

Comparing Inversion Interpretation Templates

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Summary

Seismic inversion is a powerful technique for mapping hydrocarbon bearing reservoirs and especially so when utilized with the appropriate interpretation template. With the optimal template, calibrated to well data, inversions can transform elastic properties to estimates of mineralogy, porosity, fluid saturation or facies. There are different types of templates available for a quantitative interpreter ranging from rock physics derived templates (Odegaard and Avseth, 2003) to facies defined polygons displayed in elastic property space (Coulon et al, 2006, Doyen, 2007). In the following, four different templates are discussed outlining the benefits of each.

Method

This study compares four different templates that can be applied to prestack inversion volumes, each calibrated to well logs and petrophysical estimates of the mineralogy (Quartz, Clay, Calcite and porosity). These are applied to Lambda-Rho ($\lambda\rho$) & Mu-Rho ($\mu\rho$), or LMR, attribute volumes to identify and characterize hydrocarbon reservoirs or facies.

The first template follows the work of Odegaard and Avseth (2003) who introduced the concept of rock physics templates (RPT) which uses ever evolving, fit for purpose analytical expressions to express the relationship between elastic properties and reservoir properties. The input parameters to such expression include mineralogy, porosity (amount and shape), fluid (water, hydrocarbon or a combination) and fabric (in the form of anisotropy such as VTI or HTI). Several rock physics models exist and determining which is the most appropriate requires geologic context and familiarity with physics and assumptions for each model. When used appropriately, in conjunction with dipole sonic data and core calibrated petrophysical estimates of reservoir properties, it can provide an accurate and useful interpretation template.

The second template consists of classifying a specific reservoir facies using a set of petrophysical cutoffs (GR < 75 API and porosity > 25%, for example) and describing the elastic property space it occupies through a probability density function (pdf). A Kernel Density Estimate (KDE) is used to estimate the pdf which identifies the probability of encountering this facies in LMR space. In this way, the entire elastic property space will have assigned a probability of encountering a given facies. This method is often referred to as Bayesian Classification and any number of facies can be described through these pdfs. A seismic volume is generated to represent the probability of encountering a specific facies and its likelihood of occurrence.

A third proposed methodology takes the inverse view of Bayesian Classification, instead calculating the average reservoir property (volume of clay, volume of quartz, or porosity, etc.) within a binned area of the elastic property space. If any given bin contains data, not only can the average be calculated, but also the standard deviation, which quantifies the amount of non-uniqueness in the interpretation from elastic property to reservoir property. The standard deviation will communicate the lithologic variability for given elastic properties. Any number of reservoir properties can be calculated and can be applied to the LMR attribute volume.

The fourth proposed template attempts to assess the probability of encountering thin beds, or subseismic resolution intervals, with bandlimited seismic data. The continuous wavelet transform (CWT) is used to create intervals based on the gamma-ray log, which are compared to the filtered seismic elastic property response. The comparison is used to assess the probability of encountering facies of a given thickness and the limitations of seismic resolution. The template aims to answer questions such as “within a seismic wavelet, what is the probability of finding reservoir less than 25 feet thick given this combination of elastic properties?”.

Observations

Figure 1 below shows examples of the four templates. Figure 1A is an example of a rock physics template for volume of quartz with polygons showing 10% increments. The low LR and high MR values are coincident with low Vp/Vs and Poisson’s ratio values, commonly used to identify sand intervals. Conversely, high LR and low MR are high Vp/Vs and Poisson’s ratio values associated with clay rich intervals. The advantage of an RPT is when designed on well data, it will predict where unencountered reservoirs would appear. Calibrating to reservoir of 15% porosity, the template provides elastic property estimates for 10% or 20% porosity intervals.

Figure 1B shows the Bayesian Classification method, showing the two-dimensional probability density function in LMR space of encountering a quartz rich facies. Of note it also populates an area of relatively low Vp/Vs (low LR, high MR). The template provides a quantifiable probability of encountering the defined facies, but it is biased by the input data and the criteria defining the facies. It is the simplest template to understand and it creates a seismic volume for a defined facies from inversion volumes.

Figure 1C shows an example of the mean binned template of the mineralogy built on well log data for volume of quartz. This template provides a higher resolution estimate of the most likely reservoir property (volume of quartz, in this example). The standard deviation template also provides an estimate of interpretation ambiguity – a quantified estimate of petro-elastic nonuniqueness. This template also is biased by the well data, as it will not project probabilities which have not been recorded by a well. However, this template will be the most accurate in the elastic property to reservoir property transformation.

Figure 1D shows the probability variation as a function of thickness. The example shown highlights the probability of finding reservoir intervals less than 25 feet thick. Note that the low probability of finding such intervals mimics the rock physics trends (100C) with high Vp/Vs . Conversely, high probability of finding 25-foot intervals increases with decreasing Vp/Vs and approaching a quartz rich rock physics trend (100Q). The advantage of this method, beyond a Monte Carlo simulation of many stacking patterns, is the geologic depositional information embedded into the well information. Like the three previous templates, it is highly dependent on well data available.

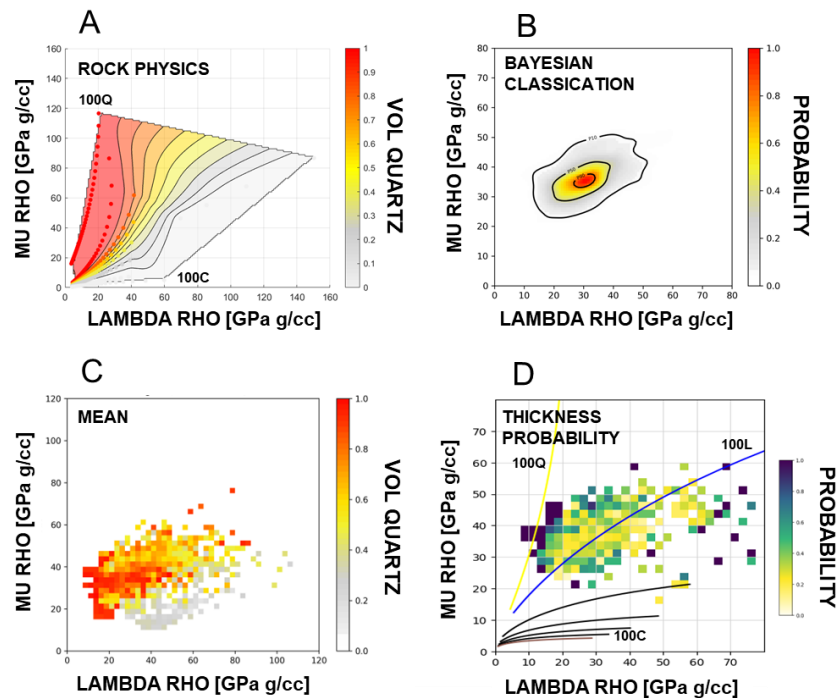


Figure 1. Seismic Inversion Templates Proposed.

Conclusions

Four templates are described as potential tools to interpret prestack inversion volumes. These templates can be applied to LMR seismic volumes to enable better mapping and characterization of hydrocarbon reservoirs. They give better insight into the facies trends and distributions given seismic resolution constraints under a given set of elastic properties.

The workflow associated with the application of these templates characterizes the distribution of the petrophysical parameters, such as zones with high volume of quartz or clay, or facies defined by different constraints of thickness or petrophysics content. Figure 2 presents the results of applying the volume of quartz mean template to an LMR seismic volume. In the visualization, red indicates high volume of quartz (100%), while white represents low values (0%), providing a clearer understanding of the volume of quartz distribution. These results are important to help geophysicists in exploration and development scenarios.

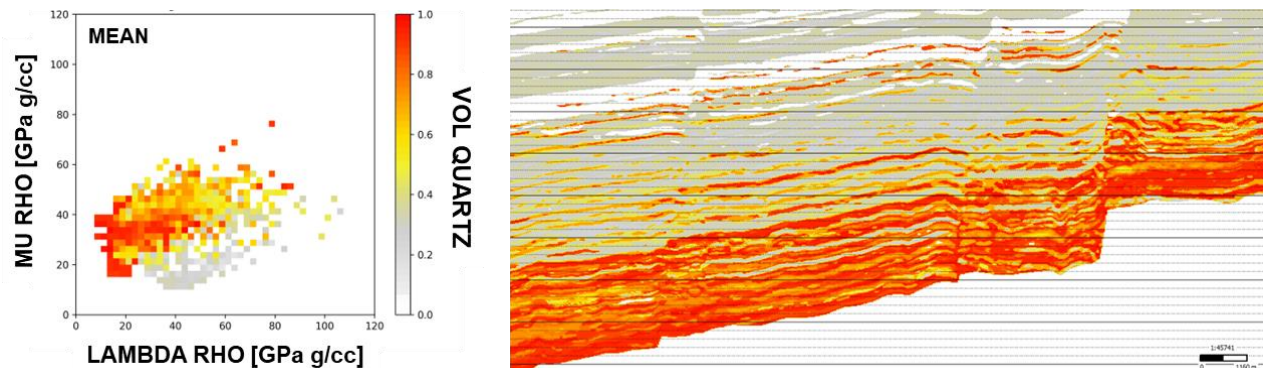


Figure 2. Volume of Quartz mean template applied to LMR volumes.

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