Impedance analysis for methane and CO_2 discrimination in coalbeds

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ABSTRACT

- Objective: Assuming 100% of brine as initial saturation, we develop a fluid simulation and a Gassmann fluid substitution to model the variation of Vp, Vs and density due to changes in fluid saturations
- We determine whether is possible to discriminate methane and CO_2 in coalbeds, and monitor the movement of an injected CO_2 flood, by using Elastic Impedance Coefficient
- Evaluated cases: Several years after depletion, 2 years after CO_2 injection starts, and 1year after stopping injection
- Area of study: Fruitland coals Fairway, in the North of the San Juan Basin U.S
- Target: 15.25m coalbed at a depth of 914.4m over an area of 31.4km^2

ELASTIC IMPEDANCE AND ELASTIC IMPEDANCE COEFFICIENT

- Elastic Impedance is a function that relates the compressional wave velocity (V_p), the shear wave velocity (V_s), and the density according to:

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

where θ is the incidence angle (Connolly, 1999) and K is defined as a constant over the section of interest, and it is estimated as the mean value of $(V_s/V_p)^2$ (Whitcombe, 2002)

- In 2008, Cao et al. introduced the concept of the Elastic Impedance Coefficient (EC)

$$EC = \frac{AI}{EI}, \quad (2)$$

where AI is the Acoustic Impedance

METODOLOGY

Fluid simulation

- Build a vertical single well model of the Fruitland Coal Fairway in the San Juan Basin, and perform the history match using its production data
- The single well model allow us to evaluate the relative permeability and relative adsorption data
- Reservoir : Model a single coalbed layer with a thickness of 15.24m (50ft) at a depth of 914.4m (3000ft),over an extension of 31.4 km^2 and using a 320-acre spacing for the producing wells
- Perform production forecast of primary depletion for 24 wells in the area of study. It started in 1999 and extends until 2031
- Perform production forecast of Enhaced Coalbed Methane (ECBM) production by CO_2 injection, using 4 CO_2 injection wells. Injection period: July 2003-October 2010

Gassmann fluid substitution

- Gassmann Fluid substitution assuming 100% brine as initial condition

$$K_{sat} = K^* + \frac{\left(1 - \frac{K^*}{K_0}\right)^2}{\frac{\phi}{K_{fl}} + \frac{(1-\phi)}{K_0} - \frac{K^*}{K_0^2}} \quad (3)$$

K_{sat}: Bulk modulus of the saturated rock
K^*:Bulk modulus of the frame of the rock
ϕ: Porosity
K_0: Mineral matrix bulk modulus
K_{fl}: Bulk modulus of the fluids in the pore space

RESULTS

- The magnitude of the changes in density and Vs are almost imperceptible
- Vp decrease from 2450m/s to 2385-2395m/s when replacing brine by methane (Figure 1a)
- After CO_2 injection: Lower Vp values in the areas surrounding the injector wells due to increase of CO_2 saturation in that zone of coalbed (Figure 1b)
- After shutting injector wells: The CO_2 flood seems to be moving to the South, where the area presents the lower pressures (Figure 1c)

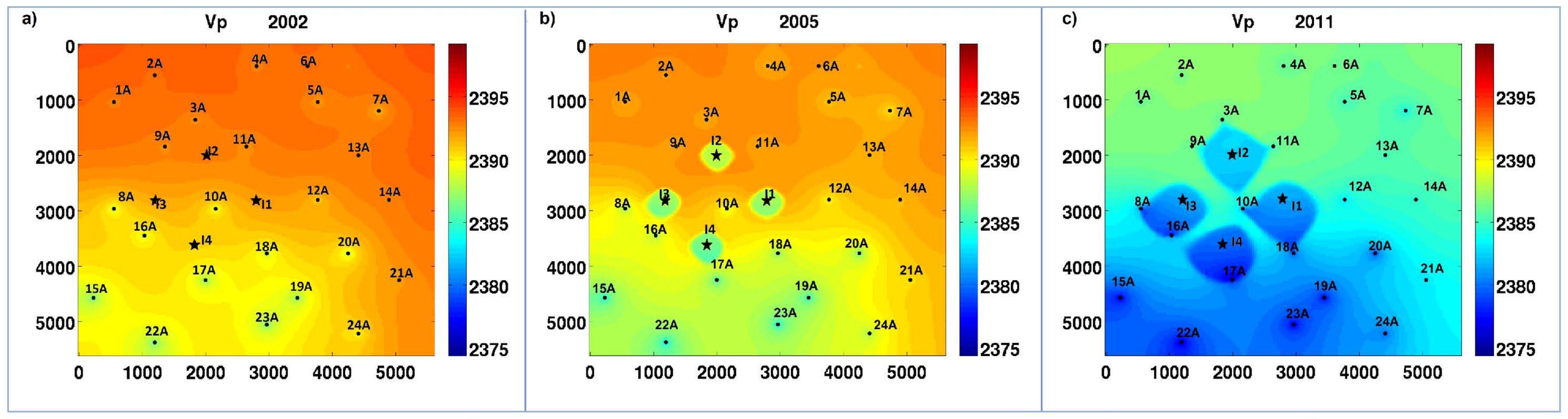

FIG. 1. Vp variation due to depletion and CO_2 injection a) After several years of depletion, b) 2 years after starting injection and c) 1 year after shutting the injector wells

- EC do not provide a good discrimination between methane and CO_2 in the coalbed
- The changes in EC allow us to monitor the movement of the CO_2 injected (Figure 2b and 2c)
- The injection zones have a high EC response and the footprint of the CO_2 is evident

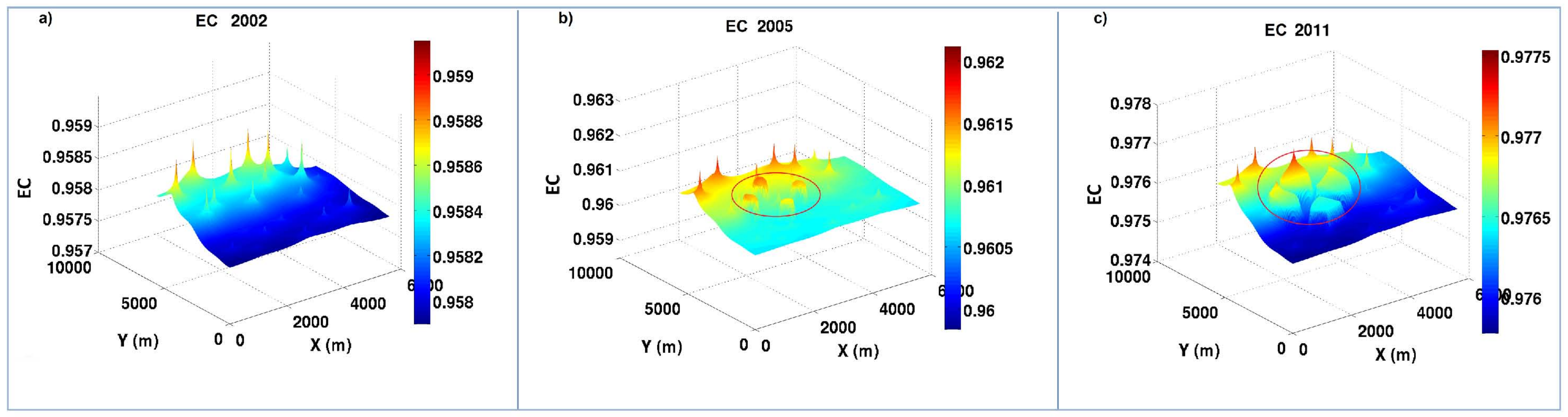

FIG. 2. Variations of th eElastic Impedance Coefficient (EC) due to depletion and CO_2 injection a) After several years of depletion, b) 2 years after starting injection and c) 1 year after shutting the injector wells

CONCLUSIONS

- The movement of the CO_2 flood can be appreciated in the velocity maps and it is associated to a decrease in V_p
- EC was not able to discriminate the presence of CO_2 from methane, but it was possible to monitor the movement of the CO_2 flood during and after injection
- The changes in EC are small and it is difficult to determine if they are going to be evident in seismic

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