CO_2 Capture Project

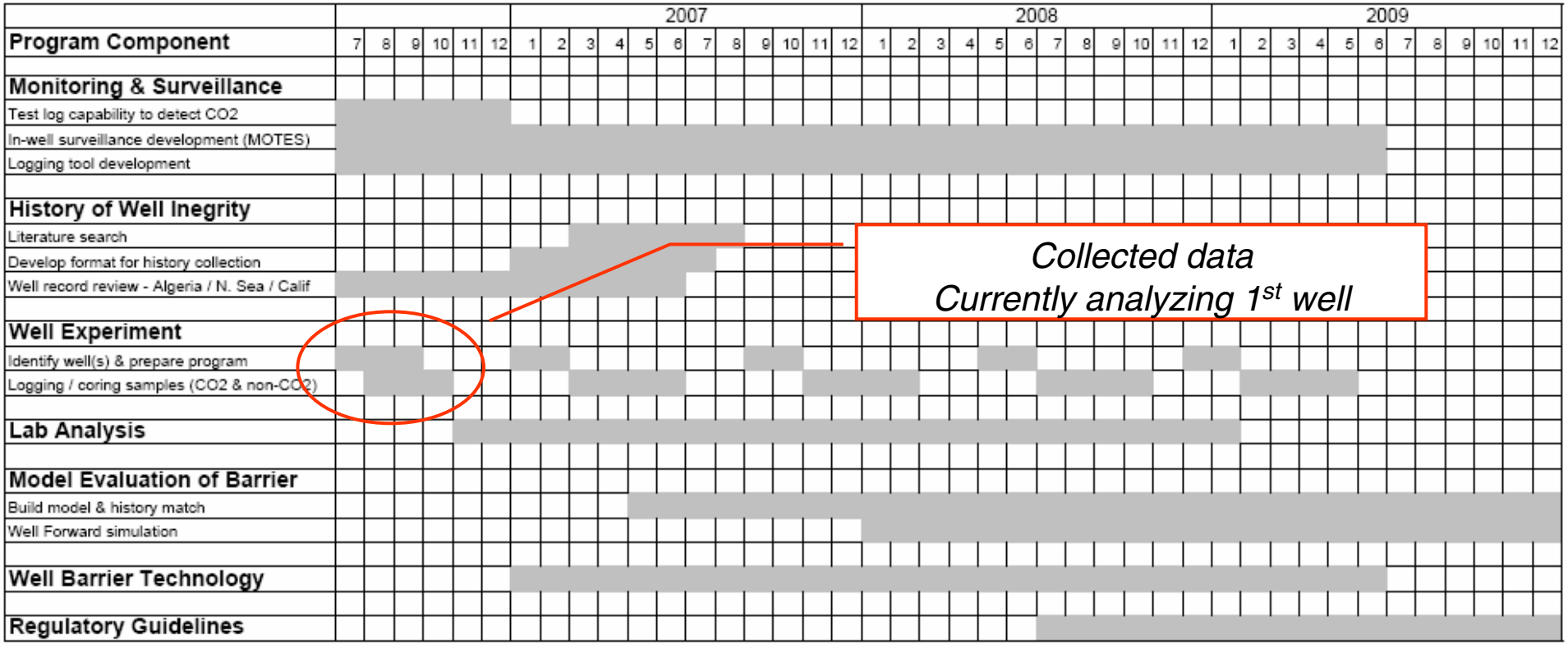
Wellbore Integrity Study

NETL Conference 5/7-10/2007

Charles Christopher Walter Crow

Comprehensive CO_2 Well Integrity Program

Objective: Establish best practices for well construction and interventions to maintain well integrity for long term CO_2 underground storage.



This is the beginning of a lengthy evaluation

CO_2 Well Integrity Survey

Objective

- Evaluate the effect of CO2 on the well barrier system and determine mitigation options

Methodology

- Use existing wells to sample and evaluate barrier conditions
- Analyze the samples
- Create simulation to project the future alteration

Status

- First field survey data/samples under evaluation
- Modeling has been progressing independent of well data. Model program details will follow sample analysis results

CO_2 Well Integrity Survey

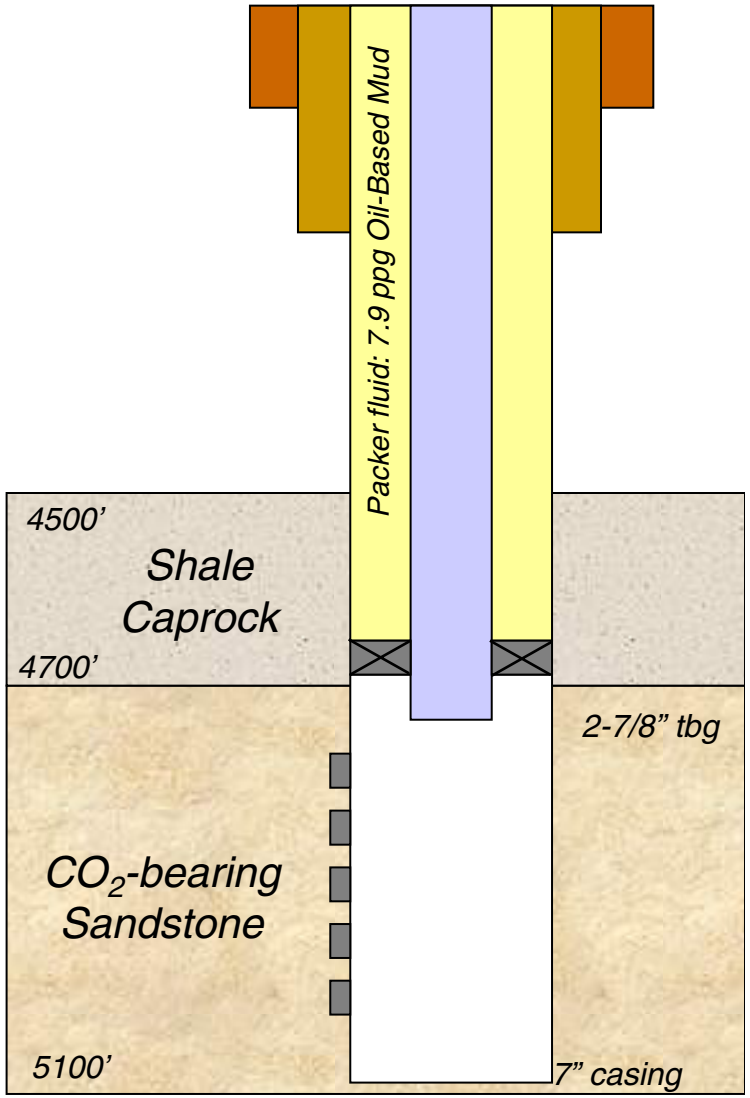
Obligation

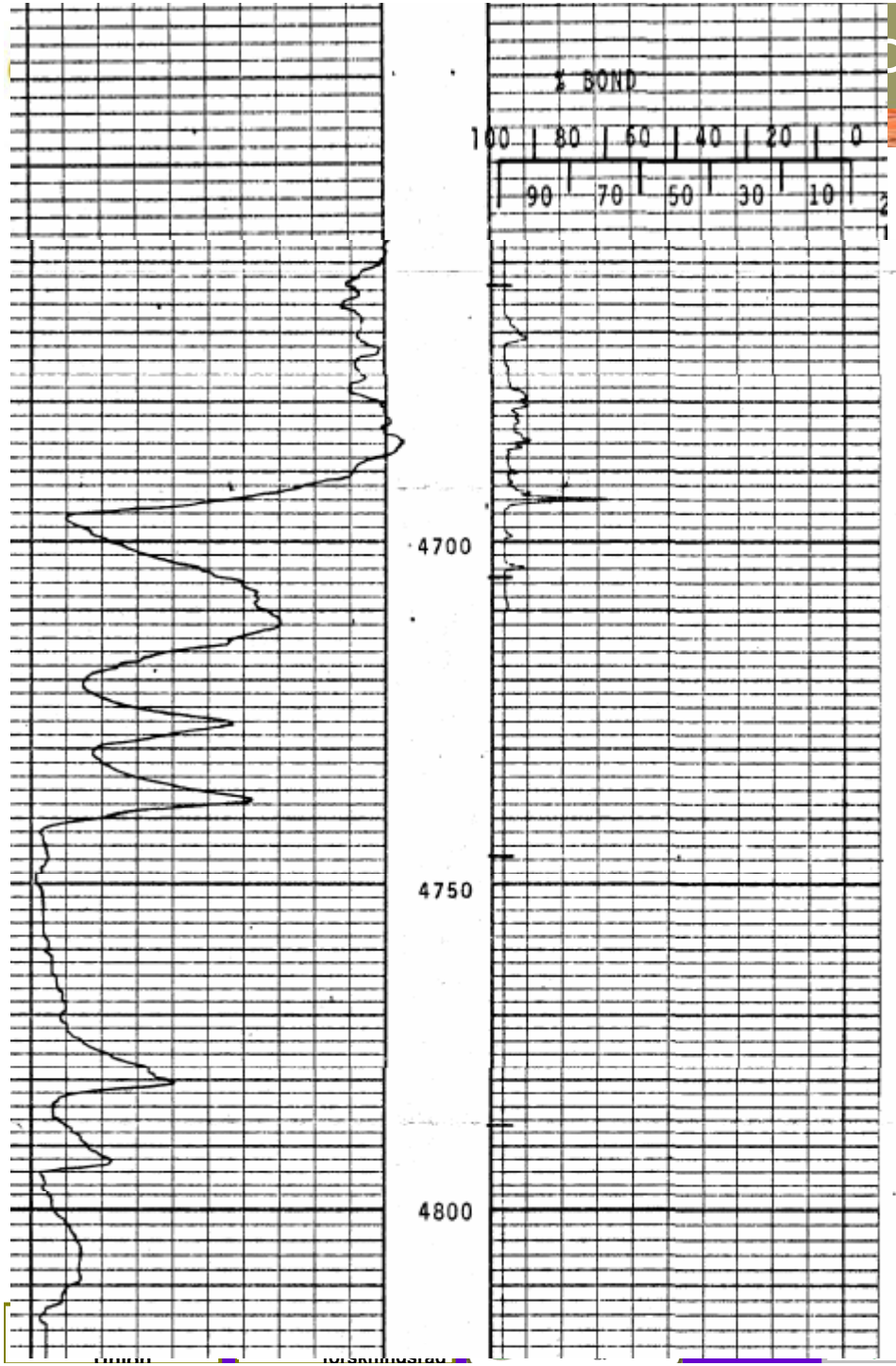
- Results will be carefully evaluated
- Nothing will be hidden
- No conclusions will be released until they have been thoroughly evaluated

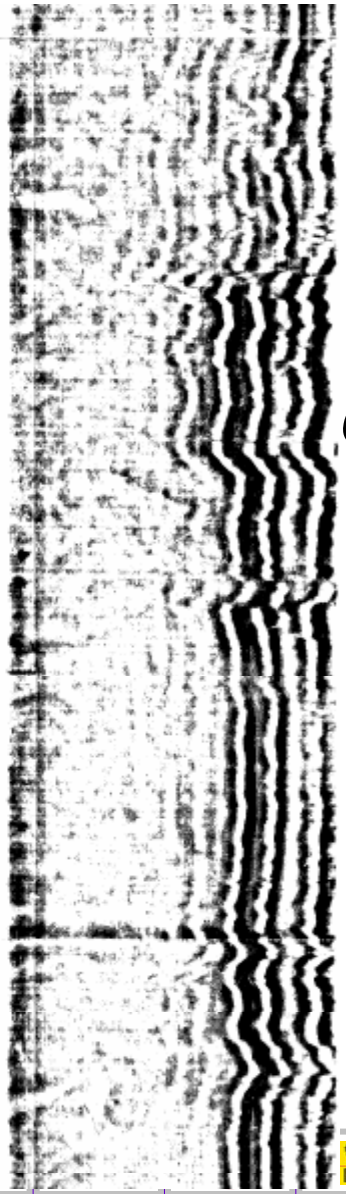
Original Well Description

- Drilled 1976 (30° deviation – 3000')
- Sandstone zone with 96% pure CO2
- Water saturation: 20 – 30%
- Cemented with 50% Class H cement / 50% pozzlan (fly ash)
- 7", 23 ppf casing, K55 grade with long thread coupling (LTC) connections
  - Carbon steel, non-premium connections
- 2-7/8" tubing, K55 grade '76-'84

Cement contacted CO2 during original completion







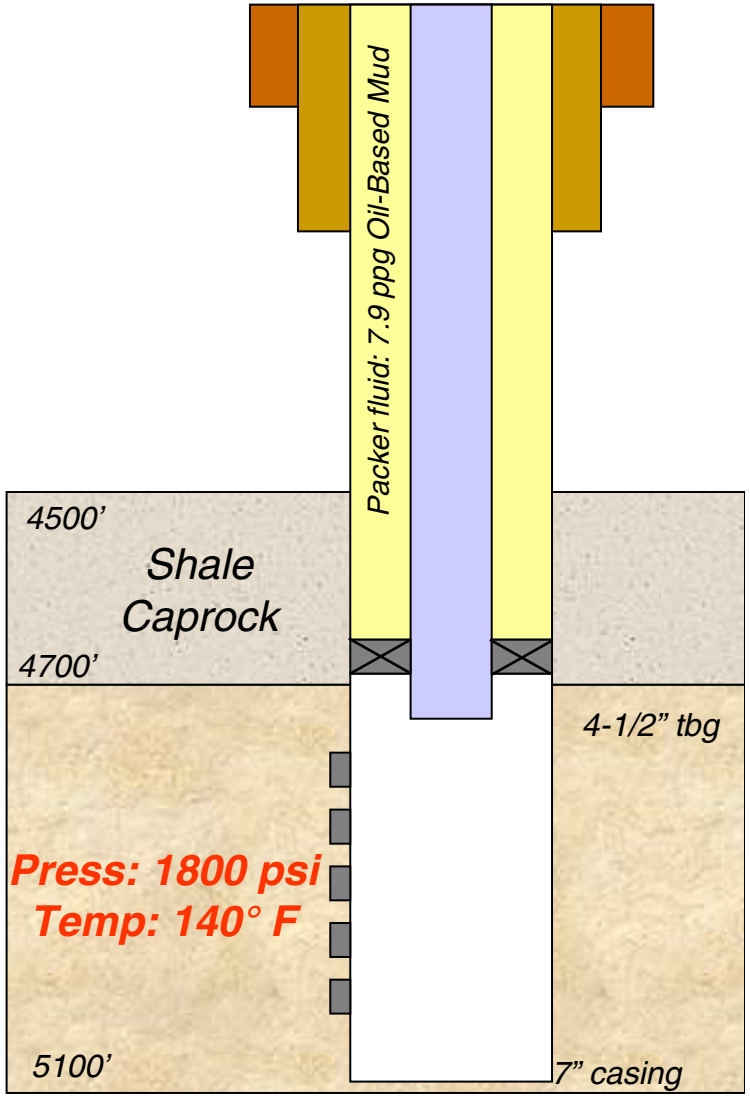
Caprock

Generally good bond indicated by CBL

Gamma
Bond Index
Variable Density Log (VDL)

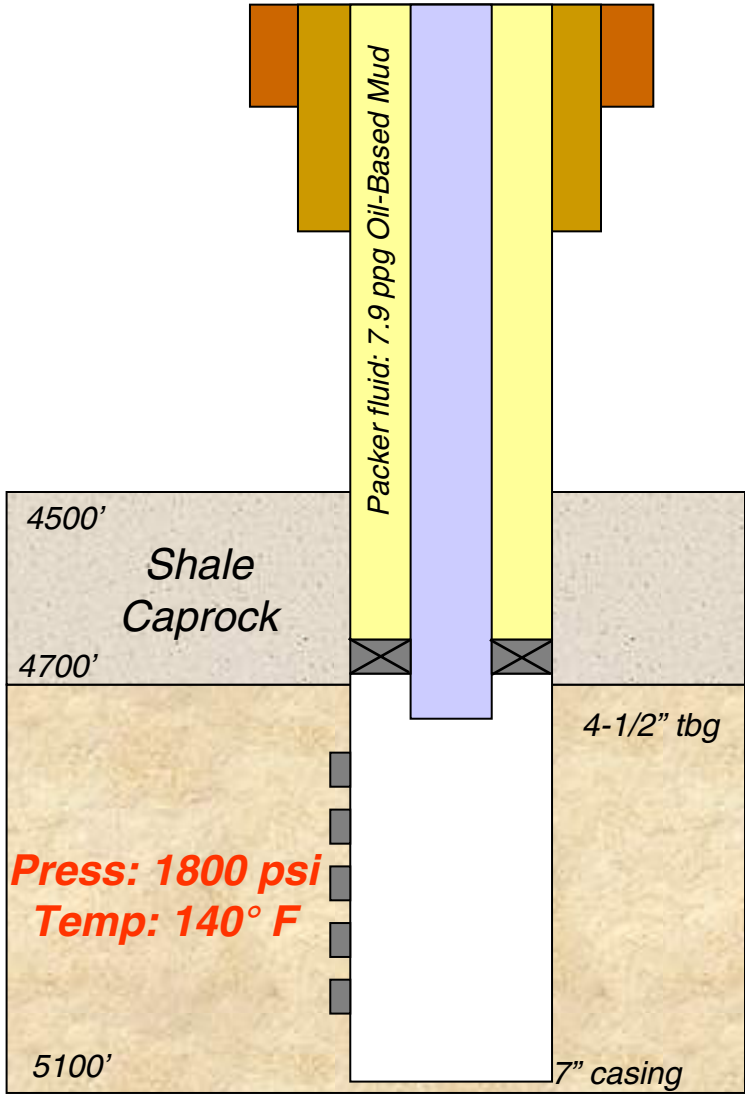
1984 Workover: Tubing Change

- Well has not been produced
- Tubing change out to increase future production capacity.
- No significant corrosion to 2 7/8”tubing that had been pulled
- 4-1/2”, 11.6 ppf, K55 grade, LTC connections, coated pipe
  - Carbon steel
  - Non-Premium Connections



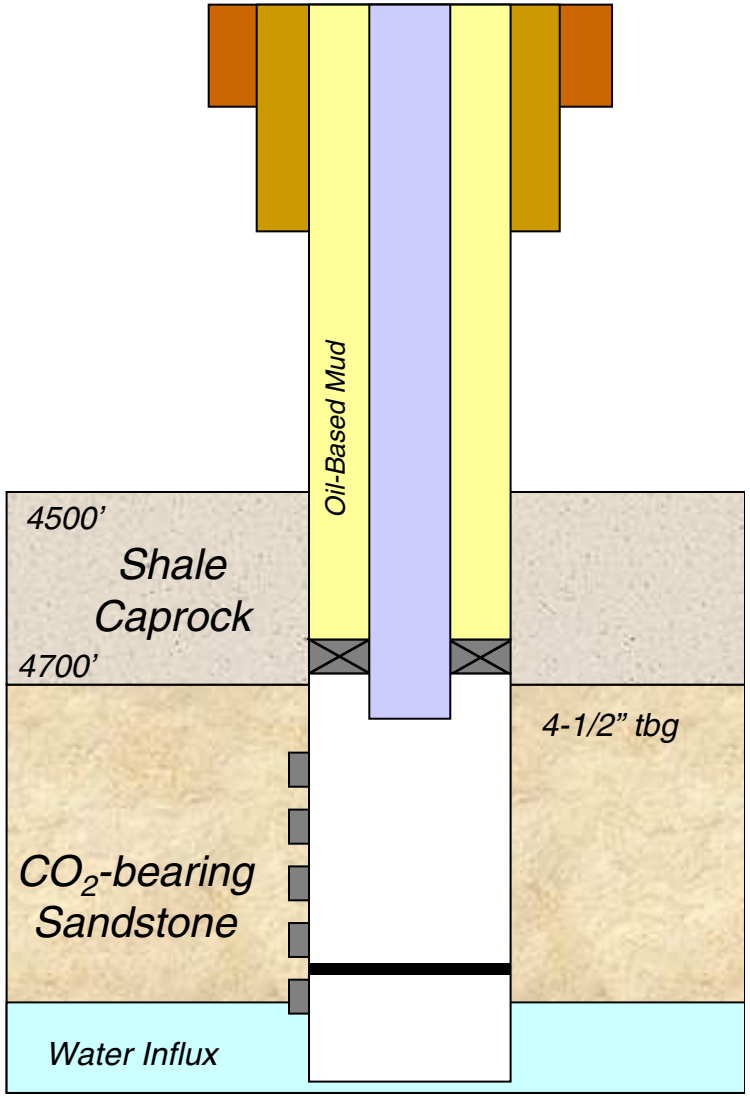
1986 Original Production

- Original production rate
  - 14 MMSCF/D (CO_2)
  - 0.6 BBL/MMSCF water
- Normally pressured reservoir ~1800 psi (0.38 psi/ft)



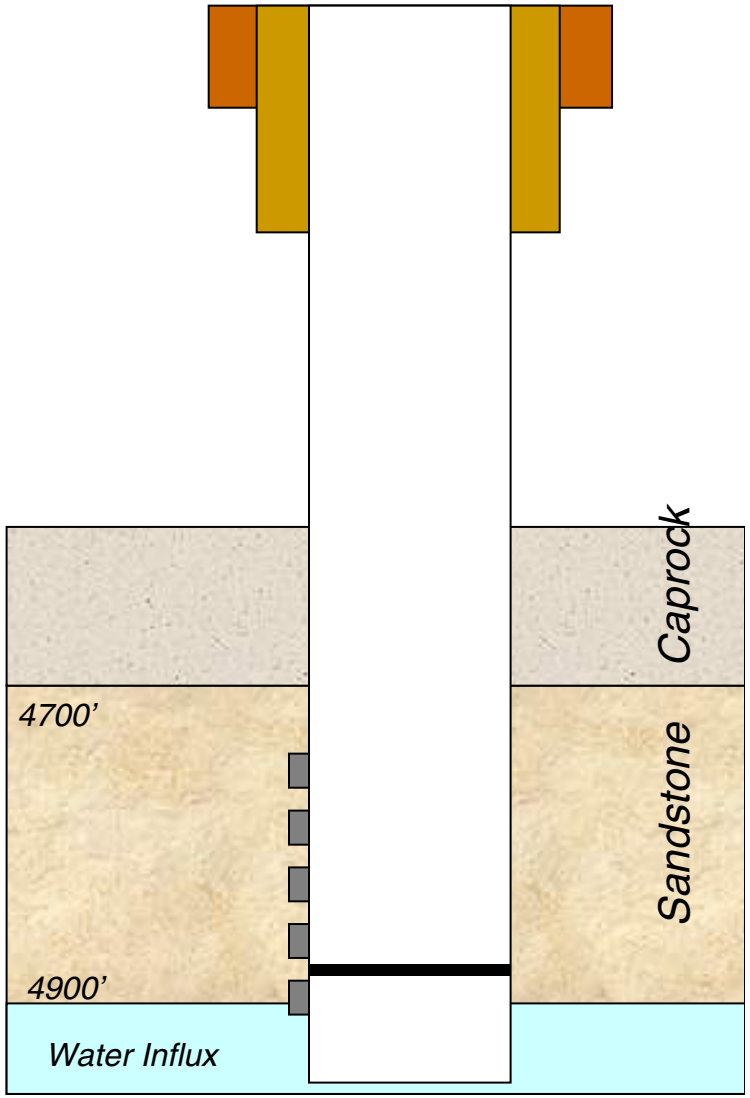
Water Cut Increase: 1997

- Production rate dropped due to water cut
- Production log: water cut from lowest zone (4888’ - 4920’)
- Attempt water shut off with bridge plug - unsuccessful
- Continued production ~1 MMSCF/D CO_2
- Current reservoir pressure ~400 psi (<0.1 psi/ft)
- No history of annulus pressure in this well



Well Integrity Survey - 2006

- Rig removed tubing and packer
- Acoustic cement evaluation tools
- Casing caliper log
- Pulsed neutron log
- Fluid samples collected
- Pressure drawdown tests in cement sheath
- Sidewall cores



Tubing in good shape after 22 years - Foundry Stencil Visible

CO_2 Capture Project

Legend

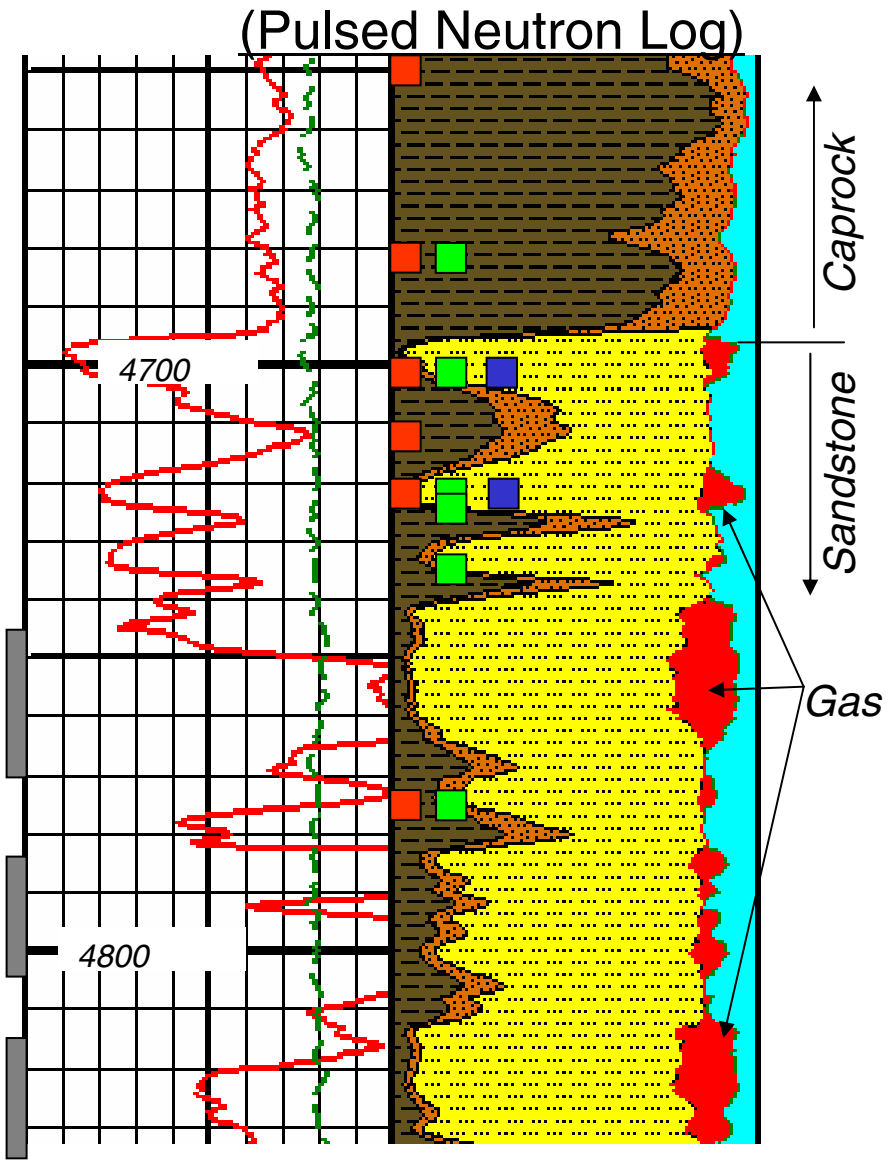
Cement core recovery

Pressure test cement sheath

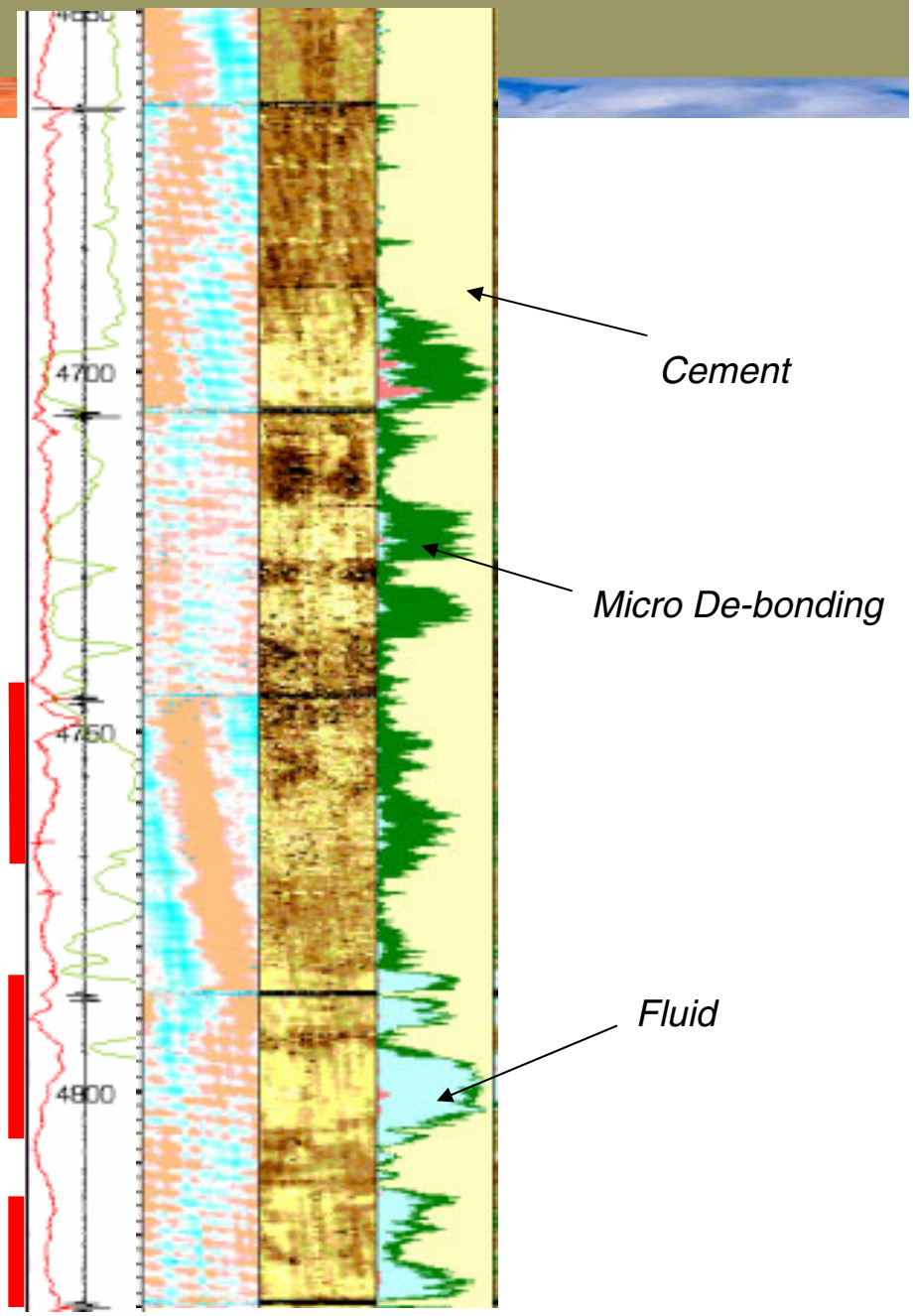
Fluid / gas sample

Recovery Summary

- *6 Cement cores*
- *6 Cement pressure tests*
- *2 Fluid samples*



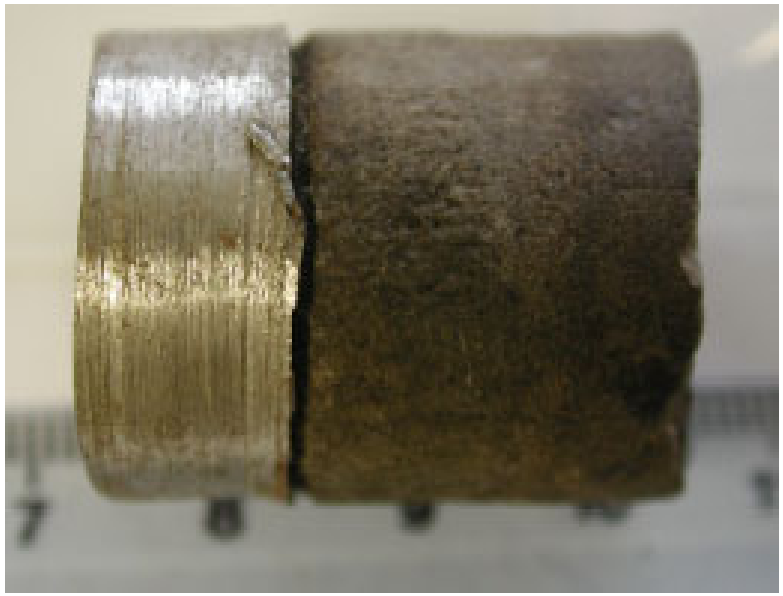
Cement analysis logs show generally good condition in caprock



CO_2 Capture Project

Caprock Sample

casing **cement**



4650' (casing / cement)

XRD shows carbonation

Calcite	**30%**
Aragonite	**3%**

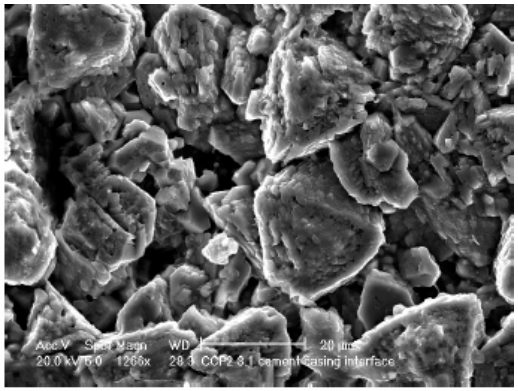


Figure 38: Close-up view of the calcium carbonate crystals in Fig. 37.

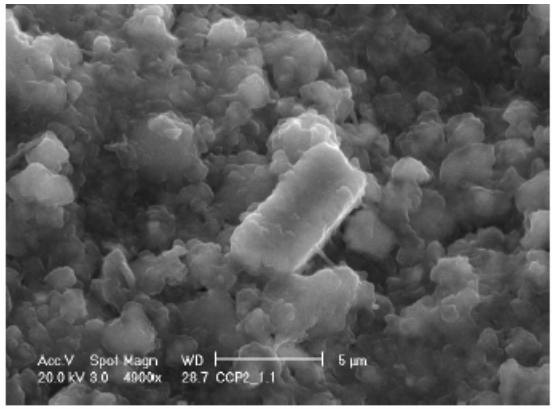


Figure 33: SEM image of tabular barite crystal in a matrix of cement-like composition. The barite may reflect drilling mud.

Cement interface with caprock

Cement interface with casing

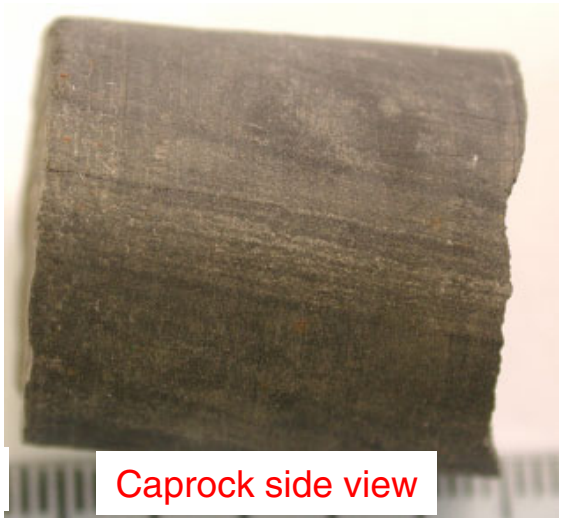
CO_2 Capture Project

Casing fragment

cement **shale**

4682' (cement / shale)

Caprock interface with cement



Caprock side view

Interface to casing

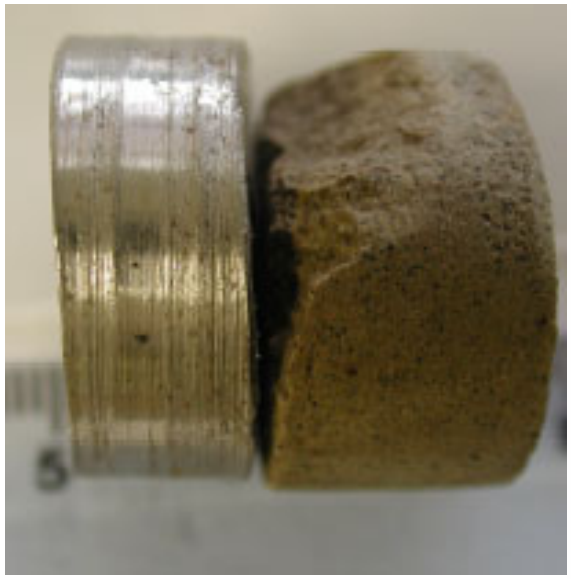
Calcite 30 – 50%
Aragonite 4 – 20%

Cement side view

Interface to caprock

Interface of Caprock and Formation

casing **cement**



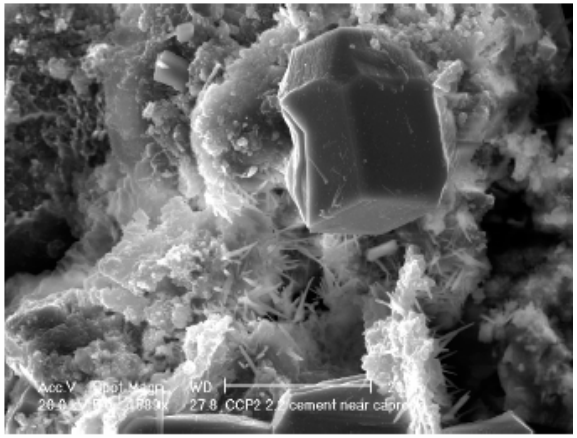


Figure 48: Close up of lower left region from Fig. 47. Large central crystal and the needles are calcium carbonate. The granu-

4701' (casing / cement)

XRD shows much carbonation

Calcite 21%
Aragonite 68%

Mineralogical Analysis to Date

- Cement is intact
- All cores have some level of carbonation but no significant deposits
- Interfaces intact (cement-formation & cement-casing)
- Fluid sample pH: 5.4

Data and Sample Analysis Underway

- Solids Analysis / Cement Cores
  - Xray diffraction
  - Scanning Electron Microscope
- Fluid/gas analysis
  - Gas-Water ratio
  - pH
  - Total dissolved solids
  - Elemental analysis
- Log Analysis
  - Permeability measurement from drawdown tests
  - Cement evaluation (bonding / gas or fluid cut)
  - Casing corrosion

Inferences

- Standard oilfield pipe with standard corrosion protection worked well.
- Cement shows evidence of carbonation in the area of the productive zone. It is not known if this occurred during placement.
- Cement adjacent to the caprock was not carbonated.
- Logs indicate good bond but are not perfect indicators.
- More to come…….