Large-scale investigation of German subsurface temperatures for time-dependent and non-conductive processes

Clauser, C. [2], Deetjen, H. [1], Hartmann, A. [2], Höhne, F. [2], Rath, V. [2], Rühaak, W. [1], Schellschmidt, R. , Zschocke, A. [1]

[1] GGA-Institut, [2] RWTH Aachen

Introduction

Fluid flow is an effective agent for the transport of heat. Thus, the analysis of temperature measurements in boreholes can be used to indicate and even quantify advective processes in the underground. Goal of the current project is to develop a method for quantifying deep groundwater movement on a regional scale based on existing temperature records. As the amount of disturbance of the geothermal gradient due to groundwater movement is unknown, other effects must be taken into account. In particular rock heterogeneity and paleoclimatic effects have to be estimated as well to be capable to quantify groundwater flow.

The project comprises two parts: In a - now completed - first stage the available temperature data all over Germany were analysed to select a promising region for a pilot study. This area will be investigated in more detail in the second phase of the project.

The pilot study will cover three major subjects:
Péclet analysis of the temperature logs to determine fluid flow
Estimating the paleoclimatic influence on the temperature logs
Establishing a detailed conductive model of the test region

After a separate analysis of these influences on the temperature field an integrated numerical model of the pilot area will be developed to quantify fluid flow and check the results obtained from the previous investigations.
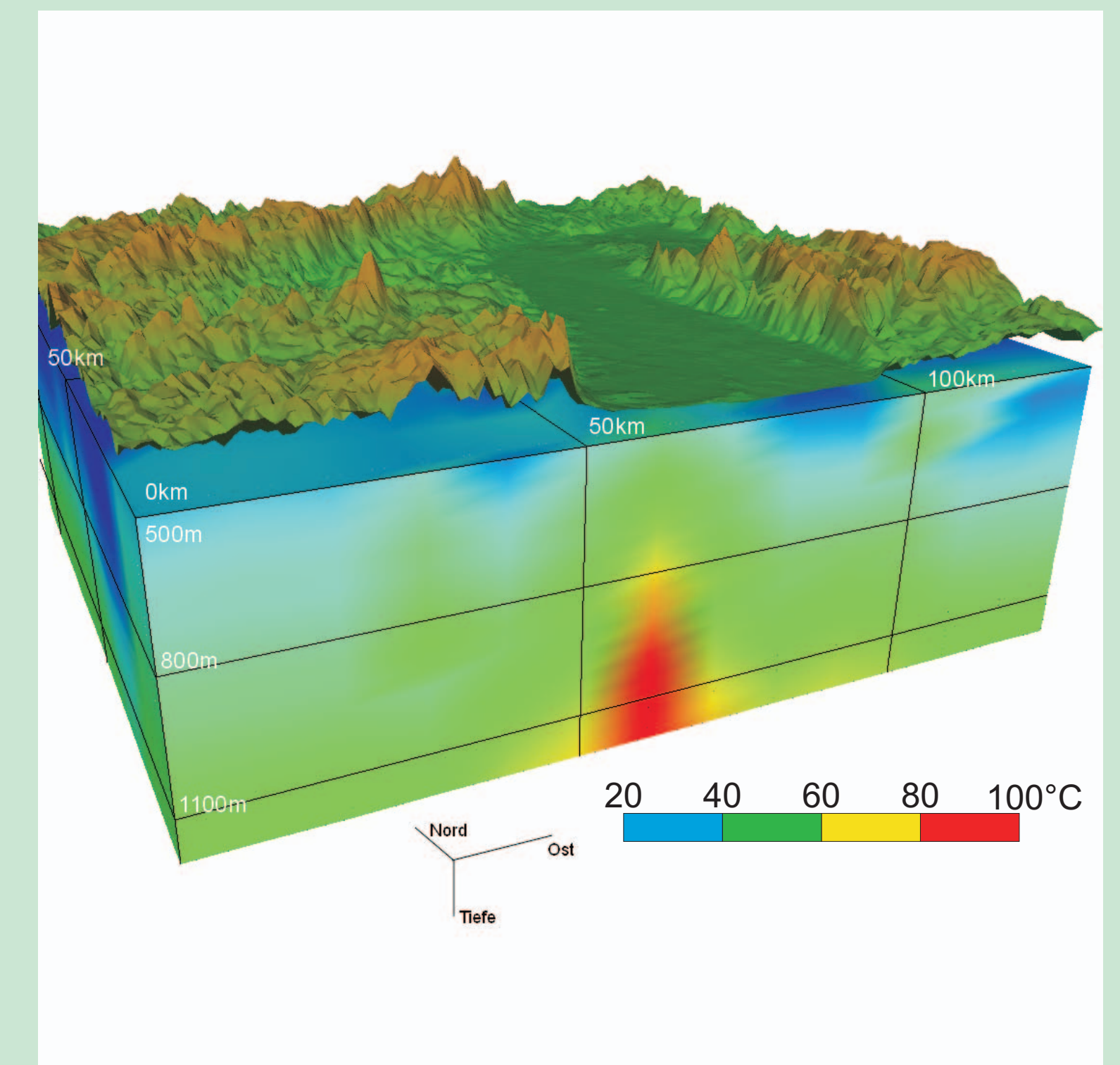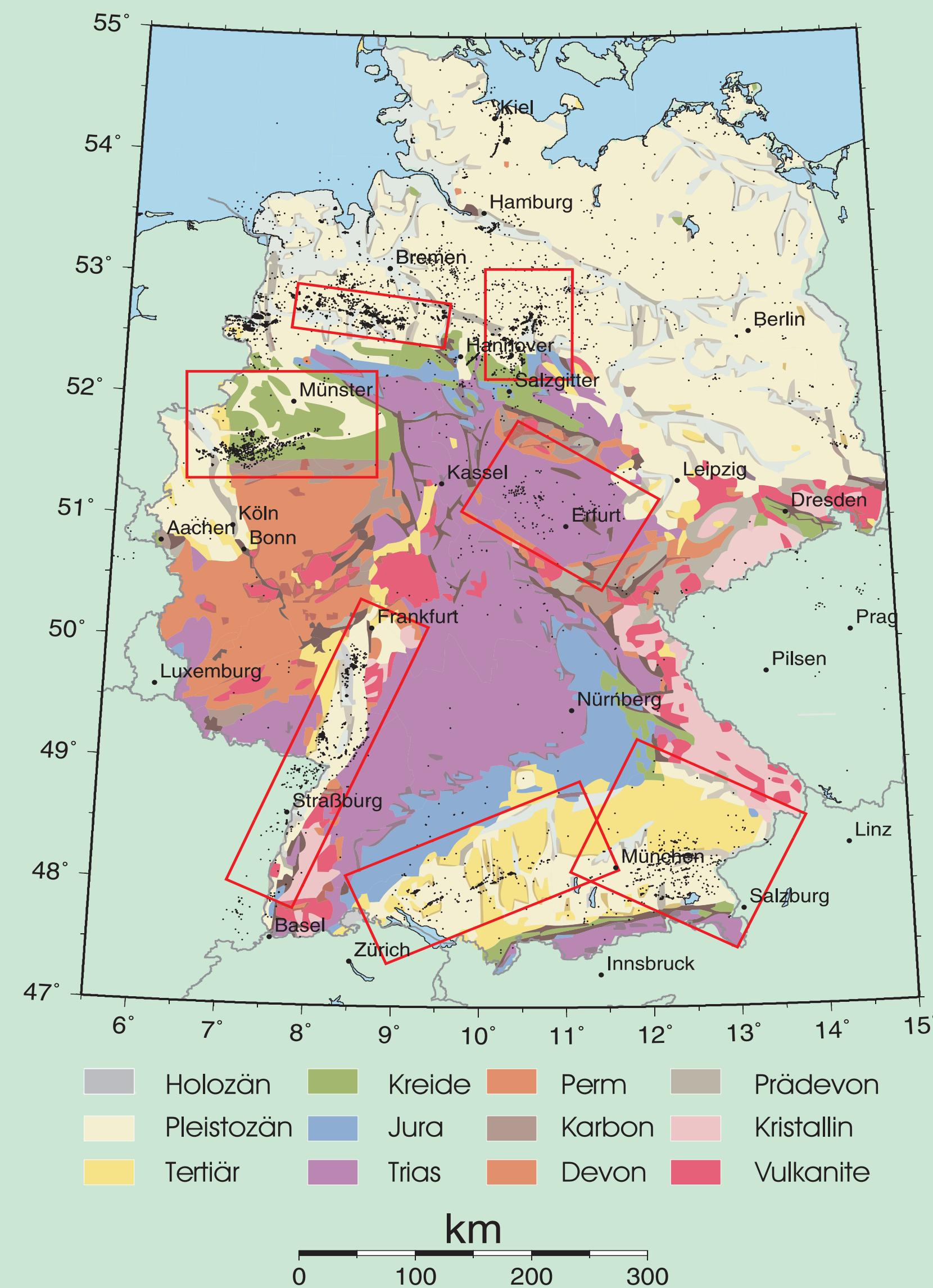

Figure 1: Map showing the general geology of Germany. Red squares show proposed pilot areas for the detailed investigations. Black dots mark borehole locations with temperature measurements deeper than 500m. The temperature data is compiled in a database at the GGA Institute and contains most of the German temperature data, currently more than 9,000 locations.

Holozän	Kreide	Perm	Prädevon
Pleistozän	Jura	Karbon	Kristallin
Tertiär	Trias	Devon	Vulkanite

Figure 2: Cross section of the temperature through the Rhine Graben showing the temperature anomaly at Soultz-sous -Forêts. The Upper Rhein Graben is one of the proposed test areas. The section was obtained by interpolation of the borehole data using the Kriging method. Topography is taken from the GTOPO30 data set. Vertical exaggeration for the temperature and topography are 60 and 22, respectively.

Paleoclimatic Analysis

One aspect of our pilot study will be the determination of the paleoclimatic signal. It can be expected that climatic variations of the Holocene will be found in the depth region of interest, that is 500 to 1200m depth. A temperature signal of 1 Kelvin was found between 1000 and 2000m in the KTB main borehole, corresponding to the model on the left.

We will select usable deep boreholes in Germany to determine the general climatic trend in Germany for the last 10,000 years. An example of this analysis is shown on the right. The results will be used to extract the regional climate from the shallower boreholes in the pilot area. Comparisons hopefully will improve our understanding of the climate variability in time and space in Germany.

Figure 3: One-dimensional vertical model for transient heat flow. A series of snapshots is shown that demonstrate the propagation of a changing ground surface temperature into the underground. Time span of the model is 15,000 years. The forcing Ground surface temperature history is shown in the upper left and corresponds roughly to the climatic trend of the last 10,000 years. It can be seen that signals of magnitude 1 Kelvin can be detected at depths down to 2000m.
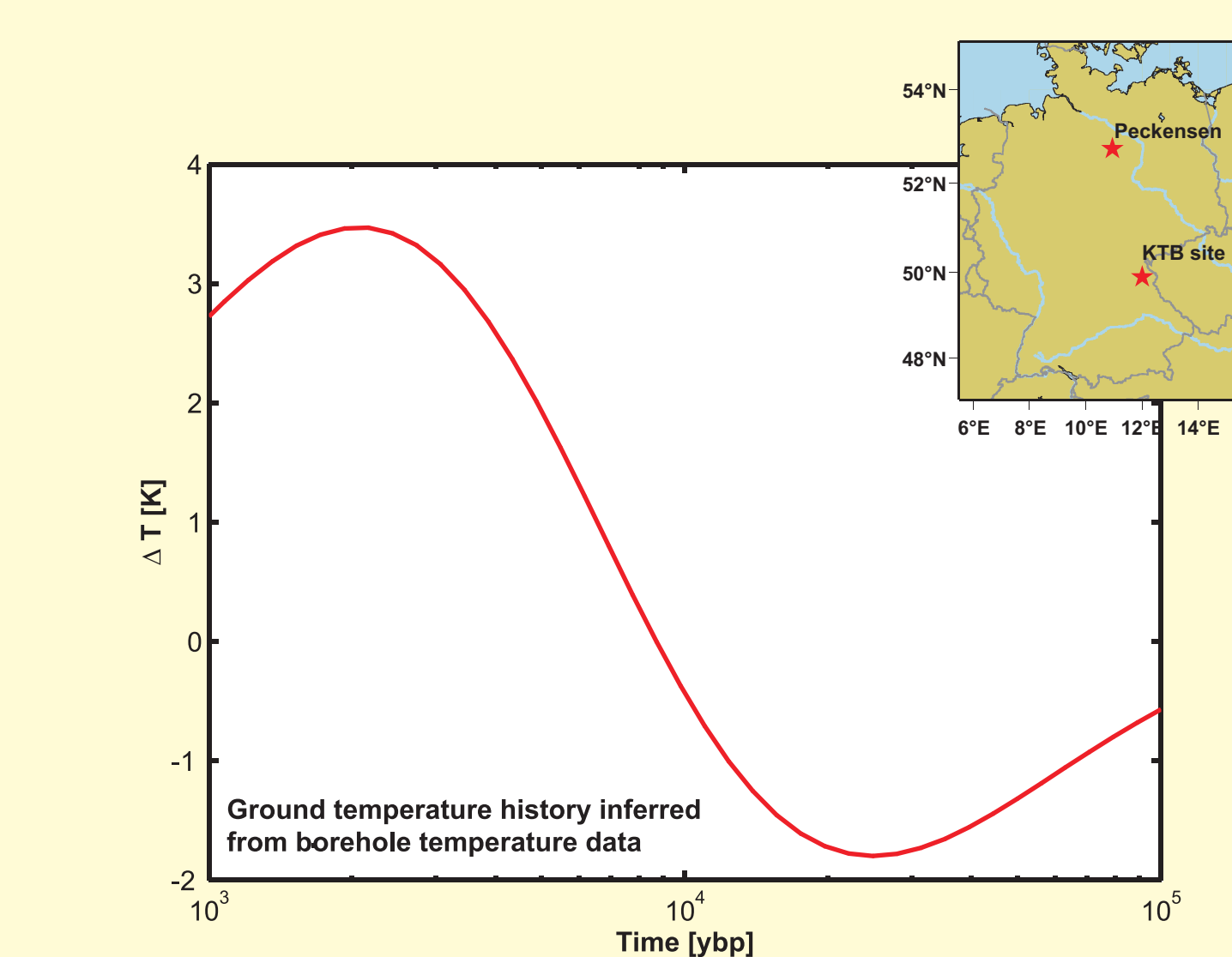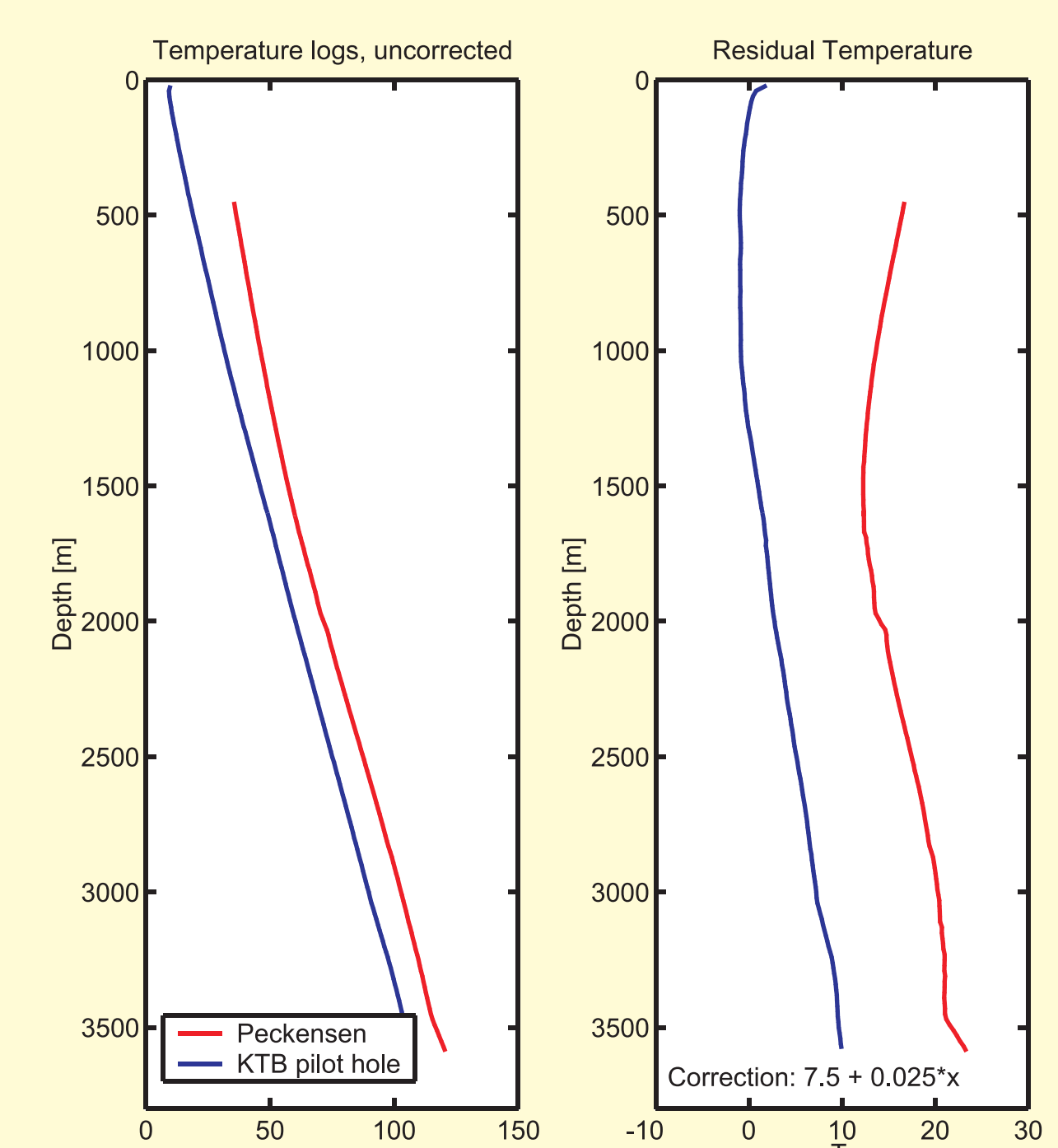

Figure 4: Example of the paleoclimatic analysis. Two boreholes deeper than 3000m were selected for the analysis. Locations are depicted in the small figure. For the inversion of the temperature profiles the code of Mareschal and Beltrami (1992) was used with modifications of Clauser and Mareschal (1995).