

AV The Appalachian Marcellus Shale Play – Discovery Thinking, Timing and Technology*

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*Adapted from presentation at Forum, Discovery Thinking, at AAPG Annual Convention, New Orleans, Louisiana, April 11-14, 2010

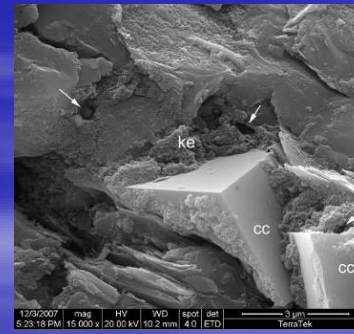
¹Range Resources, Coraopolis, PA (wzagorski@rangeresources.com)

Selected References

Harper, J.A. and C.D. Laughrey, 1987, Geology of the oil and gas fields of southwestern Pennsylvania: Pennsylvania Topographic and Geologic Survey Mineral Resource Report, v. 87, 166 p.

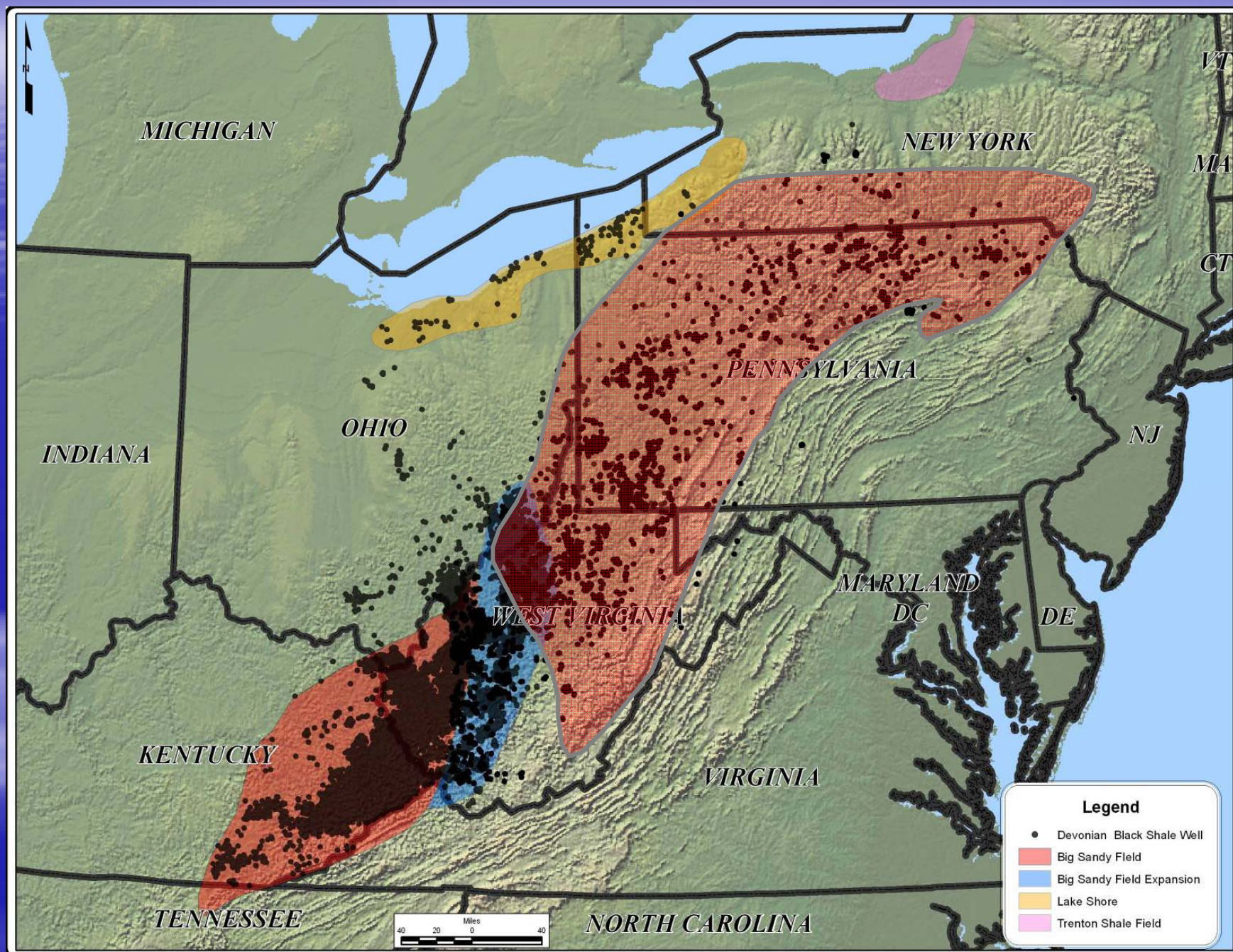
Zagorski, W.A., G.R. Wrightstone, and D.A. Bowman, in press, The Appalachian Basin Marcellus gas play – its history of development, geologic controls on production and future potential as a world class reservoir: Presented at the 2010 winter Meeting of the Independent Oil & Gas Association of West Virginia.

The Appalachian Marcellus Shale Play – Discovery Thinking, Timing and Technology



Discovery Thinking Forum – 2010 Annual AAPG Meeting – New Orleans

Appalachian Basin Shale Plays



Early SW PA Deep Tests – Key Shows

Early wells suggest overpressure and considerable lateral extent! Unsustained shows suggest lack of connected natural fracture network.

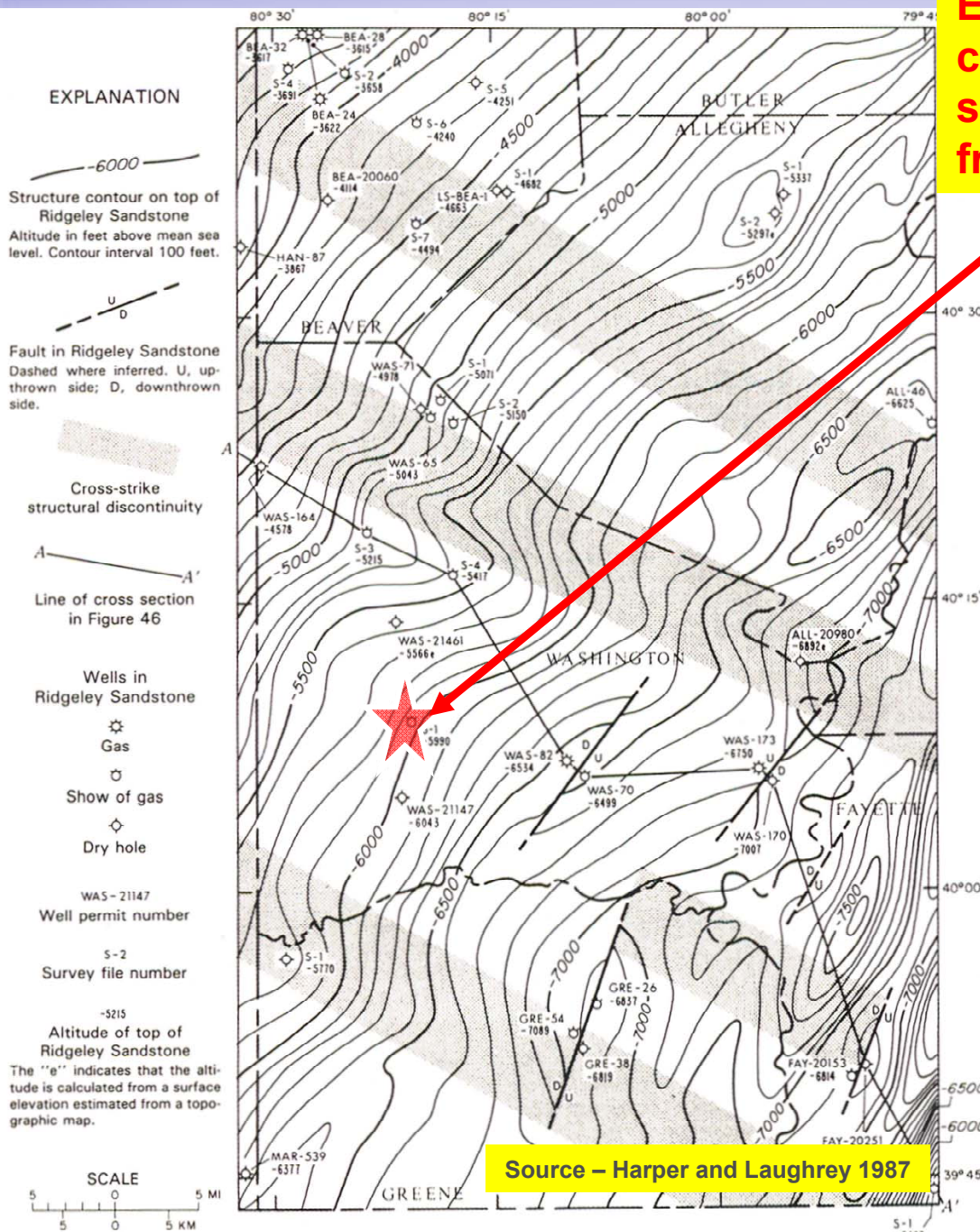
Actual well record excerpt

Gas Blow at 6,555'.

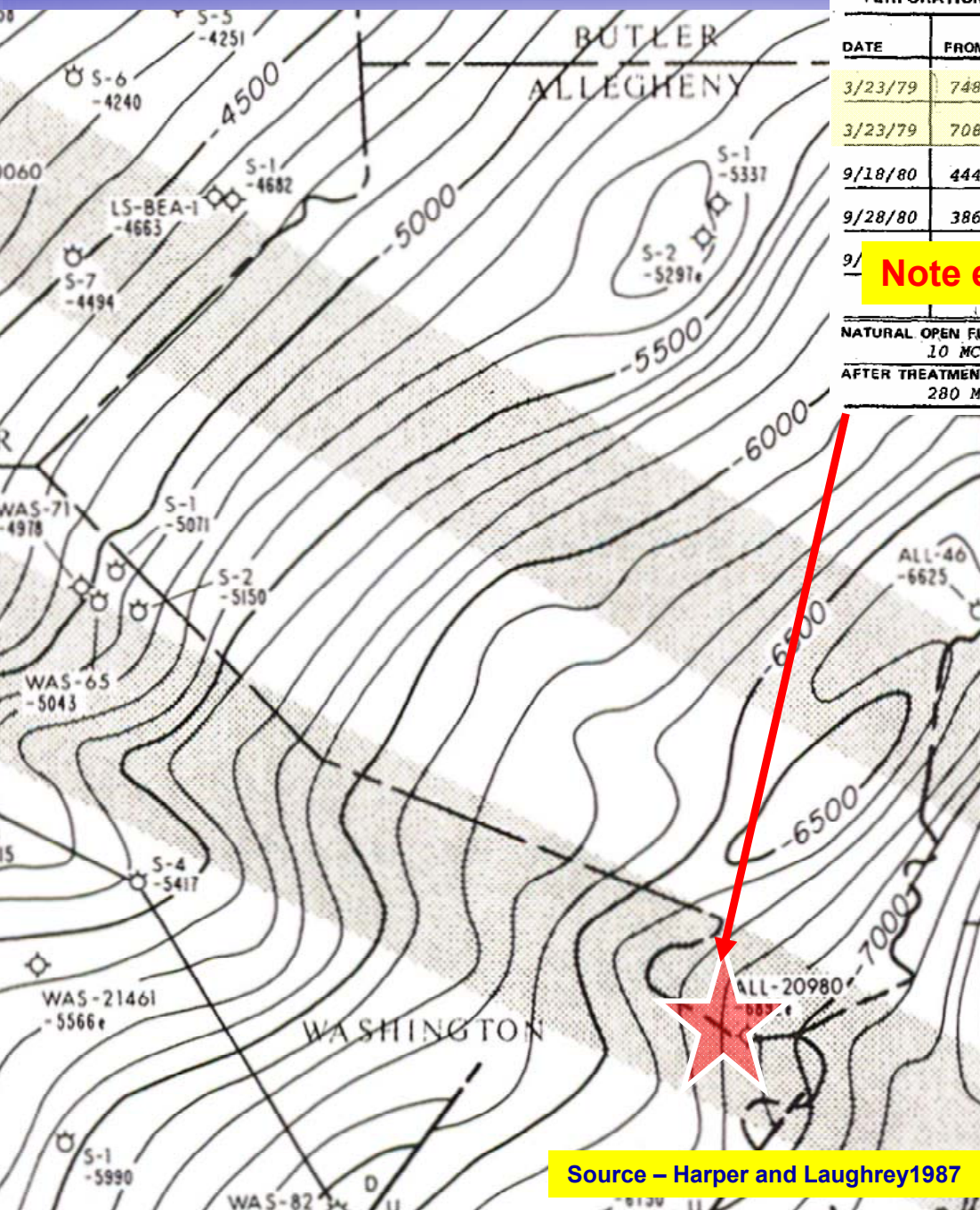
Gas Blow at 6,685', 6,737', 6,803'. While hitching on to clean out after bailing water out of hole at 6,829', a gas blowout blew tools up the hole and kinked several hundred feet of drilling line.

Run Steel Line at 7,076'. While drilling in Chert at 6,977' a gas blowout blew tools up the hole, sticking them 30' off bottom.

Water at 7,130'.

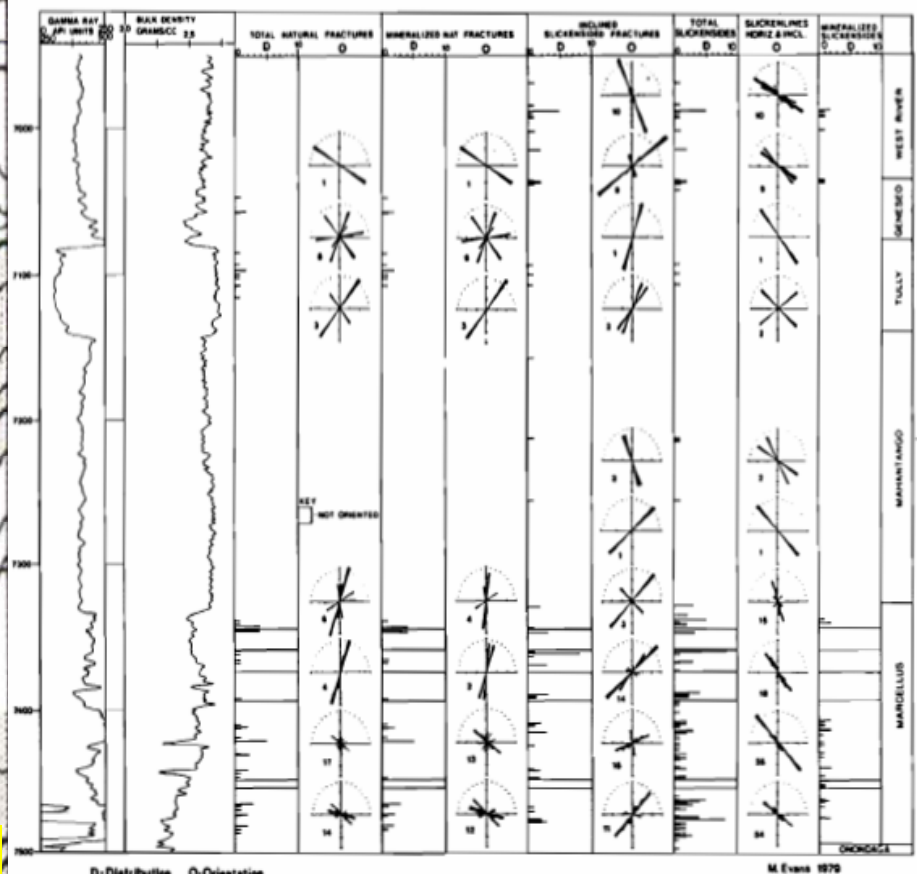


1979 Marcellus Completion – Allegheny County, PA



Source – Harper and Laughrey1987

PERFORMANCE RECORD			STIMULATION RECORD				
DATE	INTERVAL PERFORMED FROM	TO	DATE	INTERVAL TREATED	AMOUNT FLUID	AMOUNT SAND	INJECTION RATE
3/23/79	7487'	7330	5/11/79	157'	102000	1760 sks	26.9 B.P.M
3/23/79	7080'	7020	8/14/79	60'	62,500	740 sks	10 B.P.M.
9/18/80	4443'	4428	9/18/80	15'	25000	37000#	15 B.P.M.
9/28/80	3862'	3854.5	9/28/80	7.5'	26000	37500#	19.8 B.P.M
9/	Note early indication of overpressure				26000		
NATURAL OPEN FLOW 10 MCF/DAY			NATURAL ROCK PRESSURE 3120 PSI			60	DAYS
AFTER TREATMENT OPEN FLOW 280 MCF/DAY			AFTER TREATMENT ROCK PRESSURE 3250 PSI			60	DAYS



EGSP Core Study – Marcellus Shale

Note Statewide expanse of wells reporting Marcellus shows

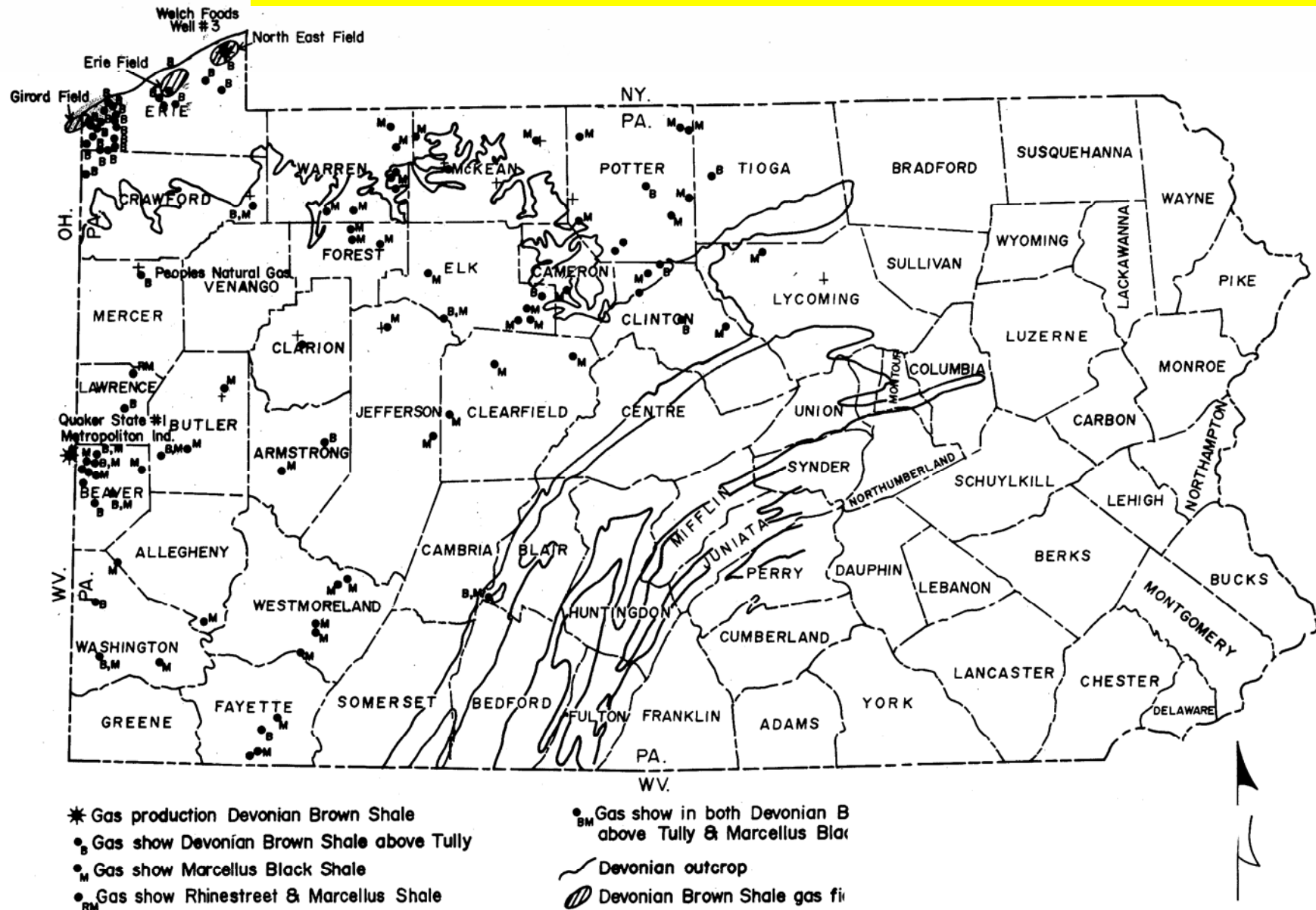


Figure 32. Gas production and show map for Devonian organic-rich
Piotrowski and Harper (1980).

Source – Piotrowski and Harper 1980

Source - Harper and Laughrey 1987

Unsuccessful N2 frac

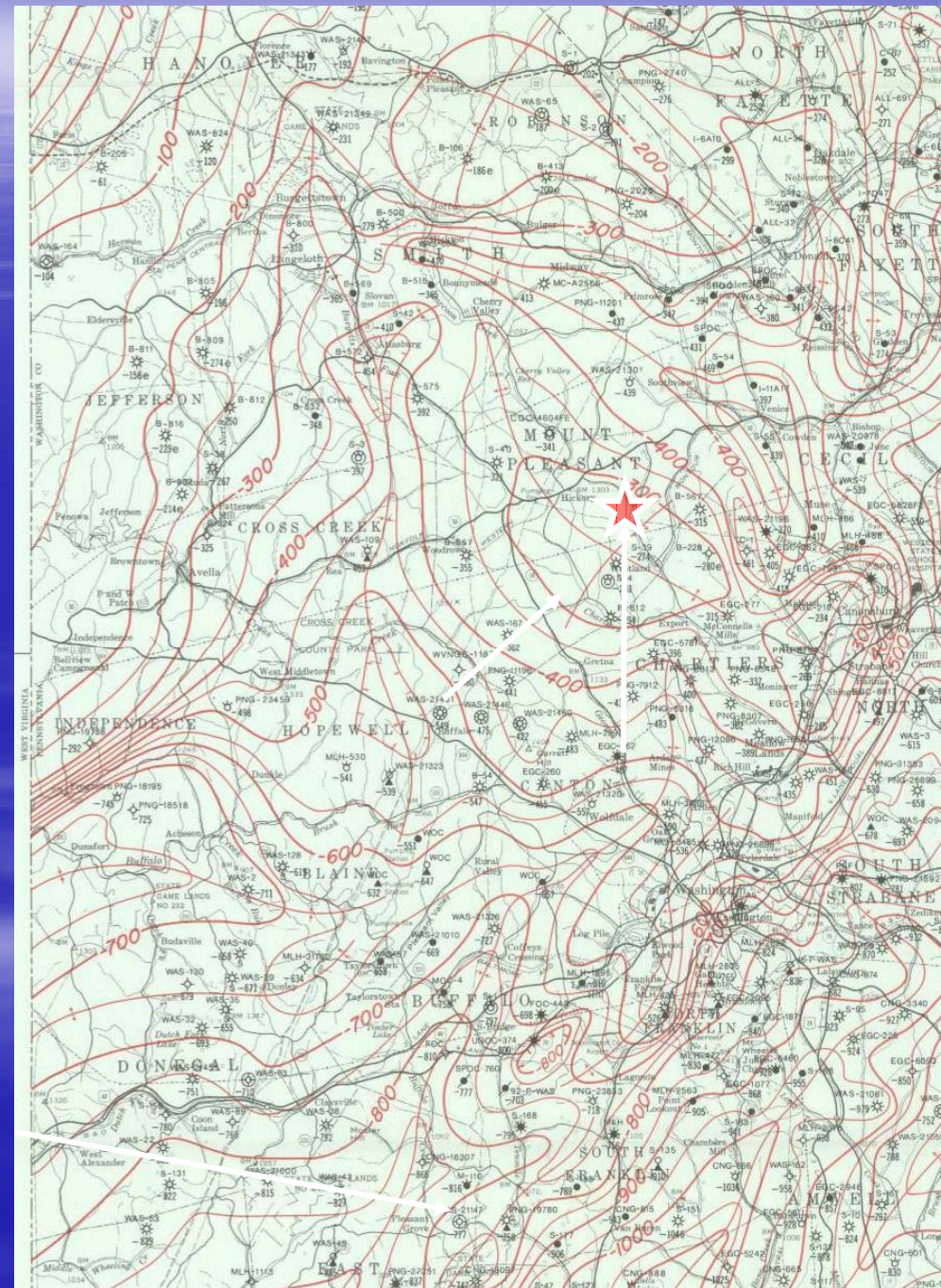
[illegible]

INTERVAL PERFORATED			STIMULATION RECORD				
DATE	FROM	TO	DATE	INTERVAL TREATED	AMOUNT FLUID	AMOUNT SAND	INJECTION RATE
6/2/83	6588	6687 (20 shots)	35% CO 2 Water 6/2/83	Marcellus Shale	50,400 gal.	40,000#	20 BPM
6/2/83	6056	6428 (30 shots)	Same	Devonian Shale	50,400 gal	40,000#	20 BPM
NATURAL OPEN FLOW 5 MCF			NATURAL ROCK PRESSURE 100#				HRS. DAYS
AFTER TREATMENT OPEN FLOW 70 MCF			AFTER TREATMENT ROCK PRESSURE 1000#				HRS. DAYS
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

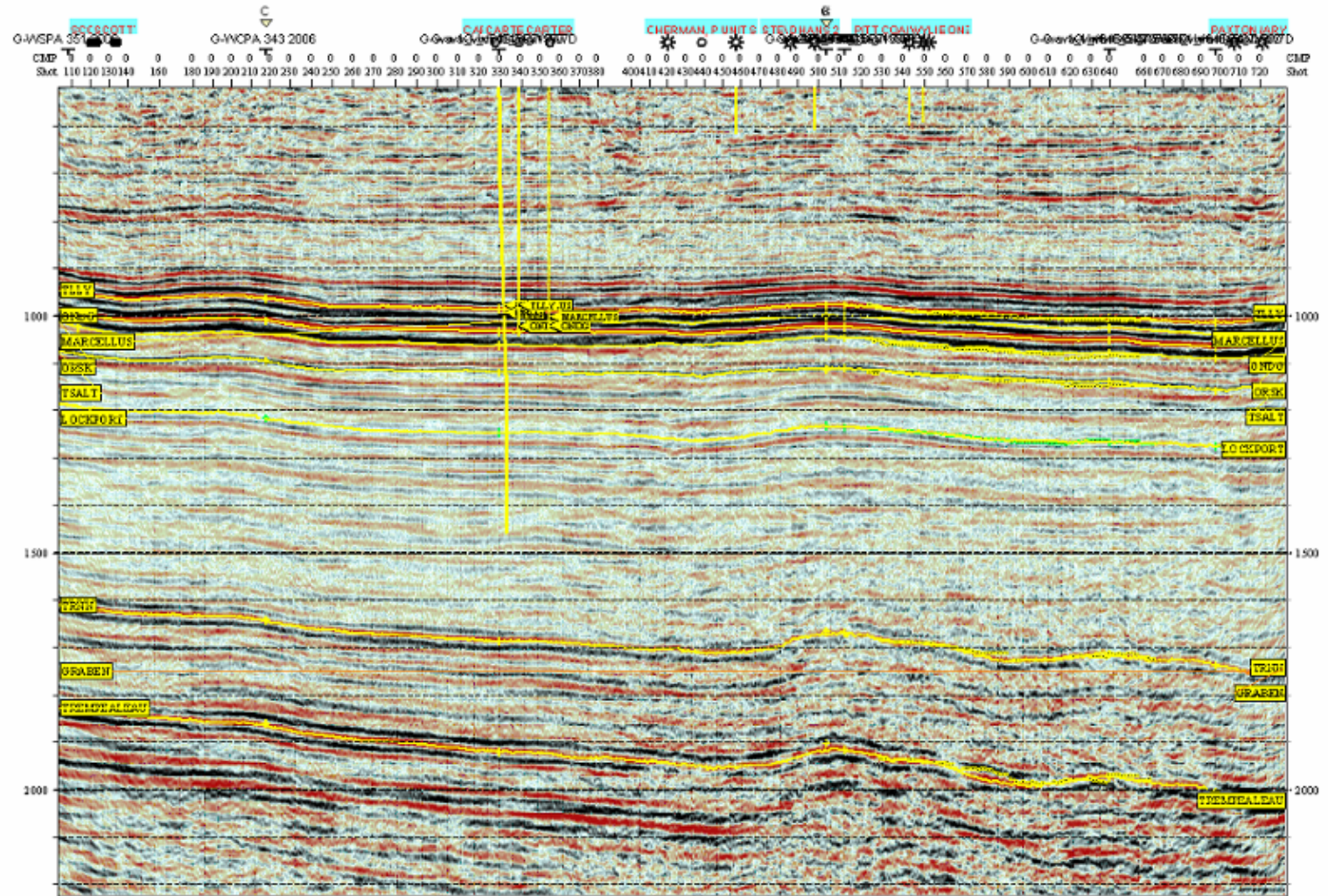
Source – Harper and Laughrey 1987

2004 - Modern Marcellus Discovery – Renz Unit #1



2004 - Modern Marcellus Discovery – Renz Unit #1

IT - GLEP-walmig-



II' - GLEP-walmig-

G-WSPA 351 G-WSPA 3

CMP Shot 110 120 130 140 150 160 180 190 200 210 220

1000 1500

PLLY

PLLY

MARCOLLUS

DESK

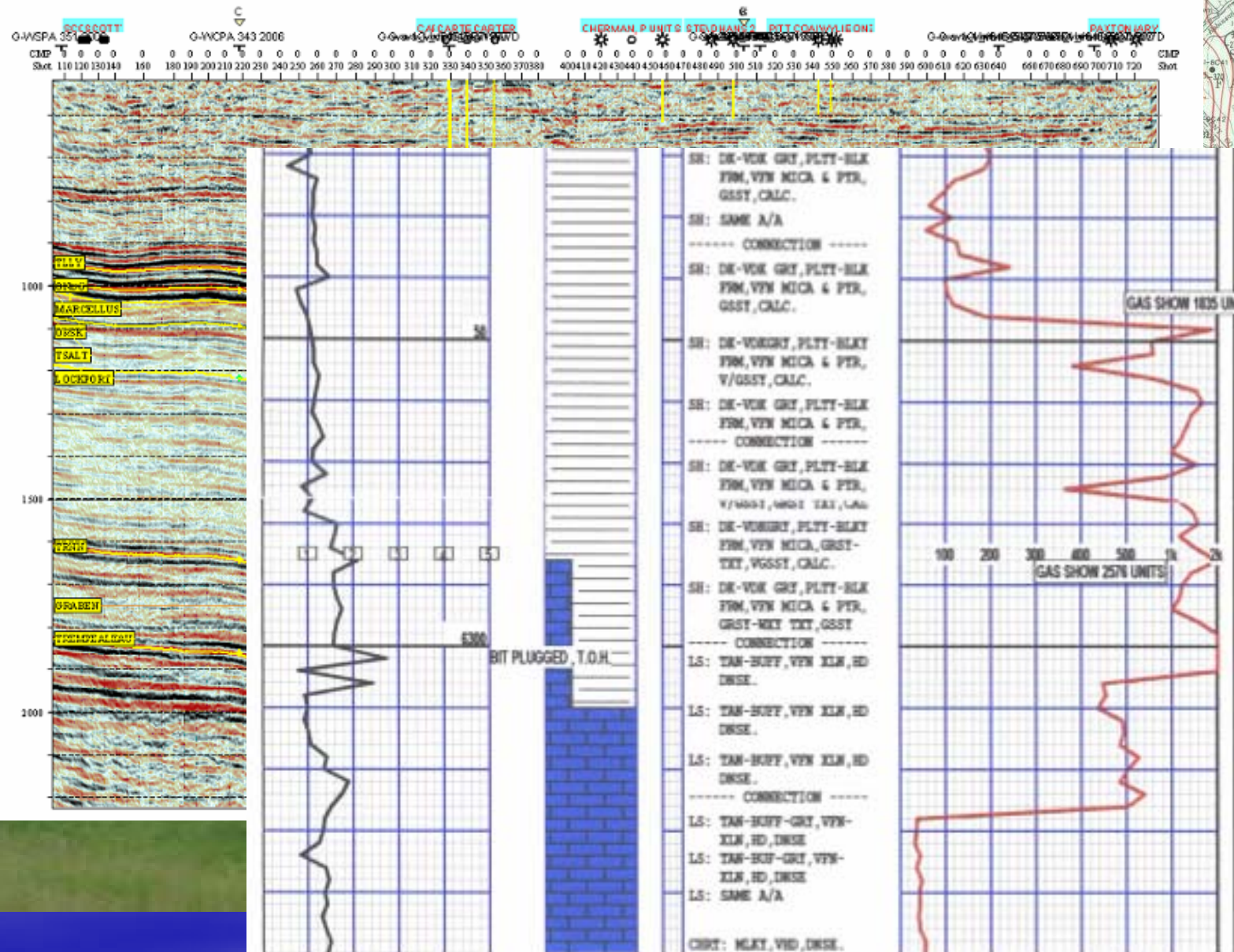
TSALT

LOCHFOKI

FEATH

GRABEN

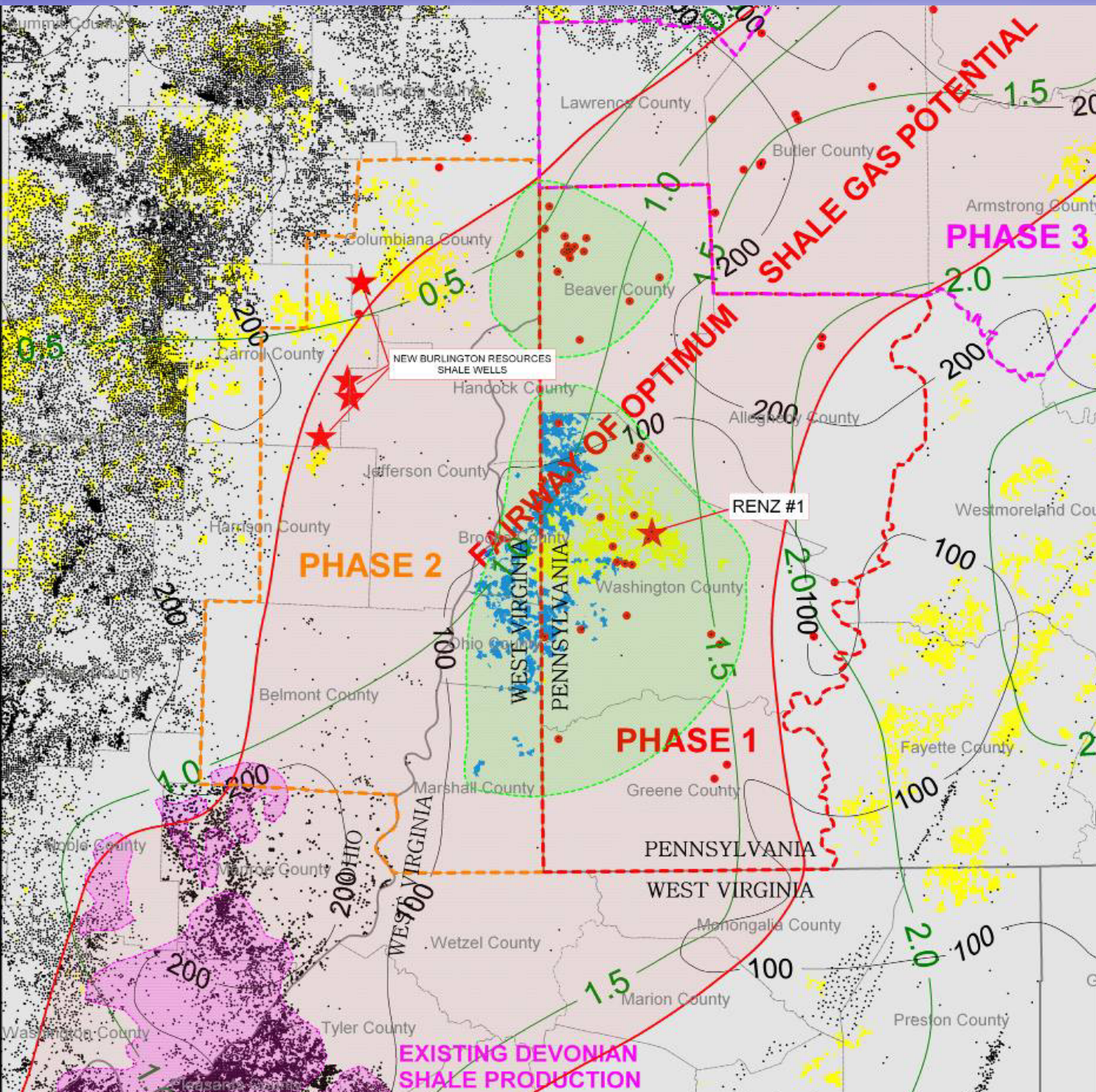
TICLOTALBAU



2004 - Modern Marcellus Discovery – Renz Unit #1

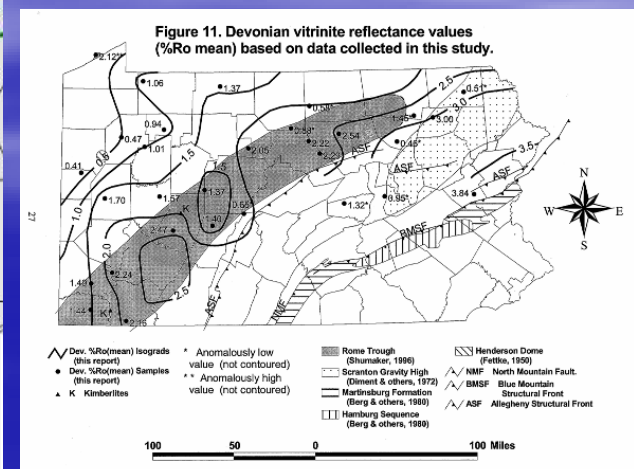
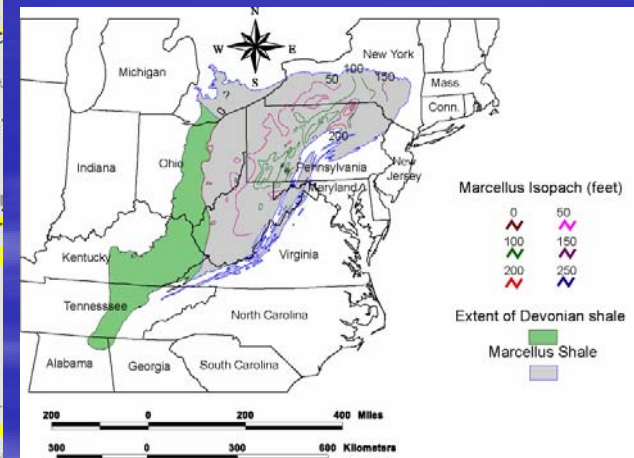


2005 – Prospecting for the Marcellus

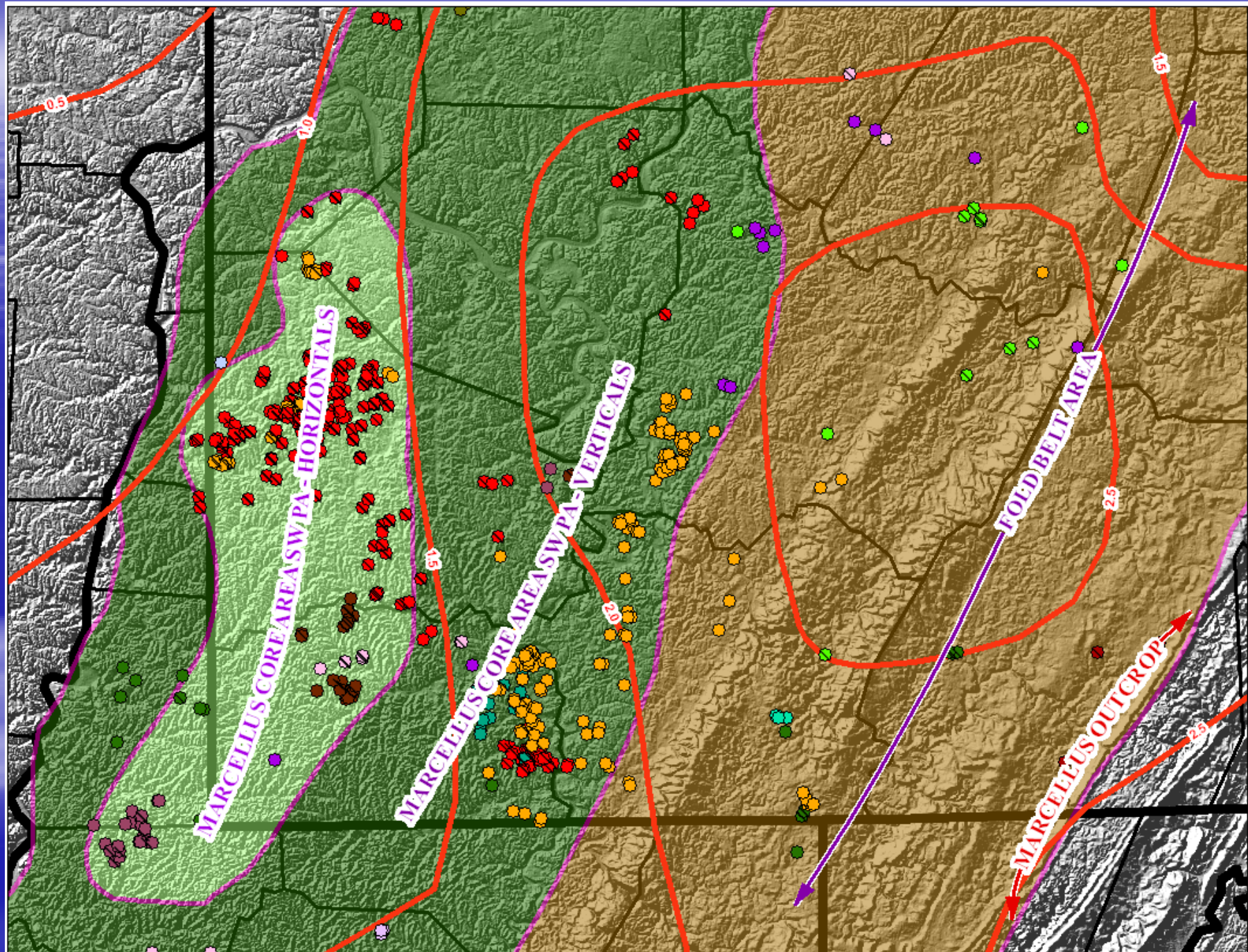


Gas Blow at 6,555'.

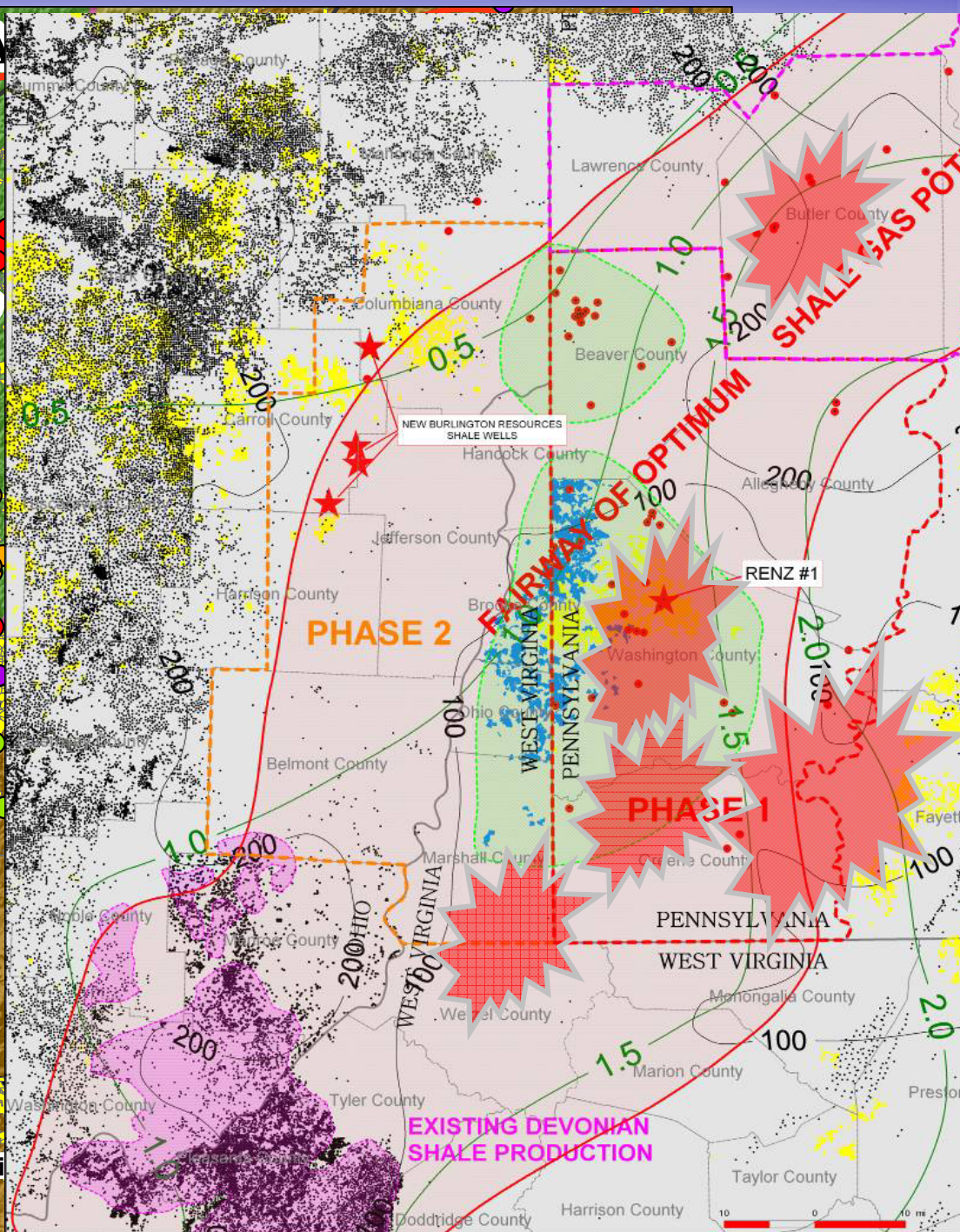
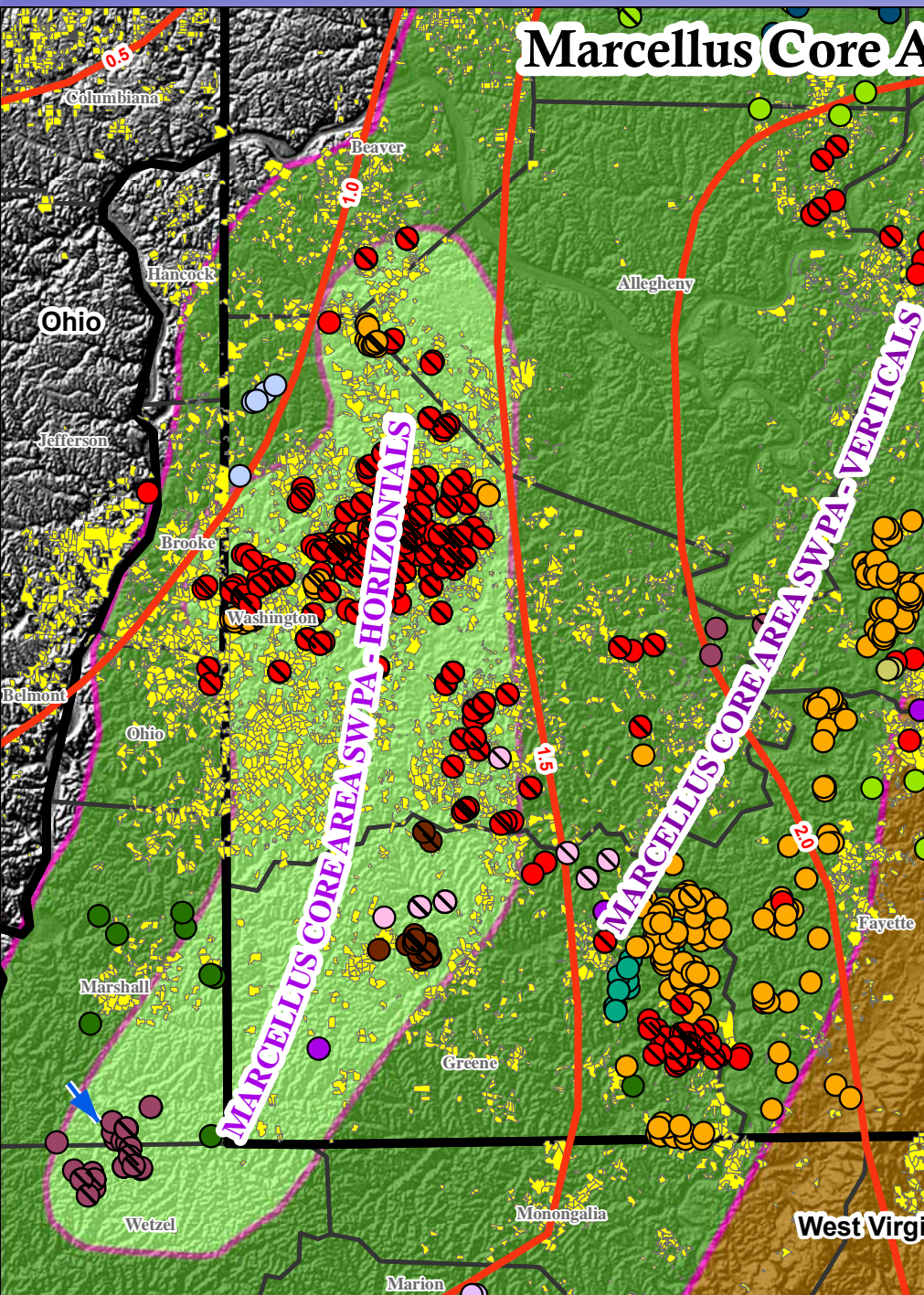
Gas Blow at 6,683', 6,737', 6,803'. While hitching on to clean out after bailing water out of hole at 6,829', a gas blowout blew tools up the hole and kinked several hundred feet of drilling line. Run Steel Line at 7,076'. While drilling in Chert at 6,977' a gas blowout blew tools up the hole, sticking them 30' off bottom. Water at 7,130'.



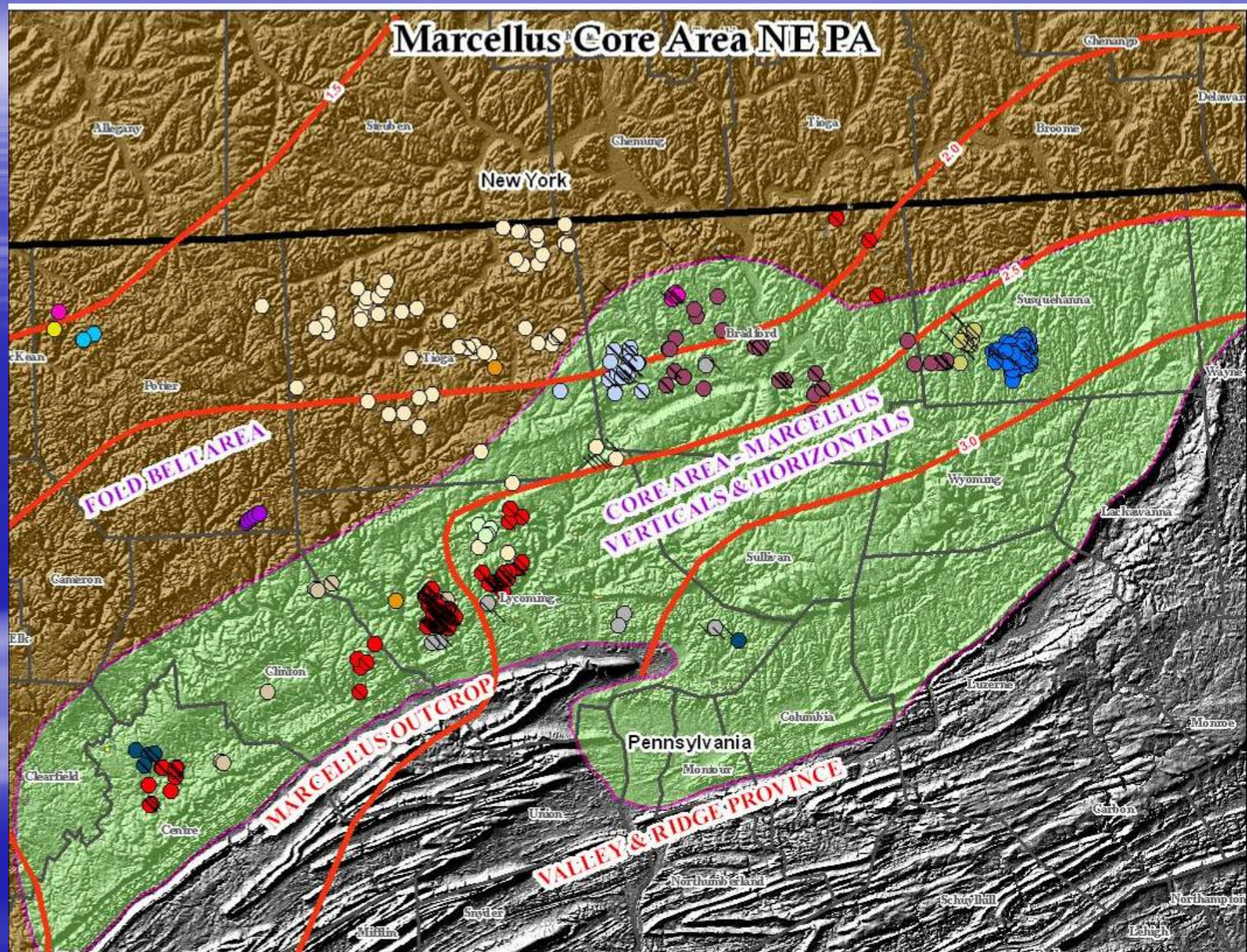
PA Marcellus Play – SW PA Core Area



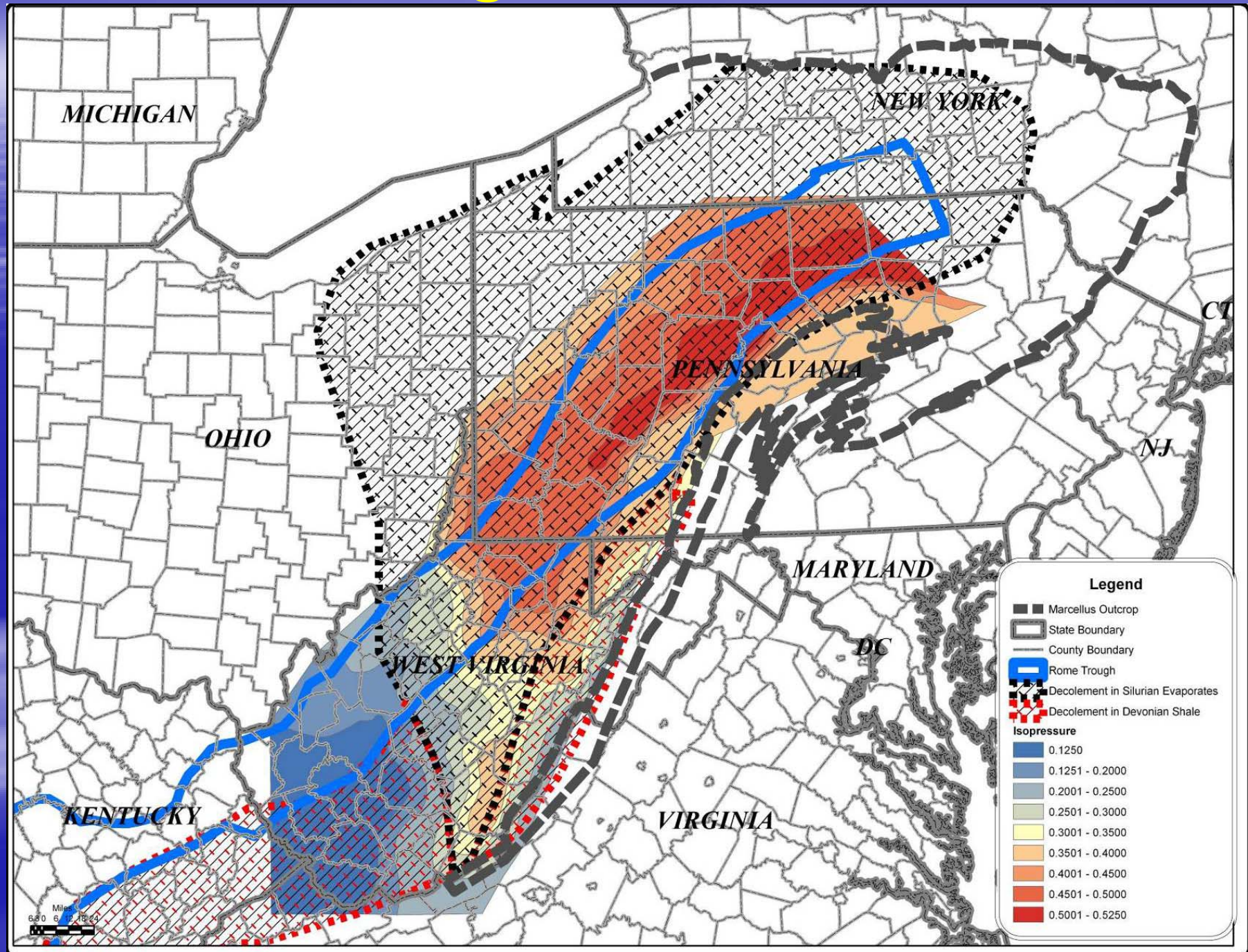
How close was our guess?



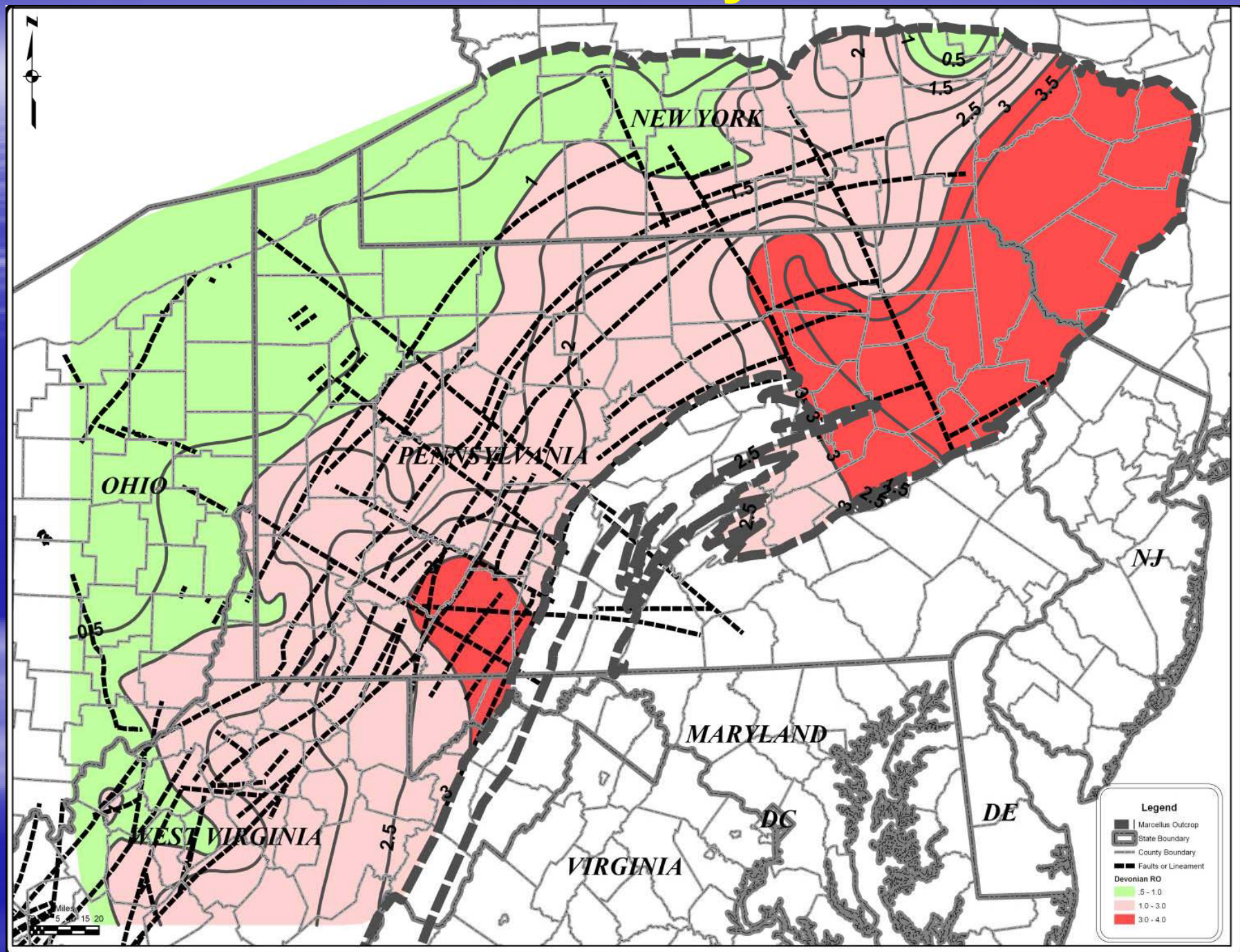
PA Marcellus Play – NE PA Core Area



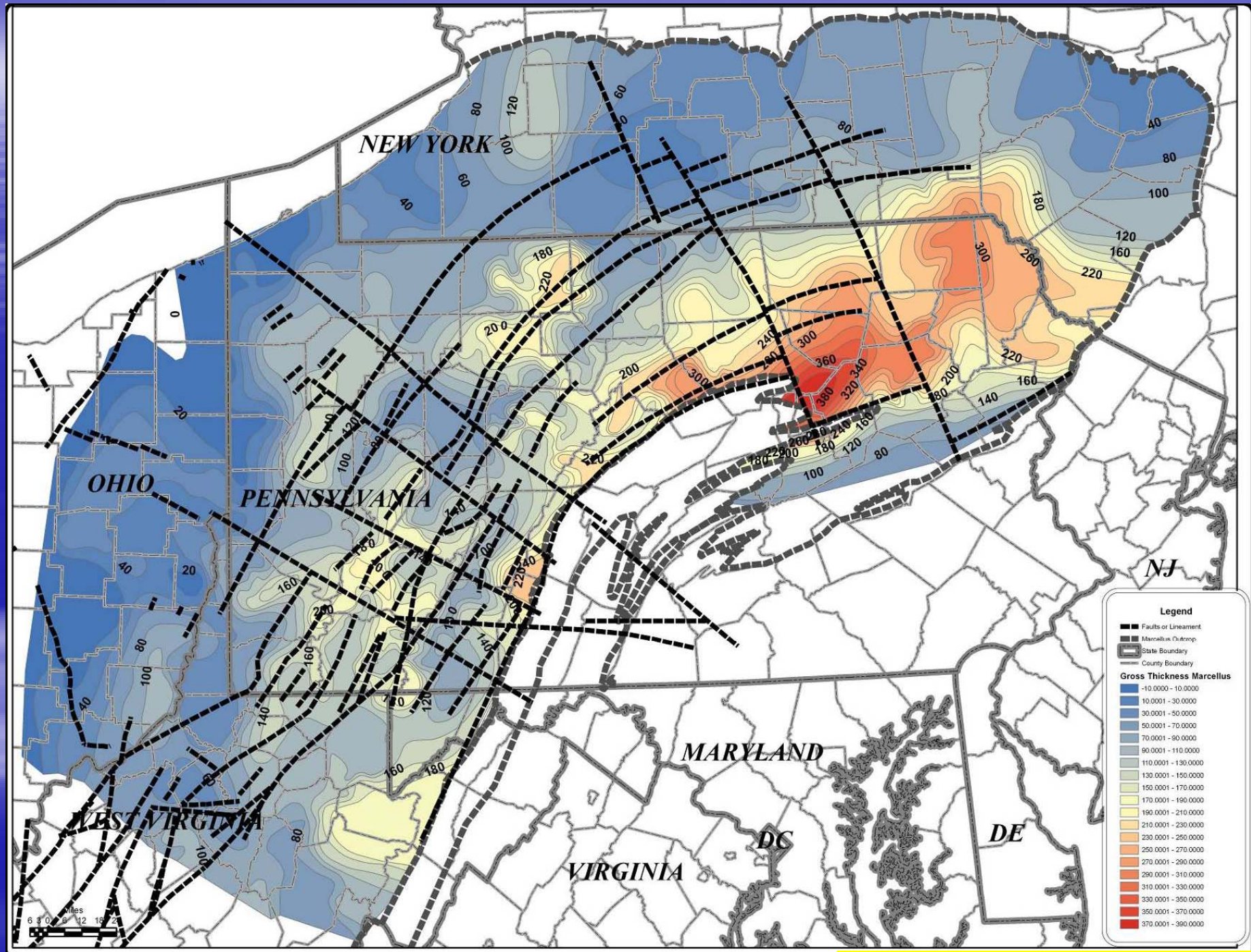
Marcellus Regional Pressure Trends



Thermal Maturity Trends

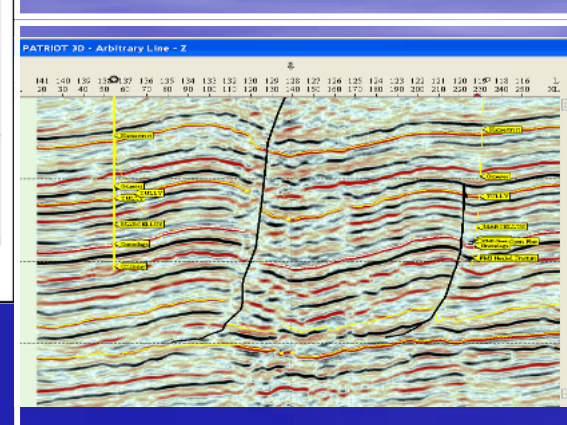
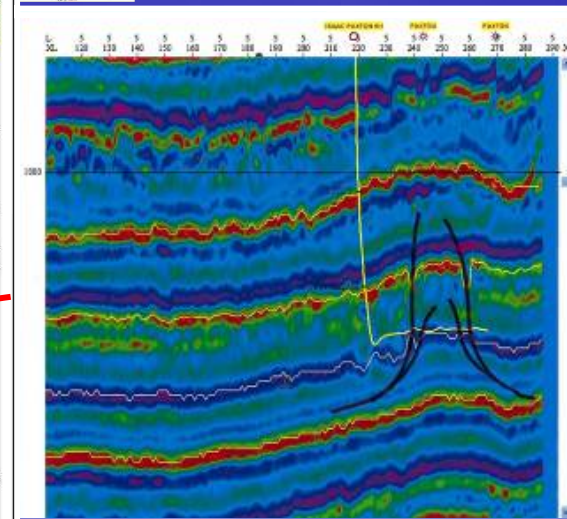
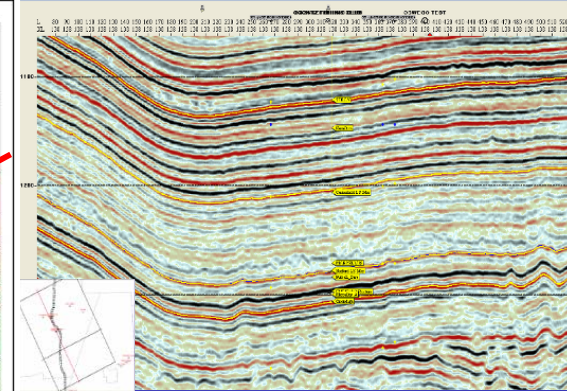
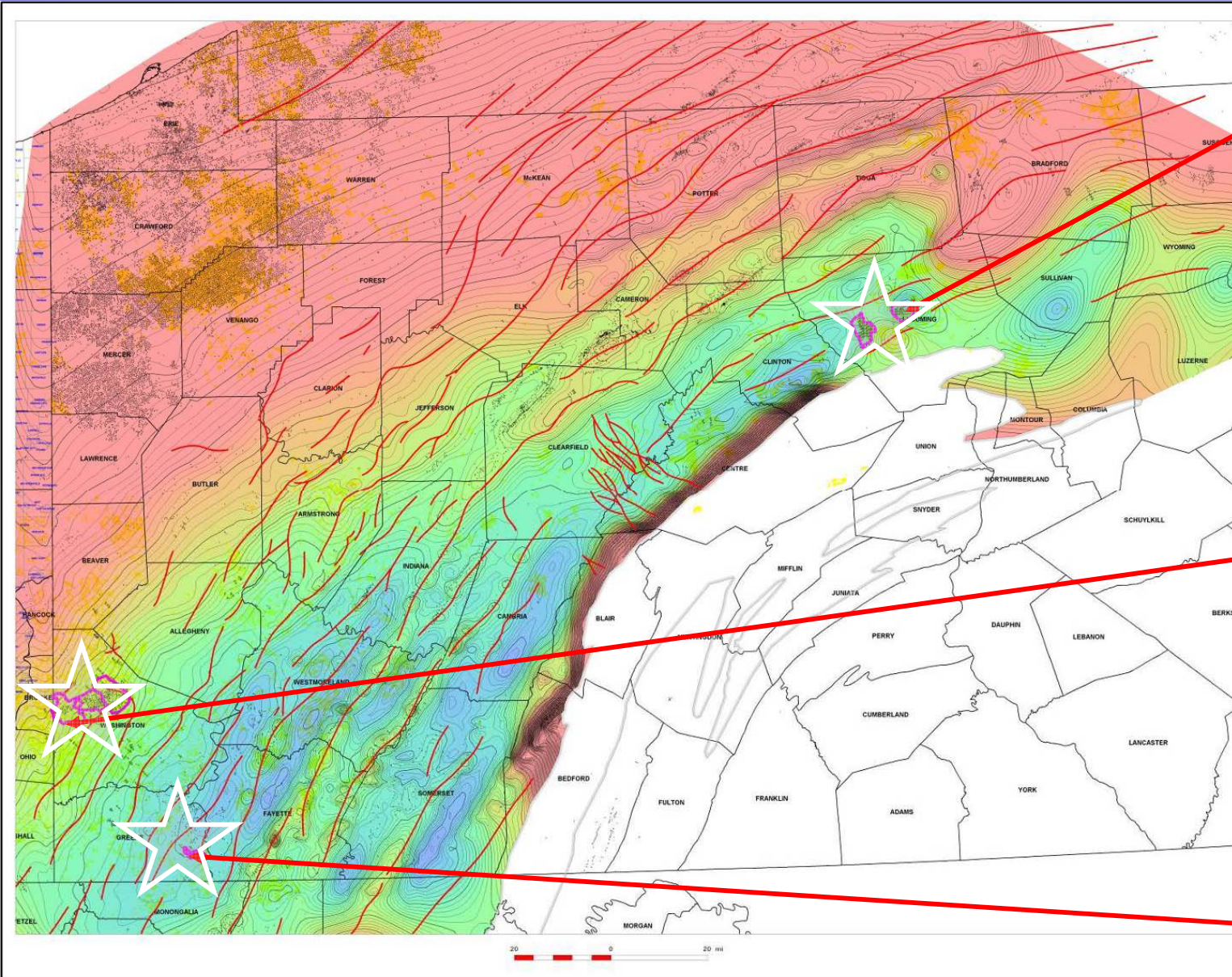


Gross Thickness / Basement Structure

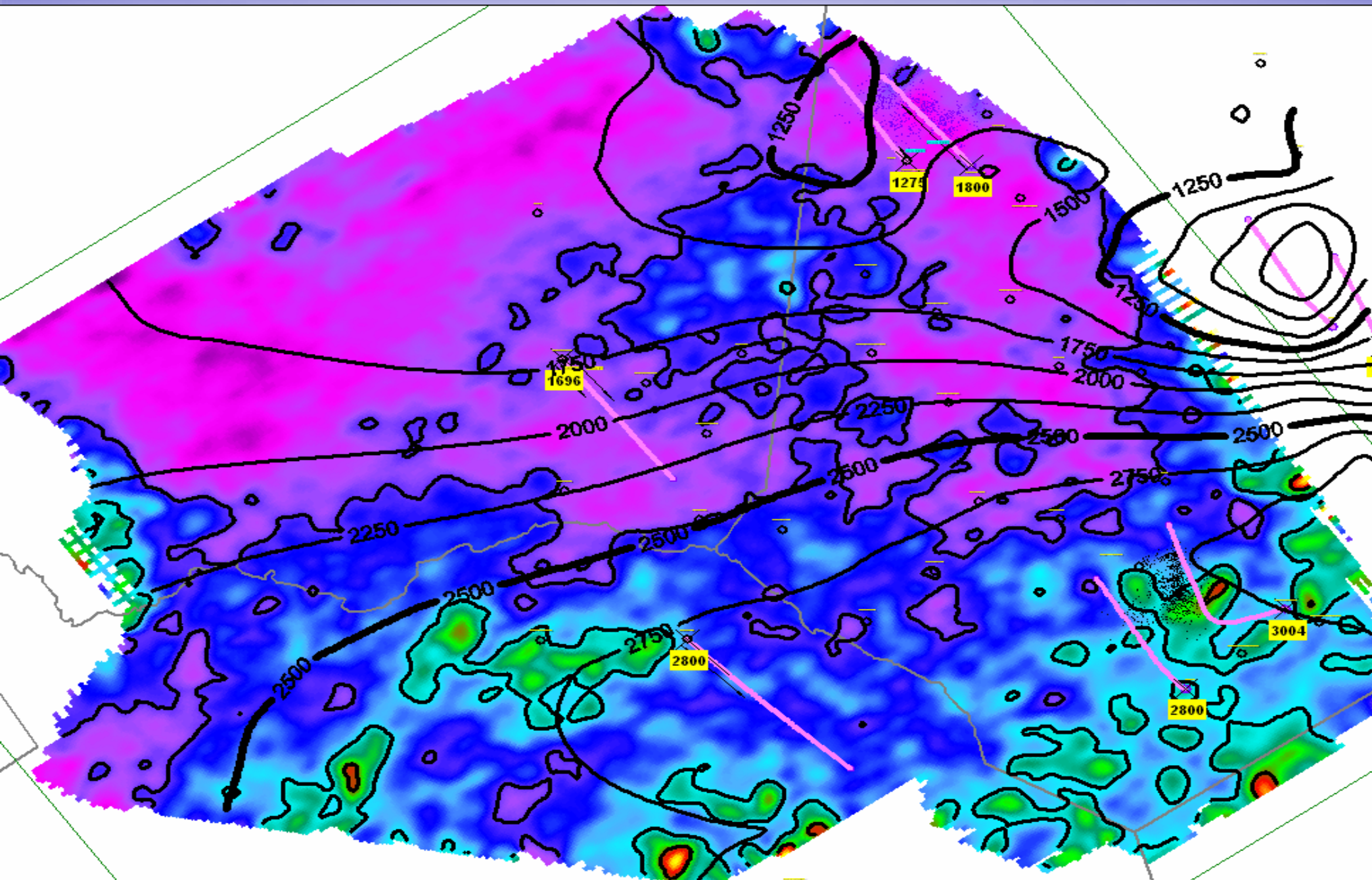


Source – Zagorski, Bowman and Wrightstone – In Press

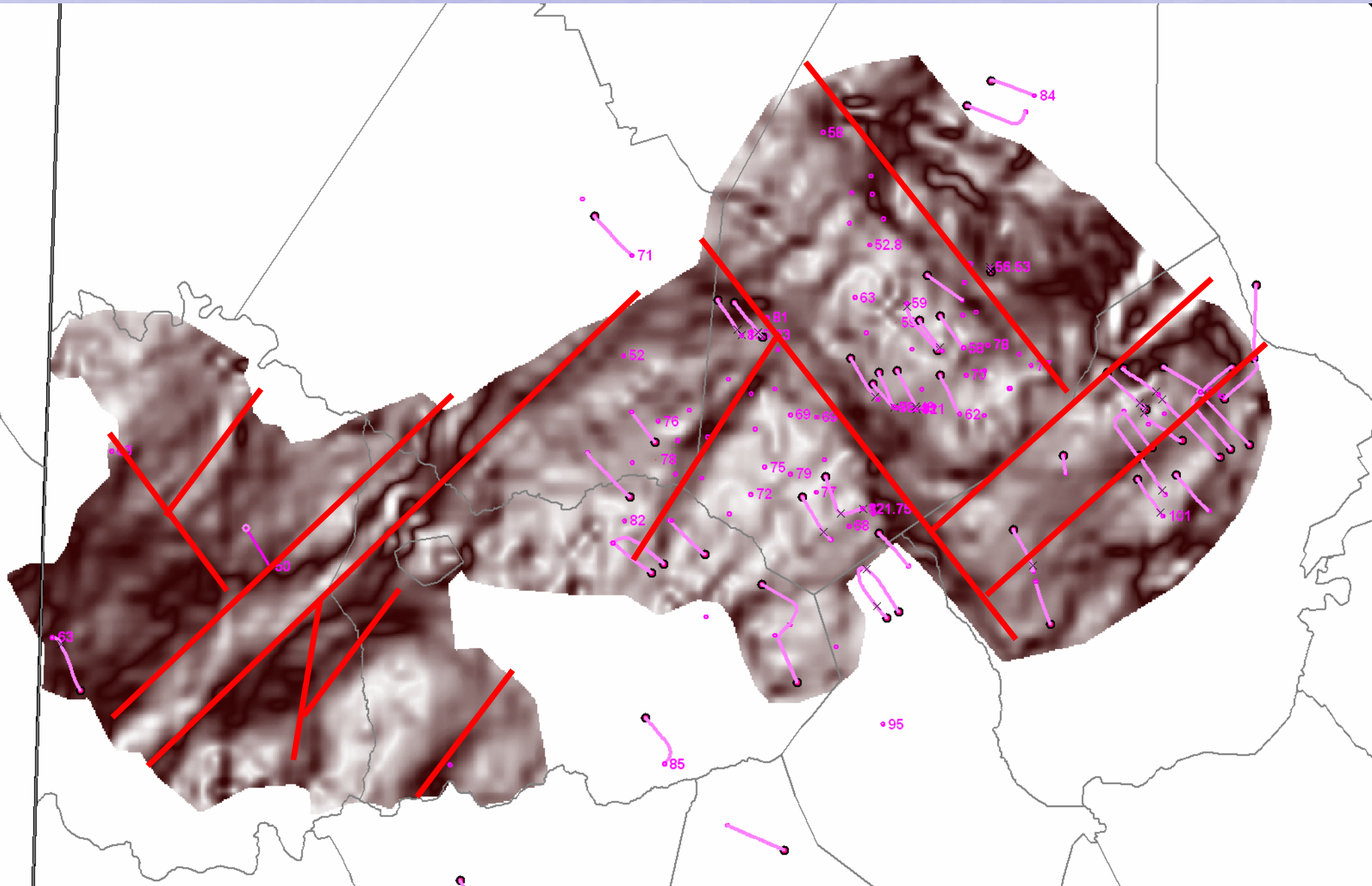
Marcellus Shale Structural Styles



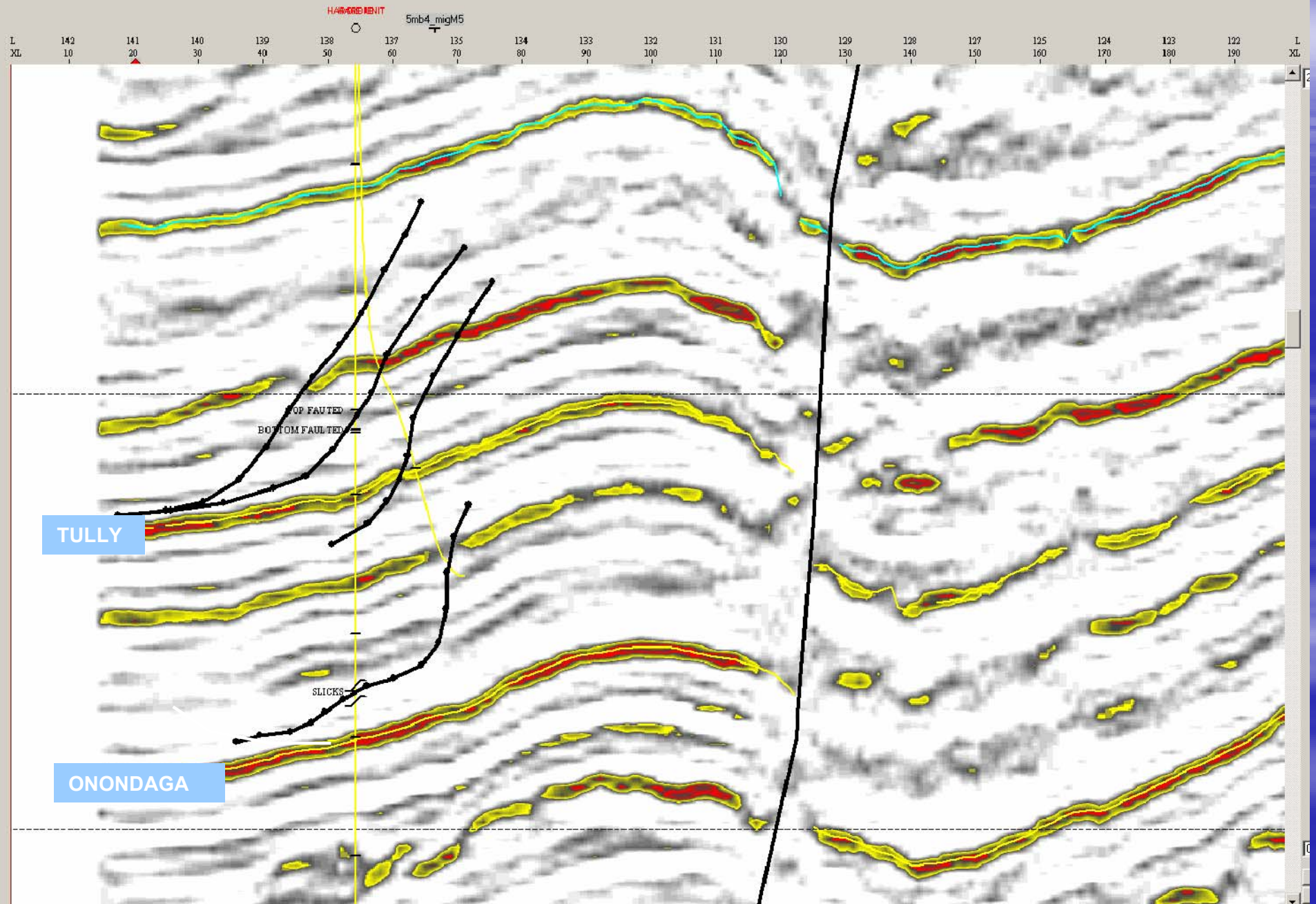
3-D Seismic SW PA- Marcellus Thickness



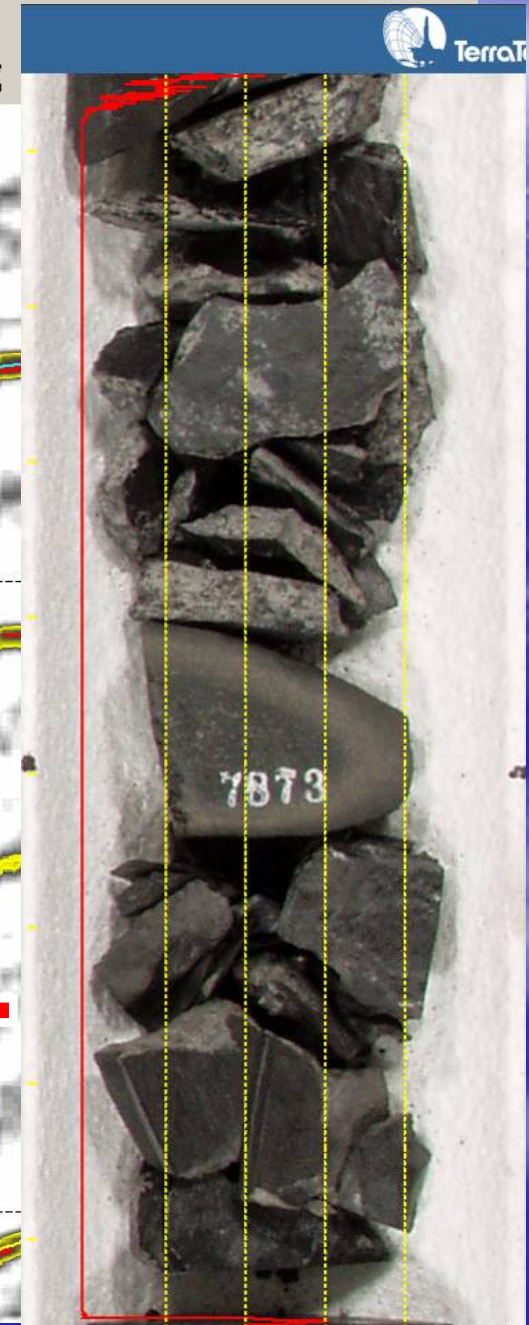
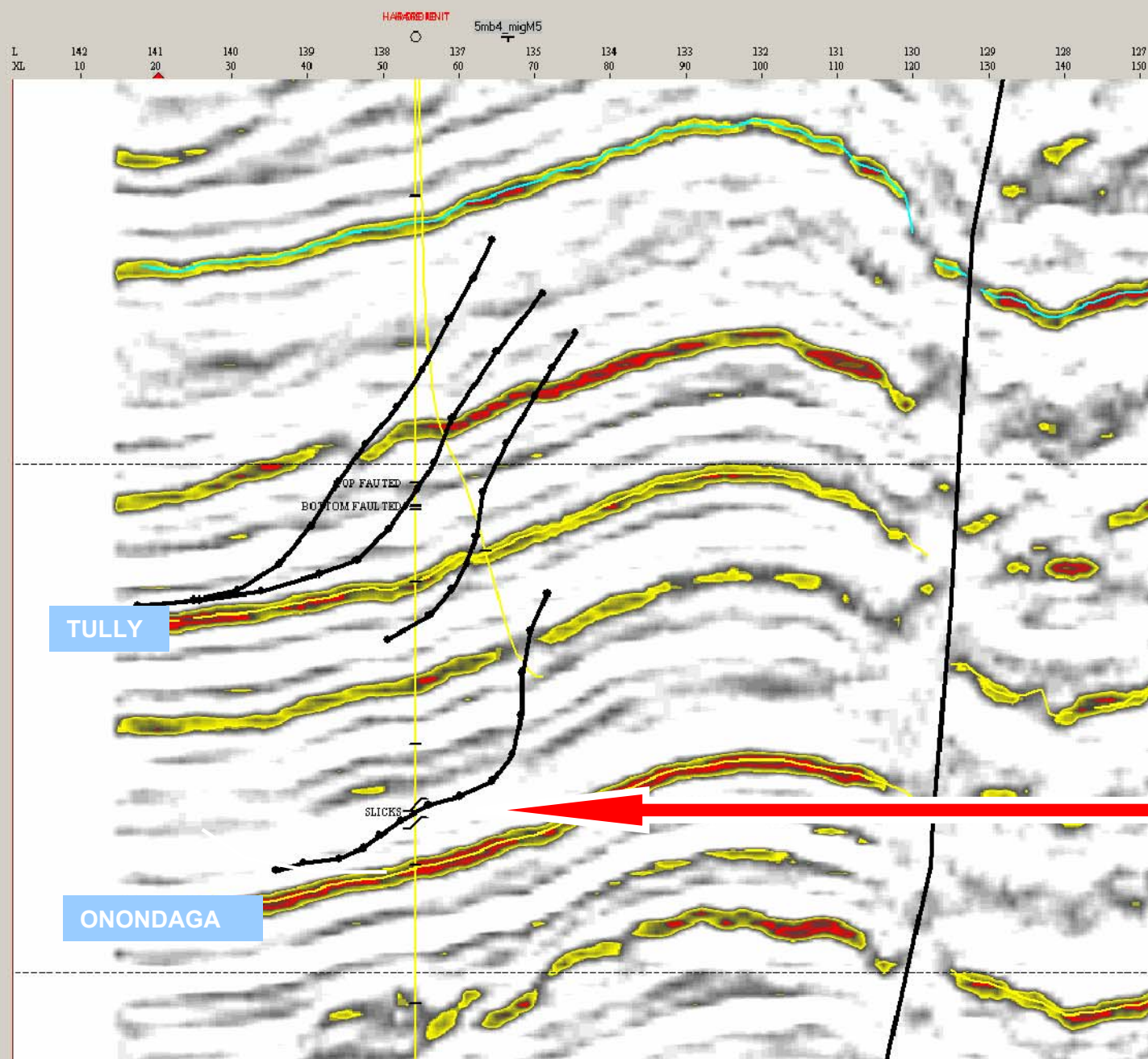
SW PA 3D Seismic Programs – Curvature & Fault Trends



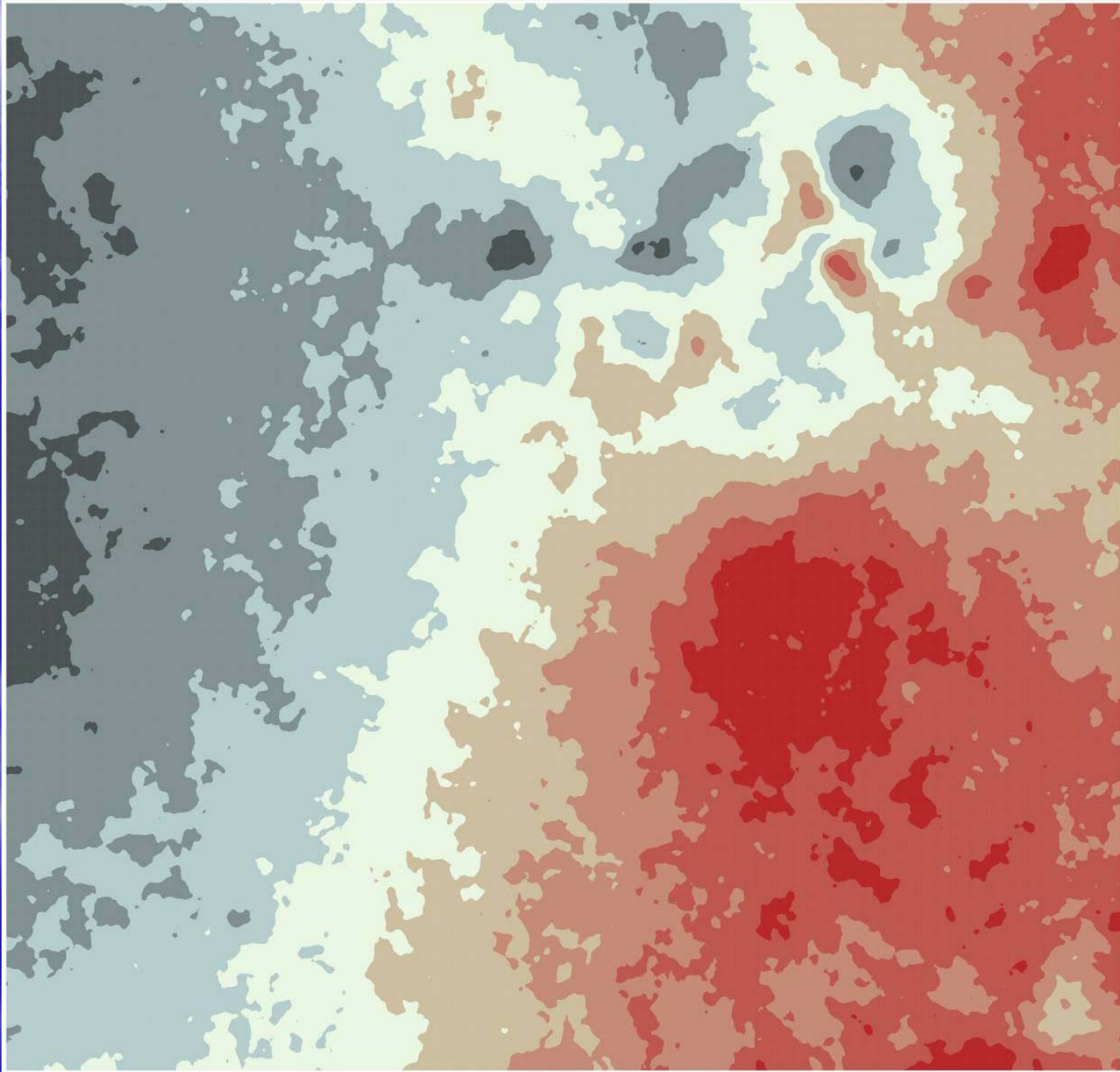
Fracturing/Faulting – A matter of scale!



Fracturing/Faulting – A matter of scale!



Gas In Place Studies – SW PA



Marcellus GIP, Porosity and Permeability

GIP – 85 BCF/mi²

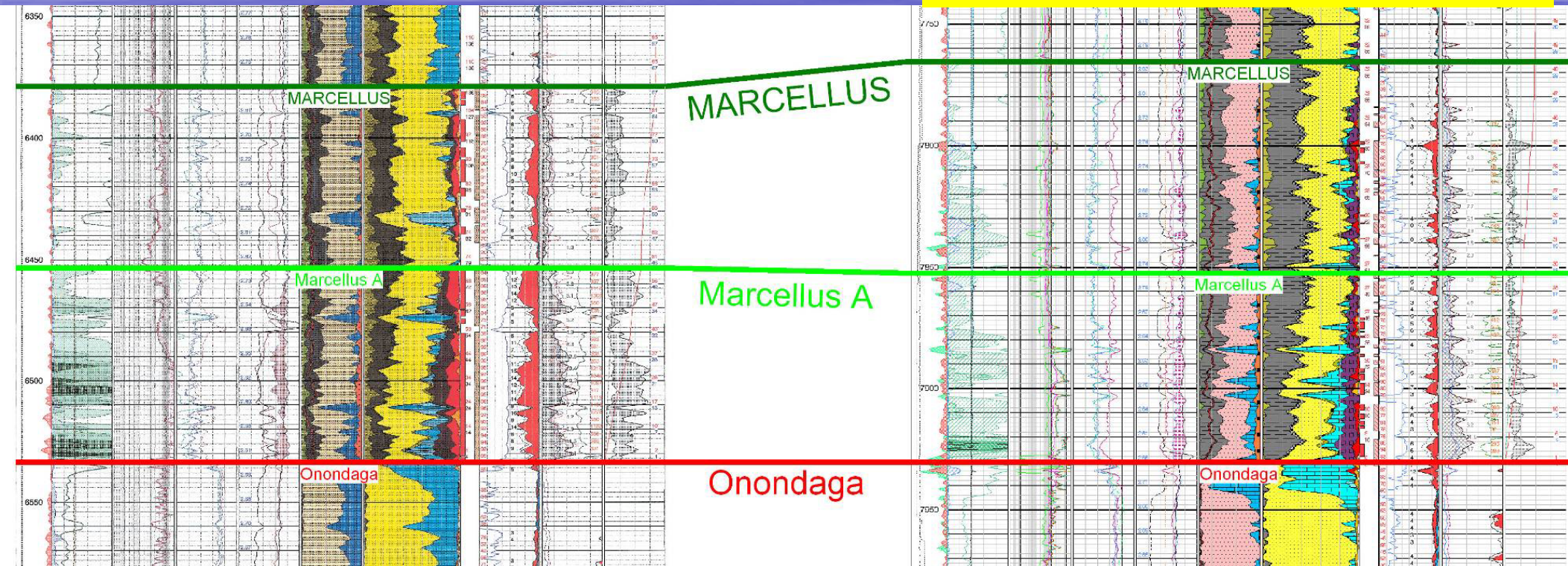
AVG PERM – 598 Nd

AVG EFFECTIVE POROSITY – 8.2%

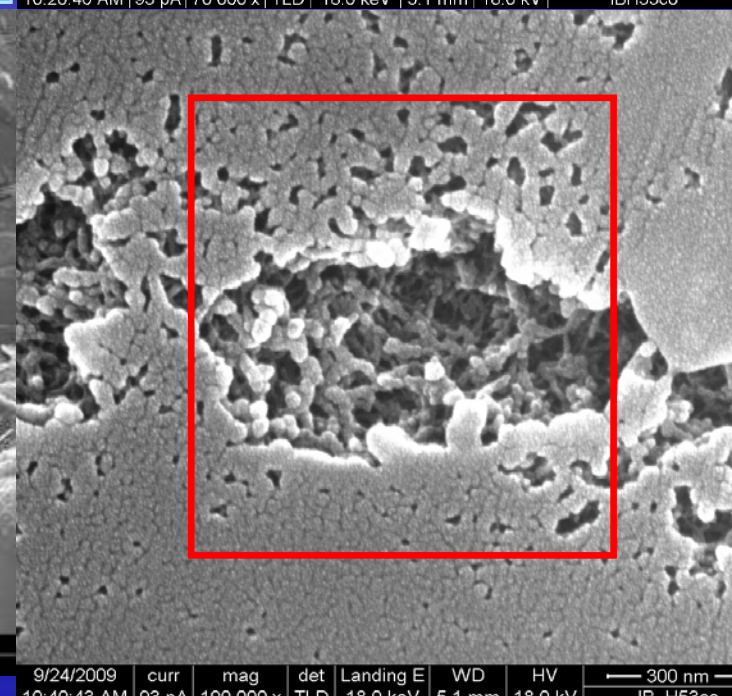
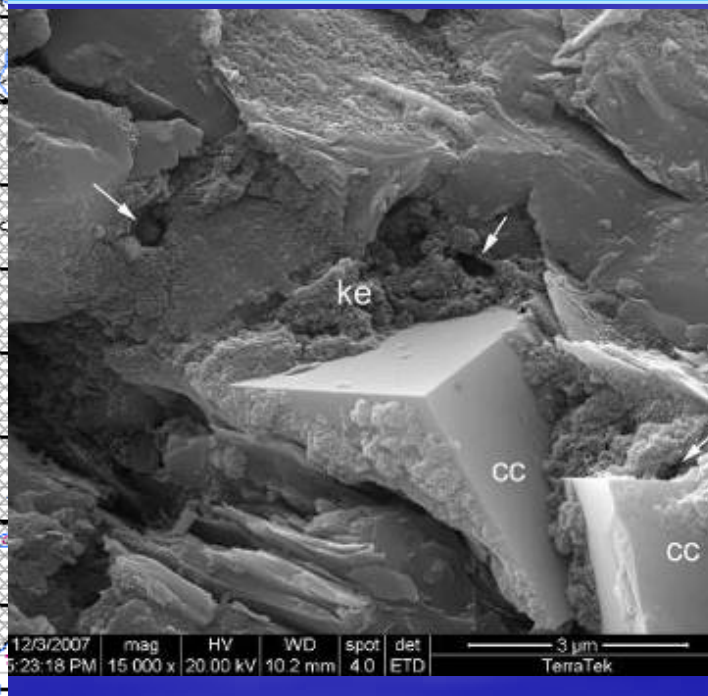
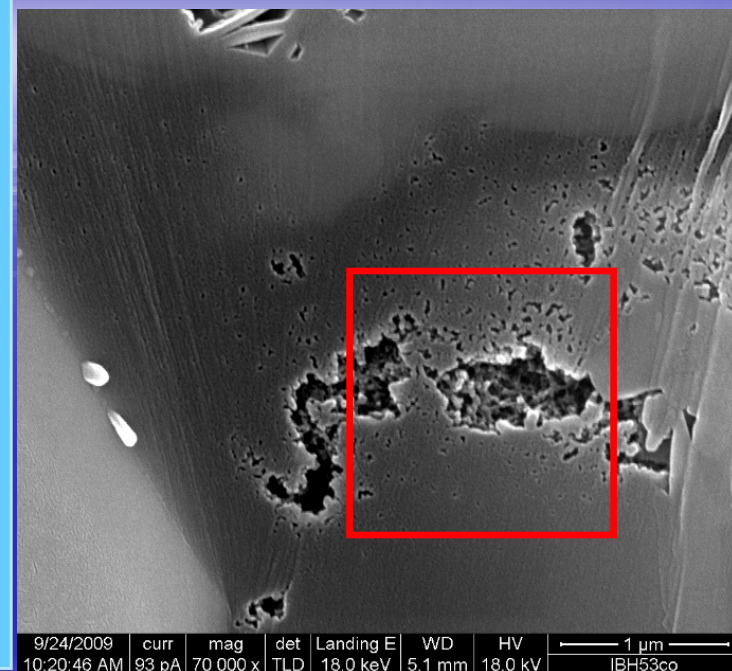
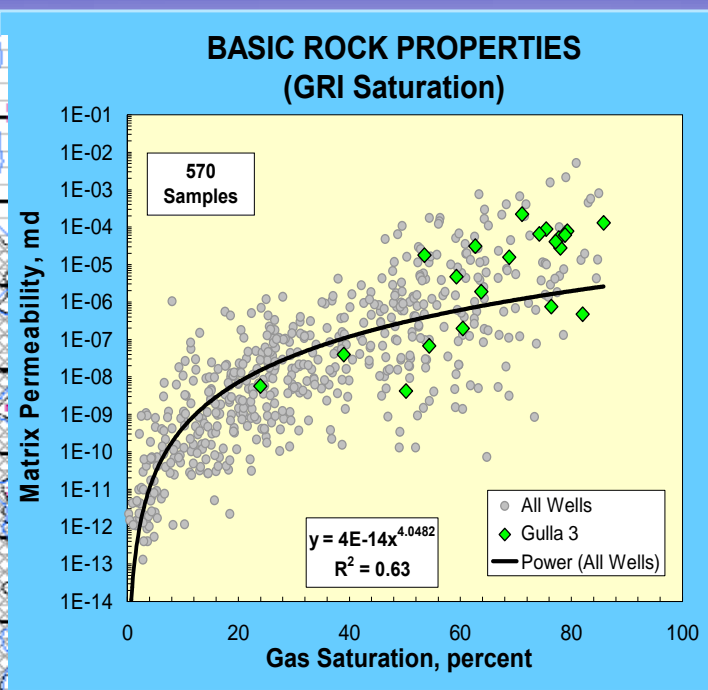
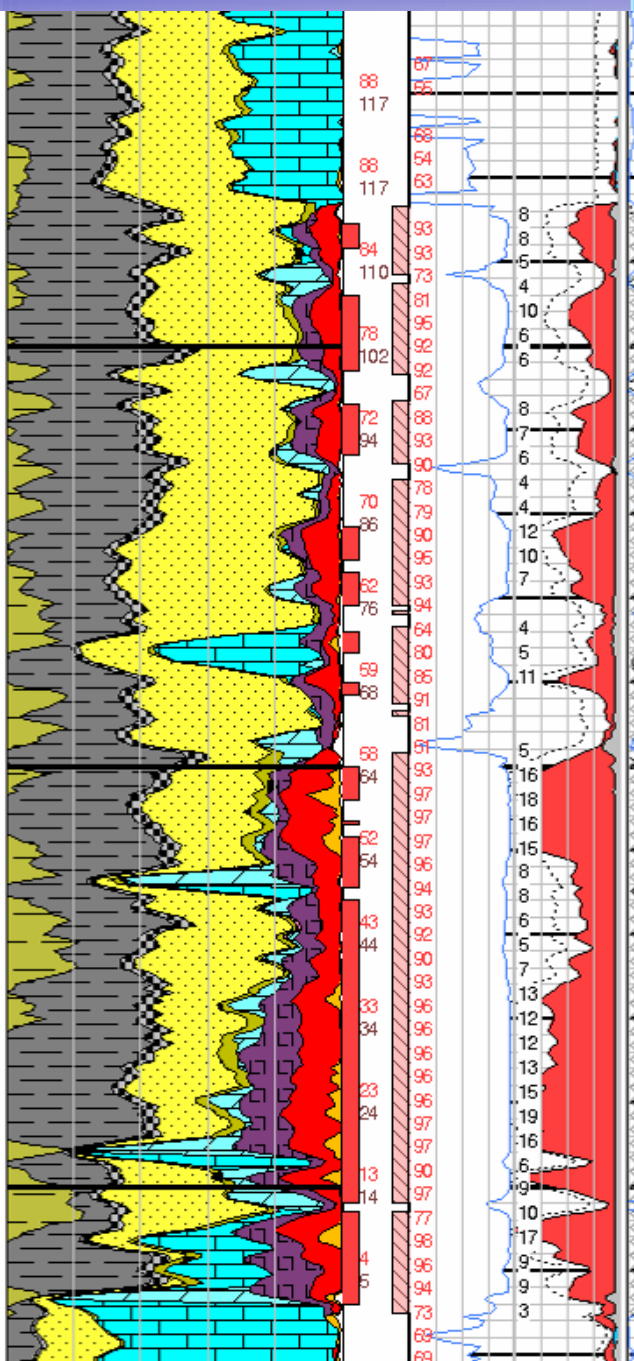
GIP 57 BCF/mi²

AVG PERM – 247.16 Nd

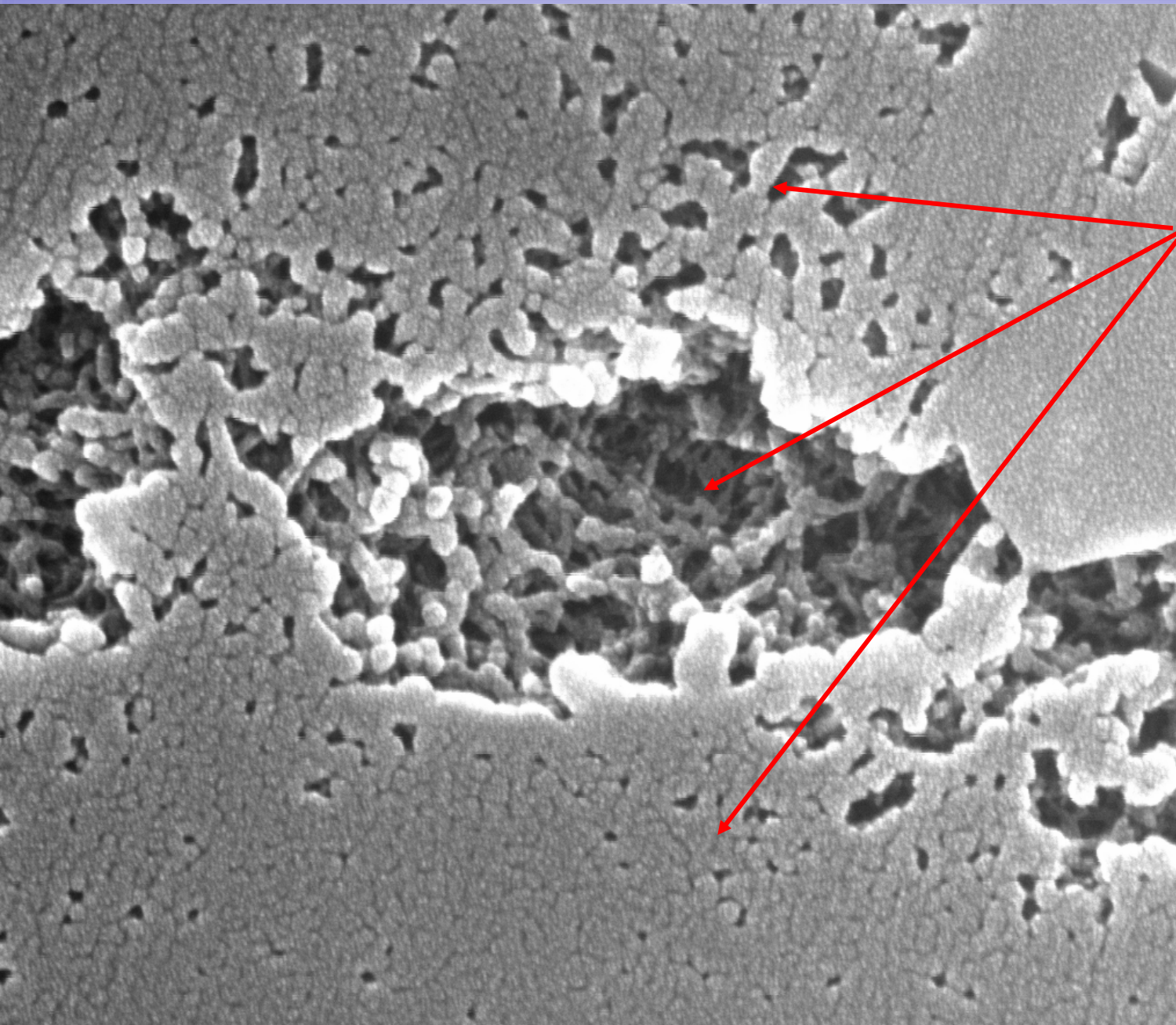
AVG EFFECTIVE POROSITY – 5.02



Marcellus Porosity and Permeability SW PA



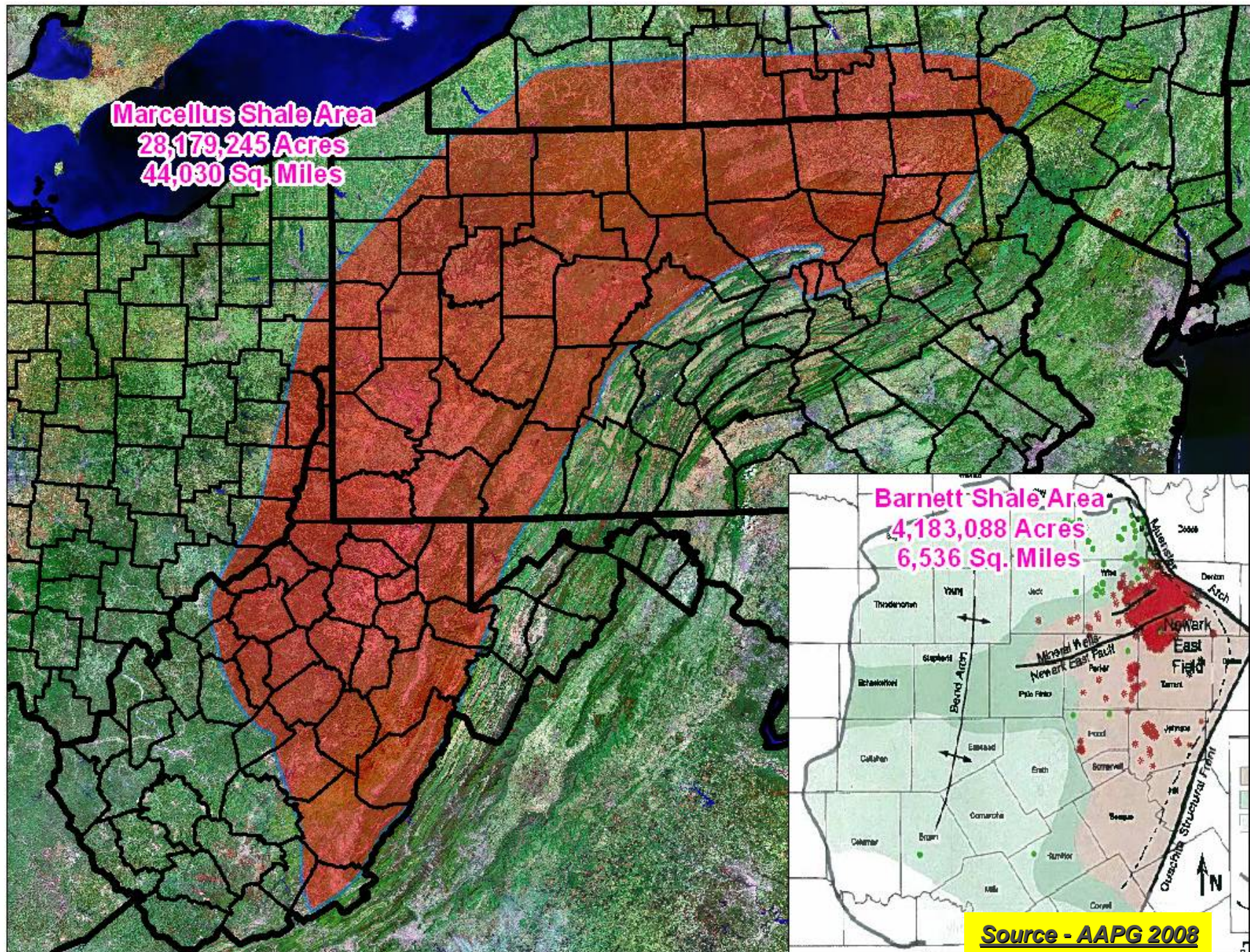
Enlarged View Marcellus Pore System SW PA



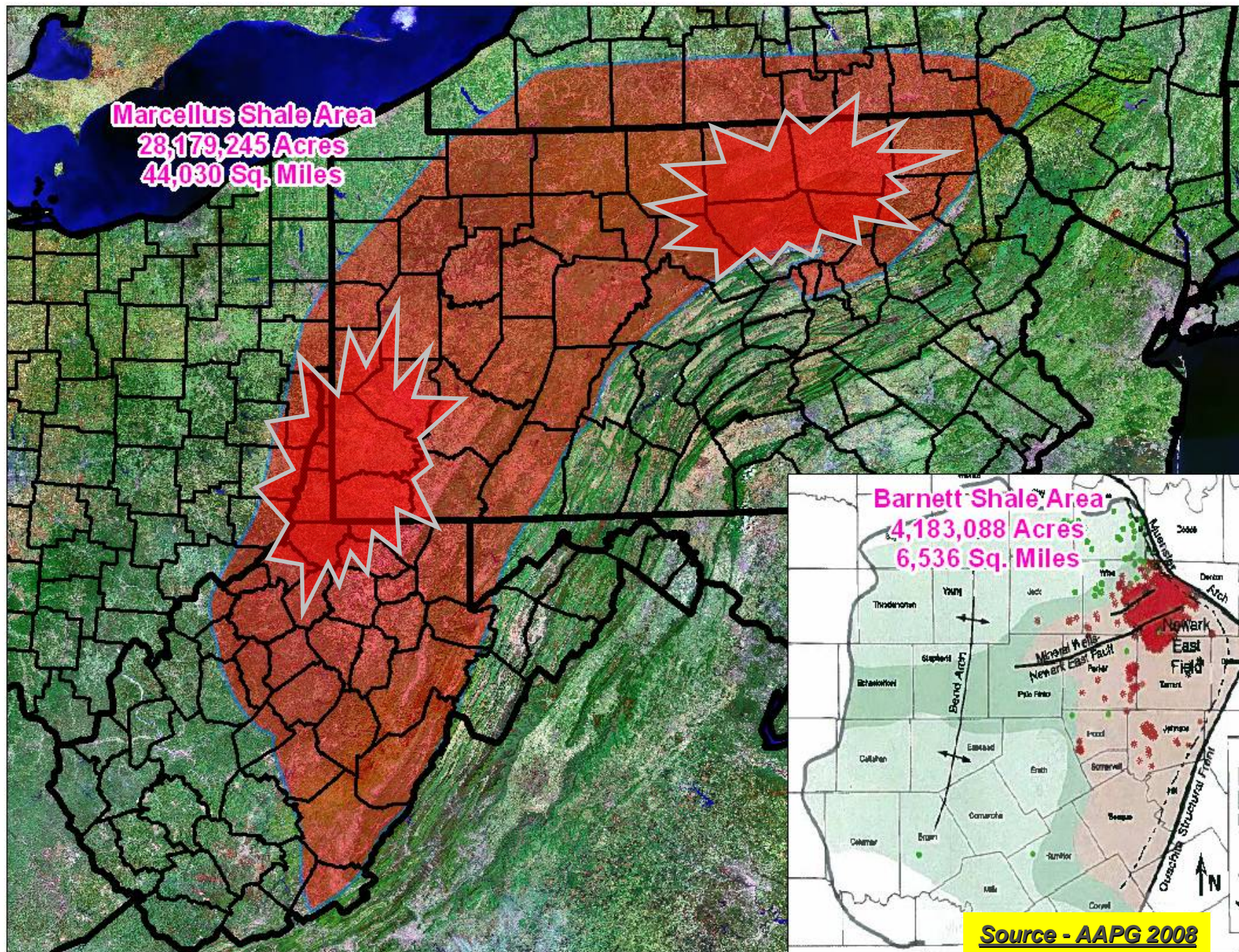
Note various scales of pore development.

Note new level of pore development!!

Marcellus Resource Potential



Marcellus Resource Potential



Worldwide Largest Oil and Gas Fields

Table 4. World's Fifteen Largest Oil and Gas Fields

Oil Fields			Gas Fields			
Field, Country	Discovery year	Size Gb	Field, Country	Discovery year	Size Tcf → Gboe	
Ghawar <i>Saudi Arabia</i>	1948	80	North Field-South Pars <i>Qatar-Iran</i>	1976	1400*	233
Burgan <i>Kuwait</i>	1938	60	Urengoy <i>Russia</i>	1966	222	37
Bolívar Coastal <i>Venezuela</i>	1917	32	Yamburg <i>Russia</i>	1969	138	23
Sufaniya <i>Saudi Arabia</i>	1951	30	Hassi R'Mel <i>Algeria</i>	1956	123	20
Rúmiala <i>Iraq</i>	1953	20	Shtokman <i>Russia</i>	1989	110*	18
Ahwaz <i>Iran</i>	1958	17	Zapolyarnoye <i>Russia</i>	1965	95*	16
Marun <i>Iran</i>	1964	16	Hugoton <i>USA</i>	1926	81	13
Kirkuk <i>Iraq</i>	1927	16	Groningen <i>Netherlands</i>	1959	73	12
Romashkino <i>Russia</i>	1948	16	Bonavenko <i>Russia</i>	1971	70*	12
Tengiz <i>Kazakhstan</i>	1979	15	Medvezhye <i>Russia</i>	1967	68	11
Gachsaran <i>Iraq</i>	1928	15	North Pars <i>Iran</i>	1973	48*	8
Aghajari <i>Russia</i>	1938	14	Dauletabad-Donmez <i>Turkmenistan</i>	1974	47*	8
Samotlor <i>Russia</i>	1966	14	Karachaganak <i>Kazakhstan</i>	1979	46*	8
Zakum <i>Abu Dhabi</i>	1964	12	Orenburg <i>Russia</i>	1966	45	7
Abqaiq <i>Saudi Arabia</i>	1964	12	Kharsavey <i>Russia</i>	1974	42*	7
Top 15		369	Top 15		2608	433
World		2000	World		9500 - 13500	

Notes: Gas fields are non associated gas and gas condensate. Size refers to ultimate recoverable reserves expressed in Tcf and Gboe. Asterisk (*) indicates the reserves estimate is volumetric.

Sources: "Natural Gas", E.N. Tirasoo, Gulf Publishing Co., 1979; Gibson Consulting Oil Statistics; EIA Reports; IIASA 2004; Author's decline estimates.

Range of some recent Marcellus shale reserve estimates – 50 Tcf to 489 Tcf!!!!!!

Congratulations! - We have come a long way in 150 years!



Acknowledgements

Range's Marcellus Shale Pioneers

Jeffrey L. Ventura – Sr. Vice President & Chief Operating Officer

John H. Pinkerton – Chairman & Chief Executive Officer

Mark D. Whitley – Sr. Vice President – Engineering Technology

Ray N. Walker – Sr. Vice President – Marcellus Shale Division

Martin Emery – Vice President – Geology

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Mike C. Forrest – Technical Advisor - Consultant

Joseph H. Frantz – Vice President – Engineering – Marcellus Shale Division

John K. Applegath – Vice President – Drilling – Marcellus Shale Division

James L. Morris – Director Geophysics – Marcellus Shale Division