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Variations in present-day temperatures in onshore and offshore Netherlands

The subsurface temperature and heat flow of onshore and offshore Netherlands (Figure 1) are subject of active study. Projects include the creation of a quality-controlled database of temperatures from released well data as well as the analysis and interpretation of temperature data. Interpretation includes the application of basin modelling. Here, we present present-day lateral and vertical temperature distributions based on offshore temperature data from the recently developed database and onshore published temperatures.

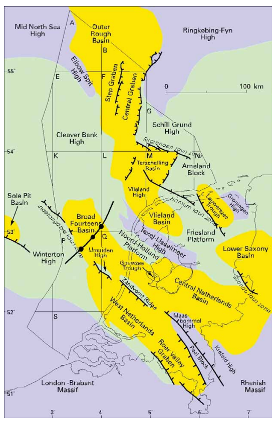

Figure 1. Main basins, platforms and highs in onshore and offshore Netherlands;

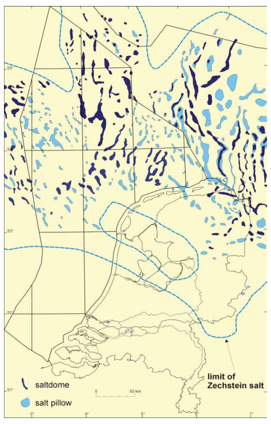

Figure 2. Distribution Zechstein salt.

Quality-controlled data base of offshore temperatures

In a Joint Industry Project with four Dutch E&P operators, TNO and CSIRO Petroleum developed an extensive, quality-controlled pressure, temperature and geological database of about 500 released wells from the Netherlands part of the North Sea Basin (Simmelink et al 2003, 2004, Vermooten et al 2004). The total number of quality-controlled temperature measurements in the data base is 7726. These include different types of measurements, such as drillstem test temperatures (TDST), bottom hole temperatures (TBHT), extrapolated bottom hole temperatures (TBHTX), repeat formation test (TRFT), along hole temperatures, mean temperatures.

Spatial variations of temperature

Preliminary analysis of the temperature data resulted in the identification of differences in temperature and associated heat flow at different spatial scales.

Vertical variations in temperature gradients are widespread both at a regional scale and at well locations. The vertical changes in bulk thermal conductivity of the subsurface play an important role inducing these variations. The relatively low thermal conductivity of the Late Tertiary and Quaternary sedimentary units of high porosity, and the high thermal conductivity of the Zechstein salts are important in this respect. The plot of temperature versus depth in the onshore Roer Valley Graben illustrates the occurrence of vertical variations.

Figure 3 reveals relatively low temperature gradients at shallow depths in

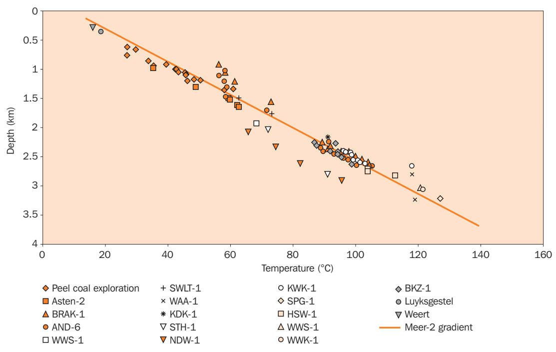

Figure 3. Temperature versus depth in the Roer Valley Graben, onshore Netherlands: DST, RFT, and Horner corrected temperature data (from Van Balen et al, 2002 and Verweij, 2003). Temperature gradient in well Asten-2 at shallow depths (0-1000m): 26°C/1000m. Temperature gradient at depths > 2000m: 34-35°C/1000m.

the basin (e.g. 26°C/1000m at well Asten-2, depth of measurement ca 1000m), while at depths of over 2000m the gradient is 34-35°C/1000m. The presence of Late Tertiary and Quaternary sedimentary units with a thickness of more than 1200 m, and the additional cooling effect of meteoric flow through the upper part of this onshore basin reduce the temperatures at shallow depths.

Figure 4 shows the regional variation in temperature gradients at depths of < 1500 m for the entire Netherlands offshore. These gradients were calculated using the temperature at sealevel (10°C) and the temperature at a point of measurement: $(T_{sealevel} - T_{measured})$/depth of measurement.

The calculated gradients are based on the most reliable measurements only: i.e. BHTX and DST data (Vermooten et al 2004). The temperature gradients in the northernmost offshore, where the Late Tertiary and Quaternary sedimentary units reach their maximum thickness, are low (<25°C/1000m) and comparable in magnitude with those encountered in the upper part of the Roer Valley Graben.

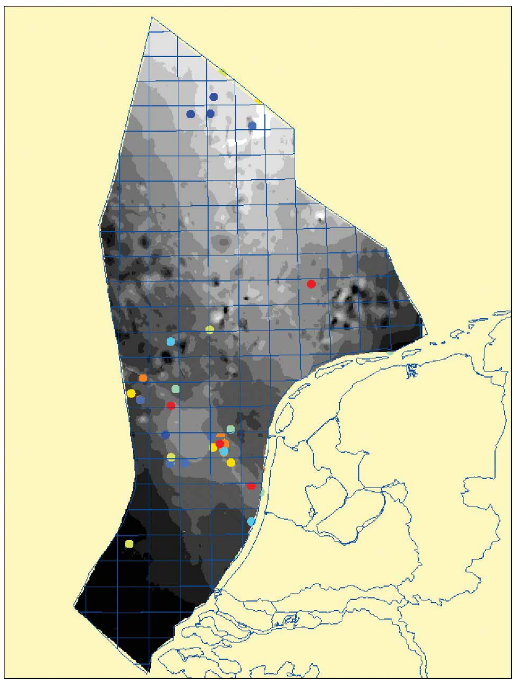

Figure 4. Distribution of temperature gradients at shallow depths (< 1500 m). For colorlegend see figure 8. The Map shows - in grey colors- the northward increase in thickness of the Upper North Sea Group(deposited after Mid-Miocene). Temperature gradients of < 25°C/1000 m coincide with largest thickness of these recent sediments.

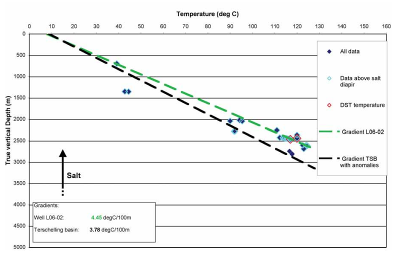

Figure 5. Increased temperature and temperature gradient (44.5 °C/1000m) in sedimentary units on top of salt diapir at well L06-02.

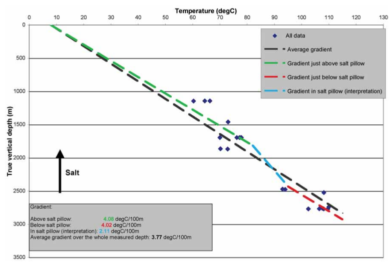

Figure 6. Temperature versus depth in well K14-03 in northern part of the Broad Fourteens Basin showing change of temperature gradient with depth related to the presence of Zechstein salt (Vermooten et al 2004).

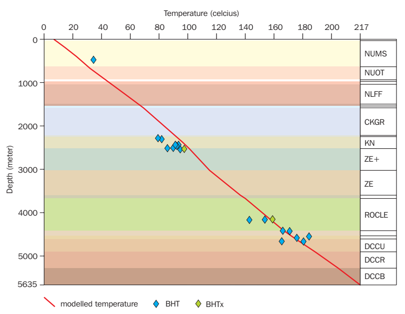

Figure 7. Results of 1D temperature simulation (Petromod 8.0) showing increase of temperature with depth;note decrease of temperature gradient in salt (green= BHTX measurements)

The temperature data from wells penetrating the Zechstein Group clearly illustrate the well known influence of the salt structures on temperature (Figures 5, 6 and 7).

Figure 8 shows the regional variation in temperature gradients for the entire Netherlands offshore. There is a difference between the temperature gradients in the Mesozoic Basins, reaching magnitudes exceeding 32.5 °C/1000m for most of the measurements, and the platforms areas, where most gradients are less than 32.5 °C/1000m. For comparison Figure 9 shows the contrasting lithostratigraphy of the basins and platforms. It should be realised that Figure 8 includes temperature gradients that cover widely

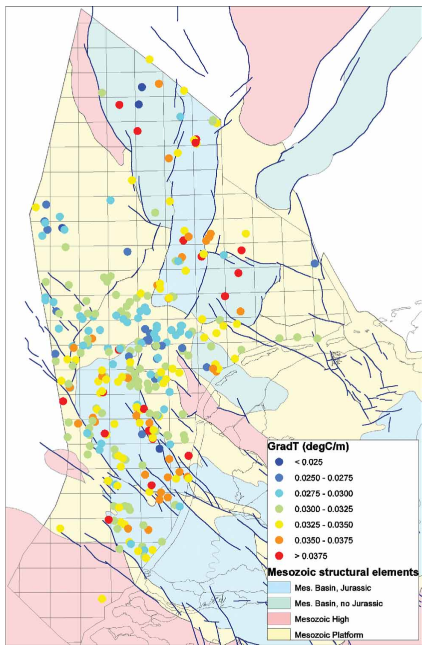

Figure 8. Temperature gradients (°C/m) in the Netherlands North Sea, based on TBHTX and TDST; gradients were calculated over depth interval from sealevel to point of measurement (assumed temperature at sealevel T= 10°C; depths between appr. 500-4500 m).

different depth ranges. The lateral distribution of temperature gradients in the Broad Fourteens Basin at depths of less than 1500 m reveals a distinct zone with relatively high temperature gradients coinciding with the thrust fault zone along the northeastern margin of the basin (Figures 4 and 9).

Conclusions and future outlook

Initial analysis and interpretation of the regional variations in temperature and temperature gradient reveal a close relation with spatial variations in bulk thermal conductivity of the Netherlands subsurface.

More comprehensive process-based interpretations and understanding of the temperature distributions are part of future projects.

Ongoing projects include:

1. Development of a quality-controlled temperature data base for the onshore Netherlands;
2. Mapping thermal properties Netherlands onshore and offshore;
3. Analysis and interpretation temperature data, including 1D-3D basin modelling.

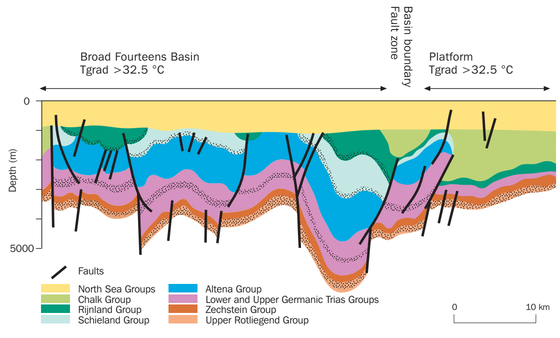

Figure 9. SW-NE cross-section through inverted Broad Fourteens Basin and adjaccent platform showing contrast in lithostratigraphic build-up of basin and platform area.

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Poster Verweij 05HB