

Real-time microseismic enables effective stimulation through actively managed diversion with a Montney example

Yuri Rodionov, Schlumberger (yrodionov@slb.com)

Richard Parker, Mike Jones and Shawn Maxwell, Schlumberger

Chris Pan, Talisman

GeoConvention 2012: Vision

Summary

Hydraulic fracturing of low-permeability shales is an essential step in hydrocarbon extraction from these rocks. Often this is accomplished with multiple treatment stages by perforating short lengths of a horizontal borehole and pumping the high pressure fluid through these perforations, with a plug to isolate previous stages, to create fractures in the rock fabric around the borehole. In cases where it is desired to reduce the number of trips in the wellbore to deploy plugs or other tools, a diversion scheme can be used to treat multiple open perforations simultaneously. Diversion 'slugs' of fibre, proppant and viscous fluid can be used to control fracturing between various perforations. Realtime microseismic monitoring can be used to track which perforations are being fracc'ed, and assess the effectiveness of the diversions. Microseismic data allows the engineers to retain a large degree of control over where the fracturing fluids should go, essentially steering the fracture treatment in the rock.

The case study presented here resulted from a case of poor cement in the heel section of a horizontal well and represents an example of simultaneous fracturing into a large number of open perforations. The objective was to minimize trips in the wellbore to set plugs and to afford a method of dealing with possible communication between stages behind the casing. It shows the use of real-time microseismic imaging of the fracture to guide the application of the diversion 'slugs' using proppant, fiber and fluid additives. By using real-time microseismic data the resulting stimulation was successful by achieving an even distribution of fractures along the perforated length of the wellbore.

Introduction

Talisman Energy faced a problem in a recently completed Montney horizontal well in NE British Columbia because the cement quality of the heelward end of the horizontal was suspect. In order to reduce the number of interventions in the wellbore an innovative completion method was planned whereby multiple stages would be completed together, monitored with real-time microseismic and controlled by accurately placed fibre and proppant diversion 'slugs'.

The main objective of this project was to achieve the best possible stimulation coverage of a 700 m long horizontal interval in the heel section of a horizontal wellbore. Conventionally an interval of this length would be treated in several fracturing stages separated from each other by bridge plugs conveyed via wireline. However, the lack of good annular isolation because of the poor cement quality means that communication between adjacent hydraulic fractures will likely be established in the annulus section and treatment fluid will be taken by the lower stress intervals along the borehole leaving much of the interval unstimulated. A pressure differential sufficient to generate a net pressure required to initiate fractures in the higher stress intervals must be induced and maintained. This can be achieved by pumping diversion slugs consisting of a specific mixture of fiber, sand and fluid to bridge existing fracture network near wellbore and divert fractures into new zones. Diversion effectiveness must be confirmed by microseismic data and the slug recipe and treatment design must be adjusted based on diversion results in real time.

Theory and Method

The ability to react rapidly to downhole changes is wholly dependent on having the located microseismic events available within seconds of their occurrence within a 3D earth model workspace. A robust automated location algorithm, Coalescence Microseismic Mapping (Drew et al. 2005), can locate, and transmit to the interpretation centre, many events per minute. An example of a microseismic event and the real time interpretive display for this project is shown below in Figure 1. For the specific event the ray paths through the velocity model are shown along with the waveform.

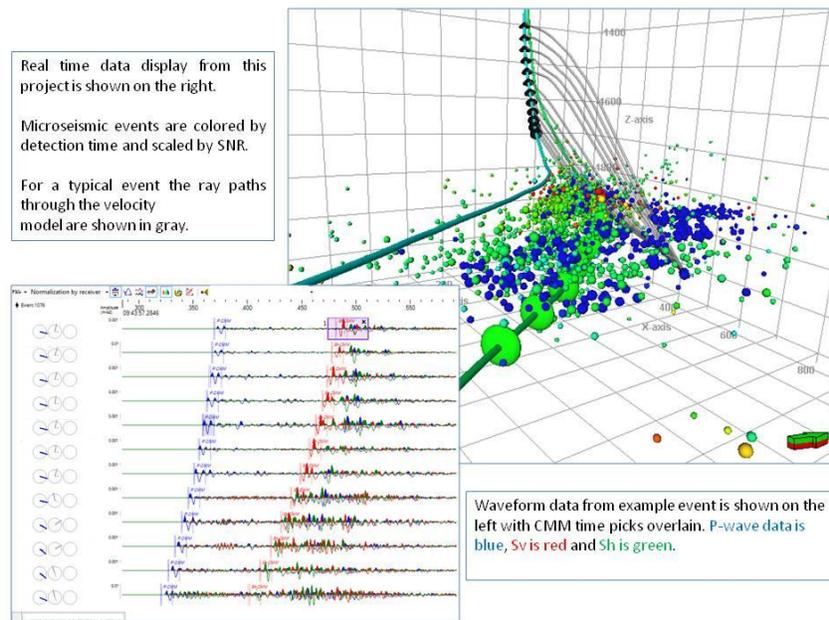


Figure 1. Real-Time microseismic display

Figure 2 below describes the basic workflow of fibre-diversion stage execution. When it is desired to restrict fluid flow through a particular set of perforations, a diversion 'slug' consisting of viscous fluid, proppant and fibre to support the proppant, is prepared and inserted into the fluid stream at surface. If the pump rate, wellbore diameter and perforation depth are known, the diversion 'slug' can be slowed at the perforation of interest to localize its effect at that perforation. The placement stage is very important because the bridging of the fiber occurs at lower fluid velocities. It is important to know which interval is taking most of the fluid in order to drop injection rates at the precise time to induce the fiber bridging. This interval is determined by engineers based on real time microseismic data.

After diversion placement the treatment rate is increased in order to build enough net pressure to initiate fractures in new zones through other perforations which have not been plugged with the fibre diversion. After fracture initiation is confirmed by microseismic data, the treatment proceeds as per design. In the case where no initiation of new fractures is observed another diversion slug is mixed and the workflow is repeated.

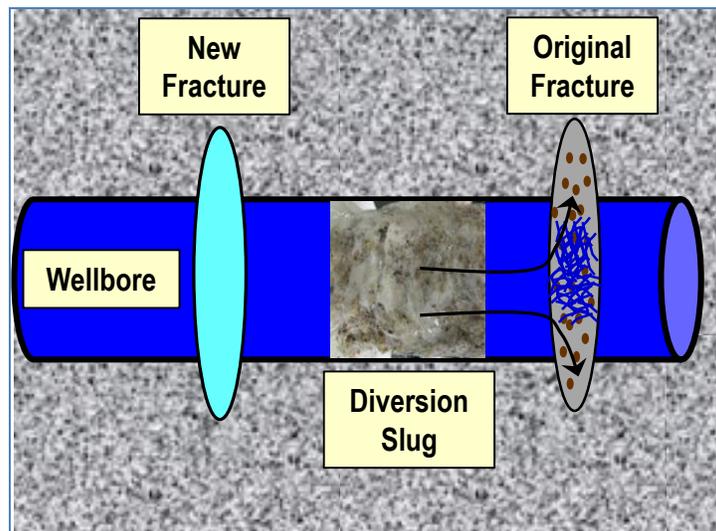


Figure 2. Diagram showing the concept of the active diversion process.

Each diversion slug consists of a unique blend of fiber, sand and fluid in accurately designed ratios to achieve effective and controlled bridging of the fiber agent in the fractures near the wellbore to generate a pressure drop sufficient to initiate and propagate a fracture in a new section of the reservoir. This technique relies on the estimation of fracture parameters such as Estimated Stimulated Volume (ESV), and the number and location of perforation clusters taking fluid etc.. Therefore it is critical to use this technique in association with real-time microseismic interpretation to calibrate the formation parameters and adjust the composition and placement of diverting slurry from one stage to the next. Since diverting decisions are made on the fly without shutting down the treatment for data analysis and evaluation it is critical that the microseismic data stream should be provided to engineers in real time fashion, within seconds of the microseismic event occurrence.

Case Study

The entire single interval to be stimulated was pre-perforated in eight clusters. Four toe perforation clusters were perforated with higher density in order to promote fracture initiation in the toe zone first. Additionally to aid in fracture breakdown of the toe portion of the zone, acid was spotted via coiled tubing prior to the job. The completion was designed to be pumped as one continuous operation. Diversion stages were planned so that the complete lateral could be effectively stimulated. Diversion decisions were to be made on the fly based on the real time microseismic response.

Pre-Diversion

At the beginning of the treatment microseismic data indicated activity in both the heel and mid lateral regions. At the end of the stage the highest density of microseismic events was located across the heel portion of the treatment interval and suggests that this portion of the well was taking most of the stimulation fluid as it can be seen on Figure 3.

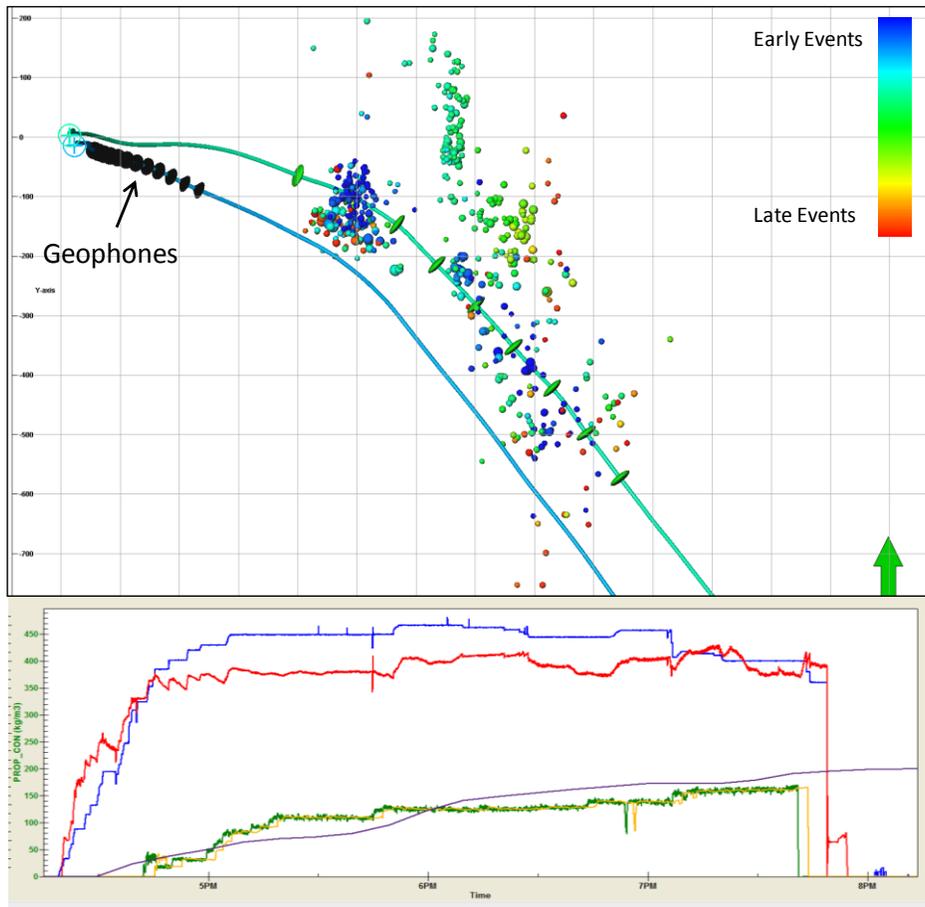


Figure 3: Map view of microseismic events prior to diversion and treatment plot (Pressure, Rate, Concentration) with ESV curve

At this point it was decided to pump a diversion slug in an attempt to move the fracture away from the heel portion of the wellbore. This diversion consisted of two slugs, after the first slug was judged to be ineffective based on the microseismic. The placement of the second slug resulted in a complete shift of the microseismic activity towards the toe of the well indicating that the diversion was successfully achieved and treatment continued in accordance with the design.

Post-Diversion 1

Figure 4 shows events recorded following this diversion. The events were primarily located within the mid-lateral and toe sections of the wellbore.

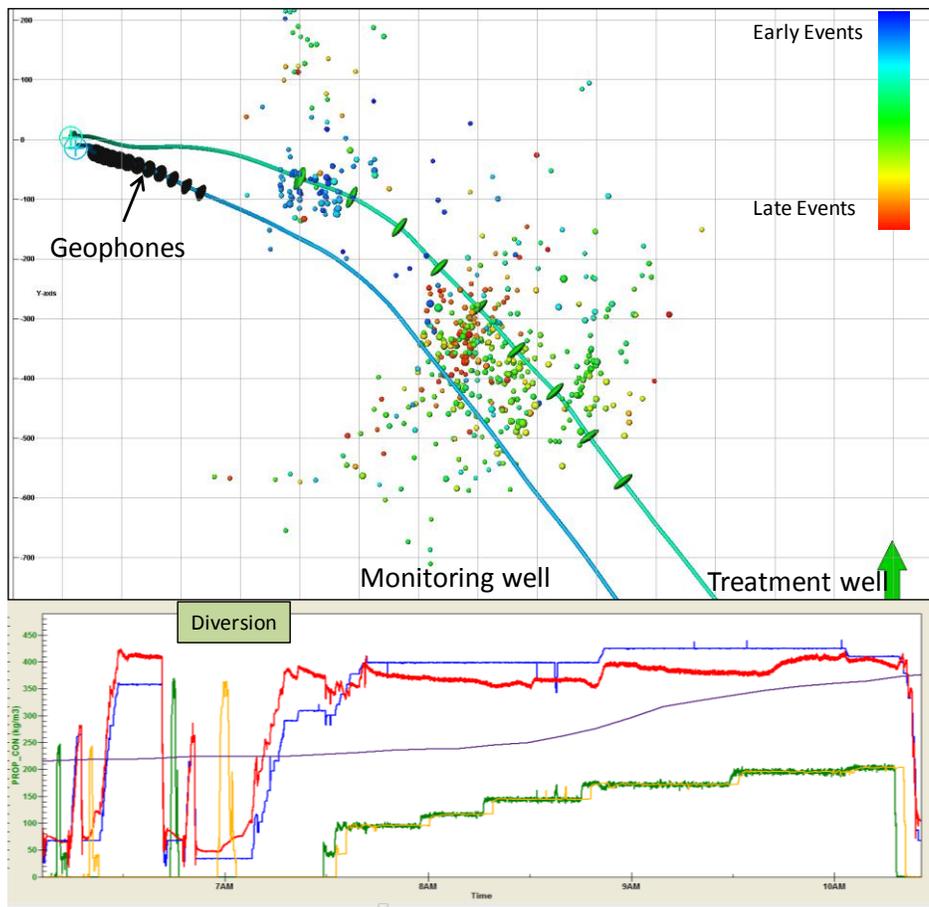


Figure 4: Map view of micropseismic events after the first diversion and treatment plot (Pressure, Rate, Concentration) with ESV curve

After the designed amount of proppant was placed, another diversion stage was placed in order to promote the fracture development across previously unstimulated zones in the heel and mid-lateral sections.

Post-Diversion 2

The diversion slug was able to generate substantial net pressure increase and evaluation of microseismic data confirmed fracture initiation in the new area. Placement of this diversion slug resulted in a complete shift of the microseismic activity from the toe to the previously unstimulated heel portion of the well. It is important to note that the first diversion slug placed in the heel was still competent and fracture initiation occurred in the adjacent perforation cluster, thus establishing contact with previously unstimulated rock. Figure 5 shows events recorded following the second diversion slug which were located within a previously virgin area in the heel section of the wellbore. Figure 6 shows a histogram of the microseismic event distribution along the wellbore for each diversion stage. This plot shows clearly how the diversion interventions have moved the fracture activity laterally along the borehole.

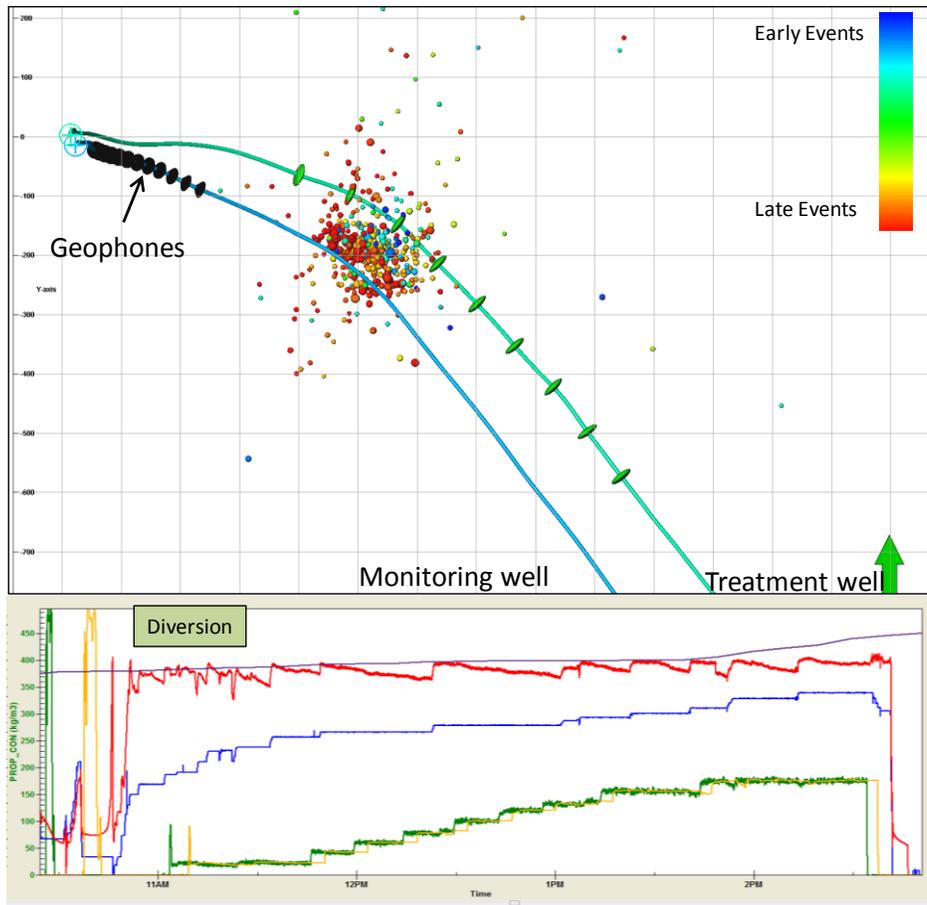


Figure 5: Map view of microseismic events after the second diversion and treatment plot (Pressure, Rate, Concentration) with ESV curve

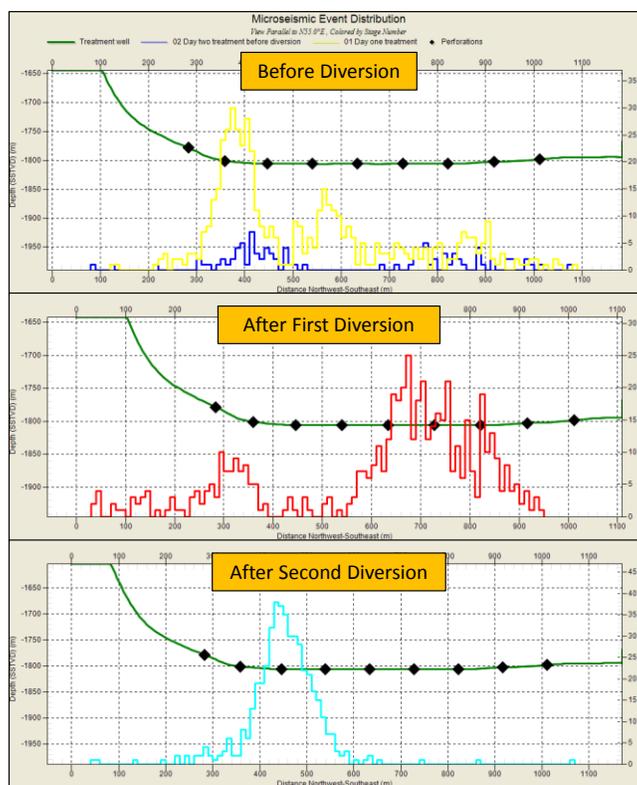


Figure 6: Histogram of microseismic event distribution along the wellbore for each diversion stage

Conclusions

The combination of dynamic fracture diversion with real time microseismic interpretation enabled good stimulation coverage along the 700 m long stimulated interval. This was achieved in one operation without employment of bridge plugs and wellbore interventions. Diversion slug composition and placement technique were assessed based on the diversion slug performance in association with microseismic and pumping data analysis. ESV and pumping data analysis shows that a substantial amount of new reservoir was contacted following the successful diversion placement and fracture initiation in new intervals.

This technique, of active intervention with diversion stages monitored and controlled by microseismic, offers possibilities for remediation of borehole problems and also for more economic treatment of multiple stage completions.

Acknowledgements

The authors would like to acknowledge the contribution of Tim Pope and Doug Pipchuk of Schlumberger in the implementation of the treating technology, and to thank Talisman Energy for their permission to show their data.

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