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Successful Application of Horizontal Through Pipe Petrophysical Technology to Model the Montney Formation

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Abstract

Worldwide the oil and gas industry acknowledges that technology is, and will continue to be, the driving force in allowing oil and gas producers and service companies; to continue to deliver results that will improve production performance in a safe, environmentally sound and cost-effective manner. This is especially true for unconventional producers who are also faced with unlocking the technical challenges of unconventional reservoirs.

To aid in evaluating the Montney liquids-rich resource play, a new through pipe well logging technology was utilized to provide reservoir formation log data through drill pipe on new horizontal wells and through casing on a vertical well. This technology was run in the 7GEN KAKWA 13-24-65-5W6 cased vertical well, then compared to open hole well logs and to core data, both standard and special core analysis. The same through drill pipe logs were run in 14 horizontal wells in the Kakwa and Karr fields. The data collected in the horizontal wells was compared to the vertical core well and to the strip log data on each well. Calibration of the vertical though casing log data to core analysis provides an accurate determination of the reservoir properties in the lateral section of the horizontal wells.

The cost / benefit of utilizing through pipe technology was analyzed. The analysis took into consideration direct and indirect costs associated with data collection and risks associated with horizontal data collection. By evaluating the associated costs and risks it was determined that through pipe data acquisition provides much lower risks and costs less than other data acquisition methods.

Introduction

The Montney is a well-established producing horizon for oil, condensate, natural gas and natural gas liquids throughout western Alberta and northeastern British Columbia. In recent years, liquid-rich “shale” gas has been a target for many producers in Western Canada. Technology advancements in horizontal drilling and completions have made this target accessible and economically viable. Horizontal drilling technology and multi-stage fracturing of horizontal wells have allowed for significant additional development of the Montney formation beyond the confines of the conventionally trapped pools that were commercially exploitable with vertical wells.

Technological advancements in one area, can create additional challenges in another. Data acquisition in horizontal wells has increased in both risk and cost, when compared to vertical wells drilled into conventional reservoirs. Many producers have opted to forego, or minimize, data acquisition in their horizontal wells to avoid the associated costs and the risks. However, government regulation requires formation data to be acquired on horizontal wells in many of the areas in Alberta where unconventional reservoirs are currently being explored for and developed.

In general, the longer a hole is left open, without setting casing, the greater the likelihood of hole problems occurring. Acquiring open hole well log data often requires additional pipe trips in and out of the well. This can decrease hole stability and can increase the probability of becoming differentially stuck. The restrictions on pipe control, such as the inability to reciprocate or rotate the pipe while logging, also increases the probability of becoming stuck. Logging while drilling (LWD) tools provide some relief to the potential of getting stuck, however with LWD the cost rises dramatically if the tools become stuck and/or are abandoned. Depending on the sensors in the LWD string, the tool replacement costs can reach levels exceeding one million dollars.

Due to the costs and risks discussed above, it is clear that operators are motivated to look into different ways to satisfy the regulatory requirements to provide horizontal well log data.

Discussion

Seven Generations Energy Ltd. ("7G") was required to collect horizontal well data on several wells in their liquids rich Montney play in North Western Alberta, **Figure 1**.

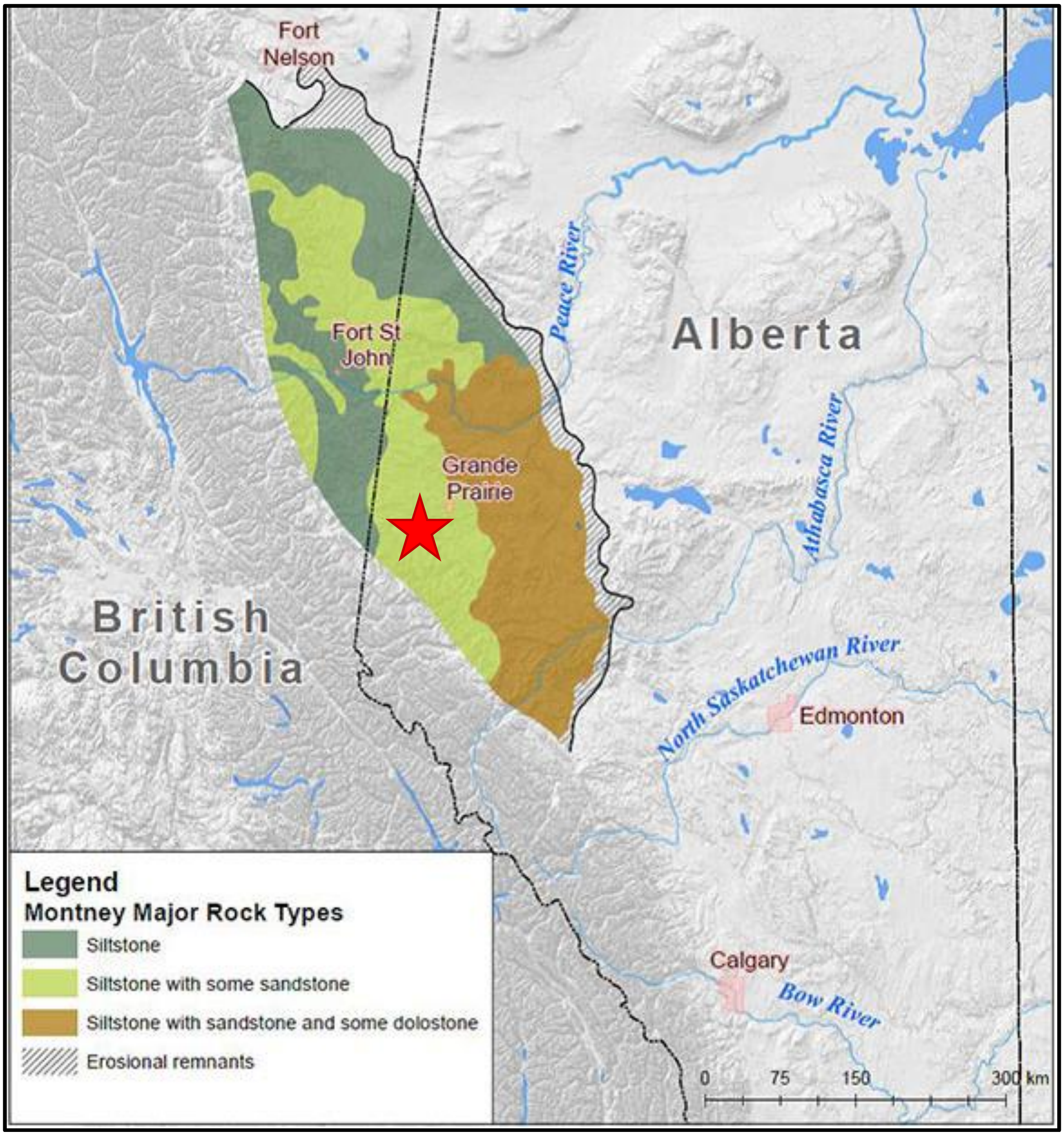

Figure 1. Map of Montney and liquids rich area (Website http://www.neb-one.gc.ca/clf-nsi/rthnb/nws/nwsrls/2013/nwsrls30-eng.html modified by Roke Technologies Ltd.)

There are a number of options for data acquisition in horizontal wells; open hole - through bit; open hole – pipe conveyed; and, LWD technologies. All are relatively well understood and are not further described in this paper. Open hole – through pipe measurement of porosity can be achieved using an acoustic device, but this will require high compressive strength material in the annulus to provide reliable quantitative formation measurements. Typical annulus material in these scenarios is drilling mud with very low compressive strength, rendering the acoustic measurements unreliable. As such, acoustic measurements are not further included in this comparison, as they were not a viable option for the operators that require more comprehensive data.

The remaining two categories attempt to establish open hole measurement quality through the drill string in a scenario that would be considered low-risk relative the other options. These options include measurements through composite drill collars (Through Composite) and through drill pipe (Through Pipe Petrophysical Technology or "TPPT")

Through Composite utilizes a non-conductive composite material drill collar to allow resistivity measurements to be made in the safety of the drill pipe. Typically neutron and density measurements are also conducted in the same trip. To reduce mechanical failure potential, the composite collar can be installed during a wiper trip and the logging tools can be pumped down once the drill string is at TD.

TPPT utilizes neutron and neutron gamma physics to provide formation evaluation data through drill pipe without the need for a composite drill collar. This simplifies the operation and allows for regular drill pipe to be used, reducing the diameter of the down hole assembly relative to the Thru Composite method. Similar to the Thru Composite method, the measurement devices never go into open hole which allows the driller to safely rotate and reciprocate the drill string as required, reducing the potential for stuck in hole situations.

To determine the best solution, cost and risk were considered. Cost comparisons are shown in **Table 1**. Risk of sticking the drill pipe and possibly losing the hole is shown in **Table 2**. Costs associated with the risks are not presented but need to be considered. These include the cost of fishing operations, side tracks, logging tool damage and replacement costs of lost logging tools.

Table 1 summarizes several data acquisition methods including open hole methods under the assumption of a 3500m well with a 1500m Hz leg and rig cost of $3,000/hr.

Acquisition Method	Data Costs	Additional Rig Time (hrs)	Total Rig Costs	Total Cost Acquisition
Open Hole – Thru Pipe	$60,000	2	$6,000	$66,000
Open Hole – Thru Composite	$60,000	2	$6,000	$66,000
Open Hole – Thru Bit	$60,000	12	$36,000	$96,000
Open Hole – Pipe Conveyed	$60,000	24	$72,000	$132,000
Open Hole - LWD	$140,000	6	$18,000	$158,000

Table 1 Acquistion method cost comparison

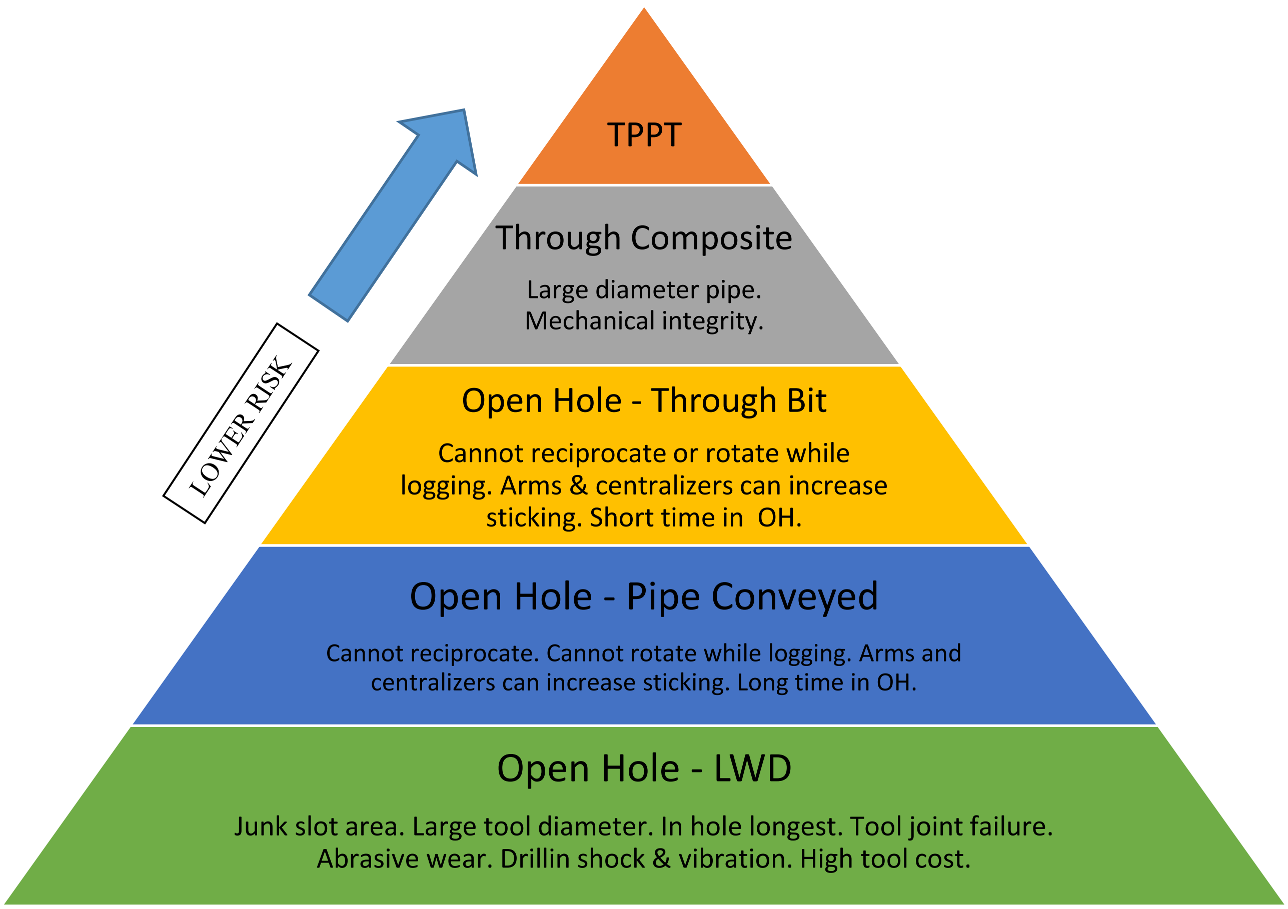

Table 2 Outline risks of horizontal well logging data acquisition methods.

TPPT in the Montney

Due to its aerial extent and reservoir variability (rock-type/facies), exploiting the Montney formation presents a number of challenges. In the unconventional liquids-rich region of the Montney, the reservoir fluids reside in a complex mixed-hydrocarbon system within an over-pressured deep-basin. The reservoir properties themselves are also variable within this area of the Montney. Porosity, clay content, and bulk density can change, not only vertically between the different stratigraphic units but also laterally. Reservoir properties often will vary within the length of a horizontal wellbore, which are often greater than 2000 meters in length. Modelling this type of reservoir with only vertical data points typically proves to be a difficult and costly task.

7G was required to gather porosity and lithology data on 15 of 16 horizontal wells logged from 2011 through June 2014, as well as on all vertical stratigraphy test wells. 7GEN KAKWA 13-24-65-5W6 is one of the wells where regulation required that the well be logged. This vertical well was drilled as a stratigraphic test to evaluate the potential of the upper and lower Montney within the liquids rich area in Alberta.

TPPT was utilized to evaluate the vertical 7GEN KAKWA 13-24-65-5W6 well and was compared to open hole well logs and core data within the same interval. The TPPT was also used to evaluate 14 horizontal wells in the Kakwa and Karr fields. By logging wells through drill pipe, a large data set of horizontal data that is comparable to both vertical data and core data was gathered. The study area and wells that were evaluated are illustrated in **Figure 2**.

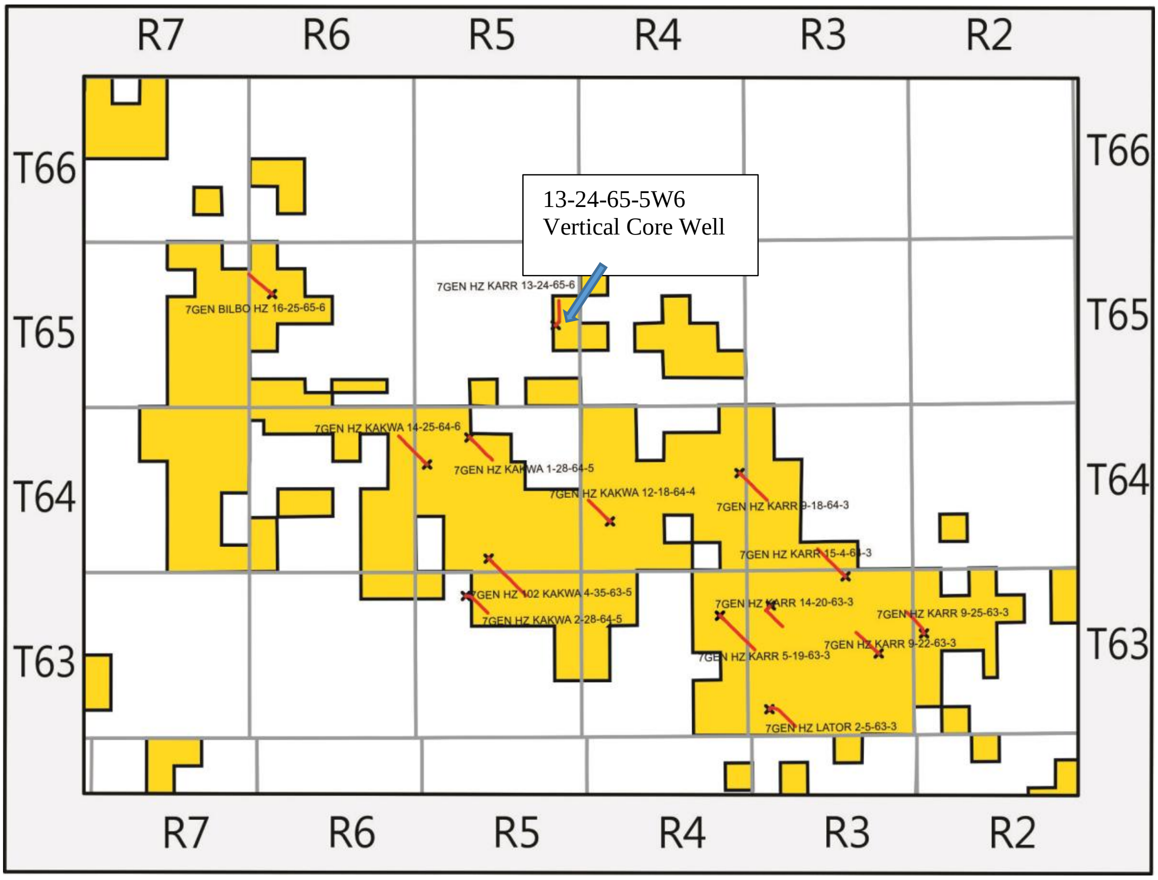

Fig 2. Location map of logged wells and core well.

Below are a number of charts comparing different well logs against core data for several reservoir properties:

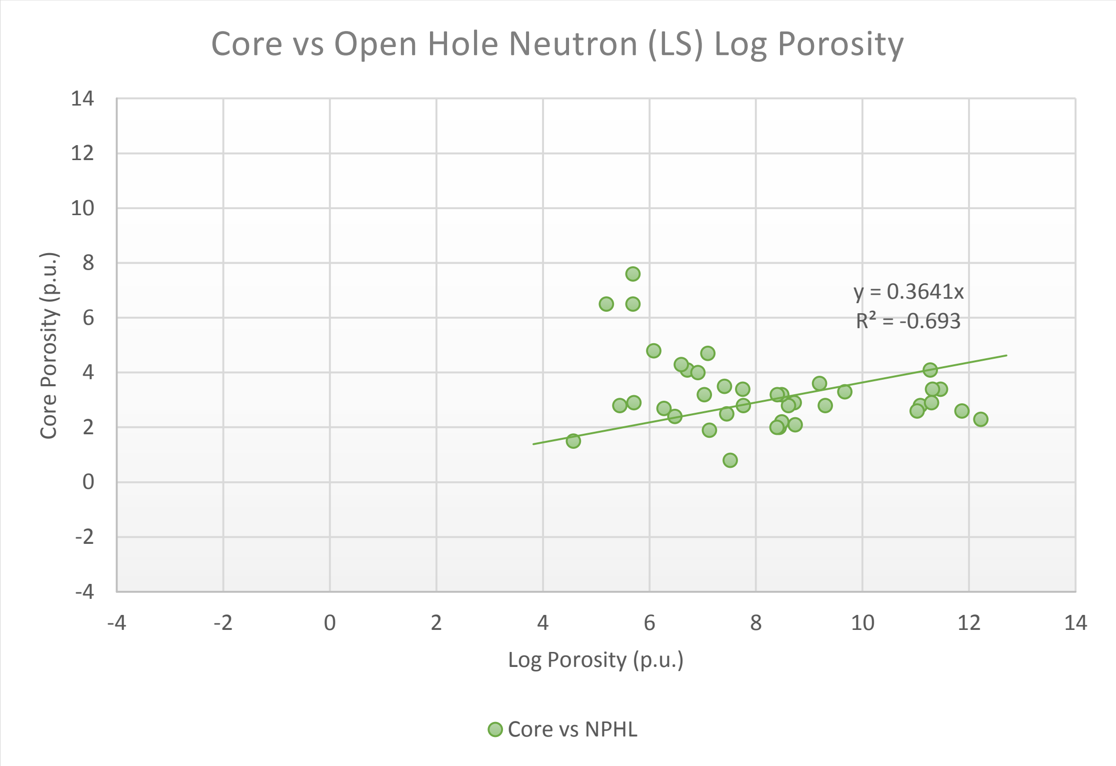

Figure 4. Core Helium Porosity data plotted against open hole Neutron Porosity using a limestone scale.

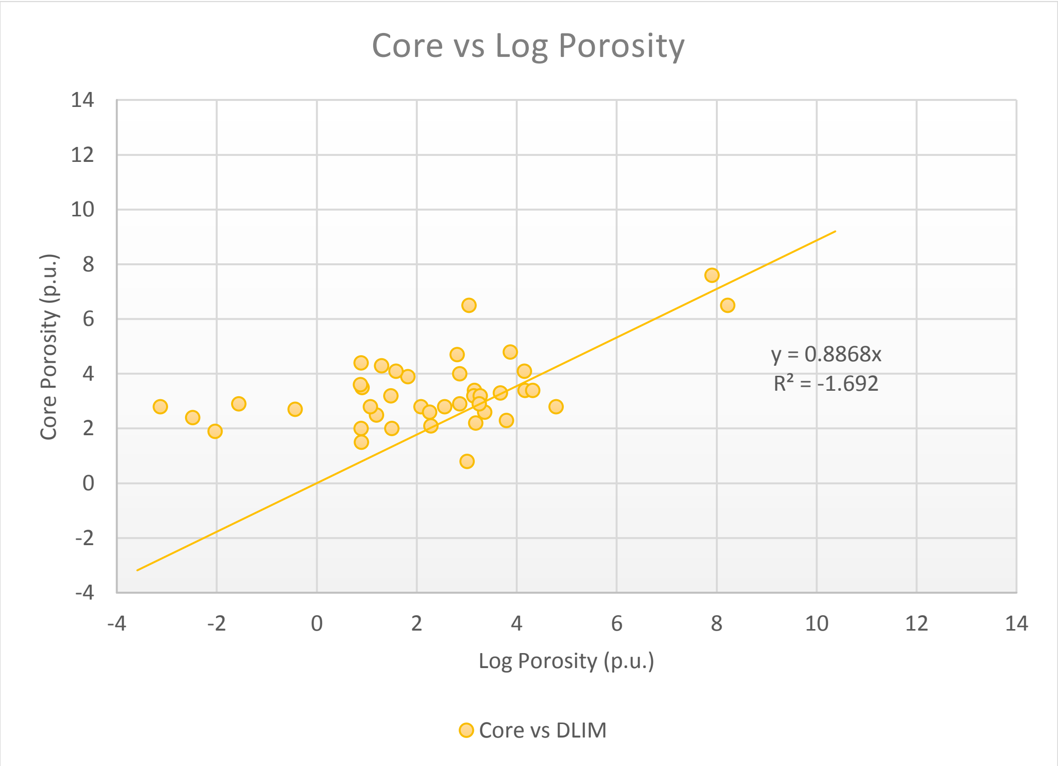

Figure 5. Core Helium Porosity data plotted against open hole Density Porosity using a limestone scale.

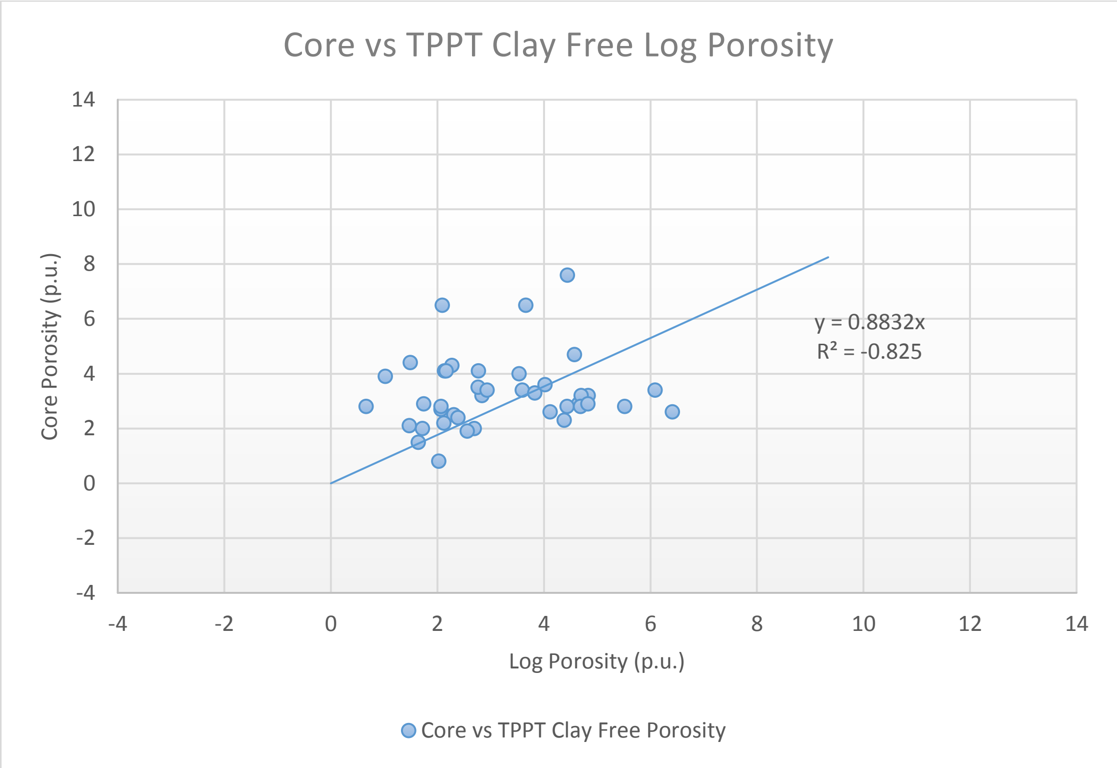

Figure 6. Core Helium Porosity data plotted against TPPT clay free porosity.

Figures 4 - 6 show the relationship between log measured porosity and core measured porosity. As seen in figure 4, open hole neutron porosity has a poor relationship to core measured porosity as it consistently measures much higher values than that of core. Open hole density and TPPT logs have a much better relationship to core measured porosity, as shown in **Figures 5 and 6**. An average error in porosity was calculated for both open hole density and TPPT logs in porosity units by using the following equation:

$$Porosity\ Error = \frac{Log\ Porosity - Core\ Porosity}{Log\ Porosity}$$

$$Average\ Porosity\ Error = \frac{Sum\ of\ Porosity\ Error\ Values}{Number\ of\ Core\ Points}$$

Using the above equations, the error in porosity on average for open hole density is -0.31pu and for TPPT is 0.06pu, illustrating that TPPT measurements have the best agreement to core porosity of the evaluated logging techniques. **Figure 7** shows the core porosity data points plotted with the three porosity logs, visually illustrating the log signatures through the entire cored interval.

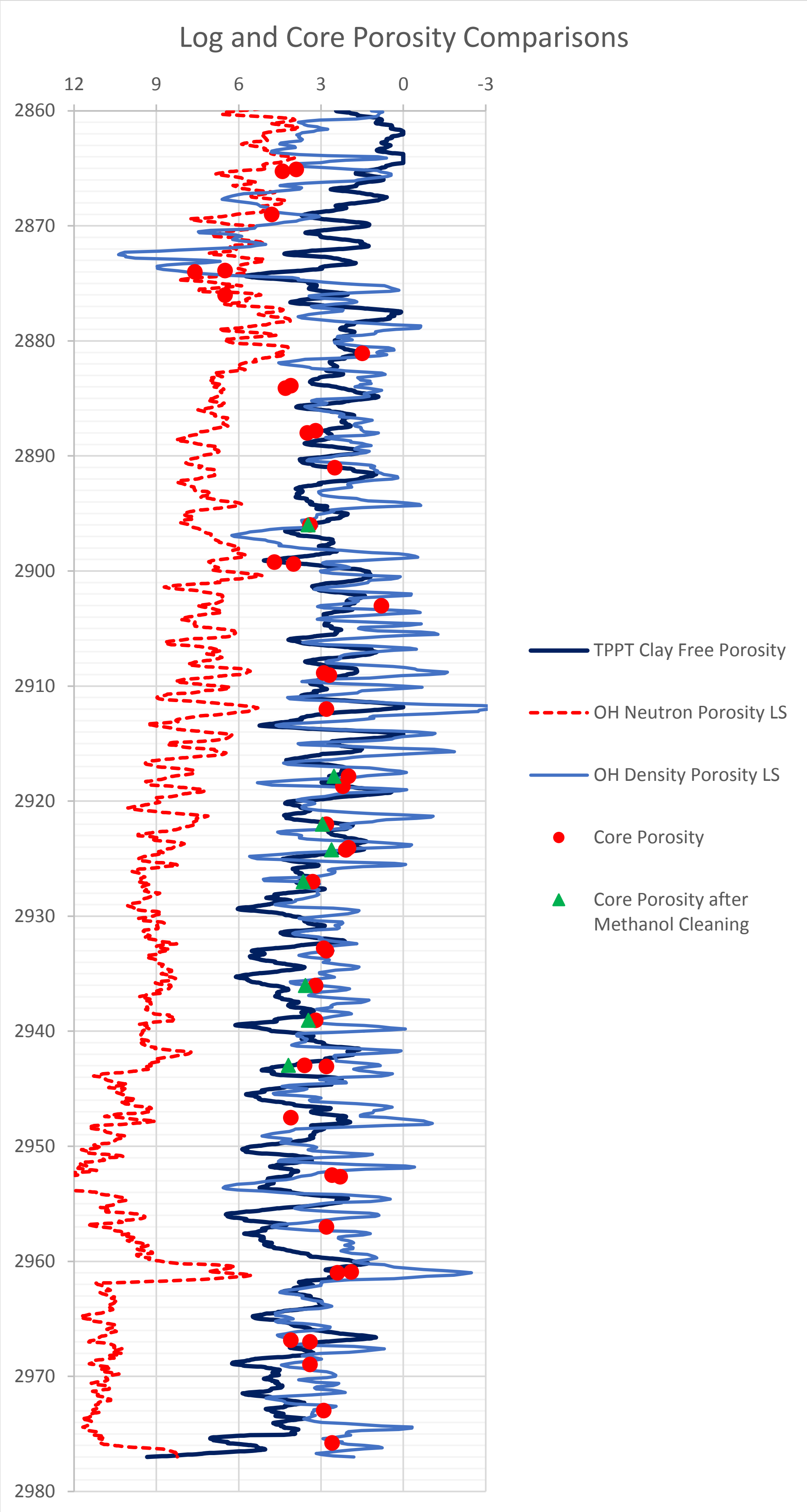

Figure 7. Core helium porosity data as received and after methanol cleaning plotted on open hole and TPPT log.

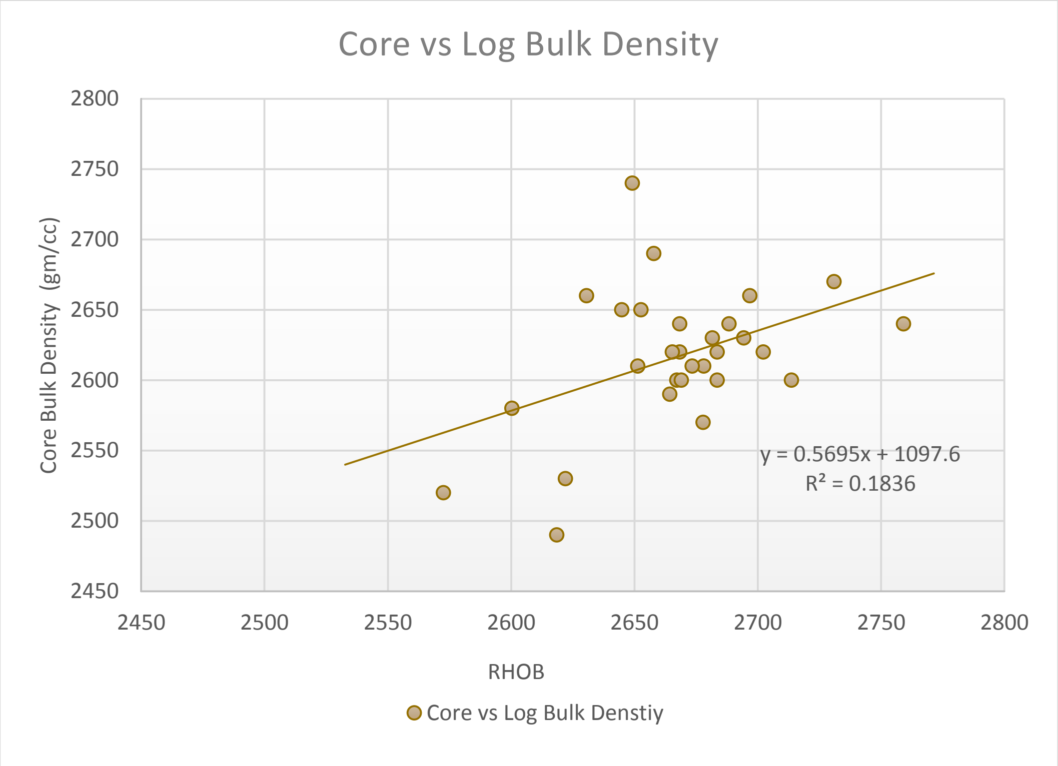

Figure 8. Core measured bulk density data plotted against open hole log measured bulk density.

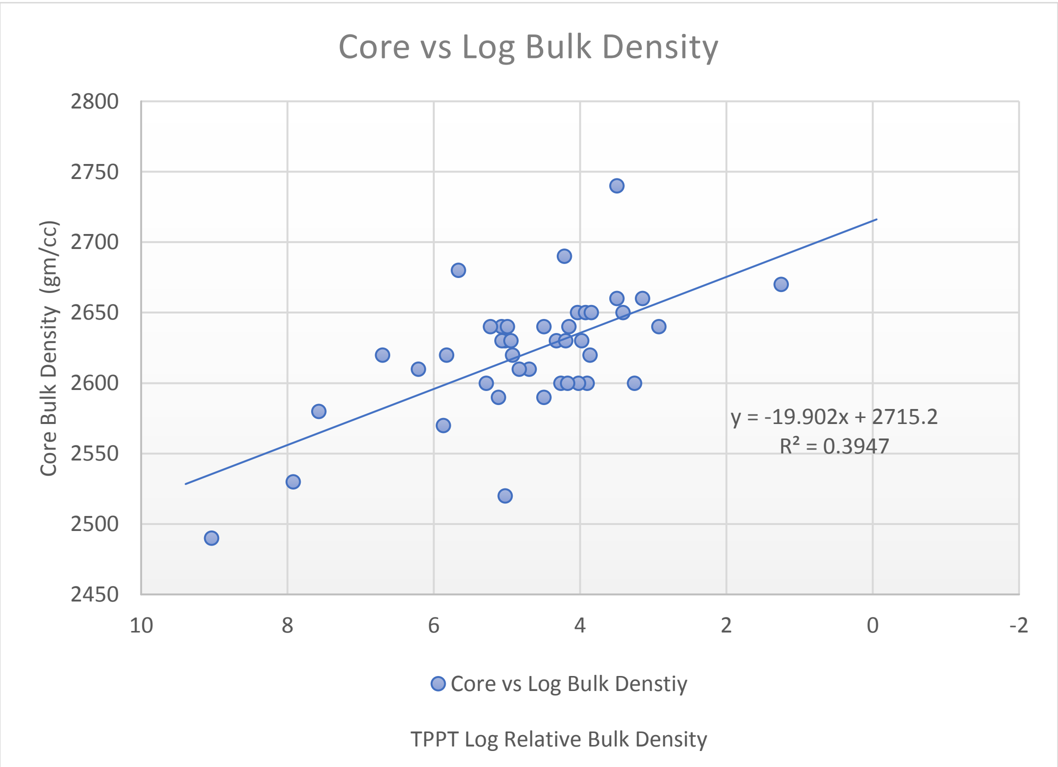

Figure 9. Core measured bulk density data plotted against TPPT relative bulk density measurement.

Figures 8 and 9 show the comparison of RHOB (open hole log bulk density) and TPPT relative bulk density measurements to core measured bulk density. The relationship between TPPT relative bulk density and core is better than that of the RHOB, however the TPPT measurement doesn’t directly measure bulk density. TPPT measures the relative density changes in the interval. The advantage of the TPPT method is that errors in core measurements through fluid loss are eliminated.

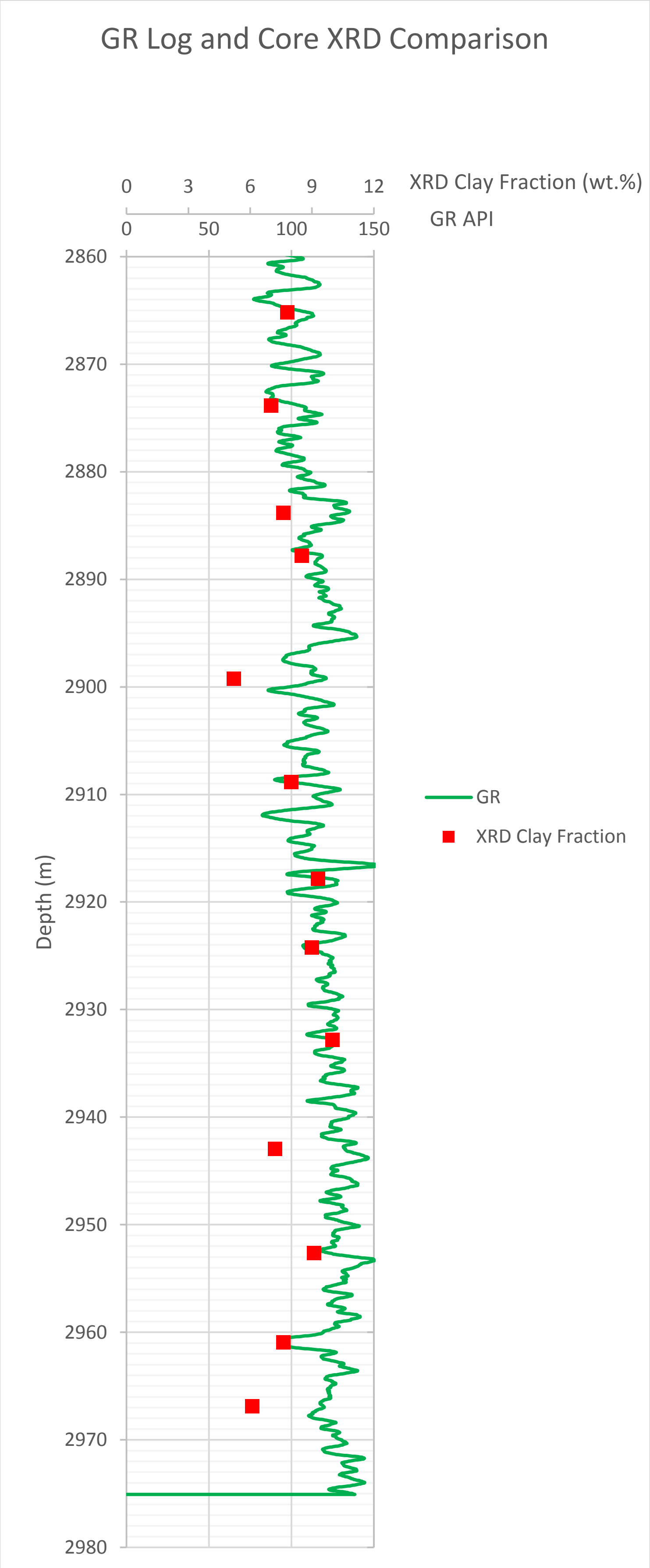

Fig. 10 Gamma ray log with XRD clay fraction data points

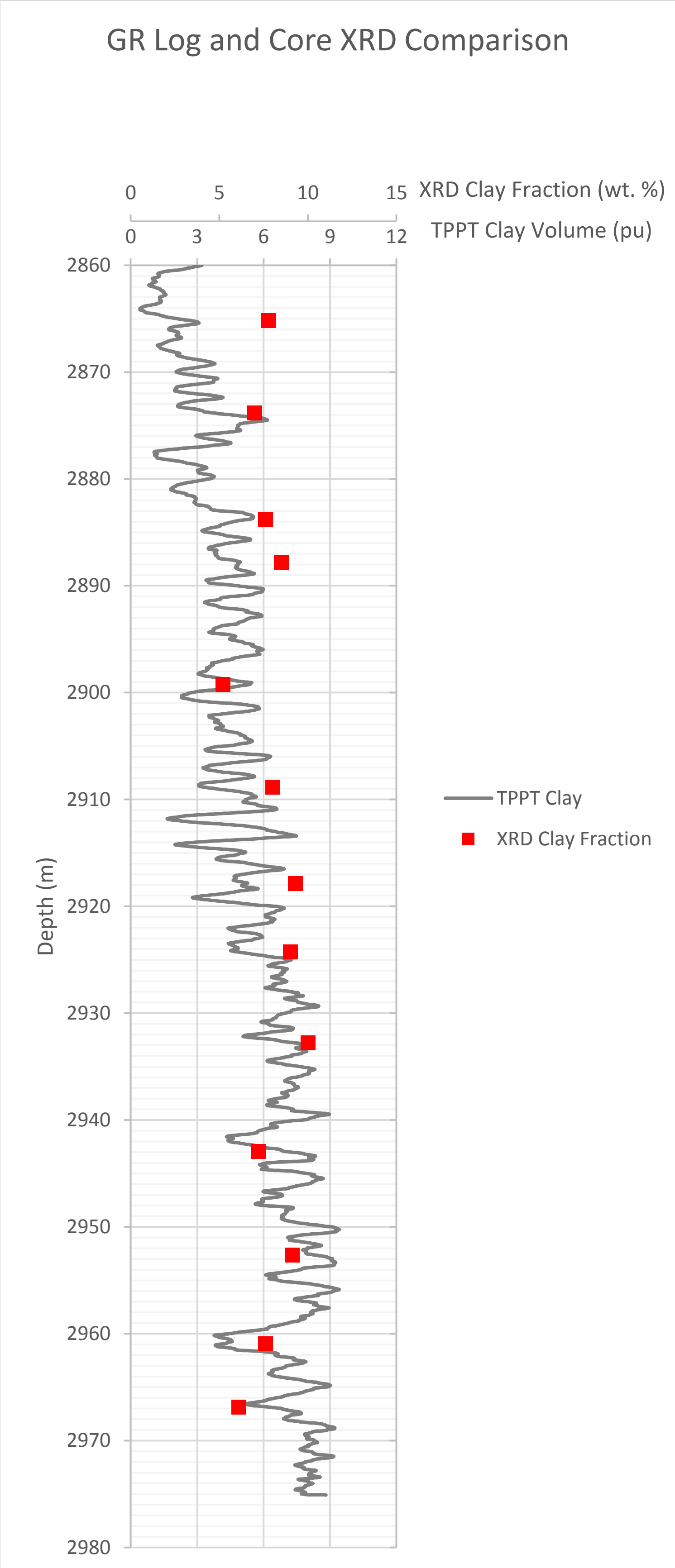

Fig. 11 TPPT clay volume log with XRD clay fraction data points, a calibrated correlation has not been established for clay content between TPPT and core. As such, the data is scaled to show the relative character of each data set in order to compare them.

Figure 10 shows the comparison between the standard gamma ray, typically used to estimate lithology and clay volumes, and XRD clay fraction measurements. The gamma ray log has a “cleaning up” signature through the interval. However, three (3) XRD data points near the base of the interval, show a low clay-fraction. This indicates that the gamma ray log might not have enough resolution to see thin clean beds, from which these samples were taken. However, generally there is an excellent correlation between the data points and gamma ray log.

Figure 11 shows the comparison between the TPPT clay volume log and the XRD clay fraction. The TPPT measures the clay volume as a function of porosity, where as an XRD measures the weight percent clay fraction directly from a sample. At this stage a calibrated correlation has not been established for clay content between TPPT and core. As such, the data is scaled to show the relative character of each data set in order to compare them. Again, the general character of the TPPT log follows that of the XRD data, only differing in a lower clay volume estimation in the upper interval. In each case, both gamma ray and TPPT clay volume are a viable method to estimate lithology.

Based on the data comparisons shown in the previous sections, it is found that the TPPT log data is a viable measurement option to use for reservoir evaluation and in many cases has a better relationship to core data than standard open hole logs

Conclusions

To aid in unlocking the Montney liquids rich resource play, TPPT was utilized to provide reservoir formation log data through drill pipe on new horizontal wells and through casing on a vertical well. This technology was applied to the 7GEN KAKWA 13-24-65-5W6 cased vertical well then compared to open hole well logs and to core data, both standard and special core analysis. The same through drill pipe logs were recorded in 14 horizontal wells in the Kakwa and Karr fields. The data collected in the horizontal wells was compared to the vertical core well and to the strip log data on each well. Calibrations obtained through correlation of the TPPT vertical though casing log data with core analysis data were applied to the accurately determine reservoir properties in the lateral section of the horizontal wells.

The cost / benefit of utilizing through pipe technology was analyzed. The analysis took into consideration direct and indirect costs associated with data collection and risks associated with horizontal data collection. By evaluating the associated costs and risks it was determined that through pipe data acquisition provides much lower risks and costs relative to other data acquisition methods.

7G now has an extensive horizontal log data set throughout their Montney play. The TPPT data has proved to be a valuable tool in evaluating the reservoir properties of this play. Also, by acquiring this data, 7G has satisfied the government requirements for horizontal data and established a consistent data set through their play. 7G continues to gather horizontal data on key wells that are not required by the government in order to continue to evaluate this liquid-rich Montney play.

The TPPT data has been used to compare horizontal well reservoir properties to one another as well as see relative changes within a single horizontal well bore, many of which are greater than 2000 meters in length. Specifically, this data can be used characterize reservoir properties across the play and aid, for example mapping, reserve and resource calculations, and completion designs.

Acknowledgements

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2. Glen Nevokshonoff and Steve Haysom; Seven Generations Energy Ltd. *Liquids Rich Unconventional Montney: The Geology and the Forecast.* SPE Canadian Unconventional Resources Conference held in Calgary, Alberta, Canada, 30 October–1 November 2012.

3. http://www.roke.ca/#!oil/c1oa0 [Accessed; June 30 2014]