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DEVELOPMENT OF A FIELD EXPERIMENT OF CO$_2$ STORAGE IN COAL SEAMS IN THE UPPER SILESIAN BASIN OF POLAND (RECOPOL)

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ABSTRACT

In 2001 the RECOPOL project, which aims at the development of the first European field demonstration of CO$_2$ sequestration in subsurface coal seams, started. The required research, design and operation of the pilot field test is executed by an international consortium of research institutes, universities and industrial partners. A site was selected in the Silesian Basin in Poland where two CBM-wells are present at short distance from each other. One injection well will be drilled in between; drilling is scheduled in spring 2003. Injection is planned to start in the summer of 2003 and will continue until the end of 2004. Reservoir modelling shows that the distance between the injection well and the updip production well should be less than 200 m to increase the chance of breakthrough of CO$_2$ within the test period. Breakthrough is important for a thorough understanding of the process. After and during the injection period monitoring will be performed by direct measurements of CO$_2$-concentration and by time lapse seismic monitoring.

INTRODUCTION

One option to reduce carbon dioxide emissions in order to control the overall levels of CO$_2$ in the atmosphere, which has become an international priority in the wake of the Kyoto protocol, is permanent storage in subsurface coal seams, while simultaneously producing methane. This option has gained increasing interest world-wide during the last couple of years, among others at the previous GHGT conferences (e.g. [1-4]). Although several desk studies illustrated the potential of the process, there are world-wide only two demonstration sites: one in Alberta, Canada (e.g. 5, 6) and one in the San Juan Basin, U.S.A. (e.g. [3], [6], [7]). In November 2001 the EU-funded RECOPOL project started which aims at the development of the first European demonstration plant of CO$_2$ storage in coal seams. An international consortium was formed to execute the research, design, construction and operation within the RECOPOL project. This consortium is formed by research institutes, universities and companies from the Netherlands (TNO-NITG and Delft University of Technology), Poland (Central Mining Institute), Germany (DBI-GUT and Aachen University of Technology), France (IFP, Gaz de France and GAZONOR), Australia (CSIRO), U.S.A. (Advanced Resources International) and by the IEA Greenhouse Gas R&D Programme.
Overall co-ordination of the project is in the hands of TNO-NITG.
This paper gives an overview of the project and status of the activities within the project.

CHARACTERISTICS OF THE PILOT SITE

The Upper Silesian Basin (Figure 1) was selected as the best coal basin in Europe for the application of ECBM [1, 2]. This basin has (relatively) favourable coalbed properties (depth, permeability, gas content, etc.), was subjected to CBM production before, and drilling costs in Poland are relatively low. A site with an already existing infrastructure for CBM production, located about 20 km south of the city of Katowice, was selected within the Upper Silesian Basin. It is ideal because two existing CBM-wells are available that are relatively close to each other (375 m) and given the existing concession rights. This short distance allows the injection tests within a short period (see "Reservoir Modelling"). CBM-production from these wells, drilled in 1994/1995, took place during 1995 to 1998.
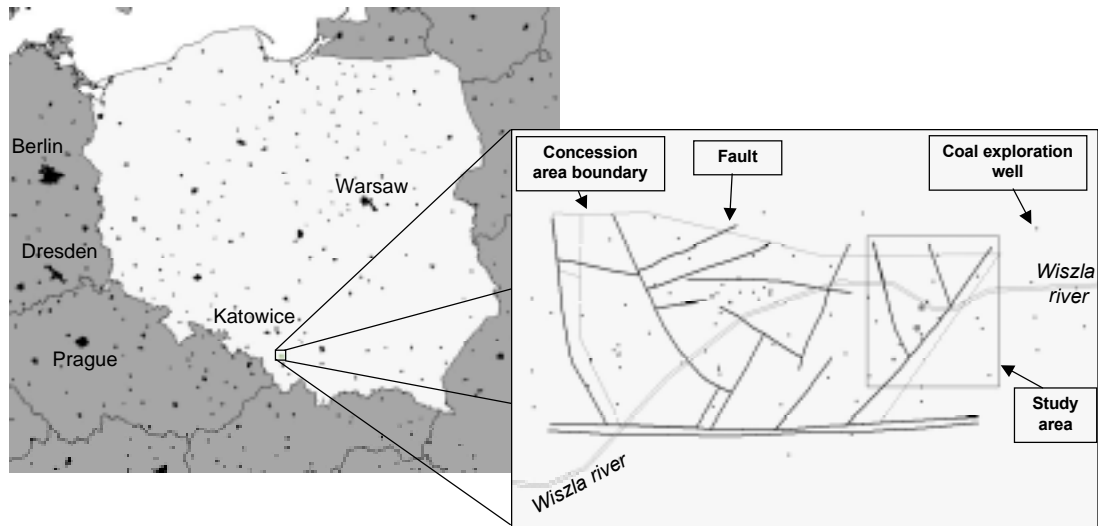

Figure 1: location of the site in Poland. The existing CBM-wells are indicated with the symbol

Geological setting

The Upper Silesian Coal Basin, bounded on the south by the Carpathian foredeep, is structurally complex compared to commercial coalbed methane basins in the U.S.A. [8]. The area of interest is located on a large block that was upthrusted during the Alpine orogeny. The principal targets for CO_2 injection are coal seams of Carboniferous age in the depth interval between 900-1250 m. The Carboniferous deposits are disconcordantly covered by Miocene shales. The depth from the surface of the top of the Carboniferous deposits in the test area (7 km^2) is about 250 m. The Carboniferous deposits, which have a total thickness of at least 1000 m in the test area, consist of an alternation of sandstones, shales and coal seams. The test area comprises a fault-block bounded by a major normal fault (NE-SW) and another normal fault, which abuts the former at an angle of 50° (NW-SE). Wells (11) on all three fault blocks were studied. These faults were pre-Miocene and already active in the Carboniferous. Probably activity of these faults ceased after the Carboniferous. The CBM-wells are located on the triangular fault block (Figure 2a).
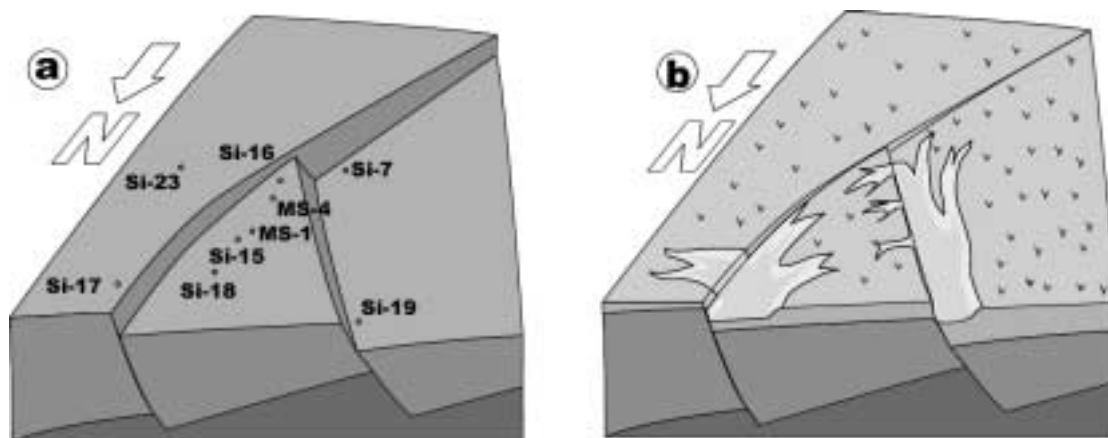

Figure 2: Cartoon of the structural framework of the Carboniferous deposits of the pilot site (a) and cartoon of the sand deposition in incised valleys along faults (b)

The Carboniferous deposits dip 12° to the north and consist of alternating layers of sandstone, clay and coal (Figure 3). The majority of the sandstone bodies are between 10 and 20 metres thick and are syn-sedimentary deposited along faults (Figure 2b). Some of these bodies cut into underlying coal seams, thereby destroying the lateral continuity of the coal. There is an upward decrease in sandstone bodies (Figure 3). The sealing capacity of the Miocene shales is proven by the occurrence of natural gas pockets in the sandstones of the top Carboniferous.
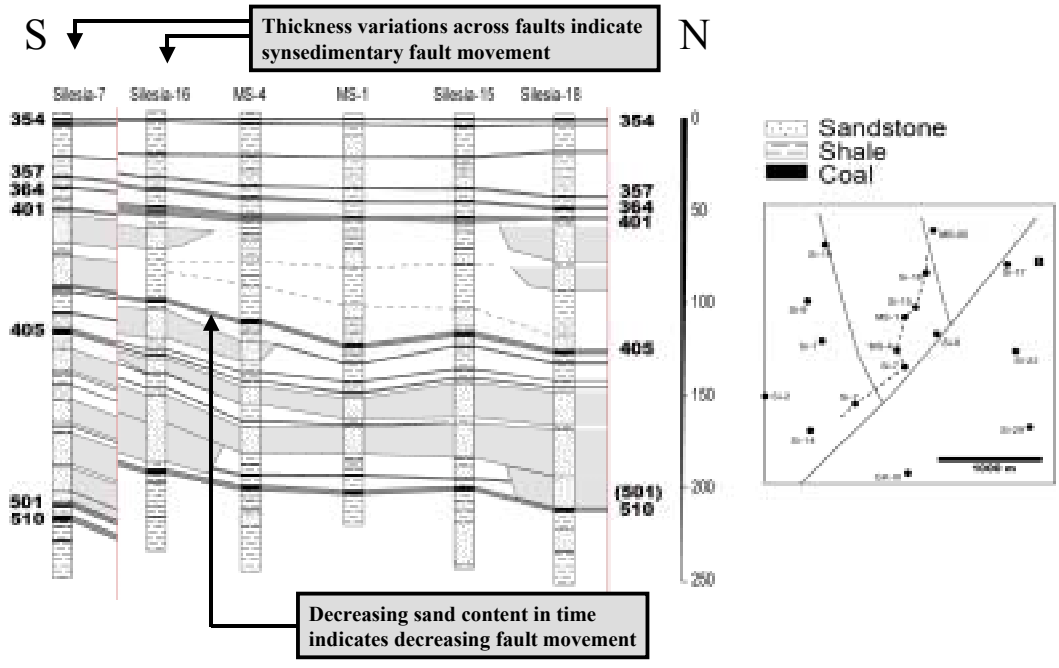

Figure 3: Cross section (N-S) of the site through 6 wells.

DEVELOPMENT OF THE SITE

In the conceptual design of the field experiment the two existing production wells are used. The water that is produced by these wells will be disposed via the nearby mine. One injection well will be drilled in between the two production wells. The exact location of the well will be mainly defined by spatial constraints at the surface. In case for some reason (e.g. cost, permits) it appears impossible to drill a new well, one of the existing wells will be used as an injection well instead of drilling a new well. However, this fall-back scenario is not preferred. The CO_2 for injection will be supplied on site by trucks. Surface facilities for CO_2 storage, handling and injection will be constructed at the site.

At the moment of publication (October 2002) preparations are going on for the development of the pilot site. These preparations will take at least until spring 2003, when drilling of the injection well is scheduled. Injection can start in the summer of 2003, and the period for injection will last at least until the end of the project in November 2004. The period available for injection is thus about 1.5 years. The net operational time depends strongly on the success of the operation and on available CO_2. It is unlikely that, as a consequence of the costs of CO_2, more than 10,000 m^3 CO_2 per day can be injected.

After the period of injection of 1.5 years, which corresponds with the end of the project lifetime, a breakthrough of CO_2 is preferred in one of the production wells. This breakthrough is important for a good and thorough understanding of the whole process, which is the main goal of this demonstration project.

RESERVOIR MODELLING

The feasibility of the breakthrough, within the project lifetime, was investigated by reservoir modelling of the operation. Two software packages were used: SIMED and COMET[1]. A set of 13 simulation cases was

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[1] SIMED-modelling by TNO-NITG and CSIRO, COMET-modelling by Advanced Resources International

modelled. Both the scenario with a new well and the fall-back scenario was modelled. With the set of simulation cases the sensitivity of several parameters (porosity, permeability, anisotropy, injection/production scheme) was investigated.
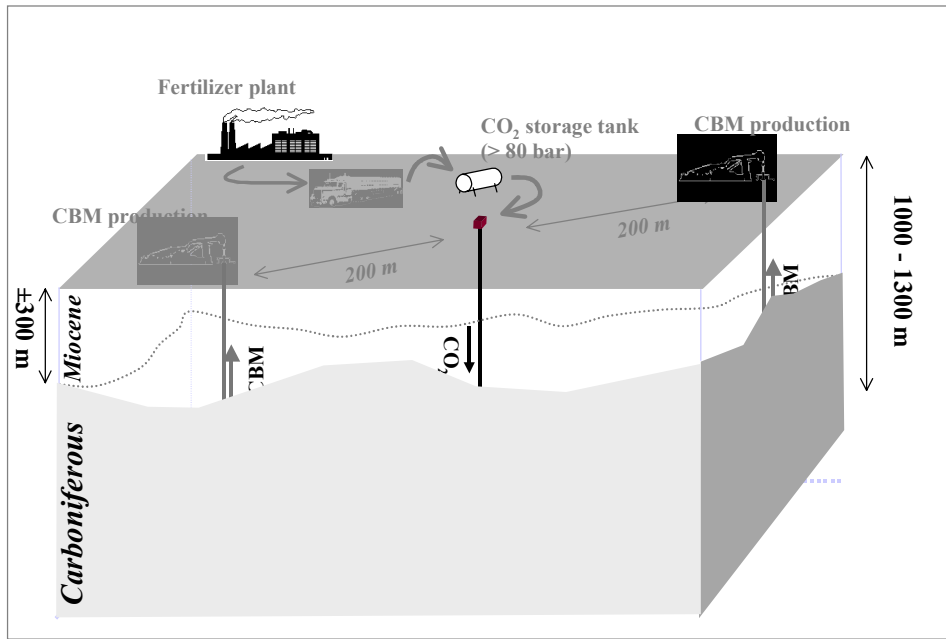

Figure 4: Cartoon of the layout of the pilot site

Figure 5 shows the layer model that was used in the modelling, with the six major coal seams in the depth interval under consideration. Based on the models it can be concluded that breakthrough is unlikely within 1.5 years when the CO_2 is injected in all six coal seams, as a result of the limited amount of CO_2. It was therefore decided that only the top three coal seams (357, 364, 401) are used for injection, which are positioned within a 20 m thick package of alternating shale and coal layers. From a sedimentological point of view, the top three coal layers are more likely to be continuous than the lower seams in absence of large sand bodies (Figure 3). Also, these top seams are more tightly packed in impermeable shales than the lower seams, which reduces the chance of leakage. Modelling results show that breakthrough is unlikely within 1.5 years when the distance between injection and production wells is more than 200 meters. In the fallback scenario, with a distance of 375 meters between the wells, no breakthrough is predicted to occur.
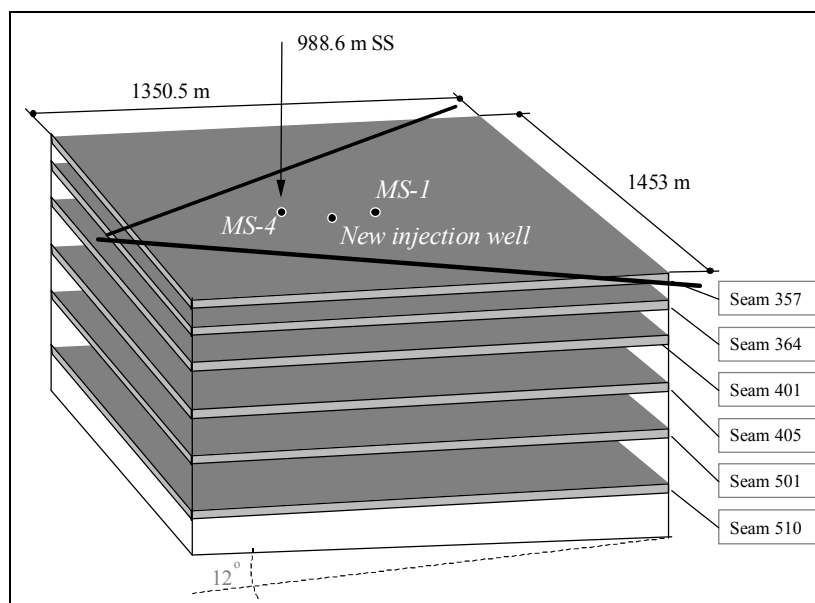

Figure 5: Layer model in SIMED for reservoir modelling of the injection/production

To increase the chances on a breakthrough, the new well should be drilled in line with the two production wells, within about 150 m from the updip well. However, spatial constraints at the surface could require a deviation from this line.

MONITORING OF INJECTED CO_2

For any subsurface CO_2 storage operation it is very important to be able to monitor the injected CO_2. Not only one would like to know that the CO_2 is injected at the intended location, but also that the CO_2 migrates towards the correct direction(s). Hence, as CO_2 can be suffocating at elevated concentrations, monitoring is important for safety reasons. Release of the injected CO_2 at the surface must therefore be prevented at any time. Another aspect is that monitoring could become important for accounting of CO_2 credits in a future international CO_2 market.

Two types of monitoring are foreseen within the RECOPOL project: direct CO2 measurement and seismic monitoring. Measurement devices will be placed at the surface and in a nearby (about 300 m to the west) abandoned mine gallery, vertically about 700 meters above the injection depth. If the CO_2-concentration at these locations increases it can be detected in an early stage.

Seismic monitoring methods have already been used for monitoring injected CO_2 (e.g. [9],[10]). Because they have never been applied for CO_2 in coal 3 techniques are currently evaluated. The methods being evaluated by using synthetic data sets are: surface High Resolution seismic acquisition, (reverse) Vertical Seismic Profiling and crosswell seismology (see Figure 6). The target, low velocity, coal seems are located at about 1100 meters depth and are maximal a few meters thick. The obtained resolution of the seismic method is therefore important.
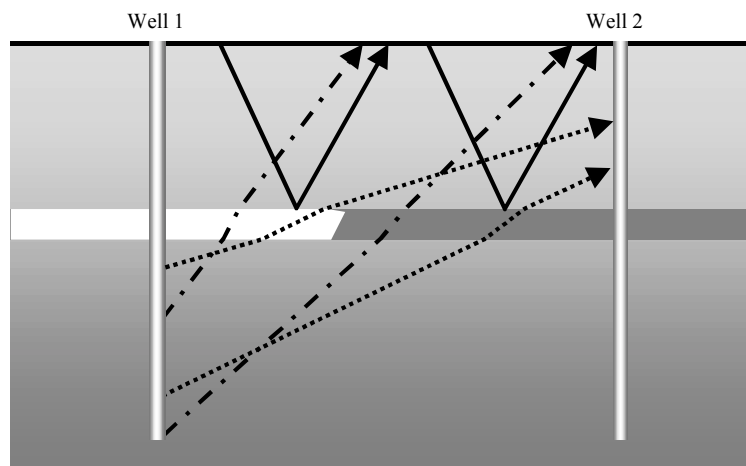

Figure 6: Schematic view of travel paths in the subsurface of the proposed seismic methods for monitoring CO_2 in a coal bed: HR seismic acquisition (solid arrows), reverse VSP (dashed arrows) and crosswell seismology (dotted arrows).

Also, before, during and after injection the seismic survey will be repeated in order to monitor CO_2 migration and possible other changes, such as methane desorption. The advantages and disadvantages of the investigated seismic methods are listed in Table 1.

TABLE 1
ADVANTAGES AND DISADVANTAGES OF DIFFERENT SEISMIC METHODS

	Surface acquisition	Vertical Seismic Profiling	Crosswell seismology
Advantages	Conventional method, standard processing and imaging	Improved resolution	Best resolution
	Vertical imaging	Vertical imaging	Highest time lapse repeatability
Disadvantages	Resolution	More processing effort	Most processing effort
			Less structural image

Gassmann modeling simulating the injection indicates that differences in the seismic signal can only be observed when the injected CO_2 content is smaller than the first approximately 15%. This implies that only the CO_2/water front can be monitored, which is sufficient for the monitoring purpose. For the final choice on which seismic method will be used besides the technical also the financial limitations will be taken into consideration. Crosswell tomography and VSP results are improved when the distance between the wells is shortened, which will be considered in the choice of the exact location of the well.

FURTHER WORK WITHIN THE PROJECT

Until spring 2003 much effort is put in the development of the site. Along with the development activities, laboratory work on coal samples from the site is ongoing at Delft and Aachen Universities of Technology. The laboratory experiments involve adsorption/desorption and flow-through tests for CO_2, CH_4 and mixtures. At the Institut Français du Petrol a detailed petrophysical model is constructed based on coal samples and geophysical logs. A 3D geological model was constructed, which will be used for upscaling of permeability data from logs to provide a 3D permeability model. The results from these activities will be used for the history matching of the injection/production process. History matching will be done by numerical simulation of the process during and after injection of the CO_2. Along with the technical work, an economical evaluation and a future-technological assessment will be executed, based on pilot results. A Decision Support System will be developed to assess the before-mentioned evaluation, thus providing European companies a rational tool for possible future investment opportunities.

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