

Final report

Shallow Stratigraphic Wells

Well: 7934/6-U-1

Well: 7934/6-U-2

Well: 7934/8-U-1

Well: 7934/9-U-1

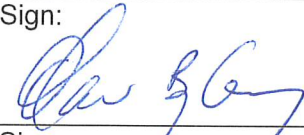
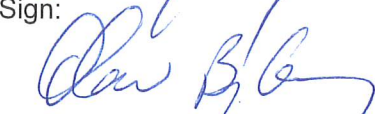
Author: Jan Frode Mossefinn

Date: December-2020

Key words:

- Plugs Cleaning and Drying
- He Porosity and Gas Permeability measurements

Client:	Norwegian Petroleum Directorate		
Country:	Norway		
Well:	7934/6-U-1. 7934/6-U-2. 7934/8-U-1. 7934/9-U-1		
Well Alias:	Shallow stratigraphic wells - Barents Sea		
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Project Manager: Stein Arild Maudal	Sign: 
Verification of Report: Olav Byberg	Sign: 
Report Approved by: Olav Byberg	Sign: 

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EXECUTIVE SUMMARY

A plug analysis study has been performed on plug material from well 7934/6-U-1. 7934/6-U-2. 7934/8-U-1 and 7934/9-U-1 in accordance with the analysis program requested by Client.

The objectives of the study were to determine core analysis properties for use in the petrophysical interpretation of the well.

Summary of plug samples Analysis Statistical Data

Well.	Plug Orientation	He Porosity	Empirical Klinkenberg Permeability	Grain Density
	Horizontal	Ambient (%)	20 Bar NCP (mD)	(g/cm ³)
Well	7934/6-U-1	22.2	87.89	2.67
Well	7934/6-U-2	21.8	37.38	2.69
Well	7934/8-U-1	32.0	63.30	2.75
Well	7934/9-U-1	20.7	140.90	2.67

NOTE: Average data calculated for Klinkenberg permeability are based on values higher than >0.005(mD).

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1 WELL INFORMATION AND PLUG ANALYSIS PROGRAM

Operator: Norwegian Petroleum Directorate

Well : 7934/6-U-1. 7934/6-U-2. 7934/8-U-1. 7934/9-U-1

Plug analysis has been performed on plug samples from well 7934/6-U-1. 7934/6-U-2. 7934/8-U-1 and 7934/9-U-1, in accordance with the analysis programme requested by client.

Plugs cleaning and drying	X
He Porosity, Gas Permeability and Grain Density	X

Table 1.1 Overview of the main plug analysis program

**Plug analysis Norwegian Petroleum Directorate
Well 7934/6-U-1. 7934/6-U-2. 7934/8-U-1. 7934/9-U-1**

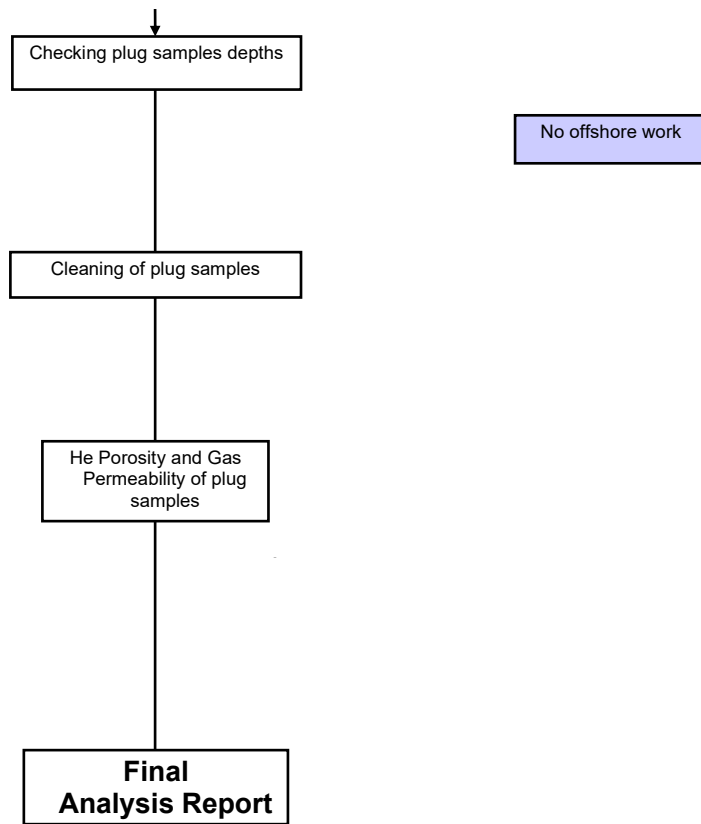


Figure 1.1 Plug Analysis Program Flow Chart

2 PLUG SAMPLING

Plug samples for analyses were drilled from all cores.

These plugs were collected by drilling with a 1 inch bore, using simulated formation brine (constructed to a standard concentration of 50 000 ppm NaCl) as a cooling agent.

In order to characterise the petrophysical properties parallel to bedding, horizontal plugs were taken on depths given by client.

The 1-inch samples were cut to one-inch lengths and the end faces were lightly brushed using the same fluid, to remove any fines induced by trimming.

Plug off cuts were labelled and retained for possible further use.

Prior to measurements the 1-inch plug samples were cleaned in a hot Soxhlet extractor using alternating sequences of methanol and toluene.

Toluene was used to remove any residual hydrocarbons and methanol to remove water and salts.

The plug samples were dried in a hot oven at 60 °C between the toluene and methanol extraction to avoid mixing of the solvents.

3 BASIC PETROPHYSICAL PROPERTIES

3.1 Analysis overview

The 1" horizontal plug samples (Onshore sampled) underwent the following laboratory procedures:

- Cleaning by hot Soxhlet solvents extraction (toluene, methanol).
- Hot Oven Drying at 60°C .
- Helium porosity at ambient conditions, no confining pressure.
- Gas Permeability measurements inclusive Empirical Klinkenberg corrected gas permeability at 20 bar net confining pressure.
- Grain and bulk volume measurements.

3.2 Laboratory Procedures for Basic Petrophysical Tests

3.2.1 Cleaning and drying of samples used for plug analysis

All samples were cleaned in a hot Soxhlet extractor using methanol and toluene.

Chemical and visual checks were made to ensure complete removal of fluids and salt.

Then the plug samples were dried in a hot oven at 60° C for 48 hours prior to analysis.

3.2.2 Helium porosity and grain density on plug samples

Method used to measure all CCA samples:

1-inch Samples

BV – Hg Imm.

GV – He Porosimeter

Grain volume was measured in a helium porosimeter on the cleaned and dried plug samples using Boyle's law to a reference volume.

Boyle's law stated that when the temperature remains constant, the volume V of a given mass of ideal gas varies inversely with its absolute pressure P.

$$V_1/V_2 = P_2/P_1 \text{ or } P_1 \cdot V_1 = P_2 \cdot V_2$$

Where:

P_1 (bar) and V_1 (cm³) = Pressure and Volume of reference cell

P_2 (bar) and V_2 (cm³) = Pressure and Volume after He expansion at equilibrium

Extension of the equation to account for temperature variation and nonideal gas behavior is required for accurate grain volume determination.

The method is a direct measurement of grain volume using a helium gas expansion porosimeter.

Prior to measurements, the porosimeter was calibrated. This is done by performing a standard measuring sequence using various combinations of steel plugs with known volumes. Based on these measurements, a function for grain volume is calculated from P_1/P_2 :

The calibration equation is determined by linear regression (least squares method) of disc volumes versus P_1/P_2 .

$$\text{Grain volume, GV} = a + b * P_1/P_2$$

Porosity and pore volume are then calculated from grain volume and bulk volume.

Bulk volume was measured by immersing the sample in mercury using the weight balance/buoyancy technique.

The stable dry weight of the plug sample divided by grain volume gives grain density of the core plug.

Number of plug samples and results from the analysis are listed in Appendix A.

3.2.3 Empirical Klinkenberg corrected gas permeability on plug samples

All permeability measured samples are automatic system resistance corrected, for high permeability samples the system resistance is corrected manually.

Steady state gas permeability was determined by flowing nitrogen gas through the cleaned and dried samples. At steady state conditions, the gas flow rate, the pressure drop over the plug sample and the upstream pressure were recorded.

The Net Confining Pressure (NCP) applied during the measurement was 20 bar. Ambient temperature was applied during the measurements.

The gas permeability (Kg) was calculated using Darcy's law.

The Klinkenberg corrected permeability value (KI) was determined empirically, based on the measured Kg and the corresponding average pore pressure (Pm).

Empirical Klinkenberg correction:

1. Kg range 0-2.0 mD

$$KI = 0.68 * Kg^{1.06}$$

2. Kg range 2.0 - x mD

Iteration loop

$$KI1 = 0.68 * Kg^{1.06}$$

$$m1 = 0.777 * KI1^{0.61}$$

$$KI2 = Kg - m1/Pm$$

$$m2 = 0.777 * KI2^{0.61}$$

$$KI3 = Kg - m2/Pm \text{ which gives: } KI_{n+1} = Kg - mn/Pm$$

When $KI_{n+1} - KI_n$ is approx. 0, then KI_{n+1} is approx. KI.

Two iterations are found to give proper result, giving $KI3 = KI$

Where:

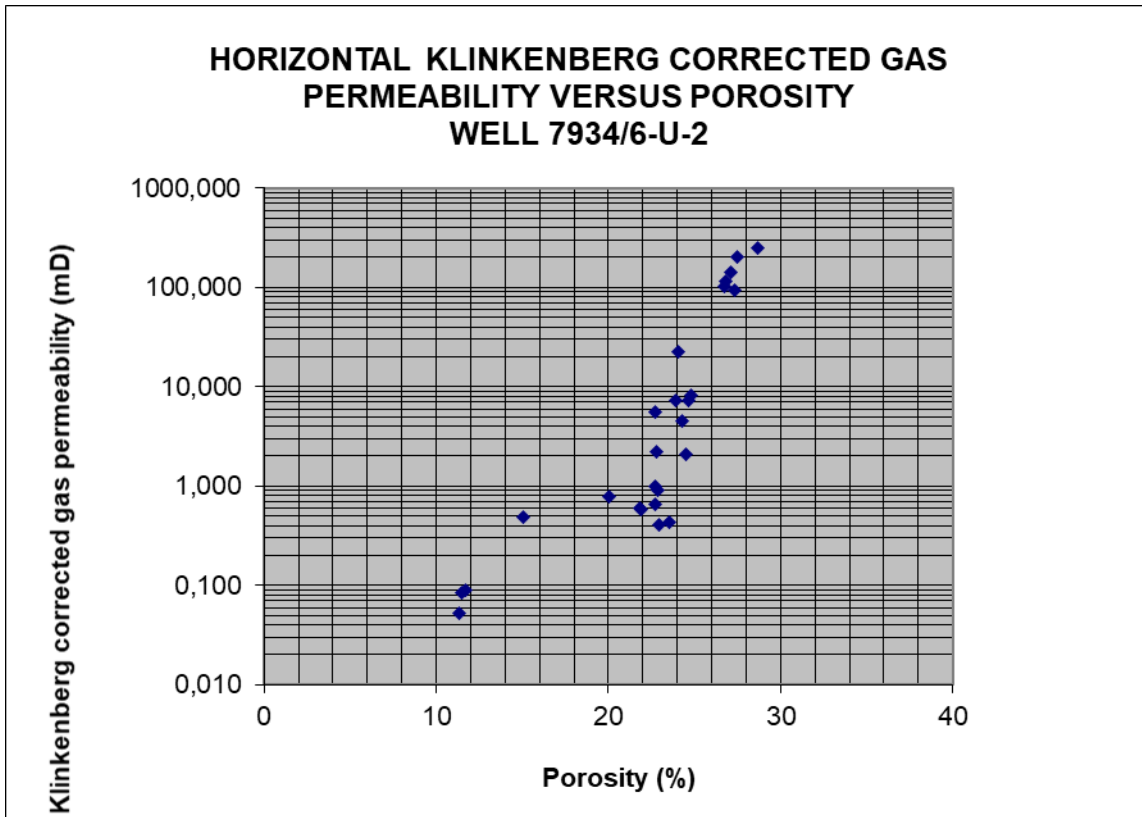
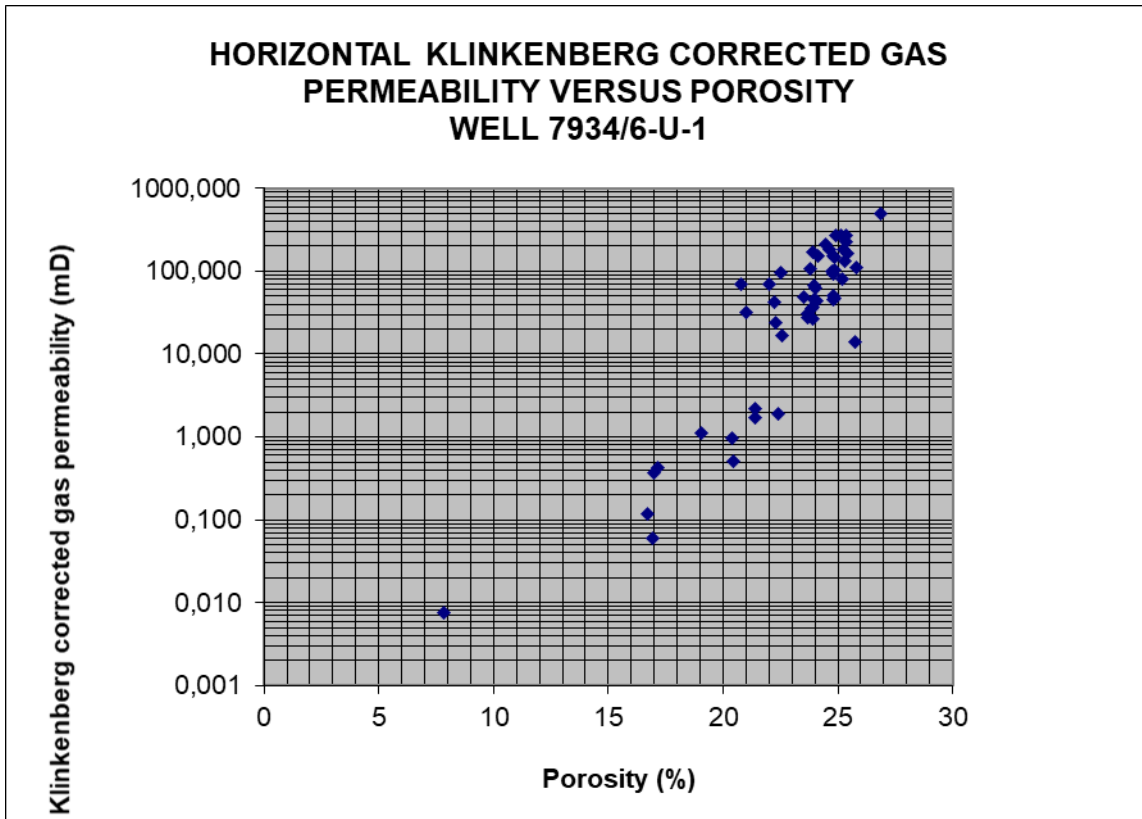
Kg : Measured permeability to gas, Nitrogen (mD)

KI : Klinkenberg corrected gas permeability (mD)

m : Klinkenberg correction (gas slippage effect).

Pm : Average pressure in the sample during measurements (atm)

3.3 Result Permeability vs Porosity Plots



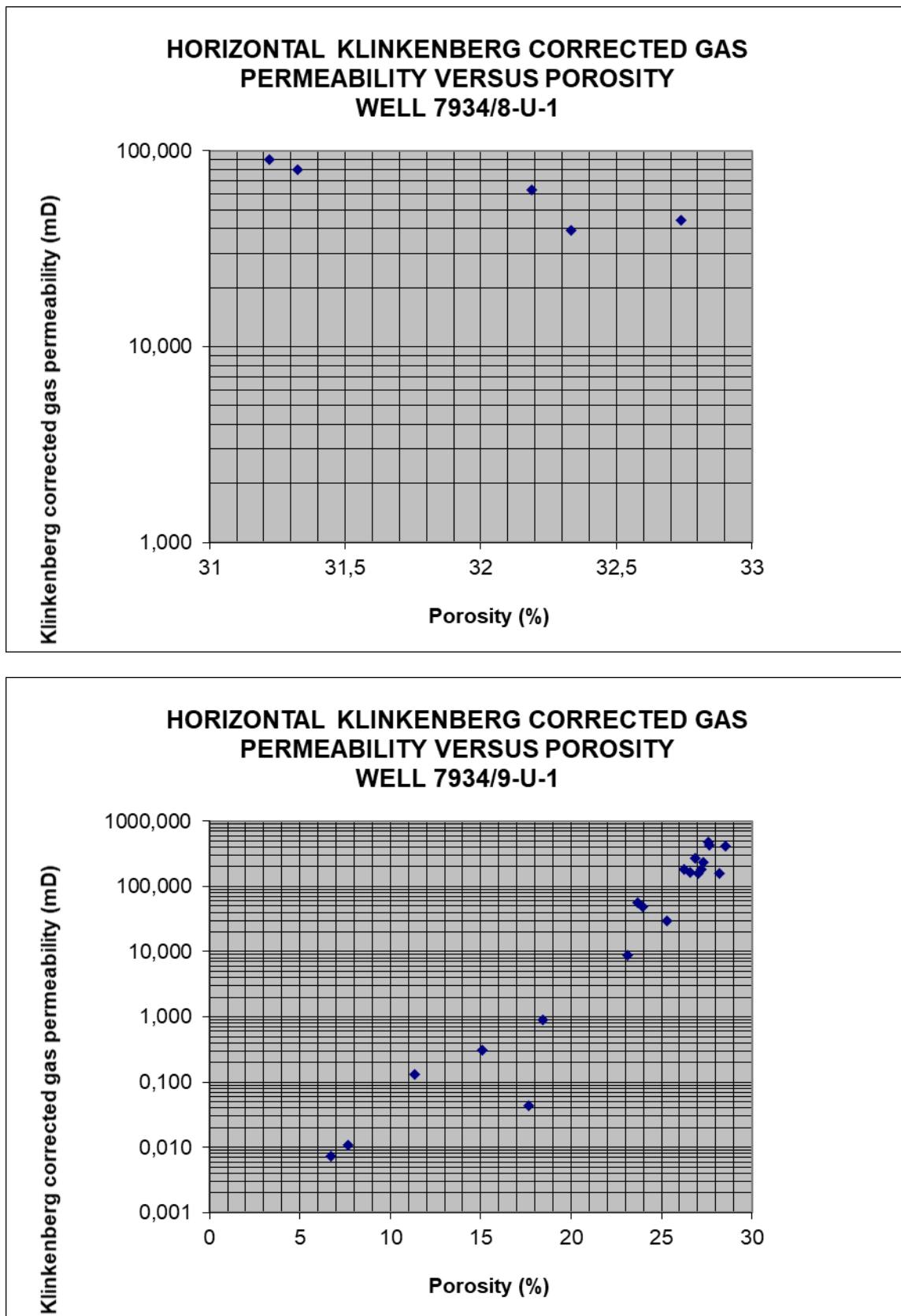


Figure 3.1 Helium Porosity vs Empirical Klinkenberg Permeability

4 NOMENCLATURE

Φ	Helium porosity (%)
GV	Grain Volume (cm ³)
PV	Pore Volume (cm ³)
BV	Bulk Volume (cm ³)
KI	Empirical Klinkenberg corrected gas permeability (mD)
Kg	Gas Permeability (mD)
GD	Grain density (g/cm ³)
Atm	Atmospheric pressure (Atmospheres, atm)
L	Length (cm)
D	Diameter (cm)

Abbreviations

NCP	Net confining pressure (Bar)
NMP	- No measurement possible
NPP	- No plug possible
N/A	- Not Available
KN ₂	- Measured nitrogen permeability (mD)
Pm	- Mean pressure in the sample during permeability measurements (atm)

5 ACCURACY AND UNCERTAINTY

Property	Range	Accuracy	Unit	Equipment
Gas Permeability	0.01 – 0.1 mD 0.1 – 100 mD 100 – 1000 mD 1 – 5 D >5 D	± 25 ± 5 ± 15 ± 25 ± 50	% % % % %	Steady State Gas Permeameter
He Porosity		± 0.5	%	Helium Porosimeter (temperature controlled room)
Grain Density		± 0.01	g/cm ³	Porosimeter
SCT Mounting		± 0.01	g	Balance
Grain Size Analysis		± 0.01	g	Balance
Temperature		± 1	deg C	Drying cabinets ovens humidity drying RH +/- 5%
Weight		± 0.01	g	Balance
Length and Diameter		± 0.01	cm	Digital Calipers
CT scan porosity estimation HU		± 1	%	
Laser Particle Size Analysis		± 0.5 to 1	%	

APPENDICES

Appendix A: Analysis Results



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/6-U-1

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)			Porosity (%)		Pore	Grain Density	Lithological Description			
Core	Plug no	Depth meters	Horizontal			Vertical			Saturation (%)		(g/cm3)		
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.		Vert.	Sw	Hor.
1	1	12.30	0.193	0.451	0.119			16.7	-		2.69		
1	2	12.60	0.752	0.633	0.503			20.5	-		2.66		
1	3	26.12	2.86	0.799	1.93			22.4	-		2.67		
1	4	26.34	32.4	0.826	27.5			23.7	-		2.69		
1	5	26.90	NMP	NMP	NMP			21.0	-		2.70		
1	6	27.70	2.40	0.626	1.72			21.4	-		2.69		
1	7	28.15	1.40	0.731	0.968			20.4	-		2.68		
1	8	30.88	0.565	0.627	0.372			17.0	-		2.66		
1	9	66.35	31.3	0.816	26.6			23.9	-		2.66		
1	10	67.15	35.8	0.831	30.6			23.7	-		2.65		
1	11	67.50	55.5	0.877	48.3			23.5	-		2.66		
1	12	68.20	20.4	0.817	16.8			22.6	-		2.67		
1	13	68.53	109	0.930	96.9			22.5	-		2.63		
1	14	68.80	70.4	0.901	61.8			24.0	-		2.65		
1	15	69.30	28.4	0.804	24.0			22.3	-		2.67		
1	16	69.90	36.8	0.836	31.4			21.0	-		2.69		
1	17	70.20	49.8	0.868	43.1			22.2	-		2.68		
1	18	70.80	79.5	0.909	70.0			20.8	-		2.67		
1	19	123.60	0.015	0.454	0.008			7.8	-		2.69		
1	20	125.30	0.101	0.454	0.060			16.9	-		2.69		
1	21	126.20	117	0.935	105			24.9	-		2.65		
1	22	127.80	0.642	0.455	0.425			17.2	-		2.68		
1	23	128.60	51.8	0.871	44.9			24.8	-		2.66		
1	24	129.05	51.2	0.870	44.3			24.1	-		2.66		



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/6-U-1

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)			Porosity (%)		Pore	Grain Density	Lithological Description			
Core	Plug no	Depth meters	Horizontal			Vertical			He		Saturation (%)	(g/cm3)	
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.		Vert.	Sw	Hor.
1	25	129.45	52.2	0.872	45.3				24.0	-		2.65	
1	26	129.85	1.61	0.892	1.13				19.0	-		2.67	
1	27	138.30	41.9	0.851	36.1				23.8	-		2.66	
1	28	139.20	122	0.938	109				25.8	-		2.65	
1	29	139.90	92.3	0.921	81.8				25.2	-		2.67	
1	30	141.10	53.8	0.876	46.7				24.8	-		2.69	
1	31	141.50	58.9	0.885	51.3				24.8	-		2.67	
1	32	142.80	17.5	0.952	13.8				25.7	-		2.66	
1	33	143.75	2.95	0.608	2.19				21.4	-		2.74	
1	34	144.35	42.3	0.852	36.3				23.9	-		2.67	
1	35	145.20	160	0.951	145				24.8	-		2.66	
1	36	146.60	148	0.947	134				25.3	-		2.66	
1	37	147.70	294	0.972	271				25.4	-		2.66	
1	38	148.80	183	0.957	166				25.4	-		2.68	
1	39	149.40	203	0.961	185				24.6	-		2.65	
1	40	150.90	104	0.929	92.9				24.8	-		2.67	
1	41	151.10	77.2	0.908	67.9				24.0	-		2.67	
1	42	152.50	167	0.953	151				24.8	-		2.67	
1	43	153.15	203	0.961	185				25.2	-		2.67	
1	44	154.50	<0.01	0.455	<0.005				4.5	-		2.69	
1	45	157.50	119	0.935	106				23.8	-		2.68	
1	46	159.15	78.2	0.909	68.9				22.0	-		2.67	
1	47	160.70	111	0.932	99.3				24.8	-		2.67	
1	48	161.50	251	0.967	230				25.3	-		2.68	



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/6-U-1

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)						Porosity (%)		Pore	Grain Density		Lithological Description
Core	Plug no	Depth meters	Horizontal			Vertical			He		Saturation (%)	(g/cm3)		
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.	Vert.	Sw	Hor.	Vert.	
1	49	162.20	228	0.964	208				24.5	-		2.67		
1	50	163.75	184	0.956	167				23.9	-		2.67		
1	51	164.35	172	0.953	155				24.2	-		2.67		
1	52	165.45	298	0.972	274				25.1	-		2.67		
1	53	166.15	297	0.972	274				24.9	-		2.66		
1	54	168.50	<0.01	0.452	<0.005				3.1	-		2.73		
1	55	170.10	522	0.984	488				26.9	-		2.64		



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/6-U-2

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)						Porosity (%)		Pore	Grain Density		Lithological Description
Core	Plug no	Depth meters	Horizontal			Vertical			He		Saturation (%)	(g/cm3)		
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.	Vert.	Sw	Hor.	Vert.	
1	56	23.20	0.090	0.456	0.053				11.4	-			2.70	
1	57	23.80	0.147	0.453	0.089				11.7	-			2.67	
1	58	25.15	NMP	NMP	NMP				NMP	-			2.66	
1	59	144.35	0.971	0.717	0.659				22.7	-			2.71	
1	60	146.15	9.23	0.786	7.20				24.7	-			2.67	
1	61	146.85	5.83	0.682	4.50				24.3	-			2.67	
1	62	147.20	0.646	0.638	0.428				23.5	-			2.77	
1	63	148.45	1.43	0.461	0.995				22.7	-			2.75	
1	64	149.25	<0.01	0.456	<0.005				5.2	-			2.70	
1	65	149.70	0.883	0.600	0.596				21.9	-			2.70	
1	66	150.45	NMP	NMP	NMP				20.7	-			2.68	
1	67	151.65	1.33	0.489	0.921				22.9	-			2.67	
1	68	156.10	114	0.932	102				26.8	-			2.65	
1	69	156.50	3.04	0.661	2.21				22.8	-			2.80	
1	70	157.15	9.25	0.783	7.22				23.9	-			2.67	
1	71	157.90	104	0.928	92.6				27.4	-			2.66	
1	72	158.70	NMP	NMP	NMP				22.2	-			2.63	
1	73	160.80	26.4	0.795	22.3				24.1	-			2.63	
1	74	163.90	10.4	0.796	8.20				24.8	-			2.69	
1	75	164.30	0.611	0.553	0.404				22.9	-			2.77	
1	76	167.50	0.872	0.371	0.588				21.9	-			2.69	
1	77	168.40	3.12	0.807	2.12				24.5	-			2.72	
1	78	169.70	1.13	0.639	0.775				20.0	-			2.69	
1	79	191.40	7.11	0.684	5.59				22.7	-			2.67	



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/6-U-2

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)						Porosity (%)		Pore	Grain Density		Lithological Description
Core	Plug no	Depth meters	Horizontal			Vertical			He		Saturation (%)	(g/cm3)		
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.	Vert.	Sw	Hor.	Vert.	
1	80	193.70	130	0.941	116				26.8	-		2.65		
1	81	195.50	0.721	0.563	0.481				15.1	-		2.67		
1	82	196.30	0.141	0.449	0.085				11.5	-		2.68		
1	83	197.35	159	0.950	143				27.1	-		2.65		
1	84	198.20	270	0.969	249				28.7	-		2.66		
1	85	199.30	223	0.964	204				27.5	-		2.65		



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/8-U-1

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)						Porosity (%)		Pore	Grain Density		Lithological Description
Core	Plug no	Depth meters	Horizontal			Vertical			He		Saturation (%)	(g/cm3)		
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.	Vert.	Sw	Hor.	Vert.	
1	86	13.55	45.7	0.860	39.4				32.3	-		2.75		
1	87	14.20	71.6	0.908	62.8				32.2	-		2.73		
1	88	15.45	102	0.927	90.3				31.2	-		2.72		
1	89	16.50	90.0	0.919	79.7				31.3	-		2.73		
1	90	18.30	51.3	0.873	44.5				32.7	-		2.81		



Conventional Core Analysis

Company: Oljedirektoratet

Well: 7934/9-U-1

Country: Norway

Field:

Date: 04.12.2020

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			Permeability (mD)						Porosity (%)		Pore	Grain Density		Lithological Description
Core	Plug no	Depth meters	Horizontal			Vertical			He		Saturation (%)	(g/cm3)		
			Kg	1/Pm	Kl	Kg	1/Pm	Kl	Hor.	Vert.	Sw	Hor.	Vert.	
1	91	94.10	35.3	0.838	30.1				25.3	-		2.68		
1	92	95.40	<0.01	0.454	<0.005				6.5	-		2.69		
1	93	96.20	<0.01	0.453	<0.005				2.9	-		2.70		
1	94	97.60	1.29	0.455	0.891				18.5	-		2.76		
1	95	98.50	177	0.955	160				27.1	-		2.67		
1	96	99.20	201	0.960	183				27.2	-		2.66		
1	97	99.55	252	0.968	231				27.3	-		2.65		
1	98	142.70	0.075	0.453	0.044				17.7	-		2.68		
1	99	143.85	10.7	0.678	8.72				23.1	-		2.67		
1	100	144.20	0.480	0.648	0.313				15.1	-		2.66		
1	101	144.80	0.020	0.452	0.011				7.6	-		2.67		
1	102	145.20	0.014	0.451	0.007				6.7	-		2.68		
1	103	146.20	56.6	0.880	49.2				23.9	-		2.65		
1	104	146.60	0.211	0.449	0.130				11.4	-		2.67		
1	105	147.50	197	0.959	179				26.3	-		2.66		
1	106	149.10	458	0.981	427				27.6	-		2.65		
1	107	150.40	506	0.983	473				27.6	-		2.64		
1	108	151.50	298	0.972	275				26.9	-		2.66		
1	109	152.10	64.2	0.891	56.2				23.7	-		2.66		
1	110	153.50	178	0.955	161				28.2	-		2.69		
1	111	154.20	447	0.981	417				28.6	-		2.65		
1	112	154.60	182	0.955	165				26.6	-		2.65		