Petrophysical Report of the Dinantian Carbonates in the Dutch Subsurface

Report by SCAN

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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 BHG-01

Company Name: NAM

Well Name: BHG-01

Field Name: Brouwershavensegat

Geological targets: Lower Carboniferous Carbonates

Country: Netherlands

Field Location: West of Island of Goeree

Longitude: 51*47’24.2”N

Latitude: 03*46’18.1”E

Maximum Hole Deviation: 12.46 (deg)

Elevation of Kelly Bushing: 23.58 m NAP

Elevation of Ground Level: NAP

Elevation of Derrick Floor: NAP

Permanent Datum: NAP

Elevation of Permanent Datum: 0m MSL

Log Measured from: 30m to TD 2888m by SLB

Maximum recorded temperature: 100 degC

TD: 2906m from Driller

Dinantian evaluation in BHG-01 (2153-2646 m MD)

Log quality, edits and depth shifts

The composite logs have been used as they are, and no logs have been shifted in the 8 3/8" hole.

In the Dinantian, the hole is of good quality with a few exceptions.

Log corrections

There are some issues with the porosity logs and particularly the density log. The density log overall indicates a too low density. This is illustrated by the density-neutron x-plot, figure 1, where the indication is that there is a mix of limestone and sandstone. We do know that the lithology is a mix of limestone and dolomite with mostly very low porosity, close to 0 in many intervals. Therefore, to get the density data in line with the x-plot, 40 kg/m3 has to be added to the density across the Dinantian (in entire 8 3/8" borehole). The reason for this unusually large correction required on the density is not known and the log header does not provide any explanation. One explanation could be that a lower than normal pressure on the density back up arm has been applied and therefore the sensor has not been pressed hard enough onto the formation. Nothing in the calibration tables point to such a large problem.

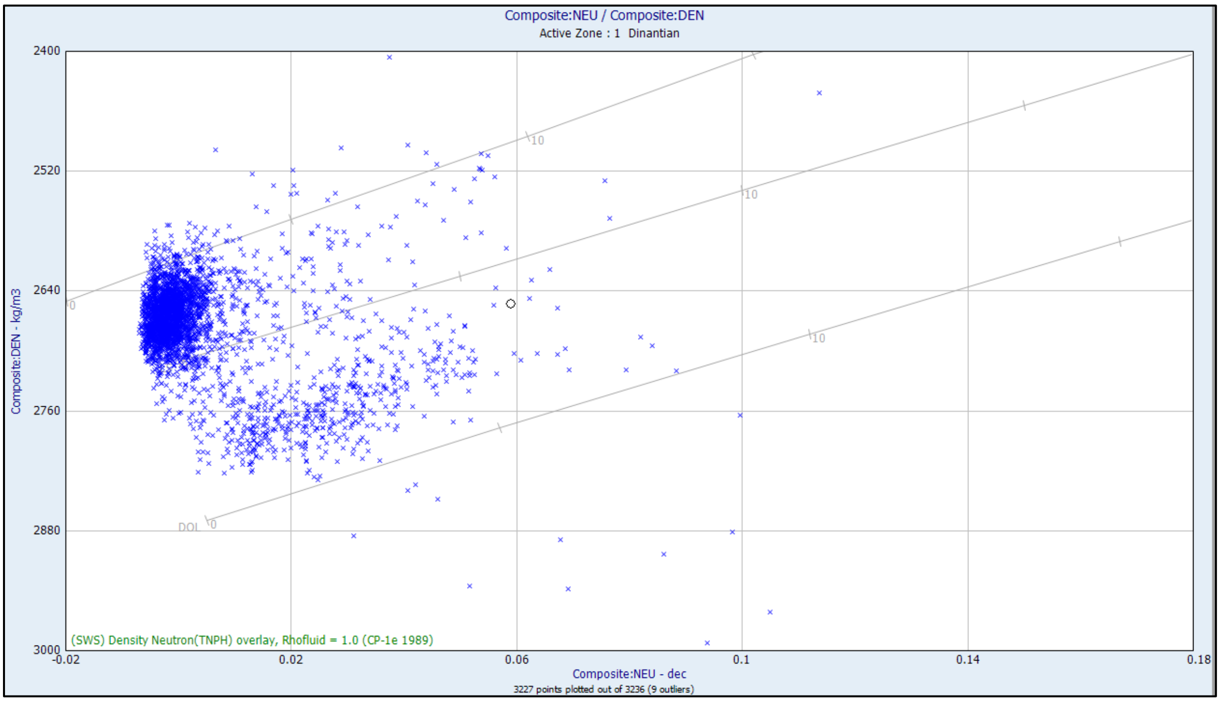


Figure 1. Density and neutron uncorrected.

The neutron porosity is also slightly too low, and the best result is when 0.005 (0.5 PU) is added to the neutron. The need for this is best demonstrated on a neutron histogram clearly showing the mode value to be negative and by adding the 0.005 it becomes positive, just above 0. The small neutron correction is clearly within the calibration interval of the tool and is not of concern. (Environmental corrections for the neutron log will not correct these issues as they are close to 0 for low porosities.

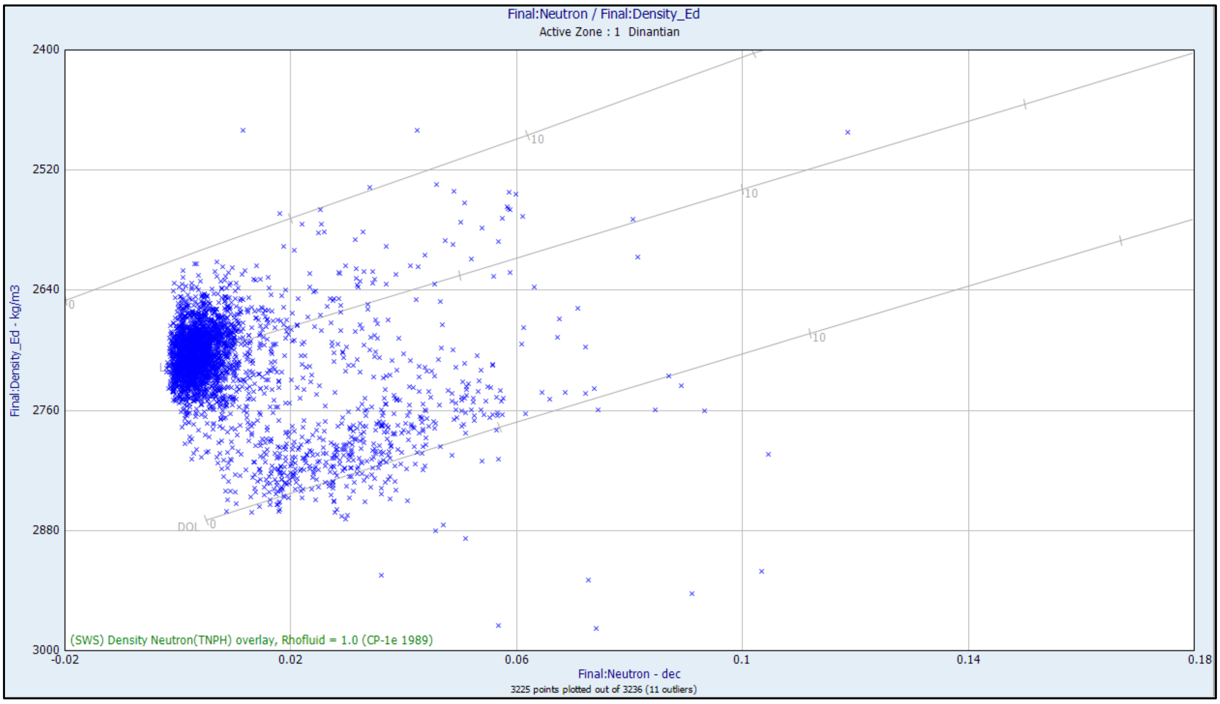


Figure 2. Density and neutron corrected.

The sonic is overall of good quality.

The GR is very high, and in some intervals, it is saturated. Essentially the tool is not capable of registering a higher GR. The tool is probably a Geiger tube tool that only can receive a certain number of gamma rays per second before it saturates, (long dead time) but it could also be a NaI crystal sensor with a relatively long dead-time.

Evaluation of Dinantian (2153-2646 m MD)

Porosity and Lithology

Porosity have been calculated from the sonic-neutron after corrections and corrected density-neutron x-plots. The two porosities agree closely in most of the intervals. However, the density is unusually jagged and therefore the primary porosity has been chosen to be the sonic-neutron x-plot porosity. There are also a few points where this tool has issues but much less than the density.

In this well only an induction resistivity tool was run. This is not a suitable tool for this formation due to large limitations at high resistivity and also because conductive minerals result in polarization horns. No porosity has therefore been calculated from the resistivity.

Lithology has been calculated using the apparent matrix slowness calculated from the sonic-neutron x-plot and from the apparent matrix slowness based on the assumption that there are only 2 minerals, Calcite and Dolomite. The exception is the interval 2172-2179.5 m, where there is a large proportion Pyrite with Limestone.

In the Limestone-Dolomite intervals the proportion Limestone is calculated (Limestone = 160 µs/m, Dolomite = 145 µs/m):

Limestone = -9.667 + 0.06667 * Apparent matrix slowness (DTMatApp)

Dolomite = 1 – Limestone

In the Pyrite-Limestone interval (2172-2179.5 m) the proportion of Pyrite is calculated (Pyrite = 129 µs/m, Limestone = 160 µs/m):

Pyrite = 5.162 - 0.03226 * Apparent matrix slowness (DTMatApp)

Limestone = 1 - Pyrite

Due to the lack of a spectral GR no Clay Indicator has been calculated for this well. The only reasonable clay indicator in this, partly extremely high GR well, is the separation of density and neutron. However, there are no particular indications that there is a higher clay content from these logs.

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 10 is the core grain density and the test intervals indicated in black. In track 11 is the calculated porosity and core porosity, on a 0 to 10 % scale. In track 12 is the core permeability and in track 13 is the calculated lithology displayed.

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

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
493,0	451,85	0,917	0,011	4,81	1,00	0,00
493,0	142,63	0,289	0,025	3,50	0,73	0,01
493,0	68,46	0,139	0,038	2,52	0,52	0,02
493,0	38,74	0,079	0,048	1,82	0,38	0,03
493,0	18,44	0,037	0,064	1,14	0,24	0,04
493,0	10,67	0,022	0,078	0,81	0,17	0,05
493,0	5,64	0,011	0,099	0,54	0,11	0,06
493,0	3,51	0,007	0,119	0,41	0,09	0,07
493,0	2,13	0,004	0,148	0,31	0,06	0,08
493,0	1,22	0,002	0,195	0,23	0,05	0,09
493,0	1,07	0,002	0,210	0,22	0,05	0,10
493,0	1,07	0,002	0,210	0,22	0,05	0,11
493,0	0,91	0,002	0,226	0,20	0,04	0,12
493,0	0,91	0,002	0,226	0,20	0,04	0,13
493,0	0,91	0,002	0,226	0,20	0,04	0,14
493,0	0,91	0,002	0,226	0,20	0,04	0,15
493,0	0,91	0,002	0,226	0,20	0,04	0,16
493,0	0,76	0,002	0,237	0,18	0,04	0,17
493,0	0,76	0,002	0,237	0,18	0,04	0,18
493,0	0,76	0,002	0,237	0,18	0,04	0,19
493,0	0,61	0,001	0,249	0,15	0,03	0,20
493,0	0,61	0,001	0,249	0,15	0,03	0,21
493,0	0,46	0,001	0,260	0,12	0,02	0,22
493,0	0,46	0,001	0,260	0,12	0,02	0,23
493,0	0,30	0,001	0,274	0,08	0,02	0,24
493,0	0,30	0,001	0,274	0,08	0,02	0,25
493,0	0,30	0,001	0,274	0,08	0,02	0,26
493,0	0,15	0,000	0,280	0,04	0,01	0,27
493,0	0,15	0,000	0,280	0,04	0,01	0,28

493,0	0,00	0,000		0,00	0,00	0,29

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 3 below.

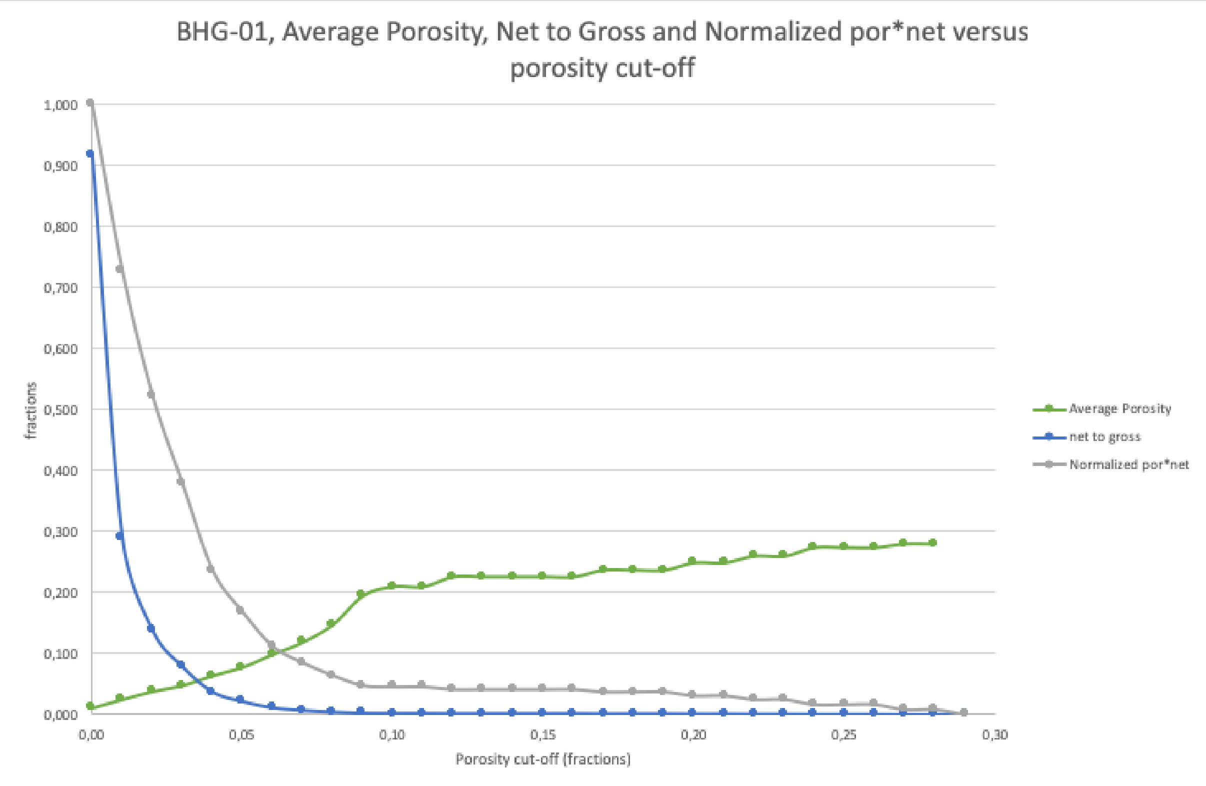


Figure 3. Average porosity, net-to-gross and normalized porosity*net thickness for increasing porosity cut-off

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 9-10 % where net becomes close to 0, net becomes 0 at 29 % porosity cut-off. The product of average porosity and net (Normalized por*net) has a fast decrease up to a porosity cut-off of 4 % and then a slowing decrease up to a cut-off of 9 %. After this cut-off, the Normalized por*net has a very long tail with only a gradual decrease up to a cut-off of 29 % where it becomes 0. The average porosity has initially a linear increase with porosity cut-off and then an accelerated trend between a cut-off of 5 and 9 % followed by a slowly increasing trend above a cut-off of 9 % up to the final cut-off of 28 %. The explanation for the behavior of all the trends are that all calculated porosity above 9 % is associated with the very sharp washout at 2413.7 m and the porosity at this depth is very uncertain and could be much lower than the calculated porosity.

Due to the large uncertainty in the porosity at the high porosity anomaly at 2413.7 m a sums and averages table excluding this is shown below followed by this data in a graph, figure 4.

Gross	Net	Net/Gross	Average Porosity	Average Porosity times net	Normalized Porosity*Net	phi cut
MD	MD	MD				
m	m	fract	fract	m	fract	fract
490,88	451,26	0,919	0,010	4,66	1,00	0,00

490,88	141,43	0,288	0,024	3,33	0,71	0,01
490,88	66,45	0,135	0,035	2,31	0,50	0,02
490,88	36,88	0,075	0,043	1,59	0,34	0,03
490,88	16,61	0,034	0,054	0,90	0,19	0,04
490,88	8,99	0,018	0,062	0,56	0,12	0,05
490,88	4,27	0,009	0,071	0,30	0,06	0,06
490,88	1,98	0,004	0,079	0,16	0,03	0,07
490,88	0,76	0,002	0,084	0,06	0,01	0,08
490,88	0,00	0,000			0,00	0,09

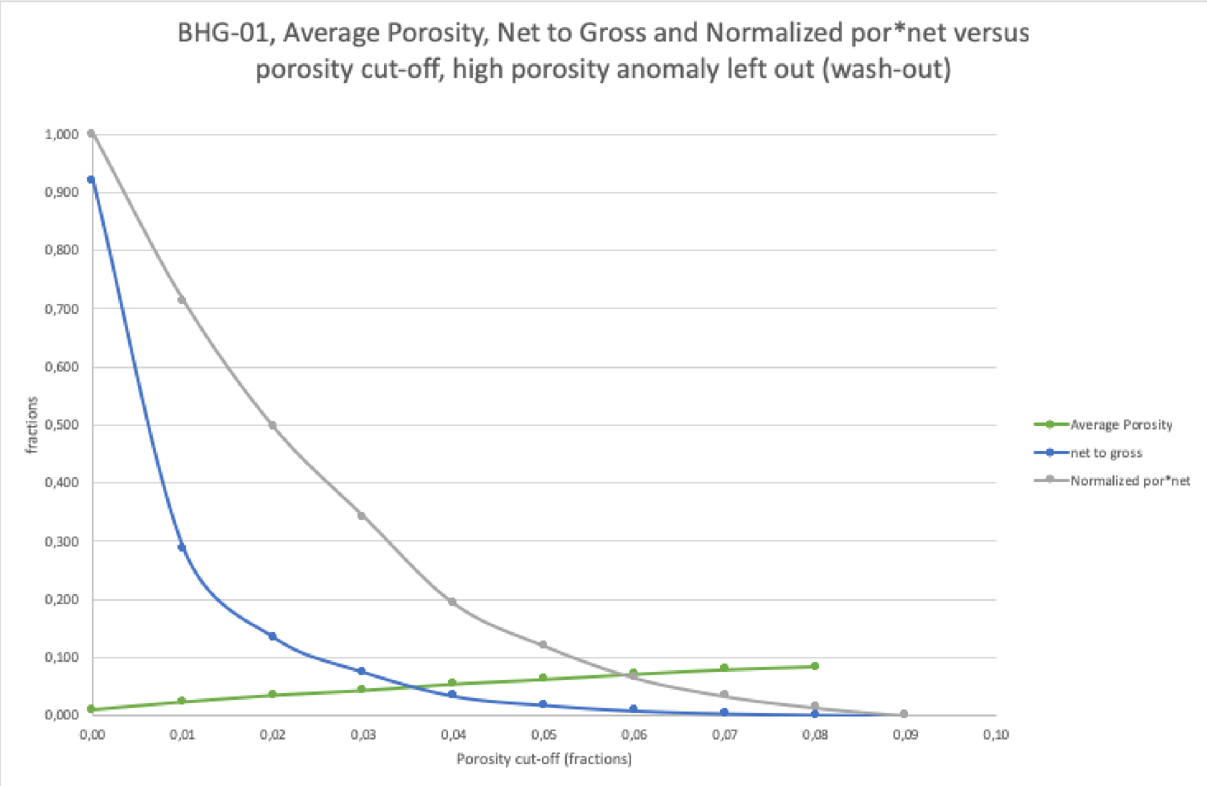


Figure 4. Average porosity, net-to-gross and normalized porosity*net thickness for increasing porosity cut-off

When the high porosity anomaly is left out the net/gross, average porosity and Normalized por*net behaves more normal. The net/gross drops very rapidly initially and then decreases with a slowing trend while the Normalized por*net has an overall more gradual decrease up to the final porosity cut-off of 9 %. The porosity has an almost linear increase throughout.

The average porosity at no porosity cut-off is 1.1 % with all data and 1.0 % with high porosity anomaly left out, which is in line with many of the other Dinantian wells.

Discussion

The upper part of the Dinantian is predominantly Limestone, partly with very high GR. There is no spectral GR but based on other wells it is certain that this primarily is caused by Uranium and that these intervals indicate secondary processes (primarily karst) something that is confirmed by the core. In this upper interval there are some, short, clearly anomalous intervals. The first one is 2173-2178 m where there are two very high density spikes (around 3000 kg/m3) both with high neutron porosity (around 0.1). This interval also has extremely high GR and the GR tool is saturated. The core shows clearly that this is Pyrite. Pyrite is indicated on the plot in gold color.

The high porosity interval, 2302-2308 m, in a Limestone matrix is probably karst based on the spiky porosity.

At 2413.7 m, the only significant hole enlargement in the Dinantian is present and it correspond to very high porosity indication on all logs. The sharpness of the wash-out and the depth of it is likely to exaggerate the sonic, neutron and the density anomalies. Density is the one most affected and then neutron and, in most cases, the sonic, the least. However, in this case, it is also affected. It is therefore likely that the porosity at this depth is much lower. The wash out is probably caused by a fracture or possibly a karst.

Below 2500 m Dolomite becomes more common and below 2615 m it is either Dolomite or Dolomitic Limestone. The interval below 2500 m is also the interval where there are more porous sections with porosity in the range .02-0.06, often, but not always, related to the more dolomitic intervals.

Outside the intervals discussed above, the porosity is low and there is limited reservoir potential.

Core Data

The well was cored in the following intervals:

2168-2183 m (100 % recovery), 2375-2387 m (100 % recovery), 2649-2658 m (0 % recovery), 2672-2681 m (100 % recovery), 2901.2-2906 m (100 % recovery).

The core has been shifted up by 2.7 m for the core 2168-2183 m and by 11 m for the core 2375-2387 m. The latter shift is very uncertain and can be wrong. The same shift has also been applied to the two lower cores, but this is below the Dinantian and has therefore no implications.

The core data in the upper cored section (2168-2183 m) corresponding to a karsted interval shows a very large scatter in the data, where two neighboring plugs can have very different properties, both porosity and grain density. The average match to the evaluated porosity is relatively good. Only 3 plugs have had permeability analyzed, the reason for this is unknown. However, it is likely that many of the plugs have been of too poor quality for permeability measurements and the another reason may be that many have had too low permeability.

One issue with the core plugs is that the grain density is a bit too high in the clean Limestone a value of 2.71 g/cm3 is expected but the typical value of the analyzed samples is 2.72-2.73 g/cm3. This is probably a small error in either the weighing of the plugs or one of the volume measurements. If it is in the latter it may also have an influence on the porosity.

Flow potential

Tests

2 tests were performed in the Dinantian:

1/6/1978: 2406.7-2418.3 m (40 shots), 5 m3 HCl (28 %). Acid squeeze with final pressure of 250 bar. Lifted with N2, no hydrocarbons and 18.5 m3 water. Fluid level at 78 m after production with Nitrogen lift. Took bottom hole sample at 2398 m. There are no report on H_2S on this test.

6/6/1978: 2165-2185 m (68 shots), 5 m3 HCl (28 %). Acid squeeze with final pressure 130 bar. Produced 3.9 m^3 sea water and 3.5 m^3 spent acid. Closed in due to H_2S, 60-80 ppm. Took 2 bottom hole samples. Ran coiled tubing and produced 4.5 m^3 fluid. Closed in well due to increasing H_2S. Lifted out 15 m^3 more with Nitrogen lift, formation water at surface.

Wireline formation tester

No pressure tests with a wireline formation testing tool was run in the 8 3/8" hole (1 RFT run in 12 ¼" hole, all tests dry (no permeability) or seal failures.

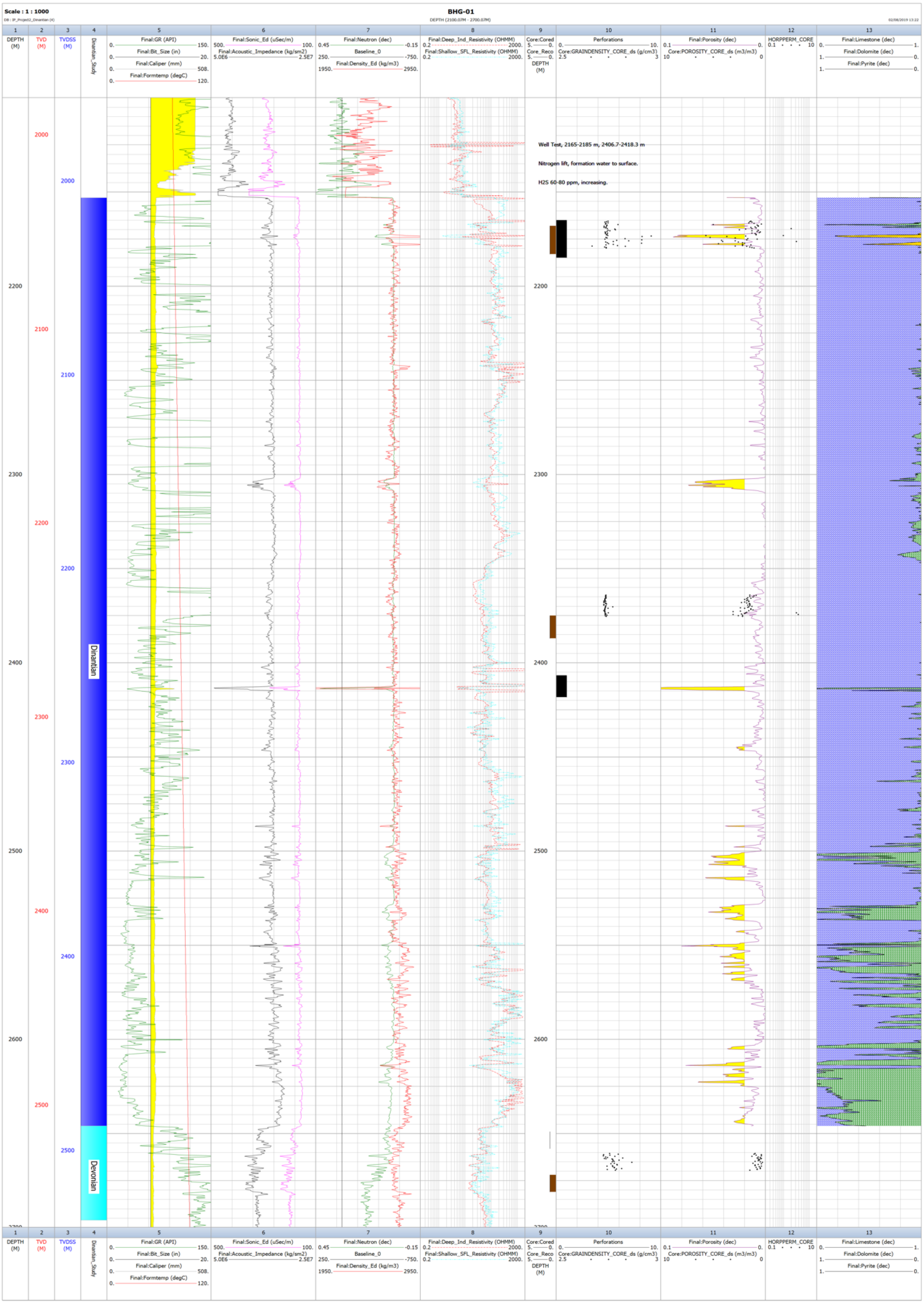
Formation temperature

During logging only one maximum temperature was recorded for each logging suite and it is not known on which run this maximum was recorded. In the shallow logging interval (1 run only) the maximum temperature recorded was 42 C (108 F) at 945 m, in the intermediate logging the maximum recorded was 79 C (174 F) at approx. 2035 m and at TD; 100 C (212 F) at approx. 2870 m. Because only one maximum temperature has been recorded on each suite of logs, it is better to do a simple formation temperature function between surface and TD and not include the intermediate sections. This could give the impression that a reliable temperature has been determined at the intermediate depth. The maximum temperature of 100 C is recorded 13 hrs after circulation stopped and the actual formation temperature is probably 3-7 degrees higher because the cooling effect in this hole size, 8 3/8", particularly offshore, is large. Therefore, the formation temperature is estimated to be 105 C and the resulting temperature gradient is in line with other wells where better data exist.

Formation temperature calculation is based on a surface temperature of 8 C at sea bed (30.5 m below rotary table) and a formation temperature of 105 C (max temp measured is 212 F = 100 C) at 2870 m (2729.3 m TVD) resulting in a function:

Formtemp = 6.95+0.03446*TVD

Evaluation plot



Well Logging Summary BHG-01

WELL LOGGING SUMMARY

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

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-ISF-SL	GR-IND-SON	SCHLUMBERGER	EWL	1	1	Main	**Up**	09-APRIL-1978	300	958	**SWM**
17 1/2"		GR-FDC-CNL	GR-DEN-NEU	SCHLUMBERGER	EWL	1	2	Main	**Up**	10-APRIL-1978	300	959	
12 1/4"		GR-ISF-SL	GR-IND-SON	SCHLUMBERGER	EWL	2	3	Main	**Up**	22-APRIL-1978	955	2045	
12 1/4"		GR-FDC-CNL	GR-DEN-NEU	SCHLUMBERGER	EWL	2	4	Main	**Up**	22-APRIL-1978	956	2045	
12 1/4"		GR-LL	GR-Dual Laterolog MSFL	SCHLUMBERGER	EWL	2	5	Main	**Up**	22-APRIL-1978	547.5	1315.1	
12 1/4"		GR-HDT	GR-Diplog	SCHLUMBERGER	EWL	2	6	Main	**Up**	22-APRIL-1978	1350	2044.5	
8 3/8"		GR-ISF-SL	GR-IND-SON	SCHLUMBERGER	EWL	3	7	Main	**Up**	18-MAY-1978	2043	2888	
8 3/8"		GR-FDC-CNL	GR-DEN-NEU	SCHLUMBERGER	EWL	3	8	Main	**Up**	18-MAY-1978	2043	2880	

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Onderzoek in de ondergrond voor aardwarmte

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