Paper 2

AVO Depth Modelling

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Elimination strategies are useful call options in the decision process of prospect evaluation and well-site selection. Enhanced confidence levels might be derived from a risk appended interpretation. The method of amplitude variation with offset analysis (AVO) from otherwise conventionally derived data is one such approach. Given a CMP gather, the horizontal display of the variation of P-wave amplitudes provide a quick-look at any promising direct hydrocarbon indicators. The method is analytic and lends itself

to a detailed search for tell-tale oil-bearing rock properties during field development. A problem arises from application of AVO analysis with data collected over basins originating from widely different geological settings and geographical recording conditions. This study addresses the problem of expected model AVO signatures with depth and attempts to provide some guidelines as to the necessary conditions that need be weighted prior to opting for an AVO analysis in risk reduction in an unknown prospect.

The partition of energy for an oblique seismic wave incident on an interface of contrasting acoustic impedence is described by the Zeoppritz's equations. In the presence of a gas-sand horizon, reflection amplitudes increase with angles from the normal. The Zeoppritz's equations, its approximations and extensions are used to compute the angular dependence of reflection coefficients for P-waves impinging on an interface. Input parameters are trival, viz. P- and S-wave velocities and densities across an interface of interest. We distinguish next between isotropic reflections and that in an anisotropic medium. Practical approximations of Shuey's three-term formulation for the isotropic case are found in Aki and Richards, pg. 153 and in Smith and Gidlow, pg 994. For weakly anisotropic reflections, Thomsen's equation 10 provides a very useful extension for describing subsurface formations which are invariably anisotropic.

In our model studies, we examined, for illustrative purposes, both isotropic and anisotropic reflection amplitudes for ideal coal/country rock interfaces and a typical Malay Basin shale/sand velocity/density column with depth. Our model study suggests that the anisotropic nature of the overlying cap rock above pay sands need be reviewed. Conventional wisdom dictates that full attention be focused on the oil/gas bearing layer; our study suggests that anisotropic shales can mask or invert an otherwise AVO anomaly or lack of it. Anomalous AVO signatures appear to manifest only at shallow depths. Our model study suggests that the deepest zone where anomalous offset amplitudes fade away demarcates the depth where the clastic velocities cross-over.

We recommend, prior to sending out data for AVO processing, the following factors be considered:

1. **Good Data Quality**
   - trade-off is a function of assigned confidence levels that can be tolerated, and, need be weighted during interpretation.
2. **Availability of P-wave velocity, S-wave velocity and density information**
   - basin characteristics are critical, there are presently no known cheap way of extracting S-wave velocities. Assuming a value of Poisson's ratio, back-calculating the S-wave velocity is an unsound option. In the worst case situation, use the rule of closest well.
3. **Combined isotropic and anisotropic amplitude modelling**
   - the basis of enhanced AVO signatures, inherent masking due to layer anisotropy, and, factors affecting seismic amplitude, need be appreciated.