

## Seismic Attenuation and Hybrid Attributes to reduce exploration risk – North Sea Case Study

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### Summary

Seismic detection of hydrocarbons is fraught with ambiguity. Not only are simple methods such as seismic amplitude mapping often uncertain, but also anomaly interpretation, such as AVO analysis, often prove ambiguous: Are always the seismic amplitude and AVO signatures responding to changing fluid type or perhaps they can be affected merely by lithological heterogeneity? In this paper, we examine two wells drilled on amplitude, both were associated with AVO anomalies, but the wells had mixed results. In one case gas was found, however, in another, despite the prominent AVO anomaly, no reservoir sand was found. This mixed result puts in question the meaning and value of AVO and whether and how AVO can be used in direct hydrocarbon detection. In the case study under examination, both elastic and inelastic analysis (attenuation) of the data has been conducted. Based on the modeling results, a strategy for using hybrid attributes that include both the elastic and inelastic seismic attributes was devised to reduce the exploration risk associated with drilling other AVO anomalies present in the prospect area.

### Introduction

The Jurassic Brent and Triassic Statfjord reservoirs have provided most of the hydrocarbons produced to date in the Gullfaks Field. However, recently attention has been paid to the Cretaceous section overlying the flanks of the field. Several wells have tested hydrocarbons in what is thought to be deep-water deposits occurring in the Cretaceous section. These have often been associated with both amplitude and AVO anomalies.

Well 34/10-B42B was drilled in 2003 as an extension to a Brent production well to test an AVO anomaly within the Cretaceous section (Figure 2). The well encountered a significant gas leg, proving up the play concept. However, the well lost pressure rapidly suggesting limited reservoir extent. Similarly, well 34/10-A48B was drilled, also as an extension to a Brent producer into another AVO anomaly present in the Cretaceous section. However, this well did not only not find gas, it did not even find reservoir quality sand, despite having an AVO anomaly akin to the B42B well. Further prospects had been identified in the Cretaceous section in the area, all associated with seismic amplitude and AVO anomalies, however, based on the results of the A48B well, these were deemed to involve considerable risk.

Other studies have shown that AVO signatures alone may be inconclusive, but AVO run in conjunction with other attributes, such as inelastic attributes may provide an unambiguous solution (Ware et. al., 1999).

Statoil in cooperation with Rock Solid Images undertook a seismic reservoir detection and characterization project aimed at reducing the risk associated with other AVO anomalies located within the area of interest. The project involved elastic and inelastic modeling and calculation of a hybrid – a combination attribute – attribute based on the results of the modeling. This new hybrid attribute is believed, if used, to reduce the risk of AVO interpretation in the area under examination.

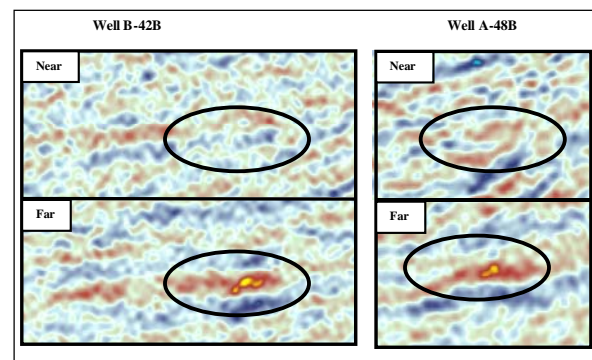


Figure 2. Seismic Sections through the two wells with AVO anomalies. Despite similar anomalies, B42B contained gas, whereas A48B had no reservoir.

### Hypotheses

The first question to be investigated in this case study, is why seismic data at the B42B location exhibits an AVO anomaly when there is no gas present (moreover, not even a sand reservoir is present) in the well. Several hypotheses were put forth to explain this so-called “false” AVO: 1.) Fizz water (small amounts of free gas that affect the elastic properties of rock in the same fashion as large amounts do), 2.) Spatial variations in shale mineralogy, e.g., quartz-rich shale that may have Poisson’s ratio small enough to produce an AVO anomaly, 3.) Anisotropy, and 4.) Seismic artifacts, including multiples.

Another question arising is whether or not the anomaly seen associated with the gas in A48B is indeed a function of the gas presence.

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This study did not involve investigating artifacts of the seismic data and multiples, though these hypotheses cannot be completely ruled out. Rather, in this project we focused on the rock physics related hypotheses. The hypothesis concerning fizz water (low saturation gas) was quickly ruled out, as there were no indications of gas on the mudlog while drilling through the target zone. Even low gas saturations tend to exhibit higher levels of gas on the mudlog. These were not observed in this well. Anisotropy was also considered unlikely (although, in principle, it could be a distinctive possibility) simply because the magnitude of anisotropy needed to create the observed AVO anomalies was determined to be too high for the region. Furthermore, no systematic pattern of AVO was observed that could be attributed to anisotropy. The remaining hypothesis left is related to shale mineralogy. The essence of this hypothesis is that the Poisson's ratio of pure quartz is about 0.08 which is very small if compared with that of clay (usually larger than 0.35). Therefore, an increase in the quartz content in the shale could give rise to an AVO anomaly. To determine the magnitude of an AVO anomaly due to mineralogical changes, compared to an anomaly due to fluid changes, Rock Solid Images employed the Rock Physics Diagnostics process to model the changes.

### Rock Physics Diagnostics – Elastic Modeling

Rock Physics Diagnostics (RPD) is the process of determining how lithologic parameters, such as mineralogy, fluid content, texture, and porosity, may affect the seismic-related properties, such as velocity and density. RPD was applied to the Gullfaks Cretaceous wells 1.) to confirm that indeed a gas-bearing sand gives rise to an AVO anomaly (as seen in B42B) and 2.) to test the hypothesis that a mineralogical change can give rise to a weaker yet discernable AVO anomaly, such as the one seen in A48B. Two models were generated; one investigating the effects of fluid content (gas versus water) in a well with a developed sand reservoir, and the other investigating the effects of quartz fraction in a shaly section on seismic reflection. The models indicate, as expected, that a gas sand has low impedance and low Poisson's Ratio resulting in a strong AVO anomaly indeed. Also the mineralogical change, i.e., a transition from a clay-rich shale to a quartz-rich shale will result in an AVO anomaly, *albeit* not as strong as the anomaly associated with gas.

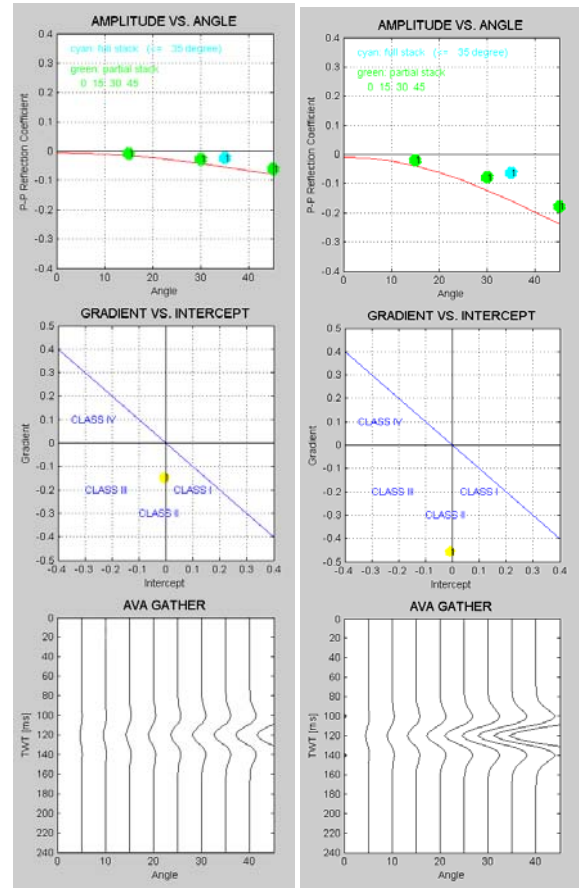


Figure 3a. (left) Elastic half-space model of quartz-rich shale Figure 3b. (right) Elastic half-space model of gas sand

### Rock Physics Diagnostics – Inelastic Modeling

To decisively discriminate gas sand from quartz-rich shale in the seismic attribute domain, we decided to employ an inelastic attribute linked to intrinsic attenuation. Our supposition was that a mineralogical change would not give rise to a seismic attenuation anomaly, whereas a gas sand would produce an attenuation anomaly. To verify this hypothesis, seismic attenuation was modeled. The modeling suggests that a gas sand gives rise to a strong attenuation anomaly, fizz gas to a weaker anomaly, and water-filled sand and a mineralogical change in shale produce no attenuation anomaly. Based on this modeling, it was postulated that seismic attenuation could be an effective attribute for exploring for the Cretaceous gas sands and discriminating gas sand from non-reservoir rock.

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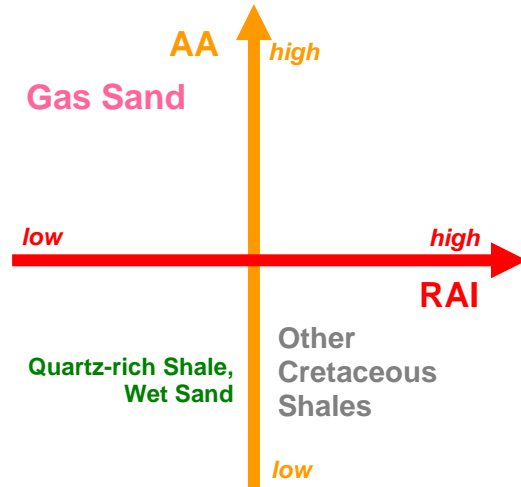
### Seismic Attributes

A strategy for extracting seismic attributes was developed based on the above-described rock physics modeling. It was concluded that a gas sand should exhibit low acoustic impedance and high absorption. These two attributes were calculated and combined to form a hybrid attribute called the RaiQ Fluid Indicator where Rai denotes “relative acoustic impedance” and “Q” stands for seismically detectable attenuation.

Relative Acoustic Impedance is calculated by integrating the real part of the complex trace. The obtained seismic attribute is centered at a zero mean and, because of the discrete frequency range of the seismic data, the attribute data are band limited. Thus, the resulting impedance values are not absolute but rather relative and as such would not match the impedance measured in the well. Instead, the relative acoustic impedance can be used to map differences in impedance within the layer of interest. The relative acoustic impedance can be qualitatively related to rock properties simply because gas sand has low impedance and, therefore, low impedance values in the time-window containing the Cretaceous prospects are likely to indicate high porosity, the presence of gas, or a combination of the above.

Seismic attenuation is calculated using a Gabor-Morlet-type spectral decomposition on the amplitude data to obtain a seismic background trend from which the local attribute values are subtracted. Where the frequency loss due to presence of gas drops below the elevated background trend, a high attribute value results, supporting attenuation because of gas presence. From the modeling we learned that low attenuation is associated with sub-commercial gas volumes while high attenuation may indicate commercial gas volumes.

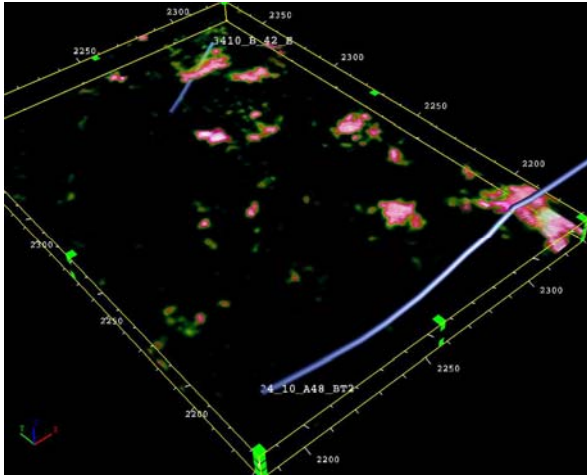
We can now combine the two seismic attributes to yield the hybrid attribute, RaiQ Fluid Indicator. The resultant hybrid attribute is a fluid indicator, in that high values should correspond to gas sand, lower values to fizz-gas or oil, and zero values should correspond to shale (clay rich or quartz rich) or water sand (Figure 4).



*Fig. 4 Post-stack seismic attribute cross-plot of relative acoustic impedance (RAI) versus anomalous absorption (AA) identifying a suite of lithologic positions some of which were encountered at tested AVO anomalies*  
*Verification and application*

The RaiQ fluid indicator was then compared to the fluid types encountered in the wells. In the A48B gas well, the seismic volume surrounding the well bore exhibits high RaiQ values, corresponding to the modeling. In the area surrounding 34/10 A 48 BT2, where no reservoir sand was found, the RaiQ attribute takes on a small positive value near zero in the Cretaceous section. This finding is compatible with the observation that there is no gas-charged reservoir in that area. Further prospects have been identified based on the AVO response. These were found to have high RaiQ values thus indicating a high probability of them containing commercial gas volumes (Fig. 5).

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*Fig. 5 Volume-rendered RaiQ attribute. Producing section in hot colors (Brent in A48B; Shetland in B42B well). Note that lower portion of A48B wellbore above BCU does not resonate in hot colors, suggesting no gas presence. Non-prospective (i.e., = anomaly-free) seismic volume has been rendered transparent.*

Based on the RaiQ attribute, the perceived risk was reduced on this prospect, and the prospect was put on the drill schedule. The final and decisive verification of the concept offered in this paper can only be given by the results of drilling wells at the locations estimated as low-risk prospects.

### Conclusions

Even sophisticated hydrocarbon indicators are prone to ambiguity, therefore multiple attributes must be used in order to reduce exploration risk. However, attributes must not be used without a thorough understanding of the rock physics behind the seismic signal. In this case, rock physics modeling suggested that a (gas) sand should exhibit low acoustic impedance, and high seismic attenuation. A hybrid attribute containing impedance and attenuation was therefore assembled to identify fluids: RaiQ Fluid Indicator. The RaiQ Fluid Indicator appears to reliably work in two existing wells (one gas bearing, and the other with no reservoir), and, as a result, using this attribute may help reduce the risk of drilling other potential prospects to a satisfactory level.

### References

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