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Role of High Frequency Stratigraphic Characterization to Measure the True Potential of Shale Plays: An Example from Eagle Ford Shale

Ajit K. Sahoo, Barnali Tokhi, Mukul Srivastava

Shale Gas Division, Reliance Industries Ltd, Navimumbai-400701, India.

Presenting author, E-mail: ajit.sahoo@ril.com

Abstract

The shale gas boom is having an unprecedented effect on the US energy market. This, in turn, has important implications for the rest of the world and India is now preparing to go for shale gas exploration in different onshore basins. To make this shale gas revolution successful in India, we need to implement the learnings from North American shale play development. Successful development of a shale gas reservoir is dependent on various G&G and engineering parameters like porosity, permeability, TOC, brittleness, proppant type, proppant volume, stage and cluster spacing etc. Apart from all the above parameters, in this paper we have explained the importance of proper lateral placement during exploration and development phase to measure the true potential of any shale play. To place the lateral at the right zone, we need to identify the most productive stratigraphic zone within the shale and this requires finer stratigraphic division of the entire shale play and proper characterization of those stratigraphic units. Eagle Ford shale is taken as an example for this study.

In the first half of this paper, we have illustrated the fracture growth and the effective drainage area based on literature survey. Significant subsurface drivers that control the well productivity are identified. To capture minute vertical heterogeneities within the reservoir, we divided the entire Eagle Ford into nine different stratigraphic zones on the basis of sequence stratigraphic approach. Based on wireline logs and core data these sequences are characterized and the most productive sequences are identified.

In the second half of this paper, we have explained the reason behind inconsistent performance of a few wells located within similar geology and fractured through same completion design. For this purpose, we have generated a three dimensional sequence stratigraphic model and the laterals are laid within the model to check their placement w.r.t. the most productive sequences. It is observed that the laterals of good performers are having maximum exposure to the best sequences whereas the laterals of the poor wells are placed away from the productive sequences.

This study gives a clear understanding that if a well will not be placed at the right stratigraphic zone then the well may not perform at its best. So at the outset of Indian shale gas revolution, a finer detailing of the reservoir is desirable to realize the true potential of any shale play.

Introduction:

Across many shale plays in North America, operators ask why production performance disparities exist among horizontal wells. For example, even though drilling and completion practices of a neighboring operator may be mimicked, significantly different production results are frequently observed. Several hypotheses have been presented on the subject with little consensus. In most of these wells, formation evaluation in the lateral section is limited to gamma ray (David et al, 2010). So large uncertainties may exist in determining the relative geologic position of the wellbore. This paper illustrates the importance of high frequency stratigraphic characterization of shale plays and proper lateral placement w.r.t. the best zone.

Why High Frequency Stratigraphic Characterization:

The extent that a created fracture will propagate is controlled by the upper confining zone or formation, and the volume, rate, and pressure of the fluid that is pumped. The confining zone will limit the vertical growth of a fracture because it either possesses sufficient strength or elasticity to contain the pressure of the injected fluids or an insufficient volume of fluid has been pumped (source: Frac Focus).The vertical and lateral extent of the fractures has been evaluated through multiple methods like microseismic, fracture modeling, pressure interference test, tracer survey etc.

Figure-1 shows a hydraulic fracture design for the Eagle Ford shale using a first-order discrete fracture network (DFN) model. The model indicates wider fractures near the well bore. Moving away from the well bore, fractures become narrow. As higher proppant concentration give more conductivity and keeps the hydraulic factures open for long time, so the narrow fractures may give less conductivity and may close after few days of production (Figure-1). The microseismic events get lesser in count with increase in distance from the well bore (Figure-2). This indicates that the hydraulic fracturing is much effective and creates a good network near the well bore. (Lucas et al, 2010)

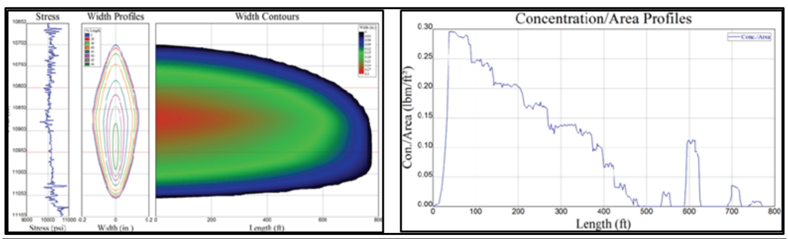
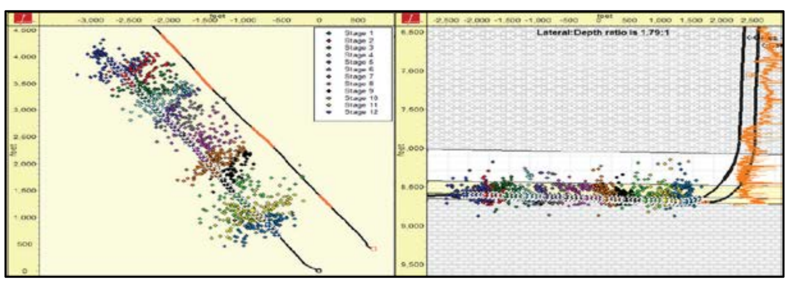


Figure-1: Stress, width contours and length of hydraulic fractures; Proppant Concentration per area (Lucas et al, 2010).



Fiugre-2: Microseismic data within Eagle Ford showing decreasing Events from the well bore (Lucas et al, 2010).

Both the data sets indicate that effective fracturing takes place in and around the well bore. The part of the formation near to the horizontal well bore mainly contributes to the well EUR. Therefore it is critical to place the lateral directly in the target zone which is HC rich and brittle in nature. So as to identify the best zone within a shale formation, it is necessary to divide the entire shale formation into several smaller zone/units and characterize them based on most important geological drivers.

Stratigraphic Zonation of Eagle Ford:

Eagle ford Formation is divided into three relatively symmetrical and regionally correlative 3rd order sequences, upper, middle and lower zones. The study entails division of these three sequences into nine high frequency stratigraphic units/zones based on fourth order sequence stratigraphic/ Parasequence concept. Thirty eight pilot wells were used for correlation and mapping of stratigraphic zones using spectral Gamma ray, resistivity and density logs. The resource play was divided into nine high frequency stratigraphic zones, with five zones within the lower EGFD (zones-1,2A,2B,2C,2D) two each in Middle (zones 3A &3B)and Upper EGFD (zones 4A & 4B)(Figure). The boundary of each stratigraphic zone is identified from low gamma, high density, low uranium with a high uranium pack above, low thorium and low potassium. Similar kinds of Parasequences are also observed in the outcrops (Figure-3). Each parasequence is characterized by coarsening upward signature and ends up with a carbonate rich brittle rock unit.

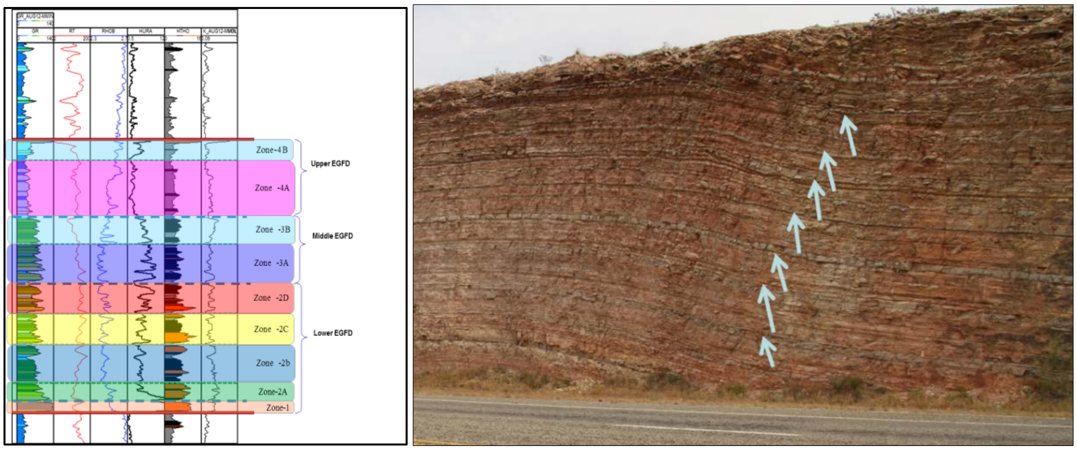
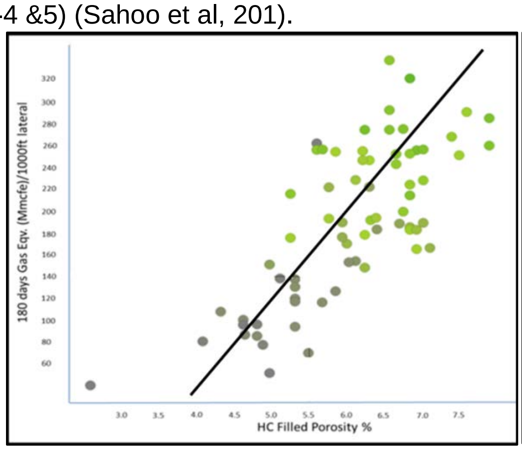


Figure-3: Nine different stratigraphic zones within Eagle Ford based on wireline log data. Similar coarsening upward units are encountered in the Eagle Ford outcrops from South Texas.

The lower stratigraphic zones in general are organic rich with high TOC and high brittleness content with a cleaning upwards total gamma. The middle sequences are moderate to high in organic richness. The upper sequences are lowest in TOC content, but have the potential to deliver fair amount of hydrocarbon.

Identification of Key Subsurface Drivers:

To identify the major geological drivers controlling the well performance in the Eagle Ford shale, 180 days normalized production data has been integrated with various geological parameters derived from the multi-mineral processing of the wireline logs. HC filled porosity, TOC, volume of clay and carbonate/quartz ratio are identified as the most effective geological parameters that control well productivity. Linear regression analysis was carried out between 180 days normalized production data and each subsurface parameter to capture these geological drivers. We have observed that the well performance is increasing with increase in hydrocarbon filled porosity and decease in Volume of clay (Figure-4 &5) (Sahoo et al, 201).



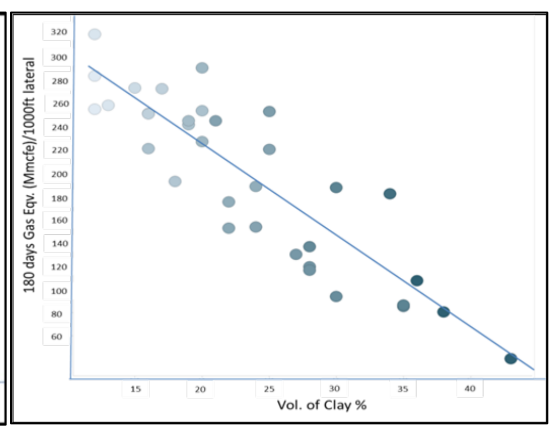


Figure-4: Cross plot showing the relationship between HC filled porosity and normalized production. Figure-5: Cross plot showing an inverse relationship between clay volume and production

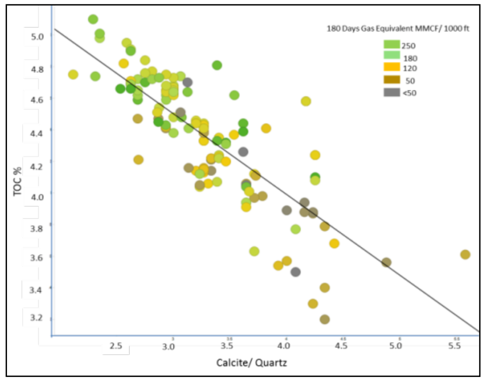


Figure-6: Cross plot showing the relationship among TOC, Calcite/Quartz Ratio and production

A Carbonate/Quartz ratio greater than 4, between 2 & 4 and less than 2 represents three different scenarios: i) high carbonate percentage-low TOC-poor production ii) moderate carbonate percentage-medium TOC- intermediate production and iii) higher quartz percentage- higher TOC-better production respectively (Figure-6).

These are very important parameters that decide the reservoir quality of Eagle Ford, thus ultimately affecting the well performance. So these are considered as the primary inputs to characterize the nine high frequency stratigraphic zones,

Characterization of Stratigraphic Zones:

Characterization of stratigraphic zones is desired to identify the best vertical section in terms of reservoir quality. Based on the identified key drivers the stratigraphic zones were characterized. Within the study area the depositional environment changes rapidly so the zones have been characterized in two different locales, one in the north and the other in the south of the reef margins. Characterization is done on the basis hydrocarbon filled porosity, Vclay and TOC derived from multimin processed wireline logs.

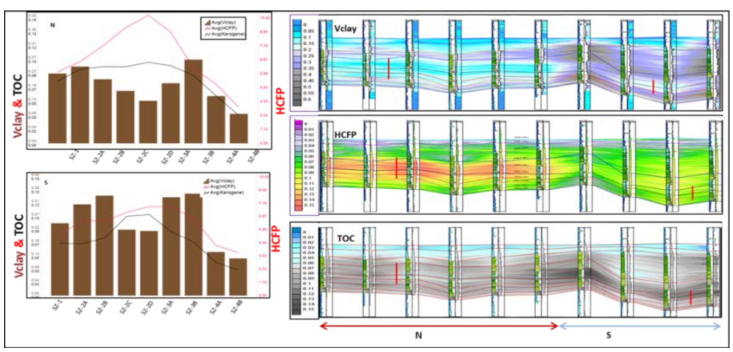


Figure-7: Histogram and Cross-Sections showing the quality of the nine stratigraphic zones.

Characterization of the stratigraphic zones indicates that zones 2C and 2D are the most productive which are rich in hydrocarbon and brittle in nature both in shallower (north) and deeper (south) areas. Whereas zones 2B and 3A have better rock quality only in the north and get inferior to the south because of high clay content (Figure-7). As we have discussed in the first section that effective fracturing takes place near to the well bore and decreases away from it. So, maximum contribution comes from the zone close to the well bore. In this area of Eagle Ford, 2C & 2D stratigraphic zones are identified as the best zones and laterals may be placed within these two zones to as to maximize the production.

In this section we are able to identify the best zones in the vertical pilot wells. But it is necessary to map them away from the pilot wells so that the laterals can be properly geosteered to stay well within the target zones. At the same time, we wanted to validate our study. For this purpose, a three dimensional stratigraphic framework has been generated.

3-D Stratigraphic Framework:

Three dimensional stratigraphic framework has been generated with the help of seismic horizons, faults and isopach of different zones (Sahoo et al, 2014). First a structural framework has been generated using the top and base seismic surfaces of Eagle Ford. Then using the well based isopach maps of all the nine stratigraphic zones, different surfaces were mapped within the study area (Figure-8). The final stratigraphic framework was used to validate the concept of lateral placement within the productive zones that can enhance the well performance.

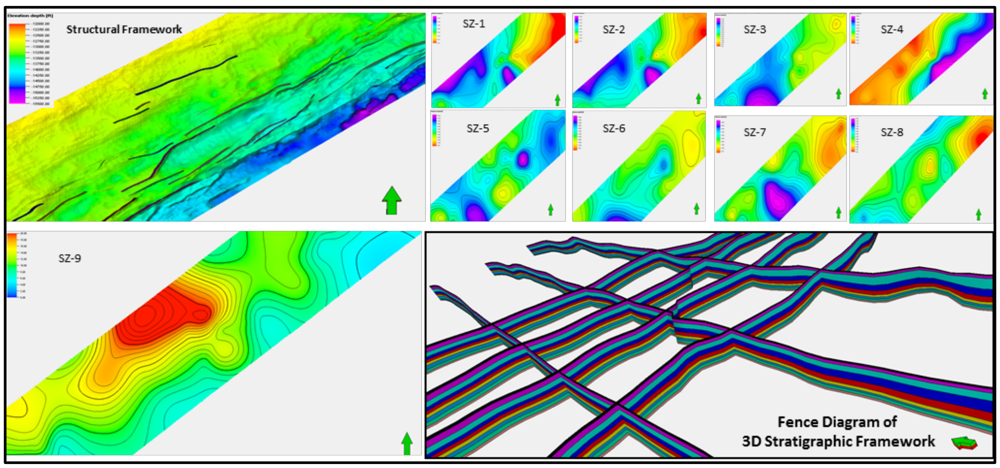


Figure-8: Stratigraphic Frame work and its components

Validating the Concept:

To validate the model and to study the impact of identification of hydrocarbon rich and brittle zone and proper lateral placement within the desired zone, two case studies were carried out. Two pairs of laterals were considered which are close to each other spatially to minimize geological property variation while comparing well performance. In case-1 (north), two wells A and B having similar lateral lengths and same completion design are considered. Lateral placement of well A is only 20 % is the desired Zone 2C & 2D (red and yellow shown in figure-9) whereas Well B is placed 80% within the desired zone. The normalized production rate of well B (1640MMCFE) is double than that of well A (816 MMCFE).

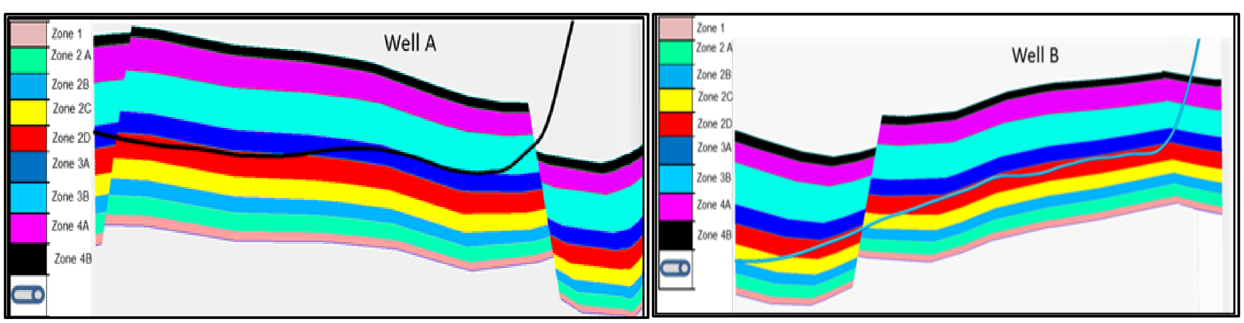


Figure-9: Case1-Lateral Placement of wells A and B

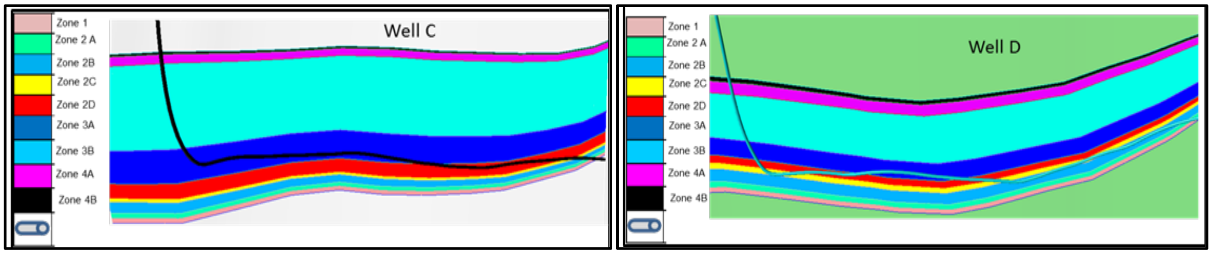


Figure-10: Case2-Lateral Placement of wells C and D

Similarly in case 2 (south), well C is placed only 40 % in the desired zone 2C& 2D (red and yellow shown in figure-10) whereas well D was landed more than 80 % in the desired zone. The normalized production rate of well D (1170MMCFE) is much higher than that of well C (672 MMCFE).

These two cases corroborate that identification of the hydrocarbon rich and brittle zones along with proper placement of laterals within the right zone is key to successful well results.

Summary:

In this paper, the importance of micro detailing of shale reservoir is clearly illustrated through fracture growth. Since the effectiveness of the hydraulic fracturing is limited to the well bore, the quality of the reservoir close to the lateral becomes important which controls the well performance. To enhance a shale well productivity or to measure the true potential of shale it is important to place the lateral within a zone which is hydrocarbon rich and brittle in nature.

In this study, the entire Eagle Ford is divided into nine stratigraphic units or zones based on sequence stratigraphic concept. Out of all the nine units, two are identified as best on the basis of the most important subsurface drivers i.e. hydrocarbon filled porosity, Vclay and TOC. A 3D stratigraphic frame work has been generated to validate the concept. It has been observed that the wells drilled through the best reservoir zones are performing better than the wells which are out of the target zones. This validates the concept that the best well performance can be obtained through proper lateral placement. So at the onset of Indian Shale Gas boom, it is very much important to measure the actual potential of a shale play so as to keep the boom alive.

Acknowledgments:

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