Volve

15/9-F-1
15/9-F-1 A
15/9-F-1 B

Petrophysical (static) well evaluation

Interpreter: Torill Vee

Date: February 2014

1 Introduction

1.1 Introduction 15/9-F-1

Objective of the 15/9-F-1 pilot was to test the Volve North upside prospect for HC accumulation and prove Minimum Economic Volume.

1.2 Introduction 15/9-F-1 A

This wellbore was side-tracked from 15/9-F-1 due to the results from drilling 15/9-F-1 where Hugin Fm. appears to be missing, hence objective of F-1 was not fulfilled.

1.3 Introduction 15/9-F-1 B

This well (planned and named as 15/9-F-1 A before drilling result from 15/9-F-1) was planned as a water injector in the Northwest segment, and placed in a down-flank location; to be supporting oil production from the Volve Northwest segment via existing producers up-flank in the Main Field.

2 Summary

2.1 Summary 15/9-F-1

TD of 15/9-F-1 was 3632 m MD RKB (Smith Bank Fm.).

The Hugin Fm. seems to be missing, probably due to faulting. The Volve stratigraphy in general is difficult to recognize.

Heather Fm. has a high net/gross ratio, N/G ~ 0.5.
From log responses two intervals might contain some residual oil:
3320.6 – 3322.5 m MD RKB / 2991.5 – 2993.0 m TVD MSL,
3332.4 – 3334.0 m MD RKB / 3001.2 – 3002.5 m TVD MSL.
However no shows on cuttings are reported.

Skagerak Fm. seems quite heterogeneous with rather poor properties, the properties are however slightly better in the lower part below 3450 m MD RKB.

LWD log data is of good quality.

2.2 Summary 15/9-F-1 A

15/9-F-1 A was side-tracked from F-1 with KOP @ 2620 m MD RKB. TD @ 3682 m MD RKB (Smith Bank Fm.).

Top Hugin was encountered 52 m shallower than expected due to depth conversion.

Hugin Fm. was water filled with Net/Gross = 0.692, which is lower than usual N/G for Hugin Fm.

One interval within Upper Hugin Fm. might contain some residual oil:
3441 – 3443 m MD RKB / 3011.5 – 3013 m TVD MSL.
No shows are however reported, and gas readings (mudlog) are not peaking. This apparent residuals might be a result of a combination of less vertical resolution of the resistivity logs (Induction) and problems – in general in this wellbore - with depth offsets on the logs.

Hugin Fm. seems quite strange with respect to facies development. Due to non-recognizable facies within Lower Hugin this has not yet been sub-divided.

Lower Hugin, Sleipner Fm. and Skagerak Fm. seem in general to have a high degree of cementation.

Formation pressure points in Hugin indicate a separate pressure regime compared to Hugin Fm. in Volve main field and in the NW segment.

LWD log data was severe affected by depth-tracking problems causing the logs to be off depth randomly thoughout the entire logging run, with the depth shifts varying - in both directions.

2.3 Summary 15/9-F-1 B

15/9-F-1 B was side-tracked from F-1 with KOP @ 2617 m MD RKB. TD @ 3465 m MD RKB (Sleipner Fm.).

Top Hugin was encountered 20 m deeper than prognosed. Except of Hugin 1.6, most of Lower Hugin seems to be missing, probably due to faulting.

Hugin Fm. was oil filled with property averages as given in table in chapter 7.3. Properties in Upper and Middle Hugin are better compared to F-11 A, but slightly poorer in Lower Hugin.

Oil Down to Top Sleipner; ~ 3304 m MD RKB / 3044.5 m TVD MSL.

Formation pressure points in Hugin confirm an oil gradient and indicate communication to Volve main field.

LWD log data is of good quality.

Due to very poor injectivity and limited fluid communication to the rest of the field even after additional perforations, F-1 B was permanently plugged and abandoned in February 2014.

3 Data Acquisition and QC

3.1 15/9-F-1 Measurement While Drilling (MWD) / Logging While Drilling (LWD)

The MWD / LWD logging contractor for the entire wellbore was Baker Hughes.
Mud type in the 8 ½" reservoir section of 15/9-F-1 was OBM, named Enviromul Yellow Spec 12. Name of base oil was EDC 95-11.
(Mud filtrate is considered to consist mainly of base oil.)
No cores were taken.

		15/9-F-1 MWD / LWD Run Summary						
		Contractor: Baker Hughes						
LWD Run	**Hole Section [inch]**	**Logging service (tool combination)**	**Pass**	**Pass direction**	**Logging speed**	**Bit depth Interval [m MD RKB]**	**Logging interval [m MD RKB]**	**Remark**
1	26	OnTrak	Drill	Down	ROP	223 – 1355	197.9 – 1339.5	Some gaps because of low flow while pumping pills and sweeps, else a god logging run.
2	17 1/2	OnTrak / ZoneTrak G	Drill	Down	ROP	1355 – 2602	1270.5 – 2598.4	Good logging run.
3	8 1/2	LithoTrak / MagTrak / OnTrak / SoundTrak / TesTrak / CoPilot	Drill	Down	ROP	2605 - 3632	2560 - 3624	Density image from LithoTrak. SoundTrak failed. TesTrak failed. Else a good logging run.
4	8 1/2	OnTrak / Soundtrak*) / TesTrak	Ream	Up	100 m/hr	2605 - 3632	2573 - 3624	*) Only logged DTC, compressional sonic. Good logging run.

Re-log (LWD run # 3) in Bit depth interval 3349 – 3390 m MD RKB, was logged while backreaming 7 hours after being drilled.

RealTime data:

The SoundTrak tool failed in run 3. Even if no error code was transmitted up from the tool, the SoundTrak data seemed quite unstable and random, with semblance values mostly below 0.5. Clear changes in lithology were not reflected in the SoundTrak data.

The TesTrak tool did also fail in run 3. At the first pressure point station, the tool extended, but immediately retracted and sent an error message proclaiming that the "tool position was unsuitable". It was re-oriented and re-tried but the same problem occurred, and now it began transmitting empty data. This should not have happened in the event of a legitimate failed test, as the tool should still have gone through its ten-minutes test cycle before transmitting data (instead of retracting immediately and still transmitting afterwards). When proceeding to the second testing station, the result was however the same after two more attempts, despite re-orientating the toolface to the low side of the wellbore.

Memory data:

All data was in memory: OnTrak, LithoTrak and MagTrak from memory in LWD run no. 3. SoundTrak and TesTrak data from memory in the re-logging run, LWD run no. 4. The data quality is in general good.

3.2 15/9-F-1 A Logging While Drilling (LWD)

The LWD logging contractor for the entire wellbore was Baker Hughes.
Mud type in the 8 ½" reservoir section was OBM.
No cores were taken.

		15/9-F-1 A LWD Run Summary						
		Contractor: Baker Hughes						
LWD Run	**Hole Section [inch]**	**Logging service (tool combination)**	**Pass**	**Pass direction**	**Logging speed**	**Bit depth Interval [m MD RKB]**	**Logging interval [m MD RKB]**	**Remark**
5	8 1/2	OnTrak / LithoTrak / TesTrak / SoundTrak / CoPilot	Drill*)	Down*)	ROP	2620 – 3682	2499 - 3675	Density image from LithoTrak. *)Fm. pressure points with TesTrak were taken while POOH after TD. Poor logging run: data gap and depth discrepancies on logs.

Re-log in Bit depth interval 3522 – 3544 m MD RKB, was logged while backreaming 17 - 19 hours after being drilled.

Memory data:

Data gap observed in Bit depth interval: 3591 – 3599 m MD RKB in first memory data delivery.
This was explained by Baker to be due to loss of depth data from the rig within this timeframe. LWD gets block height from the rig, and it appears like this signal has been out of order for a while, and drilling has been continued without depth-tracking. Data will be in the memory, but without any depth reference.

In the final memory data delivery the gaps were filled (except for the ROP curve) by interpolation of time-depth data in the interval having lack of block height signal from the rig.

Depth offsets on the logs were observed randomly throughout the whole logging run, and the depth shifts varied - in both directions.
Baker explained this as probably being caused by poor depth-tracking in the interval, where the depth obviously had been sat back and forth during the drilling. LWD depth will always be connected to Drillers depth, and in this case also dependent on the quality of the block height signal we get from the rig. Baker could not do anything with the data to solve this. Only when it is obvious errors with the time-depth file, Baker will be able to correct this.

3.3 15/9-F-1 B Logging While Drilling (LWD)

The LWD logging contractor for the entire wellbore was Baker Hughes.
Mud type in the 8 ½” reservoir section was OBM.
No cores were taken.

		15/9-F-1 B LWD Run Summary						
		Contractor: Baker Hughes						
LWD Run	**Hole Section [inch]**	**Logging service (tool combination)**	**Pass**	**Pass direction**	**Logging speed**	**Bit depth Interval [m MD RKB]**	**Logging interval [m MD RKB]**	**Remark**
6	12 1/4	OnTrak / CoPilot	Drill	Down	ROP	2617 – 3097	2533.2 – 3077.4	Good logging run.
7	8 1/2	LithoTrak / OnTrak / SoundTrak / TesTrak / CoPilot	Drill*)	Down*)	ROP	3097 - 3465	2942 – 3454	Density image from LithoTrak. *)Fm. pressure points with TesTrak were taken while POOH after TD. Good logging run.

Re-log in Bit depth interval 3236 – 3279 m MD RKB, was logged while backreaming 19 – 23 hours after being drilled.

Memory data:
All data was in memory. The data quality is in general good.

3.4 Electrical Wireline Logging

No electrical logging performed in open hole.

4 Petrophysical Evaluation

Petrophysical evaluation is performed according to the Volve petrophysical field model, described in report: “Sleipner Øst and Volve Model 2006, Hugin and Skagerrak Formation, Petrophysical Evaluation”. November 2006. Author: Elin Solfjell, Karl Audun Lehne.

The petrophysical evaluation software used is Geolog, and the Geolog project is SLEIPNER_OST (at Stavanger server: FROST_SVG).

4.1 Porosity

Total porosity, PHIF (ϕ_F), is derived from the density log which is calibrated to overburden corrected core porosity for wells drilled with either OBM or WBM.

The Neutron log, NPHI, has been used to correct for varying mud filtrate invasion.

$$\phi_F = \phi_D + A \times (NPHI - \phi_D) + B$$

where:

$$\phi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fl}} \text{ [fraction]}$$

ρ_{ma} is the matrix density [g/cm^3]
ρ_b is the measured bulk density (RHOB), [g/cm^3]
ρ_{fl} is the pore fluid density [g/cm^3].

A and B are regression coefficients.

NPHI: Neutron log in limestone units [fraction]

4.2 Shale volume

To determine VSH, the standard model VSH_{GR} from linear GR relationship is applied:

$$VSH = VSH_{GR} = \frac{GR - GR_{\min}}{GR_{\max} - GR_{\min}}$$

where:

GR = gamma ray log reading [API]
$GR_{\min}$ = GR reading in clean sand [API]

GR_{max} = GR reading in shale [API]

VSH is used quantitatively in deriving permeability, and quantitatively indirectly in Netsand cutoff.

In order to pick GR_{min} and GR_{max} in a more objective way, and to avoid over-estimating of VSH, GR is "normalized" against VSHDN (VSH from density / neutron) by cross plotting GR versus VSHDN. VSHDN is considered to be the most reliable shale indicator (except in intervals dominated by mica and heavy minerals). This shale indicator compares porosity derived from the Density log with porosity from the Neutron log. If the Neutron log reads higher porosity than the density, is this believed to be due to the hydrogen content of present clay minerals.

VSHDN is derived from the response equation for the Neutron log:

$$VCLDN = \frac{NPHICS - (PHIT * HIFL)}{HICL}$$

$$VSHDN = \frac{VCLDN}{(1 - PHISH)}$$

where:

VCLDN = Dry shale volume from density / neutron logs [fraction]
NPHICS = Neutron log corrected to sandstone matrix [fraction]
PHIT = Total log porosity [fraction]
HIFL = Hydrogen Index to fluid
HICL = Hydrogen Index to clay
PHISH = Shale porosity [fraction]

In table below are the general parameters used in Hugin Fm. for deriving VSHDN, given the assumption that Kaolinite is the dominant clay mineral:

VSHDN Parameters		
HIFL (oil / water)	**HICL**	**PHISH**
0.95 / 1	0.5	0.07

4.3 Water saturation

Water saturation is calculated using Archie equation, giving a total water saturation:

$$Sw_t = \left(\frac{a \times R_w}{\phi_F^m \times R_t} \right)^{\frac{1}{n}}$$

where:

a = Archie (tortuosity) factor
R_w = resistivity of formation water [Ohmm]
ϕ_F = Total porosity [fraction]
m = cementation exponent
R_t = true resistivity [Ohmm]
n = saturation exponent

4.4 Permeability

The horizontal log permeability, KLOGH, is derived from the following equation based on multivariable regression analysis between log porosity and shale volume (“normalized” against VSHDN) against overburden corrected core permeability:

Heather Fm.: $KLOGH = 10^{(2+8\times PHIF-9\times VSH))}$

Hugin Fm.: $KLOGH = 10^{(2+8\times PHIF-9\times VSH))}$

Sleipner Fm.: $KLOGH = 10^{(-3+32\times PHIF-2\times VSH))}$

Skagerak Fm.: $KLOGH = 10^{(-1.85+17.4\times PHIF-3\times VSH))}$

Smith Bank Fm.: $KLOGH = 10^{(-1.85+17.4\times PHIF-3\times VSH))}$

4.5 Composite curves

The following composite curves are used for the petrophysical evaluation:

GR	: GRCFM*) from OnTrak
RHOB	: BDCFM from LithoTrak
NPHI	: NPCKLFM from LithoTrak
PEF	: DPEFM from LithoTrak
RT	: RPCEHM from OnTrak
DRHO	: DRHFM from LithoTrak
CALI	: CALCM from UltraSonic Caliper, part of LithoTrak

Note in general that Baker considers the GRAFM curve as the best GR reading for large hole sizes > 17 ½" hole. The reason is as follows:

GRCFM is corrected for sensor type, collar size, carbonate content in mud, mud weight and hole size.
GRAFM is only corrected for sensor type, collar size and carbonate content in mud.
The hole size correction for GRCFM is performed by "normalizing" GRAFM to a standard which is: 6 ¾" tool, 10" borehole with 8 ppg mud. The large discrepancy between 26" hole and "the normalized standard" is the reason for why the GRAFM is considered to be the best GR in large holes > 17 1/2".

*) Hence in 26" section GRAFM is used as GR (applies only for 15/9-F-1).

15/9-F-1: Note that in the 17 ½" section a re-scaled NearBit GR (NBGRCFM) is spliced into GR for the ~ 9 last meters. NearBit GR has been re-scaled by -10 API in order to match GRCFM level.

Note also in general that the final «average» density curve - RHOB (BDCFM) - from Baker is weighted with respect to which of the 16 sectors / bins that provide the best density measurement (smallest standoff).

NPHI (NPCKLFM) is in limestone units, Caliper and salinity corrected and filtered.

The composite curves were created by Logtek from the memory data delivered by Baker Hughes.

Logtek's RDEP (Resistivity Deep) curve = RPCELM, named RD in the OW Volve project.
Logtek's RMED (Resistivity Medium) curve = RPCEHM, named RM in the OW Volve project.

4.6 Depth shift

Depth shifting has been applied, typically in limited overlap intervals around kick off depths and hole sections in Overburden. These depth shifts and the splicing of the individual runs are reported in Logtek's info file for each well; WLC_COMPOSITE_1_INF_1.PDF which is stored in Petrobank.
All depths are referenced to Driller's depth.

Logtek's general "philosophy" with respect to depth shifting in the transition zone between a mother well and a kick off well is as follows: aim to keep the stop-coupled depths as shallow as possible, preferably at KOP. But sometimes it has to be sat deeper (a few meters deeper, preferably in a shale if possible) due to a) if overlapping curves are not on depth at KOP, or b) if the depth shifts have been so large, that the logs else will be too compressed. This "philosophy" also applies of course for depth shifting in overlap between hole sections.

4.6.1 15/9-F-1 A Depth shift of logs:

Due to the random and varying depth offsets in both directions throughout the logging run, it was very difficult to establish proper depth shifts. When comparing Statoil's and Logtek's depth shifts, there were large discrepancies.

Agreement was made that the Statoil generated depth shifts were kept. Statoil decided however to keep Composite GR and ROP from Logtek wrt. depth shifting and merging.

Logtek got the depth shift documentation from Statoil, and tried to recreate these. Logtek's recreated depth shifted logs and corresponding documentation are the version stored in Petrobank. Statoil's depth shifted composite logs are the one stored in the Volve project in OpenWorks (Bergen) and at the STAT_COMP set in Geolog. The discrepancy between the two versions is of no significance for any practical uses.

Statoil's dynamic depth shifts are documented below, all depths are in m MD RKB:

All ORD and CCN curves from LithoTrak:

Merge depth: 2622 m MD RKB.

DEPTH	DEPTH_COR
2617.94625	2617.94625
2620.85667	2619.48100
2630.21413	2629.11200
2632.92167	2632.92167

Geolog Set where LithoTrak depth shifts are stored: STAT_COMP_RHOB_SHIFT.

All resistivity curves from OnTrak:

Note that Logtek's resistivity curves are kept down to merge depth = 2618 m MD RKB. This merge depth is also kept. Below 2618 m MD RKB Statoil's depth shifted resistivity curves are used, generated with the depth shifts listed below:

Note that in interval 3525 – 3595 m MD RKB the depth shifts are very difficult to establish.

DEPTH	DEPTH_COR
2615.98833	2615.98833
2620.16875	2619.58600
2630.03879	2628.53000
2639.95958	2639.95958
2671.07458	2671.07458
2672.92667	2672.29200
2679.96458	2679.96458
2686.05000	2686.57900
2689.86000	2689.86000
2709.96833	2709.96833
2714.51917	2713.46100
2716.47708	2716.47708
2723.99125	2723.99125
2726.31958	2727.48400
2728.60669	2730.34100
2735.95042	2735.95042
2767.96500	2767.96500
2769.34083	2770.18800
2776.00833	2776.00833
2777.80750	2778.70700
2786.61610	2786.85600
2790.54486	2790.45500
2795.10891	2793.94700
2800.98500	2800.98500
2814.26708	2815.43100
2861.89233	2863.05625
2868.77150	2868.93000
2929.78442	2929.94292
2931.37192	2931.74200
2934.59992	2934.97000
2935.49950	2936.39900
3053.13300	3054.03250
3054.45592	3054.87900
3082.55483	3082.97792
3085.47166	3084.56500
3089.22233	3088.90500
3121.13067	3120.49600
3130.54967	3129.91500
3135.31217	3136.21200

……continued

3210.50683	3210.29500
3225.21808	3225.00625
3228.23433	3228.49900
3275.01242	3274.11300
3332.95608	3332.05667
3334.54358	3334.91400
3389.63000	3390.00042
3403.86458	3405.18800
3426.67117	3427.99458
3430.32242	3430.11100
3437.25475	3437.04333
3455.08767	3454.87625
3457.57475	3458.15700
3472.39150	3472.97375
3473.60858	3473.76700
3477.47200	3477.10100
3482.49933	3481.49300
3483.87550	3483.39800
3494.45917	3493.98167
3495.62333	3495.94000
3519.70000	3520.01667
3523.82750	3522.02800
3524.99083	3523.93200
3526.79931	3525.52000
3530.07133	3530.17700
3534.72195	3535.20400
3535.04517	3536.68500
3542.50683	3543.77600
3549.59792	3550.49600
3553.19692	3553.46000
3556.18739	3554.62400
3559.01775	3557.90500
3564.35433	3564.62500
3590.96436	3591.29500
3598.70517	3598.43900
3625.85158	3626.00900
3633.94758	3633.73500

Geolog Set where OnTrak depth shifts are stored: STAT_COMP_RES_SHIFT.

Both sonic curves from SoundTrak, DT (AC) and DTS (ACS):

DEPTH	DEPTH_COR
2671.97417	2671.97417
2674.88458	2674.25000
2676.94833	2676.94833
2711.92625	2711.92625
2715.26000	2713.51400
2729.97083	2729.97083
2817.97125	2817.97125
2818.81792	2820.45800
2825.06208	2825.06208
3462.02000	3462.02000
3463.02542	3464.61300
3478.00083	3478.00083
3518.05875	3518.05875
3520.06958	3518.45900
3529.65686	3529.01250
3531.48359	3530.54700
3536.05042	3536.05042
3539.06667	3540.17800
3542.92950	3544.04083
3543.88200	3546.15700
3551.66125	3553.93625
3555.20667	3556.47600
3557.64083	3559.91583
3560.76292	3563.03792
3564.83750	3564.14900
3595.63517	3594.94667
3596.90517	3597.43400
3625.47992	3626.00875
3625.79742	3627.33200
3629.34283	3629.87167
3636.53950	3637.06833
3638.33867	3638.44400
3640.50825	3641.03708

Geolog Set where SoundTrak depth shifts are stored: STAT_COMP_DT_SHIFT.

4.7 Evaluation parameters

The following evaluation parameters are used for calculation of porosity, shale volume and water saturation:

15/9-F-1 Evaluation parameters			
	Formation name		
Parameter	**Heather Fm.**	**Skagerak Fm.**	**Smith Bank Fm.**
ρ_{ma}	2.66	2.68	2.65
ρ_{fl}	0.9	0.85	0.9
A	0	0	0
B	0	0	0
$GR_{\min}$	15	15	15
$GR_{\max}$	120	135	135
a	1	1	1
m	2	2.02	*)
n	2	2.03	2.45
*) $m = 1.865 \times \left(KLOGH^{(-0.0083)}\right)$			
R_w = 0.07 ohmm @ 20 ^oC.			
Temperature gradient = 2.6 ^oC / 100 m. Reservoir temp.: 111 ^oC @ 2800 m TVD MSL.			

15/9-F-1 A Evaluation parameters					
	Formation name				
Parameter	**Heather Fm.**	**Hugin Fm.**	**Sleipner Fm.**	**Skagerak Fm.**	**Smith Bank Fm.**
ρ_{ma}	2.66	2.65	2.65	2.68	2.65
ρ_{fl}	1	0.9	0.9	0.85	0.9
A	0	0	0	0	0
B	0	0	0	0	0
$GR_{\min}$	9	9	9	9	9
$GR_{\max}$	75	135	120	135	135
a	1	1	1	1	1
m	2	*)	*)	2.02	*)
n	2	2.45	2.45	2.03	2.45
*) $m = 1.865 \times \left(KLOGH^{(-0.0083)}\right)$					
R_w = 0.07 ohmm @ 20 ^oC.					
Temperature gradient = 2.6 ^oC / 100 m. Reservoir temp.: 111 ^oC @ 2800 m TVD MSL.					

15/9-F-1 B Evaluation parameters			
	Formation name		
Parameter	Heather Fm.	Hugin Fm.	Sleipner Fm.
ρ_{ma}	2.66	2.65	2.65
ρ_{fl}	1	0.9	0.9
A	0	0.4	0
B	0	0.01	0
$GR_{\min}$	5	5	5
$GR_{\max}$	130	180	150
a	1	1	1
m	2	*)	*)
n	2	2.45	2.45
*) $m = 1.865 \times \left(KLOGH^{(-0.0083)}\right)$			
R_w = 0.07 ohmm @ 20 ^{o}C.			
Temperature gradient = 2.6 ^{o}C / 100 m. Reservoir temp.: 111 ^{o}C @ 2800 m TVD MSL.			

4.8 Flag curves

Netsand flag:

Cutoffs on PHIF and VSH are used to determine Netsand; SAND_FLAG = 1.
Hugin Fm.: SAND_FLAG = 1 when PHIF > 0.10 and VSH < 0.50.

These cut offs correspond to a overburden corrected core permeability of 0.5 mD, and are also applied for the other formations, except Skagerak Fm. where a VSH cut off < 0.6 is applied.

In addition some manual editing might have been performed on the SAND_FLAG curve.

Carbonate volume, Carbonate flag:

15/9-F-1, 15/9-F-1 A:

The overall trend in these two wellbores is that from Heather Fm., the formations seem quite cemented. Due to this, a varying carbonate volume curve, VCARB, has been made instead of a carbonate flag curve. This carbonate volume curve has been calculated from an empirical relationship:

$$VCARB = \left[\frac{0.2 - (PHIF + 0.3 \times VSH)}{0.2}\right] \times \left(1 - PHIF - VSH\right)$$

Note that the volume carbonate is just meant to be used visually / qualitatively, and not for any quantitative purposes.

15/9-F-1 B:

Even if this well has more “normal” Hugin facies developed, a VCARB curve is also generated here. In addition a carbonate flag curve, CARB_FLAG, has been determined manually by visual inspection of the logs. Whenever CARB_FLAG = 1 is SAND_FLAG = 0.

Coal flag:

No coal layers were observed in the wells.

15/9-F-1: 3 intervals with enhanced organic-rich content were observed in Draupne Fm.

15/9-F-1 A: 2 intervals with enhanced organic-rich content were observed in Draupne Fm.

5 Evaluation of Formation Pressure Data

Baker's TesTrak Formation Pressure While Drilling tool was run in the 8 ½" section of 15/9-F-1, 15/9-F-1 A and 15/9-F-1 B.

In all 3 wells the formation pressures were taken after reached TD while POOH.

5.1 General remarks about Baker's TesTrak test type

In general the test type chosen will have no influence on the acquired pressures – there might however be slight differences in mobility estimates from the second and third drawdown.

If "tight supercharged" test in a Darcy sand is chosen, one will still get the same pressure as a "high mobility" test. As seen from the table below all test types are volume controlled for the first drawdown (DD) anyway – it is only the second and third DD that are different. (The only difference between High and Low Mobility is the third drawdown).

Test Type	First DrawDown (DD)	Second DD	Third DD
High Mobility	Volume	DeltaP	Steady State
Low Mobility	Volume	DeltaP	DeltaP
Tight Supercharged	Volume	Volume	DeltaP
Unconsolidated Sand	Volume w/ initialization	Volume	Volume

The "Unconsolidated Sand" test includes an initialization sequence which might be beneficial to use for the first test. It is also the safest test to run if experiencing problems with the testing. The initialization sequence does however take about 1 min extra time, so if doing a large number of tests one would save some rig-time by doing one of the other types. Under normal conditions any of the tests could be chosen and would give good results.

Test time will be dictated by the formation mobility, independent of the test type (except the 1 extra minute of the "Unconsolidated Sand") – the "smart test" downhole logic will determine when it has 3 stable formation pressures and automatically finish the test. If 3 pressures are not obtained within the specified 10 minutes, the test will abort and the recorded pressures will be transmitted to surface.

To sum up:

Picking the most permeable zones for testing and having proper depth control is far more important than worrying about which test type to choose.

5.2 General remarks about temperature measured by Baker's TesTrak

The TesTrak temperature is the temperature on the quartzdyne pressure sensor, which will require exact temperature correction. This temperature measurement is therefore strongly affected by the temperature of the drilling fluid (and also by annulus temperature and steel temperature), but minor affected by the volume of formation liquid which is drawn in (30 cc).

The temperature of the drilling fluid will also change when circulating: downhole it warms up by the formation and cools down when coming up at the rig, hence will probably be somewhat lower than absolute formation temperature. If extensive pumping it will therefore also be difficult to see relative temperature trends from TesTrak measurements.

To sum up:

TesTrak temperature measurements cannot be used for absolute formation temperature, and most likely cannot be trusted for looking for relative temperature trends either.

5.3 Evaluation of Formation Pressure Data 15/9-F-1

4 of 6 tests were successful and of good technical quality (one *might* be supercharged). When judging the pressure quality by mobility range (flag curve in OpenWorks: PRES_QUAL), the tests can be summarized as 1 very good quality pressure and 3 poor quality pressures.

The results are shown in table below.

Since Hugin Fm. appears to be missing in this well, the measured pressures in Heather and Skagerak Fm. are shown in plot with all formation pressures in Hugin Fm. at Volve (F-1 formation pressures are marked as black balls) in chapter 5.6. Note that the only pressure point measured previously in Heather Fm. at Volve (15/9-F-4, April 2008), also is plotted for comparison, this is an oil point.

In addition the drawdown mobility is plotted in the permeability track in the CPI plot for F-1, and the formation pressure is plotted in the density / neutron track, both marked as red balls.

	Well: 15/9-F-1 Date: 18. August – 19. August 2013 Rig: Mærsk Inspirer RKB: 54.9 m Baker's TesTrak tool								PORE PRESSURE (s.g ref. RKB) = 10.195*FORM. PRESSURE / mTVD RKB		
ZONE NAME	**Log Run No.**	**Test No.**	**DEPTH [m MD RKB]**	**DEPTH [m TVD RKB]**	**FORM. PRESS. [bar]**	**TEMP. [°C]**	**GOOD SEAL (Y/N)**	**REMARKS**	**DrawDown MOBILITY [mD/cP]**	**PORE PRESS. s.g ref. RKB [g/cm3]**	**MUD+ECD PRESS. s.g ref. RKB [g/cm3]**
Skagerak	4	1	3462.6	3172.2	353.49	80.8	Y	OK	7.8	1.136	1.371
Skagerak	4	2	3451.9	3162.3	351.33	75.4	Y	OK	5.3	1.133	1.370
Heather	4	3	3360.8	3080.3	342.05	76.6	Y	OK (Supercharged ?)	0.7	1.132	1.368
Heather	4	4	3337.2	3060	-	75.8	Y	Tight	-	-	1.370
Heather	4	5	3332.4	3056.1	340.64	74.7	Y	OK	217.5	1.136	1.368
Heather	4	6	3320.8	3046.5	-	74.9	Y	Tight	-	-	1.379

Total number of tests: 6

No. of Successful tests: 4

No. of Fluid samples: none

Hydrostatic gradient in logged interval: -

Minimum measured pore pressure (ref. RKB): 1.132 g/cm^3

Maximum measured pore pressure (ref. RKB): 1.136 g/cm^3

Using LWD/GR for depth correlation.

All pressure tests were taken as Test Type Option = "Low Mobility".

Formation pressure data is entered into OW. The curve is named PRES_FORM.
Mobility is named PRES_MOBL and temperature PRES_TEMP.
Formation pressure test quality in OW is called PRES_QUAL;
0: lost seal, 1: Tight, 2: Poor (<10mD/cP), 3: Good (10-100 mD/cP), 4: Very Good (>100 mD/cP).
Pressure data with qualifiers 0 or 1 are however not registered in OW, due to technical issues wrt. plotting.

5.4 Evaluation of Formation Pressure Data 15/9-F-1 A

3 of 7 tests were successful and of good technical quality. 4 tests were supercharged. When judging the pressure quality by mobility range (flag curve in OpenWorks: PRES_QUAL), the tests can be summarized as 2 very good quality pressures and 1 poor quality pressure.

Formation pressure points in Hugin were ~11 bar above fm. pressure measured in 15/9-F-11 T2 (May 2013), ~5 bar above fm. pressure measured in 15/9-F-11 A (May 2013) and ~24.7 bar above initial fm. pressure measured in 15/9-19 BT2 (January 1998). This indicates a separate pressure regime compared to Hugin Fm. in Volve main field and in the NW segment.

The results are shown in table below and in plot of all formation pressures in Hugin Fm. at Volve (F-1 A formation pressures are marked as orange balls) in chapter 5.6.

In addition the drawdown mobility is plotted in the permeability track in the CPI plot for F-1 A, and the formation pressure is plotted in the density / neutron track, both marked as red balls.

	Well: 15/9-F-1 A Date: 26. August 2013 Rig: Mærsk Inspirer RKB: 54.9 m Baker's TesTrak tool								PORE PRESSURE (s.g ref. RKB) = 10.195*FORM. PRESSURE / mTVD RKB		
ZONE NAME	**Log Run No.**	**Test No.**	**DEPTH [m MD RKB]**	**DEPTH [m TVD RKB]**	**FORM. PRESS. [bar]**	**TEMP. [°C]**	**GOOD SEAL (Y/N)**	**REMARKS**	**DrawDown MOBILITY [mD/cP]**	**PORE PRESS. s.g ref. RKB [g/cm3]**	**MUD+ECD PRESS. s.g ref. RKB [g/cm3]**
Hugin (Lower)	5	1	3493.2	3104.1	-	85.5	Y	Supercharged	-	-	1.365
Hugin (Lower)	5	2	3492.4	3103.5	-	83.3	Y	Supercharged	-	-	1.364
Hugin (Lower)	5	3	3479.4	3094.1	-	81.9	Y	Supercharged	-	-	1.362
Hugin (Lower)	5	4	3480.5	3094.9	-	81.7	Y	Supercharged	-	-	1.365
Hugin 2.3	5	5	3462.3	3081.8	351.812	82	Y	OK	623.7	1.164	1.371
Hugin 2.3	5	6	3457.5	3078.3	351.435	81.9	Y	OK	3421	1.164	1.375
Hugin 3.3	5	7	3436.3	3063.1	350.315	81.4	Y	OK	7.1	1.166	1.378
Total number of tests: 7							No. of Successful tests: 3			No. of Fluid samples: none	
							Hydrostatic gradient in logged interval: -				
Minimum measured pore pressure (ref. RKB): 1.164 g/cm^3							Maximum measured pore pressure (ref. RKB): 1.166 g/cm^3				
Using LWD/GR for depth correlation.							All pressure tests were taken as Test Type Option = "Low Mobility".				
Formation pressure data is entered into OW. The curve is named PRES_FORM. Mobility is named PRES_MOBL and temperature PRES_TEMP. Formation pressure test quality in OW is called PRES_QUAL; 0: lost seal, 1: Tight, 2: Poor (<10mD/cP), 3: Good (10-100 mD/cP), 4: Very Good (>100 mD/cP). Pressure data with qualifiers 0 or 1 are however not registered in OW, due to technical issues wrt. plotting.											

5.5 Evaluation of Formation Pressure Data 15/9-F-1 B

10 of 10 tests were successful and of good technical quality. When judging the pressure quality by mobility range (flag curve in OpenWorks: PRES_QUAL), the tests can be summarized as 5 very good quality pressures, 4 good quality pressures and 1 poor quality pressure.

Formation pressure points in Hugin show an oil gradient and were ~1 bar above fm. pressure measured in 15/9-F-11 A (May 2013). This pressure increase is in accordance with the following observations from down hole gauge measurements: Down hole pressure as measured at gauge in F-15 C May 21th 2013 (F-11 A TesTrak logging) was ~299 bara. Down hole pressure as measured at gauge in F-15 C September 6th 2013 (F-1 B TesTrak logging) was ~300 bara. This shows communication to Volve main field.

When comparing to initial fm. pressure measured in 15/9-F-12 (February 2008), the formation pressure points in Hugin in F-1 B were ~13 bar higher, again in accordance with the increased pressure in the main field area.

The results are shown in table below and in plot of all formation pressures in Hugin Fm. at Volve (F-1 B formation pressures are marked as pink balls) in chapter 5.6. Note that the one pressure point in Sleipner Fm. also is plotted for comparison, this is a water point.

When enhancing the scale of this formation pressure plot, ref. plot in chapter 5.7, it is seen that there is a small, but distinct pressure shift in the pressure points in F-1 B. The 3 uppermost points belonging to Upper Hugin, are ~0.5 bar lower than the remaining 6 Hugin points that belong to Thief Zone and Lower Hugin. A minor pressure shift can also be seen in the pressure points in F-11 A. But here the 7 uppermost points belonging to Upper Hugin and Thief Zone are ~ 0.1 bar lower than the remaining 6 Hugin points that belong to Lower Hugin. This trend in pressure shift is difficult to explain.

In addition the drawdown mobility is plotted in the permeability track in the CPI plot for F-1 B, and the formation pressure is plotted in the density / neutron track, both marked as red balls.

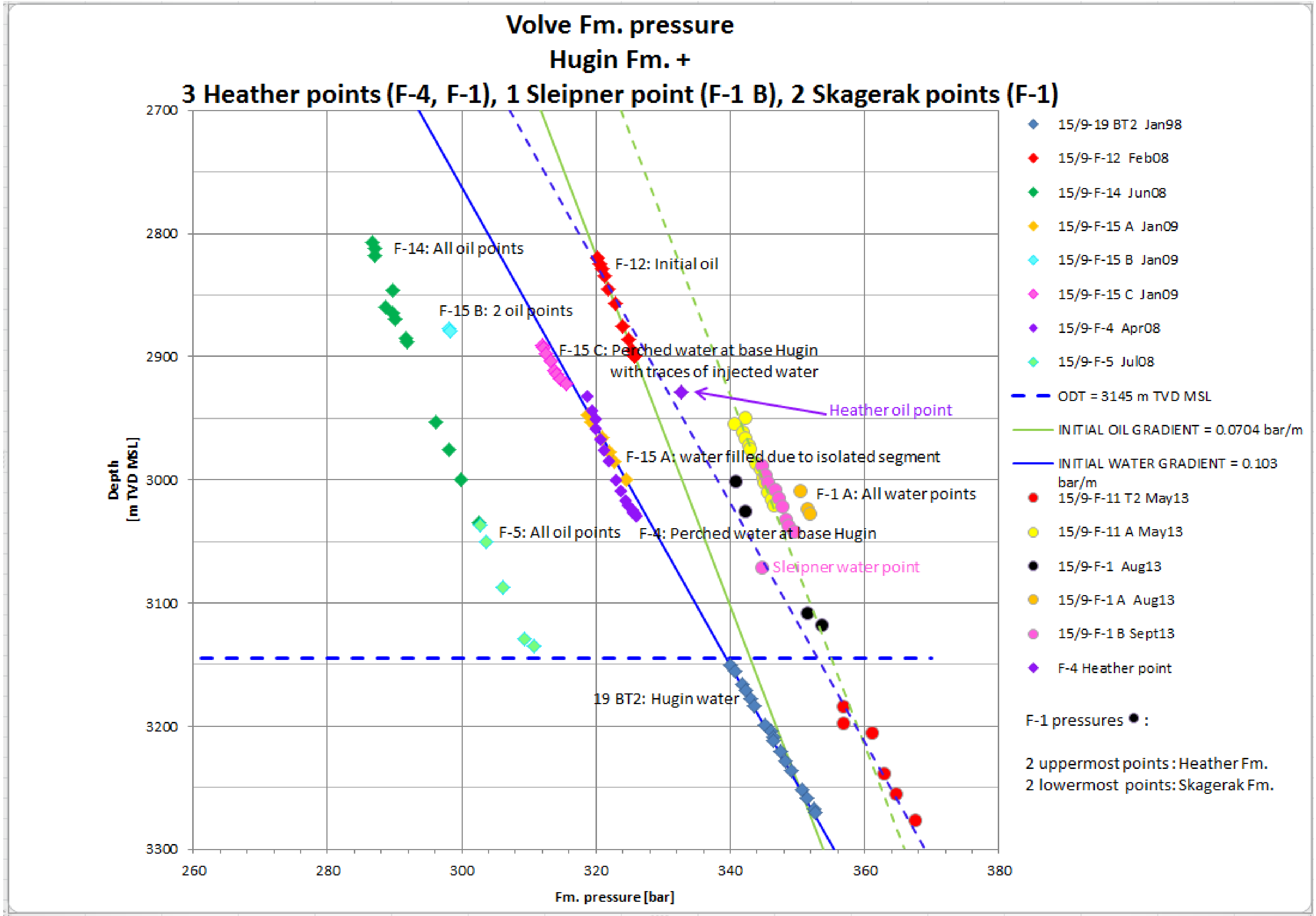
	Well: 15/9-F-1 B Date: 07. September 2013 Rig: Mærsk Inspirer RKB: 54.9 m Baker's TesTrak tool								PORE PRESSURE (s.g ref. RKB) = 10.195*FORM. PRESSURE / m TVD RKB		
ZONE NAME	**Log Run No.**	**Test No.**	**DEPTH [m MD RKB]**	**DEPTH [m TVD RKB]**	**FORM. PRESS. [bar]**	**TEMP. [°C]**	**GOOD SEAL (Y/N)**	**REMARKS**	**DrawDown MOBILITY [mD/cP]**	**PORE PRESS. s.g ref. RKB [g/cm3]**	**MUD+ECD PRESS. s.g ref. RKB [g/cm3]**
Sleipner	7	1	3330	3125.3	344.675	87.6	Y	OK	208.3	1.124	1.455
Hugin 1.6	7	2	3301.5	3097	349.407	85.4	Y	OK	9.2	1.150	1.458
Hugin 1.6	7	3	3296	3091.5	348.639	83.3	Y	OK	37.4	1.150	1.457
Hugin 2.1	7	4	3291	3086.6	348.236	83	Y	OK	1685.7	1.150	1.457
Hugin 2.2	7	5	3280.5	3076.2	347.584	82.5	Y	OK	120.2	1.152	1.459
Hugin 2.3	7	6	3273.5	3069.4	347.05	82.3	Y	OK	580.7	1.153	1.459
Hugin 2.3	7	7	3266.5	3062.5	346.523	82.5	Y	OK	237.7	1.154	1.459
Hugin 3.1	7	8	3261	3057.1	345.604	82.1	Y	OK	46.2	1.153	1.459
Hugin 3.2	7	9	3255	3051.2	345.124	81.8	Y	OK	55.5	1.153	1.459
Hugin 3.3	7	10	3247	3043.4	344.563	81.5	Y	OK	60.4	1.154	1.458
Total number of tests: 10							No. of Successful tests: 10			No. of Fluid samples: none	
							Hydrostatic gradient in logged interval: -				
Minimum measured pore pressure (ref. RKB): 1.124 g/cm^3							Maximum measured pore pressure (ref. RKB): 1.154 g/cm^3				
Using LWD/GR for depth correlation.							All pressure tests were taken as Test Type Option = "Low Mobility".				
Formation pressure data is entered into OW. The curve is named PRES_FORM. Mobility is named PRES_MOBL and temperature PRES_TEMP. Formation pressure test quality in OW is called PRES_QUAL; 0: lost seal, 1: Tight, 2: Poor (<10mD/cP), 3: Good (10-100 mD/cP), 4: Very Good (>100 mD/cP).											

5.6 Plot of Formation Pressure Data, 15/9-F-1, 15/9-F-1 A and 15/9-F-1 B

Ref. plot on next page:

Note that the initial water gradient of 0.103 bar/m has been forced through the F-11 T2 pressure points, drawn as a blue, dashed line.

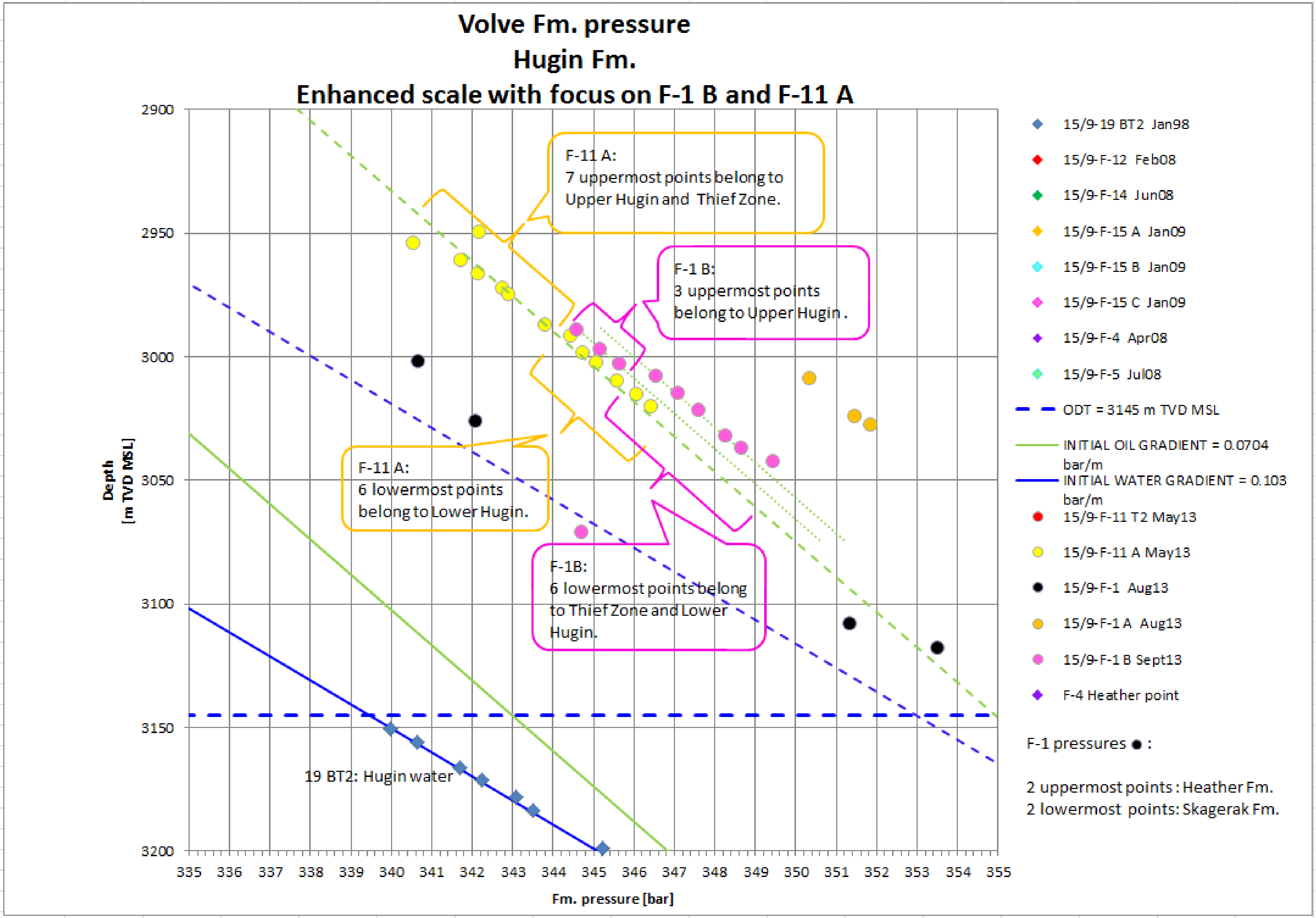
Note also that the initial oil gradient of 0.0704 bar/m has been forced through the F-11 A pressure points, drawn as a green, dashed line.


Volve Fm. pressure
Hugin Fm. +
3 Heather points (F-4, F-1), 1 Sleipner point (F-1 B), 2 Skagerak points (F-1)
F-14: All oil points
F-12: Initial oil
F-15 B: 2 oil points
F-15 C: Perched water at base Hugin with traces of injected water
Heather oil point
F-15 A: water filled due to isolated segment
F-1 A: All water points
F-5: All oil points
F-4: Perched water at base Hugin
Sleipner water point
19 BT2: Hugin water
Depth [m TVD MSL]
Fm. pressure [bar]
15/9-19 BT2 Jan98
15/9-F-12 Feb08
15/9-F-14 Jun08
15/9-F-15 A Jan09
15/9-F-15 B Jan09
15/9-F-15 C Jan09
15/9-F-4 Apr08
15/9-F-5 Jul08
ODT = 3145 m TVD MSL
INITIAL OIL GRADIENT = 0.0704 bar/m
INITIAL WATER GRADIENT = 0.103 bar/m
15/9-F-11 T2 May13
15/9-F-11 A May13
15/9-F-1 Aug13
15/9-F-1 A Aug13
15/9-F-1 B Sept13
F-4 Heather point
F-1 pressures :
2 uppermost points: Heather Fm.
2 lowermost points: Skagerak Fm.

5.7 Plot of Fm. Pressure Data with enhanced scale with focus on F-1 B and F-11 A

Ref. plot on next page:

Note that the initial oil gradient of 0.0704 bar/m has been forced through the F-1 B pressure points, drawn as two green, dotted lines.



Volve Fm. pressure
Hugin Fm.
Enhanced scale with focus on F-1 B and F-11 A
F-11 A:
7 uppermost points belong to Upper Hugin and Thief Zone.
F-1 B:
3 uppermost points belong to Upper Hugin.
F-11 A:
6 lowermost points belong to Lower Hugin.
F-1B:
6 lowermost points belong to Thief Zone and Lower Hugin.
19 BT2: Hugin water
Depth [m TVD MSL]
Fm. pressure [bar]
15/9-19 BT2 Jan98
15/9-F-12 Feb08
15/9-F-14 Jun08
15/9-F-15 A Jan09
15/9-F-15 B Jan09
15/9-F-15 C Jan09
15/9-F-4 Apr08
15/9-F-5 Jul08
ODT = 3145 m TVD MSL
INITIAL OIL GRADIENT = 0.0704 bar/m
INITIAL WATER GRADIENT = 0.103 bar/m
15/9-F-11 T2 May13
15/9-F-11 A May13
15/9-F-1 Aug13
15/9-F-1 A Aug13
15/9-F-1 B Sept13
F-4 Heather point
F-1 pressures ● :
2 uppermost points: Heather Fm.
2 lowermost points: Skagerak Fm.

6 LWD NMR – MagTrak in 15/9-F-1

Baker's LWD NMR tool, MagTrak, was logged in 8 1/2" section of 15/9-F-1.
The tool transmitted RealTime the curves: total porosity, Clay Bound Volume Index and Bound Fluid Index. MagTrak sensor offset to Bit was 48.6 m.

6.1 Logging mode and parameters

The tool was logged in "Dual Wait Time" (DTW) mode, also called "PoroPermMT+Light HC" mode, in order to process a salinity independent water saturation. Mode and parameter settings were the same as in 15/9-F-11 T2.

An average ROP of 20 m/hr (in the Section guidelines a max ROP of 20 m/hr and an optimal ROP of 10 m/hr was specified while drilling Hugin Fm.) was held from top Draupne to TD to assure a sufficient vertical resolution of the MagTrak data, and also to keep the Signal/Noise ratio high.

Vertical resolution with DTW mode and ROP = 20 m/hr was calculated to be 1.7 m. Vertical resolution with DTW mode and ROP = 30 m/hr was calculated to be 2.6 m.

The MagTrak data was logged and final post processed with the following parameters:

Running Average (Data Stacking) of 16: RA = 16
T2 Cutoffs: CBW = 3.3 ms, BVI = 33 ms (standard sandstone T2 cutoffs)
Number of T2 bins: 27 over the range of 0.5 – 4096 ms.

6.2 MagTrak output

In table below are the most important curves from MagTrak listed with explanation:

CURVE NAME	BAKER's CURVE EXPLANATION	"TRADITIONAL" NAME	CURVE RELATION	DEPENDING ON T2 CUTOFF
MBVI	MagTrak Irreducible Fluid Porosity	Capillary Bound Fluid Index	MBVI = MPHE - MBVM	YES
MBVM	MagTrak Movable Fluid Porosity	FFI (Free Fluid Index)	MBVM = MPHS - MBW	YES
MBW	MagTrak Bound Fluid Porosity	BVI (Bound Fluid Index)	MBW = MCBW + MBVI	YES
MCBW	MagTrak Clay Bound Fluid Porosity	Clay Bound Volume Index	MCBW = MPHS - MBVI - MBVM	YES
MPERM	MagTrak Permeability Index		MPERM = $\left[\left(\frac{MPHS}{C}\right)^2 \times \left(\frac{MPHS - MBW}{MBW}\right)\right]^b$ Default parameters are b=2, C=10	YES
MPHE	MagTrak Effective Porosity		MPHE = MPHS - MCBW	YES
MPHS	MagTrak Total Porosity		MPHS = MBW + MBVM	**NO***

*MPHS: MPHS is only dependent on Hydrogen Index (HI). If HI unequal 1, then MPHS is also dependent of T2 cutoffs. 15/9-F-1 is mostly water filled, hence HI ~ 1.

MPHS is comparable with PHIF (= PHIT) from conventional logs.
MPERM is qualitative (semi-quantitative) comparable with KLOGH from conventional logs.
MBW/MPHS is comparable with Swirr from resistivity logs (not applicable in this water filled well).

6.3 MagTrak purpose and achievement

- Purpose with running MagTrak was to achieve:
  - Lithology independent porosity
  - Independent (semi-quantitative) permeability indicator, possibility of detecting thief zone?
  - Salinity independent water/oil saturation
  - Discriminate between movable and bound fluid
  - Irreducible water saturation
  - Independent estimation of saturation exponent, n
  - Pore size distribution

Since the reservoir turned out to be missing and the other formations seem to be ~ water filled, some of the purposes were not any longer applicable.

- Achievements:
  - MagTrak provides both a total and an effective porosity which is lithology independent. Total porosity from MagTrak, MPHS, is plotted (magenta curve) in same track as total porosity, PHIF, from conventional logs in the F-1 CPI. Also in F-1 the overall trend in Heather Fm. is that the PHIF is slightly lower than MPHS, indicating perhaps a too low matrix density applied for this formation. Skagerak Fm. seems quite heterogeneous on the density log, and here the poorer vertical resolution of MPHS (MagTrak) compared to PHIF (Density log) is easily seen. In Smith Bank Fm. PHIF fits with total porosity from MagTrak in the sandy sequences, but underestimates in the more shaly sequences.

  - MagTrak provides an independent semi-quantitative permeability indicator, MPERM. This curve is plotted (magenta curve) in same track as the permeability from conventional logs and field model, KLOGH, in the F-1 CPI. The overall trend is that MPERM > KLOGH with the applied standard sandstone T2 cutoffs.

    SCAL (Special Core AnaLysis) data from 15/9-19 A was investigated to check if the default coefficients for the Coates-Timur permeability (MPERM) equation was appropriate, ref. chapter 6.5. This resulted in a permeability curve called MPERM_ADJUSTED which is plotted (light green curve) in the permeability track (track no. 8) in the F-1 CPI.

  - Since the formations were ~ water filled, it was no point to order a processing from Baker to get an independent oil saturation.

  - MagTrak provides a discrimination between movable and bound fluid. This is illustrated in track no. 7 in the F-1 CPI. Brown shading = clay bound fraction, turquoise shading = capillary bound fraction and yellow shading = free or movable fluid fraction.

    The discrimination between movable and bound fluid is also illustrated in the MagTrak T2 distribution plots, ref. fig. 6.4.1 and fig. 6.4.2, track no. 5 and 6.

    In Draupne Fm. the complete T2 signal is coming from the Clay bound fraction.

    In Heather Fm. the T2 signal is mainly coming from the Free Fluid fraction which mostly shows a bimodal distribution coming from formation water (to the left) and oil based mud filtrate (to the right). This reflects good formation properties for a Heather Formation.

Upper part of Skagerak Fm. shows T2 signal mainly coming from the Capillary Bound fraction (3.3 ms < T2 < 33 ms), reflecting poor formation properties. Lower part of Skagerak Fm. has however more of the T2 signal coming from the Free Fluid fraction which shows mainly a bimodal distribution. Hence reflecting better properties in this part of Skagerak Fm.

T2 signal in Smith Bank Fm. reflects the alternating shale / sand lithology with signal coming mainly from respectively Clay Bound fraction and Free Fluid fraction.

- MagTrak provides an irreducible water saturation which is the ratio: bound fluid / total porosity. This is named SWIRR_MTK and is plotted (magenta curve) in same track as the water saturation from the conventional logs. Since ~ water filled formations, comparison against water saturation from conventional logs is of course not applicable.

- Since the formations were ~ water filled, the method of estimating n from the slope when illustrating Archie Water Saturation equation graphically above transition zone, was not applicable.

- Pore size distribution: this needs 2 more processings (DTW and Grain Size Distribution) from Baker, and has not been ordered.

6.4 MagTrak T2 distribution plots

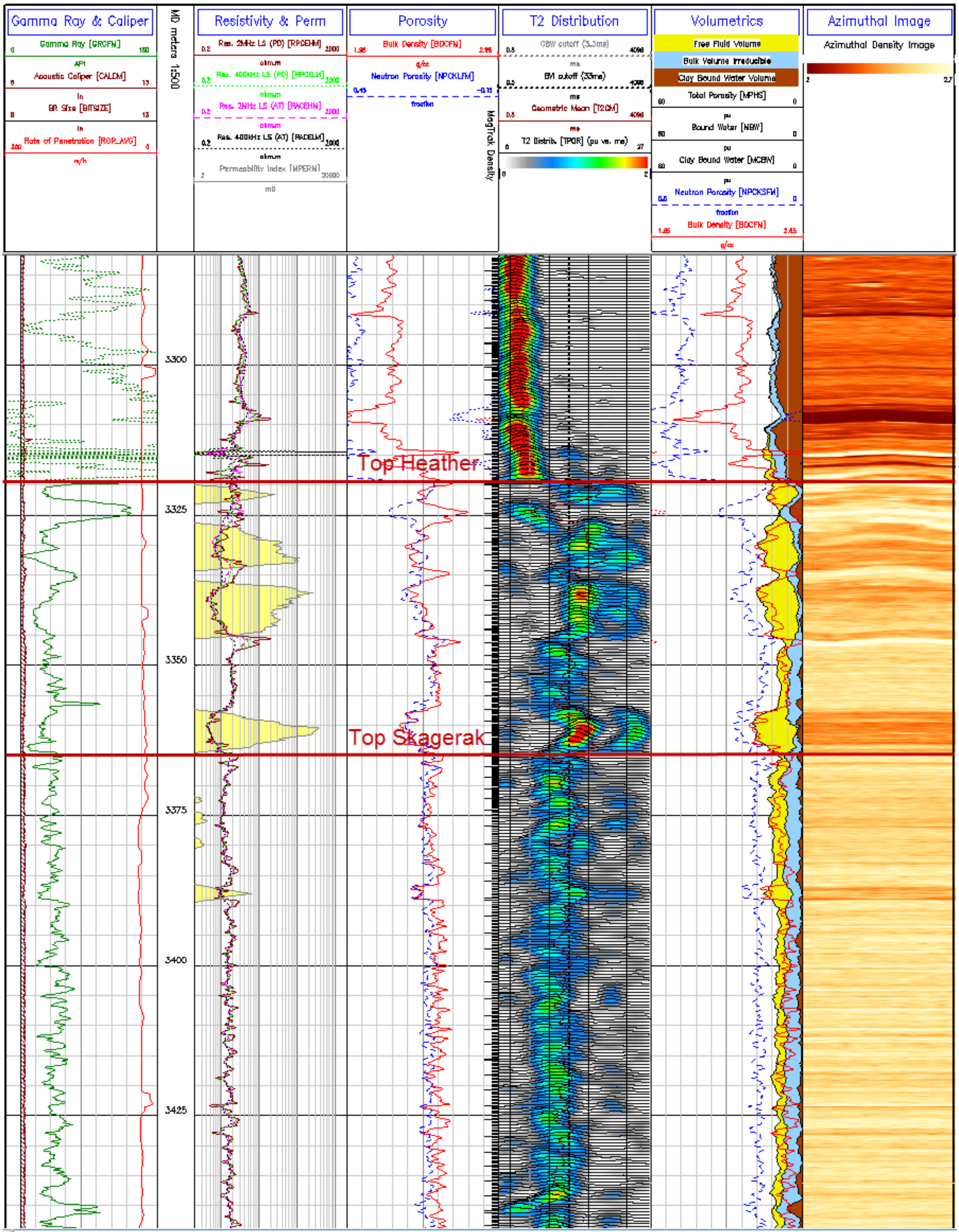


Figure 6.4.1 showing T2 distribution from MagTrak in track no. 5.
Heather Fm. shows mainly bimodal T2 distribution of the Free Fluid fraction due to invasion of mudfiltrate (OBM). OBM filtrate signal to the right and formation water signal to the left. In Upper Skagerak Fm. very

little T2 signal is coming from the Free Fluid fraction, most of the signal is coming from the Capillary Bound fraction (3.3 ms < T2 < 33 ms.)

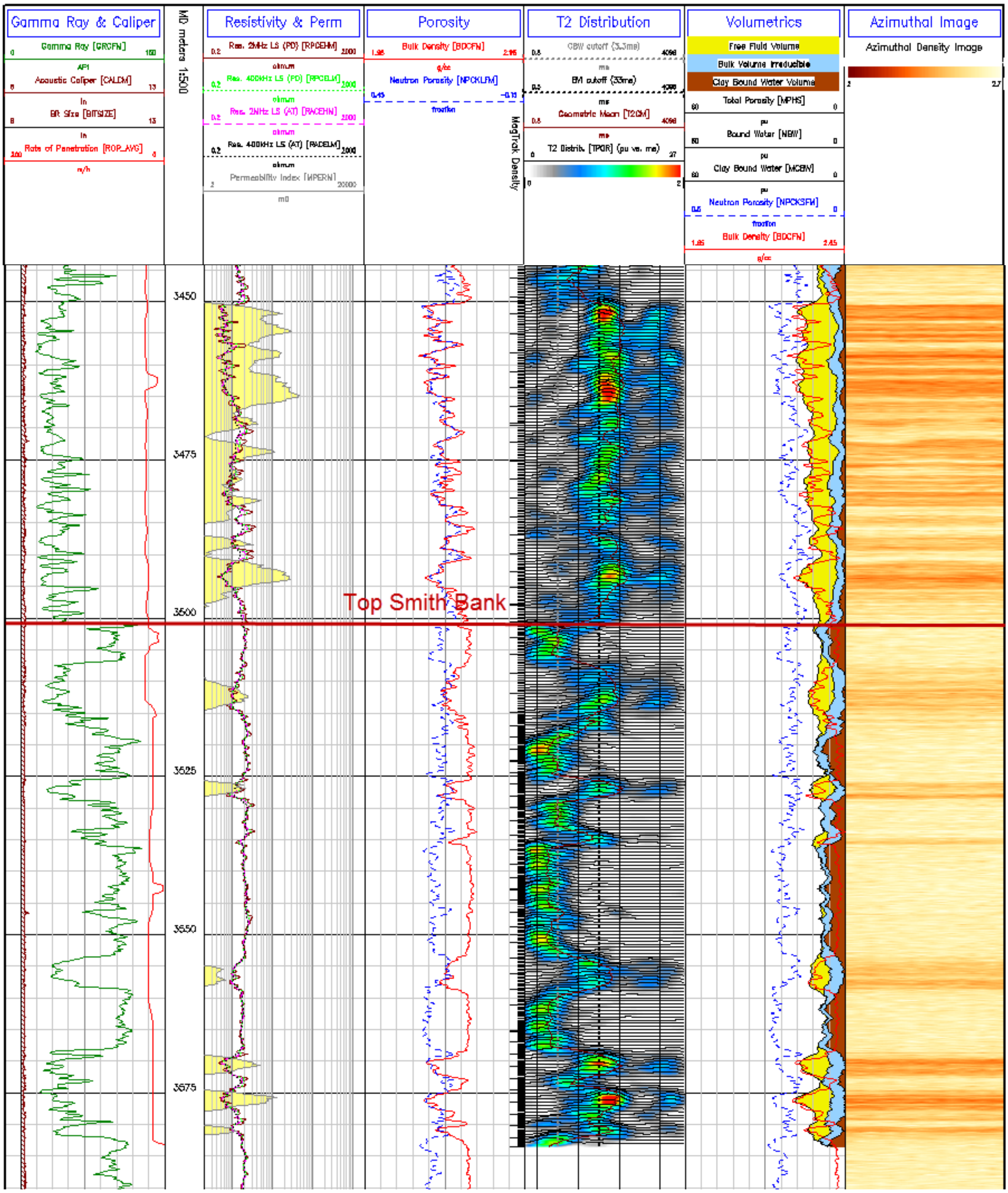


Figure 6.4.2 showing T2 distribution from MagTrak in track no. 5.
Lower part of Skagerak Fm. has more of the T2 signal coming from the Free Fluid fraction which shows mainly a bimodal distribution. Hence reflecting better properties in this part of Skagerak Fm.

6.5 Coates-Timur permeability

A verification / check of the coefficients in the Coates-Timur permeability equation has been done.

Due to lack of cores in 15/9-F-11 T2 and 15/9-F-1, the SCAL data in 15/9-19 A was reviewed. An overview over SCAL permeability versus irreducible water saturation from different methods is given in figure 6.5.1.

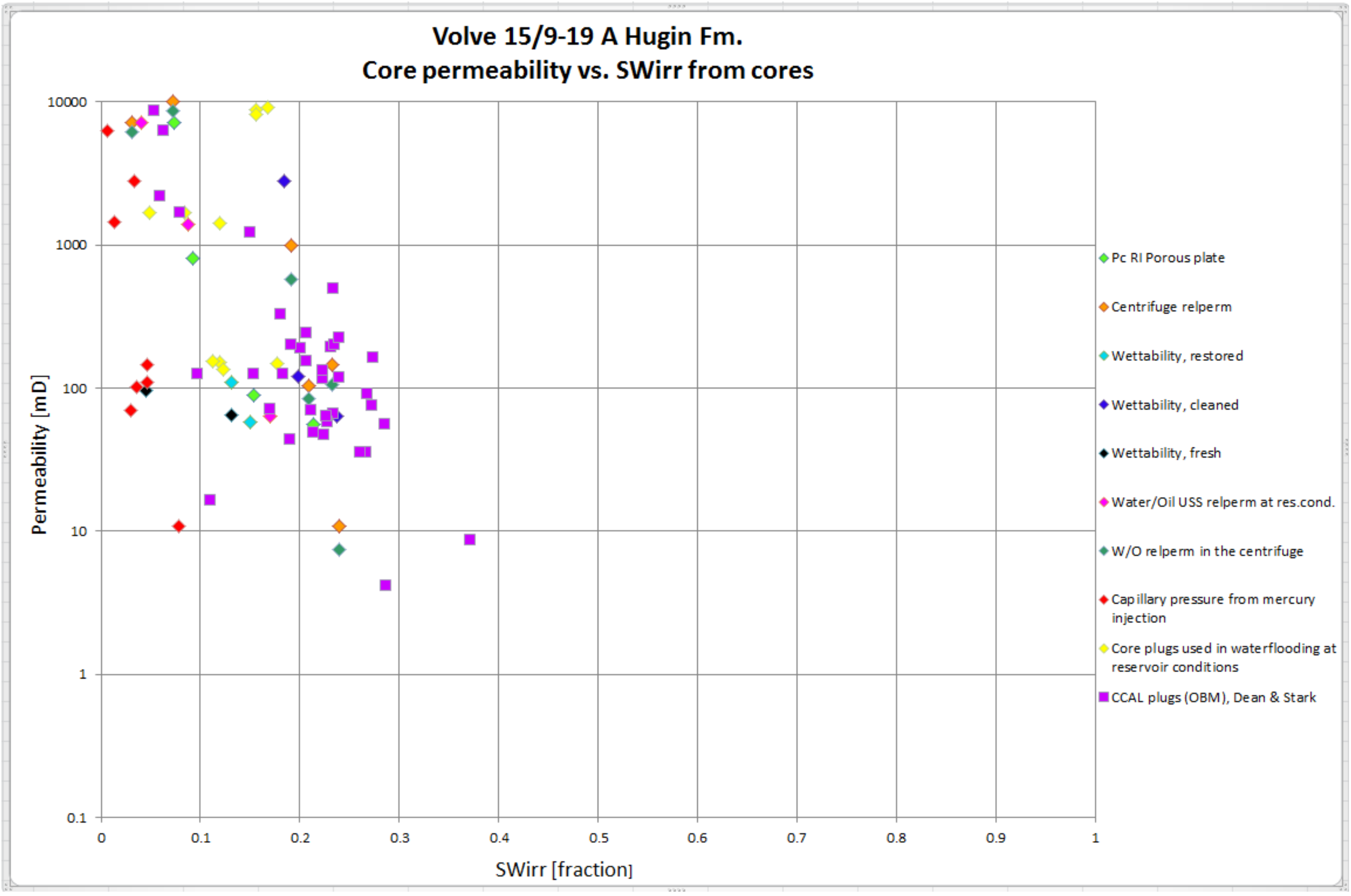


Figure 6.5.1. SCAL data from well 15/9-19 A.
All permeability data versus irreducible water saturation data derived from different methods listed to the right and separated by different colors. The data from mercury injection should be disregarded.

Data from the CCAL (Conventional Core AnaLysis) plugs are shown as purple squares in fig. 6.5.1. The water saturation is measured by Dean and Stark method (OBM) and is measured together with porosity at vertical plugs. Permeability is however not measured on same vertical plugs, but on horizontal plugs. Due to this, permeability has been picked from adjacent plugs with approximately same porosity.

The overall trend is quite a large scatter in the data range, hence corresponding large uncertainty.The mercury injection data is however clear outliers, and data from this method should be disregarded.

In order to illustrate Coates-Timur permeability equation graphically (ref. fig. 6.5.2) to verify / check the default coefficients, b=2 and C=10, the equation was split into a linear equation as shown below:

$$K = \left[\left(\frac{\phi}{C} \right)^2 \times \left(\frac{FFI}{BVI} \right) \right]^b$$

$$LOGK = LOG \left[\left(\frac{\phi}{C} \right)^2 \times \left(\frac{FFI}{BVI} \right) \right]^b$$

$$LOGK = LOG \left[\left(\frac{1}{C^2} \right)^b \times \left(\phi^2 \times \frac{FFI}{BVI} \right)^b \right]$$

$$LOGK = bLOG \left(\frac{1}{C^2} \right) + bLOG \left(\phi^2 \times \frac{FFI}{BVI} \right)$$

$$LOGK = b\left(LOG(1) - LOG(C^2)\right) + bLOG \left(\phi^2 \times \frac{FFI}{BVI} \right)$$

$$LOGK = b(-LOG(C^2)) + bLOG \left(\phi^2 \times \frac{FFI}{BVI} \right)$$

$$LOGK = -2bLOG(C) + bLOG \left(\phi^2 \times \frac{FFI}{BVI} \right)$$

$$\underbrace{LOGK}_{\text{Y-axis}} = \underbrace{-2bLOG(C)}_{\text{Intersection Y-axis}} + \underbrace{b}_{\text{slope}}\underbrace{LOG \left(\phi^2 \times \frac{FFI}{BVI} \right)}_{\text{X-axis}}$$

Fig. 6.5.2 shows that the default coefficients (solid line) in the Coates-Timur equation is not appropriate when comparing to the core data from Hugin Fm. in 15/9-19 A. Despite large scattering in the data, a new regression line has been suggested, ref. dashed line, giving the coefficients: b=2.5 and C=17.8.

New adjusted MPERM, named MPERM_ADJUSTED, according to these new parameters is plotted (light green curve) in the permeability track, track no. 8, in the F-1 CPI. In general MPERM_ADJUSTED is closer to KLOGH from field model than MPERM.

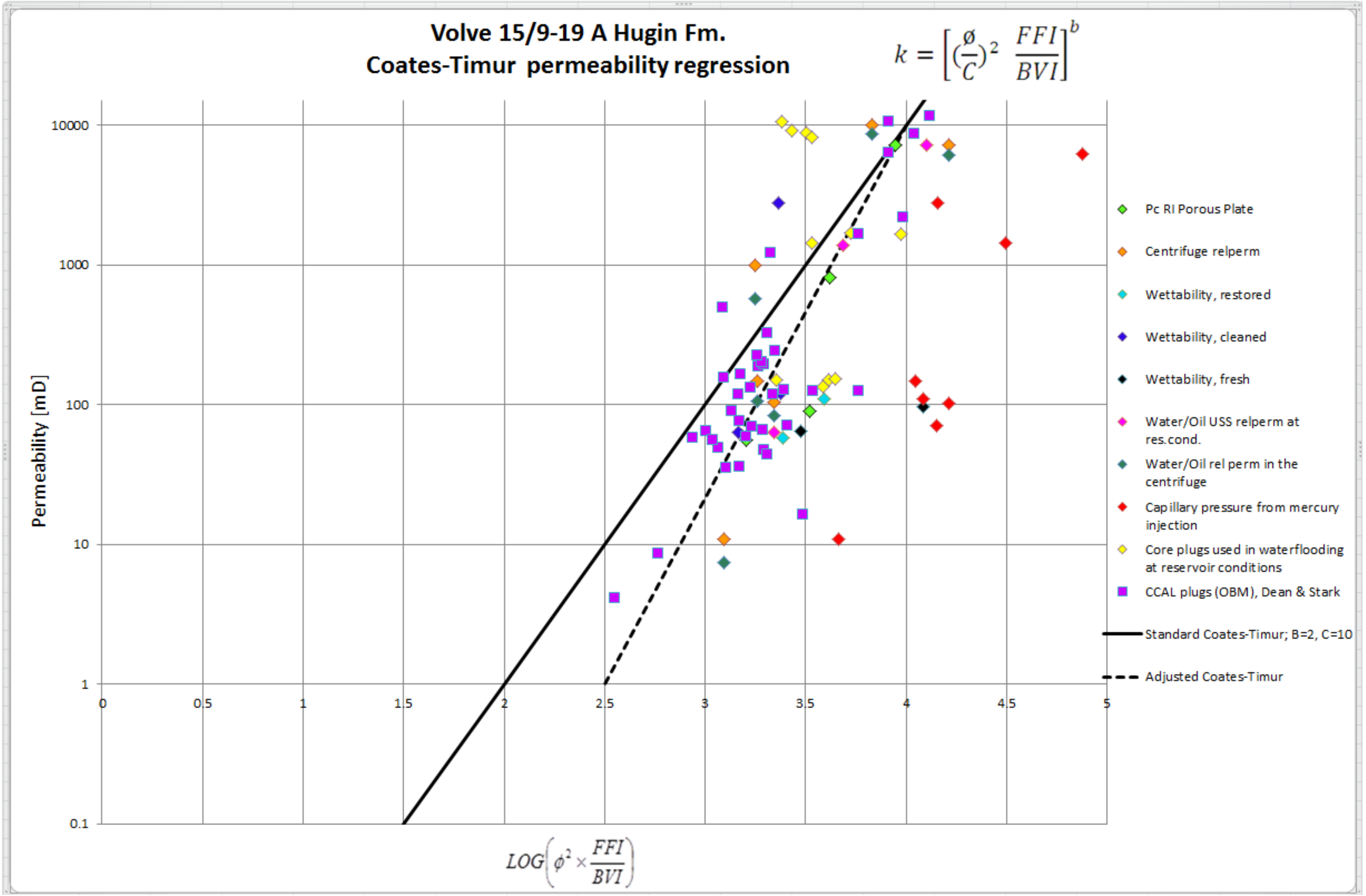


Figure 6.5.2. SCAL data from well 15/9-19 A illustrating Coates-Timur permeability equation. Solid regression line is with default coefficients; b=2 and C=10. This line seems to be off compared to the core data, resulting in a too high MagTrak permeability, MPERM. Dashed line is with adjusted coefficients: b=2.5 and C=17.8. This line seems more reasonable compared to the core data.

7 Petrophysical results

Tables below in this chapter are showing average values of Net/Gross (N/G), total porosity (PHIF), total water saturation (SW) and horizontal permeability from logs (KLOGH) in Netsand.

7.1 Petrophysical results 15/9-F-1

15/9-F-1 Averages								
Formation	**Top [m MD RKB]**	**Base [m MD RKB]**	**N/G [fraction]**	**PHIF [fraction]**	**SW [fraction]**	**KLOGH arithmetic [mD]**	**KLOGH harmonic [mD]**	**KLOGH geometric [mD]**
Heather	3319.7	3365	0.536	0.144	0.926	52	1	10
Skagerak	3365.0	3500.9	0.371	0.136	0.982	1	0.3	0.6
Smith Bank	3500.9	3632.0	0.114	0.129	0.974	0.6	0.2	0.3

7.2 Petrophysical results 15/9-F-1 A

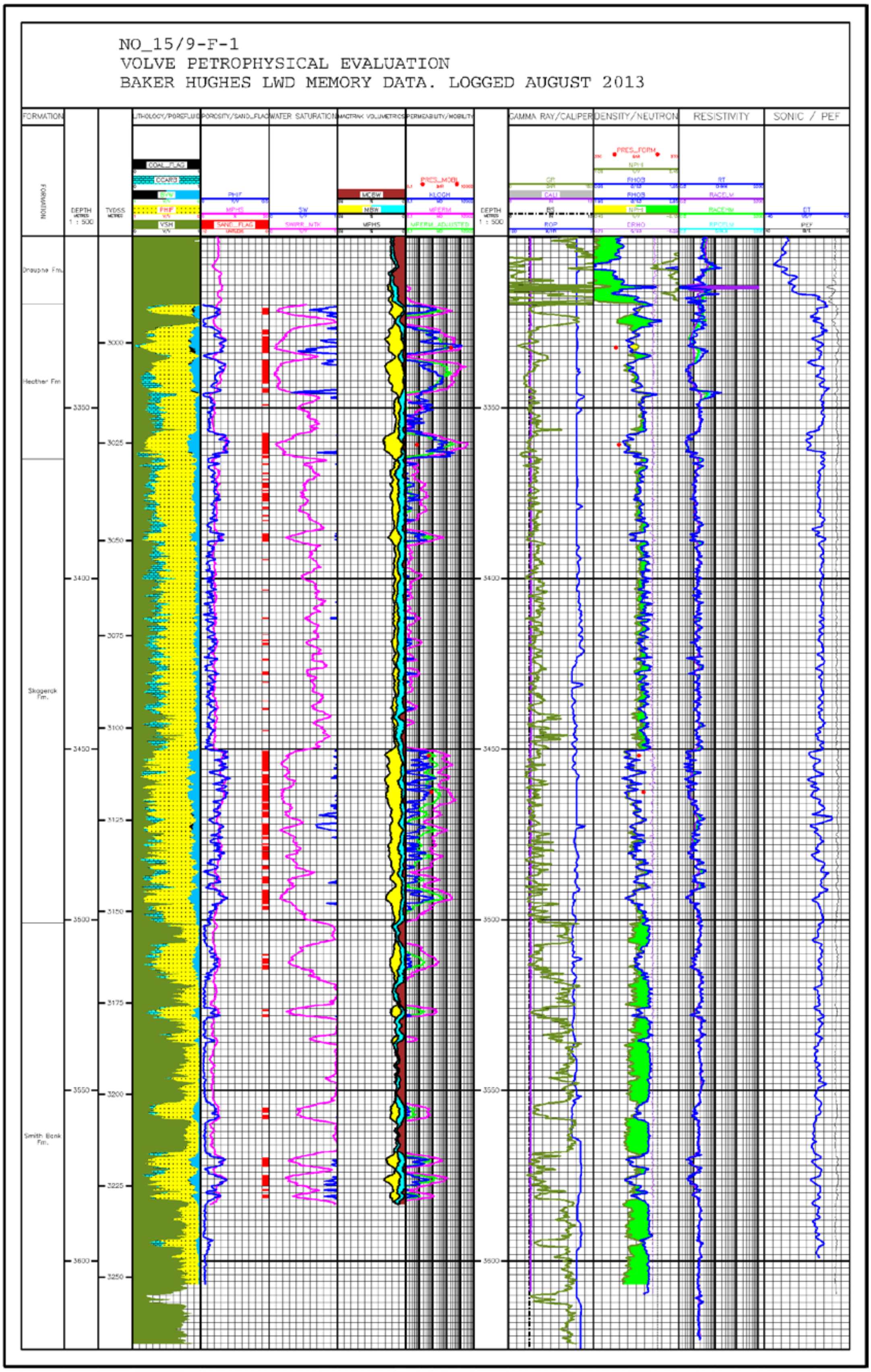
15/9-F-1 A Averages								
Formation / Zone	**Top [m MD RKB]**	**Base [m MD RKB]**	**N/G [fraction]**	**PHIF [fraction]**	**SW [fraction]**	**KLOGH arithmetic [mD]**	**KLOGH harmonic [mD]**	**KLOGH geometric [mD]**
Heather	3429.4	3435.0	0	-	-	-	-	-
Hugin	3435.0	3500.2	0.692	0.168	0.899	263	0.5	10
Upper Hugin	3435.0	3454.7	0.822	0.170	0.819	65	0.5	15
Middle Hugin (“Thief Zone”)	3454.7	3463.8	0.923	0.196	0.939	1280	48	358
Lower Hugin	3463.8	3500.2	0.565	0.156	0.946	4	0.4	1.5
Hugin 3.3 (12)	3435.0	3441.5	0.723	0.173	0.829	108	32	74
Hugin 3.2 (11)	3441.50	3448.0	0.923	0.178	0.760	66	3	26
Hugin 3.1 (10)	3448.0	3454.7	0.821	0.158	0.882	28	0.2	2
Hugin 2.3 (9)	3454.7	3463.8	0.923	0.196	0.939	1280	48	358
Sleipner	3500.2	3543.7	0.133	0.123	0.850	3	1	2
Skagerak	3543.7	3608.0	0.723	0.135	0.975	0.7	0.3	0.4
Smith Bank	3608.0	3682.0	0.051	0.119	0.973	0.3	0.2	0.2

7.3 Petrophysical results 15/9-F-1 B

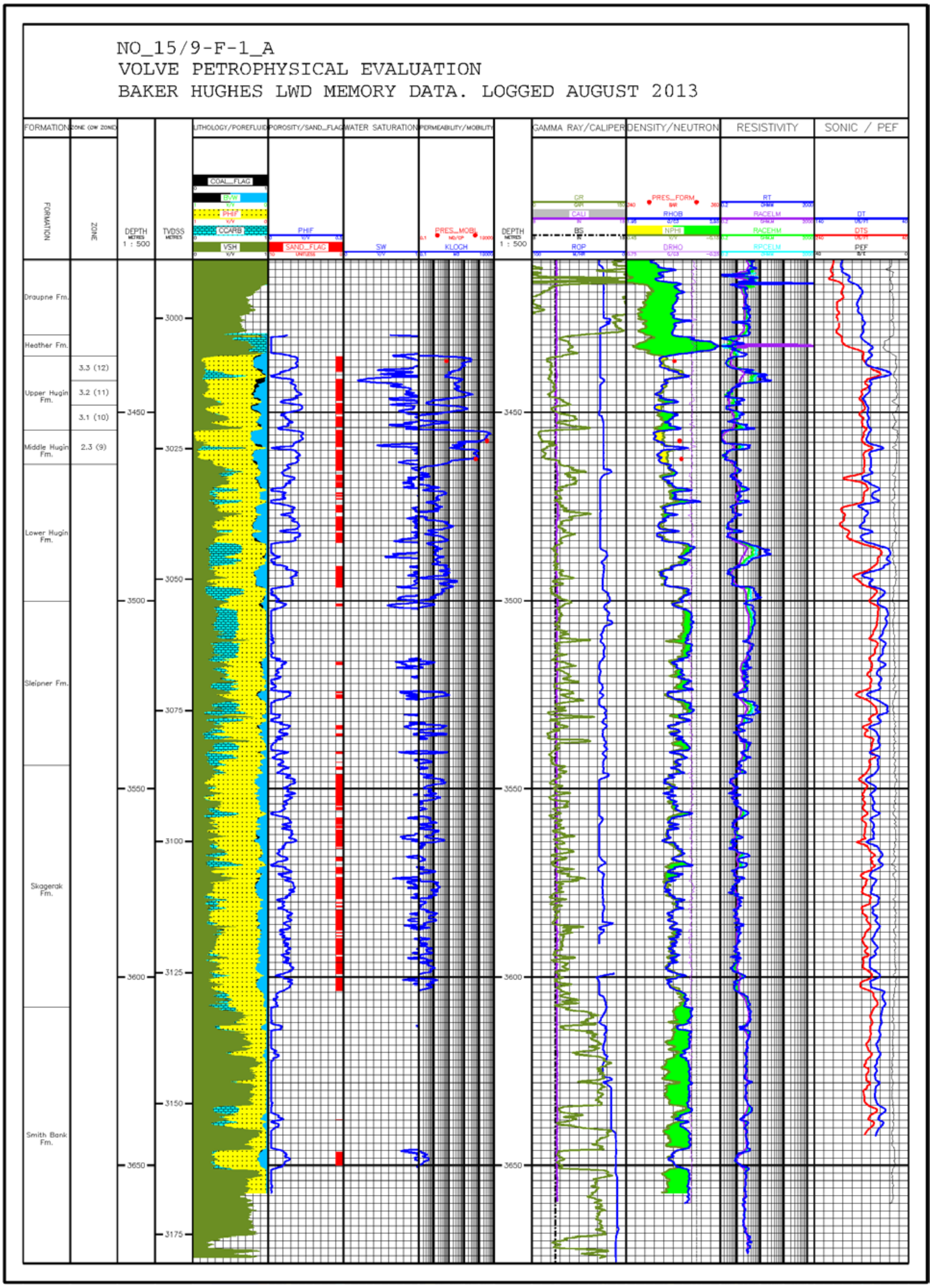
15/9-F-1 B Averages								
Formation / Zone	**Top [m MD RKB]**	**Base [m MD RKB]**	**N/G [fraction]**	**PHIF [fraction]**	**SW [fraction]**	**KLOGH arithmetic [mD]**	**KLOGH harmonic [mD]**	**KLOGH geometric [mD]**
Heather	3229.4	3245.4	0	-	-	-	-	-
Hugin	3245.4	3304.2	0.906	0.202	0.363	864	18	227
Upper Hugin	3245.4	3264.2	0.838	0.198	0.414	416	7	153
Middle Hugin (“Thief Zone”)	3264.2	3294.1	0.92	0.208	0.333	1380	56	391
Lower Hugin	3294.1	3304.2	0.995	0.193	0.369	154	60	96
Hugin 3.3 (12)	3245.4	3249	0.958	0.232	0.242	1067	914	1011
Hugin 3.2 (11)	3249	3258.5	0.921	0.186	0.458	272	8	122
Hugin 3.1 (10)	3258.5	3264.2	0.623	0.193	0.510	139	3	42
Hugin 2.3 (9)	3264.2	3276.0	0.932	0.214	0.251	1980	130	1034
Hugin 2.2 (8)	3276.0	3288.5	0.872	0.198	0.54	117	27	56
Hugin 2.1 (7)	3288.5	3294.1	1	0.214	0.12	2658	2252	2504
Hugin 1.6 (6)	3294.1	3304.2	0.995	0.193	0.369	154	60	96
Sleipner	3304.2	3465.0	0.326	0.128	0.936	63	1	3

8 CPI plots of evaluated curves and raw data

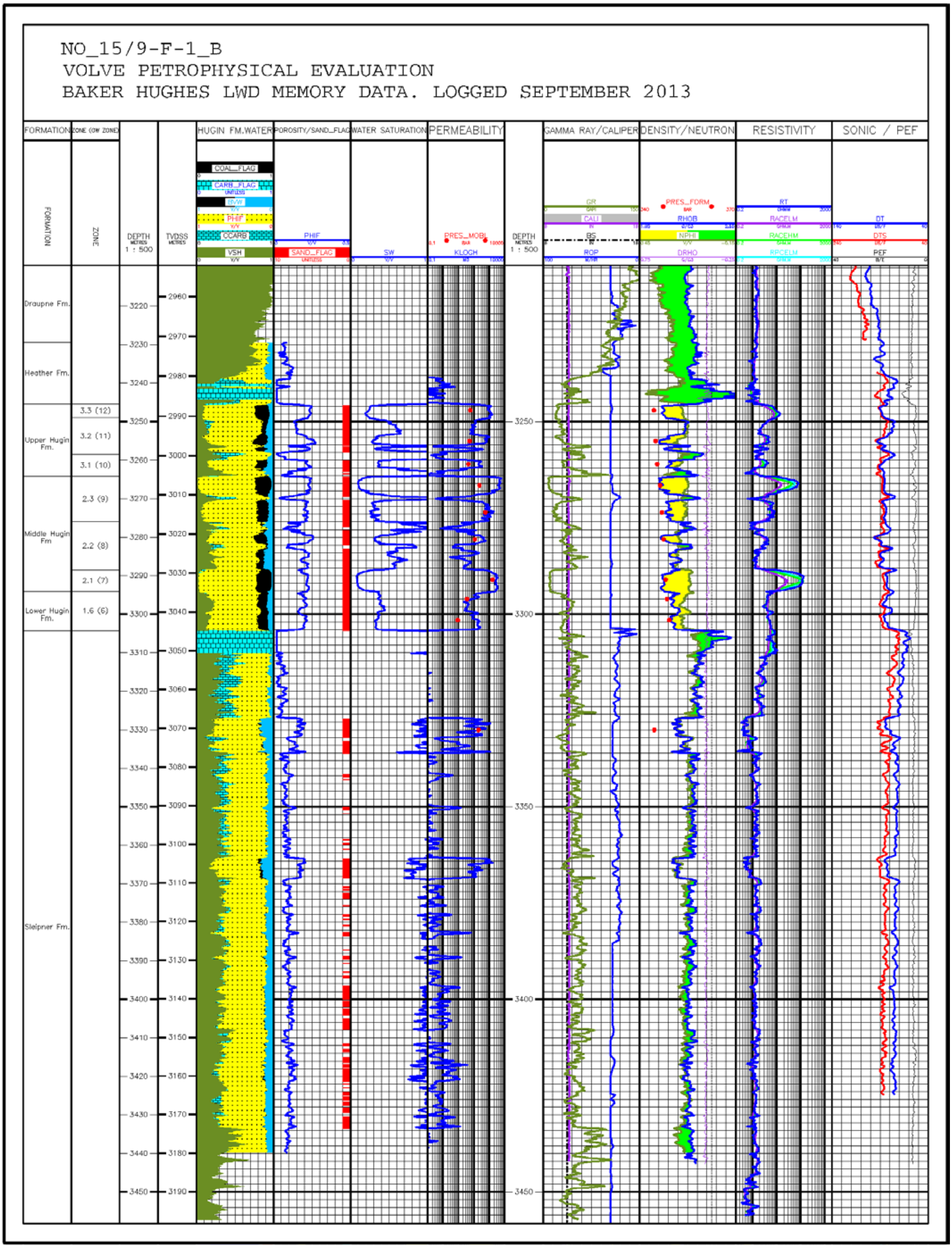
8.1 CPI plot 15/9-F-1



8.2 CPI plot 15/9-F-1 A



8.3 CPI plot 15/9-F-1 B



9 References

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