Distribution of metals in the waters of the geothermal systems of the Vallès trough (NE of Spain): Geological control

Jullien-Sicre, A. (1), Guinoiseau, D. (1), Baqués, V. (2), Travé, A. (2), Saint-Bezar, B. (1), Benedicto, A(1)., Despinois, F(3).

(1)Université Paris-Saclay, UMR CNRS 8148 GEOPS, Orsay, France.
(2)Departament de Mineralogia, Petrologia i Geologia Aplicada. Facultat de Ciències de la Terra. Universitat de Barcelona (UB). Barcelona.
(3) TotalEnergies – OneTech R&D Sustainability Line, Pau , France.

INTERNATIONAL CONFERENCE
GROUNDWATER, KEY TO THE SUSTAINABLE DEVELOPMENT GOALS
PARIS - May 18 -20, 2022

Introduction

Critical raw materials as lithium or other metals and decarbonated ressources, such as low to mid-enthalpy geothermal energy, are key to the ongoing energetic transition. Mostly located near plate boundaries (Moeck, 2014), geothermal systems undergo strong structural controls essentially through crustal faults, also known to drain fluids (Duwiquet et al., 2021). Often seen as a nuisance in geothermal plants, dissolved metals in geothermal fluids can be exploited as a by products. This study aims at defining spatio-temporal variations in metal content and the structural control along the Vallès-Penedès (VP) crustal fault, as a field analogue of a passive margin domain.

State of the art

The VP trough and its geothermal system constitute a great field analogue for passive margins low enthalpy systems

Geothermal context

- The VP graben is associated with a geothermal anomaly up to 35°C/km (Fig. 1.A).
- Several hot springs flow with temperatures from 25 to 65 °C (low enthalpy geothermal systems) (Fig. 1.A).

Thermal anomalies line-up along the VP fault on the temperature map of La Garriga, and Montbui at 50m deep, (Fig. 1.B), crossed with the localization of mapped faults.

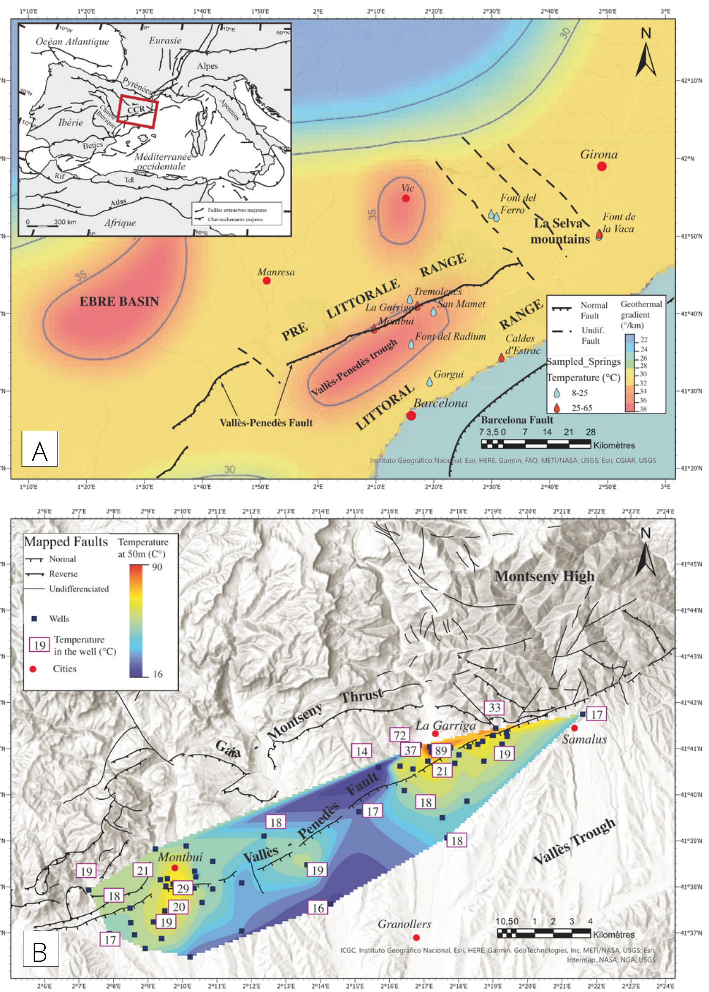
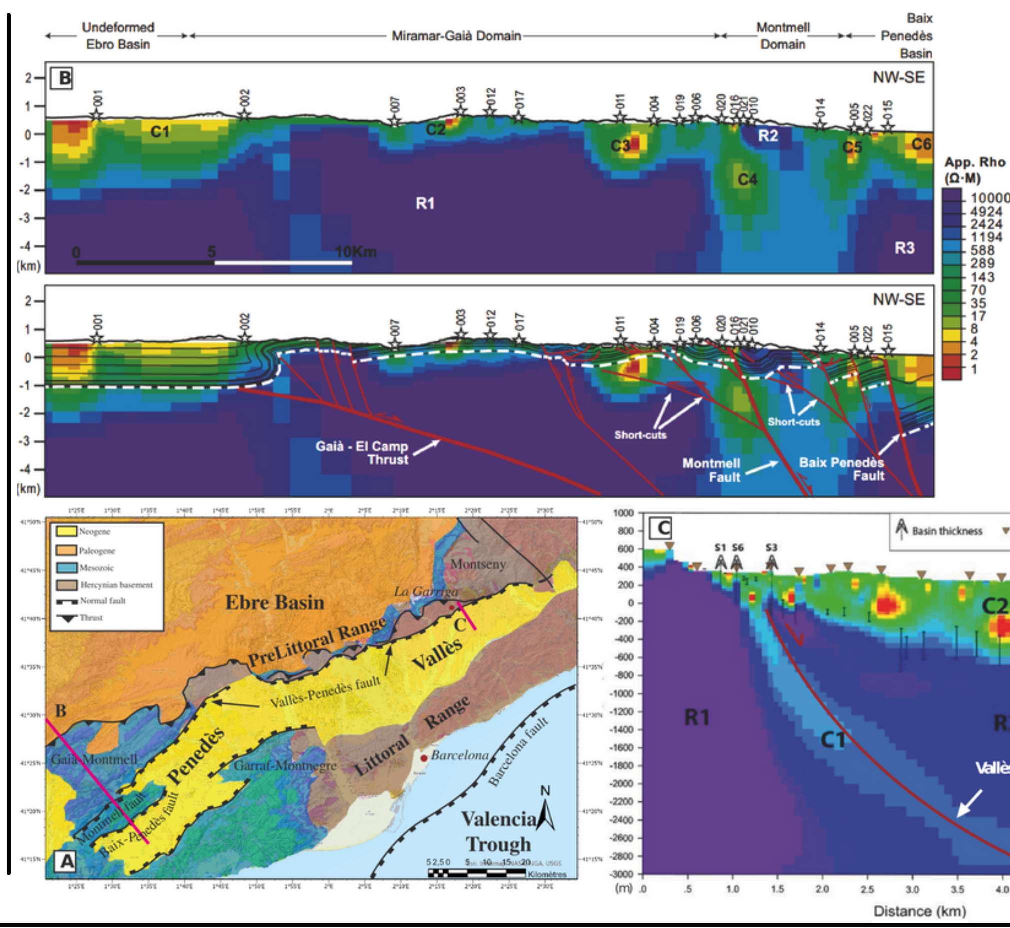


Figure 1: A-Regional geothermic gradient map of the Vallès-Penedès and Ebre Basin (Compiled from Marín et al., 2021 and the Institut Cartogràfic y Geologic de Catalunya (ICGC)) B-Map of the local geothermic gradient between Montbui and La Garriga, obtained by nearest neighborg interpolation of 56 wells data

Geophysical data



The Baix-Penedès and VP fault both bond the basin (Fig. 2.A).

They are characterized by lower resistivity values bands: C4, C5 and C1, rooting deep into the more resistive basement (Fig. 2. B and C).

Lower resistivity values is a signal for lower density or presence of a conductive material.

These bands are therefore interpreted as cataclastic zones where conductivity is enhanced by thermal water or mineralization.

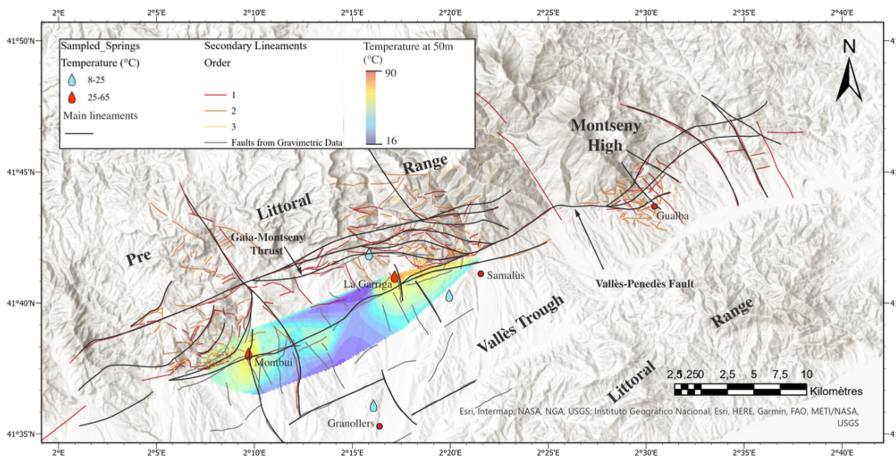
Figure 2: A-Schematic structural map of the Vallès-Penedès area B-Cross section of magneto-telluric model of Gaia-Montmell showing the differentiated conductive and resistive bodies, interpreted: stratigraphic boundaries (black lines) and the top of the Variscan basement (dashed white line) (Marín et al., 2021). C-Cross section of magneto-telluric model of La Garriga interpreted, by C (Condutive) and R (Resistive) area (Modified after Mitjanas et al., 2021).

OBJECTIVES

How does structural control impacts the spatio temporal variations of the metal content in hydrothermal fluids along the Vallès-Penedès crustal fault ?

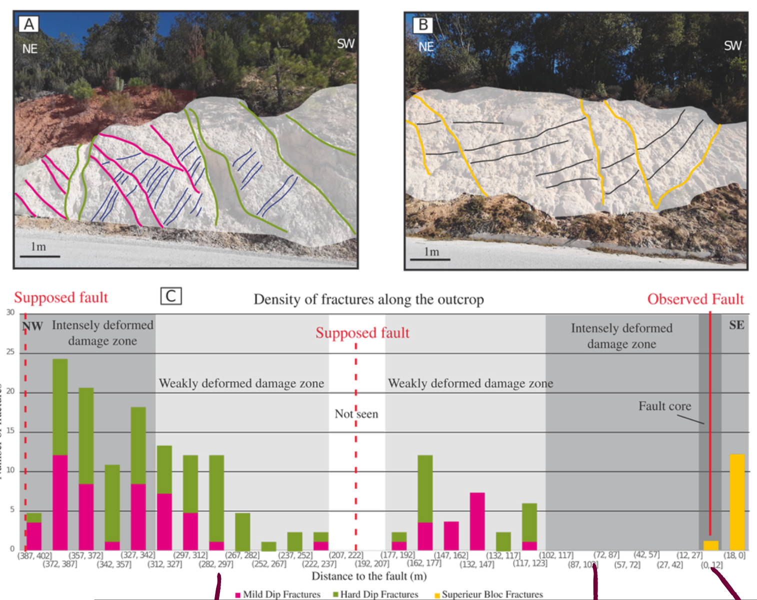
Characterizing the fracture network architecture and the fault related permeability to identify a drain for hydrothermal waters. Geochemically establishing the metal content of thermal waters.

Structural approach



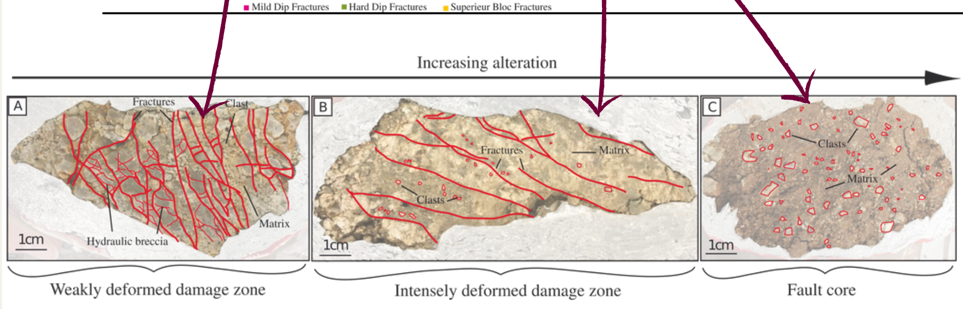
- Structural map suggests that hot springs are located at the intersection of the NE-SW VP fault and NW-SE transverse faults
- The complexe structure mainly affects the granite basement, the sedimentary Miocene infill is also affected by fractures.

Figure 3: Map of the structural framework along the VP fault. Lineaments are mapped from 1946 orthophotos.



- Polyphased fractures in the granitic basement constitute a damage zone of nearly 400m (Fig. 4.A and 4.C).
- Fractured arkosic Miocene basin infill may constitute a good reservoir (Fig. 4.B)
- The scan line shows that the amount of fractures varies with the distance to the fault (Fig. 4.C). The damage zone in the inferior block is highly fractured.

Figure 4: A-Interprated outcrop photo showing the inferior block fractures. B-Interpreted outcrop photo showing the superior block fractures. C-Scanline of fractures amount every 20 meters in Gualba (Fig. 3)



- Different faults rocks are identified, from a protocataclasite to a gouge
- The ultracataclasite and the gouge seems to act like a screen while the protocataclasite could act like a drain.

Figure 5: Microscopic analysis of fault rocks A-Protocataclasite, B-Ultracataclasite, C-Gouge

Geochemical approach

- Lithium (Li) concentrations significantly vary from to 0.008 to 1.63 mg/L. Hot springs Li concentrations are higher than cold springs ones.
- Some of these values are adnormal and higher than the values of reservoirs in sedimentary basins (Dugamin et al., 2021).
- Nevertheless these values are to low to collect Li as a byproduct of geothermal plant.

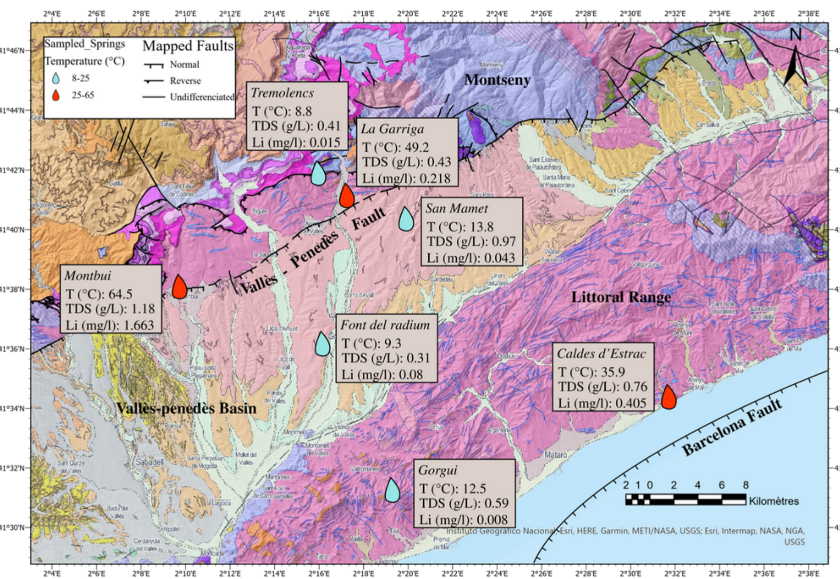


Figure 6: Distribution map of sampled springs in the Vallès-Penedès area. T: Temperature, TDS: Total Disolved Salts, Li: Lithium concentration. Data were obtained by ionic chromatography.

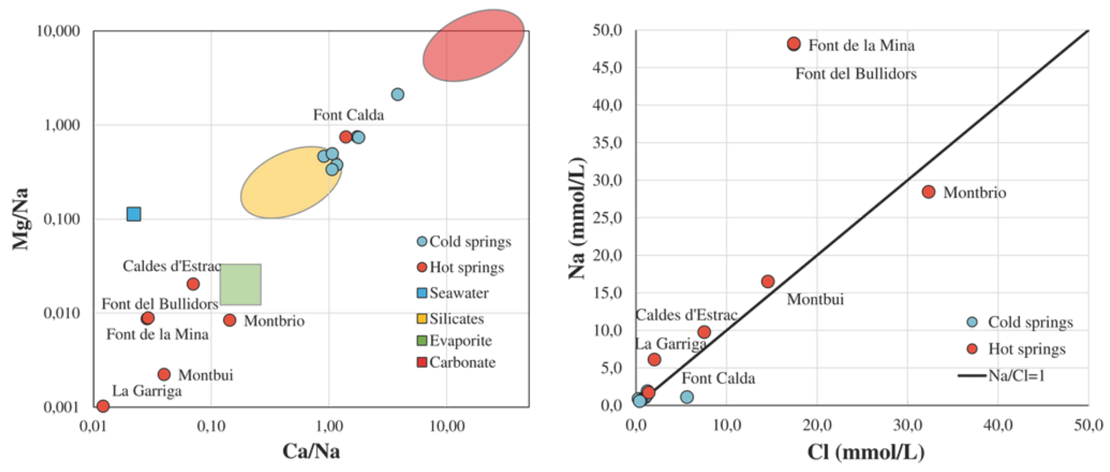
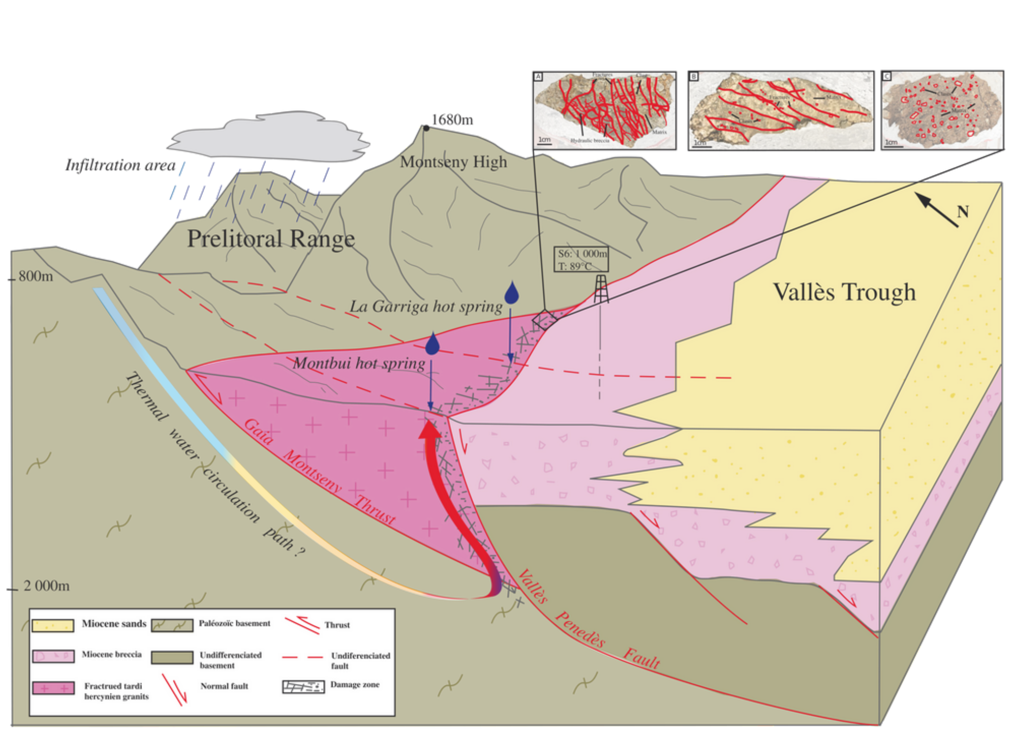


Figure 7: A- Geochemical distribution of hot and cold springs Mg/Na VS Ca/Na molar ratios compared with end members from Gaillardet et al., 1999. B- Na/Cl molar ratio of hot and cold springs

- Hot springs are bearing an evaporitic signature and cold springs a more granitic signature (Fig. 7.A)
- For hot springs Na/Cl is close to 1 (Fig. 7.B), waters might have percolated through evaporites or they might result from a mixing betxween infiltration and sea water.

Figure 8: Conceptual model of the La Garriga-Samalús geothermal system



Conclusion

- The low enthalpy system of the VP fault presents concentrations of Li too weak to be quarried. Nevertheless, variations along the fault path indicate that the structural and geological controls are strong and need to be further investigated.
- The multiscale structural analysis allowed to precisely characterize the drains for fluid flow along the fault path.

Perspectives

To pursue this project several approaches are considered. First, to complete the spatio-temporal characterization of fluids circulation, calcite veins and mineralization will be analysed in order to establish the fluid content in metals along the different stages of deformation. Then, calcite veins will be dated using the U/Pb method to constrain those stages. Ultimately, water samples could be dated and their origin might be traced to nail down the fluid flow circuation path.

REFERENCES

Dugamin, E.J.M., Richard, A., Cathelineau, M., Boiron, M., Despinois, F. and Brisset, A., 2021. Scientific Reports,, p. 11, doi: https://doi.org/10.1038/s41598-021-99912-7.
Duwiquet, H., Guillou-Frottier, L., Arbaret, L., Bellanger, M., Guillon, T. and Heap, M.J., 2021. Crustal Fault Zones (CFZ) as Geothermal Power Systems: A Preliminary 3D THM Model Constrained
Gaillardet, J., Dupré, B., Louvat, P. and Allègre, C.J., 1999. Chemical Geology, 159, p. 3–30, doi: 10.1016/S0009-2541(99)00031-5.
Marín, M., Roca, E., Marcuello, A., Cabrera, L. and Ferrer, O., 2021. Tectonophysics, 814, p. 228970, doi: 10.1016/j.tecto.2021.228970.
Mitjanas, G., Ledo, J., Macau, A., Alías, G., Queralt, P., Bellmunt, F., Rivero, Ll., Gabàs, A., Marcuello, A., Benjumea, B., Martí, A. and Figueras, S., 2021. Geothermics, 93, p. 102067, doi: 10.1016/j.geothermics.2021.102067.
Moeck, I.S., 2014. Energy Reviews, 37, p. 867–882, doi: 10.1016/j.rser.2014.05.032.