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GEOTHERMAL ENERGY in the NETHERLANDS

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In the recent years the uptake of geothermal energy through implementation of low enthalpy geothermal production systems for both electricity and heating have been growing rapidly in north-western Europe. Geothermal exploration and production takes largely place in sedimentary basins at depths from 2 to 5 km. Geothermal activities can take considerable advantage from a wealth of existing oil and gas data.
To governmental bodies, such as geological surveys, it is a major challenge to put relevant oil and gas data and derived subsurface structural, temperature, and flow property models available to the geothermal community and to facilitate in quantitative assessment of geothermal potential of targeted areas, for both heat and electricity production (EGS) . In order to face this challenge and responding to a geothermal boom as reflected by over 50 exploration license requests, TNO has developed a public web-based 3D information system connected to a geothermal performance assessment tool.
The Netherlands is a relative small country, located in region of moderately elevated heat flow. However, the Netherlands has a wealth of information of the subsurface worth over 50 billion Euros, which has been collected over the past 30 years by the oil and gas industry. It therefore stands out as an excellent location to use these data for geothermal exploration. In order to face this challenge, TNO has developed a public web-based 3D information system called thermoGIS connected to a geothermal performance assessment tool. It facilitates uptake of geothermal through free accessibility to data, models and performance assessment tools.
This paper describes the key components of the web-based system, the models underlying it and the future outlook for both heat and electricity production

Geothermal characterization in a mature oil and gas basin

In the Netherlands, over the past 30 years over 5,000 wells have been drilled and over 72,000 km of seismic has been collected for oil and gas exploration and production (Fig. 2). The Subsurface of the Netherlands are marked by various reservoirs for oil and gas, mostly in Mesozoic Sediments penetrating 3-5 km deep. Most of these wells have been

logged and cored allowing for assessment of reservoir properties. Over 300,000 core plug measurements of permeability are available. All this data is freely accessible.

In the past decades the data has been used by TNO to develop 3D models of the subsurface structure, allowing insight in geological structures and targeting of exploration and production activities (NITG, 2004). Only recently it has been recognized that the datasets serve as excellent starting point for geothermal exploration, both for known reservoirs at depth levels of 1500-3500m for heat, as well as targeting deeper (fault) structures for electricity production. However, up till now the mapping did not focus on geothermal reservoir and properties therein. In response to these needs, TNO has generated a detailed geothermal characterization, including mapping of over 8 aquifer levels, their flow properties and temperatures at a resolution of 250 m. State-of-the-art 3D modeling techniques have been used and developed to obtain the reservoir structures, flow properties and temperatures, using constraints from deep wells, and detailed subsurface mapping from 3D and 2D seismic.

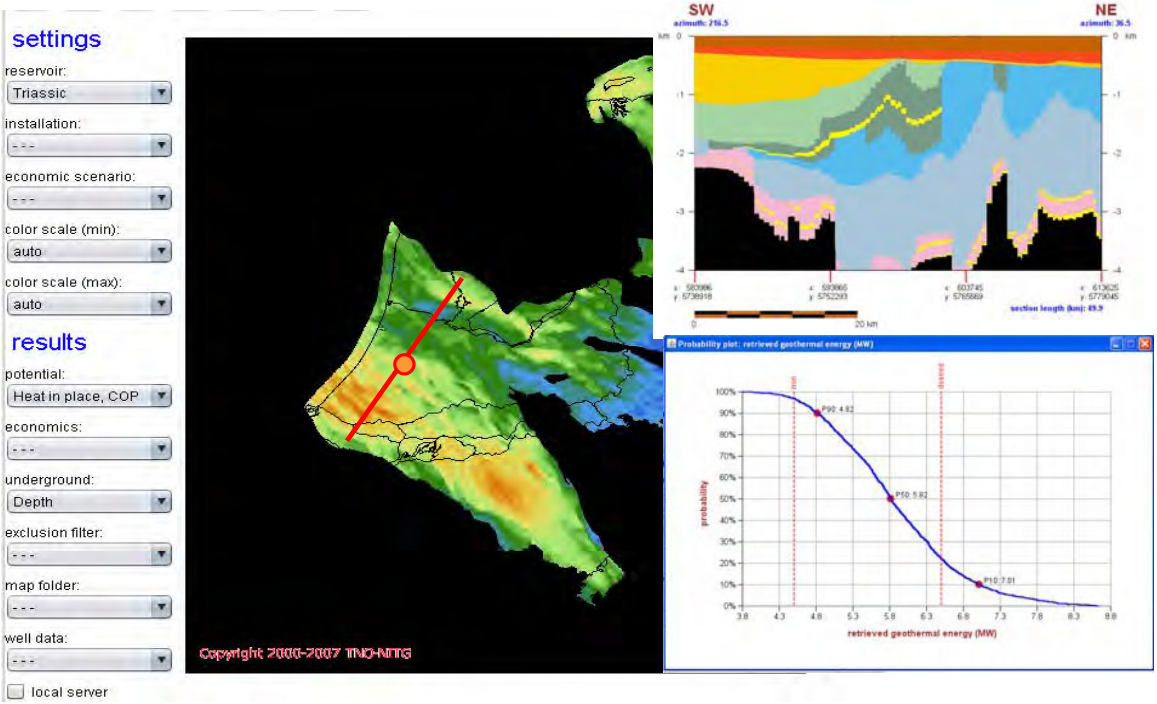

Figure 1: Overview of some of the functionalities in ThermoGIS. (left) GIS window with selection for major aquifers. (upper right) a cross section of the subsurface (red line left), showing the continuity of potential reservoirs (in yellow). (lower right) Temperature, thickness and depth maps of potential aquifers can be retrieved (at selected location) and used for performance assessment calculation

ThermoGIS

The aquifer structures and properties will be made accessible through novel interactive 3D web-based GIS interface (thermoGIS), connected to performance assessment tools. Figure 1 gives an example of the functionality of thermoGIS. It allows to asses quickly key parameters such as depth, thickness, temperature and flow properties. Tools allow to draw sections highlighting particular reservoirs and navigate simultaneously in

geographic contexts tailored to societal needs, and allows to perform a performance assessment (cf Engine, 2009) at arbitrary location to screen suitability for geothermal heat production.

Thermal models

Thermal properties of the 3D model have been based on detailed geothermal mapping. For each formation thermal properties, such as heat conductivity and radiogenic heat production, have been determined using generalized relationships of properties based on rock type, temperature and depth dependent porosity. Alternatively thermal properties have been derived directly from well log information.
The model has been calibrated to high quality temperature measurements in wells based on Drill String Tests (DST), and, if not available, on corrected Bottom Hole Temperatures (BHT). The well data are marked by a considerable variation in temperature gradient (Fig. 2, left), which can be related, among others, to spatial variations in thermal properties and basal heat flow (cf. Van Wees et al., 2009).
Temperature measurements and thermal properties are marked by considerable uncertainty, which will have a strong influence on the temperature predictions. In addition various tectonic and surface temperature evolution scenarios are possible.

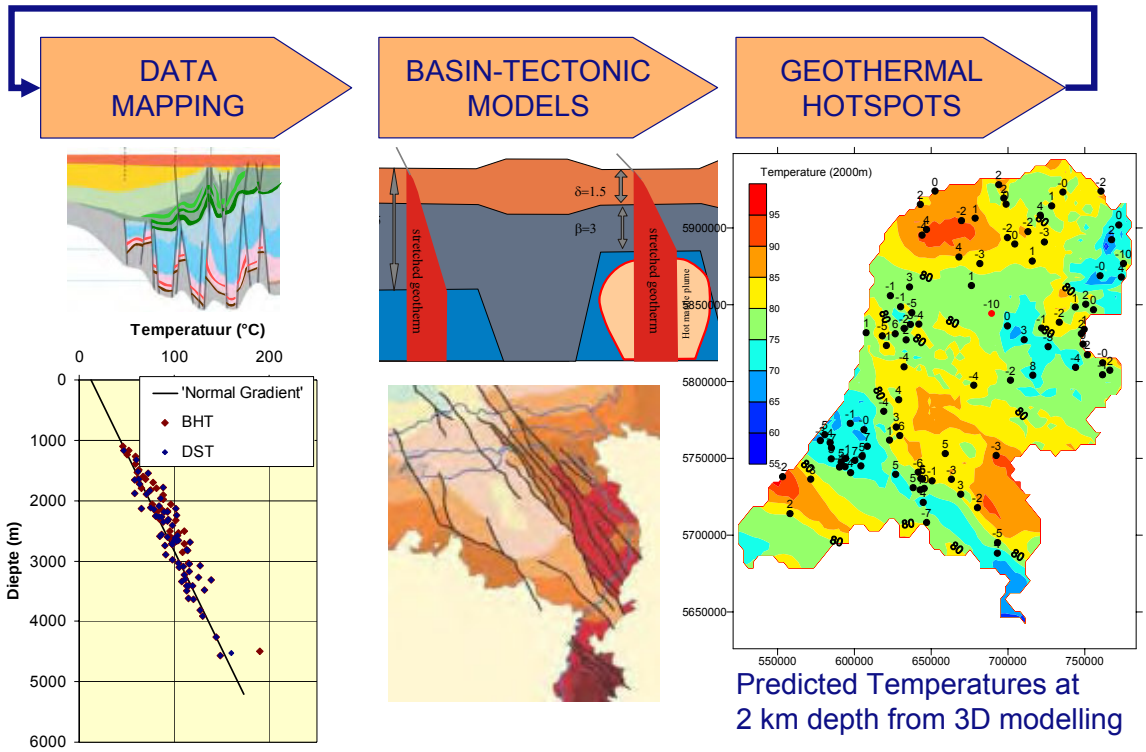

Figure 2: Workflow for 3D temperature models based on detailed geological model calibrated to over 50 DST and BHT temperature measuruments (left). (right) model temperatures. Numbers denote difference between modeled and measured well temperatures

Geothermal prospectivity and conclusions

This paper shows that information from oil and gas exploration and production activities provides an excellent stepping stone for geothermal development in the Netherlands. Over eight geothermal reservoirs levels have excellent potential for heat production. It is estimated that geothermal potential for heat production can deliver heating for an equivalent of ca 1 million houses over the next 100 years.

Mapping also contains excellent insights in active fault systems (Figure 3). Electricity production by low-bin systems is most likely possible in the SE Netherlands in the Roer Valley Graben in geothermal play settings, similar to the Upper Rhine Graben in Germany. Once proven successful through pilot projects it may well provide up to hundreds of MWe.

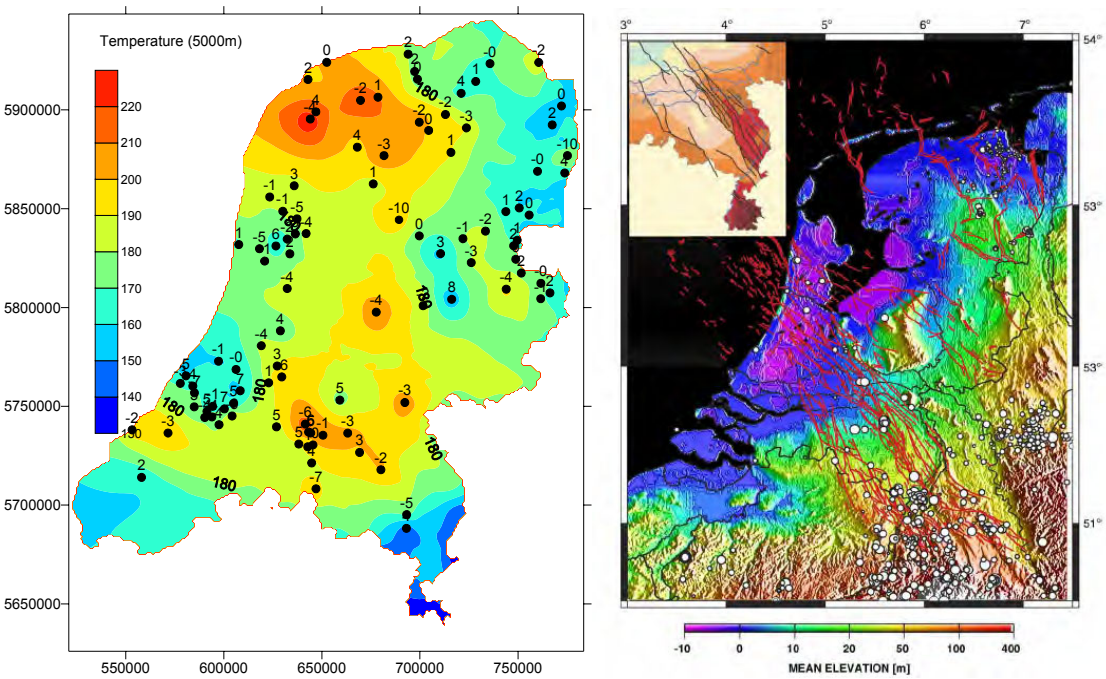

Figure 3: Temperature at 5 km depth (left). (right) Base Tertiairy faults (red) and seismicity (white dots)

References

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