Petrophysical Report of the Dinantian Carbonates in the Dutch Subsurface

Report by SCAN

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Ministerie van Economische Zaken en Klimaat
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TNO
Interreg North-West Europe DGE-ROLLOUT

Contents

Report by Torbjörn Carlson

Dit rapport is een product van het SCAN-programma en wordt mogelijk gemaakt door het Ministerie van Economische Zaken en Klimaat

WELL DATA KTG-01

Company Name : NAM

Well Name : KTG-01

Field Name : Kortgene

Geological targets : Lower Carboniferous Carbonates

Country : Netherlands

Field Location : License Zeeland

Longitude : 51*51’21.743”N

Latitude :   03*36’32.270”E

Maximum Hole Deviation : 11 (deg)@1900m

Elevation of Kelly Bushing : 7.96 m NAP

Elevation of Ground Level : NAP

Elevation of Derrick Floor : 0.3m 13 3/8 flansch

Permanent Datum : NAP

Elevation of Permanent Datum : 0m

Log Measured from : 52-1900m

Maximum recorded temperature : 70 degC

TD: 1900m

Dinantian evaluation in KTG-01 (945-1043 m MD)

Log quality, edits and depth shifts

The logs are overall of good quality. The GR, neutron and the sonic is taken from the Petrel import. However, the sonic has been edited in the up-hole section. The density with associated curves where taken from the LAS files and spliced and the density was edited in the up-hole sections. The laterolog needed a very minor depth shift. The induction logs were spliced from the 3 different sections.

Log corrections

Both the density and the neutron had to be adjusted in the 8 3/8" hole to allow a believable density-neutron and sonic-neutron x-plot in the Dinantian, see figure 1, for non-corrected density-neutron data. The neutron was too high, and no values were gathered around 0 porosity, although both the core data and the x-plots indicated that this is the case. The shift applied is -0.01, which is within the calibration limits for a neutron. The density also had to be corrected to allow a good match to the density-neutron cross plot and the adjustment applied was -20 kg/m3, something that is considered outside the calibration limit but is sometimes seen. There is Baryte in the section and there are indications that there may be some metallic minerals, and this could be part of the reason for the high density, but most indications are that the correction is justified as a significantly better match to the expected main lithologies are achieved, see figure 2.

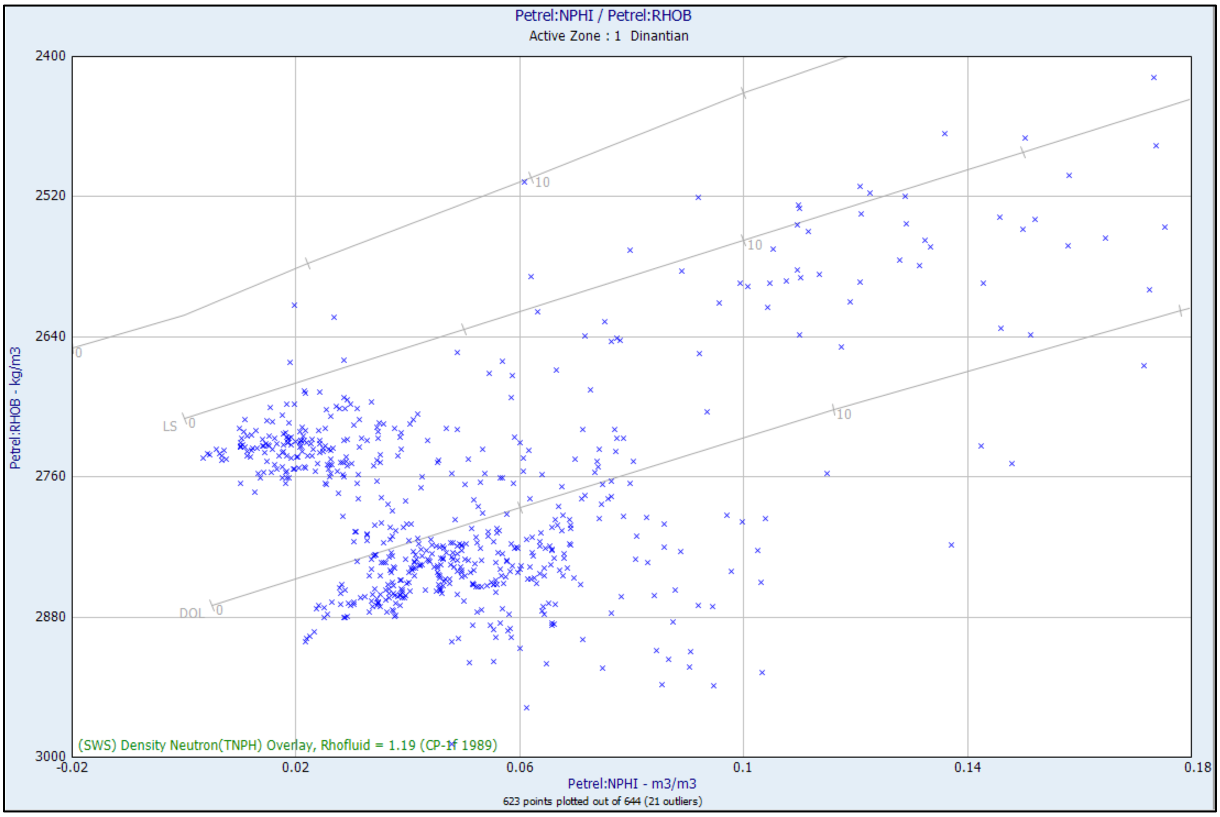


Figure 1. uncorrected density and neutron data.

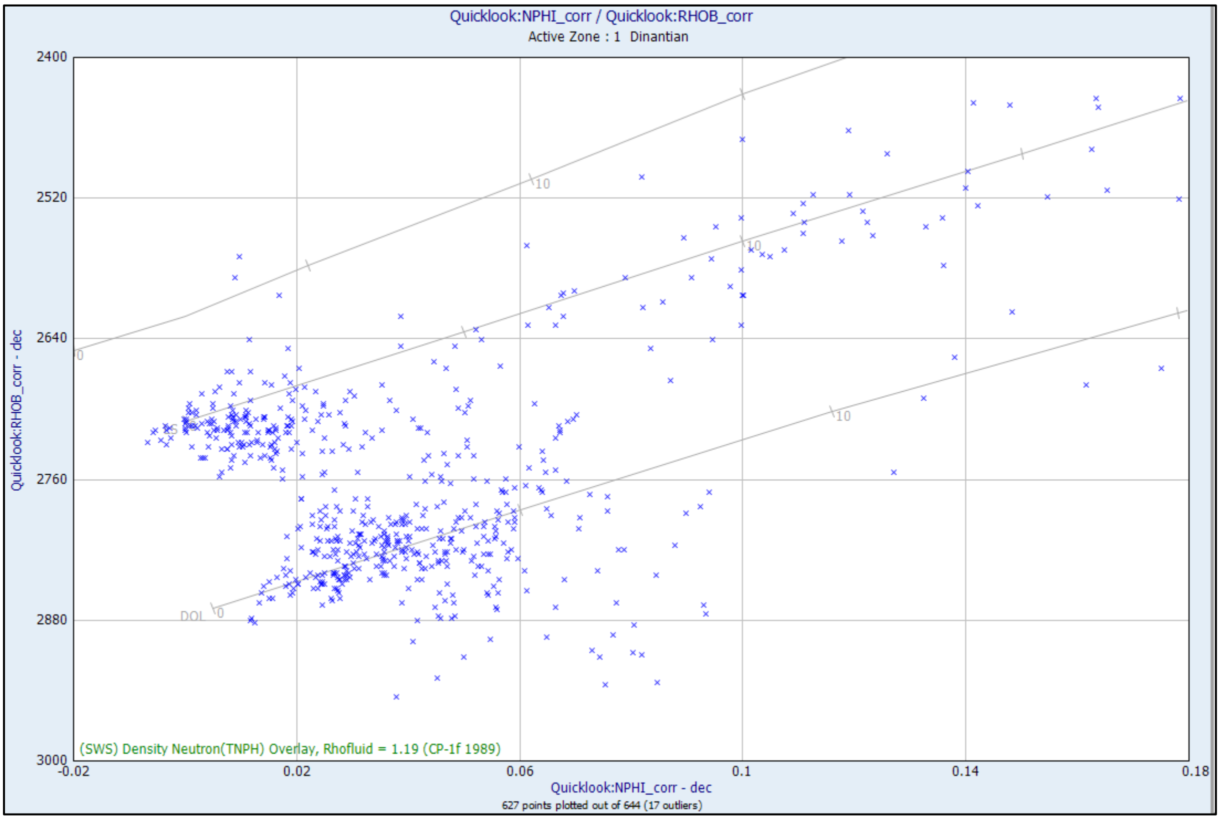


Figure 2. Corrected density-neutron data (-0.01 applied to neutron and -20 kg/m3 to the density).

Evaluation of Dinantian (945-1043 m MD)

The primary porosity is calculated from the corrected density based on a matrix density calculated from the photo electric effect, PEF (no Baryte in the mud), assuming a linear matrix density between dolomite and limestone (PEF=3.1, Rhoma=2850 kg/m3 for dolomite and PEF=5.1, Rhoma=2710 kg/m3 for limestone). Note that the PEF is limited to the interval 3.1 to 5.1 prior to calculating the matrix density. The porosity based on the density and PEF is complemented by the sonic-neutron x-plot porosity and the final porosity is the minimum of these two porosities. The match to the core porosity is overall very good in the tight intervals. In the karsted intervals with reasonable to good porosity, the interpreted porosity provides a reasonable average of the rapidly varying porosity seen in the core plugs (note that the core has not been shifted and that it is more or less on depth with the logs). Porosity has also been calculated from density-neutron x-plot, sonic and neutron, the latter assuming dolomite matrix (which is the dominant lithology) and these agrees closely to the final porosity curve.

A clay indicator was calculated from the K (Potassium) concentration with clean carbonate having K=0 and 100 % clay a K=0.05, resulting in the following equation:

Clay Indicator = 20 * K (K in fractions)

No clay cut-off has been applied on the porosity. In a few intervals 994-998 m and 1022.5-1026.4 m the porosity is above 3 % at some points and these are some of the intervals with the highest clay content and it could be argued that the porosity should be set to 0 here. However, the clay indicator is equally high in the high porosity at 959.5 m and it is clear that this should not be cut out and, therefore, a standard clay cut-out is not meaningful.

For the lithology three minerals in addition to the clay indicator has been used; Baryte, Limestone and Dolomite. The PEF has been used to calculate the mineral composition where the following PEF values have been used:

Baryte: 267

Limestone: 5.1

Dolomite: 3.1

The resulting equation for the different Lithologies are as follows:

Baryte = 0.003817*(PEF-5.1) (5.1 is PEF of Limestone and PEF is not limited to 3.1 to 5.1)

Limestone = (-1.55+0.5*PEF)*(1-Cum_Clay_Bar)

Dolomite = 1 – (Clay Indicator + Baryte + Limestone)

Due to the very high PEF of the mineral Baryte the proportion of Baryte is low and probably not sufficient to explain some of the high densities observed. In addition to the Baryte there are probably some metallic minerals present, most likely Pyrite or Sphalerite.

Result

The result of the evaluation can be seen in the log evaluation plot. In the middle depth track are the cored intervals and the core recovery indicated in brown. In the evaluation track 12 is the Clay Indicator, core grain density and the calculated matrix density. In track 13 is the calculated porosity and core porosity, on a 0 to 15 % scale, with the test interval indicated in black. In track 14 is the core permeability and in track 15 is the calculated lithology described in this report displayed.

The sums and averages for this well is provided in the table below with no Clay Indicator cut-off

Gross	Net	Net/Gross	Average Porosity	Average Porosity times net	Normalized Porosity*Net	Porosity cut-off
MD	MD	MD				
m	m	fract	fract	m	fract	fract
98,0	98,00	1,000	0,019	1,90	1,00	0,00
98,0	50,10	0,511	0,035	1,77	0,93	0,01
98,0	26,78	0,273	0,054	1,43	0,75	0,02
98,0	17,63	0,180	0,069	1,21	0,64	0,03
98,0	13,11	0,134	0,081	1,06	0,56	0,04
98,0	9,75	0,099	0,093	0,91	0,48	0,05
98,0	8,99	0,092	0,096	0,87	0,46	0,06
98,0	7,16	0,073	0,104	0,75	0,39	0,07
98,0	6,40	0,065	0,108	0,69	0,36	0,08
98,0	5,03	0,051	0,114	0,58	0,31	0,09
98,0	3,35	0,034	0,124	0,42	0,22	0,10
98,0	2,13	0,022	0,134	0,29	0,15	0,11
98,0	1,68	0,017	0,139	0,23	0,12	0,12
98,0	1,37	0,014	0,143	0,20	0,11	0,13
98,0	0,76	0,008	0,148	0,11	0,06	0,14
98,0	0,30	0,003	0,153	0,05	0,03	0,15
98,0	0,00	0,000		0,00	0,00	0,16

The second column from the right is a normalized product of average porosity and net (Average porosity*net/Average Porosity*net at no porosity cut off) to enable plotting in the same graph as the other parameters, see figure 2 below.

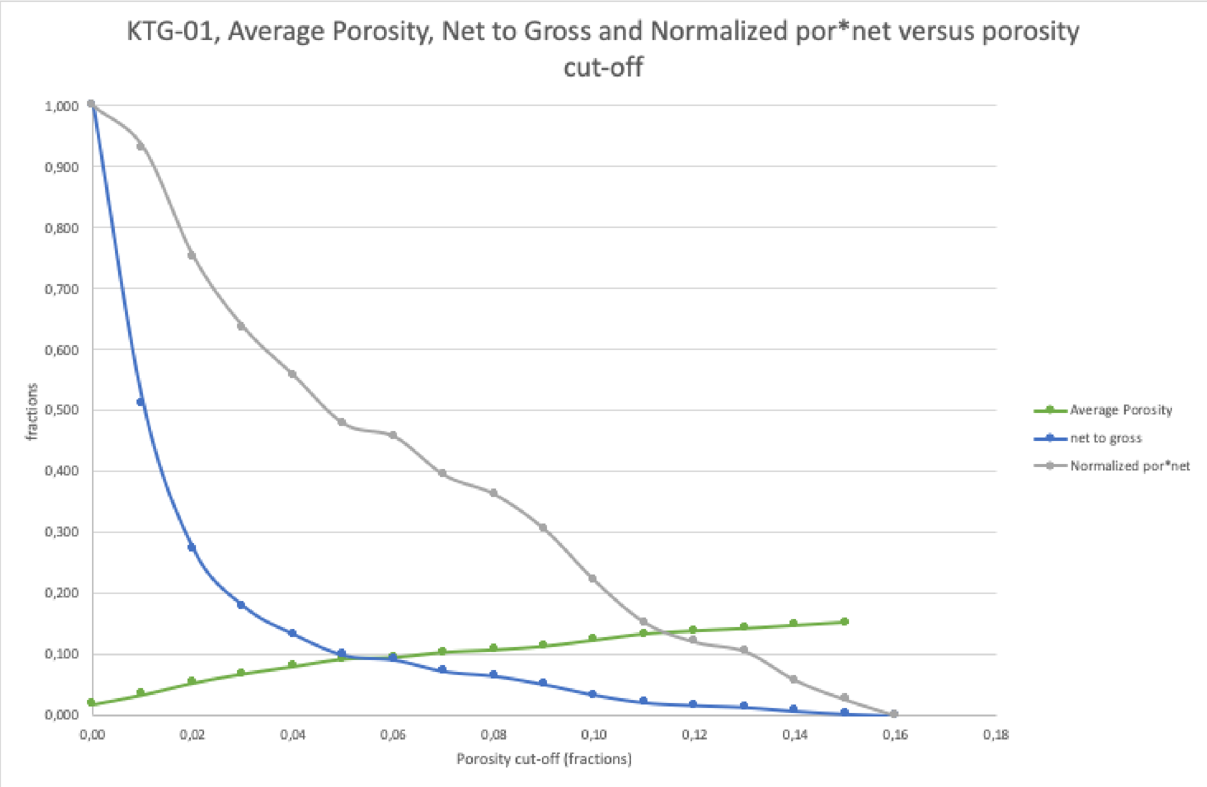


Figure 2. Average porosity, net-to-gross and normalized porosity*net thickness for increasing porosity cut-off

The graph shows a fast decrease in net to gross up to 2 % porosity cut-off and after that gradually a slowing decrease, up to 16 % where net becomes 0. The product of average porosity and net (Normalized por*net) has a much slower decrease compared to the net/gross and the reason is that the average porosity increases relatively fast initially and then almost linearly up to 15 % porosity cut-off. The average clay indicator is not displayed as no clay cut-off was applied.

The porosity at no porosity cut-off is 1.9 %, which compared to many other Dinantian wells is a relatively high value.

Discussion

There are some clear differences in the response of the porosity logs, density, neutron and sonic in some of the sections. In one extreme case at 959.5 m, the sonic indicates almost no porosity while the density indicates a porosity above 50 % and the neutron more than 30 %. There is a very minor indication of a hole irregularity, but it should not have a major impact on the density, which measured a very low density. The core shows a karsted interval (959-962 m) and is very heterogenous. The explanation to the extreme difference just above 960 m is almost certainly that one of the sides of the hole has continuous low porosity limestone/dolomite, allowing the sonic waves to travel fast while the density sees a different direction and the neutron is circumferential and sees more of an average porosity. The resistivity will, like the neutron respond more to the average porosity in such instances.

At 961 m a large difference is also observed, although not as extreme and at 962 m, it is the sonic that indicate porosity while the other logs show low or very low porosity. The section 959-962 m is a good demonstration on how heterogeneous karsts can be.

Other karsted intervals are present in the interval 971.5-983.5. Here there are no large differences in the response of the porosity curves. The core data indicate an extremely varied porosity where some very high porosities are next to low porosity. The interpreted porosity is a reasonable average of these.

The core also shows some very low grain densities in this interval and this is caused by fines (sands, silts and other detrital material filling part of the karst). The interval is very patchy, and this is obviously the reason for the extreme heterogeneity among the core plugs.

At the top of the Dinantian, 945-946 m, and in the interval 976-982 m there are some high- density spikes with high PEF response. This is interpreted as Baryte mineralization, something that is seen in the core and not much Baryte is needed to cause the high PEF response. There may also be other high-density minerals like Pyrite in these intervals.

In several intervals there are anomalous differences between the laterologs (LLD, LLS and SFLU) compared to the induction logs, particularly 959-963 m, has a very distinct difference. This is most likely due to a conductive material (pyrite most likely) dispersed in the rock that causes the induction to indicate very high resistivity (polarization horns) while the Laterolog indicate low resistivity in line with the porosity logs. In the interval 950-955.5 the laterolog has several low resistivity anomalies that does not correspond to porosity and the deep Induction has an anomalous response with horns and some very high resistivity intervals. These discrepancies are almost certainly associated with presence of conductive minerals, most likely Pyrite.

Core data

The well was cored from 946-996 m with a 100 % core recovery and the entire section has had standard porosity and grain density analyses carried out on the plugs. No corrections have been applied to the core measurements as almost all samples have very low porosity and no special core analysis were performed. Only 4 samples have had a permeability measurement, probably due to the state of the plugs in the more porous intervals but also because of the very low porosity on the majority of the core plugs. Based on the core analyses and the log signature, core shifts are not required for this well.

Flow potential

Well tests

1 open hole DST test was performed in the Dinantian:

13-14/10/1982: 930-1051 m. Second flow period flowed some 400 l of liquid.

Stimulated with 14.5 m3 acid (15 % HCl) and lifted well with Nitrogen for 1.5 hrs, produced 369 m3 of formation water. Stopped lift with Nitrogen and well was flowing water at 90 l/min (5.4 m3/hr) with a Chlorine content of 36.6 gr/l. Maximum H2S was 50 ppm. No burnable gas at surface. After well was closed in, a surface pressure of 2.5 bar was recorded.

This is the only well of the wells evaluated that has flow to surface without artificial lift.

Wireline formation tester (RFT)

One pressure test run was made with an RFT tool on 10 oct 1982 (max temp. was 65.5 C, time stopped circulation; 11:00 10 Oct., time logger on bottom; 15:00 10 Oct.

The results are tabled below (pressures both in psig and in bar):

File No	Depth	Hydr. Press. Before	Hydr. Press. Before	Hydr. Press. After	Hydr. Press. After	Stabilised Pressure during test	Stabilised Pressure during test	Remark
	m	psig	bar	psig	bar	psig	bar	

3	943.0	1467	102.2	1468	102.2	7	1.5	Dry test
4	943.3	1468	102.2	1468	102.2	10	1.7	Dry test
5	942.7	1467	102.2	1467	102.2	12	1.8	Dry test
6	965.0	1501	104.5	1501	104.5	13	1.9	Dry test
7	964.8	1501	104.5	1501	104.5	13	1.9	Dry test
8	973.0	1513	105.3	1514	105.4	13	1.9	Dry test
9	997.0	1550	107.9	1550	107.9	14	2.0	Dry test
10	996.7	1550	107.9	1550	107.9	14	2.0	Dry test
11	1023.0	1590	110.6	1591	110.7	14	2.0	Dry test
14	1703.0	2629	182.3	2629	182.3	-	-	Seal Failure
15	1702.9	2630	182.3	-	-	-	-	Seal Failure
16	1702.6	2632	182.5	2630	182.3	14	2.0	Dry test
17	1703.2	2629	182.3	-	-	-	-	Seal Failure
18	1703.4	2632	182.5	2633	182.6	12	1.8	Dry test
19	1732.0	2675	185.4	2676	185.5	12	1.8	Dry test
20	1732.5	2677	185.6	2677	185.6	11	1.8	Dry test

No test indicated any permeability and are therefore designated dry tests. There were 3 seal failures, something that is normal when the hole is enlarged or there is a fracture/karst. Note that only the RFT tests in the interval 943-1023 m are in the Dinantian.

Formation temperature

Table showing the maximum temperatures from the different logging runs in KTG-01 in intermediate hole to 931 m

Log	Depth	Log date	Time since circ.	Max Temp
	(m)		(hrs)	(deg C)
GR/SLS/DIS	≈915.	13/9/1982	4.5	38.8
GR/LDL/CNL	≈915	13/9/1982	7.5	39.4
HDT/FIL	≈925	13/9/1982	10.5	40.0

A Horner extrapolation of the above data result in an estimated formation temperature at 915 m measured depth of 41 C.

Table showing the maximum temperatures from the different logging runs in KTG-01 at TD.

Log	Depth	Log date	Time since circ.	Max Temp
	(m)		(hrs)	(deg C)
GR/SLS/DIS	≈1875	9/10/1982	20.5	68.8
GR/LDL/CNL	≈1885	9/10/1982	27.5	69.4
HDT/FIL	≈1895	9/10/1982	31.5	69.4
GR/DLL	≈1885	9/10/1982	36.5	70.0
RFT	≈1730	10/10/1982	52	65.5

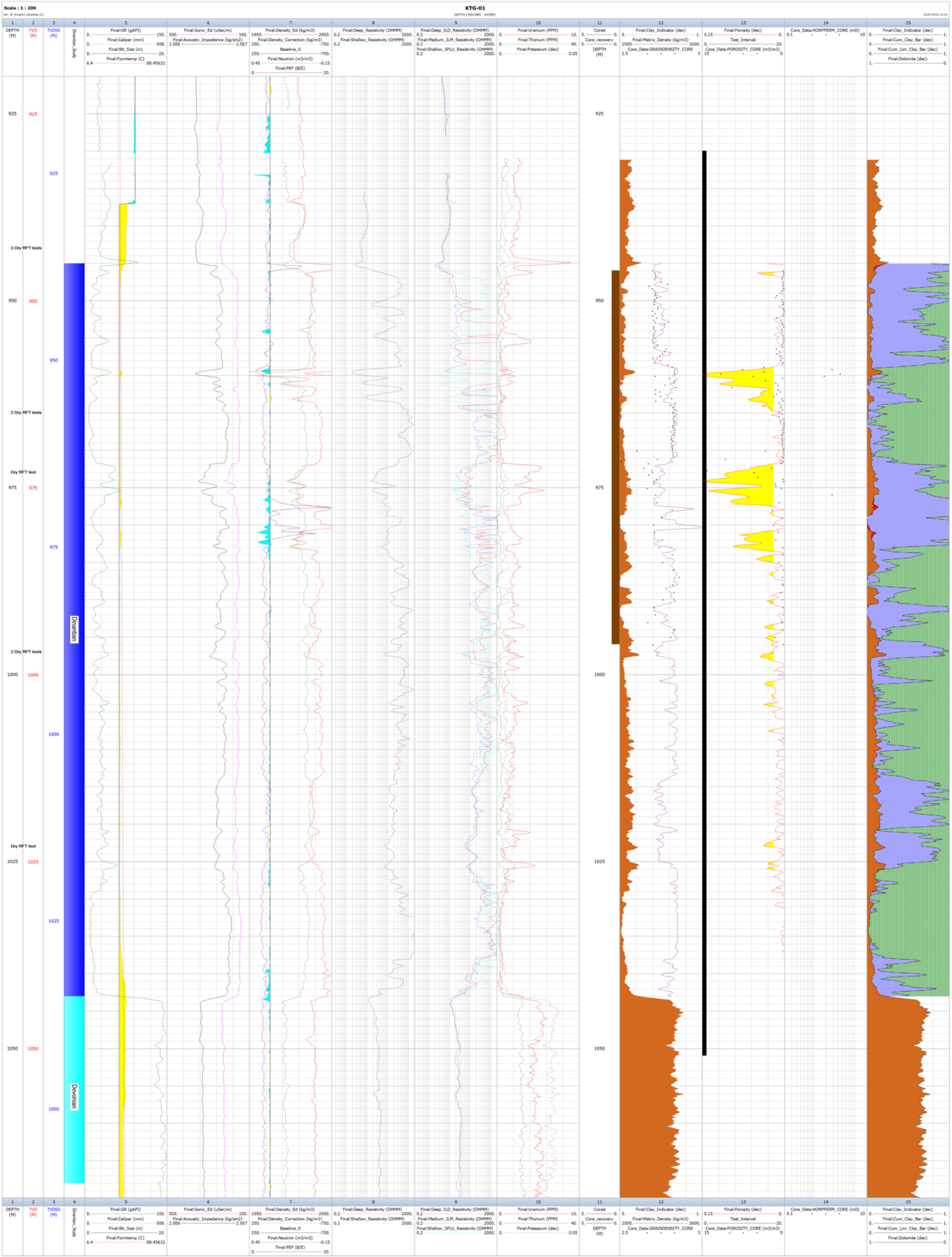
A Horner extrapolation of the above data result in an estimated formation temperature at 1875 m measured depth of 71.5 C.

The average surface temperature at this location is approximately 10 C. With this surface temperature the following equations result:

Surface to 915 m: Formtemp = 9.7 + 0.03418 * TVD (gradient = 3.42 C/100 m)

915 m to TD: Formtemp = 11.6 + 0.03217 * TVD (gradient = 3.22 C/100 m)

Evaluation plot



Well logging summary KTG-01

OPERATOR:	NAM- Netherlands
WELL:	Kortgene
WELL BORE:	WELL Nr.1
FIELD:	Kortgene
PLATFORM:	onshore
COUNTRY:	NETHERLANDS
DRILL PERMIT #:	
WELL STATUS:	P and A

WELL LOGGING SUMMARY

Hole section:	File name:	Main Service:	Generic Logs	Service Company:	Mode:	Run #:	Sub file:	Run Type	Pass Direction (Up/Down)	Date:	Interval Top (m):	Interval Bot (m):	Remarks:
17 1/2"		GR-DIL-SFL-LSSL	GR-IND-SON	SCHLUMBERGER	EWL	1	1	Main	Up	08-SEP-1982	52	603	
17 1/2"		GR-FDC-CNL	GR-DEN-NEU	SCHLUMBERGER	EWL	1	2	Main	Up	08-SEP-1982	52	604	
12 1/4"		GR-DIL-SFL-LSSL	GR-IND-SON	SCHLUMBERGER	EWL	2	3	Main	Up	13-SEP-1982	602	930.5	
12 1/4"		GR-LDT_FDC-CNL-CAL	GR-DEN-NEU	SCHLUMBERGER	EWL	2	4	Main	Up	13-SEP-1982	602	930	
12 1/4"		GR-HDT-CDR-BGT	GR-DIP	SCHLUMBERGER	EWL	2	5	Main	Up	13-SEP-1982	602	930	
12 1/4"		GR-DIP-FIL	GR-DIP-fracture identification	SCHLUMBERGER	EWL	2	6	Main	Up	13-SEP-1982	602	930	
8 3/8"		GR-DIL-SFL-LSSL	GR-IND-SON	SCHLUMBERGER	EWL	3	7	Main	Up	09-OCT-1982	931	1899	
8 3/8"		GR-LDT_FDC-CNL-CAL	GR-DEN-NEU	SCHLUMBERGER	EWL	3	8	Main	Up	09-OCT-1982	931	1899	
8 3/8"		GR-HDT-CDR-BGT	GR-DIP	SCHLUMBERGER	EWL	3	8	Main	Up	09-OCT-1982	931	1990.5	
8 3/8"		GR-DIP-FIL	GR-DIP-fracture identification	SCHLUMBERGER	EWL	3	8	Main	Up	09-OCT-1982	940 + 1650	1050 + 1750	2 runs
8 3/8"		LL1	GR-Dual Laterolog	SCHLUMBERGER	EWL	3	8	Main	Up	09-OCT-1982	931	1897	
8 3/8"		SpecGR	NGS ratios	SCHLUMBERGER	EWL	3	8	Main	Up	09-OCT-1982	931	1880	

Appendix: Horner plot

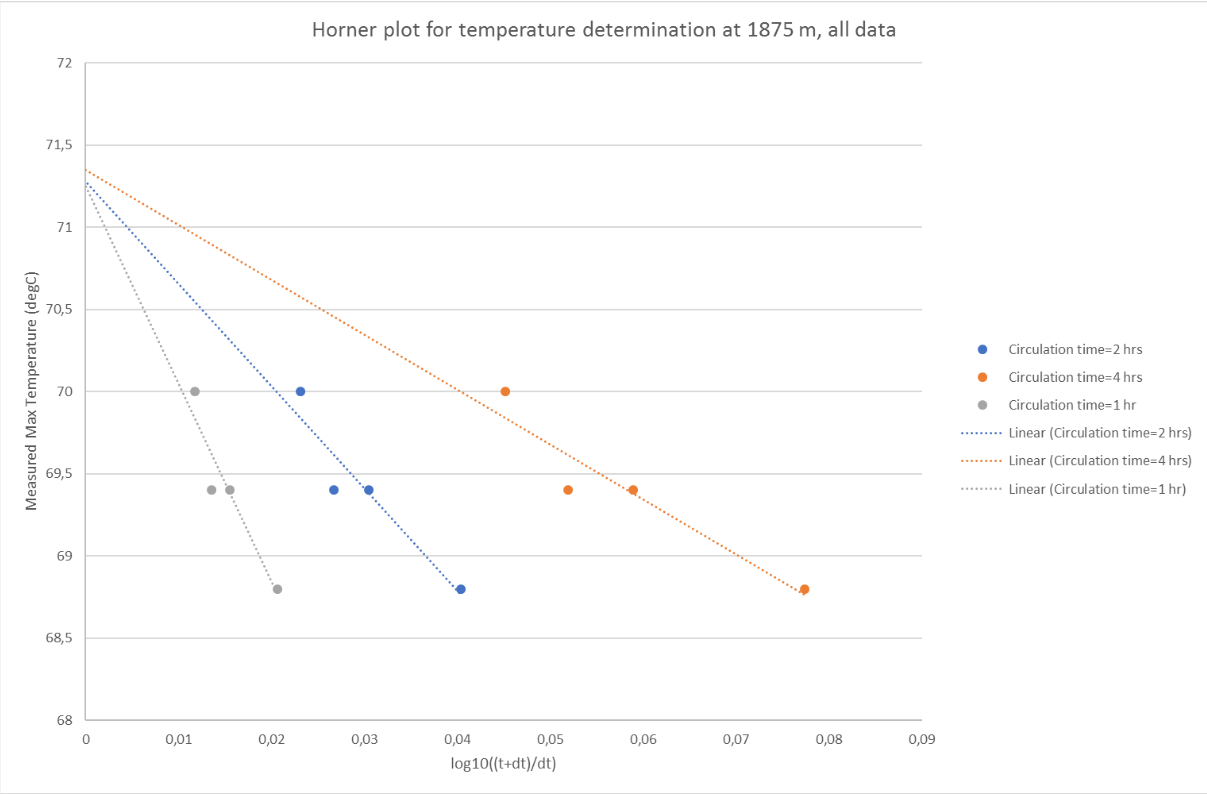


Figure 1. Horner plot at 1875m

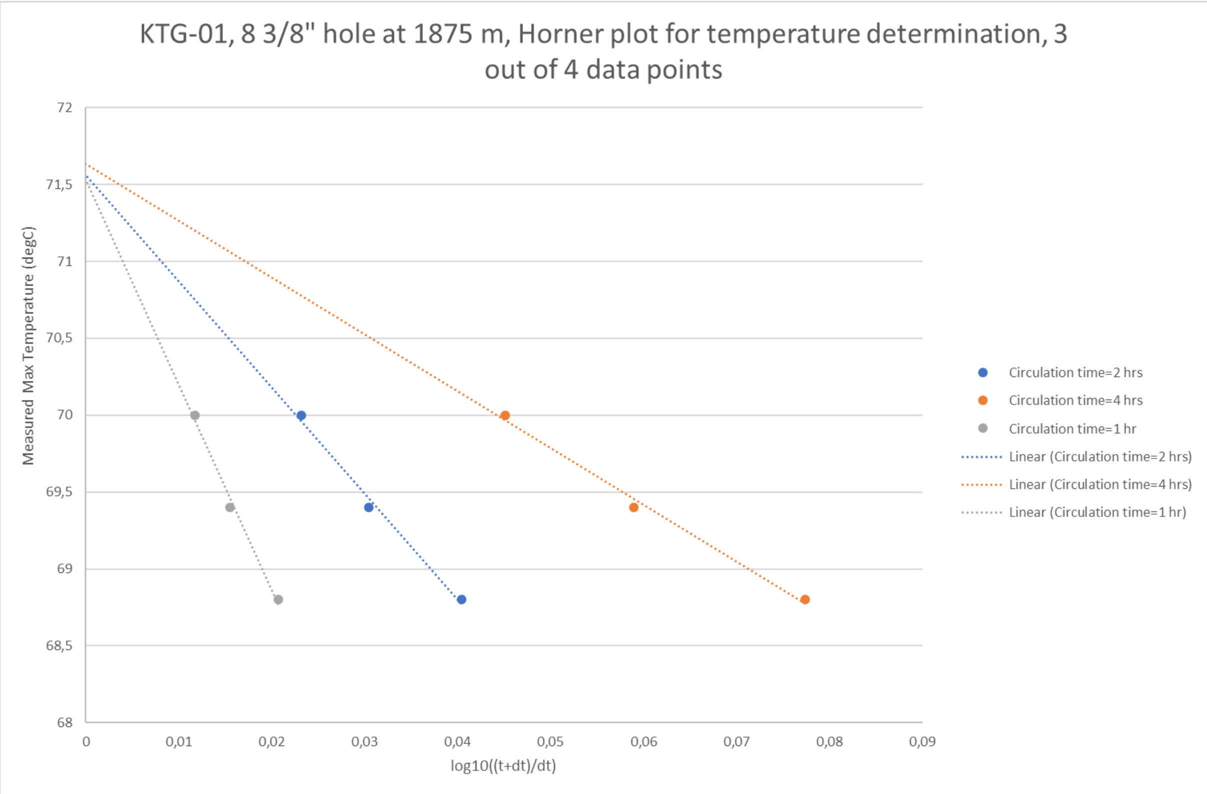


Figure 2. Horner plot at 1875m

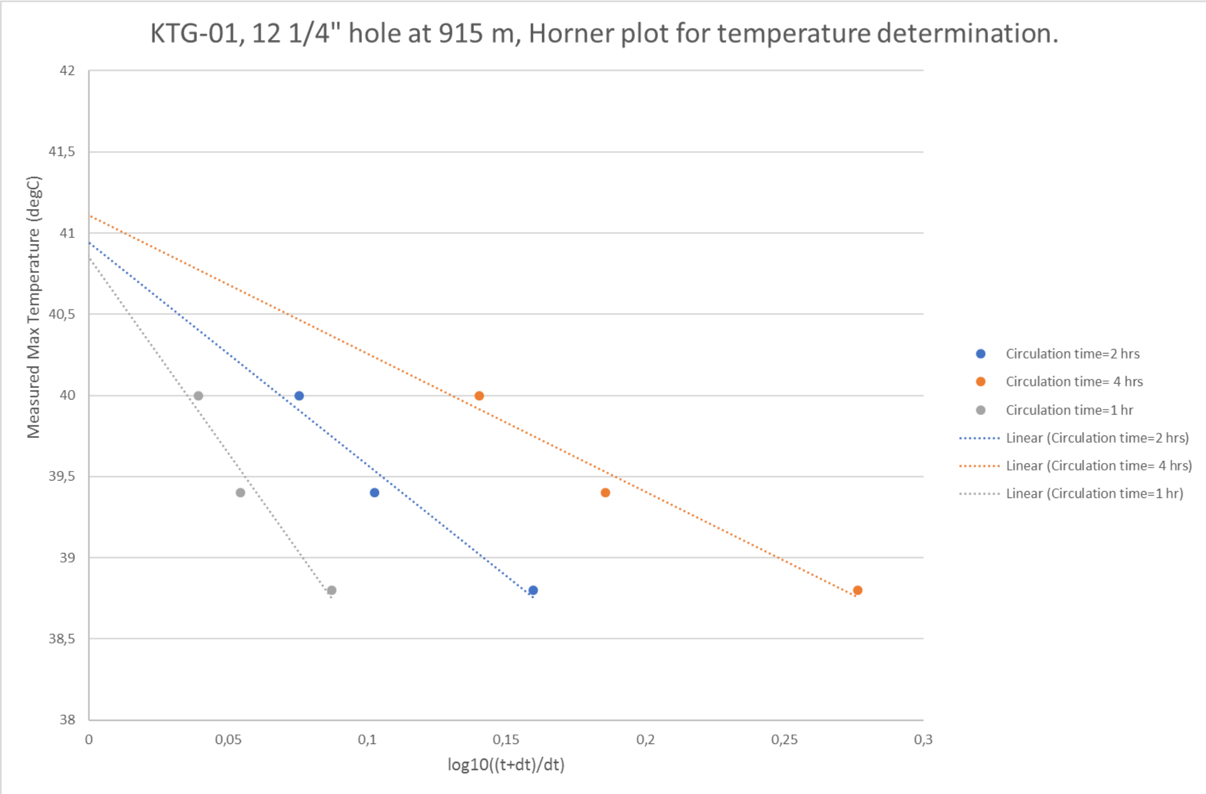


Figure 3. Horner plot at 915m

Daalsesingel 1
3511 SV Utrecht
scan@ebn.nl
www.scanaardwarmte.nl

Onderzoek in de ondergrond voor aardwarmte