CATO-2 Deliverable WP 3.01-D03

Progress report on: geological modelling, database & dynamic flow models - 2011

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1 Executive Summary (restricted)

WP3.01 contributes to the CATO-2 program by making available 3D static reservoir-geological models of the storage sites to other work packages for further study and coordinating data exchange with the site owners. Progress in WP3.01 is according to plan and objectives.
Focus of our activities in the year 2011 has been on: (a) fine-tuning of the reservoir geological model of the P18 field of TAQA Energy, and (b) a 'sweet spot' study of the offshore part of the West Netherlands Basin with the aim to pin-point optimum reservoir locations for CO_2 storage.

The P18 field is a potential storage site 20 km offshore of the "2e Maasvlakte" near Rotterdam. TAQA Energy plans to apply for a storage license at the end of this year, and technical feasibility and potential risks must be assessed before then. WP3.01 has contributed to this by making available two 3-D models of the subsurface around the P18 storage sites: a regional-scale geological model for geomechanical modeling studies, and a reservoir-scale geological model for reservoir engineering studies. WP3.01 has coordinated the data exchange with TAQA Energy. In the fine-tuning of the model consisted of a detailed study to assess leakage potential of different reservoir compartments P18-4 and P15-9 across faults.

PanTerra Geoconsultants BV joined WP3.01 as a partner in the beginning of 2011. During 2011 PanTerra has studied the Triassic and Upper Jurassic-Lower Cretaceous intervals of the West Netherlands Basin with the aim to outline "sweet spots" that are expected to be favorable and safe areas from a CO_2 retention point of view. This work was reported in December 2011. The studies provided an overview of subsurface geological properties (and their uncertainties) in the West Netherlands Basin. The work will be the basis for all further CATO studies in the basin. With the results reservoir "sweet spots" as well as areas unsuitable for storage can be easily identified. In addition, top-seal thickness (a key property for underground CO_2 storage) of the different reservoirs can be easily mapped.

Future studies will focus on reservoir continuity, reservoir connectivity and seal properties.
In addition, areas that appear to be unsuitable for storage were recognized as well. The studies provided an overview of subsurface geological properties (and their uncertainties) related to top seal and fault seals in the West Netherlands Basin. Sealing properties are key issues to consider when evaluating locations for underground CO_2 storage, in addition to the presence of reservoirs and traps. Special emphasis was placed on: (1) the geological characterization of effective top seals and possible waste-zones for Early Cretaceous and Triassic reservoirs, (2) the regional distribution of top seal properties, and (3) across-fault juxtaposition seal properties.

Distribution List

(This section shows the initial distribution list)

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Document Change Record

(This section shows the historical versions, with a short description of the updates)

Version	Nr of pages	Short description of change	Pages

Table of Content

2 Applicable/Reference Documents and Abbreviations

2.1 Applicable Documents

(Applicable Documents, including their version, are documents that are the "legal" basis to the work performed)

	Title	Doc nr	Version
~~AD-01a~~	~~Beschikking (Subsidieverlening CATO-2 programma verplichtingnummer 1-6843~~	~~ET/ED/9078040~~	~~2009.07.09~~
~~AD-01b~~	~~Wijzigingsaanvraag op subsidieverlening CATO-2 programma verplichtingennr. 1-6843~~	~~CCS/10066253~~	~~2010.05.11~~
~~AD-01c~~	~~Aanvraag uitstel CATO-2a verplichtingennr. 1-6843~~	~~ETM/10128722~~	~~2010.09.02~~
AD-01d	Toezegging CATO-2b	FES10036GXDU	2010.08.05
AD-01f	Besluit wijziging project CATO2b	FES1003AQ1FU	2010.09.21
AD-02a	Consortium Agreement	CATO-2-CA	2009.09.07
AD-02b	CATO-2 Consortium Agreement	CATO-2-CA	2010.09.09
~~AD-03a~~	~~Program Plan 2009~~	~~CATO2-WP0.A-D.03~~	~~2009.09.17~~
~~AD-03b~~	~~Program Plan 2010~~	~~CATO2-WP0.A-D.03~~	~~2010.09.30~~
AD-03c	Program Plan 2011	CATO2-WP0.A-D.03	2010.12.07

2.2 Reference Documents

(Reference Documents are referred to in the document)

	Title	Doc nr	Issue/ version
RD-01	Feasibility Study P18	CATO-2-WP3.01-D06	In writing
RD-02	Status report on remaining issues identified after the feasibility study for CO_2 injection in the depleted P18 gas field.	CATO-2-WP3.09-D14	2011.10.10
RD-03	Framework of Lower Cretaceous and Upper Jurassic clastic reservoirs in the West Netherlands Basin	PanTerra Report No. G841	August 2011
RD-04	Framework of Triassic clastic reservoirs in the West Netherlands Basin	PanTerra Report No. G917	November 2011

2.3 Abbreviations

(This refers to abbreviations used in this document)

SP	Sub programme
WP	Work package

3 Introduction

The main purpose of the CATO-2 program is to scientifically support the Dutch plans for CO_2 storage in the subsurface. SP3, of which WP3.01 is a part of, is directly aimed at optimising the site characterisation of sites under investigation. Several locations (e.g. Barendrecht) were much further in that process than others (e.g. P18). The aim of SP3 is to integrate the experiences from the different sites to arrive at an optimal, systematic site characterisation approach. WP3.01 contributes to this aim by coordinating the data exchange with the site owners, and by making available (either through updating or by creating) 3D static geological models of the storage sites to other work packages (e.g. WP3.02 Reservoir behaviour, WP3.03 Cap rock and fault integrity) for further study.

At the end of 2010 PanTerra joined the CATO2 program. The year 2011 is the first year in which PanTerra actively attributed to CATO2 deliverables.

The SP3-coordination lies with Rob Arts and Karl-Heinz Wolf. The WP-Leader for WP3.01 is Vincent Vandeweijer from TNO; Rick Donselaar is liaison and the contact person for the TUD. Andrew van de Weerd is the contact person for PanTerra.

3.1 Objectives WP3.01

WP3.01 has multiple objectives:

1. Gather all relevant and available data of potential storage sites and possibly acquire new data when necessary. Data include seismic, wire-line logs, core data, etc
2. Make the data accessible for other partners through an online database.
3. QC, update, create static reservoir-geological models of the potential storage sites:
    a. Quality-control of existing reservoir-geological models of the potential storage sites
    b. If necessary update them in order to get them up to specs for follow-up work.
    c. Create a static reservoir-geological model if no model for a particular site is available. A static reservoir-geological model displays the architecture of the reservoir in three dimensions, i.e., it is a representation of the reservoir that contains the size, shape, and spatial distribution of properties of the reservoir, which influences flow of fluids such as CO_2 through the reservoir.
4. Up-scale the reservoir-geological models for the purpose of flow simulation, to be performed with Eclipse or MoReS.
5. Execute regional geological studies to assess the storage potential of stratigraphic units (starting with the Triassic and Upper Jurassic Lower Cretaceous in the West Netherlands Basin)

The reservoir-geological models will serve as the starting point for other aspects of the overall feasibility studies.

At the start of CATO-2 several sites were discussed as potential CO_2 storage sites. Over time it became clear that P18 is the best potential storage site and focus of activities were directed to P18.

4 P18 - TAQA

The P18 fields of TAQA were selected as a one of the potential storage sites. The P18 fields are located approximately 20 km N-W of the Maasvlakte harbour of Rotterdam. The nearly depleted gas reservoirs are considered for CO_2 storage. Before gas production started the fields contained in the order of 15 Billion cubic meters natural gas under high pressures that remained in place millions of years below impermeable layers of Triassic and Jurassic claystones. The CO_2 will be injected into the depleted sandstone reservoirs present below the impervious layers. The gas reservoirs are at approximately 3 km depths.

The activities within WP3.01 on the P18 site were focused on data mining and the creation of quality-controlled 3D static reservoir-geological models of the field itself and the surrounding areas. These models will be used in reservoir flow modelling studies (WP3.02, WP3.04) and geomechanical modelling studies (WP3.03). Related activities involved the organisation of workshops at the TNO core facility in Zeist and the NAM core facility in Assen. During the workshops cores were examined and rock samples were taken for further investigation in other WPs. The results are described in the previous progress report (CATO-2 Deliverable WP 3.01-D01) and the Feasibility study P18 - Final Report (CATO-2 Deliverable WP 3.01-D06).

In 2011, the work focused on remaining issues identified after the feasibility study ahead of the FID by Eon and GdF Suez. This work is reported in CATO-2 WP 3.9-D14. The reservoir properties of the 3D static reservoir model were updated for the P18-4 section, in order to get better history matching results. Also the faults bounding the reservoir compartment P18-4 were studied in more detail, regarding the sealing potential and structural uncertainty.

5 Database - online working space

In order to allow all partners within CATO2 to work on and share essential, subsurface related data an online working space was created. The online working space is accessible to partners via the internet and will also function as a database from WP3.01. It is based on Microsoft SharePoint and implemented by TNO.

6 Regional sequence stratigraphy

Towards the end of the year 2010 a new partner, PanTerra, joined our activities in WP3.01. PanTerra is a highly-regarded geoconsultancy company, who proposed to add work regarding regional sequence stratigraphy of Triassic and Upper Jurassic -Lower Cretaceous reservoirs and seals in the West Netherlands Basin. This was regarded as a very welcome addition to the work program.

The work carried out by PanTerra for CATO during 2011 was delivered in December 2011 in two regional reports, one on the Triassic and one on the Upper Jurassic-Lower Cretaceous of the West Netherlands Basin. Each of these reports has three main components: 1) a seismic interpretation, 2) a well correlation study and 3) a petrophysical study. Based on the results of the West Netherlands Basin study areas may be selected that are optimal for CCS.

For the seismic study the top Triassic and seven Jurassic and Cretaceous horizons were mapped basin-wide on 3D surveys. The Jurassic-Cretaceous horizons illustrate the complicated tectonic rift history of the basin. Generally the basin inversion during the Late Cretaceous and Tertiary followed the fault-trends that were formed during the rifting. In selected areas the interpretation can be further refined and improved were needed and used in follow-up studies.

A network of over 80 wells in the basins was used to correlate 9 horizons in the “Main Buntsandstein” (= the Triassic reservoir section).. These horizons allow a subdivision and a definition of the better reservoirs in the Triassic. In addition the Upper Triassic (the seal for the Triassic reservoirs) was subdivided. This is needed to understand the characteristics of the seal sections and illustrates (among others) the subtle unconformities in the Upper Triassic. One of the unconformities (the Solling unconformity) truncates the reservoir and is of profound importance for the reservoir distribution in the basin.

Using a network of over ninety wells 19 horizons were correlated in the Upper Jurassic and Lower Cretaceous interval. In combination with the seismic mapping this allows sequence stratigraphic interpretations resulting in a robust subdivision. The stratigraphic distribution (and connectivity) of reservoir sands can now be understood and predicted.
The petrophysical analysis of key wells in all parts of the basins allows a first screening of reservoirs suitable for carbon storage. This combined with the seismic and well-based stratigraphy allows for clear sweet spot selection. This work is the basis for all further work in the basin on reservoirs and seals.

7 Summary on execution

The work focused on detailed investigations of questions and problems arisen after the final version of the “Feasibility Study P18” report (CATO2-WP3.01-D06). Work in WP3.01 mainly involved supporting the other WP's (WP3.02, WP3.03, WP3.04, etc) in their work. The support included for instance verifying data testing sensitivities and adjusting models so simulators could handle them.

Date	Event	Main conclusion / remark
2011.02.03	Advisory board meeting	Meeting with advisory board discussing SP3
2011.02.07	SP3 meeting with ROAD.	Discussion on the flow assurance plans for P18
2011.02.16	SP3 meeting with ROAD on MER report	Meeting with Royal Haskoning and PanTerra to discuss the draft IEA report for P18.
2011.02.22	SP3 general meeting	Whole day meeting with all project partners to show progress in SP3 (presentations). This meeting was meant as a possibility for stakeholders to provide input and make comments on the current work program as carried out.
2011.03.23	Combined SP1/2/3 meeting with ROAD project	Workshop to discuss the integrated chain (SP1/2/3) for the ROAD Project.
2011.03.24	WP3.9 meeting with ROAD	Detailed discussion on the monitoring plan for P18 with ROAD.
2011.05.24	SP1/2/3 meeting	Follow-up integrated SP1/2/3 meeting
2011.05.30	SP3 meeting with ROAD	Meeting to discuss open questions concerning the ROAD project (i.e. storage related questions in P18).
2011.06.01	CATO2 WP leaders meeting	WP leaders meeting in Rhine.

2011.06.08		Delivery progress report
2011.07.01	CATO2-day	Yearly event, where CATO2 presents itself
2011.08.23	SP3 meeting with ROAD	Discussion on progress of work related to open questions around ROAD project, Static Reservoir Model Workshop
2011.08.25	SP3 meeting with ROAD	Discussion on progress of work related to open questions around ROAD project, Dynamic Reservoir Model Workshop

Table 1: Summary on execution

8 Dissemination & Communication

Nr	Type interview, presentation, paper, etc	Author(s)	Title	Event/journal	date	remark
1.	Presentation	**Vandeweijer**	WP3.1	CATO-2 – Voortgangsbijeenkomst	2010.02.16	
2.	Presentation	**Vandeweijer**, Groenenberg, Pluymaekers, Donselaar	Progress WP3.1 – P18(/P15)	P18 Meeting at TAQA	2010.03.05	
3.	Presentation	**Groenenberg** Pluymaekers Vandeweijer Donselaar	-	Chemelot Meeting at DSM	2010.03.23	Interactive demonstration of Petrel model
4	Abstract, Presentation	**Donselaar** et al.	Targeting Reservoir Sandstone for Deep Geothermal Energy Production: Challenges and Heterogeneous Reservoir Model Construction	AAPG Conference and Exhibition, Denver, 2010		Presentation at conference
5	Extended abstract, Presentation	**Groenenberg** et al.	Targeting for geothermal energy production: Reservoir characterization and geothermal potential of the Delft Sandstone	EAGE Conference and Exhibition, Barcelona, 2010		Presentation at conference
6.	Presentation	**Groenenberg** Pluymaekers Vandeweijer Donselaar	Progress WP3.1 - P18	P18 Meeting at TAQA	2010.07.14	People from RCI were also present
7.	Presentation	**Pluymaekers** Vandeweijer	Progress Wp3.1	TNO / CATO-2 Progress meeting	2010.08.24	Internal TNO meeting
8.	Presentation	**Vandeweijer**	Results Wp3.1 - P18	P18 meeting	2010.10.04	
9.	Presentation	**Vandeweijer**	Results SP3 - P18	P18 meeting	2010.12.01	
10.	Presentation	**Vandeweijer**	Results SP3 - P18	RCI Meeting	2010.12.02	ROAD and NER related
11.	Presentation	**Pluymaekers**	Results WP3.1 – P18	P18 –ROAD meeting	2011.08.23	Workshop updated static model
12.	Extended abstract, Presentation	**Hofstee** et al.	The Feasibility of CO_2 Storage in the Offshore P18 Depleted Gas Reservoir	EAGE –SES Conference, Valencia, 2011	2011.11.08	Presentation at conference
13.	Abstract, Presentation	**Flores et at.**	Evaluation of CO2 Storage Potential in Depleted Gas Fields, West Netherlands Basin Dutch Offshore: A Case Study of the P-18 Gas Field	AAPG Annual Convention & Exhibiton, 2012	22-25 April 2012	Abstract accepted for oral presentation

Table 2: Dissemination and communication