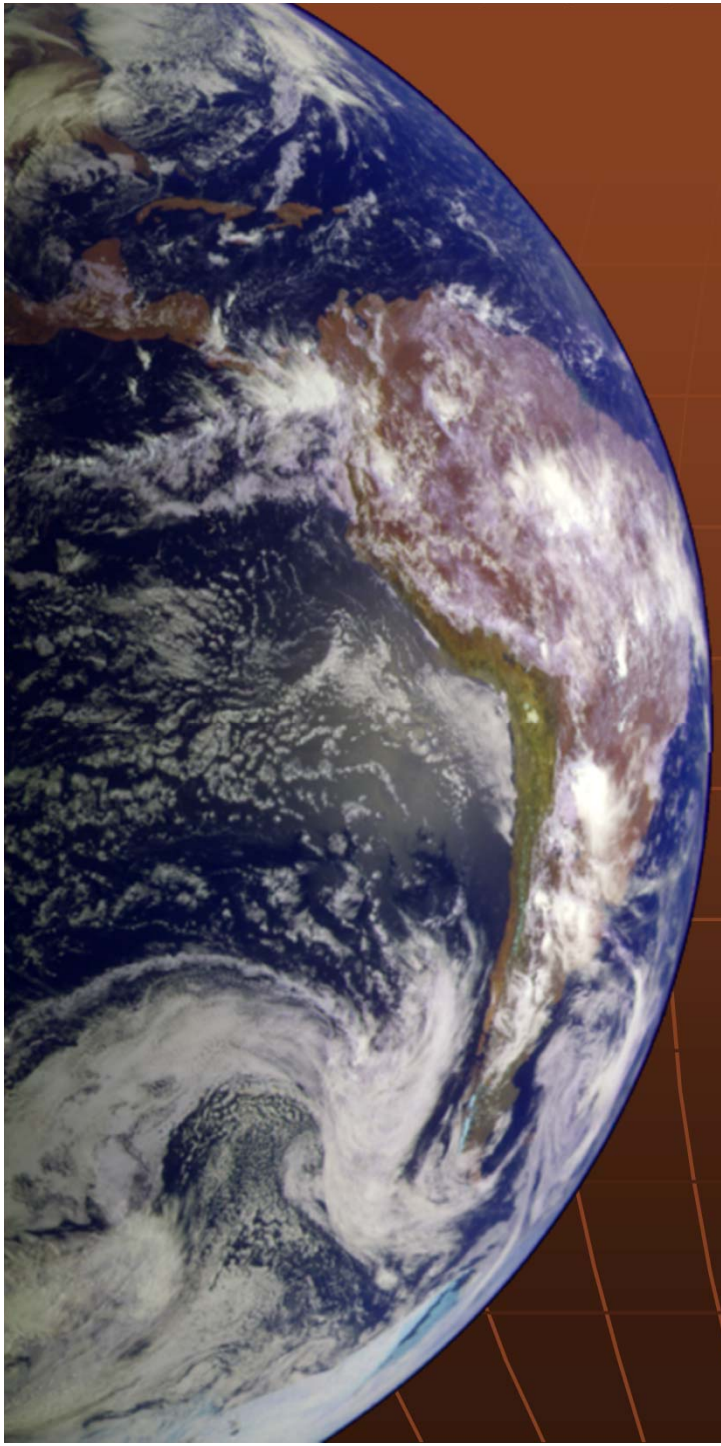

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Sensitivity of the Seismic Response in the Productive Regions of the Marcellus Shale

Presentation by:

Robert Brown

February 28th, 2011

Advisor: Dr. Robert Tatham

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Personal Background

- B.S. in Geological Sciences w/ Geophysics Option from Michigan State University
- Pursuing Masters in Exploration Geophysics at the University of Texas at Austin
- Advisor: DR. Robert Tatham
- Thesis Project: Sensitivity of the Seismic Response in the Productive Regions of the Marcellus Shale
- Expected Graduation Date: May 2011

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Outline

- Background Information
- Stratigraphy
- Working Models
- Synthetic Seismograms
- Future Work
- References

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Significance

- The Marcellus shale is a large natural gas resource in the northeast United States.
- It is estimated that between 30 and 50tcf of recoverable natural gas can be extracted from the Marcellus Shale.

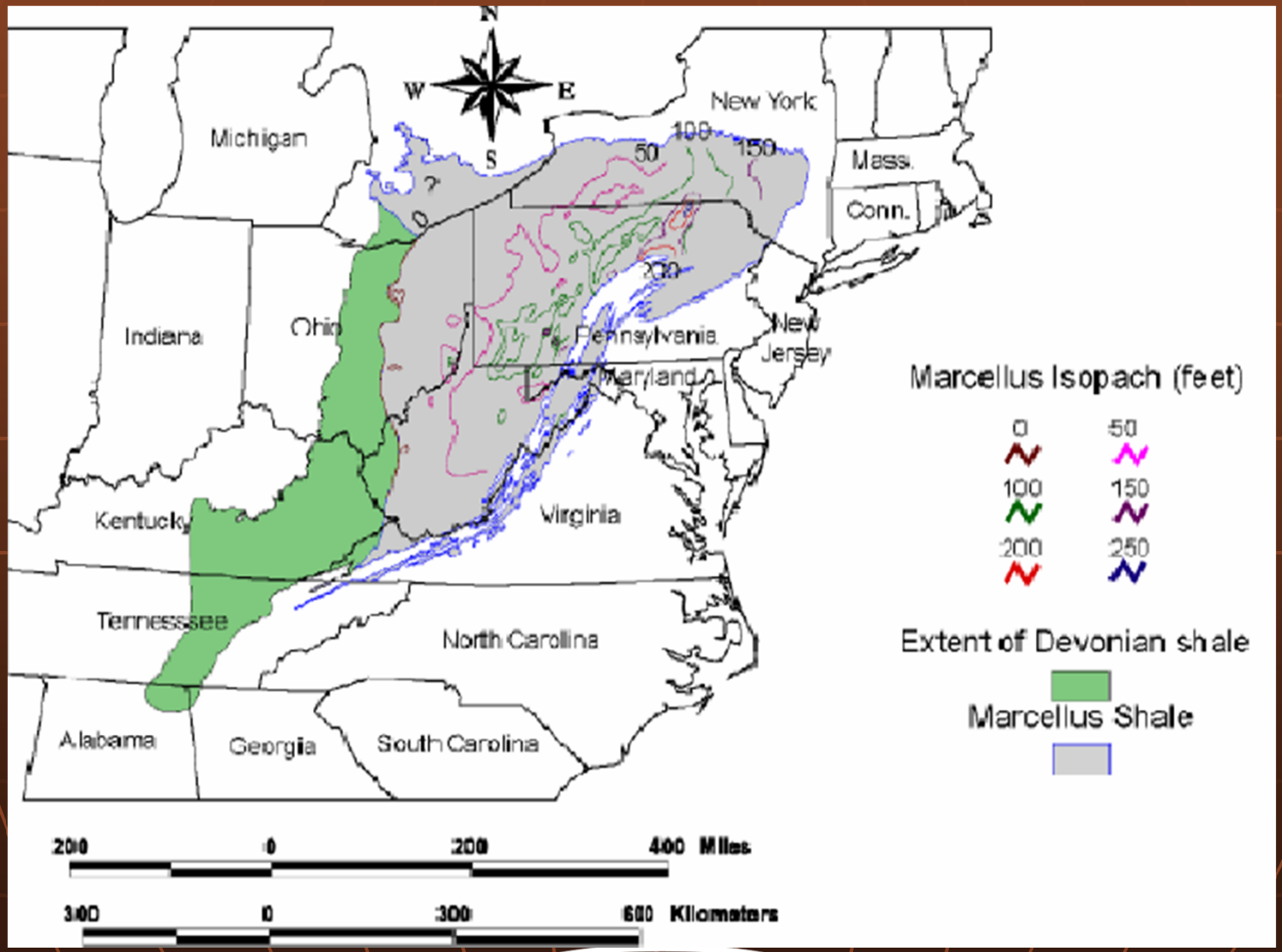
EXHIBIT 11: COMPARISON OF DATA FOR THE GAS SHALES IN THE UNITED STATES

Gas Shale Basin	Barnett	Fayetteville	Haynesville	Marcellus	Woodford	Antrim	New Albany
Estimated Basin Area, square miles	5,000	9,000	9,000	95,000	11,000	12,000	43,500
Depth, ft	6, 500 - 8,500[82]	1,000 - 7,000[83]	10,500 - 13,500[84]	4,000 - 8,500[85]	6,000 - 11,000[86]	600 - 2,200[87]	500 - 2,000[88]
Net Thickness, ft	100 - 600[89]	20 - 200[90]	200[91] - 300[92]	50 - 200[93]	120 - 220[94]	70 - 120[95]	50 - 100[96]
Depth to Base of Treatable Water[4], ft	~1200	~500[97]	~400	~850	~400	~300	~400
Rock Column Thickness between Top of Pay and Bottom of Treatable Water, ft	5,300 - 7,300	500 - 6,500	10,100 - 13,100	2,125 - 7650	5,600 - 10,600	300 - 1,900	100 - 1,600
Total Organic Carbon, %	4.5[98]	4.0 - 9.8[99]	0.5 - 4.0[100]	3 - 12[101]	1 - 14[102]	1 - 20[103]	1 - 25[104]
Total Porosity, %	4 - 5[105]	2 - 8[106]	8 - 9[107]	10[108]	3 - 9[109]	9[110]	10 - 14[111]
Gas Content, scf/ton	300 - 350[112]	60 - 220[113]	100 - 330[114]	60 - 100[115]	200 - 300[116]	40 - 100[117]	40 - 80[118]
Water Production, Barrels water/day	N/A	N/A	N/A	N/A	N/A	5 - 500[119]	5 - 500[120]
Well spacing, acres	60 - 160[121]	80 - 160	40 - 560[122]	40 - 160[123]	640[124]	40 - 160[125]	80[126]
Original Gas-In-Place, tcf[127]	327	52	717	1,500	23	76	160
Technically Recoverable Resources, tcf[128]	44	41.6	251	262	11.4	20	19.2

NOTE: Information presented in this table, such as Original Gas-in-Place and Technically Recoverable Resources, is presented for general comparative purposes only. The numbers provided are based on the sources shown and this research did not include a resource evaluation. Rather, publically available data was obtained from a variety of sources and is presented for general characterization and comparison. Resource estimates for any basin may vary greatly depending on individual company experience, data available at the time the estimate was performed, and other factors. Furthermore, these estimates are likely to change as production methods and technologies improve.

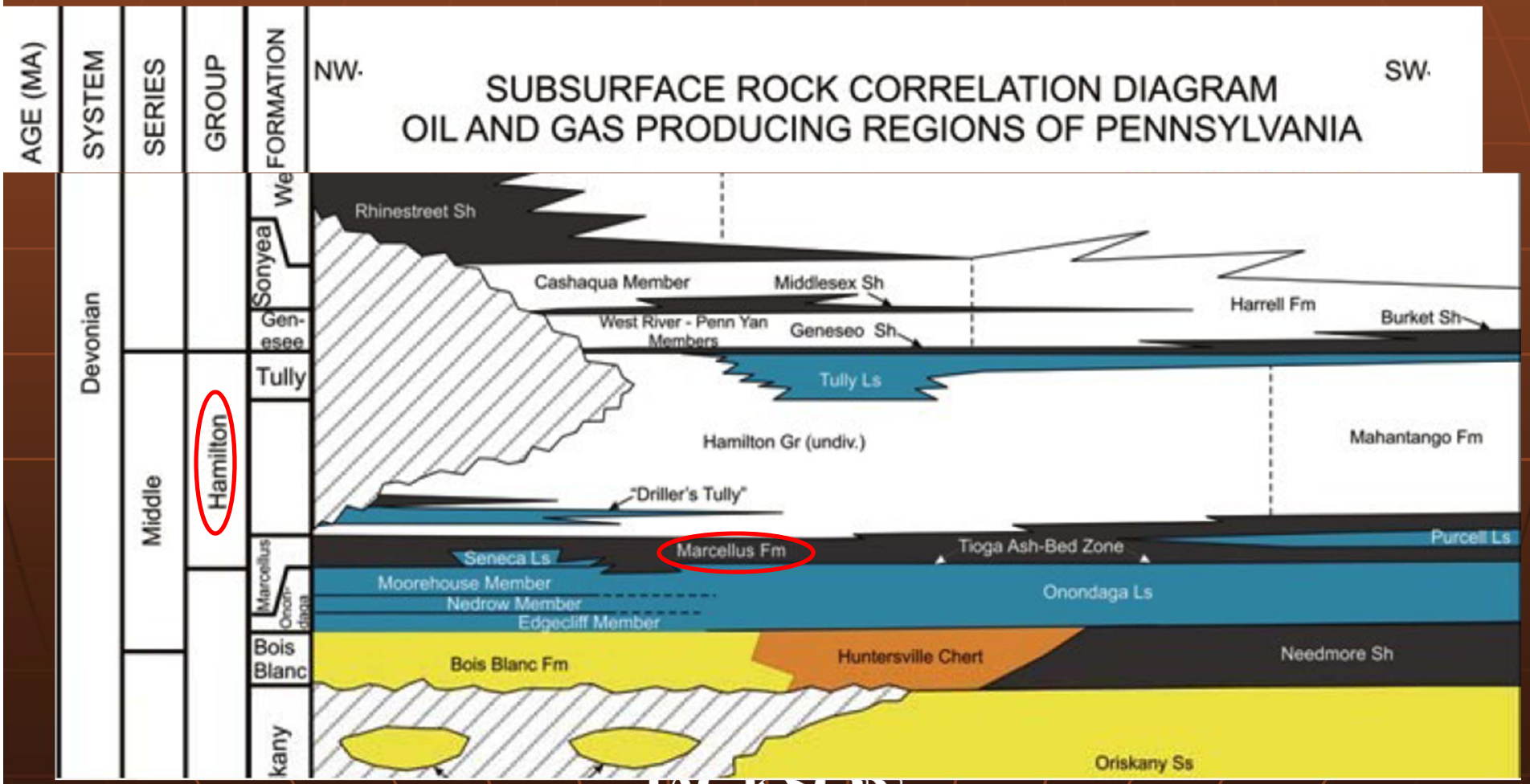
(Ground)

Extent of Marcellus Shale



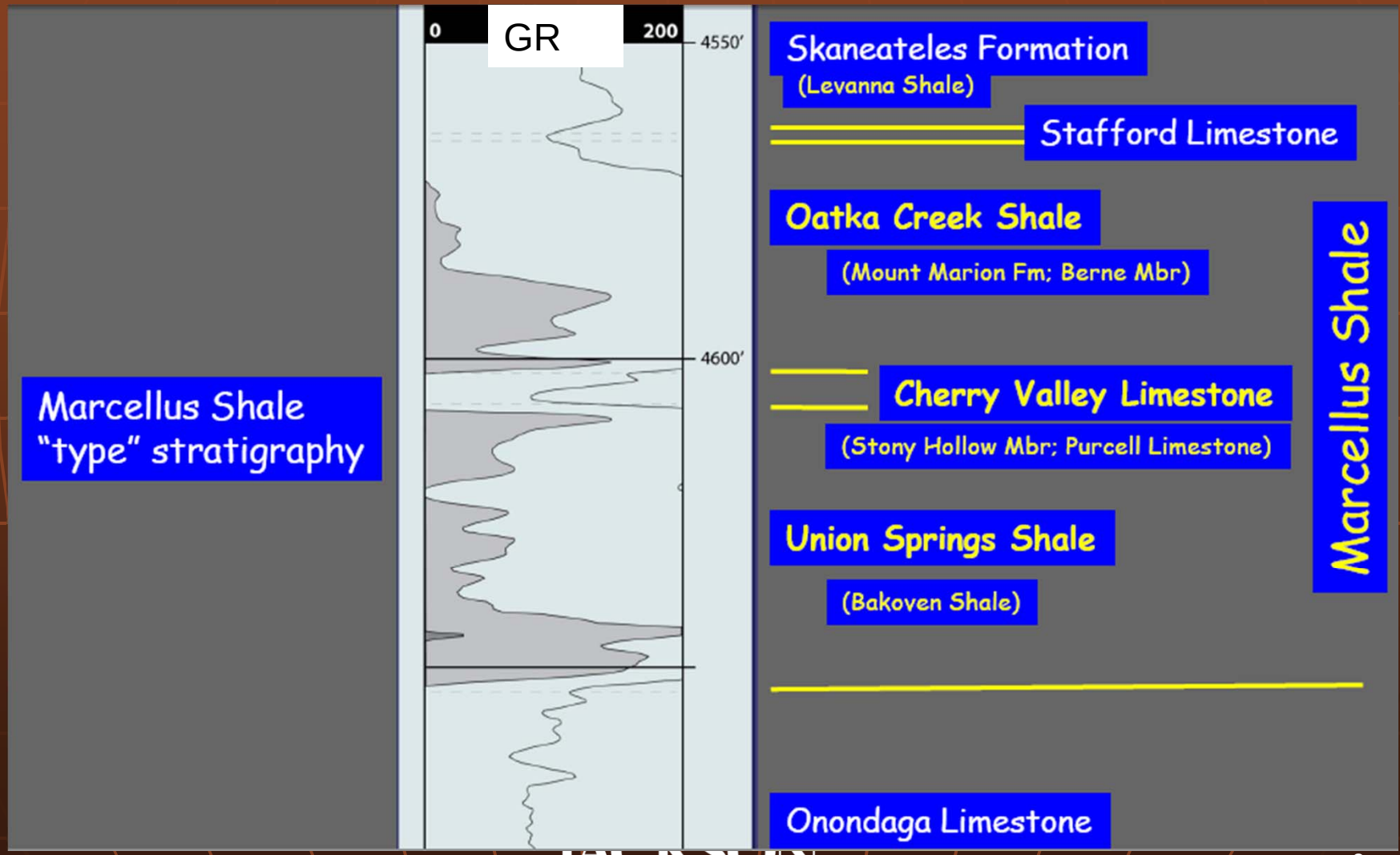
(Avary)

Stratigraphy of Pennsylvania



(Kostelnik and Laughrey)

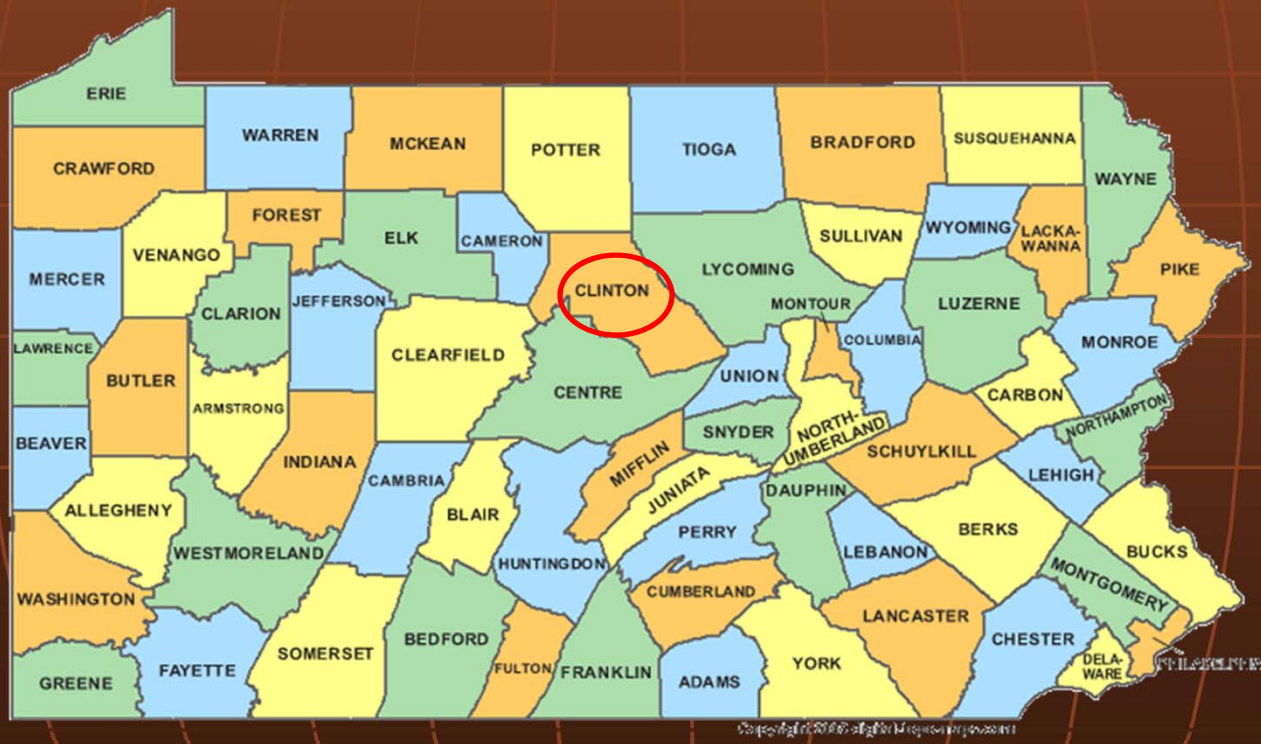
Stratigraphy



(Lash and Engelder)

Study Location

- Clinton County, Pennsylvania



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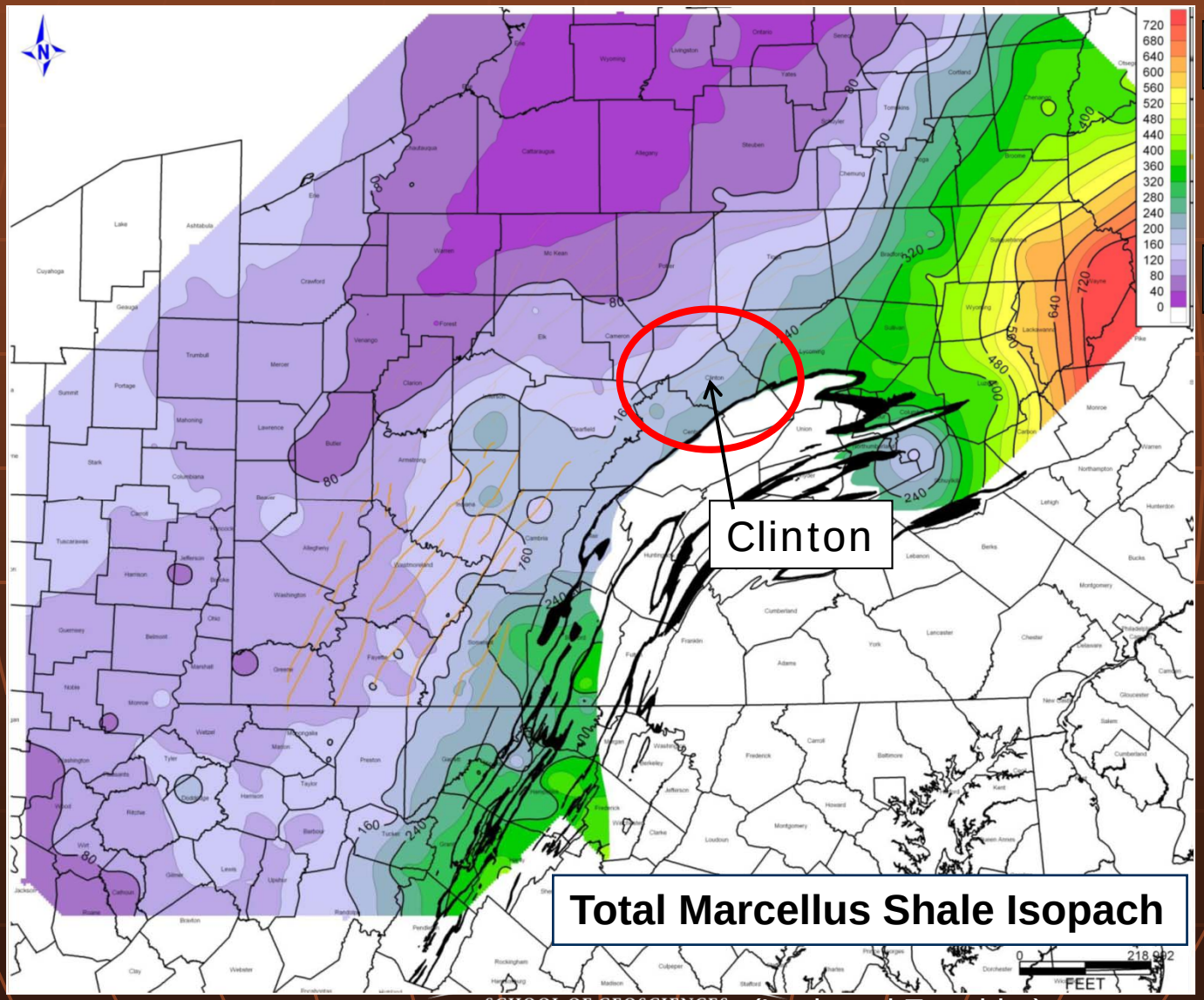
Thickness (Total Marcellus)

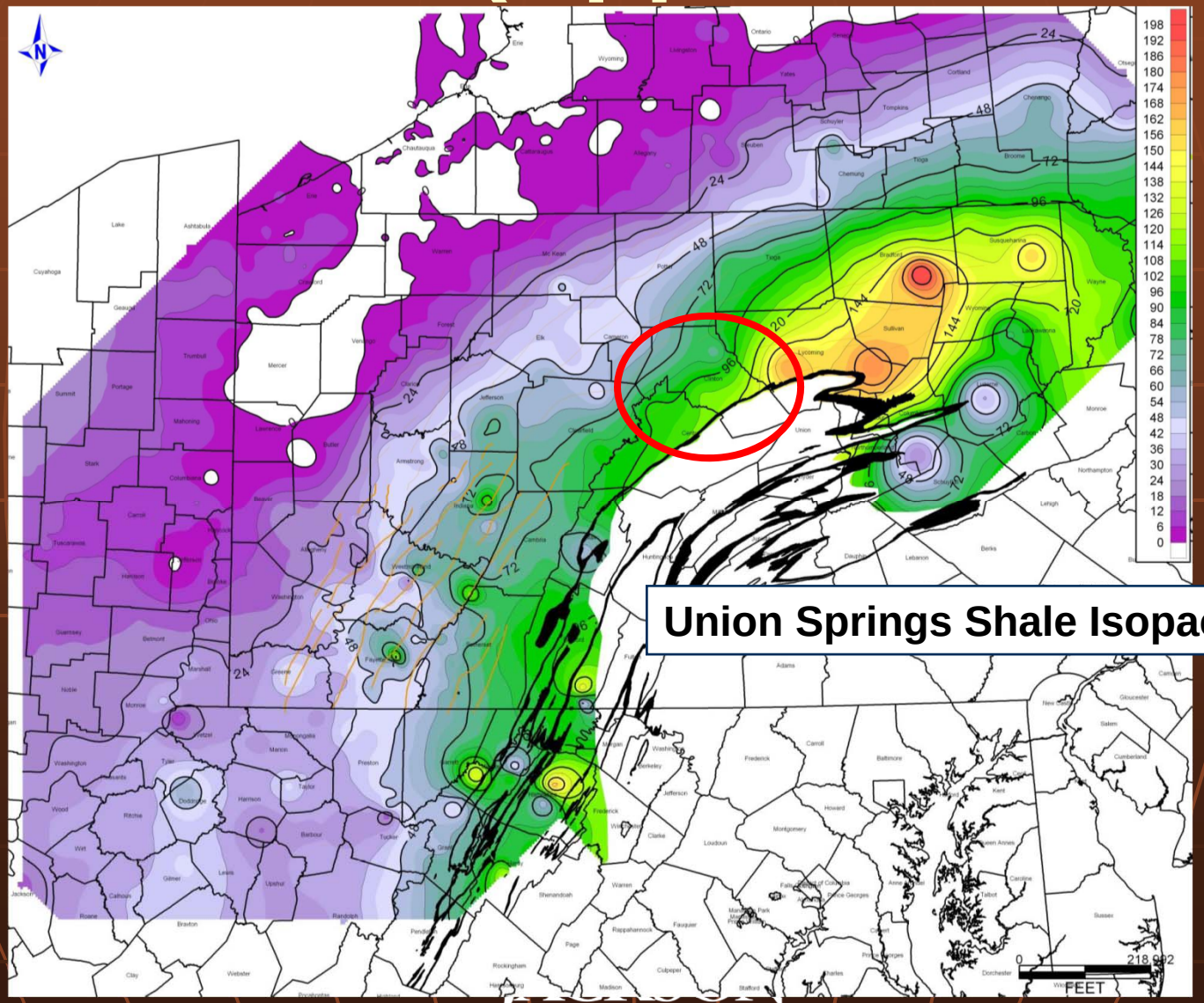


Thick

Thin

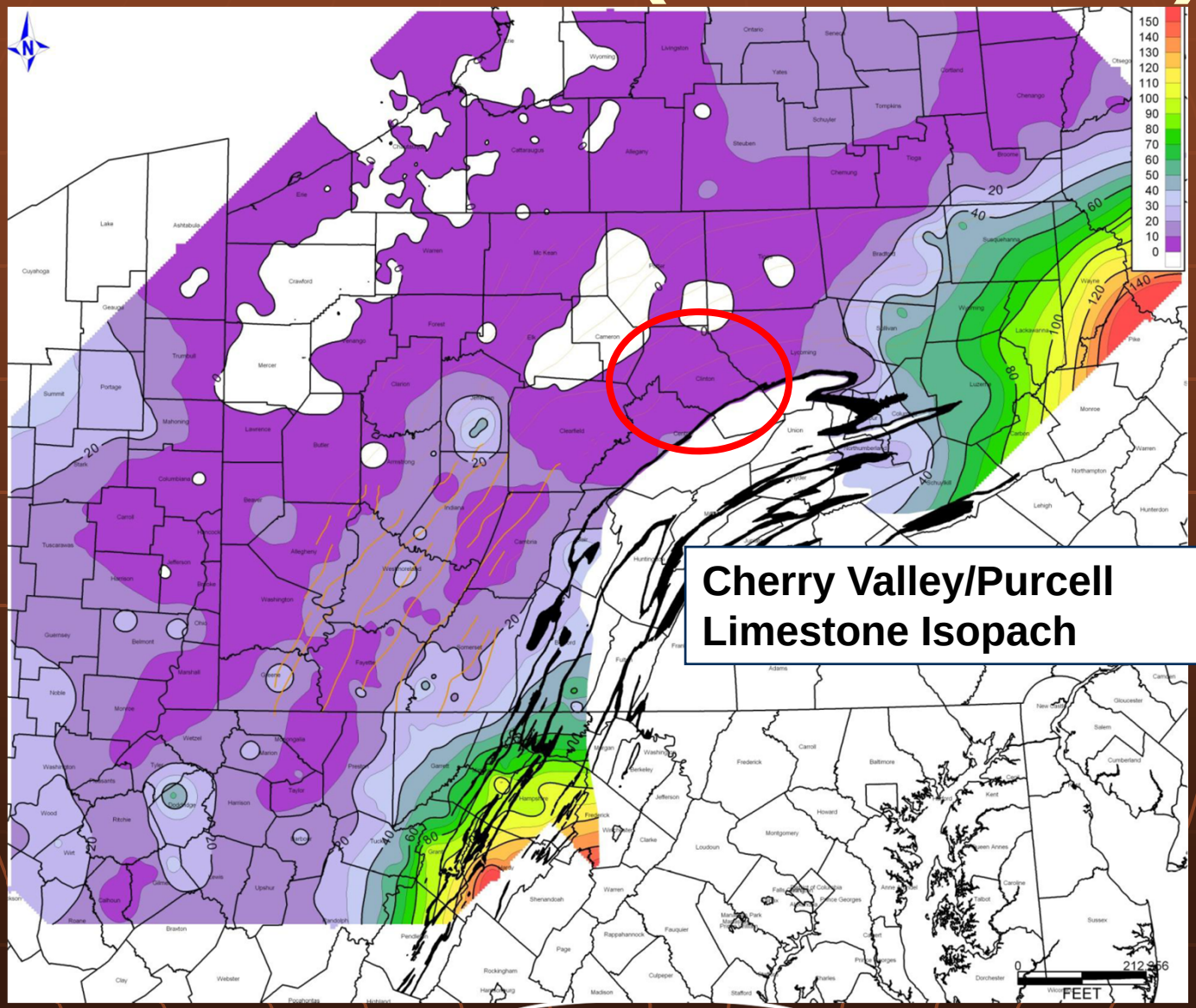
(Lash and Engelder)

Thickness (Upper Marcellus)



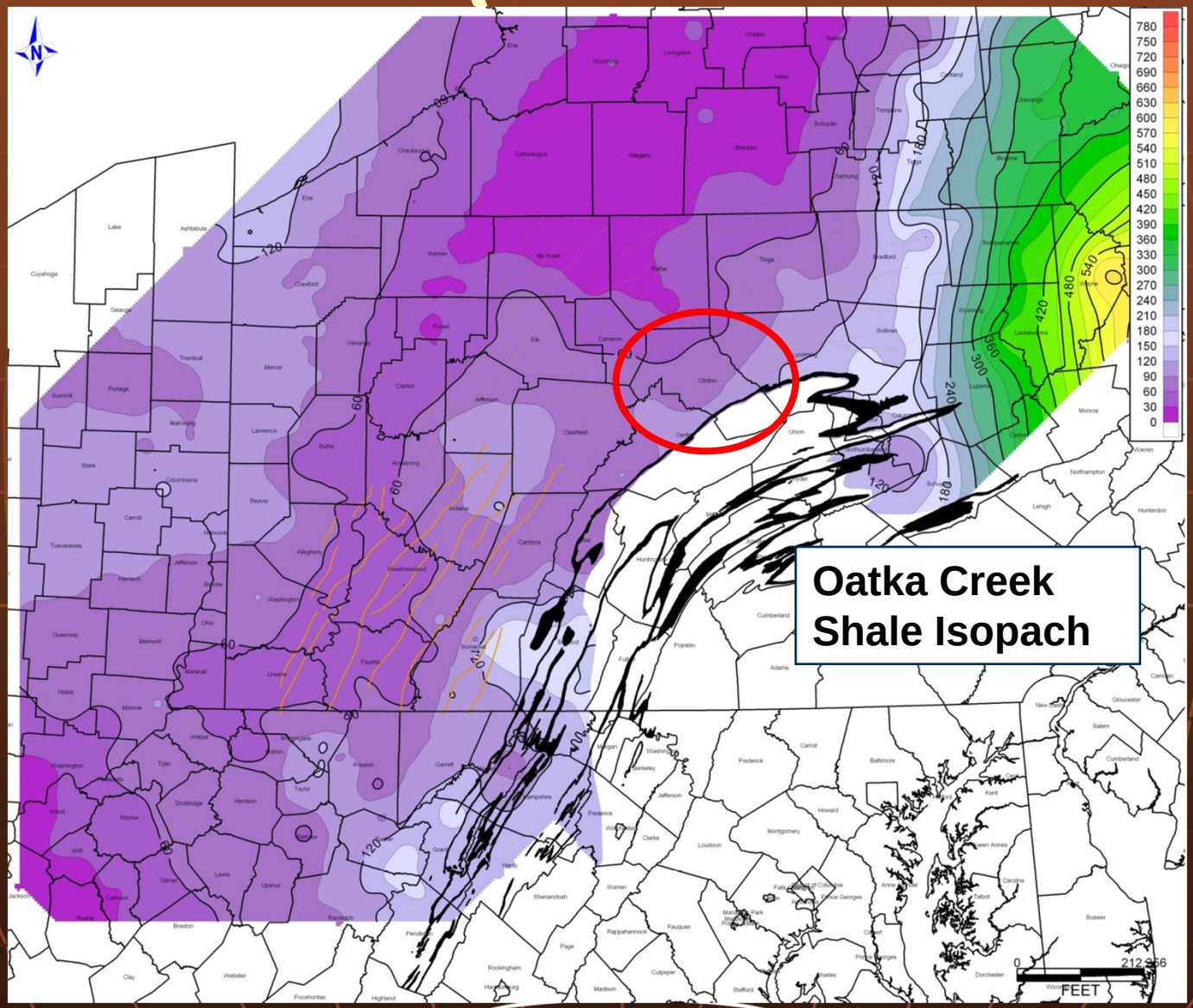
(Lash and Engelder)

Thickness (Limestone)



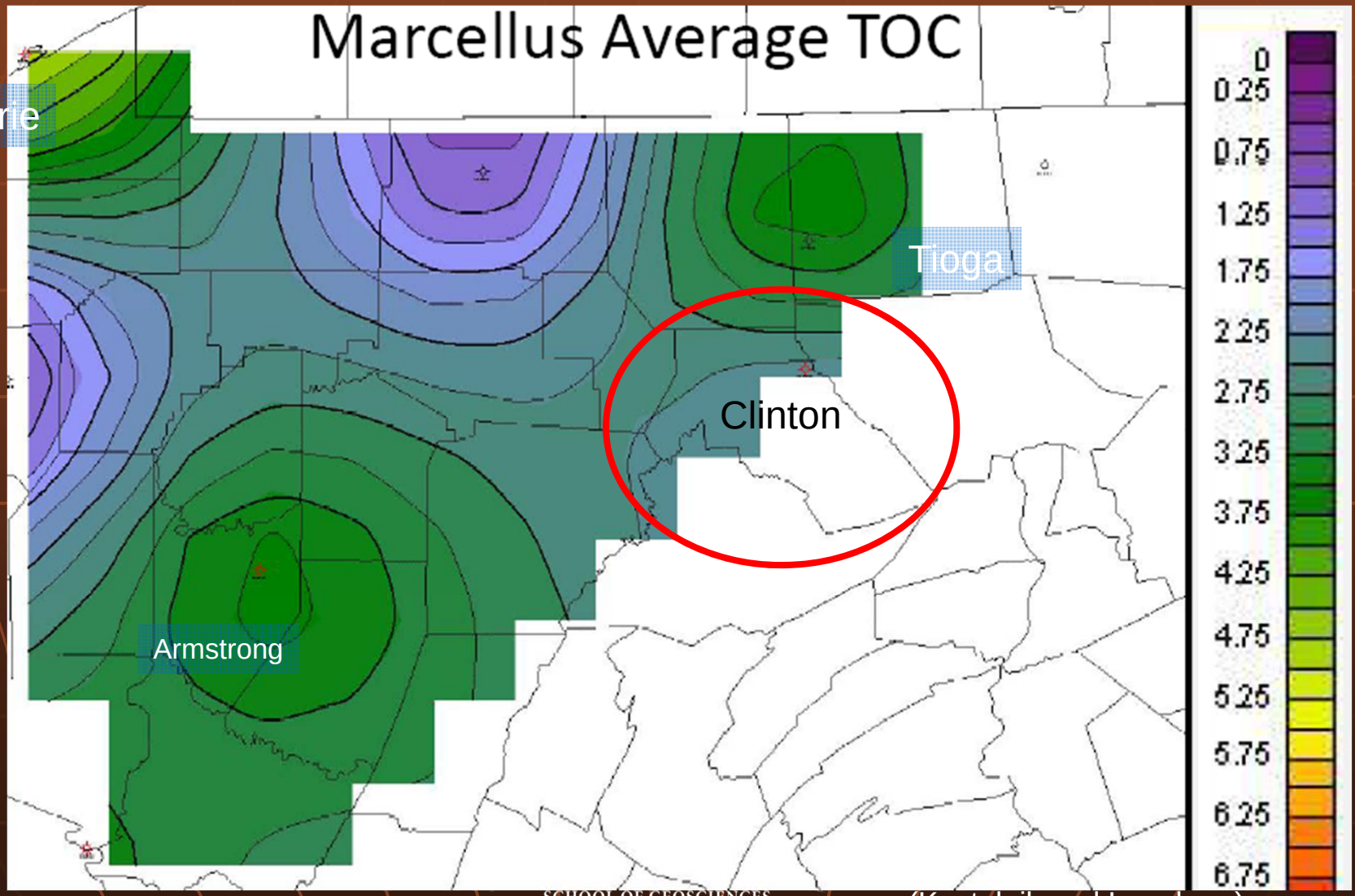
(Lash and Engelder)

Thickness (Lower Marcellus)



 (Lash and Engelder)

TOC [Marcellus Shale (Pennsylvania)]



(Kostelnik and Laughrey)

Stratigraphy: in feet and measured depth

Tops of Various zones

- Hamilton Group 7485
- Upper Marcellus 8321
- Cherry Valley Limestone 8411
- Lower Marcellus 8422
- “Uber” 8505
- Onondoga 8528.5

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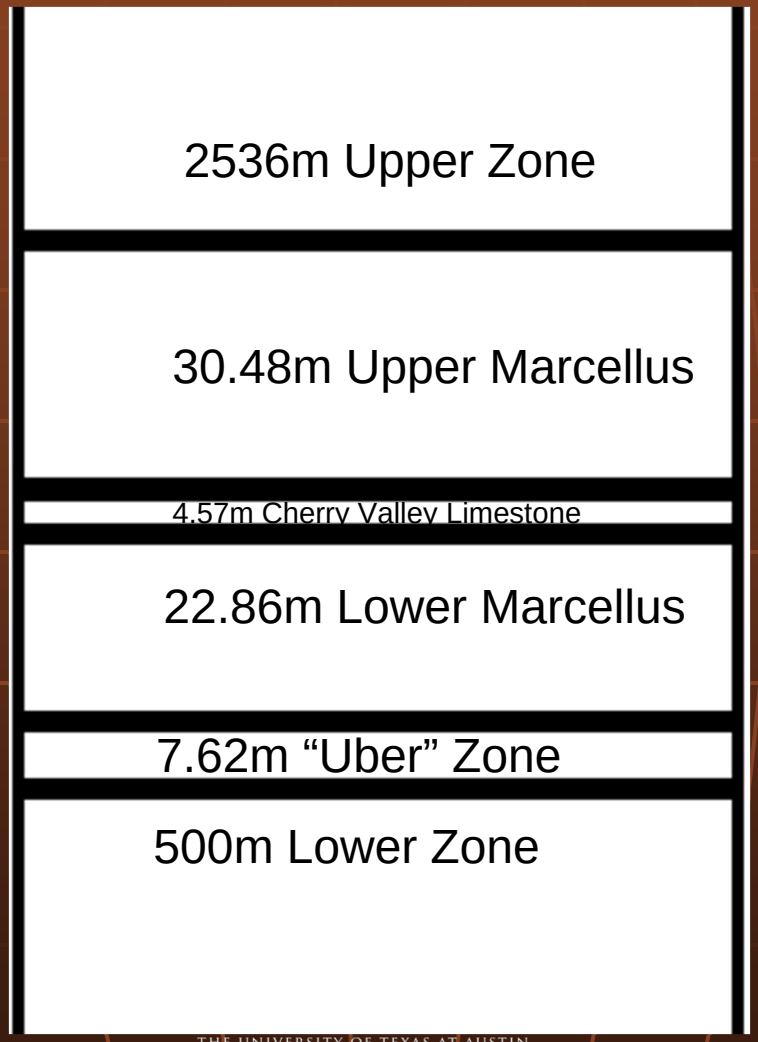
Realistic Model



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Thick Model

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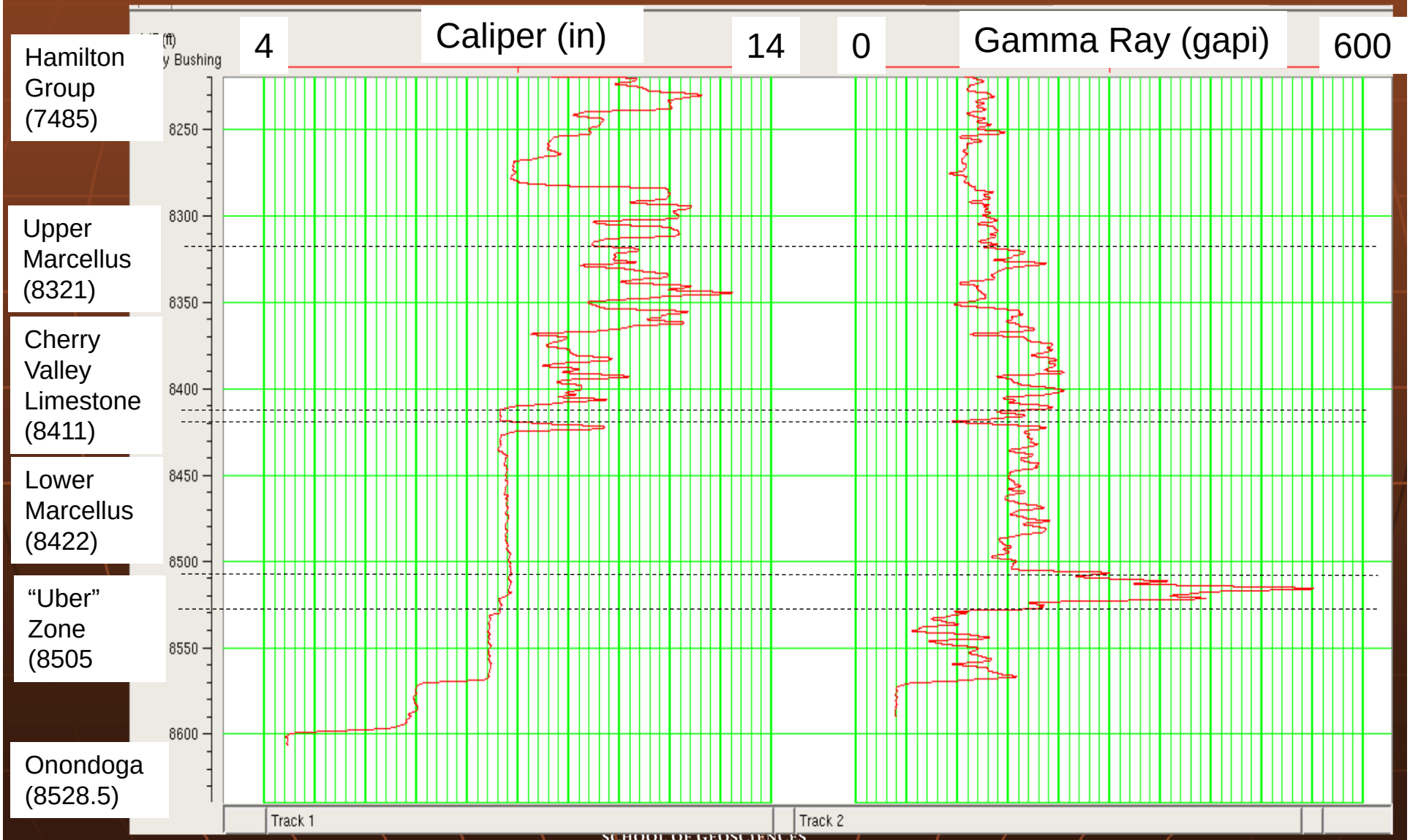
Log Data


Hamilton Group (7485)
Upper Marcellus (8321)
Cherry Valley Limestone (8411)
Lower Marcellus (8422)
"Uber" Zone (8505
Onondoga (8528.5)
4
Caliper (in)
14
0
Gamma Ray (gapi)
600
8250
8300
8350
8400
8450
8500
8550
8600
Track 1
Track 2

Logs

Hamilton Group (7485)

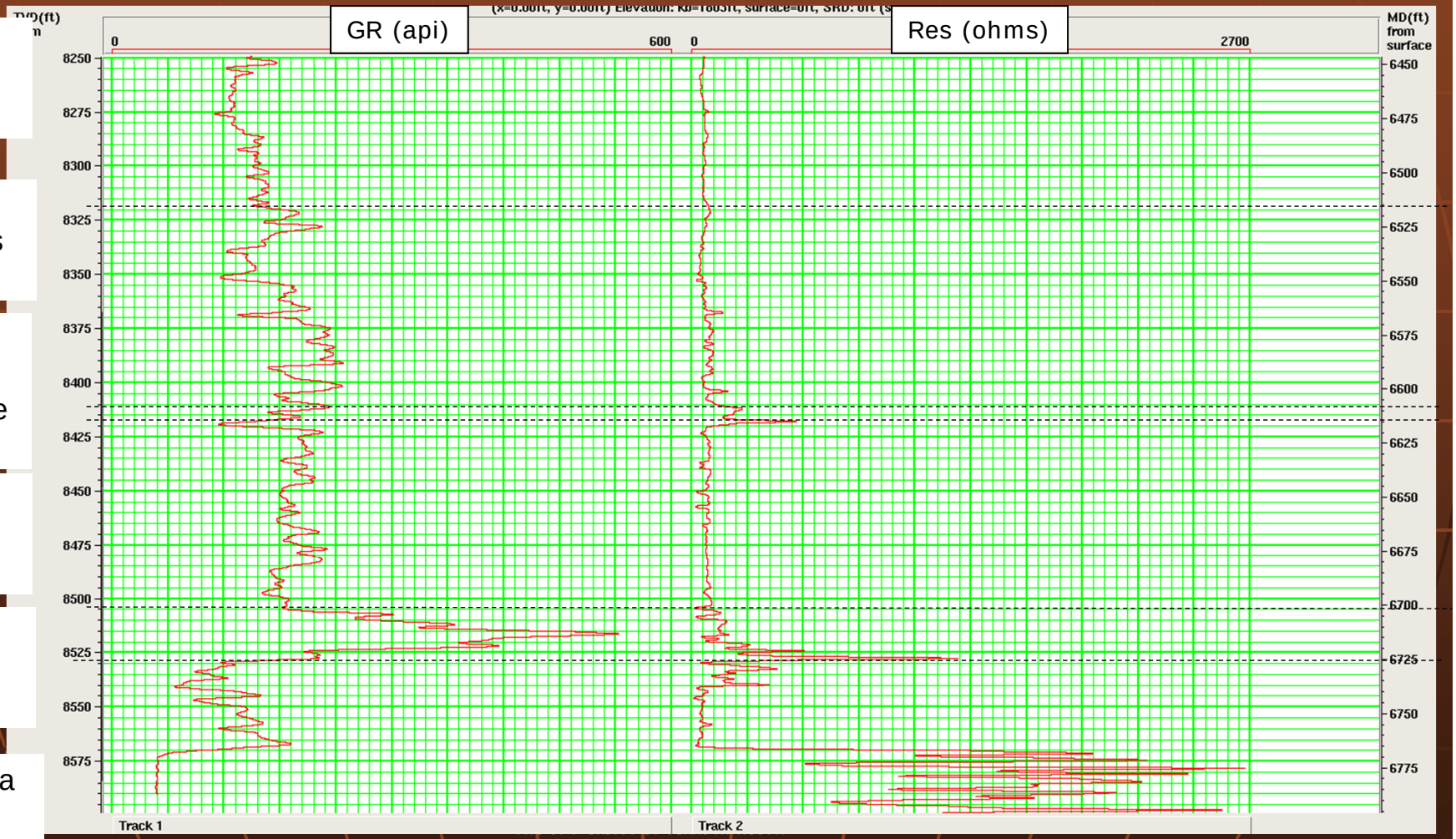
Upper Marcellus (8321)

Cherry Valley Limestone (8411)

Lower Marcellus (8422)

“Uber” Zone (8505

Onondoga (8528.5)



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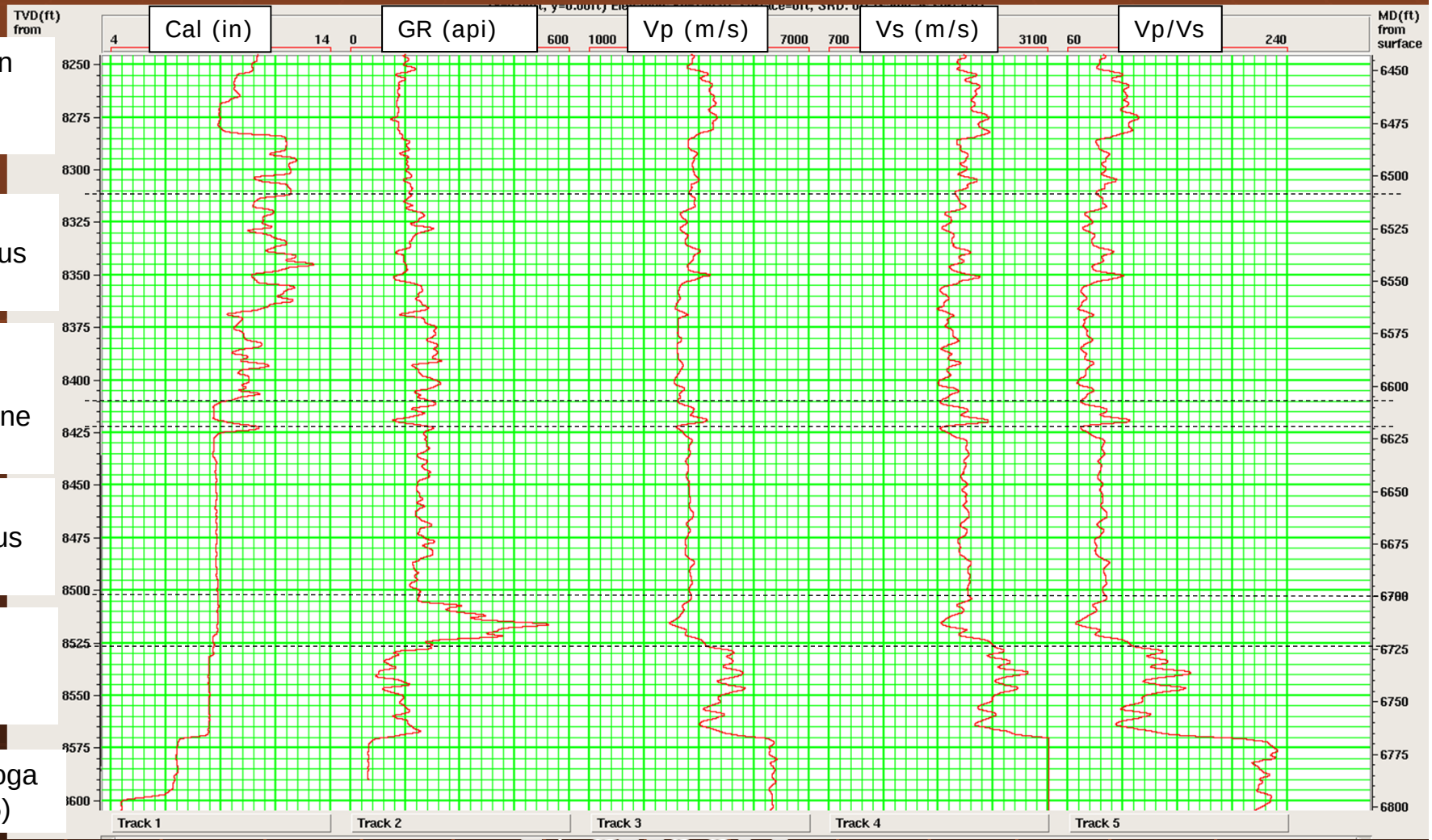
Logs



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Logs

Hamilton Group (7485)

Upper Marcellus (8321)

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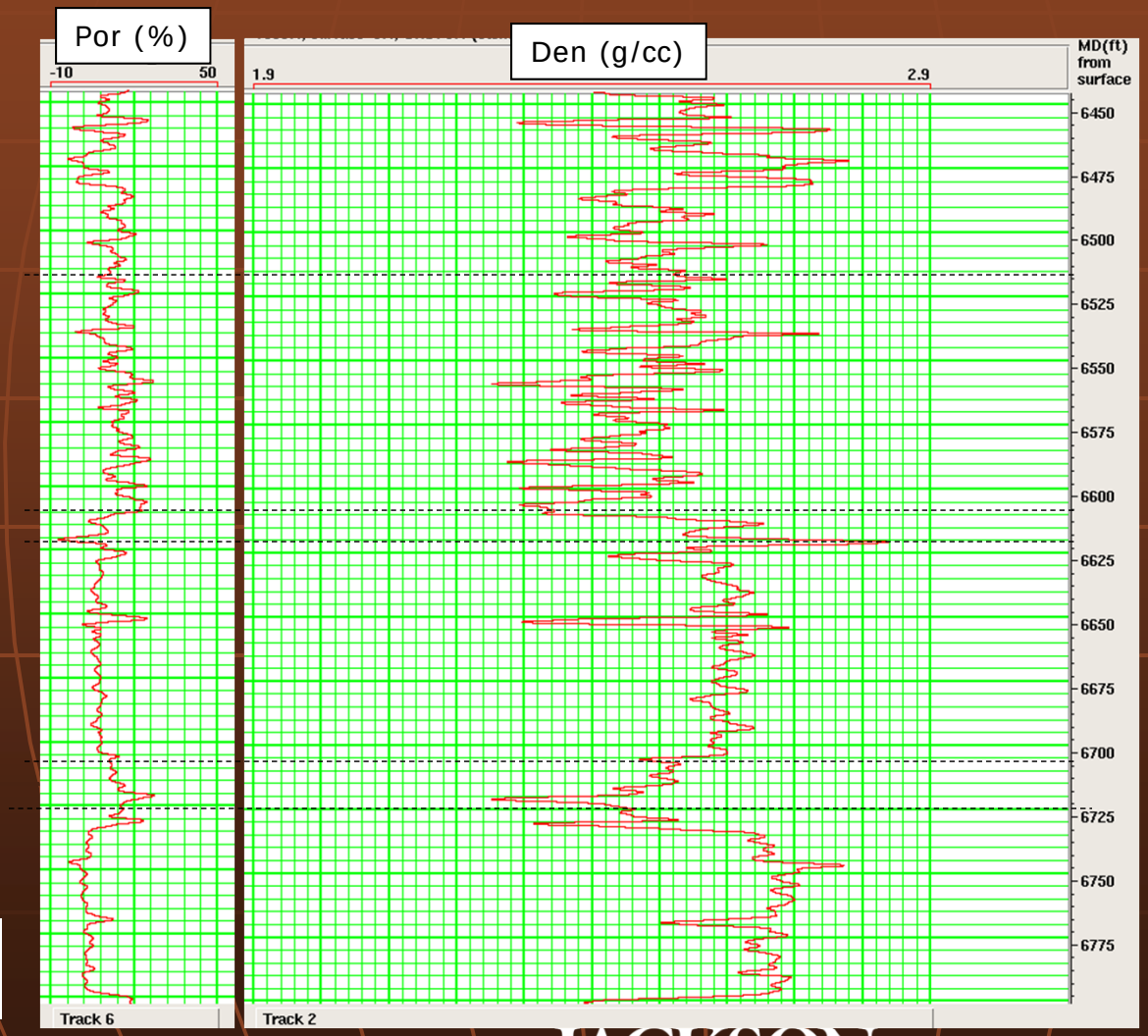
Onondoga (8528.5)



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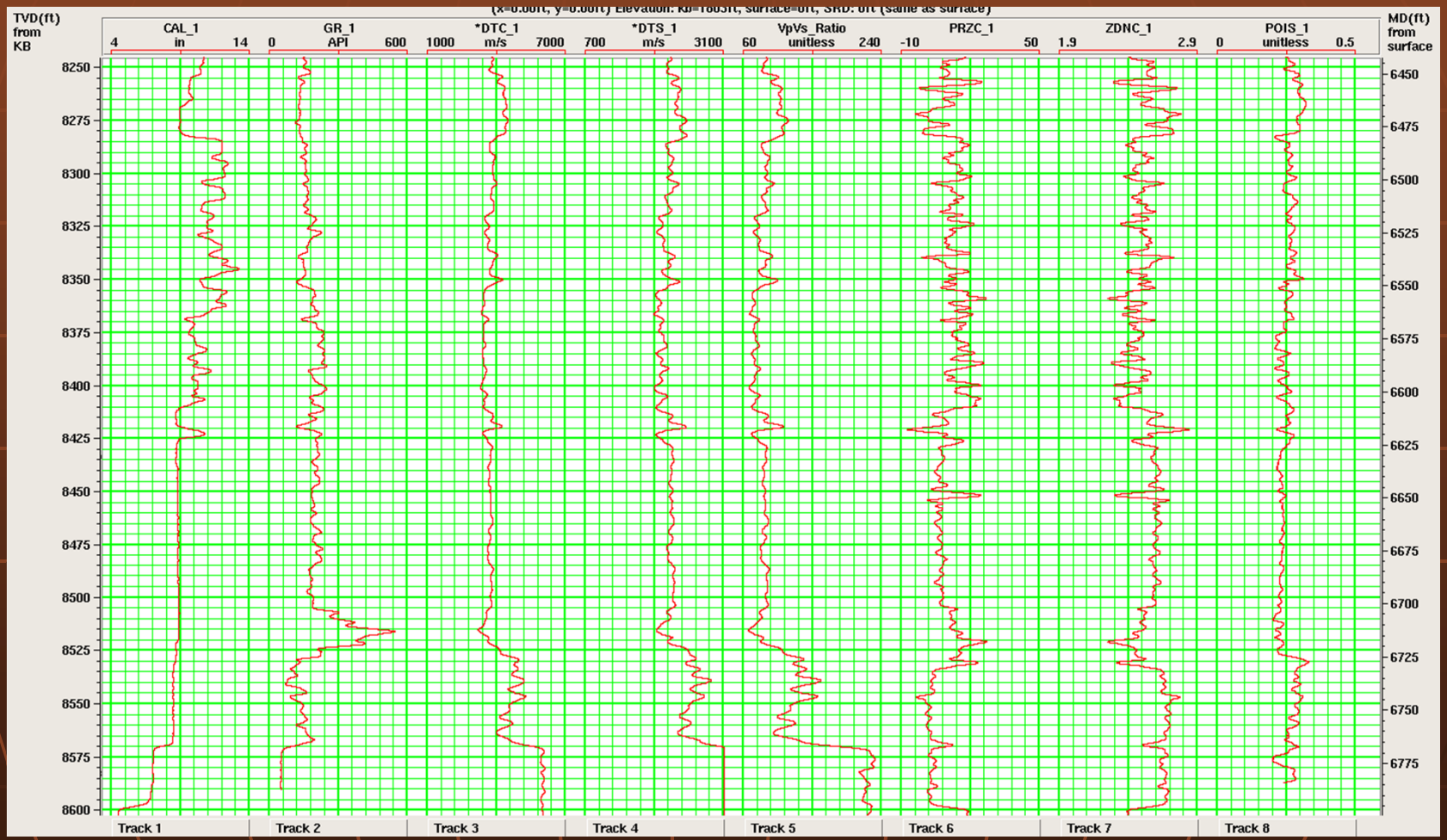
Logs



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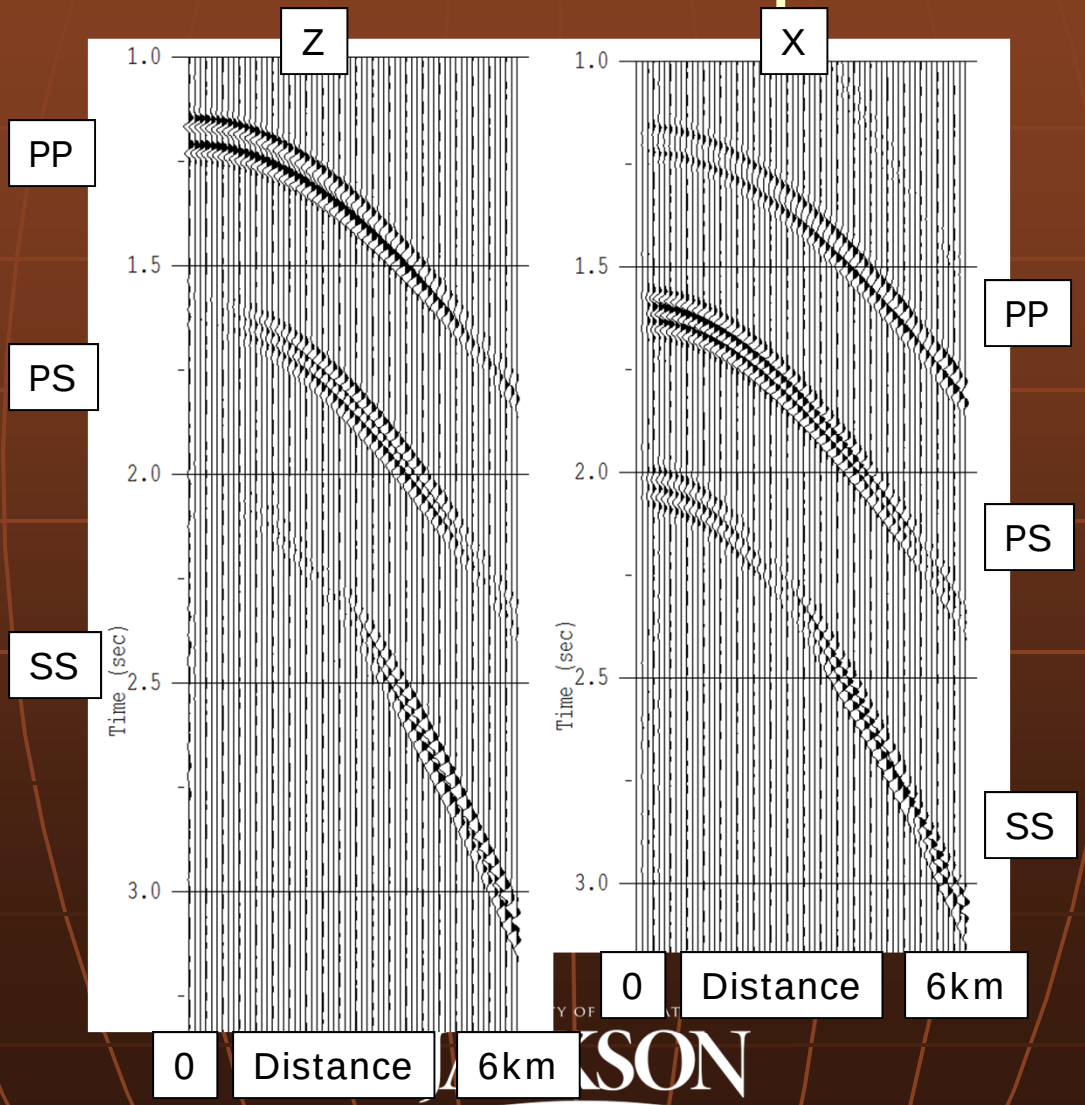
Synthetic Seismograms

Realistic Thickness and Isotropic Model (z vs. x)



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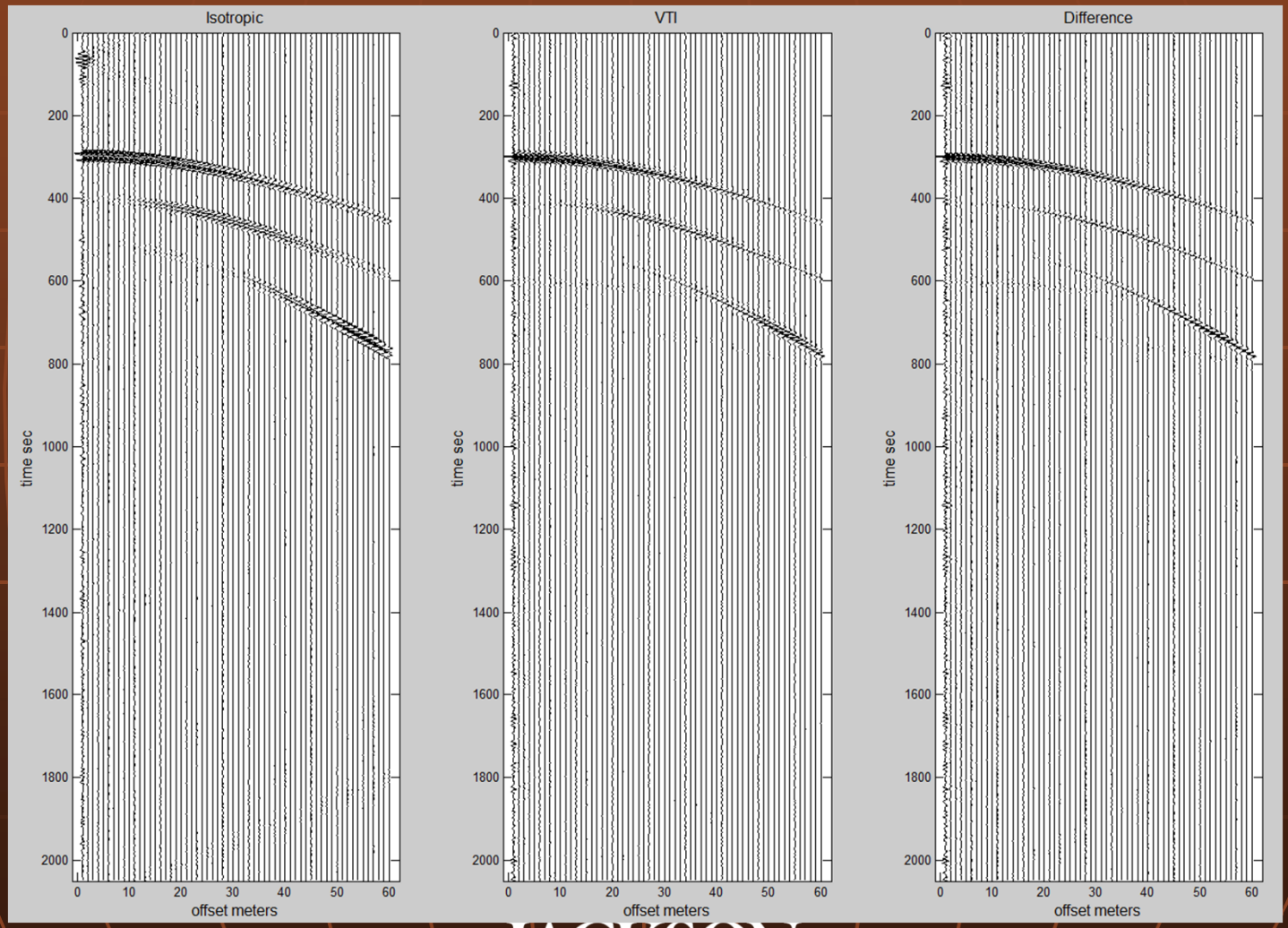

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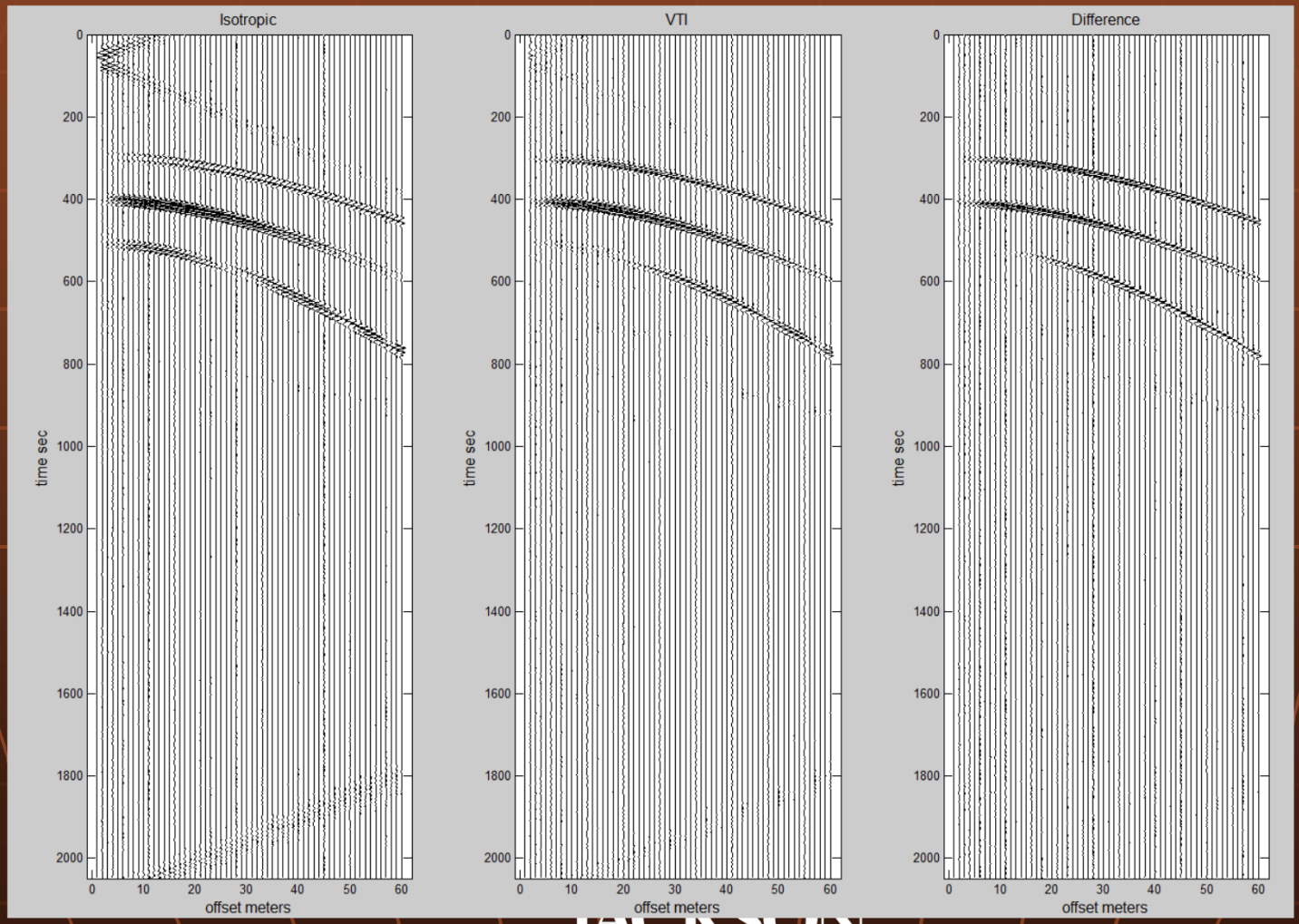

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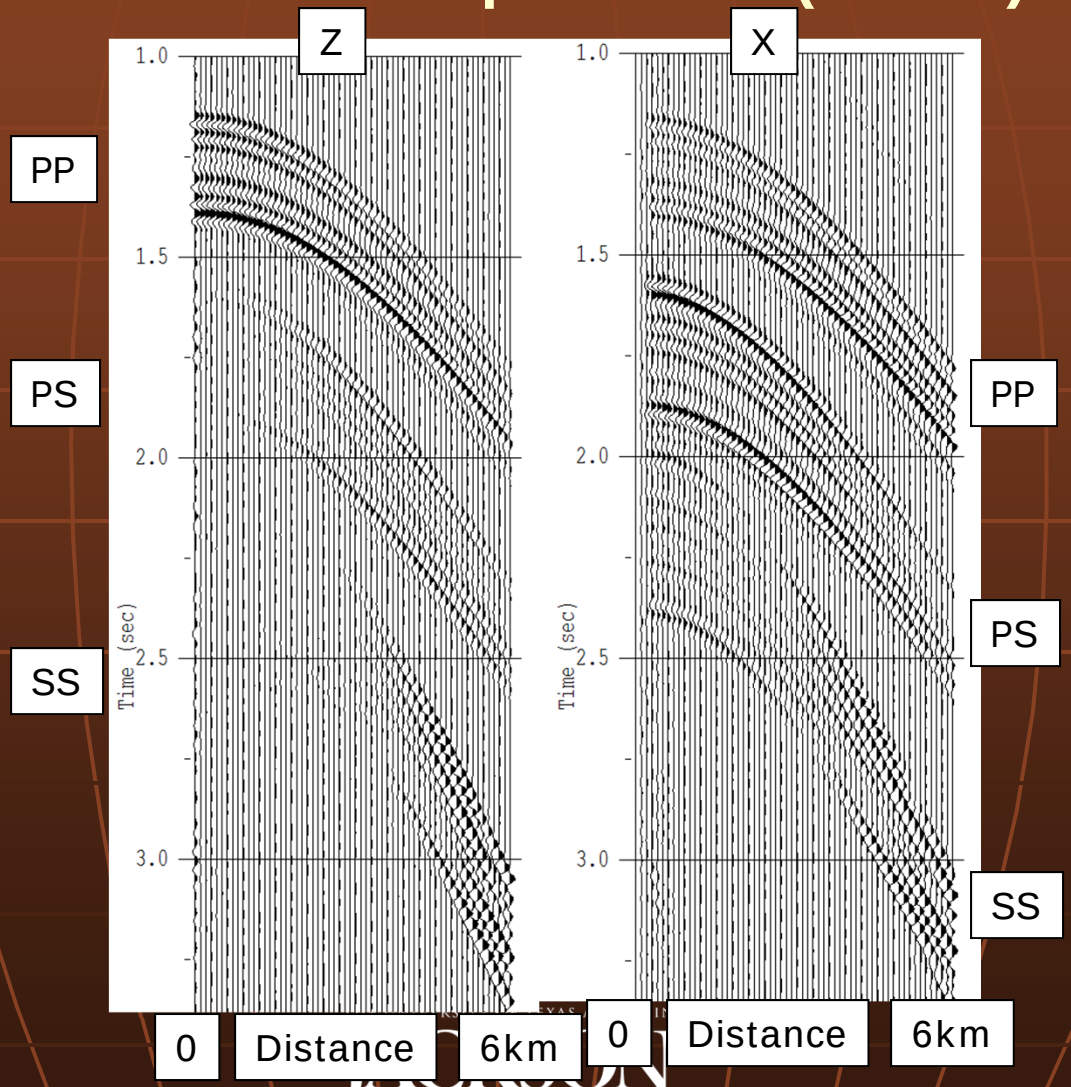
Synthetic Seismograms

Thick and Isotropic Model (z vs. x)



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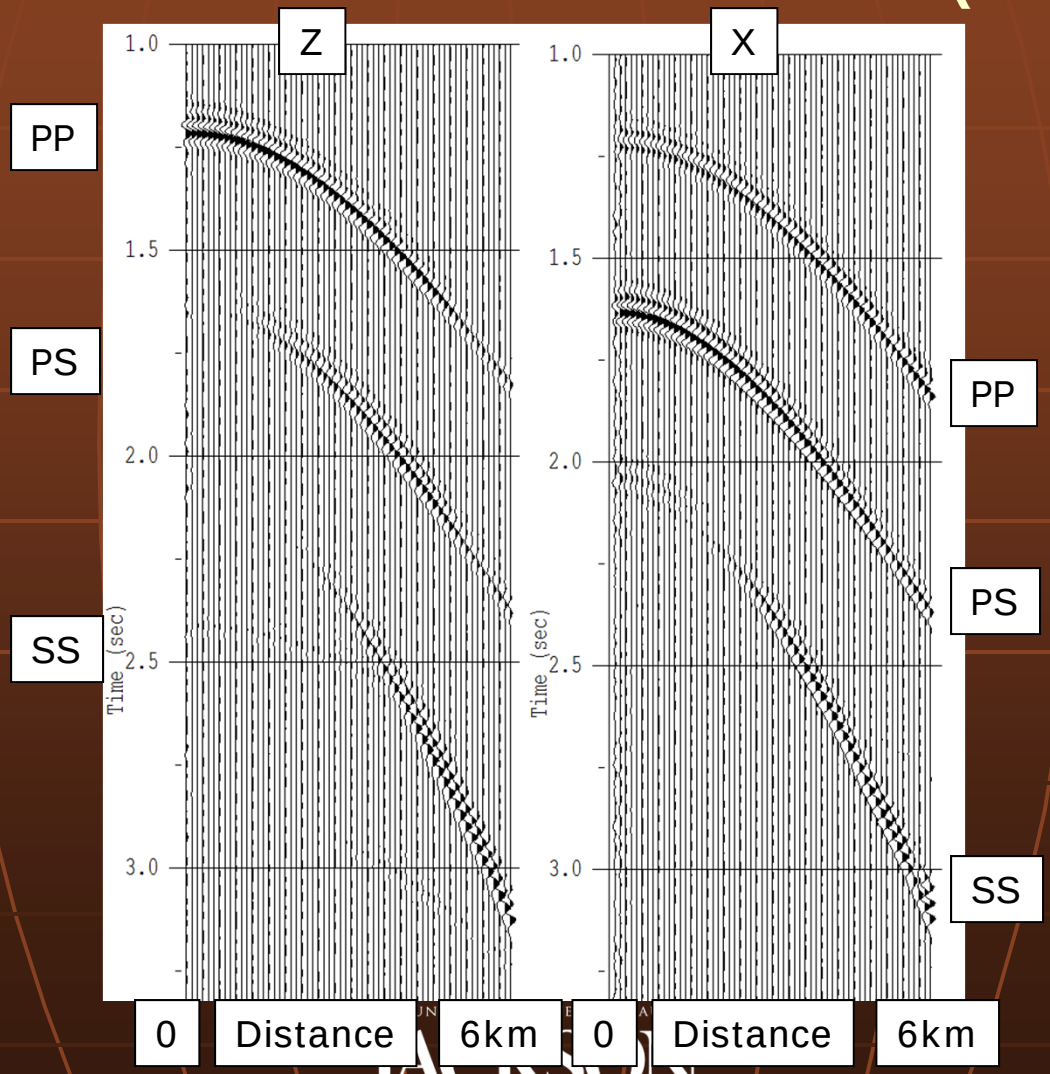
Synthetic Seismograms

Realistic Thickness and VTI Model (z vs. x)



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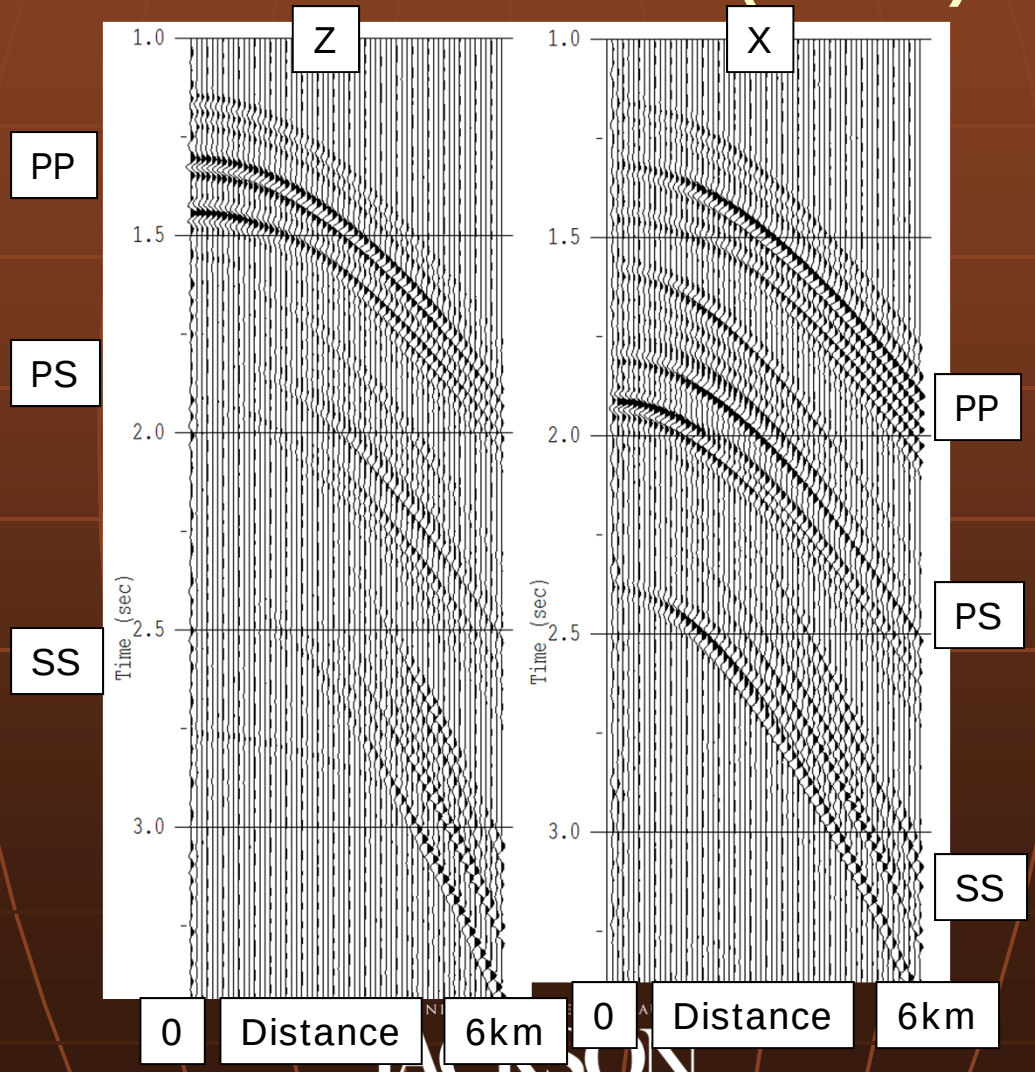
Synthetic Seismograms

Thick and VTI Model (z vs. x)



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Next Step

- Continue Modeling
- Clay Content
- Rock Brittleness

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