# The compositional simulation and seismic monitoring of CO2 EOR and sequestration in new gas condensate reservoir

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# OUTLINE

Background and Motivation

Method

Reservoir model

Simulation results

Conclusion

# Background and Motivation

(1) CO2 can be stored in coal, in aquifer and in mature oil reservoir. We will try it in new reservoir taking advantage its flooding capability to speed up recovery.

(2) In gas condensate formation, when the reservoir pressure around production wells drops below the dew point pressure, liquid hydrocarbon phase called condensate is formed and decrease gas productivity significantly. CO2 injection will keep pressure level higher to delay or relieve this problem.

(3) Can seismic signal catch the front when the density contrast is not so big in gas condensate wells than in aquifer ?

# Method

## (1) Reservoir simulation:

Model the CO2 EOR and sequestration by the compositional simulation using CMG/GEM.
PVTSIM is used for fluid characterization with Peng-Roberson Equation of State.
Geochemical effect would be neglected in short term EOR process.

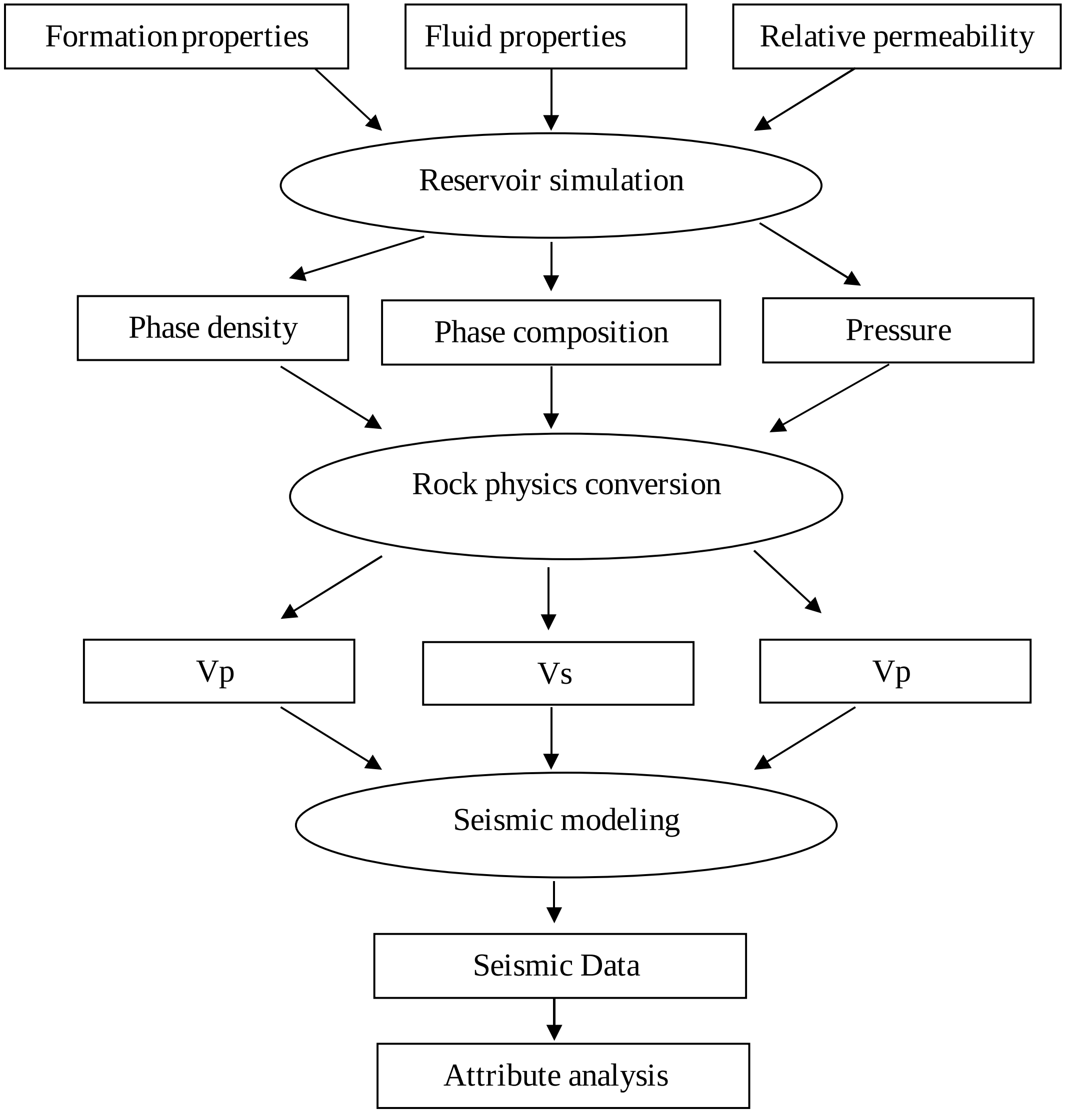
## (2) Rock physics conversion

Gassmann equation (Gassmann, 1951; Mavko, 1998) is used to convert reservoir properties to seismic properties.
Fluid properties are computed using the empirical formula (Batzle and Wang 1992; Vargaftik, 1975).

## (3) Seismic modeling.

Poststack seismic data using the simple convolution model now.
In future, we would extend to pre-stack seismic modeling using finite difference.

# Flow chart



Formation properties

Fluid properties

Relative permeability

Reservoir simulation

Phase density

Phase composition

Pressure

Rock physics conversion

Vp

Vs

Vp

Seismic modeling

Seismic Data

Attribute analysis

# Reservoir model

One quarter of the 5-spot well pattern.

50*50 cells.

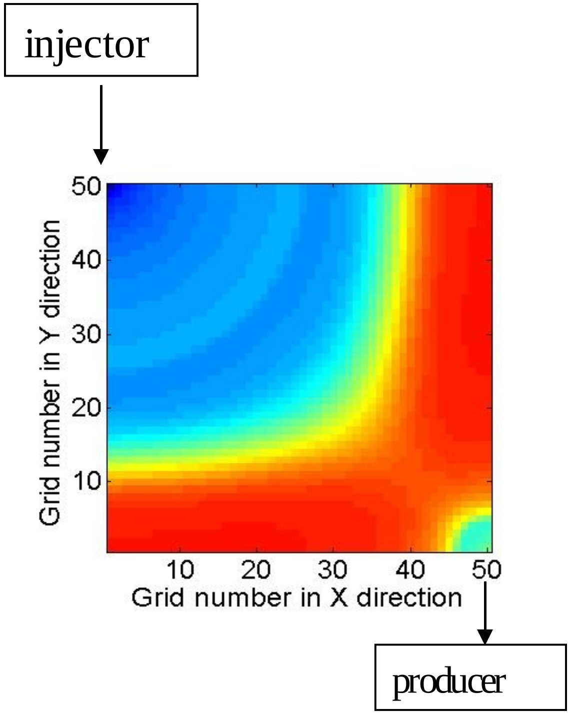
Homogenous and isotropic

The permeability is 20md

Porosity is 0.14.

The producor at bottom left corner, BHP =800 psi.

The injector at top right corner, BHP= 6000psi.



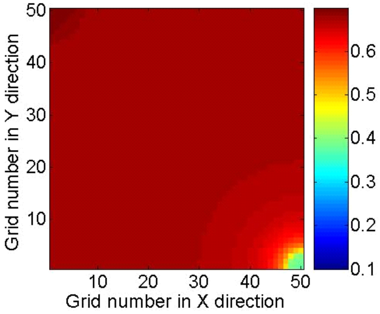
# Reservoir model

## 9 components fluid model

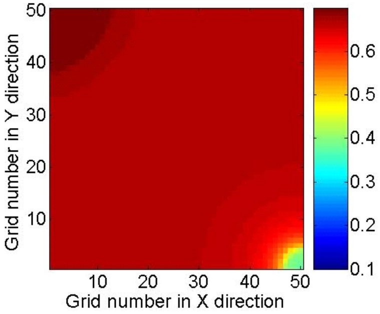
| Component | Mole % | MW | Tc (R) | Pc (Psia) | Accentric factor |
|---|---|---|---|---|---|
| N2 | 0.76 | 28.014 | 227.16 | 492.32 | 0.040 |
| Co2 | 1.54 | 44.01 | 547.56 | 1069.87 | 0.225 |
| C1 | 81.7 | 16.04 | 343.08 | 667.2 | 0.008 |
| C2-C3 | 9.68 | 34.15 | 593.25 | 673.58 | 0.118 |
| C4-C6 | 2.90 | 67.62 | 819.95 | 499.15 | 0.231 |
| C7+_1 | 1.7 | 111.64 | 1017.23 | 374.47 | 0.395 |
| C7+_2 | 1.12 | 175.76 | 1191.30 | 278.61 | 0.594 |
| C7+_3 | 0.6 | 305.44 | 1472.60 | 215.23 | 0.910 |

Table 1 Characterized fluid properties using PVTSIM with PREOS

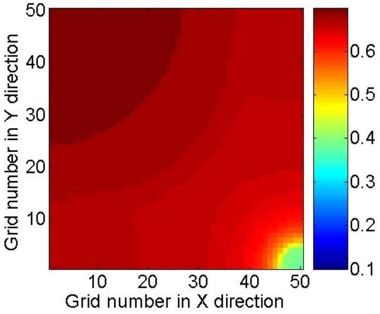
# Simulation Results



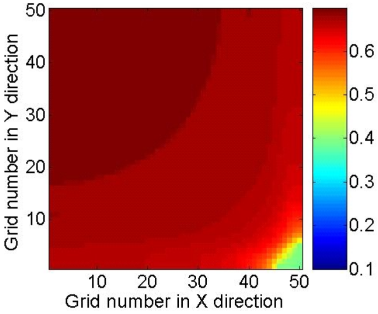
(a1)



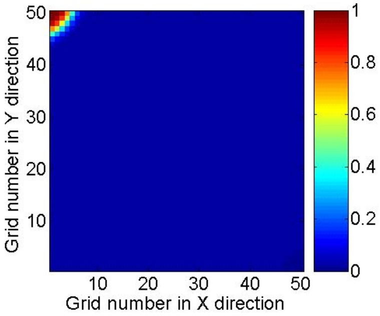
(a2)



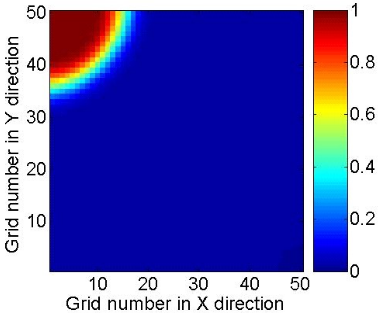
(a3)



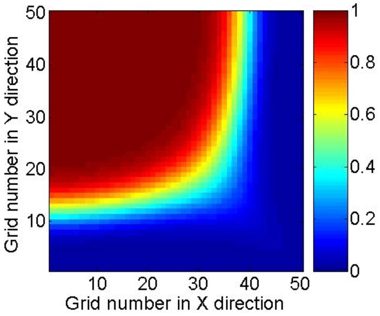
(a4)



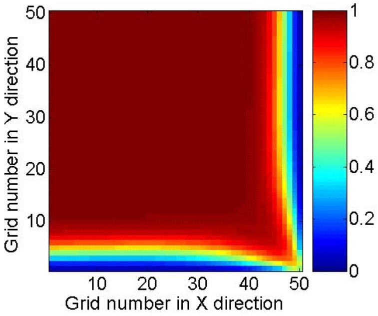
(b1)



(b2)

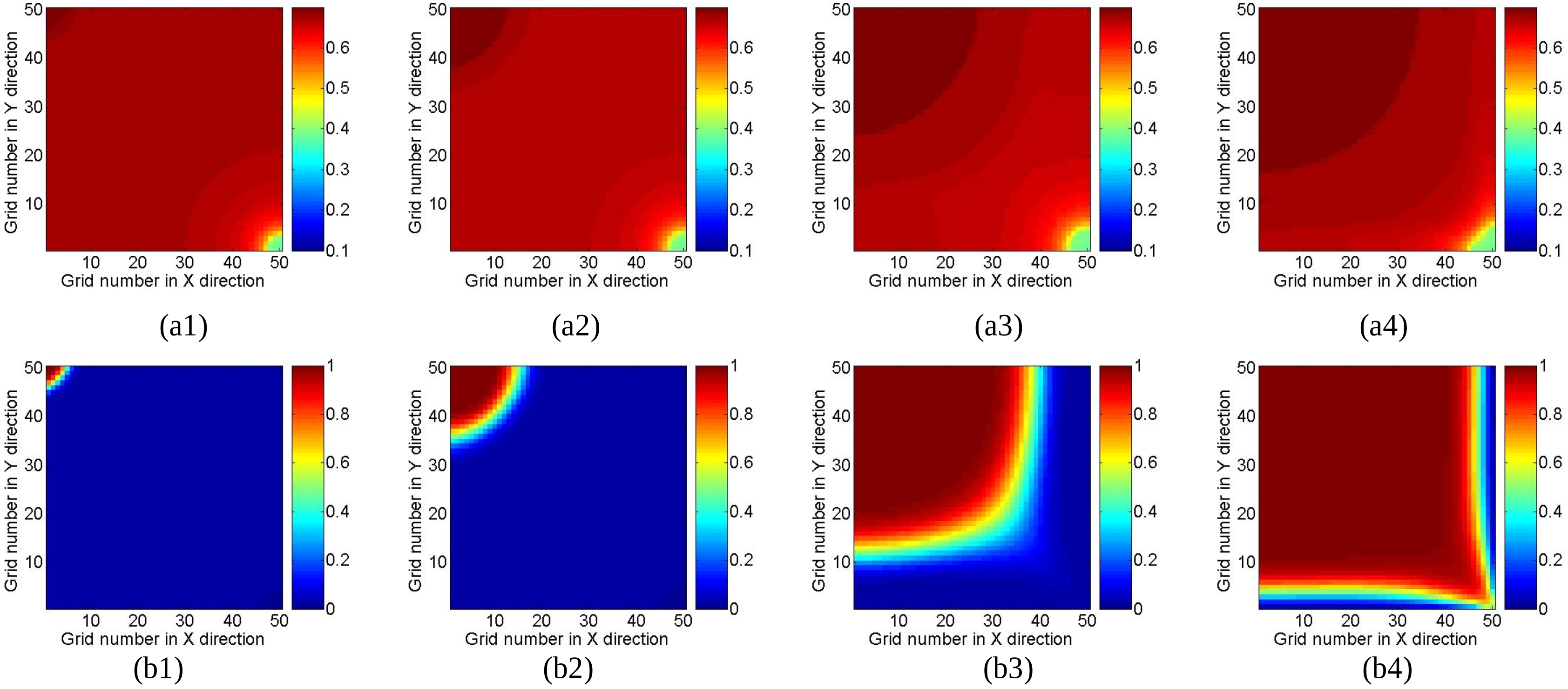


(b3)



(b4)

# Simulation Results

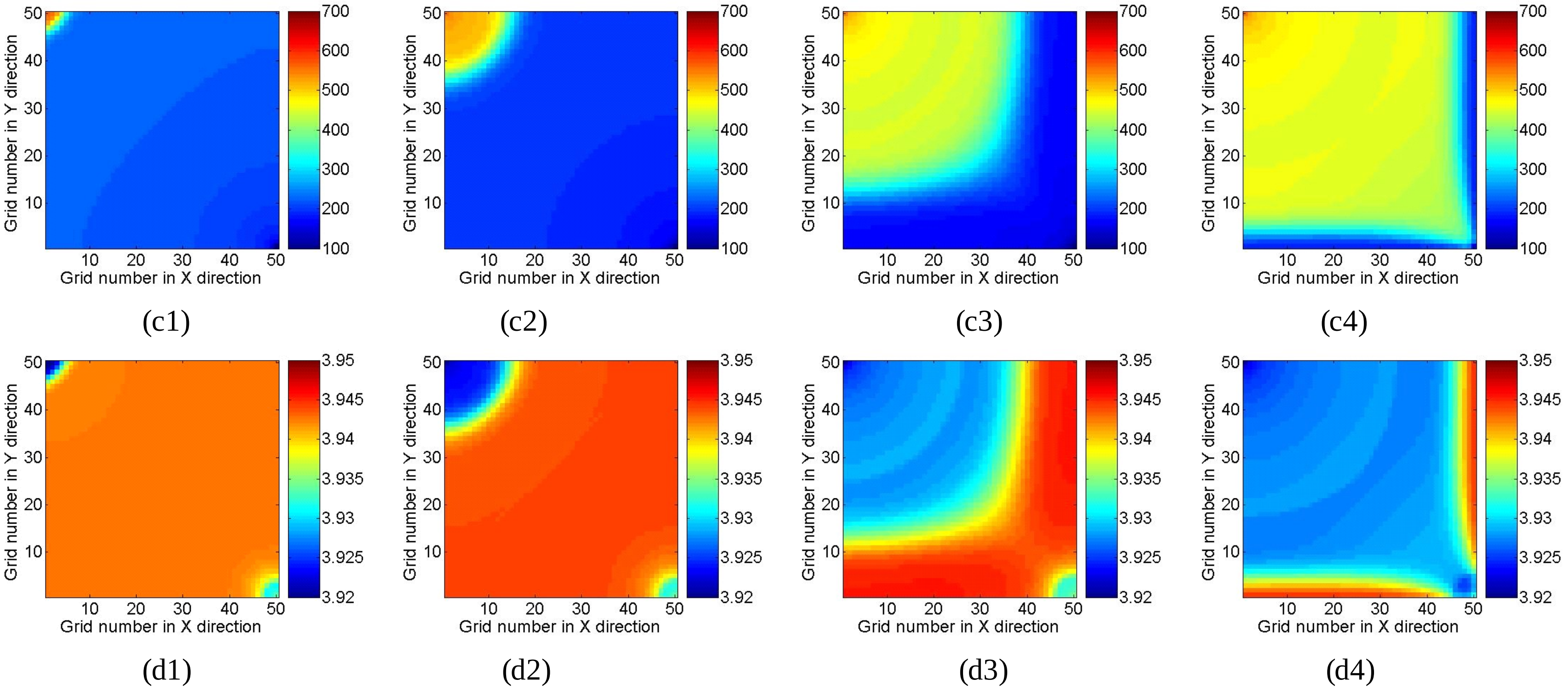


(a1) (a2) (a3) (a4)

(b1) (b2) (b3) (b4)

Figure 1. Simulation and rock-physics conversion results for 4 production steps. (a1-a4) gas saturation; (b1-b4)CO2 composition

# Simulation Results

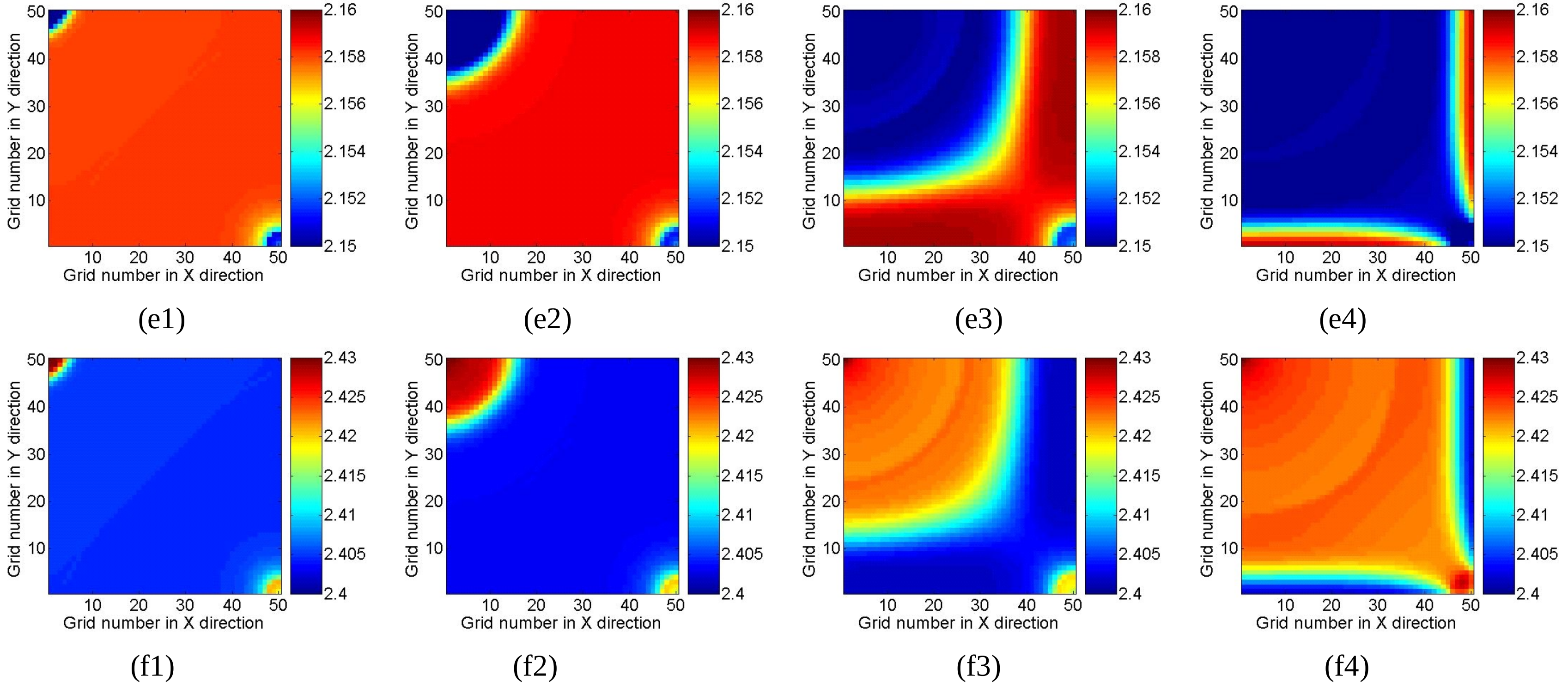


(c1) (c2) (c3) (c4)

(d1) (d2) (d3) (d4)

Figure 1. Simulation and rock-physics conversion results for 4 production steps. (c1-c4)gas density; (d1-d4) P-wave velocity

# Simulation Results

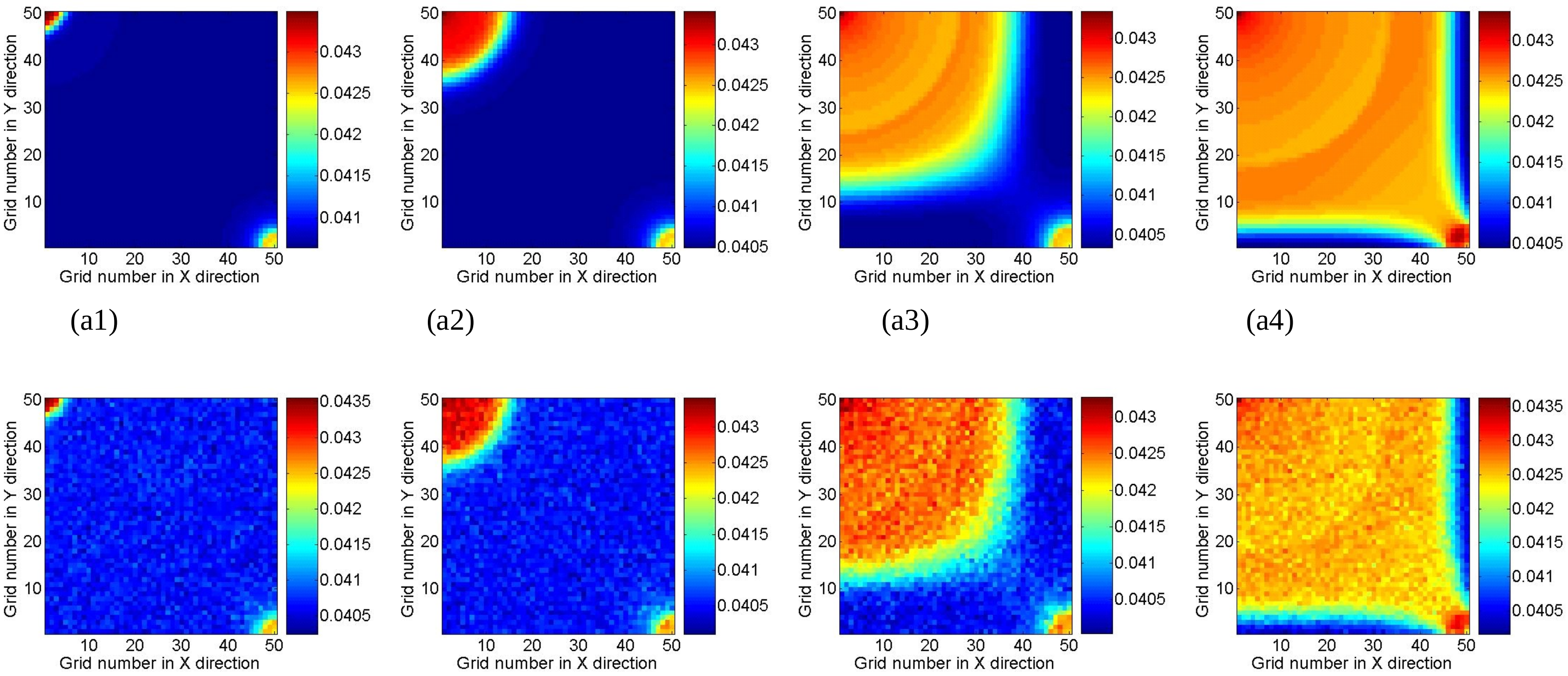


(e1) (e2) (e3) (e4)

(f1) (f2) (f3) (f4)

Figure 1. Simulation and rock-physics conversion results for 4 production steps. (e1-e4) S-wave velocity; (f1-f4) density.

# Simulation Results



(a1) (a2) (a3) (a4)

(b1) (b2) (b3) (b4)

Figure 2. Seismic modeling results.
(a1-a4) amplitude slice of poststack seismic data;
(b1-b4) amplitude slice of poststack seismic data with 10% random .

Comparison between Fig.1 and Fig.2 shows that seismic signal with adequate precision could monitor both the CO2 injection front and the condensate blocking area.

# Simulation Results

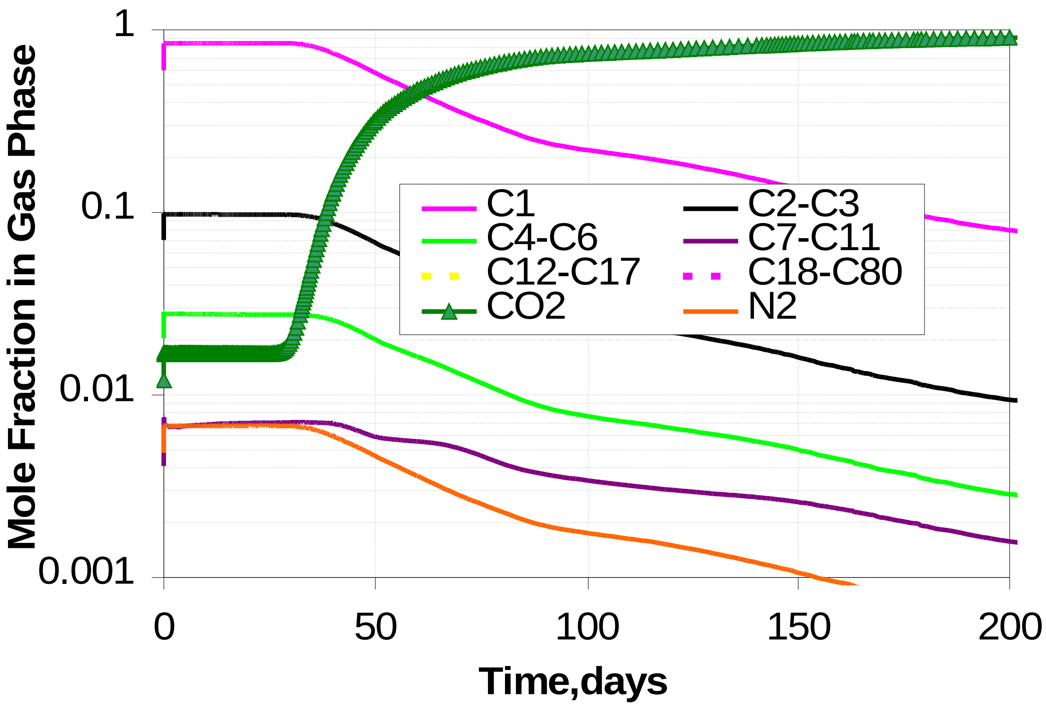


Figure 3. Mole fraction in produced gas phase (SC)

# Simulation Results

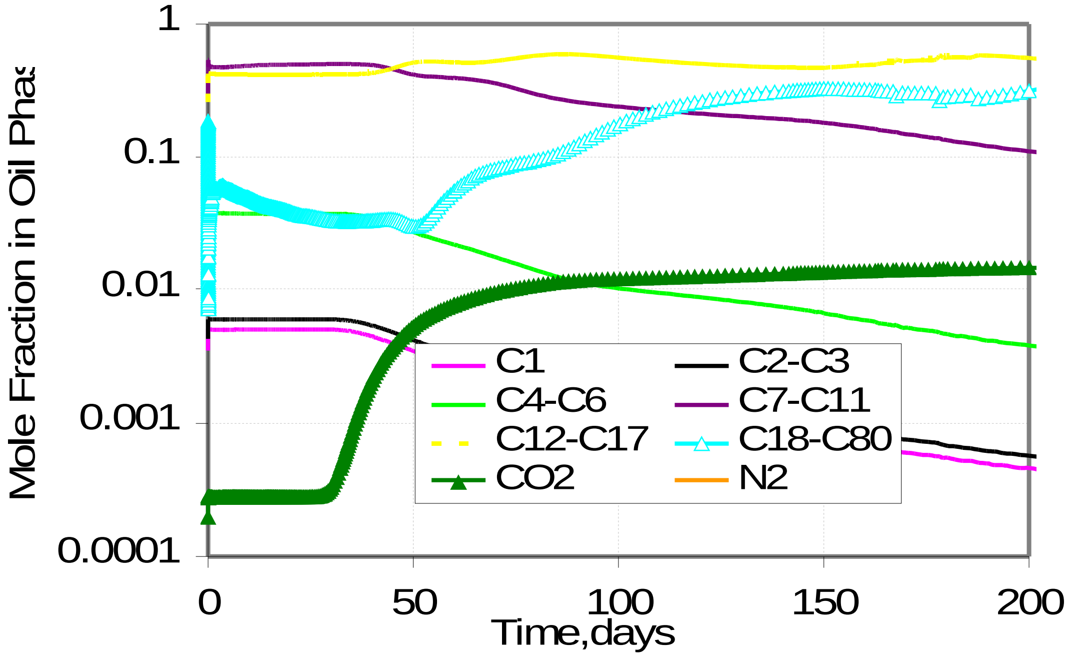


Figure 4. Mole fraction in produced oil phase (SC)

Figure **3** and Figure 4 shows CO2 mole fraction in produced gas and oil phase. CO2 breaks through in about 40 days.

Figure 5 shows cumulative gas and oil production by CO2 EOR and by natural depletion. When CO2 breaks through, difference in the cumulative gas is not big. But the cumulative oil production increased significantly, because CO2 injected keeps the formation pressure higher than that in natural depletion. More heavy components are flooded out, which otherwise would drop out as condensate in formation. This is verified in Figure 4, where C18-C20 parallels the CO2 in mole fraction in produced gas.

# Simulation Results

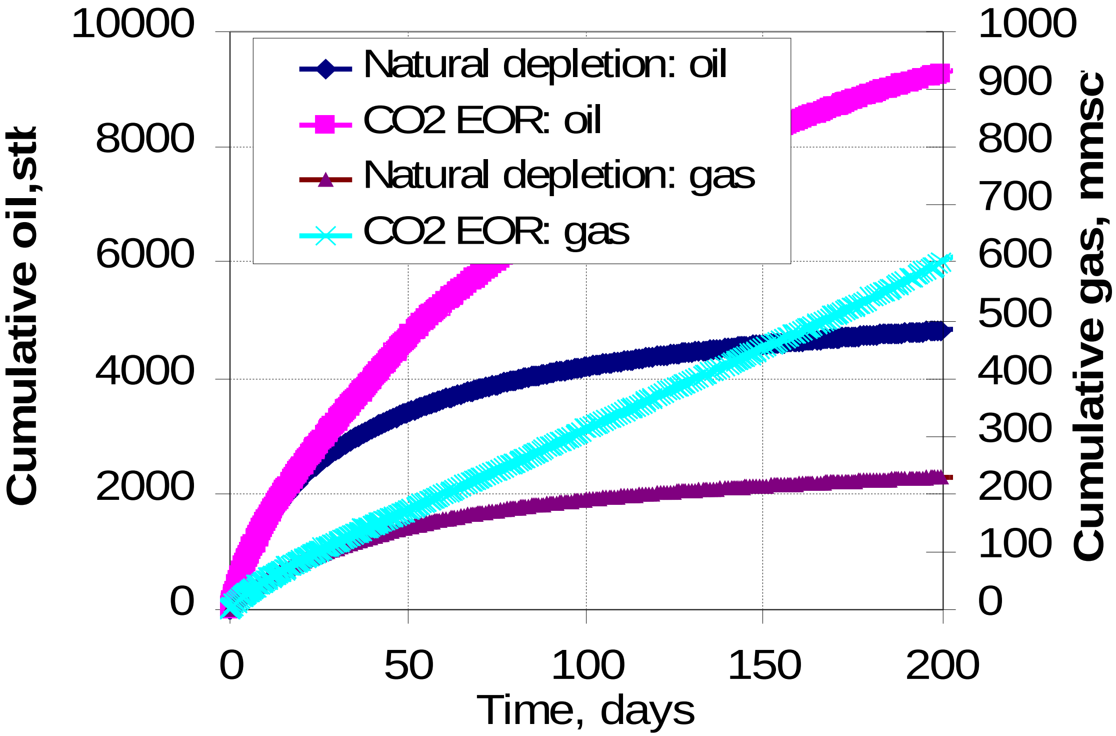


Figure 5. Cumulative production, CO2 EOR vs natural depletion

Figure 6 shows cumulative CO2 injected and produced and gas production rate.

After CO2 breakthrough, the gas rate does not vary much. And the cumulative CO2 injected tend to parallel to the cumulative produced. That means the CO2 is almost cycling in the two wells. The early CO2 injection serves as EOR and storage. It would be better than injection starts after formation is depleted where CO2 EOR capacity has been seriously compromised and wasted.

# Simulation Results

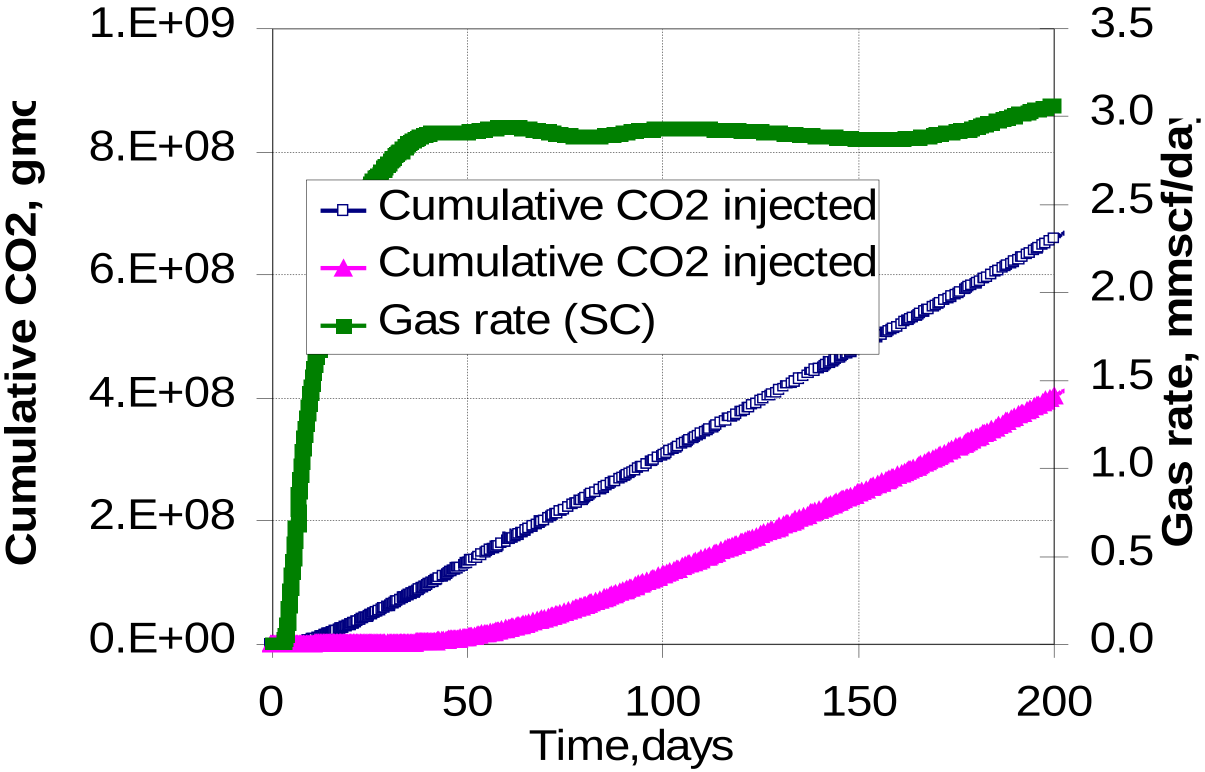


Figure 6. Cumulative CO2 injected and produced.

# Conclusion

The combined CO2 EOR and sequestration at the very beginning has advantage over natural depletion and storage after natural depletion. It will speed up the recovery process while simultaneously store CO2.

Seismic survey with adequate precision can monitor the condensate zone and CO2 front in gas condensate formation.