DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2008/17

Special core analysis for DONG Energy
Tuxen Study
Well: I-1X

Permeability and electrical properties

Niels Springer

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

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Contents

Enclosure: - Data on CD-ROM

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1. Introduction

At the request of Dong Energy A/S, GEUS Core Laboratory has performed special core analysis on samples from the I-1X well, the South Arne Field, Danish North Sea.

The experimental programme was specified in e-mail communications with Ms. Tanja Dalgaard during March-April 2007, and with Mr. Niels Balslev Jørgensen during June 2007. The following analytical programme was finally agreed on:

- Routine core analysis on a new set of plugs
- CT-screening of plugs for SCAL
- Liquid permeability at room and overburden conditions
- Electrical properties at room and overburden conditions

Preliminary data have been reported to Dong Energy by e-mail comm. during the period June 2007 to February 2008.

2 Sampling and analytical procedures

The I-1X well was drilled by DUC in 1969 and 5 cores in total were retrieved during the operation. The core material is chalk from the Upper and Lower Cretaceous. Shortly after coring, a number of full core pieces were removed for analysis and unfortunately never returned to the core boxes again. Besides, orientation lines are missing from the core and this implies that the plug depths given in this report are somewhat uncertain, but nevertheless believed to be confined to within the specific core box. Core #5 has been refered to the Lower Cretaceous Tuxen Fm that is the main objective of this core study. As no previous plugs were present, it was necessary to run a conventional plugging programme before the SCAL (Special Core AnaLysis) study could begin.

2.1 Plugging

Due to the generally poor condition of the core material and many fine fractures, 20 horizontal plugs were cut initially with simulated formation water as a coolant. The chemical composition and physical properties of the formation water is given in table 2.1. Later an additional 8 vertical plugs were taken because of the main focus on permeability of the Lower Cretaceous chalk. All plugs are 38 mm in diameter. A list of plug samples is given in table 2.2 and 2.3.

2.2 Plug quality screening

The horizontal plugs were X-ray CT-screened at the scanning facility at Department of Chemical Engineering, the Technical University of Denmark. Two longitudinal cuts perpendicular to each other are recorded for each plug. Scanning images and instrumental settings are given in chapter 7.

2.3 Preparation and routine core analysis

The plugs were initially Soxhlet cleaned until a selection of 10 fairly homogeneous plugs to be used in the SCAL study could be selected based on the CT-screening images. The selected plugs were then installed in single core holders and cold flush cleaned in methanol and toluene to secure an efficient cleaning of the low permeable core material. After cleaning the plugs were dried at 110 °C and analyzed for routine poro-perm. It was inevitable that some selected plugs had fine fractures, but it was expected that the effect of the fractures on permeability could be minimized when effective stress was later applied to the sample. Results are given in chapter 5.

2.4 Liquid permeability and electrical properties

Samples were vacuum and pressure saturated in simulated formation brine for a week, and left to equilibrate in brine under a slight vacuum in an anaerobic jar for several weeks before SCAL measurement commenced. Samples were then installed in single resistivity cells and a hydrostatic confining pressure of 145 psi [1 MPa] was applied. Approx. 1-2 PV's of fresh brine was flushed through the samples to displace air from the core holder. Confining pressure was increased to 400 psi [2.8 MPa] and the expelled brine volume recorded to allow calculation of the pore volume reduction. This was repeated later when the confining pressure was increased to 1450 psi (10 MPa)

Half of the samples (5 plugs) were now measured for the formation resistivity factor, resistivity index and endpoint oil permeability at this typical "room condition" pressure. The endpoint water saturation was adjusted to 20%, ref. the technique described in Springer et al [2].

The other half of the samples (5 plugs) were only measured for the formation resistivity factor at 400 psi [2.8 MPa].

The hydrostatic confining pressure was then increased to 1450 psi [10 MPa] for all 10 plugs and the formation resistivity factor, resistivity index and endpoint oil permeability measured again but now at effective overburden conditions.

Finally all plugs were water flooded during a period of several weeks. However, the throughput was less than 5 PV's even at a very high differential pressure due to the very low permeability of the Tuxen Fm chalk samples. The endpoint water permeability and resistivity index was measured.

The experimental programme was now concluded, the core holders dismantled and all samples transferred to Dean Stark extraction to determine the final fluid saturations.

At each experimental step readings of fluid flow and electrical resistivity (at room and overburden conditions) were taken over a period of one week to ensure stable conditions had been achieved before liquid permeability and electrical parameters were measured.

The experimental procedure is shown in the flow diagram in chapter 3, and experimental data are presented in chapter 5.

Table 2.1. South Arne simulated formation water analysis. Measured physical properties appear below.

Subject brine: Syd Arne formation brine

Element	Concentration	Compound	Gram compound per		
	mg/L		1 liter	3 liter	5 liter
Na total	32930				
Na+	32930	NaCl	83.707	251.122	418.54
Na+	0	NaHCO3	0.000	0.000	0.00
K+	522	KCl	0.995	2.986	4.98
Mg2+	665	MgCl2, 6H2O	5.561	16.683	27.81
Ca2+		CaCl2	0.000	0.000	0.00
Ca2+	5667	CaCl2, 2H2O	20.787	62.362	103.94
Sr2+	0	SrCl2, 6H2O	0.000	0.000	0.00
Ba2+		BaCl2, 2H2O	0.000	0.000	0.000
Cl-	63220				
HCO3-	0.0				

TDS:	**103004**	**mg/L**	~1.763	mol/L NaCl eqv.
pH:		**@ 23 C**		

Comments: Slightly modified compared to the brine used in the 2005 study

Physical data:			
	Resistivity Rw :	**0.075**	**ohmm @ 25.0 ºC**
	Calculated Rw :	**0.074**	**ohmm @ 25.0 ºC**
	Density dw :	**1.068**	**g/cc @ 25.0 ºC**
	Calculated dw :	**1.066**	**g/cc @ 25.0 ºC**
	Viscosity:	**1.093**	**cP @ 25 ºC**

Table 2.2. I-1X, list of horizontal plugs cut from the Lower Cretaceous Tuxen Fm. Samples selected for SCAL measurements are indicated (x).

Core # 5: 9493' - 9541'

Plugged with 10% NaCl brine
Plug trims to be used for ISR

Plug #	Box #	Depth [feet]	Selected
1	1	9493,25	
2	1	9494,21	x
3	2	9498,90	x
4	6	9510,03	
5	6	9510,23	
6	6	9510,56	x
7	8	9514,25	
8	8	9515,84	x
9	9	9517,46	x
10	9	9517,46	
11	15	9536,25	x
12	15	9536,44	
13	16	9539,25	x
14	7	9511,33	x
15	10	9522,90	
16	11	9523,25	x
17	11	9525,58	
18	13	9530,08	
19	14	9532,33	x
20	14	9534,58	

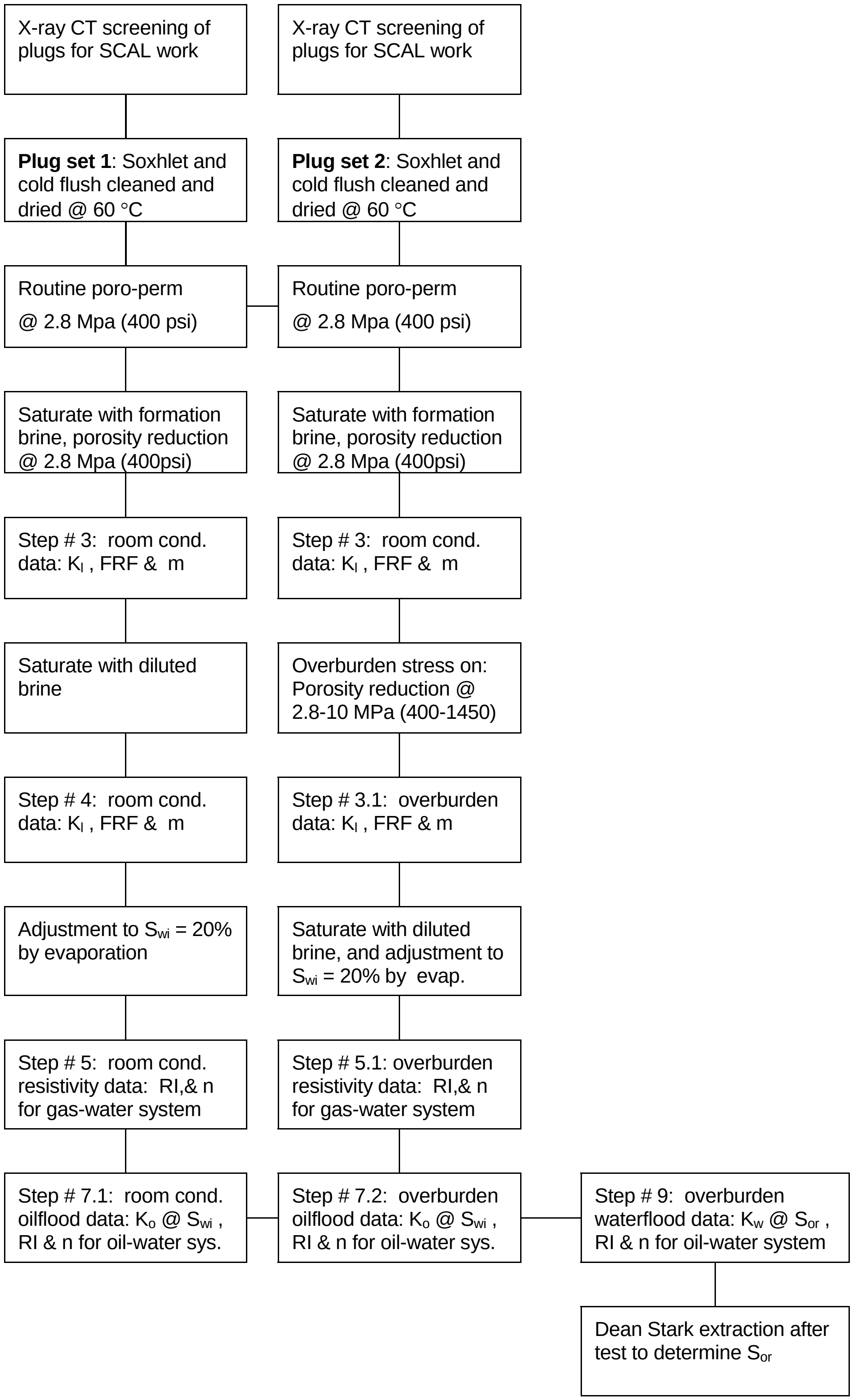
Table 2.3. I-1X, list of vertical plugs cut from the Lower Cretaceous Tuxen Fm.

Plug #	Box #	Depth [feet]
25V	4	9504,00
2V	5	9505,08
26V		9508,50
4V	8	9515,83
27.1V	11	9523,90
6V	12	9527,16
7V	14	9534,58
8V	16	9540,33

3 Flow diagram of the analytical procedures

Plug set 1: 2, 6, 9, 11 and 13

Plug set 2: 3, 8, 14, 16 and 19



4 Analytical Methods

The conventional core analysis was performed at GEUS Core Laboratory to standards defined by the American Petroleum Institute (API). For a more detailed description of methods, instrumentation and principles of calculation the reader is referred to API recommended practice for core-analysis procedure [1].

Electrical measurements are performed at 25 ± ½ ºC, and to the guidelines established by the Society of Core Analysts [4]. A temperature log may be provided on request and included with the attached CD-ROM.

4.1 Overburden measurements

The following data were supplied by DONG Energy :

Net confining pressure: 1450 psi (10 MPa) hydrostatic

Liquid permeability: The plug is mounted in a core holder and a net confining pressure of 400 psi (2.8 MPa) applied to the sleeve (or as specified by the client). The required fluid, volumetric flow and pressure is delivered from a computer controlled pumping system that handles collection of all relevant data. An initial back pressure of 75-150 psi (0.5 – 1 MPa) is applied to secure that residual gas is in solution.

Porosity: The initial porosity is determined at room conditions. An Archimedes test is applied to the fully saturated plug sample, and in combination with the sample grain density the porosity is calculated. During testing the sample pore volume decreases as overburden increases. This is observed as an amount of liquid expelled from the sample into a graduated tube, or constantly monitored using an electronic Mettler balance connected to a PC. The final reading is taken after a fixed time or when a stable level has been reached on the balance. The porosity reduction is calculated as the relative decrease in the initial porosity:

$$\O_i = \frac{V_{pi}}{V_{bi}}$$

$$\O_{i+\Delta p} = \frac{V_{pi} - \Delta V_p}{V_{bi} - \Delta V_p}$$

The porosity reduction is then given as:

$$\frac{\O_{i+\Delta p}}{\O_i} \cdot 100\% = \frac{V_{pi} - \Delta V_p}{V_{bi} - \Delta V_p} \cdot \frac{V_{bi}}{V_{pi}} \cdot 100\%$$

Where $\O_i$ = initial porosity
V_{pi} = initial pore volume
V_{bi} = initial bulk volume
$\O_{i+\Delta P}$ = new porosity induced by a certain change Δp in confining stress.
ΔV_p = change in pore volume due to the change in confining stress.

The initial change in the pore volume that occurs from room conditions to the lowest confining stress applied in the study is extrapolated from a liquid production curve (produced liquid vs effective confining stress).

4.2 Formation resistivity factor

In a “clean” formation (non-shaly) the formation factor F is described by Archie’s equation:

$$F = \frac{R_0}{R_w} = \frac{a}{Ø^m}$$

Where R_0 = resistivity of sample @ S_w = 100%
R_w = resistivity of formation brine
Ø = porosity
a = constant
m = cementation exponent

For a plug sample F is calculated from the following formula:

$$F = \frac{1}{R_w} \cdot \frac{z \cdot A}{L}$$

Where R_w = resistivity of brine in ohm-m
z = impedance of plug sample in ohm @ S_w = 100%
A = area of the plug in m^2
L = length of plug in m

Rearranging Archie’s equation for the formation factor:

$$\log F = -m \log Ø + \log a$$

produces a straight-line relationship in a double logarithmic diagram where F is plotted as a function of Ø. The constant 'a' is then determined as the intercept and the cementation exponent 'm' as the slope of the best fit straight line. Values for 'm' are usually preferred for a = 1, which is expected from theoretical grounds. Therefore a set of regression constants are given for a regression line which has been biased through (1,1).

The measurement of F is performed with the plug mounted in a 2-electrode resistivity core holder at an overburden pressure >300 psi. The plug is allowed to settle for more than 3 hours. The porosity reduction/pore volume compressibility is recorded consecutively. The plug resistance is measured as the impedance to an AC signal of 5-20 kHz frequency depending on rock properties (minimum phase angle). Data logging is performed using the HP 4276A LCZ-meter controlled by a PC. The resistivity of the brine is measured in a conductivity meter (Radiometer Analytical CDM 210). The measured formation brine resistivity is checked against a model calculated resistivity.

4.3 Resistivity index

In a “clean” formation (non-shaly) Archie determined experimentally that the water saturation could be expressed by the following equation:

$$S_w{}^n = \frac{FR_w}{R_t} = \frac{R_o}{R_t} = \frac{1}{RI}, \qquad RI = \frac{R_t}{R_o}$$

where S_w = water saturation
n = saturation exponent
F = formation resistivity factor
RI = resistivity index
R_0 = resistivity of sample @ S_w = 100% in ohm-m
R_t = resistivity of sample @ S_w < 100% in ohm-m
R_w = resistivity of brine in ohm-m

Rearranging Archie’s equation for the water saturation :

$$RI = S_w{}^{-n}$$

and

$$\log(RI) = -n \ \log(S_w)$$

In a double logarithmic diagram consecutive values of S_w and RI shall produce a straight line from which the saturation exponent 'n' can be determined as the slope.

The measurement of RI is performed with the plug mounted in a resistivity core holder at an overburden pressure >300 psi. The plug is allowed to settle for more than 3 hours. The porosity reduction/pore volume compressibility cannot normally be measured but is estimated from other sources, preferebly an overburden experiment. The two-electrode method is normally applied and the resistance measured as the impedance to an AC signal of 5-20 kHz frequency depen-ding of the resistivity cell design and the type of rock (minimum phase angle). Data logging is performed using the HP 4276A LCZ-meter controlled by a PC.

Drainage of the sample may be carried out using a porous plate, and therefore the measure-ment of RI is conveniently combined with air/brine or oil/brine capillary pressure experiments. For low permeability material this may take very long time and often uneven saturation profiles are generated in the samples that will affect the resistivity measurement. For such low permea-bility samples a different desaturation technique may be applied [2]. A diluted formation brine is used and the samples allowed to evaporate under room conditions to a precalculated weight whereby a specific water saturation is obtained and the original brine concentration re-generated. A homogeneous brine distribution is normally obtained within a week due to diffusion and capillary forces. The non-wetting phase is air.

5 Results

Nomenclature

L	– sample length	[cm]
D	– sample diameter	[cm]
A	- sample area	[cm^2]
BV	– bulk volume	[cc]
PV	– pore volume	[cc]
Δ PV	– pore volume change	[ml]
GD	– grain density	[g/cc]
V	– volume	[ml]
Δ V	– volume change	[ml]
Ø	– porosity	[pct or frc]
S_w	- water saturation	[pct or frc]
S_{wf}	- final water saturation	[pct or frc]
$_i$	- Subscript for "initial"	
imp	- impedance	[ohm]
τ	- tortuosity	

F or FRF	– formation resistivity factor	
F*	- intrinsic formation factor	
RI	– resistivity index	
m	– cementation exponent	
m*	- intrinsic porosity exponent	
n	– saturation exponent	
a	– Archie constant, or a dimensional correction factor in compressibility calculations	
R_o	- resistivity of water saturated sample	[Ω m]
R_w	- resistivity of formation water	[Ωm]
C_o	- core conductivity	[S/m]
C_w	- formation water conductivity	[S/m]
Z_o	- impedance of water saturated sample	[Ω]
Z_t	- impedance of sample at $S_w < 1$	[Ω]
nd/na	- not determined/analyzed	
WW_{calc}	- wet weight calculated from plug volume and core analysis data	[g]
WW_{meas}	- wet weight measured	[g]

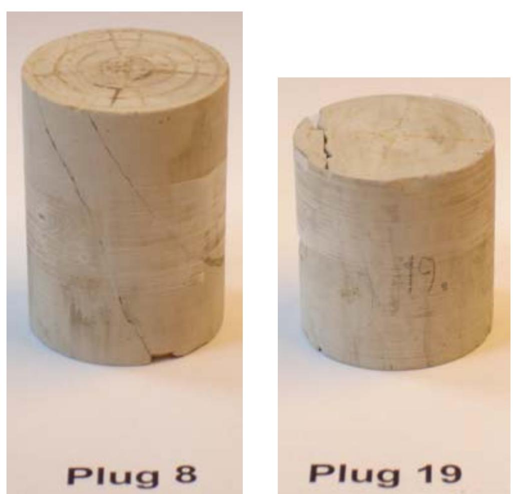
Plug conditions

The Lower Cretaceous core material from the I-1X well is fragile, and minor cracks or fractures were observed in many plugs. Because of this a number of plugs were screened from the SCAL study, but none the less fractures may have affected the measured flow and electrical data for the following plugs :

8 and 19

After completion of the measurements plug 8 was observed to have broken into 3 parts due to the presence of 2 oblique fractures, ref. the photo below. It is therefore justified to exclude plug 8 from the very fracture sensitive resistivity index measurements.

Figure 5.1. Tuxen I-1X core study. Parallel or oblique fractures transceting the whole plug were observed to affect the measured permeability and electrical properties for plug 8 and in some experiments plug 19 as well.



5.1 Conventional core analysis

The routine core analysis data for horizontal and vertical plugs are given in table 5.1 below . Only 10 plugs were selected for SCAL testing.

Table 5.1. Tuxen I-1X core study. Conventional core analysis data measured after additional cold flush, miscible liquids cleaning of plugs selected for SCAL work. Vertical plugs were not used in the SCAL study but were also cold flush cleaned. Gas permeability was measured @ 2.8 MPa (400 psi) confining sleeve pressure.

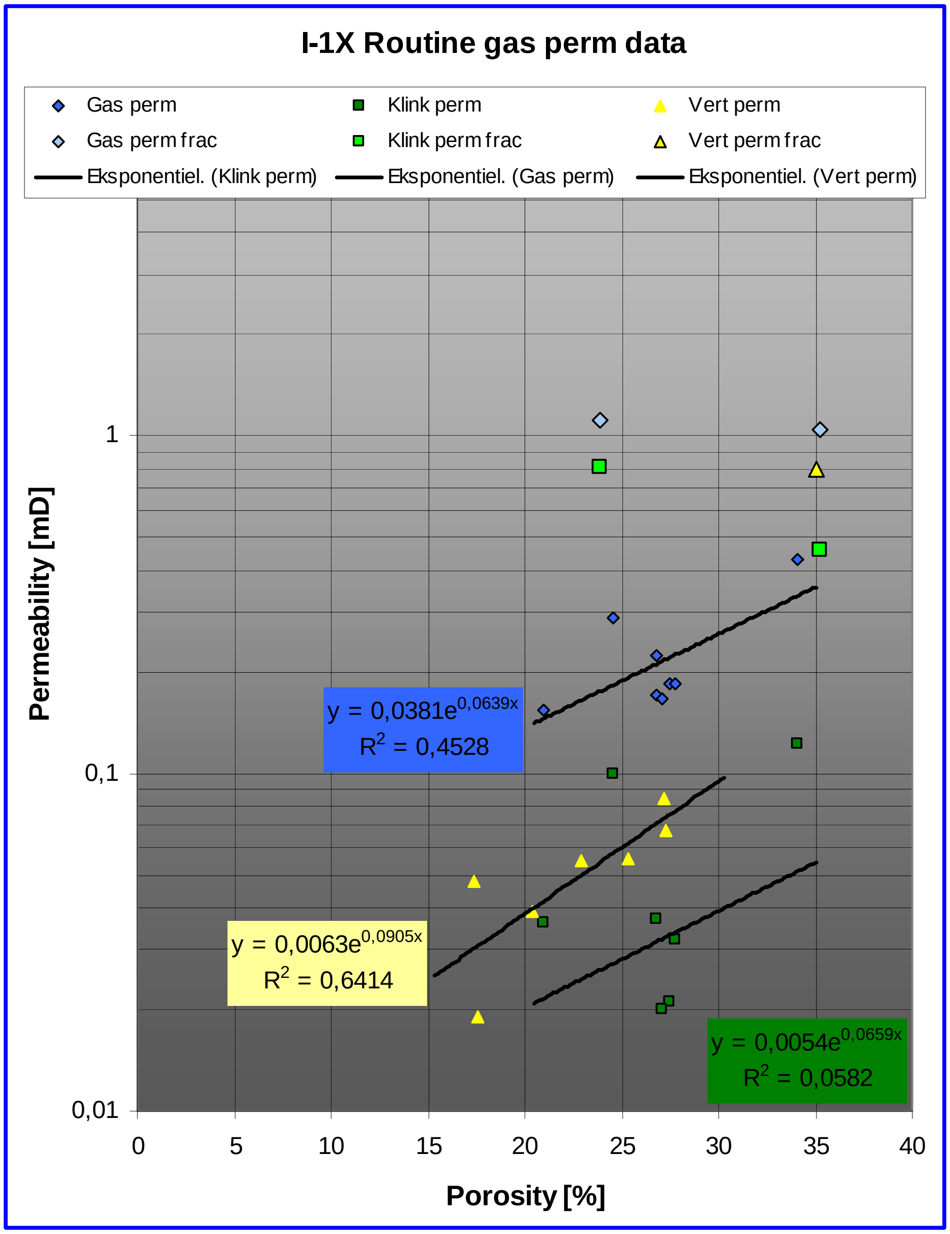
Sample ID	Depth [m]	Plug type	Gas Perm [mD]	Klink. Perm [mD]	Klink. corr coef.	Porosity [%]	Gr. Dens [g/ccm]
2	9494,21	Hori	0,430	0,123	0,998	34,04	2,696
6	9510,56	Hori	0,185	0,021	0,996	27,47	2,700
9	9517,46	Hori	0,223	0,037	0,998	26,79	2,711
11	9536,25	Hori	0,171	0,005	1,000	26,78	2,704
13	9539,25	Hori	0,290	0,099	0,993	24,54	2,700
3	9498,90	Hori	0,184	0,032	1,000	27,8	2,703
8	9515,84	Hori	1,044	0,458	1,000	35,24	2,707
14	9511,33	Hori	0,167	0,020	0,993	27,04	2,714
16	9523,25	Hori	0,155	0,036	0,986	20,94	2,726
19	9532,33	Hori	1,107	0,808	0,998	23,84	2,701

Sample ID	Depth [m]	Plug type	Gas Perm [mD]	Klink. Perm [mD]	Klink. corr coef.	Porosity [%]	Gr. Dens [g/ccm]
25V	9504,00	Vert	0,056	0,003	0,992	25,32	2,713
2V	9505,08	Vert	0,055	~ 0	0,997	22,93	2,703
26V	9508,50	Vert	0,084	~ 0	0,997	27,17	2,706
4V	9515,83	Vert	0,796	0,355	0,999	35,03	2,707
27.1V	9523,90	Vert	0,019	~ 0	0,998	17,57	2,740
6V	9527,16	Vert	0,039	~ 0	0,992	20,42	2,726
7V	9534,58	Vert	0,068	~ 0	0,958	27,29	2,685
8V	9540,33	Vert	0,048	~ 0	0,998	17,35	2,715

~ 0 : Indicates a negative Klinkenberg corrected gas perm; this happens because the flowmeter calibration is imprecise close to zero flow conditions; the regression line, however, is perfect as appears from the significant correlation coefficients.

NB: Observe that fractures in vertical plugs are perpendicular to the flow direction and therefore do not affect the measured gas perm

Figure 5.1. Tuxen I-1X core study. Conventional gas and Klinkenberg corrected gas permeability data measured for horizontal and vertical plug samples. A Klinkenberg corrected gas permeability could not be measured for the very low permeability vertical plugs. Some fracture permeability data were excluded from the regression analysis but is shown in the scatter diagram below.



5.2 Special core analysis – room condition data

Measured data are listed in table 5.2 below and scatter diagrams are collected in section 5.4 and 5.5.

Table 5.2. Tuxen I-1X core study. Data measured at room conditions and @ 28 bar confining P.

Subject: SCAL study | **Company: DONG Energy A/S**

C_p, K_l , FRF and RI properties | **Well: I-1X**

Room condition data: @ 25 °C

Plug no	Depth	CCAL data @ room cond.								
	[feet]	$L_{caliper}$ [cm]	A_{calc} [cm^2]	Wet wt [g]	Dry wt [g]	$BV_{i(Arch)}$ [cc]	$PV_{i(Arch)}$ [cc]	$Ø_{i(Arch)}$ [%]	GD [g/cc]	k_g [mD]
2	9494.21	5.287	11.10	123.64	104.04	58.67	20.51	34.95	2.696	0.43
6	9510.56	5.419	11.07	133.88	117.25	59.98	16.63	27.72	2.700	0.19
9	9517.46	5.838	11.01	144.44	127.33	64.28	17.55	27.30	2.711	0.22
11	9536.25	5.163	10.97	127.04	111.76	56.64	15.43	27.25	2.704	0.17
13	9539.25	4.679	11.07	117.78	105.23	51.80	13.08	25.25	2.700	0.29
3	9498.90	3.698	11.16	87.54	80.13	41.26	11.61	28.14	2.703	0.18
8	9515.84	5.650	11.13	132.59	110.22	62.90	22.22	35.33	2.707	1.04
14	9511.33	5.052	11.05	125.19	110.36	55.80	15.42	27.64	2.714	0.17
16	9523.25	5.063	11.02	131.78	119.96	55.80	11.86	21.26	2.726	0.16
19	9532.33	4.229	11.11	107.50	96.12	46.98	11.48	24.43	2.701	1.11

Step # 3 : FRF data for conc. SA-brine ~ 100.000 mg/L

Plug no	Depth	Plug porosity data @ 28 bar			Plug permeability data @ 28 bar			Plug resistivity data @ 28 bar		
	[feet]	ℵPV [cc]	PV [cc]	**Ø [%]**	L [cm]	A [cm^2]	**K_l [mD]**	$\|Z_0\|$ [ohm]	Phase [deg]	**FRF**
2	9494.21	0.12	20.39	34.82	5.283	11.08	0.096	54.97	0.10	15.37
6	9510.56	0.16	16.47	27.53	5.414	11.05	0.016	76.42	0.10	20.79
9	9517.46	0.18	17.37	27.10	5.833	10.99	0.013	93.67	-0.02	23.53
11	9536.25	0.25	15.18	26.93	5.155	10.94	0.014	73.80	0.05	20.88
13	9539.25	0.20	12.88	24.96	4.673	11.04	0.017	76.72	-0.14	24.17
3	9498.90	0.18	11.43	27.83	3.693	11.12	0.031	45.89	-0.10	18.43
8	9515.84	0.17	22.05	35.15	5.645	11.11	0.343	38.73	0.06	10.17
14	9511.33	0.28	15.14	27.28	5.044	11.01	0.018	66.81	-0.10	19.44
16	9523.25	0.21	11.65	20.96	5.057	10.99	0.007	108.06	-0.04	31.32
19	9532.33	0.19	11.29	24.12	4.223	11.08	0.015	80.54	0.03	28.17

Step # 4 : FRF data for diluted SA-brine ~ 20.000 mg/L

Plug no	Depth	Plug porosity data @ 28 bar			Plug permeability data @ 28 bar			Plug resistivity data @ 28 bar		
	[feet]	ℵPV [cc]	PV [cc]	**Ø [%]**	L [cm]	A [cm^2]	**K_l [mD]**	$\|Z_0\|$ [ohm]	Phase [deg]	**FRF**
2	9494.21			34.82	5.283	11.08	0.098	158.83	-0.46	11.29
6	9510.56			27.53	5.414	11.05	0.021	226.53	-0.55	15.67
9	9517.46			27.10	5.833	10.99	0.017	275.53	-0.63	17.60
11	9536.25			26.93	5.155	10.94	0.017	214.58	-0.66	15.43
13	9539.25			24.96	4.673	11.04	0.017	216.93	-0.78	17.38

Step # 5 : RI data for air saturated plugs @ S_{wi}=20%

Plug no	Depth	Plug porosity data @ 28 bar			Plug permeability data @ 28 bar			Plug resistivity data @ 28 bar		
	[feet]	ℵPV [cc]	PV [cc]	**Ø [%]**	L [cm]	A [cm^2]	**K_l [mD]**	$\|Z_t\|$ [ohm]	Phase [deg]	**RI**
2	9494.21			34.82				841.48	-1.50	15.31
6	9510.56			27.53				1082.48	-2.05	14.17
9	9517.46			27.10				1848.68	-1.93	19.74
11	9536.25			26.93				1276.68	-2.75	17.30
13	9539.25			24.96				1391.18	-3.40	18.13

Step # 7.1 : RI data for oil saturated plugs @ S_{wi}=20%

Plug no	Depth	Plug porosity data @ 28 bar			Plug permeability data @ 28 bar			Plug resistivity data @ 28 bar		
	[feet]	ℵPV [cc]	PV [cc]	**Ø [%]**	L [cm]	A [cm^2]	**K_l [mD]**	$\|Z_t\|$ [ohm]	Phase [deg]	**RI**
2	9494.21			34.82	5.283	11.08	0.103	1064.18	-2.75	19.36
6	9510.56			27.53	5.414	11.05	0.027	1317.68	-2.85	17.24
9	9517.46			27.10	5.833	10.99	0.021	2088.68	-3.14	22.30
11	9536.25			26.93	5.155	10.94	0.023	1425.68	-3.80	19.32
13	9539.25			24.96	4.673	11.04	0.026	1551.18	-3.64	20.22

Table 5.2 cont. Tuxen I-1X core study. Raw data at room conditions and @ 28 bar confining P.

Raw data below: **Company: DONG Energy A/S**

GEUS Core Lab, 10.09.2007 **Well: I-1X**

Room condition data: **@ 25 °C**

Formation brine data @ 25 °C :			20% brine:
Brine R_w :	0.075	[ohmm]	0.295
Brine d_w :	1.068	[g/cc]	1.011
Viscosity :	1.093	[cP]	0.897
Isopar-L :	1.30	[cP]	

Recording data for resistivity cells:

Plug and cell impedance measured @ 5, 10 & 20 kHz
(minimum phase angle data only given in the table below)
Intrinsic cell impedance: 0.32 ohm

Step # 3 : **Conc. SA-brine ~ 100.000 mg/**

Plug no.	Imp data @ 28 bar				Perm data @ 28 bar		Compressibility data @ 28 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
2	55.04	55.53	0.09	0.10	0.977	1.49	58.55	0.20	0.0007
6	76.91	76.56	0.10	0.09	0.527	4.89	59.82	0.27	0.0009
9	94.12	93.86	-0.01	-0.02	0.405	5.00	64.10	0.28	0.0009
11	73.87	74.37	0.03	0.06	0.461	4.90	56.39	0.44	0.0015
13	76.69	77.39	-0.14	-0.13	0.502	3.90	51.60	0.39	0.0013
3	46.15	46.26	-0.11	-0.09	0.305	0.96	41.08	0.44	0.0015
8	39.08	39.02	0.05	0.07	0.333	0.06	62.73	0.27	0.0009
14	67.16	67.09	-0.10	-0.09	0.476	3.76	55.52	0.50	0.0017
16	108.5	108.3	-0.03	-0.05	0.330	6.20	55.59	0.38	0.0013
19	80.94	80.78	0.01	0.04	0.361	2.26	46.79	0.40	0.0013

Step # 4 : **Conc. SA-brine ~ 20.000 mg/L**

Plug no.	Imp data @ 28 bar				Perm data @ 28 bar		Compressibility data @ 28 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
2	159.1	159.2	-0.46	-0.46	1.489	1.83	58.67	0.00	0.0000
6	226.70	227.00	-0.55	-0.54	1.036	6.00	59.98	0.00	0.0000
9	275.40	276.30	-0.63	-0.63	1.001	8.00	64.28	0.00	0.0000
11	214.80	215.00	-0.66	-0.65	1.025	7.10	56.64	0.00	0.0000
13	217.10	217.40	-0.78	-0.77	0.976	6.00	51.80	0.00	0.0000

Step # 5 : **Data for air saturated plugs @ S_{wi}=20%**

Plug no.	Imp data @ 28 bar				Perm data @ 28 bar		Compressibility data @ 28 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
2	840.6	843.0	-1.5	-1.5					
6	1080.6	1085.0	-2.0	-2.1					
9	1857.0	1841.0	-2.0	-1.9					
11	1281.0	1273.0	-2.8	-2.7					
13	1392.0	1391.0	-3.4	-3.4					

Step # 7.1 : **Data for oil saturated plugs @ S_{wi}=20%**

Plug no.	Imp data @ 28 bar				Perm data @ 28 bar		Compressibility data @ 28 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
2	1056.0	1073.0	-2.7	-2.8	0.341	0.58			
6	1309.0	1327.0	-2.8	-2.9	0.350	2.37			
9	2079.0	2099.0	-3.1	-3.2	0.327	3.06			
11	1419.0	1433.0	-3.8	-3.8	0.331	2.45			
13	1527.2	1575.8	-3.4	-3.8	0.271	1.61			

5.3 Special core analysis – overburden corrected data

Measured data are listed in table 5.3 below and scatter diagrams are collected in section 5.4 and 5.5.

Table 5.3. Tuxen I-1X core study. Data measured at overburden conditions @ 100 bar confining P.

Net overburden data: **@ 25 °C**

100 bar hydrostatic confining pressure :

Step # 3.1 : **FRF data for conc. SA-brine ~ 100.000 mg/L**

Plug no.	Depth	Plug porosity data @ 100 bar			Plug permeability data @ 100 bar			Plug resistivity data @ 100 bar		
	[feet]	Δ PV [cc]	PV [cc]	Ø [%]	L [cm]	A [cm^2]	K_l [mD]	$\|Z_0\|$ [ohm]	Phase [deg]	FRF
3	9498.90	0.31	11.30	27.60	3.689	11.10	0.021	47.28	-0.14	18.97
8	9515.84	0.39	21.83	34.93	5.638	11.09	0.138	38.88	0.07	10.19
14	9511.33	0.44	14.98	27.06	5.039	10.99	0.016	68.44	-0.08	19.90
16	9523.25	0.31	11.55	20.82	5.054	10.98	0.003	113.17	-0.06	32.78
19	9532.33	0.36	11.12	23.85	4.218	11.05	0.004	84.63	-0.01	29.57

Step # 5.1 : **RI data for air saturated plugs @ S_{wi}=20%**

Plug no.	Depth	Plug porosity data @ 100 bar			Plug permeability data @ 100 bar			Plug resistivity data @ 100 bar		
	[feet]	Δ PV [cc]	PV [cc]	Ø [%]	L [cm]	A [cm^2]	K_l [mD]	$\|Z_t\|$ [ohm]	Phase [deg]	RI
3	9498.90			27.60				498.68	-0.85	10.55
8	9515.84			34.93				917.68	-0.60	23.60
14	9511.33			27.06				1035.68	-0.95	15.27
16	9523.25			20.82				1102.18	-1.15	9.74
19	9532.33			23.85				710.88	-1.15	8.49

Step # 7.2 : **K_o and RI data for oil flooded plugs @ S_{wi}=20%**

Plug no.	Depth	Plug porosity data @ 100 bar			Plug permeability data @ 100 bar			Plug resistivity data @ 100 bar		
	[feet]	Δ PV [cc]	PV [cc]	Ø [%]	L [cm]	A [cm^2]	K_o @ Swi [mD]	$\|Z_t\|$ [ohm]	Phase [deg]	RI
2	9494.21	0.30	20.21	34.62	5.278	11.06	0.105	970.18	-1.40	17.65
6	9510.56	0.35	16.28	27.30	5.408	11.03	0.025	1047.18	-1.85	13.70
9	9517.46	0.40	17.15	26.84	5.826	10.96	0.017	1626.18	-2.31	17.36
11	9536.25	0.41	15.02	26.72	5.151	10.92	0.021	1029.18	-1.85	13.95
13	9539.25	0.32	12.76	24.79	4.669	11.03	0.017	1114.18	-2.15	14.52
3	9498.90	0.31	11.30	27.60	3.689	11.10	0.028	663.18	-1.38	14.03
8	9515.84	0.39	21.83	34.93	5.638	11.09	0.235	1756.18	-1.02	45.17
14	9511.33	0.44	14.98	27.06	4.992	11.09	0.021	1328.18	-1.50	19.58
16	9523.25	0.31	11.55	20.82	5.054	10.98	0.003	1523.68	-1.90	13.46
19	9532.33	0.36	11.12	23.85	4.173	11.17	0.006	889.18	-1.70	10.62

Step # 9 : **Ko and RI data for water flooded plugs @ S_{or}**

Plug no.	Depth		Overburden corr. Dean Stark data			Plug perm	Plug resistivity data @ 100 bar		
	[feet]			S_w [%]	S_{or} [%]	S_g [%]	K_w @ Sor [mD]	$\|Z_t\|$ [ohm]	Phase [deg]	RI
2	9494.21			69	30	1.5	0.0150	114.21	-0.10	2.08
6	9510.56			66	35	-0.9	0.0018	155.04	-0.16	2.03
9	9517.46			71	27	2.2	0.0011	201.38	-0.23	2.15
11	9536.25			61	39	-0.1	0.0007	155.43	-0.19	2.11
13	9539.25			65	35	-0.1	0.0009	163.63	-0.26	2.13
3	9498.90			70	31	-1.0	0.0018	111.18	-0.15	2.35
8	9515.84			75	26	-1.0	0.0577	100.49	0.01	2.58
14	9511.33			69	31	0.5	0.0016	149.42	-0.15	2.18
16	9523.25			61	38	1.5	0.0002	286.78	-0.41	2.53
19	9532.33			65	33	1.7	0.0005	177.78	-0.40	2.10

Table 5.3 cont. Tuxen I-1X core study. Raw data at overburden conditions @ 100 bar confining P.

Net overburden data: **@ 25 °C**

100 bar hydrostatic confining pressure :

Step # 3.1 : **Conc. SA-brine ~ 100.000 mg/**

Plug no.	Imp data @ 100 bar				Perm data @ 100 bar		Compressibility data @ 100 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
3	47.55	47.64	-0.14	-0.14	0.834	4	40.95	0.75	0.0025
8	39.17	39.23	0.09	0.05	1.505	1.7	62.51	0.62	0.0021
14	68.71	68.80	-0.08	-0.08	0.882	8	55.36	0.79	0.0026
16	113.3	113.7	-0.06	-0.06	0.370	18	55.49	0.56	0.0019
19	84.85	85.05	-0.01	0.00	0.359	12	46.62	0.77	0.0026

Step # 5.1 : **Data for air saturated plugs @ S_{wi}=20%**

Plug no.	Imp data @ 100 bar				Perm data @ 100 bar		Compressibility data @ 100 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
3	503.0	495.0	-0.9	-0.8					
8	930.0	906.0	-0.6	-0.6					
14	1036.0	1036.0	-0.9	-1.0					
16	1142.0	1063.0	-1.2	-1.1					
19	744.4	678.0	-1.2	-1.1					

Step # 7.2 : **Data for oil saturated plugs @ S_{wi}=20%**

Plug no.	Imp data @ 100 bar				Perm data @ 100 bar		Compressibility data @ 100 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
2	969.00	972.00	-1.40	-1.40	0.910	1.51	58.37	0.51	0.0017
6	1049.00	1046.00	-1.90	-1.80	0.850	6.00	59.63	0.58	0.0019
9	1620.00	1633.00	-2.21	-2.40	0.764	8.98	63.88	0.62	0.0021
11	1033.00	1026.00	-1.90	-1.80	0.841	6.97	56.23	0.72	0.0024
13	1115.00	1114.00	-2.10	-2.2	0.586	5.23	51.48	0.62	0.0021
3	670.00	657.00	-1.36	-1.4	0.749	3.216	40.95	0.75	0.0025
8	1763.00	1750.00	-1.00	-1.04	0.753	0.596	62.51	0.62	0.0021
14	1338.00	1319.00	-1.50	-1.50	0.651	4.996	55.36	0.79	0.0026
16	1539.00	1509.00	-1.90	-1.90	0.224	10.996	55.49	0.56	0.0019
19	898.00	881.00	-1.70	-1.70	0.375	7.996	46.62	0.77	0.0026

Step # 9 : **Data for water flooded plugs @ S_{or}=?%**

Plug no.	Imp data @ 100 bar				Perm data @ 100 bar		Compressibility data @ 100 bar		
	Imp1 [ohm]	Imp2 [ohm]	Phase1 [deg]	Phase2 [deg]	Flow rate [ml/h]	Δ P [bar]	BV [cc]	Δ BV [%]	a
2	114.39	114.66	-0.10	-0.09	1.000	9.75			
6	155.10	155.61	-0.13	-0.19	0.400	33.47			
9	201.90	201.50	-0.23	-0.23	0.250	37.56			
11	155.90	155.60	-0.19	-0.18	0.250	48.80			
13	163.90	164.00	-0.26	-0.26	0.300	43.46			
3	111.58	111.41	-0.16	-0.14	0.692	39.92			
8	100.82	100.8	0	0.01	0.887	2.40			
14	149.79	149.69	-0.15	-0.15	0.505	45.00			
16	287.2	287.00	-0.40	-0.41	0.082	74.90			
19	178.1	178.1	-0.40	-0.39	0.213	50.31			

5.4 Special core analysis – permeability diagrams

The scatter diagrams below show the mathematical and statistical correlation between the porosity and the specific (or endpoint) liquid permeability at room or overburden conditions. An exponential fit has been prefered to a power curve fit in the permeability diagrams below because of an equal or better correlation coefficient (in the insert given as the square of the correlation coefficient ‘r’).

5.4.1 Room condition liquid permeability

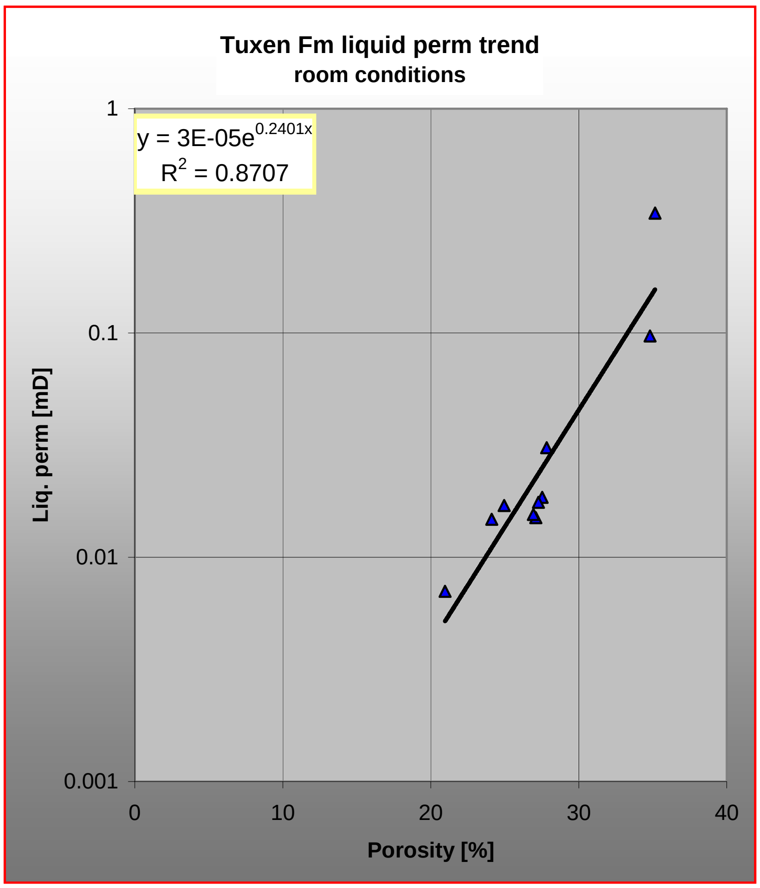
Subject: Room condition measurements **Company: DONG E&P A/S**
Liquid permeability **Well: I-1X**

Formation : **Tuxen**

Conventional data
Conf. P [psi | MPa] 400 | 2.8

Experiment step: 3 & 4

Plug no.	Depth [feet]	Ø [%]	Kl [mD]
2	9494.21	34.8	0.097
6	9510.56	27.5	0.019
9	9517.46	27.1	0.015
11	9536.25	26.9	0.016
13	9539.25	25.0	0.017
3	9498.90	27.8	0.031
8	9515.84	35.2	0.343
14	9511.33	27.3	0.018
16	9523.25	21.0	0.007
19	9532.33	24.1	0.015



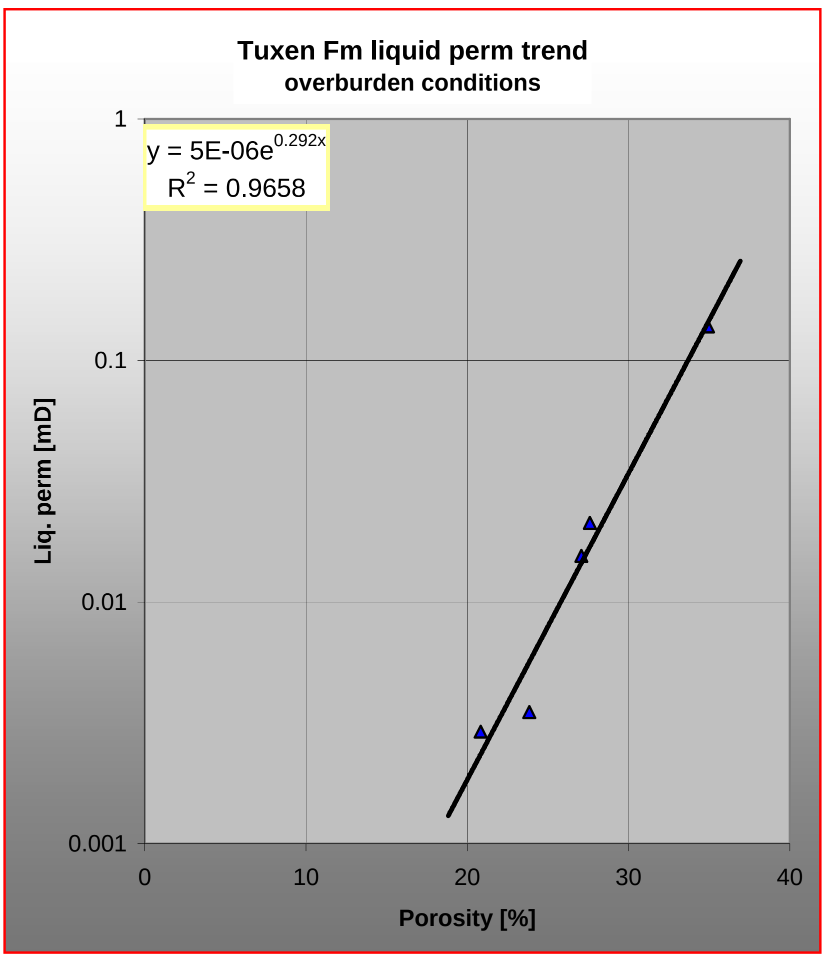
5.4.2 Overburden liquid permeability

Subject: Overburden measurements	**Company: DONG E&P A/S**
Liquid permeability	**Well: I-1X**

Formation :	**Tuxen**	**NOB data**
Comment:	**Only 5 plugs measured**	**Conf. P [psi | MPa] 1450 | 10**

Experiment step: 3.1

Plug no.	Depth [feet]	Ø [%]	Kl [mD]
3	9498.90	27.6	0.021
8	9515.84	34.9	0.138
14	9511.33	27.1	0.016
16	9523.25	20.8	0.003
19	9532.33	23.8	0.004



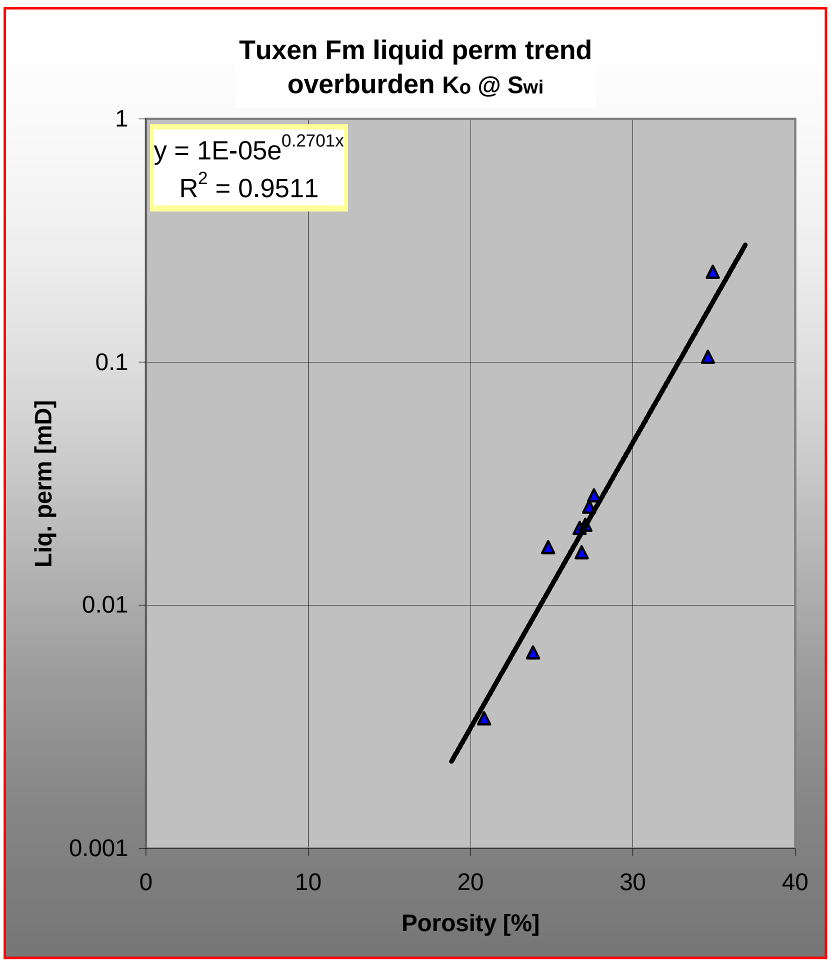
5.4.3 Overburden oil permeability @ S_{wi}

Subject: Overburden measurements **Company: DONG E&P A/S**
Oil permeability at Swi **Well: I-1X**

Formation : **Tuxen** **NOB data**
Comment: **Swi = 20%** **Conf. P [psi | MPa] 1450 | 10**

Experiment step: 7.2

Plug no.	Depth [feet]	Ø [%]	Ko @ Swi [mD]
2	9494.21	34.6	0.105
6	9510.56	27.3	0.025
9	9517.46	26.8	0.017
11	9536.25	26.7	0.021
13	9539.25	24.8	0.017
3	9498.90	27.6	0.028
8	9515.84	34.9	0.235
14	9511.33	27.1	0.021
16	9523.25	20.8	0.003
19	9532.33	23.8	0.006



5.4.4 Overburden water permeability @ S_{or}

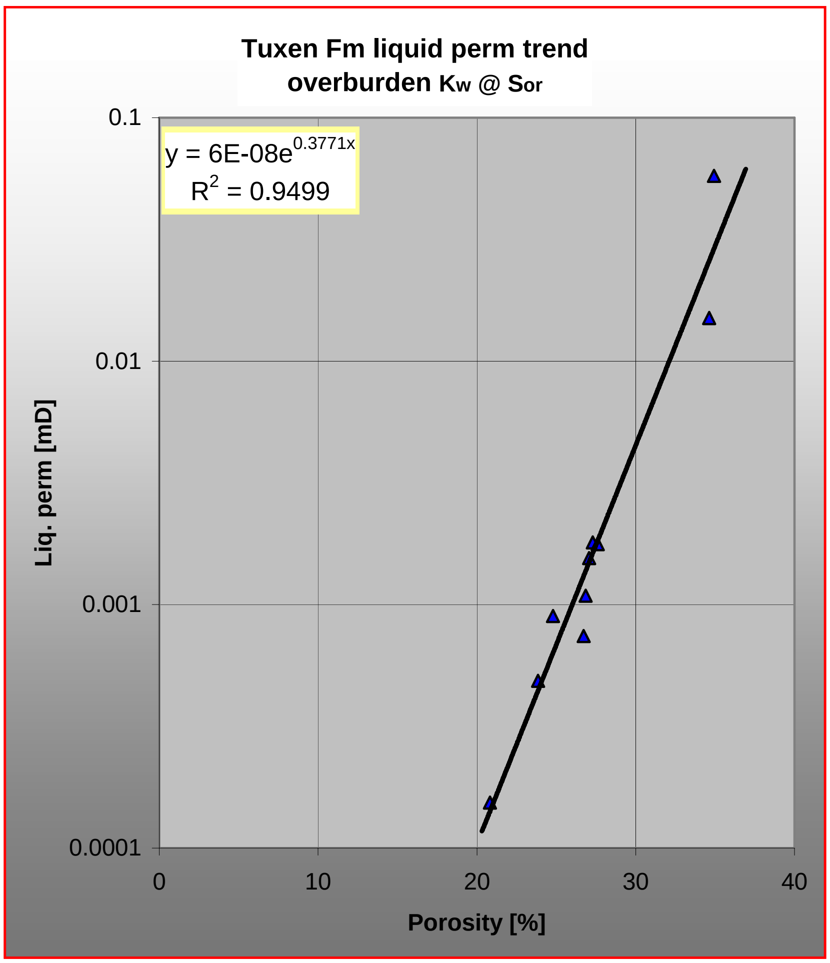
Subject: Overburden measurements **Company: DONG E&P A/S**
Water permeability at Sor **Well: I-1X**

Formation : **Tuxen**
Comment: **Sor ~ 35%, ref. the table below**

NOB data
Conf. P [psi | MPa] 1450 | 10

Experiment step: 9

Plug no.	Depth [feet]	Ø [%]	Ko @ Swi [mD]	Sor [%]
2	9494.21	34.6	0.0150	30
6	9510.56	27.3	0.0018	35
9	9517.46	26.8	0.0011	27
11	9536.25	26.7	0.0007	39
13	9539.25	24.8	0.0009	35
3	9498.90	27.6	0.0018	31
8	9515.84	34.9	0.0577	26
14	9511.33	27.1	0.0016	31
16	9523.25	20.8	0.0002	38
19	9532.33	23.8	0.0005	33



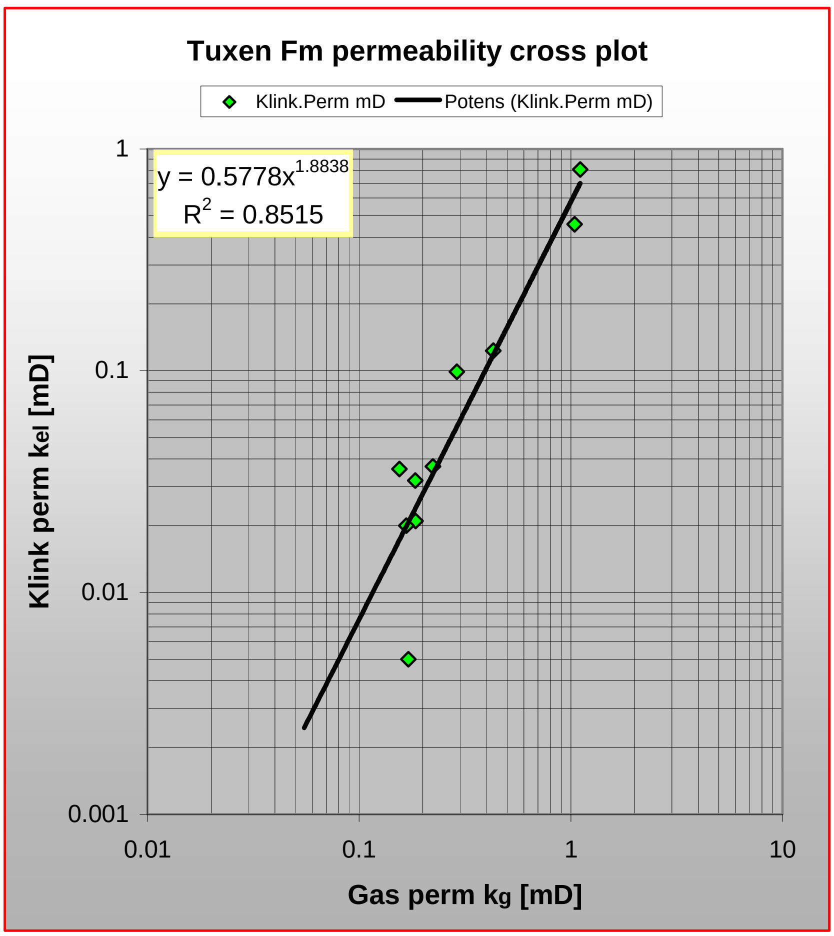
5.4.5 Permeability cross plots

Subject: Permeability cross plot	**Company: DONG E&P A/S**
Conventional gas perm vs Klinkenberg perm	**Well: I-1X**

Formation : **Tuxen**

Experiment step:

Plug no.	Depth [feet]	kg [mD]	kel [mD]
2	9494.21	0.430	0.123
6	9510.56	0.185	0.021
9	9517.46	0.223	0.037
11	9536.25	0.171	0.005
13	9539.25	0.290	0.099
3	9498.90	0.184	0.032
8	9515.84	1.044	0.458
14	9511.33	0.167	0.020
16	9523.25	0.155	0.036
19	9532.33	1.107	0.808

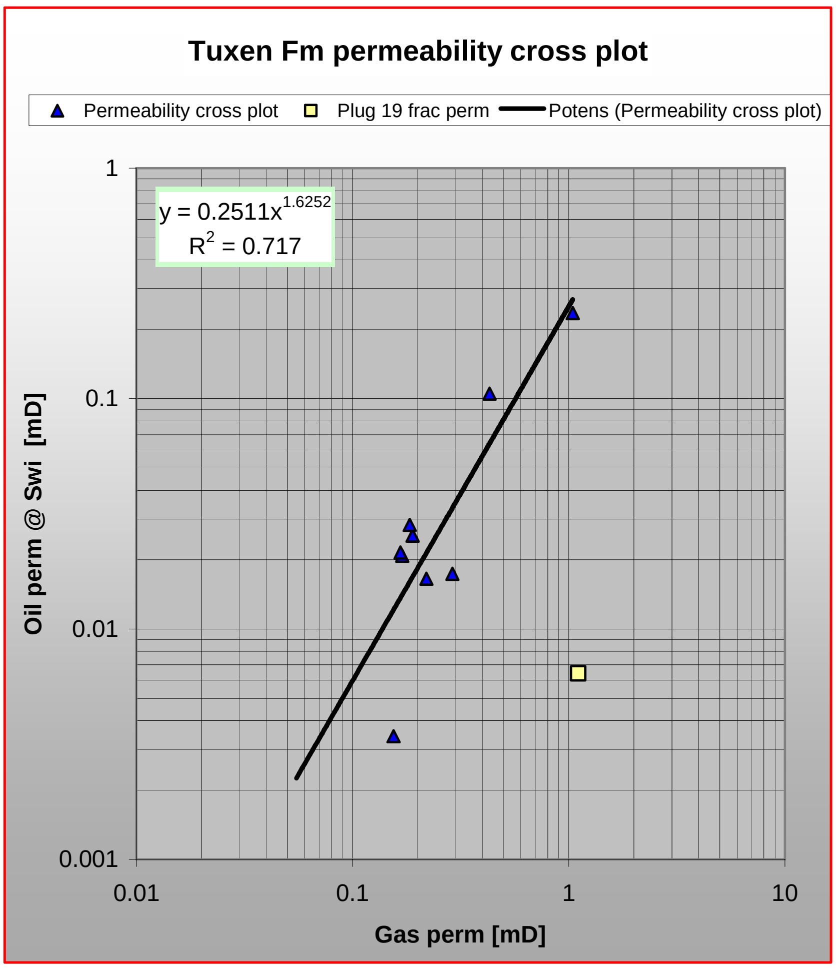


Subject: Permeability cross plot **Company: DONG E&P A/S**
Conventional gas perm vs oil perm at Swi **Well: I-1X**

Formation : **Tuxen**
Comment: **Swi = 20%**

Experiment step:

Plug no.	Depth [feet]	kg [mD]	Ko @ Swi [mD]
2	9494.21	0.43	0.105
6	9510.56	0.19	0.025
9	9517.46	0.22	0.017
11	9536.25	0.17	0.021
13	9539.25	0.29	0.017
3	9498.90	0.18	0.028
8	9515.84	1.04	0.235
14	9511.33	0.17	0.021
16	9523.25	0.16	0.003
19	9532.33	1.11	0.006



5.5 Special core analysis – electrical diagrams

From previous experience with North Sea chalk , Archie's exponents 'm' and 'n' have been obtained from forced regression through (1,1) in the double log diagrams below. In the present study there is no reason to believe that this procedure should not be valid for the Lower Cretaceous chalk as well.

The study was carried out in 2 runs, each having 5 plugs measured at the same time. For the electrical measurements, plug set 1 consisting of plug nos. 2, 6, 9, 11 and 13 are the most homogeneous and fracture free plugs and therefore believed to give the best results for Archie's exponents. In the diagrams below the 2 plug sets have been pooled into one diagram. Separate diagrams are also shown where significant deviations between the two plug sets occur.

Based on the experimental data, observations from X-ray CT images and plug descriptions (presence of fractures) the preferred overburden corrected Archie parameters are listed in table 5.5 below.

Table 5.5. Tuxen I-1X core study. Overburden corrected Archie exponents 'm' and 'n' for Tuxen Fm chalk determined from regression analysis of measured plug data.

cementation exponent 'm'	saturation exponent 'n'
2.28	1.71

5.5.1 Room condition Formation Resistivity Factor

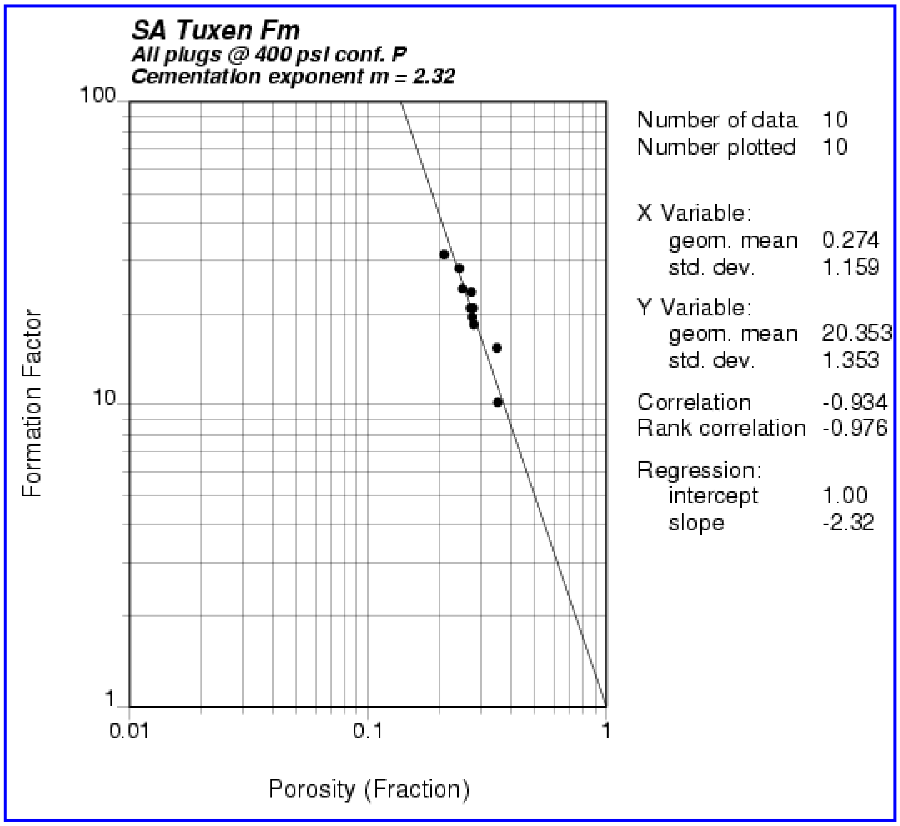
Subject: Room condition measurements	**Company: DONG E&P A/S**
Formation Resistivity Factor	**Well: I-1X**

Reservoir unit: **Tuxen Fm**

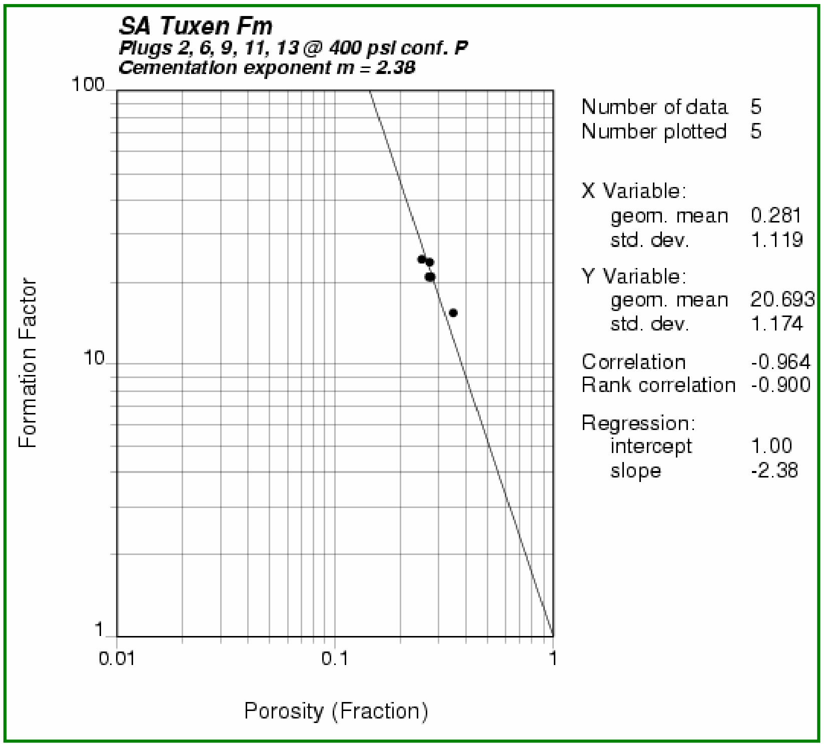
Conf. P [psi | MPa] **400 | 2.8**
Regression 'm' : **2.32**

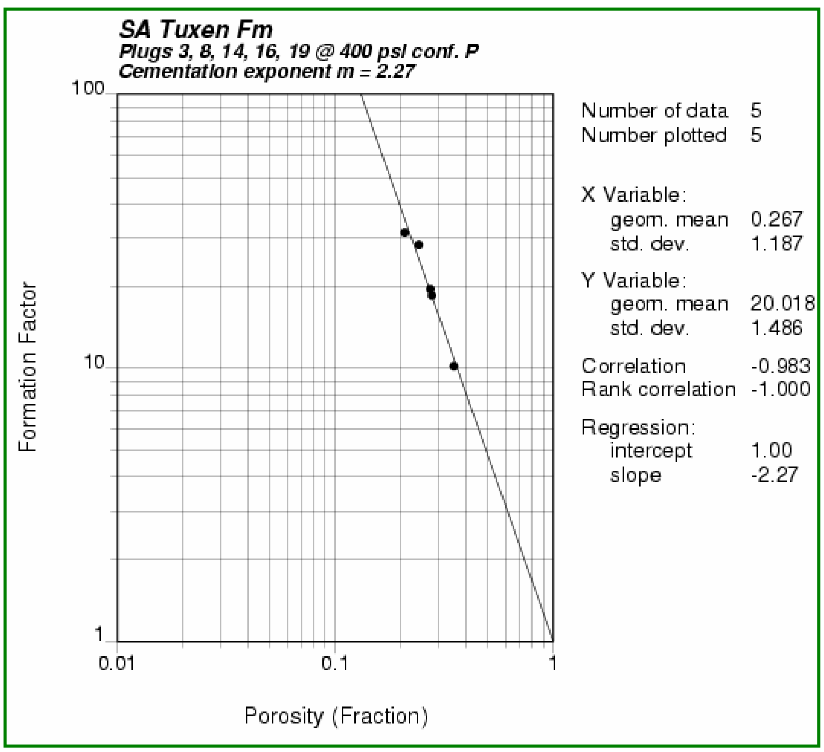
Experiment step: 3

Plug no.	Depth [feet]	Ø [%]	FRF	τ	Archie 'm'
2	9494.21	34.82	15.37	5.4	2.59
6	9510.56	27.53	20.79	5.7	2.35
9	9517.46	27.10	23.53	6.4	2.42
11	9536.25	26.93	20.88	5.6	2.32
13	9539.25	24.96	24.17	6.0	2.29
3	9498.90	27.83	18.43	5.1	2.28
8	9515.84	35.15	10.17	3.6	2.22
14	9511.33	27.28	19.44	5.3	2.28
16	9523.25	20.96	31.32	6.6	2.20
19	9532.33	24.12	28.17	6.8	2.35



Step # 3 continued, plug set 1 and 2 data:





5.5.1 continued, plug set 1 measured with 5X diluted brine ~ 20.000 mg/L :

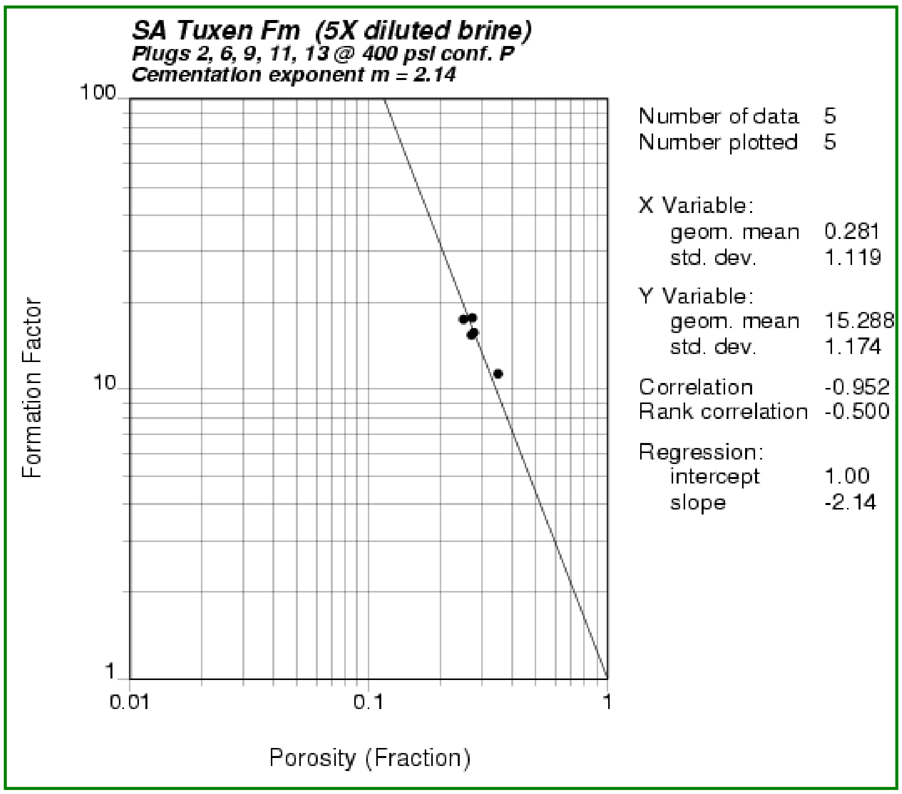
Subject: Room condition measurements **Company: DONG E&P A/S**
Formation Resistivity Factor with 5x diluted brine **Well: I-1X**

Reservoir unit: **Tuxen Fm** **Conf. P [psi | MPa]** **400 | 2.8**
Comment: **Only 5 plugs measured** **Regression 'm' :** **2.14**

Experiment step: 4

Plug no.	Depth [feet]	Ø [%]	FRF	τ	Archie 'm'
2	9494.21	34.82	11.29	3.9	2.30
6	9510.56	27.53	15.67	4.3	2.13
9	9517.46	27.10	17.60	4.8	2.20
11	9536.25	26.93	15.43	4.2	2.09
13	9539.25	24.96	17.38	4.3	2.06

NB ! Diluted formation brine ~ 20.000 mg/L :



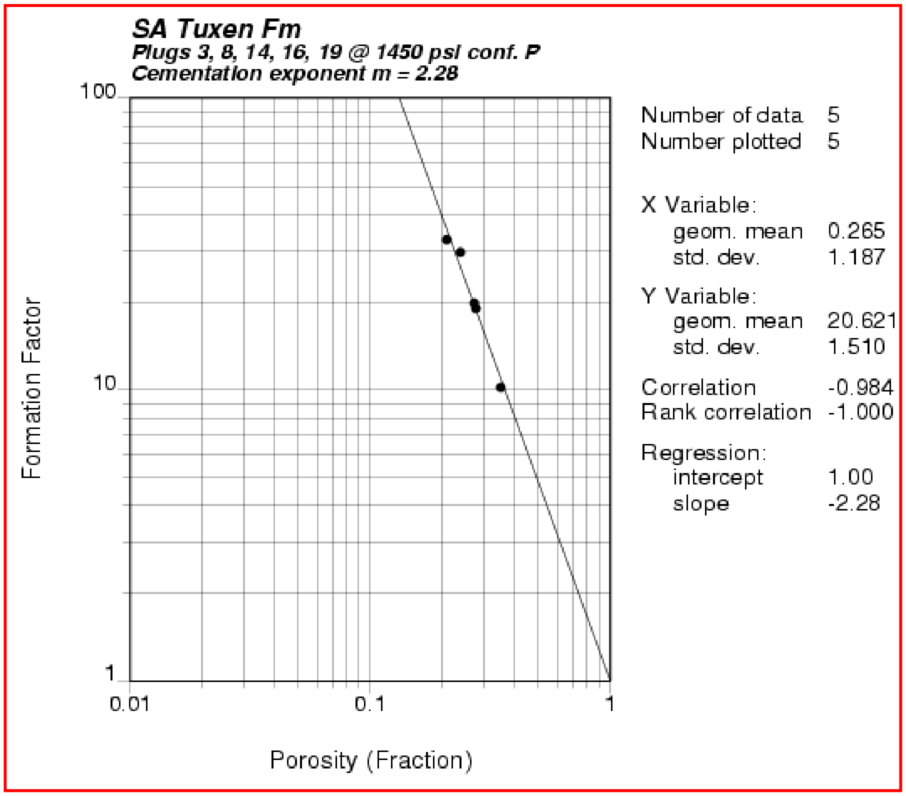
5.5.2 Overburden Formation Resistivity Factor

Subject: Overburden measurements — **Company: DONG E&P A/S**
Formation Resistivity Factor — **Well: I-1X**

Reservoir unit: Tuxen Fm — **Conf. P [psi | MPa]** 1450 | 10
Comment: Only 5 plugs measured — **Regression 'm' :** 2.28

Experiment step: 3.1

Plug no.	Depth [feet]	Ø [%]	FRF	τ	Archie 'm'
3	9498.90	27.60	18.97	5.2	2.29
8	9515.84	34.93	10.19	3.6	2.21
14	9511.33	27.06	19.90	5.4	2.29
16	9523.25	20.82	32.78	6.8	2.22
19	9532.33	23.85	29.57	7.1	2.36



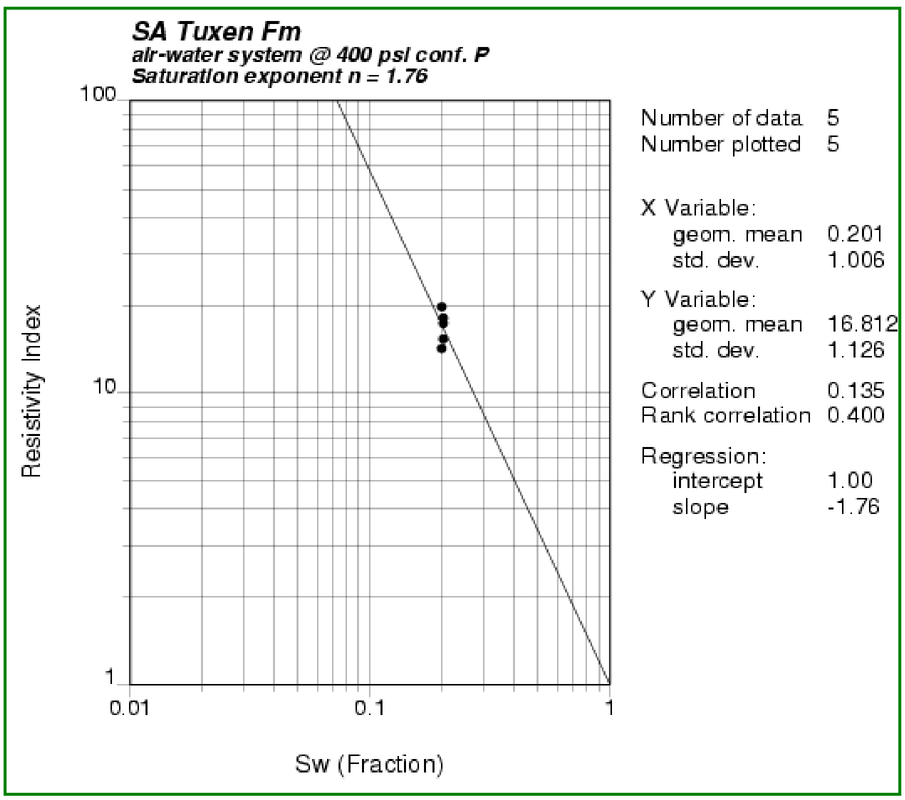
5.5.3 Room condition Resistivity Index

Subject: Room condition measurements **Company: DONG E&P A/S**
Resistivity Index (air-water system) **Well: I-1X**

Reservoir unit: **Tuxen Fm** **Conf. P [psi | MPa] 400 | 2.8**
Comment: **Swi = 20%** **Regression 'n' : 1.76**

Experiment step: 5

Plug no.	Depth [feet]	Ø [%]	Sw [%]	RI	Archie 'n'
2	9494.21	34.82	20.2	15.31	1.70
6	9510.56	27.53	20.0	14.17	1.65
9	9517.46	27.10	20.0	19.74	1.85
11	9536.25	26.93	20.2	17.30	1.78
13	9539.25	24.96	20.3	18.13	1.82

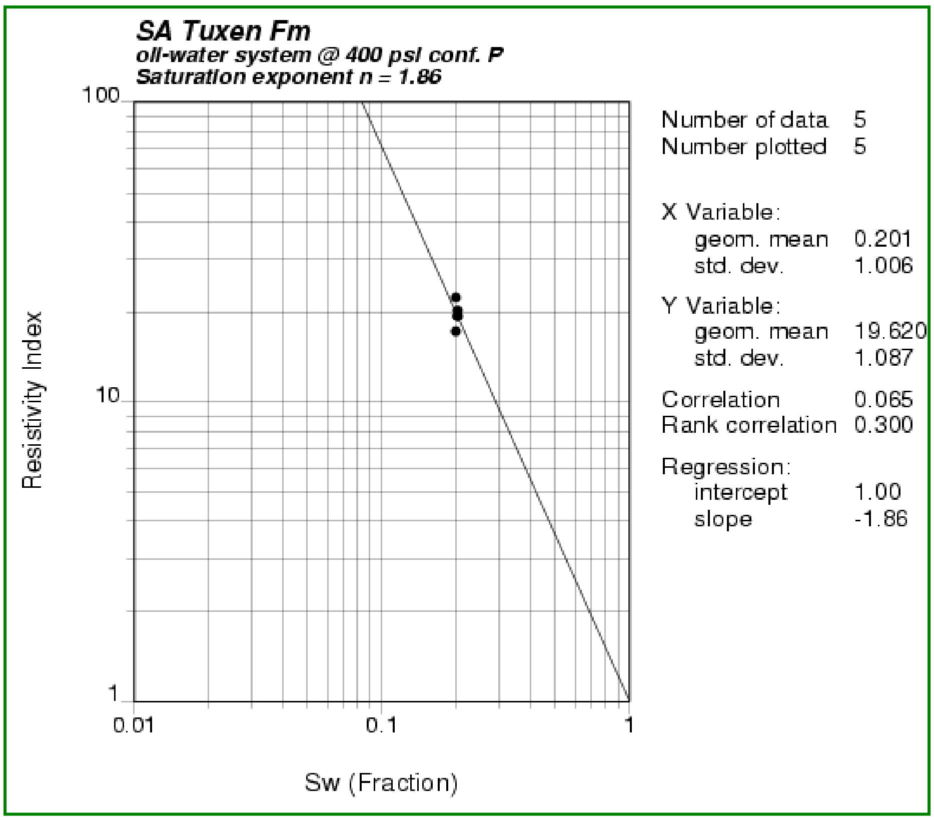


Subject: Room condition measurements **Company: DONG E&P A/S**
Resistivity Index (oil-water system) **Well: I-1X**

Reservoir unit: **Tuxen Fm** **Conf. P [psi | MPa] 400 | 2.8**
Comment: **S_{wi} = 20%** **Regression 'n' : 1.86**

Experiment step: 7.1

Plug no.	Depth [feet]	Ø [%]	S_w [%]	RI	Archie 'n'
2	9494.21	34.82	20.2	19.36	1.85
6	9510.56	27.53	20.0	17.24	1.77
9	9517.46	27.10	20.0	22.30	1.93
11	9536.25	26.93	20.2	19.32	1.85
13	9539.25	24.96	20.3	20.22	1.89



5.5.4 Overburden Resistivity Index @ S_{wi}

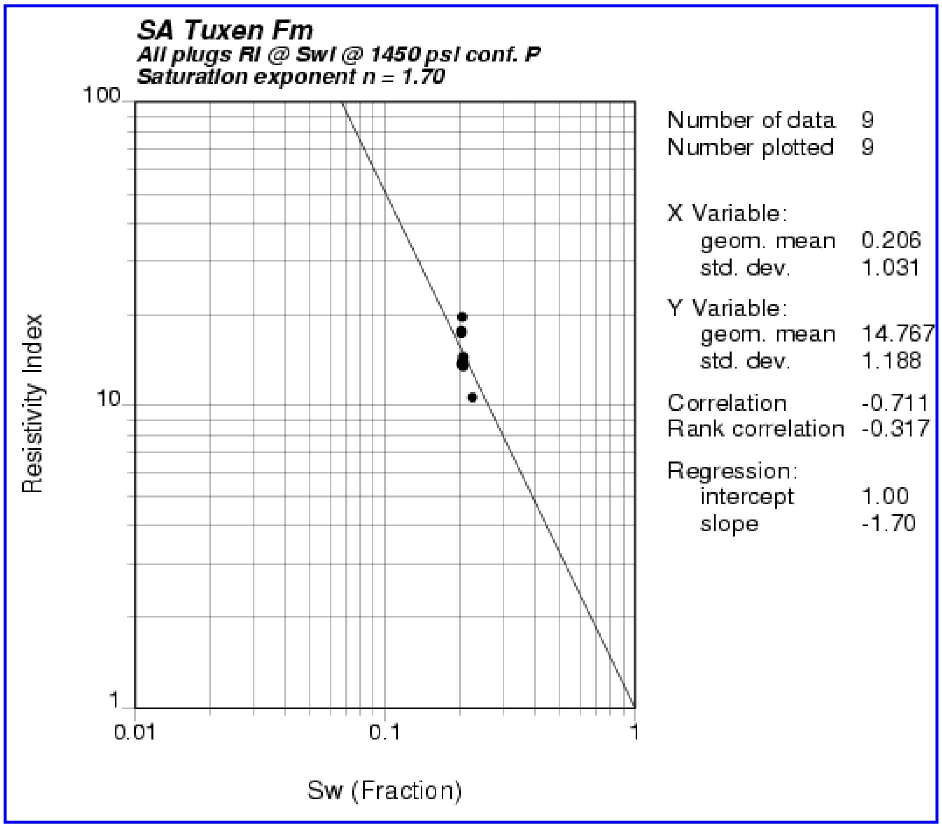
Subject: Overburden measurements **Company: DONG E&P A/S**
Resistivity Index (oil-water system) **Well: I-1X**

Reservoir unit: Tuxen Fm **Conf. P [psi | MPa]** 1450 | 10
Comment: S_{wi} = 20% **Regression 'n' :** 1.70

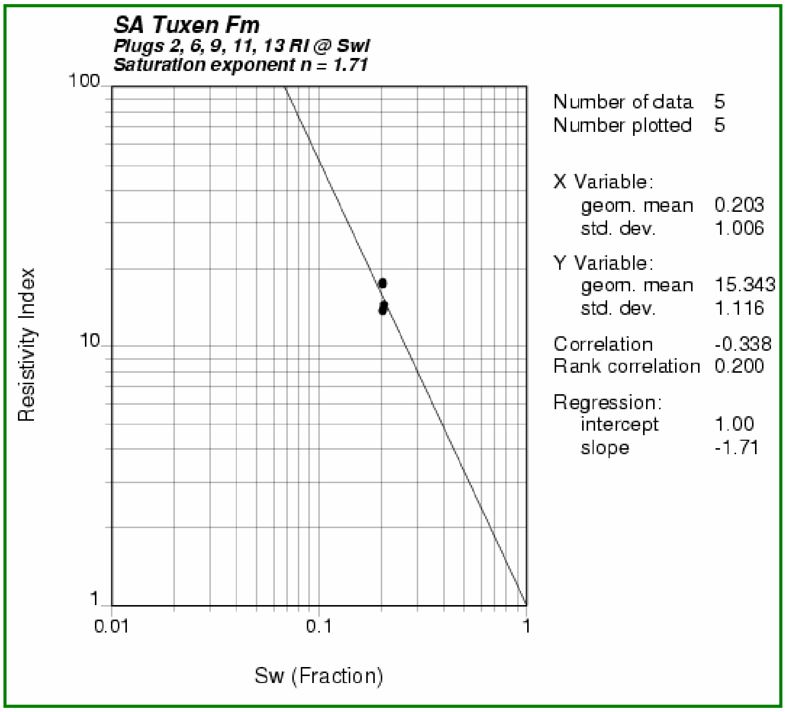
Experiment step: 7.2

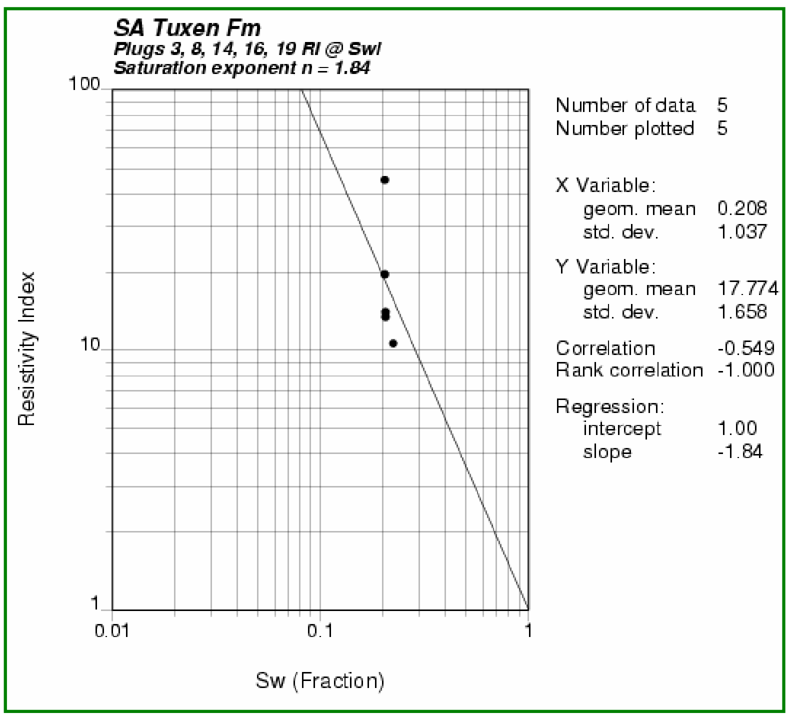
Plug no.	Depth [feet]	Ø [%]	Sw [%]	RI	Archie 'n'
2	9494.21	34.62	20.3	17.65	1.80
6	9510.56	27.30	20.2	13.70	1.64
9	9517.46	26.84	20.2	17.36	1.78
11	9536.25	26.72	20.4	13.95	1.66
13	9539.25	24.79	20.5	14.52	1.69
3	9498.90	27.60	20.5	14.03	1.67
8	9515.84	34.93	20.4	45.17	2.39
14	9511.33	27.06	20.4	19.58	1.87
16	9523.25	20.82	20.5	13.46	1.64
19	9532.33	23.85	22.4	10.62	1.58

NB ! Plug 8 was screened from the regression analysis due to parallel set of fractures giving an uneven saturation profile.



Step # 7.2 continued, plug set 1 and 2 RI data after oilflood :





5.5.5 Overburden Resistivity Index @ S_{or}

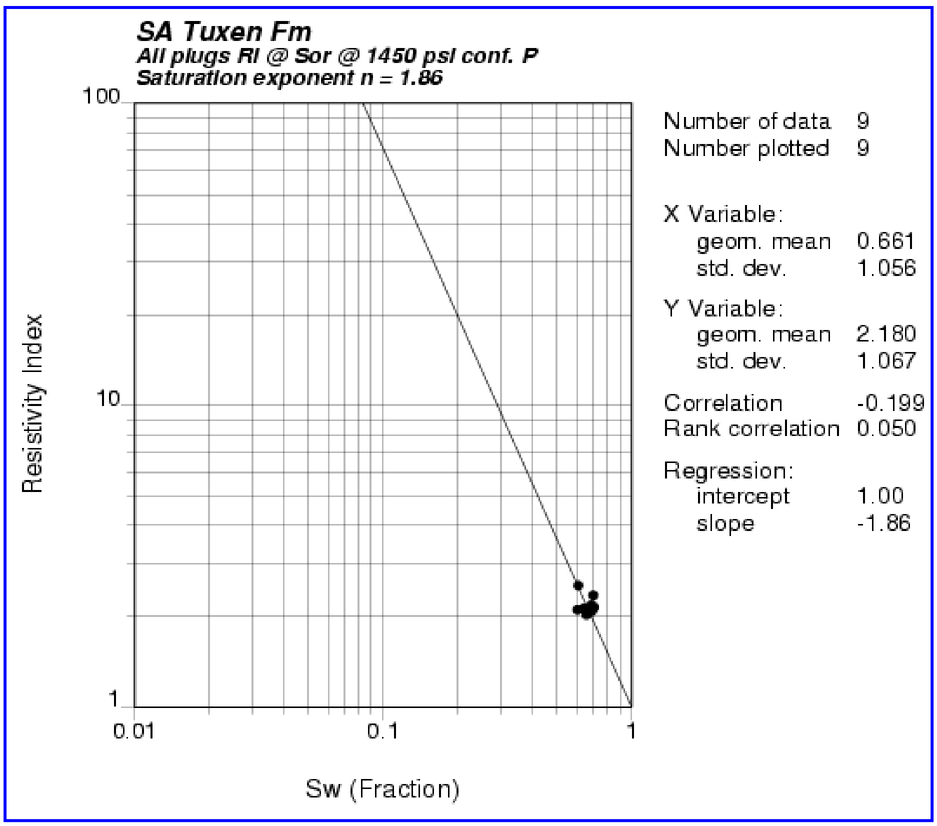
Subject: Overburden measurements **Company: DONG E&P A/S**
Resistivity Index (oil-water system) **Well: I-1X**

Reservoir unit: **Tuxen Fm** **Conf. P [psi | MPa] 1450 | 10**
Comment: **S_{or} ~ 35%** **Regression 'n' : 1.86**

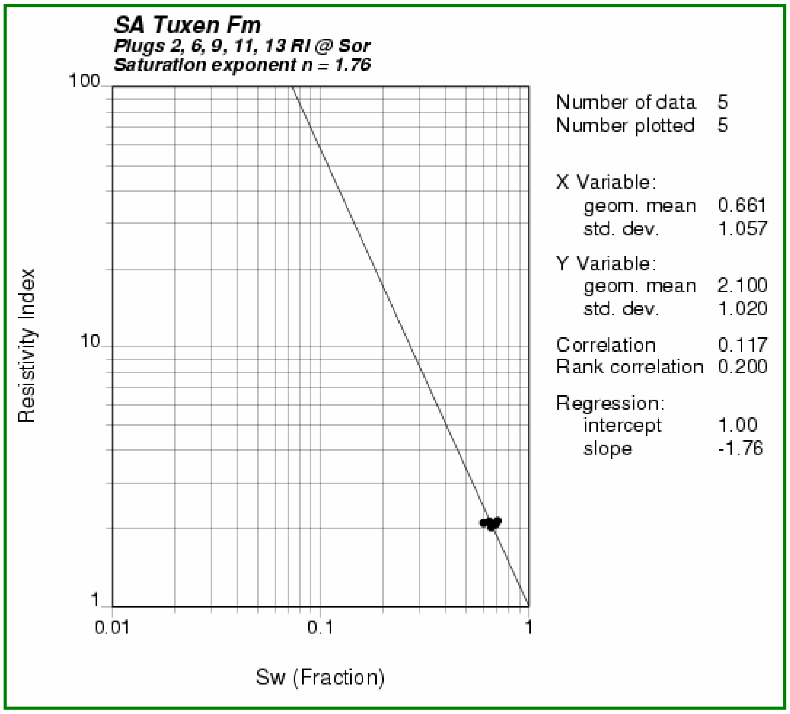
Experiment step: 9

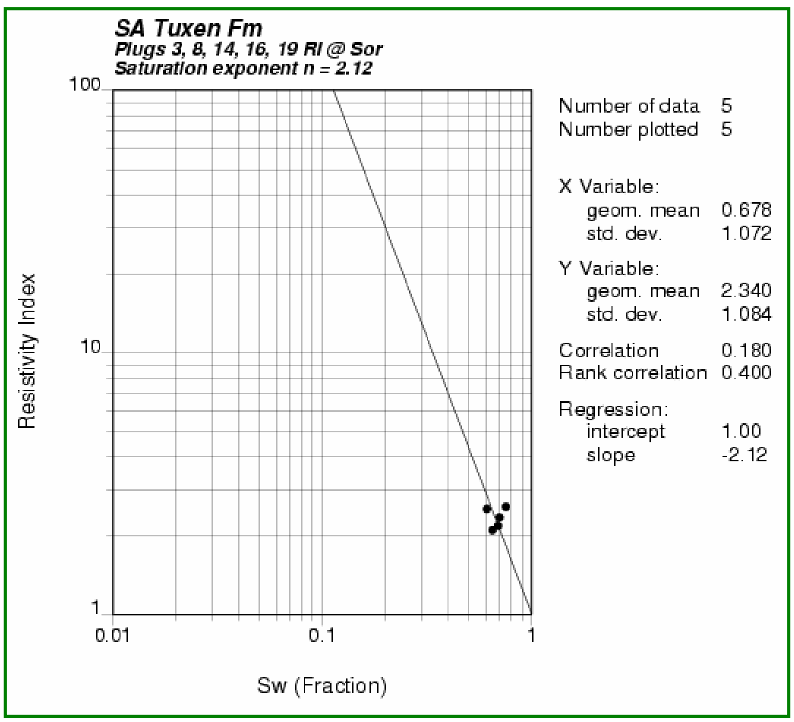
Plug no.	Depth [feet]	Ø [%]	S_w [%]	RI	Archie 'n'
2	9494.21	34.62	69	2.08	1.97
6	9510.56	27.30	66	2.03	1.70
9	9517.46	26.84	71	2.15	2.23
11	9536.25	26.72	61	2.11	1.51
13	9539.25	24.79	65	2.13	1.76
3	9498.90	27.60	70	2.35	2.40
8	9515.84	34.93	75	2.58	3.30
14	9511.33	27.06	69	2.18	2.10
16	9523.25	20.82	61	2.53	1.88
19	9532.33	23.85	65	2.10	1.72

NB ! Plug 8 was screened from the regression analysis due to parallel set of fractures giving an uneven saturation profile.



Step # 9 continued, plug set 1 and 2 RI data after waterflood :





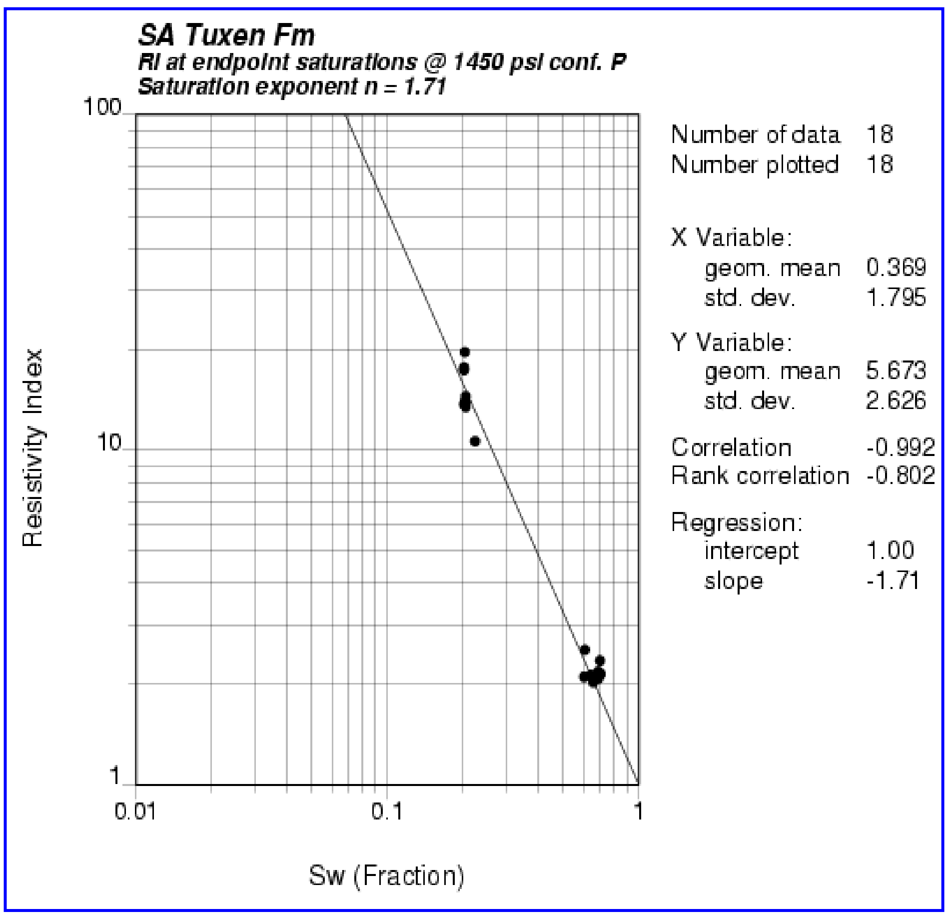
5.5.6 Overburden Resistivity Index, multi sample plot

Subject: Overburden measurements		Company: DONG E&P A/S
Resistivity Index	(oil-water system)	Well: I-1X

Reservoir unit:	**Tuxen Fm**	**Conf. P [psi | MPa] :**	**1450 | 10**
Comment:	**Multi sample plot**	**Regression 'n' :**	**1.71**

Experiment step: 7.2 + 9 **Endpoint data combined for best estimate of the saturation exponent 'n**

NB ! Plug 8 was screened from the regression analysis due to parallel set of fractures giving an uneven saturation profile.



6 References

1. API recommended practice for core-analysis procedure, API RP 40, 2nd ed. 1998.

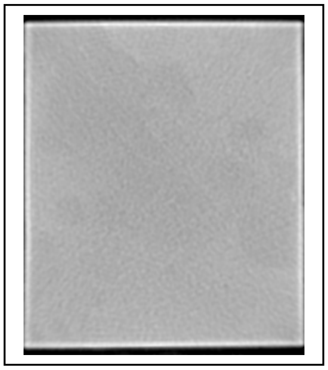
2. N. Springer, U. Korsbech, H.K. Aage: Resistivity Index Measurement without the Porous Plate: A Desaturation Technique Based on Evaporation Produces Uniform Water Saturation Profiles and More Reliable Results for Tight North Sea Chalk.
Intl SCA Symp.,Pau, (September 2003), paper SCA 2003-38, p. 459-470.

4. SCA Guidelines for sample preparation and porosity measurement of electrical resistivity samples, part I-IV.
The Log Analyst, **31**, 1 & 2, 1990.

7 X-ray CT-screening of plug samples

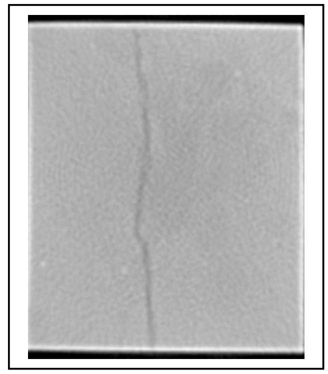
Sellar-ear	Ultra High
120 kV	330 mAs
Time=	2 s
Slice=	4 mm
Zoom=	8.0
IMG-files	16 bit signed
Width:	512
Height:	512

The images below are close to real plug size and represent 2 longitudinal cuts perpendicular to each other through the plug sample. The thickness of each slice is 4 mm. The average grey tone figure and standard deviation for the longitudinal cuts is given in the info box; this figure is proportional to the sample porosity. The grey scale figures is in Hounsfield units; -1000 represents air (100% porosity) and appears dark on the images, +3000 is dense matrix (0% porosity) and appears white on the images.



Plug 1 Depth: 9493.25 [feet]

Avg. gray value : 1750
Sdev : 85
Porosity : nd

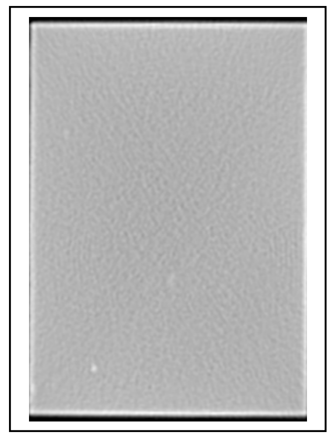


Plug 1 Depth: 9493.25 [feet]

Avg. gray value : 1759
Sdev : 102
Porosity : nd

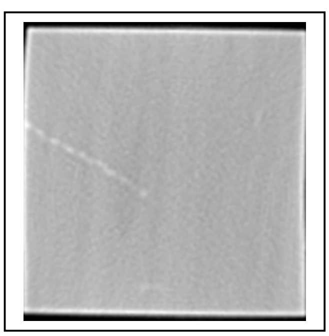
Plug 2 Depth: 9494.21 [feet]

Avg. gray value : 1563
Sdev : 70
Porosity : 34.0 [%]



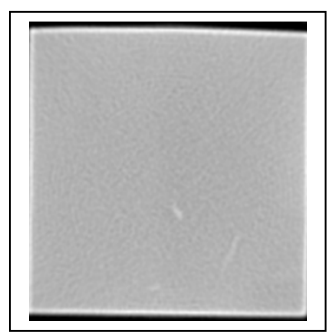
Plug 2 Depth: 9494.21 [feet]

Avg. gray value : 1567
Sdev : 66
Porosity : 34.0 [%]



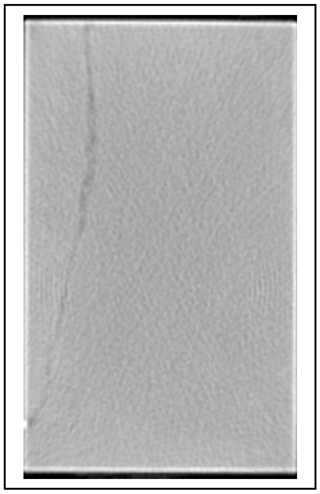
Plug 3 Depth: 9498.90 [feet]

Avg. gray value : 1844
Sdev : 90
Porosity : 27.8 [%]



Plug 3 Depth: 9498.90 [feet]

Avg. gray value : 1859
Sdev : 79
Porosity : 27.8 [%]

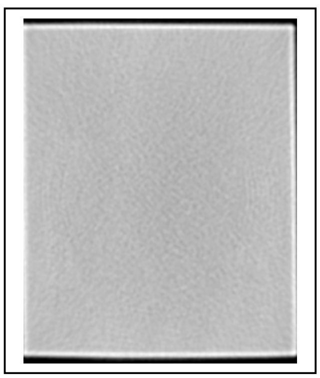


Plug 4 Depth: 9510.03 [feet]

Avg. gray value : 1805
Sdev : 109
Porosity : nd [%]

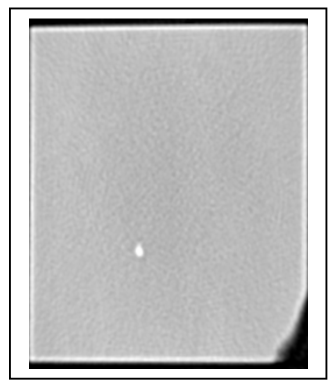
Plug 4 Depth: 9510.03 [feet]

Avg. gray value : 1798
Sdev : 94
Porosity : nd [%]



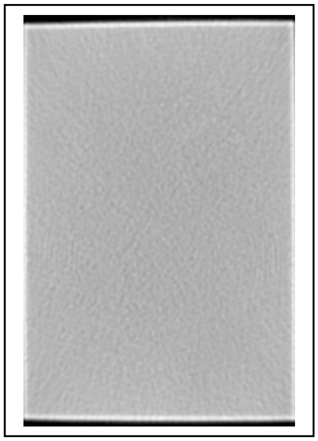
Plug 5 Depth: 9510.23 [feet]

Avg. gray value : 1988
Sdev : 85
Porosity : nd [%]



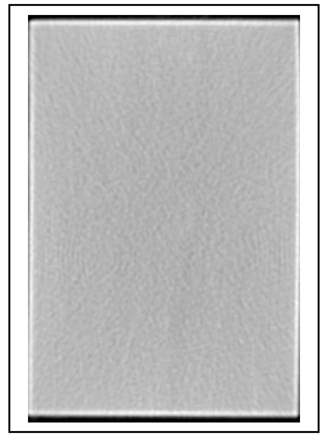
Plug 5 Depth: 9510.23 [feet]

Avg. gray value : 1982
Sdev : 144
Porosity : nd [%]



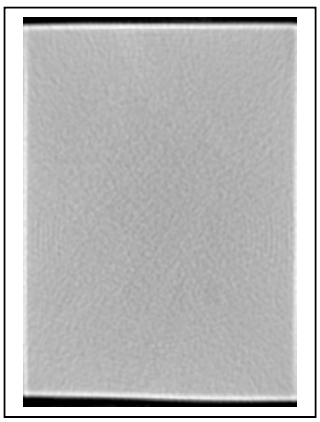
Plug 6 Depth: 9510.56 [feet

Avg. gray value : 1786
Sdev : 81
Porosity : 27.5 [%]



Plug 6 Depth: 9510.56 [feet

Avg. gray value : 1792
Sdev : 105
Porosity : 27.5 [%]

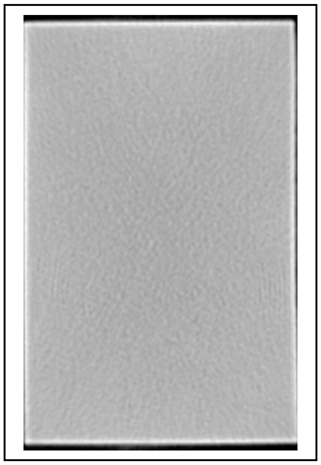


Plug 7 Depth: 9514.25 [feet]

Avg. gray value : 1856
Sdev : 86
Porosity : nd [%]

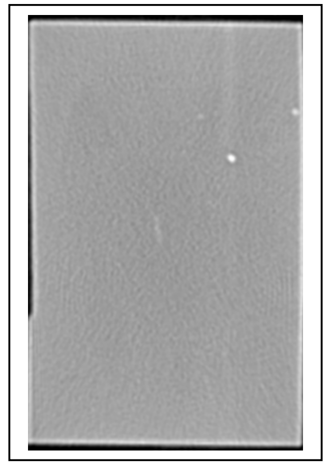
Plug 7 Depth: 9514.25 [feet]

Avg. gray value : 1848
Sdev : 82
Porosity : 27.5 [%]



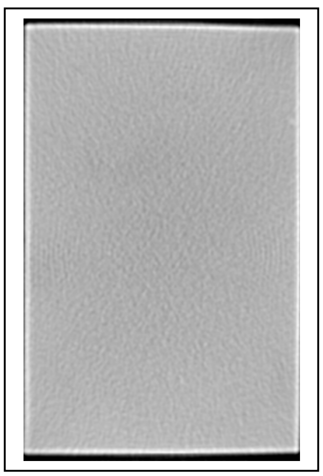
Plug 8 Depth: 9515.84 [feet]

Avg. gray value : 1548
Sdev : 77
Porosity : 35.2 [%]



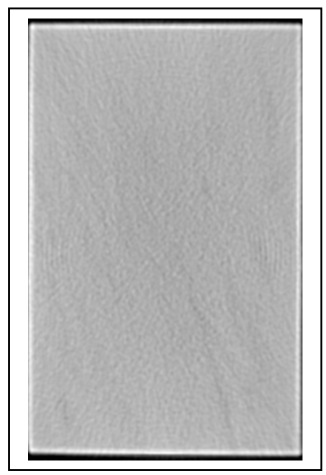
Plug 8 Depth: 9515.84 [feet]

Avg. gray value : 1553
Sdev : 88
Porosity : 35.2 [%]



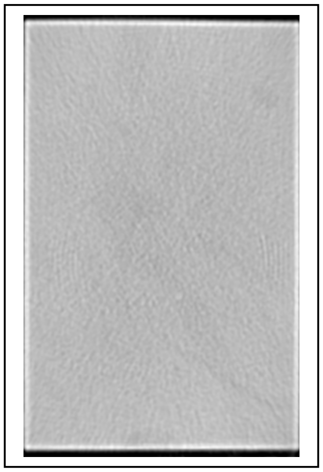
Plug 9 Depth: 9517.46 [feet]

Avg. gray value : 1819
Sdev : 98
Porosity : 26.8 [%]



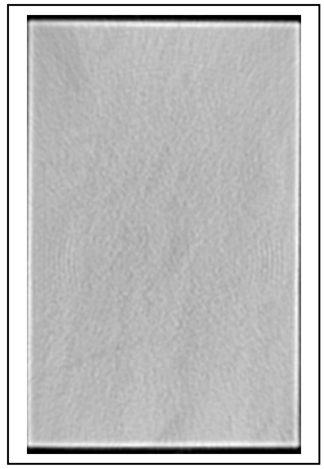
Plug 9 Depth: 9517.46 [feet]

Avg. gray value : 1813
Sdev : 102
Porosity : 26.8 [%]



Plug 10 Depth: 9517,46 [feet]

Avg. gray value : 1956
Sdev : 87
Porosity : nd [%]

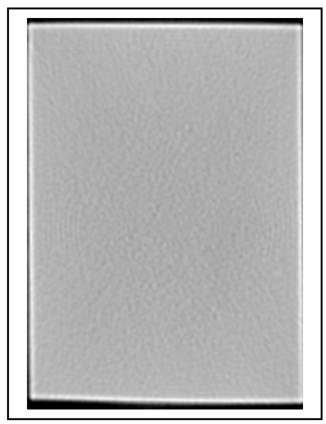


Plug 10 Depth: 9517,46 [feet]

Avg. gray value : 1942
Sdev : 95
Porosity : nd [%]

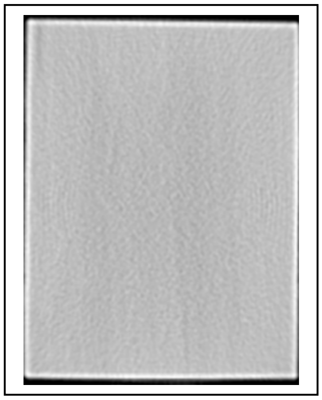
Plug 11 Depth: 9536.25 [feet]

Avg. gray value : 1819
Sdev : 84
Porosity : 26.8 [%]



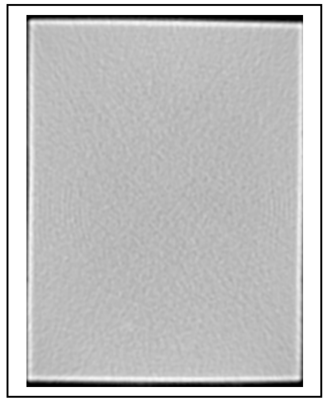
Plug 11 Depth: 9536.25 [feet]

Avg. gray value : 1816
Sdev : 79
Porosity : 26.8 [%]



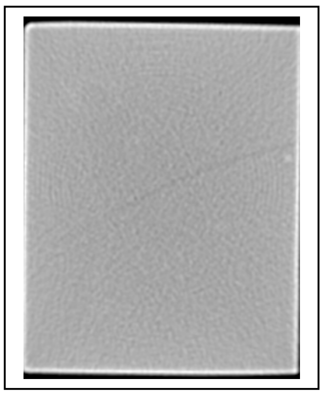
Plug 12 Depth: 9536.44 [feet]

Avg. gray value : 2000
Sdev : 83
Porosity : nd [%]



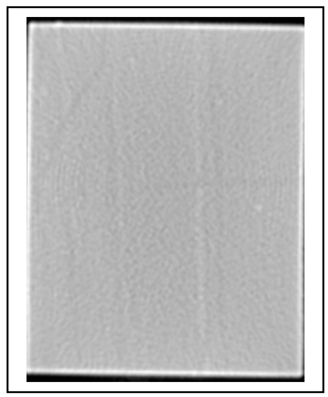
Plug 12 Depth: 9536.44 [feet]

Avg. gray value : 1991
Sdev : 71
Porosity : nd [%]



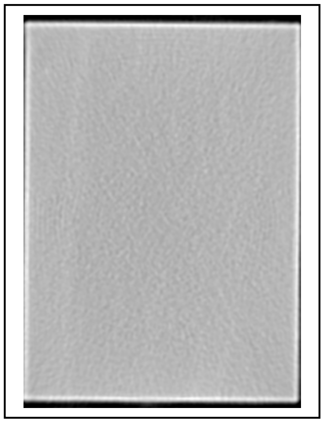
Plug 13 Depth: 9539.25 [feet]

Avg. gray value : 1901
Sdev : 79
Porosity : 24.5 [%]



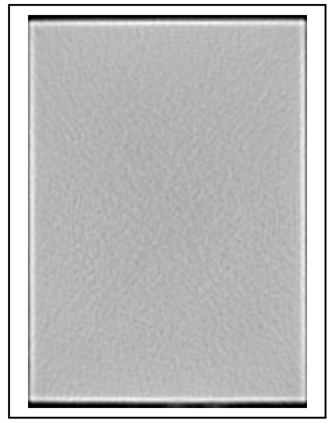
Plug 13 Depth: 9539.25 [feet]

Avg. gray value : 1910
Sdev : 85
Porosity : 24.5 [%]



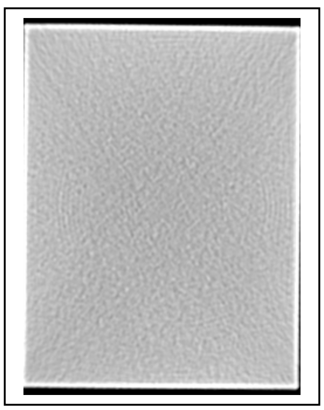
Plug 14 Depth: 9511.33 [feet]

Avg. gray value : 1891
Sdev : 73
Porosity : 27.0 [%]



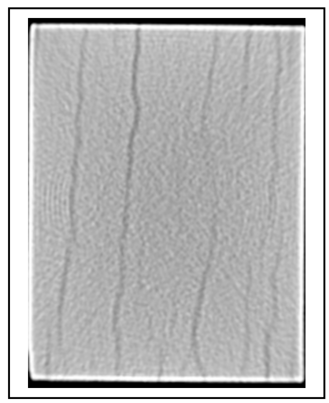
Plug 14 Depth: 9511.33 [feet]

Avg. gray value : 1891
Sdev : 72
Porosity : 27.0 [%]



Plug 15 Depth: 9522.90 [feet]

Avg. gray value : 2252
Sdev : 99
Porosity : nd [%]

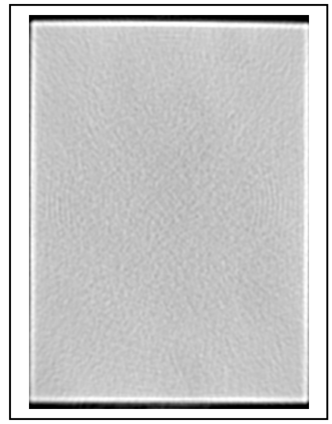


Plug 15 Depth: 9522.90 [feet]

Avg. gray value : 2247
Sdev : 107
Porosity : nd [%]

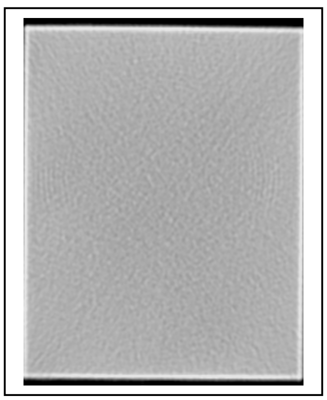
Plug 16 Depth: 9523.25 [feet]

Avg. gray value : 2113
Sdev : 93
Porosity : 20.9 [%]



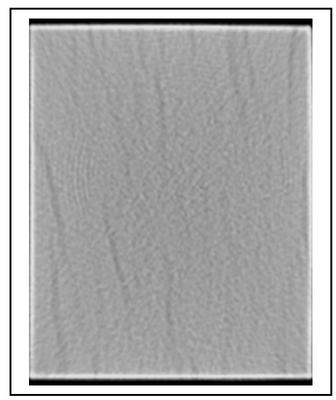
Plug 16 Depth: 9523.25 [feet]

Avg. gray value : 2127
Sdev : 90
Porosity : 20.9 [%]



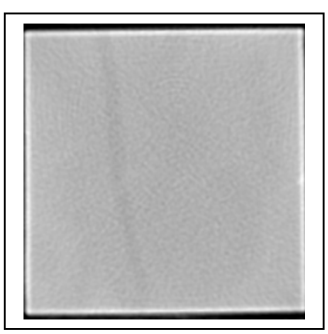
Plug 17 Depth: 9525.58 [feet]

Avg. gray value : 2180
Sdev : 93
Porosity : nd [%]



Plug 17 Depth: 9525.58 [feet]

Avg. gray value : 2185
Sdev : 100
Porosity : nd [%]

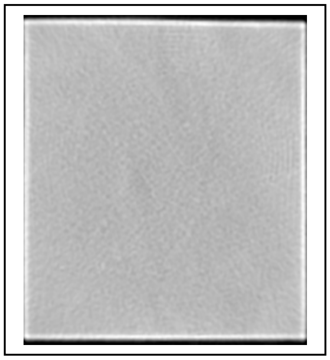


Plug 18 Depth: 9530.08 [feet]

Avg. gray value : 1862
Sdev : 84
Porosity : nd [%]

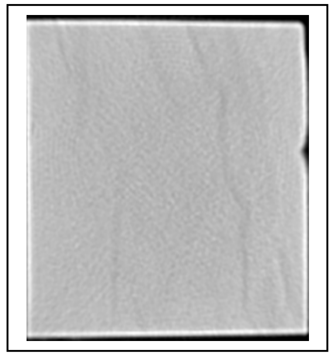
Plug 18 Depth: 9530.08 [feet]

Avg. gray value : 1875
Sdev : 92
Porosity : nd [%]



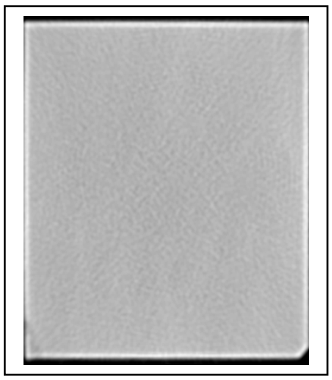
Plug 19 Depth: 9532.33 [feet]

Avg. gray value : 1953
Sdev : 81
Porosity : 23.8 [%]



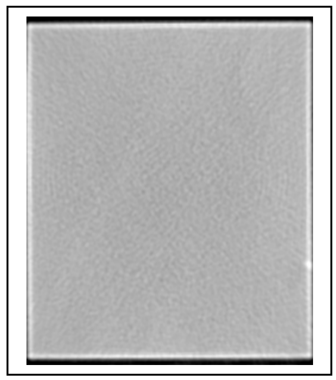
Plug 19 Depth: 9532.33 [feet]

Avg. gray value : 1959
Sdev : 90
Porosity : 23.8 [%]



Plug 20 Depth: 9534.70 [feet]

Avg. gray value : 1814
Sdev : 75
Porosity : nd [%]



Plug 20 Depth: 9534.70 [feet]

Avg. gray value : 1823
Sdev : 79
Porosity : nd [%]