CATO-2 Deliverable WP3.03-D03

Inventory of sealing, transport and mechanical properties needed

(1st Year Progress Report, 2010)

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1 Executive Summary (restricted)

The reliability of geomechanical analysis of caprock and fault integrity is depended on the availability and quality of data on rock physical properties, such as strength, elasticity and permeability as well as on knowledge of the in situ stress.

This report (deliverable WP3.3-D03) provides an inventory of sealing, transport and mechanical properties needed for geomechanical evaluation of specific sites. These properties will be largely determined by experimental testing program (WP3.3-D04, D08) aimed at determining baseline properties as well as changes in the properties as a function of mineral reactions with CO_2.

The physical and mechanical properties, which determine strength and deformability of the reservoir rock and caprock, commonly required in geomechanical analyses, are as follows: density, porosity, elasticity modulus, Poisson's ratio, bulk modulus, shear modulus, compressional and shear wave velocities, Biot's coefficient, tensile strength, unconfined compressive strength, friction angle, cohesion as well as other constitutive material parameters needed to define failure and dilatancy envelopes for the caprock. Sealing and transport properties of the caprock here of interest are: effective permeability, and capillary entry and breakthrough pressure to supercritical and gaseous CO_2.
The properties of faults and fault zones needed are: friction angle and cohesion as well as other constitutive material parameters needed to define the mechanical/frictional behaviour of faults, its evolution during slip, and the stability of slip. Sealing and transport properties of fault zones of interest are effective permeability and capillary entry and breakthrough pressure to supercritical and gaseous CO_2.
Another parameter of utmost importance for geomechanical modelling is the in situ stress. This parameter will be estimated from available regional stress data and site-specific field data.

This inventory helps with planning the experimental program carried out in this work package and with prioritizing requests for data from operators of potential CO_2 storage sites that are candidates for site-specific geomechanical analysis.

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
2010-08-30	7	Initial report by TNO	1-7

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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 date
AD-01	Beschikking (Subsidieverlening CATO-2 programma verplichtingnummer 1-6843	ET/ED/9078040	2009.07.09
AD-02	Consortium Agreement	CATO-2-CA	2009.09.07
AD-03	Program Plan	CATO2-WPD-3.03-D.03	2009.09.29

2.2 Reference Documents

(Reference Documents are referred to in the document)

	Title	Doc nr	Version/issue	Date

2.3 Abbreviations

(this refers to abbreviations used in this document)

3 General Text

3.1 Introduction

Rock physical properties, such as strength, elasticity and permeability are an essential input for geomechanical analysis of caprock and fault integrity. The reliability of such an analysis is dependent on the availability and quality of data on these properties as well as on data on in situ stress.

This report represents the first year progress report on "*Inventory of sealing, transport and mechanical properties needed"* (deliverable D03), which is a part of the WP-3.3 *"Caprock and Fault Integrity"* of the CATO-2 project. The reporting period is from project start 2009.04.15 until 2010.08.31 and addresses task T3.3.1 related to "*Geomechanical evolution of the reservoir-seal system and induced deformation*". The objective is to develop numerical modelling capability allowing prediction of the stress-strain evolution in and around a generic reservoir-seal system. This will be applied to specific sites to evaluate reservoir deformation (heave vs. compaction), caprock deformation and ground deformation at the surface, as well as the reactivation and seismic risk potential of pre-existing faults. Deliverable D03 provides an inventory of sealing, transport and mechanical properties needed for geomechanical evaluation of specific sites.

The properties of site-representative reservoir and caprock lithologies will be determined by experimental testing program in Task3.3.2 and requested from site operator where possible. The main aim of the laboratory-based task is to determine the baseline properties of intact reservoir and seal lithologies, and to determine how these are influenced by stress changes, by deformation and by chemical interaction with CO_2 under in-situ conditions, i.e. by reactive transport.

The deliverables achieved in the 1st year of the project are in agreement with the project plan.

3.2 List of properties needed for geomechanical modelling

The input required for geomechanical modelling of specific sites comprises physical and mechanical properties of the reservoir, caprock and the surrounding rock. Most of the properties of site-representative reservoir and caprock lithologies will be determined on samples in the experimental testing program in Task3.3.2. However, geomechanical models extend far beyond the reservoir-caprock pair while the core from the surrounding rock is practically never available. This implies that the physical and elastic properties of other lithologies present in the overburden, underburden and sideburden can not be directly measured, but derived indirectly from interpretation of well logs, or inferred from literature.

Caprock and reservoir

The physical and mechanical properties, which determine strength and deformability of the reservoir rock and caprock, commonly required in geomechanical analyses, are listed below.

- Physical properties: Density (ρ), Porosity (n)
- Elasticity properties: Elasticity modulus (E) and Poisson's ratio (ν); Bulk modulus (K) and Shear Modulus (G)

- Acoustic properties: Compressional wave velocity (Vp) and Shear wave velocity (Vs) (acoustic properties can be used to derive dynamic elasticity modulus and Poisson's ratio)
- Coupling parameters between stress and flow: Biot's coefficient (α)
- Tensile strength (σ_t)
- Unconfined compressive strength (σ_{UCS})
- Friction angle (φ)
- Cohesion (c)
- Other constitutive material parameters needed to define failure and dilatancy envelopes for the caprock (and the reservoir rock).
  E.g., the Modified Cam-clay model, which may be representative for shales, is defined by the slope of the critical state line (M) which is a function of the friction angle (φ), Poisson's ratio (v), initial porosity (n), compression index (λ), swelling index (κ) and preconsolidation stress (p_c).
  E.g., a power law creep model applicable to a viscous caprock such as the rocksalt requires a set of creep material parameters.

Sealing and transport properties of the caprock here of interest are:
- Effective permeability (k), if measurable
- Capillary entry pressure and breakthrough pressure to supercritical CO2 and gaseous CO2

<u>Faults and fault zones</u>
The physical and mechanical properties, which determine strength and deformability of the reservoir rock and caprock, commonly required in geomechanical analyses are listed below.
- Friction angle (φ)
- Cohesion (c)
- Stiffness of the fault zone (Normal stiffness, Dn and Shear stiffness, Ds)
- Other constitutive material parameters needed to define mechanical and frictional behaviour of faults and its evolution during slip, e.g. the rate and state friction parameters or equivalent parameters defining the evolution of slip behaviour and slip stability.

Sealing and transport properties of fault zones here of interest are:
- Effective permeability (k), if measurable
- Capillary entry pressure and breakthrough pressure to supercritical CO2 and gaseous CO2

<u>Other rocks in overburden, underburden and sideburden</u>
The reservoir is poro-elastically coupled with the surrounding rocks, which are assumed to respond to loading in an pure elastic manner. Therefore, only a limited number of physical and mechanical properties is needed. These properties will have to be derived indirectly from well logs due to the lack of core material. The properties needed are:
- Physical properties: Density (ρ)
- Elasticity properties: Elasticity modulus (E) and Poisson's ratio (ν); Bulk modulus (K) and Shear Modulus (G)

<u>Coupling chemical reactions and geomechanics</u>
Physical, mechanical, sealing and transport properties may change due to mineral alterations and reactivity associated with CO2/brine/rock interactions. Reaction rates determined in experiments and models in this and other work packages (WP3.2, 3.4) are essential input for numerical modelling of the long-term effect of mineral alterations. Changes in the properties as a function of mineral reactions are under investigation in the experimental part of this WP and will be included in geomechanical numerical models if/where applicable.

In situ stress

The in situ stress is the parameter of utmost importance for geomechanical modelling. This parameter will be estimated from available regional stress data and site-specific field data.