

Climate Initiative and CO₂ Sequestration

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Schlumberger-Doll Research

Acknowledgements

- Schlumberger
 - P. Lacour-Gayet
 - B. Altundas, K. Bennaceur, A. Boyd, N. Muller
 - V. Barlet, E. Nelson, M. Supp
 - T. Randen, H. Xu, R. Salter

- Battelle
 - N. Gupta, P. Jagucki

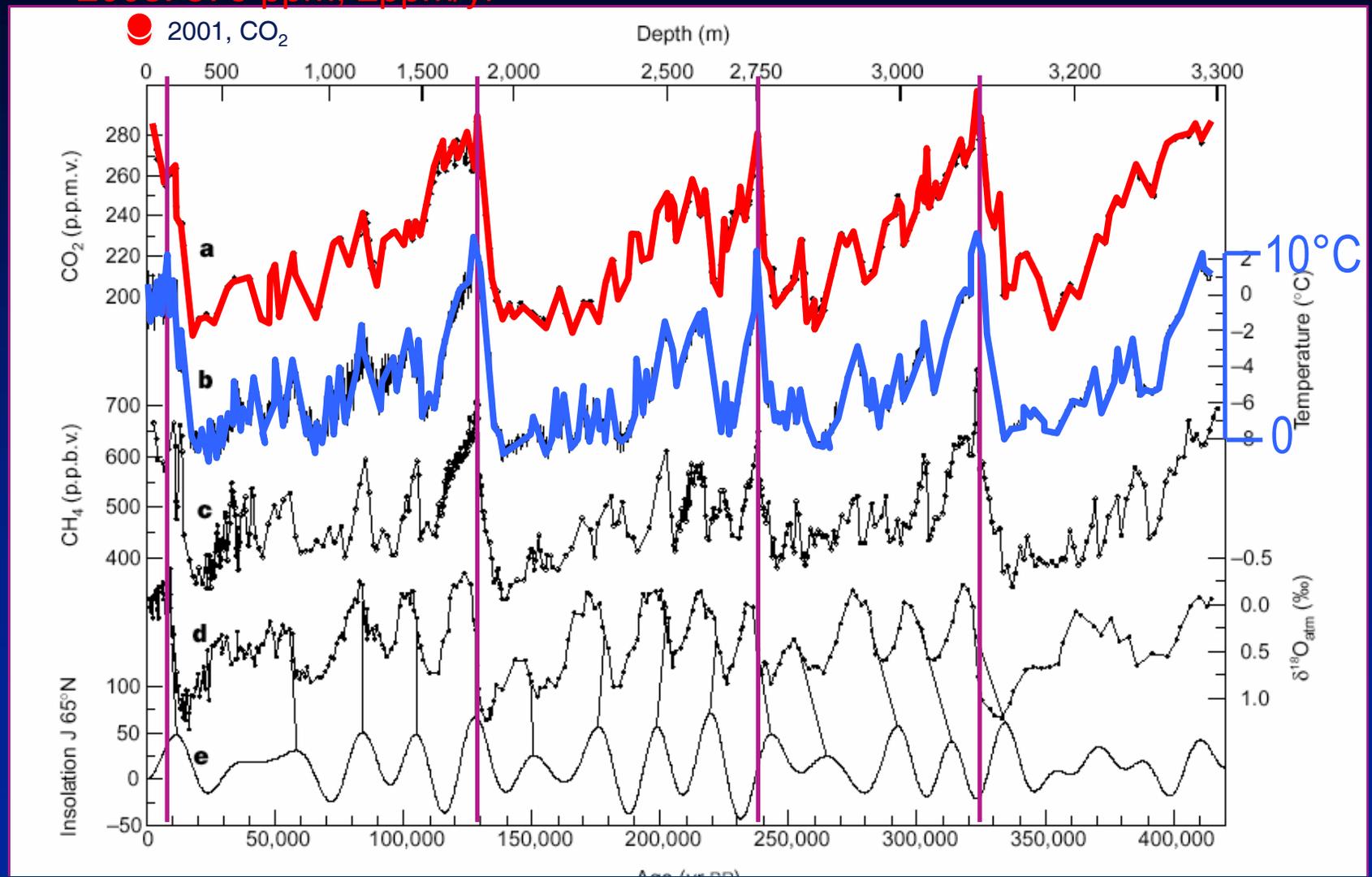
- BEG
 - S. Hovorka, S. Sakurai

- NETL / DOE

Global warming—link to CO₂

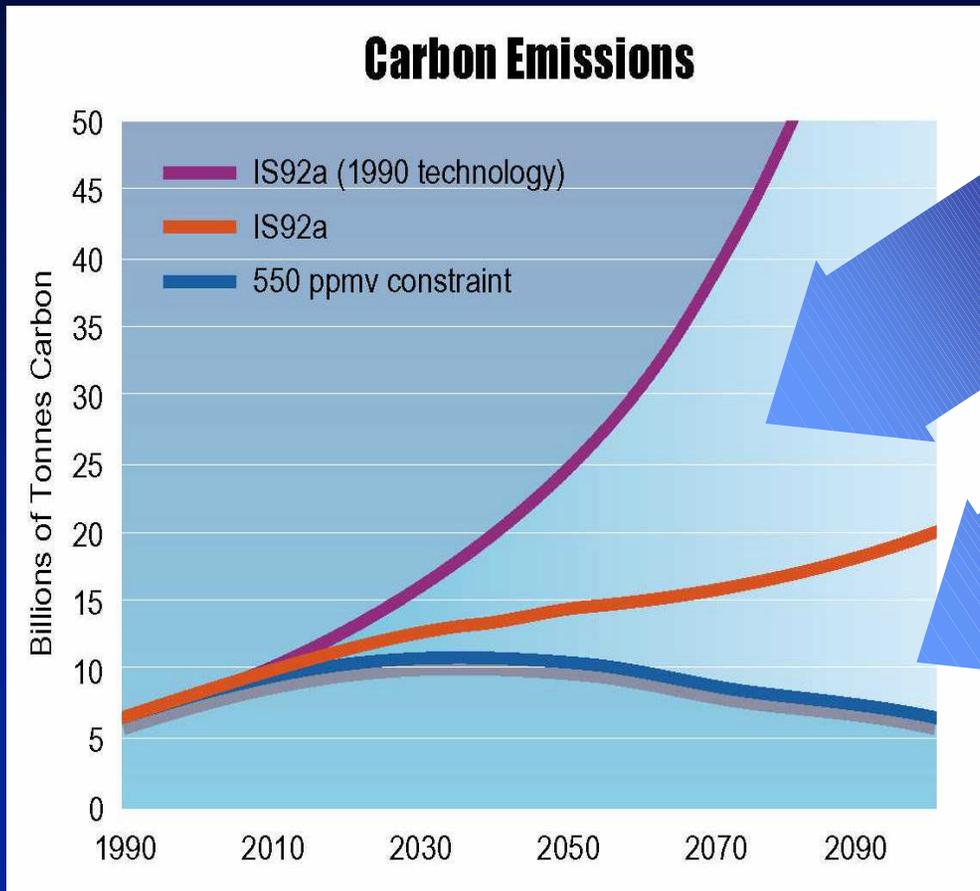
2001, CH₄ ●

2003: 375 ppm, 2ppm/yr



Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Petit, Jouzel et al... Nature, June 1999

Storage Volume



(Edmonds, 2004)

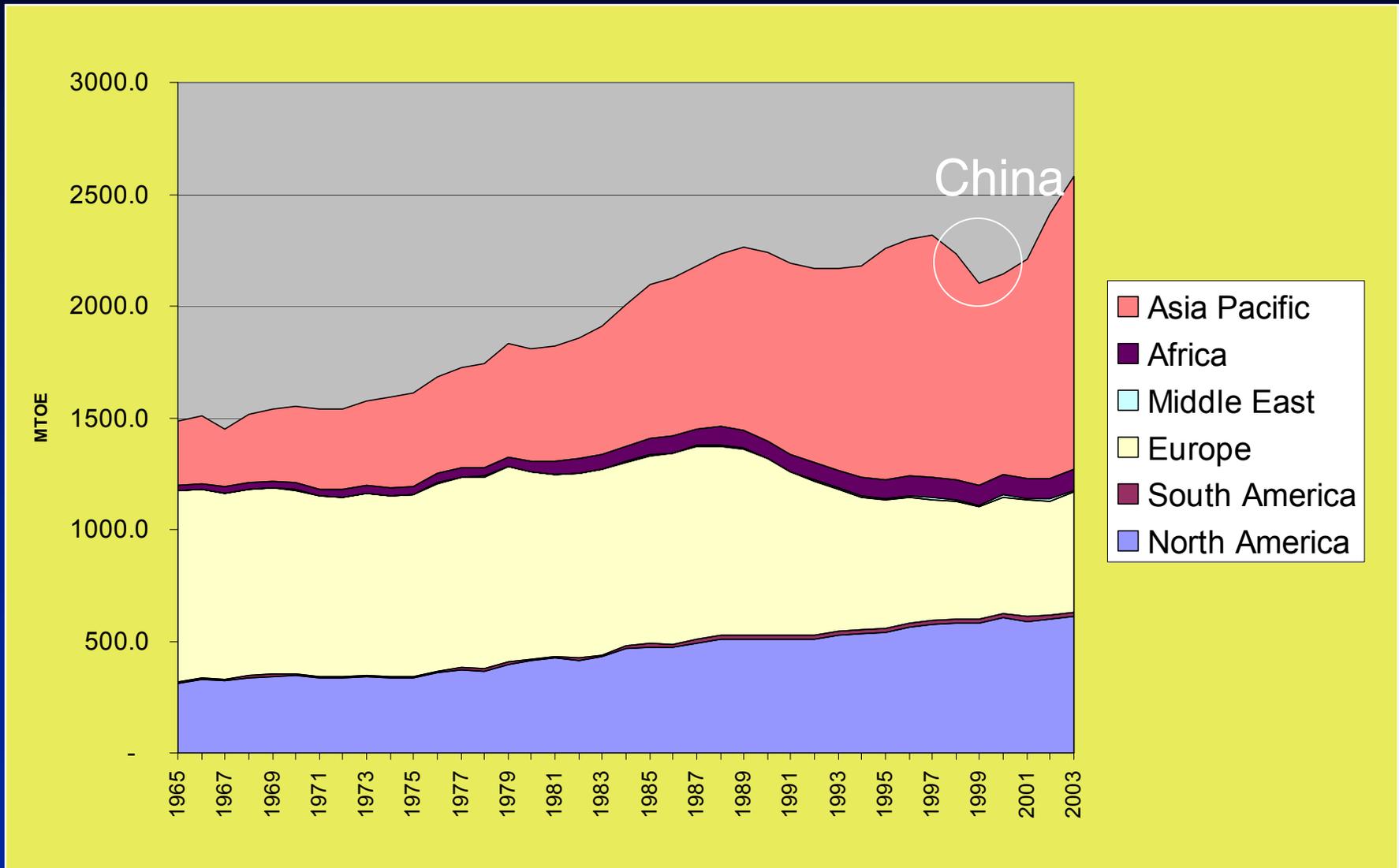
Assumed Advances In

- Fossil Fuels
- Energy intensity
- Nuclear
- Renewables

Carbon capture & disposal

13 Gt/y CO₂ ≈ 280 MBbl/day
25 Gt/y CO₂ ≈ 540 MBbl/day
Oil: 77 MBbl/d Oil Prod (2003)

Coal consumption

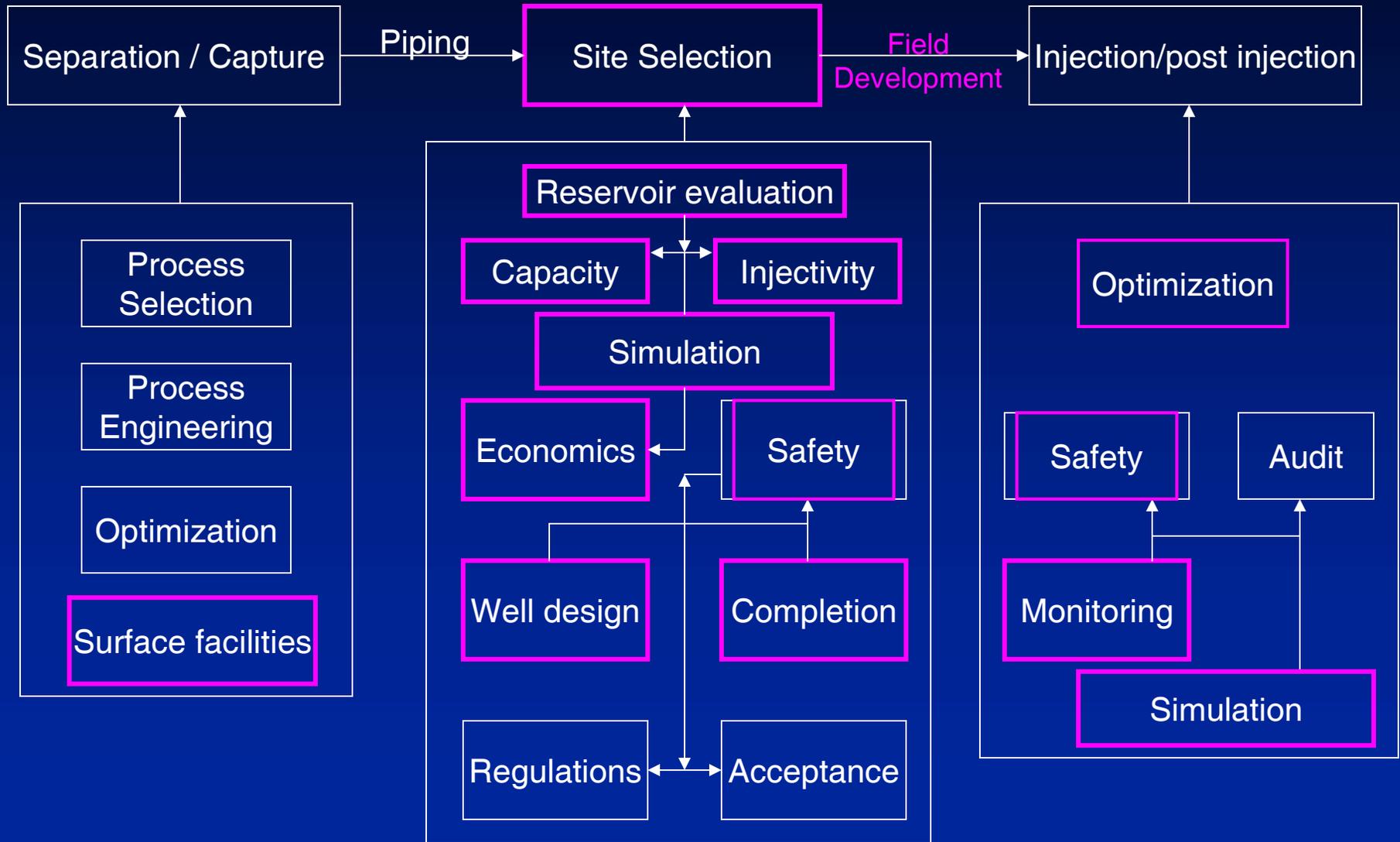


Comparison of fuels

Source	Price / Std unit \$	Cost / emit. CO ₂ \$ / ton CO ₂	E / kg CO ₂ MJ/ kg CO ₂	Price \$ / GJ
Oil	50 / Bbl	122	14.8	8.2
N. Gas	7 / Mscf	123	19.5	6.3
Coal (Bit)	26.2 / ton	10.7	11.2	1
Electricity	50 / MW-hr	155 Bit. coal plant	-	13.8

- Sequestration cost must be \$15 / ton CO₂ or less

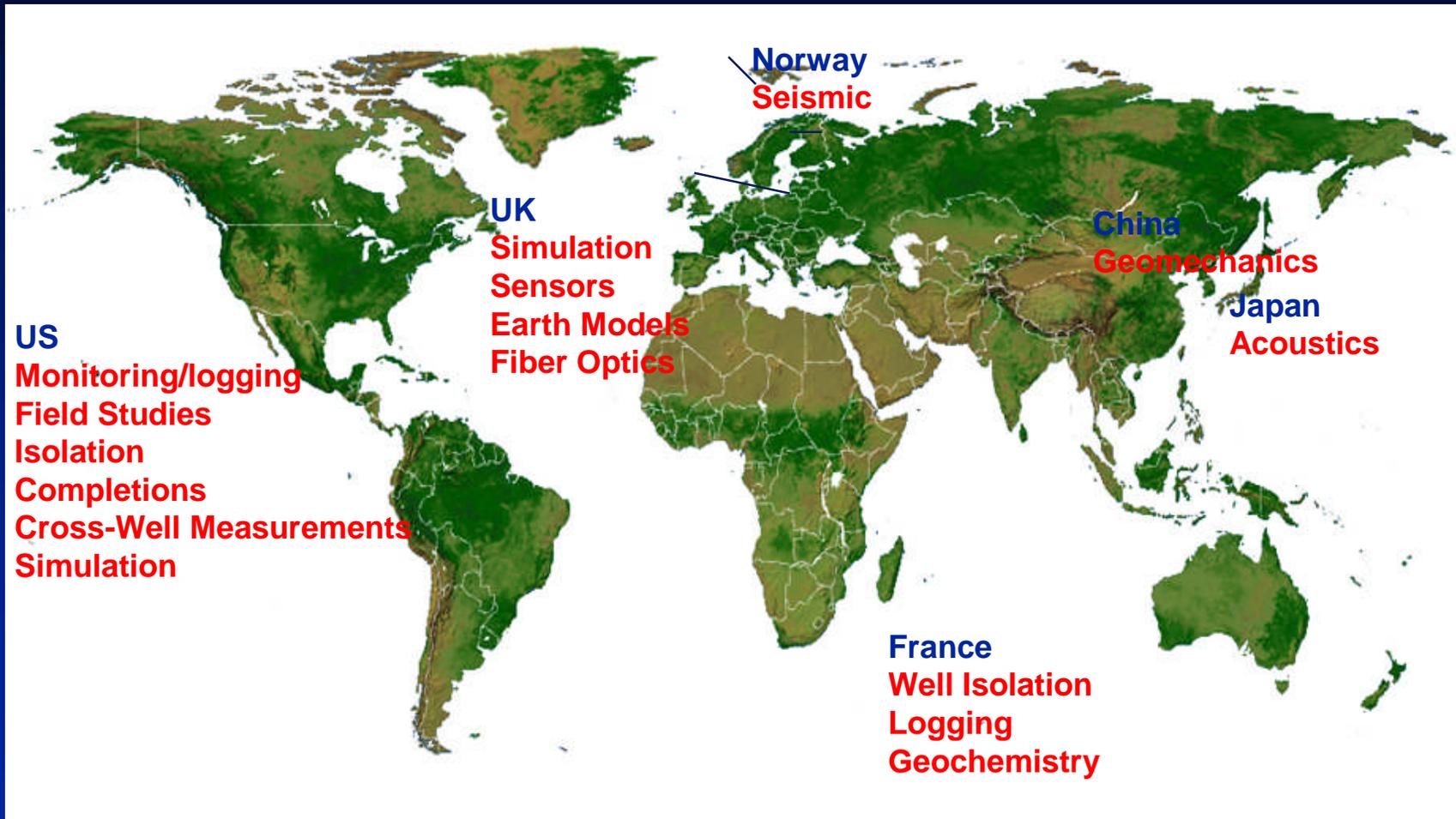
CO₂ and relevance to oil and gas



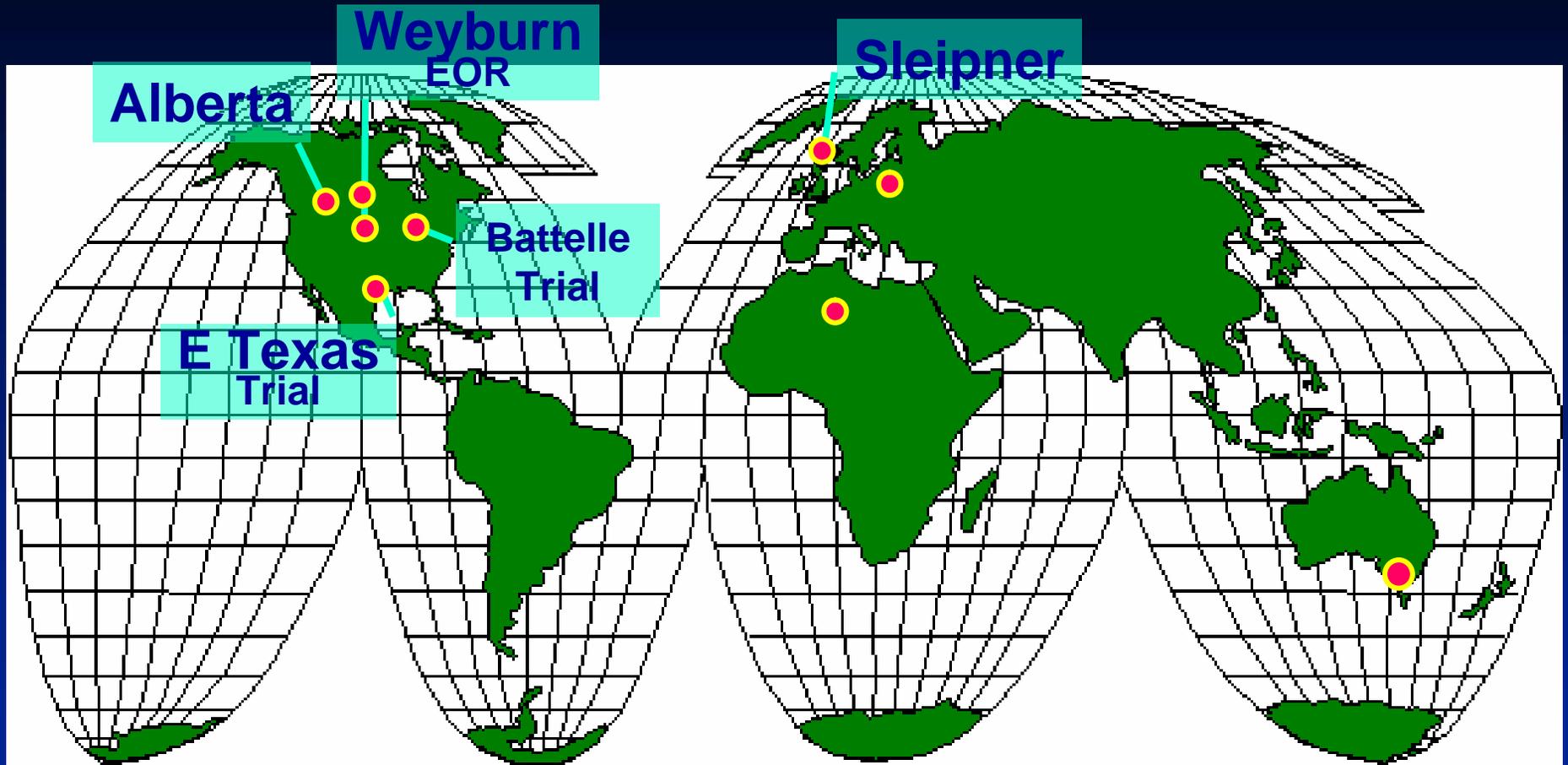
Technologies for CO2 sequestration

- Ocean sequestration
 - Monitoring (pH, ion-specific monitoring)
- Geological sequestration
 - Geology services ...(logging/evaluation, characterization, caprock integrity)
 - Monitoring services
 - » Seismic, electrode arrays, gravity
 - » CO2 sensors
 - Reservoir simulation / modeling / economics
 - Well completions, services, and stimulation
 - » Acid/Fracture treatments
 - » Optimal well construction
 - » Wellbore isolation: cementing
- Infrastructure

CO2-related R&D in Schlumberger



Worldwide projects



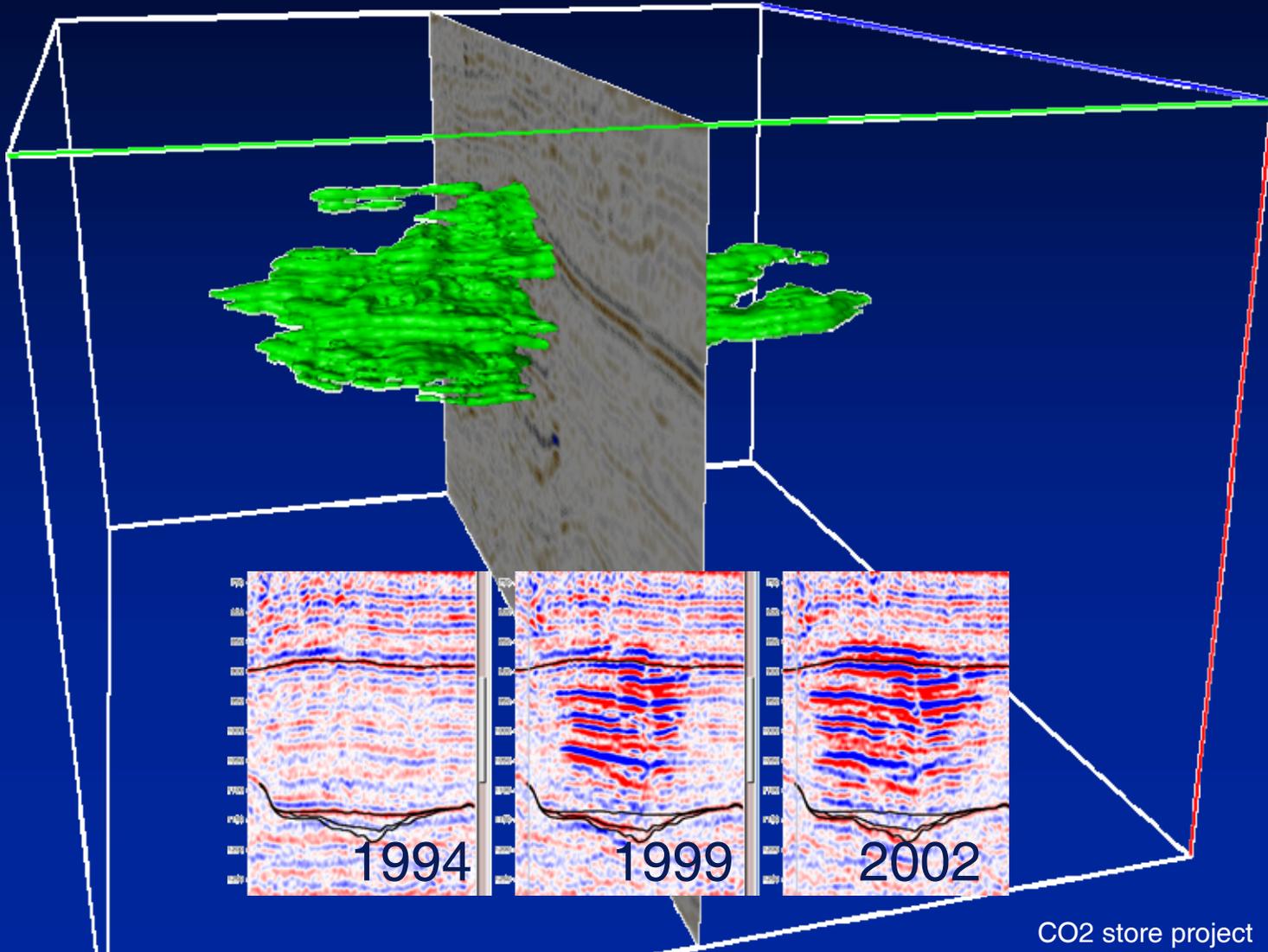
● underway

Technologies in Field Projects

- Seismic
- Logging, reservoir evaluation
- Monitoring, CO₂ dissipation, containment
- Wellbore isolation
- Simulation

Seismic

Sleipner



Reservoir Evaluation

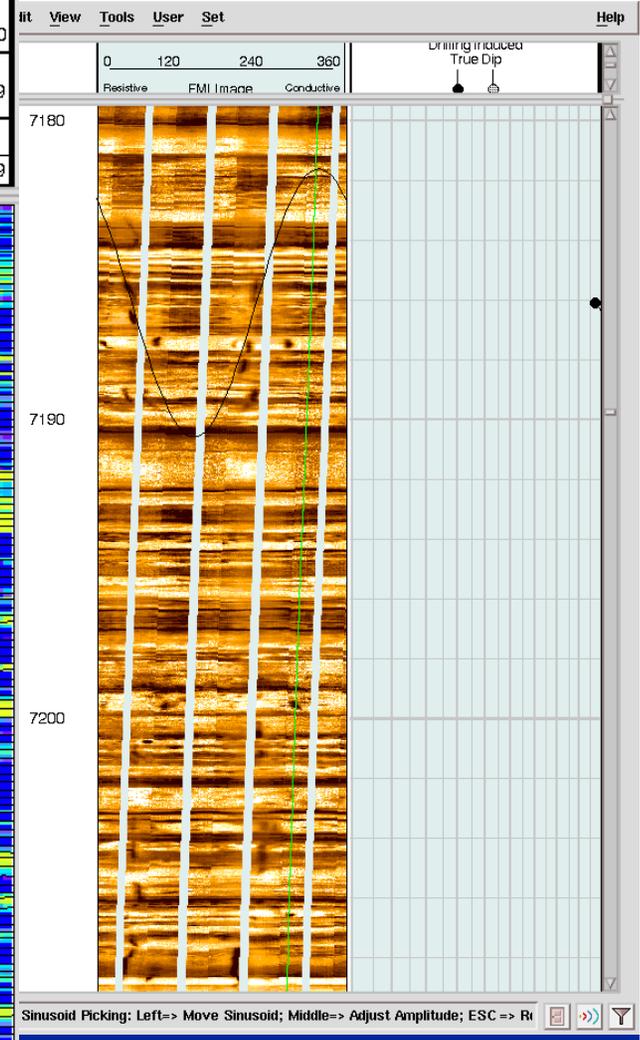
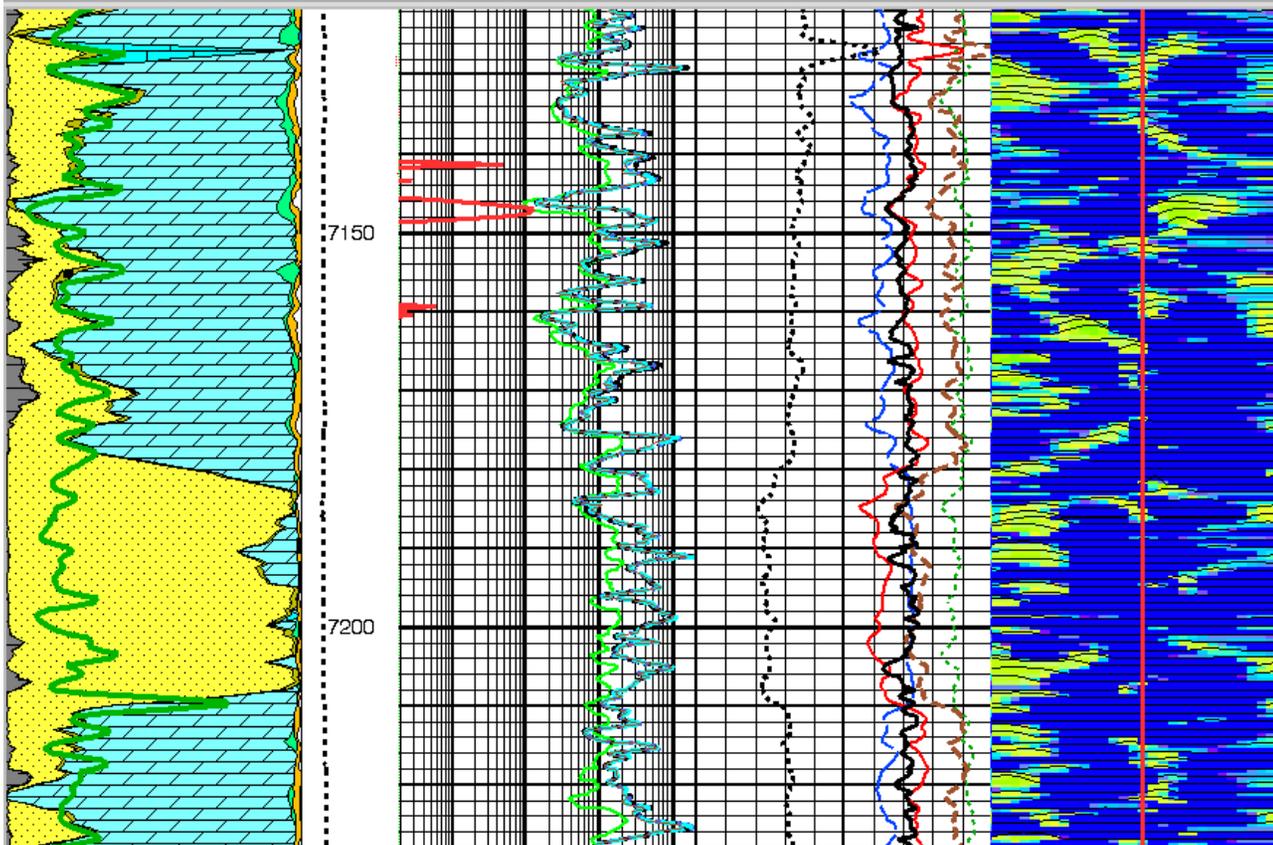
The Mountaineer Plant

- 1.3 GW pulverized-coal unit
 - By barge/rail
- 8 Mton/y of CO₂
- NO_x removal installed
- SO_x removal planned for future



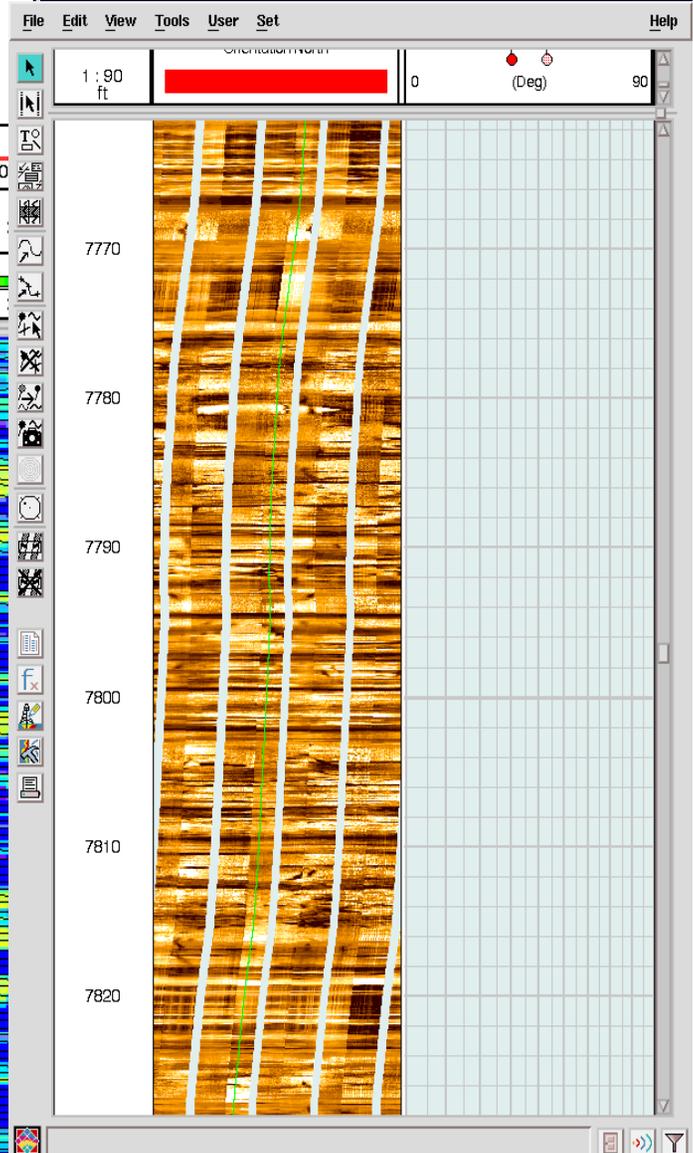
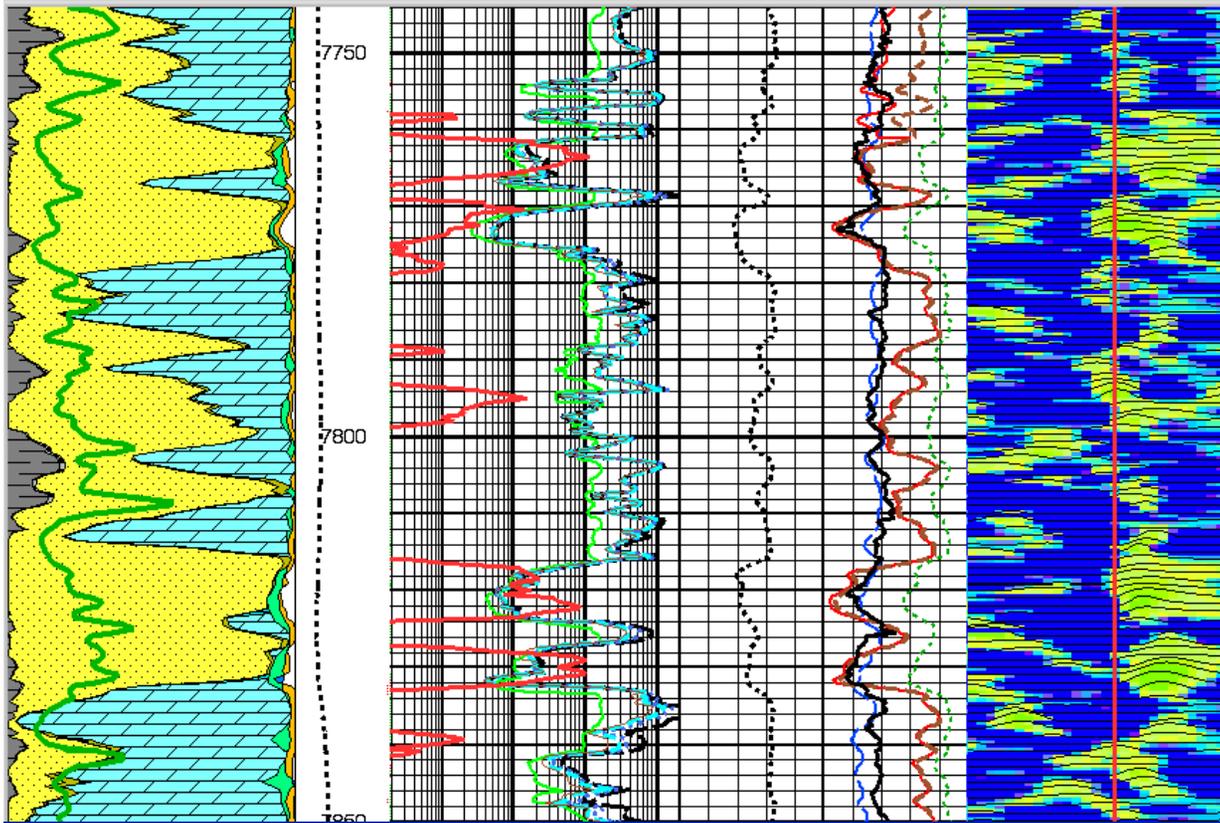
St Peters Sandstone

Siderite	HCAL_B 4 (in) 14	RXOZ_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	TCMR .5 level ave [A18] 0.45 (ft3/ft3) -0.15	
Quartz	MD 1 : 200 ft	PLA5_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	TNPH_BASIC.TLD_MCFL_ 0.45 (ft3/ft3) -0.15	
Bound Water	DSOZ_B 1.5 (in) 0	PLA4_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	DPHZ_BASIC.TLD_MCFL_ 0.45 (ft3/ft3) -0.15	
Illite	RSOZ_B 1.5 (in) 0	PLA3_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	DT_BASIC.FMI_SONIC_T 140 (us/ft) 40	T2CUT_PRES .5 level av 0.3 (ms) 3000
Volumetric Analysis 1 (V/V) 0	DSOZ	PLA2_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	RHOZ_BASIC.TLD_MCFL_ 1.95 (g/cm3) 2.95	T2_DIST .5 level ave [] 0 29
ECGR_BASIC.ECS_TLD_M 0 (gAPI) 200	RSOZ	KSDR .5 level ave [A18] 0.02 (mD) 200	PEFZ_BASIC.TLD_MCFL_ 0 10	AMP_DIST .5 level ave 0 29

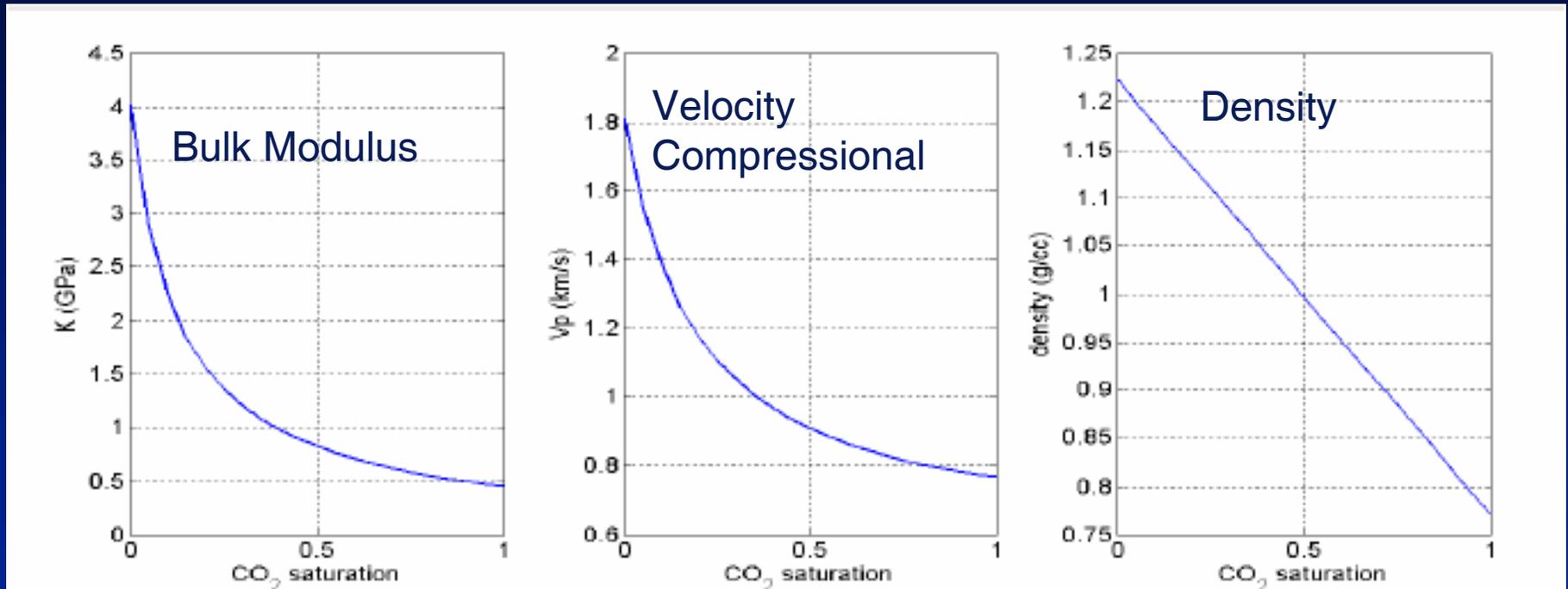


Rose Run Sandstone

HCAL_B 4 (in) 14	PXOZ_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	TCMR .5 level ave[A18 0.45 (ft3/ft3) -0.15	
MD 1 : 200 ft	PLA5_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	TNPH_BASIC.TLD_MCFL_ 0.45 (ft3/ft3) -0.15	
DSOZ_B 1.5 (in) 0	PLA4_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	DPHZ_BASIC.TLD_MCFL_ 0.45 (ft3/ft3) -0.15	
RSOZ_B 1.5 (in) 0	PLA3_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	DT_BASIC.FMI_SONIC_T 140 (us/ft) 40	T2CUT_PRES .5 level av 0.3 (ms) 30
Volumetric Analysis 1 (V/V) 0	PLA2_BASIC.TLD_MCFL_ 0.2 (ohm.m) 2000	RHOZ_BASIC.TLD_MCFL_ 1.95 (g/cm3) 2.95	T2_DIST .5 level ave[()
ECGR_BASIC.ECS_TLD_M 0 (gAPI) 200	KSDR .5 level ave[A18 0.02 (mD) 200	PEFZ_BASIC.TLD_MCFL_ 0 () 10	AMP_DIST .5 level ave ()



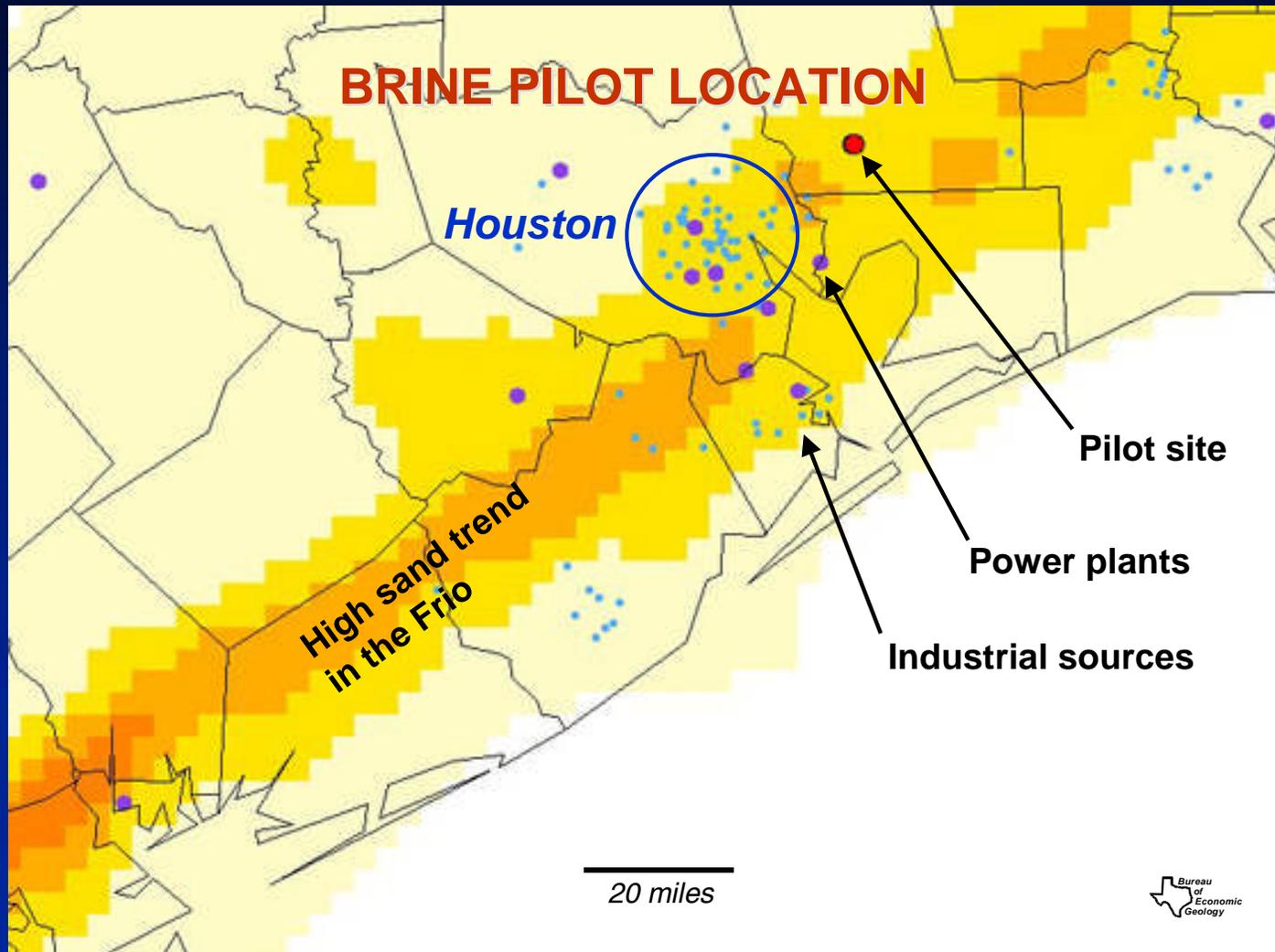
Can we monitor CO₂?



- Change in acoustic velocities, impedance < 8%

Monitoring Experiment – Frio

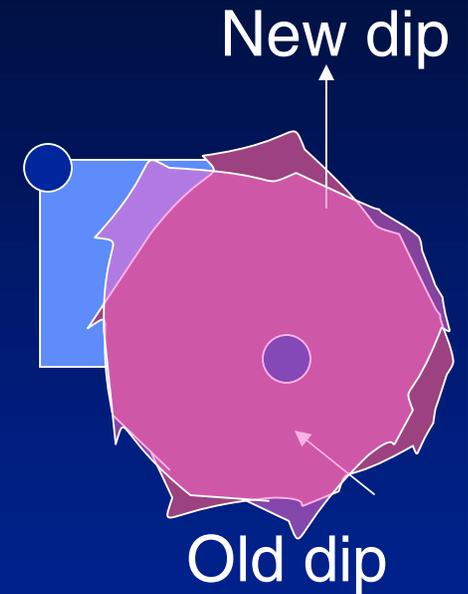
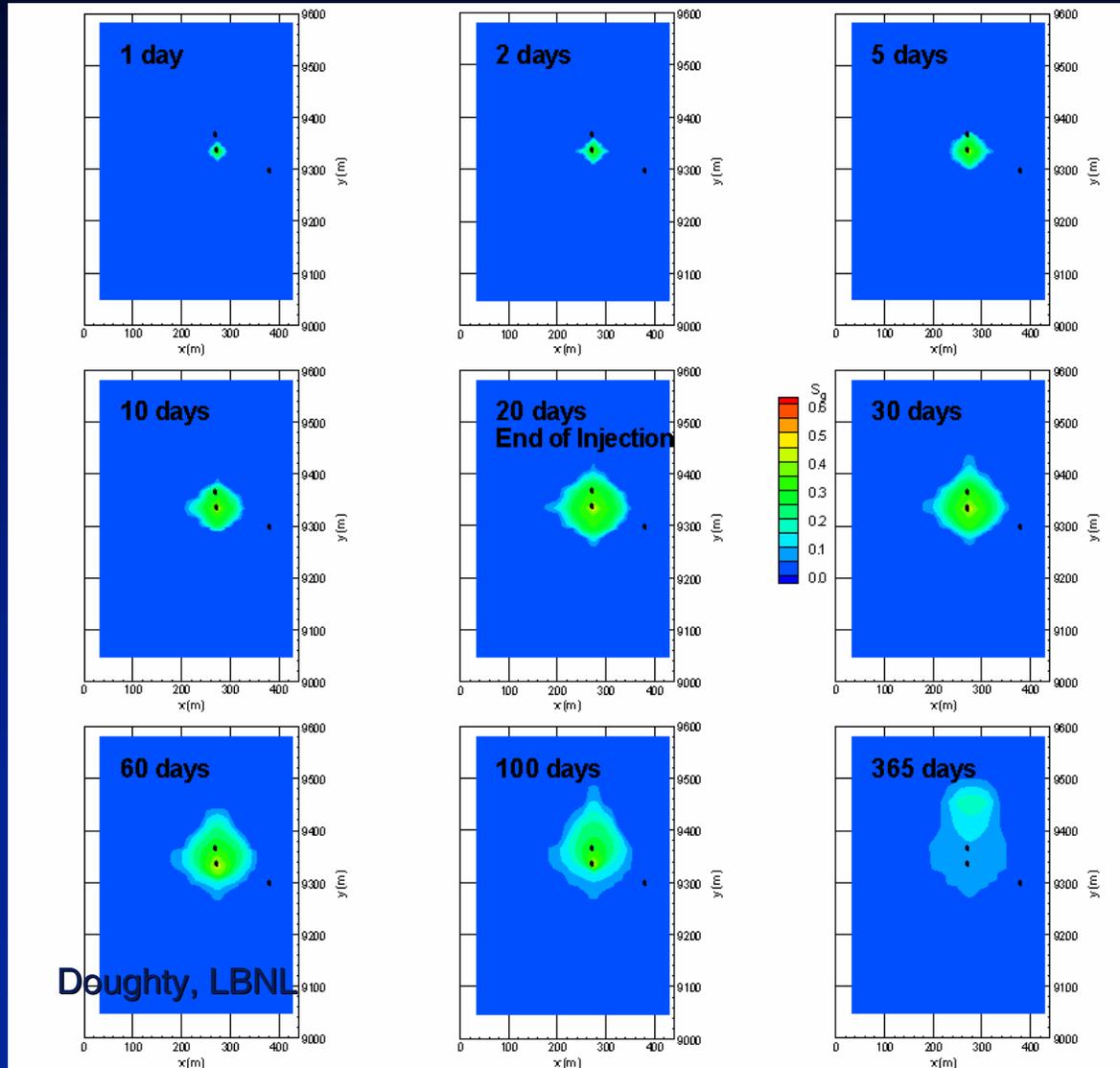
The location



Very modern facilities

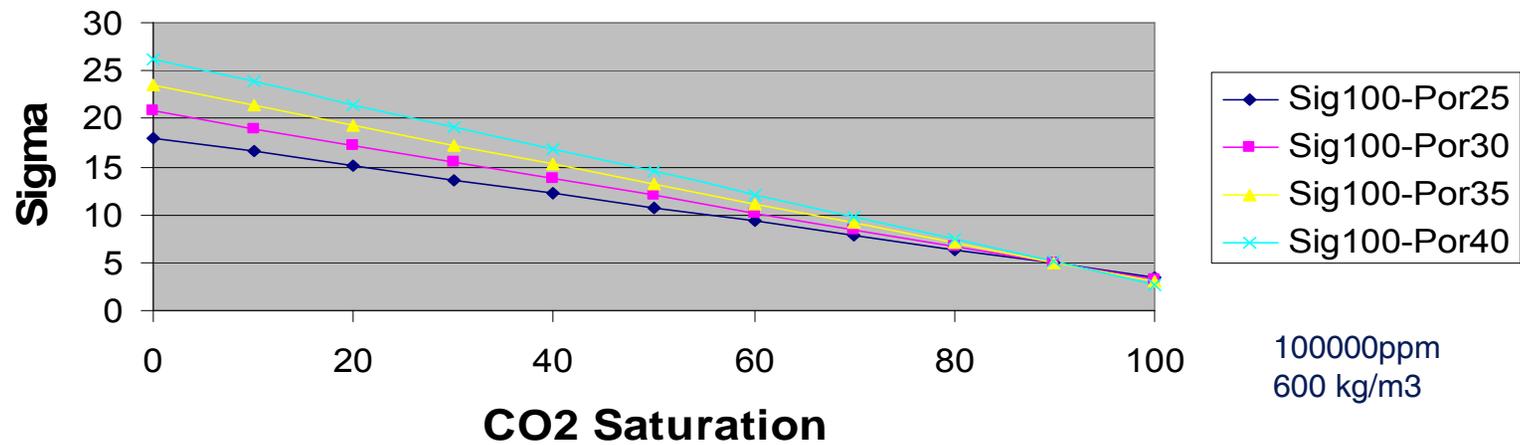


TOUGH2 Model

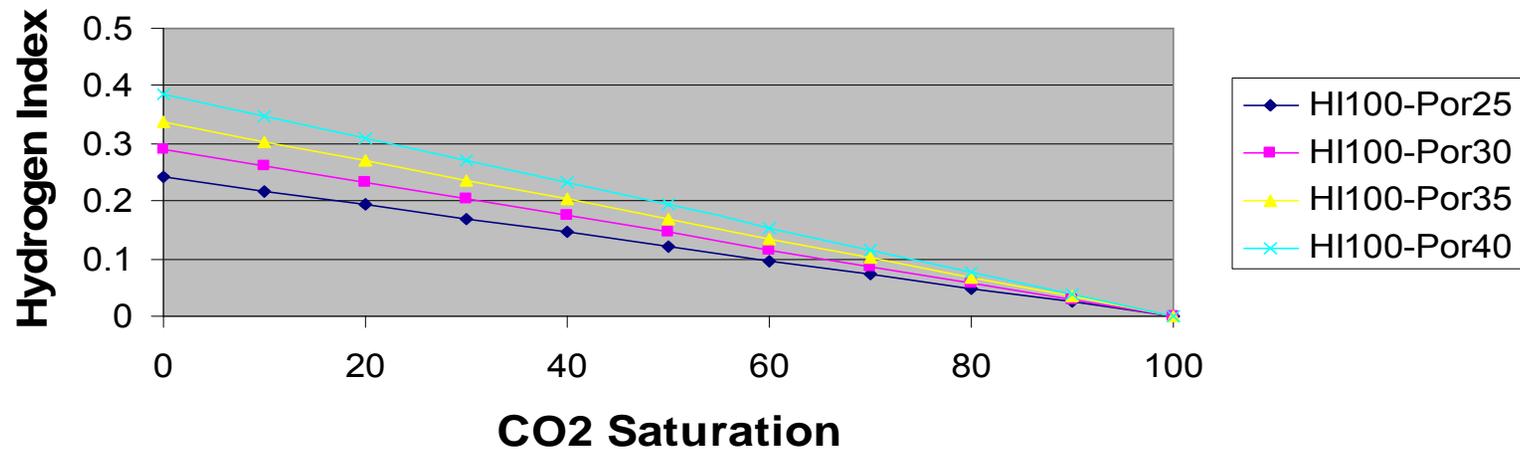


Pulsed Neutron Monitoring

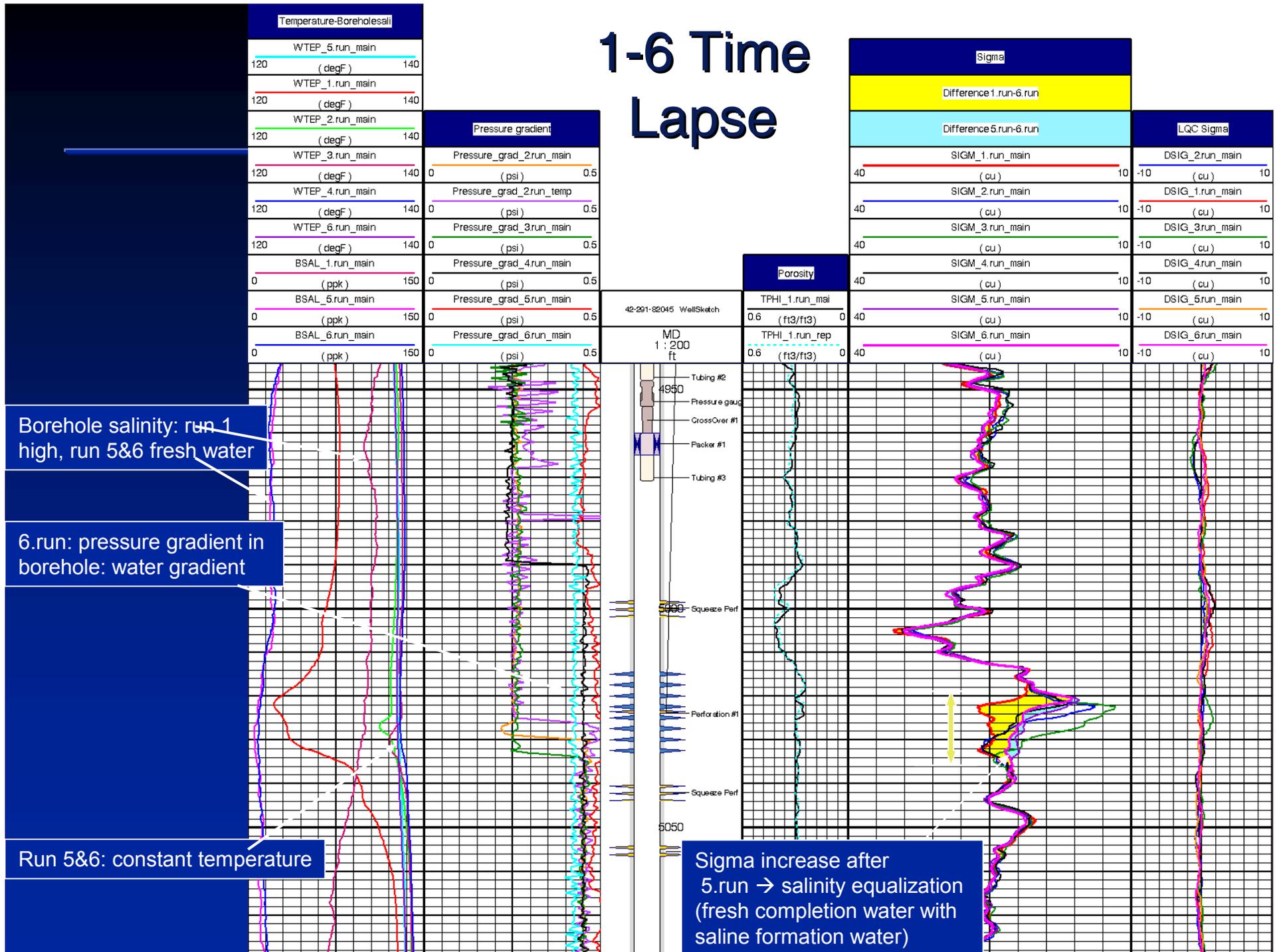
Sigma vs CO2 Saturation at 100ppk Brine



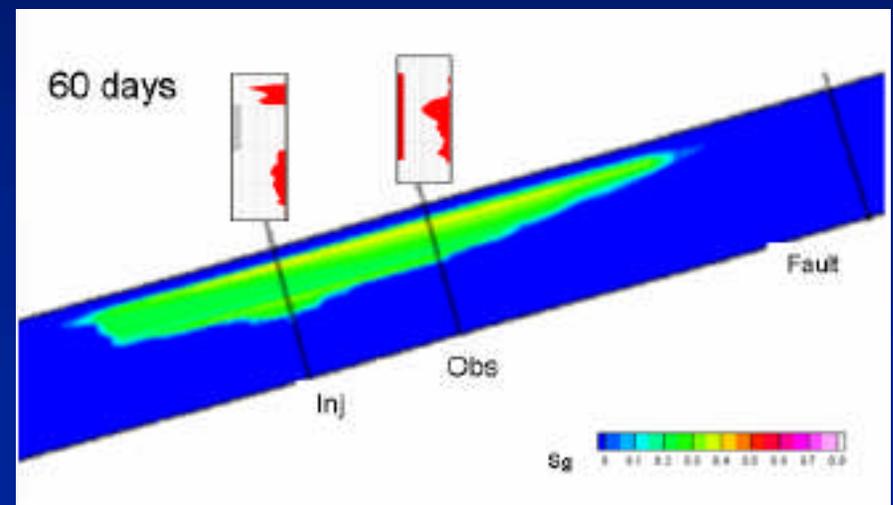
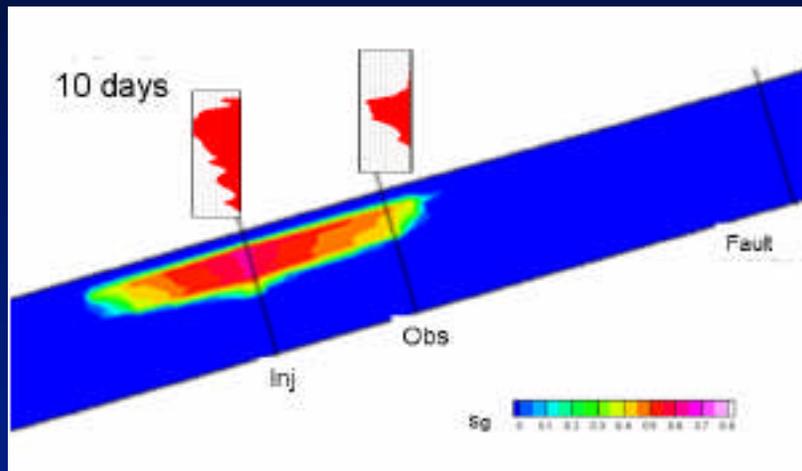
Hydrogen Index vs CO2 Saturation at 100ppk Brine



1-6 Time Lapse

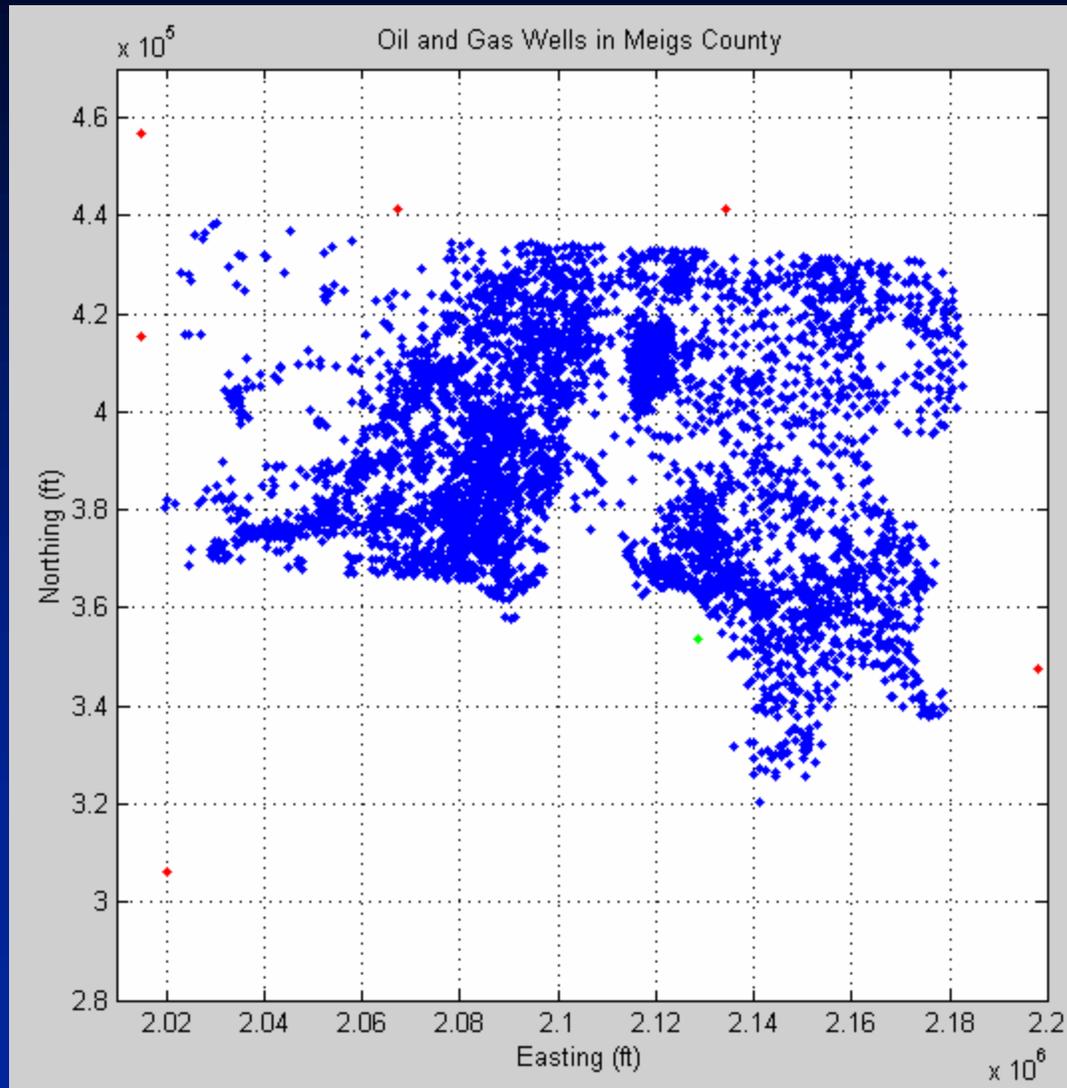


Monitoring vs. Simulation



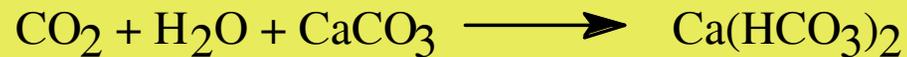
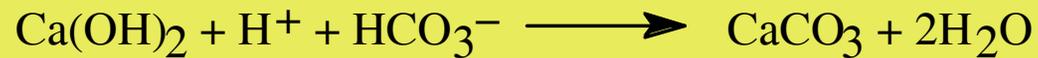
Safety

Area Well Data (Meigs County)

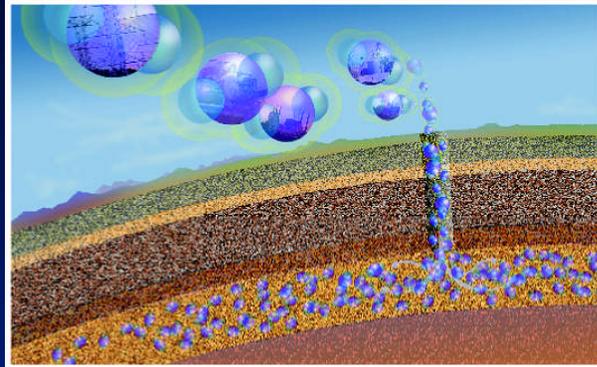


● Target

Portland cement reactions with CO₂

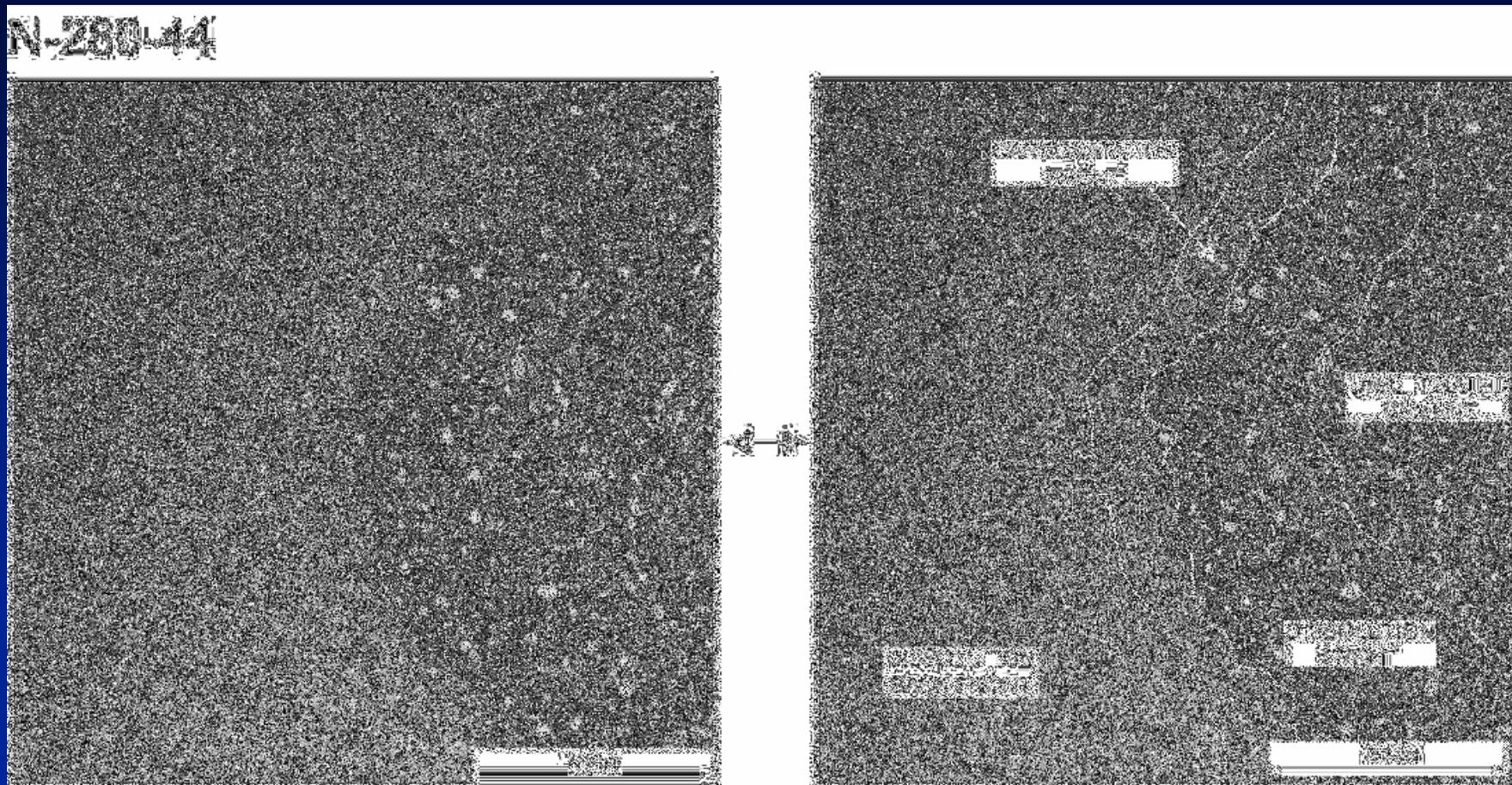


Well Integrity



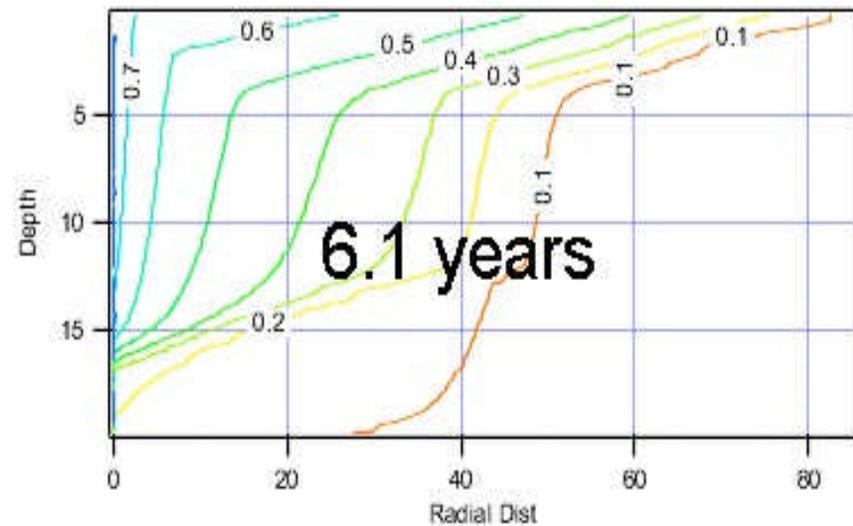
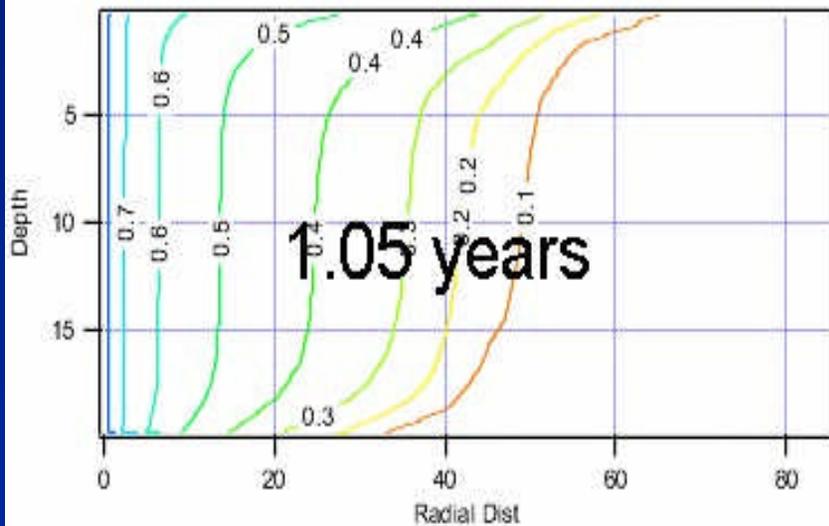
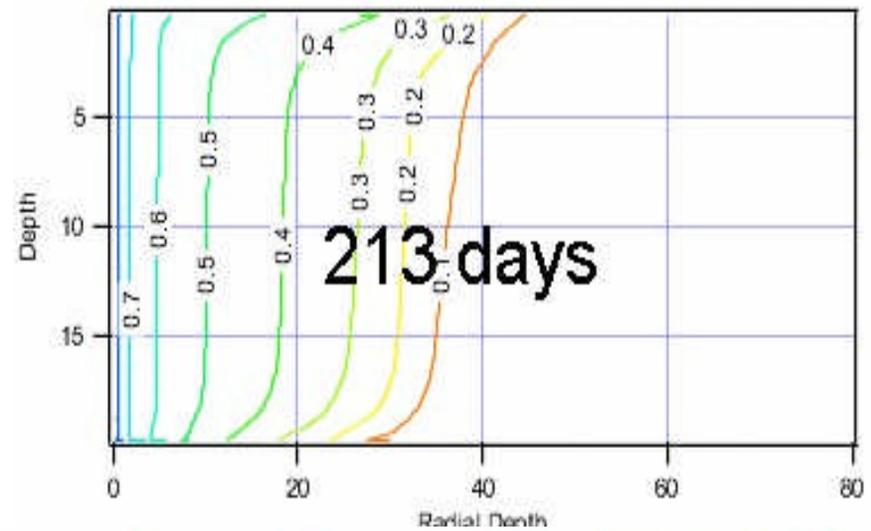
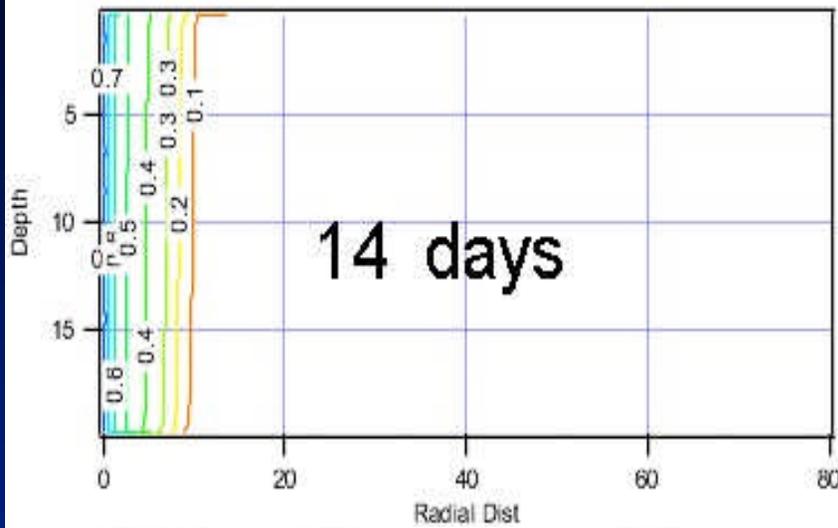
- Portland cement is unstable thermodynamically (moist CO_2)
- Industry specifications—lacking
- Development of standard testing conditions

Reaction Fronts



Simulation

Contour plots of CO2 saturation contd



External Participation

- GCEP at Stanford, CA, USA

- IPGP, France
 - Mineral sequestration

- CO2CRC, Australia
 - Field Projects
 - Consortium

- TxEC

Can the Oil and Gas Industry Help

- Planning and operation is analogous to oil & gas
 - Upstream and downstream roles are reversed
- Size and scope of CO₂ sequestration is vast
 - Cost reduction is essential
- Safety and public trust is vital
- How is it going to be paid?
 - Trading based on caps?
 - Carbon tax?