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CONTRIBUTION OF THE ACOUSTIC IMPEDANCES AND PETROPHYSICAL PARAMETERS TO LITHOLOGY AND FLUID DISCRIMINATION IN OFF-SHORE DEPOSITS, WEST NILE DELTA, EGYPT

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مساهمة المعاوقات الصوتية والبارامترات البتروفيزيائية فى تحديد الليثولوجية والتشبع بالموائع فى الرواسب البحرية فى غرب دلتا النيل، مصر

الخلاصة: تعتبر دراسة الخواص و المكونات الصخرية و تحديد السوائل المشبعة بها، من ضمن أهم الأهداف في دراسة خصائص الخزان. ساعدت الآبار المحفورة (A و B) في المنطقة علي دراسة و تحليل الخواص الفيزيائية لمنطقة الدراسة، باستخدام تسجيلات الآبار مثل: تسجيلات أشعة جاما، المقاومة، الكثافة، النيترون، الصوتية و المركبة. ساعدت هذه التسجيلات علي تحديد سمك الخزان، معرفة التكوينات الصخرية، و السوائل المشبعة بها. تبين من تسجيلات الآبار، أن خصائص الخزان المتواجدة في الشمال تختلف عن الموجودة في الجنوب. تبين أن الخزان في الجزء الشمالي يتميز بجودة عالية من الصخور، بوجود الحجر الرملي الصافي و مشبع كليا بالغاز، بينما يحتوي الجزء الجنوبي من الخزان علي حجر رملي مخلوط (مدمج) بطفلة (طين) و افتقار الخزان للجودة العالية بالإضافة إلي تشبع هذا الجزء ببقايا الغاز و المياه. تحققت دراسة الخواص الفيزيائية أيضاً عند دراسة العلاقات الثنائية بين معاوقات الموجات التضاغطية مع العمق، معاوقة الموجات التضاغطية مع أشعة جاما، ومعاوقة الموجات التضاغطية مع معاوقة الموجات القصية، المسجلة في الآبار، و أدى هذا الي إضافة معلومات جديدة عن الخزان و التفريق بين المكونات الصخرية و تحديد السوائل المشبعة بها.

ABSTRACT: *The discrimination of lithologic and fluid contents has been achieved by cross plotting the log data of two wells encountered in a channel located, off-shore West Nile Delta, Egypt. Cross plotting the log data of the two wells A and B, on the same plot, helped in comparing the properties of the reservoir at different well locations. This has been successfully achieved using depth, Gamma-ray, and P- and S- impedances data. Moreover, the same cross plots were used individually for each well using the Gamma-ray, Resistivity and Density logs as the color code. Logs of well A shows that the reservoir is characterized by clean and blocky sands, fully saturated with gas; while well B is characterized by sands inter-bedded with shale, and filled with residual gas and water. When appropriate pairs of attributes are cross-plotted, the common lithologies and fluid types can be discriminated and provide a straightforward interpretation.*

INTRODUCTION

Cross plots are a convenient way to demonstrate how various combinations of logs respond to lithology and fluid. The Cross Plot is used to plot one attribute against another, and to look for relationships between these attributes. Log data can be treated as a result of a controlled experiment, where various rock properties are measured in the subsurface. Rock and fluid prediction, away from well control, requires understanding of how rock's bulk and seismic properties are linked to each other and how they vary with geologic age, depth and location (Schlumberger, 1989; Hampson-Russell, 2004 cross-plot; and Dvorkin, 2008).

Rock Physics provides the connections between elastic properties measured at the surface of the earth, within the borehole environment or in the laboratory with the intrinsic properties of rocks, such as mineralogy, porosity, pore shapes, pore fluids, pore pressures, permeability and the overall architecture, such as laminations and fractures. Rock Physics provides the understanding and theoretical tools required to optimize all the imaging and characterization solutions based on elastic data (www.rockphysicists.org). Cross plotting of attributes was introduced to visually display the relationship between two or three variables (White, 1991). When appropriate pairs of attributes are cross-plotted, the common lithologies and fluid types often cluster together, providing a straightforward interpretation (Chopra and Marfurt, 2005).

Discriminating between the different lithologies and fluids is one of the main objectives of a reservoir characterization study. Logs are one of the most important tools used to study the rock properties of the reservoir. This has been accomplished by cross plotting the log data like: depth, Gamma-ray, P- and S- impedances, color-coded by the wells, which encountered a channel located, offshore, West Nile Delta, Egypt. The same cross-plots were applied in Delhi Field, Louisiana by Mustafayev and Davis, (2011). Moreover, the same cross-plots were used individually for each well, using Gamma-ray, Resistivity and Density logs, as the color code. This is successfully accomplished using Landmark R5000, Hampson-Russell version CE8R44 E-log module and Tech-Log 2009 version.

METHODOLOGY

The target is to cross-plot the appropriate attributes, against each other, to analyze the petrophysical parameters. The cross plots between two or three variables were carried out along the zones of interest 1584-1714m and 1593-1775m of the two wells A and B, respectively. Figure 1 shows the locations of wells.

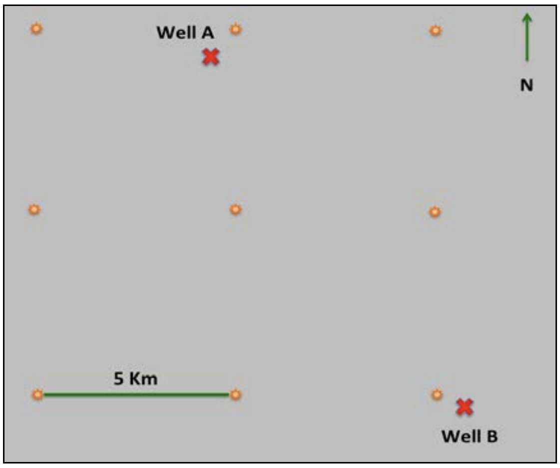
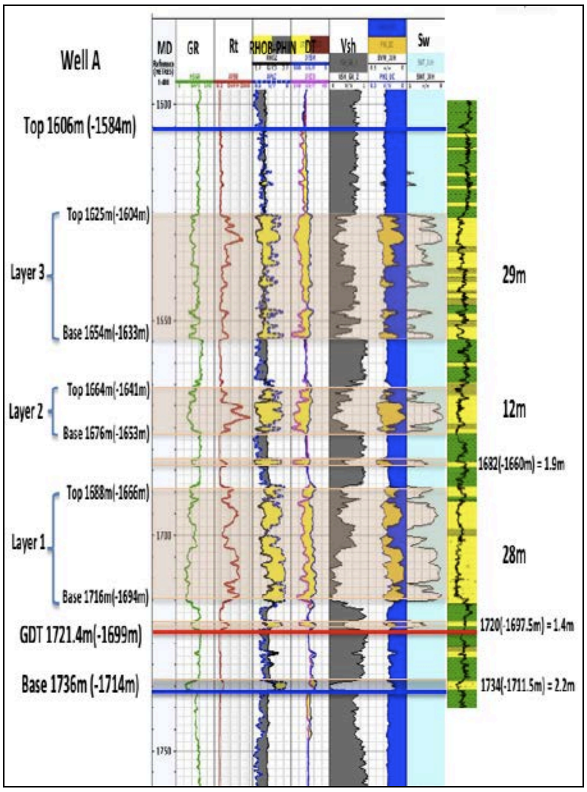


Figure (1): A base map showing the locations of the wells.

The selected logs (figure 2) are dependent on the elastic properties of the subsurface rocks, which needed to be investigated. Gamma-ray, resistivity, density, The P-impedance and S-impedance logs are data to be used in analyzing the petrophysical parameters of A, and B wells. Select the logs (attributes) to be cross-plotted against each other, as well as the color code. A cross-plot of two or three or more variables, based on the target or the properties needs to be investigated. The interpretation of the cross-plots will be straightforward, when appropriate pairs of logs are cross-plotted. Therefore, it is easy to understand the rock properties of the evaluated interval.

(A)



(B)

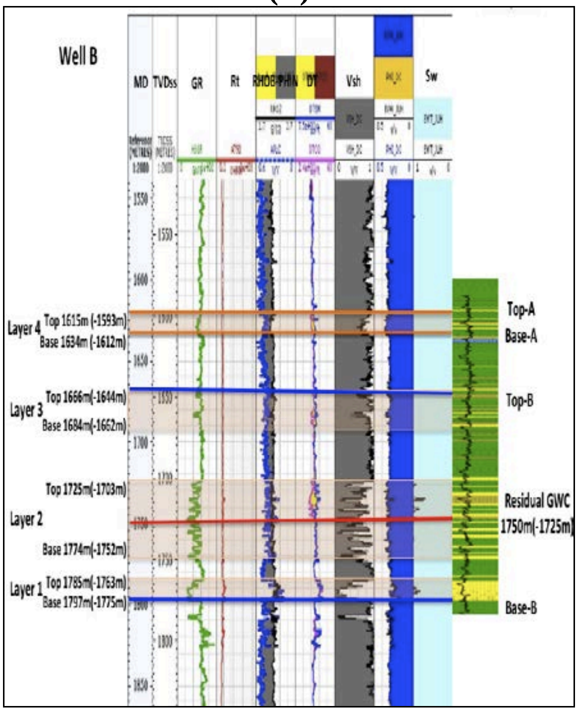


Figure (2): Logs of A and B wells.

RESULTS

1- Cross-plots of well A and well B:

The cross-plot of the P-impedance versus depth for both wells, A and B (Figure 3) demonstrated that, there is a difference in the P-impedance values of both wells. In well A, the top of the reservoir is at 1584m (TVDss), while the base is at 1714m (TVDss). Well B, the top of the reservoir is at 1593m (TVDss), while the base is at 1775m (TVDss). It is obvious that the P-impedance of well A is relatively lower than that of well B. The plot can be used to distinguish between the gas sands (softer), shale and brine sand (harder). The shale has a higher impedance than the gas sand and has a lower impedance than the brine sand. Usually the relatively soft sands are found at relatively shallow depths, where the sands are unconsolidated. At greater depths, the sands become consolidated and cemented, whereas the shales are mainly affected by mechanical compaction (Avseth et al., 2005).

The cross-plot of the P -impedance vs. GR of both wells (Figure 4) is used to discriminate the clean sand from shale, even if there is a similarity in the P-impedance values. It is obvious that, well A has cleaner sands than well B. Sands of well B are inter-bedded with shale, so that's why they have higher gamma-ray values than the sands of well A. In this case, GR values are used to help in differentiation between the lithologies in the P-impedance domain.

Using the data of the P- and S-impedances (Gassman's equation, 1951), one could discriminate between the different fluids (Figure 5). The first trend on the left with a low P -impedance is the gas sand trend, while the other trend on the right with a high P-impedance is the background shale trend.

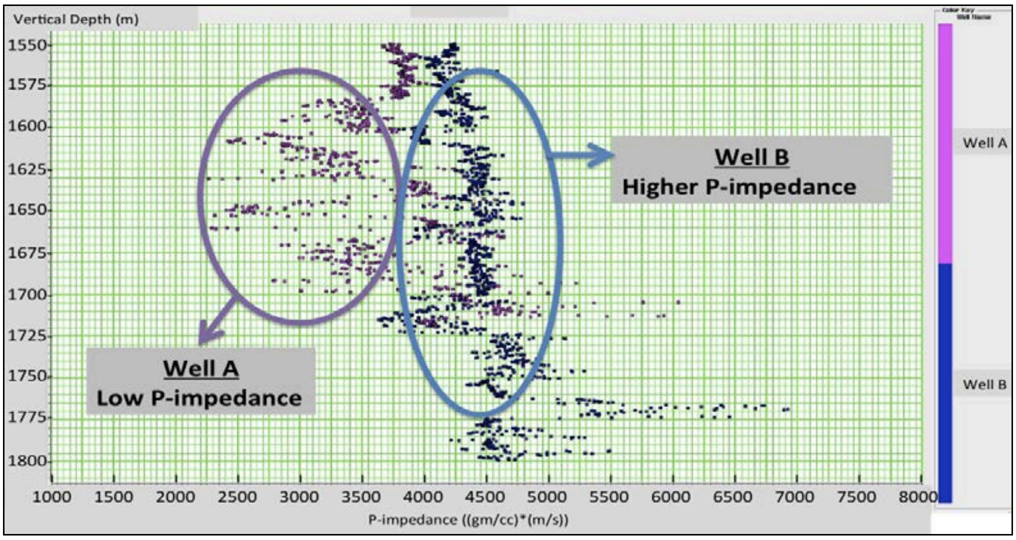


Figure (3): The P-impedance versus vertical depth cross-plot for the two wells.

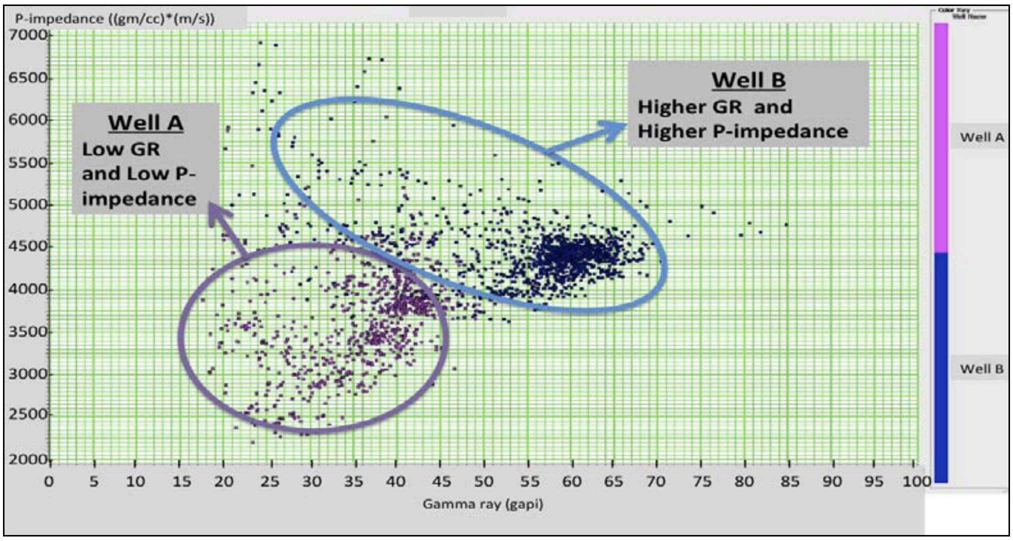


Figure (4): The gamma-ray versus P-impedance cross-plot for the two wells.

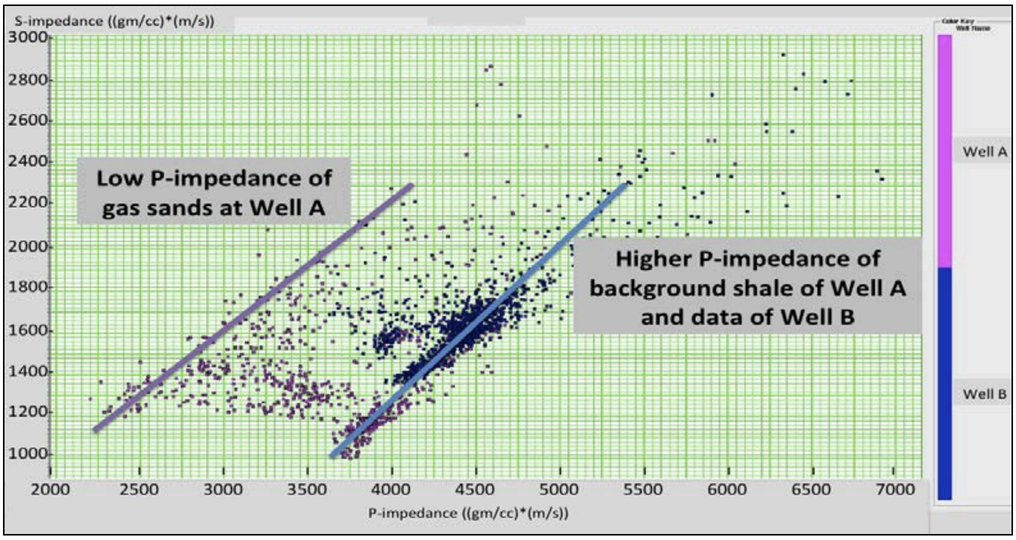


Figure (5): The P-impedance versus S-impedance cross-plot for the two wells.

The above-mentioned cross-plots give an idea about the petrophysical parameters of the reservoir itself. It helps in discriminating between the different lithologies and fluids. The same cross-plots are used for each well, individually, using the gamma-ray, resistivity and density logs, as a color code.

2- Cross-plots of each well individually:

2.1- Cross-plots: P- impedance versus depth:

The first cross plot (Figure 6) is between the P-impedance versus vertical depth and the color code of gamma-ray log values is used to differentiate between the sands and shales. There are three sand layers, Sand 1, Sand 2 and Sand 3. Well A: The three gas sands have low The P-impedance, from depth 1584 to 1699m (Gas Down To, GDT level) and all the sands have low gamma-ray values, because they are clean sands. Well B: The sands are characterized by higher gamma-ray values, because they are inter-bedded with shales. The residual gas-water contact is at depth 1725m, within Sand 2 (the upper part is filled with residual gas and the lower part is filled with water).

The sands, from depth, 1593 to 1725m (Sand 3 and a part of Sand 2), are filled with residual gas and show relatively lower P-impedance than that of the background shale.

The sands (a part of Sand 2 and Sand 1), from depth, 1725 to 1775m, have higher impedance than the background shale, because they are brine sands.

The same cross-plot of the P-impedance versus depth was generated using the resistivity log data, as the color code (Figure 7) this plot is used to discriminate between different fluids. Well A, the clean sands are characterized by high resistivity (<1000 ohm.m) and low P-impedance, due to the presence of gas. Well B, the resistivity is low (<10 ohm.m), due to the presence of residual gas and water.

The presence of residual gas can be investigated, using the density tool (Schlumberger, 1989). The plot of the P-impedance versus depth was generated, using the density log data, as the color code (Figure 8). This plot shows that, there is a subtle difference between the commercial gas and the residual gas, because the presence of residual gas over water within the sand layer will make it denser than the gas sand layer. Dewan, (1983), Schlumberger, (1989), and Brie, et al., (1998); stated that, the presence of gas would affect the bulk density readings and cause them to decrease. The density of sand sample fully saturated with gas is not as dense as that partially saturated with gas or even saturated with water. In well A, there is a huge difference between the density of gas sands and the background shale, while in Well B, there is a subtle difference between the residual gas sands and the brine sand.

2.2- Cross-plots: P- versus S-impedances:

Cross plotting between the P- and S-impedances of each well individually demonstrated to apply Gassman's equation (1951) and to discriminate between the lithologies based on different fluid contents (Mustafayev, and Davis, 2011). The gamma-ray and resistivity log data were used, as the color code, to differentiate between the pay sands and the background shale. When the gamma-ray log data were used as the color code (Figure 9), for well A, the left trend is the sand trend, while the right trend is the background shale trend, while for well B, there's almost one trend, because the sands are inter-bedded with shale. The color code was changed using the resistivity log data for the same plot (Figure 10), for well A, the left trend, which shows gas sands (low P-impedance and high resistivity) and the right trend is the background shale, while for well B, there is almost one trend and very low resistivity.

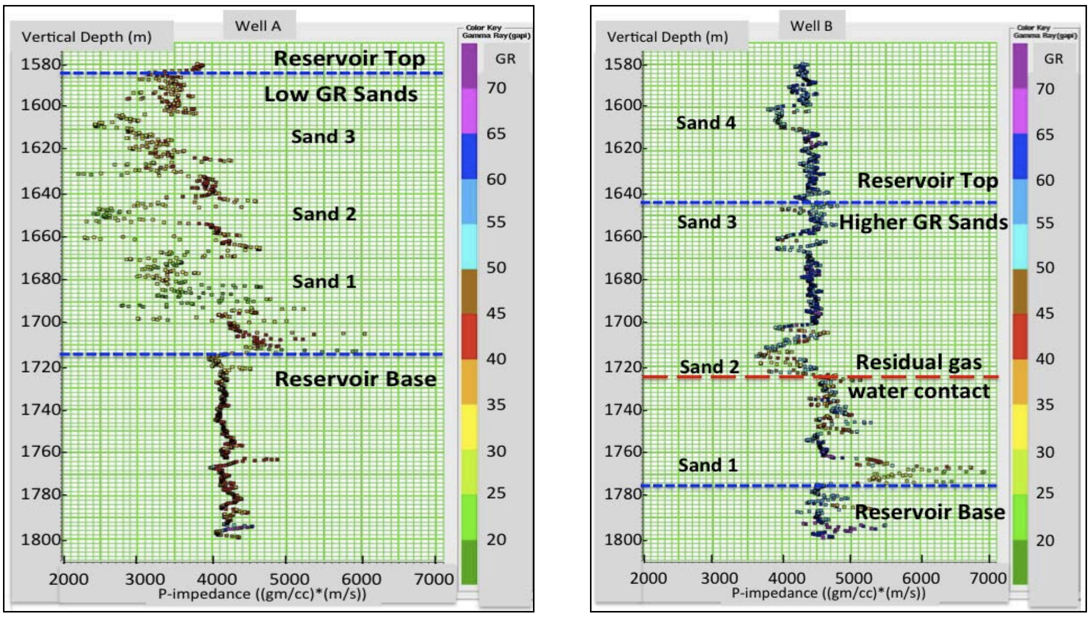


Figure (6): The P-impedance vs. vertical depth cross-plots for the two wells (the color code is gamma-ray data).

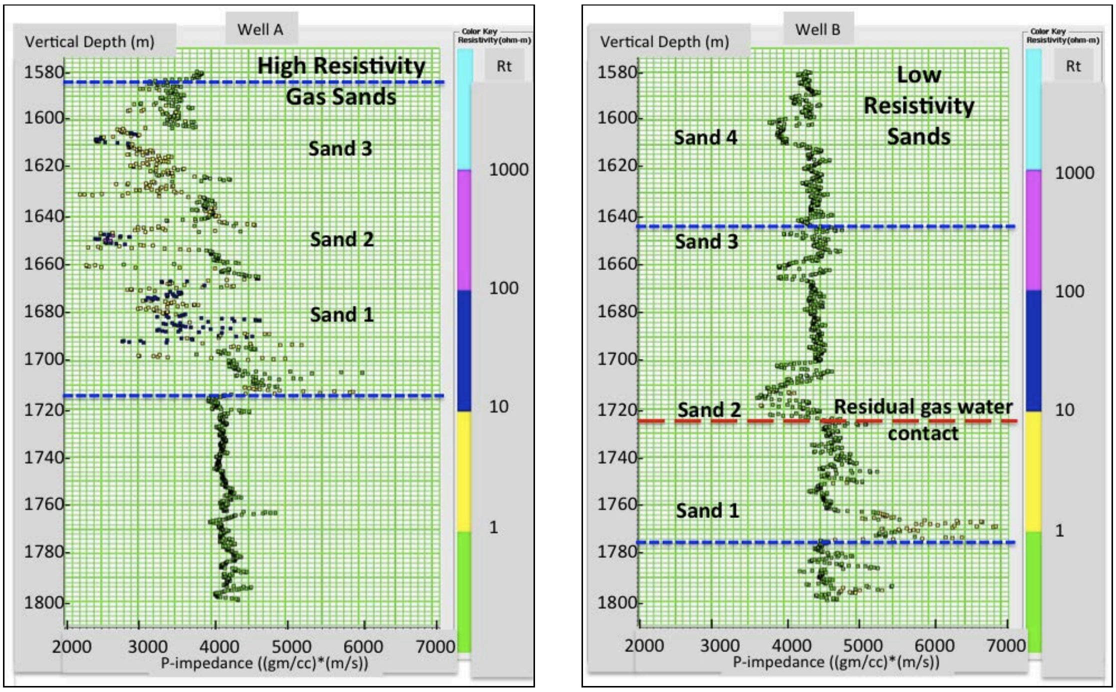


Figure (7): The P-impedance versus vertical depth cross-plots for the two wells (the color code is resistivity data).

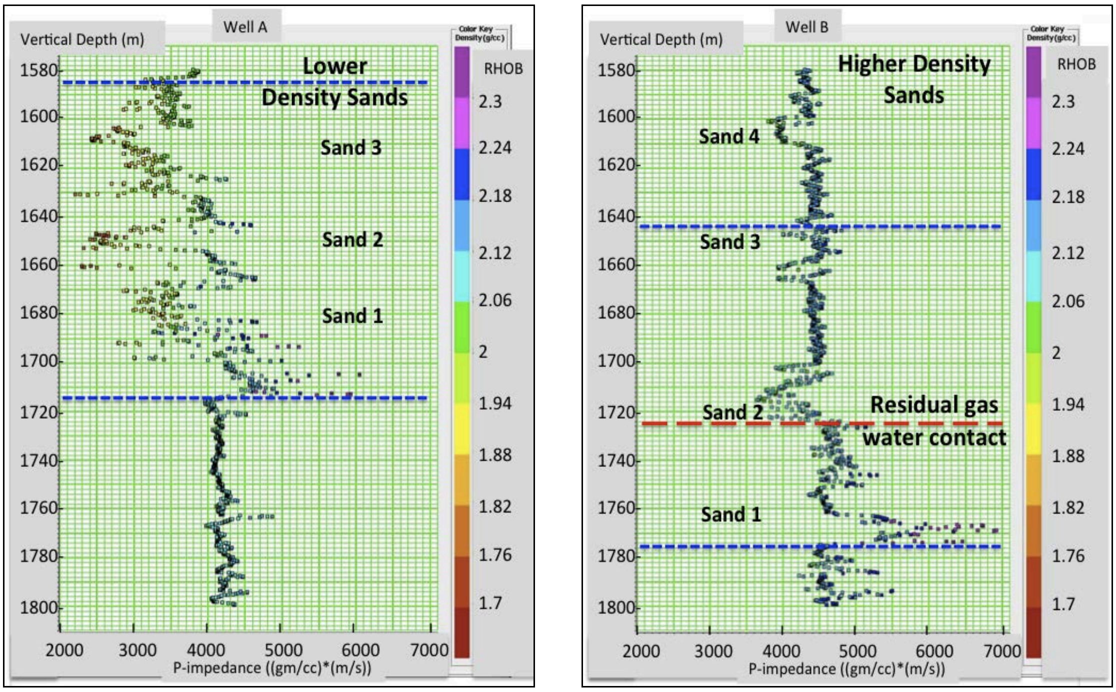


Figure (8): The P-impedance versus vertical depth cross-plots for the two wells (the color-code is density data).

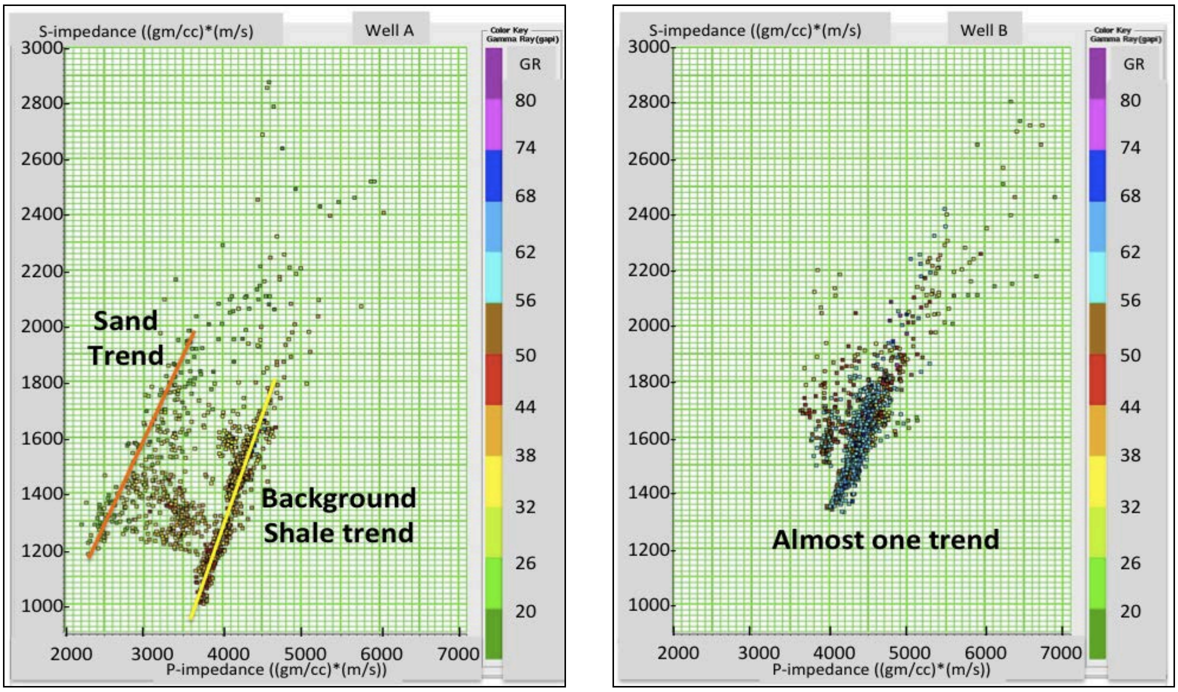


Figure (9): The P- and S-impedances cross-plots for the two wells (the color code is gamma-ray data).

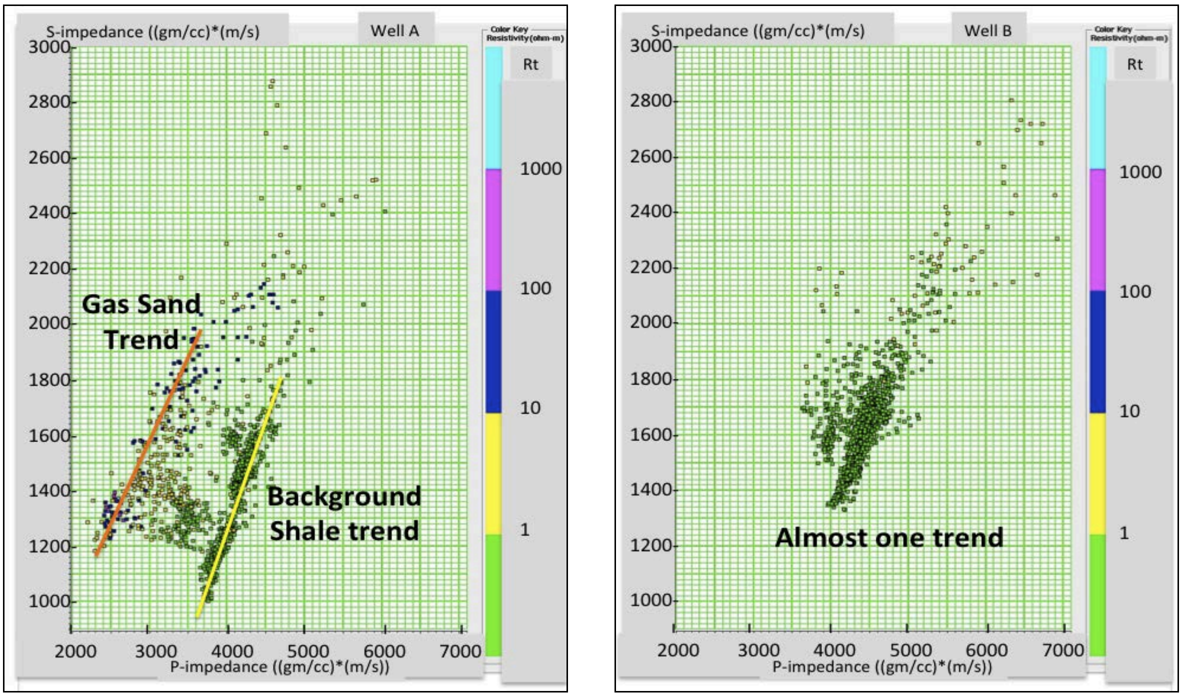


Figure (10): The P- and S-impedances cross-plots for the two wells (the color code is resistivity data).

SUMMARY AND CONCLUSIONS

Cross plots are a convenient way to demonstrate how various combinations of logs response to lithology and fluid. The Cross Plot is used to plot one attribute against another, and to look for the relationships between these attributes. The cross-plots of two wells, which encountered channel located offshore, West Nile Delta, Egypt, were used to evaluate the rock properties and to understand the responses due to the lithologies and fluids. This has been accomplished using the cross-plot of P-impedance versus depth, Gamma-ray versus P-impedance, and P-impedance versus S-impedance, the color-coded by the wells. The reservoir at well A, is characterized by clean and blocky sands highly saturated with gas, while at well B, is characterized by sands inter-bedded with shale and filled with residual gas and water. The cross plot of the P-impedance versus depth could distinguish between gas sands, shale and brine sand. The shale has higher acoustic impedance than the gas sand and lower impedance than the brine sand. The cross-plot of the P -impedance versus gamma-ray of both wells discriminates the clean sand from the shale, if there is a similarity in the P-impedance values. The gamma-ray values used as a color code helped in differentiation between the lithologies in the P-impedance domain. The data of the P- and S-impedances discriminated between different fluids. There are two trends, the first trend with lower P -impedance is the gas trend (softer), while the other trend with higher The P-impedance is the background shale trend (harder).

Moreover, the same cross-plots were used individually for each well, using gamma-ray, resistivity and density logs as the color code. Gamma-ray tool is a lithology indicator, differentiated between the sands and shale. Well A is characterized by clean and blocky sands of low gamma-ray values, while well B is characterized by sands inter-bedded with shale of higher gamma-ray values. The resistivity is used as fluid indicator, helped in discriminating between gas and water. Well A is fully saturated with gas and characterized by high resistivity <1000 ohm.m, while well B is filled with residual gas and water and it is characterized by low resistivity <10 ohm.m. It is mentioned that, the presence of gas would affect the bulk density readings and causes it to decrease. At well A, there is a difference between the density of gas sands and that of background shale, while at well B, there is a subtle difference between the residual gas sands and brine sand.

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