Permeability-based 3D model of the subsurface of the city of Darmstadt, Hesse (Germany)

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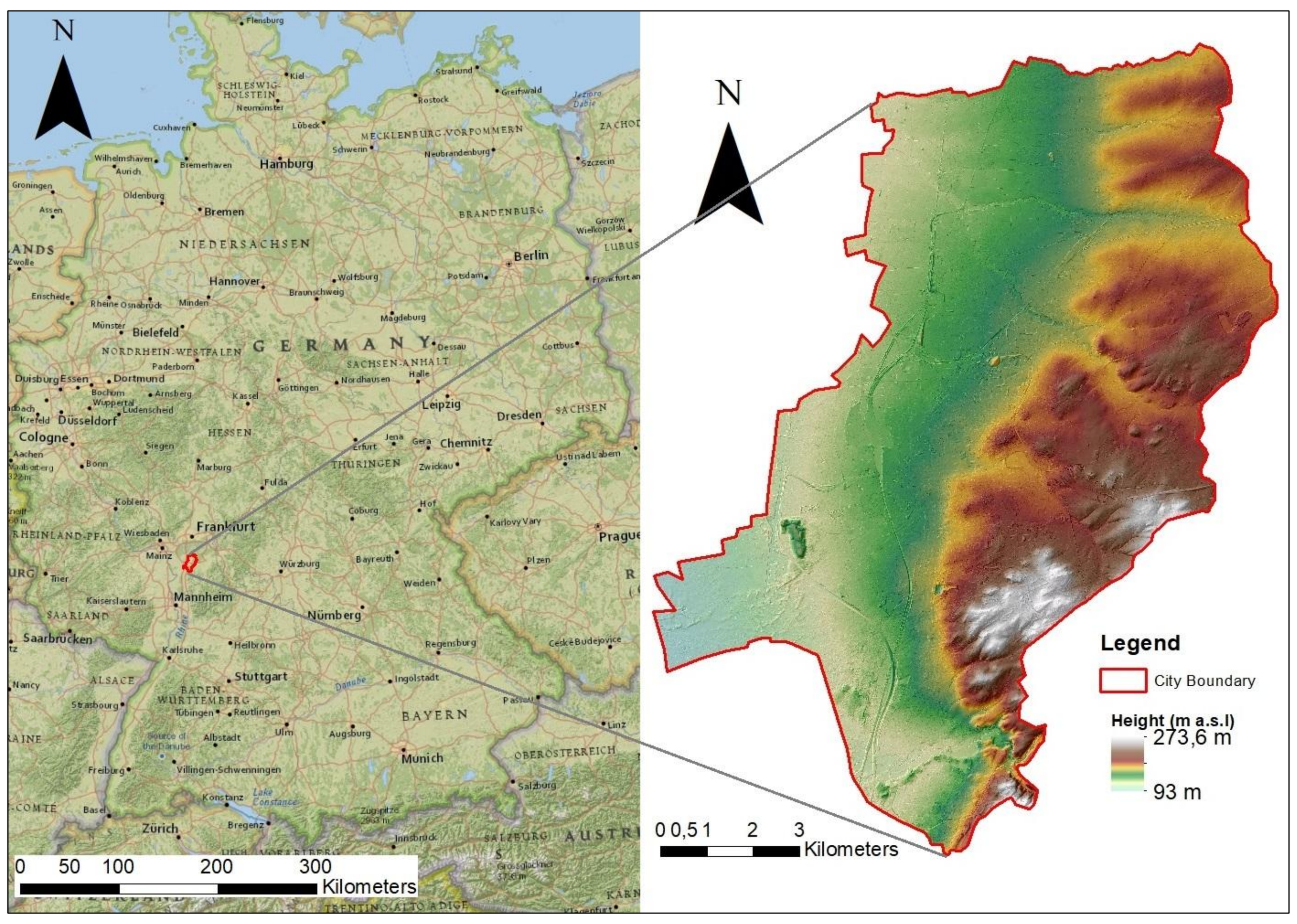

Fig. 1: Overview map of Germany and digital elevation model of the city of Darmstadt

1. Introduction

The project Darmstadt_3D, a cooperation of the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG), the Geoinformation workgroup at Darmstadt University and the city of Darmstadt, targets a high-resolution 3D model of the underground of Darmstadt (Hesse, Germany) (Fig. 1). Works look for an integrated model that combines geology, hydrogeology as well as underground infrastructure. The model is supposed to help i) answering questions on the subrecent development of the northern Upper Rhine Graben (URG) and ii) to make geological content part of decision making in urban planning.

The geological setting of Darmstadt has its origin in the Alpine Orogenesis and related tectonic stresses, which lead to the development of the URG. The eastern master fault of the URG separates Darmstadt into two parts, i.e. the western near-surface area with Quaternary sediments and the crystalline rocks of the Odenwald as well as the Rotliegend of the Sprendlinger Horst in the east (Fig. 2).

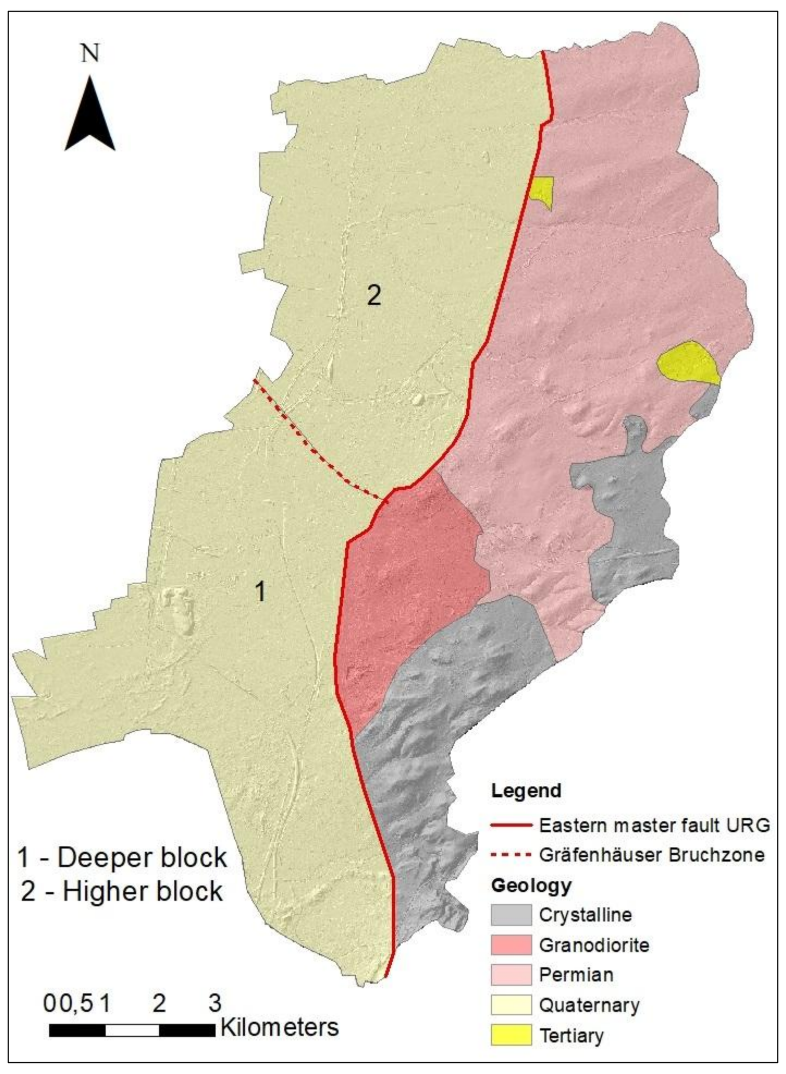

Fig. 2: Geological overview of Darmstadt

2. Methods

The 3D model has been constructed using the software ArcGIS and GOCAD and is based on 1,086 quality checked boreholes from the borehole database of Hesse and the civil engineering department of Darmstadt.

According to the petrographic description, geological layers then have been parameterized by permeability classes to become a more pooled data base (Fig. 3) and interpolated in ArcGIS. Higher permeability classes symbolize lower permeability and vice versa (Tab. 1). The interpolated sections then have been migrated back into the 3D-environment in order to derive depth dependent homogeneous areas.

Due to the geological setting, the final model reaches a maximum depth of 10 m in the east and 30 m in the west of the city, subdivided into 2 m thick depth sections.

Tab. 1: Range of the hydraulic conductivity k_f for loose rock according to Garling & Dittrich (1979) and assignment of conductivity classes according to Krimm (2015).

Loose rock	Hydraulic conductivity k_f (m/s)	Conductivity class
sandy gravel	$3 \cdot 10^{-3}$ - $5 \cdot 10^{-4}$	1
gravelly sand	$1 \cdot 10^{-3}$ - $2 \cdot 10^{-4}$	2
medium sand	$4 \cdot 10^{-4}$ - $1 \cdot 10^{-4}$	3
silty sand	$2 \cdot 10^{-4}$ - $1 \cdot 10^{-5}$	4
sandy silt	$5 \cdot 10^{-5}$ - $1 \cdot 10^{-6}$	5
clayey silt	$5 \cdot 10^{-6}$ - $1 \cdot 10^{-8}$	6
silty clay	$\sim 10^{-8}$	7

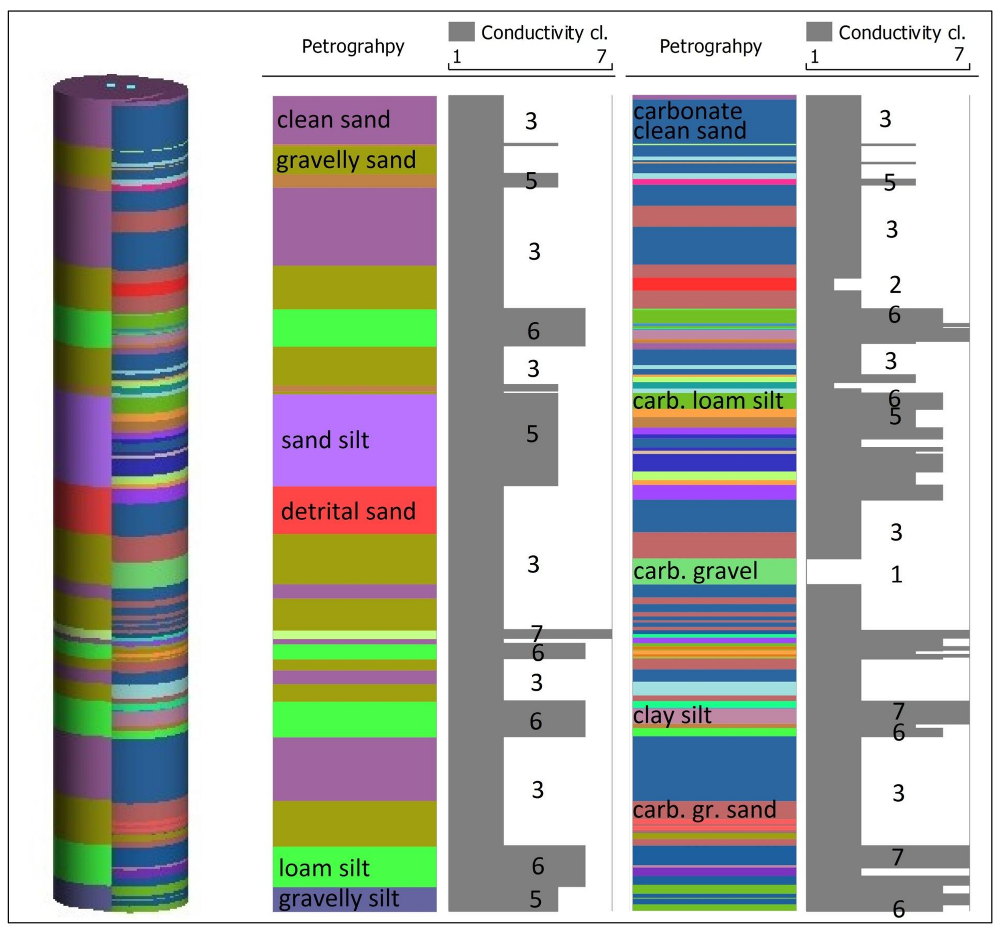

Fig. 3: Petrographical layer descriptions of two drillings (distance 10 meters) show exemplarily the general heterogeneity in the drilling descriptions and the benefits of the corresponding conductivity classes

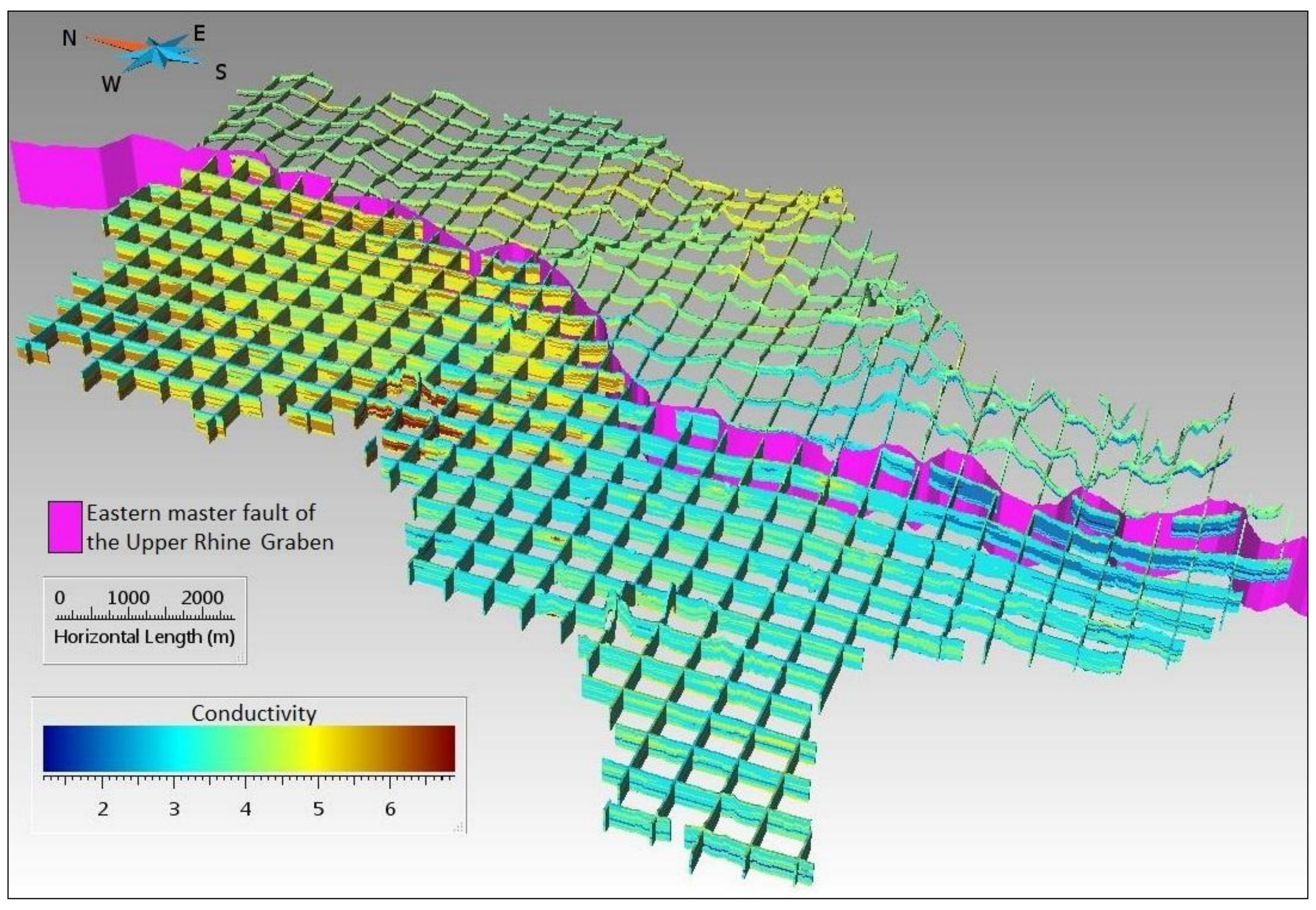

Fig. 4: NE-oriented final 3D model of the area of interest with the permeability classes (blue = low permeability, red = high permeability)

3. Results

The 3D model shows transition zones of lower to higher permeability classes in NNW- to SSE-direction (Figs. 4 & 5). These zones indicate i) a previously unknown Quaternary fault in the eastern part and ii) confirm the existence of the "Gräfenhäuser Bruchzone" in the western part, even if its shape most likely has to be re-described. Both faults fit the orientation of the stress field, leading to a sinistral component in the area. NW of the "Gräfenhäuser Bruchzone" is an area of very high permeability classes that possibly indicate another fault. Furthermore lateral entries (debris) from the rift shoulders are indicated (Fig. 6).

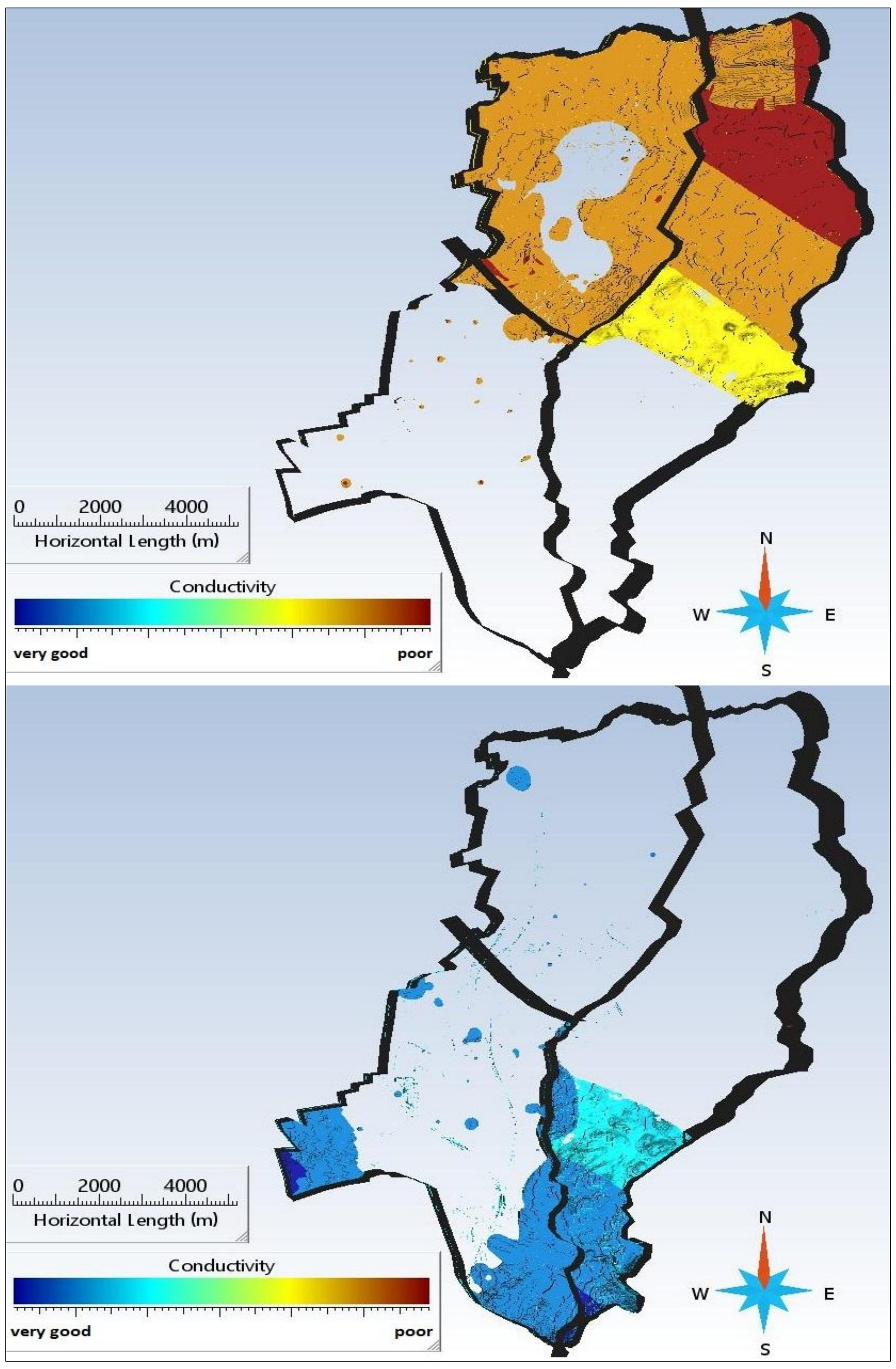

Fig. 5: Conductivity classes 4 – 7 show a domination of fine grained deposits in the northern part (top) while the conductivity classes 1 – 3 show a domination of coarse grained deposits in the southern part (bottom)

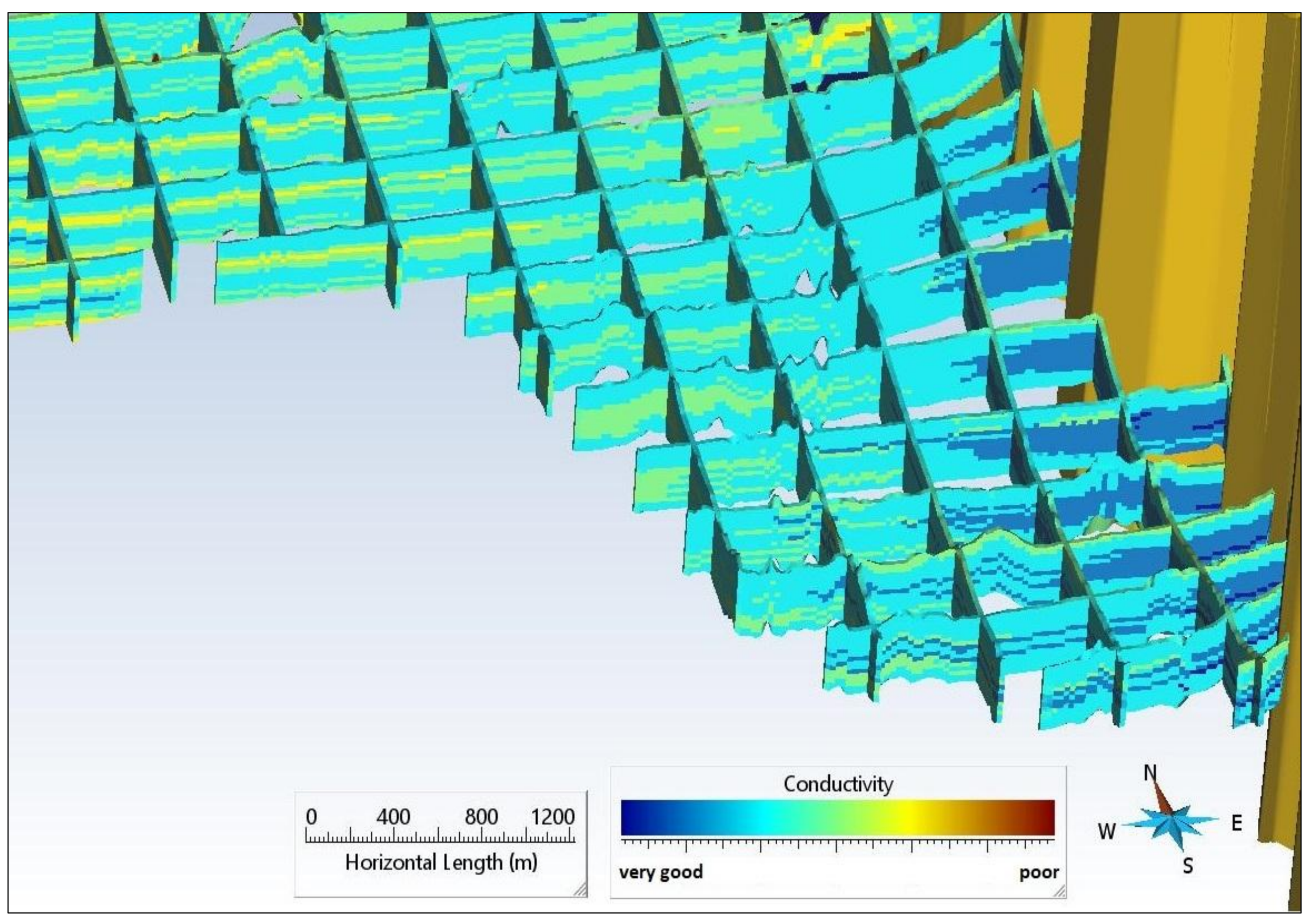

Fig. 6: Lateral input (dark blue) pinching out from the eastern master fault of the URG (yellow) towards the center of the Rhine graben

References

Garling, F., & Dittrich, J.: Hydrogeologie - Gesteinsbemusterung, Leipzig (VEB Deutscher Verlag für Grundstoffindustrie), (1979), 54 pages.

Krimm, J.: Methodischer Vergleich von 2D- und 3D-Modellierungswerkzeugen zur Interpolation von Lockergesteinsparametern in einem hochauflösenden geologischen 3D-Modell als Basis für eine numerische Grundwassersimulation – Fallbeispiel Babenhausen, Masterthesis, Technische Universität Darmstadt, (2015), 118 pages. (unpublished).