

Time-lapse CO₂ Monitoring with Pulsed Neutron Logging

GCCC Digital Publication Series #05-04o

N. Müller
T. S. Ramakrishnan
S. Sakurai
A. Boyd



Keywords:

Pulsed Neutron Logging, Time Lapse Monitoring, Calibration

Cited as:

Müller, N., Ramakrishnan, T.S., Sakurai, S., and Boyd, A., Time-lapse CO₂ monitoring with pulsed neutron logging: presented at the National Energy Technology Laboratory Fourth Annual Conference on Carbon Capture and Sequestration, Alexandria, Virginia, May 2-5, 2005. GCCC Digital Publication Series #05-04o, pp. 1-14.

Fourth Annual Conference on Carbon Capture & Sequestration

*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

Geologic – Frio Brine Field Project (1)

Time-lapse CO₂ monitoring with pulsed neutron logging

N. Müller, T.S.Ramakrishnan, S.Sakurai, A.Boyd

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia



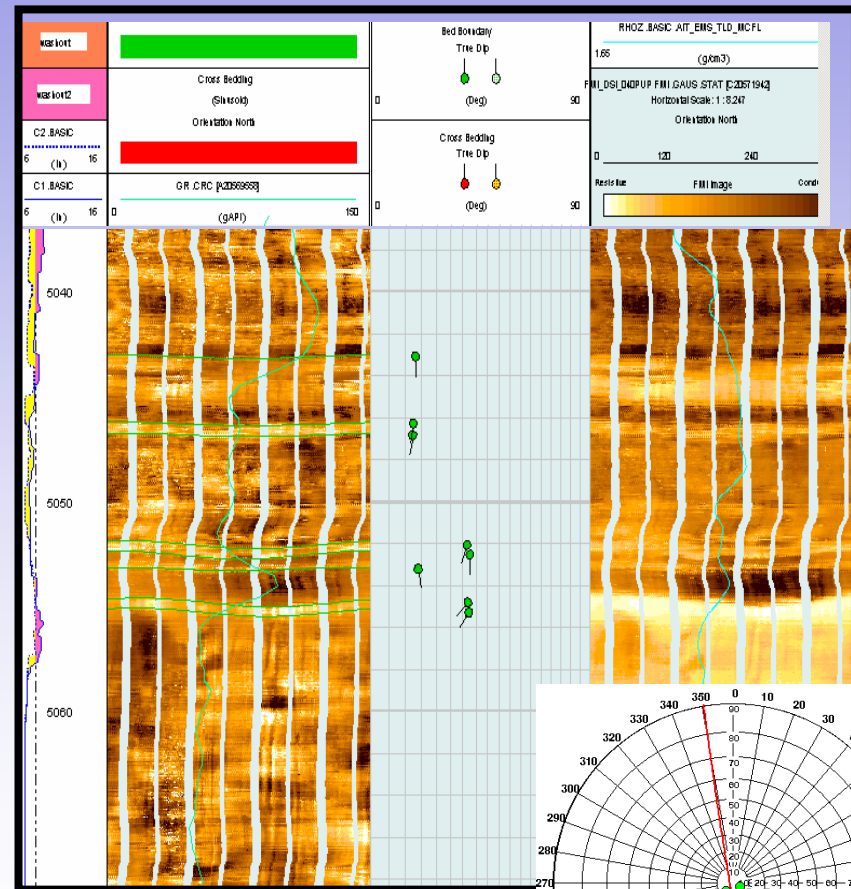
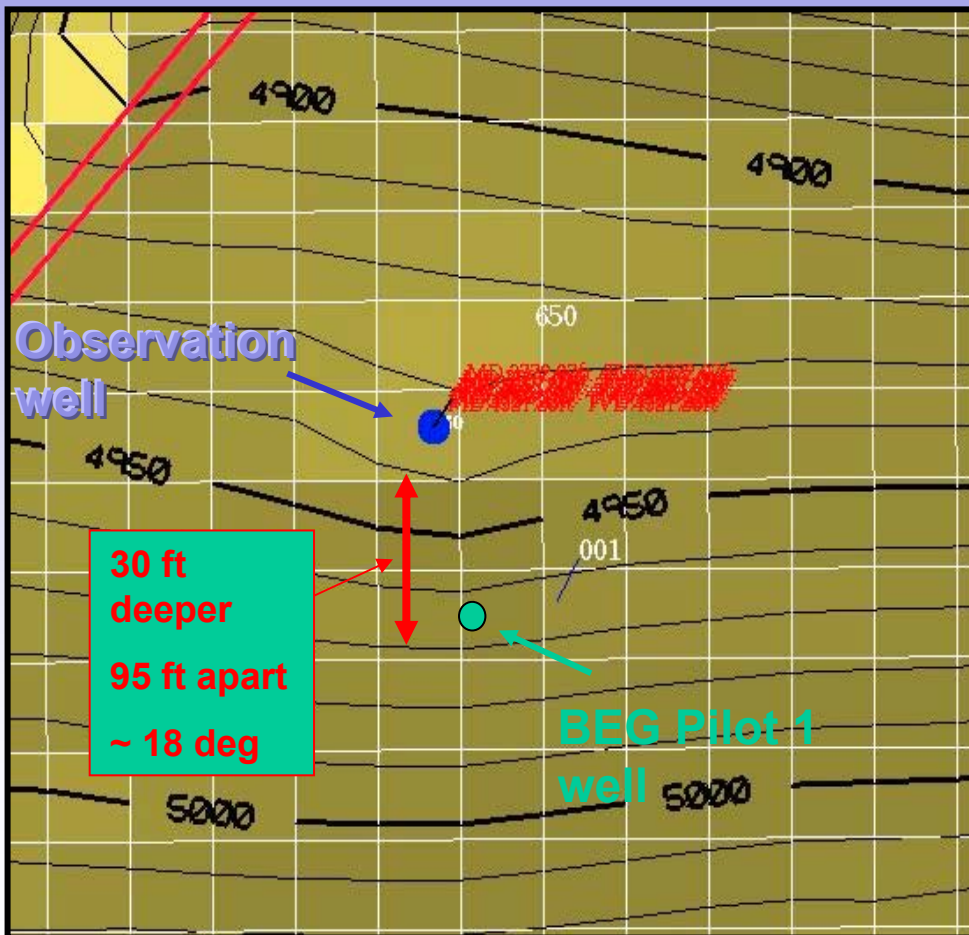
Outline

- Monitoring CO₂ injection into a saline aquifer from a log analyst point of view
- Why pulsed neutron logging?
- Calibration
- Σ environmental corrections
- Time lapse Σ monitoring
- Conclusion

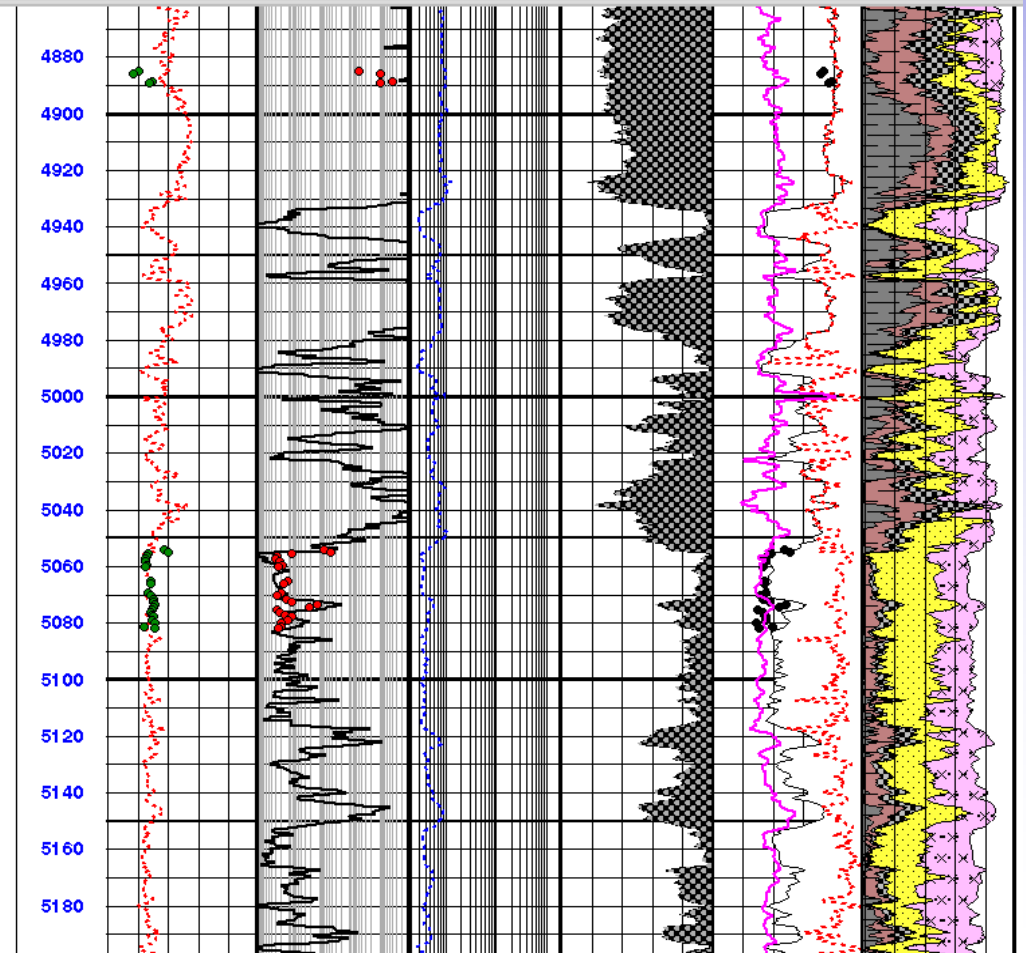
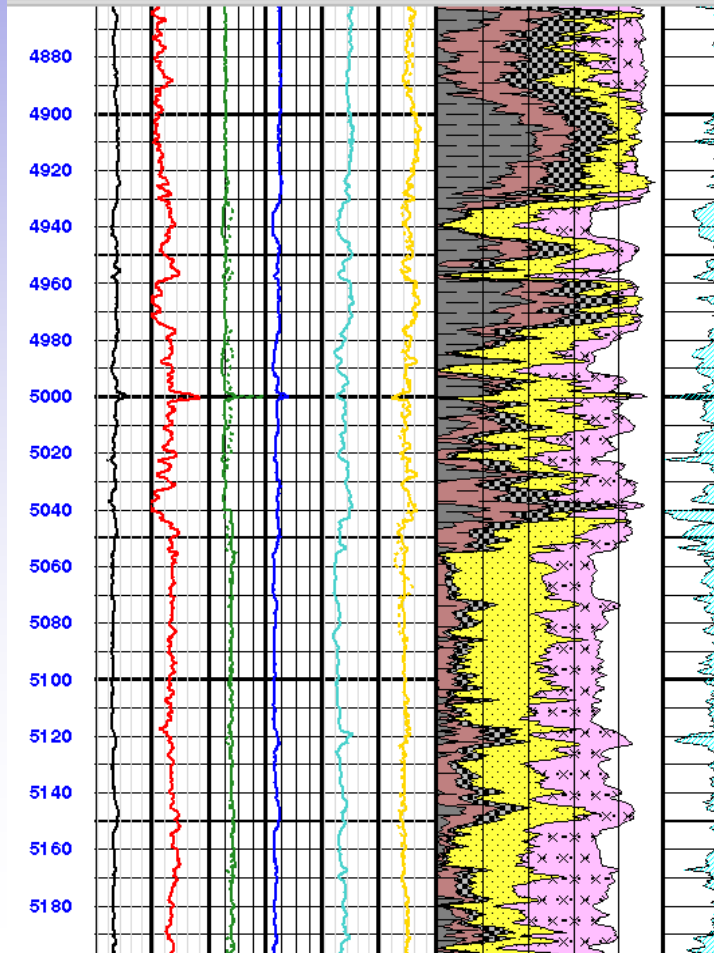
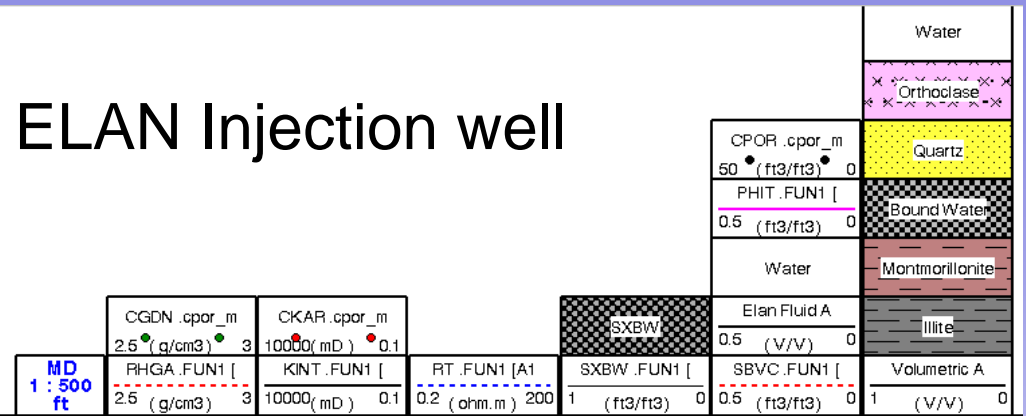
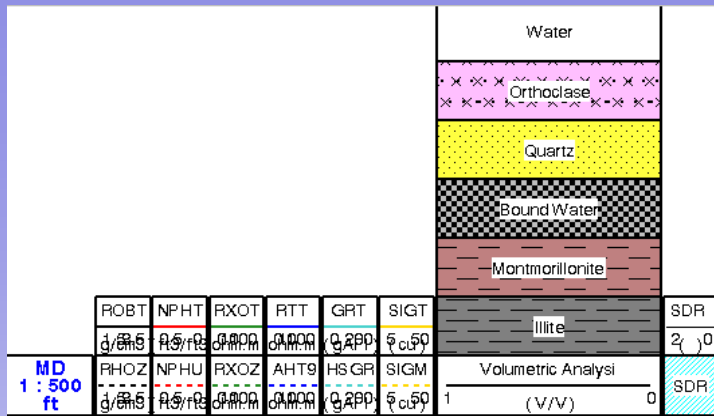
Monitoring CO₂ injection into a saline aquifer from a log analyst point of view

Structure map top Frio C

Structure dip top Frio C from FM



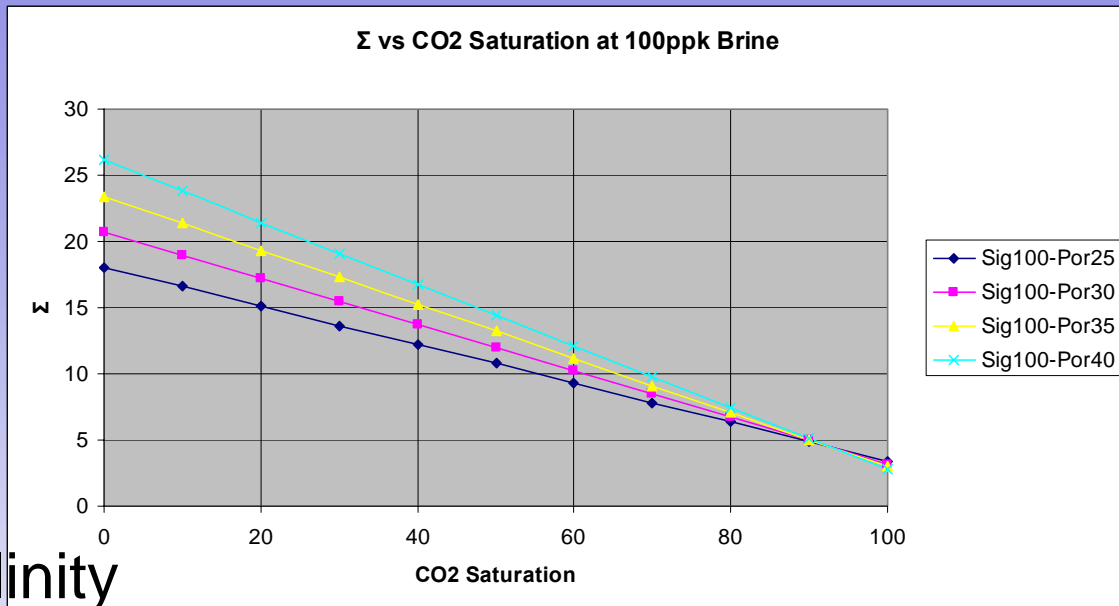
ELAN Injection well



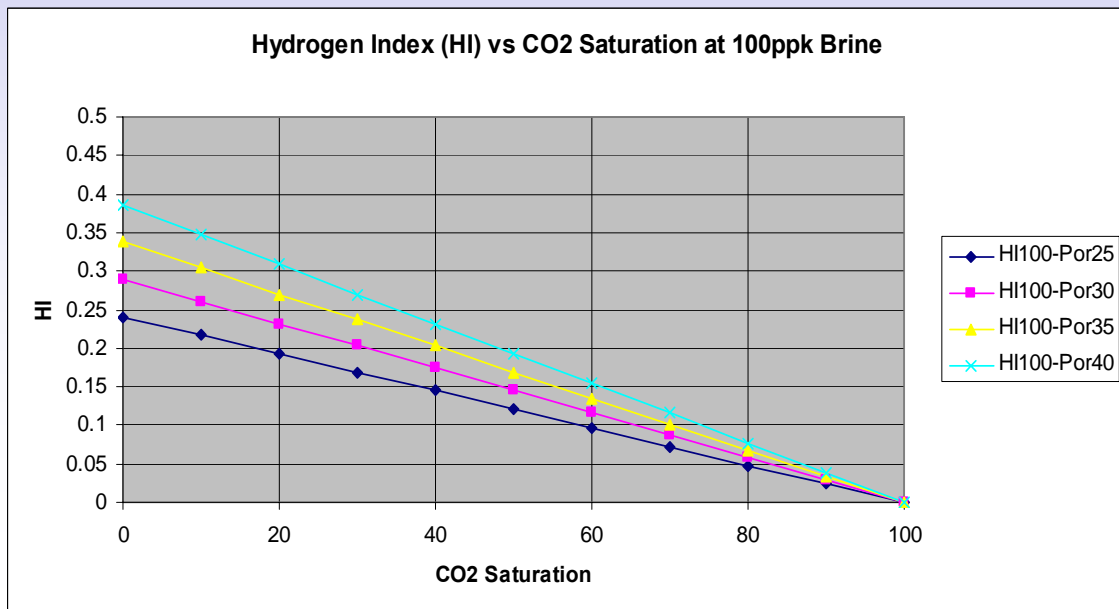
Why pulsed neutron logging?

- Cased hole application
- Thermal neutron decay time used to measure neutron capture cross-section Σ
- Increased sensitivity in porous and unconsolidated sandstones
- Very significant sensitivity in high Σ contrast environment i.e. saline formation water with 55 cu and with CO₂

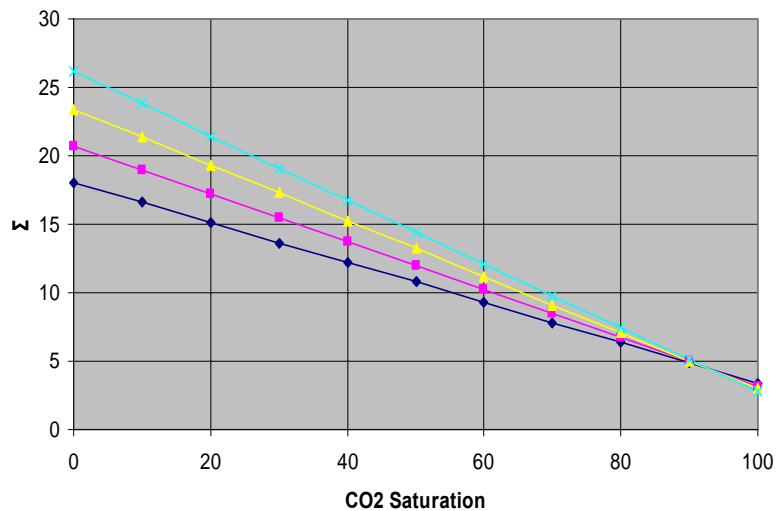
Calibration



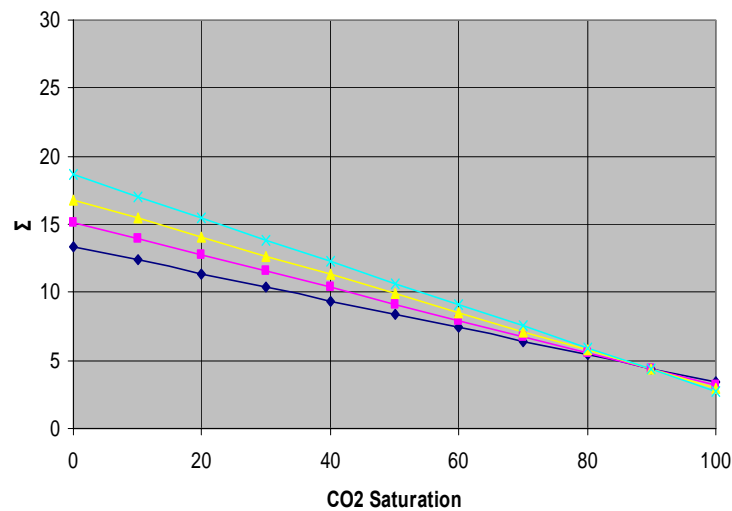
Formation water salinity
93 ppk



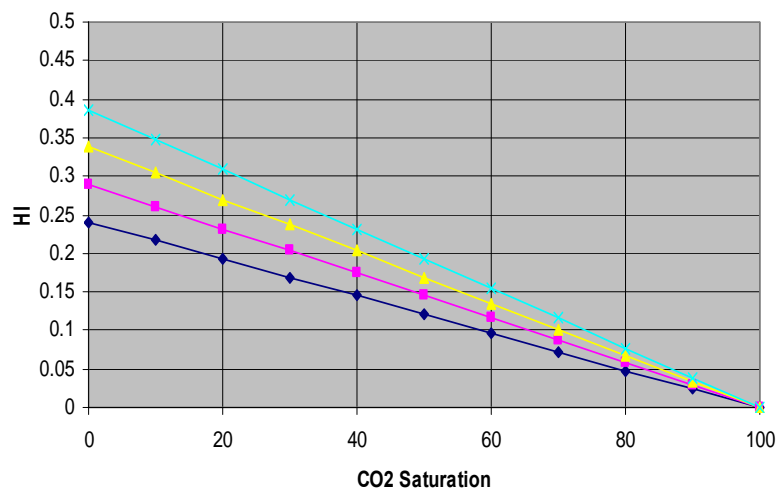
Σ vs CO2 Saturation at 100ppk Brine



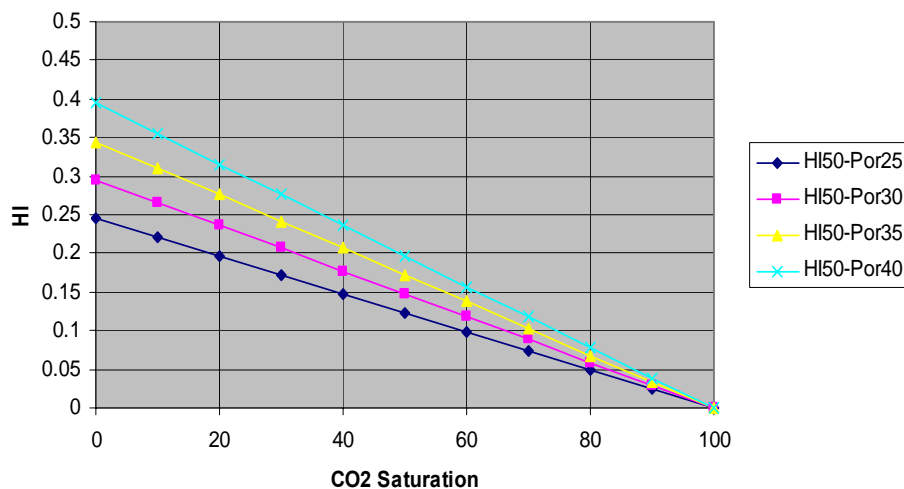
Σ vs CO2 Saturation at 50ppk Brine



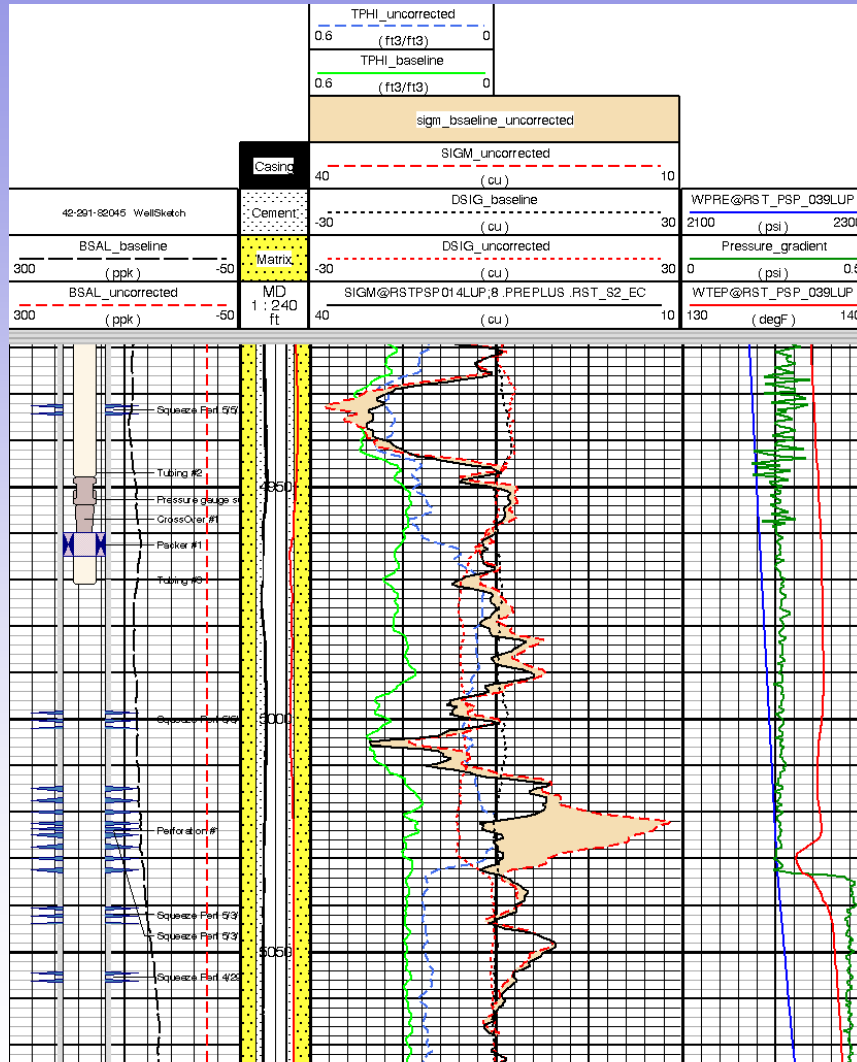
Hydrogen Index (HI) vs CO2 Saturation at 100ppk Brine



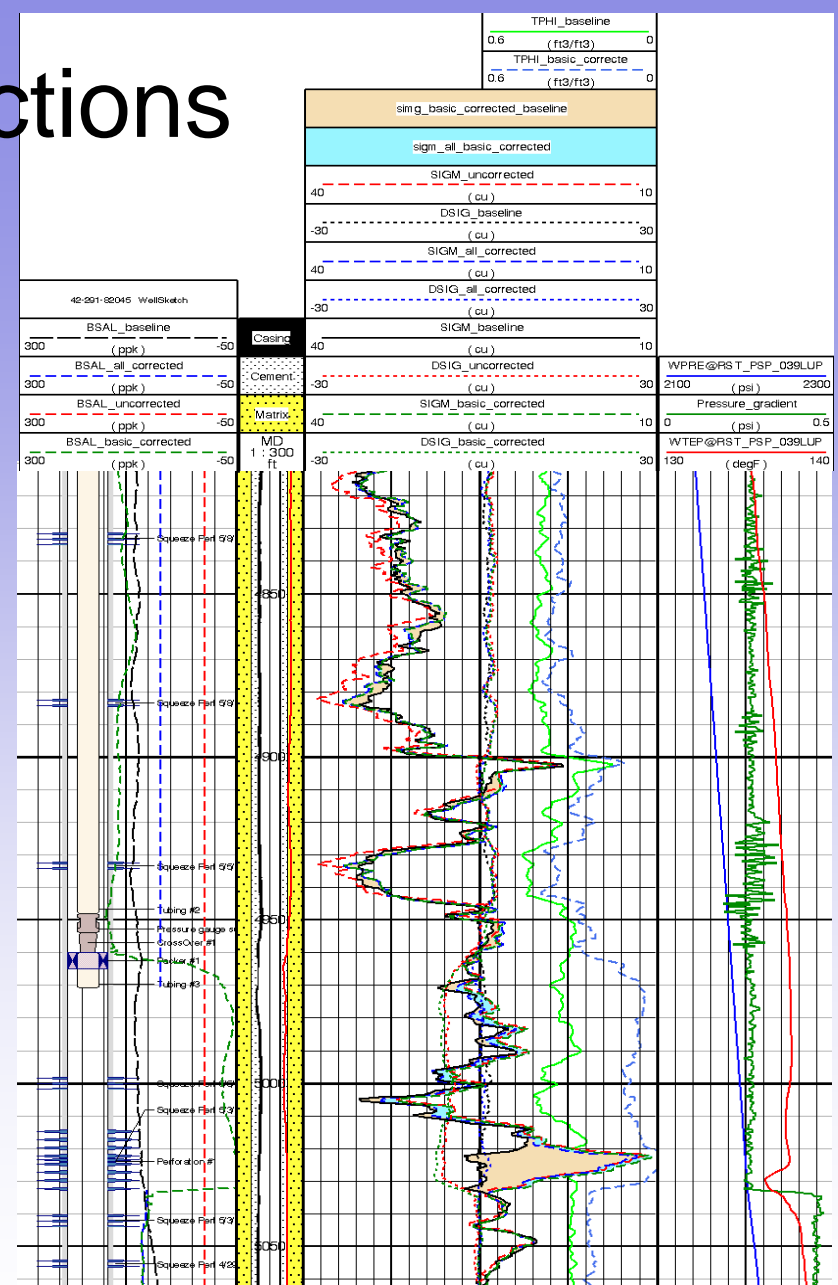
Hydrogen Index (HI) vs CO2 Saturation at 50ppk Brine



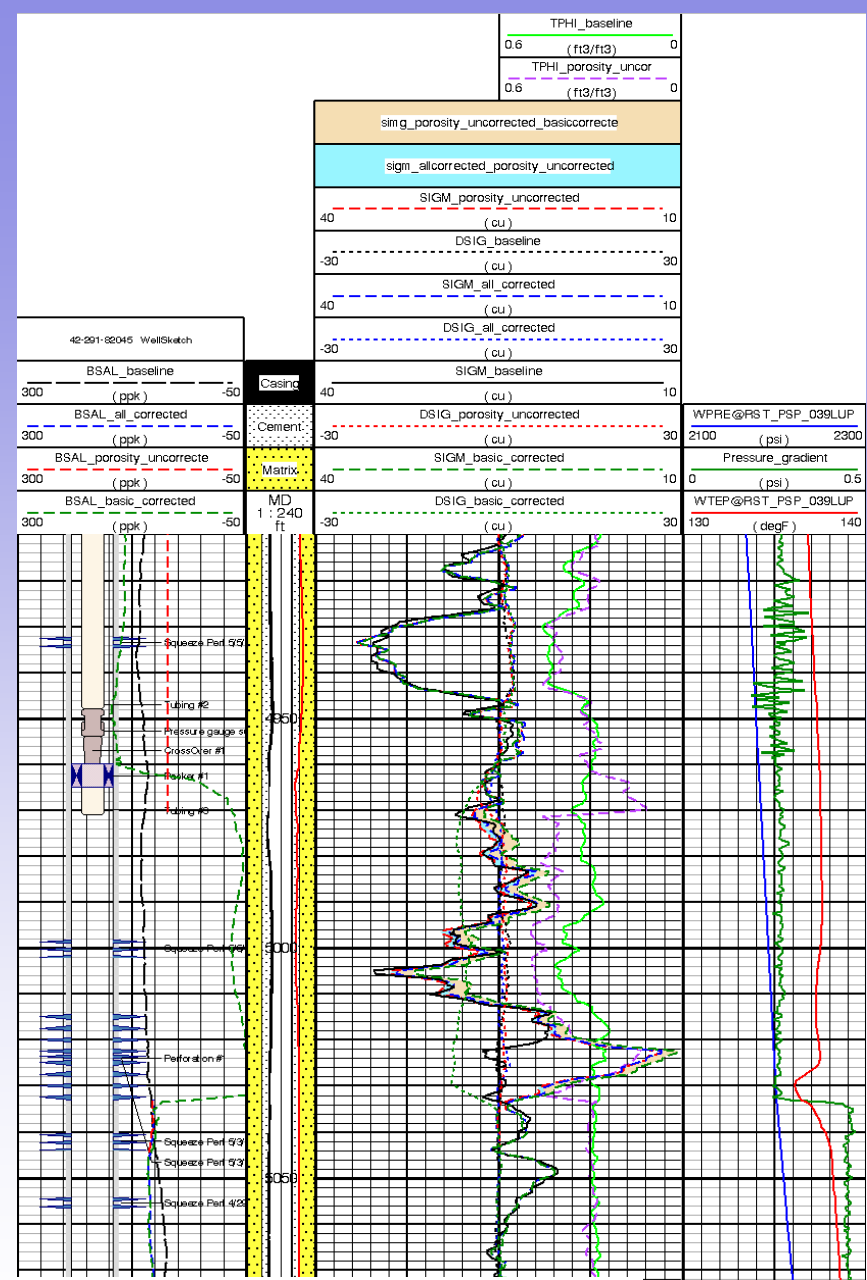
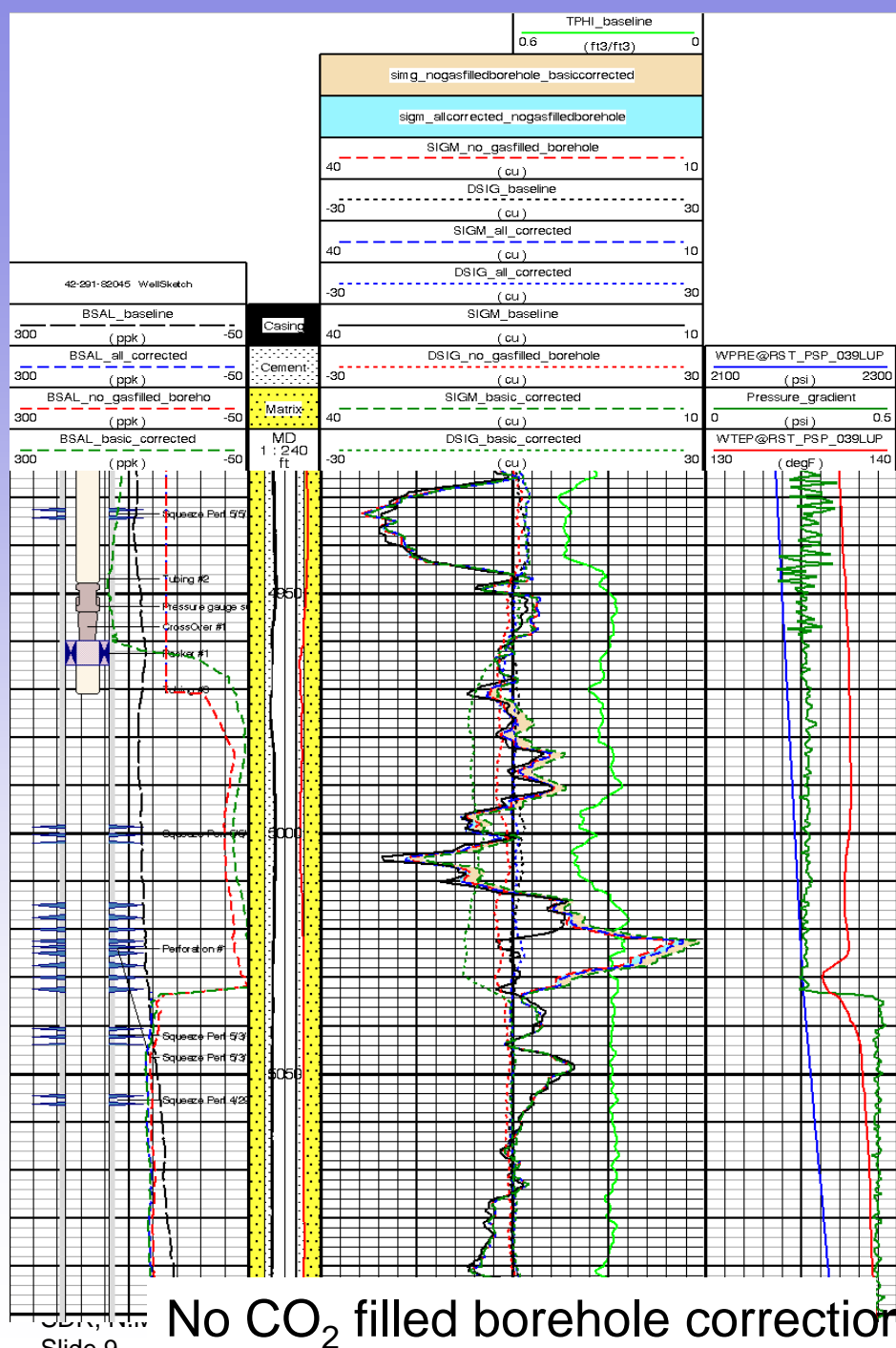
Σ environmental corrections



Comparison baseline run and uncorrected CO₂ monitoring run



Comparison baseline run & the uncorrected CO₂ monitoring run with basic corrected and specific corrected CO₂ monitoring run



Time lapse Σ monitoring

CO₂ injection starts Oct.4

Date	Observation Well	Injection Well
Sept. 26, 2004	Run 1, Baseline	
Oct. 8	Run 2 @CO ₂ breakthrough	
Oct. 14	Run 3 @close to end of CO ₂	
Oct. 15		Run 1 @end of CO ₂ Injection
Nov. 2	Run 4	
Dec. 9	Run 5	Run 2
Feb. 23, 2005	Run 6	Run 3

CO₂ breakthrough Oct.6

Well completion change

Temperature-Boreh

WTEP_5.run_m

120 (degF)

WTEP_1.run_m

120 (degF)

WTEP_2.run_main

120 (degF)

WTEP_3.run_main

120 (degF)

WTEP_4.run_main

120 (degF)

WTEP_6.run_main

120 (degF)

BSAL_1.run_main

0 (ppk)

BSAL_5.run_main

0 (ppk)

BSAL_6.run_main

0 (ppk)

Pressure gradient

Pressure_grad_2.run_main

0 (psi)

Pressure_grad_2.run_temp

0 (psi)

Pressure_grad_3.run_main

0 (psi)

Pressure_grad_4.run_main

0 (psi)

Pressure_grad_5.run_main

0 (psi)

Pressure_grad_6.run_main

0 (psi)

6 runs^{well}

42-291-82045 WellSketch

MD 1 : 200 ft

Porosity

TPHI_1.run_mai

0.6 (ft3/ft3)

TPHI_1.run_rep

0.6 (ft3/ft3)

Difference 5.run-6.run

SIGM_1.run_main

40 (cu)

SIGM_2.run_main

40 (cu)

SIGM_3.run_main

40 (cu)

SIGM_4.run_main

40 (cu)

SIGM_5.run_main

40 (cu)

SIGM_6.run_main

40 (cu)

LQC Sigma

DSIG_2.run_main

-10 (cu)

DSIG_1.run_main

-10 (cu)

DSIG_3.run_main

-10 (cu)

DSIG_4.run_main

-10 (cu)

DSIG_5.run_main

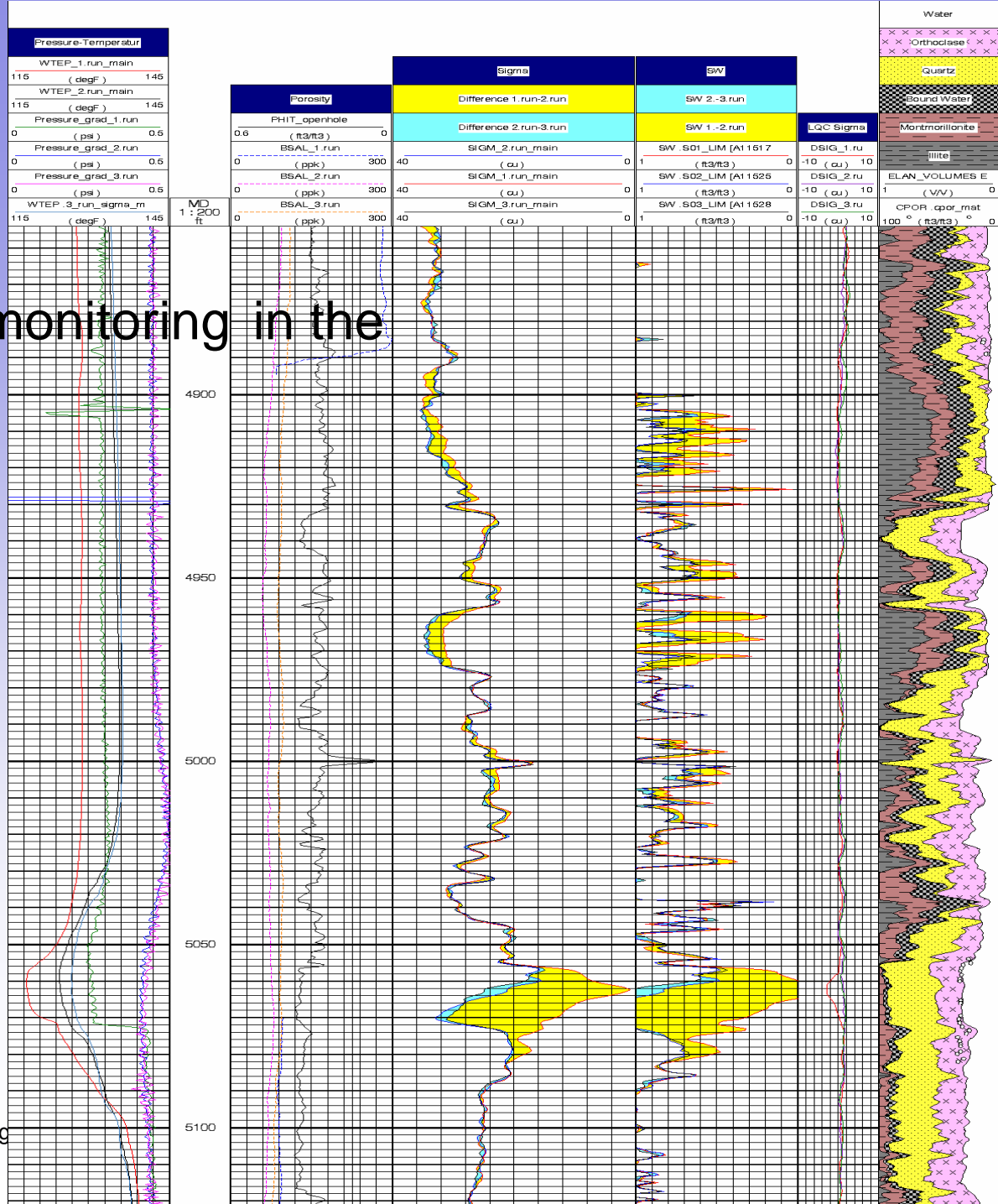
-10 (cu)

DSIG_6.run_main

-10 (cu)

SSS

Time lapse Σ monitoring in the injection well 3 runs



Conclusion

- Pulsed neutron logging viable method to monitor CO₂ accumulation and migration in a saline aquifer
- Accurate pressure and temperature measurements in the borehole important
- Recommendations for future experiments:
 - Acquire baseline prior to CO₂ injection
 - Minimize well completion changes while monitoring
 - Avoid replacing near borehole fluids while monitoring

Acknowledgements to

- DOE
- NETL
- BEG