SACS II PROJECT

TECHNICAL REPORT WORK AREA 2

Reporting period:	July 2000 – December 2000
Title of the project:	Saline Aquifer CO_2 Storage (SACS II), subtask 2
Contractor:	Netherlands Institute of Applied Geoscience – National Geological Survey (Contract number: 05.70205, contact person Ing. L.G.H. van der Meer,) SINTEF Petroleum Research (Contract number: 125432, contact person Erik Lindeberg, area co-ordinator)

Introduction

Within task 2 of the SACS project TNO NITG and SINTEF has been involved in the following subtask in this period:

2.1 Fluid properties of the fluid brine system (SINTEF)
2.2 Relative permeability measurements (SINTEF)
2.5 Simulation of present history (TNO NITG and SINTEF)
2.6 Numerical simulation of the long term fate of CO_2 (TNO NITG and SINTEF)
2.7 Raleigh convection (SINTEF)
2.9 Escape of CO_2 from a fault or spill point (TNO NITG and SINTEF)
2.10 Limitations and improvements of reservoir simulators. (TNO NITG)

Co-operation is especially important to get comparable results via different methods and tools. A discussions to redistribute of the workload for subtask 2.5 and 2.6 between SINTEF and TNO.NITRG is going on.

We still are waiting for the completion of 3 types of geological models: a coarse regional model, an intermediate detailed storage reservoir model, and a detailed well model. Furthermore, the interpretation of the time-lapse seismic is completed at the end of the reporting period.

SUBTASK 2.1 Fluid properties of the fluid brine system (SINTEF)

Work carried out

The density of CO_2 is very dependent of the temperature profile in the reservoir and very few temperature measurements in the Utsira formation exists. A suggestion that an apparent discrepancy between the modelled volume of CO_2 and the estimated amount of CO_2 obtained from the analysis from the seismic is due to unceartainty on the simulated results has started a discussion on this specific topic. Both SINTEF and TNO NITG are taking part in the ongoing discussion that has so far been non-conclusive.

Forecast of activities in the next six months

- Consensus on a temperature and density modelled has to be worked out.

SUBTASK 2.2 Relative permeability measurements (SINTEF)

Work carried out
Only minor preparing work was performed in this period and the work was postponed to next period due to that the work under task 2.5 was prioritised.

Forecast of activities in the next six months
- An alternative method to measure capillary pressure and a full relative permeability curve will be obtained at reservoir condition.

SUBTASK 2.5 – Simulation of present history

Work carried out
Activities have been performed to gain an understanding of all physical processes involved. The available tools to simulated these processes have been selected.

Preliminary test has been carried out by TNO NITG with the SIMED II reservoir simulator in order to test the ability of this simulator to handle aquifer storage problems. With the findings of a 2D radial well model a 3D full field model has been constructed. It has been found that a grid model of 100000 grid cells (50x50x40) could realistically be used on a PC. The top of the reservoir model was based on the latest interpreted Utsira top structure map (tasks 1.2). With this model several history match were made to study the 3D dimensional effects of CO_2 migration path for a number of reservoir configurations. The results of this work is presented at the Fifth International Conference on Greenhouse Gas Control Technologies, held in Cairns, Australia 13th-16th August 2000. The history match activity was based on the raw time-laps seismic data. The interpretation of the 1999 seismic 4D has shown that small amount of CO_2 have penetrated the Sand wedge on top of the Utsira formation. Furthermore, more information has been extracted from the seismic interpretation. At present we are active in the implementation of this information into an updated 3D-reservoir simulation model. Find paper enclosed.

Alternative test carried out by SINTEF with the Eclipse 100 simulator in a model which also allow dissolution has been performed on 3D reservoir grids with 230 000, 450 000 and 860 000 grid blocks. It was possible to mimic the distribution in the major five CO_2 accumulations as seen on the seismic picture. The major barriers accumulating CO_2 in the model has to have distinct holes to achieve a good match between seismic and simulations. Also these results were presented a in a paper at the Fifth International Conference on Greenhouse Gas Control Technologies, held in Cairns, Australia 13th-16th August 2000. Find paper enclosed.

Difficulties encountered
The final history match activity is largely dependable on the results of activity 5.4. At the end of this reporting period this activity was still in progress. Furthermore, the history match activity has been hindered by the lack of computer power. TNO-NITG is awaiting the installation of an 800 MHz Pentium computer with 1Gb of internal memory in order to increase its capability to run the full 3D model in a more efficient way.

Forecast of activities in the next six months
- History Matching of 3D full field model to time-lapse seismic responds.

- Uncertainty estimation of relevant reservoir parameters.
- Simulation of past reservoir performance including a sensitivity analysis of simulations performed with the results of the uncertainty estimation activity.
- Simulation of a limited number of prediction runs (prediction scenarios and parameter boundary conditions to be determined after completion of action b and c). Predictions have to be set-up in close co-operation with the geophysicist involved in the time-lapse seismic activity.

SUBTASK 2.6 Numerical simulation of the long term fate of CO_2

Work carried out

CO_2-water solubility and CO_2-rock interaction are considered to be the two main factors influencing the long-term fate of CO_2. After study it has been concluded that simulation of the effect of these processes is not considered to be a large problem. In the reporting time a study is being started to investigate the dynamics of these processes, specially related to a porous medium environment. In other research work related to CO_2 absorption is was found that the kinetic effects could play an important role, making an equation of state approach unsuitable to simulated this solubility process.

Difficulties encountered

Work is being hampered by the lack of applicable field or laboratory data concerning solubility and rock interaction

Forecast of activities in the next six months

- Literature study of present knowledge of the kinetics of CO_2 solubility in water
- Selection of best simulation approach
- Simulation of a long storage cycle.

SUBTASK 2.7 Diffusion-induced convection. (Was: Raleigh convection, SINTEF)

Work carried out

A 2-dimensional numerical reservoir simulator that can take into account both temperature gradients, gravity and compositional effects has been completed and tested. The result shows that the regular convection patterns that is characteristic for Raleigh convection is less dominating in the combined temperature/diffusion gradient field than in the pure temperature field. Strong diffusion-induced convective drape currents is, however, observed that forces heavy CO_2 rich brine towards the bottom of the reservoir, while fresh brine flows up to the CO_2/water contact, thus increasing the long term storage capacity by enhancing the contribution of solubility.

A special test to what extent a standard reservoir simulator can model this phenomena quantitatively has also been performed with the black-oil simulator Eclipse 100. This simulator includes solubility and molecular diffusion and could possibly be used as long as the temperature filed can be neglected. First a test on the molecular diffusion performance was carried pout by comparing diffusion profiles in a ultra fine Eclipse model with an analytical solution of the diffusion equitation with the same parameters. This test resulted in a very good consistency and also the next test which also included convection resulted in an interesting qualitative agreement between the dedicated simulator and the standard simulator.

Some questions still remain on how to represent the density profile in the black oil simulator to mimic the temperature effect.

Test with semi-permeable horizontal shale layers in the model has also been performed. These layers attenuates the convective current to some degree, but their contribution is still significant

Difficulties encountered
None

Forecast of activities in the next six months
- The result will be reported.
- The possibility to get extra financial support to publish the result will be investigated.

SUBTASK 2.9 Escape of CO_2 from a fault or spill point

Work carried out
From seismic and geological work there are no evidence found of faults. On the other hand evidence are found of a sand wedge on top of the Utsira formation, which are separated by a ca. 5 m thick shale unit. The time-lapse seismic survey indicates that this shale unit is possibly penetrated by the CO_2. In order to investigate the sealing capacity of the Utsira cap rock the topography of this sand wedge and shale unit is under study.

SINTEF has developed a model with "synthetic " fractures and tested it on various fracture sizes to obtain realistic escape scenarios. The work continues.

Difficulties encountered
None

Forecast of activities in the next six months
- Mapping of the sand wedge and shale unit.
- Incorporating these features in the 3D-simulation model.

SUBTASK 2.10 Limitations and improvements of reservoir simulators

Work carried out
With the utilisation of the SIMED II gas/water simulator for the simulation of CO_2 storage problem TNO NITG has created a unique opportunity to create a dedicated CO_2 storage simulator. The component solubility option into this model has been included. Furthermore, in close co-operation with SINTEF it was concluded that during the CO_2 injection time frame the temperature plays an important role on the density of the injected CO_2 and consequently on the *in situ* volume. SIMED is a simulator based on the principle of isothermal behaviour with only one average reservoir temperature to be supplied for a successful run. In case of CO_2 storage in a relative thick formation in combination with the injection in the lower part of this formation the natural temperature gradient in the reservoir could be important. For this reason a depth dependent temperature function will be implemented in SIMED. The programming work is in progress to implement this function

Difficulties encountered
None

Forecast of activities in the next six months
- Investigate if the SIMED gas /rock absorption option can be used to model the possible CO_2-rock interaction.
- Test the implemented CO_2-water solubility option of SIMED II.
- Test the depth dependent temperature function.

Enclosures:

L.G.H. van der Meer, R.J. Arts, and L. Paterson: PREDICTION OF MIGRATION OF CO_2 AFTER INJECTION IN A SALINE AQUIFER: RESERVOIR HISTORY MATCHING OF A 4D SEISMIC IMAGE WITH A COMPOSITIONAL GAS/WATER MODEL

Erik Lindeberg, Peter Zweigel, Per Bergmo, Amir Ghaderi, Ane Lothe: PREDICTION OF CO_2 DISPERSAL PATTERN IMPROVED BY GEOLOGY AND RESERVOIR SIMULATION AND VERIFIED BY TIME LAPSE SEISMIC

(Both papers were presented at the Fifth International Conference on Greenhouse Gas Control Technologies, held in Cairns, Australia 13^{th}-16^{th} August 2000.)