PS New Method of Defining Net Thickness in the Bone Spring Sandstones to Identify Prospective Reservoirs Using Petrophysical Attributes and Stochastic Simulation Techniques in the Delaware Basin, New Mexico*

Marielis Vargas Baron[1] and Joanna Fritz[1]

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[1]Devon Energy Corp., Oklahoma City, Oklahoma (marielis.baron@dvn.com)

Abstract

The main purpose of this study was to identify potential reservoirs in the 2nd and 3rd Bone Spring sandstones in the areas, Delaware Basin. These sandstones consist of alternating carbonate and siliciclastic intervals that were deposited as submarine-fans systems within the Delaware Basin during period of lowered sea level. The sandstones are composed of fine- to very-fine grains with porosity from 1% to 13% and low permeability from 1×10-6 md to 2.5 md. At the beginning of this study, some parameters such as porosity and water saturation were used to define net thickness. However, the high water saturation values in some parts of the areas of interest did not match with the high productive wells. Based on that premise, a new approach that integrate stratigraphy, petrophysical attributes (Porosity, Deep Resistivity and Sandstone Volume) and production data using stochastic simulation technique was applied to capture the geological trend and to define potential reservoir in the Bone Spring Sandstones. Two main data sources were applied: wells with petrophysical evaluation and production data. The 55 wells with petrophysical evaluation were used to build the water saturation, porosity, sandstone volume and deep resistivity models using stochastic technique. The production data of 36 horizontal wells (25 with EUR and 11 with 180 Cumulative production data) was used to investigate the relationship between productions versus net thickness. Since there is no relationship between production and Sw in the study areas, only porosity, sandstone volume and deep resistivity attributes were used to define net thickness. A detail analysis of those attributes was made for each Bone Spring zone to identify the cutoff to be applied for the net thickness model. For Porosity a cutoff of > 5%, for Deep Resistivity a cutoff of < 30 ohm and for sandstone volume a cutoff of more than 50% was defined. With those cutoffs the carbonates and tight layers with less than 5% of porosity were removed from the model. Three net thickness maps (2nd Bone Spring Upper and Lower and 3rd Bone Spring Lower) were built to identify the areas where the three attributes match the cutoffs. A good relationship between production and net thickness was observed in the three zones: 2nd Bone Spring SS Upper and Lower and 3rd Bone Spring SS Lower. High net thickness is matching with the high productive well identifying zones with potential reservoir sandstones in the study areas.

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Marielis Vargas Baron & Joanna Fritz
Devon Energy Corporation
Reservoir Technology and Optimization (RTO)
Marielis.Baron@dvn.com
Joanna.Fritz@dvn.com

1. Abstract:

The main purpose of this study was to identify potential reservoirs in the 2nd and 3rd Bone Spring sandstones in the Delaware Basin. These sandstones consist of alternating carbonate and siliciclastic intervals that were deposited as submarine-fans systems within the Delaware basin during period of lowered sea level. The sandstones are composed of fine to very fine grains with porosity from 1% to 13% and low permeability from: 1x10-6 md to 2.5 md. At the beginning of this study, some parameters such as porosity and water saturation (Sw) were used to define net thickness. However, the high water saturation values in some parts of the areas of interest did not match with the high productive wells. Based on that premise, a new approach that integrate stratigraphy, petrophysical attributes (Porosity, Deep Resistivity (Rs) and Sandstone Volume (Vss) and production data using stochastic simulation technique was applied to capture the geological trend and to define potential reservoir in the Bone Spring Sandstones.

Two main data sources were applied: wells with petrophysical evaluation and production data. The 55 wells with petrophysical evaluation were used to build the water saturation, porosity, sandstone volume and deep resistivity models using stochastic techniques. The production data of 36 horizontal wells (25 with EUR and 11 with 180 Cumulative production data) was used to investigate the relationship between productions versus net thickness. Since there is no relationship between production and Sw in the study areas, only porosity, sandstone volume and deep resistivity attributes were used to define net thickness. A detail analysis of those attributes was made for each Bone Spring zone to identify the cutoffs to be applied for the net thickness models. For Porosity a cut-offs of > 5%, for Deep Resistivity a cutoff of < 30 ohm and for sandstone volume a cutoff of more than 50% was defined. With those cut-offs the carbonates and tight layers with less than 5% of porosity were removed from the model. Three net thickness maps (2nd Bone Spring Upper and Lower and 3rd Bone Spring Lower) were built to identify the areas where the three attributes match the cutoffs. A good relationship between production and net thickness was observed in the three zones: 2nd Bone Spring SS Upper and Lower and 3rd Bone Spring SS Lower. High net thickness is matching with the high productive well identifying zones with potential reservoir sandstones in the study areas.

2. Area of Interest

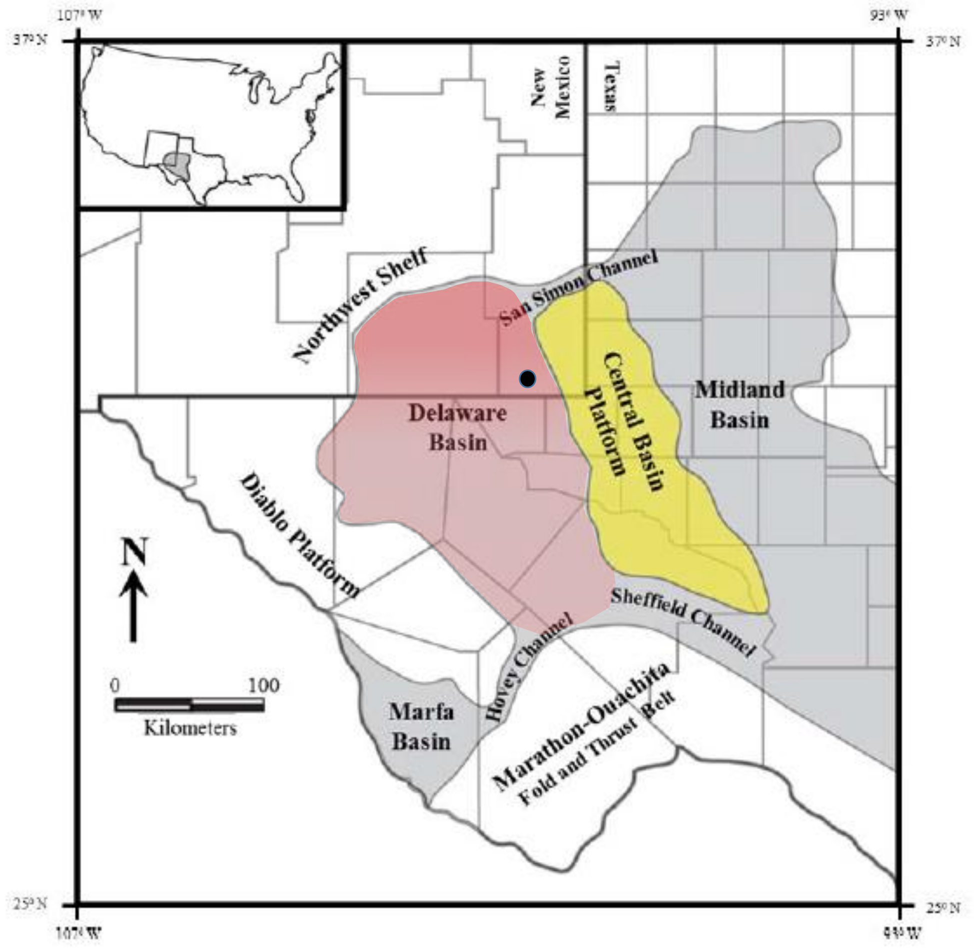


Figure 1: Map of the Permian Basin (Delaware and Midland basins) and surrounding structural elements. Midland, Delaware (in red) and Maria basins correspond to ancient depression. The white color represent uplift and the Yellow is the ancient Central Basin platform. Modified from Asmus and Grammer, 2013

3. Stratigraphic Column

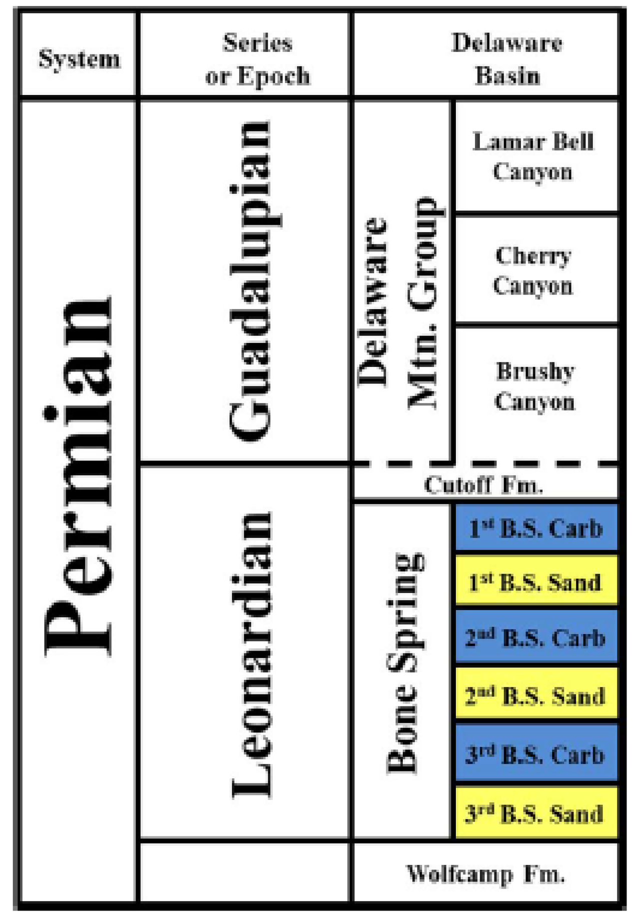


Figure 2: Stratigraphic Column of the Delaware basin subsurface. Modified from Asmus and Grammer, 2013

4. Data Set

A total of 103 vertical pilot holes with only 55 wells with petrophysical evaluation were utilized to this project. The 103 wells were used to construct the isopach maps and the 55 wells with petrophysical evaluation to built the porosity, water saturation, sandstone volume and deep resistivity models in Petrel software (Fig. 4). The models were built for the three intervals: 2nd Bone Spring Upper and Lower and 3rd Bone Spring Lower. The production data for approximately 36 horizontal wells (15 with EUR and 11 with 180 days Cumulative production data) was used to investigate the relationship between productions and net thickness.

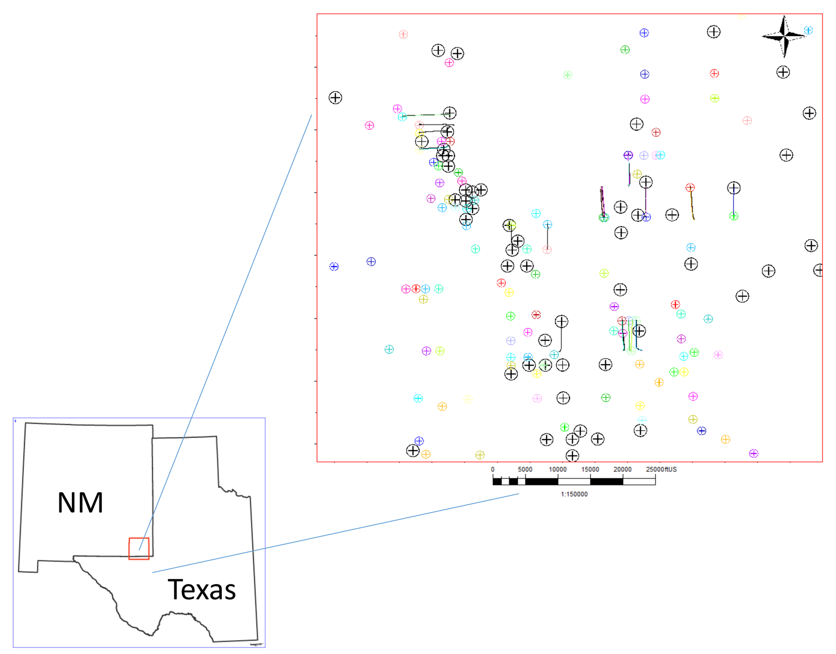


Fig.4: A total of 103 vertical wells were used for this study. The circles in black color correspond to the wells with petrophysical data.

5.Log Type

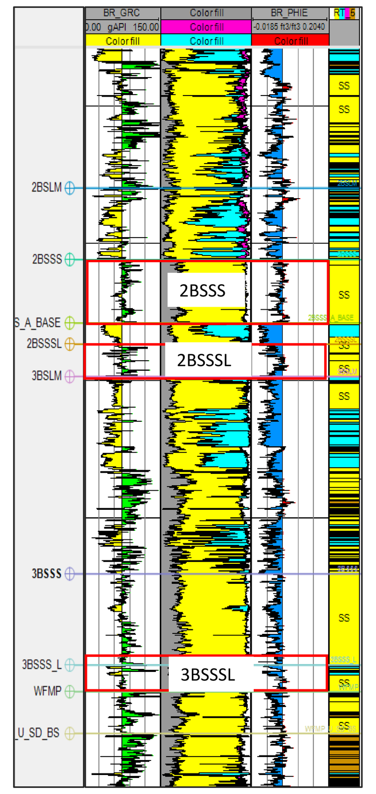
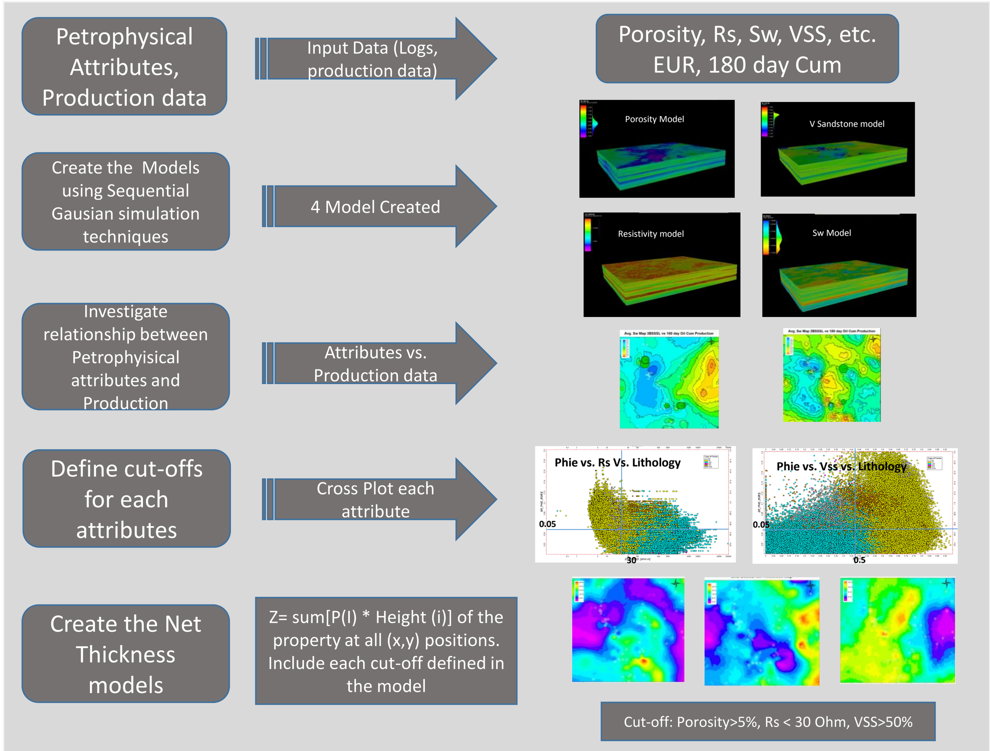


Figure 5: Log Type for the area of interest showing the three reservoirs: 2ND BSSSU, 2ND BSSSL and 3RD BSSSL.

6. Methodology

The net thickness maps were created to high-light zones of good reservoirs in the study areas. To identify the good reservoirs some petrophysical attributes were selected and Net thickness models were created for each zone. For the first attempt, five variables were selected: porosity, water saturation (Sw), sandstone volume (Vss), resistivity (Rs) and gross thickness. Since there is no relationship between Sw and production, this attribute was discarded and only four parameters (porosity, Rs, Vss and gross thickness) were used to create the net thickness models in Petrel using Sequential Gausian Simulation Technique. To define the cut-offs, each petrophysical parameter was cross-plotting vs. resistivity and vs. lithofacies (carbonate and sandstone). The models were constrained using the cut-offs and the net thickness maps were generated for each interval (2ND BSSSU, 2ND BSSSL and 3RD BSSSL). The production data was posted on those maps to observe the relationship between net thickness and Production.



7. Avg. Sw vs. Production data

Avg Sw maps were created for the 2ND BSSSU, 2ND BSSSL and 3RD BSSSL intervals. The EUR and 180 Cum Productions were posted on those maps to investigate the relationship between production and Sw. No relationship was observed between production and Sw. In general in the 2nd BSSSU and 2nd BSSSL intervals, the high productive wells are located in high Sw areas (Sw >50%) . For the 3rd BSSSL, high productive wells are located in areas with Sw values greater than 70% (Fig 6).

Based on those results, water saturation (Sw) was not taken into account as attributes to construct the Net Thickness maps.

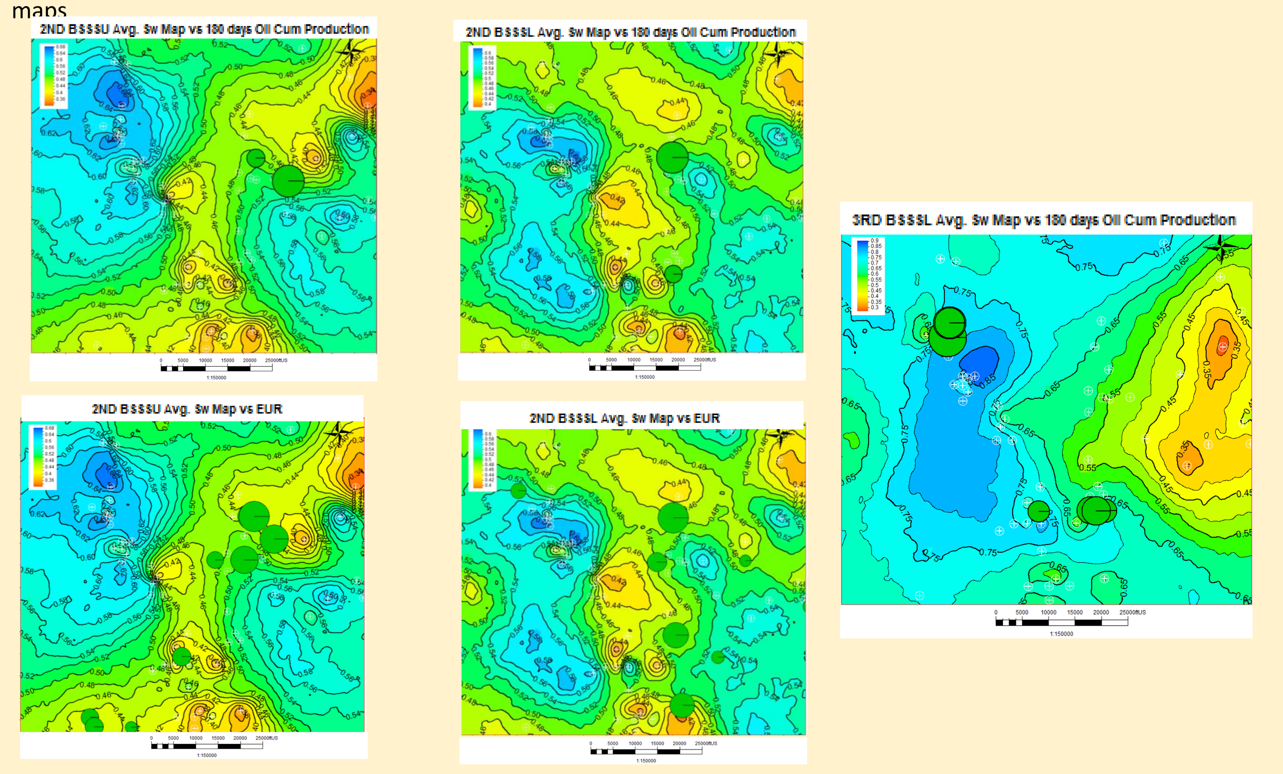
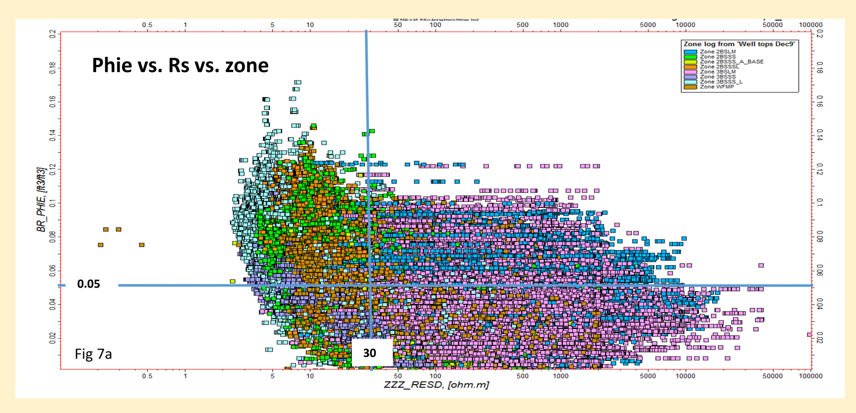


Figure 6: Avg. Sw maps were made for the three reservoirs: 2ND BSSSU, 2ND BSSSL and 3RD BSSSL and production data were posted on the maps. The circles in white correspond to wells with petrophysical evaluation. No good relationship was observed between Sw and EUR or 180 days Cum Production.

8. Cut-off Definition



Three petrophysical attributes were taken into account based on the data analysis results to define cut-offs: Porosity, Resistivity and Vss (Fig 7a, 7b and 7c). The Sw was discarded due to no good relationship or no relationship at all was found between Sw and production data (Fig. 6). The purpose to define cut-offs is to include them into the net thickness models created in Petrel software. Prospective areas were identified in where those three attributes match the criteria defined by the cut-offs.

- Based on the data analysis results (see fig. 7a, b and c.) the cut-offs were defined as follow: Porosity > 5%, Resistivity (Rs) <30 Ohm and Volume sandstone (Vss) > 50%
- Porosity > 5% includes mostly sandstone
- Resistivity less than 30 ohm to remove carbonate and organic matter
- Resistivity more than 30 ohm are related to carbonate.
- Vss more than 50 % to include only sandstone in the model.
- Those cut-offs ensure that the models mostly include a clean sandstone reservoir with more than 5% of porosity

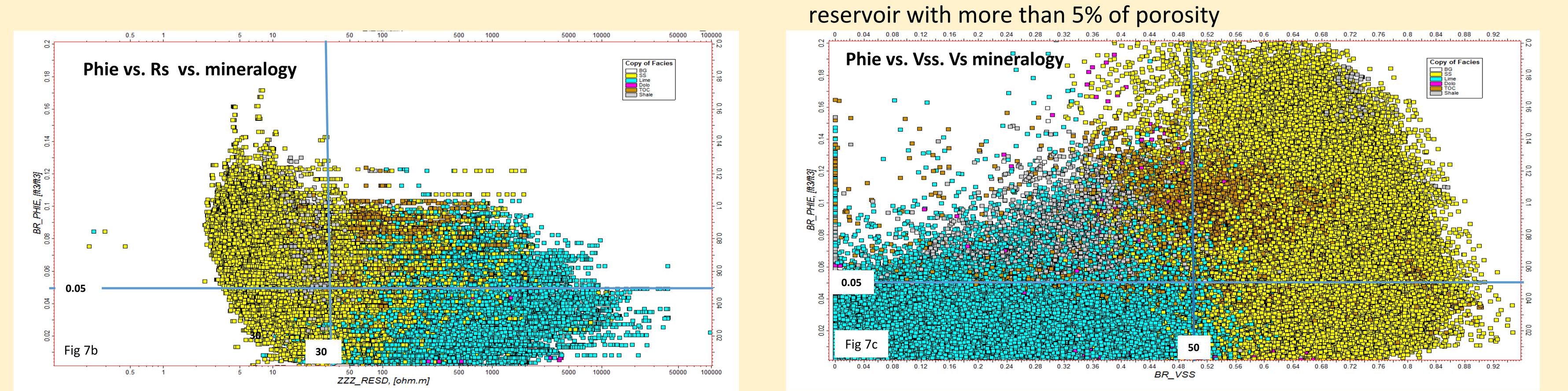
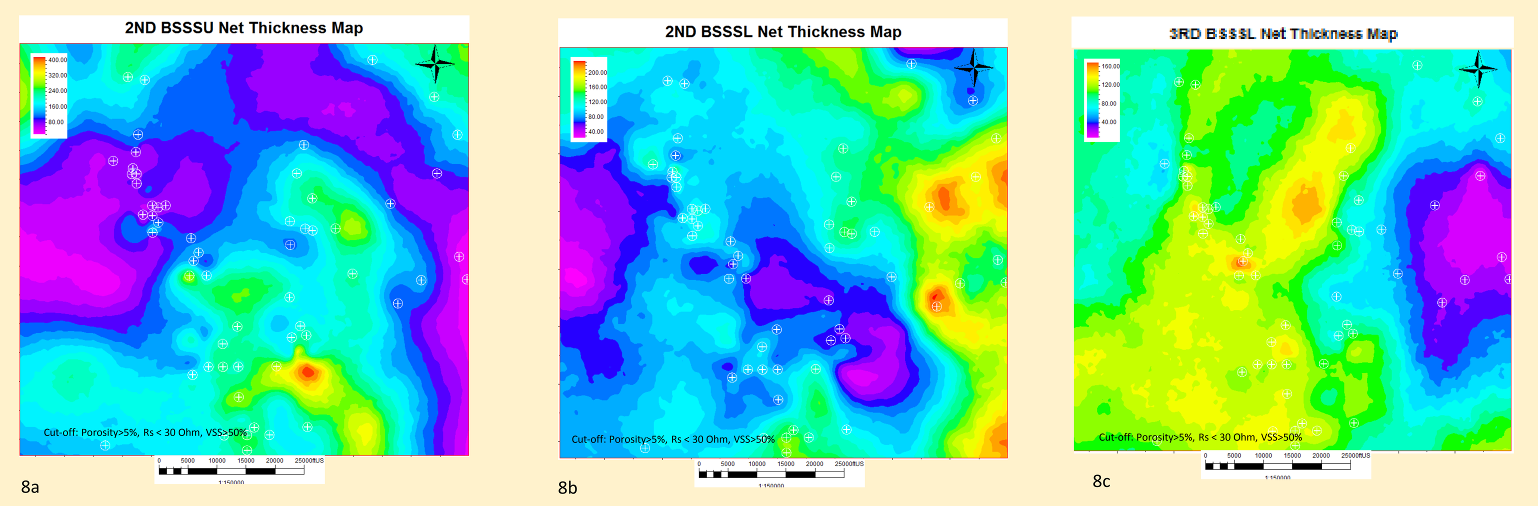


Figure 7: Cut-off was defined for three petrophysical attributes: Porosity, Vss and Resistivity. The attributes were cross plotting versus mineralogy and zones. Fig 7a shows the distribution of porosity and Rs. vs. the zones. Fig 7b shows porosity >5% and Rs <30 Ohm capture mostly the sandstones. Fig 7c shows that Porosity >5% and Vss > 50% involve only sandstone in the three zones: 2ND BSSSU, 2ND BSSSL and 3RD BSSSL

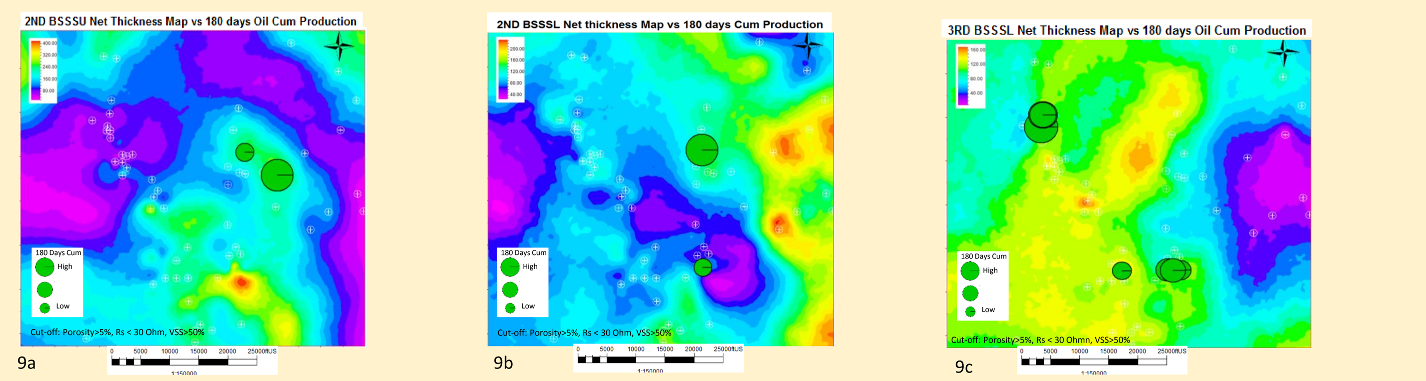
9. Net thickness maps



The Avg. net thickness maps of the three main reservoirs of the study areas are the result of the merge of four attributes: porosity, resistivity, V sandstone and gross thickness. Each one of those parameters were modeled separately using stochastic simulation techniques and then filtered out with the cut-offs defined previously. The maps represent the areas in which the reservoirs match the criteria established by the cut-offs. The color bar defines the net thickness in feet. The warm colors correspond to highest net thickness and the cold color the lowest net thickness values. In general, warm colors represent the high-graded zones or good reservoir areas.

Fig. 8 : Shows the net thickness maps for the three main reservoirs: 2ND BSSSU (8a), 2ND BSSSL (8b) and 3RD BSSSL. (8c). The yellow and purple lines correspond to Devon Units. The circles in white with correspond to wells with etrophysical evaluation. The bar color shows the net thickness in feet units. Warm color high values and low colors low values

10. Net thickness maps vs. Production data



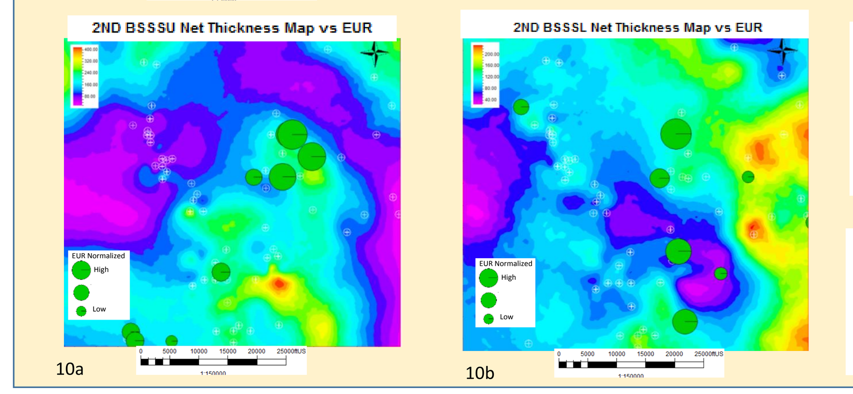


Fig. 9: Shows the net thickness maps vs. 180 day Cum Production for the three main reservoirs: 2ND BSSSU (9a), 2ND BSSSL (9b) and 3RD BSSSL.(9c). The circles in white correspond to wells with petrophysical evaluation. The bar color shows the net thickness in feet units. Warm color high values and low colors low values.

Fig. 10: Shows the net thickness maps vs. EUR data for 2ND BSSSU (10a) and 2ND BSSSL (10b) reservoirs. The circles in white correspond to wells with petrophysical evaluation. The bar color shows the net thickness in feet units. Warm color high values and low colors low values.

The 180 days Cum and EUR production data were posted on the Avg. net thickness maps of the three main reservoirs of the areas of interest to investigate the relationship between production and net thickness.

For the 180 days Oil Cum, only few data point available. The 2ND BSSSU and 2ND BSSSL have only two control points and the 3rd BSSSL interval has 5 control points. For the 3RD BSSSL, a good relationship is observed between production and net thickness maps. In general, high 180 days oil cum production is observed in the high net thickness values. For the 2ND BSSSU and 2ND BSSSL, a good relationship is observed. However, there is not enough data to make any conclusion about relationship between 180 days Cum production and net thickness maps for those reservoirs.

There are a total of 15 EUR control points for the project. For the 2ND BSSSU, nine wells and for the 2ND BSSSL six wells. The 3RD BSSSL did not have EUR data for the time this study was conducted.

In general, an excellent relationship between EUR and 2ND BSSSU net thickness map was observed. High EUR values match with high values of the net thickness map. For the 2ND BSSSL a good relationship between EUR and net thickness map was observed. However, an outlier can be observed in the eastern part of the AOI. Some investigation was made to understand the low EUR value in a high net thickness area for that well but apparently the EUR data assigned to that well is correct. More production data is necessary for a better understanding of the relationship between production and net thickness.

11. Conclusions, Recommendations and References

Conclusions

1) There is not relationship between Sw and production in the main reservoirs: 2nd Bone Spring SS Upper, 2nd Bone Spring SS Lower and 3rd Bone Spring SS Lower in area of interest. High productive wells are located in high Sw areas (>50%). The Sw is not a good parameter to be used to define net thickness.

2) The net thickness map is a new approach built using stochastic simulation techniques that combines four petrophysical attributes: porosity, V sandstone, Resistivity and gross to identify prospective areas using some cut-offs which were defined based on data analysis. Three net thickness maps were built and good reservoir areas were identified in the three intervals.

3) A good relationship between production and net thickness was observed in the three zones: 2nd Bone Spring SS Upper and Lower and 3rd Bone Spring SS Lower. The high productive wells are matching with the high net thickness zones which have been identified as potential reservoir sandstones in the study area.

Recommendations

More production data is necessary for a better understanding of the relationship between net thickness and production.

References

Asmus and Grammer, 2013, Characterization of Deepwater Carbonate Turbidites and Mass-Transport Deposits utilizing High-Resolution Electrical Bore Hole image logs: Upper Leonardian (Lower Permian) Upper Bone Spring Limestone, Delaware Basin, Southeast New Mexico and West Texas. The Gulf Coast Association of Geological Sciences. 39 p.