

Artifact-Free Population of Geologic Models from Seismic Inversions

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Summary

We demonstrate a procedure for the artifact-free population of geologic corner-point grids with information from seismic inversions, resident on rectangular, 'sugar-cube', grids. The method first computes an intermediate rectangular grid which uniquely combines reservoir property and stratigraphic information at each voxel (rectangular cell). This collective information can then be used to guide the artifact-free population of corner-point grids.

We illustrate this method on inversion data collected from seismic acquired over a Swan Hills reef. It is seen that high resolution inversion information is correctly interpolated onto the corner-point grid in a very reasonable way, even though the geologic grid is coarser laterally and finer vertically than its rectangular counter-part. Further, we show that naive attempts which do not utilize stratigraphy give inappropriate results.

Introduction

Geologic Modelling 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 and 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*. 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 to honor 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 the inversion 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. Additionally, we want to retain the flow units observed in the seismic. Here, we demonstrate a method for the artifact-free population of corner-point grids from rectangular grids.

Method

The key idea behind the method is knowledge of the stratigraphy at each rectangular cell which guides the re-sampling to the corner-point grid. Problems arising from ignoring stratigraphy are illustrated in Figure 1. A corner point grid with cells conformable to stratigraphy is shown. It contains a yellow and a blue layer. A naive sampling from a rectangular grid in the yellow layer would follow a sampling rule indicated by the black grid. Clearly, some yellow cells would be omitted and some cells from the blue layer would be erroneously included. It is important to note that the effect can be very drastic in case of transferring data from geostatistical inversions where the layer sampling is typically relatively fine.

Stratigraphy is estimated from the reservoir structure and the known behaviour of layer terminations (onlap, offlap, etc.). It is first combined with the reservoir properties from inversion onto an intermediate rectangular grid which we refer to as the *Stratigraphic Model Grid (SMG)*. Then, the reservoir properties are interpolated onto the corner-point grid, guided by the stratigraphy. The results are artifact-free geologic models which are rich with correct inter-well and flow unit information.

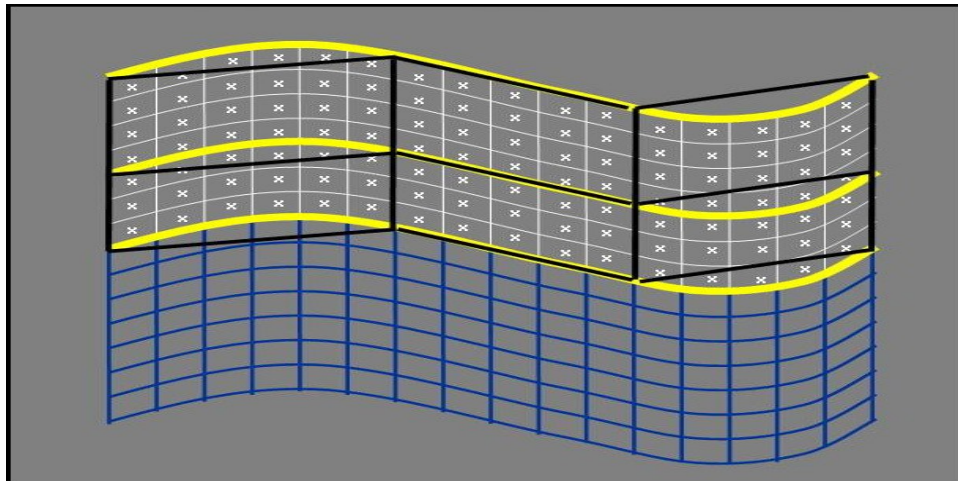


Figure 1: Illustrated are yellow and blue layers in a corner-point grid whose cells are conformable with stratigraphy. Ignoring stratigraphy in the transfer of information from the equivalent rectangular grid (not shown) would follow the black lines.

Example

We have implemented this procedure using data acquired over a Devonian reef. The region of interest in the example data set is a Swan Hills reef at 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 2. 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. Therefore, the stratigraphy of the reef is 'conformable to base'.

The stratigraphy model used to guide the transfer of information is shown in Figure 3a. The colors are important only in that they convey the stratigraphy in each layer. Note that the reef build-up is conformable with the platform but unconformable with the layers above it. Different ideas can easily be tested as the geologic model updates itself automatically whenever any changes are made to the stratigraphic model.

A geo-cellular grid was defined as shown in Figure 3b. Note that the individual cells are no longer rectangular. Rather, they are now constructed to be conformable with stratigraphic boundaries. They have been populated with impedances from inversion and knowledge of the stratigraphy. Note the enhanced porosity (low impedance) development up-dip.

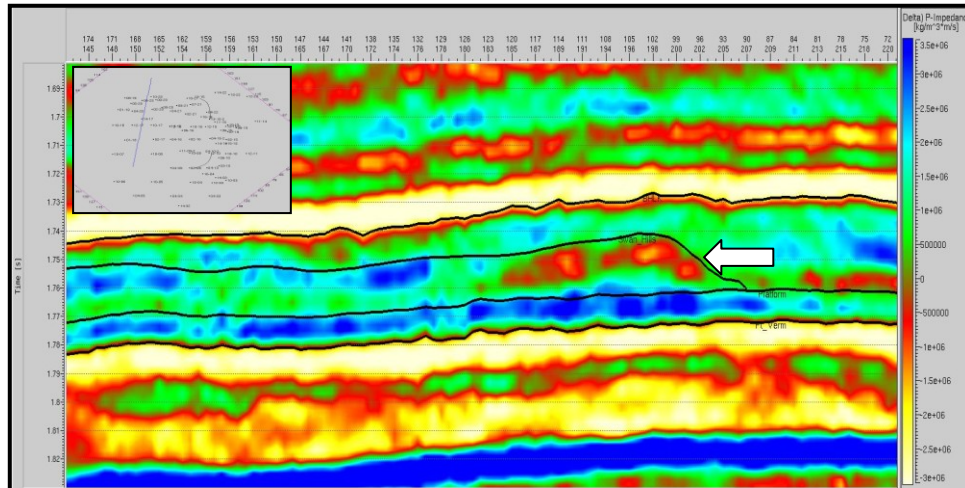


Figure 2: An arbitrary line from the inversion volume. The colors represent impedances as shown by the scale. The white arrow points to low impedances indicative of porosity development along the reef front.

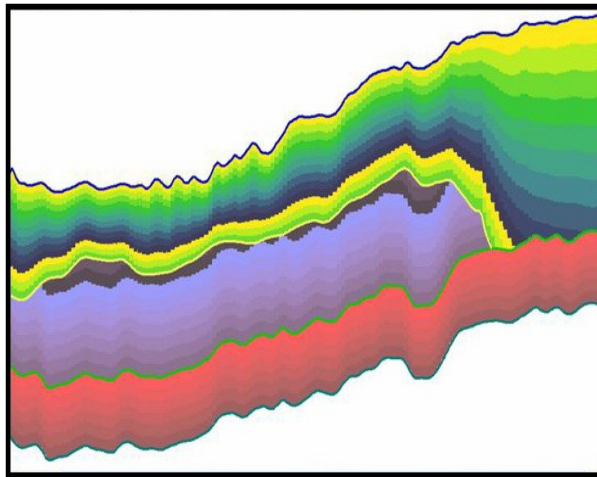


Figure 3a: Stratigraphic Section

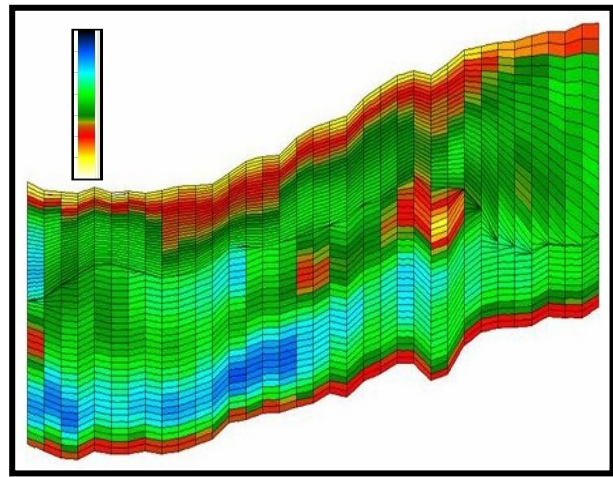


Figure 3b: Geologic Modelling Section

Figure 3: Figure 3a is a section through the stratigraphic volume. The colors are indicative of the stratigraphy in each layer. Note that the reef layer is conformable with the platform upon which it grew and unconformable with the layers above it. Figure (3b) is a section from the geo-cellular grid. It has been populated with impedance information from inversion using specifications of stratigraphy at each original rectangular voxel.

Slices through the original rectangular property grid were computed and compared to those from the geo-cellular model. In the latter case, two geo-cellular grids were constructed – one with and one without the use of stratigraphy information. The results are shown in Figure 4. The left panel shows a time slice through the Swan Hills, parallel to the platform on which it grew. There is a clear indication of enhanced porosity development along the edge of the reef in the North and East. Population to a geo-cellular grid, using stratigraphic information gives the result in the middle panel. Although the spatial sampling in the geologic model is coarser laterally, we suggest that the indications of spatial porosity are faithfully handled. That is definitely not the case in the right panel where stratigraphic information was not used and the impedance is generally overestimated. This means that porosity will be underestimated.

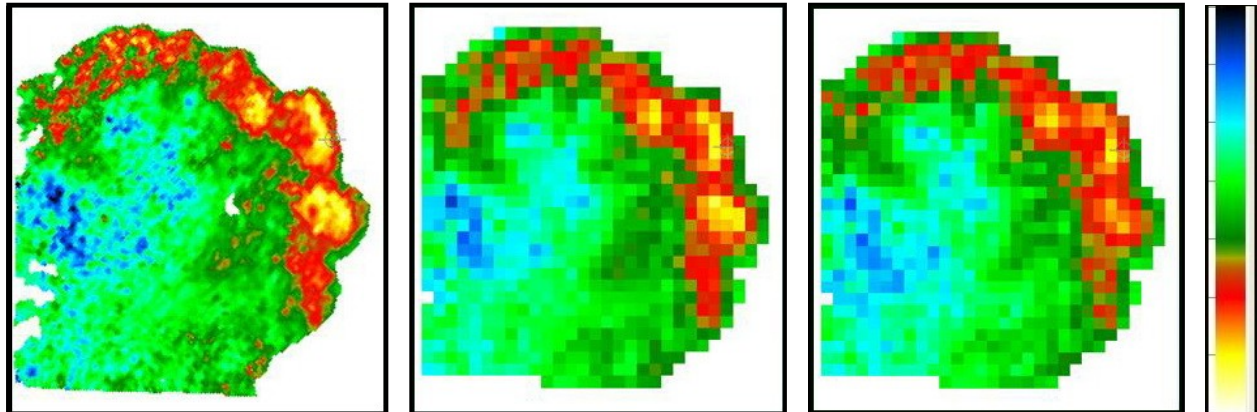


Figure 4: Shown are slices through the volumes of inversion impedances. The slices are conformable with the reef platform and set to a time of Swan Hills build-up and enhanced porosity. The left slice is from the original rectangular grid upon which the inversions were computed. The middle is from the geo-cellular grid making use of stratigraphic information, while the right panel does not make use of stratigraphy. Clearly, sampling artifacts have compromised the panel on the right.

Conclusions

We have shown that the proper use of local Stratigraphic information can be levered toward the correct interpolation of reservoir property data from seismic inversions to coarser geo-cellular corner-point grids. These will provide reservoir simulators with an extra dimension of hard information to optimize simulations. This technique should result in reservoir simulations which give better matches to production history data, requiring fewer upscaling corrections. The example which we have shown is in the time domain but the conclusions would be identical to observations made in depth.

Acknowledgements

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