Geostatistical Simulation of Porosity and Risk in a Swan Hills Reef

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Summary
We have done geostatistical simulation and inversion to determine the distribution of porosity in a Swan Hills reef. The outcome of this procedure is a set of porosity volumes, each consistent with the input seismic reflection data and in agreement with all the porosity logs. The set of porosity volumes has been used to make porosity probability density functions (pdf's) at each grid point in time and space. The pdf's were then integrated to determine the probability that the porosity exceeded 10%. The resulting probability volume was automatically interpreted to map the likely areas of enhanced porosity and reduced risk.

Introduction
Geostatistical simulation is the process of estimating the value of a geophysical property at a grid point in space and time where it is unknown. Non-uniqueness is recognized by the procedure and accounted for by creating probability density functions (pdf's) at each grid point. It is from these pdf's that simulations are randomly drawn. *A priori* information comes from well logs and spatial statistical property and lithology distributions. The logs are assumed to represent the correct solution at the well locations. It is useful to run a sparse spike inversion first, to establish this. Out of the range of the wells, we use geostatistical inversion to constrain the simulations. The geostatistical (or stochastic) inversion algorithm simply accepts or discards simulations at individual grid points, depending upon whether they imply synthetics which agree with the input seismic. The decision to accept or reject simulations can optionally be controlled by a simulated annealing strategy. The inversion option results in a tighter set of simulations, the variation of which can be used to estimate risk or make probability maps.

We have implemented this procedure for data over a Swan Hills reef. The collection of simulations and their variance were used to establish the probability of occurrence of porosity. The final output was a volume containing the probability that porosity exceeded 10%. This probability volume was then viewed in 3D perspective and regions of low probability set transparent. The remaining high probability volumes were interpreted.

Method and Example
The region of interest in the example data set is a Swan Hills reef at approximately 2800 m. Maximum porosity thickness is 25 m and there are 65 wells within the survey. Impedance is directly related to porosity. This was confirmed through log cross-plots and by doing a standard constrained sparse spike inversion. An example line from the inversion is shown in Figure 1. The low impedance regions in the Swan Hills indicate enhanced porosity. Accordingly, it was decided to first compute simulations of impedance. The stochastic inversion should control the transition from the fine scale of the input impedance logs to the lower resolution of the simulations. One of the impedance simulations is shown along the same example line in Figure 2. Note the apparent increase in resolution. The simulations admit the possibility of different connectivity regimes within the reef - an important consideration in reservoir analysis. Some of the apparent improvement in resolution may be illusory as there is an attendant increase in

variability from one simulation to the next. In the following we will examine the ramifications of this variability to porosity. Given the good relation between impedance and porosity in the logs, we formed porosity simulations by the simple transformation of the impedance simulations.

Twenty simulation sets of impedance and porosity were computed. The porosity simulations were modelled by a Normal probability density function at 3D each grid point. From these, volumes could be constructed giving the probability that the porosity lay within a specified range. Figure 3 shows an example of this for porosities equal to or greater than 10%. This volume was then viewed in 3D perspective and probabilities less than 60% were set to be transparent (Figure 4). The tops and bottoms of the viewable remainders were identified and picked automatically. The thicknesses of these high-probability bodies were then mapped (Figure 5). The colours represent the thickness, within which, the probability of 10% or greater porosity exceeds 60%. From plots such as these, uncertainty can be formally measured and input directly into risk management analyses.

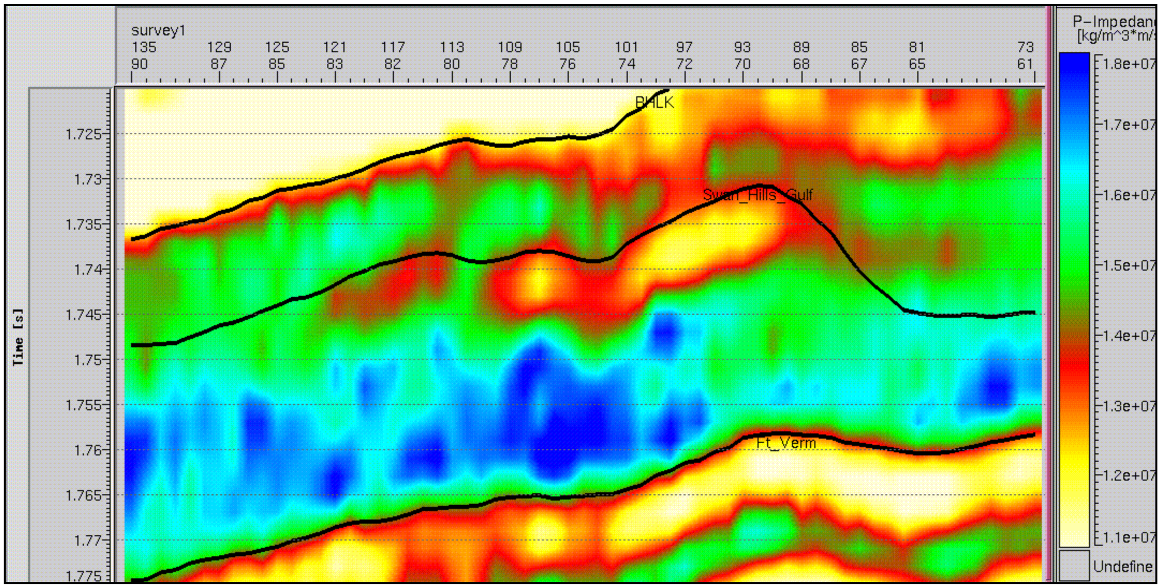

Figure 1: An example line from the constrained sparse spike inversion. The areas of low impedance below the Swan Hills horizon represent porosity.

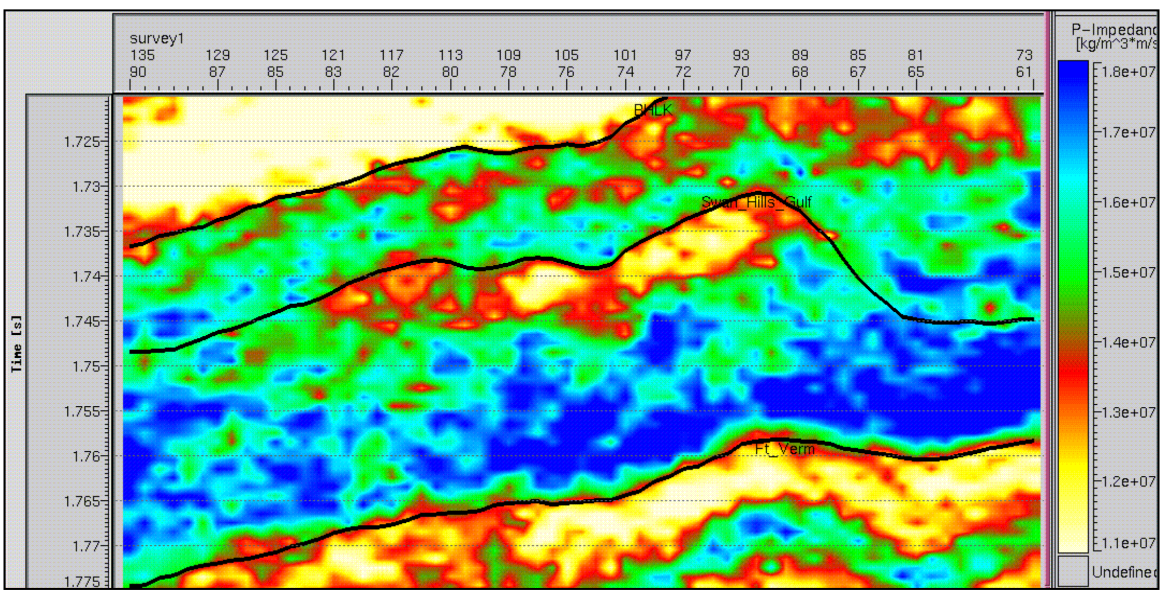

Figure 2: A line from one of the 20 simulations of impedance. The increased detail compared to Figure 1 is entirely consistent with the input seismic and log information. However, there can be significant variability from one simulation to the next. Each of the 20 simulations was transformed to porosity using a linear relation.

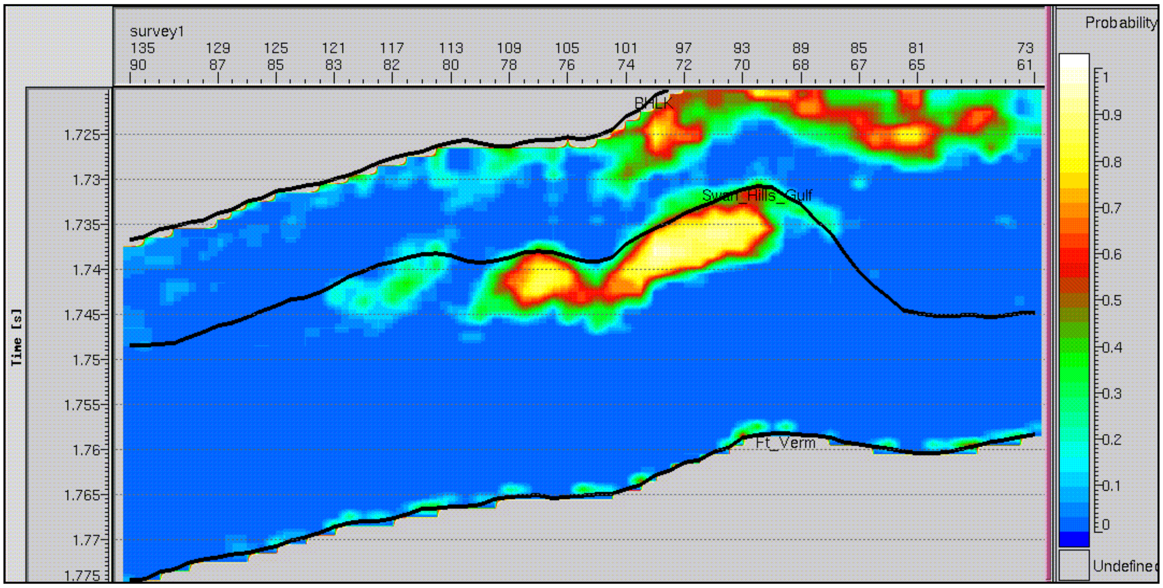

Figure 3: The set of 20 porosity simulations was modelled to make a unique porosity probability density function (pdf) at each grid point in space and time. The area under the pdf's above 10% porosity was used to form a porosity probability volume.

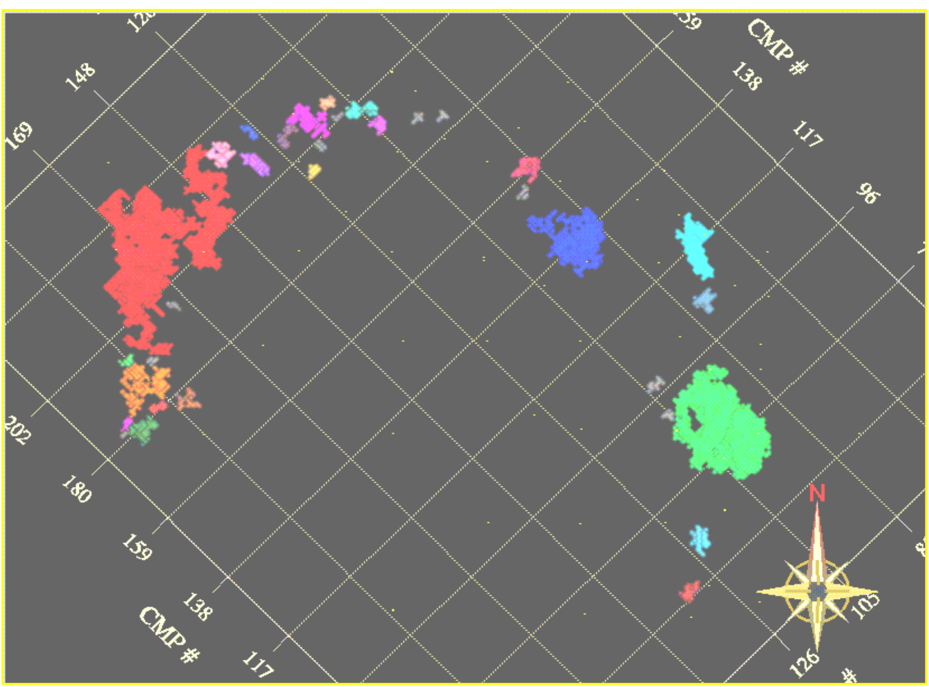

Figure 4: The porosity probability volume was viewed in 3D perspective and the probability values below 0.6 set to be transparent. The remaining visual regions were subjected to a 'body capturing' procedure. The captured bodies are shown in the figure.

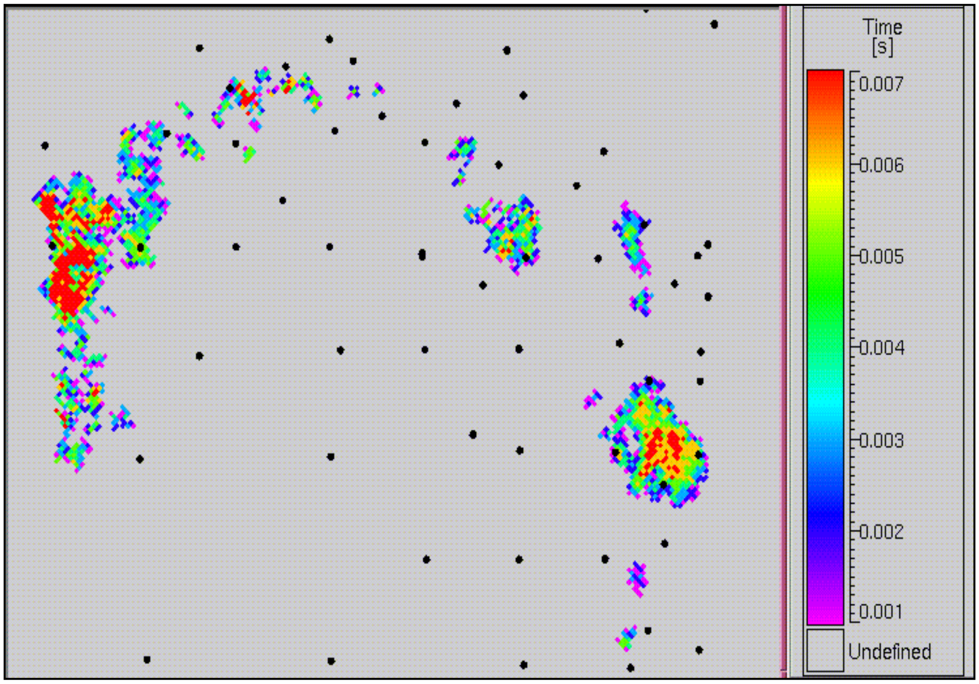

Figure 5: The 'bodies' in Figure 4 were automatically interpreted. There thicknesses are mapped in this figure. The colours represent the time thickness of bodies, within which, the probability of 10% or greater porosity exceeds 0.6.