Carbon Dioxide Sequestration Option on Alaskan North Slope

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Summary

The current research investigates different opportunities on Alaskan North Slope to sequester CO_2 gas. The approach to this study entails, mainly the characterization of CO_2 point sources and sinks, the CO_2 sequestration for enhanced oil recovery (EOR) of viscous oil in the case of heavy oil reservoir on Alaskan North Slope (ANS).

Introduction

Conventional power plants generate electricity by combustion of fossil fuels. The emission of CO_2 gas, which is a green house gas, as a result of this combustion has led to increase in CO_2 concentration in atmosphere. Carbon sequestration can be defined as the reduction of CO_2 by capture from the point sources like power plants and subsurface storage. The subsurface CO_2 storage can be achieved by injection of CO_2 for sequestration in aquifers by means of mineral trapping and hydrodynamic trapping (Gunter et al., 1996), depleted oil and gas reservoirs by taking advantage of naturally available seal, coal seams, or viscous oil recovery by CO_2 flooding. According to EPA's Energy CO_2 inventory, the state of Alaska emitted 41 Million tons of CO_2 during the year of 2000. The combustion of fossil fuels from industrial and electric utilities contributed around 20 Million tons to the total CO_2 emissions. Due to absence of any CO_2 sequestration studies for Alaska, the current project, the study of CO_2 sequestration options in Alaska, will open new avenues for the assessment of carbon dioxide disposal options in Alaska.

Methods

The amount of CO_2 emitted from power plants and other processing utilities, which are present on ANS, was determined by using EPA's eGRID database. GIS study was performed by using ArcGIS 9.0 to create a layer map (Figure 1) of CO_2 source and oil pools.

The ranking of the oil reservoirs (Table 1) to evaluate the technical feasibility with respect to their CO_2-EOR potential was performed by calculating the rank of the reservoirs for EOR studies by comparing the parameters like oil gravity (°API), porosity (Φ), permeability (k), temperature (T), pay zone thickness (h), oil saturation (S_o) and minimum miscible pressure (MMP) with the optimum reservoir parameters (Rivas et al., 1992). The detailed step-wise procedure for ranking is given as follows:

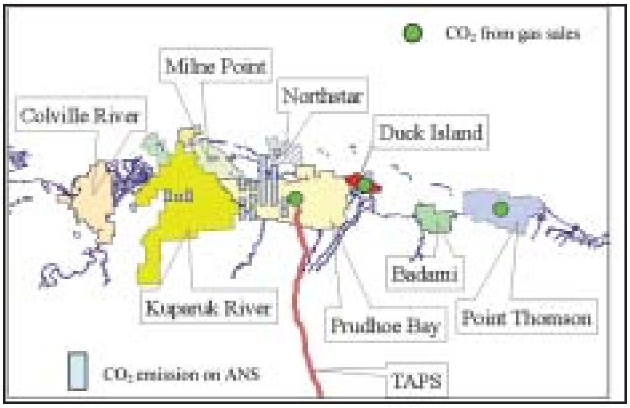


Fig. 1: Map shows different CO_2 sources such as different utilities and gas sales along with oil pools on ANS. CO_2 emitted from different facilities on ANS = 14.21 Million tons/yr and potential CO_2 available from gas sales on ANS = 24.39 Million tons/yr

1. Normalization of parameter

Normalized parameter (X) is given by,

X i,j = Abs (P i, j-P o ,j) /Abs (P w,j – P o,j)   (Equation 1)

j - parameter, i - reservoir,

P - magnitude of parameter (°API, temperature etc)

o - optimum: best case scenario

w - worst case scenario

2. Transformation to exponential parameter

A i,j = 100×exp(-4.6 *X^2 i,j)…   (Equation 2)

Exponential function is better than linear function for comparing different elements in same set

Table 1: Screening of oil pools, present on ANS, according to their potential for enhanced oil recovery (oil pools with respect to optimum reservoir are shown here)

Pool	T, °F	Φ,%	k, md	S_o	h ,ft	°API	P/ MMP	Ri
Tarn	142	20	9	0.6	40	37	1.64	1
Meltwater	140	20	10	0.6	95	36	1.5	2
Sag River	234	18	4	0.6	30	37	1.86	3
North Prudhoe	206	20	590	0.6	20	35	2.07	4
Pt. Mcintyre	180	22	200	0.6	156	27	1.27	5
Hemlock	180	10.5	53	0.7	290	33.1	2.34	6
Alpine	160	19	15	0.8	48	40	1.81	7
Lisburne	183	10	1.5	0.7	125	27	1.03	8
Prudhoe	200	22	265	0.7	222	28	0.94	9
Kupurak River	165	23	40	0.7	35	22	0.76	10
Schrader Bluff	80	28	505	0.7	70	17.5	0.4	11
Kupurak -Milne	160	20	150	0.9	100	24	0.79	12
West Sak	75	30	1007.5	0.7	70	19	0.41	13
Ivishak	254	15	200	0.5	125	44	4.11	14

3. Generation of weighted grading Matrix

W i,j = A i,j *w* j (Equation 3)

w j- weight of the parameter (obtained from studies by Rivas et al.,1992

Wi,j- weighted grading matrix

4. Rank of the reservoir

Ri = 100 W i,j W j,i / Ro (Equation 4)

W j,i - transpose of matrix Wi,j

Ro - sum of array of weighted properties of optimum reservoir

West Sak oil pool was selected (Rank = 13 in Table 1) for prediction of oil production due to viscous nature of West Sak Crude (19°API). In spite of having lower rank with respect to CO_2-EOR potential, West Sak oil pool is a potential candidate for CO_2 flooding studies because over 25 billion barrels of oil in place was estimated to be present in West Sak (Panda et al., 1989). The phase behavior of any reservoir fluid by CO_2 injection involves mass transfer and changes in composition. Traditionally, different equations of state have been used to predict reservoir fluid phase behavior at various conditions. The most common and reliable EOS, Peng-Robinson (PR-EOS), was used in this study The original form of the PR-EOS (Peng and Robison, 1976) is:

$$P = \frac{RT}{V - b} - \frac{a}{V(V + b) + b(V - b)}$$

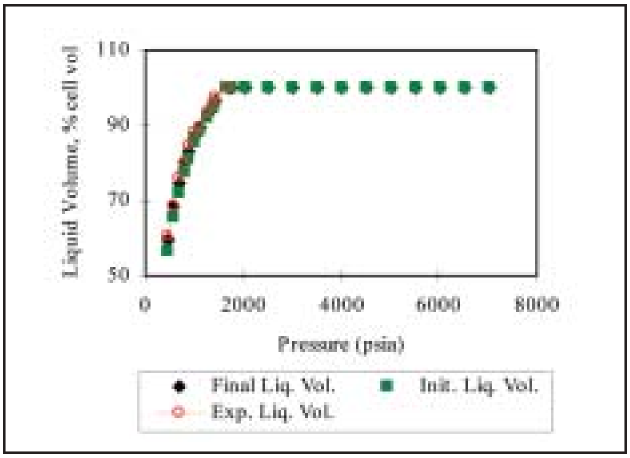
(Equation 5)

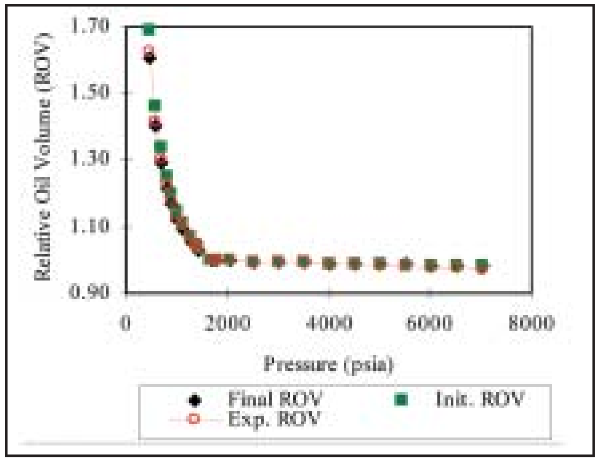
Where, a and b (attractive and repulsive terms) are functions of critical properties and ascentric factors

The inherent deficiencies of EOS for multi-component mixtures are widely known. Tuning of EOS (Ali, 1998) helps to improve the predictions of phase behavior. CMG-Winprop simulator, which minimizes the sum of squares of the relative errors by regression technique, was used to predict the phase behavior for West Sak crude and CO_2 mixture by tuning the equation of state (EOS). Regression of critical properties, ascentric factors, and omega A and B of C_{7+} components (Abrishami et al, 1997) was accomplished by previous laboratory constant composition expansion (CCE) experimental data (Figure 2). To investigate the miscibility condition of West Sak crude with CO_2, the pseudo ternary plots were plotted at different pressures. The ternary plots are plotted as shown in Figure 3.

For future production prediction studies, well log data interpretation for West Sak, obtained from work of Panda et al., 1989 were used to interpolate the values of porosity, saturation and net pay thickness at unsampled locations by using conditional simulation technique. In case of conditional simulation, Z estimates are based on a form of stochastic simulation in which measured data values are honored at their locations

The predictions of heavy oil productions by CO_2 flooding in West Sak oil pool are under way. In future, the impact of permafrost on long-term CO_2 storage will be investigated by Subsurface Transport over Multiple Phases (STOMP) computer model (developed by PNNL), and the

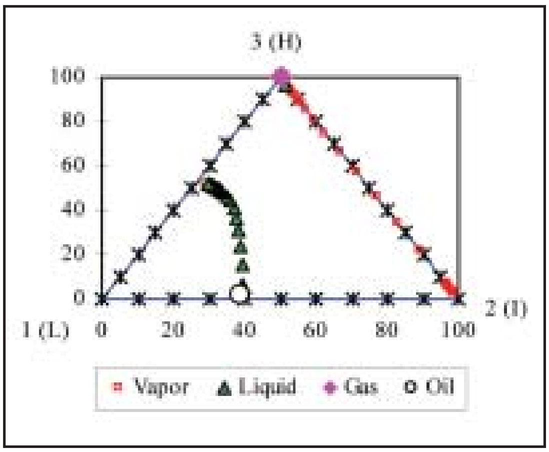




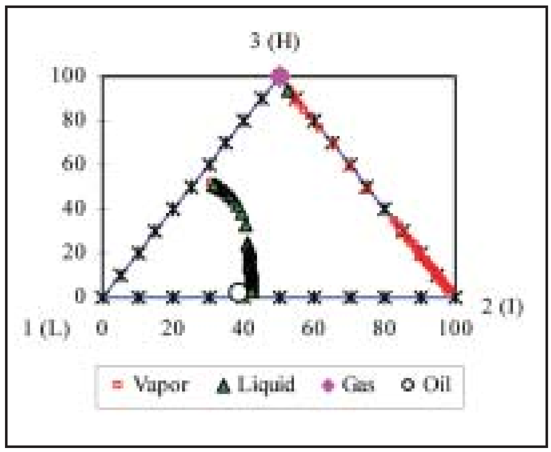
a) Liquid Volume in percentage

b) Relative oil volume

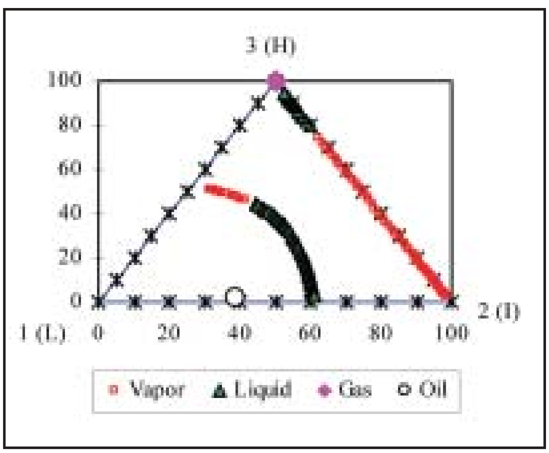
Figure 2 (a & b): Regression of CCE data to tune EOS



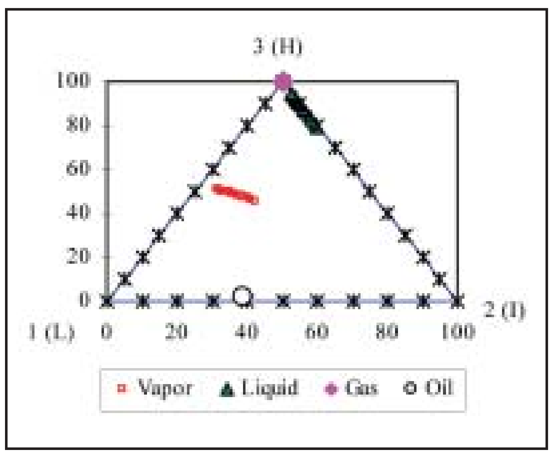
a) Ternary plot at pressure 1710 psia



b) Ternary plot at pressure 1920 psia

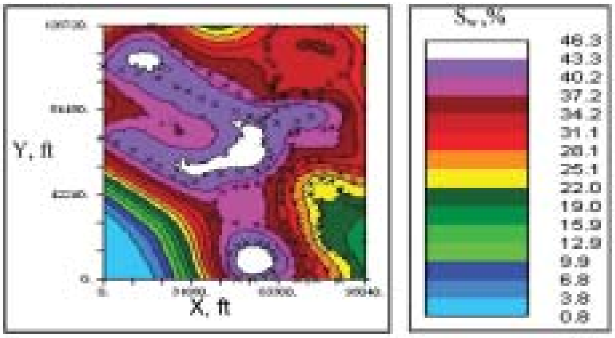


c) Ternary plot at pressure 4200 psia

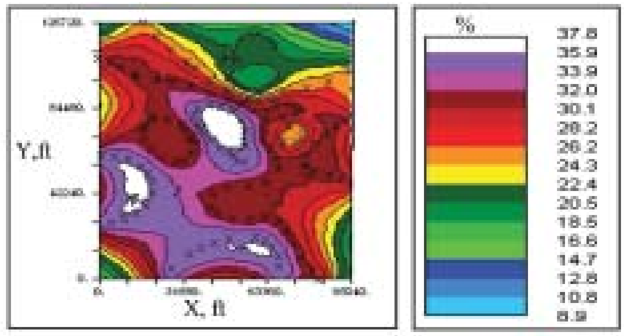


d) Ternary plot at pressure 4320 psia

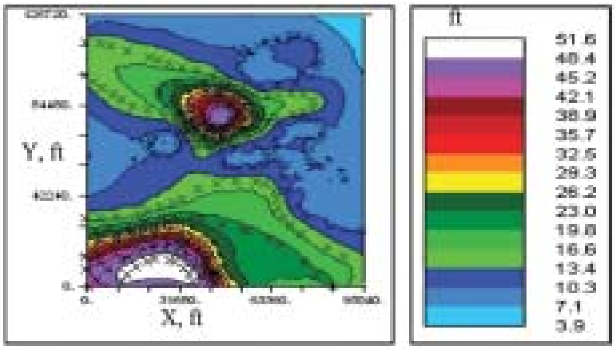
Fig. 3 (a-d): Pseudo ternary plots at different pressures for West Sak Crude + CO_2 mixtures.Where, component 1: C_{7+} as the heavy fraction (H) , component 2: N_2,C_1 as the light fraction (L), and component 3: C_2,C_3,C_4,C_5,C_6, and CO_2 as the intermediate fraction (I)



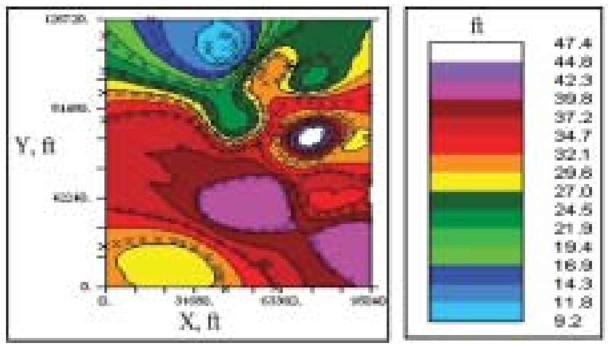
a) Iso-water saturation contour map



b) Iso-porosity contour map



c) Lower sand 1 thickness contour map



d) Upper sand 1 thickness contour map

Fig. 4 (a - d): Sequential Gaussian (conditional) Simulation method to interpret values at unsampled locations by using sample locations (denoted by 'x' in figure) in above contour maps

corresponding incremental benefits of CO_2 storage will be compared with CO_2-EOR.

Conclusions

The characterization of Alaskan oil pools with help of screening technique has the advantage of studying EOR potential of the oil pool as far as CO_2 injection is considered. True evaluation of storage technique is dependent on economics originating from transportation, compression, and injection. Thus, the GIS technique could prove, in future, to be essential tool to gain insight into related economics and in turn, assisting policy makers to make prudent decisions.

Due to the presence of heavy hydrocarbons in the West Sak crude, the miscibility of the crude with CO_2 is achieved by condensing/ vaporizing multiple contact mechanism (Zick, 1986).

Acknowledgement

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