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Shallow Play in The Netherlands - Derisked by Seismic Characterisation

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SUMMARY

The Dutch North Sea area hosts more than 160 shallow gas leads in unconsolidated, Cenozoic reservoirs that are identified by amplitude anomalies on seismic data (bright spots). Several accumulations have been proven by wells and nowadays there are three successfully producing fields using innovative sand control measures in horizontal wells. An inventory of this play has pointed out significant potential volumes, raising a lot of interest from the industry.

The present study highlights the advances in the shallow gas appraisal work in the Dutch offshore A-H blocks and includes an improved bright spot characterisation scheme in order to select those leads that have highest potential for development. Each individual bright spot is characterised based on ten parameters. The focus is on seismic expressions relating to the amplitude anomalies such as the presence of velocity pull-down, flat spots, gas chimneys and seismic attenuation. Several of the seismic features have been modelled to improve the understanding of their relation with gas saturation. The F12-Pliocene-Alpha prospect has well-expressed diagnostic features pointing towards the entrapment of shallow gas and is presented as a case study.

Introduction

Since the early seventies, the presence of shallow gas in the Dutch part of the Southern North Sea area has been known from seismic amplitude anomalies. In the eighties, producible shallow gas, associated with these anomalies (*bright spots*) was proven by several wells. For a long time these fields remained undeveloped because of expected sand production and early water breakthrough in the highly permeable, unconsolidated sands. Only as late as 2007 did Chevron develop the first offshore shallow gas field A12-FA using innovative sand control measures in horizontal wells (Chevron, 2009). Nowadays there are three successfully producing shallow fields in the area whilst additional accumulations are being developed or studied by several operators.

As the state participant in exploration and production in the Netherlands EBN B.V. has assessed the potential of shallow gas in the Dutch North Sea. This has resulted in preliminary total volume estimates of 36 - 118 bcm GIIP of which at least 50% recoverable. This sizable resource base, together with the recent development successes of the shallow play and a marginal field tax incentive, is raising a lot of interest from the industry.

The present study highlights the advances in the shallow gas appraisal work and includes an improved bright spot characterisation scheme. The focus is on the seismic expressions relating to the amplitude anomalies in order to select those leads that have highest potential for development. Several of the seismic features have been modelled to improve the understanding of their relation with gas saturation. For prospective bright spots, a volumetric assessment is performed resulting in factsheets that can be used as a starting point for detailed exploration. One of these prospects with well-expressed diagnostic features pointing towards the entrapment of shallow gas is presented as a case study.

Background

Geological Setting

In the context of this study, shallow gas is defined as gas in unconsolidated Cenozoic sediments under relatively low pressures. The accumulations most often occur in the northern Dutch offshore area above the Mid-Miocene Unconformity situated over salt domes. The sediments are part of a large fluvio-deltaic system, often referred to as the *Eridanos Delta*, which developed during the Late Cenozoic (Overeem et al., 2001). Clean sands, sealed by shales, form the reservoirs which typically range in depth from 300-800m below a water depth of some 40m. Generally it is thought that the gas has a biogenic origin which corresponds with the fact that most gas samples are almost pure methane.

Shallow Gas Developments in the Dutch Offshore

There are three producing shallow gas fields in the Dutch offshore area; A12-FA (since 2007), F02a-B-Pliocene (since 2009), and B13-FA (since 2011) (figure 2). Expandable sand screens and gravel packs as part of the well design have been proven successful in sand handling. So far no problems with water production have been encountered. The reservoir sandstones have porosities of 20-40% and generally high permeability. Reservoir thickness is typically in the range of 5-20m and pressures are 50-80bar, which is close to hydrostatic. Gas saturation in the producing reservoirs is ~55-60% and expected recovery factors range 60-75%. Development of five more fields is under consideration.

Seismic Characteristics

The presence of gas in a shallow trap causes a strong decrease in acoustic impedance, easily recognized on seismic data by amplitude anomalies, or *bright spots*. The gas is typically trapped in anticlinal structures above salt domes, sometimes fault-related, and often multiple stacked reservoirs are observed (figure 1). Brightening might also be the result of low gas saturations (residual gas) as demonstrated by several wells, or by lithology effects (including peat). Brightening conforming to structural closure is regarded as a positive indication of gas. However, there are many other seismic characteristics that can be used to localize prospective leads. These have been included in this study. A very pronounced indication of gas is a *velocity pull-down:* an apparent structural low underneath gas bearing strata. Another feature is a (pseudo) *flat spot*, pointing out a gas-water contact (GWC). Frequently, a velocity pull-down is distorting the flat spot. If the gas sands are too thin, a flat spot might be absent, as was modelled in this study. Distorted seismic signature above and below bright spots suggest *gas chimneys*. Overlying gas chimneys might indicate seal breach, as do pockmarks observed on the seabed (Schroot and Schüttenhelm, 2003). It is believed that the sealing capacity of the overlying shales is limited and that the reservoir-seal system is kept in balance by some breaching. Gas chimneys below an amplitude anomaly might indicate gas charge from deeper regions, often along faults. Subsequently, *seismic attenuation* or dimming effects can sometimes be observed. Finally, *tuning* due to interference of reservoir and GWC reflector, and *polarity change* is occasionally seen at the edge of the bright spot. All these observations, calibrated with actual well results, are used to assess the Probability of Success (POS) for the shallow leads.

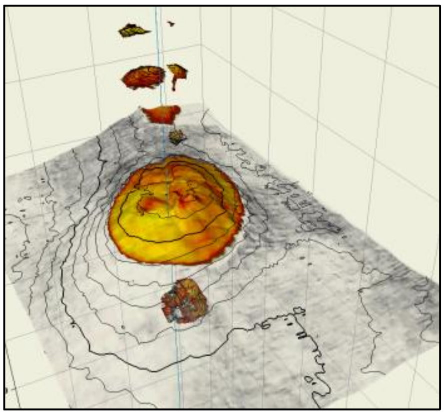

Figure 1 *Time contour map with imposed seismic amplitude of a bright spot conform to structure (650ms, 10km^2) in the Dutch offshore F-blocks. Minor overlying bright spots are also shown.*

Shallow Gas Inventory

The focus of this study is the Northern part of the Dutch offshore sector (A-H blocks) (figure 2). This ~24000km^2 area is mostly covered by 3D seismic data, including the new 3D Multi Client Survey over the DEF blocks (Fugro, 2012). Moreover, ample 2D seismic is available as well as several multi-component OBC lines. Some 200 wells have been drilled in this area, mostly for deeper targets.

Bright Spot Identification and Characterisation

Some 160 bright spots have been identified, partly using automated 3D amplitude scanning technology. A bright spot characterisation system based on trapping system, depth and size was developed in order to assist in a first pass ranking of the leads (figure 2). Whereas this characterisation scheme is helpful in selecting potential accumulations, the gas saturation remains the main challenge, because of the non-linear behaviour of seismic P-wave velocity with saturation. Moreover, few bright spots have been drilled so far, because shallow gas was long considered a drilling hazard and bright spots were preferably avoided while aiming for deeper targets. In order to get a better grip on the prospectivity of the amplitude anomalies, the previous bright spot characterisation system has been extended to include the following key (seismic) characteristics:

1. Trap type
2. Number of stacked reservoirs
3. Presence of velocity pull-down
4. Depth
5. Presence of flat spot
6. Vertical relief
7. Seismic attenuation
8. Presence of gas chimney
9. Areal dimensions
10. Gas shows (if drilled)

Each bright spot is analysed individually based on those parameters and presented in radar plots. Figure 2 shows examples of the characterisation of two prospective leads. Scaling is chosen such that the greater the green area in the plot, the higher the prospectivity of the amplitude anomaly.

Shallow Gas Potential & Opportunities

Almost 40% of the Dutch offshore area has been screened so far and a first inventory of shallow gas pointed out volumes of 36 - 118 bcm GIIP and 18 - 62 bcm UR. Currently, 160 shallow leads have been identified of which some 30 are considered attractive including 12 leads in open acreage. Fifteen leads have been analysed in detail so far, including lead F04/F05-P1 and F07/F10-P1 (figure 2) with (upside) volumes in excess of 5 bcm GIIP each (Van den Boogaard & Hoetz, 2012). Additionally, the current work includes the subsurface work on shallow prospect F12-Pliocene-Alpha, evaluated by Oranje-Nassau Energie in 2010-2011.

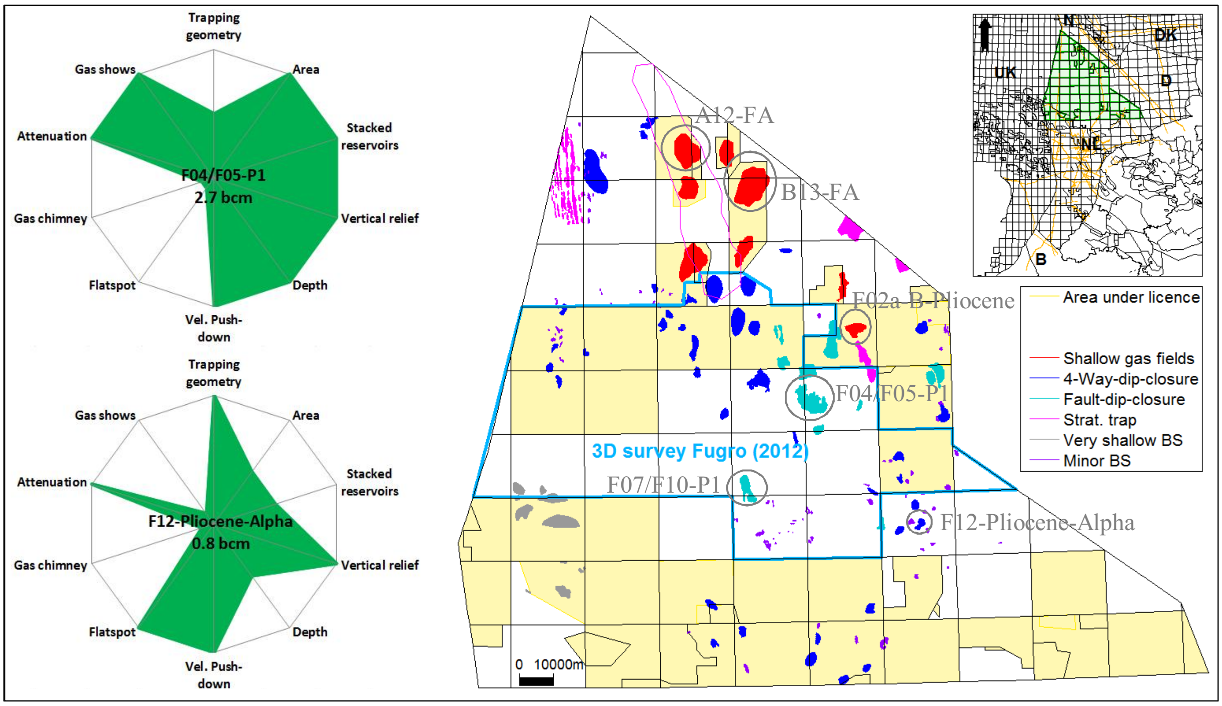

Figure 2 *Right: Shallow gas fields and leads in the study area, colour-coded based on the bright spot characterisation system. Left: Radar plots indicating how individual leads are characterized. Volumes represent P50 GIIP.*

Case study F12-Pliocene-Alpha

Block F12 hosts several excellent examples of bright spots. Although none of these have been drilled yet, they rank relatively high in the bright spot characterisation scheme based on their seismic features. *F12-Pliocene-Alpha* (figure 2) is a promising prospect showing a clear amplitude anomaly conforming to a structure with a crest at 515m MSL and a relatively high gas column of 45m. It is surrounded by three satellite bright spots at the same stratigraphic level. Offset wells targeting deeper reservoirs indicate the presence Pliocene reservoir sand with a thickness of ~50m locally.

Seismic Characteristics

The amplitude anomaly overlaps with the closing contour suggesting that the structure is full-to-spill. The local difference between amplitude switch off and closing contour depth is explained by a tuning rim as shown on a common contour stack. Underlying the amplitude anomaly is a flat spot that shows a depression and dimming below the apex of the structure (figure 3), which can be readily explained by lower internal velocities. The flat spot is interpreted as the GWC indicating that the sealing capacity of the top clay is sufficient, although small bright clouds over the crest of the accumulation might be interpreted as venting of the top seal during geological time. The termination of the flat event coincides with the extent of the amplitude anomaly as well as with the structural closure. These characteristics result in a low perceived risk towards the presence of a gas-bearing reservoir. A property model was developed from which a gas sand velocity of 1200m/s was calculated required to cause the pull-down of the interpreted GWC. This velocity cannot be used to estimate gas saturation as the velocity effect in gas bearing sands is relatively insensitive to saturation. The structure is however full-to-spill and with a 45m column, gas saturations in the range of 50-65% are considered likely. In addition, the relative high relief closure decreases the probability of a significant transition zone.

Volumetric Assessment

Based on time-depth pairs from checkshot data a layer-cake model has been set up from which probabilistic volumes are calculated using a Monte Carlo approach in which uncertainty ranges based on analogue fields and offset wells are taken into account. Calculated GIIP amounts to 0.6-0.8-1.1

bcm (P90-P50-P10). Having established a POS of 75%, with the only risk considered to be the sealing capacity, this prospect has large potential. The main challenge is the relatively small volume in relation to the distance to existing infrastructure. Considering development in combination with other leads in the region makes it a very interesting area to explore.

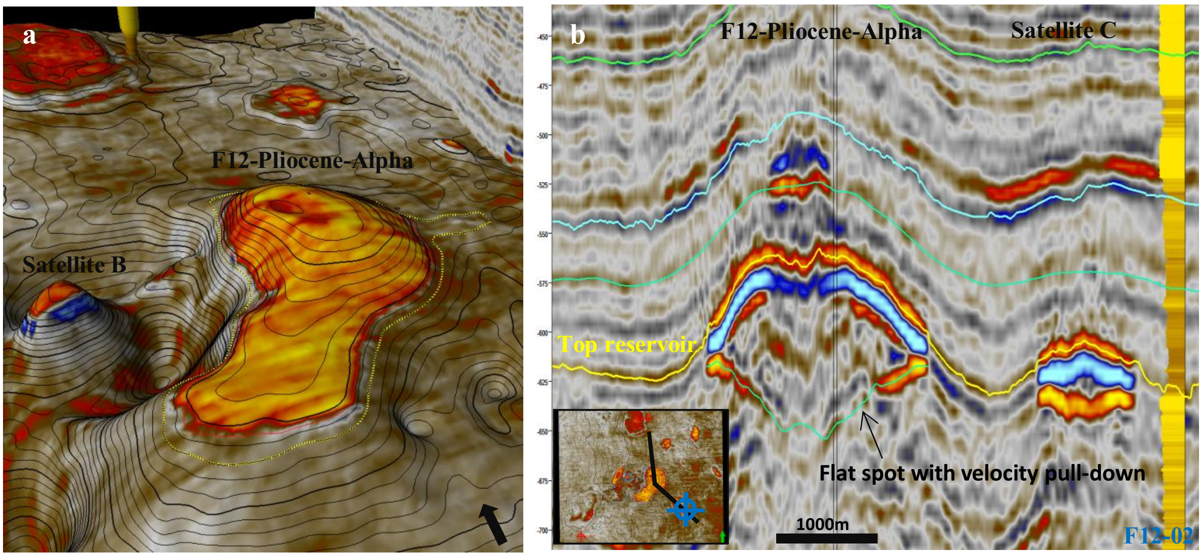

Figure 3 *a) Time contour map with imposed seismic amplitude of bright spot F12-Pliocene-Alpha (5km^2). b) Seismic line (TWT) through F12-Pliocene-Alpha, its satellite C and well F12-02 (GR).*

Conclusions

Since the discovery of shallow gas in the northern Dutch offshore in the seventies, these accumulations raised much interest. Nowadays, cost-effective techniques for development do exist and there are three fields successfully operated in the Dutch North Sea area. EBN B.V. has estimated significant potential for the shallow play in a first inventory and the current study includes the follow-up of a bright spot characterisation that now includes several key seismic properties for each lead, in order to get a better grip on their potential. Some 160 leads have been identified in offshore blocks A-H of which 30 are considered attractive. A case study is presented of a 4-way-dip closure bright spot with well-expressed diagnostic features pointing towards the entrapment of shallow gas, a POS of 75% and volumes of 0.6-1.1 bcm GIIP. In combination with the other accumulations in the region, this F12-Pliocene-Alpha prospect warrants further investigation.

Acknowledgements

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