Density patterns of the Taciba Formation and sills (well 1HV_0001_SC), eastern Paraná Basin, Brazil.

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Abstract

The sedimentary rocks of the Taciba Formation record glacial events in the Paraná Basin, which were later intruded by sills of the Serra Geral Group during the breakup of the Gondwana Supercontinent. Density, caliper, well cutting sampling, and lithology data were integrated and used to obtain the distribution patterns of density values along the well and to assess the influence of volcanic intrusions. Additionally, the results are useful for estimating density differences between sedimentary rocks and magnetic data along the well. The sedimentary rocks of the Taciba Formation have a wide range of density, where the lowest values were recorded in the stratigraphic intervals with the highest occurrence of sandstones. Also, no increase in density values was observed in these rocks when in contact with volcanic sills. On the other hand, in shales, unaffected by intrusions, the density values are much higher.

Key words: Density, Taciba Formation, Well logs, Paraná basin.

Introduction

The density log (RHOB) is a continuous record of a formation called bulk density. It has been used primarily to determine inside density of large volumes of rock from well drill. Geologically, bulk density is a function from rock forming minerals (i.e. matrix), as well as the volume and composition of free fluids in porosity). The logging technique of density tool is to subject the formation to a bombardment of medium-high energy, collimated gamma rays, and measure their attenuation between the tool source and detectors. The survey method is unique for many important reasons; for example, it is sensitive to very small variations of formation density, the measurements are unaffected by fluids, rugosity, casing, cement, or invasion by drilling fluids (Beyer & Clutsom 1988; Rider, 2002; Liu 2017).

Caliper log measures variations inside borehole diameter along depth. The measurements are made by two articulated arms pushed against the borehole wall in lateral movement, the simple mechanical records of the arms is translated size and shape of a borehole. The importance of evaluating in the quality of geophysical survey such density, it is because shows weather or not the tool had been touched to borehole wall (Rider, 2002).

Itararé Group was stablished as the thickest lithostratigraphic unit of Paraná Basin. There consists of glacial and lateglacial sedimentary rocks, which represent the Permian assemblage of Gondwana Supercontinent. Taciba Formation records the latest upper sequence of Itararé Group succession. This formation is composed of sandstone, gravelly mud, diamictite, shale and some siltstone. (Schneider *et al.* 1974; França & Potter, 1988; Milani *et al.* 2007).

Also, remarkable sill intrusion affected the Taciba Formation of Paraná Basin during the breakup of Gondwana paleocontinent. This event was economically important because hydrocarbons are probably trapped and sealed by diabase rocks (França & Potter, 1988; Milani *et al.* 2007). Furthermore, this thermal heating event could affect the organic elements, changing them into petroleum.

The location of well 1HV_0001_SC is showing in the Figure 1, it intersects two diabase sills which provide an opportunity to estimate changes of the sedimentary host rocks of Taciba Formation regarding the Serra Geral magmatism in Paraná Basin. Thus, this work reports the results of density patterns and influence of twice sills intrusion and its implications on record.

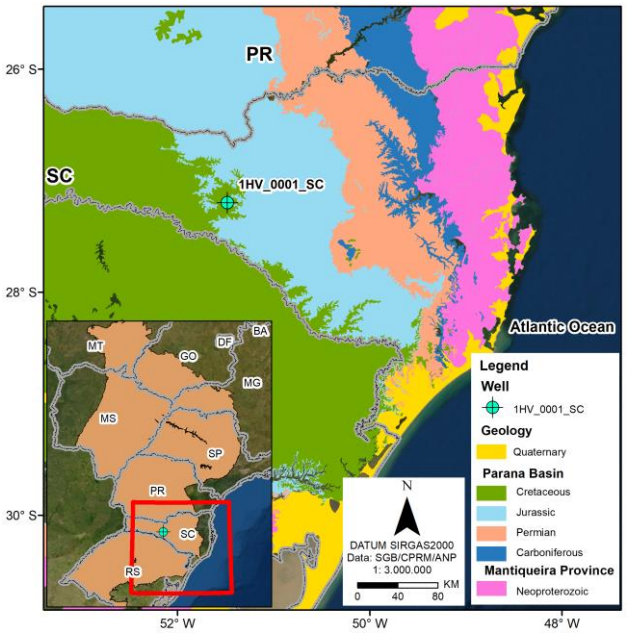

Figure 1: Geological map showing the Paraná Basin and study area of Well 1HV_0001_SC (SGB/CPRM/ANP, 2021).

Data and Methods

The data for the cartographic base of this work were obtained from the database of Geological Survey of Brazil (SGB/CPRM), and integrated by GIS software.

The well 1HV_0001_SC was drilled in 1972 when the PETROBRAS performed several surveys and borehole investigations of Paraná Basin in onshore areas, southern Brazil. This well was drilled to reach the basement rocks and verify an anomaly related to understanding an anomalous structure of Paraná Basin. As a result of exploration activities, large amount of data was acquired not only about outcrop but also the subsurface information of the wells. The geophysical logging data was provided by ANP (National Agency of Petroleum). This set of information is composed of lithology cutting reports during the drilling, wireline logging, and some accessories resources such as AGP files and profiles when the campaign was performed.

The workflow adopted that conduct the method in this research is described along: (i) the input tabulation of the data from reports during drilling were used to add information of sampling lithology cutting; (ii) The reviewed of lithostratigraphic data was made to improve the accuracy of limits between sills and sedimentary rocks; (iii) it was inputted in appropriate software to integrate them into a database of well logging.

The database used in this work involves wire-logging, from 2069 to 2575 depth meters, the resolution is 15.24 centimeter (0.5 foot) measurements. There is composed by caliper (in) and bulk density-RHOB (g/cm³) in DLIS data resource. It had been used for lithology cutting correlation and lithology interpreted from previous analysis. The processing involved the correlation, interpretation, and adjustments of lithostratigraphy interval limits. The products were made by statistics patterns and graphics.

Results

The final model outputs are plotted in Figure 2, which shows the profile with integrated data from well logging, lithostratigraphy, and lithology cutting samples during the drilling. The well cutting sampling indicates that the sedimentary rocks at well 1HV_0001_SC include sandstone, siltstone, shale, and diamictite; additionally, the magmatic rocks consist of diabase (Fig. 2). Sandstone predominates in the basal part of Taciba Formation, which locally a density average of 2.4 g/cm³. Above, it is a sequence of interbedded shales, siltstones and diamictites with minor amounts of sandstones. The interval between 2190 up to 2390 is represented, the middle part of interval, by siltstones, with the lens of shales and, sandstones. The upper part of this formation is mostly described as diamictites with some siltstones and shales bearing. Finally, the last register is composed of sandstone. Regarding the magmatic rocks, sill intrusion has been reported twice, from depth 2190 to 2202 and 2214 to 2318 meters, both emplaced between siltstones; the average density of diabase is 2.96 g/cm³.

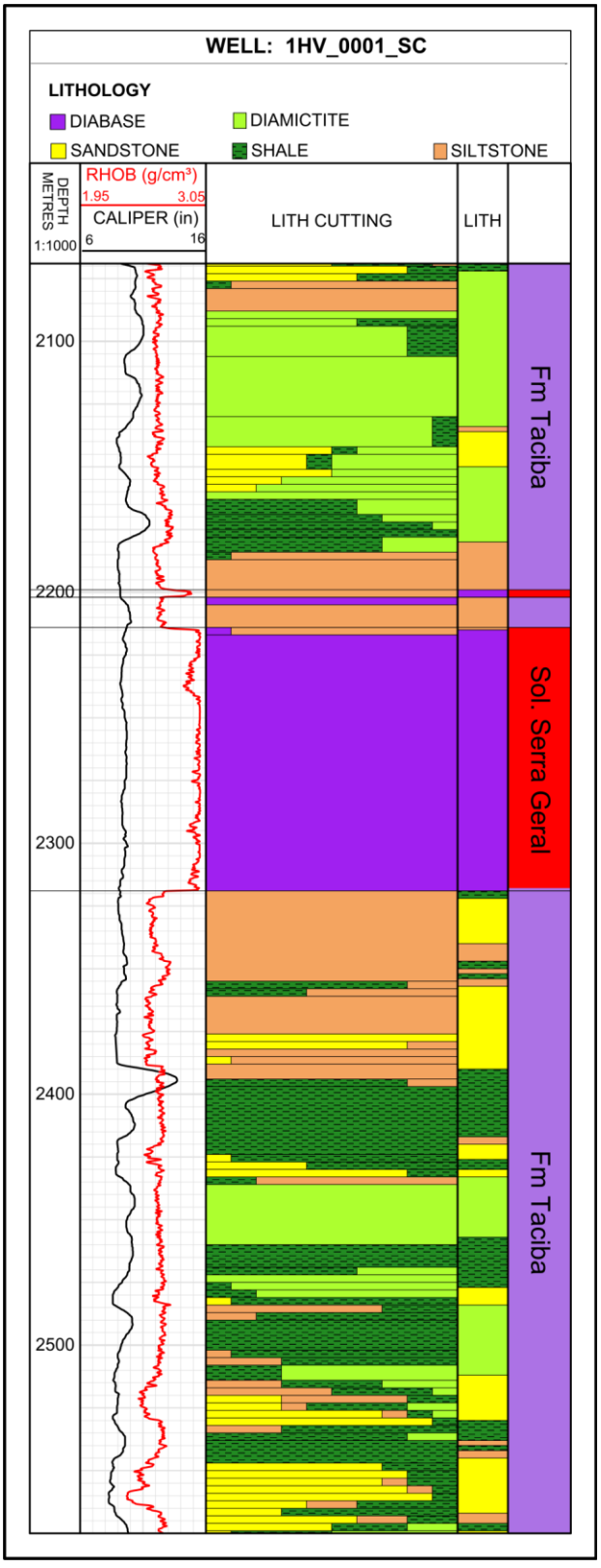

Figure 2: Lithology Cutting and Lithology inferred, lithostratigraphic column with geophysical logging of Well 1HV_0001_SC.

The caliper log gave the morphology and geometry of the well 1HV_0001_SC. It is important to verify if the efficiency of tool measurement was properly acquired. In this case, the caliper measurements assume enough quality during drilling the borehole.

On the other hand, the shales bearing rocks are more propitious to increase the diameter of the well (Fig. 2). As a result, the sandstones in lower portion of column shows an increasing of caliper diameter (Figs. 2, 4B and 4D). Additionally, the borehole diameter of diabase sills does not affect the mechanical aspects of rocks.

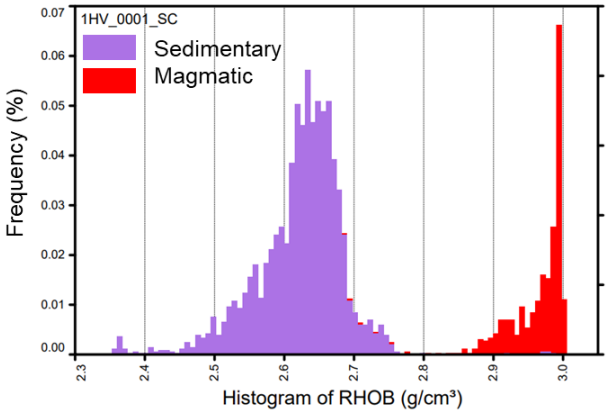

Figure 3: Histogram frequency of Density values.

The frequency of density values shows the distribution of RHOB logging measurements (Fig. 3). To estimate the behavior of the density values and investigate how this could affect the measurements of both rocks, the data were treated and interpreted separately. Thus, it was possible to verify that the statistical calculations indicate that the sedimentary rocks of the Taciba Formation have different density values.

Table 1. Density statistics values of 1HV_0001_SC

RHOB (g/cm³)	Taciba Fm. with Sills	Taciba Fm. without Sills
Values	3320	2612
Minimum	2.3585	2.3585
Maximum	3.0007	2.7617
Range	0.6421	0.4031
Mean	2.6943	2.6212
Geometric Mean	2.6901	2.6205
Variance	0.0230	0.0037
Standard Dev.	0.1517	0.0612
Median	2.6472	2.6317
Mode	2.9937	2.6325

These results represent both values of Taciba Formation with sills and without them, given 3320 and 2612 measurements, respectively. The segmentation of the Taciba Formation leads to estimate of the bimodal distribution; moreover, improvements in statistical calculations such as mean, variance, and standard deviations provide a proper behavior of data set distribution. The maximum density values were achieved from the diabase sill intrusion (3.00 g/cm³). Moreover, the lowest density values in sedimentary rocks correspond to the lithology of sandstones; otherwise, the highest density values logged were achieved in the shales. The basal sequence statistics values gave a greater range of density measurements, it has shown due to the diversity of grain size assemblage (Fig. 2, 4A and 4B).

Discussion and Conclusions

The density patterns of Taciba Formation (well 1HV_0001_SC) show considerable correlation with the lithology that compose it. This Formation is composed of wackestones, diamictites, and black shales with low-mineral and textural maturity (França & Potter, 1988). Due increase of sea level during deglaciation, the depositional cycles consist of a thinning size toward upper succession (Milani *et al*. 2007). The Interval data gives density ranges from as low as 2.35 for sandstone units to as high as 2.76 g/cm³ for shale in sedimentary rocks. The main mineral of those rocks is illite Costa *et al.* (2018), which is related to increasing of density values (Fig 4C and 4B). Not only the average density of shales might increase related to presence of illite mineral, but also when it fills the pore of sandstones.

The host rocks with diabase sills (i.e., central portion of the well) do not hold the highest density values; even when affected by heating from magmatism. Instead, shales occurrences above the sills show a higher density measurement. Furthermore, density log (RHOB) values do not reveal an important connection between pronounced changes in density and porosity from intervals surrounding the sill. It is probably due partly or wholly to porosity does not decrease in hosted rocks afterward intrusion. Therefore, the source of the magmatic heating related to sills intersected at 1HV_0001_SC and its ability to increase the density of host rocks such as siltstone is still uncertain. Additionally, the fluids would change to cement in the siltstones, which probably indicates this behavior of density values.

Acknowledgements

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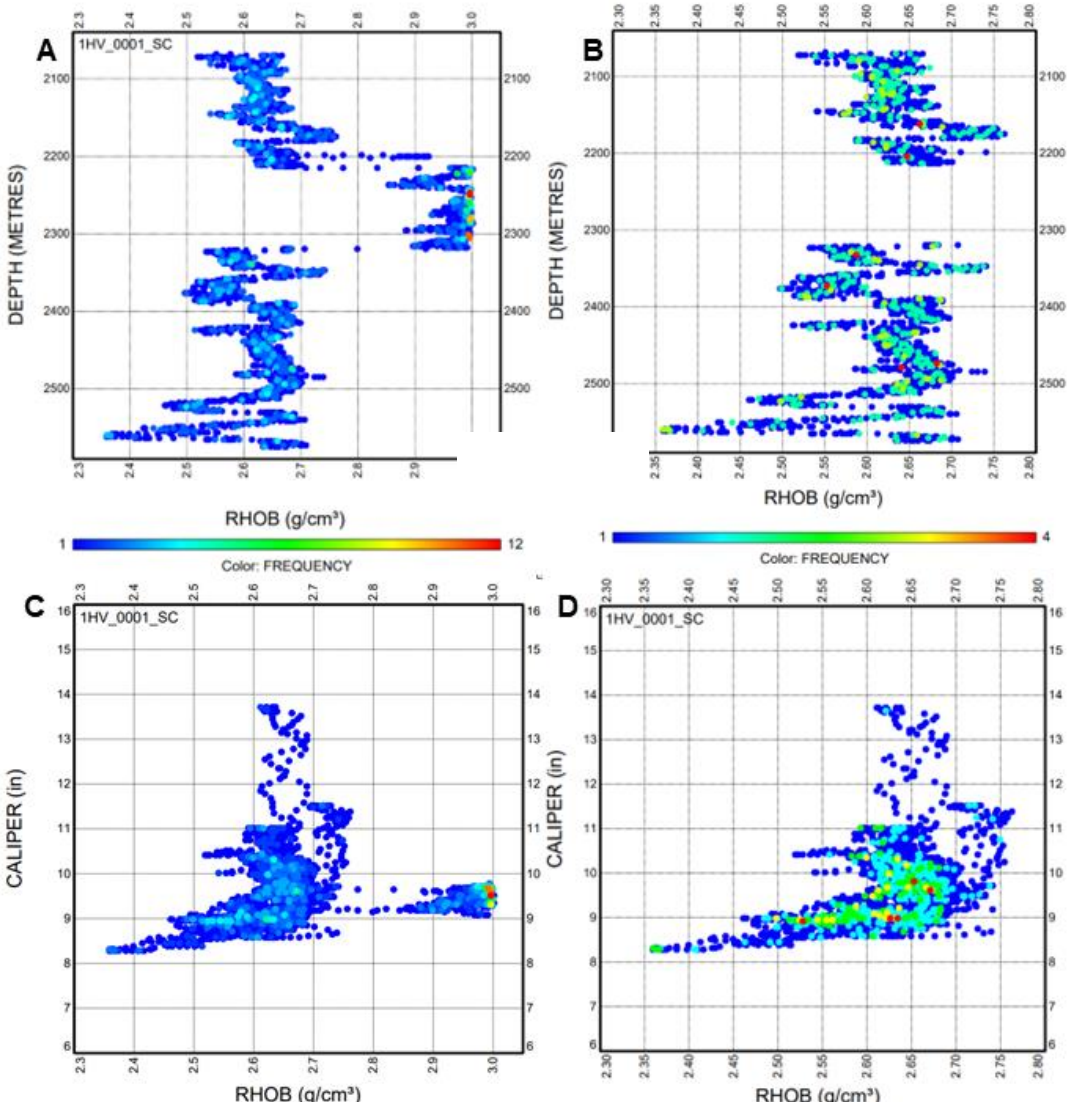

Figura 4 - Crossplot graphics of frequency values of density. A) Taciba Formation and Sills density values vs depth B) Taciba Formation without Sills density values vs depth C) Taciba Formation and Sills density values vs diameter D) Taciba Formation without Sills density values vs diameter.