Tools for Building Confidence Over Performance of Geological CO2 Storage

A proposed collaboration Project Between
ADCO/MASDAR/Masdar Institute/Petroleum Institute/MIT/Stanford

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Masdar INSTITUTE

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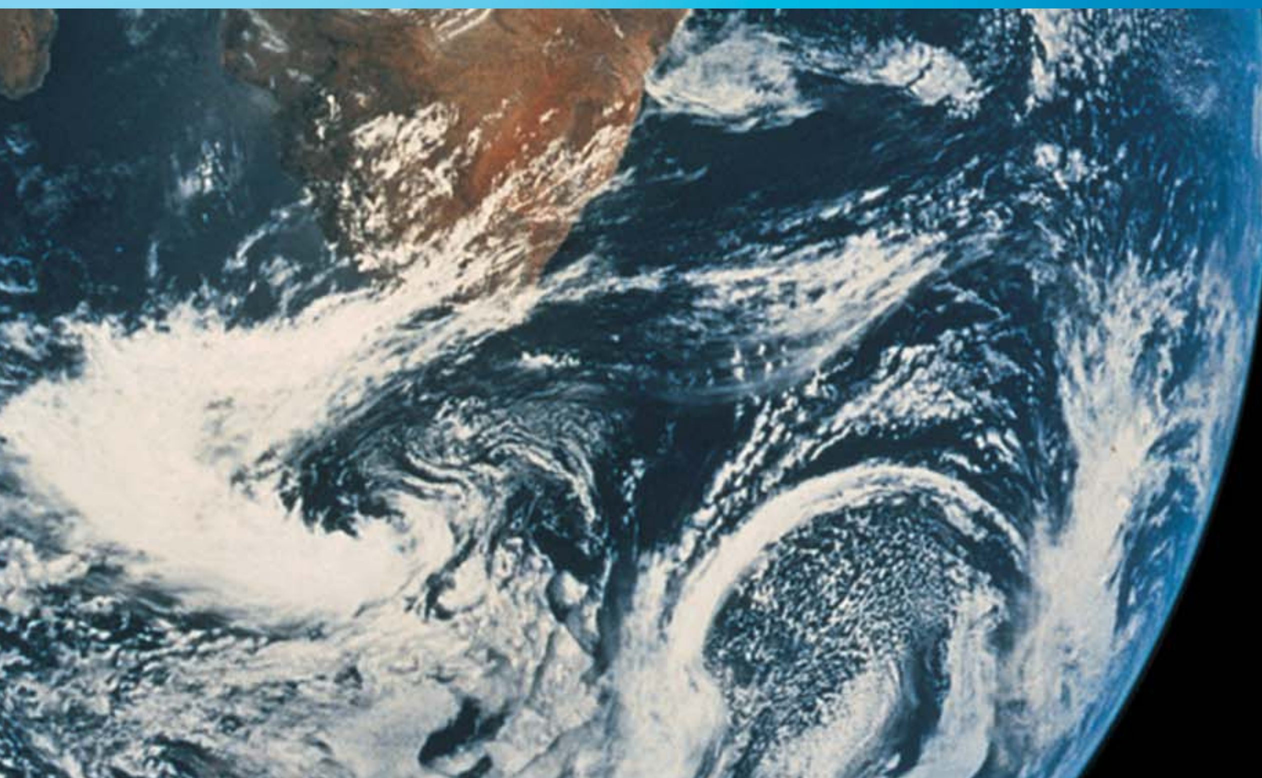
CO_2 Geological Storage

This proposed collaborative research project responds to an Abu Dhabi initiative of economic growth, diversification, creation of clean technology, and sustainable development.

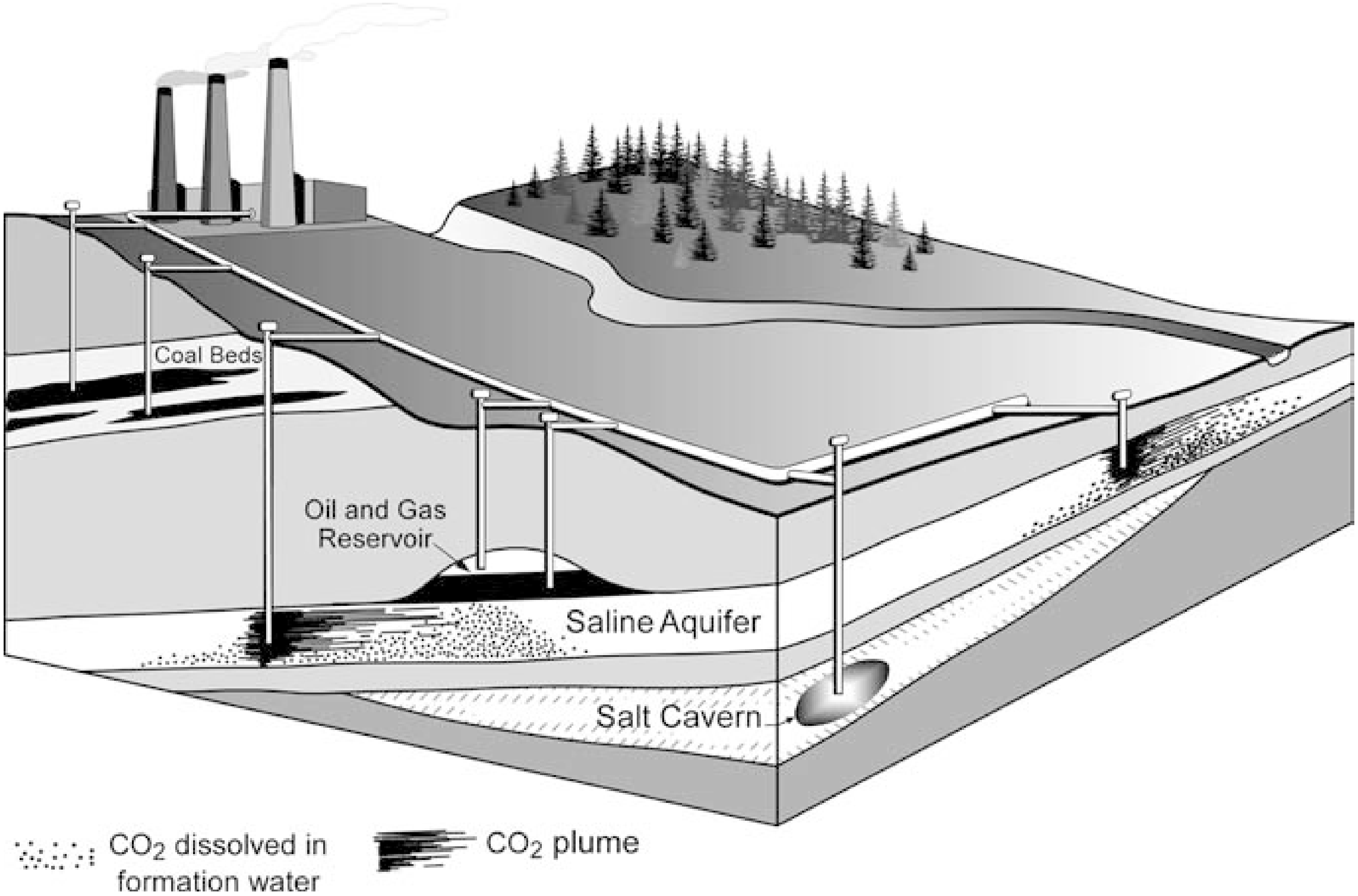
The UAE, as a result of its fast social and economic growth in an extreme climate and scares water resourses, has one of the highest carbon footprints per capita in the world.



The Abu Dhabi government has established an ambitious plan to capture CO2 from a wide range of large carbon emitting industrial plar for storage in geological formations

This way the UAE is distinguishing itself as part of the solution to clima change rather than the problem.

CO2 GEOLOGICAL STORAGE



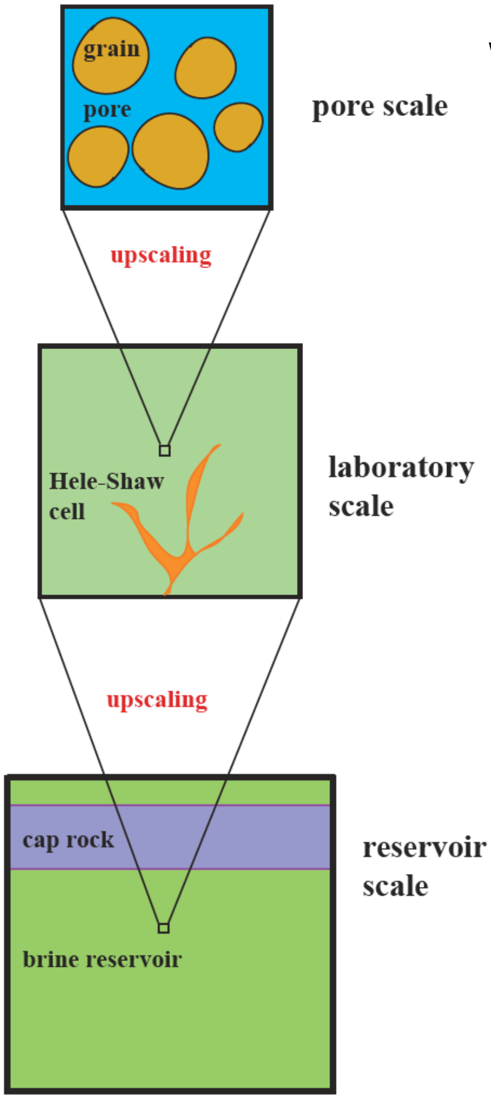
CO2 GEOLOGICAL STORAGE

1. The basic concept is to store captured CO2 underground in reservoirs that would otherwise contain water, oil or gas – there are no depleted oil and gas reservoir in UAE right now and saline aquifers are targeted.
2. We need to be deep (greater than 800m) to ensure CO2 is in dense form – the supercritical phase (liquid like density and gas like behavior)
3. These are also the depths where we are confident that natural gas has been trapped for millions of years.
4. But the big questions are
   - Where do we inject it and store it?
   - How much CO2 can we inject and at what rate?
   - Can we inject it and store it safely?
   - Can we inject it and store it cost-effectively?
5. Reservoir modeling and monitoring answer these engineering questions

CO_2 STORAGE RESEARCH CHALLENGES

- Geological Site Characterization:
  - Structural geology
  - Geophysics, Geochemistry and Geo-mechanics in storage formations
- Storage Flow-Geo-mechanical Processes and Cap-rock Integrity:
  - Development of coupled computational models of flow and geo-mechanics
  - Experimental and computational studies of flow-geo-mechanics and trapping mechanisms
- Capacity Estimates and Risk Assessment of Reservoir-scale Injection
  - Development of mathematical models for CO_2 injection and migration in UAE reservoirs
  - Development of risk assessment methodologies
- Storage Monitoring During and after Injection
  - Monitoring during injection
  - Monitoring after injection

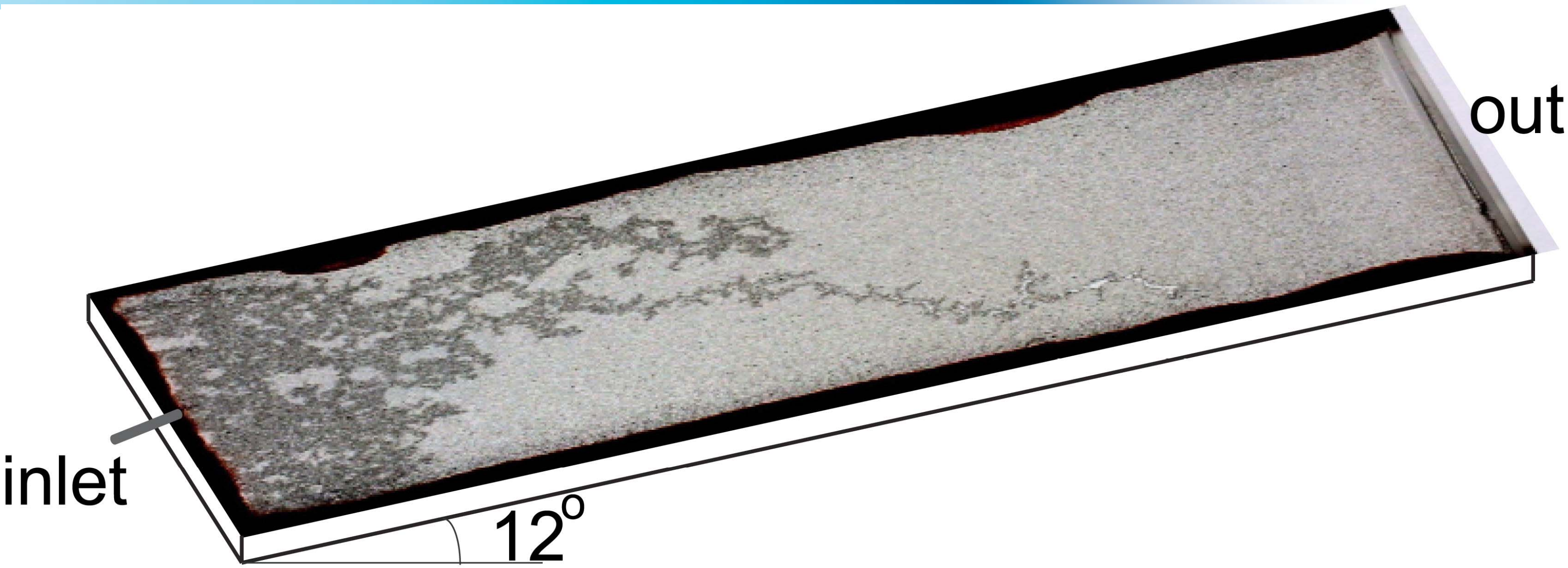
CO_2 STORAGE MODELING CHALLENGES

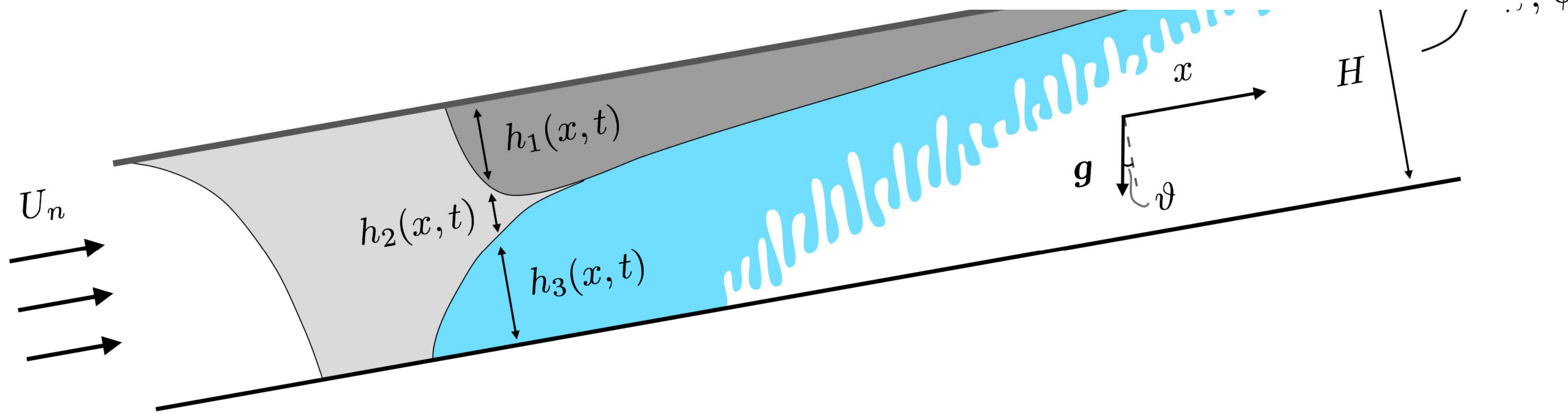


What do we need to model and at what scale?

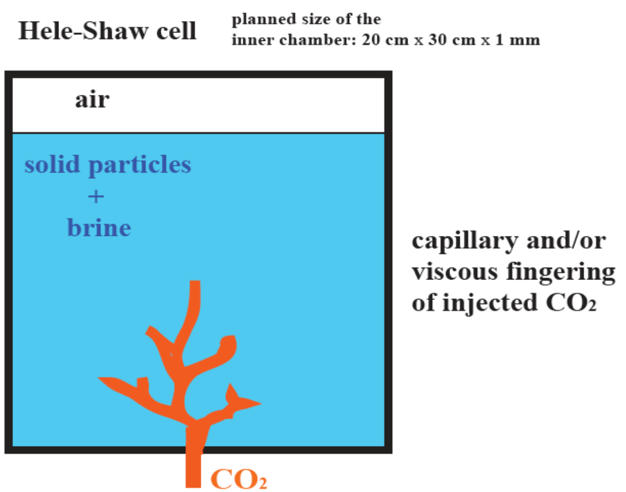
1. CO2/brine/rock phase behavior
2. Multi-phase flow in porous media
3. CO2 dissolution/diffusion in brine
4. Rock architecture (porosity, permeability)
5. Rock-fluid interactions (geochemistry)
6. Rock geo-mechanical effects
7. Flow-geo-mechanics interactions
8. Coupling between all of the above
9. Effects of impurities in injected gas or brin
10. Well design and engineering
11. Numerical representations of storage
12. …

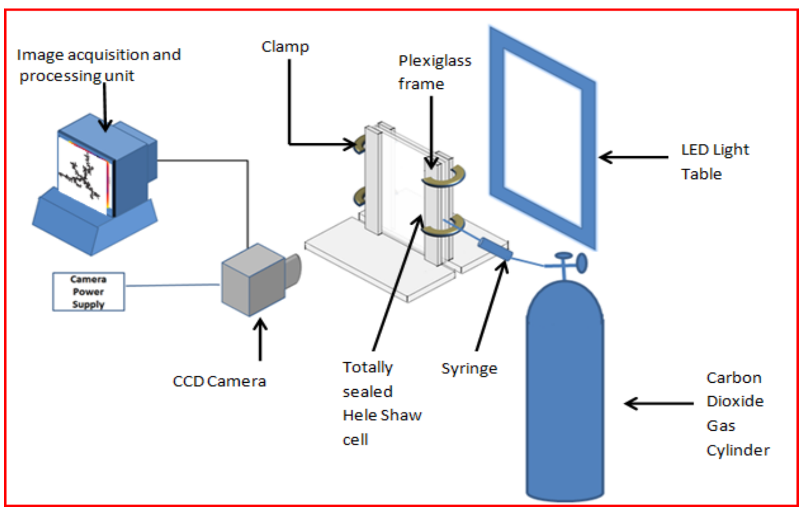
CO_2 STORAGE MODELING CHALLENGES





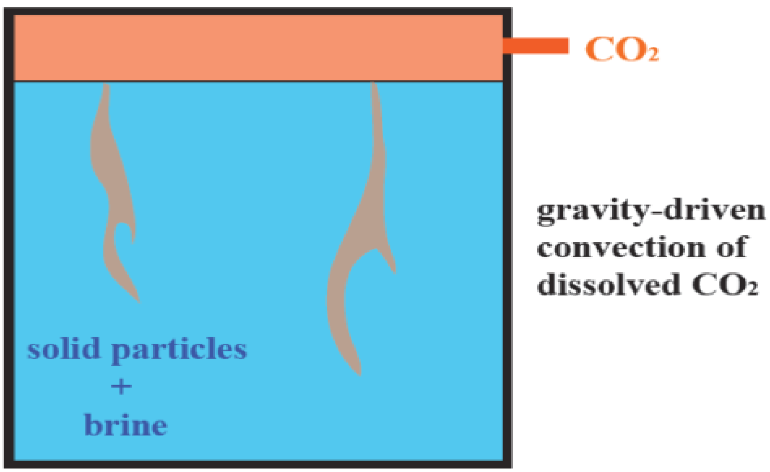
EXPERIMENTAL AND NUMERICAL STUDIES OF CO_2 INJECTION INTO BRINE-SATURATED ROCKS: DRAINAGE IN DEFORMABLE POROUS MEDIA





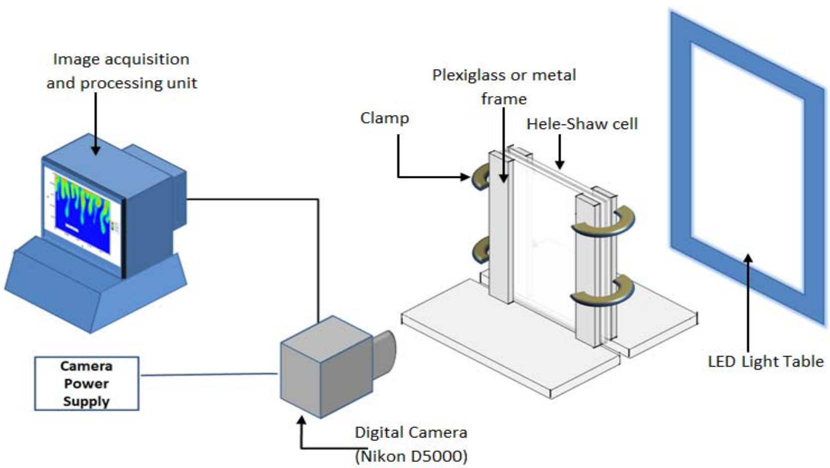
- **Objective:**
  - This work studies the interactions between the injected CO_2 and the brine saturated rock, characterizing its invasion pattern.
- **Approach:**
  - To vertically inject CO_2 into a Hele-Shaw cell filled with few layers of granular medium saturated with brine.
  - To visualize the invasion pattern and identify the different fingering mechanisms.
  - To numerically simulate the phenomena
- **Research Issues**
  - To visualize the different fingering mechanisms in the porous medium
  - To develop an understanding of fracture in porous media
  - To correctly simulate the phenomena
- **Impact:**
  - Contribute to the development of efficient CO_2 storage technologies

EXPERIMENTAL AND NUMERICAL STUDIES OF CO_2 INJECTION INTO BRINE-SATURATED ROCKS: CO_2 DISSOLUTION-DIFFUSION-CONVECTION PROCESS



Hele-Shaw cell

planned size of the inner chamber: 20 cm x 30 cm x 1 mm



- **Objective:**
  - This work studies the dissolution-diffusion-convection phenomena of the buoyant CO_2 gasket between the cap rock and the brine saturated formation
- **Approach:**
  - To visualize the phenomena in a Hele-Shaw cell filled with few layers of granular medium saturated with brine.
  - To numerically simulate the phenomena

- **Research Issues**
  - To visualize the different CO_2 trapping mechanisms
  - To develop an understanding of the coupled phenomena
  - To correctly simulate the phenomena
- **Impact:**
  - Contribute to the development of efficient CO_2 storage technologies

EXPERIMENTAL STUDIES OF GEO-MECHANICS AND MINERAL TRAPPING OF CO_2 INJECTION INTO BRINE-SATURATED ROCKS UNDER RESERVOIR CONDITIONS

ully functional tri-axial apparatus esigned to perform standard coupled rocesses of flow, geochemistry and rock echanics experiments on specimens up o 4 in diameter at reservoir conditions of verburden pressure, pore pressure and emperature.

- **Objective:**
  - Study the interactions between geo-chemistry, geo-mechanics, and trapping phenomena during CO2 storage
- **Approach:**
  - measure permeability, electrical resistivity, and acoustic wave velocities, simultaneously, while the rock samples are under reservoir loading conditions and while reactive fluids are circulating through them

- **Research Issues**
  - To visualize the invasion patterns by signal inversion methods
  - To develop an understanding of the coupled phenomena
  - To correctly simulate the phenomena
- **Impact:**
  - Contribute to the development of efficient CO2 storage technologies

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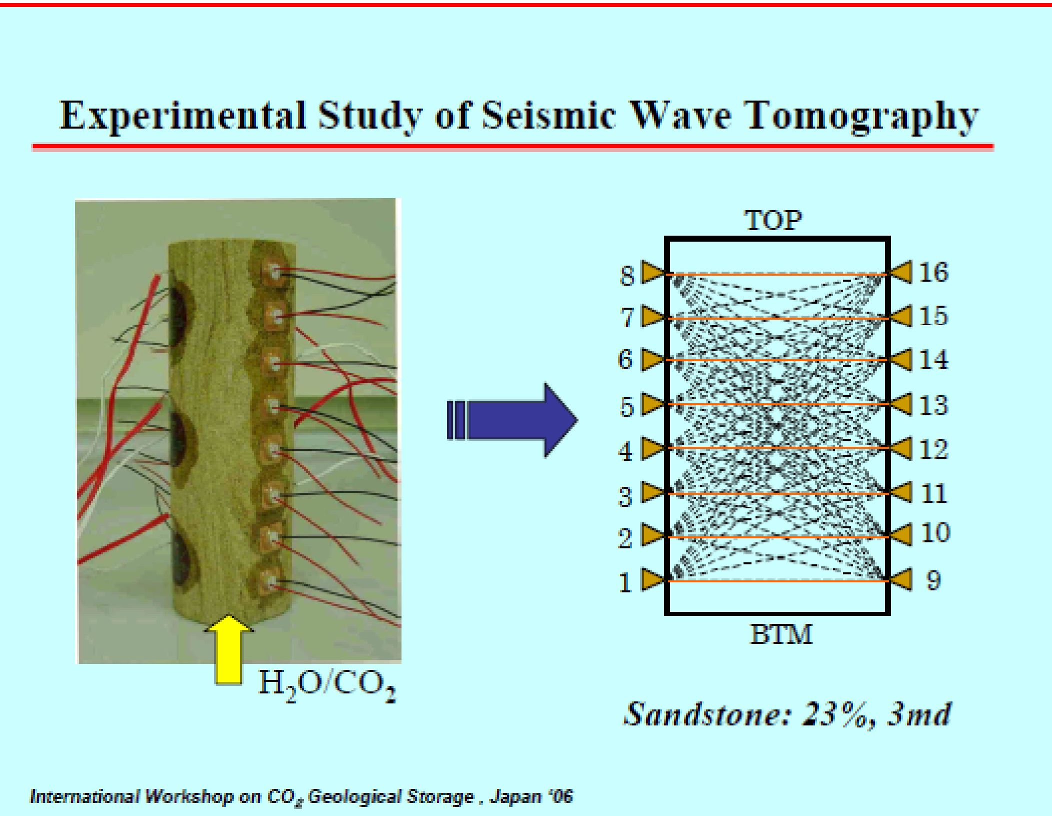
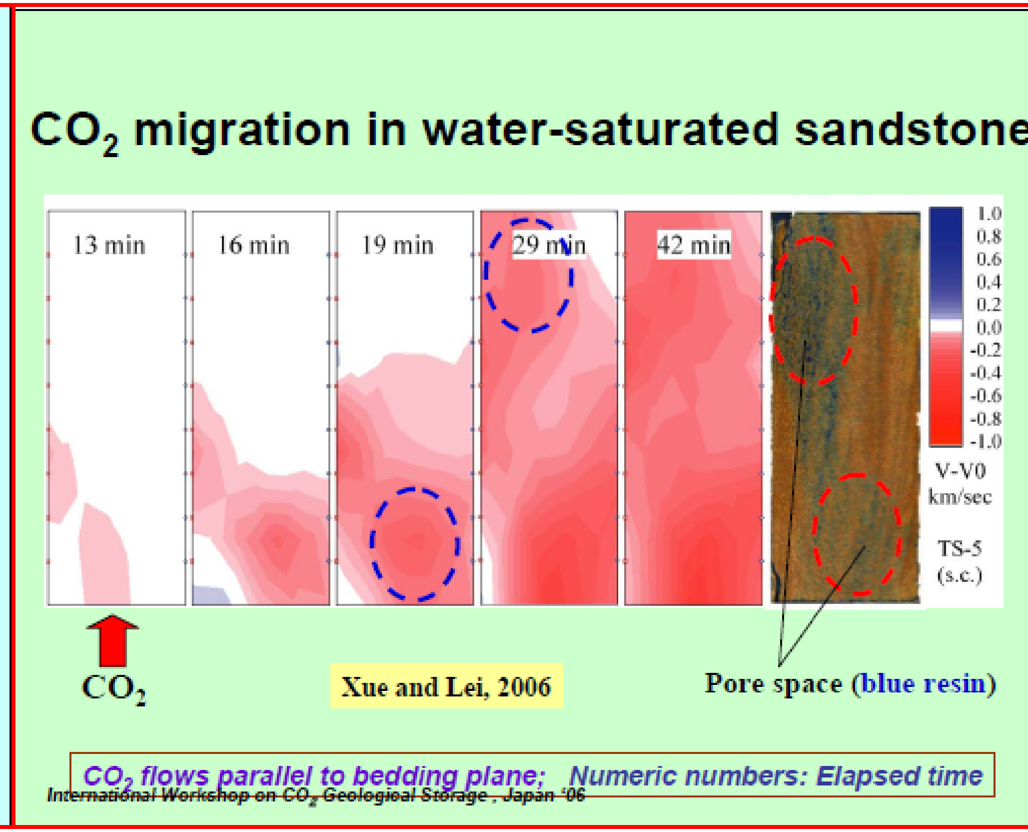
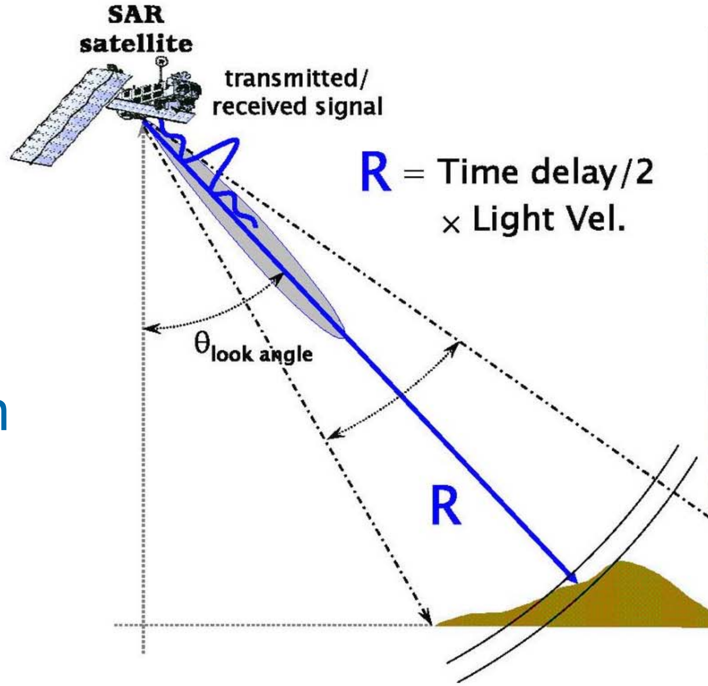


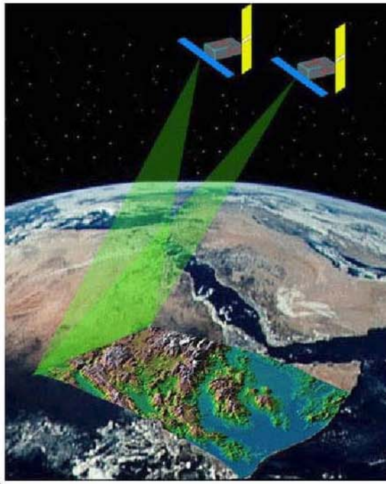


GEODETIC MONITORING WITH SATELLITE INTERFEROMETRY (INSAR)

This geodetic method uses two or more synthetic aperture radar (SAR) images to generate maps of surface deformation or digital elevation, using differences in the phase of the waves returning to the satellite.

InSAR scenes will be analyzed to obtain temporal variations in the length of the line of sight (LOS) between the regional ground surface and the satellite to estimate variations in permeability and monitor reservoir integrity with greater spatial coverage





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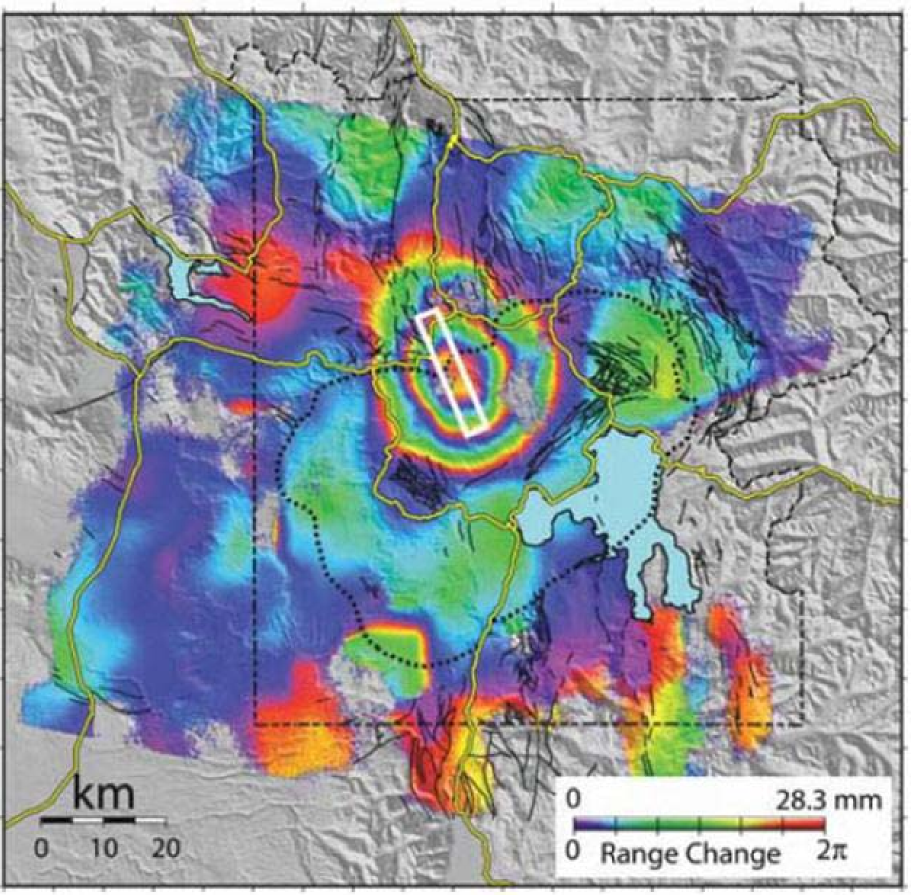


Produced 3-D vector surface deformation from two SAR satellites

We will use InSAR observations from multiple viewing geometries to obtain 2-D vector displacements with continuous spatial sampling.

By combining changes in line-of-sight range from multiple look directions, the pattern of surface deformation can be generated with unprecedented spatial resolution.

GPS MONITORING

10 geodetic dual frequency receivers with GSM communication system will be installed over the monitored area.

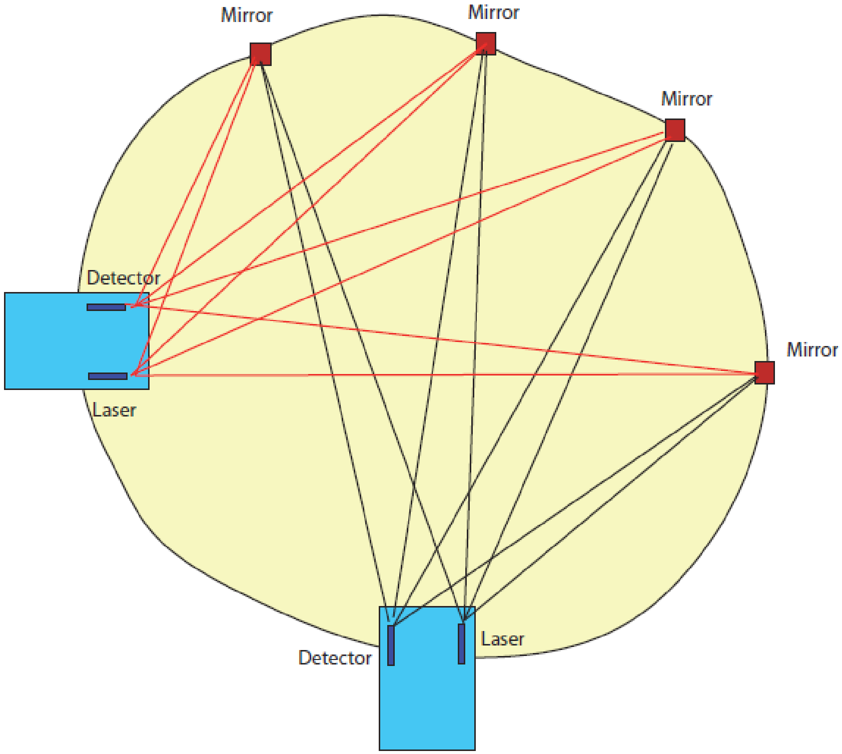
Five receivers will be used as roving sensors that will rotate between 45 campaign GPS sites over the monitored area.

Five of these receivers will be installed permanently. The expected inter-site spacing of the GPS monuments will be 1-2 km depending on the depth of the reservoir being monitored.

R DIODE LASER ABSORPTION FOR CO2 SURFACE LEAK DETECTION

CO2 surface leak detection during injection is important for safety reasons and can easily and cost-effectively accomplished by diode laser absorption

- CO2 Infra-Red diode laser absorption has been developed for combustion diagnostics
- Then used for heat seeking missile guidance and moving cars on roads
- Lately the Chinese have used it for human breath detection to localize survivors under earthquake rubbles
- Laser beam can travel kms without much attenuation and divergence
- It therefore presents an inexpensive and effective method for CO2 surface leak detection



CONCLUSIONS

- Since fossil fuels will continue to play a central role in the energy sector, CCS is expected to play the major role in the broader strategy to control the climate change.
- Abu Dhabi government has embarked on an ambitious plan to capture CO2 from a wide range of industrial plants for geological storage.
- Reservoir modeling is the only tool to forecast the subsurface CO2 migration and storage in a quantitative form to make engineering decisions.
- Several experimental and numerical modeling studies at the laboratory scale are needed to understand the interactions between the many coupled phenomena involved in CO2 geological storage and to improve the reservoir simulator predictions.
- Conventional and novel reservoir and surface monitoring tools are needed to validate the reservoir simulator predictions and to detect any early CO2 surface leaks.

Thank you

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