ELASTIC IMPEDANCE ANALYSIS FOR METHANE AND CO_2 DISCRIMINATION IN COALBEDS

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OUTLINE

- Objective
- Introduction
- Theoretical development
    - Gassmann Fluid Substitution
    - Elastic Impedance
- Area of study
- Methodology
- Results
- Conclusions

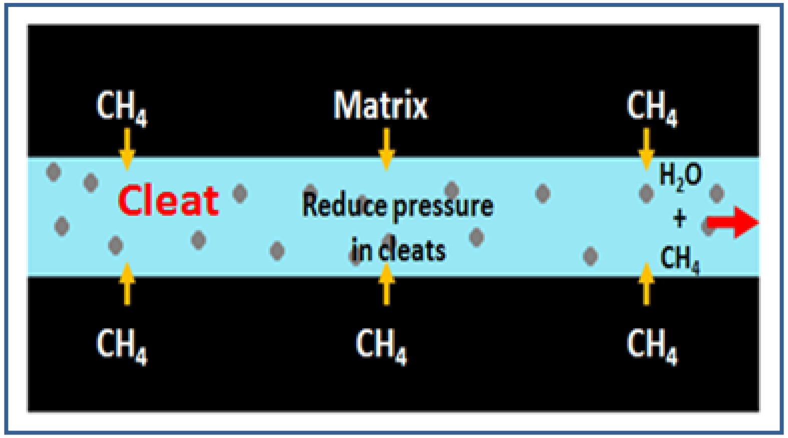
OBJECTIVE

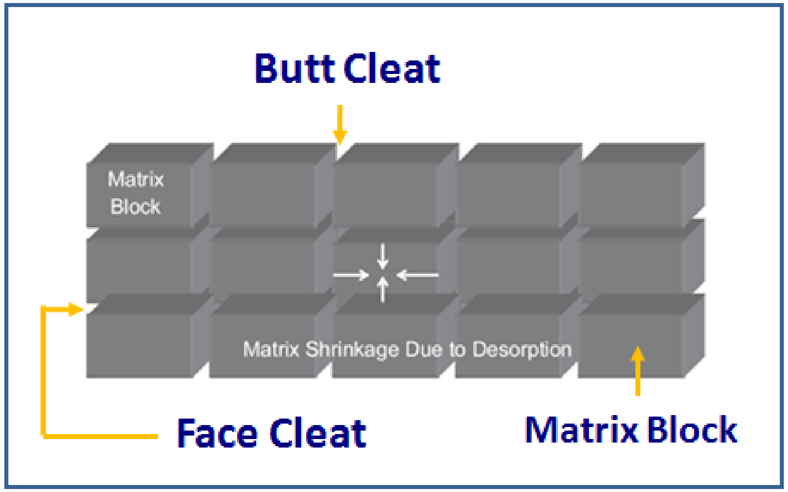
- Attempt to discriminate coals saturated with methane from coals saturated with CO_2 by estimating Elastic Impedance
- Evaluate the possibility of monitoring the movement of the CO_2 flood by using this attribute

INTRODUCTION

Coalbed Methane

- Unconventional resource
- Dual porosity system
- Methane production
- Coal matrix deformation





GASSMANN FLUID SUBSTITUTION

$$K^{*} = \frac{K_{sat}\left(\frac{\phi\, K_{0}}{K_{fl}} + 1 - \phi\right) - K_{0}}{\frac{\phi K_{0}}{K_{fl}} + \frac{K_{sat}}{K_{0}} - 1 - \phi} \qquad (1)$$

Gassmann´s equation (1951)

Applications:

- Information for well data analysis
- AVO Response
- 4D surveys

ELASTIC IMPEDANCE (EI)

- EI derivation is based on the Aki and Richards (1980) linearization for the Zoeppritz equation

- EI is defined as:

$$\mathbf{EI} = \mathbf{V_p}^{(1+\tan^2\theta)} \, \mathbf{V_s}^{(-8K\sin^2\theta)} \, \boldsymbol{\rho}^{(1-4K\sin^2\theta)} \qquad (2)$$

θ = incidence angle
$K = (V_s/V_p)^2$

- For $\theta=0$, EI=AI

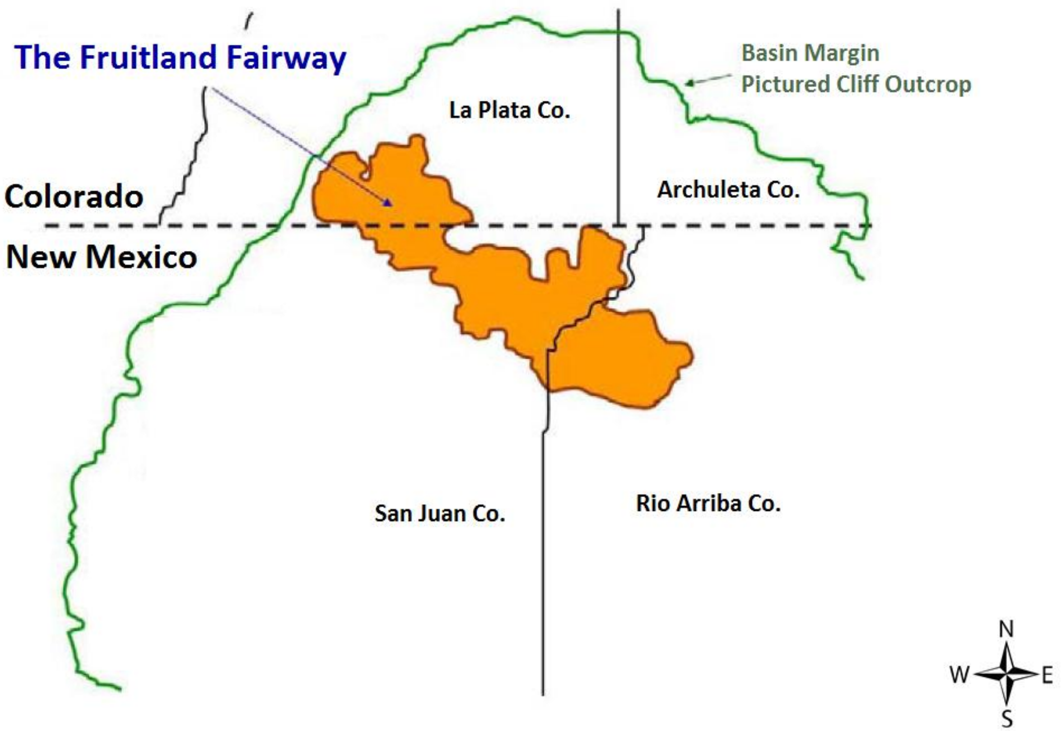
ELASTIC IMPEDANCE

Applications of EI:

- Calibration of far offset seismic data
- Perform a preliminary evaluation of the amplitude versus offset (AVO) response
- Changes in Elastic Impedance can be evaluated to determine a correlation with any rock property that allows us to achieve; for example, lithology or fluid discrimination

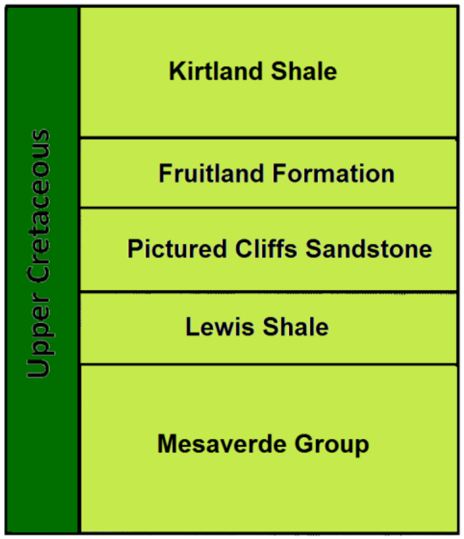
AREA OF STUDY

San Juan Basin Fruitland Coal- Location map



(Figure 1 from Ramurthy and Lyons, 2007)

Stratigraphic column of the San Juan Basin



(Modified from Figure 2, Young et al., 1991)

METHODOLOGY: Fluid simulation

- Proxy model of the Fruitland Coal Fairway in the San Juan Basin
- Vertical single well model: it allow us to evaluate the relative permeability and relative adsorption data
- The reservoir model was developed the following properties:

Model assumptions	
Coal thickness	15.24 m (50 ft)
Top of the coalbed	914.4 m (3000 ft)
Grid size	175x175x1
Area of study	31.4 km^2
Absolute permeability	80 mD
Initial pressure	1616 psia
Temperature	41.66 ^oC
Initial water saturation	100%

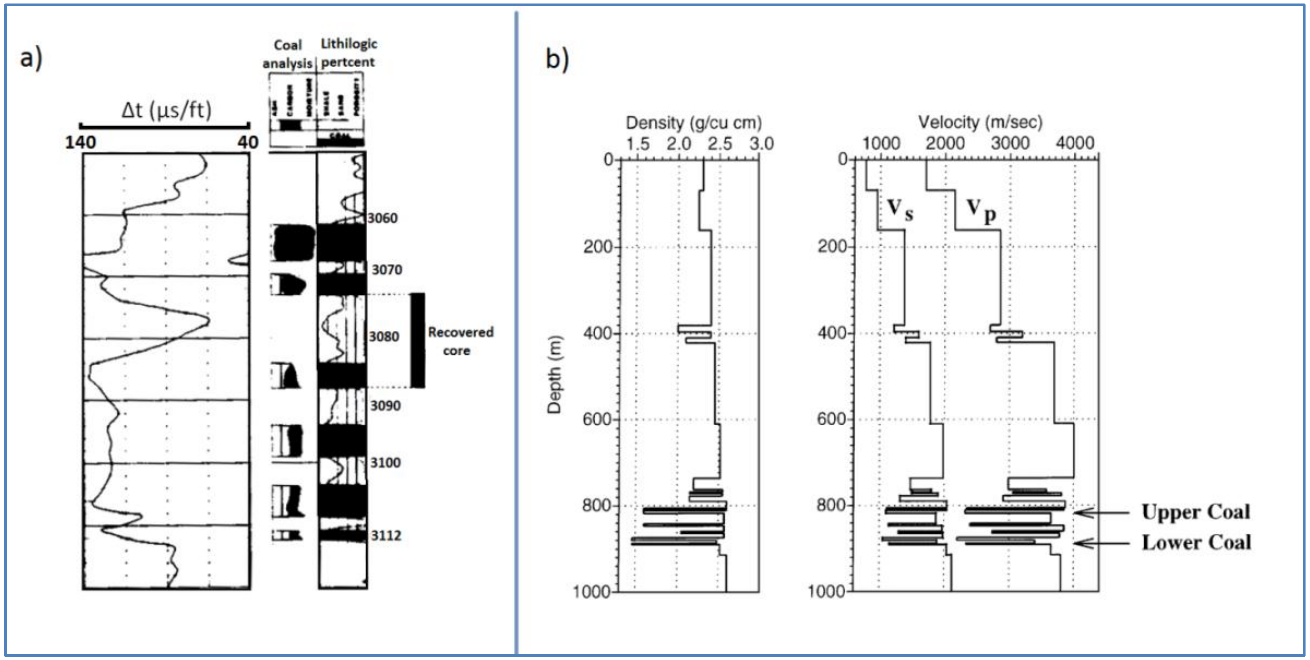
METHODOLOGY: Fluid simulation

Reservoir model:

- Perform the production forecast of primary depletion for 24 wells in the area of study
- The production forecast started in 1999 and extends until 2031
- Perform production forecast of enhanced coalbed methane by CO_2 injection. In this case, 4 CO_2 injection wells were added to the model
- Assume that the injection started in July 2003 and was shut in October 2010 and the forecast continuous until 2031

METHODOLOGY: Gassmann fluid substitution

Parameters for fluid substitution	
V_p	2450m/s
V_s	1025m/s
Density	1.6 g/cm^3



a) Sonic log of Glover Well 1. Archuleta County, San Juan Basin (Modified from Figure 6, Jones et al., 1984) and b) V_p, V_s and density model from the Hamilton 3 well, Cedar Hill, San Juan Basin. (Figure 8, Ramos and Davis, 1997)

METHODOLOGY: Gassmann fluid substitution

- Estimate the fluid properties with equations presented by Batzel and Wang (1992)

- Based on fluid simulation results, we perform a Gassmann fluid substitution for the following cases:

  - Primary production
  - Enhanced coalbed methane by CO_2 injection. Two years after injection started
  - One year after stopping CO_2 injection

- Estimate Elastic Impedance for each model

METHODOLOGY

Fluid simulation

- Vertical Single well
- Reservoir model

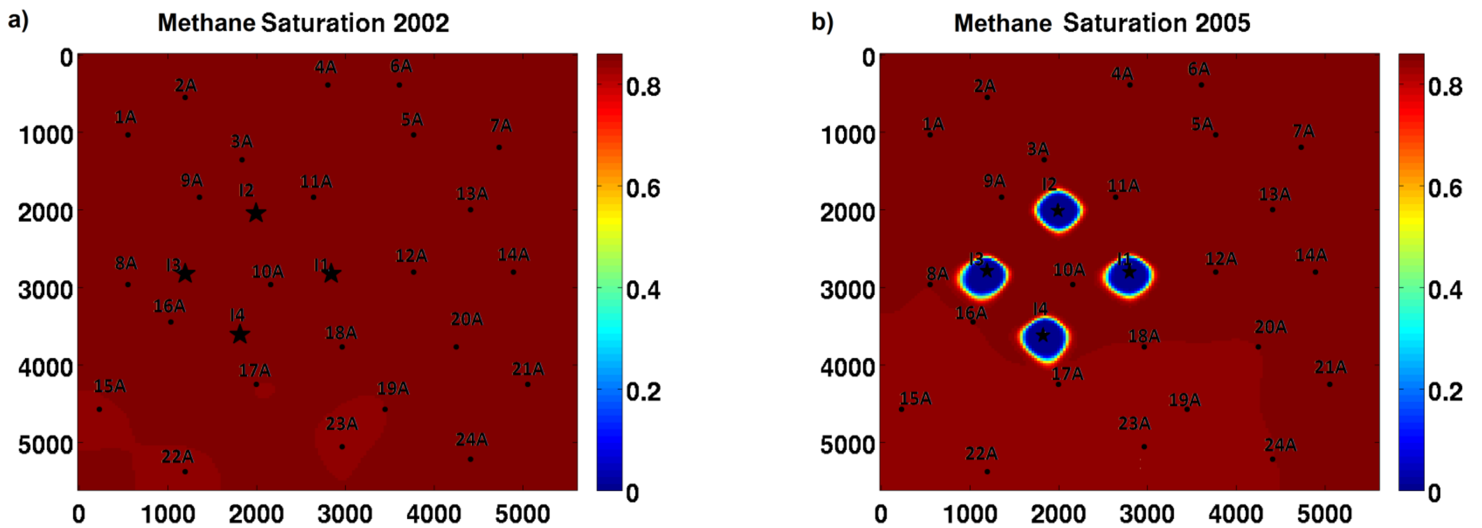
Fluid substitution

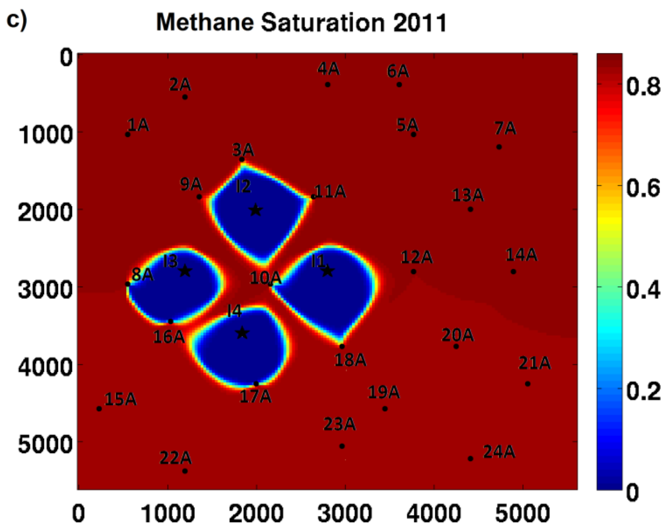
- Initial state: 100% Brine
- Primary production (2002 model)
- Enhanced Coalbed methane by CO_2 injection. Two years after injection (2005 model)
- One year after stopping injection (2011 model)

Elastic Impedance

- Primary production (2002 model)
- Enhanced Coalbed methane by CO_2 injection. Two years after injection (2005 model)
- One year after stopping injection (2011 model)

RESULTS: Fluid simulation



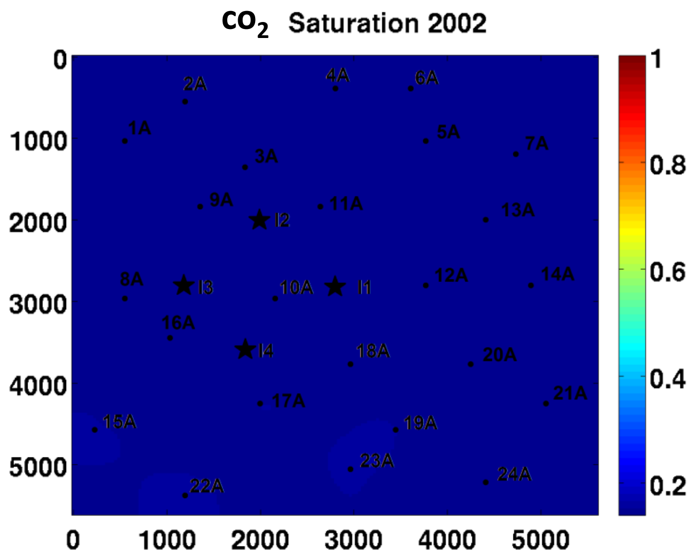


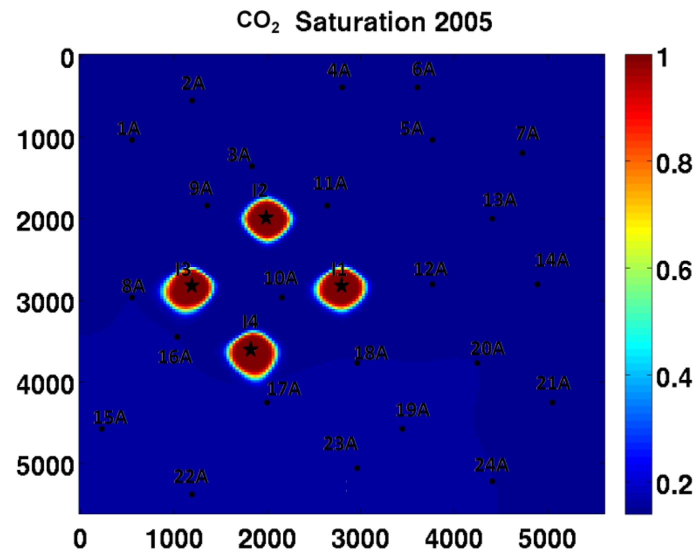
Methane Saturation decrease 80% to less than 15%

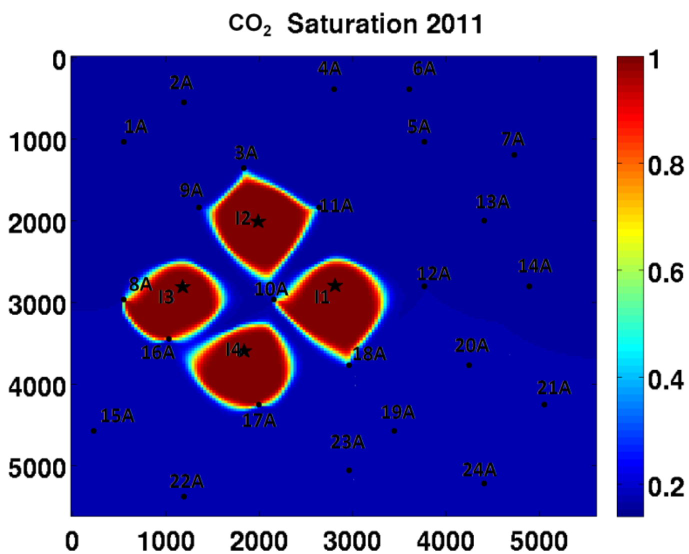
★ **Injector**

● **Producer**

RESULTS: Fluid simulation



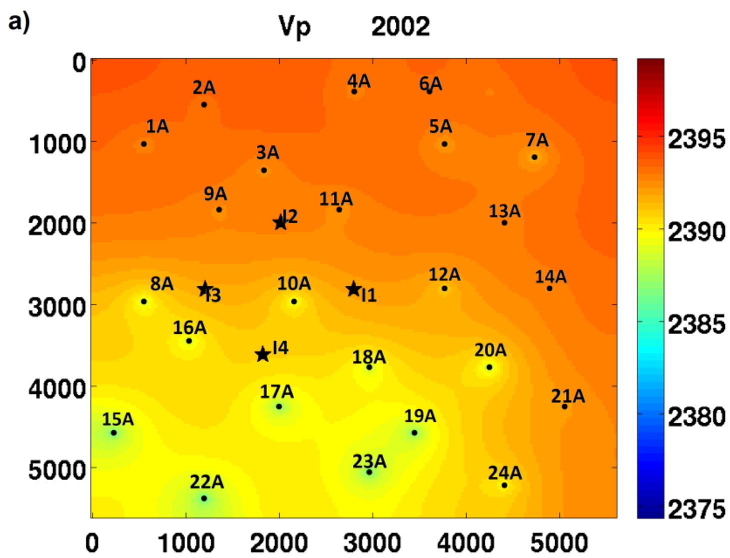


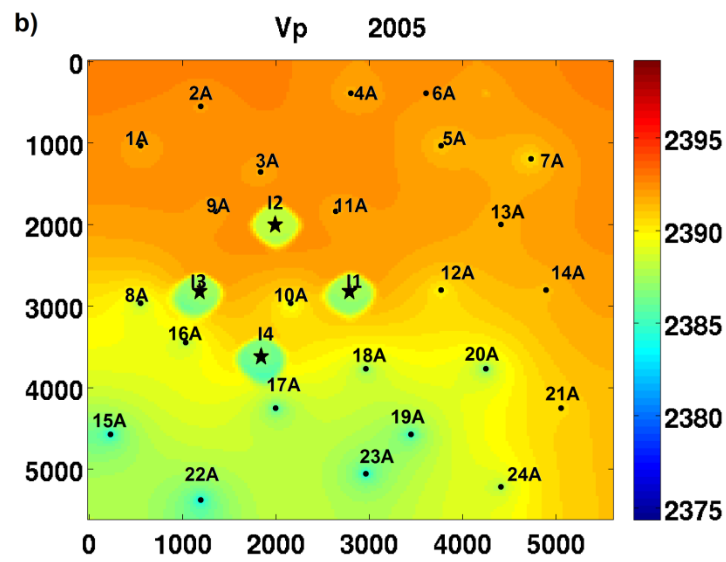


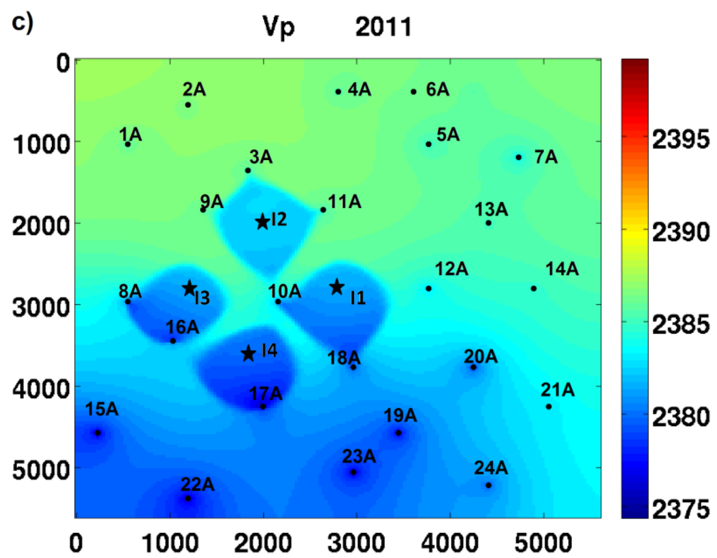
CO_2 Saturation increase from 20% to 85%

★ Injector
● Producer

RESULTS: Gassmann Fluid Substitution







Vp decrease:

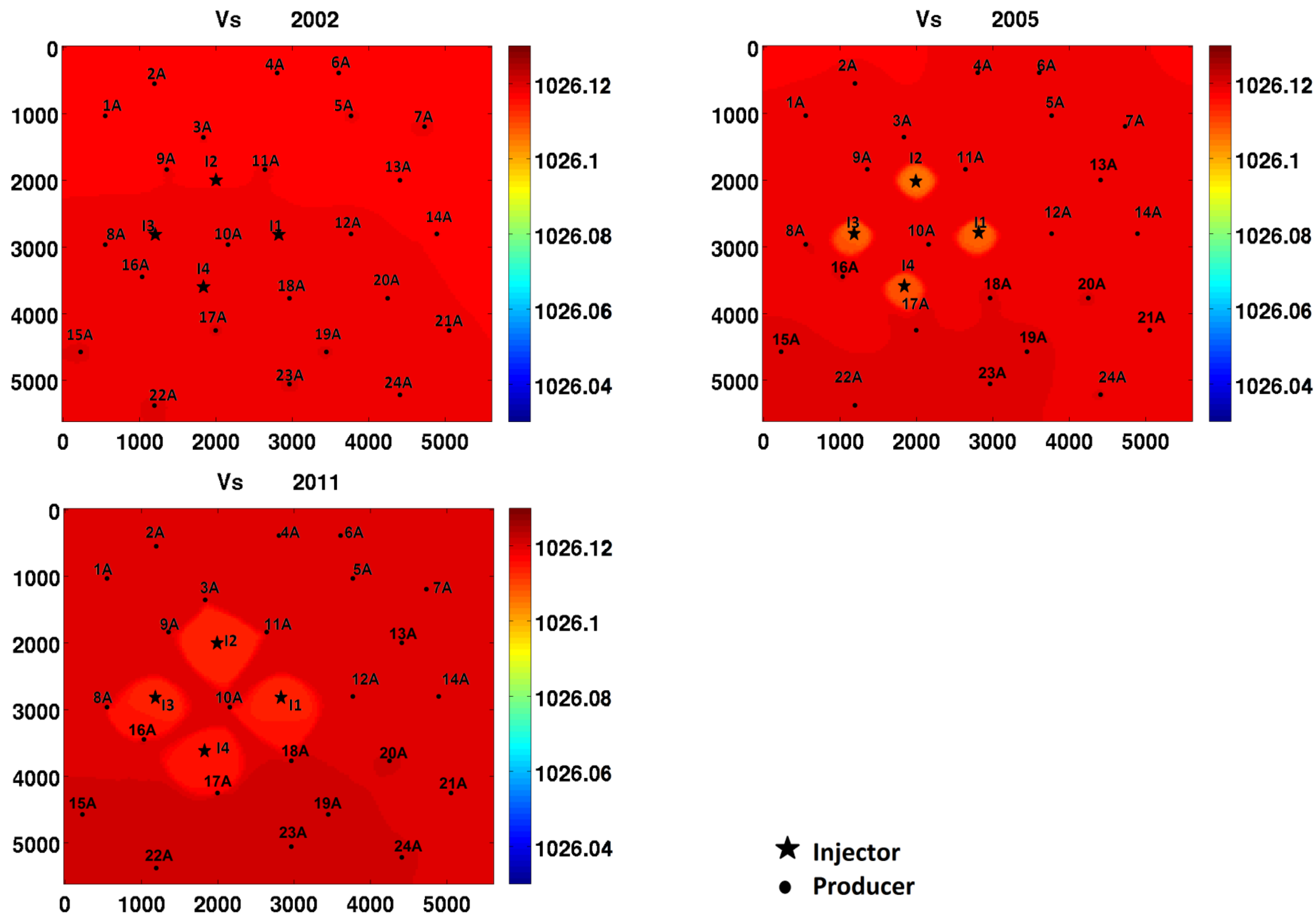
~ 55m/s for the primary production case

~ 65m/s after CO_2 injection

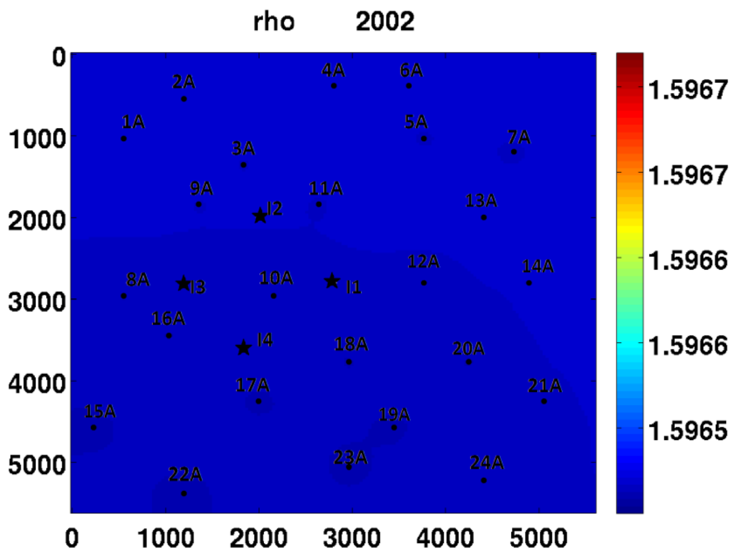
★ Injector

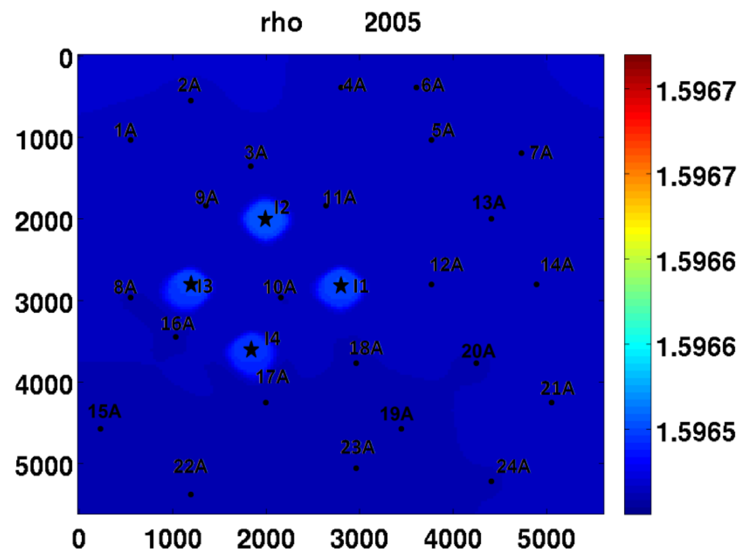
● Producer

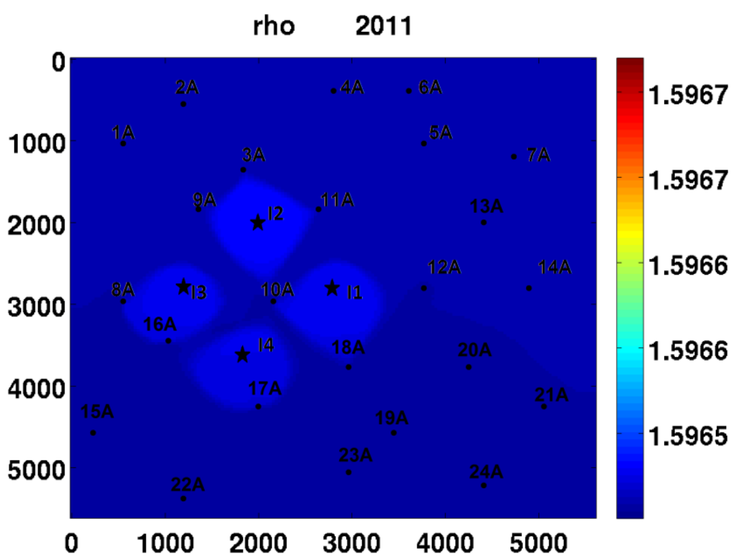
RESULTS: Gassmann Fluid Substitution



RESULTS: Gassmann Fluid Substitution

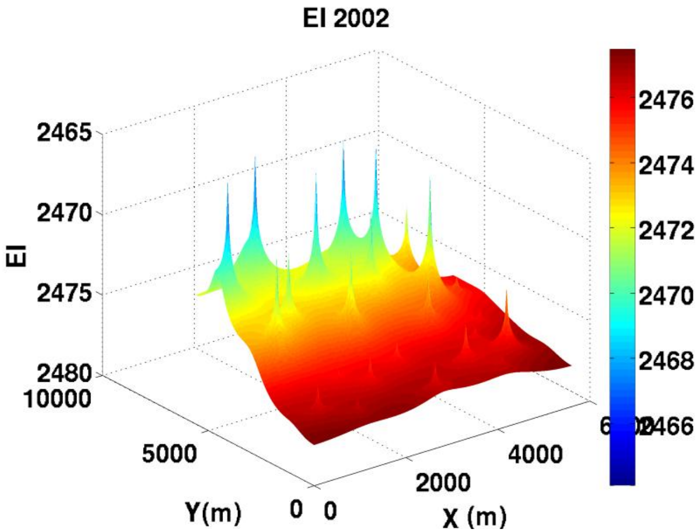


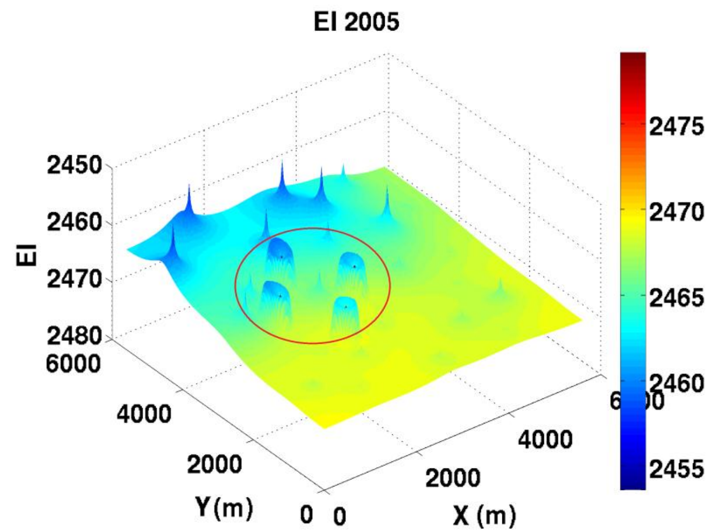


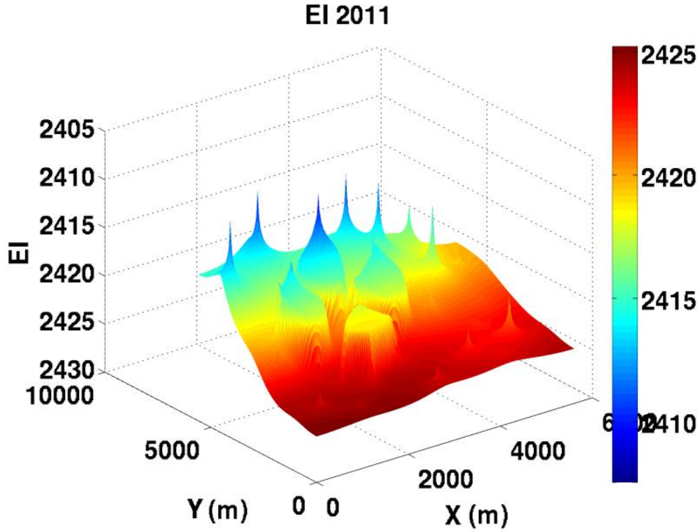


★ Injector
● Producer

RESULTS: Elastic Impedance (EI)







- CO_2 flood during and after injection

★ Injector
● Producer

SUMMARY

- The fluid simulation gives us important information about the distribution of CO_2, methane and brine, as well as the saturation of each of them

- The fluid simulation provides the data required to perform the fluid substitution and estimate changes in V_p, V_s and density

- The changes in V_p, after replacing brine by methane, were a decrease ~ 55m/s for the primary production case and ~ 65m/s after CO_2 injection

- The movement of the CO_2 flood can be appreciated in the velocity maps and it is associated to a decrease in V_p

SUMMARY

- In the case of the V_s and density, the changes present a small magnitude
- Elastic Impedance was not able to completely differentiate the presence of CO_2 and methane but it was possible to monitor the movement of the CO_2 flood during and after injection

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QUESTIONS