Advanced Techniques for Simultaneous AVO Inversion (*RockTrace*, *RockMod*)

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Since the introduction of Simultaneous AVO Inversion some five years ago, work has been underway to refine and improve the method. The issues have been several: low frequencies, stability, noise attenuation, alignment, uncertainty and resolution. This work has resulted in two distinct algorithmic flavours – Deterministic and Geostatistical.

Deterministic Simultaneous AVO Inversion delivers one most-likely set of the reservoir properties, P Impedance, S Impedance (or Vp/Vs) and Density. Uncertainty information is determined in the form of the probabilities of the various facies of interest occurring, given their prior statistics. These are usually provided by logs. These 3rd generation algorithms are capable of including more data and reservoir variables into a single objective function. In addition to the original mixed-norm parameters invoking low frequency information, accuracy and simplicity we have others. Jason's *RockTrace* includes wavelet scale, partial stack alignment, noise modelling, and reservoir parameter uncertainties. The result is greater stability and resolution combined with optimum noise rejection, while still running *blind-to-the-wells*.

Geostatistical Simultaneous AVO Inversion brings together aspects of Bayesian Inference, Geostatistics and classic AVO inversion within a Markov Chain Monte Carlo (MCMC) framework. The method can incorporate well information formally or run in a blind-to-the-wells mode. Another fundamental feature of the Geostatistical Method is the possibility of imbedding facies or lithotype estimation formally within the inversion procedure. The output attributes of each voxel are then, P Impedance, S Impedance (or Vp/Vs), Density and Facies. Indeed, any other reservoir properties (eg. Permeability, Sw) can be estimated in follow-up runs. The Geostatistical method recognizes no single answer but rather a set of solutions, all belonging to a joint probability density function (pdf) determined by the method of Bayesian Inference. The MCMC technique samples this pdf to find a fair set of possible outcomes, each consistent with the input seismic. From the variability of these outcomes (a.k.a. simulations or realizations) uncertainties and probabilities can be inferred. Since the algorithm works on a (multi-channel) voxel-by-voxel rather than a trace-by-trace basis, remarkably few realizations are required to estimate probabilities. Usually, 10 to 20 are sufficient. Figure 1 shows the results of a RockMod Simultaneous AVO inversion of the Blackfoot data for Vp/Vs. It was run in a Blind-to-Wells mode and is the mean of ten separate realizations. Note the presence of upper and lower sandstones exhibiting classic low Vp/Vs. Two of the realizations are shown in Figure 2. Note the many fine-scale details which do not survive in the mean.

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The variability between the realizations have been used to compute a probability of occurrence for the low Vp/Vs sandstones (Figure 3). The lower sandstone is determined with less certainty than is the upper. In fact, in the mean, it appears dimmer and thinner than the gas-charged upper sandstone.

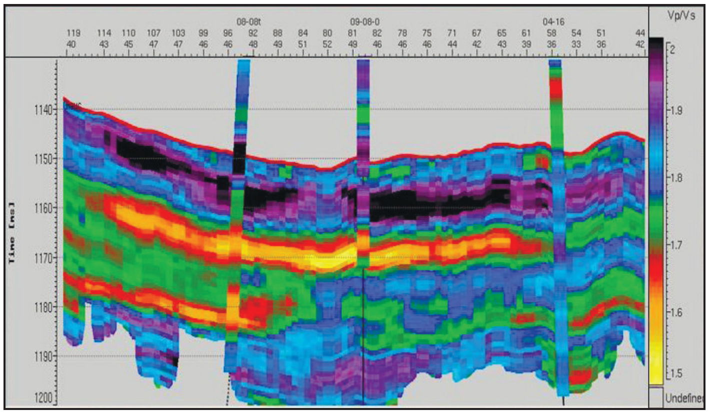

Figure 1. Vp/Vs from the *RockMod* Geostatistical Inversion of the Blackfoot data. Upper and Lower valley development is evident. RockMod was run in the *Blind-to-Wells* mode. The figure is the mean of ten realizations.

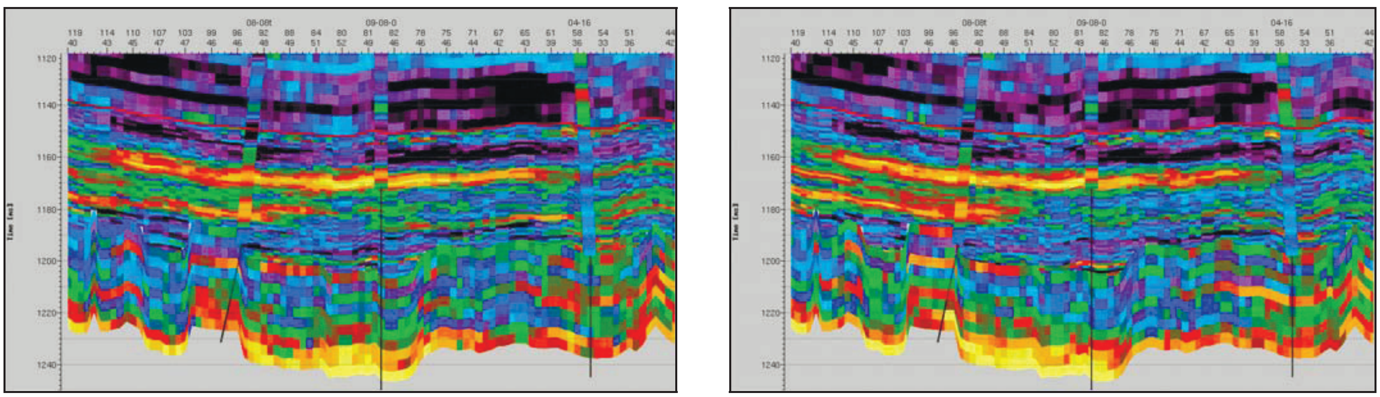

Figure 2. The figure shows two separate realizations of Vp/Vs from the RockMod AVO Inversion. They have slight differences which are mostly averaged out in the mean result (Figure 1).

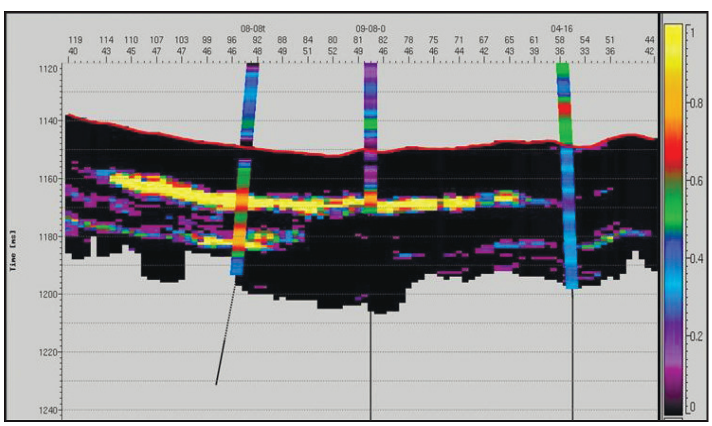

Figure 3. The variability between ten realizations of Vp/Vs was used to determine probabilities for hydrocarbon-bearing sandstones. The upper valley sandstones are better defined in the data where the probabilities are higher.

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