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PSEUDO GAMMA RAY LOG FROM MUD LOGGER DESCRIPTIONS

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Abstract Summary

This study presents a method for generating synthetic gamma ray logs (pseudo_GR) based on the lithological description of cuttings samples. The technique involves assigning gamma ray values to the described lithologies using a calibrated equation derived from reference wells. Although limited by the lower resolution of sampling compared to conventional geophysical methods, the methodology allows for real-time stratigraphic interpretation during drilling operations. When properly applied, it proves to be an efficient and cost-effective alternative for geological monitoring, especially when integrated with seismic and well log data.

Introduction

Descriptions include rock types (such as sandstone, shale, and limestone), grain size, color, texture, sedimentary structures, cementation, visible porosity, accessory minerals, and hydrocarbon shows. These samples, collected at regular drilling intervals, are used to generate lithological logs, which support stratigraphic correlation and real-time geological monitoring during drilling (Asquith & Krygowski, 2004).

The gamma ray (GR) log is acquired using a tool that measures the natural radiation emitted by geological formations, especially from isotopes of potassium (K-40), uranium (U), and thorium (Th). This radiation is detected by a scintillometer and recorded in API units. The principle is based on the fact that clay-rich rocks emit more gamma radiation than sandstones and carbonates. Key applications include lithology identification, estimation of shale volume (Vsh), and stratigraphic correlation between wells (Rider & Kennedy, 2011).

The Logging While Drilling (LWD) technique is an innovation in the oil and gas industry, allowing for continuous and real-time data acquisition during drilling. Although LWD involves higher initial costs due to the complexity and sophistication of the equipment, it offers significant operational time savings (Tariq et al., 2017). In contrast, wireline logging, performed by lowering tools into an already drilled well, is generally more cost-effective due to greater tool availability and operational robustness.

Seeking to combine the advantages of both techniques (operational efficiency vs. financial cost), the methodology for generating a pseudo gamma ray log involves assigning GR values based on the proportion of lithologies described during drilling. This creates an alternative product for tracking drilled lithologies, offering benefits like those of LWD.

Method and/or Theory

The generation of the pseudo gamma ray (pseudo_GR) log presents a scaling discrepancy when compared to conventional GR logs, as cuttings descriptions are typically carried out at a metric scale (usually 3x3 m), whereas wireline logging operates at a much finer resolution—centimetric (15x15 cm). Therefore, the pseudo_GR should be regarded as a simplified tool for tracking the progression of well drilling.

The construction of the pseudo_GR log from cuttings descriptions is based on global threshold values assigned to each lithology, as outlined in Table 1:

Rock Type	Description (%)	GR (API)
Halite	≥ 10%	0
Anhydrite	≥ 10%	0
Limestone	≥ 50%	5 ~ 10
Dolomite	≥ 50%	10 ~ 20
Clean Sandstone	≥ 80%	10 ~ 30
Clayey Sandstone	≤ 80%	30 ~ 45
Shale	≥ 50%	40 ~ 140

Table 1 – GR values (API) according to the lithology percentage. Modified from SLB (1998).

Based on data from correlatable wells, three constants used in Equation (1) are defined, namely: the minimum carbonate percentage present in the sample ($\boldsymbol{S}_{lime}$), GR from limestone (γ_{lime}) and GR from shale (γ_{shl}) (Figura 1):

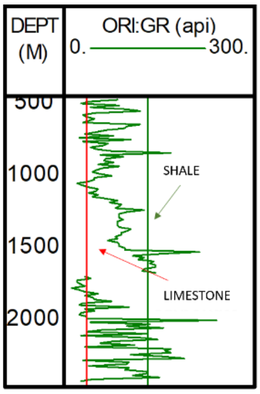

Figure 1 – Definition values of GR in correlation well.

Finally, with the constants determined, the pseudo_GR values for siliciclastic rocks are defined based on the variable representing the percentage of sandstones described in the samples ($\boldsymbol{S}_{sand}$), using the following equation (1).

$$Pseudo\_GR = \left(\left(\left(\frac{\gamma_{shl} - \gamma_{lime}}{100} \right) \times (100 - S_{sand}) \right) + \gamma_{lime} \right) \qquad (1)$$

In conclusion, the methodology follows the workflow shown in Figure 2. The first condition is tested by verifying whether the carbonate percentage in the sample meets the minimum ($\boldsymbol{S}_{\gamma lime}$) threshold to assign the pseudo_GR value equal to the carbonate GR (γ_{lime}). If this condition is not met, Equation (1) is applied.

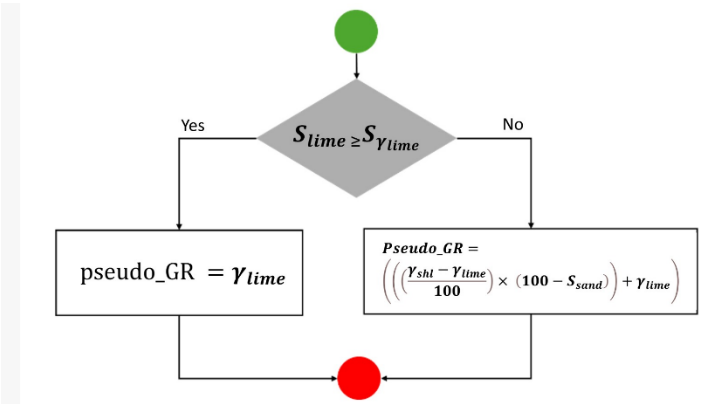

Figure 2 – Flow to create a pseudo_GR.

Results

As evidenced by the comparison with the original data obtained through conventional wireline logging (Figure 3), several considerations can be made regarding the developed technique.

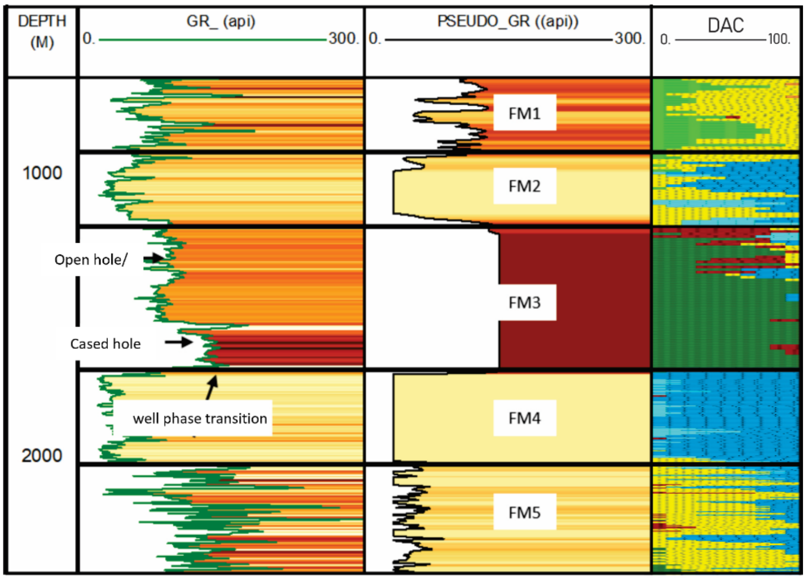

Figura 3 – Comparing GR LOG and Pseudo_GR Log and Mud Logger Description. Detail of signal attenuation due to the difference between open hole and cased hole logging, and of the drilling phase change to a more detailed sampling interval (3x3 m).

In formations FM1 and FM2, a good graphical similarity is observed between the logs, despite the low resolution of the sampling (9x9 m), which is approximately 60 times less precise than geophysical logging (0.15 m). Even with limited lithological detail, it is possible to identify the interbedding of grain-supported sandstones and clay-rich intervals.

In FM3, signal attenuation in the lower portion of the GR log is attributed to partial logging in both open and cased hole sections, as well as to tool offset (~10 m) and variations in borehole diameter. Nevertheless, both profiles indicate a predominance of shale.

In FM4, denser sampling (3x3 m) provides greater interpretative robustness, with a consistent pattern suggesting a predominantly carbonate lithology. Despite scale differences, the generated and acquired profiles are coherent.

FM5 showed the lowest correlation with the actual GR log, mainly due to the intense interbedding of carbonates and sandstones, which causes the method's initial condition to favor carbonates. Still, an approximate pattern was identifiable.

Overall, the formation thicknesses were correlatable between the generated and acquired profiles.

Conclusions

The results indicate that, despite the resolution limitations associated with cuttings descriptions, it is possible to establish good correlations with conventional geophysical logs. Even with lower detail, the methodology proves effective in identifying lithological patterns and supporting stratigraphic characterization. In more complex settings, where rock heterogeneity is higher, accuracy may decrease, requiring greater caution in interpretation and potential adjustments to the method's conditions.

Nevertheless, the consistency observed in formation thicknesses and overall trends supports the use of this technique as a complementary tool for real-time geological monitoring, especially when integrated with other data sources such as seismic and well logging (Figure 4).

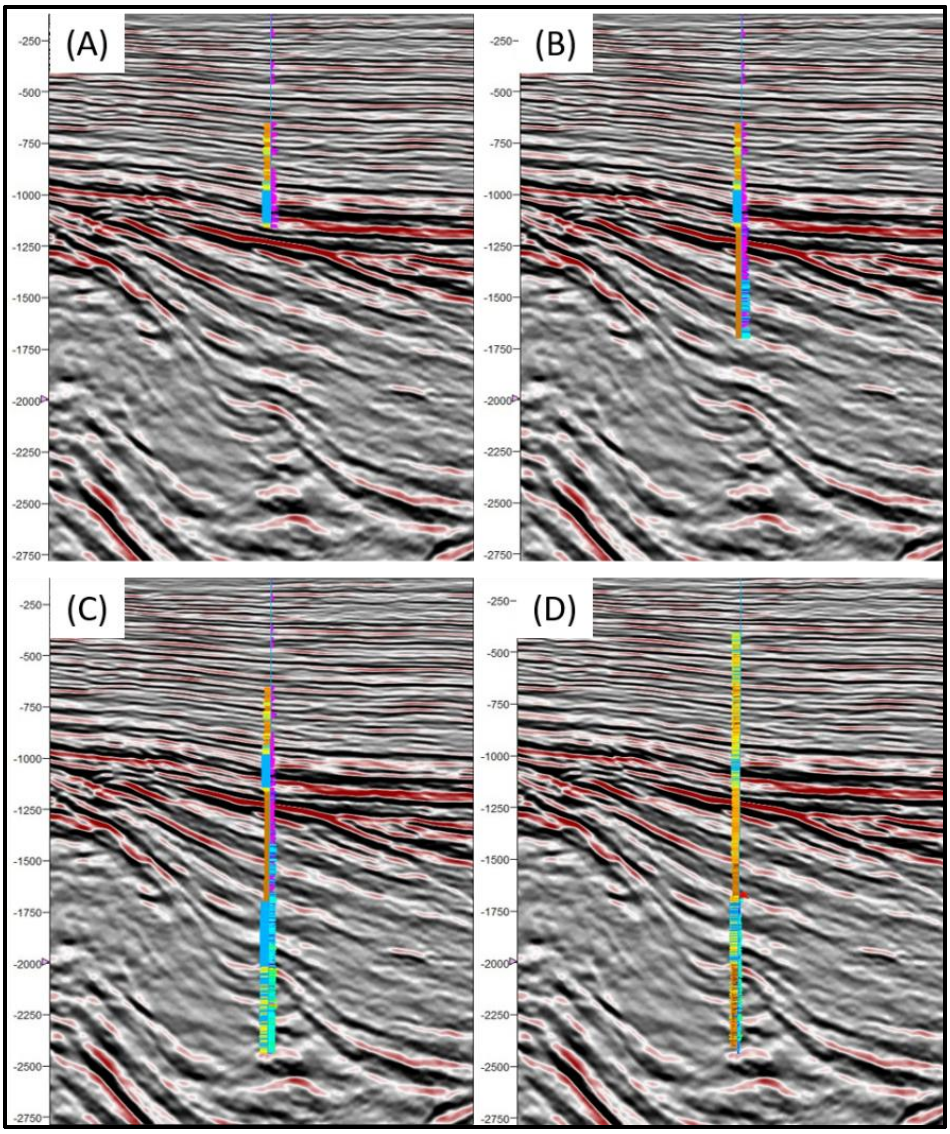

Figure 4 – Drilling evolution using pseudo_GR log (A, B e C). Acquired final GR log (D).

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