Before the Basin Model: Utilizing Formation Tops and Production Profiles to Understand the Effects of Burial History on Hydrocarbon Production

Ted Cross, Kiran Sathaye, Kristopher Darnell, Dillon Niederhut
Novi Labs

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Abstract

Many of the most important controls on hydrocarbon production in both conventional and unconventional systems are not directly measurable over large, continuous areas of the basin. Instead, the industry relies on sparse, expensive core samples in conjunction with labor-intensive petrophysical analysis and basin modeling to extend fluid predictions around a basin. What is the minimum amount of information required to learn the basin's burial history and predict hydrocarbon production?We present a decision tree-based machine learning model which uses NDIC-provided formation tops, completions intensity, and interwell spacing to predict oil, water, and gas production in North Dakota. This model predicts production of these three streams at 30-day increments out to 720 days. In order to determine the signal in formation tops alone, we omit any petrophysical information from well logs. Location information (such as Latitude/Longitude) is also excluded from the model training dataset. Utilizing a random 80%/20% split of wells, this model is able to predict oil, gas, and water production with a median error below 20% after 180 days of production.In order to extract geological insights from the model, we utilize Shapley Additive Prediction (SHAP) to determine the contribution of each feature to the model prediction. In this case, the SHAP approach quantifies the contribution in barrels or MCF of each individual variable in the model. Surprisingly, the SHAP effects from formation tops showed a strong effect on production coming from both shallow, continuous formations like the Niobrara as well as deeper

formations in the Ordovician and Precambrian. Specifically, these formation depths impacted model predictions by up to 50,000 barrels of oil at IP720. Even though these formations are thousands of feet removed from the producing Bakken and Three Forks Formations, their depths can act as a proxy for basin geometry, maximum burial depth, burial rate, and subsequent tectonic activity in the basin, just as they would within a regional basin model. Viewing the SHAP impacts spatially shows that the model identifies traps such the Nesson and Antelope Anticlines as areas of increased hydrocarbon production, while controlling for spacing and completions. These results show that integrating easily accessible information such as formation tops, completion intensity, and well spacing can identify broad geological trends in unconventional basins. These broad trends can be used to 1) inform decisions about higher resolution and more costly data acquisition efforts, like wireline log suites, coring, and laboratory tests and 2) Identify areas of the basin where different completions strategies are required.

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