Petrophysical Report of the Dinantian Carbonates in the Dutch Subsurface

Report by SCAN

April 2019

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

Contents

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

WELL DATA S02-02

Company Name : Mobil Prod. Neth. Inc.

Well Name : S02-02

Field Name : License B(4/3/68)

Geological targets : Lower Carboniferous Carbonates

Country : Netherlands

Field Location : License B(4/3/68)

Longitude : 51*51'21.743"N

Latitude :   03*36'32.270"E

Maximum Hole Deviation : 2 (deg)@2883.5m

Elevation of Kelly Bushing : 36.3m

Elevation of Ground Level : -21m

Elevation of Derrick Floor : 36m

Permanent Datum : MSL

Elevation of Permanent Datum : MSL

Log Measured from : 299-2882m

TD: 2883.5m by logger

Noord ref.: Grid North

Stelsel: Europese Datum 1950 - Universele Transversale Mercator projectie - zone 31

Dinantian evaluation in S02-02 (1883-2835 m MD)

Log quality, edits and depth shifts

Below the 9 5/8" shoe, at 1833.5 m, there is a big enlargement of the hole down to just above 1870 m. The logs in this interval are severely affected by this enlargement and the density is of too poor quality and should not be used and have therefore not been included (cut out). The calipers in this section and the other logs, specifically the MLL, indicate that it is not solid rock but probably some mushy cuttings bed that is seen. This is most prominent in the interval 1860-1870 m but can be observed higher up, towards the casing shoe. In principle all logs, except maybe the deep reading laterolog are erroneous. The neutron porosity may not seem to be wrong in this interval, however, the LSN and SSN count-rates are very low in comparison to the log further down and almost flat. One reason is the large borehole in this section. However, it is likely that the main issue is with cuttings because no other interval has the same signature, albeit the hole size being similar (large wash outs lower down). The neutron has therefore also been cut out in this section just above the Dinantian.

The density has been edited extensively in some sections of the Dinantian due to being affected by wash outs, see caliper and to some degree the density correction. The sections where there have been edits are 2115-2278 m, 2342-2350 m, 2374-2386 m, 2469.5-2473 m and 2495-2504 m. The neutron and sonic, which appear not to be affected by the hole enlargements, have been used as a guide when editing.

In the 17 ½" hole, the caliper provided is not correct and it appears that no caliper was run.

Density, Neutron and associated logs have been depth shifted as has the Dual Laterolog and its associated curves. They have been shifted to match the Petrel logs. Except for the GR, the Petrel logs have not been used in the evaluation.

The Thorium and Potassium concentrations are very suspicious in the middle and upper part of Dinantian above approximately 2725 m. It would be expected that the Thorium concentration would follow the Potassium, instead, above 2725 m it goes negative in several intervals and does not in any way respond similar to the Potassium. Towards the bottom of the Dinantian and in the Devonian this is the case. The Potassium begin to follow the Uranium above approximately 2125 m and this becomes very pronounced towards the top. It can almost certainly be concluded that the Spectral GR is not functioning as it should, and the likely explanation is that the energy windows for the different elements are not correctly positioned (see evaluation part and clay indicator). The conclusion is that the Spectral GR response above approximately 2725 m is incorrect and should not be used.

Log corrections

The Neutron (CN) is too low, also after corrections (CNC). A shift has therefore been applied to the CNC (Neutron curve after borehole corrections are applied) by adding 0.012 to the CNC value. This makes the points cluster around the 0 porosity point on the density-neutron and on the sonic-neutron cross plots. Particularly the sonic-neutron cross plot is far better, compare figure 1 (uncorrected) and 2 (corrected) where the dolomite points fall along the dolomite line and a large cluster around the 0 point on the limestone line.

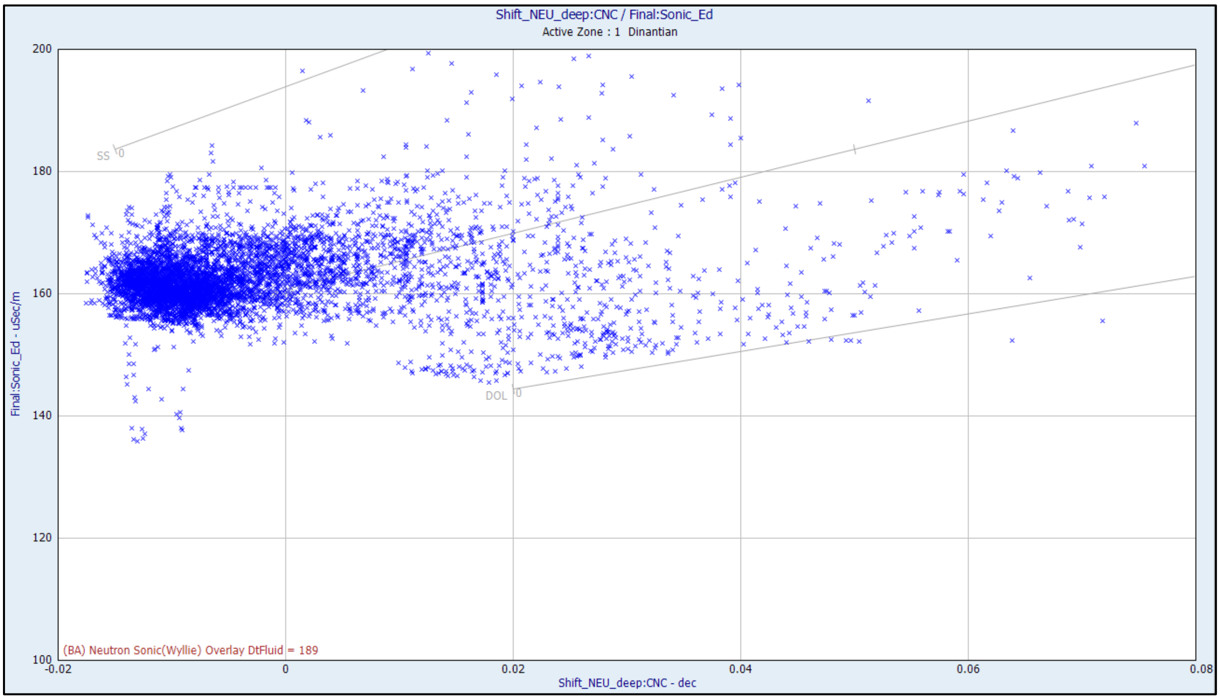


Figure 1. Sonic-neutron cross plot with uncorrected neutron.

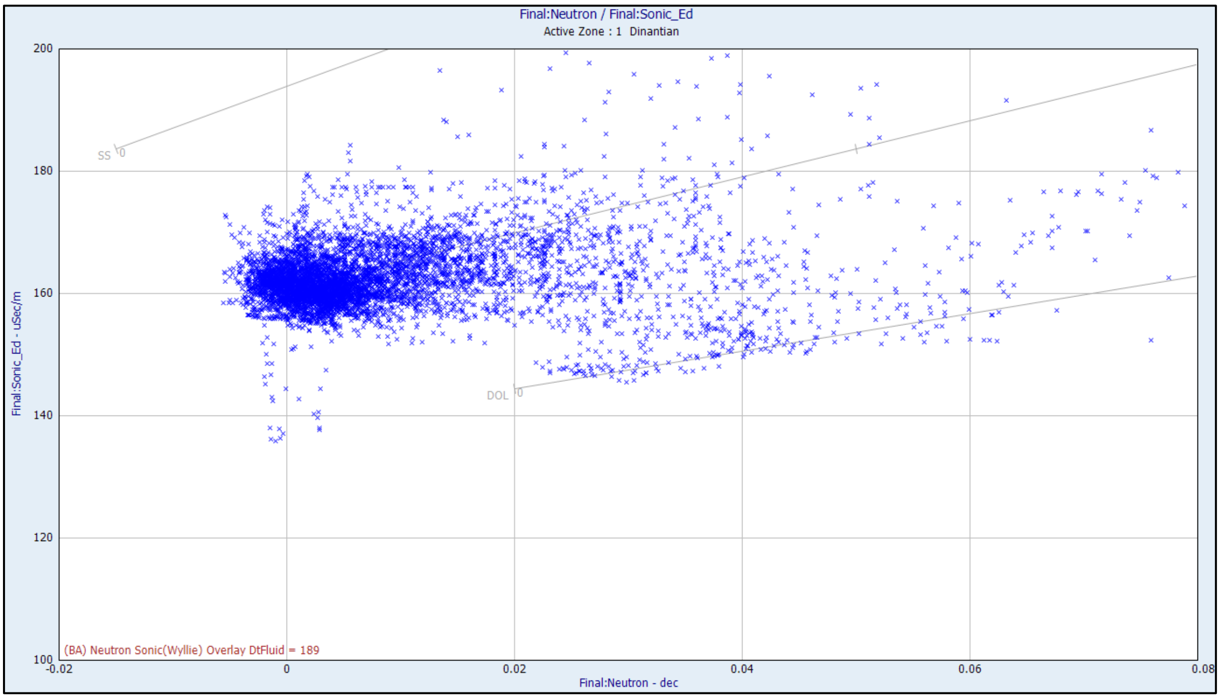


Figure 2. Sonic-neutron cross plot with corrected neutron.

Evaluation of Dinantian (1883-2835 m MD)

The porosity is clearly very low and, in many intervals, close to zero. Overall, the best calculated porosity is the sonic/neutron x-plot porosity but also this has clear issues, and, in several intervals, a negative porosity is calculated even after shifting the neutron. Some of the highest porosities are too high and it is concluded that a limit on the sonic porosity is needed and the best is to use a porosity calculated from the deep laterolog resistivity after determining the best Rw.

From a Picket plot, see fig. 3, it was concluded that a salinity of 45000 ppm with a resistivity of 0.2 ohmm at 10 deg C was the best formation water resistivity. Based on this, a porosity was calculated from the Laterolog deep curve and the Rw corrected to formation temperature (see below), using Archie with an m of 2. The porosity from the deep laterolog was then combined with the sonic-neutron cross plot porosity by taking the minimum of the two porosities. This is to limit some intervals where a clearly too high porosity was calculated with the sonic-neutron.

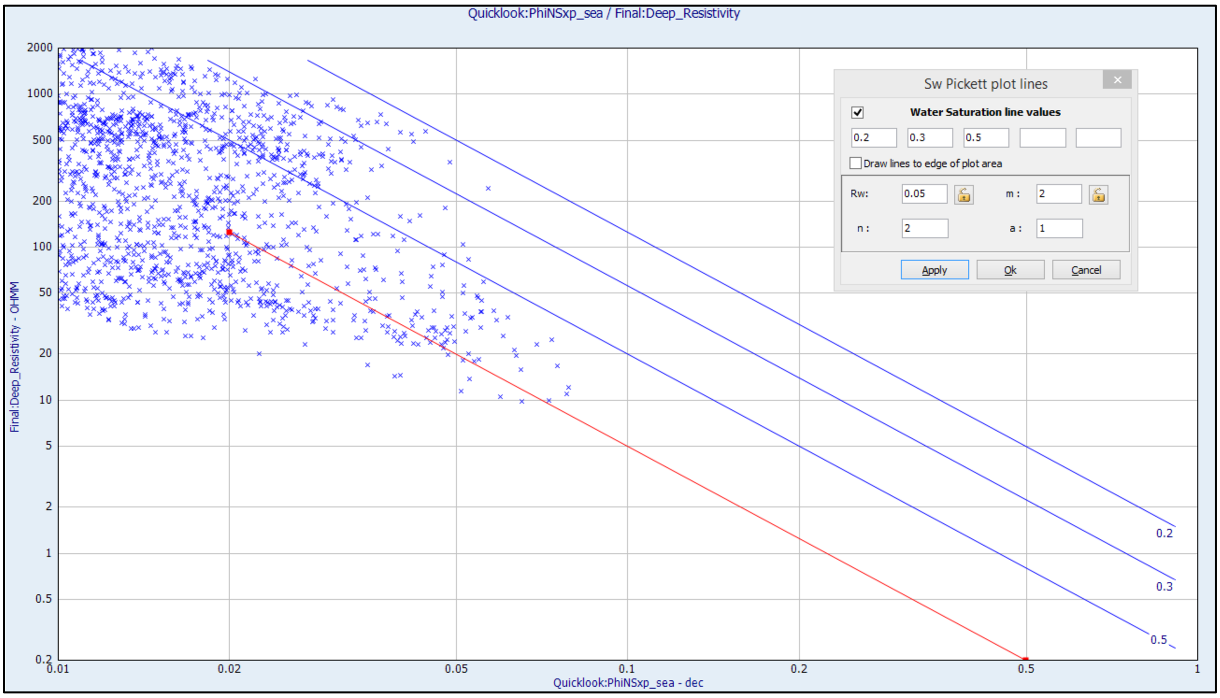


Figure 3. Picket plot for the Dinantian, indicating a salinity of 45000 ppm.

A lithology column was created based on the Dtma from final porosity and dt. The upper part of the Dinantian is dominated by Limestone with only some patches with dolomitic influence. Towards the base of the Dinantian carbonate, there is a gradual increase in Dolomite content and over the last 40-50 m, Dolomite is the dominant mineral but never clean Dolomite. The proportions of Limestone and Dolomite is based on a Limestone slowness of 160 us/m and a Dolomite slowness of 145 us/m. The resulting Limestone and Dolomite proportion is calculated with the following equations:

Limestone = -9.667 + 0.06667*Dtma

Dolomite = 1- Limestone

In the log quality section, it was concluded that the Spectral GR is erroneous above approximately 2725 m and therefore the Potassium curve cannot be used in this well for calculating a clay indicator. Due to Uranium anomalies, the GR cannot be used as a replacement for the Potassium curve and therefore no Clay Indicator has been calculated for this well.

Result

The result of the evaluation can be seen in the log evaluation plot.

The sums and averages for this well are provided in the table below. Because no Clay Indicator was calculated no clay cut off can be applied. The result is that only the sums and averages for the different porosity cut offs are tabulated.

Gross	Net	net/gross	avg porosity	Average Porosity times net	Normalized Porosity*Net	Porosity cut off

MD	MD	MD				
m	m	fract	fract	m	fract	fract
952,0	952,00	1,000	0,005	5,17	1,00	0,00
952,0	161,20	0,169	0,017	2,79	0,54	0,01
952,0	35,51	0,037	0,031	1,10	0,21	0,02
952,0	14,94	0,016	0,041	0,61	0,12	0,03
952,0	6,40	0,007	0,048	0,31	0,06	0,04
952,0	1,83	0,002	0,057	0,10	0,02	0,05
952,0	0,61	0,001	0,066	0,04	0,01	0,06
952,0	0,00	0,000		0,00	0,00	0,07

The net, net/gross and the product of average porosity and net drops off very fast with increasing porosity cut off and there is no porosity exceeding 7 % in this well. The second column (column 6) from 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, see figure 4 below.

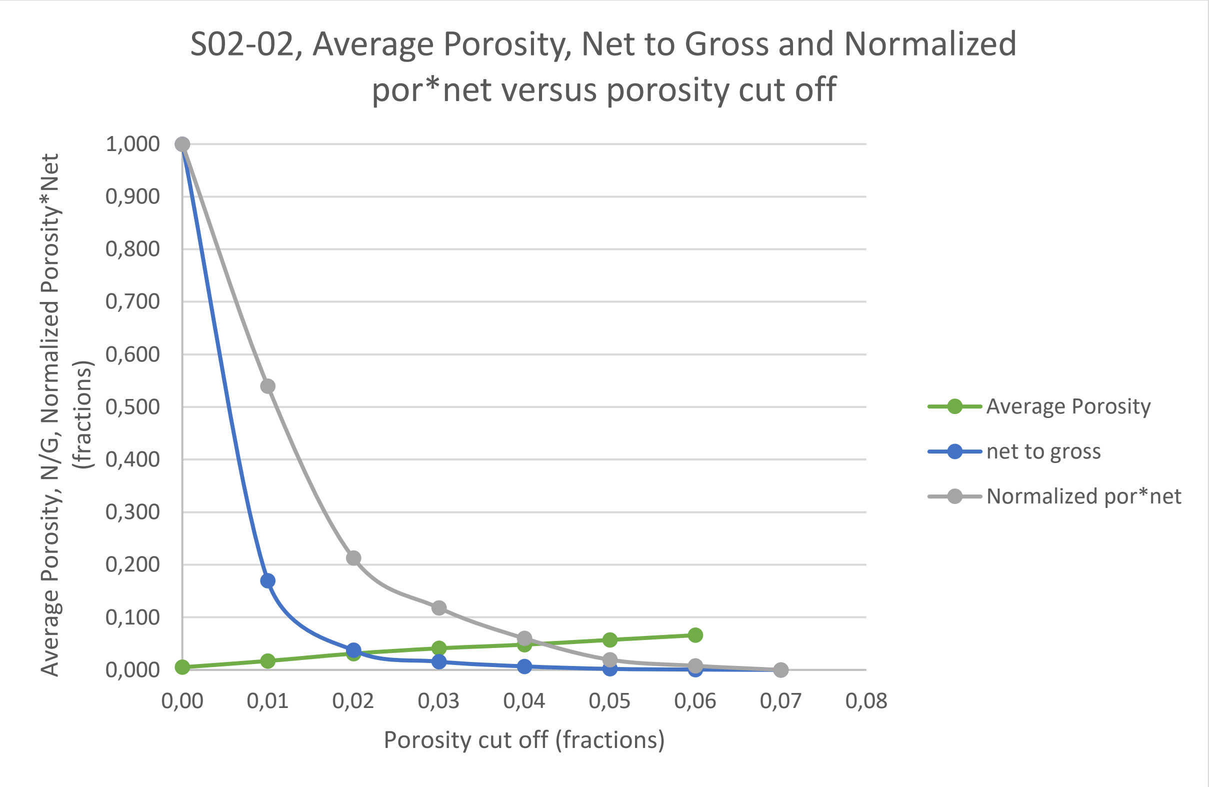


Figure 4. Average porosity, net-to-gross and normalized porosity*net thickness for increasing porosity cut-off

The graph illustrates how fast the net and the product of average porosity and net declines with increasing porosity cut off. The product of average porosity and net declines slower due to the increase in average porosity with increasing porosity cut off. The average porosity with no porosity cut off is very low in this well with a value of 0,5 % and this may be on the low side of what can be expected although a value below 1 % is relatively common for the wells evaluated.

Discussion

The Dinantian in this well is very tight and in most of the interval down to 2780 m there are only a few spikes where the porosity exceeds 2 %. Limestone dominates the lithology from the top of the Dinantian at 1883 m down to approx. 2730 m. In this interval, there are porosity spikes at 1889.5 m and 1895.5 m, close to the top of the reservoir. These two short porosity spikes could be karst infilled with some clay, as both the neutron and sonic (Potassium) have anomalies that could support this to be the case. Because the Potassium curve is erroneous, this cannot be confirmed by logs. The core could potentially solve this issue if the intervals are present in the recovered core.

The following porosity spikes are at 2100 m and at 2110 m, with very pronounced anomalies on sonic, density and resistivity, although the use of the porosity from the resistivity limits the second one, such that only the first exceeds 2 %. These could be fractures or very limited karst.

In the interval 2203-2226 m, there are 6 very short intervals (<1 m thick) with porosity exceeding 2 % (3-5 %). These are probably karsts.

The best porosity interval is 2780-2812 m with some porosities as high as 4-7 %, this is also part of the most dolomitic section of the well. The rapid variation in porosity points to that this is a karsted section.

Core data

The well was cored in the following intervals:

1886-1889 m, recovery 1.8 m (60 %); 1889-1898 m, recovery 5.5 m (61 %); 2417.3-2426.3 m, recovery 0.9 m (10 %), mostly rubble; 2615.8-2624.9, recovery 1.5 m (16 %); 2624.9-2633.4 m, recovered 5.9 m (70 %).

No core analyses appear to be available from these cores.

Flow potential

Well Tests

No well tests were performed.

Wireline Formation Tester (FMT)

Two pressure test runs with FMT was made and the result are as follows:

Run 1: 17 November 1983

Test No	Depth	Hydr. Press. Before	Hydr. Press.	Measured stabilized pressure during test	Temperature Corrected Stabilized Pressure during test	Temperature Corrected Stabilized Pressure during test	Remark
	m	psig	bar		psig	bar	
1	2791.0	4735	327.5		-	-	Seal failure
2	2787.0	4726	326.9		-	-	Seal failure
3	2786.5	4725	326.8		-	-	Seal failure
4	2785.4	4722	326.6		-	-	Seal failure
5	2741.2	4651	321.7		-	-	Seal failure
6	2740.2	4648	321.5		-	-	Seal failure
7	2405.9	4092	283.1	3597.0	3591	248.6	Stable but could be supercharged
8	2741.0	4646	321.3		-	-	Seal failure
9	2785.5	4723	326.7		-	-	Seal failure
10	2260.0	3857	266.9		-	-	Seal failure
11	2250.0	3840	265.8		-	-	Seal failure
12	2136.0	3634	251.6		-	-	Seal failure
13	2110.5	3598	249.1		-	-	Seal failure
14	1875.0	3204	221.9	2777.0	2759	191.2	Stable

15	1872.0	3199	221.6		-	-	Seal failure
16	2099.0	3578	247.7		-	-	Seal failure
17	1871.0	3201	221.7		-	-	Seal failure
18	1870.5	3198	221.5		-	-	Seal failure

Run 2: 18 November 1983

Test No	Depth	Hydr. Press. Before	Hydr. Press.	Measured stabilized pressure during test	Temperature Corrected Stabilized Pressure during test	Remark
	m	psig	bar		bar	
6	1875.5	3184	220.5		-	Tight
12	2407.0	4076	282.0		-	Tight
13	2406.0	4059	280.9		-	Tight
15	2225.7	3773	261.2		-	Tight
21	1871.0	3188	220.8	2762	191.4	Stable and fast build up. Sampled 1 gallon.
21	1871.0			2758	191.2	Pressure after sampling

Note that the point at 1871 m was sampled and is presented twice because of this. On the second run there were more tests, but these were not presented and tabulated, almost certainly because they were seal failures

The two valid pressures at 1871 m (run 2) and 1875 m just above the top of the Dinantian are the best build ups and have the same pressure. There should be a small difference of about 0.4 bar considering that the measurements were 4 m apart. However, this is not observed, and this could be due both to depth uncertainties and gauge accuracy. The latter was a relatively large uncertainty in 1983 even when using the same gauge, as in this case. The reason was that the quartz gauge was affected by hysteresis caused by temperature. (This issue has been mostly engineered away in more modern pressure measurement tools but was a real issue in 1983.)

The pressure at 1875 m is slightly overpressured compared to a sea water gradient. However, if it is assumed that it is not overpressured, the gradient to this point from surface is 0.1034 bar/m (density = 1054 kg/m3) and it is quite possible that it is correct.However, it would be a bit too high when comparing with the salinity of 45000 ppm estimated from the Picket plot.

The only pressure in the Dinantian is at 2405.9 m and this pressure is not equally good as the others and there is a possibility that the pressure is a bit lower than recorded due to supercharging . However, it is not likely to be as much as a bar too high. This point is very slightly over-pressured, 2.5 bar, compared to the pressure gradient based on the pressure point an 1875 m (0.1034 bar/m), just above the Dinantian.

Losses

There were no losses recorded in the Dinantian section. Overbalance is approximately 35-40 bar, quite considerable and it is likely that losses would occur if there were open fractures and/or open karst.

Formation Temperature

Table showing the maximum temperatures from the intermediate logging runs in S02-02.

Log	Depth	Log date	Time since circ.	Max Temp	Max Temp
	(m)		(hrs.)	(deg F)	(deg C)
GR/DIFL/BHC	≈1825	18/10/1983	6	162	72.2
GR/CDL	≈1830	18/10/1983	10	162	72.2

Only two runs were made in the intermediate section and on the second run only one maximum temperature was recorded, and it is the same as from the two highest thermometer on run 1. It is therefore likely that they have just copied the temperature from the first run onto the log record of the second. The temperatures recorded from this log suite can therefore not be used for estimating the formation temperature at this depth using Horner extrapolation, only as a check on the overall temperature gradient derived from the TD runs and the surface temperature.

Table showing the maximum temperatures from the TD logging runs in S02-02.

Log	Depth	Log date	Time since circ.	Max Temp	Max Temp
	(m)		(hrs)	(deg F)	(deg C)
GR/DIFL/BHC	≈2865	15/11/1983	7	219	103.9
GR/SPEC	≈2875	15/11/1983	9.25	220	104.4
CDL/SPEC	≈2875	15/11/1983	26	222	105.6
4-arm diplog	≈2880	16/11/1983	12	214	101.1
Dual Laterolog	≈2870	16/11/1983	28	228	108.9
CNL	≈2875	17/11/1983	33	229	109.4

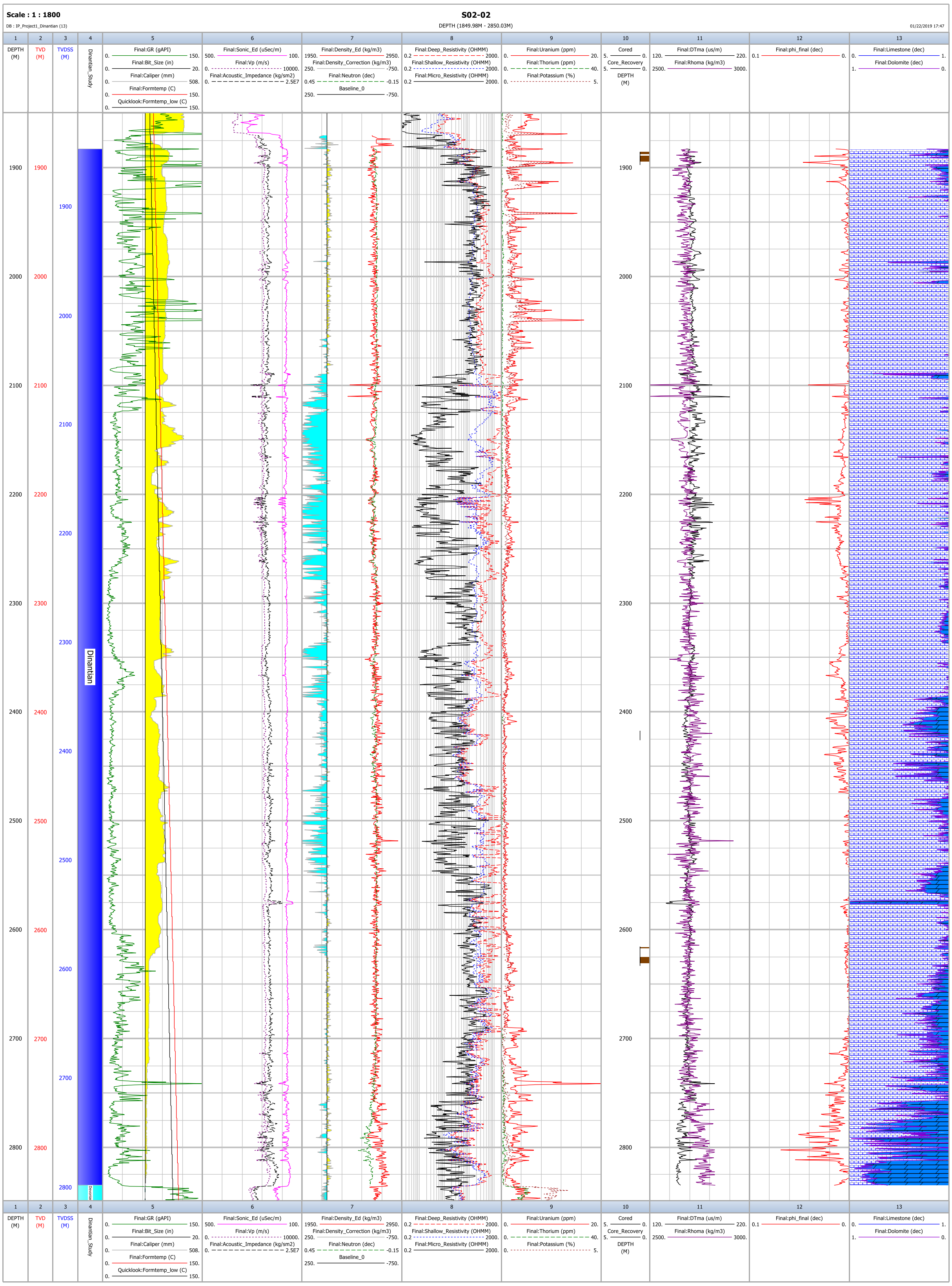
Times since circulation are very doubtful for the first 3 log runs, and some are probably wrong, and this also applies to dates recorded. It is not likely that this can be corrected. Run number does not help, because they do not refer to the same suite of logs but to tool combinations run in this well. The temperature and times since circulation for the 3 runs on 16 and 17 of November are probably correct. Based on these 3 runs a Horner extrapolation result in formation temperature of 115 C at 2870 m. If it is assumed that the times for the first three runs and the temperatures are correct, the extrapolated temperature would only be 106-107 C, 8-9 C less than for the 3 last runs. The temperatures between the two sets of logs are inconsistent with the temperature increase between runs being a lot less on the first 3 compared to the second set. The first run has a higher temperature than the 4th run, although the time since circulation is less. Normally this would result in a lower temperature. The two sets of runs cannot be reconciliated! One thing that possibly could explain the difference between the two sets is a change of thermometers. For this work the second set is believed to be the better one with less inconsistent data and therefore 115 C has been chosen as the TD temperature.

For temperature gradient a temperature of 115 C is used at 2870 m and using a surface temperature of 8 deg C at the sea bottom 21 m below sea, 57 m below the derrick floor. The resulting equation is:

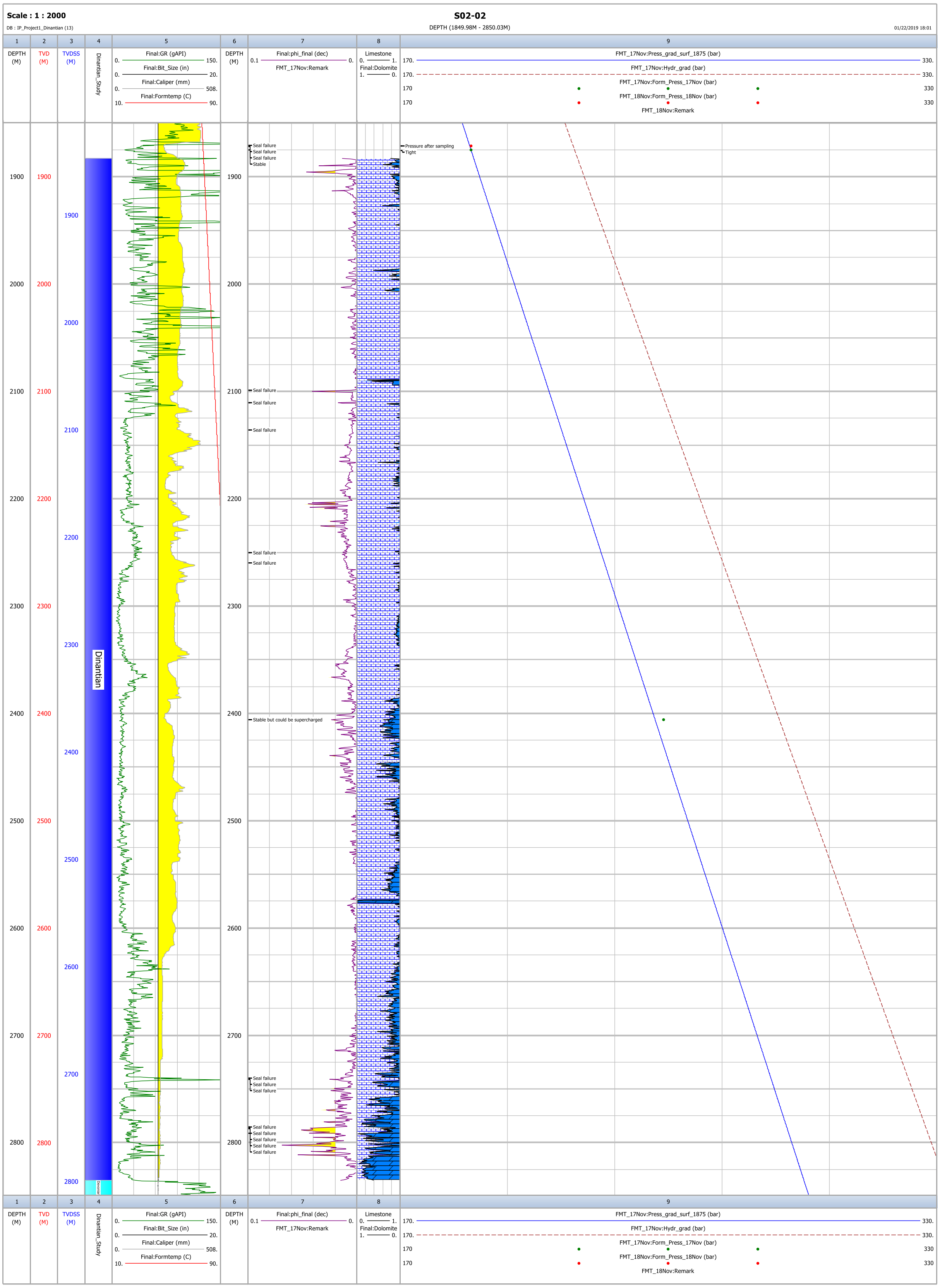
Formation Temperature = 7.2 + 0.03805 * TVDss

The formation temperature calculated at the intermediate depth of 1830 m using this calculation is 75.4 C, higher than the measured 72.2 C while with the lower estimate at TD (106.5), the calculated temperature at 2830 m is only 70.1 C, which is too low, it should be higher than 72.2, unless there is a very drastic change in temperature gradient, which is highly unlikely. It can therefore be concluded that the temperature of approximately 115 C is correct at TD, resulting in a gradient of 0.03805 C/m, a relatively high temperature gradient, which is in line with many of the Dinantian wells.

Evaluation plot



Formation tester pressure plot



Well logging summary S02-02

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-DIFL-LSAC	GR-DIFL-LSAC	GR-IND-Long Spaced Sonic Log	Dresser Atlas	EWL	1	1	Main	**Up**	09-OCT-1983	299	850.5	
12 1/4"	GR-DIFL-LSAC	GR-DIFL-LSAC	GR-IND-Long Spaced Sonic Log	Dresser Atlas	EWL	2	2	Main	**Up**	18-OCT-1983	1385	1841	
12 1/4"	GR-CDL	GR-CDL	GR-DEN	Dresser Atlas	EWL	2	3	Main	**Up**	18-OCT-1983	1385	1841	
8 1/2"	GR-DIFL-AC	GR-DIFL-AC	GR-IND-Sonic Log	Dresser Atlas	EWL	3	4	Main	**Up**	15-NOV-1983	1834	2882.9	
8 1/2"	GR-LSAC-Wave Train	GR-LSAC-Wave Train	GR-Long Spaced Sonic- Full Wave	Dresser Atlas	EWL	3	5	Main	Up	15-NOV-1983	1827	2876,0	
8 1/2"	GR-CDL-CNL-NGS	GR-CDL-CNL-NGS	GR-DEN-NEU-Spectral GR	Dresser Atlas	EWL	3	6	Main	Up	15-NOV-1983	1829	2882,0	CNL failed
8 1/2"	GR-DLL-MLL	GR-DLL-MLL	GR-Dual Laterolog-Microlaterolog	Dresser Atlas	EWL	3	7	Main	Up	16-NOV-1983	1834.5	2884,0	
8 1/2"	GR-Diplog	GR-3 arm Diplog	GR-DIP Log	Dresser Atlas	EWL	3	8	Main	Up	16-NOV-1983	1834.5	2884.0	
8 1/2"	GR-CNL	GR-CNL	GR-CNL	Dresser Atlas	EWL	3	9	Main	Up	17-NOV-1983	1829	2882,0	CNL rerun
8 1/2"	GR-VSP	VSP	VSP	Seismograph	EWL	3	10	Main	Up	17-NOV-1984	1096	2027.5	
8 1/2"	GR-FMT	GR-FMT	GR-Wireline Formation Tester	Dresser Atlas	EWL	3	11	Main	Up	NOV-1983	1097	2229.5	

Appendix: Horner plots

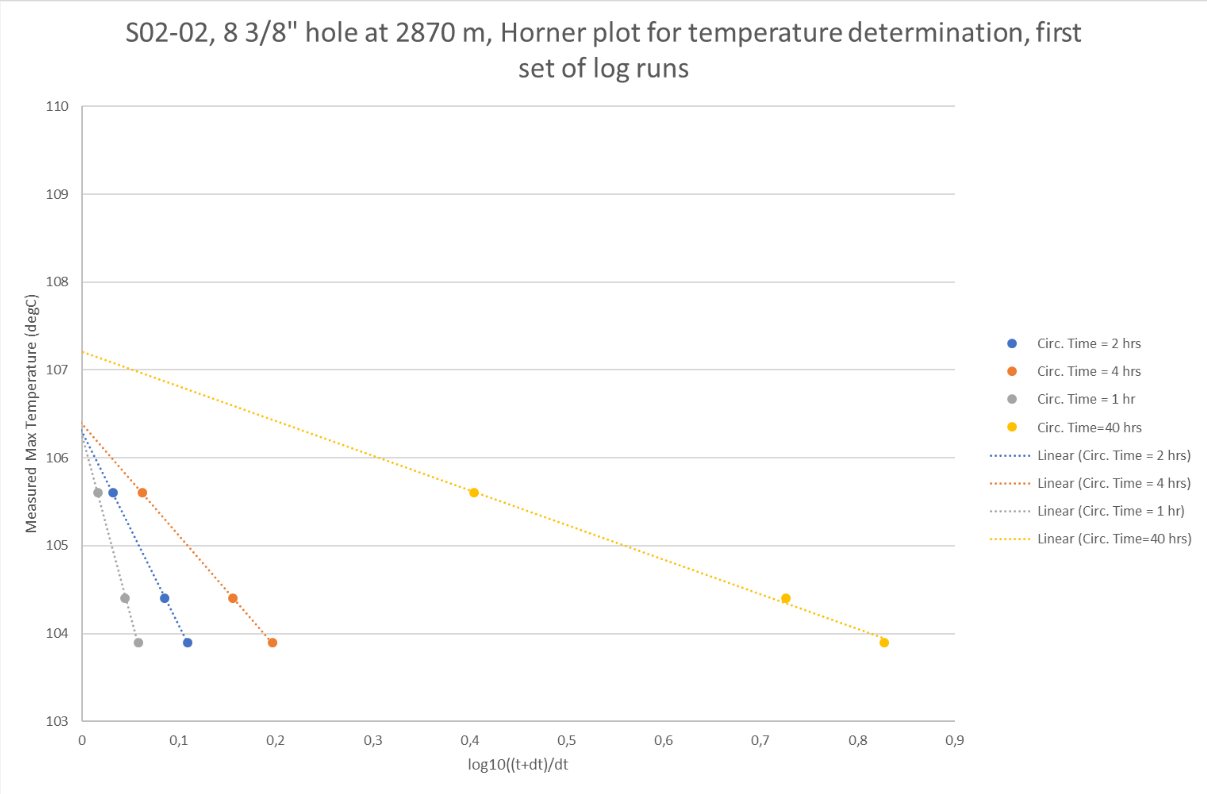


Figure 1. Horner plot at 2870m

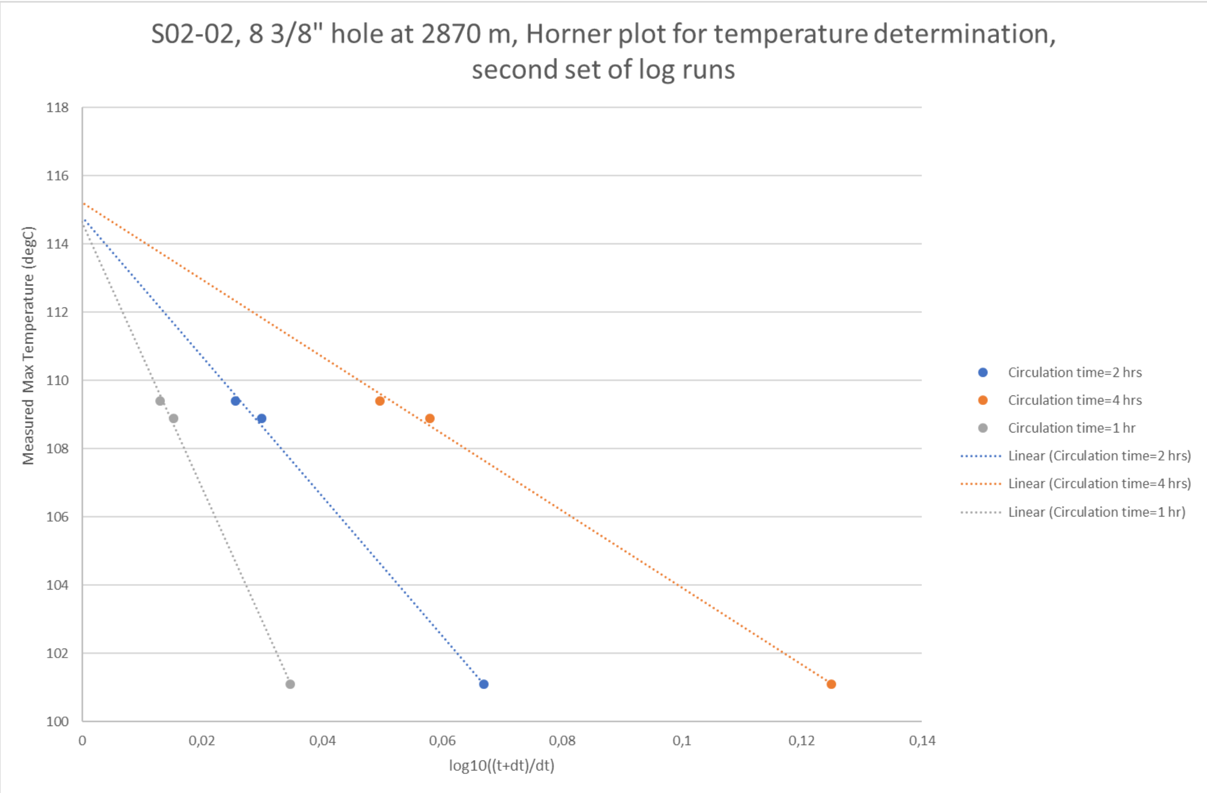


Figure 2. Horner plot at 2870m

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