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**REMAINING EXPLORATION POTENTIAL of a 'MATURE' OIL PROVINCE - The  
DUTCH CENTRAL GRABEN**

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Introduction

The Dutch Central Graben is located on the shelf, offshore the Netherlands (Figure 1) and has an area of approximately 25,000 km<sup>2</sup>. Its opening was triggered by two events; the cooling of thinned crust below the Central North Sea thermal dome and a general transtensional tectonic regime during Callovian-Kimmeridgian time (van Hulten & van Buggenum, 2008; Herngreen et al., 2003). A rapid subsidence with high sediment infill rates developed due to the rifting, and persisted until the Early Cretaceous. Four inversion phases of different magnitudes took place during the Late Cretaceous and Early Tertiary, eroding locally up to 700m of sediments (Jager, 2003).

The complex Jurassic play is very variable throughout the Central North Sea Graben System. The Upper Jurassic of the relatively mature UK and Norwegian sector of the Graben comprises 28 fields in total, 24 in the UK and 4 in the Norwegian sector (Fraser et al., 2002). One oil field in the Dutch sector (F03-FB) is currently under production.

In order to evaluate the remaining exploration potential of the Dutch central graben, the play concept proposed by TNO (Abbink et al., 2006; Figure 2) has been reviewed and refined throughout two previous studies.

Source rock(s)

The most important source rock in the Dutch Central Graben is the Posidonia shale of Lower Jurassic age (Cornford, 1998). The total organic carbon (TOC) in the North Sea area varies between 5% and 15%, with 11.4% in average (Littke et al. 1997). Values measured in samples of well F17-04 comprise ~ 8% TOC, a Hydrogen Index (HI) of ~ 600 mg/l and an Oxygen Index (OI) of ~ 10 mg/l, identifying it as a type II kerogen, structureless organic matter of marine algal origin.

The Kimmeridge Clay Formation may only have hydrocarbon potential in the most northern part of the Dutch Central Graben due to insufficient burial depth in the southern part.

A potential, deeper source rock has been identified in the late Triassic Sleen Formation. It is present in most parts of the Central Graben and is a fair oil-source rock (Clark-Lowes et al., 1987).

Reservoir rocks

The Jurassic of the Dutch Central Graben consists of clastic rocks and therefore comprises mostly shales, sand- and siltstones alternating locally with coal layers. Previous studies showed reservoir rock porosities between 10% and 25%. Three main potential reservoirs have been identified and mapped:

- The Lower Graben Formation, (Middle - Late Callovian) present across the whole study area,
- The Middle Graben Sand Member (Early - Middle Oxfordian), only locally present, and
- The Upper Graben Formation (Middle - Late Oxfordian), present in the northern section of the study area.

Additional potential reservoir rocks (E.g. Scruff Greensand, Puzzle Hole Formation) have been mapped and evaluated.

### Seals

The study area comprises several seals for potential reservoirs of Jurassic age. The risk of no seal is low for each reservoir formation:

- Lower Graben reservoirs overlain by thick Middle Graben shale.
- Upper Graben, Puzzle Hole and Friese Front Formations are overlain by Scruff and/or Rijnland shale.
- Tertiary deposits, locally Chalk, act as ultimate seals.

### The study

The presented study closes the gap between two previously conducted studies by PanTerra Geoconsultants focusing on the 'central' section of the Central Graben (license blocks F05, F06, F08, F09, F11 and F12). One proprietary (license blocks F14, F17, F18, L01 and L02) and one non-proprietary (license blocks B18, F02, F03 and F06) study were carried out, focusing on the southern, respectively the northern sections of the Dutch Central Graben. The area is covered by three major 3D seismic surveys covering the eastern part of the Central Graben and numerous 2D seismic lines in the western part (Figure 1).

All major horizons of the study area have been interpreted. Some 25 wells, drilled since the onset of exploration in this area, were tied to seismic to assist the interpretation. All major horizons (Triassic, Altena, Posidonia shale, Lower Graben, Middle Graben, Upper Graben, Puzzle Hole, Scruff, Rijnland, Chalk and Tertiary) have been mapped throughout the 3D seismic volumes.

In order to identify areas with exploration potential, source rock maturity and potential was modelled, using Petromod 9.0 1D. Five wells have been selected (F03-01, F03-05, F11-01, F17-04 and F17-07) in order to understand development and formation of the Dutch Central Graben and the timing of hydrocarbon generation in relation to trap formation. The modelling was carried out based on public domain data (TOC, HI, OI) to calibrate and verify results.

### First results

Previous studies suggest that the intensity of inversion of the Dutch Central Graben decreases towards the north (Heybroek, 1975; Dronkers & Mrozek, 1991) resulting in less erosion and deeper present day burial of Jurassic strata. As expected, the observed maturity of the Posidonia shale increases with deeper burial in northern direction. The maximum uplift and erosion is estimated to be 600 to 700m (de Jager, 2003), which cannot fully explain the observed differences in maturity. Therefore a varying heat flow regime is proposed to explain higher levels of maturity in the northern section of the Dutch Central Graben. Figure 3 shows the difference in modelled heat flow for the northern (blue line) and more southern (red line) wells. In order to predict reliable source rock maturity and hydrocarbon generation values in

the area of interest, further research will be carried out in the second phase of this ongoing project. Several interesting trap structures have been identified, whilst sealing formations are abundant across the area of interest. Identification and evaluation of these structures will be carried out during the following months.

The depositional environment of the various reservoir intervals seems to deepen in the 'central' part of the Central Graben. Its implications for reservoir development are being assessed.

#### Future proceedings, Outlook

- Interpretation of several seismic 2D surveys will be done to complete the subsurface image of the western part of the Dutch central graben in the study area.
- In depth petrophysical interpretation of identified reservoir rocks.
- Assessment of hydrocarbon potential of the Jurassic petroleum system (basin modelling)
- Further investigations on the depositional and sedimentary model.
- Identification and evaluation of remaining leads and prospects in the study area; assessment of risks.

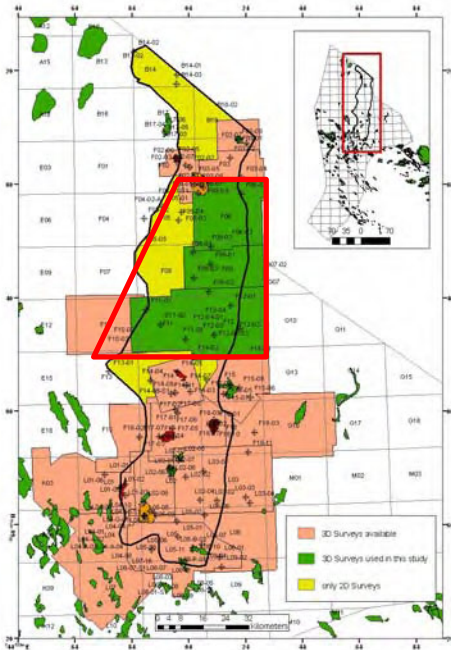
The study can be acquired by contacting PanTerra Geoconsultants B.V. ([www.PanTerra.nl](http://www.PanTerra.nl)) or through contacting the authors.

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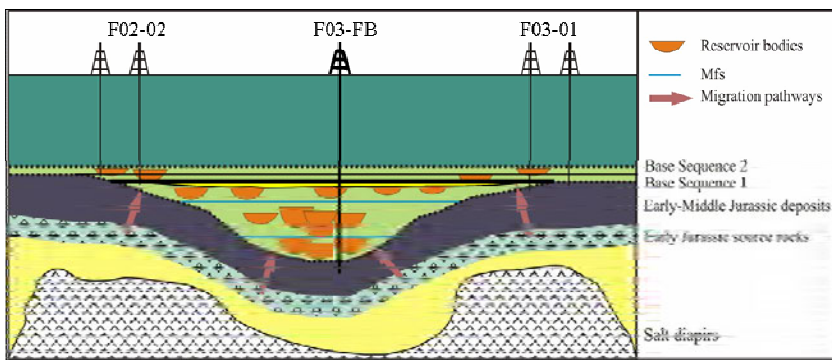
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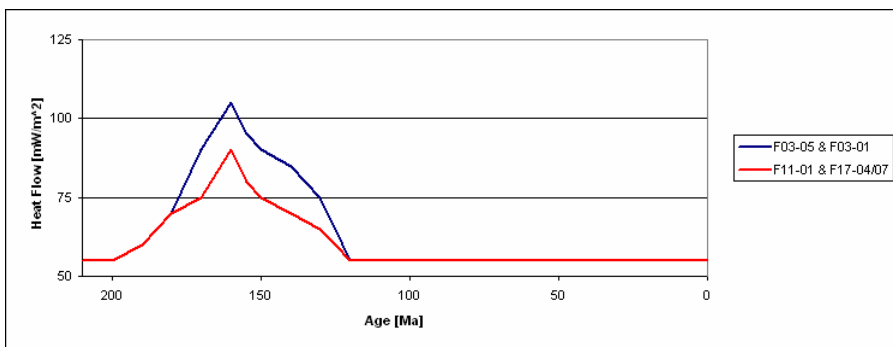
Figures:



**Figure 1: Location of the Dutch Central Graben; study area is highlighted red.**



**Figure 2 : TNO's play concept, modified after Abbink et al., 2006.**



**Figure 3 : Heat flow differences between southern and northern central graben**