

Constraining Geologic Models with Seismic Inversions

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Summary

Traditionally, inter-well information for the construction of geologic models has relied on variograms. We describe a procedure for the incorporation of information from seismic inversions into the modeling process and demonstrate the method by the sequential indicator simulation (SIS) of geologic facies in a Swan Hills reef. The method proceeds by first populating a geologic corner-point grid with inversion impedances in an artifact-free way. A relation between relevant geologic facies and impedance is then determined and input to the process via facies-impedance histograms. Finally, SIS is completed, using the inversion impedances as a trend. This process facilitates the simultaneous use of information from both geology and geophysics toward better models for reservoir simulations. In turn, we expect improved matches to production history data.

Introduction

Geologic Modeling is an important precursor to reservoir flow simulation. The cells within such models are not the rectangular 'sugar cubes' common to signal processing but are hexahedral with additional degrees of freedom to honor the geometry. They are variable across the reservoir, depending upon structure. We refer to them as geo-cells and the grids on which they reside as corner-point grids (CPGs). Typically, corner-point grids, also called geo-cellular grids, are considerably coarser laterally and finer vertically than their rectangular seismic counterparts. This is necessary to maintain reasonable compute times in reservoir simulators. The use of hexahedral cells in building grids significantly reduces the number of cells required to create a grid which honors complex geology. Commonly, the inputs to a geologic model consist of surface structures from a workstation interpretation of seismic data, and well log and core information. Interpretation within the model between well locations is controlled by variograms which are meant to describe the lateral and vertical correlations of facies and reservoir properties. The variogram parameters are determined from log data, analogues or other assumptions or models. It would be desirable to include real reservoir measurements as an aid to inter-well interpolation in geologic models. We do have this information in the form of inversions of seismic reflection data to reservoir properties such as impedance, porosity and permeability. These reservoir properties are computed on rectangular cells and must therefore

be repopulated on the corner-point grids of the geologic model. This is not a trivial procedure and naive translations from rectangular to corner-point grids will produce sampling artifacts.

Method

We demonstrate a process of incorporating elastic properties determined from geostatistical and deterministic seismic inversions to control and constrain geologic models. The key to the solution is the understanding of the relationships between depositional facies and the elastic facies used in the inversions. Geologic constraints are imposed simultaneously, making the final model consistent with all known information – geological and geophysical.

The method proceeds in two stages

1. Transfer of inter-well information from seismic inversions from rectangular to geologic corner point grids
2. Sequential Indicator Simulation of geologic facies, constrained by the inversion information

We illustrate this method using inverted seismic data acquired over a Devonian reef. We ensure that high resolution inversion information is correctly interpolated onto the corner-point grid (CPG) in a rigorous way, by a procedure which incorporates exactly the same stratigraphic layering information in both the seismic inversion and the geologic model. This facilitates the simultaneous use of both geological and geophysical constraints.

Before the elastic properties from inversions can be used as constraints in a geologic model, their relation to depositional facies must be understood. It is usual to discover that the seismic cannot resolve the full set of depositional facies and that a cluster of data points in inversion space might contain two or more. However, the inversion data can still be used to constrain the spatial distribution of the depositional facies members in the geologic model. This information is applied in the geo-model via a trend imposed on a Sequential Indicator Simulation (SIS). We observe that in doing SIS without a trend, the output is not adequately controlled spatially. One way to control the distribution is to manually draw the trend using a set of two-dimensional maps. We believe that a superior method is to use three-dimensional trends from the seismic inversion to derive trends for the geologic model.

Example

We have implemented this procedure using data acquired over a Devonian reef. The region of interest in the example data set is the Swan Hills at a depth of approximately 2800 m. Porosities of up to 15% are observed with thicknesses up to 25 m. Impedance is well correlated to porosity within the reef. An example line from the constrained sparse spike inversion is shown in Figure 1. The low impedance regions in the Swan Hills (white arrow) are indicative of enhanced porosity. The reef grew on a carbonate platform indicated by the horizon interpretation just below the reef build-up.

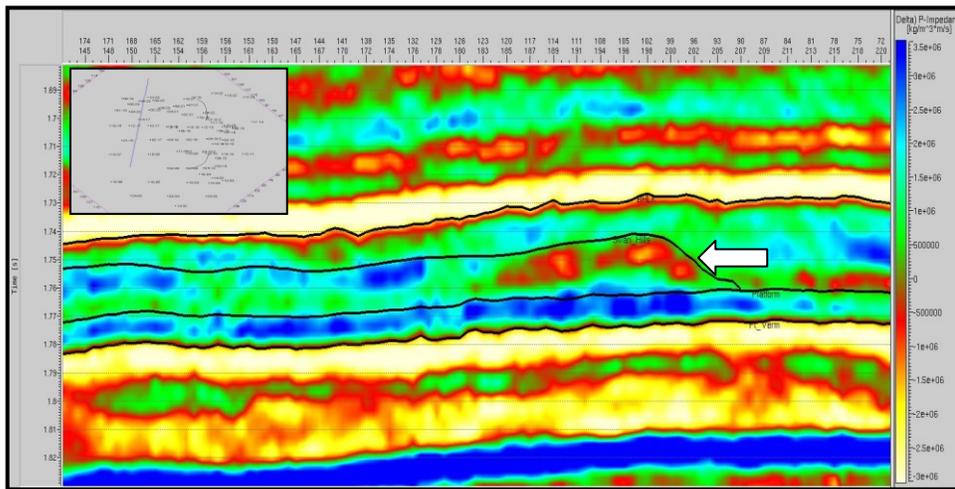


Figure 1: An arbitrary line from the inversion volume. The colors represent impedances as shown by the scale. The white arrow points to low impedances indicative of porosity development along the reef front.

Information is transferred from the seismic inversion to the CPG by an artifact-free process (Pendrel et al., 2010) and then used as a trend in SIS. The 3D trend can be a set of facies probability volumes derived from the inversion using Bayesian inference or a set of probability density functions defined from the inverted volumes. In this case, we used the latter. Figure 2, shows example SIS results with and without using a trend derived from the inversion impedances.

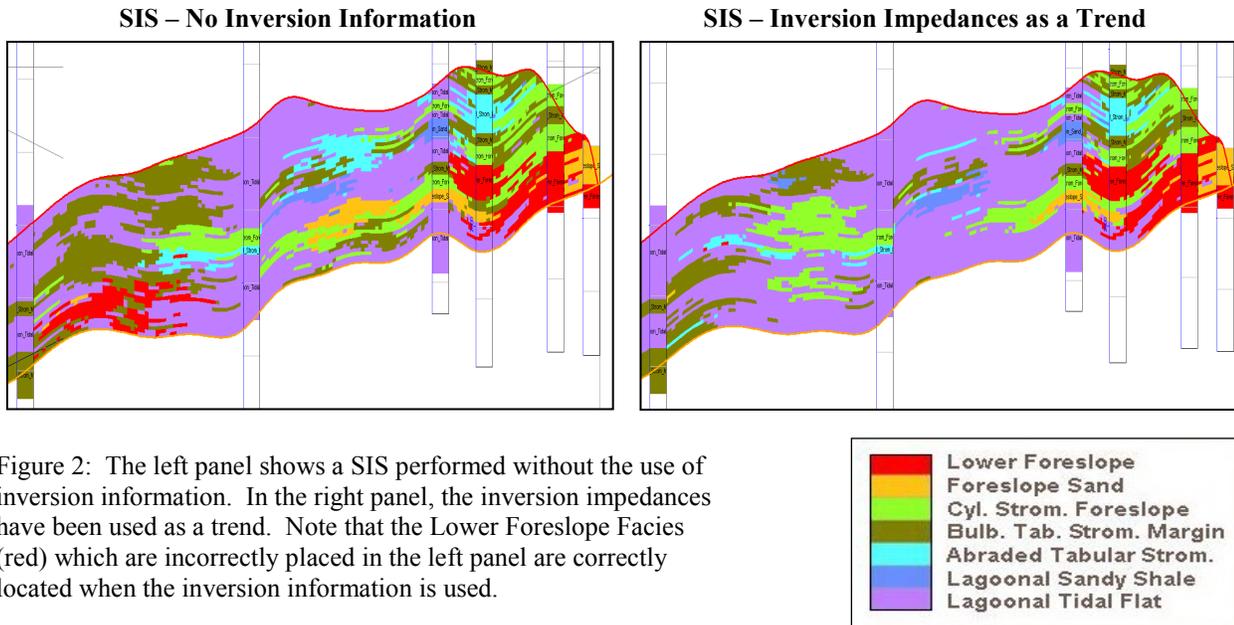


Figure 2: The left panel shows a SIS performed without the use of inversion information. In the right panel, the inversion impedances have been used as a trend. Note that the Lower Foreslope Facies (red) which are incorrectly placed in the left panel are correctly located when the inversion information is used.

Conclusions

We have shown that the proper use of reservoir property data from seismic inversions can be used to better constrain geo-cellular corner-point grids and significantly improve geologic models using the SIS process. These will provide reservoir simulators with an extra dimension of hard information to improve the accuracy of simulations. This should result in reservoir simulations which give better matches to production history data, requiring fewer upscaling corrections and simulation modifiers.

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References

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