Amplitudes, Risk and all that Geophysical Malarkey

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'There was no geophysical malarkey involved in finding the Buzzard field' said Graham Dore in his PETEX presentation last December. He was right of course as we shall discuss later, but 'malarkey', meaning humbug, foolishness or nonsense, is an interesting, if not telling, choice of word. We take it to mean that in this instance there was some satisfaction in being spared the frustration and agony of incorporating geophysical information into the decision to drill that on previous occasions has proved confusing and even misleading. The loud cheer from the audience showed that he had made an almost visceral connection with the gathered brethren.

It points to a significant problem in the industry. The problem is that although it is recognised that seismic may in certain situations show effects that are related to the presence of hydrocarbon (and if they are recognised as such they may be used to lower the perceived risk), the practice of using seismic information as an input to drilling decisions is not uniformly good or pleasant for all. In our opinion there is a good deal of 'malarkey' going on, particularly when unrealistic claims are made for the significance of amplitude information. Guarding against such 'malarkey' is the subject of this talk.

Amplitude (DHI) interpretation

The term 'amplitudes' is used here in a general sense to cover all interpretation based on reflection seismic and its derivatives (so it includes full and partial stack interpretation, AVO analysis and (elastic) inversion) and attribute derivatives. In reflection seismic the acronym DHI (Direct Hydrocarbon Indicator) is generally used within the industry to denote an effect on reflection seismic data that can be attributed to the presence of hydrocarbon. DHI's commonly comprise (but are not limited to)

- Single or associations of reflection signatures (pre and post stack, bright spots dim spots, phase reversals) or impedance characteristics linked to the effects of hydrocarbon via rock physics models
- down dip limit/termination or structural conformance of amplitude
- flat spots

The criteria for the use of the term DHI for a recognised seismic effect are in fact quite stringent but are often applied recklessly or foolishly. A clear consistency has to be shown between the observed attributes and a rock physics model that illustrates a likely hydrocarbon interpretation. In addition consistency between the signature and other expected effects predicted by the model needs to be evaluated but very often are not. It is too easy to neglect other plausible causes for the effects as they may not lead to a viable prospect – the human mind appears to be constantly engaged in a creative search of corroborative evidence for its favoured hypothesis.

There are a whole host of reasons why we can get the interpretation wrong. These include:

- non-uniqueness of the effects – (ie other geological scenarios are responsible, eg high porosity or low gas saturation)
- seismic polarity is misinterpreted
- there are interpretive problems with seismic data acquisition and/or processing
- the model fails (ie the assumption that seismic can be approximated as the convolution of a wavelet with a reflection series determined from elastic/isotropic rock properties is wrong). Anisotropy plays a role in giving a 'false positive' indicator. Given the practical problems of parameterising anisotropic models we currently don't know enough about how often this actually happens.

Amplitudes in the Risking Context

Clearly if a verifiable DHI is present on a prospect then it is possible that the risk on the prospect may be considerably reduced relative to a standard geological risk either by utilising the DHI evidence within a probabilistic risking scheme or, possibly more dangerously, by using it to override the risking scheme. There are pitfalls, however, at almost every level of the process. One pitfall is that the DHI interpretation tends to be invoked too readily, for example when there has been no play specific corroboration through modelling or direct analogy of the effect(s) under question. What is more, in these situations the term DHI implies more certainty of hydrocarbon presence and a much narrower range of outcomes than is warranted (Citron and Rose 2001). Loose thinking combined with big promises can be a fatal combination!. Equally fatal is the confidence trick where we are blinded by the elegance of the positive model, how can it possibly fail?

There is always a risk in DHI interpretation in exploration (as some of us know from bitter experience) and we must get away from the idea that if DHI's really worked there would be no need for risking. Many companies and individuals follow this 'silver bullet' idea and it is no surprise that the DHI approach moves rapidly in and out of fashion. It is better to think of the Casino analogy (Rose 1999), in which we hope to stack the odds in our favour over a certain period of time with a portfolio that is risked appropriately. We wont know necessarily which particular wells will come in but over the life of the portfolio we believe that an appropriate use of use of amplitude information will put us ahead. Companies that cannot afford another dry hole should hope for lady luck.

The relationship between DHI's and exploration risk is neatly illustrated by the classic example of the Yegua trend in the Gulf of Mexico. This is a mature gas play comprising shallow high porosity sands that give bright spots on stacked sections and increasing amplitude with offset on pre-stack gathers (shale/brine sand reflections generally show opposite polarity and decreasing amplitude with offset). 84 wells that were drilled on 'AVO anomalies' were documented in a study by Allen et al (1993). The commercial success rates improved dramatically, from around 5-10% to 50%, when AVO techniques were employed (using 2D seismic data). Clearly the DHI's and associated risks described above are specific to the Yegua play and it would be foolhardy to take these particular DHI's and expect them to work in a similar way in different types of plays for example West of Shetlands. However you could argue that on plays less mature than the Yegua the likely chance of success associated with DHI's must be considerably less than 50%.

In the North Sea, most of the oil fields have been found without the explorations being driven by amplitude information. There are numerous examples of interpreters spotting the critical seismic DHI but misinterpreting it. Later field studies bring to light the real interpretation. What is certain is that amplitude technologies are now adding considerable value in field development, owing to the high degree of calibration available. On the basis of bottom line benefit Time-Lapse Seismic techniques, underpinned by thorough rock physics, have become established practice in many of the larger oil and gas companies within the last 5-6 years.

Whilst the challenge is always there to use the lessons from the fields to drive the exploration models in partially explored basins, in these situations it is easy to convince ourselves that we know more than we actually do. Very often if a well is available there is a tendency to believe that it contains all that is necessary for calibration (including all likely variability). Our problem then is to ask ourselves 'what is the likelihood that the model will hold over the prospect area?'. In some cases significant changes can occur to invalidate close well control whilst in other situations a well 50km from the prospect may be entirely relevant.

Calibration is clearly the key to the application of DHI's in risk. Our models are only as good as the data on which they are based. In virgin basins where there is stratigraphic uncertainty and no calibration it may be completely unrealistic to try and apply DHI's in the risking process. In such areas conventional AVO analysis can give us an idea of the degree to which different responses are anomalous but it cant tell us how likely a particular seismic effect will be related to hydrocarbon rather than for example a high porosity brine sand (or any other as yet undefined lithology combination for that matter). At best (and if you are lucky enough to have a number of potential prospects) it can be used as a ranking tool.

Assigning risk to DHI's

Very often we don't have the statistics to support the risks applied to DHI's, usually because we are trying to apply the techniques in non-mature areas. And when it comes down to it, whichever way you assign a risk significance to DHI's it is highly subjective. Fundamentally it depends on the level of knowledge of the play and an understanding of the particular DHI characteristics of the target. With greater knowledge of the play the vagaries of the DHI signature (and its relationship to factors such as data quality) are likely to be more completely understood. Two companies may recognise the same seismic effects but place different significance on them simply because of differences in the understanding of the play. In the Yegua example noted above 10 out of 84 prospects had a questionable DHI (Allen et al 1993).

Many companies have attempted to formulate a way of incorporating seemingly meaningful geophysical observations into risking systems to aid the decision process. One approach is to use the seismic to give a chance of success factor which can then be compared to a traditional risking approach. A generic (and non-specialist) approach might be to use the risk matrix idea of Citron and Rose (2001) but in which the axes are related to the knowledge of the play (in terms of the seismic responses of lithology and fluid, calibration if you like) and the confidence in the recognition of the DHI(s). A questionnaire for each component would help arrive at the appropriate position on the matrix. Chance of success values will be specific to a particular play for a given range of analytical techniques.

As well as evaluating the value of a DHI in the possible lowering of risk we also need to address the significance of a lack of a DHI in a situation where one would be expected (ie where we might use the lack of a DHI to increase the risk). Interestingly, examples of 'false negatives' (ie discoveries where there is no DHI but with the given data quality one would be expected) are thin on the ground.

Figure 1. An example of a chance of success matrix based on DHI's. Note that each matrix is specific to a particular target in a specific play.

			Knowledge of Play
N/A	20%	50%	Good
N/A	10%	25%	
N/A	N/A	12%	Poor
Low		High	

Confidence in DHI

Buzzard and the idea of play development

So, what of Buzzard Field?. It cannot be denied that the decision to drill was seemingly based purely on a geological model, mass flow sands dumped in a graben and pinching out up dip to the west. A risky model in anybody's book, and many companies (most of which no longer exist) decided to give the area a wide berth. The seismic gives only general information on stratigraphy as it is contaminated with multiples of different varieties. Subsequent analysis of the pre-stack seismic, coupled with a rock physics model based on the dry well down dip, perhaps surprisingly does show attributes that appear to be related to the presence of hydrocarbon, possibly even indicating a down dip limit for 2 prominent sand prone intervals.

Whether or not the attributes described from Buzzard are convincing enough to have been used reliably in a predictive manner prior to the Buzzard discovery well or whether they provide a way of predicting further oil pools in the same play is a question that many are now trying to answer. Certainly given these results and the experiences from other North Sea fields, there is a huge incentive to unravel the signature of the oil filled sands and there is likely to be a role for calibrated amplitudes in extracting even greater value from the Buzzard field development.

Ways forward with amplitude interpretation

Probably the most important element in guarding against geophysical malarkey is a cross-discipline understanding of what amplitudes can and can't do for us. Non-specialists (i.e. most geophysicists, geologists and increasingly managers and engineers) need to be able to ask the right questions to put the seismic information into context. This would help communication and ensure that the geophysical interpretation is done in the most rigorous way possible. This technology transfer can only happen if:

1. There is a greater general understanding and access to seismic analysis techniques linked to calibration methods, including rock physics, and their limitations
2. There is access to a knowledge database of previous examples, the good, the bad and the downright ugly.

Established training courses can go some way to achieving this, but fundamentally there has to be an active mind-set within each company to synthesise past experiences into 'learnings' that are made available to those who need them. The value of the knowledge data base should not be underestimated and it is never too late to begin the process of developing it. What is not enough is for the geophysical priesthood to simply write guidelines and prescribe expert - authorised workflows. They do not ensure communication and in the worst cases can actually stop people thinking!

References

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