Towards Interactive QI Workflows

*Laurie Weston Bellman**

Summary

Quantitative interpretation (QI) is an analysis approach that is widely applied (Aki and Richards, 1980, Verm and Hilterman, 1995, Avseth et al., 2005, Weston Bellman and Leslie-Panek, 2014) to extract detailed geological information from seismic data. Simultaneously, generic 'big data' analysis techniques are evolving rapidly, 'integration' is the goal of most geoscience departments and computer storage, processing speeds and visualization capabilities continue to grow exponentially. A workflow is proposed to harness all these advancements for the development of an interactive interpretation environment. This environment would ideally allow for maximum interpretive creativity constrained by quantitative data functions, guidelines and limits. Progress towards this goal is described here including value scanning for optimum AVO and inversion parameters and a unique interactive interpretation application for the integration of quantitative information.

Introduction

QI is not new. The general idea has existed since geophysicists first started noticing variations in the wavelet several decades ago. Relatively recently however, the process has incorporated geological templates (Avseth et al., 2005, Weston Bellman, 2009) to directly relate seismically-derived elastic properties to geological properties of interest such as porosity, facies type, reservoir quality, geomechanical indicators and reservoir fluids. As such, a modern, integrated QI process consists of three main components: templating, attribute estimation and classification (Figure 1).

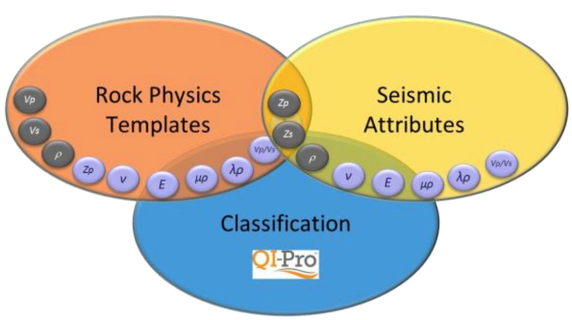

Figure 1: Integrated QI elements

Method

Templating

Geological templates represent the expression of geological properties of interest relative to elastic rock properties derived either from well log data or theoretical rock types synthesized through modeling (mineral proportions, fluids and porosity type and magnitude). Figure 2 shows a template illustrating the relationship between the elastic properties Vp:Vs ratio (y-axis) and P-impedance (x-axis) and the geological formation (colour). The plot clearly shows a pattern indicating certain ranges of elastic properties that can be associated with several distinct geological units (others are overlapping in this domain).

In an enhancement to a typical comprehensive QI workflow, several templates are investigated and constructed to represent all geological properties of interest. This allows for the contribution of information from multiple elastic properties employed where they are most useful in characterizing specific geological properties. Figure 3 shows a series of crossplot templates, each able to characterize, in increasing detail, a selected portion of the data segregated by the previous crossplot.

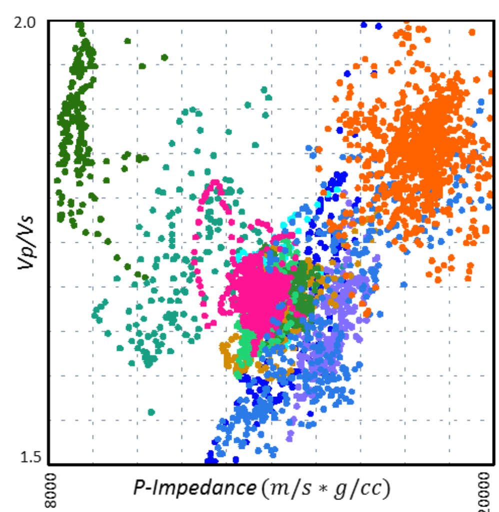

Figure 2: Geological template: Crossplot of Vp:Vs vs P-impedance with points coloured by geological formation.

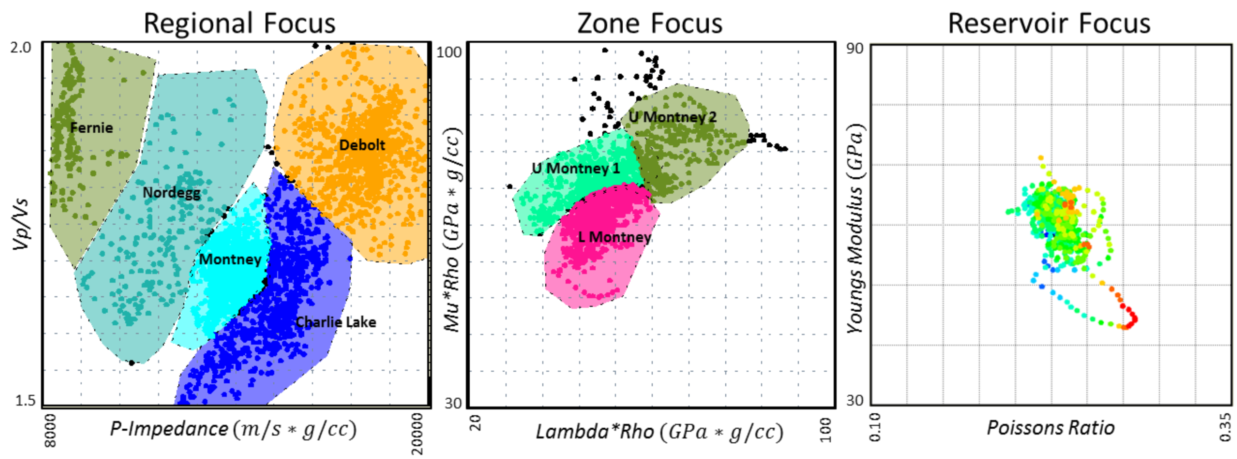

Figure 3: Series of templates with increasing reservoir detail. Regional scale (left), zone of interest scale (center) and reservoir scale with the points coloured by porosity (right).

Attribute Estimation

The templating process results in the identification of a set of elastic properties that is useful, either alone or in combination, for representing geological properties of interest. These elastic properties can all be derived from attributes of pre-stack seismic data (Goodway et al., 1997). The detailed geophysical workflow required for this purpose is complex. There are multiple steps with multiple unknowns, each requiring assumptions and educated judgment of intermediate results, all surrounded by varying degrees of uncertainty. The data conditioning and parameter choices at any particular point in the workflow most certainly affect every subsequent step. Indeed, the cumulative effect of these choices could make a significant difference to the ultimate accuracy of the derived elastic properties. Ideally, some process could be devised that would steer the parameter choices to the value that leads to the most accurate geological prediction.

The proposed workflow compares multiple realizations of final outputs that have been derived using a unique set of parameters for each analysis. These are interactively visualized in software designed to give the user 'slider-bar' control over parameter ranges. Thus, both analytical and interpretive assessments at intermediate points in the workflow allow for sensitivity investigation and 'parameter tuning' to ensure the best quality results. Figure 4 shows an example of two S-Impedance profiles created by varying a single parameter in the previous AVO step. Subtle differences may not seem significant, but if slight improvements are possible at each step, material gains in accuracy and resolution are inevitable in the final results.

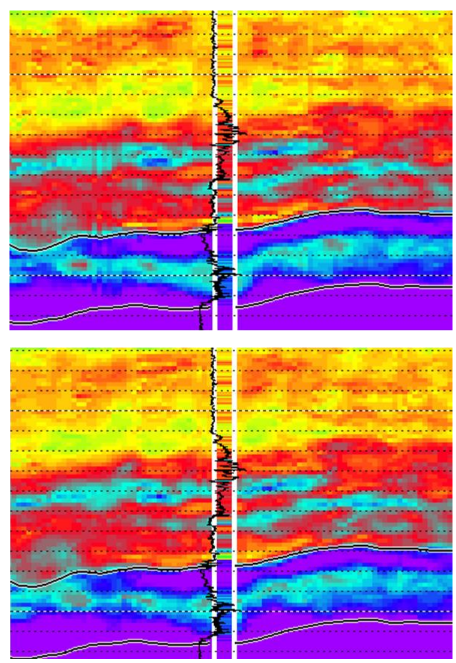

Figure 4: Comparison between S-impedance profiles (top and bottom) with only a single AVO parameter difference. S-impedance log displayed in colour with gamma-ray curve overlain. Aside from visually assessing the quality of the match at the well, other detailed features of interest can be compared between different parameter selections.

Towards Interactive QI Workflows

Classification

This element of the QI workflow uses the appropriately selected templates to assign geological properties to every sample in the seismic volume based on the associated elastic properties derived from seismic data. Since the templates were designed using elastic properties computed from log data, but applied to elastic properties derived from seismic data, a literal substitution is not always possible. It may be apparent visually that certain clusters in the seismic data do relate to equivalent clusters in the well data, but are not in alignment. In many QI examples, classification is a mathematical process, directly applying the log-data-derived template to the seismic data. In the hypothetical situation just described, this direct transformation would result in an incorrect characterization and a potential missed opportunity for the seismic data to be utilized effectively.

To overcome this kind of problem, compensation needs to be made for the misalignment of the two data types. QI-Pro, a proprietary application, has been developed to provide an interpretation environment that allows for interactive classification of the seismic data guided by the templates, but not restricted by them. Thus, the classification can be tailored to the best features of the seismic data, ultimately enhancing the validity of the classes defined in the seismic volume. Figure 5 shows how this type of creative classification honors the template, but is adjusted to fit the seismic clusters, resulting in a more meaningful geological characterization.

In the ideal interactive QI workflow, seismic attribute data plotted on crossplots would respond to the 'slider bar' adjustments in parameters regardless of which particular stage in the QI process the parameter belonged. In this way, sensitivity of the final geological prediction to individual parameter choices at any point in the workflow could be assessed and accommodated. Figure 6 shows a template overlain with seismic attributes created with different sets of QI parameters, illustrating this concept. Figure 7 highlights the cumulative effects in the classified volume resulting from the changes in seismic attributes due to the parameter variation.

Conclusions

A workflow has been described to link QI processes and allow greater interpretive control over the final results than a simple linear procedure. By interactively tuning the QI process in the ways illustrated in the examples, we are able to bring out the best of the seismic data; we achieve the most accurate attributes possible while at the same time optimizing the accuracy of the geological prediction and determining the parameters that have the most effect on the outcomes.

This workflow provides a solution tailored to seismic resolution and to extracting the most value from any dataset; it allows for the optimum integration between geology and seismic data without losing anything in translation, all within a collaborative integration environment.

In order to build an interactive process such as this, large data handling and processing capabilities would need to be employed which have not yet been fully implemented to create the examples shown. Customized software is in development and changes are definitely on the horizon.

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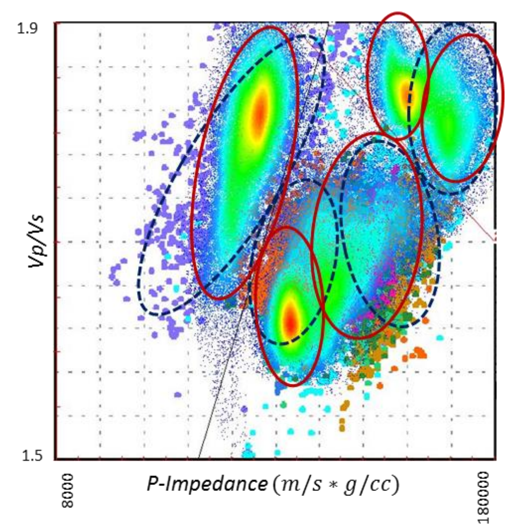

Figure 5: A QI classification view showing geological classification outlines (dashed black ellipses) based on the well log template (large points coloured by formation), and the revised classification outlines (red ellipses) adjusted to fit the actual seismic attribute clusters (small points coloured by cluster density). In the top right corner of the plot, the seismic clustering implies that two clusters would best characterize the data rather than the single one derived from the well data.

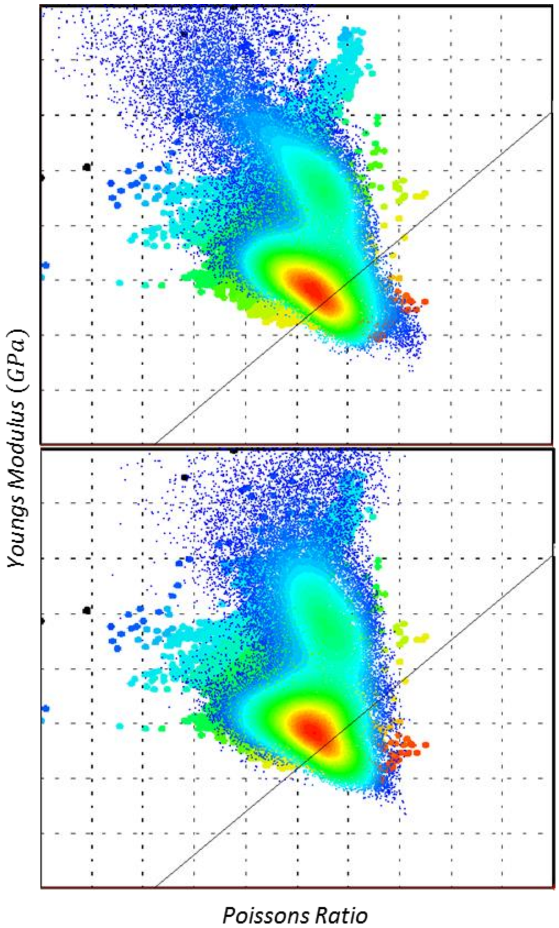

Figure 6: Comparison between classification views (top and bottom) showing identical templates overlain by seismic attributes derived with different QI parameters. Seismic attribute points are coloured by cluster density.

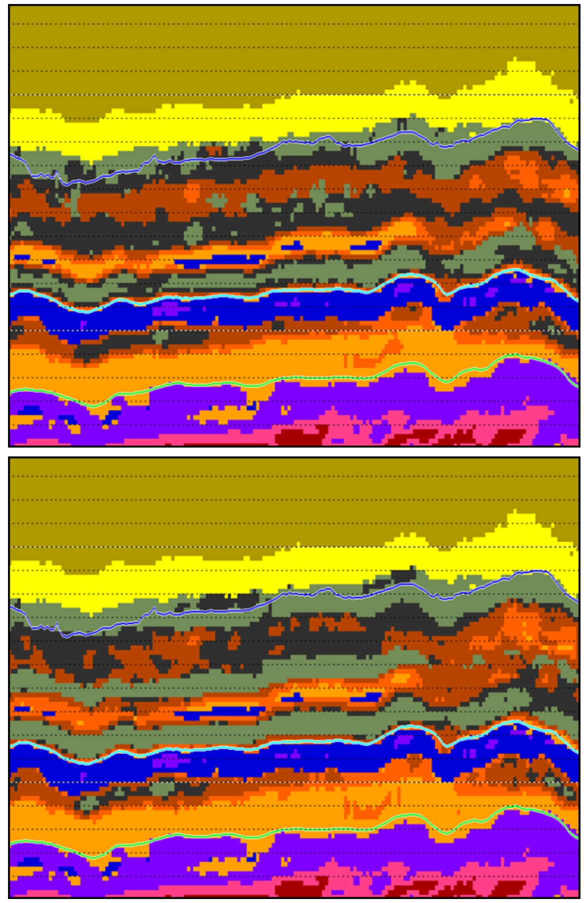

Figure 7: Two equally likely geological property classifications based on two different reasonable sets of QI parameters. Comparison between the final outcomes provides an estimate of uncertainty and sensitivity.

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