New Workflow Quantifies Uncertainties Associated with Model Building, Prestack Imaging

Analysis tool provides interpreters with information about the reliability of seismic images.

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Reservoir evaluation is often based only on the interpretation of a single seismic image. This image is traditionally the result of a tomographic velocity model building process followed by prestack depth migration and is used as the basis for critical economical evaluations of either prospective or confirmed hydrocarbon accumulations.

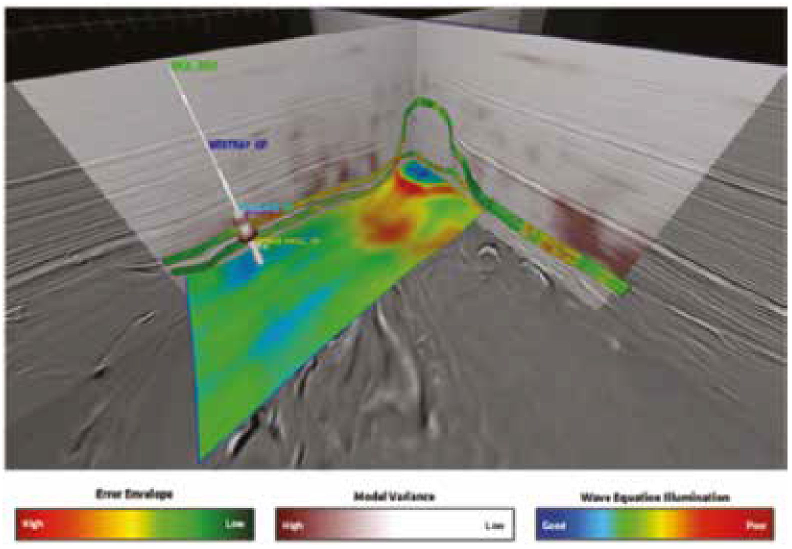
Surprisingly, the amount of uncertainty associated with the image and the velocity model that was used to generate it are poorly understood and often not quantified. The only evaluation of the quality and reliability of the produced image is usually achieved by comparison with auxiliary data such as well markers or by assessing the overall degree of gather flatness or structural simplicity displayed in the final prestack depth images.

Given the significant nonlinearity inherent in the tomographic methods to derive the earth model, multiple realizations of this same model can be produced that similarly honor the constraining data and yield the same overall gather flatness. These models can vary significantly, resulting in substantially different interpretations of critical reservoir features.

PGS has recently developed a new analysis tool that quantifies these inherent image uncertainties. These additional metrics can be directly used by interpreters to improve the understanding of the reliability of their reservoir interpretation and assist in mitigating against risk associated with any structural ambiguity.

Characterizing model uncertainty

The resolution over which a model parameter (e.g., velocity) is constrained by the observed data (e.g., seismic gather flatness) during the tomographic inversion is dependent on many variables. These include factors such as decisions made within the initial migration, namely the spatial sampling of the image space. Additionally, resolution will be strongly affected by the acquisition geometry and also influenced by subsurface geology, which will determine the local impedance contrasts that will give rise to reflections from which the velocity information is extracted. Wherever such impedance contrasts are absent or sparse, velocity information will be poorly resolved.



This image shows PGS seismic data with co-rendered model uncertainty variance attribute, error envelope analysis for two key horizons and illumination distribution generated by wavefield extrapolation. (Image courtesy of PGS)

The tomography workflow characterizing model uncertainties uses PGS' hyperTomo engine and comprises several stages. In the first step, the maximum spatial resolution of the tomographic velocity update is established. The minimum spatial wavelength and amplitude of any velocity perturbation that can be resolved by the tomographic inversion process is calculated using a classic checkerboard test. Once the intrinsic resolution of the inversion process has been established, a large population of perturbated models is generated from a given velocity model. The model population all consistently fits the observed data. Migrations are then performed for all perturbation models, and residual moveout metrics are generated from the resulting common image gathers. Finally, a tomographic inversion is performed for all the perturbations, and the resulting inversion model is compared to the starting model to establish the individual inversion error. A statistical analysis across the total population of inverted models is performed for each grid location to reveal the mean, variance and standard deviation of the local inverted velocity. 3-D volumes are computed for all three statistical parameters. Additionally, a spatial reliability indicator is created to give a positional error envelope for the data.

An example of the integrated use of these metrics is presented in the image below. The model variance cube generated with the new model uncertainty workflow is superimposed with the underlying 3-D seismic image and the error envelope analysis. The combination of these additional deliverables provides interpreters with important information as to the local reliability of the seismic image they are seeking to extract reservoir information from. Additional information about the local illumination strength, for example, can be added to highlight any possible correlations between poor illumination and high model uncertainty.

The additional products this workflow generates can be used in conjunction with delivered seismic images to assist in mitigating risk associated with uncertainty in target positioning and volumetrics.

Learn more about the new model uncertainty workflow and join a live demo at PGS booth 620. ■