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Reservoir modelling of Lower Cretaceous West Netherland Basin aquifers for geothermal energy production

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Introduction

This project aims to predict Lower Cretaceous reservoir architecture and reservoir properties of the graben blocks in the West Netherlands Basin for geothermal energy.
Horst and pop-up structures in the study area were targets of oil and gas production in the last 60 years. For the recent upcoming geothermal energy production the focus lays on the deeper and warmer graben structures in between the oil and gas fields. Reservoir property predictions like thickness and permeability are currently based on interpolations between oil and gas well measurements on horst and pop-up structures. In order to successfully produce from the current 45 geothermal licences in the province of Zuid-Holland, detailed reservoir models and associated uncertainty maps of the Lower Cretaceous sandstones are required.

Goals of the project are to model the reservoir architecture in order to simulate production and determine optimal well placement of geothermal doublets and predict possible doublet interference. In addition a workflow for geothermal energy exploration will be described. A quality control on the large amount of available subsurface data from 60 years oil and gas production in the region will be carried out by re-evaluating previous interpretations and collecting relevant data in a geothermal energy database.
Reservoir architecture of these sandstones will be studied by re-evaluating the existing lithostratigraphically based well log correlations, in combination with seismic interpretation and core studies. A palinspastic reconstruction is carried out on a cross section to indicate the paleogeography and the complex reservoir architecture.

Lower Cretaceous reservoirs in the West Netherlands Basin (WNB) can be divided in syn-rift continental deposits of the Schieland Group and post-rift (marginal) marine deposits within the Rijnland Group. This article focusses on the fluvial Schieland Group reservoirs.

Palinspastic reconstruction

In the southwest-northeast seismic section below (Figure 1) the structures of the WNB can be seen. Two Cretaceous horizons are interpreted based on Jeremiah et al. (2010).

- Turquoise: Base Rijnland Group
- Orange: Base Schieland Group

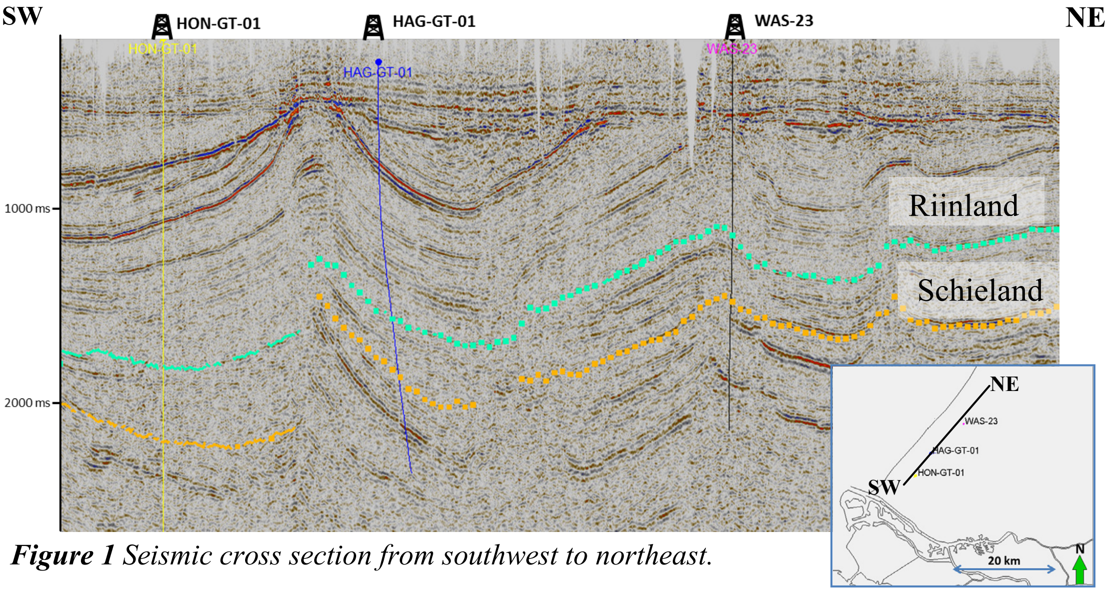


Figure 1 *Seismic cross section from southwest to northeast.*

A palinspastic reconstruction is carried out on the seismic cross section in Figure 1 by flattening the Base Rijnland horizon interpretation. The Rijnland Group was deposited in the post-rift deposition phase of the WNB. The base of the Rijnland Group represents the transgressional phase in this part of the basin where (marginal) marine deposits overlay the continental sediments of the Schieland Group.
In the reconstruction (Figure 2), the half graben structures also described by Den Hartog Jager (1996) are visible. In the cross section below, a schematic representation is sketched of the resulting occurrence of channel belts in the Schieland Group.
This model shows the complication arising from interpolation of properties and facies between oil and gas wells in the Schieland Group. Sediment deposition in each half graben might be different and interpolation of for example sandstone thickness and properties through different fault blocks is therefore invalid.

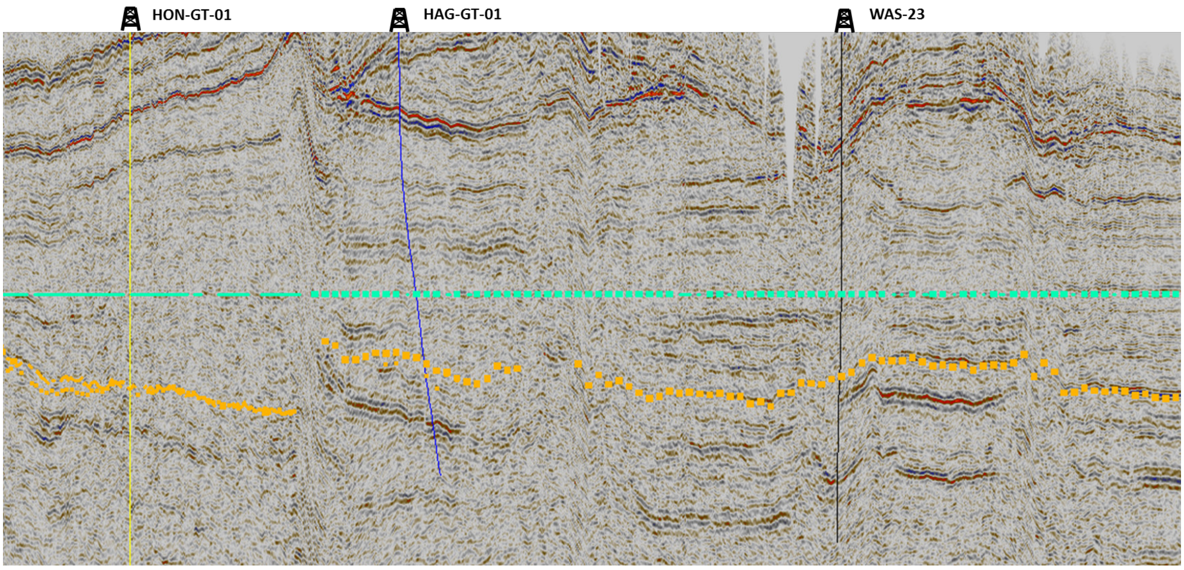


Figure 2 *Palinspastic reconstruction by flattening the base Rijnland Group horizon. Half graben structures become visible that were active during deposition of the syn-rift Schieland Group.*

The model described in Figure 2 could be an explanation for the difference in stacking patterns of fluvial sandstones that are encountered in different wells as is shown in the GR-logs of HAG-GT-01 and WAS-23 (Figure 3). Large variations in thickness of the Delft Sandstone are encountered in wells throughout the WNB. The subsidence and tectonic activity was different in each block and therefore also sedimentation was different per block. This could also have implications for facies distribution in the half grabens.

A future plan in this project is to reconstruct the post-rift half graben position in 3D with the 3D Move software in order to improve well log correlations of the Schieland Group per basin and identify sequence stratigraphic patterns, (DeVault & Jeremiah, 2002). The purpose is to predict reservoir architecture and connectivity of the fluvial sandstone bodies, especially in reservoir blocks without wells and logs.

Core studies and sequence stratigraphic well log interpretations will be carried out to study stacking patterns of the sandstones and reservoir architecture. From sedimentary logs channel belt dimensions, architecture and depositional environment could be determined as in Bridge & Tye (2000), who derived paleo channel height from sedimentary logs. In combination with a suitable analogue, 3D distribution and dimensions of the channel belts can be predicted.

Delft Sandstone Member

One of the sandstone reservoirs in the syn-rift Schieland Group is the Delft Sandstone Member. This sandstone presumably forms the reservoir of five currently producing geothermal doublets in the West Netherlands Basin and is a target of several future geothermal projects. Well log correlation, however, is not straight forward taking into account the model described in Figure 2. This complication is explained here by showing interpretations of GR logs of Delft Sandstone in several wells in Figure 3 The varying distribution and thickness of the different lithological units makes well log correlation and property predictions between different half-graben blocks rather challenging. This becomes clear from the large variation in thickness and N/G of the Delft Sandstone interpretations after Van Adrichem Boogaert & Kouwe, (1993).

There is a considerable difference in thickness and N/G even over small distances as is the case between HAG-02 and HAG-GT-02 (3km). Also the overlying Rodenrijs Member has a strong variation in thickness. For these reasons DeVault and Jeremiah (2002) did not recognize the Delft Sandstone as a separate stratigraphic unit because thick, stacked channel complexes occur throughout the formation but are not necessarily laterally connected.

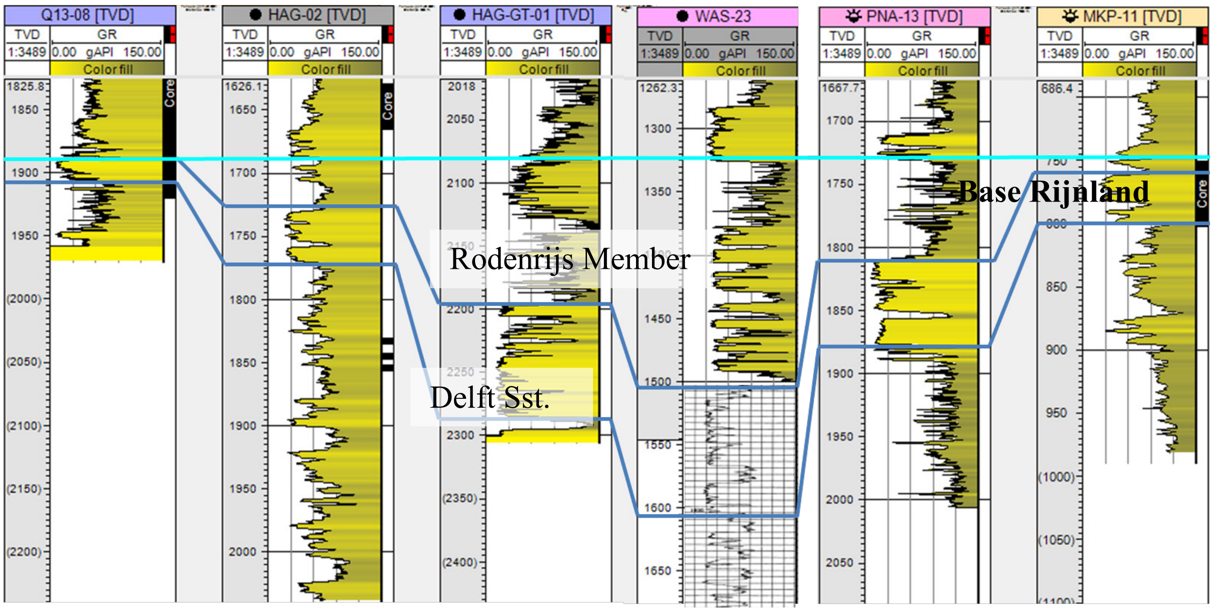
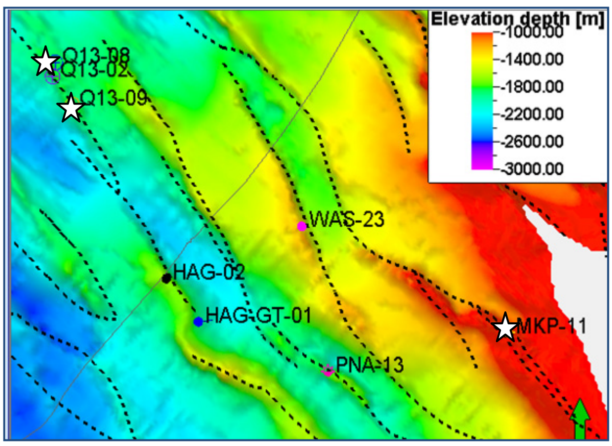


Figure 3. *Well log correlation panel of the top of the Schieland Group. Locations of the wells are shown on the map to the right. Wells indicated by a star have core measurements of permeability and porosity used in Figure 4. Depth of the base Rijnland Group by TNO from Nlog is indicated in the map. Dotted black lines indicate major faults.*



Variations in thickness are not the only complication, but also permeability and porosity prediction from the sparse core measurements is not straight forward. Cores from the Delft Sandstone were taken only in a few oil & gas fields in combination with GR-logs. Porosity and permeability measurements form these cores are presented in Figure 4. core measurements have different porosity-permeability trends at different locations in the basin.

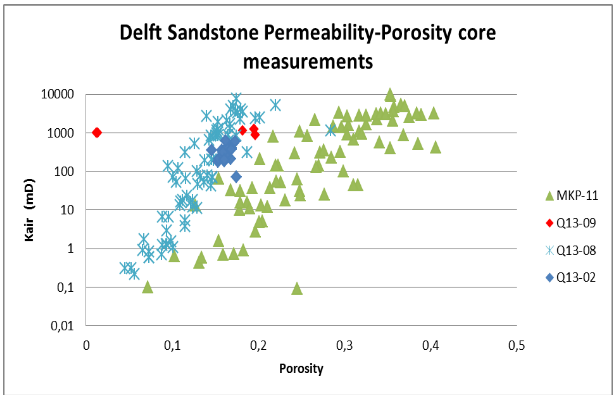


Figure 4 *Core plug porosity and permeability measurements in the Delft Sst. Locations in Figure 3*

Conclusions

The preliminary results in this project show that reservoir architecture and properties of Lower Cretaceous sandstone reservoirs in the WNB are not fully understood. Available well log and core data focus on the pop-up and horst structures. Due to the syn-rift origin of the sandstones, facies distribution and reservoir properties might vary per fault block.

Thick vertically stacked sandstones (like the Delft Sandstone) occur in most half graben structures in the WNB, however, there is a limit to their lateral continuity. Facies distribution and reservoir architecture are likely to be dependent on the tectonic activity of each fault block as can be explained by the palinspastic reconstruction in Figure 2. The extension of these deposits and hence the connectivity of channel belts is not clear, which is a major issue for geothermal energy development in the Schieland Group reservoirs of the WNB. Measurements of properties in horst structures might not be representative for similar fluvial sandstones in a different fault block (Figure 4).

This project is a quality control on the data by carrying out a re-evaluation of well log correlations, core studies, seismic interpretation and a palinspastic reconstruction. With a detailed sequence stratigraphic interpretation and core studies, reservoir properties, architecture and their uncertainty can be predicted in the grabens of the West Netherlands Basin.

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