Identification and geological validation of AVO-driven opportunities in infrastructure-led settings: examples from NW Europe

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Summary

Recently processed or reprocessed 3D data in infrastructure-rich settings in the North Sea and on the Atlantic Margin, has been subjected to relative extended elastic impedance (rEEI) inversion to screen for AVO anomalies and to identify and derisk remaining undrilled opportunities. Since the process uses only information present within the seismic data, comparison with the results of extensive drilling provides a true blind test of the effectiveness of the method. Results are presented from the North Sea and Atlantic Margin which demonstrate the effectiveness of the method and highlight some remaining undrilled opportunities.

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Introduction

As oil companies rebalance their portfolios in response to energy transition needs, infrastructure-led exploration (ILX) is expected to become increasingly important, as operators seek to maximise use of existing facilities in proven basins. Efficiently identifying low risk drilling opportunities demands extracting maximum useful information present withing existing and newly acquired seismic surveys. Part of that process is efficiently using AVO to identify and derisk opportunities in suitable plays. Rock property studies from wells typically serve as the starting point to assess whether or not lithology and fluid type may be detectable in seismic data. The second challenge is to assess whether the seismic data being used is up to the task of identifying fluid type directly. There are several ways in which this may be assessed. However, the ultimate test is to see whether lithology and fluid predictions from seismic inversions match the results of drilling, an approach which is normally feasible in data-rich, ILX settings. We present examples where this approach yields positive results and highlights opportunities that may be of interest for further investigation.

Methods

The rock physics model and relative elastic impedance (rEEI) inversion concept and method we test in this paper is summarised in Figure 1 and described fully in Went *et al.* (2023). It requires generation of intercept and gradient impedances and mathematical reweighting of the two attributes to produce rEEIχ27, a rotation of the seismic data optimised for discrimination of clastic lithology and fluid over most relevant depths of interest (typically 1000-3000m). The elegance of the method allows the inversion to be performed relatively quickly over large areas. Examples from two large 3D surveys are presented here. The first survey is from the Central North Sea and covers an area of 3000 sq. km. The second survey is from the Atlantic margin and covers an area of 2200 sq. km. Both surveys were reprocessed in the last 5 years.

Screening for AVO anomalies is a relatively straightforward process performed on a single volume, rEEIχ27. Anomalies that have been drilled can be evaluated to test whether lithology and fluid predicted by seismic, match the results in the wells. This can be done either through a detailed petrophysical evaluation and a synthetic tie or more simply through visual inspection of logs and time-depth matching. In the North Sea, the Eocene Tay Sandstone was the play being investigated and results are reported for that interval. In the Atlantic margin the entire post rift interval is susceptible to AVO and is subjected to investigation.

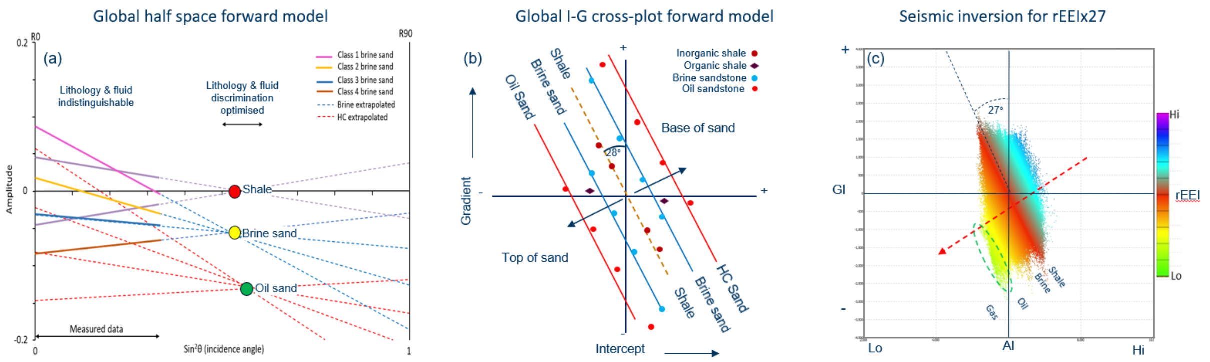

Figure 1. a) Half space forward models of intercept and gradient for globally typical siliciclastic lithologies which highlight that lithology and fluid discrimination is optimised at a projected incidence angle of 45° (θ); b) the same data plotted on an intercept-gradient plot shows the discrimination at a cross plot rotation angle (χ) of 27°; c) a relative seismic inversion for AI, GI and rEEI χ27 over a known oil discovery shows oil sands highlighted by low values of rEEI χ27 (in green) in the SW corner of the AI-GI cross plot (a and b after Went 2021, c after Went et al 2025).

Results

Results of the elastic inversion for the Eocene Tay sandstones in the greater Pilot area, have recently been documented and report a close match between the presence of AVO anomalies and wells containing heavy oil in good quality submarine channel-fan sandstones (Went *et al*. 2025). The Tay fairway continues further south to the greater Catcher area, the focus of this study, and we report the results of the elastic inversion performed over the fields in this area. In the Catcher fields, the Tay sandstones have been subject to remobilisation and injection into the overlying Horda mudstone where they are present as a series of sandstone dykes and sills. Accordingly, the geometry of the reservoir is considered challenging for seismic imaging and AVO preservation. On the other hand, the oil is considerably lighter than in the Pilot area.

A representative line through the Tay sandstone in the study area, showing a full stack section and the elastic inversion, is shown in Figure 2. Comparison of the results of the inversion over the whole of greater Catcher area with well penetrations, reveals a good match of rEEIχ27 anomalies to the presence of oil in sandstone in the wells. A careful extraction of intercept - gradient relationships for the discoveries at Carnaby-Burgman and Varadero further confirms this finding (Figure 3). Undrilled anomalies have also been identified during the investigative process. Two are shown in Figure 2, and one of them, undrilled anomaly A, is illustrated in cross plot format in Figure 3. The geology in the stack section, the AVO response and the scale of undrilled anomaly-A looks comparable to that of the proven, currently producing fields. The AVO anomalies in this location are of Class 3 or Class 2-3 type, and hence, the sands are commonly evident as soft kicks on the full stack, as well as illuminating on the rEEIχ27 maps and sections.

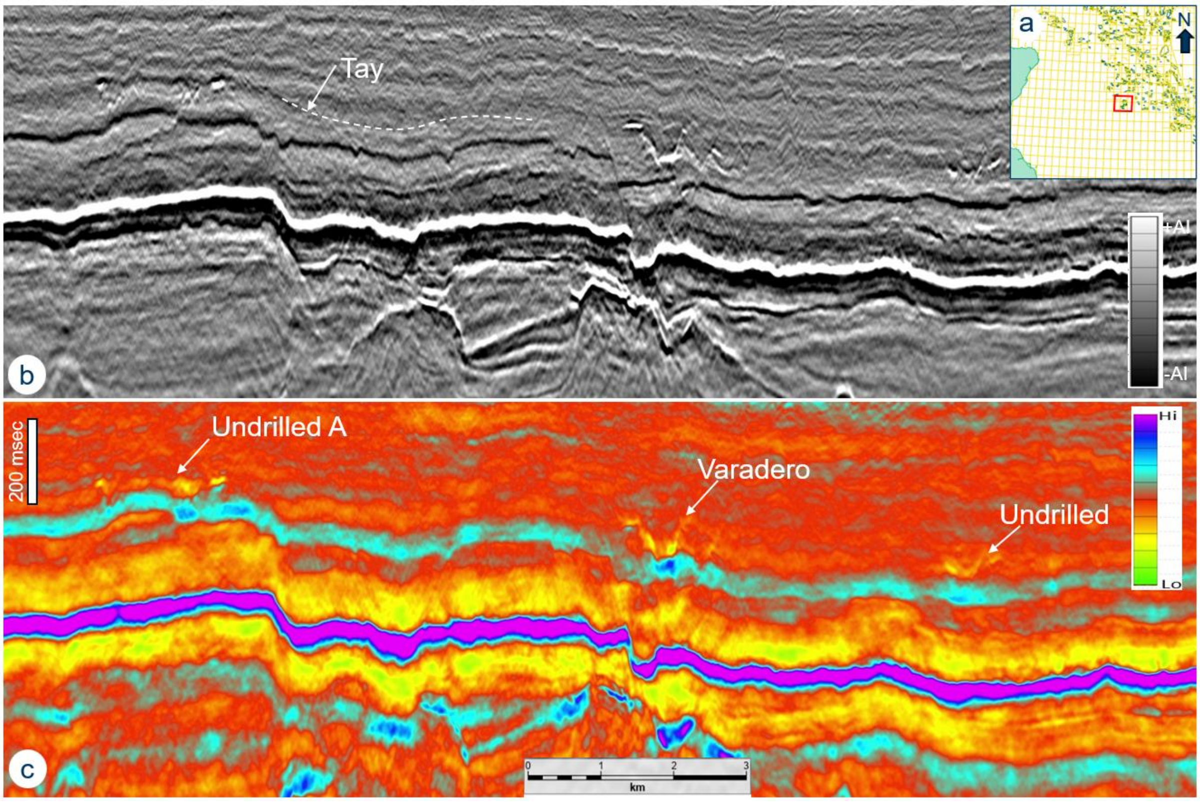

Figure 2. Arbitrary line through the target stratigraphy: a) location, b) stack section showing the location of Tay sandstone, c) elastic inversion highlighting anomalously low rEEIχ27 through irregular shaped injectite sand bodies in the Tay. The central anomaly corresponds with oil in the producing field Varadero. The anomalies to the west and east are of a comparable size but undrilled. The strong positive (white) stack reflector corresponds to top Chalk.

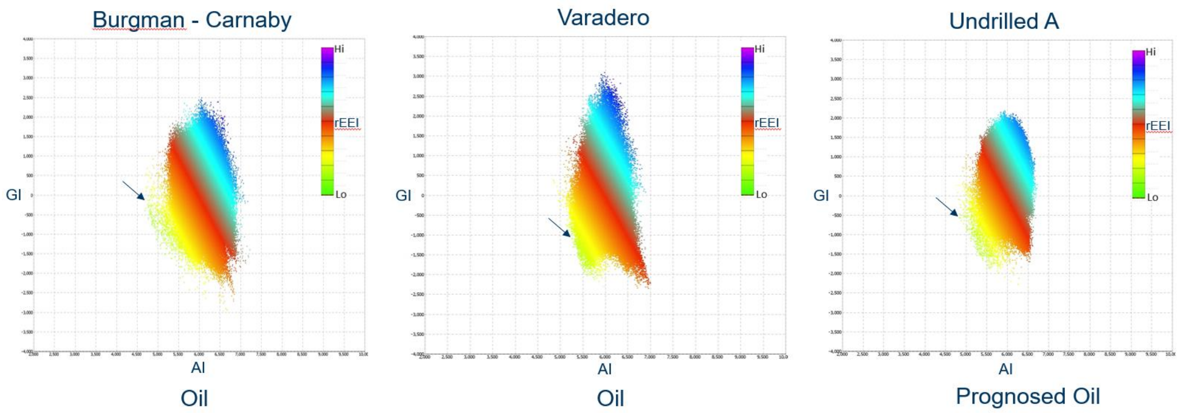

Figure 3. AI-GI cross plots colour coded by rEEIχ27 through exiting discoveries at Carnaby-Burgman, Varadero and through undrilled anomaly A. On the cross plots, the oil is indicated by the very low values of rEEI χ27 shown in green (arrowed).

The Vøring Basin is located on the eastern Atlantic margin, west of Norway. It is less mature than the North Sea but has been subject to some drilling, with several discoveries having already been made. An elastic inversion through TGS survey AM19 in the Vøring Basin was performed, to look for untested opportunities (Figure 4). The basin contains volcanic flows and sills which show very strong reflectivity and elastic impedance properties. However, once these are filtered out, the most prominent rEEIχ27 anomaly is present in the Cretaceous Springar Sandstone. This feature was drilled in faulted - up-dip pinch-out locations where approximately 50 m of gas filled sandstone of moderate reservoir quality was encountered in two wells (Finlayson *et al.* 2017). The discovery is termed Gro. The associated anomaly extends down dip for a considerable distance and covers some 900 sq. km, which translates to an estimated 30 TCF gas. Sedimentological reconstructions suggest the down dip locations may lie closer to the axis of the fan system, look less faulted and could conceivably be of better reservoir quality. In this case, the anomaly is proven by the wells, and the opportunity lies in re-appraising the play for a possible giant gas accumulation down dip of two wells drilled in up-dip locations.

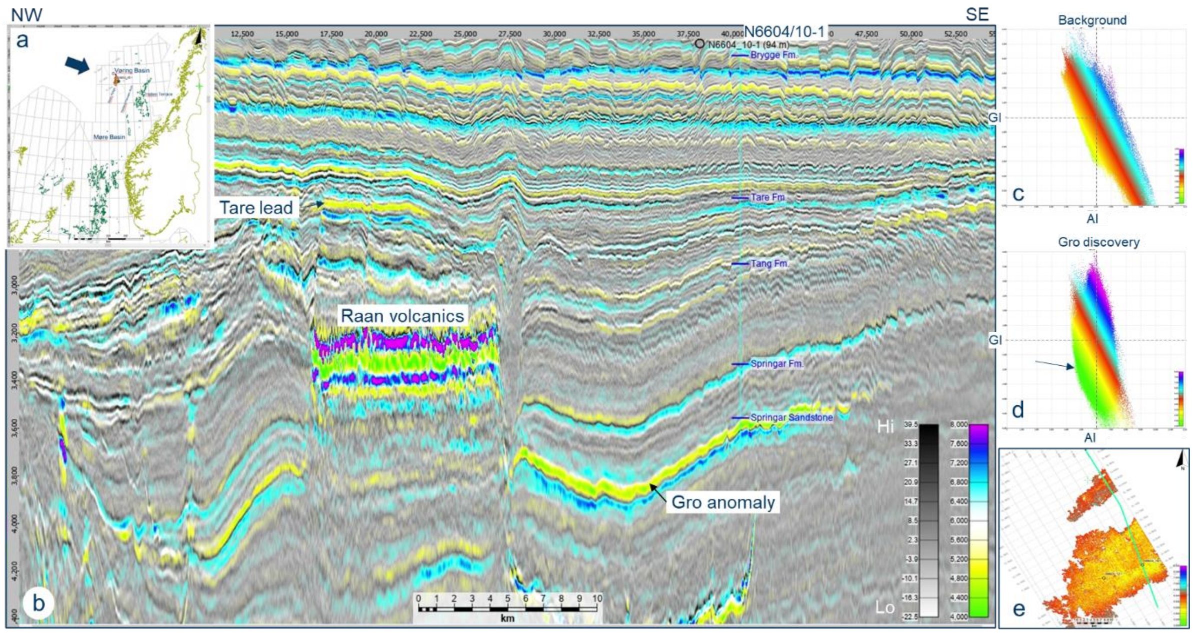

Figure 4. a) location of study area in the Vøring Basin, b) stack seismic section co-rendered with rEEIχ27 showing low values of rEEIχ27 over Gro in the Springar Sandstone, c and d) AI-GI cross plots from background and Gro discovery locations, colour coded by rEEIχ27, the green colour corresponding with the presence of gas bearing sandstone, e) map view of the anomaly extends to 900 sq. km.

Conclusions

Validation of AVO anomalies in infrastructure rich settings such as the Central North Sea and parts of the Atlantic margin, can be performed by comparing the results of relative elastic inversion with previous drilling. When the results of the elastic inversion, derived entirely from the seismic data, are validated by the results of previous drilling (both successful and unsuccessful), the AVO properties can be used with confidence alongside other more conventional means of seismic interpretation to map and derisk remaining opportunities. In this way, an efficient exploitation of the remaining contingent and prospective resources in a partially developed play may be effectively pursued.

Acknowledgments

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