MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

northeast NATURAL ENERGY

THE OHIO STATE UNIVERSITY

WestVirginiaUniversity

Schlumberger

Department of Geology and Geography

Presented by: Tim Carr
West Virginia University
Pittsburgh - August 18, 2016

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY
MSEEL

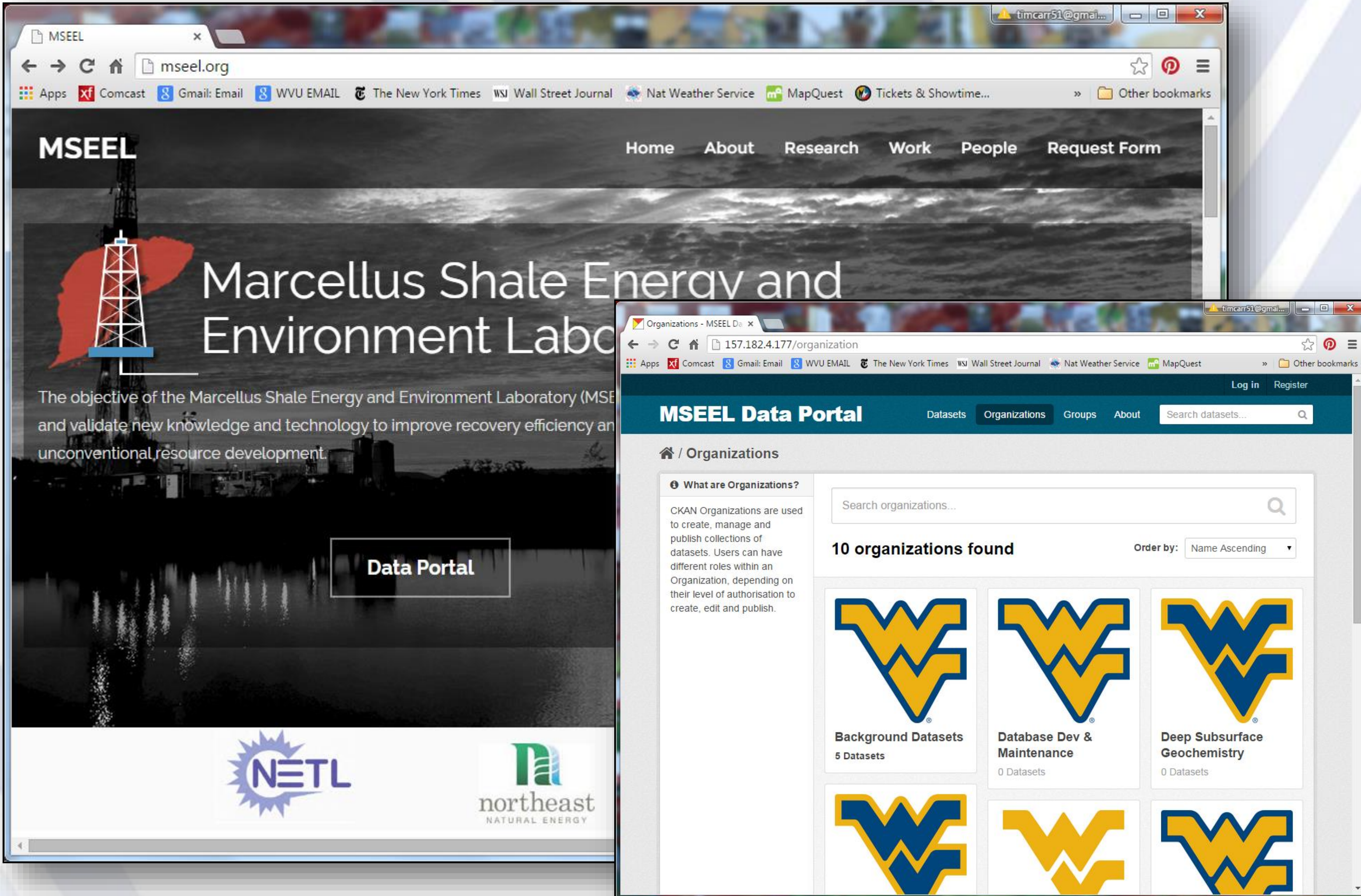
The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development

MSEEL
Marcellus Shale Energy & Environment Laboratory
Northeast Natural Energy
West Virginia University

MSEEL Vision

- Demonstrate the Best Practices to Drill, Complete and Produce a New Horizontal Well That Minimizes Any Environmental/Societal Costs While Maximizing Economic Productivity
- Monitor and Document Impacts in a Controlled Environment
  - Greenhouse Gas Emissions
  - Local Air Pollution
  - Water Supply and Quality
  - Noise and Activity
  - Societal Impacts
- Develop New Technologies to Maximize Production
  - Microseismic Monitoring
  - Production Monitoring
  - Advanced Logging
  - Simulation
- Develop New Scientific and Engineering Approaches to Apply to Multi-disciplinary and Multi-institutional Natural Resource Studies

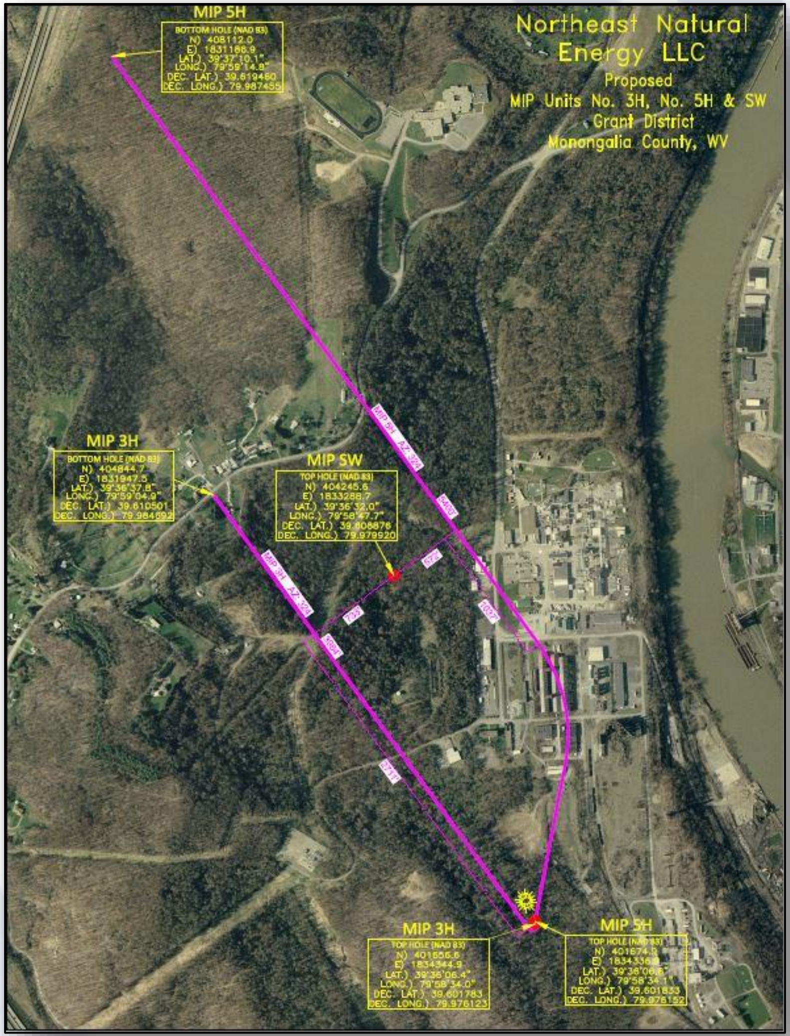
MSEEL Site

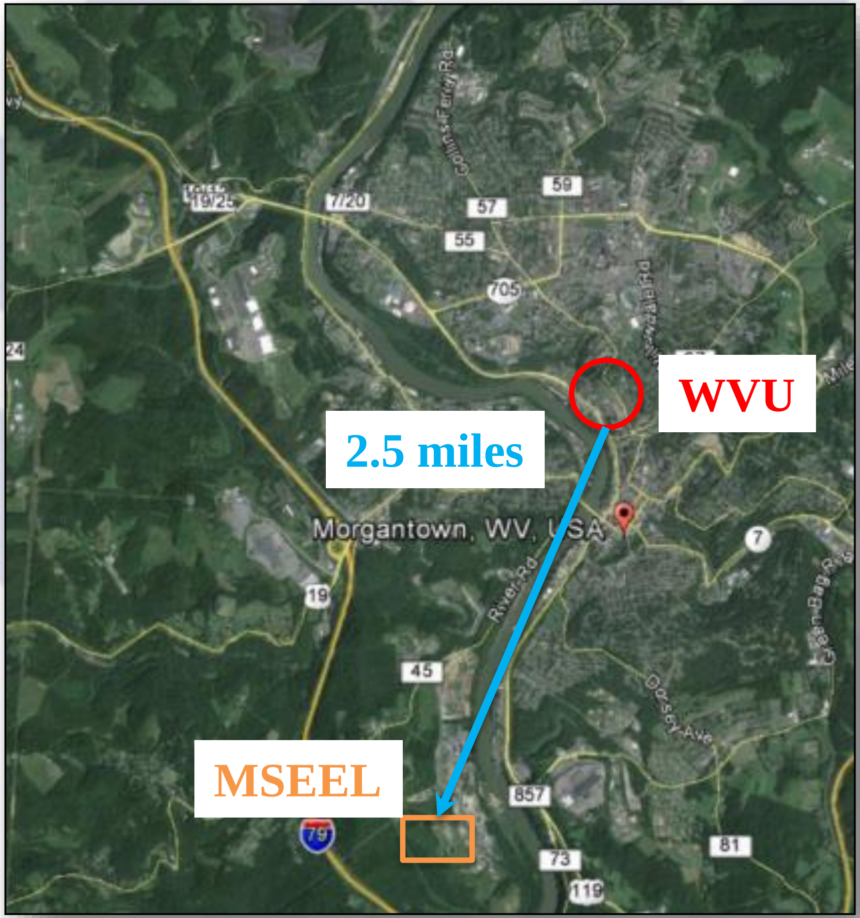


Department of Geology and Geography

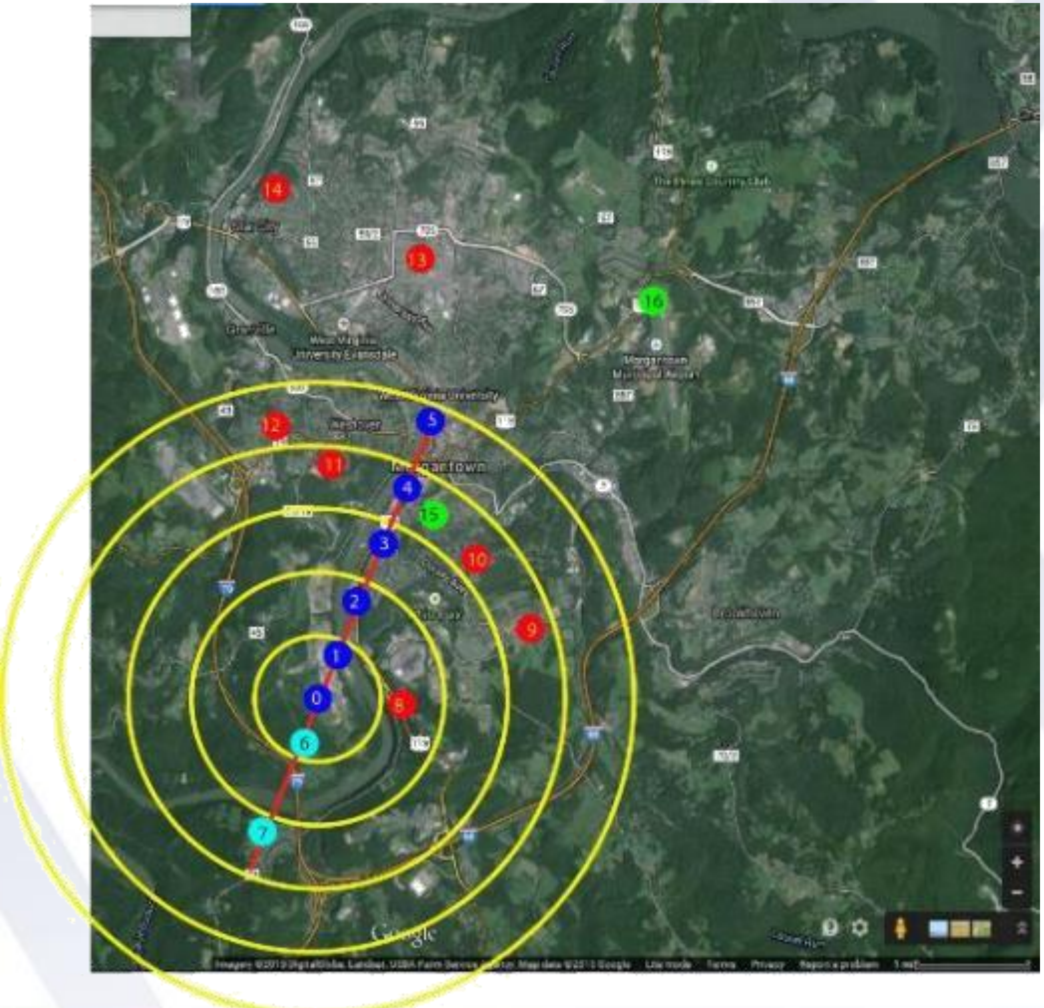
Maneesh Sharma – WVU
Frank Lafone – WVU

MSEEL Site


Northeast Natural Energy LLC
Proposed
MIP Units No. 3H, No. 5H & SW
Grant District
Monongalia County, WV
MIP 5H
BOTTOM HOLE (NAD 83)
N) 408112.0
E) 1831186.9
LAT.) 39°37'10.1"
LONG.) 79°59'14.8"
DEC. LAT.) 39.619460
DEC. LONG.) 79.987455
MIP 3H
BOTTOM HOLE (NAD 83)
N) 404844.7
E) 1831947.5
LAT.) 39°36'37.8"
LONG.) 79°59'04.9"
DEC. LAT.) 39.610501
DEC. LONG.) 79.984692
MIP SW
TOP HOLE (NAD 83)
N) 404245.6
E) 1833288.7
LAT.) 39°36'32.0"
LONG.) 79°58'47.7"
DEC. LAT.) 39.608876
DEC. LONG.) 79.979920
MIP 3H
TOP HOLE (NAD 83)
N) 401656.6
E) 1834344.9
LAT.) 39°36'06.4"
LONG.) 79°58'34.0"
DEC. LAT.) 39.601783
DEC. LONG.) 79.976123
MIP 5H
TOP HOLE (NAD 83)
DEC. LONG.) 79.976152


WVU
2.5 miles
Morgantown, WV, USA
MSEEL
River Rd
Collins Ferry Rd
Dorsey Ave
59
57
55
705
7/20
19/25
19
45
857
79
73
119
81
7

MSEEL Environmental Monitoring Air Emissions



Department of Geology and Geography

Michael McCawley – WVU
Derek Johnson – WVU

Environmental Monitoring
Surface Water

Department of Geology and Geography

Paul Ziemkiewicz / WVU-WVWRI

MSEEL
Drilling MIPU 3H and 5H

Drilling and Produced Water Waste Monitoring

Cuttings

Mud

Using ‘Green’ Drilling Mud
NO Parameters Exceeded TCLP

- In the Vertical and Horizontal (Marcellus) sections:
- TCLP organics-no exceedances
- TCLP inorganics-no exceedances

TCLP - Toxicity Characteristic Leaching Procedure

Better Drilling Performance with Steerable Bit
2011 – 3,000 feet curve & lateral in 30 days
2015 – 6,500 feet curve & lateral in 5 days

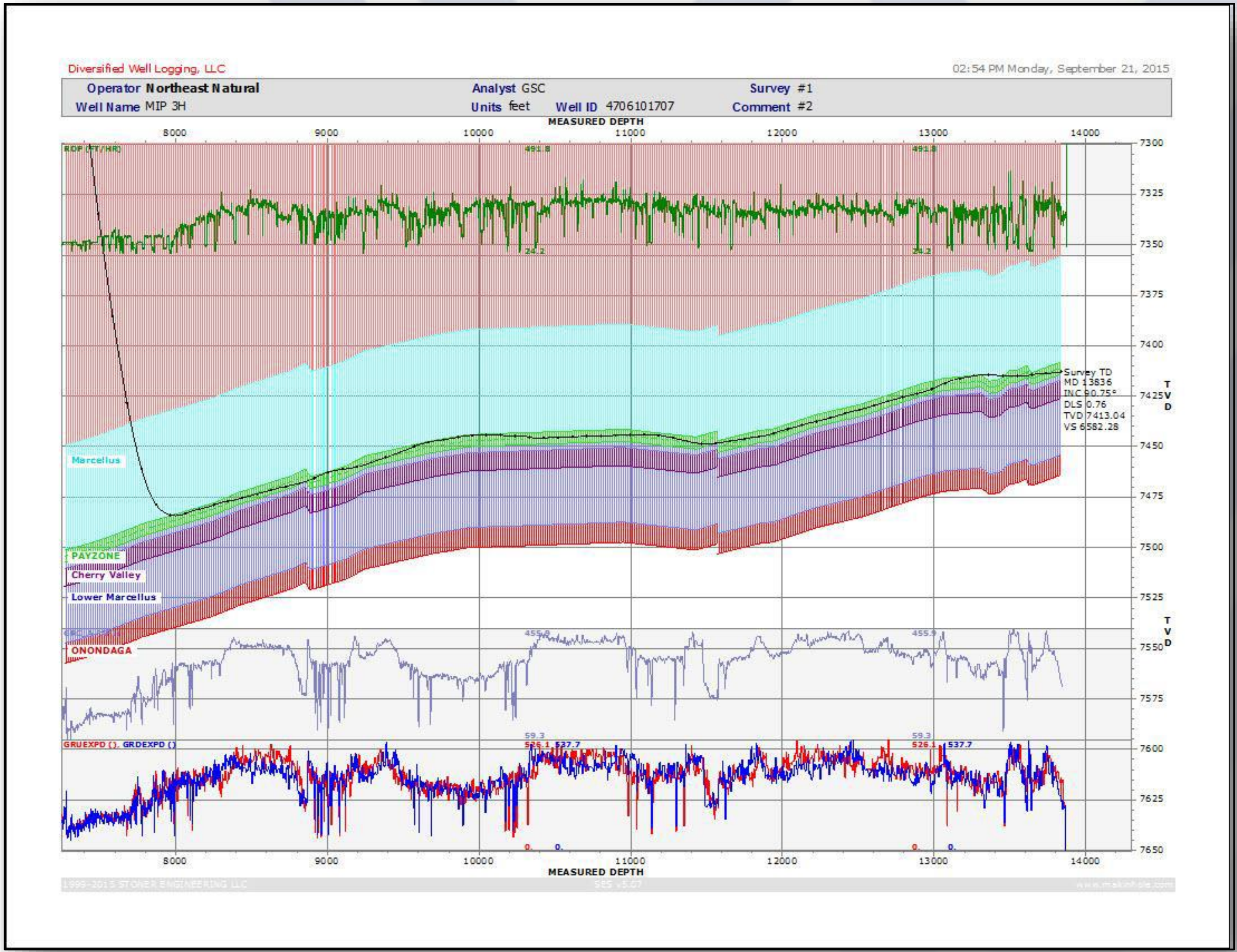
Radiochemistry: Drill Cuttings

Brazil nuts are about 12 pCi/g

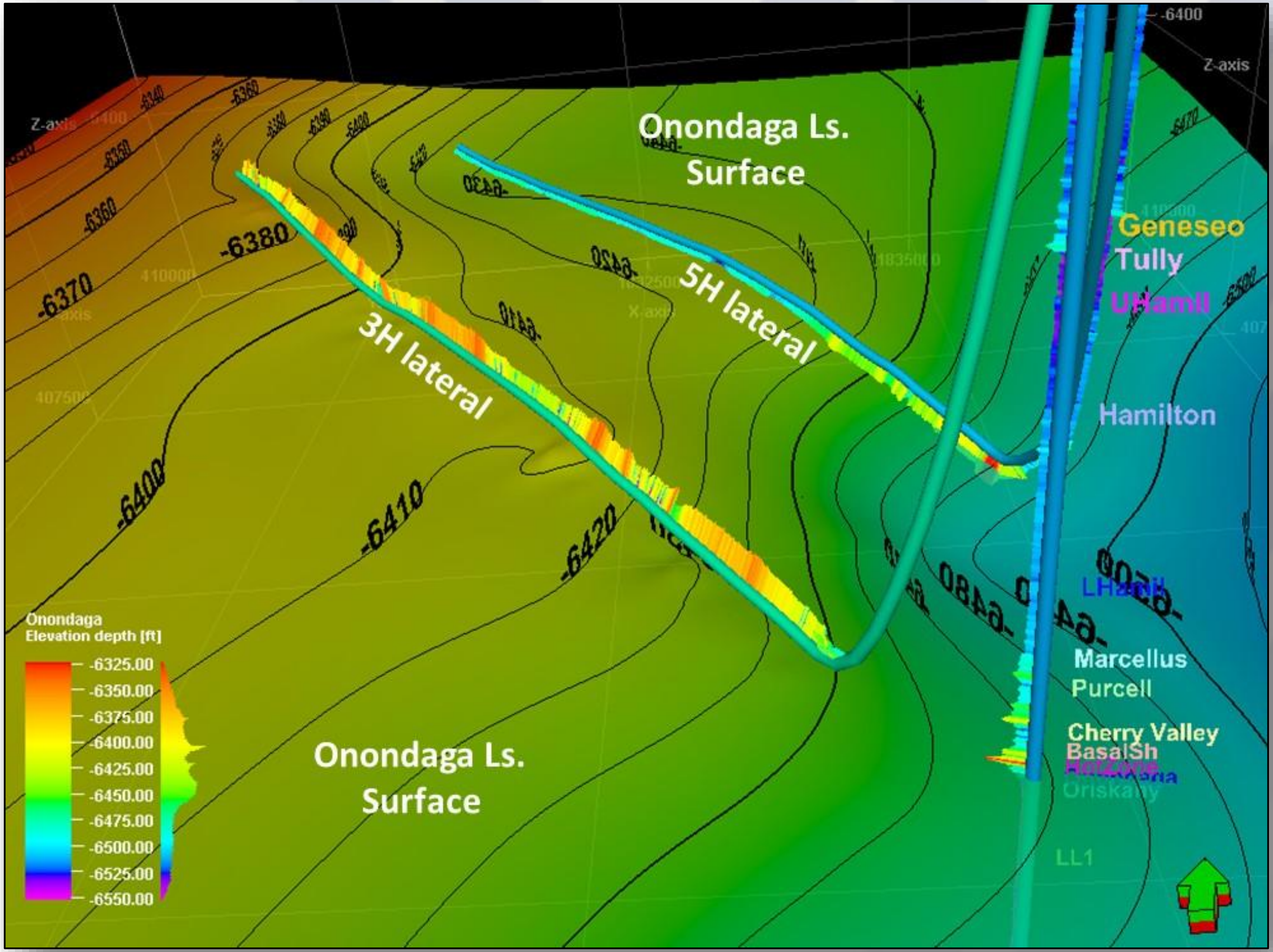
Radionuclides (pCi/g)

vertical	EPA 901.1									9310					
Marcellus	^{40}K			^{226}Ra			^{228}Ra			alpha			beta		
	Act	Unc	MDC	Act	Unc	MDC	Act	Unc	MDC	Act	Unc	MDC	Act	Unc	MDC
MIP 4400 3H	28	4.8	1.0	1.2	0.3	0.3	1.8	0.5	0.3	15.0	7.1	9.8	24.5	6.3	5.6
MIP 5026 3H	24	4.4	1.4	1.4	0.3	0.2	1.9	0.5	0.3	10.5	5.8	9.2	19.4	4.8	4.1
MIP 6798 5H	27	4.5	0.9	1.8	0.3	0.2	1.4	0.4	0.5	17.1	7.7	11.2	27.8	6.7	5.4
MIP 8555 5H	26	4.2	1.1	4.7	0.7	0.2	1.3	0.4	0.4	27.0	9.6	10.2	36.9	8.6	6.6
MIP 8555 5H DUP	25	4.6	1.5	4.6	0.7	0.3	1.1	0.6	0.6	38.1	11.1	9.1	29.8	6.8	4.9
MIP 9998 5H	17	4.3	2.7	9.2	1.3	0.3	0.5	0.9	0.9	46.8	11.0	4.7	42.9	9.0	5.9
MIP 11918 5H	22	3.7	1.1	4.0	0.7	0.2	0.7	0.5	0.5	24.4	9.2	10.3	23.0	6.2	6.2
MIP 11918 5H	20	3.4	1.1	4.2	0.6	0.2	0.8	0.4	0.6	23.8	6.8	5.2	28.7	6.3	5.1
MIP 13480 3H	18	3.2	1.2	9.2	1.3	0.2	0.8	0.6	0.5	55.7	14.7	11.5	35.4	8.2	5.8
MIP 13480 3H DUP	18	3.5	1.4	9.7	1.4	0.3	1.1	0.4	0.3	59.2	14.9	9.3	35.0	7.8	4.6
MIP 13480 3H Mud	13	3.0	1.1	5.6	0.9	0.2	0.5	0.3	0.8	60.0	15.9	10.5	42.5	9.6	6.1
MIP 14454 5H	20	3.8	1.1	5.8	0.9	0.2	1.3	0.5	0.6	28.8	7.9	6.5	37.5	8.0	5.4

Geosteering MIP-3H



Geosteering MIP-3H



Subsurface Sampling

Retrieved 111’ of a targeted 120’ whole core

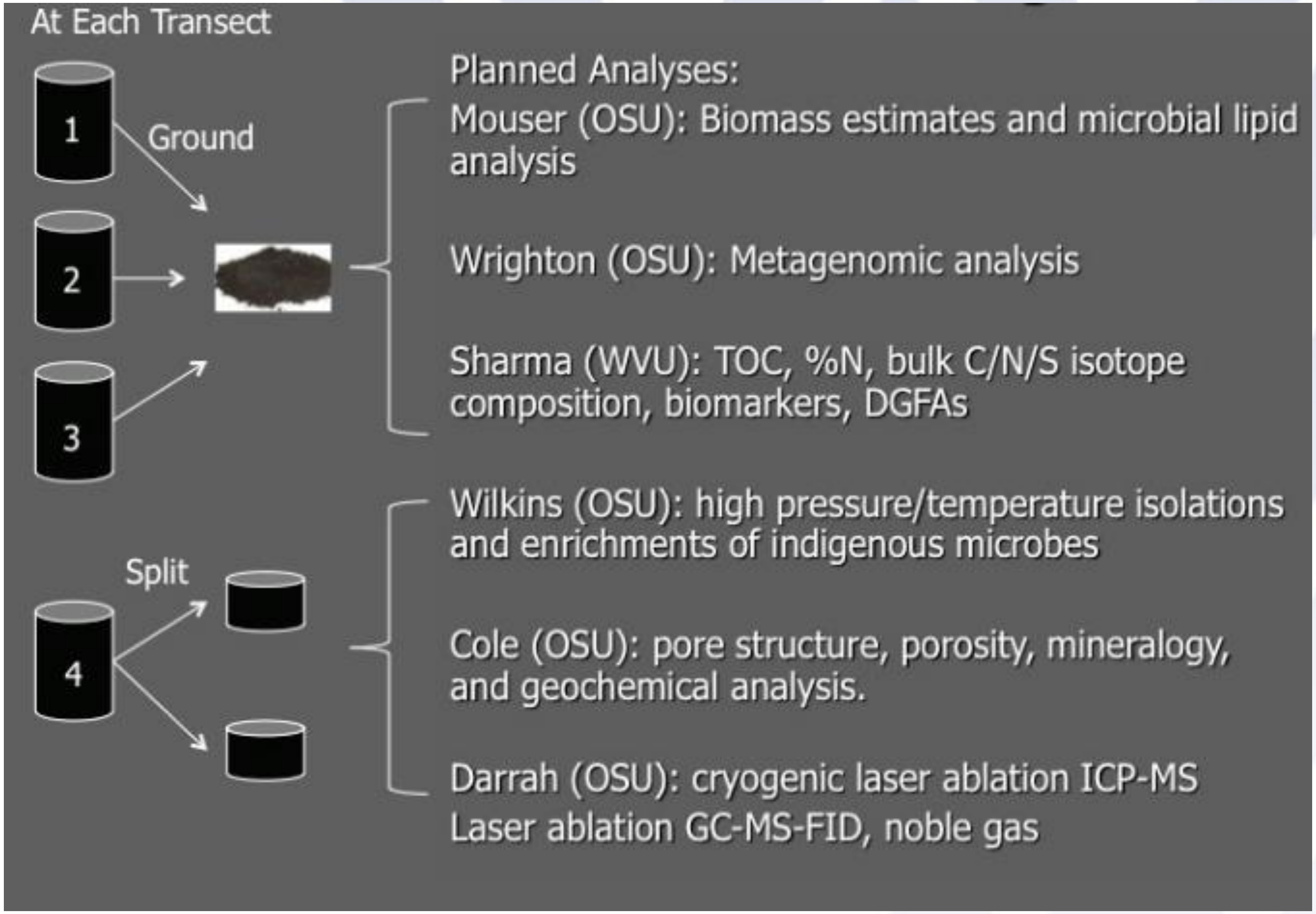
Sidewall Cores

Department of Geology and Geography

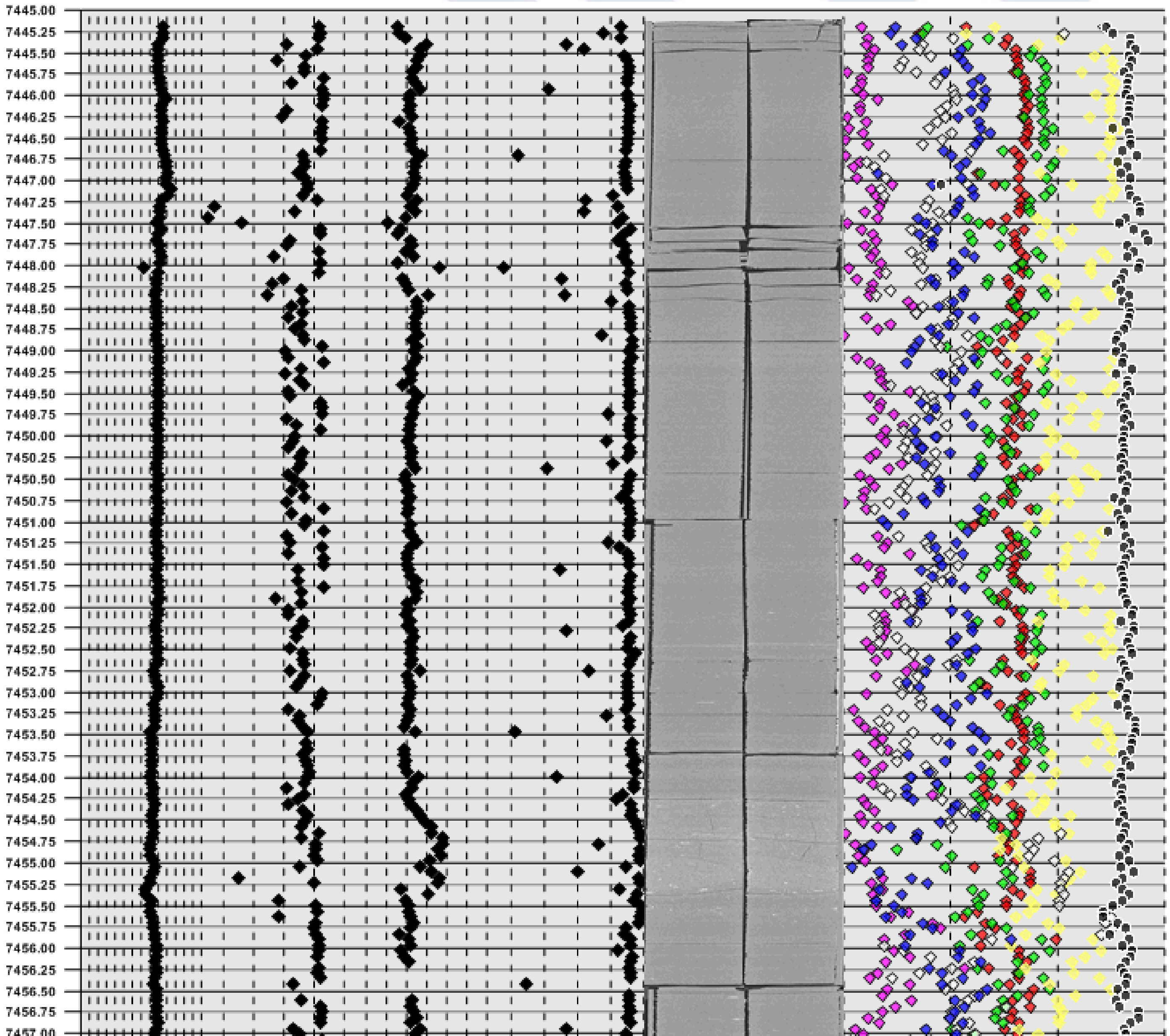
Collected 197 sidewall cores from the SW and 3H well

Shikha Sharma – WVU
Ohio State University

Sidewall Cores Geochemistry



Multi-Sensor Core Logging

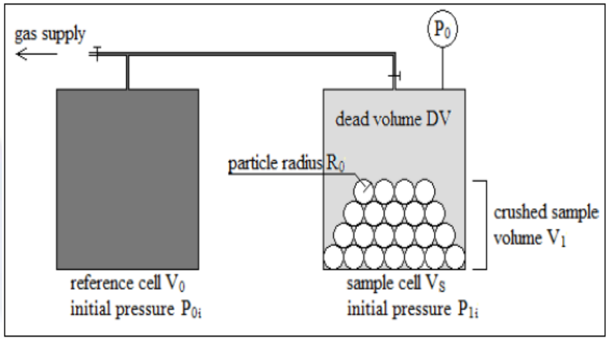


CRUSHED SAMPLE PERMEABILITY

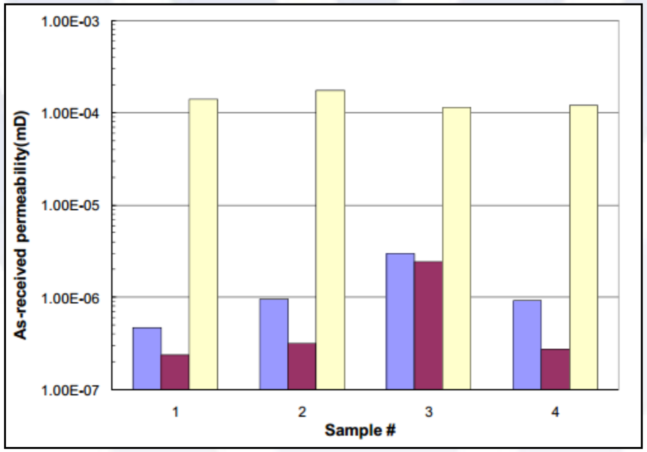
DEVELOPED BY GAS RESEARCH INSTITUTE AND IS REFERRED TO AS "GRI" METHOD.

Roosevelt Dime = 17.9 mm

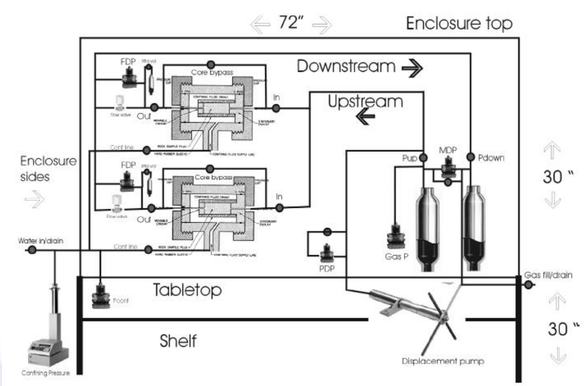
Particles in the 20-35 US mesh size range (0.85 to 0.5mm)



- ✓ ***No Standard Protocol***
- ✓ ***Inconsistent Results***



Precision Petrophysical Analysis Laboratory (PPAL) at WVU



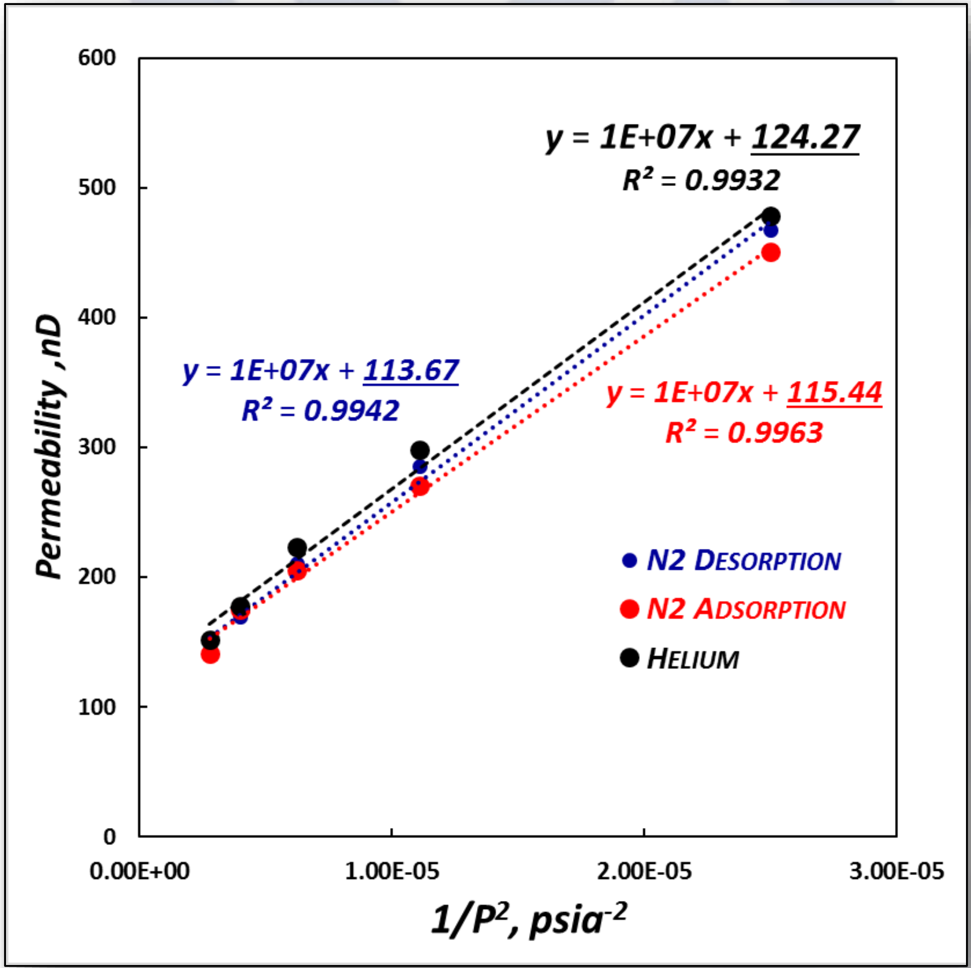
Layout of the PPAL components and plumbing

Measurement Capabilities

- Permeability (nano-darcy range).
- Pore volume (0.1% accuracy).
- Absolute Permeability (Gas Pressure Correction)
- Impact of Stress (Reservoir Conditions).
- Impact of Adsorption
- Pore structure characterization

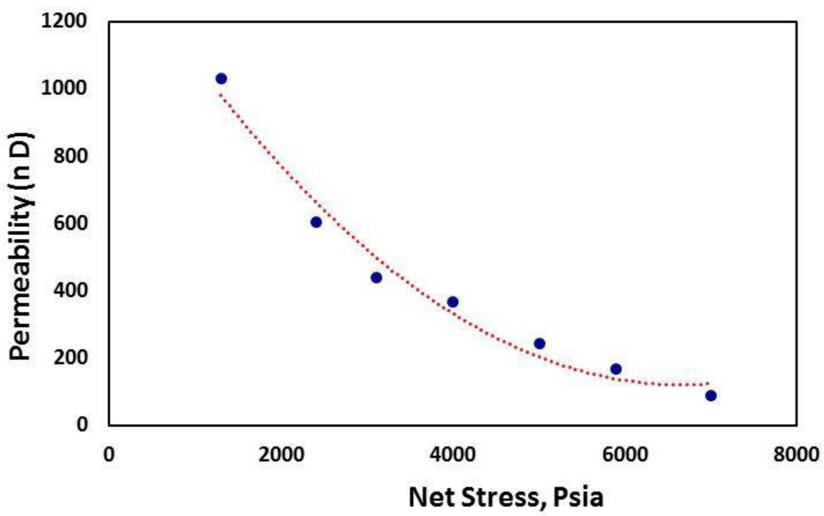
Accurate, Consistent, and Repeatable Results

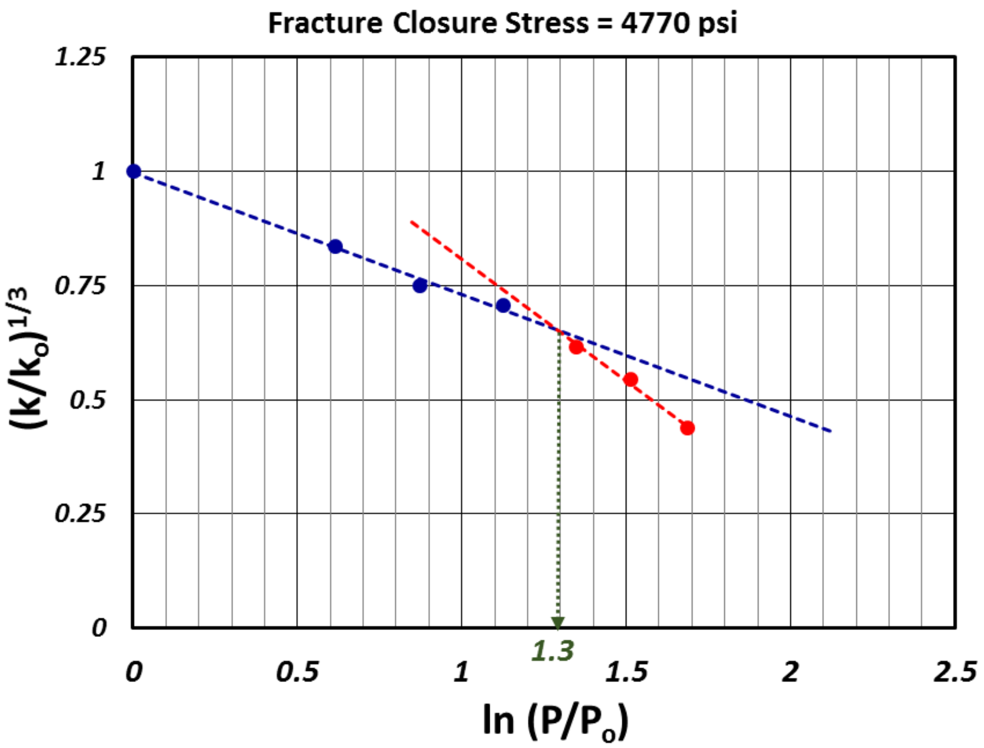
Absolute Permeability



SAMPLE 7547.03

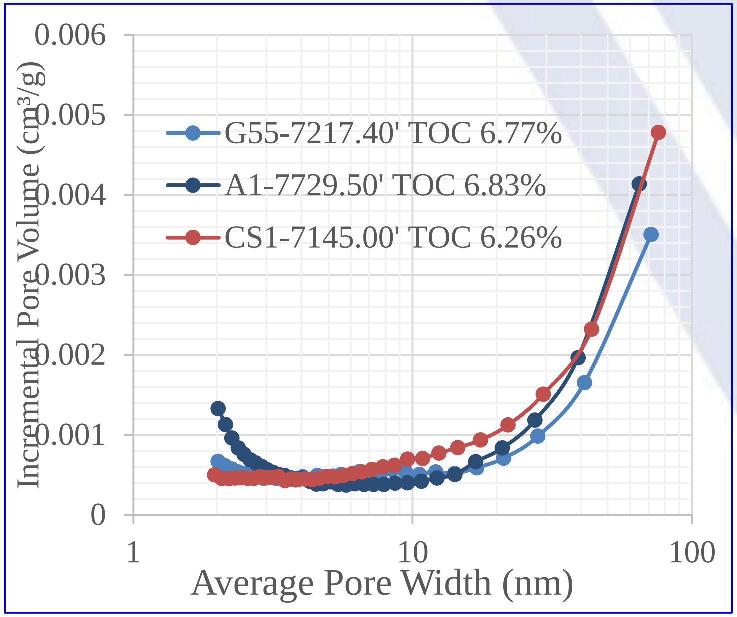
IMPACT OF STRESS

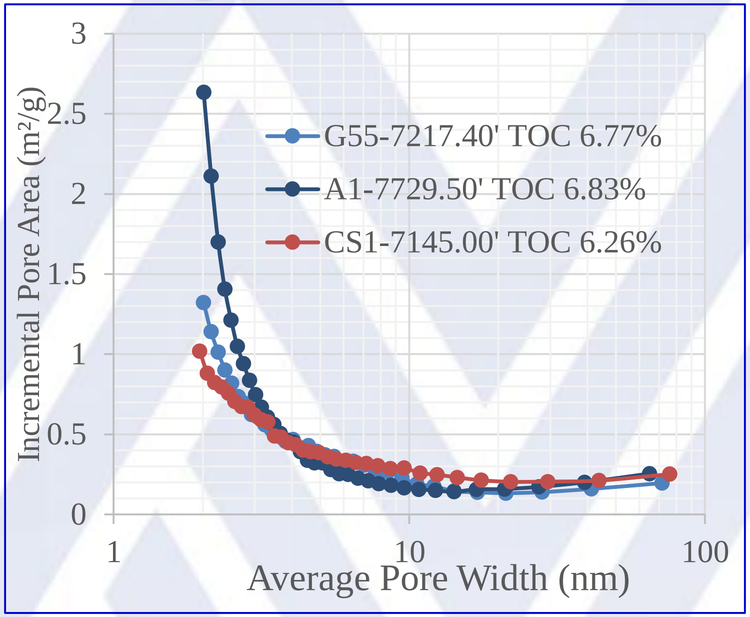


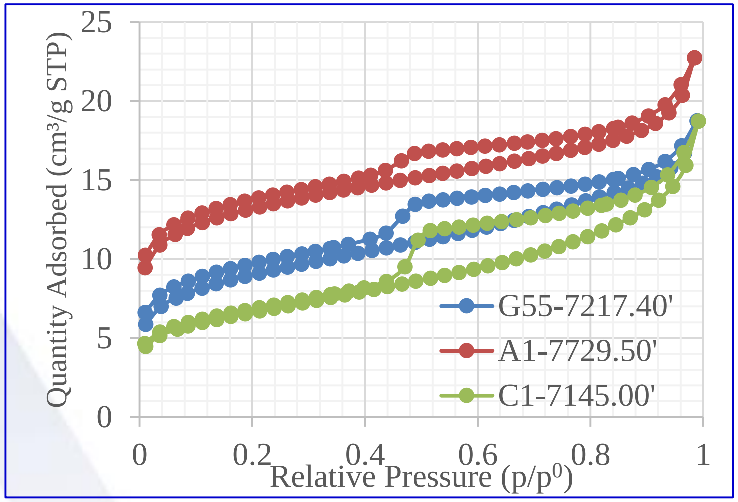


SAMPLE 7547.03

BET Core Analysis



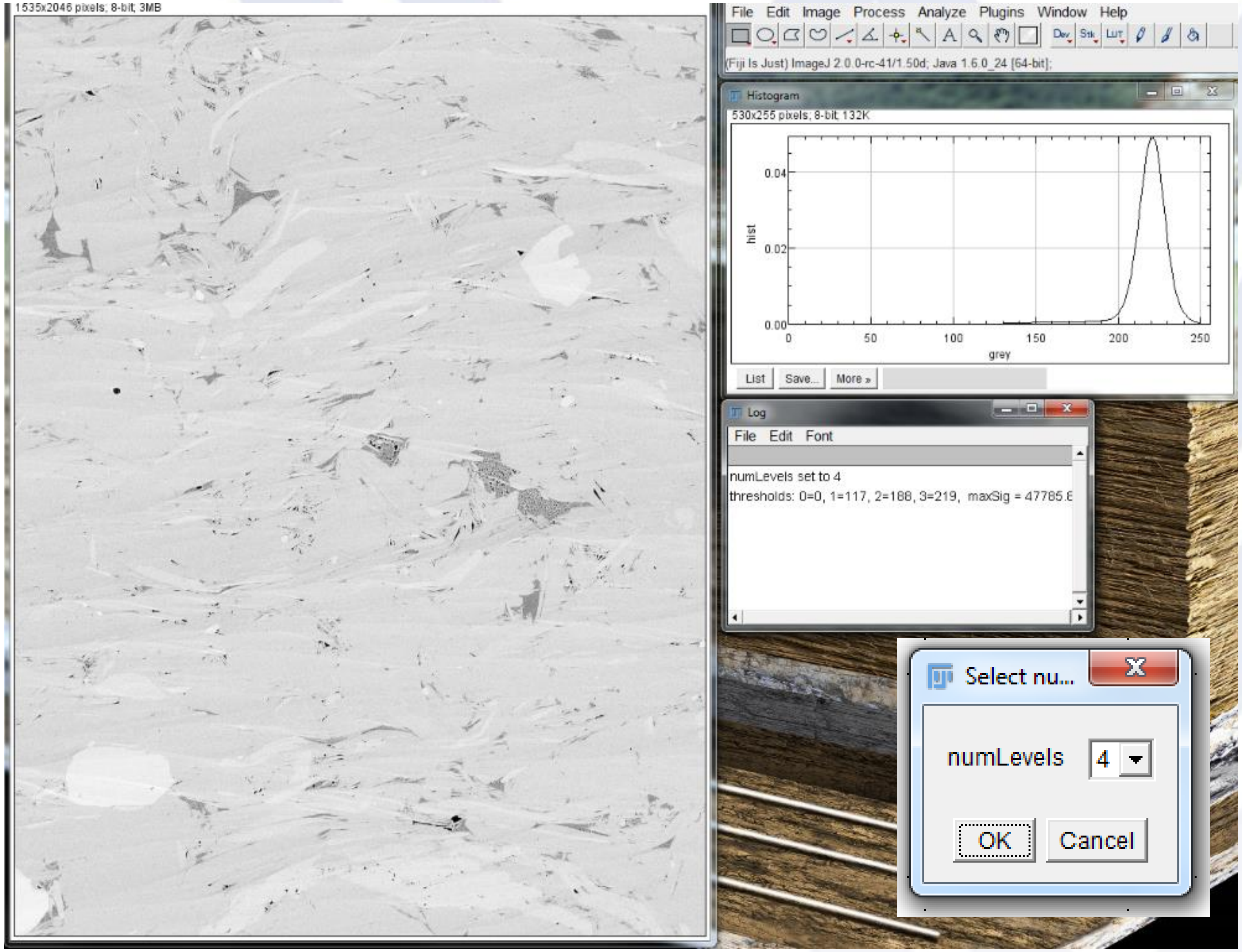




Brunauer–Emmett–Teller (BET) theory - The Type H4 loop, which does not exhibit any limiting adsorption at high p/p0, is observedas aggregates of plate-like particles and slit-shaped pores, often associated with microporosity (*IUPAC Recommendation 1984*).

Pores of diameters less than 5 nm make the greatest contribution to SSA, whereas pore volumes are affected by larger pores. Samples with higher thermal maturity have less smaller pores (pore diameter less than 5 nm).

SEM Core Analysis



This is an SE2-SEM image provided by Ingrain, and the scale of this image is 20 by 30 microns

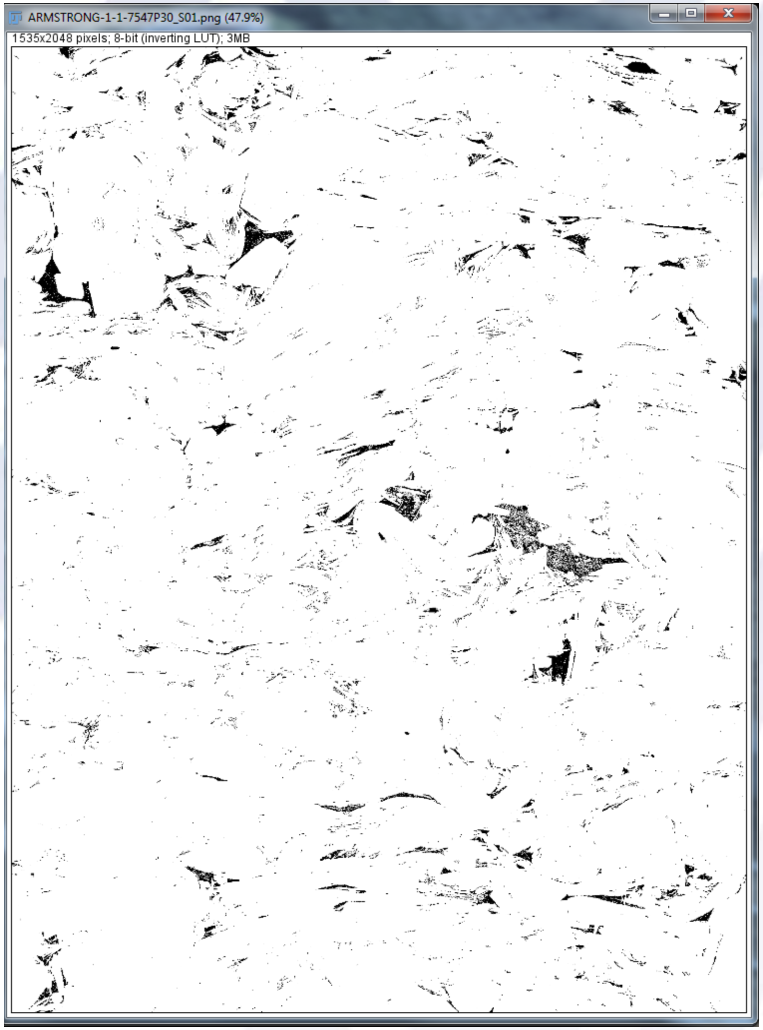
Department of Geology and Geography

Liaosha Song- WVU

SEM Core Analysis

Organic Matter Porosity

Organic Matter

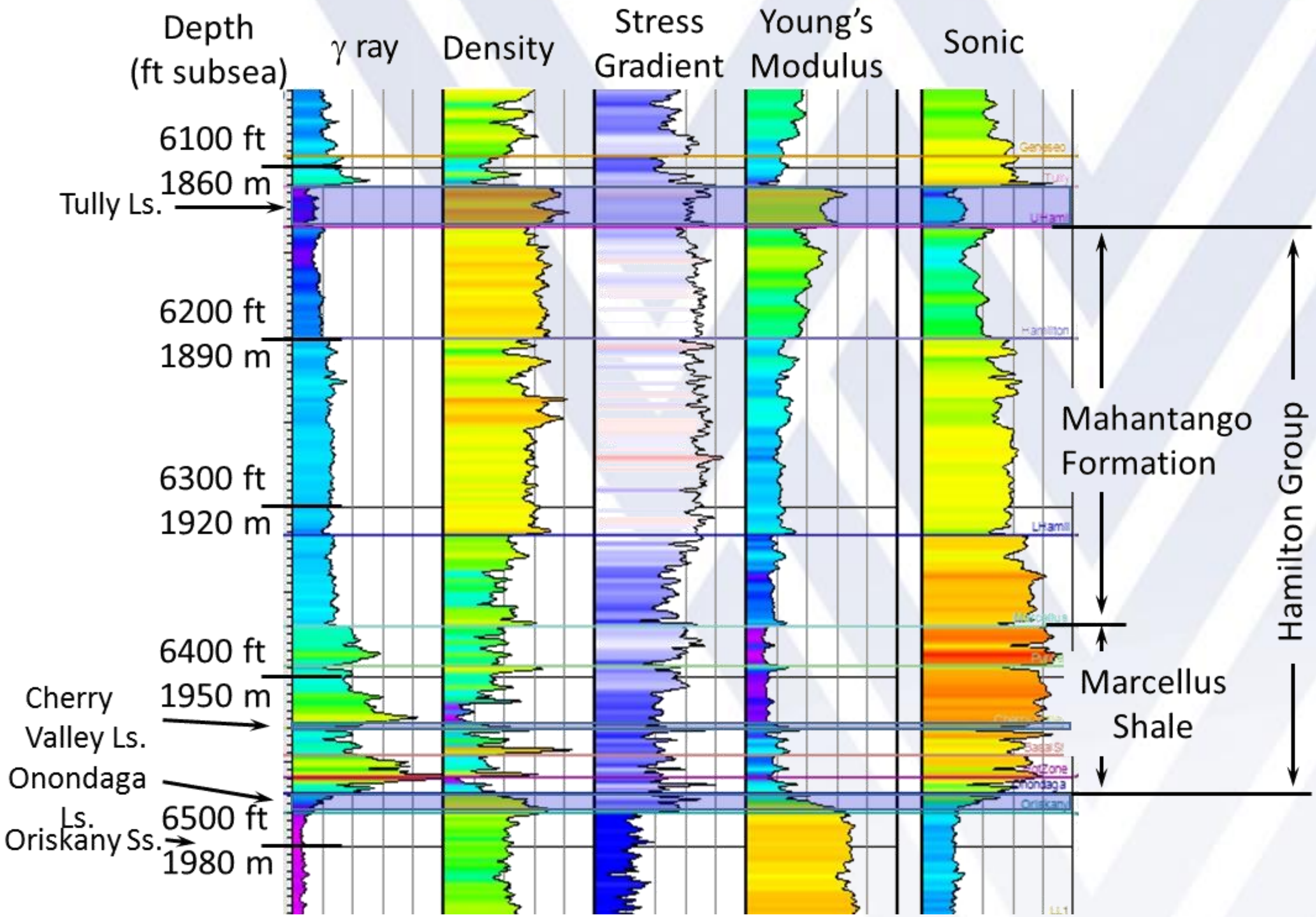


Department of Geology and Geography

Liaosha Song- WVU

MSEEL
Completion MIPU 3H and 5H

Sonic Scanner 3H Pilot Hole

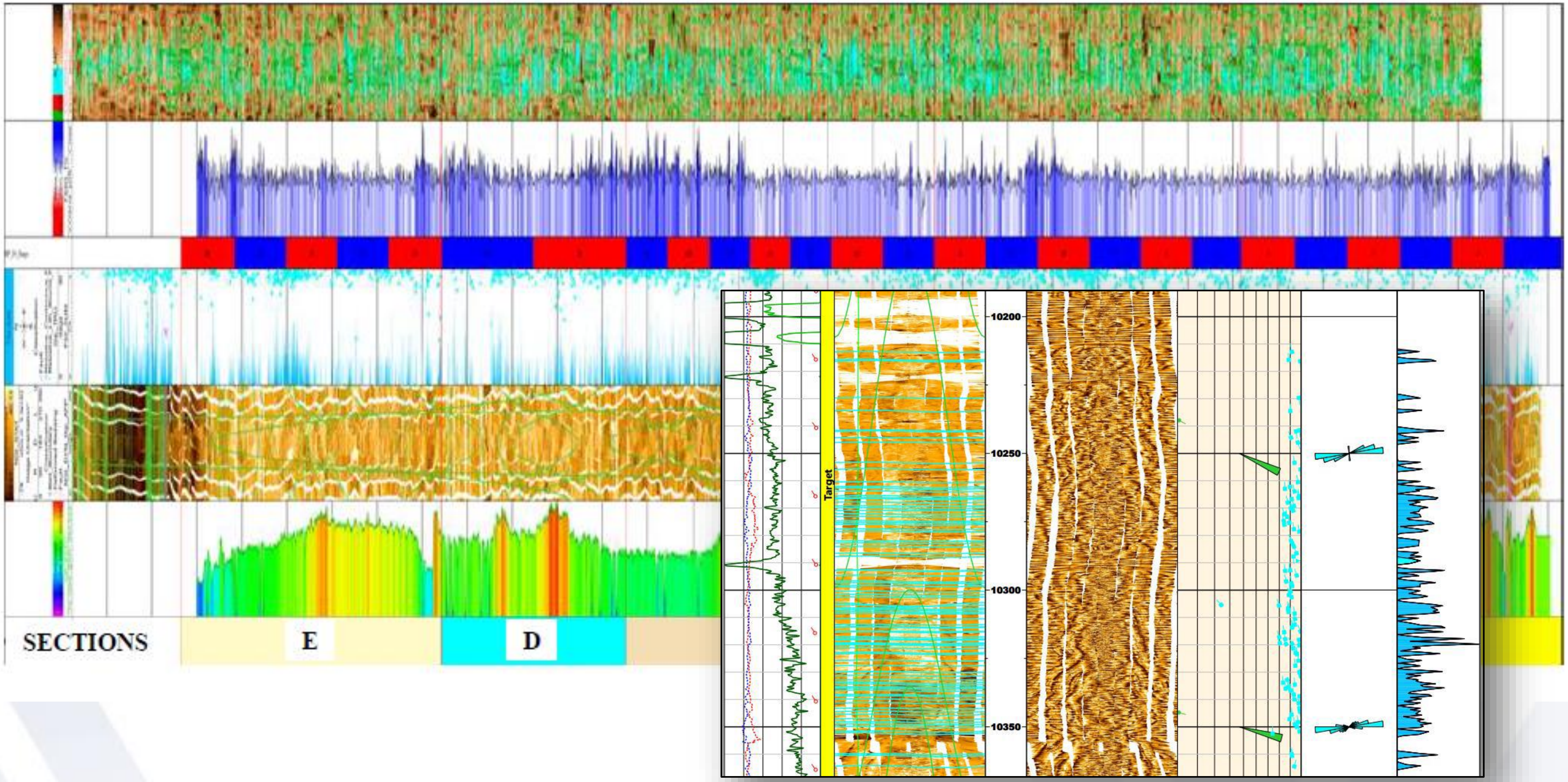


Department of Geology and Geography

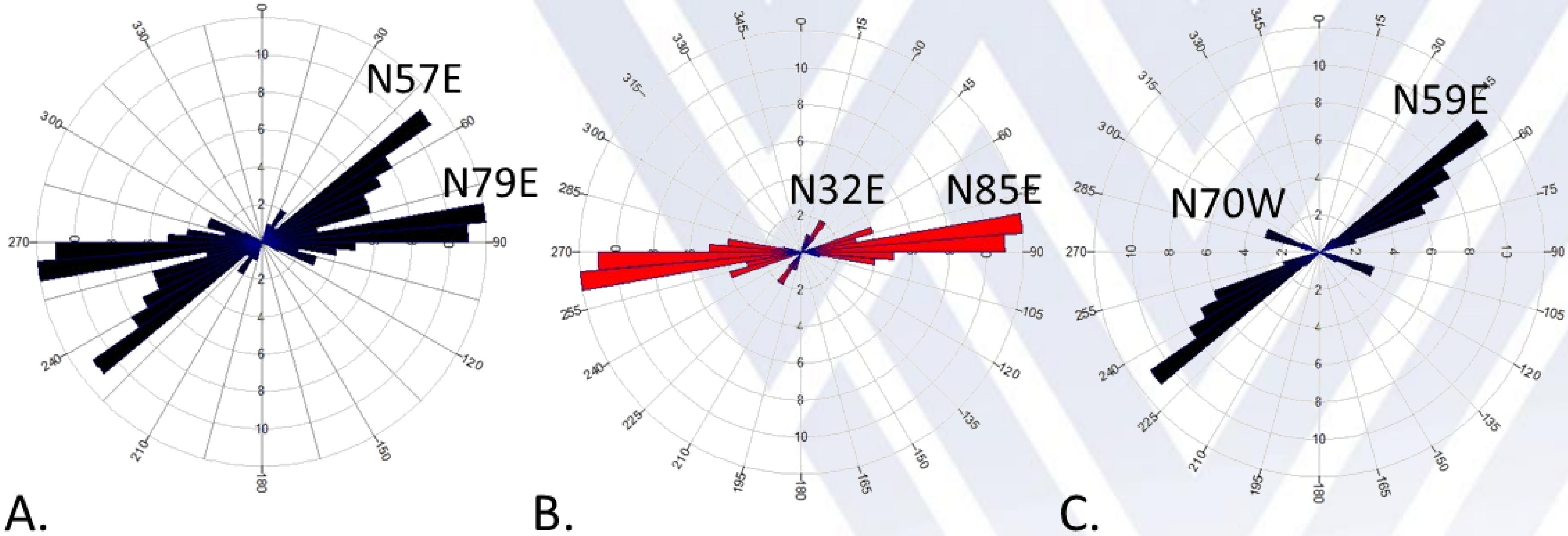
Tom Wilson

MSEEL - LOGGING LATERAL

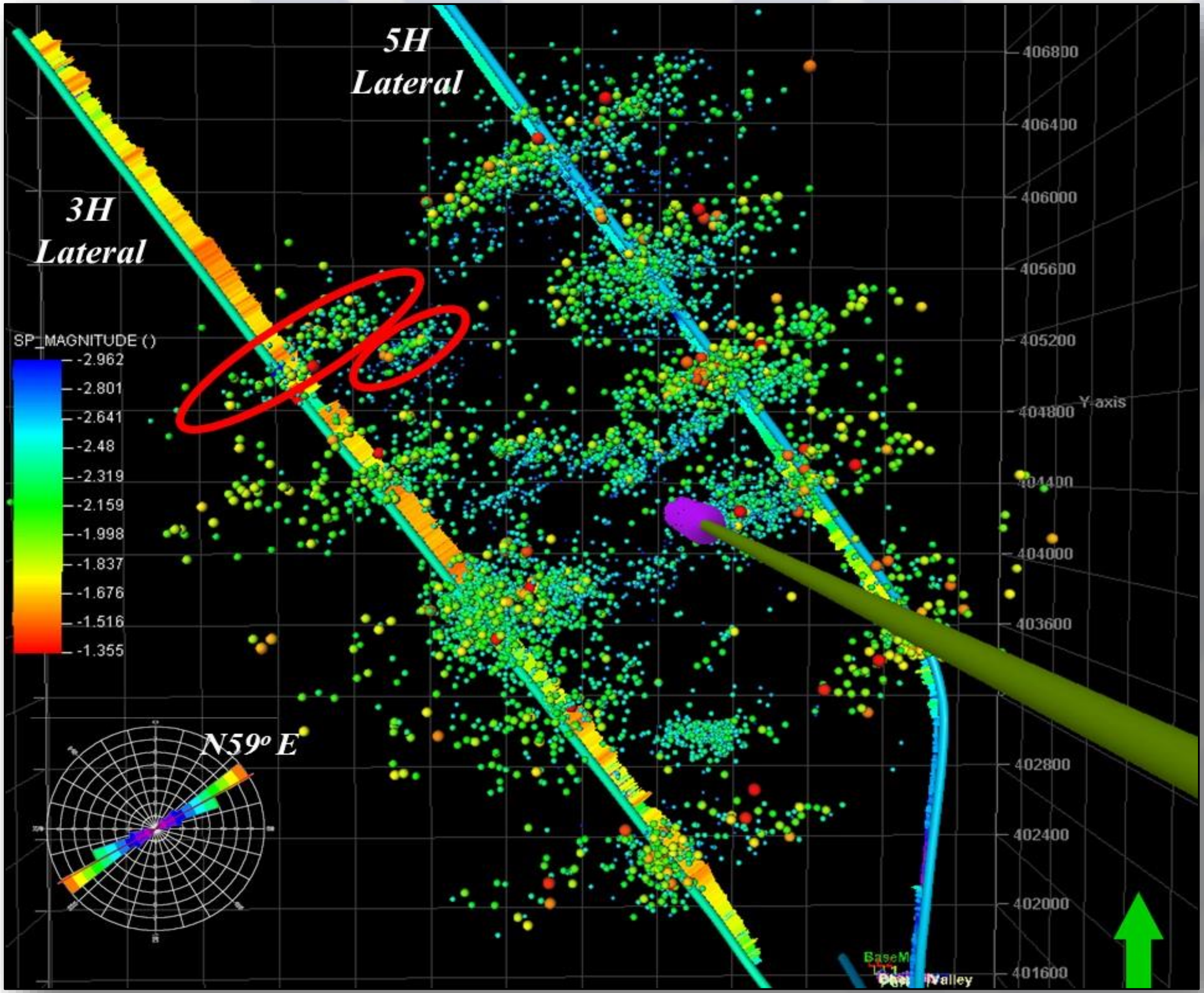
High Definition open hole logs in lateral with synthetic mud



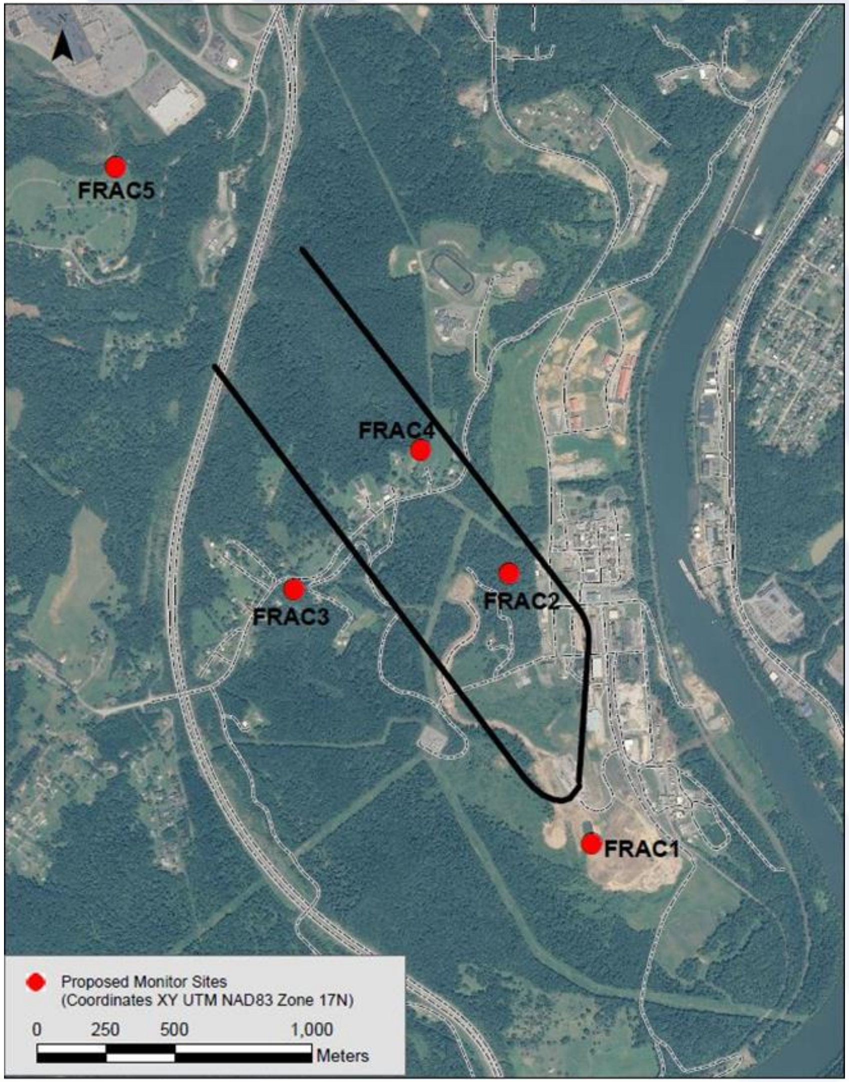
MSEEL – Microseismic and Borehole



MSEEL - Microseismic

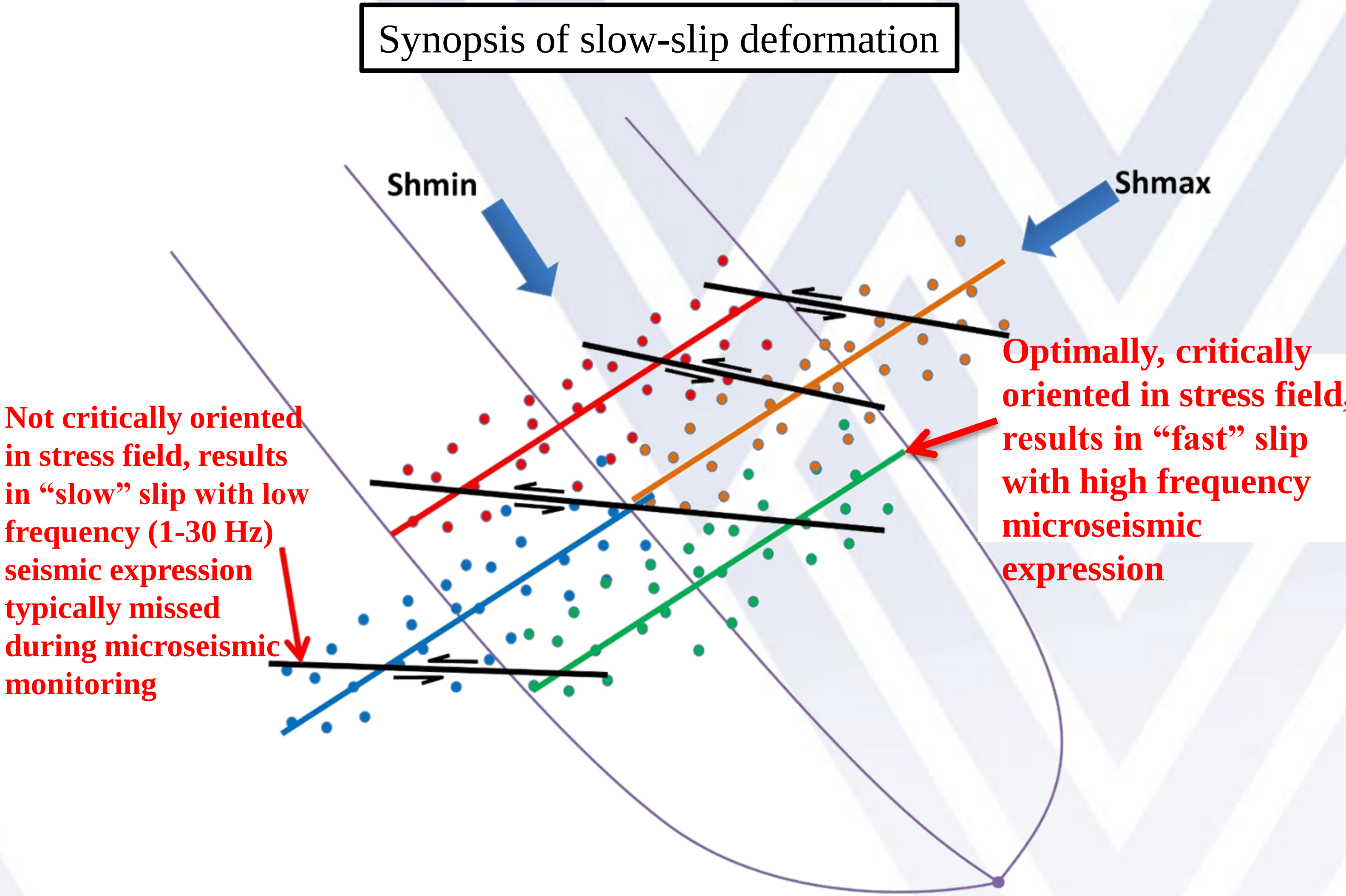


SURFACE MONITORING OF SLOW SLIP (LPLD)



Kumar at al. NETL

SURFACE MONITORING OF SLOW SLIP (LPLD)

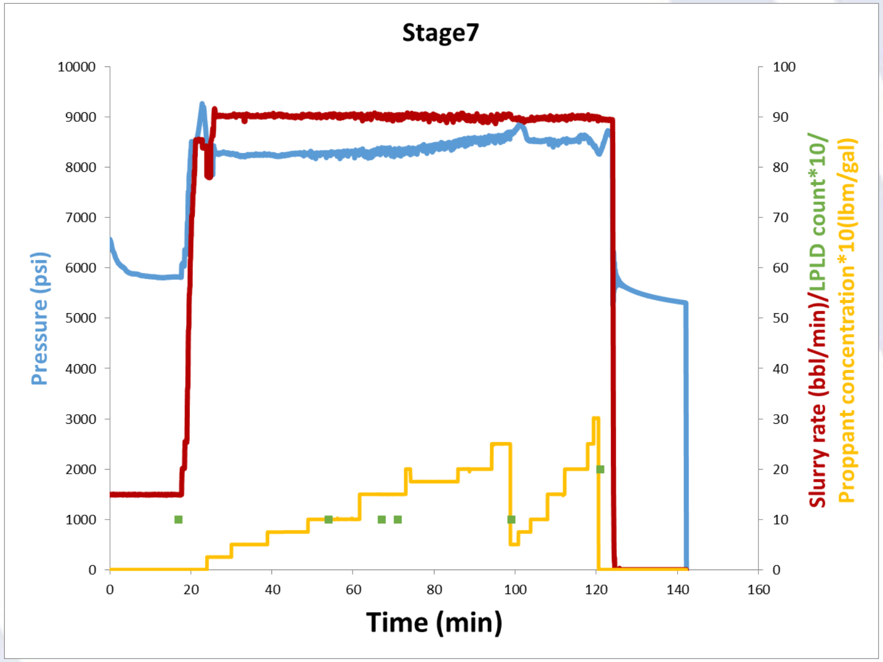


Adapted from Kumar et al. 2016 and Zoback et al., 2012

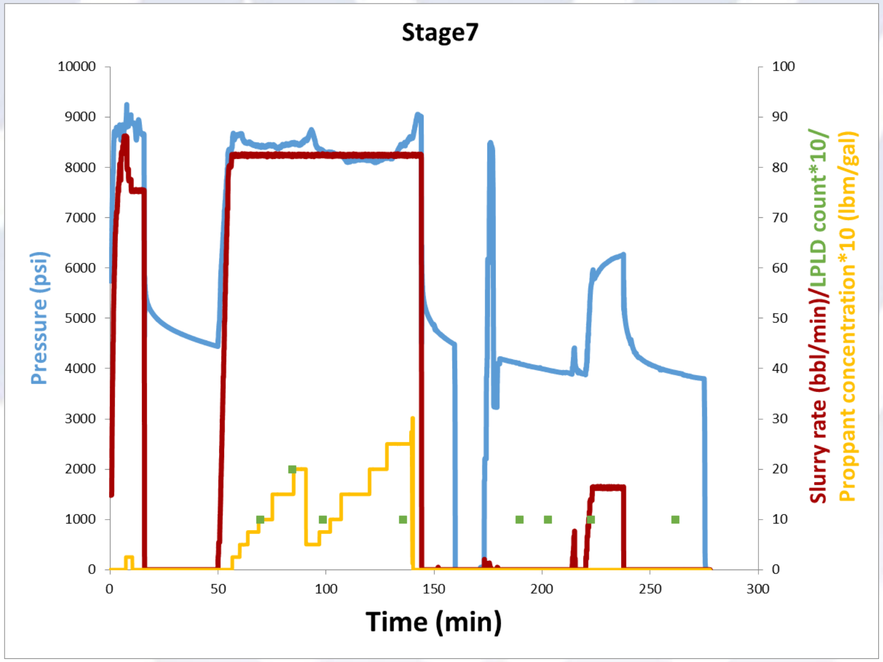
SURFACE MONITORING OF SLOW SLIP (LPLD)

LPLD and injection parameters

Well 3H



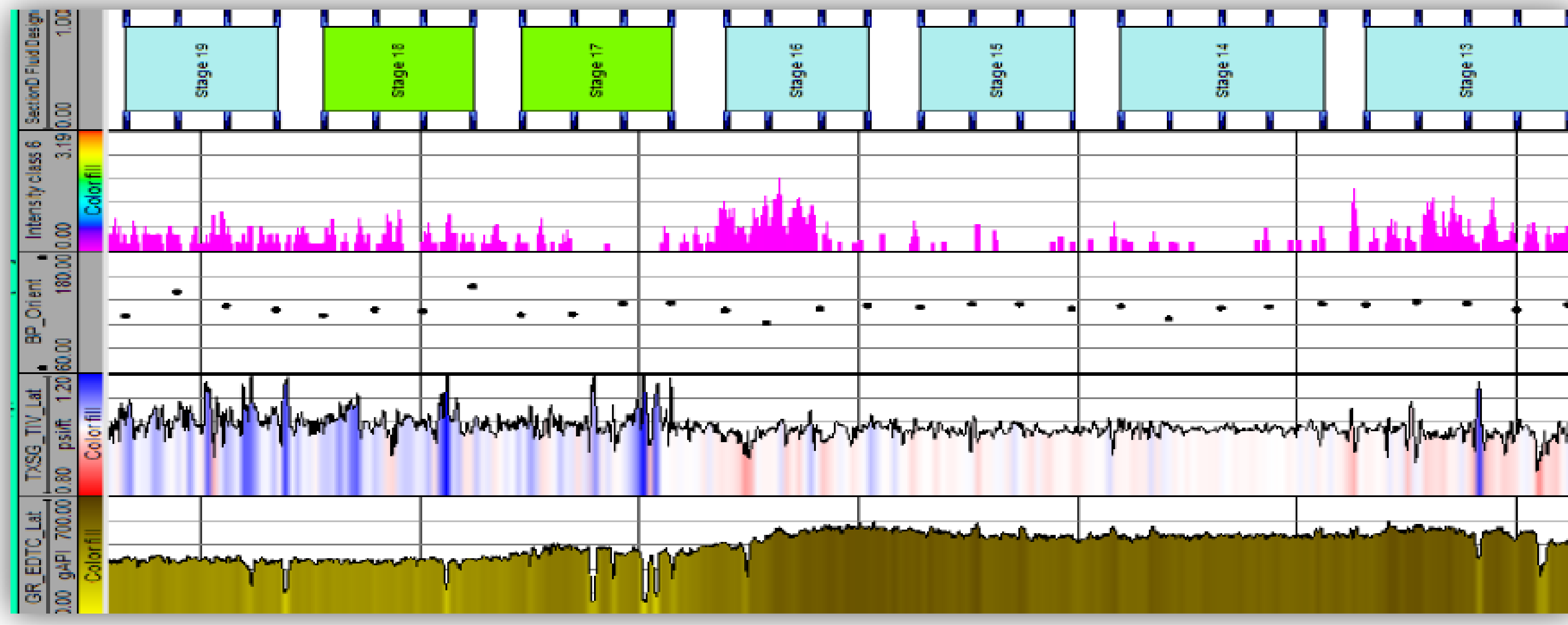
Well 5H



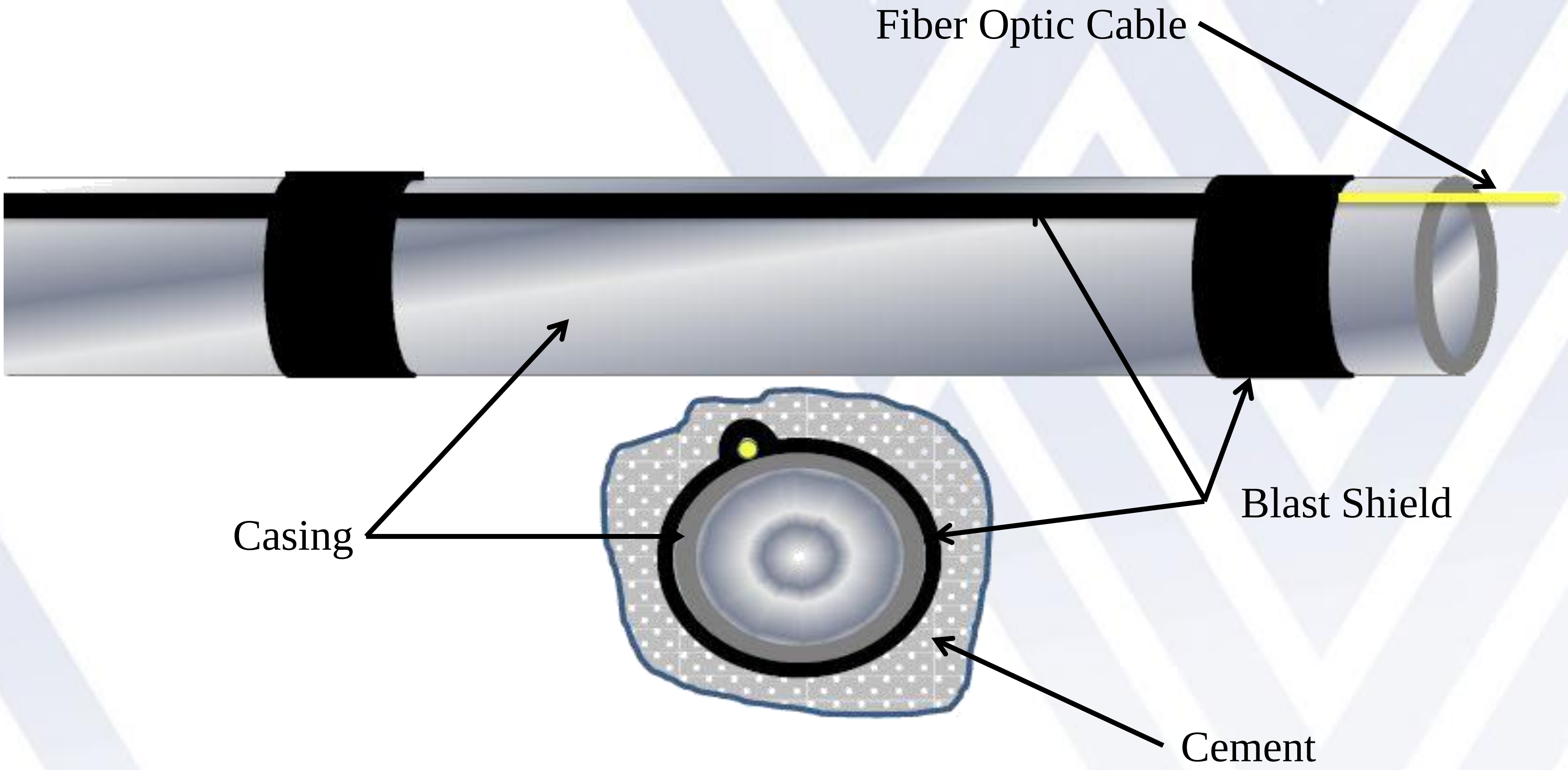
Kumar at al. NETL

MSEEL - LOGGING LATERAL

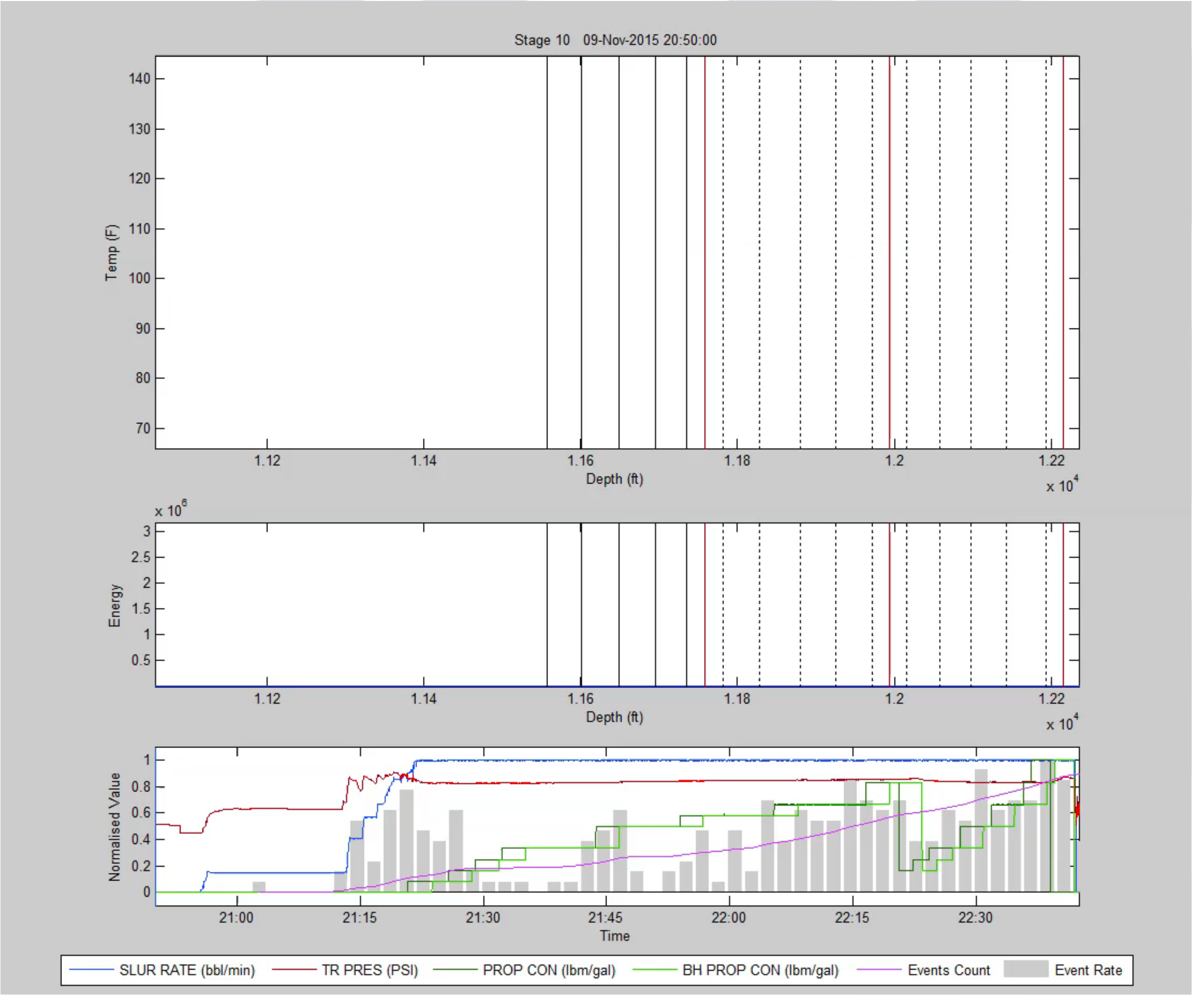
High Definition open hole logs in lateral with synthetic mud



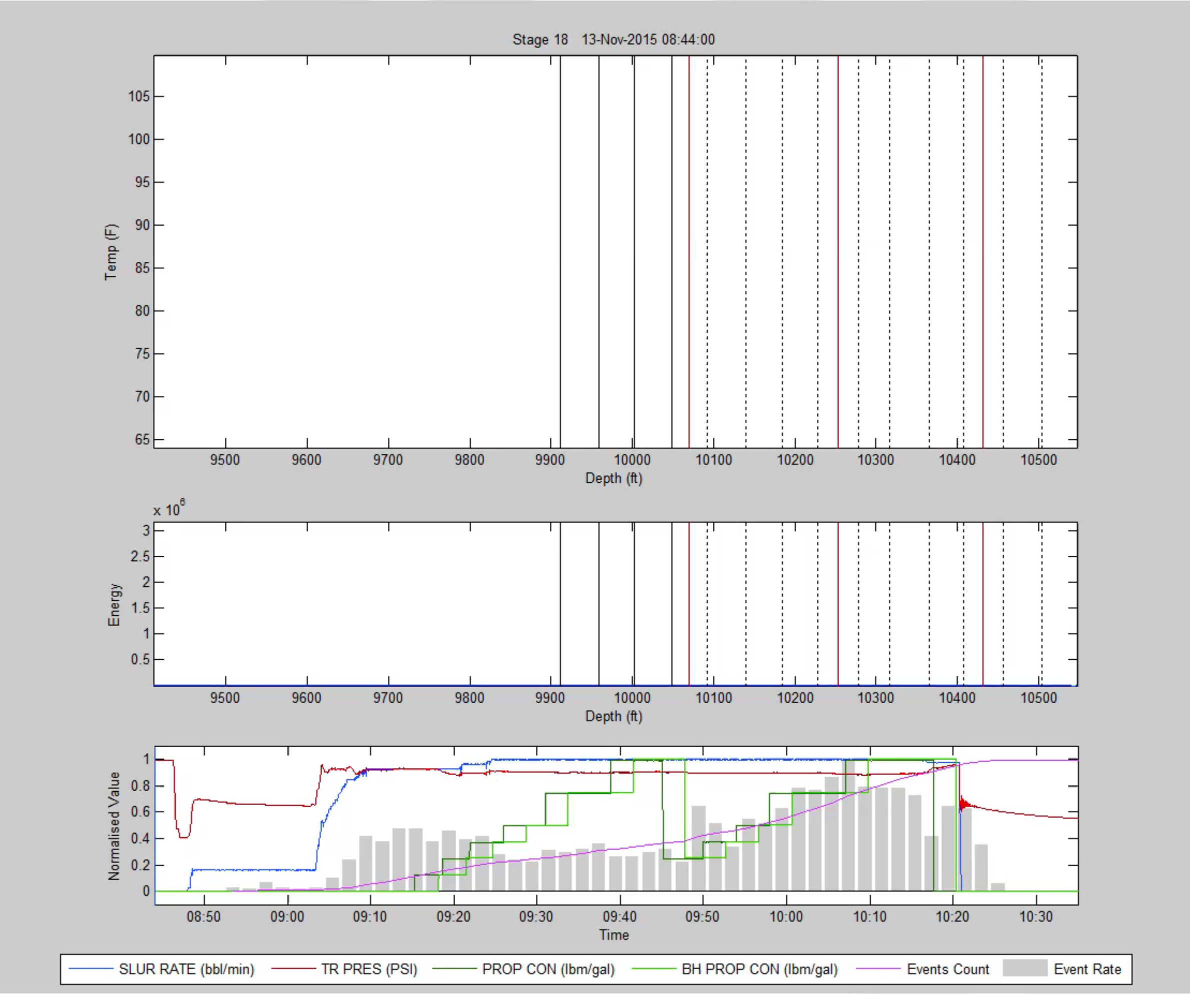
Fiber Optic Installation



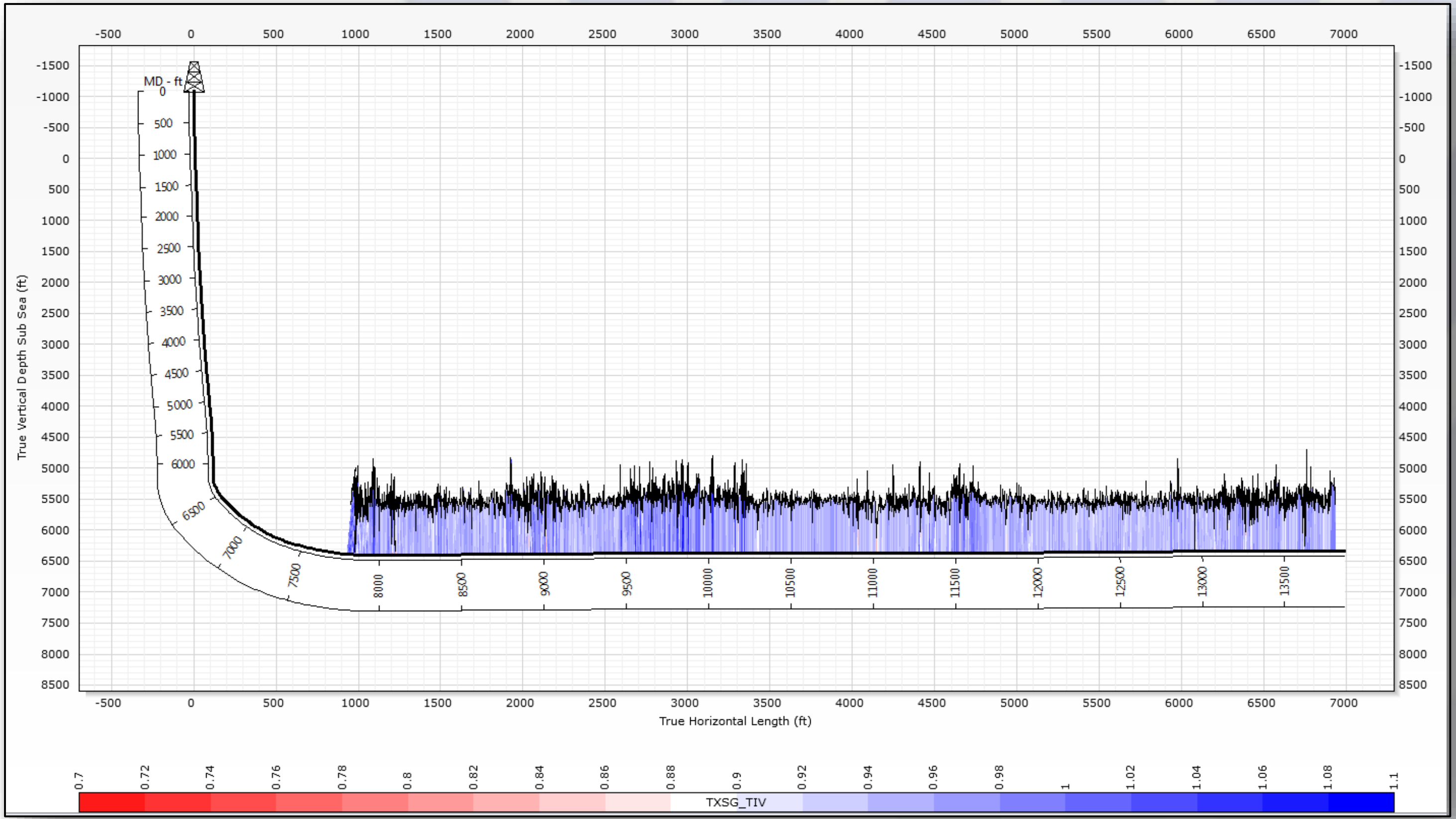
MIP3H - Stage 10: Uneven Distribution



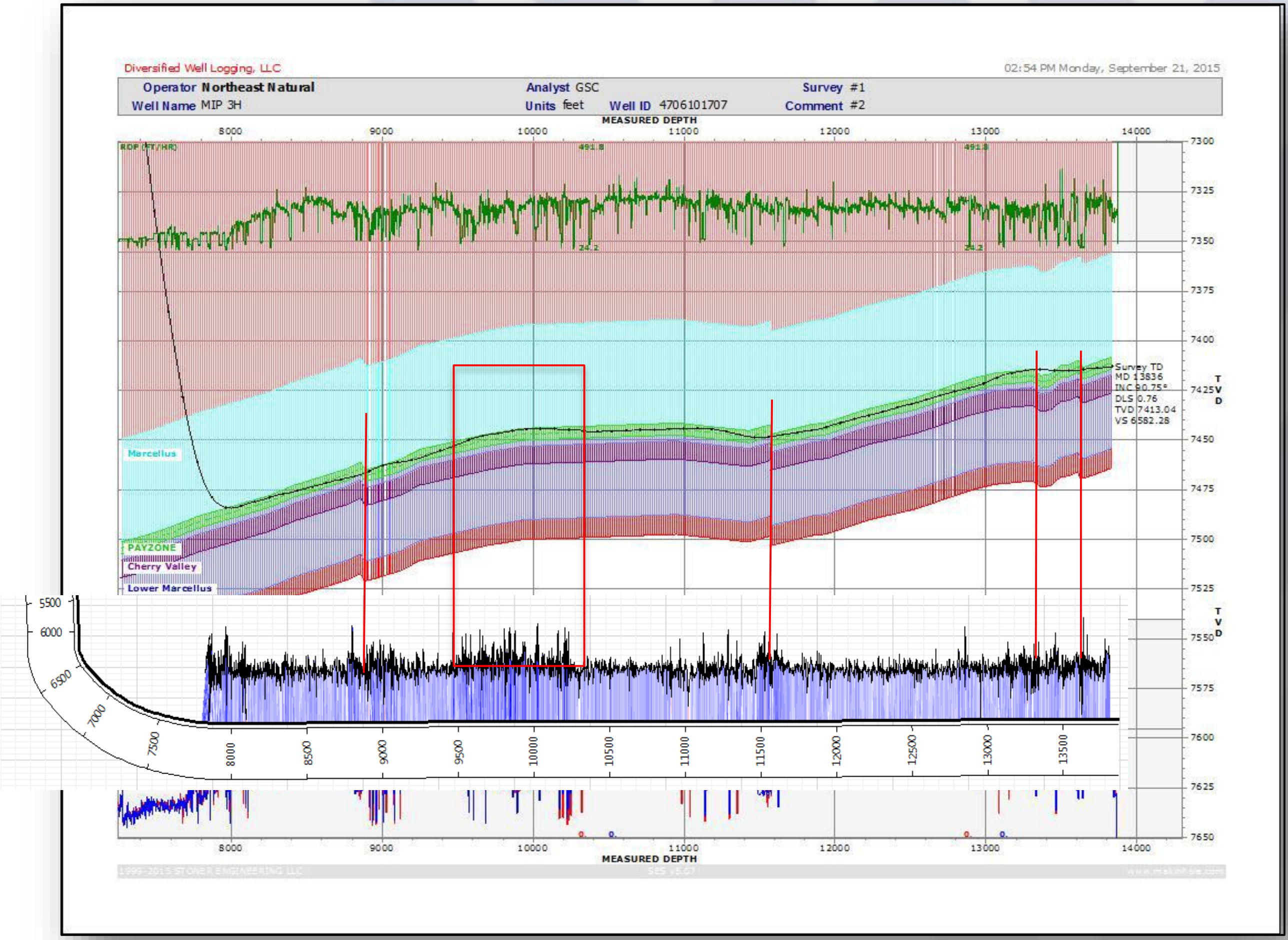
MIP 3H - Stage 18 Even Distribution



Anisotropic Closure Pressure



Anisotropic Closure Pressure Thin Data Prediction



Contacts

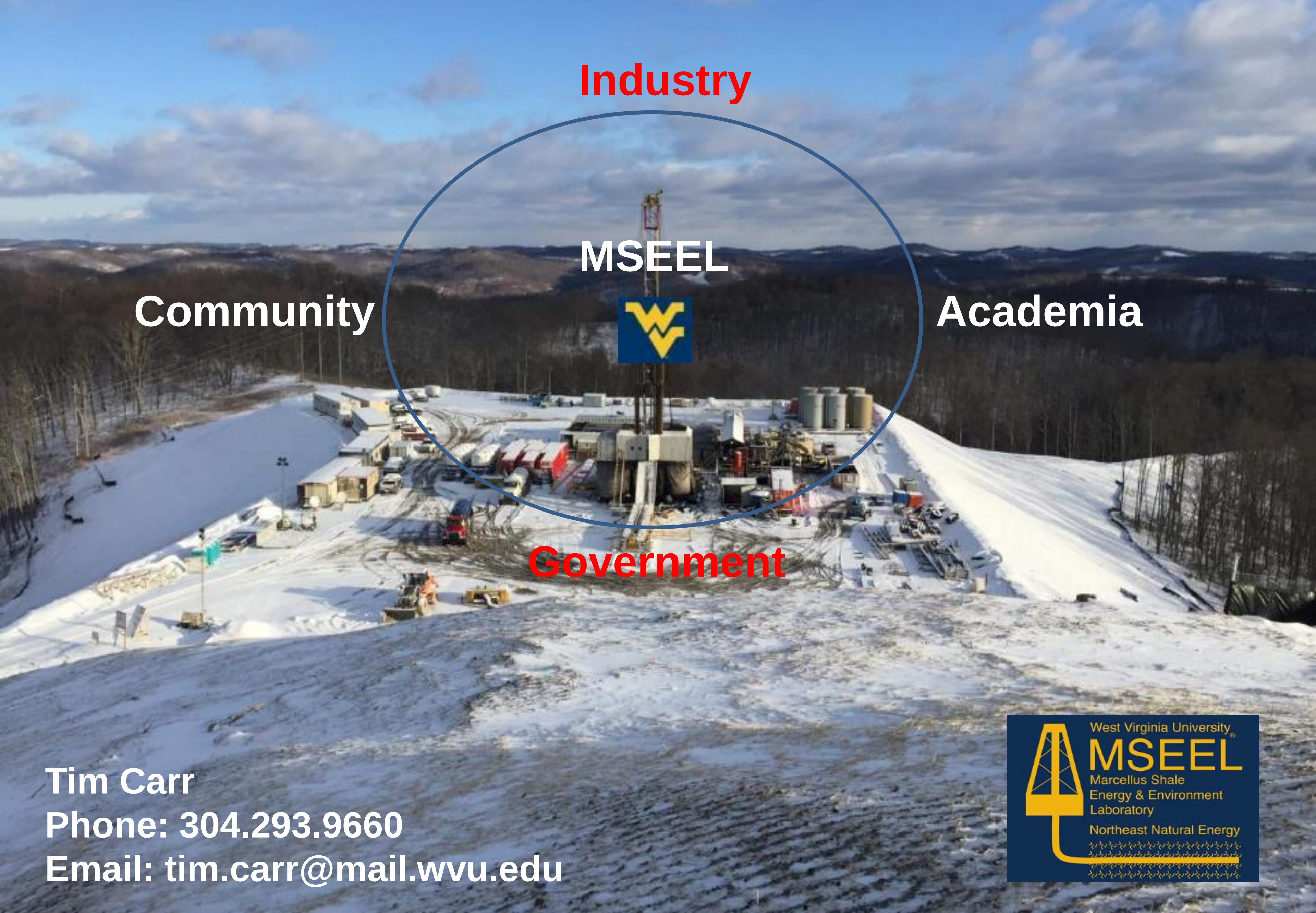
Program Management

WVU-Principal investigator	Tim Carr	Tim.carr@mail.wvu.edu
WVU-Operations mgr.	Sam Taylor	samuel.taylor@mail.wvu.edu
Northeast Natural Energy	B.J. Carney	bjcarney@nne-llc.com
Northeast Natural Energy	Jay Hewitt	jhewitt@nne-llc.com
USDOE/NETL	Robert Vagnetti	robert.vagnetti@netl.doe.gov

WVU Technical Leads

Database	Maneesh Sharma	maneesh.sharma@mail.wvu.edu
Economic, Societal	Randy Jackson	randall.jackson@mail.wvu.edu
Geologic Engineering	Kashy Aminian	kashy.aminian@mail.wvu.edu
Geophysical	Tom Wilson	tom.wilson@mail.wvu.edu
Subsurface Geochemistry	Shikha Sharma	shikha.sharma@mail.wvu.edu
Surface Environmental	Paul Ziemkiewicz	pziemkie@wvu.edu

Building Partnerships for Research, Education, and Outreach



Tim Carr
Phone: 304.293.9660
Email: tim.carr@mail.wvu.edu

West Virginia University
MSEEL
Marcellus Shale Energy & Environment Laboratory
Northeast Natural Energy