Interreg
EVROPSKÁ UNIE
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Evropský fond pro regionální rozvoj

Interreg
EUROPÄISCHE UNION
Österreich-Tschechische Republik
Europäischer Fonds für regionale Entwicklung

AT-CZ 167

HTPO

„Hydrotermální potenciál oblasti / Hydrothermales Gebietspotential“

Output T1.1.1

Structural geological - hydrogeological map series of the thermal water bearing formations in the region

Part I: Structural geological map series

Part II: Hydrogeological map series

HT PO

Co-financed by the European Regional Development Fund

Integration into the project structure:

WP T.1	09/2018-08/2021	Geowissenschaftliches Modell der Thermalwasservorkommen Laa - Pasohlávky	Geovědní model výskytu termálních vod v oblasti Laa - Pasohlávky
Akt. T1.1	09/2018 – 02/2020	Geowissenschaftliches Basismodell der Thermalwasservorkommen Laa - Pasohlávky	Základní geologický model výskytu termálních vod v oblasti Laa - Pasohlávky
T1.1.1		**Strukturgeologisch-hydrogeologische Kartenserie der Thermalwasservorkommen in der Region**	**Strukturně-geologické a hydrogeologické série map výskytu termálních vod v regionu**

The works prior to this output were realized within the activity T1.1. The explanations for these map series can be found in the output T1.1.3 „multilingual explanations related to the compiled thematic maps.

The outputs of this study were most relevant for the following activities:

- Activity T1.4 „Dynamic reservoir model of the thermal waters in Laa and Pasohlávky“
- Activity T1.5 „Measures for supporting the transferability of project results“
- Workpackage T2 „Strategic measures for a sustainable and efficient management and utilization of cross-border thermal waters“

More information and other outputs for the project "HTPO - Hydrothermal potential of the area "Laa an der Thaya - Pasohlávky" can be found at

https://www.at-cz.eu/cz/ibox/po-2-zivotni-prostredi-a-zdroje/atcz167_htpo

https://www.at-cz.eu/at/ibox/pa-2-umwelt-und-ressourcen/atcz167_htpo

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CONTENT

INTRODUCTION

The Project HTPO

The HTPO project deals with the origin, potential and joint management measures of cross-border thermal water resources in the Laa - Pasohlávky region. The thermal waters, which are already used for balneological purposes and which occur at depths of well over 1000 meters below the surface of the earth, have significant potential for future tourist or energetic applications and can contribute to the greening of the region.

Aims of the project

The HTPO project therefore aims to describe these thermal water resources in a joint geoscientific model and to evaluate the associated potential uses and conflicts of use. Based on the best possible knowledge of the thermal water resources in the region, strategies and concrete measures for future joint management are to be worked out together with decision-makers and regional stakeholders.

Aims of activity T1.1

As part of activity T1.1, existing geoscientific archive data are collected, processed and harmonized across borders (e.g. adaptation of formats). In addition, further data, in particular water samples from the existing deep waters, are collected and analysed in a harmonized measurement campaign. As part of the cooperation, cross-border geological and geoscientific basic models (stationary process models) are then set up, which are then subjected to a joint assessment (e.g. zoning of hydrostratigraphic systems or calculation of the expected reservoir temperatures and salinity) and a joint interpretation (e.g. identification of circulation systems and migration paths of the thermal waters in the border region). The determined results are made available to the regional stakeholders of the project as map series.

STRUCTURAL GEOLOGICAL AND HYDROGEOLOGICAL MAP SERIES

The cross-border maps are the product of the collection and processing of geological and hydrogeological data. The explanations for these map series can be found in the output T1.1.3 „multilingual explanations".

Part I: STRUCTURAL GEOLOGICAL MAPS AND OUTPUTS FORM 3D MODEL

Using hydrogeological data, the potentially thermal water bearing geological formations were identified. Using geological data, a 3D model of the relevant geological formations was created (main output T1.1) and is visualized via the structural geological map series. The presented topics include the boundaries as well as the relief and the thickness of relevant hydrostratigraphic systems.

Structural geological 3D-Model

In the first approach, two geological models were created: one by GBA for the Austrian part of the project area, using the SKUA-GOCAD software, and one by the MU for the Czech part of the project area, using the PETREL software. These two models were then merged in order to obtain a coherent model of the potentially thermal water bearing formations.

Database FOR CREATING THE GEOLOGICAL MODEL

Database in Czech Republic

The construction of the geological 3D model for the INTERREG project was on the Czech side based on the available subsurface data i.e. boreholes and 2D seismic profiles. The majority of the data was available as a service provided by the Czech Geological Survey – Geofond. Several hundreds boreholes were drilled in the area under study during the past decades. However, only boreholes with a sufficient depth were used for the geological model. Around 100 boreholes provided data about geological succession ranging from Precambrian basement up to the top of Neogene deposits which were used for the model.

The basal network of data for the model further constitutes of about thirty of 2D seismic profiles (i.e. 522/87, 365/87, 362/87, 357/87, 356/87, 317/84, 304/84, 304A/87, 303/84, 302/84, 298A/84, 298/82, 296/82, 294/82, 289/83, 288/87, 287A/84, 287/84, 286/84, 280/87, 184/75, 184/82, 183/75, 182A/82, 181/75, 153/74, 102/82, 63/88, 62/89, 61/88). Results of the seismic profiles were provided based on the agreement between Faculty of Science, Masaryk University and the Ministry of Environment of the Czech Republic.

Database in Austria

3D model from preliminary project "GeoMol" (2012 - 2015)

The basis of the 3D model on the Austrian side is the structural model from the EU Interreg project GeoMol. The data basis for this project is explained in detail in the publication (Pfleiderer, 2016), Chapter 2.1. Around 700 published drilling profiles, 150 published profile sections and 24 published stratification maps were used to model the entire Molasse zone in Austria. However, since this model was created on a relatively coarse scale and covers an area around 20 times as large, additional data had to be processed for the model in order to be able to characterize the area on a more detailed scale. In addition, five additional horizons were modeled.

Thermal water drilling Laa / Thaya

The "Laa TH S1" and "Laa TH N1" wells in Laa an der Thaya represent the only wells for the use of thermal water in the project area. This makes them the most important data source for the presentation of the hydrogeological conditions in the region. The geological profiles of the boreholes also provide valuable information for creating the geological model.

Hydrocarbon exploration drilling

The wells for hydrocarbon exploration in the project area provide indispensable information about the structure and rock properties of the deep underground. For the geological modeling, 33 drilling profiles from OMV AG could be used, which reach the Mesozoic basin underground. The deepest boreholes in the area have depths of around 3500 m (Staatz 1 and Stronegg 1), the majority of the boreholes cover an area between 1500 and 2500 m. The wells were drilled between 1945 (Fallbach 1) and 2000 (Buchberg B3).

Published cross sections

Cross sections not only provide an indication of the depth of the horizons at the drilling points shown, but also provide valuable information on the regional geological situation, fault courses, etc. Some cross sections are based purely on the interpretation of information from boreholes, but others are also based on an interpretation of existing 2D or 3D seismics.

The most important publications from which cross sections were used for the modeling are listed below: Explanations on sheet 23 Hadres (Roetzel et al., 2009); Geology of the Austrian Federal States - Lower Austria (G. Wessely et al., 2006); The results of the exploration work of the ÖMV AG in the Molasse zone of Lower Austria in the years 1957-1963 (Friedrich Brix & Götzinger, 1964); The Mesozoic sediment fraction of the continental shelf of the Bohemian mass (Kapounek et al., 1967).

Published structural maps

Over the years some structural maps of the region have been published. These often provide useful information on the depth of a horizon, information on the location of fault zones and the spread of horizons. They are often based on 3D seismic interpretations in combination with borehole data as well as interpretations of other geophysical variables such as magnetics or gravity. The most important structural maps that were used for the modeling are listed below: Molasse zone Lower Austria and adjacent areas 1: 200,000: Geological map of the molasse base (Kröll & Wessely, 2001); Thickness and structure map for the autochthonous Mesozoic Era, structure map upper edge crystalline (Kapounek et al., 1967); Geological map of the molasse base (G. Wessely) in explanations to sheet 23 Hadres (Roetzel et al., 2009).

Results from the geological model

The AT-CZ model of the hydrogeologically relevant modeled formations was published in a publicly accessible web 3D viewer (https://3dviewer.europe-geology.eu/?model_id=33) and at the same time serves as the geometric basis for the hydrogeological 3D model. As a result of the geological model, structural maps were created.

Web 3D Viewer

The Geological Survey of Austria published the first version of a 3D viewer back in 2015, which can be accessed via various web browsers without installing any software. The application was further developed by GBA as part of the GeoEra consortium and published on its platform in summer 2021 as part of the EGDI Initiative (European Geological Data Infrastructure), which provides Europe-wide access to data from European geological services.

Structural maps

The structural maps created from the geological model show the distribution, depth and drilling markers of the respective formations. The data base and results are explained in more detail below.

Base Eggenburgian

The Eggenburgian deposits were documented only in Czech part of the area under study: They form approx. 10x7 km large erosional relic in the NE part of studied area. This depositional system was interpreted in time using eleven of 2D seismic sections. Five wells were used for calculation of velocity model for final depth surface.

Base Egerian

The distribution of the sediments of the Egerian is almost exclusively limited to the Austrian model area; no evidence of this epoch has been described on Czech territory. In the publication by Seifert and Jiricek (Jiricek & Seifert, 1990) the distribution of the formation and the thickness distribution are described; this also shows the extent up to the Austrian-Czech border, but not beyond. The regional distribution of the formation was modeled on the basis of this publication and supplemented with information from boreholes and profile section series such as (Roetzel et al., 2009) and (G. Wessely et al., 2006).

For the modeling of the Egerian, only 12 well markers from the hydrocarbon exploration wells and 2 from the Laa TH wells were available. All of them penetrated the horizon and could therefore also be used to calculate the thickness distribution. The structure map of the Molasse base (Kröll & Wessely, 2001) based on seismic interpretation and boreholes was used to determine the base and was adapted in areas using information from more recent boreholes. The horizon lies at depths between -500 and -1700 m below Adrianull, with a maximum modeled thickness of 250 m, the greatest proven thickness is 220 m (Roggendorf 1).

Base Altenmarkt Formation („Aquifer“)

The distribution was proven by 22 well markers on the Austrian and 16 well markers on the Czech side, and extends over large parts of the project area, towards the east it pinches out at in the area of Pottenhofen - Wildendürnbach - Gaubitsch. Although the western state border between Laa / Thaya and Altprerau is essentially also the limit of distribution, according to (Adámek, 2005) the formation in the Altprerau area continues into the Czech Republic with great thickness, as e.g. the Březí 1 well shows. Further east, in extension of the boreholes around Pottenhofen, the Březí 2 borehole, Adámek no longer describes an Altenmarkt formation, but rather a basinal development. However, since the Altenmarkt formation was described in the Pottenhofen 2 borehole, it can be assumed that the formation pinches out in the border area to Březí.

11 well markers were available for modeling the base Altenmarkt Formation, modeled depths are between about -1000 and -2700 m below Adrianull with the greatest proven depth in the Laa TH S1 hole with -2340 m. The maximum modeled and also measured thickness is 660 m in the Altenmarkt 1 borehole.

Base Kurdejov Formation

Occurrence of the deposits of the Kurdějov Formation was interpreted in the area of the Czech Republic based mainly on the results of 15 seismic sections and 14 boreholes. The carbonates of the Kurdejov Fm. are in the NE part of the area under study developed above the basinal facies of the Mikulov Marls.

Base Middle Jurassic

Occurrences of the sedimentary rocks of the Middle Jurassic can be found in both countries, but the great depths and thicknesses are limited to the Austrian side of the project area. There are only locally limited deposits in the Czech Republic, which could only be detected by individual boreholes. According to (Adámek, 2005), Dogger was found to be thin in the Mikulov 1 borehole, so the distribution on the Austrian side was adjusted accordingly. The distribution was proven in Austria by 12 well markers, the base was penetrated by 9 of these wells.

Modeled depths are between -300 and -4300 m below Adrianull with the greatest proven depth in the Staatz 1 borehole at -3370 m. The maximum modeled thickness is 2500 m south of the Mailberger Bruch, the maximum proven thickness is 1060 m in the well Porrau 2.

Top Crystalline Basement

The Crystalline Basement of the Bohemian Massive represents the deepest model unit. It was reached by 14 wells on the Austrian and 45 wells on the Czech side of the model area. To the west of the area, the formation lies relatively shallow in depths only about 100 m under terrain and reaches great depths of up to -4300 m below Adrianull to the southeast of the area.

Part II: HYDROGEOLOGICAL MAPS

Hydrogeological maps were created on the basis of data from the geological model. Those data were used for the background maps and for the construction of the model of the studied hydrogeological structure. This structure consists of the main Jurassic carbonate aquifer (Altenmarkt Gr.) and hydraulically connected underlying and overlying layers. Attached hydrogeological maps show data that were fundamental for the numerical groundwater flow model described in WPT1.4.

PART I: STRUCTURAL GEOLOGICAL MAP SERIES

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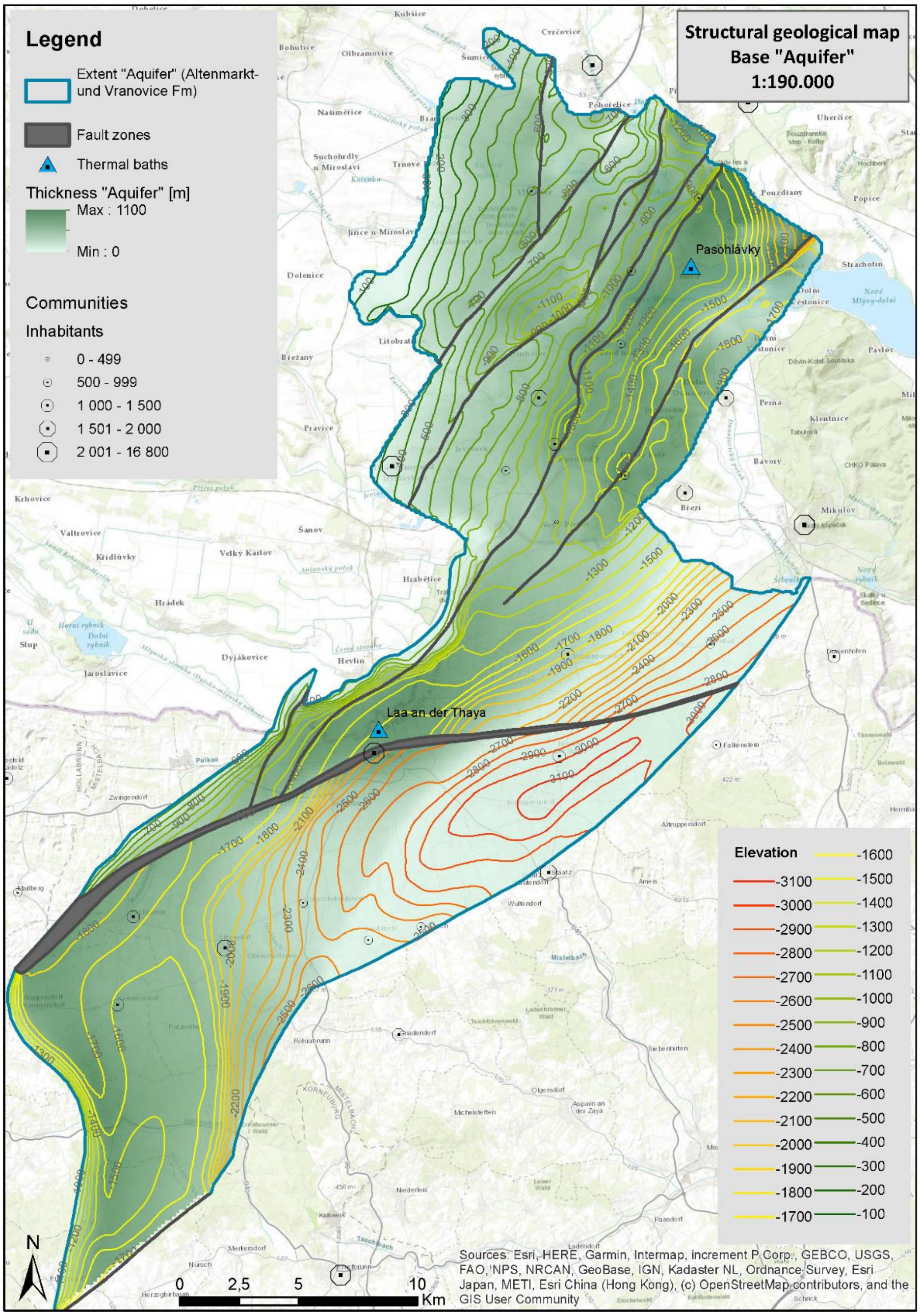

Figure 1: Map of the thickness and structure of the main thermal water bearing geological formation, the base „Aquifer“ – the base of the Altenmarkt and Vranovice Formation in the scale of 1:190.000. Structural data is exported from the geological 3D model (main output T1.1).

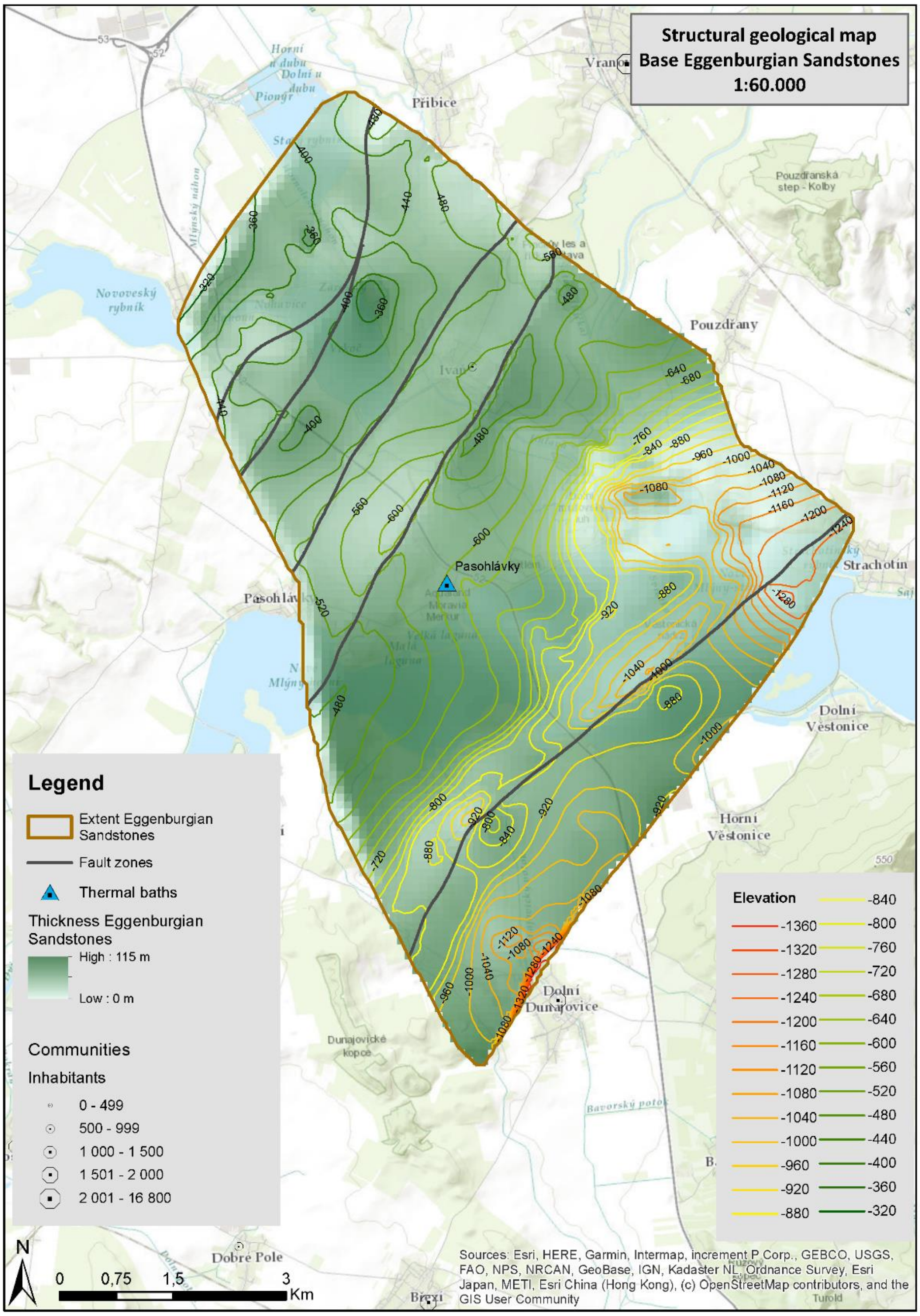

Figure 2: Map of the thickness and structure of the base Eggenburgian Sandstones in the Czech Republic in the scale of 1:60.000. Structural data is exported from the geological 3D model (main output T1.1).

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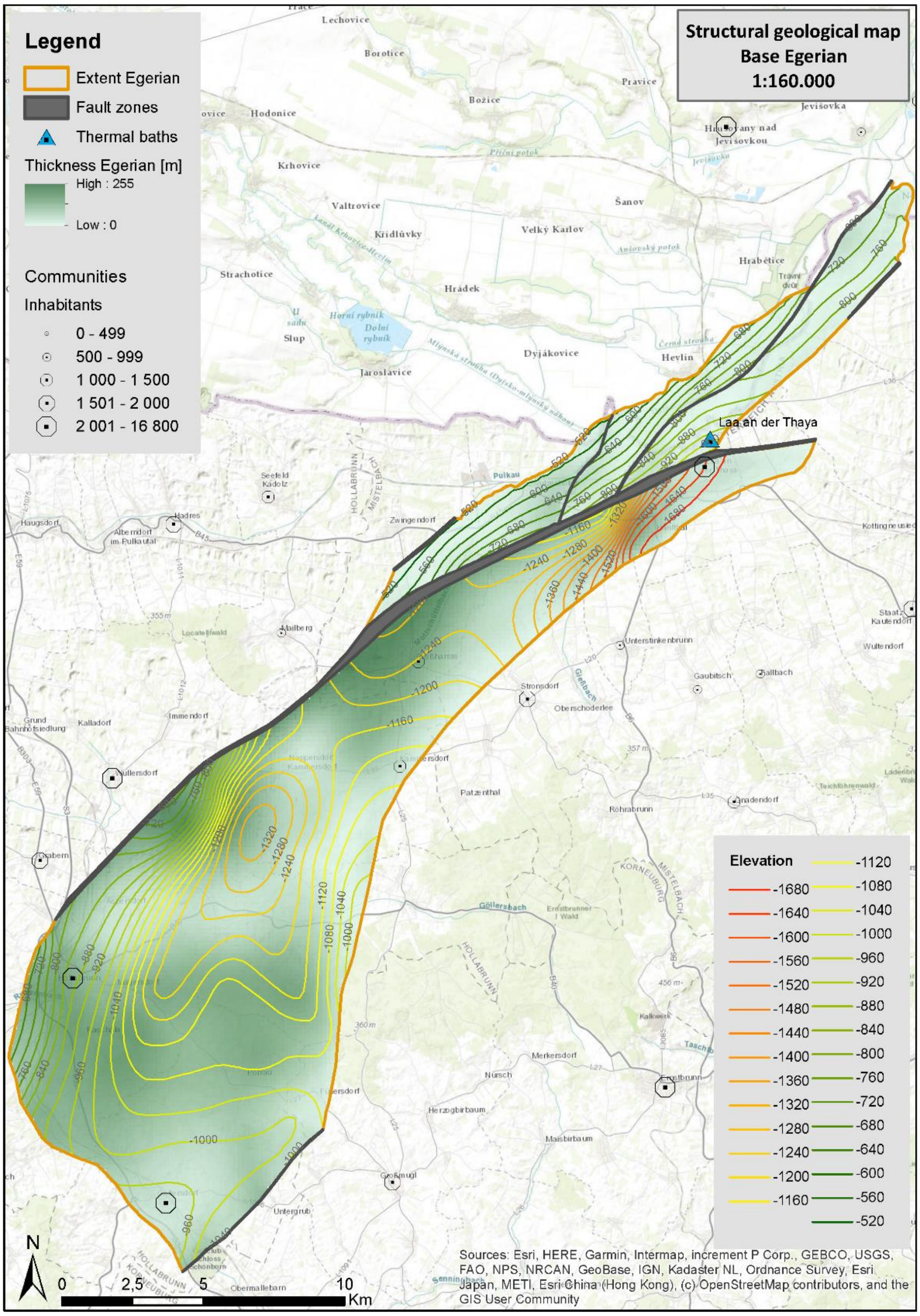

Figure 3: Map of the thickness and structure of the base Egerian Sandstones in Austria in the scale of 1:160.000. Structural data is exported from the geological 3D model (main output T1.1).

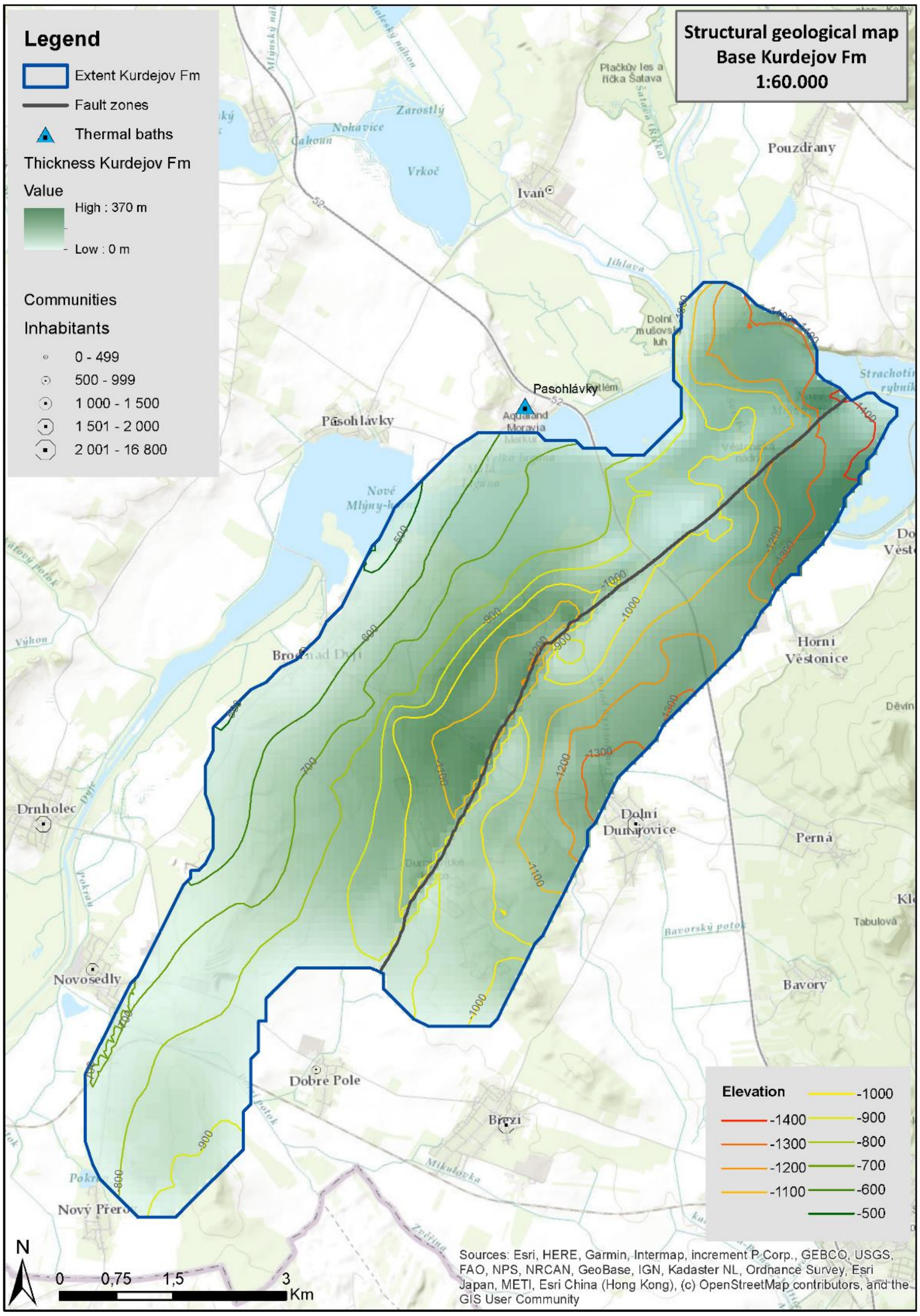

Figure 4: Map of the thickness and structure of the base Kurdejov Formation in the Czech Republic in the scale of 1:60.000. Structural data is exported from the geological 3D model (main output T1.1).

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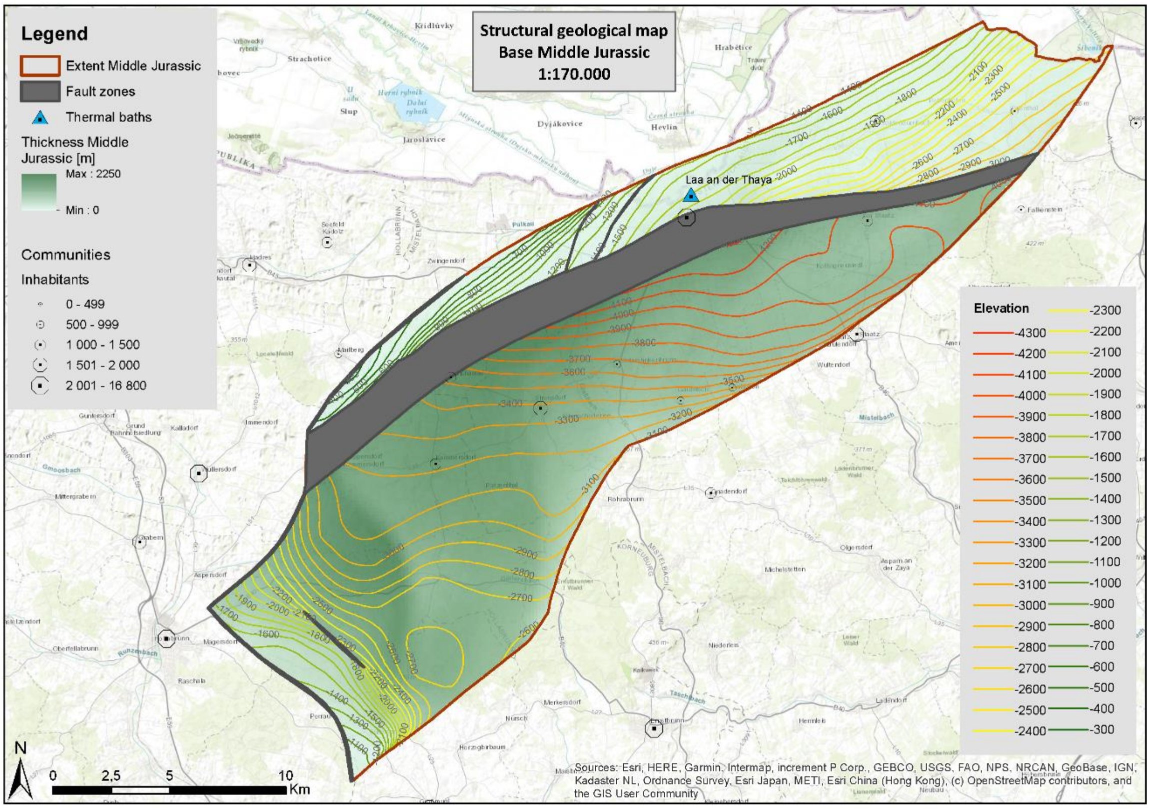

Figure 5: Map of the thickness and structure of the base of Middle Jurassic deposits in Austria in the scale of 1:170.000. Structural data is exported from the geological 3D model (main output T1.1).

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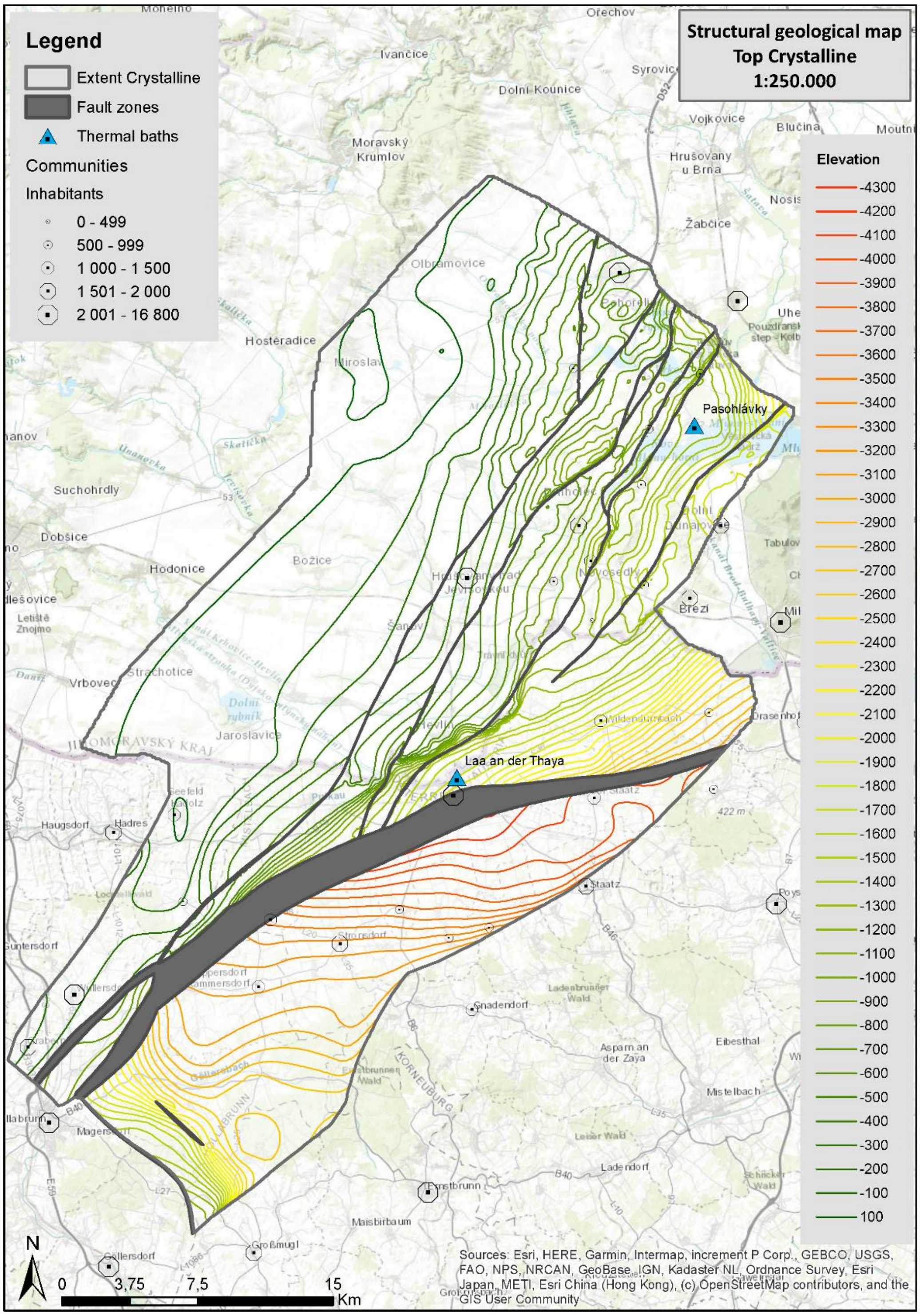

Figure 6: Map of the thickness and structure of the base of top Crystalline Basement in the scale of 1:250.000. Structural data is exported from the geological 3D model (main output T1.1).

Map of hydrostratigraphic units

On the map in Figure 7Figure **7**, the model of the hydrogeological structure (based on the geological model) is shown in the left part of the figure. This model consists of six hydrostratigraphic units, which are distinguished by different colours: Crystalline rocks – red, Middle Jurassic (Dogger) – dark blue, Upper Jurassic: Altenmarkt Gr., main aquifer – blue, Mikulov Marls – grey, Kurdejov Lm. – light blue and Lower Miocene (Egerian and Eggenburgian) – yellow. The legend for these units is located in the upper left corner. The model shows the location of the active thermal water wells. This location is represented by a black dot with a description of the well name MUS-3G and Laa TH N1. In the close vicinity of these deep wells, two cross-sections were created: AA' by the well MUS-3G and BB' by the well Laa TH N1. The cross-sections are represented by a white line with the description. The map is completed by a graphic scale and a north arrow. The cross-sections are shown in the right part of the figure. The cross-sections show the intersected hydrostratigraphic units and the position of the pumped wells – in the cross-section AA' there is the well MUS-3G and in the cross-section BB´ there is the well Laa TH N1. The cross-sections are supplemented by the vertical scale with the depth values in metres above sea level (masl). Each cross-section has the graphic scale and the north arrow. The hydrogeological model and cross-sections are 3x exceeded for a better illustration. The model was created in the software Groundwater Modeling System (GMS, Aquaveo) and subsequently processed in the program Surfer (Golden Software). Because of the used features in Surfer (Golden Software), the map was supplemented by graphic scale, not representative fraction in ratio 1:50000.

Map of hydraulic heads

On the map in Figure 8, there are the derived hydraulic heads ($h_{f,i}$) plotted on the background map of the surface of the main Jurassic carbonate aquifer (Altenmarkt Gr.). The background map was created on the basis of data from the geological model, which were used in the form of XYZ points. This background map shows the top of Jurassic carbonates that lie at depths approx. from 100 to 3000 m below sea level. The top of Jurassic carbonates is displayed in shades of blue colour, the darker it is, the deeper they lie. The map includes a colour scale showing the depth of the top of the Jurassic aquifer in metres above sea level (masl), the scale shows an interval of 200 m, the shallowest parts are displayed in light blue and the deepest parts in dark blue colour. For a better visualization of the depths, the background map is supplemented by light grey isolines. On the map there are also faults displayed in the form of dark grey thin lines. The map shows the location of deep wells (reaching the aquifer) by a black dot. By the each well, there is the label with the well name and given hydraulic head ($h_{f,i}$). The map also shows the course of the Dyje river, the main river in the studied area, which is represented by the blue line. By this line there is the label with the river name and the arrow showing the flow direction. The state border is displayed as a black line with the label CZ/AT. In the lower part of the map there is a graphic scale and the north arrow. Below the map there is a legend. The map was processed in the program Surfer (Golden Software). Because of the used features in Surfer (Golden Software), the map was supplemented by graphic scale, not representative fraction in ratio 1:50000.

Map of hydraulic conductivities

On the map in Figure 9, there are the derived hydraulic conductivity values plotted on the background map of the surface of the main Jurassic carbonate aquifer (Altenmarkt Gr.). The background map was created on the basis of data from the geological model, which were available in the form of XYZ points. This background map shows the top of Jurassic carbonates that lie in depths approx. from 100 to 3000 m below sea level. The top of the Jurassic carbonates is displayed in the shades of blue colour, the darker it is, the deeper lie the carbonates. The map includes a colour scale showing the depth of the top of the Jurassic aquifer in metres above sea level (masl), the scale shows an interval of 200 m, she shallowest parts are displayed in light blue and the deepest parts in dark blue colour. For a better visualization of the depths, the background map is supplemented by light grey isolines with the given labels. On the map there are also faults displayed in the form of dark grey thin lines.

The map shows the location of deep wells (reaching the aquifer) by a black dot. By each well, there is the label with the well name and given hydraulic conductivity values (m/s). The hydraulic conductivity values of the Lower Miocene sediments are displayed by brown colour, the Kurdejov Lm. by light blue colour, the Jurassic carbonates (Altenmarkt Gr.) by blue colour, the Dogger by dark blue colour and the Crystalline rocks by red colour. The map also shows the course of the Dyje river, the main river in the studied area, which is represented by a blue line. By this line there is the label with the river name and the arrow showing the flow direction. The state border is displayed as a black line with the label CZ/AT. In the lower part of the map there is a graphic scale and the north arrow. Below the map there is a legend. The map was processed in the program Surfer (Golden Software). Because of the used features in Surfer (Golden Software), the map was supplemented by graphic scale, not representative fraction in ratio 1:50000.

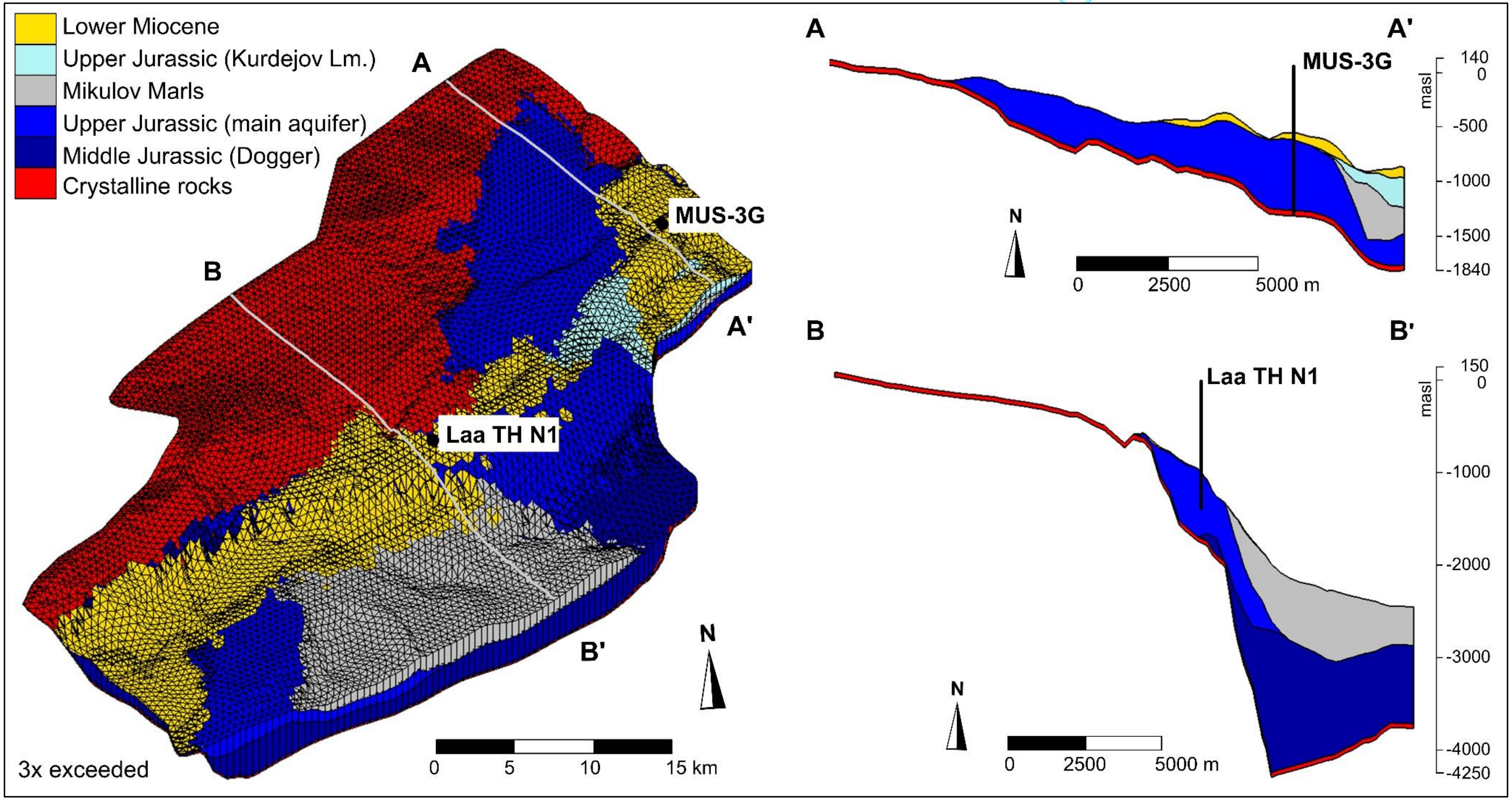

Figure 7: Map of the hydrostratigraphic units based on the geological model. The map shows the 3D model of the hydrogeological structure and two cross-sections AA‘ and BB‘ created in the close vicinity of the thermal wells MUS-3G and Laa TH N1.

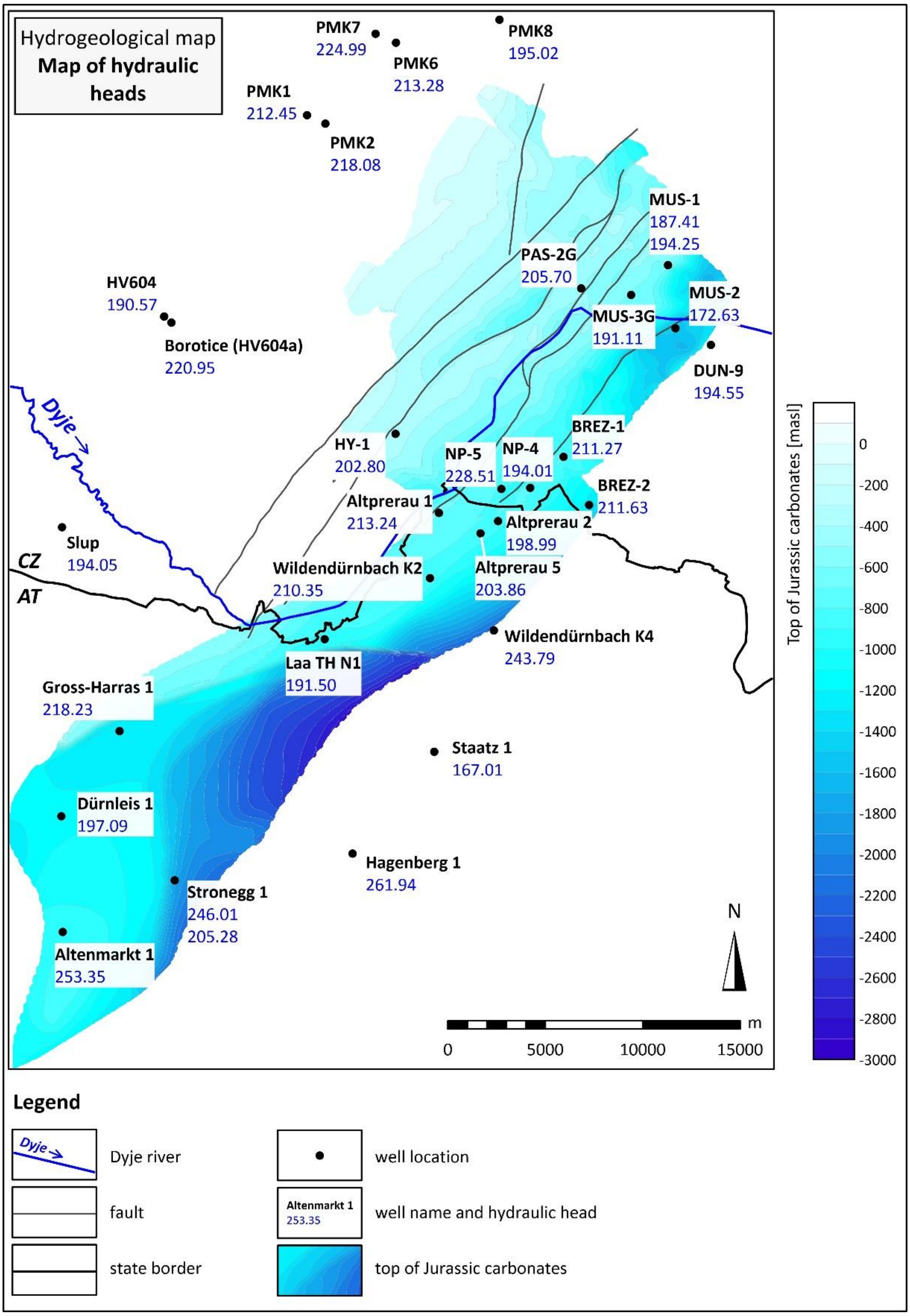

Figure 8: Map of hydraulic heads on the background map of Jurassic carbonates. Hydraulic heads were derived from pressure measurements and direct observations at 30 deep wells. The map was processed in Surfer (Golden Software).

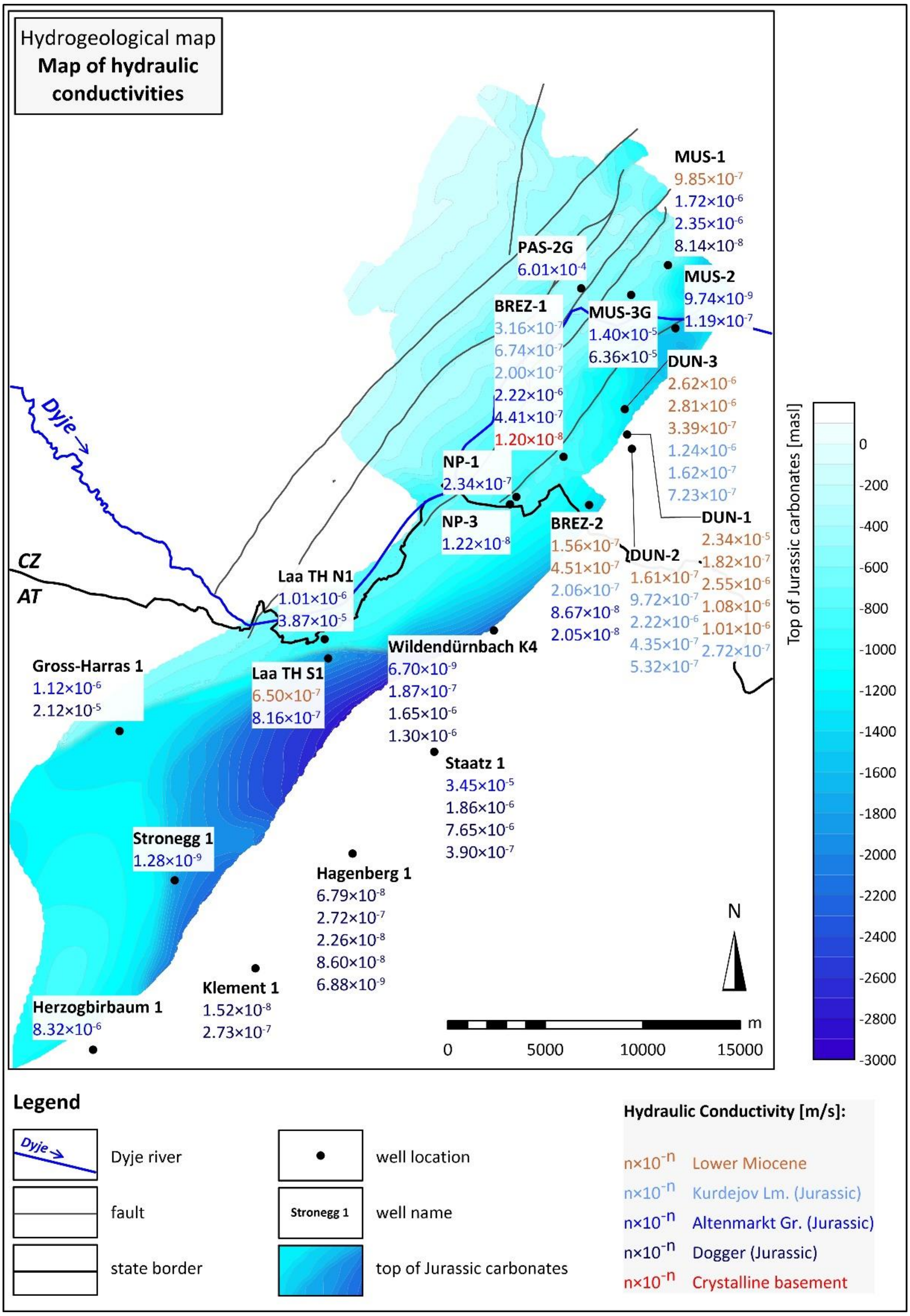

Figure 9: Map of hydraulic conductivities on the background map of Jurassic carbonates. The map was processed in Surfer (Golden Software).

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