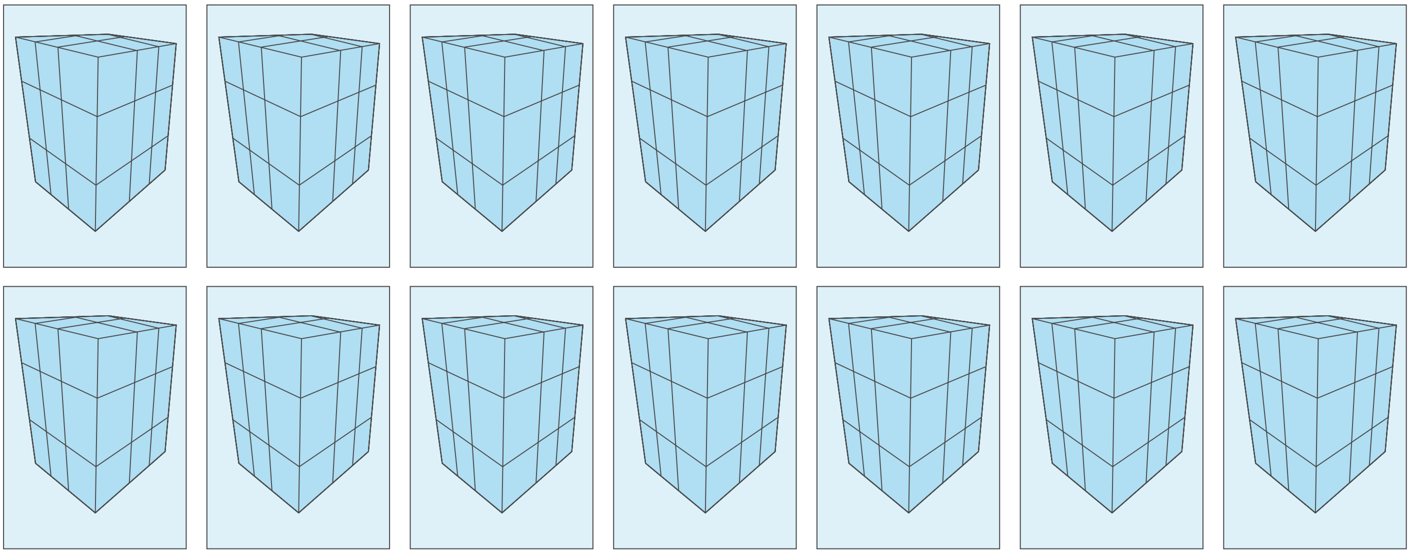
TechNote

Imaging



Estimating Model Uncertainty

The PGS model uncertainty analysis tool helps mitigate the risk associated with target positioning and volumetrics. The workflow quantifies the uncertainty inherent in a final velocity model and the associated image. It helps to derisk prospects with additional deliverables to accompany your velocity model and image.

Reservoir evaluation is often only based on the interpretation of a single seismic image. This image is traditionally the result of a tomographic velocity model building process followed by pre-stack 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 that is displayed in the final pre-stack depth images.

Given the significant non-linearity inherent in the tomographic methods to derive the earth model, multiple realizations of this same model can be produced that similarly honour 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 developed an analysis tool that quantifies the inherent image uncertainties as mentioned above. 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.

KEY BENEFITS

- Additional products that assist in quantifying the uncertainty of a final model.
- An understanding of areas in a final seismic image that might have positional ambiguity
- An opportunity to mitigate risk from the delivery of one model realization and its associated image

Factors Affecting Model Resolution

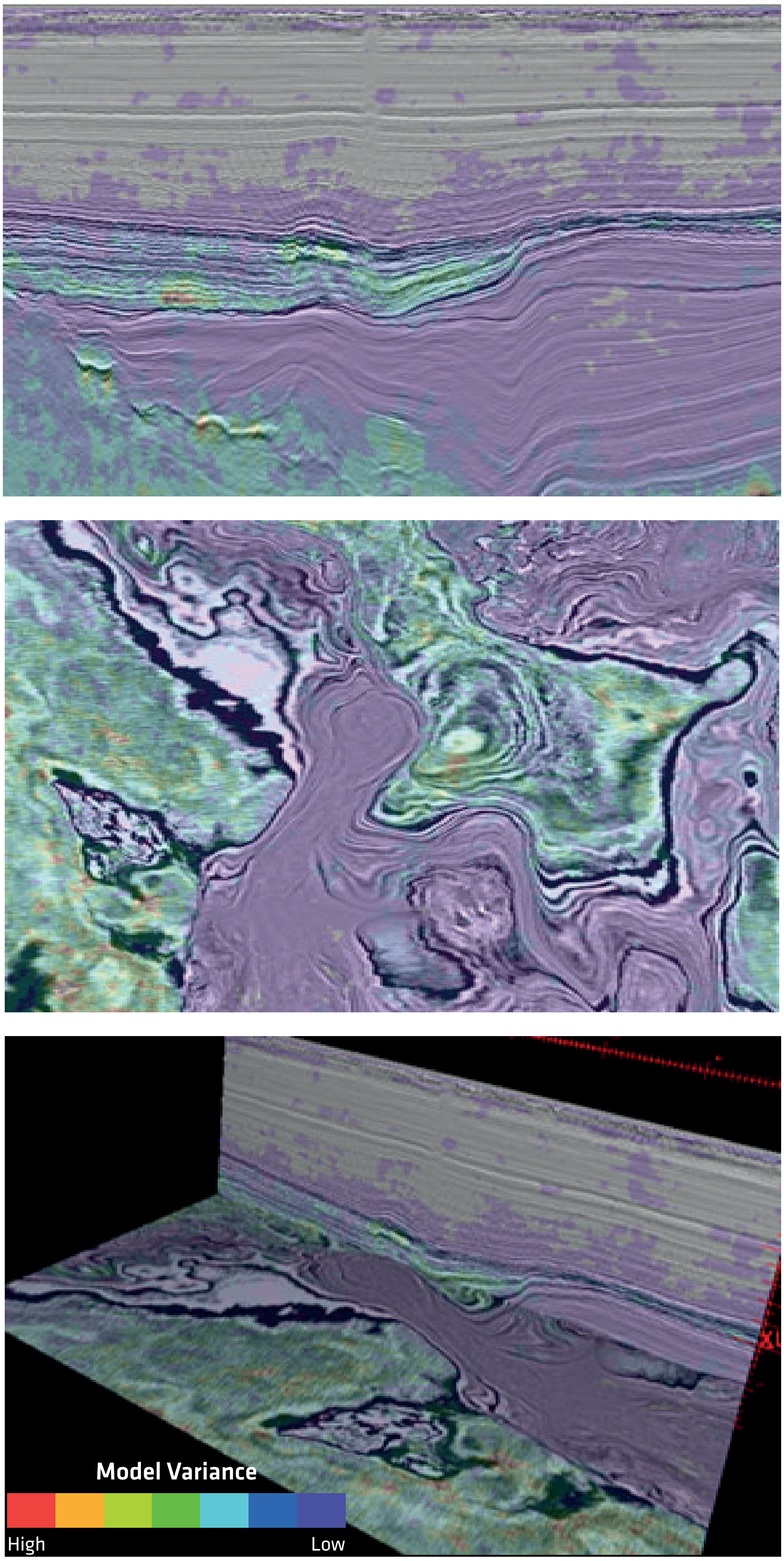
The resolution over which a model parameter (e.g. velocity) is constrained by the observed data (e.g. seismic gather flatness) during the tomographic inversion is dependent on many variables. These include factors such as decisions taken within the initial migration namely the spatial sampling of the 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 from. Wherever such impedance contrasts are absence or sparse, velocity information will be poorly resolved.

Characterizing Model Uncertainty

The tomography workflow characterizing model uncertainties uses PGS' hyperTomo engine and comprises a number of 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 checker-board 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 fit 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.

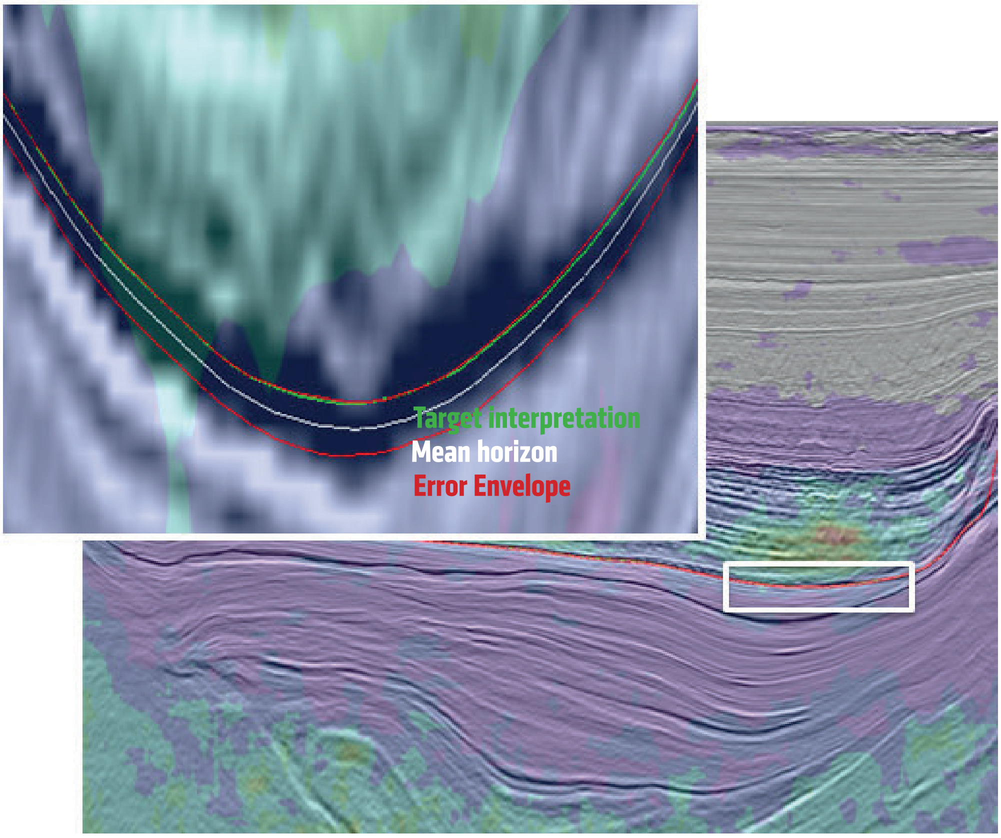
Additional Deliverables

A statistical analysis across the total population of inverted models is performed to reveal the mean, variance and standard deviation of the local inverted velocity as illustrated below. 3D volumes are computed for all three statistical parameters.



Inline, depth slice and 3D intersection showing the model population variance co-rendered on the seismic data.

Additionally, spatial reliability indicators are created to give a positional error envelope for the data as shown in the example below.

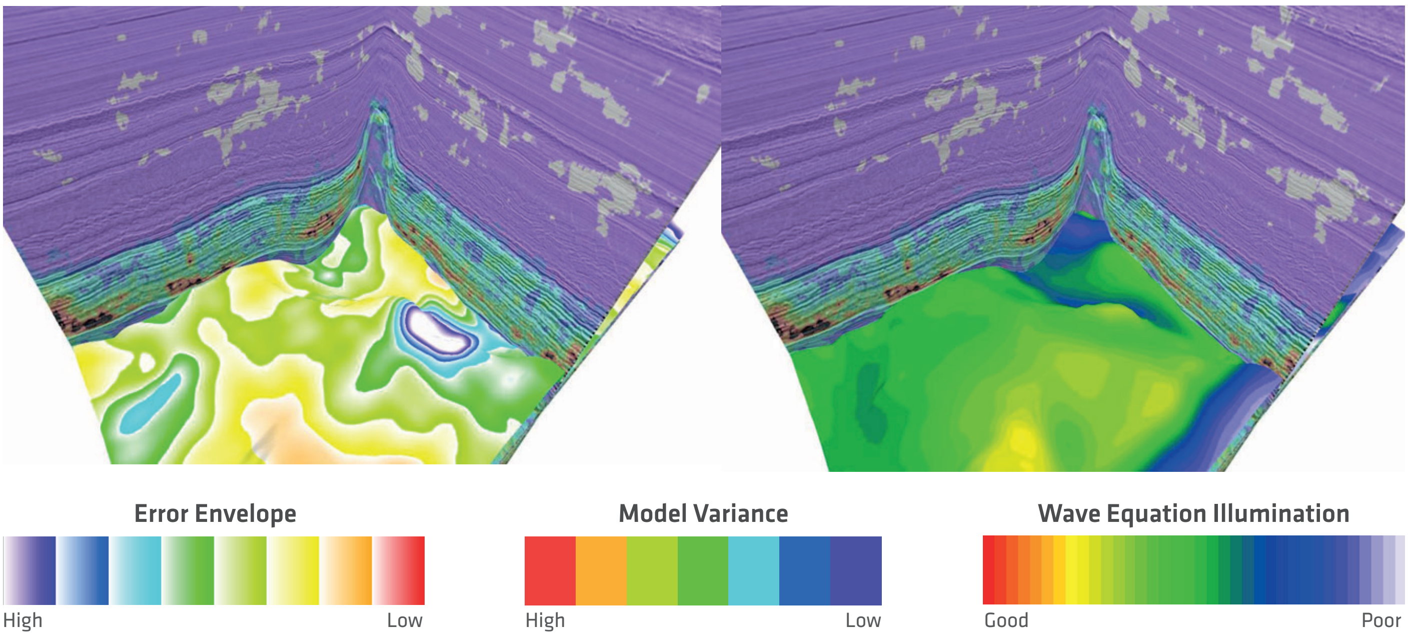


Error envelope on target reflector with model variance co-rendered.

An example of the integrated use of these metrics is presented in the image below. The model variance cube generated with the model uncertainty workflow is superimposed with the underlying 3D 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 that 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 PGS' model uncertainty workflow generates can be used in conjunction with delivered seismic images to assist in mitigating risk associated with uncertainty in target positioning and volumetrics.



PGS seismic data with co-rendered model uncertainty variance attribute, error envelope analysis for one horizon (left) and illumination distribution on the same surface generated by wavefield extrapolation (right).

PGS Model Uncertainty in Brief

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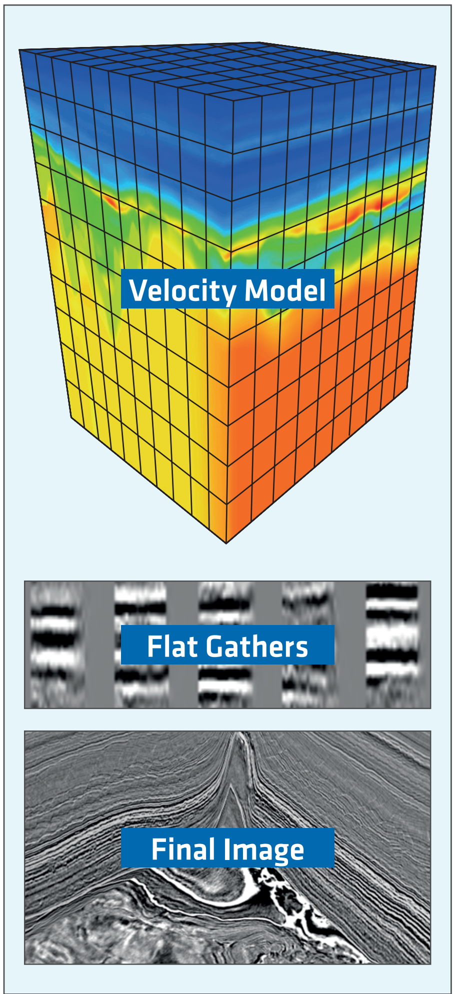
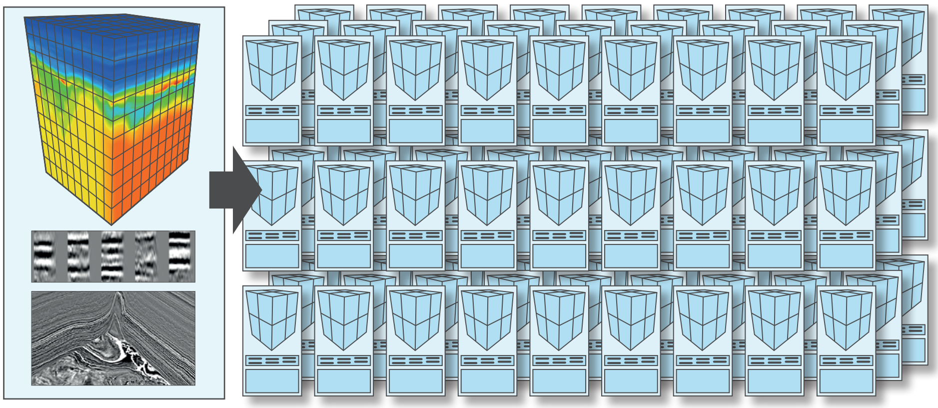
Standard Deliverables



PGS Workflow

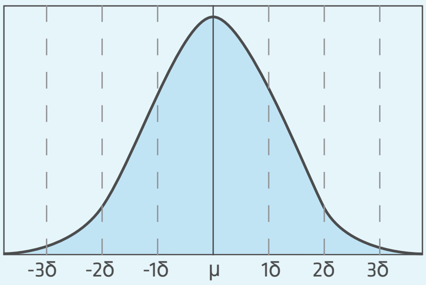
Taking the standard deliverables package, creating a large population of velocity models, each of which lead to flat gathers, and generating an associated range of images. All to quantify the uncertainty.



Additional Deliverables

The model uncertainty workflow quantifies the inherent error in the final image by calculating the mean, variance and standard deviation of the velocity model and gives a spatial reliability indicator for the final image.

MODEL STATISTICS



SPATIAL RELIABILITY INDICATORS