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GeotIS – the Geothermal Information System for Germany

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ABSTRACT

The geothermal information system (GeotIS) provides information and data compilations on deep aquifers in Germany relevant for geothermal exploitation. GeotIS is a public internet based information system and satisfies the demand for a comprehensive, largely scale-independent form of a geothermal atlas which can be continuously updated. GeotIS helps users identify geothermal potentials by visualizing temperature, hydraulic properties and depth levels of relevant stratigraphic units. A sophisticated map interface simplifies the navigation to all areas of interest. An additional component contains a catalogue of all geothermal installations in Germany.

The project is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The Leibniz Institute for Applied Geophysics (LIAG, formerly known as GGA) realises this project in close collaboration with partners. The purpose of the project is to minimise the exploration risk of geothermal wells and to improve the quality in the planning of geothermal plants. The current stage of expansion includes the South German Molasse Basin, the Upper Rhine Graben, and the North German Basin.

1. INTRODUCTION

The German government has set itself the target of expanding in the near term the proportion of renewable energy in the overall energy supply mix of the Federal Republic of Germany. As part of the 5th Energy Research Programme of the German government, the German Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports research and development measures in various fields including deep geothermal energy. The German government has also decided to raise the compensation for geothermal electricity fed into the grid from 0.15 €/kWh to 0.16 €/kWh as of 2009. In addition, there will be several bonuses: 0.03 €/kWh for cogeneration of heat and power, 0.04 €/kWh for petrothermal systems and 0.04 €/kWh for power plants starting operation until 2015. It is expected, that these steps will improve the economic efficiency of geothermal projects in Germany.

This is the background against which the project "Development of a Geothermal Information System for Germany" (GeotIS) is funded by the BMU under funding number 0327542.

The project has been implemented under the management of the Leibniz Institute for Applied Geophysics (LIAG), Hannover, with the support of the Wirtschaftsverband Erdöl- und Erdgasgewinnung. Project partners were:

- Bayerisches Landesamt für Umwelt / LfU, Augsburg (Geological Survey of Bavaria)
- Landesamt für Bergbau, Energie und Geologie / LBEG, Hannover (Geological Survey of Lower Saxony)
- Abteilung Umwelt im Regierungspräsidium Freiburg (Department of Environment, Regional Council Freiburg)
- Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern / LUNG, Güstrow (Geological Survey of Mecklenburg-Vorpommern)
- Freie Universität Berlin (FU), FB Geowissenschaften, Arbeitsbereich Hydrogeologie (Free University of Berlin, Department of Earth Sciences, Workgroup Hydrogeology)
- Geothermie Neubrandenburg GmbH (GTN)

The primary objective of GeotIS is to make a contribution to improving the quality of geothermal-plant project-planning by providing preliminary figures on the crucial parameters for determining exploration risks: aquifer temperature and productivity (Schulz et al. 2007). However, concrete, location-specific analyses still remain the task of local feasibility studies.

The system is based on data on deep aquifers suitable for geothermal exploitation. Thus, it is restricted to hydrogeothermal resources. Other areas of deep geothermal energy, like for instance petrothermal systems, will be considered for future developments of GeotIS.

The most important regions for hydrogeothermal exploitation in Germany are the North German Basin, the Upper Rhine Graben, and the South German Molasse Basin (Fig. 1). The horizons relevant for geothermal exploitation in these three regions are listed in table 1.

Table 1: Regions and horizons of hydrogeothermal interest in Germany.

Region	Horizon
North German Basin	Lias-Rhaetian aquifer complex
	Middle Bunter sandstone
	Lower Cretaceous sandstone
	Dogger sandstone
	Keuper sandstone
Upper Rhine Graben	Upper Muschelkalk
	Middle Bunter sandstone
South German Molasse Basin	Upper Jurassic (Malm)

Figure 1: Map of areas with potential for hydrogeothermal exploitation in Germany.

To make a statement about the hydrogeothermal resources at a certain location the properties of the deep aquifer have to be estimated as precisely as possible: underground temperatures as well as thickness and hydraulic properties of an aquifer are the determining factors for the exploration risk. Thus, they constitute the major part of the geothermal information system.

GeotIS is designed as a digital information system which is available to the public through the World Wide Web (www.geotis.de). It offers a comprehensive, largely scale-independent form of a geothermal atlas which will be continuously updated. GeotIS is a dynamic system which, in addition to the usual standard data, also includes the latest findings and results in geothermal energy. In order to protect the property rights to the data, GeotIS uses statistical methods and sophisticated mapping tools for data visualisation.

2. DATA

The data to be incorporated in the information system is derived from a very wide range of data sources, and therefore has to be standardised and analysed to assess its quality. Temperature data and hydraulic parameters required for predicting exploration risk are data measured in deep boreholes. Geological sections have been derived from reprocessed seismic data. Stratigraphic models have been developed on the basis of geological maps and well profiles.

2.1 Well data

The most accurate data available on the deep underground originate from approximately 30,000 wells. The largest proportion, approximately 27,000 wells, is related to the hydrocarbon exploration. The remaining wells were drilled for other purposes, e.g. geothermal energy, drinking water, thermal water or mining.

The main source of information on deep boreholes and their geological profiles is the Hydrocarbon Information System (FIS KW) created by LBEG (Brauner 2003). It currently contains approximately 22,000 geological profiles from approximately 11,000 deep wells in Germany. The most important data source for the area covered by the new German federal states is the “Hauptspeicher Bohrungsdaten” (Main Well Database). It is managed by Gaz de France and incorporates all the hydrocarbon wells drilled in the former German Democratic Republic (GDR). It provides data on approximately 2,500 wells with approximately 2,000 geological profiles and large amounts of core analysis data. Data on non-hydrocarbon deep wells can be found in databases operated by the state geological surveys.

In order to use well data from different sources with varying structures and processing levels, comprehensive data conversions towards standardised formats are essential. These conversions include among others the calculation of true vertical depths from measured depths, the implementation of a hierarchical data structure for geological profiles, coordinate transformations and the application of the so-called ATS key of the German oil & gas industry as the final key for the description of stratigraphic sequences as well as for lithologic and tectonic details (Brauner et al. 2001).

2.2 Hydraulic data

Porosity and permeability data from core analyses provide important input for determining the hydraulic properties of underground formations. Digital data is stored in the Hydrocarbon Information System of LBEG, and the “Hauptspeicher Bohrungsdaten“ for wells drilled in the former GDR. Standardisation of the data is relatively uncomplicated because both data sets contain the information catalogued in similar structures. However, correct correlation – necessary for interpretation – between sample analyses and cores, and cores and specific boreholes, was possible in the case of the GDR data after a great deal of intensive revision, only.

The distribution of the sample analyses naturally reflects the geographic as well as the stratigraphic interests of oil and gas exploration. More than half of all the analysed wells (1,296 wells) were drilled in Lower Saxony. In addition to the North German Basin (1,952 wells), the remaining wells are concentrated in the Thuringia Basin (105 wells), the Upper Rhine Graben (93 wells) and the South German Molasse Basin (256 wells). 23 wells are from the German North Sea. But relatively few results are available on the geothermal relevant horizons.

Test data constitute another important source of hydraulic data. Our project partners prepared test data from approximately 360 wells. All the data come from various types of wells. Approximately 110 wells with test data are located in the North German Basin. Investigations on the Upper Rhine Graben contributed approximately 130 wells with test data, and approximately 120 wells in the South German Molasse Basin with test data.

2.3 Temperature data

The mean increase in temperature with depth is generally around 3K per 100 m. Local deviations from this trend may occur due to increased thermal conduction inside salt domes or as a result of rising groundwater.

The LIAG runs the Geophysical Information System (Kühne et al. 2003) which contains log data and single values from a range of geophysical methods, primarily within Germany, and consists of a main system and various subsystems. The geothermal subsystem contains temperature information from approximately 9,500 wells (Fig. 2). Equilibrium temperature logs and reservoir temperatures are considered to be of optimal quality. They require no corrections. Because of the regular monitoring of production wells over many years, reservoir temperatures are available in time series. The fluctuation in these temperatures is generally less than 1 K.

Bottom hole temperatures (BHT) are also available in this subsystem. BHT values are recorded in almost all industrial boreholes at the deepest point of the well immediately after drilling has stopped, and are therefore thermally disturbed by the drilling process (the circulation of mud). These BHT values can be corrected (extrapolation) to produce undisturbed temperatures because the distorting effect of the mud circulation on the temperature field is lowest at the deepest point in the well. Various extrapolation methods can be used depending on the waiting time after the end of drilling, the circulation period, and the number of temperature measurements made available (Schulz & Schellschmidt 1991). Despite such corrections, these results still have errors of approx. ± 5 K, and are therefore much less accurate than undisturbed temperature logs.

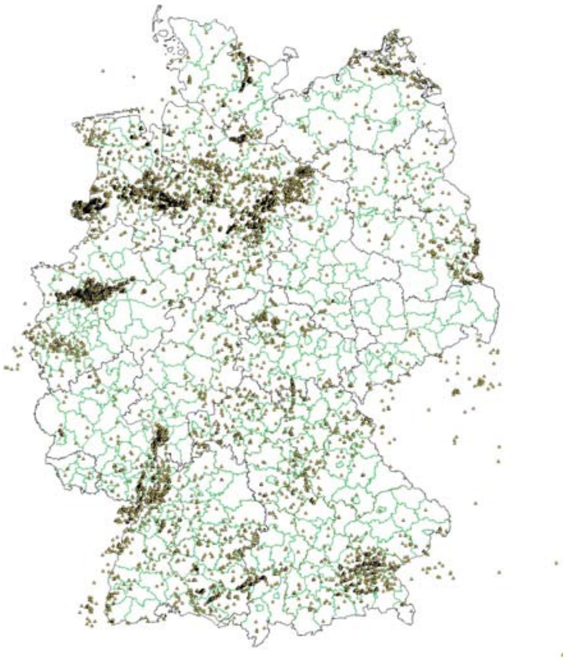

Figure 2: Geographic distribution of temperature information in Germany stored in the Geophysical Information System. It contains approximately 9,500 wells.

Soil temperatures have been obtained from the meteorological service of Germany (DWD). The data comprise all air temperature measurements at 2 m above ground of the years 1961 - 1990. The mean air temperature is a good approximation of the soil temperature at a depth of 13 m. The mean temperature values of 675 locations have been mapped using a kriging interpolation method. Since air temperature decreases with altitude (3.5 K/km) the applied interpolation procedure accounts for temperature variations due to varying terrain levels.

The subsurface temperature distribution has been spatially interpolated using the universal kriging algorithm in a 3D-space reaching from ground level down to 5,000 m below mean sea level. The lateral and vertical grid resolutions are 2000 m and 100 m, respectively. The data have been added to the GeotIS-database as binary large objects (BLOBs). Each BLOB covers an area of 20 by 20 km. This fragmentation is necessary for performance reasons.

2.4 Stratigraphic data

Information on the occurrence and depth level of stratigraphic units containing major aquifers relies on the development of specialised underground models. The starting point for the modelling of the Northeast German Basin was a collection of geothermal maps of NE Germany which are available at a scale of 1:200,000 (e.g. Gesellschaft für Umwelt- und Wirtschaftsgeologie 1992, Zentrales Geologisches Institut 1988-1990). These maps provide information on the occurrence and base level of Mesozoic horizons relevant for geothermal exploitation. In order to use this material, maps of five stratigraphic units have been carefully digitised and vectorised by the LUNG. The digital maps have been checked and reworked using the ArcGIS software. The reworked data have been converted into triangulated surfaces using the Gocad software package (Mallet 2002). Geological profiles of wells were used for regional correction and the creation of top level surfaces. In a final step, these triangulated surfaces have been transformed to orthogonal 2½D grids with a resolution of 100 m. Like the temperature grid, all surface grids are stored as BLOBs in the database.

The Bavarian Molasse Basin has been modelled very similarly on the basis of a map at a scale of 1:500,000 which is part of the "Bayerischer Geothermieatlas" (Bayerisches Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie 2004). This 3D model consists of a single triangulated surface representing the top level of the Purbeck formation (above Malm). It is planned to extend the 3D model in a westward direction for the part of the Molasse Basin located in Baden-Württemberg. Up to the present, the Molasse Basin in Baden-Württemberg is represented by ten geological sections which have been created on the basis of seismic data provided by the hydrocarbon industry. For the Upper Rhine Graben 24 additional geological sections have been created. The distribution of these sections has been chosen in such a way as to cover the whole area in both regions. Finally, it is intended to add 3D models for all regions with hydrogeothermal resources in Germany to GeotIS.

3. RESEARCH USER INTERFACE

The GeotIS project breaks new ground in helping users to find and visualise data relevant for geothermal project planning. Using GeotIS for research and data retrieval requires no more than a current browser and an internet connection. The user interface provides maps, charts, tables and cross sections for screen display or PDF download. One major advantage of this system compared to conventional maps is the ability to always use the latest findings and data, and make them immediately available to users as soon as they have been entered into the information system.

GeotIS offers a geographic research tool based on an interactive map with a range of zoom and navigation options. Routes, cities, borders and other topographic features can be selected for display for better orientation. GeotIS makes use of topographic datasets (ATKIS® DLM250/1000, GN250/1000 and VG250) from the Federal Office for Cartography and Geodesy (BKG). A menu tree facilitates the handling of various background layers with technical or topographic information. A query tool enables the user to find communities and wells by name on the map. Meta data on wells and seismic sections can be retrieved in table form.

There are two visualisation options to provide a detailed insight into the underground which allow for interactive generation of vertical and horizontal cross sections. The vertical cross section can be generated by drawing a line at any position in the already mentioned regions (Northeast German Basin, Molasse Basin and Upper Rhine Graben). The result is a geological section which displays the horizons relevant for geothermal exploitation and the wells nearby up to a maximum depth of 5000 m below sea level. It is possible to couple each display with a temperature contour plot (Fig. 3). An additional detail of the map shows the geographic position of the section.

The horizontal cross section can be generated by expanding a rectangle with a maximum length of 50 km at any position in one of the mentioned regions. It allows a view on the horizontal temperature distribution as well as the stratigraphic units in a certain depth up to a maximum of 5000 m below sea level. Furthermore, another visualisation option produces maps showing the temperature distribution on top or base of a stratigraphic unit (Fig. 4). There is also the possibility to obtain maps of soil temperature and relief. All created cross sections can be exported as pdf-files.

The current legal situation in Germany however, has complicated the use of the data, particularly the data derived from oil & gas industry's seismic surveys and deep wells. This information is classified as confidential, no matter how old it is and whether or not the concession still exists. Although these data are incorporated in the underground models, users cannot usually be given access to the original data. Therefore, restricted data are offered in a generalised and anonymous form. One way to hide original values is the use of interpolation methods such as the kriging method applied to underground temperature values.

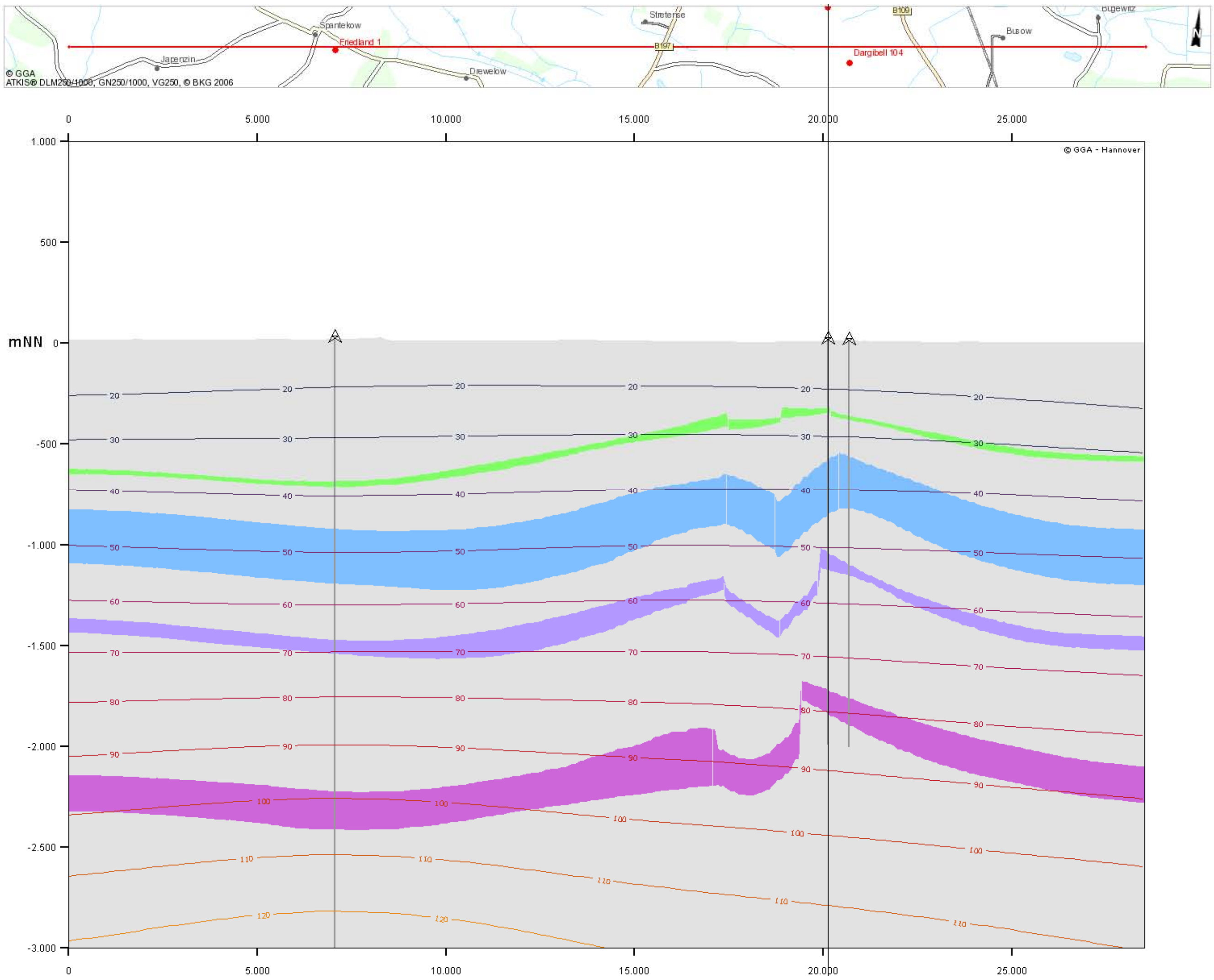

Figure 3: Example of a geological section with 5-fold exaggeration in GeotIS. Length, locations of end points, maximum depth level and exaggeration can be selected individually. Relevant geothermal aquifers are located within the coloured areas (colour legend not displayed, here). Isolines mark the temperature profile. Faults are displayed as white vertical lines. The map section at the top shows the location of the geological section and adjacent wells in red. Filled circles indicate wells with temperature data.

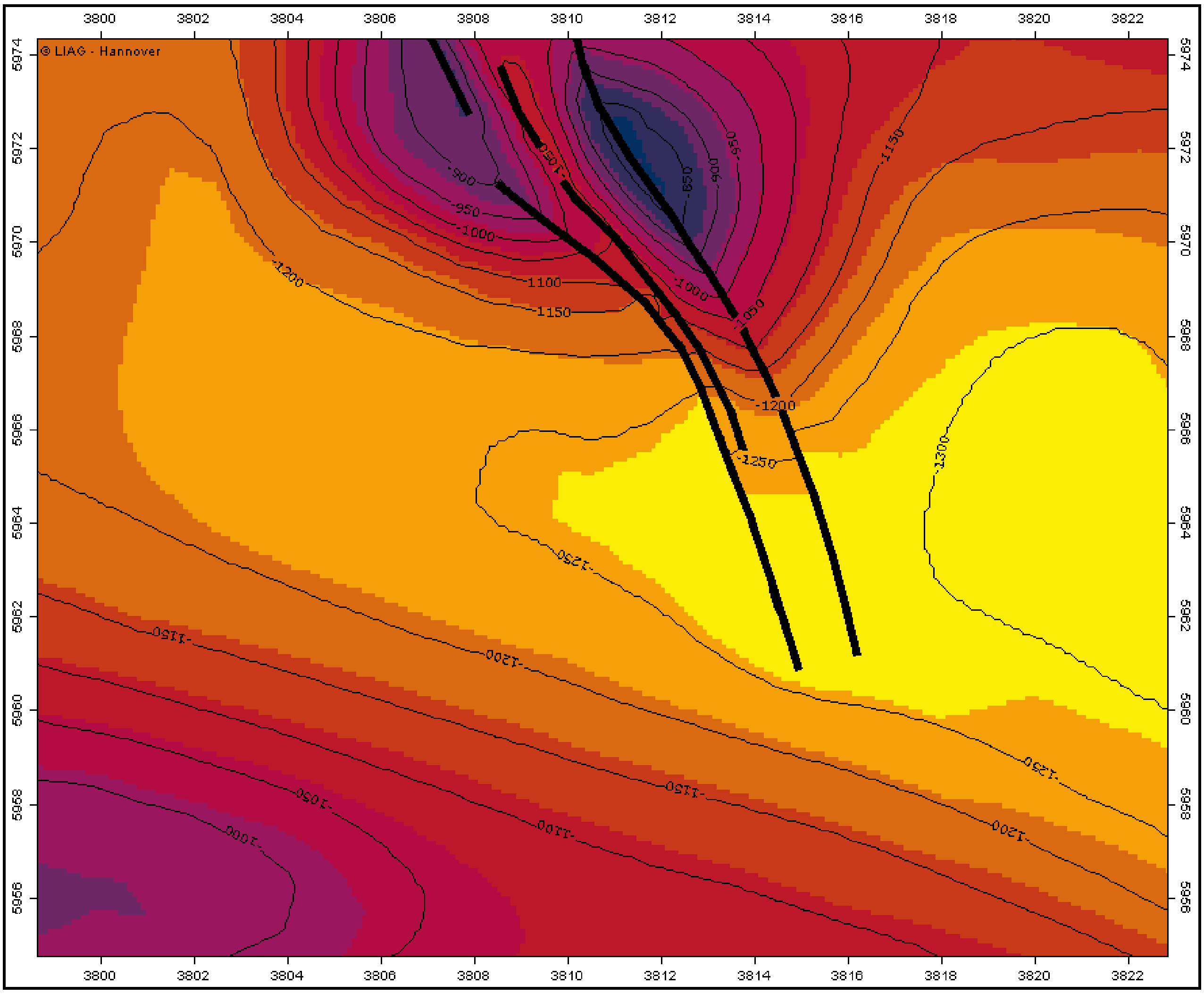

Figure 4: Example of a stratigraphic plot (here: Lias base level); the colours represent temperature intervals (colour legend not displayed, here), the thick black lines represent faults. The temperature scale adjusts automatically to the temperature range.

The user interface has been realised as a JAVA, AJAX and PHP based web application. Microsoft's SQL-Server is used as primary storage and database solution. An internal database holds all project-relevant data. A second, external database stores publicly available data, a subset of the data stored in the internal database. This strict separation of working and presentation data is necessary for legal reasons. Restricted data must not be passed in original form and full detail to third parties.

The geographic research tool has been realised with the UMN MapServer (Fischer 2003), an open source software product developed at the University of Minnesota. JAVA programmes have been developed for import, export (backup) and conversion of data. Kriging was done with the ESRI ArcGIS and the Paradigm Gocad software.

4. GEOTHERMAL INSTALLATIONS IN GERMANY

GeotIS also offers a public catalogue service of geothermal installations in Germany (Pester et al. 2007). This service is based on a table which was elaborated by the "Deep Geothermal energy" working group of the national/federal panel of state geological surveys (Bund/Länder-Ausschuss Bodenforschung, BLA-GEO). The content of this table are geothermal plants in Germany which are being operated or under construction.

The internet presentation is based on an interactive map which allows a comfortable navigation (Fig. 5). A wide range of research tools is being offered, e.g. to search for a specific location. An information frame shows the most important parameters of selected installations (name, use, temperature, flow rate, depth, and production data) combined in a table. By clicking on a single installation a complete overview is being given including all available information on that geothermal plant such as coordinates, aquifers, references, and links.

A matter of particular interest is information about the installed geothermal output and the provided energy. Unfortunately, these data are not made available by all operators and thus, have to be calculated (Pester et al. 2007). All statistic data about geothermal energy can either be displayed for Germany, a certain federal state or a for any selected area.

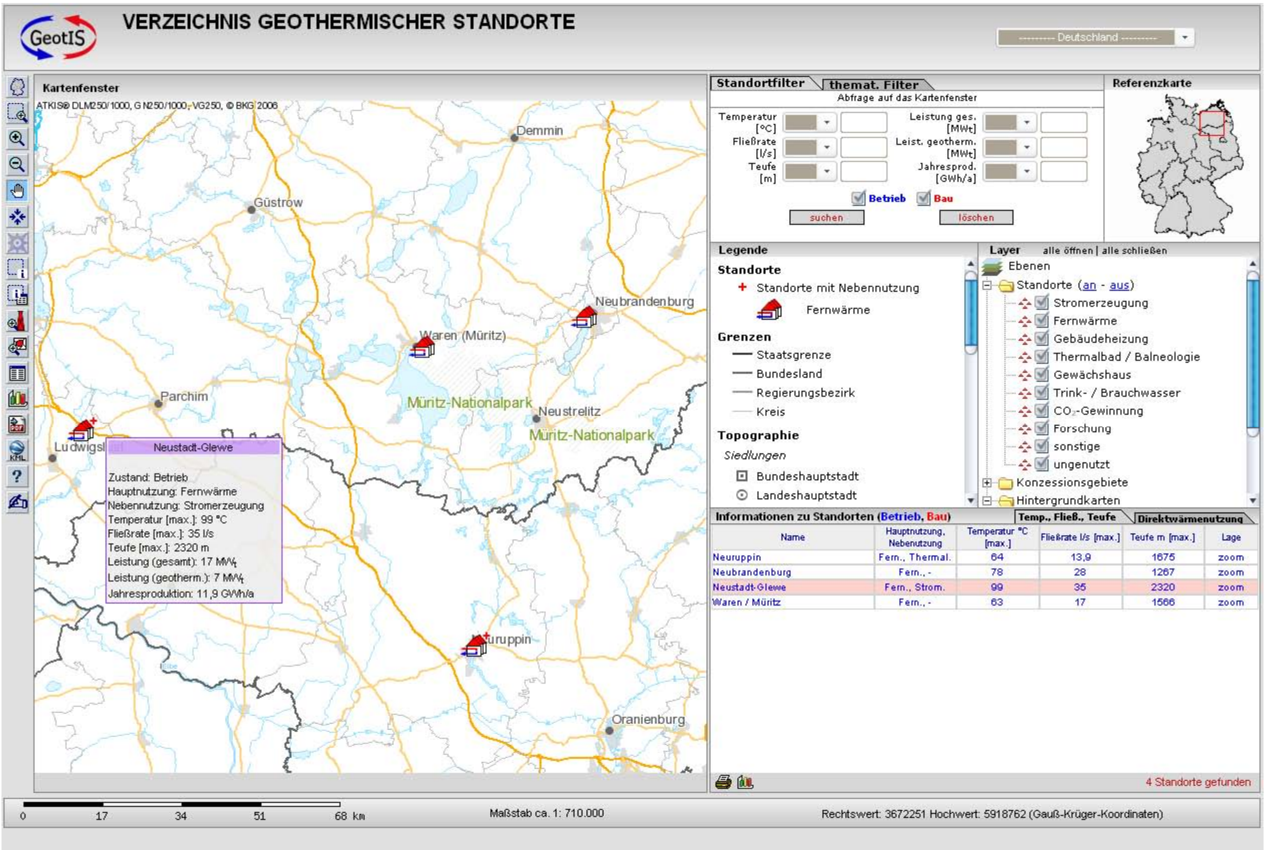

Figure 5: Public catalogue service of geothermal installations in Germany. The map detail shows an area in Mecklenburg-Vorpommern. The district administration boundaries and topography are superimposed as the background. The locations are shown on the map, and the most important data for each installation is shown in the information table (below right). More detailed data on each installation can be accessed by mouse click.

5. OUTLOOK

The geothermal information system is open to the public at www.geotis.de.

The further development and support of the information system will take place in a new project – funded by the BMU. Optimisation of the software and the implementation of feedback by users will be a large part of the new project. Furthermore, new regions and other geothermal resources such as petrothermal usage are going to be added. An English version of the system is also going to be developed.

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