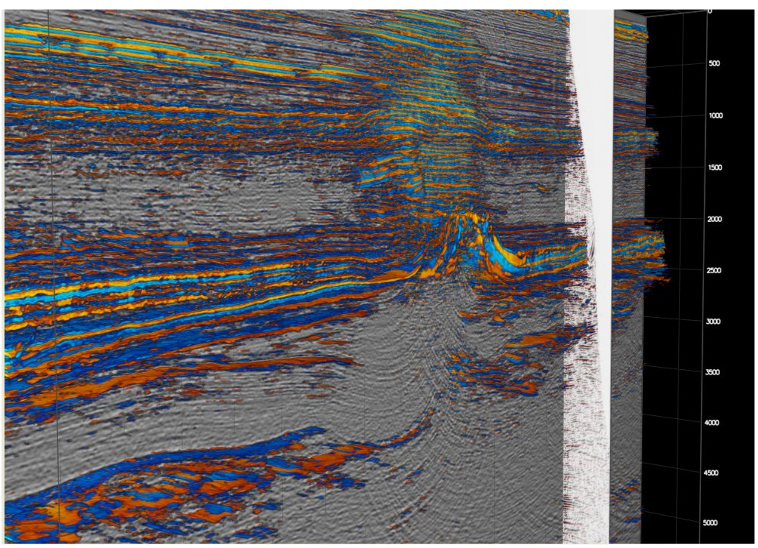
Fifth EBN-TNO one-day workshop on

Using seismic amplitudes for high-grading prospects and reservoir characterization

“Direct hydrocarbon indicator” examples from deep and sub salt reservoirs in the Netherlands



H. POELEN & H. DE HAAN

Organised by EBN and TNO Geo-Energy
January 14th 2010, Utrecht

Welcome and Introduction

By **F.F.N. van Hulten & J.E. Lutgert - Conveners**

Ladies and gentlemen, we would like to welcome you all to this years EBN-TNO workshop, which will be dedicated to the use of seismic amplitudes in oil and gas exploration and reservoir characterization.

In 2004 EBN decided to actively support symposia focussing on the subsurface issues encountered in the E&P industry. The idea of these meetings is to address a specific issue or problem that concerns various operators active in the Netherlands. The workshops are intended to discuss these issues with academics, researches and specialists working in the industry. This now will be our fifth workshop. Previous workshops addressed topics such as:

2004 Squeezing salts - an expensive problem
2006 Tight gas fields in the Netherlands
2008 Rifting systems and their significance for exploration in the Netherlands
2009 Fifty years of exploration in the Netherlands after the Groningen discovery

We would like to express our deep appreciation for all the participating oil and gas companies. Without their enthusiastic support and professional contributions these symposia could never be a success. The symposia *are organized for the operators by the operators*!

Seismic amplitudes

In the Dutch subsurface seismic amplitudes have been studied for over 30 years. Despite the use of 3D data and improved subsurface imaging techniques, up till recently the use of amplitude information failed to provide a significant contribution in raising the number of gas finds in the Netherlands. Especially for deeper formations like the Bunter and in particular the sub-salt Rotliegend, amplitude characterization was not without poorly understood failures. Only rarely did these studies prove decisive in delineating fields or de-risking exploration prospects.

The last few years new techniques give more confidence in the information from amplitudes. In 2008, Bruhl *et al*. presented a paper on DHI enhancement at the EAGE. They illustrate that more consistent results can be obtained by the use of stacking technology.

The question we raise today is: “is this the way forward”? Can we expect a new string of exploration successes comparable to the introduction of 3D seismic during the early 90-ties? There are many reasons why amplitude information provides poor results in certain geographical areas or rock formations. Important issues to be addressed are whether we need new and improved data acquisition techniques or if we can rely on reprocessed old 3D surveys?

This symposium aims to fill a number of gaps in our knowledge. The workshop will touch on the theoretical background of data processing techniques but will also highlight a number of detailed field examples with respect to the study and application of amplitude responses encountered in the Dutch subsurface.

Enjoy !

Program

Coffee	**9.30**	**Registration**
Session 1		
	10.00	Welcome (TNO/EBN)
	10.10	PAUL DE BEUKELAAR – Brief Introduction to Seismic Amplitudes
	10.20	MARIO TRANI AND ROB ARTS (TNO/TUD) part 1 – Data Assimilation of Time-Lapse Seismical Data
	10.40	Questions/discussion
	10.45	ANDRIES WEVER (Wintershall - Rijswijk) **–** Developing Integrated Amplitude Driven Solutions for Pore Content Prediction through Effective Collaboration
	11.05	Questions/discussion
Coffee		**11.05**
Session 2		
	11.30	MATTIAS BRUEHL, RIK SNEEP, RUTGER VAN SPAENDONCK, WICHER VAN LINGEN, RUUD VAN BOOM, NAIMO YILO (NAM – ASSEN) – DHI Enhancement as Key-enabler to Portfolio Rejuvenation – part I, *Examples from the Southern Permian Basin*
	11.50	Questions/discussion
	12.00	FILIP NEELE AND ROB ARTS (TNO/TUD) part II - CFP analysis of 4D pre-stack seismic monitoring data of the Sleipner CO2 storage site
	12.20	Questions/discussion
	12.30	ARNAUD HUCK AND FRITS BLOM (dGB Earth Sciences – Enschede / Petro Canada / Suncor - Voorburg) – Geometrical Stacking for Fluid Contact Analysis
	12.50	Questions/discussion
Lunch		**13.00**
Session 3		
	13.45	PETER MESDAG AND LEX DE GROOT (FUGRO JASON – LEIDSCHENDAM / GDF SUEZ – ZOETERMEER) – Seismic Calibration and Low Frequency Modeling – The Key to Quantitative Reservoir Characterization
	14.15	Questions/discussion
	14.25	HUGO POELEN AND HARALD DE HAAN (EBN & Headwave – Utrecht / EBN - Utrecht) Prestack Seismic for QC and Inspection of Amplitudes for High-Grading Prospects and Reservoir Characterization
	14.45	Questions/discussion
Tea		**14.55**
Session 4		
	15.30	RIK SNEEP, MATTIAS BRUEHL, RUTGER VAN SPAENDONCK, WICHER VAN LINGEN, RUUD VAN BOOM, NAIMO YILO (NAM – ASSEN) – DHI Enhancement as Key-enabler to Portfolio Rejuvenation – part II, *Examples from the Southern Permian Basin*
	15.50	Questions/discussion
	16.00	**Panel discussion**
	16. 40	Closing Remarks
Drinks		**16.45**

Abstracts

The importance of localization in the assimilation of 4D seismic data with the Ensemble Kalman Filter

MARIO TRANI AND ROB ARTS (TNO/TUD)

The Ensemble Kalman Filter (EnKF) is considered a fast and efficient algorithm in the data assimilation process to estimate reservoir properties from measured data. 4D seismic is an important source of information for the reservoir monitoring and the improvement of the geological model. The use of low frequencies for deep surface seismic makes it very complicated to discriminate and estimate properties for fine-grid reservoir models. In this paper it is demonstrated that using vertically averaged seismic data, inverted as time-lapse differences in pore pressure and saturation, greatly improves the quality of the history match and the estimation of the reservoir state. The EnKF may present some problems when assimilating large amounts of data (frequent 4D seismic), as the flexibility of the model solution is strongly reduced. The conditioning of the covariance matrix in the Kalman gain is a key to avoid the filter divergence. In this study the localization criterion is based on the mere distance or on the streamlines trajectories. Results from 3D synthetic examples show the importance of localization to ensure the correct functioning of the filter.

Developing Integrated Amplitude Driven Solutions for Pore Content Prediction through Effective Collaboration

ANDRIES WEVER (Wintershall - Rijswijk)

Today's challenges for successful exploration in the Southern North Sea are typical for a very mature basin. Firstly, all obvious, big, easy and clear prospects have been drilled; what remains are those prospects with more subtle traps and the new play types not previously recognized. With the decreasing prospect size, extensive de-risking of prospects is required before justification can be made for an exploration well on the structure, which might be your sole producer as well. Lastly, the increased technical challenges are combined with a push for shorter turn-around time, as typical license periods are reduced, and more data needs to be analysed and integrated in a more effective and concise way.

This 'mature basin' environment is ideal for mid-size E&P companies, which can swiftly react to new opportunities and insights, both operationally and technologically. However, with no proprietary R&D departments, innovative approaches are needed to develop and implement technology. Wintershall achieves this by pursuing collaborative technology projects with selected service companies and universities. Key in this is the ability to quickly go from ideas through knowledge into solutions, and to implement these solutions into mainstream software. This is then immediately applied to real-life problems to maximize the value added.

This way, Wintershall can effectively turn ideas into practical solutions which helps to better understand a play or prospect, improve the characterisation of reservoirs, and better assess associated risks. For the partners in these collaborative projects, there are also clear benefits. Service companies get an insight into practical exploration challenges, which help them to better steer development of solutions and services. Universities gain access to industry standard tools, data and challenges, so students get better prepared for reality, and researchers can test their most innovative concepts on realistic environments.

The effectiveness of this approach is demonstrated by two case studies. First, a methodology to screen for flat-spots, fluid contacts, and AVO anomalies within raw pre-stack data volumes is presented. Then, an implementation of modified Gassmann theory is shown to substitute between water, gas and salt in the reservoir pore-space. Both approaches rely on 3D visualisation of a multitude of data-types, interpretive use of pre-stack data, and the integration of seismic modelling with 3D interpretation.

These case studies represent some of the successes in turning ideas into solutions which can improve the understanding of risk on a prospect.

Wever, Pacek, Arts and Kemper; 2010; Application of solid and fluid substitution to salt-plugged sandstones, using generalized Gassmann theory; submitted to 72nd EAGE Int. Conf. & Ex. Barcelona

Wever, Chandler, Huck and Blom; 2010; Re-binning pre-stack seismic data for flat-spot and fluid contact determination, AVO screening and visualisation; submitted to 72nd EAGE Int. Conf. & Ex. Barcelona

DHI enhancement as key-enabler to portfolio rejuvenation part I & II - Examples from the Southern Permian Basin

MATTIAS BRUEHL, RIK SNEEP, RUTGER VAN SPAENDONCK, WICHER VAN LINGEN, RUUD VAN BOOM, NAIMO YILO (NAM – ASSEN)

Introduction

Around 2003 NAM's offshore prospect portfolio looked rather grim and drilling activity was expected to decline quickly. At the same time a Direct Hydrocarbon Indicator (DHI) enhancement method called Common Top Depth (CTD) stacking was developed that showed a reasonably consistent score for the offshore fields [1]. Experts could identify the proven GWC in 70% of the fields in a blind test. For the remaining prospect portfolio, however, the approach provided less conclusive results. Improved data quality was considered essential to achieve a similar success rate.

During the years 2004 - 2006 NAM acquired approximately 2500 km^2 long-cable seismic survey with 6 km streamers in the Dutch offshore. The long-cable acquisition geometry was expected to yield a step change improvements in imaging and improved accuracy of the seismic velocity model that would support additional exploration drilling.

The combination of long-cable 3D data, state-of-the-art velocity model updating methods and CTD stacking technology had significant impact on our business:

- We were better able to image deep Rotliegend fault blocks
- We obtained better structural definition underneath (abundant) salt ridges
- We achieved more consistency of the DHI's
-

The large area covered by the surveys also enabled the use of an integrated regional prospect evaluation that encompasses structural interpretation, basin modelling and geochemistry, fault seal analysis, geological modelling and evaluation of seismic DHI's. The integrated regional approach enriched the prospect portfolio and we were able to rank the portfolio in a consistent manner.

DHI enhancement

Seismic DHI's have been an important component of exploration for a long time. These vary from the more traditional flat spot and structural conformable amplitudes to the latest developments in wavelet frequency imprint due to gas presence. In the Southern Permian Basin the conventional DHI-chase only led to sporadic success – certainly not consistent enough to justify drilling of increasingly smaller targets. The failure of detecting reliable DHI's has various reasons:

- Rock properties; porosities vary between 8 and 14 percent and DHI's are rather subtle (Fig. 1)
- Imaging quality; the overburden is often complex which makes it challenging to produce a clear structural image of the target.
- Remnant multiples; inter-bed multiples are very difficult to remove and produce amplitude anomalies of a similar order of magnitude like the DHI's.

In some areas the presence of residual gas makes it virtually impossible to detect the present day GWC from seismic.

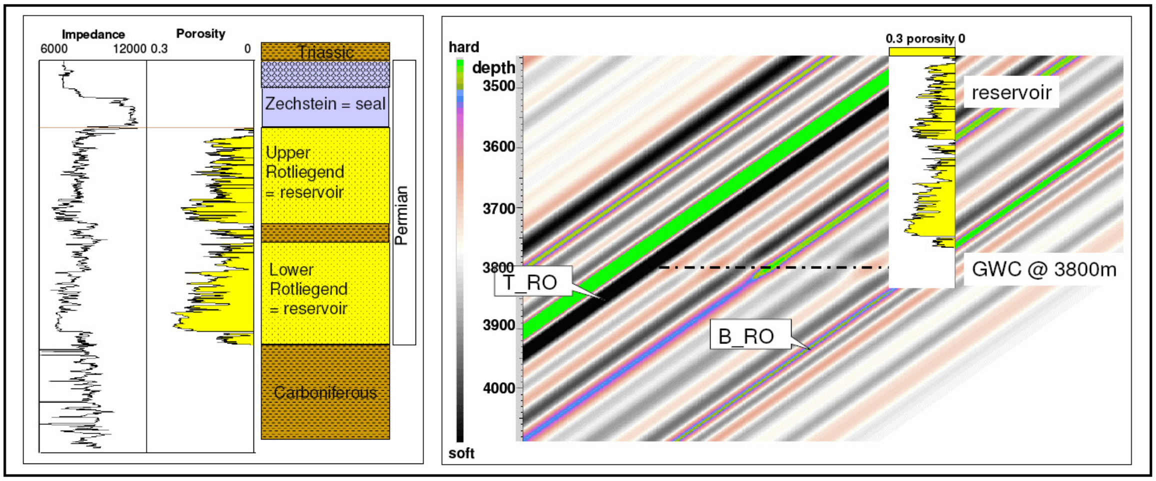


Fig. 1: Geological sequence and characteristic acoustic impedance and porosity profile (left hand side). The corresponding seismic response of a dipping reservoir with a GWC at 3800m (wedge model) is shown on the right hand side. The markers T_RO and B_RO correspond to resp. the Top and Base Rotliegend.

Our CTD stacking technology aims to enhance the subtle DHI's while suppressing the remnant multiples in the averaging procedure. CTD stacking exploits the fact that the Rotliegend geology in the Southern North Sea is largely parallel at fault block scale. Within a fault block all seismic traces that pertain to a common top reservoir depth (CTD) are stacked and organized in the same way as for the wedge model of Fig. 1. This provides a one-to-one comparison with the wedge model (Fig. 2).

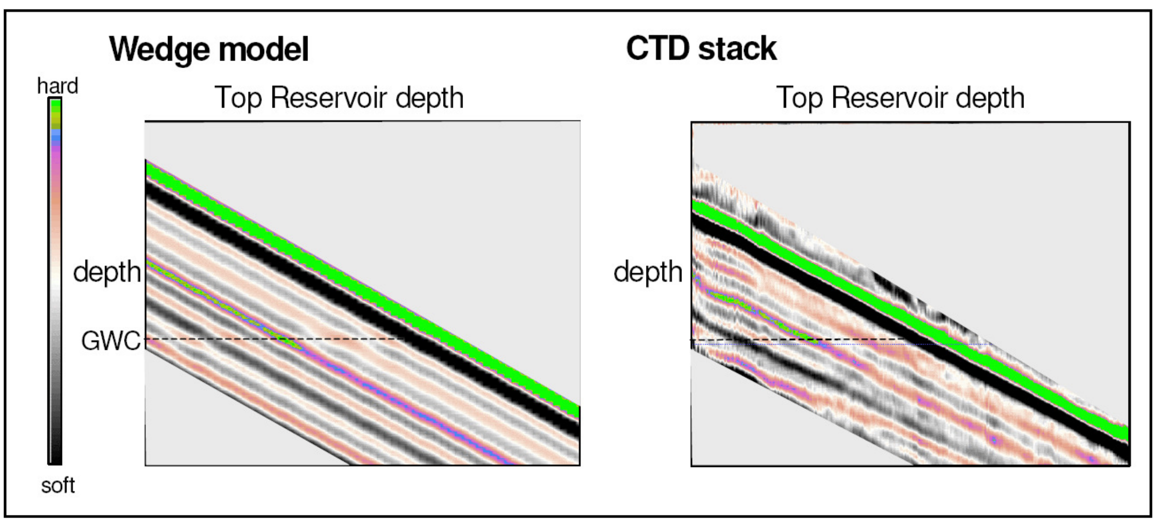


Fig. 2: Comparison of wedge model (based on well data) and CTD stack. The hardening of various reflectors due to the interfering flat spot and the updip amplitude brightening is observed on the wedge model and the CTD stack. The over- and under-burden are overlain by a semi-transparent gray. Since these are not parallel to the Rotliegend stratigraphy, the signals are obscured in the stacking process.

The CTD stack enhances depth conformable features (e.g. flat spot) and structurally conformable features (e.g. amplitude brightening) in one fell swoop while suppressing the non-parallel features (e.g. remnant multiples). Multiple DHI's are therefore visible within a single seismic display facilitating the identification of a potential GWC.

Application of CTD stacking in Southern Permian Basin

Due to the presence of sealing faults, hydrocarbon columns in the Southern Permian Basin sometimes extend beyond the dip-closured component of a trap. This implies that even fault blocks in a downthrown structural setting may be gas bearing. CTD stacks are an essential tool for identification of these deep GWC scenarios and therefore impact both a prospect's probability of success and mean success volume.

The vintage-data CTD stacks provided the correct GWC (within a +/-30 m depth margin) for some 70% of discovered fields (in an area where residual gas is not an issue). In order to evaluate the remaining prospectivity all un-drilled fault blocks were considered as leads and a CTD stack was produced for each of them. This approach yielded a large number of CTD stacks within a license block and ensured that DHI's were evaluated for each fault block in a consistent and efficient manner. We interpreted each CTD stack by either picking a GWC or flagging it as most likely brine bearing. In addition, we assigned a subjective confidence score. In spite of the high success rate of the blind test for the discovered fields, on the vintage data this approach only yielded mixed results for the remaining leads and only a few DHI's were considered to be of high confidence.

The success rate discrepancy for discovered fields and prospects is easily understood when considering that the remaining prospects are smaller fault blocks or downthrown closures. Since CTD stacking is an averaging procedure that produces a depth dependent seismic response, small fault blocks deliver poorer averaging statistics and the quality of each trace used for CTD stacking therefore needs to be as high as possible. Since imaging quality deteriorates with depth the downthrown fault blocks often deliver a less reliable results.

The long cable data provided us with a much improved velocity model. Based on this velocity model we obtained a more reliable image from our pre-stack depth migration. Figure 3 illustrates the superior image quality associated with the long cable data.

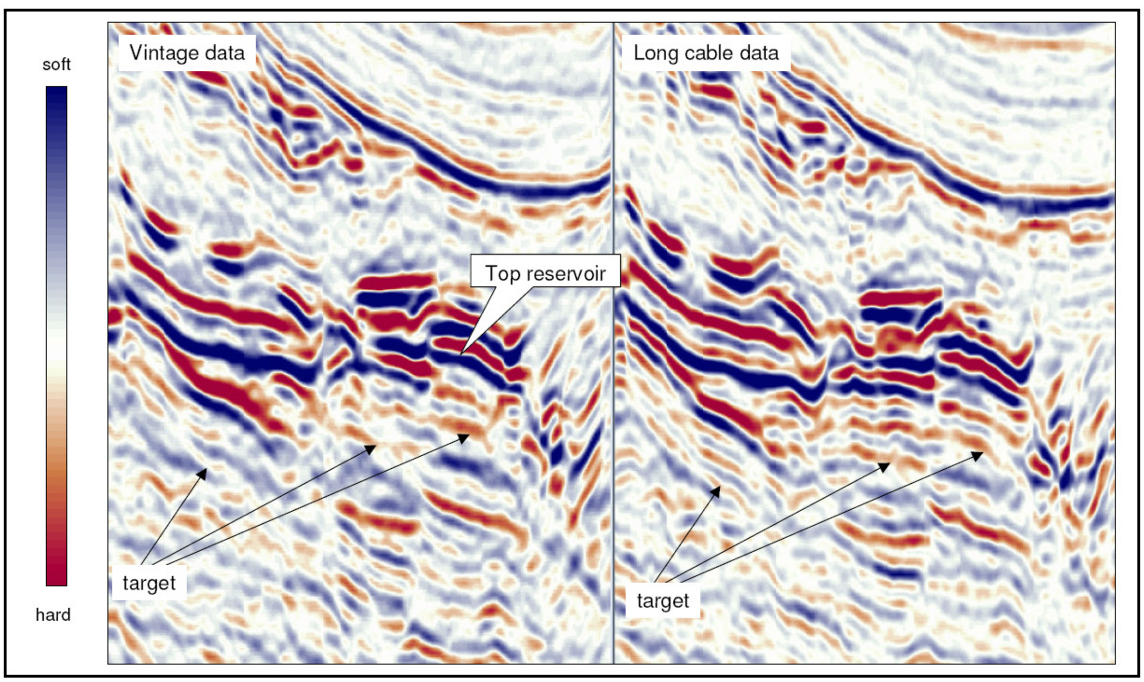


Fig. 3: Comparison of vintage data and long cable data along an arbitrary line with relatively simple overburden geology. We observe improved intra-reservoir definition (annotated by arrows) on the right hand side (LC data).

The improvement of imaging quality also yielded an uplift of the DHI confidence. Figure 4 compares the CTD stack associated with a discovery for the vintage data with the one for the long cable data.

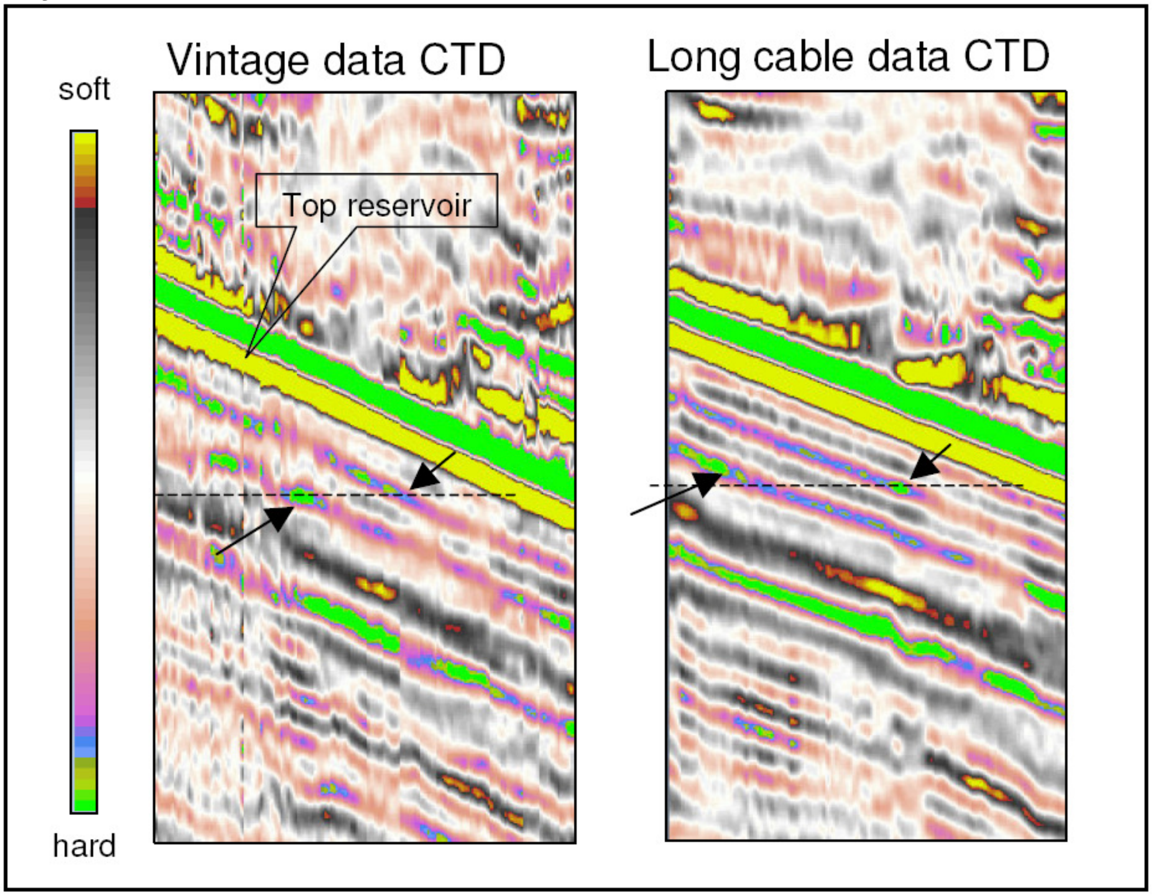


Fig. 4: CTD stack for the same fault block – based on vintage and long cable data; the dashed line represents the known GWC. The CTD stack on the right hand side is less noisy and the confidence in the DHI (amplitude brightening) is therefore considerably increased.

The uplift in CTD stack quality due to the new acquisition resulted in an improved prospect portfolio polarization. The percentage of prospects with a high-confidence DHI increased from 18 to 33 whilst the number of inconclusive CTD stacks reduced from 26% to 19%. Furthermore, for the discovered fields a slight additional improvement of the already high rate of predictive power was achieved.

The long cable seismic survey facilitated field development planning and well design due to improved structural definition. Besides, it provided a significant advance in our understanding of the area's remaining potential.

DHI's as enabler for integrated regional evaluation

The CTD stacking technology has proven its value in several areas, amongst others in the Joined Development Area (JDA) in the Dutch offshore. The gas fields of the JDA have been a loyal supplier to the Dutch gas market since the early 80's. With the majority of the fields offplateau and declining towards end of economic field life additional gas volumes (either stranded gas or new discoveries) need to be brought on stream to fill capacity and sustain or grow production levels in an economic manner.

Before the acquisition of state-of-the-art seismic and the kick-off of the integrated regional study the prospect portfolio was about to dry up pretty soon.

In maximizing the value of the JDA assets the regional approach to subsurface evaluation proved to be a key enabler. The regional evaluation offers the possibility to integrate the knowledge and subsurface understanding on a large scale:

- Reservoir development trends and implications on the seismic expression of presence of HC
- Structural styles and fault seal potential
- Basin modeling mapping out kitchens and timing of charge
- Geochemical trends, leading together with the structural interpretation to an understanding of likely HC migration pathways
- Consistency of DHI's in conjunction with charge, fault seal potential, migration paths, petrophysical analysis and geological trends

Integrating the various elements of prospect evaluation within a regional framework reduces the uncertainty significantly and therefore increases the value of interpreted DHI's that otherwise would be ambiguous.

Example of CTD stack results and portfolio impact

DHI risking is especially challenging in areas where the reservoir is variable and where a risk of residual gas exists. In these cases interpreting CTD stacks within the regional context is key to success.

Based on the regional trend of deteriorating reservoir quality from south to north we defined an analogue well and associated wedge model for each prospect. In Figure 5 the effect of the changes in reservoir quality in the (modeled) DHI response of the CTD stack is shown. We observe that the DHI response ranges from amplitude "brightening" (Well1) to a very clear flat spot (Well 4).

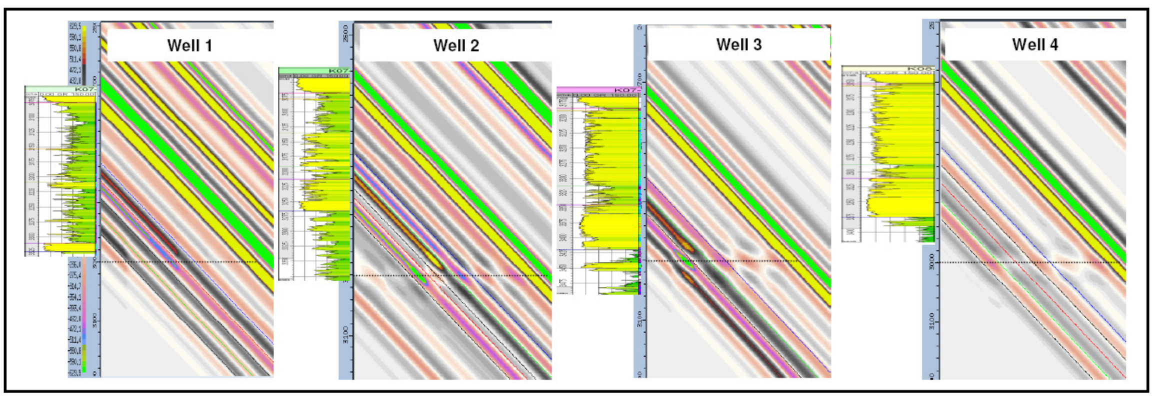


Fig. 5 Wedge models (organized from North to South) showing the effects that the changes in reservoir quality can have on the DHI signature.

Basin modeling and geochemical analysis suggest that parts of the study area do not receive present day charge. In these areas residual gas is observed on well logs. The presence of residual gas implies that the prime DHI is likely to be associated with a palaeo-GWC. As a consequence the CTD stack interpretation yields the deeper palaeo-GWC rather than the present day GWC.

The presence of residual gas in parts of the study area impacted the raw statistics of valid interpreted DHIs for the fields significantly. The score for correctly interpreting DHI's of the fields dropped to about 50%. Excluding the cases with evidence for residual gas yields an accurate prediction in about two thirds of the cases in spite of the considerable lateral variability of the Rotliegend reservoir.

Figure 6 illustrates that distinguishing residual gas from commercial gas based on a CTD stack is not possible in this geological setting. For field A a deep DHI (black dotted line) is interpreted (left hand side of Fig. 6). The amplitude effects visible on the CTD stack resemble those seen in the wedge model. The interpreted DHI lays 150m deeper than the actual GWC. The associated well logs indicate the presence of residual gas, which explains the absence of a DHI at the actual GWC and the deep DHI associated with a palaeo-GWC. For field B the wedge model indicates the subtle amplitude brightening due to flat spot interference. This feature is also interpreted on the CTD stack and coincides with the GWC.

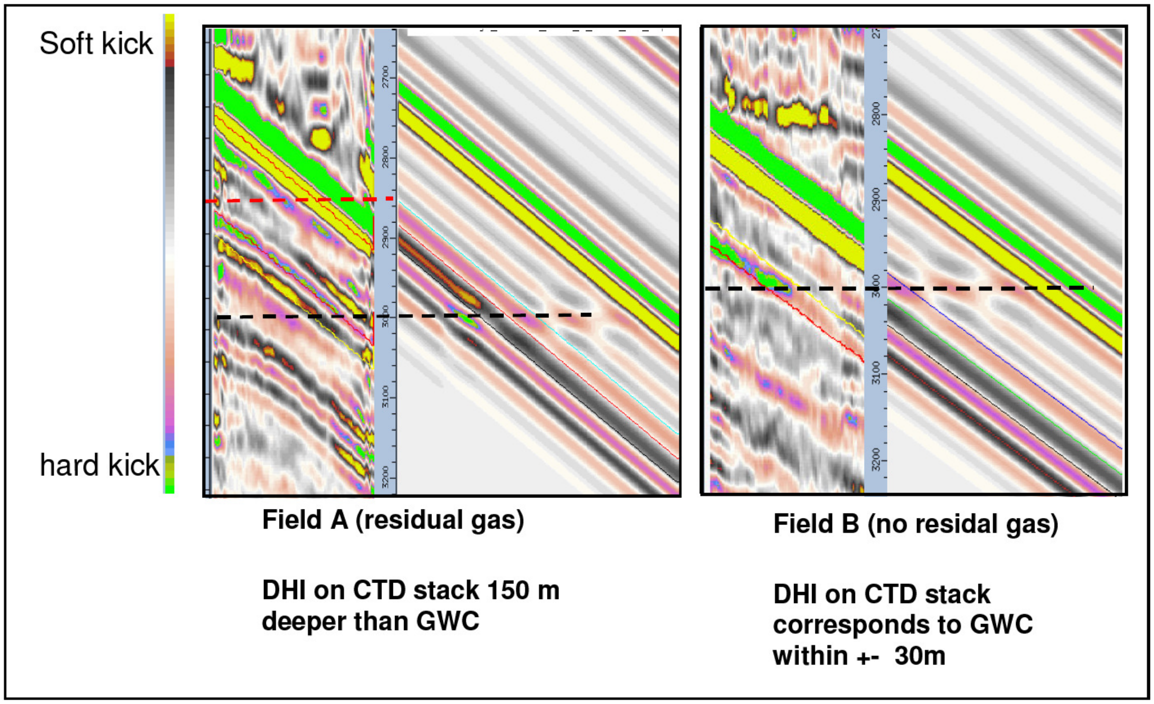


Fig. 6 CTD stacks results for two fields: Field A shows a DHI (back) that lies 150m deeper than the GWC (red) due to the presence of residual gas; for field B the DHI (black) corresponds to the actual GWC and no residual gas is seen on well logs.

Placing the CTD stack interpretations of the fields into their aereal context allows us together with the basin modeling, geochemical analysis and petrophysical work to distinguish areas that are prone to the presence of residual gas and areas where this is not the case. Figure 7 shows an area where CTD stacks consistently indicate too deep DHI's (red circles) and well logs show residual gas below the GWC. At the fringes of the area high confidence CTD stacks are visible that show a DHI at the correct GWC depth. Distinguishing areas with high likelihood of residual gas from those with a low likelihood has a significant effect on the impact that an observed DHI has on prospect risking. In areas with residual gas the DHI contains little information other than confirming presence of charge. In areas where the DHI consistently corresponds to the present day GWC a large weight can be attached to an observed DHI or the absence of it.

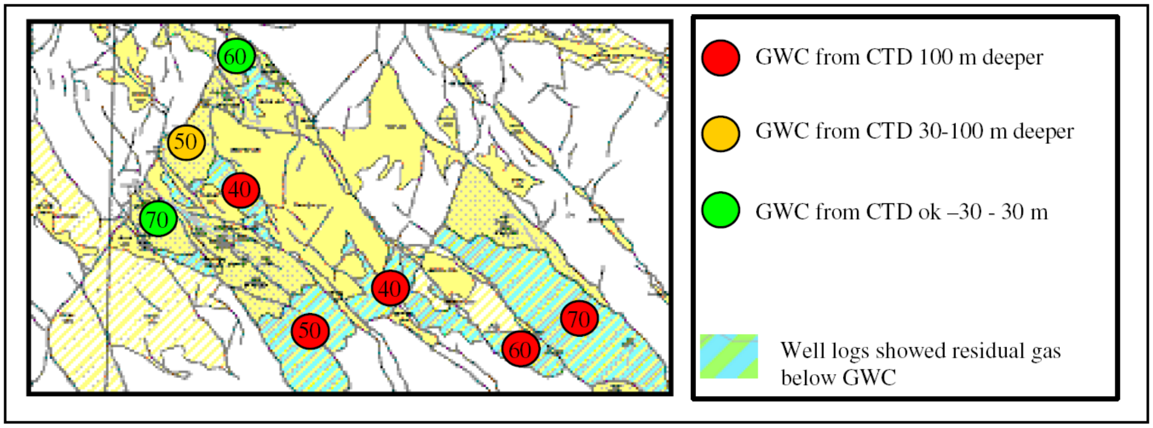


Fig. 7 Structural map showing the CTD stack result distribution, confidence level and the fields where residual gas was observed in the well logs.

Conclusion

In the Southern Permian Basin DHI’s are often subtle and traditional ways of highlighting DHIs often led to inconclusive results. CTD stacks allow viewing the various subtle gas related effects in one display and thus facilitating a reasonably confident interpretation. High data quality and limited geological variability are key to success. Evaluation of DHI’s within an integrated regional study further enhances our ability to distinguish between false DHI’s and reliable ones.

References

[1] Brühl et al., 2008. High-grading the Prospect Portfolio with Latest Technology - Impact on Southern Permian Basin. 70th EAGE Conference and Exhibition, Rome, Italy.

CFP analysis of 4D pre-stack seismic monitoring data of the Sleipner CO2 storage site

FILIP NEELE AND ROB ARTS (TNO/TUD)

Abstract:
The Sleipner CO2 storage site has been in operation for more than a decade. The site has been monitored intensively, with seismic surveys. Time-lapse surface 3D seismic surveys have been acquired in 1994 (baseline), 1999, 2001, 2002, 2004, 2006 and 2008. The seismic data have shown the migration of CO2 from the injection point at the base of the Utsira Formation towards the top of the sandstone layers. Clay or shale layers within the formation result in a complex plume of CO2, with a central, vertical chimney and CO2 collecting at several depth levels.

A new processing technique, Common Focus Point (CFP), has been used to analyse the top of the CO2 plume in detail. A strong point of the CFP technique is that it can strip the effect from the overburden from the signal from a reflector at depth. This means that the signal from the top of the Utsira Formation can be analysed in more detail than with commonly used processing methods.

The CFP technique results in ready-to-use AVP data. AVP data derived from the different surveys show the development of the CO2 plume. These data will form the basis for subsequent analysis, in terms of rock properties, such as pore content and pore pressure.

Geometrical stacking for fluid contact analysis

ARNAUD HUCK AND FRITS BLOM (dGB Earth Sciences / Petro Canada / Suncor)

Summary
A geometrical stacking approach called common contour binning has been applied in two P Blocks offshore The Netherlands Dutch North Sea. The study focused on several Rotliegend and Base Cretaceous Unconformity prospects. The objective was a better definition of the possible gas water contact (GWC) in the Bunter and Rotliegend reservoirs below the Cretaceous Vlieland shale. Four areas were investigated for fluid-related amplitude anomalies.

Although common contour binning should ideally be applied to seismic data in the depth domain, data in depth were not available for this study. Common contour binning was thus applied to seismic volumes in two-way time.

Two probable gas/water contacts were clearly localized using this stacking technique at base Vlieland Shale (example 1) and top Rotliegend (example 2). In isolation, common contour binning cannot uniquely prove the presence (or absence) of hydrocarbons. The technique highlights subtle fluid-related seismic anomalies and allows delineating fluid contacts with more accuracy. In this study, GWC contacts were picked with confidence at base Vlieland Shale (example 1) and at Top Rotliegend (example 2). However, other prospects showed ambiguous results. In one prospect (Top Rotliegend, example 3) the interval around top reservoir showed multiple amplitude variations. Another prospect (top Middle Bunter, example 4) showed monotonous amplitude increase/decrease with bin depth. Such difficult cases cannot be interpreted with merely the application of common contour binning. These cases require further study including additional structural information and sensitivity analyses.

References
Flierman, W., van der Weide, J.G., Wever, A., Brouwer, F., and Huck, A., 2008, Use of spatial, frequency and curvature attributes for reservoir, fluid and contact predictions. SEG Las Vegas Annual Meeting.

Seismic Calibration and Low Frequency Modeling – The Key to Quantitative Reservoir Characterization

PETER MESDAG AND LEX DE GROOT (FUGRO JASON / GDF SUEZ)

Introduction

For quantitative interpretation of full band width seismic inversion results it is necessary to accurately reconstruct the low frequency information. This low frequency information is often obtained by stratigraphic interpretation of well log information. Often, due to sparse well control and preferential drilling locations the well control is insufficient to capture the lateral variability in the low frequencies. This phenomenon is well known when it concerns the lateral changes in the reservoir layer itself. However, imprecise information about high contrast layers directly above or below the reservoir causes residual sidelobes and other artifacts within the reservoir, leading to incorrect imaging close to high contrast layers. If the contrast of elastic parameter in the low frequency model is too small (for instance if the fast layer is not interpreted in the LFM) an overshoot of the elastic parameter values occurs in the neighboring layers. On the other hand, if the contrast in the LFM is too large, the high contrast layer will tend to smear into the neighboring layers.

In this paper we propose an iterative approach to inversion in which, after a first pass inversion, information about the laterally variable high contrast P-impedance layer is extracted from the bandlimited inverted P-impedance volume. The contrast information is then used to update the P-impedance low frequency model and the inversion is run again with the updated trend model. The accurate interpretation of the hard layer and the inclusion of correct contrast information in the LFM remove most of the side lobes artefacts.

A case study is presented from a gas field located within the Dutch sector in the Southern North Sea. The Rotliegend reservoir in the gas field, which comprises high porosity Aeolian sandstones, lies just below the Top Rotliegend horizon, a marker that locally is the base of a hard Zechstein salt layer. Reservoir characterization in sub-salt formations is a well known daunting task, see e.g. Bergeon (2004) or Whaley (2006), and the characterization of the P-Impedance in the Rotliegend reservoir is not an exception, Maguire et al. (2009). The high impedance Zechstein Salt layer varies in thickness and is in places interleaved with shale. This causes its impedance response to vary rapidly within the seismic band width. Eight wells drilled on the field were used in the study. Figure 1 shows a cross section from the P-Impedance full bandwidth inversion along a line through the five wells in the north reservoir zone. A newly drilled well, not used in the inversion, is also shown (third from the left).

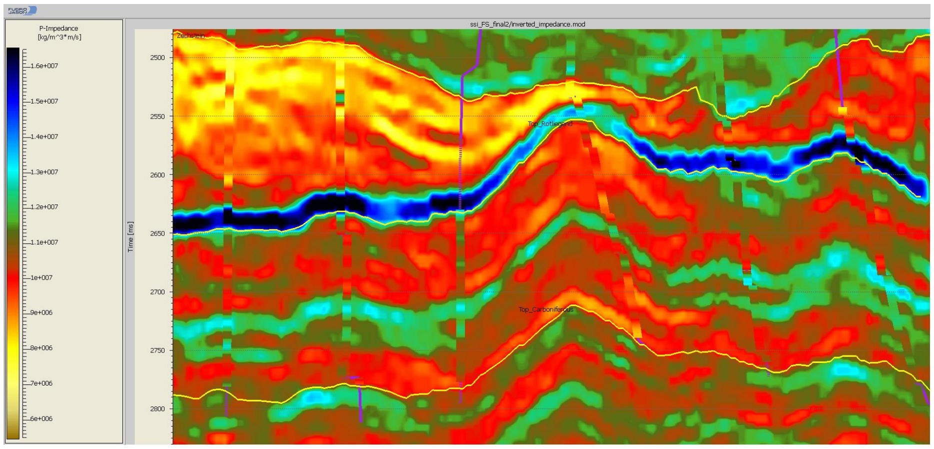


Figure 1 *P-impedance section from inversion with (high-cut) P-impedance logs in overlay.*

The newly drilled well encountered lower porosity (higher Impedance) in the reservoir than was predicted by the first inversions. The well coverage is not sufficient to generate a low frequency model that capture the lateral variability of the high contrast Zechstein. Sidelobe effects originating from an imprecise trend model account for the lower impedance values predicted by the inversion result, as compared with those observed in the newly drilled well.

Updating the low frequency model and Inversion results

The updating scheme proposed in this paper is based on the observation that the P-impedance contrast among neighbouring layers is independent of the actual P-impedance values of the layers. By interpreting and incorporating the contrast information into the LFM in a second pass inversion, we are able to alleviate most of the sidelobe effects. The P-impedance trend model update scheme can be outlined as follows:

Step 1. Calculate the P-Impedance contrast from the band limited first-pass inversion. The minimum P-impedance directly below the base of the high contrast layer is subtracted from the maximum P-impedance directly above the horizon.

Step 2. Extract the average P-Impedance at the reservoir interval from the original LFM.

Step 3. Define the new P-impedance of the Zechstein salt by adding the mean P-Impedance background to the bandlimited P-Impedance contrast.

Step 4. Update the LFM by replacing the 'fast' layer P-Impedance in the original LFM by the new horizon defined in step 3. The previous 'fast' layer P-impedance need to be removed first from the LFM. This requires an accurate interpretation of top and base of the high contrast layer in order to guarantee the effectiveness of the method.

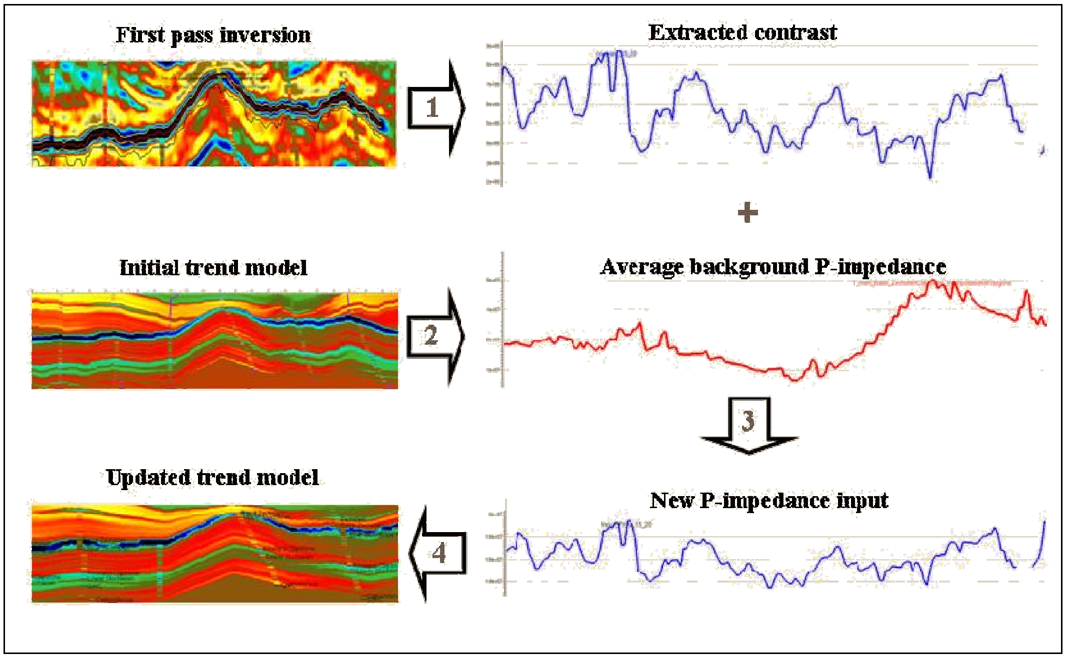


Figure 2 *Updating low frequency model.*

The updated LFM resulting from the procedure can now be used as a trend for P-impedance inversion. Here, the updated P-impedance trend model was merged with the P-impedance full bandwidth inverted volume.

Figure 3 shows a cross section of the resulting 'merged' P-impedance, together with the original inversion.The lower panel shows the average P-impedance of the Rotliegend layer extracted from the original inversion (black curve) and the newly merged P-impedance (red curve). Note the higher average impedance around the newly drilled well in the new merged model, showing a better match with the P-impedance values in this well.

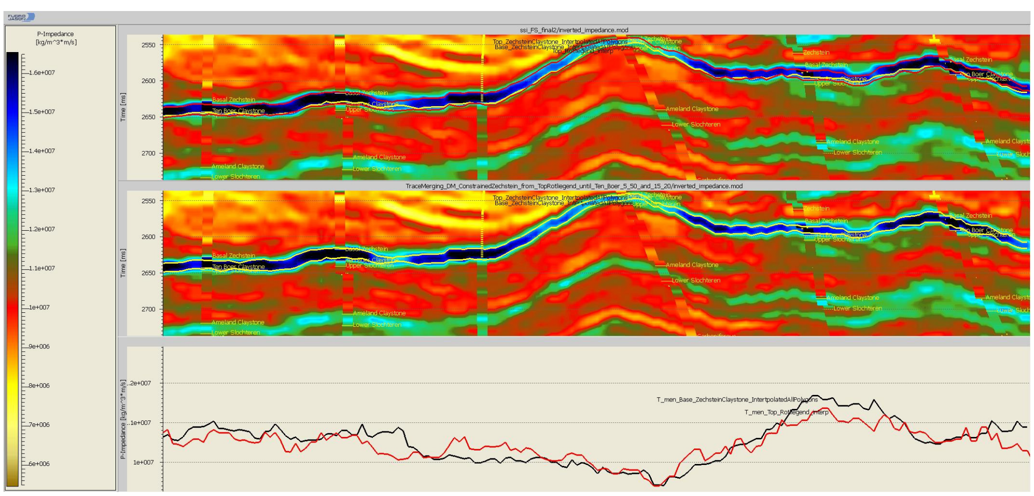


Figure 3 *Upper panel: P-impedance section from original inversion. Middle panel: newly merged P-impedance. Lower panel: mean from the original (black) and new (red) P-impedance, extracted from 5 to 50 ms below the Top Rotliegend horizon.*

Maps of the average P-impedance of the Rotliegend layer for the original inversion and the newly merged model are shown in Figure 4. The area with most well control in the fault block to the North-East shows minimal change. Away from well control the changes are more dramatic. There is more consistency in the new merged P-impedance model

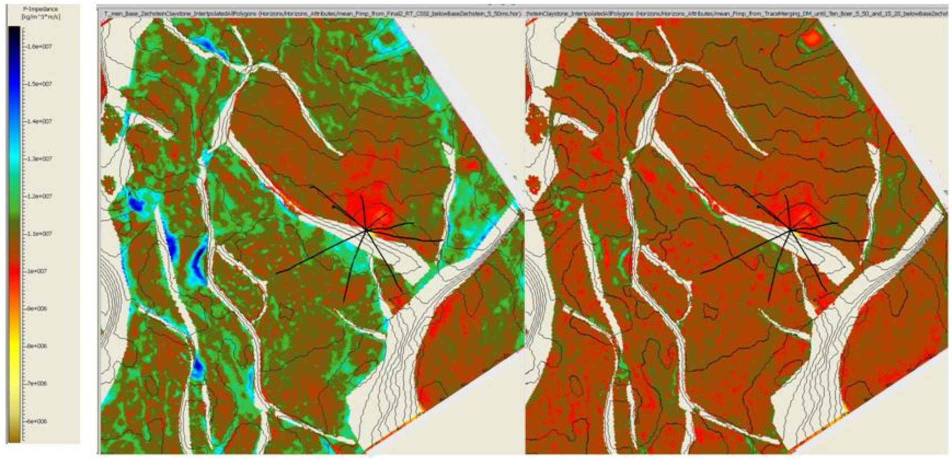


Figure 4 *Mean P-impedance extracted from 5 to 50 ms below the Top Rotliegend horizon. Left panel: from newly merged P-impedance. Right panel: from the original inversion. The contours are from the Top Rotliegend time representation.*

Another useful QC to demonstrate the value of this new method is to compare the well log P-impedance to the P-impedance pseudo logs from the original inversion and the new merged P-impedance volume. Figure 5 shows the P-impedance well log data (blue) together with the extracted pseudo logs from the original inversion (black) and from the newly merged P-impedance model. Note the reduction of sidelobes at the Top of the Upper Rotliegend layer in the newly drilled well as well as in the deviated wells.

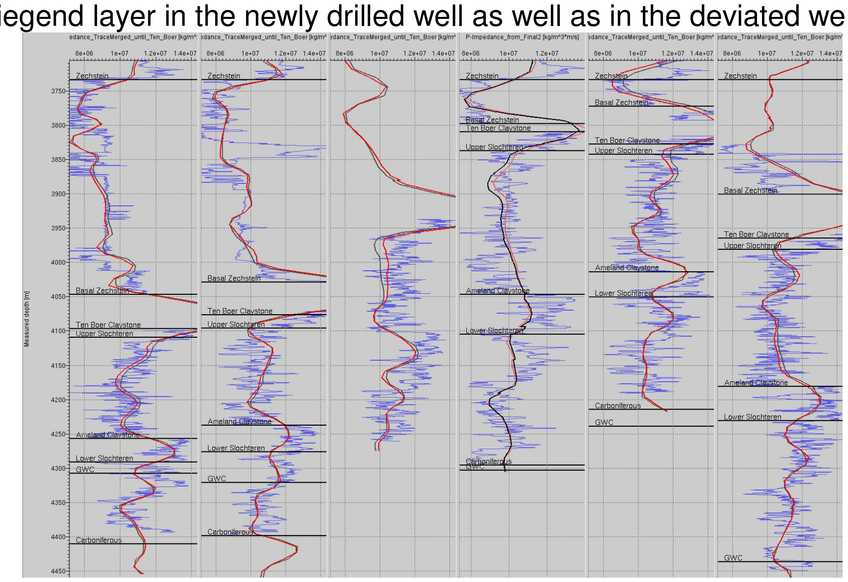


Figure 5 *P-impedance (pseudo) logs. Blue = well data; Black = from original inversion; Red = from newly merged model.*

Conclusions

We propose a method to update the P-impedance low frequency model in order to account for high contrast P-impedance layers. The updating methodology is integrated in an iterative inversion scheme in which, after a first pass inversion, information of a laterally variable high contrast P-impedance layers is extracted from the bandlimited inverted P-impedance volume and used to update the P-impedance low frequency model. This updated model is used as trend in a new run of the inversion.

The updated low frequency model removes the residual sidelobes and other artifacts observed in the original full band inversions. The result is a better imaging in zones close to high contrast layers.

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References

- Bergeon, T., 2004. Seismic Imaging at Conger: Lessons Learned in Gulf of Mexico Subsalt Imaging, 24th Annual Gulf Coast Section SEPM Foundation abstracts.
- Whaley, J., 2006. The Sub-Salt Imaging Challenge, GEO ExPro September 2006
- Maguire, R., de Groot L., Castoro, A., and Forsyth, D. 2009. Optimal Integration of Geophysical and Field Production Data for Reservoir Modelling and Asset Development. 71st EAGE Conference & Exhibition, extended abstracts, Q044.

Prestack Seismic for QC and Inspection of Amplitudes for high-grading prospects and reservoir characterisation

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Abstract

The current geophysical interpretation studies for Exploration and Field Development are geared to work with stacked seismic. Even for QI interpretation, it is common practice to use seismic data in full stack or in sub-stacks of offset ranges or offset angles. However, the NMO and migration results are not perfect. This results in unwanted data scatter, where very subtle variations are studied.

__For 3D seismic__: This paper will demonstrate the impact of the use of Prestack seismic QC for reservoir prediction in a 3D seismic data set. Now the correctness of NMO and migration can checked in key areas, where AvO studies are applied or wells planned. The Prestack QC can be combined with interactive scanning in AvO crossplots linked to A and B probes.

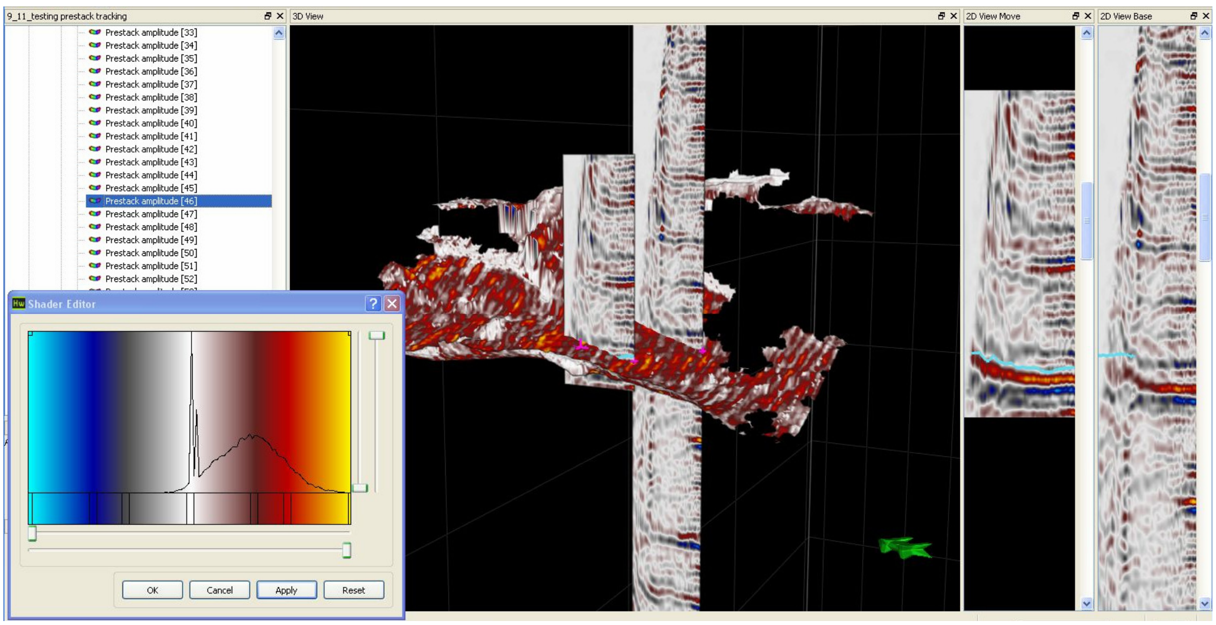

Figure 1 Examples for Prestack QC and Analysis: Prestack amplitude @ offset 46 posted on poststack horizon, Locator gathers & histogram@ offset 46

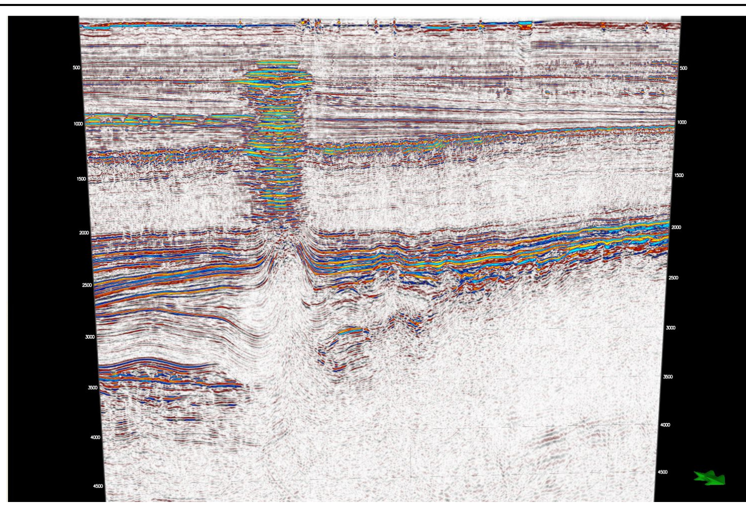

Figure 2 Long Cable line stacked. Clear shallow Gas Chimney

__For 2D Seismic:__
This Prestack QC and Analysis technology is also applied to regional, long cable 2D lines. Now the Prestack QC and Analysis can be used to inspect the impact of ultra-long offsets for subtle plays covered by a regional grid of 2D seismic. The ultimate goal of such evaluation is to locate prospects and predict the fluid content of these prospective structures, through AvO and Modelling studies.

The results of the 2D long cable lines can be related back to the “classic” 3D surveys, where the outline of prospects could be mapped. Alternatively they can be used to design the parameters for follow-up seismic data acquisition.

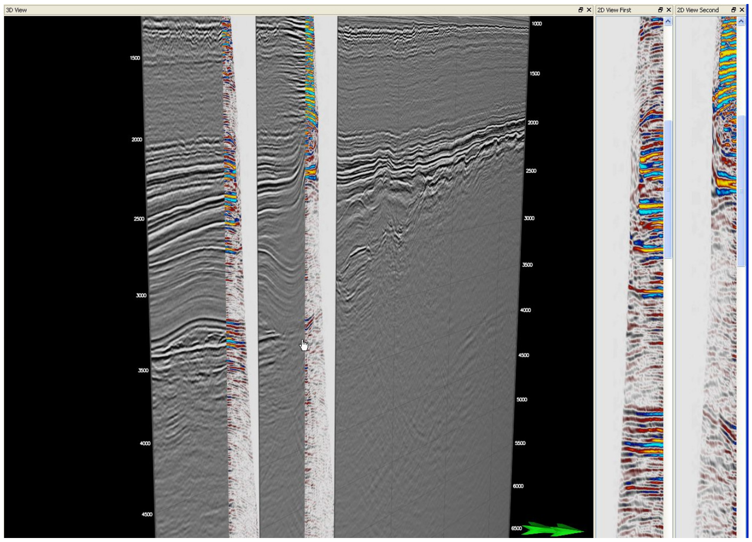

Figure 3 Long cable regional line with Prestack gathers with clear effect of undershoot of Gas Chimney

Various tools will be discussed:

- Prestack visualisation for Exploration & Production
- Prestack attributes posted on poststack horizons
  - T_0 amplitudes
  - Delta T and Tracked Prestack Amplitudes
- Cross plots of Nears en Fars / A and B in testing Probes
- Locator on horizon and wells
- A en B volumes, calculated externally

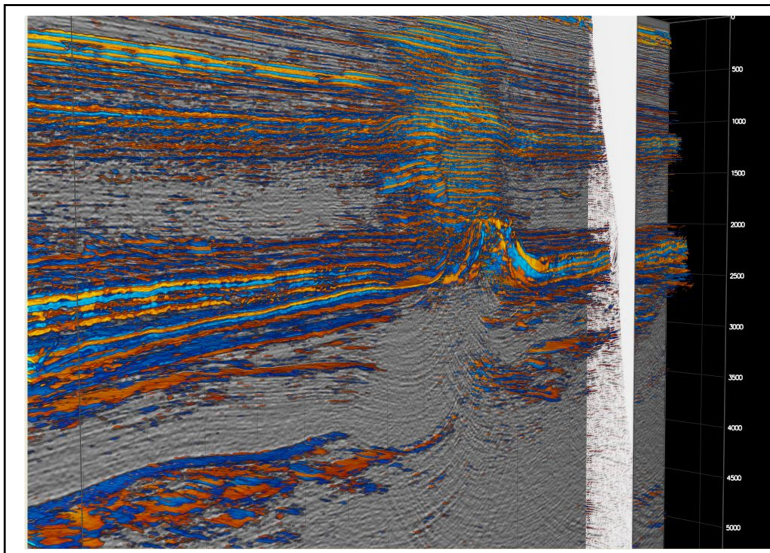

Figure 4 Long cable regional line with all Prestack extremes displayed.

The paper will consist of a presentation of this functionality and can be appended with a demo during the break(s).

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