# EUROPEAN GEOLOGICAL ANALOGIES OF PUSZTAFÖLDVÁR (HUNGARY) GEOTHERMAL LITHIUM ANOMALY


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# CONTENTS

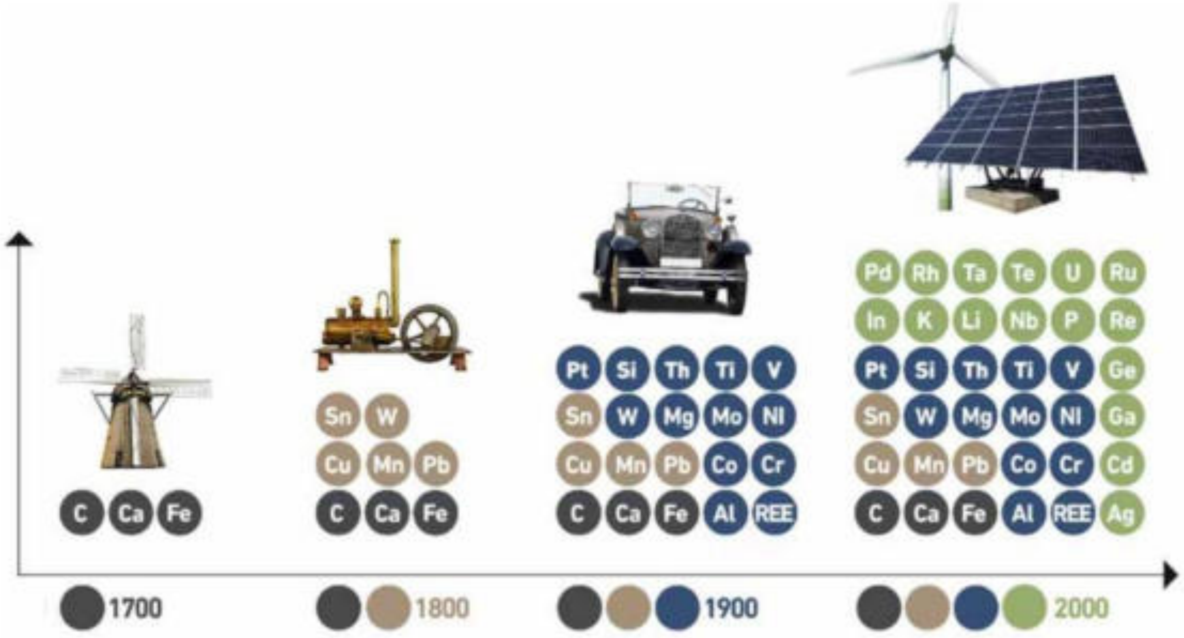
# INTRODUCTION

**1. New questions emerged by energy transition:**

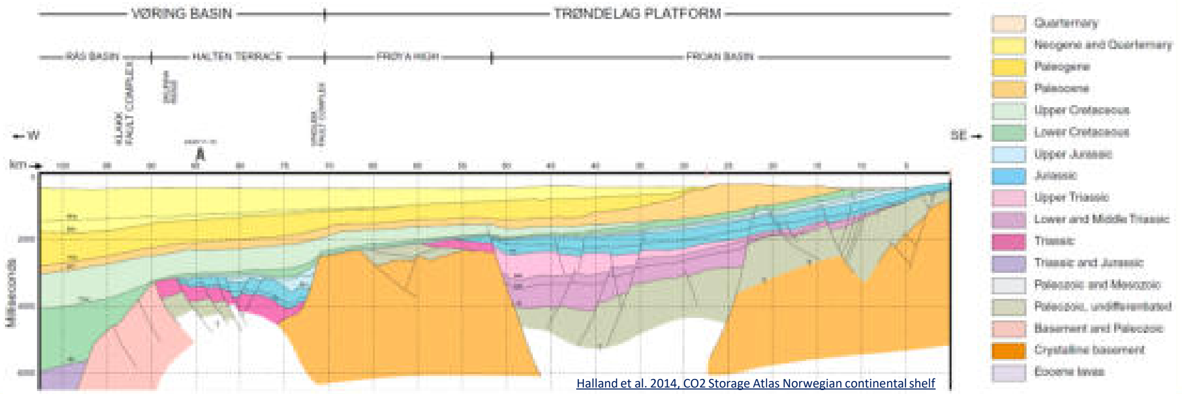
- The last years changes require continue flexibility and adjustments
- The new requirements are yet less understood, however the general trendline calls for new perspectives
- Increased importance is given to Li, Co, Cu, Ni and REE

**2. Potential answers:**

- The vast amount of data and knowledge could be used to accommodate and answer the new requirements
- The classical hydrocarbon related exploration methods can be used for other, inorganic element mappings, dissolved in reservoir brines or being present in the gas phase
- Proven technologies are available for green transition element removal onshore (e.g. Cornish Li project in Cornwall, UK)
- Eastern and Central European countries experience in ore mining could be coupled with HC E&P knowledge




NGU Thematic issue No. 1 . Minerals for the Green economy 2019

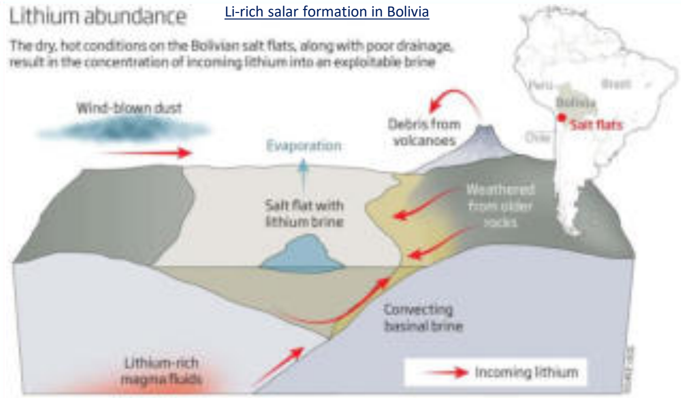



Halland et al. 2014, CO2 Storage Atlas Norwegian continental shelf

# INTRODUCTION

**Lithium: where does it come from?**

- Salt solutions from salars (mainly S America)
- Hard rock ores (relevant in Australia)
- Geothermal brines (in Europe, N America, and Asia)



Li-rich salar formation in Bolivia


Li rich Salars in Bolivia

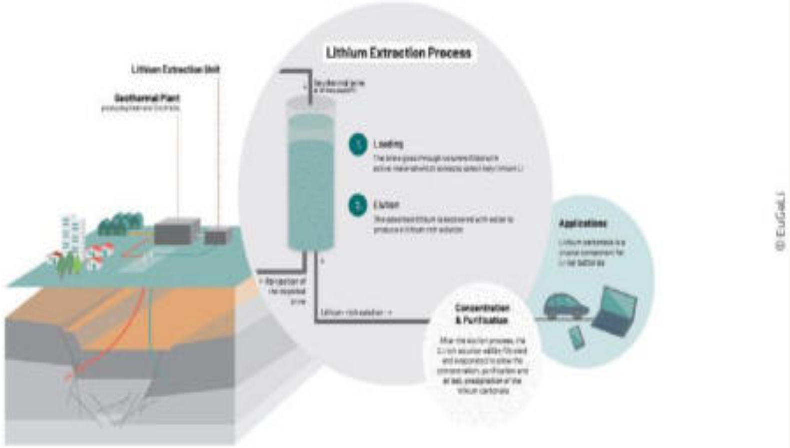

Salar de Uyuni


Open pit Li ore mining site in Australia


Spodumene – Li source mineral


Spodumene

EuGeLi

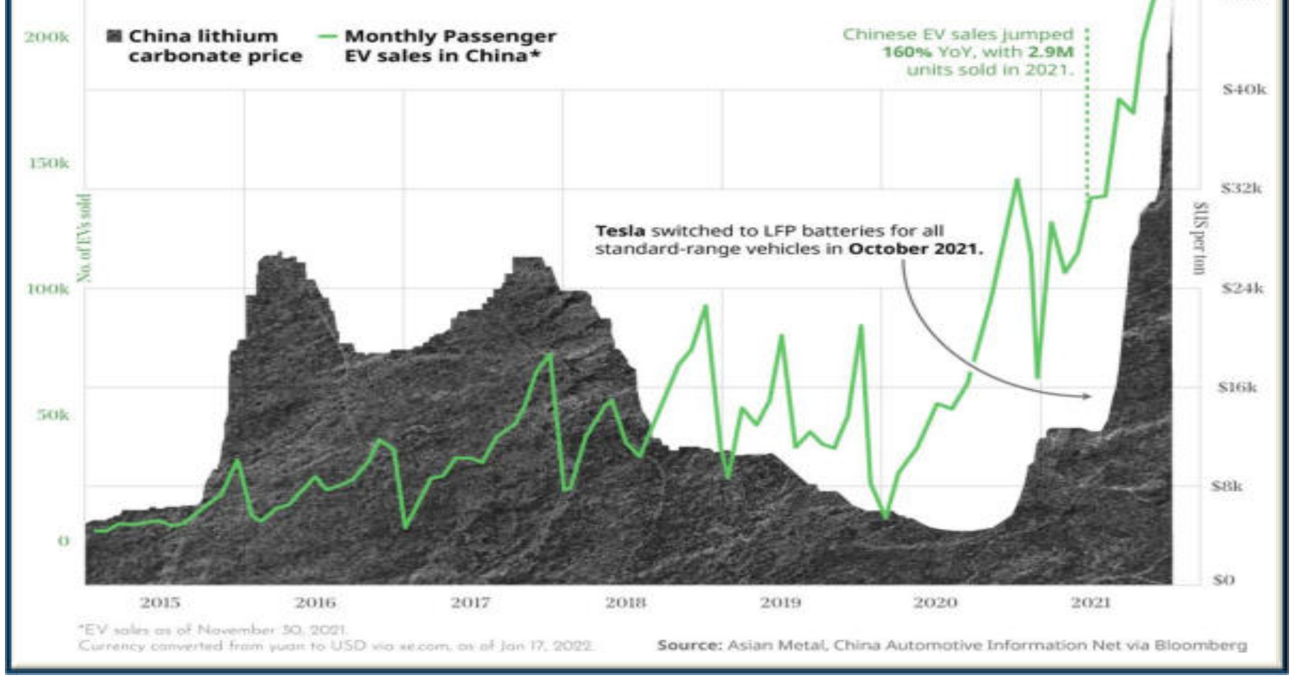


EuGeLi project aims to extract Li from European geothermal brines

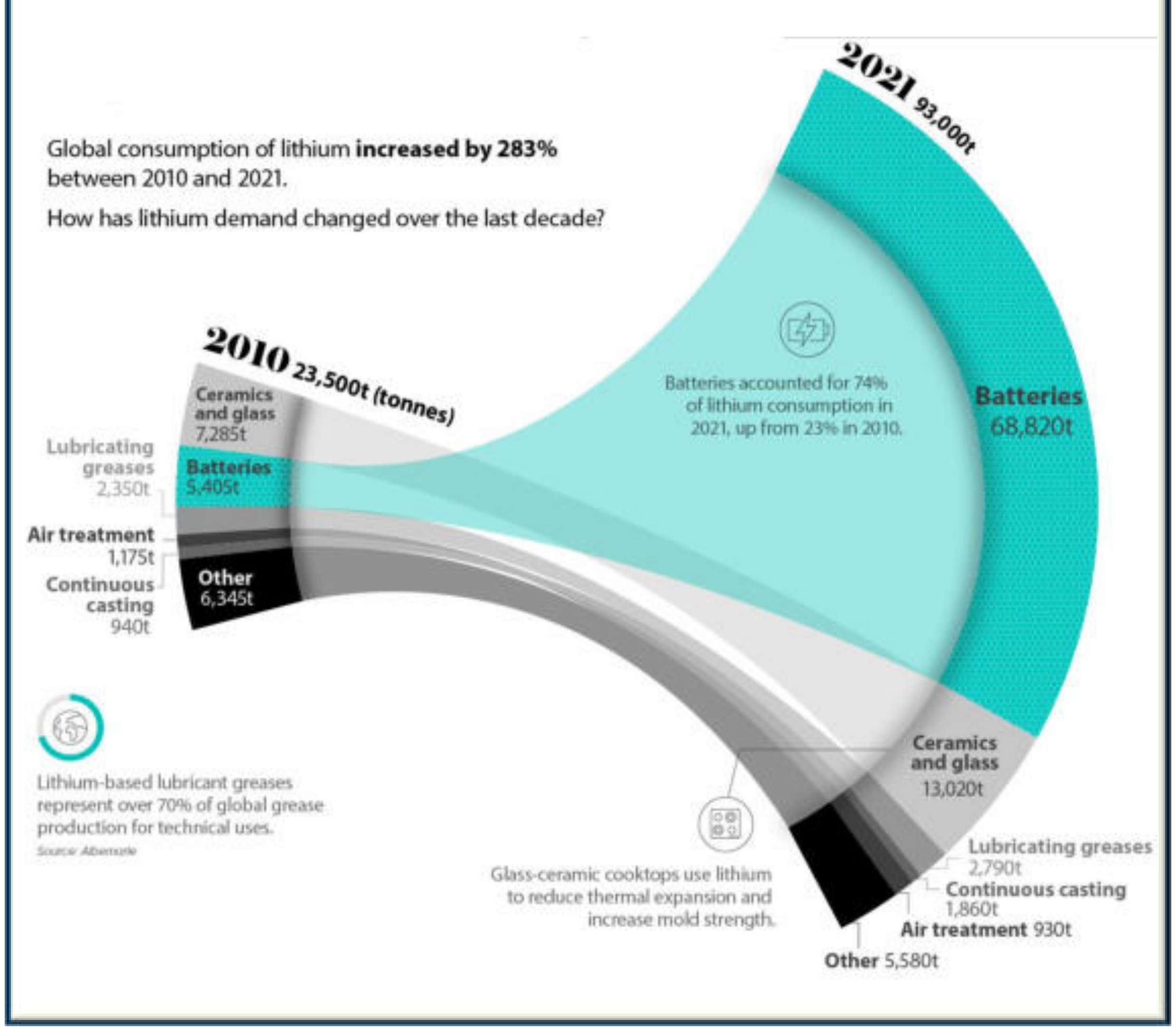
# INTRODUCTION

- **Lithium: for what is used for?**
  - Batteries, ceramics & glass, medicaments, & others.
- **Lithium: is it worth to deal with?**
  - Due to its relevance in Li-Co-P batteries and others.
- **Lithium: could be a win-win for O&G E&P?**
  - The HC production could be coupled with „petro-lithium” and geothermal heat extraction.

Visual capitalist 2022 - Lithium Prices Surge on EV Demand from China



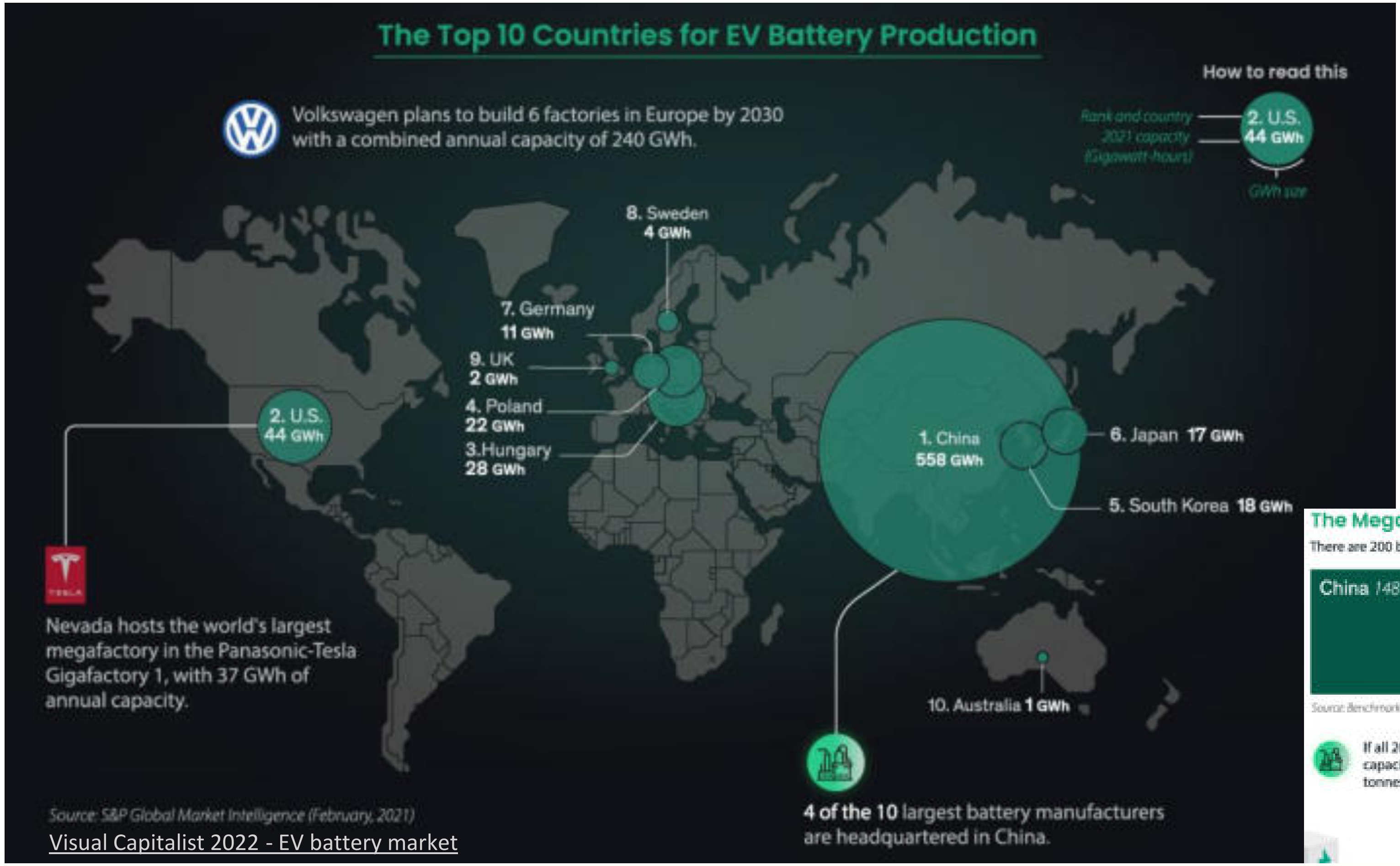

Visual capitalist 2022 - Global Li consumption 2010-2021



# INTRODUCTION

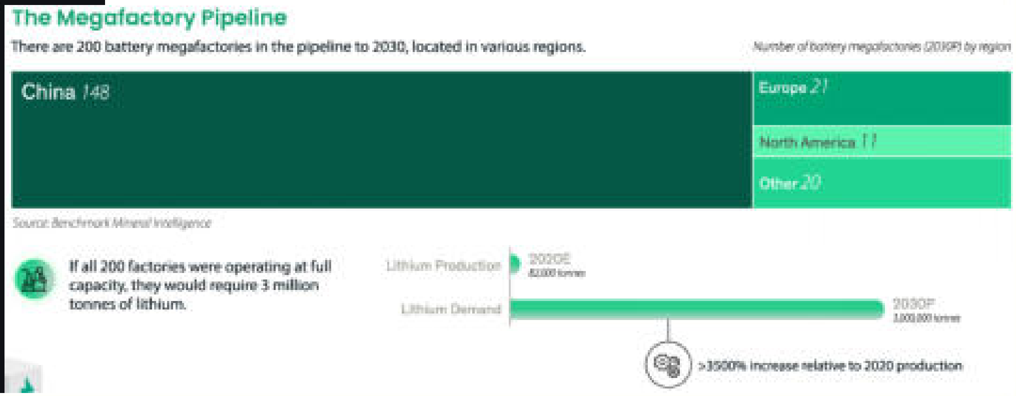
**How does the European Li-battery market look like?**

- Hungary is a leader within Europe.




Visual Capitalist 2022 - EV battery market

| Rank | Country | 2021 Li-ion manufacturing capacity (GWh) | % of World Total |
|---|---|---|---|
| #1 | China | 558 | 79.0% |
| #2 | U.S. | 44 | 6.2% |
| #3 | Hungary | 28 | 4.0% |
| #4 | Poland | 22 | 3.1% |
| #5 | South Korea | 18 | 2.5% |
| #6 | Japan | 17 | 2.4% |
| #7 | Germany | 11 | 1.6% |
| #8 | Sweden | 4 | 0.6% |
| #9 | UK | 2 | 0.3% |
| #10 | Australia | 1 | 0.1% |
| N/A | Rest of the World | 1 | 0.1% |
| N/A | Total | 706 | 100.0% |



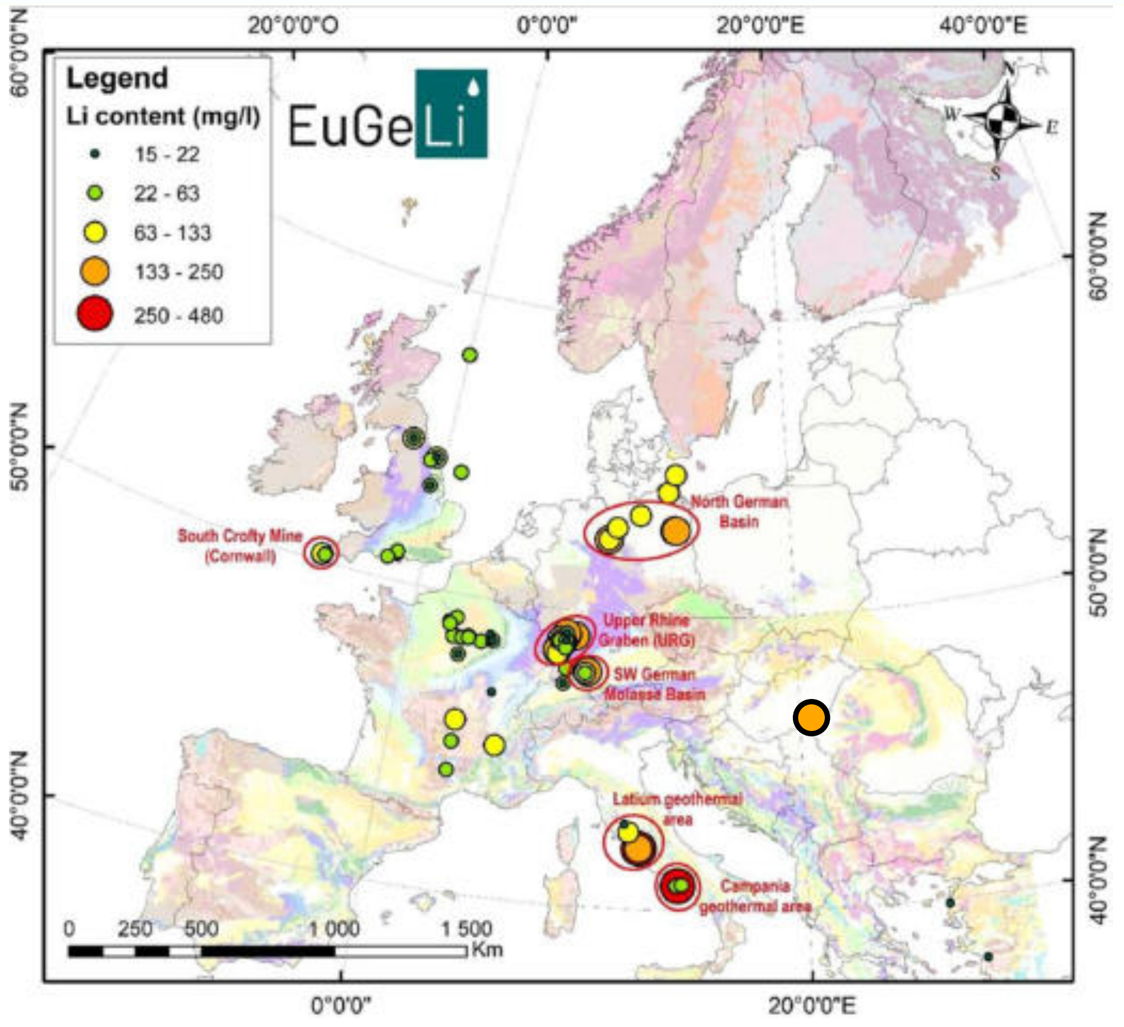
# THE SIX KNOWN EUROPEAN GEOTHERMAL LI ANOMALY

**1. Where are the six known European geothermal Li anomalies located?**

- The Monte Sabatini area (Latium) – Italy
- The Campi Flegrei area (Campania) – Italy
- The North German Basin (NGB) – Germany
- The Molasse Basin – Germany
- The Upper Rhine Graben (URG) – France/ Germany
- The South Crofty Mine (Cornwall) – UK

**2. How are they classified?**

- They are grouped based on Li concentration and temperature gradient/ geological setting(s).




Map of Europe showing the six main geothermal areas with Li-rich fluids (red and orange circles) and Li-concentration ranges in such fluids (after Sanjuan et al., 2022).

# THE SIX WELL KNOWN EUROPEAN GEOTHERMAL LI ANOMALY

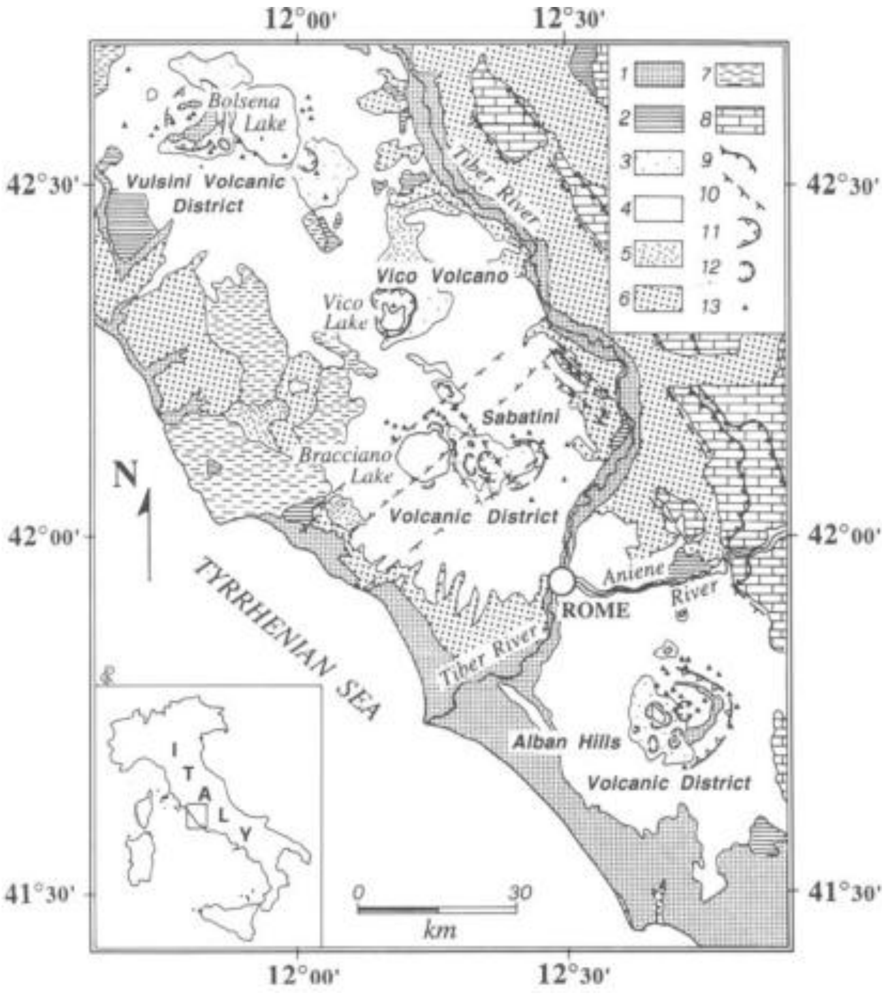
**1. What should we know about the Monte Sabatini area?**

- This area is located along the peri-Tyrrhenian sector of Central Italy. A post-collisional tectonic activity occurred during the Neogene, generating dominantly extensional NNW-SSE-trending fault systems and minor NE-SW-trending transtensive structures that accommodated differential extension. The progressive eastward migration of the extension wave produced a strong crustal thinning (cc. 25 km), high heat flow (200 mW/m$^2$) and subduction-related magmatism (De Rita et al., 1997, Sanjuan et al., 2022).

**2. What should we know about the Campi Flegrei area?**

- This area is a large volcano situated to the west of Naples and was the result of voluminous Pliocene-Quaternary volcanism in the Campania margin, which presents peculiar physiographic, volcanic, and tectonic features and is of critical importance in understanding the tectonic and geodynamic evolution of the Tyrrhenian Sea back-arc basin (Sanjuan et al., 2022).

**Sketch map of the Latian volcanic area** (De Rita et al., 1997)




Legend: (1) continental and marine sediments (upper Pleistocene to Holocene); (2) travertine; (3) hydromagmatic units; (4) Tolfa Cerite Manziate acidic volcanic district; (5) K-alkaline volcanic products; (6) Plio-Pleistocene marine sediments; (7) Cretaceous-Oligocene marls and marly limestones; (8) Meso-Cenozoic limestones and marls; (9) thrusts; (10) normal faults; (11) calderas; (12) craters; (13) scoria cones.

# THE SIX WELL KNOWN EUROPEAN GEOTHERMAL LI ANOMALY

**1. What should we mention about the North German Basin (NGB)?**

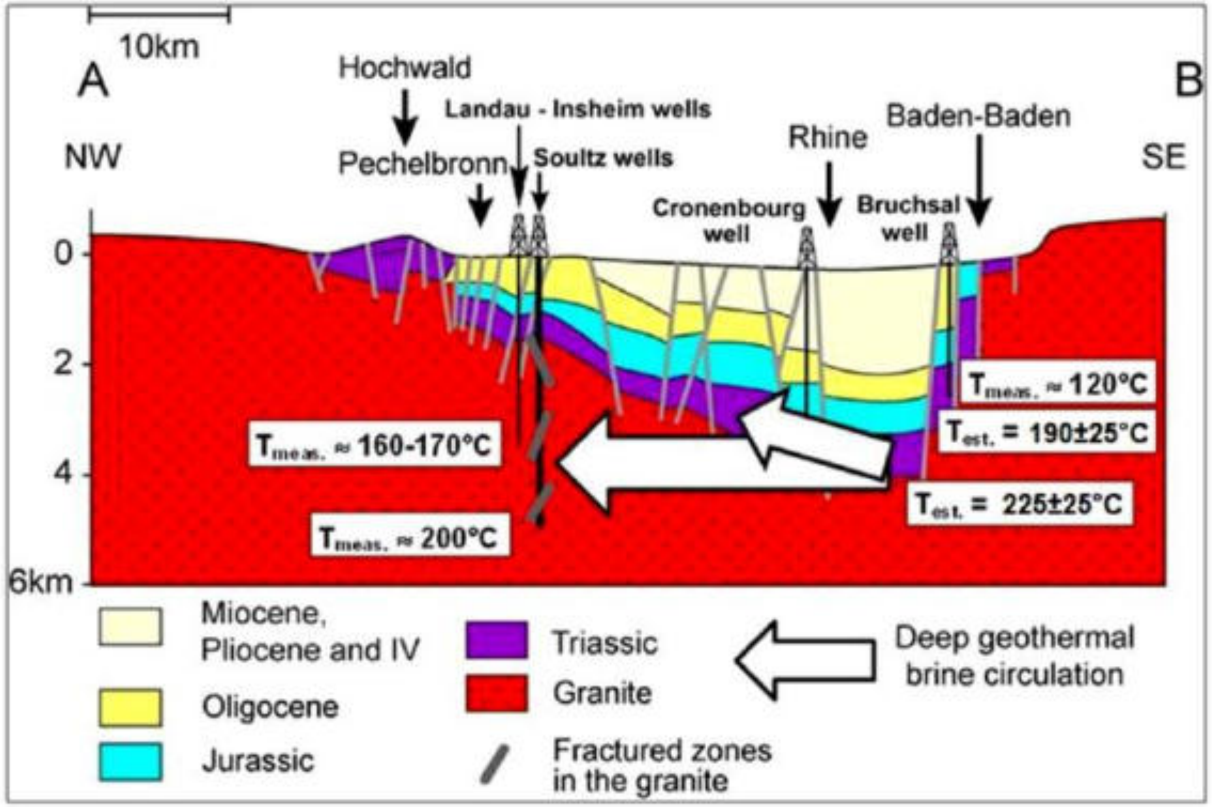
- The North German Basin is a sub-basin of the Southern Permian Basin, that accounts for a composite of intracontinental rift basin composed of Permian to Cenozoic sediments, which have accumulated to thicknesses around 10–12 km.

**2. What should we know about the Upper Rhein Graben (URG) area?**

- The NNE-trending URG of the European Cenozoic Rift System developed from *ca*. 47 Ma onwards. The Graben itself (35 x 300 km) is in the upper-middle Rhine river basin (Sanjuan et al., 2016).

**3. What should we flag about the Molasse Basin area?**

- Is a foreland basin of the Alps that formed during the Cenozoic Oligocene and Miocene because of the flexure of the European plate under the weight of the orogenic wedge of the Alps. The basin filled with a sedimentary sequence for the most part removed from the developing mountain chain by erosion and denudation (Sanjuan et al., 2022).

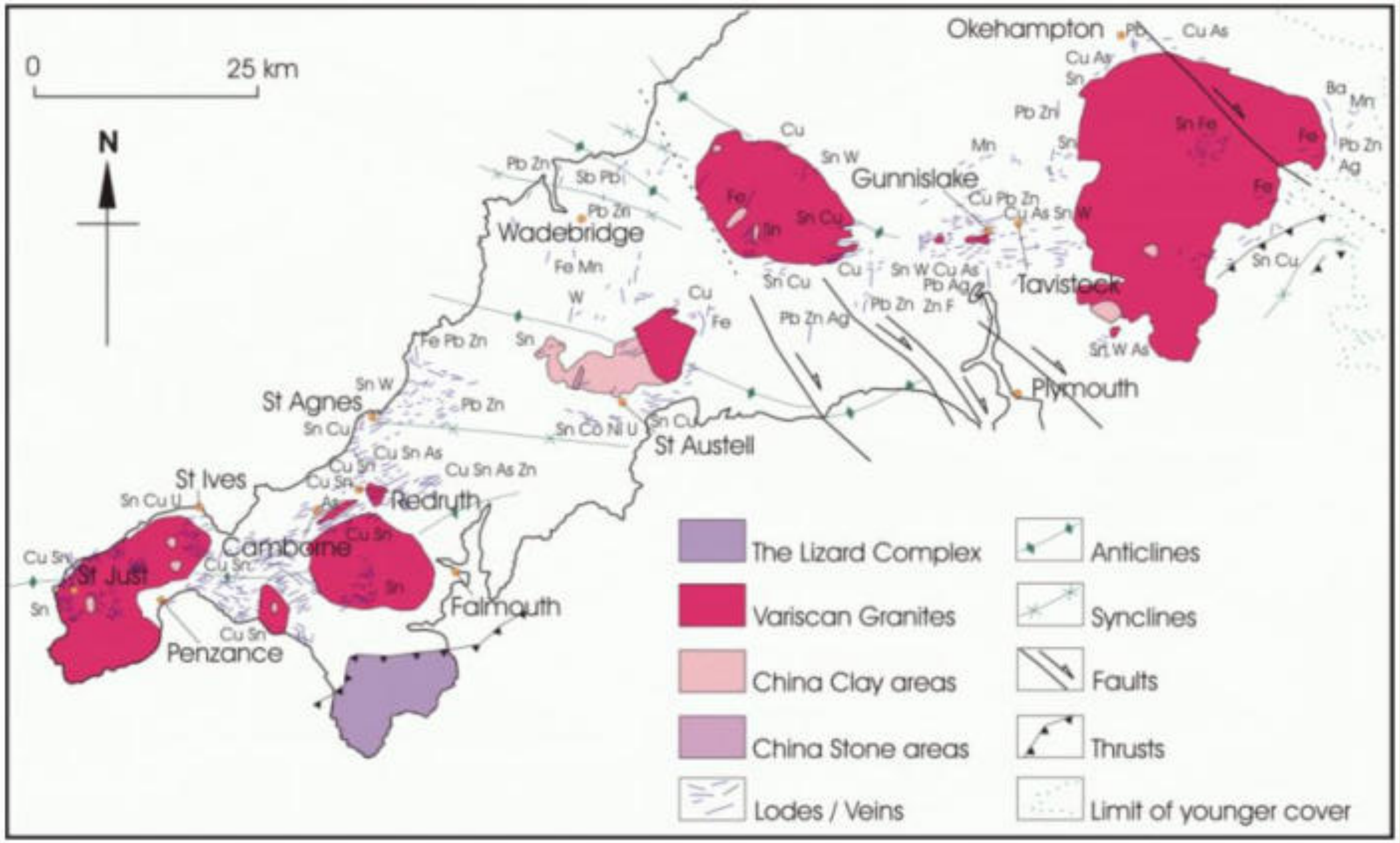



Schematic NW-SE cross-section of the Upper Rhine Graben showing several deep wells drilled to depths of 2540 to 5000 m. Thermal-gradient values of 40 to 60 ◦C/km were observed in the URG sedimentary formations of deep wells. The Triassic Buntsandstein sandstone at depths of cc. 4 km (in the graben centre) could represent the potential reservoir at 225 ± 25 ◦C for most of these brines - the deep geothermal brine would then migrate from the graben centre to its outer boundaries, circulating both in granite and in the deep sedimentary rocks through a complex system of deep, still poorly defined faults (Sanjuan et al., 2016 and 2022).

# THE SIX KNOWN EUROPEAN GEOTHERMAL LI ANOMALY

**1. What should we know about the South Crofty mine (Cornwall, UK) area?**

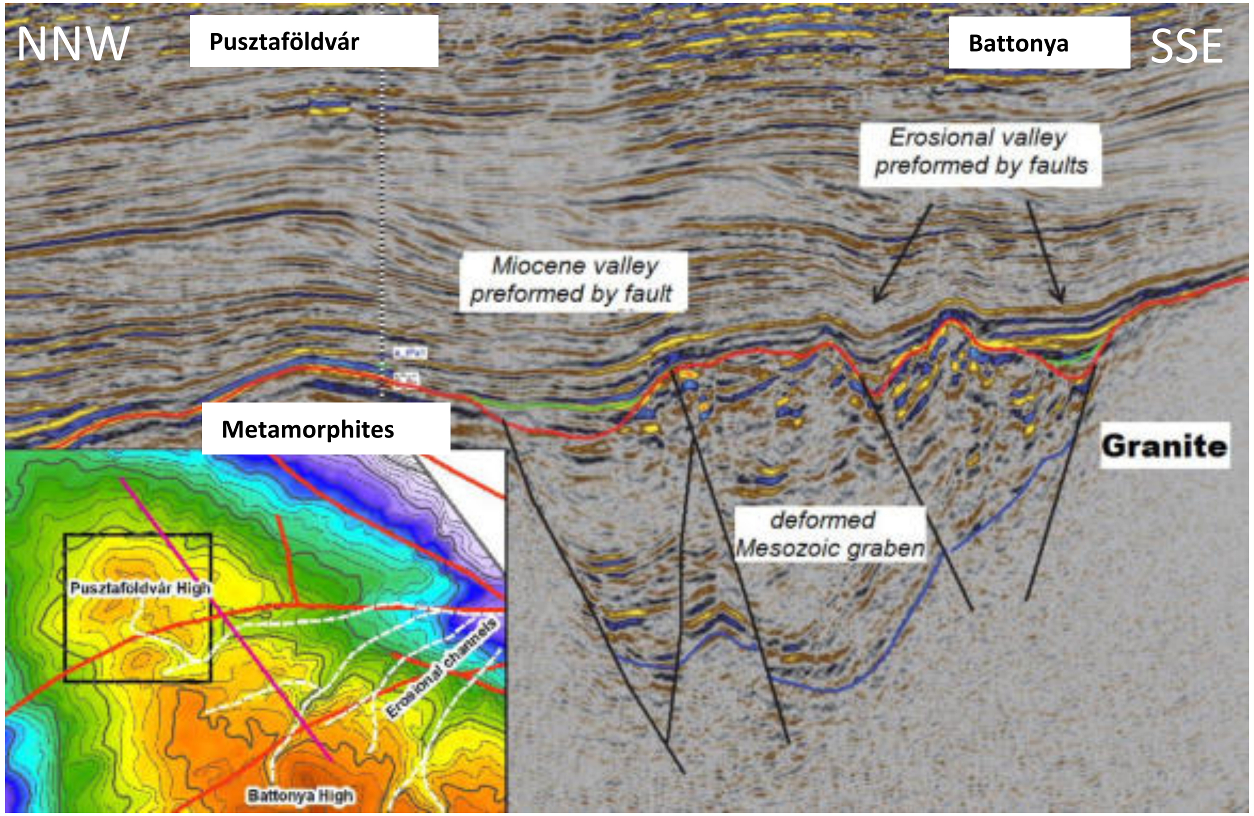
- Here economic vein deposits of Sn, Cu, Pb and Zn were found in the Carnmenellis granite which forms a near-circular outcrop of the Cornubian batholith intruded about 290 Ma ago into Devonian argillaceous sedimentary rocks – what can be considered as a very low temperature geothermal system (100 ◦C) (Sanjuan et al., 2022).
- The last saline groundwaters (up to 19 g/l) are found in four tin mines in granite or its thermal aureole, as well as in several closed mines along the northern margin of the granite belt. They generally show discharges between 1 and 10 l/s, occur at depths between 200 and 700 m below surface and have discharge temperatures up to 52 ◦C (Sanjuan et al., 2022).

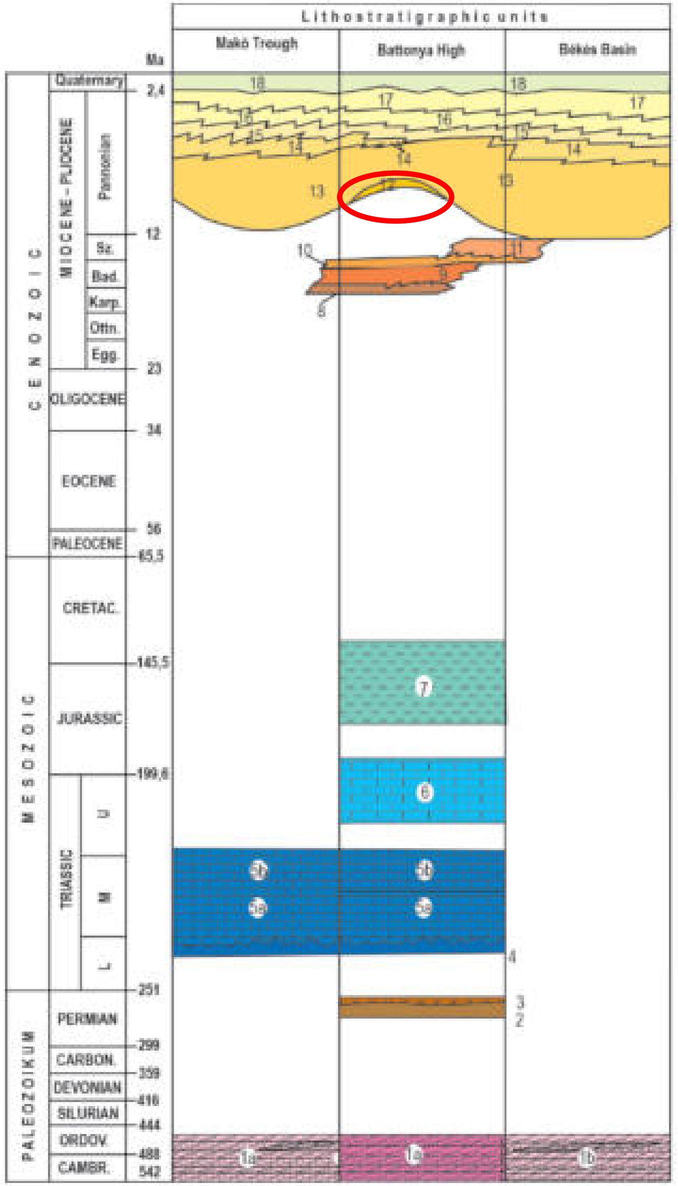



Geological map of Southern England showing the main ores and the location of the Cornubian batolith (Le Boutillier, 2005).

# PUSZTAFÖLDVÁR GEOLOGY

- **What is the lithostratigraphy column composed of at Pusztaföldvár-Battonya high?**
  - Basement: Variscan metamorphites + granite pegmatite veins. GT 60-70 °C/km.
  - Main reservoir is Lower Pannonian („Miocene”) coastal, conglomerate – sandstone – Békés formation.




**General lithostratigraphic column of the Makó Trough, Battonya–Pusztaföldvár High and the Békés Basin (Kun et al., 2022)**

## Legend:

VVV – traces of volcanic activity. Formations seen in the profile: 1. Variscan crystalline rocks without subdivision and metamorphites (gneiss, mica, amphibolite); 2. Permian continental clastic formations; 3. Permian rhyolite; 4. Lower Triassic siliciclastic formations of fluvial and delta facies; 5 a, 5 b. Middle Triassic shallow marine, siliciclastic and carbonate formations; 6. Jurassic shallow marine and condensed pelagic limestone formations; 7. Jurassic – Lower Cretaceous pelagic limestones, marls; 8. Lower Badenian breccia-conglomerate; 9. Badenian shallow-marine biogenic limestones; 10. Sarmatian basal debris; 11. Sarmatian shallow-marine carbonate and siliciclastic beds; 12. Pannonian littoral conglomerates, sandstones; 13. Pannonian open-lake calcareous marls, marls, argillaceous marls; 14. Pannonian deep-water succession of turbidite origin; 15. Pannonian sediments of delta-slope facies; 16. Pannonian siliciclastic succession of littoral facies; 17. Pannonian siliciclastic succession of fluvial and lacustrine facies; 18. Quaternary sediments.

# PUSZTAFÖLDVÁR GEOLOGY

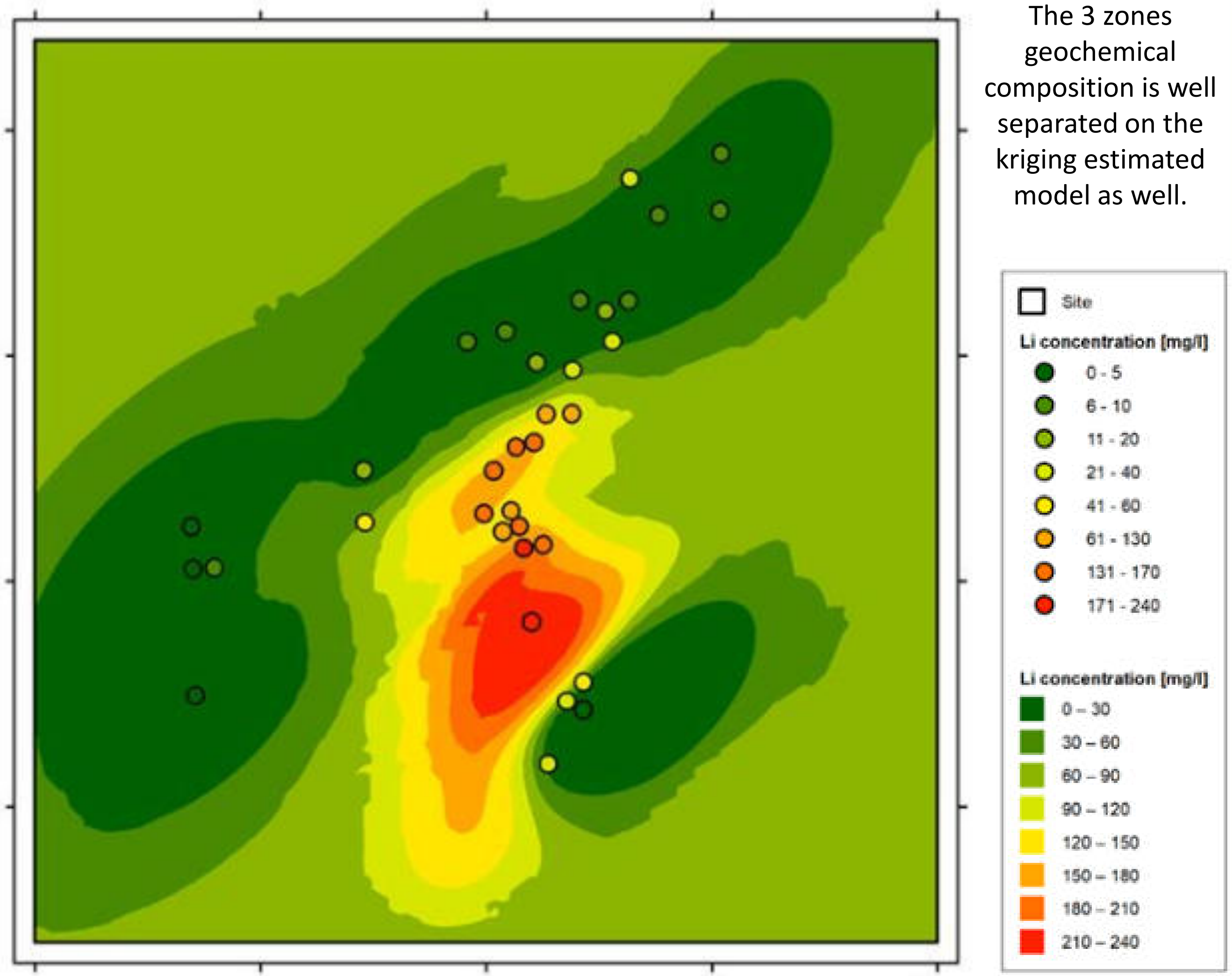
**What could the water geochemistry of the reservoir brines of Pusztaföldvár explain us so far?**

- Low 0-20 ppm
- Medium 20-60 ppm
- High > 60 ppm

- The results - depending on **Li** concentration - delimit so called:
  - green,
  - yellow and
  - red zones.

- There are several elements, which correlate well with Li variations, these are:
  - **Cs**, **Cl**,
  - F, Br, B, Na, K, Si, Rb, As, Mn, Fe and Tl.

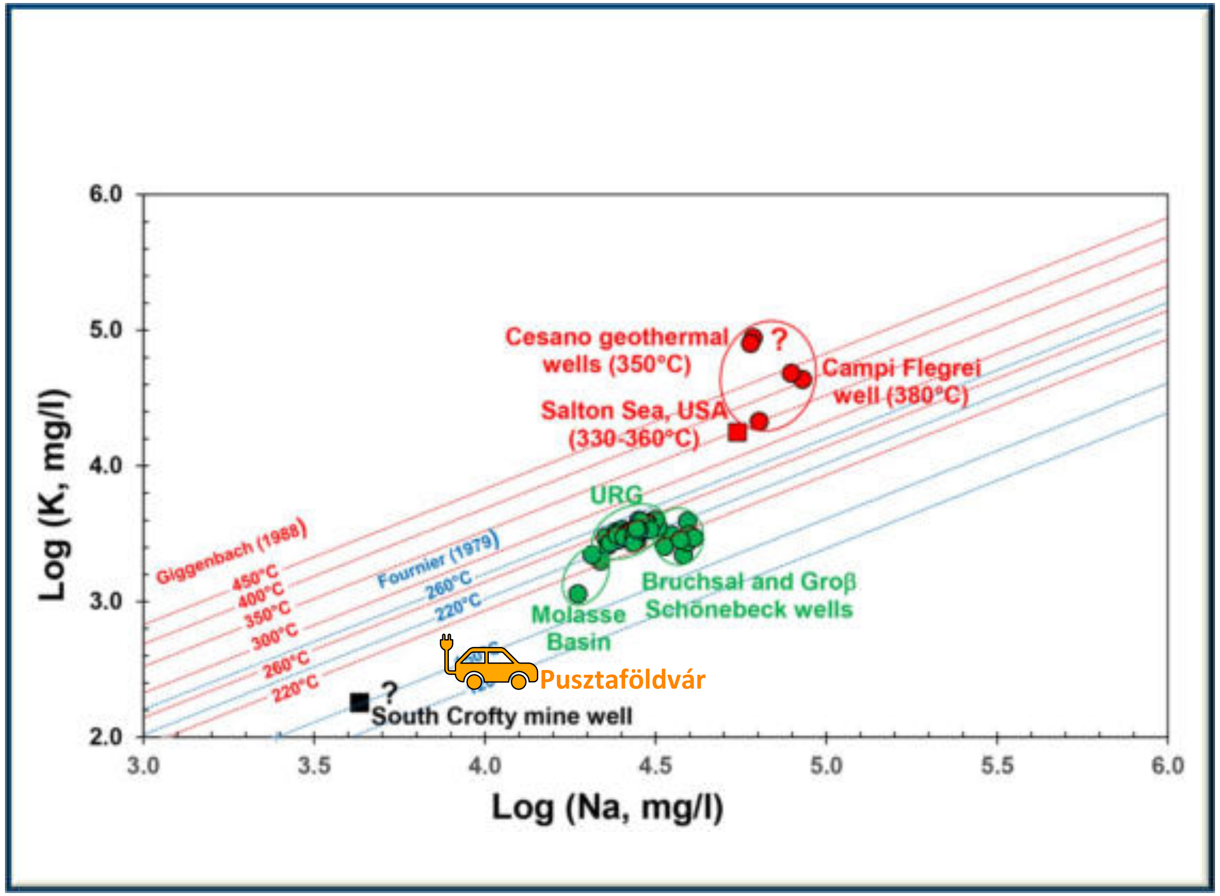
- From the main elements the Cl content is measured from the beginning of production, while in a few wells, the presence of Li was signaled with cross marks, only.

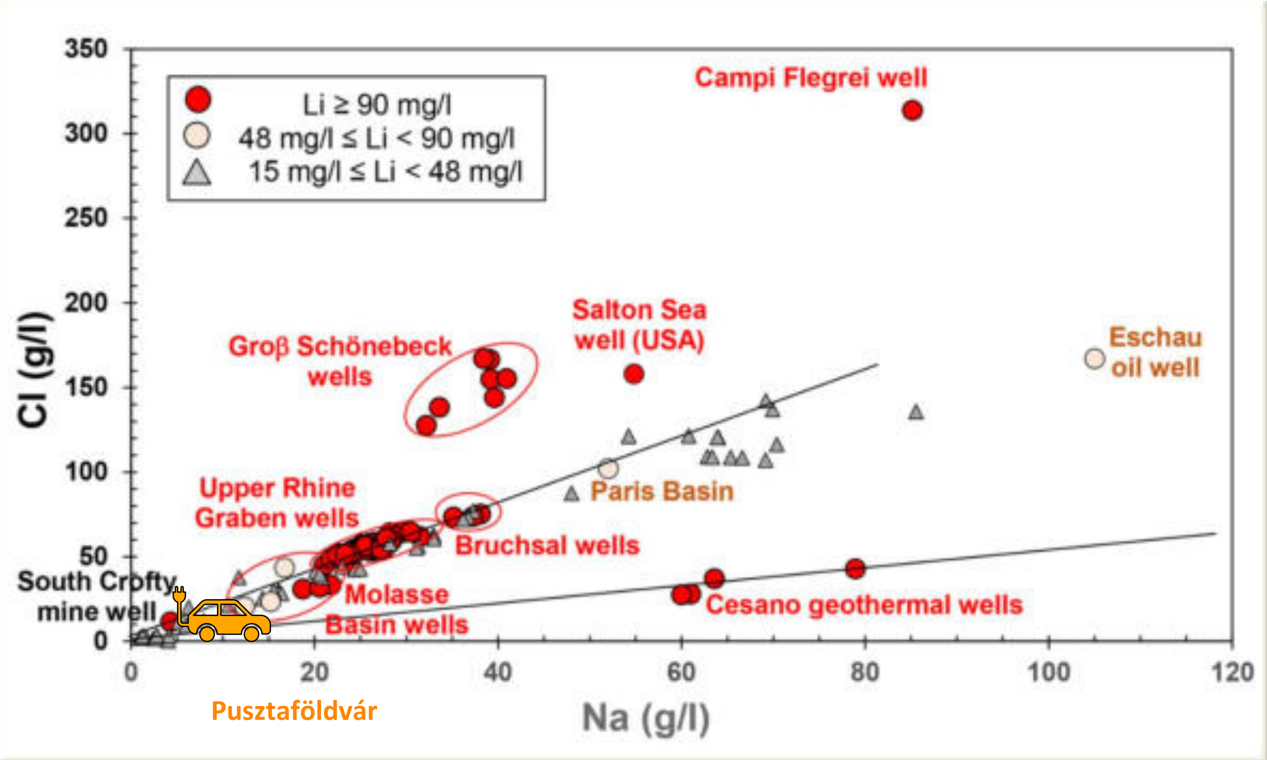



The 3 zones geochemical composition is well separated on the kriging estimated model as well.

# DISCUSSION

- **How does the Pusztaföldvár anomaly fit within other relevant European geothermal lithium occurrences?**
  - It shows some similarities to South Crofty mine - Cornwall, UK.



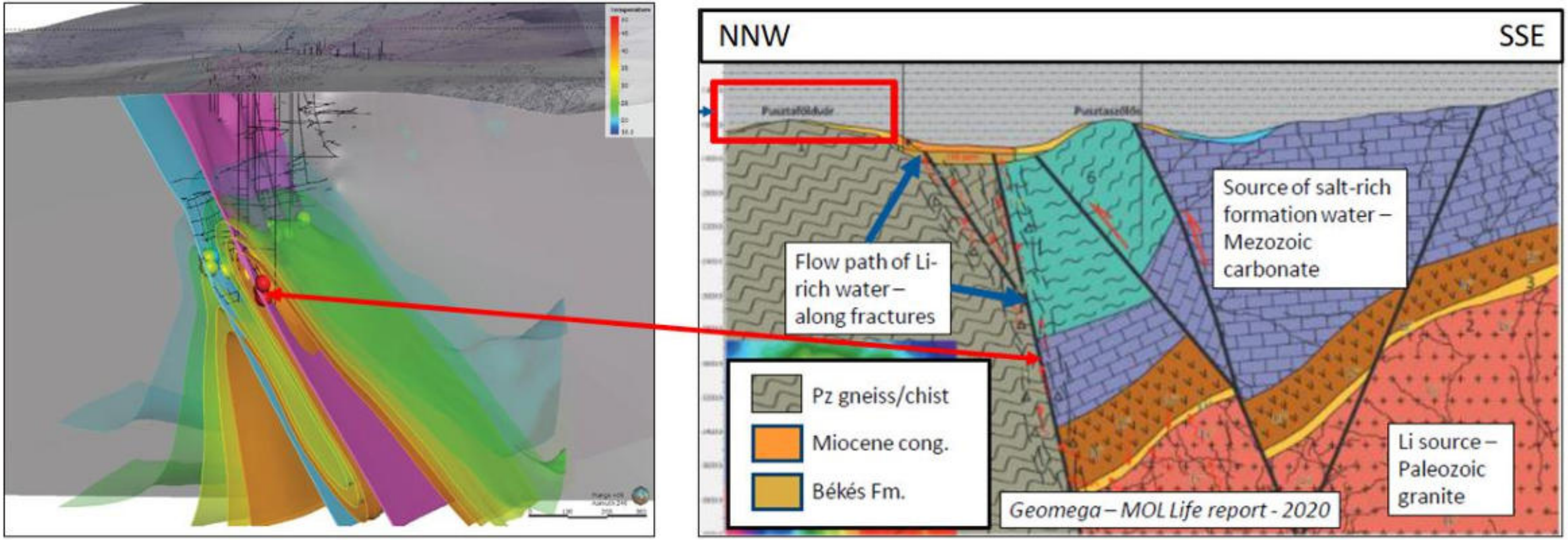




- **What do the geothermometer calculations tell us?**
  - We were estimating the Li dissolution depth with several different equations.
  - The Fournier (1979) Na/K gave 119-136 C°, while the Fouillac and Michard (1981) Na/Li - what considers the Cl content as well,- resulted in 278-352 C°.

# DISCUSSION

**How does the Pusztaföldvár anomaly compare to South Crofty mine geothermal lithium occurrence?**

- Is located on a fractured granite batolith: - beside the open pit Li-spodumene mining, DLE is aimed from the geothermal brines located in the fault systems – proven Li upwelling since 1864.




Historical temperature data modelled in South Crofty mine – UK, 2021 (Maptek).

# CONCLUSIONS

- The energy transition represents the global level change of classical energy markets and energy security
- The open-minded geoscientific and economic approaches are quintessential in adapting to new requirements
- The European Li extraction (less than 1%) lags far behind the Li production usage, which is why the geothermal lithium deposits found on the old continent have received considerable attention
- Our research presents the geological similarities and differences of the Southern Great Plain (Hungary) lithium anomaly in comparison with other relevant European geothermal occurrences
- Due to the relatively low levels of Na, Cl and K, the Pusztaföldvár reservoir brine is among the best within the compared geothermal brines
- The presented geothermal Li anomalies could solve the Li-dependence on foreign lithium, and could help decreasing the carbon footprint of the EVs produced in Europe

- THANK YOU FOR YOUR ATTENTION!

- CA QUESTIONS: