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A comparison between Deterministic Inversion and Microseismic to be predictive about Geomechanical Parameters as they apply to Stimulation of Unconventional Reservoirs

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Summary

Geomechanical parameters are critical to understanding unconventional plays, with the engineering literature focusing on key parameters including Young's Modulus (E) and Poisson's Ratio (v). (Goodway et al., 2010) Microseismic on the other hand has been shown to help map the stimulation of the rock volume during hydraulic fracturing. (Rutledge and Phillips, 2003) Using deterministic seismic inversion, particularly the volume around the wellbore, the tie between stimulation and geomechanical properties can be mapped for the Vaca Muerta Formation in the Neuquen Basin. The area of interest offers seismic data that was shot prior to the collection of microseismic, allowing predictive analysis of geomechanical parameters optimal for stimulation.

Introduction

The Neuquen Basin sits in the shadow of the Andes in Western Argentina spreading over into central Chile between 32 and 40 degrees South. The total area of the basin is 120,000 km2 (Howell et al., 2005) with the Vaca Muerta formation covering at least 25,000 km2. The thickness of the Vaca Muerta formation ranges from 25 – 450 m, with the total organic content (TOC) ranging from 3 – 8%. (Stinco et al., 2014) Typically speaking the availability of data for the Vaca Muerta formation within the Neuqeun Basin is less than unconventional plays in both the US and Canada. However, there is starting to be a small collection of both new and reliable data available for the Vaca Muerta. Figure One summarizes the dataset provided by Wintershall.

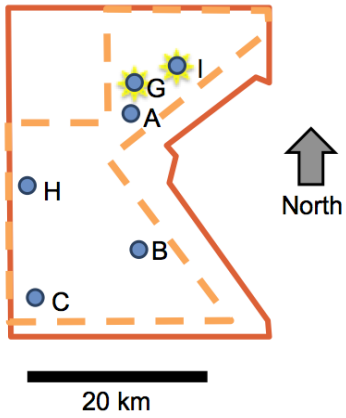

Figure One: The dataset provided by Wintershall has six wells that were drilled in between 2010 – 2015, with two (Wells G and I) that have surface microseismic data within the same region as the conventional seismic. The full stack data is outlined in dark orange, with the pre-stack data outline in light orange. The pre-stack data has a range of 36 degrees broken out in 9 degree increments

Theory and Methodology

Deterministic seismic inversion was completed utilizing the pre-stack data in combination with all six wells that were available. Simultaneous inversion results have created volumes of P-Impedance, S-Impedance, and Density. Critically, very stable results were found for both the P-Impedance and S-Impedance. Although the angle range was not sufficient to obtain density results (Francis, 2014), the information that is proximal to the wellbore should be accurate. Better results are to be expected from a geostatisitcal inversion (Pendrel, 2001) currently under way. However, this paper will focus on the results from the deterministic inversion alone.

The deterministic inversion results were converted into the geomechanical properties of Young's Modulus (E) and Poisson's Ratio (v) which were derived using the following equations respectively:

$$E = \rho * Ve^2$$

$$\nu = \frac{(Vp^2 - 2 * Vs^2)}{2 * (Vp^2 - Vs^2)}$$

Once converted into geomechanical parameters, the volumes of Young's Modulus (E) and Poisson's Ratio (v) were converted from time to depth. Using a simple velocity model created through the use of the well logs and a statistical interpolation method, the time-depth conversion was completed. This step made it possible to compare surface microseismic acquired in depth, and the geomechanical properties around the wellbore acquired in time.

The microseismic provided for two wells (G and I) were acquired during hydraulic stimulation. The acquisition included 10 lines with 2140 channels. The spacing between the channels was 14m with 12 geophones per a station. Recording for the microseismic was done by a Sercel 428 with a sample rate of 2 ms. Well G has four stages, while Well I has five stages that were distributed relatively evenly throughout the length of the Vaca Muerta interval. This provided for interaction with a range of geomechanical properties throughout the Vaca Muerta.

It should be noted that surface microseismic has uncertainty inherent to it, specifically around the location of the events. (Thornton and Mueller, 2013) The greater uncertainty is in the Z direction, with lesser uncertainty in the X and Y directions. (Eisner et al., 2009) In this case the uncertainty in the X and Y directions has been determined to be 10m, while the uncertainty in the Z direction is 35m. This is comparable to the uncertainty of the determinsitic inversion in scale given the seismic resolution. A mitigating factor in the uncertainty in the Z direction is a change in the focal mechanism and strike for the events within the overlaying Quintuco as opposed to the events in the Vaca Muerta.

Analysis of bottom hole pressure during completions has revelead that variation in the degree of stimulation within the Vaca Muerta and overlaying Quintuco is responding to rock properties, not to pressure variation or other variances in engineering parameters.

Examples

Volumes of the geomechanical properties close to the wellbore of wells G and I were extracted for comparison to the microseismic. Overlaying volumes of Youngs Modulus (E) and Poisson's Ratio (v) with the microseismic has provided a platform to compare the data both qualitatively and quantitatively.

Figure Two shows the qualatative comparison of both Young's Modulus and Poisson's Ratio with the microseismic data for Well G. The qualatative comparison reveals critical information regarding the nature of the heterogenous shale. Poisson's Ratio (v) provides a clear marker for the shift from the Quintuco to the Vaca Muerta formation. Due to depositional factors, this is a transition that is often hard to pick on seismic alone. (Bishop, 2015) Young's Modulus (E) on the other hand seems to show a qualitative collection of microseismic events in relatively higher values. This suggests that a relative high of Young's Modulus within the Vaca Muerta is tied to stimulation of the rock.

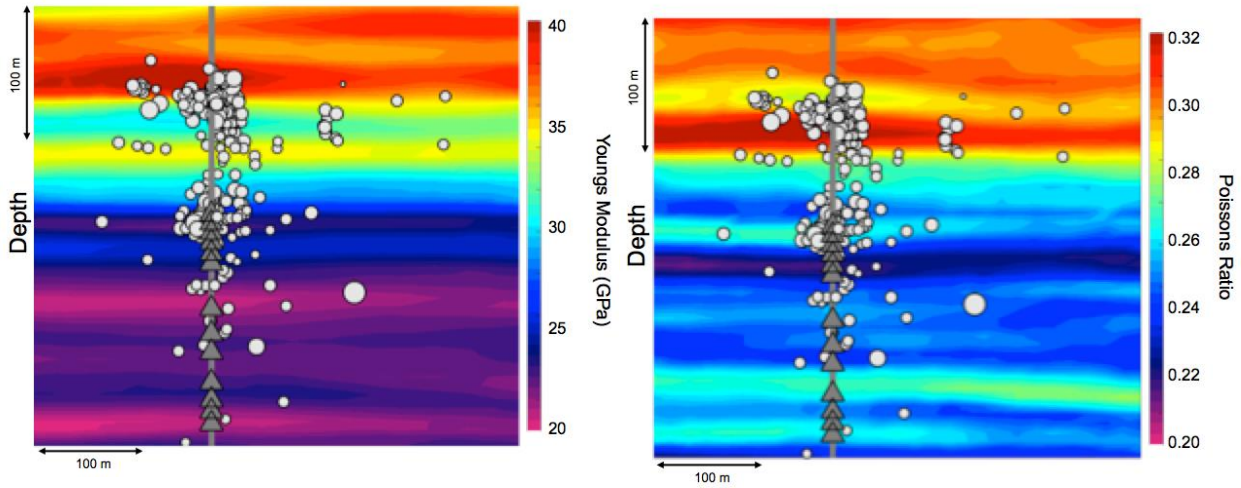

Figure Two: Shows an overlay of geomechanical properties, derived from deterministic inversion with microseismic data, presenting a qualitative comparison of the two in depth for Well G. Youngs Modulus (left) and Poissons Ratio (right)

A quantitative comparison has also been done between the geomechanical parameters and the microseismic. This was done by looking at where the microseismic events occurred in relationship to the nearest node within the geomechanical volumes around the wellbore. This data was then distributed by value for both Young's Modulus (E) and Poisson's Ratio (v) in relationship to the background trend. The background trend looked at all possible data points within the volume.

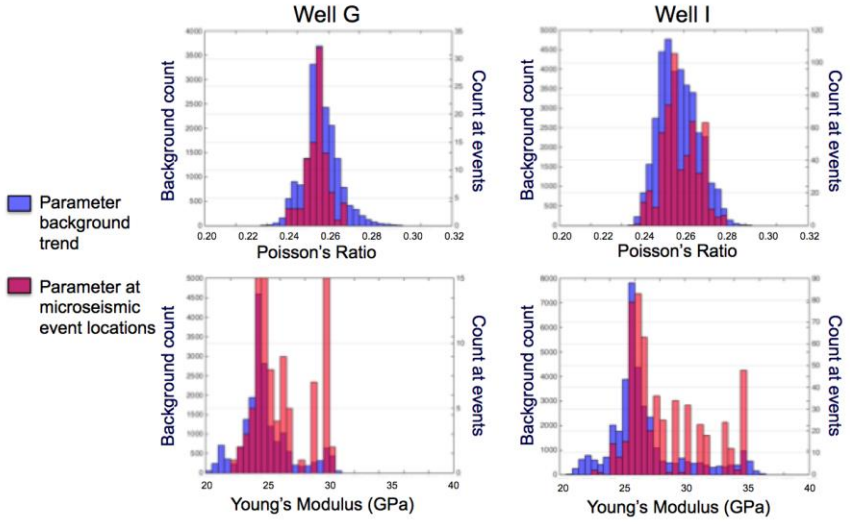

Figure Three: Shows a quantitative comparison of geomechanical values that tie with the microseismic compared to the background trend from the overall model

The quantitative comparison also reveals a couple of key learning's. Specifically, that the relationship between microseismic and Poisson's Ratio (v) shows the same trend for the microseismic events as the background trend. This suggests that there is no relationship between Poisson's Ratio (v) and stimulation for the Vaca Muerta. In strong contrast to this were the results from the Young's Modulus (E). It was found that relatively higher values of Young's Modulus (E) within the zone of interest are associated with the microseismic events for both wells. This suggests that a relative high of Young's Modulus (E) is associated with better rock stimulation within the Vaca Muerta. Specifically it can be seen that values greater than 26 GPa for Young's Modulus (E) break away from the trend and see a greater amount of stimulation within the rock by volume for both wells.

Conclusions

Using the combination of deterministic inversion and microseismic both qualitative and quantitative determinations about the geomechanical properties of the rock in relationship to stimulation can be made. In this case it has been found that (1) Poisson's Ratio (v) is a good marker for the break between the Quintuco and the Vaca Muerta, as also seen by the change in strike and focal mechanism within the microseismic (2) Relatively higher values of Young's Modulus (E), specifically those greater than 26 GPa are associated with greater stimulation of the rock volume within the Vaca Muerta.

In addition, this provides a groundwork for using geostatistical inversion alongside microseismic to analyze the relationship between geomechanical properties and stimulation. This work, currently under way will also bring a greater sense of clarity around the uncertainty of the data being looked at.

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