Summary of Wellbore Integrity Evaluations

Well Mechanical Integrity Technical Discussion
Cal/EPA Headquarters Building
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Outline

- Legacy wells as potential leakage pathways
- Wellbore integrity and corrosion
- Data collection
- Wellbore evaluation
- Corrosion study
  - Integrity evaluation logs/tools
  - Corrosion observations
- Summary

Legacy Wells as Potential Pathways

- Plan to discuss (from the well integrity handout):
  - Can legacy wells be categorized in terms of risk and associated response in terms of certain characteristics (e.g., age, depth, materials)?
  - Are there recommendations on what tests and analyses could and should be performed on located legacy wells in the project area to ensure they have mechanical integrity and will not serve as leak points?
  - Are there recommendations on what criteria ARB should use to define a legacy well as a leakage risk?

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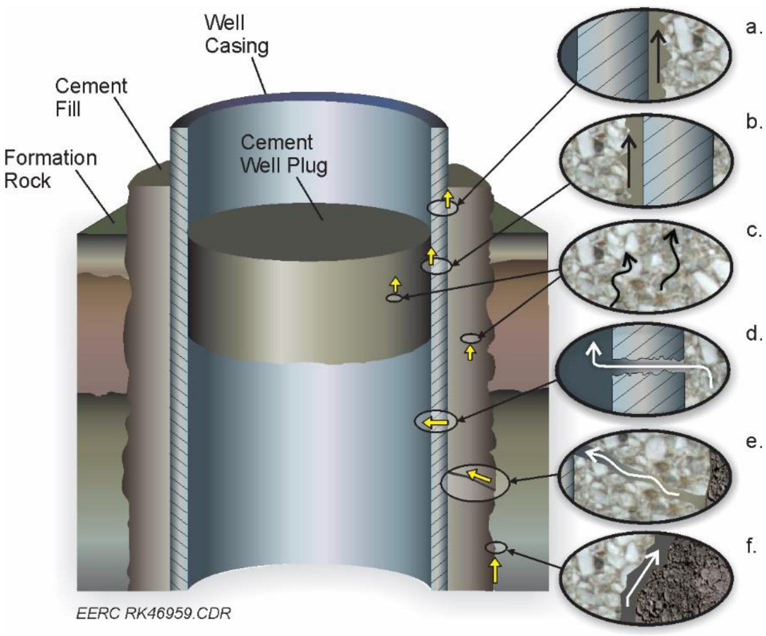
Wellbore Integrity



From Celia and others, 2004.

- Wellbore integrity is the ability of a well to maintain isolation of geologic formations and prevent the vertical migration of fluids. (Zhang and Bachu, 2011; Crow and others, 2010)
- For our discussion, leakage is defined as a loss of CO_2 or other fluid from its intended storage formation and not necessarily losses to the atmosphere.
- Important in retention of injected CO_2.

Corrosion

- Corrosion is a complex, naturally occurring phenomenon involving the deterioration of materials because of reactions with the environment.
- Total cost of corrosion according to NACE International (2014):
  - US$1.372 billion
    - ♦ US$589 million in surface pipeline and facility costs
    - ♦ **US$463 million annually in downhole tubing**
    - ♦ US$320 million in capital expenditures related to corrosion

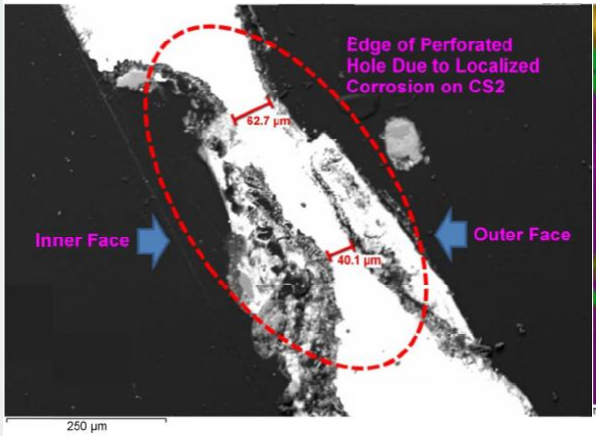


Figure 13. SEM backscatter electron micrograph of the Specimen CS2 cross section.

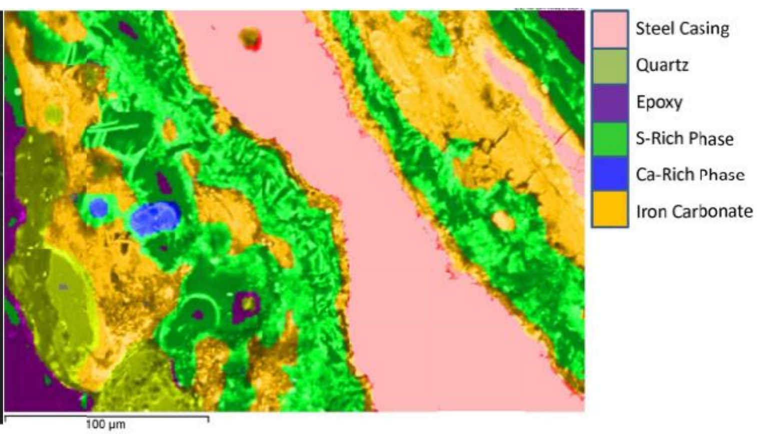


Figure 14. SEM mineral phase map of Sample CS2, with the outside surface on the right and the inside surface on the left.

Wellbore Data

- Challenge is to collect pertinent existing legacy well data.
- State oil and gas regulatory agency databases.
  - Numerous documents:
    - ♦ Well completion reports
    - ♦ Wellbore diagrams
    - ♦ Technical reports
    - ♦ Cementing records
    - ♦ Correspondence
- Studies are driven by the available data.
- This process can be time-consuming and costly.

Wellbore Evaluation

- Methodologies have been developed for evaluating leakage potential. (Watson and Bachu, 2007, 2008; Bachu and others, 2012)
- Need to be adapted to study area.
- Risk factors based upon observed surface casing vent flow (SCVF) and gas migration (GM) at wells.
  - Earlier work assigned qualitative descriptions of the risk factors.
    - No apparent impact.
      - i.e., well age, CO_2 presence, depth of completion interval
    - Minor impact.
      - i.e., licensee, surface casing depth, total depth, well density
    - Major impact.
      - i.e., geographic area, well type, oil price and regulatory changes, abandonment method
- More recent methodology added a scoring system (quantitative vs. qualitative).

Wellbore Evaluation

- Deep well leakage factors:
  - Fracture treatments
  - Acid treatments
  - Abandonment type – cement plugs, cast iron bridge plugs
  - Completions
  - Cement/additive types
    - Studies indicate different responses to CO_2.
    - Quality of cementing job a large factor.
    - Lacked data to make a proper evaluation.
- Shallow well leakage factors:
  - Spud date – proxy for level of drilling activity
  - Well type – i.e., drilled and abandoned (no production casing), drilled and abandoned with casing
  - Well total depth
  - Additional plug near surface
  - Cement to surface
- Score does not indicate the size or impact of a leak that may occur.

Wellbore Evaluation

- This method is useful as a screening-level evaluation for leakage potential of a group of wells but is limited by the nature and extent of available data.
- Areas targeted for CO_2 injection should be evaluated and/or monitored on a site-by-site basis based on the unique risk factors for the given project.
- Results intended to direct future efforts to assess wellbore integrity.

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Corrosion Study

- Goal was to estimate in situ corrosion rates of casing/cement for wells in a CO_2 EOR field.
- Identified case study wells for corrosion evaluation.
- Logs included:
  - Cement evaluation: sector bond tool/log (SBT/SBL) and ultrasonic radial scanner (URS)
  - Casing evaluation: casing imaging tool (CIT), multisensor caliper (MSC), multifinger imaging tool (MIT), EM pipe scanner, and vertilog/micro vertilog.
- Ideal case studies are wells with varying degrees of corrosion and some wells that have been exposed to CO_2.

Note: Not from study area.

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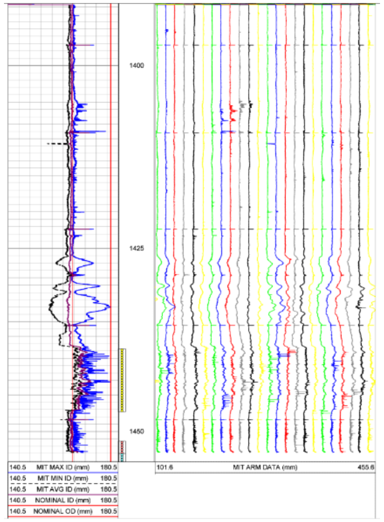
Figure 1. Photos of the corroded production casing samples recovered from [redacted] well on October 1, 2013, from a depth of [redacted]

General Approach

- Gathered all available logs for the five selected case study wells.
- Gathered as much additional information about the wells as possible.
  - Operational history, completion information, etc.
- Some logs had interpretations available from the service company that logged the well.
- Looking for trends in the corrosion observations throughout the wellbore (i.e., not an exercise in precise log interpretations).
- Determine corrosion rates and contributing factors.



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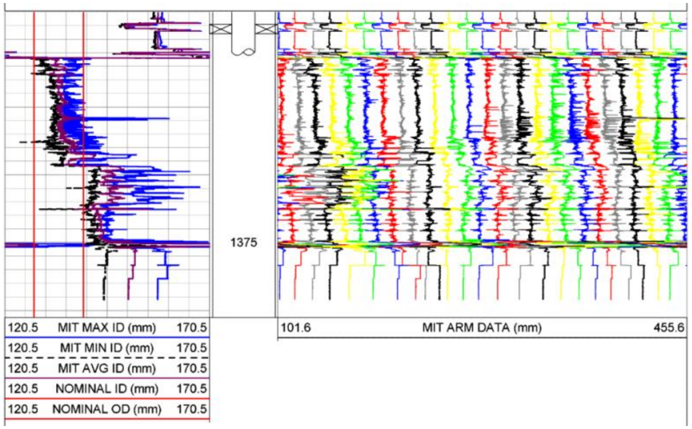
Study Observations

- Gathering logs/well data is a significant effort.
  - Limit area of review to an area that makes sense in order to limit cost.
- In all cases, rate of casing corrosion increased near injection zone layer near the existing production perforations.
- Overall, conditions of cemented intervals were sufficient to provide zonal isolation.
- Areas exposed to reservoir and injected fluids experienced accelerated corrosion and cement degradation.
- Greatest safeguard remains a good cement job and effective isolation from reservoir and injected fluids.



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Summary

- Logs are typically run only when there is an indication of a problem with a well or when required by regulations.
  - Operational data monitored by the operator.
    - Production rates or pressure changes may be indicators.
  - Logs typically targeted to a specific depth interval.
- Quality of drilling, casing, cementing, and completion practices is extremely important in determining the actual potential for leakage. However, this is not easily determined from well files.
  - Field crew notes, pressure tests, cement bond logs, etc., may provide some indications as to the quality of work.
- Good data can be hard to find.
- Limit area of review to a reasonable extent→$$$.
  - No need to invest when not needed.

Conclusions

- Methodology exists for screening-level categorization of legacy well risk.
  - Was developed for Canada but can be modified.
  - Driven by available wellbore data.
- Corrosion logs used in collaboration with MIT provide insight into the integrity of the casing and cement.
- Some logs work better than others in certain scenarios.
- Operational data can help monitor for issues.

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