DOE-ARRA Geologic Sequestration Training and Research 2011 Yearly Review Meeting

Project DE-FE0002190 Title: Rock Physics of Geologic Carbon Sequestration/Storage

Stanford University

Presenter: Dr. Gary Mavko/Jack Dvorkin, Department of Geophysics

February 24-26, 2011

Project Participants

- List project participants
- Dr. Gary Mavko -- PI
- Dr. Jack Dvorkin
- Amrita Sen – Ph.D. Candidate
- Adam Tew -- Ph.D. Candidate
- Nishank Saxena -- Ph.D. Candidate

Introduction

- Background – CO_2 geologic sequestration has been conducted by several petroleum companies. The challenge is often monitoring the location of the injected gas in the subsurface. Another challenge, of course is to select a reservoir for sequestration (enough storage, no leakage). Monitoring and selecting is based on remote (often seismic) imaging of the subsurface. Rock physics helps relate the seismic properties to porosity, permeability, and fluid location. The rock physics of CO_2 geologic sequestration is practically nonexistent neither are rock physics experts.

- Anticipated benefits -- (a) train experts in the rock physics of monitoring, verification, and accounting (MVA) of CO_2 and (b) establish a framework for an industry standard for predictive modeling of the said parameters.

Project Objectives

- Major Objective -- The primary objective of this effort is to establish theoretical rock physics relations between the type of CO_2 injection (pressure and volume versus time) into clastic and carbonate reservoirs and the resulting changes in the reservoir's texture, porosity, elastic-wave velocity, electrical formation factor, and permeability. This work will be conducted by Ph.D. candidates and, hence, results thus produced will:

- Train experts in the rock physics of monitoring, verification, and accounting (MVA) of CO_2 and
- Establish a framework for an industry standard for predictive modeling of the said parameters

Project Funding

- Total Project Cost: $ 385,276
- DOE Share: $ 295,777
- Non-DOE Cost Share: $ 89,499
- Cost Share Provider: (Stanford Rock Physics Laboratory)

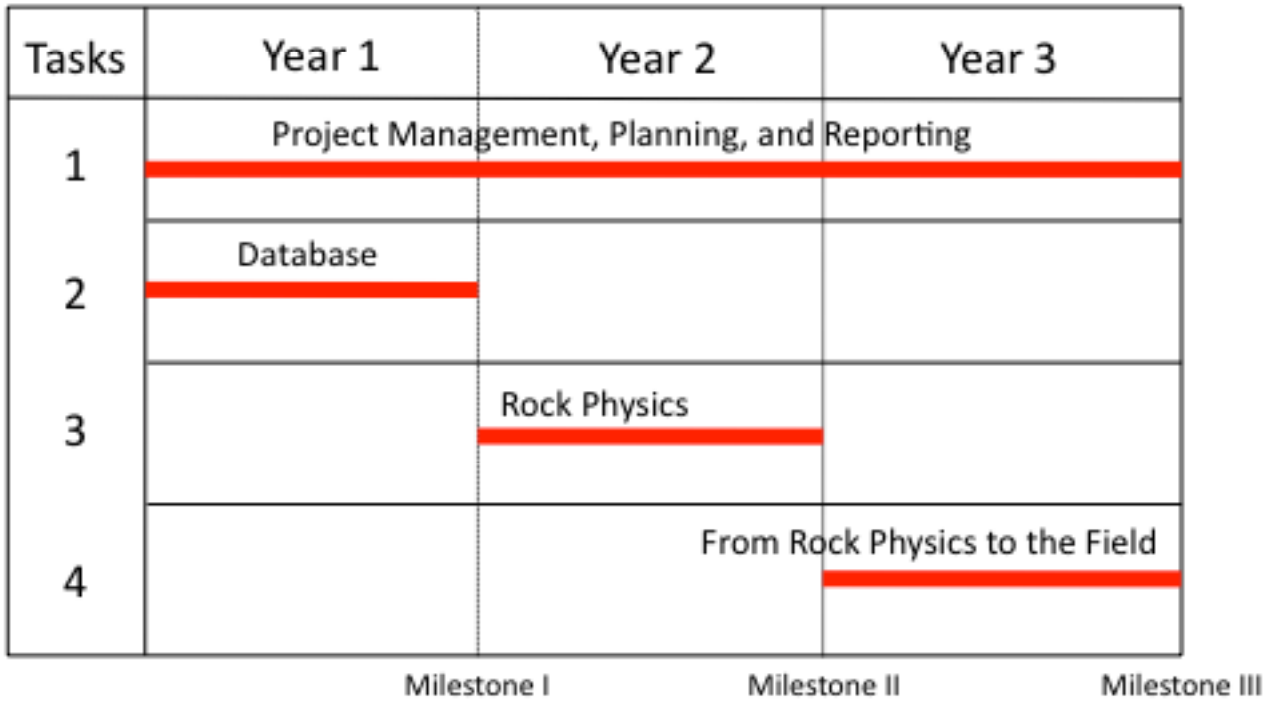
Highlights of Project to Date

- Database on rock properties related to CO_2 sequestration has been completed.
- Part of developing rock physics of CO_2 sequestration – effects of pore fluids (CO_2 + water) on the elastic properties of the host rock.

Tasks – Overview

Task No.	Task Description	Task Duration	Task Funding
1	Project Management and Planning	12/01/2009 – 11/30/2012	$ 31,879
2	**Database.** Compile a systematic database of existing laboratory data on CO_2 sequestration and storage as well as field observations. Include into consideration geological and geochemical variables. Link these variables to mineral and mineral frame alterations.	12/01/2009 – 11/30/2010	$ 114,580
3	**Rock Physics.** Use the database to identify potential changes in sediment fabric due to CO_2 sequestration and storage. Theoretically link these changes to the elastic properties of rock. Derive concurrent variations in permeability and electrical conductivity using appropriate existing theoretical models.	12/01/2010 – 11/30/2011	$ 117,766
4	**From Rock Physics to Field.** Use the rock physics framework thus established to explain existing filed observations and forecast plausible seismic responses by means of synthetic seismic cataloguing.	12/01/2011 – 11/30/2012	$ 121,051

Project Schedule

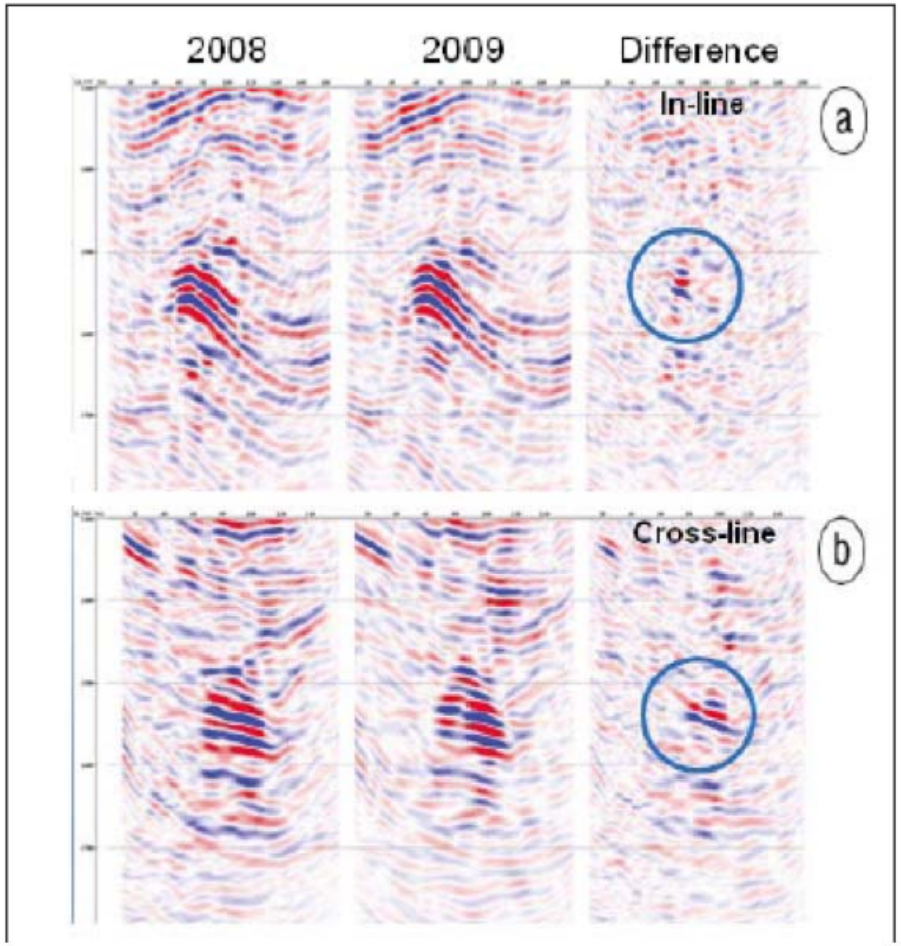


Discussion – Task 2

- Task 2: Compile a database of existing experimental data on the effects of CO_2 injection and storage on the said rock properties as well as the properties of CO_2 itself and its interactions with other reservoir fluids.
- Responsible parties: Mavko, Dvorkin, Sen.
- Task Status (100 % complete)
- Major accomplishments:
- (a) Seismic database has been completed
- (b) Rock data database has been completed

Discussion – Task 2

Seismic Study E ¶



Urosevic, M., Shulakova, V., and Sharma, S., 2010, Time-lapse seismic monitoring of CO2 injection into a depleted gas reservoir-Naylor Field, Australia, The Leading Edge, February 2010, 164-169.

Discussion – Task 2

Tiziana Vanorio, Stanford Rock Physics Laboratory

		Before Injection				After Injection			
Sample ID	**Injected Volumes***	**Φ (%)**	**k (mD)**	**Vp (m/s)**	**Vs (m/s)**	**Φ (%)**	**k (mD)**	**Vp (m/s)**	**Vs (m/s)**
5139	730	15.4	255	3628	2333	16.4	565	3523	2193
RU7855A	710	25.4	15.3	4095	2383	24.6	>4000	3917	2111
MA2a	40	28.6	135.3	2745	1488	29.1	140.6	2581	1371
MA2b	25	23.6	4.9	3786	2194	23.7	4.9	3112	1619
MA2d	771	29.8	135.7	3014	1905	33.2	750.5	2403	1397
MA3d	722	26.5	75.3	3528	2088	31.5	448.9	2657	1645

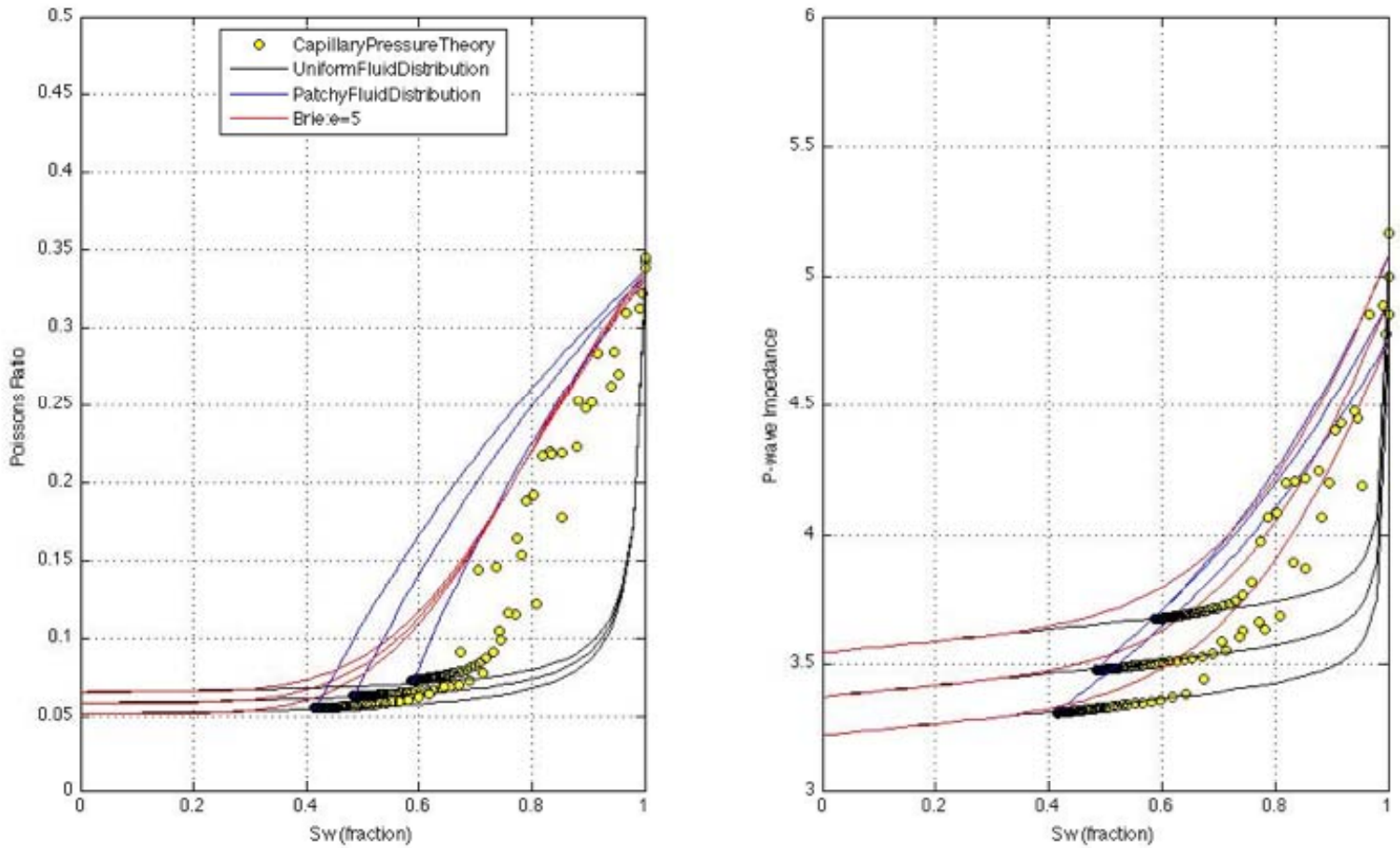
*in numbers of initial pore volumes

Discussion – Task 3

- Task 3: Use the database to identify potential changes in sediment fabric due to CO_2 sequestration and storage. Theoretically link these changes to the elastic properties of rock. Derive concurrent variations in permeability and electrical conductivity using appropriate existing theoretical models.

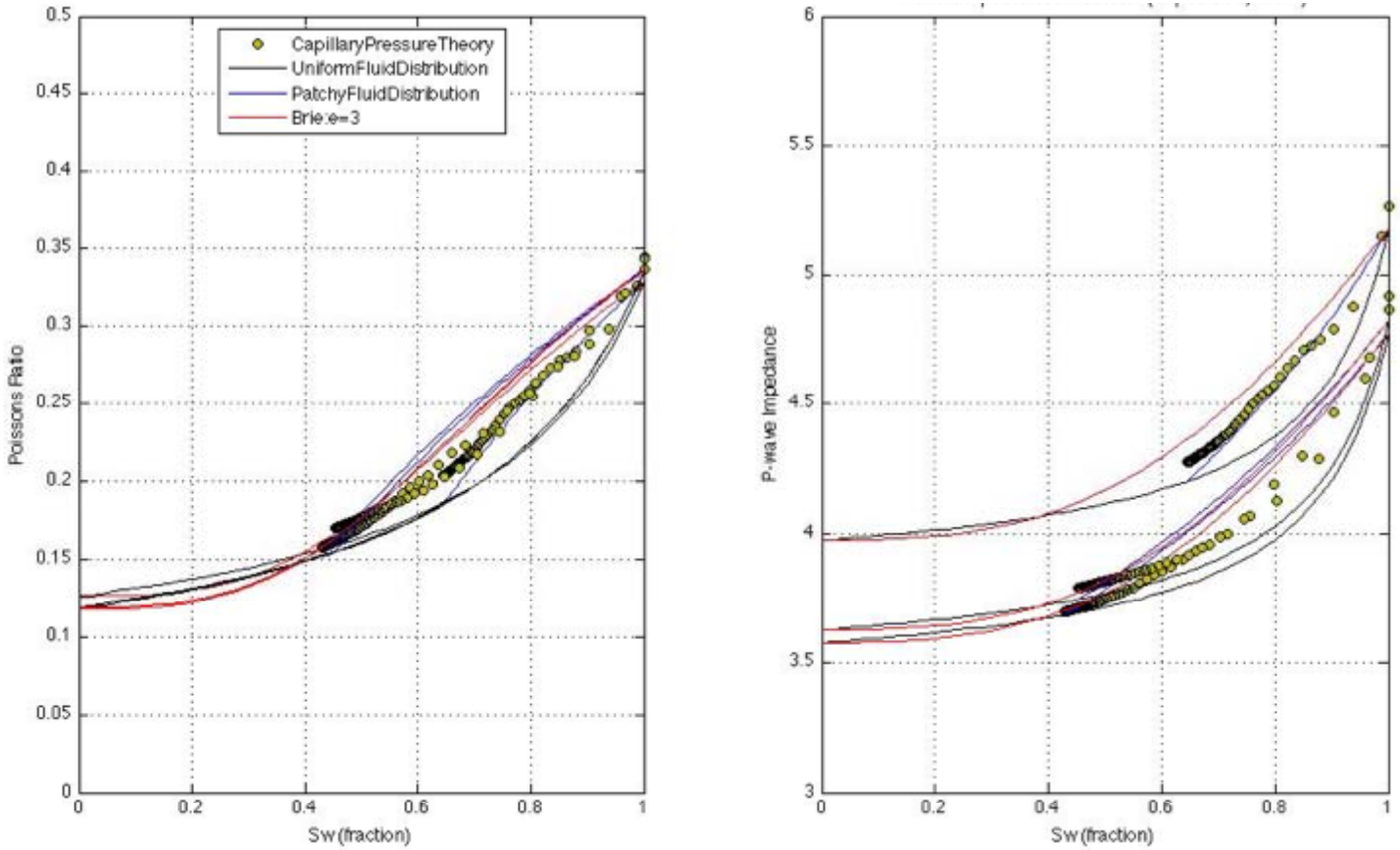
- Responsible parties: Mavko, Dvorkin, Sen, Tew.
- Task Status (30 % complete)
- Major accomplishments:
- (a) A new physically relevant fluid substitution method has been developed.

Discussion – Task 3



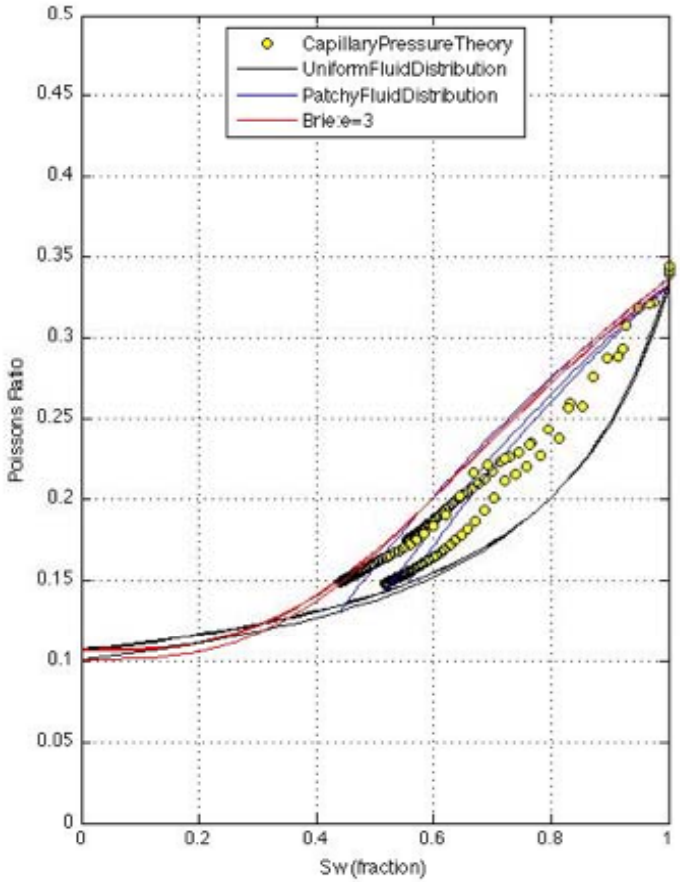
Impedance and Poisson's Ratio versus Water Saturation for a Gas CO_2 and water saturated Troll unconsolidated sand reservoir.

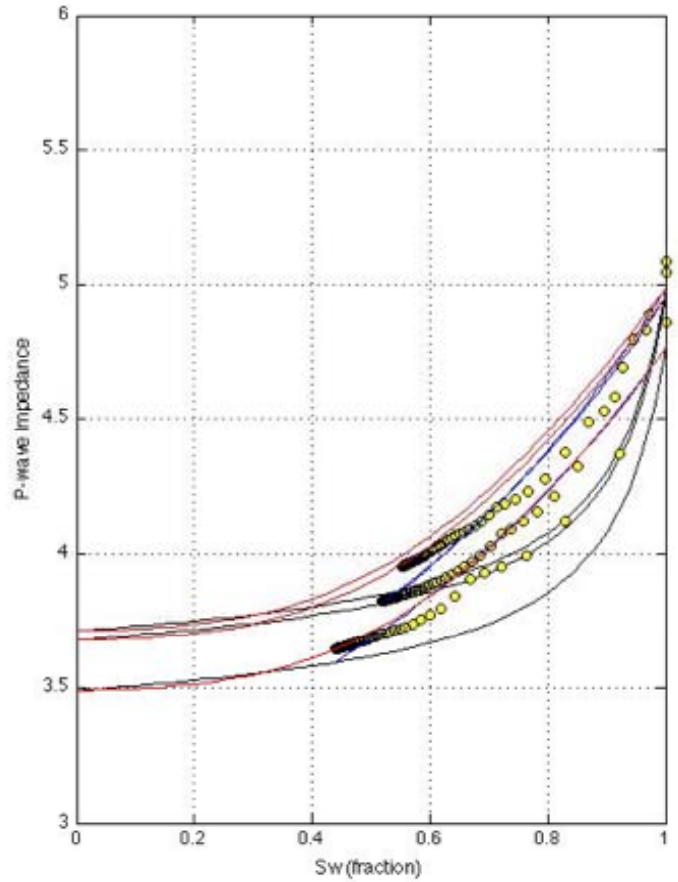
Discussion – Task 3



Impedance and Poisson's Ratio versus Water Saturation for a Liquid CO_2 and water saturated Troll unconsolidated sand reservoir.

Discussion – Task 3





Impedance and Poisson's Ratio versus Water Saturation for a Supercritical CO_2 and water saturated Troll unconsolidated sand reservoir.

Discussion – Task 4

- Task 4: . Use the rock physics framework thus established to explain existing filed observations and forecast plausible seismic responses by means of synthetic seismic cataloguing.
- Responsible parties:
- Task Status (0 % complete)
- Major accomplishments: Scheduled start date 12/1/11

Project Milestones

(Include HQ and project milestones)

Milestone	Planned Completion Date	Actual Completion Date
HQ Milestone: Project Kickoff Meeting	3/31/2010	3/26/2010
Database	11/30/2010	11/30/2010
HQ Milestone: Educational Program Instituted	06/30/2010	01/2/2010
HQ Milestone: Semi-Annual Progress Report	09/30/2010	08/5/2010
HQ Milestone: Yearly Review Meeting	03/31/2011	02/23/2011
HQ Milestone: Semi-Annual Progress Report	09/30/2011	
Rock Physics	11/30/2011	
HQ Milestone: Yearly Review Meeting	03/31/2012	
From Rock Physics to Field	11/30/2012	

Anticipated Efforts for the Coming Year

- Activity 1: Theory for the elastic property variation and porosity and permeability variation during CO_2 injection into reactive rock.
- Activity 2: Combining the elastic theory with fluid substitution theory.
- Activity 3: Effects of reactive rock alteration on permeability – theory based on lab data.

PI Contact Information

- If you have any questions or would be interested in collaboration please contact
- mavko@stanford.edu