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Improving the Reliability of Well Log Data Recorded in Oil and Gas Wells through Quality Control Approaches: A Case Study from a Southern Iraqi Field

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Abstract

Quality control of well logs has always been an important objective in reservoir studies because of the key role played by well logs as input data. This study aims to make a quality control on well logs data for two wells of Yamama formation in southern Iraqi field to ensuring and enhancing the measurement accuracy. In the beginning, the calibration data of before and after surveys are applied as initial evaluation for the quality of density log in well R-1. Then, depth matching is used to fit the depth of all logs in each well. After that, the comparison between the main and repeat sections is helped to check the repeatability. Finally, all uncorrected logs are environmentally corrected to remove the effects of the borehole conditions. The results show that most of the logs measurements are of the best quality and they are perfect for any analysis due to the study findings that the density log has approximately equal calibration readings, and the depth of all logs in each well is matched thus giving the best accuracy, moreover, most logs have good repeatability except for flushed zone resistivity and caliper logs in well R-2 in addition to the environmental correction is improved the measurements of gamma-ray and neutron logs.

Keywords: Log Quality Control, Calibration, Main section, Repeat section, Environmental corrections.

تحسين موثوقية بيانات المجسات المسجلة في آبار النفط والغاز من خلال أساليب مراقبة الجودة: دراسة حالة لحقل في جنوب العراق

الخلاصة

لطالما كانت مراقبة جودة مجسات الابار من الامور المهمة في الدراسات المكمنية بسبب الدور الرئيسي الذي تشكله مجسات الابار كبيانات ادخال. تهدف هذه الدراسة لإجراء مراقبة جودة المجسات في بئرين لتكوين اليمامة في حقل جنوبي العراق لضمان

وتعزيز صحة قراءتها. في البداية، استخدام بيانات المعايرة لقبل وبعد التحري لأجراء تقييم اولي لدقة مجس الكثافة في البئر R-1 ثم، اجراء عملية تطابق الاعماق للمجسات في كل بئر. بعد ذلك، المقارنة بين جزء القراءة الرئيسية والجزء المكرر للتأكد من التكرارية. اخيراً، اجراء عملية التصحيحات البيئية للمجسات غير المصححة وذلك لإزالة تأثيرات ظروف الابار. تشير النتائج الى أن قراءات معظم المجسات هي بأفضل حالة وهي جاهزة لأي عملية تفسير نتيجة للنتائج المتحصلة والتي هي عبارة عن تساوي قراءات المعايرة تقريبا لمجس الكثافة، ايضا مطابقة اعماق المجسات في كل بئر وعليه اعطاء أفضل دقة، بالإضافة الى الحصول على تكرارية جيدة جدا عدا مجس مقاومية منطقة الغزو ومجس قياس قطر البئر في البئر R-2 وايضا التصحيحات البيئية التي حسّنت قراءة مجس اشعة كاما ومجس النيوترون.

1. Introduction

Well logs have a vital role in the oil and gas industry, as they provide detailed and continuous measurements of the physical and petrophysical properties of subsurface formations. These logs are recorded from specialized tools that are lowered into the wellbore and subsequently brought up to the surface while continuously recording a variety of parameters such as resistivity, density, sonic velocity, and gamma ray response, among others [1]. Logging facility is digitally recorded and transfers the data either to a printed paper log or a digital data (LAS file) and may have both types in many cases. Printed logs are useful to the interpreter when he decides to make a quick review and log correlation. On the other hand, digital files offer the best way for deriving values and rescaling, as they represent the electronic input for most software applications used for analysis and integration with other data sources [2]. The concept of well logging holds different significance for different professionals in the field. For instance, a reservoir engineer relies on well logs and their interpretations as crucial input data when constructing a reservoir simulation model, which is then used in the evaluation of the recovery processes, predicting the future performance and optimizing the development strategies of the field. Conversely, geoscientists probably use the log data to calibrate and evaluate the seismic interpretations and enhance the understanding of stratigraphic and structural frameworks. On the other hand, petrophysicists and geologists employ these logs to determine the lithology, reservoir boundaries, fluid types, saturation level and identify hydrocarbon-bearing zones [3]. Well logs, core studies and other data that are planned for reservoir analysis, should be examined and carefully reviewed for internal consistency whenever possible to ensure a reliable input for reservoir studies. This review helps to determine any errors, gaps, or discrepancies in the dataset, because accurate forecasts cannot be achieved without accurate data and a well-defined reservoir model [4]. Log quality control (LQC) is an essential part of any user that use well logs in his study, ensuring that the recorded parameters are both reliable and representative of the formation properties [5][6].It contains several activities at different stages of the logging and interpretation process, all aimed to ensure that the data are more suitable and more consistent, and to provide good results[7].Generally, the quality of the input data has a direct and significant impact on the reliability and accuracy of the resulting interpretations. High-quality and consistent measurements lead to high-quality analyses and minimize the uncertainty level that may be associated with the results. Conversely, inconsistent, or poor data will introduce many errors that propagate during the workflow, leading to increasing uncertainty. Therefore, ensuring data quality at the beginning of analysis is a crucial step for achieving accurate and dependable results [8]. The quality control process typically begins with calibrations, which confirm that the logging tool is performing within its specified tolerance limits. A master calibration is carried out at the service company's facility and is compared with standard reference measurements of the logging tool. Further calibrations are then conducted before and after each logging run at the well site, and the differences in the calibration readings between these surveys are compared. The derived variance is then evaluated against the tool tolerance to detect any drift and ascertain the accuracy of the readings. [9][10]. Once the logs are calibrated, an additional step is carried out on the recorded logs known as depth matching, since the logs of the same run or different runs in the same well may exhibit a mismatch in depth for a given geological level; therefore, this step should be applied before any process. Depth mismatch may happen due to many reasons, such as cable elasticity and tool sticking, leading to discrepancies in subsurface formation tops or reservoir units [11]. Furthermore, repeatability is one of the most essential steps in log quality control, which can be checked by comparing the repeat section that is usually recorded in the well at a desired 60 ft minimum interval against the main section of the same depth to confirm that the reading parameters are consistent and stable [12].Another key aspect of quality control includes understanding and correcting the factors that play a major role in influencing logging measurements: the borehole environment, bed thickness and tool noise, since these factors have the capacity to fluctuate the log readings. To overcome these concerns, environmental corrections are applied to compensate for these effects and to restore the readings as accurately as possible. These corrections have different orders and are often applied to the older and legacy logs, since most modern logs are already corrected [9]. This study aims to perform a quality control on well log data in the Yamama Formation-south Iraqi field. The objective is to confirm, evaluate and improve the measurements of the available log data before being used in future analysis.

2. Material and methods

The research depends on two wells (R-1 and R-2) that penetrate the Yamama formation in the southern Iraqi field. The available open hole data that are included in this study are: Gamma ray logs (GR), Spectroscopy Gamma-ray log (SGR), Caliper logs (CALI), Neutron logs (NPHI, TNPH), Density logs (RHOB, RHOZ), Flushed Zone Resistivity logs (RXO, RXOZ) and True Resistivity log (RT). At the beginning, NeuraLog (version 2015.04) was used to digitize well logs of the main and repeat passes from field prints to those that are not available in digital format to export these logs to LAS format to make them suitable for software analysis. An illustration of a specific section of the caliper log digitizing procedure is shown in Figure (1). This part presents how NeuraLog assisted the conversion of caliper log data to a digital format. Following this digitization phase, the subsequent steps of the study's workflow are conducted using Techlog software (Version 2017.1), as presented in the flow diagram exhibited in Figure (2). Techlog is Schlumberger software for well log analysis, which plays a leading role in completing the remaining phases.

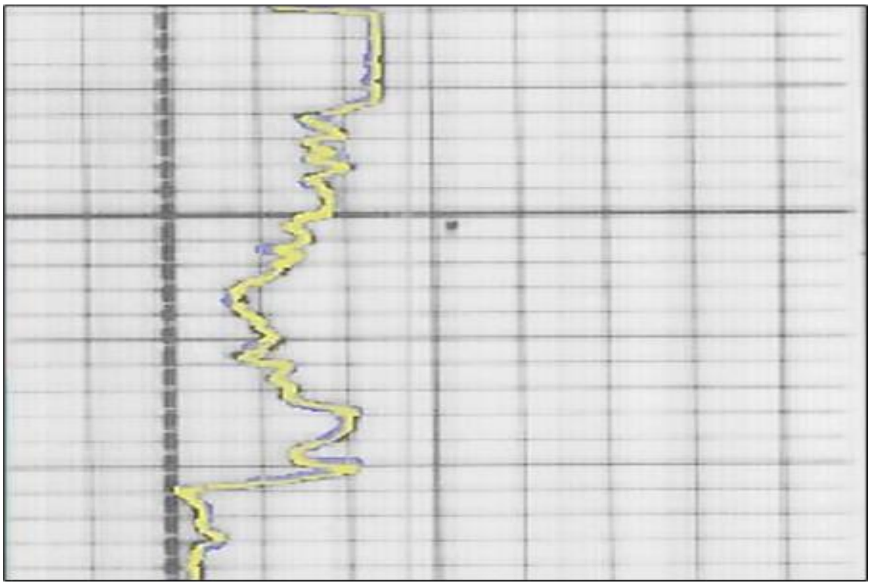

Fig. (1): Digitization plot of caliper log in well R-1 by NeuraLog software as an example

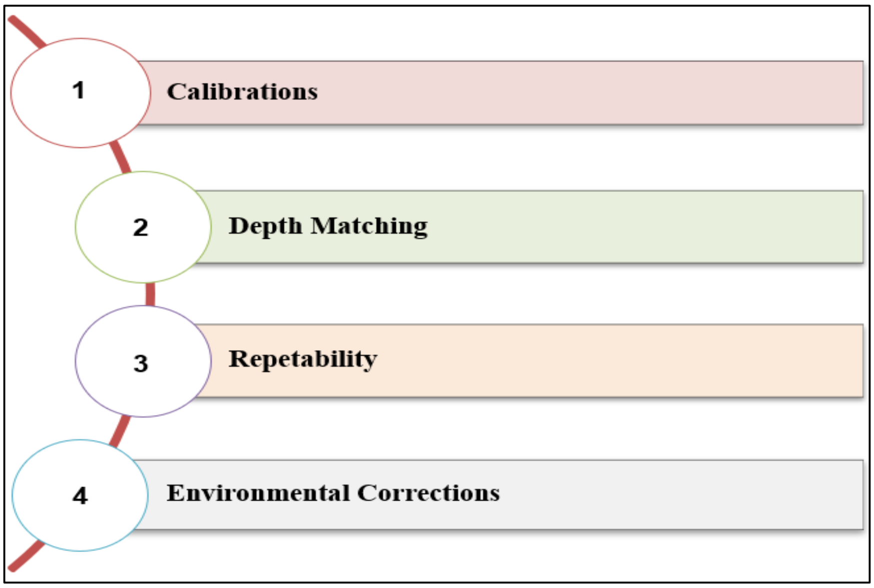

Fig. (2): Flow diagram of methodology

3. Results and Discussion

Based on the flow diagram of methodology, the main results that hold significant importance in the context of the study are listed below:

3.1 Calibrations

A sequence of calibrations is conducted on different logging tools, serving the dual purpose of upholding the integrity of data and validating the precise functionality of the tools, and these calibrations have different recording methods depending on the service company and the available technology [13]. The calibration data is only available for the density log in well R-1 as illustrated in Figure (3).

Through the observation and examination, the calibration records and the mechanical zero of the before survey exhibit a high degree of matching to the calibration readings obtained after the survey. The close alignment between the calibration data shows the consistency and accuracy of the density log, supporting the certainty in its precision and dependability. Moreover, this level of agreement also points out that the logging tool is set up correctly and maintained properly. This is highly significant because it ensures that the data collected is dependable and can be trusted for any interpretation and analysis, as indicated by the excellent quality and good reliability of the logging tool.

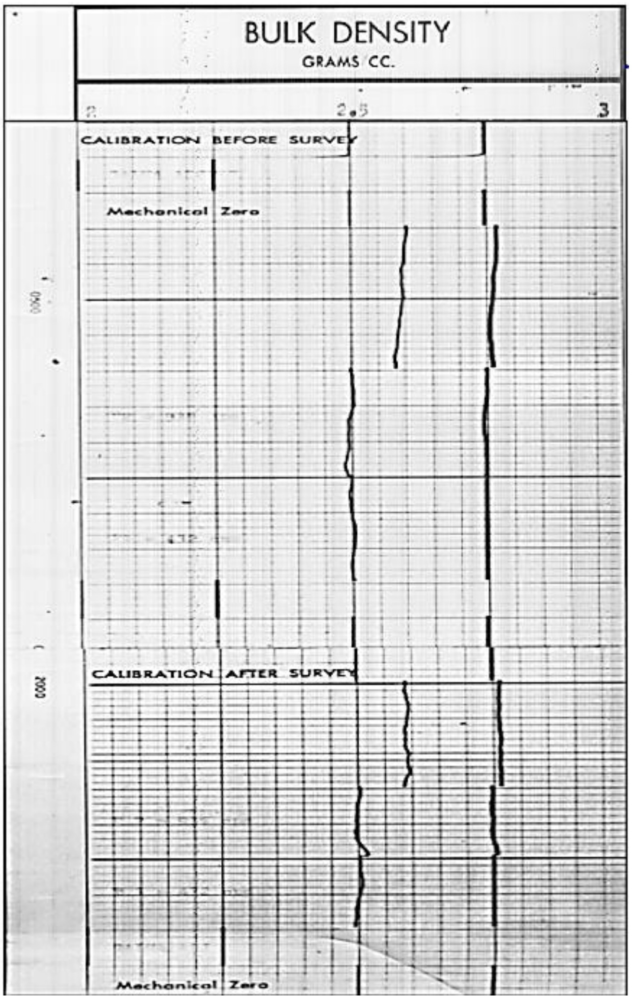

Fig. (3): Calibration records of density log in well R-1

3.2 Depth matching

To maintain coherence in the expected trend at the same point, it is essential to match the depths of all logs in any single well before proceeding with interpretation. The difficulties of depth control cause depth mismatch for logs in a specified formation or at a given point; hence, a shift is needed for these logs. This can be done by aligning each log with a reference log, such as a gamma-ray or by taking two logs with the same trend when a gamma-ray is not available [14]. In this study, gamma-ray is employed as a reference log for both wells. Upon examining all the logs using Techlog, it is observed that a minor difference exists in depth, which requires a few adjustments. Consequently, a corrective step is implemented to enhance the overall data quality. This depth matching procedure is performed on all logs of well R-1. However, in the case of well R-2, a similar procedure is carried out where it is found that only the spectroscopy gamma-ray and neutron logs required adjustment, since other logs already exhibited an excellent level of matching. Figure (4) presents the outcomes of this step for well R-1, while Figure (5) shows the results for well R-2, where the red and blue curves represent the log data before and after depth matching, respectively.

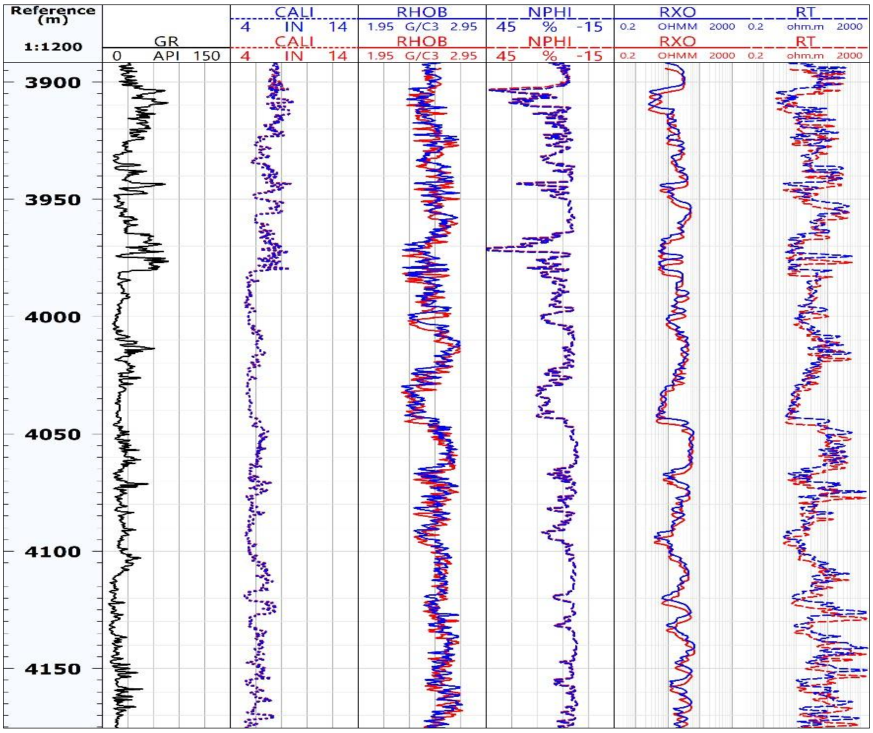

Fig. (4): Depth matching for the selected logs in Well R-1

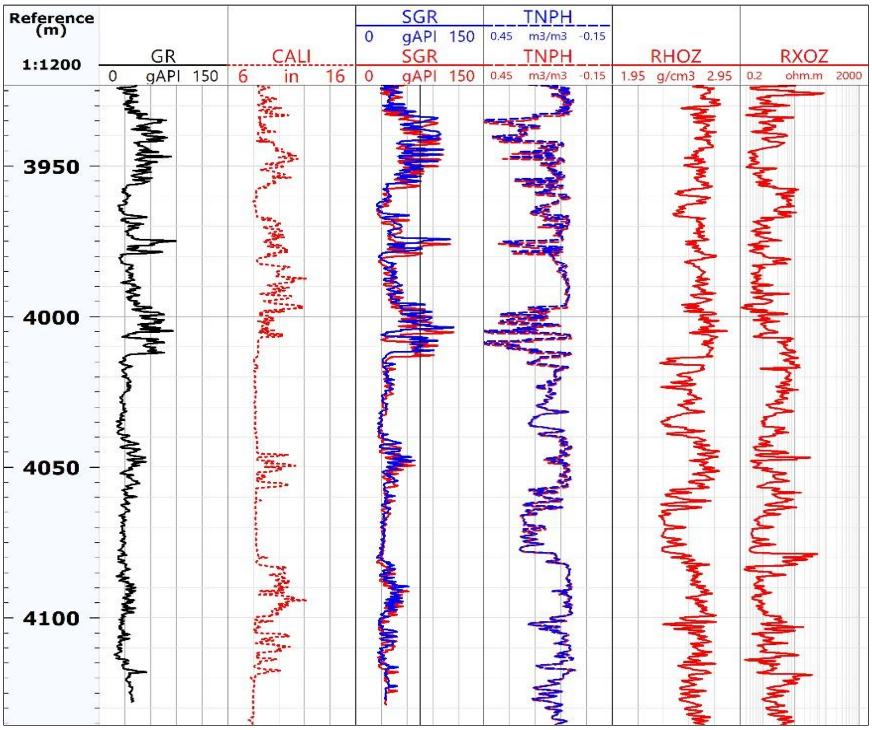

Fig. (5): Depth matching for the selected logs in Well R-2

3.3 Repeatability

To ensure optimal repeatability and thoroughly assess the quality of logging tools, it is vital to closely align the main logging run with the repeat run at the specified intervals. To improve repeatability, the repeat section has been depth-matched to the main section. Figure (6) and Figure (13) present the depth matching process and the repeatability check as a log view for well R-1 and well R-2, respectively. In the mentioned Figures, the black curve is referred to main logging, while the red one corresponds to the repeat pass, which is labeled as "log_R". Moreover, the shifted repeat run is presented in a blue color, which is referred to as "log_Rsft". Besides, Figure (7) to Figure (12) present the cross plots that resulted from a comprehensive repeatability check conducted on all logs within well R-1. Each cross plot highlights the level of repeatability achieved at different intervals, offering a detailed analysis of the data's consistency and reliability. On the other hand, Figure (14) to Figure (19) provide a detailed view of the repeatability assessment carried out on well R-2. Similar to well R-1, these cross plots depict the outcome of the repeatability analysis, but for the logs specific to well R-2. The depth intervals are selected based on the recommendations of the Schlumberger company, ensuring a comprehensive examination of the log data's consistency within these wells.

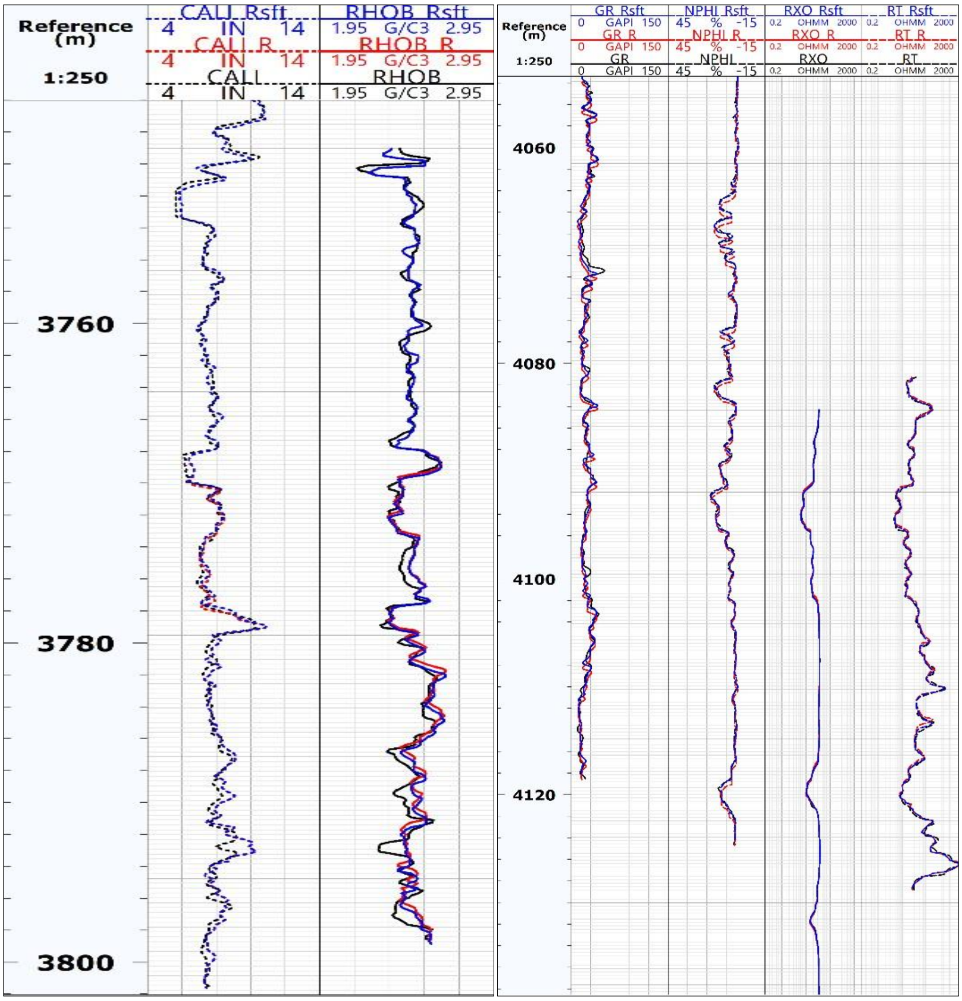

Fig. (6): Repeatability Log view for the selected logs in well R-1

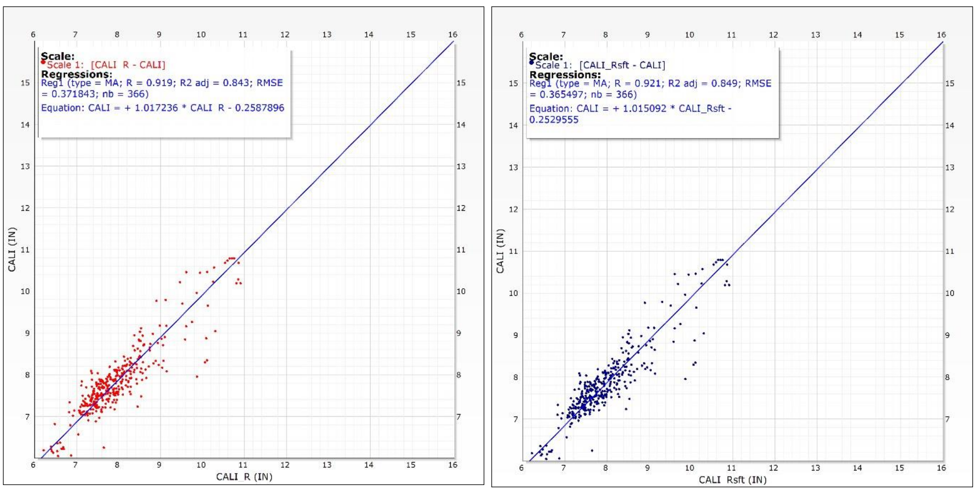

Fig. (7): Repeatability cross plots of CALI in well R-1

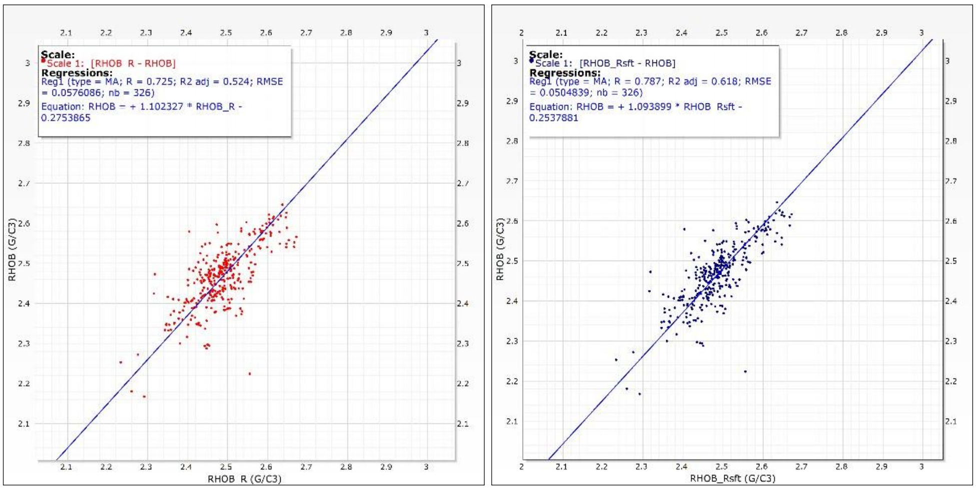

Fig. (8): Repeatability cross plots of RHOB in well R-1

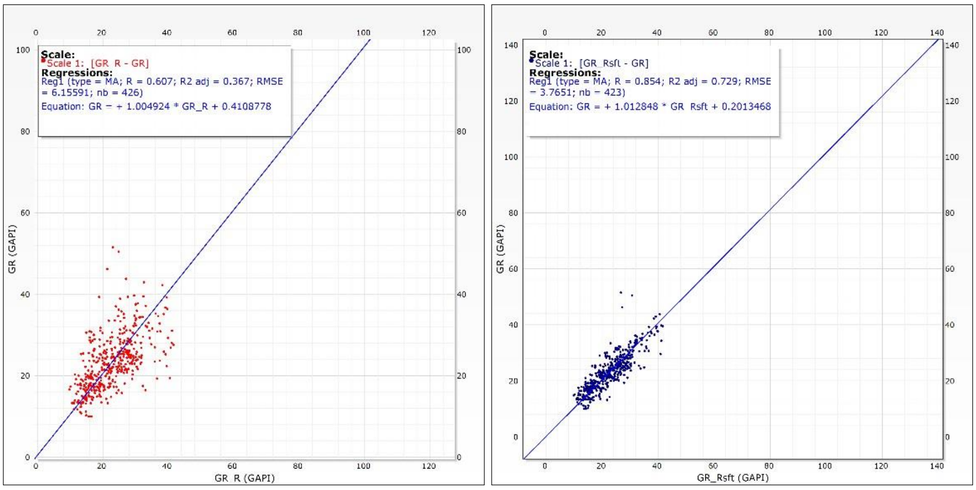

Fig. (9): Repeatability cross plots of GR in well R-1

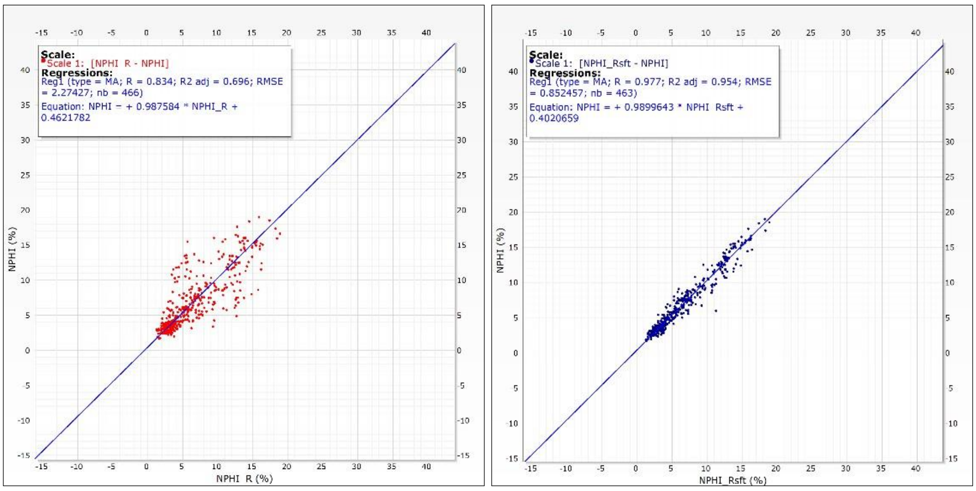

Fig. (10): Repeatability cross plots of NPHI in well R-1

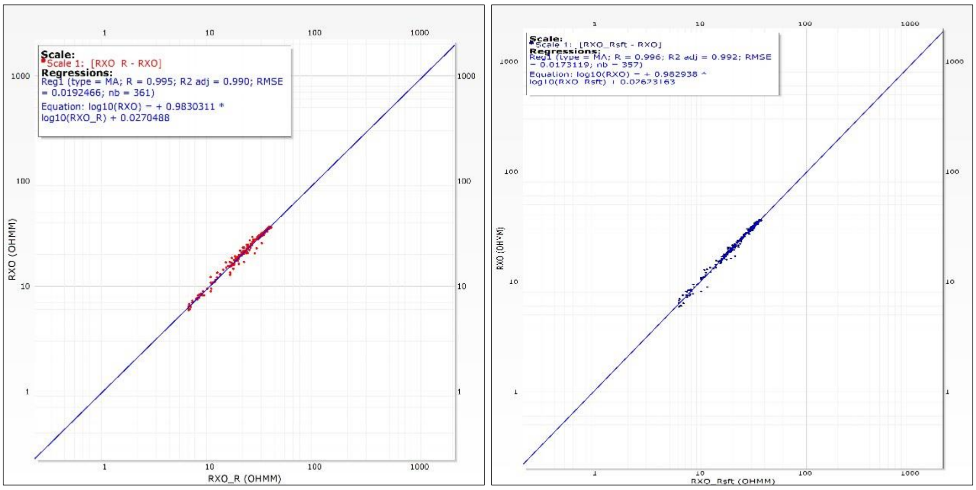

Fig. (11): Repeatability cross plots of RXO in well R-1

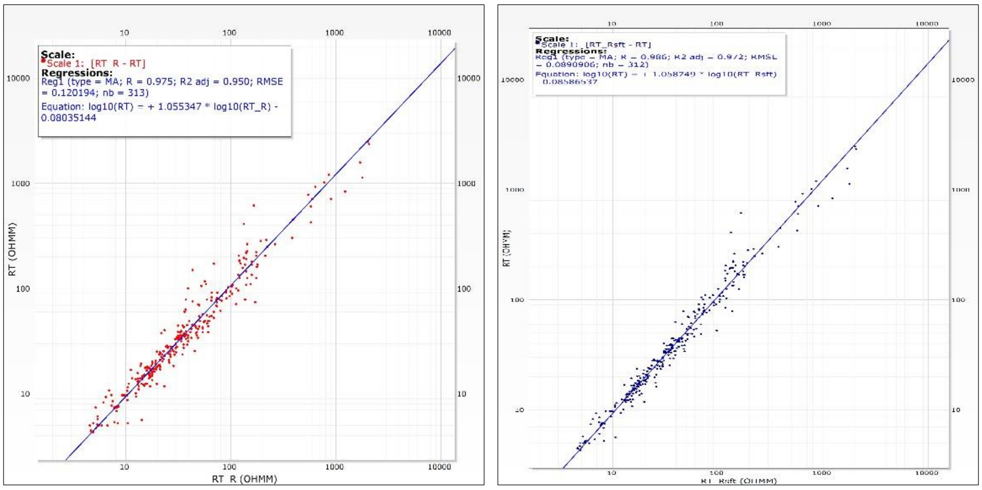

Fig. (12): Repeatability cross plots of RT in well R-1

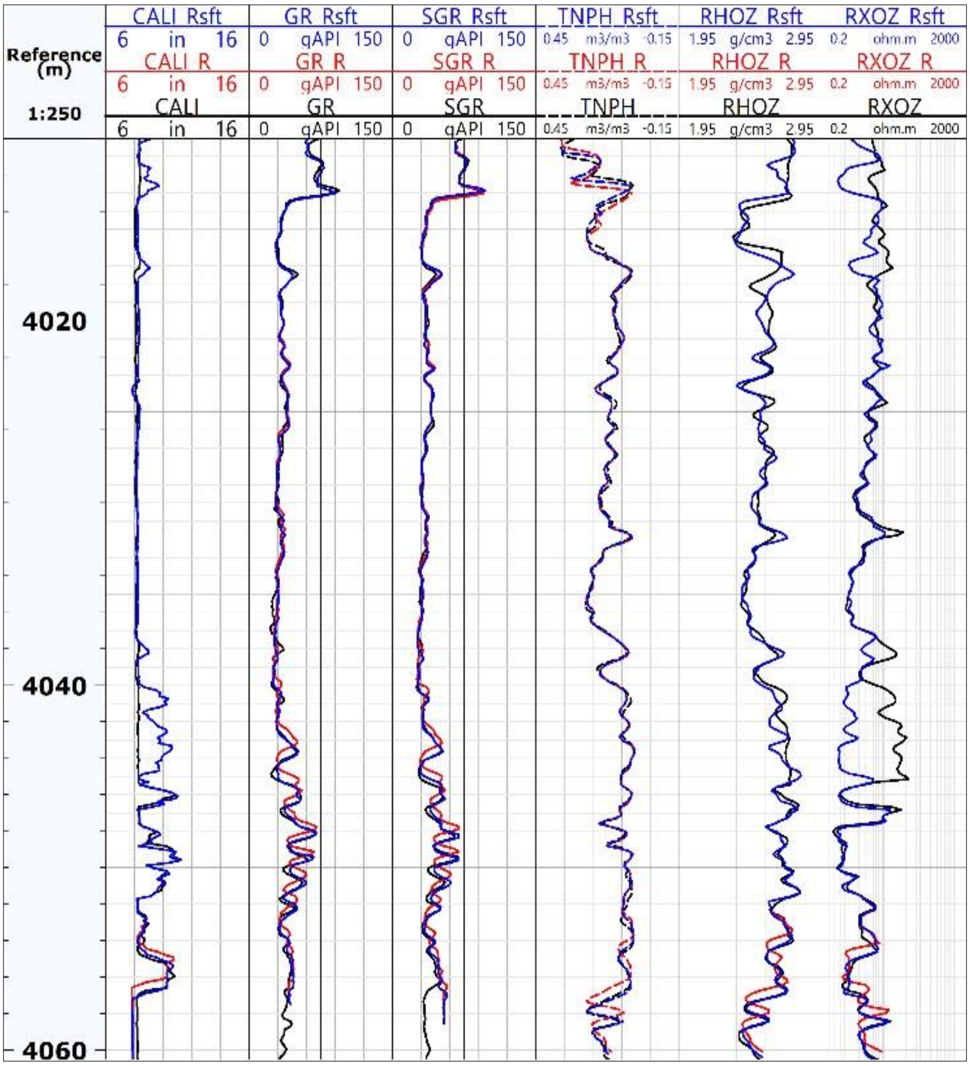

Fig. (13): Repeatability log view for the selected logs in well R-2

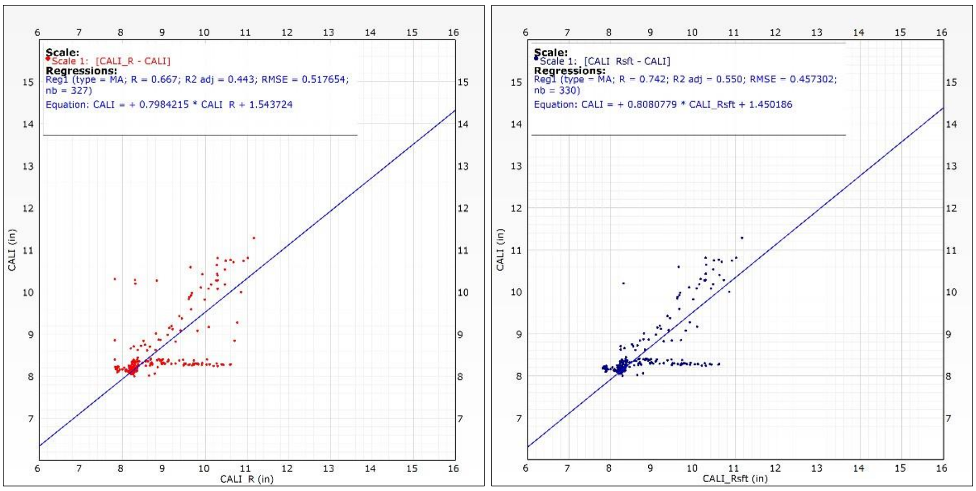

Fig. (14): Repeatability cross plots of CALI in well R-2

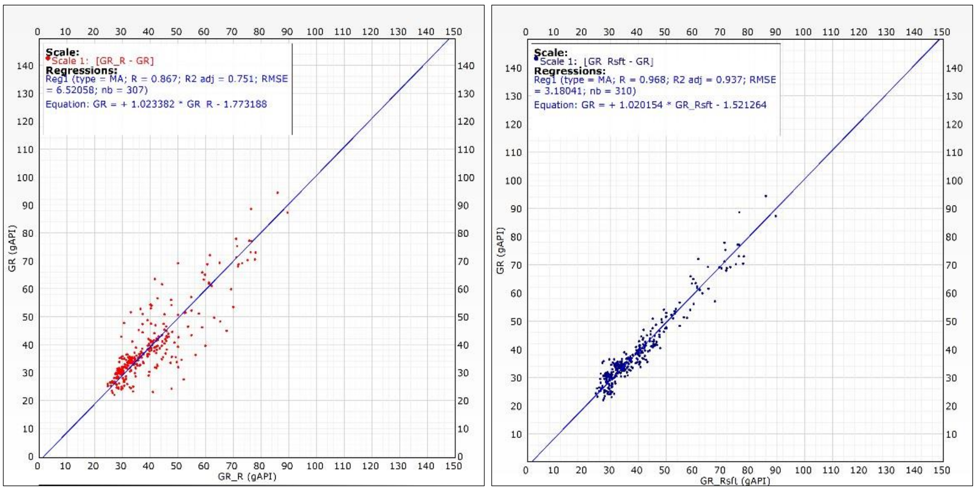

Fig. (15): Repeatability cross plots of GR in well R-2

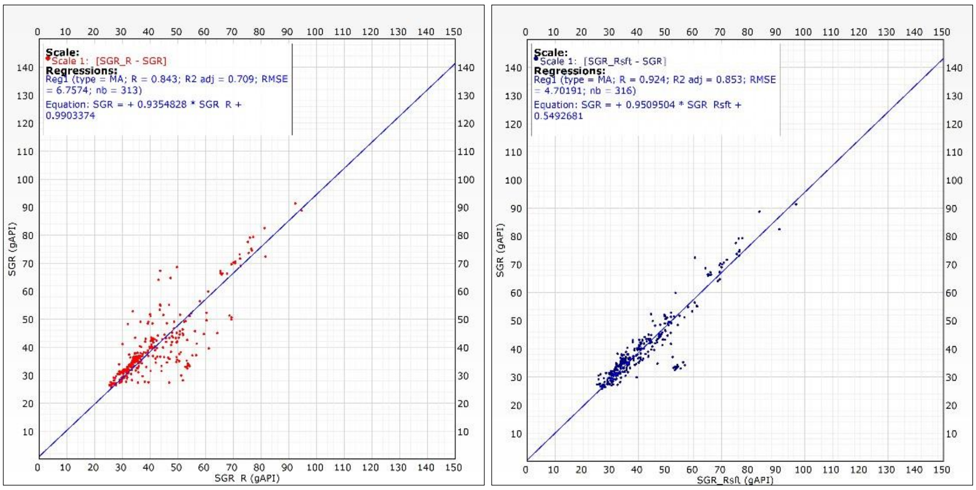

Fig. (16): Repeatability cross plots of SGR in well R-2

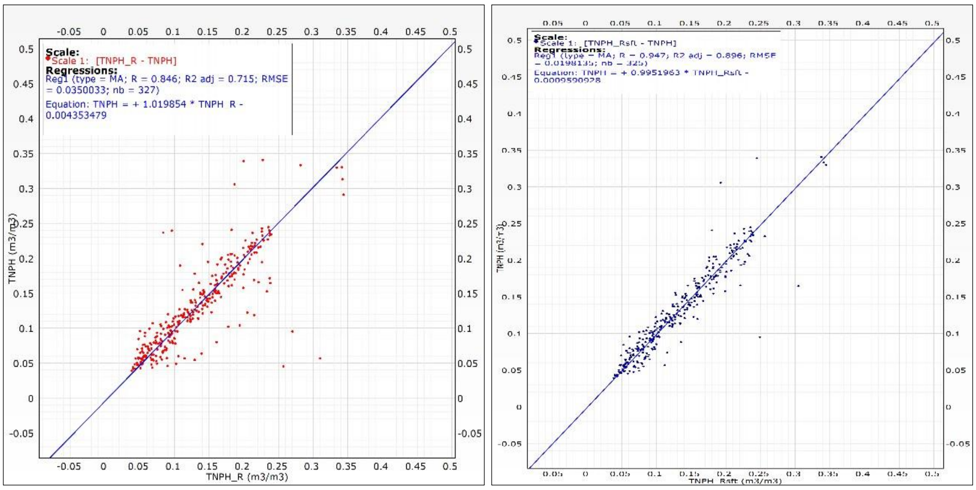

Fig. (17): Repeatability cross plots of TNPH in well R-2

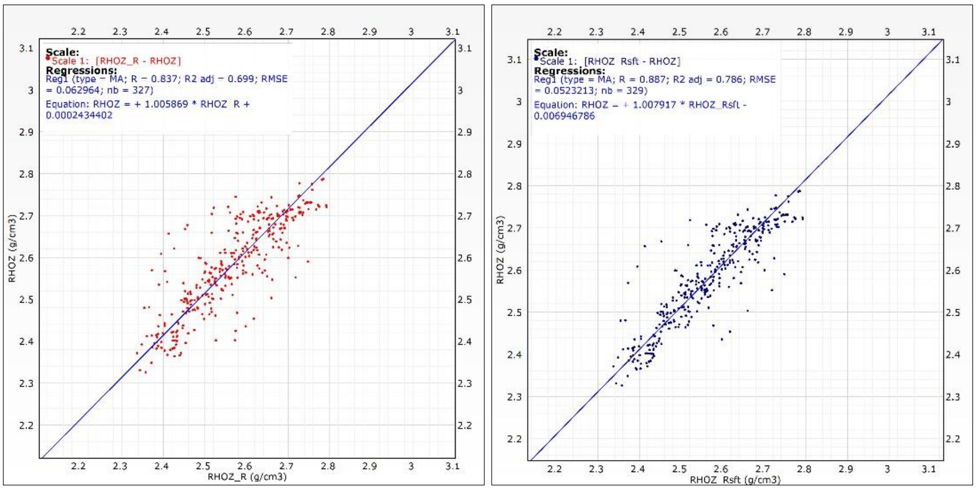

Fig. (18): Repeatability cross plots of RHOZ in well R-2

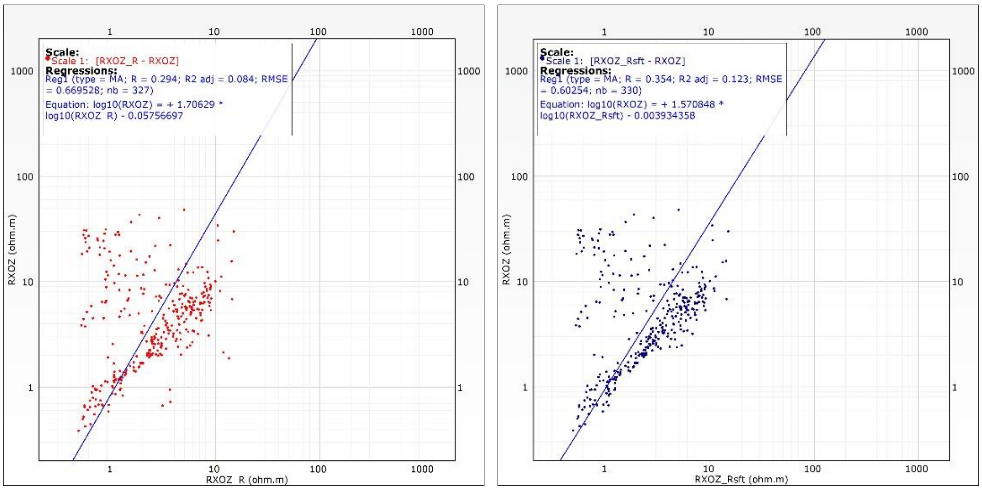

Fig. (19): Repeatability cross plots of RXOZ in well R-2

As a result, the log views and cross plots first indicated that the matching of the repeat run to the main log run improves the repeatability check in all logs, as indicated by the statistical records of the adjusted coefficient of determination (R^2-adj) and root mean square error (RMSE). Also, the neutron, flushed zone resistivity and true resistivity logs have excellent repeatability in well R-1, while only the gamma-ray log in the second well, where R^2-adj is more than (0.93) for these logs. In addition, the caliper and especially the flushed zone resistivity in well R-2 have the lowest repeatability as reflected by the statistical records where R^2 adj is equal to (0.55) and (0.123), respectively. Finally, other logs in both wells have moderate to good repeatability. The reasons behind the good repeatability are probably due to similar controlling parameters, such as logging speed between the main and repeat runs, the run time was equal, the same logging parameters and also due to limited statistical variation that may have occurred in radioactive logging tools [12].

On the other hand, the occurrence of a washout during the repeat run within the interval (4040-4045 m) is the primary cause of the low repeatability of the caliper in well R-2. Similarly, the lowest repeatability in the flushed zone resistivity reading in the same well can be attributed to the same reason, where the replacement of the formation rock by drilling fluid. Furthermore, the absence of any of the mentioned parameters can also lead to low repeatability.

3.4 Environmental corrections

Environmental corrections are utilized to eliminate the change that possibly happens in log readings caused by borehole conditions in comparison to the reference test bit calibration. This step is taken after the depth matching process to enhance measurement accuracy. The corrections are applied sequentially, not only for logs that have not been corrected by the service company but also in cases where corrections are lacking for tools that have already been corrected [15]. The corrections are applied for borehole size, mud type, mud weight, and tool eccentricity effects by using charts of the Schlumberger company that are already available in Techlog. Fig. (20) shows the corrections of well R-1 for selected logs that are available in this well. While for well R-2, the corrections are carried out only for gamma-ray and density logs, as illustrated in Fig. (21). The results indicate that the gamma-ray log is affected by the borehole conditions and displays a minor increase opposite washout intervals, where these intervals are presented by the yellow area between caliper log and bit size. In these intervals, the presence of a significant amount of drilling mud between the tool and the formation leads to a decrease in the number of gamma-rays returning to the tool. On the other hand, the neutron porosity log in well R-1 exhibits a slight decrease in regions with mud cake and tight spots. These regions are presented by the green area, where these intervals cause an overestimation in neutron porosity log readings, and that is why the gamma-ray log is slightly increased in well R-2 in the same regions [3].

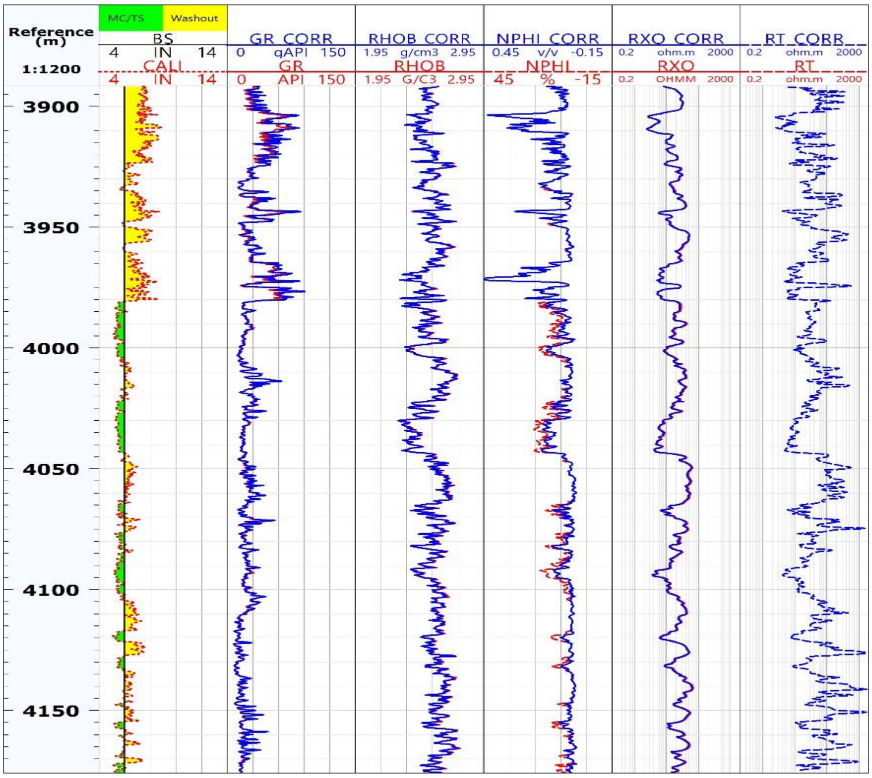

Fig. (20): Environment corrections for the selected logs in well R-1

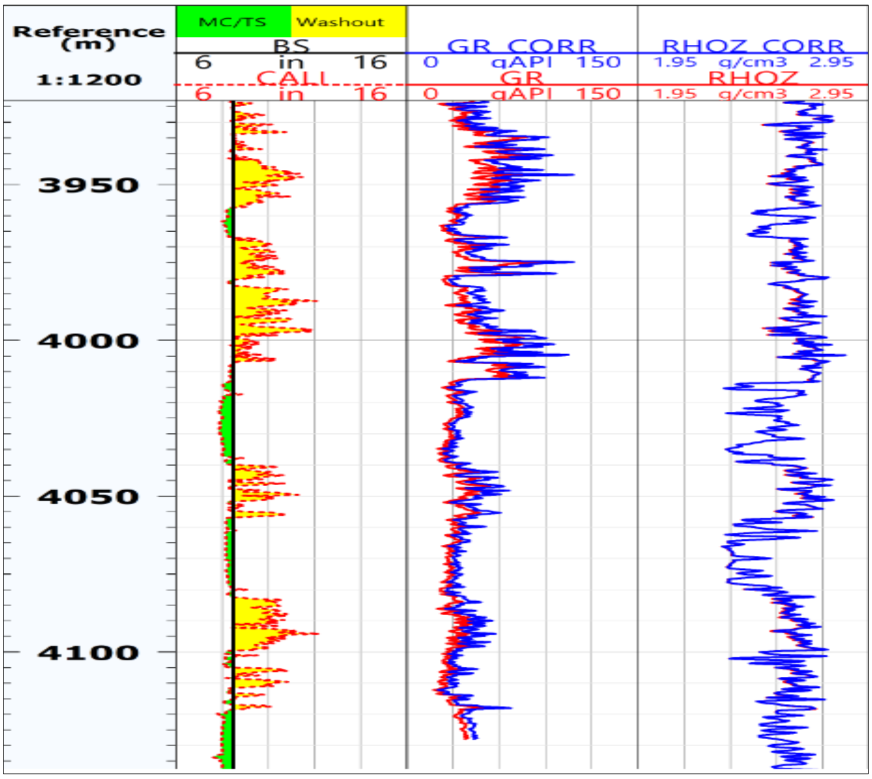

Fig. (21): Environment corrections for the selected logs in well R-2

4. Conclusions

Overall, the quality control procedure enhanced and confirmed the reliability and consistency of all well log data in this formation, making these logs an excellent quality source for analysis, evaluation, and integration with other sources. The main findings can be summarized as follows:

- The density log in well R-1 met the calibration standard, confirming the quality and reliability of this logging tool.
- The precision of logging tools is significantly improved by employing depth matching.
- High-level repeatability for all logs recorded at different intervals, except for the caliper and flushed zone resistivity logs in well R-2.
- Environmental corrections indicated that the gamma ray and neutron logs were slightly affected by borehole conditions, where these effects are minimized after corrections.

Author Contributions Statement: Hussein Y. Ali contributed to the Conception; Data Curation/ Analysis and Interpretation; Writing Original Draft. Ghanim M. Farman contributed to the Methodology, Data Analysis and Interpretation; Writing Original Draft; Writing – review & editing. Mohammed H. Hafiz contributed to the Conception; Methodology, Data Curation/ Analysis and Interpretation; Writing – review & editing. All authors have read and approved the final version of the manuscript.

Nomenclature

BS	Bit Size
CALI	Caliper Log
CALI_R	Caliper Log-Repeat Section
CALI_Rsft	Caliper Log-Repeat Section (Shifted)
GR	Gamma Ray Log
GR_R	Gamma Ray Log-Repeat Section
GR_Rsft	Gamma Ray Log-Repeat Section (Shifted)
LQC	Log Quality Control
MC/TS	Mud Cake / Tight Spot Region
NPHI	Thermal Neutron Porosity (Original Ratio Method) in Selected Lithology
NPHI_CORR	Thermal Neutron Porosity (Original Ratio Method) in Selected Lithology (Corrected)
NPHI_R	Thermal Neutron Porosity (Original Ratio Method) in Selected Lithology-Repeat Section
NPHI_Rsft	Thermal Neutron Porosity (Original Ratio Method) in Selected Lithology-Repeat Section (Shifted)

R^2adj	Adjusted Coefficient of Determination
RHOB	Bulk Density Log
RHOB_CORR	Bulk Density Log (Corrected)
RHOB_R	Bulk Density Log-Repeat Section
RHOB_Rsft	Bulk Density Log-Repeat Section (Shifted)
RHOZ	Standard Resolution Formation (Bulk) Density Log
RHOZ_CORR	Standard Resolution Formation (Bulk) Density Log (Corrected)
RHOZ_R	Standard Resolution Formation (Bulk) Density Log-Repeat Section
RHOZ_Rsft	Standard Resolution Formation (Bulk) Density Log-Repeat Section (Shifted)
RMSE	Root Mean Square Error
RT	True Resistivity Log
RT_CORR	True Resistivity Log (Corrected)
RT_R	True Resistivity Log-Repeat Section
RT_Rsft	True Resistivity Log-Repeat Section (Shifted)
RXO	Flushed Zone Resistivity Log
RXO_CORR	Flushed Zone Resistivity Log (Corrected)
RXO_R	Flushed Zone Resistivity Log-Repeat Section
RXOZ	Flushed Zone Resistivity Log
RXOZ_R	Flushed Zone Resistivity Log-Repeat Section
SGR	Spectroscopy Gamma Ray Log
SGR_R	Spectroscopy Gamma Ray Log-Repeat Section
SGR_Rsft	Spectroscopy Gamma Ray Log-Repeat Section (Shifted)
TNPH	Thermal Neutron Porosity (Ratio Method) in Selected Lithology
TNPH_R	Thermal Neutron Porosity (Ratio Method) in Selected Lithology-Repeat Section
TNPH_Rsft	Thermal Neutron Porosity (Ratio Method) in Selected Lithology-Repeat Section (Shifted)

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