Advanced Formation Evaluation to Optimize Shale Development in Permian Basin

Dr. Vladimir Ingerman, Amros Corporation

Abstract

Permian Basin reserves exceed the reserves of the largest conventional field in the world, Ghawar, Saudi Arabia [1].

To develop this field many companies use ‘factory drilling’ or ‘geometrical approach’. This approach decreases the cost of drilling and make sense for source rocks because these are hydrocarbons saturated rocks or the rocks where hydrocarbons have been cooked. Geometrical approach would be ideal for homogeneous formations, but as it will be shown below shale place are very inhomogeneous vertically and laterally. While a drilling cost for a single well is reduced, this approach significantly increases the overall development costs and environmental impact because of drilling a big number of low producing wells.

We found the way to solve this problem developing a technology that uses standard open-hole log data to calculate Production Profile that shows predicted production along the entire well.

Objectives/Scope

Traditional methods and techniques for log data interpretation, successfully used for conventional reservoirs, are not applicable to shale plays. It happens because of geological nature of shale oil that is trapped in the source rock with very low permeability; meantime traditional formation evaluation techniques are developed for permeable rocks [2]. As result the operators have been developing shale deposits blindfolded. According to industry experts, 95% of shale oil is left in the ground and two thirds of hydraulic fracturing stages do not produce commercially.

The laboratory analyses show that the EOR in the Permian Basin can reach 60% [1], meaning that the current low recovery efficiency is not because shale oil is unmovable. There is another reason – we just miss the best spots of the field and concentrate on the low producing areas. Reducing cost of drilling is not a goal. When we reduce the cost of drilling in dry or low producing formations, we just decrease useless expenses. Same as fracking the rocks with high brittleness. The goal is to increase production and recovery efficiency with the minimum cost. This could be reached utilizing the technology that separates good and bad zones. As we know now and will be shown below, this technology will increase production up to 1000% and double or triple recovery efficiency. At the same time, the development cost and environmental impact could be decreased because of avoiding drilling of low producing wells.
The objective of this study is to provide to shale operators the new information about the location of big volumes of movable hydrocarbons that, till now, have been available for only rare wells with special core or cutting analysis. This information is a key for optimization of shale development.

**Method, Procedure, Process**

We use advanced formation evaluation technique that was developed by Amros Corporation to generate a Production Profile (PP) that shows predicted production in barrel per day as well as Brittleness along the entire well. The input data for this technology can be limited to only standard open-hole log data: gamma ray, resistivity, neutron and density porosity.

The basic equation for calculation PP was distilled from a unique set of data that included open-hole logs and permeability derived from hundreds pressure build-up well tests. This permeability refers to the drainage area with a volume comparable to the log data average scale. It is notable that well test results correspond to in situ conditions in contrast to common core lab measurements [2]. The equation was used successfully to develop many thousands wells in conventional reservoirs in different countries: USA, Russia, Canada, Mexico and Kazakhstan. Later it was modified for shale plays.

Adjusting the coefficients of the equation for different reservoirs (calibration) makes the techniques more enhanced. The data for calibration includes open-hole log data, fracking intervals and production history. Because of the nature of the technology, more calibration data result in a more accurate interpretation. Each new well contributes to the tuning of the model; and, accordingly each subsequent well is processed more accurately than the previous.

Using Brittleness, an operator can calculate breakdown pressure and the cost of fracking each stage of a vertical or horizontal well. The PP shows predicted production of each stage. So, operators can calculate the economics of the development and make informed decisions.

PP for vertical well allow to identify the highest producing formations and pick fracking zones. PP for group of vertical wells allow to map the best spots and identify the best locations and trajectories of horizontal wells. It removes the blindfolds.

To apply the technology in the field, operator should provide the information about the location of vertical wells and open-hole log data. The technology delivers:

- PP with recommended fracking stages and brittleness
- Identification of the best formations
- Production maps for the best formations
- Recommended trajectories for horizontal wells with initial production estimation

The technology can also be applied in old wells.

The results are available in 24 hours after recording log data, making it a key information for operating decisions, including picking fracking zones and planning trajectory and production of horizontal wells.

**Results, Observations, Conclusions**

The technology has been verified in more than 100 wells in Permian Basin and shows that for this basin the best producing formations are distributed sporadically with different orientation. This is very significant difference between shale fields and conventional reservoirs.

Figure 1 demonstrates five fracking stages for vertical well in Permian Basin, pink intervals in the left column, with total thickness 374 ft.
According to calculated Production Profile, brown curve in the right column, the total production of these stages is 8 bbl./day or 2.1 bbl./day per 100 ft.

According to PP the best zone in this interval, brown interval in the left column, has thickness 157 ft. with average production 13 bbl./day or 8.3 bbl./day per 100 ft.

Accordingly, horizontal well 7000 ft. for the pink area will have initial production 150 bbl./day, for recommended brown area it will be 580 bbl./day.

Calculated production profile confirmed in blind test.

Figure 2 shows the same well as Figure 1. In this section four pink fracking stages with total thickness 424 ft. according to Production Profile have total production 9 bbl./day or 2.1 bbl./day per 100 ft.

According to PP the best zone, brown interval has thickness 87 ft. with average production 11 bbl./day or 12.6 bbl./day per 100 ft.

Accordingly, horizontal well 7000 ft. for the pink are will have initial production 150 bbl./day, for recommended brown area it will be 880 bbl./day.

The examples above demonstrate that the technology can identify previously missed good intervals and optimize the horizontal wells placement.

The technology can navigate horizontal well through the best intervals and predict future initial production of the well based on PP from neighboring vertical wells.

Designing the trajectory of horizontal well through the correlating PPs of the vertical wells located nearby is the best way to drill only high producers.

The absence of such correlation indicates the end of a good zone. The more vertical wells with calculated PP, the more accurate is the mapping of the best producing formations.
Figure 4 shows open-hole log data and PP in the right column for vertical well in Permian Basin. The well was drilled as a pilot for two candidates for horizontal drilling: Wolfcamp A (upper circle) and Cline (bottom circle).

Based on PP it was clear next day after recording open-hole log data that Wolfcamp A looks better. This recommendation was verified using selective fracking.

In the first stage of the verification process only Cline was fracked and tested for 2 months. The initial oil production was zero.

In the second stage, after plugging top of the Cline, Wolfcamp A was fracked and tested for 2 months. The initial oil production was 33 bbl./day.
Verification process that took 4 months and cost $0.5 million confirmed the results produced by PP during a day.

Figure 5 shows predicted initial production vs. actual initial production for 51 vertical wells in Permian Basin.

Predicted production was calculated based on PP.
The chart shows great correlation with coefficient of correlation $R = 0.93$ that demonstrates high reliability of the technology.

Figure 6 below shows direct comparison of initial production for five groups of wells in Permian Basin. For each group the average distance between wells is around 2000 ft. Completion techniques and total thickness of fracking stages for all wells in the group are very similar. The only difference is that for the wells marked green, fracking stages were picked using PP.

For each group we can see the increase in production in the wells that used PP. The average production increase for five groups with 22 wells is 48%.

Analysis of PP in the Permian Basin shows that 80% of the thickness produced 12 times less than the remaining 20%, Figure 7. The technology separates low and high producing formations, allowing operators to avoid drilling of 80% of low producing horizontal wells and drill only horizontal wells with top production.

![Figure 6—Case study: Well production comparison](image)

![Figure 7—Production rate distribution](image)
Figure 7 presents histograms for production rate in 5 vertical wells located in the different parts of Permian Basin.

As one can see, 70% to 90% formations have production rate from zero to 2 bbl./day per 100 ft. But maximum rate can reach 65 bbl./day per 100 ft.

The separation of low and high producers is a key to optimizing the development of this field. According to the recent field study, four to five high producing horizontal wells can be drilled at the same location. Figure 8 below shows production profile, with the best zones for horizontal wells highlighted. Initial Production (IP) of horizontal wells is calculated for the length of lateral part 7,000 ft. and based on the correlation with the neighboring vertical well.

![Figure 8—Entry point for horizontal well based on PP](image)

For this well, there are three more recommended entry points at the depth of 5800, 8400 and 9000 ft. with the estimated initial production for horizontal wells, accordingly, 450, 400 and 620 bbl./day.

Production map for one of the identified high producing formations is presented on the Figure 9 below.
Figure 9—Production map for Wolfcamp A with color scale in bbl./day per 100 ft.

**Novel/Additive Information**

The technology is Global Petroleum Show 2018 Award Winner in the category Innovation in Technologies: Process Controls. This category recognizes a project, product or service to controls, that creates high impact disruptive innovation that will have a major influence on energy efficiency, emissions, economics, schedule or quality and practical consideration.

The technology presents new advanced formation-evaluation approach that radically increases operator's success rate:

- Increasing production and reducing development cost
- Accessing reserves missed by conventional development
- Increasing recovery efficiency
- Reducing environmental impact

The technology can also be applied in old wells for refracking and drilling new high producing horizontal wells.

**References**

2. Vladimir G. Ingerman "Optimising Oil Field Development" *Oil Field Technology*, Volume 07, 10 October 2014