Illinois Basin Tanquary Field Project

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Regional Carbon Sequestration Partnerships
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Midwest Geological
Sequestration Consortium
www.sequestration.org

Acknowledgements

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- The MGSC is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky

Tanquary S/ECBM Pilot Test

Purpose: To determine the CO_2 injection and storage capability, and the ECBM recovery potential of Illinois Basin coal

- Single Coal Seam
- CO_2 (gas) Injection Test
- Injection of up to 200 tons of CO_2 depending on injectivity rate and monitoring well results
- Pressure above CH_4 adsorption pressure

The Coal

- Springfield Coal, high volatile bituminous rank
- 7 feet thick at 900 ft depth; 385 psig
- Undersaturated; 150-210 scf/ton (dmmf); >92% CH_4 w/ lesser N_2 and CO_2
- CO_2 adsorption isotherm 3x CH_4
- Well developed cleats; 1-2 cm spacing
  - Calcite and/or kaolinite filling

Coal Characterization

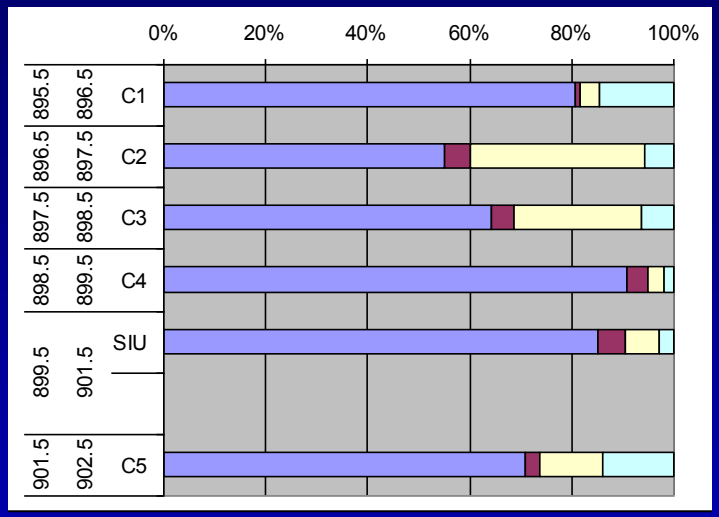
- Maceral description
- Gas adsorption
  - Maceral
  - By foot
- Open hole log analyses
  - Cleats
  - Maceral
  - Gas content

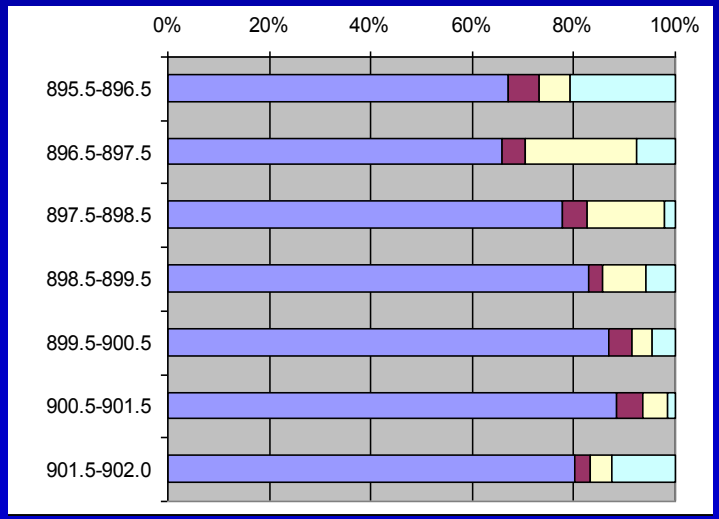
Vitrinite

Liptonite

Inertinite

Mineral Matter





Masterlz, et. al

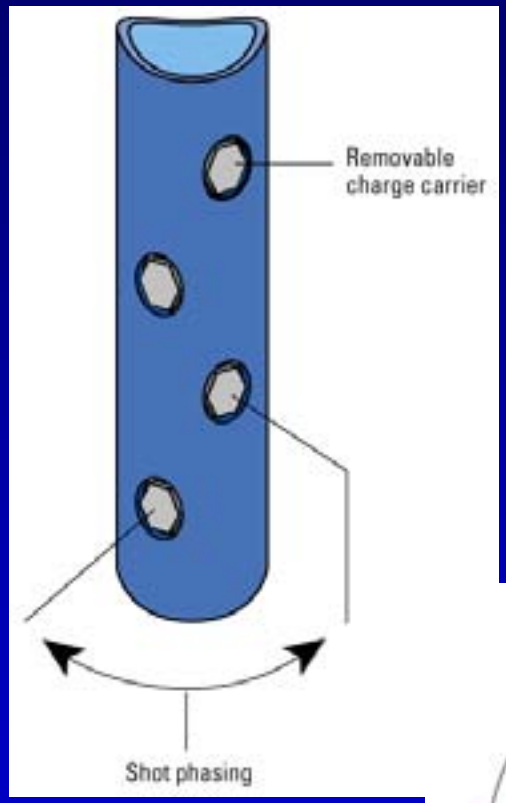
The Well Arrangement
Four Wells

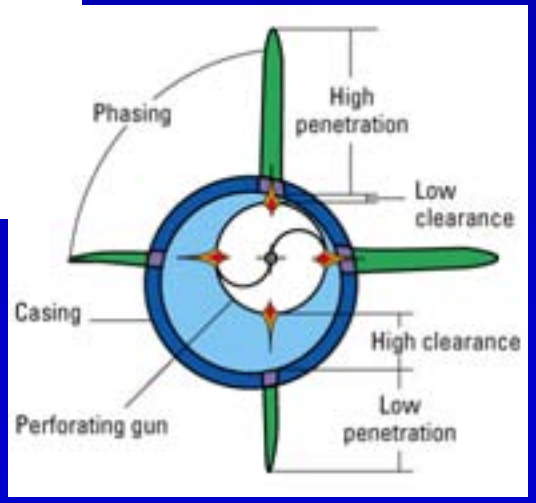
All Wells Cased to TD and Cemented to Surface

- Central injector
- One, 100 ft face cleat observation well (6 feet high to injection wells)
- Two, butt cleat observation wells
  - 50 and 100 ft

Well Completion

- Perforation
  - 6 shots per foot
  - 60° phasing
  - 3/8” diameter
- Acid
  - 9% formic acid
  - 250 gallon
  - 1000 gallon water
  - 1250 gallons swabbed





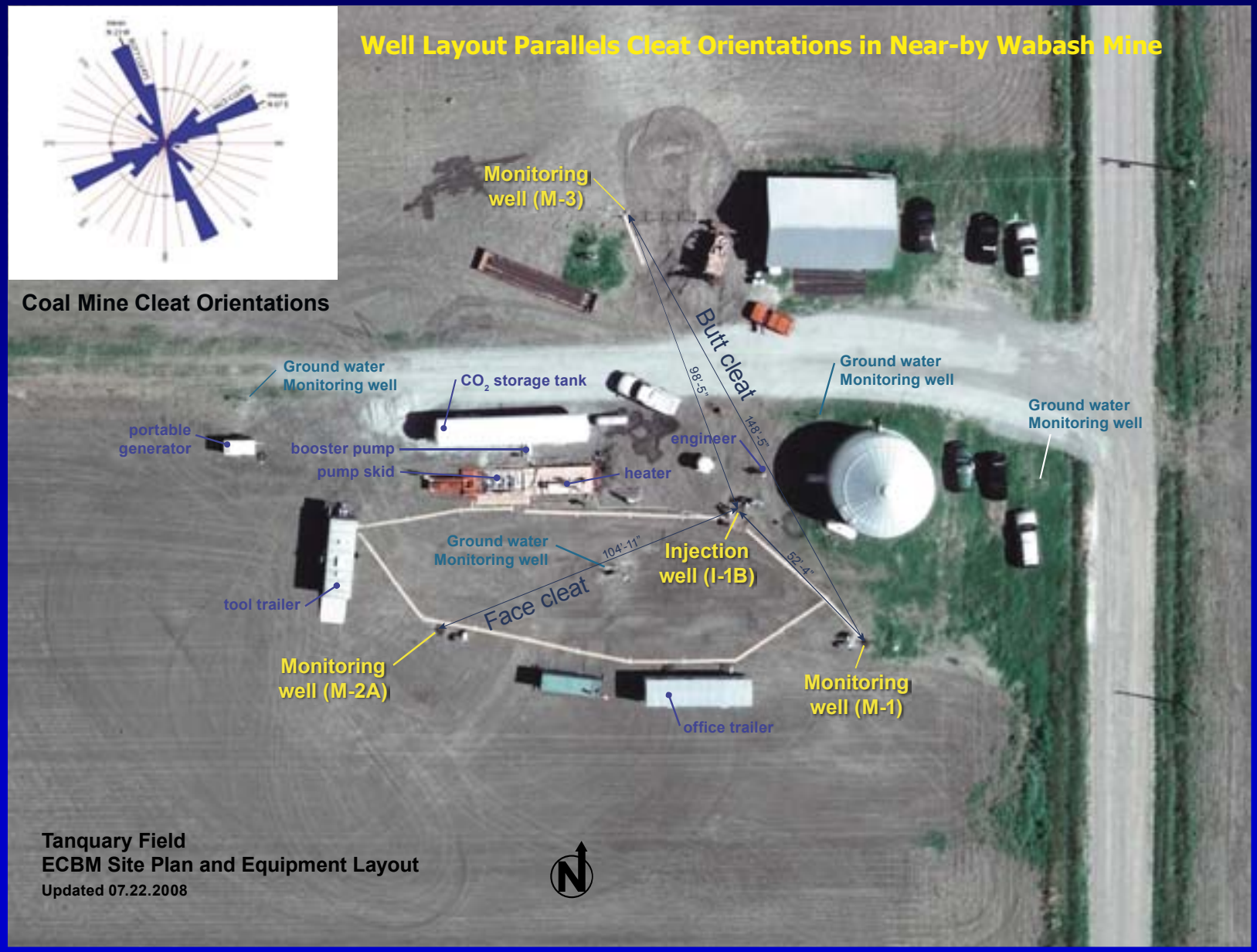
Pictures: Schlumberger Glossary

CO_2 Storage Tank and Pump Skid

Injection Equipment & Wellhead

Injection and Storage Equipment

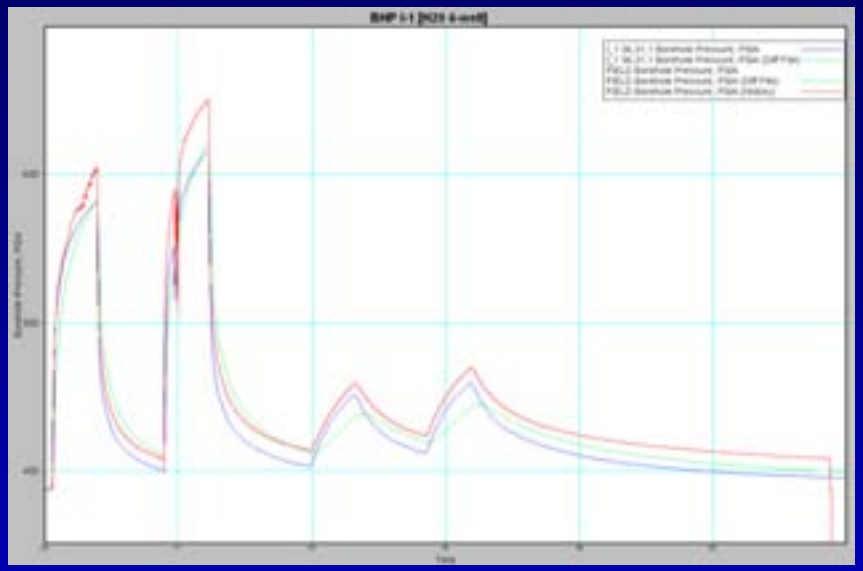
Coal Mine Cleat Orientations

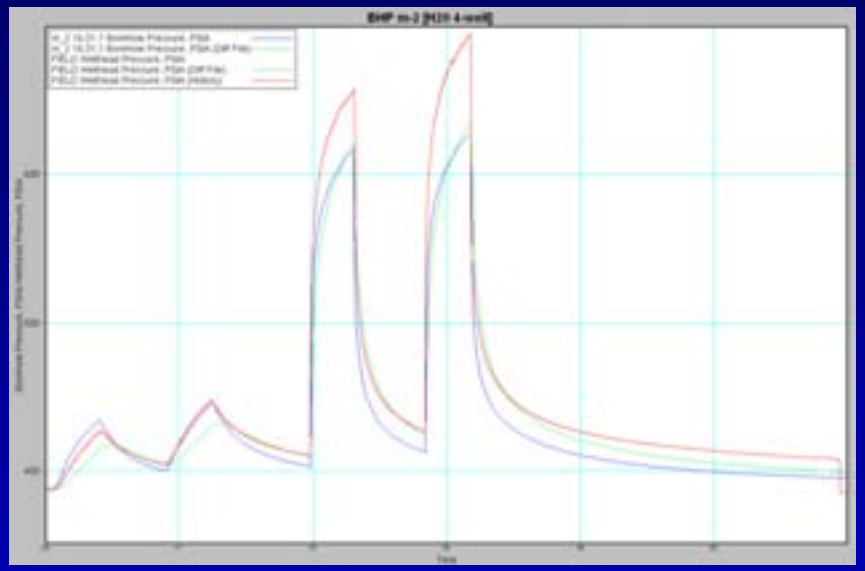


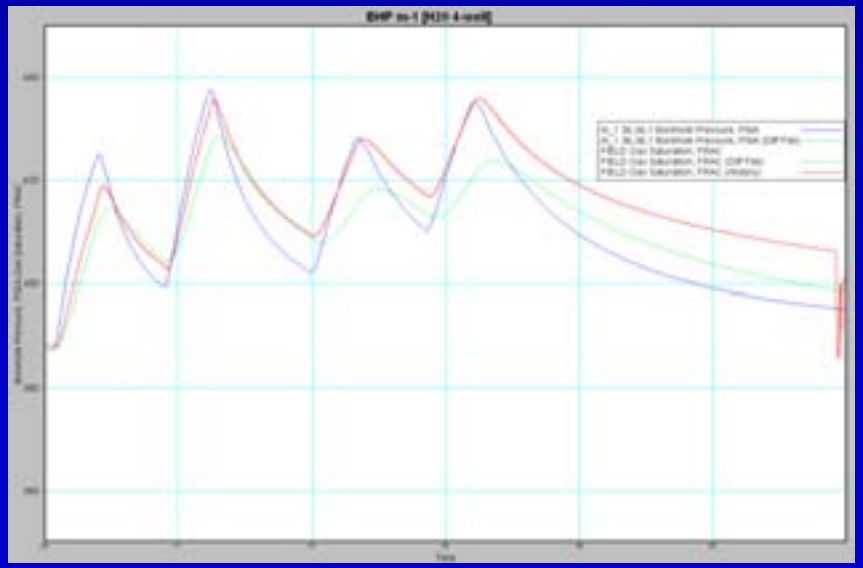
Pre-CO_2 Water Pressure Transient Testing: Analytical Models

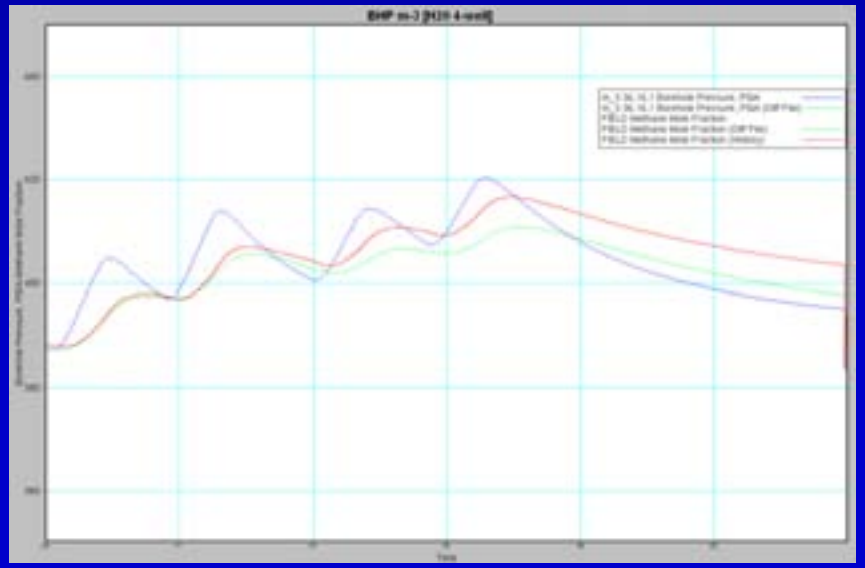
- Injection-falloff tests
  - Permeability: 3.3-4.7 md; -1.5 to -3.0 skin
- Pulse tests
  - Confirm permeability anisotropy: 6:1 to 8:1
  - Confirm permeability anisotropy direction aligned with well locations

Pre-CO_2 Water Pressure Transient Testing: Numerical Models





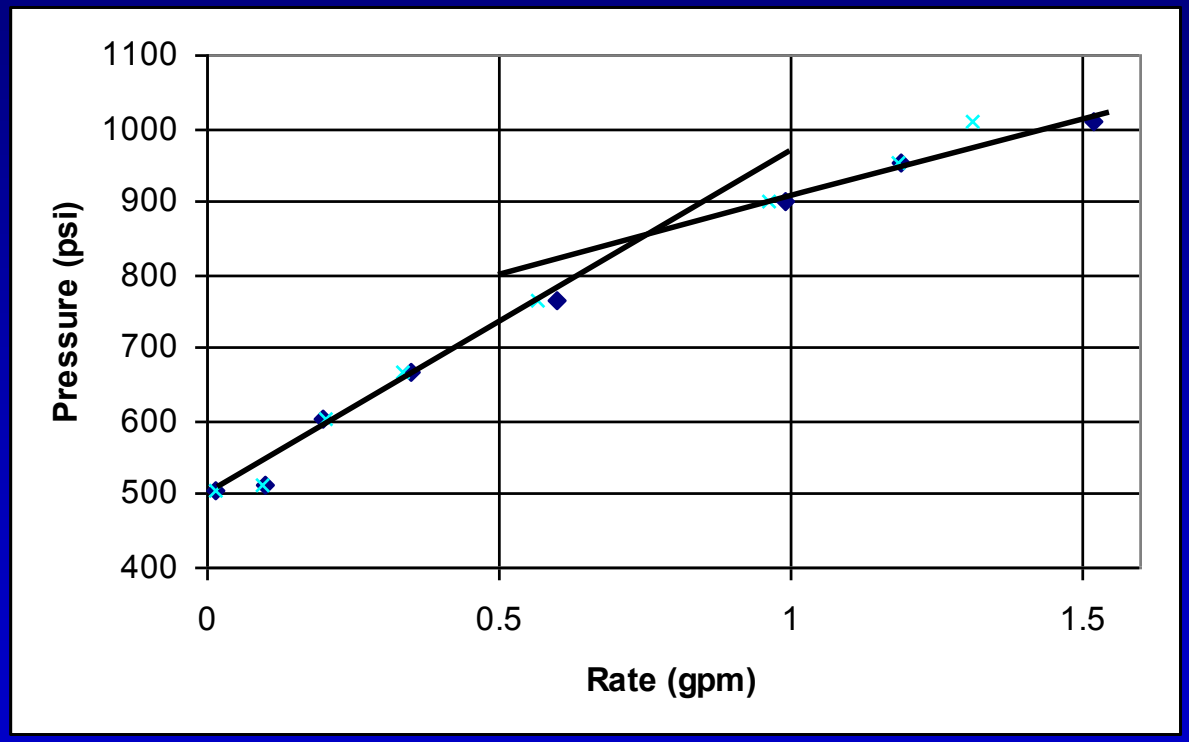




Numerical Modeling

- Sensitivities
  - Grid size and orientation with respect to wells
  - Face and butt cleat perm
  - Cleat orientation with respect wells
- Match three well responses but not fourth
  - Start of pulse and strength of pulse
- Movement of wells location only means to match

Pre-CO_2 Water Step Rate Test (M-3)



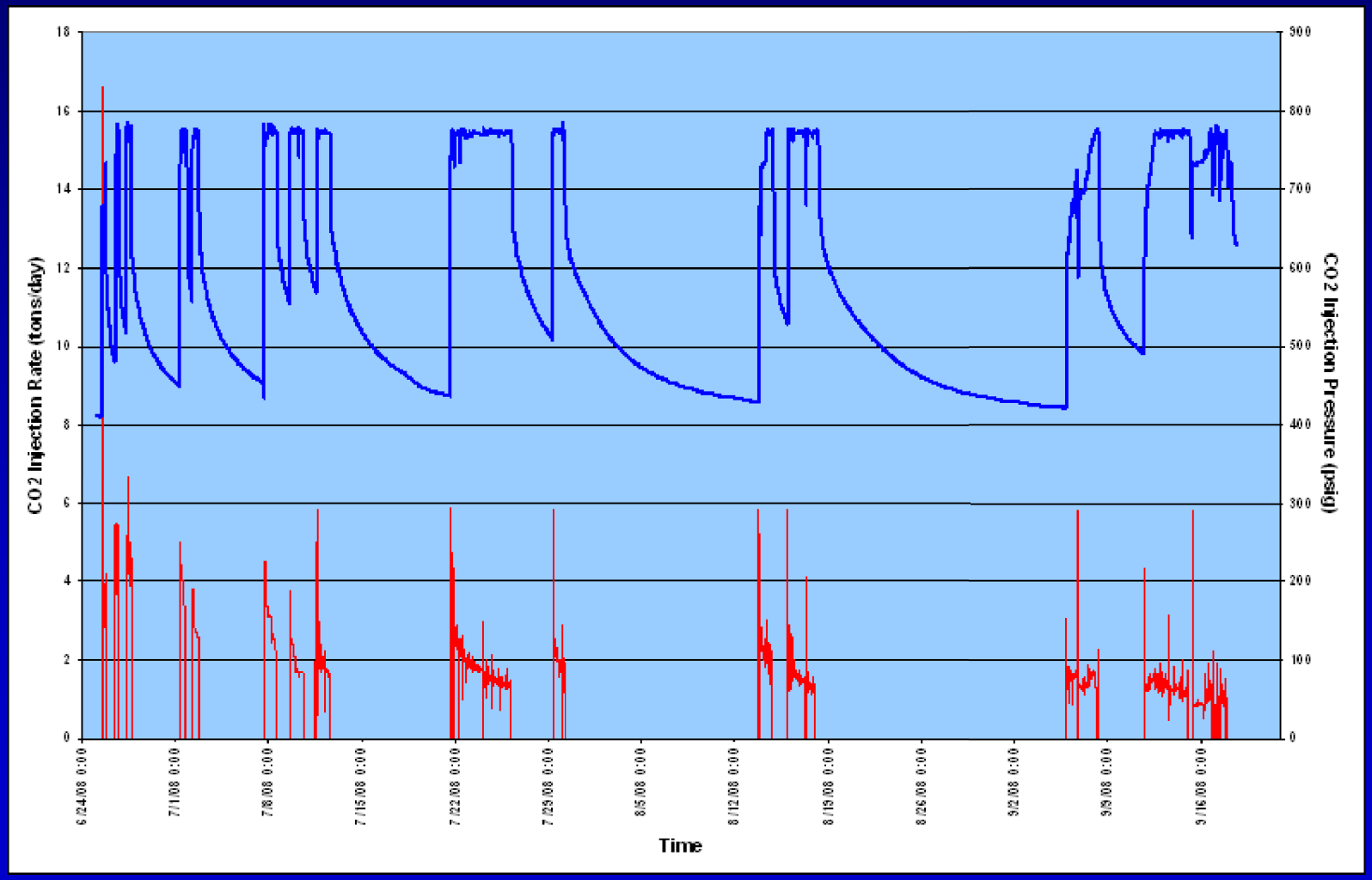
- Step rate test (100 ft butt cleat observation well)
- 0.96 psi/ft fracture gradient

Regulated bottomhole injection pressure: 775 psig

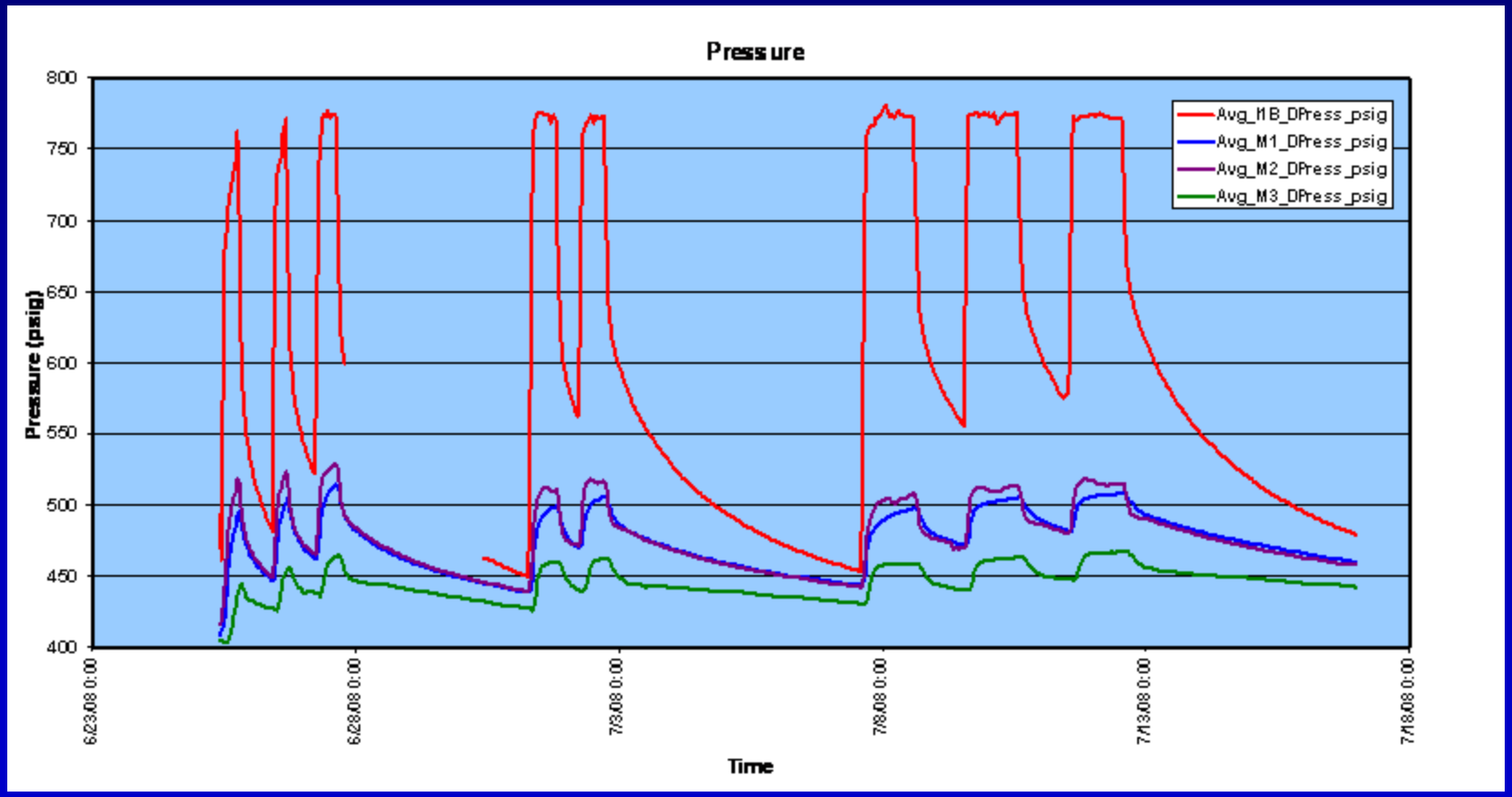
CO_2 Pressure Transient Testing

- CO_2 injection started June 25, 2008
- Series of CO_2 injection transients or pulses followed by shut-in periods
  - Week 1: three 8 hours injection pulses
  - Week 2: two 12 hour injection pulses
  - Week 3: three 24 hour injection pulses
- Several multiday operational shut-ins
- Near end of CO_2 injection, another series of pressure transient periods with CO_2

CO_2 Pressure Transient Testing Injection Well (1st 3 weeks)

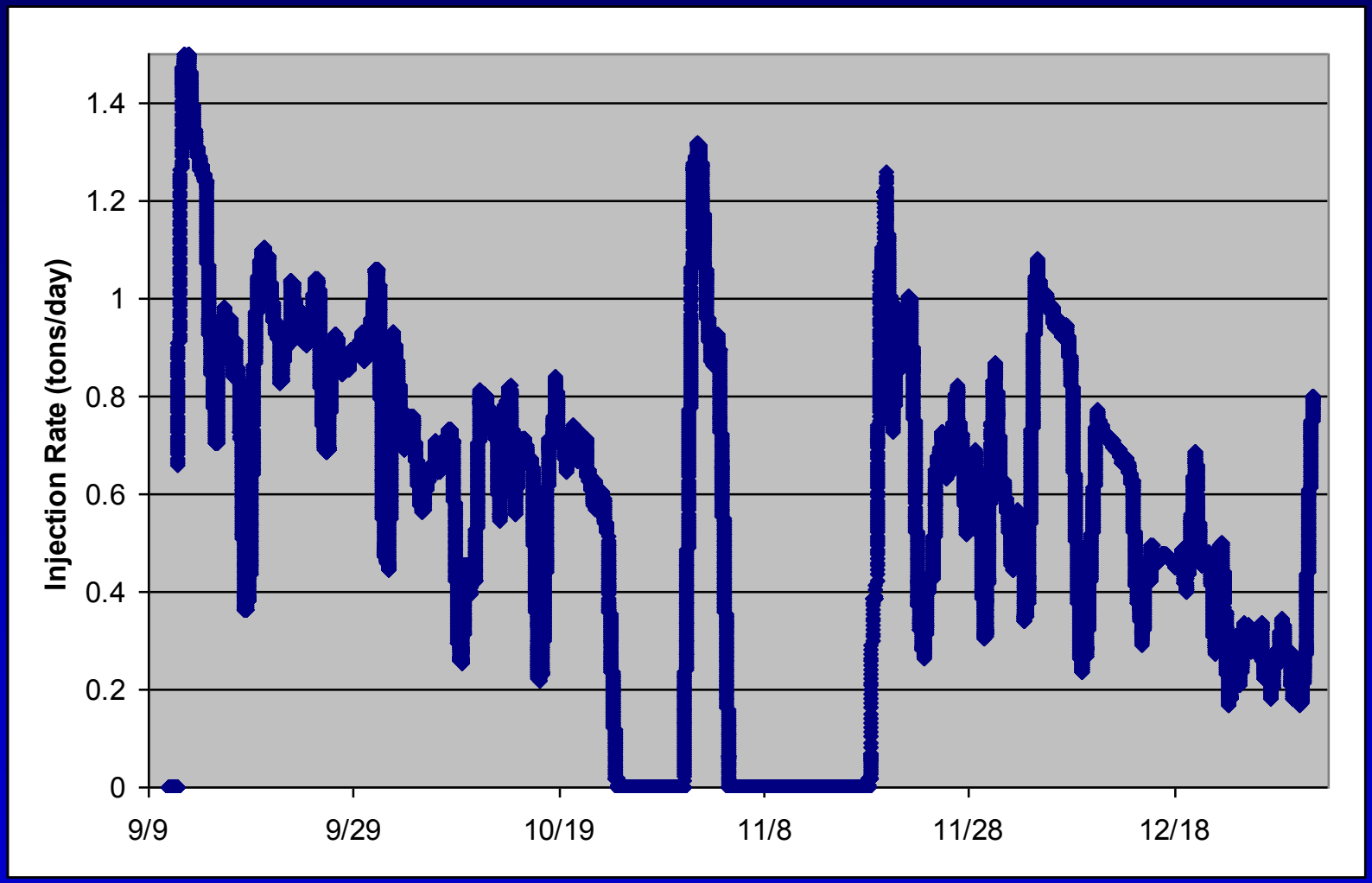


CO_2 Pressure Transient Testing Observation Well Responses



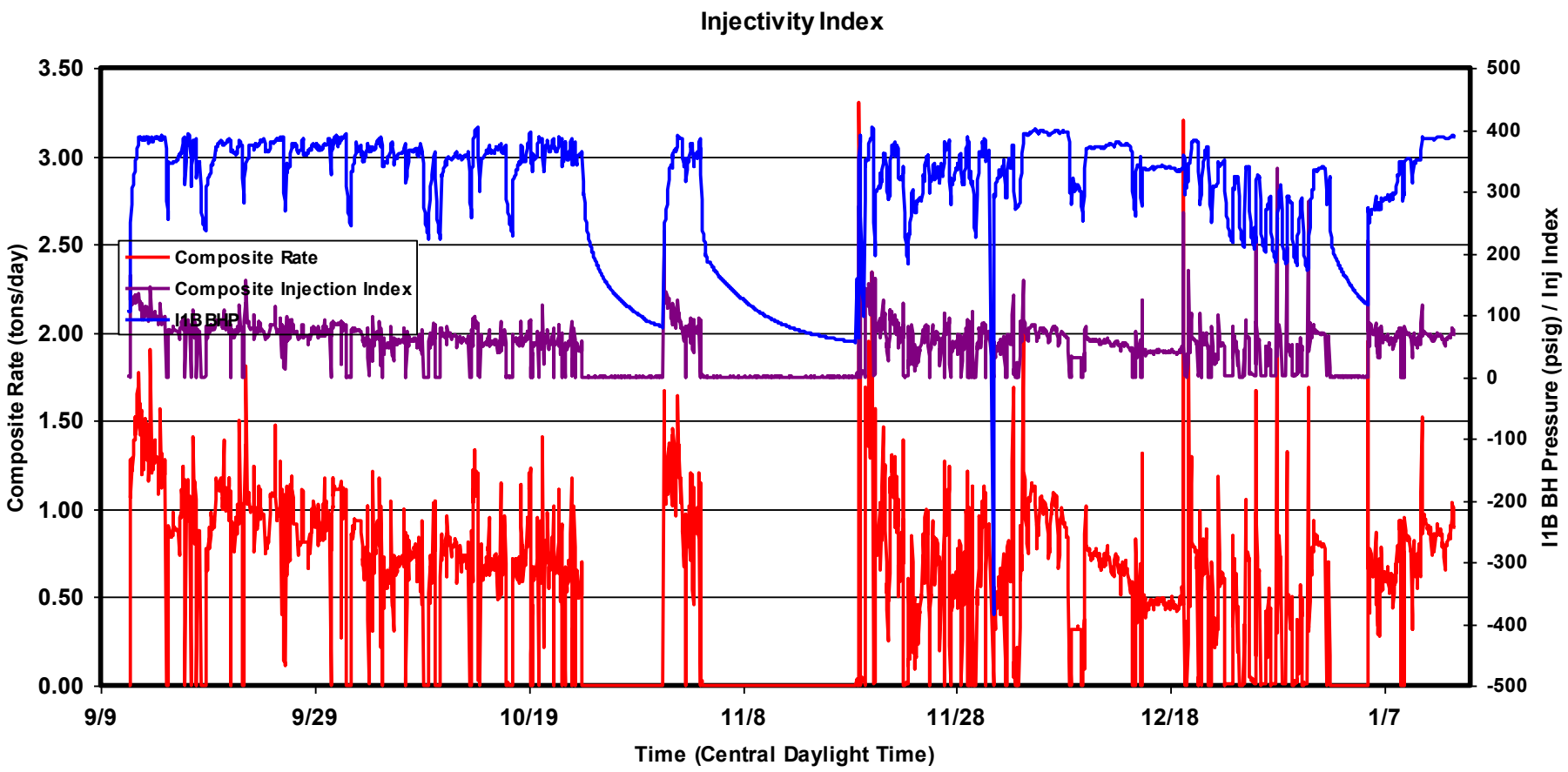
Fastest, largest pressure response in Face Cleat direction

Continuous CO_2 Injection

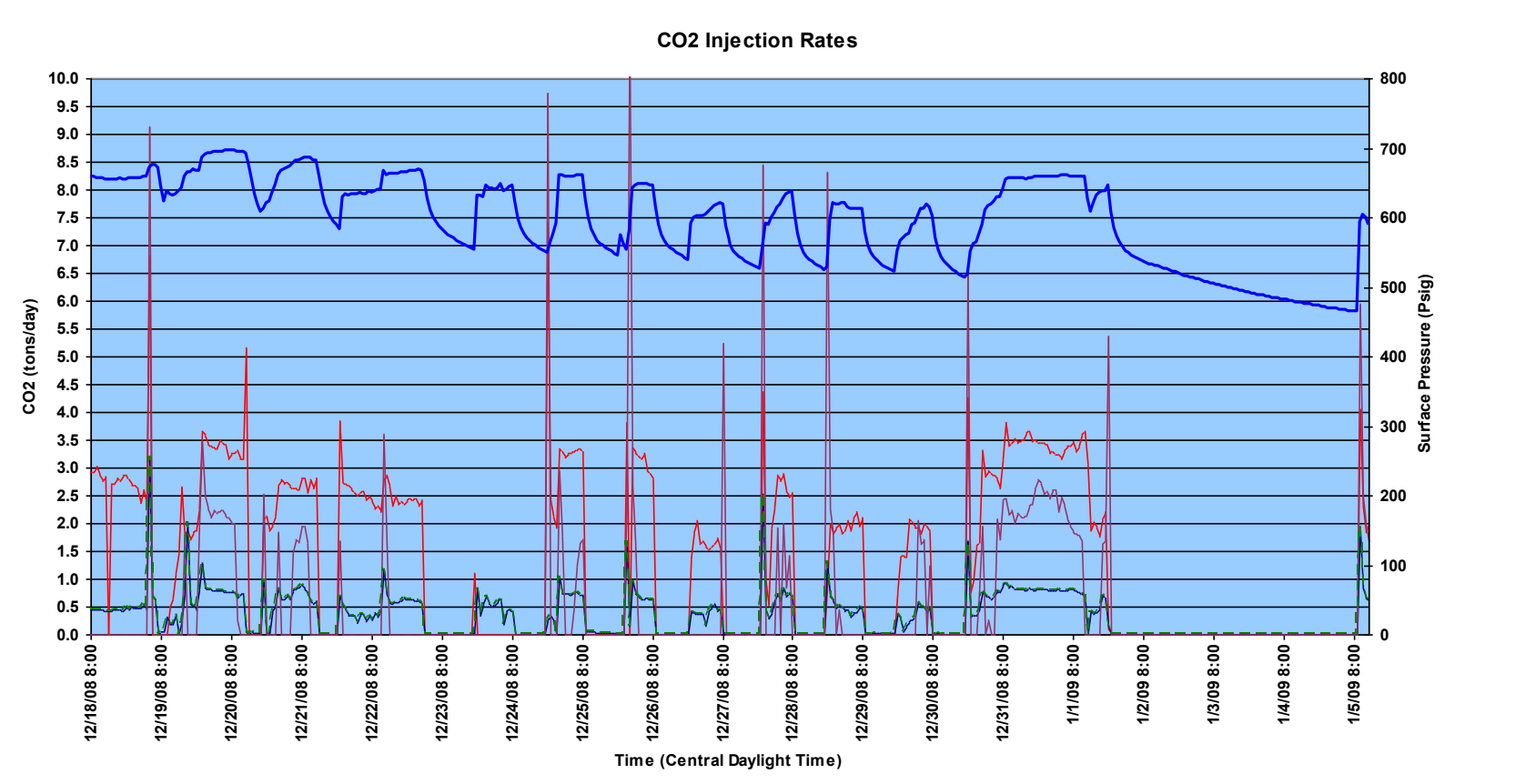


Cumulative Injection 100 tons

Continuous Injection Injectivity (rate/Δp)



CO_2 Pressure Transient Testing After Continuous Injection

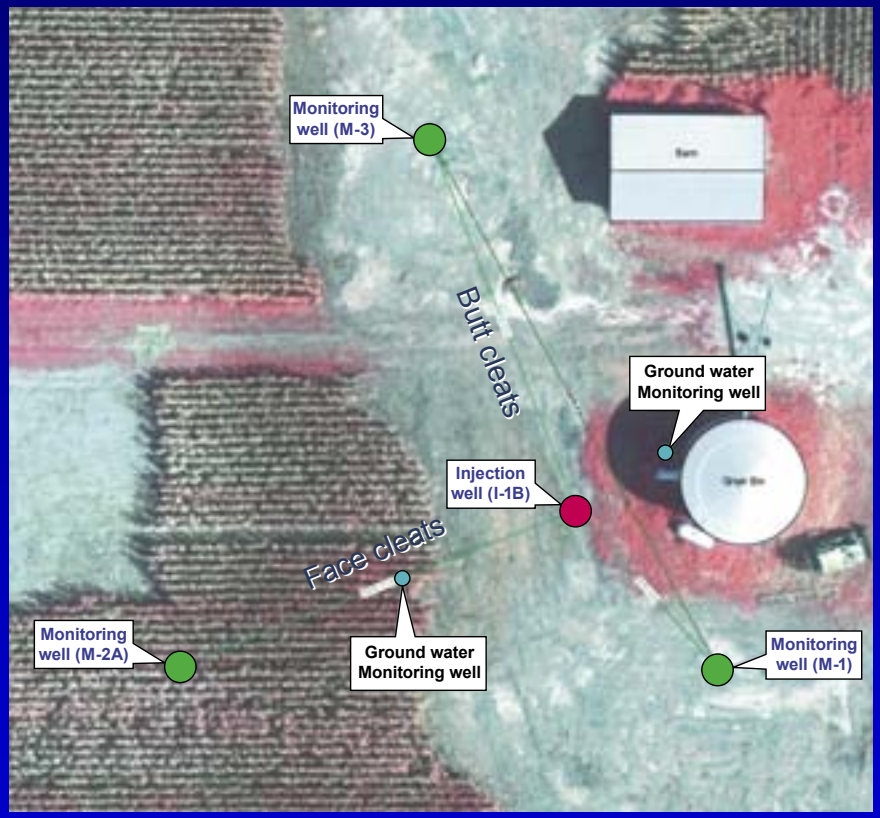


Interpretation of Injection

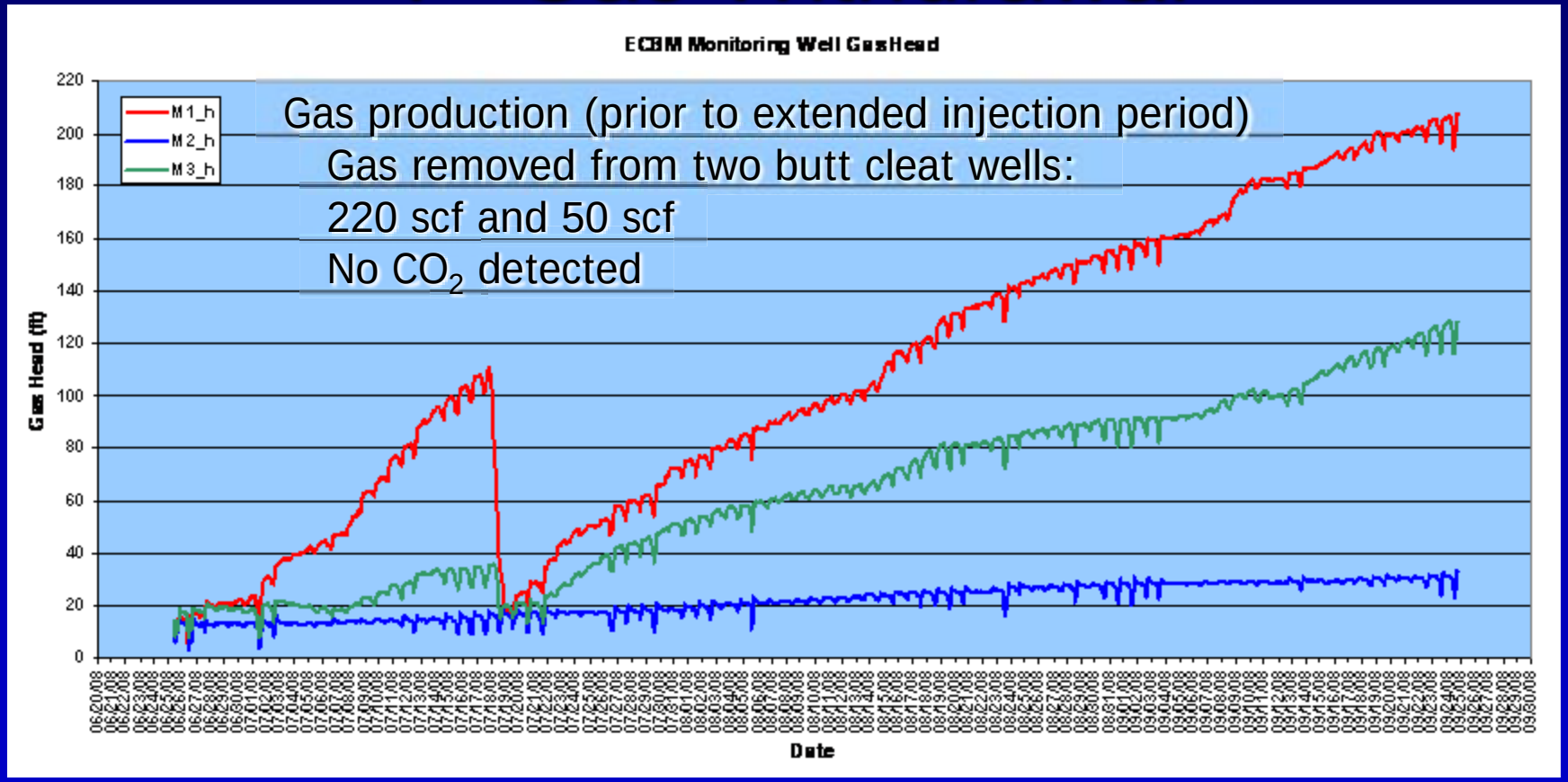
- **Injection rate:** decreased over several weeks; followed by relatively constant rate
- **Injectivity:** Includes effects of pressure buildup, **injectivity** decrease over only a few days
- Perm reduction due to coal swelling
  - After shut-in, relative high rates returned; perm reduction not obvious directly from field data
  - To be verified with numerical modeling

Observation Wells' Gas Detection

- CH_4 gas at M-1 and M-3 within hours of CO_2 injection
- CO_2 at M-1 within a month of injection at 11-13% and remained constant
  - M-3 no CO_2
  - M-2 water only



Gas Column in Observation Wells
1st Gas Withdrawal



- Pressure above adsorption pressure, free gas via competitive desorption from CO_2
- In situ water returned to each well.

Gas Column in Observation Wells 2nd Gas Withdrawal

- Four months after CO_2 injection
- CO_2 concentration
  - M-1: spiked to 95%
  - M-2: spiked to 90%
  - M-3: spiked to 70%
- Observations
  - Subsequently all CO_2 concentration lowered
  - Water did not return to wells

Interpretation of Gas Detection

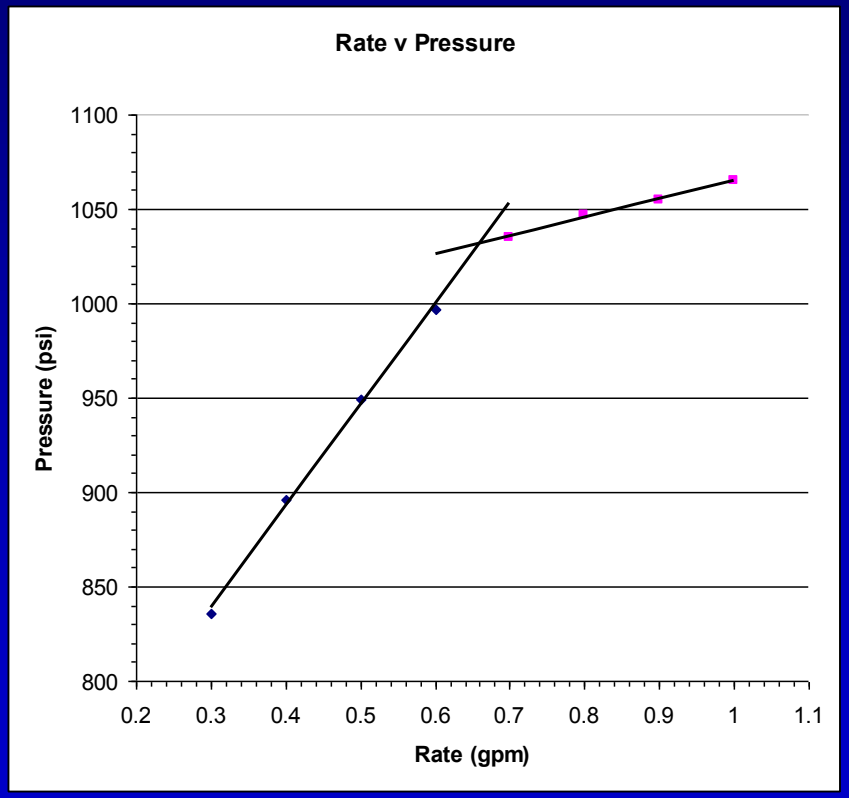
- ECBM (mmscf-CH_4 / ton CO_2)
  - CH_4 competitively desorbed via CO_2 above the desorption pressure of CH_4
  - Production rates via numerical modeling
- CO_2 Storage (ton CO_2 / ton coal)
  - Estimate plume size and coal volume
  - Based on numerical modeling

Post-CO_2 Injection Water Pressure Transient Testing

- Lower rates and higher injection pressures.
- Preliminary interpretation water perm is slightly lower than pre-CO_2 water perm.
- Possibilities
  - Coal swelling
  - Gas/water relative permeability effect
  - Slightly greater skin factor

Post-CO_2 Water Step Rate Test (CO_2 Injection Well)

- 1.15 psi/ft fracture pressure gradient
- Difference in coal between wells?
- CO_2 affect mechanical strength of coal?
- Increase compressibility?



MVA: Post-Injection

- Groundwater: No indication of CO_2
- Areal CIR: No indication of CO_2
- Cased hole logging:
  - Logged 10/09
  - Interpretation in progress

Tanquary S/ECBM Pilot Summary

- Cumulative injected 100 tons
- Sustained Rate 0.5-0.75 tons per day
- Field observations
  - Desorbed methane via CO_2 injection
  - CO_2 and CH_4 first detected in low perm direction
  - Face cleat well gas detected only after small drawdown
- No indication of reduced injectivity after first few days of injection

Tanquary S/ECBM Pilot Summary, contd.

- Preliminary interpretation of post-CO_2 water pressure transient tests
  - permeability reduced
    - Indicates coal swelling, relative permeability effect, or near wellbore damage
    - Additional water tests in progress to eliminate 1 or more of these
  - Fracture gradient higher in CO_2 injection well compared to pre-CO_2 injection (in M1)

S/ECBM Remaining Work

- Field data acquisition
  - Final cased hole log analyses
  - Final water pressure transient test
- Computational
  - Numerical modeling (COMET) of water and CO_2 injection periods
  - Analytical modeling (PIE) of Pressure transient data

S/ECBM Remaining Work, contd.

- Integration of coal characterization and related laboratory work with field observations and modeling
- Plugging and abandoning wells

Tanquary Pilot Staff

- Dave Morse: drilling/coring logistics, gas content
- John Rupp, Maria Mastalerz: lab experiments
- Satya Harpalani: laboratory experiments
- Jim Kirksey: pilot coordination, operations
- Damon Garner: database management/ analyses
- Ivan Krapac, Abbas Iranmanesh, Bracken Wimmer: water and gas sampling
- Keith Hackley and Joe Chou: gas analyses

Tanquary Pilot Staff

- Mike Dodd: pump operations
- Kevin Wolfe: data acquisition, site logistics, data analyses
- Steve Sargent: data acquisition
- Andrew Anderson: COMET Modeling
- Gallaghers: field operations and logistics, drilling and completion design
- Trimeric Corp: equipment design

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