A Progress Energy Montney Case Study in Risk Identification Grouping and Mitigation

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Introduction

Unconventional reservoirs are very complex and often require a multi-disciplined approach for successful exploration and development. A method that is often deployed to resolve this complexity utilizes composite map amalgamation of various attributes such as geochemistry, sedimentology, geophysics and rock mechanics. This method is often referred to as "Sweet Spot Mapping" (SSM). SSM can be an effective way to high-grade certain areas within a large unconventional play – but there are potential dangers associated with this methodology. Often, parameters used in SSM are not well defined or easily measured. For instance, accurate and meaningful permeability values in an unconventional play can be exceedingly hard to define. Porosity values may have a very low dynamic range – and can also be hard to measure (and map) accurately. Amalgamating attributes that are not well defined (or are downright wrong) may result in high-grading non-optimal areas of unconventional plays. This paper presents a technique that has a proven track record and has been utilized for successful field development by Progress Energy over the North Montney Joint Venture (NMJV) development.

It allows for areas to be assessed with dominant "risk profiles" that are assigned to the specific reservoir being targeted and is termed Risk Identification, Grouping and Mitigation (RIGM). The technique generates a very different output to "Sweet Spot Mapping" as SSM is a simple summation of values while RIGM is a multivariate approach that allows one risk to trump all other input parameters. Moving from Sweet Spot Map to RIGM can be used to advance the development of a field to overcome hurdles from initial exploration to development by identifying, grouping and allowing for the potential mitigation of "primary risks". These risks are unique to the play or area – but are easily identified and defined – as opposed to the parameters that are generally used in SSM. Essentially, this is a simple but very robust method analyzing exploration and development risk in unconventional plays.

Theory and/or Method

"Risk Identification, Grouping and Mitigating" (RIGM) utilizes multivariate statistics and binning to identify important risk factors. Once these risks are identified, they can be plotted in polar plots allowing for areas to be grouped with other areas sharing similar regions and – from this plot - the primary risk factor can be identified and defined by the largest vector in the plot. This process is dynamic - in that the initially identified risks can easily change with time as further development and knowledge evolve within the area.

As Progress Energy's North Montney Joint Venture (NMJV) enters the full field development phase - ten risk factors have been identified. These risk factors are: Retrograde Condensate, Sour Gas, Hydrostatic Pressure, Fracability (further subdivided based on relative breakdown pressures), Total Isopach, Regional Facies Heterogeneity, Terrain Challenges, Facility Challenges and Drill Costs. Each of these will be discussed in detail and amalgamated into composite polar risk identification plots, with a brief discussion on the analytical techniques used to identify and mitigate each where possible.

Retrograde Risk: Catagenesis is the primary process of hydrocarbon generation within the Montney Formation. Understanding how compositional blends and phase relationships change with respect to thermal maturation and drawdown is an important factor to identifying areas that may be prone to retrograde oil banking. This is deemed a primary risk because of diminishing relative permeability with phase behavior change below the dew point. As kerogens experience increased thermal maturation from immature to dry gas the resultant phase envelope of the hydrocarbon mixture shrinks as the hydrocarbon stream gets leaner. Phase envelopes, from immature to wet gas, can be generated and easily evaluated from geochemistry derived from pyrolysis and known bottom hole conditions. Wells drilled to date in oil banking areas have all underperformed to date. Unfortunately this is a difficult risk to mitigate once encountered.

Sour Gas Risk: Sour gas is another primary risk factor due to safety, pipeline and facility constraints - as well as shrinkage. Before steps to mitigate this risk can be deployed, the source of the gas must first be identified. To identify the source of sour gas, Progress Energy has conducted a regional isotope study of all natural gases across the NMJV. These results have identified two geographically distinct sources of H2S, both of which have been determined to be Thermochemical Sulfate Reduction generated. The first source is associated with a unique and identifiable type of faulting on the western portion of the NMJV. While the second source is localized to mappable NNW-SSE striking trends associated with overlying sour Doig units. Communication with overlying Doig Formation during Upper Montney completions may occur if the lateral is placed too high. Mitigation involves vertical well placement optimization.

Pressure Depletion: As indicated by Darcy's Law, the change in pressure has a very large impact flow rate, especially in very fine grained porous media. For this reason, areas with non-overpressure Montney (normally pressured) may be deemed as a primary risk. Two scenarios have been identified in the NMJV: First - in thermally immature areas, and second - where the system has been breached (faulted or fractured) allowing over-pressured gas from the source rock to migrate into conventional reservoirs via fault conduits. This primary risk can be identified by combining geochemical catagenic modeling with extrapolated reservoir pressures and fault classification (through 3D geophysics).

Fracability: Fracability risk (in this context) is firstly: the ability to achieve some fracture complexity in the rock, while secondly not encountering an area that exceed the capacity of the surface pumping equipment, which may result in a failed stimulation. Both ends of this spectrum can lead to either over capitalizing or under stimulating the reservoir. For this reason, on the polar plots, fracability has been split into two risk factors: very low break down or very high break down. The "fracability" of wells in the NMJV varies greatly and is identified with such factors as regional stress anisotropy, rock mechanical properties, and the type of fracture stimulation. Mitigation of this risk may be limited (for various reasons) changing the type and/or style of the stimulation can be very effective as a risk mitigation technique..

Regional Facies Heterogeneity: Through detailed core and chip sample analyses, Progress has characterized six distinct Montney lithofacies within the NMJV area. This work has led to the development of a new sedimentological model *(Moslow, Adams, and Terzuoli in press).* The sedimentological model has identified three important target intervals within the Montney (for simplicity referred to as upper, middle and lower). Each of these intervals has been mapped with the dominate risk identified. In the central portion of our land base, both the Lower and Middle intervals contain large amounts of bioclastics. This bioclastic content grades from a more siliclastic facies (proximally - east) to a dolosiltstone hemipelagite with lesser bioclastics (distally - west). In these two intervals the bioclastics are believed to enhance the Stimulated Rock Volume (SRV) – or fracture complexity - through bioclastic anisotropy. Obviously, categorizing this bioclastic anisotropy is important in identifying zones within the Montney that can be effectively fracture stimulated as permeability above and below each zone does not deviate greatly.

Alternatively, the upper Montney contains almost no bioclastics. The main risk that has been identified in this zone is enhanced porosity and permeability via bioturbated horizons. These horizons have been noted in MICP analysis of intact recovered cores and can, now, also be identified with NMR logs. AS a mitigation technique in some areas of the NMJV – the bioturbated horizons have almost “conventional” reservoir characteristics and are avoided because of a potential lack of fracture complexity.

Thin Total Isopach: The total the number of horizontal wells that can be placed in a vertical section without interfering with proper vertical spacing is directly correlated to the total isopach of the Montney. In areas with a total isopach less than 230m this is a risk as cost efficiencies cannot be realized through the economy of scale and is therefore deemed a risk.

Drill Cost, Terrain and Facility Challenged: The final risks are economic or time dependent risk functions and are subdivided accordingly in the polar plot as drill cost, facility constrained, and terrain challenged. Risks such as high drill costs due slow ROP or extreme bottom hole pressures or even special casing design can be mitigated through technology and persistence, however terrain and facility constraints are a function of time in the field development lifecycle.

Conclusions

Understanding the development lifecycle of an unconventional resource is a valuable mindset to occupy. This coupled with a growing understanding of geological and reservoir risks specific to the target reservoir is paramount for successful economic field development as shown through a case study of Progress Energy’s Montney development. By understanding these risk factors and employing the RIGM methodology to mitigate these risks, well performance has been improved. RIGM is a proven technique that demonstrated that data can be complex and answers can be simple, not vice versa.

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References

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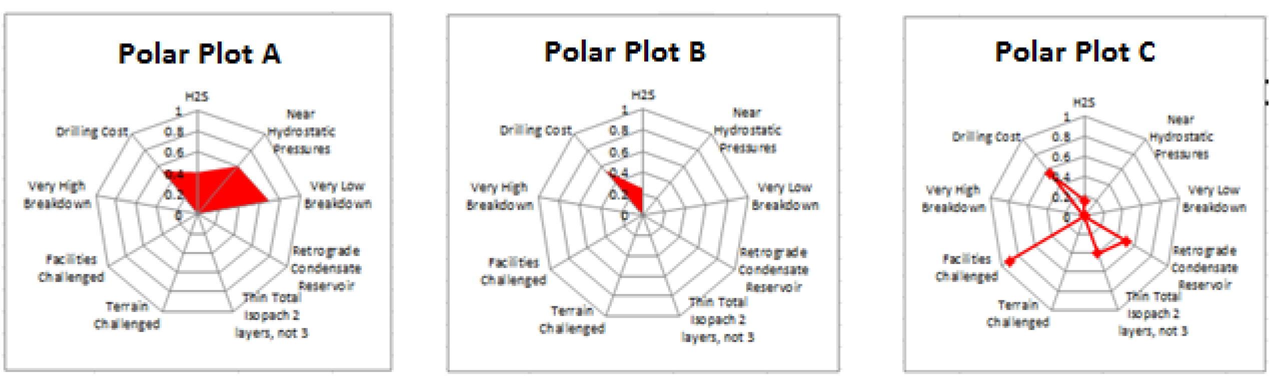

Example of three different polar plot outputs from three different areas showing risk