Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

Well Integrity

A Review Of Wellbore Issues Surrounding Geological Storage Of CO2

Charles A. Christopher

May 8-11, 2006 • Hilton Alexandria Mark Center • Alexandria, Virginia

Well Bore Integrity Workshop
WBI2

Princeton University, Princeton, NJ

Organised by IEA Greenhouse Gas R&D Programme and BP
with the support of EPRI

4-5 April 2005

It is Well Known that Cement Reacts with CO_2

"Effects of CO_2 Attack on Cement in High-temperature Applications," paper SPE/IADC 18618 presented at the 1989 SPE/IADC Drilling Conference.

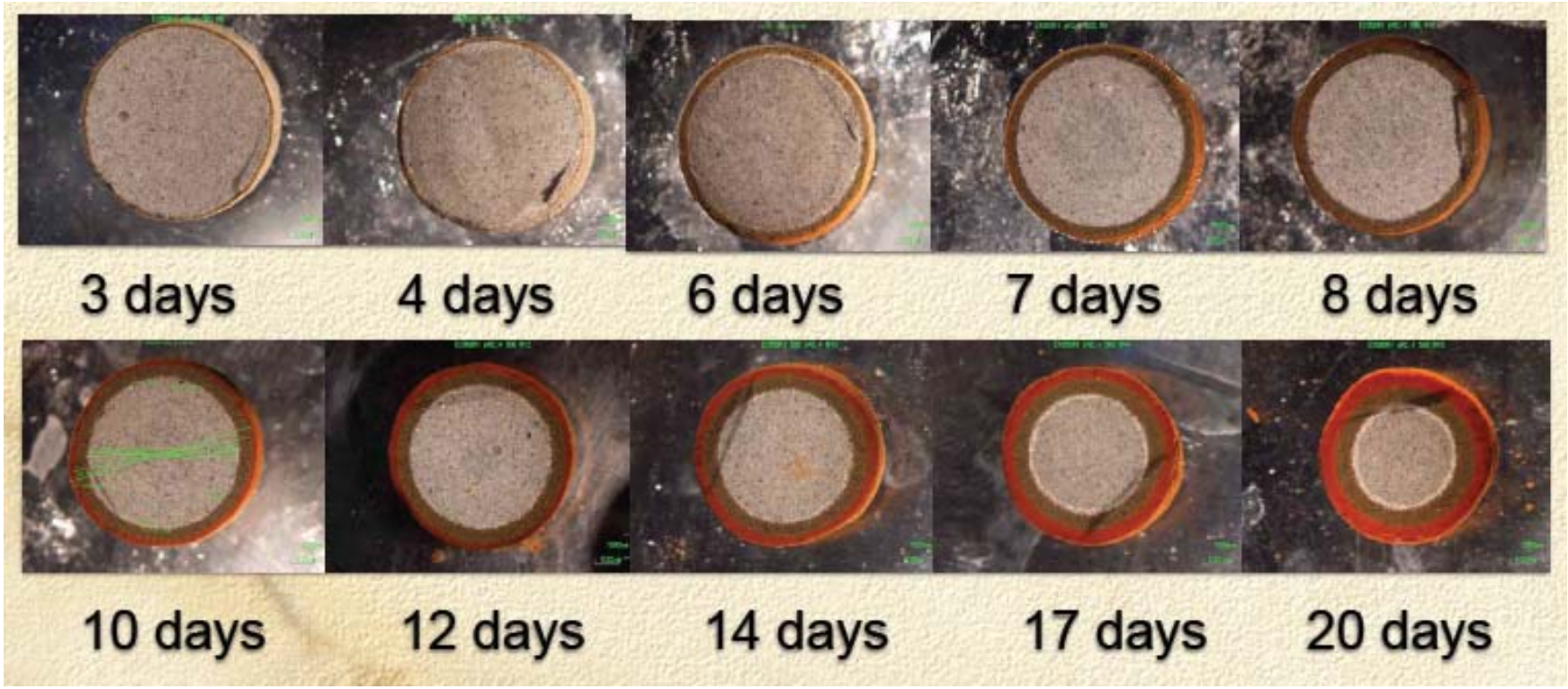
"Carbon Dioxide Corrosion in Oilwell Cements," paper SPE 15176 presented at the 1986 Annual Meeting.

"Natural CO_2—Rich Steam Heated Waters in the Broadlands-Ohaaki Geothermal System, New Zealand: Their Corrosive Nature," Geothermal Resources Council, Transactions, Vol 10.

"The Long Term Sealing Capacity of Cemented Petroleum wells in a CO_2 Storage Project," SINTEF Petroleum Research Mid-term report, June 2002.

Brothers

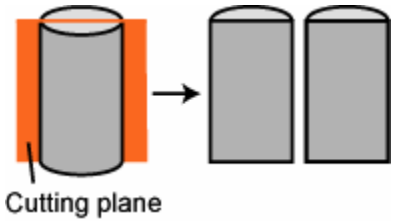
The Reaction in the Laboratory is Rapid

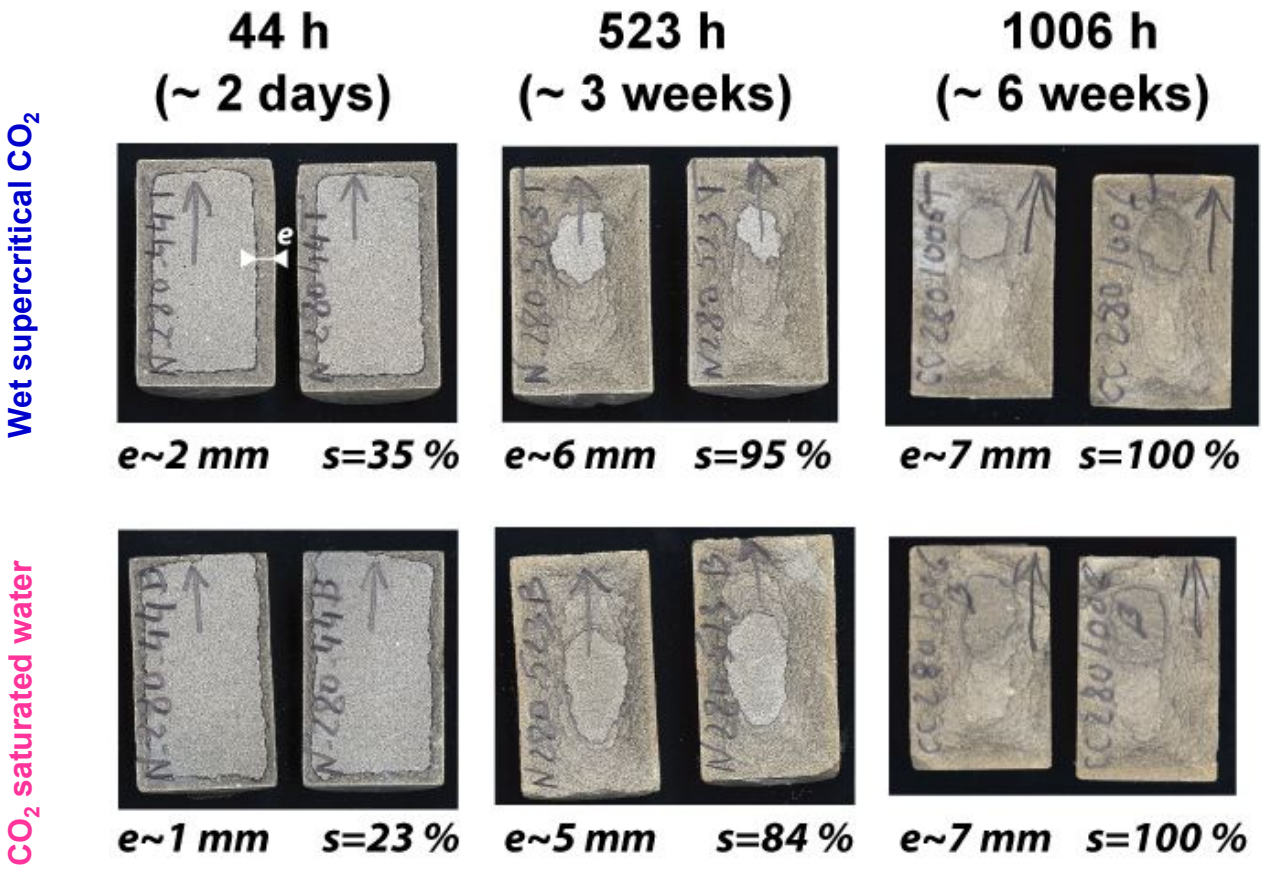


Sandstone, pH = 3, T = 50°C

Duguid, et al, Princeton

Shown in More than One Laboratory





e : thickness of the alteration front

s : ratio between the alteration front surface and the whole core surface

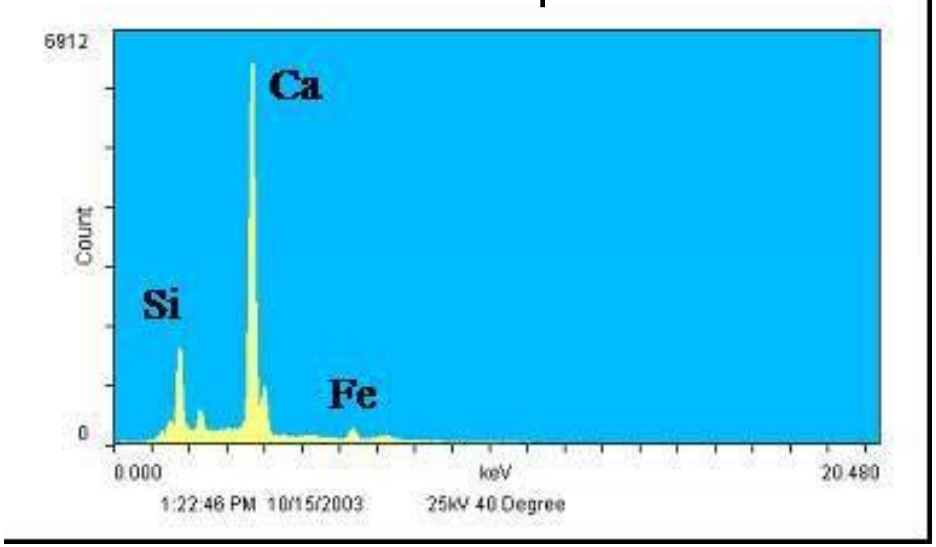
Rimmelé, et al

Exposure to H_2CO_3 Decalcifies Cement

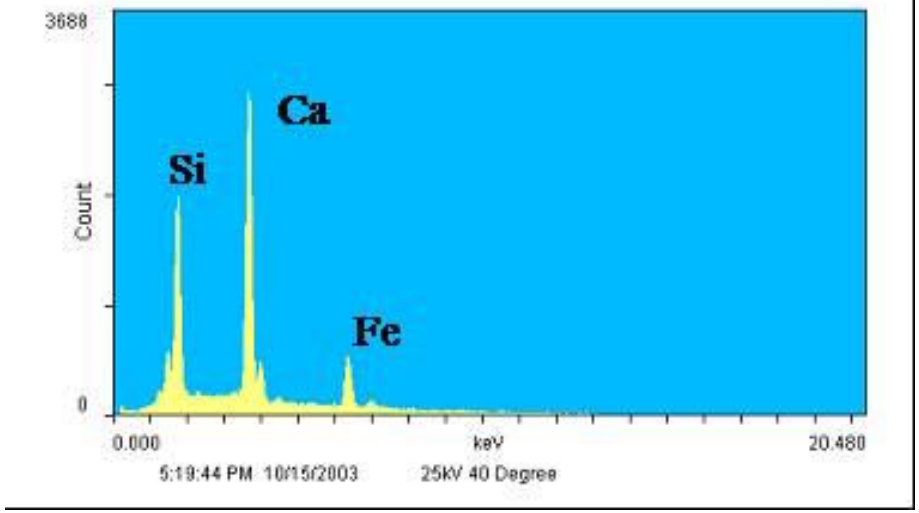
Orange color caused
By CO2 reaction

Duguid

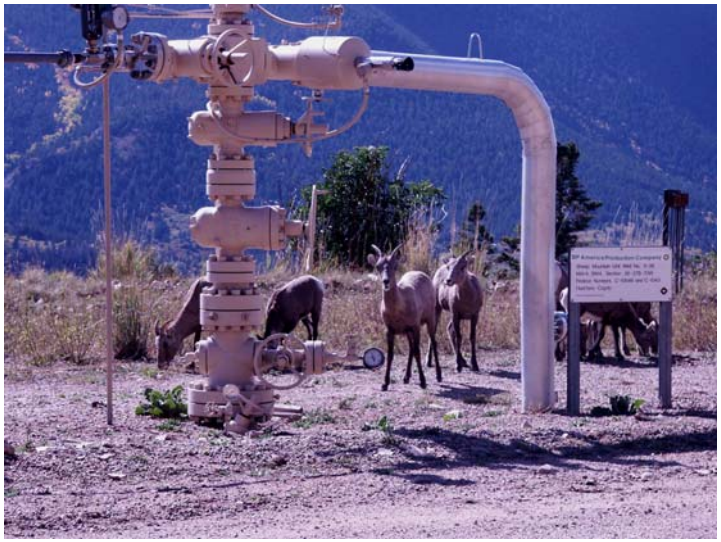
Before Exposure



After Exposure



But, At The Sheep Mountain CO_2 Reservoir Cement Was Not A Problem



Cement Has Not Been A Particular Problem In West Texas CO_2 Floods

1561185 Ft/In

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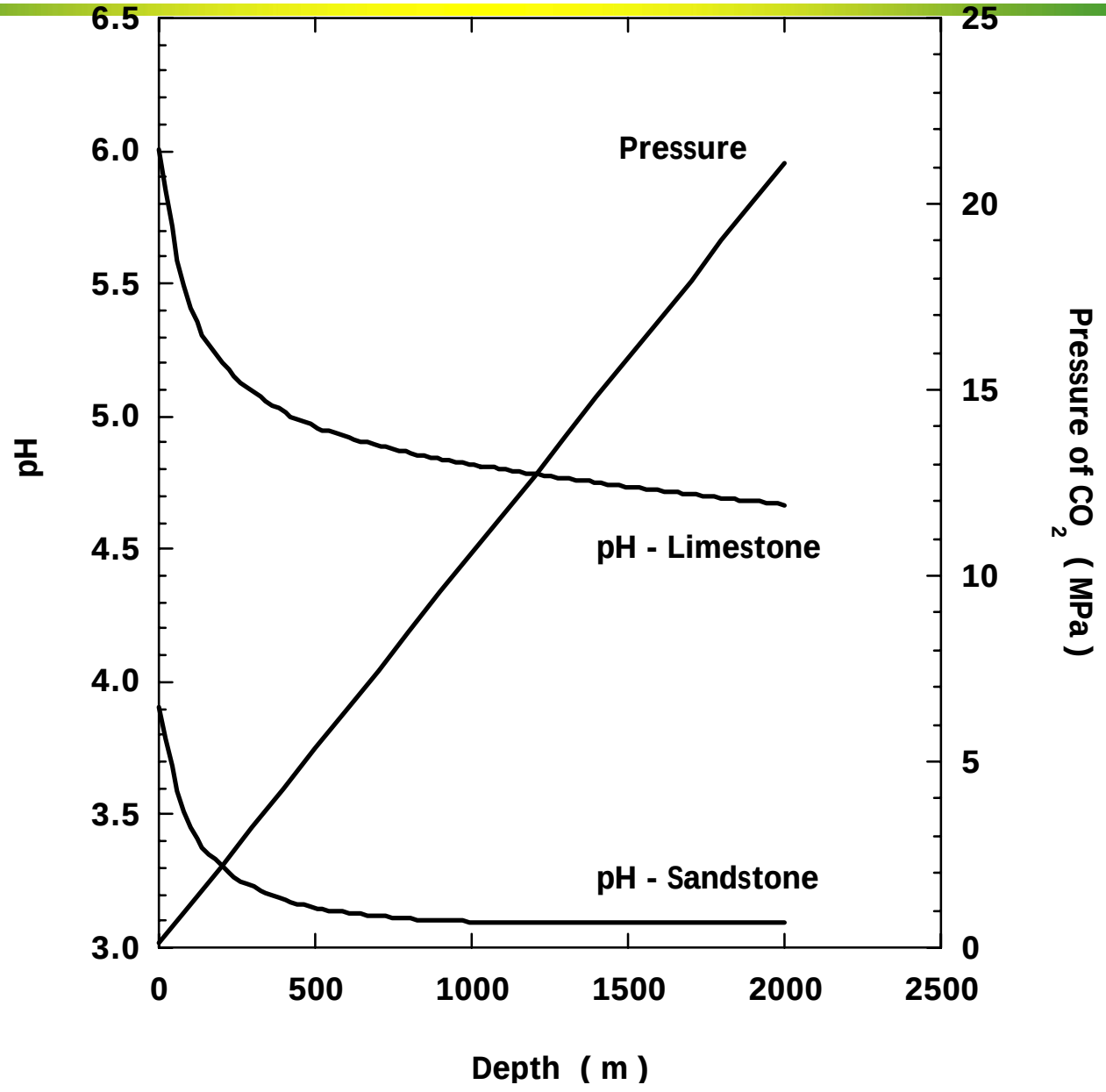
Cement is Not Just Cement

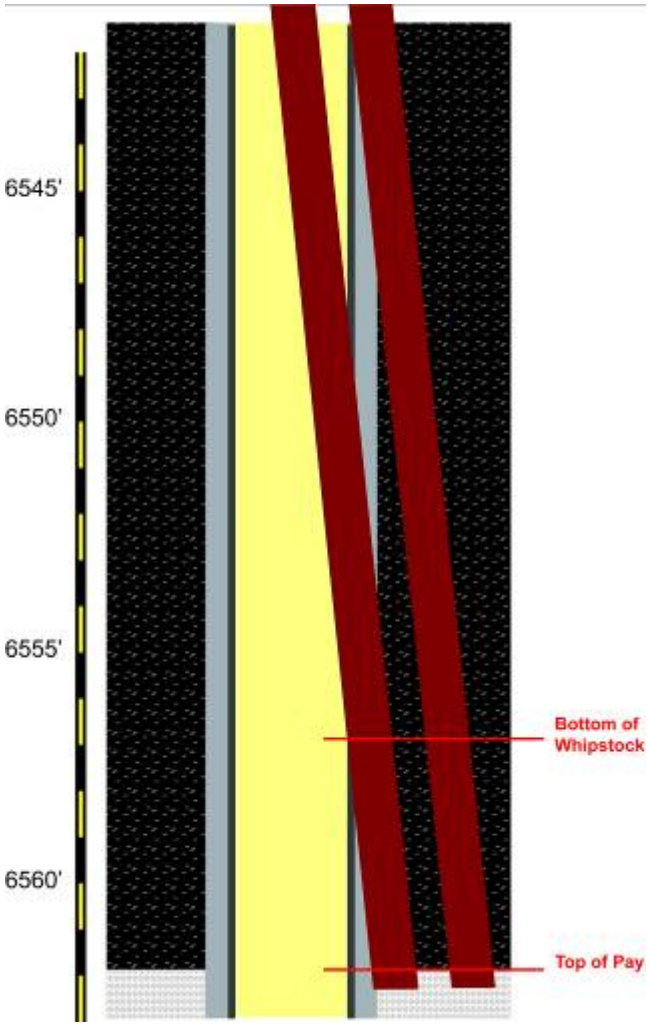
- Contains additives
- Makeup water varies
- Conditions of curing vary widely within a single well:
  - Temperature
  - Pressure

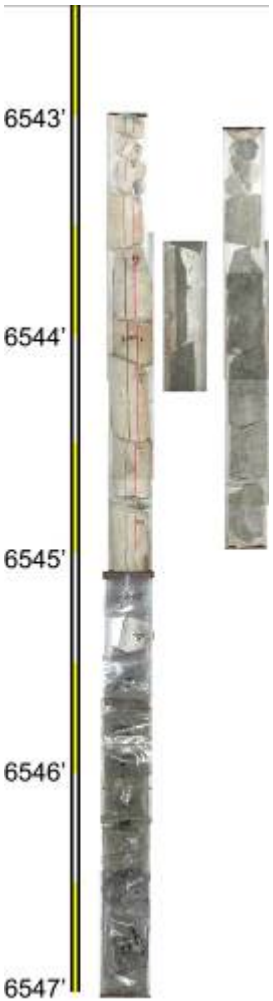
- Effects on reactivity to CO_2 not known

Reservoir Minerology Affects Equilibrium pH



Reaction Has Also Been Seen In The Field





Sacroc Core: 49-6 Producer/Injector

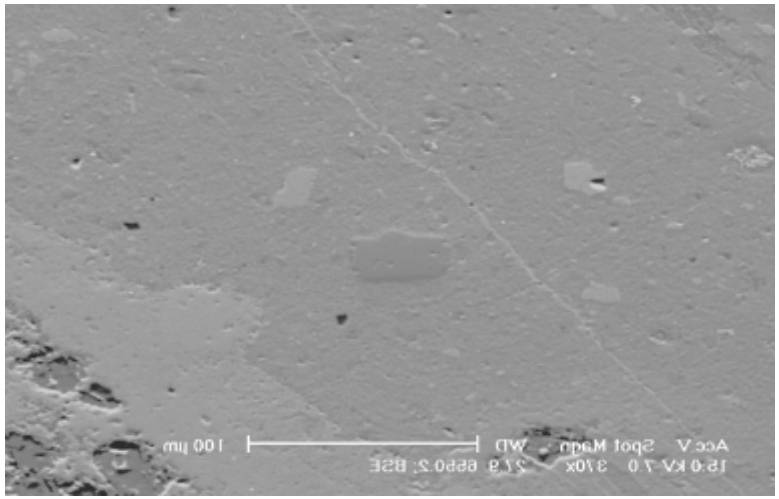
Drilled 1950
First CO_2 exposure 1975
Years of CO_2 operation: 17
Amount of CO_2 produced/injected:
2.2 Bscf

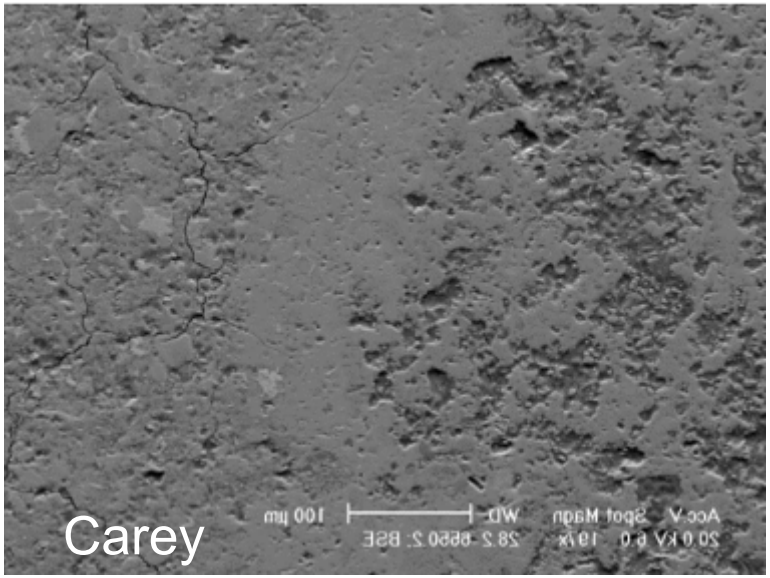
Carey

Gray Cement – Orange Zone – Shale Fragment Zone

Phase	Gray Zone
Amorphous	Major
Portlandite	15-58%
Calcite	0-28%
Katoite	22-26%
Brucite	3-9%
Ettringite	3-4%
Friedel's Salt	2-4%
Halite	9-32%

Phase	Orange Zone
Calcite	44%
Aragonite	8%
Vaterite	33%
Halite	13%



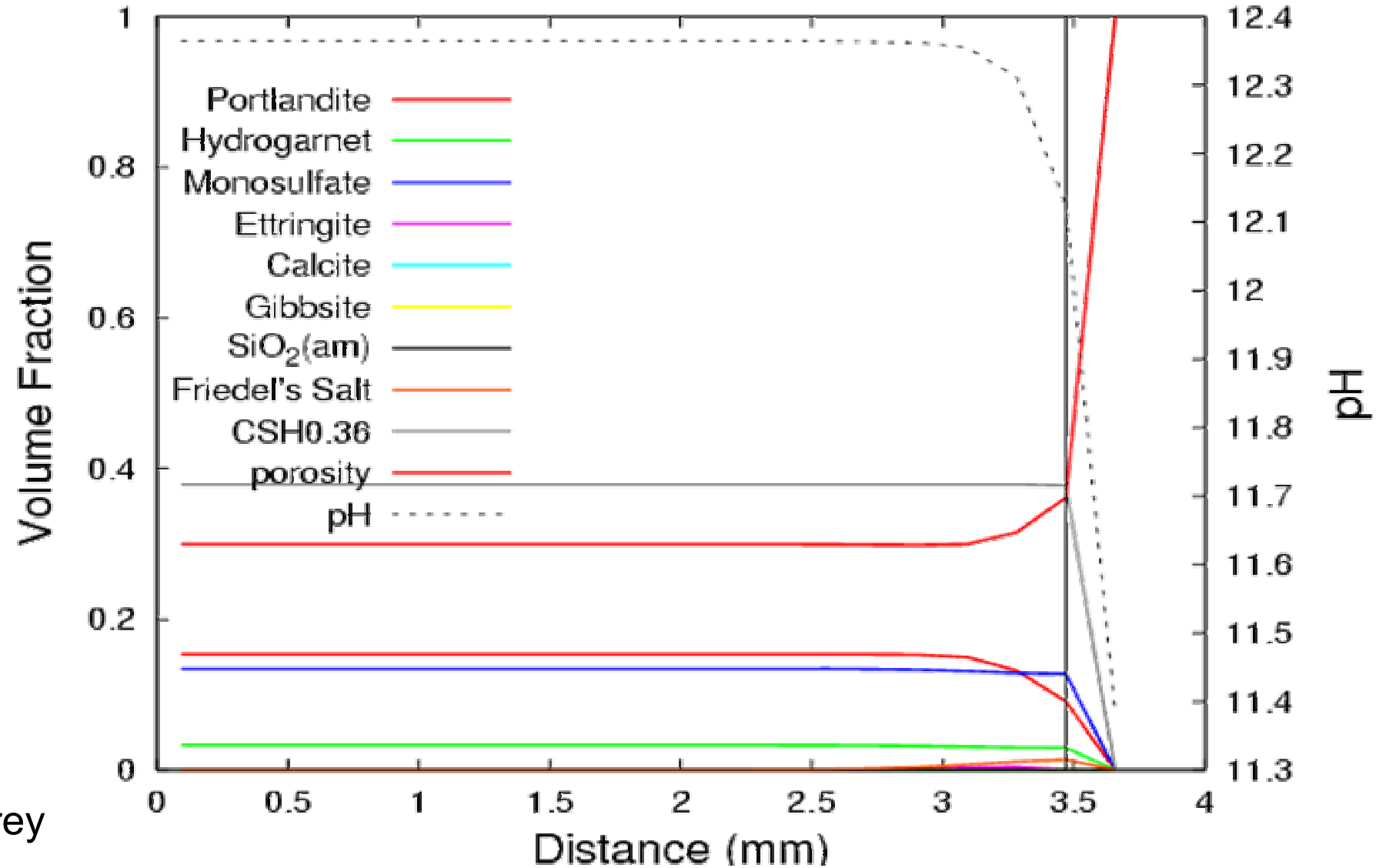


Preliminary Observations

- Presence of structurally competent cement (and orange zone) precludes inundation of well-bore contact zone with circulating, CO_2-rich fluids
- Presence of calcium carbonate indicates some CO_2 mobility
- Presence of portlandite in cement indicates incomplete carbonation
- CO_2 pathways appear along the casing-cement interface and the cement-shale interface
- Amount of CO_2 moving along these interfaces unknown
- Point of origin of CO_2 moving along these interfaces unknown

Carey

Reactions Can be Simulated but What Rate Constants?



Carey

Are Exotic Cements Needed?

- CO_2 deteriorates Portland cement over time while leaving calcium phosphate cement virtually unaffected.

Brothers

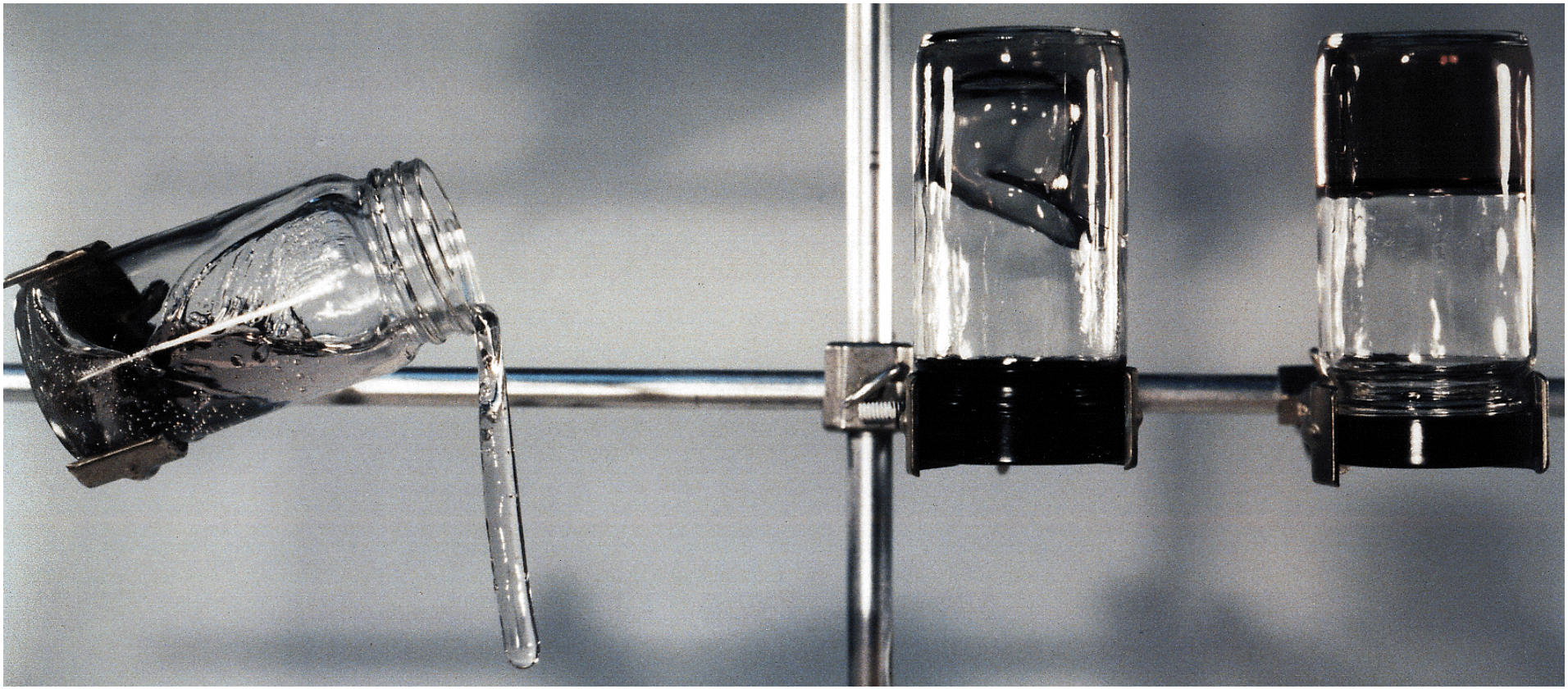
The Paradox

- CO_2 is known to react with Portland Cement
- CO_2 reacts strongly in the laboratory
- Field installations have not shown catastrophic degradation of cement or tubulars
- Why?
- When CO_2 reacts with portlandite, the carbonic acid is neutralized
- Unless fresh carbonic acid is brought to the reaction front, the reaction stops
- So, under this theory, if a leak starts, it can develop rapidly

What to do?

- Invoke permanent storage mechanisms
- Understand what might happen to a well in the presence of CO2
- Place the well out of harms way
  - J well
  - Downdip
- Consider non-reactive cements
- Monitor for leakage
- Repair leakage if needed

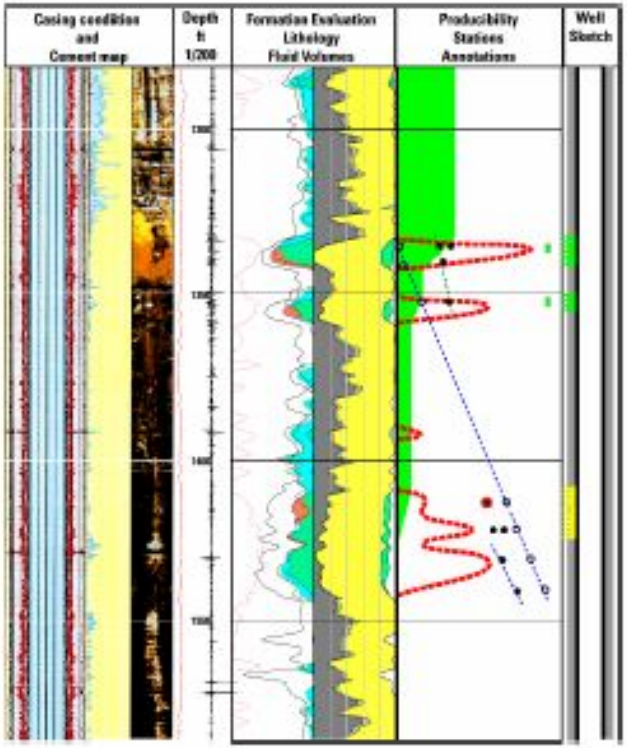
Gels and Resins Are Used for Repair



Sabins

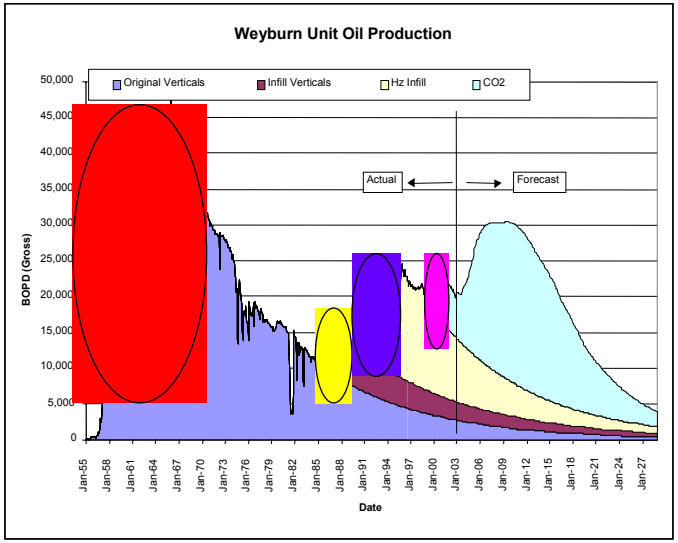
Monitoring Techniques are Available but Sensitivity not Known

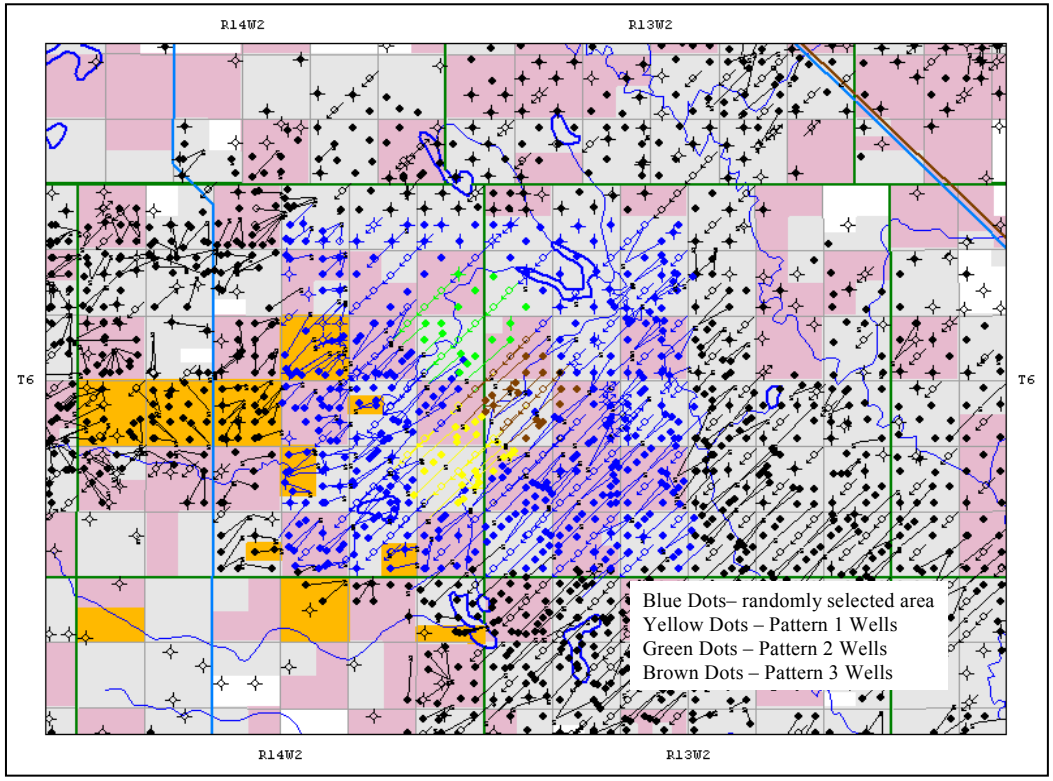
- Testing & Sampling through Casing
  - Cased Hole Dynamic Tester
- Novel Sonic Tool
  - Modular Sonic Imager (MSIP)
  - Multiple depths of Investigation
  - Azimuthal Mapping



V. Barlet-Gouedard

Need Statistics on Old Wells





Chalaturnyk

A Program to Understand Wellbore Integrity

- Evaluating the current well stock
- Investigating the reactivity of wellbore materials with CO2
- Studying the types, frequency, modes of detection, and responses to well problems
- Investigating in detail how a few wells have been affected by CO2
- Developing techniques to monitor low level leaks
- Developing remediation techniques fit for purpose

Concluding Remarks

- CO_2 reaction with Portland cement is well known
- Reaction can increase both the porosity and permeability of the cement
- Effect depends on cement composition, curing environment, water chemistry
- Reactivity with distant well depends on mineralogy of reservoir through which fluids flow
- Special cements are available which do not react with CO_2 in the same way as Portland cement
- A standard methodology for testing cements against CO2 is needed