Introduction

After the Permian Rotliegend play, the Triassic Main Bundsandstein is the second most important gas play in the Netherlands. In the southern North Sea the Triassic play has been proven with over 70 fields, but it remains underexplored in the northern Dutch offshore. In the study area (fig. 1), only 17 wells have been drilled with the Triassic Main Bundsandstein as a primary or secondary target. This is a result of the conviction that the aeolian and fluvial ly sourced reservoir rocks of the Lower Volpriehausen and Lower Detfurth Sandstone Members with their southern Variscan origin decrease in both thickness and quality towards the North. However, recent studies indicate the presence of local depocentres and the potential for northerly sourced sediments in the study area (Kortekaas et al., 2018 and Olivarius et al., 2017). Another issue which led to possible oversight of the hydrocarbon potential in the Triassic sediments is the presence of Zechstein halite inhibiting vertical migration from the Carboniferous source rocks. However, the presence of salt windows has been proved to enable charge through the Zechstein just south of the study area and Tertiary dykes, which pierce the Zechstein salt, have charged Triassic fields across the border in the United Kingdom and are present in the southwest of the study area (Doornenbal et al., 2019).

![Figure 1](image_url)  
**Figure 1** Paleogeographical map of the Southern Permian Basin during early Triassic times, showing sediment influx. Study area is outlined in blue. (from Kortekaas et al. 2018, after Bachmann et al. 2010)

Further de-risking of the Triassic prospectivity in the northern Dutch offshore is essential to raise attractiveness. As the reservoirs in the study area are relatively thin, prospective volumes are generally smaller than in the southern Triassic fields. Future discoveries are unlikely to be economical for stand-alone development, hence prospective volumes need to be evaluated, risked and drilled in a concerted effort at portfolio level. Inter-dependent and therefore shared risks between prospects may offer the opportunity to unlock significant parts of a prospective portfolio by drilling those prospects which provide the highest value of information (VOI). A VOI analysis is achieved through a dedicated Play Based Exploration approach. The large amount and the quality of the (seismic) data in the Dutch offshore make the study area very well suited for this method. Based on many studies that have been performed on the different play elements in the northern Dutch offshore the creation of high quality risk maps has been achieved, which are presented here.
Methods

Play Based Exploration (PBE) is an exploration method which allows to risk prospects within a play in a systematic and spatial manner. Plays (Petroleum Systems with a shared geological character) are analysed on their specific risks and characteristics resulting in the compilation of Common Risk Segment (CRS) maps for all different play elements. Stacking of these CRS maps results in an overall play risk map which shows the areas in which prospects will have a relatively high geological chance of success. The risk of the polygons on the map should approximate the average Probability of Success (POS) of prospects in this polygon. The polygons in the CRS maps are then risked using a split risking method, i.e. the risk is divided in a shared and a non-shared risk. This is an essential step in the play analysis workflow to allow for dependencies between prospects with shared geological circumstances to be determined and quantified.

Four CRS maps for the Triassic play in the northern Dutch offshore are constructed for the following play elements: (1) Reservoir presence, (2) Reservoir effectiveness, (3) Seal and (4) Charge. These maps provide a POS for their specific play elements and are multiplied to make an overall risk map of the Triassic play.

Reservoir Presence & Effectiveness

The Lower Volpriehausen Sandstone- (RBVML) and the Lower Detfurth Sandstone Members (RBMDL) form the main reservoir of the Triassic play. The RBVML is chosen to build the reservoir risk maps since it is thicker than the RBMDL and it is the primary Triassic target. The reservoir presence map is based mostly on 3D seismic data and well data. Where RBVML is present, the overall POS for reservoir presence is set to 100% since it is based on high confidence data. Some smaller local basins in the west of the study area are identified on seismic data but are not yet proven by wells and consequently have a lower POS (64%).

The reservoir effectiveness CRS map is based on nett to gross ratios measured in wells and gridded using the convergent interpolation method (Kortekaas et al., 2018). The N/G ratio is an indication of the sand/clay alteration of the reservoir and is taken as a proxy for reservoir effectiveness. Porosity and permeability data are not used in this map as there is only sparse core data available and porosity or permeability maps would have a low credibility.

Figure 2 (A.) N/G map of RBVML, (B.) Reservoir Presence CRS map, (C.) Reservoir Effectiveness CRS map. Both reservoir presence and effectiveness have map A. as input.

Seal

The primary seal of the Triassic play in the Dutch offshore consists of the Main Röt Evaporite and/or the Solling Claystone formation. Cretaceous claystones (Vlieland Formation) are also proven to act as a seal where they truncate the RBVML unconformably. In this study, only the Röt and Solling seals are used as the Cretaceous clays are found throughout the study area. Input data used to compile the CRS map is based on a combination of 2D/3D seismic data and well data (e.g. fig. 3). The seal POS of areas where no Röt and Solling are present is therefore relatively high (~30%) to incorporate possible Cretaceous sealing. In areas where both Röt salt and a thick Solling Claystone are present, the seal POS is set at 100% as the seal is proven. In some areas where well data is lacking, albeit the presence
of Röt and Solling intervals can be interpreted and mapped with sufficient confidence using seismic data, the POS is set at 54% as the sealing capacity is unknown. Areas where thin Solling and anhydrite Röt are present the POS is set at 70%.

**Figure 3** (left) Main Röt Evaporite presence map based on seismics and well data. (right) resulting CRS map based on the Main Röt Evaporite presence and Solling Claystone presence maps.

**Charge**

The Charge CRS map is constructed using both a source rock and a vertical migration map. The potential source rocks of the Triassic play are the Westphalian, Epen and Scremerston coals. The Westphalian source rock presence, maturity and timing are incorporated using a Cenozoic expulsion map with buffers to account for lateral migration. The combination of this map with Epen and Scremerston source rock presence and maturity maps results in a final source rock CRS map (fig. 4).

The largest risk causing lack of migration in the Triassic play is the presence of the Zechstein salt in between the reservoir and the source rocks which can inhibit vertical migration. A vertical migration risk map is therefore constructed based on a Zechstein thickness map. Where the Zechstein is thin (<200 ms in TWT) and salt windows occur, vertical migration of hydrocarbons is possible. This is proven in the F blocks just south of the study area where fields are present above thin Zechstein. Also a vertical Tertiary dyke identified in the southwestern corner of the study area could charge the Triassic reservoir. The vertical migration and the source rock CRS maps are stacked into a final charge CRS map (fig. 4).

**Figure 4** (left) Final source rock CRS map (middle) Vertical migration CRS map (right) Final stacked Charge CRS map.

**Results**

The four CRS maps are stacked by multiplication to produce a final Composite CRS (CCRS) map (fig. 5 left). This map allows for the identification of sweet spots of the Triassic play in the study area. As can be seen in fig. 5, the overall POS of the Triassic play in the study area is relatively low in most areas. As these areas share risks, prospects in the same CRS polygons can be de-risked when a prospect is drilled with a successful outcome.
A weakest element map is derived from the CCRS map (fig. 5 right). This map shows which of the CRS maps has the largest negative impact on the overall POS. Logically, where no reservoir is present, the reservoir presence and effectiveness maps are the weakest link. More interesting is that where reservoir is present, Charge is usually the most limiting factor, except for where the seal effectiveness is unknown. These polygons could therefore be de-risked effectively if efficient seal would be found inside these polygons. Prospects in these polygons would therefore have a relatively high Value Of Information.

![Figure 5 (left) Final CCRS map of the Triassic play in the northern Dutch offshore. Prospects are outlined in black. (right) Weakest element map.](image)

**Conclusions**

CRS maps of four different play elements were made for the Triassic Play in the northern Dutch offshore based on geological knowledge and post drill well analyses. The Composite CRS map created from these CRS maps shows spatial variability of the overall POS of the play. This provides insight into which areas are most promising (based on current knowledge). It also enables future VOI analyses on prospects, showing which prospects to drill to de-risk the largest dependent volumes. This is an essential step to open up the underexplored Triassic prospectivity in the northern Dutch offshore.

**References**


