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BRITISH GEOLOGICAL SURVEY

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Keywords

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Foreword and acknowledgements

This report is a published product of the 21st Century Exploration Road Map (21CXRM) Palaeozoic project. This joint industry-Government-BGS project comprised a regional petroleum systems analysis of the offshore Devonian and Carboniferous in the North Sea and Irish Sea.

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Summary

This report details the source rock total organic carbon (TOC) content calculated from geophysical logs for 31 wells across the Palaeozoic rocks of the UK Central North Sea for the 21CXRM Palaeozoic project. A companion report examines the reservoir evaluation of 12 wells based on petrophysical evaluation of digital wireline log curve data (Hannis, this study).

The TOC weight % was calculated for source rock intervals using geophysical well logs calibrated to measured TOC values from core and/or cuttings in the petrophysics software Interactive Petrophysics (IP™), which uses the TOC estimations equations defined by Passey et al. (1990).

The Passey et al. method is most reliable in thick shale intervals and cannot calculate TOC in coals and reservoir intervals, which were removed from the analyses. Where possible the geographical distribution of calculated TOC was commented on, however, in general the spatial distribution of the assessed wells was too great to make any confident extrapolations of TOC on a regional scale.

Petrophysical log analysis has been used as a regional screening tool to highlight potential TOC rich source rock intervals (shales), over larger depth ranges than is available for core/cuttings sample data. Given time constraints, data availability and the variable nature of the Carboniferous sedimentation, kerogen types have not been taken into consideration. To further the work presented in this report, investigation of the kerogen type in conjunction with the calculated TOC would give a more complete understanding of the hydrocarbon source rocks.

Outputs of this part of the project include continuous (along borehole) interpretations of total organic content and clay volume. These interpreted curves were used to calculate net shale to gross formation thickness, 'pay' TOC rich (>1 wt%) shale thickness to gross formation thickness (known as Pay to Gross in this report (P/G)) and calculated TOC over the net shale thickness.

The source rock formations (according to the reinterpreted stratigraphic formations defined and correlated for this project) assessed for TOC calculation and a summary of the results are given in Table 1.

In summary, the results indicate significant thicknesses of organic rich shale through the Carboniferous succession.

The Lower Devonian had very low calculated TOC of 0.7 wt% and P/G of 0.07, however, the cutting measured TOC suggest even these figures may be an overestimation.

Table 1: A summary of the calculated TOC, P/G and Pay Thickness for each potential source rock formation. (* The pay thickness does not remove wells where total drilling depth (TD) was reached within the target formation)

Formation	*n*	Avg TOC over Net Shale thickness (calculated wt %)	Pay (TOC >1wt%) thickness to gross formation thickness	Avg Pay Thickness* (m)
Coal Measures Group	7	0.8-3.3	0.08-0.61	46.1
Millstone Grit Formation	12	1.4-2.7	0.18-0.71	239.5
Yoredale Formation	8	1.1-3.4	0.37-0.74	294.8
Scremerston Formation	10	1.4-2.7	0.20-0.65	175.0
Cleveland Group (incl. Upper Bowland Shale)	6	1.5-3.4	0.64-0.98	678.1
Upper Bowland Shale	6	1.4-3.4	0.64-0.93	57.6
Lower Devonian	1	0.7	0.07	4.7

1 Introduction

The 21CXRM Palaeozoic Project aimed to stimulate exploration of the Devonian and Carboniferous plays of the Central North Sea - Mid North Sea High - Moray Firth - East Orkney Basin and in the Irish Sea area. The objectives of the project included regional analysis of the plays and building of consistent digital datasets, whilst working collaboratively with the OGA, Oil and Gas UK and industry.

The project results are delivered as a series of reports and as digital datasets for each area. This report describes the methodology and results of a regional-scale petrophysical study of source rock total organic carbon content in the Central North Sea study area.

Traditionally, assessments of total organic carbon (TOC) in shales for source rock estimations are done using laboratory measurements on core samples or cuttings samples. However, core data are generally very limited in both geographic and stratigraphic extent, and cuttings in particular are affected by a number of drilling-related problems such as contamination and poor depth control. More recently therefore, methods to calculate weight percent (wt %) TOC continuously along well bores have been devised using analysis of geophysical well logs (Passey et al. 1990).

The Passey et al. method is most reliable in thick shale intervals and cannot calculate TOC in coals and reservoir intervals, which were removed from the analyses. This study is aimed at assessing the additional potential source of the shale intervals rather than the gas mature coal sources.

The key aim of this report is to present TOC estimates for 31 wells across Quadrants 26-44 of the Central North Sea including graphical log displays. The intervals of interest are:

- The Coal Measures Group
- The Millstone Grit Formation
- The Yoredale Formation
- The Scremerston Formation
- The Cleveland Group (including the Upper Bowland Shale)
- The Lower Devonian

2 Method

The method used for the study is outlined below:

1. **Literature search:** study of literature relating to methods of deriving TOC weight percent from geophysical logs and level of maturity (LOM) from vitrinite reflectance with reference to the appropriateness of deploying these methodologies and choosing suitable parameters for this study.
2. **Locating and uploading data:** relevant geophysical log curves located and extracted from RECALL database. Measure total organic carbon values located and digitised for the wells with cuttings and core data available. All data loaded into petrophysics software Interactive Petrophysics (IP) for further analysis.

3. **Verification of data:** verification of formation tops and log quality assessment using data from a variety of sources. If inconsistencies were found, the most reliable source of data was selected.
4. **Analysis and calculations using geophysical well logs:** various calculations undertaken to determine LOM (for certain formations) for use in IP, TOC (from the Passey method) and the volume of clay (VCl).
5. **Presentation of results:** the TOC results are displayed with graphical logs, histograms, cross plots and tabulated plots by formation. Total organic carbon statistics for each formation include averages, max/min and thicknesses of high TOC intervals relative to total reservoir thickness.

2.1 LITERATURE SEARCH

Passey et al. (1990) developed a method to quantitatively calculate TOC in weight percent from level of maturity (LOM) estimations and log responses in lean versus organic rich shales using a log overlay method known as ΔlogR. The resistivity curves were overlaid against either sonic, density or neutron logs at particular scales and shaded where they overlaid to indicate organic richness (See section 2.4). This method was chosen for this study as it is an industry-accepted method for calculation of TOC for shale gas and test results compared favourably with those derived by other calculation methods (not described here). Note that, in general, density log quality over the intervals of interest was not sufficiently consistent to deploy TOC-calculation methodologies relying heavily on density log data.

Hood, Gutjahr and Heacock (1975) developed the LOM scale required by in the Passey equation. The scale describes a single numerical scale applicable to the thermal range of interest. It is based on a combination of coal rank, vitrinite reflectance and spore carbonization. They inferred that Vitrinite Reflectance (known as VR or Ro, the latter will be used in this report) is directly related to LOM therefore with accurate Ro values, LOM can be calculated.

LeCompte and Hursan (2010) published a graph relating LOM and Ro with an associated equation of the line of regression (See section 2.4). This equation was used to calculate LOM from the Ro gathered from measured data for this study.

Gent, Hannis and Andrews (2014) used the Passey method to calculate TOC in Jurassic shales of the Weald Basin. The methodology outlined in Gent, Hannis and Andrew (2014) was used as the basis for the current TOC calculations. Additionally, the authors outline the effects of different maturities on the calculated TOC values.

2.2 LOCATING AND UPLOADING DATA

The well list provided contained 78 wells which were all contained in the BGS database, 'RECALL' (Figure 1).

a. The first step was to extract the well data from RECALL as *.las files to import into IP.
b. The TOC and Ro data for the wells with data available (core or cuttings derived) was extracted from a combination of individual well geochemical reports, published geochemical data and geochemical analysis held in the National Geological Records Centre. The TOC data were then formatted and loaded into IP. Use of the Ro data is described in section 2.4.

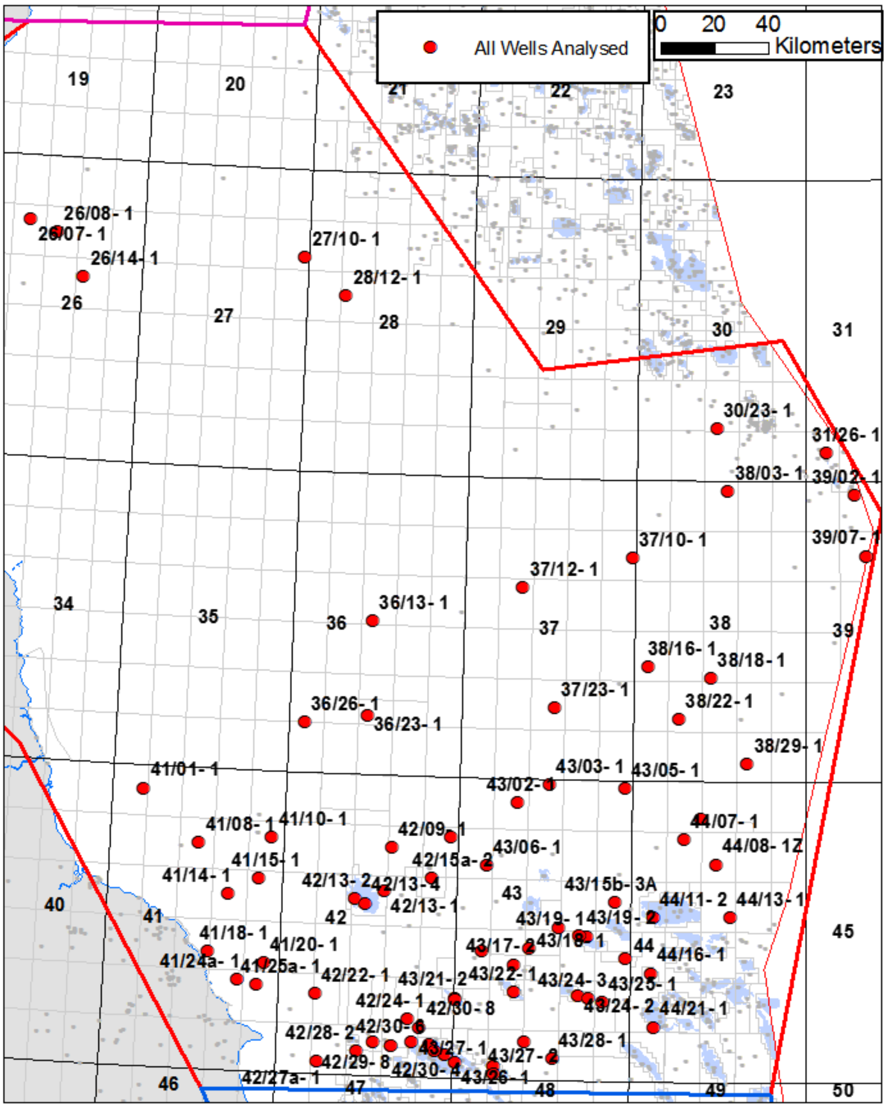


Figure 1: Location of wells assessed for TOC calculation from geophysical logs

2.3 VERIFICATION OF DATA AND QUALITY CHECKING

The data extracted required verification as follows:

a. The digital curves in IP were compared to those on the composite log plot scans:
   - Any wells without deep resistivity were discarded as the Passey method for calculating TOC relies on a deep resistivity log.
   - Verification of the curve responses with depth and their scales: any differences between the digital plot and log plot composite were noted and corrected where possible.
b. The formation tops interpreted for the 21CXRM Palaeozoic project (Kearsey et al., 2015 and well tops spreadsheet) were loaded into IP and verified.
c. The cored intervals were loaded into IP to highlight areas where known core was taken.
d. The logging curves were assessed for quality, by checking for unusual responses, checking responses were within tolerance (where suitable curves were available) and noting where poor hole conditions affected the data:
   - CALI, the caliper curve, measures hole size and indicates wash outs (enlargement) in some places, particularly in clay-rich intervals, which can reduce

the quality of other curve responses. Logs that require good contact of the measuring equipment with the borehole wall to read correctly, such as density or neutron tools, will be affected by washouts. Where the caliper was open to its maximum extent (curve flat-lining), data from those tools were treated as suspect or unreliable.

- DRHO the density correction curve should fall within the -0.1 and 0.1 range for good density (RHOB) data. Outside of this range, the density data were treated as suspect or unreliable.

Many of the wells had intervals of poor density data (DRHO out of tolerance), requiring the use of sonic data (less affected by poor hole conditions) for the Passey TOC calculations.

2.4 ANALYSIS AND CALCULATION FROM GEOPHYSICAL WELLOGS

The main objective of this study was to produce TOC curves for wells across the central North Sea, accompanied by statistical TOC outputs for each well. To be able to calculate the TOC, LOM values had to be established. In addition, clay volume curves (VCl) with a suitable cut-off value were required to be able to distinguish potential shale source rocks from clean reservoir rock. Coal identifiers and TOC curve cut off values were also applied to the final calculations

Volume of Clay (VCl): The volume of clay parameter is calculated based on the gamma ray response. The output curve is scaled between 0-1 (1 represents 100% clay and 0 represents 100% ‘clean’ reservoir). It was used as a discriminator in subsequent calculations, to remove intervals with less than 50% clay (i.e. those considered unlikely to be a source rock). Depending on the thickness of the succession, some wells were divided into two intervals and processed individually to define the GR minimum and maximum parameters required. Neutron-density data, where data of a suitable quality existed, was used to cross-verify the GR-derived VCl curves.

Level of Maturity (LOM): A key parameter in the Passey equation for calculating TOC is the level of maturity (LOM). This can be calculated from Ro values, measured on core samples (Hood et al. 1975). However the Ro values supplied from several boreholes, when plotted against depth and by formation, in general showed only very poor correlations. Therefore, ranges of values were used on a well by well basis using a combination of published maps and individual well geochemical reports. The same vitrinite reflectance data set was used in this report as the basin modelling work (Vincent, this study). Given the size, complexity and relative data paucity for the area of interest, it was not possible to utilise a simplistic maturity map, such as may be found to be sufficient in other areas (e.g. the Weald Basin). For the central North Sea study area, the type of sedimentation and complex basin history has resulted in a significant variation of Ro values over relatively short distances (tens of kilometers). The nature of vitrinite reflectance analysis is such that reworked material is often indistinguishable in appearance from autochthonous material and vitrinite reflectance data should be assessed using a range of potential maturities, rather than one single maturity value. Therefore for each interval a range of LOM values were assigned, to incorporate the maximum and minimum potential LOM values for each formation (in accordance with the literature).

Coal Discriminator: The Passey method is accurate for calculating TOC in shale intervals but not in coals; if coals are not removed they give inaccurate spikes on the calculated TOC curve. The coal signal has to be removed using discriminators based on the distinctive geophysical log response; namely, a high interval velocity, high neutron porosity and low density. This was done individually by well, comparing the responses with the mudlog lithology track from the company composite logs. The final results presented do not incorporate coals and account only for shale source rocks.

Passey Method for Calculating TOC: The TOC was calculated using the Passey-method inbuilt into the IP TOC calculator. Wells with geochemical (core or cuttings derived) data were implemented first to assist in selecting the parameters and calibrating the output TOC curve to the measured data where appropriate. In the Passey method, scaled sonic and resistivity curves were made to overlay in a 'lean shale' defined as a non-source shale. Wells with a thick logged Palaeozoic sequence were split into multiple maturity zones to represent the increasing maturity with depth (Vane, this study; Vincent, this study). The density and neutron overlay plots were used to verify those of the sonic. Where significant sonic spikes occurred (either due to noise or cycle skipping) these were recorded and removed by manual curve editing.

The output TOC curves were calculated first using the average or expected maturity. The LOM parameters were then adjusted to the maximum and minimum values (Appendix 1) and the TOCs recalculated (High Ro and Low Ro, respectively) to represent the sensitivity of TOC outputs to the LOM parameter, which is displayed as the blue shading on the TOC curve in the graphical log plots, where higher LOM values give **lower** TOC values for a given set of logs.

2.5 PRESENTATION AND EXPLANATION OF RESULTS

The main TOC findings and geographical trends are documented by Formation in Section 3. Summary tables and maps are also included. Results by well are included as appendices in the form of graphical log plots, cross plots and tables of summary statistics. The produced log plots have been terminated at either the base of the formations of interest or the base of the geophysical log data. The TOC for each formation on the log plots, as well as corresponding histograms of calculated TOC, can be found with a cumulative frequency curve. The colours used for the histograms match those denoted on the log plots and in the rest of the overarching project. For each well there are two tables of statistics, the first contains the statistics for each formation and each calculated TOC curve, including the range of calculated TOC (High Ro TOC and Low Ro TOC). The second table shows net to gross and pay to gross values for each formation and all formations combined. The net here is for shale (rather than the conventional sand-net), which was calculated using a volume of clay cut off of 50%. **Pay is defined as net shale with TOC > 1 wt%**.

Results are displayed graphically for each well in a seven track log plots; these include (in track order, left to right):

1. **Formations intervals**;
2. **Measured Depth** (MD) below Kelly Bushing (KB) in metres;
3. **Cored interval and coal indicator** track: cored intervals are distinguished with colours. Coals are indicated with black fill. Coals have been removed from the TOC curve calculations (see Section 2.4);
4. **Gamma Ray (GR) and Caliper**: GR shows natural formation gamma ray response, which tends to be higher in shales. Caliper indicates hole size and can give an indication of an enlarged or rugose hole which may affect data quality (see Section 2.3d);
5. **Volume of Clay (VCl)** with the 50% clay cut-off represented by 'clean' and 'clay rich' shading;
6. The **Passey Sonic-Resistivity curves**, with yellow shading representing TOC-rich intervals. From the right there is red shading indicating where the density correction curve is out of a 0.1 tolerance, this highlights area where the geophysical logs may be affected by poor data quality (see Section 2.3d);
7. Final **TOC values** with grey shading to indicate >1 wt% TOC, blue shading to indicate TOC range (between high Ro and low Ro) and, where possible, measured TOC values (from geochemical analysis of samples from core or cuttings).

2.6 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations should be considered when analysing the results and graphical TOC log plots:

- Formation or interval thicknesses are measured along the borehole, and do not necessarily represent the true stratigraphic thickness (depending on bedding dip and borehole deviation);
- The Level of Maturity parameter required for the Passey method TOC calculation is assumed to fall within the range chosen (Appendix 1). Values of LOM outside of this range could change the final TOC value significantly. Sensitivity on this parameter is represented by the blue shading on the log plots and the high Ro and low Ro values in the tables are based on the values in Table 1;
- The Passey method also requires the selection of a 'lean shale' point where a shale is assumed to have no organic carbon. Where possible, similar lean shale stratigraphic intervals have been chosen for each well for consistency. In general, a different "lean shale" point has been chosen for each group of formations. No sensitivity on this parameter has been done for this study, so this should be taken into consideration when examining the absolute TOC values reported here;
- The VCl parameters selected have been chosen as consistently as possible between wells, backed up by a neutron-density data where possible to be able to distinguish clean and clay-rich intervals. A cut-off of 0.5 has been arbitrarily applied to remove intervals with a low clay content;
- Stratigraphic formation tops for each well are consistent with the formation tops used in the 21CXRM Palaeozoic project;
- The number and location of wells used in this study was limited by the availability of suitable, good quality geophysical log data with accompanying geochemical data in the form of measured TOC values and/or vitrinite reflectance data;
- The vertical resolution of the calculated TOC is limited by the resolution of logging tools. This means that, for example, sharply varying TOC values across thinly interbedded shales, coals and sands intervals may not be distinguishable and is likely to be presented as a smoother "average" TOC curve response. By contrast, each TOC measurement from cores or cuttings samples represent a single point in the succession. In addition it was not always possible to precisely depth shift the core depths to log depths, depending on the density of data points and data availability. Therefore there may be some small depth differences between core TOC measurement points and the calculated TOC curve. The sample-derived TOC measurements are assumed to be correct, but these in themselves may have their own limitations, which are not discussed here.

3 Results

Each interval has been assessed and results reported separately. Over such a large area of interest it is difficult to make comments on the geographical distribution of wells in relation to their TOC values calculated, as the burial history and sedimentology can vary in the Carboniferous and Devonian succession within a relatively small (tens of kilometers) distance.

The reader should refer to the TOC plots (Appendix 4) to assess the scaled sonic and ΔlogR overlays with the calculated TOC values. In the presented TOC plots reservoir intervals and coals have been removed from the calculated TOC curve leaving only the shale intervals (Figure 2).

After conducting the data quality checks (Section 2.3), 31 wells were retained for TOC calculation spread across the area of interest (Figure 3). Classification of source-rock relating to TOC as defined in the Millennium Atlas (Figure 17.1 in Kubala et al., 2003) has been applied to the investigated source-rock intervals (Table 1).

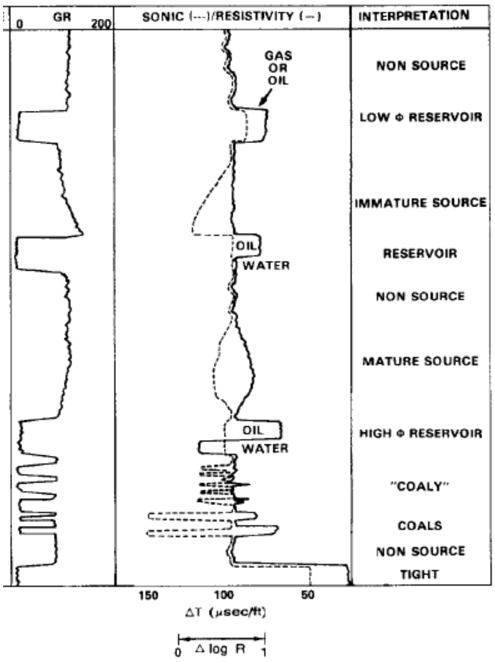


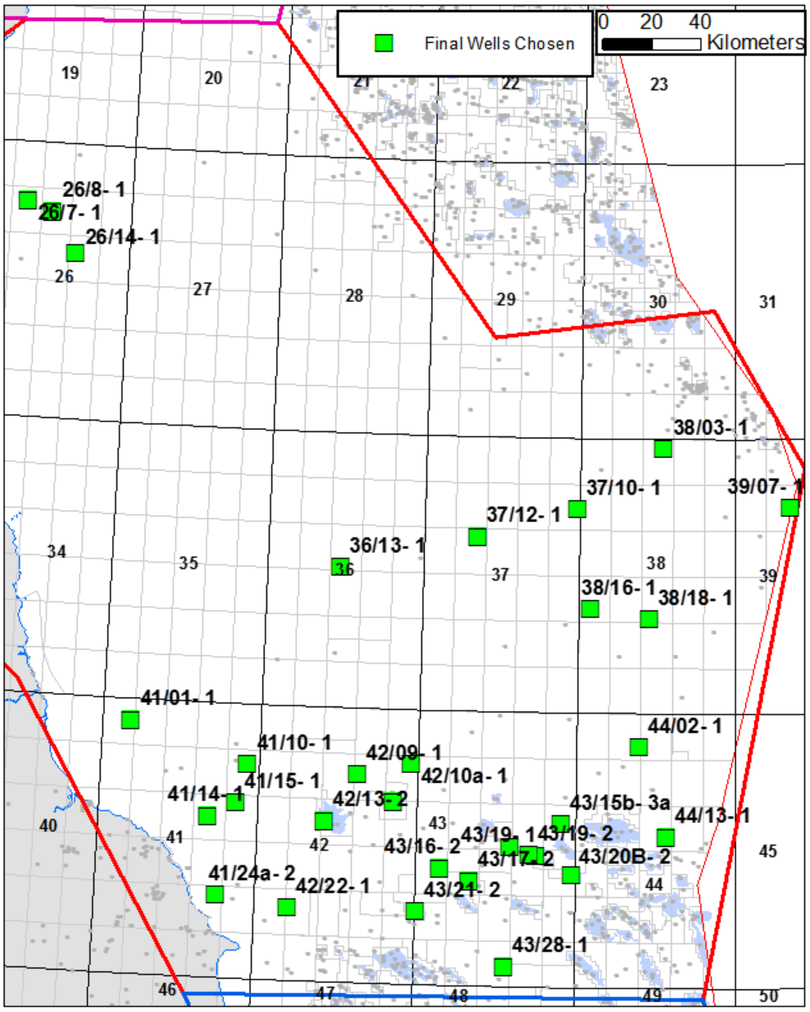
Figure 2 (above): A schematic guide for the interpretation of a variety of features seen on the ΔlogR overlays. (from Passey et al., 1990)

TOC (wt %)	Description
0.5	Very Poor
0.5-1.0	Poor
1.0-2.0	Fair
2.0-4.0	Good
4.0-8.0	Very Good
>8.0	Excellent

Table 2: Source-rock classification in relation to TOC as defined by Kubala et al. (2003).

The results for each individual well are reported in the appendices. This includes graphical log plots, histograms of TOC calculated for each formation, a cross plot of calculated TOC against cutting/core measured TOC and tabulated curve statistics. When assessing the absolute values and quality of the results reported here, the assumptions and limitations outlined in Section 2.6 should be taken into consideration. **Note that N/G=net shale to gross thickness, P/G=pay/gross shale with TOC > 1 wt% to gross thickness.**

Figure 3: Location of 31 wells chosen for TOC calculation



3.1 THE COAL MEASURES GROUP

The Coal Measures Group consists of several formations; for this study formations of interest included:

- The Boulton Formation;
- The Westoe Formation;
- The Caister Formation; and
- Undivided Coal Measures

The Boulton Formation is interpreted only in well 26/08- 1. However it does not show thick shale successions and any shales have a low calculated TOC content.

The Westoe Formation is interpreted only in well 44/13- 1 and shows a net shale thickness (140.5m, with a N/G of 0.84), although after calibrating to the measured TOC values, the calculated TOC are poor, falling below the 1 wt% cut-off (P/G of 0.24).

The Caister Coal Formation is interpreted in 5 wells across the Silverpit Basin with fair to good calculated TOC's over the net shale thickness (1.4 wt% in 44/13- 1 to 3.3 wt% in 43/19- 1).

Undivided Coal Measures are found only in 26/08- 1, with a fair to good average TOC and P/G of 0.41 over the whole interval.

Well	Zone	Avg TOC over Net Shale thickness (calculated wt %)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
26/08- 1	Boulton Formation	1.0	427.78	70.9	0.17	33.2	0.08
26/08- 1	Coal Measures Undivided	1.7	180.6	100.2	0.56	74.7	0.41
44/13- 1	Westoe Coal Formation	0.8	166.4	140.5	0.84	39.5	0.24
43/15b- 3a	Caister Coal Formation	1.6	195.7	97.5	0.50	70.8	0.36
43/19- 1	Caister Coal Formation	3.3	101.3	62.6	0.62	61.7	0.61
43/19- 2	Caister Coal Formation	3.0	59.0	28.2	0.48	26.7	0.45
43/20b- 2	Caister Coal Formation	1.5	100.5	39.2	0.39	28.3	0.28
44/13- 1	Caister Coal Formation	1.4	78.3	41.5	0.53	34.0	0.43

Table 3: Net and Pay to Gross summary for the Coal Measures Group

3.2 MILLSTONE GRIT FORMATION

The Millstone Grit Formation shows fair to good calculated TOC values (1.4 wt% to 2.5 wt%). In wells 41/14- 1 and 41/15- 1 the Millstone Grit Formation is very thin, however for the majority of the wells the Millstone Grit Formation is >150 m, and is up to 1027 m in 43/28- 1. The P/G for the thick formations normally lie between 0.3 and 0.5, and although some of the pay is thin, shale intervals there are thick and clay rich, with high TOC intervals visible on the presented logs (Appendix 4). A possible geographical difference is observed between the higher TOC, northern wells of Quadrant 43 and the lower TOC, southern wells with a difference of around 0.5 wt% TOC. However, small Ro variations and parameter changes could account for this minor difference.

Well	Zone	Avg TOC over Net Shale thickness (calculated wt%)	G, Gross Formatio n Thickness (m)	N, Net Shale Thicknes s (m)	N/G	Pay (>1% TOC) Thicknes s (m)	P/G
41/14- 1	Millstone Grit Formation	2.4	10.0	1.8	0.18	1.8	0.18
41/15- 1	Millstone Grit Formation	2.7	17.0	0.2	0.01	0.2	0.01
41/24a- 2	Millstone Grit Formation	2.1	447.0	320.3	0.72	316.5	0.71
43/13b- 4	Millstone Grit Formation	2.1	563.3	284.8	0.51	271.6	0.48
43/15b- 3a	Millstone Grit Formation	1.4	183.9	123.7	0.67	86.0	0.47
43/16- 2	Millstone Grit Formation	2.1	369.6	152.6	0.41	144.5	0.39
43/17- 2	Millstone Grit Formation	2.0	492.9	165.2	0.34	159.4	0.32
43/19- 1	Millstone Grit Formation	2.5	293.0	146.9	0.50	135.2	0.46
43/19- 2	Millstone Grit Formation	2.5	677.8	360.2	0.53	349.5	0.52
43/20b- 2	Millstone Grit Formation	1.4	847.5	462.5	0.55	376.9	0.45
43/21- 2	Millstone Grit Formation	1.6	921.7	397.4	0.43	367.7	0.40
43/28- 1	Millstone Grit Formation	1.6	1027.0	481.8	0.47	425.2	0.41

Table 4: Net and Pay to Gross summary for the Millstone Grit Formation

3.3 YOREDALE FORMATION

The Yoredale Formation shows fair to good calculated TOC values (1.1 wt% to 3.4 wt%). For all of the wells the Yoredale Formation is >110 m thick and up to 862.7 m in 41/10- 1. The P/G for the thick formations normally lie between 0.3 and 0.6. Although some of the pay is thin shale intervals there are thick clay rich TOC rich intervals visible on the presented logs (Appendix 4). For the wells assessed there does not seem to be any detectable regional trends in TOC values.

Well	Zone	Avg TOC over Net Shale thickness (calculated wt%)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
36/13- 1	Yoredale Formation	2.0	110.9	56.5	0.51	40.5	0.37
39/07- 1	Yoredale Formation	1.1	475.0	264.5	0.56	173.2	0.37
41/01- 1	Yoredale Formation	3.3	776.6	413.7	0.53	385.5	0.50
41/10- 1	Yoredale Formation	2.4	862.7	559.5	0.65	501.6	0.58
41/15- 1	Yoredale Formation	2.3	740.0	554.2	0.75	547.4	0.74
42/09- 1	Yoredale Formation	1.8	370.9	236.6	0.64	185.8	0.50
42/10a- 1	Yoredale Formation	3.4	433.3	235.3	0.54	230.8	0.53
42/13- 2	Yoredale Formation	1.8	447.1	306.1	0.69	293.3	0.66

Table 5: Net and Pay to Gross summary for the Yoredale Formation

3.4 SCREMERSTON FORMATION

The Scremerston Formation and time equivalent Firth Coal Formation show fair to good calculated TOC values (1.3 wt% to 4.1 wt%). The majority of the wells the Scremerston Formation have pay thicknesses of <50m, but three wells are >100 m thick, with a succession up to 678.2 m thick in 41/10- 1. The P/G for the thick formations normally lie between 0.3 and 0.65, and although the majority pay is thin shale intervals there are a few thick clay rich intervals visible on the presented logs (Appendix 4). For the wells assessed there does not seem to be any detectable regional trends in TOC values. Results for well 44/02- 1 are notably higher than for other wells, and this could be a real result or amplified by calibrating the curve to higher than representative TOC values.

Well	Zone	Avg TOC over Net Shale thickness (calculated wt%)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
38/16- 1	Scremerston Formation	1.4	237.7	93.7	0.39	47.2	0.20
38/18- 1	Scremerston Formation	2.5	97.2	54.3	0.56	34.1	0.35
39/07- 1	Scremerston Formation	1.5	109.0	50.8	0.47	42.9	0.39
41/01- 1	Scremerston Formation	3.1	380.5	240.9	0.63	240.7	0.63
41/10- 1	Scremerston Formation	2.8	1040.0	717.1	0.69	678.2	0.65
42/13- 2	Scremerston Formation	1.3	11.0	5.6	0.51	4.9	0.44
42/15a- 2	Scremerston Formation	1.9	203.0	121.9	0.60	111.0	0.55
44/02- 1	Scremerston Formation	4.1	87.5	42.0	0.48	29.3	0.34
26/07- 1	Firth Coal Formation	1.6	565.0	371.7	0.66	248.6	0.44
26/08- 1	Firth Coal Formation	3.0	689.1	346.2	0.50	313.2	0.45

Table 6: Net and Pay to Gross summary for the Scremerston Formation and time equivalent Firth Coal Formation

3.5 CLEVELAND GROUP

The Cleveland Group comprises of 6 defined units, in wells in Quadrants 41-43. The Cleveland Group units in stratigraphic order (youngest to oldest) are:

- Cleveland Group E;
- Upper Bowland Shale;
- Cleveland Group D;

- Cleveland Group C;
- Cleveland Group B;
- Cleveland Group A

All of the units are summarised in Table 5. The Upper Bowland Shale has the thickest consistent shale intervals, shown by the high P/G values up to 0.98 in 42/22- 1. The Upper Bowland Shale also has better TOC wt% than the other units, ranging from 1.4 wt% to 3.4 wt%.

Cleveland Group A was interpreted only in one well; 41/14- 1 and was relatively thin (46 m gross with 19.5 m pay thickness). Cleveland Groups B, C and E also have good P/G (0.5-0.9) with good TOC (1.3 wt% to 2.6 wt%). Cleveland Group D exhibited the lowest TOC (1.2-2.5 wt%) and P/G (0.4-0.65) values of all the Cleveland Group units. When present, clay rich intervals are usually hundreds of meters thick, rather than the thinner, tens of metre beds seen in the Scremerston and Yoredale Formations.

Geographically it appears that in the more eastern parts of Quadrant 43 the TOC wt% is lower than in the western Quadrant 41 area.

Well	Zone	Avg TOC over Net Shale thickness (calculated wt%)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
41/14- 1	Cleveland Gp 'E'	3.2	234.0	124.4	0.53	124.4	0.53
41/24a- 2	Cleveland Gp 'E'	2.2	200.0	116.4	0.58	116.4	0.58
43/17- 2	Cleveland Gp 'E'	1.5	1264.7	975.2	0.77	905.4	0.72
43/21- 2	Cleveland Gp 'E'	1.6	569.7	535.6	0.94	481.5	0.85
41/14- 1	Upper Bowland Shale	2.8	85.0	79.8	0.94	78.7	0.93
41/15- 1	Upper Bowland Shale	2.6	17.0	13.7	0.81	13.7	0.81
41/24a- 2	Upper Bowland Shale	3.4	56.0	48.5	0.87	48.5	0.87
42/22- 1	Upper Bowland Shale	2.5	53.0	51.9	0.98	51.9	0.98
43/17- 2	Upper Bowland Shale	1.4	90.0	81.8	0.91	81.8	0.91
43/21- 2	Upper Bowland Shale	1.6	110.1	73.2	0.67	70.7	0.64
41/14- 1	Cleveland Gp 'D'	1.7	154.0	62.0	0.40	61.8	0.40
41/24a- 2	Cleveland Gp 'D'	1.9	59.0	38.6	0.65	38.6	0.65
42/22- 1	Cleveland Gp 'D'	2.5	153.0	89.9	0.59	89.5	0.59
43/17- 2	Cleveland Gp 'D'	1.3	619.2	507.5	0.82	499.6	0.81
43/21- 2	Cleveland Gp 'D'	1.2	229.7	190.7	0.83	116.8	0.51
41/14- 1	Cleveland Gp 'C'	1.8	872.0	558.9	0.64	553.2	0.63
41/15- 1	Cleveland Gp 'C'	2.6	186.0	161.1	0.87	161.1	0.87
41/24a- 2	Cleveland Gp 'C'	2.0	419.0	320.2	0.76	308.8	0.74
41/14- 1	Cleveland Gp 'B'	1.7	88.0	86.0	0.98	84.8	0.96
41/15- 1	Cleveland Gp 'B'	1.7	248.0	174.1	0.70	161.6	0.65
41/14- 1	Cleveland Gp 'A'	1.4	46.0	21.9	0.48	19.5	0.42

Table 7: Net and Pay to Gross summary for the Cleveland Group (including the Upper Bowland Shale)

3.6 LOWER DEVONIAN

Data for the Lower Devonian was interpreted only in 26/14- 1. Overall, the Lower Devonian had a thin net shale thickness of 35 m. The interval was TOC-poor, resulting in an average TOC of 0.7 wt% and P/G of 0.07. The measured TOC values, which cover the whole interval of interest, suggest that even these low calculated TOC values could be an overestimation.

Well	Zone	Avg TOC over Net Shale thickness (calculated wt%)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
26/14- 1	Lower Devonian	0.7	70.1	35.6	0.51	4.7	0.07

Table 8: Net and Pay to Gross summary for the Lower Devonian

3.7 MEASURED TOC VS. CALCULATED TOC CROSS-PLOTS

A cross-plot was produced for wells with measured TOC values. If the calculated data were to fit well with the measured TOC data then a straight line 1:1 relationship would be expected. All of the cross plots have been assembled in Appendix 3. In general the cross plots show good correlation, especially in wells with large shale intervals; that is, those from the Cleveland Group. The anomalous readings in the measured TOC values could be a result of sampling of carbonaceous sediments, coals, or thin high TOC beds which the loggings tools cannot resolve (see Section 2.6).

4 Conclusions

Volume of Clay (VCl), coal identification and Total Organic Carbon (TOC) values were calculated from geophysical log responses using the Passey et al. (1990) method in each of 31 wells across the Central North Sea. In addition, a range of potential TOC values were calculated to incorporate potential maturity variability in each well. The curves were used to calculate net shale thickness to gross formation thickness (N/G) and pay thickness (defined as >1 wt% TOC shale) to gross (P/G) for each formation of interest. It must be noted that the method used excludes coals and carbonaceous sandstones from the final TOC values and quotes TOC only for the shale intervals.

The formations assessed for TOC calculation were:

- The Coal Measures Group;
- The Millstone Grit Formation;
- The Yoredale Formation;
- The Scremerston Formation;
- The Cleveland Group (including the Upper Bowland Shale); and
- The Lower Devonian

Overall, the highest pay thickness and P/G formation was the Cleveland Group, particularly the Upper Bowland Shale, with the rest of the Group giving high P/G. The Yoredale and Scremerston Formations had broadly similar pay thickness, P/G and TOC values to each other. The Millstone Grit exhibited lower P/G but with similar TOC. Finally, the Lower Devonian had very low calculated TOC, and although having a good N/G, its P/G was 0.07 and TOC 0.7 wt%. However, the spread of measured TOC data for this formation suggests even those figures are an overestimation.

Formation	*n*	Avg TOC over Net Shale thickness (calculated wt %)	Pay (TOC >1wt%) thickness to gross formation thickness (P/G)	Avg Pay Thickness* (m)
Coal Measure Group	7	0.8-3.3	0.08-0.61	46.1
Millstone Grit Formation	12	1.4-2.7	0.18-0.71	239.5
Yoredale Formation	8	1.1-3.4	0.37-0.74	294.8
Scremerston Formation	10	1.4-2.7	0.20-0.65	175.0
Cleveland Group (incl Upper Bowland Shale)	6	1.5-3.4	0.64-0.98	678.1
Upper Bowland Shale	6	1.4-3.4	0.64-0.93	57.6
Lower Devonian	1	0.7	0.07	4.7

Table 9: A summary of the calculated TOC, P/G and Pay Thickness for each potential source rock formation. (* The pay thickness does not remove wells where total drilling depth (TD) was reached within the target formation)

In summary, the results indicate significant thicknesses of organic rich shale through the Carboniferous succession.

The produced cross-plots highlight the fact that the TOC values calculated using the Passey method versus measured sample data is most reliable in formations with thick shale succession such as observed in the Cleveland Group. The Passey method gives a relatively good fit in other interbedded formations such as the Yoredale and Scremerston, although it cannot take into consideration thin TOC rich intervals and the effect of coaliferous sedimentary successions and coals. Due to the large geographic spread across the Central North Sea and relative paucity of wells for which TOC was calculated, analysis of the distribution of regional trends was not possible.

The results of this work have been input directly into the basin modelling work of Vincent (this study). The basin modelling from Vincent presents a comprehensive study of 8 wells across the CNS, the work has incorporated kerogen type and burial history and furthers understanding of the effect the calculated TOC on hydrocarbon generation.

Appendix 1 Level of Maturity Table

The level of maturity is a necessary parameter in the Passey method, it is based on a conversion of vitrinite reflectance to a value usually between 6 and 13. The table defines the zones on each well and what level of maturity was used, including a maturity range for uncertainty.

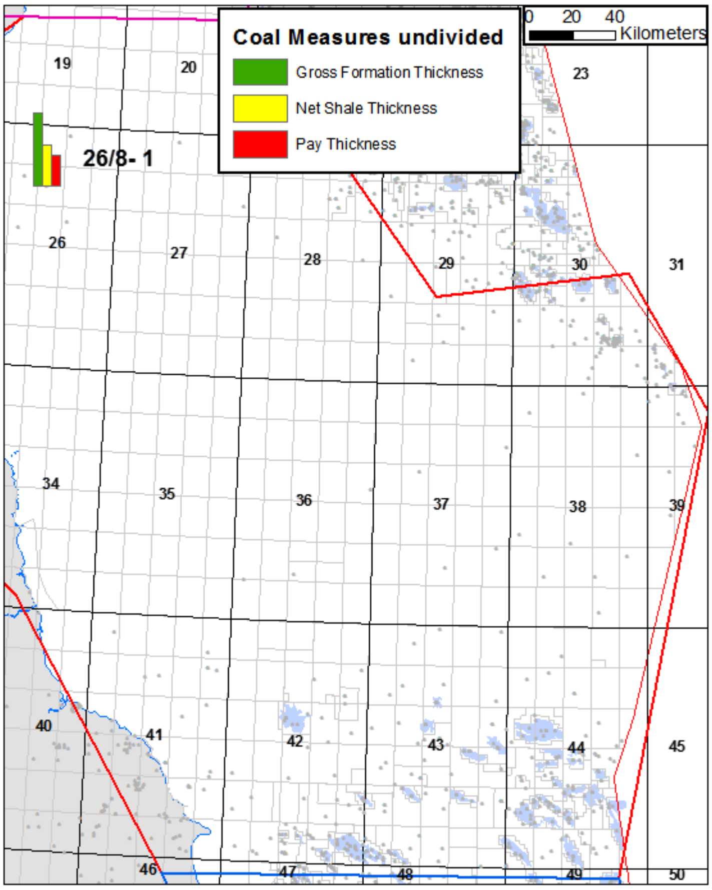
Well	LOM Zone 1	±LOM Z1	Zone 2 Split	LOM Z2	±LOM Z2	Zone 3 Split	LOM Z3	±LOM Z3
26/07- 1	**10.3**	1.3						
26/08- 1	**10.3**	1.3						
26/14- 1	**10.3**	1.3						
36/13- 1	**8.2**	1.0						
37/10- 1	**10.6**	1.0						
37/12- 1	**10.6**	1.0	Top Kyle Limestone	**10.6**	1.0			
38/03- 1	**10.6**	1.0						
38/16- 1	**9.2**	1.0						
38/18- 1	**8.2**	0.5						
39/07- 1	**12.0**	0.5						
41/01- 1	**9.2**	0.5	Top Scremerston	**11.0**	0.5			
41/10- 1	**10.0**	0.5	Top Fell Sandstone	**11.0**	0.5			
41/14- 1	**10.0**	0.5	Top Cleveland Grp 'D'	**12.5**	1.0			
41/15- 1	**11.0**	0.5	Mid Yoredale Fm 2889m	**12.0**	0.5	Mid Cleveland Grp 'B' 3300m	**12.5**	0.5
41/24a- 2	**11.0**	0.5	Top Upper Bowland Shale	**11.8**	0.3	Top Cleveland Grp 'D'	**12.3**	0.5
42/09- 1	**9.9**	0.3						
42/10a- 1	**9.5**	1.0						
42/13- 2	**11.5**	0.3						
42/15a- 2	**10.6**	0.5						
42/22- 1	**10.6**	1.0						
43/13b- 4	**10.5**	1.0						
43/15b- 3a	**10.0**	1.0						
43/16- 2	**10.5**	0.5						
43/17- 2	**11.0**	0.5	Top Cleveland Grp 'E'	**12.0**	0.5	Top Cleveland Grp 'D'	**14.0**	1.0
43/19- 1	**9.2**	0.5						
43/19- 2	**10.0**	1.0						
43/20b- 2	**10.3**	0.3	Mid Millstone Grit 4300m	**11.5**	0.5			
43/21- 2	**11.2**	0.5	Top Upper Bowland Shale	**11.8**	0.5			
43/28- 1	**11.0**	0.5	Mid Millstone Grit 4147m	**11.8**	0.5			
44/02- 1	**8.2**	0.5	Top Cementstone	**9.9**	0.5			
44/13- 1	**10.3**	0.3						

Appendix 2 Maps summarising Gross, Net and Pay (TOC>1 wt) thickness.

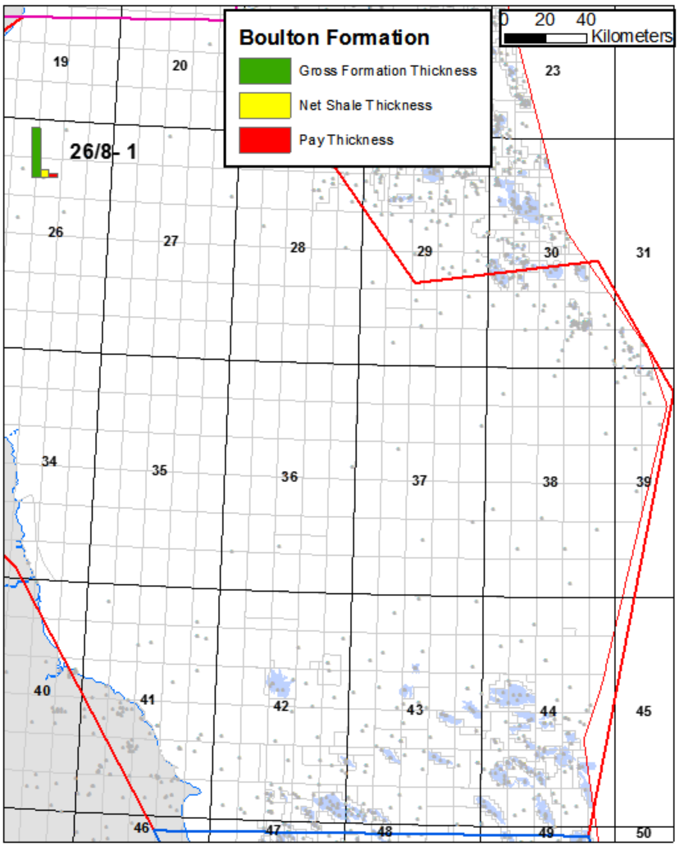
The graphical representation of the gross, net and pay is displayed in a bar chart form with the furthest left bar on each well representing the gross formation thickness in green, the central yellow bar representing the net shale thickness and the furthest right red bar representing the pay (>1 wt% TOC shale) thickness. Note, the height of the largest bar is not standardised for all plots. This format gives an indicator of relative thicknesses, net to gross and pay to gross per formation. Actual thicknesses are documented in the summary tables within Section 3 of the report.

COAL MEASURES GROUP

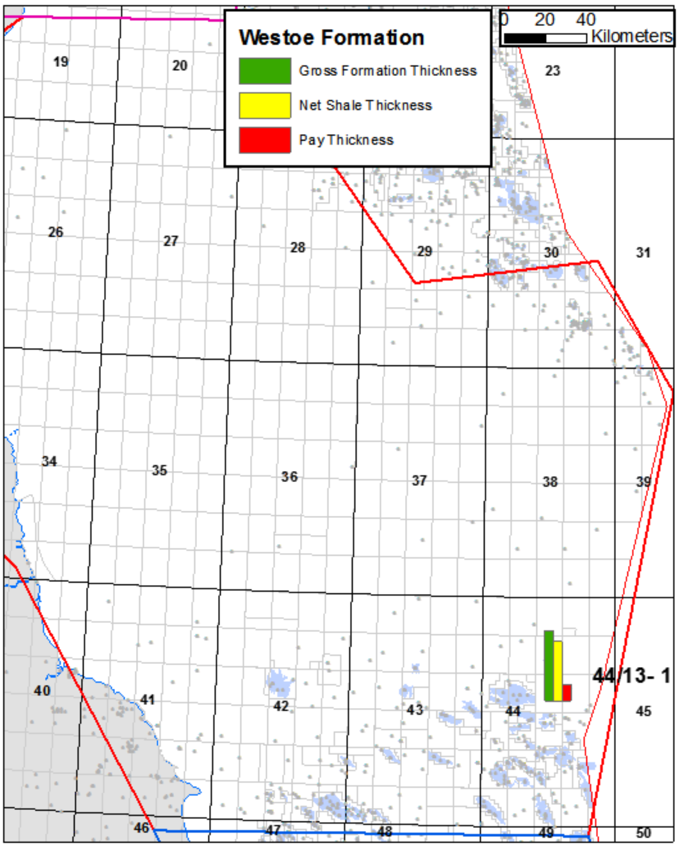
Coal Measures Group Undivided



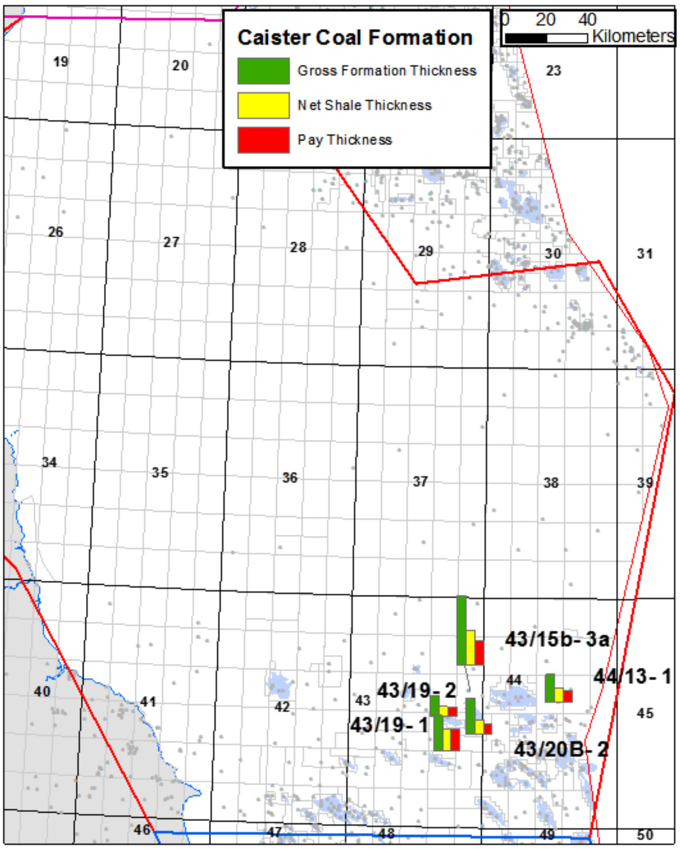
Boulton Formation



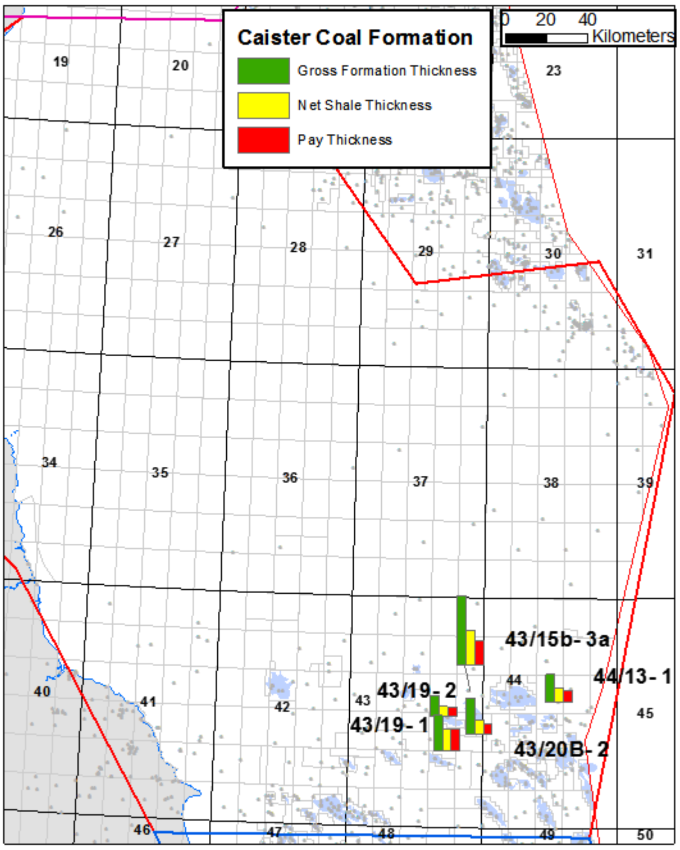
Westoe Formation

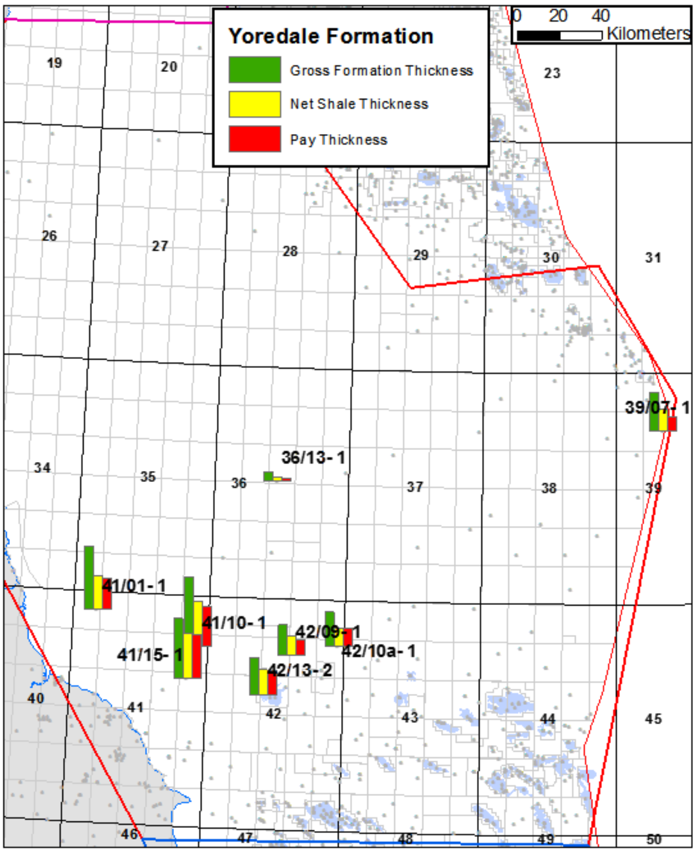


Caister Coal Formation



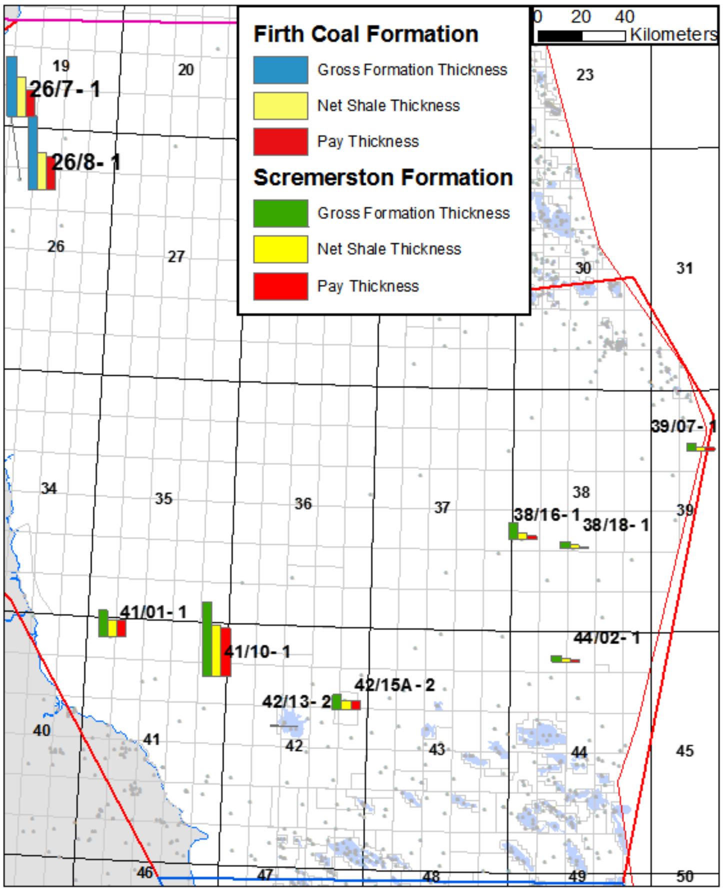
MILLSTONE GRIT FORMATION

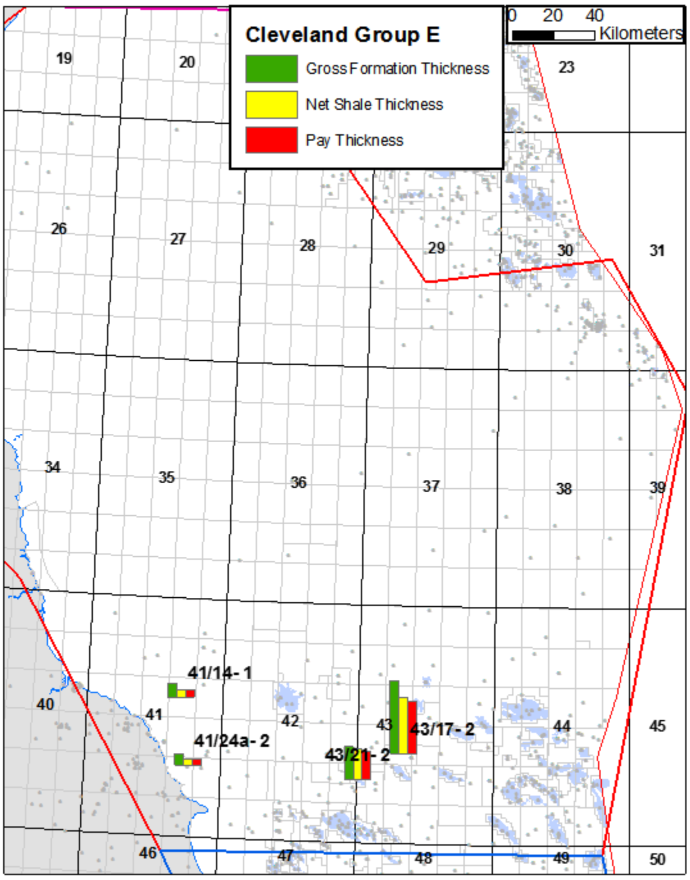




YOREDALE FORMATION

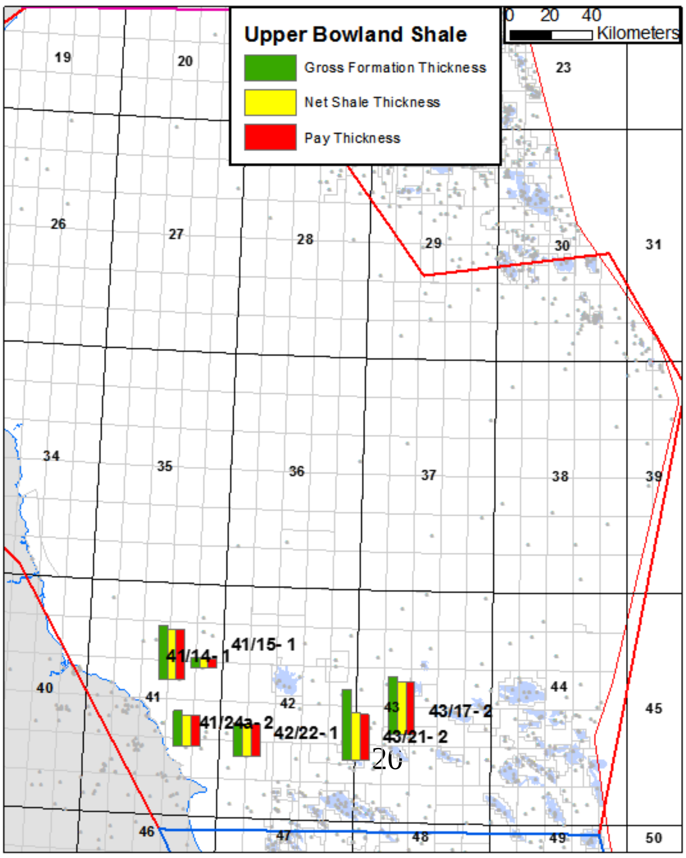
SCREMERSTON FORMATION AND FIRTH COAL FORMATION

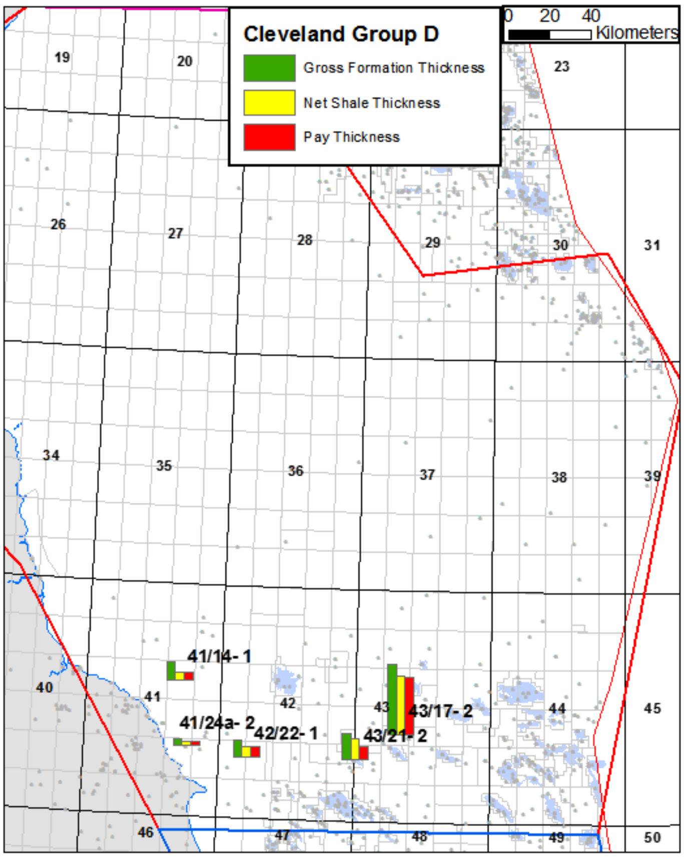




CLEVELAND GROUP E

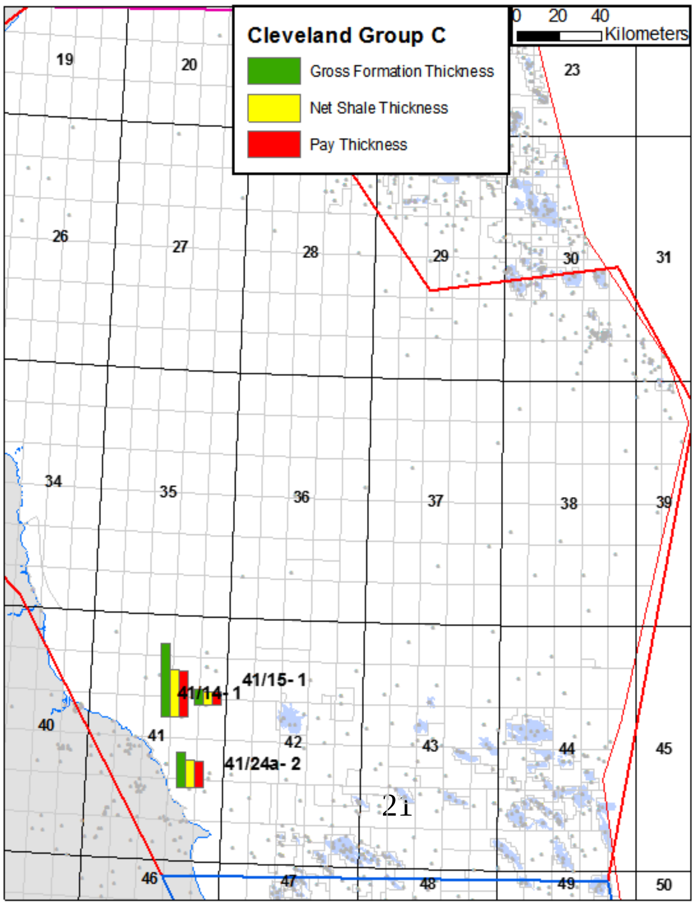
UPPER BOWLAND SHALE



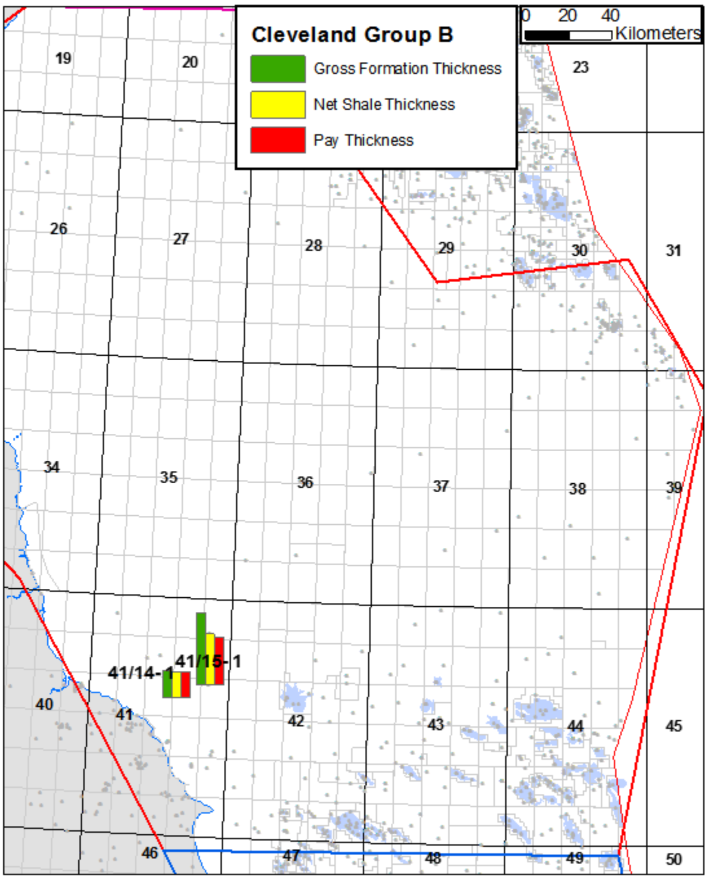


CLEVELAND GROUP D

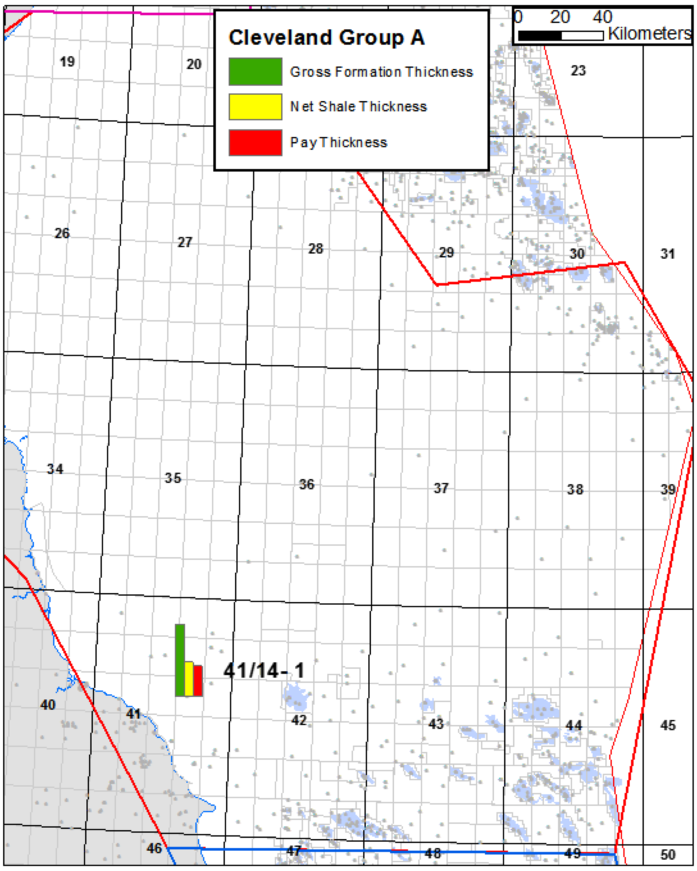
CLEVELAND GROUP C



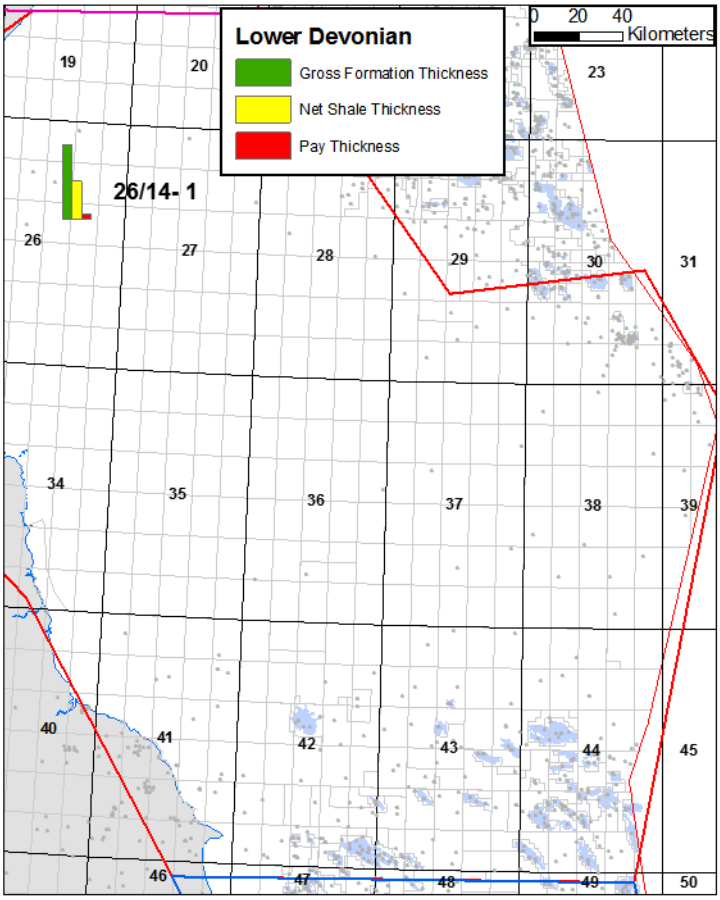
CLEVELAND GROUP B



CLEVELAND GROUP A



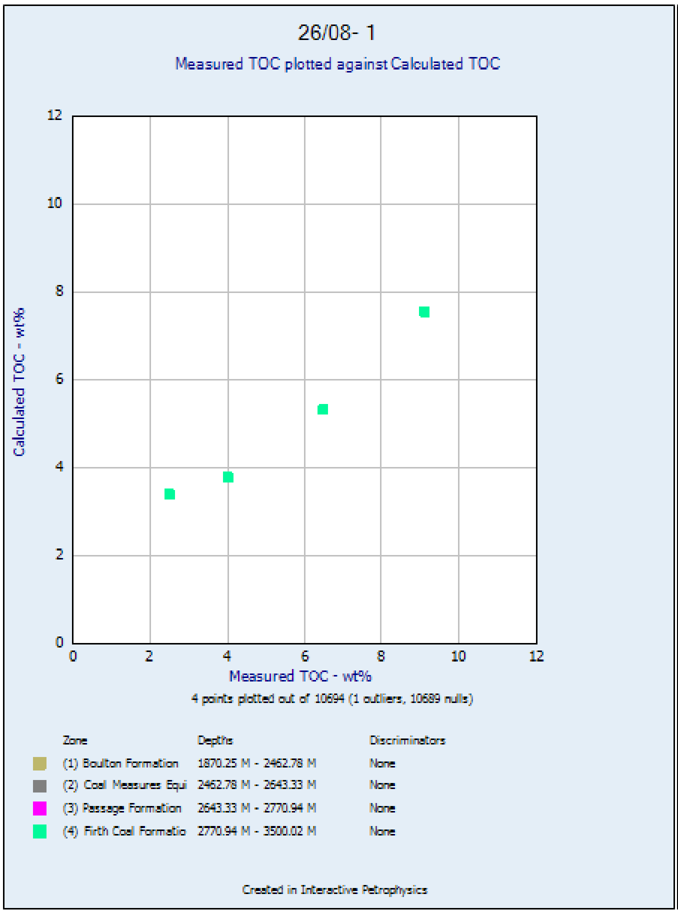
LOWER DEVONIAN

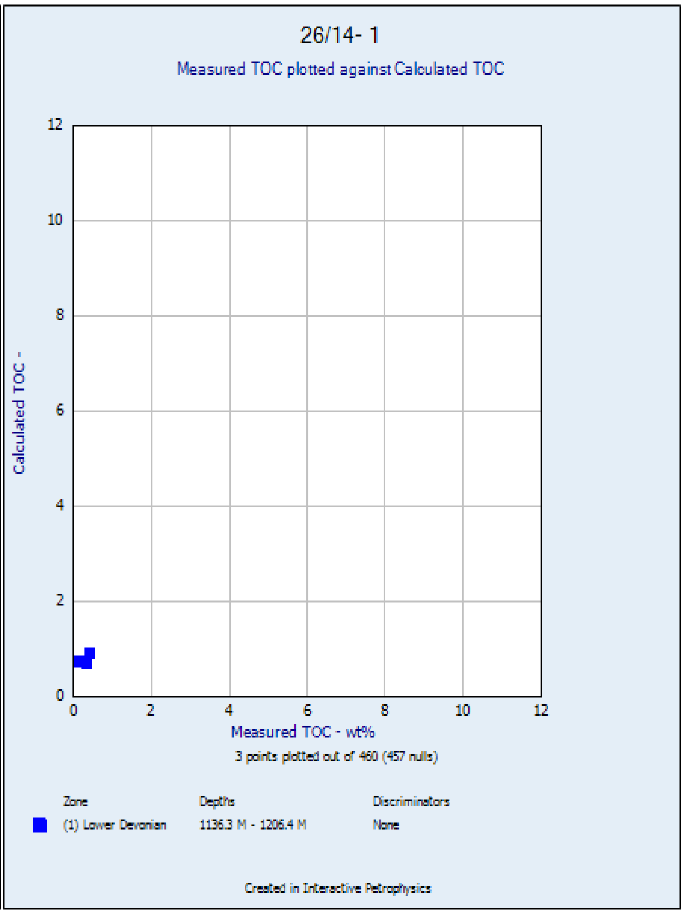


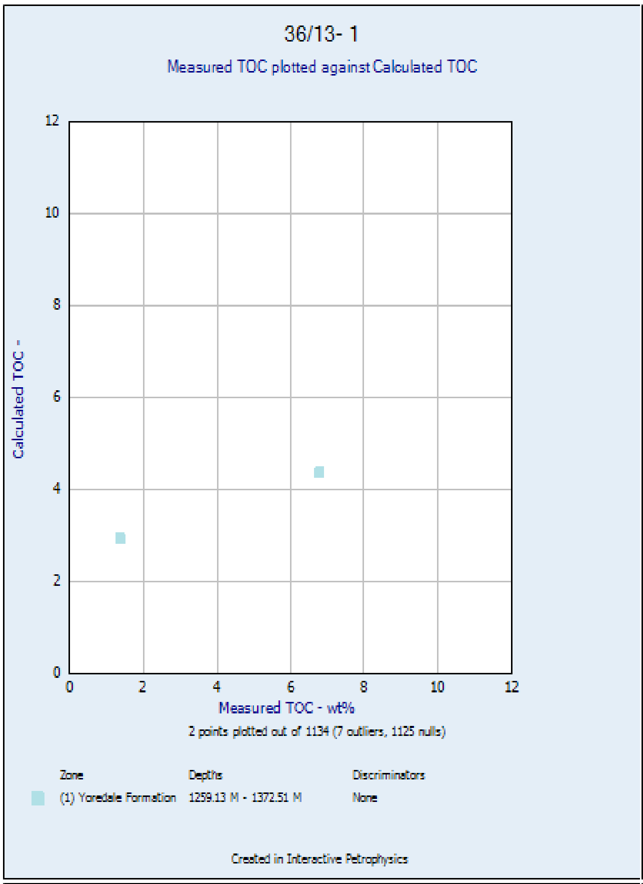
Appendix 3 Measured TOC vs Calculated TOC cross-plots

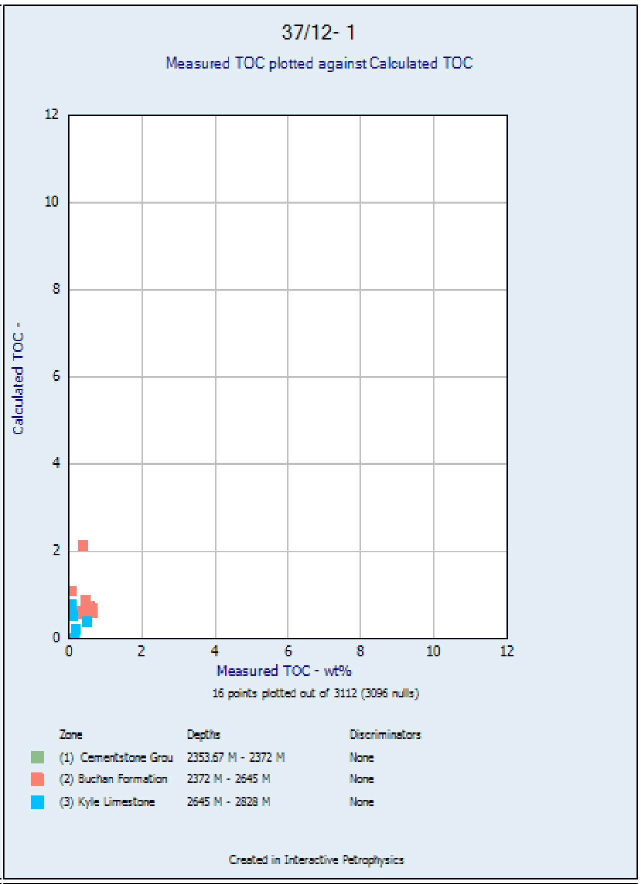
Twenty three of the 31 wells have measured TOC data over the shale intervals of interest. Cross plots of the measured TOC and calculated TOC, give an indication of the accuracy of the calculated TOC. For a good relationship, a linear 1:1 trend would be expected.

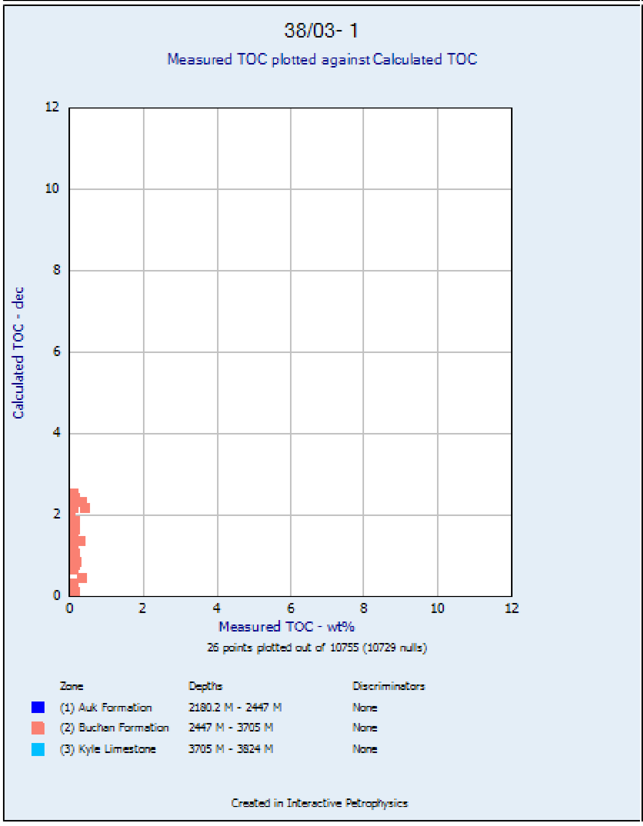
In summary, the calculations seem to match well with the measured TOC data, especially in the Cleveland Groups and Upper Bowland Shale. The Yoredale Formation and the Millstone Grit Formation show the poorest correlation; for explanation of potential mismatches see Section 2.6.






36/13- 1
Measured TOC plotted against Calculated TOC
Calculated TOC -
Measured TOC - wt%
2 points plotted out of 1134 (7 outliers, 1125 nulls)
Zone Depths Discriminators
(1) Yoredale Formation 1259.13 M - 1372.51 M None
Created in Interactive Petrophysics


37/12- 1
Measured TOC plotted against Calculated TOC
Calculated TOC -
Measured TOC - wt%
16 points plotted out of 3112 (3096 nulls)
Zone Depths Discriminators
(1) Cementstone Grou 2353.67 M - 2372 M None
(2) Buchan Formation 2372 M - 2645 M None
(3) Kyle Limestone 2645 M - 2828 M None
Created in Interactive Petrophysics


38/03- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - dec
Measured TOC - wt%
26 points plotted out of 10755 (10729 nulls)
Zone Depths Discriminators
(1) Auk Formation 2180.2 M - 2447 M None
(2) Buchan Formation 2447 M - 3705 M None
(3) Kyle Limestone 3705 M - 3824 M None
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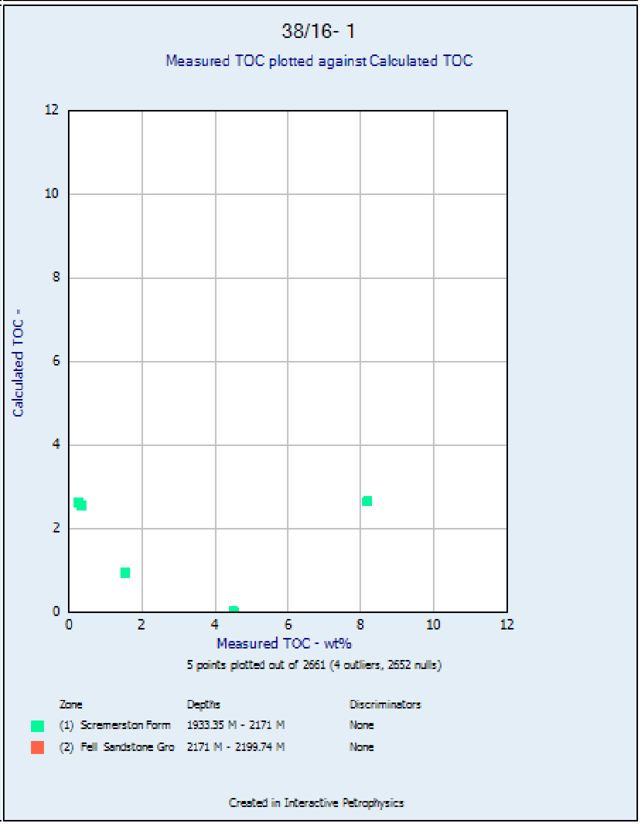
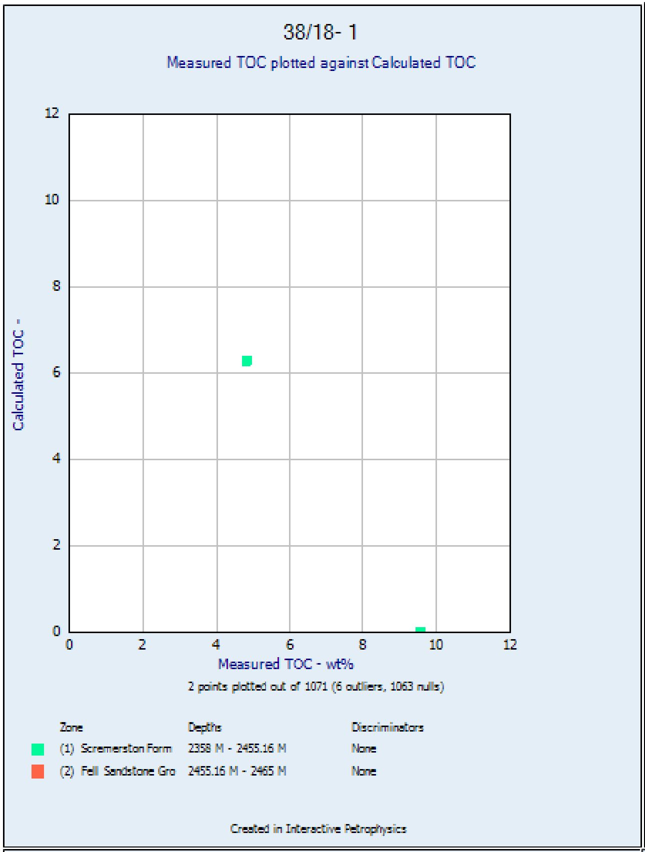

38/16- 1
Measured TOC plotted against Calculated TOC
Calculated TOC -
Measured TOC - wt%
5 points plotted out of 2661 (4 outliers, 2652 nulls)
Zone Depths Discriminators
(1) Scremerston Form 1933.35 M - 2171 M None
(2) Fell Sandstone Gro 2171 M - 2199.74 M None
Created in Interactive Petrophysics


38/18- 1
Measured TOC plotted against Calculated TOC
Calculated TOC -
Measured TOC - wt%
2 points plotted out of 1071 (6 outliers, 1063 nulls)
Zone
Depths
Discriminators
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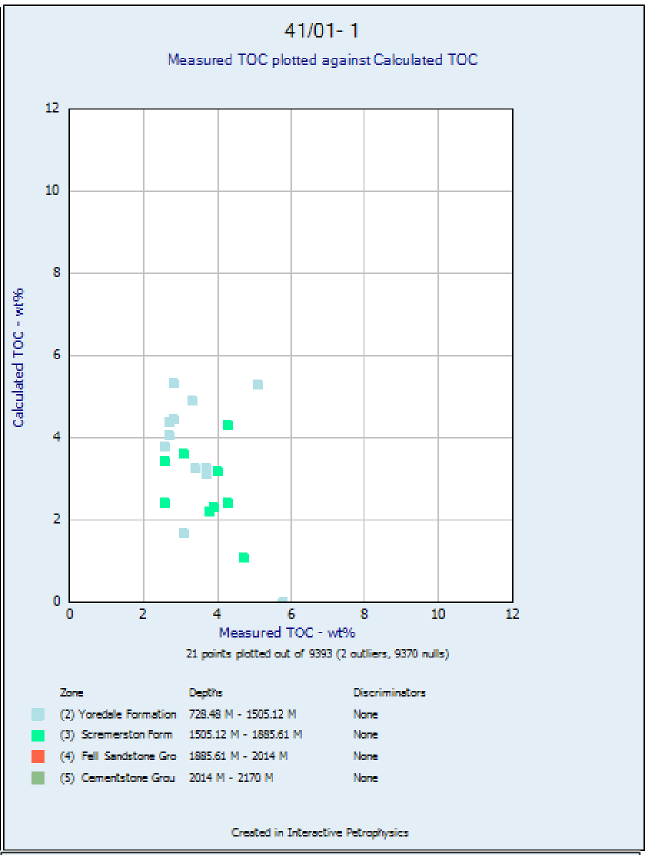
2358 M - 2455.16 M
None
(2) Fell Sandstone Gro
2455.16 M - 2465 M
None
Created in Interactive Petrophysics


41/01- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
21 points plotted out of 9393 (2 outliers, 9370 nulls)
Zone
Depths
Discriminators
(2) Yoredale Formation
728.48 M - 1505.12 M
None
(3) Scremerston Form
1505.12 M - 1885.61 M
None
(4) Fell Sandstone Gro
1885.61 M - 2014 M
None
(5) Cementstone Grou
2014 M - 2170 M
None
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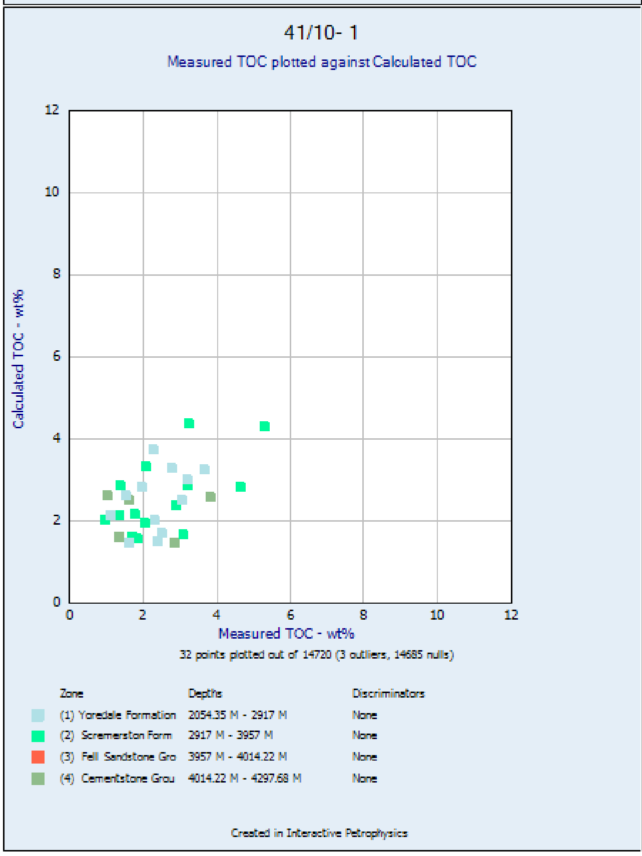
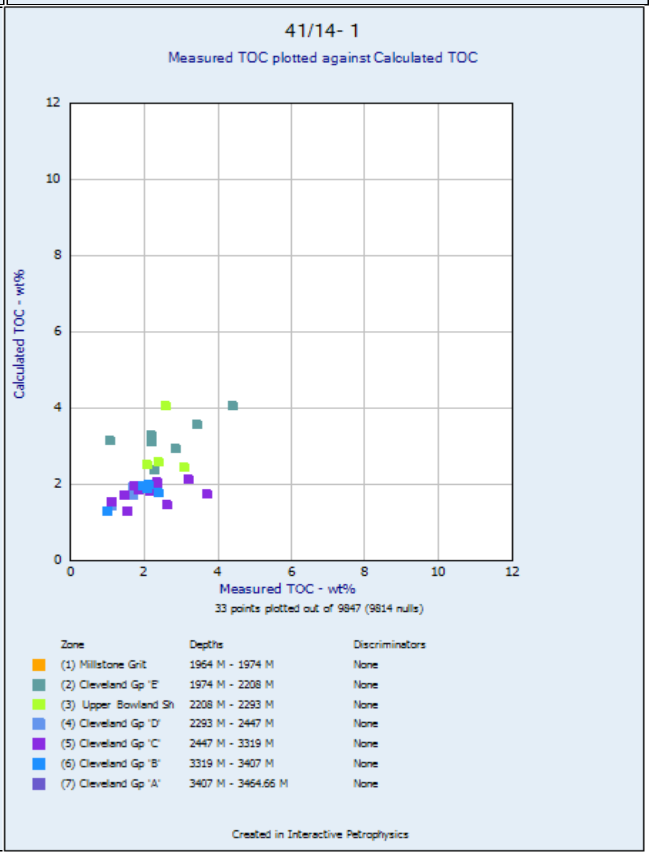
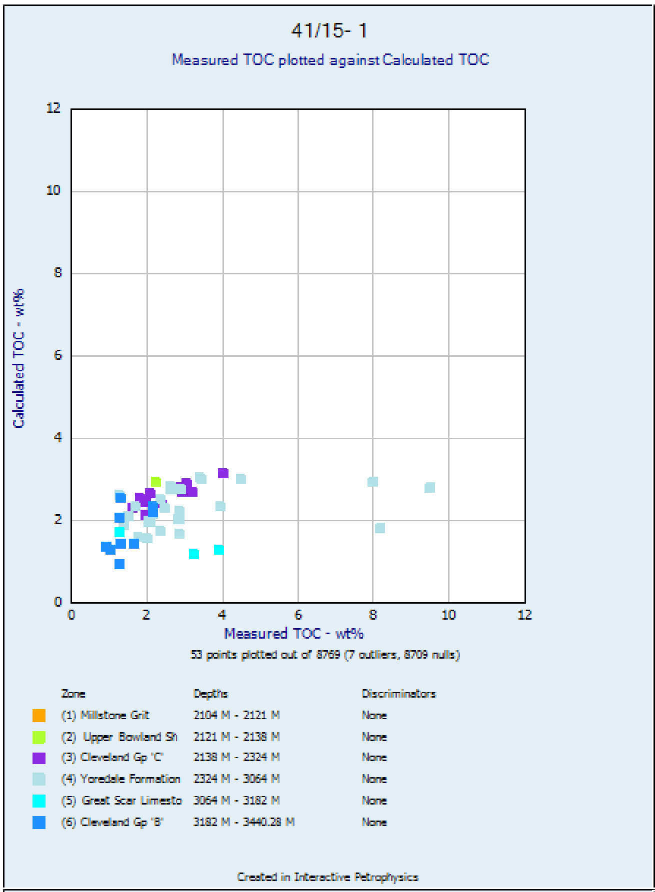
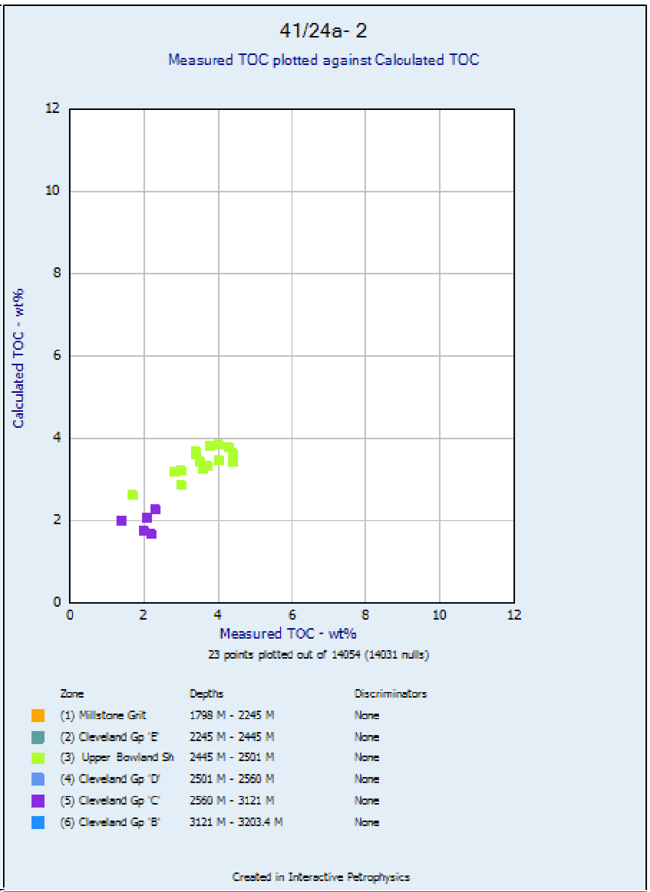
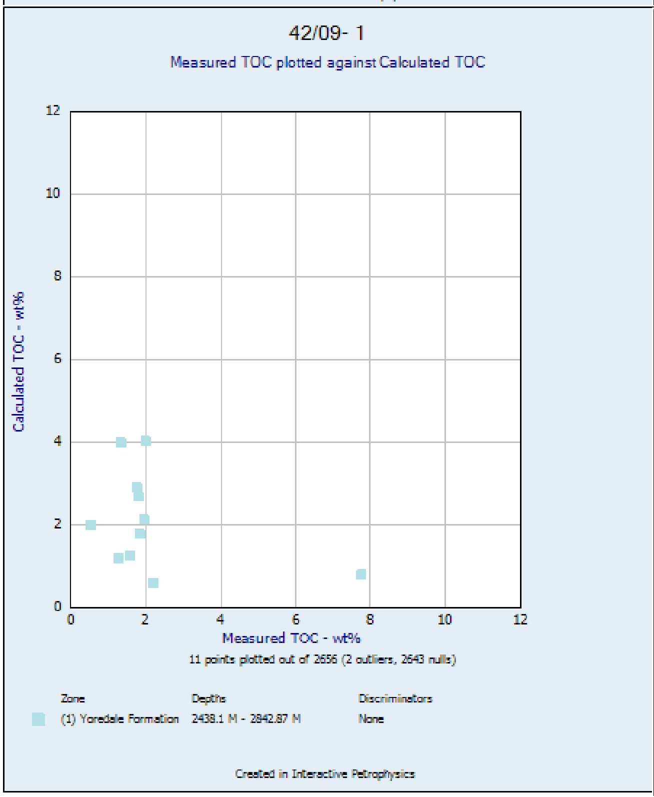
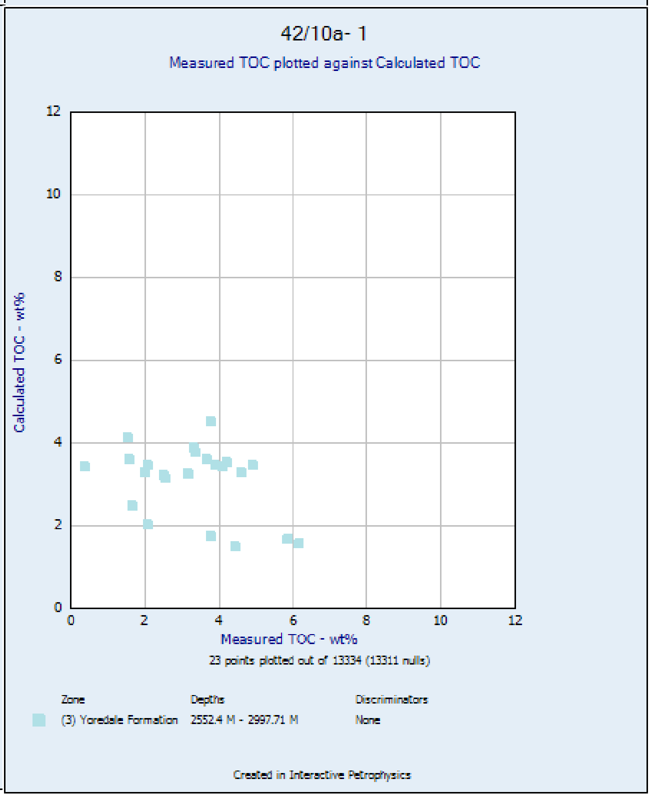

41/10- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
32 points plotted out of 14720 (3 outliers, 14685 nulls)
Zone
Depths
Discriminators
(1) Yoredale Formation
2054.35 M - 2917 M
None
(2) Scremerston Form
2917 M - 3957 M
None
(3) Fell Sandstone Gro
3957 M - 4014.22 M
None
(4) Cementstone Grou
4014.22 M - 4297.68 M
None
Created in Interactive Petrophysics

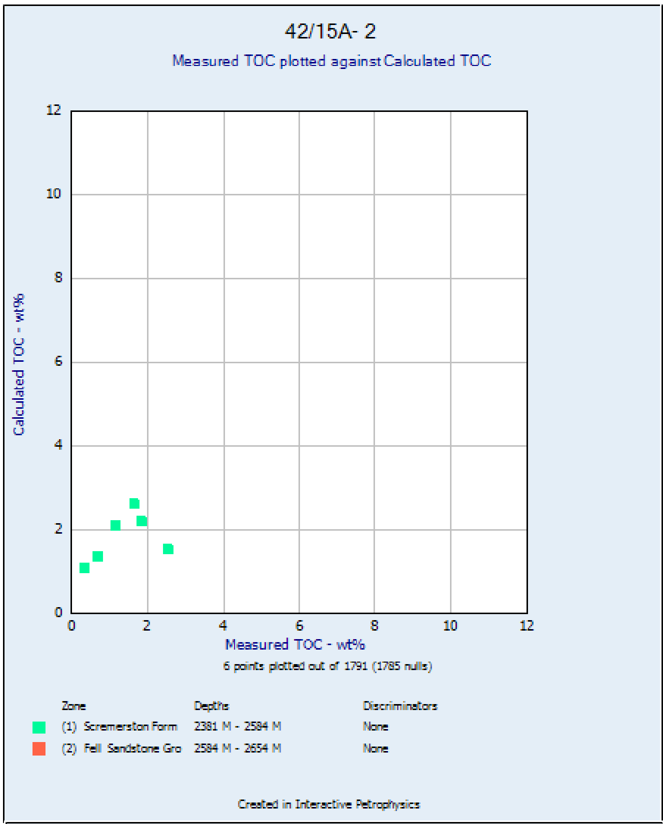

41/14- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
33 points plotted out of 9847 (9814 nulls)
Zone
Depths
Discriminators
(1) Millstone Grit
1964 M - 1974 M
None
(2) Cleveland Gp 'E'
1974 M - 2208 M
None
(3) Upper Bowland Sh
2208 M - 2293 M
None
(4) Cleveland Gp 'D'
2293 M - 2447 M
None
(5) Cleveland Gp 'C'
2447 M - 3319 M
None
(6) Cleveland Gp 'B'
3319 M - 3407 M
None
(7) Cleveland Gp 'A'
3407 M - 3464.66 M
None
Created in Interactive Petrophysics

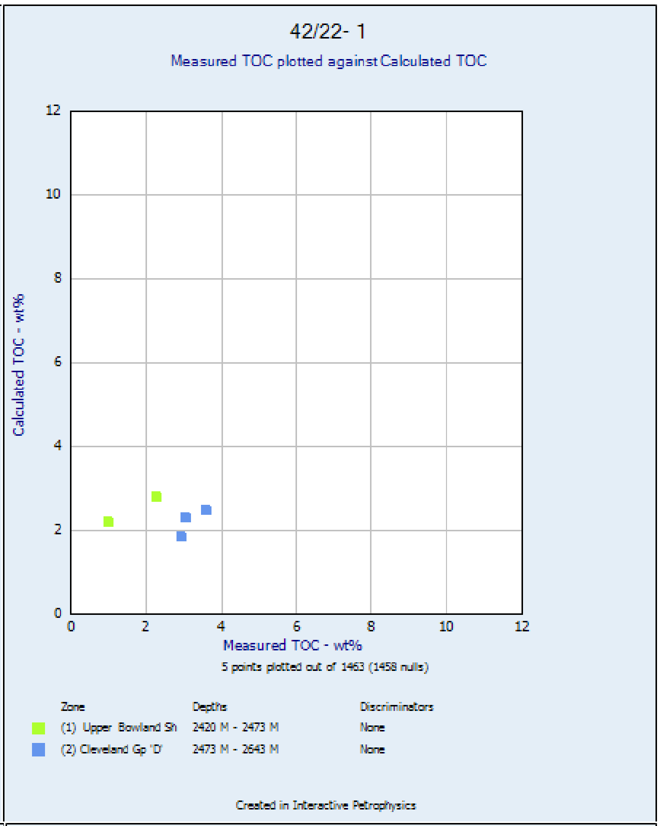

41/15- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
0
2
4
6
8
10
12
53 points plotted out of 8769 (7 outliers, 8709 nulls)
Zone
Depths
Discriminators
(1) Millstone Grit 2104 M - 2121 M None
(2) Upper Bowland Sh 2121 M - 2138 M None
(3) Cleveland Gp 'C' 2138 M - 2324 M None
(4) Yoredale Formation 2324 M - 3064 M None
(5) Great Scar Limesto 3064 M - 3182 M None
(6) Cleveland Gp 'B' 3182 M - 3440.28 M None
Created in Interactive Petrophysics

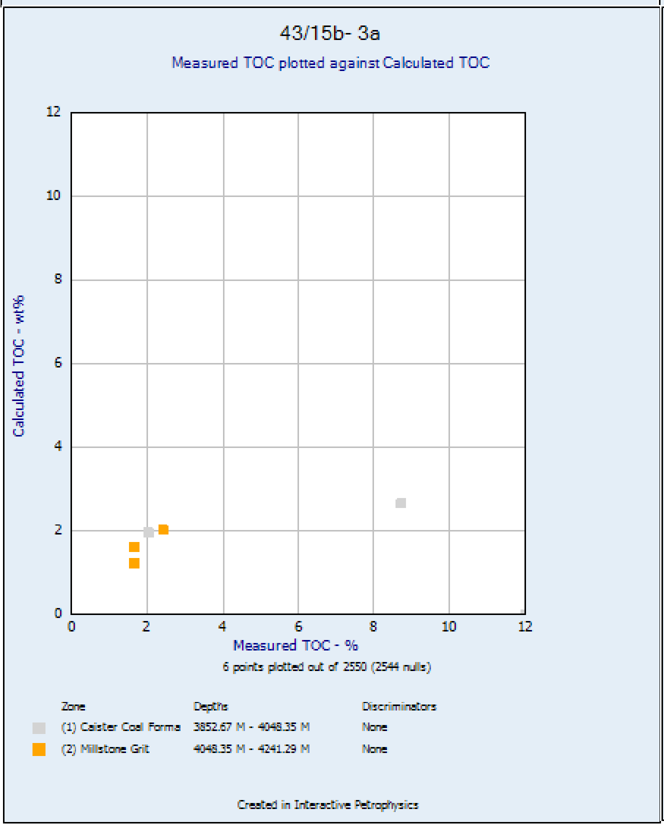

41/24a- 2
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
0
2
4
6
8
10
12
23 points plotted out of 14054 (14031 nulls)
Zone
Depths
Discriminators
(1) Millstone Grit 1798 M - 2245 M None
(2) Cleveland Gp 'E' 2245 M - 2445 M None
(3) Upper Bowland Sh 2445 M - 2501 M None
(4) Cleveland Gp 'D' 2501 M - 2560 M None
(5) Cleveland Gp 'C' 2560 M - 3121 M None
(6) Cleveland Gp 'B' 3121 M - 3203.4 M None
Created in Interactive Petrophysics

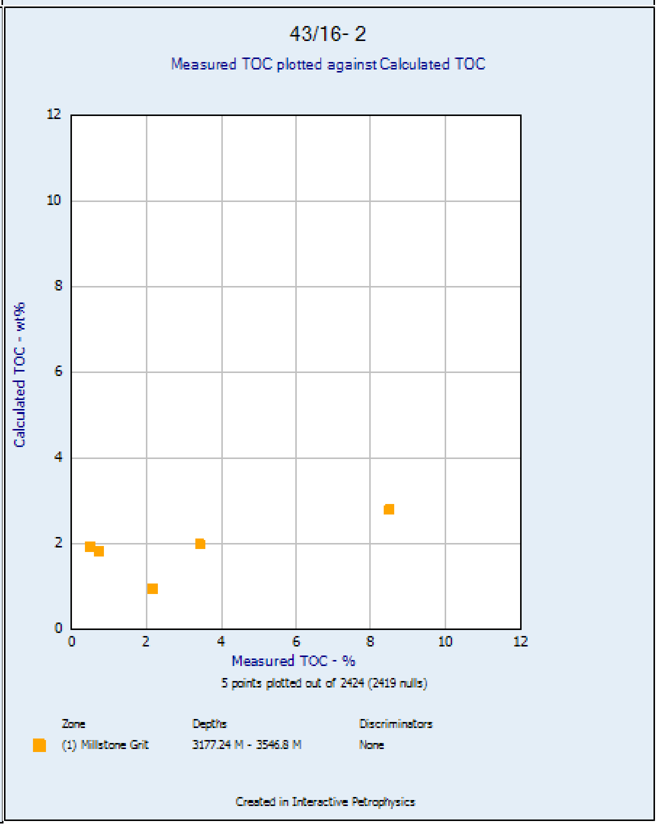

42/09- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
0
2
4
6
8
10
12
11 points plotted out of 2656 (2 outliers, 2643 nulls)
Zone
Depths
Discriminators
(1) Yoredale Formation 2438.1 M - 2842.87 M None
Created in Interactive Petrophysics

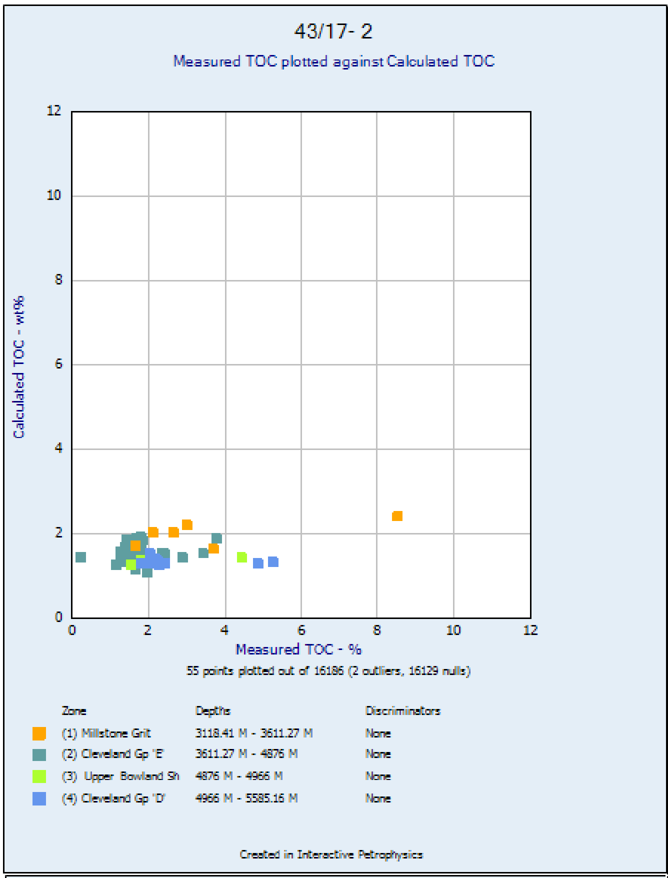

42/10a- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
0
2
4
6
8
10
12
23 points plotted out of 13334 (13311 nulls)
Zone
Depths
Discriminators
(3) Yoredale Formation 2552.4 M - 2997.71 M None
Created in Interactive Petrophysics

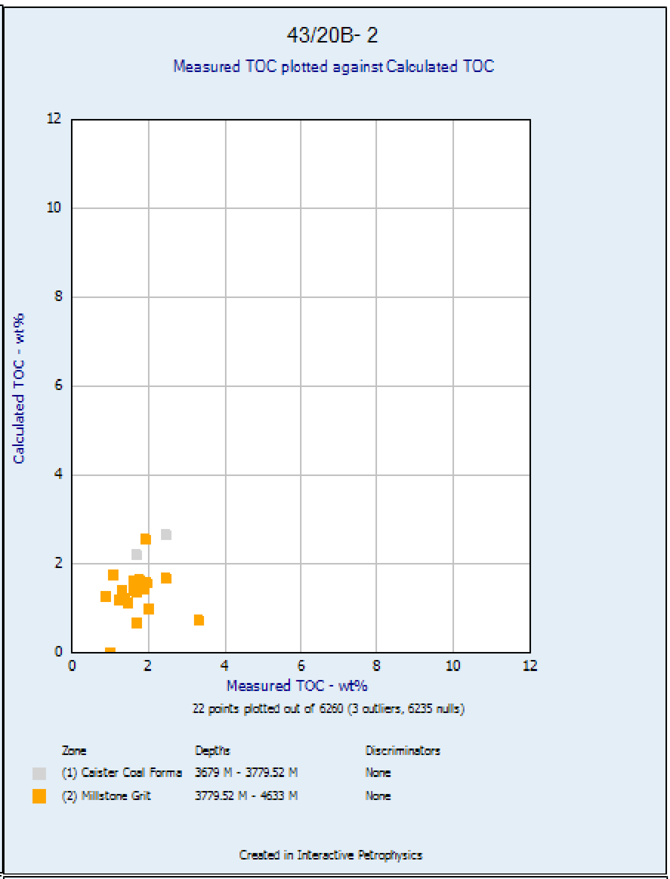

42/15A- 2
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
6 points plotted out of 1791 (1785 nulls)
Zone Depths Discriminators
(1) Scremerston Form 2381 M - 2584 M None
(2) Fell Sandstone Gro 2584 M - 2654 M None
Created in Interactive Petrophysics

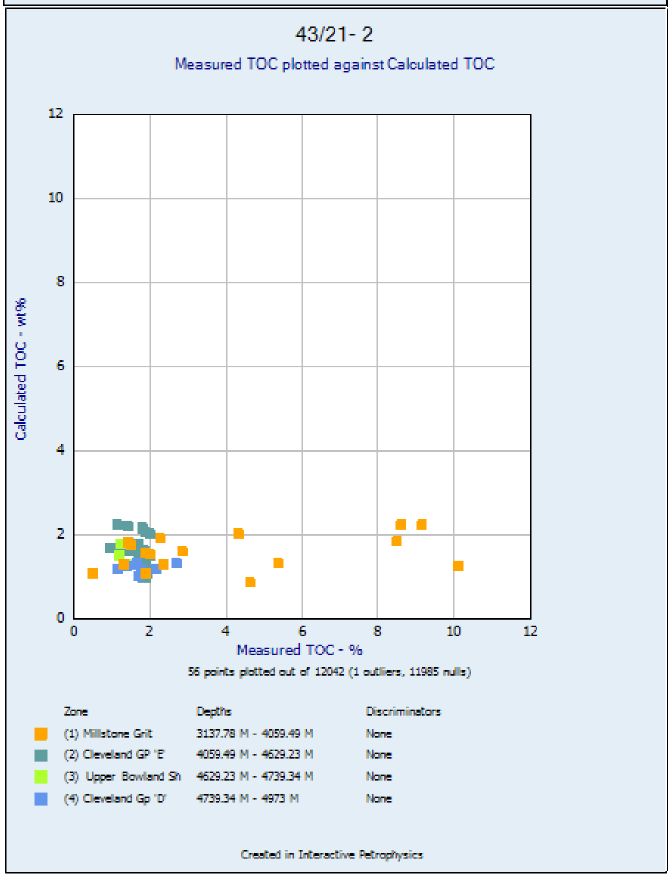

42/22- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
5 points plotted out of 1463 (1458 nulls)
Zone Depths Discriminators
(1) Upper Bowland Sh 2420 M - 2473 M None
(2) Cleveland Gp 'D' 2473 M - 2643 M None
Created in Interactive Petrophysics

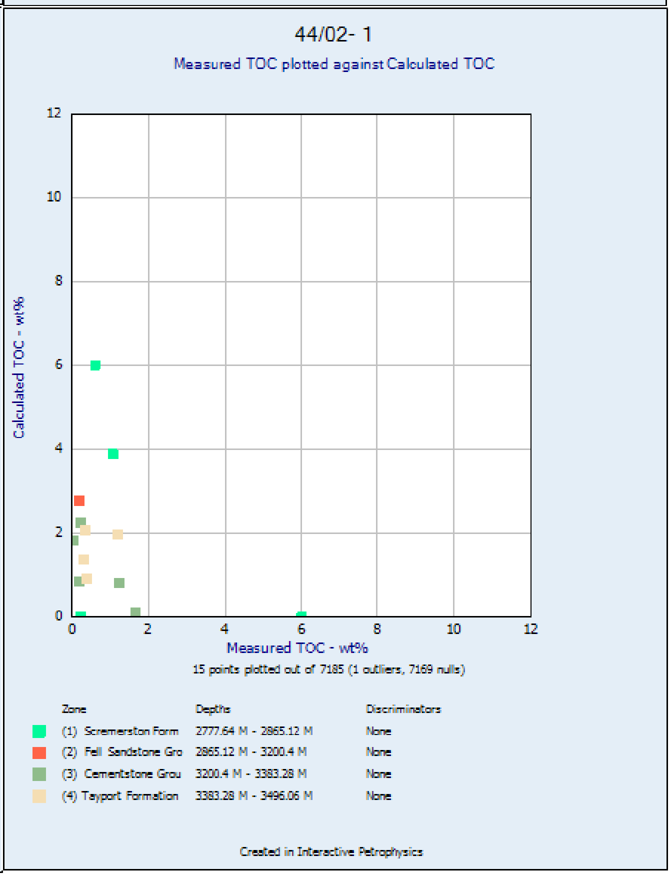

43/15b- 3a
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - %
6 points plotted out of 2550 (2544 nulls)
Zone Depths Discriminators
(1) Caister Coal Forma 3852.67 M - 4048.35 M None
(2) Millstone Grit 4048.35 M - 4241.29 M None
Created in Interactive Petrophysics

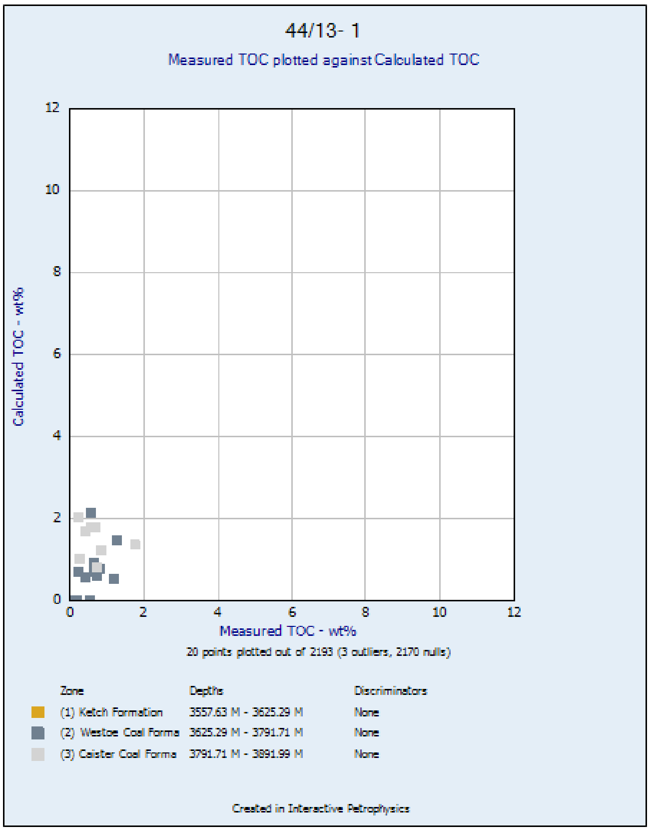

43/16- 2
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - %
5 points plotted out of 2424 (2419 nulls)
Zone Depths Discriminators
(1) Millstone Grit 3177.24 M - 3546.8 M None
Created in Interactive Petrophysics


43/17- 2
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - %
55 points plotted out of 16186 (2 outliers, 16129 nulls)
Zone
Depths
Discriminators
(1) Millstone Grit
3118.41 M - 3611.27 M
None
(2) Cleveland Gp 'E'
3611.27 M - 4876 M
None
(3) Upper Bowland Sh
4876 M - 4966 M
None
(4) Cleveland Gp 'D'
4966 M - 5585.16 M
None
Created in Interactive Petrophysics


43/20B- 2
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
22 points plotted out of 6260 (3 outliers, 6235 nulls)
Zone
Depths
Discriminators
(1) Caister Coal Forma
3679 M - 3779.52 M
None
(2) Millstone Grit
3779.52 M - 4633 M
None
Created in Interactive Petrophysics


43/21- 2
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - %
56 points plotted out of 12042 (1 outliers, 11985 nulls)
Zone
Depths
Discriminators
(1) Millstone Grit
3137.78 M - 4059.49 M
None
(2) Cleveland GP 'E'
4059.49 M - 4629.23 M
None
(3) Upper Bowland Sh
4629.23 M - 4739.34 M
None
(4) Cleveland Gp 'D'
4739.34 M - 4973 M
None
Created in Interactive Petrophysics


44/02- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
15 points plotted out of 7185 (1 outliers, 7169 nulls)
Zone
Depths
Discriminators
(1) Scremerston Form
2777.64 M - 2865.12 M
None
(2) Fell Sandstone Gro
2865.12 M - 3200.4 M
None
(3) Cementstone Grou
3200.4 M - 3383.28 M
None
(4) Tayport Formation
3383.28 M - 3496.06 M
None
Created in Interactive Petrophysics


44/13- 1
Measured TOC plotted against Calculated TOC
Calculated TOC - wt%
Measured TOC - wt%
20 points plotted out of 2193 (3 outliers, 2170 nulls)
Zone
Depths
Discriminators
(1) Ketch Formation
3557.63 M - 3625.29 M
None
(2) Westoe Coal Forma
3625.29 M - 3791.71 M
None
(3) Caister Coal Forma
3791.71 M - 3891.99 M
None
Created in Interactive Petrophysics

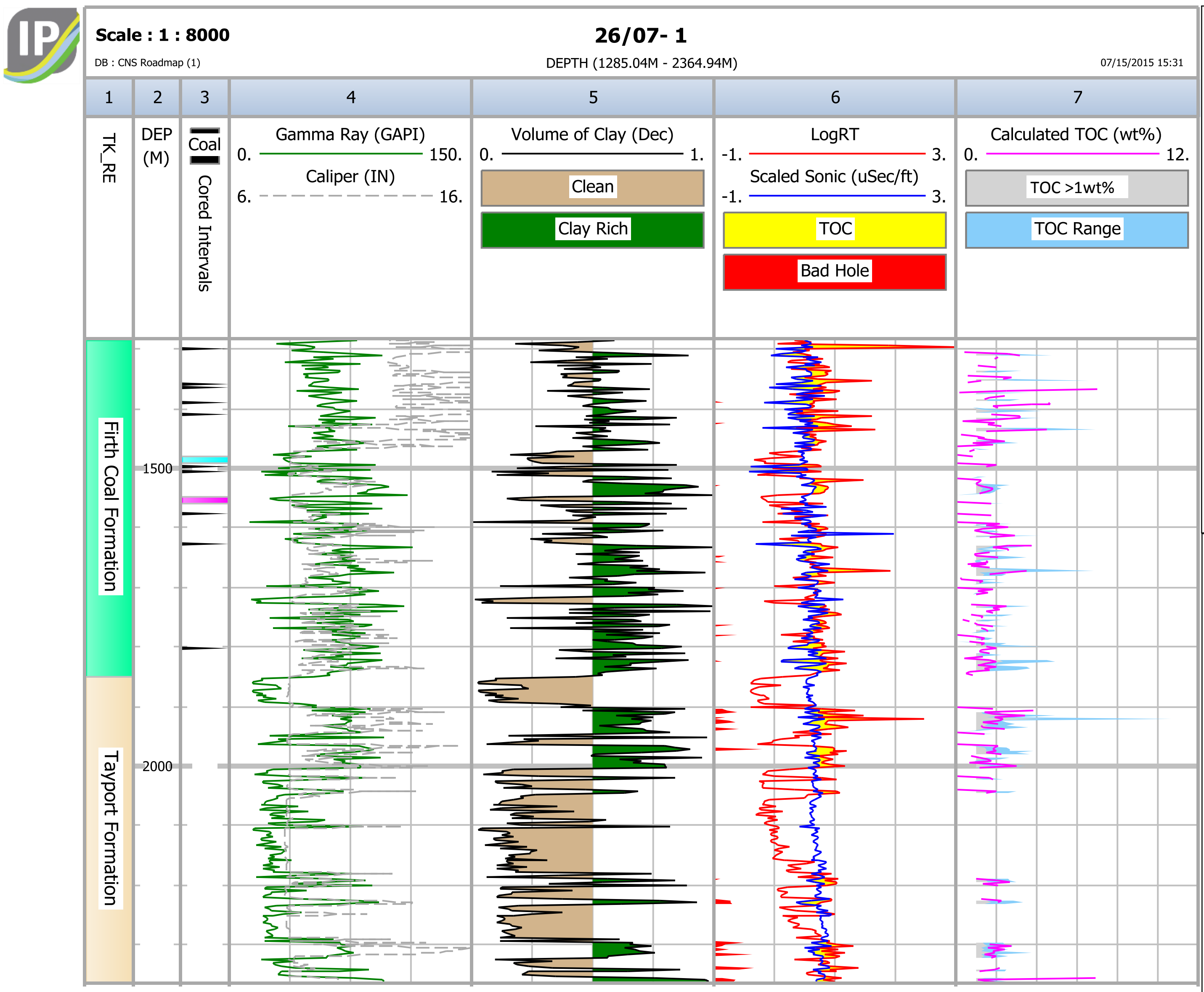
Appendix 4 Log Plots and Statistics

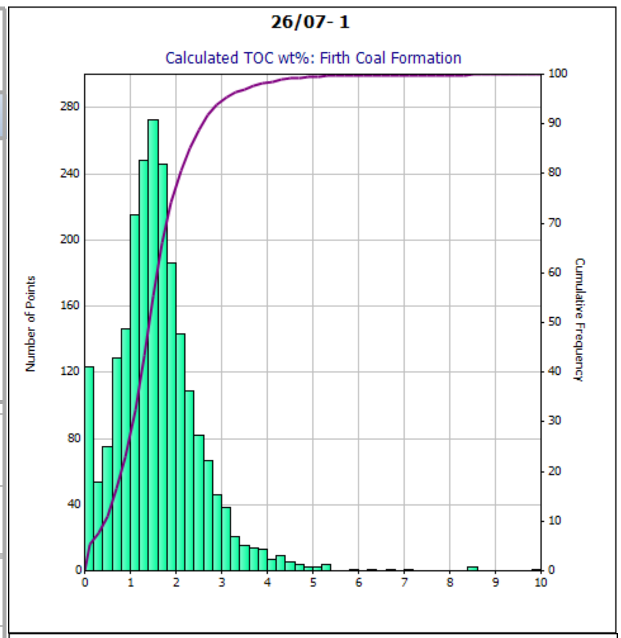
Each track displayed is explained in Section 2.5. Due to the large differences between the thickest and thinnest Palaeozoic successions, two different scales (1:2000 and 1:8000) have been used to plot the data.

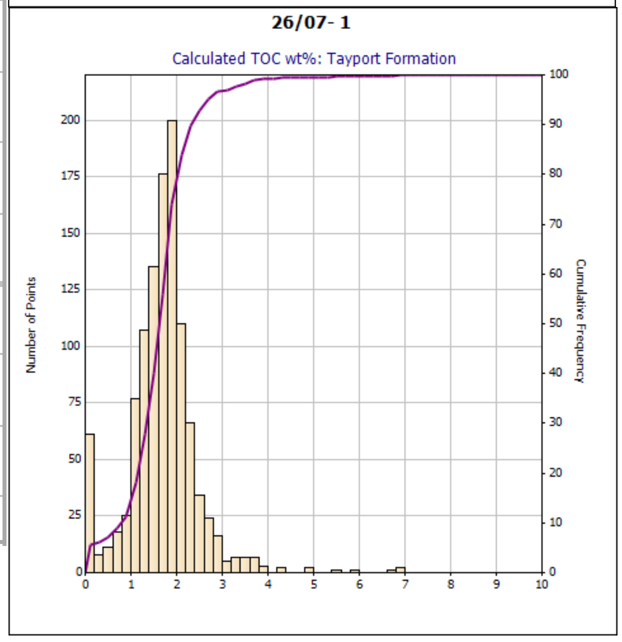
The produced log plots have been terminated at either the base of the formations of interest or the base of the geophysical log data.

The TOC for each formation on the log plots, as well as corresponding histograms of calculated TOC, can be found with a cumulative frequency curve. The colours used for the histograms match those denoted on the log plots and the rest of the overarching project.

For each well there are two tables of statistics: the first contains the statistics for each formation and each calculated TOC curve, including the range of calculated TOC (High Ro TOC and Low Ro TOC). It should be noted that a higher maturity denoted by a higher vitrinite reflectance (Ro) value will result in a lower calculated TOC for the same geophysical log signals; the second table shows net to gross and pay to gross values for each formation and all formations combined. The net value represented is for shale (rather than the conventional sand-net), which was calculated using a volume of clay cut off of 50%. Pay is defined as net shale with TOC > 1 wt%.

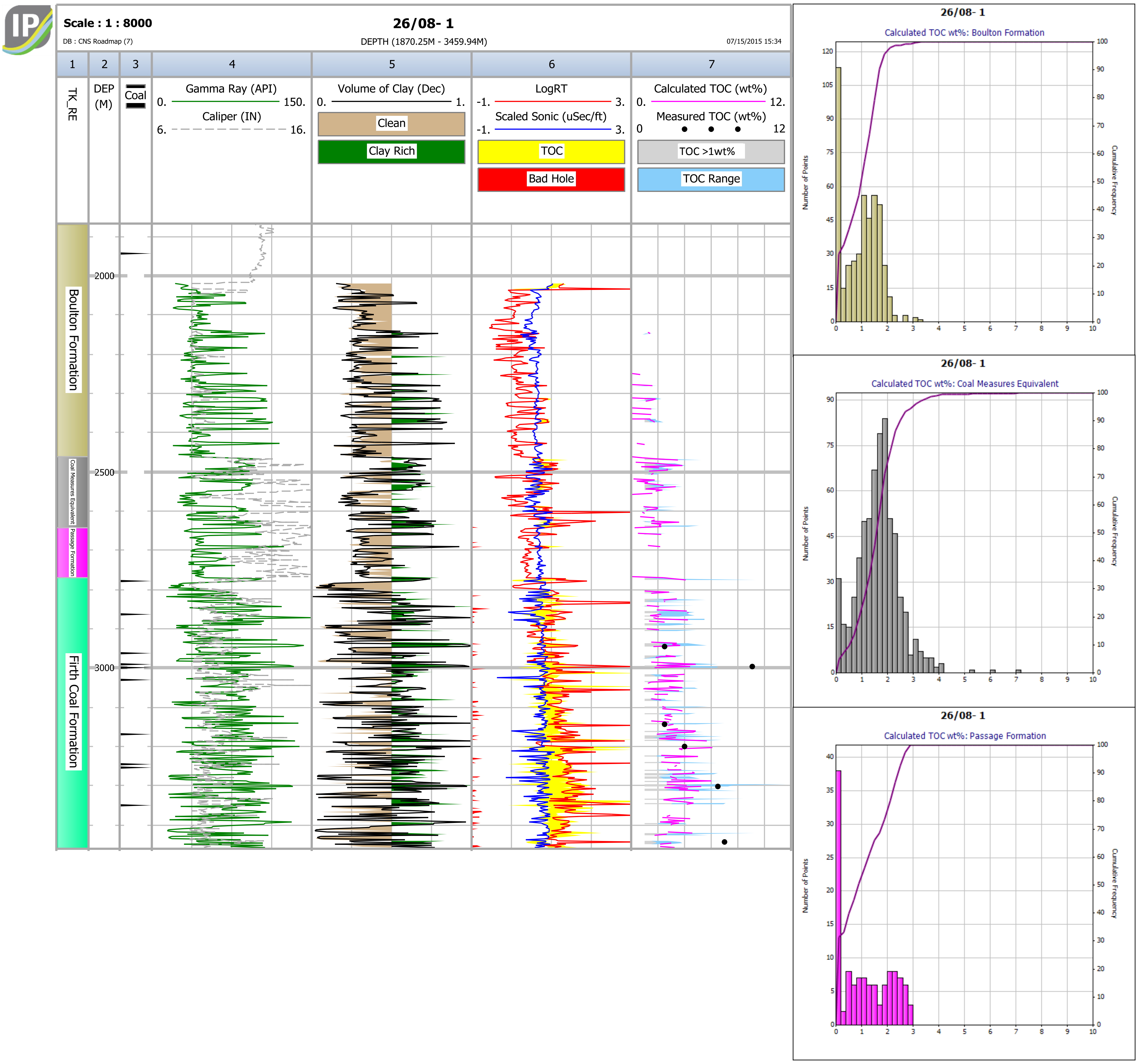






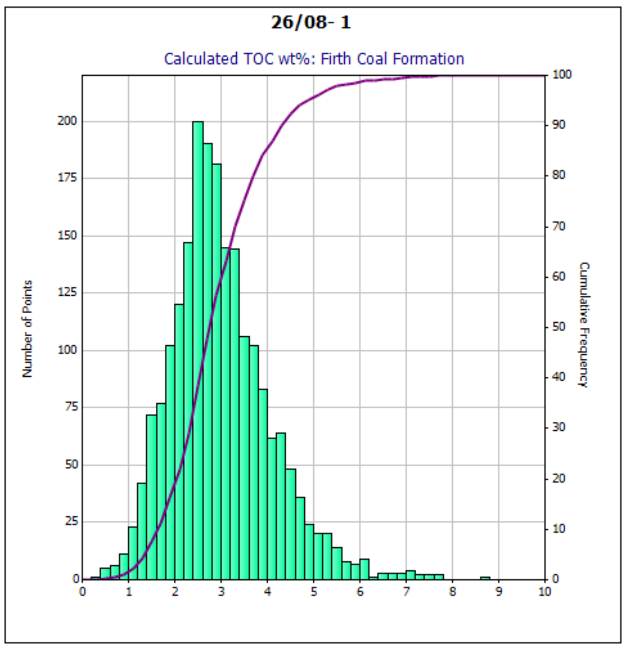
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Firth Coal Formation	Calculated TOC	0.0	10.0	1.6	1.5	1.5	0.93
Firth Coal Formation	High Ro TOC	0.0	6.3	1.3	1.2	1.2	0.58
Firth Coal Formation	Low Ro TOC	0.0	16.0	2.1	2.0	2.1	1.49
Tayport Formation	Calculated TOC	0.0	7.0	1.7	1.7	1.9	0.76
Tayport Formation	High Ro TOC	0.0	4.5	1.3	1.4	1.4	0.49
Tayport Formation	Low Ro TOC	0.0	11.0	2.3	2.3	2.5	1.21

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Firth Coal Formation	1285.0	1850.0	565.0	371.7	0.66	248.6	0.44
Tayport Formation	1850.0	2365.0	515.0	169.1	0.33	142.6	0.28
All Zones	1285.0	2365.0	1080.0	540.8	0.50	391.2	0.36

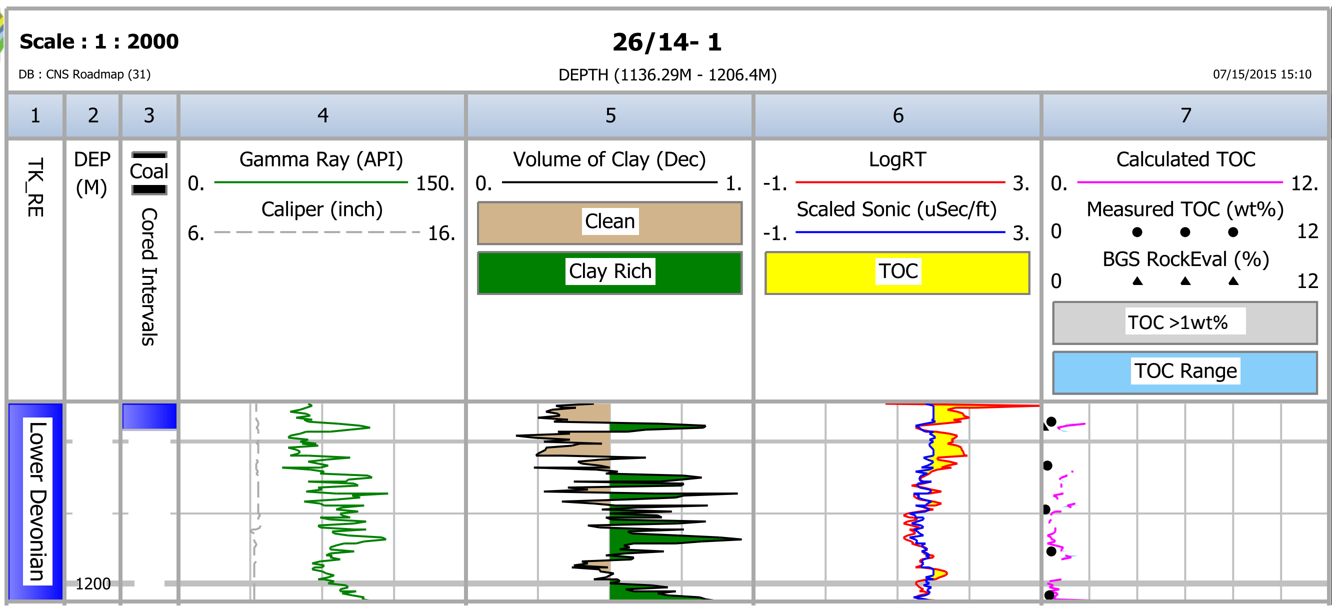


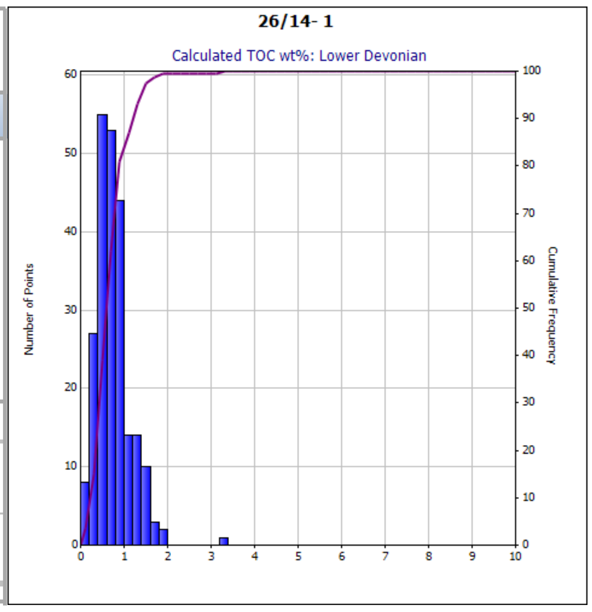
Scale : 1 : 8000
26/08- 1
DB : CNS Roadmap (7)
DEPTH (1870.25M - 3459.94M)
07/15/2015 15:34
TK_RE
DEP (M)
Coal
Gamma Ray (API) 0. 150.
Caliper (IN) 6. 16.
Volume of Clay (Dec) 0. 1.
Clean
Clay Rich
LogRT -1. 3.
Scaled Sonic (uSec/ft) -1. 3.
TOC
Bad Hole
Calculated TOC (wt%) 0. 12.
Measured TOC (wt%) 0 12
TOC >1wt%
TOC Range
Boulton Formation
Coal Measures Equivalent
Passage Formation
Firth Coal Formation
2000
2500
3000
Calculated TOC wt%: Boulton Formation
Calculated TOC wt%: Coal Measures Equivalent
Calculated TOC wt%: Passage Formation
Number of Points
Cumulative Frequency

Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Boulton Formation	Calculated TOC	0.0	3.2	1.0	1.1	0.0	0.70
Boulton Formation	High Ro TOC	0.0	2.3	0.9	1.0	0.0	0.48
Boulton Formation	Low Ro TOC	0.0	4.8	1.2	1.3	0.0	1.00
Boulton Formation	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Coal Measures Equivalent	Calculated TOC	0.0	7.1	1.7	1.7	N/A	0.84
Coal Measures Equivalent	High Ro TOC	0.0	4.6	1.3	1.3	1.5	0.52
Coal Measures Equivalent	Low Ro TOC	0.0	11.3	2.3	2.3	2.1	1.36
Coal Measures Equivalent	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Passage Formation	Calculated TOC	0.0	2.9	1.1	1.0	0.0	0.97
Passage Formation	High Ro TOC	0.0	2.1	0.9	0.9	0.0	0.67
Passage Formation	Low Ro TOC	0.0	4.3	1.5	1.1	0.1	1.44
Passage Formation	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Firth Coal Formation	Calculated TOC	0.4	10.1	3.0	2.9	2.6	1.10
Firth Coal Formation	High Ro TOC	0.5	6.4	2.2	2.1	1.9	0.68
Firth Coal Formation	Low Ro TOC	0.1	16.2	4.6	4.3	3.8	1.87
Firth Coal Formation	Measured TOC	2.5	71.8	24.0	17.8	11.2	24.28



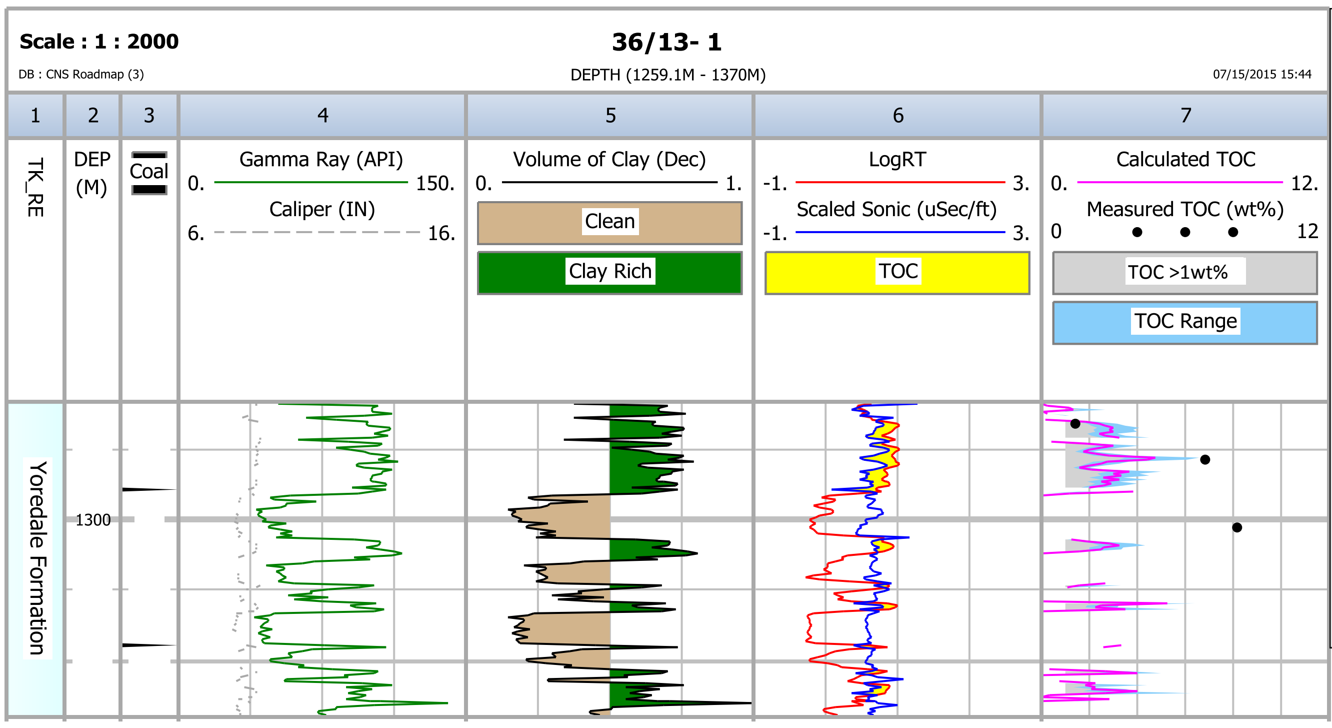
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Boulton Formation	1870.3	2462.8	592.5	70.9	0.12	33.2	0.08
Coal Measures Equivalent	2462.8	2643.3	180.6	100.2	0.56	74.7	0.41
Passage Formation	2643.3	2770.9	127.6	18.4	0.15	8.4	0.07
Firth Coal Formation	2770.9	3460.0	689.1	346.2	0.50	313.2	0.45
All Zones	1870.3	3460.0	1589.8	535.8	0.34	429.5	0.29

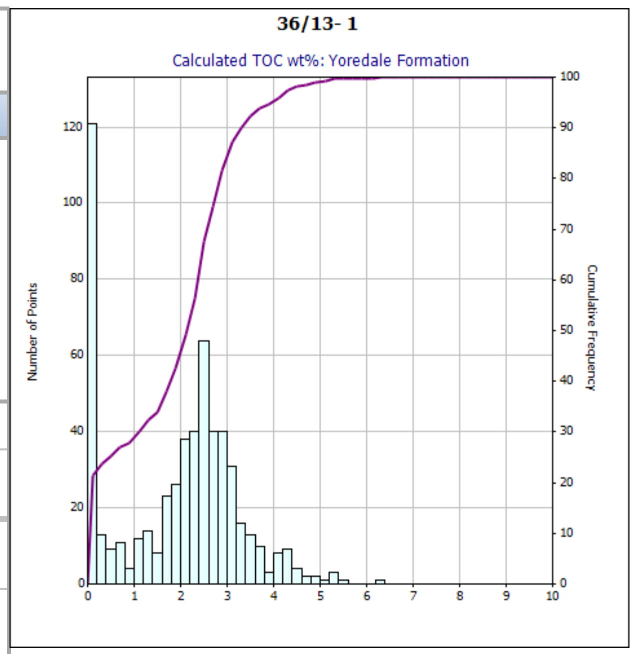




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Lower Devonian	Calculated TOC	0.0	3.3	0.7	0.7	0.5	0.39
Lower Devonian	High Ro TOC	0.3	2.3	0.8	0.7	0.6	0.24
Lower Devonian	Low Ro TOC	0.0	4.9	0.7	0.6	0.0	0.63
Lower Devonian	Measured TOC	0.1	0.4	0.3	0.4	N/A	0.11
Lower Devonian	RockEval TOC	0.1	0.1	0.1	0.1	N/A	N/A

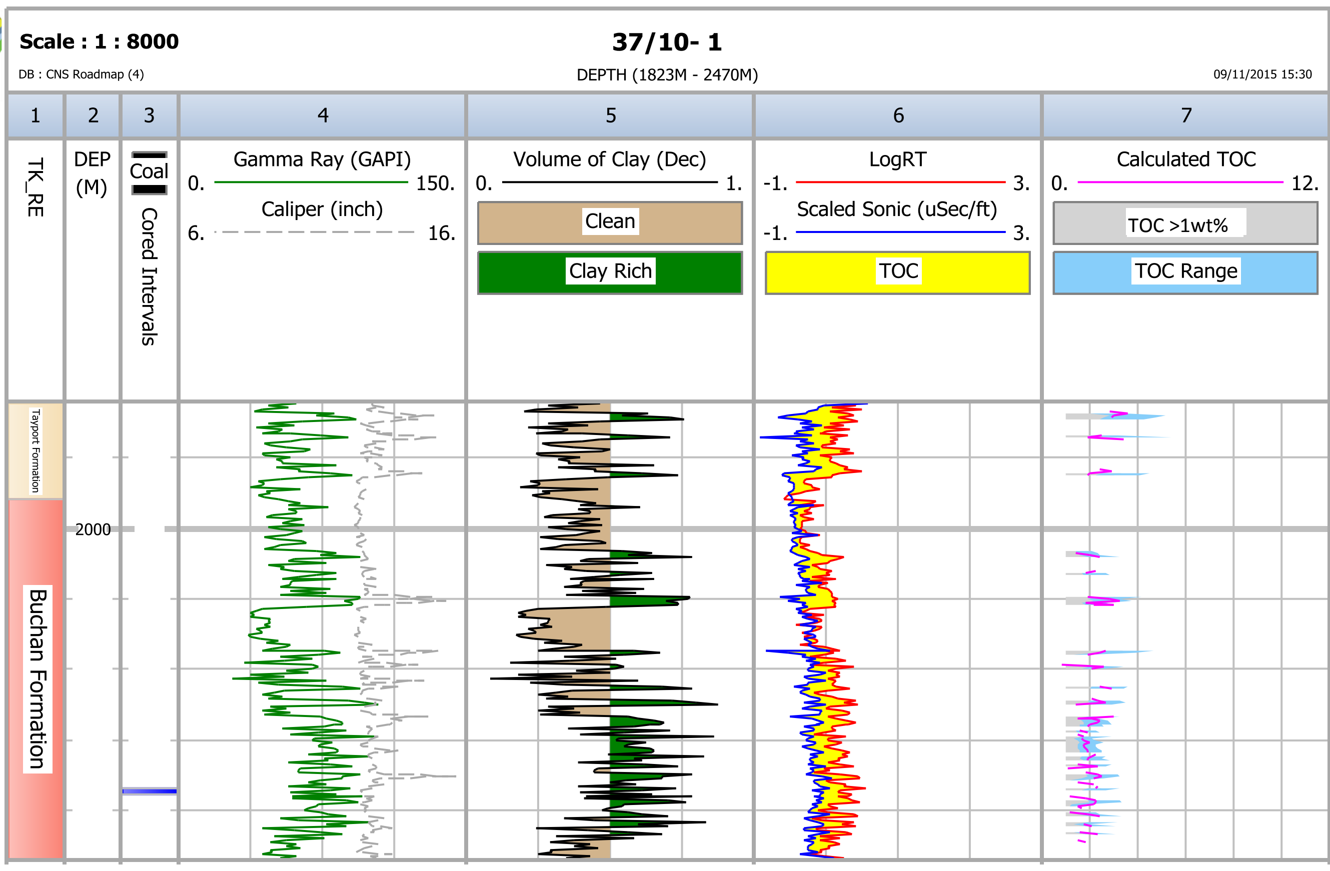
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Lower Devonian	1136.3	1206.4	70.1	35.6	0.51	4.7	0.07

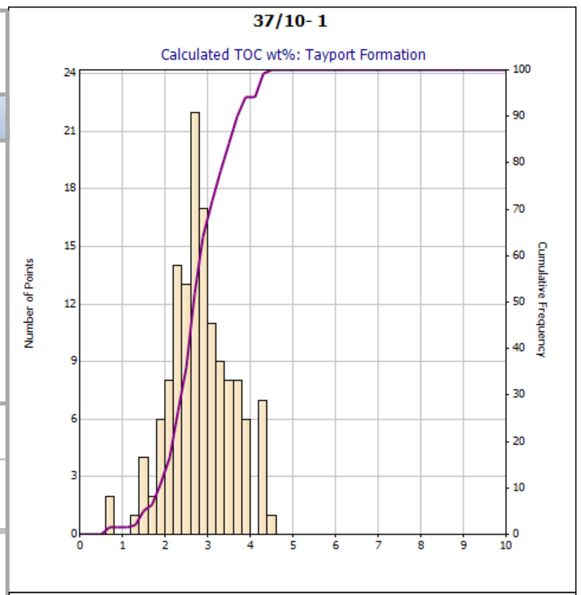


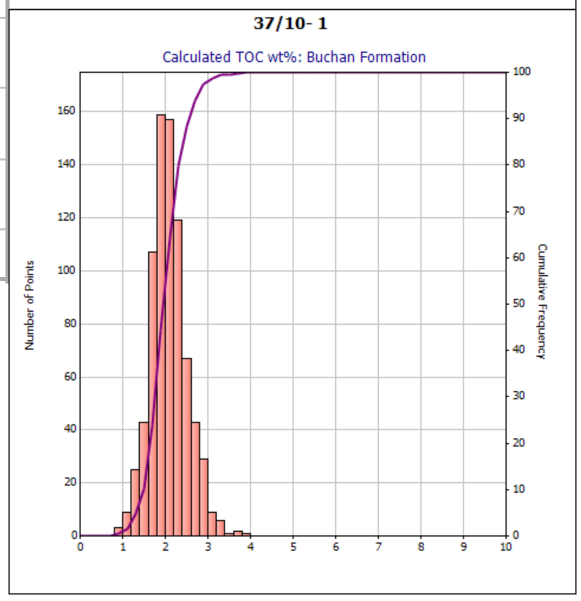


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.0	6.2	2.0	2.2	0.1	1.31
Yoredale Formation	High Ro TOC	0.0	4.5	1.5	1.8	0.0	0.96
Yoredale Formation	Low Ro TOC	0.0	8.8	2.6	2.9	0.1	1.83
Yoredale Formation	Measured TOC	1.4	62.0	33.4	40.2	51.9	22.70

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Yoredale Formation	1259.1	1370.0	110.9	56.5	0.51	40.5	0.37

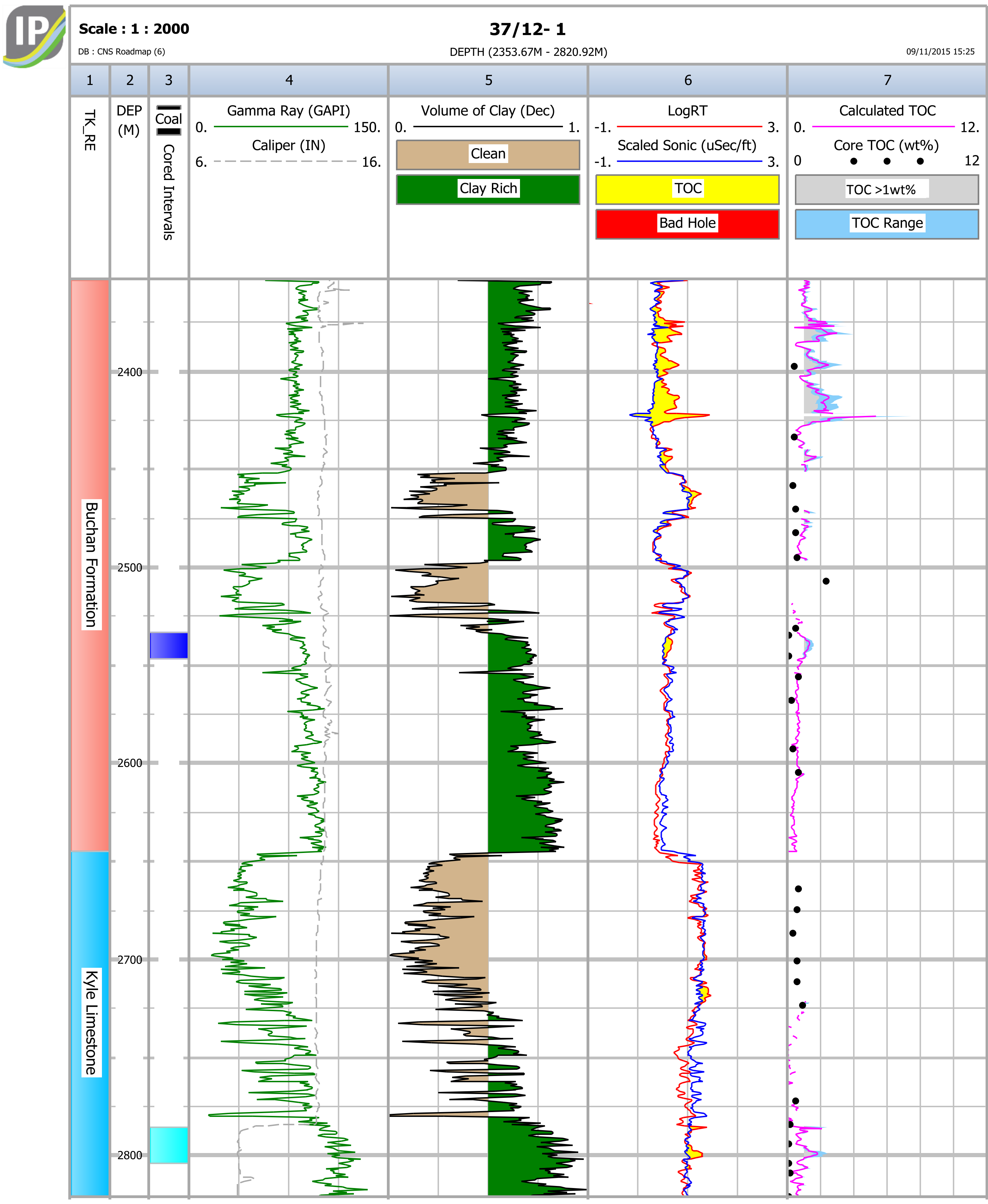


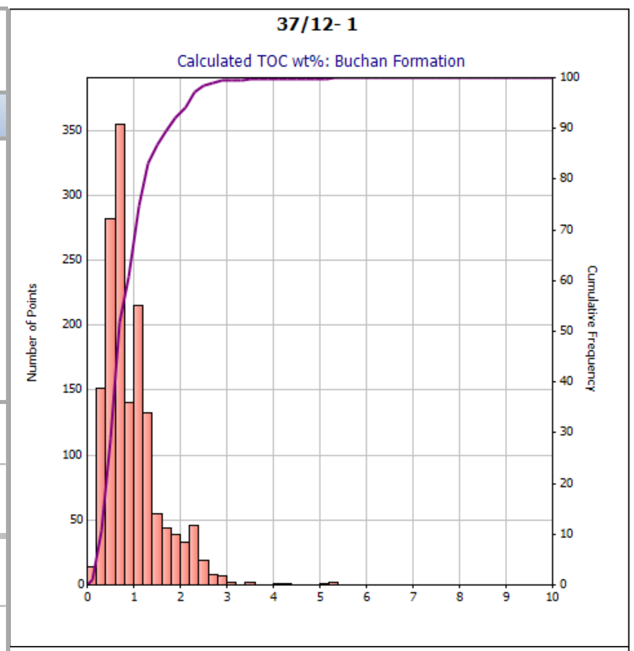


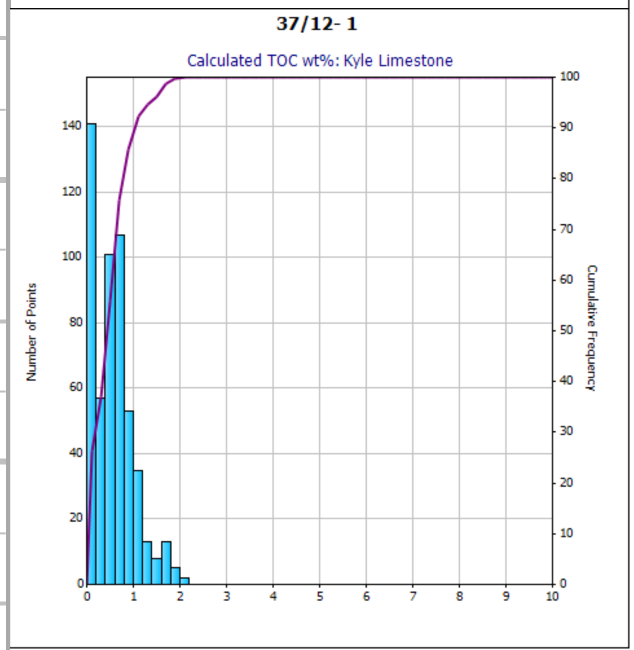


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Tayport Formation	Calculated TOC	0.7	4.5	2.8	2.8	2.4	0.73
Tayport Formation	High Ro TOC	0.7	3.3	2.2	2.1	1.9	0.49
Tayport Formation	Low Ro TOC	0.7	6.3	3.8	3.7	3.2	1.07
Buchan Formation	Calculated TOC	0.8	4.0	2.1	2.1	2.0	0.43
Buchan Formation	High Ro TOC	0.8	2.9	1.7	1.7	1.6	0.29
Buchan Formation	Low Ro TOC	0.8	5.5	2.7	2.7	2.5	0.64

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Tayport Formation	1823.0	1959.0	136.0	34.8	0.26	34.3	0.25
Buchan Formation	1959.0	2470.0	511.0	195.0	0.38	193.8	0.38
All Zones	1823.0	2470.0	647.0	229.8	0.36	228.0	0.35

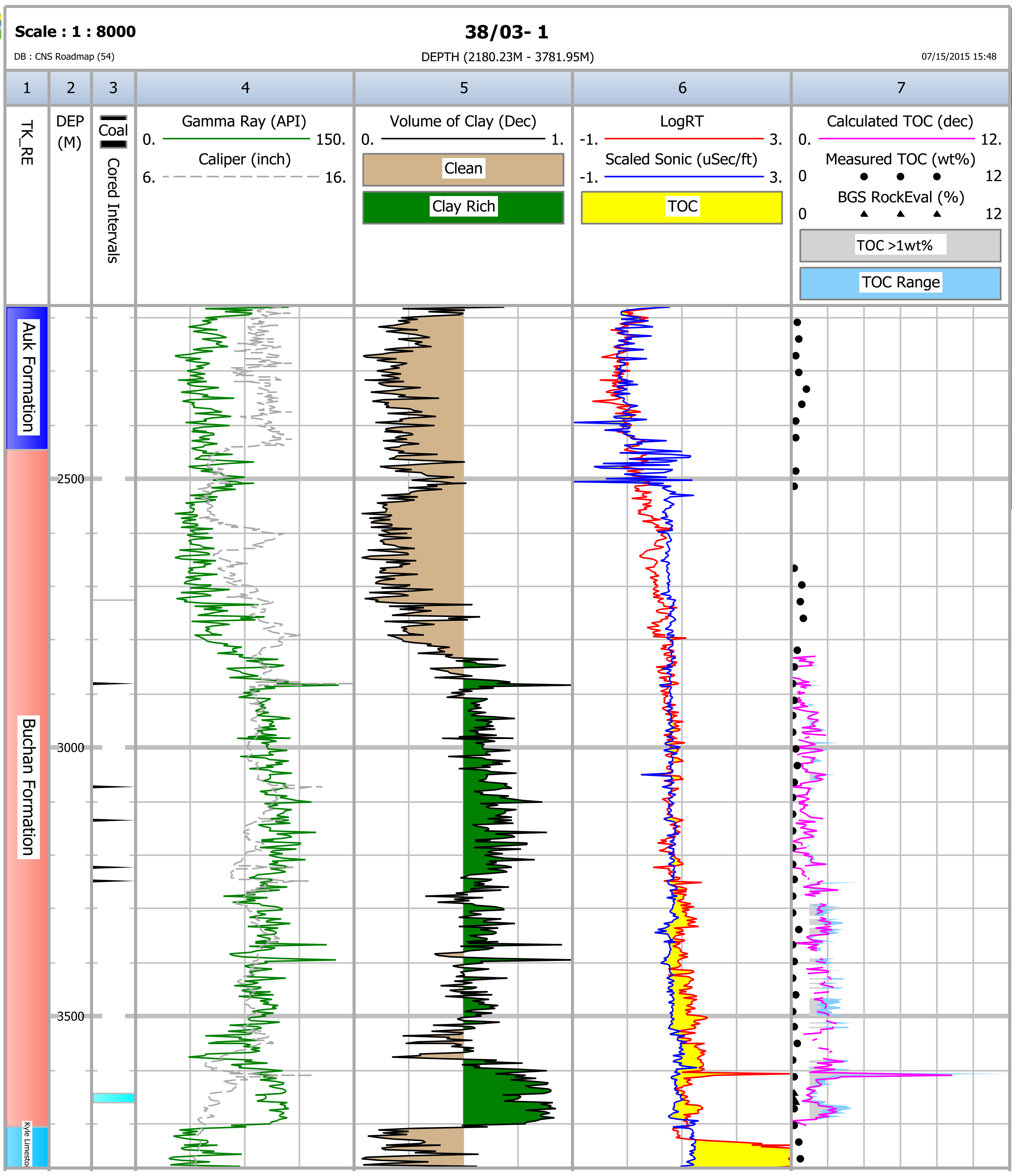


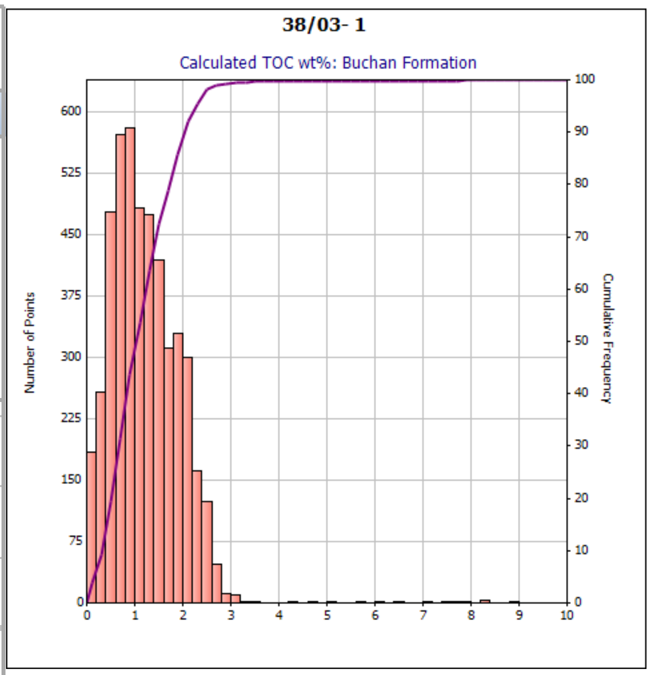




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Buchan Formation	Calculated TOC	0.0	5.4	1.0	0.7	0.6	0.63
Buchan Formation	High Ro TOC	0.1	3.9	0.9	0.8	0.7	0.43
Buchan Formation	Low Ro TOC	0.0	7.5	1.0	0.7	0.5	0.92
Buchan Formation	Measured TOC	0.1	2.4	0.5	0.5	0.3	0.56
Kyle Limestone	Calculated TOC	0.0	2.2	0.6	0.5	0.0	0.46
Kyle Limestone	High Ro TOC	0.0	1.7	0.6	0.6	0.7	0.33
Kyle Limestone	Low Ro TOC	0.0	2.9	0.5	0.4	0.0	0.58
Kyle Limestone	Measured TOC	0.1	0.9	0.4	0.5	0.2	0.28

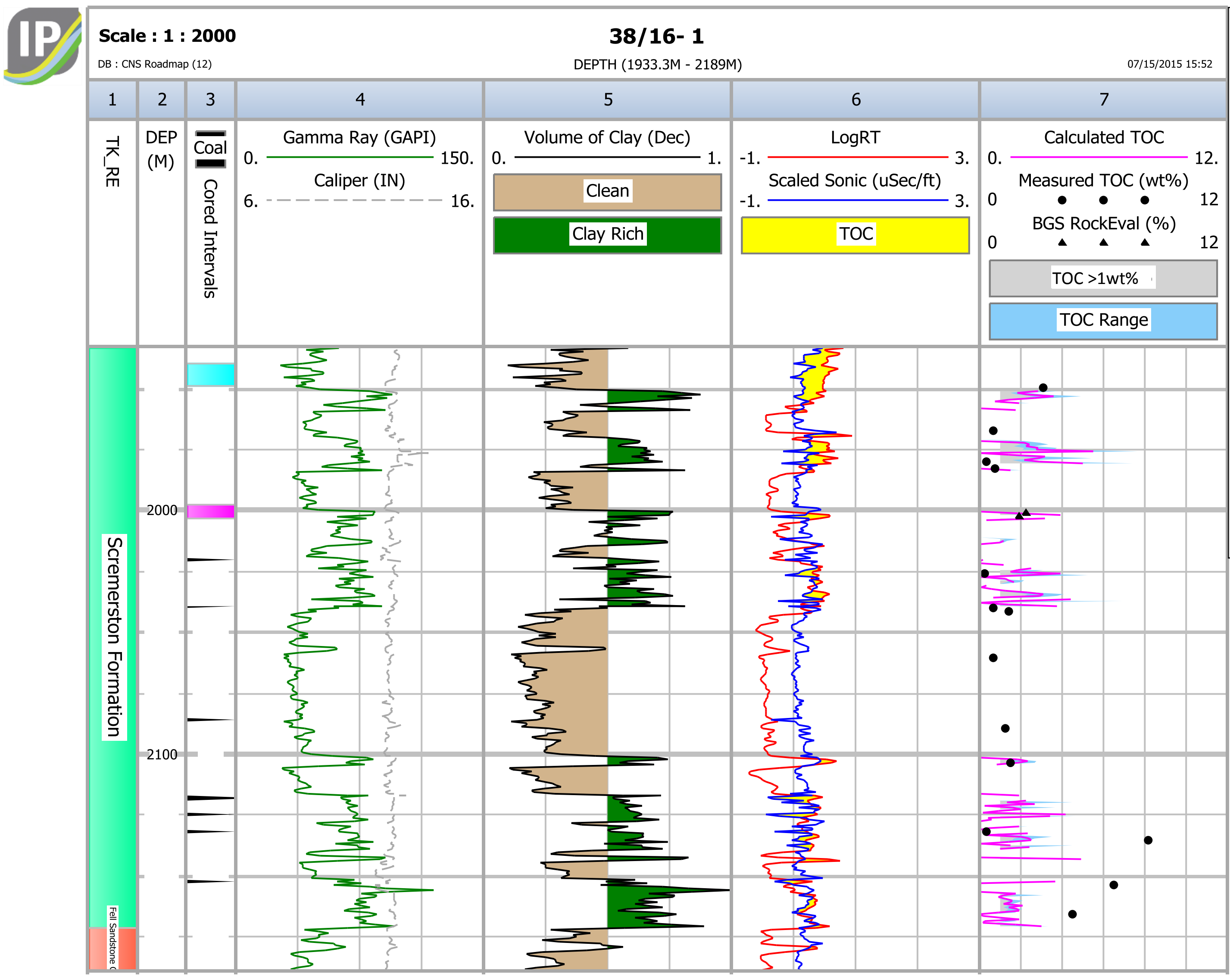
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Buchan Formation	2353.7	2645.0	291.3	235.9	0.81	75.0	0.26
Kyle Limestone	2645.0	2821.0	176.0	75.9	0.43	8.8	0.05
All Zones	2353.7	2821.0	467.3	311.8	0.67	83.8	0.18

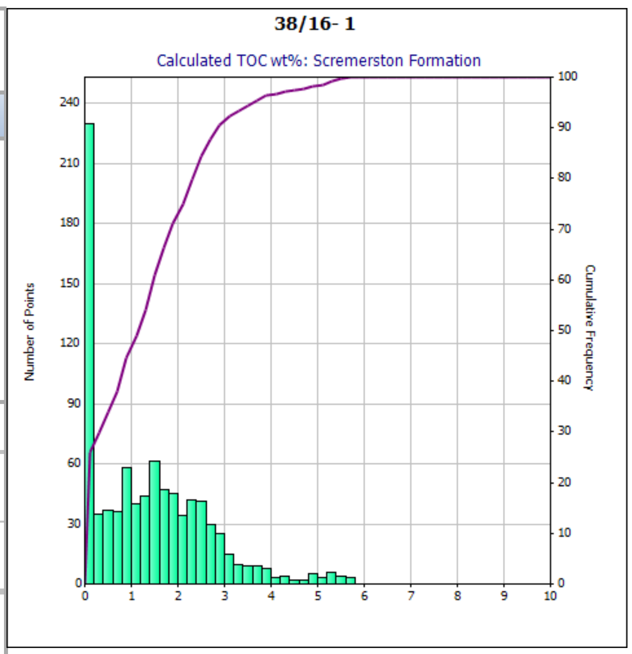




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Buchan Formation	Calculated TOC	0.0	8.8	1.2	1.1	0.6	0.75
Buchan Formation	High Ro TOC	0.0	6.2	1.1	1.0	0.8	0.51
Buchan Formation	Low Ro TOC	0.0	12.6	1.4	1.3	0.9	1.09
Buchan Formation	Measured TOC	0.1	0.6	0.2	0.1	0.1	0.15
Buchan Formation	RockEval TOC	0.1	0.3	0.2	0.2	N/A	0.06
Kyle Limestone	Calculated TOC	1.6	9.0	7.0	8.2	8.5	2.73
Kyle Limestone	High Ro TOC	1.4	6.3	5.0	5.8	6.0	1.85
Kyle Limestone	Low Ro TOC	2.0	12.9	9.9	11.8	12.2	4.02
Kyle Limestone	Measured TOC	0.4	0.5	0.4	0.5	N/A	0.08
Kyle Limestone	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A

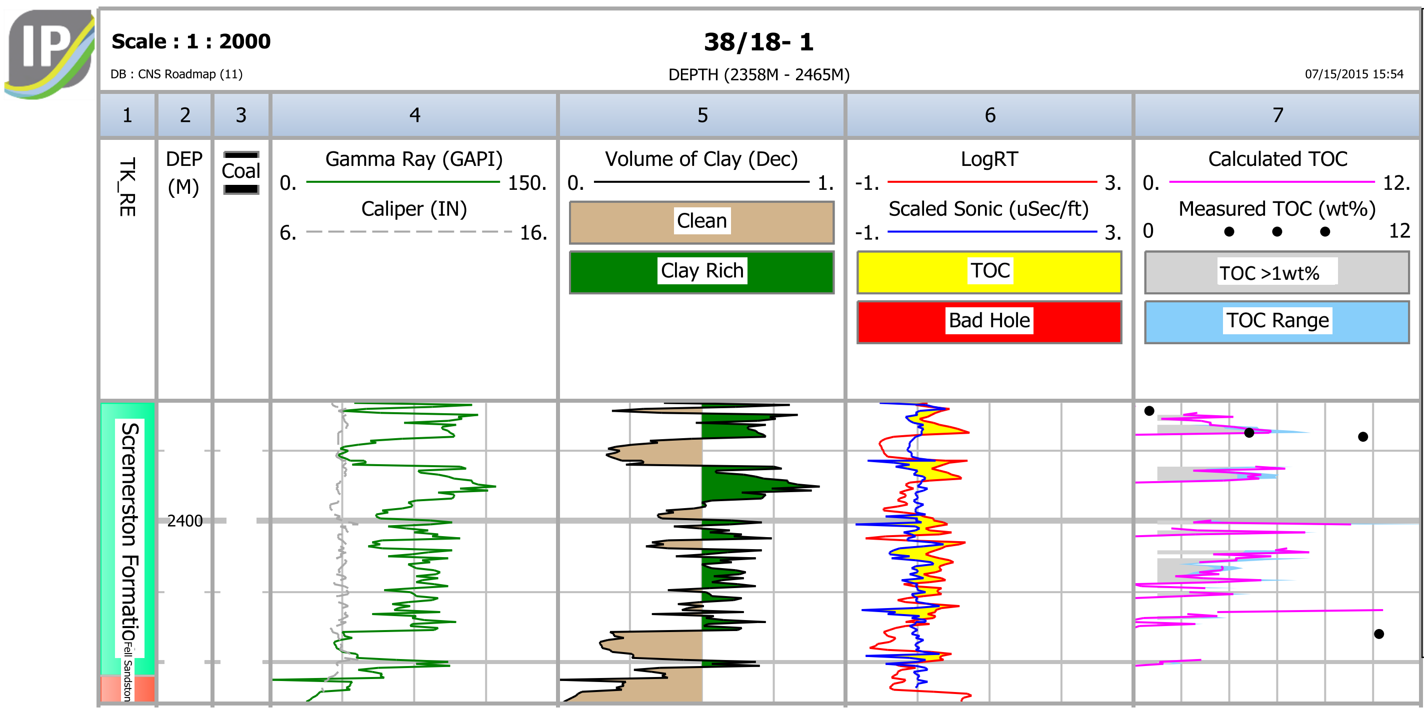
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Auk Formation	2180.2	2447.0	266.8	2.7	0.01	2.3	0.01
Buchan Formation	2447.0	3705.0	1258.0	733.7	0.58	376.2	0.30
Kyle Limestone	3705.0	3782.0	77.0	3.7	0.05	3.7	0.05
All Zones	2180.2	3782.0	1601.8	740.2	0.46	382.2	0.24

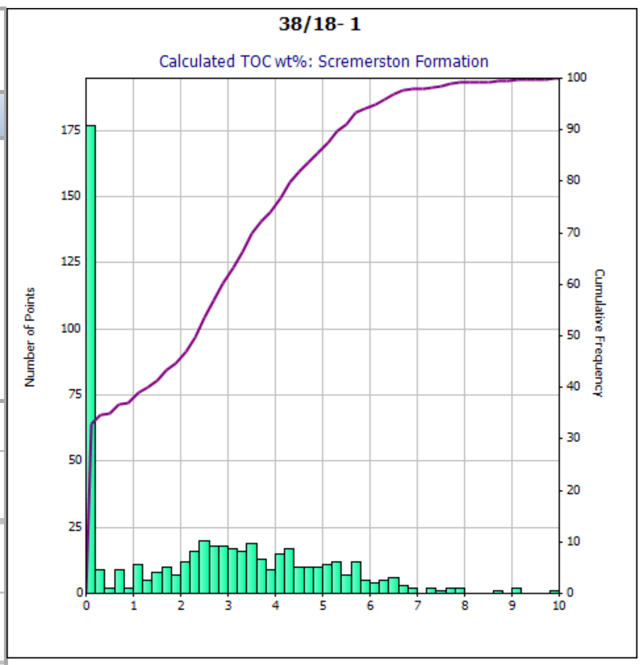




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Scremerston Formation	Calculated TOC	0.0	5.7	1.4	1.2	0.1	1.26
Scremerston Formation	High Ro TOC	0.0	4.1	1.1	1.1	0.0	0.91
Scremerston Formation	Low Ro TOC	0.0	8.0	1.8	1.5	0.1	1.76
Scremerston Formation	Measured TOC	0.3	52.2	13.6	3.1	4.6	19.01
Scremerston Formation	RockEval TOC	1.9	2.2	2.1	2.2	N/A	0.20
Fell Sandstone	Calculated TOC	2.8	2.8	2.8	2.8	N/A	N/A
Fell Sandstone	High Ro TOC	2.2	2.2	2.2	2.2	N/A	N/A
Fell Sandstone	Low Ro TOC	3.8	3.8	3.8	3.8	N/A	N/A
Fell Sandstone	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Fell Sandstone	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A

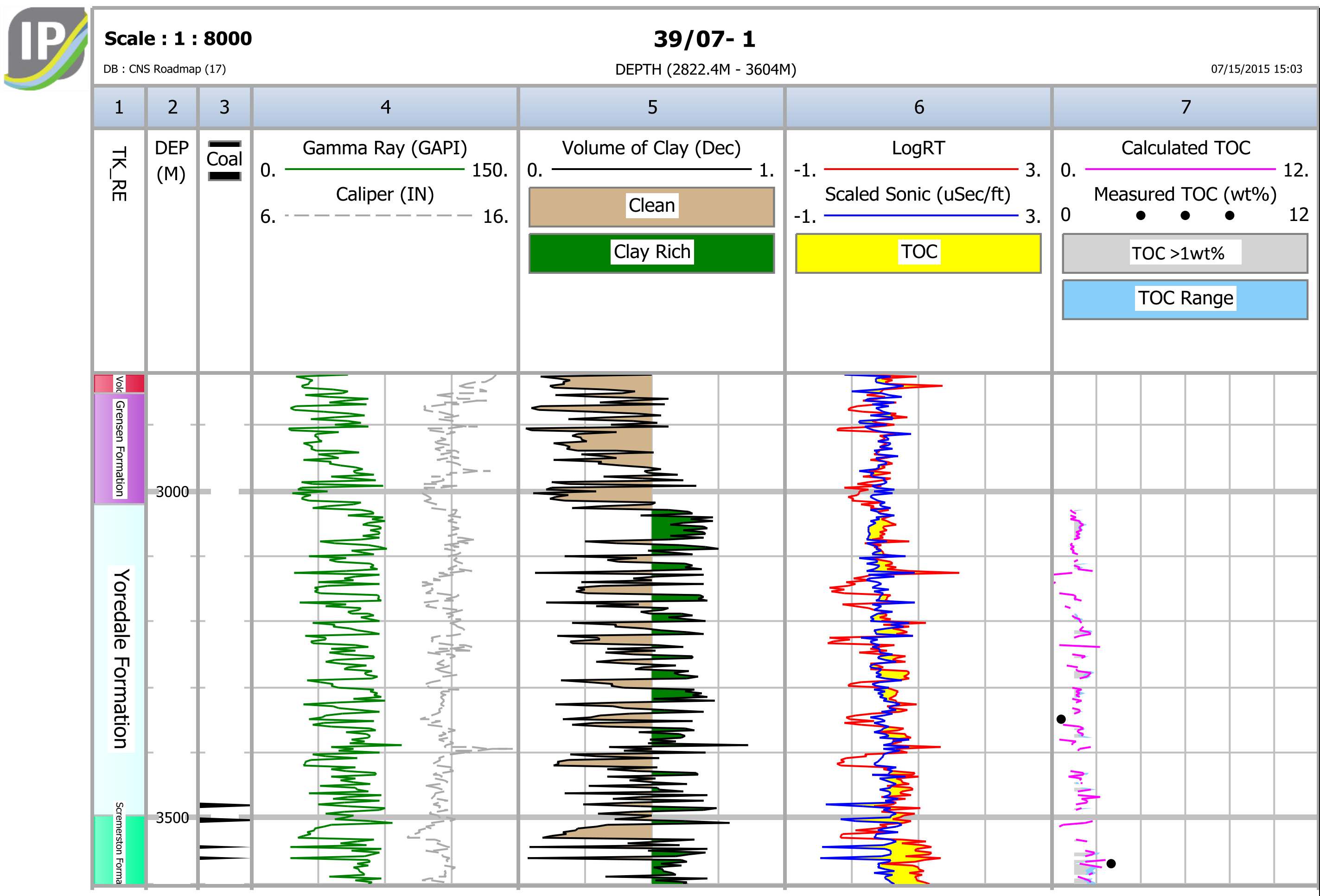
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Scremerston Formation	1933.4	2171.0	237.7	93.7	0.39	47.2	**0.20**
Fell Sandstone Group	2171.0	2189.0	18.0	1.7	0.09	0.1	**0.00**
All Zones	1933.4	2189.0	255.7	95.3	0.37	47.2	**0.19**

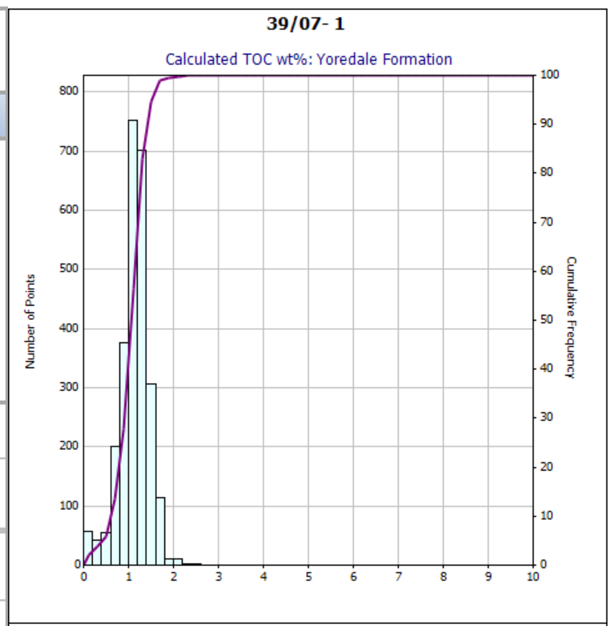


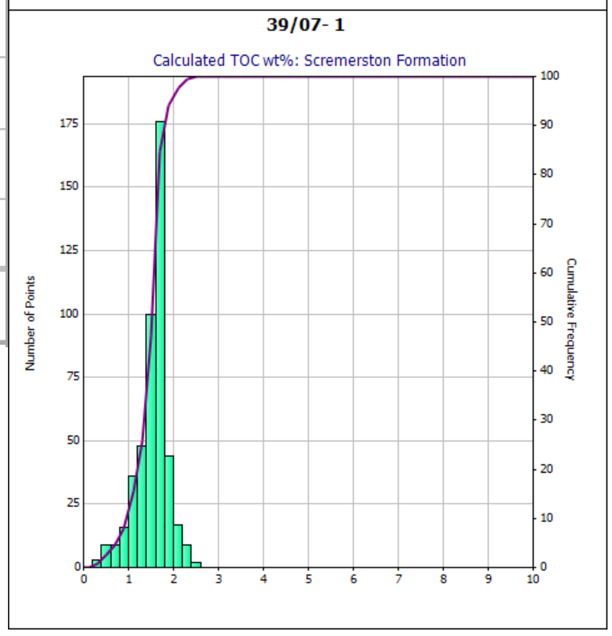


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Scremerston Formation	Calculated TOC	0.0	11.3	2.5	2.4	0.1	2.35
Scremerston Formation	High Ro TOC	0.0	9.5	2.1	2.1	0.1	1.98
Scremerston Formation	Low Ro TOC	0.0	13.6	2.9	2.8	0.1	2.79
Scremerston Formation	Measured TOC	0.7	43.8	21.9	22.3	N/A	13.92

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Scremerston Formation	2358.0	2455.2	97.2	54.3	0.56	34.1	0.35
Fell Sandstone Group	2455.2	2459.0	3.8	0.0	0.00	0.0	0.00
All Zones	2358.0	2459.0	101.0	54.3	0.54	34.1	0.34

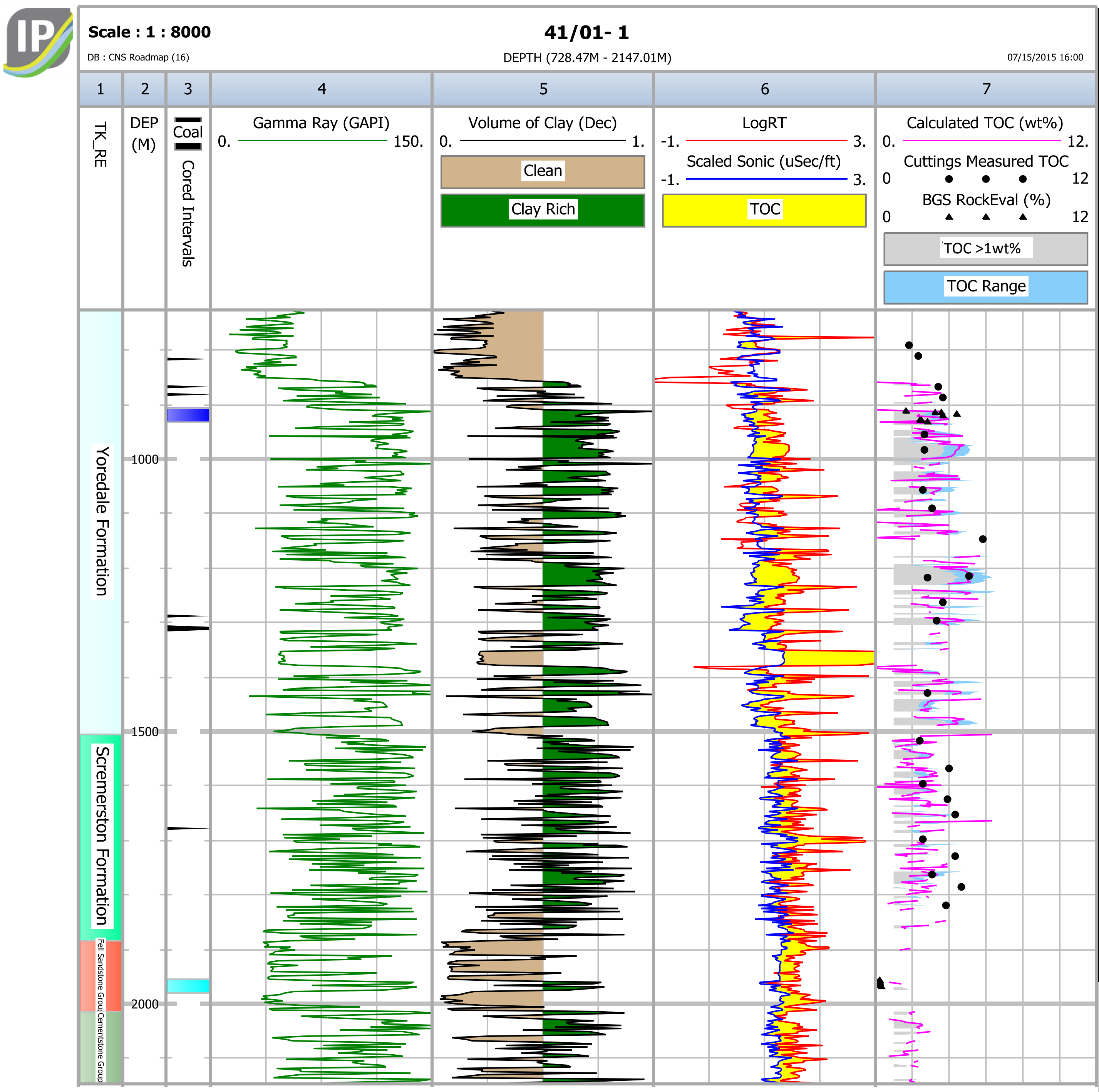


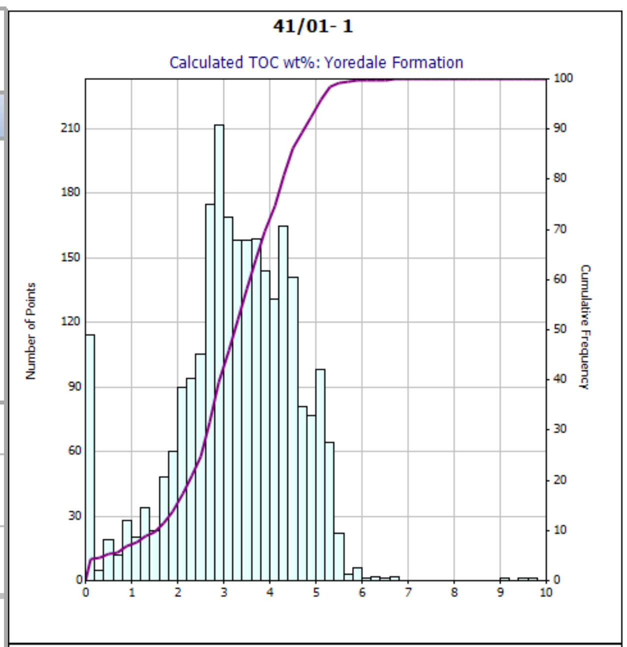


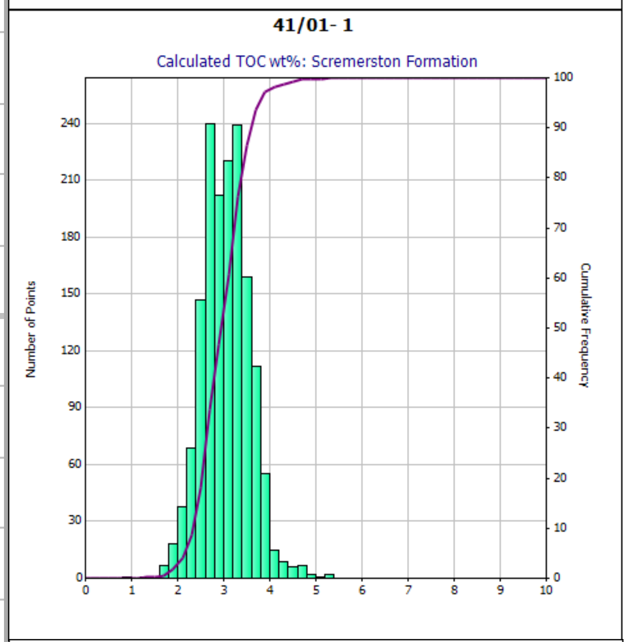


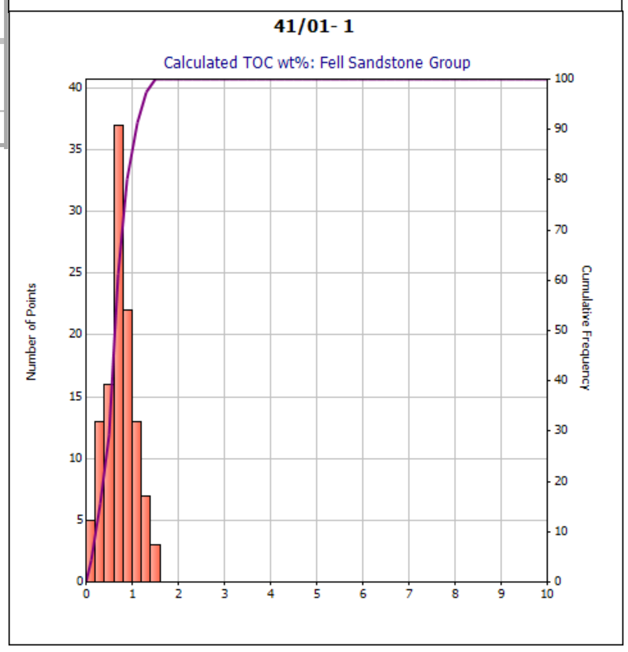
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.0	2.4	1.1	1.2	1.0	0.33
Yoredale Formation	High Ro TOC	0.0	2.1	1.1	1.1	N/A	0.28
Yoredale Formation	Low Ro TOC	0.0	2.8	1.2	1.2	1.4	0.40
Yoredale Formation	Measured TOC	0.4	23.4	11.9	23.4	N/A	16.26
Scremerston Formation	Calculated TOC	0.3	2.5	1.5	1.6	1.7	0.35
Scremerston Formation	High Ro TOC	0.4	2.2	1.4	1.5	1.5	0.29
Scremerston Formation	Low Ro TOC	0.2	2.8	1.7	1.8	1.8	0.43
Scremerston Formation	Measured TOC	2.7	20.5	14.1	19.0	N/A	9.87

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Yoredale Formation	3020.0	3495.0	475.0	264.5	0.56	173.2	0.37
Scremerston Formation	3495.0	3604.0	109.0	50.8	0.47	42.9	0.39
Inge Volcanics	2822.5	2852.0	29.6	1.3	0.04	0.0	0.00
Grensen Formation	2852.0	3020.0	168.0	27.4	0.16	0.0	0.00
All Zones	2822.5	3604.0	781.6	343.9	0.44	216.1	0.28

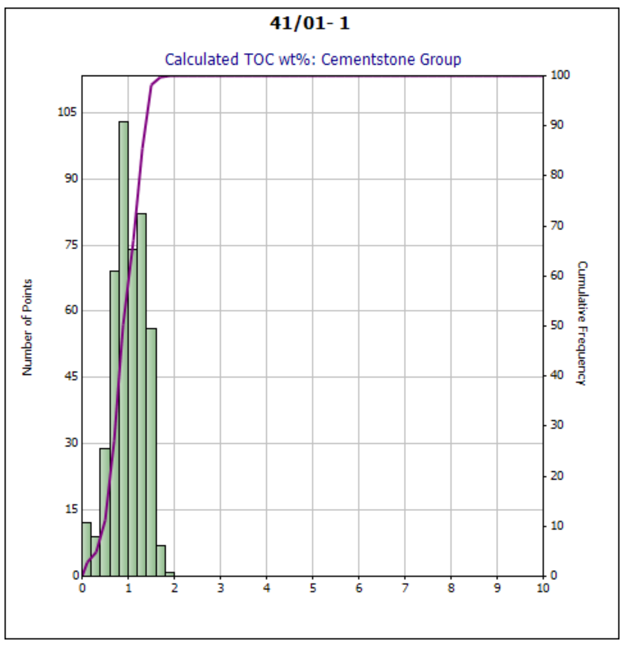




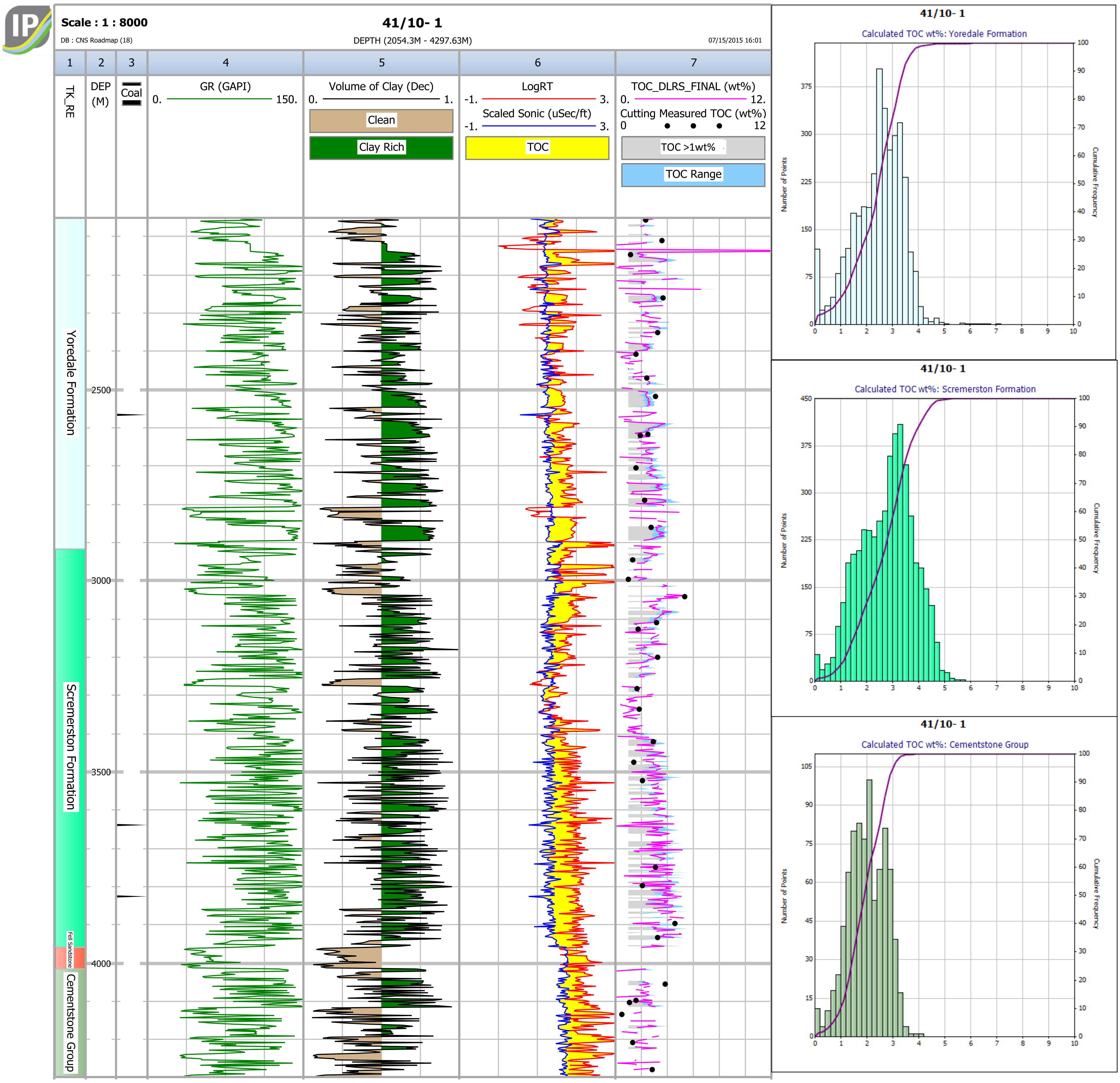




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.0	9.7	3.3	3.3	3.0	1.30
Yoredale Formation	High Ro TOC	0.0	8.1	2.8	2.9	2.5	1.08
Yoredale Formation	Low Ro TOC	0.0	11.6	3.8	3.9	3.4	1.56
Yoredale Formation	Measured TOC	1.8	45.4	6.1	3.1	6.2	10.93
Yoredale Formation	RockEval TOC	1.6	39.0	7.0	3.3	7.9	12.02
Scremerston Formation	Calculated TOC	0.0	6.3	2.4	2.4	3.0	0.88
Scremerston Formation	High Ro TOC	0.0	4.7	1.9	1.9	N/A	0.62
Scremerston Formation	Low Ro TOC	0.0	6.6	2.4	2.4	1.8	0.92
Scremerston Formation	Measured TOC	2.4	66.8	9.3	3.9	13.1	19.08
Scremerston Formation	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Fell Sandstone	Calculated TOC	0.4	2.5	1.6	1.6	1.6	0.37
Fell Sandstone	High Ro TOC	0.4	2.5	1.6	1.6	1.6	0.37
Fell Sandstone	Low Ro TOC	0.4	2.5	1.6	1.6	1.6	0.37
Fell Sandstone	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Fell Sandstone	RockEval TOC	0.2	0.3	0.2	0.2	N/A	0.05
Cementstone Group	Calculated TOC	0.6	3.0	1.9	1.9	1.6	0.40
Cementstone Group	High Ro TOC	0.6	3.0	1.9	1.9	1.6	0.40
Cementstone Group	Low Ro TOC	0.6	3.0	1.9	1.9	1.6	0.40
Cementstone Group	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cementstone Group	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A



Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Yoredale Formation	728.5	1505.1	776.6	413.7	0.53	385.5	0.50
Scremerston Formation	1505.1	1885.6	380.5	240.9	0.63	240.7	0.63
Fell Sandstone Group	1885.6	2014.0	128.4	20.7	0.16	2.7	0.02
Cementstone Group	2014.0	2147.0	133.0	64.7	0.49	31.2	0.24
All Zones	728.5	2147.0	1418.5	740.0	0.52	660.1	0.47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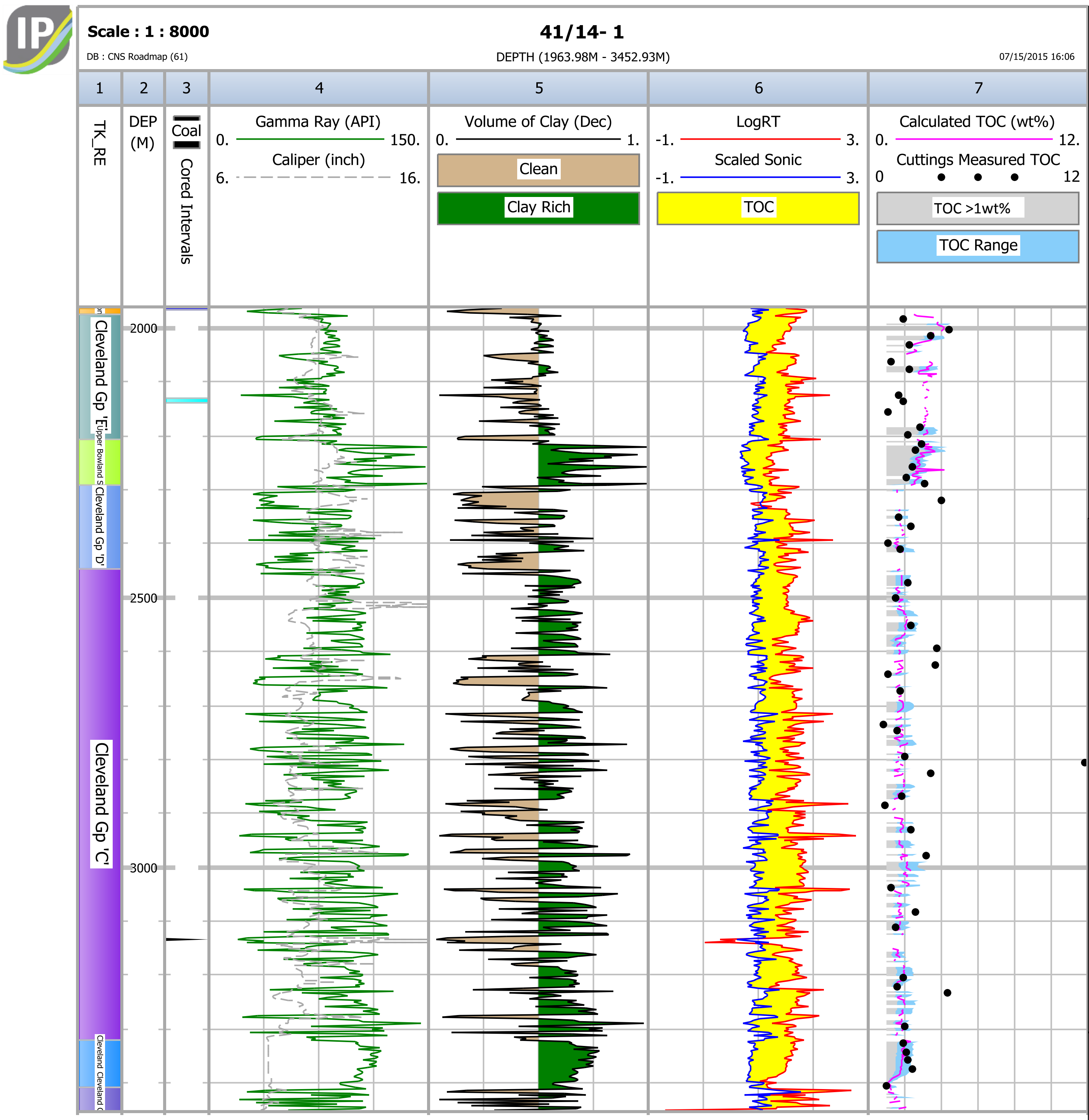
DB : CNS Roadmap (18)
41/10- 1
DEPTH (2054.3M - 4297.63M)
07/15/2015 16:01
TK_RE
DEP (M)
Coal
GR (GAPI)
0. 150.
Volume of Clay (Dec)
0. 1.
Clean
Clay Rich
LogRT
-1. 3.
Scaled Sonic (uSec/ft)
-1. 3.
TOC
TOC_DLRS_FINAL (wt%)
0. 12.
Cutting Measured TOC (wt%)
0 12
TOC >1wt%
TOC Range
Yoredale Formation
Scremerston Formation
Fell Sandstone
Cementstone Group
2500
3000
3500
4000
41/10- 1
Calculated TOC wt%: Yoredale Formation
41/10- 1
Calculated TOC wt%: Scremerston Formation
41/10- 1
Calculated TOC wt%: Cementstone Group
Number of Points
Cumulative Frequency

Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.0	14.6	2.6	2.6	2.5	1.60
Yoredale Formation	High Ro TOC	0.0	12.2	2.3	2.3	2.3	1.32
Yoredale Formation	Low Ro TOC	0.0	17.6	3.0	3.0	3.0	1.94
Yoredale Formation	Measured TOC	1.1	74.5	9.0	2.5	8.5	19.37
Scremerston Formation	Calculated TOC	0.0	5.8	2.8	2.9	3.0	1.03
Scremerston Formation	High Ro TOC	0.0	4.9	2.4	2.5	2.6	0.85
Scremerston Formation	Low Ro TOC	0.0	6.9	3.2	3.4	3.5	1.25
Scremerston Formation	Measured TOC	1.0	37.6	4.8	2.9	4.6	8.82
Fell Sandstone	Calculated TOC	1.6	3.0	2.0	1.9	N/A	0.50
Fell Sandstone	High Ro TOC	1.5	2.6	1.8	1.7	N/A	0.41
Fell Sandstone	Low Ro TOC	1.8	3.5	2.3	2.2	N/A	0.61
Fell Sandstone	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cementstone	Calculated TOC	0.0	4.0	2.0	2.0	2.1	0.72
Cementstone	High Ro TOC	0.0	3.5	1.8	1.8	1.9	0.60
Cementstone	Low Ro TOC	0.0	4.7	2.3	2.3	2.4	0.87
Cementstone	Measured TOC	0.5	3.8	1.9	1.6	N/A	1.23

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Cementstone Group	4014.2	4297.7	283.5	128.0	0.45	116.0	0.41
Yoredale Formation	2054.4	2917.0	862.7	559.5	0.65	501.6	0.58
Scremerston Formation	2917.0	3957.0	1040.0	717.1	0.69	678.2	0.65
Fell Sandstone Group	3957.0	4014.2	57.2	0.9	0.02	0.9	0.02
All Zones	2054.4	4297.7	2243.3	1405.5	0.63	1296.7	0.58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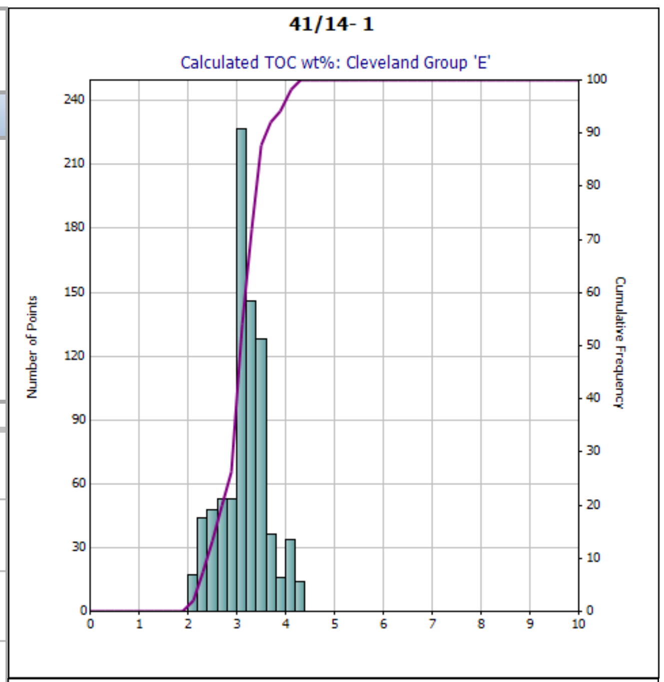
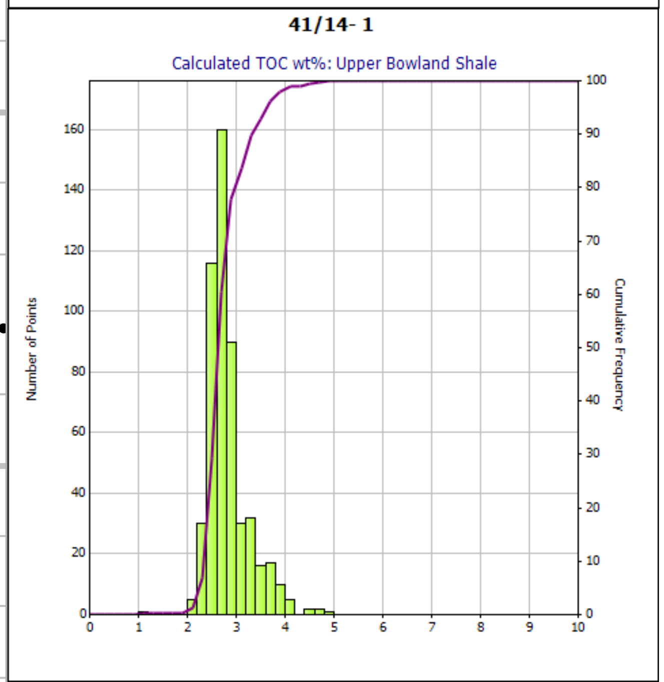
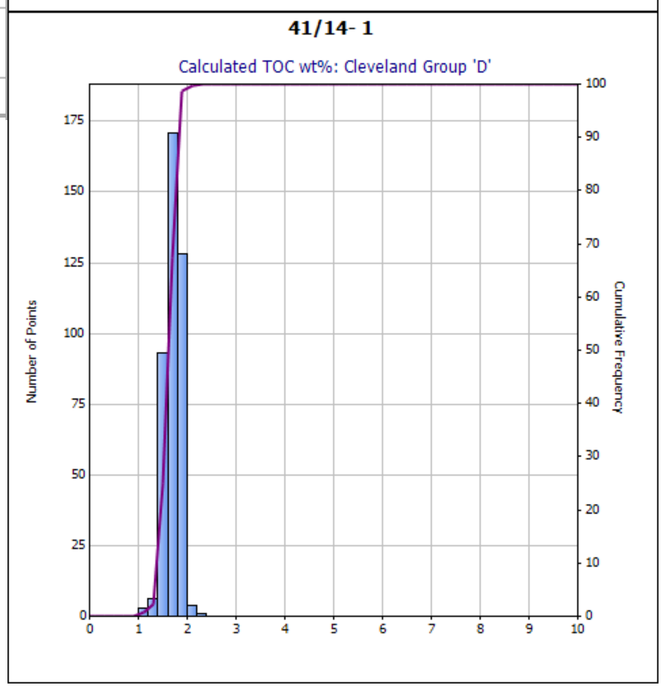
DB : CNS Roadmap (61)
41/14- 1
DEPTH (1963.98M - 3452.93M)
07/15/2015 16:06
1
2
3
4
5
6
7
TK_RE
DEP (M)
Coal
Cored Intervals
Gamma Ray (API)
0. 150.
Caliper (inch)
6. 16.
Volume of Clay (Dec)
0. 1.
Clean
Clay Rich
LogRT
-1. 3.
Scaled Sonic
-1. 3.
TOC
Calculated TOC (wt%)
0. 12.
Cuttings Measured TOC
0 12
TOC >1wt%
TOC Range
Cleveland Gp 'E'
Upper Bowland S
Cleveland Gp 'D'
Cleveland Gp 'C'
2000
2500
3000

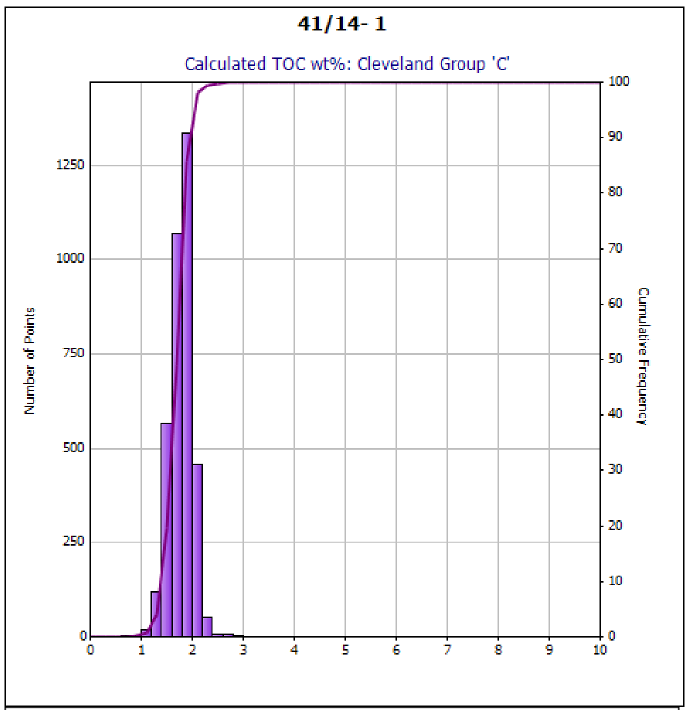

41/14- 1
Calculated TOC wt%: Cleveland Group 'E'
Number of Points
Cumulative Frequency

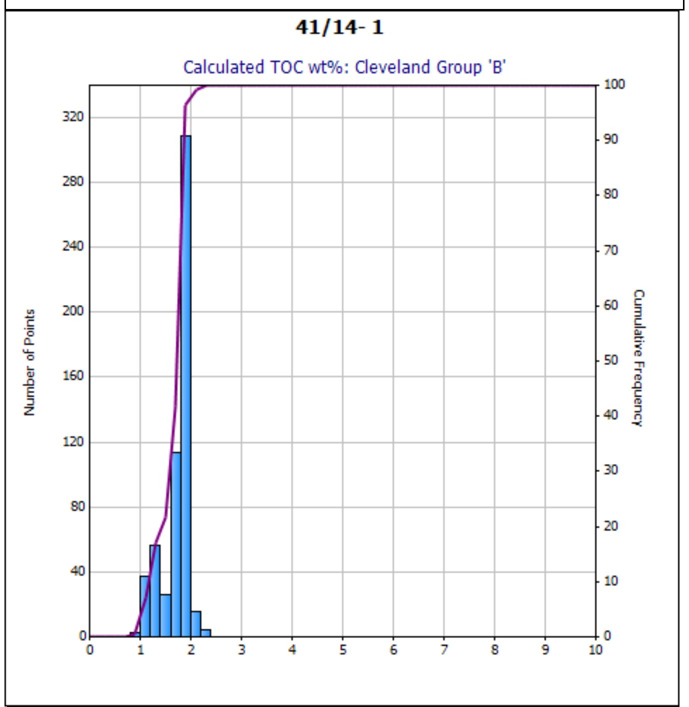

41/14- 1
Calculated TOC wt%: Upper Bowland Shale
Number of Points
Cumulative Frequency

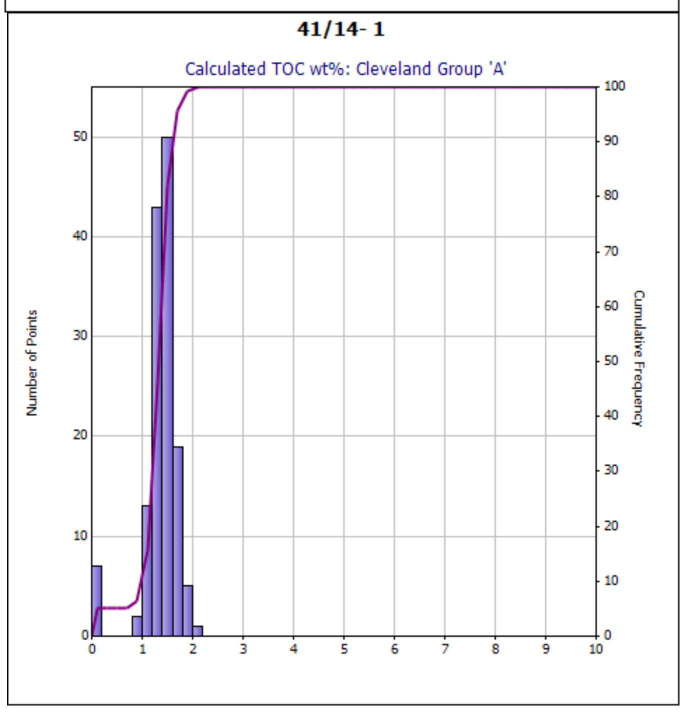

41/14- 1
Calculated TOC wt%: Cleveland Group 'D'
Number of Points
Cumulative Frequency

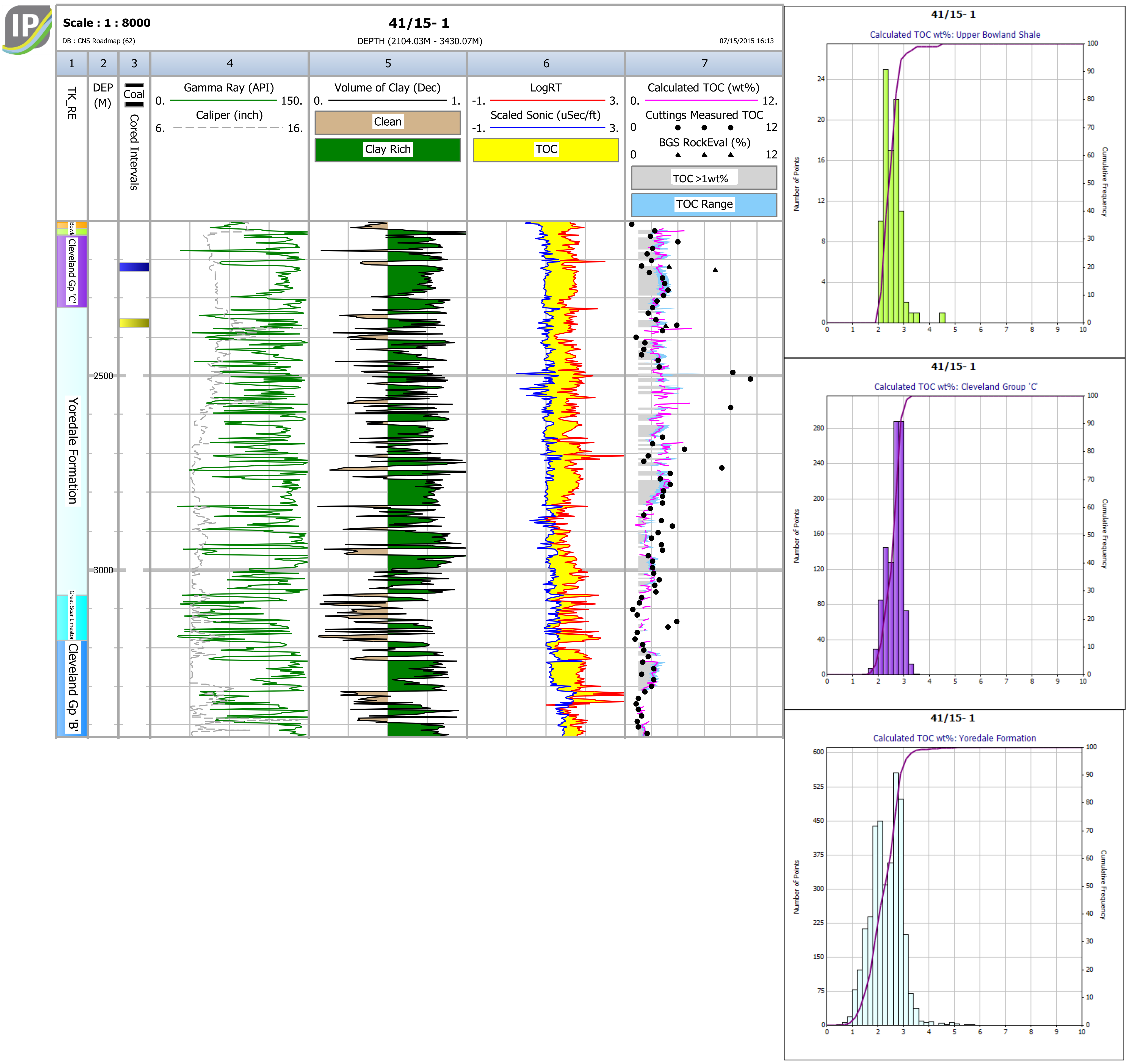
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Millstone Grit	Calculated TOC	2.2	2.7	2.4	2.3	2.2	0.20
Millstone Grit	High Ro TOC	1.9	2.3	2.1	2.0	2.0	0.16
Millstone Grit	Low Ro TOC	2.5	3.1	2.7	2.6	2.5	0.24
Millstone Grit	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group E	Calculated TOC	2.0	4.3	3.2	3.2	3.1	0.46
Cleveland Group E	High Ro TOC	1.8	3.7	2.7	2.8	2.7	0.38
Cleveland Group E	Low Ro TOC	2.3	5.0	3.7	3.7	3.7	0.56
Cleveland Group E	Measured TOC	1.1	4.4	2.3	2.2	1.6	0.96
Upper Bowland Shale	Calculated TOC	1.2	4.8	2.8	2.7	2.7	0.43
Upper Bowland Shale	High Ro TOC	1.1	4.1	2.5	2.4	2.3	0.35
Upper Bowland Shale	Low Ro TOC	1.4	5.7	3.3	3.1	3.0	0.52
Upper Bowland Shale	Measured TOC	2.1	3.1	2.6	2.6	N/A	0.41
Cleveland Group D	Calculated TOC	1.1	2.3	1.7	1.7	1.8	0.16
Cleveland Group D	High Ro TOC	1.0	1.8	1.4	1.4	1.5	0.11
Cleveland Group D	Low Ro TOC	1.3	3.0	2.1	2.2	2.3	0.23
Cleveland Group D	Measured TOC	1.1	4.0	2.2	1.7	N/A	1.10
Cleveland Group C	Calculated TOC	0.7	2.8	1.8	1.8	1.8	0.22
Cleveland Group C	High Ro TOC	0.8	2.2	1.5	1.5	1.5	0.15
Cleveland Group C	Low Ro TOC	0.7	3.8	2.3	2.3	2.3	0.32
Cleveland Group C	Measured TOC	0.8	11.8	2.6	2.0	1.6	2.22
Cleveland Group B	Calculated TOC	0.9	2.3	1.7	1.8	1.9	0.26
Cleveland Group B	High Ro TOC	0.8	1.8	1.4	1.5	1.5	0.18
Cleveland Group B	Low Ro TOC	0.9	3.0	2.2	2.3	2.4	0.39
Cleveland Group B	Measured TOC	1.0	2.4	1.9	2.1	N/A	0.52
Cleveland Group A	Calculated TOC	0.0	2.1	1.4	1.4	1.3	0.35
Cleveland Group A	High Ro TOC	0.0	1.7	1.2	1.2	N/A	0.28
Cleveland Group A	Low Ro TOC	0.0	2.7	1.7	1.7	1.5	0.46
Cleveland Group A	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	1964.0	1974.0	10.0	1.8	0.18	1.8	0.18
Cleveland Gp 'E'	1974.0	2208.0	234.0	124.4	0.53	124.4	0.53
Upper Bowland Shale	2208.0	2293.0	85.0	79.8	0.94	78.7	0.93
Cleveland Gp 'D'	2293.0	2447.0	154.0	62.0	0.40	61.8	0.40
Cleveland Gp 'C'	2447.0	3319.0	872.0	558.9	0.64	553.2	0.63
Cleveland Gp 'B'	3319.0	3407.0	88.0	86.0	0.98	84.8	0.96
Cleveland Gp 'A'	3407.0	3453.0	46.0	21.9	0.48	19.5	0.42
All Zones	1964.0	3453.0	1489.0	934.7	0.63	924.2	0.62





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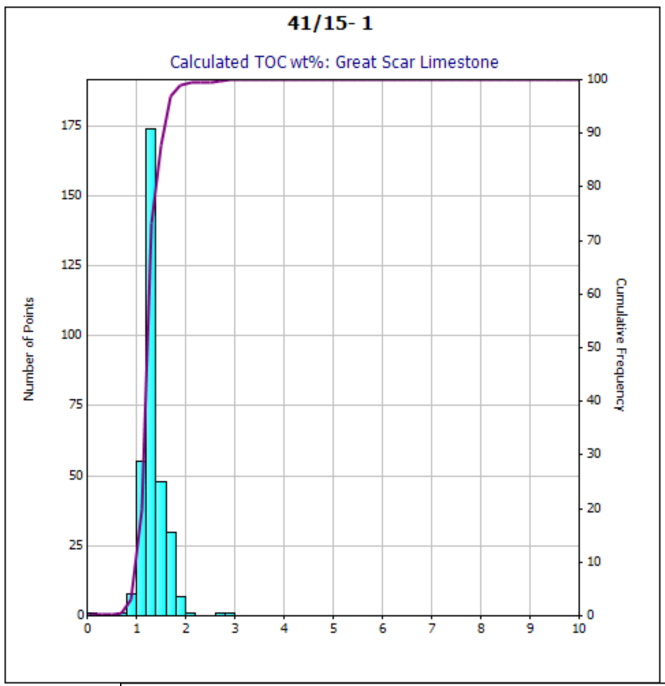
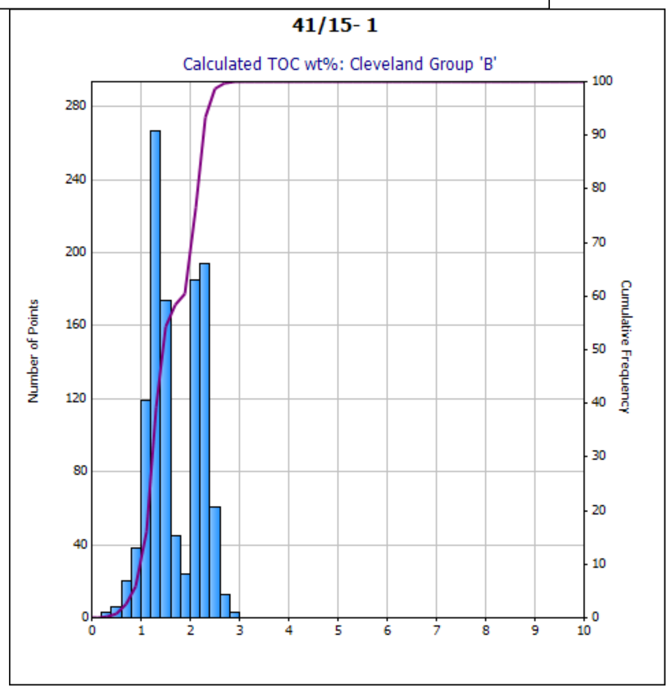
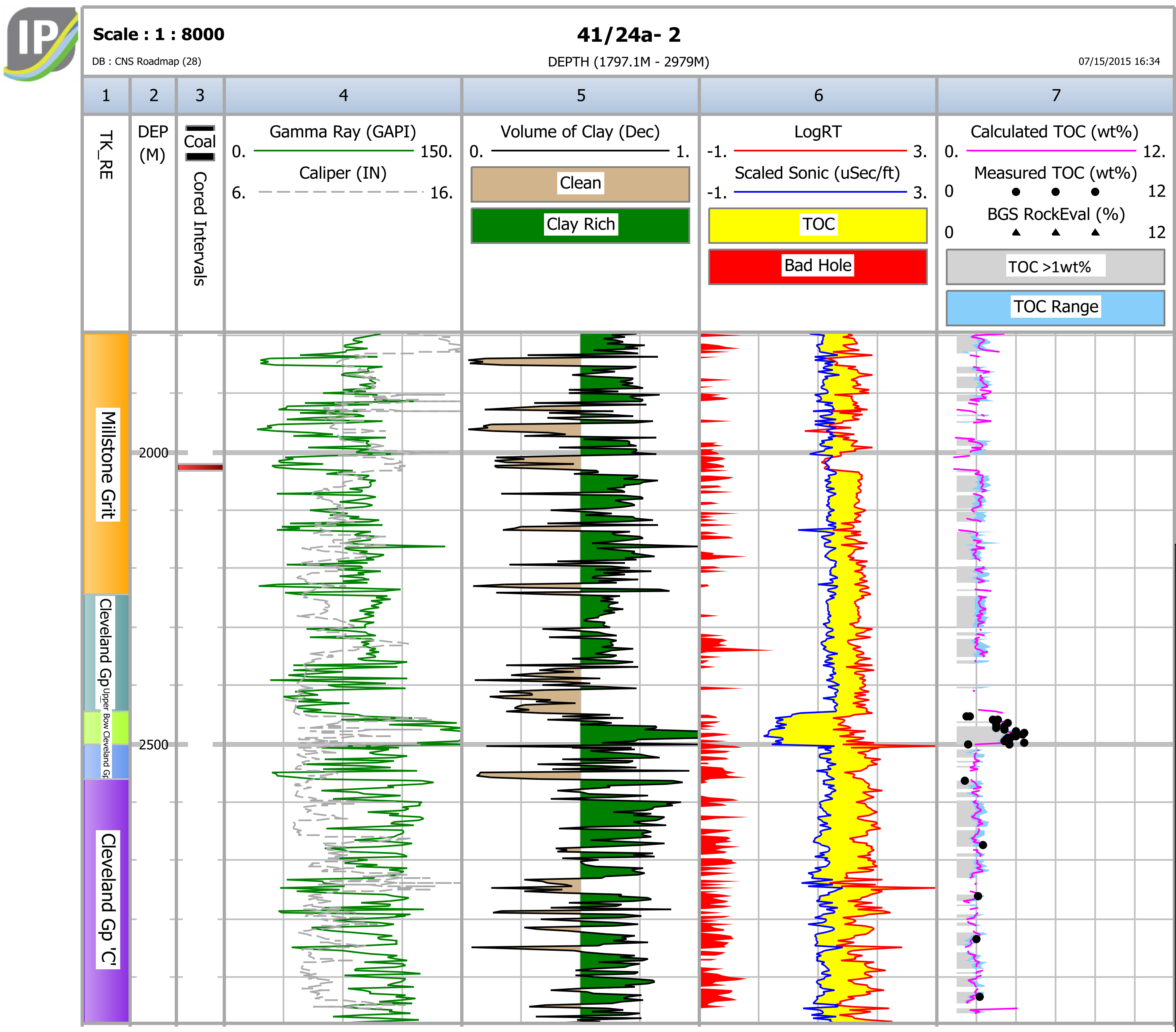
41/15- 1
DB : CNS Roadmap (62)
DEPTH (2104.03M - 3430.07M)
07/15/2015 16:13
TK_RE
DEP (M)
Coal
Cored Intervals
Gamma Ray (API)
Caliper (inch)
Volume of Clay (Dec)
Clean
Clay Rich
LogRT
Scaled Sonic (uSec/ft)
TOC
Calculated TOC (wt%)
Cuttings Measured TOC
BGS RockEval (%)
TOC >1wt%
TOC Range
Cleveland Gp 'C'
Yoredale Formation
Cleveland Gp 'B'
2500
3000
Calculated TOC wt%: Upper Bowland Shale
Calculated TOC wt%: Cleveland Group 'C'
Calculated TOC wt%: Yoredale Formation
Number of Points
Cumulative Frequency

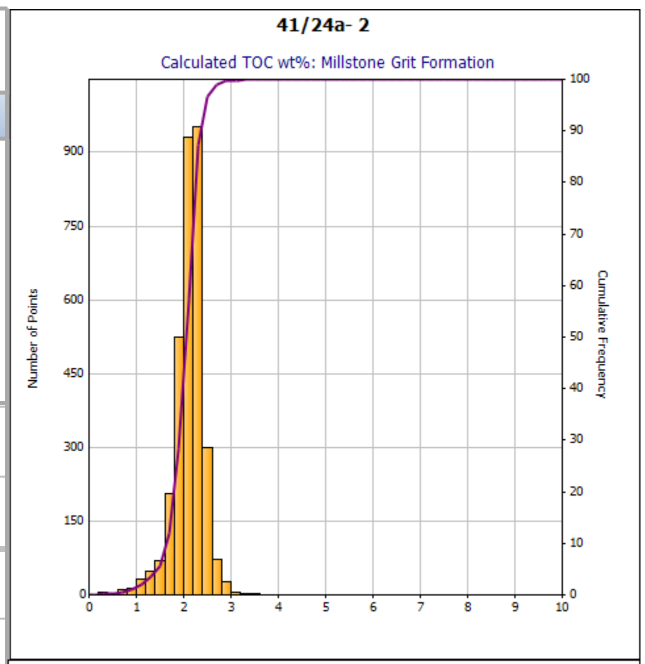
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Millstone Grit	Calculated TOC	2.7	2.7	2.7	2.7	N/A	N/A
Millstone Grit	High Ro TOC	2.4	2.4	2.4	2.4	N/A	N/A
Millstone Grit	Low Ro TOC	3.1	3.1	3.1	3.1	N/A	N/A
Millstone Grit	Measured TOC	0.5	0.5	0.5	0.5	N/A	N/A
Millstone Grit	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Upper Bowland Shale	Calculated TOC	2.0	4.5	2.6	2.6	2.2	0.35
Upper Bowland Shale	High Ro TOC	1.8	3.8	2.2	2.2	2.0	0.29
Upper Bowland Shale	Low Ro TOC	2.3	5.3	2.9	2.9	2.6	0.43
Upper Bowland Shale	Measured TOC	2.2	2.2	2.2	2.2	N/A	N/A
Upper Bowland Shale	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group C	Calculated TOC	1.5	3.5	2.6	2.7	2.7	0.32
Cleveland Group C	High Ro TOC	1.4	3.0	2.3	2.4	2.4	0.26
Cleveland Group C	Low Ro TOC	1.6	4.1	3.0	3.1	3.2	0.39
Cleveland Group C	Measured TOC	1.3	4.0	2.4	2.1	N/A	0.77
Cleveland Group C	RockEval TOC	3.4	6.8	5.1	6.8	N/A	2.43
Yoredale Formation	Calculated TOC	0.5	5.7	2.3	2.4	2.0	0.60
Yoredale Formation	High Ro TOC	0.5	4.9	2.1	2.1	1.8	0.49
Yoredale Formation	Low Ro TOC	0.4	6.8	2.7	2.7	2.3	0.73
Yoredale Formation	Measured TOC	0.8	29.0	6.3	2.7	1.7	7.95
Yoredale Formation	RockEval TOC	3.1	3.1	3.1	3.1	N/A	N/A
Great Scar Limestone	Calculated TOC	0.0	2.8	1.3	1.3	1.3	0.23
Great Scar Limestone	High Ro TOC	0.0	2.5	1.2	1.2	1.2	0.20
Great Scar Limestone	Low Ro TOC	0.0	3.3	1.5	1.4	1.4	0.28
Great Scar Limestone	Measured TOC	0.6	3.9	1.6	1.1	N/A	1.25
Great Scar Limestone	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group B	Calculated TOC	0.3	2.9	1.7	1.5	1.4	0.51
Cleveland Group B	High Ro TOC	0.4	2.5	1.5	1.4	1.3	0.42
Cleveland Group B	Low Ro TOC	0.2	3.4	1.9	1.7	1.5	0.62
Cleveland Group B	Measured TOC	0.8	2.2	1.4	1.3	1.0	0.43
Cleveland Group B	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A

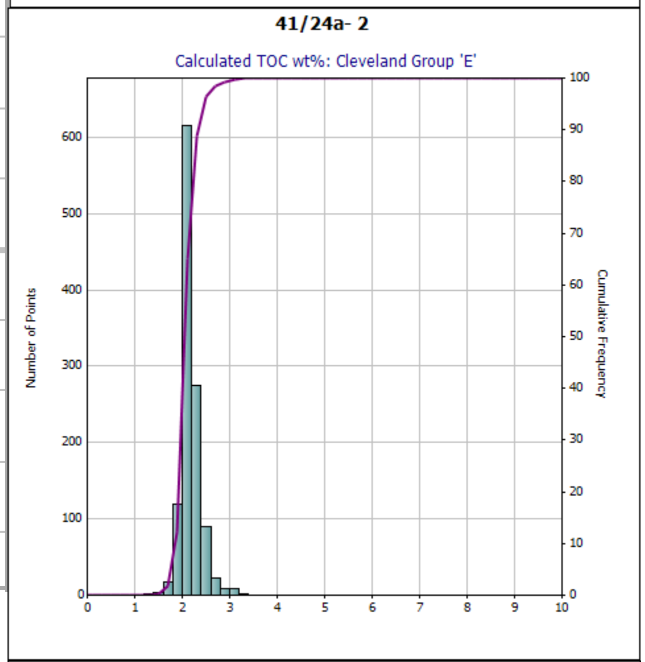


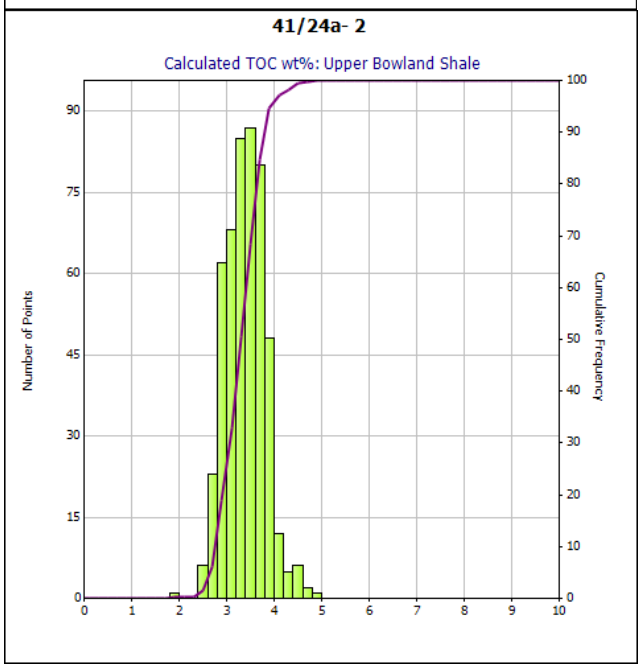


Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	2104.0	2121.0	17.0	0.2	0.01	0.2	0.01
Upper Bowland Shale	2121.0	2138.0	17.0	13.7	0.81	13.7	0.81
Cleveland Gp 'C'	2138.0	2324.0	186.0	161.1	0.87	161.1	0.87
Cleveland Gp 'B'	3182.0	3430.0	248.0	174.1	0.70	161.6	0.65
Yoredale Formation	2324.0	3064.0	740.0	554.2	0.75	547.4	0.74
Great Scar Limestone	3064.0	3182.0	118.0	49.8	0.42	48.0	0.41
All Zones	2104.0	3430.0	1326.0	953.0	0.72	931.9	0.70





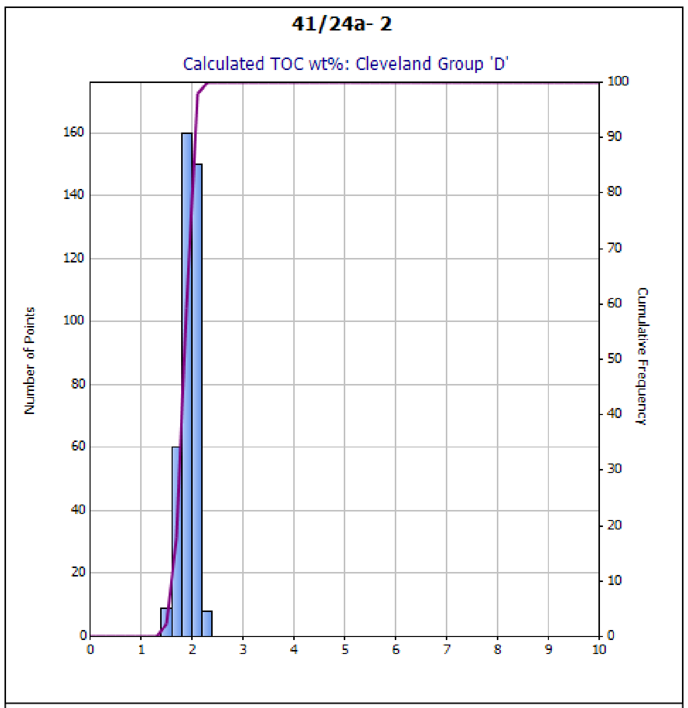


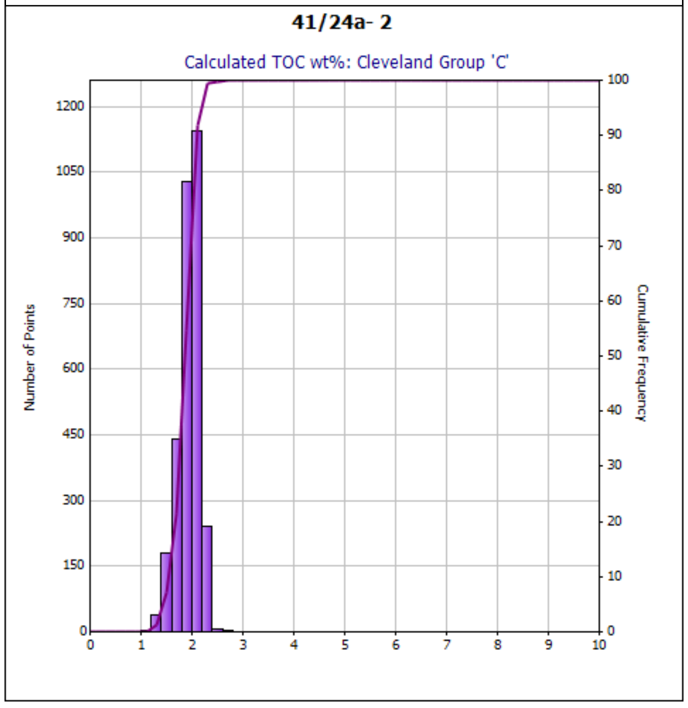


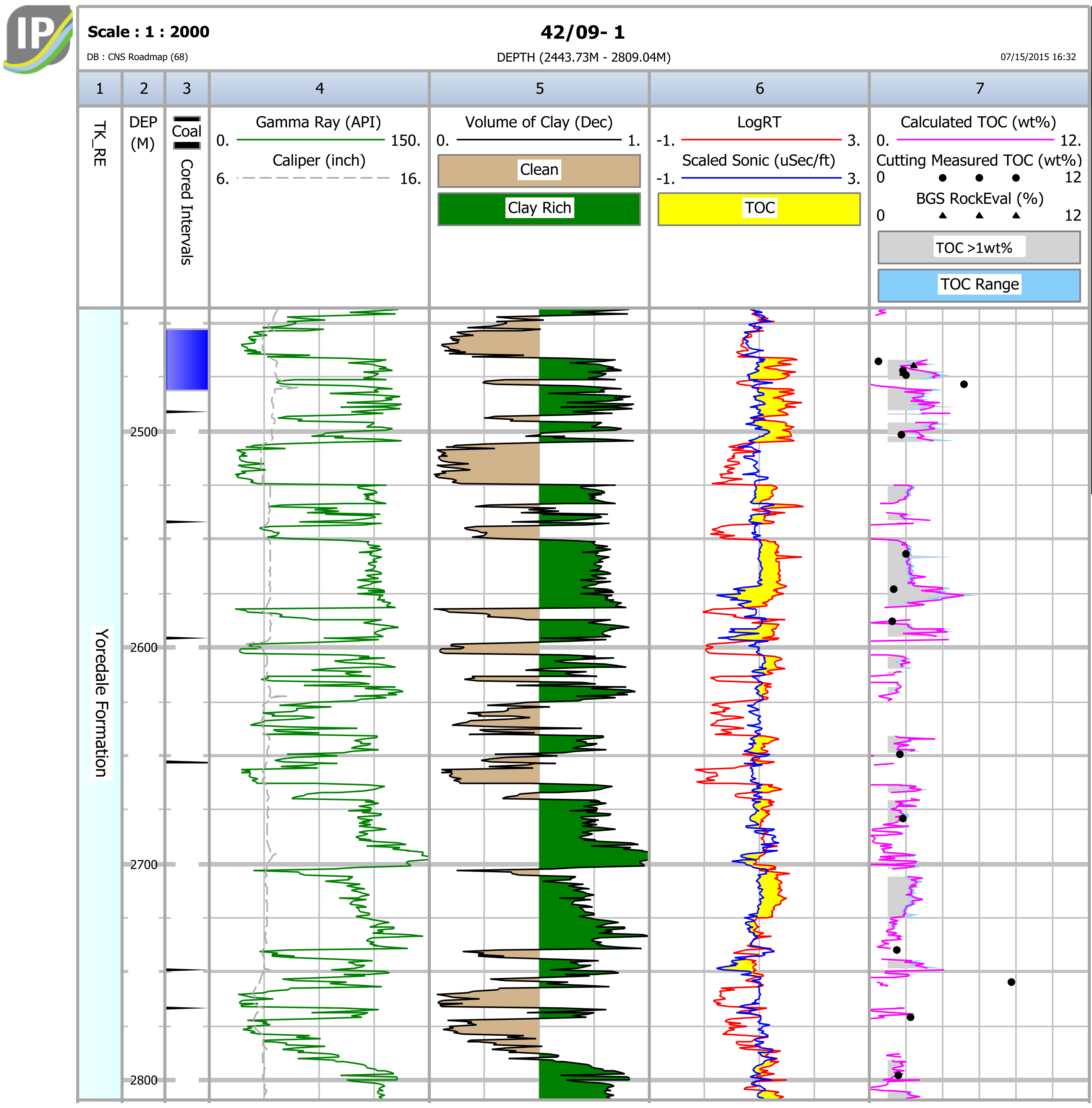
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Millstone Grit	Calculated TOC	0.3	3.4	2.1	2.2	2.3	0.32
Millstone Grit	High Ro TOC	0.4	3.4	1.9	1.9	2.0	0.27
Millstone Grit	Low Ro TOC	0.1	3.7	2.4	2.4	2.6	0.39
Millstone Grit	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Millstone Grit	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group E	Calculated TOC	1.4	3.3	2.2	2.2	N/A	0.21
Cleveland Group E	High Ro TOC	1.3	2.8	1.9	1.9	N/A	0.17
Cleveland Group E	Low Ro TOC	1.5	3.8	2.5	2.4	N/A	0.25
Cleveland Group E	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group E	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Upper Bowland Shale	Calculated TOC	2.0	4.8	3.4	3.4	3.4	0.41
Upper Bowland Shale	High Ro TOC	1.8	4.5	3.2	3.2	3.2	0.37
Upper Bowland Shale	Low Ro TOC	2.2	5.2	3.7	3.7	3.7	0.45
Upper Bowland Shale	Measured TOC	1.5	4.4	3.4	3.6	4.2	0.75
Upper Bowland Shale	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group D	Calculated TOC	1.5	2.3	1.9	2.0	2.0	0.15
Cleveland Group D	High Ro TOC	1.3	2.0	1.7	1.8	1.8	0.12
Cleveland Group D	Low Ro TOC	1.6	2.6	2.2	2.2	2.3	0.18
Cleveland Group D	Measured TOC	1.6	1.6	1.6	1.6	N/A	N/A
Cleveland Group D	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
Cleveland Group C	Calculated TOC	1.0	4.1	2.0	2.0	2.0	0.21
Cleveland Group C	High Ro TOC	1.0	3.5	1.7	1.8	1.8	0.18

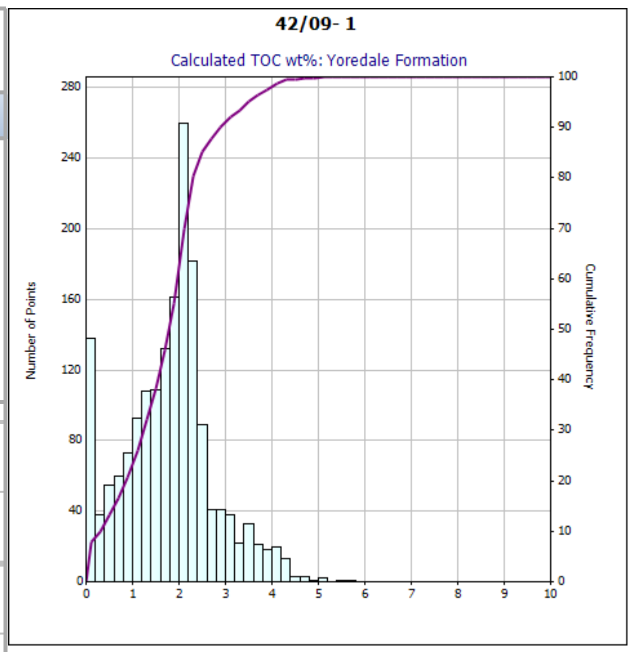
Cleveland Group C	Low Ro TOC	1.1	4.8	2.2	2.2	2.2	0.26
Cleveland Group C	Measured TOC	1.2	3.8	2.3	2.2	2.5	0.83
Cleveland Group C	RockEval TOC	2.5	4.0	3.2	4.0	N/A	1.03

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	1798.0	2245.0	447.0	320.3	0.72	316.5	0.71
Cleveland Gp 'E'	2245.0	2445.0	200.0	116.4	0.58	116.4	0.58
Upper Bowland Shale	2445.0	2501.0	56.0	48.5	0.87	48.5	0.87
Cleveland Gp 'D'	2501.0	2560.0	59.0	38.6	0.65	38.6	0.65
Cleveland Gp 'C'	2560.0	2979.0	419.0	320.2	0.76	308.8	0.74
All Zones	1798.0	2979.0	1181.0	843.9	0.72	828.7	0.70



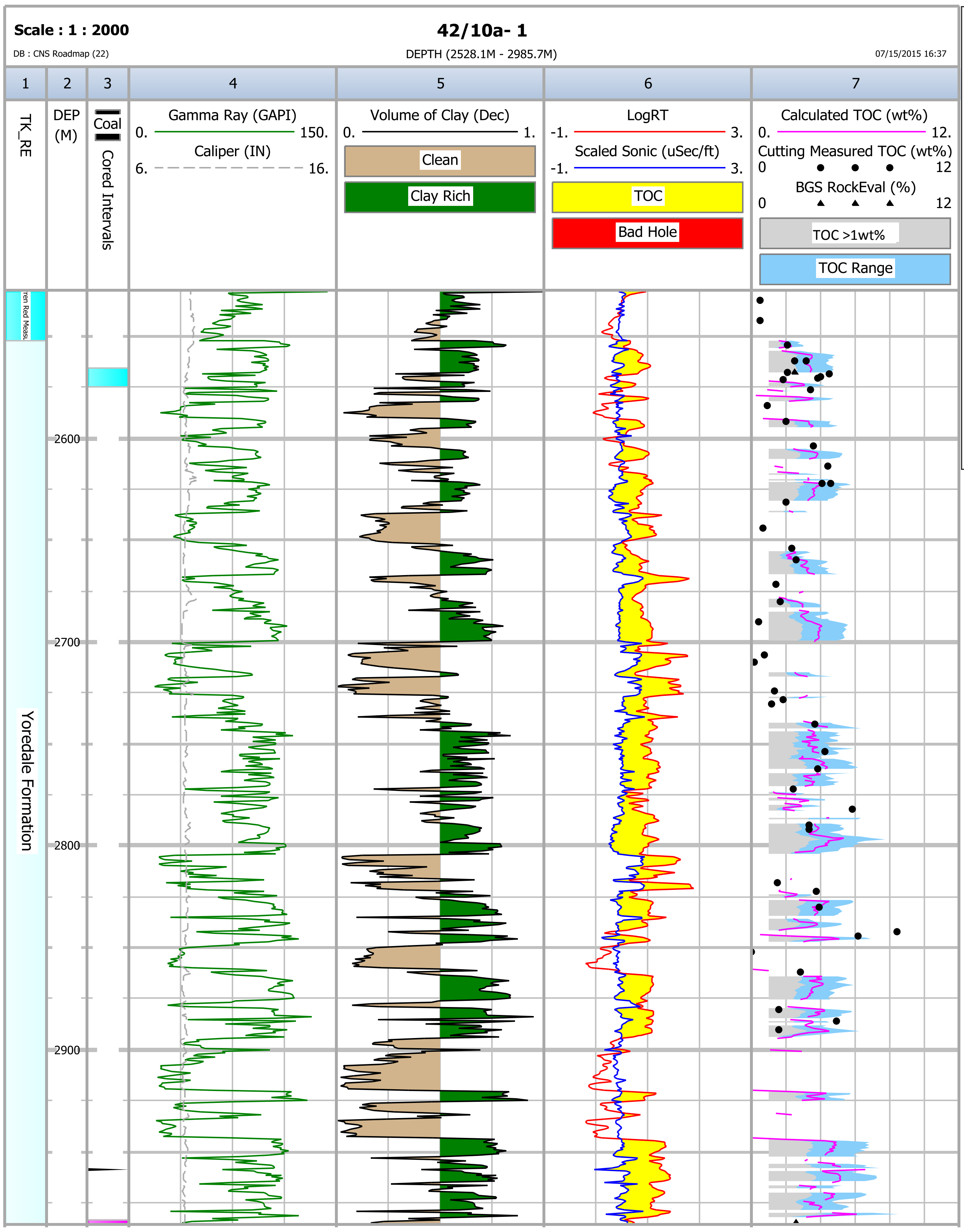


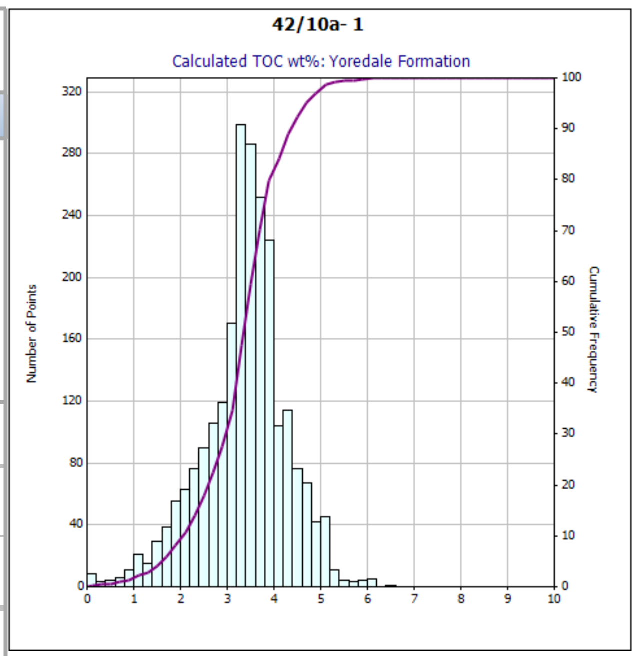




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.0	5.8	1.8	1.9	2.1	0.99
Yoredale Formation	High Ro TOC	0.0	5.2	1.7	1.8	1.9	0.88
Yoredale Formation	Low Ro TOC	0.0	6.4	2.0	2.1	2.2	1.10
Yoredale Formation	Measured TOC	0.5	61.6	11.8	2.0	5.6	19.68
Yoredale Formation	RockEval TOC	1.8	58.0	20.7	2.5	N/A	32.24

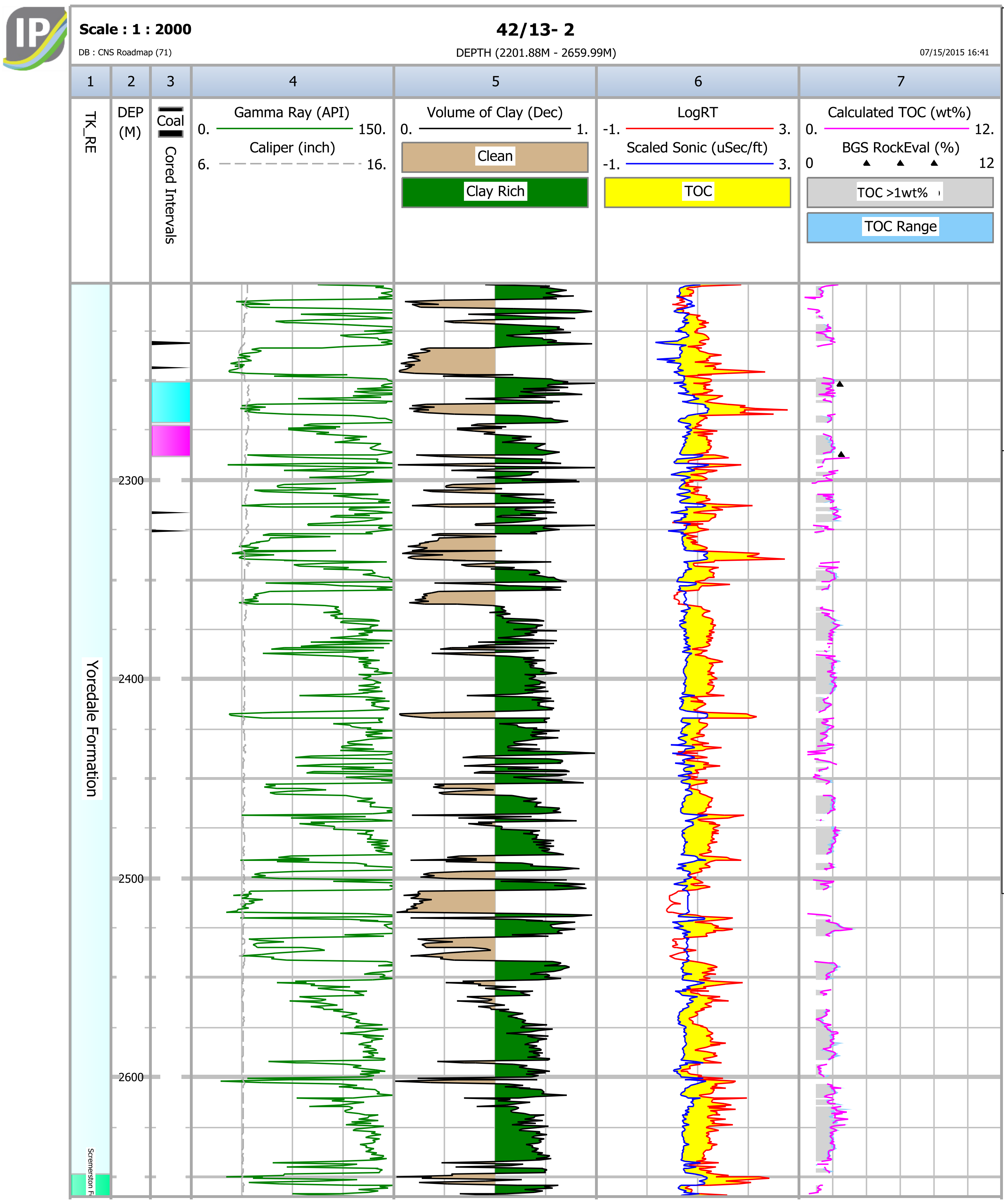
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Yoredale Formation	2438.1	2809.0	370.9	236.6	0.64	185.8	0.50

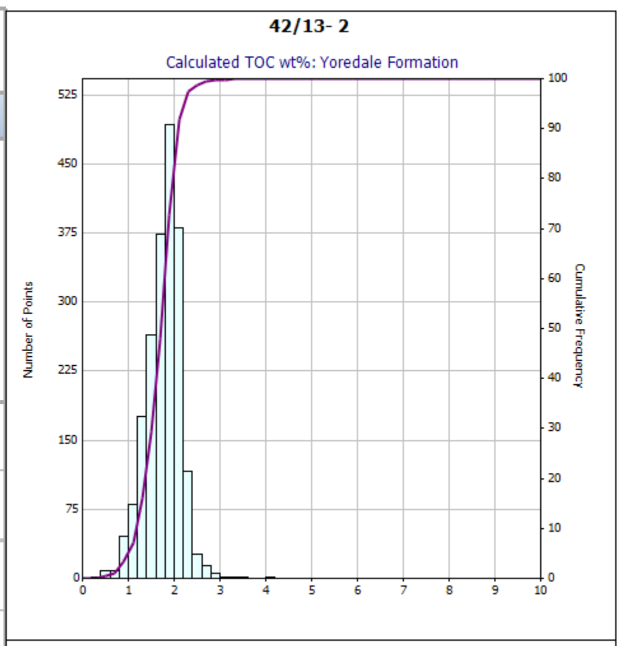


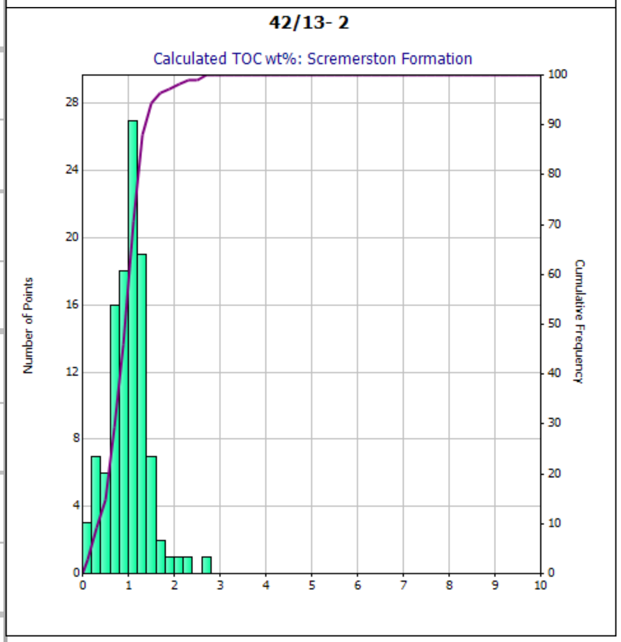


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.0	6.5	3.4	3.4	3.5	0.91
Yoredale Formation	High Ro TOC	0.0	4.7	2.5	2.6	2.5	0.62
Yoredale Formation	Low Ro TOC	0.0	9.3	4.6	4.7	4.7	1.34
Yoredale Formation	Measured TOC	0.0	8.4	2.8	2.6	1.5	1.72
Yoredale Formation	RockEval TOC	2.5	2.6	2.6	2.6	N/A	0.05

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Barren Red Measures	2528.0	2552.4	24.4	14.1	0.58	0.1	0.00
Yoredale Formation	2552.4	2985.7	433.3	235.3	0.54	230.8	0.53
All Zones	1639.2	2985.7	1346.5	295.4	0.22	230.8	0.17

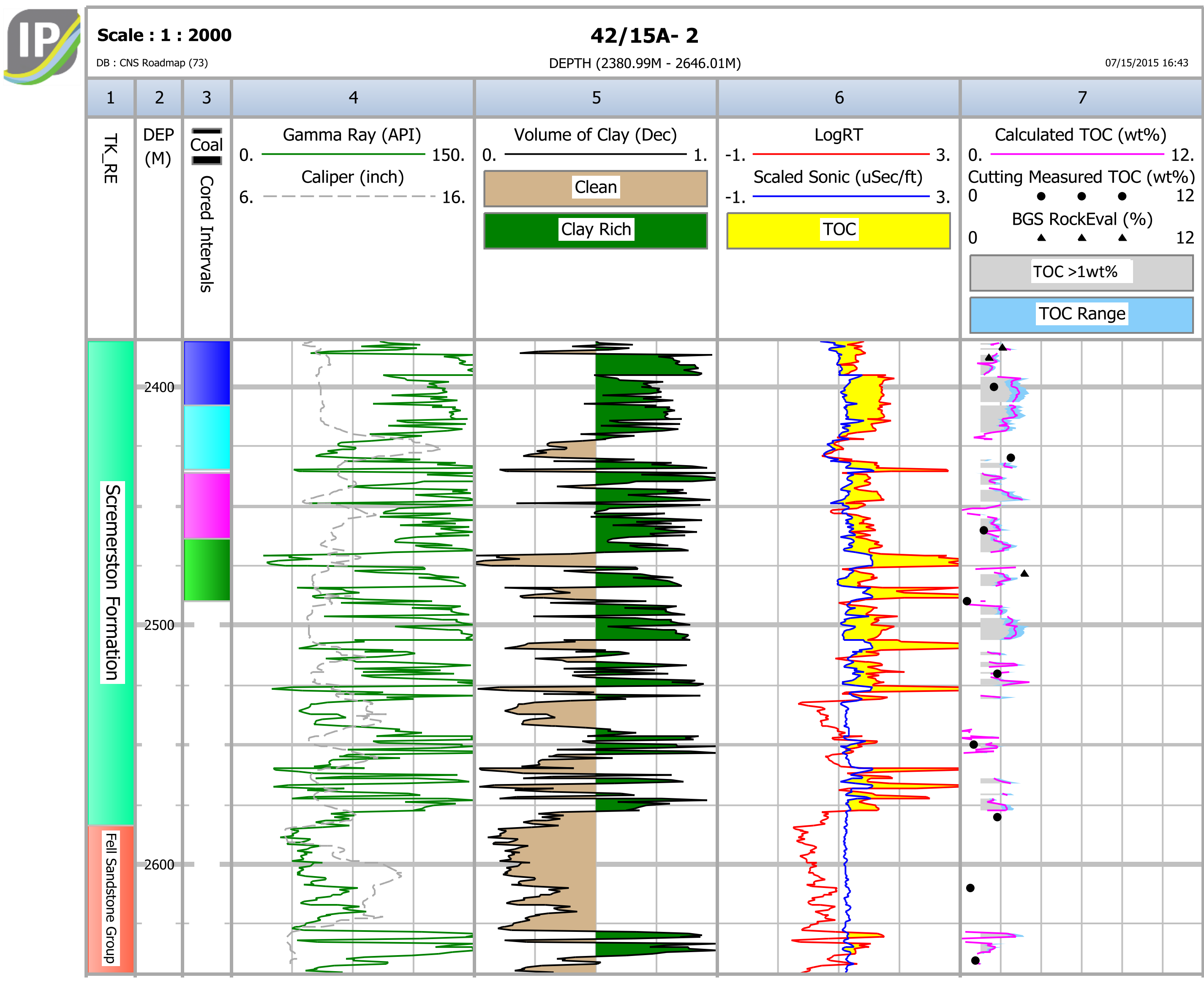


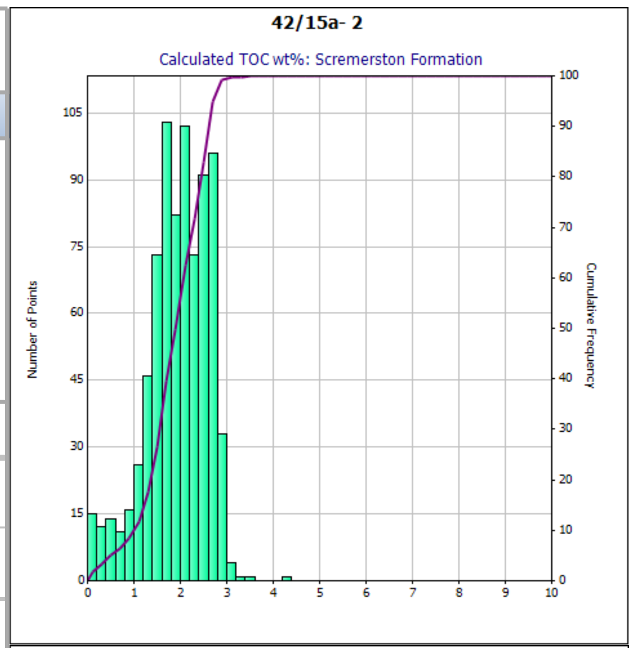


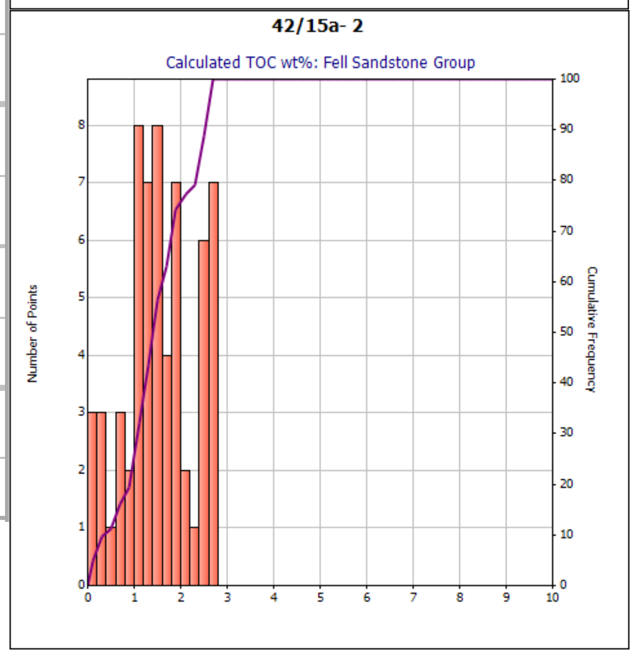


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Yoredale Formation	Calculated TOC	0.3	4.2	1.8	1.8	N/A	0.38
Yoredale Formation	High Ro TOC	0.3	3.8	1.7	1.7	N/A	0.34
Yoredale Formation	Low Ro TOC	0.2	4.5	1.9	1.9	N/A	0.41
Yoredale Formation	RockEval TOC	2.4	2.5	2.4	2.5	N/A	0.04
Scremerston Formation	Calculated TOC	0.4	2.7	1.3	1.2	N/A	0.43
Scremerston Formation	High Ro TOC	0.5	2.5	1.2	1.2	N/A	0.39
Scremerston Formation	Low Ro TOC	0.4	2.9	1.3	1.2	N/A	0.47
Scremerston Formation	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Yoredale Formation	2201.9	2649.0	447.1	306.1	0.69	293.3	0.66
Scremerston Formation	2649.0	2660.0	11.0	5.6	0.51	4.9	0.44
All Zones	2201.9	2660.0	458.1	311.6	0.68	298.2	0.65

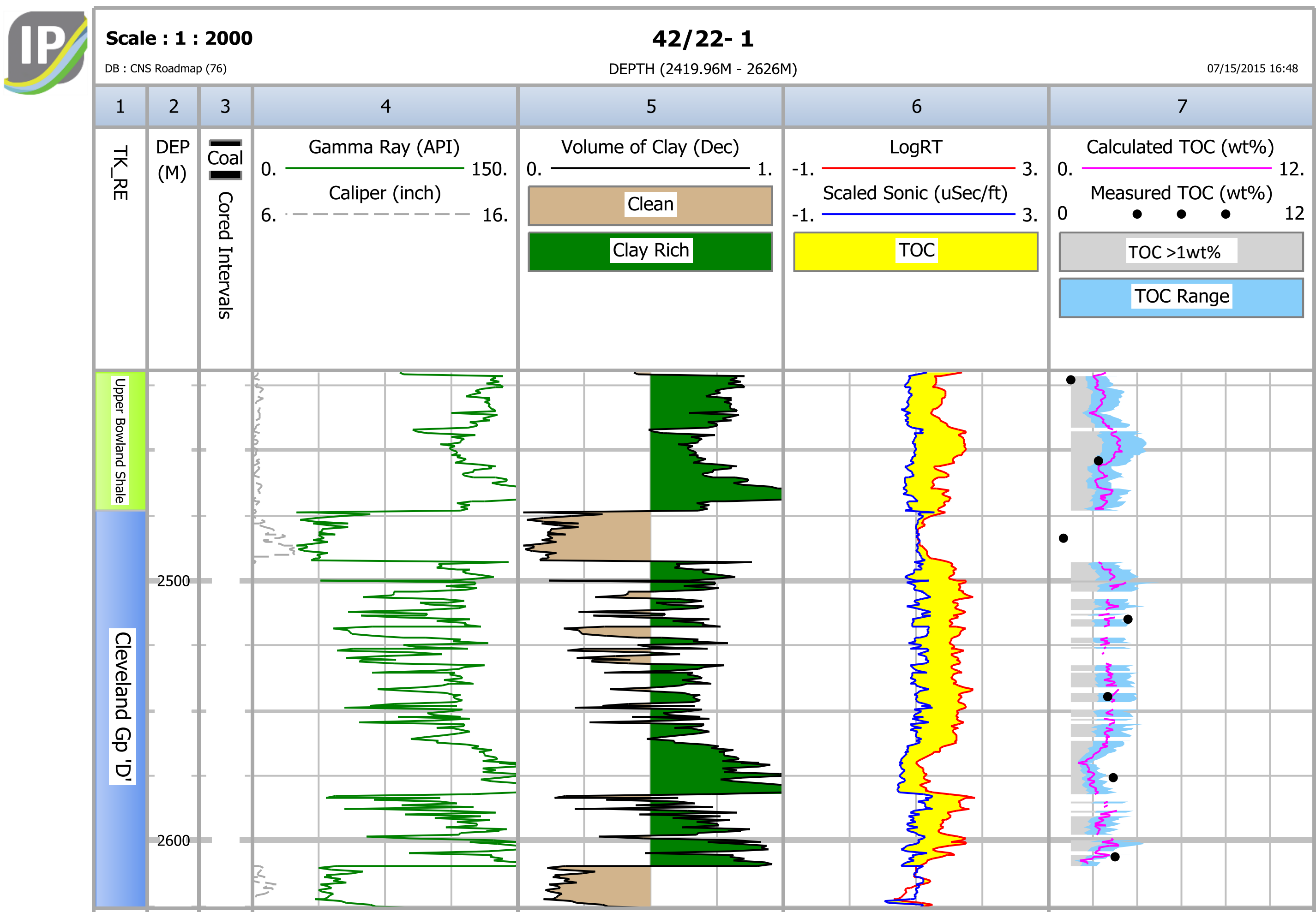


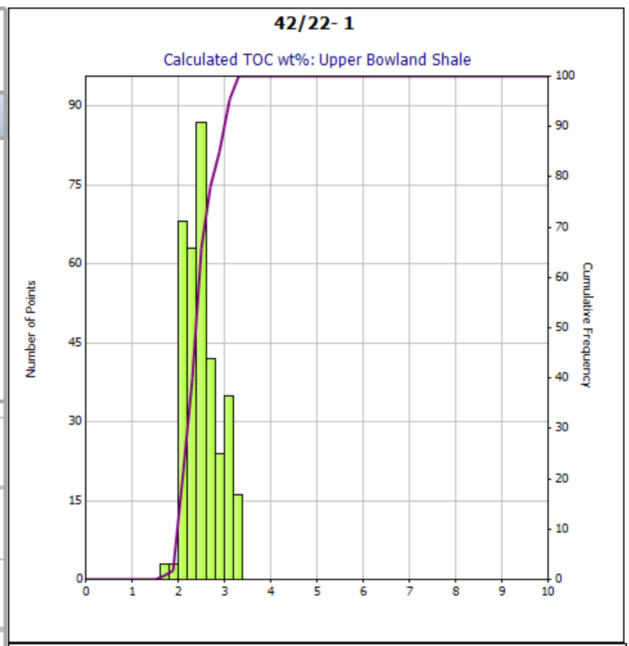


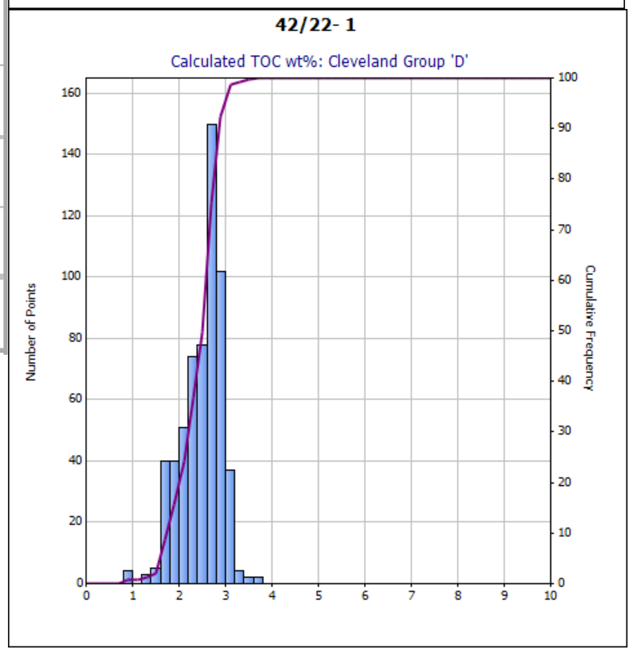


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Scremerston Formation	Calculated TOC	0.0	4.4	1.9	2.0	1.7	0.66
Scremerston Formation	High Ro TOC	0.0	3.7	1.7	1.8	1.8	0.55
Scremerston Formation	Low Ro TOC	0.0	11.8	2.3	2.1	0.1	1.97
Scremerston Formation	Measured TOC	0.4	2.5	1.4	1.7	N/A	0.76
Scremerston Formation	RockEval TOC	1.4	3.1	2.2	2.1	N/A	0.88
Fell Sandstone	Calculated TOC	0.0	2.8	1.6	1.5	1.5	0.76
Fell Sandstone	High Ro TOC	0.0	2.4	1.4	1.3	1.3	0.63
Fell Sandstone	Low Ro TOC	0.0	3.2	0.3	0.0	0.0	0.71
Fell Sandstone	Measured TOC	0.5	0.7	0.6	0.7	N/A	0.16
Fell Sandstone	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Scremerston Formation	2381.0	2584.0	203.0	121.9	0.60	111.0	0.55
Fell Sandstone Group	2584.0	2646.0	62.0	9.5	0.15	7.3	0.12
All Zones	2381.0	2646.0	265.0	131.4	0.50	118.3	0.45

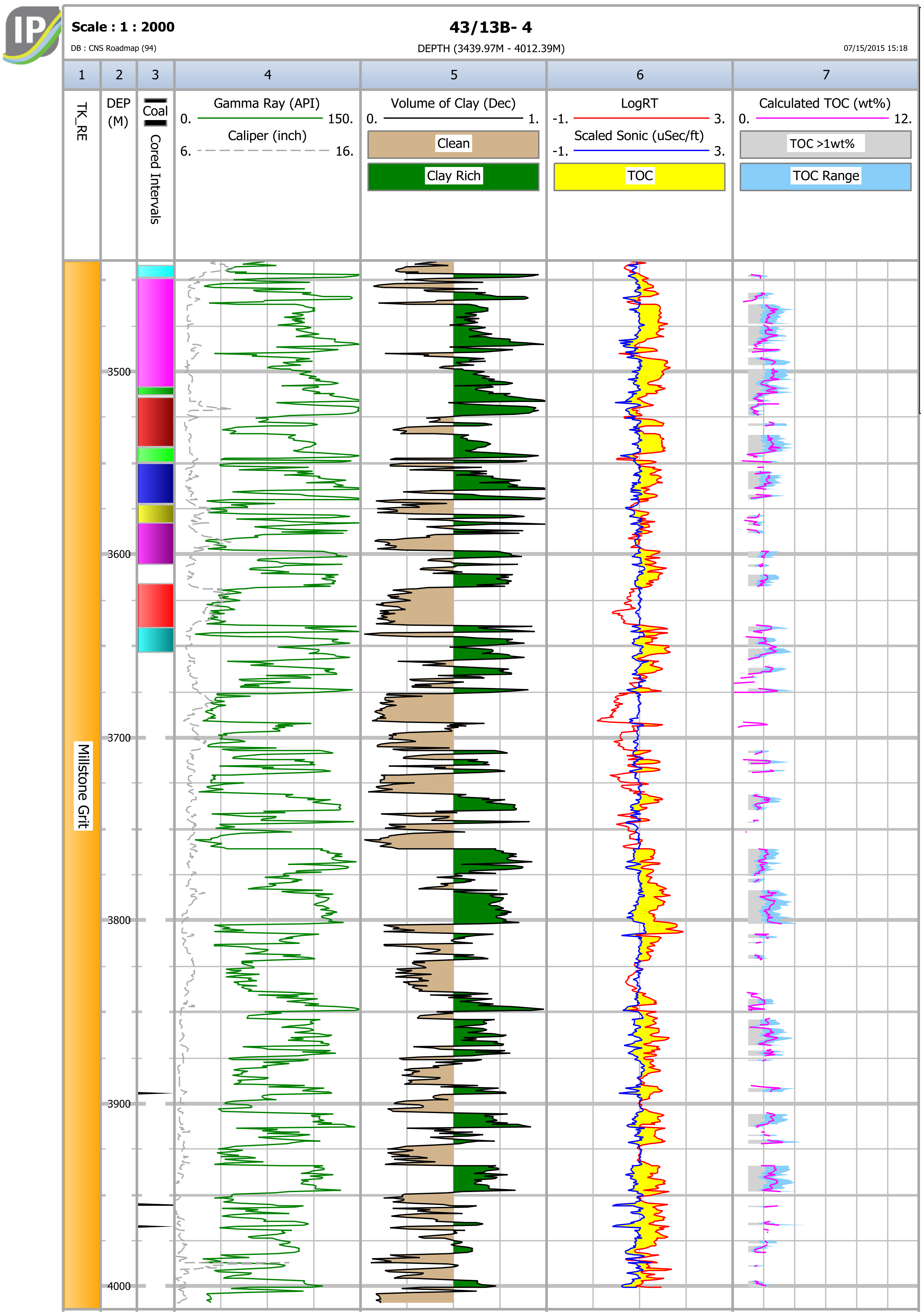


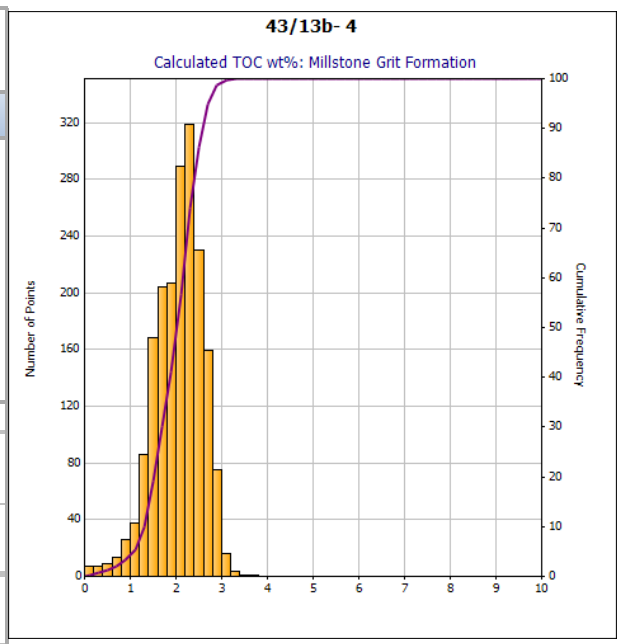




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Upper Bowland Shale	Calculated TOC	1.8	3.4	2.5	2.5	2.2	0.35
Upper Bowland Shale	High Ro TOC	1.5	2.6	2.0	1.9	1.7	0.24
Upper Bowland Shale	Low Ro TOC	2.2	4.6	3.4	3.3	2.8	0.52
Upper Bowland Shale	Measured TOC	1.0	2.3	1.6	2.3	N/A	0.90
Cleveland Group 'D'	Calculated TOC	0.8	3.7	2.5	2.6	2.8	0.43
Cleveland Group 'D'	High Ro TOC	0.8	2.8	1.9	2.0	2.2	0.29
Cleveland Group 'D'	Low Ro TOC	0.0	5.1	2.6	3.0	3.7	1.19
Cleveland Group 'D'	Measured TOC	0.7	3.6	2.3	2.9	N/A	1.23

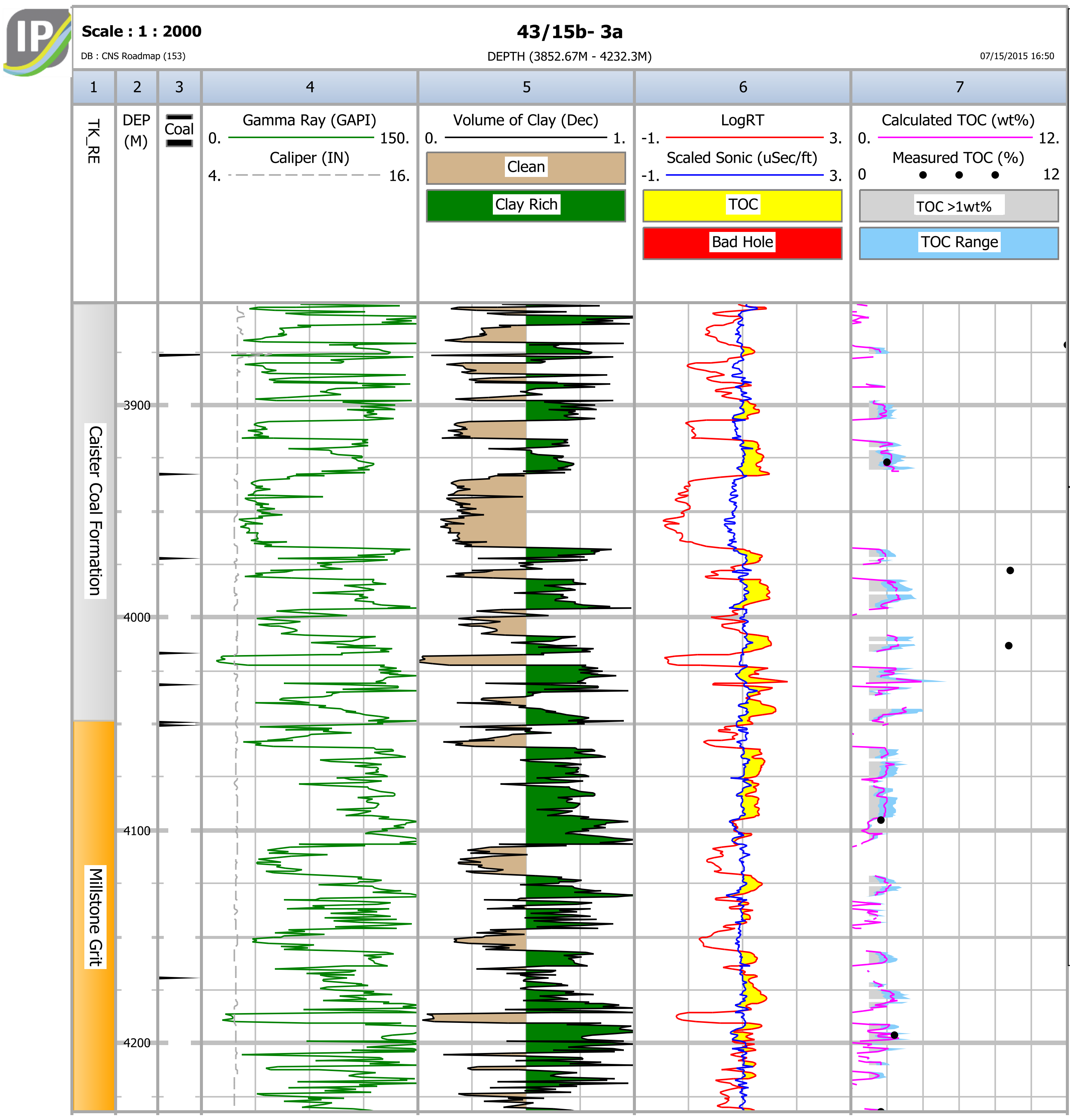
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Upper Bowland Shale	2420.0	2473.0	53.0	51.9	0.98	51.9	0.98
Cleveland Gp 'D'	2473.0	2626.0	153.0	89.9	0.59	89.5	0.59
All Zones	2420.0	2626.0	206.0	141.8	0.69	141.4	0.69

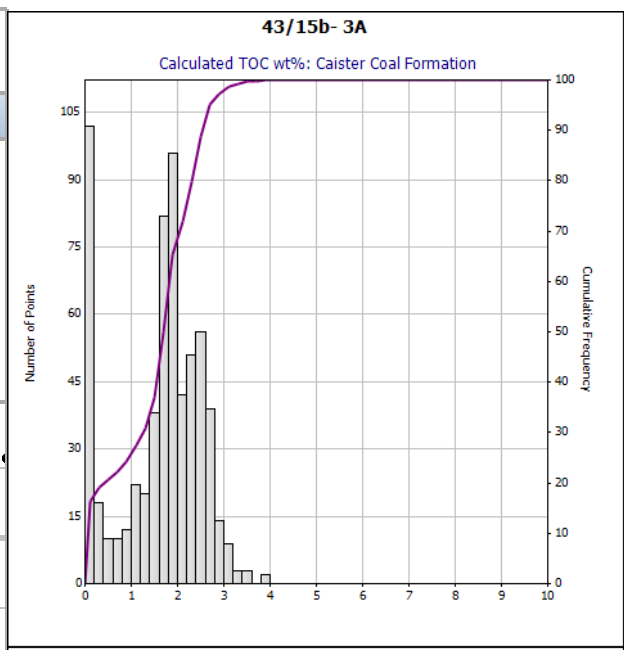


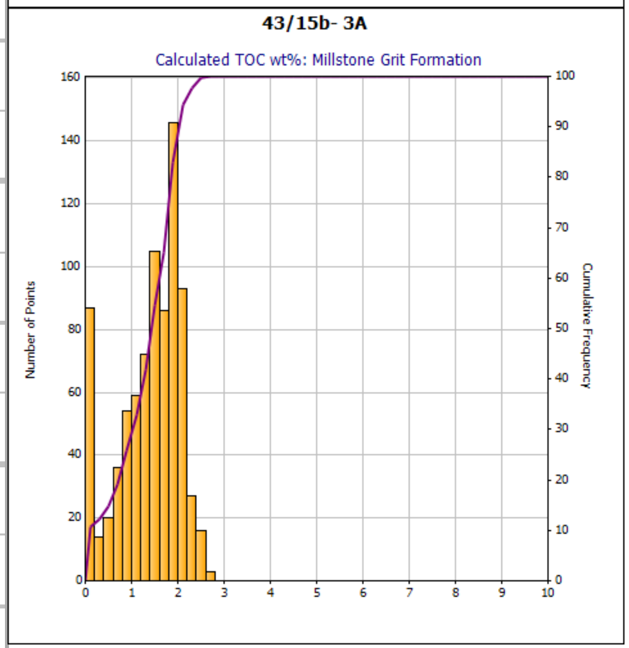


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Millstone Grit	Calculated TOC	0.0	3.8	2.1	2.1	2.1	0.52
Millstone Grit	High Ro TOC	0.0	2.8	1.7	1.7	1.8	0.36
Millstone Grit	Low Ro TOC	0.0	5.2	2.6	2.8	2.9	0.77

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	3440.0	4003.3	563.3	284.8	0.51	271.6	0.48

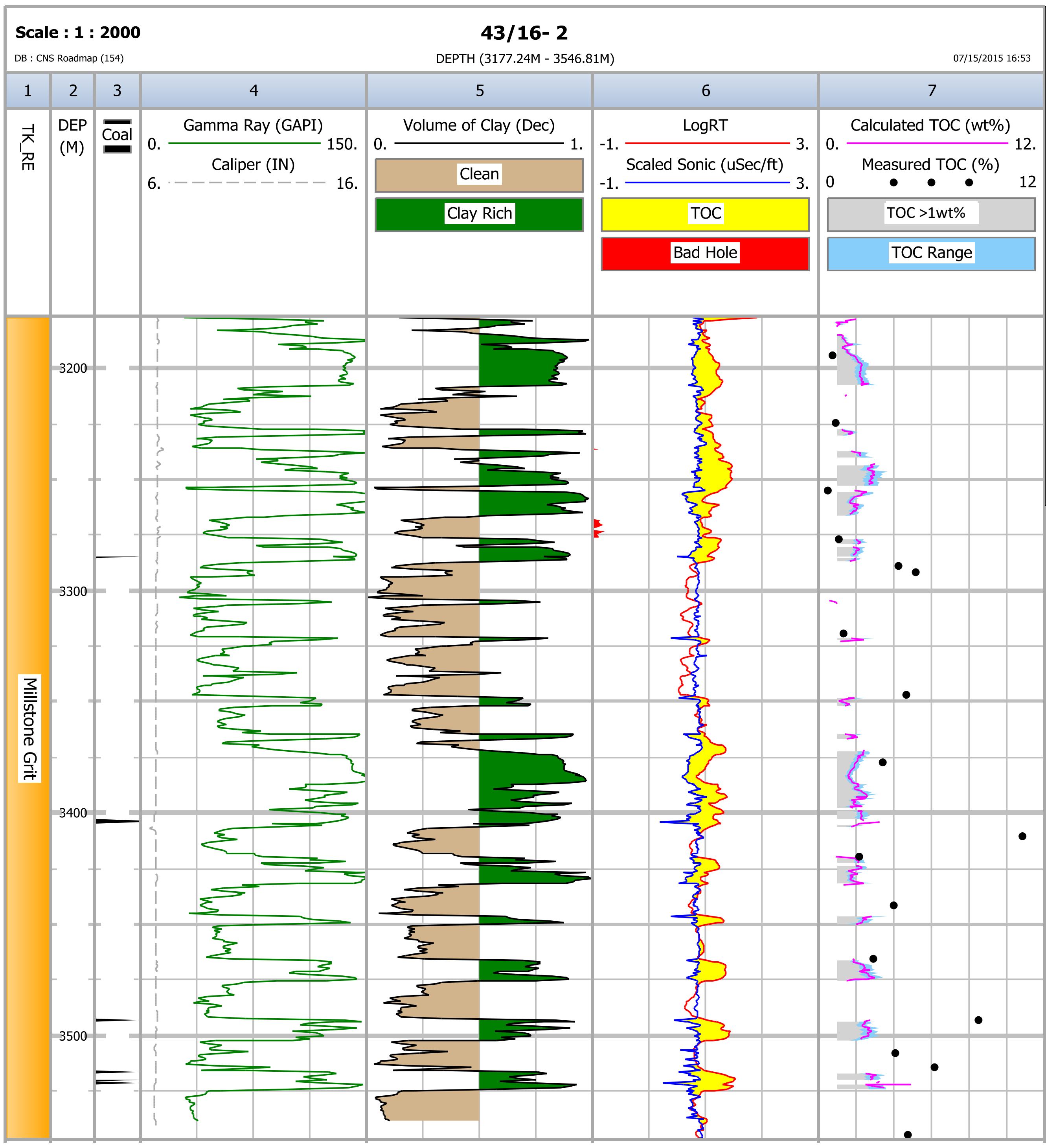


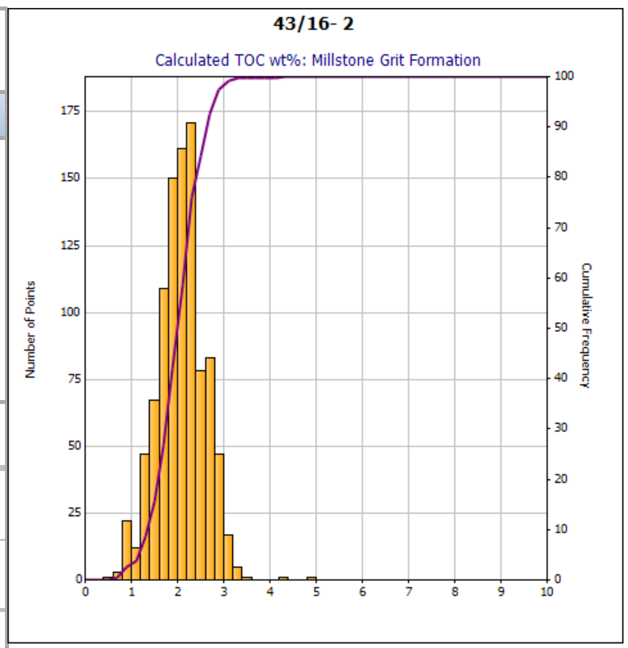




Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Caister Coal Formation	Calculated TOC	0.0	4.0	1.6	1.8	0.0	0.92
Caister Coal Formation	High Ro TOC	0.0	2.9	1.3	1.5	0.0	0.68
Caister Coal Formation	Low Ro TOC	0.0	5.5	2.0	2.3	0.1	1.26
Caister Coal Formation	Measured TOC	2.0	42.6	16.3	12.0	N/A	14.70
Millstone Grit	Calculated TOC	0.0	2.7	1.4	1.5	0.0	0.68
Millstone Grit	High Ro TOC	0.0	2.1	1.2	1.3	1.6	0.50
Millstone Grit	Low Ro TOC	0.0	3.6	1.7	1.9	0.0	0.93
Millstone Grit	Measured TOC	1.7	2.4	1.9	1.7	N/A	0.44

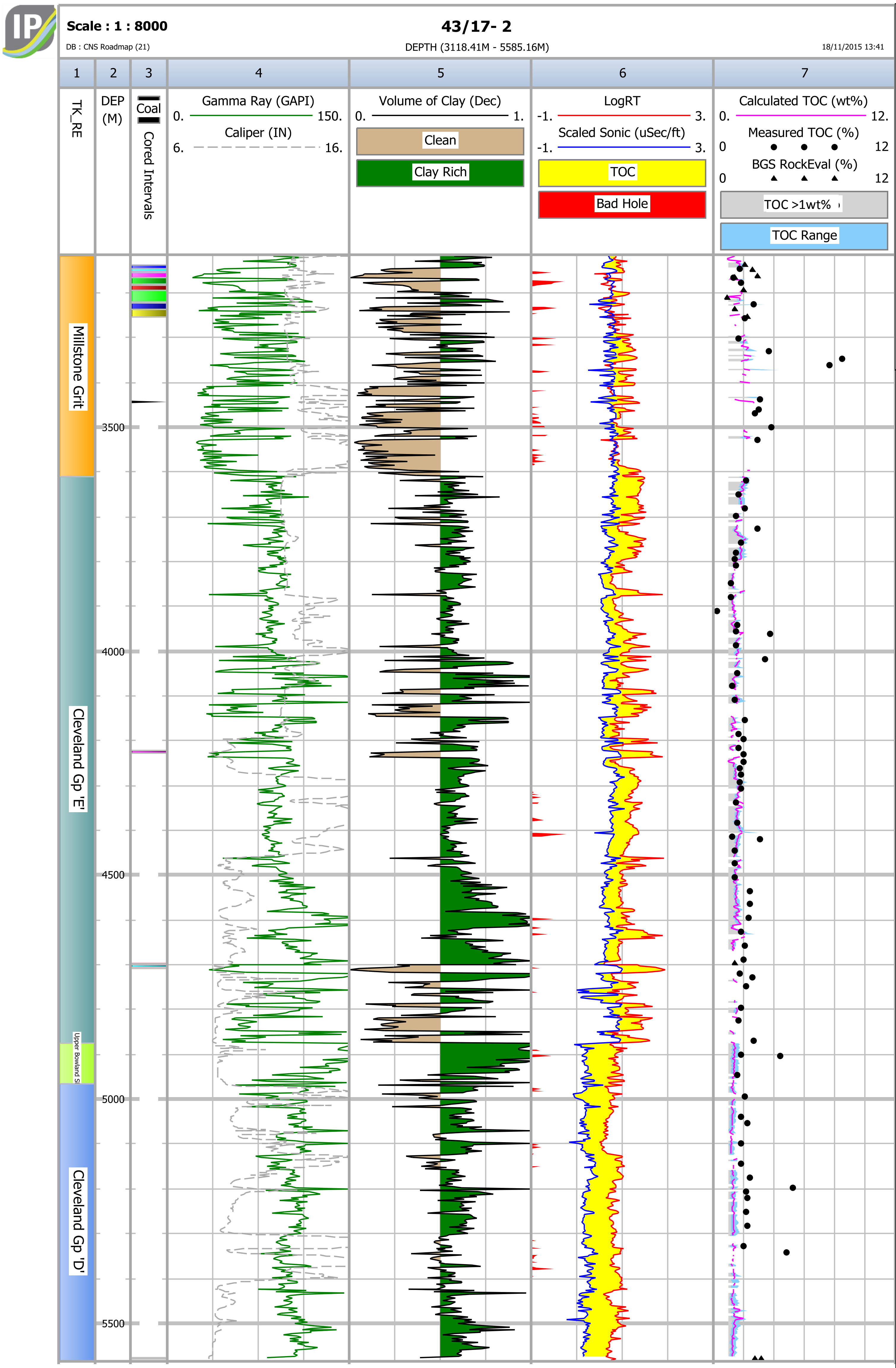
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	4048.4	4232.3	183.9	123.7	0.67	86.0	0.47
Caister Coal Formation	3852.7	4048.4	195.7	97.5	0.50	70.8	0.36
All Zones	3852.7	4232.3	379.6	221.2	0.58	156.7	0.41





Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Millstone Grit	Calculated TOC	0.6	4.9	2.1	2.1	2.3	0.50
Millstone Grit	High Ro TOC	0.6	4.2	1.9	1.9	2.0	0.41
Millstone Grit	Low Ro TOC	0.5	5.8	2.4	2.4	2.6	0.61
Millstone Grit	Measured TOC	0.5	10.8	3.8	4.0	1.5	2.81

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	3177.2	3546.8	369.6	152.6	0.41	144.5	0.39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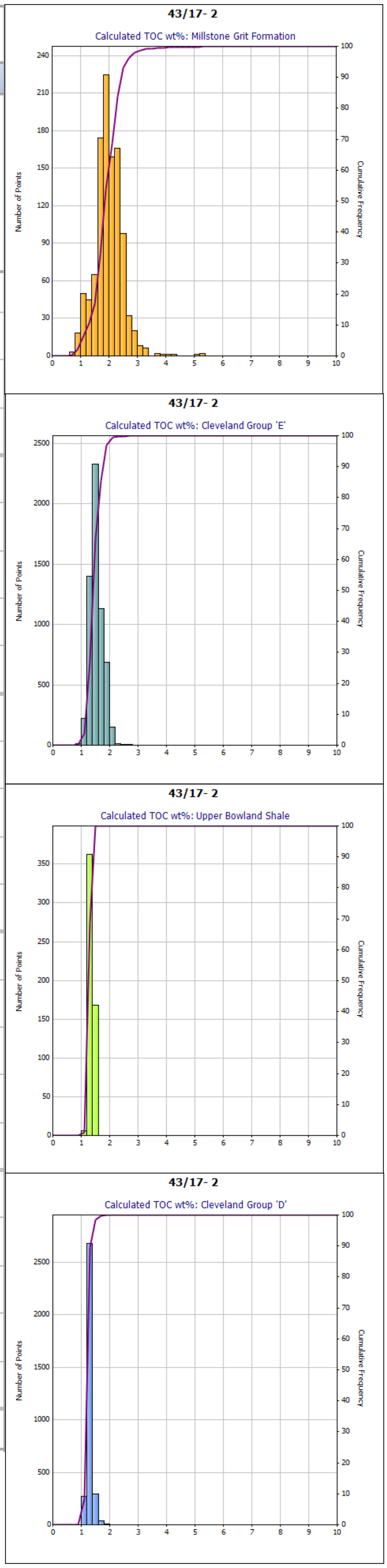
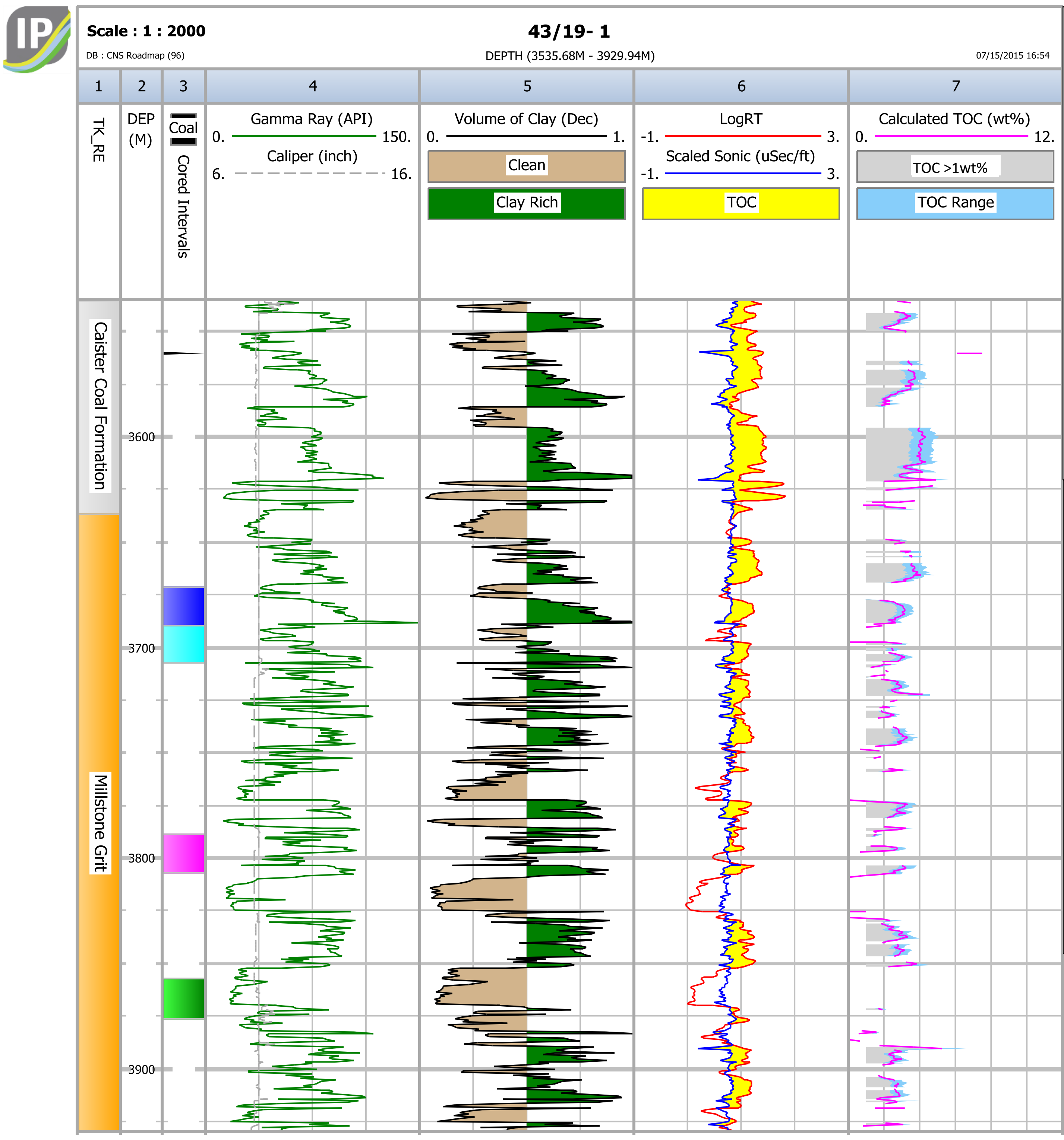
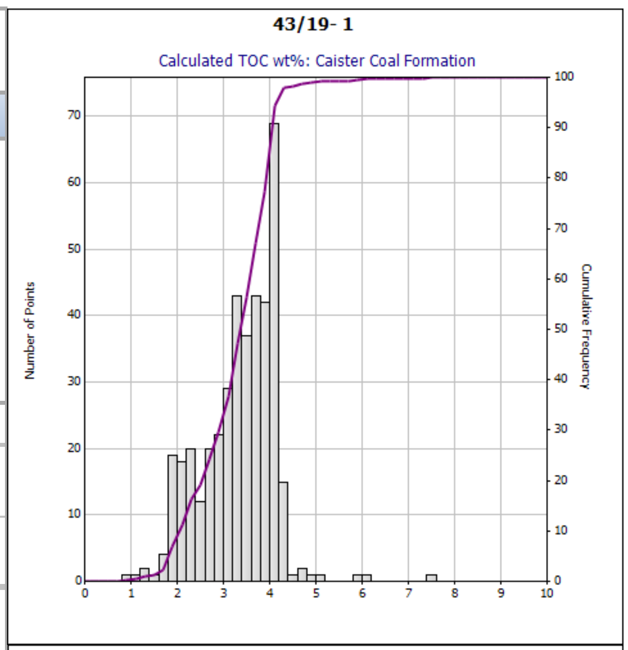
DB : CNS Roadmap (21)
DEPTH (3118.41M - 5585.16M)
18/11/2015 13:41
TK_RE
DEP (M)
Coal
Cored Intervals
Gamma Ray (GAPI)
0. 150.
Caliper (IN)
6. 16.
Volume of Clay (Dec)
0. 1.
Clean
Clay Rich
LogRT
-1. 3.
Scaled Sonic (uSec/ft)
-1. 3.
TOC
Bad Hole
Calculated TOC (wt%)
0. 12.
Measured TOC (%)
0 12
BGS RockEval (%)
0 12
TOC >1wt%
TOC Range
Millstone Grit
Cleveland Gp 'E'
Upper Bowland Sh
Cleveland Gp 'D'
3500
4000
4500
5000
5500

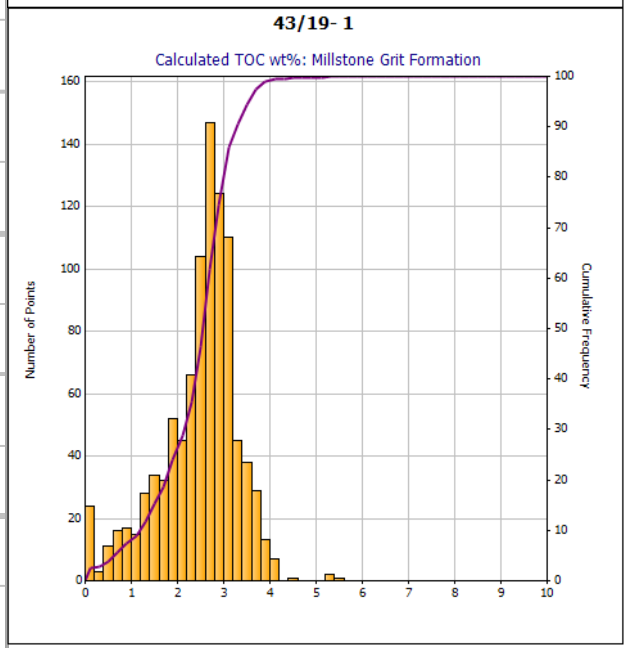

43/17- 2
Calculated TOC wt%: Millstone Grit Formation
Number of Points
Cumulative Frequency
43/17- 2
Calculated TOC wt%: Cleveland Group 'E'
Number of Points
Cumulative Frequency
43/17- 2
Calculated TOC wt%: Upper Bowland Shale
Number of Points
Cumulative Frequency
43/17- 2
Calculated TOC wt%: Cleveland Group 'D'
Number of Points
Cumulative Frequency

Well	Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
43/17- 2	Millstone Grit	Calculated TOC	0.7	5.4	2.0	2.0	1.8	0.49
43/17- 2	Millstone Grit	High Ro TOC	0.8	4.6	1.8	1.7	1.6	0.41
43/17- 2	Millstone Grit	Low Ro TOC	0.7	6.4	2.2	2.2	2.0	0.60
43/17- 2	Millstone Grit	Measured TOC	1.4	43.1	9.5	3.1	4.8	13.09
43/17- 2	Millstone Grit	RockEval TOC	0.9	2.9	1.9	2.1	N/A	0.64
43/17- 2	Cleveland Group E	Calculated TOC	0.9	3.6	1.5	1.5	1.5	0.23
43/17- 2	Cleveland Group E	High Ro TOC	0.9	3.1	1.4	1.4	1.4	0.19
43/17- 2	Cleveland Group E	Low Ro TOC	0.9	4.2	1.7	1.7	1.7	0.28
43/17- 2	Cleveland Group E	Measured TOC	0.2	3.8	1.9	1.8	1.4	0.61
43/17- 2	Cleveland Group E	RockEval TOC	1.4	1.4	1.4	1.4	N/A	N/A
43/17- 2	Upper Bowland Shale	Calculated TOC	1.2	1.5	1.4	1.4	1.4	0.06
43/17- 2	Upper Bowland Shale	High Ro TOC	1.1	1.3	1.2	1.2	1.2	0.04
43/17- 2	Upper Bowland Shale	Low Ro TOC	1.4	1.9	1.6	1.7	1.7	0.09
43/17- 2	Upper Bowland Shale	Measured TOC	1.6	4.4	2.6	1.8	N/A	1.59
43/17- 2	Upper Bowland Shale	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
43/17- 2	Cleveland Group D	Calculated TOC	1.0	2.2	1.3	1.3	1.3	0.10
43/17- 2	Cleveland Group D	High Ro TOC	0.9	1.8	1.1	1.1	1.1	0.07
43/17- 2	Cleveland Group D	Low Ro TOC	1.0	2.9	1.6	1.5	1.5	0.14
43/17- 2	Cleveland Group D	Measured TOC	1.8	5.3	2.6	2.2	2.2	1.13
43/17- 2	Cleveland Group D	RockEval TOC	2.8	3.2	3.0	3.2	N/A	0.26

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	3118.4	3611.3	492.9	165.2	0.34	159.4	0.32
Cleveland Gp 'E'	3611.3	4876.0	1264.7	975.2	0.77	905.4	0.72
Upper Bowland Shale	4876.0	4966.0	90.0	81.8	0.91	81.8	0.91
Cleveland Gp 'D'	4966.0	5574.6	619.2	507.5	0.82	499.6	0.81
All Zones	3118.4	5574.6	2466.8	1729.7	0.70	1646.2	0.67

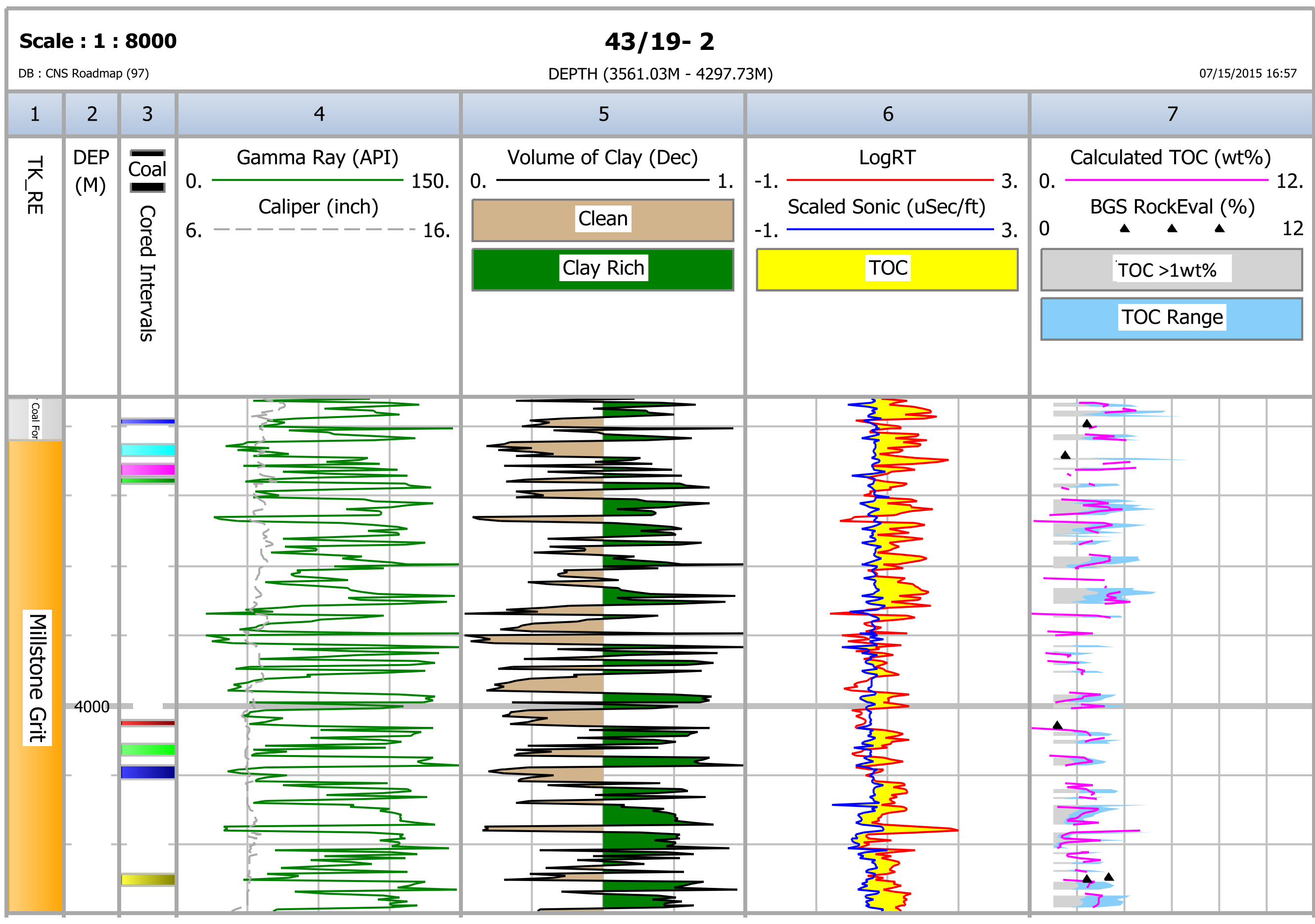


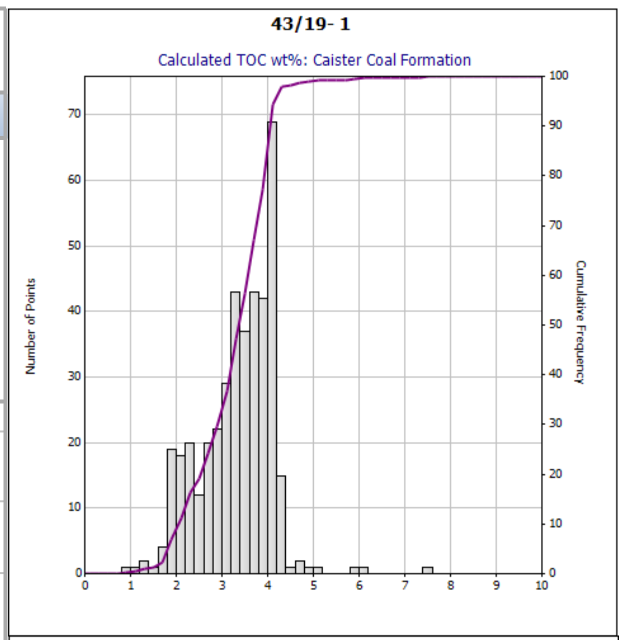


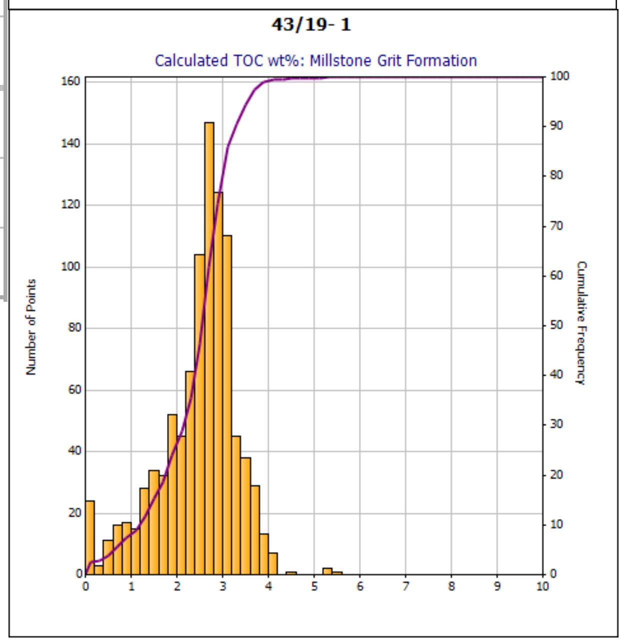


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Caister Coal Formation	Calculated TOC	0.9	7.5	3.3	3.5	4.0	0.80
Caister Coal Formation	High Ro TOC	0.9	6.3	2.9	3.0	3.4	0.66
Caister Coal Formation	Low Ro TOC	0.9	8.9	3.9	4.0	4.6	0.98
Millstone Grit	Calculated TOC	0.0	5.6	2.5	2.7	2.7	0.85
Millstone Grit	High Ro TOC	0.0	4.7	2.2	2.3	2.4	0.71
Millstone Grit	Low Ro TOC	0.0	6.6	2.8	3.1	3.2	1.02

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	3637.0	3930.0	293.0	146.9	0.50	135.2	0.46
Caister Coal Formation	3535.7	3637.0	101.3	62.6	0.62	61.7	0.61
All Zones	3535.7	3930.0	394.3	209.6	0.53	196.9	0.50

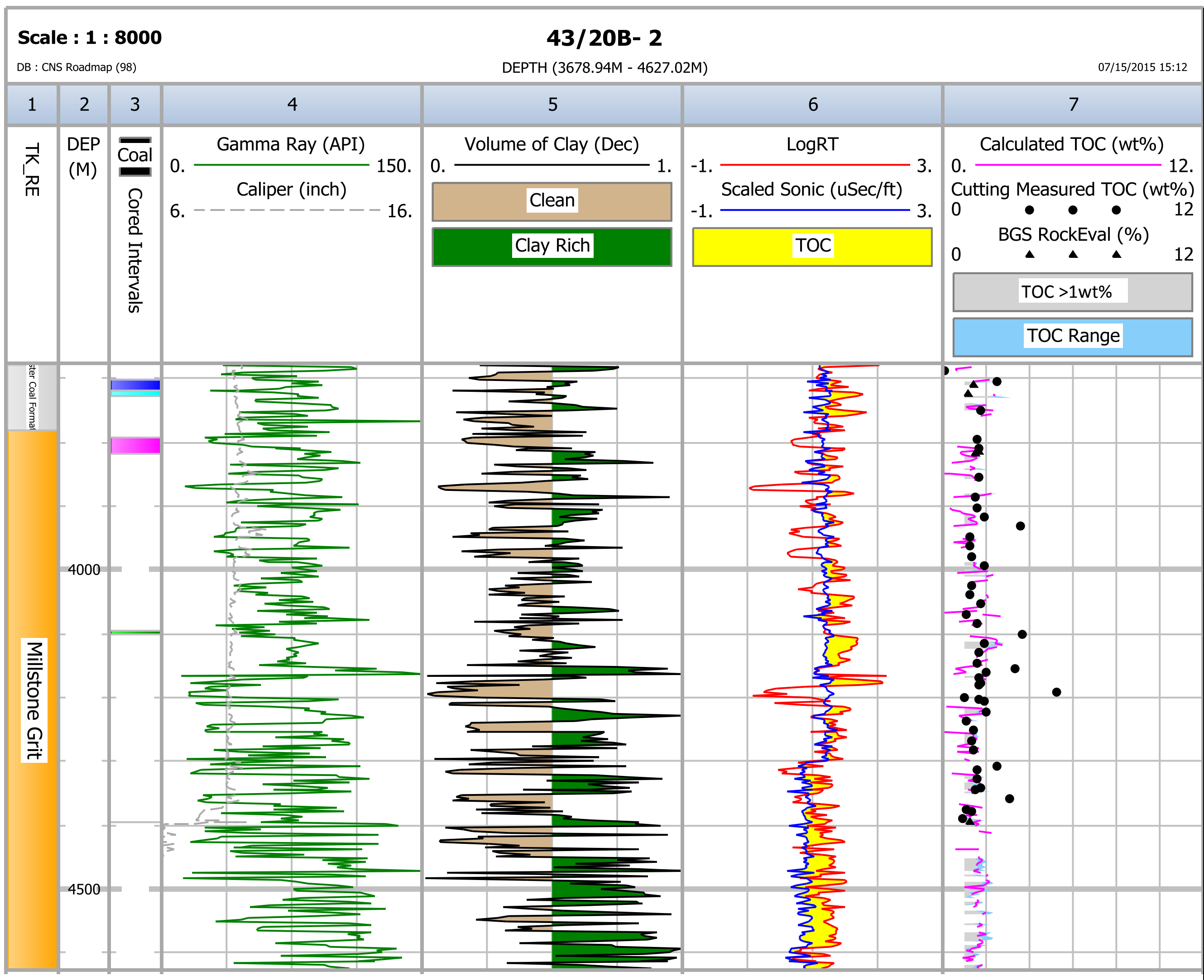


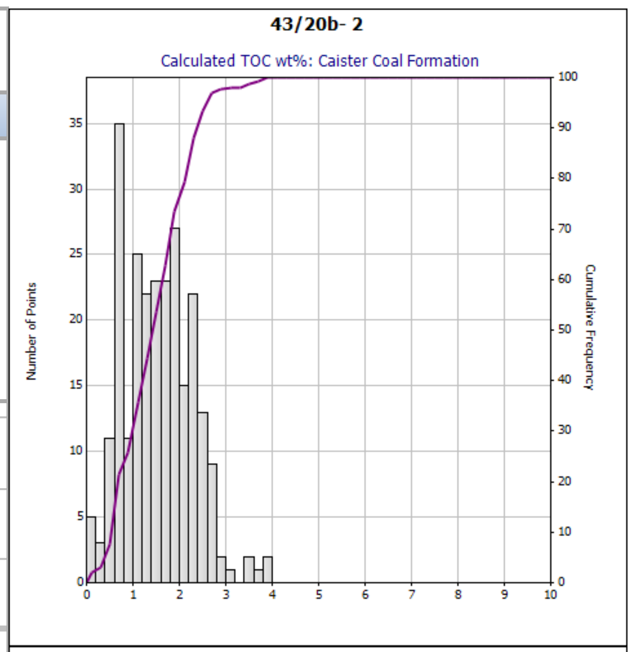


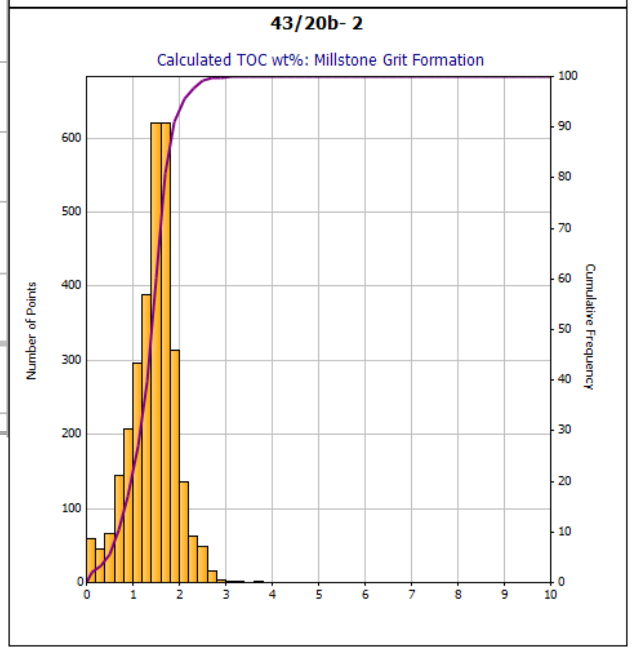


Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Caister Coal Formation	Calculated TOC	1.0	4.7	3.0	3.0	3.4	0.72
Caister Coal Formation	High Ro TOC	0.9	3.4	2.3	2.3	2.5	0.48
Caister Coal Formation	Low Ro TOC	1.0	6.5	4.0	4.0	4.6	1.06
Caister Coal Formation	RockEval TOC	2.4	2.4	2.4	2.4	N/A	N/A
Millstone Grit	Calculated TOC	0.0	4.9	2.5	2.5	2.9	0.76
Millstone Grit	High Ro TOC	0.0	3.6	1.9	2.0	2.2	0.51
Millstone Grit	Low Ro TOC	0.0	6.8	3.3	3.3	3.9	1.11
Millstone Grit	RockEval TOC	1.2	20.9	5.9	2.5	N/A	8.45

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	3620.0	4297.8	677.8	360.2	0.53	349.5	0.52
Caister Coal Formation	3561.0	3620.0	59.0	28.2	0.48	26.7	0.45
All Zones	3561.0	4297.8	736.8	388.4	0.53	376.2	0.51

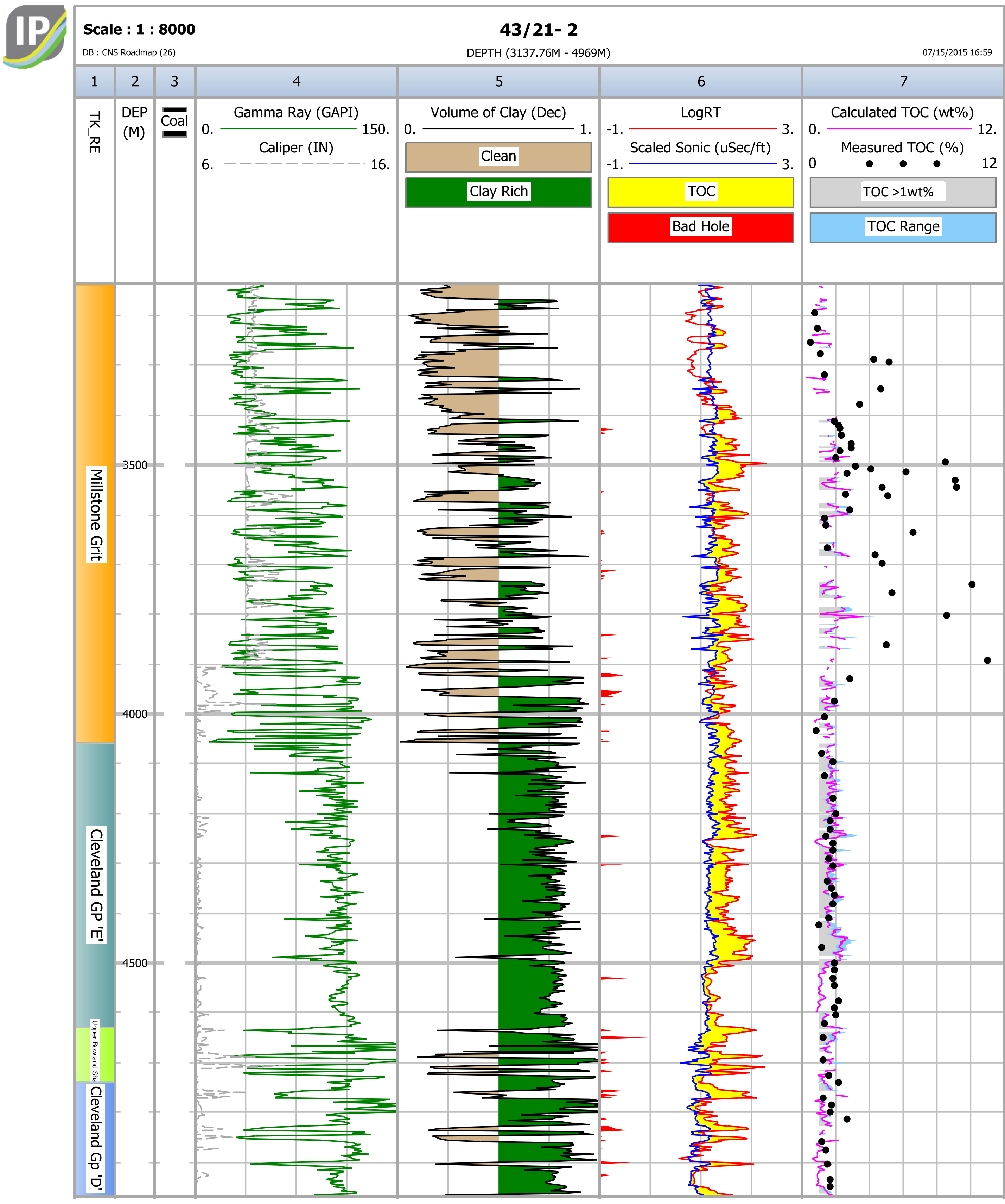


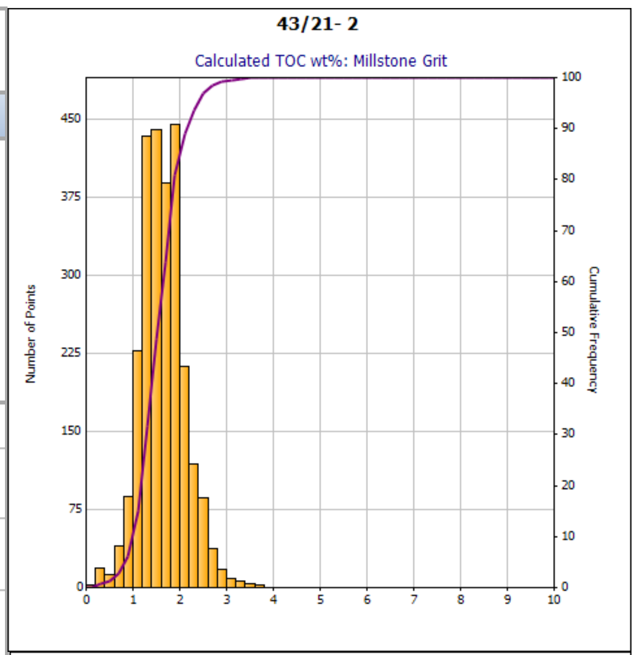


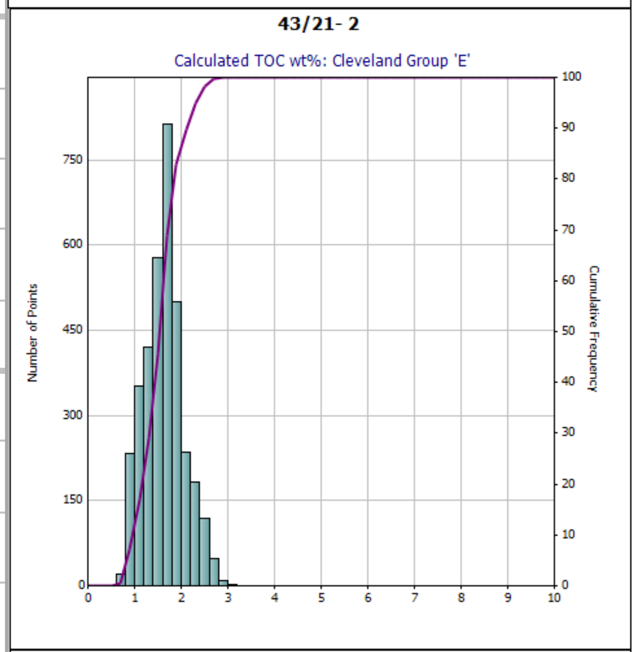


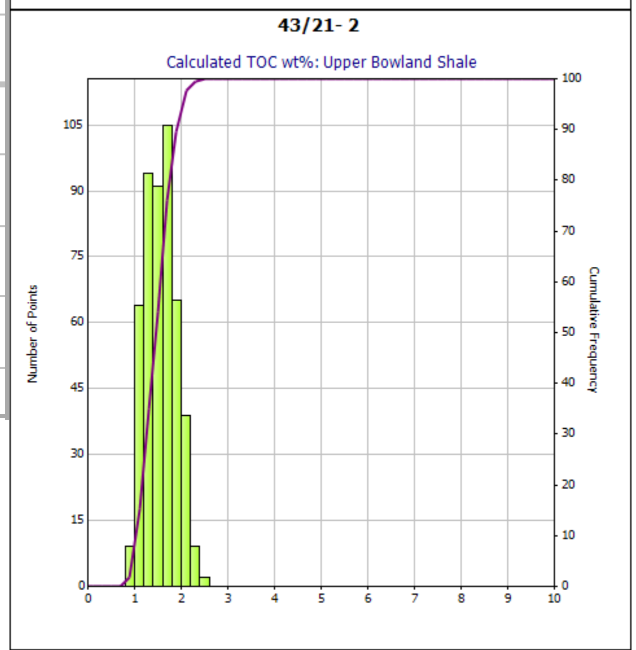
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Caister Coal Formation	Calculated TOC	0.0	3.9	1.5	1.5	0.7	0.75
Caister Coal Formation	High Ro TOC	0.0	3.6	1.5	1.4	0.7	0.67
Caister Coal Formation	Low Ro TOC	0.0	4.3	1.6	1.6	0.7	0.84
Caister Coal Formation	Measured TOC	0.1	64.7	27.9	15.3	N/A	29.40
Caister Coal Formation	RockEval TOC	1.2	1.4	1.3	1.4	N/A	0.19
Millstone Grit	Calculated TOC	0.0	3.8	1.4	1.5	1.6	0.49
Millstone Grit	High Ro TOC	0.0	3.5	1.3	1.4	1.5	0.43
Millstone Grit	Low Ro TOC	0.0	4.2	1.5	1.6	1.8	0.56
Millstone Grit	Measured TOC	0.9	59.6	3.7	1.7	2.8	9.08
Millstone Grit	RockEval TOC	1.3	1.7	1.5	1.5	N/A	0.20

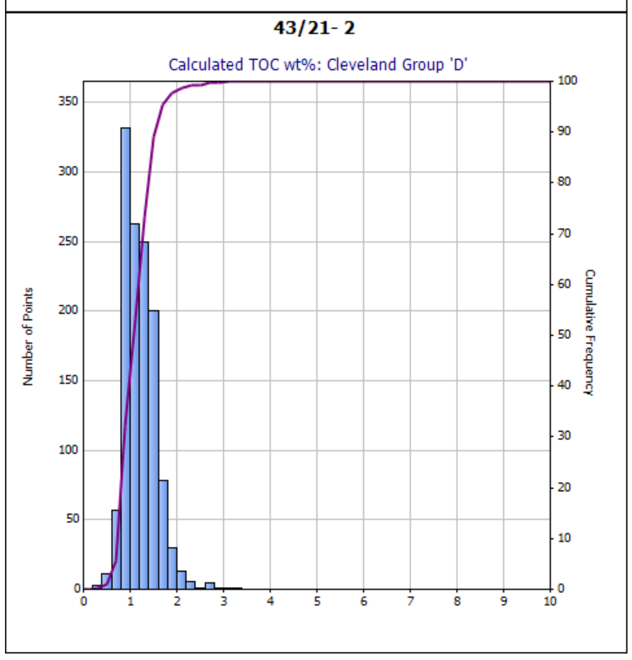
Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Caister Coal Formation	3679.0	3779.5	100.5	39.2	0.39	28.3	0.28
Millstone Grit	3779.5	4627.0	847.5	462.5	0.55	376.9	0.45
All Zones	3679.0	4627.0	948.0	501.8	0.53	405.1	0.43





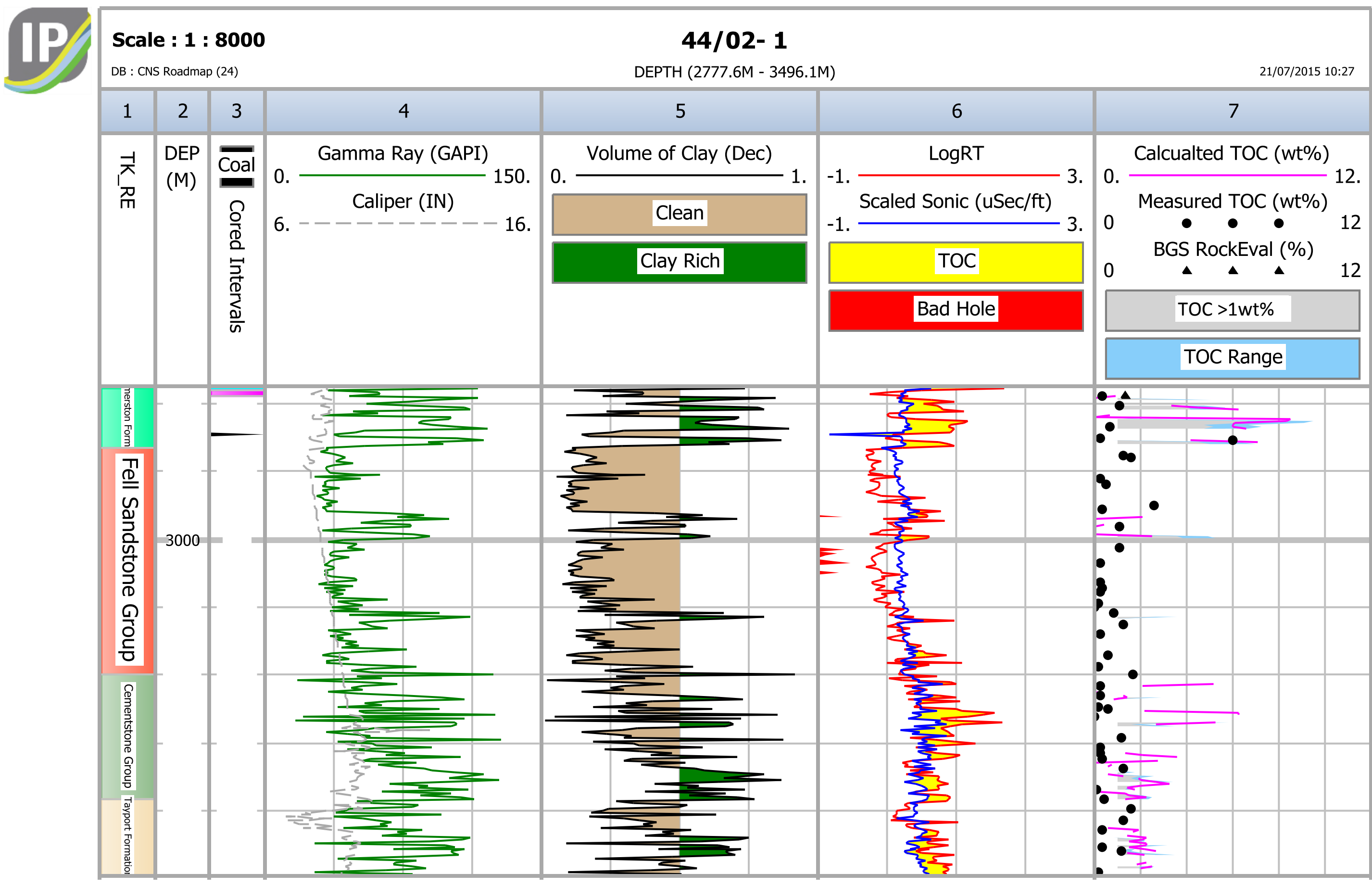


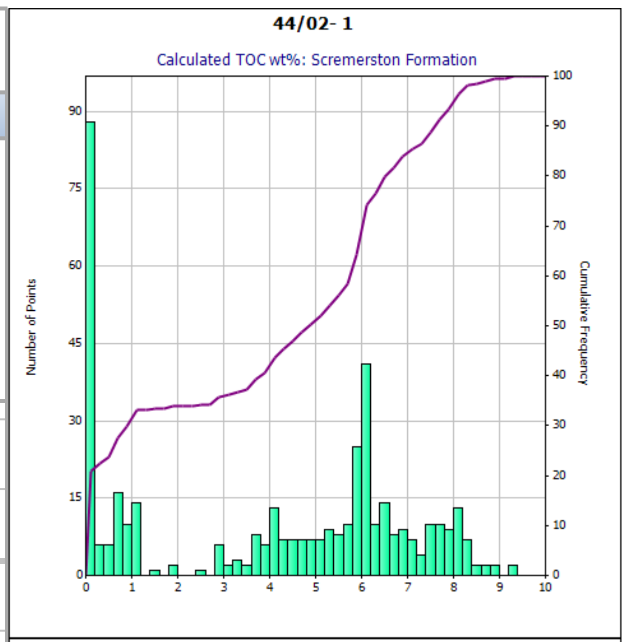


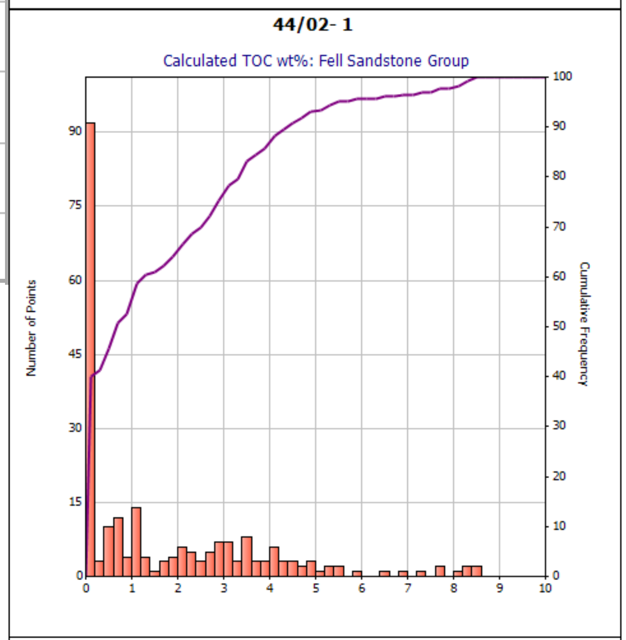


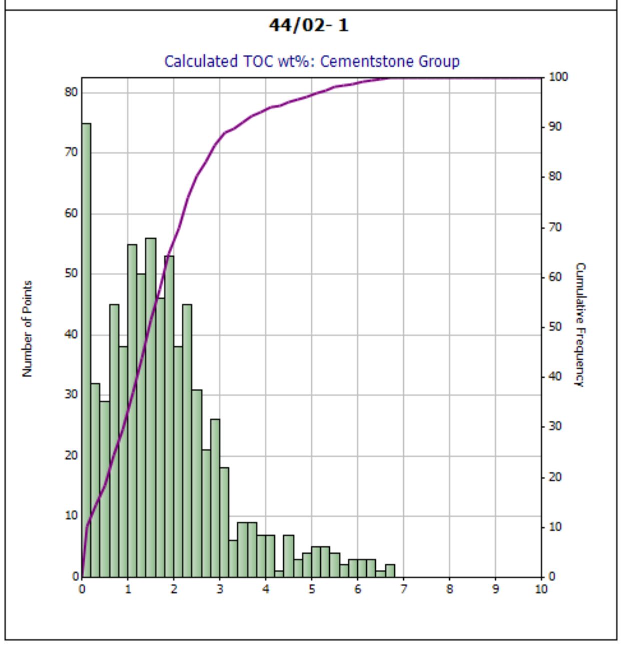
Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
Millstone Grit	Calculated TOC	0.0	3.8	1.6	1.6	1.6	0.48
Millstone Grit	High Ro TOC	0.0	3.3	1.5	1.5	1.3	0.39
Millstone Grit	Low Ro TOC	0.0	4.4	1.8	1.8	2.2	0.58
Millstone Grit	Measured TOC	0.5	75.1	6.7	3.1	3.0	11.93
Cleveland Group E	Calculated TOC	0.7	3.2	1.6	1.6	1.6	0.42
Cleveland Group E	High Ro TOC	0.7	2.7	1.5	1.5	1.5	0.35
Cleveland Group E	Low Ro TOC	0.7	3.7	1.8	1.8	1.8	0.51
Cleveland Group E	Measured TOC	1.0	2.2	1.7	1.8	1.8	0.29
Upper Bowland Shale	Calculated TOC	0.8	2.5	1.6	1.6	1.2	0.32
Upper Bowland Shale	High Ro TOC	0.8	2.1	1.4	1.4	1.1	0.25
Upper Bowland Shale	Low Ro TOC	0.8	2.9	1.7	1.7	1.3	0.39
Upper Bowland Shale	Measured TOC	1.2	1.6	1.3	1.2	N/A	0.19
Cleveland Group D	Calculated TOC	0.4	3.3	1.2	1.2	0.9	0.34
Cleveland Group D	High Ro TOC	0.5	3.3	1.1	1.1	0.9	0.27
Cleveland Group D	Low Ro TOC	0.3	3.3	1.3	1.3	0.9	0.41
Cleveland Group D	Measured TOC	1.2	2.7	1.7	1.7	1.4	0.44

Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
Millstone Grit	3137.8	4059.5	921.7	397.4	0.43	367.7	0.40
Cleveland Gp 'E'	4059.5	4629.2	569.7	535.6	0.94	481.5	0.85
Upper Bowland Shale	4629.2	4739.3	110.1	73.2	0.67	70.7	0.64
Cleveland Gp 'D'	4739.3	4969.0	229.7	190.7	0.83	116.8	0.51
All Zones	3137.8	4969.0	1831.2	1196.9	0.65	1036.7	0.57



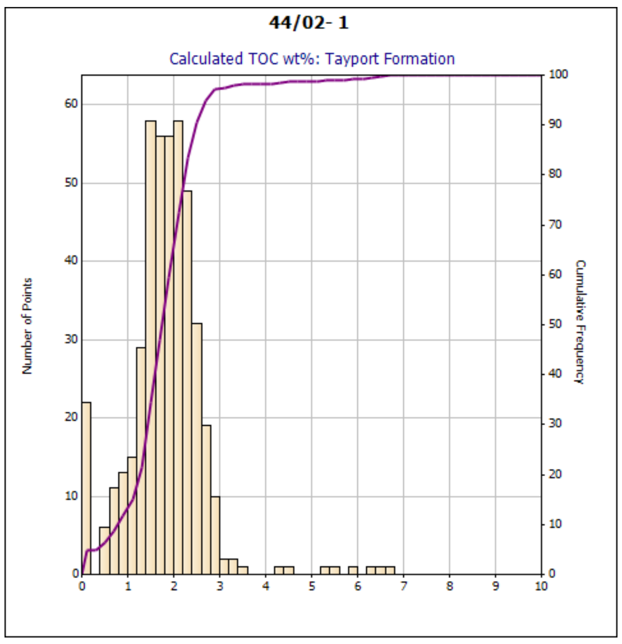


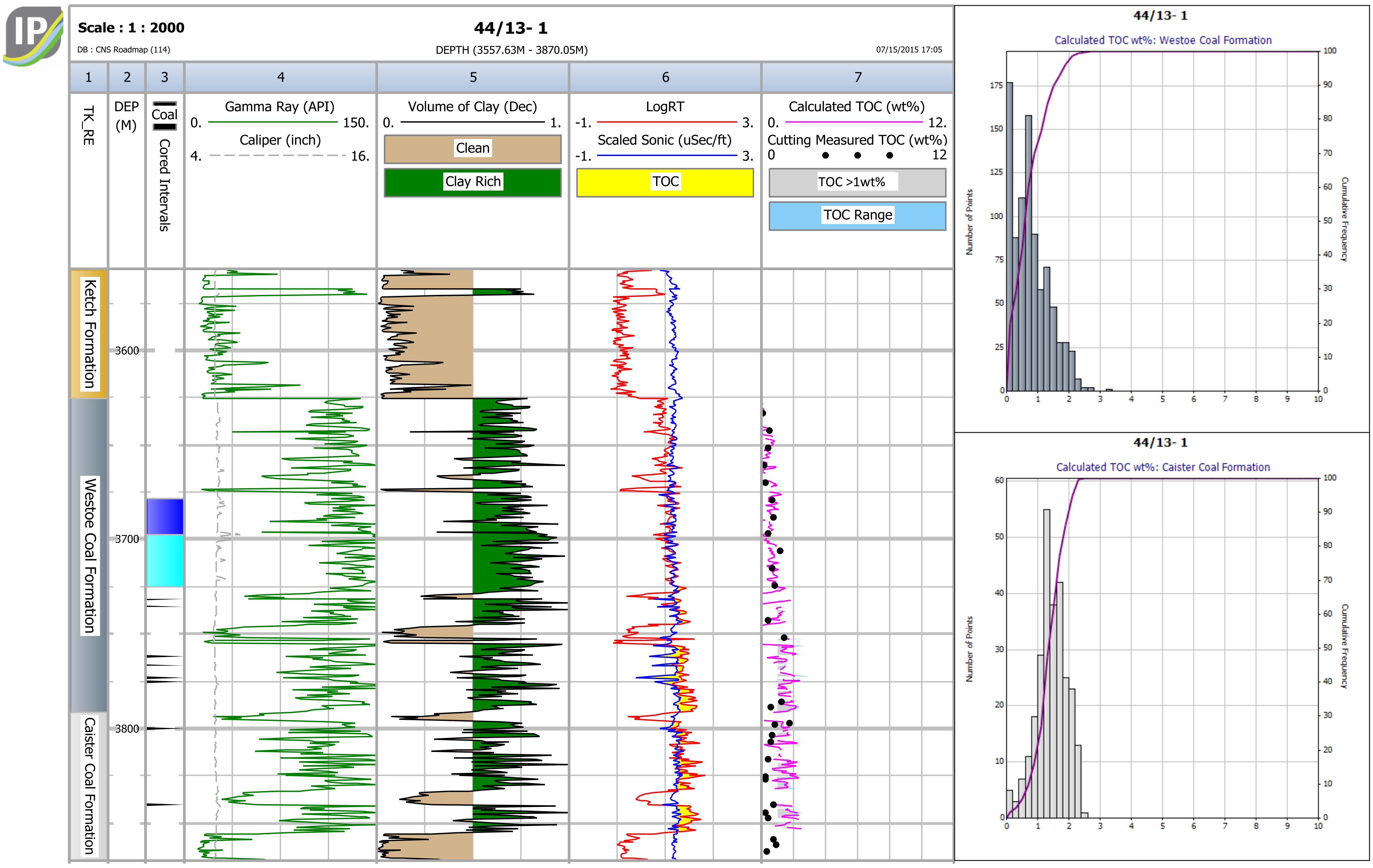




Well	Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
44/02- 1	Scremerston Formation	Calculated TOC	0.0	9.3	4.1	5.0	0.1	2.95
44/02- 1	Scremerston Formation	High Ro TOC	0.0	7.8	3.5	4.2	0.1	2.46
44/02- 1	Scremerston Formation	Low Ro TOC	0.0	11.1	4.8	5.8	0.1	3.53
44/02- 1	Scremerston Formation	Measured TOC	0.2	54.3	13.3	1.1	N/A	21.13
44/02- 1	Scremerston Formation	RockEval TOC	1.3	1.3	1.3	1.3	N/A	N/A
44/02- 1	Fell Sandstone Group	Calculated TOC	0.0	8.6	1.7	0.8	0.1	2.07
44/02- 1	Fell Sandstone Group	High Ro TOC	0.0	7.2	1.5	0.8	0.1	1.75
44/02- 1	Fell Sandstone Group	Low Ro TOC	0.0	10.3	1.9	0.8	0.1	2.47
44/02- 1	Fell Sandstone Group	Measured TOC	0.0	50.5	3.1	0.5	3.6	10.89
44/02- 1	Fell Sandstone Group	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
44/02- 1	Cementstone Group	Calculated TOC	0.0	6.8	2.0	1.7	0.1	1.81
44/02- 1	Cementstone Group	High Ro TOC	0.0	5.7	1.8	1.5	0.1	1.51
44/02- 1	Cementstone Group	Low Ro TOC	0.0	8.0	2.3	1.9	0.1	2.16
44/02- 1	Cementstone Group	Measured TOC	0.0	1.7	0.5	0.3	0.2	0.52
44/02- 1	Cementstone Group	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A
44/02- 1	Tayport Formation	Calculated TOC	N/A	N/A	N/A	N/A	N/A	N/A
44/02- 1	Tayport Formation	High Ro TOC	N/A	N/A	N/A	N/A	N/A	N/A
44/02- 1	Tayport Formation	Low Ro TOC	N/A	N/A	N/A	N/A	N/A	N/A
44/02- 1	Tayport Formation	Measured TOC	0.2	1.6	0.7	0.4	N/A	0.56
44/02- 1	Tayport Formation	RockEval TOC	N/A	N/A	N/A	N/A	N/A	N/A

Well	Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
44/02- 1	Scremerston Formation	2777.6	2865.1	87.5	42.0	0.48	29.3	0.34
44/02- 1	Fell Sandstone Group	2865.1	3200.4	335.3	23.0	0.07	10.4	0.03
44/02- 1	Cementstone Group	3200.4	3383.3	182.9	73.8	0.40	12.7	0.07
44/02- 1	Tayport Formation	3383.3	3496.1	112.8	44.7	0.40	0.0	0.00
44/02- 1	All Zones	2777.6	3496.1	718.4	183.4	0.26	52.4	0.07





Well	Formation	Curve	Min	Max	Mean	Median	Mode	Std Dev
44/13- 1	Ketch Formation	Calculated TOC	0.0	0.3	0.0	0.0	0.0	0.06
44/13- 1	Ketch Formation	High Ro TOC	0.0	0.3	0.0	0.0	0.0	0.08
44/13- 1	Ketch Formation	Low Ro TOC	0.0	0.2	0.0	0.0	0.0	0.04
44/13- 1	Ketch Formation	Measured TOC	N/A	N/A	N/A	N/A	N/A	N/A
44/13- 1	Westoe Coal Formation	Calculated TOC	0.0	3.2	0.8	0.7	0.0	0.59
44/13- 1	Westoe Coal Formation	High Ro TOC	0.0	3.0	0.8	0.7	0.0	0.54
44/13- 1	Westoe Coal Formation	Low Ro TOC	0.0	3.5	0.8	0.7	0.0	0.65
44/13- 1	Westoe Coal Formation	Measured TOC	0.1	58.2	9.8	0.7	4.9	19.39
44/13- 1	Caister Coal Formation	Calculated TOC	0.1	2.5	1.4	1.4	1.3	0.48
44/13- 1	Caister Coal Formation	High Ro TOC	0.1	2.3	1.4	1.4	1.3	0.43
44/13- 1	Caister Coal Formation	Low Ro TOC	0.0	2.7	1.5	1.5	N/A	0.54
44/13- 1	Caister Coal Formation	Measured TOC	0.3	18.8	1.9	0.7	2.6	4.87

Well	Zone	Top Depth (m)	Bottom Depth (m)	G, Gross Formation Thickness (m)	N, Net Shale Thickness (m)	N/G	Pay (>1% TOC) Thickness (m)	P/G
44/13- 1	Ketch Formation	3557.6	3625.3	67.7	3.1	0.05	0.0	0.00
44/13- 1	Westoe Coal Formation	3625.3	3791.7	166.4	140.5	0.84	39.5	0.24
44/13- 1	Caister Coal Formation	3791.7	3870.0	78.3	41.5	0.53	34.0	0.43
44/13- 1	All Zones	3557.6	3870.0	312.4	185.0	0.59	73.5	0.24

Glossary

GR – Gamma Ray (in reference to gamma ray logging tool reading).

IP – Interactive Petrophysics. Petrophysics software used for total organic carbon calculation.

LOM – Level Of Maturity. A maturity parameter between 0-15, although typically between 6 and 13, used in the Passey method equations (Passey et al., 1990) based on measured Ro values.

MD – Measured Depth (well depth measured downhole, which may not be vertical).

N/G – Net to Gross. Indicates the amount of each formation that is considered to be shale. Intervals where VCl is greater than 0.5 (50% clay) are included as "Net". Gross is the total formation thickness.

P/G – Pay to Gross. Indicates the amount of each formation that is considered could be potentially a source rock. Net intervals where TOC is greater than 1 wt% are included as organic-rich "Pay". Gross is the total formation thickness.

RECALL- Database software containing the geophysical logs used for this project.

Ro – Reflectivity index. (See VR)

TOC- Total Organic Carbon (expressed as wt %).

VCl - Volume of Clay. Based on a normalised Gamma Ray curve between 0 and 1 (1 represents 100% clay and 0 represents 100% 'clean' reservoir).

VR – Vitrinite Reflectance. Measured % of light reflected from a vitrinite sample in oil, expressed as a % usually between 0 and 3%. Also often expressed as Ro.

Refer to the TOC plots (Appendix 4) to assess the scaled sonic and ΔlogR overlays with the calculated TOC values. As according to Passey et al. (1990) a mature source interval can be distinguished from an immature source rock interval by a positive deflection of the resistivity in conjunction with a decrease in the scaled sonic (Figure 2)

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British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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