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Consolidation of Field Knowledge

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Abstract

The cyclic variation of oil and gas prices, the advance of exploration in hostile environments, such as in ultra-deep waters and drilling through long salt formations, as well as new technologies in the drilled wells geometry are challenges in the upstream of the oil industry. The lessons learned in the development of such fields are an important source of knowledge that can be used to improve the construction of new wells, fulfilling industry needs regarding economical, environmental and operational levels, based on the E&P constant changes. One way to use this knowledge is to apply it in new projects, making sure is used in order to improve the technical solutions and mitigate risks, thereby avoiding or minimizing the effects of abnormalities found. This paper presents a post analysis methodology to implement a structure and data organization of drilled wells in an oil field. The developed work is within a larger project to combined geomechanical and operational information in order to achieve a holistic view of the field development in years to come. This research is under way in an offshore field in Brazil and has an objective not only to show the lessons learned, but also to identify the best in class examples to be followed in the future operations of this field.

1. Introduction

One question that arises during drilling in a given field is about the value of the aggregated knowledge of that field. In this sense, a possible answer can be drawn based on Figure 1. The graph shown in the figure compares the loss rate of exploratory wells and development wells in an offshore oilfield in Brazil from 1980 to 2005. Once can see that there has been a 14% reduction in lost wells.

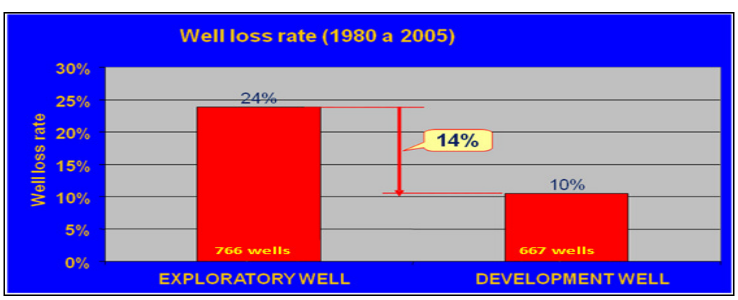

Figure 1: Comparison of the loss rate of exploratory and development wells in an offshore oilfield in Brazil, from 1980 to 2005.

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Another issue is that after the period of the development campaign of a field, the drilling engineers of this campaign usually leaves this activity: some embark once again, others start working in other fields, while others retire, etc. When the Infill Drilling campaign starts, the new engineers arrive, who received training in designing the well, but did not receive the knowledge of the field in which they will be working. The knowledge of the previous team is not recorded in an explicit manner; they took such knowledge with them.

In this context, the methodology proposed herein seeks to rescue and expand the knowledge of the field through the re-reading of data and information recorded as well as to facilitate the consolidation and dissemination through the use of graphical information that compares what is expected (standard reference) with the information acquired.

In general, the methodology includes studies on:

- Geological and geomechanical information of the field, such as lithologies drilled, fracture gradient, pore pressure, and stress in situ;
- Technologies applied in the field and the success and failure factors found;
- Usual depths of casing shoes in the field;
- Abnormalities that have occurred in drilling and the causes found, stratified by local tectonism (azimuth, inclination), per lithology, and per drilling technology (well phase, dogleg, fluid type and weight);
- The same abnormalities shown in the form of risk maps per well phase;
- Criteria to define best performance, such as relative time of the phase ("total construction time of the phase" / "total length of the phase") and metric cost of the phase;
- Cases of best performance (best-in class) for each phase of the well, with the operational sequence executed and the parameters used in drilling;
- Performance Analysis of drill bits in relation to the rate of penetration (ROP) and the duration of the phase.

To develop this work, the whole range of data that are recorded during the drilling of each well were collected, such as: daily drilling report; directional report (survey); casing and cementing report; bit and BHA reports; fluid report; mudlogging; lithological profile; and profiles of interest of the drilling.

Processing and analyzing all this information at once is not a trivial task. The difficulty includes the search for and collection of large amounts of data, as well as the quality control of such data. This work is aided by the use of graphical tools that allow one to examine various parameters of several wells simultaneously.

2. Methodology

The methodology was applied in a Brazilian offshore field with more than 200 wells drilled.

We sought to structure the information for each well in a graphical manner. Initially we structured the information regarding technology, lithology, casing and depth of shoes, abnormalities, durations, ROP, and bit performance.

We also used several graphical analyses already established and widely practiced in the industry, for example: lithology x casing and depth of shoes, and comparison of time x depth (TxD) curves.

Other types of analysis were proposed, because they proved useful to establish correlations in the field, such as abnormality x azimuth, abnormality x lithology, abnormality x inclination, risk map per phase, ROP x total duration of the phase, abnormality x cause.

The structuring of this information in graphical format allowed conclusions about patterns of occurrence of abnormalities and operational behaviors of major interest in terms of risk, cost and quality of the well, i.e., the lessons learned to be avoided and the best performances to be pursued.

The record of these graphs with the findings compose a knowledge base on the wells drilled in the field. The result of this study was validated with the professionals who work in the field.

Thus, this knowledge ceased to be implicit (it was the domain of the professionals who worked in the development of the field) and became explicit for the Company, and is available for new professionals. This knowledge base has now become a company asset, rather than a by-product of the process.

3. Data Management

All the data of each well were collected from their respective data repositories of the Company and fed into a single software system. This system was developed with a focus on structuring the analysis of the drilling data and various comparisons of multi-well data, as in the example shown in Figure 2 below:

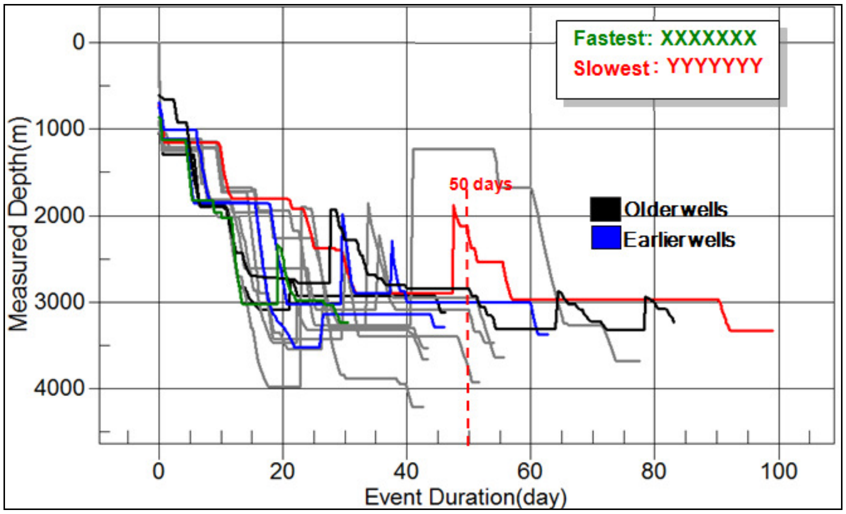


Figure 2: Comparison of the Time x Depth curve of the wells in the field made with the technology of construction of pilot well + horizontal. The green line is the fastest while the red is the slowest well in this set.

We also used another software system that accesses the database of the system described above, allowing us to correlate distinct drilling data for the set of wells studied. This tool allowed us to search for the various correlations that indicate drilling patterns that are desirable or that should be avoided. Figure 3 shows an example of such a correlation.

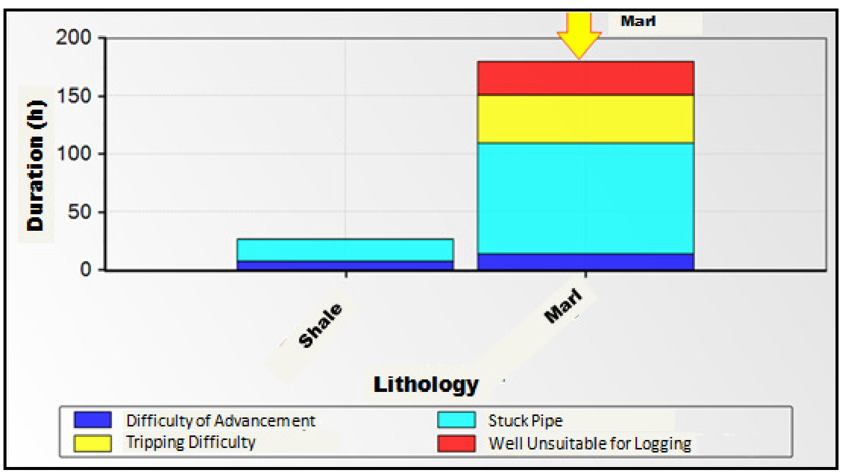


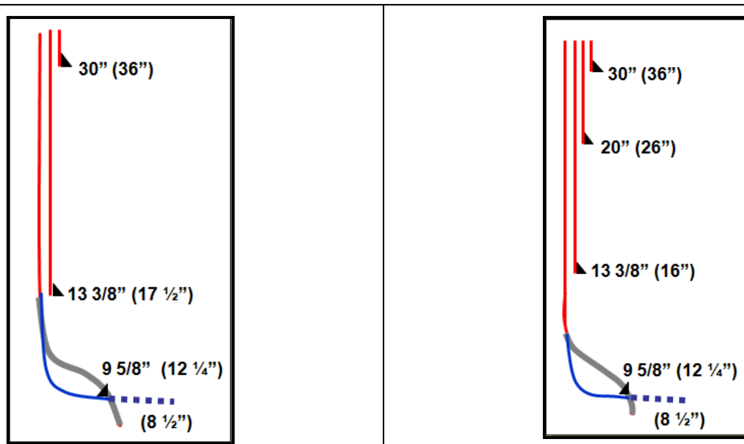
Figure 3: Graph showing non-productive time x lithology. This figure was obtained from the records of occurrence of Difficulty of Advancement, Tripping Difficulty, Stuck Pipe and Well Unsuitable for Logging, its duration, and the lithology where each abnormality occurred in the various correlation wells.

4. Knowledge of Drilling in the Field

To exemplify the application of the methodology, a few case studies and their conclusions are presented below.

4.1 Technologies Applied in the Field

Analyzing the geometry of the wells, 14 technologies were identified as used in the field over time. Two examples with their respective periods of usage are shown in Figure 4.



"Slender" Pilot Well + Horizontal 1999-2004	Conventional Pilot Well + Horizontal 1998-2006

Figure 4: Examples of technologies used in the geometry of the wells drilled in the field.

This classification of technologies is essential – in the continuation of the study – for selecting the phases that are comparable among one another. For example, the 20" surface phase can be compared regardless of the well technology. However, the 9 5/8" phase must undergo classification between vertical, directional and horizontal wells to allow fair comparison.

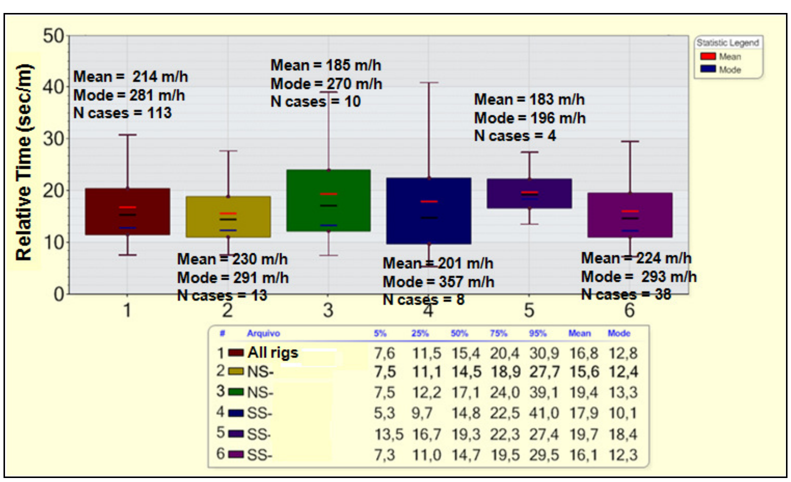
4.2 Performance Analysis

4.2.1. Performance Analysis of the Rigs that Operate in the Field

The operations of the wells made in the last five years received a codification whose statistical time distribution allowed to compare the distribution curve (log normal) of trip speeds, casing trip-in, running BOP and durations of preparing the rig for each of these tasks.

This approach allows us to compare the efficiency of the rig that comes to drill a new well in the field, with its own historical data (if the rig has been operating in the field) or with the performance of all the rigs that have operated in the last five years.

Below is an example of monitoring the performance of the Rig in a specific operation of a given well.



#	Arquivo	5%	25%	50%	75%	95%	Mean	Mode
1	All rigs	7,6	11,5	15,4	20,4	30,9	16,8	12,8
2	NS-	7,5	11,1	14,5	18,9	27,7	15,6	12,4
3	NS-	7,5	12,2	17,1	24,0	39,1	19,4	13,3
4	SS-	5,3	9,7	14,8	22,5	41,0	17,9	10,1
5	SS-	13,5	16,7	19,3	22,3	27,4	19,7	18,4
6	SS-	7,3	11,0	14,7	19,5	29,5	16,1	12,3

Figure 5: Box Plot graph of relative time (sec/m) obtained in the trip-in operation in an open well, for all rigs (case 1) and each rig individually (case 2 to 6). The data collected to generate this graph is used in the operational monitoring shown in Figure 6.

Note: The choice of using the "relative time" (sec/m) as a metric of comparison over time is due to the fact that *time* is the main variable that is subject to log-normal distribution, and not *depth*.

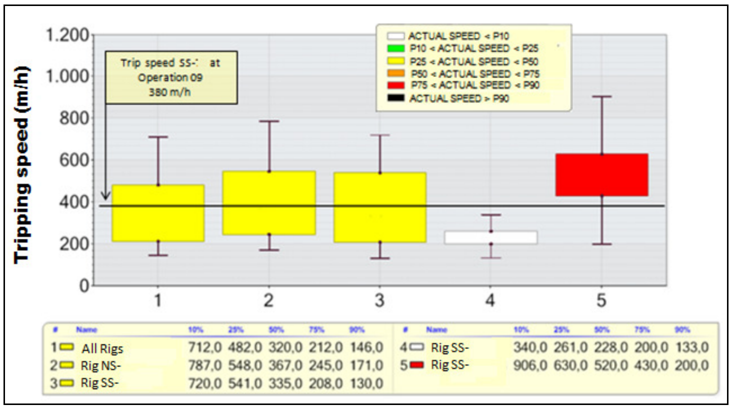


Figure 6: Graph showing the performance of the rig generated immediately after the completion of a trip-out operation in an open well. Through the graph, one can verify that the rig carried out this operation (horizontal line) fits in the 2nd quartile (between P25 and P50), compared with the history of all rigs (case 1). This graph is than distributed to all personnel involved in the operation of the well, including the personnel on board the rig. To facilitate communication, the data is generated in relative time (s/m), but shown graphically in speed (m/h).

It is anticipated that frequent monitoring in the drilling of new wells in this field will help control the process of carrying out the operation, thus reducing the difference between P90 and P10 for each parameter analyzed, representing a real and measurable gains from the application of this methodology.

4.2.2. Performance Analysis of Well Operations

As mentioned in section 4.1, the classification of the technologies used in the geometry of the well facilitated the definition of phases of wells and be able to compare one to another. The phases with the following structure were studied:

- Conductor Phase
    - Drilled Conductor Phase
    - Jetted Conductor Phase
- Surface Phase
    - Surface Phase in Conventional Wells
    - Surface Phase in Slender Wells
- Intermediate Phase
    - Vertical Intermediate Phase 13 3/8"
    - Directional Intermediate Phase 13 3/8"
- Pilot Phase
- Production Phase
    - Vertical Production Phase 9 5/8"
    - Directional Production Phase 9 5/8"
    - Horizontal Production Phase 9 5/8"
- Drill In Phase
    - Vertical Drill In Phase 8 1/2" or 9 1/2" PA
    - Directional Drill In Phase 8 1/2" or 9 1/2" PA
    - Horizontal Drill In Phase 8 1/2" or 9 1/2" PA
    - Vertical Drill In Phase 6 1/8" PA

- Directional Drill In Phase 6 1/8" PA
- Horizontal Drill In Phase 6 1/8" PA
- Vertical Drill In Phase with Liner 7"
- Directional Drill In Phase with Liner 7"
- Horizontal Drill In Phase with Liner 7"

For each phase listed above, we surveyed the set of wells that had the specific phase in its construction and, for this set of wells, we calculated the histogram of the phase length, the total duration of the phase, and relative time of construction of the phase (total time of construction of the phase / phase length). Based on the histogram, we calculated the probabilistic distribution curve of each parameter (normal distribution for length and lognormal for duration and relative time), and the mean and the mode of each parameter. Figures 8 and 9 show some examples of this study.

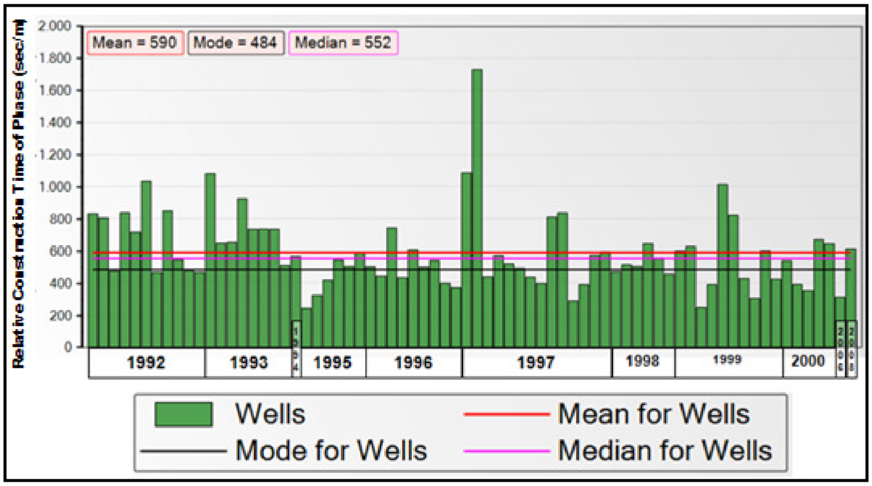


Figure 7: Relative Construction Time of Directional Production Phase 9 5/8".

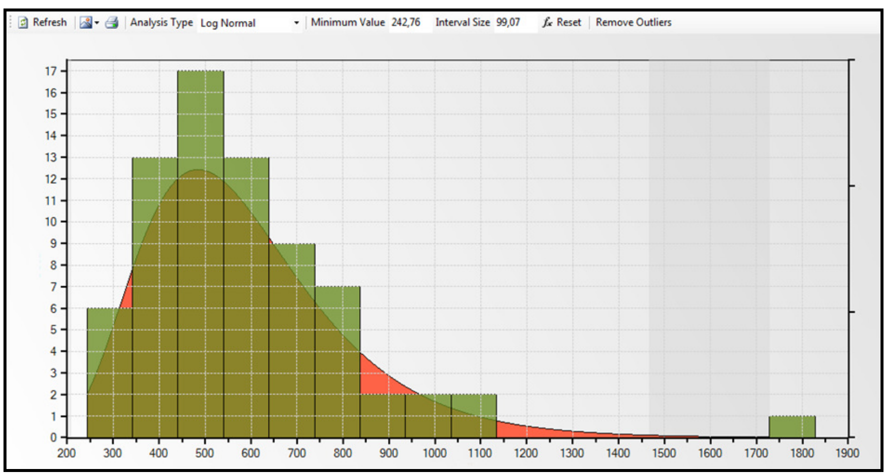


Figure 8: Lognormal distribution curve for the histogram in Figure 7.

The well that had the shortest relative time of construction of the phase was considered the one with the best performance (Best-in-class) and had its drilling parameters fully described in the study. These parameters should be pursued in the similar drilling phase of next wells.

4.3. Study of Abnormalities

For each phase studied, we calculated the abnormalities that occurred by time and quantity, as shown in Figure 9.

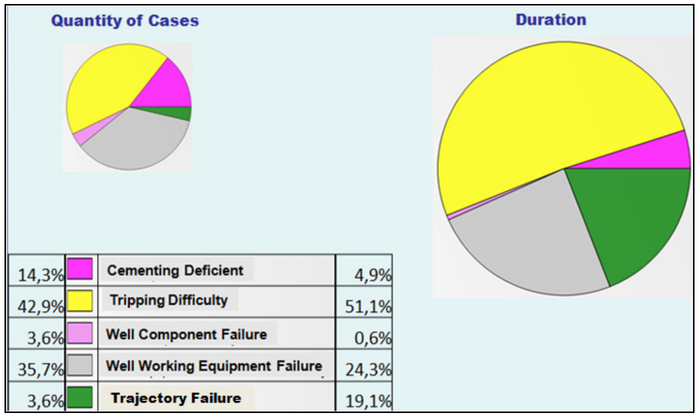


Figure 9: Abnormal Occurrences, by number of cases and by duration for the Surface Phase in Slender Wells. One can see that Tripping Difficulty (in yellow) is among the greatest impact, not only by duration but also per number of cases.

The abnormal occurrences were also plotted against azimuth, inclination and lithology.

4.4 Consolidated Report of Correlation Wells

The studies of abnormal events mentioned above were performed for all wells in the field (as presented in this study) and also separately for each phase listed in item 4.2.2.

Additionally, these same studies can be developed very quickly just for the set of correlation wells for future wells to be drilled in the field. In this case, with a reduced set of wells (approximately 8 to 10 wells), other more specific analyses are added, including the following:

- Abnormal Occurrences x Azimuth drilled (in order to verify if it is possible to indicate any azimuth to be avoided) (as shown in the example in Figure 10);
- Plotting abnormal occurrences on a map near the next well to be drilled;
- Lithology x Casing Designs and Shoes Depths.

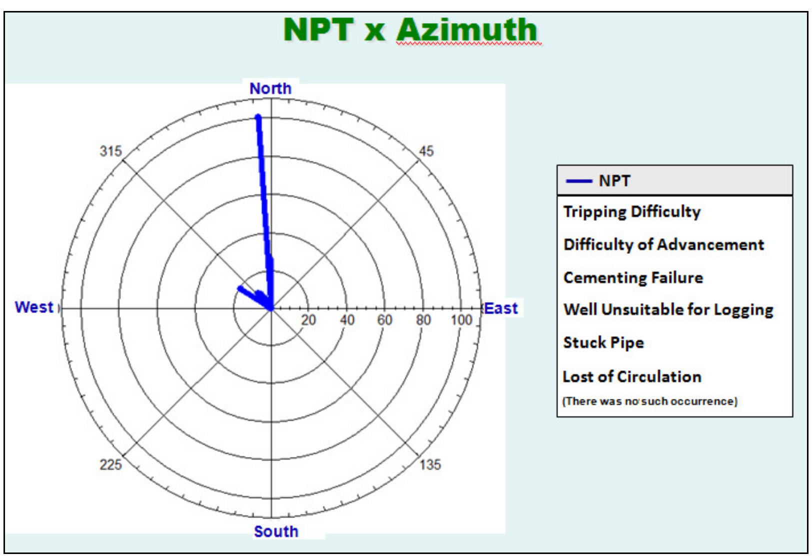


Figure 10: NPT x Azimuth for the correlation wells, indicating the incidence of abnormalities in the direction N5W that, if possible, should be avoided in the drilling of the new well.

4.4. Bit Analysis

For each step listed in item 4.2.2, two types of graphs were prepared to analyze the best-performing bits in each phase. Examples of these graphs are shown in Figures 11 and 12.

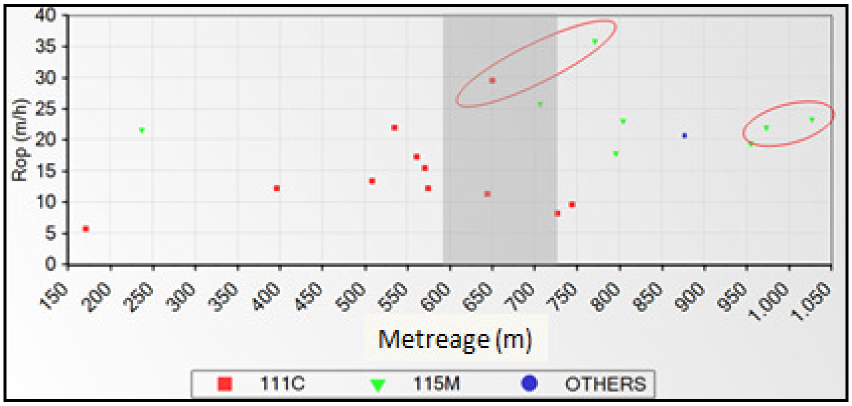


Figure 11: Graph showing ROP x Length drilled, for each IADC code applied, for 17½" tricone bits. Note that the IADC code 115M presented higher ROP for the longest drilled length, while the IADC code 111C had the highest ROP in the mean length of the phase (shown in the darker stripe on the graph).

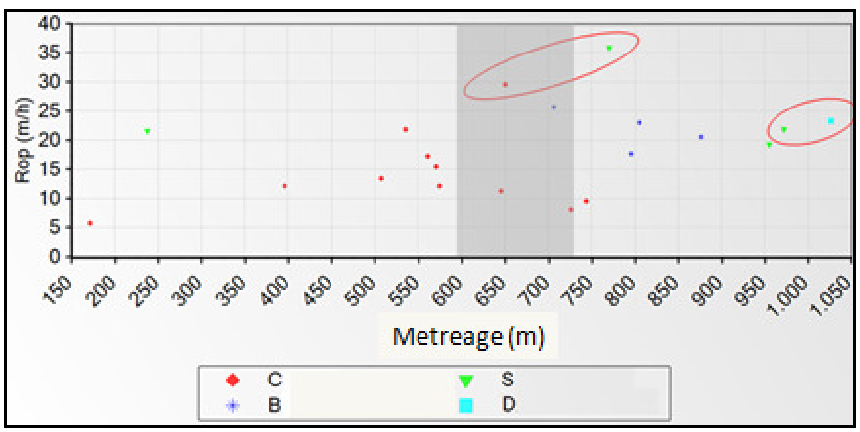


Figure 12: Graph showing ROP x Length drilled, classified by bit manufacturer, for 17½" tricone bits. Note that the bit from manufacturer S presented the highest ROP and the second in longest drilled length, while manufacturer D had the longest drilled length and manufacturer C had the highest ROP in the mean length of the phase (shown in the darker stripe on the graph).

5. Conclusions

The methodology developed in the study of this field allowed us to show the correlation between various drilling parameter, the majority of which had already been perceived by professionals who have worked and are currently working in the field, but were not explicit as knowledge of the Company. This study makes it possible to update new professionals who join the drilling operations staff in the field.

Performance evaluation of the operation of the well, through the selection of the well that best drilled each phase studied, allows one to know the drilling parameters that have shown the best performance and the respective results that should be pursued or superseded in the drilling of the next wells.

The performance analysis of the rigs that have operated in the field, in the last five years, allows an assessment of the rig that is executing the next well in the field. By measuring the speeds of each operation and presenting a comparison with the history of the field, the professionals involved in the process are able to assess the performance thereof and, where appropriate, to control and improve the process.

The study of applied technologies in the field allows comparisons that lead us to know what has been done and which options presented the best results. The geological and geomechanical information of the field, as well as the study of abnormalities occurring in the wells and their correlation with direction, lithology, fluid, and area of occurrence, allow one to know the operational risks that should be avoided in future wells.

The software tools used in this methodology allow the search, combination and easy presentation of a large amount of information. These tools are essential resources for the development of the study.

The consolidated report of correlation wells that can be obtained from the knowledge base compiled by the study presented herein is the basis for the design of new wells in the field that contributes to the management of Well Engineering in the optimization of performance for each well construction.

6. References

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