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The importance of predictive modeling to geologic and engineering grading and information sharing for optimizing results in unconventional hydrocarbon development

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Background

This paper presents basic concepts regarding predictive modelling and geologic and engineering practices for grading prospective acreage to optimize results in unconventional hydrocarbon development.

Also presents the benefits of information sharing for also optimizing unconventional developments.

The paper also analyzes how predictive modelling is being applied in other new plays in the U.S. and how expanding the practice globally could result in extensive benefits, mainly in those plays in mature basins with plentiful geological information.

For example, this is the case for the Vaca Muerta formation in Argentina, which has more than 10,000 penetrations and plentiful 2D and 3D seismic sampling, were some of the concepts presented in this paper could be applied.

Aim

Thanks to research and technological development in hydraulic fracturing, directional drilling and a short term high price deck in the U.S. for natural gas and a global and longer lasting high price deck for liquids, huge amounts of shale gas resources were identified and brought online while the techniques migrated to shale oil, and have culminated in the U.S. becoming the largest oil producing country on Earth.

The proliferation of new shale exploration activity has increased the shale gas resources in the U.S. as well as gas production, which is estimated at 37.4 BCF at the end of 2014. Also this production from shale formations is the result of ten years of vast activity with over 145,000 wells drilled and fractured. Liquid production also increased drastically over the last four years to reach 3.67 MMBbl/d.

This increased supply of natural gas has triggered an effect not only in the U.S., but also regionally and globally, with a strong reduction of natural gas imports, increase number of Liquefied Natural Gas (LNG) projects, a Henry Hub between 3 to 4.5 USD/MMbtu, an historically unprecedented decoupling of natural gas prices to oil prices, lowering of CO2 emissions driven from switching carbon to natural gas, reactivation of manufacturing, and petrochemical industries and more.

It is expected that new oil price scenario for unconventional developments will not hurt natural gas production but mainly oil production due to the nature of the shales which is very gas prone.

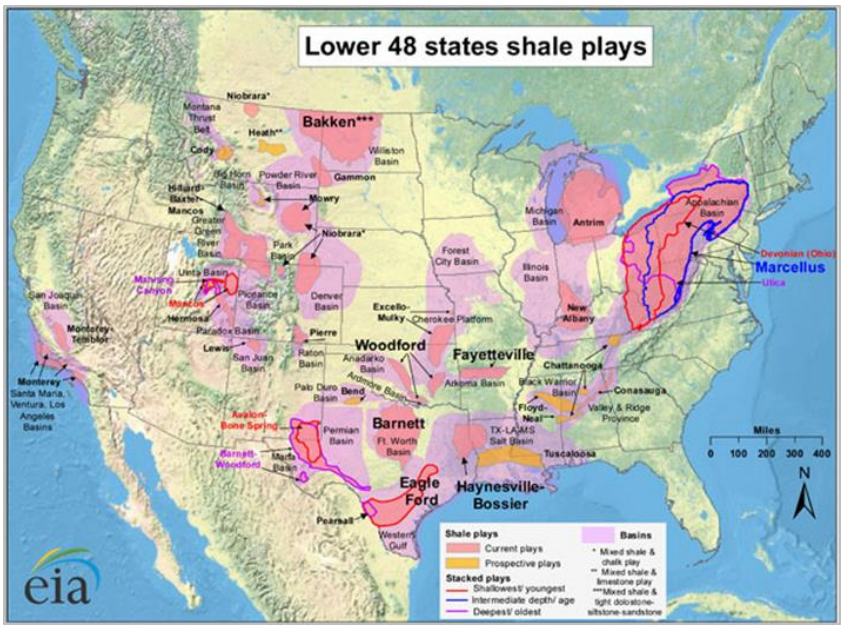

Figure1. Map of U.S. shale gas and shale oil plays
Source: EIA, 2011

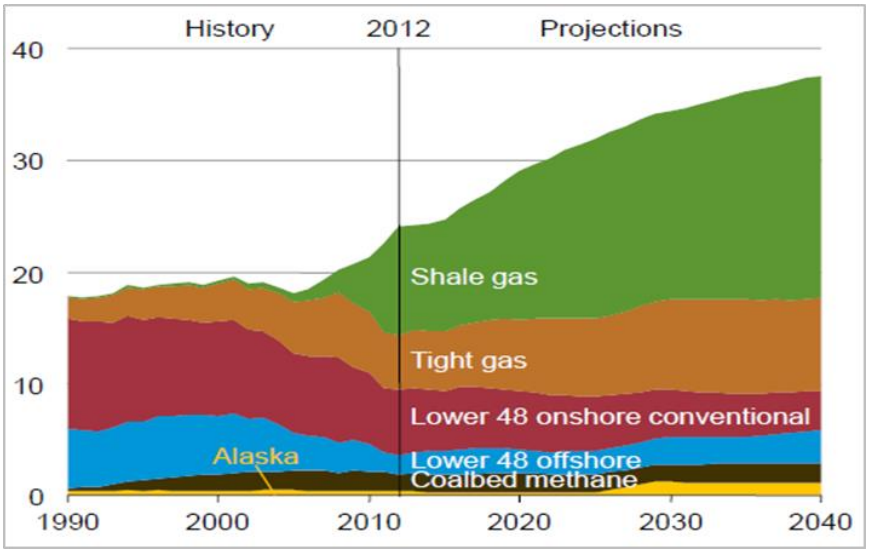

Figure2. U.S. natural gas production by source - reference case
Source: EIA, 2014

Moreover, the U.S. is not the only country with large technically recoverable resources of shale gas. Based on the list of the EIA, U.S. is the 4th ranked country with 665 TCF after China (1115 TCF), Argentina (802 TCF) and Algeria (707 TCF).

Argentina is exerting a great effort to develop its unconventional shale resources. In the Neuquén Basin, the Vaca Muerta formation has the greatest potential at 308 TCF and hopefully, with the correct above the ground decisions and strategies, Argentina can somehow replicate the unconventional resource revolution that is happening in the U.S.

Let's explore how predictive modelling can be used to grade both the geology and the engineering techniques necessary to optimize unconventional production and development, techniques that are hugely accelerated in an atmosphere of free information exchange.

What is predictive modelling?

There are two general concepts important to understand. The first one is that predictive analytics encompasses a variety of statistical techniques from modelling, machine learning, and data mining that analyze current and historical facts to make predictions about future, or otherwise unknown, events. (Wikipedia, 2011)

The second one is that predictive models are the relation between the specific performance of a unit in a sample and one or more known attributes or features of the unit. The objective of the model is to assess the likelihood that a similar unit in a different sample will exhibit the specific performance. (Wikipedia, 2011)

For the shale gas/oil industry, predictive modelling techniques, such as regression analysis, are used to grade the acreage. Acreage grading uses predictive models to find the relationship between geology and engineering data, and known production. It is important to use as much relevant data as available.

Examples of geology data are well log attributes such as gamma ray, resistivity, porosity and many others. Other subsurface data such as 2D, 3D, microseismic and more lately 3-C and 9-C seismic can be used where available to enhance analytical results. Examples of engineering data are amount of proppant, lateral length, amount of fracture fluid and literally dozens of other parameters. Once the data is collected it is input into the predictive model and the correlation between it and known production is established.

This correlation can then be used to predict production anywhere where the geology data exists, regardless if there is production or not. The end result is predicted production in all areas of the play. These predicted production values can be binned for example into 10 bins, A-J. A is the best, and J is the worst. *Clearly, predictive modelling to grade the acreage allows for us to characterize regional or local sweetspots, which are of enormous value to monetization techniques, recovery factors and creating value to capital.*

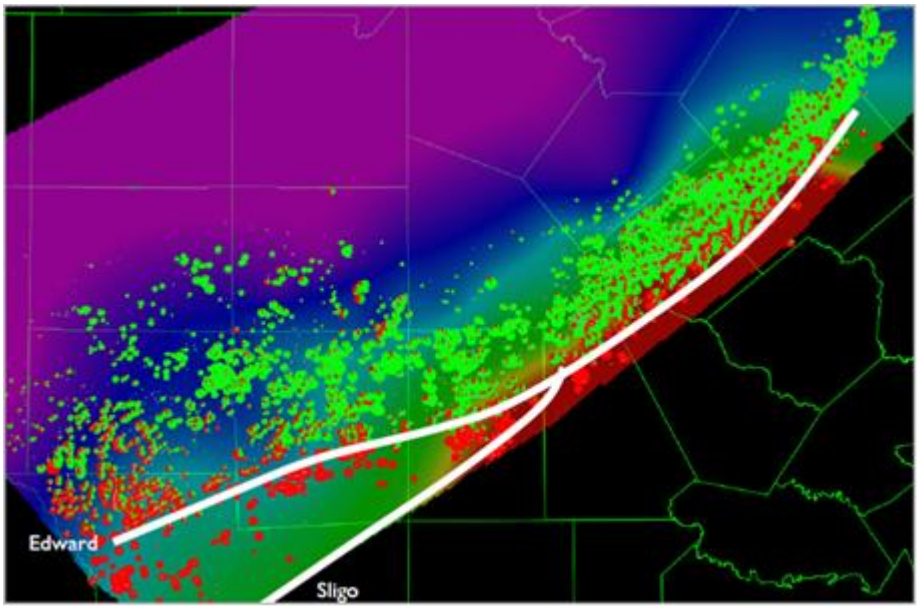

Figure3. Eagle Ford sweetspot map with normalized engineering
Source: DrillingInfo, 2013

What is grading acreage?

Graded acreage is an evaluation of a plot of land and ascribed to its natural prospectivity to produce hydrocarbons. This is especially important for unconventional resources and, to be accurate, requires a lot of well data (well logs) used to compute various structural, lithologic, rock properties, and thickness parameters, and reasonable interpolations and extrapolations of such between and beyond well bores.

These observations are compared to production data in a sophisticated non-linear manner to generate graded acreage maps that normalize what rocks have the highest propensity to produce. These analyses are done for gas, liquids, and economic deliverability independently. In the following figure we present the economic deliverability grading result of the Eagle Ford play in south-central Texas.

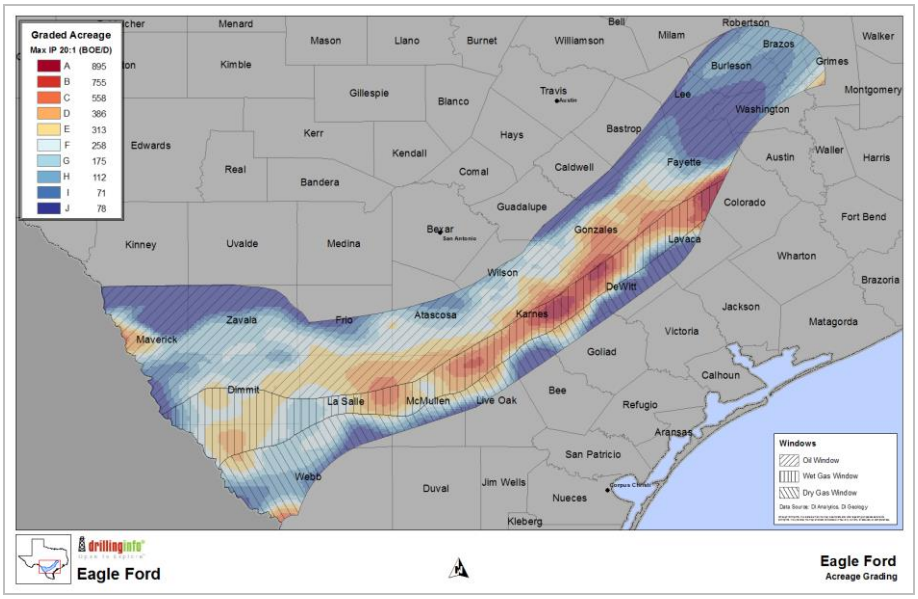

Figure4. Eagle Ford Acreage Grading
Source: DrillingInfo, 2013

Once the acreage is graded for geological propensity to produce, many other benefits fall out:

- **Explore Acquisitions and Divestiture (A&D) opportunities**
    - Rank operators based on productivity for possible acquisitions or partnerships
        - Acreage grading allows for accurate operator performance benchmarking. We can evaluate production in similar grades to understand marginal operators versus best in class operators. Every operator can be ranked using unbiased, data driven analysis. This can be a very useful screening tool for entities looking to buy working interest in US unconventional plays. The idea is to buy the interest from an operator that ranks highly because they are maximizing production. The difference between a marginal operator and best in class can be upwards of 30%-40% productivity.

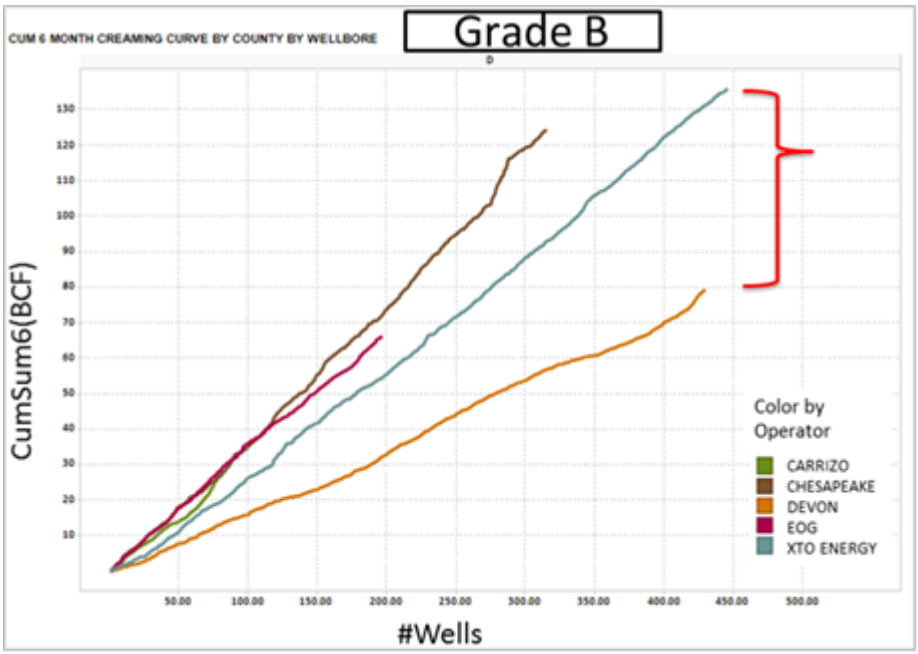

Figure5. Creaming Curve by County by Wellbore
Source: DrillingInfo, 2014

- Quantify risk with sensitivity analysis in various grades
  - A $/BOE sensitivity analysis reveals that in the core areas of the Eagle Ford, the difference in breakeven prices between best in class and marginal operators is fairly small, about $3-$6 / BOE. The risk begins to increase as acreage quality diminishes. The same $/BOE sensitivity analysis performed in mediocre areas of the Eagle Ford shows a difference in breakeven prices of $20-$30 / BOE between best in class and marginal operators. The risk increases by almost a factor of 10. This suggests that if an operator is fortunate to be in the core of the play, there is a much better chance the operator will drill favourable wells even when compared to other operators in core acreage.
- Gives context to leasing information, better decisions during the leasing process
  - One particular dataset that benefits greatly from graded acreage is DrillingInfo leasing data. In the past, when presented with 10k acres, it was difficult to make a quick decision on the position's quality. What graded acreage allows is a very fast, baseline understanding of the position's quality. It adds context.

- Identify and quantify the particular engineering practices that maximize production in particular grades
    - We can quickly identify which engineering parameters benefit production and can quickly converge on optimal practices and identify new practices that "defy" the prediction.

- **Evaluate assets**
    - Quantify core versus non-core
        - Graded acreage shows that there are about 10k square miles of productive acreage in the Eagle Ford (grades A-F). Grades E and F tend to be at about 0-10% after-tax rate of return (ATROR) in the Eagle Ford. Only 3% of the Eagle Ford is A grade acreage. A grade wells tend to produce about 900 BOE/D in their peak month.
    - Assess recoverable resource potential
        - Graded acreage allows for baseline productivity estimation at all areas in the play. When combined with simple decline curve analysis, acreage grading allows for production forecast modelling assessing the recoverable resource potential in an asset.
    - Target underperforming assets

- **Understand Best Practices**
    - Identify and quantify how engineering practices work in varying levels of acreage quality. Ex: Marginal benefit of longer laterals diminishes in lower acreage quality

- **Explore productivity potential in plays with no production**
    - If geologists believe a geologic basin is similar to another where acreage grading exists, the predictive model used to grade the current basin of interest. In this fashion the predictive model is used to understand the potential productivity of analogs.

What is sharing of information?

Development of the unconventional industry in U.S. has been driven by sharing of information or the exchange of data and information. Operators are forced to share most relevant information to local and federal agencies. Operators from time to time also share information to each other directly, or through companies like DrillingInfo that clean, structure and provide the data and benchmark analytics back to the participating companies.

The shared data (permits, completions, production, well data, lease/land data, choke size, geological and other) is then available for companies to organize, clean, interpret, model, and give value added results such as the case of predictive modelling to grade the acreage and deliver sweet spots and predict production.

The next figure shows examples of the drilling/completion variables modelled against production synthesized from the data. These models permit us to optimize production through best practices:

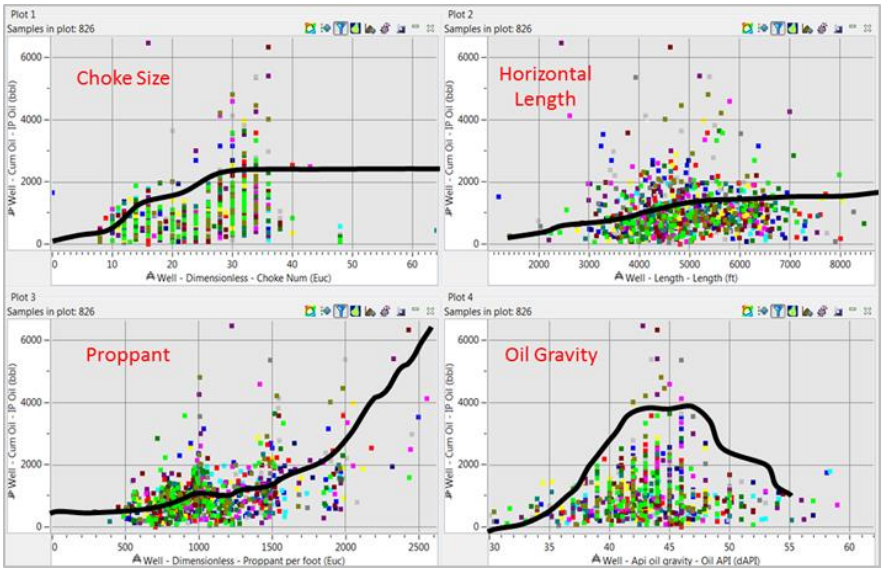

Figure6. Determination of a model for analogy (best practices) in areas with similar characteristics
Source: DrillingInfo, 2014

Without sharing of information valuable analysis could be lost, and operators could not perform geological comparative studies, contrast various engineering strategies and tendencies to improve their performance across zones in a determined play.

Ultimately over time, all operators may increase production and of course the returns of their investments with benefits for the overall industry (landowners, operators and countries).

Without sharing data, it would be very difficult to perform more accurate predictive modelling and acreage grading, which in turn will not allow more clearly determining or predicting sweetspots within a play, neither compare best practices across a play or plays around the world.

How to use predictive modelling to grade the acreage to develop Vaca Muerta

U.S. graded acreage models can be extensively used to evaluate new unconventional plays in the U.S. and other plays of the world. How can this work?

First of all, information from well logs and seismic must be shared to complete detailed geologic studies of the basin. Once these studies are completed, geologist can compare the play of interest to the U.S. basins were graded acreage exists. Once the analogy is identified (using geological analogy) predictive model for the particular U.S. basin can be used with geology and seismic data in the exact format the model requires.

When data preparation is complete you can run the model and use the results to grade the basin. This is a beneficial technique because a vast amount of oil and gas production is not needed for the evaluation. It only requires geologic and/or seismic data. This will result on sweetspot determination and predictive production on the whole new play on or a determined area within a play.

For Vaca Muerta play in Argentina, even though the formation has not been exploited extensively yet using modern hydraulic fracturing technologies, the formation has been extensively been penetrated for decades. It is estimated that data for over 10,000 penetrations exist and also extensive 2D and 3D data.

Data from these wellbores can provide the subsurface data needed for predictive modeling. If a U.S. analog is identified for the Vaca Muerta, the predictive model for the U.S. basin can be used to grade the Vaca Muerta and thereby improve the understanding of the entire basin, identify sweetspots, predict production and perform development optimization later in the development.

It is to be noted that Vaca Muerta is considered to be a very prolific shale, not only because its favorable geological conditions, but also for the large amount of geological information that has generated over the years, which allows to perform intensive and precise analytics to improve productivity.

It will be encouraging for Argentina to establish a mandatory centralized data base to share information for optimally develop Vaca Muerta and other prospective shales.

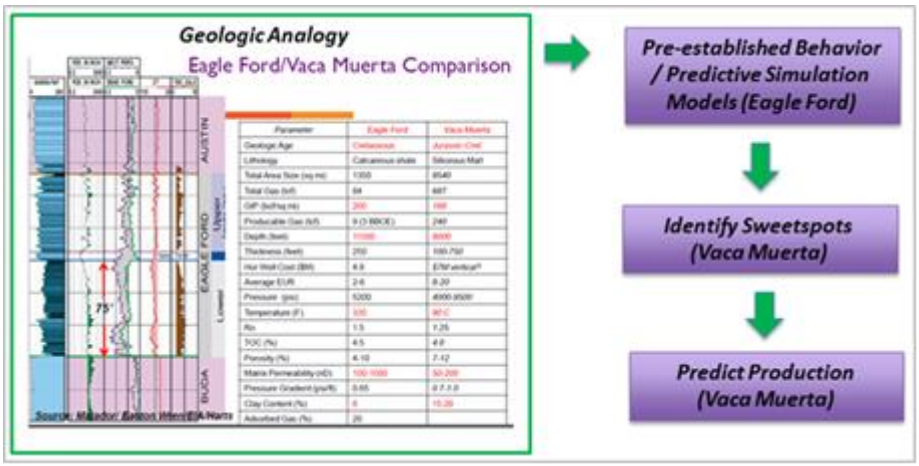

Figure7. Proposed process for the development of Vaca Muerta

Conclusions

Operators continuously employ new techniques and software to improve productivity, reduce costs and increase revenues.

Predictive modeling to grade the acreage is a valid scientific approach to achieve better and improved results in unconventional developments.

It is somehow imperative that other unconventional plays in other countries around the world allow mechanisms to share information to get improved results and perform same type of activities.