Internship Report

Inventory of Hydrocarbon Shows in the Northern Dutch offshore (Phase 2)

Youri Kickken
(3594912)

September, 2016

Supervisors:
Guido Hoetz (EBN)
dr. Fred Beekman (Utrecht University)

Utrecht University

Abstract

Hydrocarbon (HC) Shows are valuable as potential exploration tool. HC Shows provide a first indication to whether a formation contains mobile hydrocarbons. Additionally, valuable information can be obtained with respect to hydrocarbon migration paths, and potential kitchen maturity and source rock typing.
In the current project an evaluation and QC of a previously developed 'EBN HC Show database' has been performed. This consisted of evaluating and enhancing the existing workflow. Secondly, the focus was on expanding the database with wells in the Dutch northern offshore DEFAB area. Moreover, the existing 2D interactive topview QGIS visualization has been evaluated, improved and complemented with a user manual. The QGIS visualization is used in order to generate regional maps showing occurrences of hydrocarbons to assist exploration studies. The background surfaces are constructed by combining both the 'EBN DEF survey' and the 'TNO 2012 offshore survey'.
Besides the 2D QGIS visualization setup a new 3D visualization setup is designed for the Petrel E&P software. The goal for this is to visualize the HC Show data in the most important exploration window applications within the software. Also for this visualization setup a user manual is created, describing the workflow steps in Petrel projects.
Furthermore, a QC on the data has been performed by correlating the Log Show data with the corresponding Drill Stem test (DST) intervals. A clearly positive correlation between these data types gives confidence in the methodology used in this project.
Lastly, a smooth handover has been realized by enhancing the HC Show 'classification' workflow with a new HC Show 'Example Atlas' and a project introduction for two new analysts.

Contents

1. Introduction

The Dutch northern offshore is an area, which has been subject to extensive hydrocarbon exploration over the last decades. Several hundreds of exploration wells were drilled during this time. Not all wells were successful in terms of finding commercial hydrocarbon accumulations. However, these wells provide us with a large amount of data, which is collected in the database of the TNO NLOG site. This data consists of several different well reports (mudlogs, well logs, completion reports, sidewall cores , etc.) organized per well. As the exploration for hydrocarbons in this mature area becomes more challenging, it is of importance to optimally use all available data, including hydrocarbon show data, for future exploration. This data has already been acquired, however is not ordered in a way which can be used easily for future analysis.

Hydrocarbon (HC) shows provide a first indication to whether a formation contains mobile or immobile hydrocarbons. Additionally, valuable information can be gained with respect to hydrocarbon migration paths, potential kitchen maturity and source rock typing. A good HC show can give rise to further testing or formation sampling (Crain, 2015).

Currently HC show data is scattered in many well files and difficult to analyze. Compiling all available HC show data in one single comprehensive database can therefore be a powerful exploration tool. Combining this HC show data with other available HC indicators such as, (sidewall-)core data, RFT samples and DST's will only enhance the value of the new database.

For these reasons EBN has started with designing the '<u>EBN HC Show database</u>'. At the start of this project the basic design of the HC show database was available. Some 100 wells, mainly situated in the most Northern offshore block (DEFAB area) had been evaluated as a pilot (fig. 1). The primary database design and the evaluation of the pilot wells has been done by former UU intern Chris Heerema (phase 1 of the HC Shows database project).

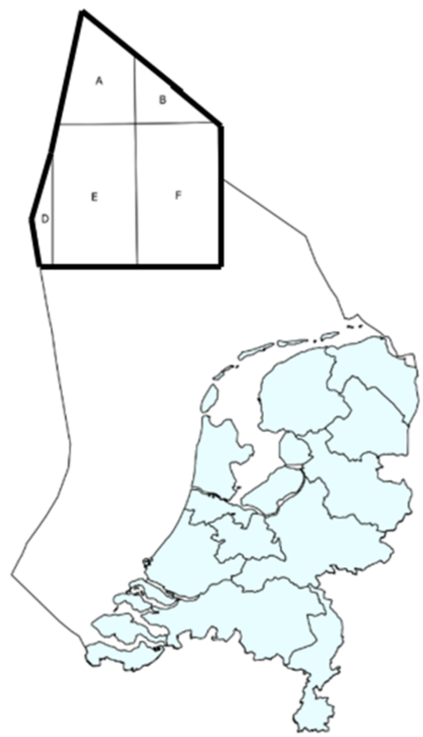


Figure 1: Focus area of the project and initial focus area of the EBN HC Show database.

1.1 Goal of the HC Show database

The HC Show database designed by EBN consists of a combination of three different data types that together form a powerful tool. Not only mudlog data, but also test and core data (incl sidewall cores) is evaluated jointly during the show analysis. Eventually the database could cover all on and offshore boreholes. Moreover, it is the aspiration of EBN to make this database available for partners in the Dutch petroleum industry. In order to access the content of this database, several visualization options are developed. A start for this has been made by the previous intern by setting up a 2D visualization in QGIS. The next step (part of this project) would be creating a 3D visualization using the Petrel platform. Also validating (QC) the data in the database is necessary to ensure reliability. Therefore several goals have been set for this project, which are listed below.

1.2 Goals/Focus of the current project

The initial objective for this internship (phase 2) is expanding the database towards the south with the existing methodology. A second goal is to enhance the design, visualization and analyses tools of the database.

Focus:

- Expanding EBN's new HC show database with new wells, complementing the DEFAB area (fig. 1).
- Visualization of HC Show data with the use of the QGIS software. The main goal here is to generate regional maps showing occurrences of hydrocarbons to assist exploration studies.
- Investigate the use of Petrel as 3D GIS system. This can be useful for HC show analysis in conjunction with seismic data and structural features as expressed on the seismic data.
- Data analysis and QC with the Spotfire software. This might provide a better insight in the occurrence of HC shows by analysing multiple parameters.

2. EBN HC Show database basic design

The EBN HC Show database contains of three different data types which are relevant to assess the quality of a HC occurrence in a well. The following data types are addressed:

- Data type 1: Log data
  In this category continuous data logs (e.g. Mudlogs, Formation Evaluation logs, Composite logs) are analysed. The format is based on the TNO defined stratigraphy per well. The boreholes are evaluated from top to bottom, even stratigraphic intervals in which HC shows are absent, are also documented. Per formation the strongest gas and oil show is documented and several relevant attributes and comments are described and noted down.

- Data type 2: Test data
  The test data category comprises methods of formation testing and sampling. Drill stem tests (DST's), production tests and repeat formation sampling tests (RFT samples) are documented in this section. Whether an interval is tested is not always easy to track back. Often this information is just annotated as text comment on wellbore logs. Documenting results of these different tests, therefore often serves as QC (and sometimes supplement) for the log data section. In this way test data can confirm and possibly enhance the documented Log data shows.

- Data type 3: (sidewall-)Core data
  This data section comprises of core and sidewall-core data and focusses on the HC show descriptions in the samples. Such as the test data this section functions as supplement and QC for the Log data section. The main focus analysing well core data is documenting the oil shows and (if described) gas bubbling. Additionally, since coring an interval can disturb Log data , (sidewall-)Core data provides a good quality control.

Combining the three data types for each well is done per stratigraphic interval as defined by TNO. This provides the opportunity to compare the different data types and check whether there is a (mis)match between mudlog HC show classifications and test or core data.

2.1 Hydrocarbon Shows

A HC show can be defined as a significant occurrence of hydrocarbon gases or fluids detected from the drill mud stream and identifiable as being the result of drilling a specific formation interval (Yassin, 2012). In case of a gas show this is any deviation in gas reading, amount or composition, from the established background. The deviation in gas may or may not accompany a change in lithology or be a significant or economic hydrocarbon accumulation (Yassin, 2012).
The background gas is the consistent gas reading to be recorded throughout a consistent lithology. This background reading can have a considerable variation in certain lithologies. (Yassin, 2012).
Generally taken, the key to interpret shows lies not in the magnitude of the reading reached, but the extent to which it did change compared to background gas. Oil and gas can occur in the subsurface in different modes (Schowalter and Hess, 1982). (1) continuous phase oil or gas in water saturated porous rocks; (2) isolated droplets of oil or gas in water saturated porous rocks, similar to waterflood residual oil or gas occurrence; (3) molecular-scale dissolved hydrocarbons; and (4) hydrocarbons incorporated in kerogen or directly associated with oil or gas source rocks. The different modus are listed below in table 1.

Table 1: Classification chart for subsurface hydrocarbon shows (modified after Schowalter and Hess, 1982).

Mode of HC occurrence	Show type	Significance	
		Producible	*Exploration*
Continuous phase	1	Productive???	Trapped oil
Residual	2	Non-productive	Migration path
Dissolved	3		HC in system
In Kerogen	4		Source rock

3. Methods

3.1 Primary HC Show database workflow model

In order to summarize the workflow of the HC show database and its corresponding components, a workflow box model is designed (fig. 2). This model visualizes all different components and steps related to the complete HC show database. The model is also useful for future analysts and users to get familiar with the database and its components. Moreover, improvements to this initial workflow can be made easily by evaluating all different steps. This will become evident later in this report.

The model consists of different components; the input data, the database itself and the outputs with corresponding visualization setups.

The database input consists of 2 different components. The mudlog, test and (sw-)core data gathered from the TNO NLOG site (centralized database of all Dutch subsurface related data, www.nlog.nl). Secondly, confidential well data from Livelink (EBN's file database).

The database itself consists currently of an Excel interface spreadsheet, which will be updated preferably on a monthly basis in the GISbase. The GISbase is the central SQLserver database from EBN in which geodata is stored and updated. In this database all borehole related data, such as stratigraphy and deviation data, can be internally updated to the HC show database. This ensures the database to be up to date at all time.

The output of the database consists of 2 different visualization setups. Firstly, an interactive topview (2D) visualization in the QGIS software. Secondly, a newly designed interactive (3D) visualization in the Petrel E&P software.

3.2 HC Show database expansion

Key focus of the project is expanding and improving the Shows database by evaluating more wells. The pilot area mainly focussed on the Northern A, B, D and E blocks. For this project (phase 2) it was decided to complete the pilot blocks and start with the adjacent F block. Eventually if time permitted an expansion to more southern blocks (H, N, G and M) could be realized.

3.3 HC Show database enhancement

Several enhancements to the HC show database have been discussed during the final presentation of Chris Heerema and during the course of this internship.

1) Describing the workflow for the HC Shows database, in particular the input, output and analysis steps.
2) Improving the workflow with special emphasis on enhancing the HC show 'classification' steps to ensure unambiguous classification rules.
3) Enhancing the value of the database by developing QGIS 2D visualization and Petrel 3D visualization functionality (see chapters 3.4 and 3.5).

3.3.1 MS Access interface

One of the main enhancements to the HC show database is the transition from MS Excel to a MS Access input interface, which will increase the efficiency of database control. There are two main motivations for this transition. The fact that the GISbase works with a MS Access interface, will speed up the database updates. Furthermore, using MS Access enables users to comfortably sort columns and rows, without alternating the data. This is a major improvement, as the risk exists that in the future the HC show database becomes corrupted by column and row sorting.

3.3.2 Workflow 'HC Show classification' enhancement

After careful appreciation of the existing HC show 'classification' workflow in the "HC Show Workflow" (C.Heerema, 2015) it was decided to revise several aspects. It became clear that the part (step 7 to 11), which includes the actual classification workflow does not meet the level of clarity of which every future user can benefit and perform HC show evaluations. The primary goal for this revision is to give future analysts of the database the opportunity to meet a certain level when classifying HC shows.

As Yassin (2012) already stated; 'The manner and extent to which shows will manifest themselves varies so greatly among the many different regions that it is impossible to set even a general set of requirements which must be met to qualify a show for additional evaluation or to determine to what that evaluation should be'.
Moreover, 'To decide whether a gas show is 'GOOD' or 'POOR' i.e., whether or not a significant hydrocarbon accumulation is indicated, requires a total evaluation of all mudlogging parameters plus consideration of the many variable system conditions'.
This means that the future user not only needs to consider the revised classification workflow, but at all-times needs to use his/hers geological and petrophysical knowledge.
The main goal is to make sure that the database keeps its high potential as a powerful exploration tool in the future. After careful evaluation it is decided to create a HC Show 'Example Atlas' covering different formations in different areas. This atlas, in combination with weekly review meetings with colleagues within EBN, gives the future analyst the necessary background for keeping the show classification at the same level.

3.4 QGIS interactive topview (2D) visualization

Data visualization is an important aspect in the light of potential HC exploration. Moreover, the aspiring accessibility of the HC show database calls for clear visualization and symbolism setups in both 2D and 3D.
Therefore, one of the goals of this project was to enhance the QGIS visualization designed by Chris Heerema (2016). During Chris' end presentation it became clear that the designed symbolism only needed some minor expansion. One example for this is: the use of one single symbol for both 'NO SHOW' and 'NO DATA' was considered to be inadequate. In addition, the construction of an user manual for setting up the QGIS visualization was considered as an useful additive to the database package. Lastly, both the visualization and the manual needed to be carefully tested. All of this will be explained in the following paragraphs.

3.4.1 Visualization symbols

The QGIS setup uses carefully constructed symbolism in order to show different aspects (log and core data) of an evaluated HC show at a glance. The main focus lies on visualizing classified log and test data shows, of which, due to partial symbolism and transparency and ensuring that each improved show overlaps a lesser show, the strongest show is always depicted. The improvements to this symbolism are mainly related to the data that isn't directly related to HC show indications. It is important for users to have all available data, including indications of no data, visualized in one window. Therefore a letter symbolism has been introduced to visualize several inputs of the database. This enables the user to identify unclear data and wells that are for instance confidential. A next step for the user can be to personally complement the well by re-evaluating the data. The updated symbols used in the QGIS setup are shown in figure 3.

3.4.2 User Manual

A new manual for the QGIS visualization is created. It lets the user follow several different steps resulting in a basic visualization setup. Furthermore, it discusses the import of depth surfaces, which can be used as background and at the same time give context to the data. This is however for the user to decide; either to use the proposed maps, or his own.

3.4.3 Testing and Implementation

The manual is carefully tested and reviewed by colleagues within EBN. Feedback is reviewed and incorporated in the manual. The first implementation of the visualization setup is done by creating maps, which visualize different HC show intervals per stratigraphic level. The background maps are made by combining the EBN 'DEF Survey' (northern part DEFAB area) and the TNO '2012 offshore survey' (southern part DEFAB area).

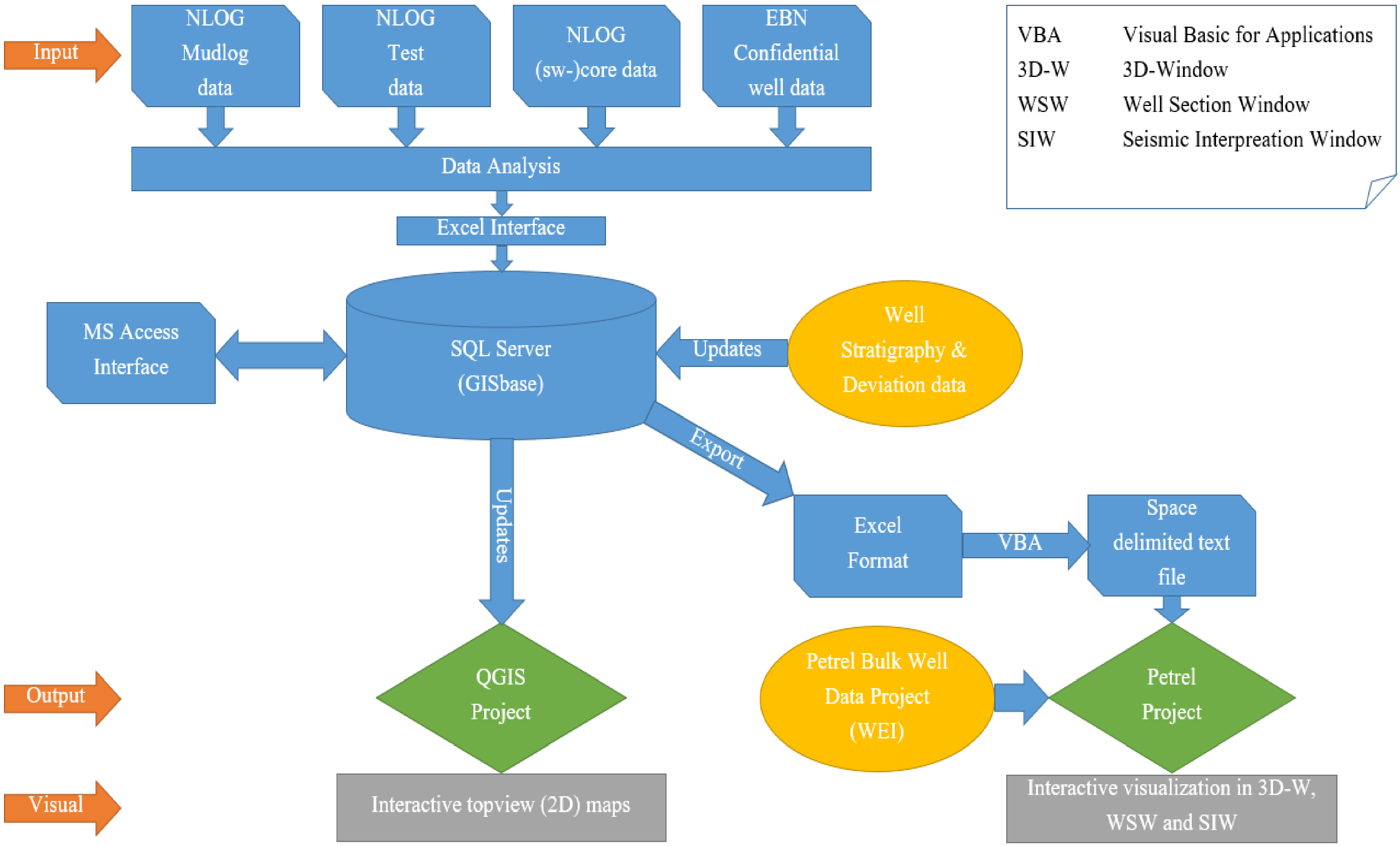


Figure 2: Initial EBN HC Show workflow box model. The workflow consists of an input, output and visualization of the data. In this box model the initial workflow using a VBA code for the Petrel visualization is still incorporated.

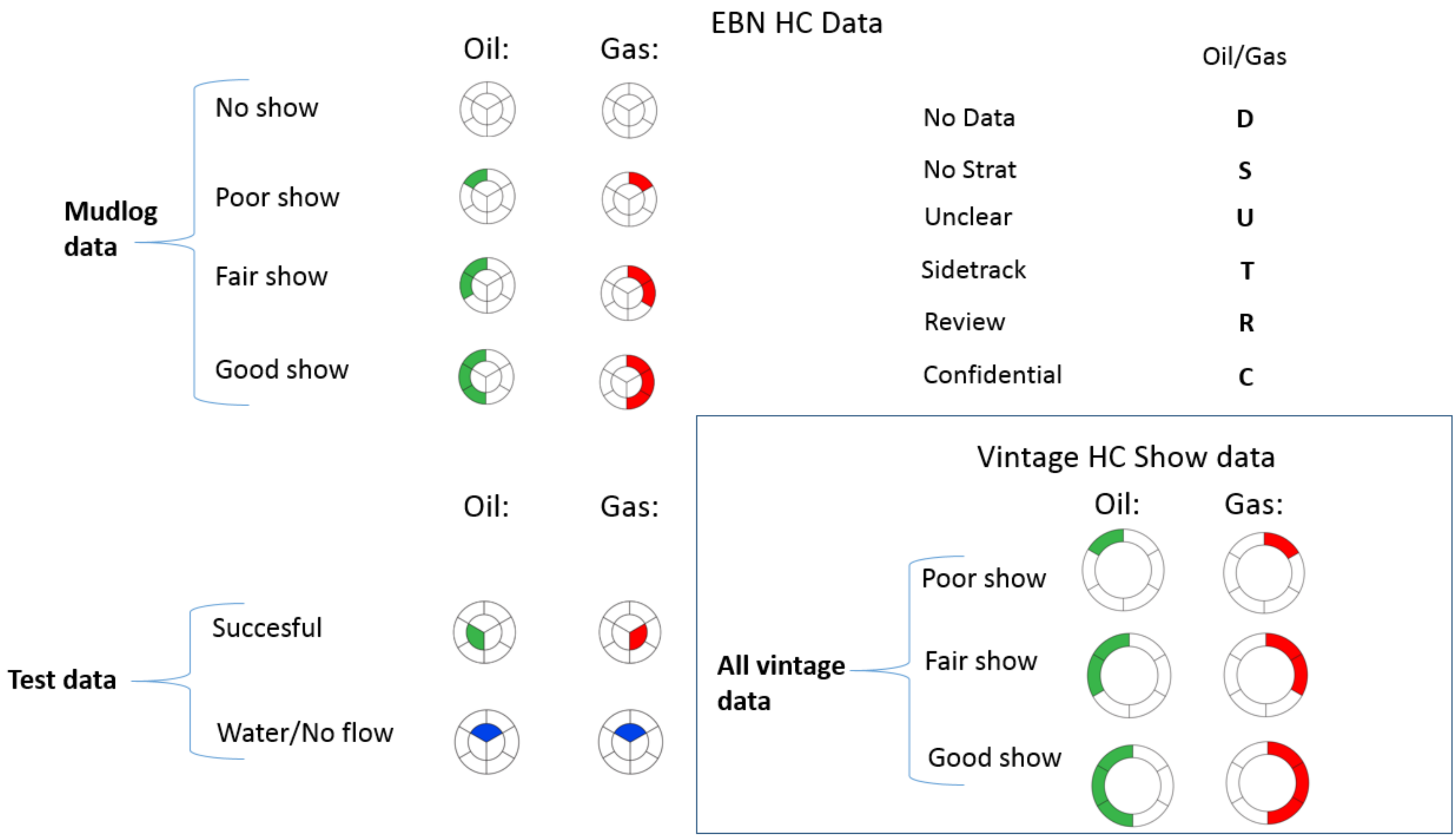


Figure 3: QGIS visualization symbolism (modified after Heerema, 2016).

3.5 Petrel E&P software interactive 3D visualization

Another goal of this project is expanding the HC Show database package by designing a (3D) visualization setup in the Petrel E&P software. The method initially designed for this 3D visualization setup is shown in the workflow box model and consists of using a “Visual Basic for Applications” (VBA) code. This code converts the HC show data in the GISbase to a Petrel compatible import format.
The visualization setup itself is initially designed by introducing different setup possibilities. These 4 possibilities were carefully evaluated in several meetings, by analyzing pros and cons. Eventually, a combination of two setups has been chosen to be further developed.
Similar to the QGIS visualization an user manual was considered as an useful additive to the total package.

3.5.1 Visualization setups

The inspiration for the four different visualization setups came partly from the QGIS visualization, and partly from the setup of the database itself. The four different setups are shown in appendix A.

3.5.2 VBA code designing

It was initially decided to use a Visual Basic for Applications (VBA) code to convert the data in a Petrel compatible format. VBA allows users to easily convert and modify large datasets in different formats. This is an ideal starting point for getting the correct data in Petrel. As Petrel import files can have different formats and designs, a first evaluation of the correct format and file extension was performed. After evaluation it was decided to go for an ‘Point well data format’ with a ‘text file’ extension. The code itself consisted therefore of different components. Copying and pasting of data, followed by deleting empty rows and overall data sorting. Moreover, the code needed to produce two different files. A new Excel workbook that enables users to do a fast QC at all time. Secondly, a text file with the correct data and format that can be directly imported in the Petrel software.

3.5.3 User Manual

A manual for the basic visualization setup in Petrel is constructed. It follows the same step-by-step hands on concept as the QGIS manual.

3.5.4 Testing and Implementation

The manual is carefully tested and reviewed by colleagues within EBN. Feedback is reviewed and integrated in the manual. Implementation of the visualization setup will mostly be done in the future by the exploration team within EBN. For this reason a short demo during the presentation will make everyone familiar with the applications of the Petrel setup.

3.6 Data Analysis and QC

In order to control the database quality it is important to check the documented data on a regular basis. One way to do this is by analyzing the correlation between DST test -and log data using an intra-database correlation. Linking the test result with the mudlog HC shows within the DST perforation interval gives a clear representation of the database quality. When the test results do not correlate with the evaluated mudlog HC shows within the test interval, it’s possible that important data is missing in the database. Most importantly because a production test is performed after careful evaluation of the data while drilling (mudlog, etc.). A direct correlation (“Match”) exists when, within a test interval (“GAS/OIL” result) a corresponding log show is evaluated. A semi correlation occurs when the corresponding log show is evaluated outside the test interval, but within the same stratigraphic formation. Test results do not correlate with the evaluated mudlog shows when neither of these previous rules is met.
The evaluation of the mudlog data in the HC Show database is based on evaluating the strongest gas and oil show per stratigraphic formation. Moreover, several relevant attributes and comments are noted down. On the other hand production tests are always performed over a large interval, perforating the formation in smaller intervals. Therefore a tolerance of up to 50 meter is used while doing the correlation.

4. Results

4.1 The EBN HC Show database workflow

During a workflow evaluation with the database coordinator within EBN (Peter Bange), all steps for the EBN HC show database were evaluated. This eventually resulted in a step efficiency improvement. Moreover, it was decided to add step descriptions to the workflow model (fig. 4).

The step efficiency improvement is related to the Petrel visualization setup. Earlier the user required to use a complex VBA code in order to transform the database (via a MS Excel interface) from the GISbase to a Petrel compatible import format. After a recommendation from my end, these steps were improved to a more user friendly solution. From now on the user can directly generate the Petrel import file from the GISbase (step 4, fig. 4), followed by importing the file in Petrel (step 6, fig. 4).

Adding the workflow step descriptions helps analysts and users in extracting maximum value from the HC show database.

4.2 Database Completion

During this project the completion of the DEFAB, H and N areas is realized. Except for approximately 40 wells all the well data has been evaluated and put into the database. The missing wells are mainly divided in wells for which no data is available on NLOG or internally in EBN (livelink) and confidential wells. Contact with the TNO NLOG administration about the missing data is made. Further steps on complementing these wells will be discussed in the recommendations.

At this moment Claudia Haindl (TUD) is expanding the database for the G, M and L blocks. This means that the database at this moment contain shows data from approximately 300 wells.

4.3 Database enhancements

The transition from a MS Excel interface to a MS Access interface was investigated and some major benefits were identified. As discussed earlier these benefits are mainly related to efficiency improvement and lowering the risk of database corruption. Moreover, the possibility exists to combine several well related databases from EBN using a MS Access interface. At this moment it is decided that this transition will be performed in the near future when the design of these databases has been completed. As of now a fluent transition is anticipated.

Several enhancements concerning a fluent handover of the project to a new analyst, have been done to the ‘classification’ workflow. These include constructing a table format HC Show classification workflow (page 36, Appendix B). This table is only meant as a basis for the classification and needs to be used in combination with a second improvement: the Example Atlas (Appendix C). This atlas gives examples of typical shows and the corresponding classification. With the atlas as reference, the classification of shows from further wells is made easier. Using both enhancements in combination with weekly ‘review meetings’ will give the future analyst a strong basis during the classification of the HC shows.

4.4 QGIS Visualization and Maps

The user manual for setting up a QGIS project with the EBN HC show database visualization is given in appendix D. With this description it is possible to make comparable maps as show in figure 6 (A-F). This can be done by filtering on different stratigraphic groups, formation or even members by setting specific queries. This is combined with background depth maps. More information on this can be found in the QGIS user manual.

One of the goals of this project was to generate regional maps showing classified occurrences of hydrocarbons to assist exploration studies. Classified Show maps are given in figs. 6 for the following stratigraphic intervals; Tertiary & Quaternary, Upper Cretaceous (Chalk), Jurassic, Triassic, Permian (Zechstein) and Permian (Rotliegend) & pre-Permian. The data shown on the maps has been discussed in a HC show review meeting with members of the exploration team. This resulted in several re-evaluations of HC show data.

A good example of a HC show that needed re-evaluation is within the green box of figure 5. This HC show was originally classified as a ‘GOOD’ gas show. The analyst commented that it was annotated as a ‘ well kick’ in the mudlog and therefore decided that it should be a ‘GOOD’ show.

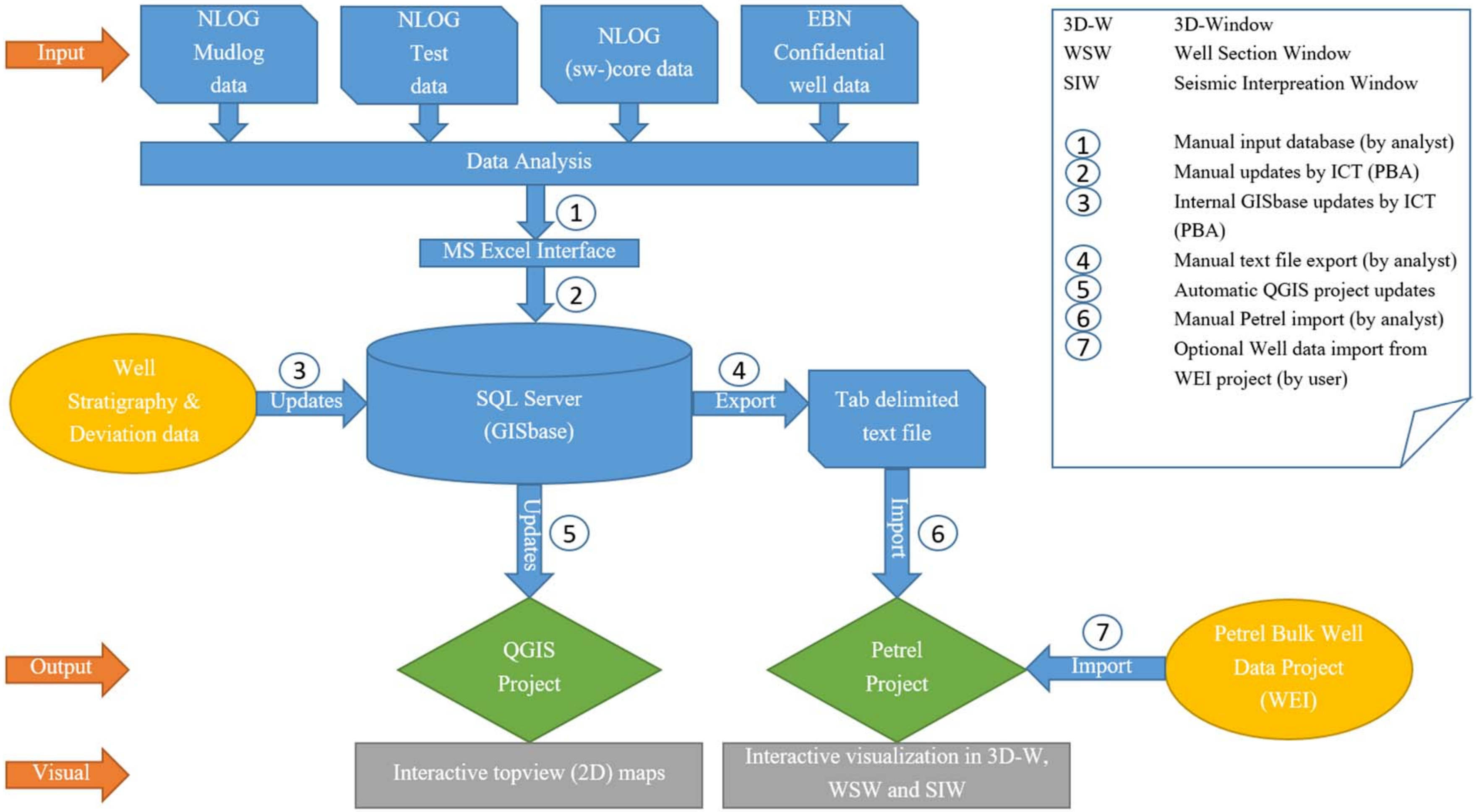


Figure 4: The 'EBN HC Show database Workflow model'. This updated box model includes all components and steps of the database workflow. All steps are provided with short descriptions according to the numbering.

However, this HC show is situated in an area for which no 'GOOD' shows are anticipated in the Triassic, as is believed that this reservoir interval has not been charged in this area. For this reason a re-evaluation of the mudlog has been performed. The overall conclusion of this review was that the 'well kick' annotation in the mudlog was related to a pressure kick. There were two main reasons for this. Firstly, there was no indication of background gas and the absolute value of the peak was small. Secondly, the peak is documented at the boundary of a major lithology transition from claystone to sandstone. This led everyone believe that there is a pressure kick between the possible seal-reservoir pair. Eventually leading to a 'No Show' classificiation shown within the purple box of figure 6D.
This example shows that these maps are ideal for reviewing evaluated data efficiently, resulting in a increase of the database overall strength. For this reason the primary results of these maps have to be considered carefully and combined with previous exploration studies.

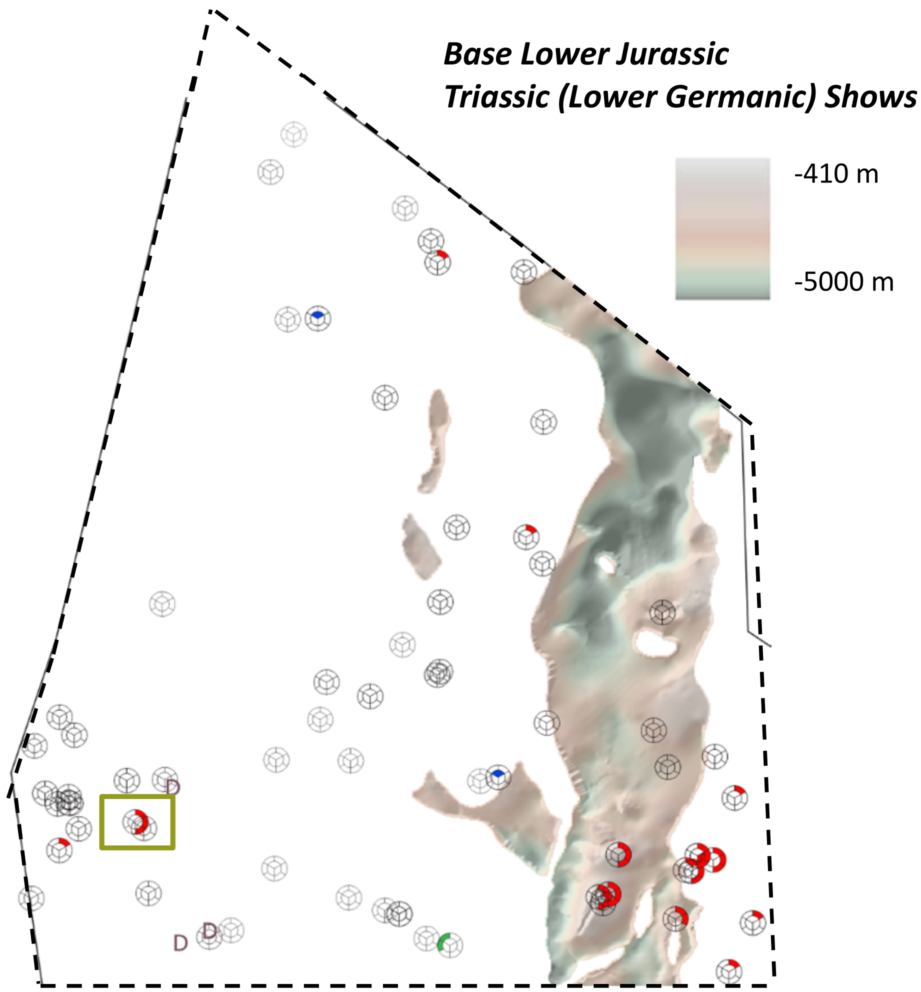


Figure 5: Previous version of the Triassic shows visualized on the base lower Jurassic depth map. The green box indicates a primary HC show classification that has been reviewed and corrected. The new results are visualized within the purple box of figure 6D.

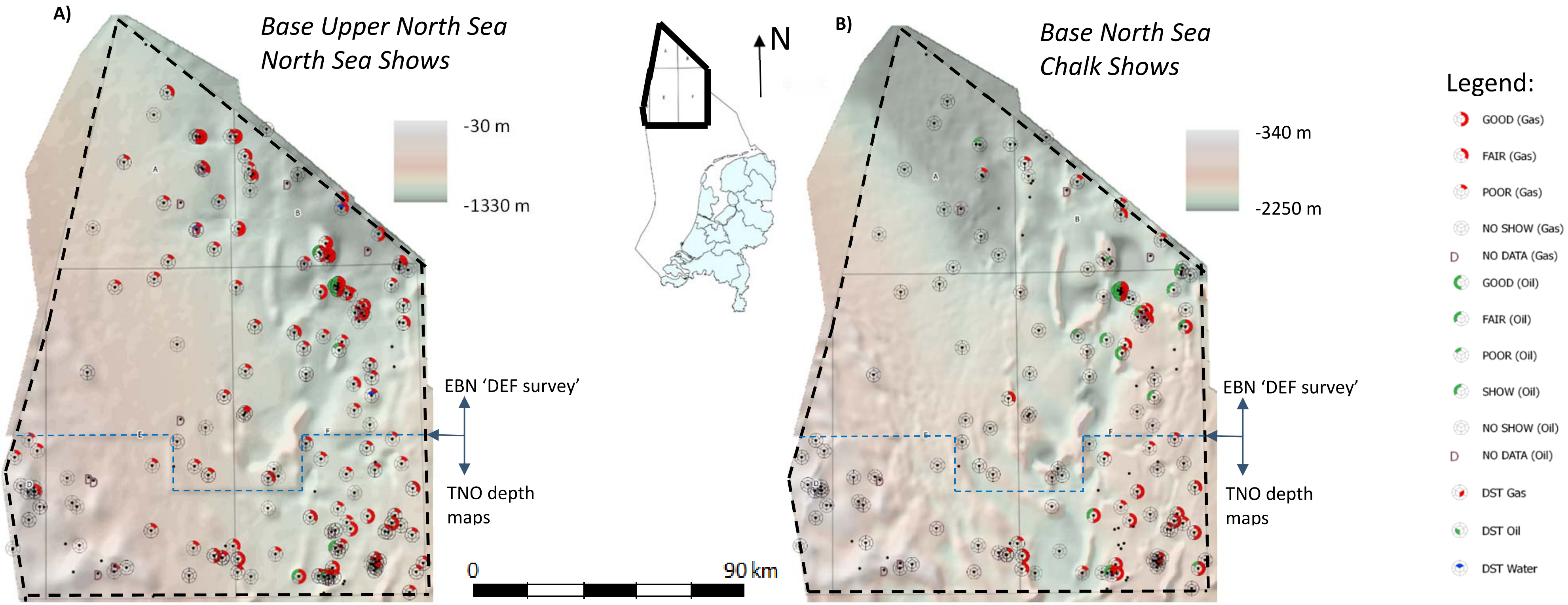


Figure 6 A&B: Formation base maps (depth in meter) of the Dutch offshore DEFAB area, combined with underlying EBN HC Shows (Log data and Test data). Legend, scale and overview map is added. A) Base Upper North Sea, Tertiary and Quaternary Shows. B) Base North Sea, Upper Cretaceous (Challk) Shows.

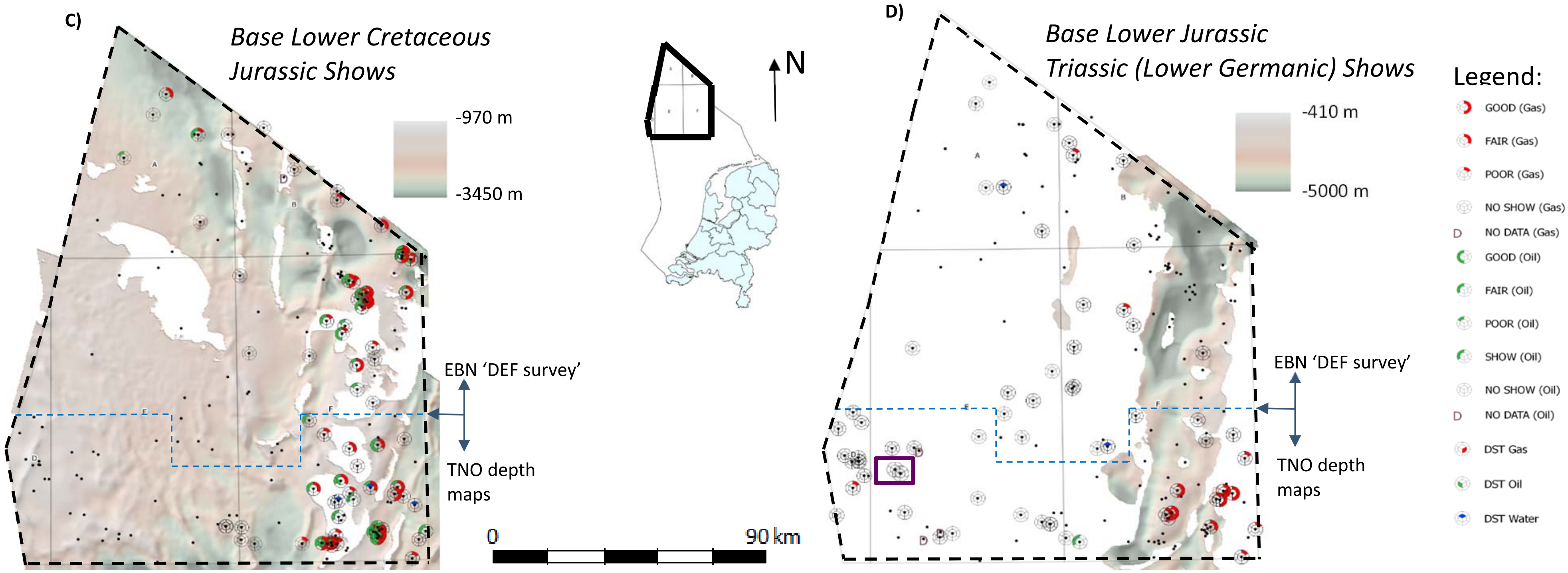


Figure 6 C&D: Formation base maps (depth in meter) of the Dutch offshore DEFAB area, combined with underlying EBN HC Shows (Log data and Test data). Legend, scale and overview map is added. C) Base Lower Cretaceous, Jurassic Shows. D) Base Lower Jurassic, Triassic Shows. The purple box in figure 6D indicates re-evaluated results.

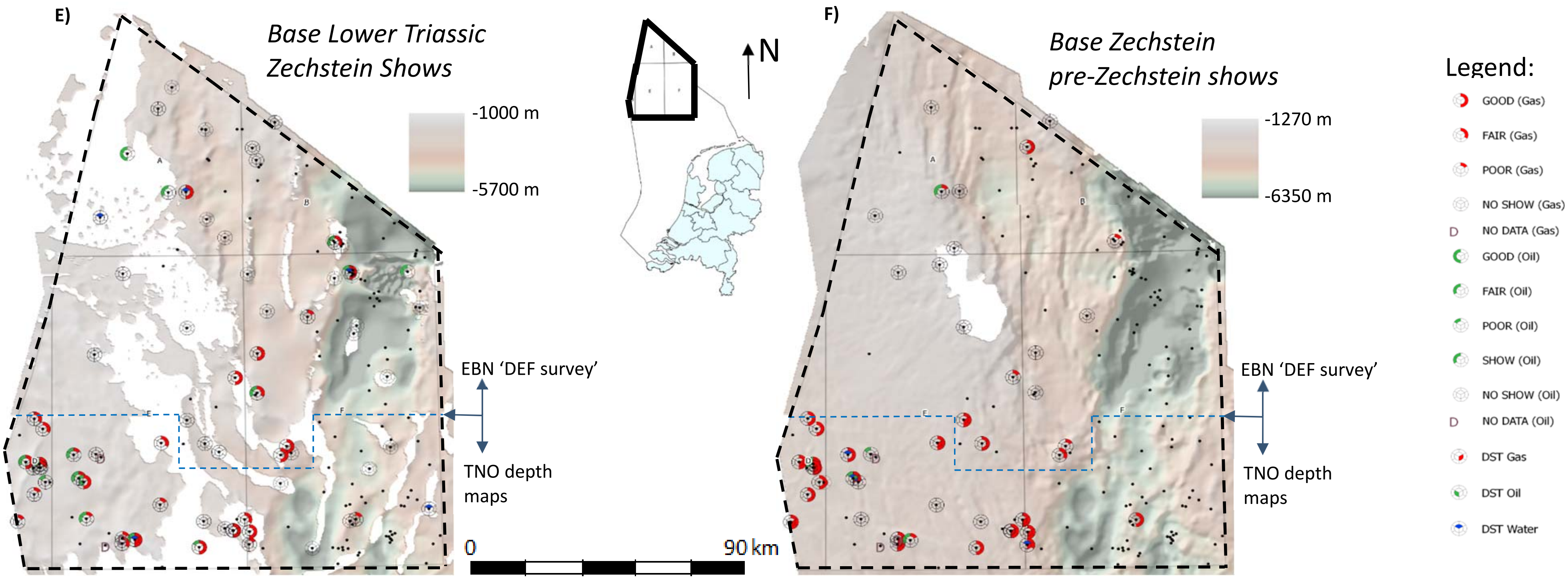


Figure 6 E&F: Formation base maps (depth in meter) of the Dutch offshore DEFAB area, combined with underlying EBN HC Shows (Log data and Test data). Legend, scale and overview map is added. E) Base Lower Triassic, Permian (Zechstein) Shows. F) Base Zechstein, Permian (Rotliegend) and pre-Permian Shows.

4.5 Petrel visualization

A major goal for this project was designing and creating a 3D visualization of the HC show data in Petrel. The user manual for setting up your own Petrel project with the EBN HC show database visualization can be found in appendix E. Furthermore, the constructed VBA code as basis for the new GISbase view resulting in a Petrel compatible import file can be found in appendix F. In this appendix the different sections from which the code is composed are shortly explained.
The visualization setup, which has been chosen after careful evaluation, is a combination of setup 2 and 3 found in appendix A. The combination means that for the "Well Section Window" setup 2 is used, but for the "3D Window" a classification following colored symbols (setup 3) is found adequate. As Petrel doesn't support classifications by the use of words (GOOD, FAIR, POOR and NO SHOW) a numbering is used, which can be found in table 2 below. The overall Petrel visualization setup is designed in order to be applicable in the three most important windows; "Well Section Window", "Seismic Interpretation Window" and the "3D/2D Window".

Table 2: Hydrocarbon Show classification in numbers. These numbers are incorporated in the Petrel import file and can therefore be used for the different windows.

Gas Show	Oil Show
GOOD = 5	GOOD = 5
FAIR = 4	FAIR/OIL SHOW = 4
POOR = 3	POOR = 3
NO SHOW = 2	NO SHOW = 2
NO DATA = 1	NO DATA = 1

4.5.1 Well Section Window

For the "Well Section Window" the visualization setup is based on exact depth (Along Hole) points, which correspond with the HC shows per formation interval. As can be seen in figure 7, the HC depth points are visualized as green (gas) and red (oil) filled circles. Moreover, plotting the HC show depth points overlaying other important petrophysical logs is also possible (fig. 7). The show classification numbering is visualized by plotting the depth points on the different vertical column lines. Counting from 1 (left border) to 6 (right border). This means that "NO DATA" is plotted at the left border and so on (fig. 8).

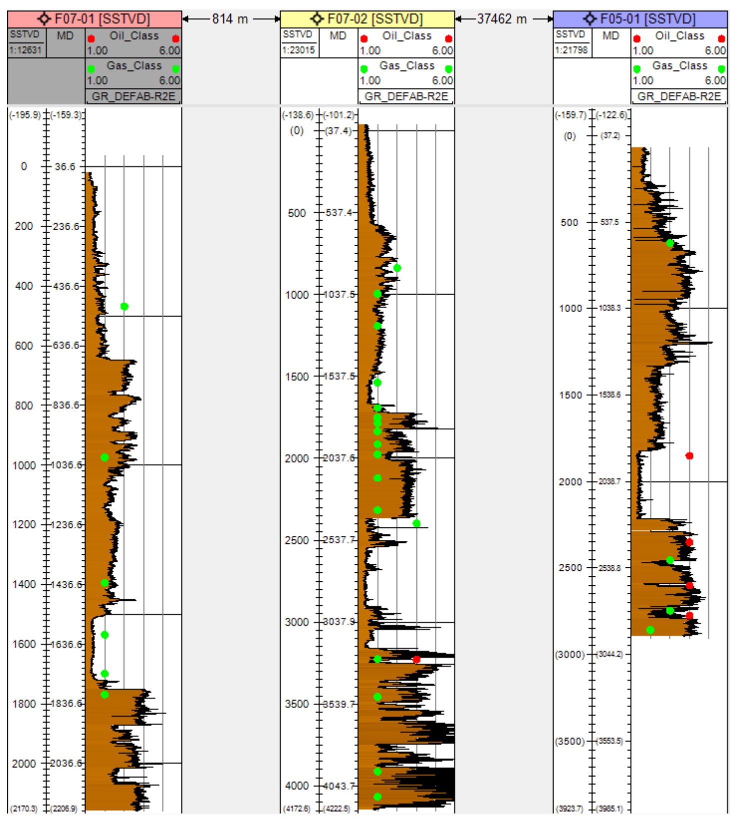


Figure 7: Petrel visualization setup in the "Well section window", showing an overlay format of different logs. In this case the gamma ray log with the "Gas_-and Oil_Class" as overlay. Gas is set as green and oil as red filled circles.

4.5.2 Seismic Interpretation Window

In the "Seismic Interpretation Window" the visualization setup is based on plotting the exact depth (AH) points along the well trajectory.

A side note here is that the seismic line is obviously projected in time domain and the HC show data in depth domain. However, carefully evaluating the HC show data in combination with seismic data is still possible in this window. As can be seen in figure 9, it is possible to plot both classification numbering (according to table 2) and group/formation codes next to the data points. The responsibility for the user here is to set the locations for the different labels matching their own preferences or needs. Overlapping labels occur due to the small distance between data points. Getting around this can be done by zooming in to the area of interest.

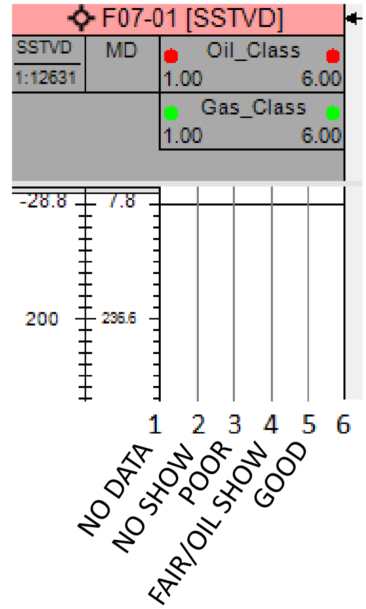


Figure 8: "Well Section Window" classification in the track columns. Classification follows numbering table 2.

4.5.3 3D Window

Lastly, for the "3D Window" a lot of different projection possibilities are available. The HC show classification can be done both on numbering as on symbol color. This is up to the user. Moreover, it is possible to use different filters on stratigraphic groups and formations. The info on stratigraphy can be plotted next to the data points (3D spheres) as can be seen in figure 10A. Other projection possibilities are plotting horizons, surfaces (fig. 10B) or seismic cubes/lines next to the data points.

For more information on all possibilities in the different Petrel windows, I would like to refer to the Petrel visualization user manual in appendix E.

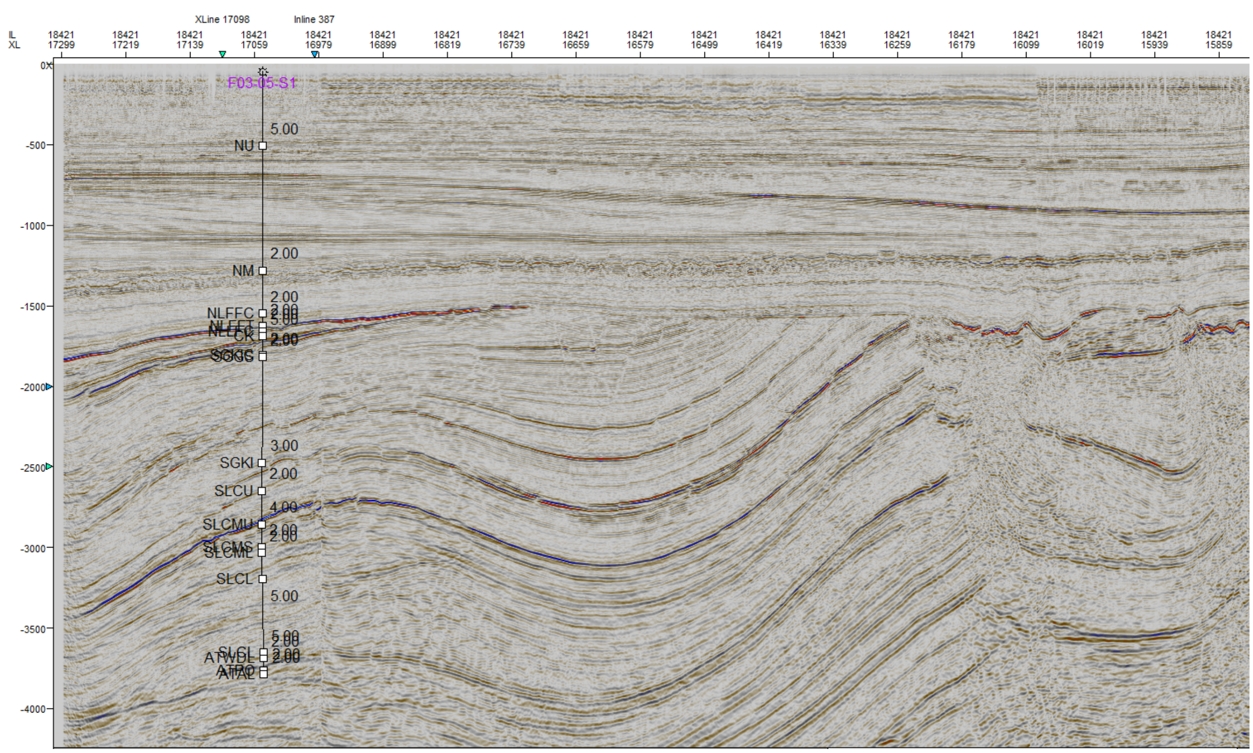


Figure 9: Petrel visualization setup in the "Seismic interpretation window". Seismic line crossing well 'F03-05-S1' in time domain. Well trajectory showing the evaluated HC Shows (white squares) in depth. To the left of the points the different formations and members are given and to the right the HC Show classifications. Some formation/member codes overlap due to relative close positioned HC Shows. When zooming in this overlapping will not be a problem anymore. It is also possible to distinguish in gas and oil classifications, by setting different positions relative to the white squares.

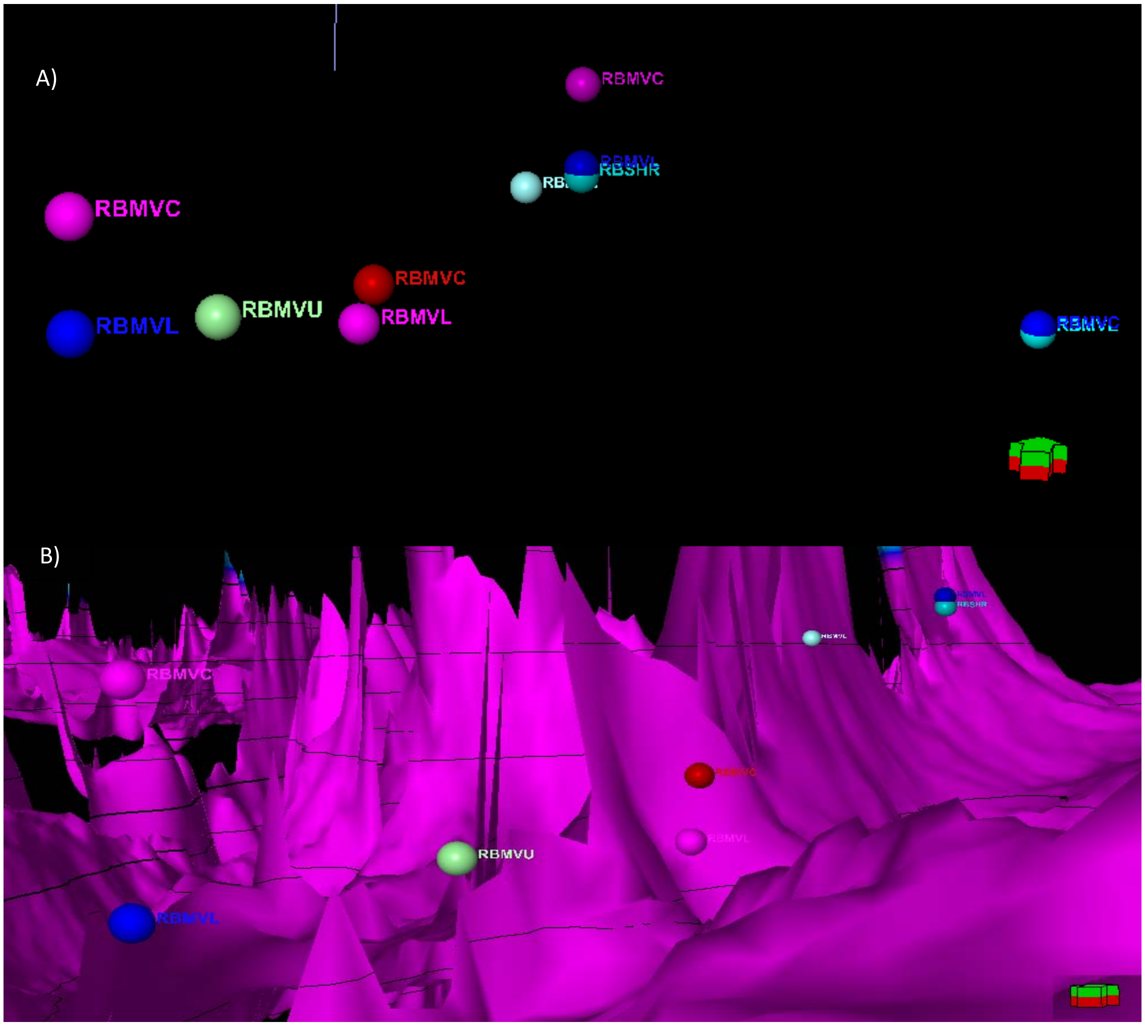


Figure 10 A&B: Petrel visualization setup in the "3D window". 8A) Several "GOOD" shows from the RB ("Lower Germanic Trias") Group. Next to the points the different Formation and Member codes are indicated. 8B) In the Petrel 3D window a lot of different visualizations are possible. One example is given in the lower part of the figure, where the corresponding base surface (TNO 2012) of the "Lower Germanic Trias Group" is shown next to the "GOOD" Gas Shows. It is also possible to show a seismic section and/or well trajectories etc. in this window.

4.6 Data analysis and QC

An intra-database correlation has been performed on the DST and log data. The correlation shows the result of all logged DST's with corresponding log data gas and oil shows per formation interval. The different graphs depicts all producible DST's (>100.000 Nm3/day) were assigned to a positive log data classification. This means that every classification of log data (GOOD, FAIR, POOR) has been used in the correlation.
The first step was looking at the correlation matches between the DST's (<u>GAS and OIL results</u>) and the Log data (<u>Gas and Oil shows</u>). As can be seen in figure 11 (Gas) the correlation can be seen as successful. 35% of the DST's, *with a GAS result*, show a positive correlation with the classified Gas shows. Only 1 DST shows no correlation and over half of the DST's have no classified Gas show within the perforated test interval.

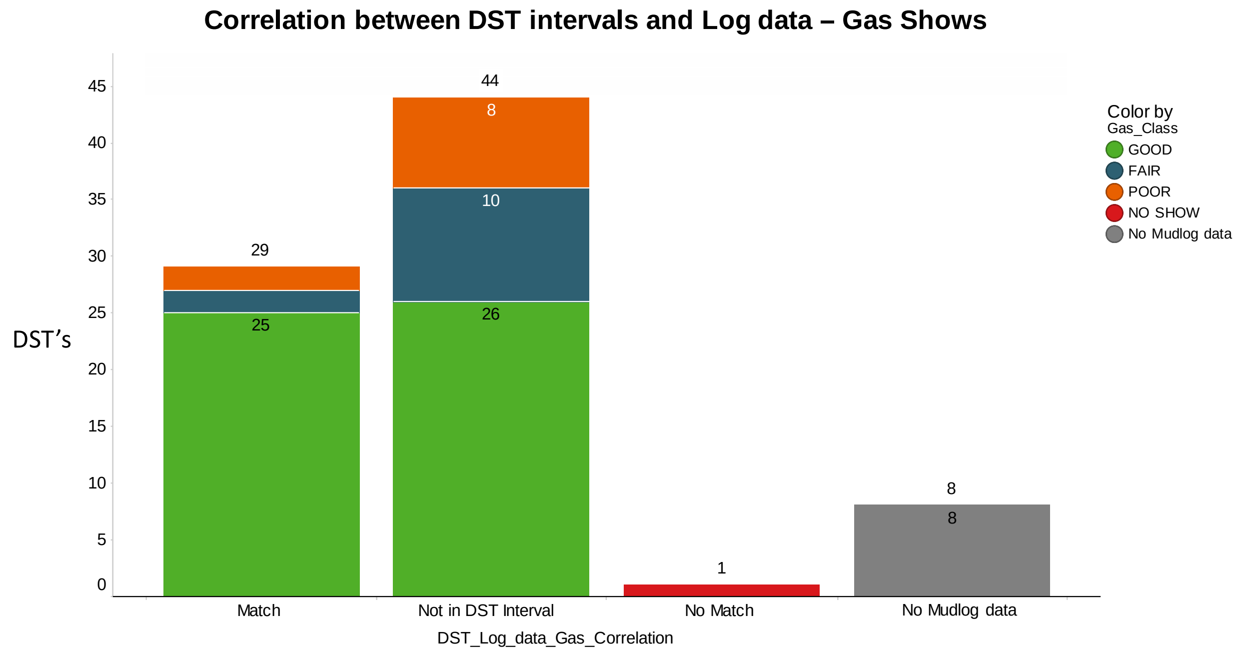


Figure 11: Intra-database correlation between DST perforation intervals (GAS result) and Log data (Gas Shows). The bars are colored by Log data Gas Show classifications. N = 82.

For the oil shows an even better correlation can be seen (fig. 12). Over 50% of the DST's, *with an OIL result*, show a positive correlation with the classified Oil shows. Less than half of the DST's have no classified Oil show within the perforated test interval.

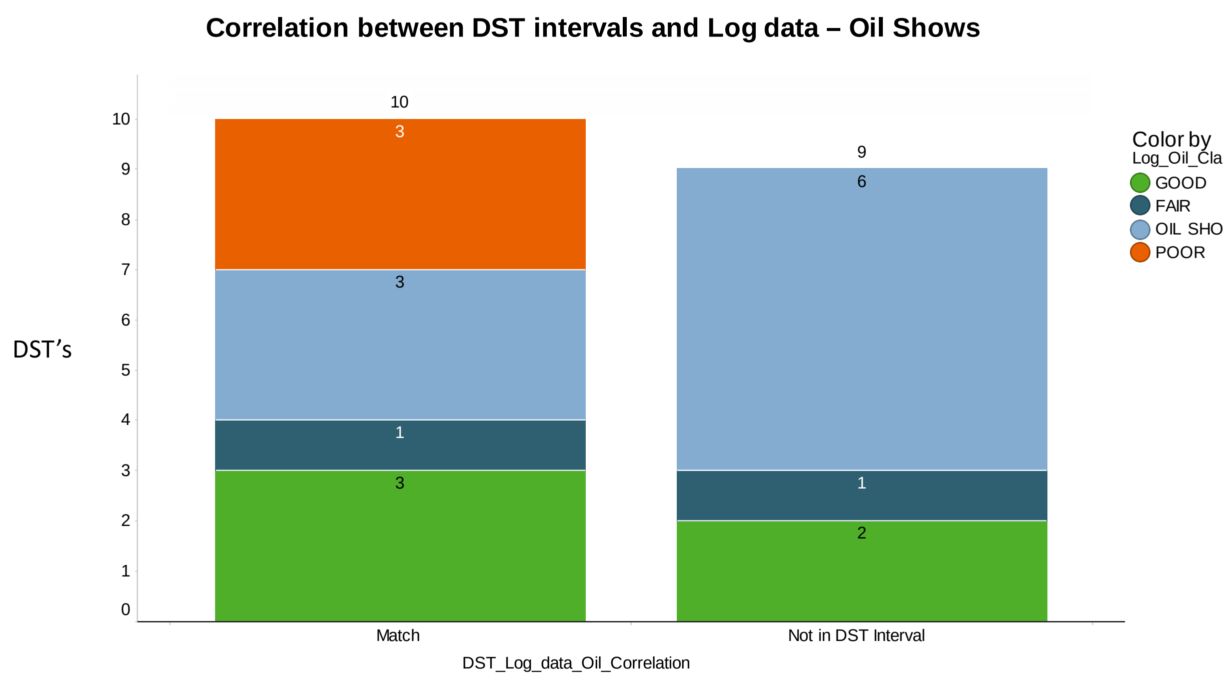


Figure 12: Intra-database correlation between DST perforation intervals (OIL result) and Log data (Oil Shows). The bars are colored by Log data Oil Show classifications. N = 19.

As the classified Gas and Oil Shows are evaluated as points in depth and Gas and Oil shows can be seen as intervals in depth, it is justifiable to use a tolerance to the test intervals. It was decided that a tolerance of up to 50 meter is preferable. This will lead to a more reliable representation of the intra-database correlation of the Test and log data.

Looking at figure 13, it becomes clear that from the 44 DST's, with no corresponding Gas show within the test perforation interval, 13 fall in a tolerance of 10 meter and 11 in a tolerance of 50 meter. This means that 65% of the DST's have a corresponding log data Gas show. Leaving the 8 DST's with no log data (missing data at this moment) out of the correlation it means that 72% of the DST's (with GAS result) have a corresponding log data Gas show. Given an even more positive signal is the fact that 75% of these positive correlations have been classified as 'GOOD' Gas Shows.

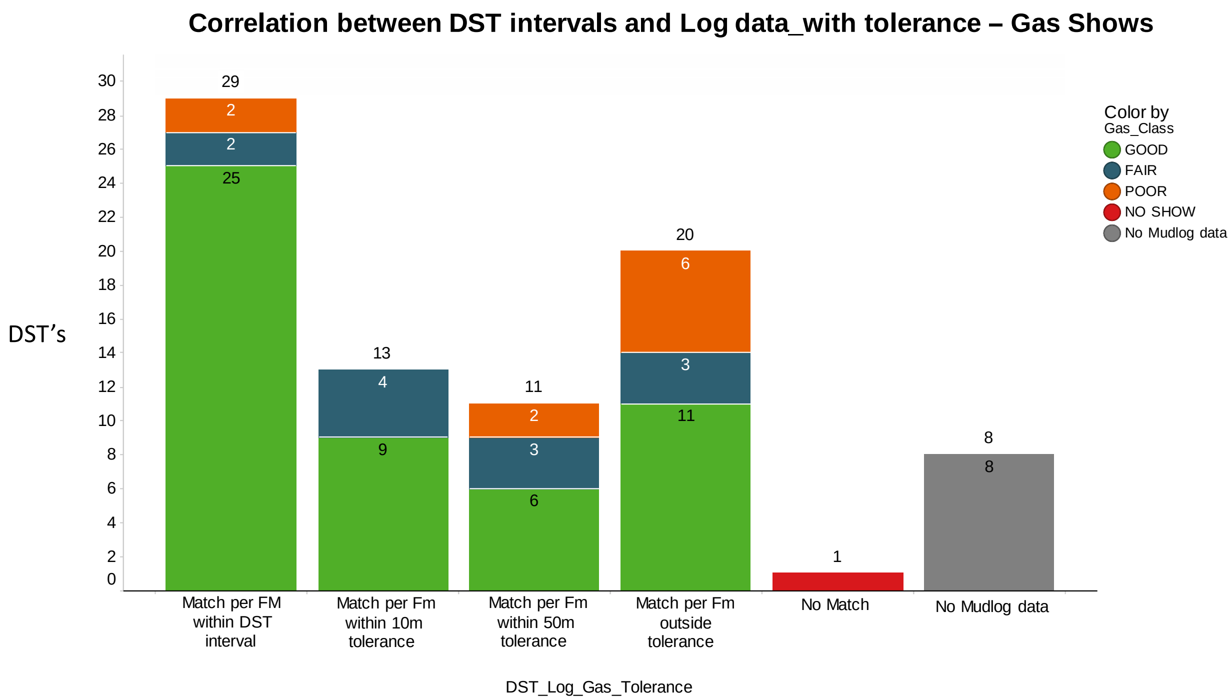


Figure 13: Intra-database correlation between DST perforation intervals (GAS result) and Log data (Gas Shows). In this correlation two different tolerances are incorporated (up to 10 and 50 m). The bars are colored by Log data Gas Show classifications. N = 82.

The correlation (fig. 14) with tolerance of DST's (with OIL result) and log data Oil shows leads to a good result. From the 9 DST's with no corresponding Oil show within the test perforation interval, 2 fall in a tolerance of 10 meter and 4 in a tolerance of 50 meter. Leaving only 3 DST's with no direct correlation to the log data. This means that 84% of the DST's with an OIL result have a corresponding log data Oil show. However, only 25% of these have been classified as a 'GOOD' Oil show.

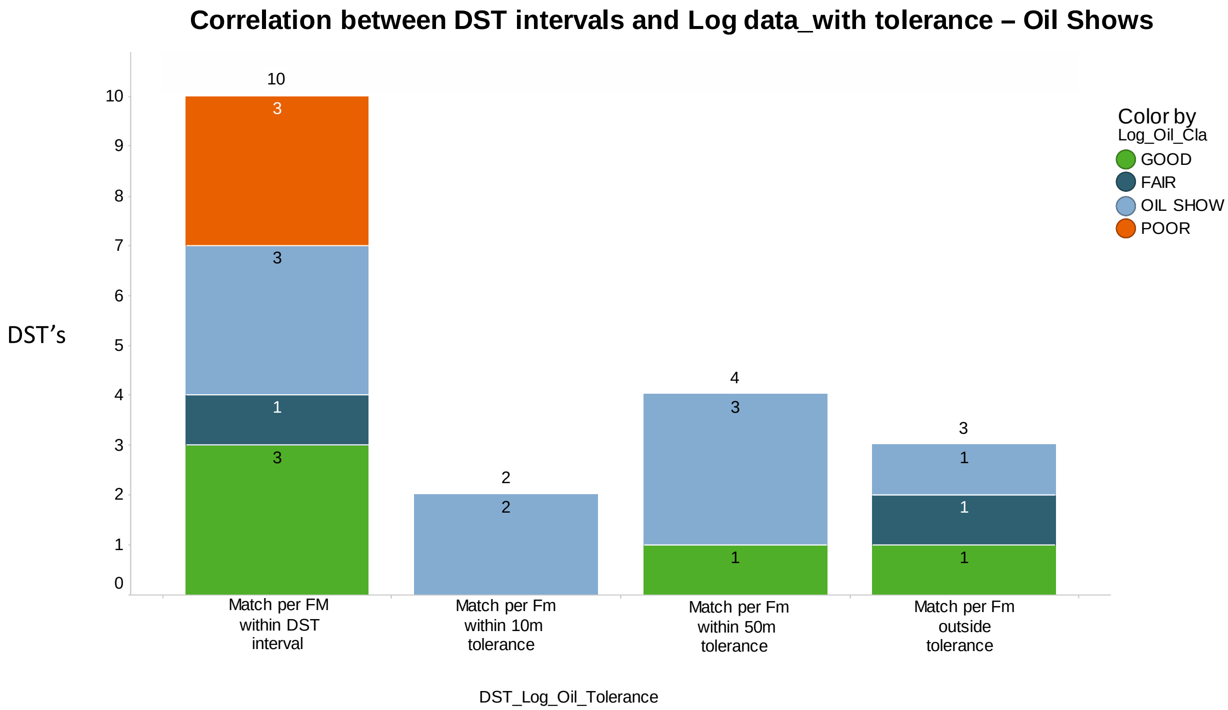


Figure 14: Intra-database correlation between DST perforation intervals (OIL result) and Log data (Oil Shows). In this correlation two different tolerances are incorporated (up to 10 and 50 m). The bars are colored by Log data Oil Show classifications. N = 19.

Additionally, a correlation with 'GOOD' classified Gas shows, within DST test intervals, that not give a GAS result (fig. 15), gives extra positive results on this overall QC. Of the 19 DST's, 10 are outside the test interval. These are therefore not discussed any further. However, the 9 DST's that have a different result than GAS within the test interval, 6 have an OIL result, 1 OIL/WATER and 2 WATER.

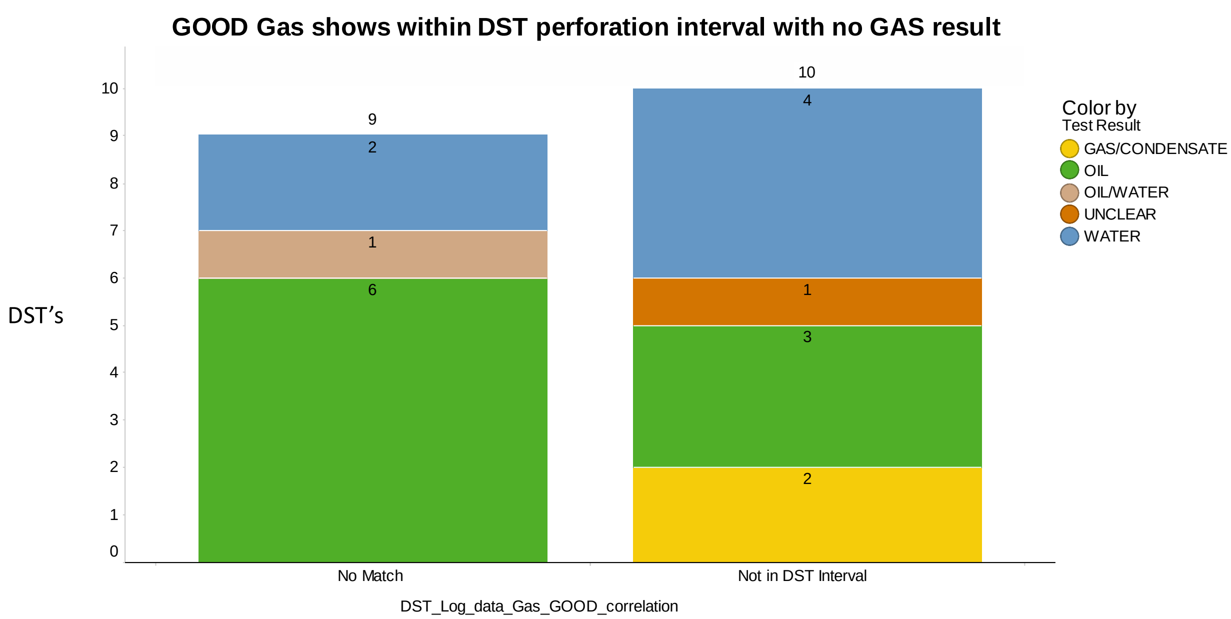


Figure 15: Intra-database correlation for 'GOOD' classified Gas Shows falling in a DST perforation interval with no Gas result. N = 19.

At last the same correlation has been done for the correlation between 'GOOD' classified Oil Shows within DST's, with no OIL result (fig. 16). Of the four DST's, 2 fall outside the test interval. The other 2 have a Gas result and OIL/WATER result.

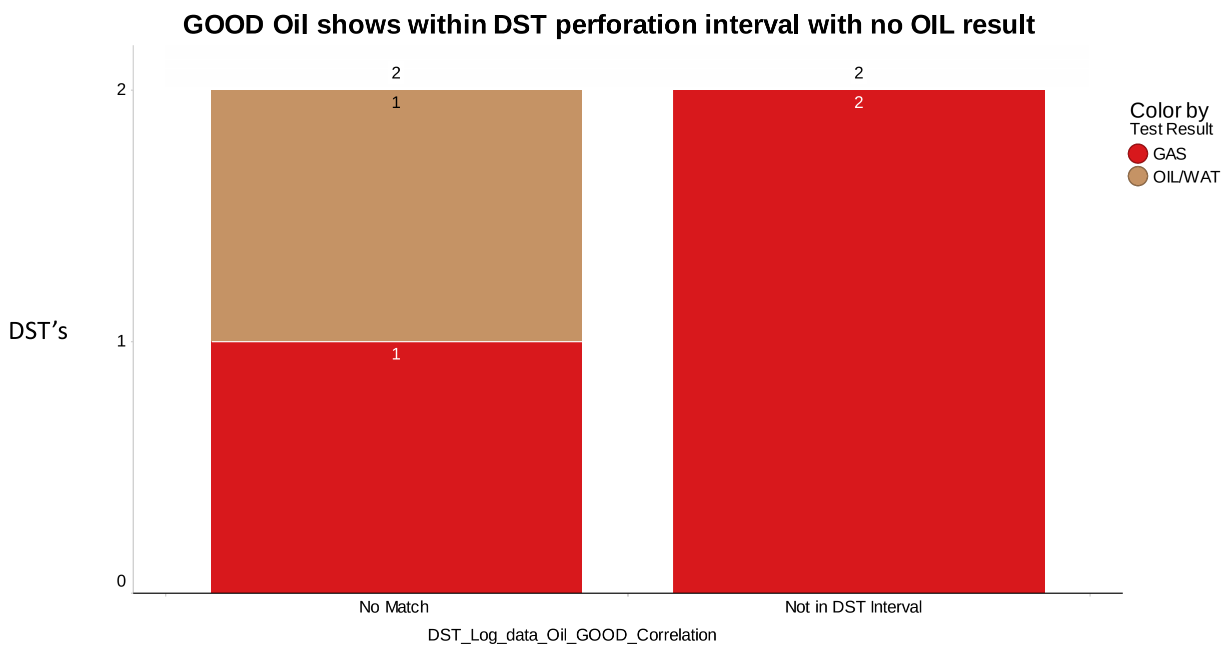


Figure 16: Intra-database correlation for 'GOOD' classified Oil Shows falling in a DST perforation interval with no Oil result. N = 4.

5. Discussion & Recommendations

The main goal of this project was to complement, design and create different aspects of the EBN HC show database. In this section all strengths, weaknesses of all components of the database will be addressed. Moreover, the results of the data analysis will be commented on. At last the way forward and several recommendations concerning the database and connected applications will be discussed.

5.1 HC Show database design

I would like to refer to the report of Chris Heerema for a detailed discussion on the strengths and drawbacks on the database design itself. He did a great job on highlighting the most important factors. However, one big strength of the database has shown to be very important during the progress of this project; The 3-way data seperation as described in the database design section. It allows for an integrated view of all HC indicators and it faciliates QC of the evaluated data. For exploration purposes this design is key in the 'dry well analysis'. Allowing the users to differentiate between 'dry wells' and 'dry formations'.

5.1.1 Workflow

The initial workflow as shown in figure 2 consisted of the primary steps for the Petrel visualization setup. However, these steps were update sensitive. Meaning that several updates to the database required an update to the VBA code. With the recommendation from me it was decided that a more user friendly and efficient workflow was preferred. The new workflow as shown in figure 4 is a well-constructed and balanced workflow. All steps can be performed within several minutes, and steps that require more time (QGIS and Petrel visualization setup) are supported by manuals. This means that every future analyst or user is able to perform every step within the workflow without problems. Moreover, the workflow gives future analysts and users the ability to become familiar with the whole database within several minutes. Lastly, the most important use of the workflow is the possibility to keep expanding the database by evaluating new expansions to the database and adapt it to the workflow.

5.1.2 Classification workflow

The workflow as constructed by Chris lacked some extensive step explanations. These were mainly related to the actual '<u>classification</u>' of the HC shows. After careful evaluation these workflow steps have been extended and edited. For the enhancements I would like to refer to the blue text in appendix B.
Secondly, an 'Example Atlas', covering different formations in different areas of the northern offshore, has been constructed. Combining these two enhancements with a weekly review meeting will enable the new analyst to evaluate HC Shows on the same level as before. However, as evaluating HC Shows is not an exact science, a subjective evaluation of HC shows will always be part of the database. Using your geological/petrophysical background will make sure that this subjective part is always well grounded.

5.2 QGIS visualization setup

Again for the discussion on the QGIS visualization I would like to refer partly to the report of Chris. However, some import aspects have changed during this project.
Firstly, a total data classification segregation has been comprised, as letter symbols have been introduced in order to cover all non-show related data (NO DATA, SIDETRACK, etc.). This gives the user the ability to evaluate all wells and where necessary re-evaluate the data. A drawback could be that the maps become chaotic especially in small dimensions. This is the reason why only a symbol for 'NO DATA' (D) is used in the map generation in this report (fig.6 A-F). Other symbols such as for instance 'SIDETRACK' are left out. However, real exploration maps will always have bigger dimensions which opens the possibility to use all symbols comfortably. In the QGIS software, zooming in covers this problem. Secondly, the introduction of the hands-on setup manual gives all users the possibility to visualize the HC show data in their own QGIS projects.

In these projects all necessary background data can be uploaded an used accordingly. This manual can also be used as basis for future use when the database becomes publically available.

5.2.1 Generated maps

Looking at the generated exploration maps, it becomes clear that two different surveys (EBN DEF Survey and TNO depth map survey) have been used for the background maps. The clear explanation for this is that the EBN survey has a higher resolution and therefore will be more accurate. The reason for no total EBN survey coverage is the fact that the southern part of the DEFAB area is not yet available (interpreted).
The real strength of these maps are the fact that easy filtering in stratigraphic group or formation can be done and for this reason the maps give a fast and clear overview of the HC show distribution over the area. The symbolism is extensive and clear an gives therefore a fast overview of the different show data.
The primary results described earlier have to be considered carefully, as the link with the major Mesozoic structural elements is normally not applicable to pre-Triassic show data. On the other hand the distribution of the HC shows corresponds with the structural elements and should always be considered during the exploration. This becomes also clear when evaluating the results. It becomes obvious that the distribution of show clusters changes between different stratigraphic groups and even formations within the groups.

5.3 Petrel visualization setup

The Petrel visualization setup is designed in order to be applicable in the most important exploration window applications. Starting with four different examples (Appendix A) resulting in a visualization setup based on simplicity and applicability. Simplicity in points used as depth points and colours used as show classification or HC typing. Applicable in different windows and in different parts of the exploration workflow.
One of the biggest strengths is the ability to be used in every user project via a hands on setup manual (Appendix E). Moreover, it is applicable to different scales of interpretation via different windows in Petrel. The relation between drill data and geological structures can be obtained from the seismic interpretation window in combination with the HC show data. Also, the data can be easily filtered on both show classification numbering or stratigraphic group/formation, making it very user interactive. Most importantly introducing the potential for besides 2D, also 3D exploration application of the HC show database.
A potential weakness, which can be removed by expanding the visualization setup, is the lack of test data and core data in the setup as it stands now. This will open the potential for combining the different HC show data in Petrel.

5.4 Intra-database correlation

DST and log data correlation is used as a database quality control. A bad correlation could implicate mainly two things. The HC evaluation of the different analysts of the database isn't sufficient or the workflow used in this database doesn't correspond with industry standards for well testing. Meaning for instance that taking the highest gas reading in a formation interval doesn't correspond sufficiently with a potential interesting interval for HC testing.
However, looking at the results it becomes clear that the correlation is valuable for both oil and gas. The overall trend is a match and especially taking a tolerance up to 50 meter makes the correlation geologically defendable. For the reason that a show can't be seen as a point, but always as an interval in depth. A sort of conclusion that we can take from this is; testing an interval isn't only related to high/good gas or oil readings, but also other factors such as lithology.
For the gas show correlation, it is noted that one gas show doesn't match with the test data as it is evaluated as 'NO SHOW'.
After re-evaluation of the data it is decided that this is still 'NO SHOW', keeping the data as no match. Besides this DST corresponds with an oil show, implicating that the test result could be related to dissolved gas. However, overall most tests correspond with 'GOOD' classified gas shows (fig. 13).

Looking at the oil show correlation, over 50% of the tests match directly with oil shows within the test interval. Noting that possibly an overall distorted image is seen as a 4th classification ('OIL SHOW') is used for oil related shows.
This means that only 25% of the matches correspond with 'GOOD' classified oil shows. Going for this classification is a choice of the database setup. In the same time this means that these oil shows can be classified as all other 3 classifications (GOOD, FAIR and POOR), giving potentially different outcomes to the overall correlation. However, only 3 DST's don't match directly with an oil show, giving the overall correlation a very positive result (fig. 14).
The correlation of 'GOOD' classified Oil or Gas shows with non-corresponding test results gives a positive result. For gas the results only correspond with WATER and OIL. At the same time all OIL and OIL/WATER results correspond with 'GOOD' oil shows. Meaning that the gas show probably corresponds with dissolved gas or water saturated formations.
For oil, the results correspond with either GAS or OIL/WATER. This means that the oil shows possibly correspond to residual oil in the formation.

5.5 Continuation of the Project

Direct continuation of the project by expanding the area and the total HC show database is important for mainly two reasons. Firstly, at the moment several persons within the EBN organisation are familiar with the total project, its applications and eventual goal. Secondly, keeping contact with the former students responsible for the design and documentation of the total HC show database package is still possible. It would be regrettable to let the project come to a hold resulting in a difficult continuation in the future. A strong recommendation would be to go on with the weekly or once every two weeks review session. During this session several HC show evaluations can be reviewed quickly and this leads to a strong classification basis for the analyst.

5.5.1 New Analyst

It is preferable for new interns to have a strong geological and/or petrophysical background. This is not only recommended for the evaluation of the different well files, but also for the interpretation of the data, resulting in the classification of the HC shows.

5.5.2 Addition of missing data

During the evaluation of all wells in the DEFAB area, it became evident that for several wells not all necessary data were available on the TNO NLOG site. Different steps have been undertaken to obtain this data. Firstly, Livelink has been consulted by searching for data per well. However, this proved to be a very time consuming undertaking, without the anticipated result. Therefore it was decided to try recovering the missing data via contacting TNO. A table listing all wells with missing data is send to the NLOG administration. TNO will try to recover this missing data. It is highly doubtful that all data will be recovered in the future as the missing data relates often to old wells. This data is either not available anymore or has been lost by company overtaking's etc. Although, the expectancy is that most wells can be completed in the future.

5.6 Recommendations

The total project with all its components is getting to a stage of being applicable for HC exploration purposes, however many opportunities still remain. The most important part of the whole database is to keep expanding in southward direction. Complementing the whole Dutch offshore area in the database will give many analytic possibilities to the database. Moreover, the possibility of expanding the database to onshore boreholes will give it an extra dimension.

5.6.1 Document source linking

If the document source linking is preferred to be useable in the future, it will be necessary to re-evaluate the storing method in Livelink. As saving well files in Livelink at first is a very promising idea, in reality this method is vulnerable for updates. During this project it became evident that some links documented by Chris are already corrupted for an unkown reason. It will take some time to revise all these links, however finding a safe and reliable storage mechanism, that can't be corrupted by updates in the future, could be a valuable addition to the HC show database tool. Moreover, in the light of making the database publically available, finding a storing mechanism that could be applied for this purpose makes the database package even more powerful.

5.6.2 Stay in contact with TNO

Obviously, the missing well data is not only restricted to the DEFAB area. This became evident during the evaluation of the G and M blocks by Claudia. Therefore, it is highly recommended to stay in contact with TNO in order to gather as much well data as possible. The best way to do this is by contacting the Nlog Servicedesk (info@dinoloket.nl). Secondly, evaluating confidential wells can be done by utilizing Livelink. Most confidential data will already be available on Livelink. When this is not the case, obviously waiting until the confidentially period (5 years) is finished is another possibility, but obviously not preferable due to time constraints.

5.6.3 Test and revise

Start using the HC Show data as exploration tool. This will identify possible missing data or data that should be added to the database. The design and inputs of the database have been discussed extensively. However, it could be possible, when starting to use the database for its anticipated purpose, a certain input that isn't documented, during the well evaluation, would be preferable to add to the database. An example could be expanding the test data section with more valuable exact parameters (e.g. pressures, porosity, mechanical skin, etc.). At this moment it is still possible to add this data by re-evaluating the analyzed wells. This will be a time consuming undertaking, but when the whole offshore is evaluated it will be extremely time consuming to re-evaluate all wells. This could eventually make the effort not worth while. Moreover, with the data source linking it is possible to review the test data rather quickly and straightforward.

5.6.4 Efficiency and user friendly workflow

It is important to in the future always be sharp for efficiency improvements. Always evaluate new steps and make it as efficient and most important user friendly as possible. Especially as the aspiration is for the database to be publically available for petroleum partners.

5.6.5 Expanding HC Show database tool

Expanding the HC Show database will add to the overall value of the tool. Especially, related to the aspired public availability, but more important to applicability as exploration tool overall. Some examples are; adding test and core data to the Petrel visualization setup, using Studio E&P Knowledge Environment as direct link between the GISbase and Petrel. The change in the workflow for the last example is visualized in appendix G.

5.6.6 Investigate combining EBN well databases

As explained in the results, the transition in a MS Access interface is postponed to the near future. During a meeting with the EBN employee responsible for the 'EBN Post-Mortem database', it became obvious that there is a huge potential in combining several database within EBN in an overall MS Access input format. Investigating this potential would increase the value and applicability of the different databases as all well related data is directly accessible.

5.6.7 Integrated HC show review sessions with exploration team EBN

As has been mentioned in the introduction and background sections, HC shows can be used as exploration tool. As the HC show database comprises now both of 2D and 3D visualization setups, it is time to integrate the database in the exploration activities performed within EBN. I foresee a four step workflow for this integration for now. Starting by obtaining lists of all wells analysed by the exploration team members at this moment. In the meantime this will introduce the analyst to all exploration projects. Secondly, the analyst will evaluate the missing wells in the database where possible.
Thirdly, several meetings with the different exploration team members will be held in order to evaluate the specific wells. These meetings can be beneficial for both parties as valuable data interpretations are shared. Lastly, the feedback from these meentings will be integrated in the HC show database, resulting in a updated dataset for the visualization setups. This enables the exploration geoscientist to visualize the correct data in his exploration activities.

6. Conclusions

For this project several objectives were defined at the start. Eventually all major goals have been met and carefully elaborated in this report. The EBN HC show database consist now of two major visualization setups in 2D (QGIS) and 3D (Petrel). Moreover, the database workflow has been reviewed in order to realize a smooth project handover. Lastly, potential database expansions have been identified and elaborated in the recommendations. The major conclusions are listed below:

- A QC of the previous workflow designed by Chris Heerema, resulted in an enhancement of the 'HC show classification' section and a HC show 'Example Atlas'. Overall the initial data evaluation workflow is considered as well designed and structured.
- The database complementation resulted in a total DEFAB, H and N blocks coverage, with the exception of approximately 40 wells. Contact has been made with TNO NLOG in order to retrieve this data.
- An overall database workflow has been constructed, re-evaluated and re-designed. Giving future analysts and users the possibility to become familiar with all components and steps of the database package. Moreover, gives the possibility to identify improvements and expansions to the EBN HC show database.
- The initial QGIS visualization has been reviewed and enhanced by adding a total classification segregation. Moreover, a hands on user manual is added in order to directly implement the HC Show database in different QGIS projects.
- Several regional maps have been generated as exploration tool with the use of both EBN and TNO surveys. At the same time the corresponding HC show clusters have been identified.
- A 3D visualization setup in Petrel has been created. This setup covers the most important exploration applications in Petrel. The setup is designed for simplicity and log data coverage. A link between the EBN central database (GISbase) and Petrel has been designed. Moreover, an user manual is added in order to directly implement the HC show database in different Petrel projects.
- A QC control on the database has been performed by correlating the Test and Log data. This correlation has proven to be positive. Giving the database design a positive review.
- The potential combining of well related databases within EBN has been identified and recommended. This combination could be realized in an MS Access format with the help of the next analyst (Constantijn).
- A fluent handover of the project has been realized by enhancing the initial 'classification workflow', construction of a 'HC Show Example Atlas' and the subject introduction of two new analysts (Claudia and Constantijn).

Acknowledgements

Above all, I would like to thank EBN as a whole for offering me the opportunity to accomplish this educational and at the same time very challenging internship for the past 5 months. During my period at EBN I experienced a very professional and open work community. I was able to communicate with everybody within EBN, without exceptions. This made it possible for me to confidently search for help when needed during my internship.
I would like to thank my EBN supervisor Guido Hoetz, not only for offering me this internship, but also for guidance and thorough feedback during the project. Moreover, I would like to thank Jan Lutgert for his specific help and feedback on different important components of my internship. During our discussions, I learned a lot about not only my subject, but also other things related to the E&P industry. I would also like to thank Walter Eikelenboom for all his help, time, valuable feedback and ideas. Furthermore, I would like to thank Marloes Kortekaas and Eveline Roosendaal for the HC show review meetings and the help with the HC show classification workflow enhancement. I would also like to thank Marten ter Borgh, Annelieke Vis, Abdul Hamid, Guido van Yperen and Tom Leeftink for their help and feedback on specific topics during my internship. A big thank you to Peter Bange for all his patience and help with the GISbase. I would also like to thank dr. Fred Beekman for his guidance and feedback as university supervisor. A special thanks to Chris Heerema for starting up of the project and all the help in getting me set to work during the first weeks of my project. Chris did a tremendous job by setting up the whole database and creating an extensive and clear workflow. At last I would like to thank Claudia Haindl and Constantijn Blom for the continuation of the project. I wish you the best of luck during your further studies.

References

Crain, R. (2015). *Crain's Petrophysical Handbook*. Attained from Sample Description Logging: https://www.spec2000.net/08-samples.htm

Fattah, R.A., Verweij, J.M., Witmans, N., ten Veen, J.H. (2012). *Reconstruction of burial history, temperature, source rock maturity and hydrocarbon generation in the northwestern Dutch offshore.* Attained from volume 91 of the Netherlands Journal of Geosciences.

Heerema, C. (2015). EBN HC Show database workflow. Attained from Livelink. http://ebnecm/OTCS/llisapi.dll?func=ll&objaction=overview&objid=5236110

Heerema, C. (2016). Interactive topview (2D) visualization in QGIS setup.

Schowalter, T.T., Hess, P.D. (1982). *Interpretation of subsurface hydrocarbon shows.*

Versan, M. (2010). *METU Petroleum & Natural Gas Engineering Department*. Attained from Chapter 1: Hydrocarbon Indications: http://users.metu.edu.tr/kok/pete424/PETE424_CHAPTER1.pdf

Yassin, A. (2012, 6 21). *Origins of Gas Shows*. Attained from Petroleum Blogspot: http://petroleum2050.blogspot.nl/2012/06/origins-of-gas-shows.html

Background knowledge

American Association of Petroleum Geology. *Show evaluation*. http://wiki.aapg.org/Show_evaluation

Bloys, B., Davis, N., Smolen, B., Bailey, L., Fraser, L., Hodder, M. (1994). *Designing and Managing Drilling Fluid.* Attained from slb.com.

Haworth, J.H., Sellens, M., Whittaker, A. (1985). *Interpretation of Hydrocarbon Shows using light (C1-C5) Hydrocarbon gases from mud-log data.*

Katz, B.J. (2003). *Hydrocarbon shows and source rocks in scientific ocean drilling.*

Schlumberger (2006). *Fundamentals of Formation Testing.* Attained from slb.com.

Appendices

Appendix A: Petrel visualization setups

Appendix B: Revised HC Show database workflow manual (Modified after C.Heerema, 2015)

Livelink here: http://ebnecm/OTCS/llisapi.dll?func=ll&objaction=overview&objid=5420642

Appendix C: HC Show Example Atlas

Livelink here: http://ebnecm/OTCS/llisapi.dll?func=ll&objId=5427686&objAction=browse&viewType=1

Appendix D: QGIS visualization setup user manual

Livelink here: http://ebnecm/OTCS/llisapi.dll?func=ll&objId=5391260&objAction=browse&viewType=1

Appendix E: Petrel E&P Software visualization setup user manual

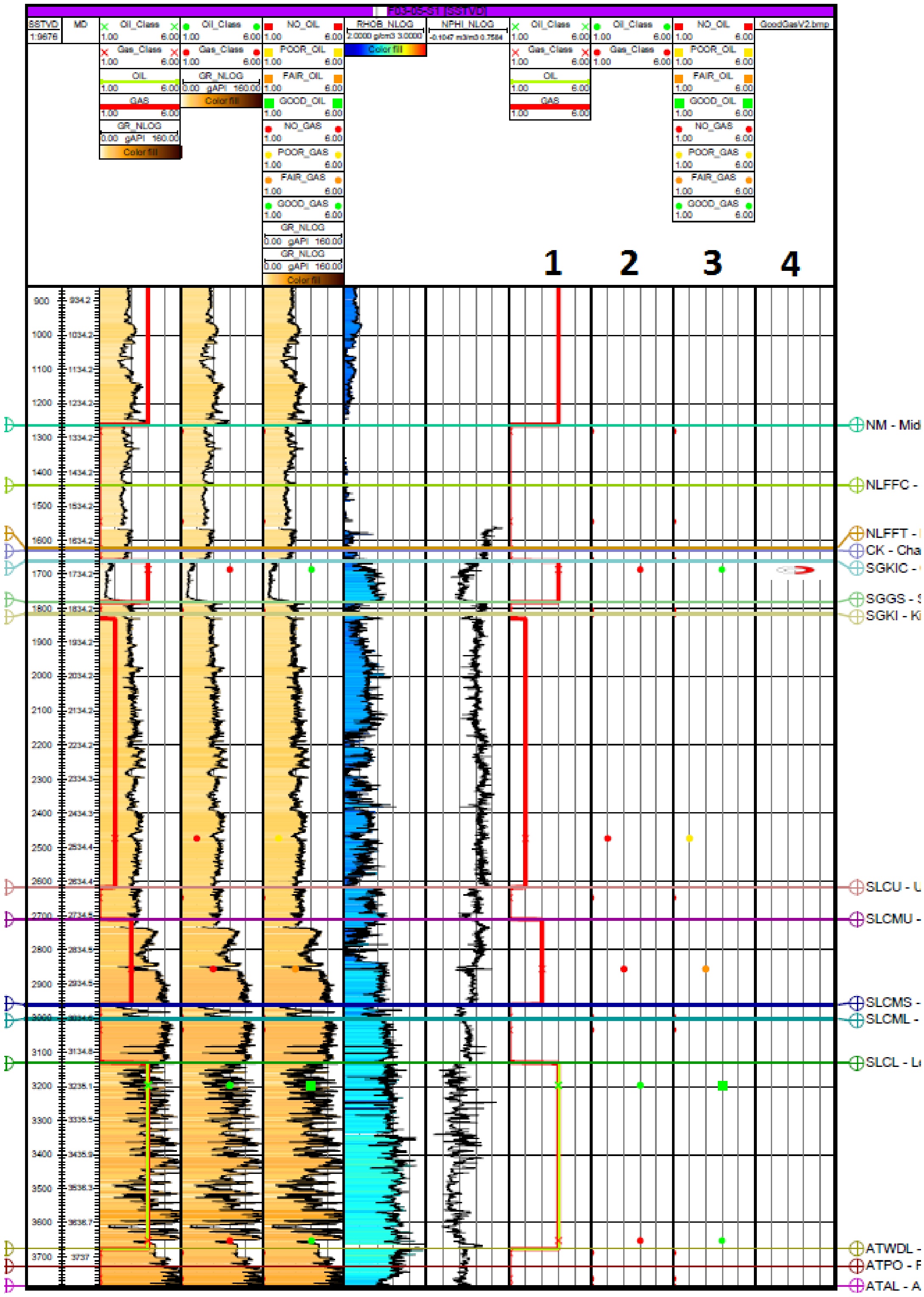
Livelinkg here: http://ebnecm/OTCS/llisapi.dll?func=ll&objId=5391802&objAction=browse&viewType=1

Appendix F: VBA code

Livelink here: http://ebnecm/OTCS/llisapi.dll?func=ll&objId=5391802&objAction=browse&viewType=1

Appendix G: Studio E&P Knowledge Environment – Workflow

Appendix A: Petrel visualization setups



Appendix A: EBN HC Show visualization setups for Petrel. The vertical lines are used for the classification numbering. 1) Exact measurement depth points combined with a pseudolog. 2) Exact measurement depth points colored by gas (Red) and oil (Green). 3) Exact measurement depth points colored by show classification combined with symbolism for gas (circle) and oil (square). 4) QGIS visualization symbolism as exact measurement depth point.

Appendix B: Revised (changes indicated in blue) HC Show database workflow manual (Modified after C.Heerema, 2015)

Data analysis workflow – Version 2.0

General remarks

- If abbreviations are used in a description, translate them to full words. Abbreviations are often explained at the top of the log.
- Use quotation marks to quote a remark from the document.
- Keep the datasheets in alphabetical order (as on Nlog), when adding new borehole entries.
- Read the document 'Database lay-out, examples, and pitfalls', and references therein, to become familiar with the database set-up.

Log data

Step 1.
Open excel file 'HC Show Datasheets' , tab 'Log data'

Step 2.
Check whether for the selected borehole TNO stratigraphy is available in the excel file. (Mud-)logs will be analyzed per TNO defined stratigraphic layer.

- If stratigraphy is unavailable, add a new row and note down the (TNO) borehole code in column 'borehole', and 'NO STRAT' in columns 'data_source_gas', 'gas_show', and 'oil_show'. Select a new borehole for analysis or check with your supervisor.
- Alternatively choose to enter the stratigraphic intervals by hand if advised by your supervisor.

Step 3.
Go to www.nlog.nl, click 'boringen', click 'keuzelijst' and select the borehole you are analyzing.

- If your selected borehole is not available in the list, note down 'NO DATA' for the entire borehole, in the columns 'data_source_gas', 'gas_show' and 'oil_show'.
- If the selected borehole has one or more sidetracks (ST's) due to technical failure (wich will be indicated in the "administratieve gegevens"), analyze the borehole with the deepest stratigraphy (usually the last sidetrack). The entire columns 'gas_show', 'oil_show' and 'data_source' of the other sidetracks and original borehole are annotated with 'SIDETRACK'. If several sidetracks were completed successfully analyze the logs of all of them as usual.

Step 4.
Check whether a document with a gaslog is available for your selected borehole. These documents can be named 'Composite Well log', but more often gaslogs can be found under the heading 'Documenten', named e.g. 'Litholog', 'Geological log', 'Exlog', 'Mudlog' etc. Check column 'data_source' for the various document names of previously analyzed wells.

- Any general comments about the entire selected log, can be mentioned in the column 'general_borehole_comments', preferably in the first row of the selected borehole. It's better to note down too much instead of too little information.

- If the selected borehole has no log data because the borehole is confidential/recently drilled (there will be no data files at all on nlog), enter 'CONFIDENTIAL' in columns 'gas_show', 'oil_show', and 'data_source'. If there are data files but the gaslog has not been put online annotate the entire columns with 'REVIEW' and talk to your supervisor about contacting the nlog administration. In both cases you can try to find the data on livelink (search for the well name).

Step 5.

Check whether the depth is 'measured along hole below rotary table' (MAHBRT), instead of 'rotary table', also 'kelly bushing' (KB) is often referred to. A good method to verify this, is to correlate some formation depths or terminal depth (TD) with the TNO stratigraphy.

- If not measured from the 'rotary table' or 'kelly bushing', correct for it or select another log.
- If displayed only as true vertical depth (TVD), select another document with along hole (AH) annotation or ask supervisor
- If your selected log is measured in feet, use the conversion factor (feet = meter*3.2808) to translate the depth into meters. For the convenience you can temporarily copy and converse the imported formation depths into feet, in a separate tab, to better match it with the log.

Gas shows per formation

Step 6.

Check whether the gas log data is based on continuous measurements or on (ir)regular measurements for the selected stratigraphic interval.

- If completely missing, note down 'NO DATA' for the selected formation, in the column 'gas_show' and go to Step 14
- If partially missing, mention it in the 'comments_gas' column

Step 7.

Read off, from the chromatograph section on the log, the highest methane (C1) gas reading for the selected stratigraphic interval and note it down in column 'c1_max'. Additionally, note down the exact depth of this measurement in column 'exact_measurement_depth_gas'. Furthermore, note down the other measured alkanes (C2-nC5) in column 'c2_max' to 'nc5_max', measured at the same depth as C1. The sum of all alkane columns is noted in column 'accumulated_gas'. Lastly, note down the measurement unit (ppm or %) in column 'gas_unit'.

- If an alkane concentration is measured at 0 or is below the measurement threshold, the entered value is '0'.
- If an alkane is not measured, note down 'NOT MEASURED' in respective alkane column ('c1_max' to 'nc5_max').
- If the gas reading is illegible, note down 'UNCLEAR' in respective alkane column ('c1_max' to 'nc5_max').
- If all gas readings are '0' or below the detection limit, enter 'NO SHOW' in the column 'gas_show' and select the next stratigraphic interval.
- If the gas readings are non-zero but constant, such that you cannot identify any maxima, enter 'NO SHOW' in the column 'gas_show', note down the background level and enter 0 in the columns for accumulated gas and for all the measured alkanes.
- If no chromatograph analysis is available, use the total gas graph and enter its value directly into the 'accumulated_gas' column and note down 'NOT MEASURED' in the columns 'c1_max' to 'nc5_max'.
- If no total gas graph is available but point measurements annotated with numbers instead, note the 'highest' spot measurement within this formation. In this case also check the well report for additional information.

- If a gas peak is exactly at the boundary between two stratigraphic units it will count towards the unit below.

  Example:
  ROSLU 2500-2700m
  ROSLL 2700-2840m
  Show at 2700m is considered part of ROSLL

- Ignore peaks that coincide with coal beds. In a stratigraphic unit with many coal shows find and enter the largest peak that does not coincide with coal. It's important that you mention the coal shows in the comments though.
- Ignore peaks that are annotated as connection gas (sometimes CG) or trip gas (sometimes TG or TRG) – check the header of the log for the used abbreviations but be aware the loggers often don't stick to the suggested format. These gas shows are usually very narrow, strong spikes that don't necessarily coincide with lithological changes. If you are unsure ask your supervisor and note it in the 'comments' column.

Step 8.
Estimate the background gas concentration associated with the highest gas reading and note it down in column 'background_gas'.

Step 9.
Mention of any other gases (incl. non-HC e.g. N_2, H_2, CO_2, H_2S) in the selected stratigraphic interval is noted down in the column 'other_gases'

Step 10.
Read off the lithology at the same depth as the highest gas reading and note it down in column 'lithology_gas' (max. two words, preferably one). If available, use the interpreted lithology column on the log, else use the cuttings description column or find lithology at same depth on other log. Any other relevant lithology related info can be described in the 'comments_gas' column.

Step 11.
Based on the highest gas reading, background gas and lithology the gas show needs to be classified. The classification scheme consists of 'NO SHOW', 'POOR', 'FAIR' and 'GOOD', one of which has to be entered in the column 'gas_show'. Below some rules of thumb for the classification are given but in the end you may have to rely on your geological background and adjust depending on the specific situation. These rules are for "classic" cases of gas shows. Before you start your evaluation do consult the atlas of show-examples which also contains less obvious situations, so you get a feeling of how to judge gas shows in different geological contexts.

(PtBR = Peak-to-Background Ratio)

("Peak" = absolute difference between the maximum accumulated gas and the background)

Rules of thumb as a step-by-step guide:

- Peak < 500ppm (0,05%), or peak in halite → NO SHOW

  For larger peaks:
  - PtBR < 2 → NO SHOW
  - PtBR < 3 → POOR

    For ratios > 3:
    - Mudstone/shale/claystone/marl → POOR
    - Siltstone → FAIR

For sandstone/limestone/chalk:
- PtBR < 5 and/or peak < 1000ppm (0,1%) → FAIR
- Otherwise → GOOD

Rules of thumb as a table:

	NO SHOW	POOR	FAIR	GOOD
Peak gas	< 500ppm (0,05%)	> 500ppm (0,05%)	> 500ppm (0,05%)	> 1000ppm (0,1%)
Lithology	halite	mudstone/shale/ claystone/marl	siltstone	sandstone/ limestone/chalk
PtBR	< 2	2 < PtBR < 3	> 3	> 5

Note when using the table: Out of the 3 criteria (peak gas, lithology and PtBR) the one which results in the worst classification determines the final classification given to the show. Further, as an example, if a show just makes it into the 'FAIR' category based on peak and PtBR and it is in siltstone, this further lowers the show quality, so it may be placed in the 'POOR' category.

Peaks in halite (or rock salt) are classified as "NO SHOW" because halite has zero porosity and permeability. Due to drilling complications in this lithology you may often encounter peaks in gas readings, but these are artefacts which stem from stuck pipes, pulling out and so on.

It is important to note that these rules are not set in stone. If for example in a sandstone the background reading is already in the 10000s of ppm then a peak which is 3 times that is so large that can already be considered a GOOD show, even though according to the above scheme it would be at the POOR/FAIR boundary. Also, in situations where different lithologies are interbedded, where a show coincides with a thin bed, or when there is grading from one lithology to another, a middle ground between the classifications has to be chosen. Another common case is that limestone and sandstone can have high silt or mud contents tendentially lowering the quality of the show, so if the PtBR is at the boundary between two classifications you might choose the lower one. Comments about this should be put into the column 'additional_description_gas'.

A noteable exception from these rules that you need to be aware of, is the shallow North Sea formation which has generally high porosity, even if the lithology is clay – so strong shows in clay within this formation should be classified as good.

Making a well constructed HC show evaluation can sometimes be very challenging – if you are not sure what to do, ask your supervisor.

Step 12.

Read off the mud type. Do this by looking up the first mention of mud data you encounter above (shallower than) the depth measurement of the highest gas reading. We assume here that, if any significant alteration is made to the mud type, this is stated on the log.

- For mud type, distinguish between water based mud (WBM), oil based mud (OBM) or polymer based mud (PBM), enter this in column 'mud_type'.
- If the mud type is not specified, note down 'NOT SPECIFIED' in column 'mud_type'.

Step 13.

Read off the mud weight similarly to step 12 and enter this in column 'mud_weight'.

- Mud weight is either measured in pounds per gallon (ppg) or kg/m3, note this down in column 'mw_unit'.
- If the mud weight is not specified note down 'NOT SPECIFIED' in column 'mud_weight'.
- Any other relevant info regarding mud, can be noted down in 'comments_gas'.

Oil shows per formation

Step 14.
Check whether oil show related data is missing (e.g. part of the selected log is missing) in the selected stratigraphic interval. Be aware that many wells have no oil shows, so if there is no mention of oil that does not necessarily mean that the data is missing.

- If completely missing, note down 'NO DATA' for the selected formation, in the column 'oil_show'. Select the next stratigraphic interval.
- If partially missing, make a mention of it in the 'comments_oil' column.

Step 15.
If available, read off the 'best' oil classification from the selected log for each stratigraphic unit and note it down in column 'oil_show'. Additionally, note down the exact depth in column 'exact_measurement_depth_oil'. Always carefully check the comments and description section for any oil show mentions.

- Adjust the show classification so that it fits the 'POOR', 'FAIR' and 'GOOD' subdivision.
- If no classification of the oil show is given, note down 'OIL SHOW' in column 'oil_show'.
- If no oil show is present or the oil show is in halite, note down 'NO SHOW' in column 'oil_show'.

Step 16.
Note down the description (fluorescence, cut, staining etc.) of the oil show in column 'oil_show_description'. If abbreviations are used, translate them to full words. Any other relevant remarks to the show are noted down in column 'additional_description_oil'.

Step 17.
Read off the lithology at the same depth as the 'best' oil show and note it down in column 'lithology_oil' (max. two words, preferably one). If available, use the interpreted lithology column on the log, else use the cuttings description column. Any other relevant lithology related info can be described in the 'comments_oil' column.

Documentation

Step 18.
Save the used document in Livelink, name it as displayed on Nlog and add the borehole name in front of it.

Step 19.
Paste the name in column 'data_source' and paste the Livelink-link in column 'data_source_link'.

Step 20.
Give the used data source a quality label (POOR, FAIR, GOOD), note down in column 'data_quality'.

Step 21.
Enter the interpretation date in column 'create_date', your 3-letter user ID in column 'create_user_id' and enter 'EBN' in column 'show_interpreter'.

Step 22.
Select the next stratigraphic interval (Step 6) or next data type.

(Sidewall-)Core data workflow

Step 1.
Open excel file 'HC Show Datasheets' , tab '(SW-)core data'.

Step 2.
Insert the name of the borehole you want to analyze in column 'borehole'.

Step 3.
Go to www.nlog.nl, click 'boringen', click 'keuzelijst' and select your desired borehole.

- If your selected borehole is not available, note down 'NO DATA' for the borehole entry, in the columns 'show_classification' and 'data_source' and select a new borehole or data type.
- If the selected borehole has one or more sidetracks (ST's) be sure to check for core data in all the sidetrack files since they are often mixed up, and double-check in the header of the file which sidetrack the core is from.
- If no (SW-)core data of the selected borehole is available because the borehole is confidential/recently drilled (i.e. you can't find any files on nlog), enter 'CONFIDENTIAL' in columns the columns 'data_source' and 'show_classification'.

Step 4.
Check the documents for any core or sidewall-core analyses. This data can often be found in e.g. '(Sidewall-)core report', 'Core analysis', 'Composite log', 'End of well report' etc.

- If no core or sidewall-core data is found note down 'NO DATA' for the borehole entry, in the columns 'result' and 'data_source' and select a new borehole or data type.
- (SW-)core data is often mentioned on the same document from which log data is retrieved.
- If an (SW-)core is mentioned in other files but no descriptions have been put online, also enter 'NO DATA' but add in the 'comments' column that the data file is missing.

Step 5.
Not all (sidewall)core data is focused on HC show description. Often, (SW-)core samples are only analyzed for petrophysical characteristics (e.g. permeability, porosity), whereas HC indications are not described. In this case interpret as 'NO DATA'. Additionally, be alert for any negative indications regarding whether any cores or (SW-) cores were sampled, this can save you some time.

Step 6.
Group the cored intervals or sidewall cores together based on stratigraphic interval and show/lithological description. To get an idea of the stratigraphic intervals, check the tab 'Log data' and look for the selected borehole. The determined intervals are entered in columns 'top_depth' and 'bottom_depth', each new interval receives a separate row.

- The depth of a single sidewall core samples is entered in column 'exact_measurement_depth'.

Step 7.
Enter 'Core' or 'SWC' in column 'show_source' for each created interval or sample.

Step 8.
Detailed description of the hydrocarbon show (for each interval) is entered in column 'oil_gas_show_description'.

- (Large) intervals, which do not contain any hydrocarbon shows get classified as 'NO SHOW', entered in column 'data_source' and 'show_classification'.

Step 9.
The lithology is determined by evaluation of the litholog and the cutting descriptions for the chosen interval and entered in column 'lithology' (2 words max.). Any important structural or lithological features, related to the HC show can be added in column 'oil_gas_show_description'.

Step 10.
Based on the HC show description, continuity of the show, and lithology of the determined interval, classify the show as 'POOR', 'FAIR' or 'GOOD'. This is entered in column 'show_classification'.

Step 11.
Based on overall quality and completeness of the data description, classify the data quality as 'POOR', 'FAIR' or 'GOOD' in column 'data_quality'.

Step 12.
Any additional remarks (e.g. about the lithology, sampling interval, quality) can be noted down in the 'comments' column.

Step 13.
Save the used document in Livelink, name it as displayed on Nlog and add the borehole name in front of it.

Step 14.
Paste the name in column 'data_source' and paste the Livelink-link in column 'data_source_link'.

Step 15.
Enter the interpretation date in column 'create_date', your 3-letter user ID in column 'create_user_id' and enter EBN in column 'show_interpreter'.

Test data workflow

Step 1.
Open the Excel file 'HC Show Datasheets' , tab 'Test data'.

Step 2.
Insert the name of the borehole you want to analyze in column 'borehole'.

Step 3.
Go to www.nlog.nl, click 'boringen', click 'keuzelijst' and select your desired borehole.

- If your selected borehole is not available, note down 'NO DATA' for the entire borehole, in the columns 'result' and 'data_source' and select a new borehole or data type.
- If no test data of the selected borehole is available because the borehole is confidential/recently drilled, enter 'CONFIDENTIAL' in columns the columns 'data_source' and 'show_classification'.

Step 4.
Check the documents for any DST and/or RFT data. Only RFT samples are recorded in the data sheet. You can ignore measurements where no samples were taken. Test data can often be found in e.g. ‘production test data’, ‘End of well report’, ‘Composite log’, ‘Technische gegevens’ etc.

- If no test data is found note down ‘NO DATA’ for the borehole entry, in the columns ‘result’ and ‘data_source’ and select a new borehole or data type.
- DST and RFT data is often mentioned on the same document from which log data is retrieved, this saves some search time.
- Additionally, be alert for any negative indications regarding whether any DST’s or RFT’s were carried out, this can save you some time.

DST

Step 5.
Enter ‘DST’ in column ‘test_type’.

Step 6.
Enter the top and bottom of the tested interval in columns ‘top_depth’ and ‘bottom_depth’, if more intervals are tested for **this** DST, enter up to 4 intervals (‘top_depth1’ to ‘bottom_depth4’).

- If a single test comprises more than four intervals, the intervals are lumped together. The top of the cumulated intervals is entered in column ‘lumped_top_depth’ and the bottom in column ‘lumped_bottom_depth’.

Step 7.
Note down the result (‘OIL’, ‘GAS’, ‘WATER’ or ‘NO FLOW’) of the DST in the column ‘result’.

- If the data is not clear enter ‘UNCLEAR’.
- If you are unsure about the data enter ‘REVIEW’ in column ‘result’, so someone else can have a look at it/ask supervisor.
- If the maximum gas flowrate is below 50.000 Nm^3/d, the entry is annotated as ‘INSUFFICIENT GAS’.
- If the maximum oil flowrate is below 100 m^3/d, the entry is annotated as ‘INSUFFICIENT OIL’.

Step 8.
Per given DST, select the flow period with the highest flow rate and note the magnitude of the flow rate in column ‘max_flowrate’ and the flow rate unit in column ‘flowrate_unit’.

Step 9.
Any other relevant data can be entered in column ‘comments’.

Step 10.
If applicable, repeat these steps for all DST's related to this borehole.

RFT

Step 11.
Enter ‘RFT’ in column ‘test_type’.

Step 12.
Enter the RFT testing depth (mAHBRT) in the column ‘exact_measurement_depth’.

Step 13.
Note down the result ('OIL', 'GAS', 'WATER') of the RFT in the column 'result'.

- Failed tests are ignored.
- If a combination of the above is found, note it down as 'OIL WATER', for example.
- If the data is not clear enter 'UNCLEAR'.
- If you are unsure about the data enter 'REVIEW' in column 'result', so someone else can have a look at it later.

Step 14.
If a chromatographic analysis was performed, note down the results in columns 'c1_max' to 'nc5_max'.

Step 15.
Based on overall quality and completeness of the data description, classify the data quality as 'POOR', 'FAIR' or 'GOOD' in column 'data_quality'.

Step 16.
Any additional remarks (e.g. about the lithology, sampling interval, quality) can be noted down in the 'comments' column.

Step 17.
Save the used document in Livelink, name it as displayed on Nlog and add the borehole name in front of it.

Step 18.
Paste the name in column 'data_source' and paste the LiveLink-link in column 'data_source_link'.

Step 19.
Enter the interpretation date in column 'create_date', your 3-letter user ID in column 'create_user_id' and enter EBN in column 'show_interpreter'.

Appendix C: HC Show Example Atlas

ATLAS

Hydrocarbon Show Interpretation – Examples for the HC Database

Claudia Haindl and Youri Kickken, EBN, October 2016

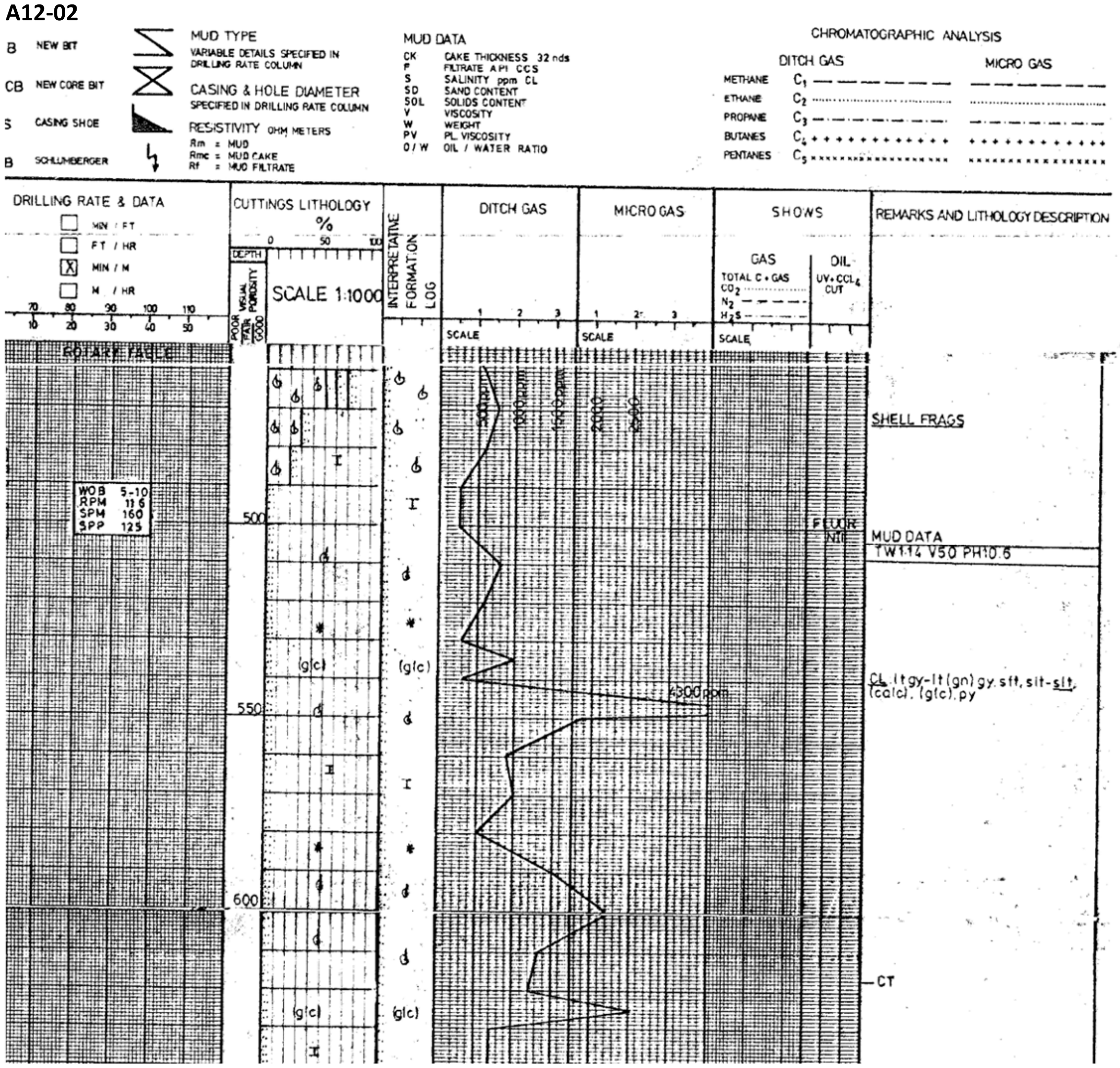
In this atlas some examples of HC shows which are rather hard to interpret are discussed. This can hopefully serve as a guide for new users working on the HC shows database intending to classify peaks of gas concentrations in mudlogs. As you will have read in the HC Database workflow, you need to choose one of the categories “NO SHOW”, “POOR”, “FAIR” and “GOOD” for a peak in gas concentration. There is a rule of thumb of how to do this in the more obvious cases. But as you will see here, there are many more things to consider than the peak-to-background-ratio, the lithology and the absolute difference between peak and background.
In the following sections several similar shows will be shown and differences in categories will be explained.

Content:

1. The North Sea Supergroup

Stratigraphic units in the North Sea Supergroup are typically shallow (above 1000m) and hence not very compacted. Clay is the major constituent of this section and is often still quite porous (as we know clays may even have porosities of 30%). Furthermore, the reservoirs of the A B gas fields are shallow gas sands of Pliocene- Pleistocene age which are found in the North Sea Supergroup at around 400-600m - so this is a known reservoir level. In conclusion, HC shows can be given a higher classification than the lithology would usually allow. Here are some examples:

A12-02

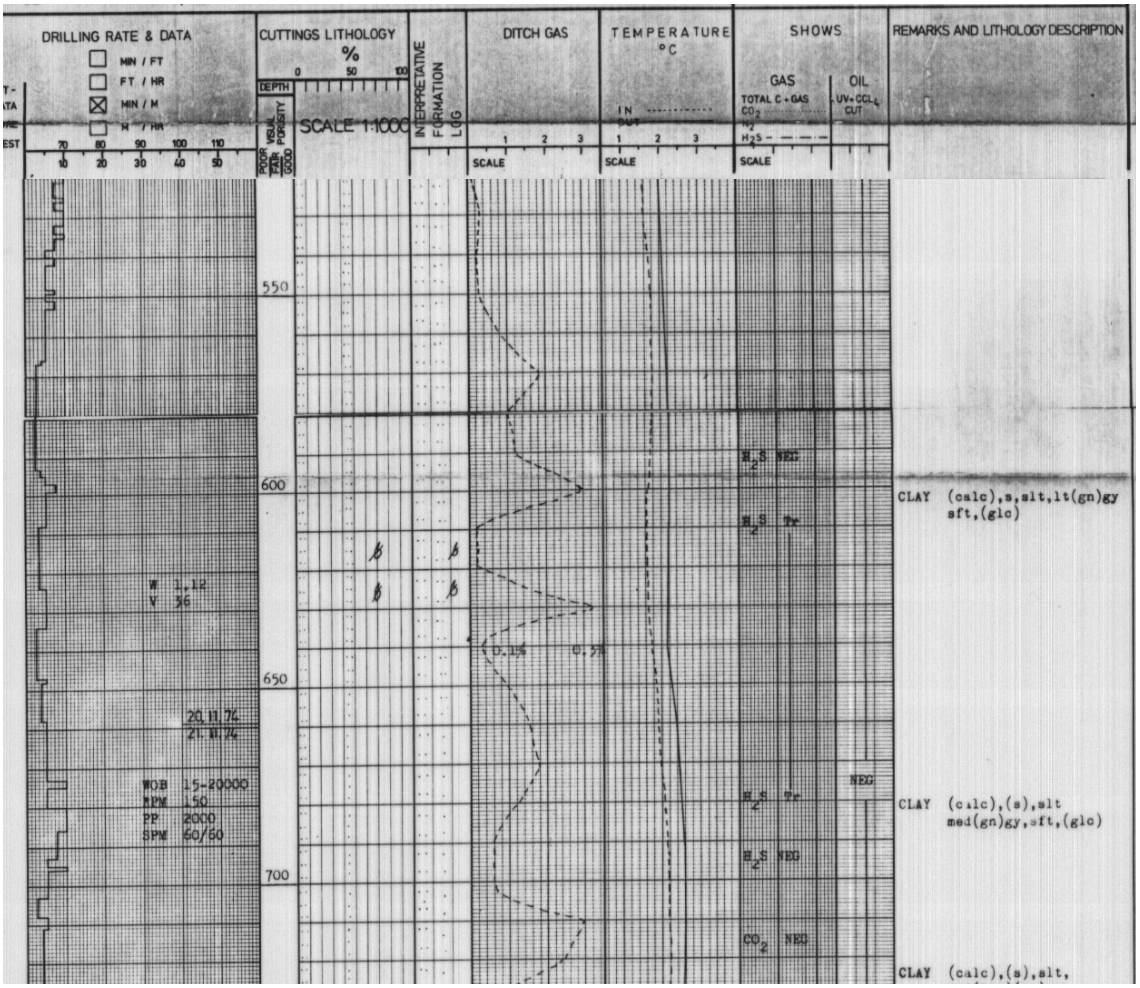


Depth: 548m
Peak: 4300ppm
Background: 500ppm
Lithology: clay
Classification: FAIR

In a sandstone this might even be considered a GOOD show. Being placed in clay would usually make it a POOR show, however, since this is part of the North Sea Supergroup this criterion relaxes and the show is classified as FAIR. Note that there is 10% of sand in the cuttings column, evenly distributed.

Cuttings may only have been sampled every 25 m (due to high drilling rates), so thin sand beds within a clay intercalation will be mixed in with the clay cuttings. It is likely that the gas peak around 550m is coinciding with a thin sand.

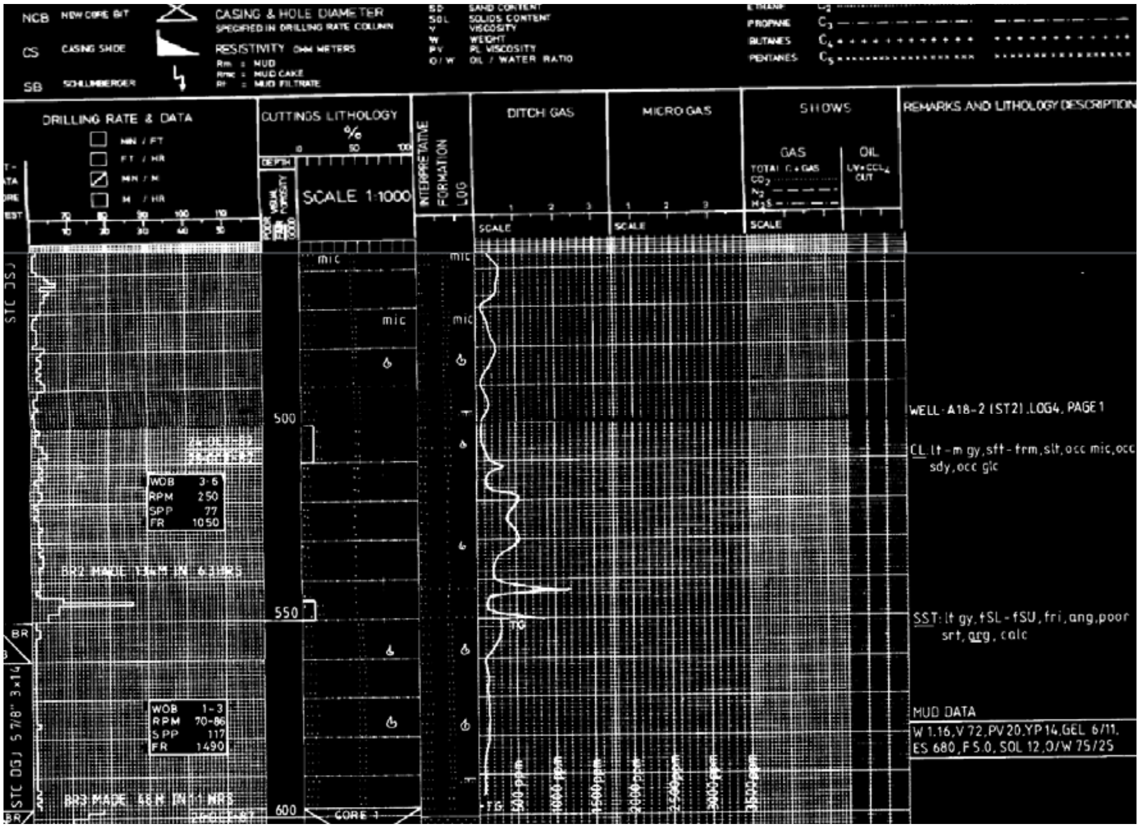
A18-01



Depth: 630m
Peak: 3200ppm
Background: 200ppm
Lithology: clay
Classification: POOR

Note how the PtBR and the absolute difference between peak and background are only a little lower than in the previous example, so one might expect this show to be classified as FAIR as well. In this case, however, there are several similar gas peaks suggesting a variable background (maybe due to lithological changes) and hence lowering the perceived quality of the show.

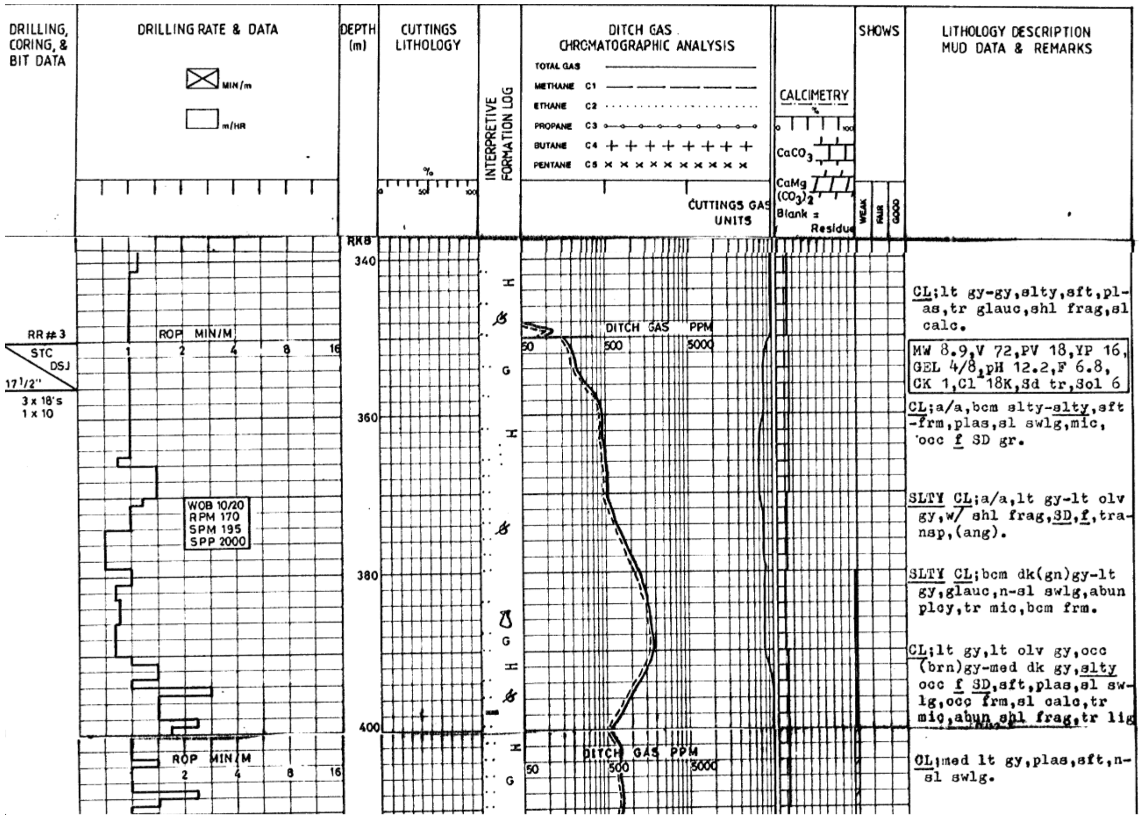
A18-02-S1



Depth: 542m
Peak: 1200ppm
Background: 100ppm
Lithology: sandstone (thin layer in clay)
Classification: FAIR

Even though compared to the show in A18-01, both the ratio and the absolute difference between peak and background are lower in this show, it was given a better classification. This is on one hand because of the absence of other peaks in the same order of magnitude (note that the peak at 550m was annotated as trip gas and is hence ignored). On the other hand, if you look carefully at the interpretative formation log and at the remarks, there is also a small sandstone layer which coincides with the peak. This improves show quality because of higher expected porosity and permeability.

D12-01

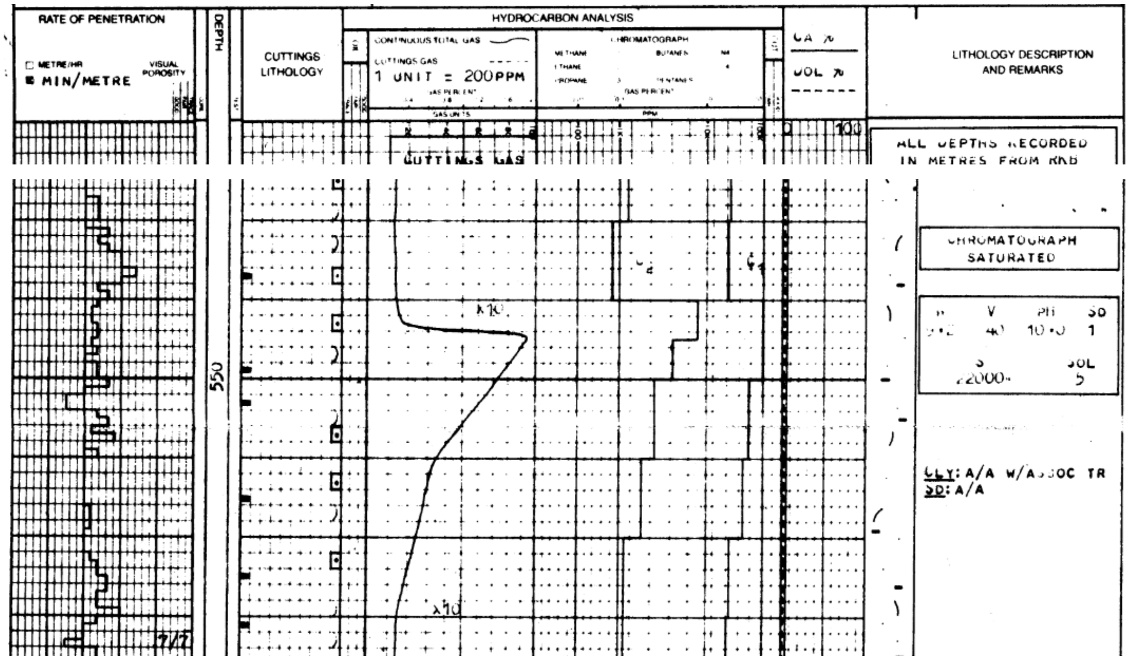


Depth: 390m
Peak: 2000ppm
Background: 500ppm
Lithology: clay (silty)
Classification: POOR

Note the logarithmic scale which makes the peak appear more stretched out. In this case, despite the high silt content (which tendentially improves show quality) and the absence of other peaks, the magnitude of the peak and the PtBR are just not high enough to warrant a FAIR classification. It also seems like the measuring device was switched on at 345m and is increasing to the background gas values.

2. Pitfall with Hand-Drawn Curves

B10-02-S1



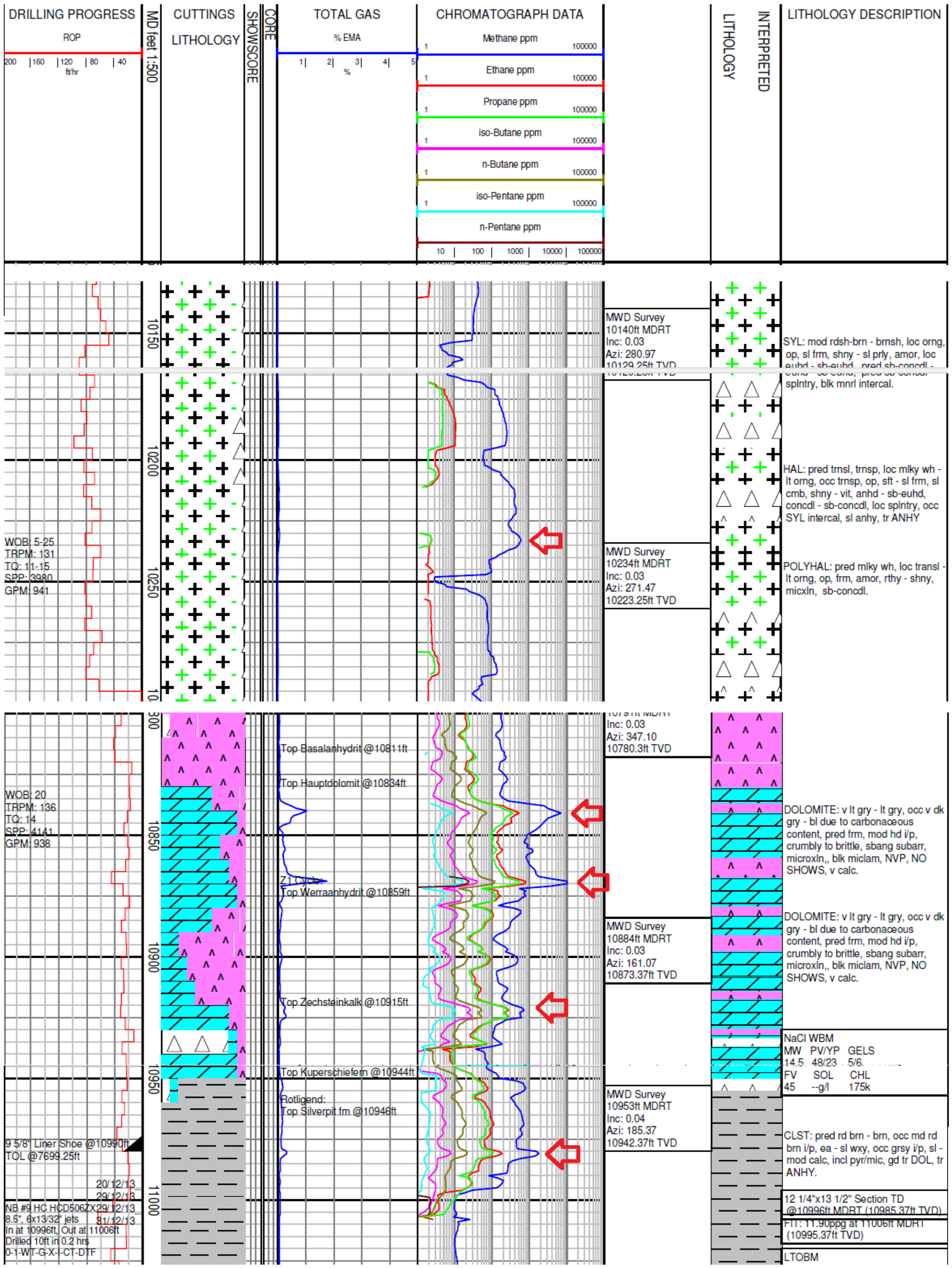
Depth: 545m
Peak: 110000ppm
Background: 10000ppm
Lithology: clay
Classification: FAIR

If you compare this show with the one from A12-02 (previous section) it may seem strange that this one received a lower rating. The PtBR is slightly higher, the total gas concentrations are higher by a factor 20 and the peak stands alone in a very constant background. But if you look closely at the hand-drawn curve you recognise that actual measurements have only been taken where there are kinks in the curve and that these points have merely been connected by more or less straight lines. So this peak is not very well constrained, and we only have one point with a high gas reading. Also unlike in A1-02, the cuttings show no indication of sand or silt in the clay and there is no drilling break.

3. The Zechstein

The Zechstein Group does often contain gas shows since the anhydrites and the rock salt can act as a good seal, trapping gas in sediment layers in between. Remember when working in this stratigraphic unit that gas peaks in halite should be ignored!

E11-01



This log contains several shows in different sections of the Zechstein. From top to bottom we find:

Depth: 10260ft
Peak: 600ppm
Background: 50ppm
Lithology: halite
Classification: NO SHOW

Depth: 10840ft
Peak: 7500ppm
Background: 150ppm
Lithology: dolomite
Classification: GOOD

Depth: 10870ft
Peak: 11500ppm
Background: 150ppm
Lithology: dolomite
Classification: GOOD

Depth: 10922ft
Peak: 1300ppm
Background: 100ppm
Lithology: dolomite
Classification: POOR

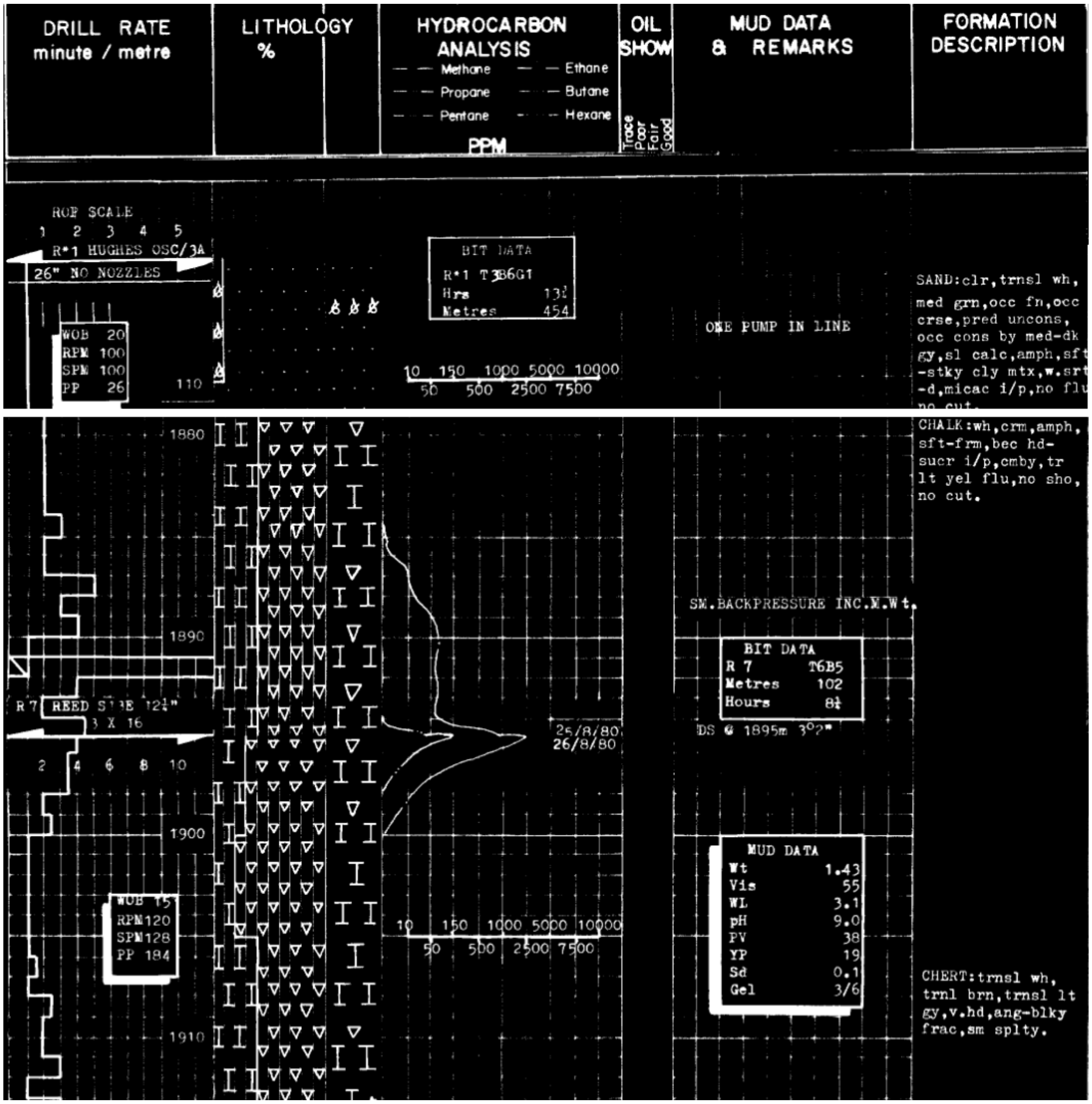
Depth: 10982ft
Peak: 2100ppm
Background: 80ppm
Lithology: claystone
Classification: POOR

The show in halite automatically becomes NO SHOW. The next two shows in dolomite/anhydrite are classic good shows. The 4^{th} show may normally classify as at least FAIR, but again there are many peaks of a similar magnitude around it, so it is part of the background variability making it a POOR show. The show in claystone is POOR because of the lithology, as it is no outstanding show like the ones that will be discussed later.

4. Low Backgrounds and Single Versus Multiple Peaks

A particularly low background means that even relatively small peaks (over 1000ppm) may get a GOOD classification - but only if they are clearly isolated peaks.

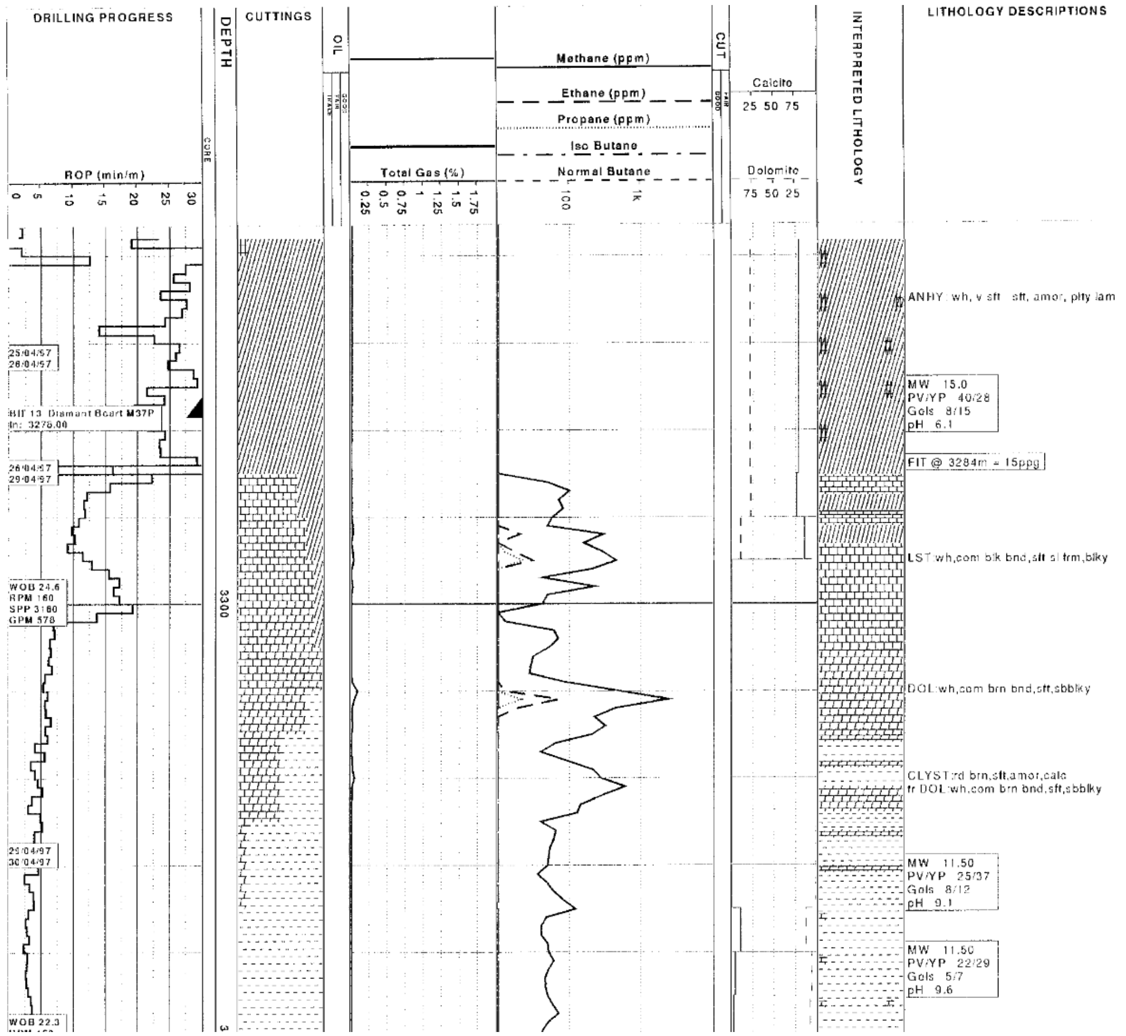
E09-01



Depth: 1895m
Peak: 2650ppm
Background: <5ppm
Lithology: chalk
Classification: GOOD

This is an isolated peak in a potentially porous lithology with a background of almost 0. So even though the absolute gas concentration is not particularly high, this show is rated as GOOD. This is further supported by the C2 spike – peaks that are also seen in longer chain alkanes should be rated a bit more favourably. But keep in mind that on some logs higher chained alkanes are not measured.

D12-05-S1

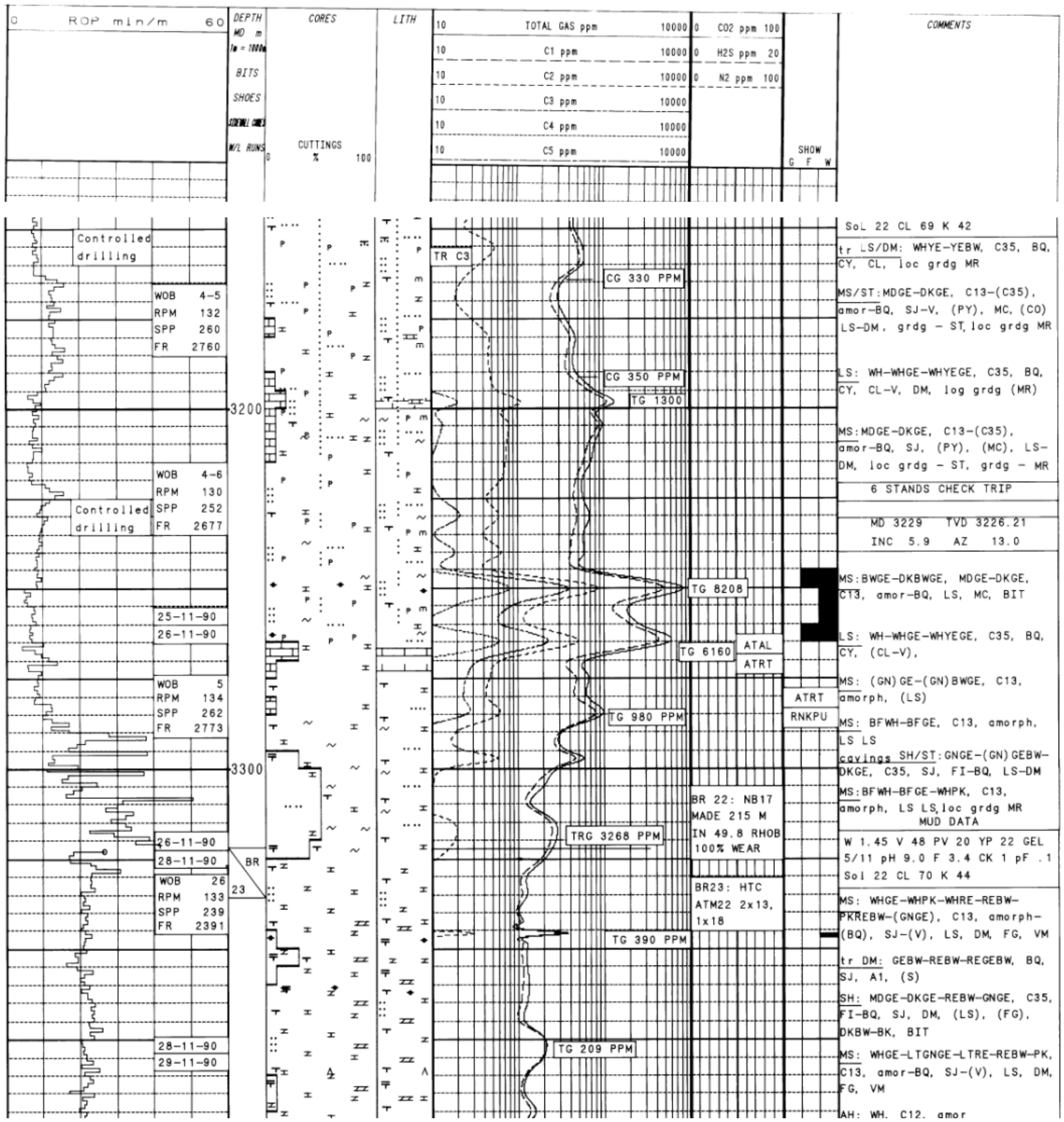


Depth: 3312m
Peak: 3000ppm
Background: 50ppm
Lithology: dolomite
Classification: FAIR

In this example the absolute gas concentration of the main peak is actually a little higher than before, again in a porous lithology, and we also see C2. But because the main peak is close to another smaller peak and because the background increases from 0 to about 50ppm at the peak, this does no longer qualify as a GOOD show.

5. GOOD and FAIR Shows in Claystone and Marl

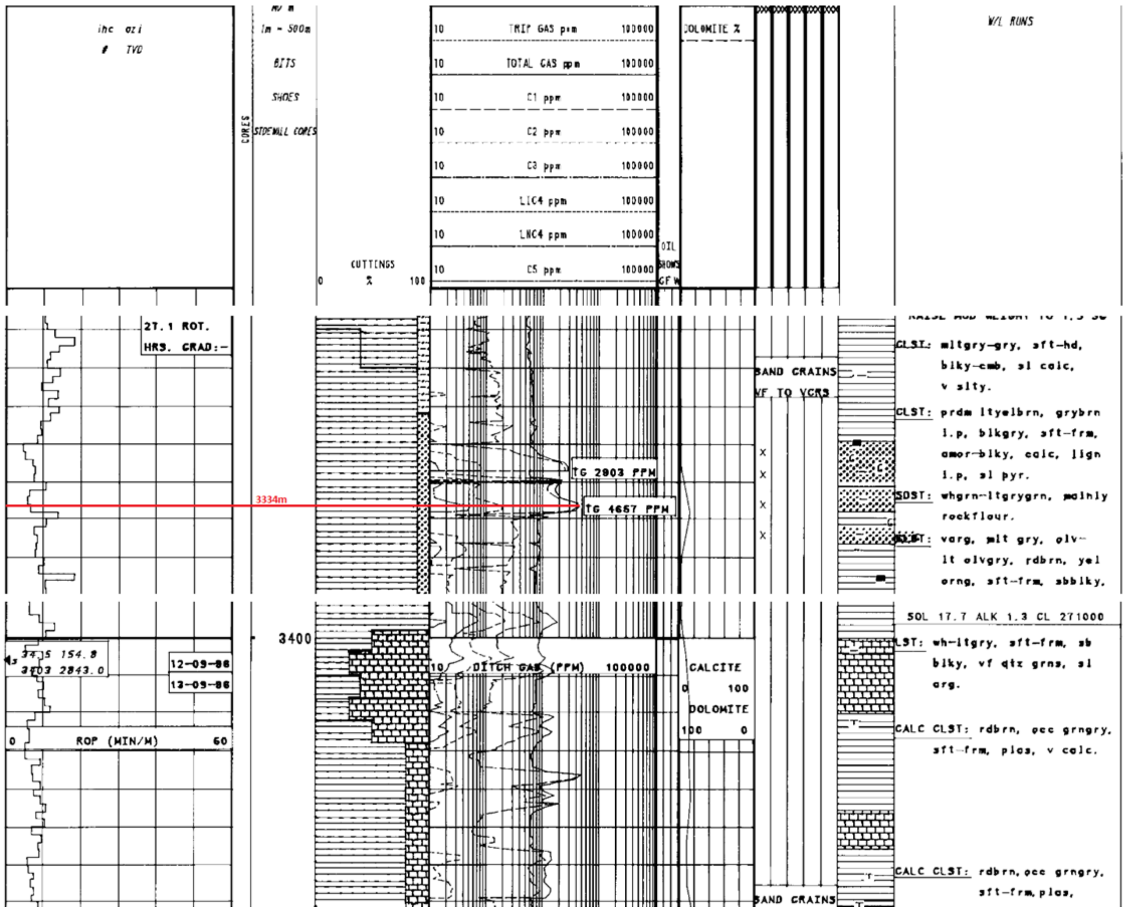
L03-02



Depth: 3250m
Peak: 8200ppm
Background: 500ppm
Lithology: claystone
Classification: FAIR/GOOD

With a PtBR of over 10 and an absolute peak value close to 10000ppm (1%), as well as strong peaks in the longer chained alkanes and a high sand content in the lithology, this show is at the FAIR to GOOD boundary (in these cases you still need to choose a single classification – but both options are acceptable), despite the lithology being claystone. The peaks also coincide with oil shows, so there is definitely an accumulation of various hydrocarbons.

M07-05-S1



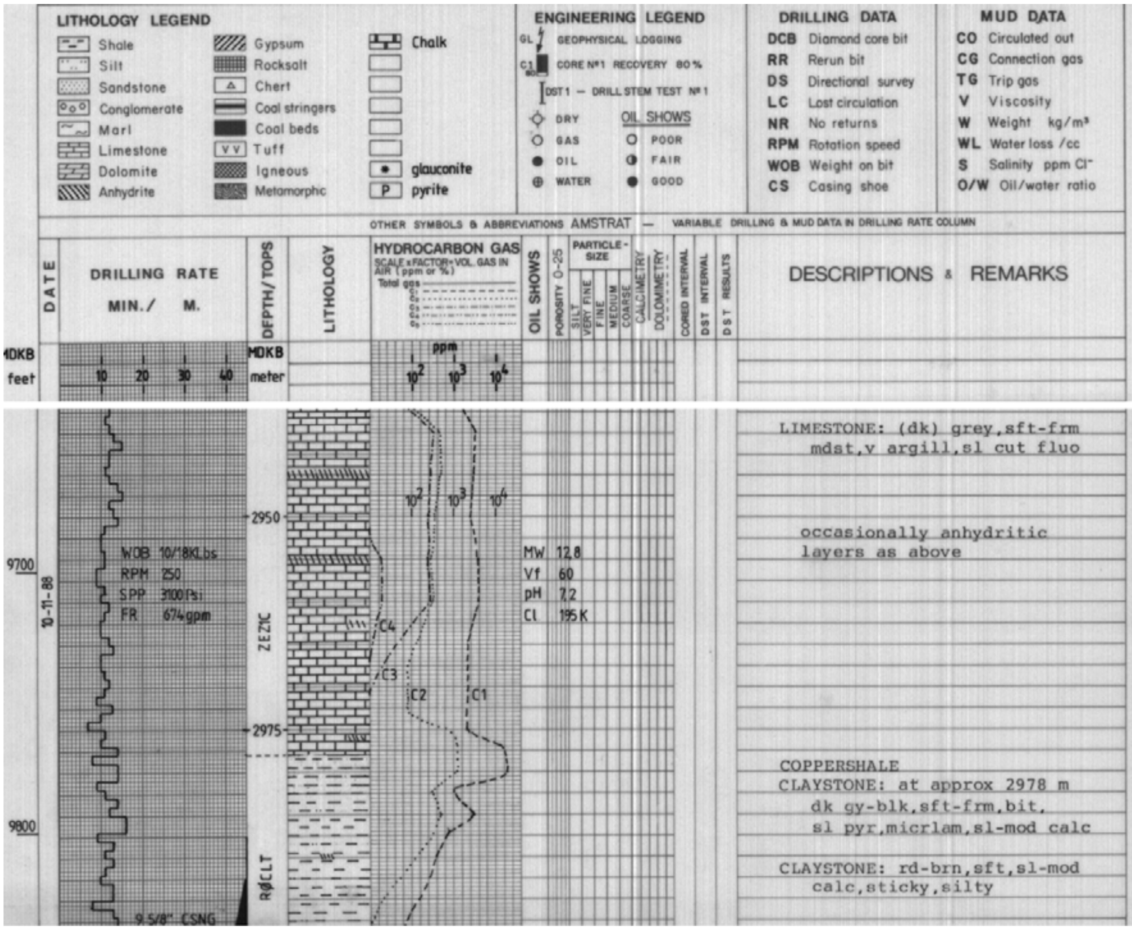
Depth: 3328m
Peak: 2900ppm
Background: 700ppm
Lithology: sandstone
Classification: POOR/FAIR

Depth: 3418m
Peak: 5000ppm
Background: 1000ppm
Lithology: claystone
Classification: FAIR

Depth: 3334m
Peak: 4700ppm
Background: 700ppm
Lithology: claystone/sandstone
Classification: FAIR

In this log 3 stratigraphic units are displayed. Two of them (in the middle section) are separated by the red line and another one is shown in the separate bottom section of the log. Note that the second show is at the boundary between two stratigraphic units and that it is hence being counted towards the lower unit. The upper two shows get FAIR ratings despite being strong shows in sandstone because they don't stand alone. The peak in the bottom formation is only a little stronger and is placed in claystone, but it is a clear isolated event, so that it gets the same classification as the two shows above.

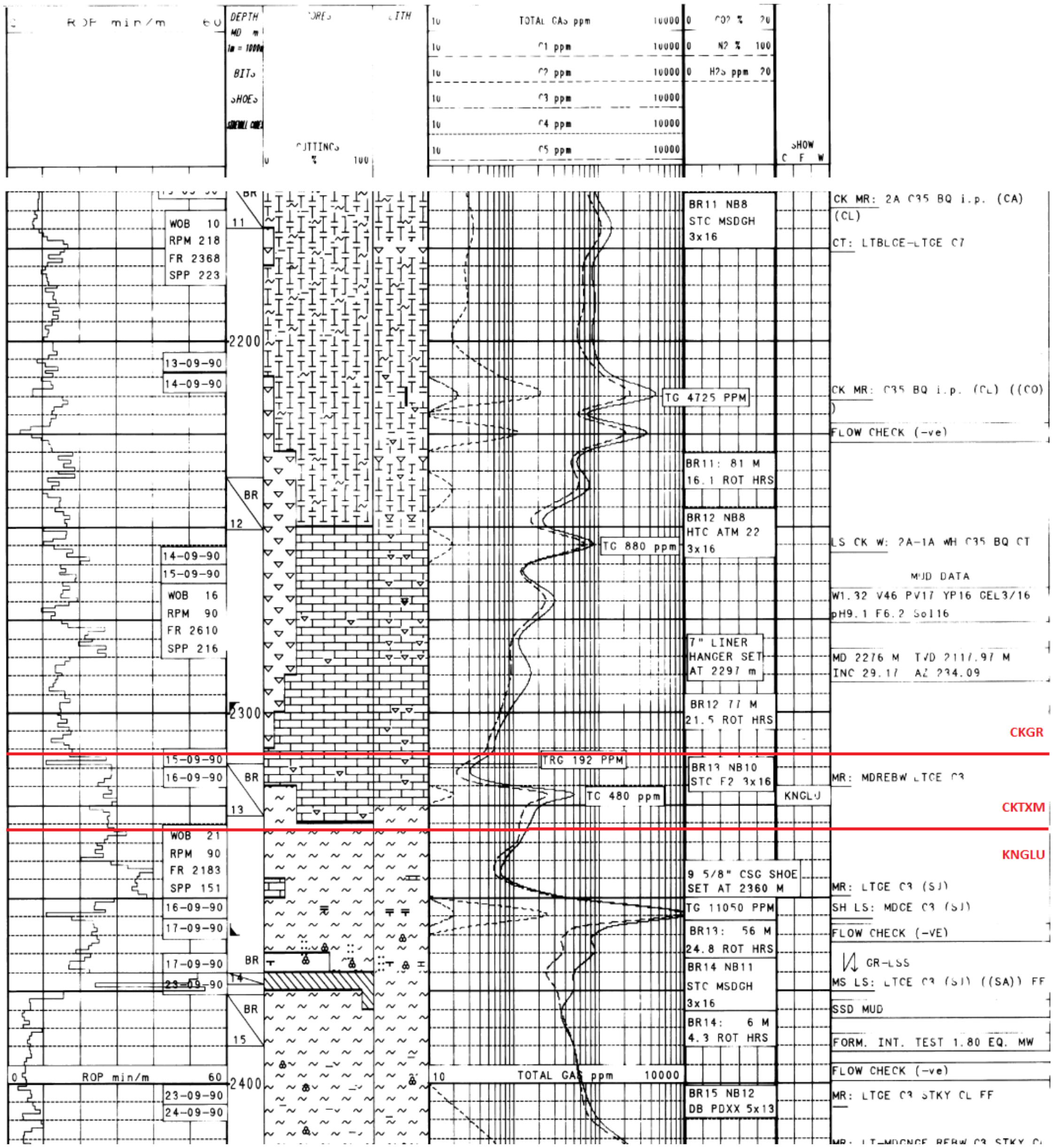
M10-04



Depth: 2980m
Peak: 26000ppm
Background: 4000ppm
Lithology: claystone
Classification: FAIR

This is a show with a very high absolute gas concentration value (more than 3 times of the concentration in L03-02 which got a tendentially better rating). But note that the background is also really high resulting in a lower PtBR (6,5 compared to >10) this indicates that the high values are caused by low mud weight or other instrument settings rather than by high hydrocarbon concentrations in the formation. But even with that in mind the values are high (they appear to drop off on both ends of the log), there are other alkanes, and a PtBR of >6 is still quite sizeable warranting a FAIR rating for this show.

G16-03



Depth: 2215m
Peak: 4725ppm
Background: 700ppm
Lithology: chalk
Classification: FAIR

Depth: 2322m
Peak: 480ppm
Background: 100ppm
Lithology: chalk
Classification: NO SHOW

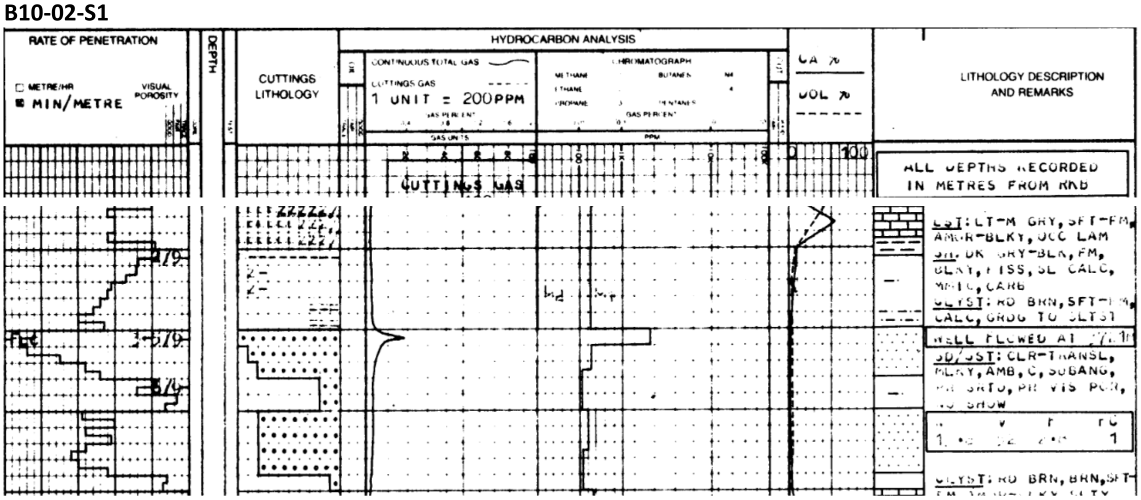
Depth: 2355m
Peak: 11000ppm
Background: 300ppm
Lithology: marl (possibly limestone bed)
Classification: GOOD

Here we see 3 stratigraphic units. The gas peak in the middle unit is not large enough to count as a show (<500ppm). The lower show is in marl, a low porosity lithology which is treated similarly to claystone. The PtBR is huge, however, and the well isolated peak seems to coincide with a limestone bed (seen in the cuttings column), so the classification given to this show is GOOD. The show at the top only gets a FAIR classification despite being in a more porous lithology because it is not an isolated peak and because the PtBR does not compare to the one of the marl-show. The classification of a show also depends on the maximum gas concentrations seen in other peaks across the same log. If the show at the top was the only one reaching values above 4500ppm in this log one could contemplate giving it a GOOD rating.

6. Well Kicks

A well may kick (or flow) if there is an abrupt pressure increase upon drilling into a new lithology. The kick can be caused by water, oil or gas, but in any case it is proof that the formation above acts as an effective seal trapping pore fluid of the underlying formation. That means that whenever there is a well kick (obviously for a gas kick but also for a water kick) coinciding with a gas show, it improves the rating given to the show significantly. Even peaks under 500ppm may be classified as POOR or FAIR shows if there is a well kick, and shows that would otherwise be POOR or FAIR are rated as GOOD depending on the setting. Well kicks are not obvious from the gas concentration curve, but they are usually annotated on the log.

B10-02-S1



Depth: 3721m
Peak: 4000ppm
Background: 300ppm
Lithology: sandstone
Classification: GOOD

This show would normally be FAIR but in the rightmost column it is remarked that the well flowed, warranting a GOOD rating.

Appendix D: QGIS visualization setup user manual

Workflow manual HC Show database interactive top view (2D) visualization in QGIS

Youri Kickken September, 2016

Introduction and General Remarks

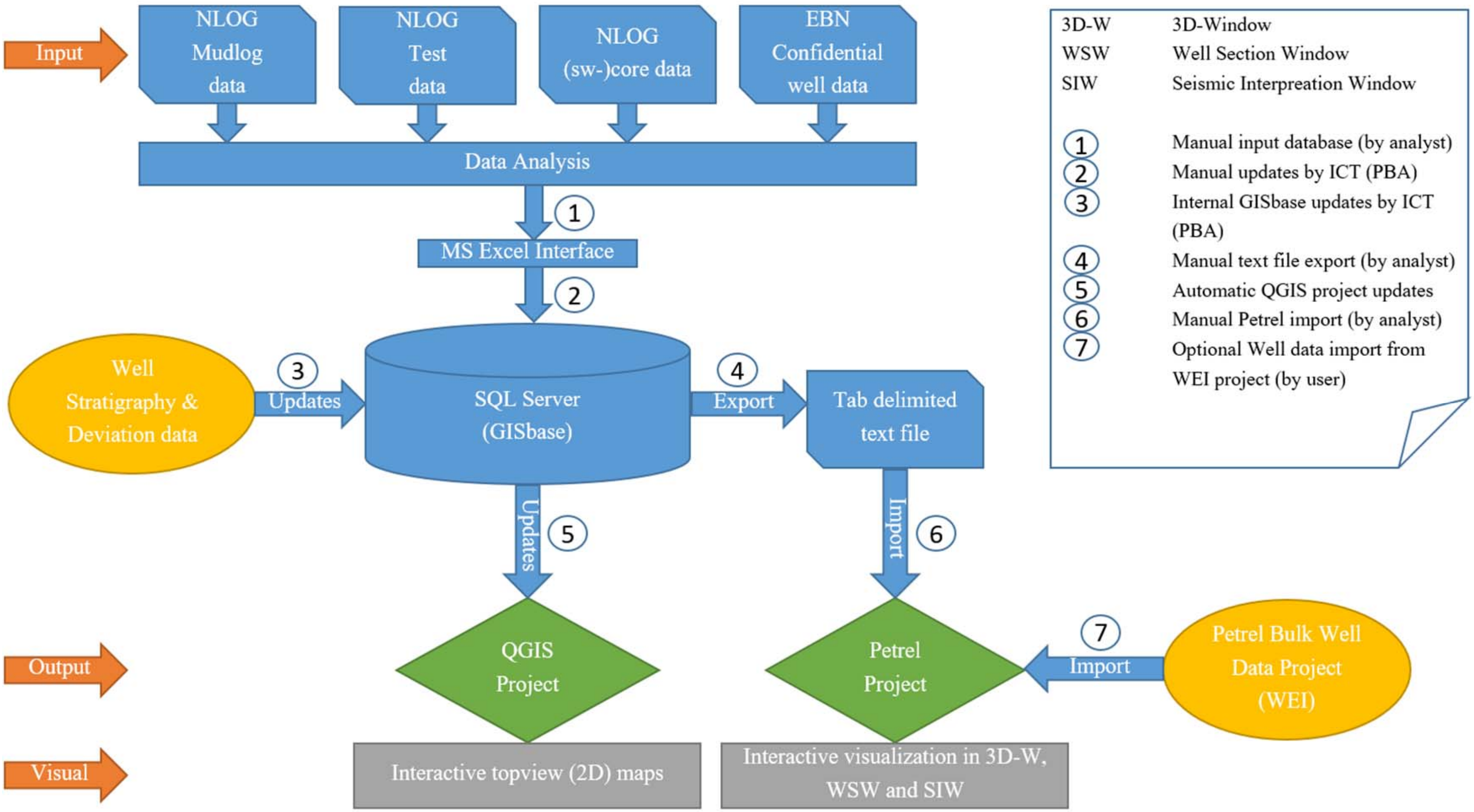
This workflow is designed to create a basic interactive visualization for the HC Show database in QGIS. It consists of 6 steps. The first step is linking your QGIS project to the GISbase and importing the EBN HC Show data. During the second step the user will put the right settings to each layer. In the third part the interactive possibilities of visualizing HC shows of different stratigraphic intervals are shown. Parts 4 and 5 explain the procedures of adding contextual maps as backgrounds and of inserting links to the original data files respectively, and in the last step the map making is explained.
For new users of the QGIS software it is always important to keep in mind that the software uses a layering system. This means that you can visualize several layers on top of each other. If you think in advance about the components you want to visualize and adjust your order of layers to this.

- On the next page the workflow with all components of the "EBN Hydrocarbon Show database" is shown. The workflow consists of several different steps, which eventually will result in outputs in both QGIS (2D) and Petrel (3D).

- To become familiar with the method concerning the classification of the HC shows in this database, please check the "HC Show Workflow.docx" on *Livelink* **here:**
  http://ebnecm/**
  or on the *GeoStore (H:)* drive **here:** *H:\Petrel\2016 HC Shows database_Youri Kickken\HC Show Workflow_v2.docx*

- If you are interested in the interactive (3D) visualization of the HC Show database in the Petrel E&P software, please check the "Workflow manual HC Show database visualization in Petrel E&P Software". This file can be found on *Livelink* **here:**
  http://ebnecm/**
  or on the *GeoStore (H:)* drive **here:** *H:\Petrel\2016 Youri Kickken - Stage - HC Shows\Report & Presentation\Workflows QGIS and Petrel visualization\HC_Show_database_visualization_Petrel_manual.docx*

EBN Hydrocarbon Show database Workflow



Step 1: Importing the HC Show data from the GISbase

The steps to connect QGIS to the GISbase will not be discussed here. For more information on this refer to the "GIS Cursus" manual, which can be found on *Livelink* **here:** http://ebnecm/***

Note: Use the "GIS Cursus" manual also when you are not familiar with the QGIS software yet. This manual will give you a quick basic introduction to the software. There are also several free manuals online including comprehensive Youtube tutorials.

Open your QGIS project, connect to the GISbase and continue as follows:

- In order to import the HC show data you need to add a "MSSQL spatial-layer". Click  (on the left taskbar) and in the pop-up window select "GISbase" and confirm by clicking "Connect" (Verbinden). A list will appear with all the data in the "GISbase" (Fig. 1). Click on the plus next to "@hydrocarbon_shows", select "vwgLogDataShows" and click "Add" (Toevoegen). There are two different "vwgLogDataShows" in this list; you need to choose the one with "Point" (Punt) as type. Use the same type for all other layers, you import, from the HC Show database. The log data of the HC Show database will now be loaded in your project.

- Repeat step 1 for "vwgTestData", and in case you want to compare the EBN and NAM show databases for "vwgAllNam".

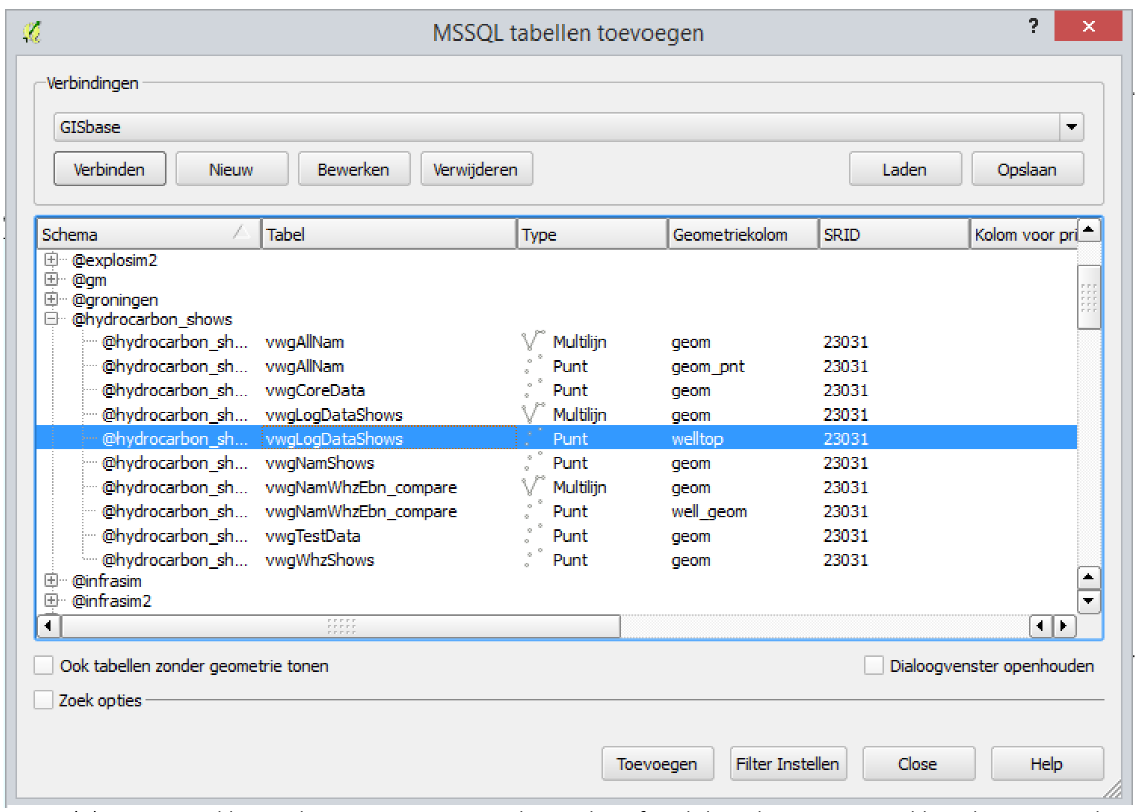


Figure (D)1: You can add a new layer to your project in this window after clicking the MSSQL spatial-layer button. Start by selecting "GISbase" and click "Connect" (Verbinden). Select the data layers from the HC Show database under the "@hydrocarbon_shows" tab and click "Add" (Toevoegen).

Note: For the purpose of visualization it is also useful to add layers such as "tbgWells", "tbgProvinces", *"tbgBlocks" and "vwgTerritoryNL" to your project. To give a better context to the data. These layers can be found in the "basic" and "background" tabs in the GISbase list.*

Step 2: Creating filters for the different layers

- Next, double click on the layer "vwgLogDataShows" and go to the "Style" (Stijl) tab in the pop-up window. Change the upper selection menu to "Rule-Based" (Regel-gebasseerd), see figure 2.

- The window will be empty when you start. In order to add all layers seen in figure 2, click on the green "plus" sign indicated by the red box (fig.2).
  In the new window start by adding a "label", followed by a "filter" (table 1). Click on symbol (red box fig.3), and select "SVG-Symbol" (Symbool) in the selection menu (brown box fig.3). Change the "Size" (Grootte) to at least 10,0 and then click on "browse" (green box fig.3). Go to the "QGIS Symbols" folder, double click and select the "Inner Circle" folder. Select the "GoodGasV2.svg" file and click "OK".

- Do the same for all the other rules. Keep the size the same as the first one. See table 1 for all the information you need.

You can download the "QGis Symbols" folder from Livelink **here:**
http://ebnecm/**
or copy it from the GeoStore (H:) drive **here:** *H:\Petrel\2016 Youri Kickken - Stage - HC Shows\QGIS\QGIS\QGIS Symbols*

Note: You can change the "label" to your preference, however you should keep the "filter" the same. The "filter" needs to be the same in order to show the intended data, as this the link to the HC Show database in the GISbase.

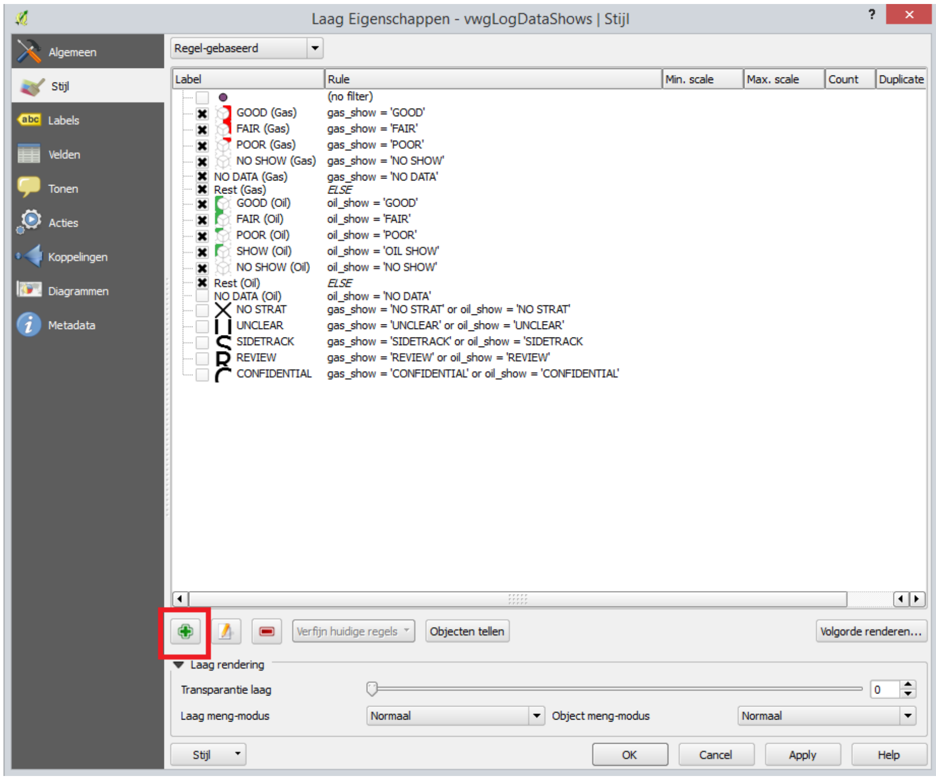


Figure (D)2: In this window, select "Rule-based"(Regel-Gebasseerd) and add new rules by clicking on the green plus sign indicated by the red box.

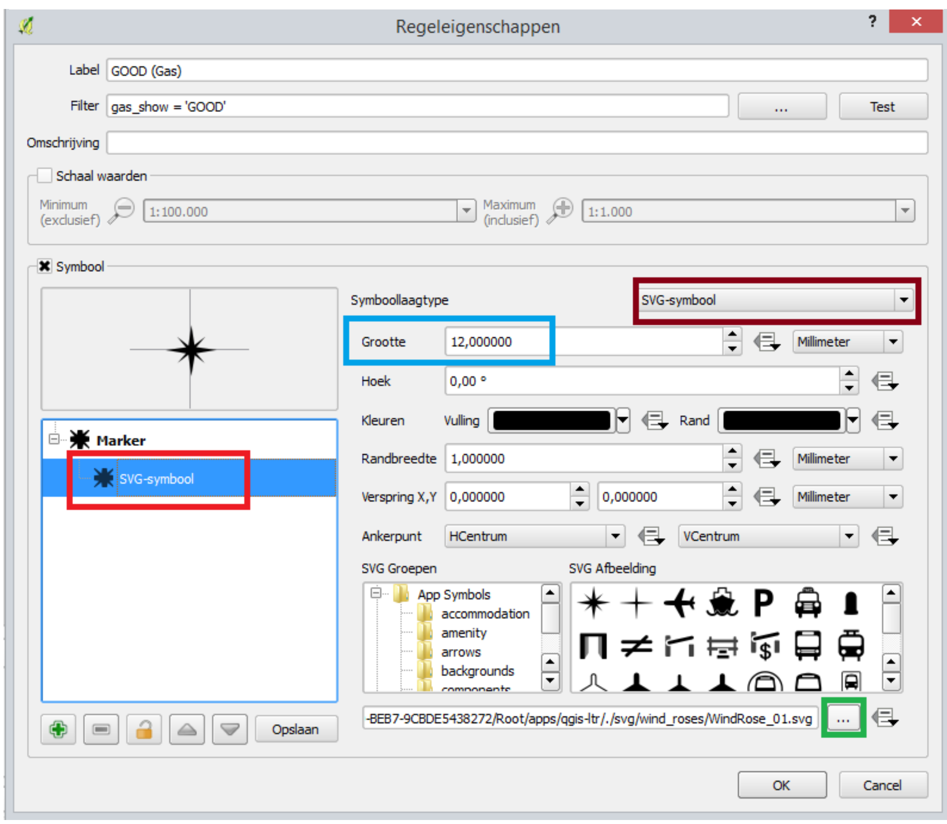


Figure (D)3: Name the "Label" and set a filter to make a direct link with the GISbase. Select symbol in the red box followed by setting the correct settings. See table 1 for all info.

Table (D)1: Recommended settings for the different rules of the "vwgLogDataShows" layer. The symbols for each rule are listed in the last column.

Rule	**Label**	**Filter**	**SVG-Symbol / Letter-Symbol**
1	GOOD (Gas)	gas_show = 'GOOD'	GoodGasV2
2	FAIR (Gas)	gas_show = 'FAIR'	FairGasV2
3	POOR (Gas)	gas_show = 'POOR'	PoorGasV2
4	NO SHOW (Gas)	gas_show = 'NO SHOW'	InnerEmptyCircleV2
5	NO DATA (Gas)	gas_show = 'NO DATA'	D
6	Rest (Gas)	*ELSE*	-
7	GOOD (Oil)	oil_show = 'GOOD'	GoodOilV2
8	FAIR (Oil)	oil _show = 'FAIR'	FairOilV2
9	SHOW (Oil)	oil_show = 'OIL SHOW'	FairOilV2
10	POOR (Oil)	oil _show = 'POOR'	PoorOilV2
11	NO SHOW (Oil)	oil _show = 'NO SHOW'	InnerEmptyCircleV2
12	NO DATA (Oil)	oil _show = 'NO DATA'	D
13	Rest (Oil)	*ELSE*	-
14	NO STRAT	gas_show = 'NO STRAT' or oil_show = 'NO STRAT'	S
15	UNCLEAR	gas_show = 'UNCLEAR' or oil_show = 'UNCLEAR'	U
16	SIDETRACK	gas_show = 'SIDETRACK' or oil_show = 'SIDETRACK'	T
17	REVIEW	gas_show = 'REVIEW' or oil_show = 'REVIEW'	R
18	CONFIDENTIAL	gas_show = 'CONFIDENTIAL' or oil_show = 'CONFIDENTIAL'	C

Note: In this example we make use of the recommended SVG-symbols which have been designed for the purpose of visualizing the HC Show database. However, you can of course use other standard symbols or even your own custom symbols as you see fit.

- Repeat the last 3 steps the same for “vwgTestData” and fill in the information that is in table 2 below.

Table (D)2: Recommended settings for the different rules of the “vwgTestData” layer. The symbols for each rule are listed in the last column.

Rule	Label	Filter	SVG-Symbol / Letter-Symbol
1	DST Gas	test_type = ‘DST’ and Result = ‘GAS’	DSTGasV2
2	DST Oil	test_type = ‘DST’ and Result = ‘OIL’	DSTOilV2
3	DST Water	test_type = ‘DST’ and Result = ‘WATER’	DSTWaterV2

- If you want to compare the NAM database with the EBN database repeat the same steps again for “vwgAllNam”. Fill in the information in table 3 below. For this layer you can use the “Outer Circle” folder.

Table (D)3: Recommended settings for the different rules of the “vwgAllNam” layer. The symbols for each rule are listed in the last column.

Rule	Label	Filter	SVG-Symbol
1	GOOD Gas	show_quality = ‘GOOD’ and show_type = ‘GAS’	OuterGoodGasV2
2	FAIR Gas	show_quality = ‘FAIR’ and show_type = ‘GAS’	OuterFairGasV2
3	POOR Gas	show_quality = ‘POOR’ and show_type = ‘GAS’	OuterPoorGasV2
4	GOOD Oil	show_quality = ‘GOOD’ and show_type = ‘OIL’	OuterGoodOilV2
5	FAIR Oil	show_quality = ‘FAIR’ and show_type = ‘OIL’	OuterFairOilV2
6	POOR Oil	show_quality = ‘POOR’ and show_type = ‘OIL’	OuterPoorOilV2

Note: you can also select and deselect filters in the window shown in figure 2 by checking and unchecking the boxes in front of the labels.

- Having followed the steps described in this manual with the recommended settings, you will end up with a symbols classification as shown in figure 4.

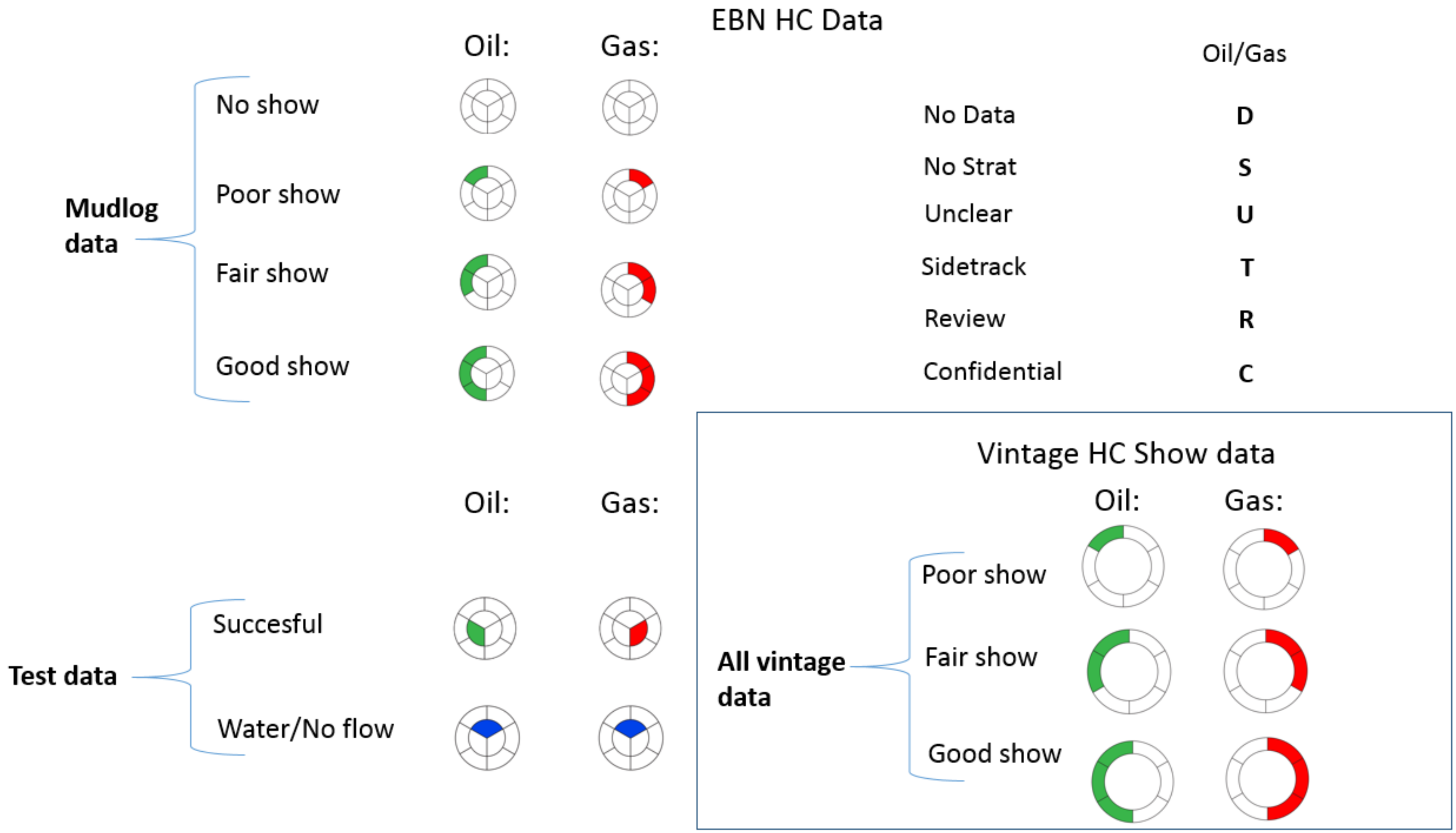


Figure (D)4: Hydrocarbon Show classification symbols in QGIS.

Step 3: Creating Queries for all layers

- In order to make use of the interactive component of the database, you need to set queries for the different layers. This way you can see shows for different stratigraphic groups, formations and members.
  Double click on “vwgLogDataShows” and select the “General” (Algemeen) tab. Next click on “Querybuilder” (Querybouwer), indicated by the red box in fig. 5, and type (for example): “STRAT_CODE” like “ZE%” (fig 6). Finish by clicking “OK” and then “Apply” in the previous window.

- Do the same for “vwgTestData” and for “vwgAllNam”. More info for possible queries for the 3 different layers is given in table 4. As an example the Upper Cretaceous Chalk Group is given, the Texel Formation and the Texel Greensand Member. The same format of queries is applicable to all other groups and formations. Refer to the “Stratigraphic Nomenclature of the Netherlands, version 2016.1” for the stratigraphic abbrevations.

  Note: These queries create a link between the QGIS layer and the GISbase database. A column is defined followed by Stratigraphic abbreviations, which are set in this column. This filters between the different groups, formations and even members.

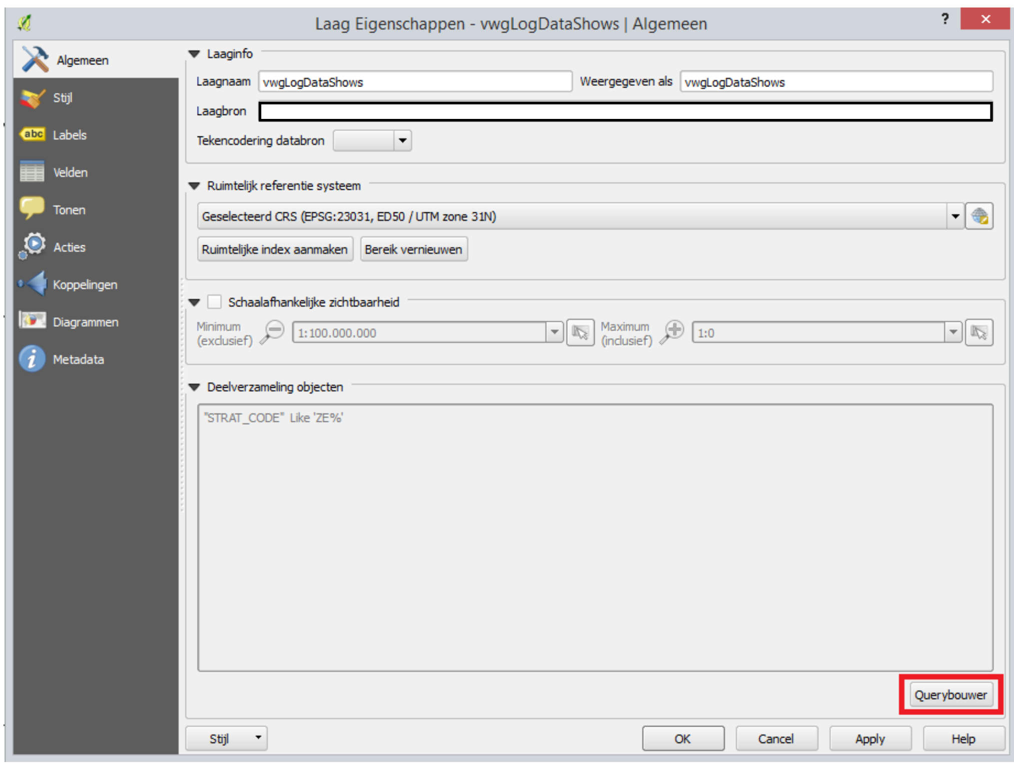


Figure (D)5: Build a Query by selecting the button in the red box.

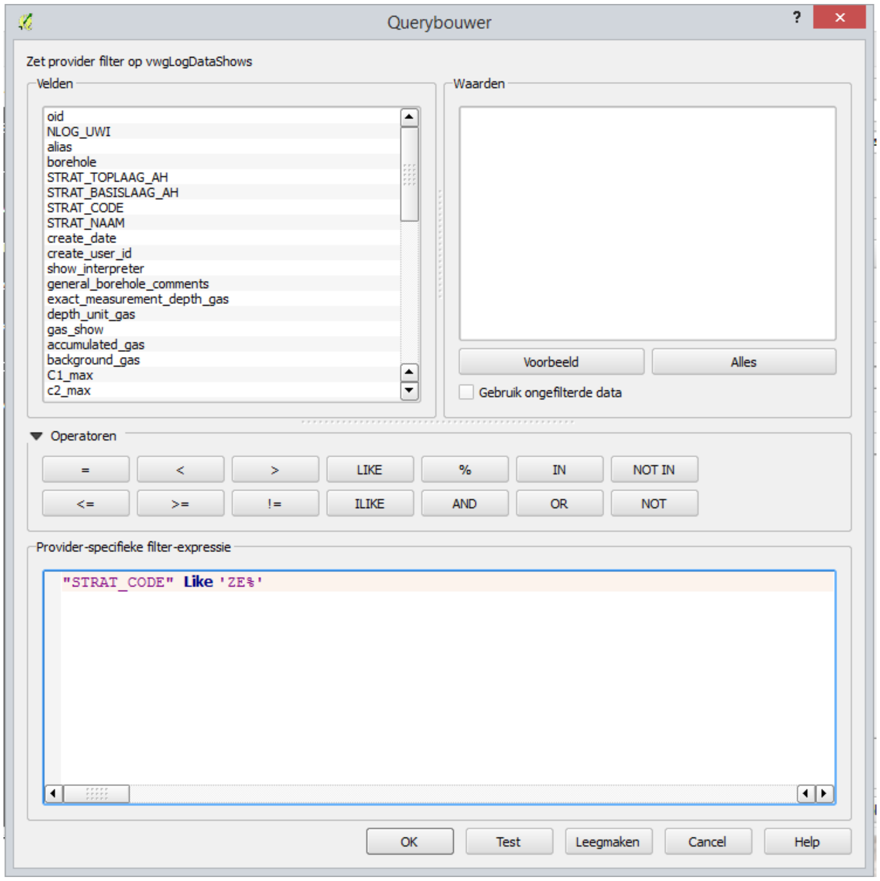


Figure (D)6: Use the info in table 4 to set different queries. This allows you to visualize the data of different stratigraphic groups, formations and even members.

- ***Make sure that the queries for the layers “vwgLogDataShows”, “vwgTestData” and “vwgAllNam” are set for the same group, formation or member.*** Otherwise the visualized layers are not on the same stratigraphic level. For the background depth maps you may choose a different stratigraphic interval, which meets your needs of visualization. Adding these background depth maps is described in the next step.
  Note: If you have your own project and you don’t need context maps. You can skip step 4 and take a look at step 5 and 6.

Table (D)4: Queries for the different layers. These queries allow you to visualize the data of different stratigraphic groups, formations and even members. The queries given below are only examples. You can of course use different stratigraphic codes. However, at all-time make sure that the queries are set to the same stratigraphic code.

Layer	**Group**	**Query**	**Formation**	**Query**	**Member**	**Query**
“vwgLogDataShows”	Chalk Group	"STRAT_CODE" Like ‘CK%’	Texel	"STRAT_CODE" Like ‘CKTX%’	Texel Greensand	"STRAT_CODE" Like ‘CKTXG’
“vwgTestData”	Chalk Group	"top_stratigraphy" Like ‘CK%’	Texel	"top_stratigraphy" Like ‘CKTX%’	Texel Greensand	"top_stratigraphy" Like ‘CKTXG’
“vwgAllNam”	Chalk Group	"top_strat_cd" Like ‘CK%’ or "bottom_strat_cd" Like ‘CK%’	Texel	"top_strat_cd" Like ‘CKEK%’ or "bottom_strat_cd" Like ‘CKTX%’	Texel Greensand	"top_strat_cd" Like ‘CKTXG’ or "bottom_strat_cd" Like ‘CKTXG’

Step 4: Placing the data in context by adding background layers of the different stratigraphic groups

- In order to give some context to the shown data you can add some background layers. There are several depth maps created by TNO of the different stratigraphic groups for the Dutch territory. Start adding these by clicking on the "Add rasterlayer" (Rasterlaag toevoegen) button  in the left taskbar.

  Note: you can of course also import other background/depth maps.

- Browse to GeoStore (H:), followed by "Petrel", "2014 GM study", "QGIS", "TNO depth maps". In this folder depth maps for 10 different stratigraphic groups are given. One by one, select all .asc files (or the ones that you need) in the different folders, followed by clicking "OK".

- The following step is to make "Hillshades" for every stratigraphic depth map. These are used to create relief (depth) in the maps. Go to "Raster", "Analysis" (Analyse) and "DEM (Hoogtemodellen)". The previous steps are visualized in figure 7.
  Select one of the depth maps as "input file" (invoerbestand) and type in a file name for the "output file" (uitvoerbestand). Preferably choose a name which clearly refers to the original file, such as for example; "N_diep_hill". Keep all other options as default (see fig. 8) and click "OK". In the next pop-up screen select the coordinate system "ED50 / UTM zone 31N", and click "OK". Confirm all the following pop-up windows, and the new "Hillshade" will be created.

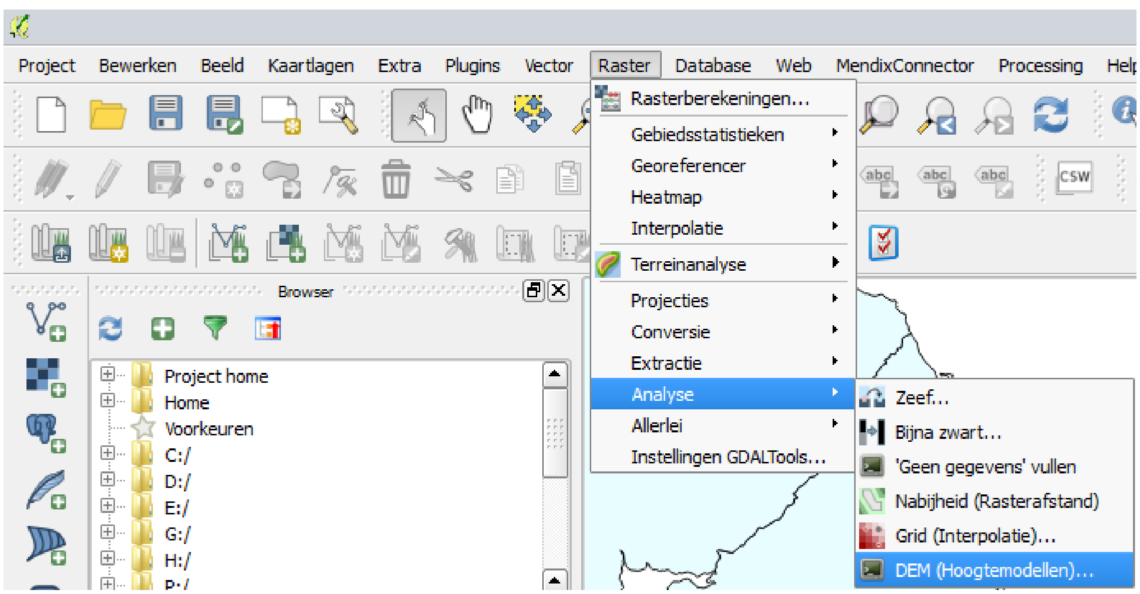


Figure (D)7: Start creating "Hillshades" for every depth map. Do this by selecting "Raster" in the upper task bar followed by "Analysis" (Analyse) and "DEM (Hoogtemodellen)".

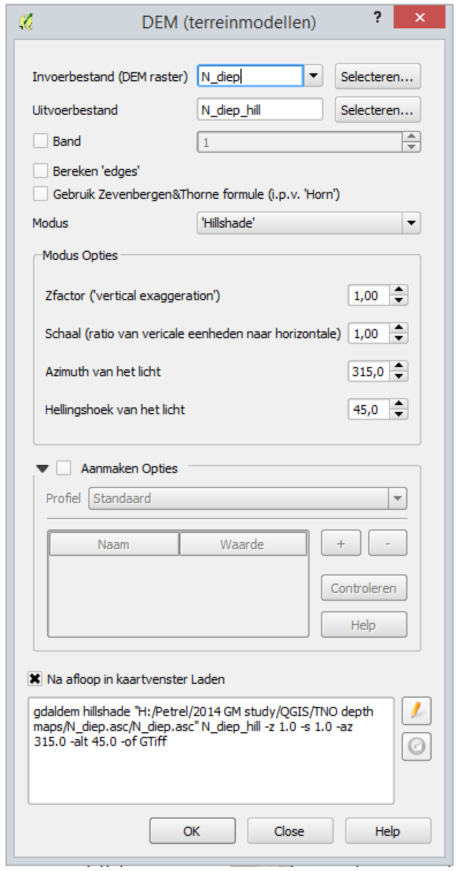


Figure (D)8: Select the depth map and name the "Hillshade". Keep the rest of the settings as default and click "OK"

- Do the same for all other stratigraphic depth maps. Also make sure that the "Hillshade" is above the depth map in the layer tree.

- The next step is to set a colour scale for the different depth maps. Double click the depth map and select the "style" (stijl) tab. Select "Singleband pseudocolour" (Enkelbands pseudokleur) as "Rendertype". Then, select "tpushuf" as "color pallet" (kleurenpalet). If it is not available in the list, select "New colourgradient" instead, and then select "cpt-city" (fig. 9). In the new pop-up window go to "Topography" and select "tpushuf" (fig. 10), and click "OK". Next you can change the name of the colourgradient to your own preference.
  Choose "equal intervals" (gelijke intervallen)" as "modus" and click "classify"(classificeren).

  Note: For the purpose of creating clear legends it is recommended to change the amount of intervals, by trial and error, to the extent that the boundaries of all intervals have rounded numbers (see fig. 9 as example). Also the min and max have to be set to round numbers for this purpose.

- All other recommended settings for the "style" tab window are shown in figure 9.

- Now for the “Hillshade” you only need to choose “Singleband gray” (Enkelbands grijs) as colour gradient.

- To see both both layers at the same time, change the transparency of the “Hillshade” layer. Double click on the “Hillshade” layer and go to the “Transparency” (Transparantie) tab. Change the “Global transparency” (Globale transparantie) to around 70%. This makes sure that both the depth map and the corresponding “Hillshade” are visible when selected together.

  Note: Do a quality control on the depth maps in combination with the corresponding “Hillshades”. Make sure that the combination of these two maps show the correct data. Such that highs coincide with highs and deeps coincide with deeps. If this is not the case, double click on the “Hillshade” layer and change the “Colougradient” (Kleurverloop) in the “style” tab from “black to white” (zwart naar wit) to “white to black” (wit naar zwart) or vice versa.

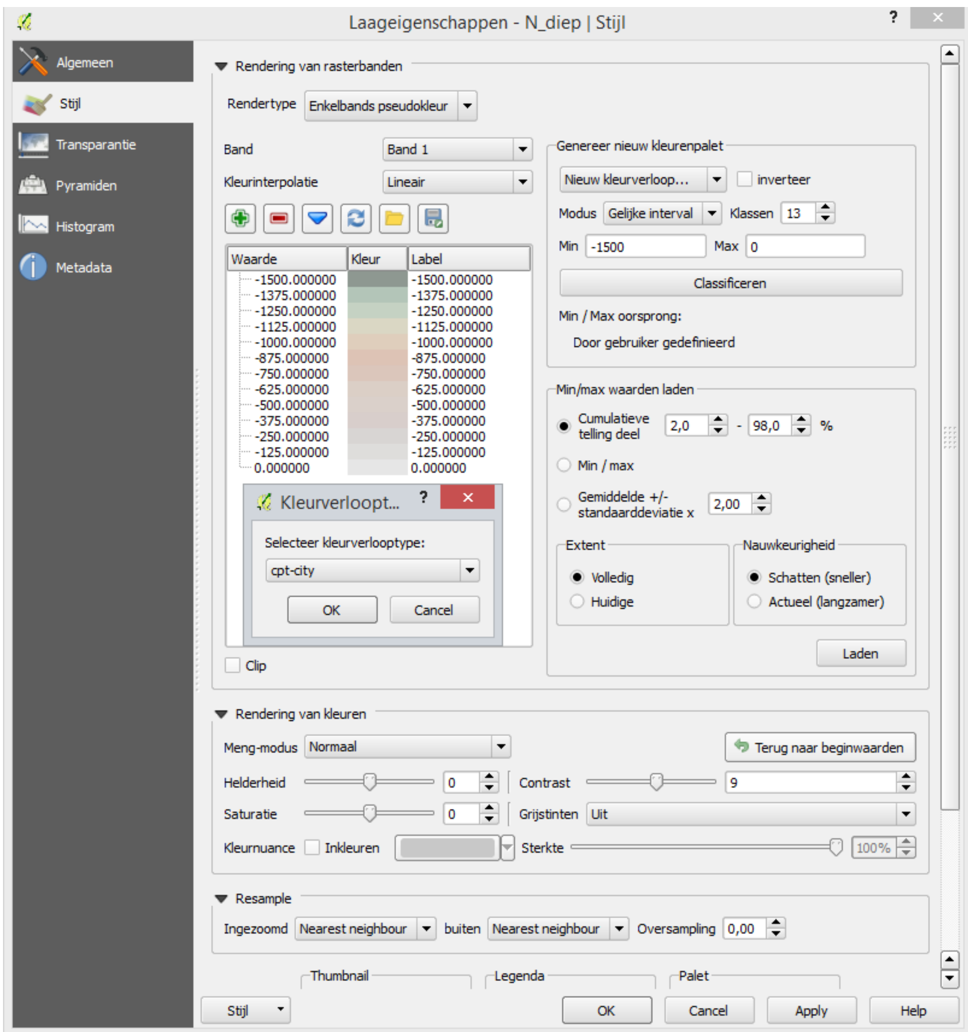


Figure (D)9: Style tab window of the depth map. Change the “Rendertype”(Rendertype) to “Singleband pseudocolor” (Enkelbands pseudokleur). Select “tpushuf” as “colour pallet”(kleurenpalet) and choose “Equal intervals” (gelijke intervallen). Select the amount of “Classes” and the “Min” and “Max” by trial and error. Change all other settings as shown in this figure.

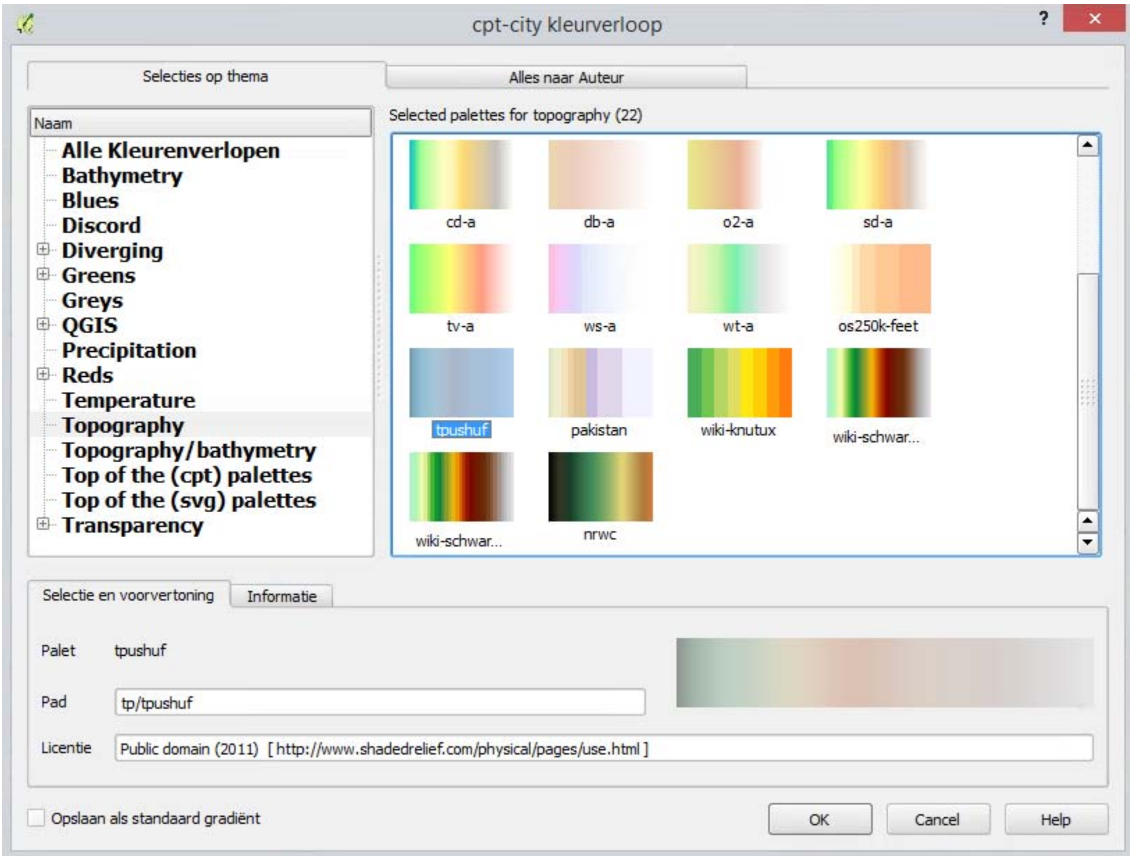


Figure (D)10: Select "tpushuf" under "Topography" as "colour pallet" (kleurenpalet).

Step 5: Enabling data review link

There is the possibility to review the data shown in QGIS by adding an "Action" to the layer "vwgLogDataShows". Which works as a link to the original data file, in Livelink. To enable this option do the following steps:

- Double click on the "vwgLogDataShows" layer and go to the tab "Actions" (Acties). Fill in the options which are shown in figure 11 and click on "Add to action list" (Toevoegen aan actielijst).
- Now, if you want to use the link, click on the "Object action button"  in the upper task bar followed by clicking on one of the data points in the map. This will open the Livelink web page with the linked file in your web browser.

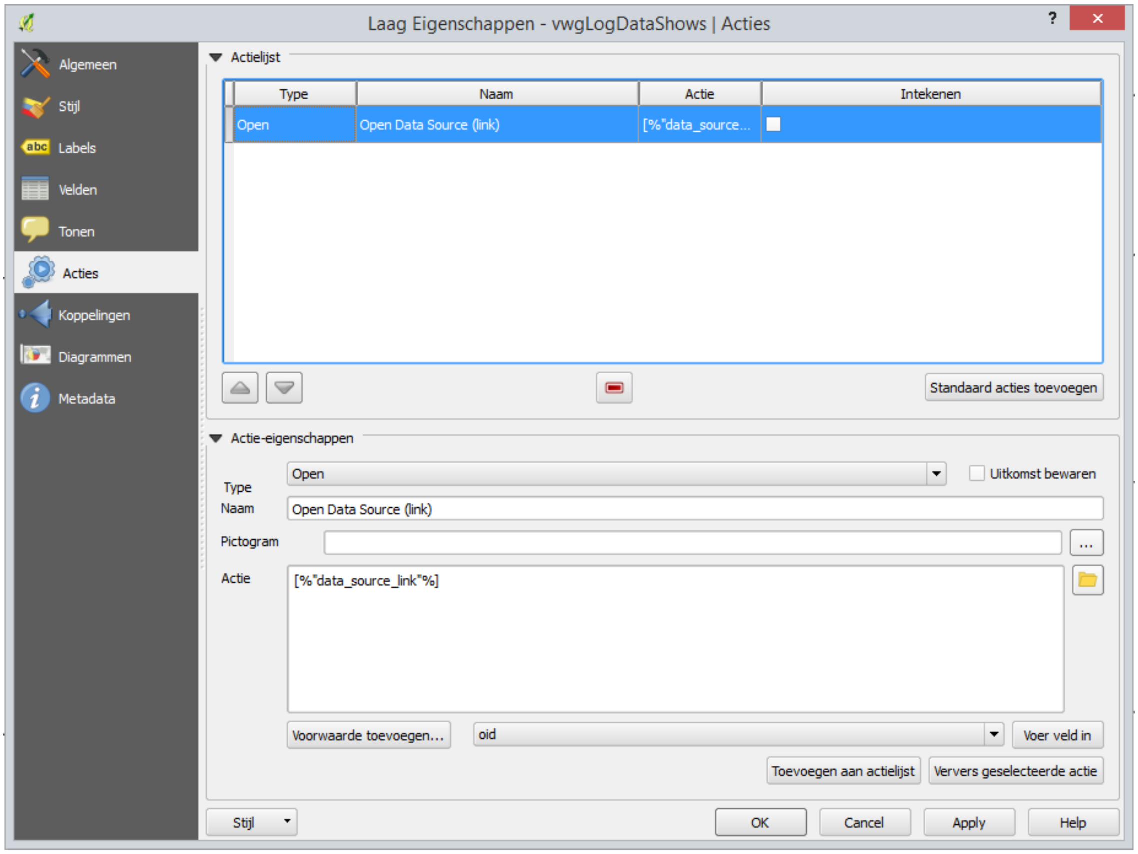


Figure (D)11: Add an "Action" to the vwgLogDataShows" layer. This enables you to review data from the original evaluation file saved on Livelink.

Step 6: Creating maps

- It is important to set the layer ordering in a way that all data is displayed properly. The layers that visualize the HC Show data should be on top of the other layers with maps and hillshades and so on. An example for a good layer ordering is given in table 5 below.

Table (D)5: Example of layer ordering.

Layers
"vwgLogDataShows"
"vwgTestData"
"vwgAllNam"
"Depth_Maps"
"tbgProvinces"
"tbgBlocks"
"vwgTerritoryNL"
"tbgOcean"

Note: this is not necessarily the right ordering of layers for your own needs. However, it is important at all times to be conscious of the layer ordering. It can drastically influence the time it takes you to make maps.

- To create maps click on “Project” in the upper task bar, followed by “New Printdesign” (Nieuwe Printvormgeving). Type a name for the design in the pop-up window. In the left taskbar select “Add new map” , and select the area of the map on the white paper to the right by using your left mouse button.

- The options in this window are comprehensive and user friendly. Some of the possibilities are adding a legend, a north arrow and a title. I would like to recommend trying different options. You will become familiar with all options in the print design very quickly.
  For more info on all options for creating maps, I would like to refer to the “GIS Cursus” manual, which can be found on *Livelink* **here:**
  http://ebnecm/**
  or search on google for manuals concerning map making in QGIS.

  Note: Always do a quality control on your selected data before printing and finishing the map. Check if all data is correct and meets your intentions.

Appendix E: Petrel E&P Software visualization setup user manual

Workflow manual HC Show database visualization in Petrel E&P Software

Youri Kickken September, 2016

Introduction and General Remarks

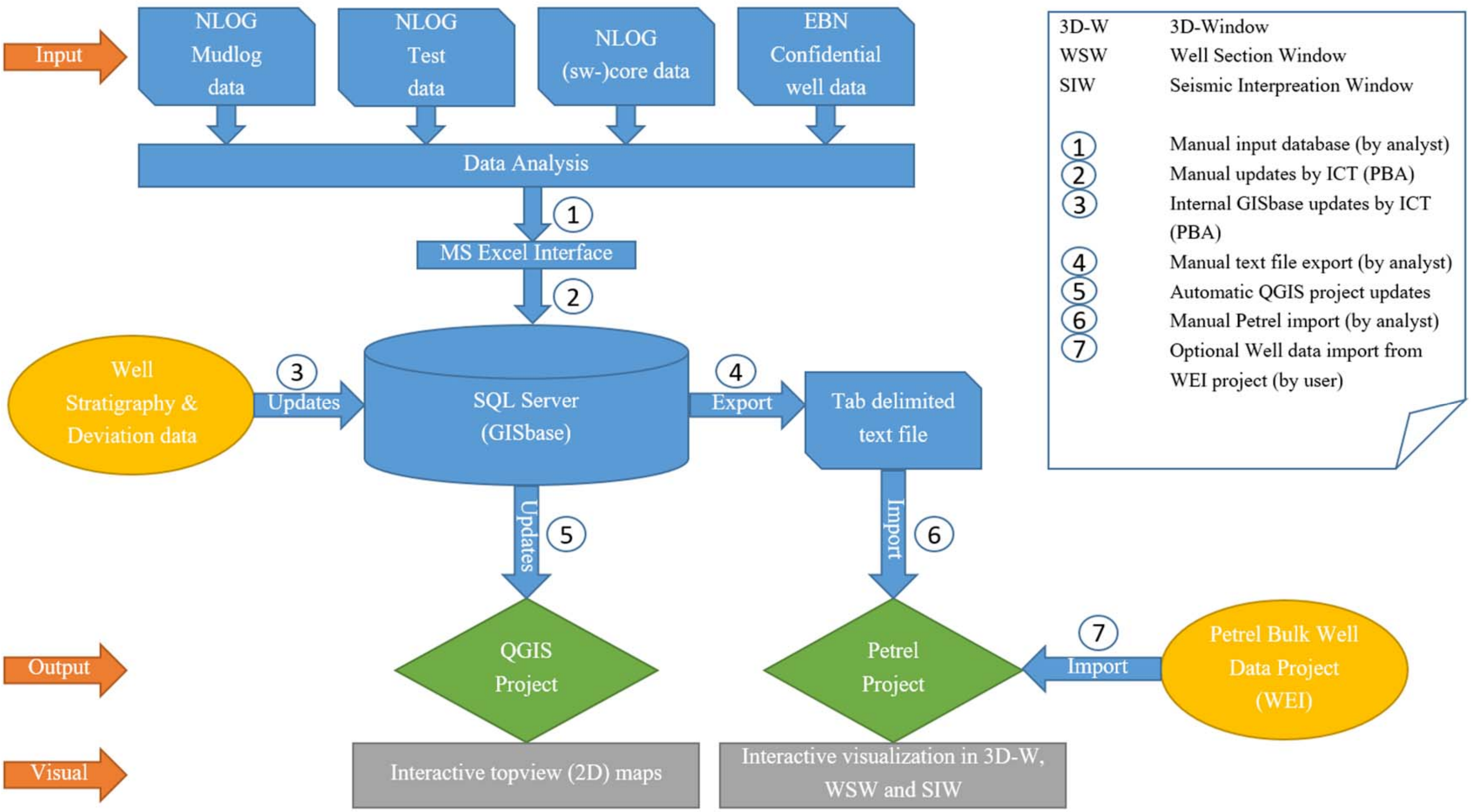
This workflow is designed to create a basic interactive visualization for the HC Show database in Petrel E&P software. It consists of 3 steps. The first step is to export the HC database from GISbase into a text file format. With the second step the user will import the data into Petrel software using a specific import format. Finally, a visualization method is explained, which is based on the show classification used in the HC Show database. However, users can decide at any point to replace this last step by their own custom visualization.
This workflow will introduce several visualization possibilities on show classification and grouping, in three different Petrel windows. This means that the visualization possibilities are extensive and interactive in both show classification and lithological Group or Formation.

- On the next page the workflow with all components of the "EBN Hydrocarbon Show database" is shown. The workflow consists of several different steps, which eventually will result in outputs in both QGIS (2D) and Petrel (3D).

- To become familiar with the method concerning the classification of the HC shows in this database, please check the "HC Show Workflow.docx" on *Livelink* **here:**
  http://ebnecm/***
  or on the *GeoStore (H:)* drive **here:** *H:\Petrel\2016 HC Shows database_Youri Kickken\HC Show Workflow_v2.docx*

- If you are interested in the interactive topview (2D) visualization of the HC Show database in QGIS, please check the "Workflow manual HC Show database interactive top view (2D) visualization in QGIS". This file can be found on *Livelink* **here:**
  http://ebnecm/***
  or on the *GeoStore (H:)* drive **here:** *H:\Petrel\2016 HC Shows database_Youri Kickken\Workflows QGIS and Petrel visualization\HC_Show_database_visualization_QGIS_manual.docx*

EBN Hydrocarbon Show database Workflow



Step 1: Exporting the HC Show database from the GISbase

The manual to connect MS Access to the GISbase will not be discussed here. For more information on this refer to the "GIS Cursus" manual, which can be found on *Livelink* **here:**
http://ebnecm/**

Open MS Access, connect to the GISbase and continue as follows:

- Select "@hydrocarbon_shows.vwgLogDataExport" from the list and Click "OK" (fig. 1). A new window pops up. Select all options in the Unique Record Identifier and click "OK" (fig. 2).
  The Log export data of the HC Shows is now shown in your viewer (if not, double click the label in the "tables" tab to the left).

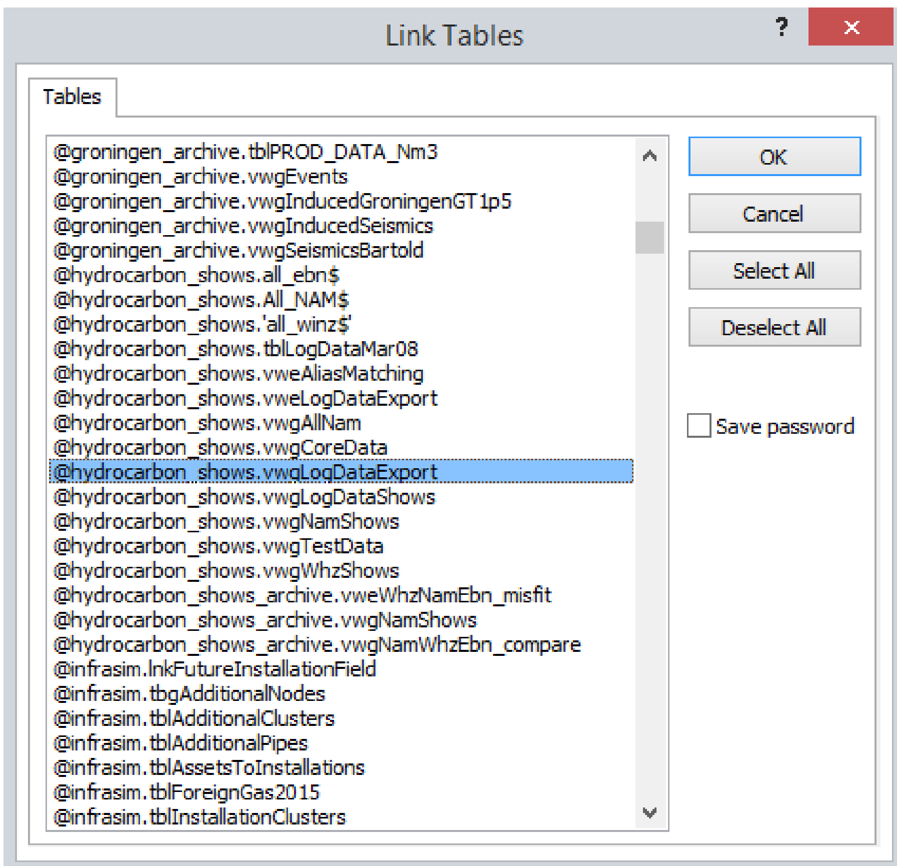


Figure (E)1: Select "@hydrocarbon_shows.vwgLogDataExport" from the Tables list when connected to the GISbase.

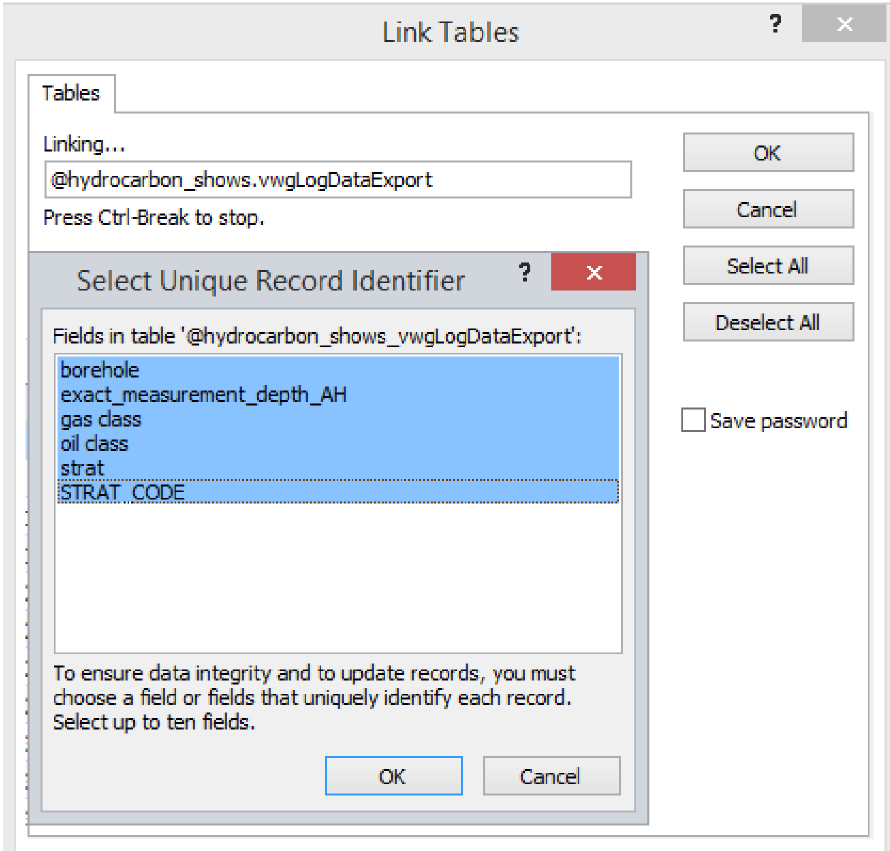


Figure (E)2: Select the first 8, "exact_measurement_depth_gas_AH" and "exact_measurement_depth_oil_AH" from the list in the Unique Record Identifier.

- Go to “EXTERNAL DATA” un the upper task bar and press this icon: 

 In the new window that pops up (fig. 3) browse to a file directory to your choosing and rename the file preferably as “HC_Show_Database.txt”, followed by clicking “OK”.

  Note: Make sure that when you click the “Export as Text file” button that the correct table is selected in the viewer. When this is not the case the wrong table will be exported.

- In the next window select “Delimited” and click “Next”. A new window will appear. In this window check “Tab” as “delimiter”, select “Include Field Names on First Row” and “{none}” as “Text Qualifier” (fig. 4). Click “Next”, followed by “Finish”.

- The text file will now be created in your selected file directory.

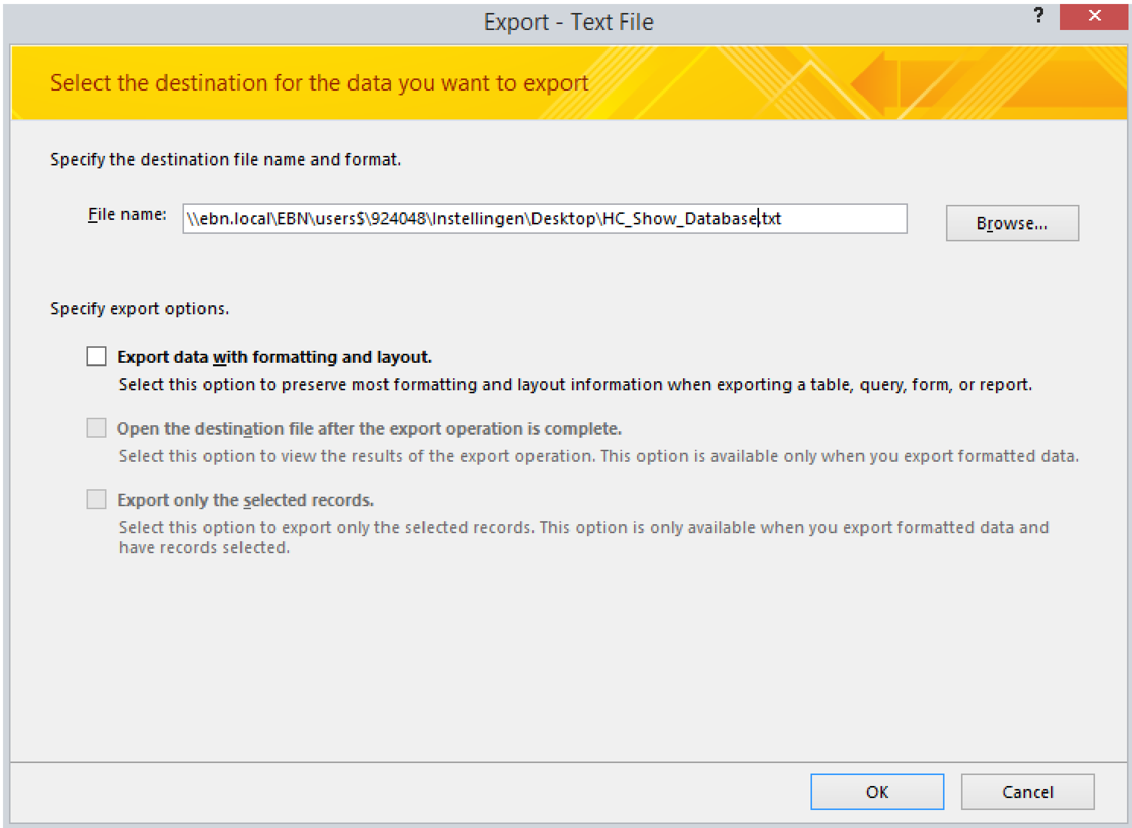


Figure (E)3: Change file name, file path and file format in this Excel-Export window.

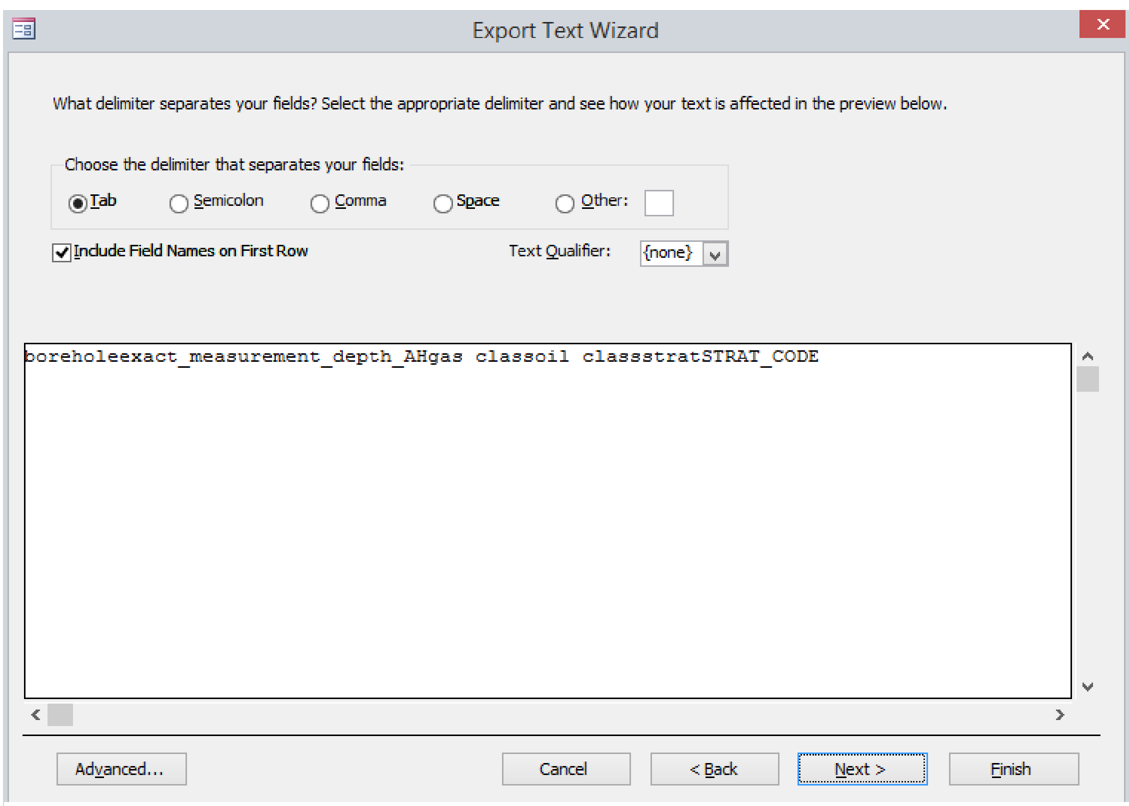


Figure (E)4: Check the boxes "Tab", "Include field Names on First Row" and select "{none}" as "Text Qualifier".

In the Petrel import file (HC_Show_Database.txt) the following data is incorporated:
Column A: All evaluated wells in the HC Show database.
Column B: The exact measurement depths (AH) for both oil and gas.
Column C: Gas classification in numbers (see table 1 below).
Column D: Oil classification in numbers (see table 1 below).
Column E: Stratigraphic Groups linked to the show depth.
Column F: Stratigraphic Formations and Members linked to the show depth.

In the petrel import file the following HC classification is used:

Table (E)1: Hydrocarbon show classification in numbers.

Gas Show	**Oil Show**
GOOD = 5	GOOD = 5
FAIR = 4	FAIR/OIL SHOW = 4
POOR = 3	POOR = 3
NO SHOW = 2	NO SHOW = 2
NO DATA = 1	NO DATA = 1

Step 3: Importing HC Show data in the Petrel E&P Software

- The next step starts with opening your own Petrel project. Make sure that before you start importing, the wells which you would like to evaluate are already set in the project.
  Right click on the "Wells" folder and select "Import (on selection)..." (fig. 5). A new window will pop-up (fig. 6). In the new window chose the settings as shown in figure 7.

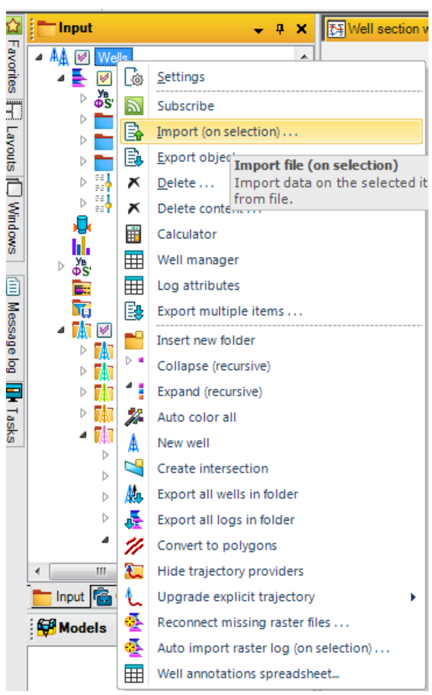


Figure (E)5: Right click on the Wells folder and select "Import (on selection)..."

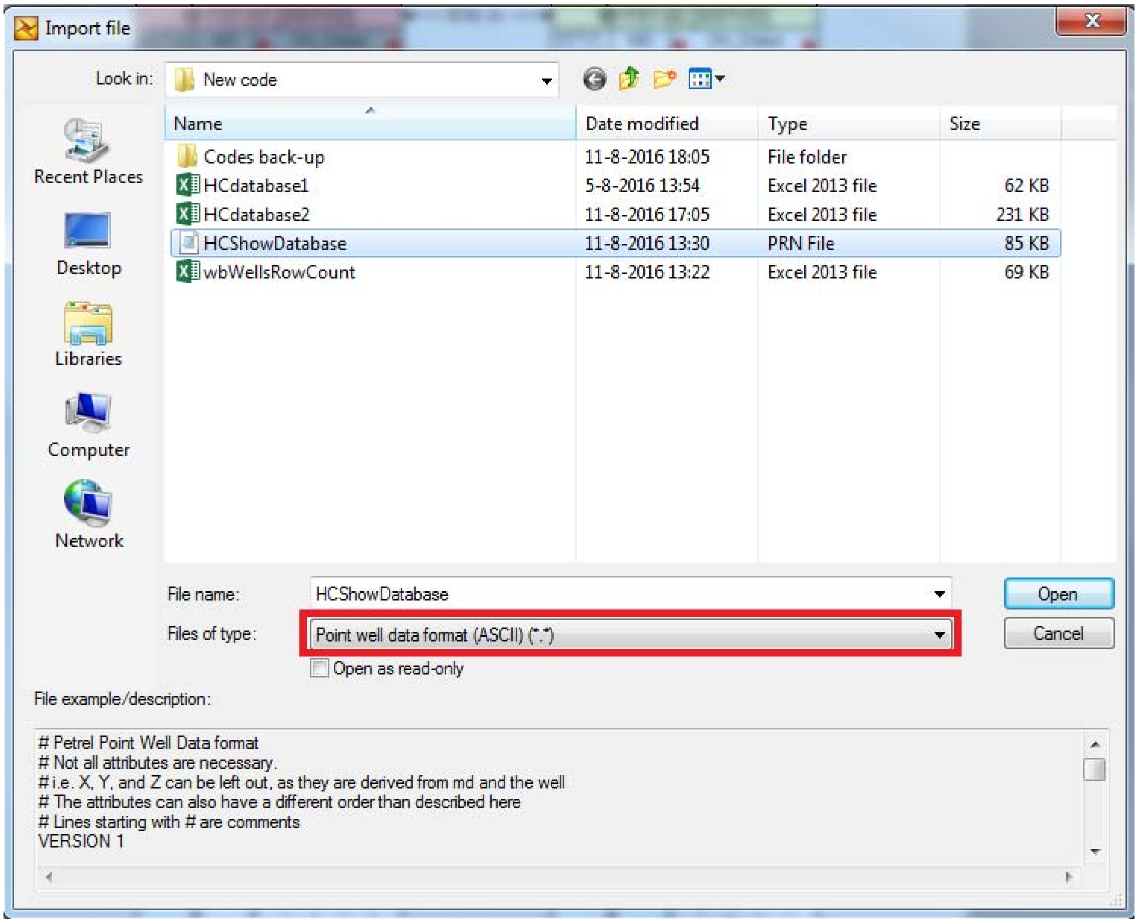


Figure (E)6: Example of directory. Choose files of type, "Point well data format (ASCII)(,*)" and select "HCShowDatabase".*

Note: A perfect basis for the HC Show database is the petrel project (Bulk Well Data) created by <u>Walter Eikelenboom</u>. In this project all Dutch wells are incorporated and all available log data, deviation data, etc. is linked to the wells. You can use the "Project Reference tool" in Petrel to update your own project with the well data from the "Bulk Well Data" project. This can be very powerful when using the HC Show database as exploration tool.

- In the new window insert the following settings (see fig. 7).

  Note: The more experienced Petrel users can decide from this point on to create their own visualization, conform their needs.

  Make sure the 4 columns are set as in Figure 7. You can add or delete columns by using the buttons in the upper taskbar. The number of header lines needs to be set to "1". Also, make sure that the undefined value is "-999" and click "OK".

- If you don"t have all the wells which are, evaluated in the HC Show database, in your own Petrel project, you will get the next window (fig. 8) as pop-up. Just click "OK" and Petrel will not load the data for these wells. In the next window also click "OK". If you want to change the name of the "Global well log", you can do this here at the top.

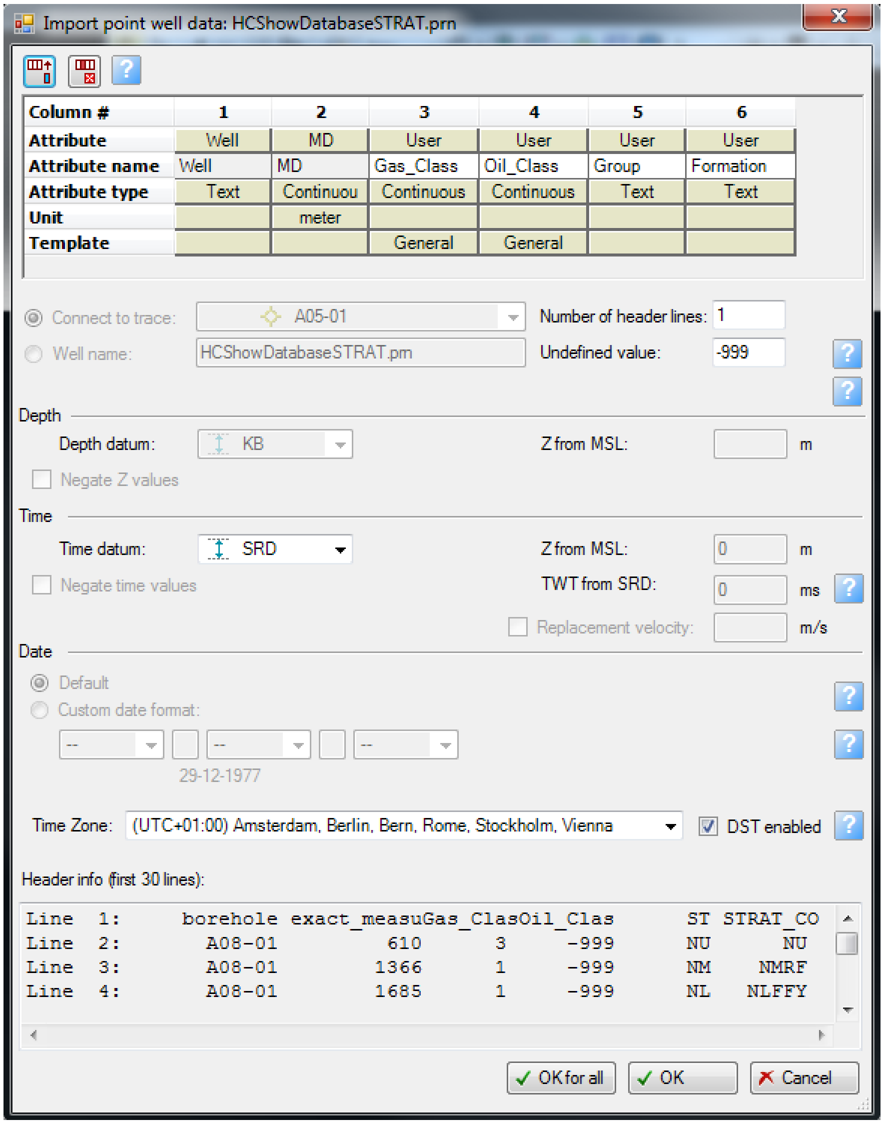


Figure (E)7: Put all settings as in this window. More experienced Petrel users may decide to choose their own templates.

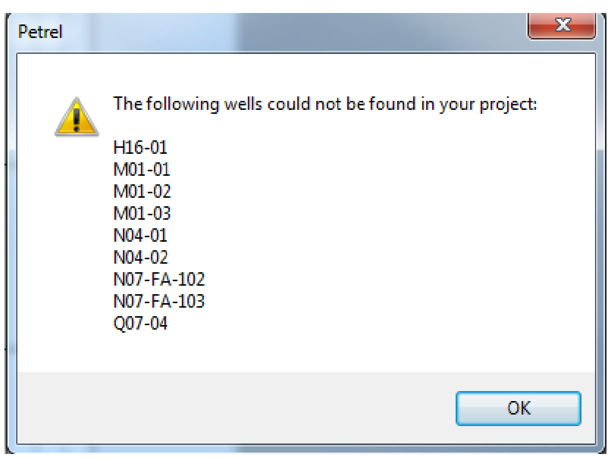


Figure (E)8: Petrel will alert you when not all wells in the database are in your project. Just click "OK" here.

The HC Show data is now imported in Petrel and you are set to start with the steps for visualization of the data.

Step 4: Visualization of HC Show data in the Petrel E&P Software

- Next right click on "HCShowDatabase.txt" in the "Global well logs" tab and select "Calculator". In the log calculator (fig. 9) insert the 10 codes listed in Table 2, and between every code press "ENTER":

Table (E)2: The 10 codes used for the classification in the log calculator.

Gas Classification	**Oil Classification**
GOOD_GAS=if(Gas_Class=5,Gas_Class, U)	GOOD_OIL=if(Oil_Class=5,Oil_Class, U)
FAIR_GAS=if(Gas_Class=4,Gas_Class, U)	FAIR_OIL=if(Oil_Class=4,Oil_Class, U)
POOR_GAS=if(Gas_Class=3,Gas_Class, U)	POOR_OIL=if(Oil_Class=3,Oil_Class, U)
NO_GAS=if(Gas_Class=2,Gas_Class, U)	NO_OIL=if(Oil_Class=2,Oil_Class, U)
NO_DATA_GAS=if(Gas_Class=1,Gas_Class, U)	NO_DATA_OIL=if(Oil_Class=1,Oil_Class, U)

When finished close the window by clicking on the red cross. The newly created logs are now put under the "Attributes" tab on the left (fig. 10).

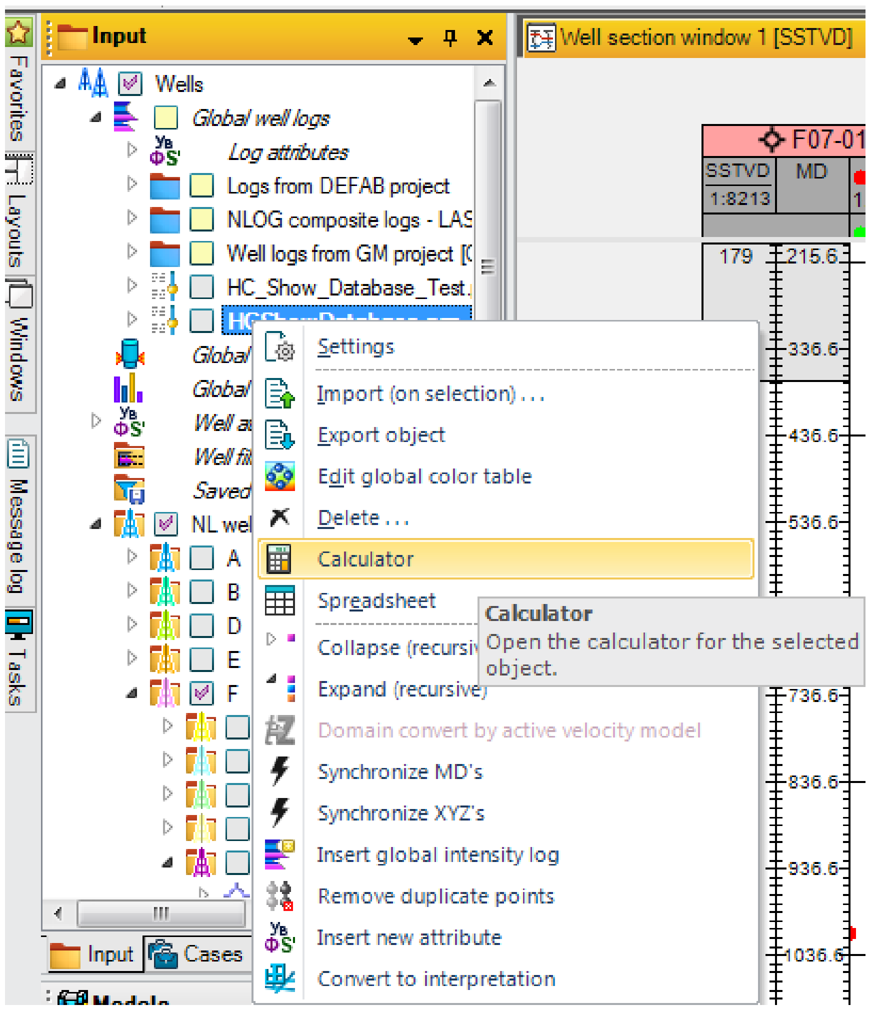


Figure (E)9: Right click on "HCShowDatabase.prn" and select "Calculator". The log Calculator will now pop-up.

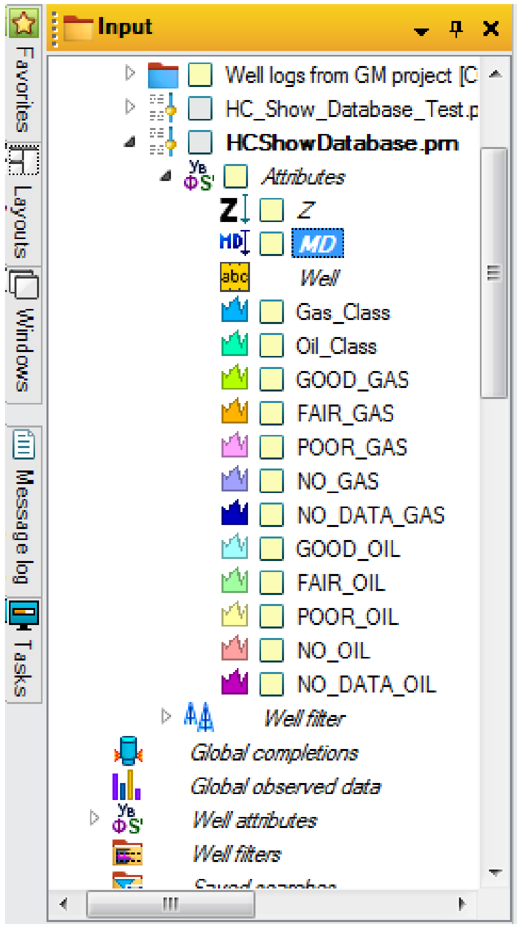


Figure (E)10: The newly created logs are shown in the Attributes tab of "HCShowDatabase.prn" global well log.

- To set a colour classification for the 3D window double click on all newly created attributes and go to the colours tab (fig. 11). Change the colour in the red box indicated in Table 3.

The following table is an example of a colour classification in the 3D window:

Table (E)3: Colours following the classification of the Hydrocarbon shows.

Gas Show	**Colour**	**Oil Show**	**Colour**
GOOD	Blue	GOOD	Blue
FAIR	Orange	FAIR/OIL SHOW	Orange
POOR	Yellow	POOR	Yellow
NO SHOW	Purple	NO SHOW	Purple
NO DATA	Pink	NO DATA	Pink

Note: This colour classification is chosen without using Red and Green (international Gas and Oil indicators). Making sure that confusion is minimized. You can use your own choice of colours. You can even distinguish between Oil and Gas colour classifications.

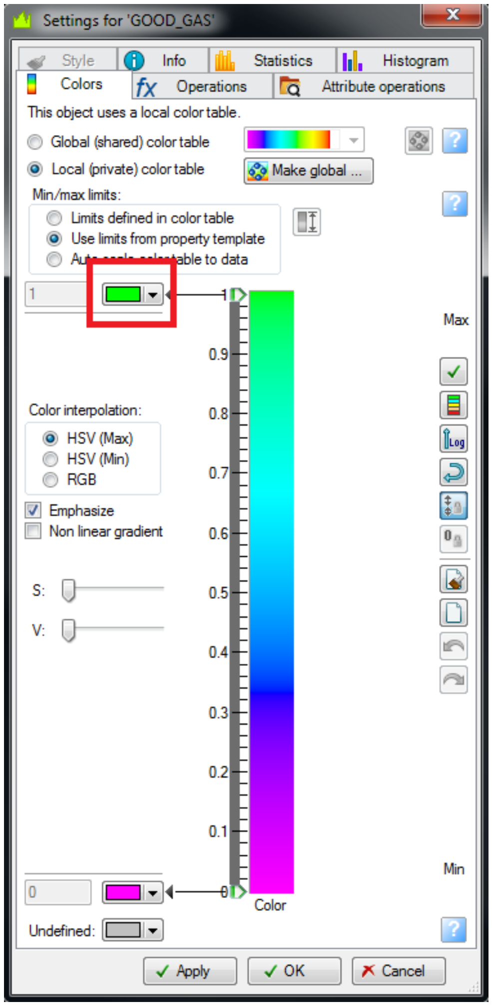


Figure (E)11: Select the "Colours" tab and insert the colours as listed in Table 2.

- Now open a 3D window and check the box "HCShowDatabase.txt" in the global well log. Select one of the new attributes in order to check if all colours have been set correctly. An example of how the data should look like in the 3D window is given in figure 12. Here all GOOD Gas shows are shown with the green spheres, the grey spheres indicate all other data points from the HC Show database.

- It is also possible to filter on Classification number and only show the data points of one certain class. This is done by right clicking on "Gas_Class" and select "Create 1D filter". In the window that pops-up choose the class that you want to show by setting min and max as the class number (see Fig. 13). In the 3D window only the data points from one particular class will be shown.

  Note: When you create a 1D filter a new folder will be added to the bottom of the Input tree. In order to reverse the filter, deselect the box: 

  To customize size and shape of the symbols, you can double click on "HCShowDatabase.txt" and select the "style" tab.

Note: It is also possible to use the attributes per well in order to keep the data filtered to the well you are analysing.

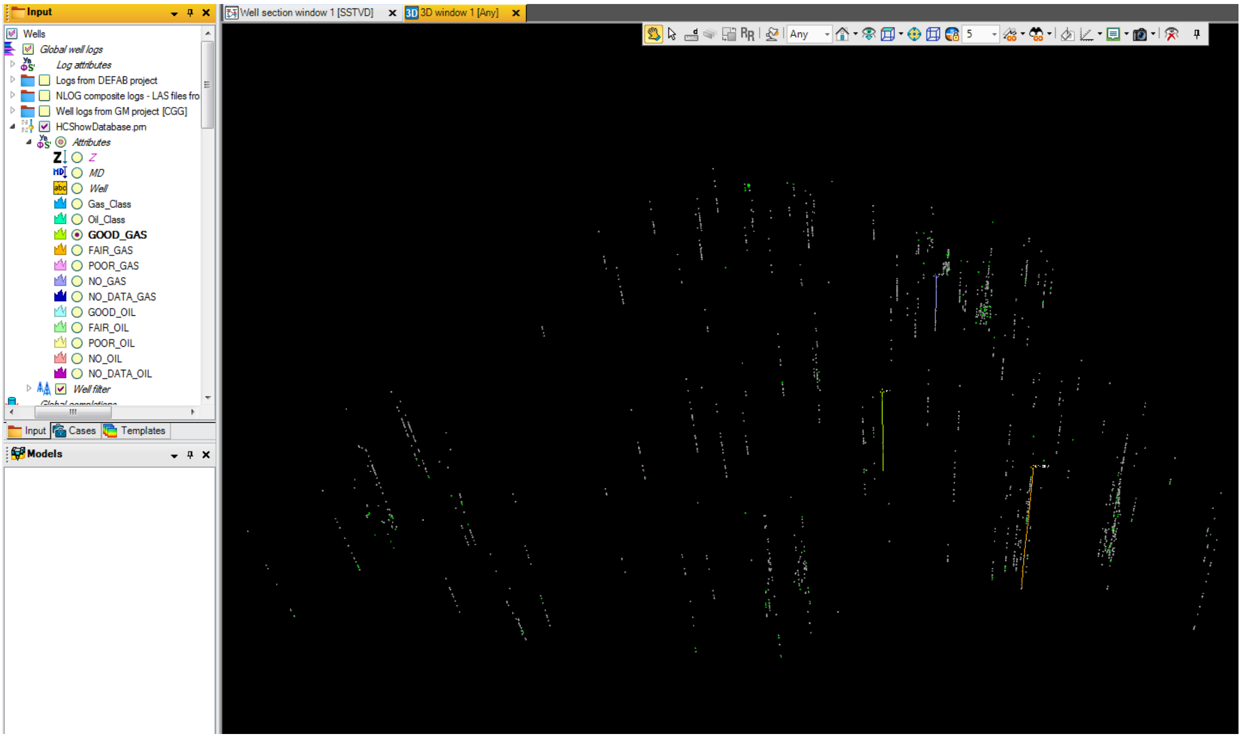


Figure (E)12: 3D window in Petrel showing all hydrocarbon show data points in the DEFAB area. Green spheres indicate the GOOD gas shows and the grey spheres indicate all other data points.

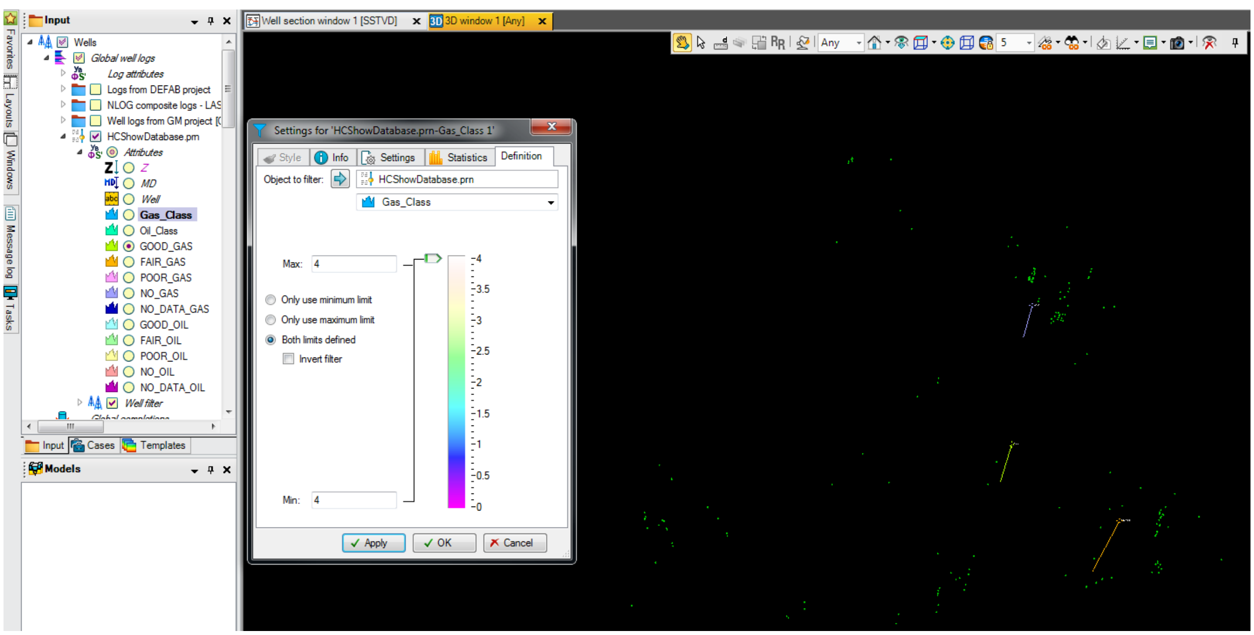


Figure (E)13: Filter data points in the 3D window by right clicking "Gas_Class", selecting "Create 1D filter" and set the min and max values as for instance shown above.

➢ Moreover, it is possible to filter on Group, Formation or even Member. This will show only the data points related to that filter. To do this, right click on “Group” and select “Create filter” (fig. 14). This will create a new folder below the “Well filter” folder. In this folder you can select whatever Group you want to visualize. The same applies for “Formation”.

Note: Play with the different filter possibilities. There are many possibilities in combining all these filters. An example is showing only “GOOD” shows in a certain “Group”, with next to it the “Formation” name (fig. 15)

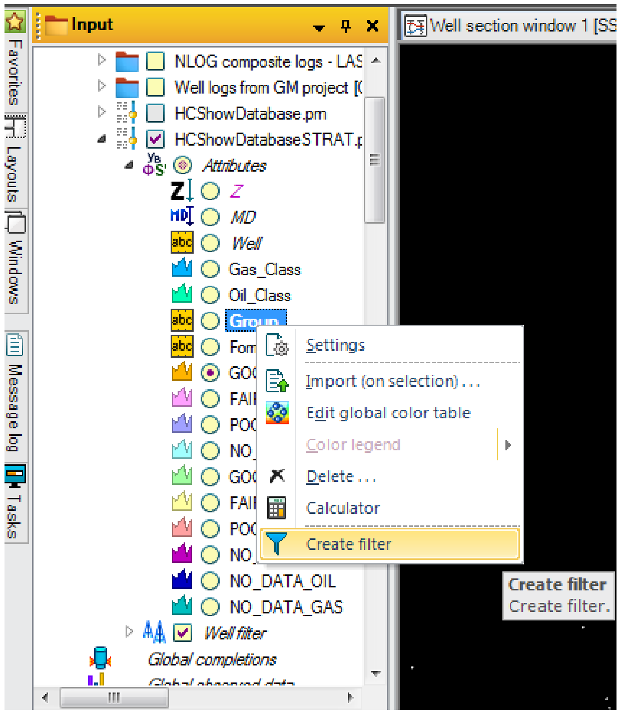


Figure (E)14: Create a filter per Group or Formation by right clicking the attribute and select “Create filter”

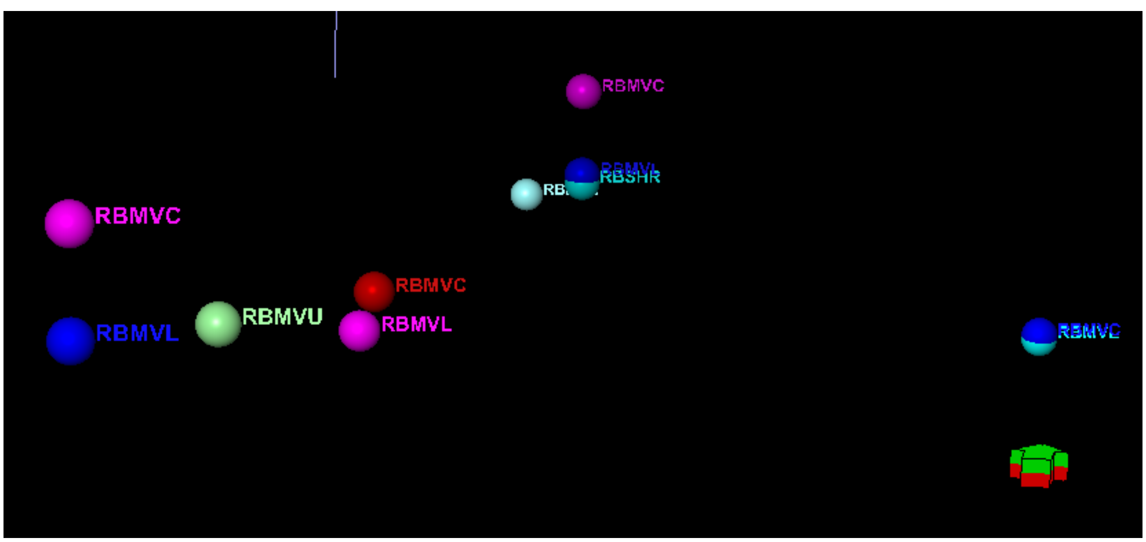


Figure (E)15: Several “GOOD” shows from the RB (“Lower Germanic Trias”) Group. Next to the points the different Formation and Member codes are indicated.

In the following part the visualisation in the “well section window” is explained:

- Open a “well section window” and create a new section and template or if available use previous settings of the project. Click on “template settings” indicated with this symbol in the well section taskbar:

- A new window will pop- up. Add a new track by clicking on the “new object” button  in the left taskbar followed by selecting “Track”. The new track is now added to your vertical tracks. It is also recommended to add at least add one index track (MD).

- Right click on your newly created track and select “Points Attribute”. The settings shown in figure 14 will appear in your window. Set “Type” to “Point well data” and “Template” to “General” (see Fig. 16). Select “Gas_Class” and click “Apply”. Now go on to the next tab.

  Note: If “Gas_Class” isn”t on the top of the list select it and click on the upward pointing blue arrow on the left until it reaches the top of the list and press “Apply” (see red box in fig. 16).
- In the “Limits” tab check both boxes min and max value. Set min as 1 and max as 6 and click “Apply”. Now go on to the next tab.

  Note: The min and max values have been set to 1 and 6 in order to show the symbols of the HC shows on the vertical lines in the track (fig. 18), which makes the classifications more easily identifiable. First vertical line is 1, second is 2 etc.
- In the “Style” tab check the box “points” and select further settings as shown in Figure 17. The colour green is recommended for Gas. When every option is set select “Apply”.

  Note: every user can of course decide to create their own colours and symbols.

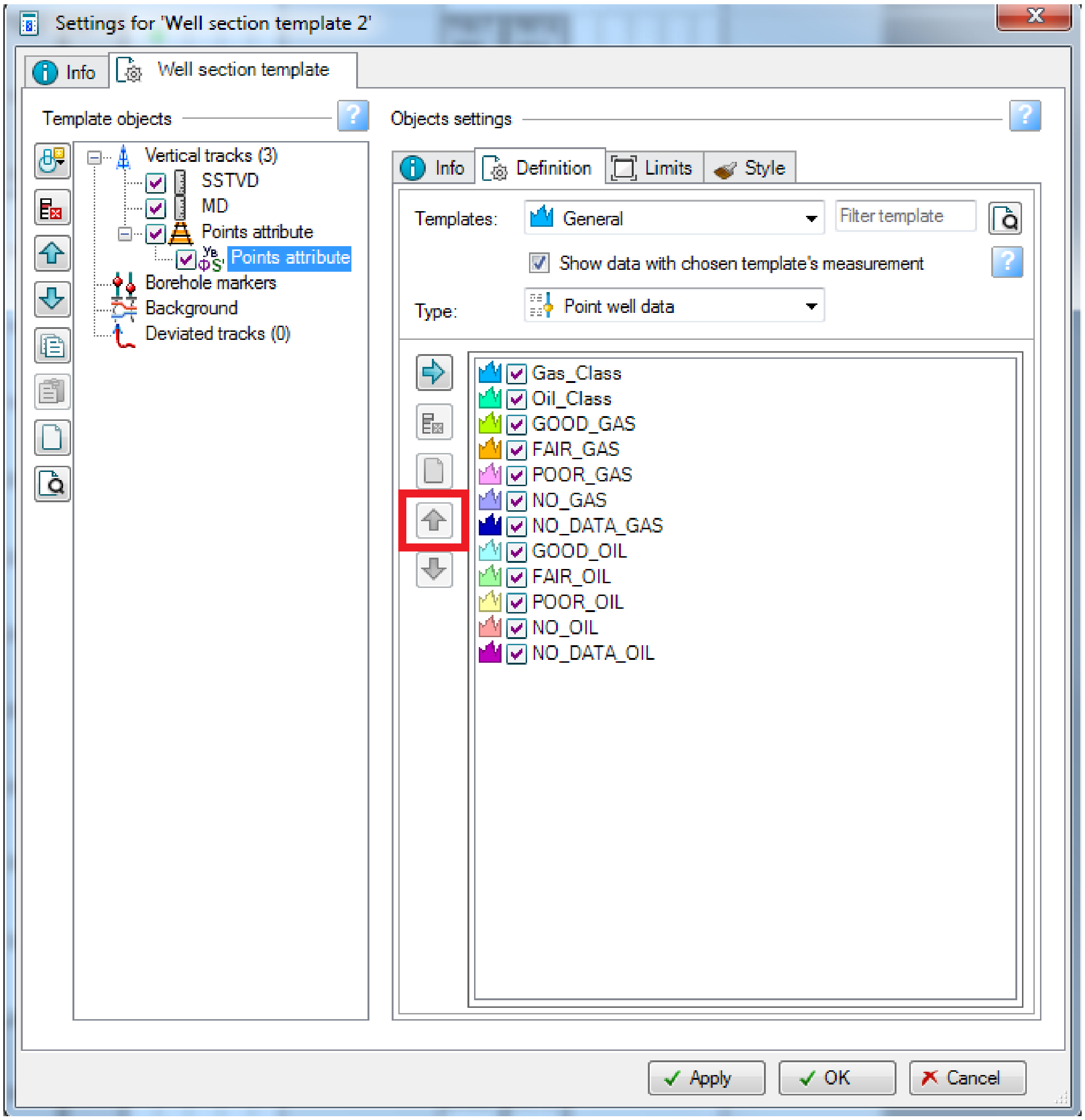


Figure (E)16: Settings for "Well section template" window. "Points attribute" is selected below the "Track". "General" is the selected template and "Point well data" as type. The red box indicates the arrow for selecting one of the templates in the list to the right.

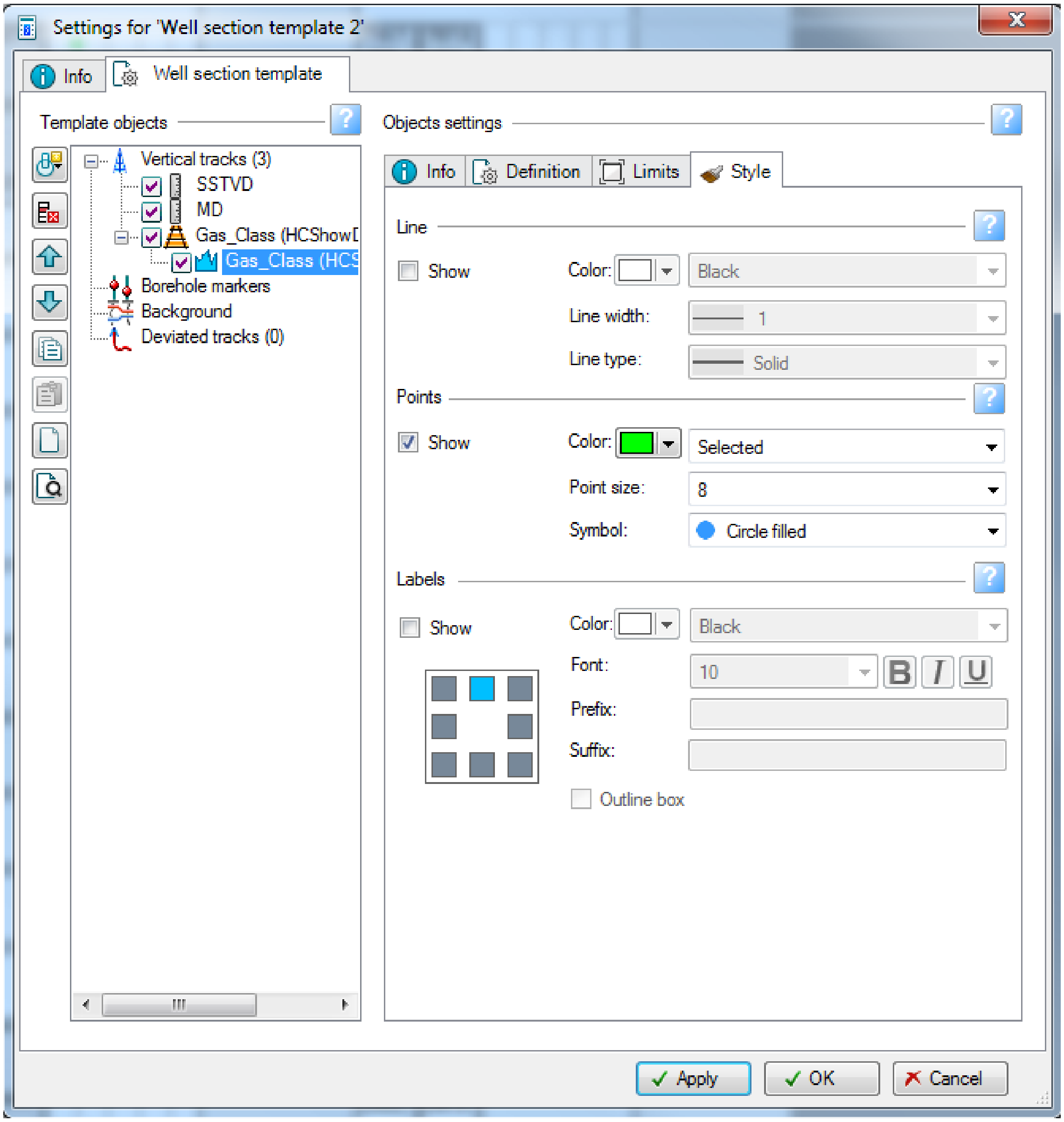


Figure (E)17: Style tab for "Gas_Class". Apply all these settings to your project. Do the same for Oil_Class, but select red as symbol colour.

- Do the last steps again for Oil by selecting "Oil_Class" and use red as symbol colour. At the end press "OK".

  Note: It is also possible to use the attributes as "GOOD_GAS" and "GOOD_OIL" etc. This gives you the possibility to distinguish not only in colour but also in symbols between classifications. This is totally up to the logic of the user and his needs.

- In order to visualize different wells in the "well section window" check the boxes for the well names in the left taskbar (same as global well logs taskbar used in fig. 9).
  After going through all the steps as explained the result should look similar to figure 16.

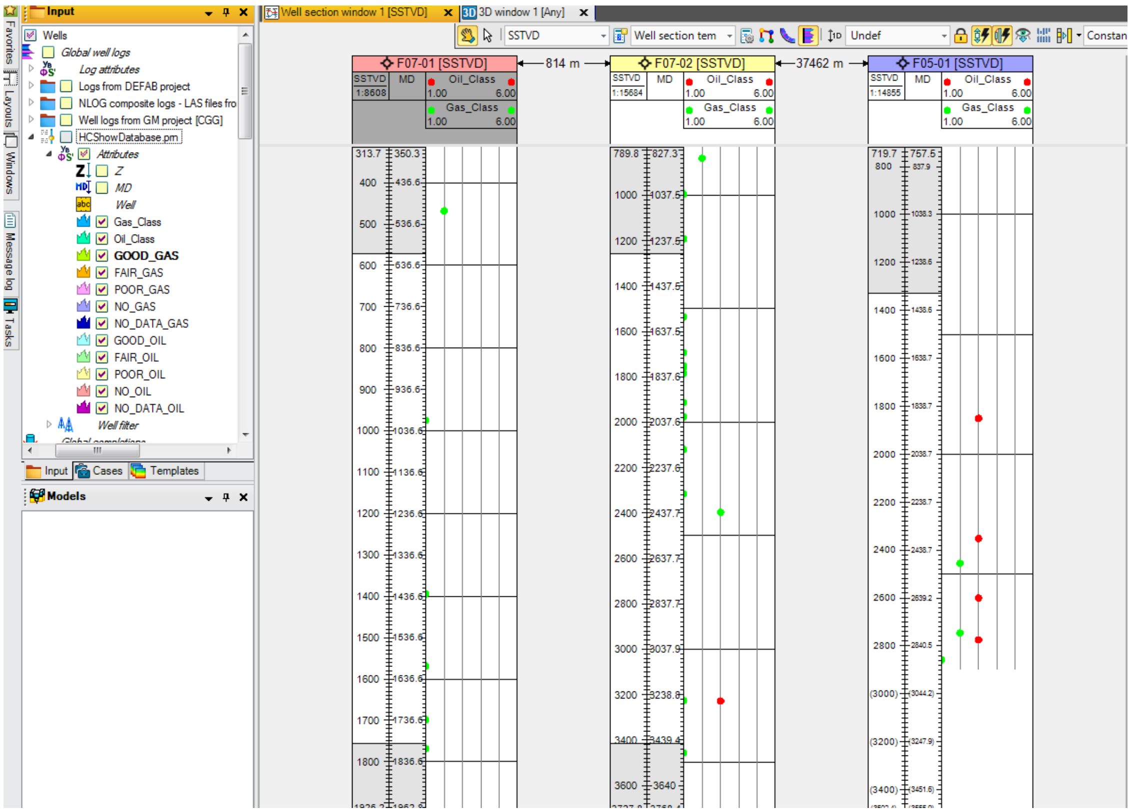


Figure (E)18: Well section window showing hydrocarbon shows for 3 different wells. Green circles represent Gas and red circles represent Oil. The vertical lines in the Gas_-and Oil_class track represent the classification of the hydrocarbon shows. First line is 1 (NO Data), 2 (NO Show), etc.

- It is also possible to set the "Oil_-and Gas_Class" vertical track as overlay for other petrophysical logs (Gamma Ray, Neutron-Density, etc.). This can be very useful for cross-checking the different trends of other petrophysical logs linked to the HC shows.
  You can do this by selecting the "Gas_Class" in the well section window settings. Use the blue arrows, indicated with the red box in figure 19, to put it under the preferred track.
  The result should look similar to figure 20.

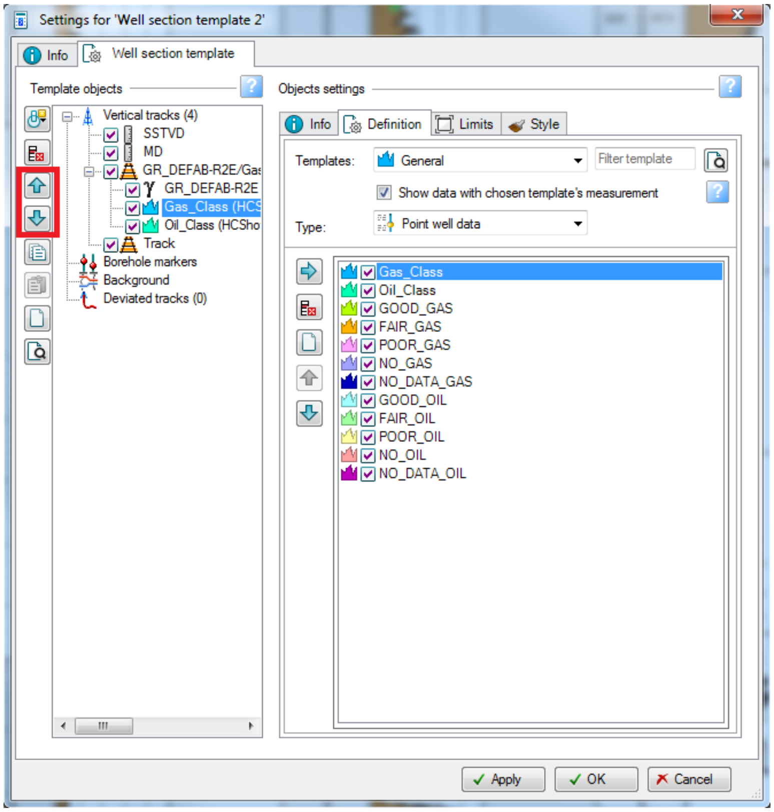


Figure (E)19: Settings for "Well section template" window. Use the blue arrows indicated with the red box to put the "Gas_-and Oil_Class" below other tracks. This with the purpose of using the overlay function in the "Well section window".

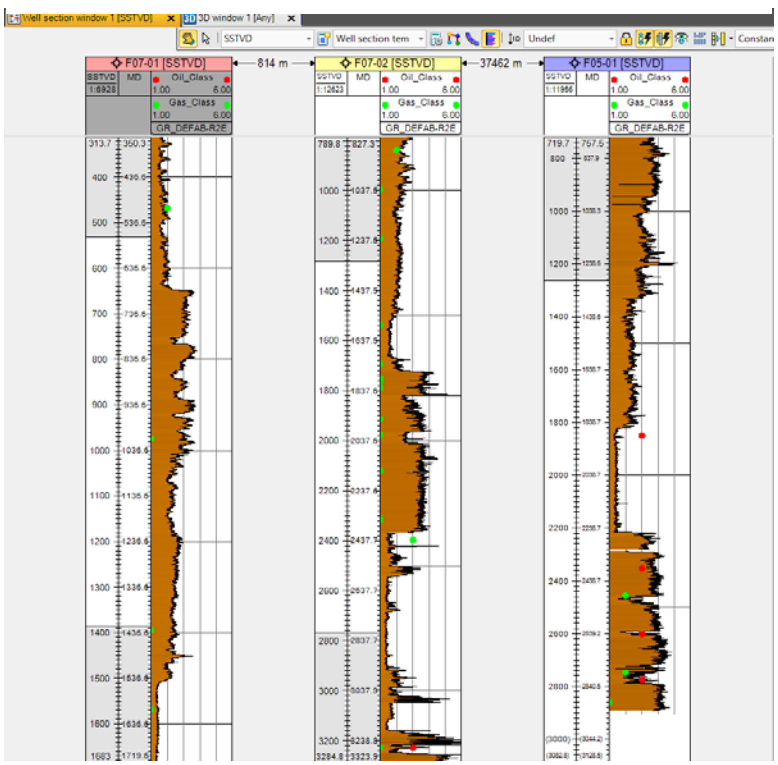


Figure (E)20: "Well section window" showing an overlay format of different logs. In this case the gamma ray log with the "Gas_-and Oil_Class" as overlay.

The following paragraph explains the visualisation of the shows in a seismic line:

- In order to visualize the HC show data on seismic sections or lines, start with opening a "seismic interpretation window". Select the seismic line, which crosses the well you want to visualize, and select the well. Finally, check the class you want to see to obtain a visualisation as shown in figure 21.
  Use the "Well filter" tab to choose only the well that you want to look at. This for the purpose of only showing the data points of this well.

  Note: you can also use the Group and Formation filters you created before in the Seismic interpretation window. However, it is not possible to use the 1D filters in the Seismic interpreation window.

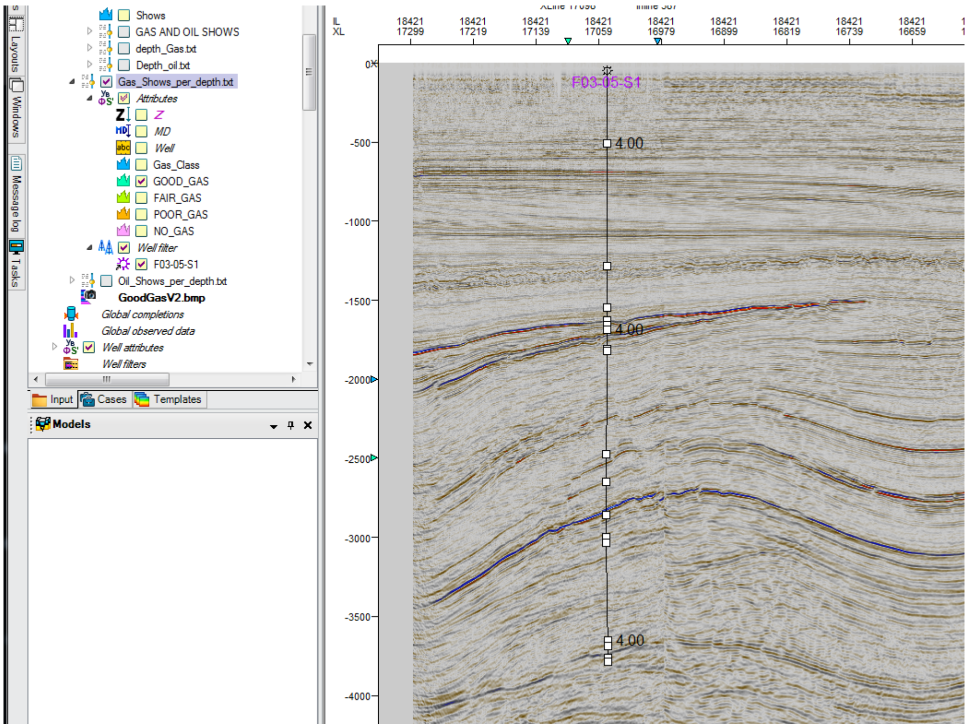


Figure (E)21: Seismic interpretation window showing a seismic line crossing a certain well. The squares indicate all data points, along the well trajectory, and the number next to the squares indicate all "GOOD" gas shows (old version of the classification numbering).

Appendix F: VBA code as basis for the Petrel visualization. Short section (A-G) descriptions on page 96

```
' ***************************************************************************
' * Author    :   Youri Kickken                                            *
' * Company   :   Energie Beheer Nederland, EBN                            *
' * Date      :   August 2016                                              *
' * Subject   :   Expansion Hydrocarbon Show Database to Petrel E&P Software *
' * Version   :   2                                                        *
' ***************************************************************************
' ***************************************************************************
```

A

```
Option Explicit

Sub RowCount()
    Dim Oldstatusbar As Boolean
    Dim DOF As Integer, Counter As Integer
    Dim CurrentMin As Long, StartRow As Long, StartColumn As Long
    Dim OutputColumn As Long, OutputRow As Long, InputValue As Long
    Dim Borehole As String, Start_Row As String, End_Row As String, Output As String, FolderPath As String
    Dim CurrentName As String
    Dim rng As RANGE, Cell As RANGE, brh As RANGE, Undef1 As RANGE, Undef2 As RANGE
    Dim r1 As RANGE, r2 As RANGE, r3 As RANGE, r4 As RANGE, r5 As RANGE, r6 As RANGE, r7 As RANGE, r8 As RANGE, r9 As RANGE
    Dim r10 As RANGE, r11 As RANGE, r12 As RANGE, r13 As RANGE
    Dim wbMain As Workbook, wbWellsRowCount As Workbook
    Dim wsLog As Worksheet, wsSheet1 As Worksheet, wsSheet2 As Worksheet
    Dim HCdatabase2 As Variant

    Oldstatusbar = Application.DisplayStatusBar
```

```
 '------------------------------------------------>>> Data Definition Section <<<----------------------------------------
```

B

```
    Set wbMain = Workbooks("HCdatabase2.xlsm")
    Set wsLog = wbMain.Sheets("@hydrocarbon_shows_vwgLogDataSh")
    FolderPath = ThisWorkbook.Path

    DOF = 1
    Counter = 1

    wsLog.Select
    StartColumn = 2
    StartRow = 1
    wsLog.Cells(StartRow + DOF, StartColumn).End(xlDown).Select

    Set rng = wsLog.RANGE(wsLog.Cells(StartRow + DOF, StartColumn), wsLog.Cells(StartRow + DOF, StartColumn).End(xlDown))
    CurrentName = wsLog.Cells(StartRow + DOF, StartColumn).Value
    CurrentMin = Cells(StartRow + DOF, StartColumn).Row


    Set wbWellsRowCount = Workbooks.Add
    wbWellsRowCount.SaveAs FolderPath & "\wbWellsRowCount.xls"


    Set wsSheet1 = wbWellsRowCount.Sheets("Sheet1")
    wsSheet1.Select
    OutputColumn = 1
    OutputRow = DOF + 1
    wsSheet1.Cells(OutputRow, OutputColumn).Value = CurrentName
    wsSheet1.Cells(OutputRow, OutputColumn + 1).Value = CurrentMin

    wsSheet1.Cells(1, 1).Name = "Borehole"
    wsSheet1.Cells(1, 2).Name = "Start_Row"
    wsSheet1.Cells(1, 3).Name = "End_Row"
    wsSheet1.Cells(1, 4).Name = "Output"

    ActiveWorkbook.Sheets.Add After:=Worksheets(Worksheets.Count)
    Set wsSheet2 = wbWellsRowCount.Sheets("Sheet2")
```

```
'---------------->>> Copy section of important columns (data) from HC Show Database to Sheet2 new workbook  <<<-------------
```

C

```
    Set r1 = Workbooks("HCdatabase2.xlsm").Worksheets("@hydrocarbon_shows_vwgLogDataSh").RANGE("D:D")
    Set r2 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").RANGE("A:A")
    Set r3 = Workbooks("HCdatabase2.xlsm").Worksheets("@hydrocarbon_shows_vwgLogDataSh").RANGE("M:M")
    Set r5 = Workbooks("HCdatabase2.xlsm").Worksheets("@hydrocarbon_shows_vwgLogDataSh").RANGE("P:P")
    Set r6 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").RANGE("C:C")
    Set r7 = Workbooks("HCdatabase2.xlsm").Worksheets("@hydrocarbon_shows_vwgLogDataSh").RANGE("AG:AG")
    Set r8 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").RANGE("D:D")
    Set r9 = Workbooks("HCdatabase2.xlsm").Worksheets("@hydrocarbon_shows_vwgLogDataSh").RANGE("AJ:AJ")
    Set r10 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").RANGE("E:E")
    Set r11 = Workbooks("HCdatabase2.xlsm").Worksheets("@hydrocarbon_shows_vwgLogDataSh").RANGE("G:G")
    Set r12 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").RANGE("F:F")
    Set r13 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").RANGE("G:G")

    Application.CutCopyMode = True
    r1.Copy r2
    r3.Copy r4
    r5.Copy
    r6.PasteSpecial Paste:=xlPasteValues
    r7.Copy r8
    r9.Copy
    r10.PasteSpecial Paste:=xlPasteValues
    r11.Copy r12
    r11.Copy r13
    Application.CutCopyMode = False


    Application.ScreenUpdating = False
```

```
---------------->>> Start sorting data in Sheet2 in import format Petrel E&P Software. <<<----------------------------------------
```

D

```
    With wbWellsRowCount.Sheets("Sheet2")
        With .RANGE("A2", .Cells(.Rows.Count, 1).End(xlUp))
            .Offset(.Rows.Count).Value = .Value
            .Offset(.Rows.Count, 1).Value = .Offset(, 3).Value
            .Offset(.Rows.Count, 4).Value = .Offset(, 4).Value
            .Offset(.Rows.Count, 5).Value = .Offset(, 5).Value
            .Offset(.Rows.Count, 6).Value = .Offset(, 6).Value

            .Offset(, 4).ClearContents
            .Offset(, 3).EntireColumn.Delete

            With .Offset(, 1).Resize(2 * .Rows.Count)
                If WorksheetFunction.CountBlank(.Cells) > 0 Then .SpecialCells(XlCellType.xlCellTypeBlanks).EntireRow.Delete
            End With
        End With

        With .RANGE("A2", .Cells(.Rows.Count, 1).End(xlUp)).Resize(, 7)
            .Sort key1:=.Cells(1, 1), order1:=xlAscending, key2:=.Cells(1, 2), order2:=xlAscending, Header:=xlNo, Orientation:=xl
        End With
    End With
```

```
---------------->>> Begin of first calculation loop: Putting Undefined value "-999" in all empty cells. Everything after this li
```

E

```
    Set Undef1 = Workbooks("wbWellsRowCount.xls").Worksheets("Sheet2").UsedRange

    InputValue = -999
    For Each Cell In Undef1
    If IsEmpty(Cell) Then
    Cell.Value = InputValue
    End If
    Next

---------------->>> Begin of second calculation loop: Creating Group abbrevations from formation abbrevrations bij deleting ever

    For Each Cell In r12
    Cell.Value = Left(Cell.Value, 2)
    Next
```

```
'---------------->>> Begin of second calculation loop: Creating Group abbrevations from formation abbrevrations bij deleting ever

    For Each Cell In r12
    Cell.Value = Left(Cell.Value, 2)
    Next

    Columns("A:F").HorizontalAlignment = xlRight
    Columns("A:F").AutoFit
    Columns("E").ColumnWidth = 9
```

E

```
'---------------->>> Begin of third calculation loop: Creating Start_Row and End_Row table in Sheet1 new workbook.  Everything af
    For Each Cell In rng

        If Cell.Value <> CurrentName Then

        wsSheet1.Cells(OutputRow, OutputColumn + 2).Value = Cell.Row - 1
        CurrentName = Cell.Value
        CurrentMin = Cell.Row
        OutputRow = OutputRow + 1
        wsSheet1.Cells(OutputRow, OutputColumn).Value = CurrentName
        wsSheet1.Cells(OutputRow, OutputColumn + 1).Value = CurrentMin

        wsSheet1.Cells(Counter + DOF, "D").Value = Counter
        Counter = Counter + 1
    End If

    Next Cell
    Set Cell = rng.End(xlDown)
    wsSheet1.Cells(OutputRow, OutputColumn + 2).Value = Cell.Row
    wsSheet1.Cells(Counter + DOF, "D").Value = Counter
```

F

```
 '---------------->>> End of calculation loop. Everything after this line is after the calculation is done. <<<------------------
    wbWellsRowCount.Save
    wbWellsRowCount.Worksheets("Sheet2").SaveAs FolderPath & "\HCShowDatabase.prn", FileFormat:=xlTextPrinter
    Workbooks("HCShowDatabase.prn").Close True
    wbMain.Activate
    RANGE("A1").Select
    ActiveWindow.ScrollRow = RANGE("A1").Row

    Application.ScreenUpdating = True
    Application.DisplayStatusBar = Oldstatusbar
End Sub
```

G

Code section (A-G) explanation:

A : Section covering the different variables used in the code. These variables are set to a particular numeric or non-numeric data type.

B: Data definition section. Coding every section of the database that is used.

C: Copy and pasting of used data (classifications and show depths) in new workbook.

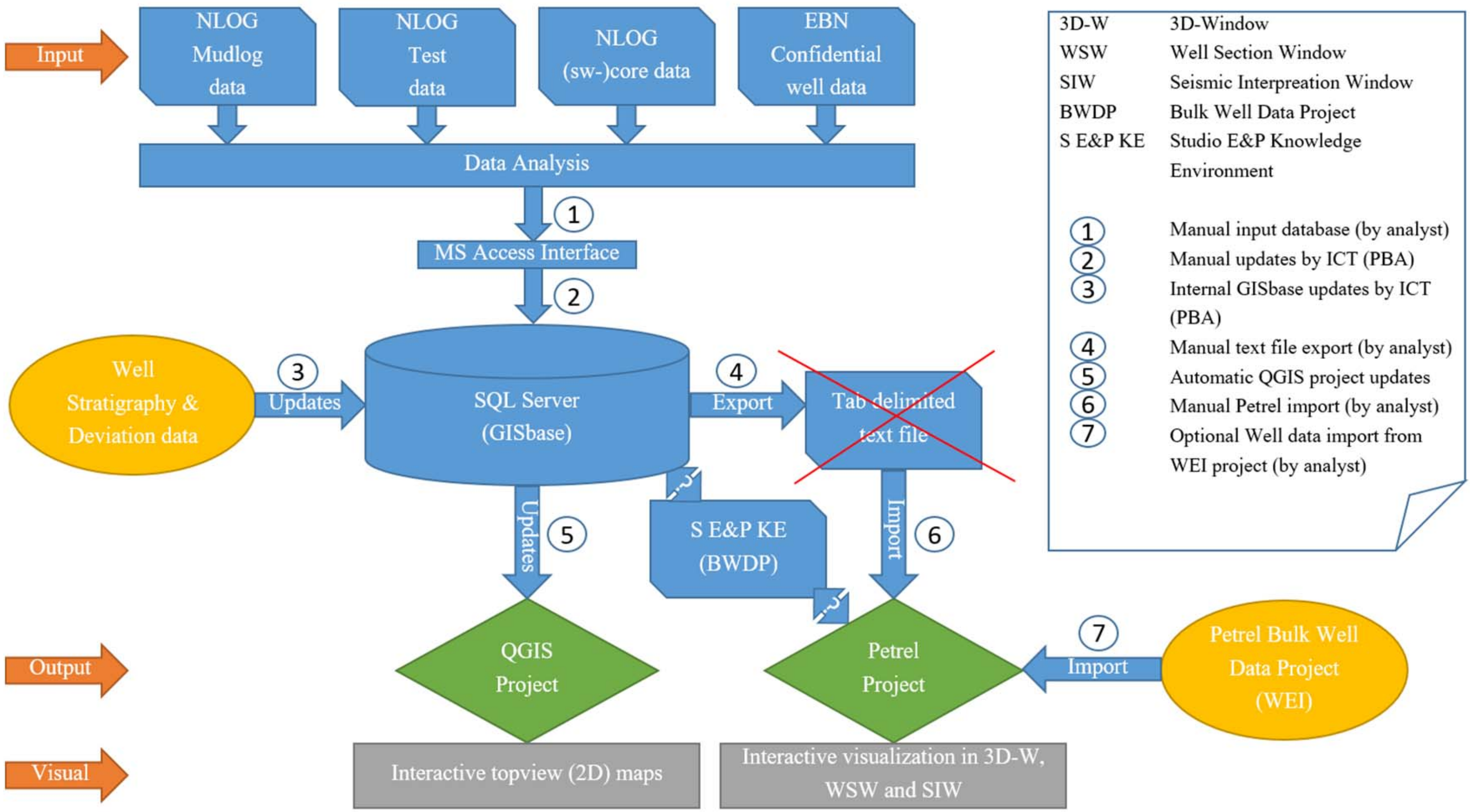
D: Sorting de data copied data in the correct format for Petrel.

E: Deleting empty rows and setting '-999' as undefined value. Moreover, in this section column alignment and width is set for the Petrel format.

F: QC sheet. Listing all wells and corresponding rows (start and end row) in a new excel sheet. Easy for controlling the data and searching for different wells in the database.

G: Saving new Excel file and exporting as space delimited text file (.prn). This text file is used in the actual Petrel importing step.

Appendix G: Studio E&P Knowledge Environment – Workflow



Appendix G: The 'EBN HC Show database Workflow model'. This model used as recommendation includes all components and steps of the database workflow. All steps are provided with short descriptions according to the numbering.