

## **Estimation of Porosity and Permeability by using Conventional Logs and NMR Log in Mishrif Formation/Buzurgan Oil Field**

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### **Abstract:**

Permeability and porosity values regarded as important fundamentals in the petroleum studies and researches especially for the interests in the reservoir topics, many methods and tools were founded for this purpose from time to time. The modern log technology one of this tools but consumes more time and financial possibilities in addition to the experts, such as Nuclear Magnetic Resonance Tools which considered one of the unconventional logs, so that, for this it was necessary to find a method to get the permeability and porosity values for the NMR log by using the conventional logs, note that it has been confirmed the modern studies the high accuracy and reliability for the NMR permeability and NMR porosity. Because the importance of this values , this study deals with the possibility of get these values from the conventional logs with these from NMR log, because of ease dealing with conventional logs and ease of getting it. After making the data analyses and processing this study results that led to putting many transformation formulas which give high correlations to high accuracy applying for this values in the researching and applying aspects and relating with reservoir prediction and modeling which connecting with drilling and producing works. The carbonate Mishrif Fm. In the Buzurgan oil field was selected to achieve this study by chose four oil production wells(Bu-40, Bu-51, Bu-52) in the south and north domes, in the future facilitate the prediction ways for any well has been logged by the open hole logs.

**Keywords:** NMR log, conventional logs, transformation, formulas, Mishrif Fm.

## تخمين المسامية و النفاذية بواسطة استخدام المجسات التقليدية و مجس الرنين المغناطيسي في تكوين المشرف\حقل بزركان النفطي

### الخلاصة:

تعتبر قيمتي النفاذية والمسامية من الاساسيات المهمة في الدراسات والبحوث النفطية وخاصة للمعنيين بالمجال المكمني، وقد تعددت طرق ووسائل الحصول عليهما من وقت لآخر. تعد تقنيات الجس الحديثة احدى اهم هذه الوسائل والتي قد تستغرق وقت وتحتاج كلفة مالية عالية اضافة الى ضرورة وجود الخبراء المختصين بها مثل مجس الرنين المغناطيسي والذي يعتبر من المجسات غير التقليدية، لهذا كان من الضروري ايجاد طريقة للحصول على قيم النفاذية والمسامية لمجس الرنين المغناطيسي من خلال اعتماد المجسات التقليدية ، علما انه قد اكدت الدراسات الحديثة المهتمة بهذا الموضوع ان قيمتي النفاذية والمسامية من مجس الرنين المغناطيسي ذات درجة موثوقية ودقة عالية. بسبب اهمية هاتين القيمتين ، تناولت هذه الدراسة امكانية الحصول عليهما من المجسات التقليدية بقيم مقارنة جدا لتلك الناتجة من مجس الرنين المغناطيسي، وذلك بسبب سهولة التعامل مع المجسات التقليدية وسهولة الحصول عليها. بعد تحليل ومعالجة نتائج هذه الدراسة تم وضع العدد من معادلات التحويل والتي اعطت قيم ارتباط عالي جدا والتي تؤدي الى تطبيق عالي الدقة لهاتين القيمتين سواء في المجال البحثي او التطبيقي والمرتبطة بعمليات التقييم والتمثيل المكمني ذو العلاقة بعمليات الحفر والانتاج. من اجل انجاز هذه الدراسة تم اختيار تكوين المشرف الكاربوني في حقل بزركان النفطي كمنطقة دراسة، اختيرت اربعة ابار منتجة: (Bu-40, Bu-51, Bu-52) للنفط في القبتين الشمالية والجنوبية والتي تسهل في المستقبل اجراء عمليات التخمين ولاي بئر قد تم اجراء الجس البئري المفتوح له.

### Introduction

Nuclear magnetic resonance (NMR) logging tools have captured the interest particularly for the petroleum researchers [1]. The principle of NMR logging by the use of the large permanent magnets to create a strong static magnetic field to align the spin axes of protons in a preferred orientation and polarization, which consumes time called polarization time T1. The second main NMR measurement known as the transverse relaxation time, or T2, which is a composite of a number of individual fluid decays in a formation [6]. A small pore has a rapid relaxation time and a large pore provides slower relaxation. For bulk crude oils, the T2 distribution reflects the oil composition molecularly [4]. The long T2 distribution in the crude oil corresponds to effect of the molecules that mobile, while the short T2 is associated with signals from larger molecules, the viscosities of the macroscopic oil can be computed by using the crude oil

of the T2 logarithmic mean distributions. The diffusion (D) considered as the protons move through the gradient of the applied field. Molecular diffusion is the thermal motion for the molecules moved randomly; a molecule have constant diffusion limiting the mean square distance that the molecule will move per unit time, for the gas and water is described by a single molecular diffusion constant [7].

### Methodology (Weatherford methods)

#### **1. Open Hole Analyses (OHA)**

**Log Quality Control:** By using PETROLOG program, the data was sampled at 0.1m. Before the petro-physical analysis the data was properly checked. It was noted that it does not require any editing as the data is of good quality.

**Environmental corrections:** Environmental corrections have been applied to the data using standard Weatherford charts for compact tools from the field and during the analysis the Compact Tornado Chart used for deriving the  $R_T$  (formation resistivity).

And  $R_{xo}$  (flushed zone resistivity).  $\emptyset_N$  (neutron porosity).was corrected for pressure, based on the mud density.

**Porosity determination:** To determine  $\emptyset_T$  (total porosity)and  $\emptyset_E$ (effective porosity )the model of complex lithology was used,  $\emptyset_S$ (sonic porosity):

$$\emptyset_E = \emptyset_S * (1.0 - V_{CLAY}) \dots\dots\dots (1)$$

$$\emptyset_T = \emptyset_E + V_{CLAY} * \emptyset_{CLAY} \dots\dots\dots (2)$$

The D-N X-plot was used to compute  $\rho_m$  (matrix density) after correcting  $\rho_b$  (bulk density) and  $\emptyset_N$  for  $V_{CLAY}$ (clay volume)and hydrocarbon corrections. Where the  $\rho_b$  was not good  $D_{T35b}$  (compensated sonic log) and  $\emptyset_N$  were used.

$$\emptyset_T = (\rho_m - \rho_b) / (\rho_m - \rho_f) \dots\dots\dots (3)$$

$$\emptyset_E = \emptyset_T * (1.0 - V_{CLAY}) \dots\dots\dots (4)$$

**Uncertainty Analysis:** The uncertainty values should preferably be entered following a full Monte Carlo analysis (is a mathematical modeling technique that allows you to see all possible outcomes and assess risk to make data-driven

decisions) and using a fix cut-off for all parameters, but for this wells, it was use default value provided on the software with industry general concept of uncertainty associated with each logging tools.

**Permeability Determination:** Multiple linear regression [6] widely used as a statistical approach. The technique of linear regression were familiar to establish geological variables predictors, this ways were useful to predicted the means value, fast in computing, are majority existed in packages of the statistical software dependency. The prediction by using one or more than one input variables, a relationship of a straight-line between  $\log(k)$  and  $\emptyset$  finds the computation for  $\log(k)$  by Eq. (5)

$$\text{Log}(K)=a+b \emptyset \dots\dots\dots(5)$$

## 2. NMR Analyses (NMRA)

**Porosity existence:** The micro-porosity related to the clay which have water, from an NMR view, show same a solid because water in the micro-pores give a very rapid T2, consequently, this water is difficult to be noticed [9]. Porosity determination from NMR, involves the area under the T2 distribution curve in a form of bins. The bins resulted from the NMR tool reflects different decay time of hydrogen presented at the pores 4 m sec, 8m sec, 16 m sec, 32 m sec, 64 m sec, 128 m sec, 256 m sec and 512 m sec [1, 3]. The short decay time reflects a small pore size while the long decay time represented the coarse pore size meaning every bin considered a pore sizes ranges at the smallest 0 m sec and ending by the coarsest 512 m sec [5]. The distribution of the pore size is a relative measure of the S/V ratio of the pores.

**Permeability estimation:** The free-fluid model (Coates model) may be used in the reservoirs that saturated with water or hydrocarbon, while the mean-T2 model (SDR model) may be used in the reservoirs that saturated with water [8]. In the Coates model, the pore-size value used from T2cutoff, which resulted the ratio of Free Fluid Index(FBI) to the Bulk Volume Index(BVI) while in the SDR model, the pore-size value used from the T2 geometric mean( $T_{2LM}$ ) [9]. The Timur-Coates (TC) equation applying Bulk Volume of Irreducible water and Free Fluid Inde, where C is constant depending on

formation, K is permeability and  $\emptyset$  is porosity [3]. As in equations (6 and 7):

1. The Coates Model 
$$K_{Coates} = \left[ \left( \frac{\emptyset}{c} \right)^2 \left( \frac{FBI}{BVI} \right) \right]^2 \dots\dots\dots (6)$$

2. The SDR Model 
$$K_{SDR} = C \times \emptyset^4 T_{2LM}^2 \dots\dots\dots (7)$$

**Results and Discussion:**

**1. Conventional and NMR logs results Correlations:**

Available conventional wire lines logs for this work including DT (Sonic log),  $\rho_b$ ,  $\emptyset_N$  (Neutron log),  $R_T$  (Resistivity log), PEF (Photoelectric factor), GR (Gamma Ray), and Caliper. Caliper log was firstly used to identify an undesirable whole intervals. The intervals have wicked hole must be removed to avoid the non-good reads. PEF is a litho-log which determines composition of reservoir rocks. NMR log is having no lithology dependency. Therefore that, the Photoelectric was not important to use as an input data. GR considered as a shale indicator. In this study, four conventional well logs including DT,  $\rho_b$ ,  $\emptyset_N$ , and RT were chosen as input data. These are known appropriate input logs having logical relationship with outputs, because the first three logs are porosity logs and the last one is attributed to fluid flow pass (tortuosity) [2]. Figures in appendix one, show the logical dependency of chosen traditional wire lines information with nuclear magnetic resonance log parameters using the concept of correlation coefficient. In all wells there is a strong correlations (colored with blue), moderate correlations (colored with pink) and weak correlations (colored with red) as illustrated in Table (1).

**Table (1) Correlations sorting between Conventional and Unconventional (K, PhiT, PhiE)**

Well No.	No. of Strong correlations	No. of Moderate correlations	No. of Weak correlations
Bu-40	5	7	8
Bu-51	3	2	11
Bu-52	16	0	0

In Table (1) the strong correlations show in different manner in the study wells; for instance.

**In the wells Bu- 40 the strong correlations was between:**

- Logarithmic mean of conventional permeability (LogKcon.) versus conventional total porosity (PhiT con.).
- Logarithmic mean of conventional permeability (Kcon.) versus conventional effective porosity (PhiEcon.).
- Logarithmic mean of COAT permeability (Log KCOAT) Logarithmic mean of SDR permeability (LogKSDR).
- NMR total porosity (PhiTNMR) versus NMR effective porosity (PhiENMR).
- Conventional total porosity (PhiT con.) versus conventional effective porosity (PhiEcon.).

**In the wells Bu-52:** all the correlations was strong.

**In the wells Bu51 the strong correlations was between:**

- Logarithmic mean of COAT permeability (Log KCOAT) Logarithmic mean of SDR permeability (LogKSDR).
- NMR total porosity (PhiTNMR) versus NMR effective porosity (PhiENMR).
- Logarithmic mean of conventional permeability (Kcon.) versus conventional total porosity (PhiT con.).

## **2. Conventional and NMR logs results Transformations**

After making the correlation test between conventional logs results and NMR log results that represented in values of NMR permeability (KSDR and KCOAT), NMR total porosity ( $\emptyset_T$  NMR), NMR effective porosity ( $\emptyset_e$  NMR), conventional permeability (k con.), conventional total porosity ( $\emptyset_T$  con.) and conventional effective porosity ( $\emptyset_e$  con.), many transformations formulas appears with strong positive correlation as shown in Table (2) and appendix two:

**Table (2) Transformations Formulas with strong correlations**

Well No.	Formula	Variables		correlation	
		x	y		
<b>Bu-40</b>	6	$y = 0.0324x + 0.165$	Logk con	$\emptyset_T$ con.	0.92
	7	$y = 0.0272x + 0.1152$	Logk con	$\emptyset_e$ con.	0.94
	8	$y = 0.6637x + 0.3537$	LogkCOAT	LogkSDR	0.8
	9	$y = 0.982x + 0.0117$	$\emptyset_e$ NMR	$\emptyset_T$ NMR	0.71
	10	$y = 0.7813x - 0.0156$	$\emptyset_T$ con.	$\emptyset_e$ con.	0.88
<b>Bu-51</b>	11	$y = 1.1424x - 0.6152$	LogkSDR	LogkCOAT	0.82
	12	$y = 0.7068x + 0.0123$	$\emptyset_T$ NMR	$\emptyset_e$ NMR	0.69
	13	$y = 0.0628x + 0.0705$	Logk con	$\emptyset_e$ con.	0.98
<b>Bu-52</b>	14	$y = 3.6065x + 8.183$	Logk con.	$\emptyset_T$ NMR	0.77
	15	$y = 0.3601x - 3.8118$	$\emptyset_T$ NMR	Logk COAT	0.77
	16	$y = 0.3718x - 3.6163$	$\emptyset_T$ NMR	Logk SDR	0.83
	17	$y = 0.9647x - 0.3113$	Logk SDR	Logk COAT	0.92
	18	$y = 3.7336x + 7.5523$	Logk con.	$\emptyset_e$ NMR	0.81
	19	$y = 0.3623x - 3.5971$	$\emptyset_e$ NMR	Logk COAT	0.8
	20	$y = 1.5629x - 0.8464$	Logk con.	Logk COAT	0.86
	21	$y = 1.5356x - 0.5606$	Logk con.	Logk SDR	0.84
	22	$y = 0.0269x + 0.0936$	Logk COAT	$\emptyset_T$ con.	0.88
	23	$y = 78.084x + 1.9887$	$\emptyset_T$ con.	$\emptyset_e$ NMR	0.82
	24	$y = 2.323x + 8.8428$	Logk SDR	$\emptyset_T$ NMR	0.88
	25	$y = 1.0038x - 0.6698$	$\emptyset_T$ NMR	$\emptyset_e$ NMR	0.98
26	$y = 0.0104x - 0.0149$	$\emptyset_T$ NMR	$\emptyset_T$ con.	0.79	
27	$y = 0.0472x + 0.0712$	Logk con.	$\emptyset_T$ con.	0.96	
28	$y = 0.0265x + 0.0856$	Logk SDR	$\emptyset_T$ con.	0.85	

**Conclusion:**

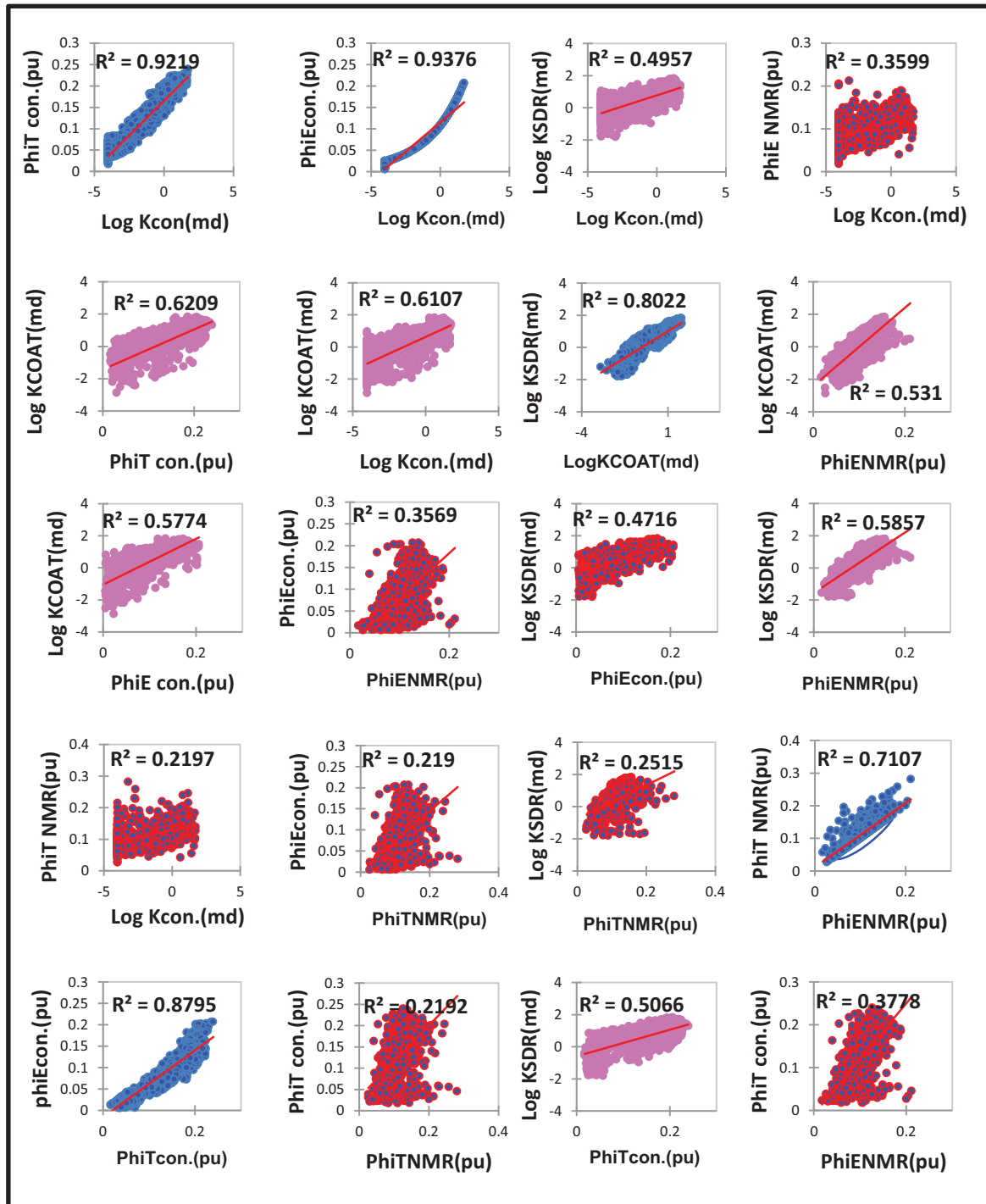
In the equation  $\log k = a + b\emptyset$ , the correlations of  $k_{con}$  with  $\emptyset_e$  con. offered a better performance than with  $\emptyset_T$  con. Than led to applied  $\emptyset_e$  in the equation for more accurate results. When, the value of  $\emptyset_T$  be approximately such as  $\emptyset_e$  value, and this reflected the improvement in the flow properties and more homogenous porosity system because the effective porosity represents the connected pores in the rock. The highest correlation value was in the well Bu-52. The relation between  $\text{Log } k_{COAT}$  and  $\emptyset_e$  NMR can led to use the value of  $k_{COAT}$  as an indicator to the effective porosity, where the correlation value about 0.8. While, these relations were not found with KSDR. The correlation between  $k_{COAT}$  and KSDR in all the wells approximately 0.8 excepted the one value in well Bu-52 reached to 0.92. The best correlation between  $\emptyset_e$  and  $\emptyset_T$  appear in the well Bu-52 recorded equal to 0.98. The relation between NMR log results and conventional results appear in the study wells and the best correlation values was in well Bu-52 between  $\text{Log } k_{COAT}$  and  $\emptyset_T$  con. (0.88),  $\text{Log } k_{SDR}$  and  $\emptyset_T$  con.(0.85).



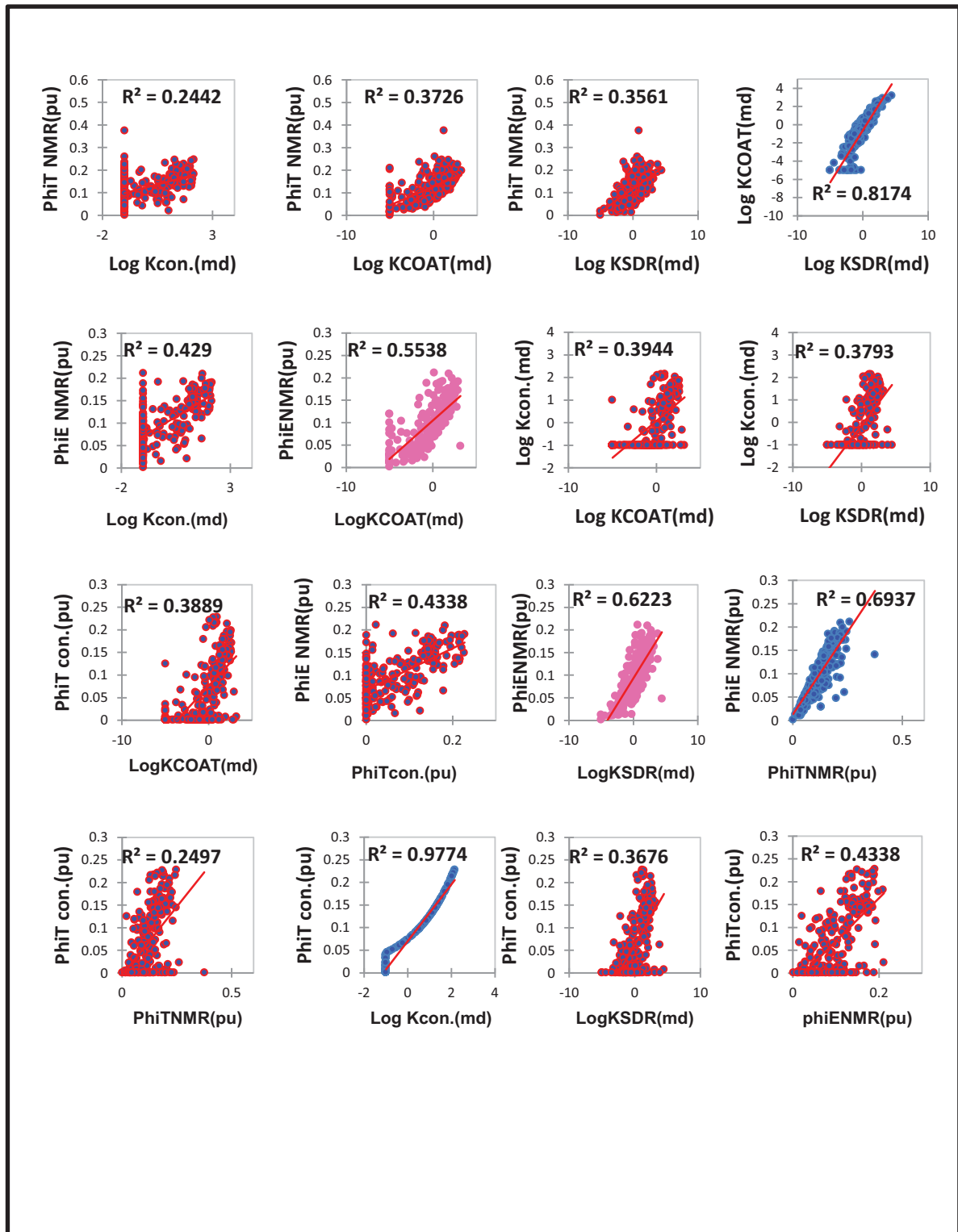
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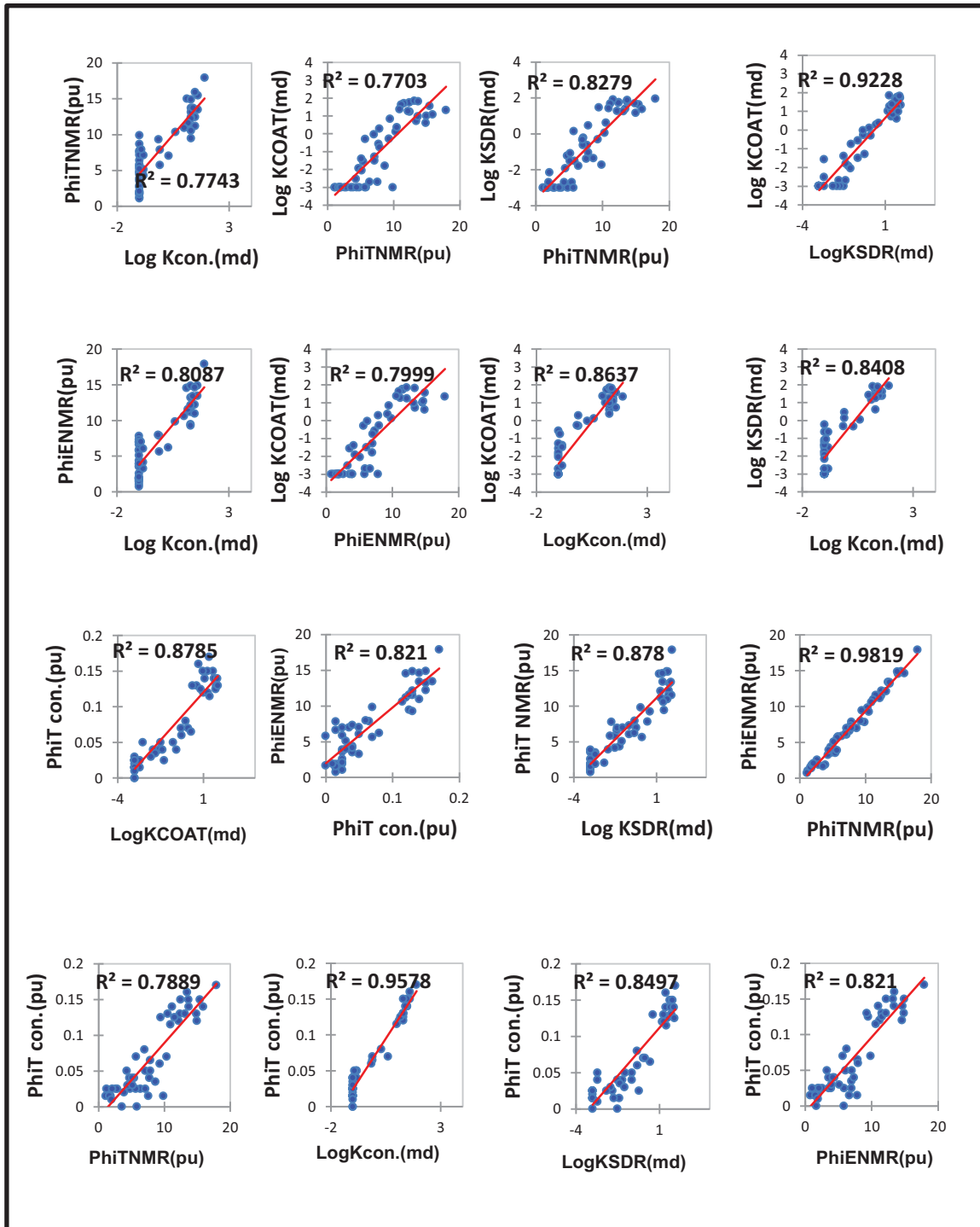
Appendix One: Correlation Test results for the Study Wells



Correlations in well Bu-40

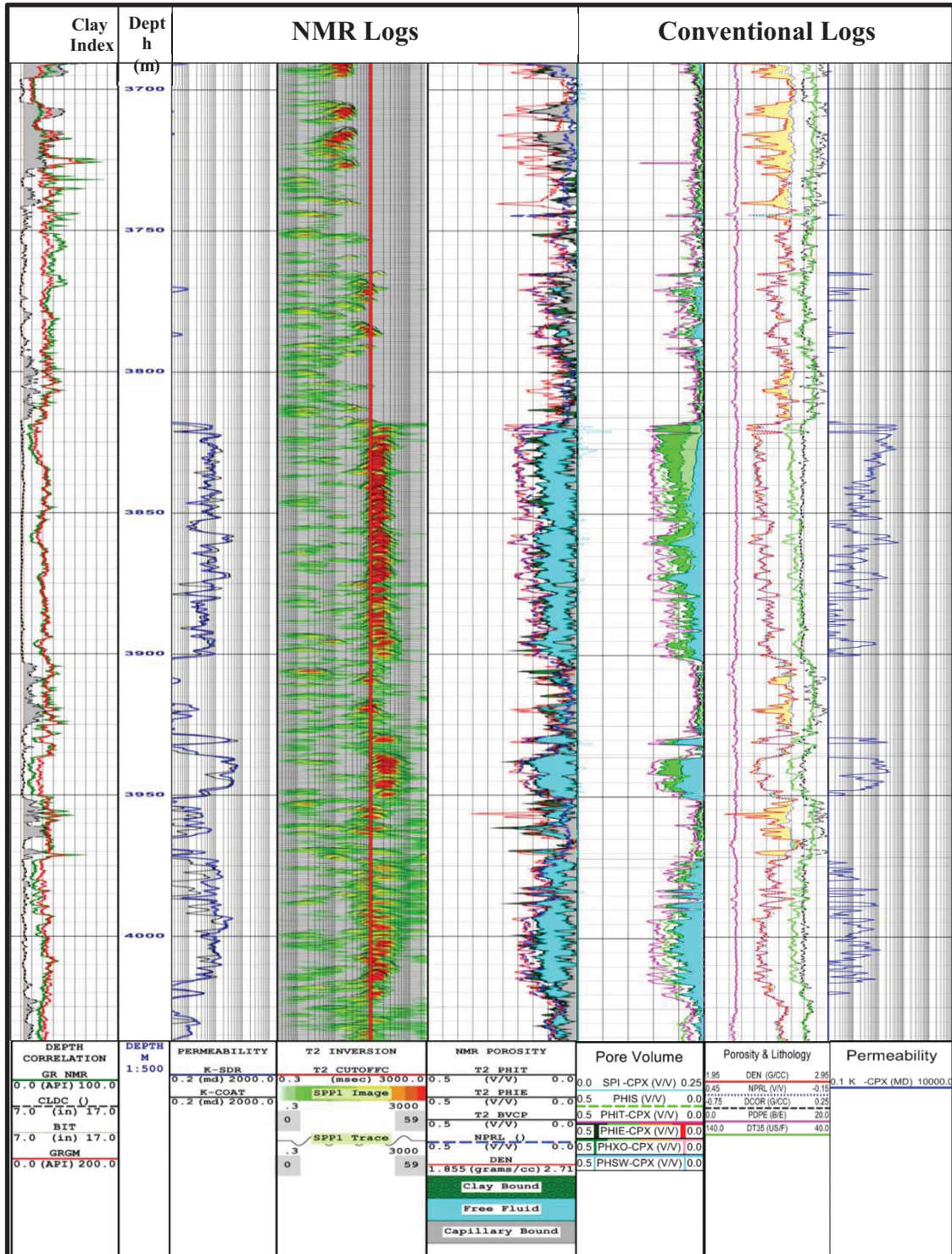


Correlations in well Bu-51

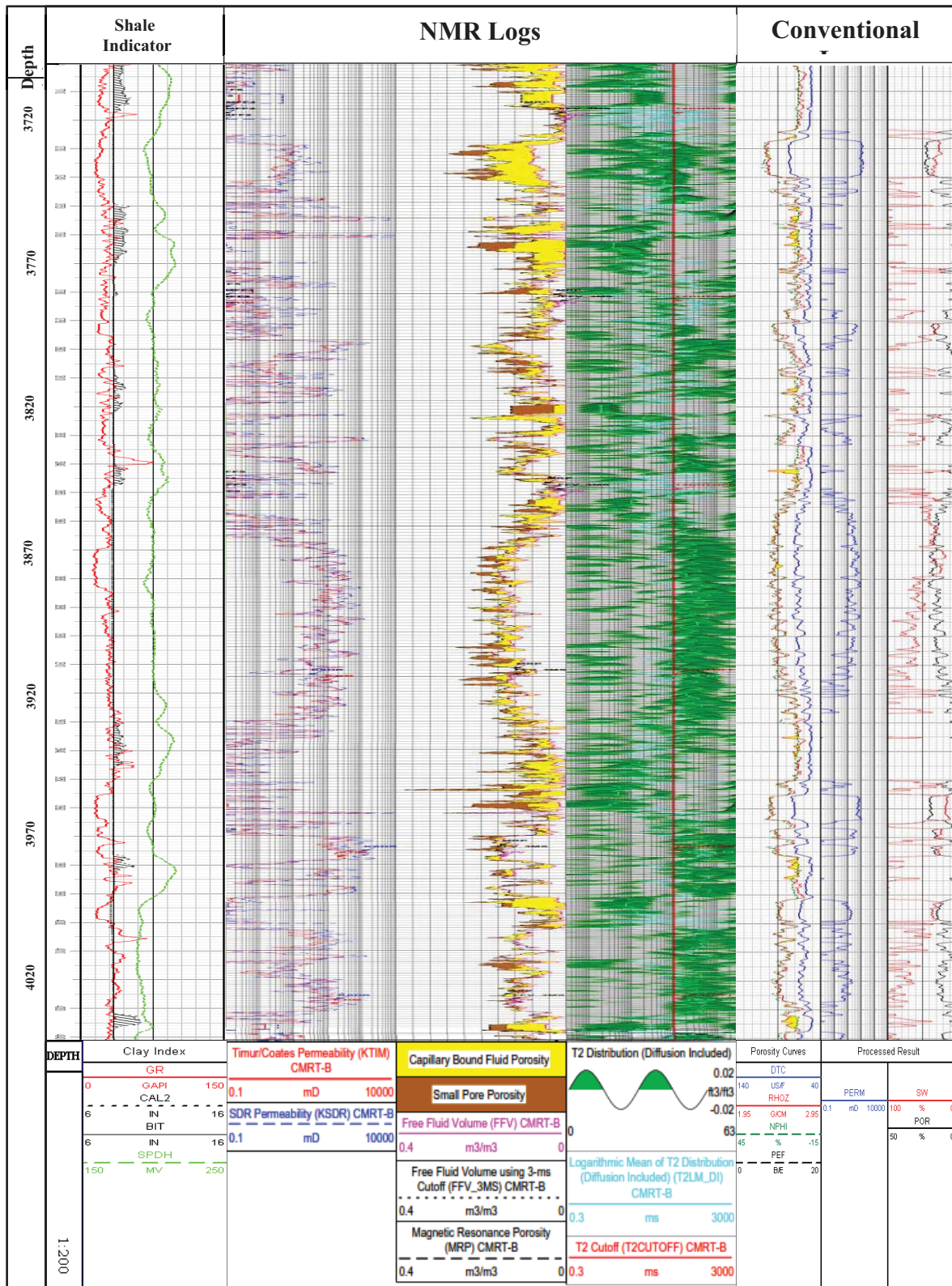


**Correlations in well Bu-52**

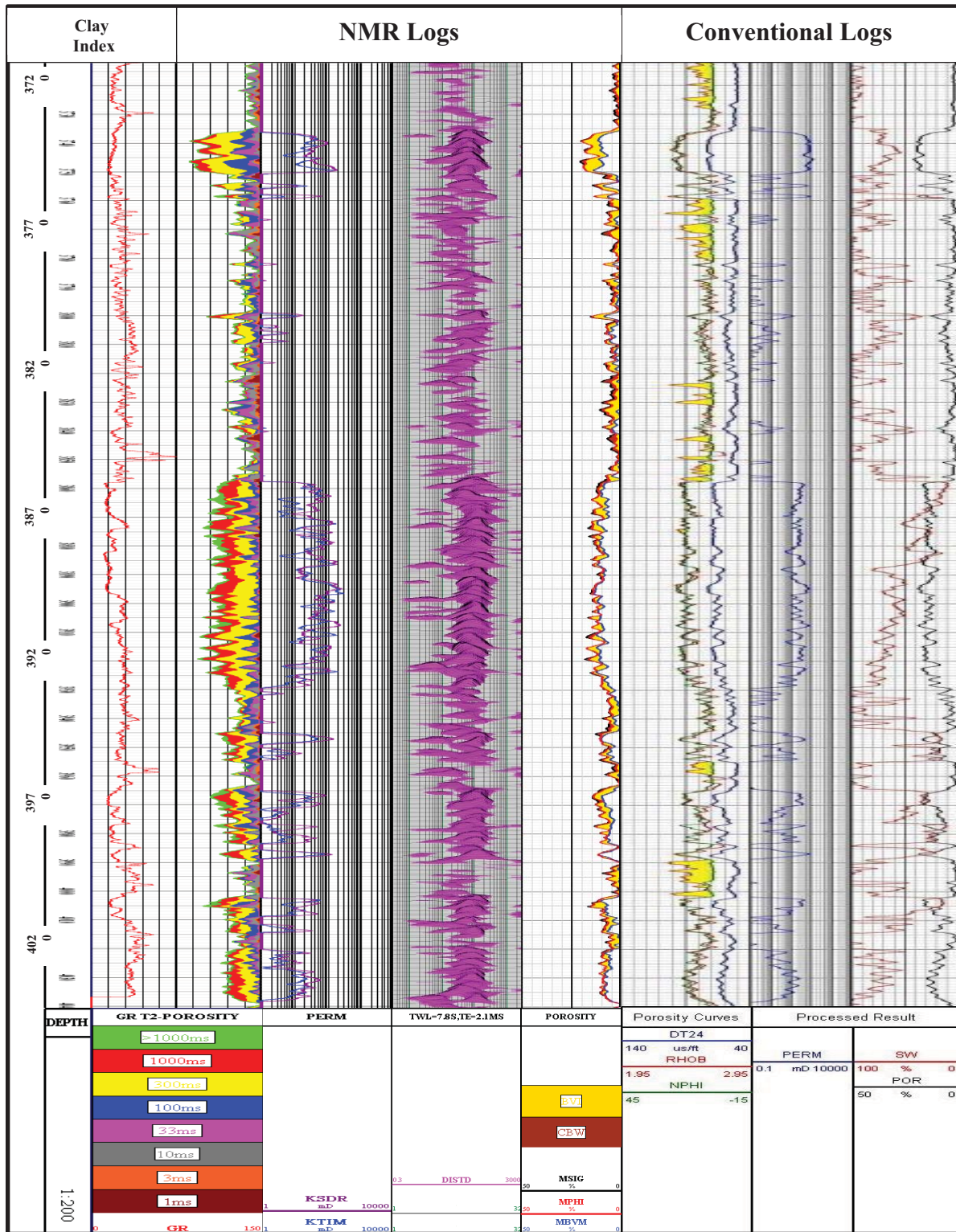
Appendix Two: Transformations results for the Study Wells



Analyses Comparisons for the Well Bu-40



Analyses Comparisons for the Well Bu-51



Analyses Comparisons for the Well Bu-52