TA ČR project TK05020137 “Development of the play-fairway system for the low-temperature geothermal system exploration in sedimentary basins; with application to the Vienna Basin“

Final Report, 31st March, 2025

Planned Aim

Aim of the project was to develop the play-fairway-map construction technique for low-temperature geothermal systems in sedimentary basins in the GIS environment. The goal was to parameterize the exploration by the system of factors characterizing the geothermal system, its efficiency and its engineering geology characteristics, such as production index for specific power producing technology, reinjection index, environmental impact index and cost index for specific technology; to subsequently normalize those factors and, finally, combine them in such a way that the color-coded play fairway map indicates areas of the basin with the best potential for the geothermal system commercialization, fair potential, poor potential and areas lacking data allowing their evaluation.

Planned Schedule

The project schedule was set for 2 years. Stage 1 of the project (March 2023 – March 2024) was focused on the development of the database, which contains structural geology, lithological, thermal and geochemical data. The development included a map visualization of the aforementioned data. The data were planned to be collected from about 400 hydrocarbon exploration/production wells located in the Czech portion of the Vienna Basin. Stages 2-3 of the project (March 2024 – March 2025) included: Stage 2 focused on the parameterization of the factors controlling the existence of low-temperature geothermal systems in the study area and risks associated with their successful commercialization and Stage 3 focused on the development of the Arc GIS-based play fairway map.

Results developed between the end of year 2024 and 31st March 2025

The research team consisting of the work group of the Technical University Ostrava (TUO) and work group of the Moravské Naftové Doly (MND) spent the time interval of January – March 2025 on:
1) the calculation of parameters needed for the play-fairway map development, and
2) the play-fairway map development.

Indexes and parameters calculated for the needs of the play-fairway map development

The first calculated parameter, which was used for the construction of the play fairway map of the Czech portion of the Vienna Basin is the ***Thermoelectric Production Index***, represented by the ratio P/P_r (Soldo and Alimonti, 2015). P is the thermal energy of the reservoir, calculated from the equation:

$$P = (\rho_{oil} c_{p\ oil} + WOR*\rho_{water} c_{p\ water})\ Q_t \Delta T/(WOR+1),$$

where ρ is the geothermal fluid density, c_p is the specific heat of the fluid, Q_t is the quantity of the fluid flow, ΔT fluid temperature change, which equals to the temperature of the penetrated reservoir in well minus the average annual surface temperature in the Czech Republic (9.7 °C in year 2023 according to the web site Statista), and WOR is the water/oil ratio in the geothermal fluid. Pr is the reference value of the energy, which is equal to the output of the ORC power plant. It ranges from 1 to 5 MW according to the power plant type.

The second calculated parameter is the ***Temperature Flow Rate Index***, represented by the ratio q/T (Soldo and Alimonti, 2015). q is the rate of the inflow of the geothermal fluid from the reservoir and T is its temperature.

The third calculated parameter is the ***Outlet Temperature Index***, represented by ratio $T_i/(2T_{min})$ (Soldo and Alimonti, 2015), which correlates the temperature of the geothermal fluid at well outlet with characteristic temperature of the power plant converting the thermal energy of the reservoir into the electric energy.

The fourth calculated parameter is the ***Corrosion Index,*** derived from the Langelier Saturation Index (LSI), defined as (Roberge, 2007):

$$LSI = pH - pH_s,$$

where pH is the measured pH of the geothermal fluid flowing into the well and pH_s is the pH of the fluid saturated by calcite or $CaCO_3$, which is calculated from the equation:

$$pH_s = (9.3 + A + B) - (C + D),$$

where
$A = [Log_{10}(TDS) - 1]/10$
$B = -13.12 * Log_{10}(^{o}C + 273) + 34.55$
$C = Log_{10}[Ca^{2+} \text{ as } CaCO_3] - 4$
$D = Log_{10}[\text{alkalinity as } CaCO_3]$
TDS = total dissolved solids in the fluid.

Results of this calculation were divided into the following categories (Carrier Air Conditioning Company, 1965):

LSI	Indication
-2,0<-0,5	Serious corrosion
-0,5<0	Slight corrosion
LSI = 0,0	Balanced but pitting corrosion possible
0,0<0,5	Slight corrosion
0,5<2	No corrosion

The fifth calculated parameter is the ***Cementation Index***, derived from the LSI described in the text on the previous index. Calculated results were divided into the following categories (Carrier Air Conditioning Company, 1965):

LSI	Indication
-2,0<-0,5	No scale formation
-0,5<0	No scale formation
LSI = 0,0	Balanced, no scale formation
0,0<0,5	Slight scale formation
0,5<2	Scale formation

The last calculated parameter is the ***Cost Index***, represented by the time of the return of the (1) initial investment into the power plant, (2) investment into the construction and completion of the entire electric power-developing system, (3) investment into all annual maintenances and (4) investment into the energy spent on the power plant activity.

NOTE:
Originally planned calculation of the Pumping Aided Production Index, represented by the ratio E_p/E (Soldo and Alimonti, 2015), was omitted, because its impact on the final state of the play-fairway map overlaps with impact of the Cost Index to a certain extent, which would cause an artificially enhanced cumulative impact of these two indexes on the final map.

Play-fairway map

Thermoelectric Production Index was divided for a need of the play-fairway map development into the following categories:

Range	$P/P_r < 0.1$	$0.1 \le P/P_r < 0.2$	$0.2 \le P/P_r < 0.4$	$0.4 \le P/P_r < 0.6$	$0.6 \le P/P_r < 1.0$	$P/P_r \ge 1.0$
I_p	0	0.2	0.4	0.6	0.8	1

The first two columns from the left represent the category „poor“, following two columns represent category „fair“ and the last two columns represent category „good“. **Fig. 1** shows the study area and its characteristics by the Thermoelectric Production Index, together with location of data used for its development, and indication of the territory lacking the data coverage.

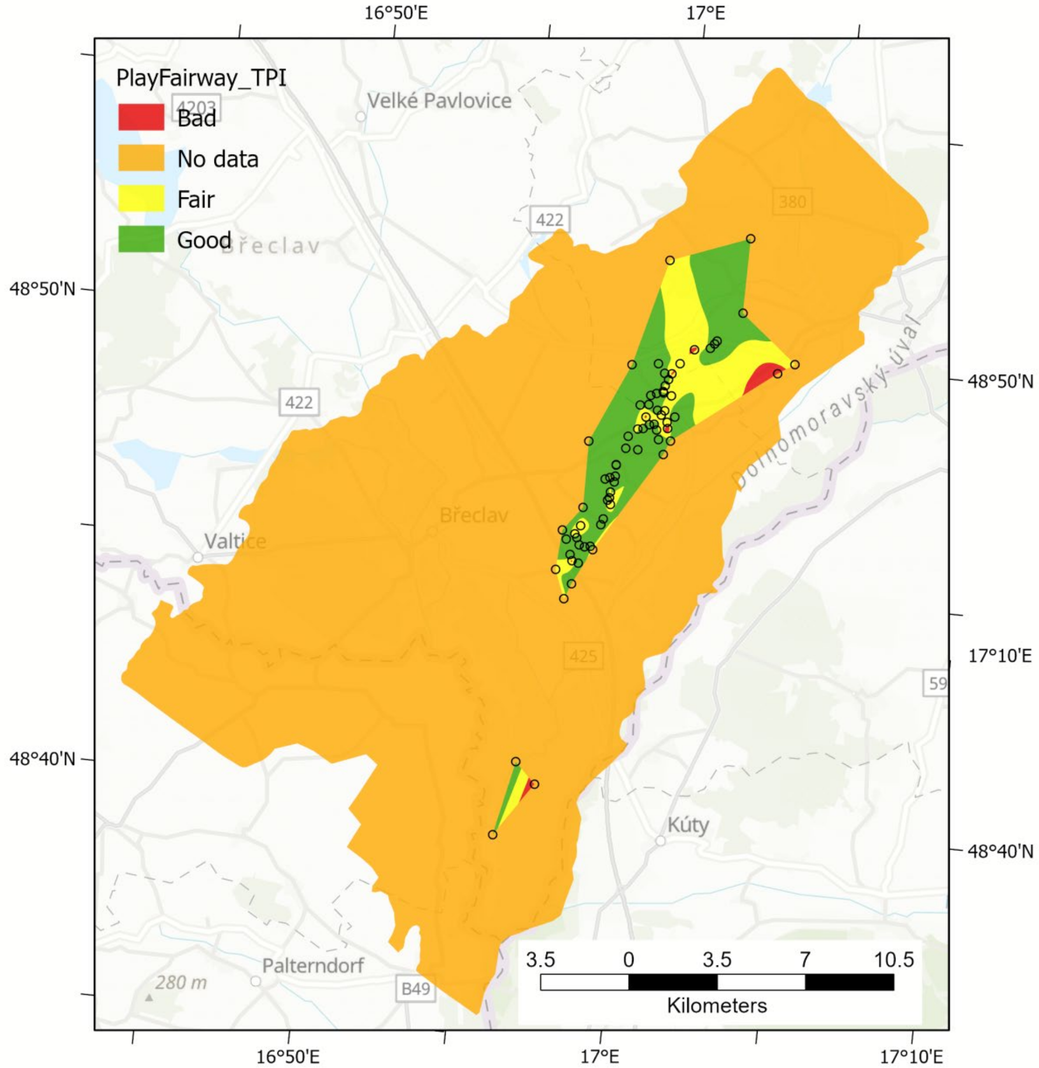

Fig. 1. Map of the Thermoelectric Production Index of the study area.

The ***Temperature Flow Rate Index*** was divided for a need of the play-fairway map development into the following categories:

Range	q/T < 0.055	0.055 ≤ q/T < 0.125	0.125 ≤ q/T < 0.55	0.55 ≤ q/T < 12.5	q/T > 12.5
I_{qT}	1	0.75	0.5	0.25	0

The category „good“ is represented by the first two columns from the left, the category „fair“ by the following two columns and the category „poor“ by the last column. **Fig. 2** shows the study area and its characteristics by the Temperature Flow Rate Index, together with location of data used for its development, and indication of the territory lacking the data coverage.

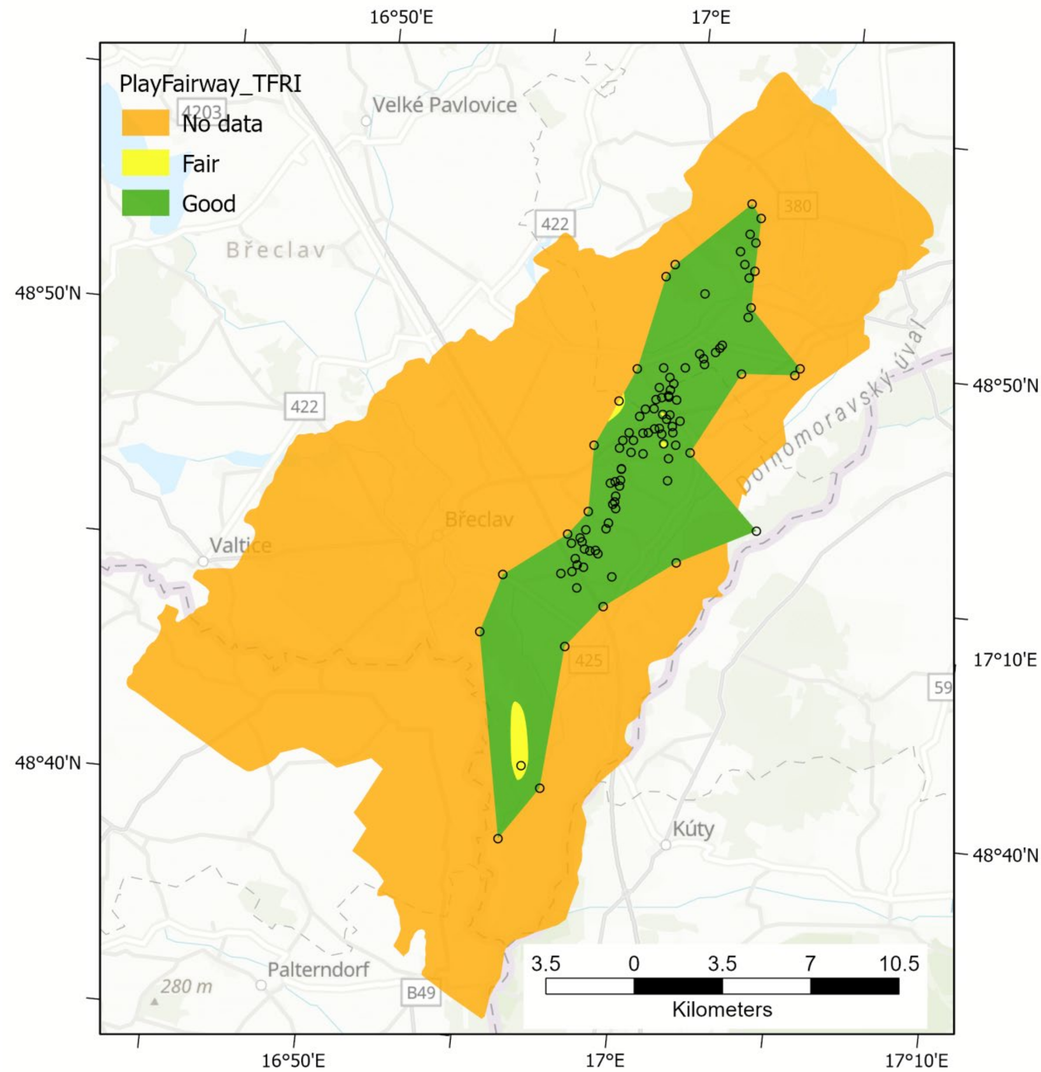

Fig. 2. Map of the Temperature Flow Rate Index of the study area.

The Outlet Temperature Index was divided for a need of the play-fairway map development into the following categories:

Range	$T_i/(2T_{min}) < 1$	$T_i/(2T_{min}) \geq 1$
I_{Texit}	0	1

The category „inappropriate area“ is represented by the left column and the category „appropriate area“ by the right column. **Fig. 3** shows the study area and its characteristics by the Outlet Temperature Index, together with location of data used for its development, and indication of the territory lacking the data coverage.

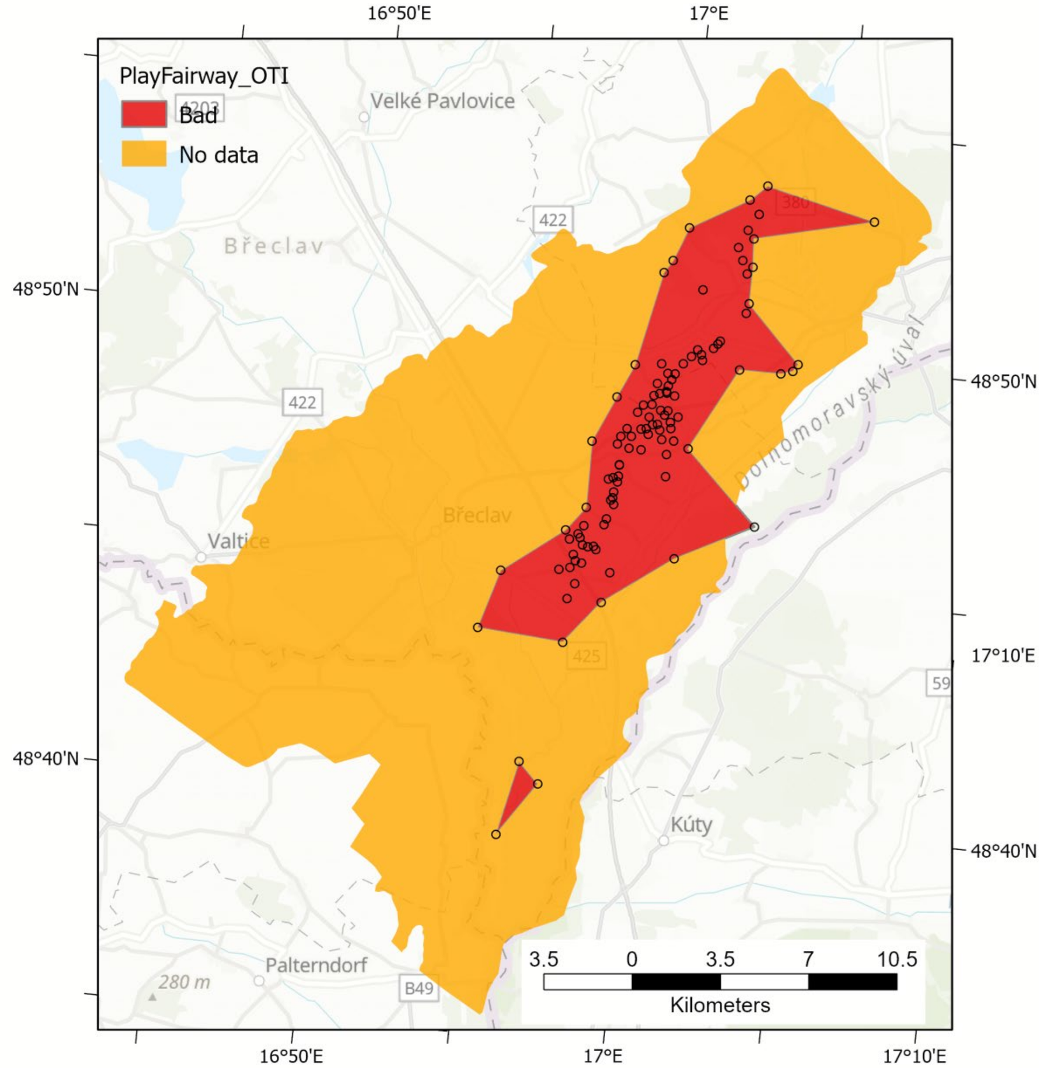

Fig. 3. Map of the Outlet Temperature Index of the study area.

The Corrosion Index was divided for a need of the play-fairway map development into the following categories:

LSI	Indication
-2,0<-0,5	Serious corrosion
-0,5<0	Slight corrosion
LSI = 0,0	Balanced but pitting corrosion possible
0,0<0,5	Slight corrosion
0,5<2	No corrosion

Category „poor“ is represented by the first row from the top, category „fair“ is represented by the second row, category „good“ is represented by the remaining rows. **Fig. 4** shows the study area and its characteristics by the Corrosion Index, together with location of data used for its development, and indication of the territory lacking the data coverage.

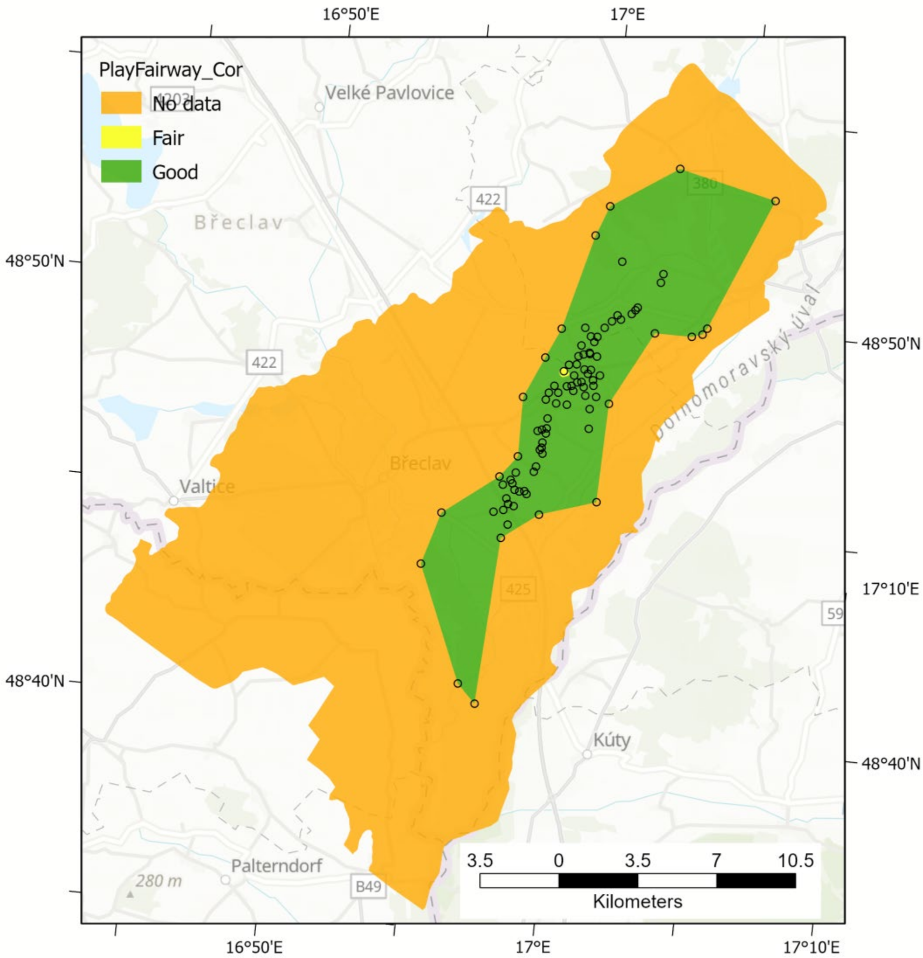

Fig. 4. Map of the Corrosion Index of the study area.

The Cementation Index was divided for a need of the play-fairway map development into the following categories:

LSI	**Indication**
-2,0<-0,5	No scale formation
-0,5<0	No scale formation
LSI = 0,0	Balanced, no scale formation
0,0<0,5	Slight scale formation
0,5<2	Scale formation

The category „poor“ is represented by the first row from the bottom, the category „fair“ is represented by the second row, the category „good“ by the remaining ones. **Fig. 5** shows the study area and its characteristics by the Cementation Index, together with location of data used for its development, and indication of the territory lacking the data coverage.

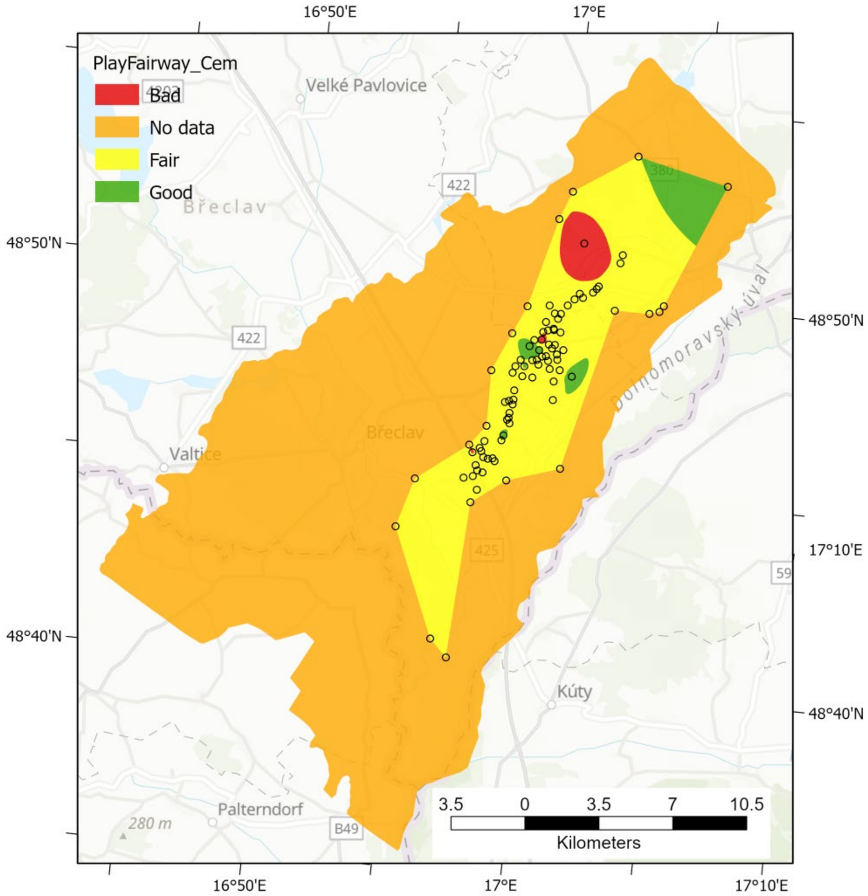

Fig. 5. Map of the Cementation Index of the study area.

The Cost Index was divided for a need of the play-fairway map development into the following categories:

Range	t_{pb} < 3 yr	3 yr ≤ t_{pb}< 4 yr	4 yr ≤ t_{pb}< 5 yr	5 yr ≤ t_{pb}< 6 yr	6 yr ≤ t_{pb}≤ 7 yr	t_{pb}> 7 yr
I_C	1	0.8	0.6	0.4	0.2	0

The category „good“ is represented by the first two columns from the left, the category „fair“ by the next two columns and the category „poor“ by the last two columns. **Fig. 6** shows the study area and its characteristics by the Cost Index, together with location of data used for its development, and indication of the territory lacking the data coverage.

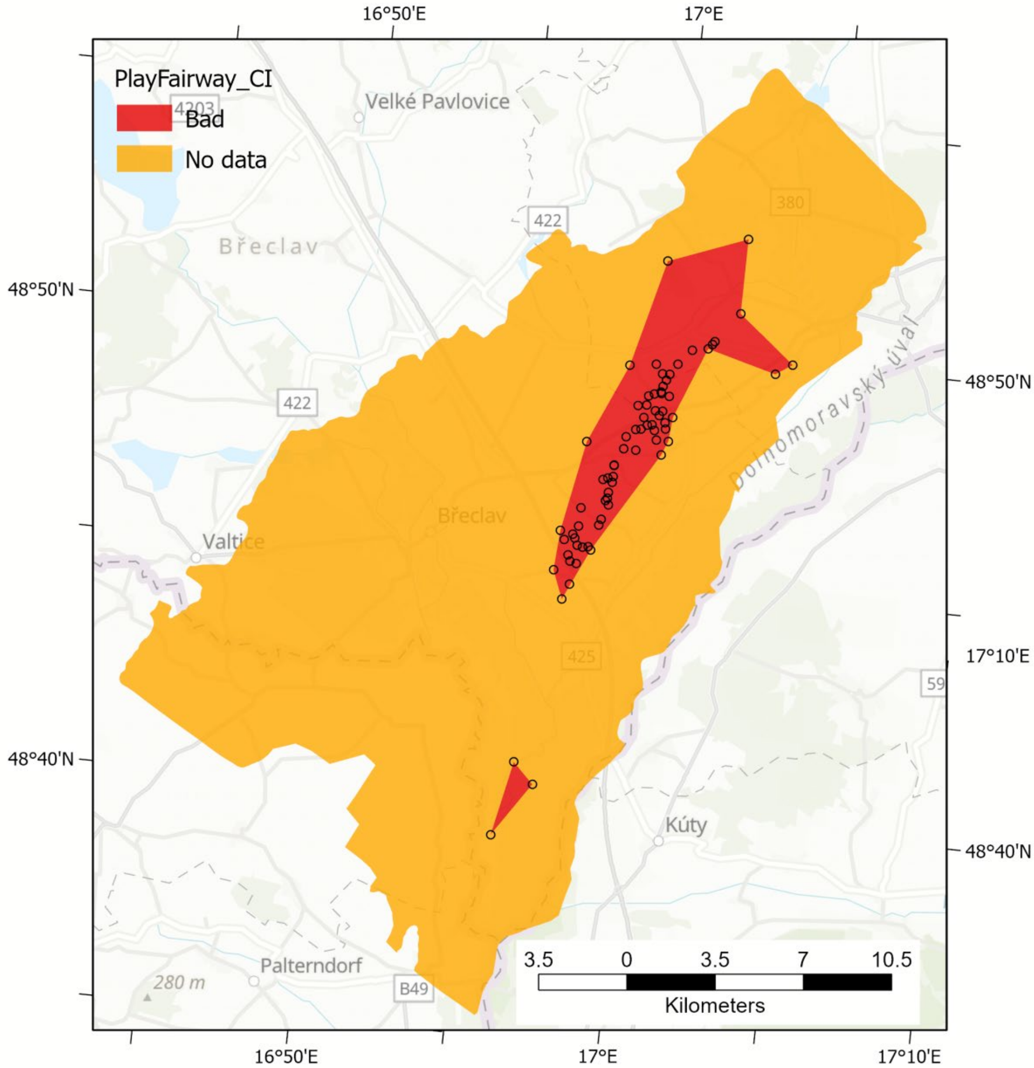

Fig. 6. Map of the Cost Index of the study area.

The aforementioned six maps of categorized indexes were subsequently placed on top of each other, using the software ArcGIS Pro, each in the grid map format. The resultant play-fairway map grid originated from the overlap of six values located above each other for each grid node, using the rule that the least advantageous value represents the resulting grid node. The resultant grid map was subsequently turned into a polygon map, with polygons representing the areas with nodes falling into the same category (**Fig. 7**).

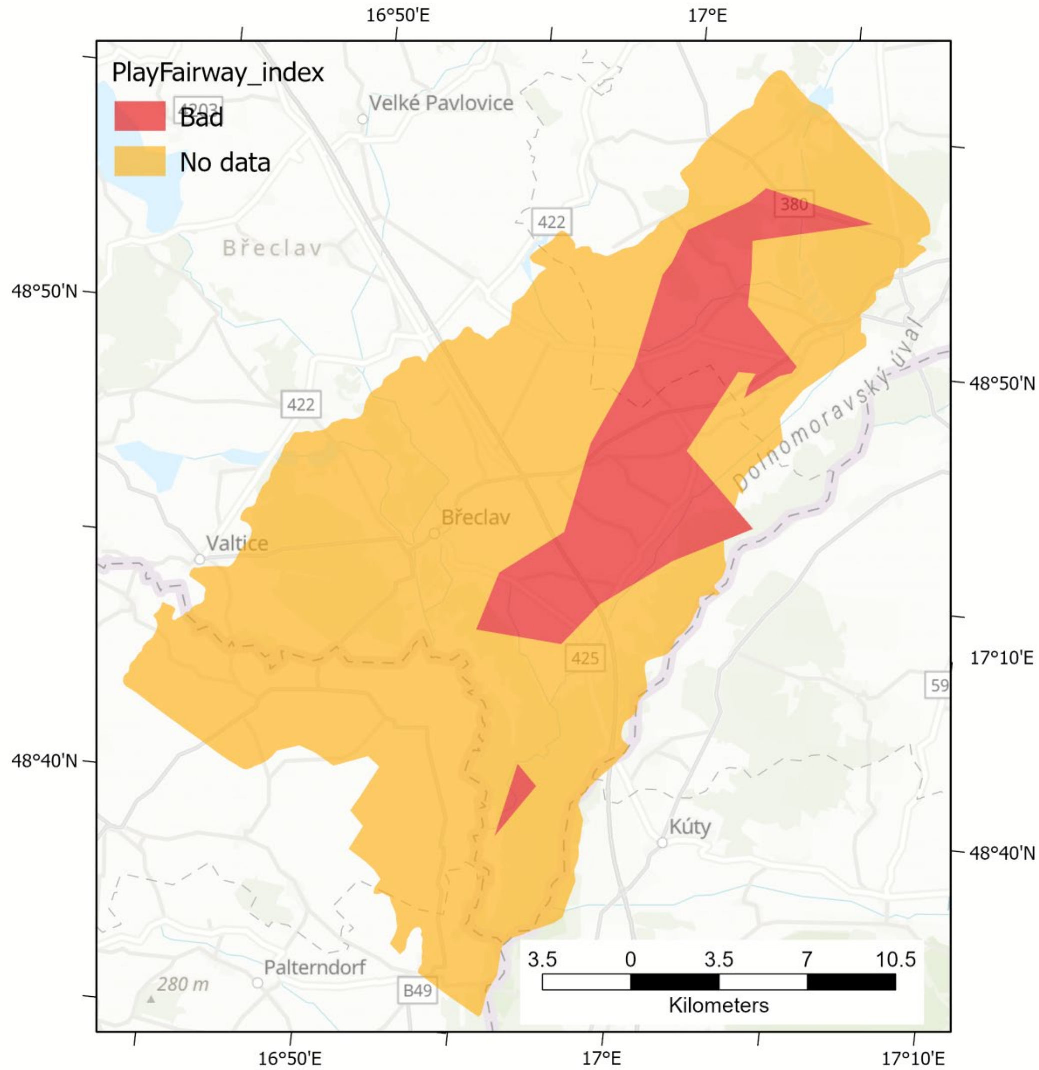

Fig. 7. Play-fairway map of the study area.

Fig. 7 shows that a significant portion of the study area does not contain data allowing to analyze whether there is a geothermal fluid flow system appropriate for the electric energy production or not. Portions of the study area covered by data indicate that there is no geothermal fluid flow system appropriate for the electric energy production in them. These areas are appropriate only for the production of the geothermal fluid and its direct use for the heating and other activities not requiring the electric energy production. This conclusion is made under the assumption of the use of already existing wells without their deepening into depths characterized by the more favorable values of the Cost Index instead of the ones calculated above. This is the main reason for the conclusion that there is not a single portion of the study area indicating a potentially commercially successful electric power production in the play-fairway map, i.e., not containing a sufficiently hot geothermal fluid flow system, which would source a commercially successful electric power production.

In the case of interest in the electric power production, interested parties would have to count on the business plan, which would be commercially successful even if it would include deepening of existing wells in the most appropriate areas or a business plan based on the direct use of geothermal fluid.