PS Sweet Spot Identification and SRV Estimation by Correlation of Microseismic Data and the Shale Capacity[SM] Concept: Application to the Haynesville*

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Abstract

With low gas prices, Haynesville well economics dramatically improve when drilled and fractured in locations capable of high gas production rates. Finding such sweet spots requires seismically driven 3D estimation of four shale drivers: Total Organic Carbon (TOC), porosity, brittleness, and natural fracture density. These four shale drivers are estimated from post-stack and pre-stack inversions, post-stack volumetric curvature and spectral imaging attributes, and previously derived shale drivers. These are placed in a neural network capable of determining the correlation between the log of each shale driver and the seismic attributes. With the four shale drivers available in the 3D volume of the Haynesville study area, the Shale Capacity[SM] model is computed by multiplying the four shale drivers. Previously published studies in the Haynesville showed a strong correlation between well production and Shale Capacity. In this study, the focus is on the microseismic and its relationship to sweet spots identified by the Shale Capacity model. Although the interpreted microseismic shows good correlation with the fracture density, a stronger quantitative correlation is found with the microseismic when only the Shale Capacity model is considered. Ultimately, it is determined that the microseismic may be used to validate the Shale Capacity model. As the validated Shale Capacity model is available throughout the limits of the seismic data, it may be used to estimate the Stimulated Reservoir Volume (SRV) in another location, before a well is drilled and before microseismic is acquired. Additional acquired microseismic may then be used to further validate the Shale Capacity model.

SWEET SPOT IDENTIFICATION AND SRV ESTIMATION BY CORRELATION OF MICROSEISMIC DATA AND THE SHALE CAPACITY℠ CONCEPT: APPLICATION TO THE HAYNESVILLE

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SUMMARY

- Haynesville well performance improves when drilled in sweet spots
- Identifying sweet spots requires 3D modeling of geologic drivers which affect production
- Shale Capacity℠ is computed by combining these drivers
- Previously published studies (Reagan et al. 2013 Ouenes et al. 2014) in the Haynesville showed a strong correlation between well production, SRV, and Shale Capacity
- In this study, the focus is on the quantitative use of microseismic (MS) and its correlation with the Shale Capacity (SC) model
- Microseismic (MS) may be used to validate the Shale Capacity (SC) model
- Shale Capacity may be used to estimate Stimulated Reservoir Volume (SRV), even before a well is drilled and before microseismic is acquired

BACKGROUND

- Reservoir simulation showed that regularly spaced horizontal wells are not recommended in Haynesville wells (Ouenes et al. 2014)
- Well completion and frac design cannot fully account for Haynesville production variation (Modeland et al., 2011)
- The Shale Capacity (SC) model reveals the shale heterogeneity
- A previous Haynesville case study (Reagan et al., 2013) showed quantitative correlation between Shale Capacity and well production, by means of the Relative Intercepted Shale Capacity calculation (RISC)
- This study aims to determine the relationship between Shale Capacity (SC) and microseismic (MS) event locations

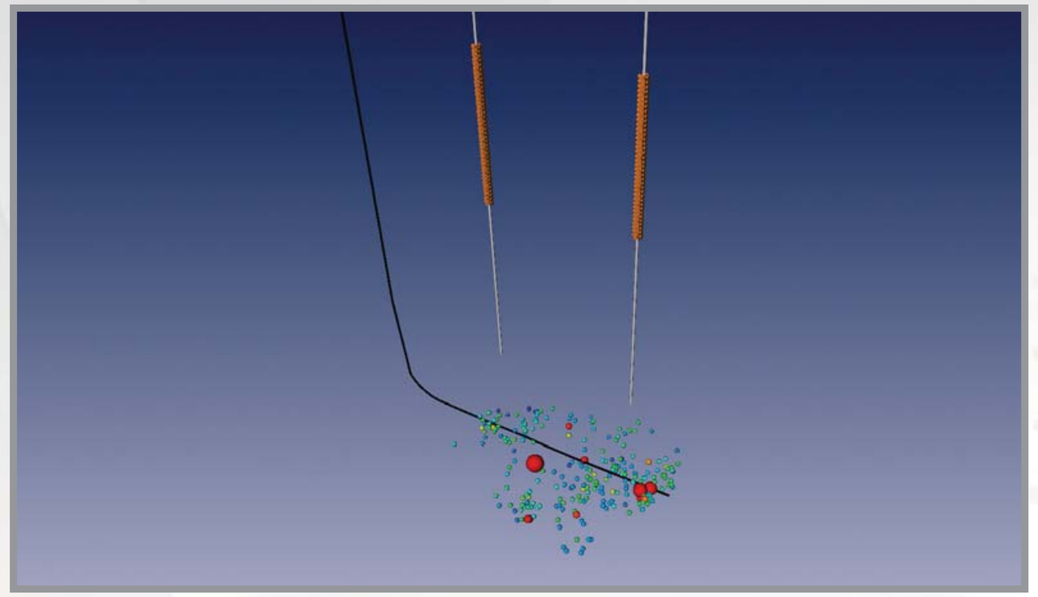

FIGURE 1: Two observer wells placed directly above the treatment well, reducing attenuation effects. Orange shapes around the wells represent the geophones. Events are sized and colored by amplitude, higher amplitude events being larger.

METHOD

- Data includes post and pre-stack seismic, well logs, production data, horizons, and microseismic
- Microseismic acquisition survey and events (Figure 1)
- Data was integrated with CRYSTAL™ software
- Post-stack and pre-stack attributes and inversions run to generate impedance, elastic properties and brittleness models
- Attributes and inversions were snapped to a 3D geocellular grid
- A neural network integrates post and pre-stack attributes with logs of Gamma Ray (GR), Porosity (Φ), Brittleness (BRT), and Resistivity (RT), to create 3D models of these log properties

HAYNESVILLE EXAMPLE

- Gamma ray used as a proxy for Total Organic Carbon (TOC) (Luning and Kolonic, 2003)
- Resistivity used as a proxy for fractures (Laongsakul and Dürrast, 2011)
- Four shale drivers used to create the Shale Capacity (Figure 2)
- The four shale drivers, GR, Φ, BRT, and RT, are normalized and multiplied to create Shale Capacity model (Ouenes 2014)
- Areas of non-zero Shale Capacity are non-zero in all four models
- Zero cells in the Shale Capacity were zero in at least one of the four input models

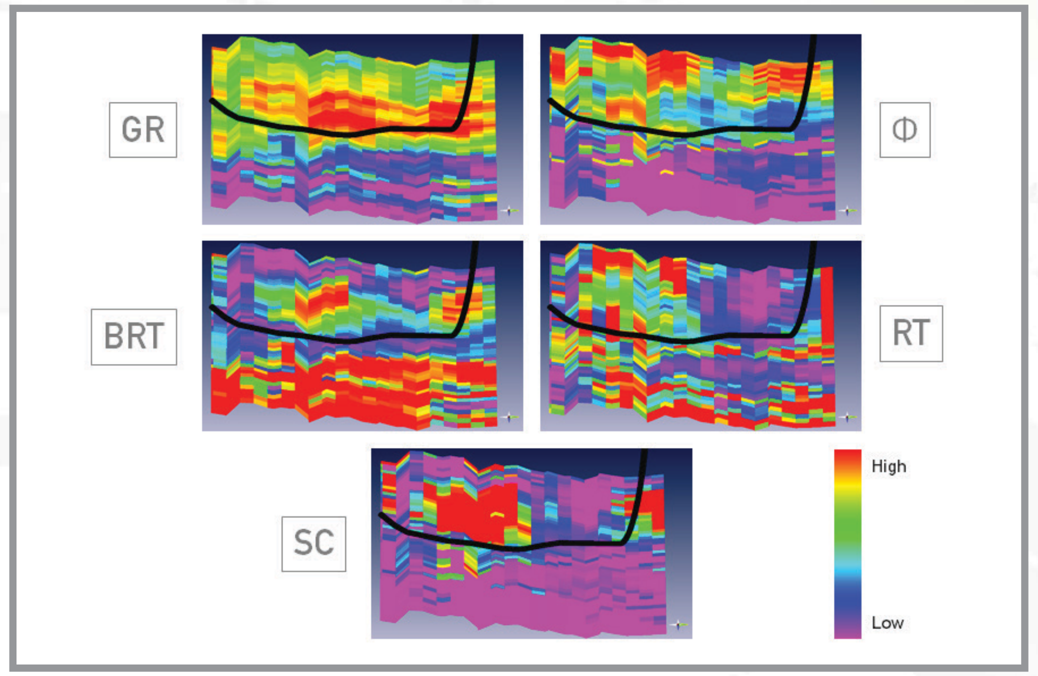

FIGURE 2: Figure 2: Four seismically driven geologic property models, Gamma Ray (GR), Porosity (Φ), Brittleness (BRT), and Resistivity (RT), were normalized and multiplied to create the Shale Capacity (SC) model.

CORRELATING MS AND FRACTURES

- Resistivity is a proxy for natural fractures and could be used to investigate possible correlations with microseismic
- Microseismic correlated with resistivity (Figure 3) using pipe models
- Pipes represent the edges of the grid cells from the geocellular grid
- Displaying the grid as edges of the cells gives the advantage of transparency for comparison with microseismic
- Events follow high resistivity sections of pipes, as high resistivity represents natural fractures
- In general low resistivity areas lack natural fractures, and therefore lack microseismic events

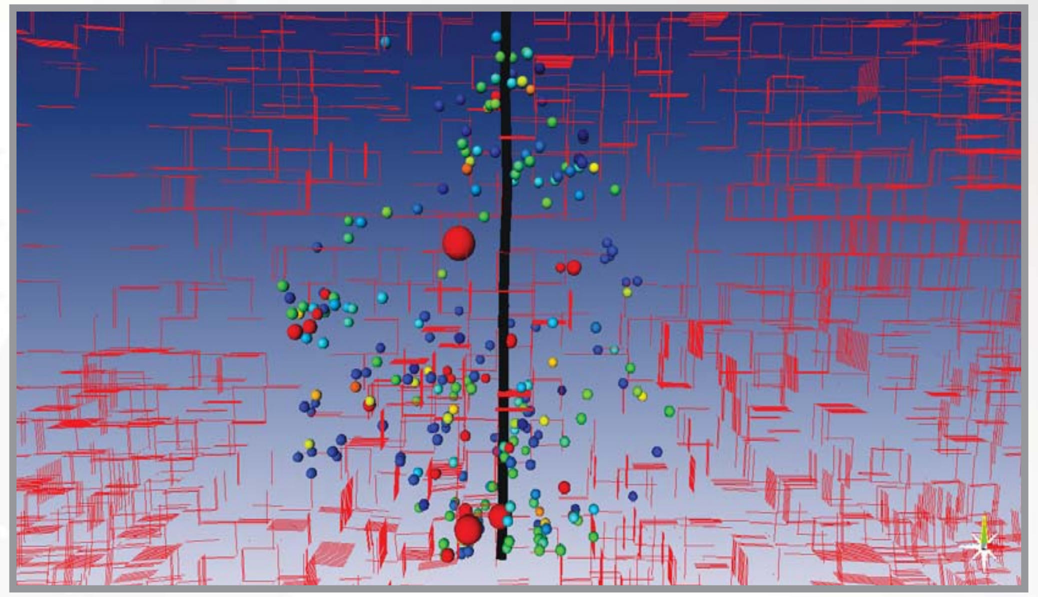

FIGURE 3: : Microseismic displayed with Resistivity (RT) pipes. Only pipes representing high resistivity are displayed. The data is viewed from above. Events are sized and colored by amplitude, higher amplitude events being larger.

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MS QUALITATIVE CORRELATIONS WITH SC

- Microseismic correlated with Shale Capacity (Figure 4)
- Events follow high Shale Capacity pipes
- Spread of events is larger in areas of high Shale Capacity
- Event spread is constricted in low Shale Capacity locations
- Large events occur at the edge of high Shale Capacity locations, areas more resistant to fracturing

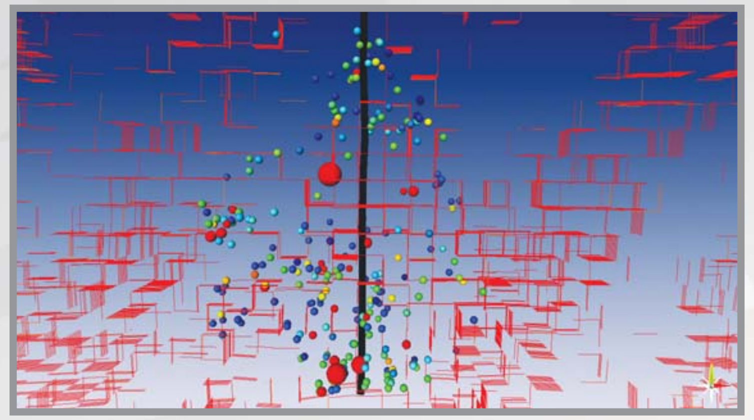

Figure 4: Microseismic events displayed with Shale Capacity (SC) pipes representing the combination of the four property models (GR, Φ, BRT, RT). Only pipes representing very high SC are displayed. Data is viewed from above. Events are sized and colored by amplitude, higher amplitude events being larger.

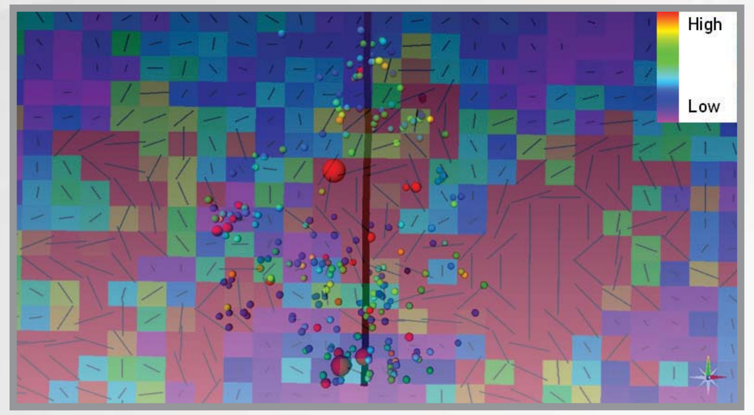

FIGURE 5: Microseismic events displayed with a Shale Capacity anisotropy map of a layer intersected by the wellbore. The data is viewed from above. Events are sized and colored by amplitude, higher amplitude events being larger.

- Microseismic correlated with one layer of Shale Capacity anisotropy map (Figure 5)
- Anisotropy map predicts fracture magnitude and orientation for each cell
- Microseismic follows high Shale Capacity and triggers in medium Shale Capacity

MS QUANTITATIVE CORRELATIONS WITH SC

- Quantitative analysis of Shale Capacity and microseismic event locations (Figures 6, 7, and 8)
- Cylinders colored based on average Shale Capacity, and sized based on average Shale Capacity and extent of microseismic events
- 0.81 correlation coefficient between microseismic (MS) and Shale Capacity (SC)

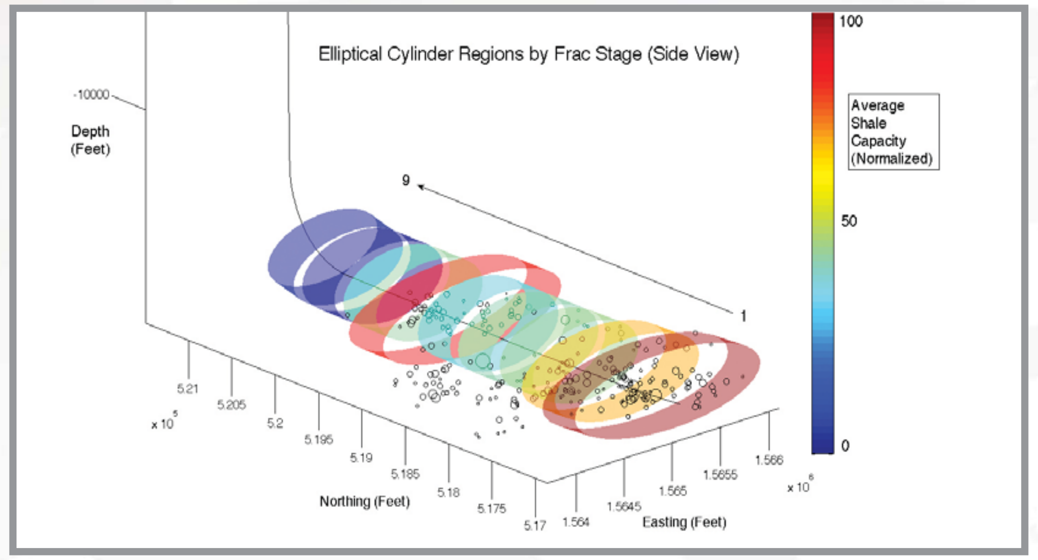

FIGURE 6: Elliptical cylinders used to quantitatively compare Shale Capacity with microseismic events for each of the nine stages. Cylinders are colored by the average Shale Capacity within the cylinder, and sized based on average Shale Capacity and extent of microseismic events.

GEOLOGICALLY DRIVEN SRV FROM SC

- Shale Capacity and microseismic high correlation allows for Shale Capacity to be used as a proxy for calculation of Stimulated Reservoir Volume (SRV)
- With Shale Capacity, SRV may now be predicted throughout 3D model before wells have been drilled

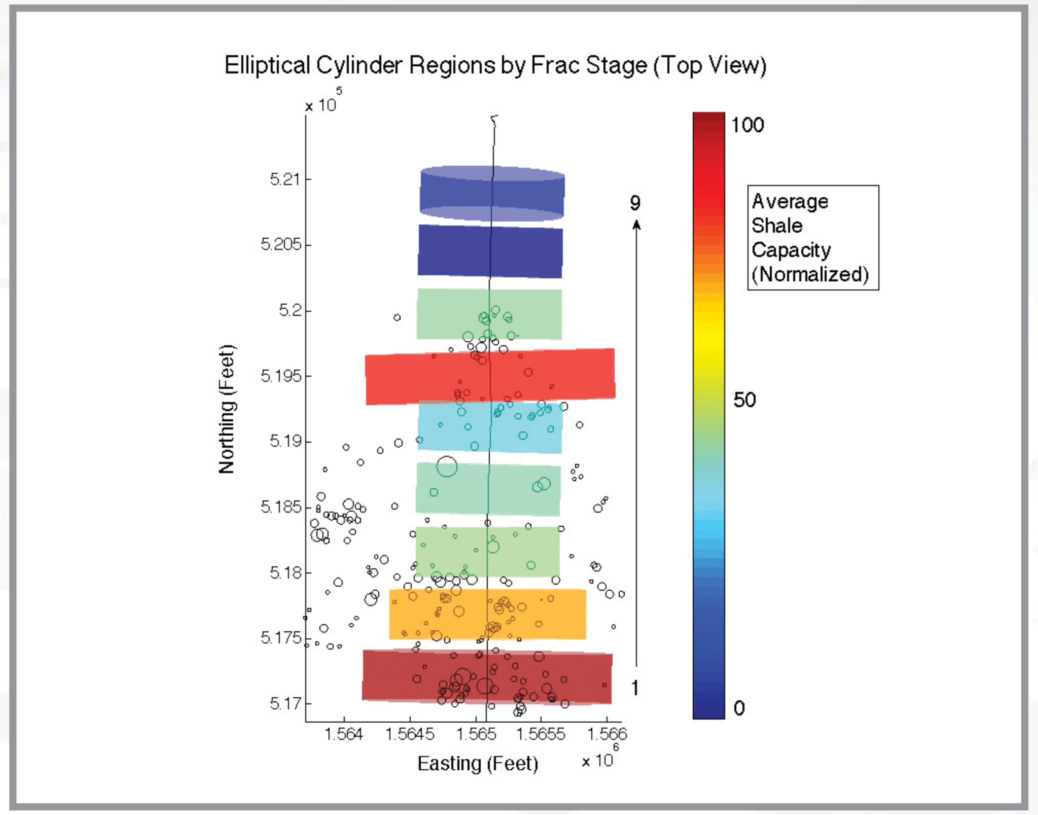

FIGURE 7: Top view of the elliptical cylinders used to quantitatively compare Shale Capacity with microseismic events for each of the nine stages. Cylinders are colored by the average Shale Capacity within the cylinder, and sized based on average Shale Capacity and extent of microseismic events.

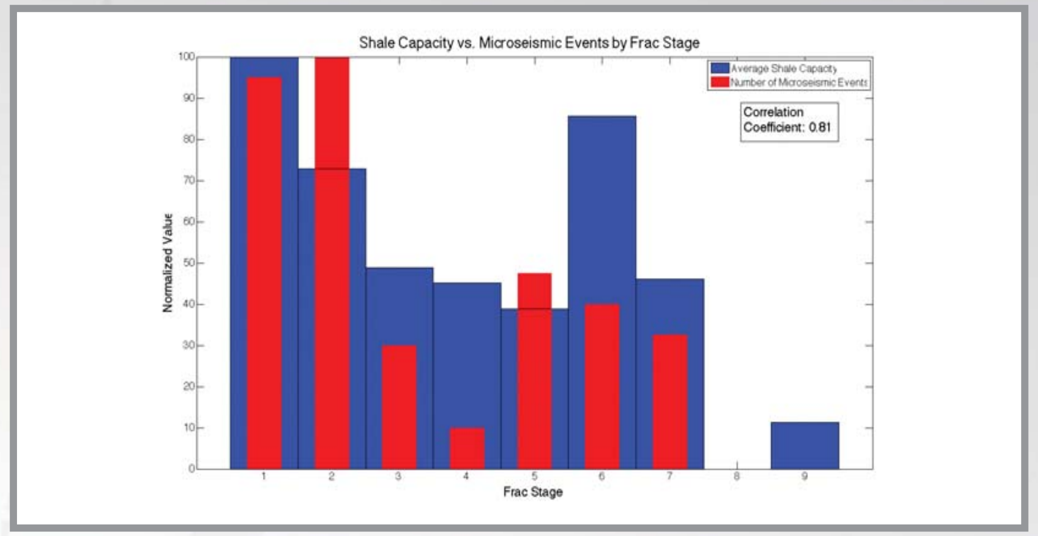

FIGURE 8: Quantitative comparison of Shale Capacity and number of microseismic events for each frac stage. 0.81 correlation coefficient.

CONCLUSIONS

- 3D property models derived from post and pre stack seismic could be used to build a Shale Capacity model , which shows strong correlation with micro-seismic, allowing microseismic to be used as validation of the model, and to understand microseismic locations
- Shale Capacity could be used to identify sweet spots and predict SRV prior to drilling wells

REFERENCES

Laongsakul P. and H. Dürrast, 2011, Characterization of reservoir fractures using conventional geophysical logging: Songklanakarin Journal of Science and Technology, 33, 237-246

Luning, S. and S. Kolonic, 2003, Uranium Spectral Gamma-Ray Response as a Proxy for Organic Richness in Black Shales: Applicability and Limitations: Journal of Petroleum Geology, 26, 153-174, DOI: 10.1111/j.1747-5457.2003.tb00023.x.

Modeland N., D. Buller, and K.K. Chong, 2011, Statistical Analysis of Completion Methodology: SPE-144120-MS, DOI: 10.2118/144120-MS.

Ouenes, A., 2014, Distribution of Well Performances in Shale Reservoirs and their Predictions Using the Concept of Shale Capacity: SPE-167779-MS, DOI: 10.2118/167779-MS.

Ouenes, A., A. Bachir, D. Boukhelf, and M. Fackler, 2014, Estimation of Stimulated Reservoir Volume Using the Concept of Shale Capacity and its Validation with Microseismic and Well Performance: Application to the Marcellus and Haynesville: SPE-169564-MS

Reagan, J., E. Wójcik, M. Fackler, and A. Ouenes, 2013, Predicting Well Performances Using the Shale Capacity Concept: Application to the Haynesville: AAPG Search and Discovery Article #41204

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