

Key technologies and solutions in providing reliable and efficient CO₂ geological storage services

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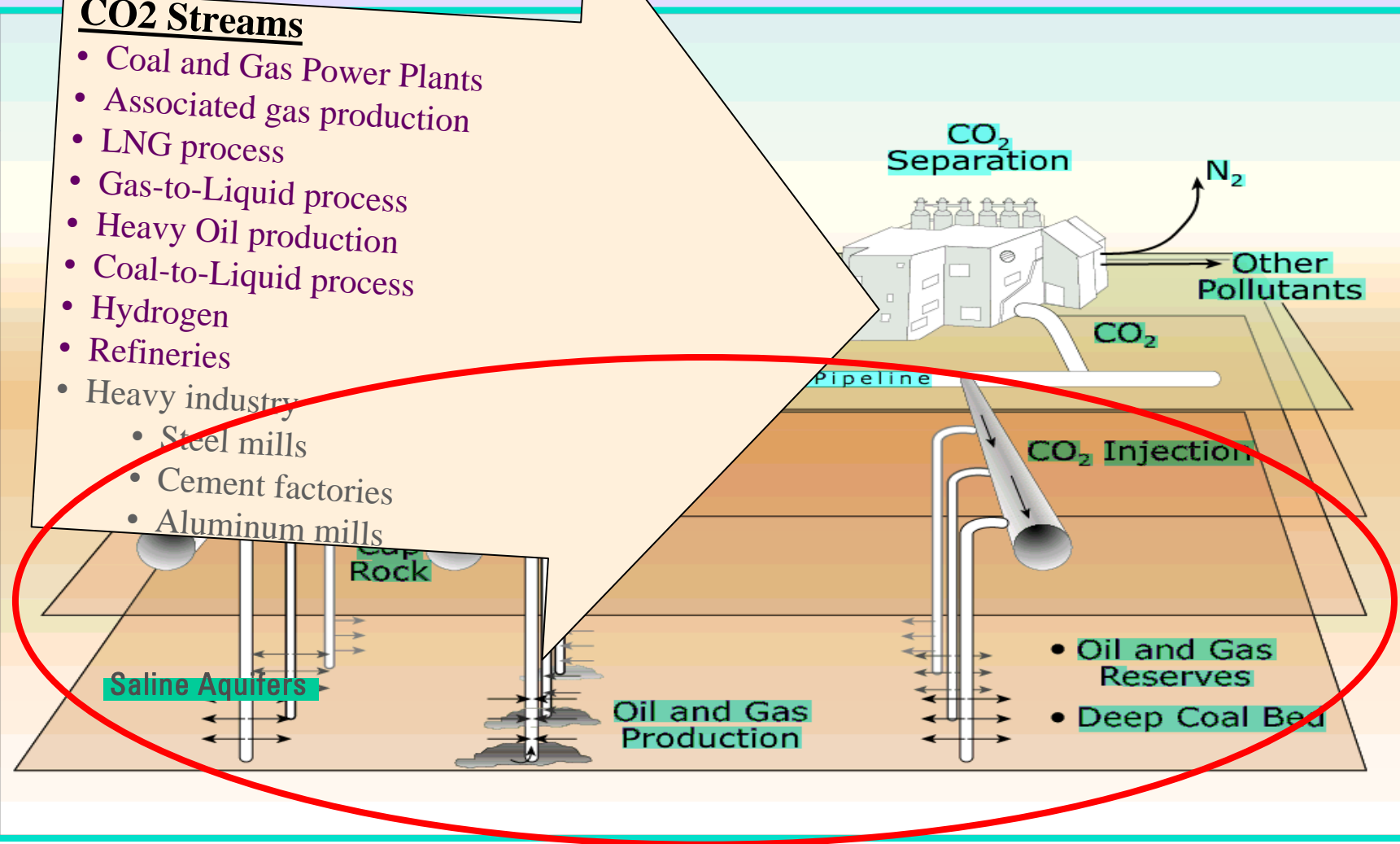


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CO2 Capture and Geological Storage





CO2 Streams

- Coal and Gas Power Plants
- Associated gas production
- LNG process
- Gas-to-Liquid process
- Heavy Oil production
- Coal-to-Liquid process
- Hydrogen
- Refineries
- Heavy industry
 - Steel mills
 - Cement factories
 - Aluminum mills



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The CCS Cost (or Value!) Chain

 Capture	 Transport	 Storage	 Monitoring
<p>\$20 - 50/t CO₂</p>	<p>\$1 - 10/t CO₂</p>	<p>\$2 - 10/t CO₂</p>	<p>\$0.1 - 0.3/t CO₂</p>
<p>IPCC Estimations: NGCC \$44/t CO₂ PC \$29/t CO₂ IGCC \$20/t CO₂</p> <p><i>Sensitive to Energy prices</i></p>	<p>IPCC:(500km) Ships \$10/t CO₂</p> <p>Hydro:(250km) Pipeline: 230M\$</p> <p>University of Newcastle Pipeline 570M\$/y</p> <p><i>Distance dependant</i></p>	<p>IPCC: Aquifer \$0.5 - 8/t CO₂</p> <p>Pöyry: Aquifer \$2/t CO₂ Gas or oil field \$9.5/t CO₂</p> <p><i>Sensitive to Reservoir quality</i></p>	<p>IPCC: \$0.1 - 0.3/t CO₂</p> <p>Benson et Al 2006 \$0.16/t CO₂</p> <p><i>Remediation not included</i></p>

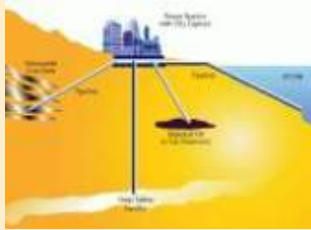
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An Integrated Solution to CO2 Storage

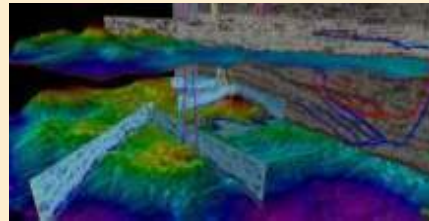
Pre-Operation Phase

~ 2-5 year

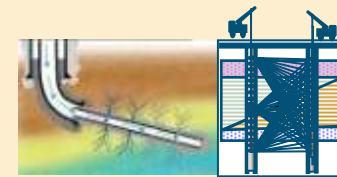
Site Selection



Site Characterization (SCP)



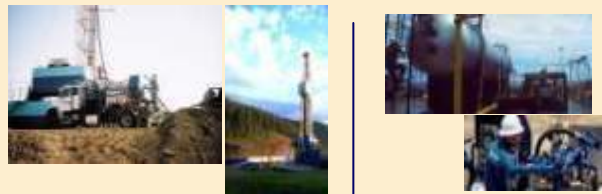
Field Design



Operation Phase

~ 10-50 years

Site Construction / Site Preparation



Injection

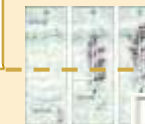


Monitoring (M&V)

• Operation



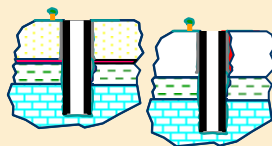
• Verification



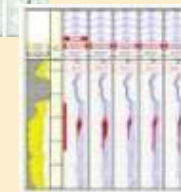
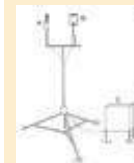
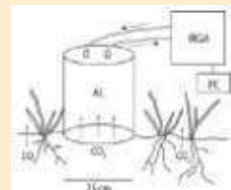
Post-Injection Phase

~50-100+years

Site Retirement Programme (SRP)



• Environmental

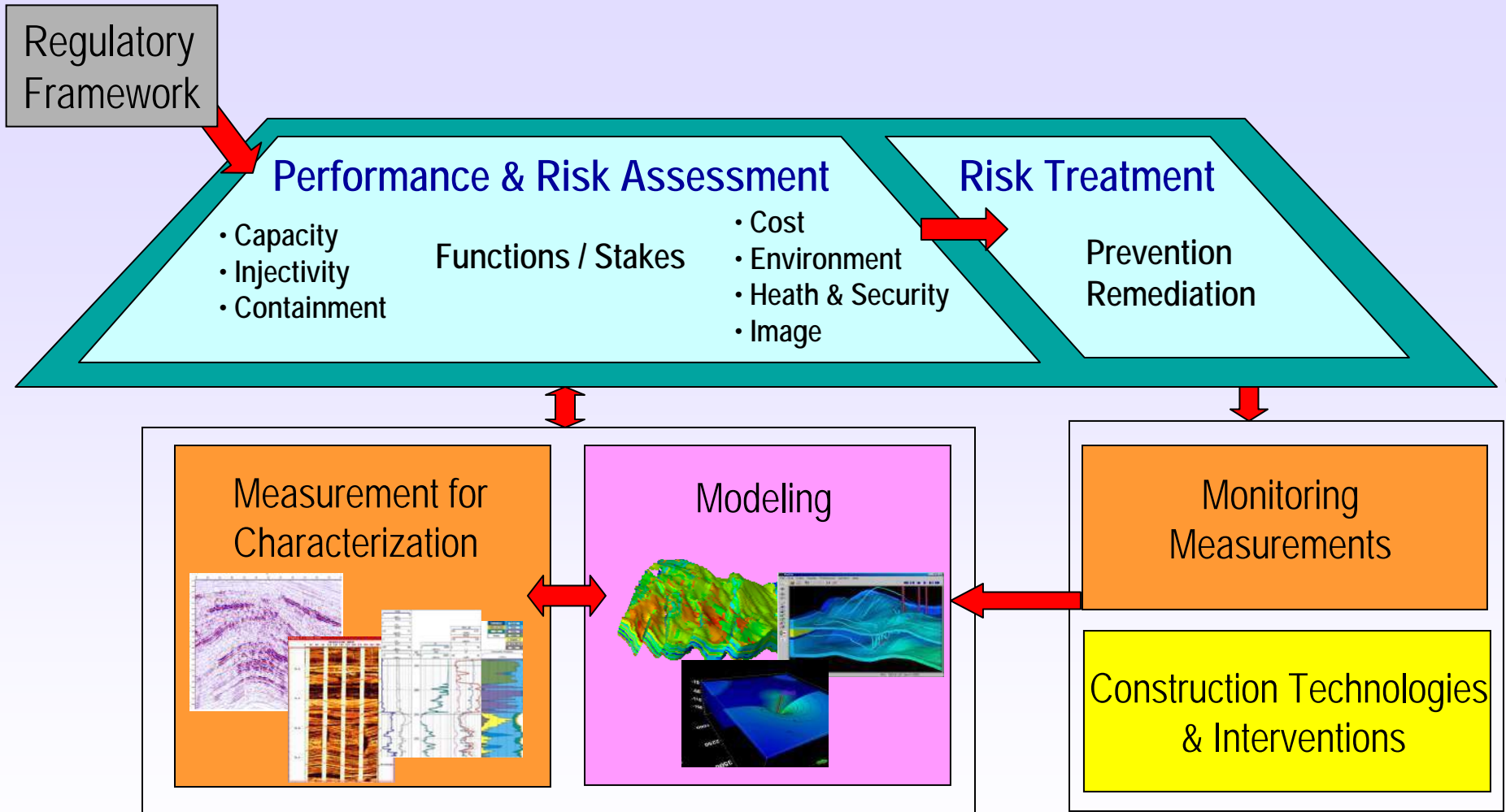


Performance & Risk Management System (PRMS)
Communication and Public Acceptance

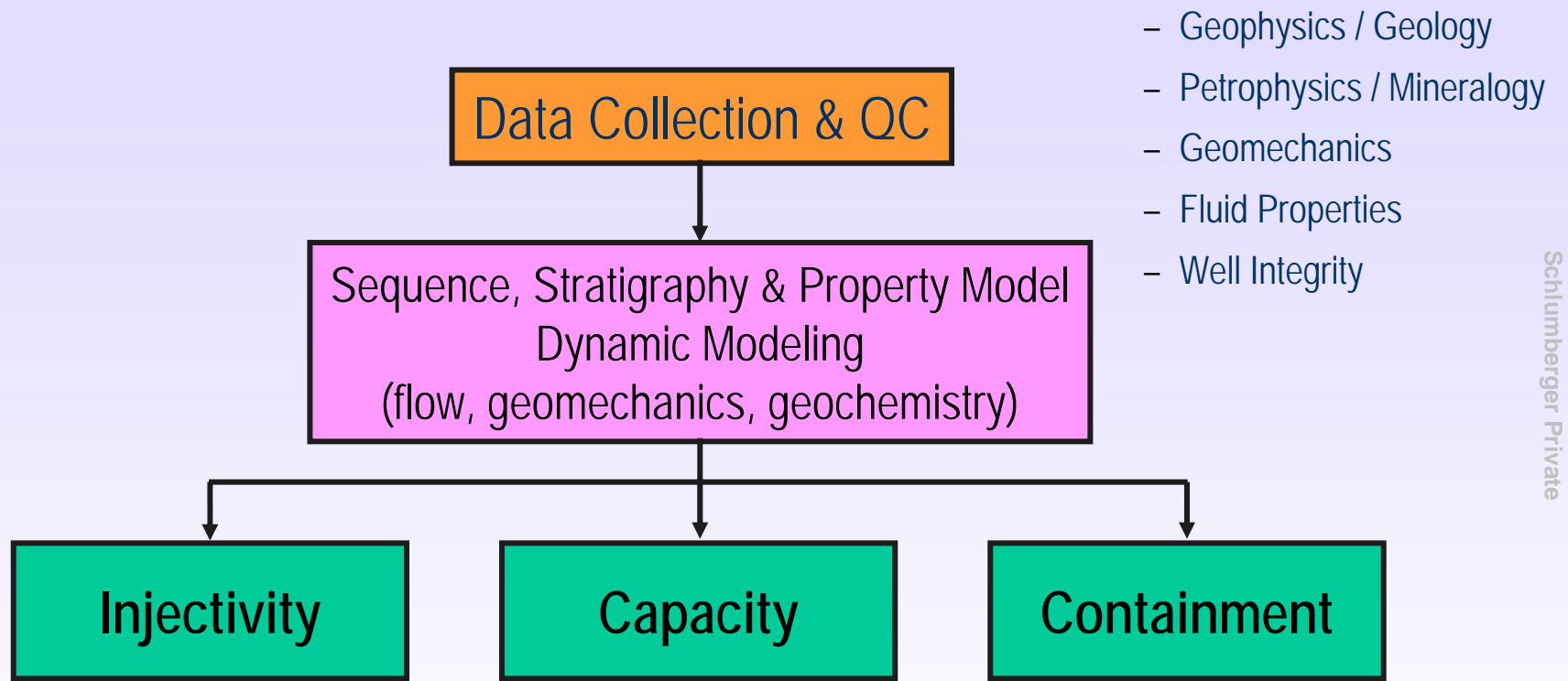


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Performance & Risk Management System



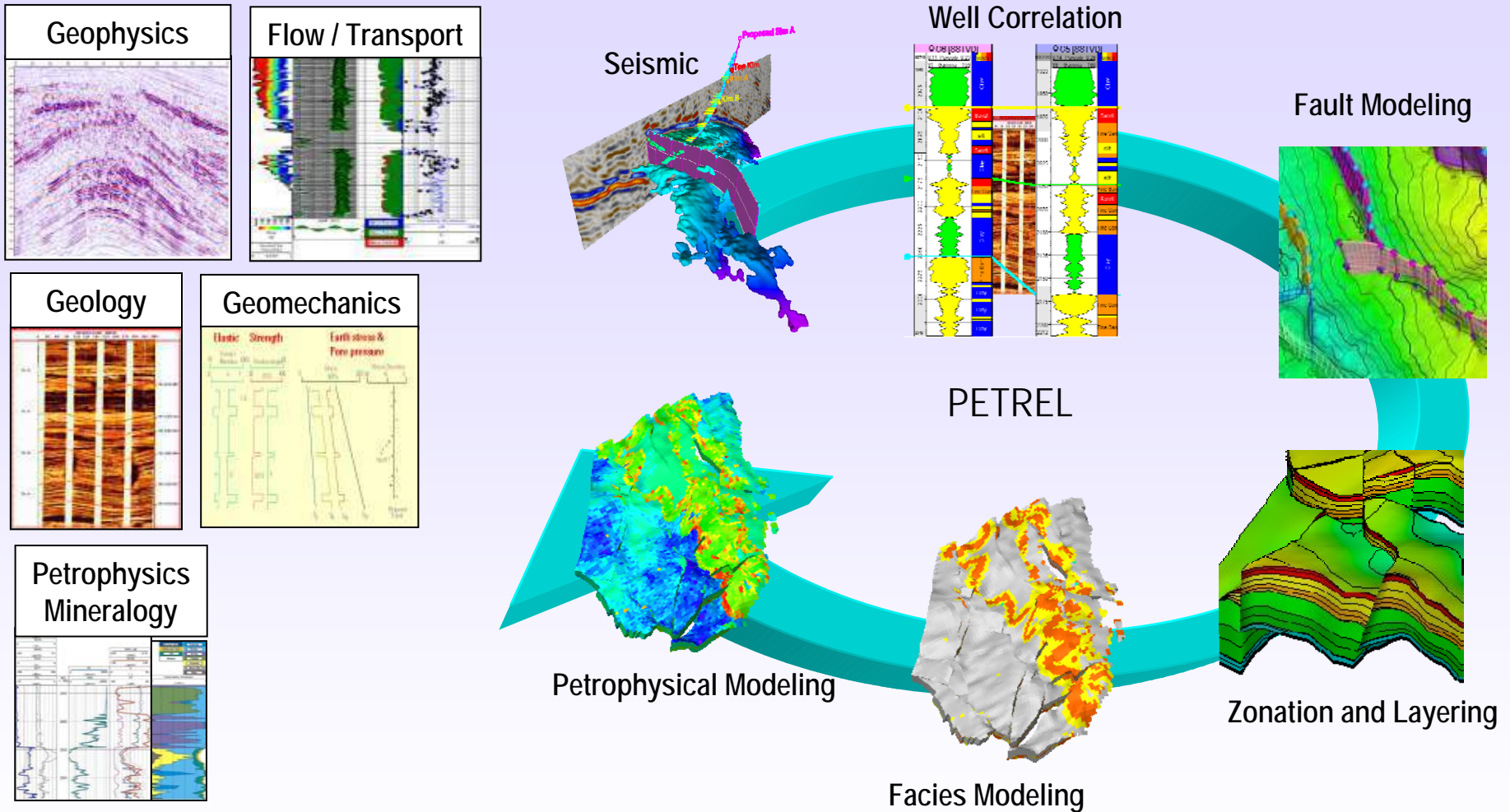
Initial Assessment – Site Characterization



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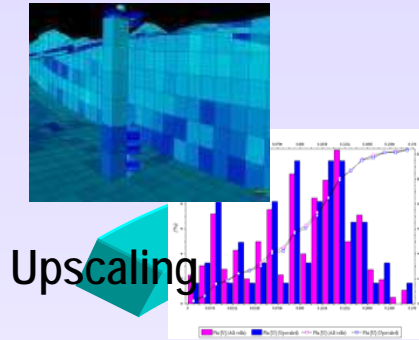
From CO2CRC – Latrobe Valley Study

Building a Static Model – Structure & Properties



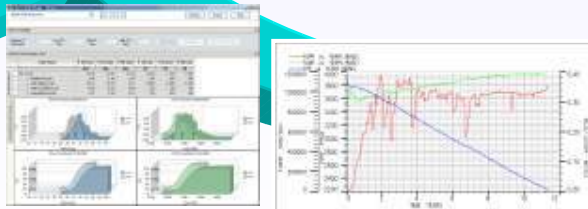
Model needs to include overburden

CO2 Injection Dynamic Modeling

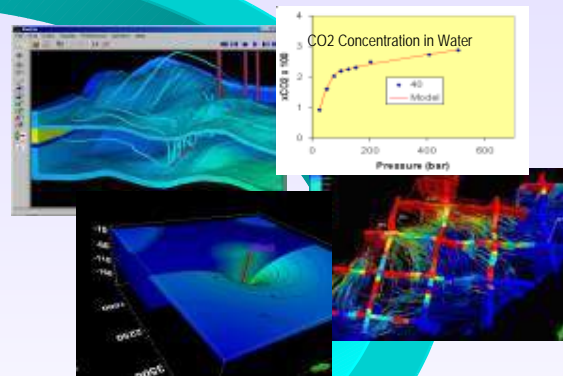


ECLIPSE – E300

Calibration on monitoring measurements
(History match)



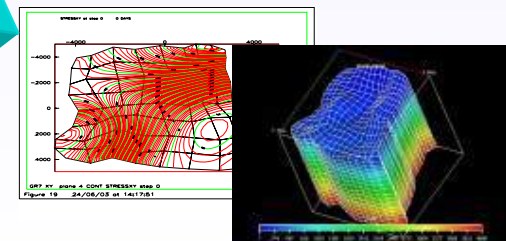
Thermodynamics
Geochemistry



Thermal Modeling

3D Full Compositional
Flow Simulator

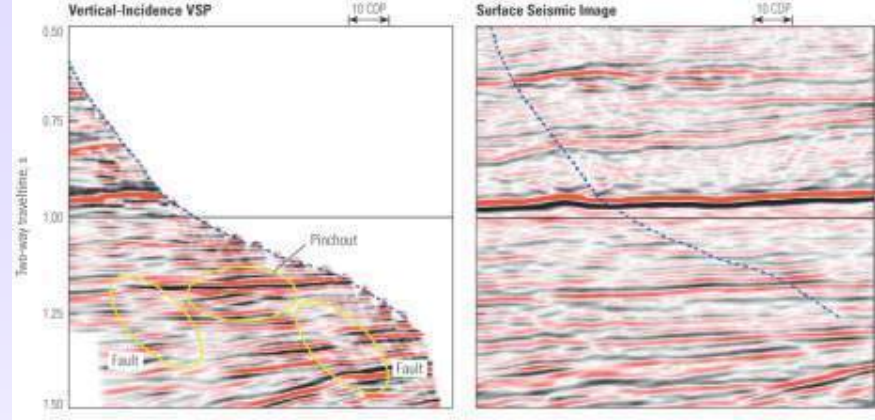
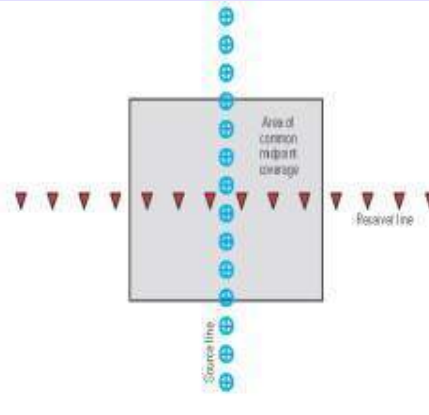
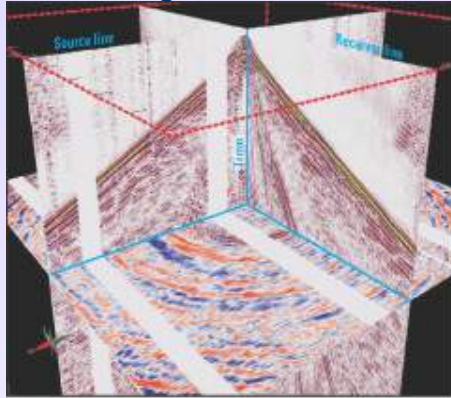
Geomechanics Simulator



Capacity – Measurements

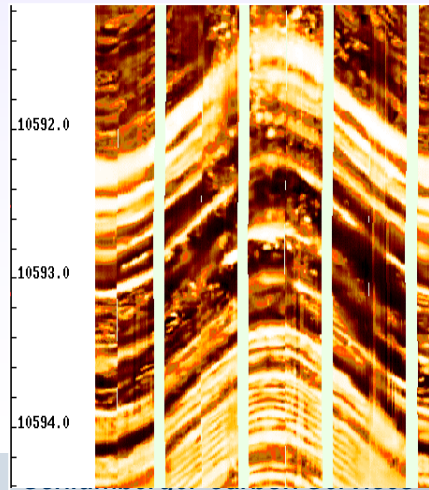
Structure

- High-Resolution Seismic, VSP's and Sonic

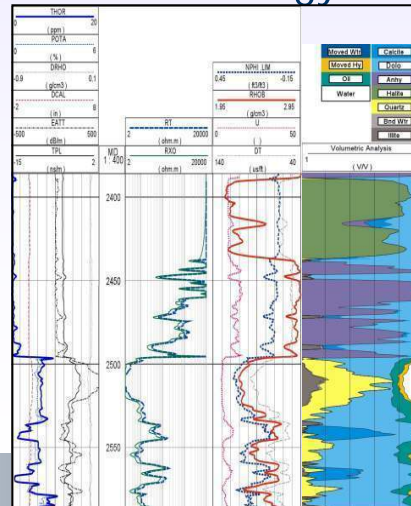


Properties

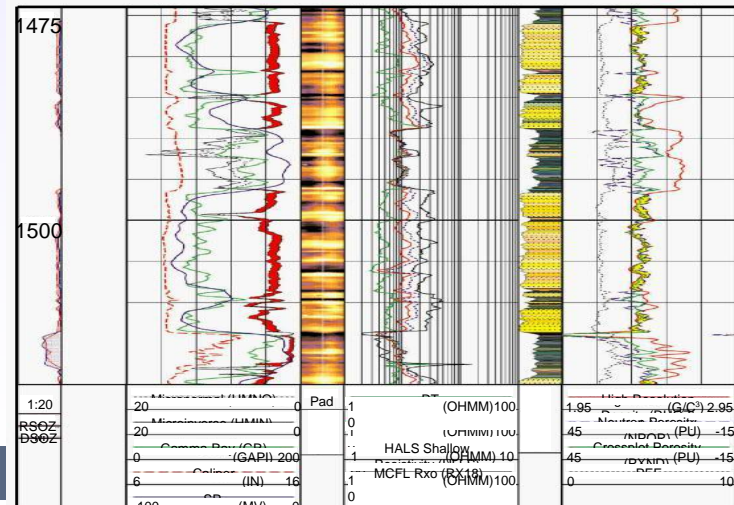
- Borehole imagers



- Mineralogy

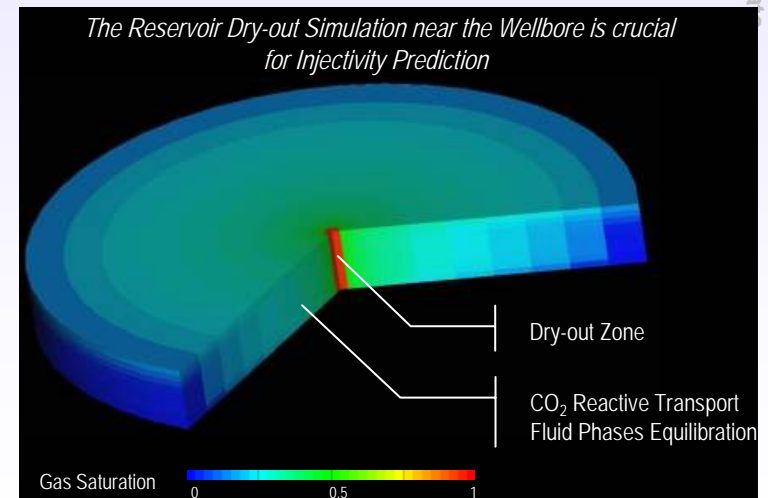
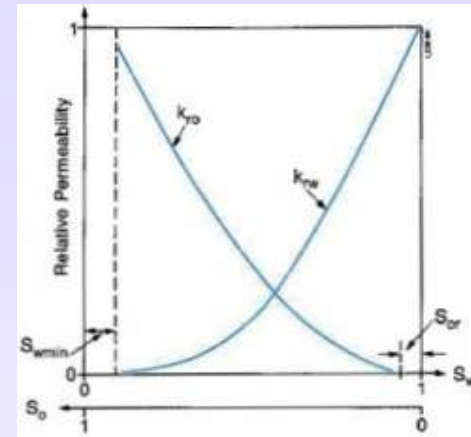


- Formation Evaluation



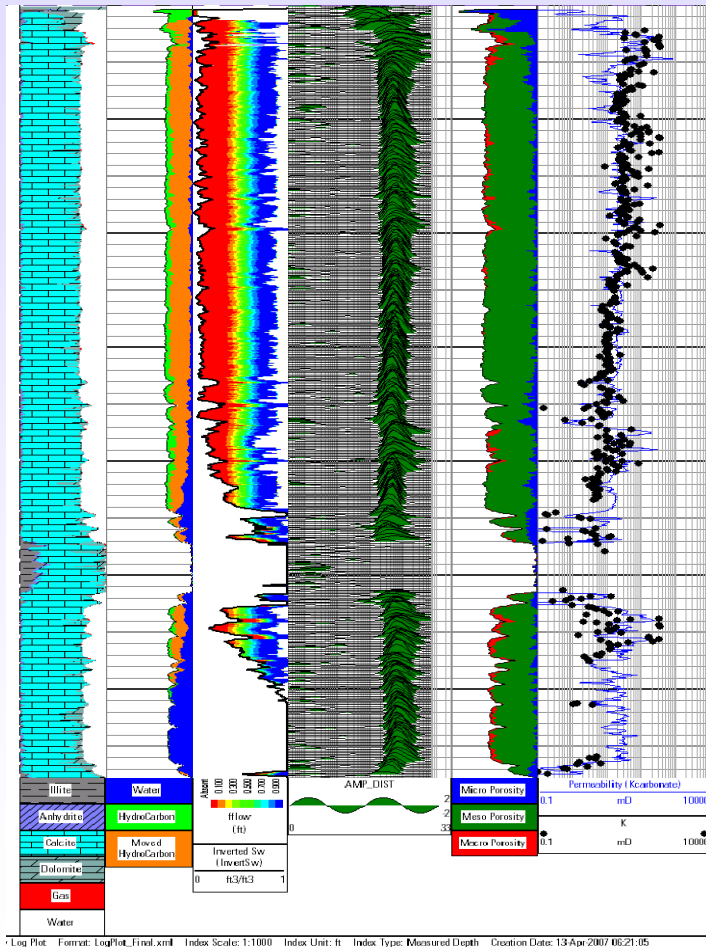
Injectivity

- Permeability
 - Core
 - Logs
 - Formation testers
 - Well tests
- Injection induced near-wellbore effects
 - Dry-out
 - Salt precipitation – Carbonate dissolution
- Optimization
 - Injection well design, placement and number
 - Hydraulic fracturing

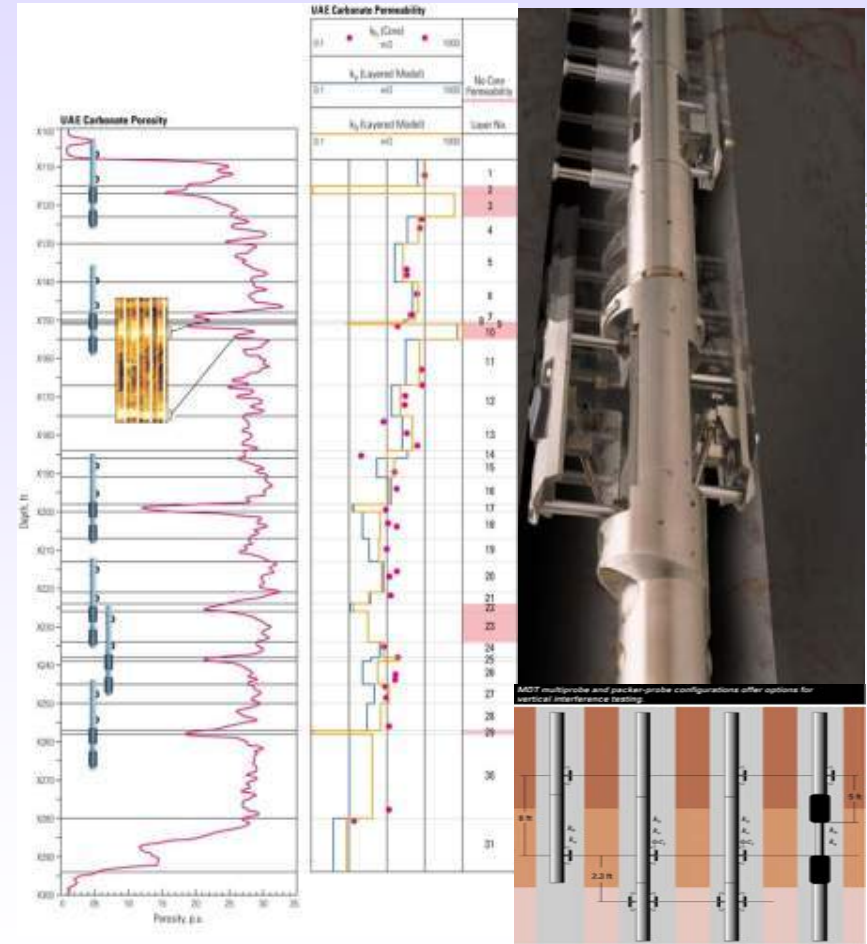


Injectivity - Measurements

- Permeability from Wireline Logging



- Permeability from Well Testing



Containment

- Caprock & Overburden

- Hydrostratigraphy
- Composition
- Mechanical properties
- Flow properties

- Faults

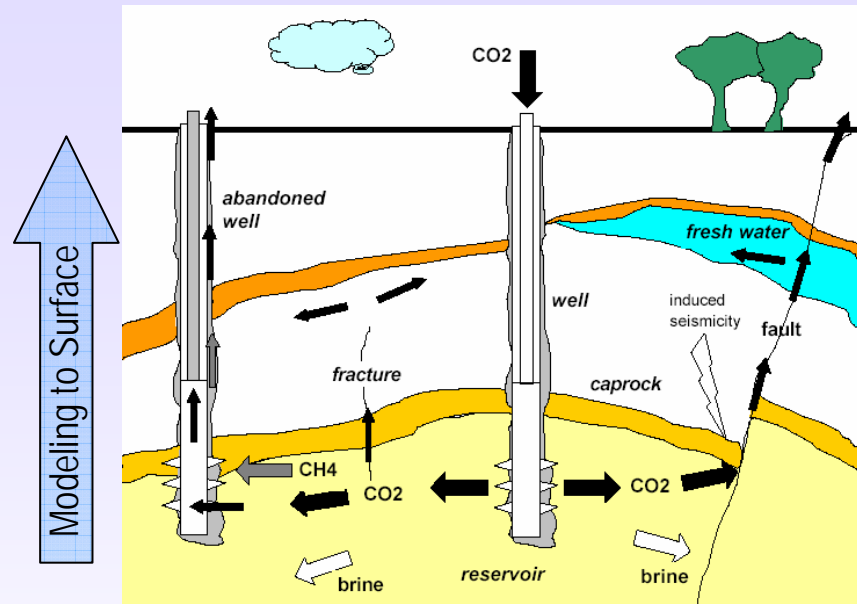
- Transmissibility
- Mechanical Properties

- Wells

- Completions state
- Isolation issues
- Degradation mechanisms



Importance of reservoir geomechanics and evaluation of wells



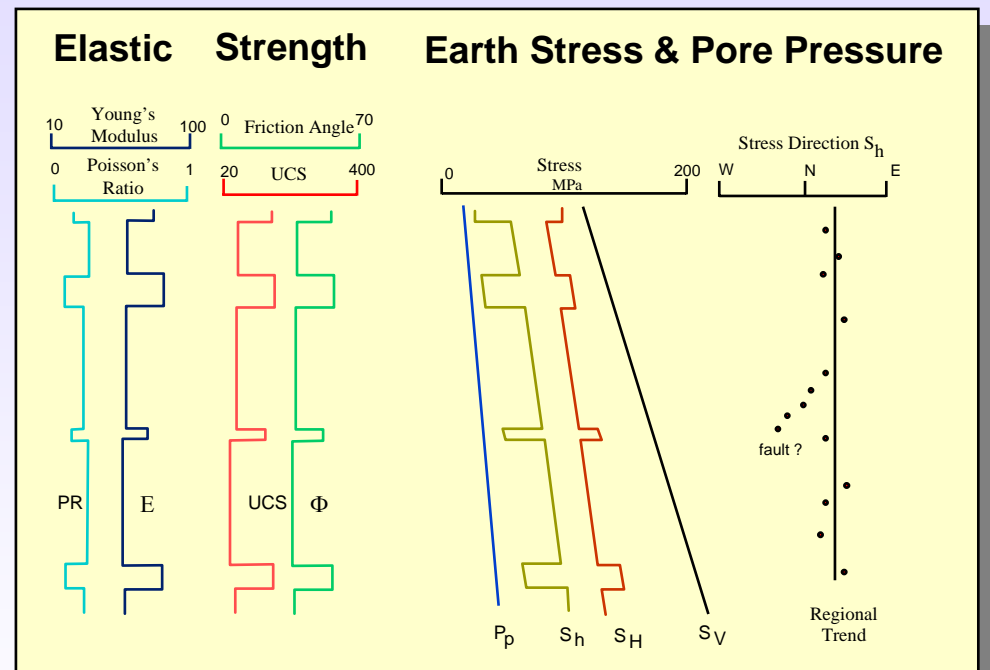
(from Damen et al, 2003)

(from Latrobe Valley study, CO2CRC, 2005)

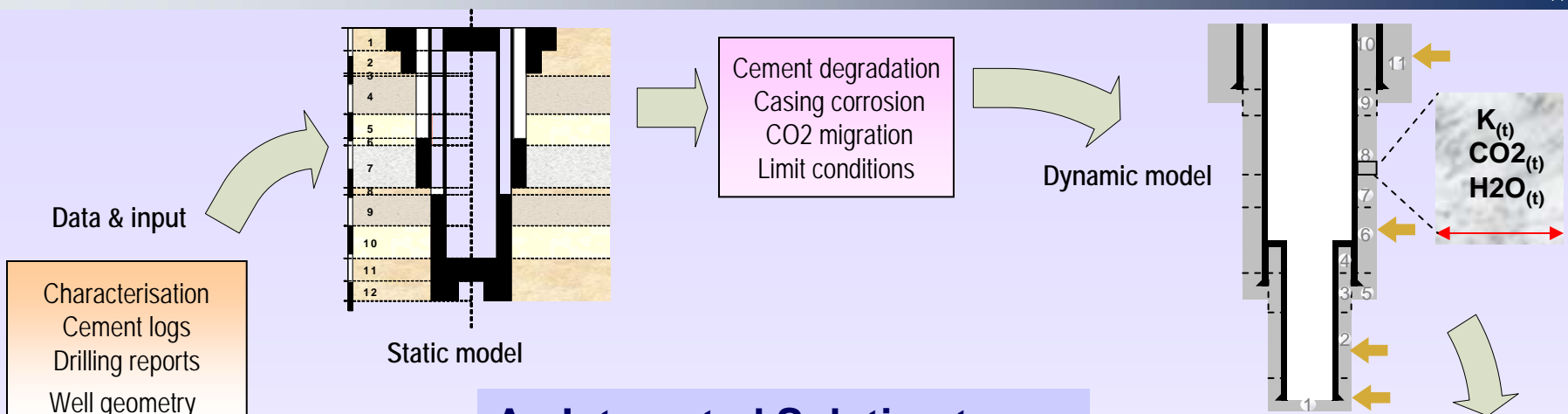
Containment – Measurements for Geomechanics



Along the wellbore trajectory:



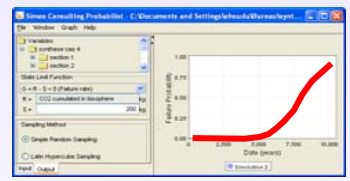
Containment – Integrity of Wells (1)



An Integrated Solution to:

- Leakage and Degradation Modeling
- Leakage scenarios
- Risk criticality estimation

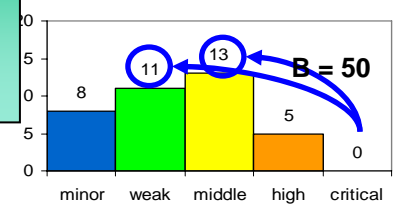
Leak amount & probability



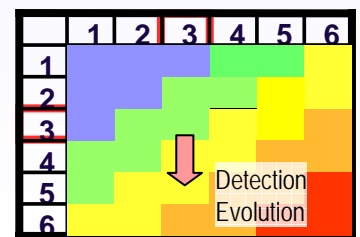
X

Conclusions

Can we re-use existing wells?
 More data needed?
 Probability of leakage
 Type of leakage to expect



Sensitivity analysis
 Risk mitigation options
 Cost / Benefits ranking



Stakes	F	A	B	C	SAFETY	...
Level	Financial	Reliability & availability	Asset	People	3rd-P	Envir.
1 - Minor						
2 - Marginal	<0.2 ME					
3 - Serious	<1 ME					
4 - Major	<5 ME					
5 - Critical	<20 ME					
6 - Catastr.	>20 ME					

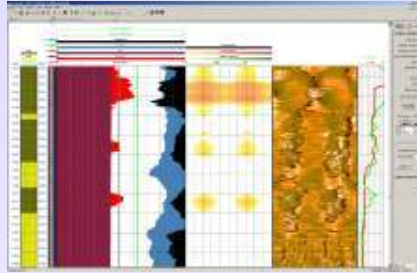
Consequence grid & transfert fonction



Containment – Integrity of Wells (2)

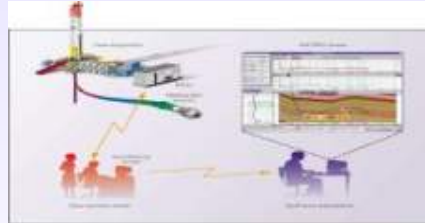
Prevention

- Good drilling practices



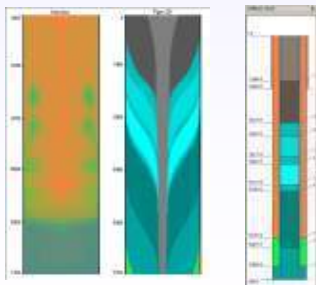
Stonefish

- Optimal Well Placement



GeoSteering

- Cement job planning



WellCLEAN

Materials

- Metallurgy
- CO2-Resistant cement



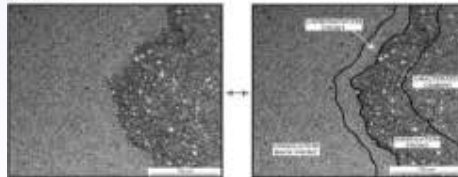
2 days

1 week

6 weeks

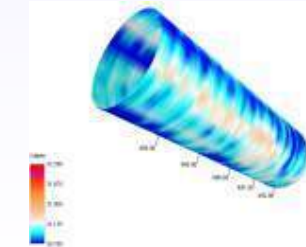
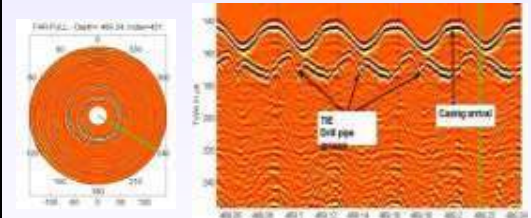
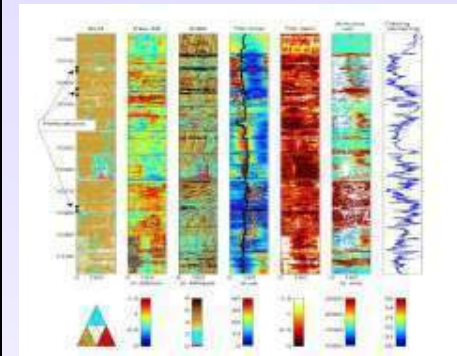


N-200-44



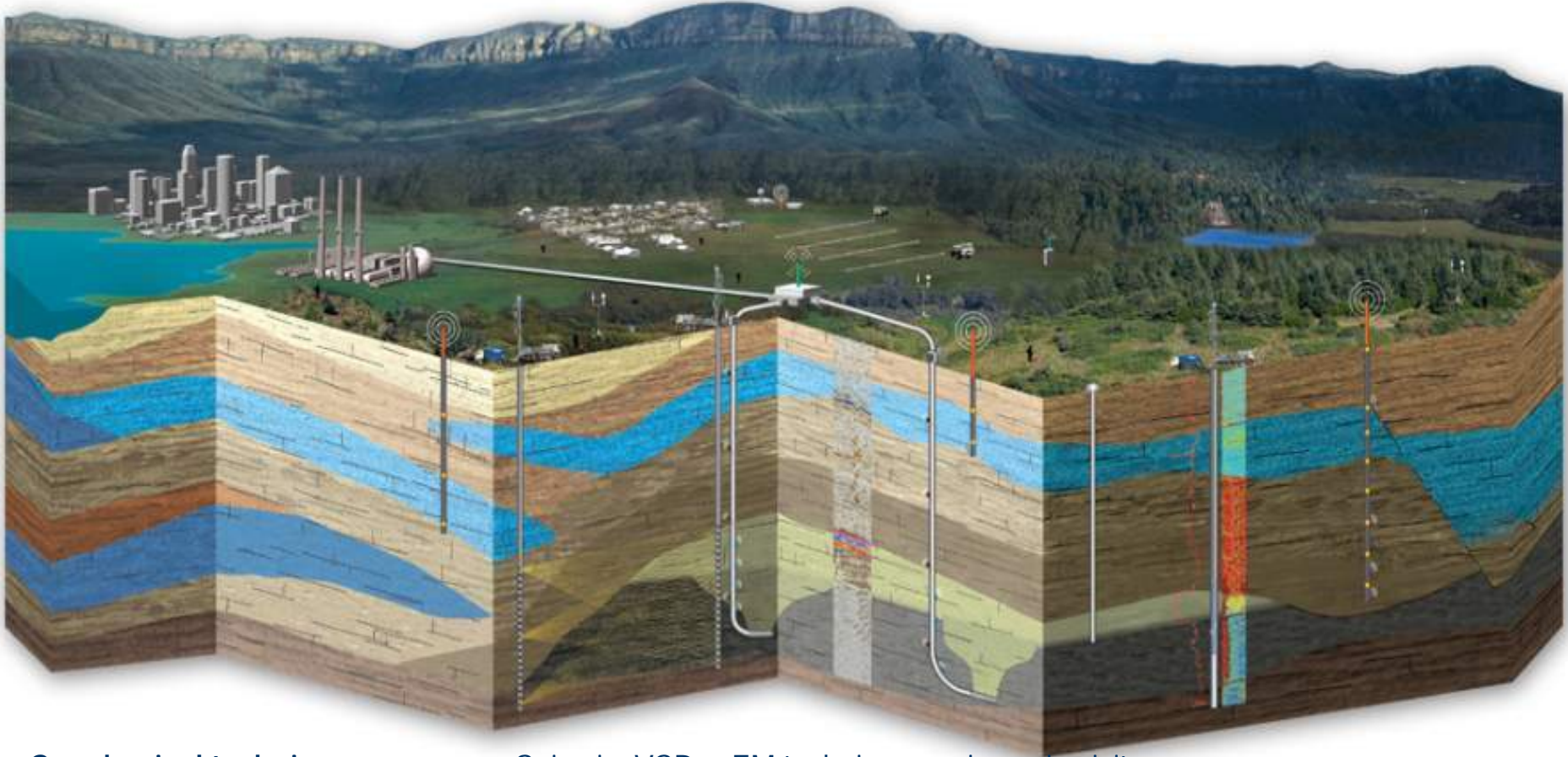
Evaluation

- Sonic Scanner
- Isolation Scanner



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Monitoring and Verification during CO2 Injection



Geophysical techniques:

Logging:

Sampling:

Permanent sensors:

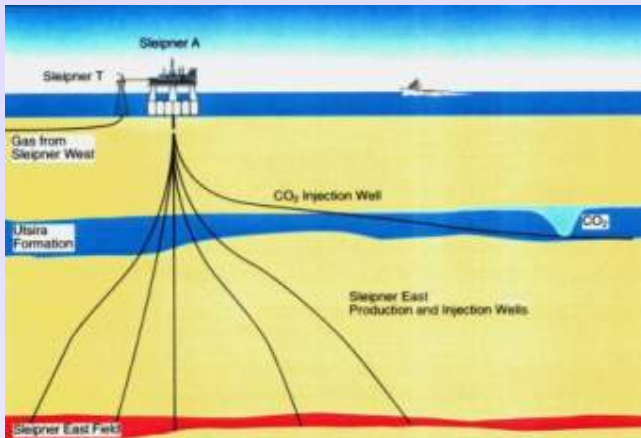
Seismic, VSP's, EM techniques, microseismicity

Saturation (Resistivity, Sigma), Well integrity (Casing corrosion, cement bond)

Pressure, Fluid properties, CO2 concentration

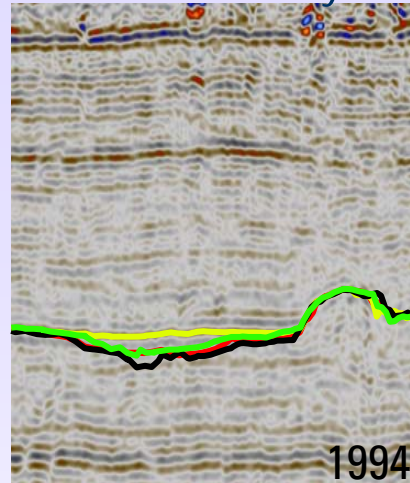
Pressure, Temperature

CO₂ Displacement from Seismic - Sleipner



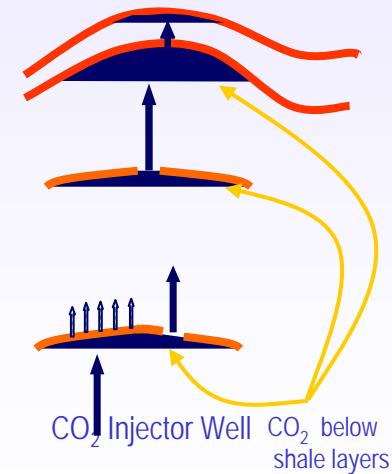
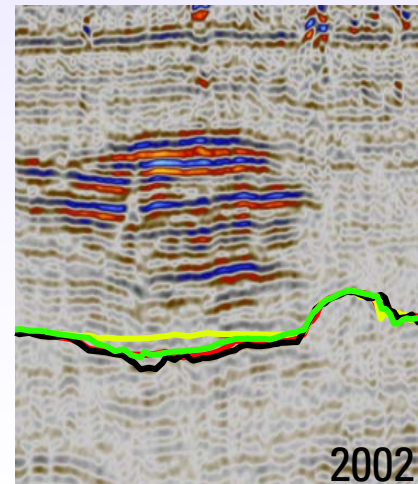
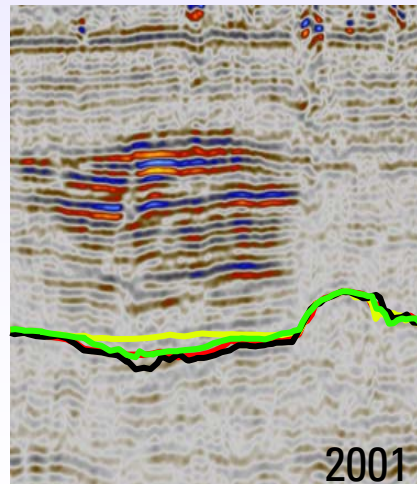
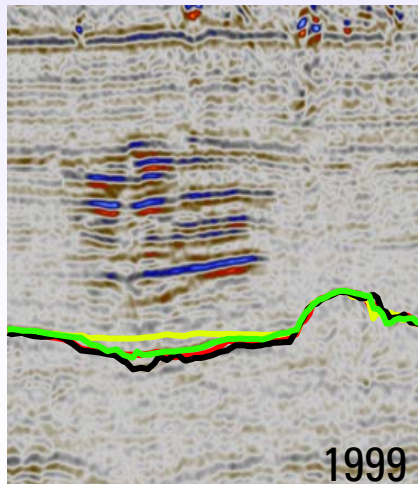
CO₂ Injection Start: Sept 1996
4D Seismic Survey

Baseline Survey



- Interpretation of flow patterns (CO₂ displacement and trapping)
- Verification of cap rock integrity

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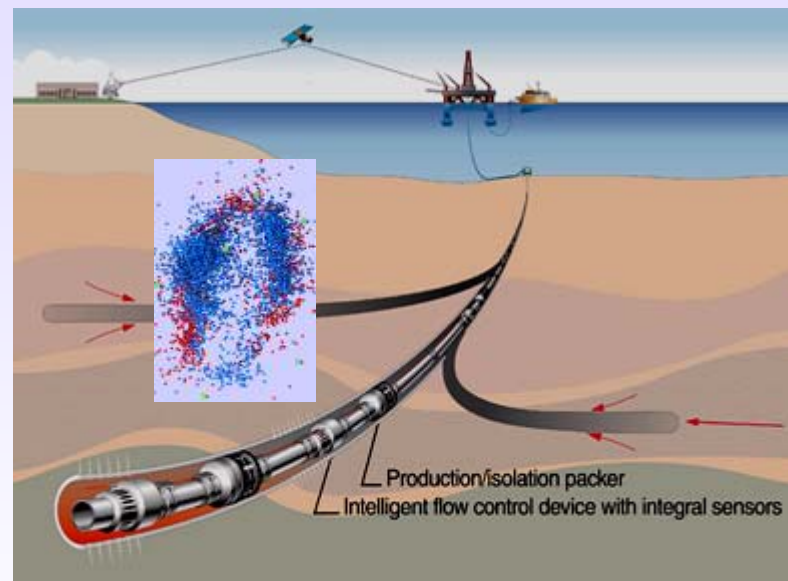
Courtesy of Statoil
Schlumberger Carbon Services

Cap Rock & Fault Integrity

19

Microseismicity events are micro cracks occurring in the formation due to pressure increase

Listening to these cracks is a powerful monitoring technique



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- Detection, Location in 3D and Classification of Microseismicity Events
- Control of Pumping Rate to Avoid Fracturing the Cap Rock
- Detection of Fault Reactivation

Schlumberger involved CO2 Storage Projects



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Conclusions

- Key Technologies focus on:
 - Capacity-Injectivity-Containment
 - Long term storage integrity
- Key Technologies are
 - Measurement (surface and downhole in wells)
 - Modeling (static-dynamic-predictive)
 - Well Construction (drilling, cementing, completions, remediation)
- The Technology is ready !
 - But continuous investment in Engineering and Learning While Doing

Thank You !