Objectives:

The objectives of the well evaluation are to review test and log data to describe the main reservoir properties and lithologies encountered in the formations. The quantified results can then help to better constrain the gross depositional environment maps.
A deterministic petrophysical evaluation for shale content (VSH), effective porosity (PHIE) and water saturation (SW) has therefore been carried out for three (3) wells. Secondly, the determination of lithologies from log data is performed through statistical electrofacies determination for the three (3) wells (Figure 1/Table 1: Bandol B-1, East-Wolverine G-37 and Heron H-73)

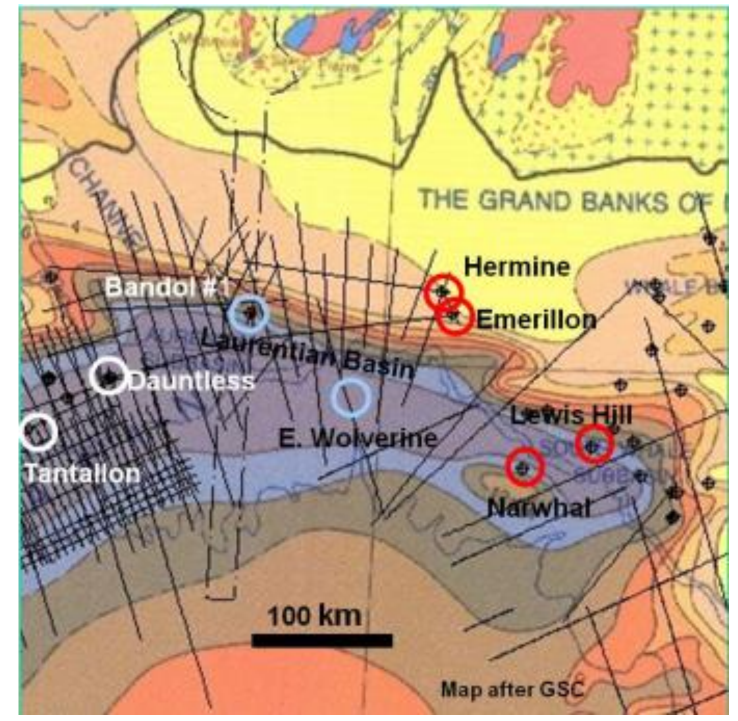


Figure 1: Study Area Well Locations

Year	Operator	Name & ID	FTD (m)	Status
1974		**Emerillon C-56**	3277m MD	Abandoned
1972	Amoco Canada Petroleum	**Heron H-73**	2834m MD (9299ft MD)	Abandoned
2001	ExxonMobil	**Bandol B-1**	4046m m MD	Plugged and abandoned
2010	ConocoPhillips Canada Resources Corp	**East- Wolverine G-37**	6857m MD 6820.4m TVDSS	Plugged and abandoned

Table 1: Study Area Wells

Well Database:

The log database consists in a full set of logs in wells Bandol and Heron and partial data and low log quality in East Wolverine (Table 2). Log mnemonic equivalence as used in this project is listed in Table 2 together with the top and base depths (in MD) for the interpreted intervals.
Database homogenization has been performed, including Neutron limestone calibration (originally already limestone calibrated NPLS in Heron) and recalibration of neutron from sandstone (NPOR_SAN in Bandol and East Wolverine).
Discription and loading of mudlogging lithology as lithologies (Sandstone, Limestone, Dolomite, Chalk, Claystone, Shale, Marl, Siltstone, Salt, Coal and Anhydrite).

Well	GR (GAPI)	DT (µs/ft)	NPHI (v/v)	RHOB (g/cm3)	PEF (b/e)	RESD (Ohm.m)	Top Interval (m MD)	Base Interval (m MD)
Bandol B-1	GR	DT4P	NPOR_SAN	RHOZ	PEFZ	AHT90	1230	4050
East-Wolverine G-37	GR	DT4P*	NPOR_SAN°	RHOZ°	PEFZ°	AF90	° 3500	° 6760
Emerillon C-56	GR	DT	NPLS	RHOB	-	ILD	1190	3250
Heron H-73	GAM	DT	NPLS*	RHOB	-	ILD	770	3562

Table 2: List of logs in wells and interpretation intervals.
* Edited
° Gap

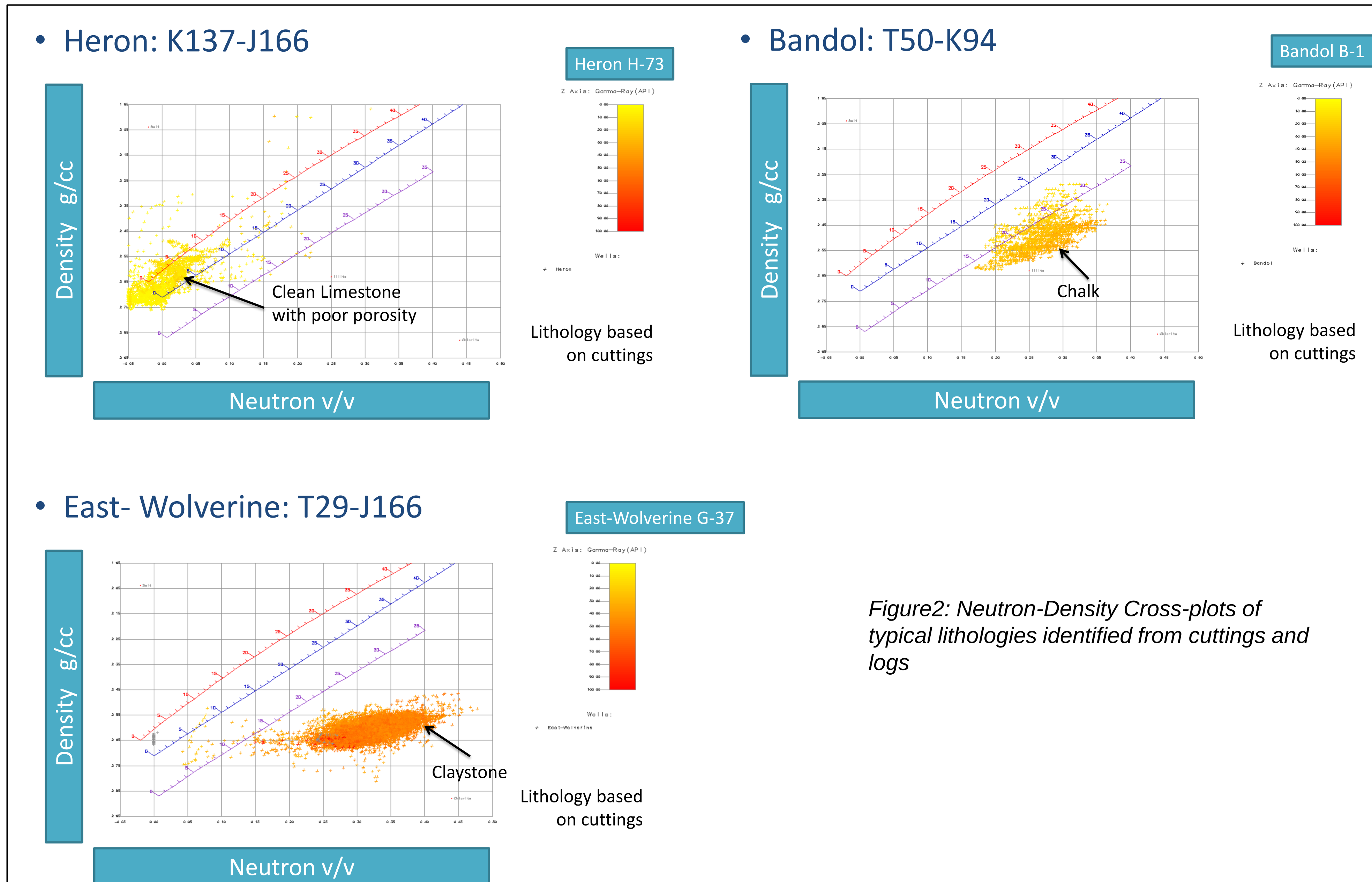


Figure2: Neutron-Density Cross-plots of typical lithologies identified from cuttings and logs

Well Results:

The wells have locally been side-wall cored (Table 3) and tested (Table 4). The results, integrated with log analysis results are described on Plate 2.1.2 and detailed in Plate 2.1.6.

Well	Sidewall core/ full-hole core	Core Porosity	Core Permeability	Core Grain density
Bandol B-1	No Full-hole core; side wall core available	X	X	X
East-Wolverine G-37	No core measurements			
Emerillon C-56				
Heron H-73	No Full-hole core /side wall core available	X	X	Not visible

Table 3: Core Data

Well	Test type	Test #	Top depth (m MD)	Base depth (m MD)	Result
Bandol B-1					
Heron H-73	DST	1-1	9080'	9100'	@750' Salinity=77.3g/l
Heron H-73	DST	1-3	9080'	9100'	@3700' Salinity=87.5g/l
Heron H-73	DST	1-6	9080'	9100'	@7600' Salinity=91.2g/l
Heron H-73	DST	1-8	9080'	9100'	@8400' Salinity=90.6g/l
Heron H-73	DST	1-10	9080'	9100'	@8900' Salinity=43g/l
Heron H-73	DST	2-1	8190'	8230'	@450' Salinity=64.3g/l
Heron H-73	DST	2-3	8190'	8230'	@2700' Salinity=79.3g/l
Heron H-73	DST	2-5	8190'	8230'	@5400' Salinity=81.2g/l
Heron H-73	DST	2-7	8190'	8230'	@8000' Salinity=81.4g/l
Heron H-73	DST	3-1	7810'	7850'	@1200' Salinity=23.6g/l
Heron H-73	DST	3-2	7180'	7150'	@3000' Salinity=32.9g/l
Heron H-73	DST	3-3A	7810'	7850'	@5100' Salinity=32.4g/l
Heron H-73	DST	3-4A	7810'	7850'	@7600' Salinity=32.4g/l
Heron H-73	DST	2	8190'	8230'	Salinity=80.7g/l

Well Heron H-73
DST 1 2767 2773.7 Reverse circulated 8.1 m3 (51 barrels) water (46 717 ppm Cl-) with slight trace oil
DST 2 2496.3 2508.5 Recovered 7.6 m3 (48 barrels) water (46 384 ppm Cl-)
DST 3 2380.5 2392.7 Reverse circulated 0.31 m3 (2 barrels) formation water (16 895 ppm Cl-) DST 4 2293.6 2305.8 Recovered 0.1 m3 (3/4 barrel) water (19 879 ppm Cl-) and 0.473 litres (1 pint) tar
DST 5 2293.6 2305.8 Misrun
DST 6 2293.6 2305.8 Recovered 16.2 m3 (102 barrels) salt water and 3.5 m3 (22 barrels) heavy oil (6.7°API)

Table 4: Well Test Results

Log Analysis Methodology

A deterministic workflow was applied to identify the shaliness, porosity and water saturation. Log signatures in specific intervals and lithologies (based on cuttings data) were compared and analyzed in order to define specific interpretation parameters suitable for each interval (Figure 2). 11 lithologies were thus determined: Sandstone, Limestone, Dolomite, Chalk, Claystone, Shale, Marl, Siltstone, Salt, Coal and Anhydrite.
Shale volume evaluation was performed by calculating the shale content based on the neutron-density cross-plot methodology as well as gamma-ray. A good correspondence was obtained between GR-based and Neutron-Density based shale volume curves. The minimum curve of these two was retained as final shale volume (Figure 3).
Porosity was evaluated by implementing the neutron-density cross-plot method, allowing the matrix composition effect on porosity to be discounted. The porosity interpretation was compared to the occasionally available sidewall core porosity. The porosity interpretation defined total porosity and effective porosity, the latter corrected for the shale effect as well as the microporosity in chalks (Figures 4 & 5). No effective Porosity is considered present in the chalks, albeit high plug porosity (measured under ambient conditions), knowing microporosity is reported in core description and compaction of the chalks in reservoir condition. The low resistivity and absence of staining or gas in mud reports comforts the view that these chalks represent tight reservoir. In the porosity interpretation QC, the computed matrix density was also compared to core grain densities and porosity interpretation showing good coherency and supporting the interpretation results.
The water saturation in the formation is evaluated using a modified Archie, Indonesia method, accounting for the influence of shale on the resistivity measurement. Formation water resistivity was determined based on the measured salinity of the water. The value for water salinity has been determined as an average from DST sampled formation water (Table 4) at 81 kppm NaCl , corresponding to an Rw = 0.045 @ 67°C. This value may be expected to vary somewhat over the area and interval of the Abenaki. The evolution of this resistivity with the temperature has been related to the thermal gradient defined for the formation. Quality control of the saturation results has included review of staining and shows listed in mud reports and low resistivity to verify high interpreted water saturation in specific intervals.

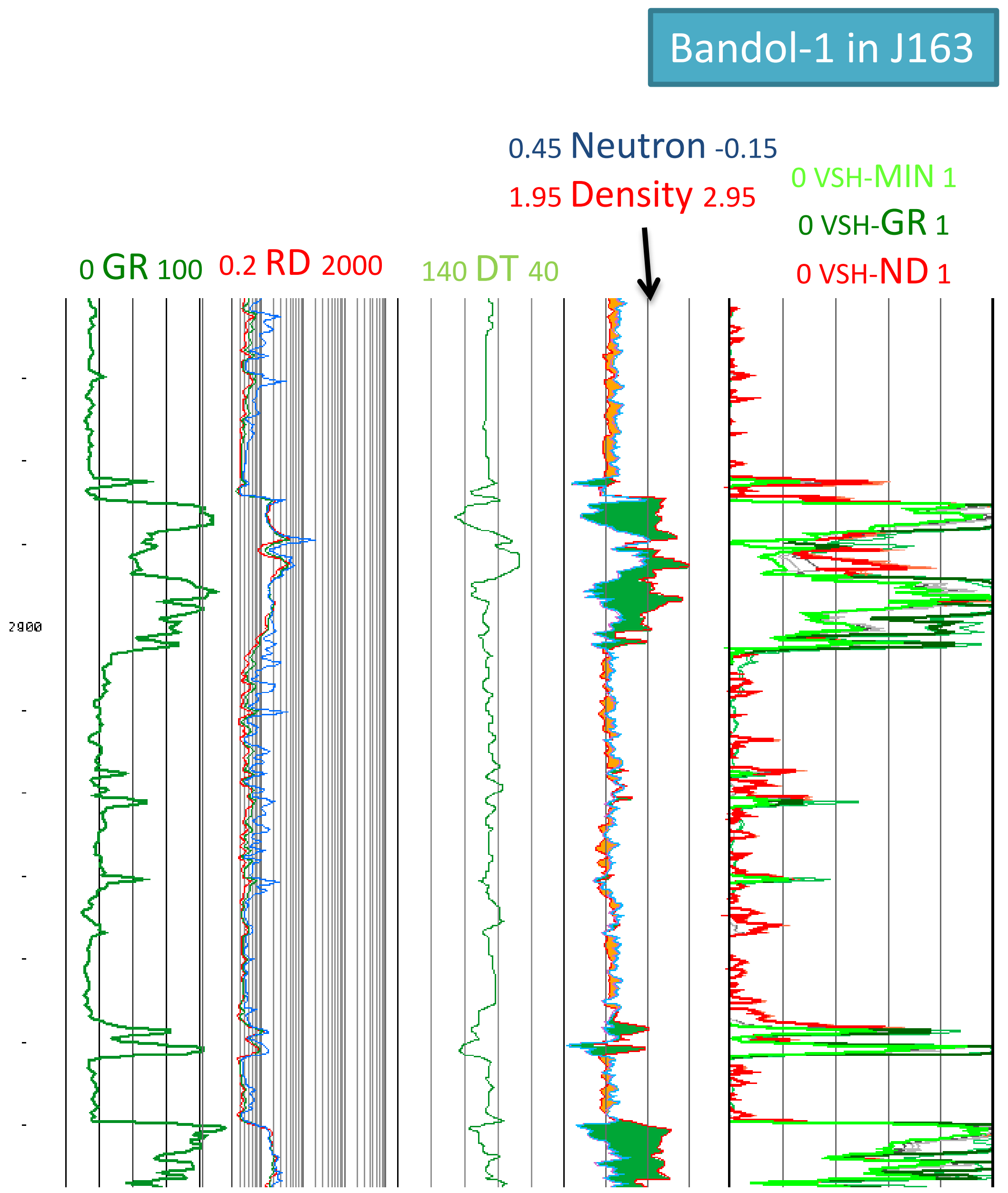


Figure 3: Example Shale Volume Interpretation form Bandol-1

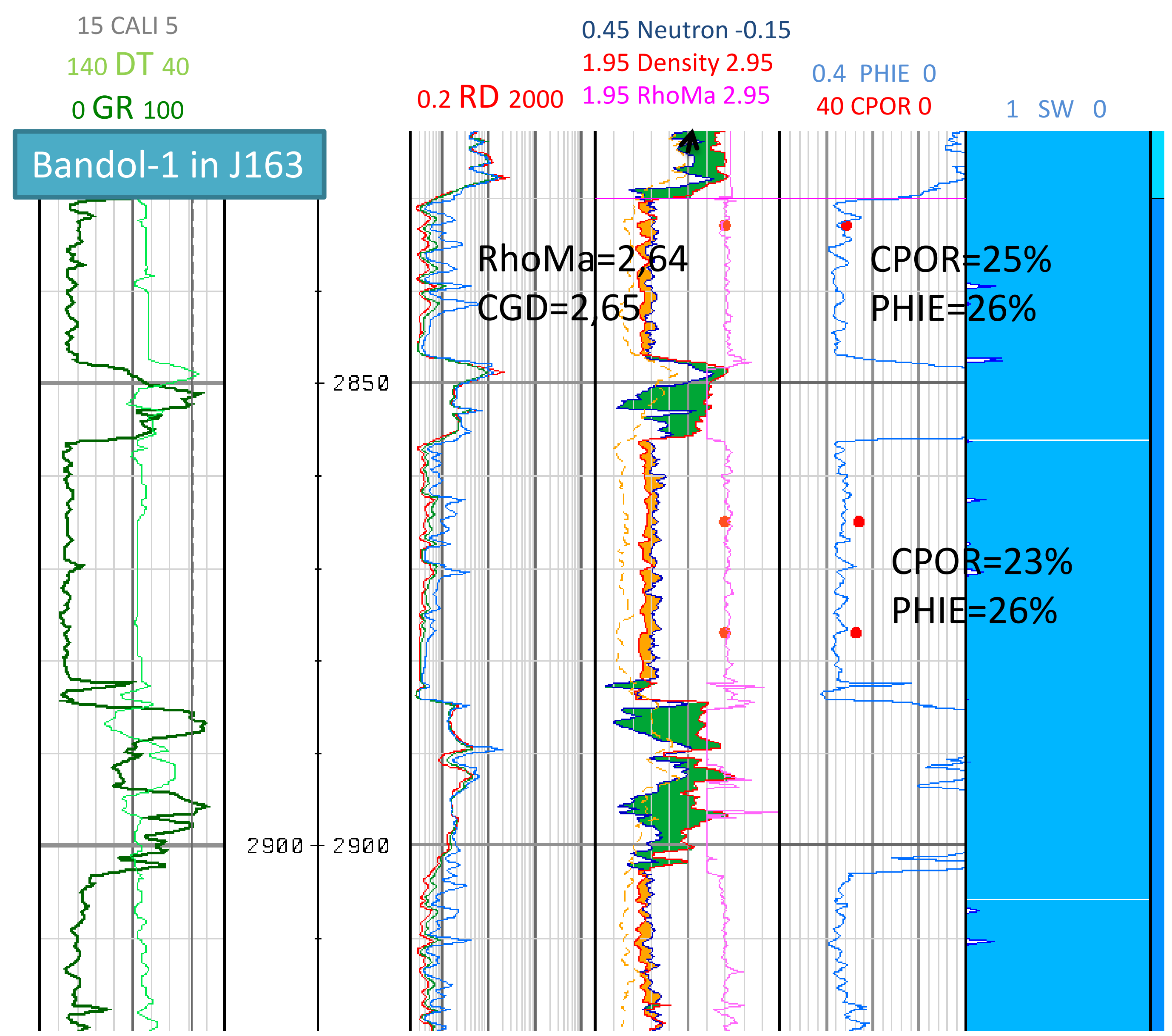


Figure 4: Example Porosity Interpretation form Bandol-1

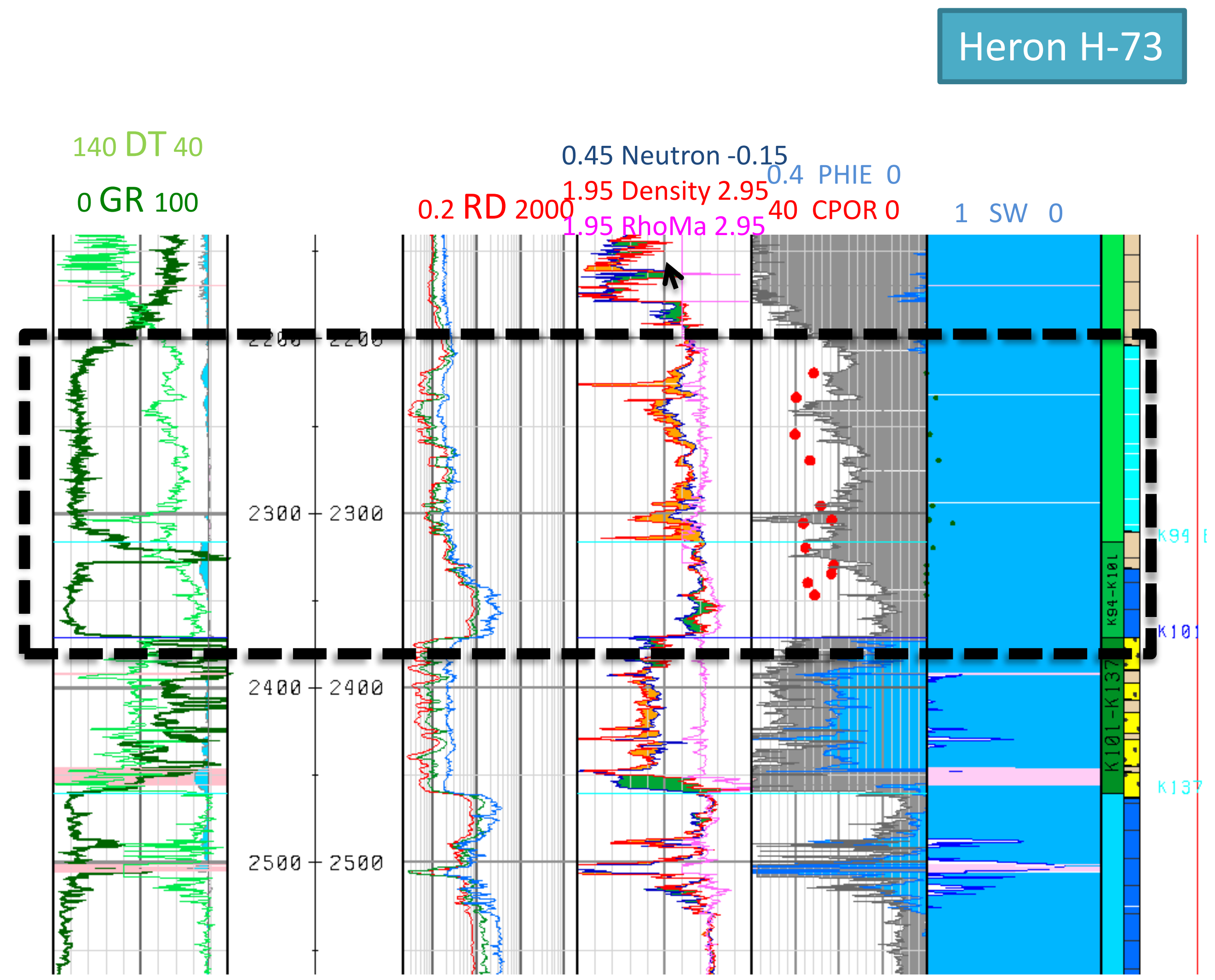


Figure 5: Example Porosity Interpretation in Chalks (Heron-73)

Well-by-Well Review

Bandol-1

Very good porosity in sandstone (22% average); very high water saturation (>80%); No shows No stains.
Interval: 1230-4050 m MD
Interval 1210-1644 m MD (marker T29-T50): bad log interval quality with very high Neutron and Density values. Very shaly interval (GR>60) described as claystone in striplog.
Interval 1645-1955 m MD (T50-K94): Chalky interval (1645-1918m MD) with low argillaceous content (1730-1740 m MD & 1790-1810m MD for example), grading to marl at base.
Interval 1955-2060 m MD (K101-K137): high Claystone content with some quartzose layer of fair good porosity (18-25%) (1955-1990 m MD). Blocky shale at base (1990-2060m MD).
Interval 2060-2378m MD (K101-K137): increase of sandstones interval thickness becoming less argillaceous intercalated with thick shale intervals. From poor-fair porosity (2060-2075 m MD) to good porosity in base (2370-2375 m MD).
Interval 2375-2445m MD (K101-K137): thin intercalations of shale and sandstone with poor porosity.
Interval 2445-2496: 2 Thick chalky limestone intervals with poor porosity showing a high density and separated by a shaly interval.
Interval 2496-2830 m MD (K137-K163): intercalation of sandstone with kaolinitic matrix with poor to good porosity (2630 m MD) grading to blocky Shale. Few chalky Limestone interbeds.
Interval 2830-3542 m MD (K163): intercalation of sandstone slightly argillaceous with blocky shales. Very Good core porosity (22 to25%) slightly lower than computed porosity due to presence of chalk.
Interval 3589-3702 m MD (K163): intercalation of limestone, chalky in top to soft and crumbly in base, and Shale. Good to Very good porosity.
Interval 3702-4037m MD (K163): clean sandstone with very low amount of shale grading to shale. Good to fair core porosity (15-20%). At 3985 m MD presence of black carbonaceous partings were core porosity is lower than computed porosity.

There is neither oil show nor fluorescence in this well. Deep resistivity deep is always lower than the shallow resistivity. No HC reservoirs are available in this well.
OBM in interval 1221-4046 m MD

Heron H-73

Mainly limestone with low to fair porosity. High water saturation (>60%); few gas shows in tight limestone @2300-2600 m and stains @2371 m.

Interval 1500-1740 m MD (T29-T50): claystone with high GR , few interbeds of sandstone
Interval 1740-1765 m MD: Chalky limestone without macroporosity porosity. High Microporosity content visible in total porosity calculation.
Interval 1765-2203m MD (T50-K94): claystone grading to shale. Occasional sand stringers. Some badhole area seen on Neutron Density impacting porosity calculation.
Interval 2203-2371m MD(T50-K101): On top Chalky limestone with few dark brown oil staining grading to micritic limestone in base. There is no macroporosity in chalky limestone , only microporosity. microporosity is seen on total porosity and on Core porosity measurements. At base Micritic limestone shows a poor to fair macroporosity (5-10%)with some live oil staining and gas in the mud recaord (2295-2305m MD).
Interval 2371-2462m MD (K101-K137): coarse unconsolidadted sandstone with good porosity (20% in average), no shows or stain in this interval. High GR reveal presence of sandy shale and low RD the absence of hydrocarbon in formation.
Interval 2462-3048m MD (K137-J166): thick micritic limestone interval with live oil stain and poor to fair porosity (0-10%). Cuttings reveal no visible porosity and vuggy porosity. Total porosity calculated varies between 6-10%.
Interval 3002-3048m MD (J166-J188) : sandstone interval. It present a high GR seen on shale volume. Prosity wasn't calculated in this interval do to badhole log problem. Density is missing. No stain nor gas show.
Interval 3048-3375 m MD (J166-J188): intercalation of shale and limestone interbedded grading to thick shale layer in base. Facies is changing with fine crystalline porosity at top to cryptocrystalline porosity at base . Calculated porosity reflects these changes with values from 15% in top to 5% in base. No gas was seen in mud log and trace of dead oil.
Interval 3375-3502 m MD (J166-J188): dolomite interval described as 5-10% of intercristalline porosity. Density not available in this interval . Oil stains are visible and gas in mud logs RD are increasing in this area with few peaks at 2000 ohm.m. Salty layers below may affect resistivity.
After 3502m : salt layer

East Wolverine G-37

Mainly claystone with very few reservoir intervals; few gas shows @5140 m and @6313 m; no stains.
Interval 3750-4250 m MD (T29-T50): intercalation of claystone slightly calcareous and limestone . Limestone layers are becoming thicker in base. GR present regular values in claystone (between 50 and 60API). Limestone is revealed by decrease of Gamma-Ray. Neutron log is not relevant in this interval showing irregular values. Porosity is poor (0 -10 %) in limestone intervals. There are no relevant shows in this formation.
Interval 4250-5200 m mD (T50-K137): claystone interbedded with few sandstones. Neutron and density are missing between 4800-5220m MD and Gamma-Ray shows inconsistent values in this same interval. A badhole flag was created to highlight this area. A gas peak was observed (29.6% maximum total gaz)at 4922 m MD.
Interval 5220-6620 m MD (K137-J170): Claystone interbedded with thin beds of sandstone. Claystones are seen in Neutron and Density with a clear separation. Inflexion in GR and Neutron density signature reveals 4 main sandstone layers visible at 5330 m MD, 5925 m MD, 6220 m MD and 6423 m MD. No major variation in resistivity and no major gas show have been identified. Porosity is poor (below 5%) in all interval.

No core data were available in this well. Absence of stain or gas in the mud record confirms that the well does not contain hydrocarbons.

Interval T50-K94

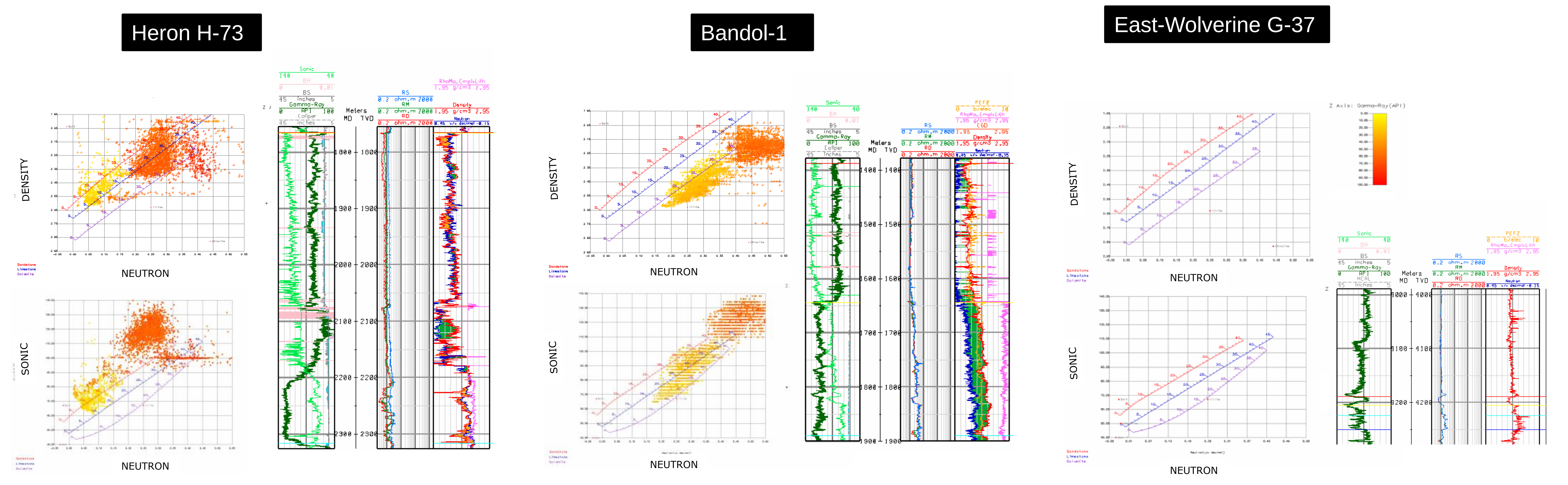


Figure 6: Neutron-Density and Neutron-Sonic crossplots and composite log display for interval T50-K94 in wells H-73, B-1 and G-37

Interval K94-K101

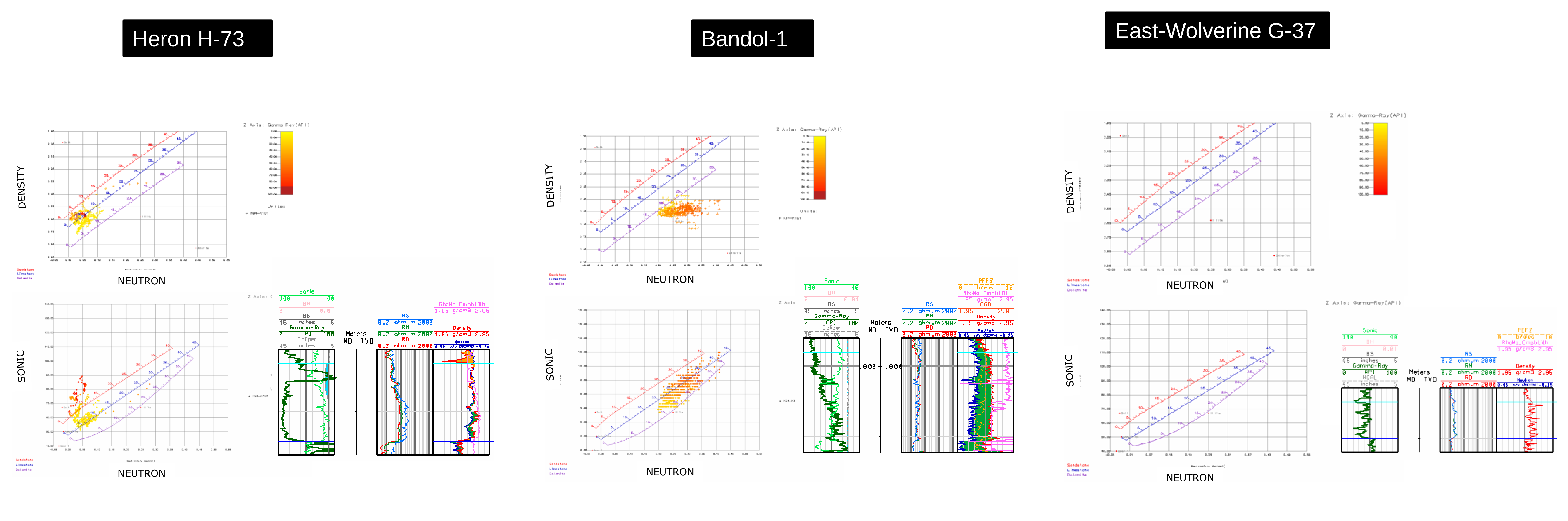


Figure 7: Neutron-Density and Neutron-Sonic crossplots and composite log display for interval K94-K101 in wells H-73, B-1 and G-37

Interval K137-J163

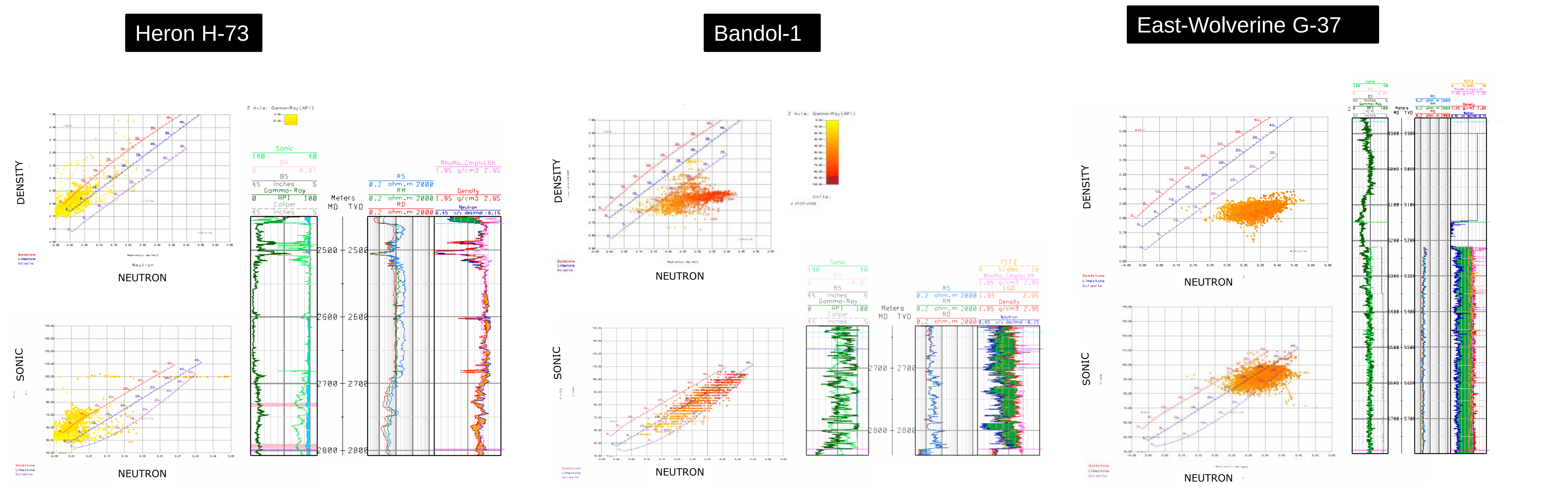


Figure 8: Neutron-Density and Neutron-Sonic crossplots and composite log display for interval K137-J163 in wells H-73, B-1 and G-37

Interval K101-K137

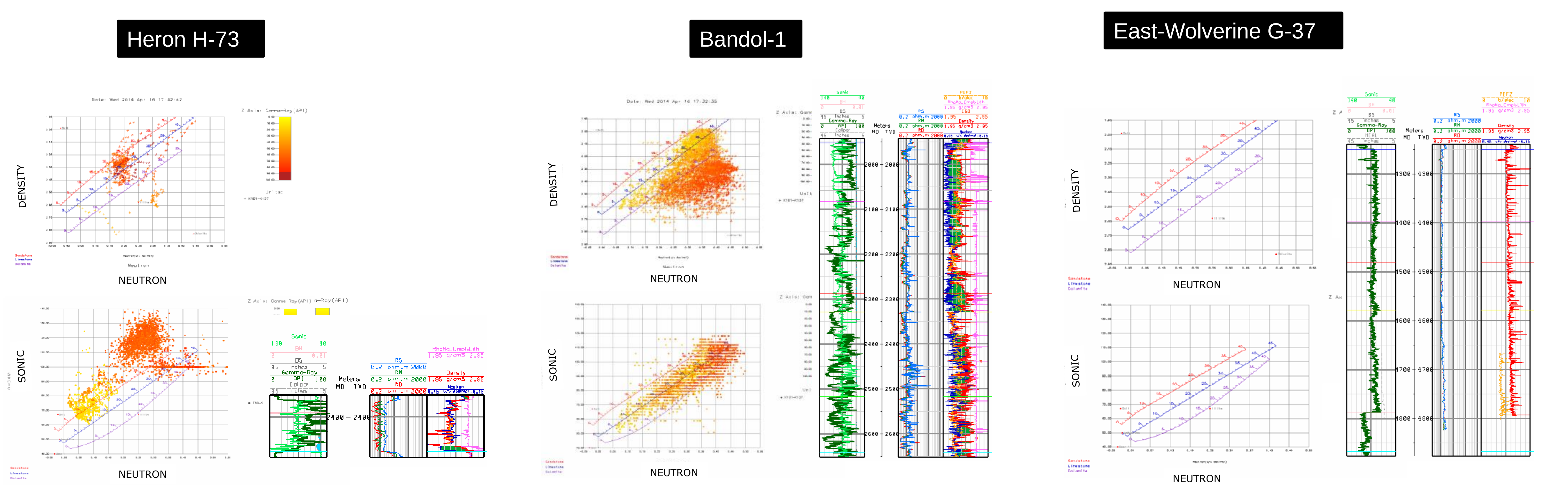


Figure 9: Neutron-Density and Neutron-Sonic crossplots and composite log display for interval K101-K137 in wells H-73, B-1 and G-37

Interval J163-J166

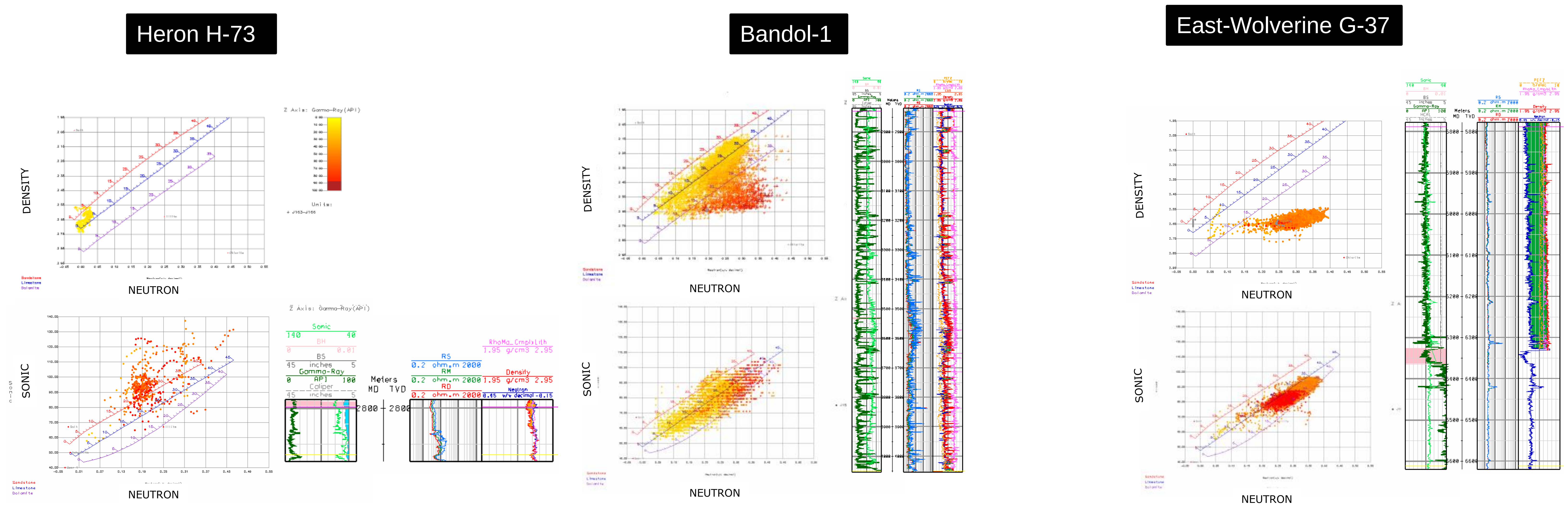


Figure 10: Neutron-Density and Neutron-Sonic crossplots and composite log display for interval J163-J166 in wells H-73, B-1 and G-37

Interval J166-J188

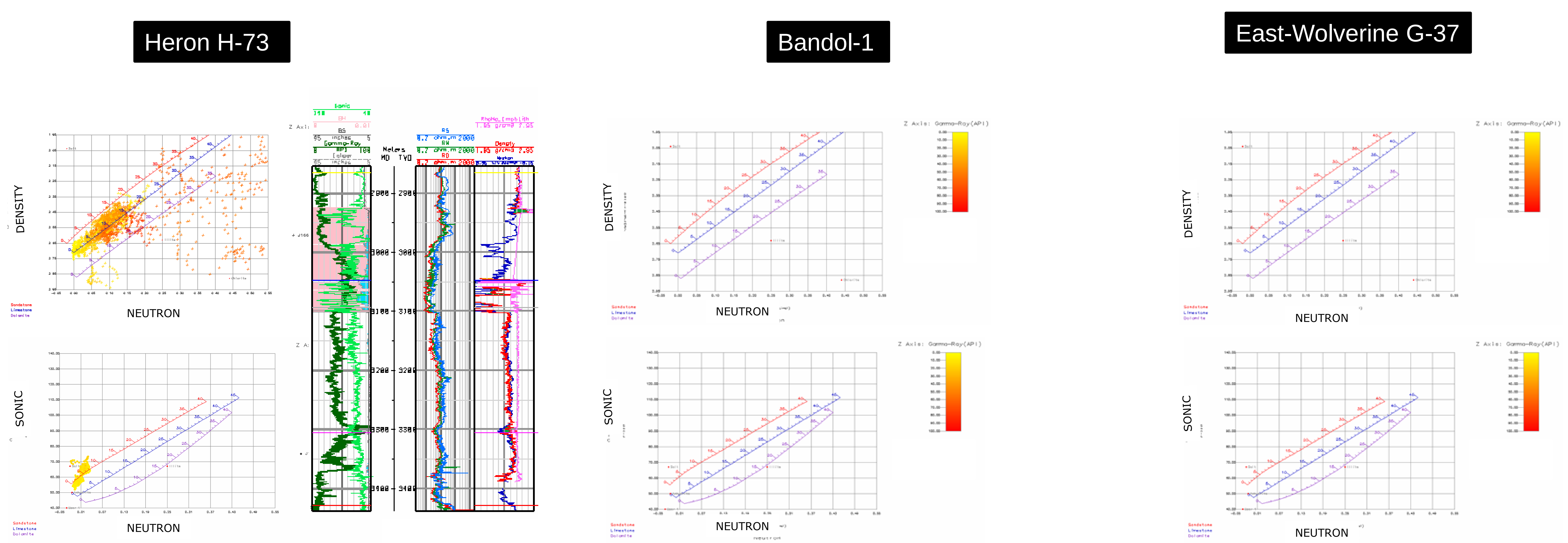


Figure 11: Neutron-Density and Neutron-Sonic crossplots and composite log display for interval J166-J188 in wells H-73, B-1 and G-37

Interval	Heron H-73	Bandol B-72	East Wolverine G-37
T29 – T50	Shales with occasional beds of shaly sand or limestone, no PHIE or shows. At base interval a **porous limestone (PHIE 15-20 %) with gas shows but no log saturation**	Down to Intra Campanian UC: shales with very thin (<1m) levels of slightly porous clastics, no shows	Shales with occasional limestone intervals (~20m thick), with low porosity (<10%) and without HC saturation
T50 – K94	250m of shales overlying 100m of clean tight limestone, no log saturation and a minor gas show at the very base of the interval.	Intra Campanian UC to 1925m MD: **chalks with no PHIE or shows**. Overlying 40m thick shale interval	Shales and porous lst: PHIE ~10-15%, no HC sat.
K94 – K101	Shale bed (~10m) overlying tight clean limestones, no saturation, no shows		Tight limestones: PHIE << 10%; no HC sat.
K101 – Alb/Apt MFS	Porous sandstone interval between two shaly layers. **Sands with PHIE ~20-25% showing no saturation on logs but some gas shows and oil staining**	Mainly shales with **several 10 to 20m thick shaly sand layers (PHIE > 20%) no HC saturation or shows**	Shales
Alb/Apt MFS - IntraApt			
IntraApt – Mississauga			
Mississauga – K130		**50m thick Porous clean sands (PHIE ~25%) no HC saturation or shows** overlying section of alternating metric shales and sands. Low porosity limestone interval around 2450m, occasional thin porous layers (~1-2m, PHIE > 20%) without shows or saturation.	Shales with occasional metric thick shaly-sand bodies (no PHIE)
K130 – K137		Alternating decametric beds of clean porous sands and shales. **PHIE in sands 20-30%, no HC saturation or shows**	
K137 – K147	Tight clean limestones with: • 10m thick porous limestone interval (caved, hence logs not reliable) **where gas shows and oil staining** are observed • Below that three thin porous intervals (~2-4m thick, ~10% PHIE) **with some gas shows and oil staining**	Shales with occasional thin beds of moderate porosity sandstones or limestones (PHIE 10-15%) without HC saturation or shows.	Shales with one (~4m) thick sand body (PHIE not evaluated lacking logs but **with gas shows**) Sand interval at transition around Top K147 **tested gas**
K147 – Base Callovian			Shales with occasional few-metre thick shaly-sand bodies (no PHIE). The lowermost of these shows minor PHIE (~5%) and had some **supercharged gas shows**
Base Callovian – J163	Tight clean limestones, no PHIE or saturation	Shales	
J163 – Intra Bathonian		Below J163 to TD thick succession of **clean porous sands (25-30% PHIE, no HC saturation or shows).** Alternating with 5 to 20m thick shales; possible coal occurrence from cuttings not evidenced by logs. One interval of moderate porosity (~10%) clean limestone interval occurs between the sand succession at 3540-3680mMD.	
Intra Bathonian – J166			Shales, on thin (~4m) thick sand body with low PHIE (< 10%)
J166 – J170	Tight limestones overlying a thick (~40m) shale interval		*Not reached*
J170 – J181	Shales		*Not reached*
J181 – J186	Low porosity (<10%) limestones with thin shale interbeds, no significant HC saturation and **no shows**		*Not reached*
J186 – J188	Dolomite with 15-20% porosity , no HC saturation from logs or shows. Overlain by tight limestones and/or dry shales		*Not reached*
J188 -	At top interval layer of non-porous dolomite with occasional thin shale beds, shows indicate heavy HC and gas (C3&C4) Below, a thick salt column		*Not reached*

Table 5: Overview of well results

Objectives of the electrofacies analyses:

A log-based facies analysis is performed to complement the evaluation of shale and porous volumes from logs to better constrain geological model and facies maps. This allows us to (1) compare cuttings lithologies with log readings at different scales of observations, (2) positioned results to log depths and (3) compare results with petrophysical analyses.

Electrofacies Methodology and Results

A clustering technique (developed in EasyTrace ™ software) in a multidimensional space generated by selected input logs is used to group facies based on their characteristic log signatures. Cluster analysis of log data was performed for the 3 wells, Bandol, East Wolverine and Heron, using the following logs: RHOB, NPHI, DT, VSHfin, PHIEfin.
Non-supervised approach is applied. Interpretation was controlled based on the petrophysical signatures and cuttings analysis results.
From cluster analysis 10 electrofacies are defined as training samples. This is illustrated by the probability density function (PDF) shown in Figure 12. The PDF is estimated in the multidimensional space generated by the 5 considered logs. Then it is plotted to produce the graphics which are displayed here. Peaks or « modes » of the pdf correspond to different electrofacies. Colored peaks shown here serve as « training samples » (Figure 13). These are subsequently assigned to all relevant log samples in the wells (Figure 14).
Lithologies from Cuttings description match fairly well with electrofacies (Figure 15):
Coal is not seen in log signatures and is usually associated to sands (coal only sporadically present?)
No dolomite observed in logs: these are characterized as limestone in the electrofacies.
Some overlap between clean porous limestone and stanstones is observed as NPHI-RHOB signature for both not very different (function of minor shale content)
Chalks well identified, two main types are distinguished by electrofacies
Electrofacies have been determined in the Bandol-1, East-Wolverine (G-37) and Heron (H-73) wells. This has allowed defining main log-based facies in all three wells. It is observed that the electrofacies match rather well with cuttings lithologies and show a higher degree of facies bedding notably the sand-shale layering in Bandol B-73 (Plate 2.1.8)

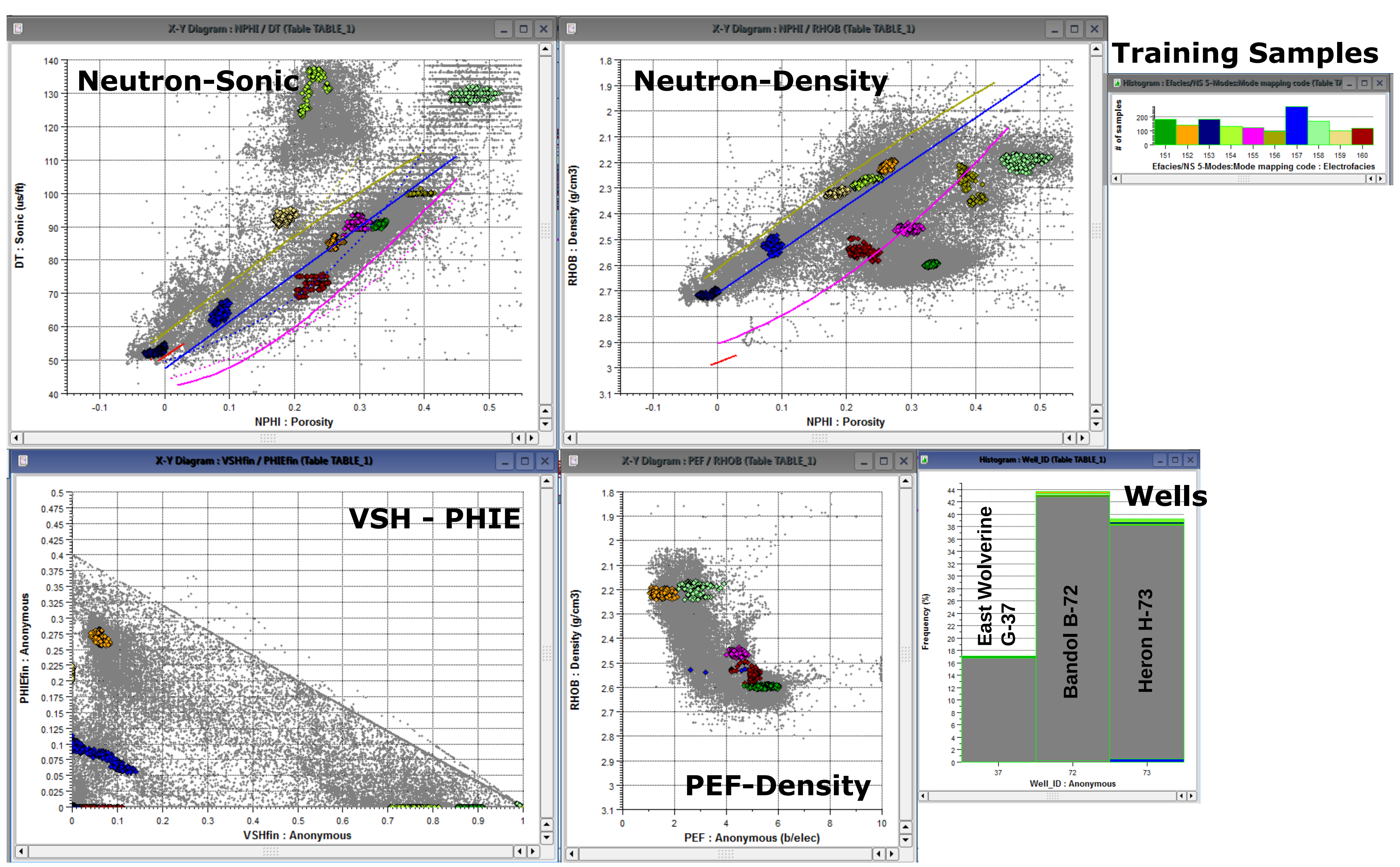


Figure 13: Display of training samples (see also Figure 12) compared to overall log signatures

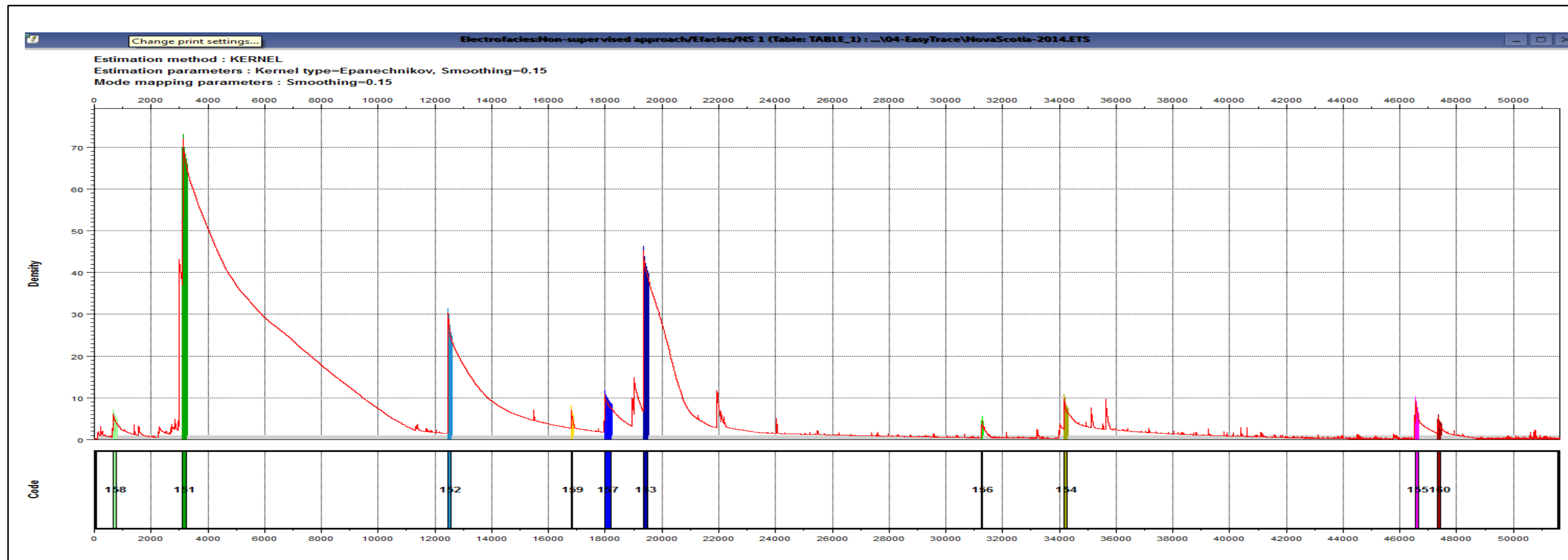


Figure 12: Neutron-Density Cross-plots of typical lithologies identified from cuttings and logs

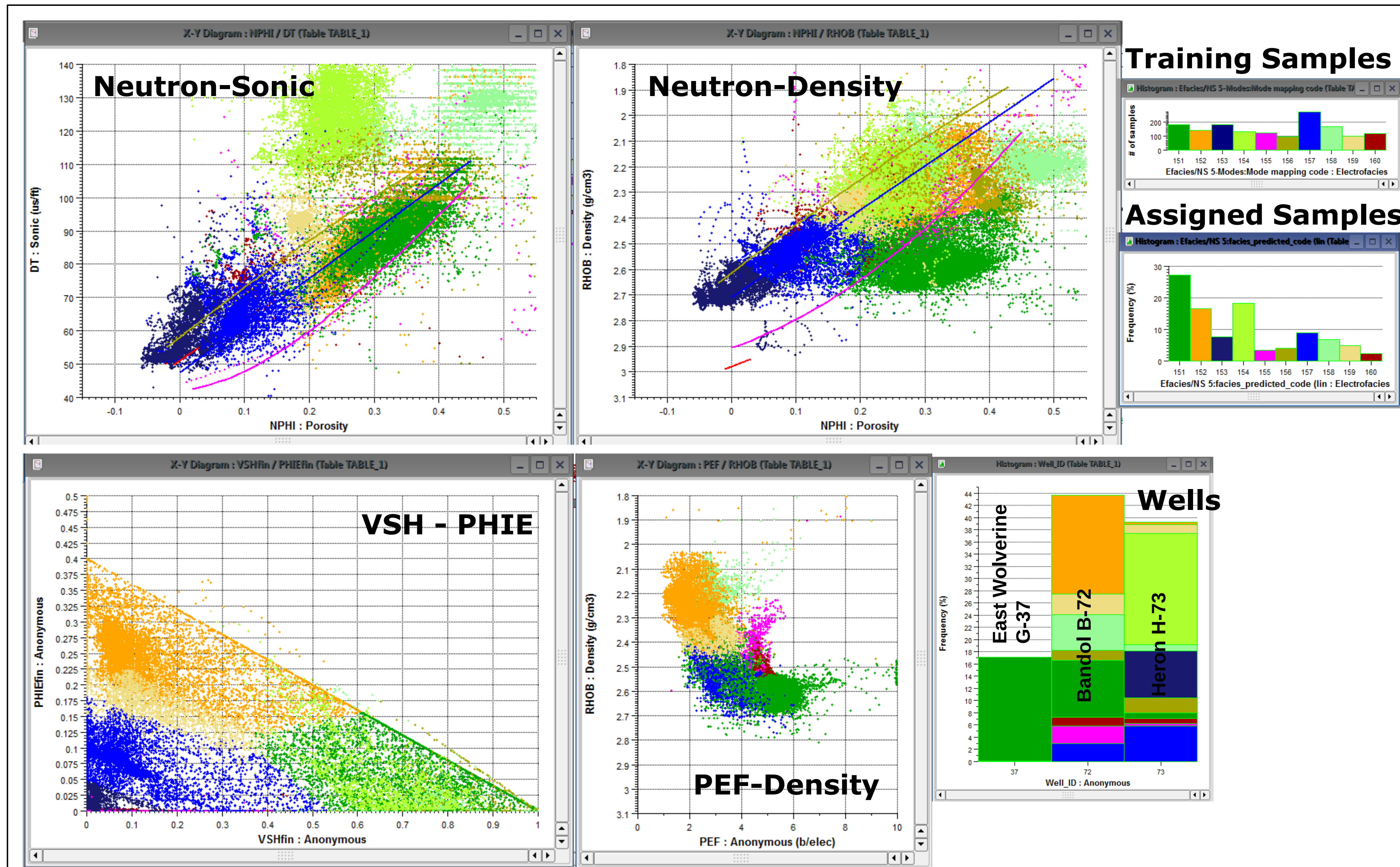
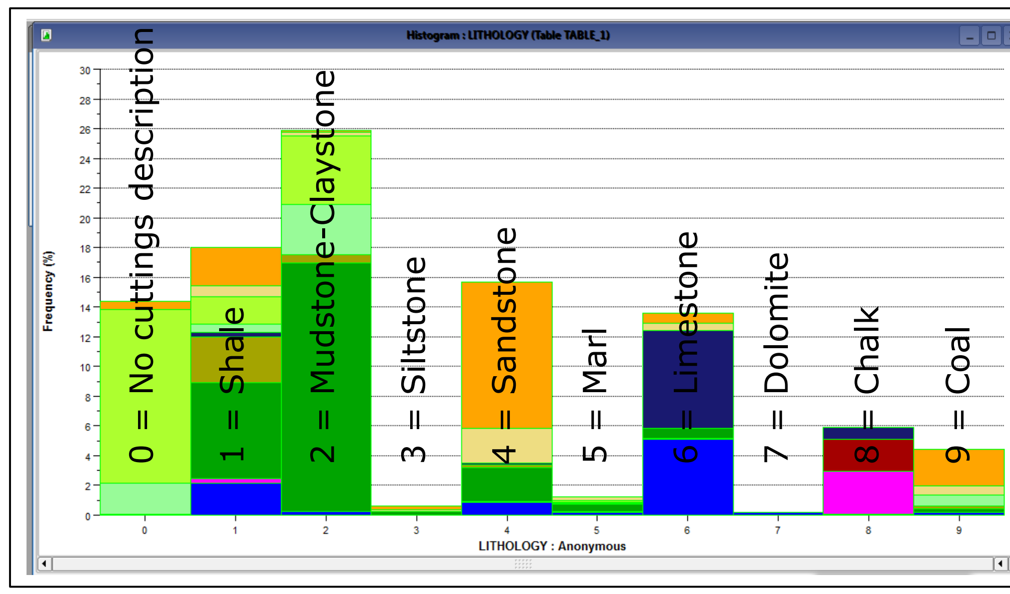


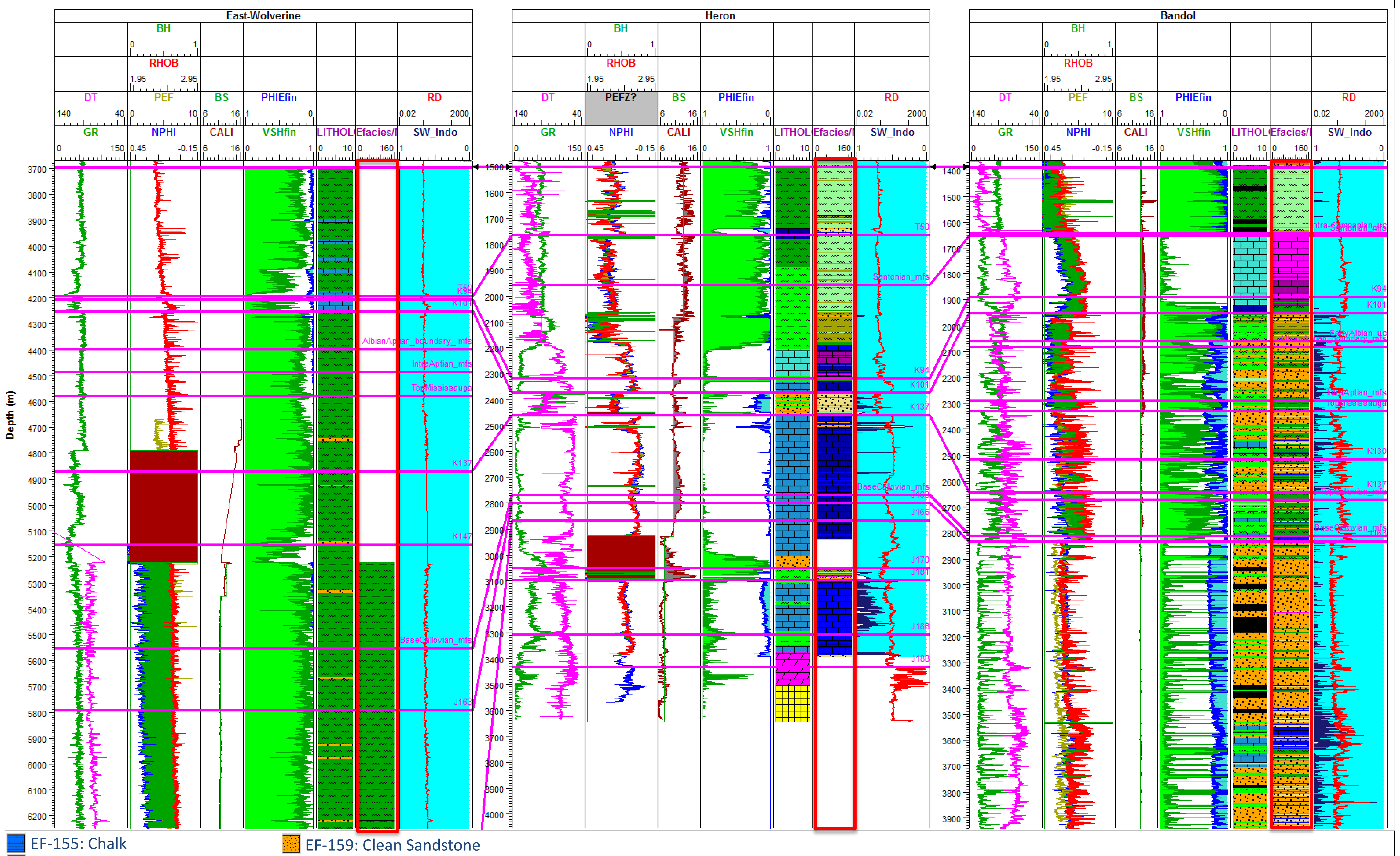
Figure 14: Display of electrofacies assignment in log-log crossplots and histograms



Electrofacies color:

- EF-155: Chalk
- EF-160: Low porosity Chalk
- EF-157: Porous Limestone
- EF-153: Low Porosity Limestone
- EF-152: Sandstone
- EF-159: Clean Sandstone
- EF-158: Sandy Shale
- EF-151: Shale
- EF-156: Shales
- EF-154: Claystone

Figure 15: Comparison of Electrofacies and Cuttings Lithology (histogram axis)



- EF-155: Chalk
- EF-160: Low porosity Chalk
- EF-157: Porous Limestone
- EF-153: Low Porosity Limestone
- EF-152: Sandstone
- EF-159: Clean Sandstone
- EF-158: Sandy Shale
- EF-151: Shale
- EF-156: Shales
- EF-154: Claystone

Figure 16: Composite display for wells B-1, H-73 and G-37 showing logs, log analysis results, cuttings lithology and electrofacies (column outlined in red).

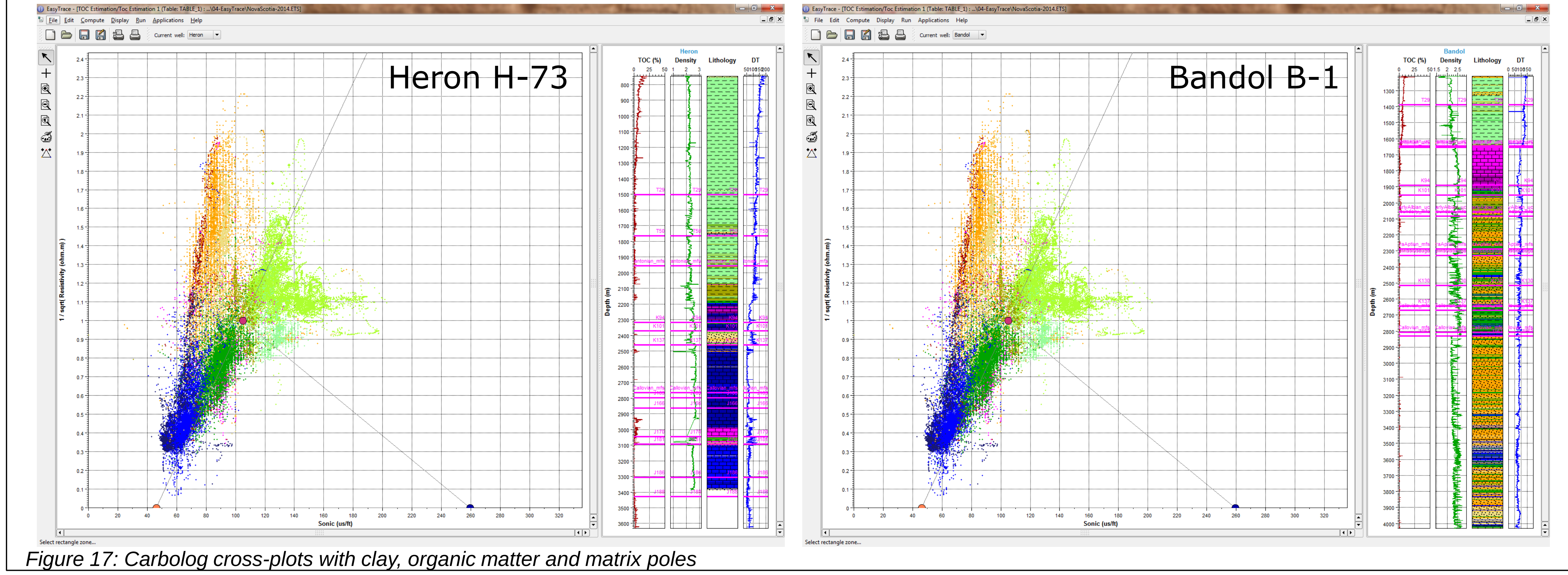


Figure 17: Carbolog cross-plots with clay, organic matter and matrix poles

Total Organic Carbon Estimation Test (TOC)

A TOC detection method based on log data has been attempted in the wells in order to illustrate the potential variation of organic carbon (or organic matter volume) present in the formation intervals along the wells.

The method applied is Carbolog® as determined by Carpentier et al. (1991) and implemented in EasyTrace™. The method is based on the comparison between sonic and resistivity logs to indicate the vertical variation of organic carbon contents of the formation. The method uses ternary diagram on sonic and 1/√Rt built between the matrix, shale and organic matter poles to determine the content of TOC in the formation (Figure 17) The calibration has been performed on log data, lacking core or cuttings TOC measurements (RockEval) to calibrate to and should therefore be considered qualitatively. The resulting TOC curves (shown in Figure 18 for Bandol B-1 and Heron H-73) show that some intervals could potentially contain higher TOC, notably in the shales above T29 horizon, and for Heron in the tighter limestones of J166-J170 interval. The higher TOC readings computed at the base of well Heron should be considered as highly uncertain, lacking full log coverage and may be influenced by end-of run effects.

Ref. Carpentier B., A.Y. Huc and G. Bessereau, 1991, Wireline Logging and Source Rocks – Estimation of Organic Carbon Content by the CARBOLOG® Method; The Log Analyst, SPWLA, May-June 1991, 19pp.

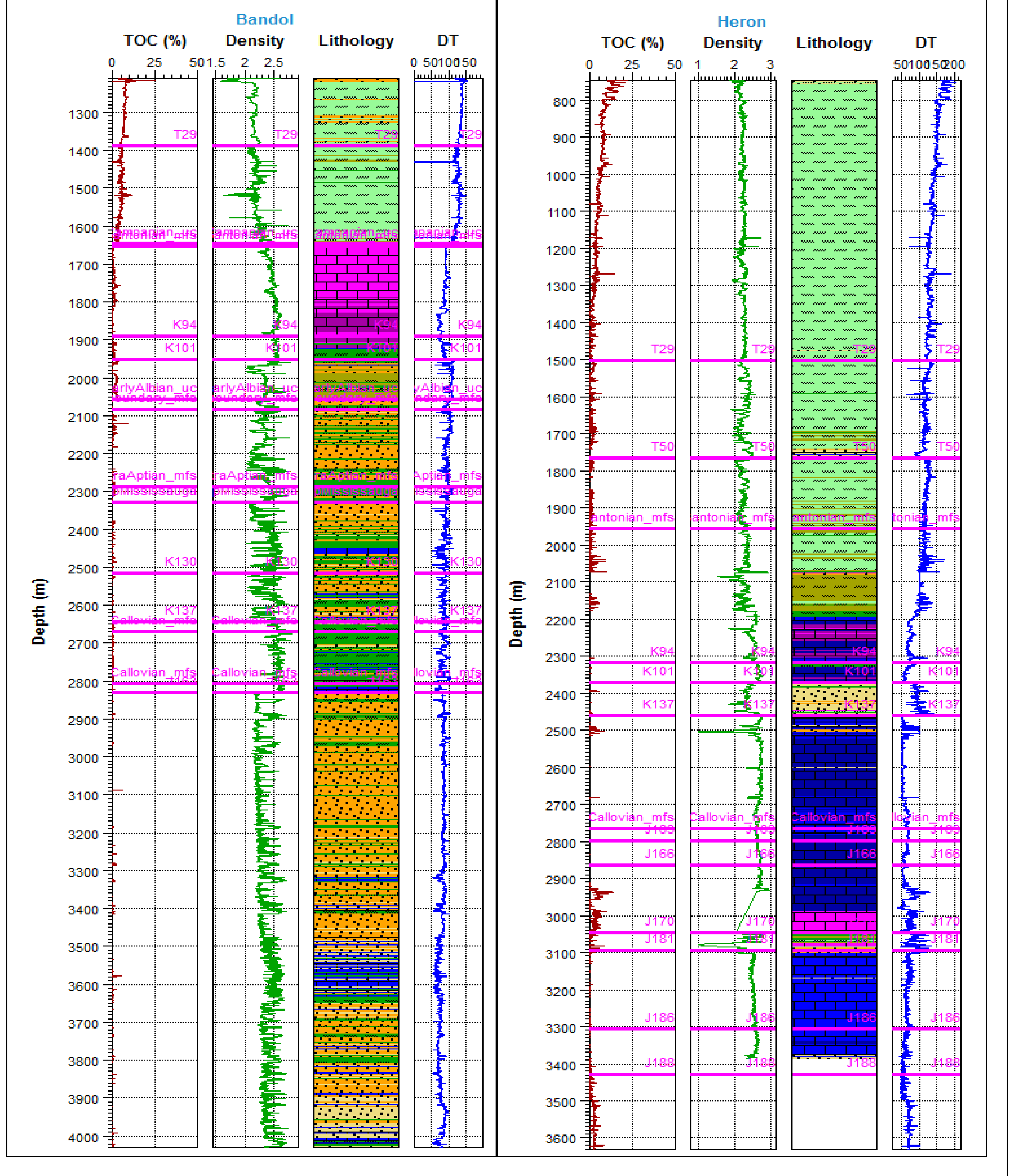


Figure 18: Log display showing TOC computation results for Bandol B-1 and Heron H-73