Exploration, Appraisal and Development of Unconventional Reservoirs: A New Approach to Petroleum Geology

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Abstract

The discovery of commercial oil and gas production from shale, or mudstone, reservoirs has dramatically changed how we explore for and develop oil and gas accumulations. In conventional exploration, appraisal and development there is a fairly standard and accepted application of processes and technologies. However, the processes and technologies that are employed in the exploration, appraisal and development of mudstone reservoirs are significantly different, and they are often employed for different reasons and at different stages of the cycle.

Prospect identification is always the initial phase of any exploration project. In most cases in the conventional world this is a result of the interpretation of seismic data, either 2D and/or 3D, in order to identify the areal extent of the prospect, which would typically be on the order of a few hundred acres or, in some instances, a few thousand acres. However, in the unconventional world the identification is done at a basin level and is typically not supported initially by seismic, but rather by detailed analysis of a few key wells and their associated petrophysical attributes. Once those attributes are deemed to have the potential of supporting a commercially productive mudstone reservoir, then the utilization of seismic is employed to help define the boundaries of the reservoir, understand the structural components of the basin and, in many instances, preliminarily map the thickness of the reservoir. The third preliminary source of data that would identify the quality of the prospect would be a geochemical analysis of the reservoir. While this can often be difficult to obtain due to the lack of core or drill cuttings to obtain the analysis, it can be a very critical component of the identification process.

Once the prospect has been identified, the evaluation processes during the exploratory drilling phase are dramatically different. During conventional exploration the determination as to whether hydrocarbons are present is largely done by the acquisition and interpretation of data from openhole wire line logs. While cores, either whole or sidewall, will often be taken, they are typically not acquired to validate the productivity of the reservoir, but rather to supplement the openhole log data. In unconventional exploration, the opposite is the case. While the openhole logs are extremely important once the discovery is made to calibrate the reservoir, the most critical data around the validation of the quality of the reservoir is the detailed analysis of the rock acquired from whole core. While some of the attributes that are measured from the mudstone core are common to conventional exploration, there are many more measurements that are taken on mudstones that are totally unique to this type of reservoir.

As the prospect moves into appraisal and development mode, there are also unique processes and technologies in the unconventional world that are used to more fully understand the reservoir. The most important of those is the calibration, through the use of specific algorithms, of the data acquired from the whole core data to the openhole data that is being acquired from the appraisal and development drilling. Because the cost and time necessary to acquire an extensive collection of whole core data can be prohibitive, there will be a limited number of wells from which whole core is taken in any given field. Therefore, it is critical to be able to calibrate the various measurements from the whole core to the

openhole log data that will be available on many more wells. This is also the point during which 3D seismic would be acquired, as opposed to the acquisition of that type of data during the identification process in conventional exploration. In unconventional development, the primary benefit of the 3D seismic data is not to identify where you want to drill, but rather where you don't want to drill. Specifically, the horizontal lateral is placed to minimize the effect of faulting on the lateral.

Throughout the entire period of field appraisal and development, the practice of geosteering is critical to the economic success of the field. Since virtually all of the unconventional development is done with the application of horizontal drilling, it is critically important that the drill bit maintains its position within the identified target window while the lateral is being drilled. This target window can be within the section where the highest quality reservoir has been indentified, within the optimum stratigraphic position of the reservoir in order to optimize the completion, or, in most cases, a combination of both. Since the drilling operations are performed around the clock, and unexpected changes in dip or the presence of faults can cause the bit to rapidly change its relative stratigraphic position, a Gamma Ray tool is incorporated into the bottom hole drilling assembly in order to provide continuous measured depth Gamma Ray log data, which is then converted to a true vertical depth (TVD) log using software designed specifically for this process. This TVD log data is subsequently correlated with nearby well control to determine where the lateral is positioned stratigraphically at all times during the drilling operation. When the bit has been interpreted to be out of the desired target window, it is the responsibility of the geosteerer to collaborate with the drilling organization to make the necessary changes to get the bit back into the target window.

While the previous example of the role of the development geologist is focused on the day to day operations of the field, one of the most critical inputs that they have is in the long range development of the field. Due to the extremely large area that these fields typically encompass, the early establishment of unit spacing and unit configuration is critical to minimize the amount of spoiled acreage that will occur as a result of faulting, surface limitations and the complexity of integrating land not under your control. This is a multi-disciplined effort between geology, land, and engineering, but the lead must be taken by the development geologist in order to maximize the value of the asset.

All of these processes and technologies have truly transformed how geoscience is applied to the exploration and development of mudstone reservoirs. Additionally, considering the fact that the exploration and development of mudstones is still relatively immature, it is likely that many more changes will be developed as the science matures.