Field Laboratory for Emerging Stacked Unconventional Plays (ESUP)

VIRGINIA TECH

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ESUP Project Update – 8/23/2021

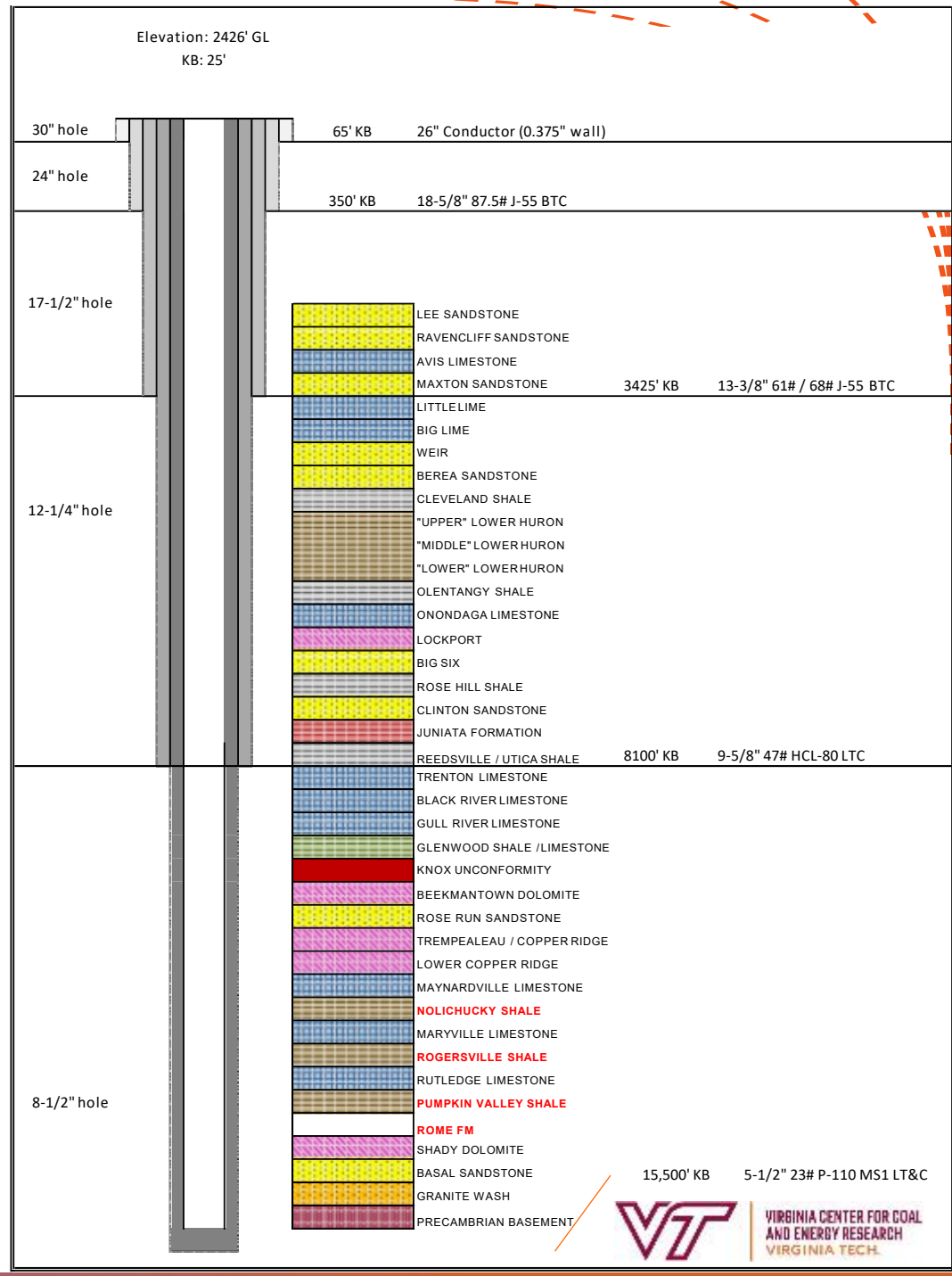
Acknowledgments

- Financial assistance for this work was provided by the U.S. Department of Energy through the National Energy Technology Laboratory's Program under Contract No. DE-FE0031576.
- Robert Vagnetti, U.S. DOE/NETL Project Officer
- Kevin Miller, James Ayers and the rest of the EnerVest team
- Advisory Stakeholder Group (ASG)

Objectives

Investigate and characterize the resource potential for multi-play production of emerging unconventional reservoirs in Central Appalachia.

- **Drill and selectively core a vertical Basement Test well**, drilled to approximately 15,000 ft., through the Conasauga-Rome Petroleum System
- **Well logging**, **core analysis**, **reservoir testing** and production information will be integrated with **reservoir simulations** to develop an assessment of the multi-play resource potential
- An assessment will be made of the multi-play resource potential and a recommended strategy advanced for prudent development that considers regional **environmental** and **socioeconomic impacts**.



Deep Activity / Production in the Vicinity of the Nora Field

14 total wells drilled deeper than the Devonian in Buchanan, Dickenson, Russell, and Wise Counties

Buchanan (3)

- Clinton Sandstone: 2
- Beekmantown Dol: 1

Dickenson (3)

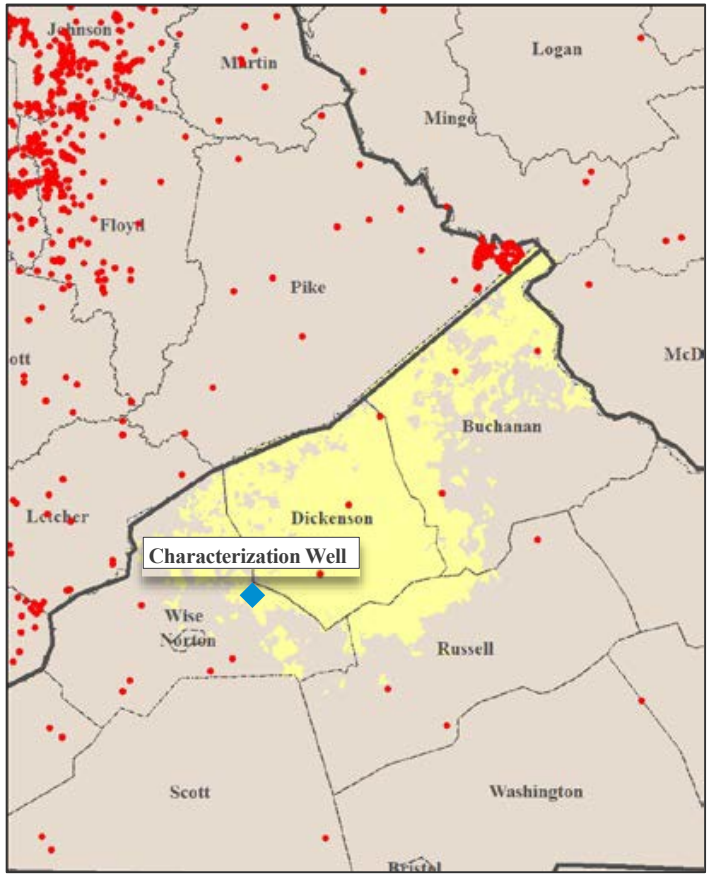
- Clinton Sandstone: 2
- Beekmantown Dol: 1

Russell (3)

- Trenton/ Black River: 1
- Rome Fm: 1
- Basement: 1

Wise (5)

- Clinton Sandstone: 2
- Reedsville Shale: 1
- Trenton/ Black River: 1
- Knox (?): 1



* 6 wells drilled to Clinton Ss. (~7,000 ft.)

* 8 wells drilled to Trenton Ls. Or deeper (~8,000 ft.)

Age	Formation	Depth	
Pa	Coalbed Methane (CBM)		✸
Mississippian	Ravencliff Ss	3,125	✸
	Maxton Ss	3,325	✸
	Big Lime Ls	4,260	✸
	Weir Fm	4,667	✸
	Berea Ss	5,184	✸
Devonian	Cleveland Shale	5,223	✸
	Lower Huron Shale	5,805	✸
	Rhinestreet Shale	6,165	✸
Devonian Base			
Silurian	Lockport Dol / Newburg / McKenzie Fm	6,600	✹
	Keefer Ss / Big Six Ss	6,647	✹
	Clinton Ss / Rose Hill Fm / Tuscarora Ss / Clinch Ss	7,000	✹
Ordovician	Trenton Ls	7,900	✸
	Black River Ls	8,550	✹
	Beekmantown Dol	9,851	✹
	Rose Run Ss	10,637	✹
	Trempealeau Dol / Copper Ridge Dol	10,817	✹
Conasauga Top			
Cambrian	Maynardville Ls	11,737	
	Nolichucky Shale	11,812	✹
	Maryville Ls	12,144	✹
	Rogersville Shale	12,886	✹
	Rutledge Ls	12,983	✹
	Pumpkin Valley Shale	13,224	✹
Rome Top			
	Rome Fm	13,314	✹
	Shady Dol	14,372	✹
	Granite Wash	15,019	
	PreCambrian Basement	15,144	

✸ Virginia Producing Formation Target
✹ Non-production Formation Targe

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Historic Conasauga / Rome Tests and Producers vs. Recent Rogersville Shale Activity

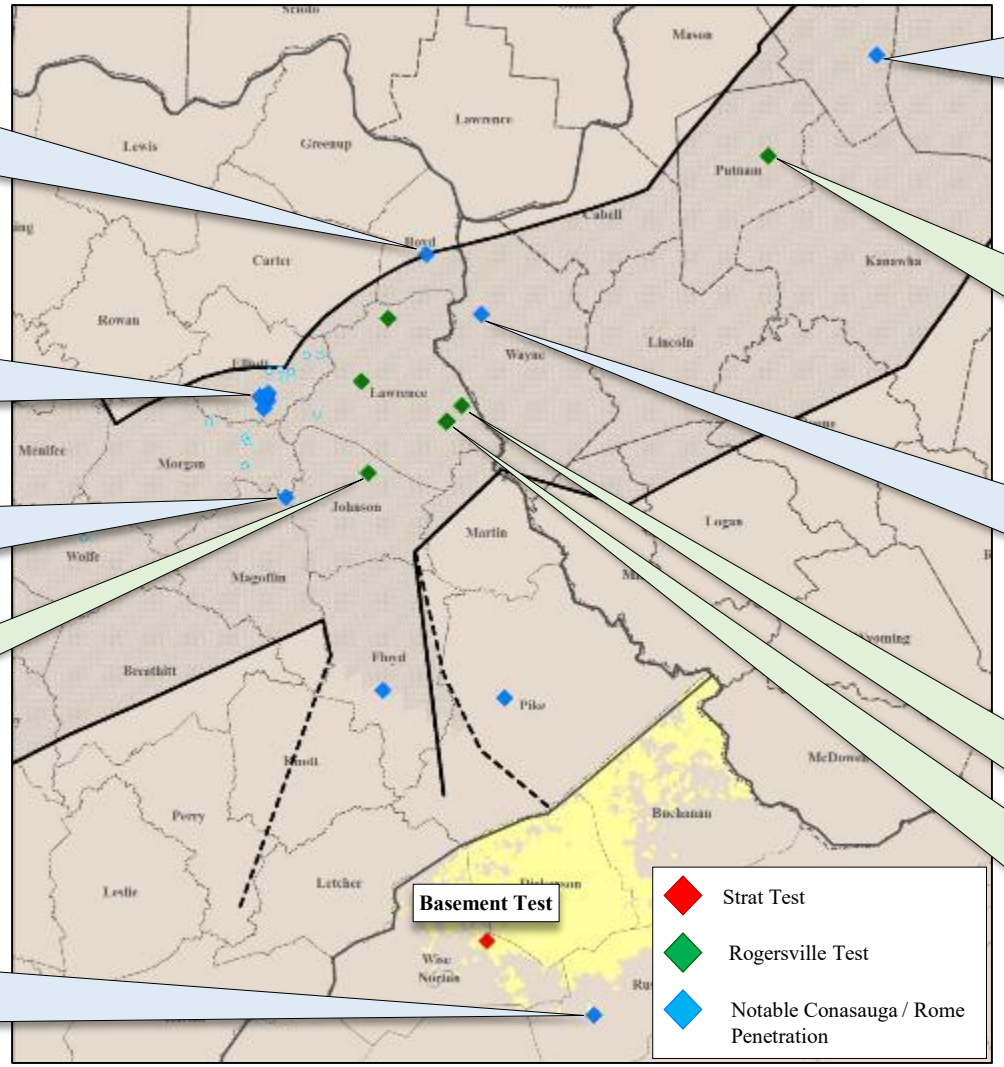
White #529
Inland Gas Co
Drilled 1967
Maryville Ls. Producer
- 90 MCFD / 32 BOPD
- 10,000 BO Produced
- Oil sourced from Rogersville Sh.

Homer Field
Discovered 1994
- Wells producer from sandstones within the Conasauga and Rome
- Structural Trap

Williams E #1
Ashland Exploration
Drilled 1985
- Nolichucky Sh. Producer
- Fractured Shale Reservoir
- 1.2 BCF / 42,000 BBL Condensate

EQT Prod Co #572360 H
Horizontal Tech Energy Co (EQT)
Horizontal Rogersville Test
TD Date: 6/7/2015
Fm @ TD: Rogersville Shale
Shut In

Price #1
Gulf Oil
Drilled 1977
- Indicates the presence of both Rogersville Shale and Pumpkin Valley Shale south of the proposed Characterization Well



McCoy #1
EXXON
Drilled 1975
Maryville Ls. Producer
- 6 – 9 MMCFD Natural
- .5 BCF Produced in 6 mo.
- Plugged: 9/9/1978
- Rogersville TOC: .29-.57

Amherst Industries #50
Cabot Oil & Gas
Vertical Rogersville Test
TD Date: 10/27/2014
- Maryville Ls. Producer
- 2.2 MMCFD (1st Month Avg.)
- CUM: 339,819 MCF

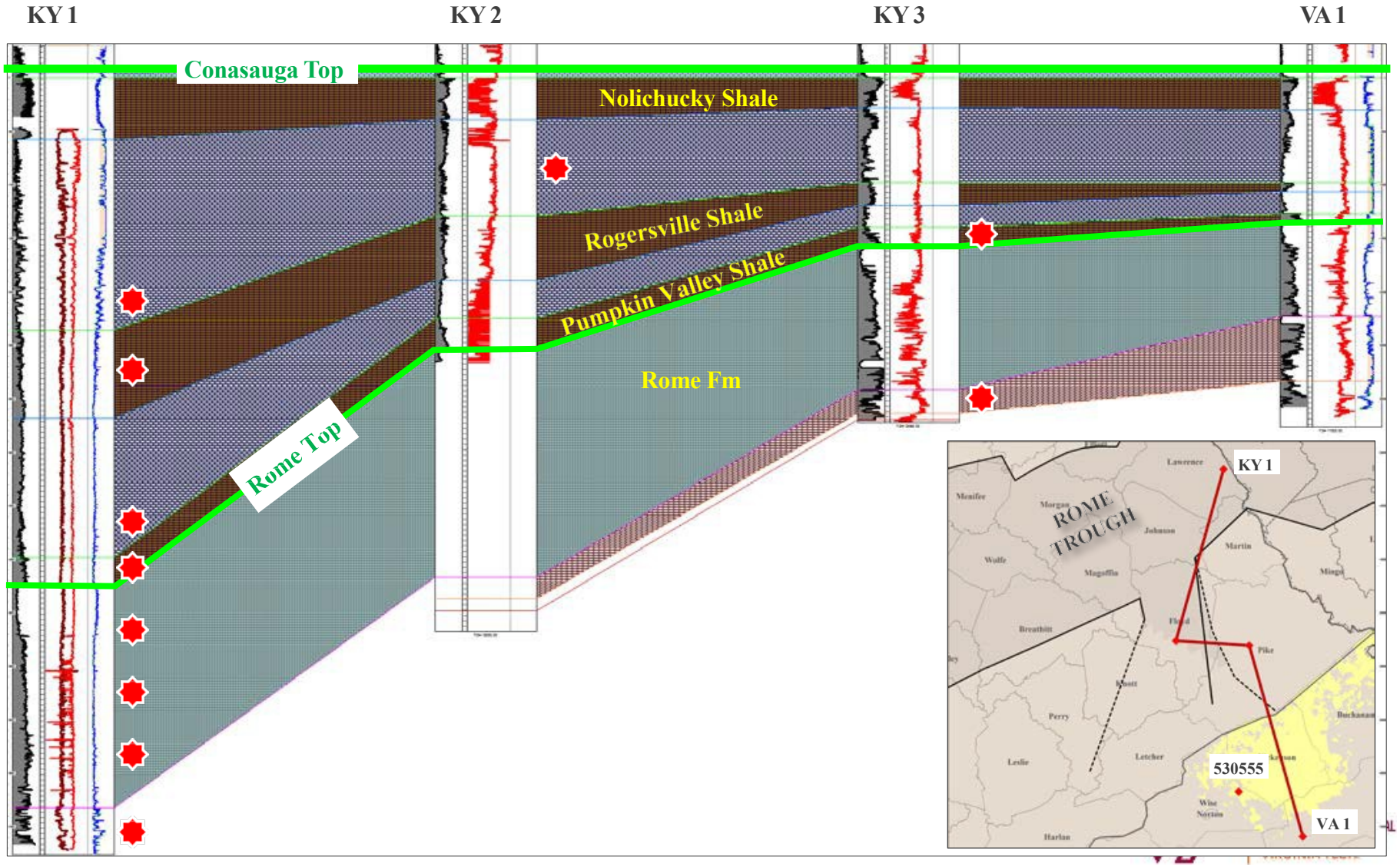
Smith JP #1
EXXON
Drilled 1974
- Excellent hydrocarbon shows
- Analysis indicates Rogersville is likely oil source for the White #529
- Rogersville TOC: 1.2-4.4

JH Northrup Estates #LAW 1
Chesapeake Appalachia
Vertical Strat Test
TD Date: 9/3/2015
- Excellent hydrocarbon shows in Maryville Ls., Rogersville Shale, Pumpkin Valley Shale & Rome Fm

Walbridge Holdings #1H
Bruin Exploration (Cimarex)
Horizontal Rogersville Test
TD Date: 2/23/2017
Fm @ TD: Rogersville Shale
Temporarily Abandoned

Conasauga and Rome Formation Oil and Gas Shows

- **KY1: Northrup #Law1 (2015)**
  - Rogersville Test Well
  - Drilled through Rome Fm
  - Gas shows and fluorescence / milky cut (oil) recorded from Maryville Ls through Rome Fm
- **KY2: Hall #1 (1974)**
  - Basement Test
  - Gas show in Maryville Ls (8,550')
- **KY3: Stratton #1 (1971)**
  - Basement Test
  - Rome Trough Consortium data indicates gas shows in the Pumpkin Valley Shale and Shady Dolomite
- **VA1: Price #1 (1977)**
  - Gas shows reported in the Trenton Ls
  - No shows reported in the Conasauga or Rome



ESUP Field Site and Drilling Operations

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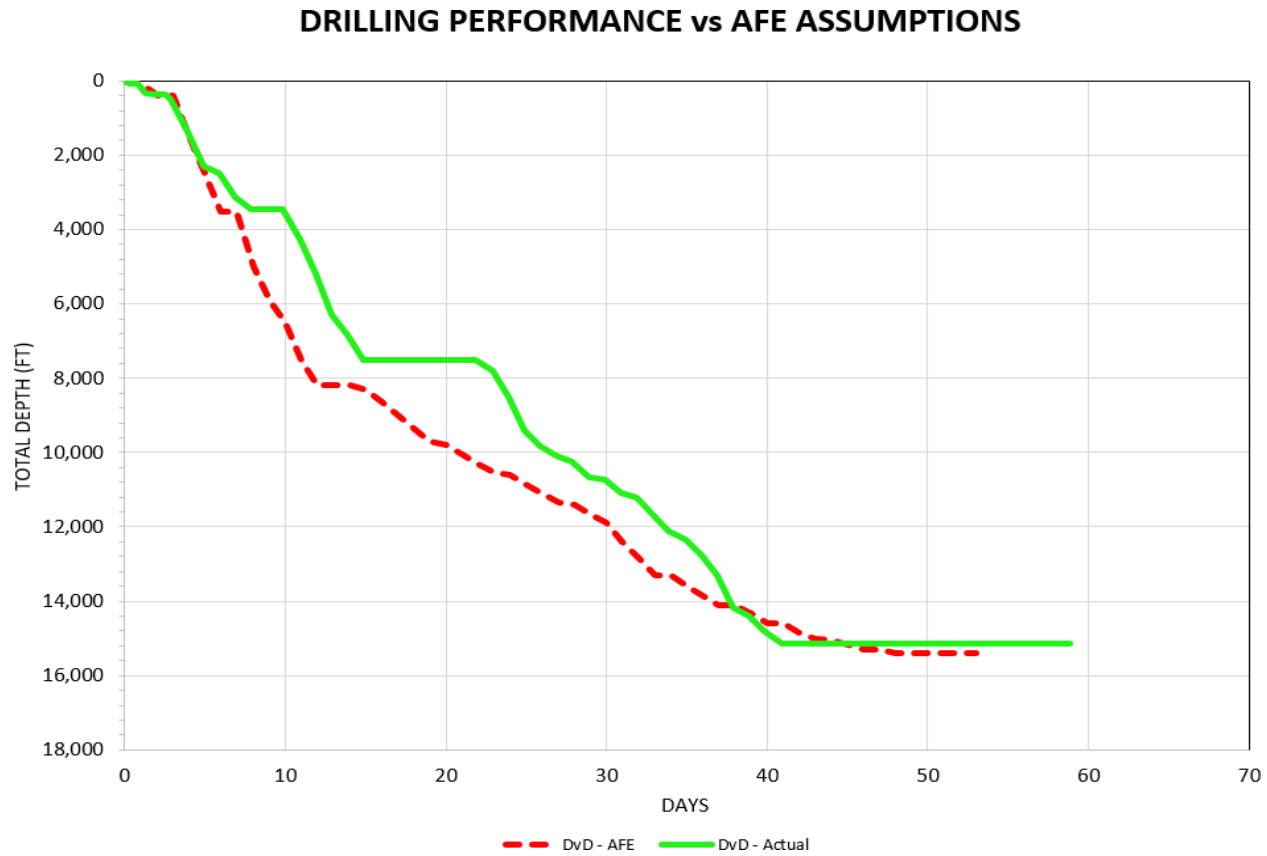
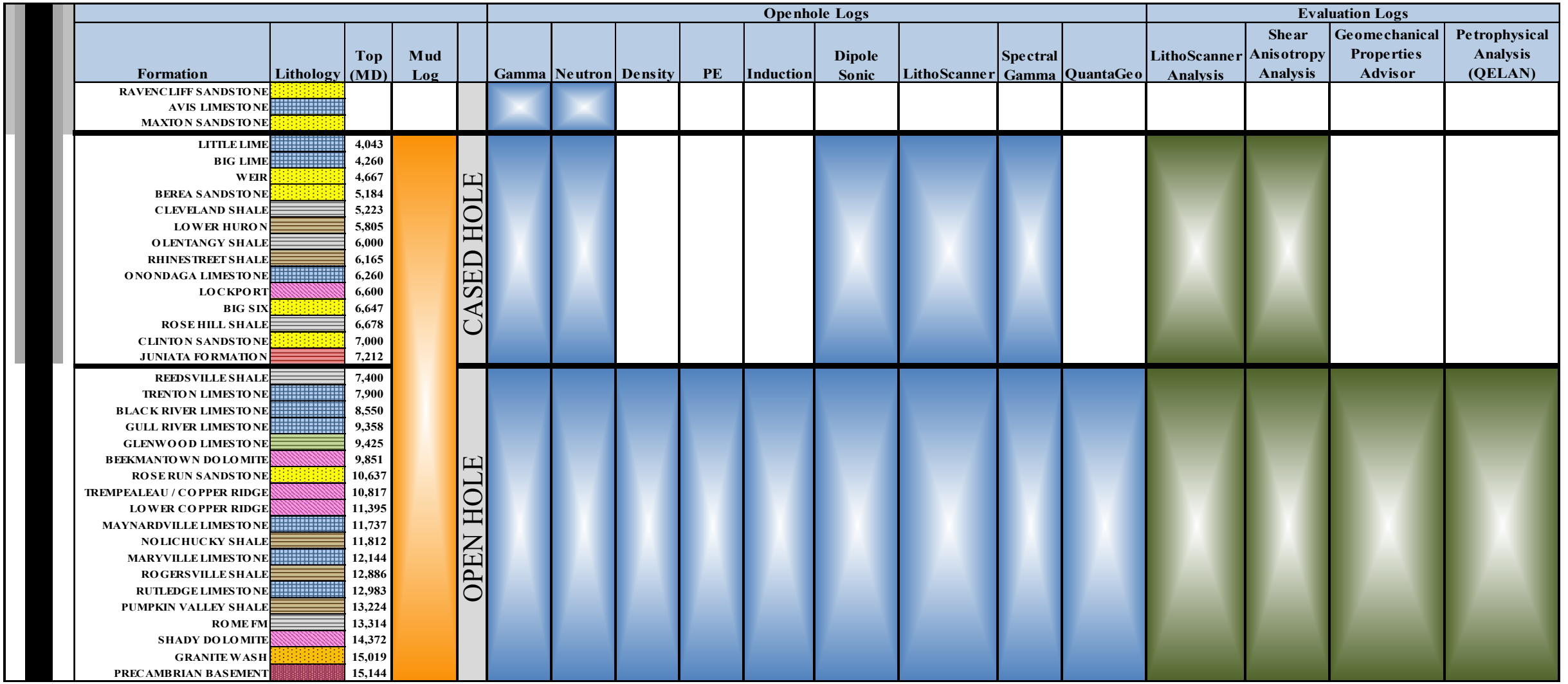
V-530555 Drilling Time Curve



- Target of Pre-Cambrian basement for full section characterization successfully reached.
- Time required to reach target formation was less than forecasted.
  - AFE'd @ 48 days, but completed in 42 days. (Inclusive of NPT time in previous slide).
- Accurately identified and predicted geo-hazards, though some still gave us trouble
- Successfully completed operations without any injury, illness, or environmental issues.
  - Over 30,000 man hours worked

Wireline and Mud Logging Data Gathered from the 530555

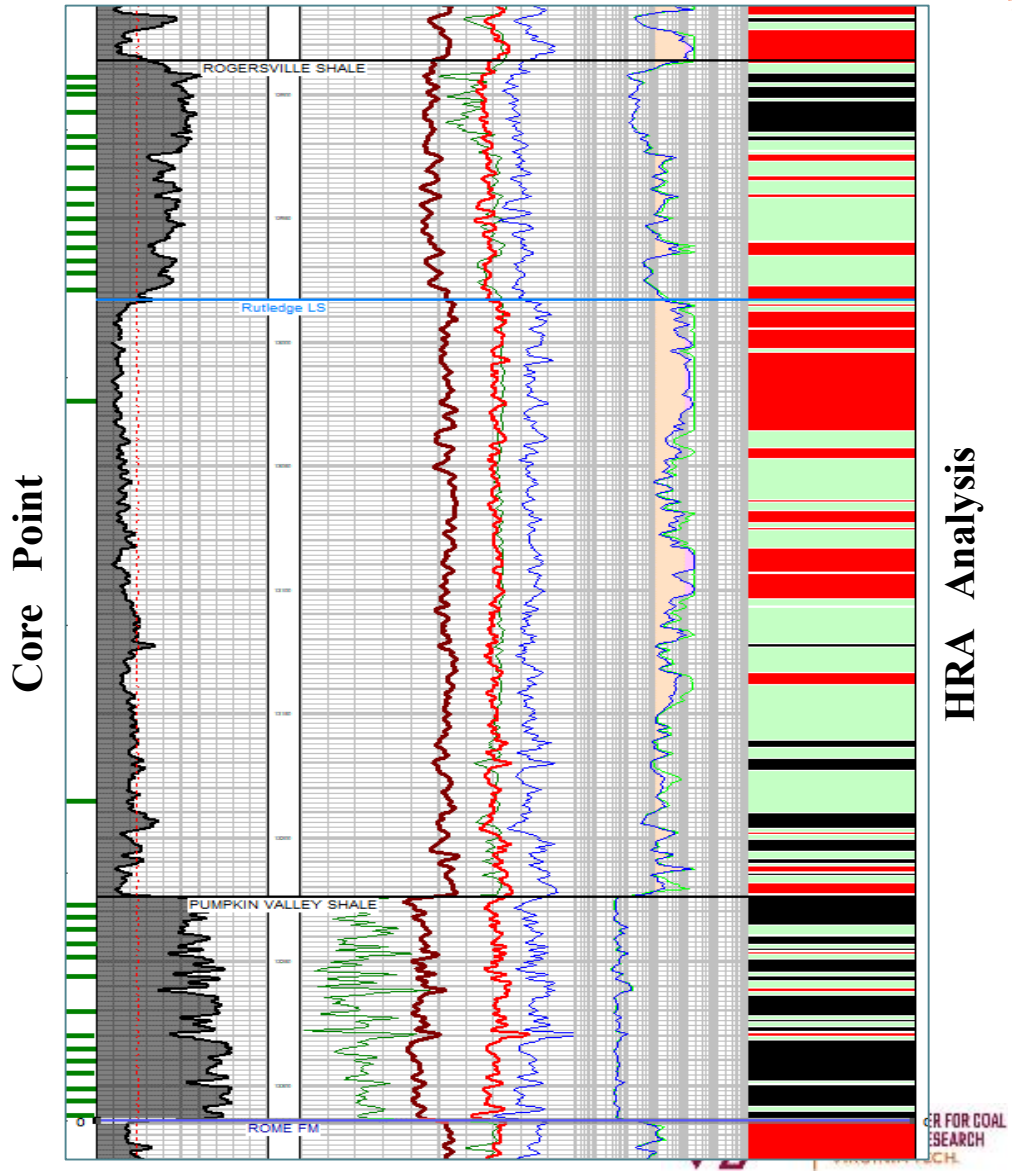


Core Point Determination

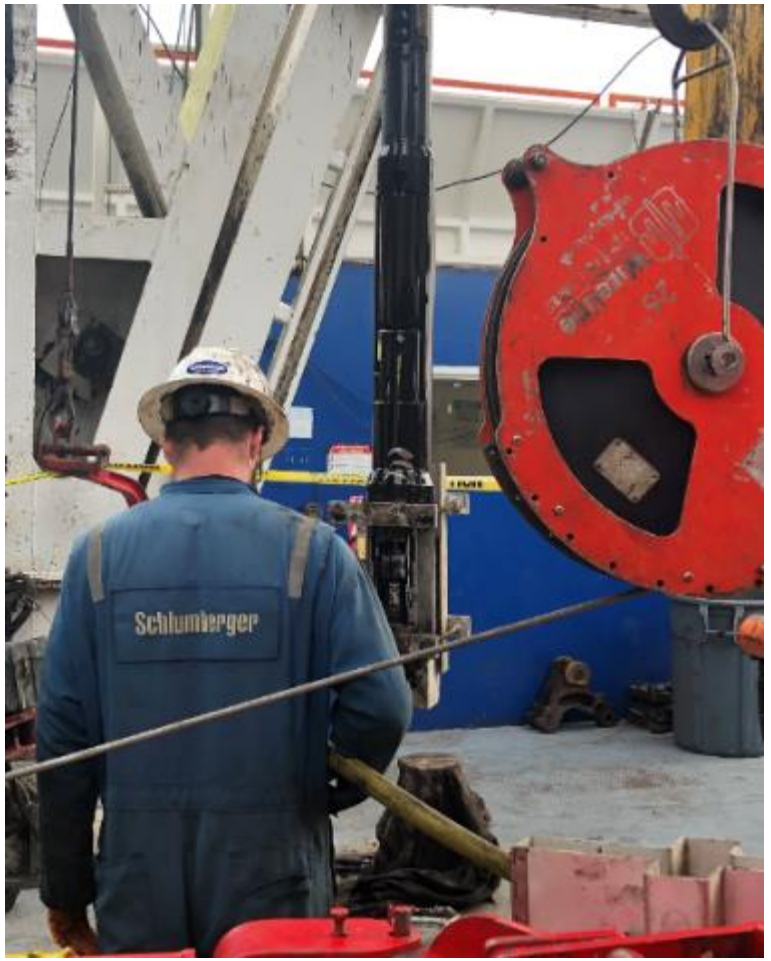
- A Heterogeneous Rock Analysis (HRA) was conducted to evaluate the variability of log responses based on Triple Combo data and identify packages (Facies) of like rock and ensure optimal distribution of the Rotary Sidewall Cores (RSWC).

- The HRA was performed on 10 individual formations of interest:

  - Trenton / Black River Ls
  - Glenwood through Rose Run
  - Nolichucky Shale
  - Maryville Limestone
  - Rogersville Shale
  - Rutledge Limestone
  - Pumpkin Valley Shale
  - Rome Fm
  - Shady Dolomite
  - Granite Wash



Core Recovery



Coring Summary

FORMATION	UNIQUE CORE POINT ATTEMPTED	UNIQUE CORE POINT RECOVERED	# OF RSWC RECOVERED	COMMENTS
REEDSVILLE	1	0	0	
TRENTON	7	4	4	
BLACK RIVER	2	1	1	
GLENWOOD / WELLS CREEK	4	4	4	
BEEKMANTOWN	4	3	3	
ROSE RUN	3	3	4	Duplicate core recovered at 10,708'
MAYNARDVILLE	1	1	1	
NOLICHUCKY	7	4	4	
MARYVILLE	17	15	15	
ROGERSVILLE	16	16	16	
RUTLEDGE	2	2	2	
PUMPKIN VALLEY	16	15	17	Duplicate core recovered at 13,306' & 13,312'
ROME	9	7	7	
SHADY DOLOMITE	9	8	8	
GRANITE WASH	4	4	4	
TOTAL	102	87	90	

RECOVERY RATE: **85%**

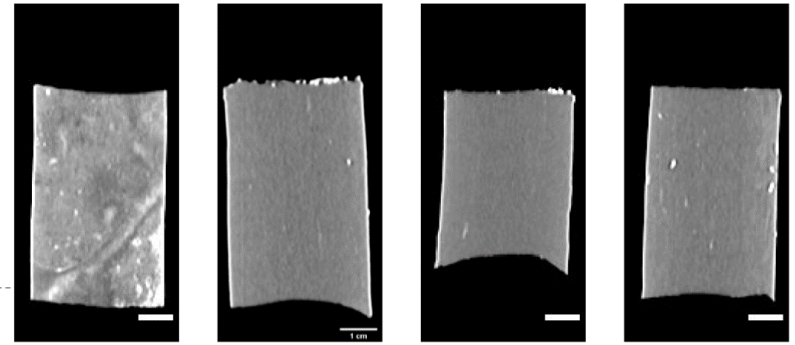
RSWC Data Summary

ANALYSIS DESCRIPTION	STATUS	# PROPOSED	# RECEIVED
Bulk Density	COMPLETE	90	90
Photagraphy (W/UV)	COMPLETE	90	90
Thin Section / SEM Analysis	COMPLETE	26	26
XRD	COMPLETE	45	45
TOC (LECO)	COMPLETE	45	45
Rock Eval	COMPLETE	85	85
TRA Porosity	COMPLETE	45	45
TRA Pulse Decay Perm	COMPLETE	45	41
TRA Pressure Decay Perm	COMPLETE	45	45

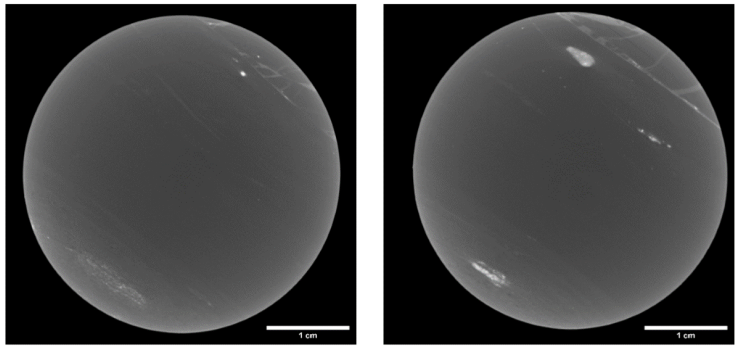
CT Scanning National Energy Technology Laboratory (NETL)

work led by Dustin Crandall, NETL

- 90 cores in Medical CT and 11 high-res Industrial CT scanner

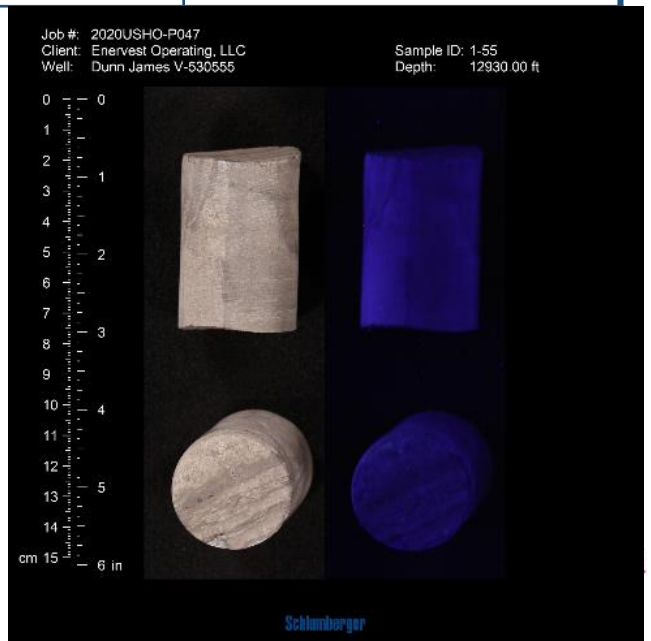


13,270 ft Core 34 | 13,280 ft Core 32 | 13,285 ft Core 31 | 13,290 ft Core 29

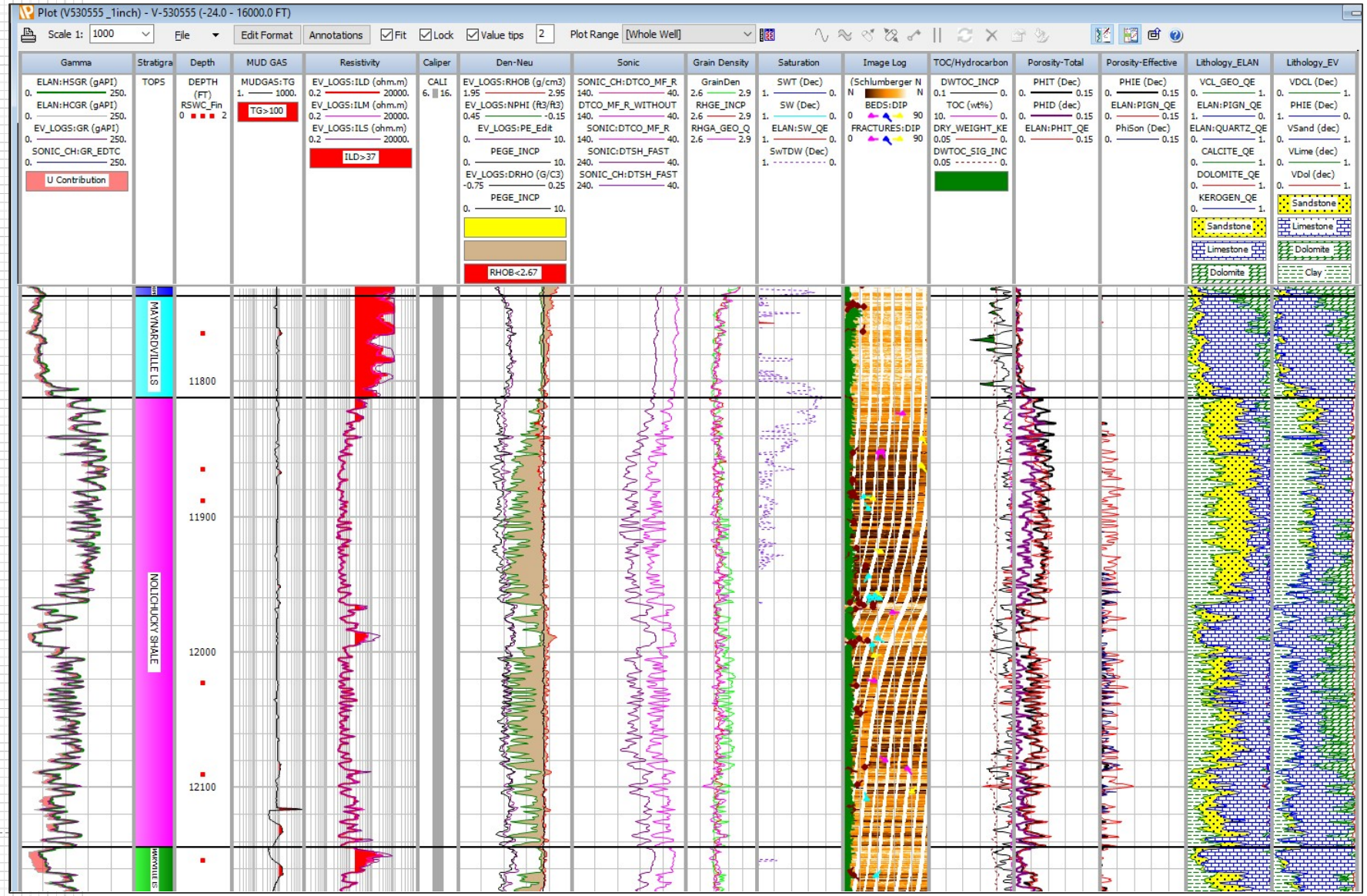


CT Slice 1288/4000 | CT Slice 2768/4000

Run 1, Core 17, 14,000 ft



Nolichucky Shale



Observations:

- Moderate to high clay content, but low U content
- Low Res and low mud gas
- High Res corresponds to some cleaner tight carbonate

Avg. Clay Volume: 28 - 35%

Average Porosity: ~4%

- Dominantly clay derived

Water Saturation: 100%

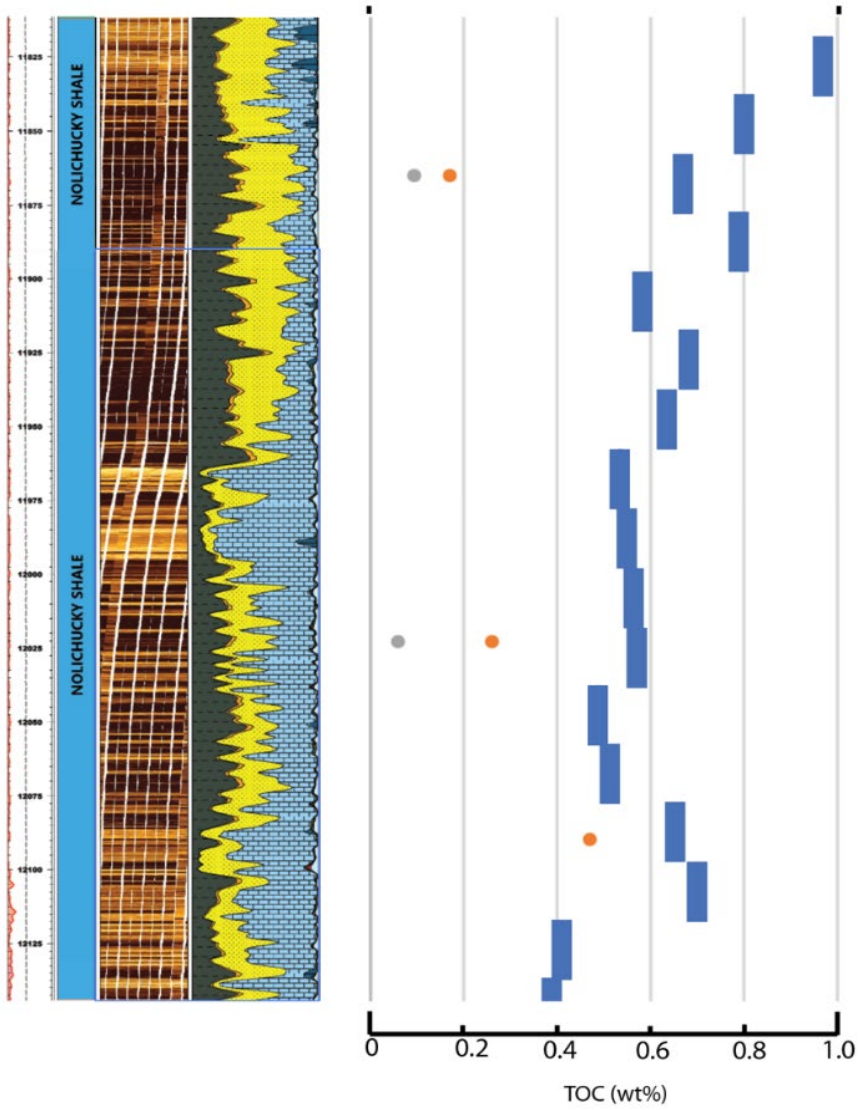
TOC: No indication of elevated TOC from U, RES, RHOB or Lithoscanner

Fractures: Few open and healed, some micro-faults in tight carbonate streaks

Key Interpretive Differences:

- Lithoscanner indicates more quartz and less clay/dolomite than 3 mineral model → higher matrix density for 3min model
- SLB uses Den-Neu porosity whereas EV model using density porosity

Nolichucky Shale



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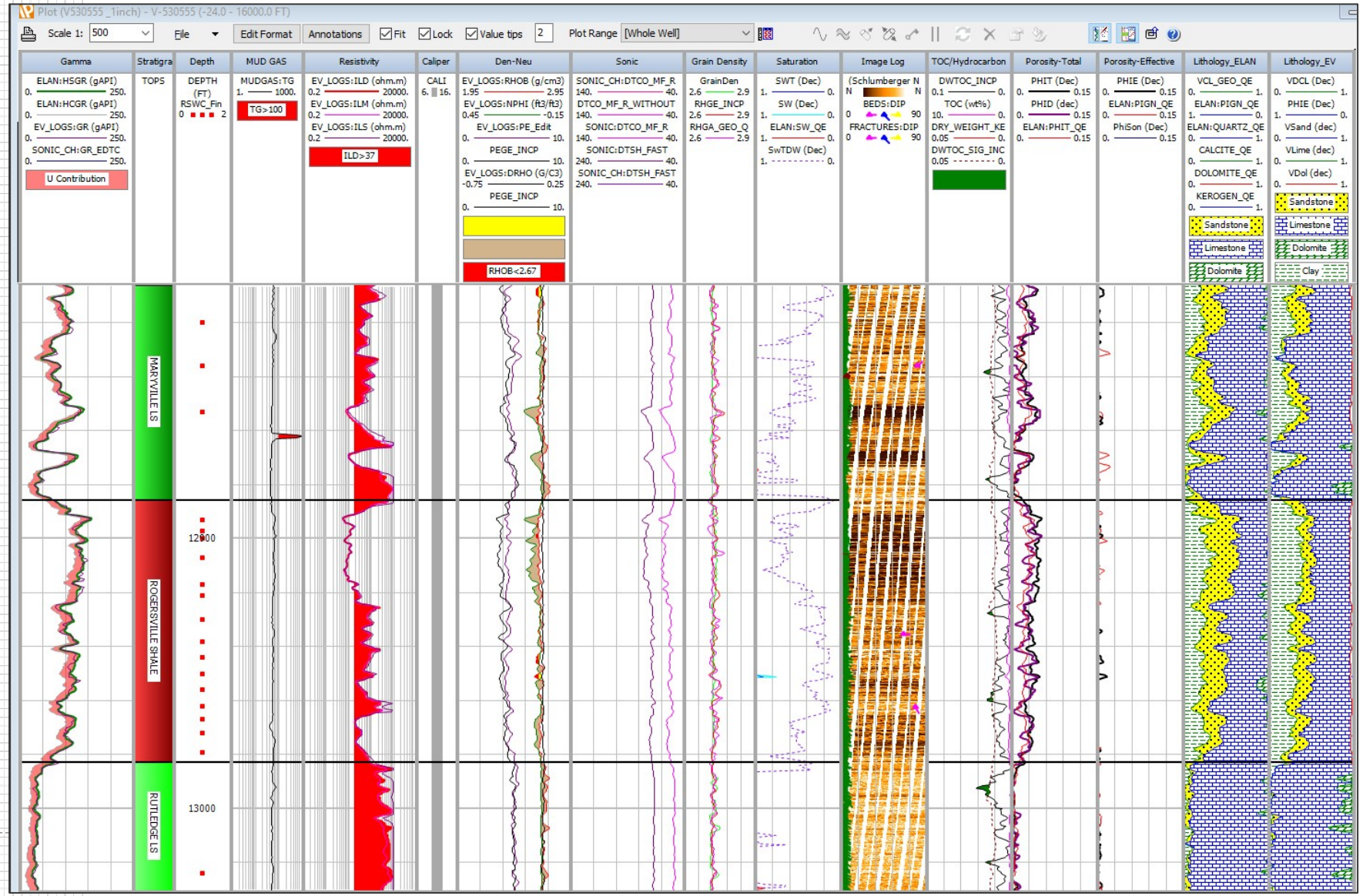
Rogersville Shale



Observations:

- Moderate clay content, but low U content
- Moderate to High Res, but low mud gas

Clay Volume: 22 - 34%

Average Porosity: 2.5 - 3.5%

- All clay derived

Water Saturation: 100%

- DW lower saturation is unrealistic given PHIT and clay content

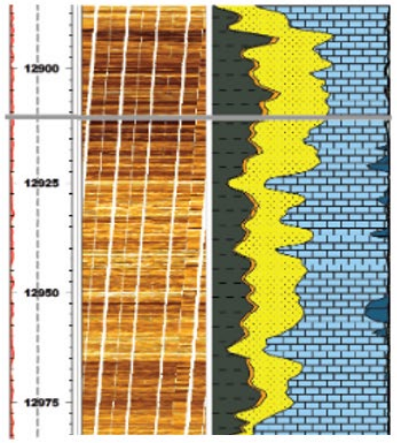
TOC: No indication of elevated TOC from U, RES, RHOB or Lithoscanner

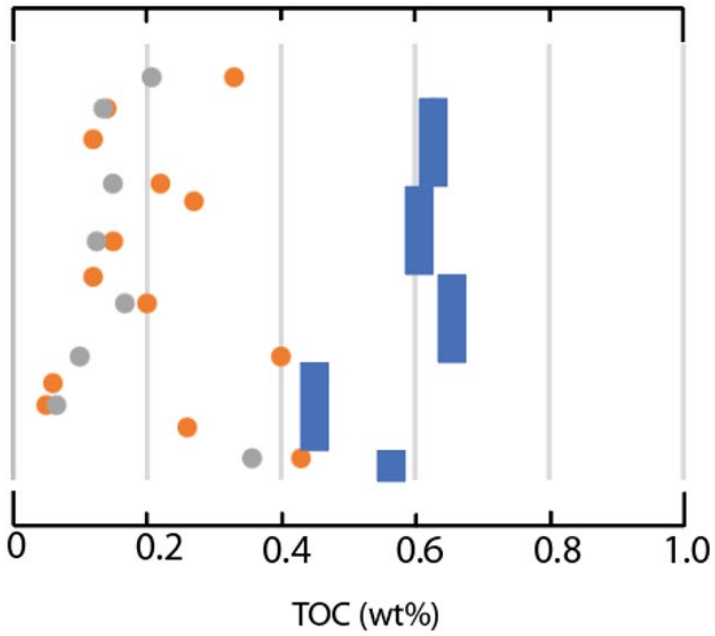
Fractures: Sparse (2 open)

Key Interpretive Differences:

- EV interpretation predicts slightly more clay, so slightly higher PHIT

Rogersville Shale





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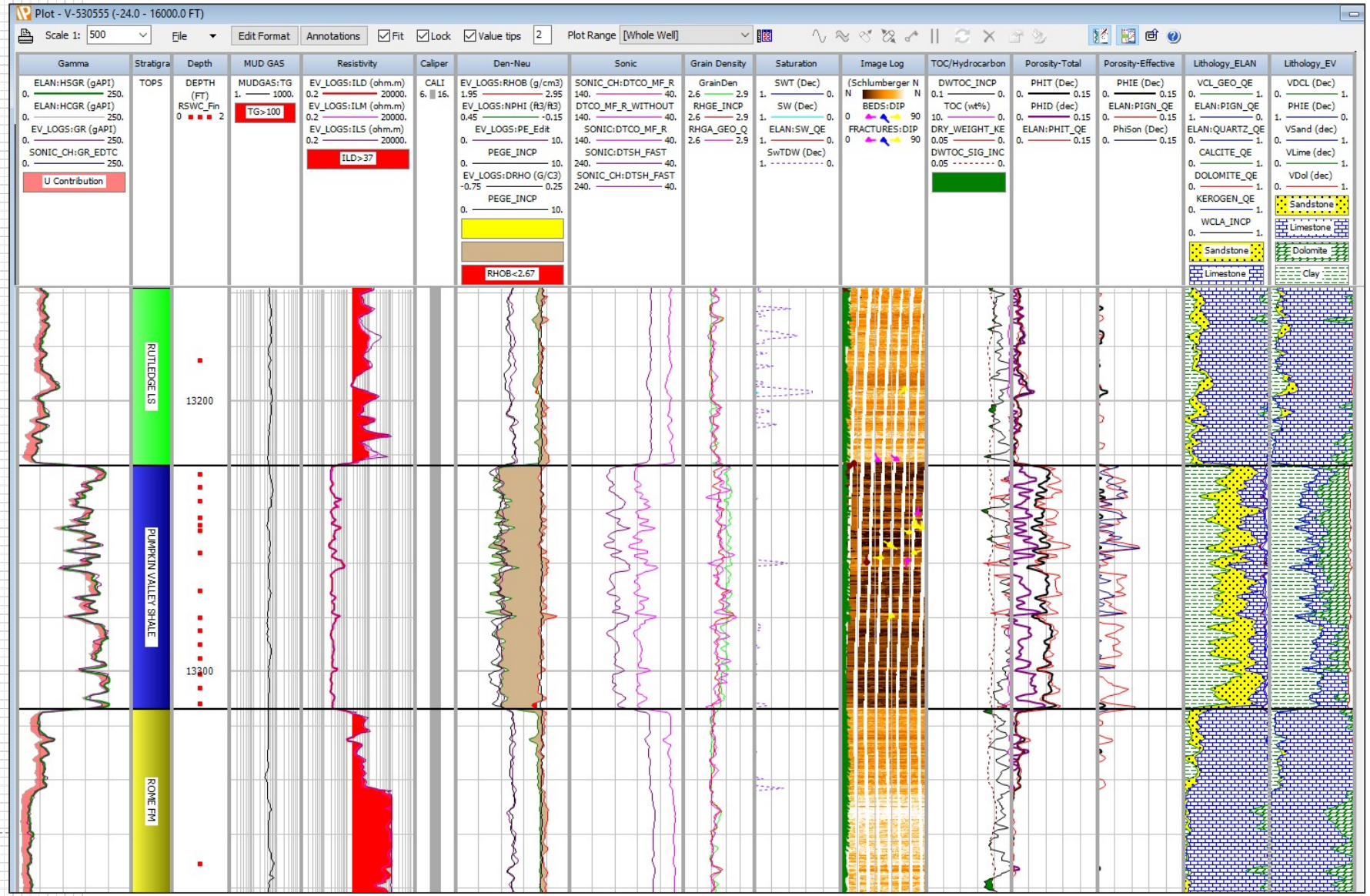
Pumpkin Valley Shale



Observations:

- High clay content, but low U content
- Low Res and low mud gas

Clay Volume: 42 - 54%

Average Porosity: 5.5 - 6.5%

- All clay derived

Water Saturation: 100%

TOC: No indication of elevated TOC from U, RES, RHOB or Lithoscanner

Fractures: Few open and healed

Key Interpretive Differences:

- Lithoscanner indicates more quartz and less dolomite than 3 mineral model → higher matrix density for 3min model
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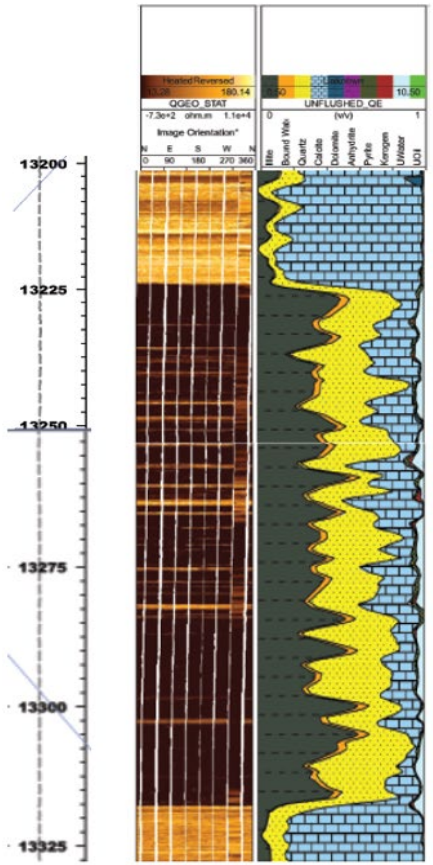

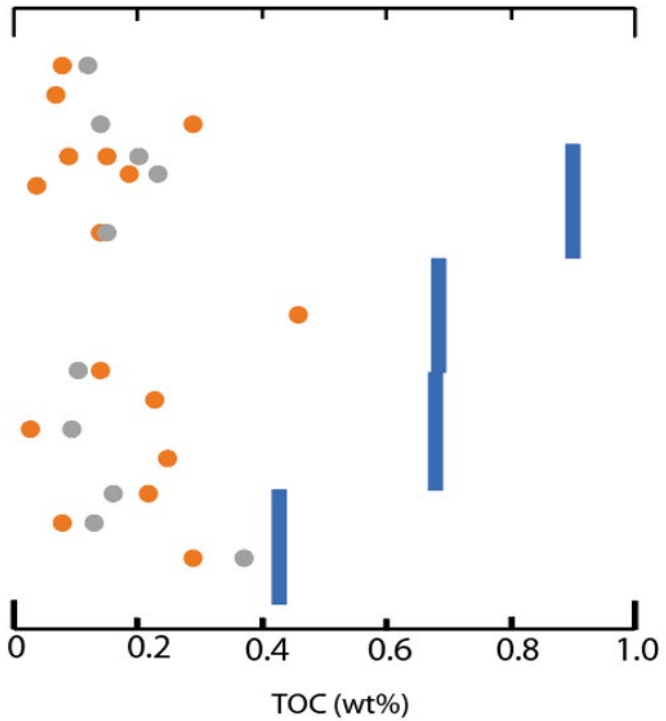

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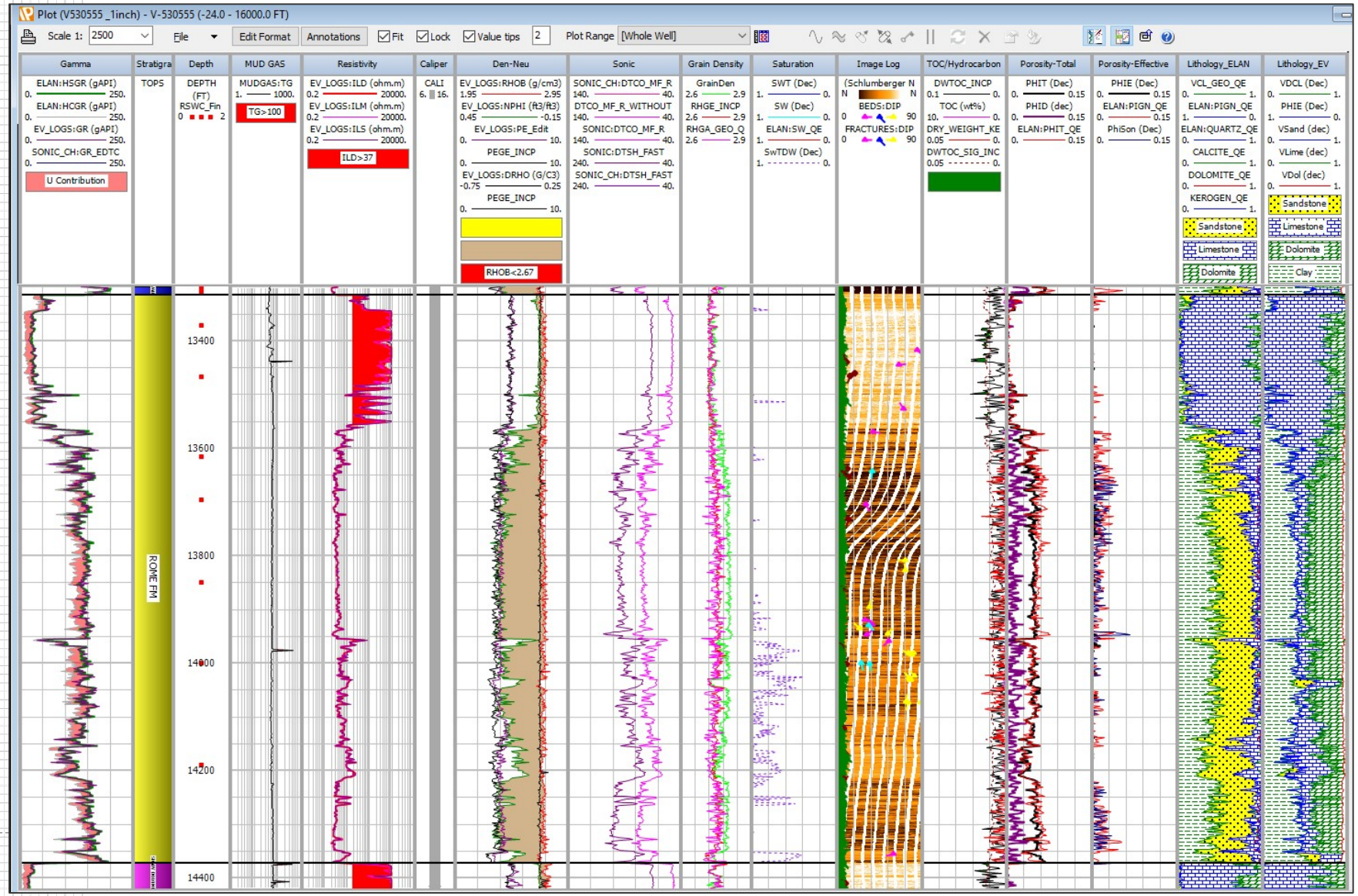
Rome Formation



Observations:

- Moderate clay content, but low U content
- High Res in tight upper carbonate, low in shale

Clay Volume: 32 - 34%

Average Porosity: 0% in clean carb and 4 -6% in shale

- Dominantly clay derived

Water Saturation: 100%

- DW lower saturation (60-80%) could be possible given PHIT and VCL

TOC: No indication of elevated TOC from U, RES, RHOB or Lithoscanner

Fractures: Cluster of open, healed and a few microfaults

Key Interpretive Differences:

- Good agreement on clay but EV model again predicts more dolomite instead of quartz → EV model has higher grain density but porosity interpretation is nearly identical due to higher neutron porosity

Results to Date – Wireline Interpretation

FORMATION	MUD GAS (units)		CLAY VOLUME (%)	POROSITY (%)	WATER SATURATION	TOC
	BACKGROUND	MAX				
NOLICHUCKY SHALE	75	112	28 - 35	4	100	No indication of elevated TOC from U, RES, RHOB or Lithoscanner
ROGERSVILLE SHALE	50	73	22 - 34	2.5 - 3.5	100	No indication of elevated TOC from U, RES, RHOB or Lithoscanner
PUMPKIN VALLEY SHALE	45	68	42 - 54	5.5 - 6.5	100	No indication of elevated TOC from U, RES, RHOB or Lithoscanner
ROME FORMATION	55	74	32 - 34	4 - 6	100	No indication of elevated TOC from U, RES, RHOB or Lithoscanner

Gas / Oil Shows:

- Gas shows were unimpressive with the largest gas shows in Knox section (~350 unit Max)
- Oil shows were limited to the basal Shady Dolomite and Granite Wash where the greatest fluorescence and milky cut was experienced in the upper 50 feet of the GW

Porosity:

- Porosity within the Target Interval was low (see detail above), ranging from 2.5 – 6.5% throughout the Conasauga and Rome Shales

Water Saturation:

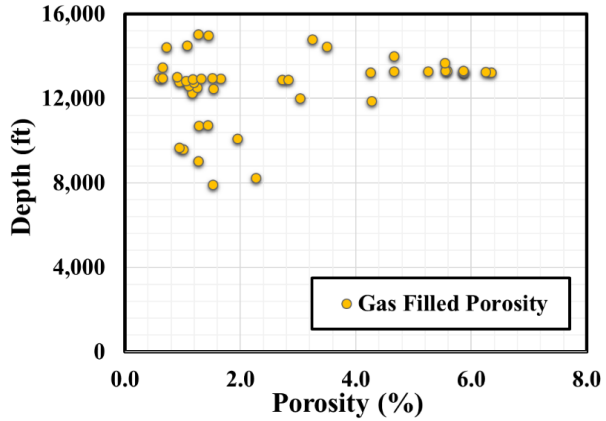
- Water saturation within the Target Interval was high (see detail above), at or approaching 100%

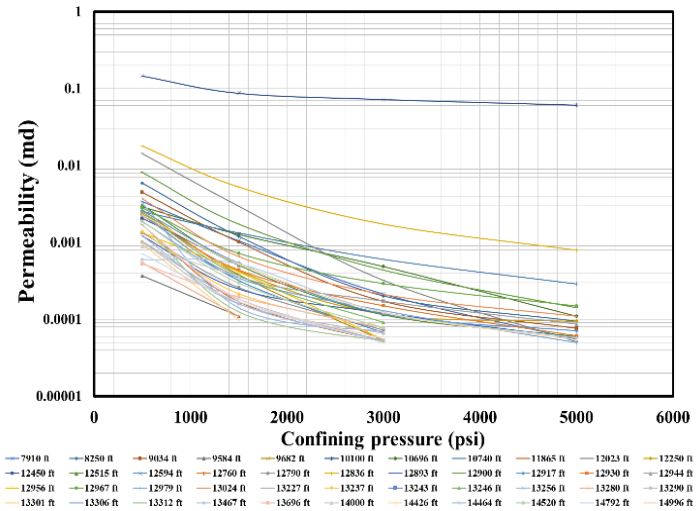
TOC:

- Wireline data provides no indication of elevated TOC within the Target Interval

Fractures:

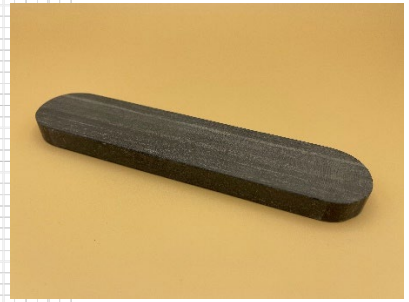
- Relatively low intensity fractured interval. 419 natural fractures were identified (without preferred strike trend)





On-going Research

- Sedimentology and Geochemistry
- Core Analysis (Fracture Conductivity & Permeability)

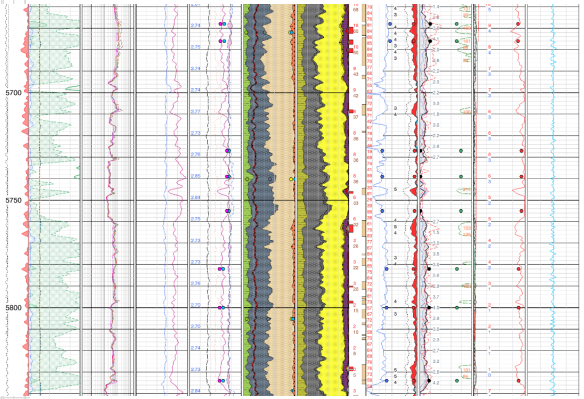


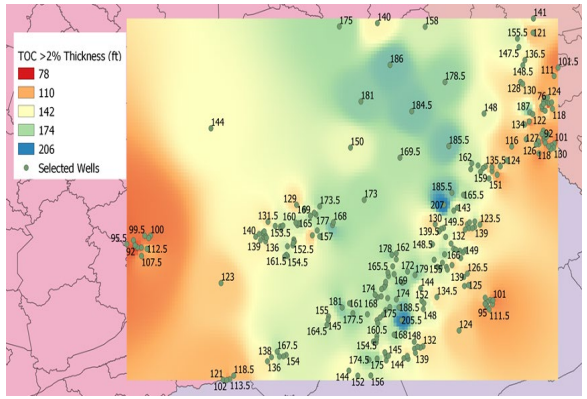
a) before experiment

b) after experiment with monolayer proppant

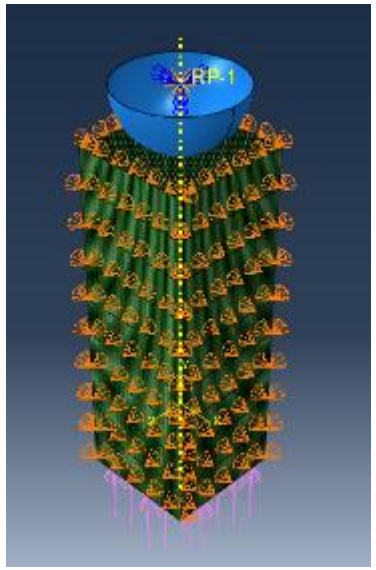
c) after experiment with 10-layer proppant

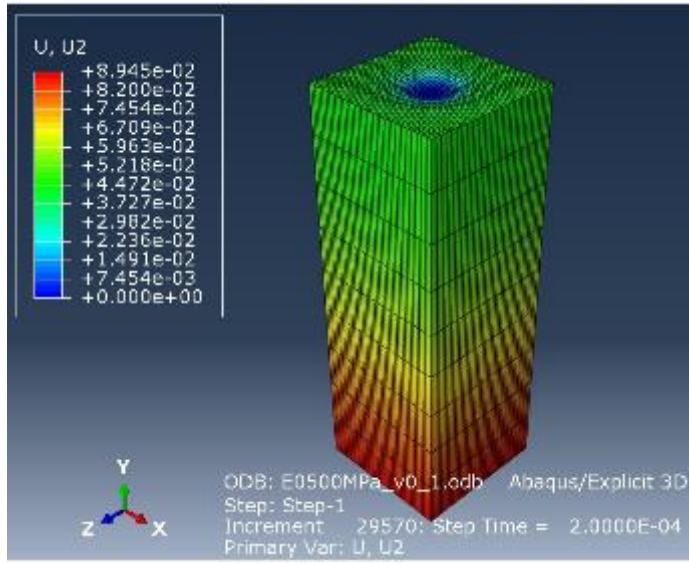
- Log Analysis and Sweet Spot Identification





- Reservoir Modeling and Proppant Compaction





Dissemination of Results

- Advisory Stakeholder Group includes community leaders
- Local outreach events completed, and future ones planed
- Multiple press releases by DOE and VT
- Project Website: www.esup.energy.vt.edu
- 2 MS and 2 PhD Degrees completed
- 1 MS and 1 PhD Degrees in progress
- Multiple journal and conference publications

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