

ET-FORUM

ENERGY TRANSITION FORUM

VILNIUS • 18 SEPTEMBER 2026

PEOPLE • IDEAS • SOLUTIONS
FOR A CLEANER TOMORROW

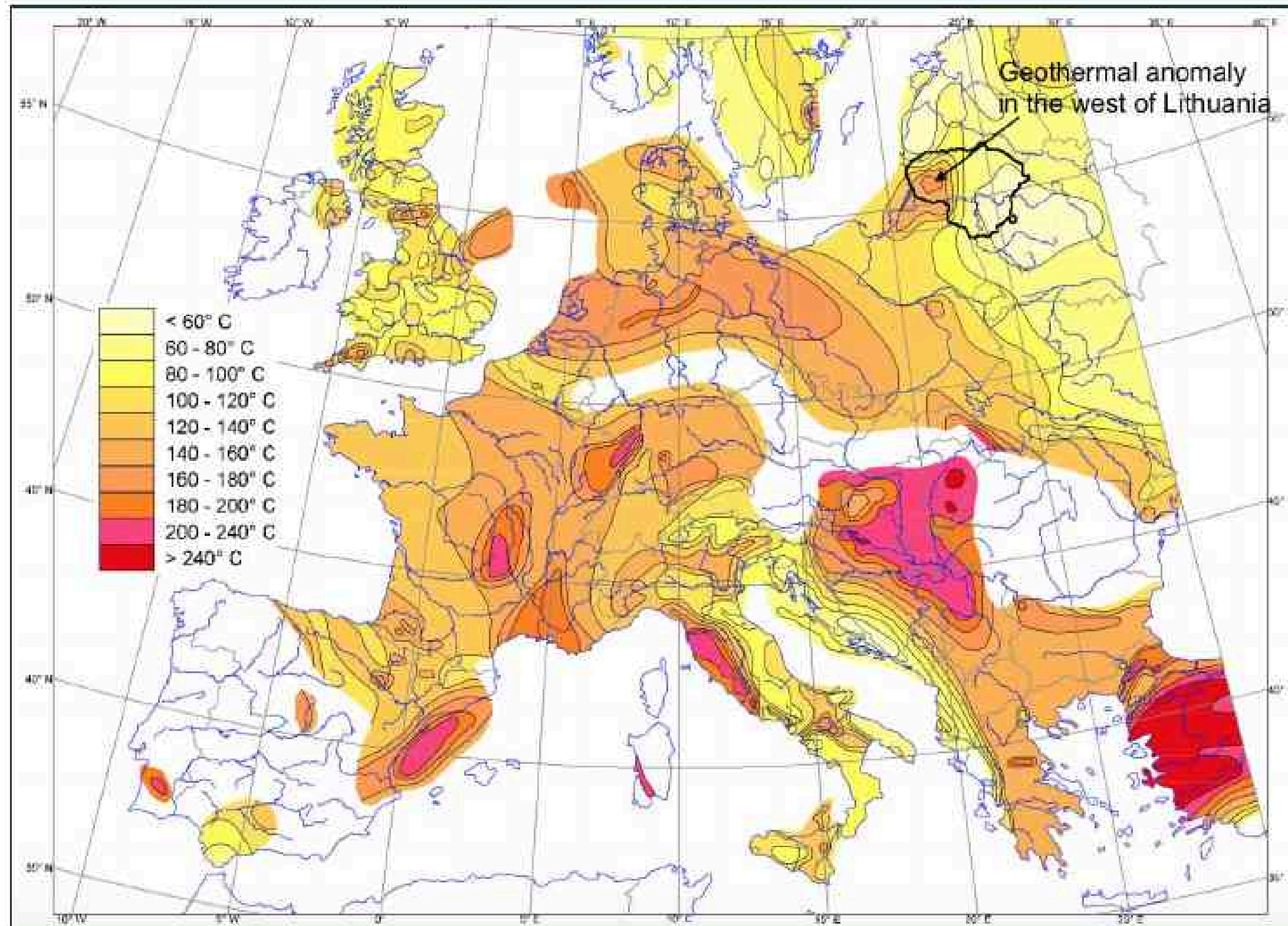
Cambrian and Devonian Geothermal Complexes and their Geothermal Potential in Lithuania



Pijus Makauskas

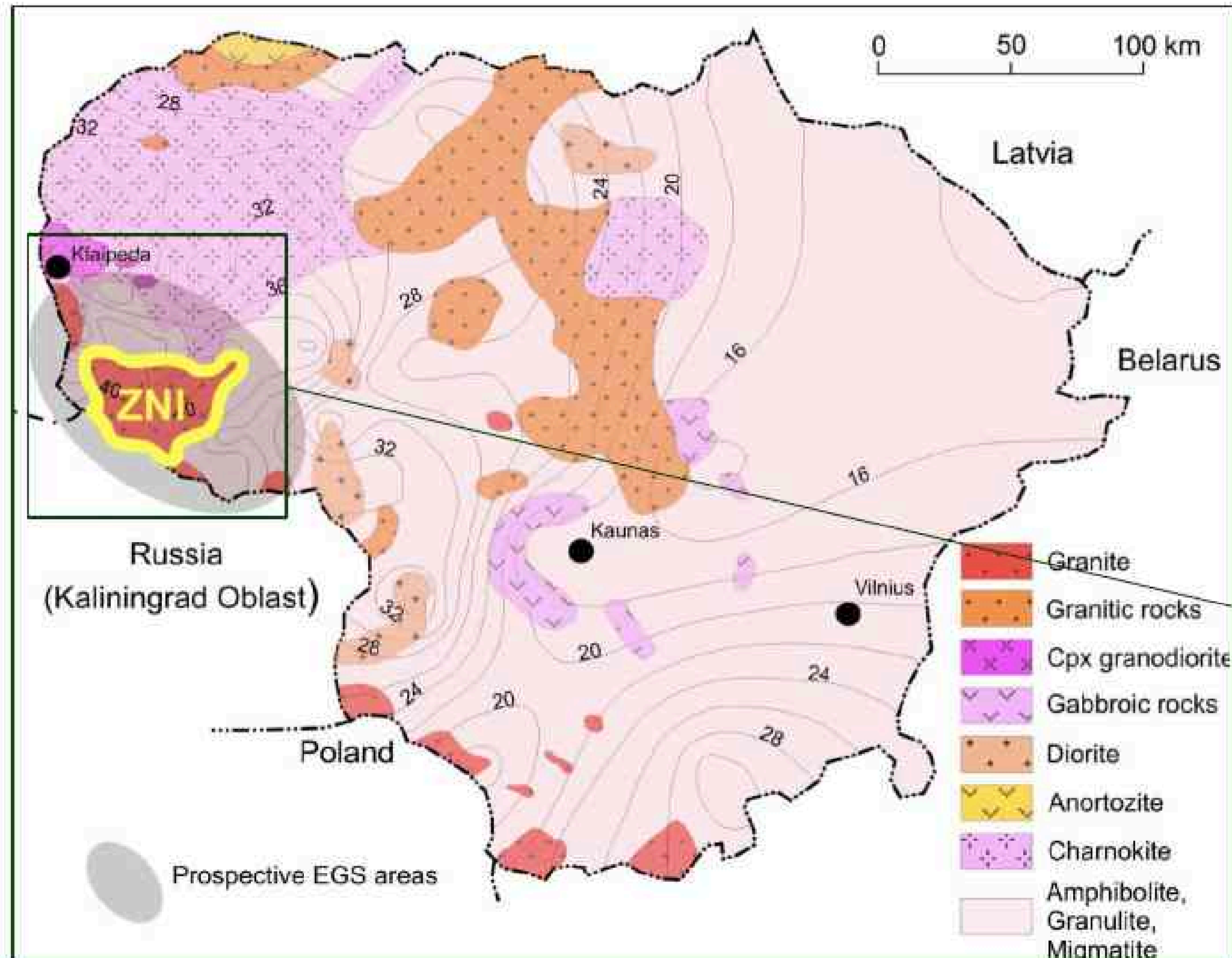
Faculty of Mathematics and Natural Sciences
Kaunas University of Technology

GEO THERMAL ANOMALY NORTH-WEST OF LITHUANIA

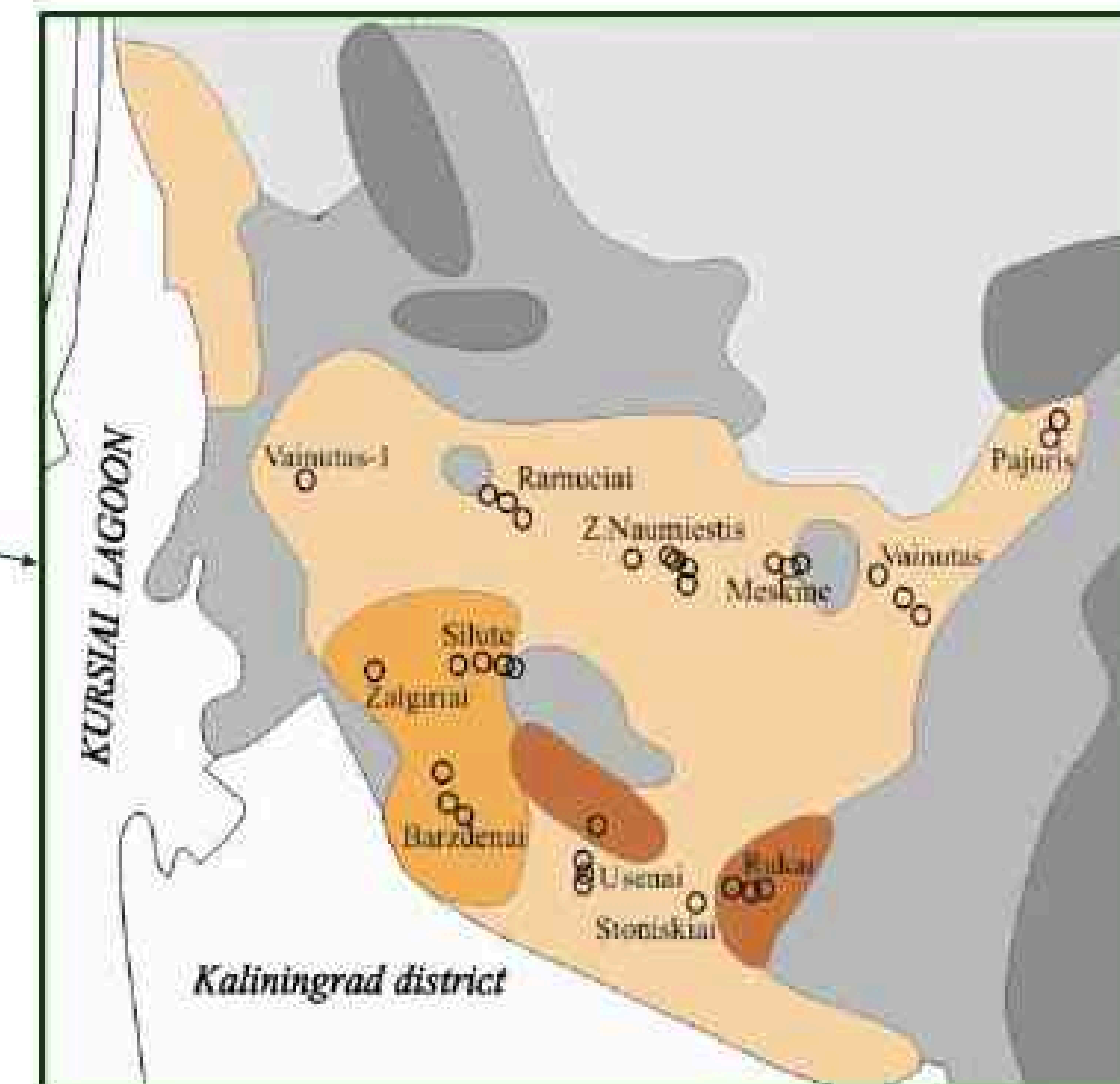


Average temperature
7.4 °C
Geothermal gradient
43 °C/km

“HOT” GRANITOID INTRUSIONS



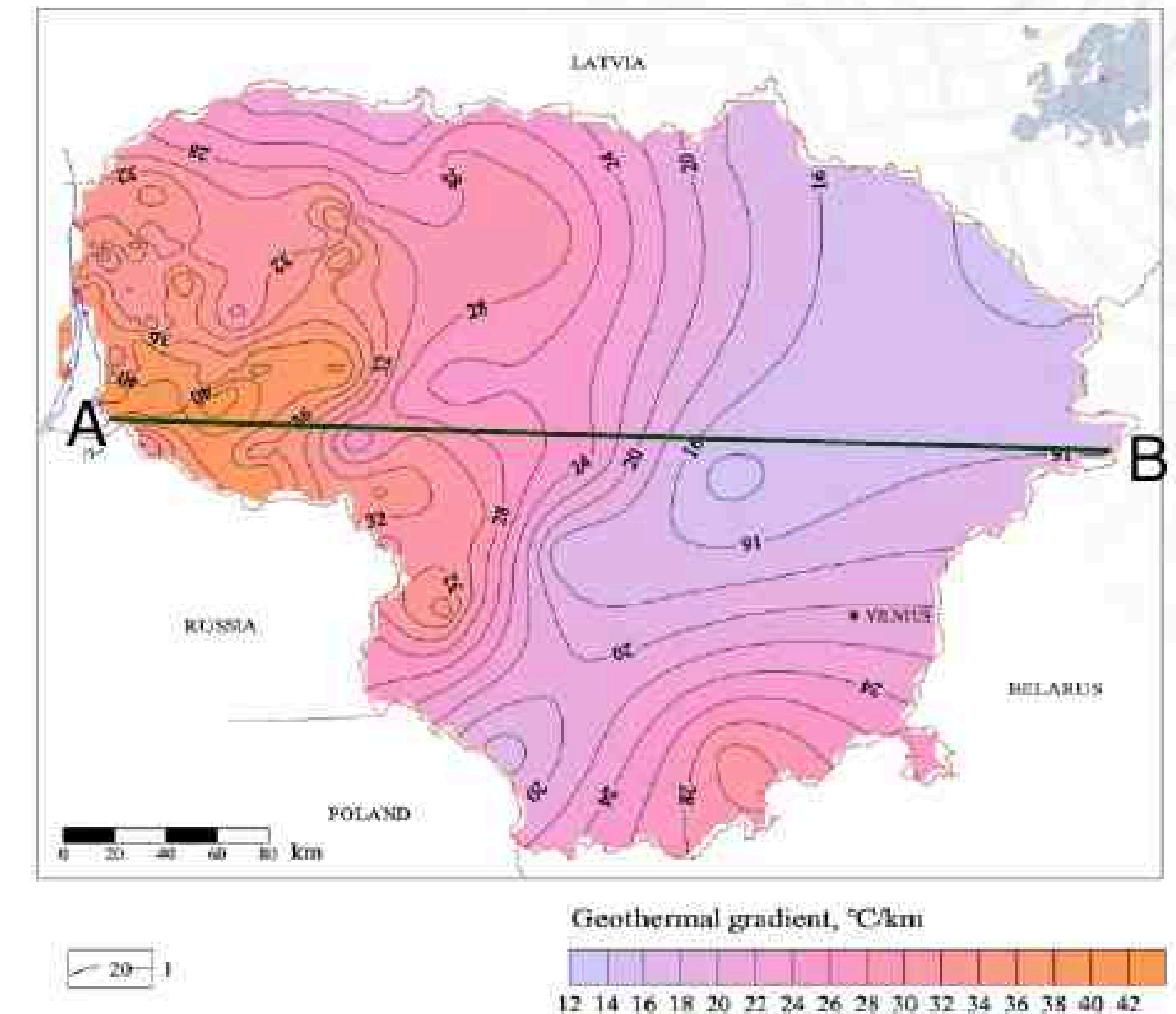
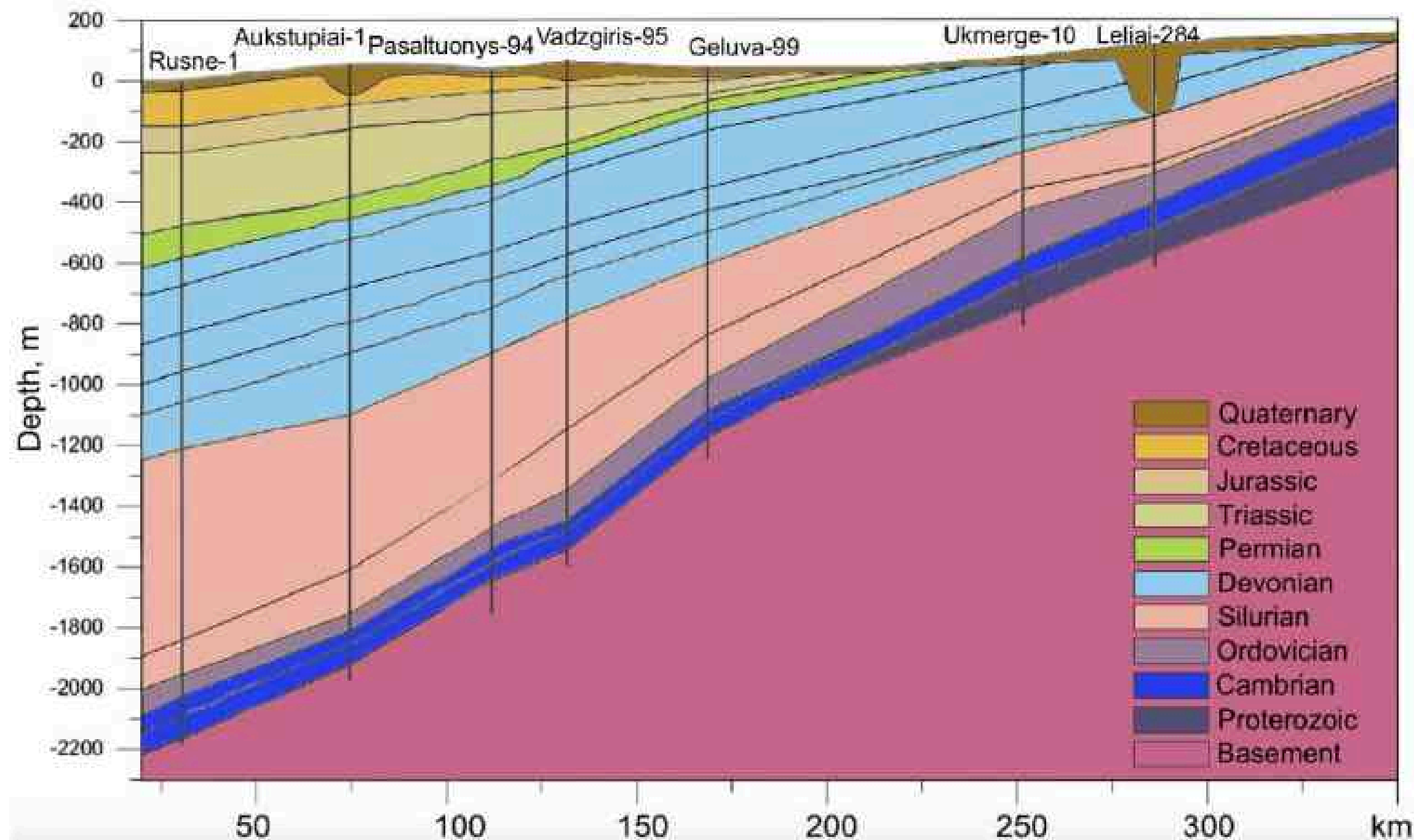
Žemaičių Naumiesčio Intrusion



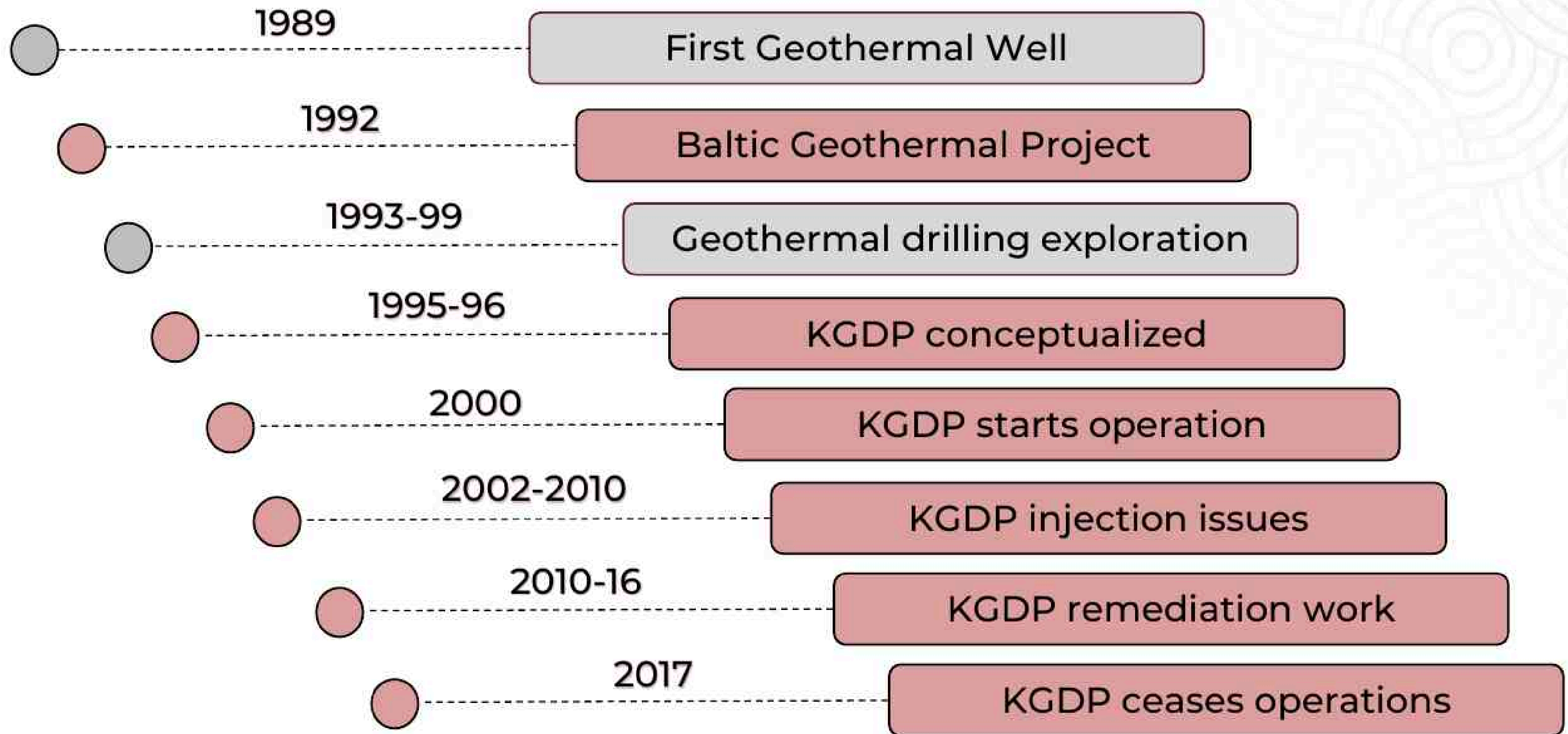
SEDIMENTARY COVER

Thermal blanketing effect:

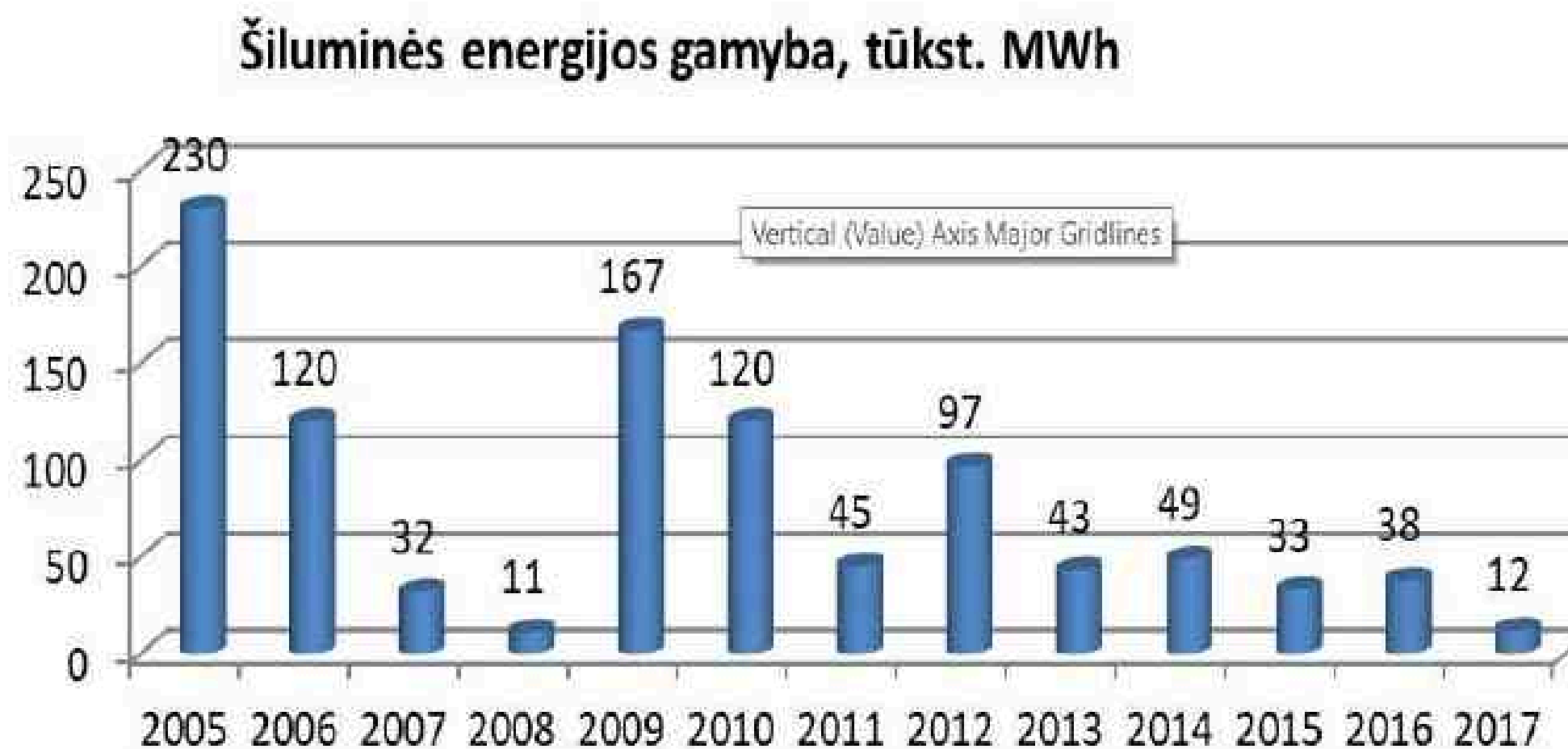
- **East** Lithuania basement is at **400m** depth.
- **West** Lithuania basement is at **2200m** depth.



LITHUANIAN GEOTHERMAL OPERATIONS

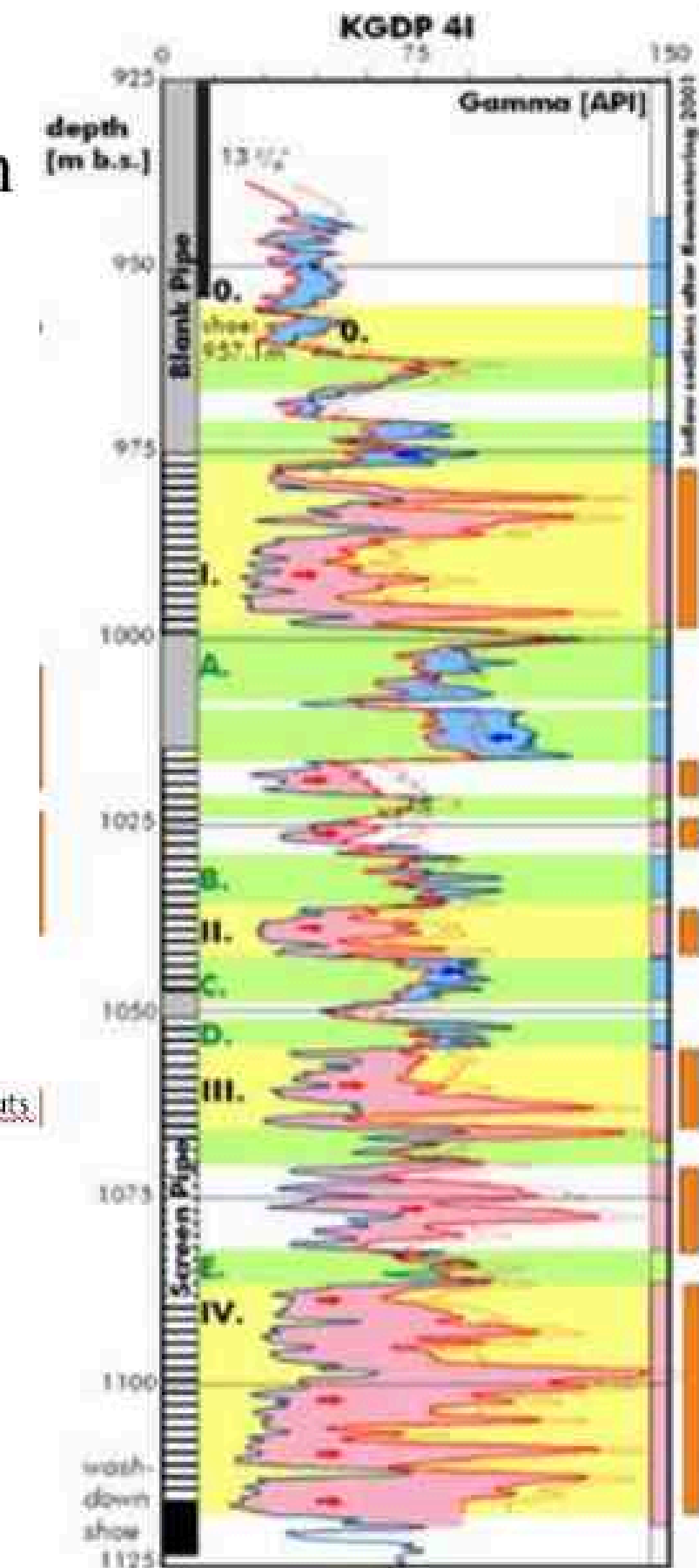
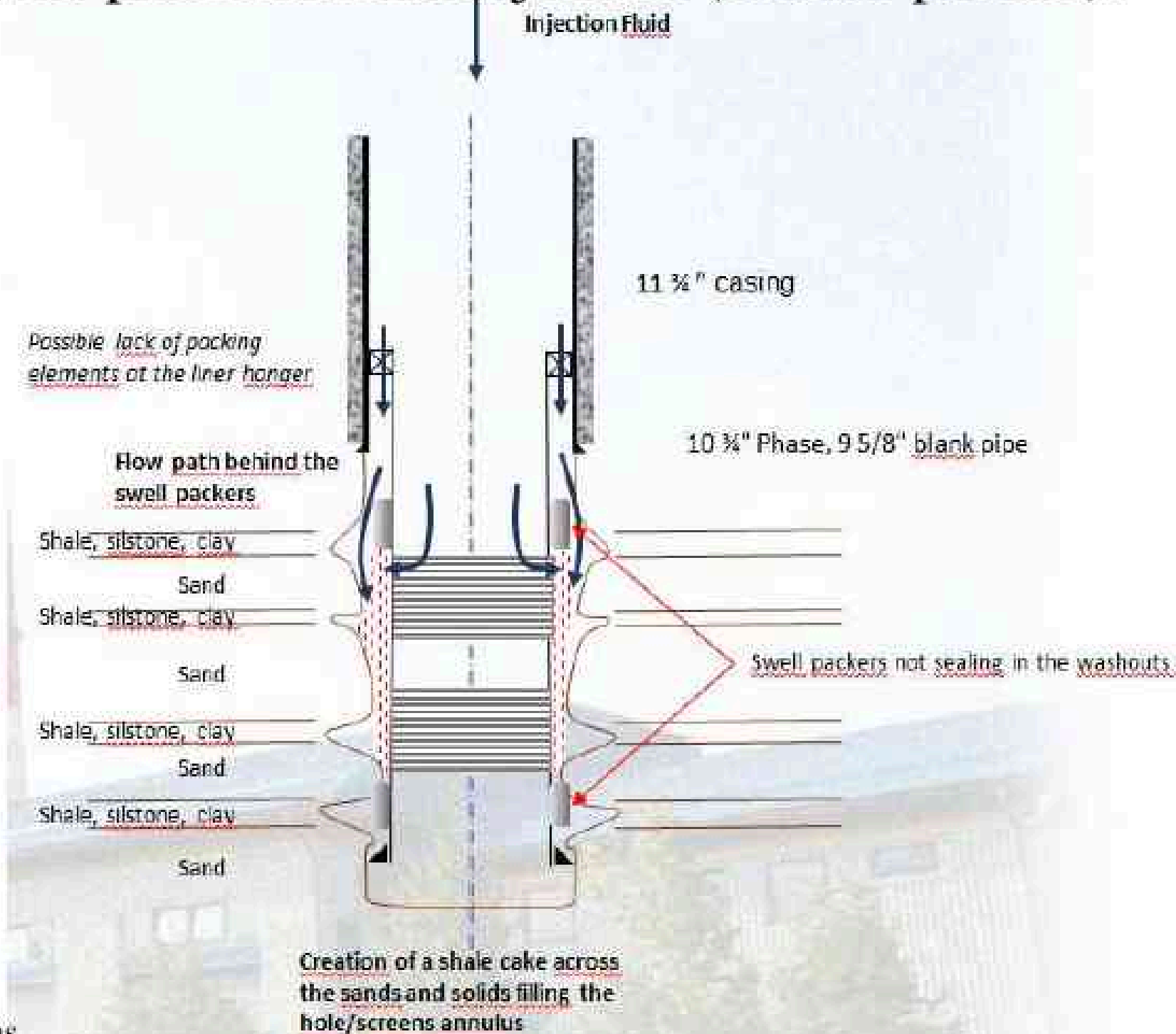


- Klaipėda geothermal station has encountered various technical and bureaucratic difficulties.
- The main technological problem is the decrease in the acceptability of injection wells.
- It seems that the reasons are already clear. The desire of the current city authorities to revive the station's work is encouraging.

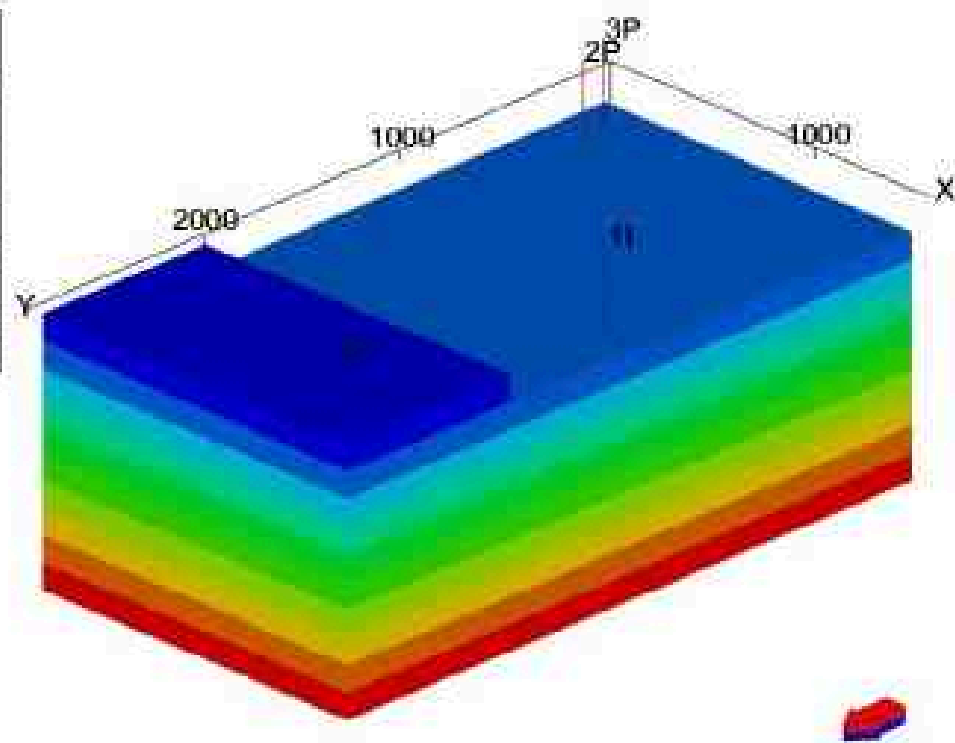
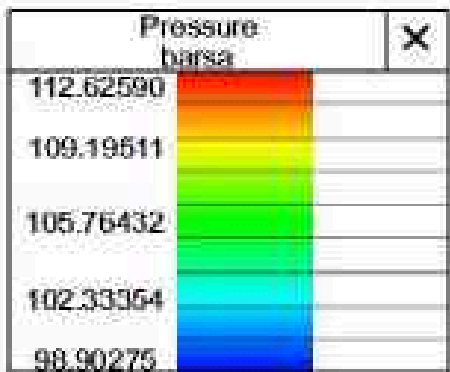
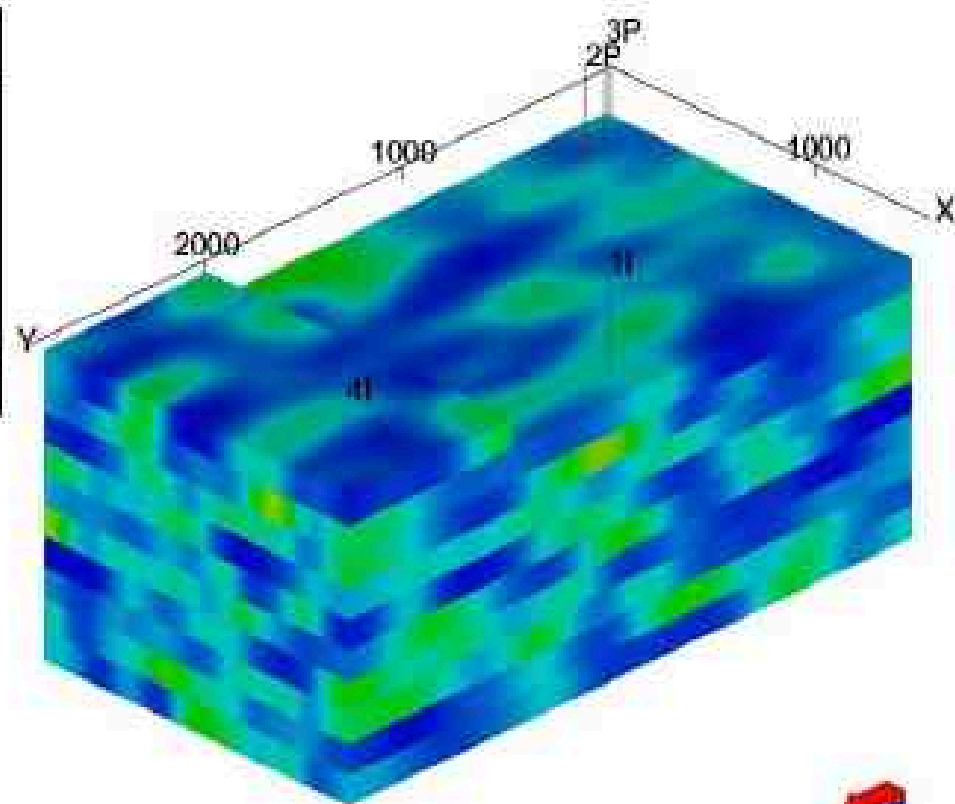
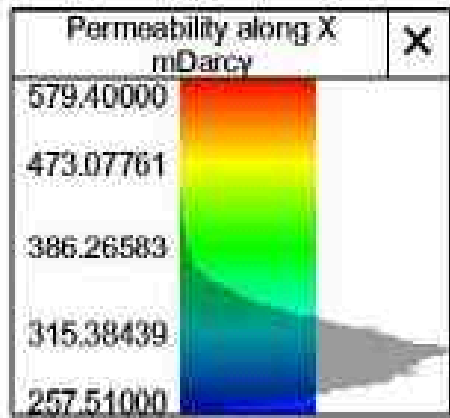


- The injected water washes the clayey interlayers, the clays form a clay film and make injection difficult (picture on the left).
- In the right picture, the blue line is gamma measurements in 1998, the red line is in 2008.
- To improve injection, protective columns must be inserted instead of filter columns, cemented and only targeted clean sandstone layers perforated for injection (middle picture).

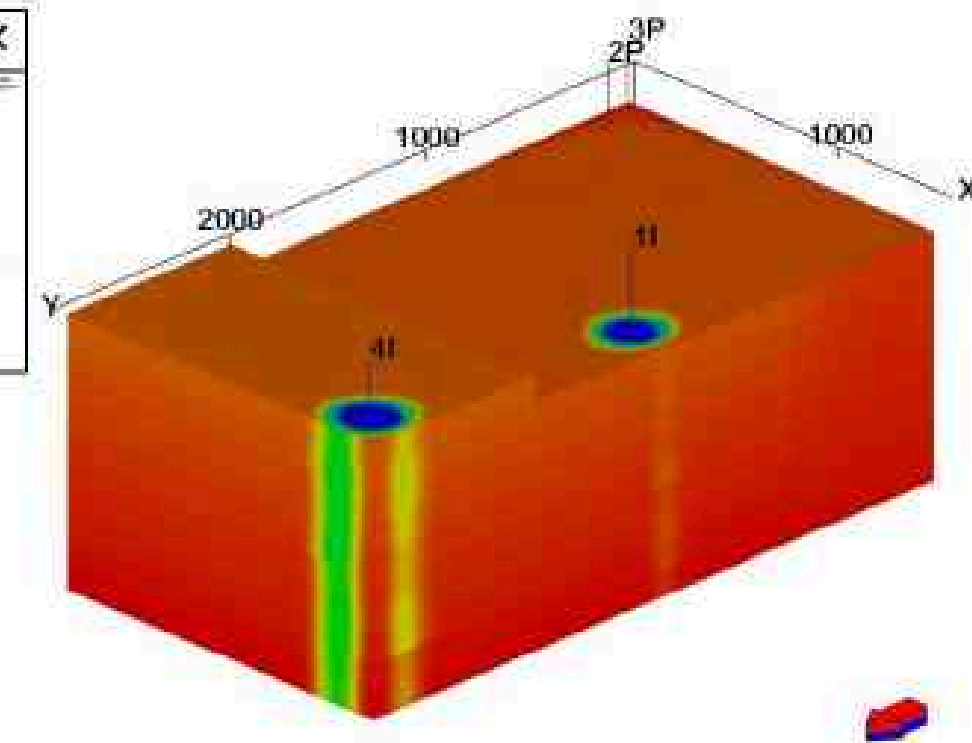
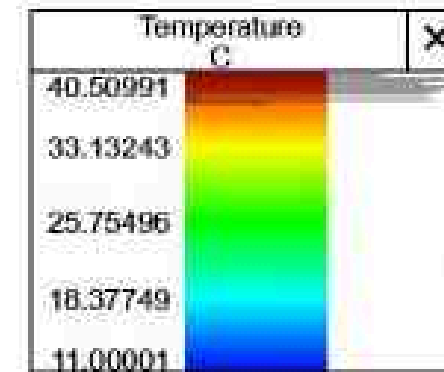
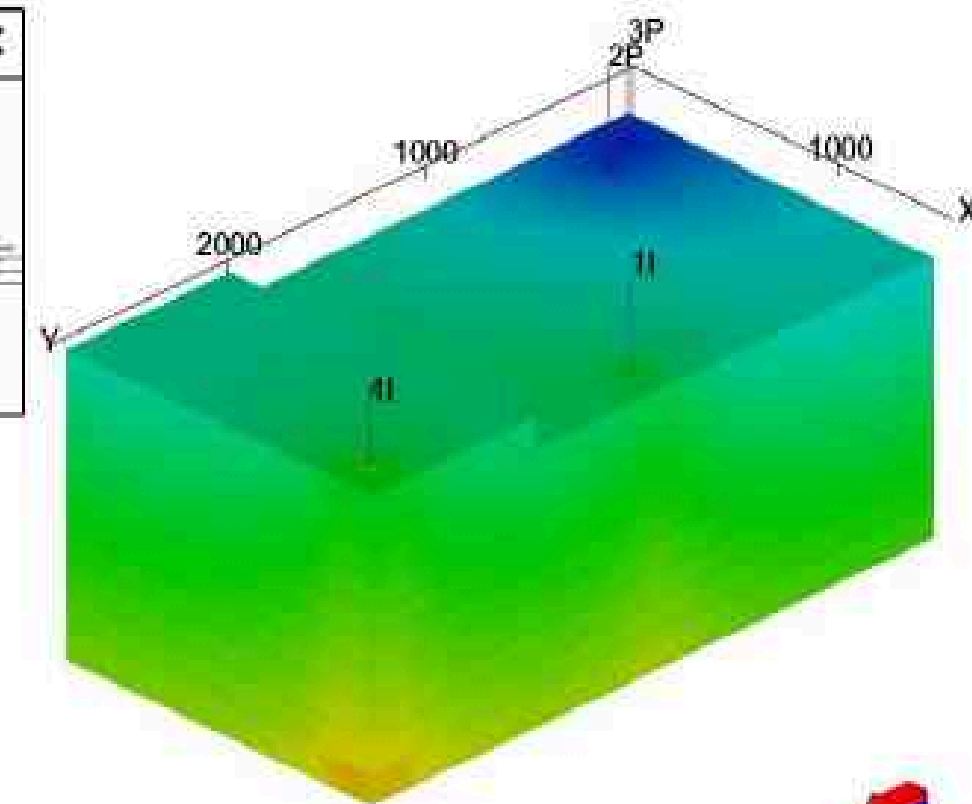
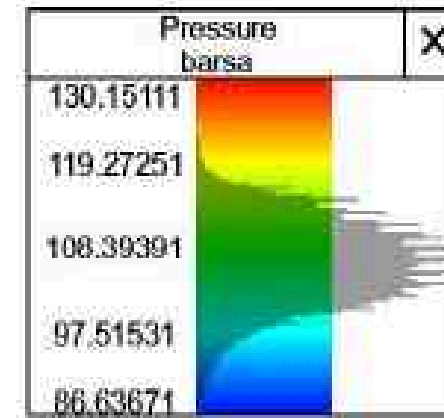
Death by Injection: Reopening the Klaipėda Geothermal Cold Case, Frédéric Guinot & Serge Marnat, Klaipėda Geothermal Conference January 17, 2024



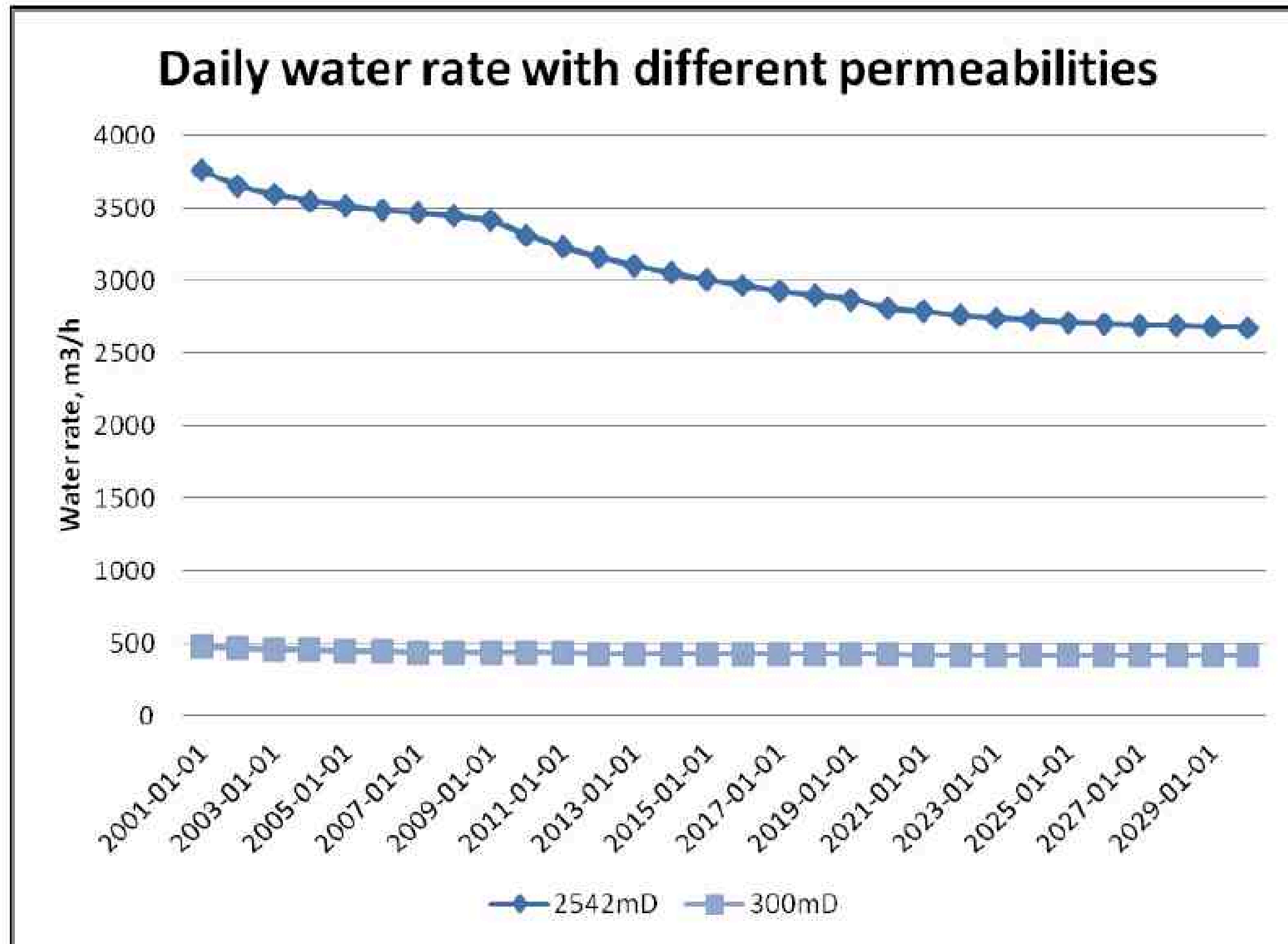
KGDP SIMULATIONS



Reservoir
Simulation
Platform

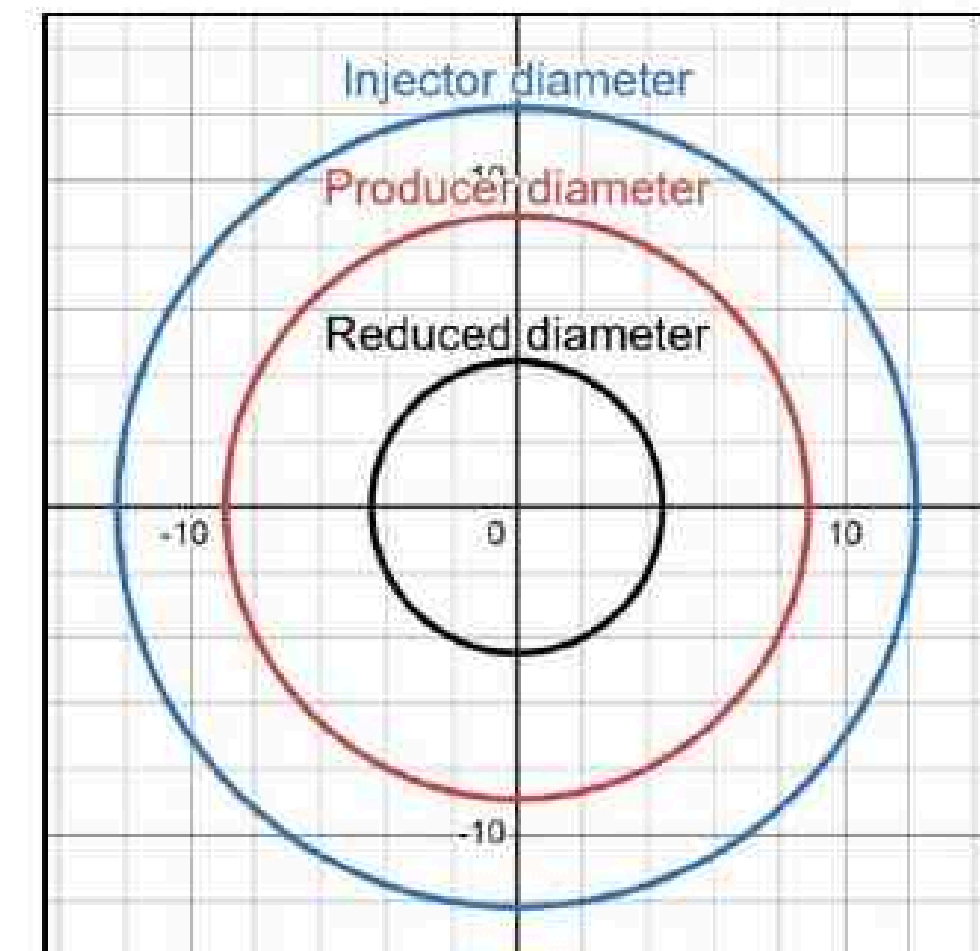


DATA INCONSISTENCY



Permeability difference of **x8.5** produces a water rate difference of **x6.5-7.8**:

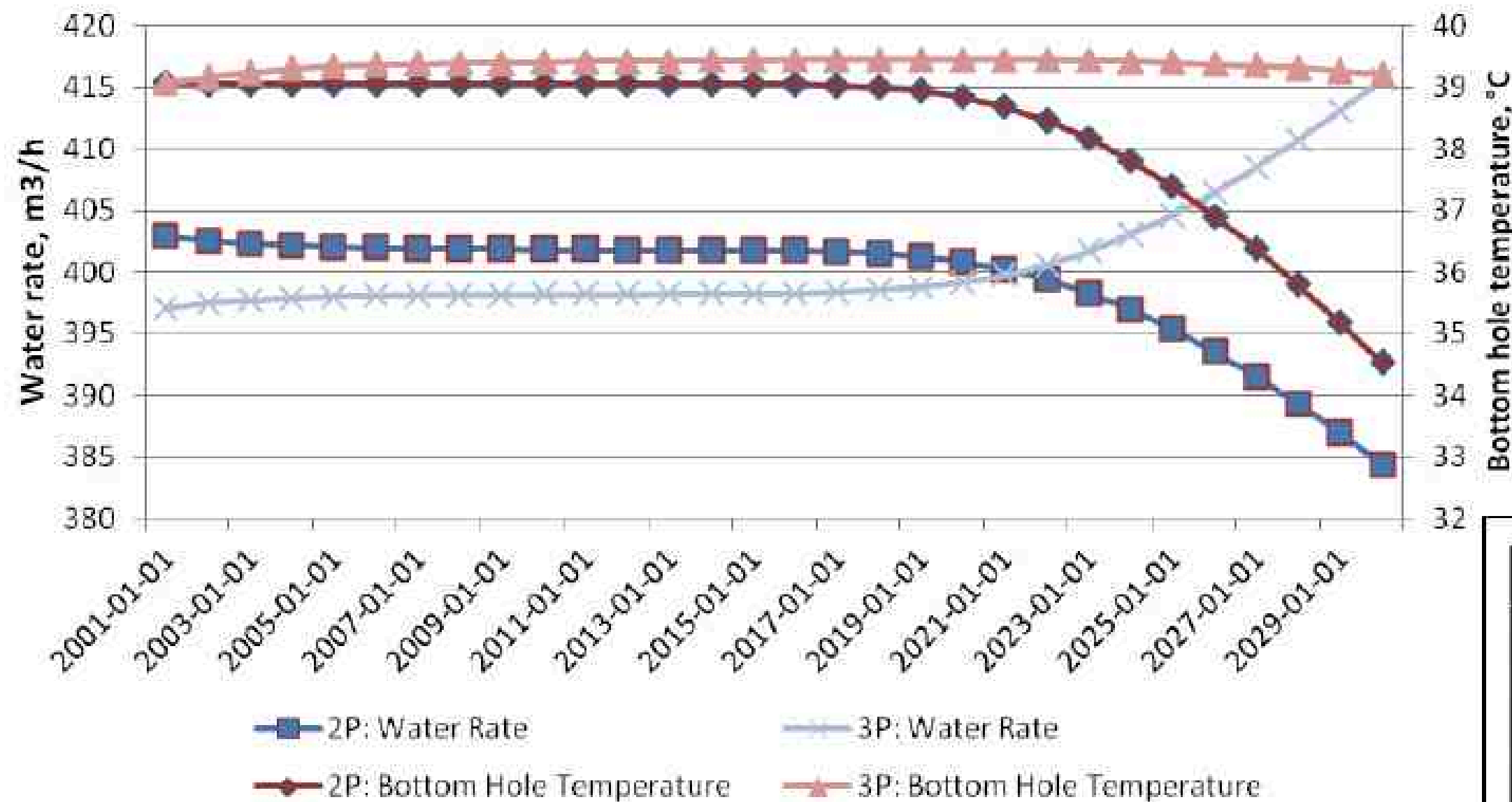
- $2542\text{mD} \approx 8.5 \times 300\text{mD}$
- $2678\text{m}^3/\text{h} \approx 7.1 \times 432\text{m}^3/\text{h}$



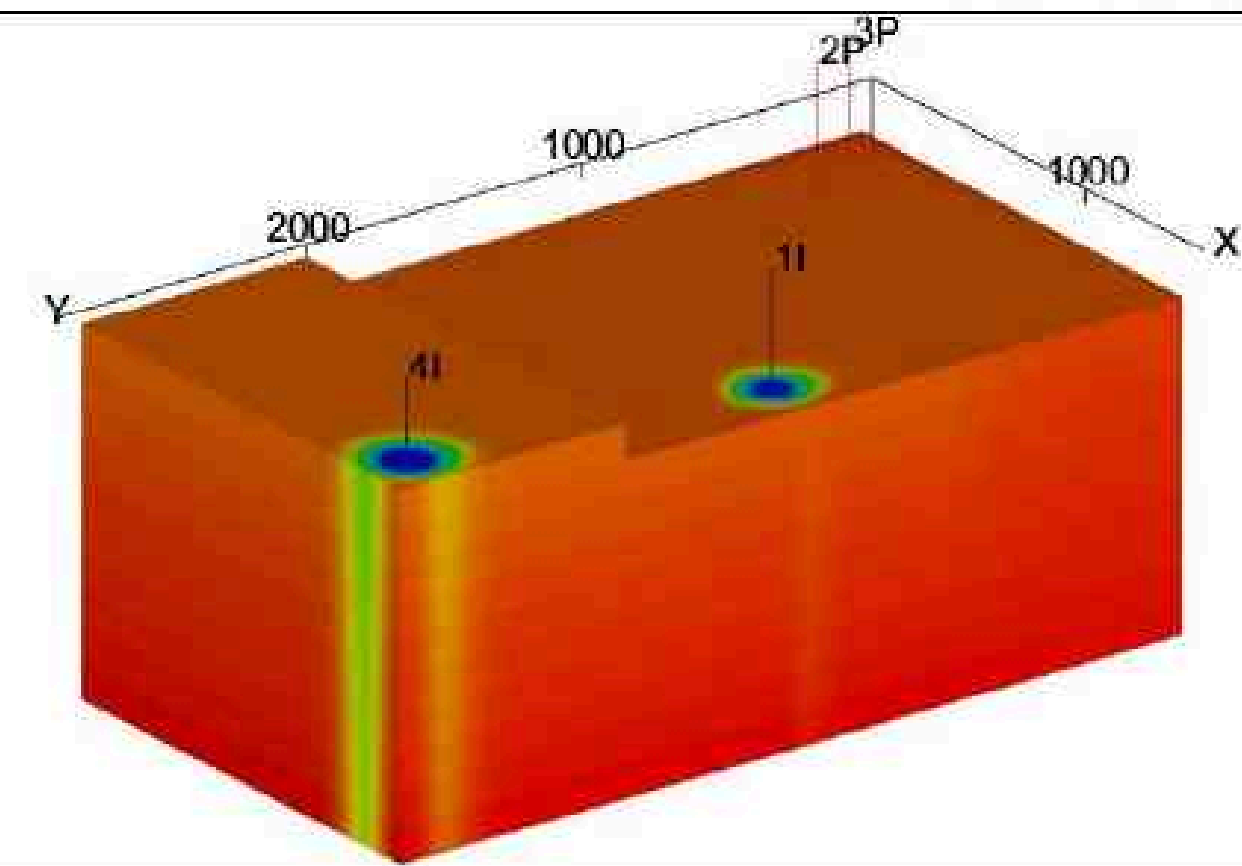
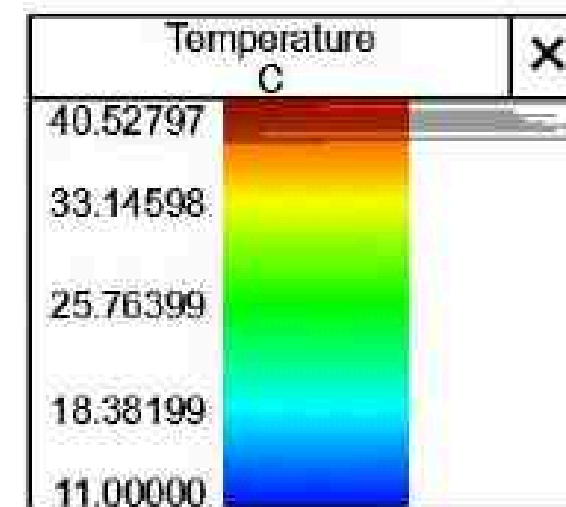
(Around 14% rate drop)

CONSTRAINED OPTIMISTIC MODEL

Temperature and water rate profiles of producer wells



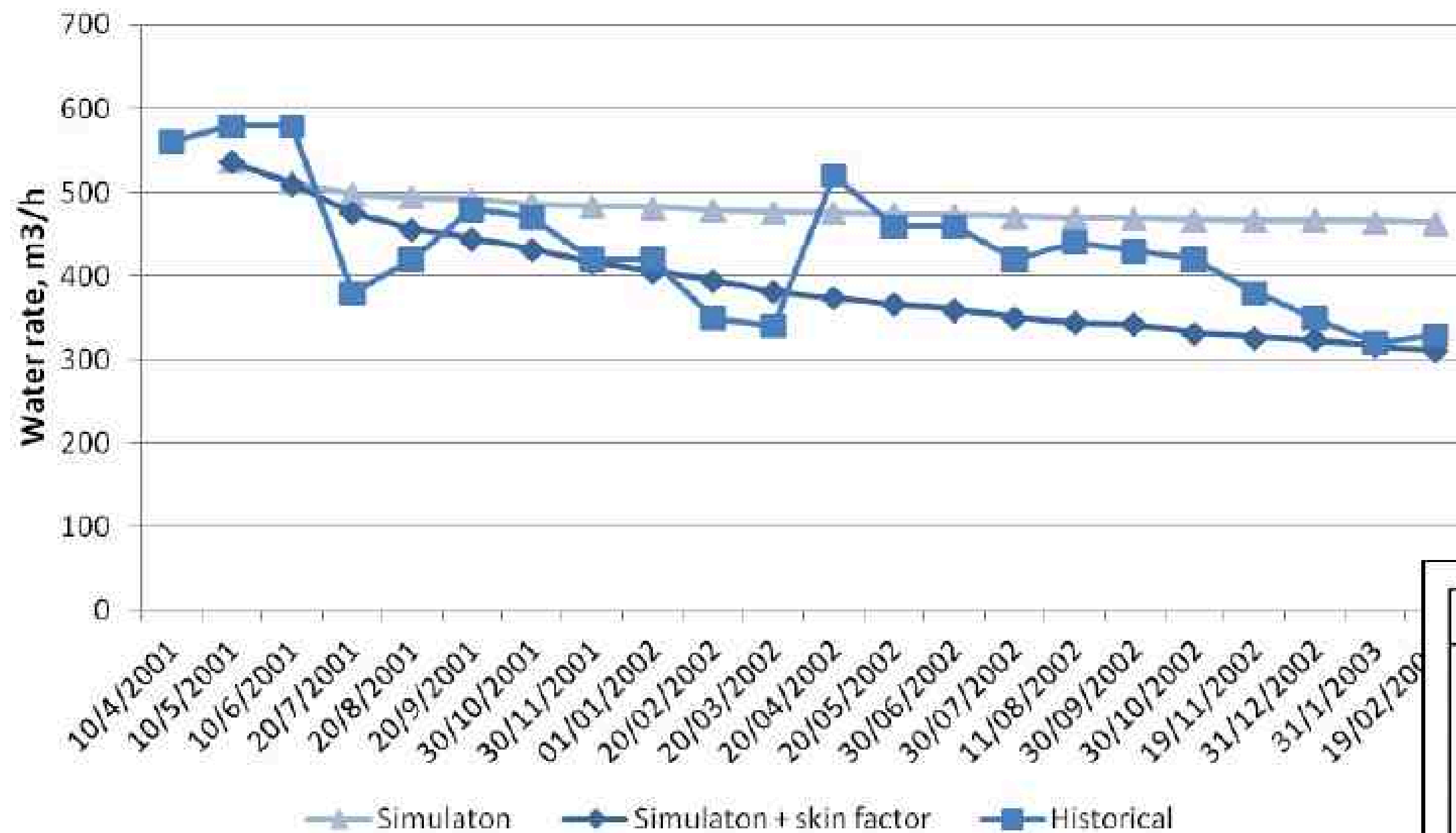
- Early projections showed brine rates of **800 m³/h**.
- Continuous fixed-rate 30 year simulation showed a thermal breakthrough after **20 years**.



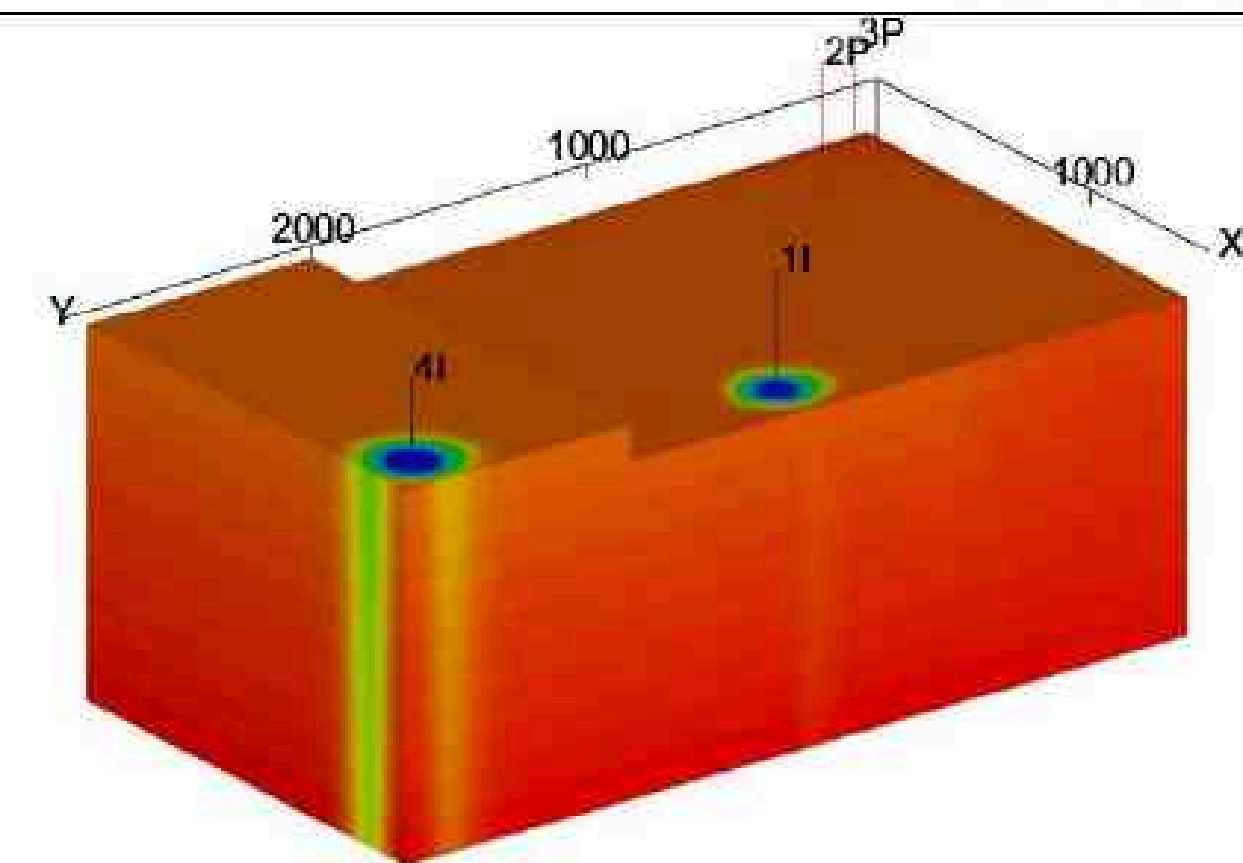
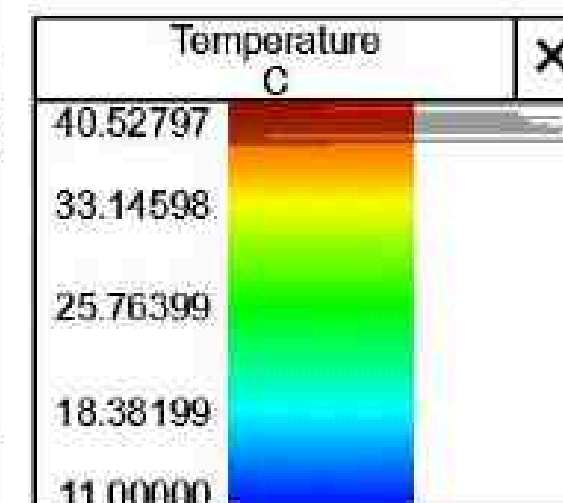
This is excluding the **17 years** of discontinuous and low injection.

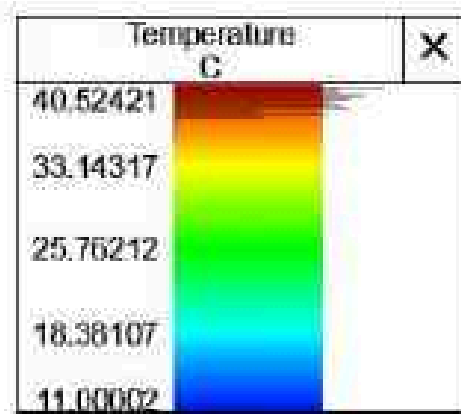
CONSTRAINED OPTIMISTIC MODEL

Injection trends and impact of skin factor



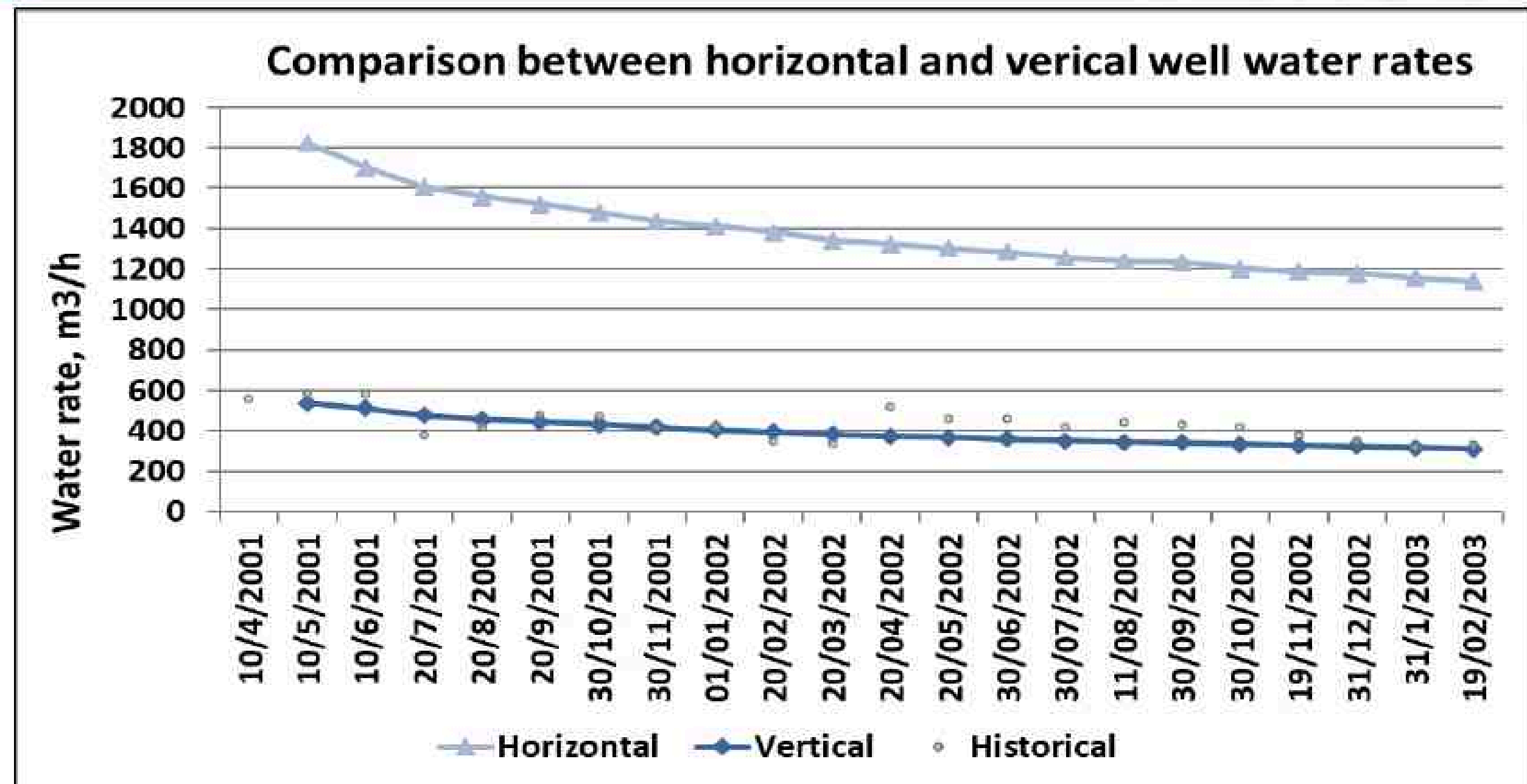
- Rate of **800 m³/h** looks feasible assuming II rates to be equal to 4I.
- Proposed steps further: **proper wellbore completion and maintenance, fracking, horizontal drilling.**

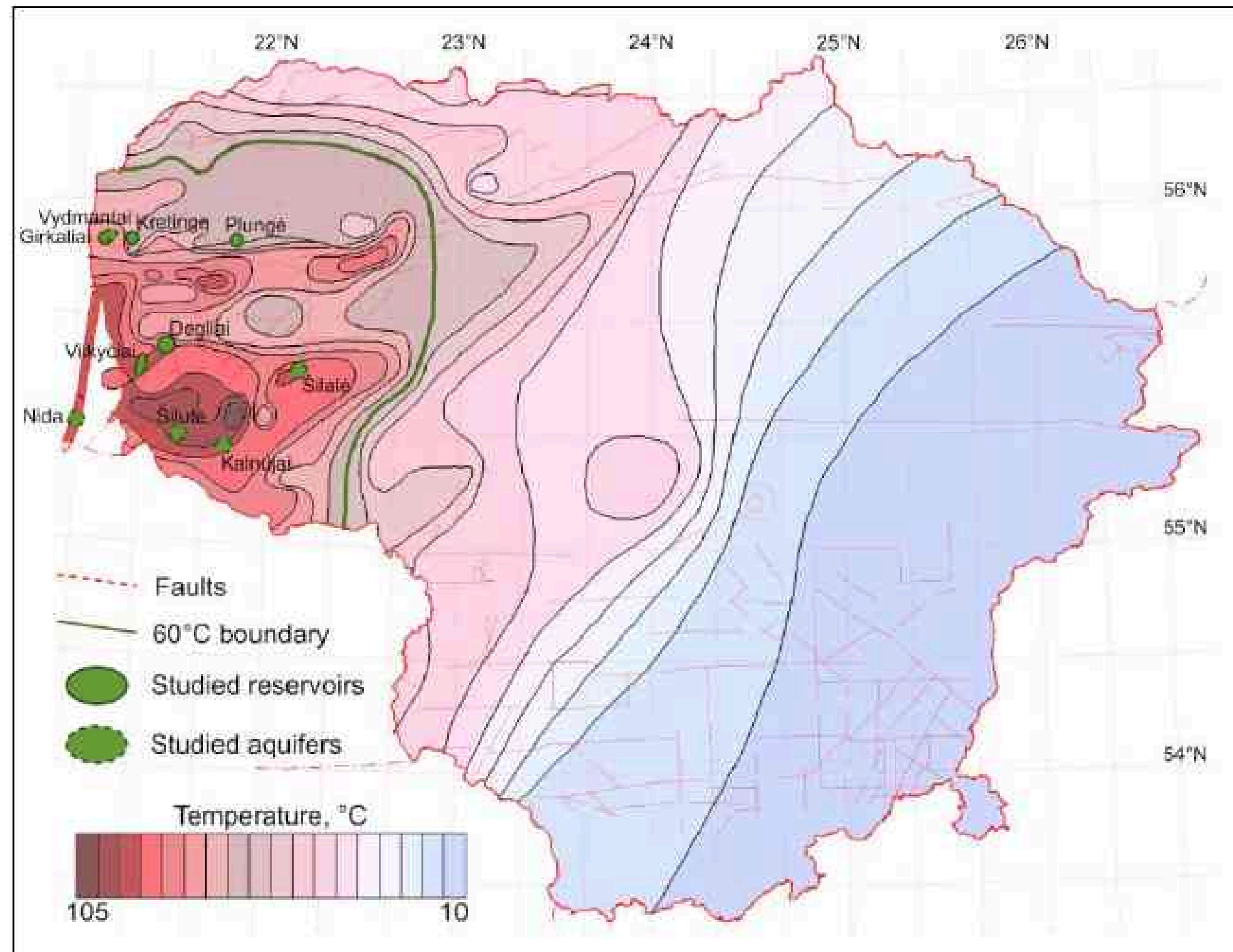




HORIZONTAL WELLS

- Horizontal wells are **costly**, but the rate increase could be **x2-3** the projections.
- This would require **relocation** of the current injector setup.





I. Site screening

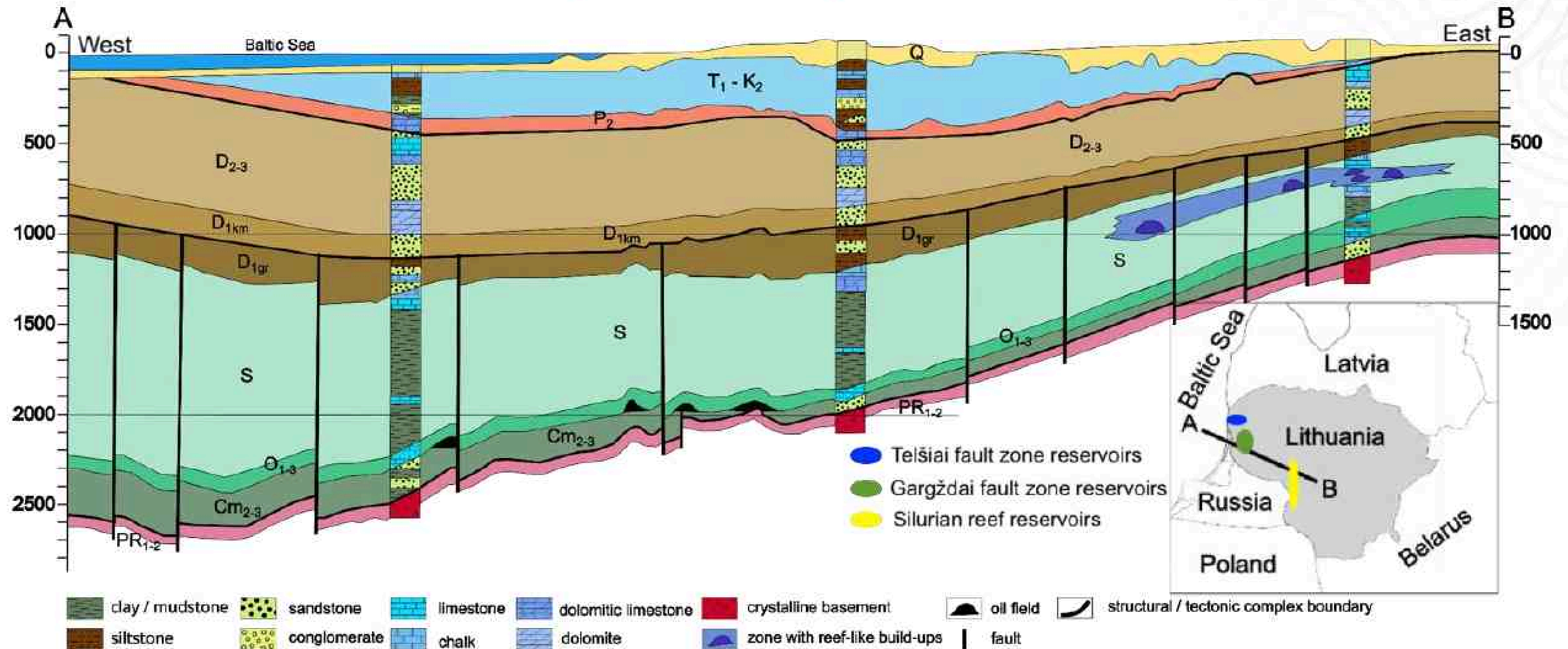
**II. Geothermal
potential map**

**III. Vilkyčiai case
study**

CAMBRIAN SANDSTONE RESERVOIRS

PROVEN OIL RESERVOIRS IN LITHUANIA

- 18 Ordovician-Cambrian oil reservoirs with ~200 wells in western Lithuania.
- 7 Silurian reef structures penetrated by 73 boreholes in central Lithuania.



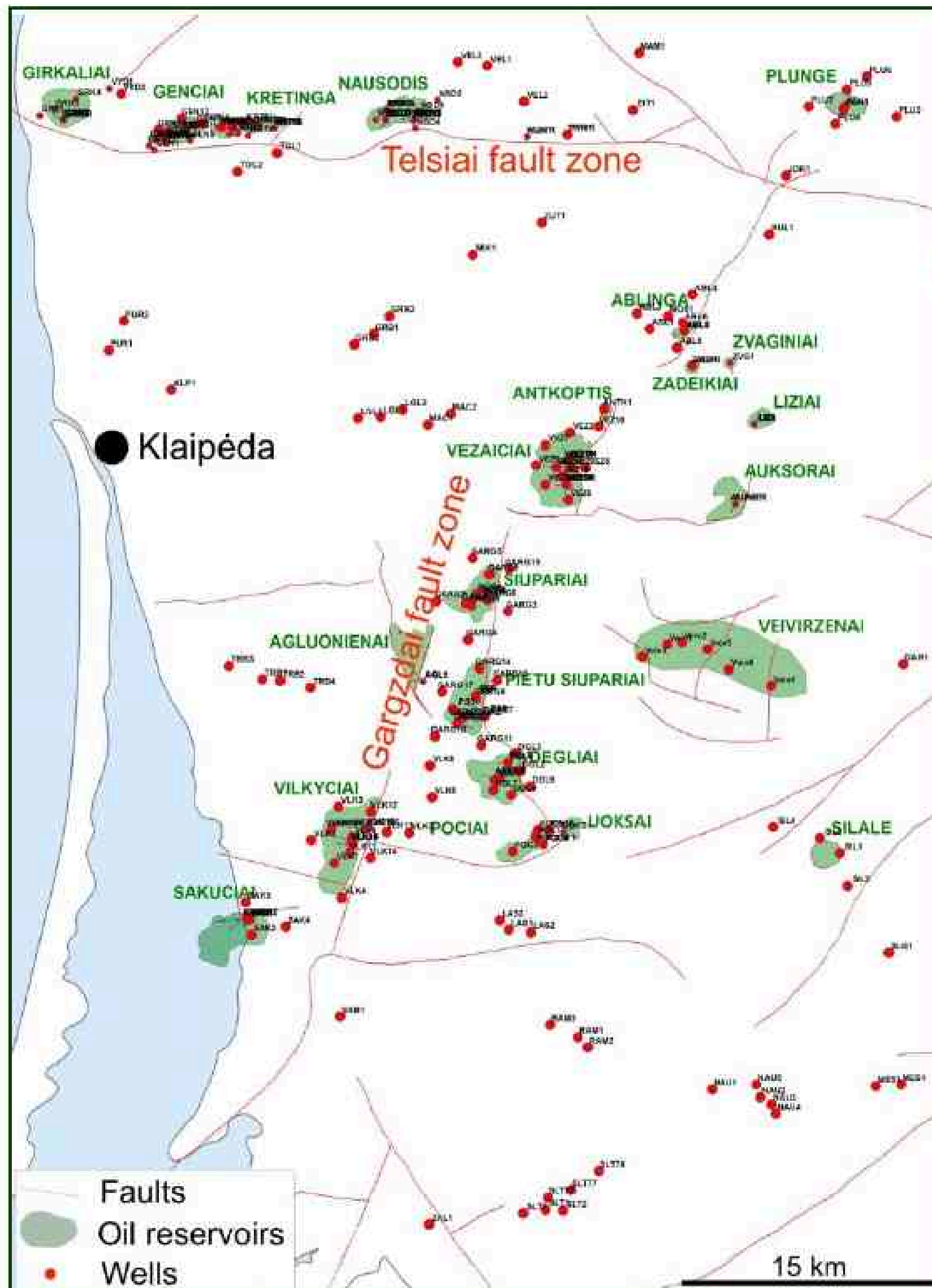
LOWER ORDOVICIAN - CAMBRIAN RESERVOIRS

West Lithuania has two main faulting zones:

- W-E oriented **Telšiai** fault zone:
 - Defined by singular long intrusion.
 - Reservoirs located ~1700 m deep.
 - Temperature 74 °C.
- SW-NE oriented **Gargždai** fault zone:
 - Defined by multiple compression domes.
 - Reservoirs located ~2000 m deep.
 - Temperature 90 °C.

Prospective Cambrian reservoirs in Lithuania are usually located in the hanging walls of the faults.

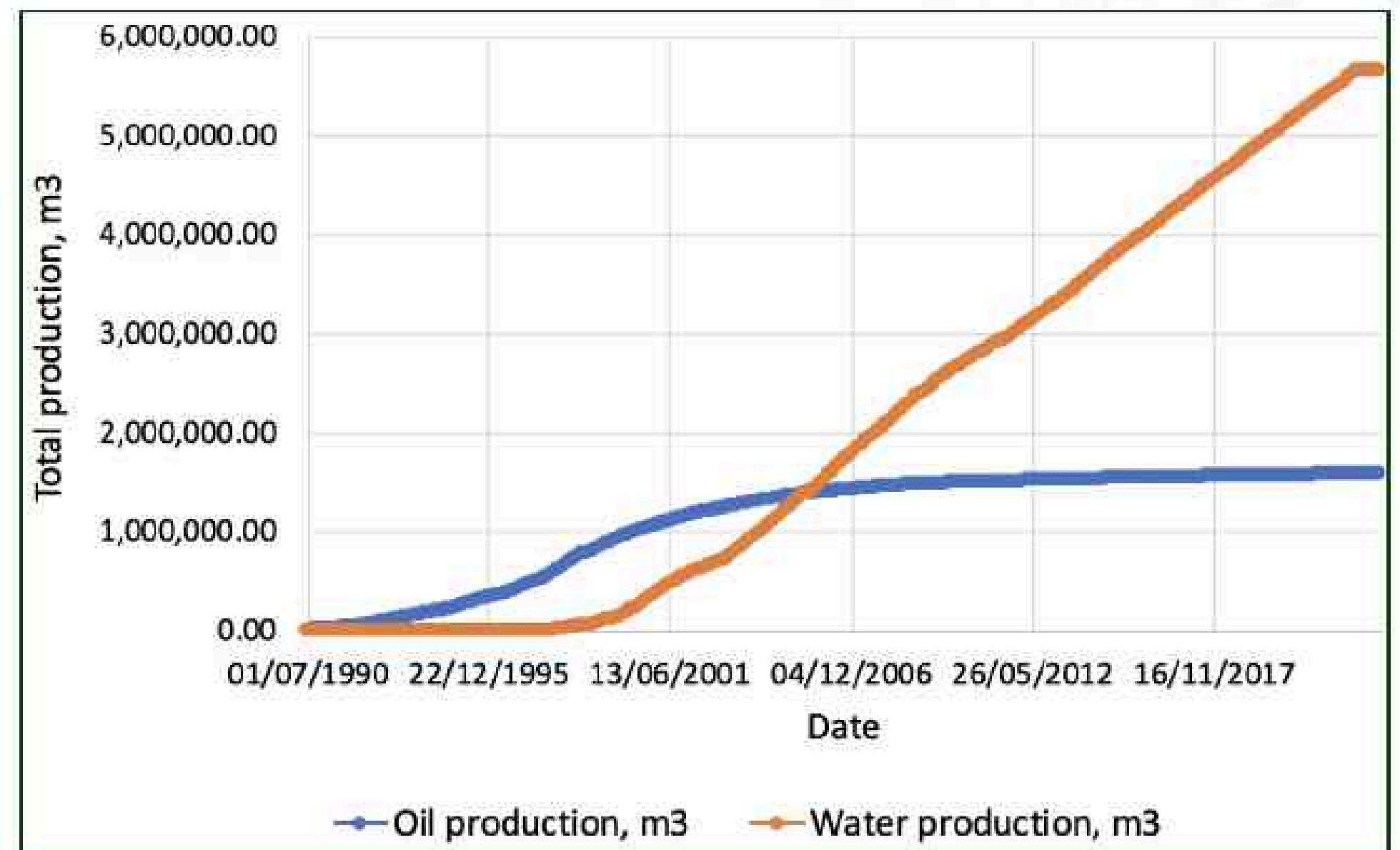
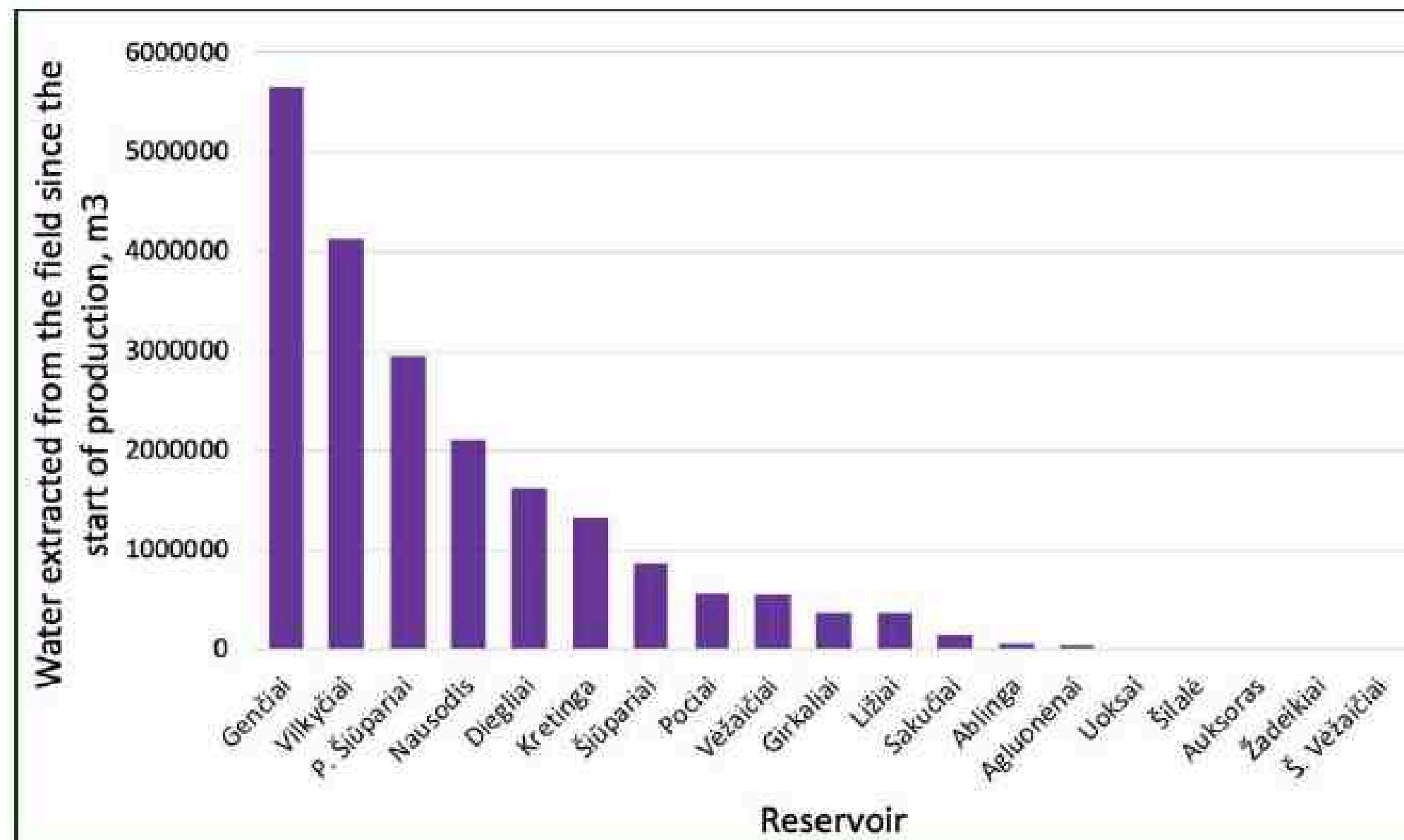
Compression of the faulting can create local uplifts that reach heights up to ~70m.



CO-PRODUCED WATER

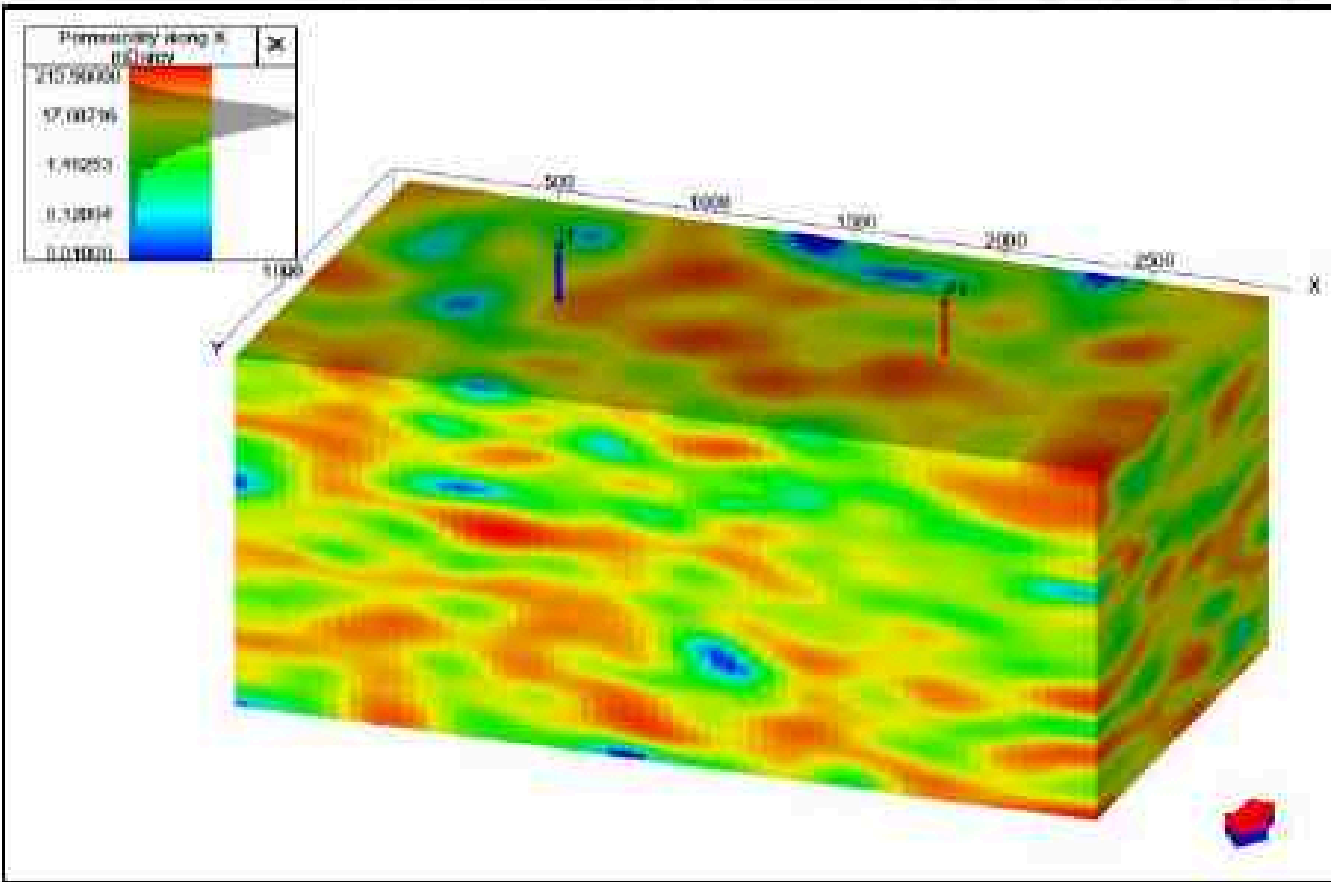
Since the start Genčiai field production, more than 5.7 Mm³ of water was extracted.

- 10 wells co-produced 86 236 m³ of ~74°C water in 2022.

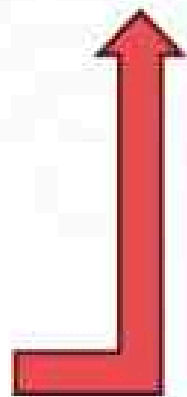


I. FLOW MODELING

Subsurface flow models were built using **high, mid, and low** case properties for each reservoir.

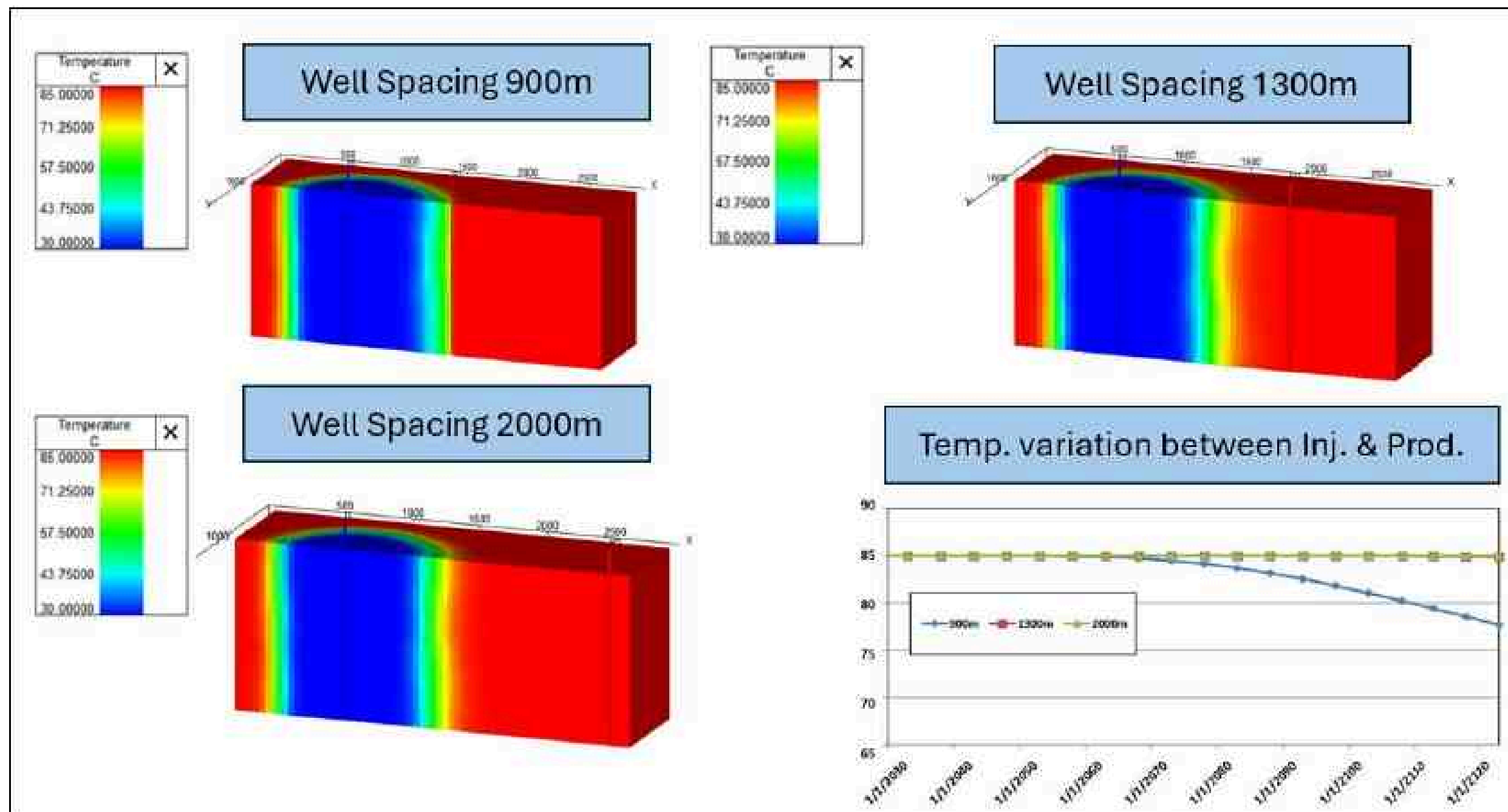
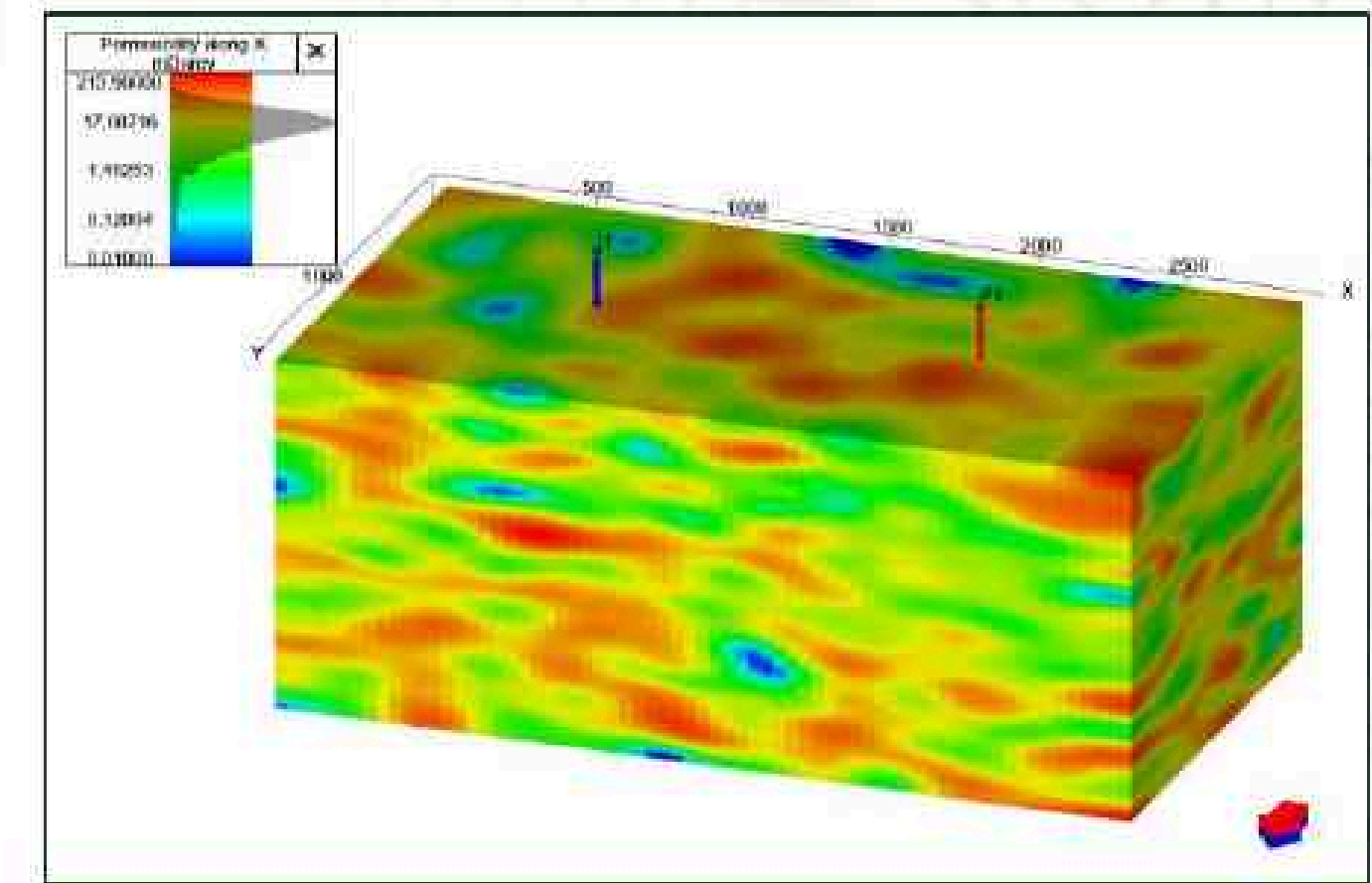


Reservoir Parameters	Genčiai	Vilkyčiai	South Siupariai	Nausodis	Diegliai
Effective porosity, % (min-average-max)	6–8–10	4.6–6.5–9.7	5.4–6.2–7.7	0.3–8–15	6–8.5–11.3
Permeability, mD (min-average-max)	0.1–12–219	0.1–10.4–41.4	0.01–16.7–45.14	0.01–9.4–895.6	0.1–10.8–47
Depth, m	1800–1826.4	1975–1992.5	1958–1988	1765–1860.6	1940–1990
Average temperature, °C	73.64	88	83	75	85
Water salinity, mg/L	146,217.33	229,000	-	138,241.18	200,000
Injection water temperature, °C	55	55	55	55	55
Reservoir Pressure, bars	191.66	222	216	190.491	213
Reservoir thickness, m (total and effective)	26.4; 16.19	68; 17.5	30; 16	95.6; 82.28	61; 25
NTG (Net-to-Gross), units	0.61	0.26	0.53	0.86	0.41



I. WELL SPACING

Thermal breakthrough and pressure gradient were the main factors in determining optimal well spacing.



I. OTHER INVESTIGATED SITES

		TRUE	CALCULATED	
Site	Cases	Temperature, °C	Production rate, m3/d	Potential energy differential, MWh
Nausodis	Low	75	647	1.52E+05
	Mid		799	1.87E+05
	High		967	2.27E+05
Diegliai	Low	85	258	9.06E+04
	Mid		284	9.99E+04
	High		319	1.12E+05
Vilkyčiai	Low	88	195	7.56E+04
	Mid		217	8.37E+04
	High		242	9.37E+04
P. Šiūpariai	Low	83	225	7.38E+04
	Mid		247	8.12E+04
	High		276	9.05E+04
Genčiai	Low	74	142	3.11E+04
	Mid		176	3.84E+04
	High		213	4.64E+04

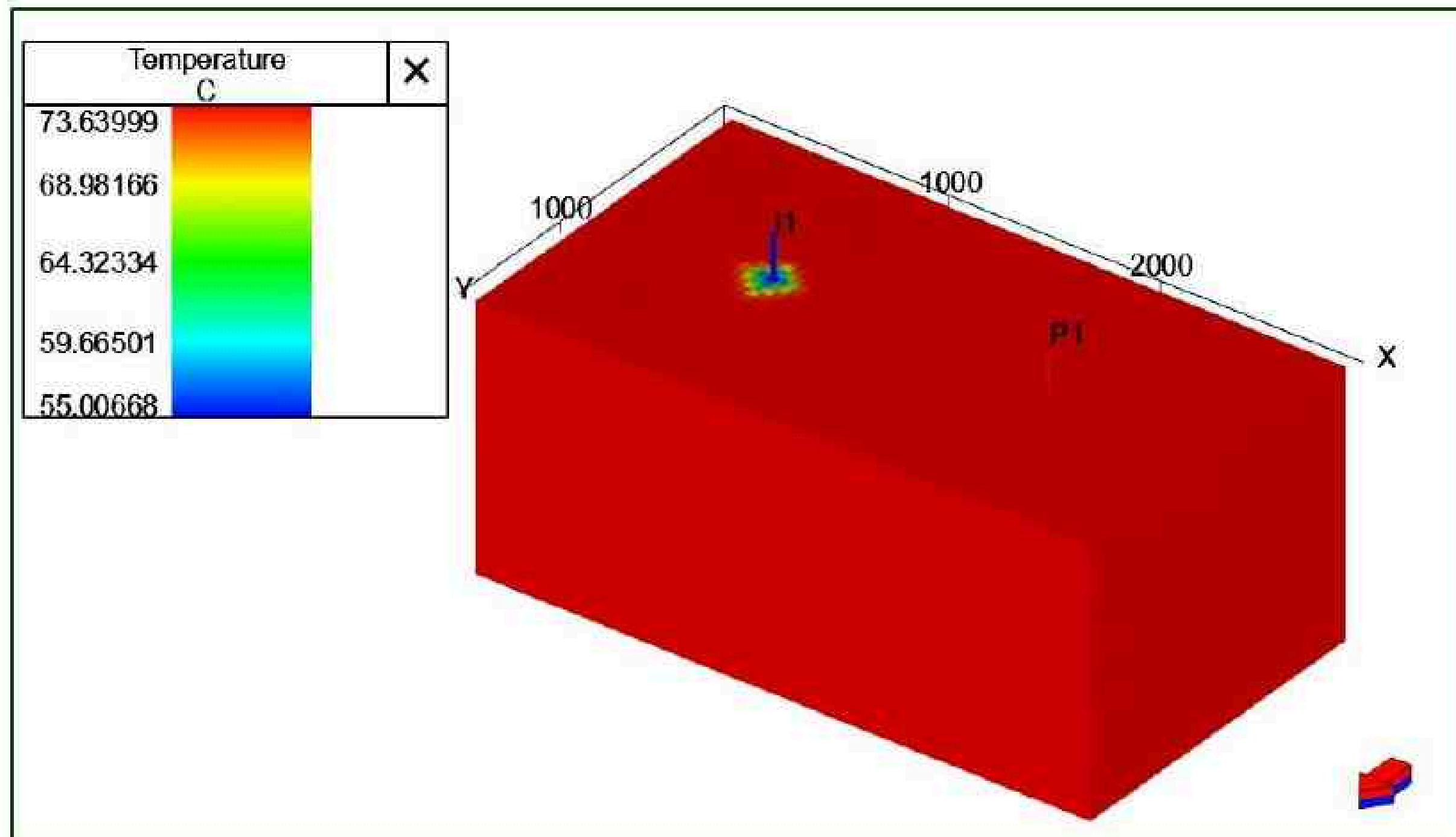
Simulations show:

- Production ~**250 m³/day** for most Cambrian reservoirs, given the simulation constraints.

Energy production ranges:

- **1.5-7.5 GWh** annual heat production (**179-855 kW**).

I. TEMPERATURE DISTRIBUTION: GENČIAI FIELD



Simulations show:

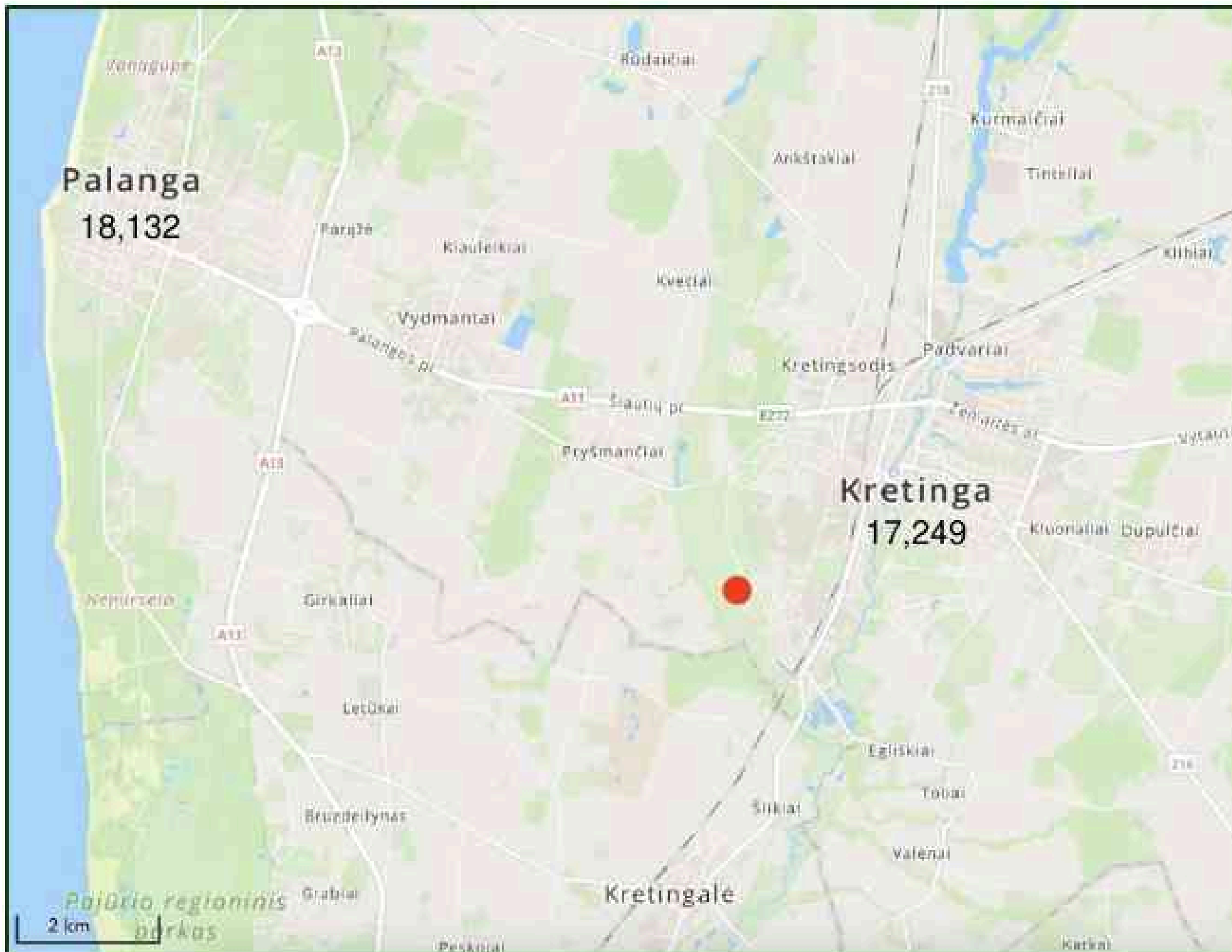
- Production of **176 m³/day** for Genčiai reservoir.

Worst case scenario:

- **1.5 GWh** annual heat production (**179 kW**).

I. GENČIAI FIELD: LOCATION

Kretinga houses **17k** people with district heating demanding **18 630 MWh** per season.

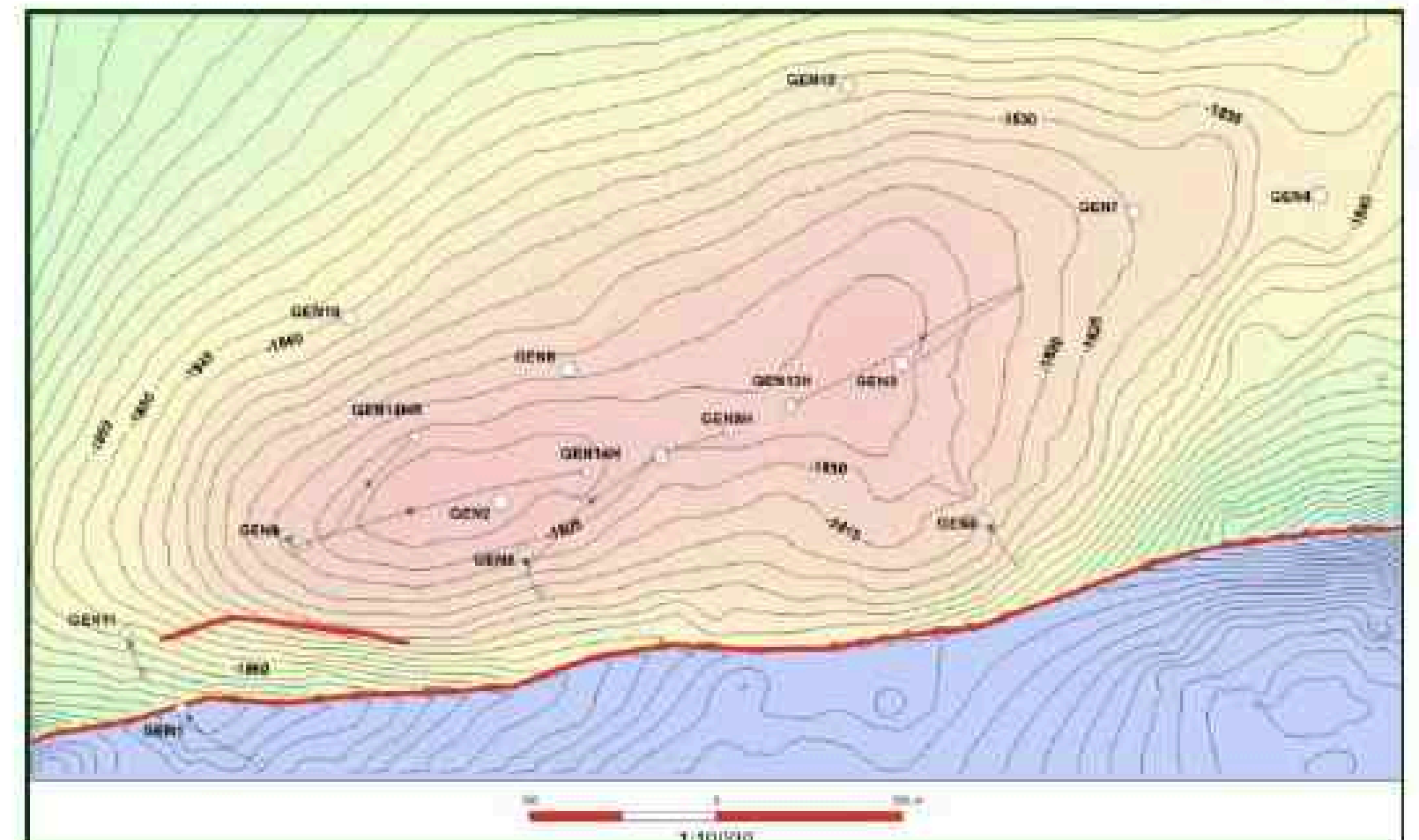


Water co-production **86k m³/y** of **74 °C**:

- Preliminary output **~1050 MWh**.

Well workover could form **6 doublets**:

- This could accommodate **4 500 MWh**.



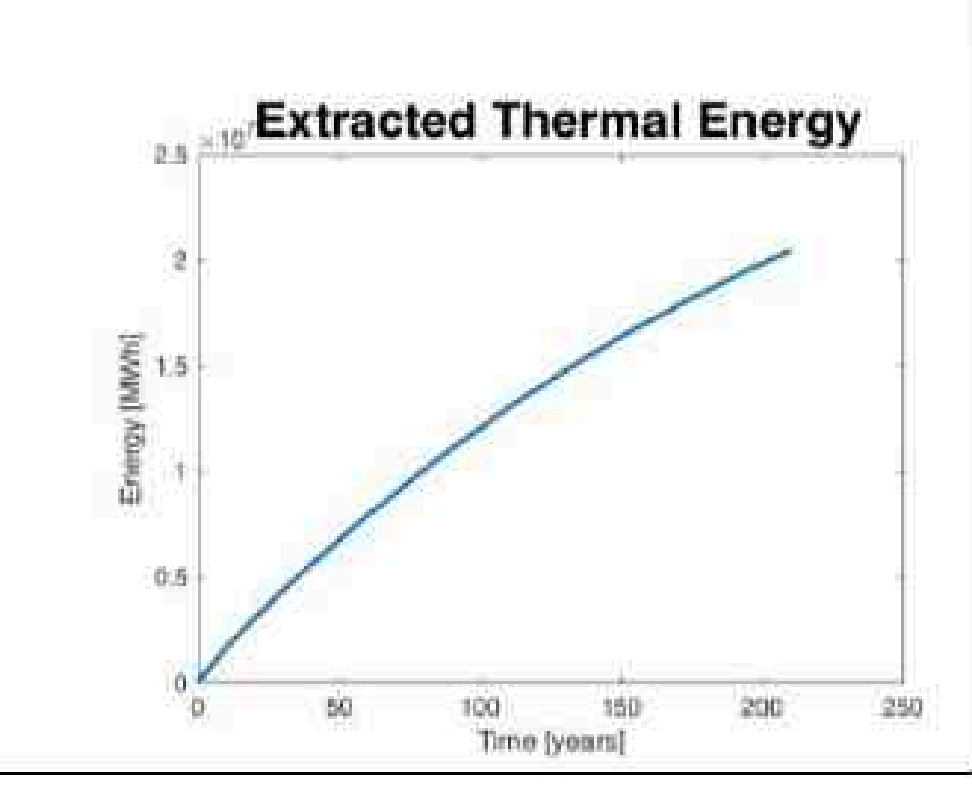
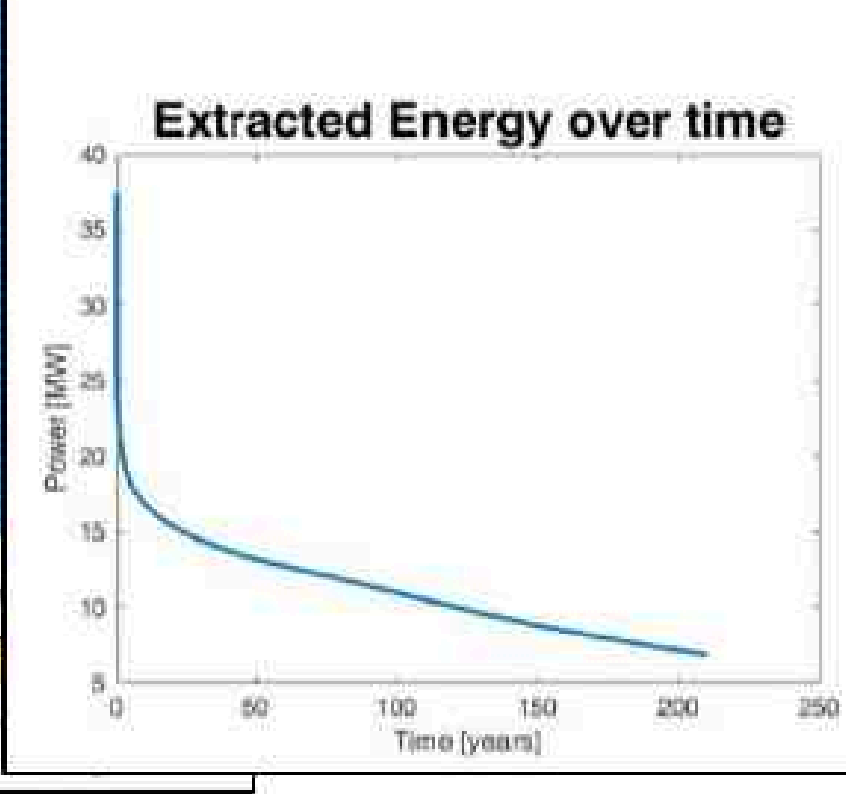
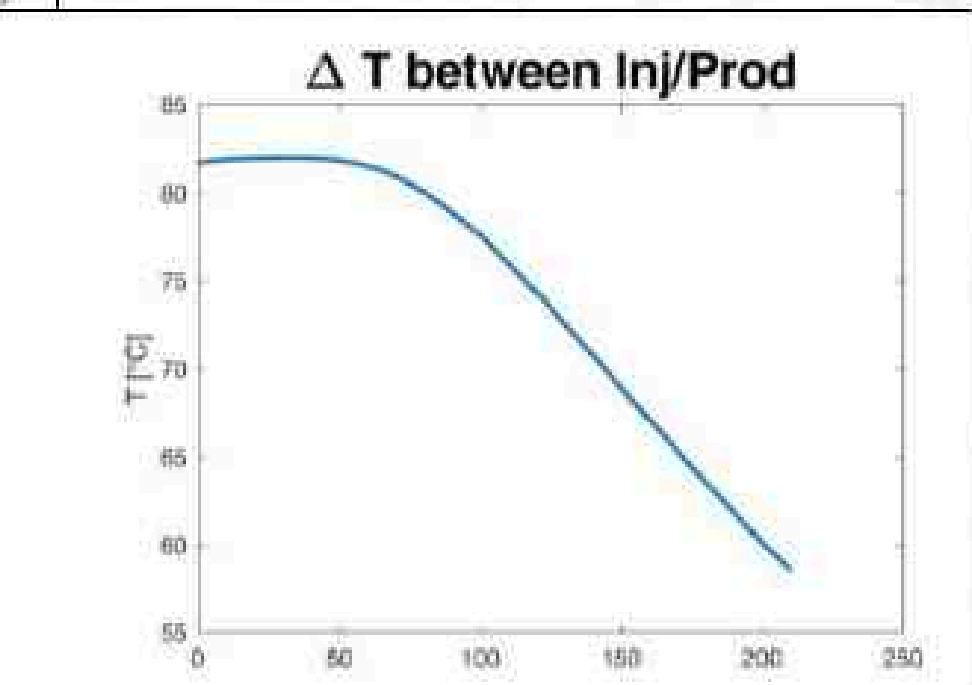
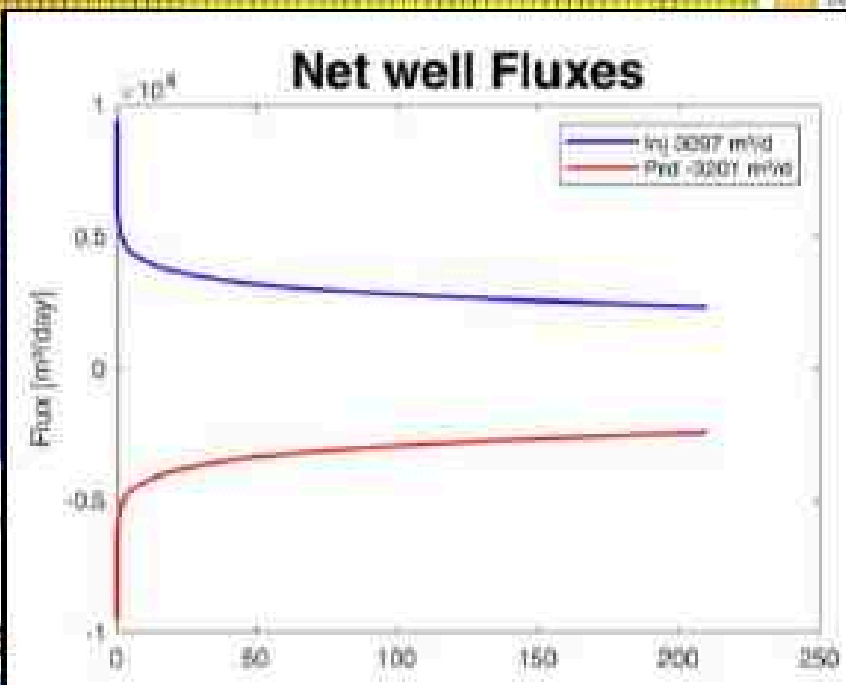
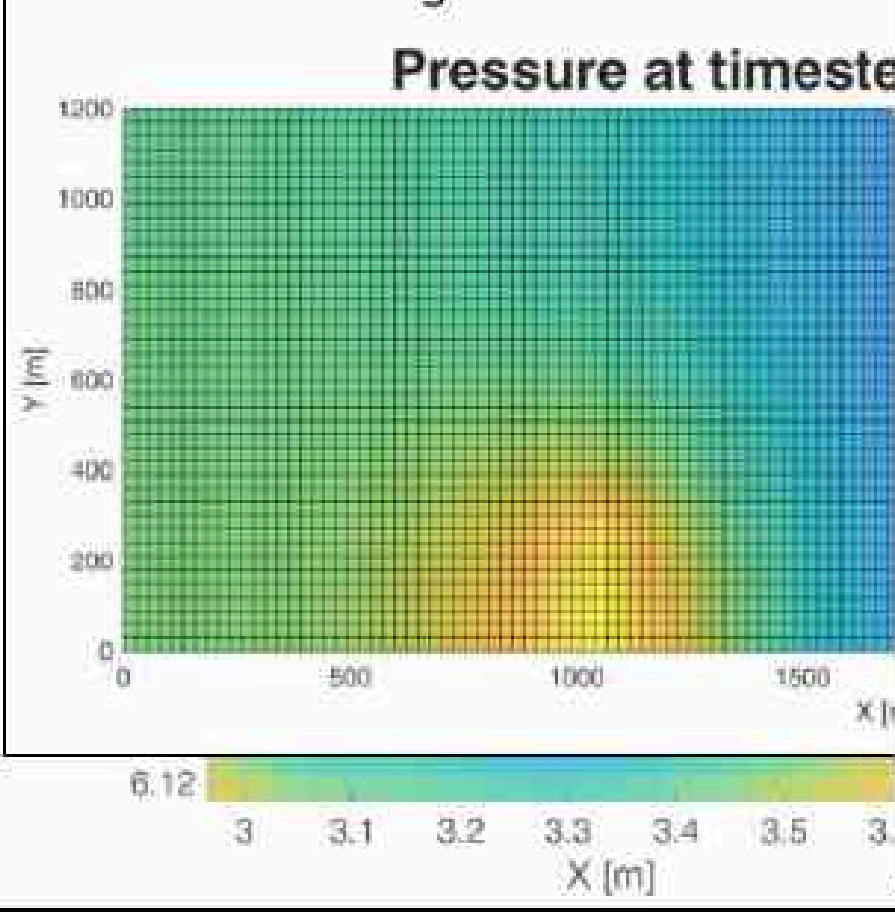
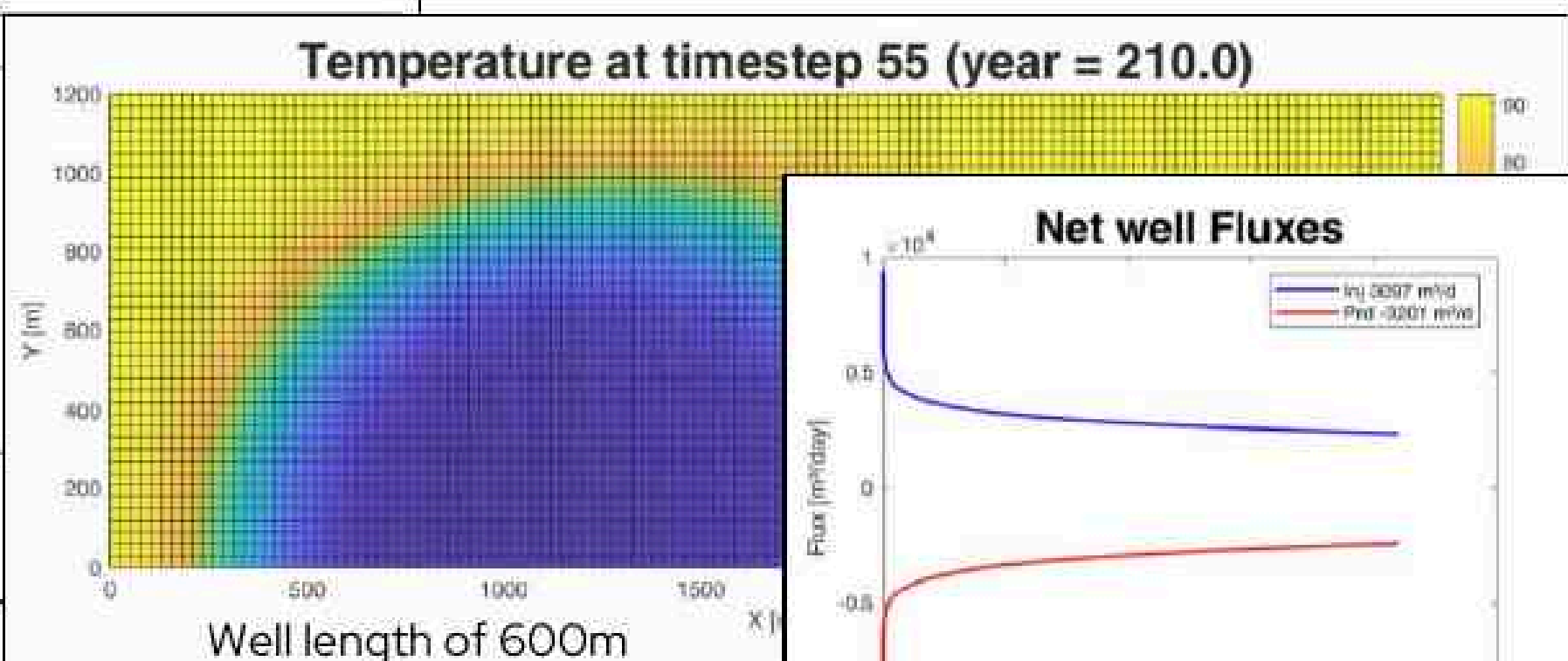
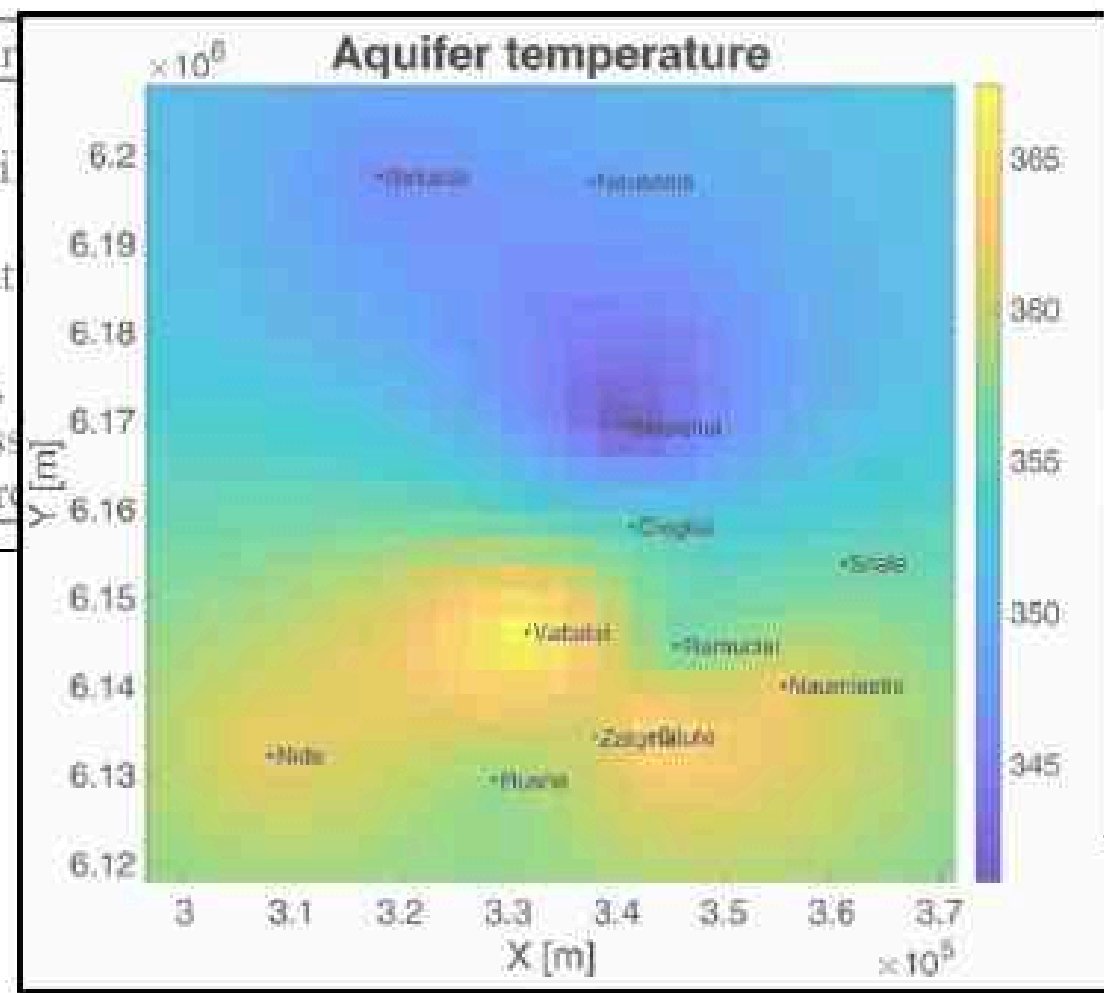
II. GEOTHERMAL POTENTIAL MAP: INTERMEDIATE RESULTS

Table 1: Reservoirs 1–6 with their respective properties.

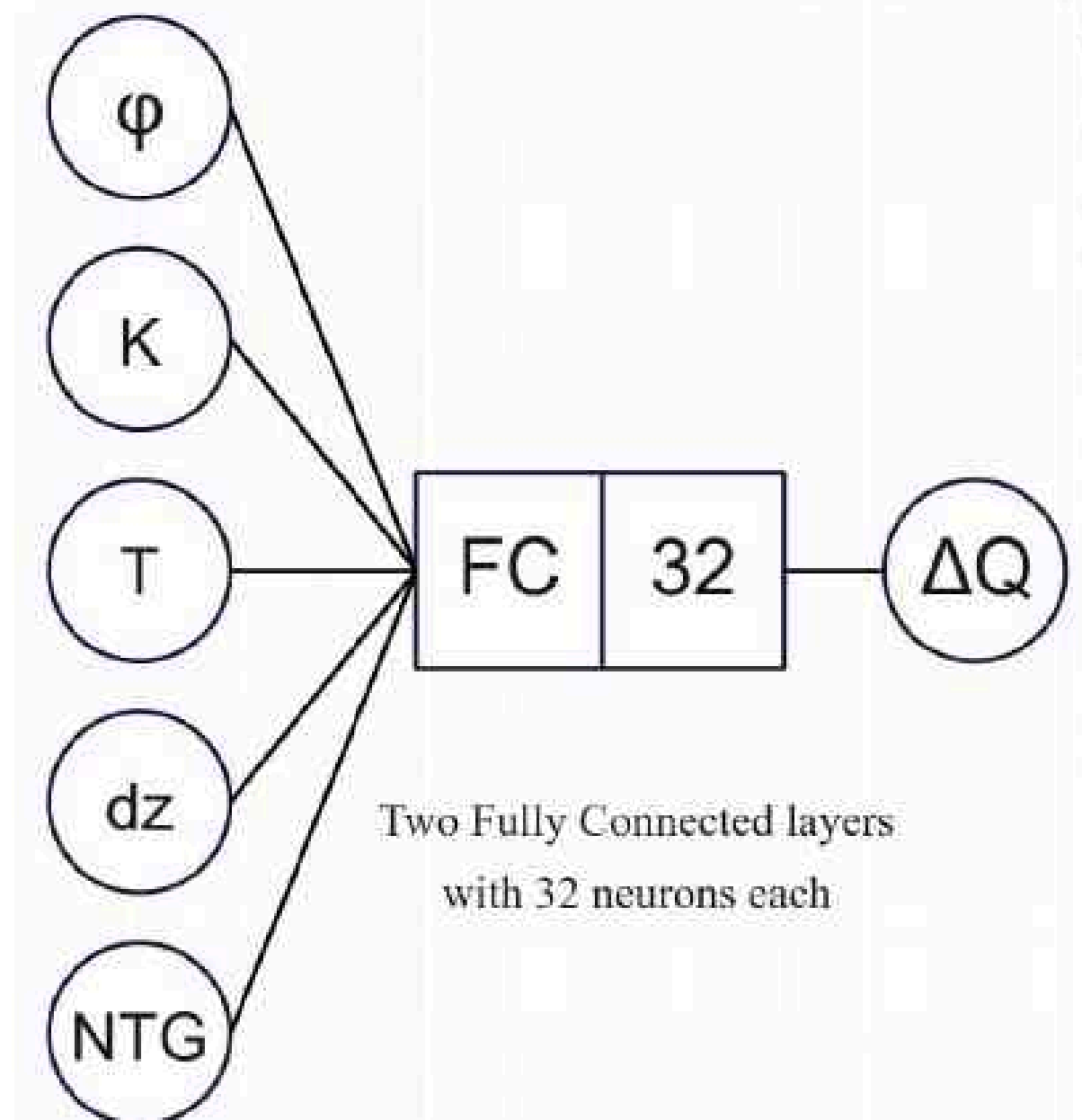
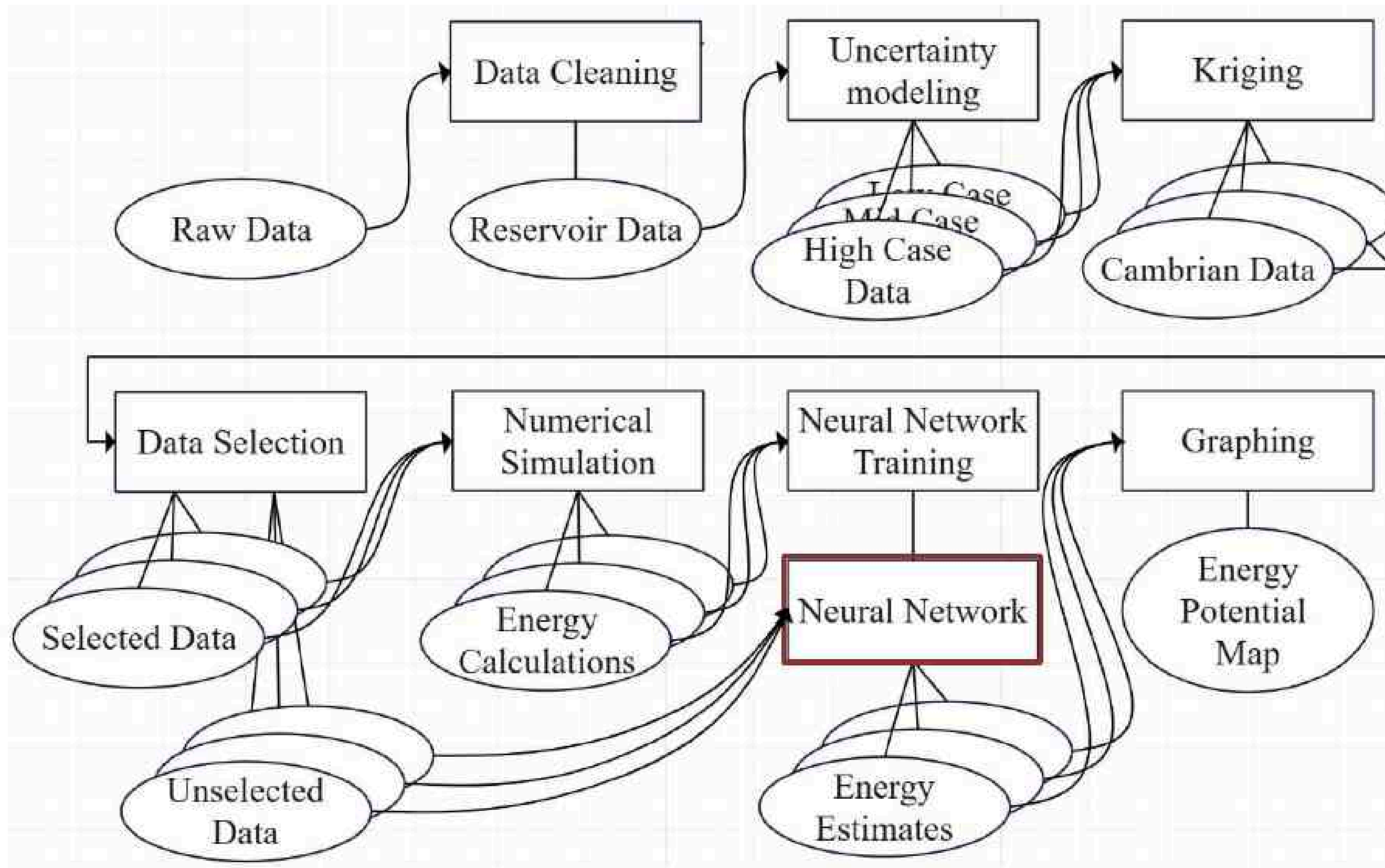
Reservoirs	Girkaliai	Nausodis	Šilalė	Šilutė
Porosity, %	8.10	8.50	7.70	10.20
Permeability, mD	10.10	53.80	8.20	38.0
Temperature, °C	73	75	83	92
Pressure, bar	207	188	220	233
Thickness, m	157.40	82.30	73.0	138.0
Net-to-gross, %	50.10	61.0	30.0	39.30

Table 2: Reservoirs 7–12 with their respective properties.

Reservoir	
Porosity, %	6.2
Permeability, mD	6.19
Temperature, °C	6.18
Pressure, bar	6.17
Thickness, m	6.16
Net-to-gross, %	6.15

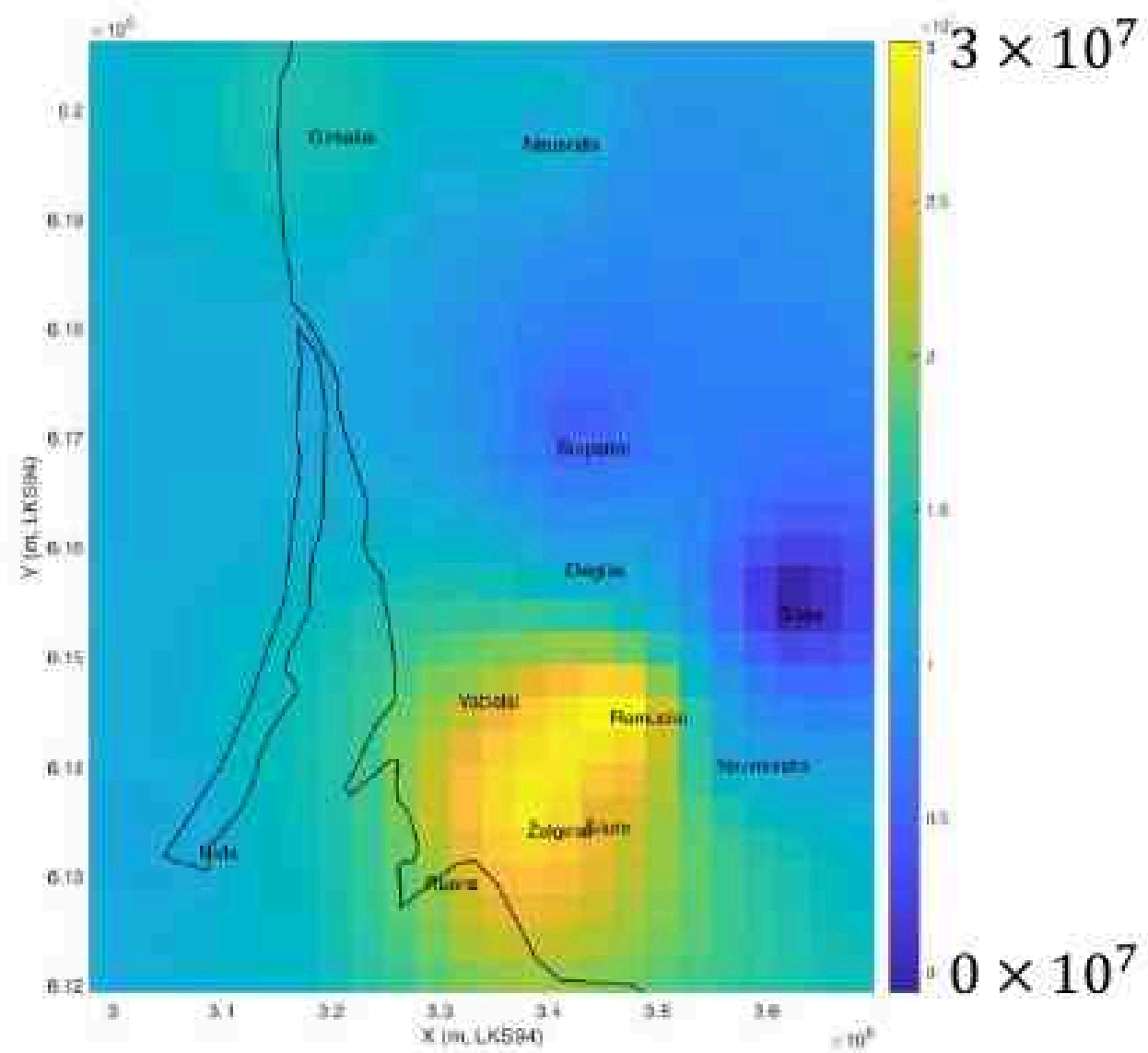


II. GEOTHERMAL POTENTIAL MAP: WORKFLOW

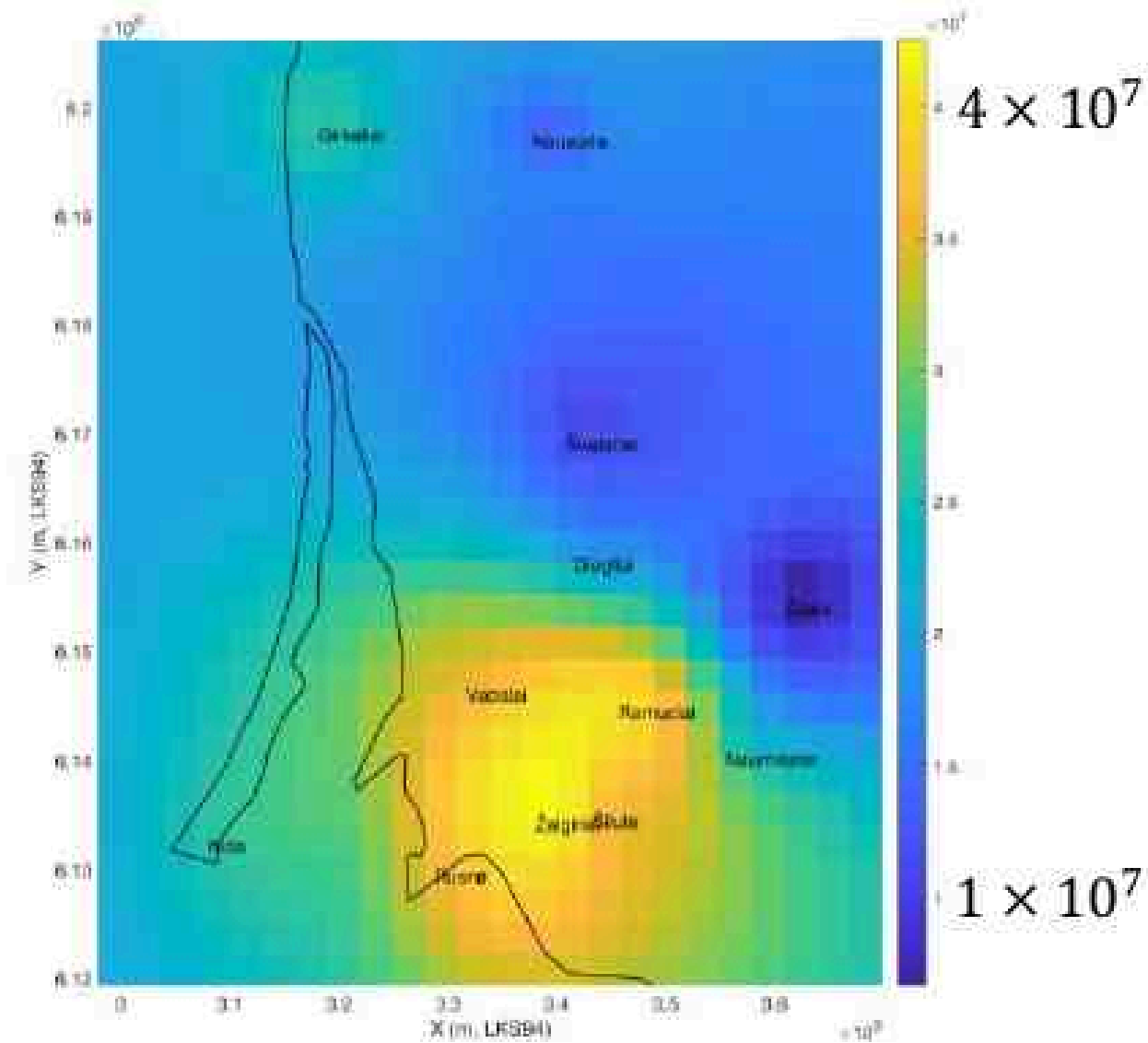


II. GEOTHERMAL POTENTIAL MAP: SIMULATION RESULTS

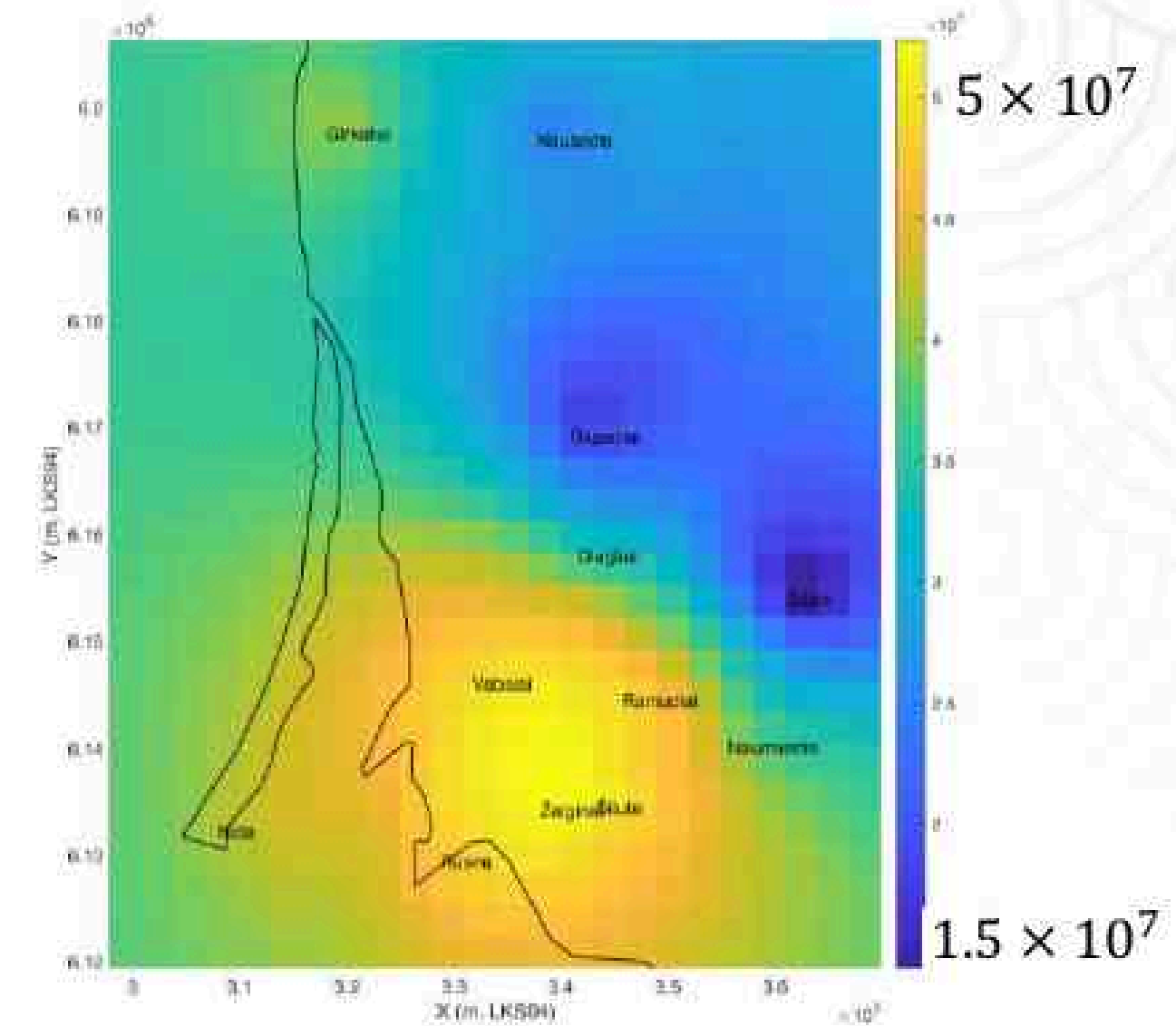
Low (-10%) case



Mid case

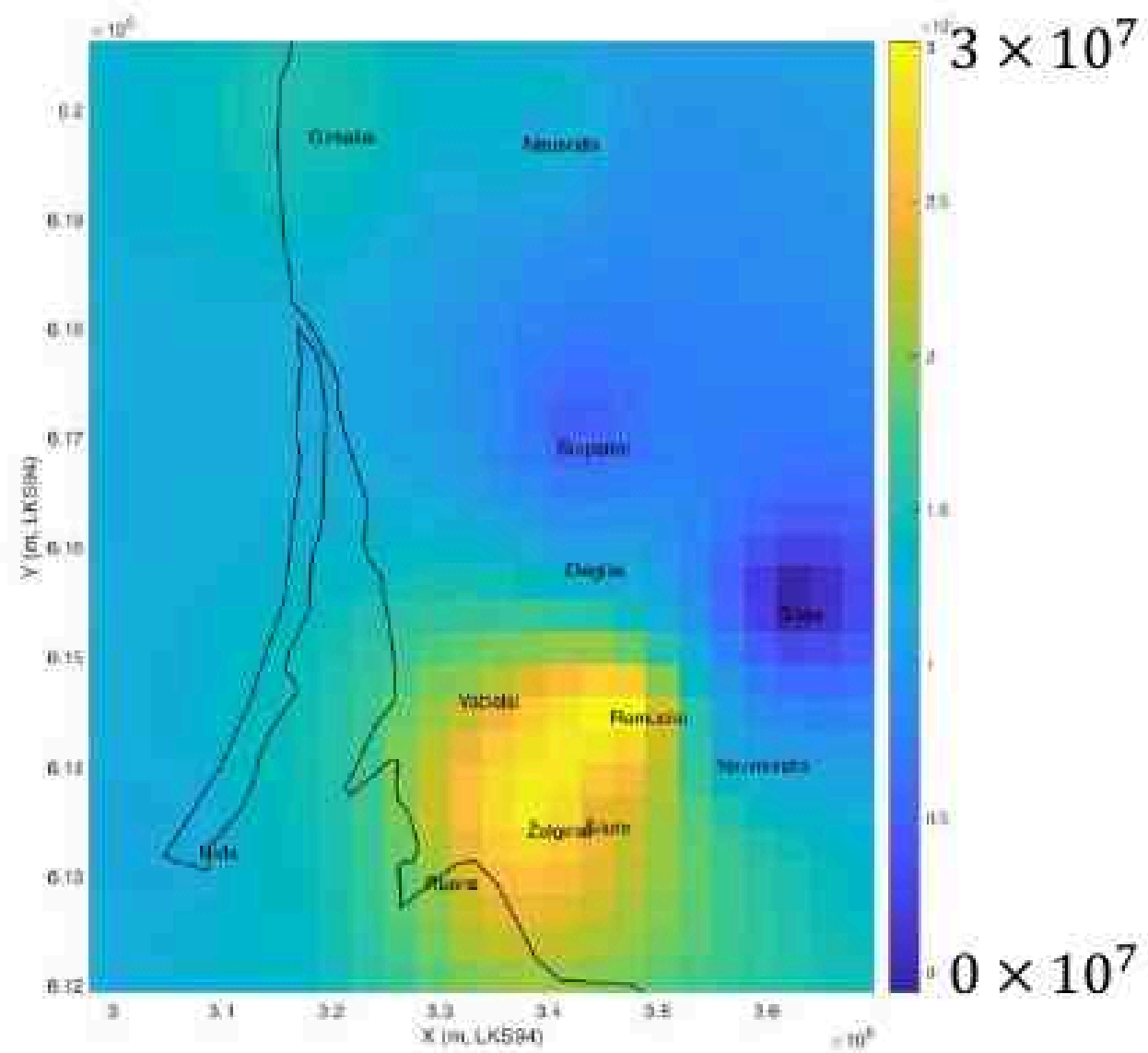


High (+10%) case

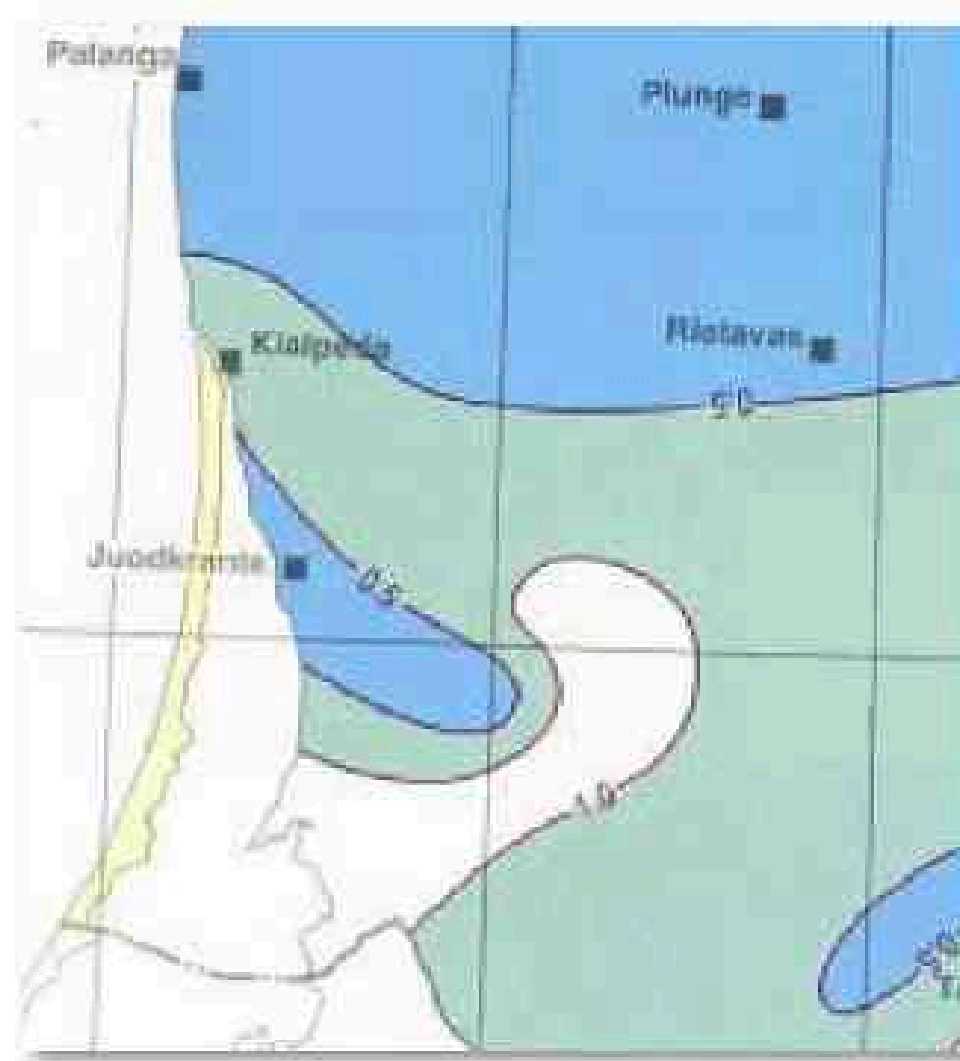


II. GEOTHERMAL POTENTIAL MAP: SIMULATION RESULTS

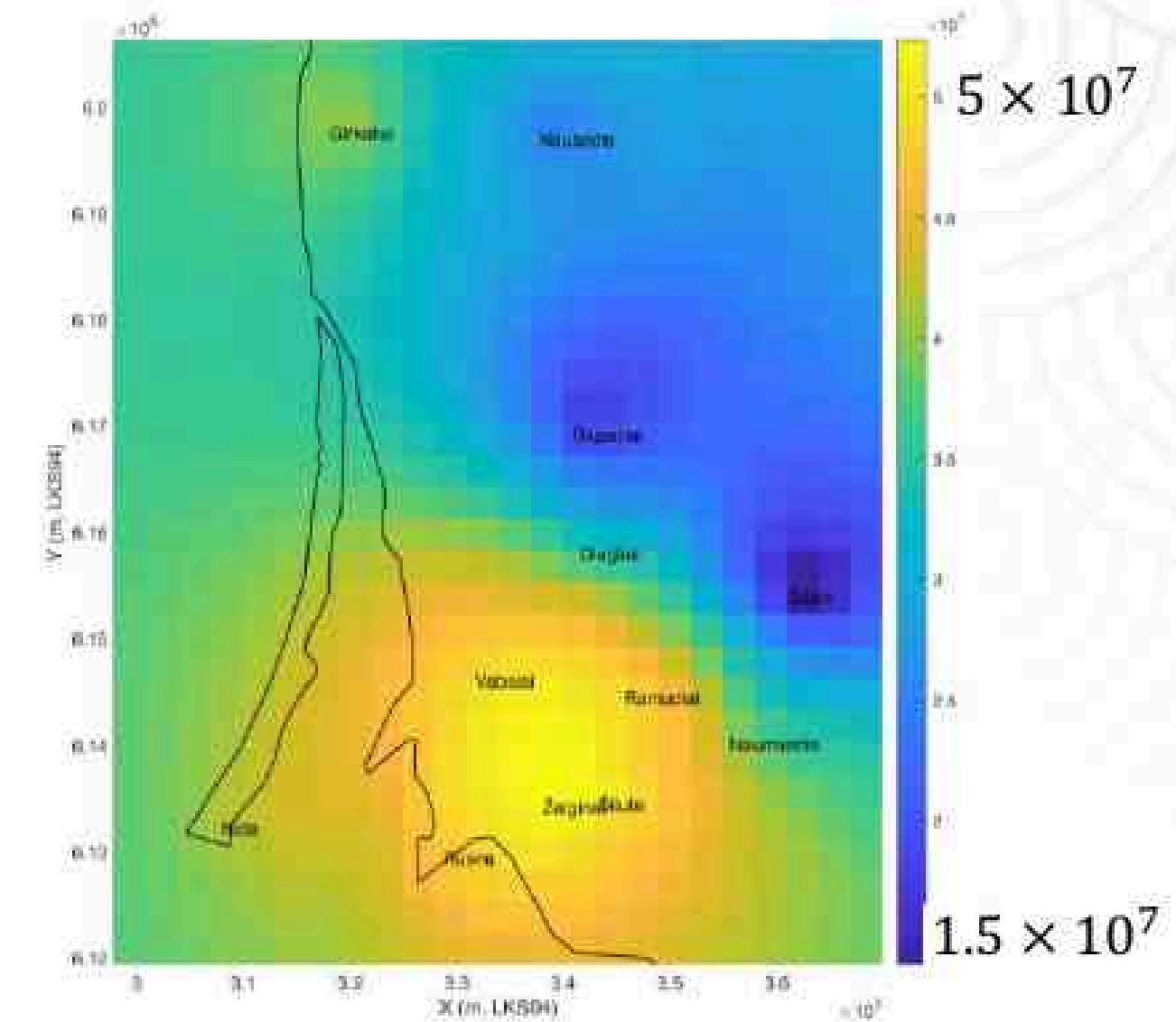
Low (-10%) case



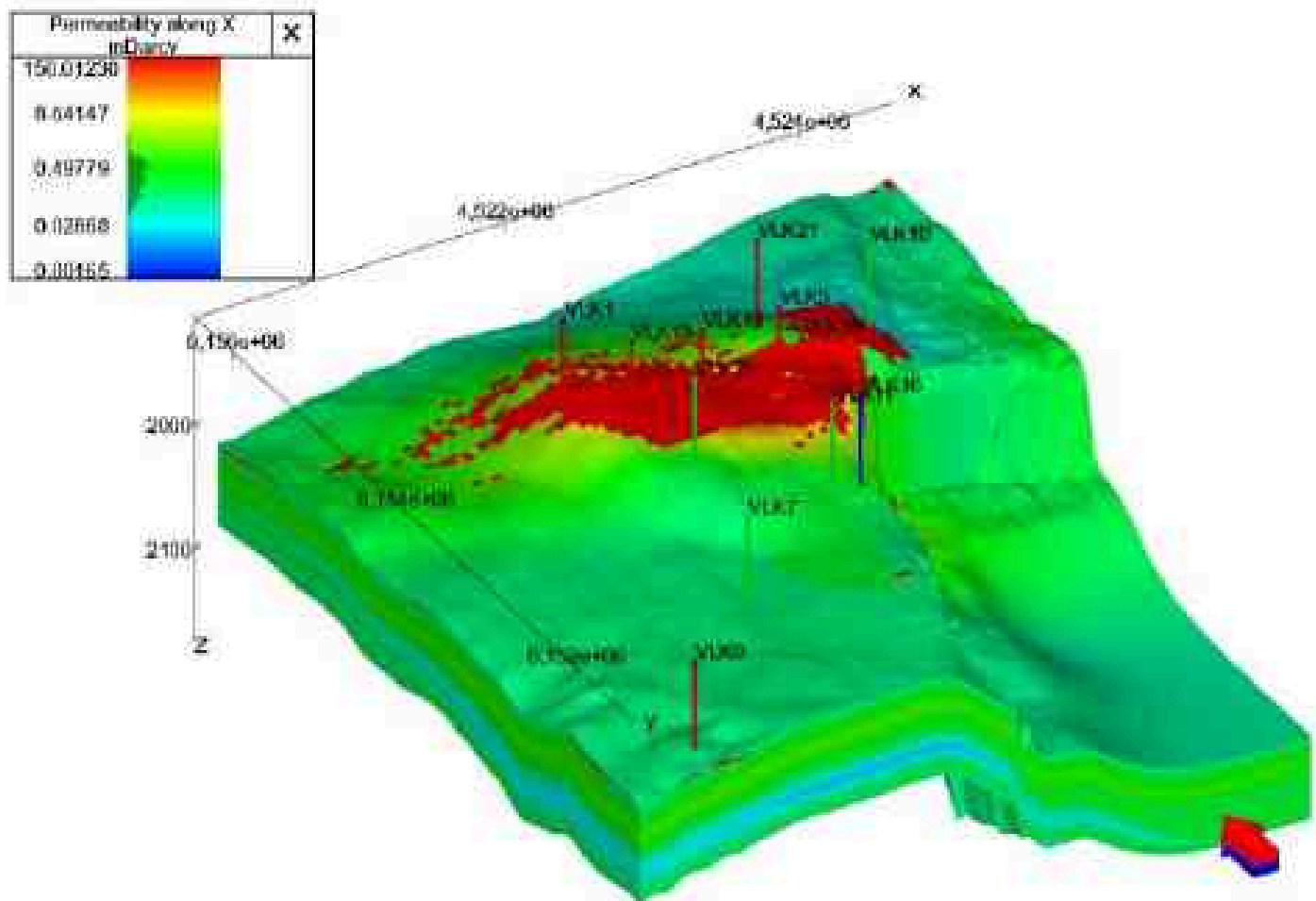
Mid case



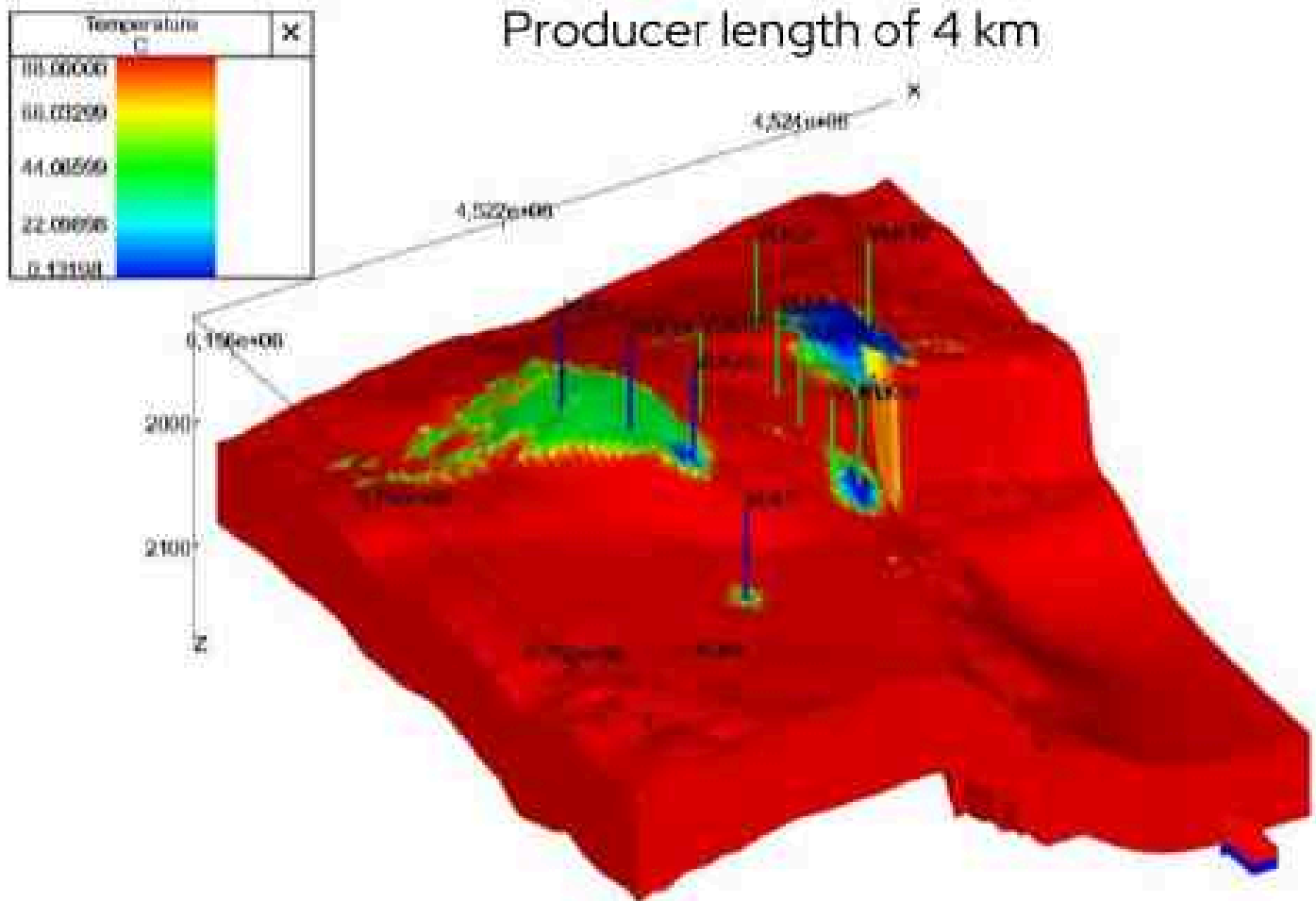
High (+10%) case



III. VILKYČIAI FIELD INVESTIGATION



Producer length of 4 km

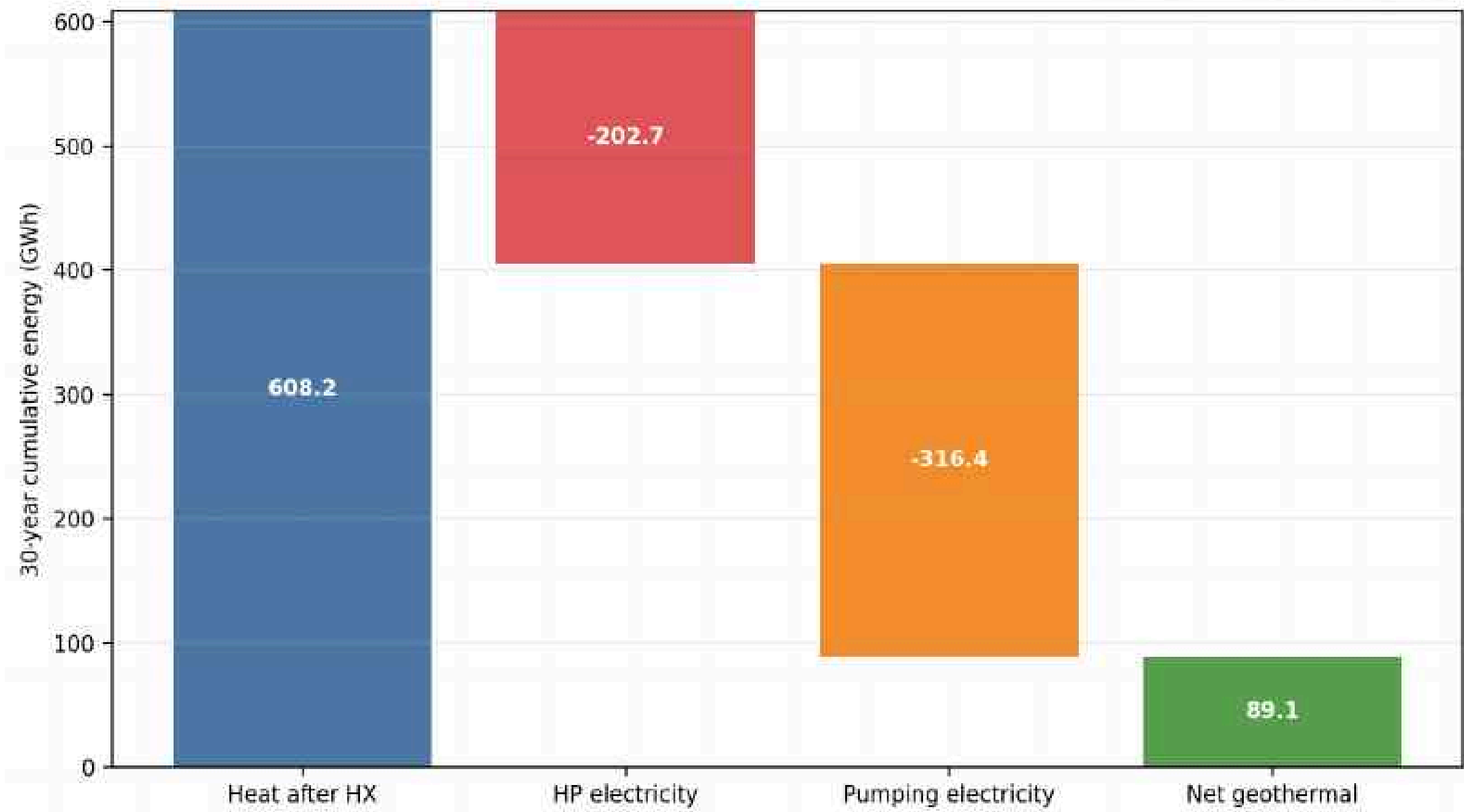


Case no.	Avg. distance, km	Depth	Injector layout	Fracture length, m	Fracture gap, m	Injection, rm ³ /day	Production, rm ³ /day	Temperature at last year
0.	N/A	Both	0 th	N/A	N/A	217.78	278.79	72.61
0.1.1	2	Upper	1 st	N/A	N/A	370.55	287.88	87.70
0.1.2	1.5	Upper	1 st	N/A	N/A	442.97	386.61	87.22
0.1.3	1	Upper	1 st	N/A	N/A	460.72	385.13	84.96
0.1.4	1.1	Upper	2 nd	N/A	N/A	288.88	278.30	86.49
0.1.5	0.6	Upper	2 nd	N/A	N/A	333.18	353.19	82.47
0.2.1	2	Lower	1 st	N/A	N/A	275.28	144.77	88.00
0.2.2	1.5	Lower	1 st	N/A	N/A	289.62	169.39	88.00
0.2.3	1	Lower	1 st	N/A	N/A	293.37	178.74	87.99
0.2.4	1.1	Lower	2 nd	N/A	N/A	217.84	141.31	88.00
0.2.5	0.6	Lower	2 nd	N/A	N/A	229.01	163.94	88.00
1.1.2	1.5	Upper	1 st	250	500	470.04	424.71	87.31
1.1.4	1.1	Upper	2 nd	250	500	302.30	305.14	87.16
1.2.2	1.5	Lower	1 st	250	500	297.12	187.82	88.00
1.2.4	1.1	Lower	2 nd	250	500	223.25	157.16	88.00
2.1.2	1.5	Upper	1 st	250	250	489.39	450.78	87.34
22.1.2	1.5	Upper	1 st	250	150	509.85	476.14	87.32
2.2.2	1.5	Lower	1 st	250	250	302.39	199.78	88.00
2.2.2	1.5	Lower	1 st	250	150	307.75	209.50	88.00
3.1.2	1.5	Upper	1 st	500	500	487.01	447.45	87.36
3.2.2	1.5	Lower	1 st	500	500	296.03	191.76	88.00

IV. VILKYČIAI PARAMETER PERTURBATION

Parameter	Case	Multiplier		Q _{net} (GWh)
None	Base	—		89.093
Injection temperature	Low	1.60		-13.205
	High	0.40		181.956
Pressure difference	Low	0.67		104.464
	High	1.33		53.857
Lateral permeability	Low	K _x 0.56	K _x 0.42	53.524
	High	K _y 1.63	K _y 1.70	115.956
Net-to-gross ratio	Low	0.89		83.041
	High	1.27		102.190
Fracture aperture size	Low	0.9 (K 0.73)		83.305
	High	1.1 (K 1.33)		91.038
Vertical permeability	Low	0.56		82.489
	High	1.63		90.931
Producer well index	Low	0.9		88.260
	High	1.1		89.782
Injector well index	Low	0.9		88.889
	High	1.1		89.262
Porosity	Low	0.98		89.124
	High	1.03		89.073

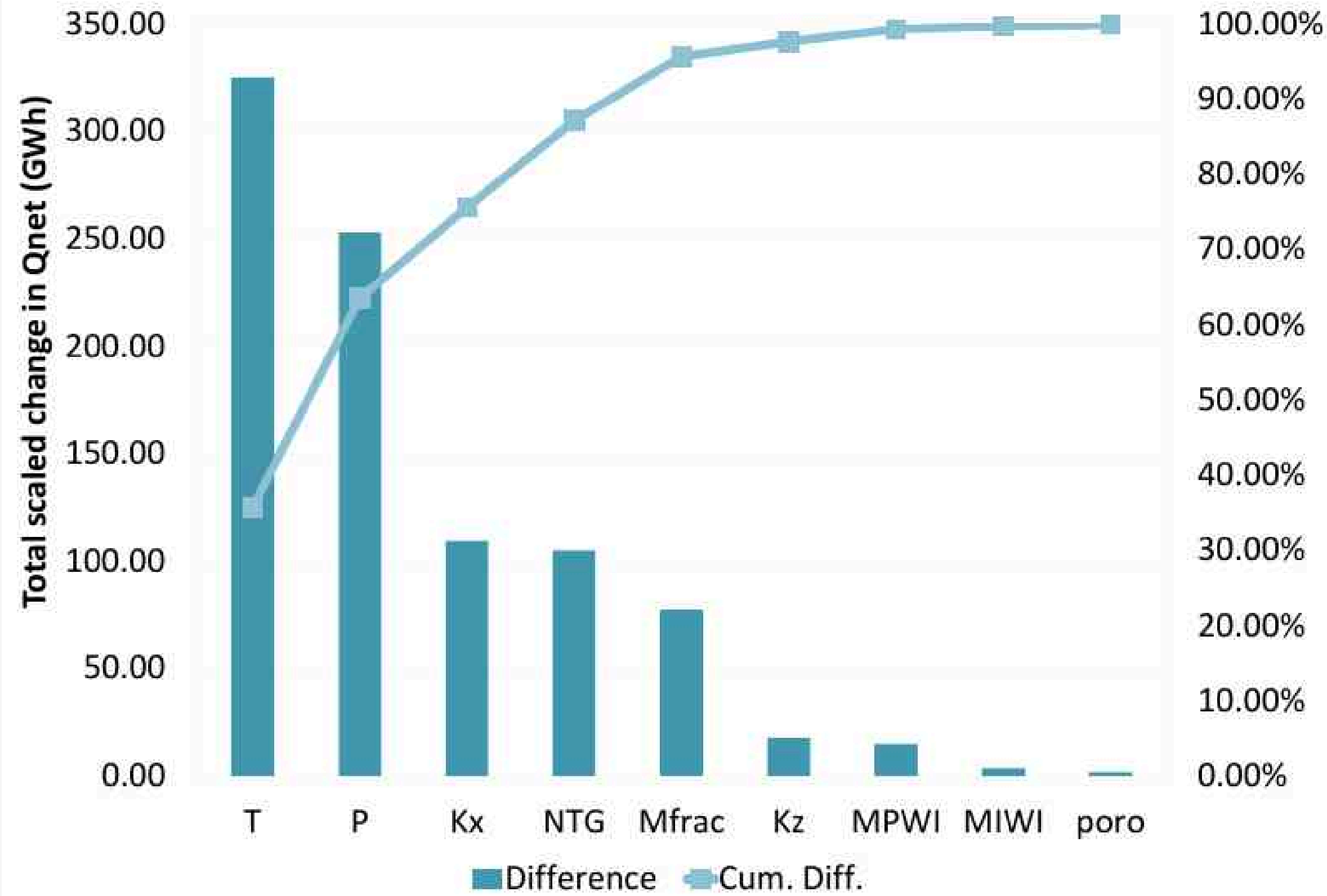
Energy constitution



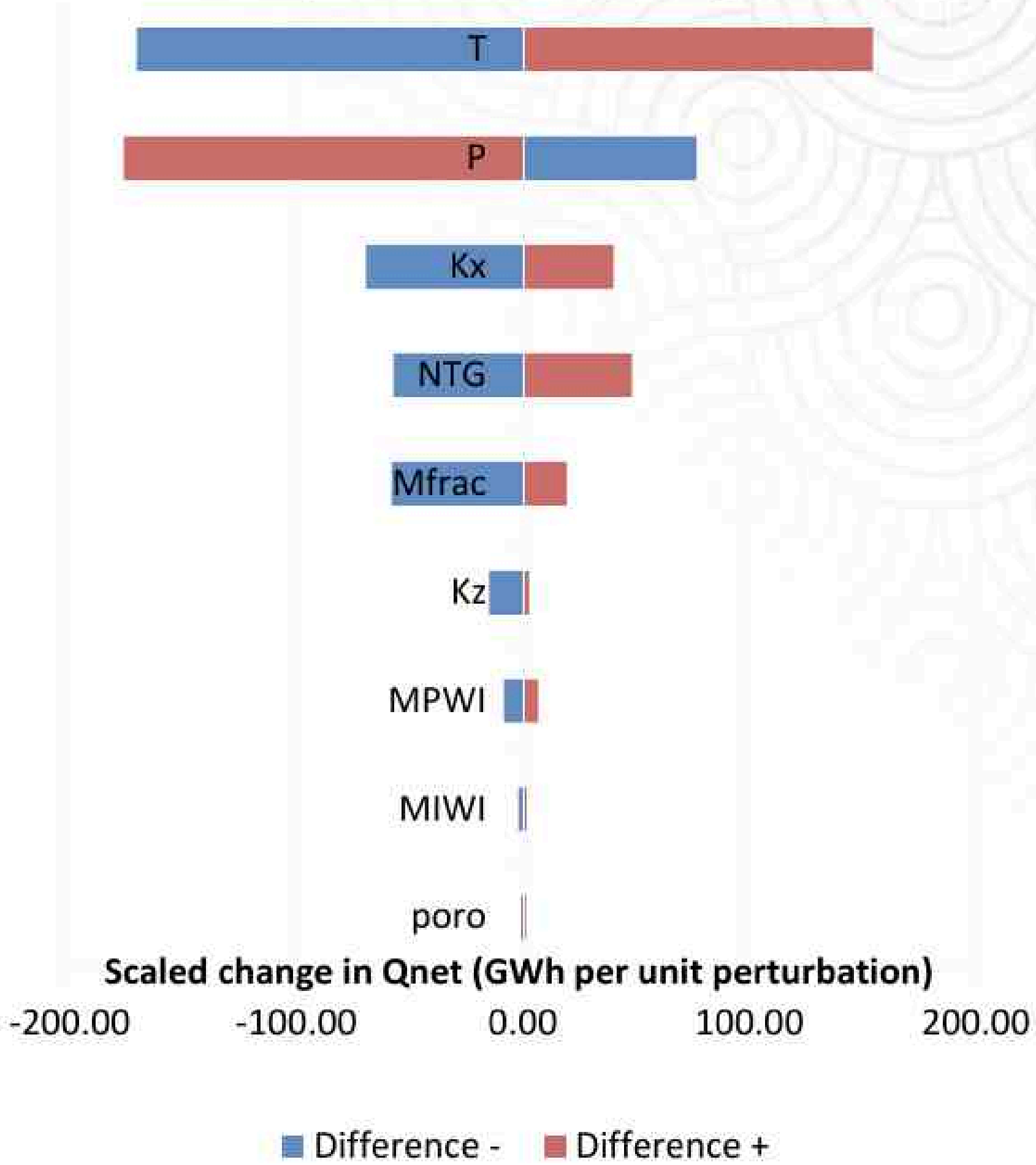
IV. VILKYČIAI

SENSITIVITY ANALYSIS

Vilkyčiai Pareto Chart



Vilkyčiai Tornado Diagram



ET-FORUM

ENERGY TRANSITION FORUM

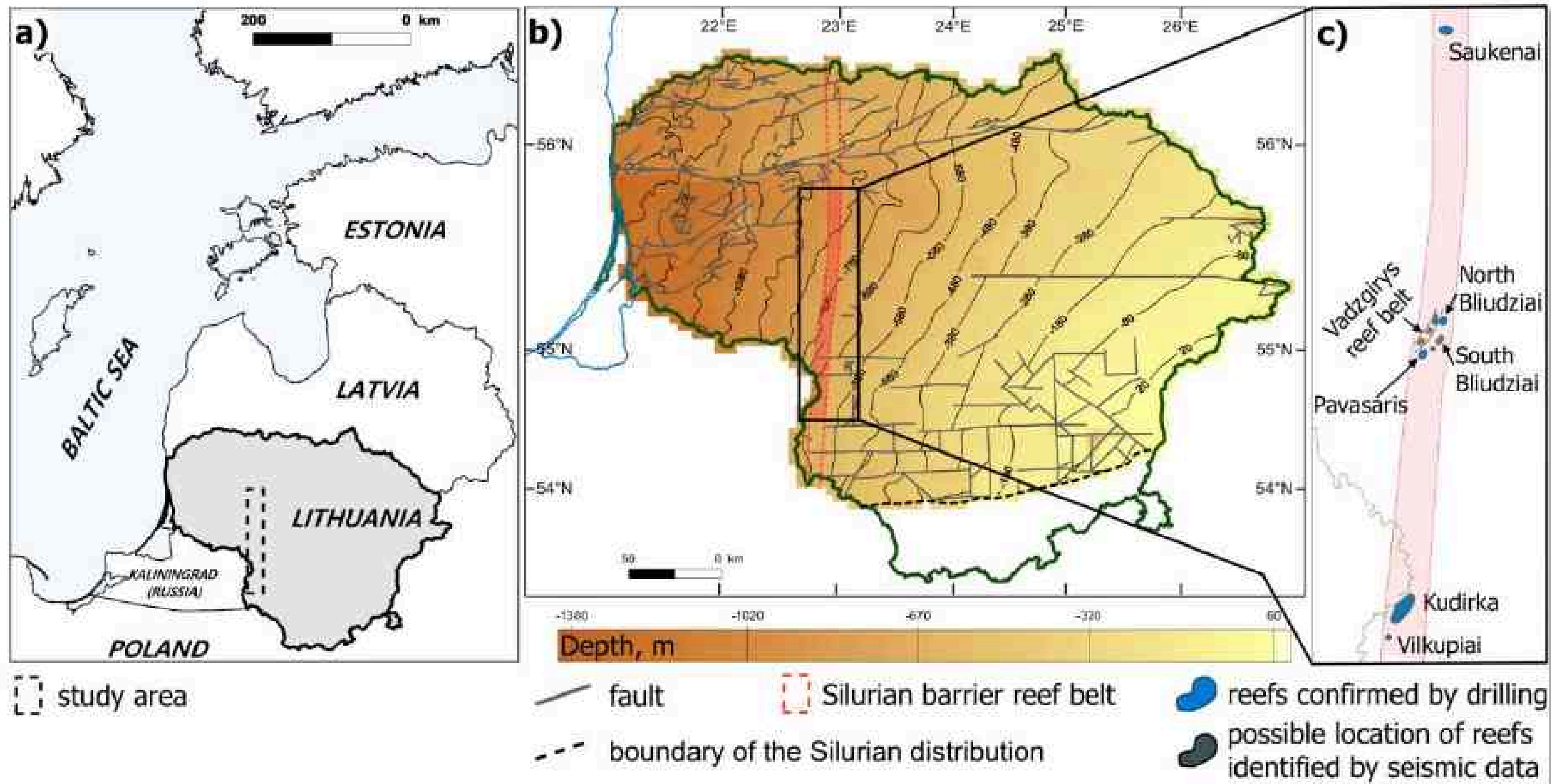
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PEOPLE • IDEAS • SOLUTIONS
FOR A CLEANER TOMORROW

QUESTIONS & ANSWERS

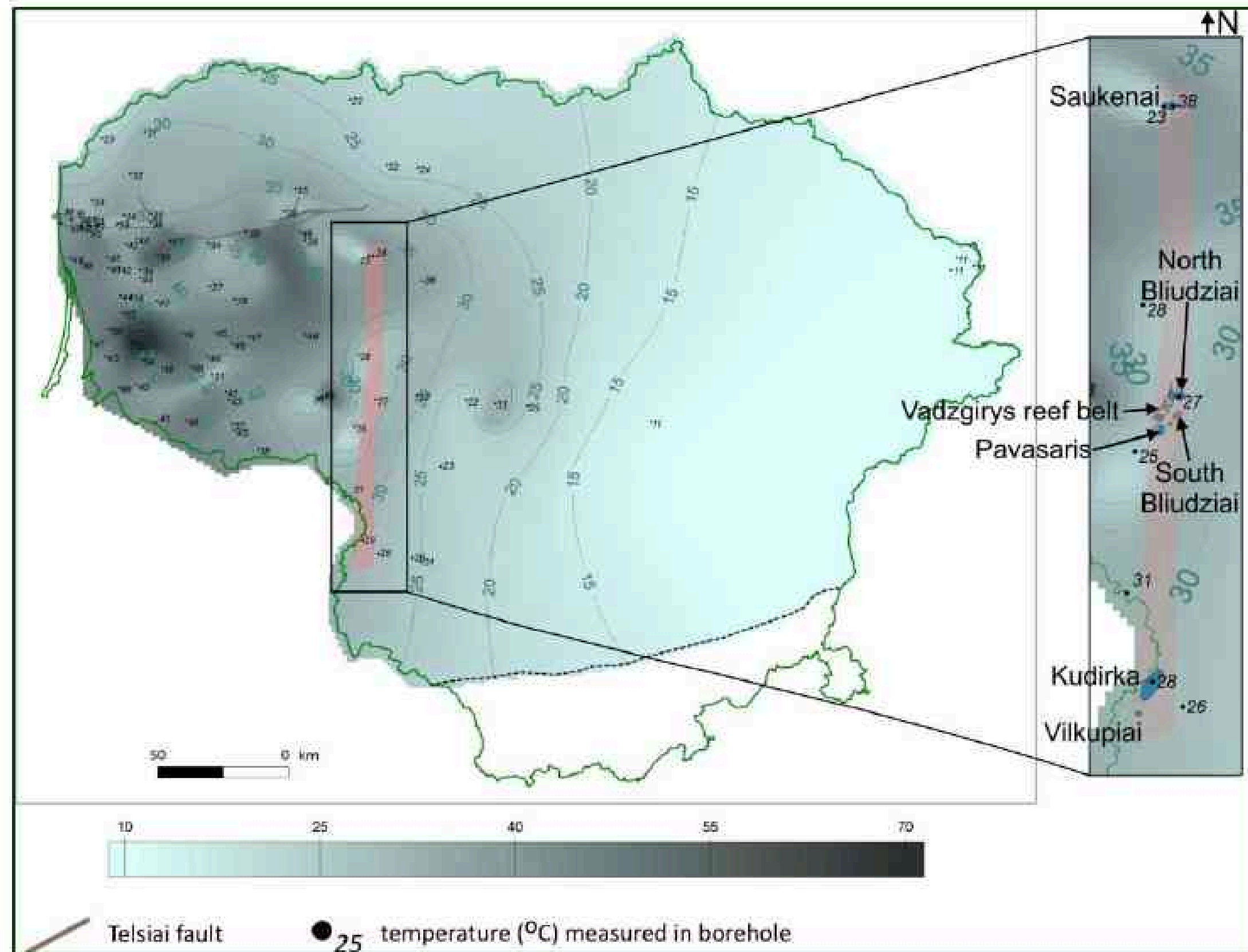


LET'S DISCUSS A CLEANER,
MORE SECURE ENERGY FUTURE



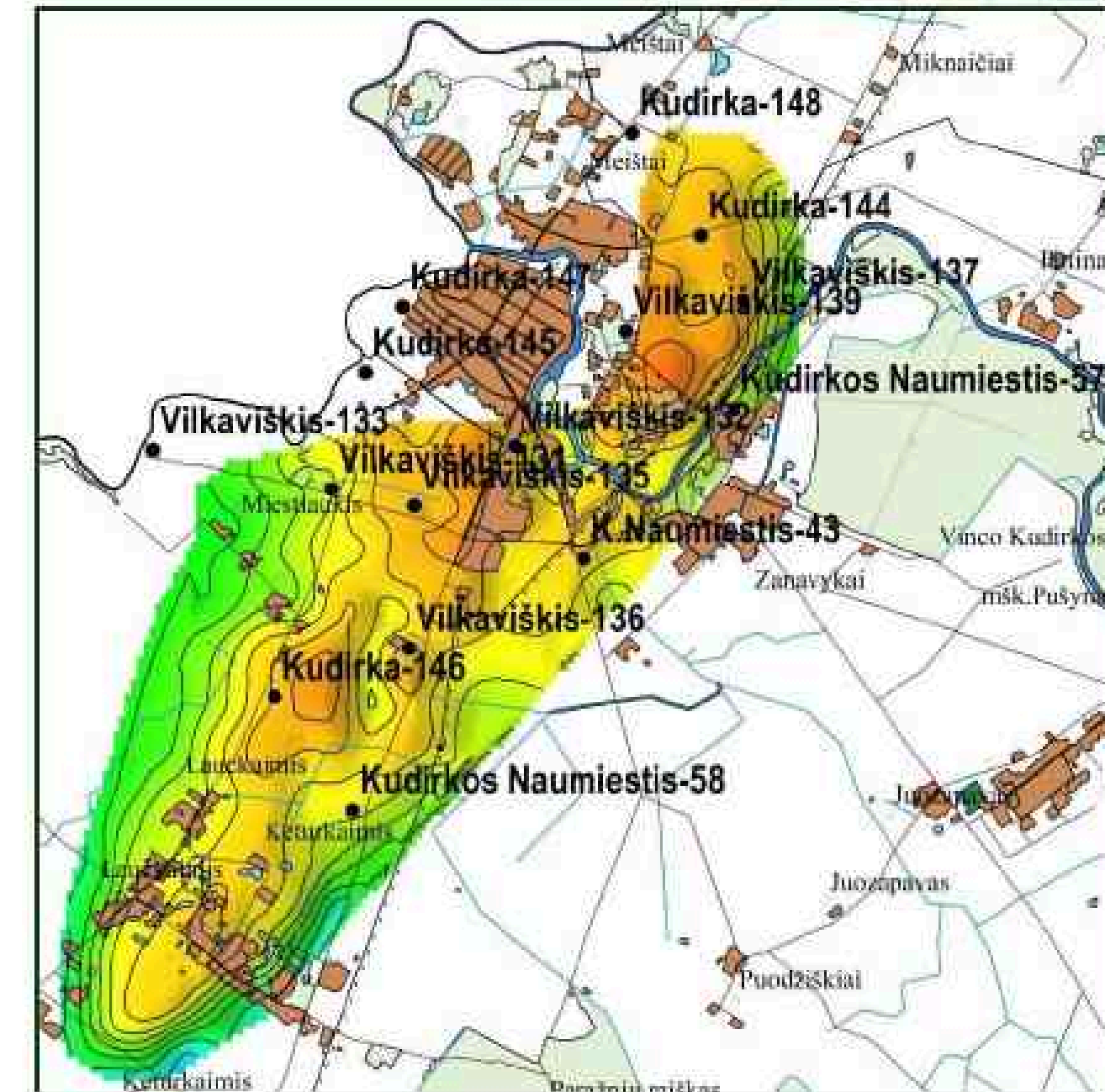
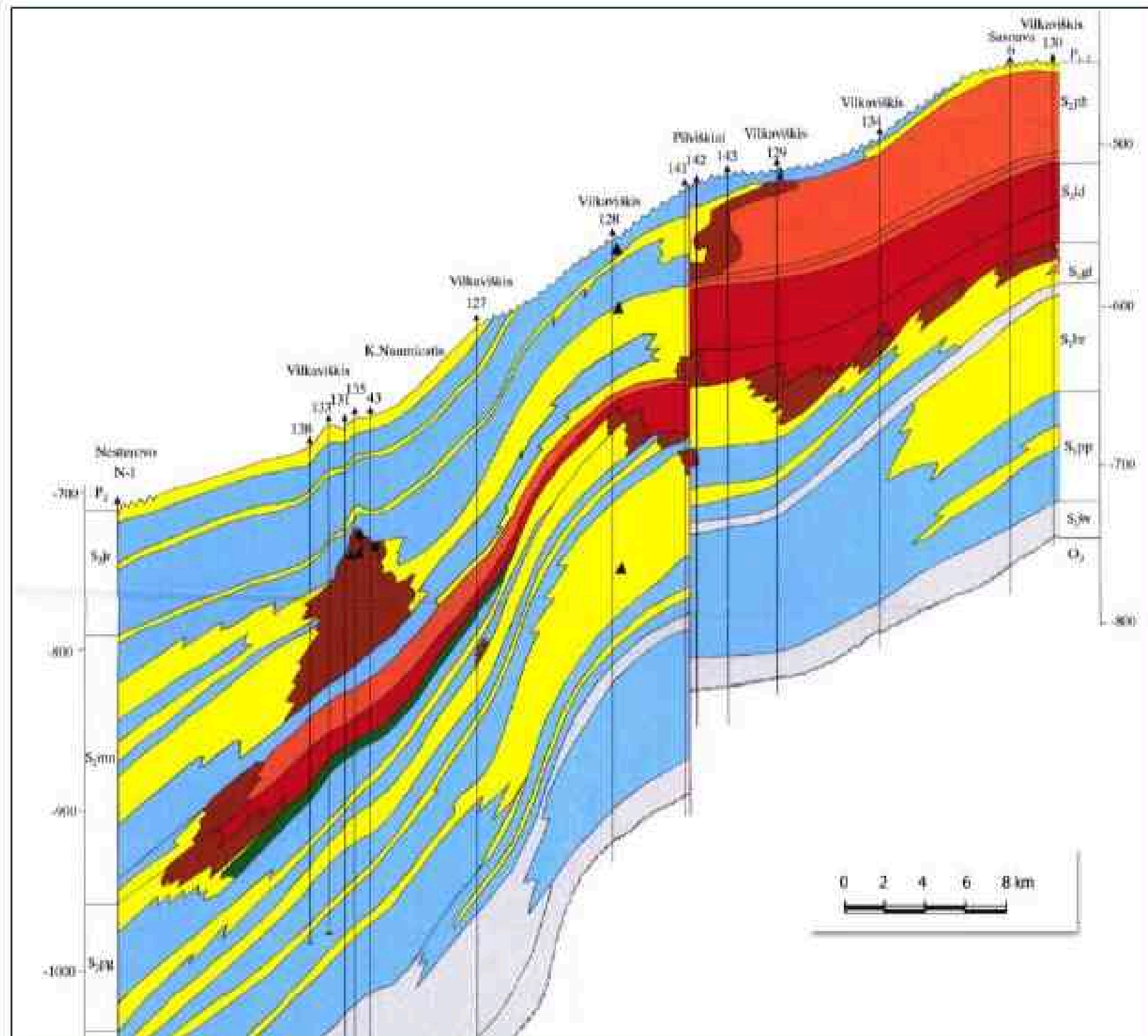
SILURIAN CARBONATE RESERVOIRS

TEMPERATURE OF SILURIAN FORMATION WATER



Depths of 750-1100 m.
Temperature of 25-38 °C.

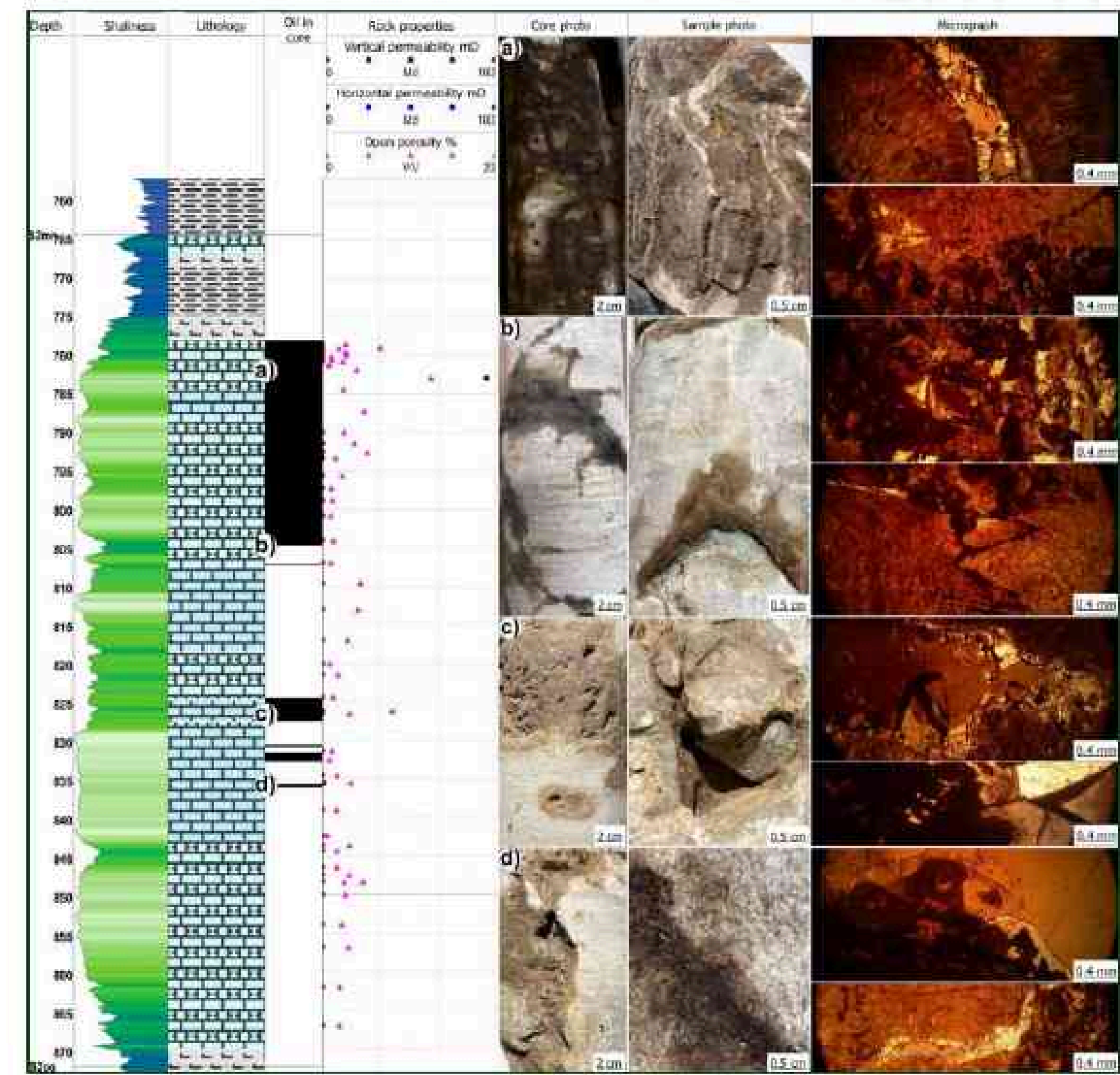
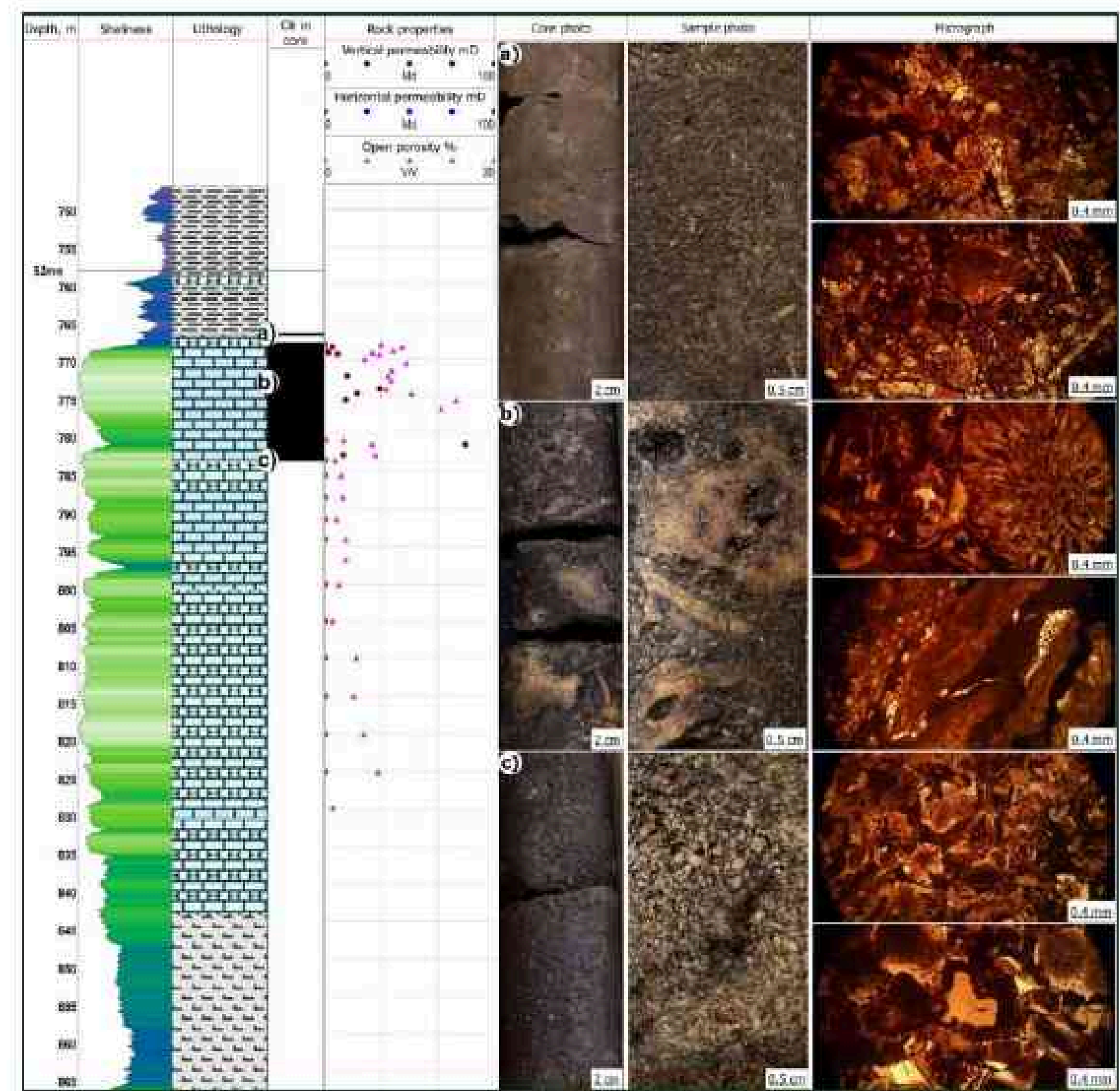
KUDIRKA FIELD



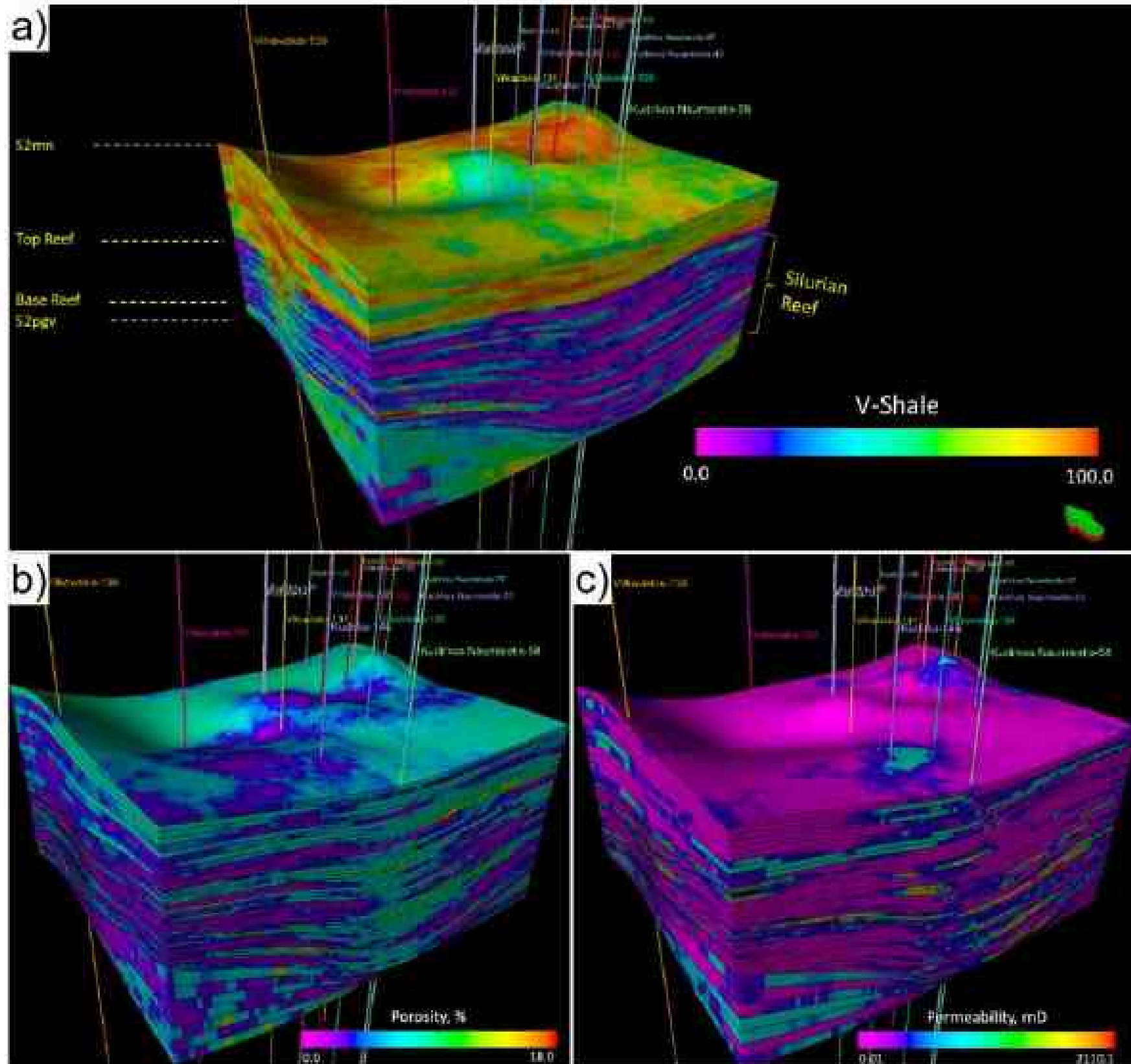
Kudirka reef is the largest structure:

- 4×7 km in area.
- 60-90 m total thickness.
- 23 m effective thickness.

PRIMARY AND SECONDARY POROSITIES

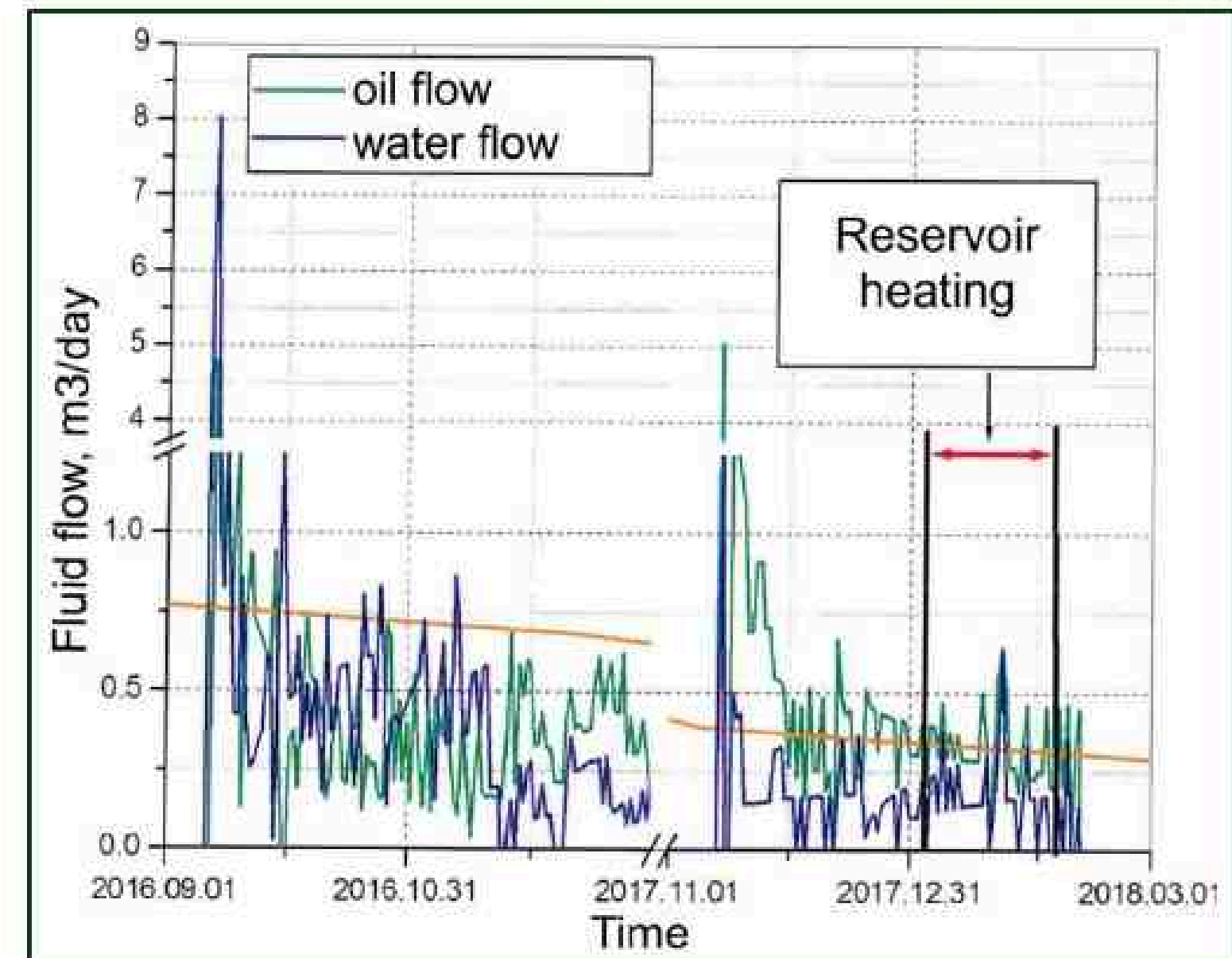


FLOW PROPERTIES OF SILURIAN REEFS



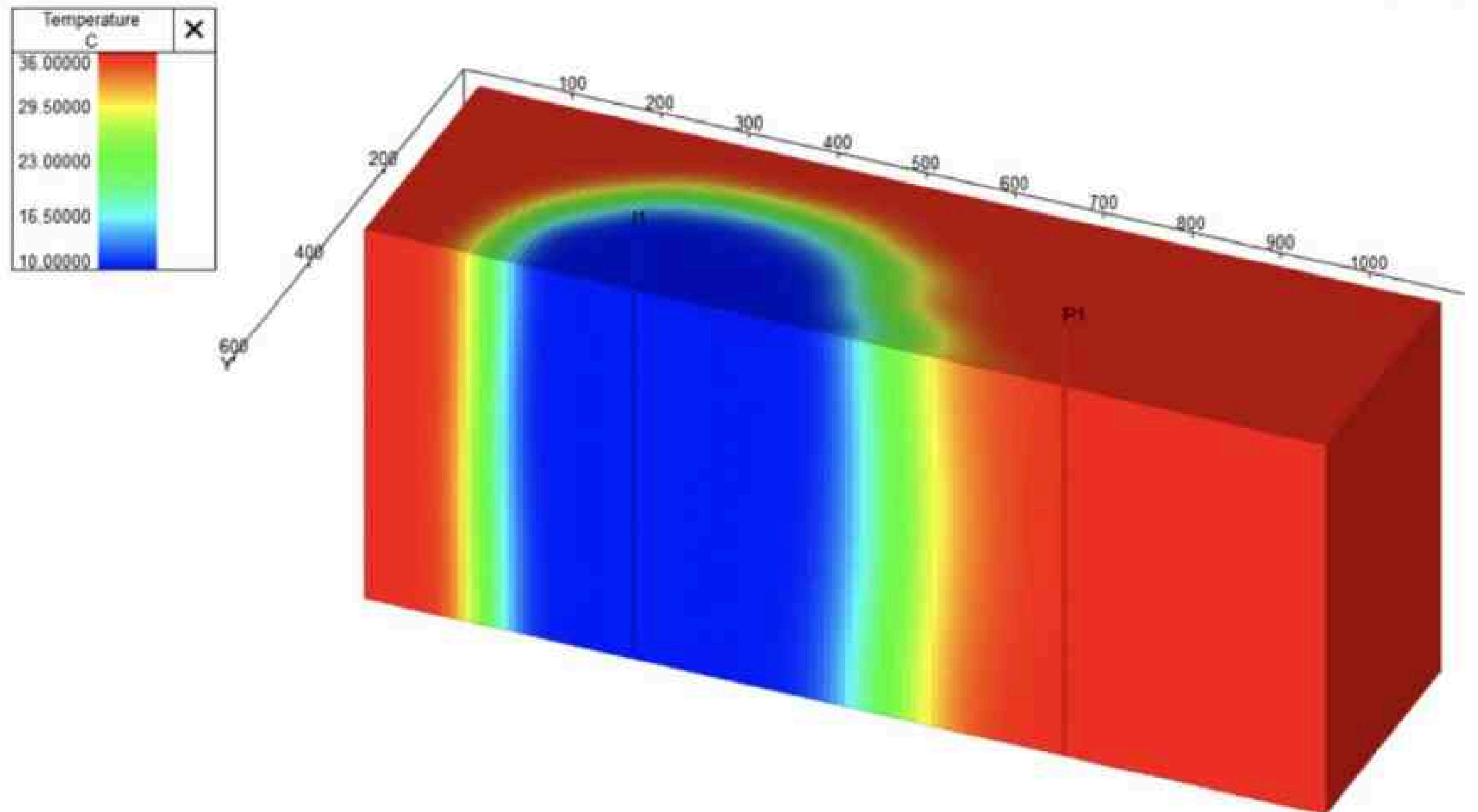
Porosity and permeability are higher within:

- Central part of the reefs.
- Reef crests.
- Individual thin layers across the structure.



VILKAVIŠKIS CITY

Vilkaviškis district heating system requires 10 000 MWh per season.



15 exploration wells could form **6 doublets** which would produce **2 836 MWh**.

CONCLUSIONS

Repurposing oil wells for geothermal heat extraction

Gargždai fault zone reservoirs:

- Are warmer ($85\text{ °C} > 73\text{ °C}$).
- Have better geothermal energy potential overall.
- Has one potential city in proximity (4 km from Šilutė).

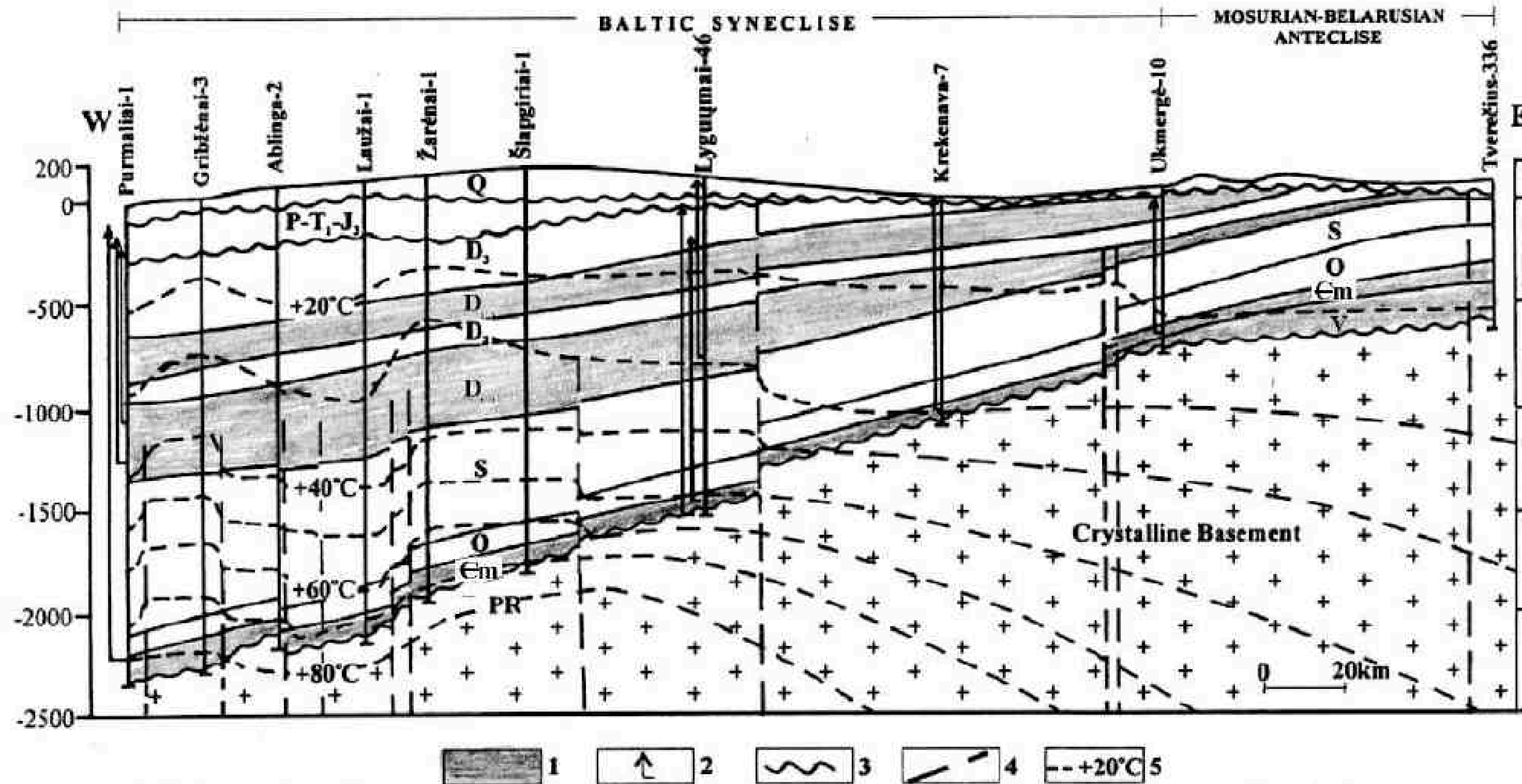
Telšiai fault zone reservoirs:

- Have bigger production rates per well.
- Still co-producing large amounts of water (Gargždai are nearly depleted).
- Located near larger populations with district heating systems.

Silurian reefs show:

- Low potential for the application of geothermal energy in Middle Lithuania.
- Although small geothermal projects could be achieved in the Kudirka and Pavasaris sites.

Geological setting



1-hydro-geothermal complex, 2-hydrostatic head, 3-stratigraphic angular discordance, 4-fractures, 5-geoisotherm

Sensitivity analysis

Parameter analysis:

- Net-To-Gross;
- Permability;
- Porosity;
- Reservoir thickness;
- Etc.

Systemic analysis:

- Well doublet separation;
- Horizontal well placement;
- Fracture intensity, frequency, positioning;
- Etc.

Economic analysis:

- Distance to major cities;
- Energy price fluctuation;
- Seasonal demand;
- Transportation costs;
- Etc.

Mechanistic analysis:

- On-ground facility heat loss;
- Mechanical efficiency;
- Geothermal battery alternatives;
- Etc.