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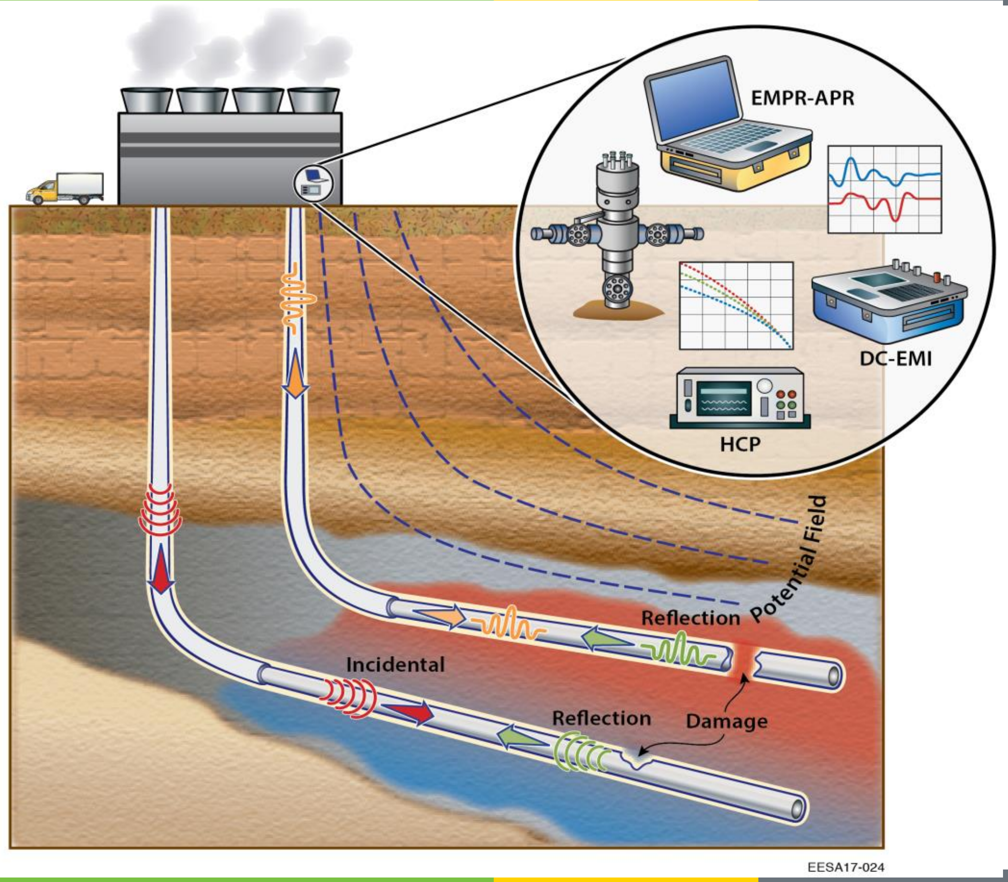


Wellbore Integrity asSEsment with Casing-based Advanced senSING (WISE-CASING)

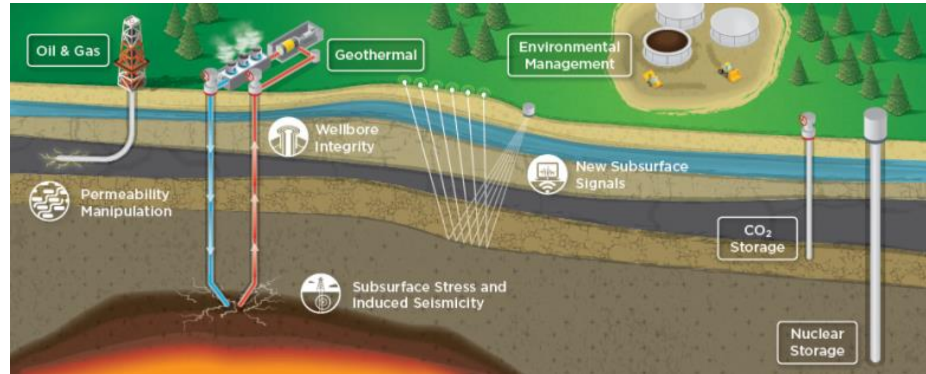
Project Officer: Alex Prisjatschew
Total Project Funding: $1.2M
November 14, 2017

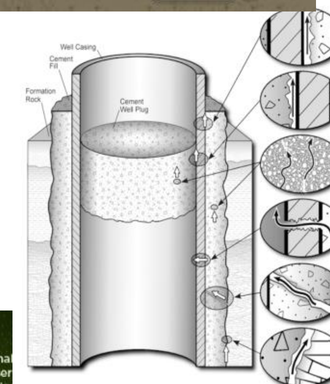
Principal Investigator
Yuxin Wu
Lawrence Berkeley National Lab

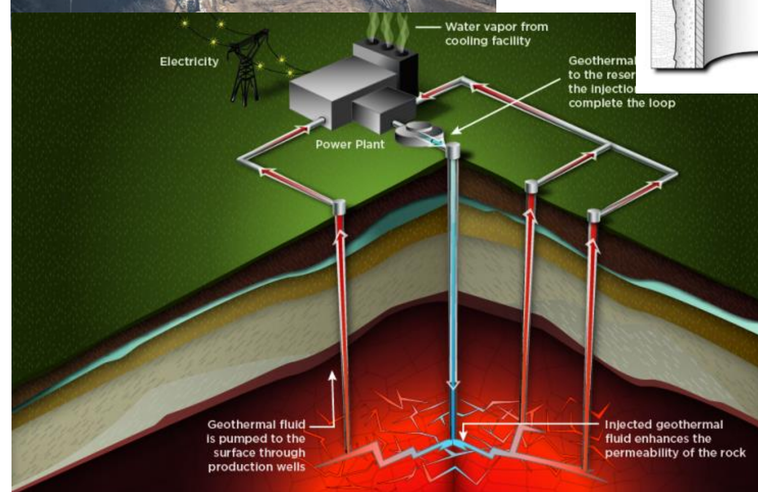
SubTER

- **Wellbore corrosion and impact**
  - COST: $170B /year due to corrosion in energy/chemical industry
  - Health/environmental risks

- **Geothermal fluid-cement–steel system**
  - Mechanical/thermal/chemical
  - Thermal cycling and stimulated corrosion rates
  - Stress induced damage
  - Corrosion due to low pH, CO_2/brine (also H_2S)




(Casey, 2013)



Corrosion Monitoring

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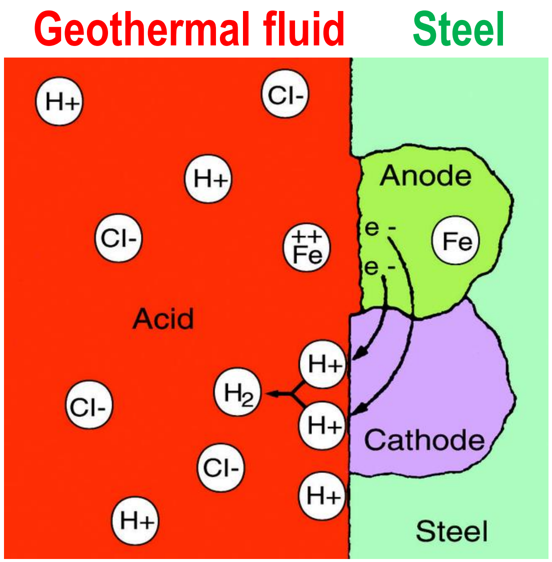
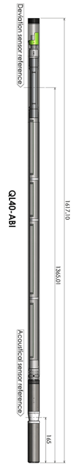
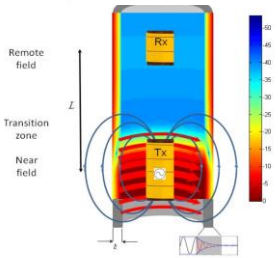
- Corrosion is pervasive, while may or may not lead to imminent borehole failure
- Wellbore corrosion monitoring is challenging due to the long length and pressurization of the casing, complex geological, mechanical, chemical conditions
- Corrosion monitoring state-of-the- art: Wireline based downhole logging tools (e.g. EM, acoustic, mechanical)







Corrosion Monitoring Challenges

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- **Downhole logging tool**
  - High resolution
  - Intrusive and interruptive
  - Expensive to obtain, leading to infrequent application
  - Incapable of frequent monitoring for degradation trajectory prediction
  - Incapable of early warning of potential failure

- **New innovation**
  - Non-invasive: No in- or behind- casing deployment
  - Cost effective: Wellhead based, no wireline tools/borehole trips
  - High efficiency: No borehole trips, short acquisition times
  - Model/Data integration: data interpretation/model -> predictive capability

Proposed Approach

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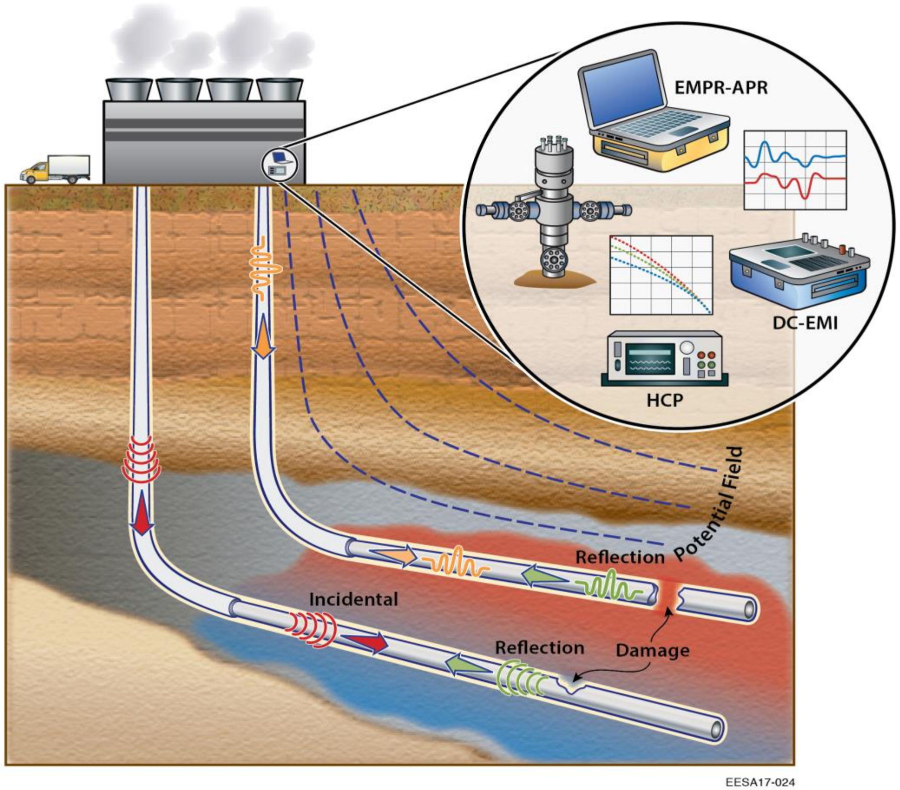
- Non-invasive, casing based approach combines fast/low cost screening with higher-precision investigation
- Based on monitoring the response of the casing when energized at the wellhead, thereby interrogating the casing without well intervention.

A toolbox that combines

- **Low frequency EM** – potential field imaging
- **EM and acoustic pulse reflectometry** – travel time positioning
- **Electrochemical sensing** – casing half cell potential and corrosion rate estimation

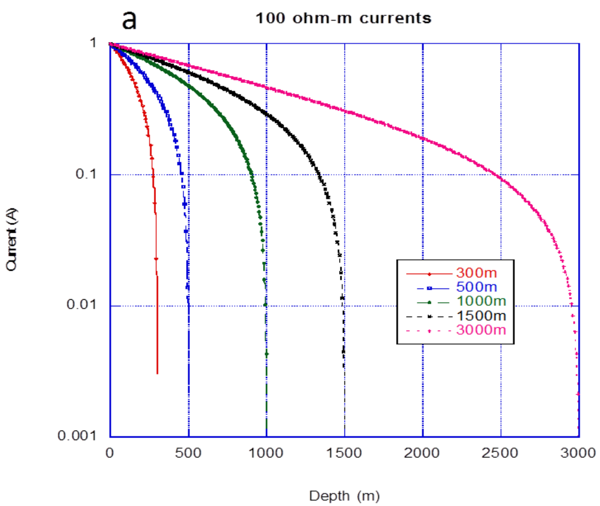


- **Low frequency EM**

$$I_{cas}(z) = I_0 \exp(-\frac{z}{L_c})$$

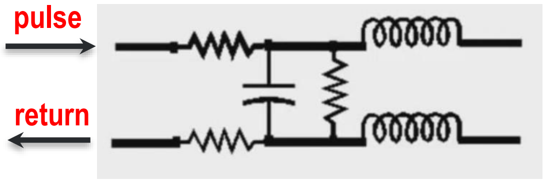
Where

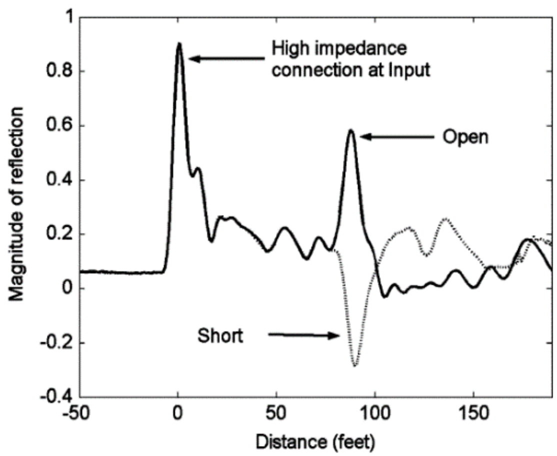
$$L_c = \sqrt{\rho_{formation}\sigma_{case}A_{case}}$$



- **Pulse reflectometry**

$$\Gamma = \frac{V_{reflected}}{V_{incident}} = \frac{Z_d - Z_0}{Z_d + Z_0}$$

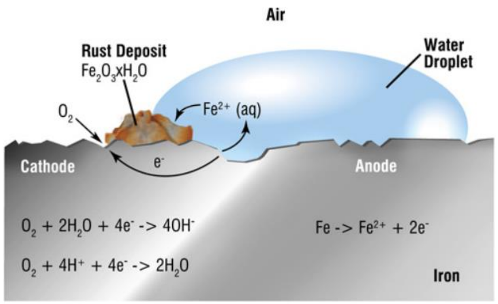


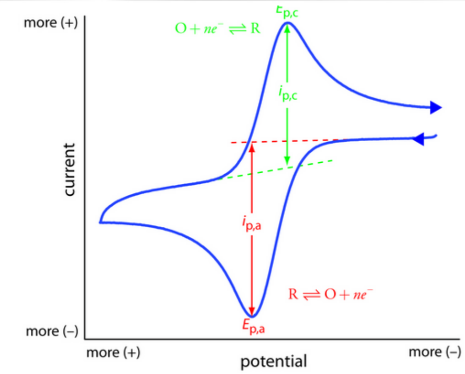


- **Electrochemical monitoring**

$$\alpha A + \beta B \leftrightarrow \gamma C + \delta D + ne^-$$

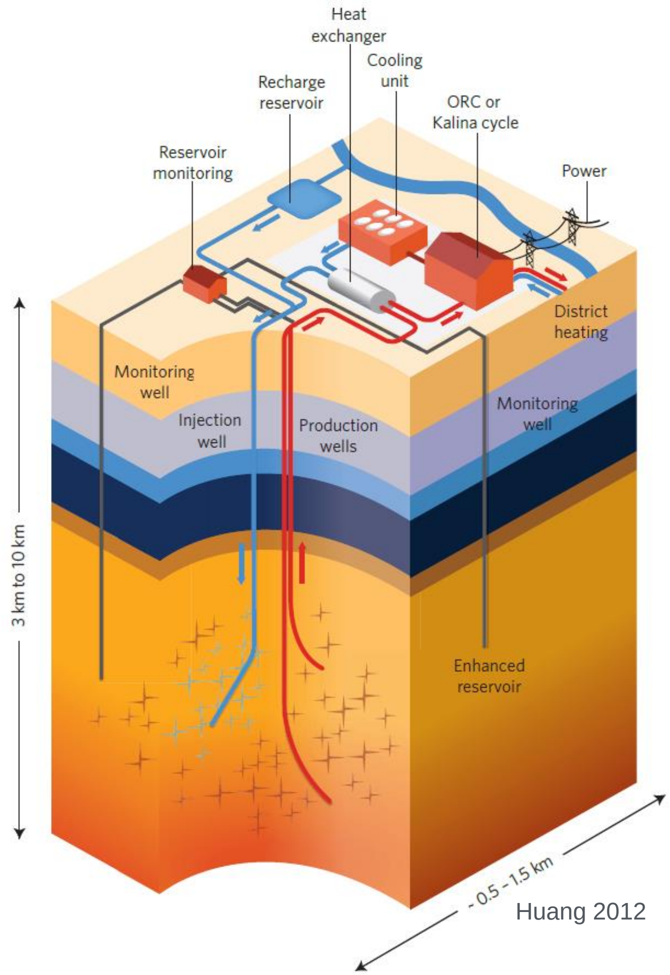
$$E = E^0 + \frac{RT}{nF}\ln\left[\frac{a_C^\gamma a_D^\delta}{a_A^\alpha a_B^\beta}\right]$$





Technical Challenges

- **Ambient noise, infrastructure and geology** – Ambient noise and infrastructure on signal quality, complex geology and geochemistry
- **Signal attenuation and dispersion**: current leakage to formation may limit depth of penetration
- **Reflectometry:** Critical reflection identification from background noise of generic irregularity
- **Electrochemistry challenge**: Borehole environments (cement resistivity, moisture, Cl content) effects on signal
- **Electrochemical challenge**: Identify critical signals associated with tipping point of casing failure
- **Numerical model**: develop fast and effective failure prediction models



Huang 2012

Technical Tasks

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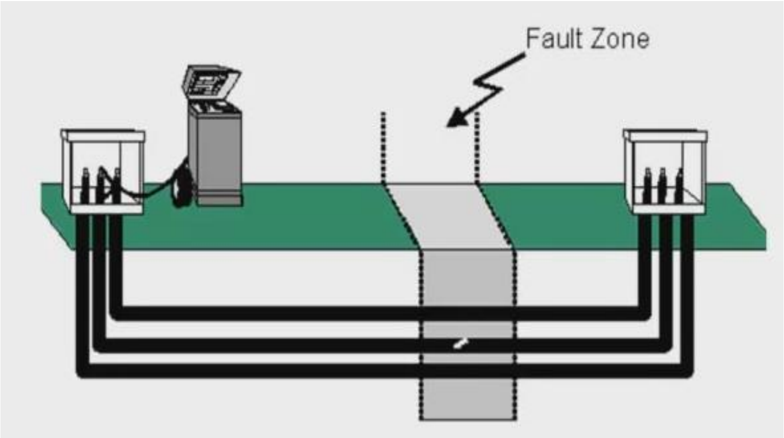
Three-year Goal : **Proof of concept - > Field demonstration (TRL 1/2 -> 5/6)**

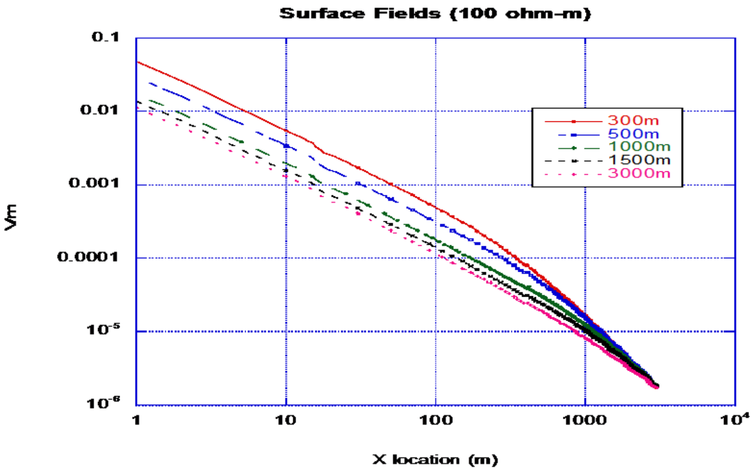
1st Year Tasks:

- **Initial technological feasibility evaluation (1st -3rd month)**
  - Literature survey on theory and case studies
  - Preliminary modeling with current codes
- **Laboratory studies** to develop the technologies and their integration for simple baseline cases with no corrosion (3rd -8th month)
  - Understand signal characteristics
  - Optimize data acquisition parameters
  - Evaluate sensitivity and signal attenuation/dispersion
- **Numerical model** calibration and improvements based on laboratory datasets (4th – 9th month)
  - Attenuation coefficient, EM/acoustic velocity model, borehole geometry and geology effects
- **Proof-of-concept field demonstration** in shallow boreholes (9th -11th month)
  - Baseline case with relatively shallow wells, simple geometry, minimal corrosion

Technological feasibility study

- Survey borehole corrosion patterns and impacts from geothermal fields
- Literature in cable fault identification applications
- Corrosion electrochemistry and quantification tools





- Conducting potential field modeling with wellhead energization with existing codes
- Surface electric field profile measurements shows sensitivity to completion depths
- Corroded or broken casing analogous to shorter casing above break

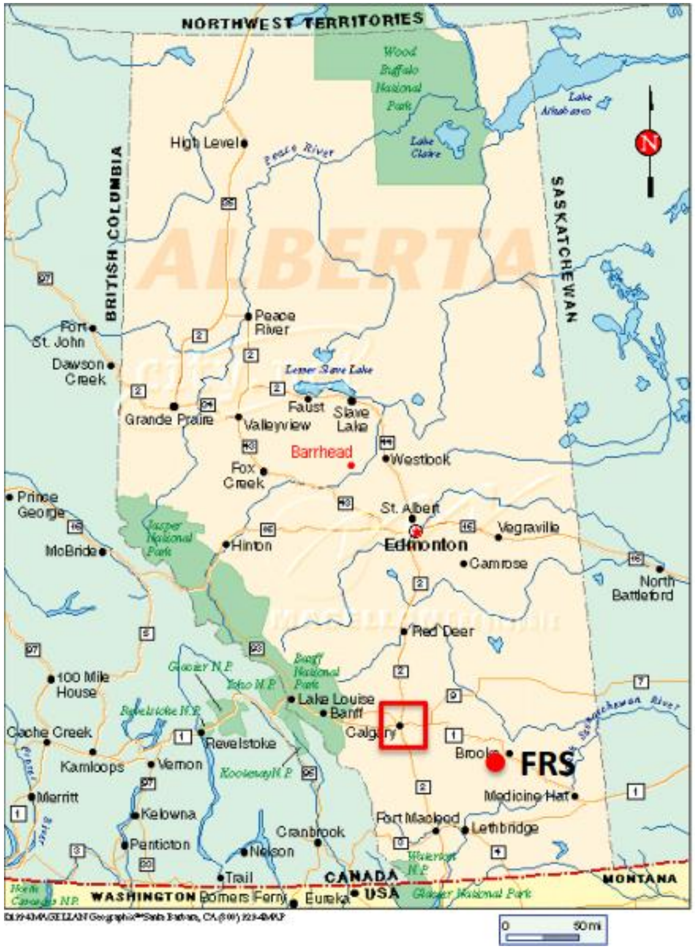
Baseline Lab Experiments

- Lab experiment design ongoing. Will focus on fresh low carbon steel tubing with no natural corrosion, but controlled damage
- Setting up physical model (30x3x3 ft)
- Instrumentation procurement in process for Time Domain Reflectometry and Potentiostat

Numerical Modeling & Improvements

Low frequency EM

- Numerical Modeling:
  - Calibrating numerical modeling codes for single casing & with pipe network
  - Design surface EM configurations for monitoring wellbore integrity
- Field Data Acquisition:
  - Electric and electromagnetic data acquisition at Field Research Station (Brooks, Alberta)
  - Three wells (100, 300 and 500m in depth) to be considered

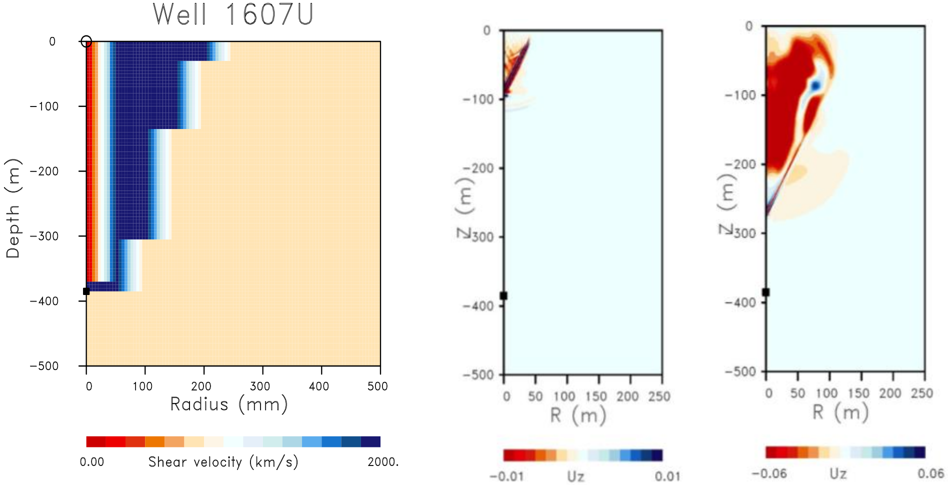


Containment and Monitoring Institute (CaMI)
Carbon Management Canada/U. Calgary

Finite difference modeling of tube waves

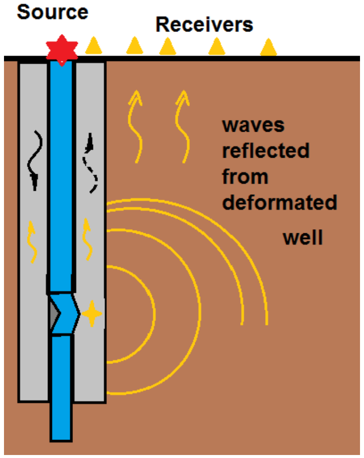
Hammer – Recently tested

Weight drop –near future



Finite difference modeling

Simulation of wave propagation in Laplace Fourier domain



Tasks:

- Large scale 3D simulation in Laplace-Fourier domain
- Calculate parameters of signals from well deformations
- Definition optimal frequencies and source-receivers positions
- Model integration

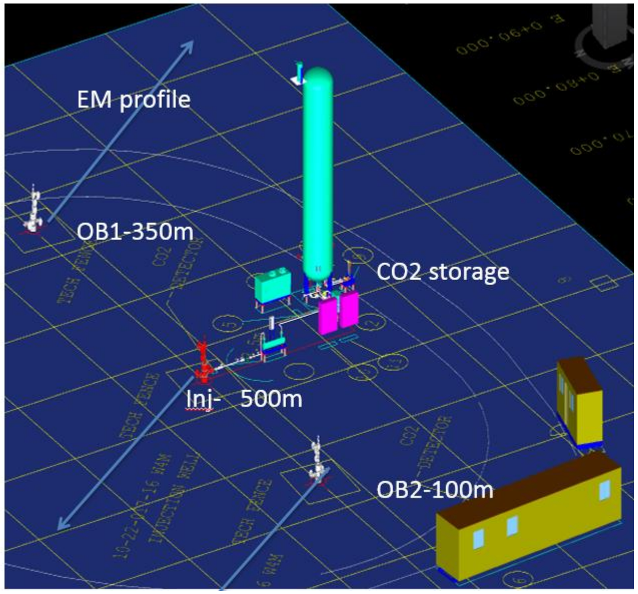
Tools:

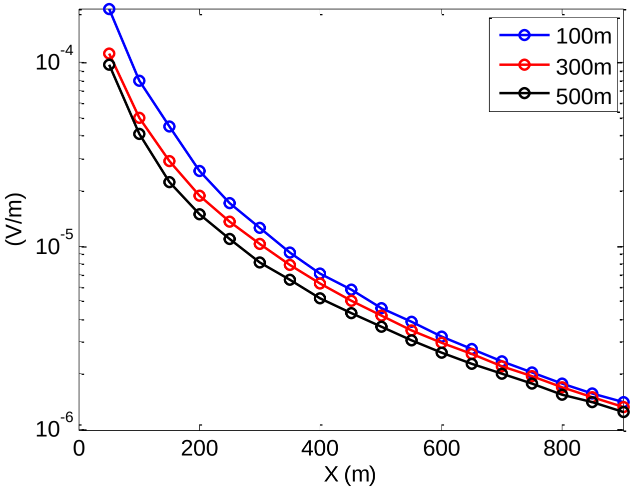
- LBL parallel 3D finite-difference elastic code

Field Site Identification and Experiments

CaMI Field Research Station

- Three wells (100, 300 and 500m steel casing)
- Time lapse cross well EM will be used to track CO_2 injection
- Separate EM profile measurements to be made to determine (known) completion depths





- Low frequency EM profiles from each well are distinct
- Additional models to determine optimal frequency, position of return electrodes, effect of noise and infrastructure, effect of geological stratigraphy

Potential geothermal sites: The Geysers

Technical Accomplishments and Progress

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Q1M: Literature/model survey + model selection/parameterization	Survey ongoing, models identified, parameterization ongoing	
Q2M: Complete feasibility study based on model + lab work, complete TMP	Model ongoing, lab experiment in preparation (construction, equip.)	
Q3M: Complete initial techn. development and numerical model improvements	Not yet started	
Q4M:Complete field tests and identify technology limitation and improvements needs	Not yet started	

Research Collaboration and Technology Transfer

- Collaborating with Sandia lab (Chet Weiss) and their EM model capability for networked boreholes
- Working with CaMI Field Research Station to establish first field test site. Initial low frequency EM survey is underway
- Exploring wells at UCB Richmond Field Station (RFS), and Geyser geothermal field as future sites
- Halliburton and Chevron are collaborators on the project that can provide test wells and logging support in outer years
- Technology transfer to the private sector is planned for outer years.

Future Directions

Planned activities for FY18

- Finish technological feasibility evaluation
- Iterative laboratory studies – modeling interactions to improve technology and model capability
- Conduct proof-of-concept demonstration at relatively simple fields
- Establish TMP and path forward

Outer year activities

- Controlled study to simulate casing corrosion/failure and associated signal under realistic conditions
- Model improvements to simulate corrosion failure under field conditions
- Deep, complex borehole field test
- Technology readiness progress and recommendations for path forward toward commercialization

Summary

- A very innovative approach that can disrupt the state-of-the-art
- First year focus on technology proof-of-concept
- An excellent team of experts with many years of experience in experiments, modeling and field work
- Project just started, but well underway
- Wide application and strong industry interests in the technology