Petrophysics Report

Craigow-1

Prepared for:

The Saros Group
Petroleum Services
1/949 Wellington Street
WEST PERTH, WA 6005

Michael Isherwood

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EXPERTISE, RESULTS

EXECUTIVE SUMMARY

This report summarises the available data, methodology and the interpretation results of a petrophysical evaluation of the Craigow-1 well through the Eastern View Coal Measures (1145.0m) through to TD. This well was interpreted after first running interpretation on the neighbouring wells King-1 and Barramundi-1.

The logging tools used in the analysis were recorded by Schlumberger open hole logging in a single suite over the 12 $^{1}/_{4}$" hole section from 1764-75m, see table 1. The PEX was not acquired above 1145m. Only Sonic-GR was acquired over the casing from 735m to seabed at 75m. The wireline data was loaded into Petrolog, and quality control, depth matching and environmental corrections were applied to the data as required. Craigow-1 was interpreted using the Petrolog CPX analysis module, utilising the Sand-Silt-Shale formation model. The borehole conditions and log quality were good with no quality issues noted.

The formation water was quite saline, exhibiting a Pickett plot derived salinity of approx 55,000ppm and freshening to 40,000ppm below 1584mMD. Using a standard analysis approach works fine in this well, the thinly laminated interval present in King-1 and Barramundi-1, at the top of the main sands, was not observed.

There are several reasonably thick sandstone intervals which are clean and show a porosity range from 25-30% and are water saturated. These sands were not as thick as those seen in King-1 or Barramundi-1. Formation water salinity is supported by King-1, no shows and the gas logs are not elevated over the sands.

Before examining the various cross-plots in this report it would be worth looking at the section titled *Data grouping and associated lithology*. This section looks at the various data clouds seen on the key cross-plots and what lithology they are best described as.

See Pay Summary Results section at the end of this report. This section contains several variations in NET cut-off, these are; VCL < 30%, VCL < 40% (results as shown below) and Permeability >10mD.

Unit	From (mMD)	To (mMD)	Gross int. (m)	Res. Int. (m)	VCL (%)	Phie (%)	Perm (md)	Swe (%)	NTG (%)
300	1174.1	1308.0	133.9	1.067	17.335	11.076	6.832	86.989	1%
350	1308.0	1384.0	76.0	8.026	26.648	21.397	124.24	99.956	11%
450_50	1384.0	1433.5	49.5	5.283	28.582	21.328	111.85	99.997	11%
450_40	1433.5	1460.9	27.4	0.0					0%
450_30	1460.9	1499.4	38.5	15.646	28.94	21.458	100.17	99.944	41%
450_20	1499.4	1533.0	33.6	21.946	21.895	24.718	232.15	99.718	65%
450_10	1533.0	1566.2	33.2	12.446	23.608	22.875	153.98	100.0	37%
450	1566.2	1667.0	100.8	30.734	21.955	22.338	144.08	98.774	30%
0500_30	1667.0	1799.99	132.996	18.745	23.351	22.041	105.78	99.898	14%

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Tables and Figures

INTRODUCTION

Craigow-1 well located offshore in the North-Western Bass basin in permit T/47P. The primary objective was the Top Aroo Formation, a series of high quality sands below thick sealing claystones.

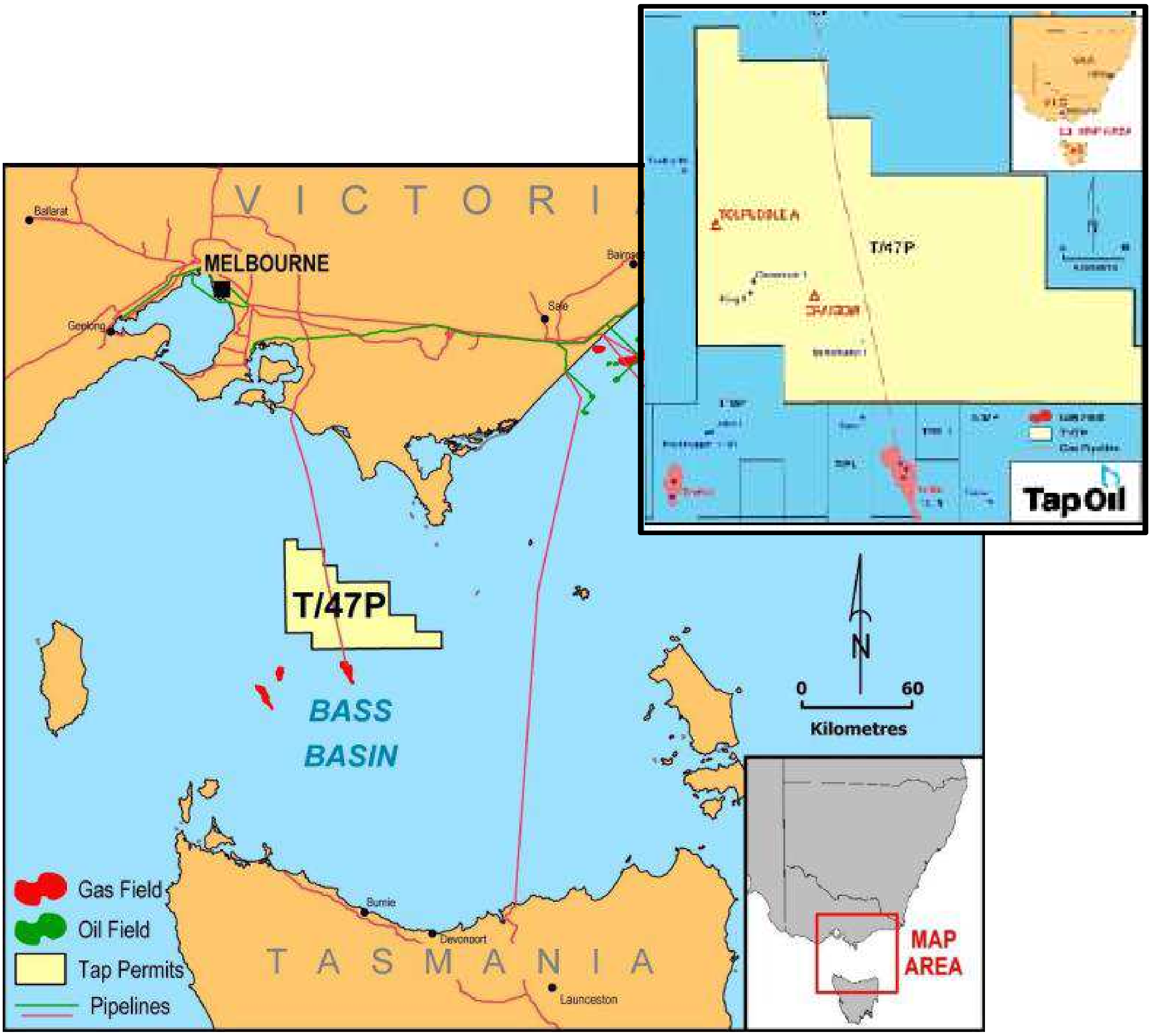


Figure 1: Well location map

DATA AVAILABILITY AND QUALITY

Mudlog & Drilling Data

Mudlog and drilling data was available in PDF format for the petrophysical interpretation. The following plot demonstrates the mud logs over a section of the target interval.

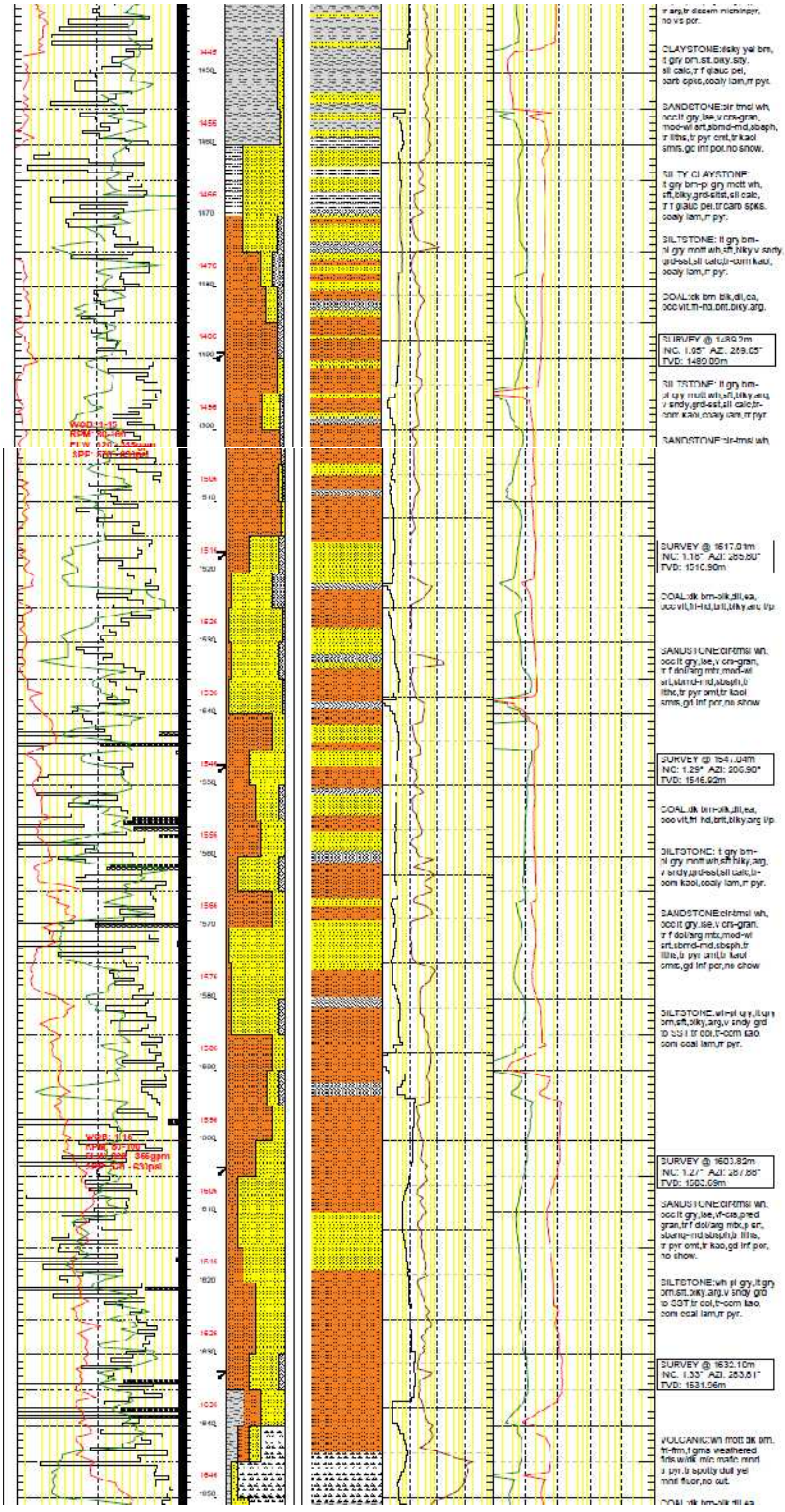


Figure 2: Mud log (Drill & Gas) data over zone of interest

Logging While Drilling Data

LWD-gamma ray - resistivity were run in the 12 1/4" hole to monitor formation penetrated to TD.

Wireline Log Data

Wireline PEX-HRAL-MSIP-SP was acquired. High resolution PEX data was recorded from 1145m-TD. HRAL-MSIP-SP recorded from 735m-TD with MSIP recorded in casing to seabed. High resolution Neutron was noisy and required filtering, the filter used was a Gaussian with 4 frames either side.

Suite/Run	Service Company	Tool String	Interval (mRT)
1/1	Schlumberger	PEX-HRAL-MSIP-SP-GR	75-1764

Table 1: Log Data Acquired

Core Data

Not acquired.

Formation Test Data

Not acquired.

BOREHOLE DATA

Hole Conditions

The borehole conditions over the reservoir section in Craigow-1 were good at the time of logging. Apart for several rugose intervals in the upper shales (the 300 interval), best highlighted by the DRHO and HCAL logs, the recorded log data reflects the formation response correctly.

Mud Properties

The $12^{1}/_{4}$" hole section was drilled using KCL/PHPA/CLAYSEAL mud with chloride concentration of 51000mg/L at mud weight of 1.21g/cc.

Bottom Hole Temperature

Formation temperature for the purposes of this analysis was calculated using the bottom hole temperature supplied. Maximum recorded was 75.5^{O}C in the 12 1/4" hole at from the wireline tool at TD.

RESERVOIR QUALITY

The Eastern View Coal Measures is a large unit and is best described as highly variable consisting of coal, sandstone, silt and shale layering. There are several reasonably thick sandstone intervals which are clean and show a porosity range from 25-30% and are water saturated. Both King-1 and Barramundi-1 which are located either sided of Craigow-1 showed thicker sand intervals. Cuttings descriptions report no shows throughout the sandstones and the gas logs do not vary far from the background level.

LOG ANALYSIS METHODOLOGY

Log Quality Control and data editing

Wireline log data was loaded from DLIS files into Petrolog software. The logs were checked for depth-matching and general acquisition quality. Where available the high resolution logs were used in the analysis. Compressional and shear logs were processed from the sonic full waveform data over both open and cased hole, this is detailed in the Craigow-1 sonic report.

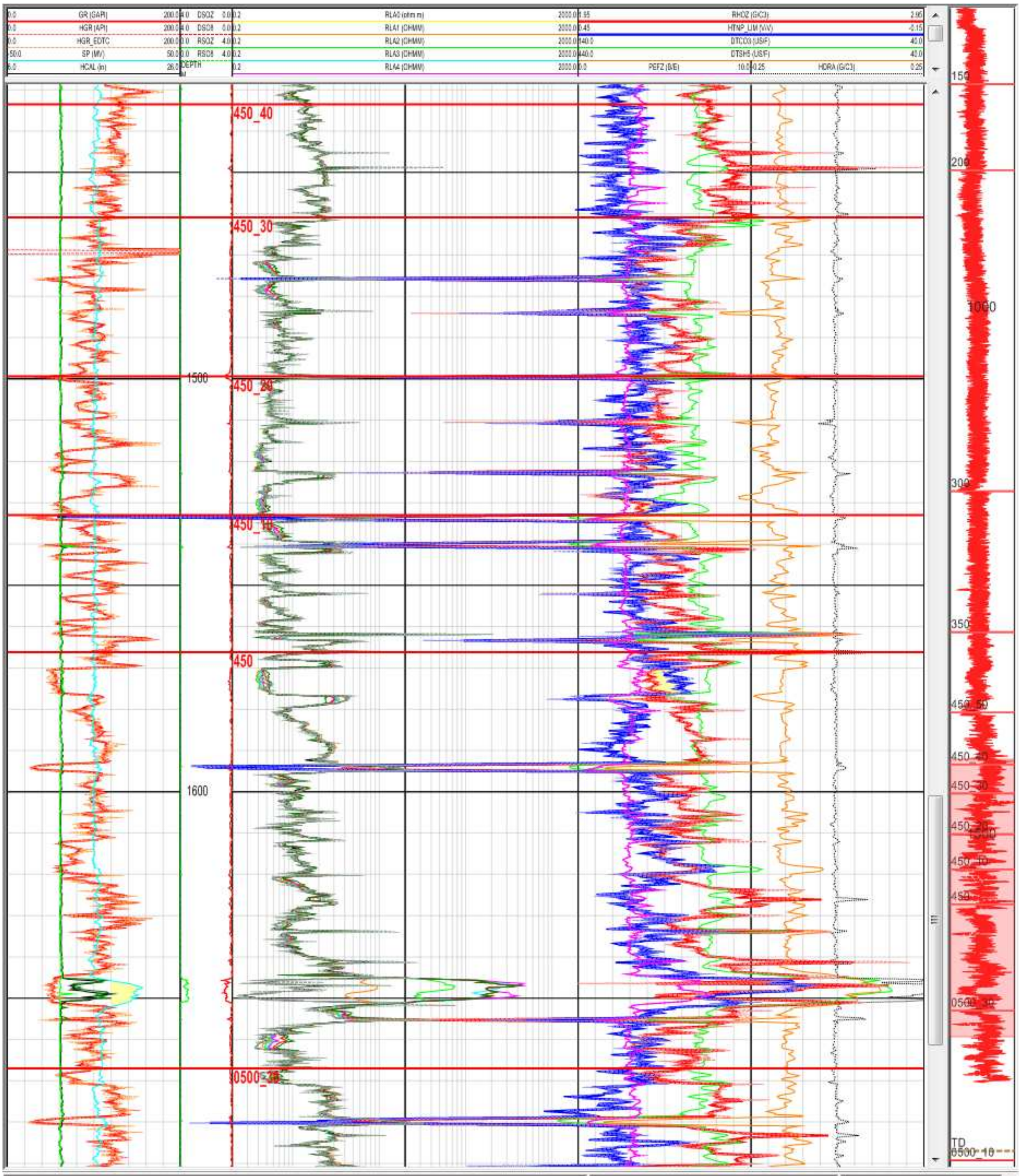


Figure 3: Recorded log data

Environmental Corrections

PEX data is typically field corrected.

Rt Determination

The HRLA resistivity data set can include a computed formation resistivity log (RT-HRLT) invaded zone resistivity (RXO-HRLT) which were both used for the analysis.

Interpretation Technique

Craigow-1 was interpreted using the Petrolog software. A deterministic approach was used for this analysis of the target formations. The following is a summary of the methodology utilised for this analysis:

- QC and depth match raw log data
- Utilise the CPX formation model
- Estimate volume of clay (minimum of D-N and GR - Linear)
- Estimate total and effective porosity (Density – Neutron)
- Estimate total and effective water saturation (Indonesia Equation)
- Estimate permeability (Coates equation).

Volume of Clay Determination

Volume of clay (Vclay) was estimated with the minimum value technique and the final Vclay log using the standard linear equation (red curve in figure 4). There was a close agreement between the GR (black VGR curve in figure 4) and Density-Neutron (orange VDN curve in figure 4) Vclay values over the full interval. Final parameters used are summarised in table 2 in the Porosity Determination section of the report.

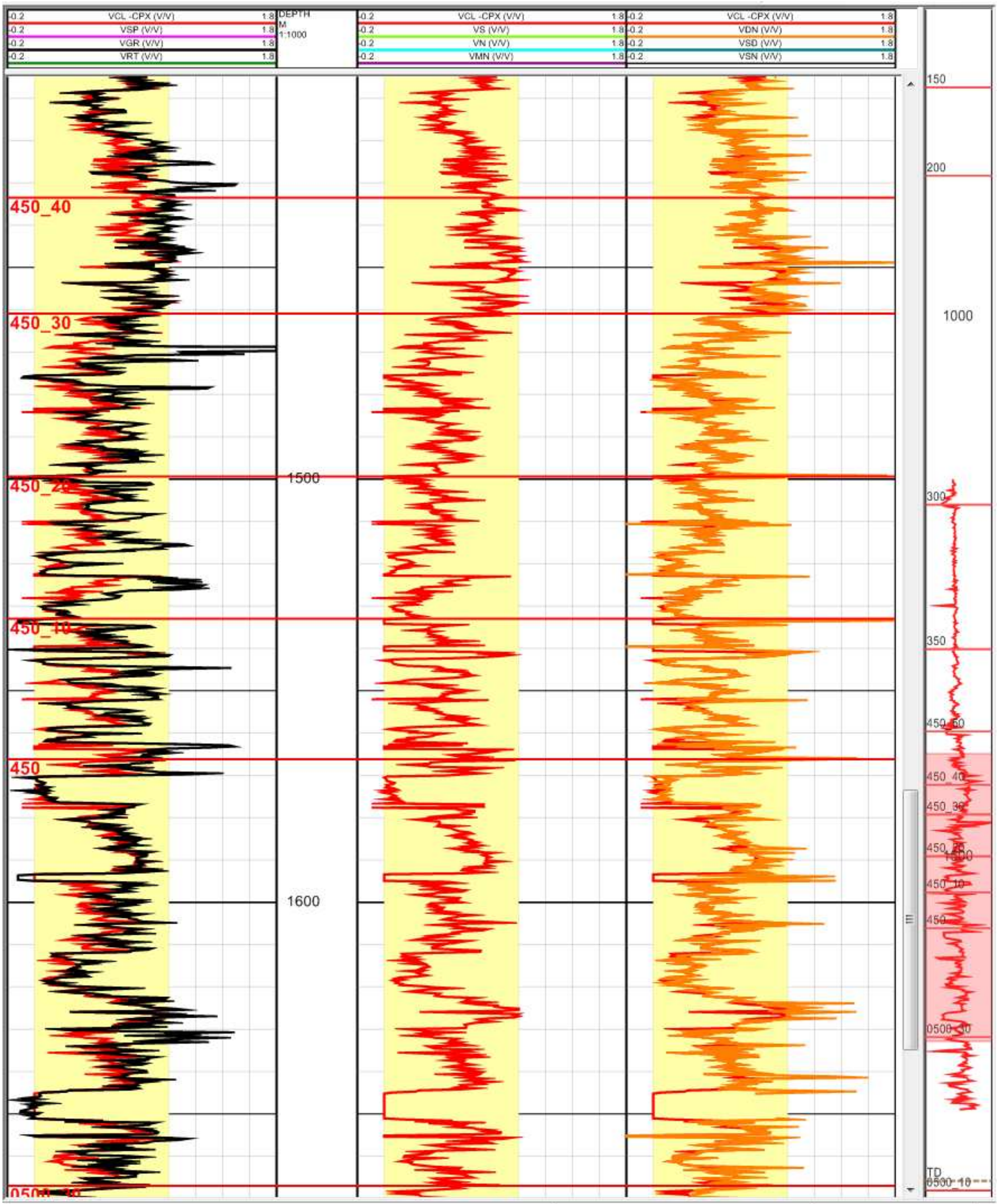


Figure 4: Volume of clay plot showing Vclay (red) from minimum of DN (orange) and GR (black)

Porosity Determination

A Silt-Sand-Shale (SSS) model was used over the processed interval to compute porosity. In good hole conditions RHOB is used to compute porosity using the equations:

PHIE = (RHOB - Vclay * (RHOBclay - RHOMA) - RHOMA) / (RHOF - RHOMA)

PHIT = (RHOB - Vclay * (RHOBdry - RHOMA) - RHOMA) / (RHOF - RHOMA)

The wet and dry clay points chosen are displayed on the figure 5 cross-plot. Note that the wet clay point can be defined from the log data, while a definitive dry clay point is not available from log data and must be calibrated against core porosity measurements.

Outputs from this equation were then quality controlled against porosity calculated from the sonic porosity (utilising the Raymer-Hunt-Gardiner transform), see figure 6. The key matrix, fluid and clay parameters used are summarised in Table 2.

Zone (Interval)	GR	GR	ρ_{ma}	ρ_{cl}	$NPHI_{ma}$	$NPHI_{cl}$	DT_{ma}	DT_{cl}
	min	max	(g/cc)	(g/cc)	(v/v)	(v/v)	(us/ft)	(us/ft)
300 (1145-1308m)	0	70	2.65	2.15	-0.035	0.5	55.5	126
350 (1308-1395m)	15	84	2.65	2.26	-0.035	0.42	55.5	115
450_50 - 450 (1395-1584m)	15	105	2.65	2.43	-0.035	0.39	55.5	103
450 - 0500_30 (1584-1737m)	18	105	2.65	2.43	-0.035	0.39	55.5	103

Table 2: Analysis parameters for Vclay and porosity determination.

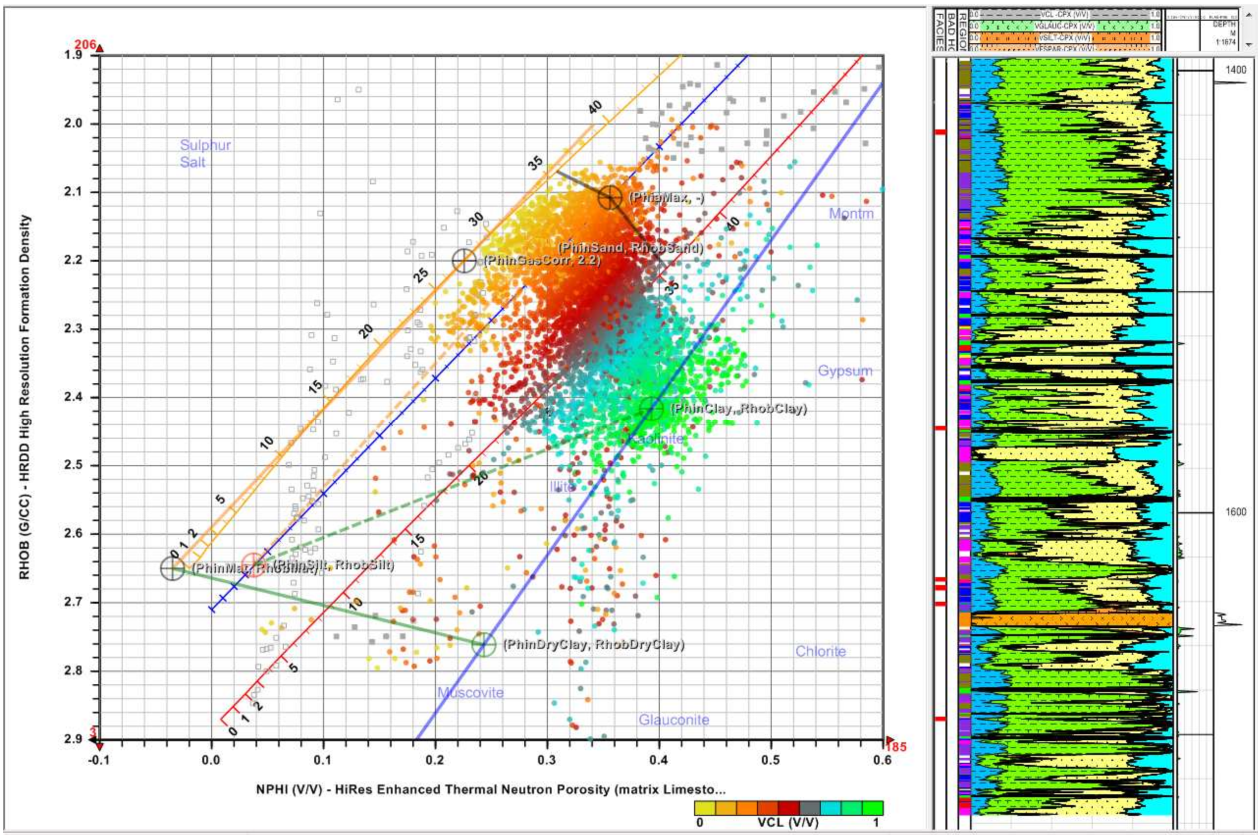


Figure 5: D-N cross-plot showing matrix and clay points for porosity determination below the 450_50 marker.

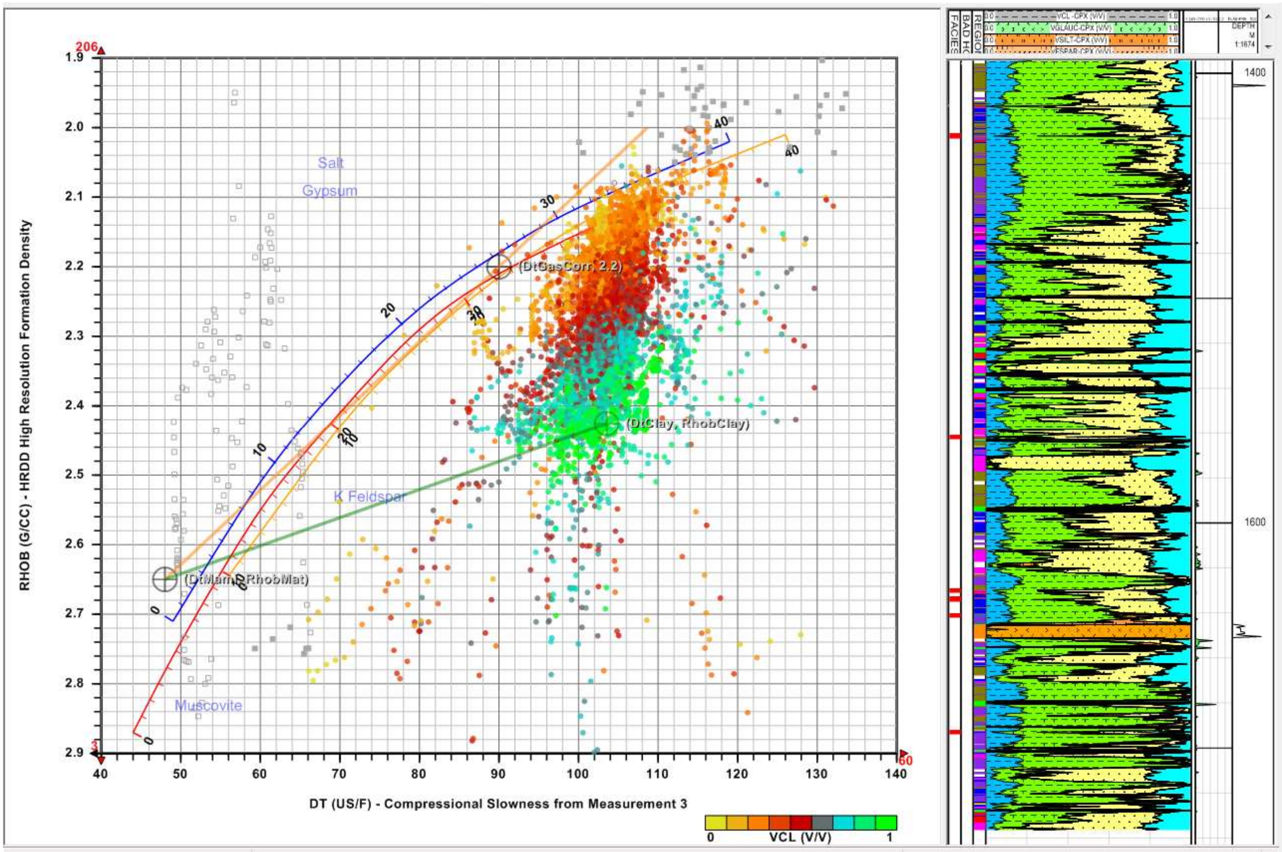


Figure 6: D-S cross-plot showing matrix and clay points for porosity determination below the 450_50 marker.

Permeability Determination

Permeability has been computed from the porosity using a Coates equation as defined below. Ideally a porosity-permeability relationship should be derived for core analysis, this can either be used to define a log-linear relationship or adjustments to the parameters in the Coates equation. With limited core in King-1 a reasonable Coates relationship was established and used in this well.

Coates permeability (k):

K = Gascoef * (Kcoef * PHIE ^ Exp) / (SWirr^2)

Where

Kcoef = the Coates Coefficient.

EXP = the Coates Exponent.

SWirr = Irreducible water saturation for a zone.

The value set for the above were

K=62500

EXP=6

Rw Determination

Various methods of determining the formation water were investigated as follows:

- **SP**

SP showed very little response, however this can be expected when the mud and formation water salinity are similar. Over the cleaner high porosity interval at 1570mMD the SP deflection is 0 which gives an Rw estimate of 0.084ohmm @ 68.8DegC (~40kppm). Lower in the section the SP deflection is closer to 5 which shows a lower formation water salinity.

- **Recovered Water Sample**

Not acquired.

- **Rwa Method**

The apparent water resistivity (Rwa) is calculated using the basic Archie equation assuming that Sw = 100%.

From the GR vs. Rwa cross-plot, using the Archie equation, a value of 0.063ohmm @ 68.8DegC or 55,000ppm NaCl equivalent was interpreted (figure 7). Lower in the well the apparent formation water salinity is less, a value of 0.078ohmm@73.6DegC or 40,000ppm NaCl equivalent was interpreted (figure 8). This variation with depth is looked at in more detail later in this report.

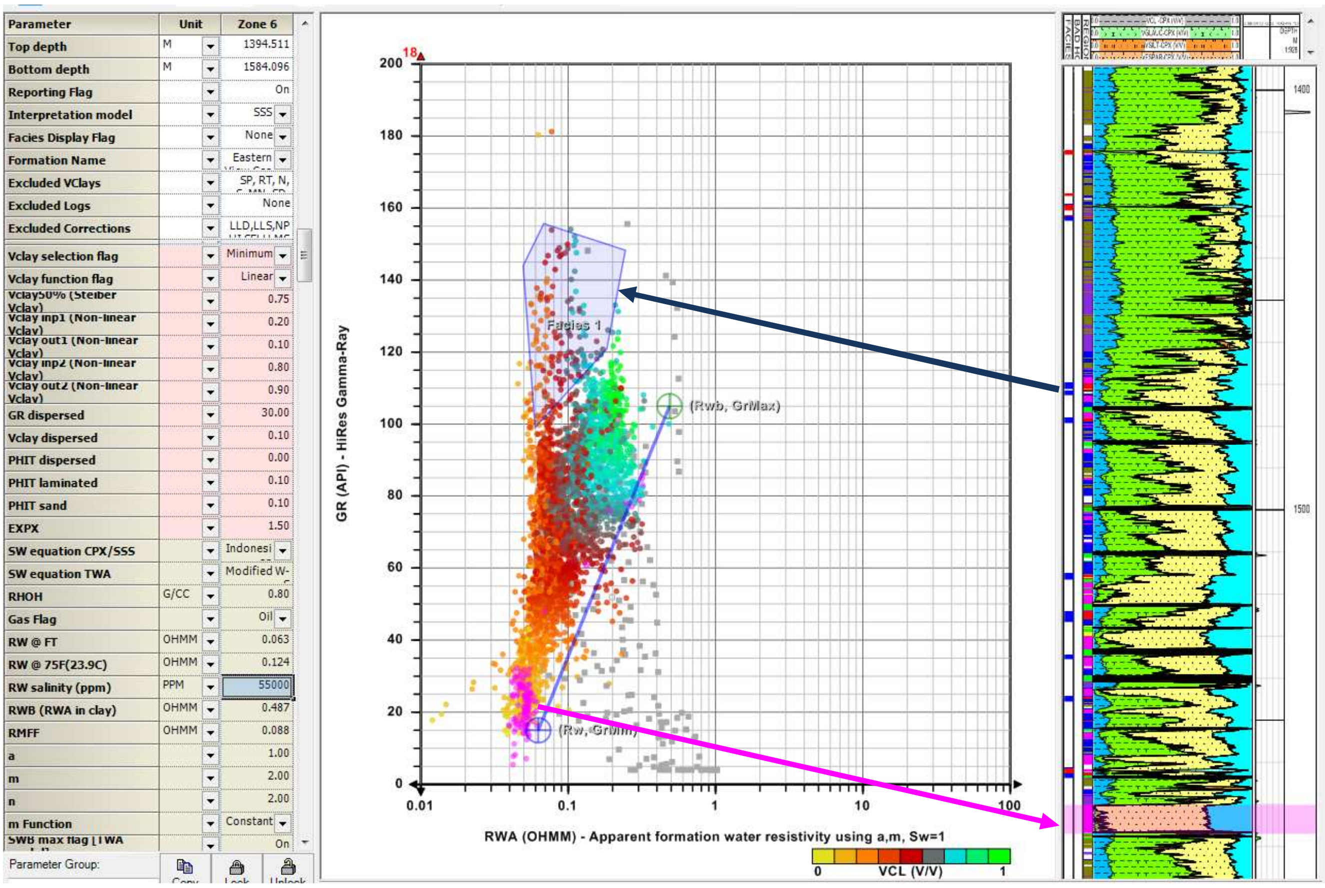


Figure 7: Rwa - GR cross-plot using 55,000ppm NaCl equivalent above ~Z_0450

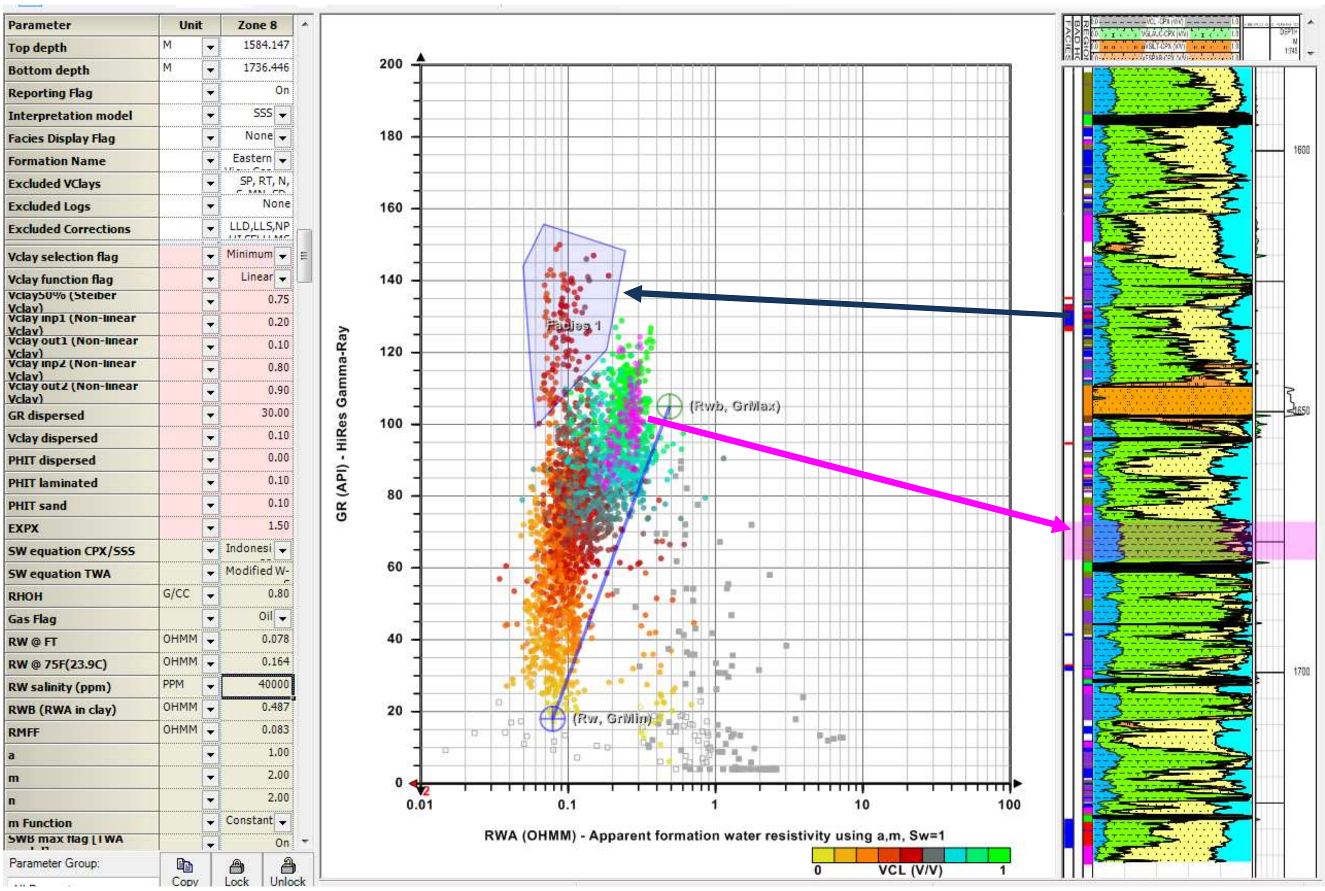


Figure 8: Rwa - GR cross-plot using 40,000ppm NaCl equivalent below ~Z_0450

Saturation Evaluation

Water saturation in this analysis was determined using an effective saturation model with the Indonesia equation clay corrections.

Archie Equation:

$$SW^n = \frac{FRw}{Rt}$$

Where

$$F = \frac{a}{PHIe^m}$$

S_W = Water saturation

a = 1.0

Rw = Formation water resistivity

RT = True formation resistivity

PHIe= Effective Porosity

m = 2.0 (Cementation factor)

n = 2.0 (Saturation exponent)

In both models the Indonesia equation to compensate for Vclay has been used as follows:

$$Sw = \left(\frac{1.0}{Y\sqrt{RT}}\right)^{2/n}$$

$$Y = \frac{Vcl^{(1-0.5Vcl)}}{\sqrt{RT}} + \frac{PHIe^{m/2}}{\sqrt{aRw}}$$

$$Sw = \left(\frac{1.0}{Y\sqrt{RT}}\right)^{2/n}$$

Saturation Equation Parameters:

In the absence of representative electrical properties information from core or otherwise, the m factor can be derived from a Pickett Rwa plot (figure 9, filtered of VCL<30%) when there is a significant variation in porosity for a constant water saturation. Default values listed above were used, note a variation in porosity from clay or silt volume increasing is not the variation we can use to define these parameters.

A mean Rclay value of 5-6ohmm was determined from the HRLA. Rclay used in the analysis for the Rwa vs. GR cross-plot (figure 8 & 9) is typically set to the high side of the shale resistivity cloud to reduce hydrocarbon computed in the shales.

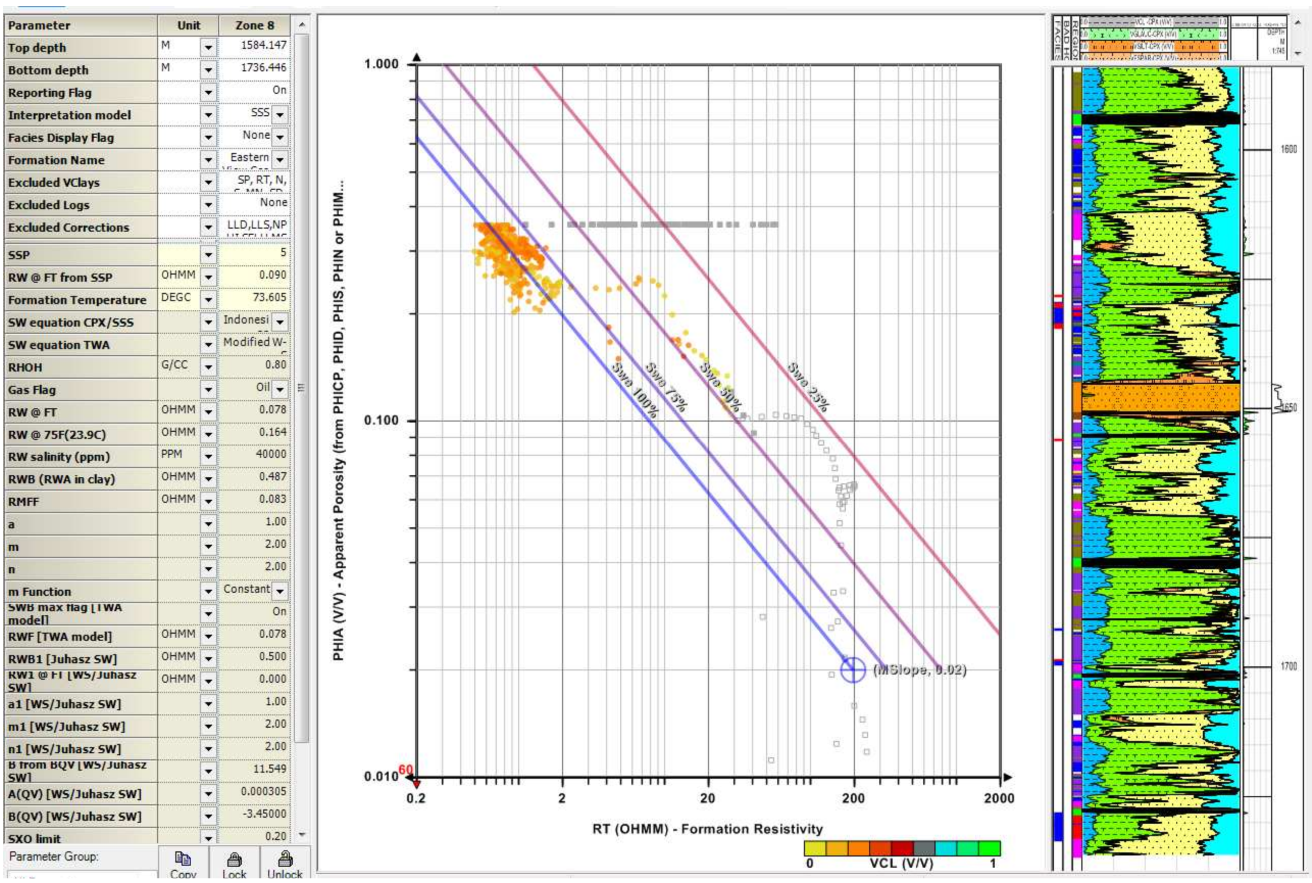


Figure 9: Pickett plot for the interval below ~Z_0450 (VCL<30%)

Formation water salinity variation with depth

There is a fairly clear change in formation water salinity over the processed interval. The salinity drops from 55,000ppm to 40,000ppm below 1584mMD. Figures 7 & 8 show RWA in the zone either side of this depth.

King-1 showed a similar change in formation water salinity at approximately 1530mMD. In this well the Salinity dropped from 55,000ppm to 40,000-45,000ppm also.

Barramundi-1 again showed a salinity change with depth. There was no easily definably split in this well, after several adjustments the final boundary was pick at 1680mMD, The salinity above was interpreted at 40,000ppm and 30,000ppm below, This is fresher than Craigow-1 and King-1.

PAY SUMMARY RESULTS

HYDROCARBON VOLUME REPORT - Craigow-1_2inch - Measured Depth Results

Report Generated By Saros
Petrolog Version Version 10.6 (Beta)
Report Date 13/02/2011
Report Time 2:03 PM

Zone Method By Strata
Analysis Uncertainty P50 (Expected)
Cutoff Uncertainty P50 (Expected)
Min. Included Thickness 0.200 M

Net Reservoir Vclay Cutoff 40.0 %
PHIE Cutoff 5.0 %
Net Pay SWE Cutoff 50.0 %

FORMATION	FROM M	TO M	GROSS INTERVAL M	RESERVOIR INTERVAL M	RES AVE VCL %	RES AVE PHIE %	RES AVE PERM MD	NET AVE SWE %	NTG %	PAY INTERVAL M	PAY AVE VCL %	PAY AVE PHIE %	PAY AVE PERM MD	PAY AVE SWE %
300	1174.1	1308.0	133.9	1.067	17.335	11.076	6.832	86.99	1%	0.0				
350	1308.0	1384.0	76.0	8.026	26.648	21.397	124.246	99.96	11%	0.0				
450_50	1384.0	1433.5	49.5	5.283	28.582	21.328	111.859	100.00	11%	0.0				
450_40	1433.5	1460.9	27.4	0.0					0%	0.0				
450_30	1460.9	1499.4	38.5	15.646	28.94	21.458	100.171	99.94	41%	0.0				
450_20	1499.4	1533.0	33.6	21.946	21.895	24.718	232.153	99.72	65%	0.0				
450_10	1533.0	1566.2	33.2	12.446	23.608	22.875	153.981	100.00	37%	0.0				
450	1566.2	1667.0	100.8	30.734	21.955	22.338	144.081	98.77	30%	0.0				
0500_30	1667.0	1799.996	132.996	18.745	23.351	22.041	105.787	99.90	14%	0.0				
	TOTAL		**625.896**	**113.894**	**23.908**	**22.467**	**145.62**	**99.46**	**18%**	**0.0**				

VCL<40% (above) vs. VCL<30% (below)

HYDROCARBON VOLUME REPORT - Craigow-1_2inch - Measured Depth Results

Report Generated By Saros
Petrolog Version Version 10.6 (Beta)
Report Date 13/02/2011
Report Time 2:07 PM

Zone Method By Strata
Analysis Uncertainty P50 (Expected)
Cutoff Uncertainty P50 (Expected)
Min. Included Thickness 0.200 M

Net Reservoir Vclay Cutoff 30.0 %
PHIE Cutoff 5.0 %
Net Pay SWE Cutoff 50.0 %

FORMATION	FROM M	TO M	GROSS INTERVAL M	RESERVOIR INTERVAL M	RES AVE VCL %	RES AVE PHIE %	RES AVE PERM MD	NTG %	PAY INTERVAL M	PAY AVE VCL %	PAY AVE PHIE %	PAY AVE PERM MD	PAY AVE SWE %
300	1174.1	1308.0	133.9	0.965	15.594	10.802	6.972	1%	0.0				
350	1308.0	1384.0	76.0	3.912	18.826	22.97	196.375	5%	0.0				
450_50	1384.0	1433.5	49.5	2.083	19.524	25.656	227.615	4%	0.0				
450_40	1433.5	1460.9	27.4	0.0				0%	0.0				
450_30	1460.9	1499.4	38.5	5.944	21.237	24.552	190.144	15%	0.0				
450_20	1499.4	1533.0	33.6	14.63	16.194	26.821	314.957	44%	0.0				
450_10	1533.0	1566.2	33.2	7.518	16.238	25.363	229.421	23%	0.0				
450	1566.2	1667.0	100.8	19.456	14.772	24.516	204.345	19%	0.0				
0500_30	1667.0	1799.996	132.996	13.208	18.828	23.306	134.687	10%	0.0				
	TOTAL		**625.896**	**67.716**	**16.993**	**24.625**	**213.636**	**11%**	**0.0**				

Below shows the summary results using Permeability cut-off for NET instead of VCL

HYDROCARBON VOLUME REPORT - Craigow-1_2inch - Measured Depth Results

Report Generated By	Saros	Report Date	17/02/2011
Petrolog Version	Version 10.6 (Beta)	Report Time	7:24 AM

Zone Method	By Strata
Analysis Uncertainty	P50 (Expected)
Cutoff Uncertainty	P50 (Expected)
Min. Included Thickness	0.200 M

Net Reservoir	Vclay Cutoff	100.0 %
	PHIE Cutoff	5.0 %
Net	SWE Cutoff	100.0 %
Net Pay	SWE Cutoff	50.00%
Other Reservoir Conditions:		10 < K -CPX < 100000

FORMATION	FROM M	TO M	GROSS INTERVAL M	RESERVOIR INTERVAL M	RES AVE VCL %	RES AVE PHIE %	RES AVE PERM MD	NET AVE SWE %	NTG	PAY INTERVAL M	PAY AVE VCL %	PAY AVE PHIE %	PAY AVE PERM MD	PAY AVE SWE %
300	1174.1	1308.0	133.9	0.0					0%	0.0				
350	1308.0	1384.0	76.0	16.358	36.207	19.709	72.765	99.957	22%	0.0				
450_50	1384.0	1433.5	49.5	9.195	34.232	19.685	72.978	99.998	19%	0.0				
450_40	1433.5	1460.9	27.4	0.0					0%	0.0				
450_30	1460.9	1499.4	38.5	21.082	32.261	20.382	79.534	99.956	55%	0.0				
450_20	1499.4	1533.0	33.6	26.365	25.317	23.435	196.667	99.76	78%	0.0				
450_10	1533.0	1566.2	33.2	15.291	27.389	21.933	129.074	100.0	46%	0.0				
450	1566.2	1667.0	100.8	34.798	24.838	21.866	128.356	99.286	35%	0.0				
0500_30	1667.0	1799.996	132.996	20.98	25.373	21.453	96.063	99.894	16%	0.0				
	TOTAL		**625.896**	**144.069**	**28.251**	**21.499**	**119.24**	**99.757**	**23%**	**0.0**				

DATA GROUPING AND ASSOCIATED LITHOLOGY

The data appears to contain many repeating facies. This is an attempt to plot those and compare the recorded logs, interpretation and location on key cross-plots used in this report. Over the next two pages we show most of the interpreted interval vs. a 1-10 flag (colour bar on right in figures 10 &11) and Density-Neutron, Density-Sonic and GR-Resistivity cross-plots.

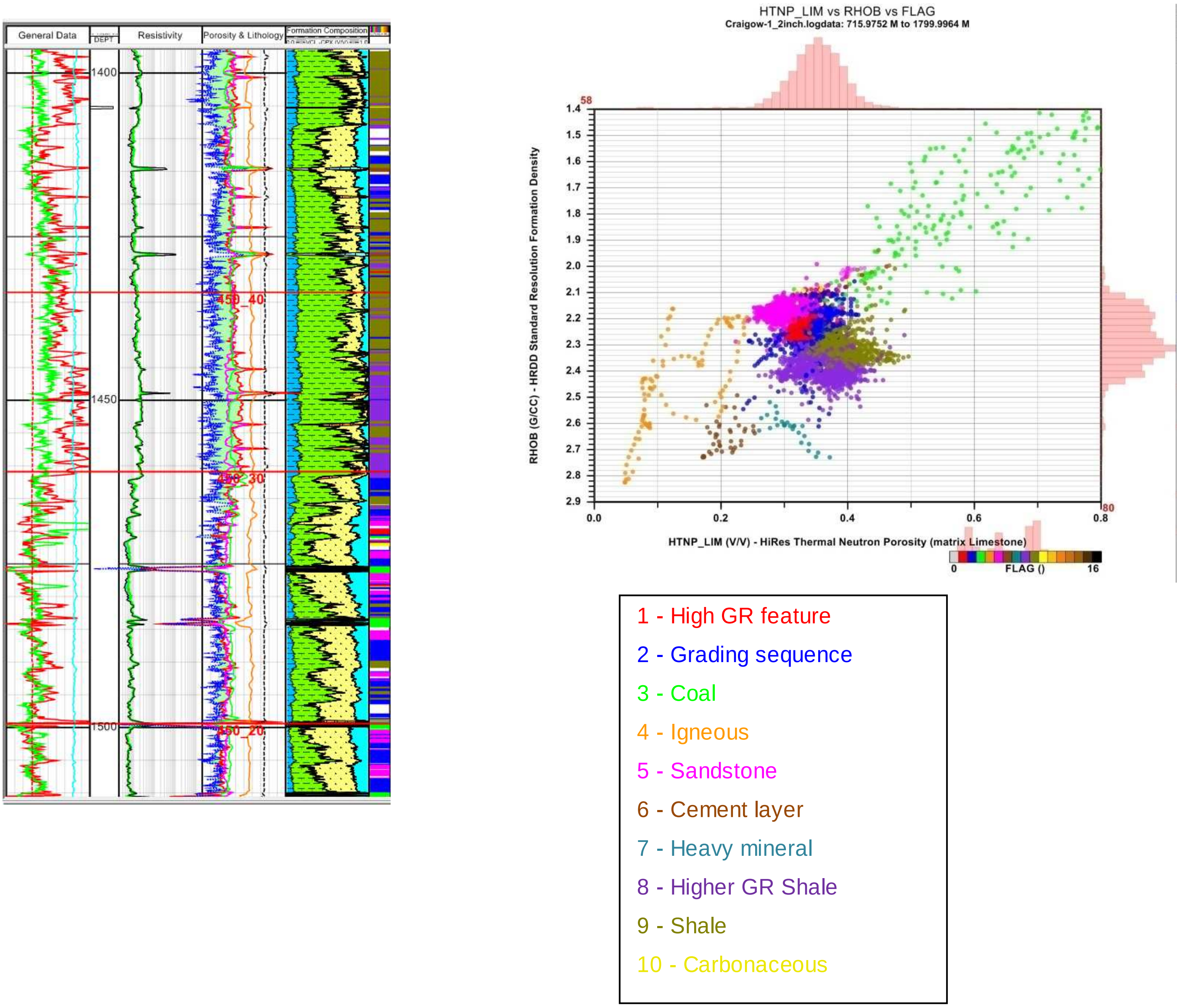
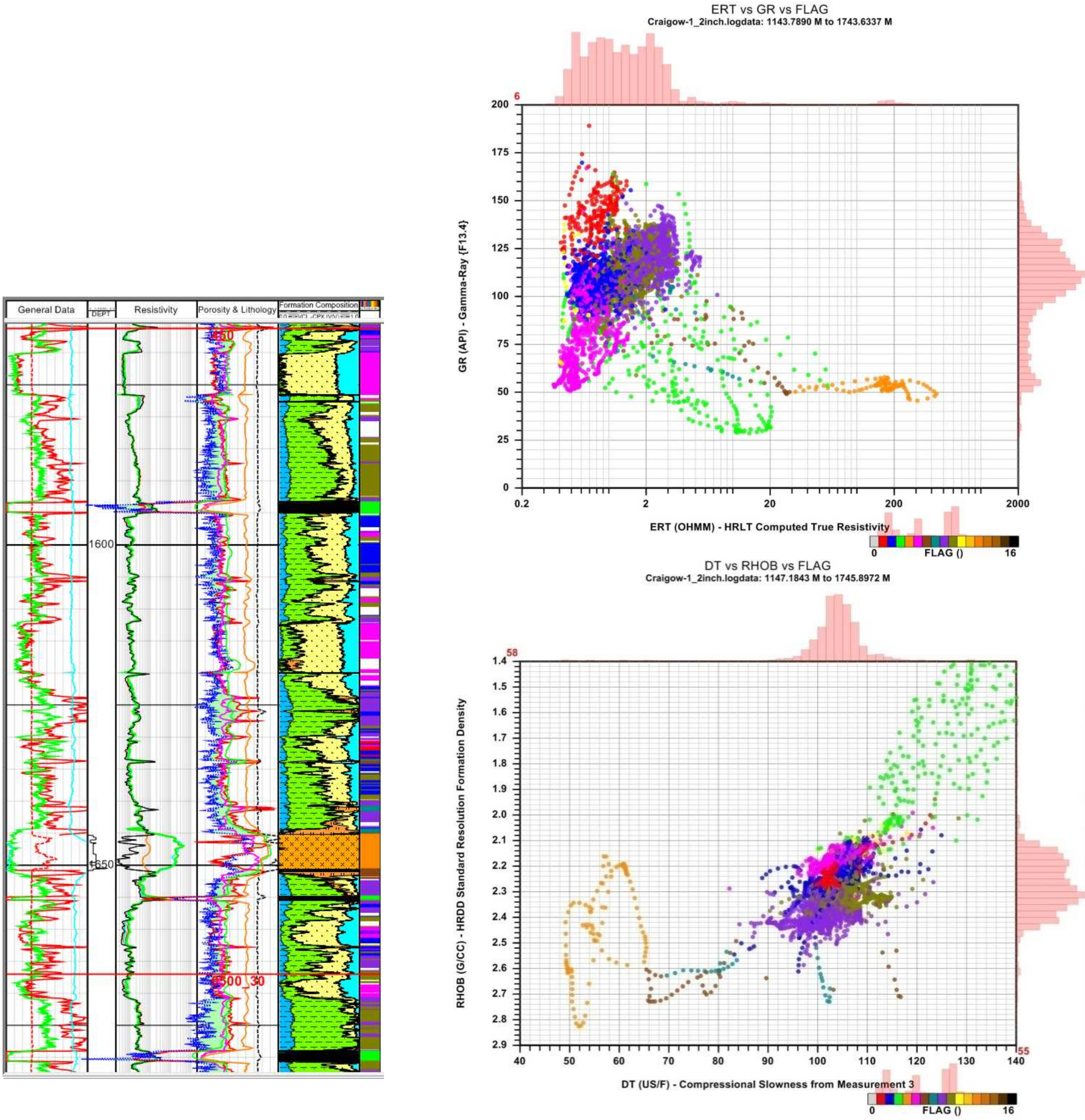


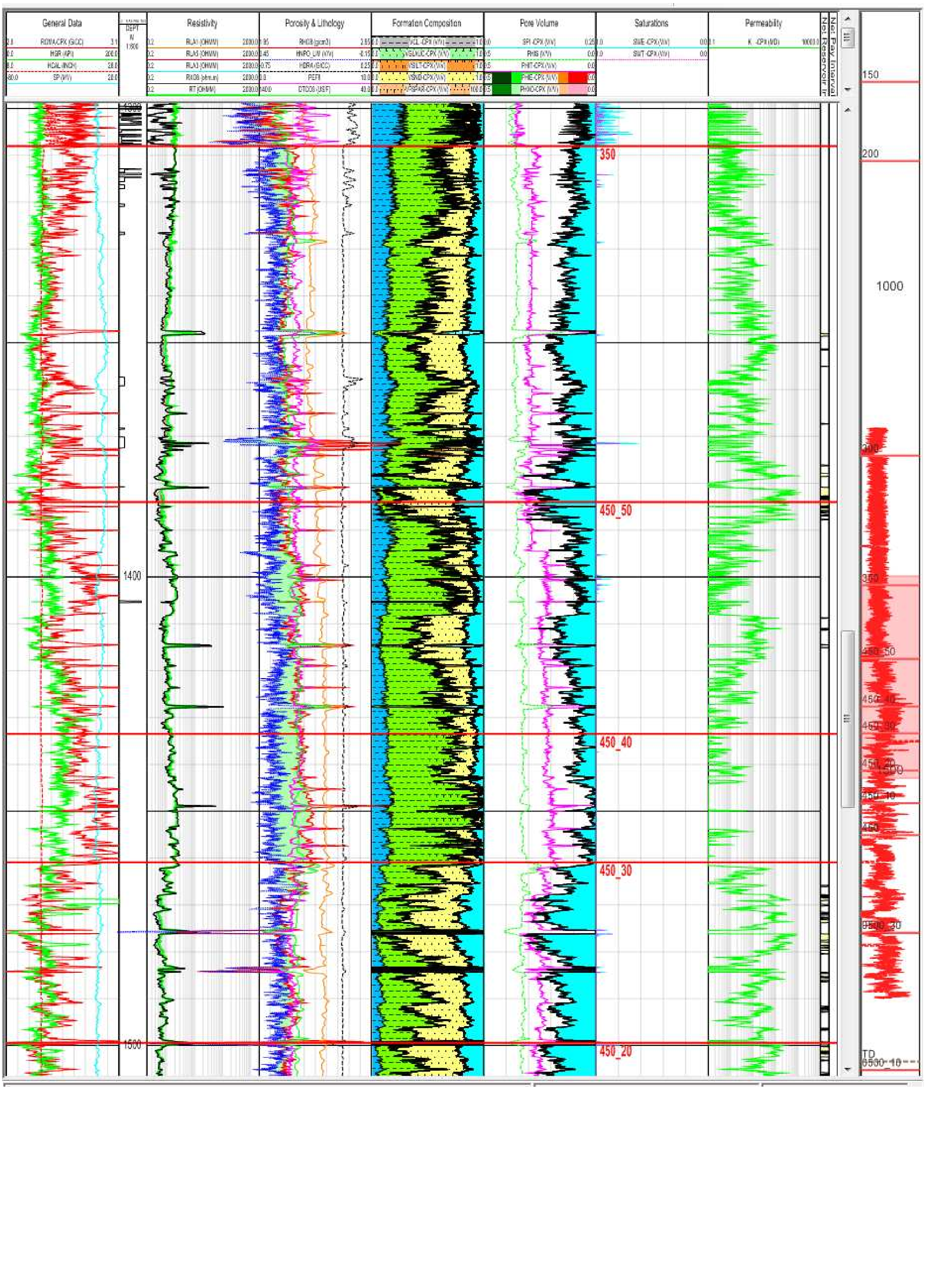
Figure 10: Data grouping



1 - High GR feature
2 - Grading sequence
3 - Coal
4 - Igneous
5 - Sandstone
6 - Cement layer
7 - Heavy mineral
8 - Higher GR Shale
9 - Shale
10 - Carbonaceous

Figure 11: Data grouping

GRAPHICAL RESULTS



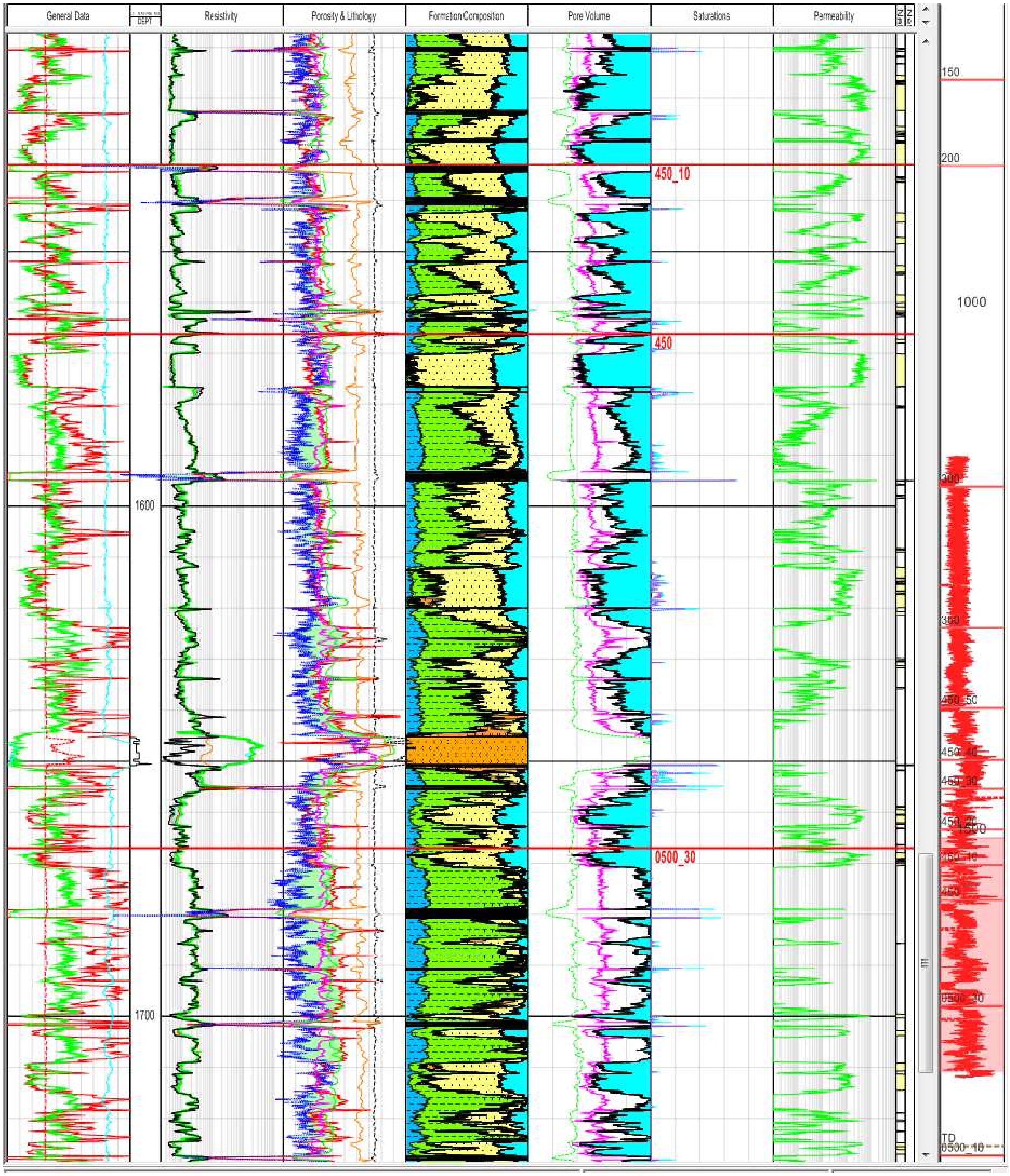


Figure 12: Complex lithology plot

Track 1-4 show the original input logs.
Track 5 displays the following from left to right

- *VBW: Clay bound water volume*
- *Vcl: Dispersed clay volume*
- *Vsand: Volume of sand*
- *PHIe: Effective porosity*

- *PHIe*Sw: Volume of hydrocarbon*
- *PHIe*Sxo: Moved hydrocarbons*

Track 4 displays the porosity (0.5-0).
Track 5 displays the formation water saturation.
Track 6 shows the permeability.
Track 7 is the net flag using the following cut-off: PHIe>5% and Vclay < 40%.
Track 8 is the pay flag using the additional cut-off: Sw<50%.

ENCLOSURE 1: COMPOSITE SUMMARY DEPTH PLOT (1:500)