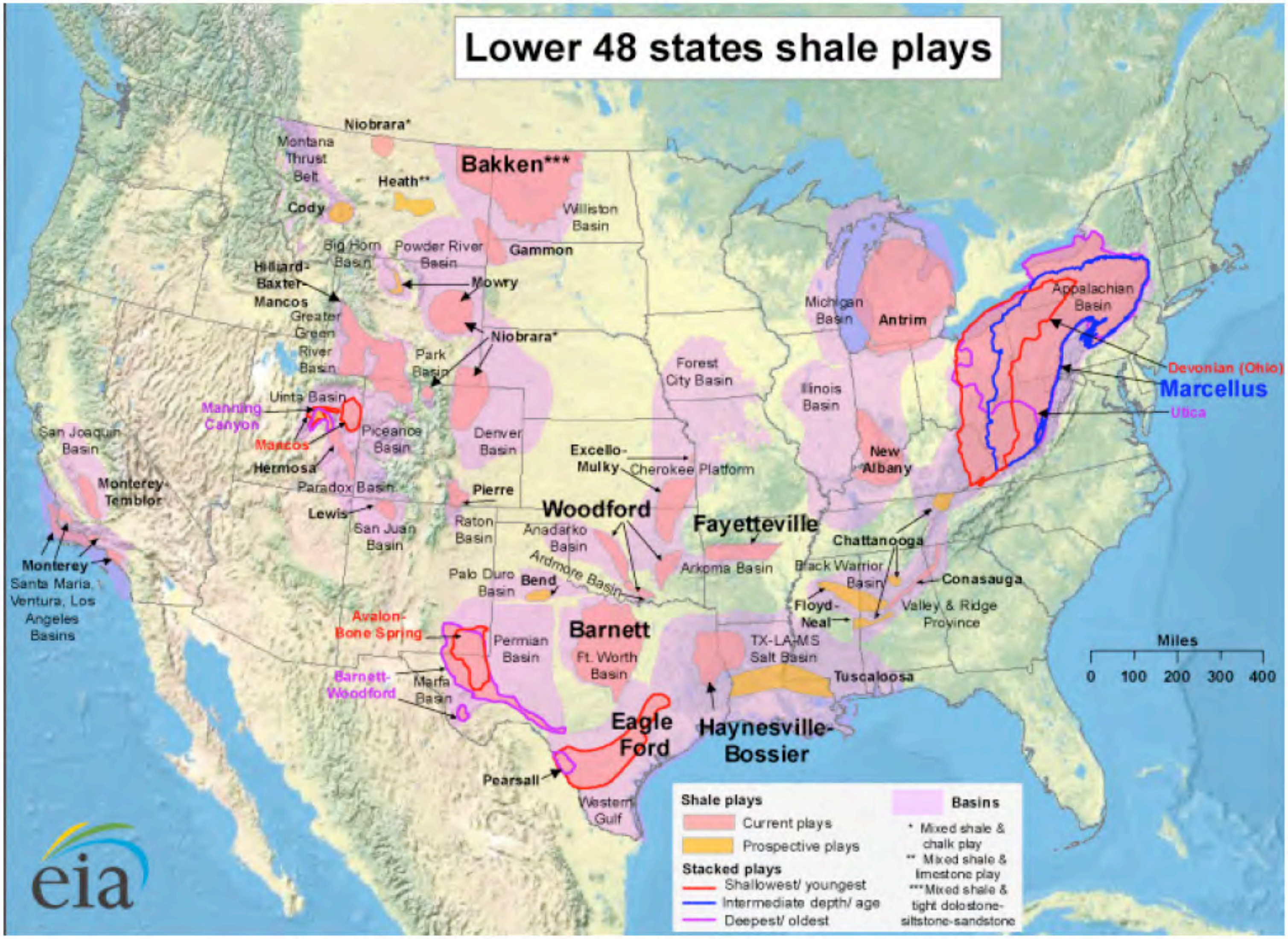
Nicot & Scanlon 2012

Average Drill Depth to Selected U.S. Shale-Gas Plays



How big is this resource? Opinions differ . . .

Figure 1. Map of U.S. shale gas and shale oil plays (as of May 9, 2011)



Source U.S. Energy Information Administration based on data from various published studies.
Upeate: May 9, 2011

. . . . Consider production decline curves . . .

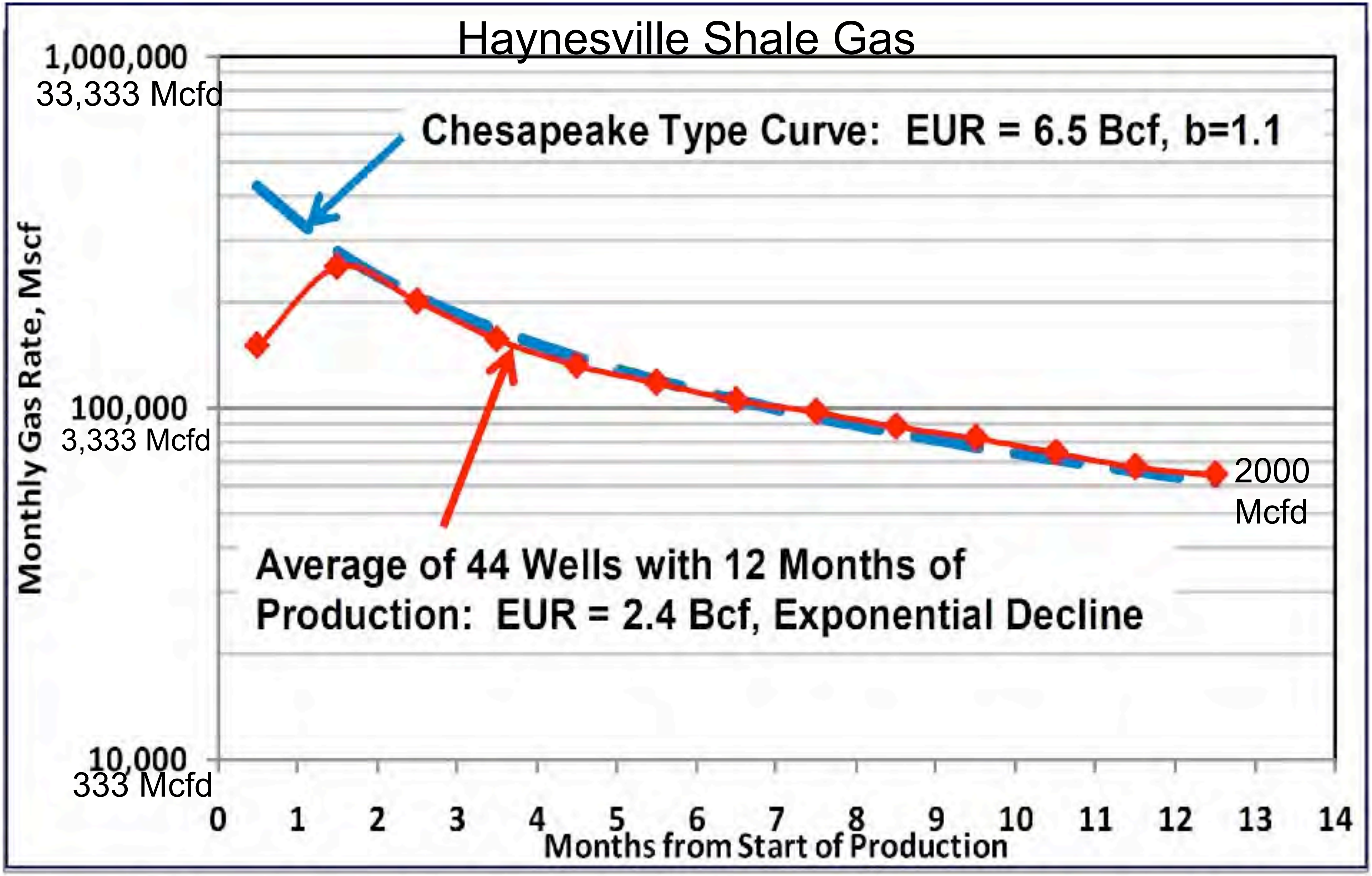
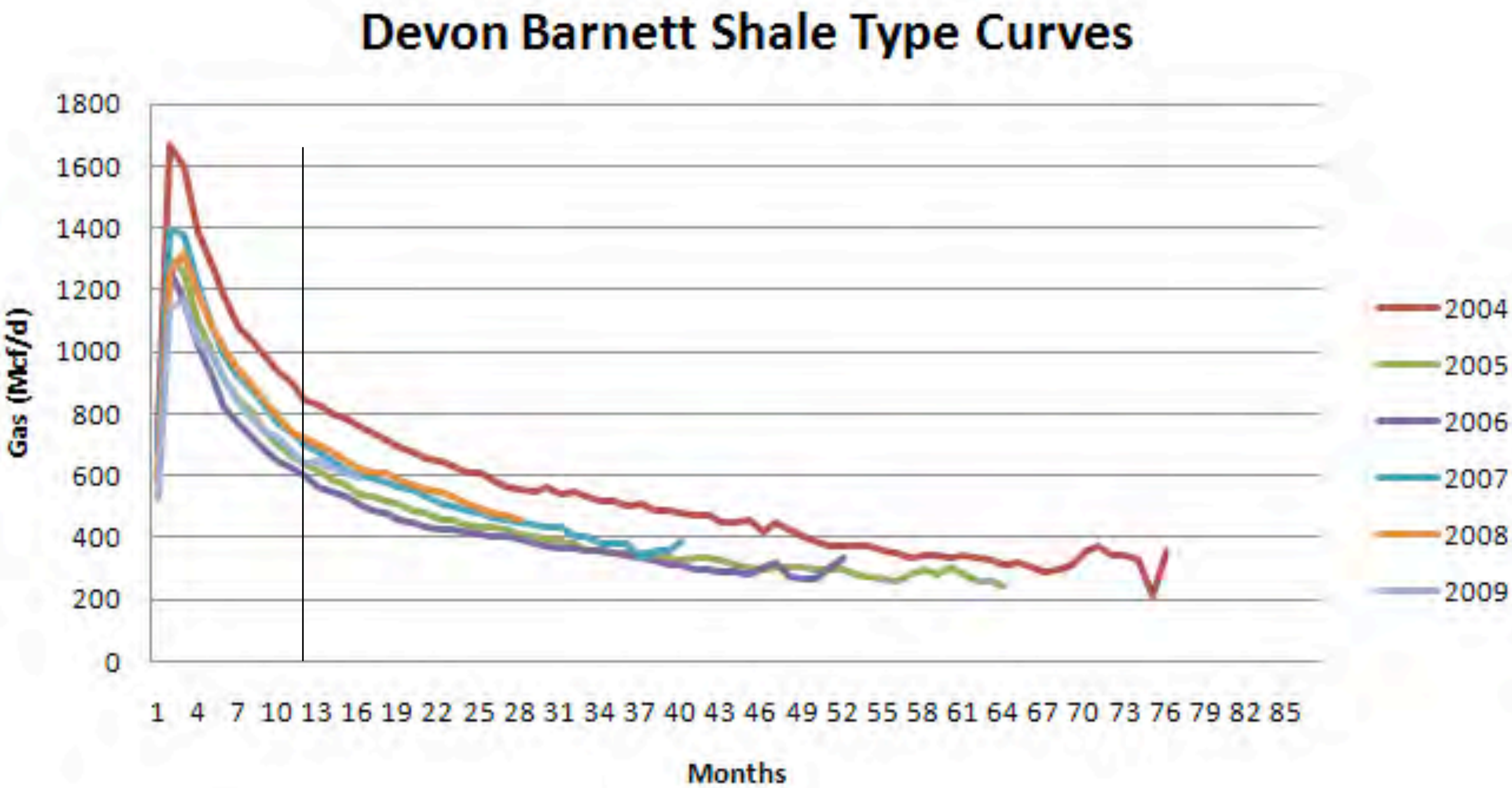


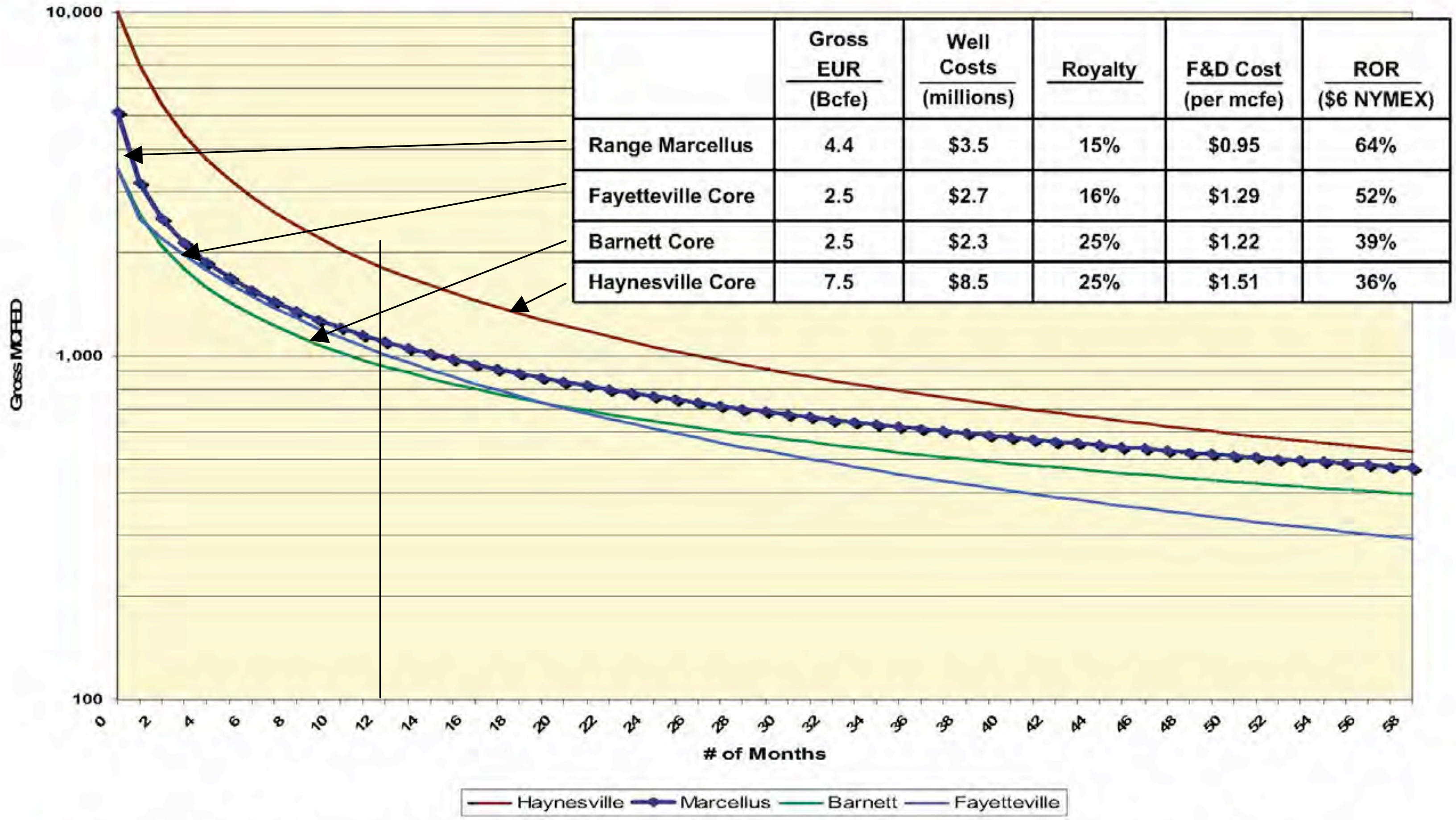
Figure 11.Chesapeake Energy type curve for Haynesville Shale and normalized production data.

http://www.sqwalk.com/q/shale-gas—abundance-or-mirage-why-marcellus-shale-will-disappoint-expectations



http://www.worldoil.com/Arrival-of-IOCs-and-increasing-legislative-interest-signal-critical-mass-for-Marcellus.html

Shale Play Comparison



	Gross EUR (Bcfe)	Well Costs (millions)	Royalty	F&D Cost (per mcfe)	ROR ($6 NYMEX)
Range Marcellus	4.4	$3.5	15%	$0.95	64%
Fayetteville Core	2.5	$2.7	16%	$1.29	52%
Barnett Core	2.5	$2.3	25%	$1.22	39%
Haynesville Core	7.5	$8.5	25%	$1.51	36%

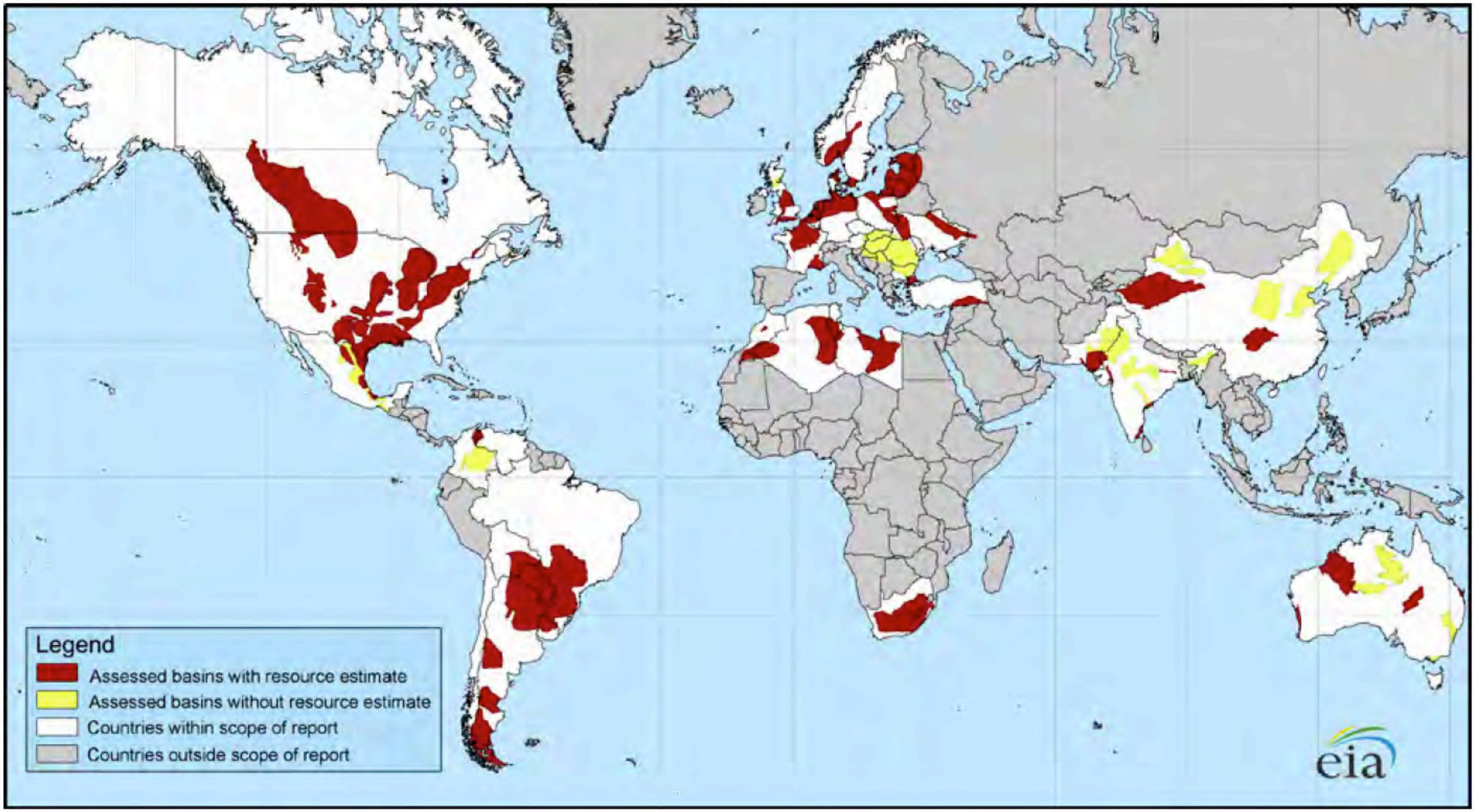
- **Type curves for Barnett, Fayetteville and Haynesville based on public production information**
- **Zero time curve for Marcellus based on production results from 24 Range wells only**

http://www.oilandgasevaluationreport.com/2010/03/articles/oil-patch-economics/shale-economics-watch-the-curve/

Total Potential Gas Resources (mean values)

Data source: Potential Gas Committee (2009)

Figure 1. Map of 48 major shale gas basins in 32 countries



EIA February 2011

Table 1-2. Risked Gas In-Place and Technically Recoverable Shale Gas Resources Six Continents

Continent	Risked Gas In-Place (Tcf)	Risked Technically Recoverable (Tcf)
North America	3,856	1,069
South America	4,569	1,225
Europe	2,587	624
Africa	3,962	1,042
Asia	5,661	1,404
Australia	1,381	396
Total	22,016	5,760

EIA February 2011

Table 1-4. Comparison of Rogner's and This Study Estimates of Shale Gas Resources In-Place

Continent	H-H Rogner (Tcf)	EIA/ARI (Tcf)
1. North America*	3,842	7,140
2. South America	2,117	4,569
3. Europe	549	2,587
4. Africa**	1,548	3,962
5. Asia	3,528	5,661
6. Australia	2,313	1,381
7. Other***	2,215	n/a
Total	16,112	25,300

* Includes U.S. shale gas in-place of 3,.824 Tcf, based on estimated (ARI) 820 Tcf of technically recoverable shale gas resources and a 25% recovery efficiency of shale gas in-place.

** Rogner estimate includes one-half of Middle East and North Africa (1,274) and Sub-Saharan Africa (274 Tcf).

*** Includes FSU (627 Tcf), Other Asia Pacific (314 Tcf) and one-half of Middle East/North Africa (1,274) Tcf.

Rogner, H-H., "An Assessment of World Hydrocarbon Resources", Annu. Rev. Energy Environ. 1997, 22:217-62.

EIA February 2011

EIA
March
2011

Table i U.S. Shale Gas Unproved Discovered Technically Recoverable Resources Summary

Play	Technically Recoverable Resource		Area (sq. miles)		Average EUR	
	Gas (Tcf)	Oil (BBO)	Leased	Unleased	Gas (Bcf/ well)	Oil (MBO/ well)
Marcellus	410.34	...	10,622	84,271	1.18	...
Big Sandy	7.40	...	8,675	1,994	0.33	...
Low Thermal Maturity	13.53	...	45,844		0.30	...
Greater Siltstone	8.46	...	22,914		0.19	...
New Albany	10.95	...	1,600	41,900	1.10	...
Antrim	19.93	...	12,000		0.28	...
Cincinnati Arch*	1.44	...	**NA**		0.12	...
Total Northeast	**472.05**	**...**	**101,655**	**128,272**	**0.74**	**...**
Haynesville	74.71	...	3,574	5,426	3.57	...
Eagle Ford	20.81	...	1,090		5.00	...
Floyd-Neal & Conasauga	4.37	...	2,429		0.90	...
Total Gulf Coast	**99.99**	**...**	**7,093**	**5,426**	**2.99**	**...**
Fayetteville	31.96	...	9,000		2.07	...
Woodford	22.21	...	4,700		2.98	...
Cana Woodford	5.72	...	688		5.20	...
Total Mid-Continent	**59.88**	**...**	**14,388**		**2.45**	**...**
Barnett	43.38	...	4,075	2,383	1.42	...
Barnett Woodford	32.15	...	2,691		3.07	...
Total Southwest	**75.52**	**...**	**6,766**	**2,383**	**1.85**	**...**
Hilliard-Baxter-Mancos	3.77	...	16,416		0.18	...
Lewis	11.63	...	7,506		1.30	...
Williston-Shallow Niobraran*	6.61	...	**NA**		0.45	...
Mancos	21.02	...	6,589		1.00	...
Total Rocky Mountain	**43.03**	...	**30,511**		**0.69**	...
Total Lower 48 U.S.	**750.38**	**...**	**160,413**	**136,081**	**1.02**	**...**

***Cincinnati Arch and Williston-Shallow Niobraran were not assessed in this report.**

US Estimates

1997 Rogner: 960 TCF technically recoverable shale gas

2009 PGC: 616 TCF technically recoverable shale gas

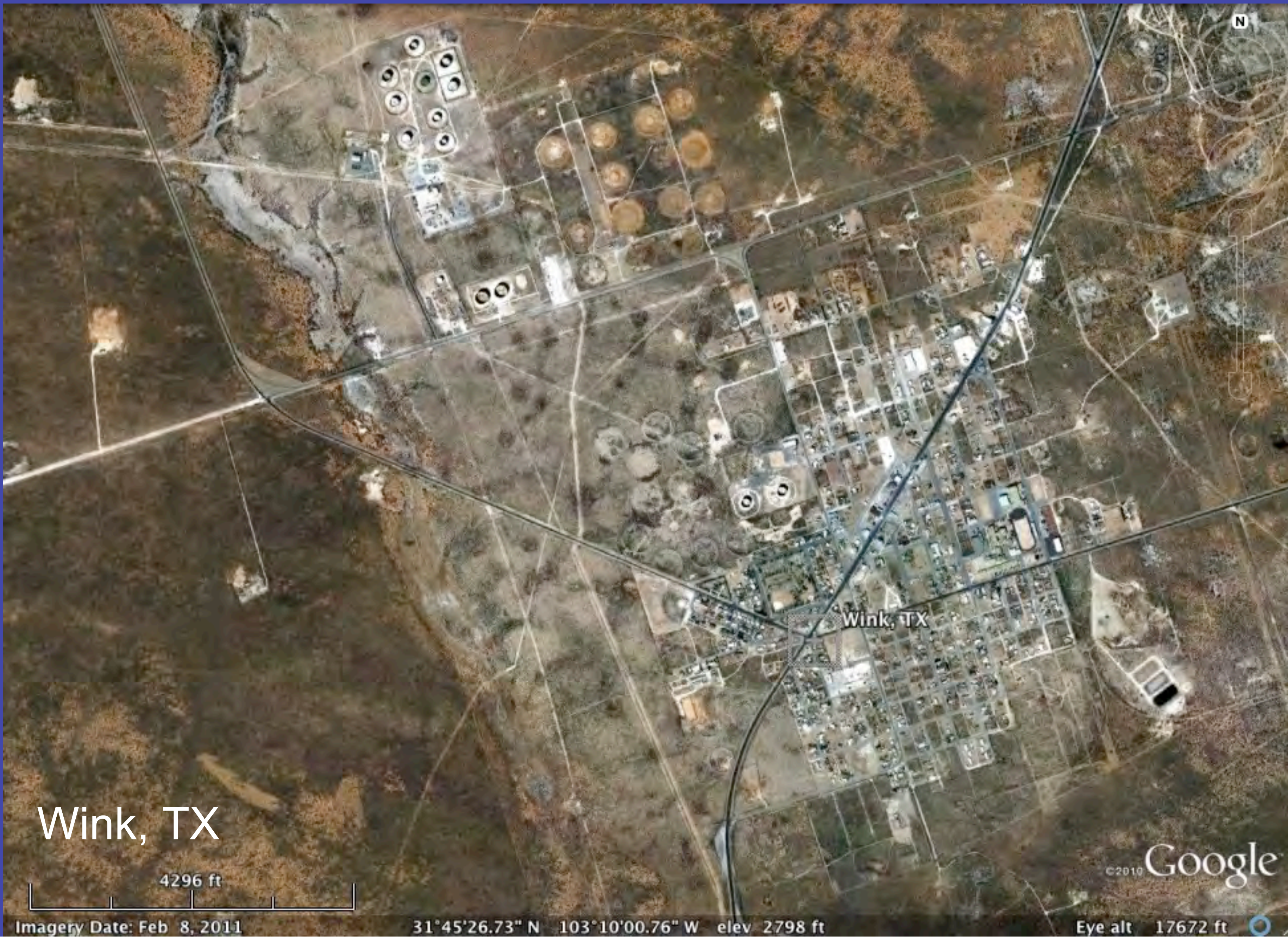
2010 ARI: 820 TCF technically recoverable shale gas

2011 EIA 750 TCF technically recoverable shale gas

Why have these estimates changed?

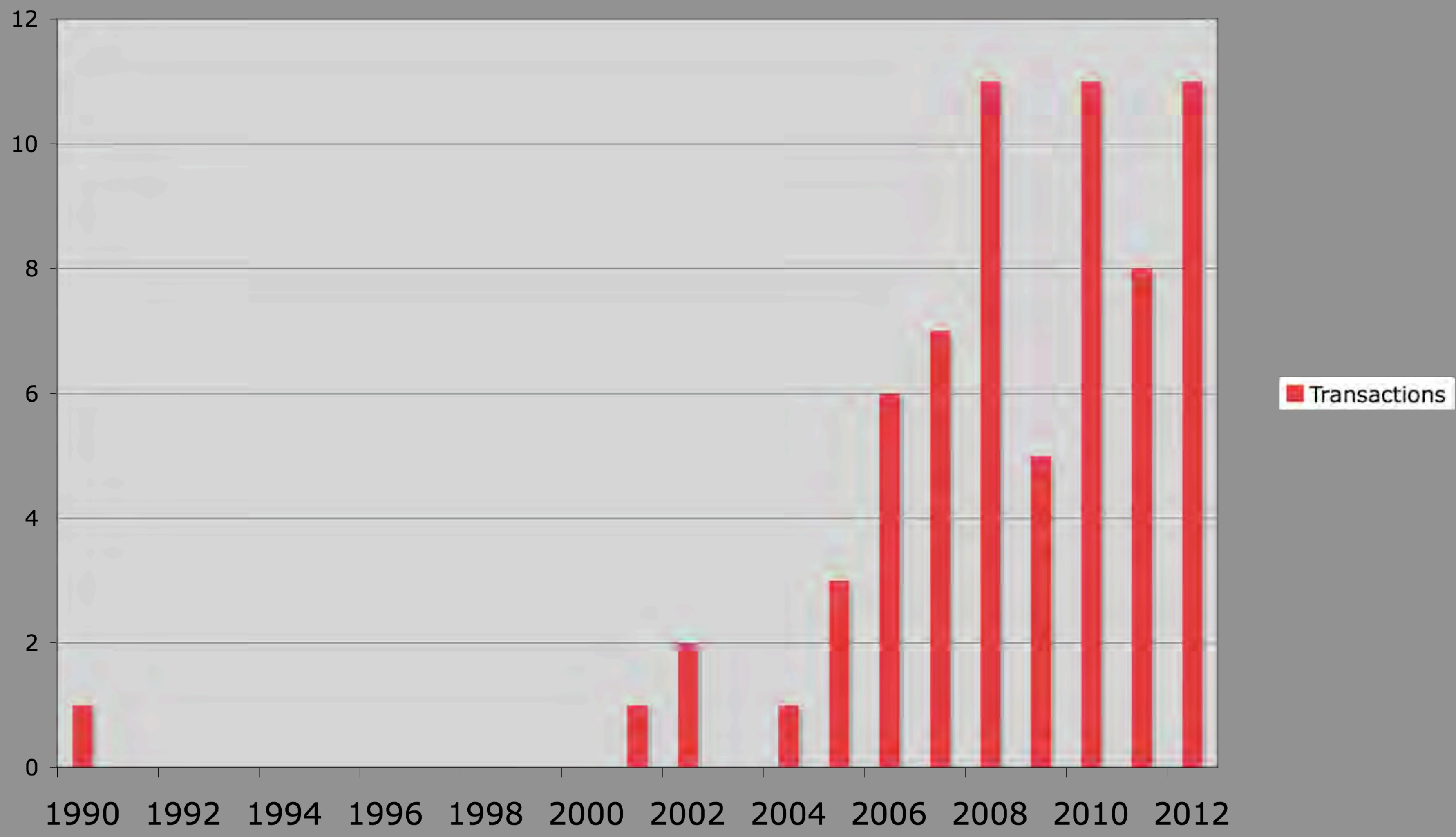
1. Better definition of play areas
2. Better but limited well production data
3. Changing gas prices

Are further changes in shale gas assessments likely?



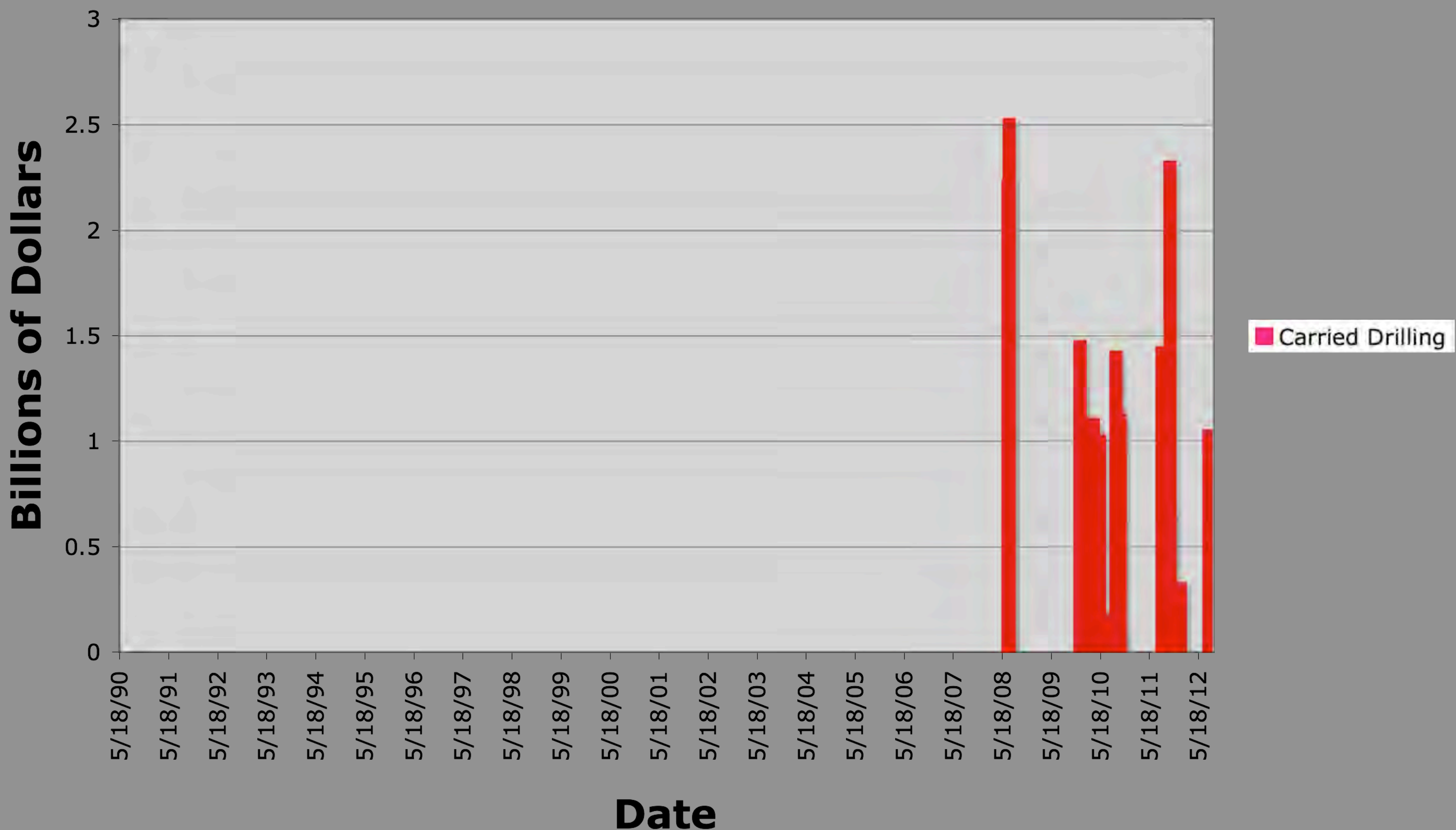

Henry Hub Gulf Coast Natural Gas Spot Price
Dollars/Mil. BTUs
20
15
10
5
0
1998
2000
2002
2004
2006
2008
2010
2012
Henry Hub Gulf Coast Natural Gas Spot Price
Source: U.S. Energy Information Administration

Annual Shale Gas Transactions

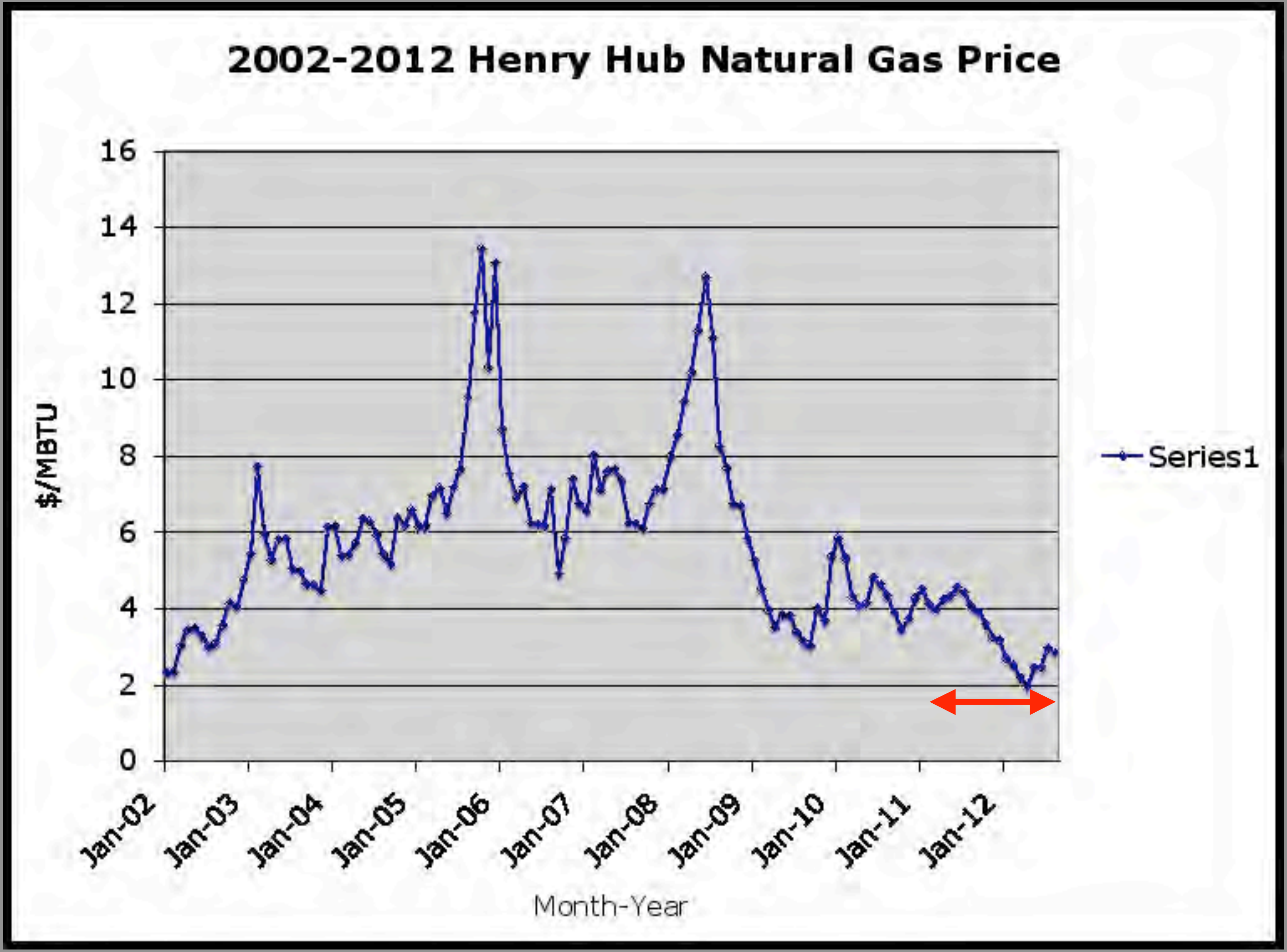


Over $67 billion in sales and joint-ventures

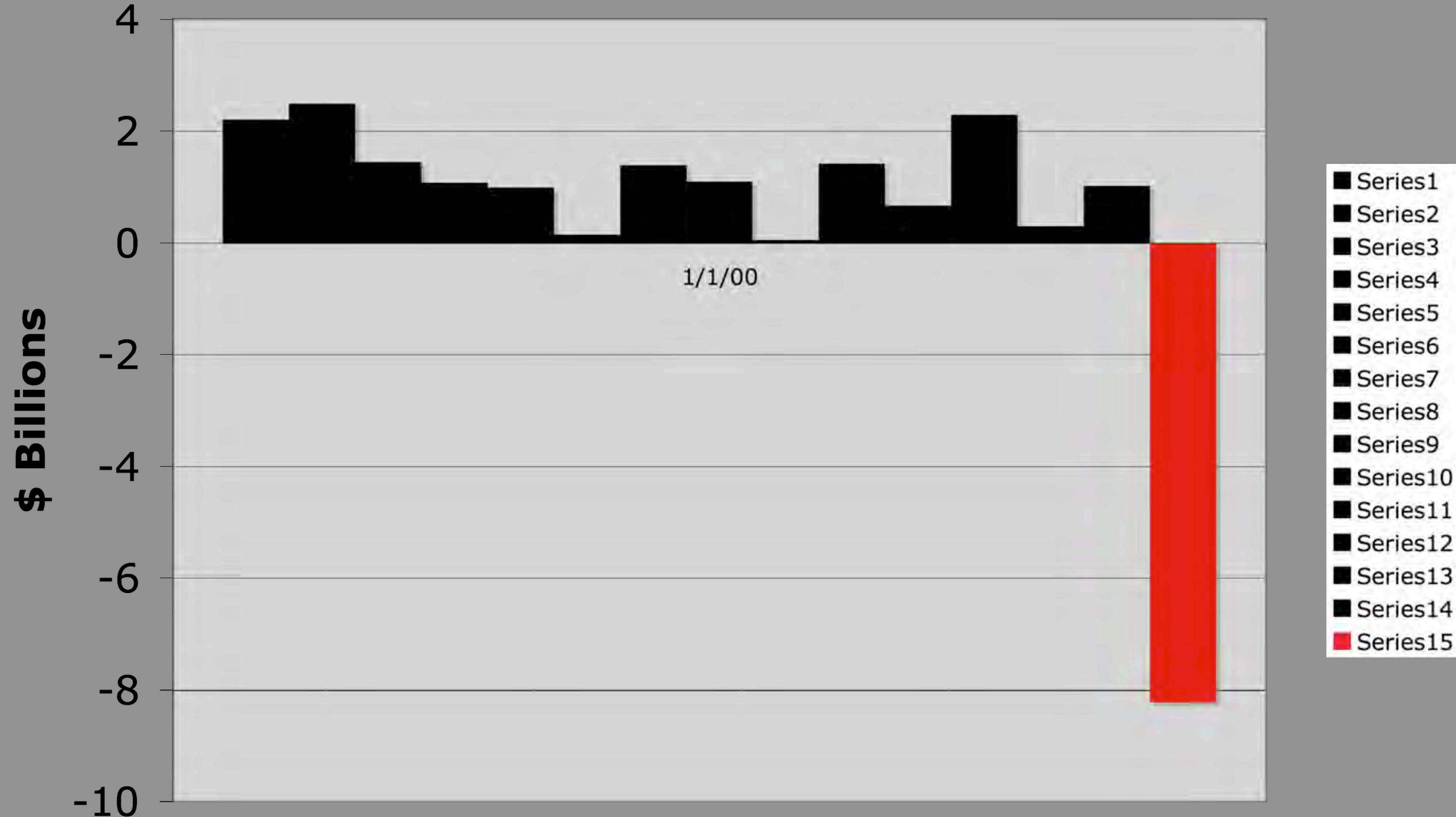
Carried Drilling Expenses



$16.7 billion in carried drilling expenses

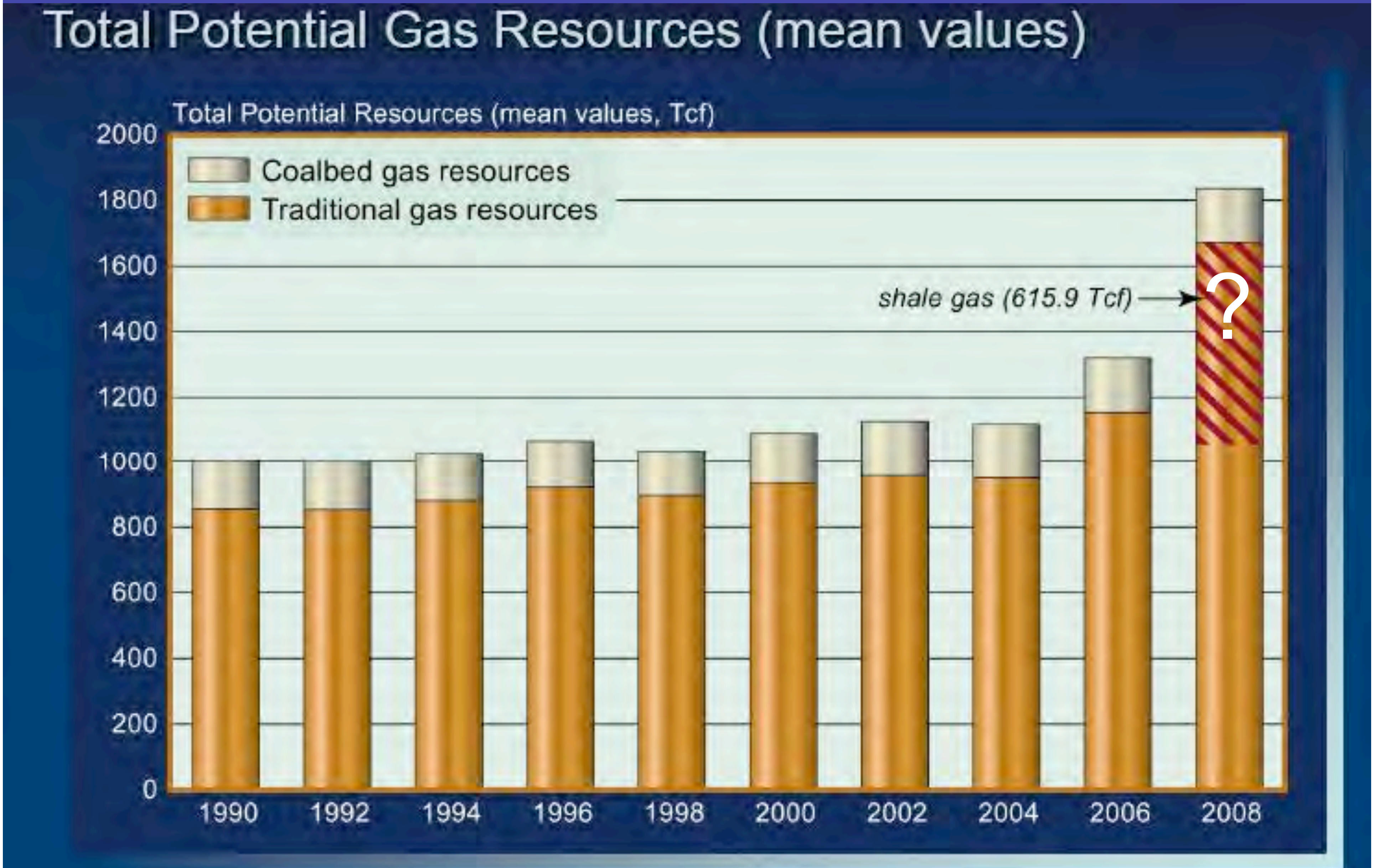

2002-2012 Henry Hub Natural Gas Price
16
14
12
10
8
6
4
2
0
$/MBTU
Series1
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Month-Year

Carried Interest and Write-Downs



$8.2 billion in write-downs since July 2012

In the near term assessments are likely to go down . . .



But how low and for how long?

Data source: Potential Gas Committee (2009)

Conclusions

- CBM was engineering precursor to shale gas
- Shale gas represents low risk exploration target
- Shale gas production due to improving well completion techniques
- Size of resource is unclear at this time, due to gas price volatility and limited well data
- Several environmental problems unsolved
- Will regulators effectively oversee operators?

Thank you