EBN’s HC Show Database:

Correlating HC Shows with structural attributes

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Abstract

The Dutch subsurface represents a mature area for hydrocarbon exploration. In light of future exploration activities, research and geothermal projects, well-organized HC Show (HCS) data and integration of different data formats is highly valuable. HC Shows are already observed during the drilling and testing phase, but their value in follow-up exploration is often underutilized. Besides indirect hydrocarbon indications from wireline logging (resistivity), direct evidence of HC occurrence can generally be observed in mudlog-, core- and test data. These Direct Hydrocarbon Indicators (DHI) are rarely comprehensively accessible via the integrated platforms and are often provided in non-standardized data formats.

To enable an easily accessible overview of HCS occurrence in the Dutch subsurface, EBN designed and developed the **HC Show Database**, whereas a sophisticated workflow allows the integration of the different data formats. A well-structured classification approach ensures the analysis of each defined stratigraphic level along the borehole trajectory. Classification of encountered HCS and subsequent implementation via multiple visualization tools generates an overview of (potentially) mobile HC occurrence in the Dutch subsurface.

The HC Show Database is currently in a phase where its applicability to research can be tested. A significant amount of boreholes is analyzed and good coverage of the Dutch Northern Offshore is established. By employing different visualization techniques, extracted data from the HC Show Database can be used for specific research in the Upstream oil industry.

Alongside expansion of the dataset and refining and improving the workflow and visualization set-up, the main objective of this particular research is testing the applicability of the database in exploration. This is achieved by the means of an analysis of HC Shows from the Shallow Gas play. Indication for shallow gas presence in the subsurface is given by the occurrence of seismic amplitude anomalies. The gas saturation at these bright spot levels is considered one of the main key uncertainties, but actual statistics are lacking. With use of HC flow tests, being part of the HC Show Database, a semi-quantitative analysis is conducted to quantify the relation between amplitude anomalies vs. gas saturation. Eventually, shallow gas leads identified in the Dutch sector can be de-risked in terms of saturation by the statistics produced here.

Promising results from integrating other datatypes such as DHI's demonstrate the value of the HCS database for exploration and research purposes. Therefore, EBN's long-term aspiration is to roll out the HCS Database to its partners as a (interactive) visualization tool via an external Spotfire interface. Development of this new tool will be comparable to EBN's GDE-Database tool and its release is currently expected by the end of 2018.

Table of contents

1. Introduction

In the past few decades, exploration in the Dutch subsurface has led to numerous discoveries of hydrocarbon oil and gas accumulations. Although not every well drilled is successful in terms of producible hydrocarbons, and commerciality, all gathered well data are highly valuable in light of future exploration activities and research.

Well data are generally stored in standard data formats and openly accessible through the TNO NLOG website. However, the key enabler to successful exploration is not just the availability of data, but the integration of different data sources. Although multiple data formats are provided per borehole, Hydrocarbons Shows (HCS) observed during the drilling and testing phase are often underutilized. HCS are defined as significant occurrences of HC gases or fluids combined with lithological alterations *(Yassin, 2012)* and can generally be observed in mudlog-, core- and test data. They provide a direct reference to hydrocarbon presence and constrain exploration-related properties such as charge, reservoir size, permeability and seal integrity. Whilst HCS data is generally provided in non-standard data formats and capturing this data in a database is not trivial, this information is rarely comprehensively accessible via integrated interpretation platforms.

In the past few years, EBN has developed a detailed workflow allowing the integration of all available well data related to (direct) HCS occurrence (mudlog-, test- and core data) from on- and offshore wells in the Dutch subsurface. In the 'EBN HC Show database', the relevant HCS observations at each stratigraphic interval encountered along a borehole trajectory are incorporated. Integration of these different data types in combination with a semi-quantitative classification tool eventually allows the assignment of a general HC classification to each interval. Throughout the course of the HC show database project, implementation of this data with multiple visualization tools (QGIS, Spotfire and Petrel E&P Software) has been established. Easy accessibility of HCS data is provided through these different visualization techniques, generating an overview of potential mobile HC occurrence in the Dutch subsurface.

Multiple interns *(Chris Heerema, Youri Kickken, Claudia Haindle, Constantijn Blom and Jan Westerweel)* have contributed to this project and continuous improvements and expansion of the database and workflow have led to the development of a powerful exploration tool. Especially in recent times, where exploration in the Dutch subsurface becomes more challenging and fields show declining production due to increasing maturity, advanced analytical techniques need to be established to support future exploration. A comprehensive overview of HCS data can be of great use for the explorer, whereas it also opens possibilities in terms of applicability to general research. Because EBN acts in the interest of the Dutch petroleum industry, the aspiration is to share this HC show information with its partners using advanced visualization technology.

The HC show database is currently in a phase where its applicability to research purposes can be tested. A significant amount of boreholes (>650) has been analyzed and good coverage of the Dutch Northern Offshore regions is established. By employing different visualization techniques, data extracted from the HC show database can be used for specific research, which will be the main objective of this particular internship.

1.1 EBN's HC Show Database

General goal

The trigger for designing the EBN HC Show Database came by the realization that there is a general requirement for systematically evaluated HC show data. The basic data is openly available, but generally hard to access in a consistent way. We can learn a lot from existing drill- and test data and therefore this database has been developed with the aim to provide an easily accessible overview of all HC observations in the Dutch subsurface.

For this database, the focus remains on direct HC indicators which are HC shows observed from mudlog-, test- (DST and RFT samples) and (sw-)core data. HC show evidence derived from resistivity logs are therefore excluded as it is considered an indirect HC indicator. The real challenge for deriving HC show evidence remains in the integrating and harmonization of these different data types.

Previous work

The initial inspiration for the HC show database came from a HCshow.xls spreadsheet provided by the NAM. This spreadsheet contained HC show evidence from a limited number of boreholes using limited datatypes. Realization that there was an overall requirement for easily accessible HC show evidence led to the initial EBN HC show database design. The first stage of database design was established by *Heerema (2016).* Whereas the development of classification schemes and a general workflow played a significant part of the development. From that moment onward, several interns have contributed to the set-up and refinement of the database *(Youri Kickken, Claudia Haindl, Constantijn Blom and Jan Westerweel).* Detailed information on their individual contributions can be found in the according reports.

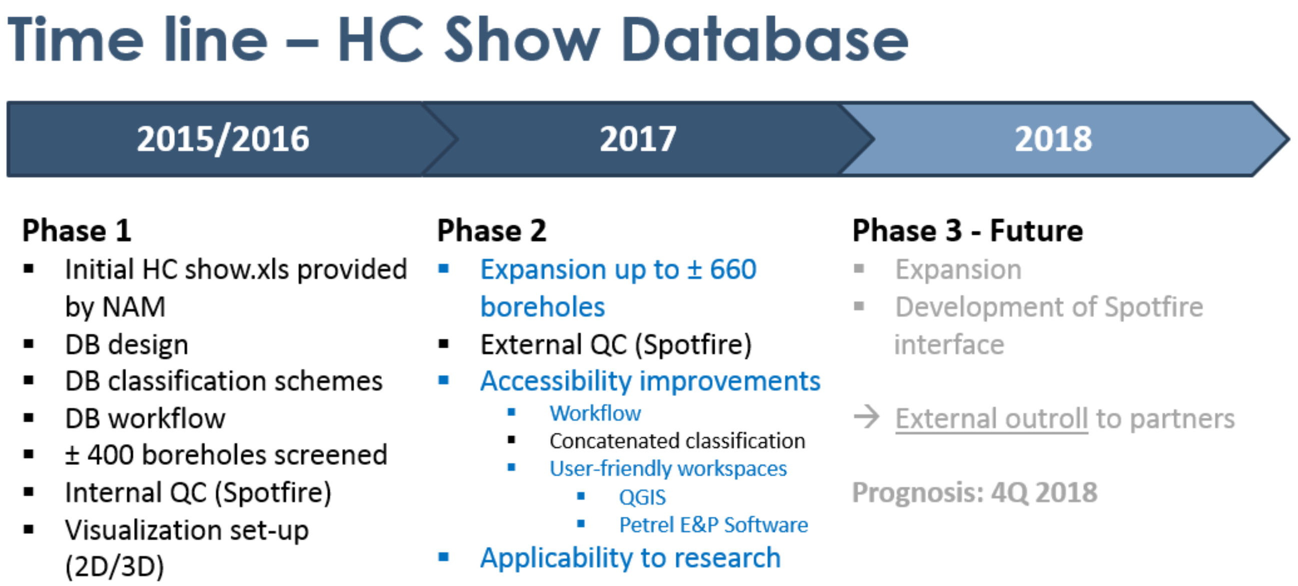

Figure 1. HC Show Database – time line (3 phases)

Figure 1 shows the overall time line of database-development, going from the initial start-up in phase 1, the refinement and applicability focused phase 2 and the aspirations for the future as set in phase 3. ***Steps that are completed are indicated in black, steps that find their (partial) contribution in this internship are appointed in blue and steps that are planned in the future are assigned in grey.***

As mentioned, the database initiated from the provided HC show spreadsheet by the NAM. A comprensive database design addressing all direct HC data observations and a classification methodology with a robust workflow defined the basis of the EBN HC show database. With this framework in place the first batch of boreholes was analyzed in detail for records of Hydrocarbons. Internal QC *(Heerema, 2016)* showed a good correlation between mudlog- and test data derived HC shows, which confirmed the overall approach to be consistent. Based on these results, a first visualization set-up was created for the QGIS and Petrel interfaces *(Kickken, 2016).*

During the second phase, the focus was mainly on accessibility refinement and applicability testing. The Spotfire interface was utilized for extensive internal QC as well as external QC (i.e validation with other data sources including Panterra's

Missed Pay Analysis (MPA), TNO Gas Composition Database and Total Pressure Database) *(Blom, 2017; Westerweel, 2017)*. Results proved that the quality of the database is high and that Spotfire is the correct tool to analyze large datasets, suitable for both internal and external QC. Because at this stage the data types could only be visualized separately, an integrated classification was introduced to provide a consistent and quick overview *(Westerweel, 2017)*. This **'concatenated classification'** generates the 'best' classified (i.e. most representative) show label based on the available mudlog-, test- and core data shows and gives you the overall result at a certain stratigraphic level. According to this newly introduced HC Show category, symbolization needed to be adjusted in order to visualize the data in a consistent manner *(Westerweel, 2017)*.

This internship is part of the second phase and addresses the extension of the database, accessibility improvements. In addition, as a research application for the HCS database, this intership investigates the relationship between HC Shows and certain seismic structural attributes. Each element will be explained separately in the following sections.

Eventually, the long-term aspiration is to make the HC show database available to external partners via an external Spotfire interface. The idea is to do this in a similar manner as has been done with the GDE-Database *(Kuiper, 2016; Baud, 2018)*. The third phase will mainly address the development of the Spotfire interface and the external outroll at the end of 2018 (prognosis).

Workflow (box model)

Figure 2 shows a refined version of the initial workflow *(Blom, 2017)*. A subdivision is made between input data from NLOG and the internal EBN server and the output in multiple visualization set-ups. Different steps are appointed, whereas some actions are automatically generated and some need to be manually adjusted. Further on in this report, a refined visualization of the workflow will be presented to further detail the different steps of HC Show analysis.

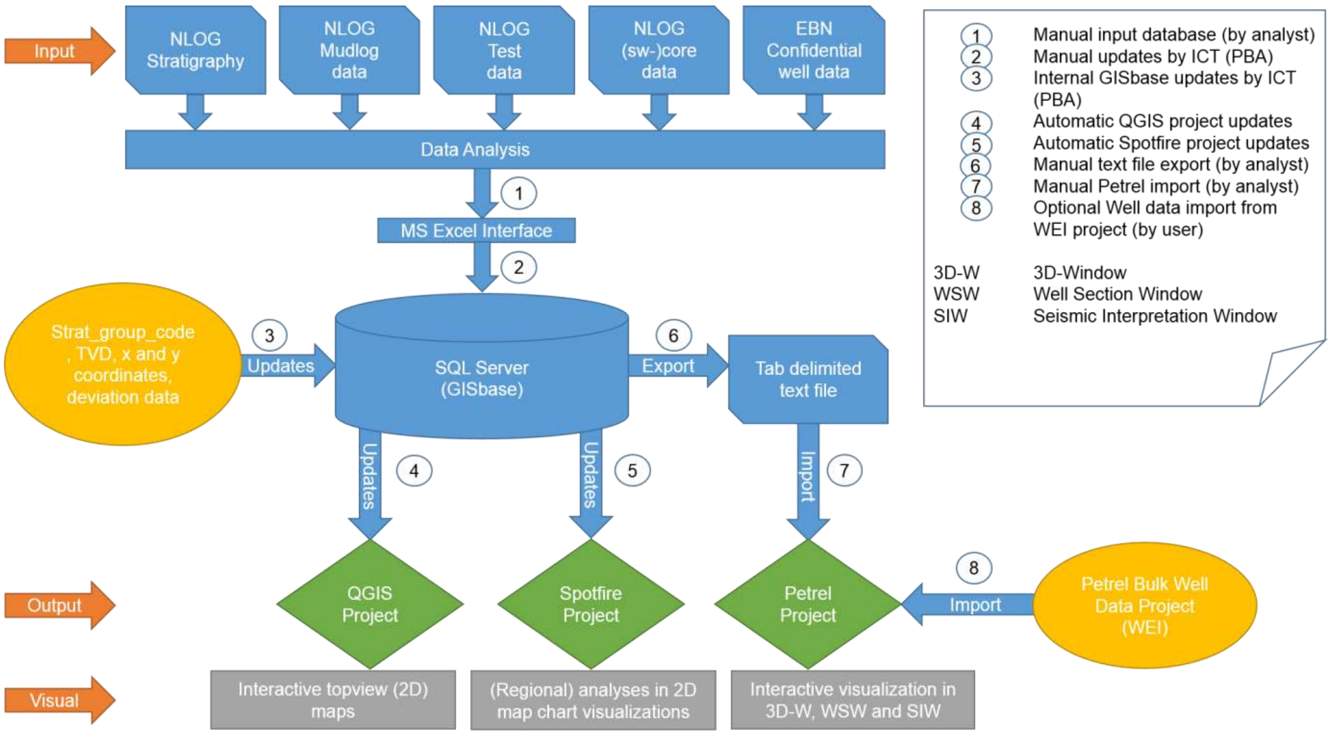

Figure 2. Box-model of the HC show database workflow (Blom, 2017).

1.2 Project goals

At the beginning of this internship, the database consists out of 584 analyzed boreholes from the A-H, M, N and L quadrants of the Dutch offshore and 49 onshore boreholes. Besides the goal of further expanding the database and adding boreholes to the overall dataset, it is the intention to refine the workflow, improve the visualization set-up and test the database-applicability for research purposes (figure 1. blue highlighted sections).

During this study, database applicability is the main purpose. The initial goal was to introduce a new seismic attribute and testing how it can be used in a structural analysis. By classifying trap geometries, a general relation between structures and HC show occurrence can be established, which is useful information in exploration. However, an internal project at EBN presented itself. This shallow gas project initiated a shift in the main focus of the internship from trap geometric analysis to a shallow gas analysis. The main focus is still based on structural analysis, but the underlying topic of the project changed. Furthermore, the applicability of the database is also tested in a situation outside the Dutch sector. Analyzing the newly drilled UK Sillimanite well shows the scope of the database and reveals possible problems.

During this internship, multiple topics are addressed. Each topic will be separately introduced and discussed. If relevant, the generally handled methodology and results will be presented. A short discussion will conclude the different sections, possibly opening-up possibilities for further research or refinement.

2. HC Show Database

2.1 Database expansion

The initial goal of the database was to provide good coverage in the Dutch Northern Offshore region. However, this study area over time extended to the more southern located license blocks L, M and N. Moreover, it was decided to incorporate the onshore boreholes, potentially useful for upcoming geothermal projects. Continued extension of the database is important as it ensures a better coverage of the Dutch subsurface in terms of HC show evidence.

At the start of this internship, a total of 633 boreholes were analyzed. Expansion during this project mainly focused on the D, E and F quadrants, as this was also the focus point of the follow-up structural analysis. Most boreholes in that region were already analyzed, however, a significant number needed to be revised for several reasons. Besides these 3 quadrants, an internal EBN request required the evaluation of 2 boreholes from the Q license block. And in addition, the coverage in the onshore region also needed to be extended.

For a detailed description of the analysis workflow and the used classification rules; a revised workflow can be found in Appendix 2. Here, only a short description will be provided on the overall analysis process.

As mentioned, the evaluated data types incorporating direct HC indicators are:

- *Mudlog data*
- *Test data (DST and RFT samples)*
- *Core data (barrel and sidewall cores)*

In first instance, HC shows are evaluated according to mudlog observations. For each stratigraphic interval, the most significant increase in HC concentration (gas chromatography: C1-C5 levels) with respect to the established background (*peak to background ratio*) and associated lithology (*porosity and permeability*) is determined. These observations are in turn confirmed by the test- and (sw-)core data *(Crain, 2015;* Verçan*, 2010; Yassin, 2012)*. Classification is according to the maximum measured flow rate in the testing phase. For RFT samples the (sw-) core data generally contains only evidence for oil show occurrence. However, in some rare cases, also indications of gas can be observed. Because coring can have a negative effect on the release of gas while drilling and hence mudlog readings, this data type is also considered complementary to mudlog data. The classification of cores revolves around a detailed show description, HC show continuity and the related lithology.

In total 59 additional boreholes have been analyzed in this study and these results are incorporated into the database. From this batch, 26 boreholes are located onshore and the remaining 33 are localized in the D, E, F and Q quadrants, as mentioned. From the offshore selection, 30 boreholes were already included the database but lacked certain data and needed to be revised. This had multiple reasons, for instance, confidentiality issues (5 years), unreadable files or a general lack of data from the operator. With this revision and the 3 newly added boreholes, complete coverage of the D, E and F region has been established. By adding the newly analyzed boreholes to the existing dataset, a total of **662 boreholes** are currently covered by the database, of which 587offshore and 75 onshore boreholes. Figure 3 shows the coverage over the different regions, whereas figure 4 shows the coverage of analyzed boreholes against the total number of drilled boreholes (sorted by spud date). Although there is still a long way to go and analyzing wells is a time-consuming process, already a good and representative coverage in the Dutch Northern Offshore region is established.

An overview of the current coverage in terms of boreholes in the HC show database is incorporated in Appendix 1.

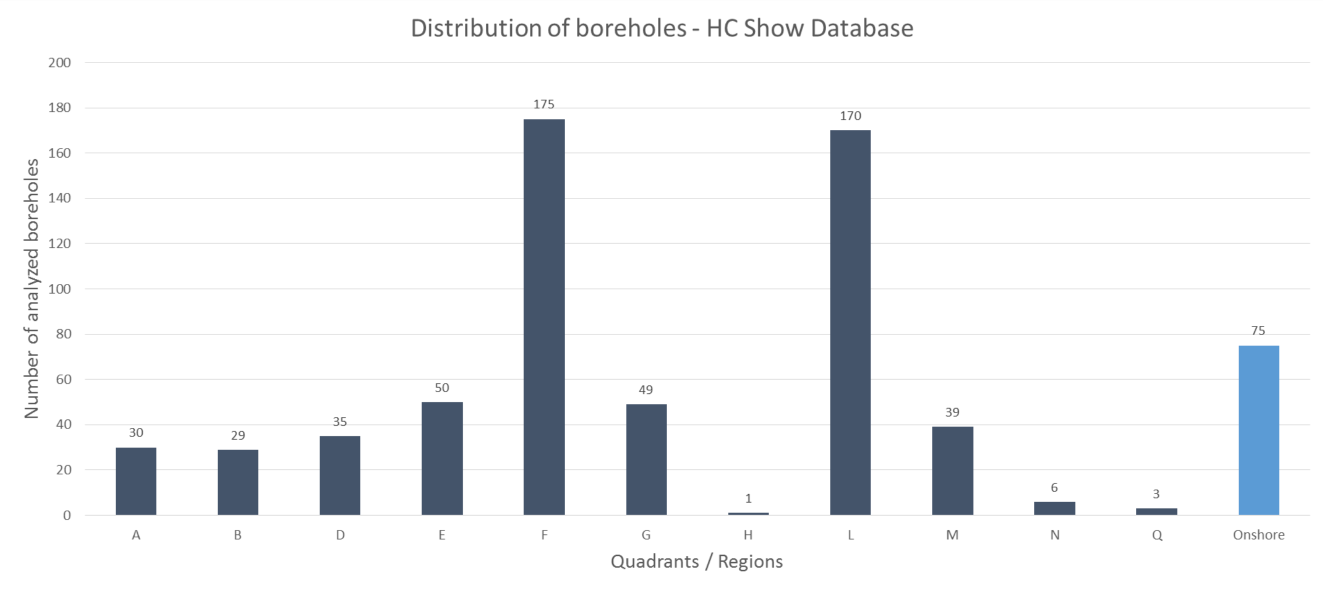

Figure 3. Distribution of analyzed boreholes in the HC Show Database – Dutch license blocks (reference figure 19).

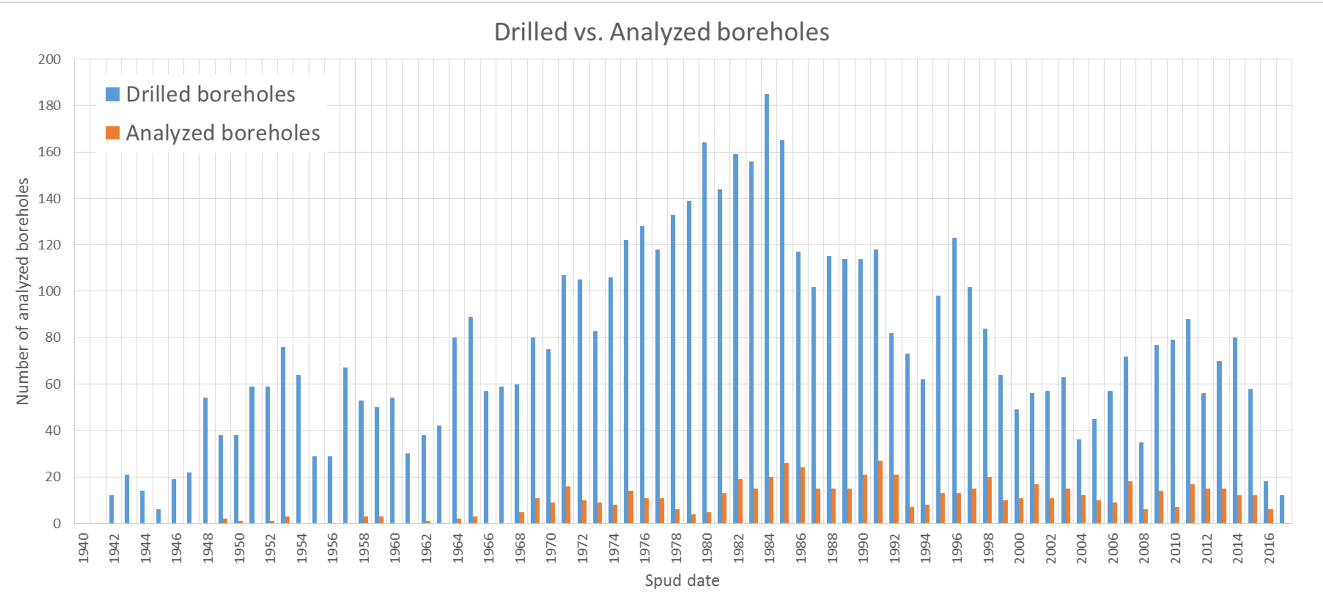

Figure 4. Coverage of analyzed boreholes vs. drilled boreholes – organized on spud date.

2.2 Updated workflow (box-model)

Because the overall workflow and according box-model already have been refined multiple times, only minor adaptions have been made to create a clearer overview (figure 5). A clear distinction has been made between the input-, storage- and (visual) output stages in the workflow around the HC show database.

The input section shows the different data sources from which data incorporated in the database is extracted. Most data is derived from NLOG. After a confidentiality period of 5 years, data from operators becomes publically available and accessible for every user. If certain boreholes are still in their confidentiality phase, data is generally derived from the internal EBN data sources. For future roll-out to external users, confidential data will be filtered out. The subsequent data analysis is a manually process which follows the well-defined analysis workflow as presented in Appendix 2.

The database working environment is a large excel spreadsheet, which is occasionally manually uploaded onto EBN's local SQL Server. This server provides the necessary means for the overall storage and the coupling with generic well data.

Automated updates from the SQL server allow data visualization in the QGIS and Spotfire applications, whereas visualization in the Petrel interface is possible after manual input of specific data (text file). In the latter case, the user has the option to start with a pre-set Petrel project with the all available Bulk Well data from the entire Dutch subsurface (available at EBN).

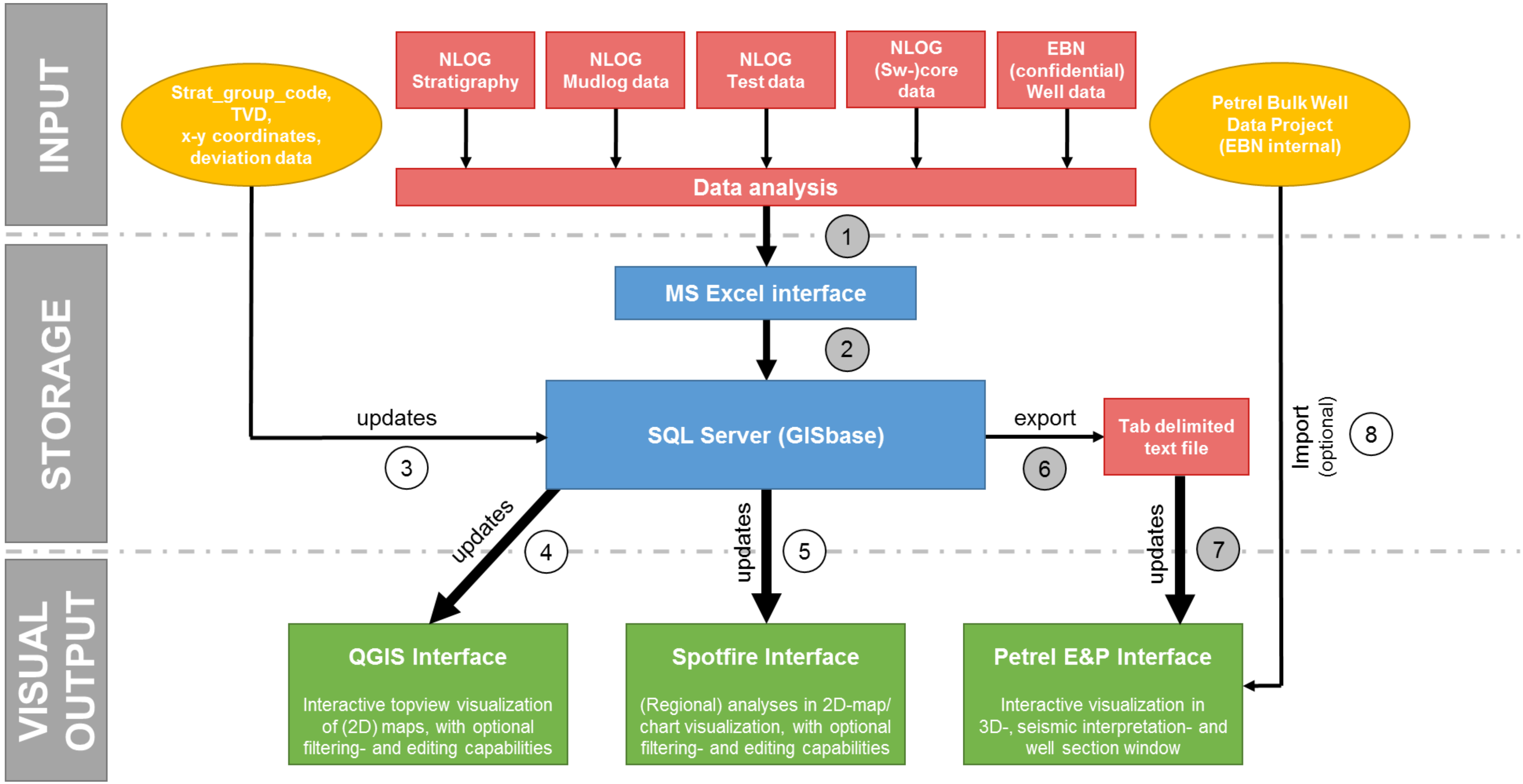

Figure 5. Updated box model of general workflow for the EBN HC Show Database.
Subdivision has been made between the input-, storage- and visual output sections. In grey, the manual actions are indicated, while in white, the automated updates are assigned.

2.3 Database applicability

Visualization

The applicability of the HC show database is to a large extend a matter of effective visualization. As already mentioned, HC show data can be visualized in both 2D and 3D with the use of different applications.

For 2D visualization, mainly Spotfire and QGIS interfaces are used. Spotfire is extremely powerful in the process of analyzing large data sets, and is therefore used for the internal and external QC in the current database setting. The QGIS interface provides the option of interactive topview visualization in a (2D) map window. This interface contains multiple data filter options and allows the user to edit the settings according to personal preferences. Multiple data formats can be incorporated into the interface and combined with HC show data extracted from the database.

For more research related purposes, the Petrel E&P interface is an extremely useful application. A specific HC show data (sub)set can be manually imported as a text-file into a preset project, allowing interactive visualization in several window settings (3D-window, well section window and seismic interpretation window). Multiple additional data types can be integrated, such as, well log data and seismic, which might reveal underlying relations.

The possibility of visualizing data with multiple visualization techniques demonstrates that the HC show database has the potential to be a very useful tool in future exploration and research. Within this particular study, the applicability of the database and the use of these different visualization techniques will be tested on an in-house shallow gas project.

In-house use - EBN

Internal usage of the HC show database in EBN is already established. In the process of exploration or well planning, EBN occasionally appeals to the available HC show data. Focused data on drilling- and well testing phases in a certain area can be of great value in the process of exploring a certain area or in the planning phase of a well.

A specific example of the internal usage of the HC show database is a recent analysis performed in the Q quadrant. The area around the **Q10-02** and **Q07-01** boreholes needed to be evaluated. This detailed analysis was conducted to make an estimation of what hydrocarbons can be expected in that area. Therefore, the HC show database is used as one of the sources for data extraction. Results of the conducted analysis for these specific borehole selection are included in Appendix 3.

Across-border applicability

HC show database applicability does not necessarily has to be limited to the Dutch subsurface. Although this is the main operating/interest area of EBN the Dutch industrial E&P sector, applicability of the data set should not be limited by these borders. Therefore, a **pilot analysis** is performed on a recently drilled well on the border area between the UK and the Netherlands. Analysis of this joint industry project, of which EBN is a partner, should reveal the possibilities as well as the problems of across-border data analysis. In particular possible issues around data formats and coordinates were investigated.

3. Visualization optimization

3.1 QGIS visualization

Westerweel (2017) introduced a user-friendly and efficient GIS workspace where HC show data can be viewed easily by EBN employees without needing experience in QGIS programming. Visualization symbols were optimized for this cause and a pre-set general framework was introduced to enable a more efficient workflow in visualizing HC shows in the Dutch subsurface. Different data types can be visualized separately, but also simultaneously and HC shows can for instance be plotted at their wellhead- or subsurface position. Multiple filter options are presented to visualize different stratigraphic levels and relevant information about the associated gas quality (TNO Gas Composition Database) can also be included to complement the HC show data.

Building further on the existing workflow, some improvements have been implemented, which will be discussed in the following sections.

Refinement of user-friendly workspace

Several refinement steps address the user-friendliness of the workflow. Small adaptions have been made in, for instance, the ordering of different filter options, color coding/size of (concatenated) HC show symbols and the visualization of the legend. Previously, the legend numbering contained fractions, but these are now set as integers with a constant increment. This adjustment improves the readability of the maps. Furthermore, a preset backdrop of an overview map of the Netherlands is incorporated in the print-manager window.

An overview of the current interface with the recent implementations is presented in figure 6.

Confidentiality filter

For external use of the HC show data, it is necessary to have a build-in confidentiality filter. In QGIS, this is a manually implemented filter by programming code.

For each visualization tab in the right (option) window, a filter can be incorporated. By setting the code as written in Appendix 4, data from boreholes within their confidentiality period (completion date < 5 years) are filtered out. ***Note that this filter options should be implemented for each tab separately!***

A filter option in the earlier stages of data analysis (storage – SQL server) would be a more efficient option, however, the implementation of a certain filter is rather complex, so manual adjustment is recommended at this moment.

Stratigraphic domains – (pre)Perm vs. post-Perm

A number of visualization options in terms of stratigraphic intervals were already defined by *Westerweel (2017).* Data can be visualized in the **North Sea Supergroup,** the **Zechstein** and the **Rotliegend Formation.** However, these options do not cover all data and the only remaining option is to show all data simultaneously.

To allow the user to differentiate between HC shows occurring in the **(pre)Perm** stratigraphic formations and the **post-Perm** stratigraphic formations, an option is build-in to visualize this subdivision separately, but also simultaneously (figure 7a-c). This way, the user can easily discriminate between the subsurface section that is most interesting in terms of HC show occurrence and filter out the other interval.

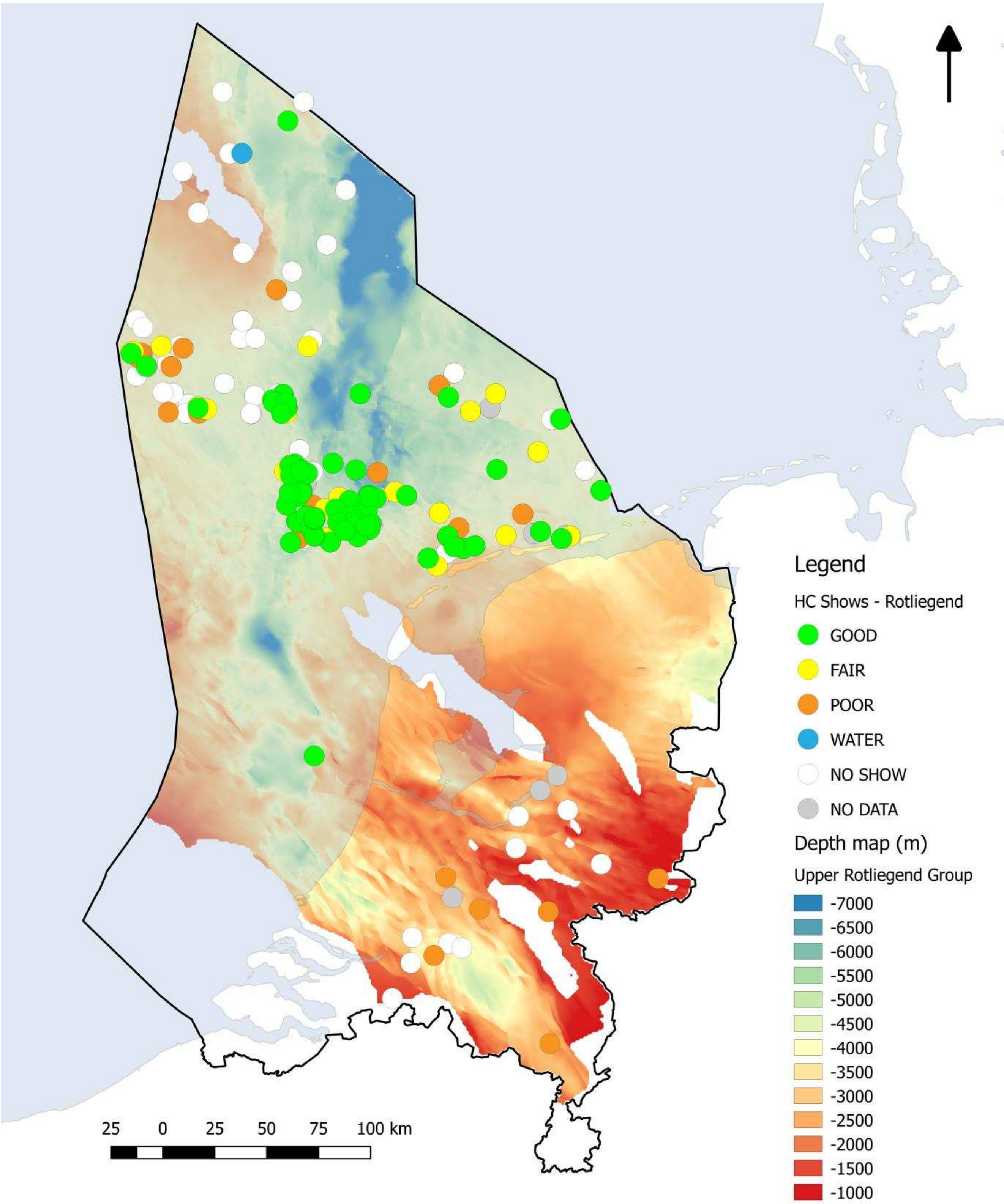

Figure 6. Overview of current QGIS interface and recent implementations.
Concatenated HC shows at the Rotliegend level projected on the Upper Rotliegend depth map (m).

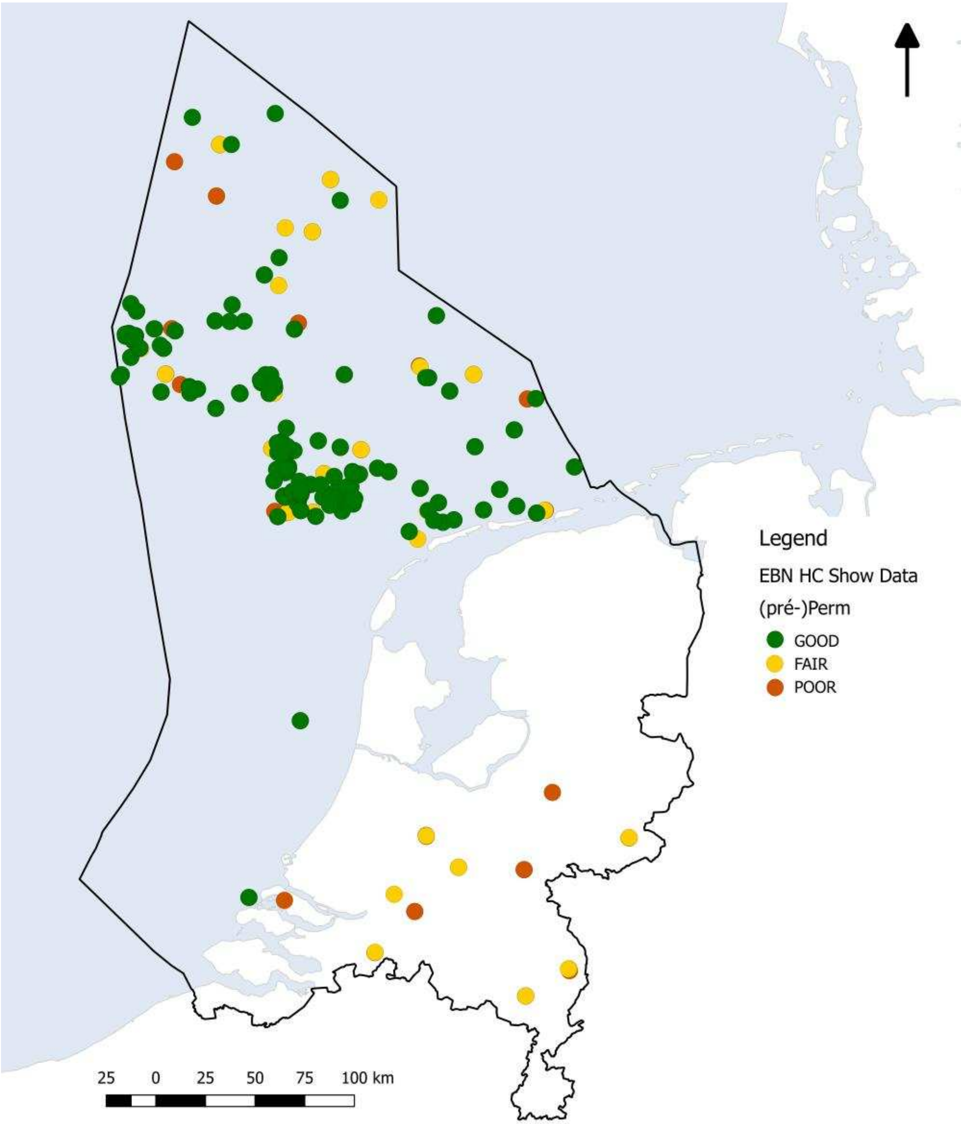

Figure 7a. Visualization of (pre)Perm GOOD / FAIR / POOR HC shows.

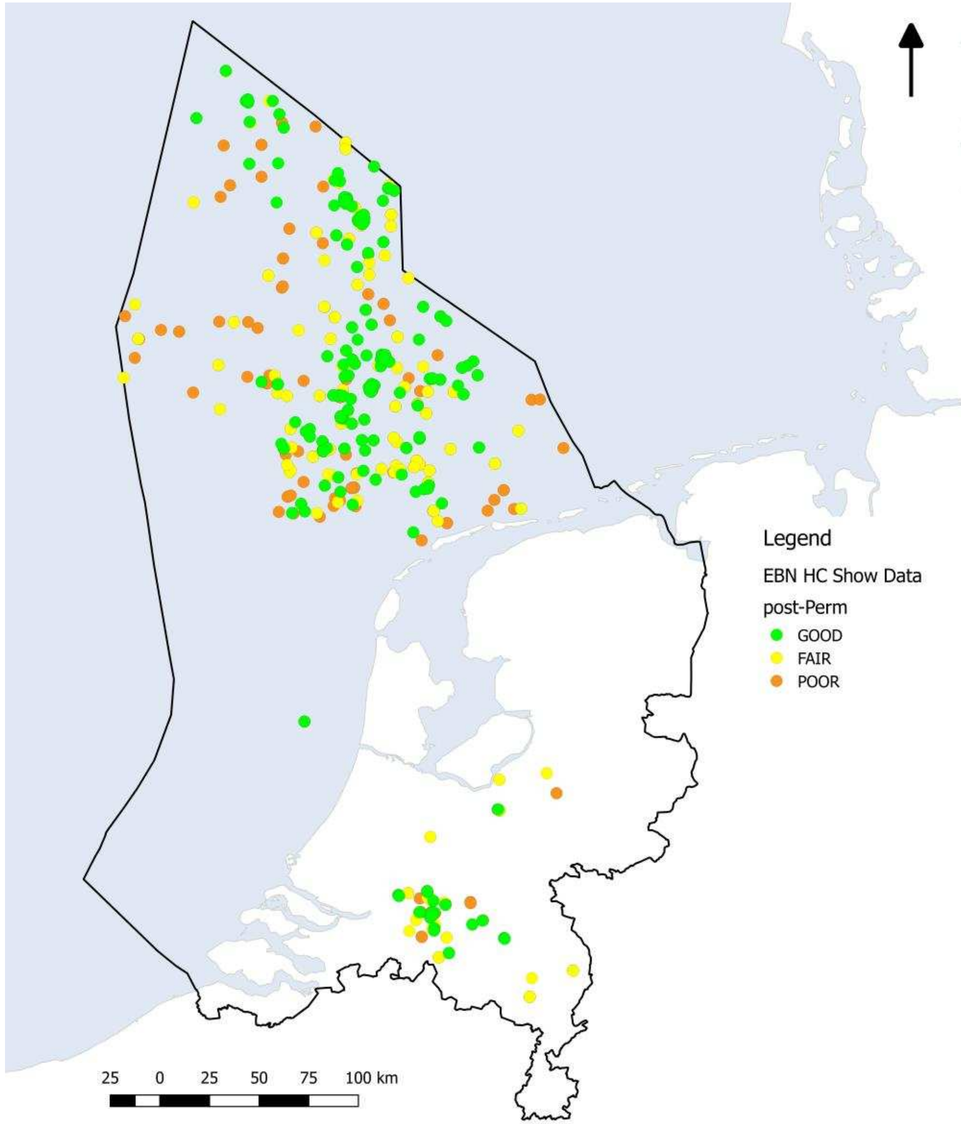

Figure 7b. Visualization of post-Perm GOOD / FAIR / POOR HC shows.

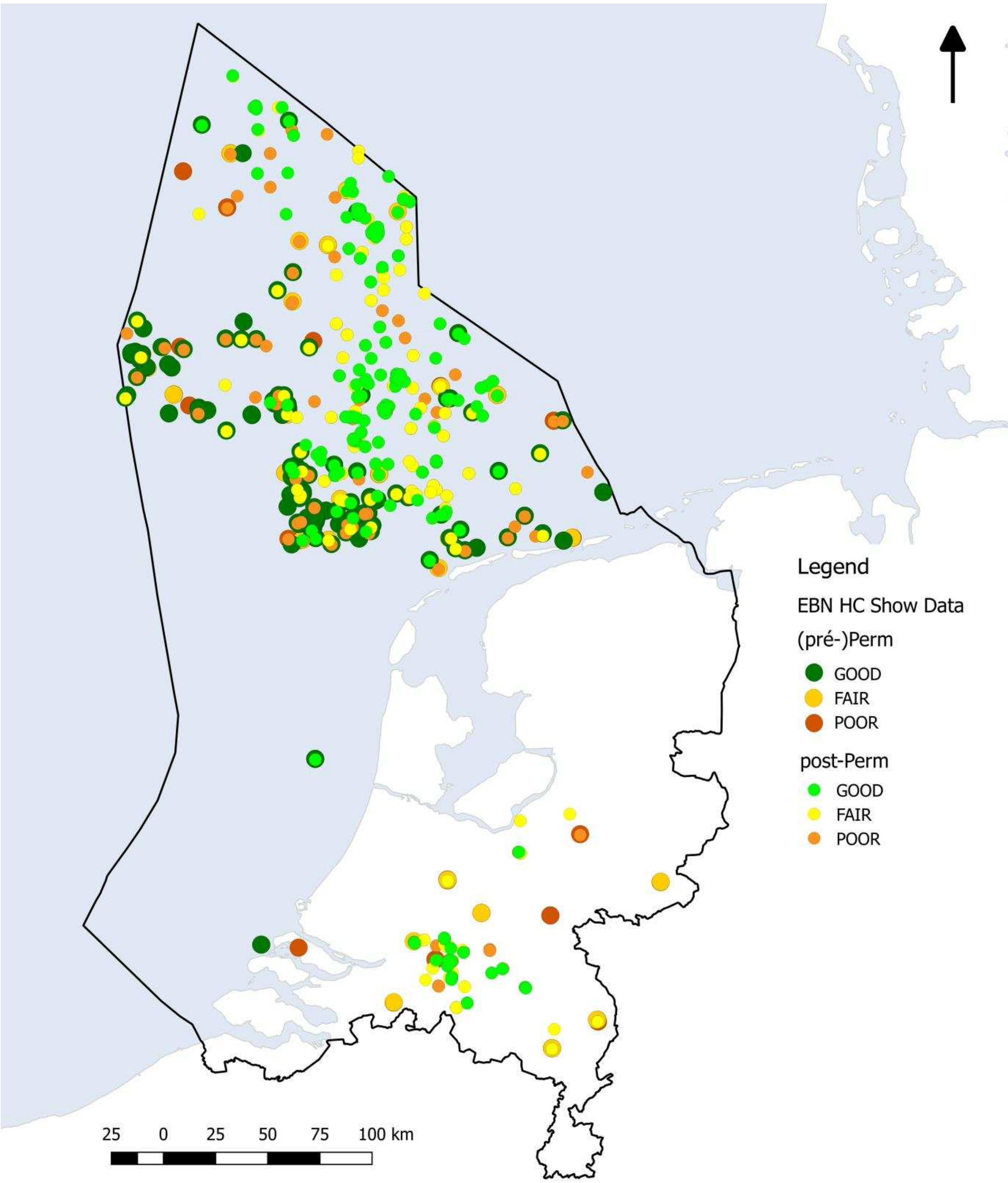

Figure 7c. Combined visualization of (pre)Perm and post-Perm GOOD / FAIR/ POOR HC shows.

3.2 Petrel visualization

The initial visualization set-up for HC show visualization in the Petrel E&P interface was established by *Kickken (2016).* For this particular study, adaptions in the initial workflow are necessary in order to visualize all the preferred data.
Each adaption will be discussed briefly in the following sections. Additional information on the general workflow and the exact steps and settings according to the adjustments can be found in an updated version of the Petrel visualization workflow via:

Import as well tops

In the initial set-up developed by *Kickken (2016),* the HC data set was imported as a point dataset. However, this import-setting has some limitations in visualizing the HC show data. Importing the data as **well tops** allows the user to make more adjustments and provides the possibility of **time-depth conversion**. In this way HC show data can be visualized along the borehole trajectory and projected on the according seismic x-section also in the time domain. This allows the user to relate HC shows to seismic features and draw conclusions on according relations.

Implementation of concatenated shows (label)

The concatenated classification is only recently introduced, and therefore its visualization was not yet established in the initial workflow related to the Petrel E&P interface *(Kickken, 2016).* Importing the according data set occurs in a similar manner as importing the separate data sets for mudlog-, test- and core HC shows, however, some additional adjustment need to be made in the different window settings.

In the preset Petrel project, the mudlog HC show data (oil and gas) and the concatenated show data is imported. ***Note that the concatenated data combines all HC show evidence and provides a classification according to the 'best' classified data type (Appendix 6).*** Color grading of the show classification occurs according to the set standards and each window option is provided with its own particular settings (Appendix 5). Multiple filters can be implemented to visualize a certain HC show classification or a certain group/formation.

Depending onthe additional concatenated data, visualization in the well section window requires some adjustments in the settings. This window plots the **oil (color-coded red)** and **gas (green)** class according to the mudlog HC evidence, however, the **concatenated class (black circle)** only refers the dominant HC type at that particular level. Two examples are provide in figures 8a and 8b.

Figure 8a shows that if both oil and gas have been observed at a certain stratigraphic level, the black circle indicates the 'best' classified show type (i.e. concatenated show) at that level. In this case, this is the GOOD classified gas show. However, some interesting situations might evolve from incorporating the concatenated class. In figure 8b it is visible that although the mudlog HC evidence might classify a certain show as FAIR, the test and core data might have a positive effect (i.e. higher quality show) on that classification label. This eventually results in a higher HC show classification (GOOD) as appointed by the concatenated class.

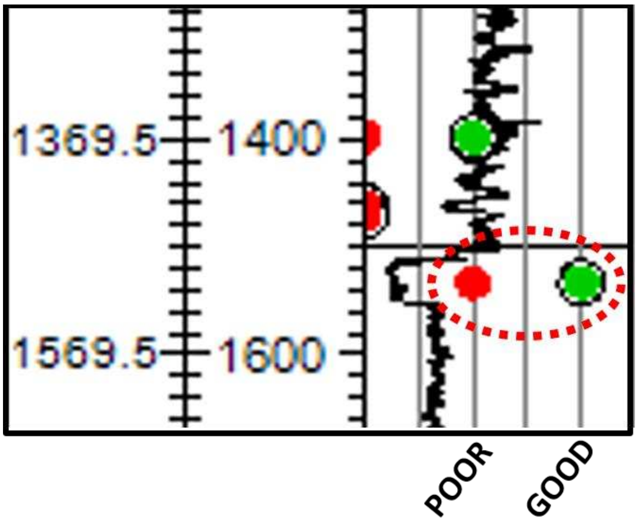

Figure 8a. Visualization overview of HC shows in the well section window.
<u>Focus on the red dotted area</u> - POOR oil class (red dot), GOOD gas class (green dot) and a subsequent GOOD classification for the concatenated class (black circle, here coinciding with the green dot). Meaning that the 'best' show classification (concatenated classification) at that certain interval is the GOOD gas show.

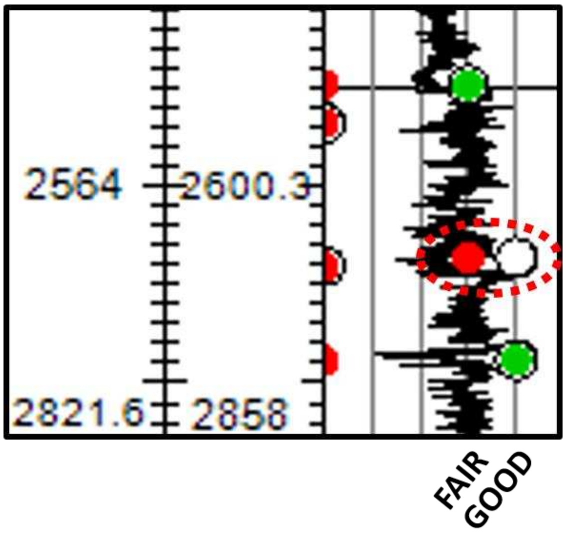

Figure 8b. Visualization overview of HC shows in the well section window.
<u>Focus on the red dotted area</u> – FAIR oil class (red dot) and GOOD classification for the concatenated class (black circle). Meaning that the 'best' show classification (concatenated classification) is upgraded by taking test and core data into consideration. The oil show gets an upgrade from FAIR to GOOD at that certain stratigraphic level.

Modification of associated AH_depth attribute (**along hole depth*)

The incorporation of the concatenated show classification also requires some adjustments in the **AH_depth relation** at which HC shows will be projected along the borehole trajectory. Previously, when only mudlog HC shows were incorporated, the according AH_depth value of the mudlog oil or gas show was considered. However, by incorporating the concatenated class, this process does not always select the correct AH_depth and thus requires a modification in the methodology. This is because there is no consistent rule defined for the concatenated class if the show is related to the oil or the gas show classification at that level. **In other words, it is directly dependent on the show classification both classes receive at that level and which is appointed the 'best'.** The according AH_depth of the 'best' classified show (oil or gas) should be matched to this concatenated AH_depth.

This relation can be established by introducing an IF ELSE statement in the excel format.

Rules of thumb:
IF concatenated classification = gas classification → *AH gas depth*
ELSE IF concatenated classification = oil classification → *AH oil depth*
ELSE → *AH average interval depth (stratigraphic level)*

<u>CODE:</u>
IF Gas_class≥Oil_class (BUT NOT 0 or 1) THEN Gas_depth → ELSE IF Oil_class>Gas_depth THEN Oil_depth → ELSE av. Depth strat interval

4. Shallow gas analysis

4.1 Introduction

The focus of this analysis is the relatively underexplored shallow gas play in the North Sea Supergroup of the Dutch subsurface. Shallow gas in this context is defined as the presence of gas in the unconsolidated Cenozoic sands under relatively low pressures *(Van den Boogaard and Hoetz, 2012).* The associated sediments are considered part of a larger fluvio-deltaic system (Eridanos Delta) that is widely present in the Dutch Northern Offshore. In this region, shallow gas presence is generally associated with the occurrence of (faulted) anticlinal structures related to underlying salt domes, and often multiple stacked reservoirs can be identified. The entrapment of shallow gas creates a strong decrease in acoustic impedance, which is generally associated with the occurrence of bright spots or seismic amplitude anomalies *(Van den Boogaard and Hoetz, 2012).*.

The E&P industry has been aware of the presence of shallow gas since the early 1970's from the occurrence of these seismic amplitude anomalies. However, skepticism remained as the expectation from several drillings was that the highly permeable, unconsolidated Cenozoic sands will cause sand production and early water breakthrough *(Van den Boogaard and Hoetz, 2012).* Furthermore, it is presumed that also low gas saturations (residual gas) can create these bright spots which leads to a large uncertainty in terms of gas saturation levels.

EBN as the state participant in exploration and production in the Netherlands has great interest in potential shallow gas and is currently conducting a shallow gas inventory focused on the A-, H-, B- and F-license blocks in the Northern Offshore region. Several questions arise in relation to this play; *'Should we consider shallow gas an opportunity rather than a hazard?*' and *'Are we too sceptic about the saturation in shallow gas opportunities?'.*

The general hypothesis underlying these questions describes the assumption that seismic amplitude anomalies are the result of (locally) increased gas saturations and lithological changes. But this assumption does not exclude the presumption that also low gas levels are capable of generating bright spots. When accurate, bright spot identification is highly unreliable in the search for shallow gas opportunities, as saturation is considered a very high risk. However, this presumption derives only from a small number of well control points, and statistics on possible saturation ranges were lacking.

As gas saturation is one of the key uncertainties in shallow gas exploration, this particular research strives to provide the missing saturation statistics. By combining seismic data (amplitude anomalies) with actual HC test results (mobile HCs) derived from the HC show database, a relation can be drawn between <u>gas saturation vs. bright spot occurrence</u>. The goal is to use these statistics to de-risk identified shallow gas leads in the Dutch sector.

4.2 Methodology

As the Dutch Northern Offshore is the most promising area related to the shallow gas play, this region is also the focus of the EBN shallow gas analysis. Within the scope of this particular research, the focus region is narrowed down to the A-, B- and F-license blocks. The first statistics on shallow gas saturation in relation to bright spot occurrence will be derived from analysis in these quadrants of the Dutch sector.

Bright spot identification

Shallow gas occurrence is generally linked to seismic amplitude anomalies (bright spots). But to what extend do pronounced seismic amplitude anomalies correlated with mobile (i.e. producible) gas? To answer this, the first step is to identify the bright spots at the stratigraphic level of the North Sea Supergroup. Seismic anomaly tracking with the aid of RMS (Root Mean Square) amplitude scanning highlights the acoustic impedance contrast, which enables identification of bright spots in this part of the Dutch subsurface. This identification can in turn be used to make a subdivision between boreholes encountering seismic amplitude anomalies along their trajectory and boreholes that don't.

The actual RMS amplitude scanning is not conducted during this research, as the seismic amplitude anomaly map of the Dutch Northern Offshore was already produced in previous research by *Mijke den Boogaard (EBN).* This map will be used as the basis of bright spot identification and the subsequent <u>anomaly vs. no anomaly</u> subdivision of the borehole selection.

Amplitude anomaly classification

The second step in this analysis is classifying the encountered anomalies by the offset wells in this area. In this way for each borehole a new seismic attribute is measured: *Quality of Seismic Anomaly*. This classification follows a semi-quantitative approach, in which anomalies are classified based on reflector intensity and interpreted according to set examples (figure 9).

The 4 considered options in this classification are; **GOOD / MEDIUM / POOR / INCONCLUSIVE**. The first 3 options are based on the set examples (figure 9), while the **INCONCLUSIVE** label is used in case classification difficulties arise. For the latter category, multiple reasons can be applicable, for instance;

- *Absence of data*
- *Poor seismic quality*
- *Borehole trajectory 'missed' the anomaly*
- *Fault proximity*

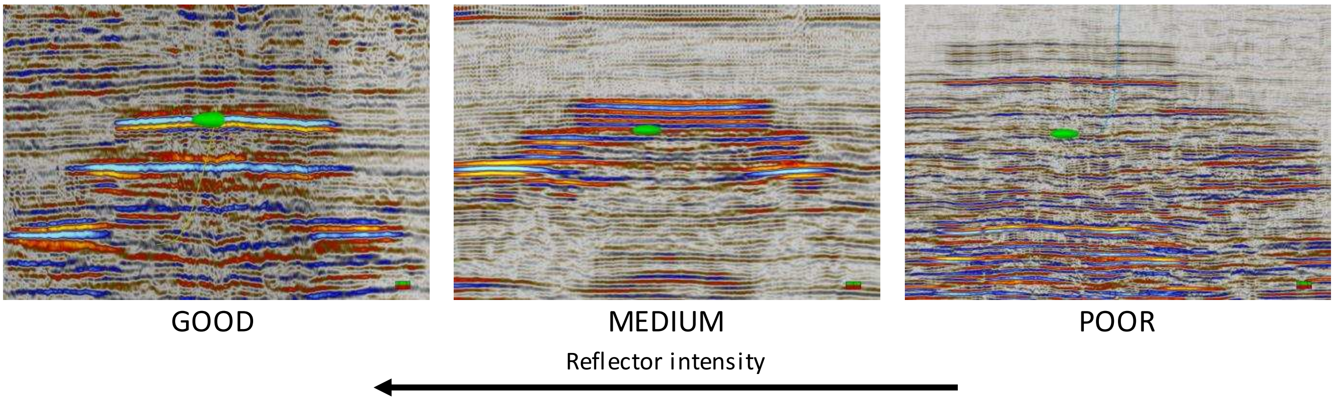

Figure 9. Classification examples (reflector intensity) - semi-quantitative classification approach.
The amplitude anomaly in each example is highlighted by the level of the green sphere (representing the HC flow test result – discussed later on).

HC flow tests – North Sea Supergroup

After the subdivision amongst boreholes based on anomaly occurrence as described above, a second subdivision can be made based on conducted HC flow tests in the area (tested vs. non-tested). It is assumed that a successful test indicate mobile hydrocarbons . By combining the quantified anomaly and test data sets, it can be established how well these attributes do correlate.

The HC show database contains information on performed flow tests per borehole (and depth). Classification of these tests occurs according to the DST gas rules set for the HC show database (Appendix 2 and table 1). In this study, only test data at the North Sea Supergroup level from boreholes in the A-, B- and F-quadrants is extracted from the database.

	GAS FLOW RATE (M3/DAY)			
	FR > 50.000	10.000 < FR < 50.000	1 < FR < 10.000	FR < 1
Test result	**GOOD**	**FAIR**	**POOR**	**NO FLOW**

*Table 1. HC test classification table of DST gas rules – HC show database. *FR = maximum flow rate (m3/day).*
Color codes spheres are used in the different visualization applications.

Petrel implementation – time-to-depth conversion

The following step is to link amplitude anomalies to the extracted HC test results. This action requires the implementation of HC show test data into the Petrel interface as well as a correct time-to-depth conversion.

HC test results from the HC show database need to be (manually) imported into Petrel according to the approach presented in the Petrel workflow manual (Appendix 5). *Note: the only difference in this case is that HC show evidence* *from test data is imported instead of HC evidence extracted from mudlog data*. The imported HC tests are projected as spheres along the according trajectories. The measured depth at which the spheres are projected match the depths at which the tests were performed. Visualization settings of these spheres are set to match the color codes that have been provided in table 1.

For the time-to-depth conversion, each borehole is checked in terms of its time-to-depth relations and complemented with velocity data from neighboring boreholes if necessary. The actual conversion is then conducted on the basis of available check shot and sonic data.

Saturation vs. bright spot occurrence statistics

Because the HC test result is now projected at the correct depth along the borehole trajectory, the relation between the test result and seismic can be evaluated. For each test result, the associated amplitude anomaly is classified according to the presented classification set-up (figure 9). Obtained results show how frequent a certain match ('HC test result' vs. 'amplitude anomaly') occurs, from which conclusions in terms of saturation in bright spots can be drawn.

Ultimately, these results can be used to predict saturation levels in boreholes that have not been tested, but that do encounter an anomaly along their trajectory.

4.3 Results

As mentioned, the focus area of this analysis is limited to the A-, B-, and F-license blocks. Within these quadrant, a total of 239 boreholes have been drilled. These boreholes will be considered in the following result sections.

Bright spot identification

With RMS amplitude scanning, the seismic amplitude anomalies associated with shallow gas in the Dutch Northern Offshore have been identified (figure 10). This area seems quite promising in terms of shallow gas potential, as 4 of the identified fields are currently under production (A12-FA, A18-FA, B13-FA and F02a-Pliocene (Hanze field)) and 4 more proven fields are under consideration for development (A15-FA, B10-FA, B16-FA and B17-FA). But more importantly, besides the identified fields, >150 shallow gas leads have been identified in this region. Approximately 15 of those leads could be economically viable assuming a certain level of development cost reduction (ref…..

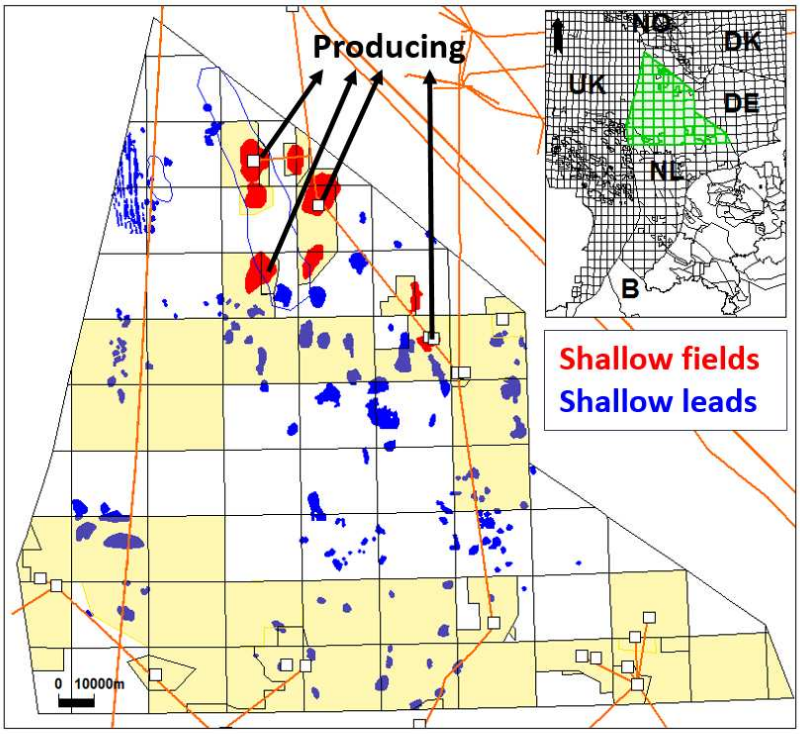

Figure 10. Shallow gas portfolio – Dutch Northern Offshore. Bright spot identification map created by RMS amplitude scanning (figure adopted from Mijke van den Boogaard).

By locating the seismic anomalies in relation to the trajectories of the 239 drilled boreholes in the A, B and F quadrants, a subdivision amongst the boreholes can be established based on <u>anomaly vs. no anomaly</u> association (figure 11).

Of the 239 boreholes, 76 boreholes have been identified that penetrate a mapped seismic anomaly in the North Sea Supergroup along their trajectory. Those drilled anomalies (bright spots) can be classified according to the semi-quantitative classification approach explained in section 4.2 (figure 9). This shows that a rather large portion of the encountered anomalies can be classified as either MEDIUM or GOOD (figure 11).

The remaining 163 boreholes do not encounter a seismic amplitude anomaly along their trajectory in the Cenozoic. In light of this particular analysis, those boreholes are of less interest, because no conclusions can be drawn on amplitude occurrence in relation to saturation levels.

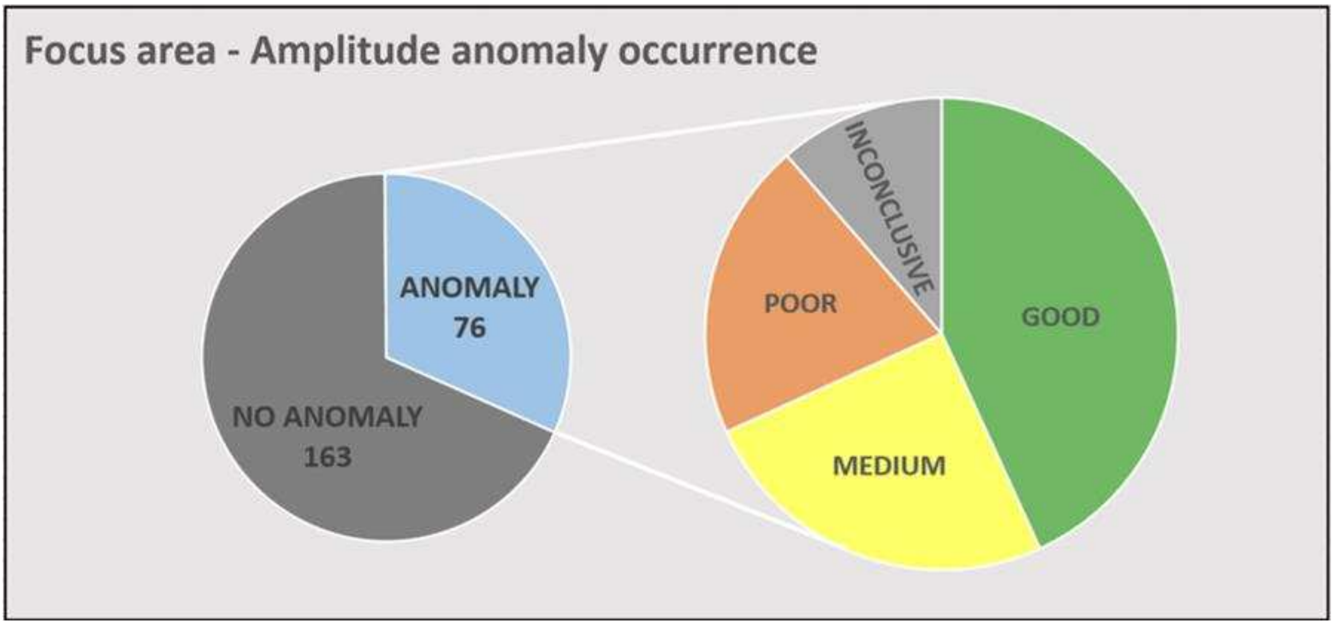

Figure 11. Subdivision boreholes encountering anomalies vs. boreholes not encountering anomalies along their trajectory.

HC flow tests – North Sea Supergroup

The second subdivision is based on HC flow test data extracted from the HC show database. Out of the 76 selected boreholes that penetrate an anomaly, 30 boreholes contain HC flow test data in the North Sea Supergroup. Common practice in conducting flow tests comes from wireline logging. Resistivity data provides a first indicator for the saturation, but is not accurate enough for complete saturation de-risking. For the remaining 46 boreholes, no flow tests were conducted in the North Sea Supergroup, because this stratigraphic interval was not appointed the initial target reservoir.

In the 30 boreholes, a total number of 41 flow tests have been performed. In most cases only 1 flow test is conducted at the North Sea Supergroup interval per borehole, however, there are some examples where multiple tests have been performed at this stratigraphic interval (*example: borehole A15-03 – Appendix 7*). The test results are projected along the trajectory of the according boreholes following the 'Petrel implementation' approach mentioned in section 4.2. (Appendix 5). Subsequently, the integration of different data types (seismic, HC test data, well data) allows seismic characterization analysis. Figure 12 provides an overview of the implemented integration of data in the Petrel interface.

Saturation vs. bright spot occurrence statistics

Anomaly classification at each of the tested levels results in the presented distribution chart in figure 13. By combining these with associated HC test results, a plot is constructed that shows the frequency a certain 'match' (figure 14).

From figure 14, it is striking that out of the 41 flow tests, 38 showed producible gas. Only 2 tests showed NO FLOW at all and only 1 produced WATER. These statistics show that > 92% of the conducted flow tests in this particular area showed gas. Furthermore, the diagram also shows that a significant amount (33/41 = > 80%) of the encountered amplitude anomalies can be classified as MEDIUM or GOOD. These classification categories are for a large part linked to GOOD HC test results. The exceptions are 1 GOOD anomaly that had NO FLOW during the test and 1 MEDIUM anomaly that had a POOR HC test result. However, the link between **MEDIUM/GOOD** anomalies vs. **GOOD** HC test result is very clear.

Besides the tested boreholes encountering an anomaly in the North Sea Supergroup, also 46 boreholes penetrating an anomaly were non-tested. This selection might hold potential for shallow gas based on their encountered amplitude anomalies. On the basis of this analysis MEDIUM/GOOD amplitude anomalies provide a significant likelihood of encountering producible amounts of shallow gas. These 46 boreholes are also screened and classified in terms of amplitude anomalies, providing the distribution chart as presented in figure 15.

In figure 16, we add anomaly classifications of non-tested boreholes to the earlier created frequency diagram based on tested borehole data. In the non-tested case, > 56 % of the encountered anomalies are classified as MEDIUM/GOOD.

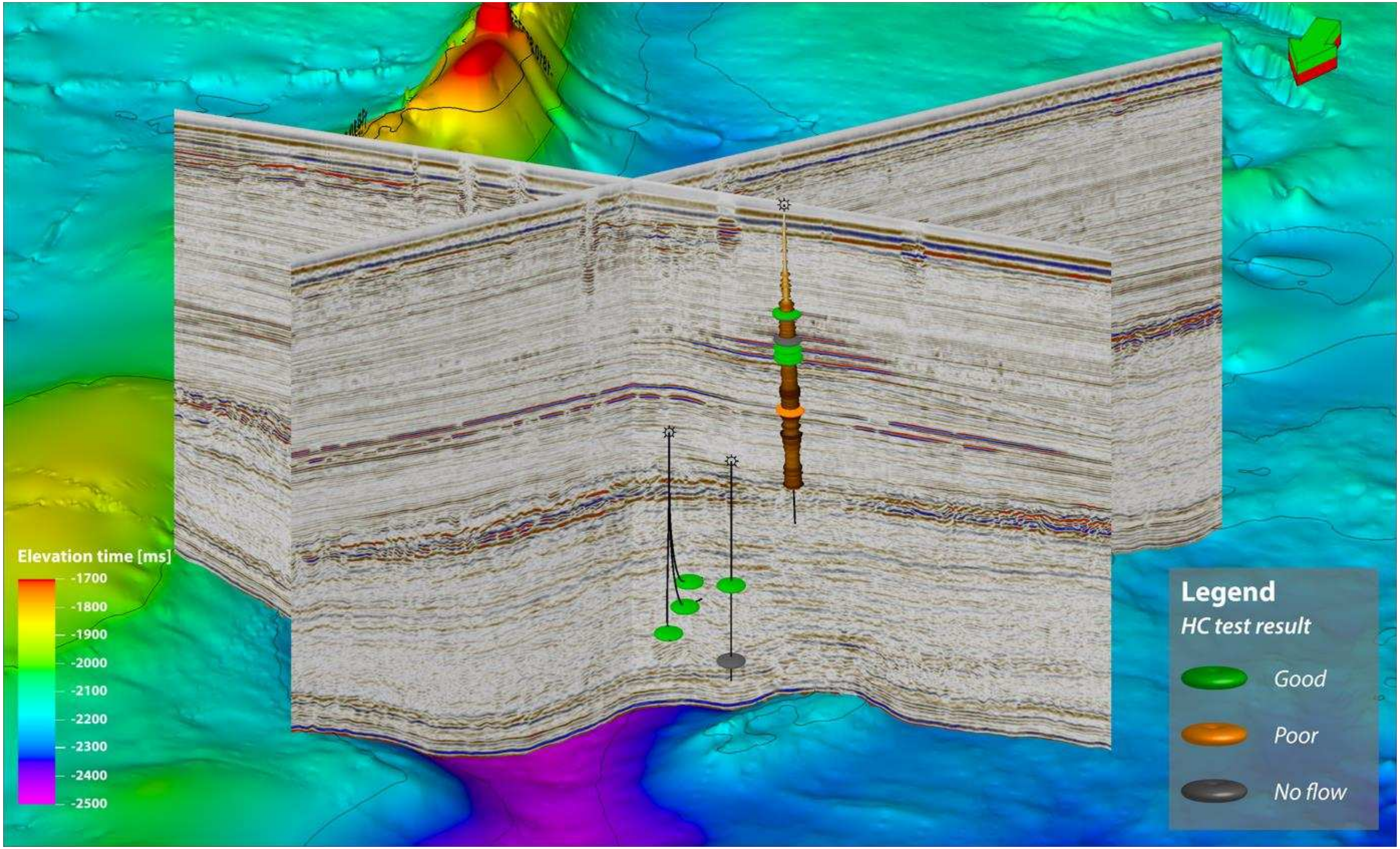

*Figure 12. Overview of implemented data integration (seismic, HC tests and well data) in the Petrel interface. *The visualized surface represents the Base North Sea Supergroup.*

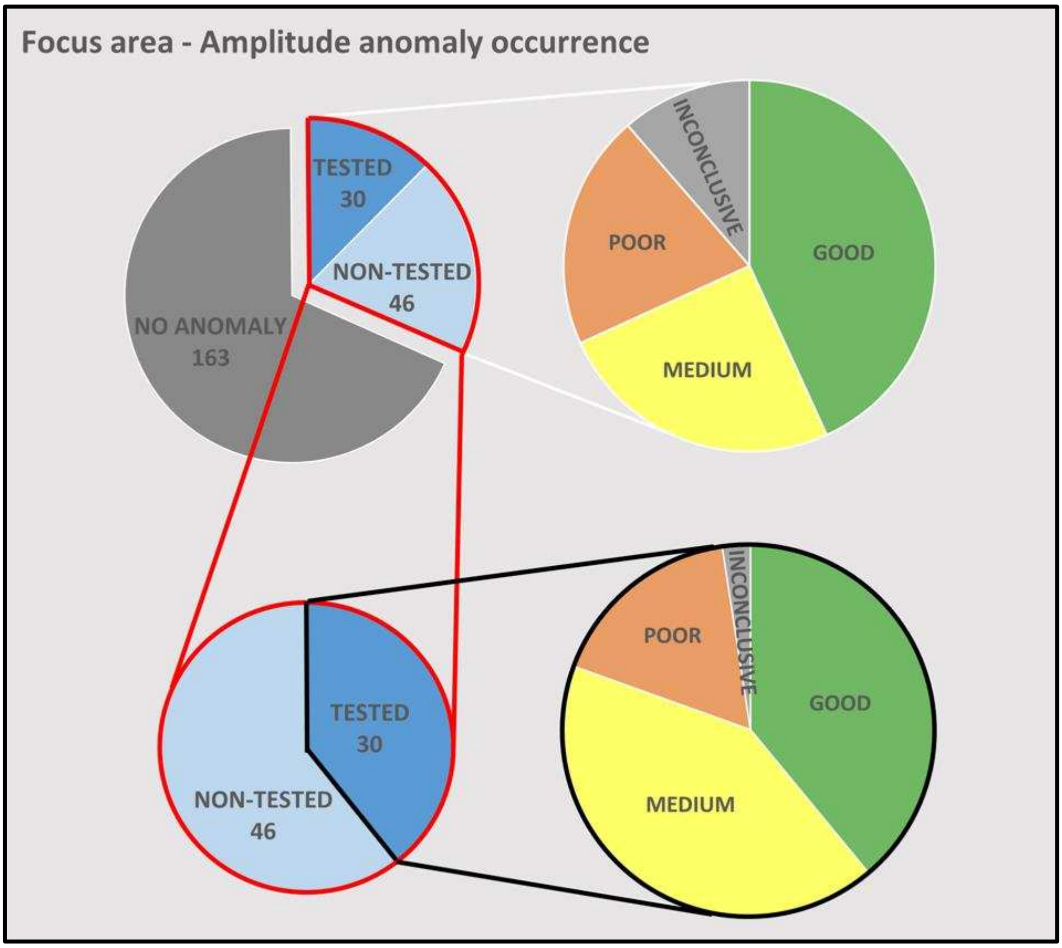

Figure 13. Amplitude anomaly classification of tested boreholes.

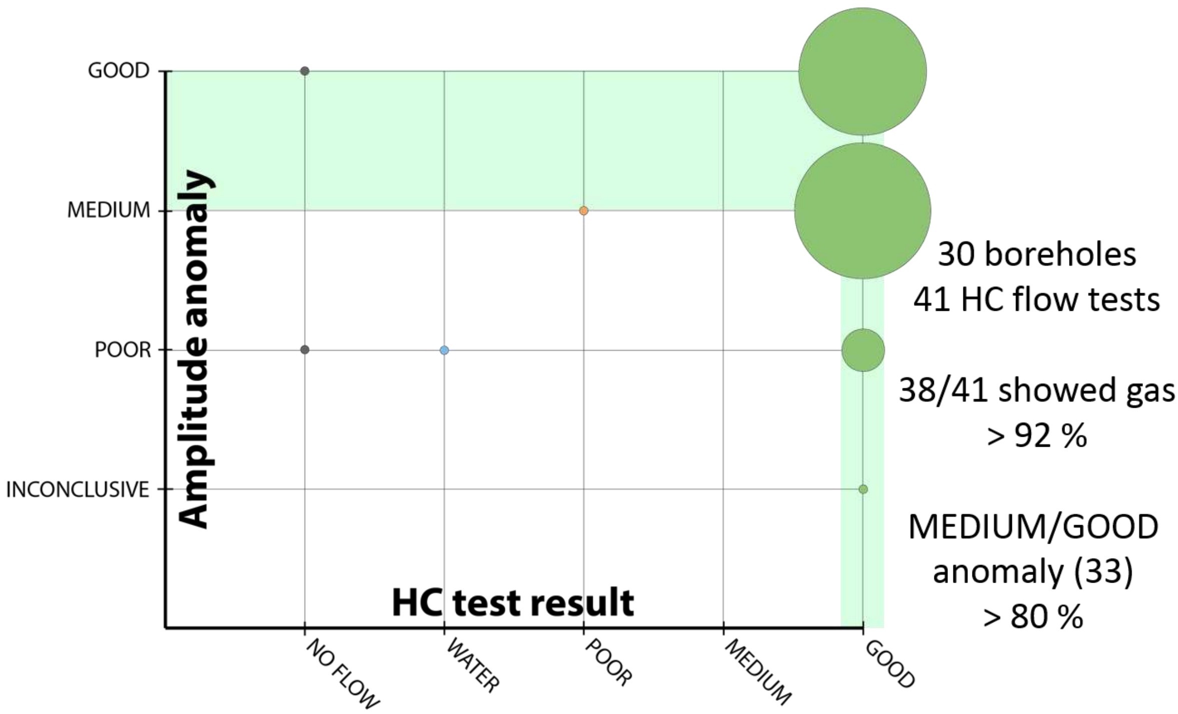

Figure 14. HC test result vs. Amplitude anomaly – tested boreholes.
GOOD/MEDIUM anomalies are often associated with GOOD HC test results.

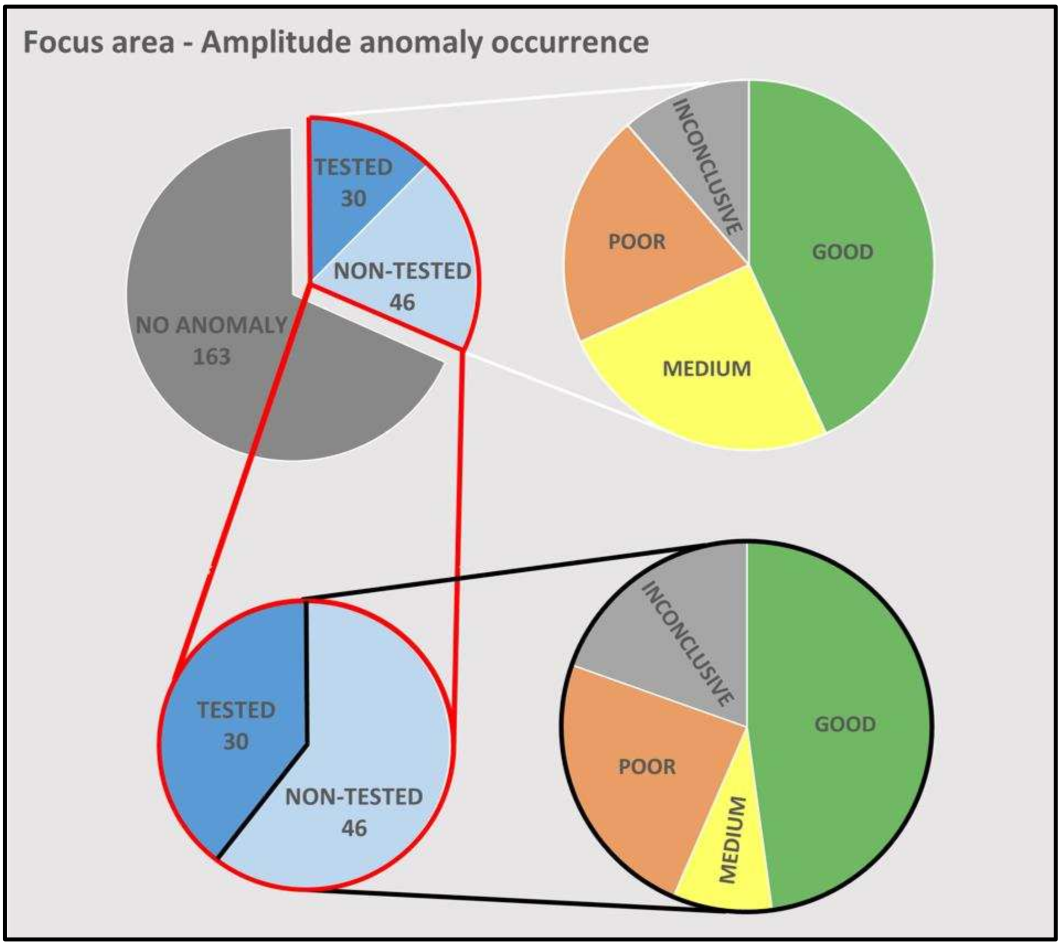

Figure 15. Amplitude anomaly classification of non-tested boreholes.

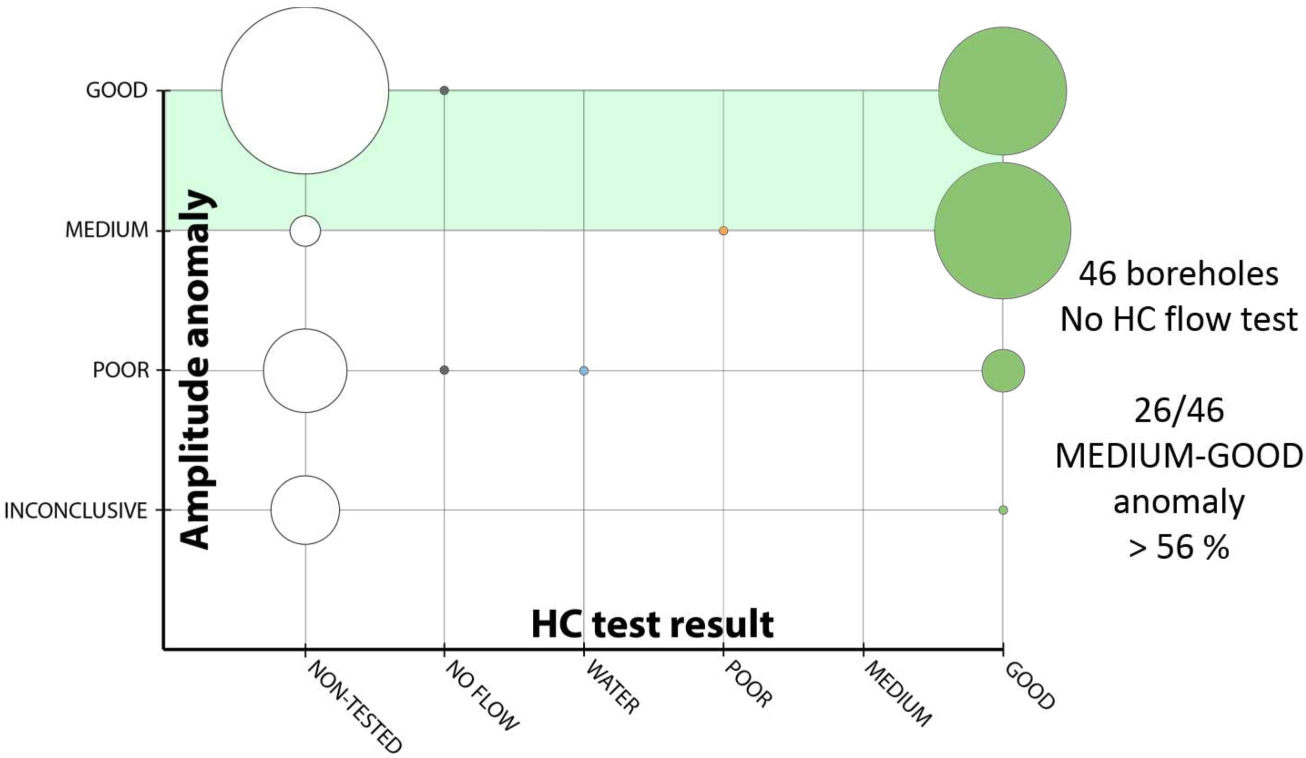

Figure 16. HC test result vs. Amplitude anomaly – non-tested boreholes (white circles).
Based on provided statistics in figure 14, GOOD/MEDIUM anomalies hold HC potential for shallow gas.

4.4 Discussion

Based on the statistics provided by tested boreholes (figure 14), it is suggested that the non-tested boreholes with MEDIUM/GOOD amplitude anomalies represent significant shallow gas potential.

To demonstrate this potential in non-tested boreholes in the A-, B- and F-license blocks, three boreholes are evaluated in more detail, **F05-02 / F16-02 / F05-05** (figure 17a, b and c – respectively). Each of these examples will be discussed shortly and additional information on potential leads associated with these boreholes can be found in Appendix 8.

- **Borehole F05-02**

  This borehole encounters a GOOD classified amplitude anomaly along its trajectory at an approximate MD of 855m (figure 17a). At this depth the gas chromatographic reads around 7500 ppm on the mudlog, C1 levels . The associated lithology shows an alternation between silty and sandy intervals, which brings the 'raw' gas classification to FAIR/GOOD according to the HC show database standards.

  From internal research at EBN, it became clear that the borehole F05-02 is actually situated inside an evaluated shallow gas lead, F04/F05-P1 (Appendix 8A). This exploration well targeted just the Cretaceous and Triassic reservoir sections, but also showed gas at the shallower bright spot depths. However, from the *End Of Well Report (EOWR)* it is clear that these were considered a drilling hazard rather than a potential reservoir section. The well was eventually plugged and abandoned.

  In the evaluation of the F04/F05-P1 lead, a fault-dip closure was identified at the bright spot level in the Upper North Sea Group Formation. This structure holds an alternation of sand and clay intervals (partially) conform the structure. Multiple stacked reservoirs have been identified, whereas 3 sandy intervals are considered as the main reservoir levels. Volumetric calculations show that these intervals together could contain a P50 GIIP around 2.7 BCM.

- **Borehole F16-02**

  This borehole also encounters a GOOD classified amplitude anomaly along its trajectory (figure 17b). The bright spot is located at an approximate MD of 600m and highlights a folded structure. A clear flat spot is visible, which provides a possible indication of the GWC. The lower middle part of the bright spot is affected by a small velocity pull-down effect and a reflection of the entire bright spot can be observed on seismic. The matching gas chromatographic reading on the mudlog shows a significant increase in gas at this level with a C1 value around 20000 ppm. In combination with the multiple sandy intervals indicated on the litholog, this gas reading receives a GOOD 'raw' classification label.

  This particular offset well is also situated inside a lead identified by EBN, F16-P3. The initial target was the Chalk Formation, but gas shows were also encountered at shallower depths. No actions in relation to shallower levels was undertaken and the well was eventually plugged and abandoned.

  Evaluation of the F16-P3 lead (Appendix 8B) presented a 4-way dip closure with multiple stacked reservoir sections in the Upper North Sea Formation. Detailed seismic characterization showed the presence of 5 prospective intervals as indicated by bright spot identification. From well data analysis, 4 out of the 5 intervals show significant thickness, N/G, porosity, resistivity and gas readings. Added together, these sandy reservoir sections represent a GIIP with a P50 GIIP of 1.17 BCM. Out of all intervals, the 4th interval is the largest and associated with the clearly visible bright spot in the seismic x-section (figure 17b).

- **Borehole F05-05**

  Also here, a GOOD anomaly is encountered along the trajectory, whereas even a second bright reflector can be spotted at a somewhat deeper level (figure 17c). When evaluating the mudlog at the associated depth, a gas reading with an approximate C1 peak around 8000 ppm is observed. The alternating silt and sandy lithology provide this gas reading with a FAIR/GOOD 'raw' gas classification.

  However, the F05-05 borehole is not located inside an identified shallow gas lead by EBN analysis. The official target was the Chalk Formation and gas shows were encountered at shallower levels. Similar to borehole F05-02, these shows were considered a hazard rather than an opportunity. The well was eventually classified dry and is currently abandoned.

  Because this location is not considered a shallow gas lead, although a bright spot with an identifiable gas peak is encountered, a quick evaluation of this borehole was conducted during this research (Appendix 8C). Multiple seismic perspectives (including top view visualization) show 5 different intervals generating bright spots. These intervals are located at approximate MDs of 563m, 620m, 650m, 706m and 880m and are numbered from 1-5 in the same order. When comparing these intervals with the according lithology, the overall lithology in the North Sea Supergroup is dominated by claystone. This lithology is in certain parts alternating with thin silty intervals, but at some bright spot levels only claystone is present.

Further research is necessary to evaluate the shallow gas potential associated with the bright spots encountered by this offset well. Although the gas reading is rather positive and clear bright spots are visible on seismic, associated lithological intervals are less assuring.

4.5 Conclusions

In the process of answering the question whether *'shallow gas should be considered an opportunity rather than a hazard?'*, it mainly revolves around the gas saturation risk. This is one of the main uncertainties in shallow gas exploration and with the gathered statistics this risk can be reduced in current shallow gas leads.

This research linked bright spot occurrence and their classification to available HC test data in the North Sea Supergroup. With the A-, B- and F-quadrants as the focus area, it became apparent that the gas saturation in this region of the Dutch Northern Offshore is not as high a risk as initially expected. Out of all conducted HC flow tests at bright spot levels, > 92 % showed producible amounts of gas. Only 2 tests did not flow at all and only 1 encountered water during the testing phase.

Classification of the tested amplitude anomalies showed that > 80% of the bright spots can be classified as MEDIUM/GOOD. Even more apparent is that these MEDIUM/GOOD amplitude anomalies generally correspond with GOOD HC flow tests. These statistics clearly show that in case of observing a clear bright spot amplitude anomaly , there is a significant chance of finding producible amounts of gas.

With this research the first statistics in relation to gas saturation in bright spots is provided. From the results, it is clear that the risk of not encountering producible gas in a Cenozoic amplitude anomaly of the category Good/medium is lower than 8%. This risk is much lower than was perceived by EBN explorers until now and a Shallow Gas portfolio review is envisaged.

In light of pointing out opportunities, the first options arise from the non-tested boreholes in the A-, B- and F-quadrants that encounter a seismic amplitude anomaly along their trajectory. This might result in the identification of possible leads that were not yet under consideration. As a second measure, EBN is encouraged to update their saturation POS on shallow gas leads/prospects based on this analysis. Their current shallow gas portfolio can possibly be expanded and with de-risking known leads/prospects, a higher percentage might present economic viability in case of development.

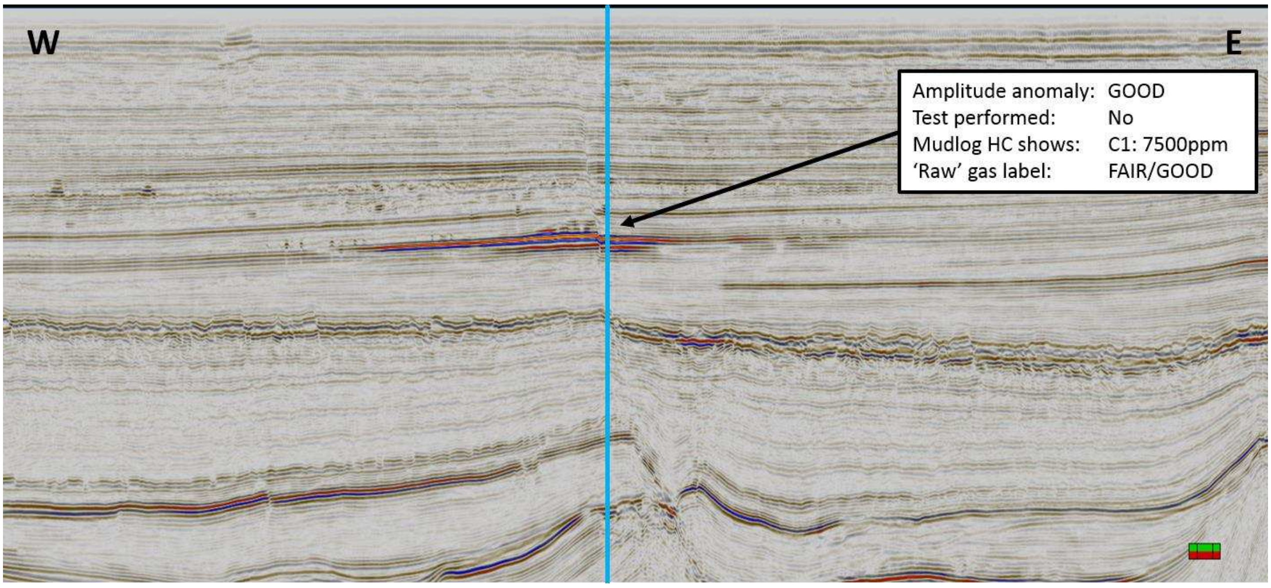

Figure 17a. Borehole F05-02 encountering a GOOD amplitude anomaly along its borehole trajecory (blue).

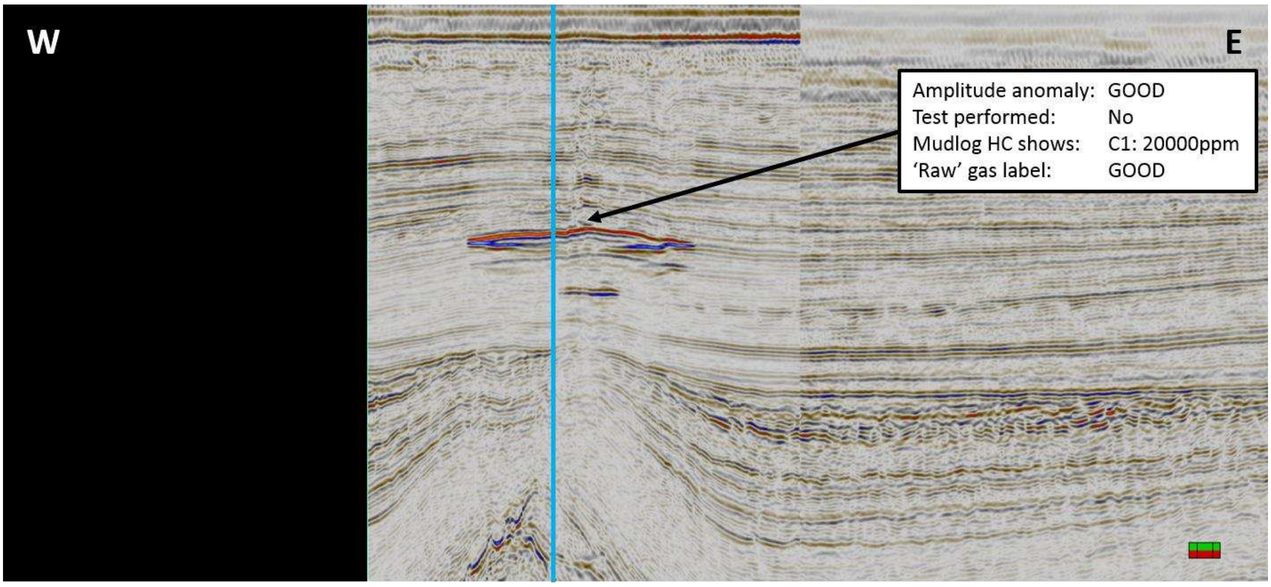

Figure 17b. Borehole F16-02 encountering a GOOD amplitude anomaly along its borehole trajectory (blue).

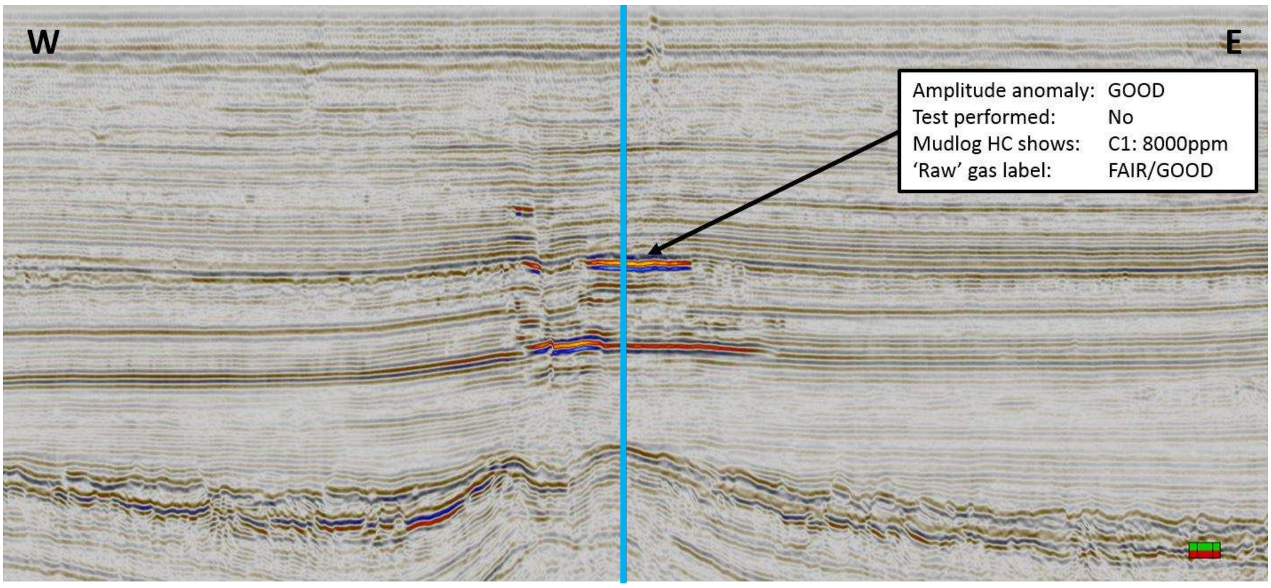

Figure 17c. Borehole F05-05 encountering a GOOD amplitude anomaly along its borehole trajectory (blue).

5. Structural attributes

5.1 Introduction

In the general sense, hydrocarbon accumulations are related to the occurrence of trap geometric structures or hydrocarbon migration pathways. Identifying these trap geometries and coupling them with the observed HC evidence can reveal certain relations. This allows you to draw certain conclusions on HC show occurrence and their structural association and enables you to make certain predictions in advance. This (upfront) insight can be extremely useful in exploration and can be used in future exploratory studies.

To establish insight in these relations, the HC show database is very suitable in terms of data completeness and accessibility. Dutch offset wells contain information of HC shows observed during the drilling- and testing phase, which can be coupled to seismic data by Petrel implementation. However, it should be noted that these HC shows are observed along the borehole trajectory, which needs to be taken into consideration when evaluating the according trap geometric structures.

The initial goal of this study was to define this relation between structures and HC shows. By developing a well-defined structural classification method and conducting a thorough analysis on the Dutch Northern Offshore boreholes, it was intended to investigate any relationship. However, as mentioned, the scope of the intended study was modified somewhat in order to support EBN current operations. Therefore from the original study plan only the structural classification methodology is developed and tested during this particular internship. The actual analysis part is not executed and is therefore noted in the recommendations as a possible follow-up project.

5.2 Methodology and results

To set up a consistent analysis and the establishment of a general relation between structures and HC accumulations, a well-defined classification scheme characterizing structural trapping styles using seismic is required. The options should contain all possible scenarios, whereas they should not be to complex. Both **trap type** and (offset) **borehole position** (relative to 'crestal/reference point' of the structure) should be taken into consideration in defining the classification methodology.

In first instance, the **trap type** needs to be identified. An initial subdivision is made between geometries related to structural traps and geometries related to stratigraphic traps. '**Structural**' and **'stratigraphic'** are defined as the main classification categories, whereby each category contains a number of options that define the possible occurring geometries;

Structural:

- **4-Way dip closure**
- **Fault-dip closure**
- **Salt enclosed trap**
- **Unconformity trap**

Stratigraphic:

- **Pinch-out trap**

When a particular structure cannot be assigned to one of the abovementioned classes, the category **'Other'** can be used to classify the structure. In case there are no indications at all for the occurrence of a certain structure able to trap hydrocarbons, it can be classified as **'No trap'**. The label **'Unclear'** is only used in case there is too little information to enable classification. This can have multiple reasons such as poor seismic quality or the general absence of (seismic) data, etc.

After the trap type is defined based on the available seismic information, the location of the borehole trajectory (offset well) needs to be taken into consideration. Offset wells can be drilled at the margin of a certain trap geometry instead of going through the crest of the structure. This position of the borehole relative to the entire structure can cause a significant difference in HC show evidence, which should be considered when relating structures to HC shows. To discriminate between the different positions relative to the 'crestal point' of the structure, a subdivision has been made. This subdivision divides the structure into 3 sections from **'up-dip'** to **'intermediate'** to **'flank'** position. It is assumed that **'**up-dip**'** wells have a greater likelihood of encountering hydrocarbons compared to **'**intermediate**'** wells. Furthermore, that **'**intermediate**'** wells have a greater likelihood seeing HC shows than (very much down-dip) flank wells.

Delineation of these 3 positional sections is determined by several analysis tests. The initial idea was to divide the increments as measurable sections (in meters). However, problems in this approach were detected in a few situations during the testing phase. Because each structure differs in size, no generalized subdivision can be made that considers each structure equally. This complicates deriving a robust relationship between structure (type and position) and classified HC shows. Therefore it is decided to relate the delineation of the **'up-dip'**, **'intermediate'** and **'flank'** zone, to the structure size in case of a 4-way dip closure and a fault-dip closure. The increments are divided in equal portions based on ratio (relative to the overall size of the observed structure). For an unconformity trap type or a pinch-out trap, measurable sections for the locational ranges are considered, whereas the salt enclosed trap locational ranges are fully depended on the size of the 'trapped reservoir block' inside the salt.

The resulting classification (8 categories) including example situations is shown in figure 18.

5.3 Discussion

According to the established (and tested) classification scheme, an analysis can be performed to derive the relationship between trap geometric structures and HC accumulations.

The HC show database is the good candidate to provide the data regarding HC evidence and additional seismic data can be loaded in the project for the chosen region. HC shows can be implemented in the Petrel interface by following the Petrel workflow manual (Appendix 5). Visualization of classified HC shows along the borehole trajectory allows the coupling with associated structural information extracted from seismic.

By analyzing structures in relation to the HC show evidence, first the geometrical trap type as well as the total structure size needs to be determined. Based on the type and structure size, the 3 positional sections can be determined according to the guidelines as presented in figure 18. Subsequently, the position of the borehole relative to the structural 'crest/reference point' can be determined.

Relating these observation with the associated HC show classification (according to HC show database approach (Appendix 2)) allows the drawing of conclusions that might be useful as an insight in future exploration activities.

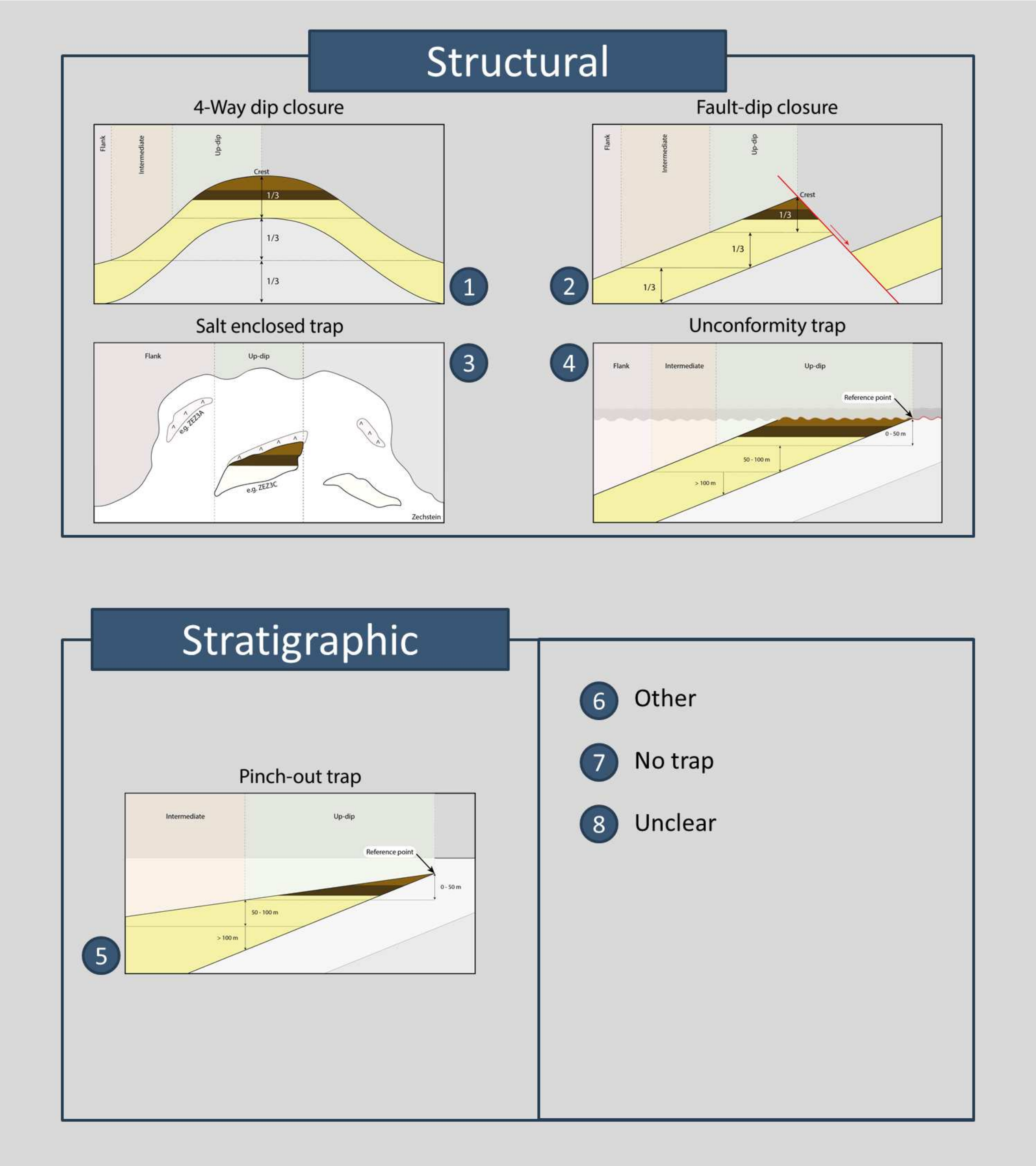

Figure 18. Classification standards for trap geometries – considering trap type and (relative) borehole position.

6. Database applicability outside Dutch sector

7. Conclusions

The main objective of this internship was to test the applicability of the HC show database in exploration research. Although the initial project was related to structural trap geometric analysis, the shift in focus to a shallow gas analysis did not have any consequences for the initial project goal.

During the shallow gas analysis, it became clear that the HC show database is an extremely useful source for HC show data extraction. The well-defined methodology (*Westerweel, 2017*) secures equivalent classification of encountered HC shows. This generalized classification method opens up opportunities in the process of analyzing HC accumulations and defining underlying relations with for instance, structural- (seismic) or well data. However, the main pillar in applicability mainly revolves around the visualization possibilities of the data set. In case of the HC show database, these different visualization tools are presented in detail. Multiple visualization techniques are now available in QGIS, Spotfire and Petrel E&P Software to visualize and analyze the dataset. HC show data can be selected and visualized according to the users preference and the specific research objective.

Besides applicability to research, also the applicability of the HC show database outside the Netherlands was tested. Pilot testing of HC show analysis in boreholes outside the Dutch sector showed that there are a few problems of which the main obstacle is presented by the stratigraphic nomenclature. Other countries/sectors use other nomenclature for their stratigraphic intervals, which do not correspond with the handled nomenclature in the Dutch sector. Although this is not an insurmountable problem, it should be evaluated if changing the approach of HC show analysis is worth the effort. The fact is that the number of international boreholes (outside the Dutch sector) in which EBN has a stake is very small so changing the approach would be a time-consuming and minimal rewarding action.

Besides representing valuable information for future petroleum exploration activities, HC show data also shows its value in applicability to wider research (this study). Conducted (internal and external) QC showed the value of HC evidence in the HC show database and due to the generalized classification method, the HC show database is an extremely useful tool for the E&P industry as well as for the geothermal sector. Therefore, the intention is to make this tool available to the partners of EBN at the end of 2018. A comparable Spotfire interface as the GDE-database will be build, which allows multiple visualizations of the HC show dataset. Besides making it available to partners in the E&P sector, it should also be evaluated if there are possibilities to make this data public for geothermal operators (e.g. DAGO). HC show data from onshore boreholes holds significant value for the geothermal sector, whereas unexpected encounters of HCs while drilling is undesirable.

However, before reaching this phase, first the existence of the HC show database should be brought to attention within the industry. Awareness should be created before the actual out roll of the HC show database tool.

A first attempt has been made by presenting the database and its research applicability to exploration geologists at the NAM (Nederlandse Aardolie Maatschappij). In addition to that, an extended abstract submitted for the 80th annual EAGE Conference and Exhibition (Hoetz and Korevaar, 2018). The abstract, enclosed in Appendix 10, has been accepted for present for the conference.

8. Recommendations and follow-up projects

This section proposes several personal recommendations for further improvement on the EBN HC show database as well as follow-up projects by future interns, EBN employees or partners.

Expanding the HC show dataset

The main purpose of the HC show database is to present the available data on HC show evidence in the Dutch sector and to provide a good overview of its HC potential. Therefore, continued expansion of the dataset by the addition of analyzed boreholes is the main goal. Both offshore and onshore coverage is necessary and recommended. Coverage of Dutch Northern Offshore is already established, so this region needs to be extended to the more Southern North Sea license blocks. In terms of onshore coverage, the initial focus should be on areas suitable for geothermal activity. Whereas hydrocarbon exploration onshore is put to a stop, geothermal exploration is an emerging sector. EBN employees working on the Ultra Deep Geothermal (UDG) project should be able to provide important onshore boreholes for geothermal risk assessment.
HC show analysis should be performed by a well-informed employee. When handing over the HC show database project to the next intern, good communication and supervision are beneficial. This way, continuous expansion will be more robust and the database will be further improved to enable serving as an exploration tool in the future.

Complementing missing data

A number of analyzed boreholes in the HC show database lack data. This can have multiple reasons; missing files, confidentiality issues, corrupted files, etc. Several files have been recovered by Wintershall and are added to NLOG. However, it is very important that close contact with NLOG is remained in the process of trying to complement the missing files.

Updating source linking

In the process of analyzing boreholes, the data source files are stored on Livelink and linked to the analysis in the database. However, a large number of these files has been corrupted by unknown reasons. Furthermore, this source linking method is not suitable for external users in case the HC show database becomes available for the partners in a later stage. It might be necessary to investigate different source linking methods.

External roll-out

To establish external roll-out to the partners of EBN, a Spotfire interface needs to be build which allows optimal data visualization of the HC show dataset. A similar interface as the GDE-database tool needs to be developed, however, it should be evaluated if Spotfire does not present any limitations in the data visualization.

The HC show database holds different dataset, but also requires the option to visualize the different data types simultaneously. It should be evaluated if Spotfire supports this visualization options, otherwise another alternative should be considered as it is important to allow the user to discriminate between HC show evidence derived from the different data types as well as the option of visualizing the 'concatenated' classification.

Furthermore, the option of making the database available to geothermal partners in addition to E&P partners should also be taken into consideration. Whereas HC show data is also valuable in a geothermal context.

Confidentiality filter

As borehole related data only comes available after a confidentiality period of 5 years, this period should also be considered in case of making the data available to external partners. A manual build-in filter is already inserted into the QGIS interface, however, for external out roll a better solution needs to be found. Automatic filtering of borehole with a completion data < 5 years should be filtered out before making the dataset public.

It is recommended to evaluate the options based on experience with the GDE-database tool. Peter Bange currently manages the database, so his expertise might be of use.

Combining the EBN developed databases

In the past few years, EBN developed a number of useful databases and according (analysis) approaches.

- HC show database
- GDE-database

- Post-mortem database

Each database has its own documentation methods. By generalizing these methods, an overall documentation habit is established which allows the combination of different databases and provides a more easy overview of available data within EBN.

Structural analysis – Trap geometries vs. HC accumulations

As mentioned, a well-defined and tested methodology for the classification of trap geometric structures is established (this study). By considering and analyzing trap type and relative borehole position, trap geometries can be related to occurring HC shows along the borehole trajectory. Subsequently, general conclusions can be drawn on the occurrence of (classified) HC shows in relation to certain trap geometries.

The shift in research objective, limited the trap geometric analysis to a defined classification method. However, this analysis can provide a useful insight for future exploration activities and is therefore highly suitable as a follow-up project by another intern.

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