Progress report on:

The set-up and calibration of specific laboratory measurements regarding complex impedance in the frequency range from 1 kHz to 1 MHz

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1 Executive Summary (restricted)

This proposed PhD research project has not started yet. However, we have done related research on geophysical monitoring of the behaviour of a subsurface reservoir. Geophysical monitoring of dynamical behaviour of subsurface reservoirs remains an important issue in geophysical research. Among the possible applicable techniques are 4D seismic measurements and off-shore electromagnetic measurements. On-shore monitoring remains an important but not well-resolved issue, as repeated seismic measurements on-land are costly and suffer often from poor repeatability.

A new idea for monitoring based on electrical resistivity tomography was tested by computer simulation in 2009 at TNO. The essential element of the so-called BSEMT (Borehole to Surface Electrical Monitoring Technique) technique is the use of one electrode below the reservoir. The computer simulation results were promising, but concerns about the ability to measure the effect also arose. Therefore measurements in a tank in the laboratory were carried out to assess the feasibility of the BSEMT concept. The result of these measurements is that the expected effect of changes in the reservoir can indeed be seen by BSEMT. The surprising part of it is that the effect is bigger than the expectation based on computer simulations. This point has to be clarified further in future.

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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 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

Geophysical monitoring of dynamical behaviour of subsurface reservoirs remains an important issue in geophysical research. Among the possible applicable techniques are 4D seismic measurements and off-shore electromagnetic measurements. On-shore monitoring remains an important not well resolved issue, as repeated seismic measurements on-land are costly and suffer often from poor repeatability.

A new idea for monitoring based on electrical resistivity tomography was tested by computer simulation in 2009 at TNO. The essential element of the so-called BSEMT (Borehole to Surface Electrical Monitoring Technique) technique is the use of one electrode below the reservoir. The computer simulation results were promising, but concerns about the ability to measure the effect also arose. Therefore measurements in a tank in the laboratory were carried out to assess the feasibility of the BSEMT concept.

Activities

A configuration for the laboratory was prepared to carry out the measurements. The basic configuration is shown in

Figure 1. The bottom of a pvc-tank (75 cm x 55 cm) was covered with a layer of 7 cm of sand. Then three electrodes A, B and C were placed as indicated. Then another 5 cm of sand was added. On this sand layer a piece of strong plastic type of material was placed as indicated in the figure. The plastic can be shifted by pulling it out of the tank. Another sand layer of 13 cm was put on top. The sand was filled with water (almost saturated).

The plastic sheet is intended to correspond to a high resistive layer. The ratio of the resistivity of the sand and that of the plastic sheet is probably more than 100, which is the value mostly used in the computer simulations. For the simulation, 1 Ohm-m corresponds to the brine filled rock, whereas 100 Ohmm corresponds to the oil-filled rock.

Computer simulation showed that shifting the resistivity ratio of 100 to 10000, doubles the anomaly. On the other hand: the sheet is about 8 times thinner than the oil body used in the computer simulations, which compensates the too high resistivity of the plastic sheet.

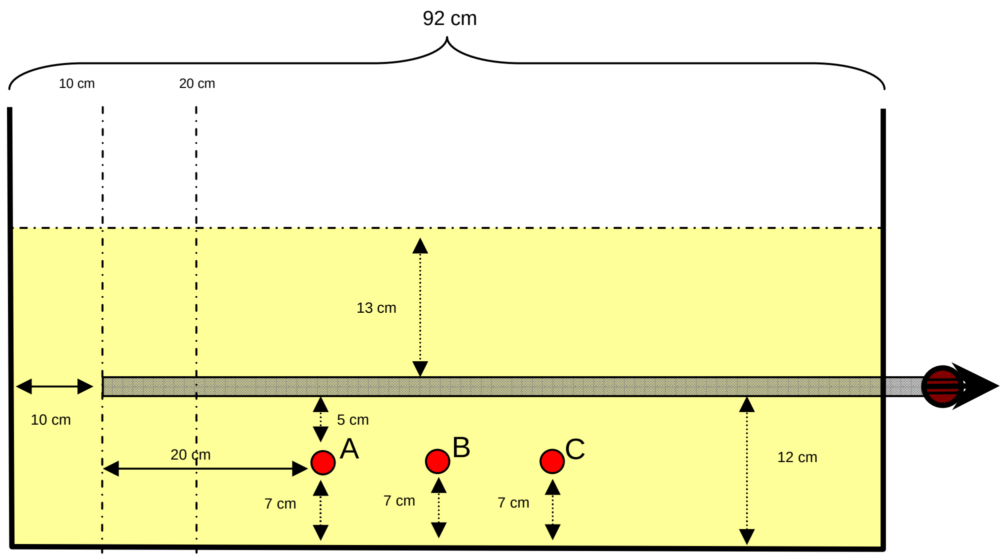

Figure 1: Basic layout of tank experiment.

On top, a wooden board with stainless steel nails was placed. The layout of the board is shown in Figure 2. A 2D grid of 60 (6 * 10) electrodes is used with a spacing of 6 cm. The potential is measured relative to a reference electrode positioned a few centimetres away (at the right in the figure) from the end of the regular grid. The reference actually consisted of 4 electrodes about 1 cm apart, to accommodate for the 4 channels that were used for simultaneous measurements to speed up the measurement.

Measurements were conducted using one of A, B and C as current electrode and using one current electrode of the regular grid. For such a configuration the potential field was measured relative to the reference electrode using the other electrodes. Then the surface current electrode was shifted one position and the potential field measurements were carried out again using the remaining electrodes. This procedure was repeated until all surface electrodes were used as current electrode.

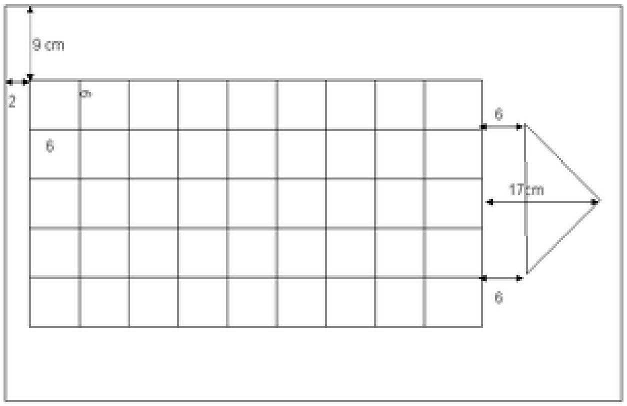

Figure 2: Layout of nails on wooden board.

More than 50 measurements (each taking about 3 hours) were carried out.

Unfortunately it turned out that the instrument was not always performing well: sometimes one of the four channels did function well. More than half of the measurements could therefore not be used in the data evaluation.

Nevertheless enough data remained to be processed. The processing consisted of carrying out a quality check (to eliminate mentioned bad measurements), and calculating differences of the potential field for different positions of the edge of the reservoir fill. Typical examples of such graphs are shown in
Figure 3.

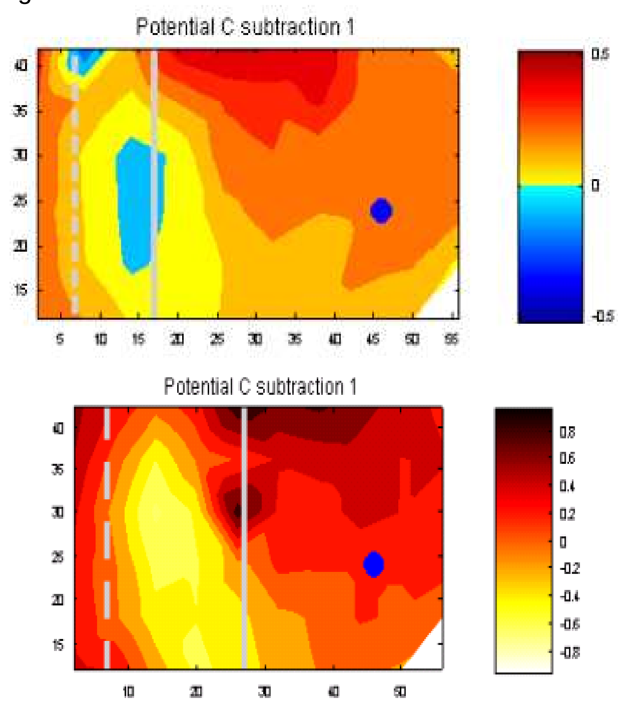

Figure 3: Difference of the potential field for two (indicated) positions of the edge of the reservoir fill, two times.

The negative anomaly shown between the lines indicates the position of the reservoir fill. The positive anomaly is caused by the measurement errors near the current electrode.

The positive thing is that an anomaly as expected is observed in the measurements. The strange thing is that its amplitude is bigger than foreseen in computer simulations carried out previously by TNO. This is still a subject of research.

Conclusion

The result of these measurements is that the expected effect of changes in the reservoir can indeed be seen by BSEMT. The surprising part of it is that the effect is bigger than the expectation based on computer simulations. This point has to be clarified further.