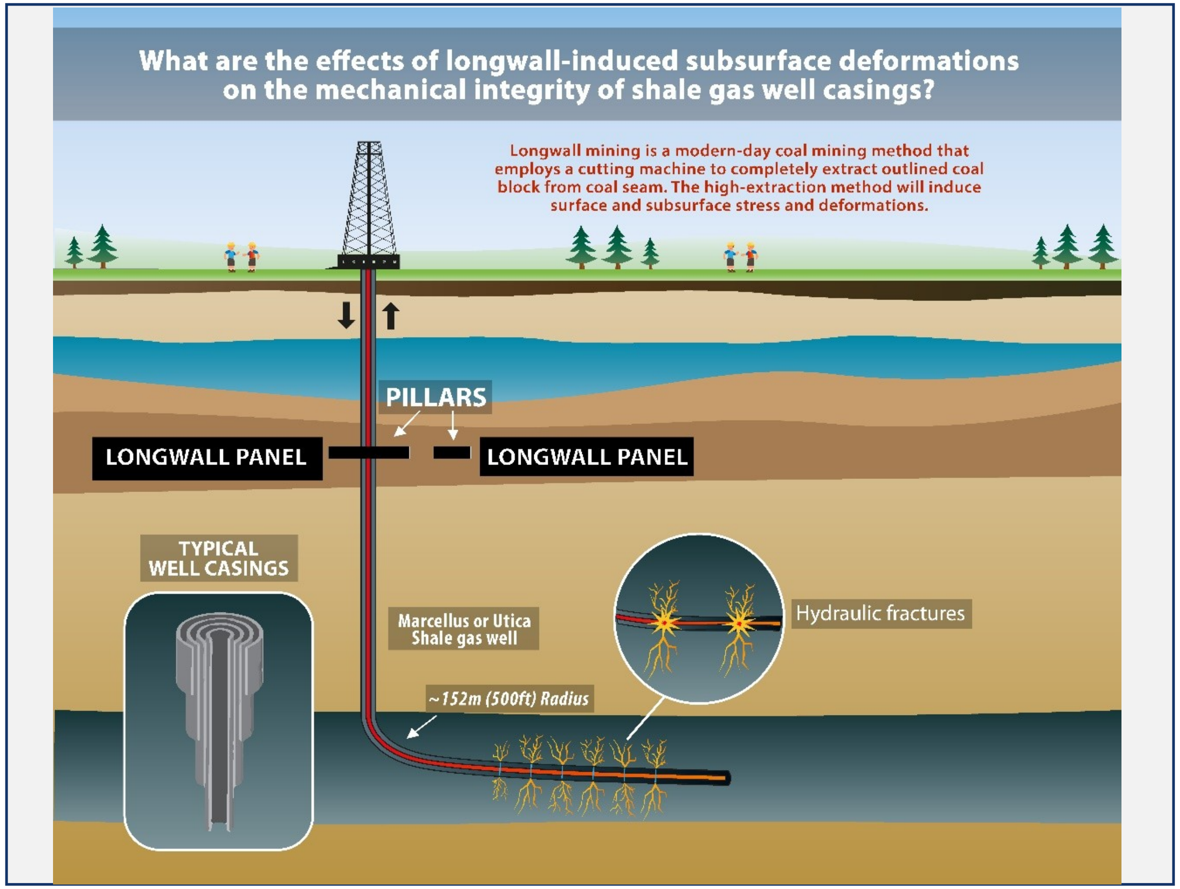
NIOSH's role in developing ventilation input to new engineering guidance for shale gas wells near longwall mining



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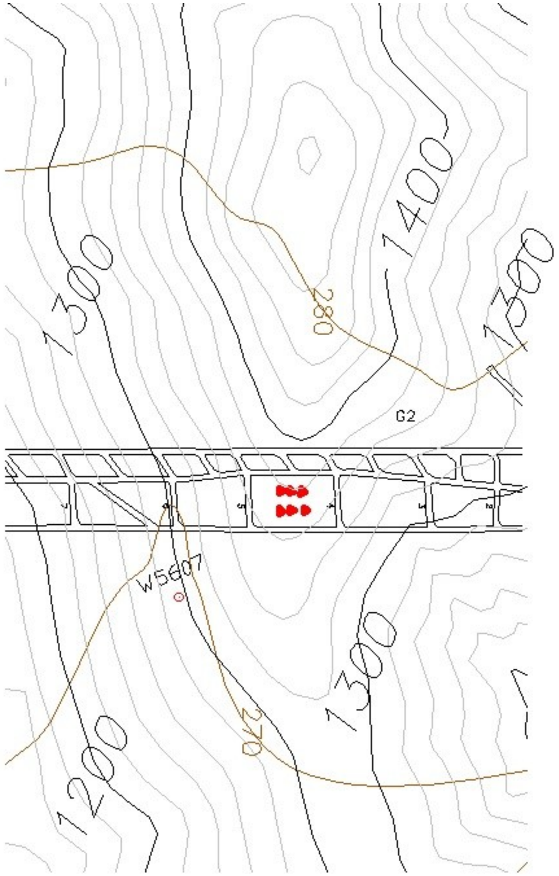
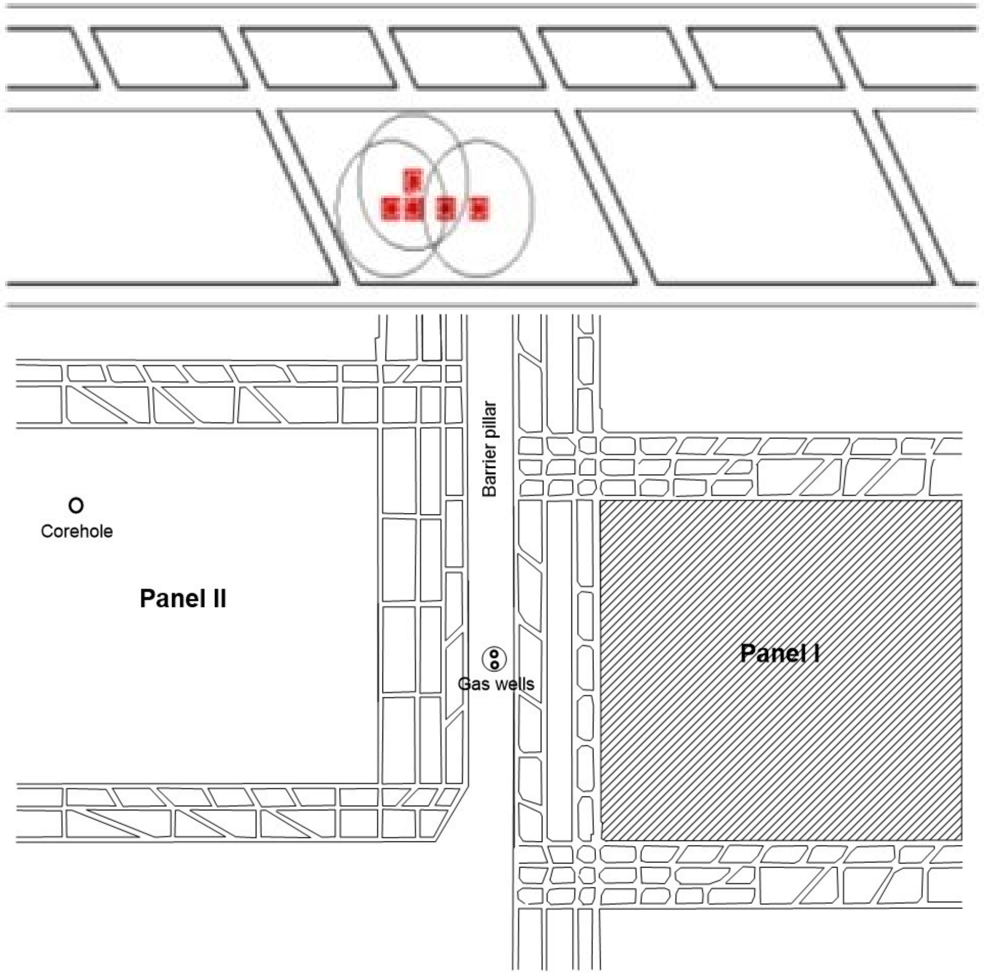
Problem Statement and outline

- Problem statement- Need for research input
- If a well casing breach occurred, what quantity of breached gas would flow towards an underground mine?
- Once gas from a breached well event reached a mine, what safety and health issues would occur?
  - How could they be identified, mitigated?
- What are the effects of overburden depth and variable geology?
- How does a change in the stratigraphic position of the zone of maximum horizontal movement effect transport from a hypothetical gas breach to a mine and to the surface?
- Can coalbed gas sources be distinguished from shale and underground storage field sources?
  - How could a procedure be implemented by coal and unconventional gas industries to monitor gas sources?

Problem statement -

- Could ground movement associated with longwall mining compromise the integrity of unconventional gas well in abutment pillars and what would be the safety and health consequences of this hypothetical event?





Need for research input - Regulatory agencies as well as coal and gas industries need critical scientific data

Longwall Mining

Positioning of unconventional gas wells in pillars was based in the 1957 PADEP Gas Well Pillar Guidance, now updated with 2017 PADEP Technical Guidance Document

- Surface and subsurface subsidence
- Stress changes in the overburden
- Induced fracturing, pathways for potential gas transport
- Potential incursions may require detection
- Identification of gas potential from non-coal sources

Gas Wells

Well operators need input on the configuration and positioning of new gas wells to insure miner, gas worker and public safety

- Protected by chain pillars or barrier pillars
- Could be damaged if longwall mining induces excessive stresses and deformations in the well casings
- Assessment of permeability changes with face retreat

Estimate In-flow

- Experimental Data
- DFN 3DEC
- DFN FFC

Model Gas Migrati on

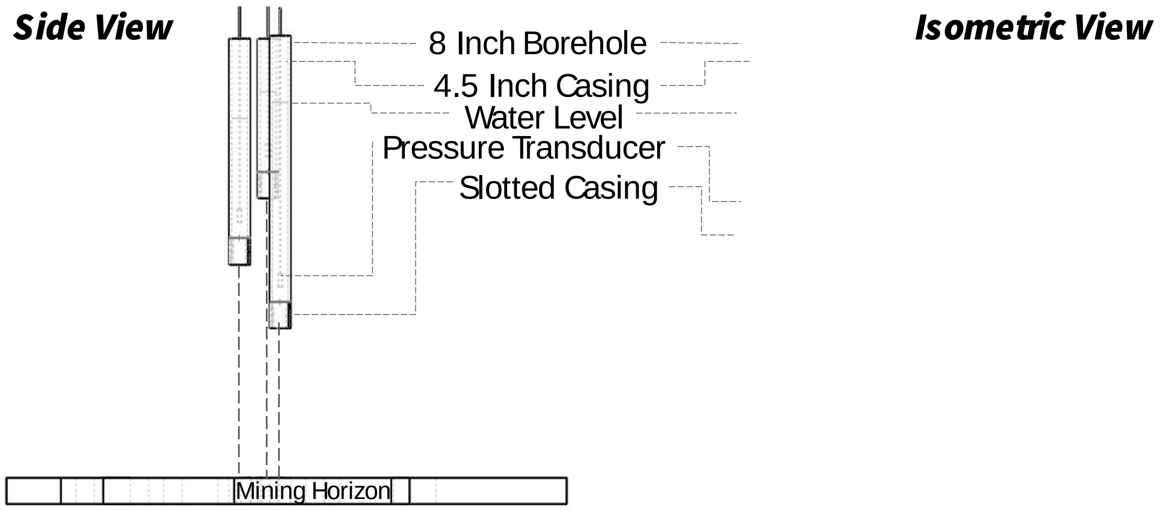
- CFD
- Network
- LIAM

Distinguish Gas Sources

- Gas Composition al Analysis

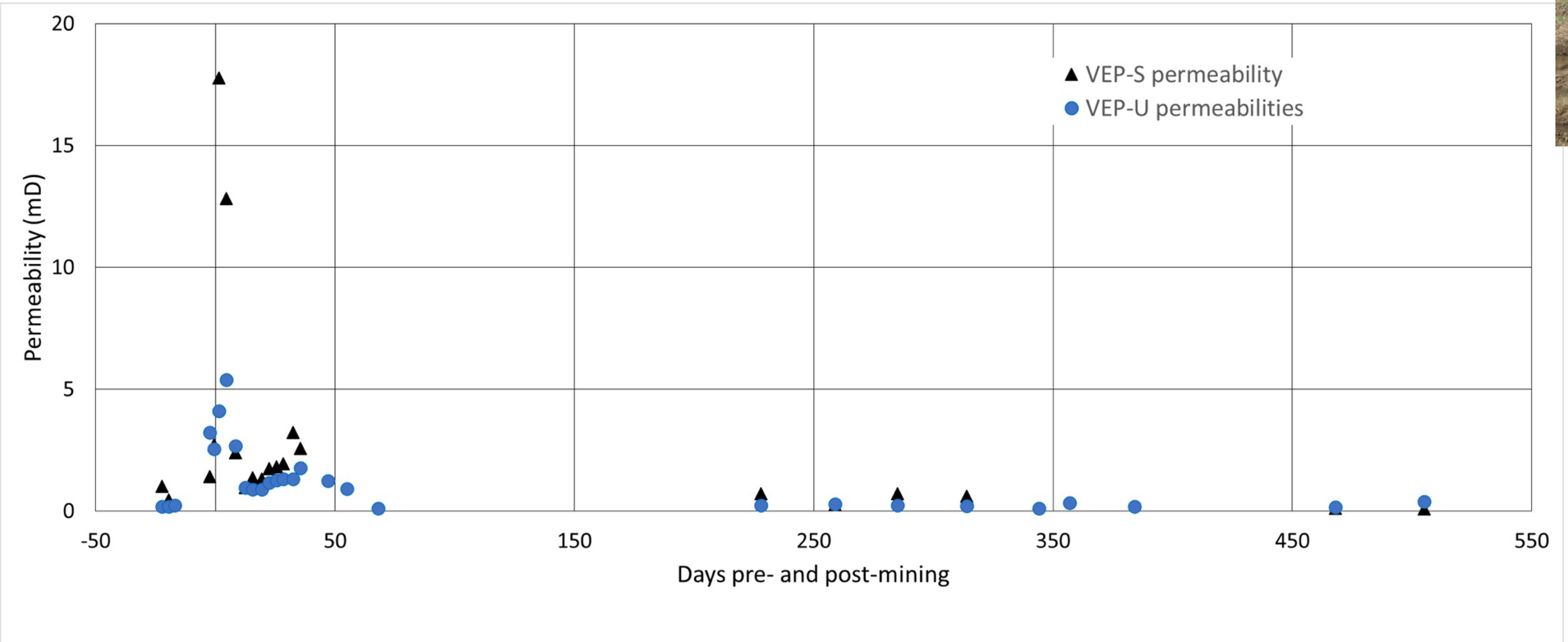
Field sites for experimental data from different overburden depths

- Deep cover- Over 900 ft of overburden to mined unit
- Intermediate cover- Between 500 ft and 900 ft to mined coal bed
- Shallow cover- Less than 500 ft to mined coal bed
- Site data, Shallow and deep cover
  - Experimental data
    - Ground movement
    - Permeability monitoring
  - Simulations of ground movement and fracture development
    - Ground movement, maximum values
    - Second panel mining generally represents the most movement, greatest fracture apertures
- New site, Intermediate cover
  - Experimental data



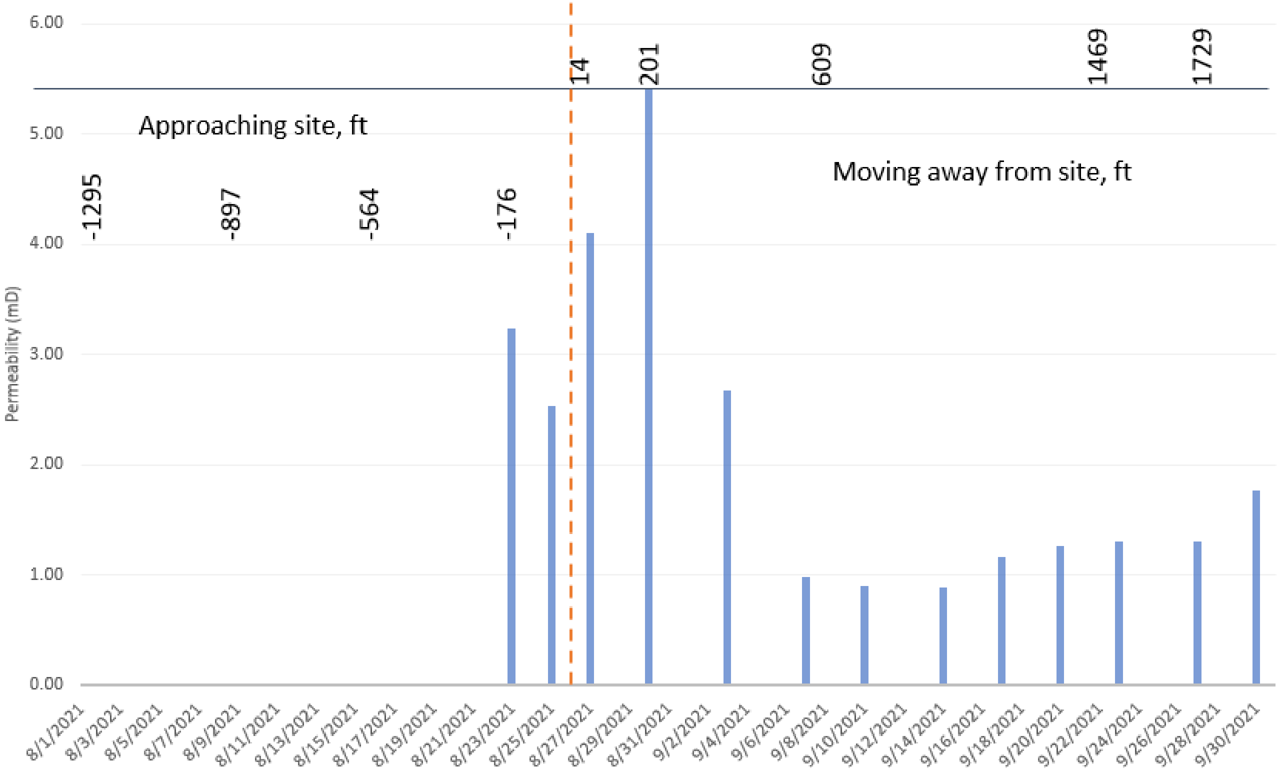
Modification of overburden permeability due to mining induced fracturing

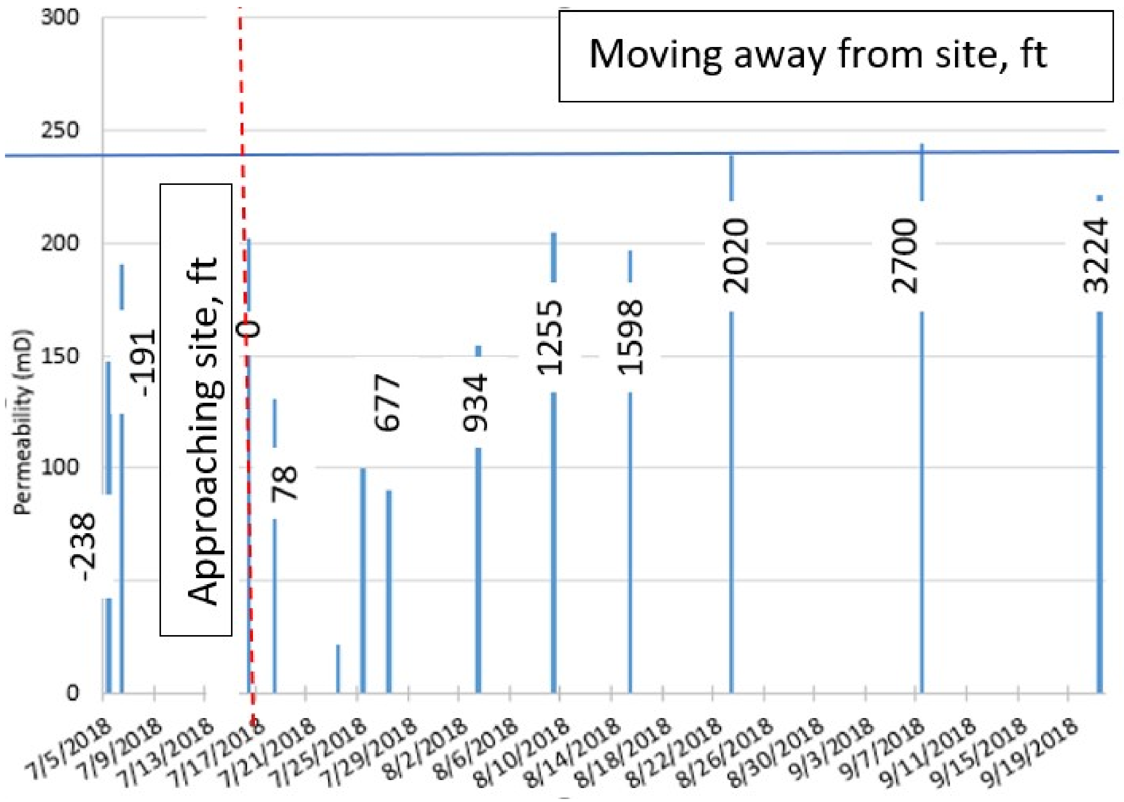
- **Overburden deformation induced through mine by of the well pad**
  - Fracture permeability produced by longwall increases the overburden fracture permeability over in situ values, changes with longwall face position
  - Under deep cover, fracture permeability over abutment pillar returned to pre-mining values during long term monitoring



Modification of overburden permeability due to mining induced fracturing

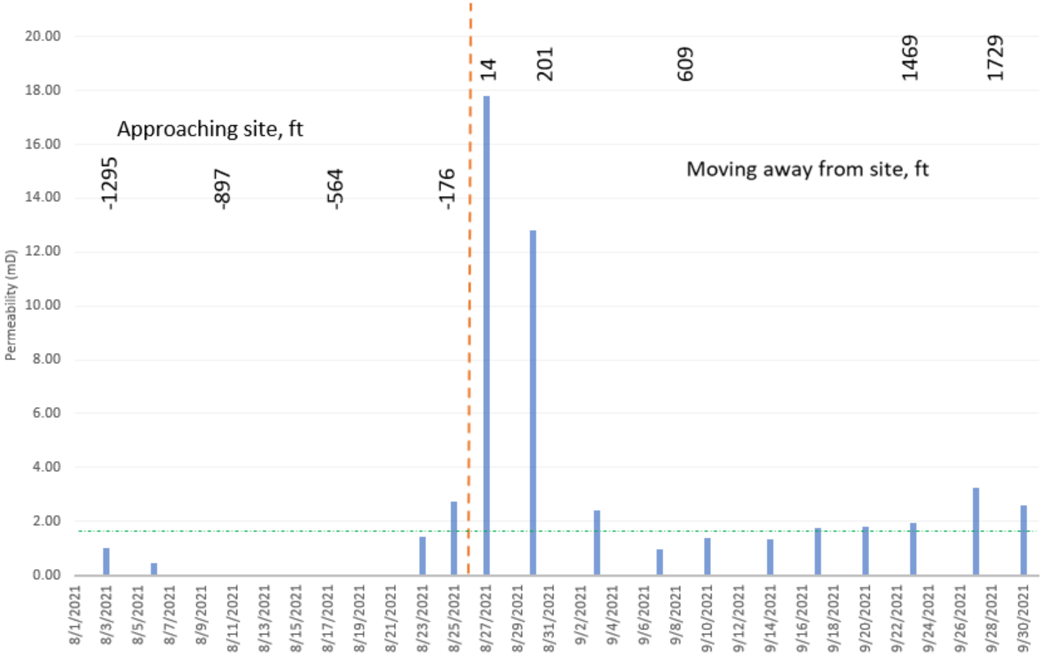
- **Overburden deformation induced through mine by of the well pad**
  - Maximum permeability for shallow cover (<500 feet) is 2 orders of magnitude greater than in deep cover settings (>900 feet), for first panel mining
  - Second panel mining under shallow cover (<500 feet) increases maximum permeability by about 1.5 to 3 times the first panel mine by

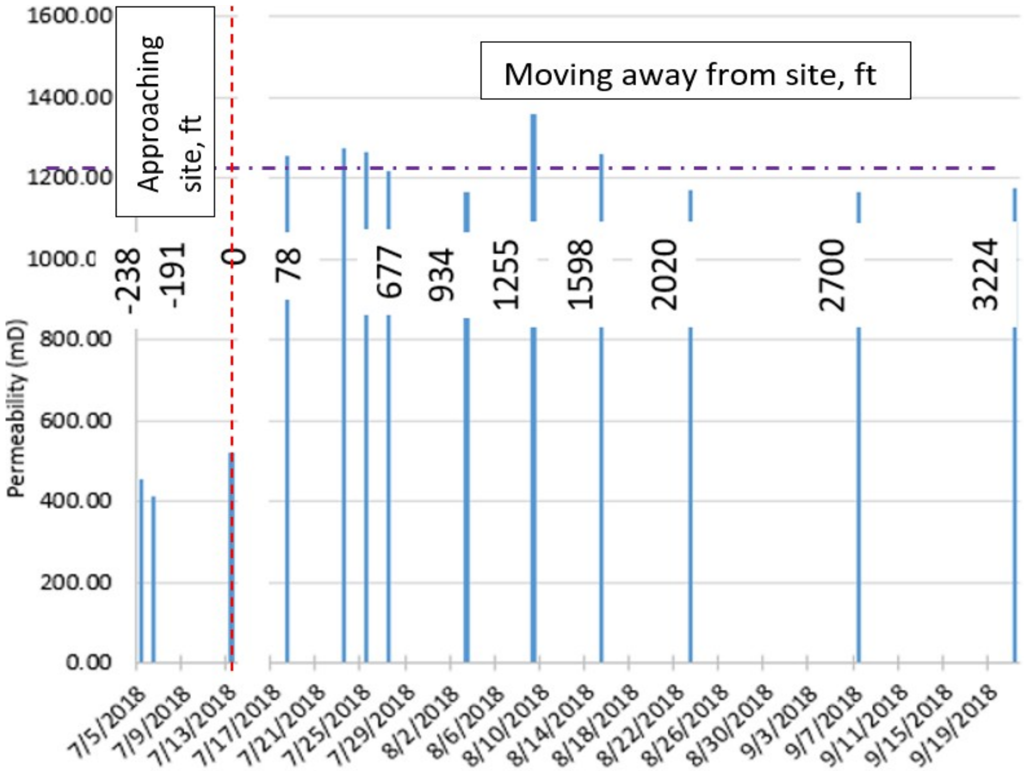




Impact of topography on fracture network behavior

- **(a) Sites with typical southwestern PA topography show different permeability behavior than those near stream valleys**
  - First panel mine bys near stream valleys show the permeability remains in the range of 90% of the maximum value achieved for about 2000 feet after mine by
  - For more typical topography, first panel mine bys showed permeability dropping to about 10 to 20% of the maximum value achieved for about 2000 feet after mine by





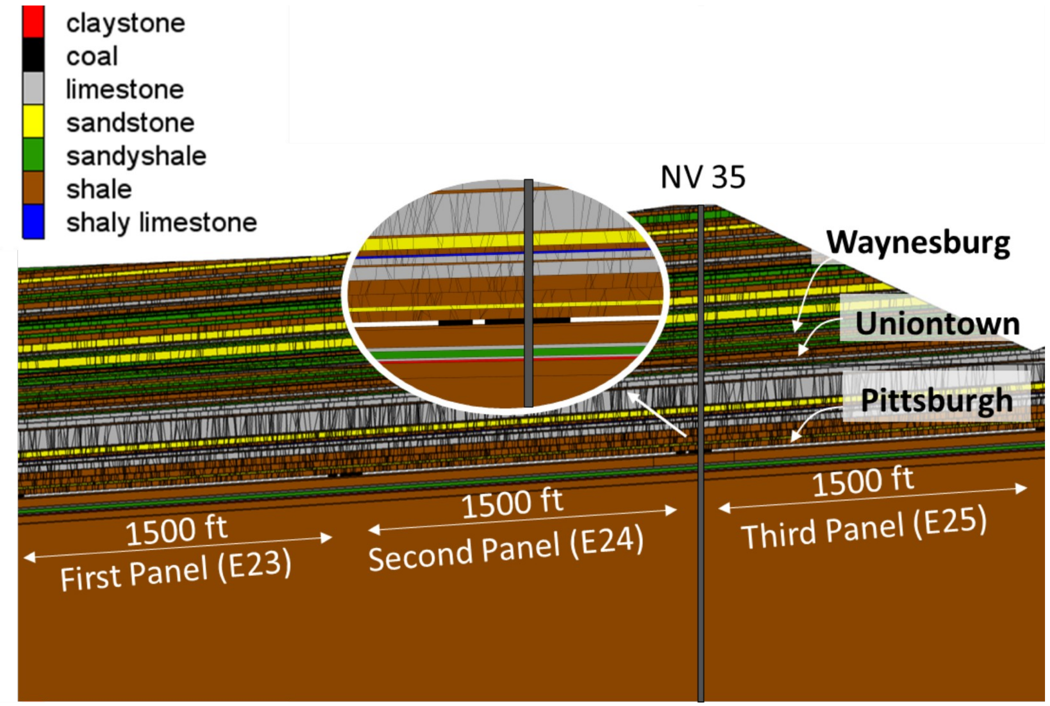
Importance of position of maximum horizontal movement of strata in gas transport

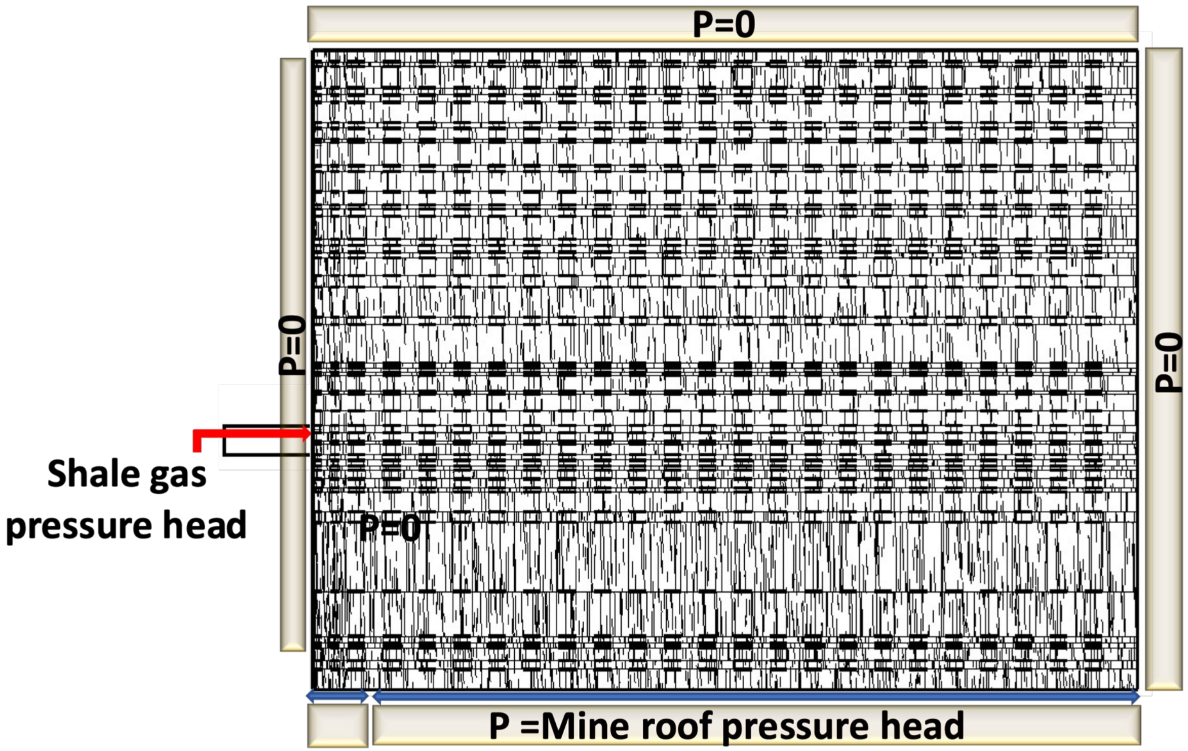
- **When the horizon of maximum horizontal displacement occurs above the zone of mine induced fracturing (more than 300 feet above the Pittsburgh seam), the likelihood of hypothetical breached gas reaching the mine is low**
  - For simulations under intermediate cover (between 500 and 900 feet) and deep cover (>900 feet) where the zone of maximum movement was above the mine induced fracture zone (more than 300 feet above the Pittsburgh seam) 0 cfm of hypothetical breached gas reached the mine
  - Increasing from 1 to 10 boreholes typically increases inflow prediction quantity about 2 to 3 times above the lower rate at 3000 psi

3000 psi inflow simulations	Hypothetical breach location	1 borehole	10 boreholes
Tunnel Ridge	168 ft below surface	0 cfm	0 cfm
NV35	395 ft below surface	<1 cfm	Not determined

Modeling of gas transport in longwall gobs

- Discrete fracture network (DFN) modeling using 3DEC and FFC code





Summary of hypothetical inflow at differing depths

- Simulations for hypothetical breach for mines under shallow cover (< 500 ft)
  - Field site that produced these data was near a stream channel, producing enhanced permeability and inflow estimates
- Simulations for hypothetical breach for mines under intermediate cover (> 500 feet, <900 ft)
  - No inflows indicated (less than 1 cfm) for these sites
  - Zone of maximum horizontal movement was above gob fracture height
- Simulations for hypothetical breach for mines under deep cover (> 900 ft)
  - No inflows indicated for maximum movement above gob fracture zone
  - Low inflow quantities were estimated for maximum movement within the fracture zone

Summary of hypothetical inflow findings for 350 psi for a single casing

Overburden depth	1 casing	Comments
Shallow cover	736 cfm[1]	Maximum movement within fractured zone
Intermediate cover	0- <1 cfm	Maximum movement above fractured zone
Deep cover	0- 44 cfm[2]	Maximum movement above and within fractured zone

[1]Inflow data from stream channel environment, enhanced permeability and transport

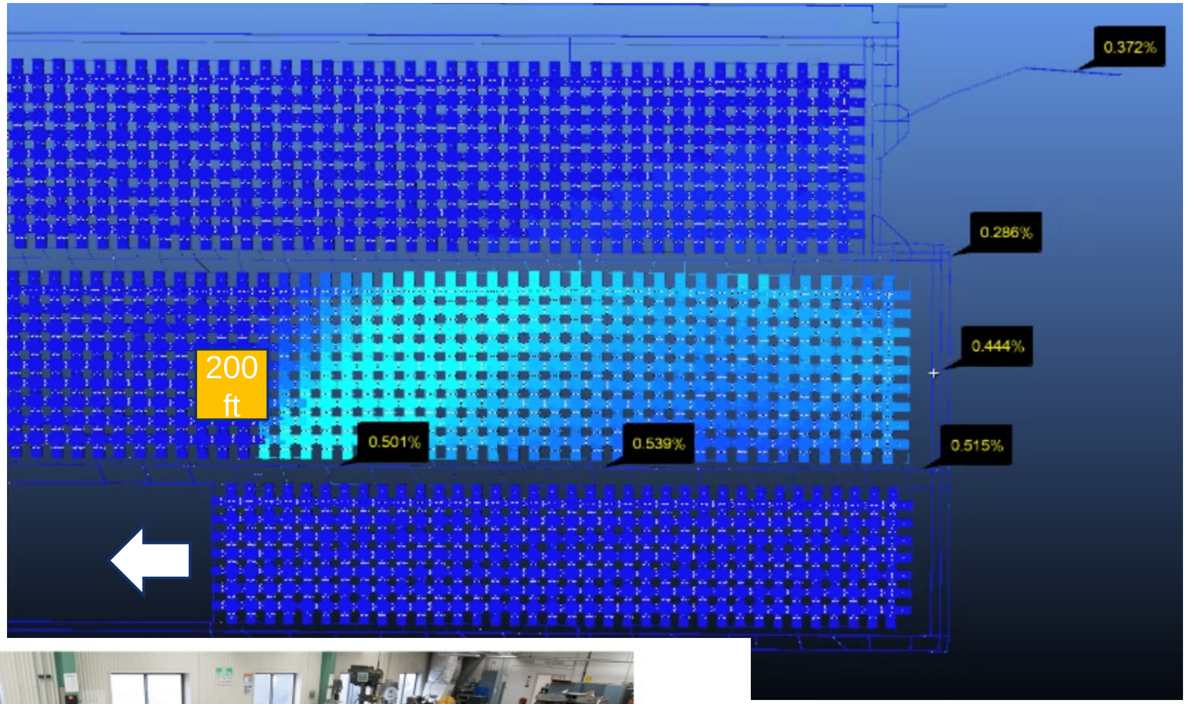
[2]One site with hypothetical breach within fractured zone produced predicted inflow

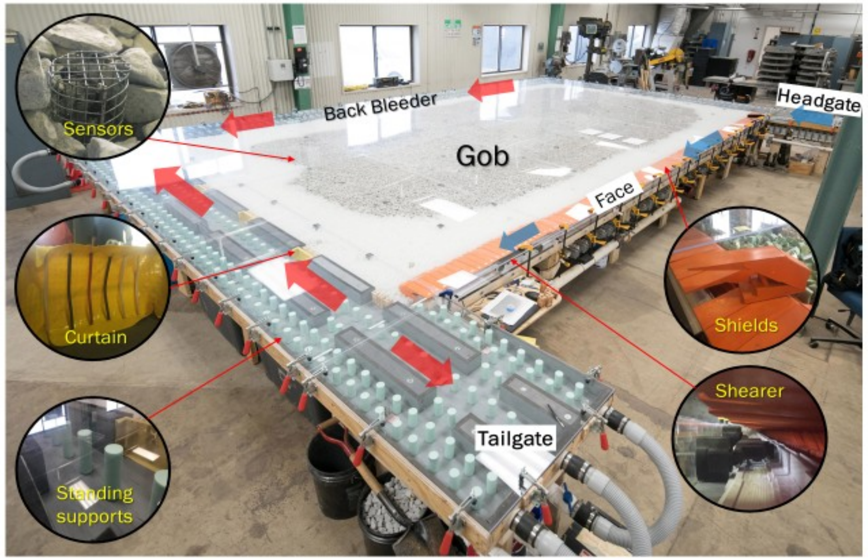
Behavior of gas transport in underground mine ventilation systems and possible methods for mitigation

- **If inflow quantities from a hypothetical well breach do not exceed about 400 cfm, dilution by the mine's standard ventilation system may be possible**
  - Ventilation systems using a conventional Pittsburgh coal mine strategies showed good potential for controlling this level of additional inflow
  - Simulations showed added gas was primarily concentrated at the BEPs and bleeders but below statutory limits, some gas in the gob and no gas on the active longwall face
- **If hypothetical breach inflow quantities reach 2100 cfm or more**
  - Ventilation airflow simulations for conventional Pittsburgh coal mines with a hypothetical breach of 2100 cfm showed methane concentrations at elevated levels, above or near statutory limits in the BEPs and the bleeders
  - Hypothetical inflows of this magnitude or greater would likely require a form of mitigation to re-establish safe conditions underground

Gas concentration increases at key underground locations from a hypothetical breach, 340 and 400 cfm inflows

Monitoring Location	340 cfm Inflow	400 cfm Inflow
	Increased CH_4 concentration due to hypotehtical well breach, %	
Tailgate Bleeder Inby BEP Evaluation Point	0.131	0.301
Tailgate Bleeder outby BEP Evaluation Point	1.080	1.328
Tailgate #1	0.000	0.000
Tailgate #2	0.033	0.049
Tailgate #3	0.047	0.064
Longwall Face	0.000	0.000
Back Bleeder #5	0.000	0.000
Back Bleeder #6	0.016	0.019
GVB #1	0.002	0.004
GVB #2	0.000	0.000

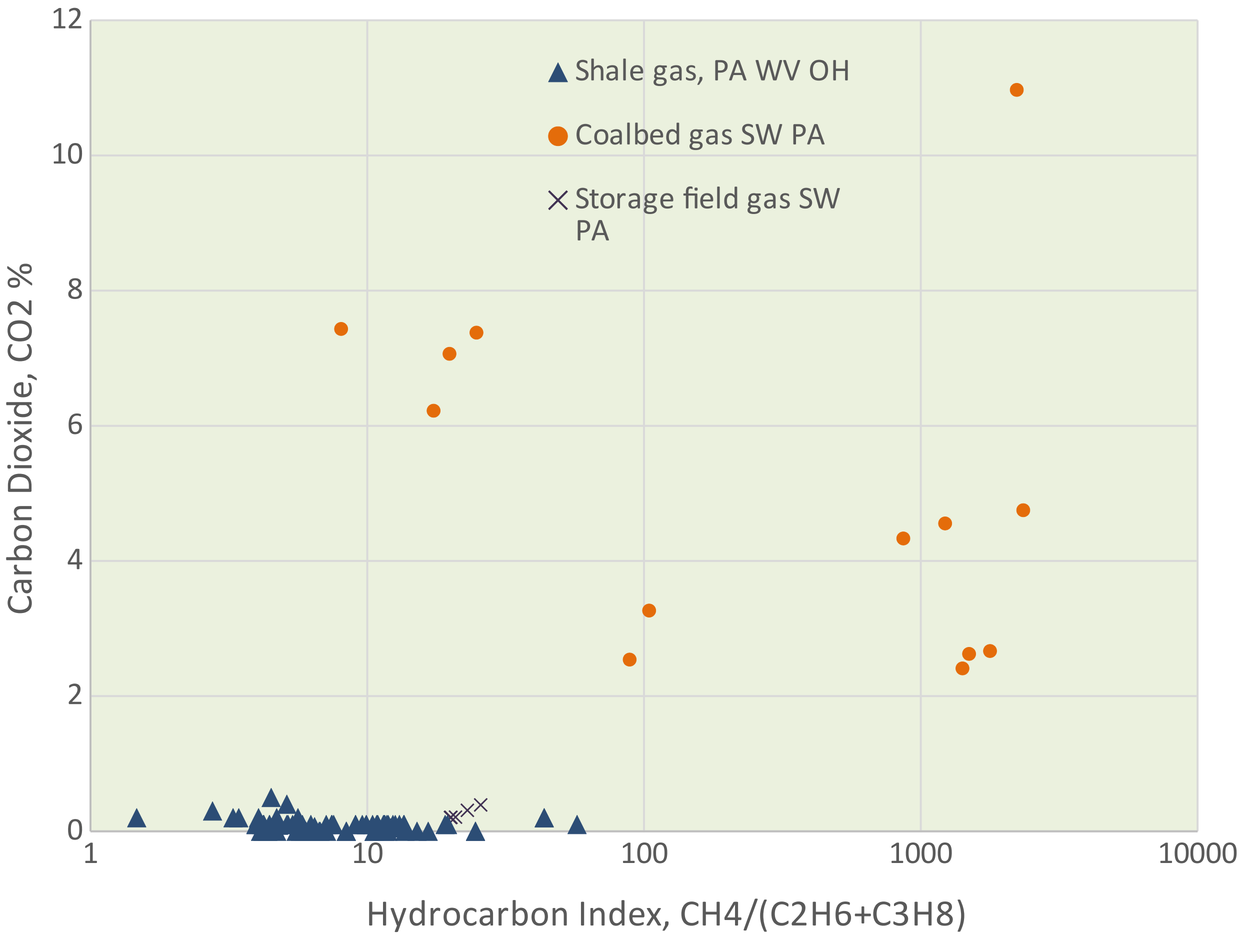


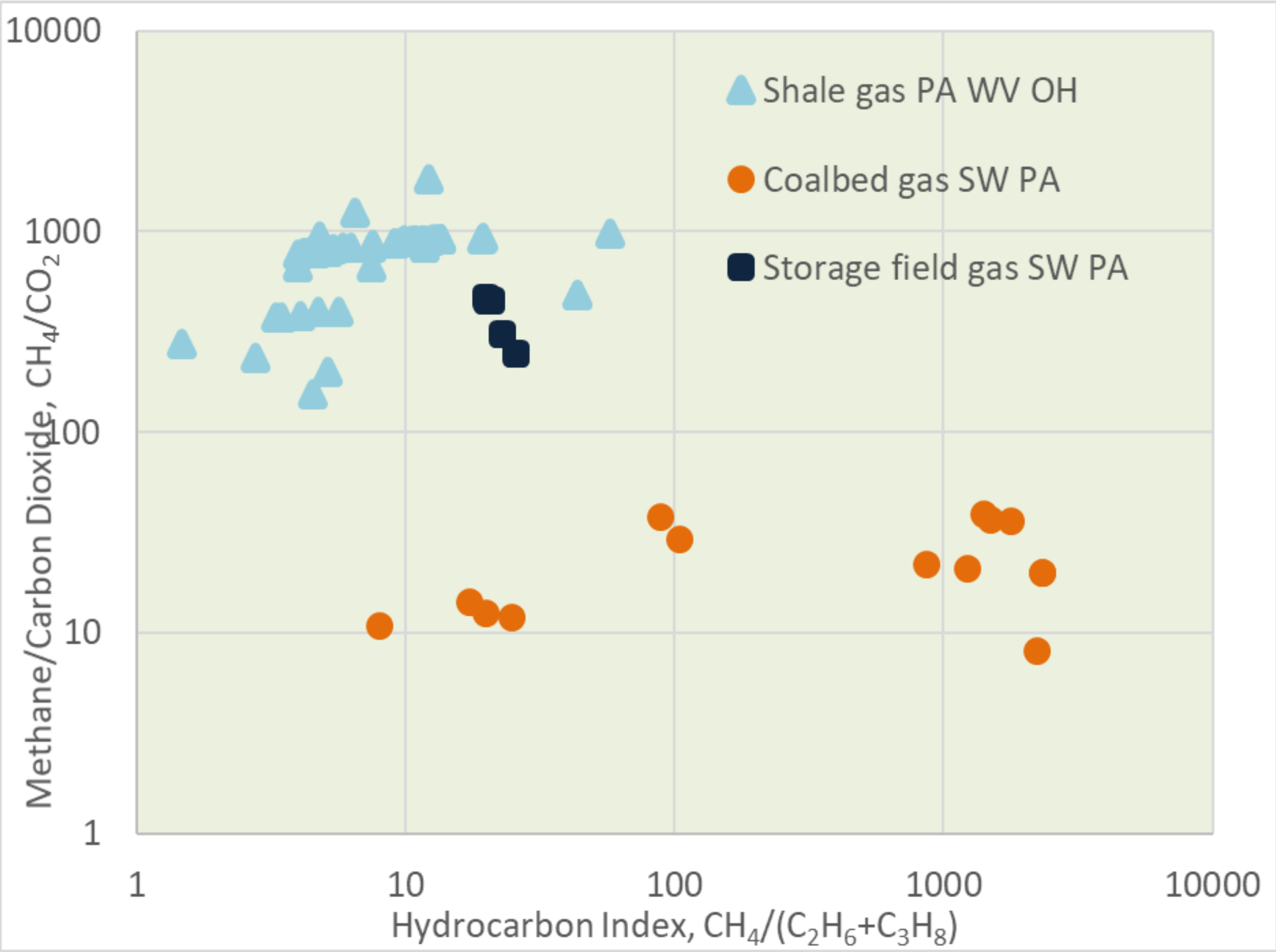


Methodology for distinguishing gas sources within near well sites or within mines

- **A gas chromatography (GC)-based method of distinguishing was developed to distinguish coalbed methane, shale gas, and storage field gas sources**
  - Bivariate plots using the hydrocarbon index and CO_2 concentration show coalbed gas plotting above 2% CO_2 with shale gas and storage field gas below 1% CO_2 on initial data set
  - Plots of the hydrocarbon index and CH_4/CO_2 ratio show coalbed gas below 100 for the CH_4/CO_2 ratio with shale gas and storage field gas over 100 for the CH_4/CO_2 ratio
  - A strategy for implementation of this technique has been presented and published using small diameter boreholes, sampling and analysis by GC to identify incursions of non-coal gas

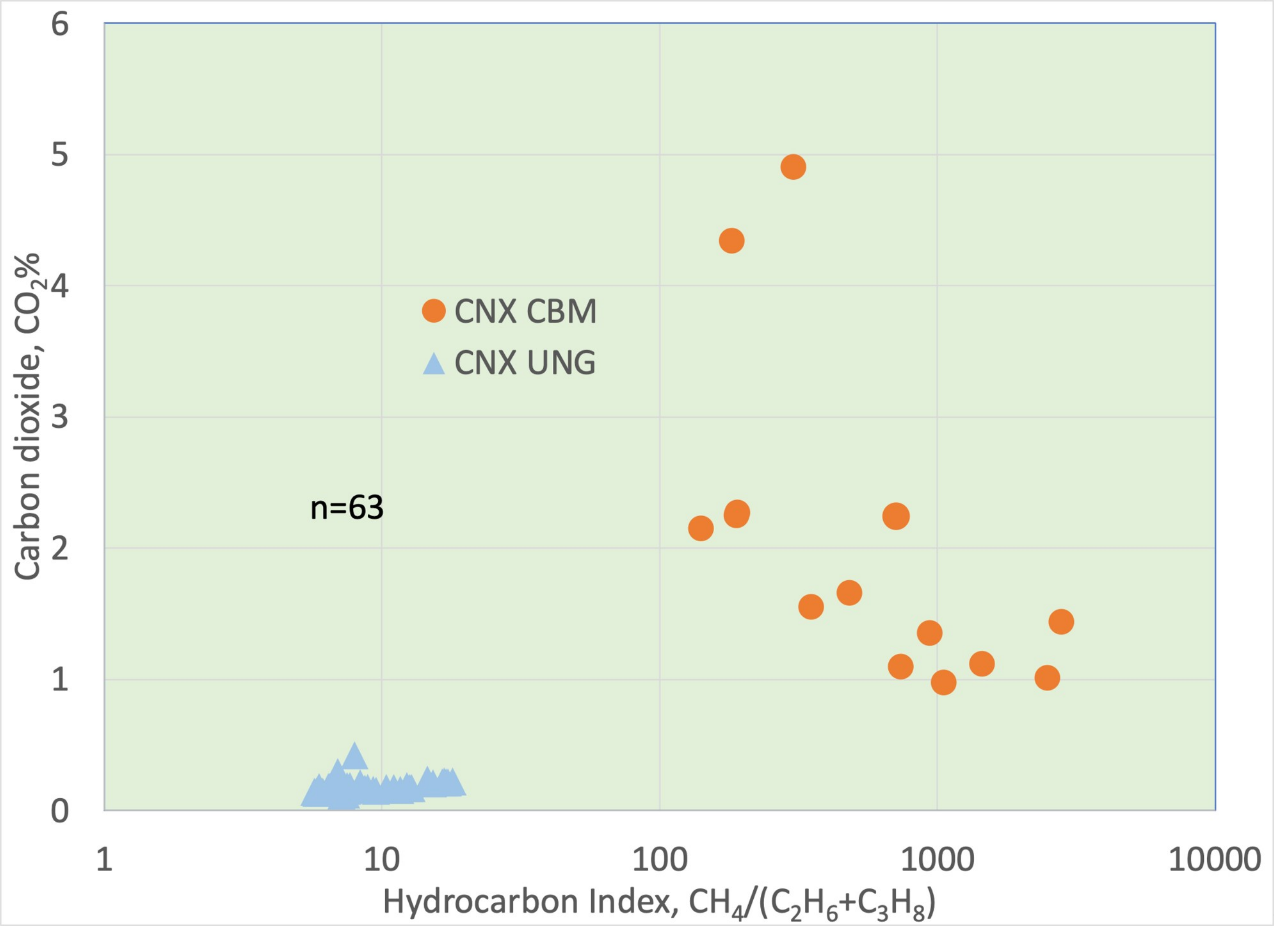
Findings from gas source identification

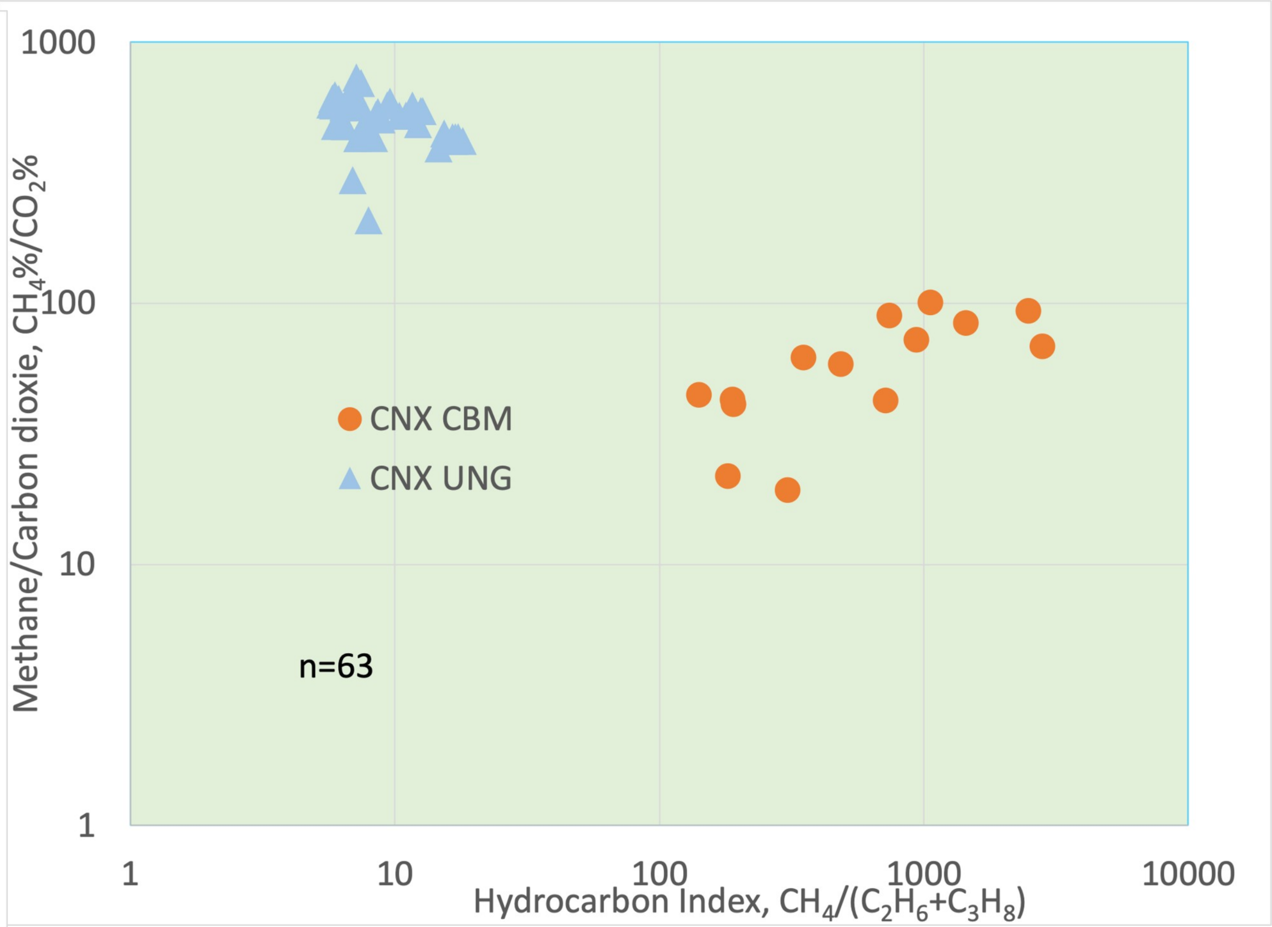




Additional sample analyses to produce statistically valid dataset

- Materials Transfer Agreement with CNX to expand database
- Demonstrate the application of the methodology for the mine-by of unconventional gas wells in abutment pillars





Take away points

- Overburden depth and permeability
  - Maximum shallow cover permeability 2 orders of magnitude greater than in deep cover
  - Under deep cover, permeabilities over abutment pillar returned to pre-mining values in long term monitoring
- Impact of topography on fracture network behavior
  - Near stream valleys, first panel mine bys remain at about 90% of the maximum permeability
  - For typical SW PA topography, first panel mine-bys, permeability drops to 10 to 20% of the maximum permeability in two to three months of monitoring
- Importance of location of maximum horizontal movement
  - When maximum horizontal displacement occurs above the zone of mine induced fracturing, likelihood of hypothetical breached gas reaching the mine is greatly decreased
- Summary of hypothetical inflow findings
  - Shallow cover, stream valley site, hypothetical breach in fracture zone produced highest inflow rates, enhanced transport scenario
  - Intermediate and deep cover sites showed no gas inflows for breaches above the fractured zone
- Behavior of gas transport in underground mine ventilation systems, possible consequences
  - For hypothetical inflow quantities below 400 cfm, management by the mine's ventilation may be possible
  - If hypothetical breach inflow quantities are 2100 cfm or more, mitigation may be required
- Methodology for distinguishing gas sources
  - Gas chromatography (GC)-based method for distinguishing coalbed methane, shale gas, and storage field gas sources
  - Expanding database of samples, interaction with cooperators

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Thank you

NIOSH Mining Program