Preparations for a PhD thesis on electric properties, as a function of pressure, temperature and water saturation, of porous reservoir- and cap-rocks saturated with gas-water mixtures

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1 Executive Summary (restricted)

This proposed PhD research project has not started yet. However, we have done preparatory studies for the research that will be undertaken from the second year by a PhD student. As a result, the research idea has been further refined and progress has been made in understanding the dynamic situation in the reservoir in course of injecting CO2 and capturing the signature of change through monitoring the electrical properties in association with the seismic properties. From these studies it has been clear that the displacement of brine by CO2 will cause a change in the electrical resistivity and also changes in seismic velocities and amplitudes. Seismic and perhaps electrical measurements will be sensitive to the CO2 phase changes occurring at the critical point. Seismic properties may be affected by the quantity as well as the distribution of the phases. We conclude that in the lab experiments and theoretical studies to be carried out by the PhD student the sample behaviour should be tested under reservoir conditions as a function of injected CO2, the phase of the CO2, and the brine salinity. This will give us a powerful tool to monitor pore pressure and the CO2 saturation.

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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-WP0.A-D.03	2009.09.29

2.2 Reference Documents

(Reference Documents are referred to in the document)

	Title	Doc nr	Issue/version	date

2.3 Abbreviations

(this refers to abbreviations used in this document)

3 General Text

Introduction

This proposed research under a PhD project has not started in the first year. We have, nevertheless, performed preparatory studies that are directly relevant to this project. It is clear that not only electrical but also seismic properties depend on the mineralogical composition of the rock, porosity, fluid content, and in situ stress state. Previous work on the effects of CO2 on seismic velocities is limited. A few earlier studies measured both compressional (P-wave) and shear (S-wave) velocities on a number of sandstones saturated with nhexadecane and then flooded with CO2. They made measurements at different pore pressure and temperature conditions, finding that CO2 caused P-wave velocities to substantially decrease under all conditions while S-wave velocities were decreased at high pore pressure and increased at low pore pressures. Some other studies, however, have found that both P- and S-wave velocities decreased in carbonate rocks when CO2 was injected at pore pressures from 1200 psi to 2600 psi.

Earlier laboratory experiments showed that displacement of brine by CO2 will result in an increase in resistivity and a decrease in seismic velocities and amplitudes. Seismic measurements (and perhaps electrical) will be sensitive to the CO2 phase changes occurring at the critical point. Seismic properties may be affected by the quantity as well as the distribution of the phases.

Based on a study of these recent works and discussion with colleagues we have made progress in our understanding and refined the plan for the PhD research that will commence from the second year. In this report, we shall briefly summarize the main outcomes of our study.

Primary challenges identified

Much more work needs to be done to establish the relationships between geophysical properties and fluid properties near the critical point. It is of great importance to evaluate the effects of fluid displacement mechanics on the phase distribution in rock and the resulting effects on the geophysical parameters. There has been very limited research so far on the effects of CO2 on electrical properties of rock - even less than that for seismic properties.

Differences between seismic velocity and EM resistivity are to be expected. Differences between velocity and electrical measurements are seen on a positive aspect of this monitoring approach in that these differences can be used to further constrain interpretation of the geophysical measurements. Laboratory measurements of seismic and electrical properties are essential to interpretation of field measurements since they provide quantitative relationships between seismic and electrical parameters and the quantity of CO2 in the rock of interest.

Rapid reduction of seismic velocity near the critical point has been verified both theoretically and experimentally. Increasing the pressure of CO2 in the gaseous phase causes an increase in sample resistivity. Further testing needs to be done to evaluate changes in electrical resistivity in the region of the critical point of CO2 and define the underlying physics. If successful this, in combination with seismic velocity change, can be a powerful diagnostic tool. There has not been any lab experiment designed to test this possibility on actual reservoir rocks.

Conclusions

The results of the recent studies indicate the potential of combined electrical and seismic measurements to monitor the dynamics of CO2 sequestration in an underground reservoir. In the PhD research, which is expected to start from the second year of CATO2 project, one should attempt at measuring both seismic and electrical properties while the sample is subjected to CO2 injection, and measurements should continue after the injection has stopped to monitor the system returning from non-equilibrium to its equilibrium state. This should include those measurements being taken during transition of CO2 from gas phase through the critical point to the liquid or liquid-like state. Also stress-induced anisotropy in mechanical and electrical parameters should be investigated by applying different axial and normal stresses to the sample during and after CO2 injection. Finally a rock-type specific, integrated seismic-electrical monitoring approach for CO2 should be developed.