Identifying Gas Channel Sweet Spots through Multi-Component Seismic Interpretation*

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Abstract

Lower Cretaceous fluvial sands offer tantalizing, yet challenging gas plays in the Rocky Mountain basins of Canada and the United States. Reservoirs range from single sand channels, often with high porosity and permeability, to stacked sequences of channels hundreds or even thousands of feet thick, generally of low porosity and permeability. Across this spectrum of reservoir types the similar objective is to identify drilling "sweet spots" using available seismic and other E&P data.

In this case study, the effectiveness of multi-component seismic interpretation is compared for two very different gas plays. The first example, from the Western Canadian Sedimentary Basin, illustrates how mode-converted (PS) seismic amplitudes complement traditional (PP) channel interpretation to highlight prospective drilling targets. The second example, from the US Piceance Basin, illustrates how mode-converted and traditional seismic data can be coupled to highlight fault and fracture trends and guide well placement for 250-metre thick tight-gas sand sequences. Emerging techniques for registering and interpreting multi-component seismic data will be introduced and compared.

Multi-Component Seismic Background

Multi-component seismic techniques have been refined over the past few decades, with sophisticated acquisition technology and processes being developed for both land and marine scenarios. Seismic processing algorithms and workflows have emerged to adapt to statics, imaging, and other challenges in a range of geologic settings. Interpretation of multi-component seismic data, however, is in its infancy with few commercial options currently available. As seismic interpreters adapt techniques and workflows to address the challenges of these new seismic datasets, much is being learned about the unique needs for multi-component seismic interpretation.

Successful case studies are essential for wider acceptance of multi-component seismic techniques. A clear and compelling case has been made for the application of this new technology for the interpretation of seismic events beneath "gas cloud" zones, largely in marine settings. While traditional seismic data is obscured by the acoustic properties of "leaked" gas, shear seismic modes provide a much clearer view of underlying reflectors.

Technical and economic barriers, related to acquisition and processing challenges, have limited the number of successful land-oriented "success stories". The latest wave of seismic acquisition technologies and state-of-the-art processing workflows are beginning to produce much better quality and more interpretable seismic products. As the focus moves to interpretation, pioneering interpreters are struggling with fundamental challenges such as "registering" multiple seismic datasets with not only different time scales, but different amplitude, frequency and phase characteristics (Figure 1).

Multi-Component Seismic Registration

While PS seismic data can provide new insights into reservoir lithology and fluid characteristics, interpretation results are dependent upon the quality of the registration between PP and PS seismic times. A simple vertical matching function may be sufficient for qualitative analysis, with simple geology and negligible spatial variations in PS and PP velocities. However, detailed vertical and spatial registration can often play a major role in reducing uncertainty and improving the quality of multi-component seismic interpretation.

In this study, a detailed effort was made to register PS seismic data to match PP seismic time scales, using various seismic attributes and new registration techniques. An interactive "stretch-and-squeeze" approach was developed to dynamically modify the vertical scale of the PS seismic data to match key events in the PP seismic (Figure 2).

A number of seismic attributes and processes were used in this work to improve the quality of the multi-component seismic registration. Phase uncertainty between the PS and PP seismic data lead to the use of magnitude (instantaneous amplitude), removing phase effects, and simplifying the initial correlations. Other attributes, including colored inversion and semblance provided useful perspectives for matching certain regions of the multi-component seismic datasets.

Case Study: Stacked Fluvial Sands

Fluvial sands of the Lower Cretaceous Williams Fork Formation, and their regional US Rocky Mountain equivalent, contain extraordinary gas reserves. In the Piceance Basin of west-central Colorado, low matrix permeabilities in the range of .1 to 2 microdarcies and porosities of 6 to 14% make economic gas production a challenge (Davis 2006). In the southern part of the basin, the Rulison Field produces gas from a 700-foot column of 20 to 30 stacked channels (Figure 3). With proper alignment with natural fractures, complemented with typically 4 or 5 hydraulic fracture treatments, effective permeabilities can be enhanced to between 10 and 50 microdarcies and individual wells can produce over 1.5 BCF.

Traditional development strategies in tight-gas reservoirs consists of methodically placing vertical well paths at increasingly denser spacing intervals. As part of the Reservoir Characterization Project, coordinated by the Colorado School of Mines, multiple vintages of multi-component seismic data have been acquired in 2003, 2004, and 2006. Travel time comparison of "slow and fast" PS and SS seismic data provided estimates of lateral anisotropy, related to fracture density and orientation (Figure 4). Registration of PS and SS data to match PP seismic data supported correlation of amplitudes with well production and estimated ultimate recoverable reserves. For this tight-gas field example, multi-component seismic data provides unique insights that can aid the optimization of well placement.

Summary

A new, interactive technique for registering PS data to match PP times proved to be robust, particularly with the use of seismic attributes and processes. In particular, magnitude, spectral enhancement, inversion, and semblance all were useful techniques for identifying correlations between seismic volumes. Preliminary tests indicate that, for good quality PS and PP data, automated “tuning” of registration functions is a feasible workflow step, after design of a gross matching function.

Detailed registration of multi-component seismic data opens up a number of approaches for extracting more useful information from the data investment. An accurately registered PS volume appears to reduce the risk of correlations and reduce uncertainty in well targeting. Registered multi-component data can be visually correlated using various co-rendering techniques, enhancing the interpreter’s ability to combine multi-dimensional data to improve well targeting.

Fluvial sands of the Lower Cretaceous Williams Fork Formation of central Colorado, while much thinner than the single-channel example, also have applications for new seismic techniques. Multi-component seismic measurements of shear anisotropy and gamma are able to highlight fracture orientation and density, and larger channel features. Recent results complement microseismic, FMI, and other fracture-related measurements, providing options for better well placement optimization.

Selected References

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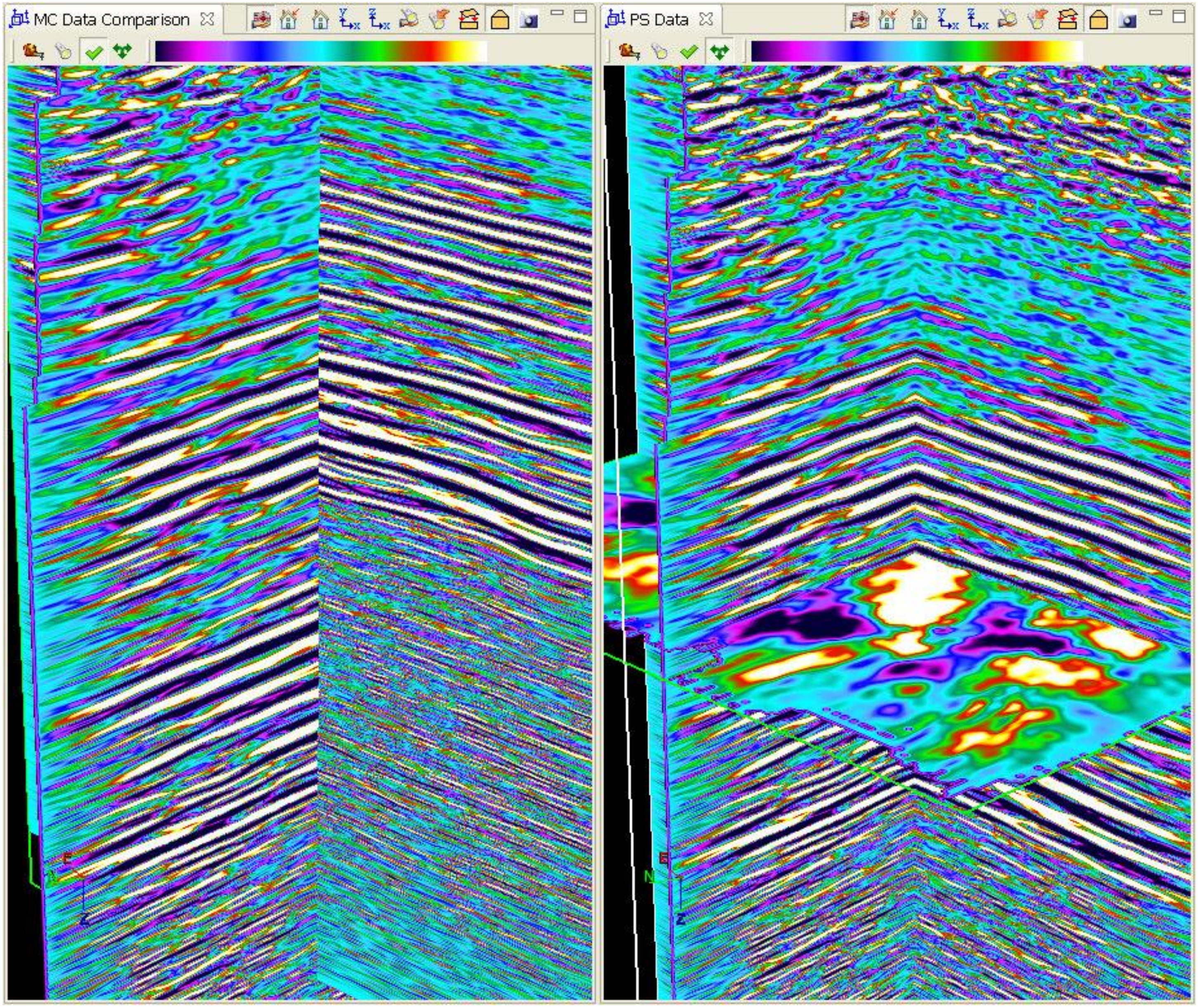

Figure 1. Comparison of PS and PP seismic data (left) and illustration of quality of modern PS seismic data (right).

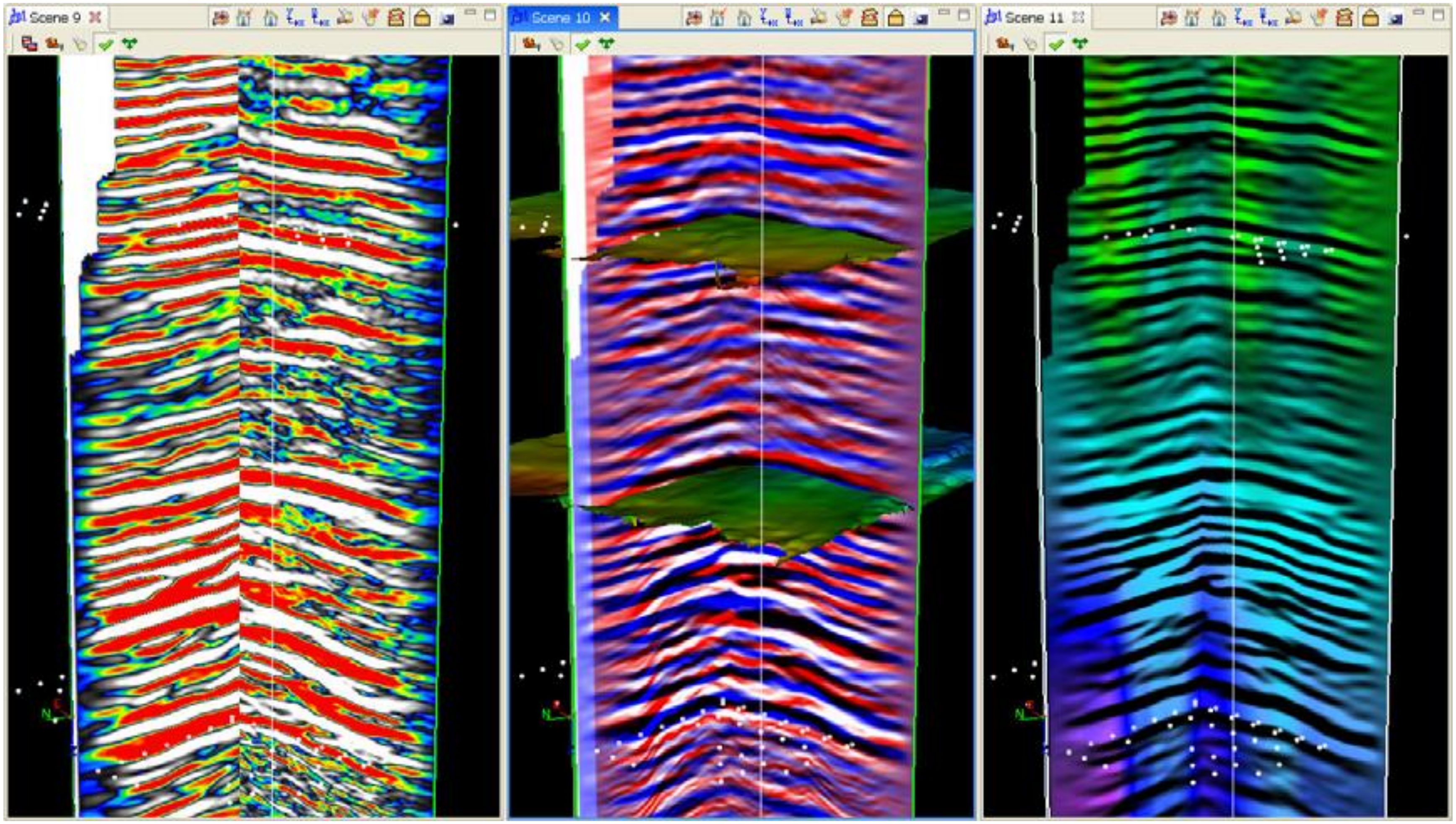

Figure 2. Interactive stretching (left) is used to register PS seismic data to PP times (center) and create a 3D registration (gamma) function.

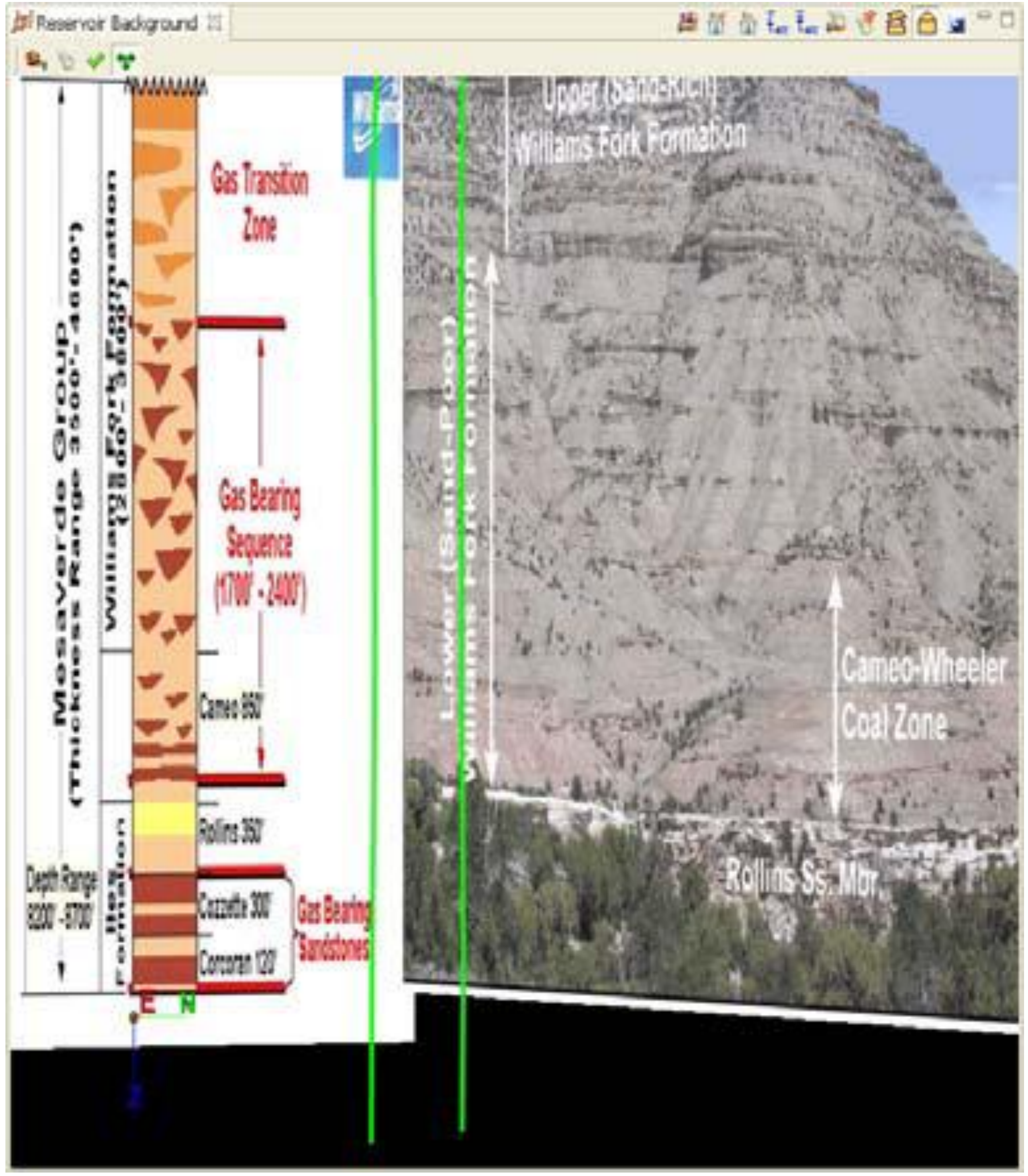

Figure 3. Over 200 m of stacked fluvial gas sands provide reservoir.

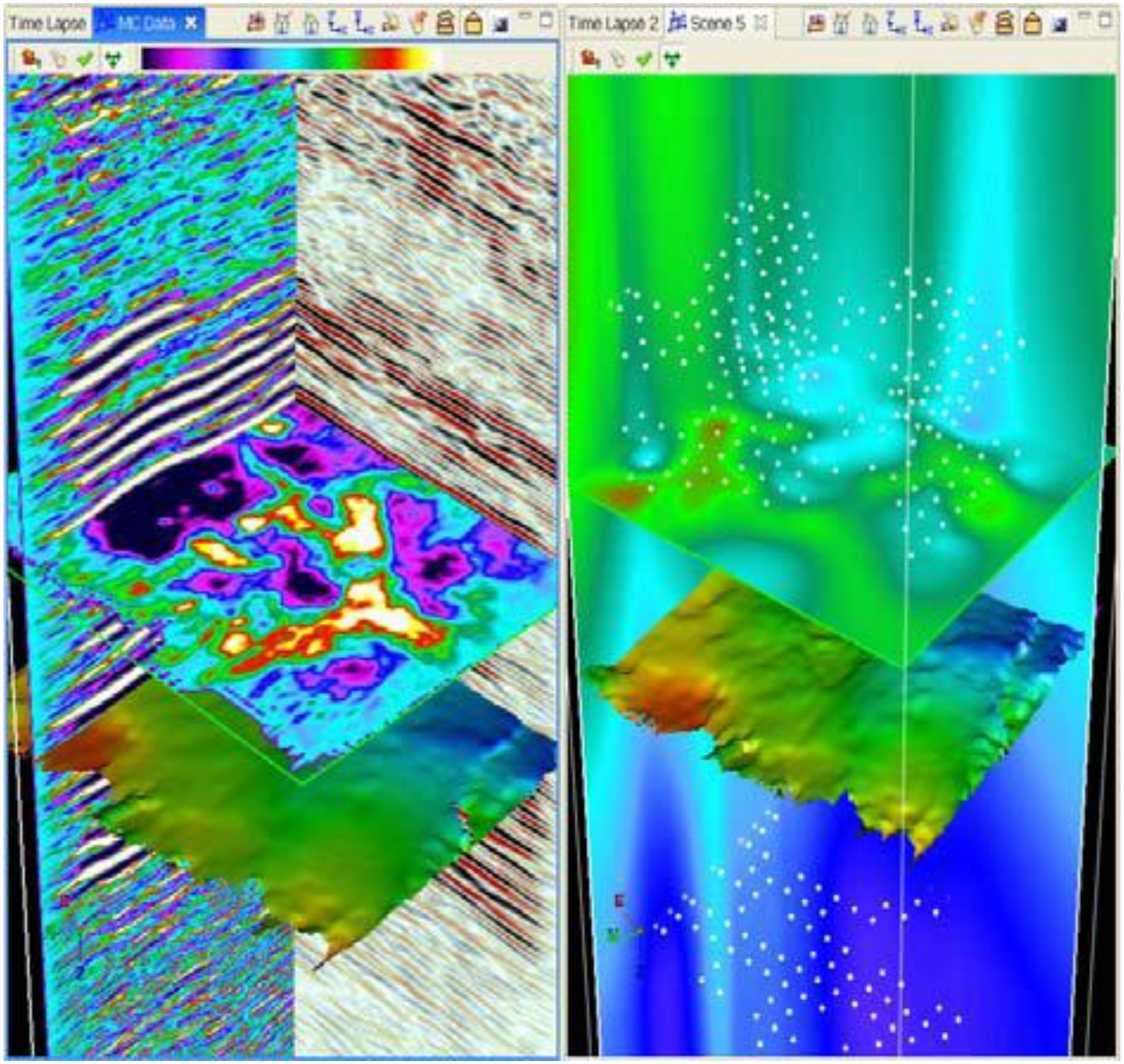

Figure 4. Anisotropy times (left) and gamma (right) provide fracture insight.