# MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL





ST. OF STREET



### West Virginia University



Department of Geology and Geography

Presented by: Tim Carr West Virginia University NACBM– April 12, 2017

## 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



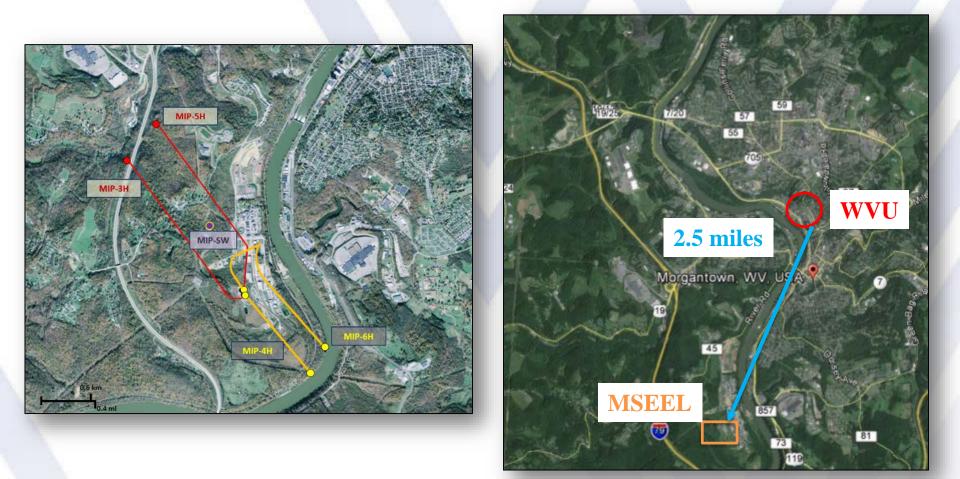
# **MSEEL Site**

- The understudy well is located in Morgantown Industrial Park (MIP) site in the state of West Virginia (USA).
- It is a part of the Marcellus Shale Energy and Environment Laboratory (MSEEL) research.





# **MSEEL Site**



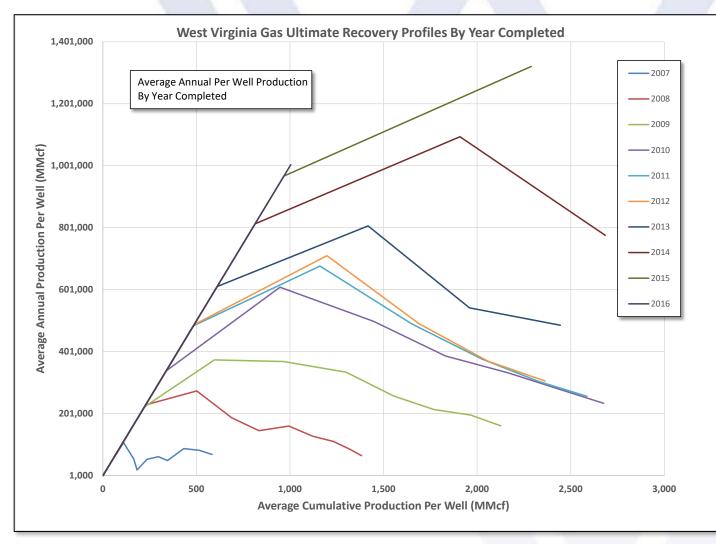


# MSEEL Drilling MIPU 3H and 5H



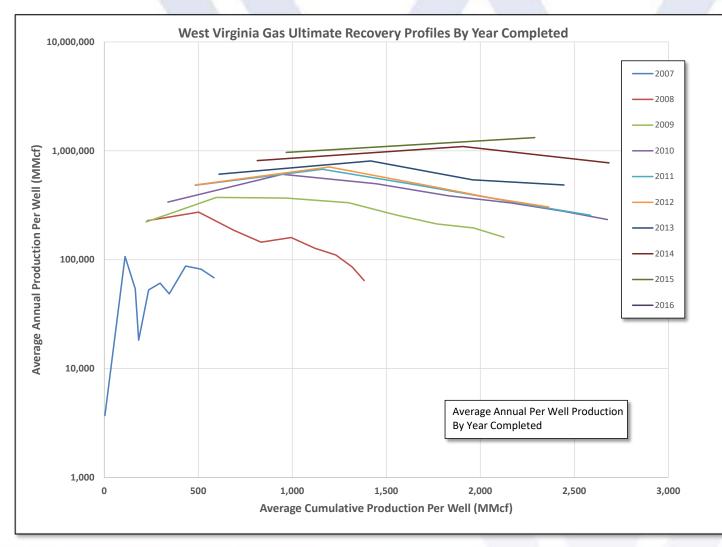


# **Estimated Ultimate Recovery**



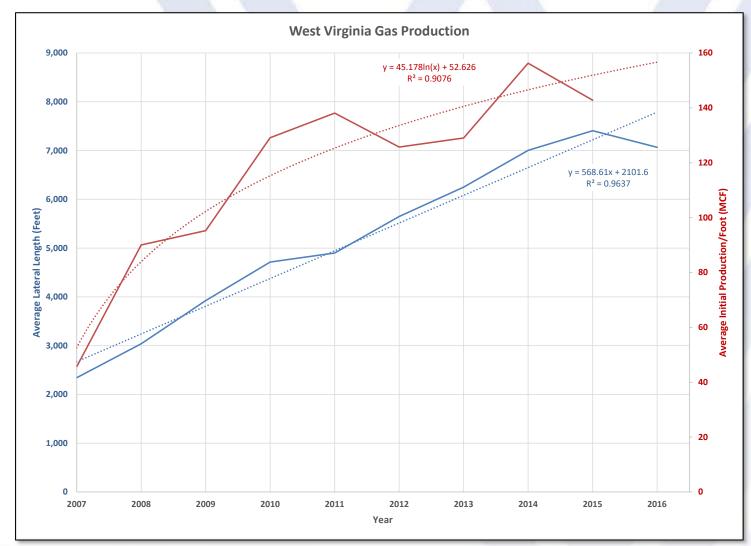


## **Estimated Ultimate Recovery**



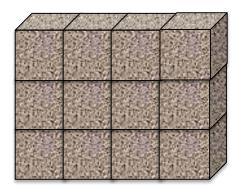


# **Drilling Efficiency**





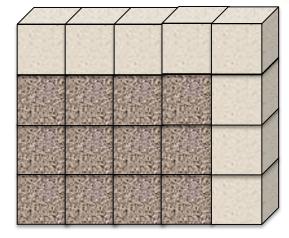
# **Increased Productivity Per Well**



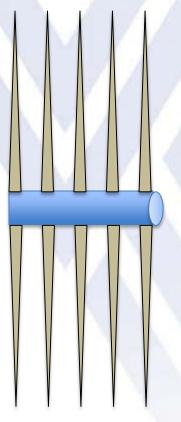
Proppant 1,157 to 1,342 lbs/ft. 12 cubic feet of sand per foot 2011 ~30 days drilling Total Completed Horizontal MIP-4H – 3,782 Feet MIP-6H – 2,342 Feet



# **Increased Productivity Per Well**



Proppant 1,858 to 1,917 lbs/ft. 20 cubic feet of sand per foot

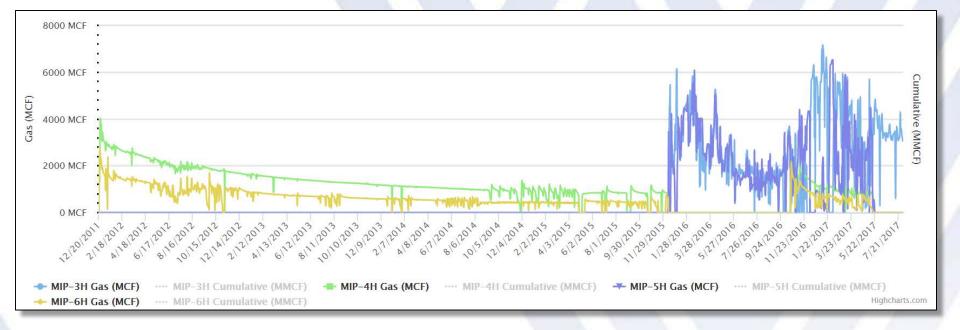


2011 ~30 days drilling Total Completed Horizontal MIP-4H – 3,782 Feet MIP-6H – 2,342 Feet Proppant 1,157 to 1,342 lbs/ft. 12 cubic feet of sand per foot

2015 ~7 days drilling Total Completed Horizontal MIP-3H – 6,058 Feet MIP-5H – 5,784 Feet



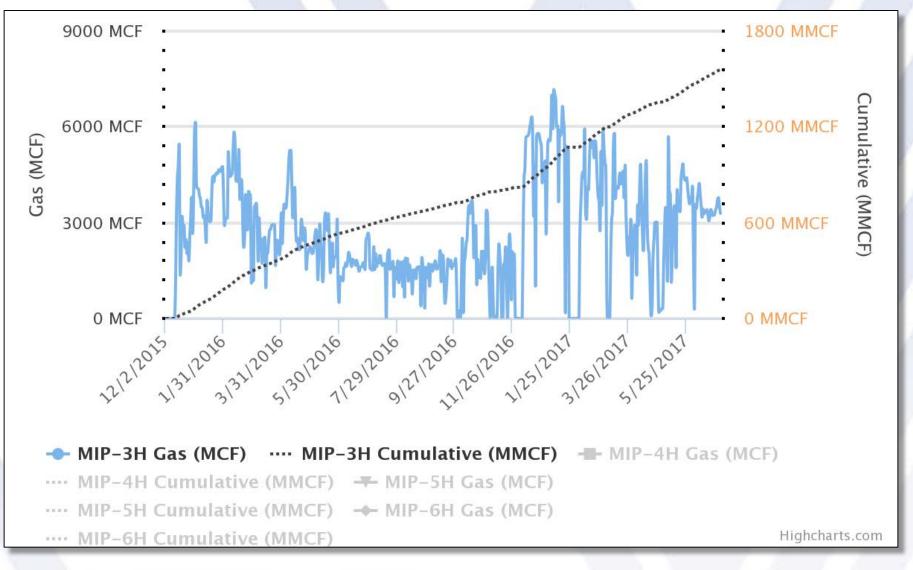
# Production Volumes: MIP 3H, 5H, 4H, 6H







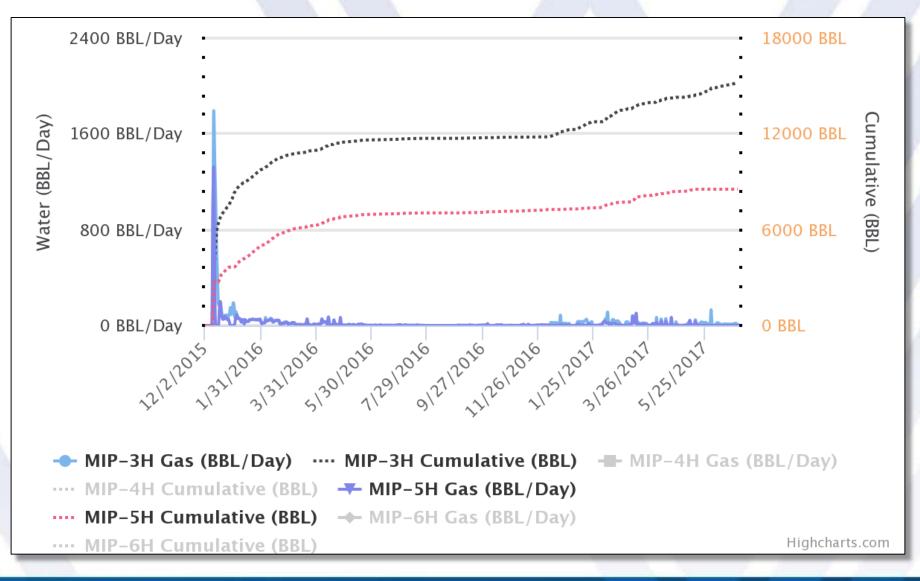
# **Production Volumes: MIP 3H**



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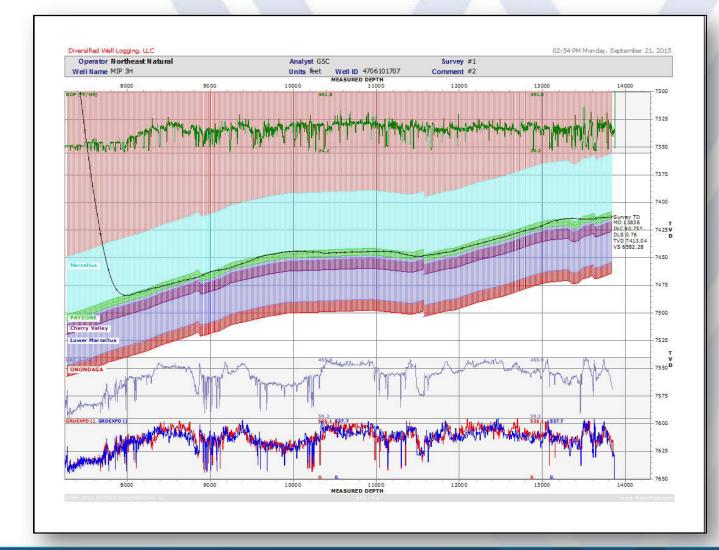
Downloaded from MSEEL.ORG

# Flowback Volumes: MIP 3H & 5H



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# **Geosteering MIP-3H**





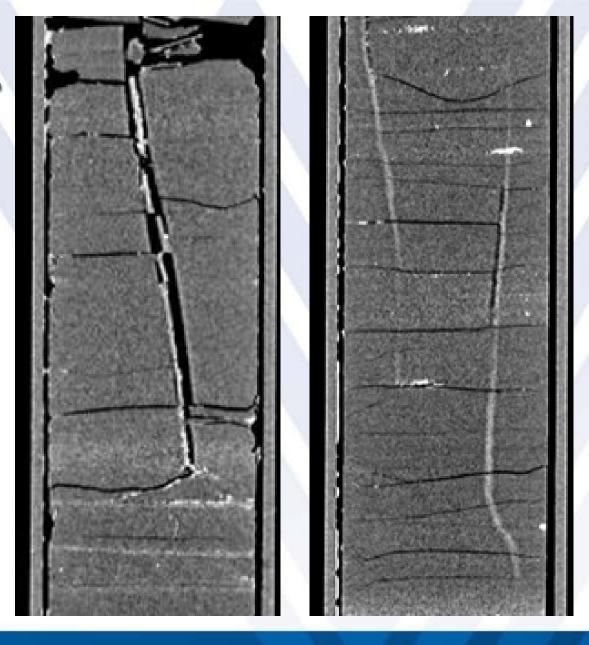
Northeast Natural Energy

# MSEEL Completion MIPU 3H and 5H





# High Resolution CT Scanning – Fractures

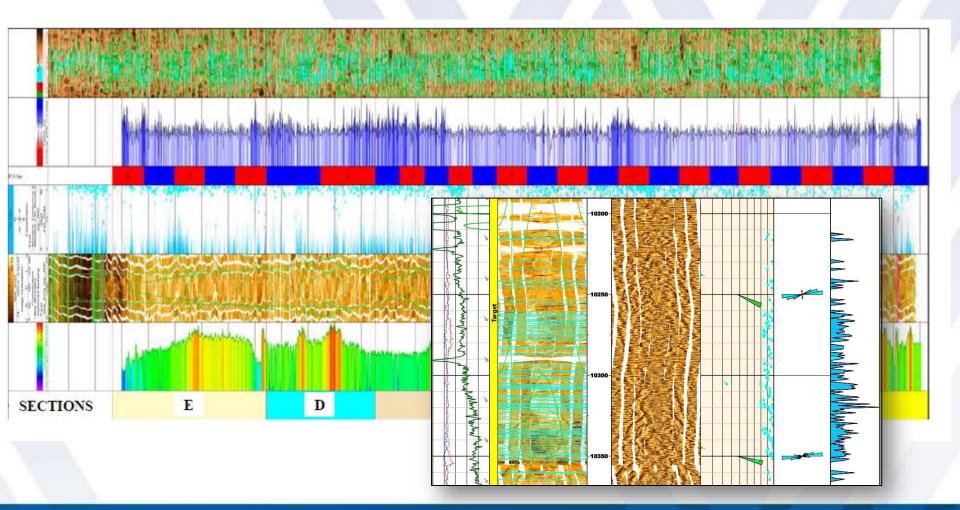




Dustin Crandall - NETL

# **MSEEL - LOGGING LATERAL**

High Definition open hole logs in lateral with synthetic mud

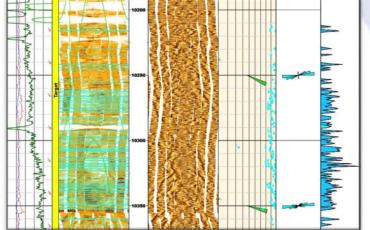


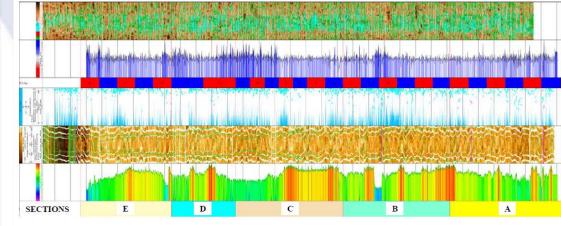


Schlumberger

# **MSEEL - LOGGING LATERAL**

High Definition open hole logs in lateral with synthetic mud



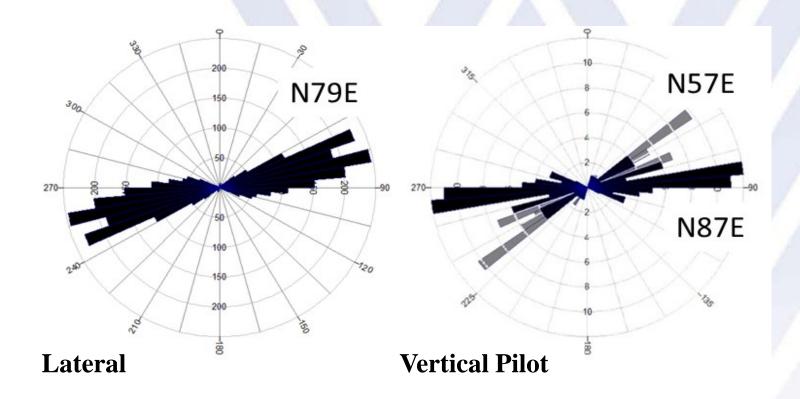


Stage Fault/Fracture	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
No of Faults	3				2	1				2	1																	
No of Fractures	41	25	48	29	15	69	47	51	97	160	86	65	72	17	14	90	25	56	68	71	37	46	21	41	42	89	66	28

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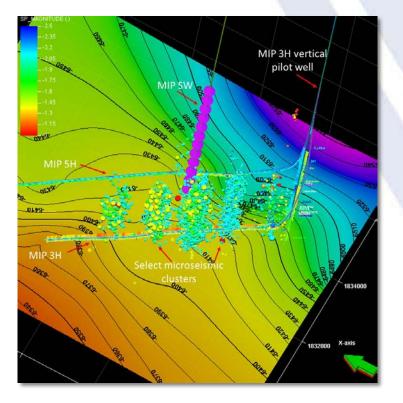


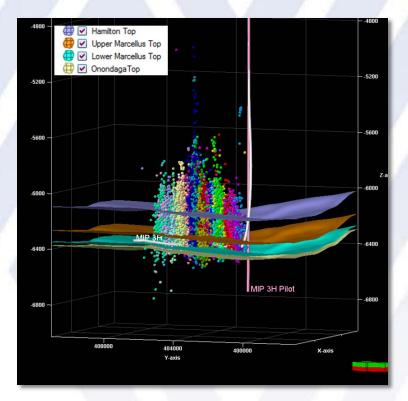
# Natural Fractures MIP-3H





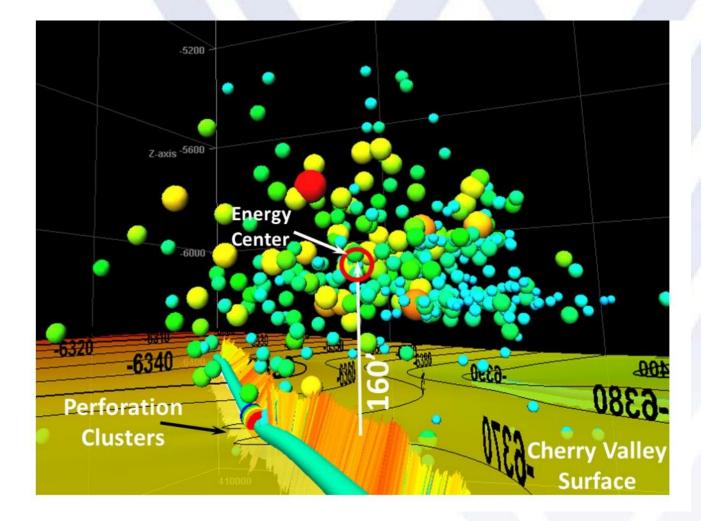
# Microseismic







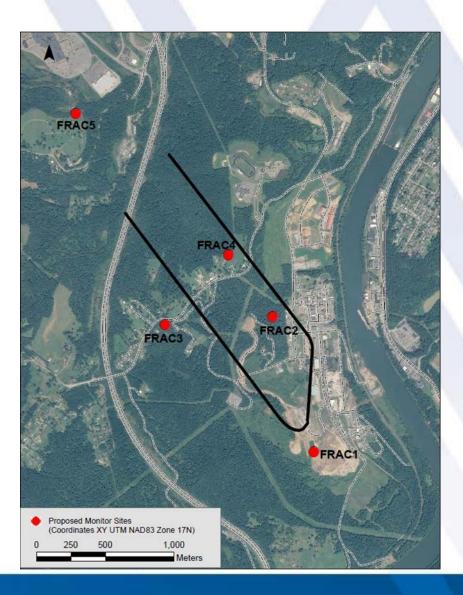
## **MSEEL - Microseismic**





Thomas Wilson - WVU

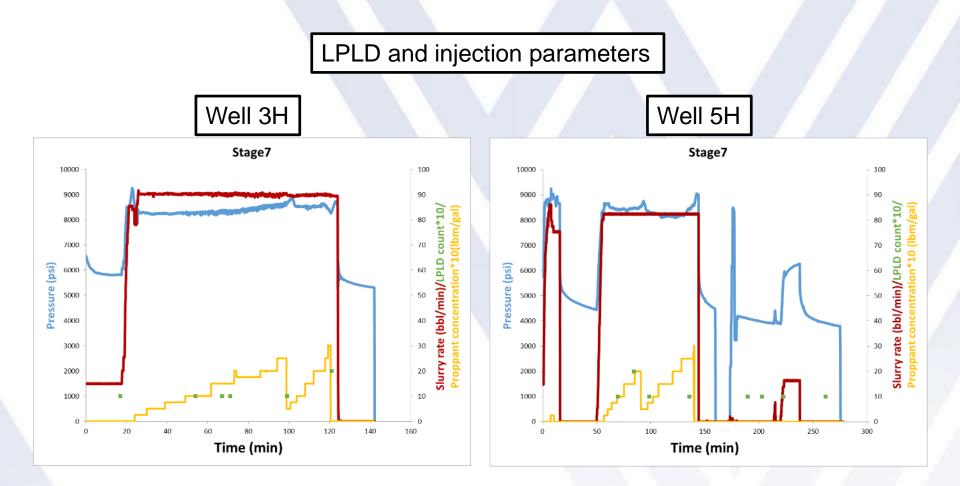
### SURFACE MONITORING OF SLOW SLIP (LPLD)





Kumar at al. NETL

### SURFACE MONITORING OF SLOW SLIP (LPLD)

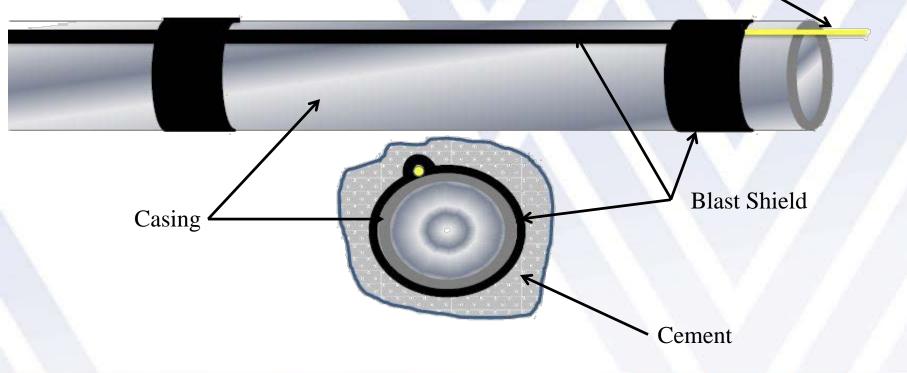




Kumar at al. NETL

# **Fiber Optic Installation**

Fiber Optic Cable





## **MIP 3H Completion Design**

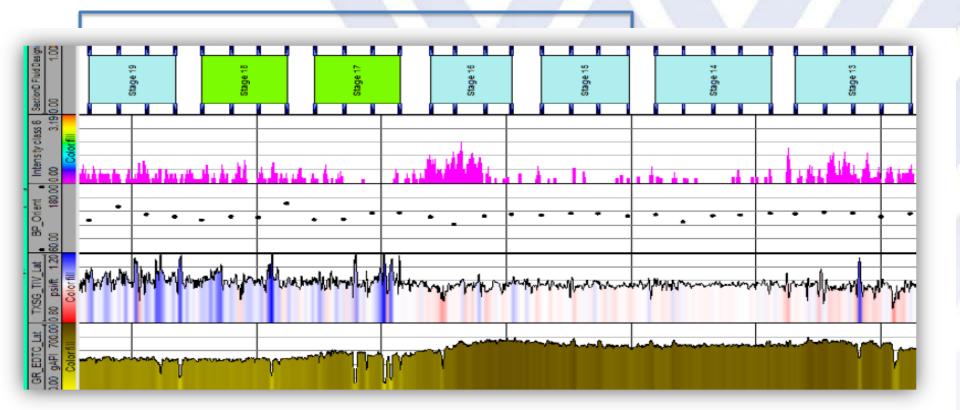
Se	ction	Stage	Cluster Count	Total Shot Count	Shot Density (shot/ft)	Stage Length (ft)	Pump schedule
		28	4	40	6	191	А
	ల	27	4	40	6	184	А
E	Best Practice Applied	26	5	40	6	225	А
	Prae	25	5	32	6	231	А
	st Practi Applied	24	5	30	6	222	А
	Be	23	5	40	6	237	С
		22	5	40	6	220	С
	e ph	21	5	40	5	218	D
P	Saph ire VEF	20	5	40	5	240	D
c		19	4	32	6	180	С
	red	18	4	32	8	180	С
	tior	17	4	32	6	181	С
	SLB Engineered Completion	16	4	26	6	178	С
	E E	15	4	26	6	186	С
	SLE C	14	5	30	6	228	А
	•1	13	5	30	6	230	А
		12	5	50	5	231	В
	100	11	5	50	5	232	В
	%	10	5	50	5	227	В
В	NNE 75% 100- Mesh	9	5	50	5	237	В
	NE	8	5	50	5	222	В
	Z	7	5	50	5	224	В
	<b>7 -</b>	6	5	50	5	245	А
	lard Iesl	5	5	50	5	234	А
	and 0-N	4	5	50	5	230	А
A	10 10	3	5	50	5	238	А
	NNE Standard 35% 100-Mesh	2	5	50	5	223	А
	Ζm	1	5	50	5	233	А



#### Northeast Natural Energy

# **MSEEL - LOGGING LATERAL**

High Definition open hole logs in lateral with synthetic mud





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# **Mapped Faults & Fractures**

For MIP-3H the number of faults and fractures encountered at each stage is reported as:

Stage Fault/Fracture	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
No of Faults	3				2	1				2	1																	
No of Fractures	41	25	48	29	15	69	47	51	97	160	86	65	72	17	14	90	25	56	68	71	37	46	21	41	42	89	66	28





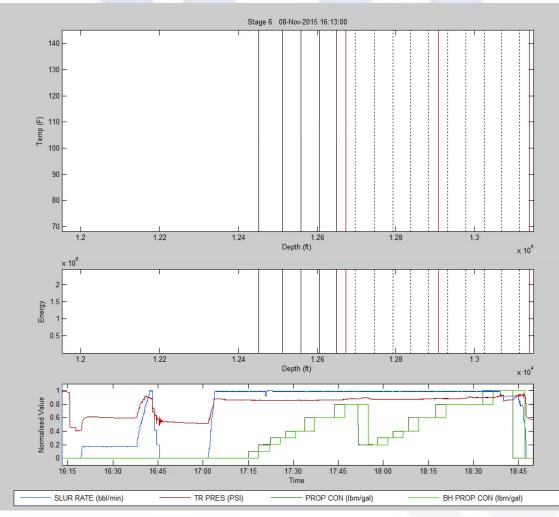
# **DTS** Data

TIME	(5-2)	(S-1)	Current Fracked Stage	(\$+1)	(\$+2)	Stimulation @ Stage	TIME	(5-2)	(5-1)	Current Fracked Stage	(S+1)	(5+2)	Stimulation @ Stage	TIME	(5-2)	(5-1)	Current Fracked Stage	(5+1)	(5+2)	Stimulation @ Stage	1
11/6/2015 12:10 11/6/2015 12:26 11/6/2015 12:32 11/6/2015 12:32 11/6/2015 18:13 11/6/2015 18:13 11/6/2015 18:44 11/6/2015 19:00 11/6/2015 19:15	e Well					Stage-1	11/11/2015 4:17 11/11/2015 4:32 11/11/2015 4:48 11/11/2015 5:04 11/11/2015 5:35 11/11/2015 6:42 11/11/2015 6:57						Stage-11	11/13/2015 16:96 11/13/2015 16:32 11/13/2015 16:37 11/13/2015 16:53 11/13/2015 17:08 11/13/2015 17:08 11/13/2015 17:24 11/13/2015 18:20 11/13/2015 18:20						Stage-19	
11/7/2015 2:07 11/7/2015 2:29 11/7/2015 2:38 11/7/2015 2:54 11/7/2015 3:55 11/7/2015 3:55 11/7/2015 4:09 11/7/2015 4:24 11/7/2015 4:24 11/7/2015 4:55 11/7/2015 5:51	Toe of the Well					Stage-2	11/11/2015 10:04 11/11/2015 10:20 11/11/2015 10:35 11/11/2015 10:31 11/11/2015 11:06 11/11/2015 11:06 11/11/2015 11:38 11/11/2015 11:33 11/11/2015 11:33						Stage-12	11/13/2015 18:45 17/13/2015 19:00 17/13/2015 19:00 11/13/2015 19:46 11/13/2015 19:47 11/13/2015 19:47 11/14/2015 0:28 11/14/2015 1:55 11/14/2015 1:55 11/14/2015 1:57 11/14/2015 1:47 11/14/2015 1:20						Stage-20	
11//7015 5.27 11//7015 8.28 11/7/2015 8.43 11/7/2015 8.43 11/7/2015 9.30 11/7/2015 9.30 11/7/2015 9.30 11/7/2015 10.53 11/7/2015 10.53 11/7/2015 11.58						Stage-3	11/11/2015 13:28 11/11/2015 15:34 11/11/2015 15:50 11/11/2015 16:65 11/11/2015 16:67 11/11/2015 16:37 11/11/2015 16:52 11/11/2015 18:13 11/11/2015 18:13						Stage-13	11/14/2015 2:18 11/14/2015 2:23 11/14/2015 5:41 11/14/2015 5:41 11/14/2015 5:57 11/14/2015 6:28 11/14/2015 6:38 11/14/2015 7:54 11/14/2015 7:54 11/14/2015 7:54						Stage-21	
11/7/2015 18-26 13/7/2015 18-52 13/7/2015 18-52 13/7/2015 18-52 11/7/2015 18-29 11/7/2015 18-29 11/7/2015 21-01 11/7/2015 21-01 11/7/2						Stage-4	11/11/2015 20:33 11/11/2015 20:33 11/11/2015 20:49 11/11/2015 21:04 11/11/2015 21:36 11/11/2015 21:36 11/11/2015 21:51 11/11/2015 22:07 11/11/2015 22:23 11/11/2015 22:23						Stage-14	11/14/2015 9:50 11/14/2015 9:51 11/14/2015 9:51 11/14/2015 10:07 11/14/2015 10:38 11/14/2015 10:38 11/14/2015 11:08 11/14/2015 11:08 11/14/2015 11:08 11/14/2015 11:06 11/14/2015 11:56						Stage-22	-
11/8/2015 8:50 11/8/2015 9:06 11/8/2015 9:22 11/8/2015 9:27 11/8/2015 12:23 11/8/2015 12:23 11/8/2015 12:54 11/8/2015 18:10 11/8/2015 18:10 11/8/2015 18:41						Stage-5 Stage-6	11/11/2015 22:54 11/11/2015 23:10 11/12/2015 3:30 11/12/2015 3:51 11/12/2015 3:51 11/12/2015 4:06 11/12/2015 4:22 11/12/2015 4:33						Stage-15	11/14/2015 15:43 11/14/2015 15:59 11/14/2015 15:59 11/14/2015 20:00 11/14/2015 20:16 11/14/2015 20:21 11/14/2015 20:32 11/14/2015 21:30 11/14/2015 21:35 11/14/2015 21:35						Stage-23	
1/8/2015 19:51 11/8/2015 20:56 11/9/2015 20:56 11/9/2015 2:50 11/9/2015 2:11 11/9/2015 2:43 11/9/2015 2:58 11/9/2015 3:30 11/9/2015 4:14 11/9/2015 4:14						Stage-7	11/12/2015 5:09 11/12/2015 5:25 11/12/2015 8:16 11/12/2015 8:32 11/12/2015 8:33 11/12/2015 9:03 11/12/2015 9:19 11/12/2015 9:35 11/12/2015 10:30						Stage-16	11/14/2015 23:55 11/15/2015 0:11 11/15/2015 0:6 11/15/2015 0:42 11/15/2015 0:58 11/15/2015 1:29 11/15/2015 1:29 11/15/2015 2:16 11/15/2015 2:16 11/15/2015 2:16						Stage-24	
11/9/2015 4:45 11/9/2015 5:01 11/9/2015 8:43 11/9/2015 8:59 11/9/2015 9:30 11/9/2015 9:30 11/9/2015 10:01 11/9/2015 11:50 11/9/2015 16:59						Stage-8	11/12/2015 10:46 11/12/2015 11:01 11/12/2015 22:10 11/12/2015 22:26 11/12/2015 22:42 11/12/2015 22:57 11/12/2015 23:13 11/12/2015 23:34						Stage-17	11/15/2015 4.21 11/15/2015 4.36 11/15/2015 4.52 11/15/2015 5.08 11/15/2015 5.23 11/15/2015 5.23 11/15/2015 5.35 11/15/2015 6.10 11/15/2015 6.10 11/15/2015 6.10 11/15/2015 6.11 11/15/2015 7.01						Stage-25	
11/9/2015 16:35 11/9/2015 16:50 11/9/2015 17:06 11/9/2015 17:21 11/9/2015 17:37						Stage-9	11/13/2015 0:00 11/13/2015 0:15 11/13/2015 0:31 11/13/2015 0:47 11/13/2015 1:02							11/15/2015 8:52 11/15/2015 9:08 11/15/2015 9:24 11/15/2015 9:39 11/15/2015 13:36						Stage-26	
11/9/2015 18:20 11/9/2015 18:36 13/9/2015 18:51 11/9/2015 21:31 11/9/2015 21:47							11/13/2015 9:07 11/13/2015 9:23 11/13/2015 9:38 11/13/2015 9:54						Stage-18	11/15/2015 13:52 11/15/2015 14:08 11/15/2015 14:23 11/15/2015 14:23 11/15/2015 14:39 11/15/2015 17:23					Heel of the Well	Stage-27	
11/9/2015 22:02 11/9/2015 22:18 11/9/2015 22:34 11/1/2015 4:01						Stage-10	11/13/2015 10:09 11/13/2015 10:25 11/13/2015 12:05						Prefe-10	11/15/2015 12:19 11/15/2015 17:55 11/15/2015 18:10 11/15/2015 18:26					Heel W	Stage-28	



#### Shohreh Amini

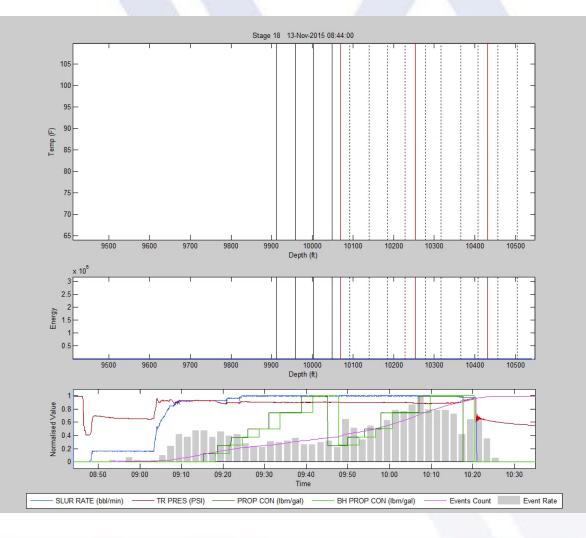
# MIP3H - Stage 6: Geometric Completion Uneven Distribution



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#### Schlumberger

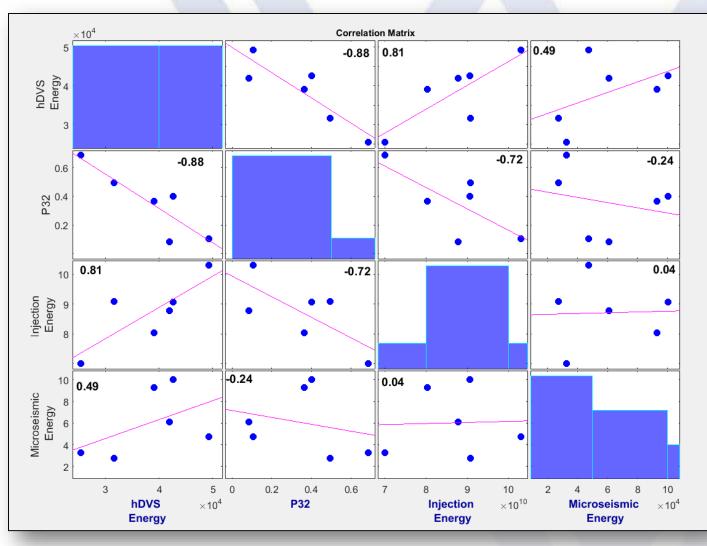
## **MIP 3H - Stage 18 Even Distribution**





#### Schlumberger

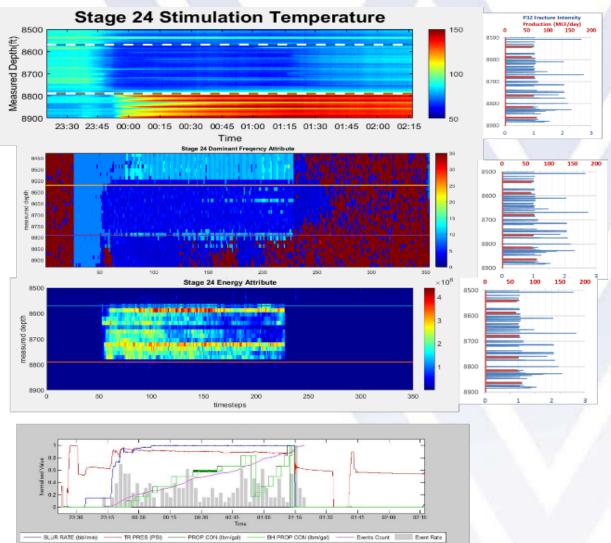
# Microseismic, Injection Energy & Fractures





Payam Kavousi et al.

# **Dominant Frequency Imaging Using DAS Data**

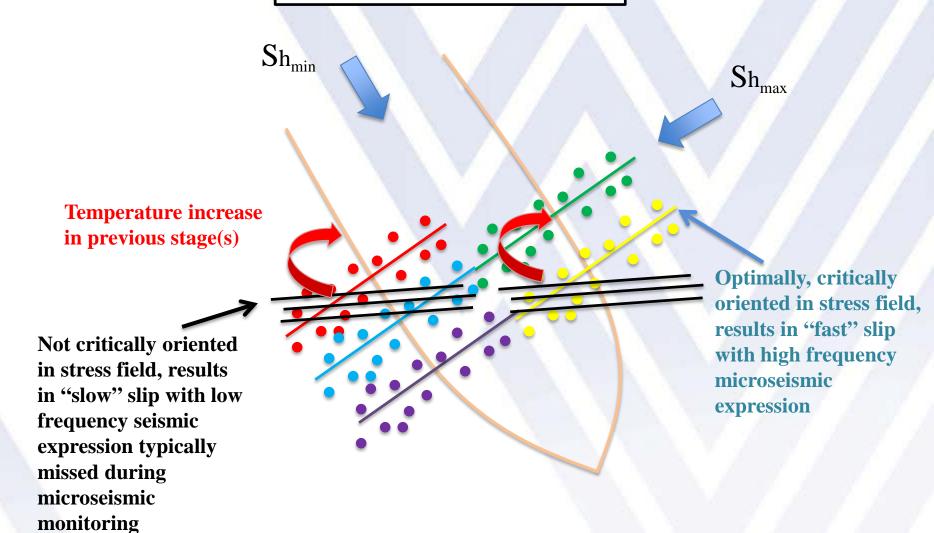




#### Payam Kavousi et al.

### SURFACE MONITORING OF SLOW SLIP (LPLD)

Synopsis of slow-slip deformation





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

# Conclusions

- The Marcellus Shale is a complex unconventional reservoir that does not respond in a straightforward manner during large scale hydraulic fracture stimulation.
- Completion efficiency along the lateral is affected by preexisting fractures oriented at an angle to existing principal stresses and strongly influence hydraulic fracture propagation. The results can be utilized as a guide to optimize the hydraulic fracturing design parameters for new wells.



### Building Partnerships for Research, Education, and Outreach

Industry

**MSEEL** 



### Academia

#### Government

This research was funded by a grant from Department of Energy's National Energy Technology Laboratory (DE-FE0024297).

