AVOImpedance: A New Attribute for Lithology and Fluid Discrimination

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Summary
AVOImpedance is a data adaptive attribute based on a weighted combination of AI (acoustic impedance) and EI (elastic impedance). Using a well dataset from the Central North Sea, the AVOImpedance attribute is shown to be comparable (in terms of its predicting power) to other attributes based on projections of AI and GI and MR (mr) and L/M (l/m). The simplicity of the AVOI attribute and the direct relevance to the outputs of near and far stack inversions is compelling.

Introduction
Porosity and fluid discrimination from seismic using elastic inversion techniques is currently an area of considerable interest for oil and gas exploration. Since the formulation of elastic impedance (Connolly 1999) many workers have been evaluating the possibilities of combining the benefits of inversion (i.e. calibration) with the exploitation of AVO phenomena that potentially provide enhanced discrimination of fluid and lithology.

The work of Goodway et al (1997) highlighted the benefits of rock property related attributes (l and m) in terms of both physical interpretation and discriminating power. Recently, Whitcombe and Fletcher (2001) formulated the attribute GI (effectively a projection of elastic impedance), and showed that projections on AIGI crossplots can be used to differentiate fluid or lithology. This paper presents another elastic attribute, termed AVOImpedance that can be considered alongside attributes such as LMR and AIGI.

Dataset
A dataset from a well in the Central North Sea is used as a means of comparing the different attributes. A 300m section of the well is used in which variable thickness brine bearing sands of Jurassic age were encountered. Rock physics analysis and fluid substitution to oil bearing was undertaken as well as depth to time conversion (2ms sampling). Various facies were then described from the time sampled data.

AVOImpedance Construction
If acoustic impedance is crossplotted against elastic impedance (at an angle of 25^0) it is evident that the trends of the various facies is similar (i.e. diagonally from bottom left to top right) but that there is an arrangement of shales at the top, then brine sands and finally oil sands progressing down the plot). AVOImpedance effectively normalizes the data to a trend on this plot (usually the brine sand trend is chosen as the normalising trend).

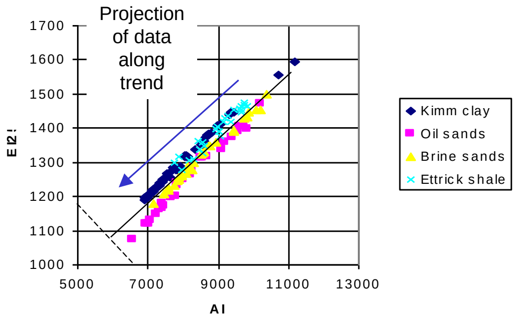

Figure 1. AI vs. EI Crossplot

The equation that performs this normalization is quite simply (AI*a+b)-EI where a is the slope of the trend and b is the regression intercept. Essentially this operation is a projection of the data points along a trend, a technique borrowed from weighted stacking of AVO attributes.

AVOImpedance Interpretation Template

It has been found that a crossplot of AVOImpedance vs AI provides a very useful template for the interpretation of porosity and fluid fill. A porosity and fluid fill framework is established using rock physics analysis of well data.

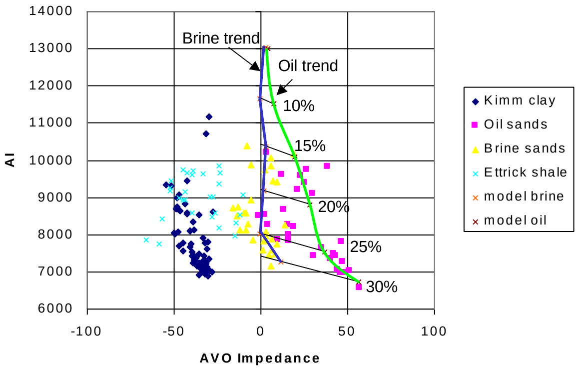

Figure 2. AVOImpedance interpretation template

In the example shown in Figure 2 the AVOImpedance attribute is normalized to the brine sand data of the rock model. On the crossplot. the shales (denoted by Kimm Clay and Ettrick shales points) plot to the left, with the brine sands in the center of the plot and oil sands to the right. It illustrates that of the two attributes plotted (AI and AVOI) AVOImpedance is the principal discriminator of fluid. Porosities plot successively down the crossplot showing the dependency of acoustic impedance on porosity. The plot also highlights the difficulties in differentiating fluid and lithology at low porosities (<15%) using elastic attributes.

Of course, if there is variation in the fundamental nature of the rock fabric of the sands then the framework becomes more complex. However, in many cases the sands in a localized area can be defined adequately by a simple porosity dependent rock physics model (e.g. Dvorkin et al 2002).

Comparison with LMR and AIGI

An LMR and an AIGI crossplot for the same data are shown in Figures 3 and 4. The framework trends for fluid and porosity are also shown, as is the projection trend that gives optimum discrimination of fluid (red arrow).

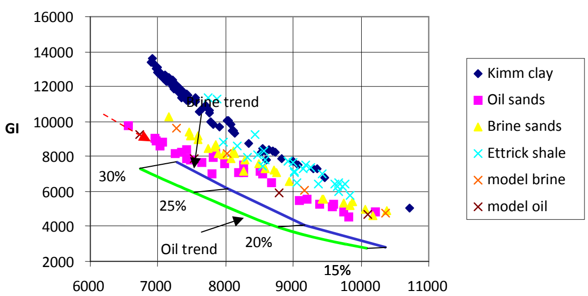

Figure 3. AIGI Crossplot

The AIGI and MR vs. L/M crossplots show that individually the attributes have limited discriminating power. However, as Whitcombe and Fletcher (2001) note the discriminating power is in the projection of the data.

Projections designed to discriminate fluid have been applied to both crossplots and projection attributes generated. To compare the attributes, histograms were created to which Gaussian fits were made for each of the facies.

The results (shown in Figure 5) show that AVOImpedance, the 'ortho-fluid' projection of AI and GI and the projection of MR and L/M have comparable discriminating power. In fact, fuzzy logic cross-validation techniques (i.e. facies prediction on the learning dataset) yields a 90% hit rate in the prediction of facies using each of the attributes.

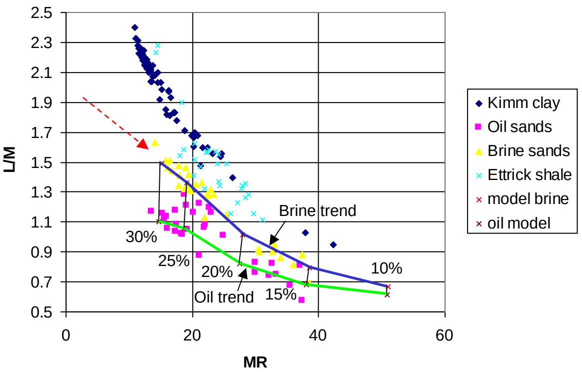

Figure 4. MR (mr) vs. L/M (l/m) Crossplot

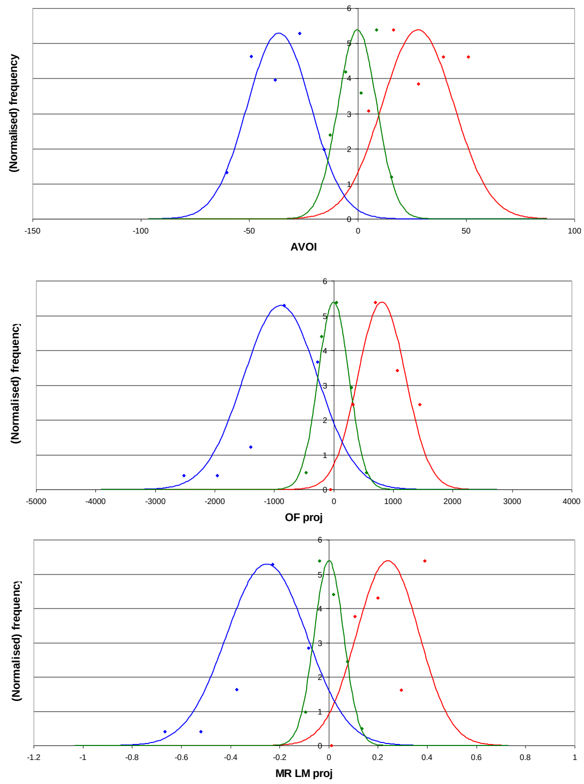

Figure 5. Gaussian distribution fits to the facies for AVOI, Ortho-fluid projection of AI and GI, and projection of MR and L/M

Discussion

The AVOImpedance attribute as described here would appear to be as good a discriminator as any other projection of elastic attributes. In a sense this is not surprising as they are all derivatives of the same elastic parameters. However, AVOImpedance is elegant in its simplicity of construction and has a direct relevance to the outputs of near and far angle stack inversions. When crossplotted against acoustic impedance and linked to a rock model framework it provides a useful template for the interpretation of elastic inversions.

The limits of practical application of the elastic attributes discussed here is an area yet to be fully explored (and documented in the literature). Clearly, projections of AVO related attributes are sensitive to noise and much depends on the pre-stack data quality as to the success of application. It follows that noise free comparisons of different attributes may be misleading. White (2000) illustrated that whilst there may be a theoretical justification of the LMR attributes in comparison to the AVO intercept and gradient, the LMR attributes are more sensitive to noise. In the presence of noise LMR related attributes gave the same misclassification rates as the AVO attributes. Limiting the adverse effects of noise in inversions is one of the challenges of applying this technology.

An evaluation of AVOI, AIGI and LMR related attributes generated from real seismic data is currently being undertaken.

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