F016 Net pay estimation from seismic attributes

PAT CONNOLLY

BP Exploration & Production Technology, Chertsey Road, Sunbury-upon-Thames, Middlesex, TW16 7LN, U.K

Abstract

An improved method to estimate net pay from seismic attributes is presented. The outline of the process is:

- Tune seismic response to reservoir property using extended elastic impedance theory
- Apply coloured inversion and extract average amplitude and time thickness attributes
- Model tuning response of wavelet, detune and calibrate attributes

The algorithm is validated by testing on synthetic data derived from power-law based geological models.

Introduction

The derivation of net pay estimates from seismic attributes is a technology that has been around for quite a while (Brown *et al*, 1984). It has been applied much more widely in recent years and is now an important tool for many geoscientists. This has been driven largely by the need to reduce appraisal well count and development well failures particularly in expensive deep-water environments and has been facilitated by continuous improvements in seismic data quality. In many parts of the world seismic net pay estimates are routinely used for assessing in-place volumes, targeting wells and providing input for reservoir models.

Techniques for estimating net pay from seismic divide into two broad categories. Full inversion involves processing the seismic to absolute impedance, or multiple impedances, which can then be calibrated to the desired reservoir property (e.g. Vernik *el al*, 2002). It is usually assumed that wavelet effects have been removed. The second approach is based on the conditioning and calibration of attributes extracted from stratigraphic horizons usually from bandlimited data such that wavelet effects will not have been removed. This presentation is concerned with the latter technique.

Earlier attribute methods generally used trough and peak time separation and amplitude values extracted from zero phase data and assumed a simple two lithology "box-car" acoustic impedance profile (Hanna *et al*, 1991). These become increasingly unreliable as the gross interval increases beyond tuning requiring an assumption that the net pay is uniformly distributed across the interval and they become more difficult to apply for more complex impedance profiles (Neff, 1993). Interval attributes derived from band-limited impedance data were increasingly used in the 1990's (Hanna *et al*, 1996) however very little has been reported on the details or the accuracy of these approaches.

It is generally difficult to assess the accuracy of these methods. The ultimate test is of course in predicting the net pay of a well penetration. However, there are many sources of error in this; seismic noise, variable rock properties, wavelet non-stationarity, relative well to seismic positioning etc. making it very difficult to objectively assess the quality of the net pay algorithm itself. Such arguments also apply to inversion based approaches.

Method

A combination of recent developments has now allowed some progress to be made to overcome some of the limitations and drawbacks listed above. These are;

1. Extended elastic impedance technology to control the impedance profile
2. Coloured inversion (CI) to improve control of the wavelet spectrum
3. Power law geology models to provide more realistic synthetic datasets to assess accuracy and optimise algorithms

Extended elastic impedance theory (Whitcombe *at al*, 2002) provides a method to increase the correlation of the impedance profile with a reservoir property such as a gamma ray curve (Neves et al, 2004). This simplifies and improves the accuracy of the net pay inversion process and it also potentially allows selection between fluid and lithology data for net pay or net rock volume computation (Connolly *et al*, 2002).

The objective of coloured inversion (Lancaster & Whitcombe, 2000) is to shape the spectrum of the seismic data to have the same "colour" as the geology, within the seismic bandwidth, thereby ensuring that the wavelet spectrum is flat. The resultant trapezoidal wavelet spectrum optimises resolution and allows the tuning response to be more easily modelled.

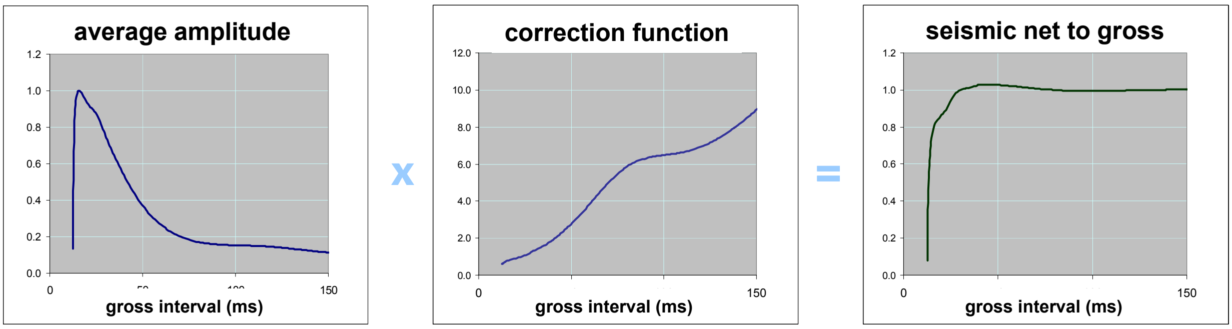

Figure 1. The algorithm detunes the average amplitude response of a 100% net to gross wedge (left) using a correction function (centre) modelled from the wavelet specification to estimate the seismic net to gross (the net divided by the seismic interval).

The net pay algorithm works by correcting average amplitude to *seismic* net-to-gross, which is the total net divided by the seismic gross interval (fig.1). The average amplitude and time thickness are extracted between zero crossings of colour inverted data (fig. 4). The correction function is calculated by dividing the seismic net-to-gross by the average amplitude, both modelled based on a 100% net-to-gross wedge. The correction is scaled using a combination of self-calibration (fig. 2) and well calibration and is then applied to attributes extracted from real CI data. The method assumes that net-to-gross is proportional to average amplitude between zero and the 100% tuning curve.

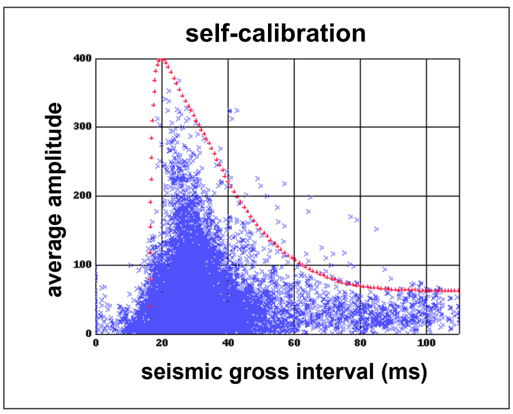

Figure 2. Self-calibration is performed by scaling the modelled tuning curve to fit the envelope of the average amplitude / gross interval crossplot. This assumes that points on the envelope above tuning have a net-to-gross of one.

Validation

The application of power law geological models provides more accurate synthetic datasets on which to test and optimise net pay estimation algorithms. The linear spectra of reflectivity series with positive gradient (Todoeschuck, 1990) and the corresponding linear negative gradient of impedance spectra (Stefani & De, 2001) have been recognised for a while. Both of these are consistent with a power law distribution of bed thicknesses which has also been noted many times (Malinverno, 1997) and all of these observations are consistent with the coloured inversion model.

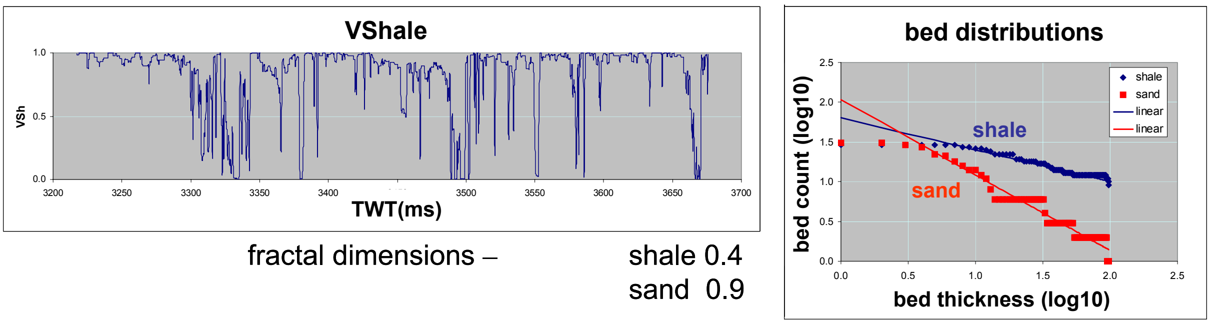

Figure 3. Analysis of a VShale curve to compute the sand and shale fractal dimensions

More detailed analysis of log data shows that in binary systems the two lithologies will generally have different fractal dimensions (fig. 3). This is not surprising given the different depositional mechanisms of, for example, pelagic shales and turbiditic sands, and the equally unsurprising implication that thick shales are usually more common than thick sands. Using a twin power law model and fractal dimensions measured from real log data it is simple to generate multiple synthetic logs with arbitrary gross interval and net to gross. From these, synthetic CI traces can be generated (fig. 4) and any net pay estimation technique tested.

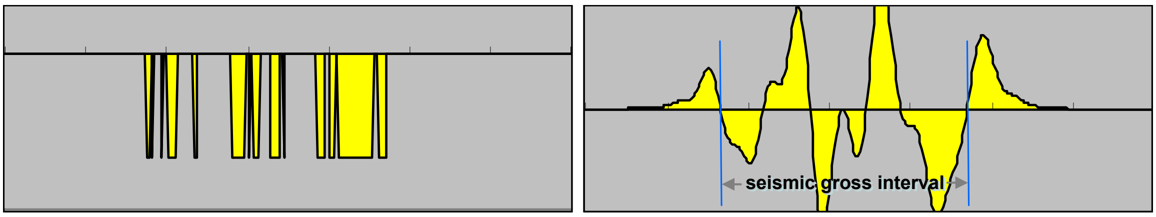

Figure 4. Example of an artificial impedance log and corresponding CI synthetic based on a twin fractal model. The method described here uses average amplitude extracted between zero crossings as shown on the right

A Monte Carlo type statistical analysis of the performance of any algorithm can be carried out using this approach. Sensitivities to noise, impedance variability, picking error, wavelet specification error etc. can all be investigated and compared with alternative algorithms. Such an analysis shows that average amplitude attribute performs better than alternatives such as average negative amplitude (fig. 5). Accuracy decreases as the gross interval increases but can give useful results over intervals containing multiple loops. The algorithm has also been tested on real datasets.

Summary

An improved method of net pay estimation is proposed based on detuning and calibrating average amplitude extracted from coloured inversion seismic data. The seismic must be first processed to ensure the corresponding impedance profile correlates with the desired reservoir property. The algorithm has been extensively tested on real and synthetic datasets based on a "twin fractal" earth model. Results suggest that this method is more accurate than other attribute based techniques and can give reliable results for a wide range of conditions.

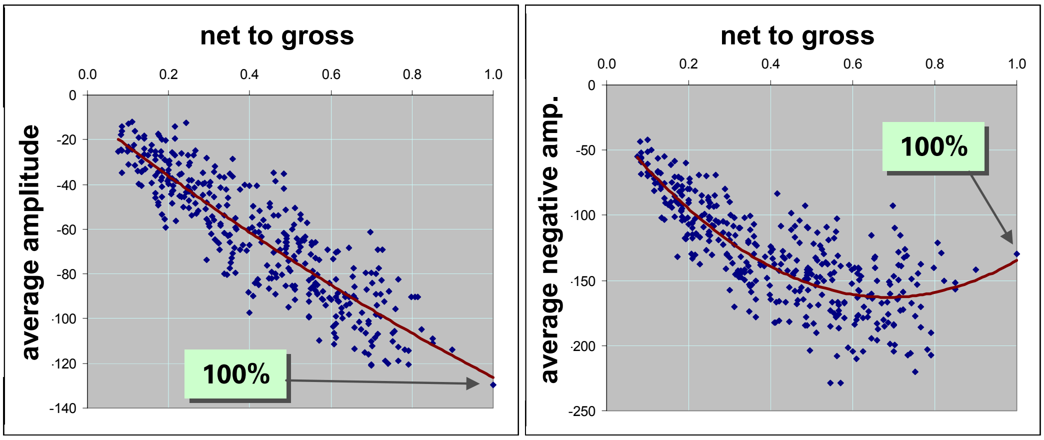

Figure 5. The relationship between two attributes, average amplitude and average negative amplitude, and net to gross for a fixed gross interval of 120ms. Each point represents the data from one realisation as shown in figure 4. This shows that whereas the average amplitude relationship remains linear with some scatter, average negative amplitude becomes non-unique. The 100% net to gross realisations are highlighted.

Acknowledgements

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