DYNAMIC EFFECT IN CAPILLARY PRESSURE-SATUARATION RELATIONSHIP FOR CO_2-H_2O-SAND SYSTEM: APPLICATION TO CO_2 SEQUESTRATION

BY

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INTRODUCTION

- Aquifers and reservoirs are primarily hosts to water and brine.
- Being water-wet, displacement pressure is required to overcome the capillary forces in order for oil or other non-wetting fluids to replace the original water/ brine.
- The capillary pressure curve describes the pressure required to displace from the rock a wetting fluid at initially 100% saturation to a given saturation.

Capillary pressure is a direct measurement of wettability (Anderson, 1987) and is employed in:

- determining reservoir initial fluid saturations and its variations across a reservoir.
- cap rock seal integrity.
- and as ancillary data in the assessment of relative permeability data.
- To find optimal well path in reservoirs of different or folded sand layers.

MULTIPHASE THEORY

- Traditional multiphase capillary equation

$$P_{nw} - P_w = P^c(S_w) \qquad (1)$$

- **CHALLENGES**

  - Assumes validity under all conditions
  - Assumes the capillary pressure to be a function of the wetting phase saturation only
  - Inability to describe dynamic portion of flow
  - Non-uniqueness of capillary pressure for drainage and imbibition

MODIFICATION TO CAPILLARY PRESSURE RELATION

$$P^{c,dyn} - P^{c,equ} = -\tau \frac{\partial S}{\partial t} \qquad (2)$$

Hassanizadeh and Gray (1990), Kalaydjian (1992).

Characteristics

- Accounts for dynamic portion of the flow
- τ is fluid and material property (Joekar-Niasah and Hassanizadeh, 2011).
- It is an indication of how close or far the system is to equilibrium (Das et al., 2007).
- τ may be related to phase trapping, capillary blockage (and consequently interfacial area) and contact angle (Hassanizadeh et al., 2002)

PREVIOUS WORK

PREVIOUS WORKS ON τ

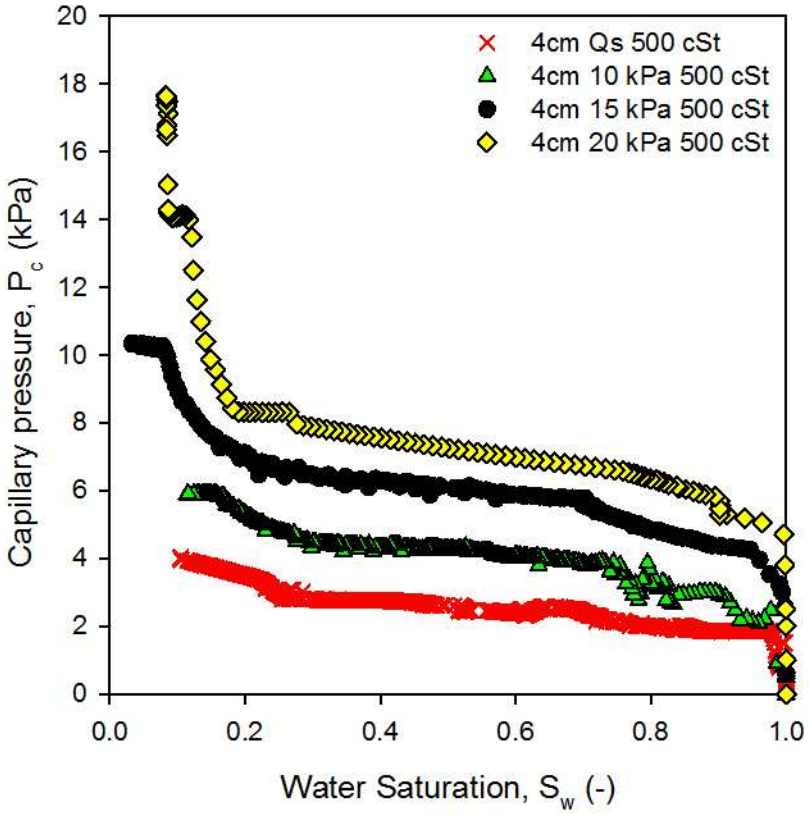
▪ Paraffin oil-water system	(Tsakiroglou *et al.*, 2006)
▪ Silicon oil-water-sand system	(Mirzaei and Das, 2007)
▪ PCE-water-sand system	(Das *et al.*, 2007; Bottero 2009)
▪ Multistep flow experiments	(O'Caroll *et al.*, 2005)
▪ Influence of wettability	(O'Caroll *et al.*, 2010)
▪ Grain size dependency and Upscaling.	(Camps-Roach *et al.*, 2010)
▪ Impacts on Unsaturated flow: vadoze zone.	(Hassanizadeh *et al.*, 2002)
▪ Dynamic Pore network model	(Joekar-Niasar and Hassanizadeh, 2010)
▪ Darcy-Scale models	(Das et al., 2005; Manthey et al., 2005)
▪ Pore-scale models	(Dahle *et al.*, 2005; Gielen *et al.*, 2005)

SILICONE OIL-WATER SYSTEM

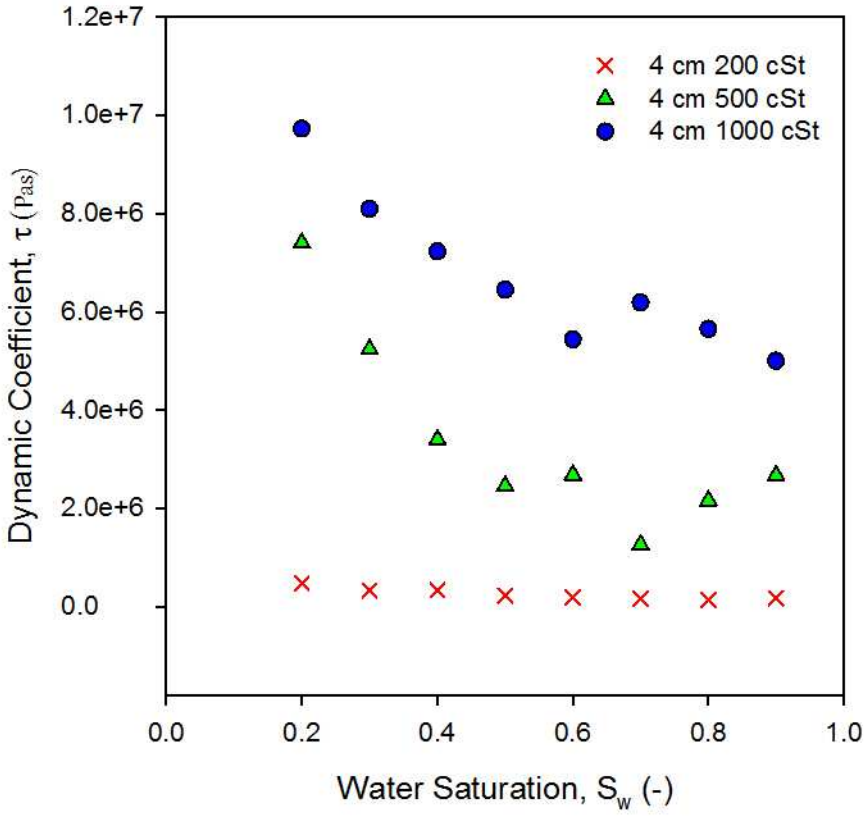
Preliminary experiments utilised silicone oil of the following viscosities with scales:

- Viscosities: 200, 500 and 1000 cSt
- Scales: 4, 8 and 12 cm.

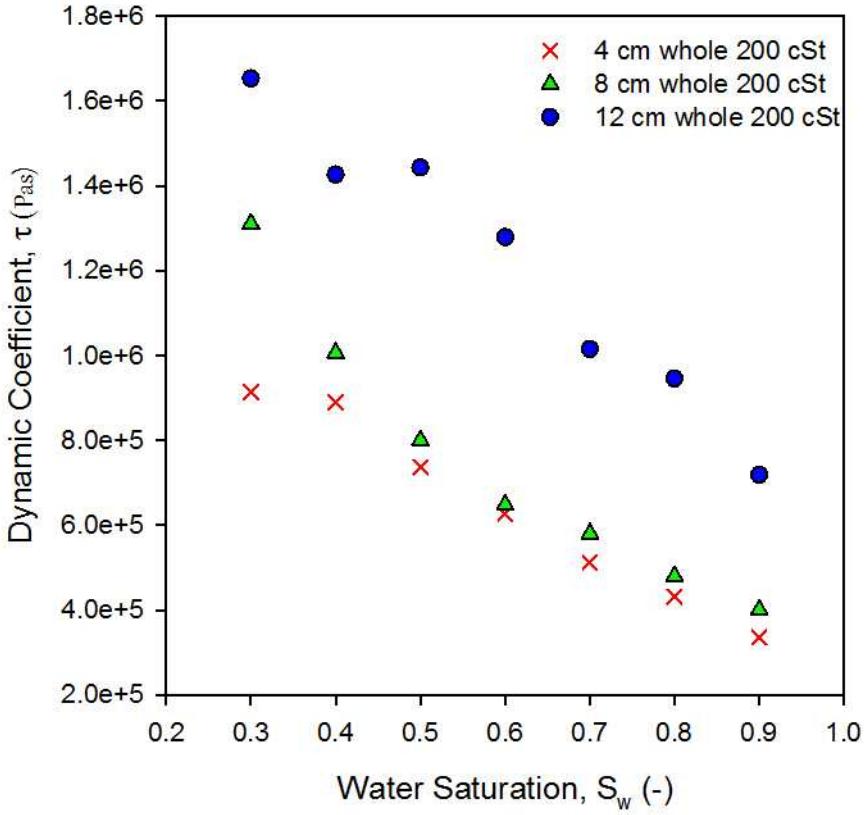
CAPILLARY-PRESSURE PROFILE



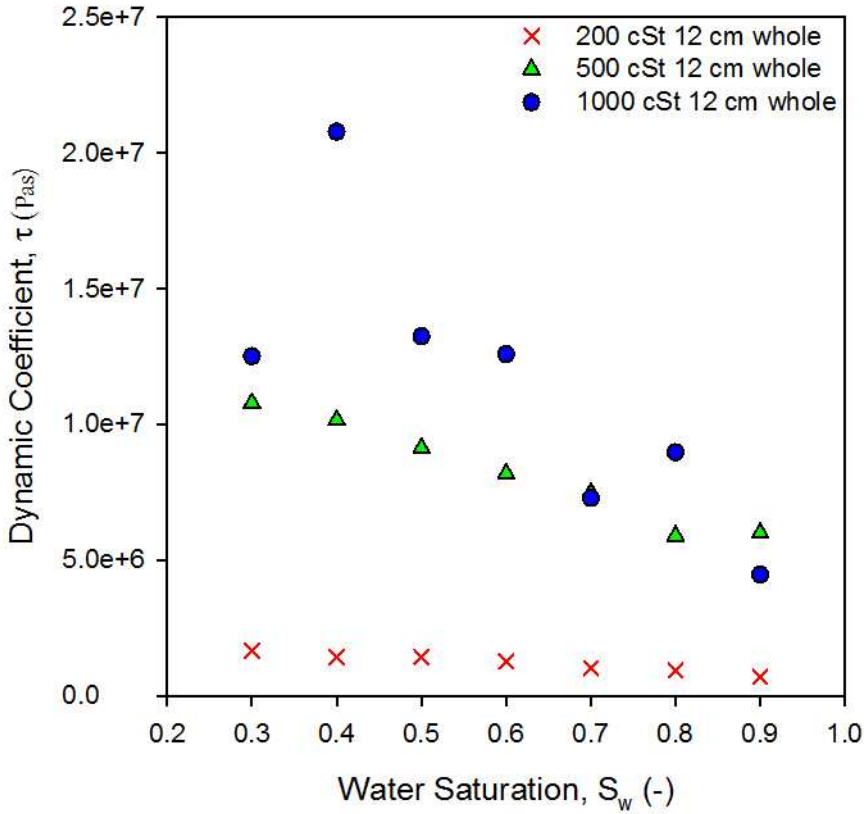
DYNAMIC COEFFICIENTS AT DIFFERENT SCALES AND VISCOSITIES



4, 8 and 12 cm – 200 cSt



200, 500 and 1000 cSt – 12cm (Whole)



NUMERICAL SIMULATION OF A CO_2-H_2O SYSTEM

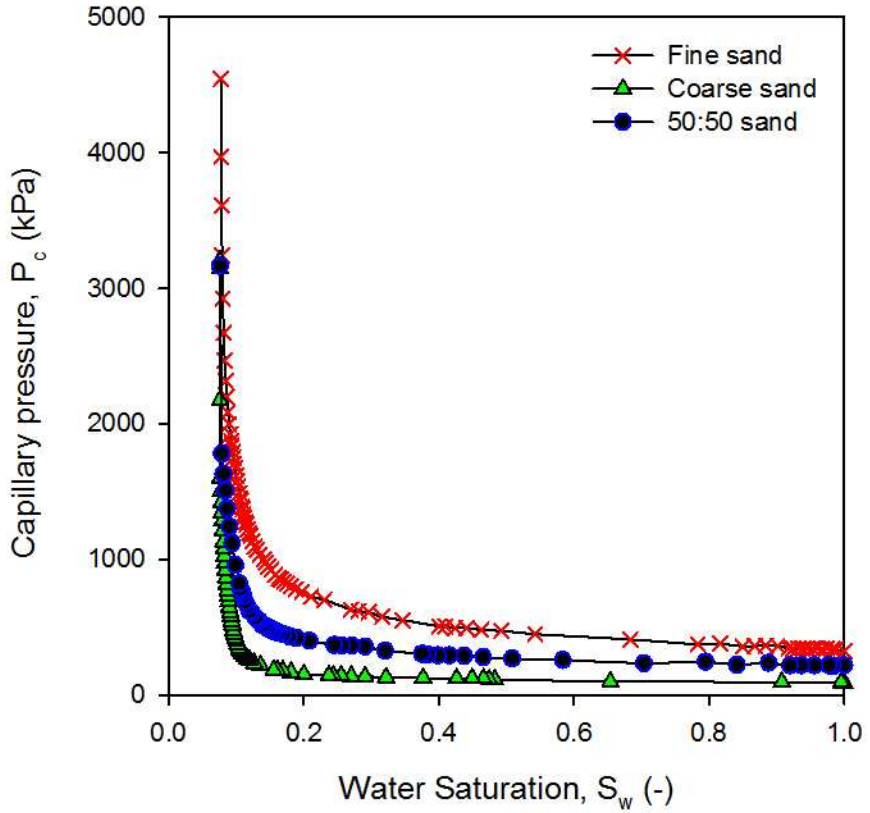
Software

- Subsurface Transport over Multiple Phases (STOMP) (PNNL, USA).

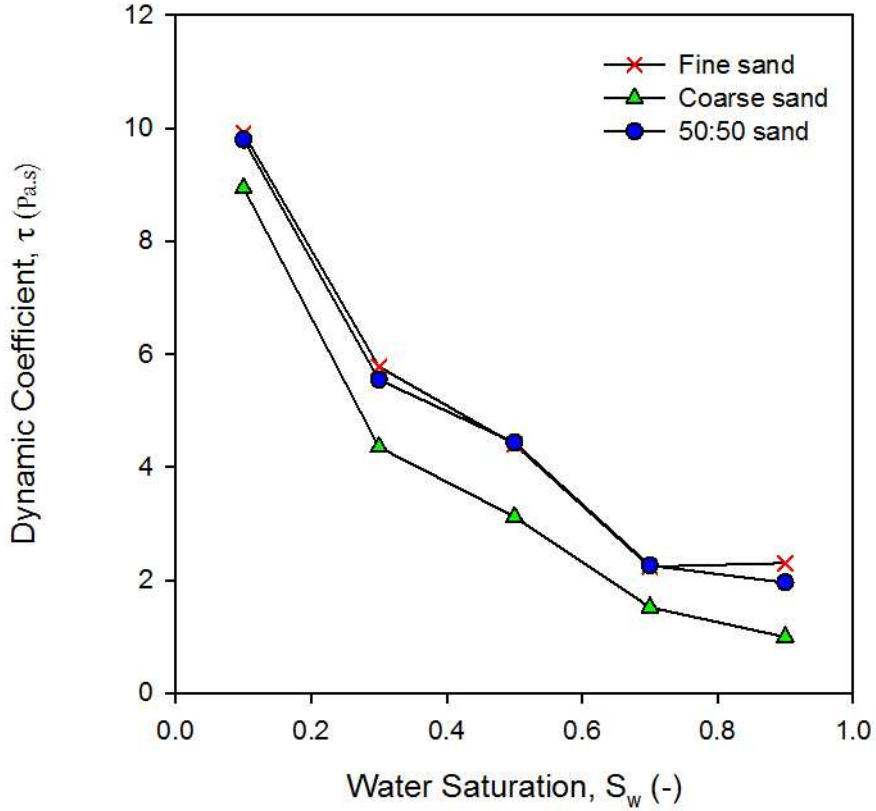
Material Properties (Permeability)

- Fine Sand (5. 66 x 10^{-11} m^2)
- Coarse Sand (3.65 x 10^{-10} m^2)
- Mixed Sand (5.95 x 10^{-11} m^2)

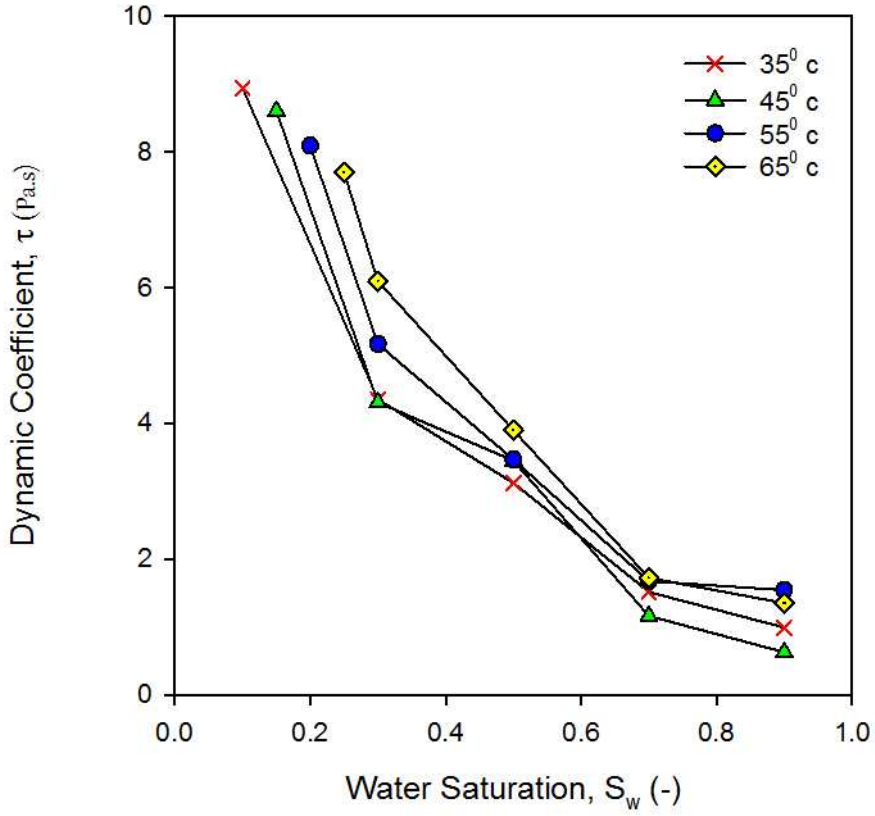
EFFECTS OF MATERIAL PROPERTY ON P_C-S_w RELATION @35



EFFECTS OF MATERIAL PROPERTIES ON DYNAMIC EFFECTS



EFFECTS OF TEMPERATURE (COARSE)



Similar Findings

- Effects of Upscaling : Bottero et al., (2011 a, b)
- Effects of Viscosity : Goel and O'Carroll (2011)
- Effects of Temperature: Hanspal and Das (2010)

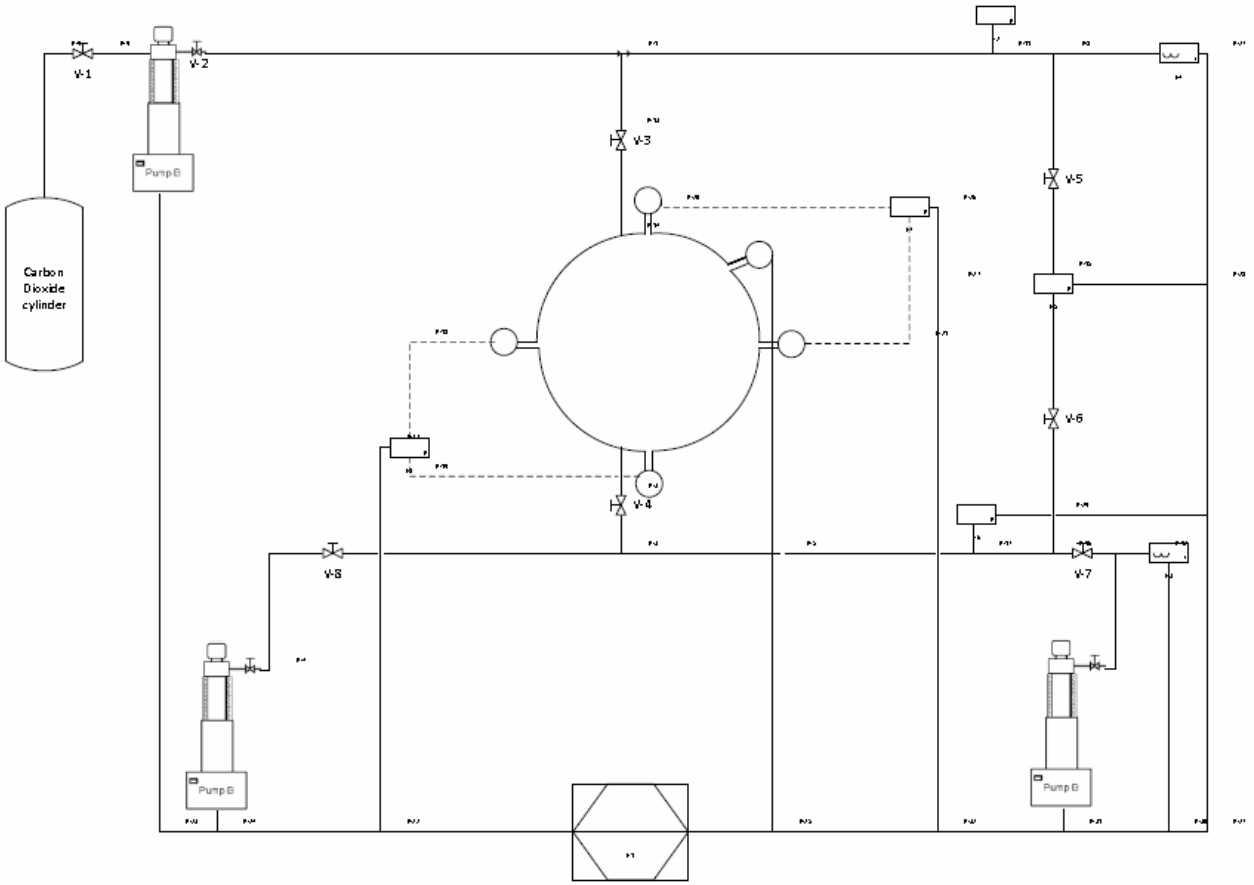
Previous P_c-S_w Works on CO_2- Water System:

- Plug and Brunning (2007): Capillary Pressure – Saturation Relationship. Water not brine.
- Pentland et al. (2011); End Capillary pressure and Irreducible saturation as well as capillary trapping.

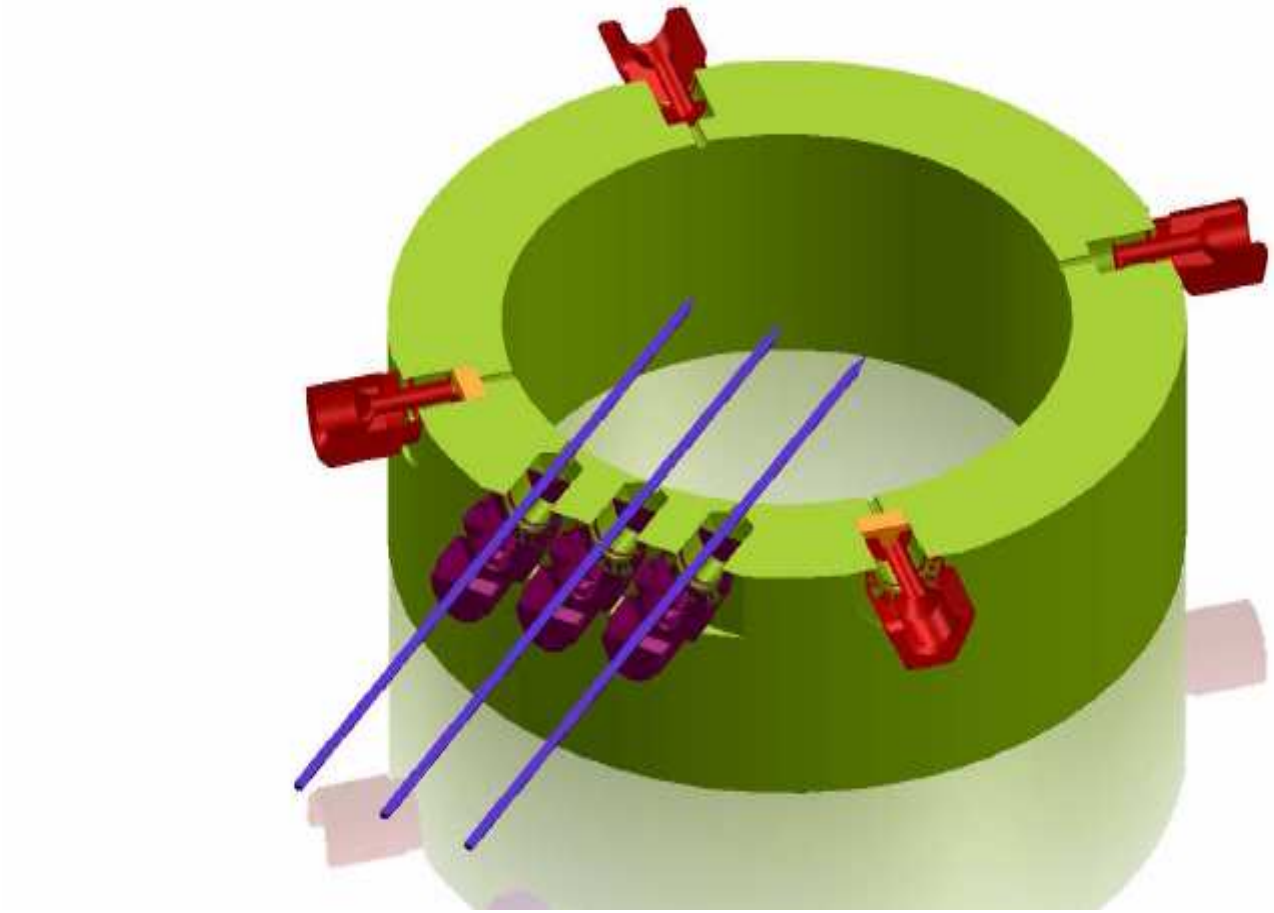
WHAT IS NEW?

- P_c-S_w relationship for CO_2-water/brine under quasi static and dynamic drainage and imbibition.
- Investigation of the relationship in different porous media; fine and coarse sands .
- Determination of the dynamic effects and coefficients for above systems.

PROPOSED EXPERIMENTAL SETUP



IN-SITU PRESSURE MEASUREMENT



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THANK YOU FOR LISTENING