Permanent CO_2 Sequestration Supported by Water Injection in Coalbeds.

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Summary

Coal formations have the natural capacity to retain methane absorbed on its surface through the geologic time under appropriated pressure conditions, which are mainly established by water contained in the fracture network (the cleat system). Taking advantage of this adsorption capability, we study in this paper the potential of retaining CO_2 in coalbeds when the pressure in the fracture system is increased by water injection.

Capture and storage of carbon dioxide in subsurface formations has been proposed as a technology that could contribute to reduce the atmospheric concentration of anthropogenic CO_2, the greenhouse gas with the greatest influence on the global climate. The injection of CO_2 in coal reservoirs for long term storage offers the advantage of methane recovery enhancement as well. At the same time, water injection to support the CO_2 sequestration can provide additional solution for environmental problems generated by water disposal at surface.

A commercial simulator is used to predict the stability of CO_2 sequestered in coal under two different scenarios. Firstly, the injection of CO_2 in a depleted coalbed area and the evaluation of its stability by monitoring the likeability to flow through a fracture which is communicating two coal areas. Secondly, the first scenario followed by water injection.

The simulation results show that depressurization of a coal cleat system is faster in presence of water. In addition, water filling the coal cleats decreases significantly the amount of CO_2 produced, as well as the CO_2 production rate, which could indicate long term stability of CO_2 sequestered in a coalbed. The use of a reservoir fracture to monitor the CO_2 stability in a coalbed have been introduced.

The findings of this study can be useful for both, environmental and production purposes.

Methodology

By using a numerical simulator that considers the modified Warren and Root dual porosity model, we investigate whether the CO_2 sequestered could be indefinitely stored in coal after reinjecting the amount of water that has been initially extracted from coal cleats.

The steps followed on this study are:

- Model design.
- Search for representative reservoir data.
- Selection of initial conditions.
- Adjustments of the model.
- Simulations.
- Results: visualization and analysis.

▪ Model Design

A synthetic Coalbed Methane model is used to explore our idea. This model is polygonal in shape and represents 1/3 of a hexagonal area proposed to be produced by using pinnate well technology.

The synthetic model is built in a corner point grid with dimensions: 100 x 100 x 3 grid-blocks in X, Y, and Z direction, respectively. The model design includes two coalbed layers, each one with 388 acres of area, interconnected by a reservoir fracture modeled through local grid refinement, where both size and number of the refined grids control the fracture conductivity for a specific fracture permeability and fracture porosity value.

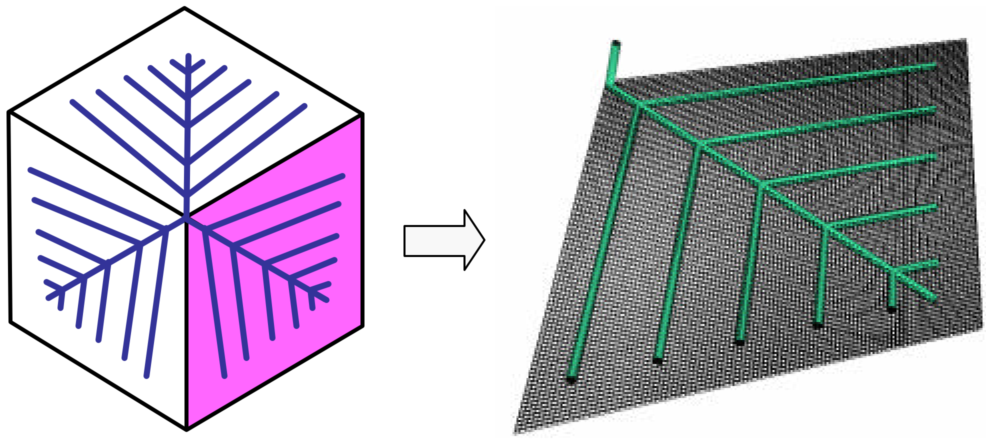

Figure 1: Hexagonal Reservoir Shape Proposed and Polygonal Area Modeled with a Multilateral Well.

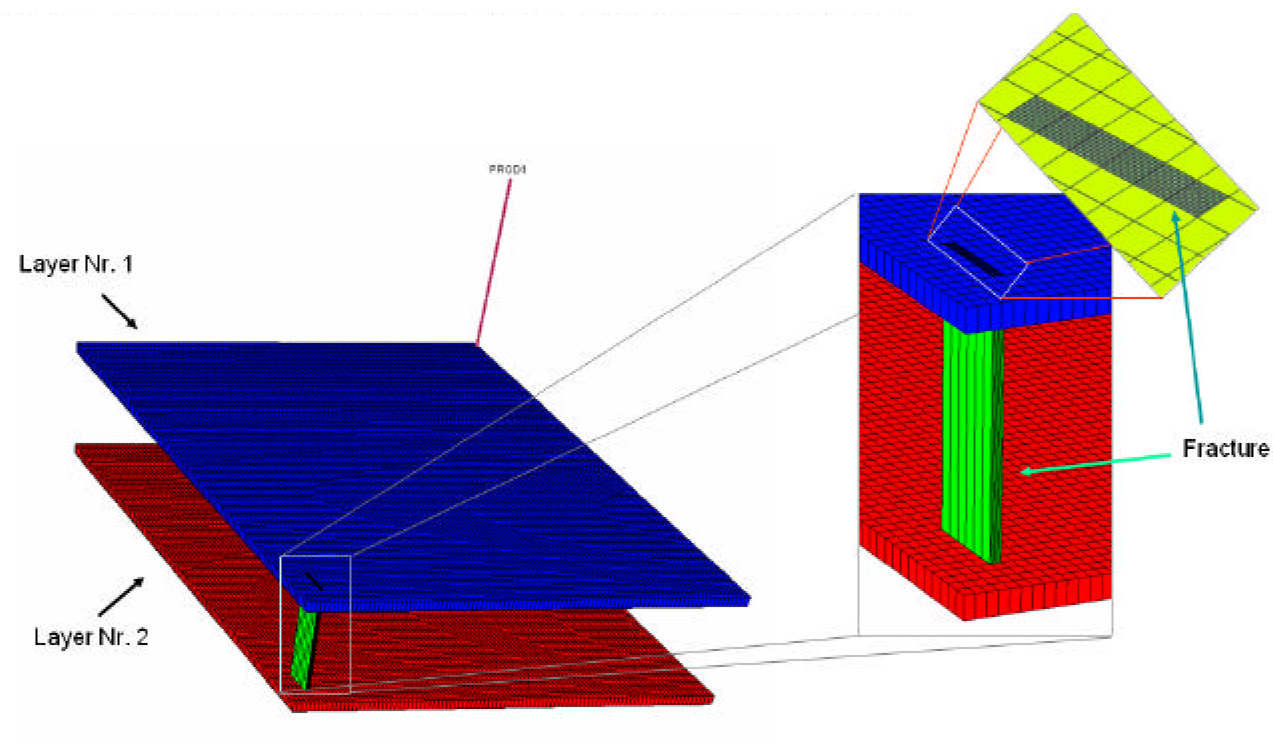

Figure 2: The Synthetic Model and Detail of the Local Grid Refinement to Represent the Fracture .

Search for representative reservoir data

The confidence in reservoir simulation results is built over the use of representative reservoir properties values. Ranges of coal properties values corresponding to the Appalachian Basin Region were selected, see Table 1. These values are obtained from different sources: literature(1,2,3), database of CBM characteristics (WVU), and values recommended by experienced professionals.

Table 1: Representative Data for the Seam Pocahontas 3 in the Appalachian Basin.

Parameter	Minimum	Maximum	Most Likely
Ash Content (fraction)	0.02	0.5	0.17
Depth (ft)	400	2400	1000
Fracture Permeability I (md)	0.01	26	10
Fracture Permeability J (md)	0.005	13	5
Fracture Permeability K (md)	0.001	2.6	1
Fracture Porosity (fraction)	0.02	0.08	0.06
Moisture Content (%)	0.02	0.15	0.04
Pressure Gradient (psi/ft)	0.3	0.45	0.435
Temperature (Fahrenheit deg)	58	94	72
Thickness (ft)	0.5	8	3
Time Constant (days)	5	100	30
SBSL (ft)	200	1500	750
Gas Gravity			0.624
Matrix Porosity (fraction)			0.01
Sw Matrix (%)			100

Methane and carbon dioxide adsorption isotherm reported on literature(3,4) for the San Juan Basin Coal, are digitized and incorporated in our model, see Figure 3.

- **Selection of Initial Conditions**

Two scenarios are considered to analyze the stability of the CO2 sequestered in a coalbed. First scenario has CO2 sequestered in a coal layer (Layer Nr. 2 in the model) and free CO2 gas filling the cleats with no water. Second scenario has CO2 sequestered again in the coal Layer 2 but now water is filling the cleats.

Conditions in both scenarios are set to produce methane gas through a multilateral well completed in Layer Nr. 1, as well as, to monitor changes in Layer Nr. 2, as result of the pressure difference created by a reservoir fracture that communicates both layers. For both scenarios 100 years of production are simulated. Table 2, summarizes the initial conditions for both layers by each scenario.

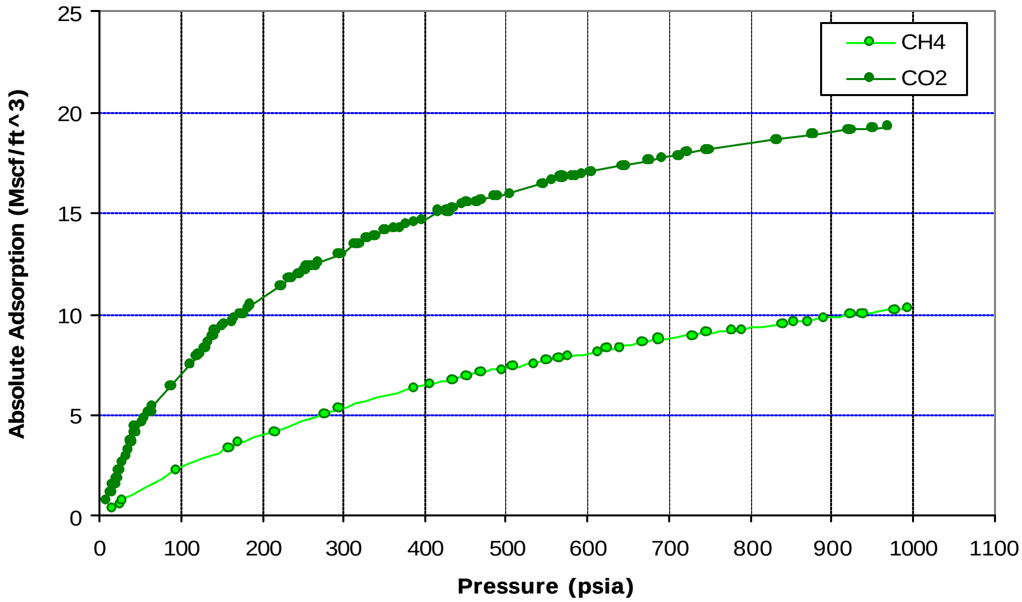

Figure 3: Methane and CO2 Langmuir Isotherms Measured for the San Juan Basin Coal.(3,4)

Table 2: Initial Conditions Selected for Two Different Scenarios.

	Model Layers	LAYER Nr. 1		FRACTURE LAYER		LAYER Nr. 2	
	Dual Porosity Systems	Matrix	Cleat	Matrix	Cleat	Matrix	Cleat
Scenario 1	Water Saturation	0	0	0	0	0	0
	Reservoir Pressure	682	682	700	700	721	721
	CO_2 Saturation	0	0	0	0	1	0.7
Scenario 2	Water Saturation	0	0	0	0	0	1
	Reservoir Pressure	682	682	700	700	721	721
	CO_2 Saturation	0	0	0	0	1	0.7

Results

Reservoir pressure, cumulative production and production rates are obtained for both scenarios. Figure 4 (a, b, c & d) shows graphically the results. Figure 5 (a, b, c & d) shows screenshots of the progress of the simulation for reservoir pressure and CO2 concentration.

Important differences in reservoir pressure, CO2 cumulative production and CO2 production rate are observed when comparing the values obtained for both scenarios. Table 3 summarizes the results.

Table 3: Summary of Results for both Scenarios.

Parameter & Figure Nr.	Pressure (psia) Figs. 4a, 4b, 4c & 4d.				CO2 Cumulative Production, (MSCF/day) Figs. 4a & 4b.				CO2 Rate of Production, (MSCF/day) Figs. 4c & 4d.			
Scenario \ Time (years)	**20**	**40**	**60**	**100**	**20**	**40**	**60**	**100**	**20**	**40**	**60**	**100**
1	415	390	380	365	0	12,000	33,500	82,500	0.02	2.6	3.0	3.6
2	120	80	65	60	0	1	36	140	0	0.001	0.008	0.0035

Conclusions

- Depressurization of the coal cleat system is faster in presence of water.
- Water filling the coal cleats decreases significantly the amount of CO2 produced, as well the observed production rate of CO2 coming from Layer Nr. 2.
- A lower amount of CO2 produced when water is filling the cleats, in comparison with the amount of CO2 produced when the cleat system does not contain water, could indicate long term stability for the CO2 sequestered in a coalbed.
- A new technique for monitoring the CO2 stability, consisting in the use of a reservoir fracture, has been introduced.
- Differences observed between the fracture and the two layers account for characteristics of the fracture design as well as higher porosity and permeability values. Further analysis of the fracture design will be subject of future investigation.

References

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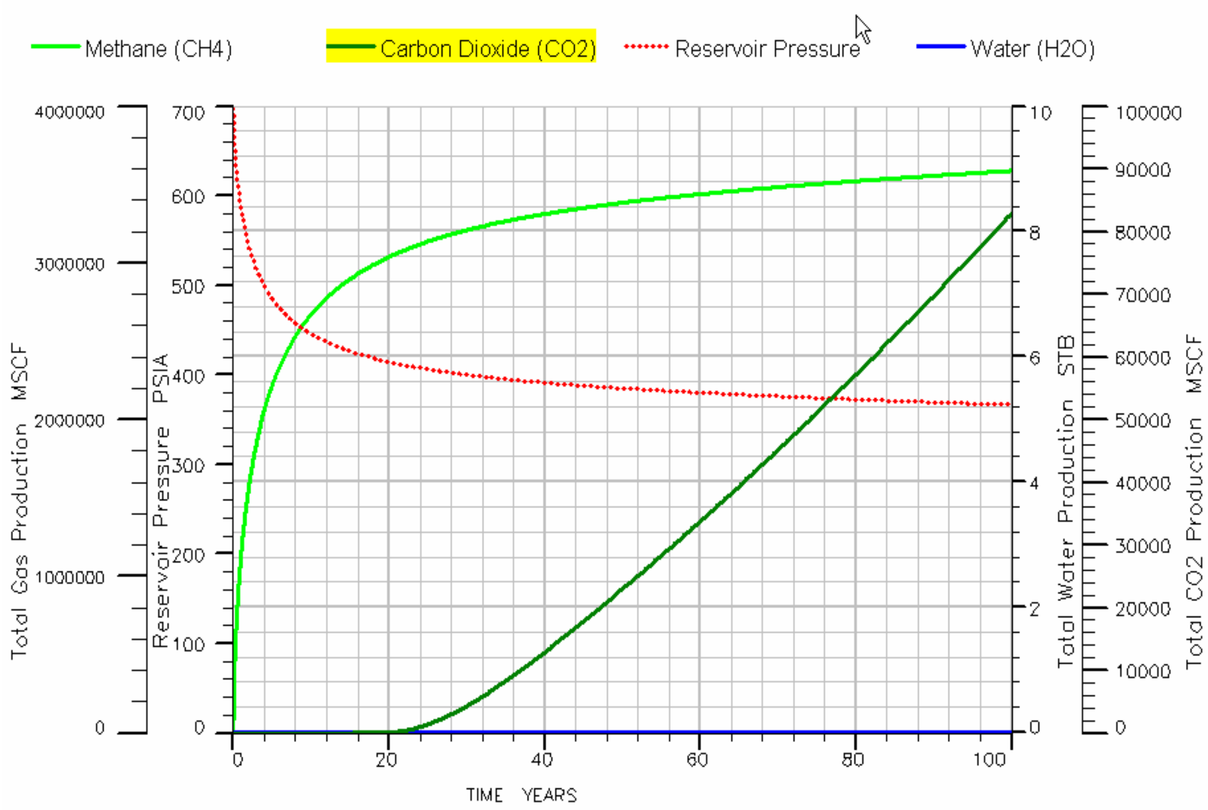

Figure 4a: Total Production Obtained on Scenario 1.

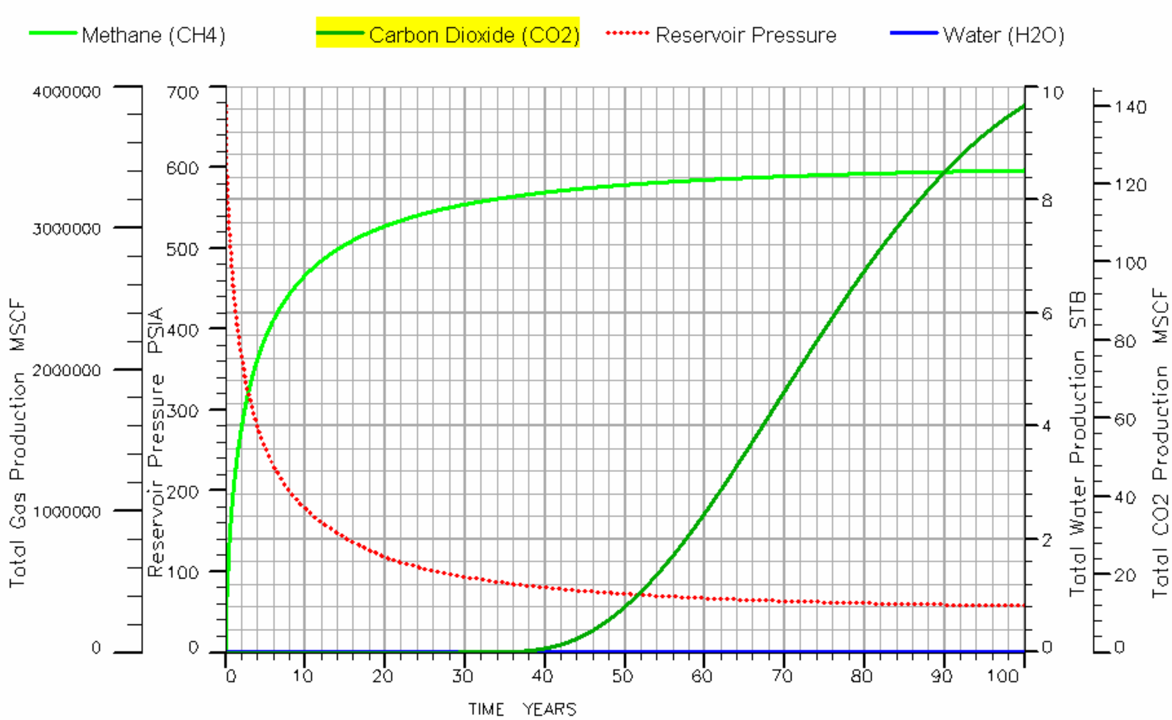

Figure 4b: Total Production Obtained on Scenario 2.

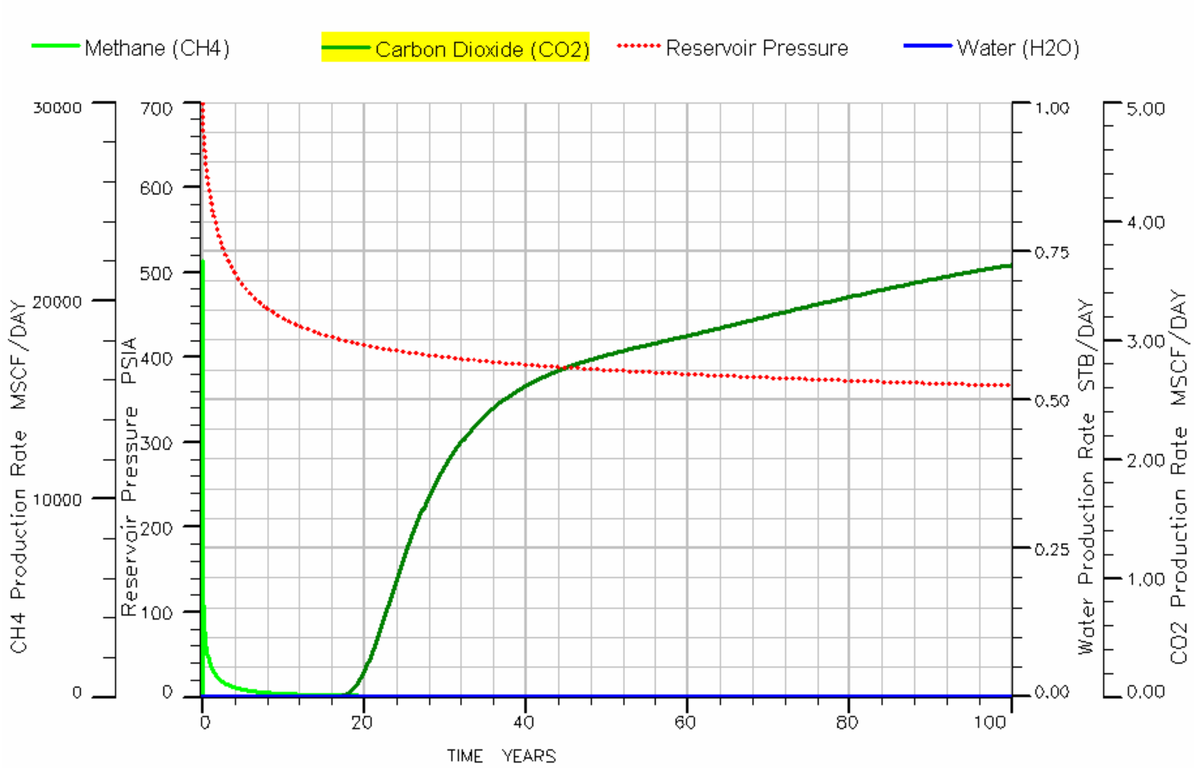

Figure 4c: Production Rates Obtained on Scenario 1.

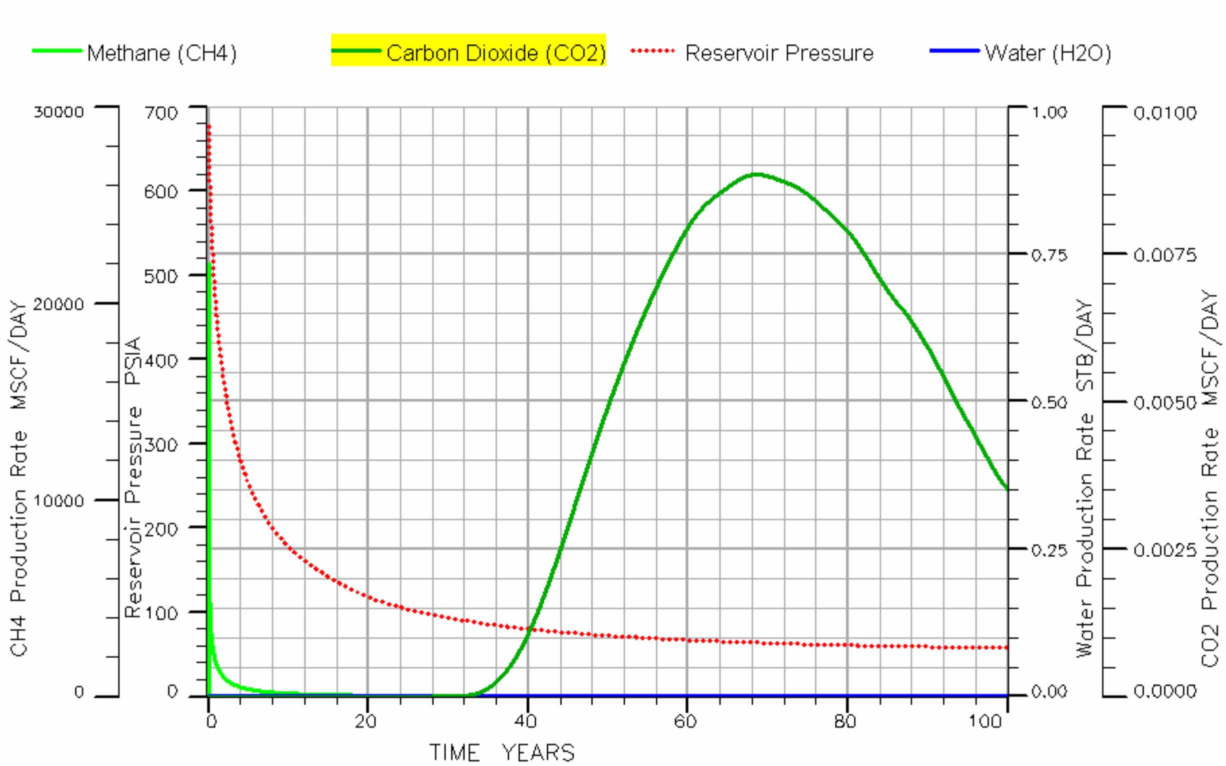

Figure 4d: Production Rates Obtained on Scenario 2.

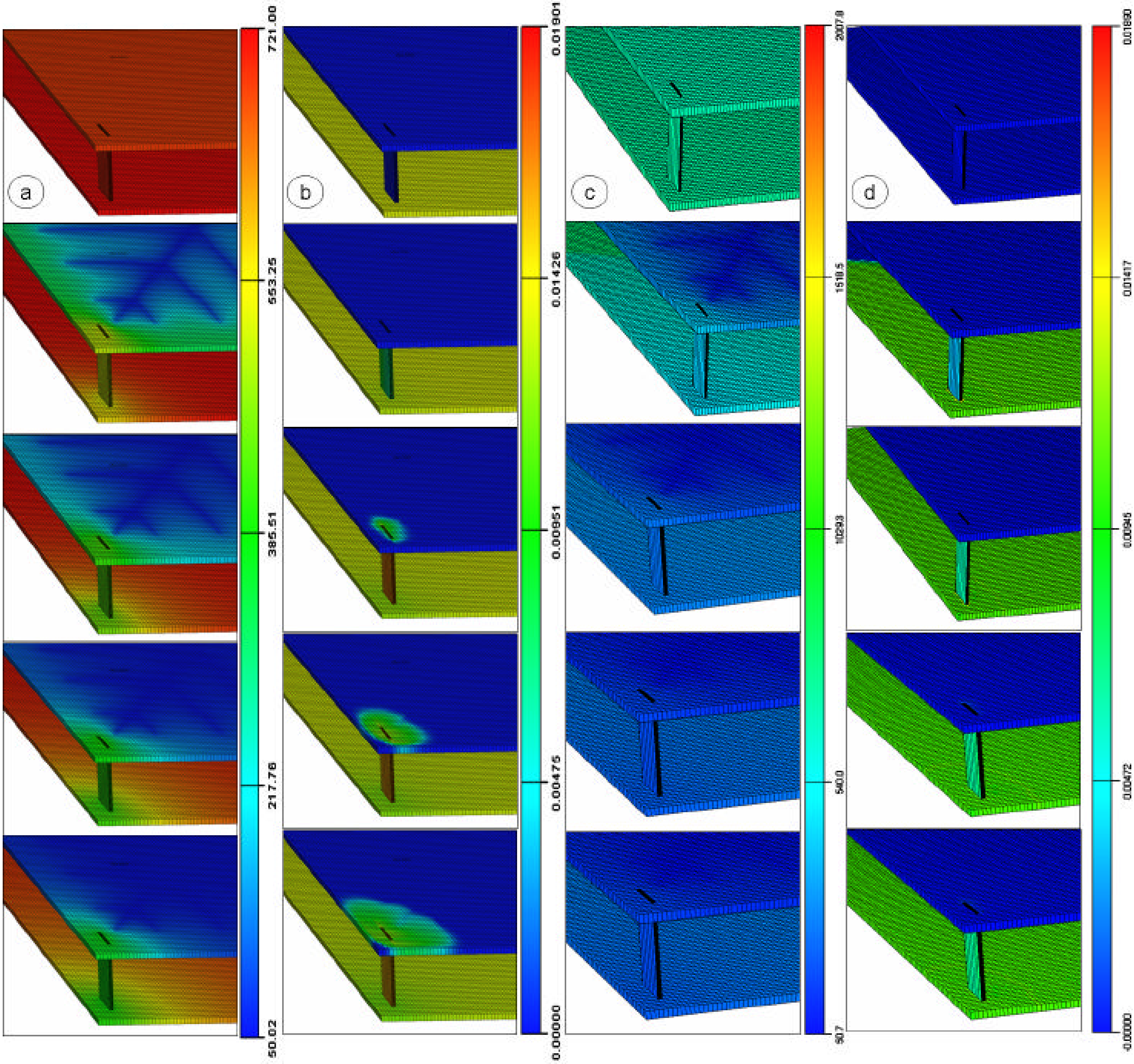

Figure 5: Comparison of Results Scenarios 1 and 2.
Scenario 1: a) Pressure Distribution (psia), b) CO2 Concentration (Mscf/ft^3) &
Scenario: 2 c) Pressure Distribution (psia), d) CO2 Concentration (Mscf/ft^3).