CO_2-rich mineral groundwaters from East Belgium

Geological origin and where can we find them ?

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Inspiring Groundwater

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Intro & objectives

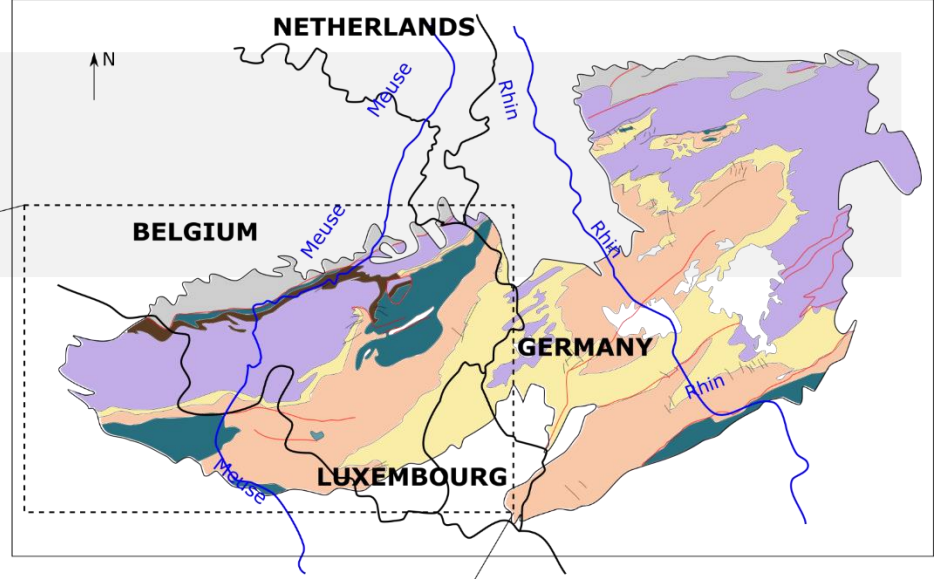
- **Naturally enriched in dissolved CO_2** (2-5 g/l)
- **Low mineralization** (TDS 80 mg/l to 160 mg/l)
- **Rich in iron** (1-2 mg/l)

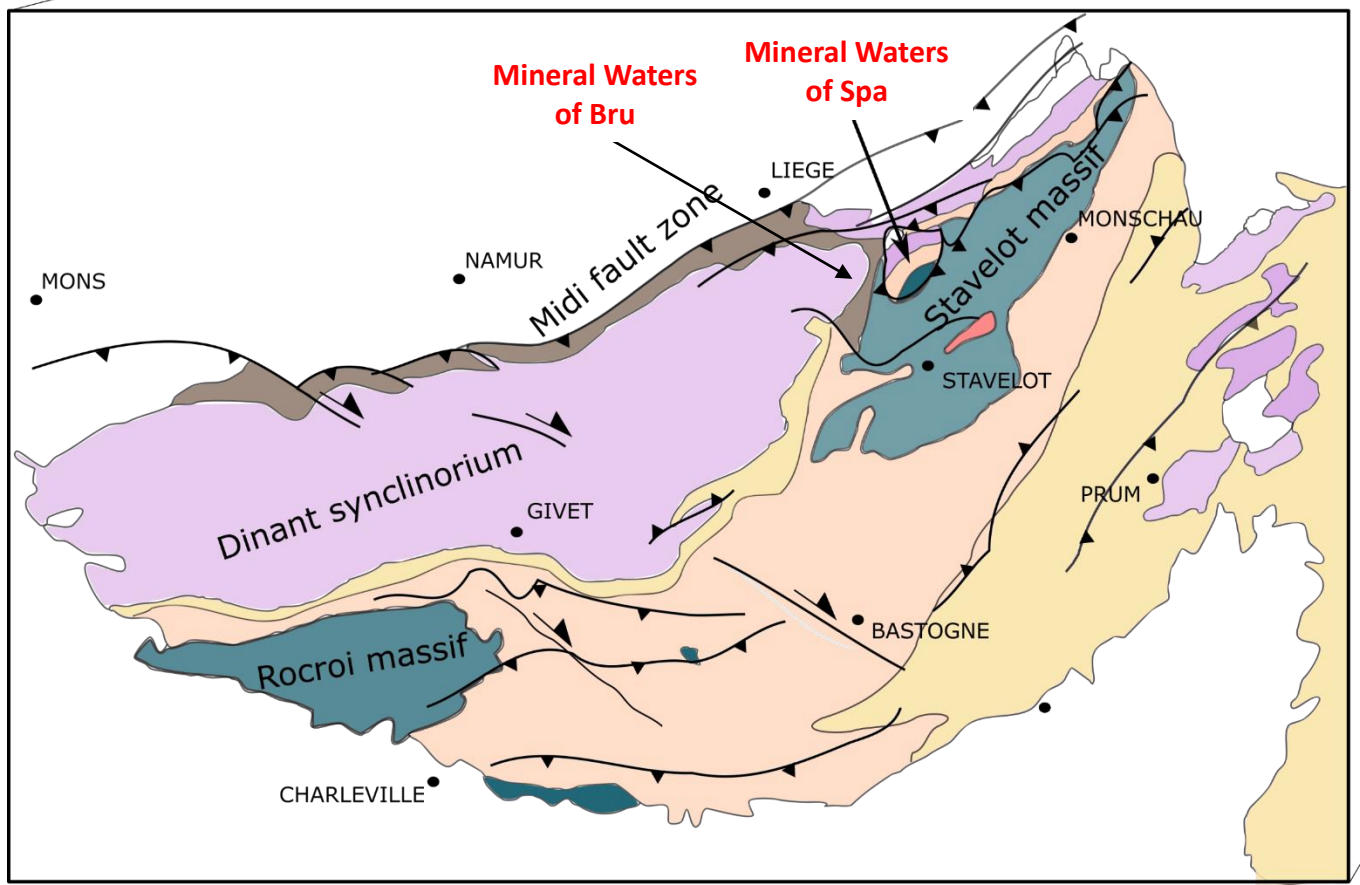
Where does the dissolved gaz come from ?

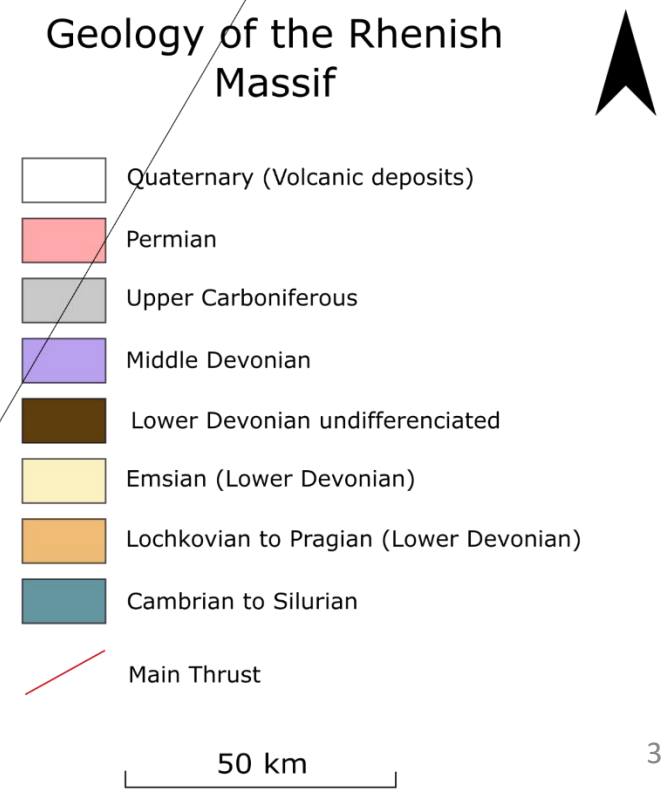
What can be a suitable method to efficiently prospect thoses waters ?

Geological context

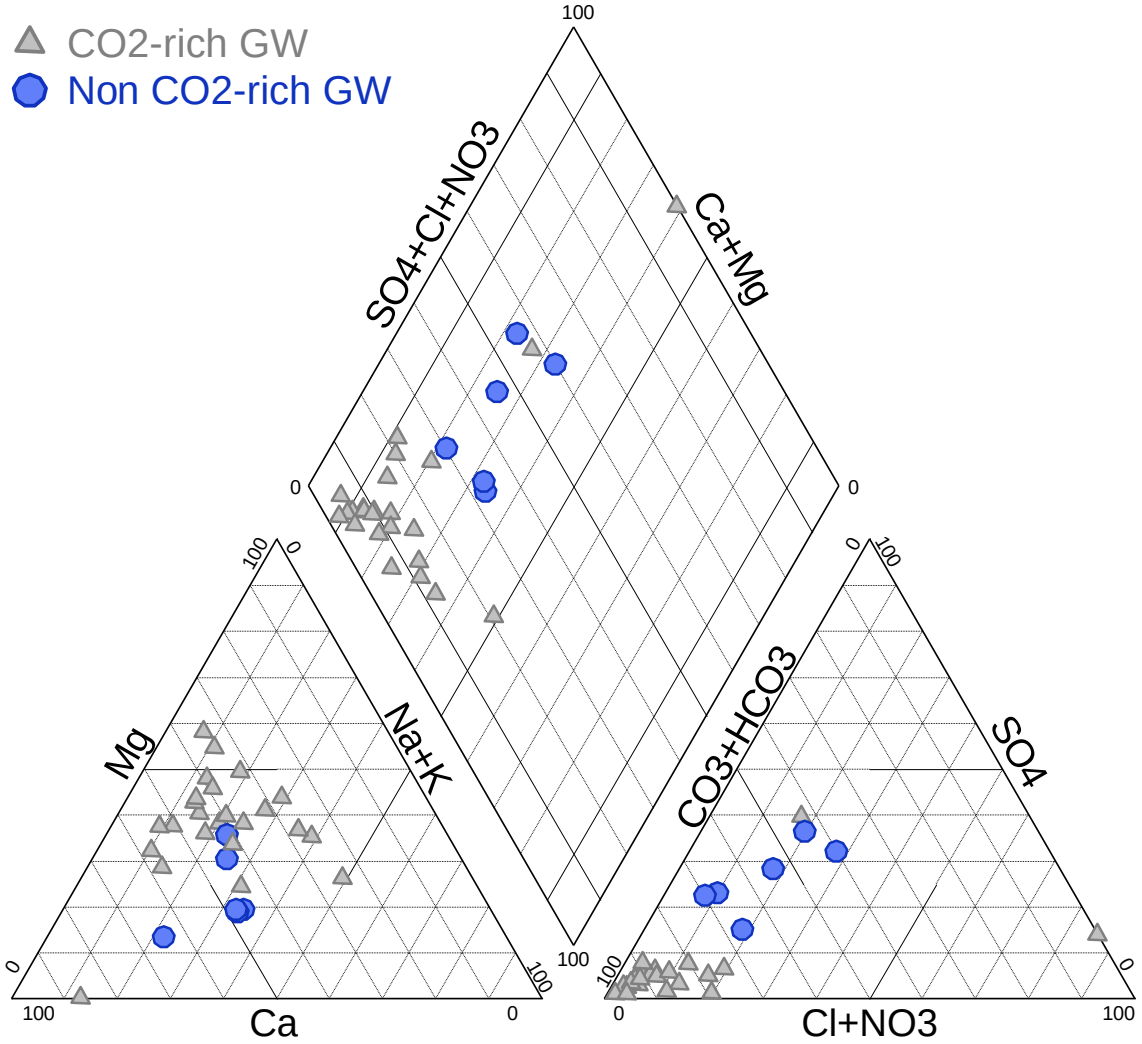
The western part of the Rhenish Massif – The Ardennes Allochtone







Groundwater composition

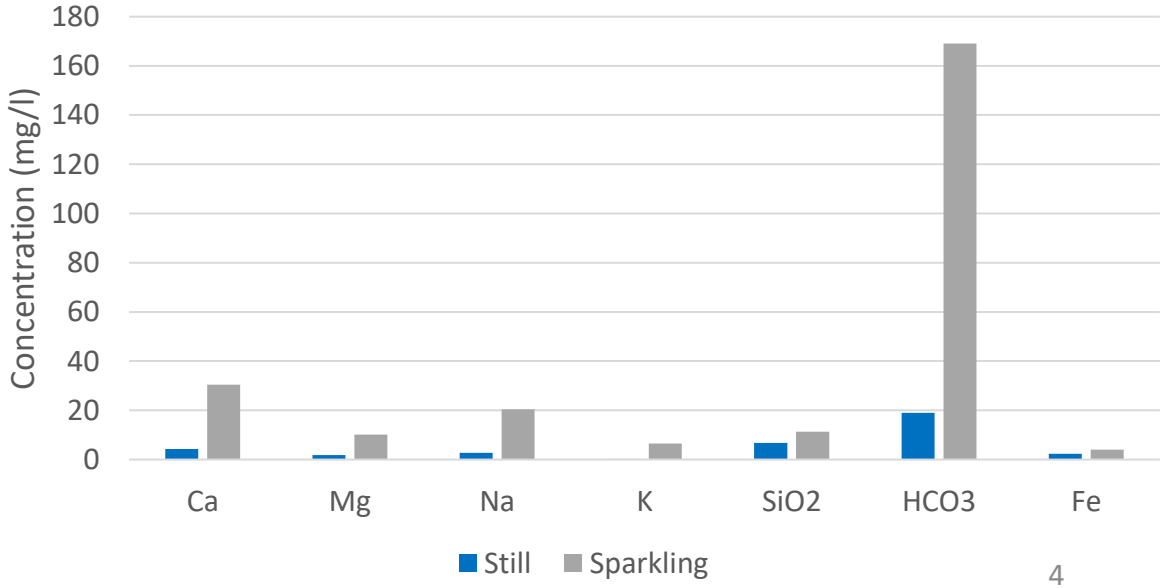


Consequence of CO_2 dissolution in groundwater

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

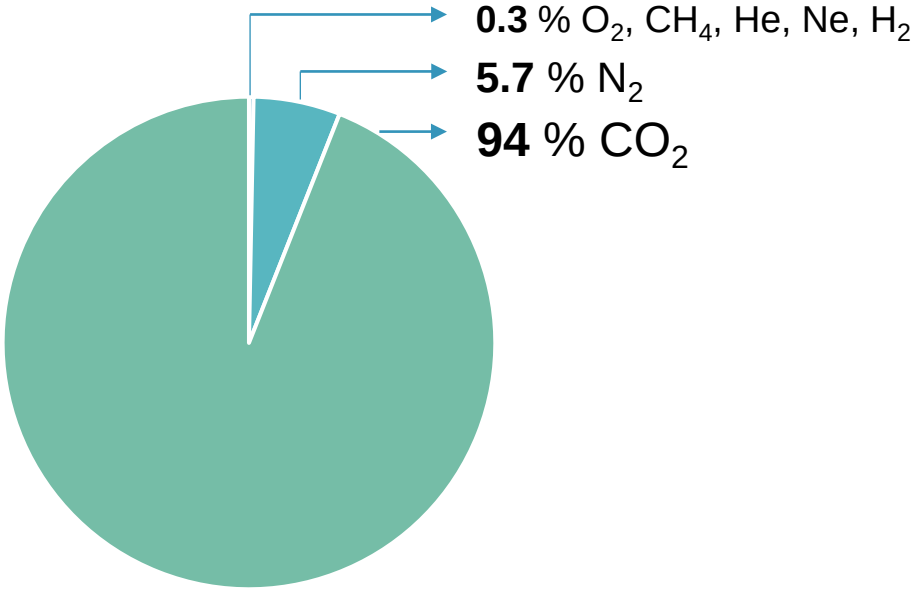
$$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

↓ **pH**



Question 1.

Where does the gas come from ?



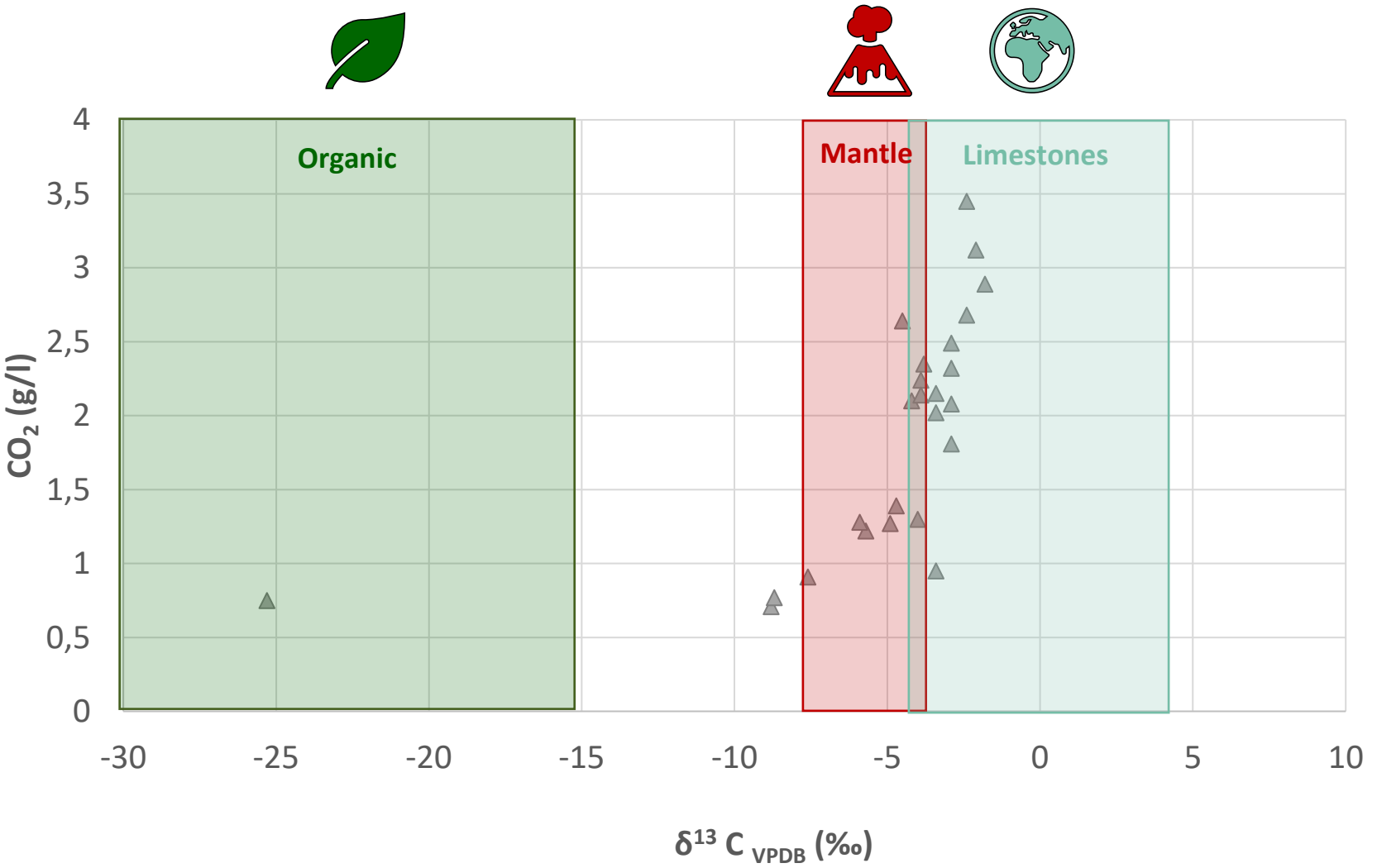
Usually, 3 main origins are considered

Mantellic

Crustal

Organic

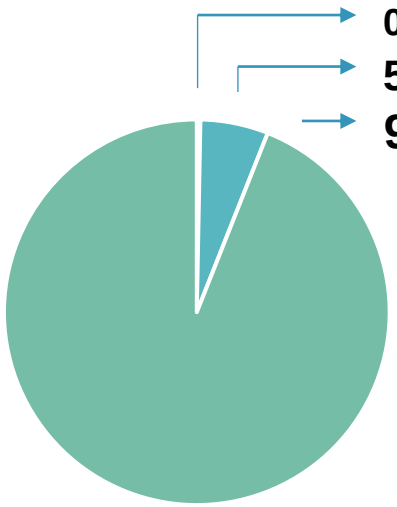
Isotopic analysis of the dissolved gases



- Clearly not an organic origin
- But the distinction between mantle and limestones is tricky, due to degassing and potential isotopic fractionation

Sano and Marty (1995) – Origin of carbon in fumarolic gas from island arcs. Chemical Geology

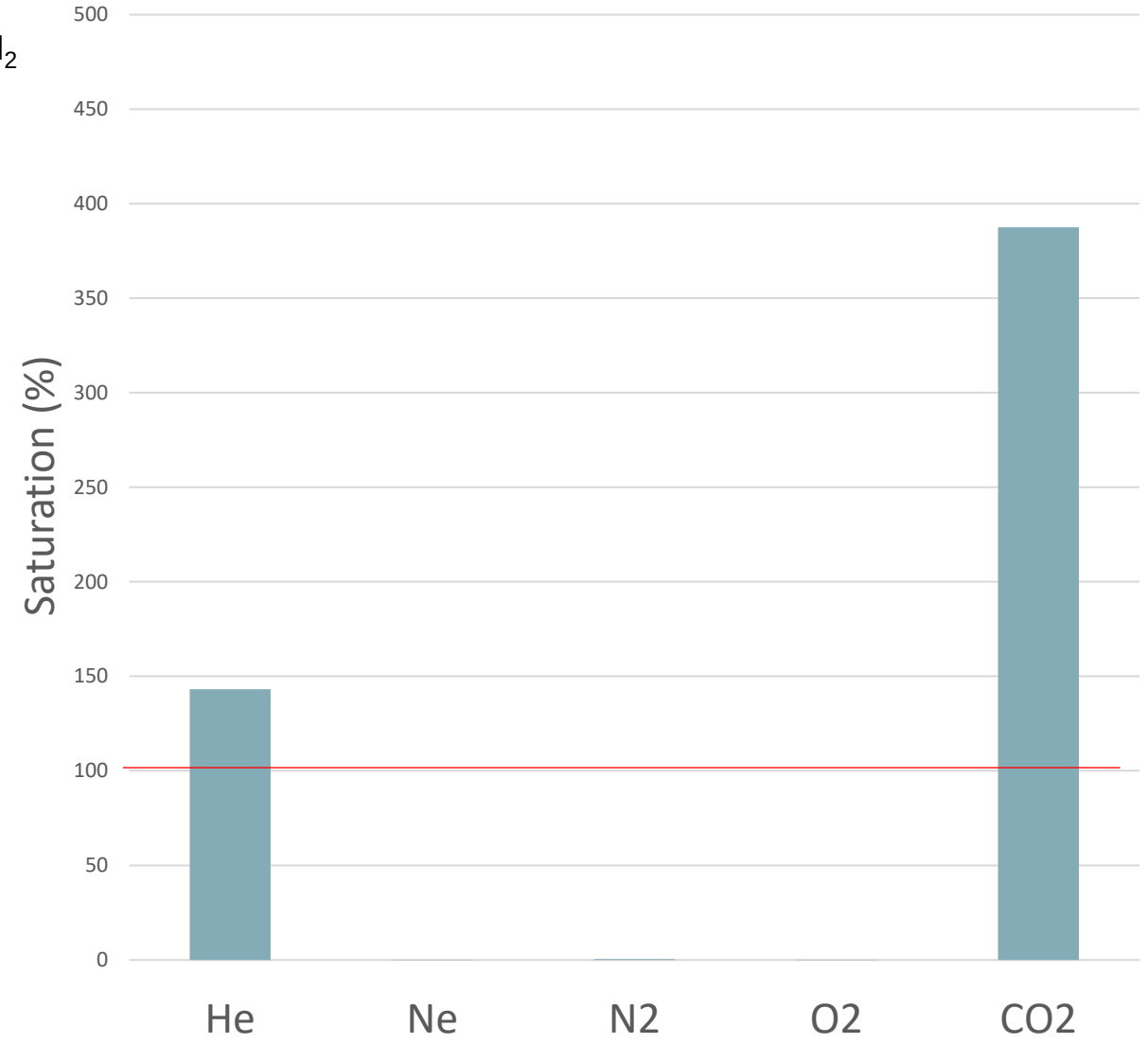
Isotopic analysis of the dissolved gases



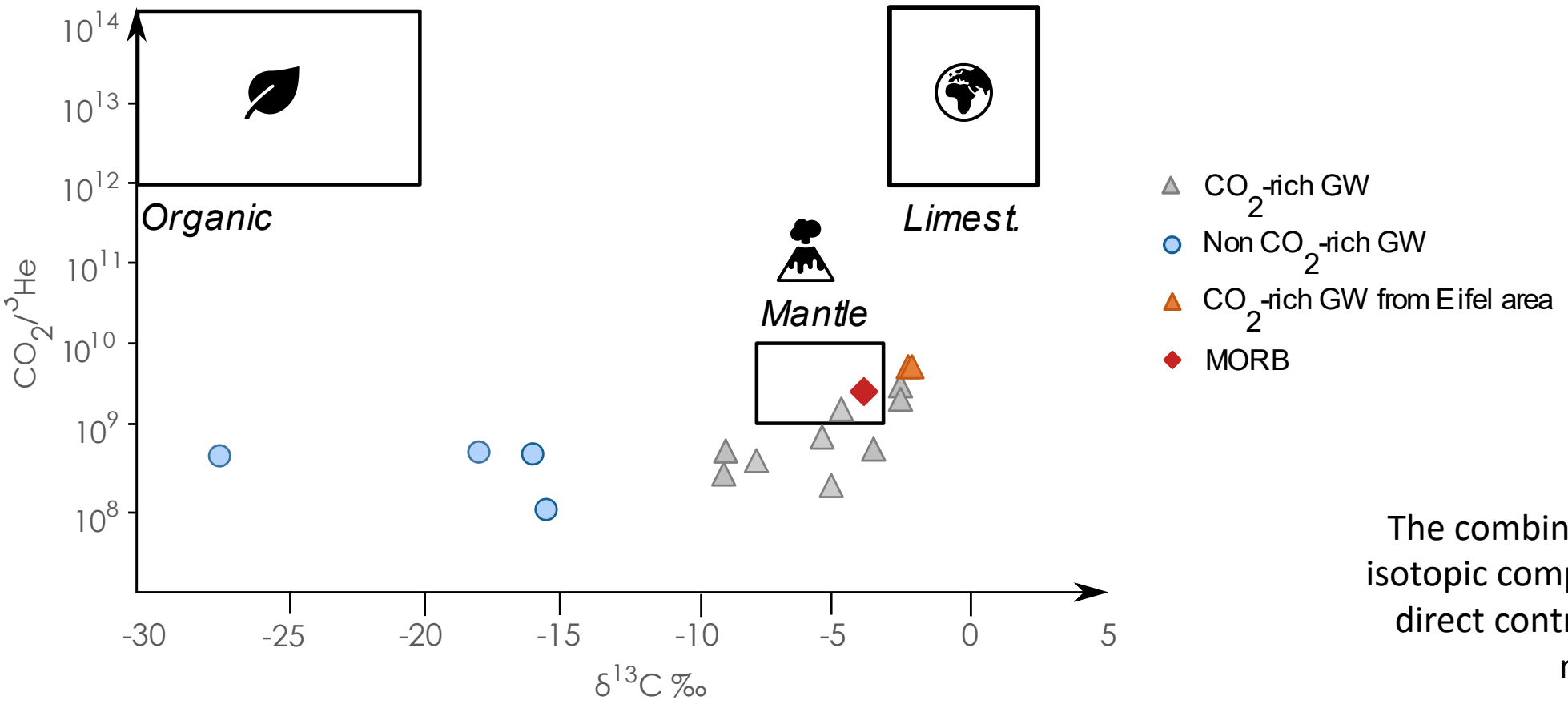
When we look at gas concentrations, **He** is negligible (~10^{-8} mol/l)

But saturation tells another story…

Oversaturation in **He** suggests a direct contribution from the mantle



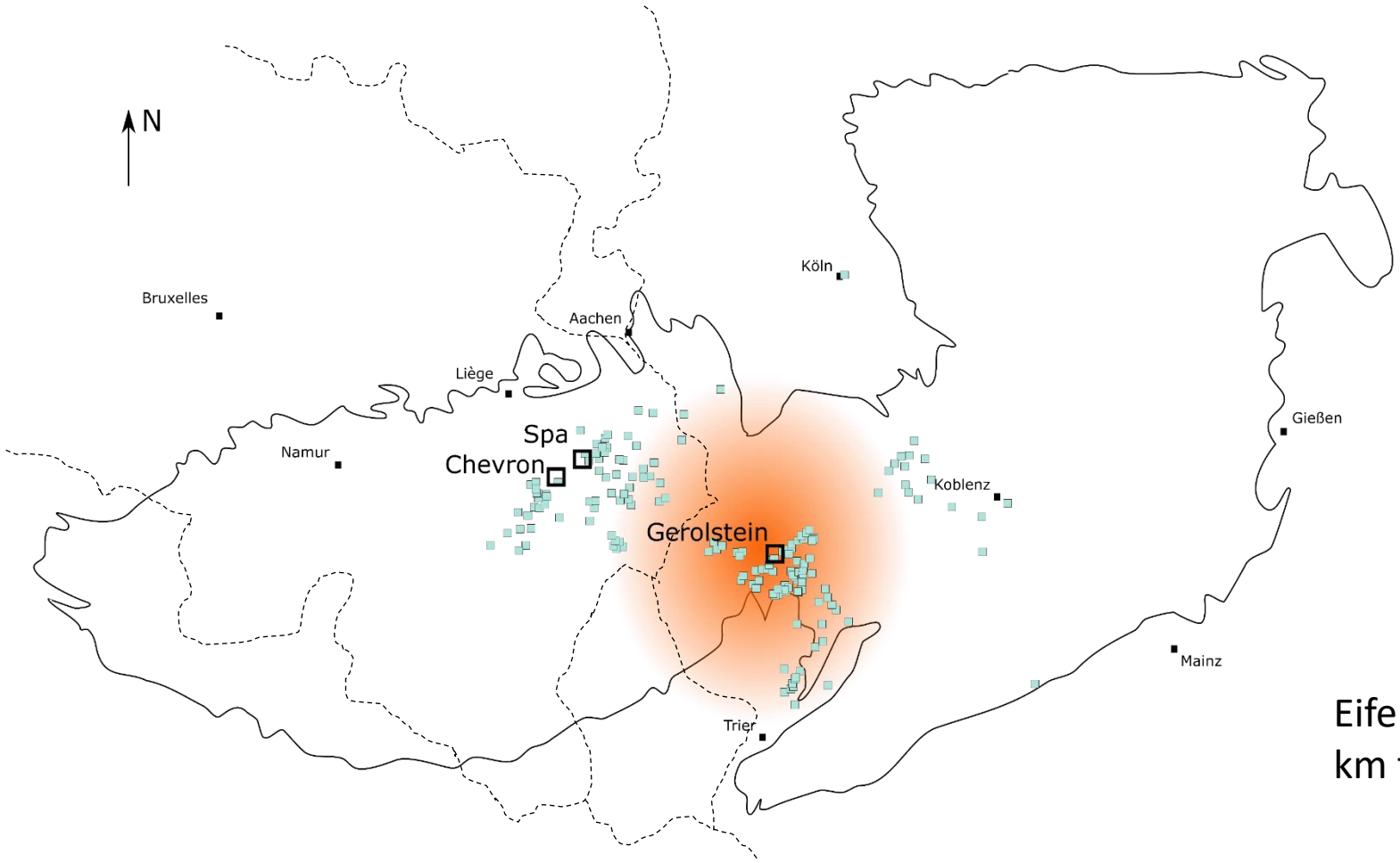
Isotopic analysis of the dissolved gases



The combination of C and He isotopic composition confirms a direct contribution from the mantle

Sano and Marty (1995) – Origin of carbon in fumarolic gas from island arcs. Chemical Geology

From the mantle ?



Volcanic activity and CO_2-rich groundwater springs in the Rhenish Massif

- Sparkling mineral water bottling sites
- Main CO_2-rich groundwater springs
- Projection of the Eifel volcanic plume at the surface

0 25 50 km

Eifel volcanic fields located about 80 km from the springs… and still active !

Bräur et al. 2013 - Indications for the existence of different magmatic reservoirs beneath the Eifel area (Germany): A multi-isotope (C,N,He,Ne,Ar) approach
Kreemer et al. 2020 – Geodetic evidence for a buoyant mantle plume beneath the Eifel volcanic area, NW Europe

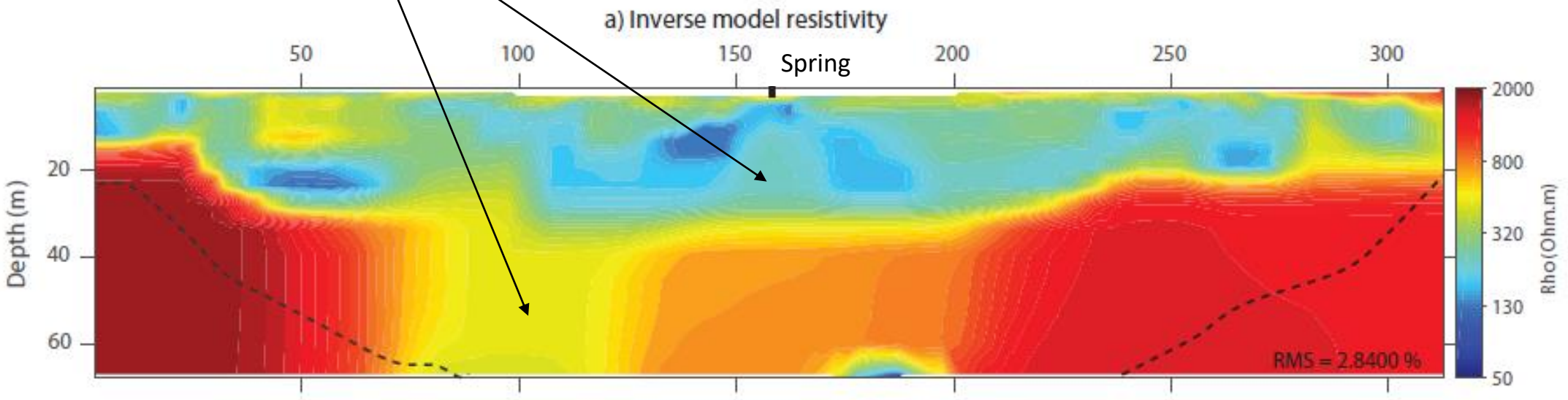
Question 2.

Where can we drill to find CO_2-rich groundwater?

From hydrochemistry to geophysics…

ERT measurements

Low resistivity areas,
potentially aquifers



This might be water-saturated zones.

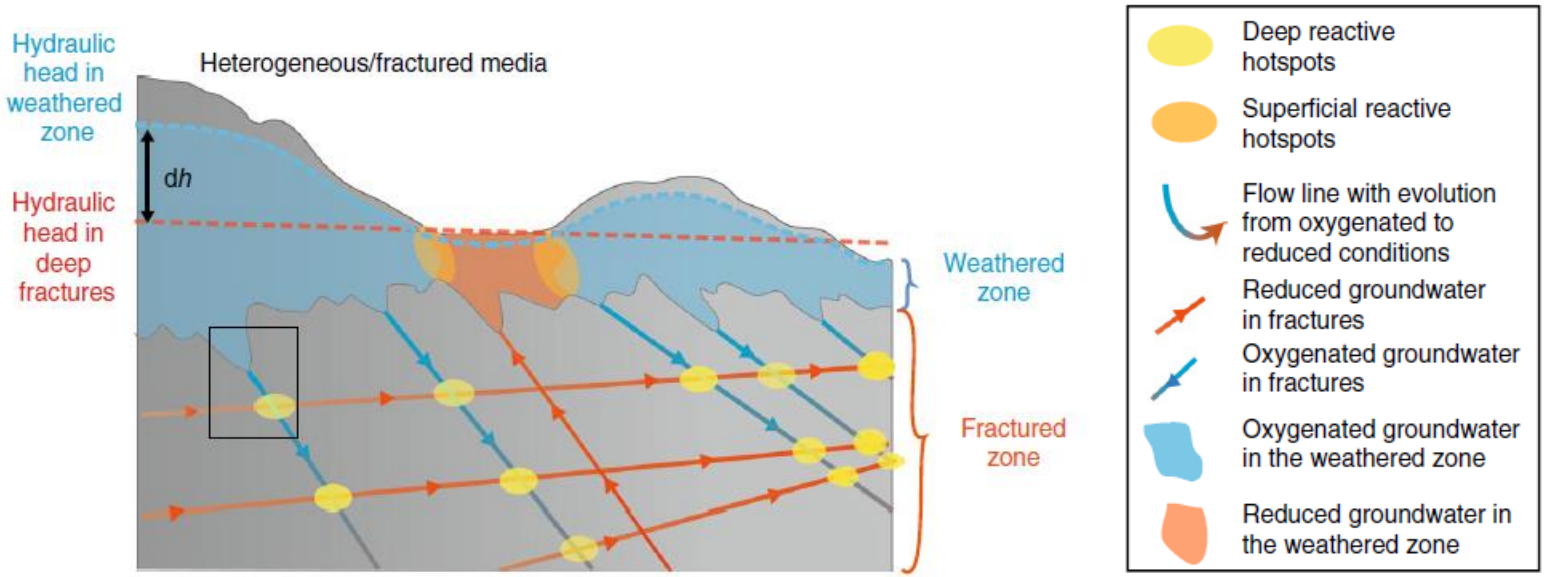
But is it sparkling water ?

IP measurements

Iron hydroxydes

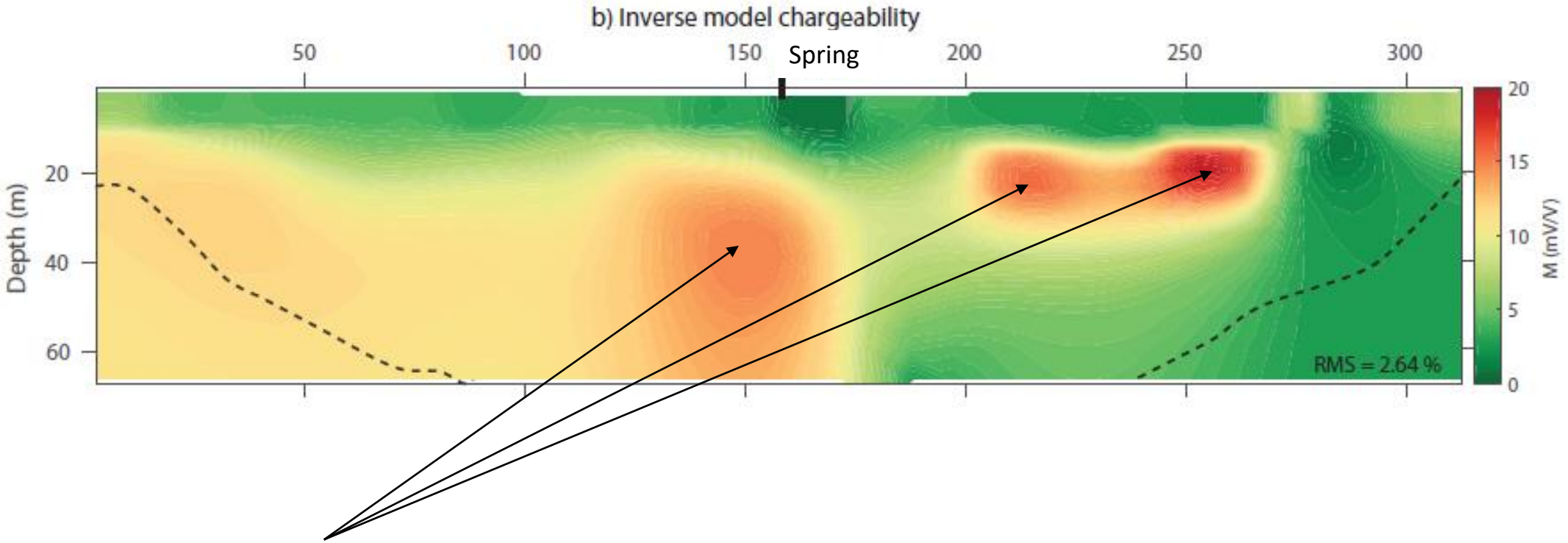
CO_2-rich groundwaters characterized by the presence of **iron hydroxydes hot spots** formed by intermittent oxic–anoxic fluid mixing in fractured rocks.

Goal : highlight their presence thanks to the **polarizable** character of theses elements.



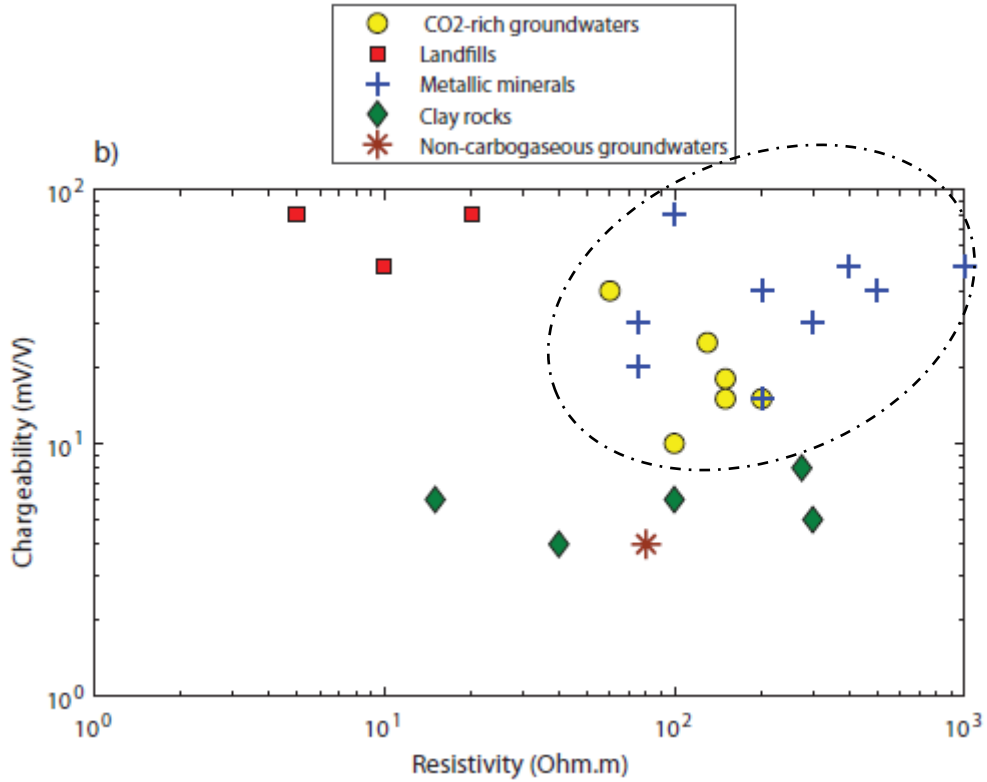
Bochet et al. (2021) – Iron-oxidizers hotspots formed by the intermittent oxic-anoxic fluid mixing in fractured rocks. *Nature Geoscience*

IP measurements



High IP response, zones rich in metallic hydroxydes

Comparison with the litterature

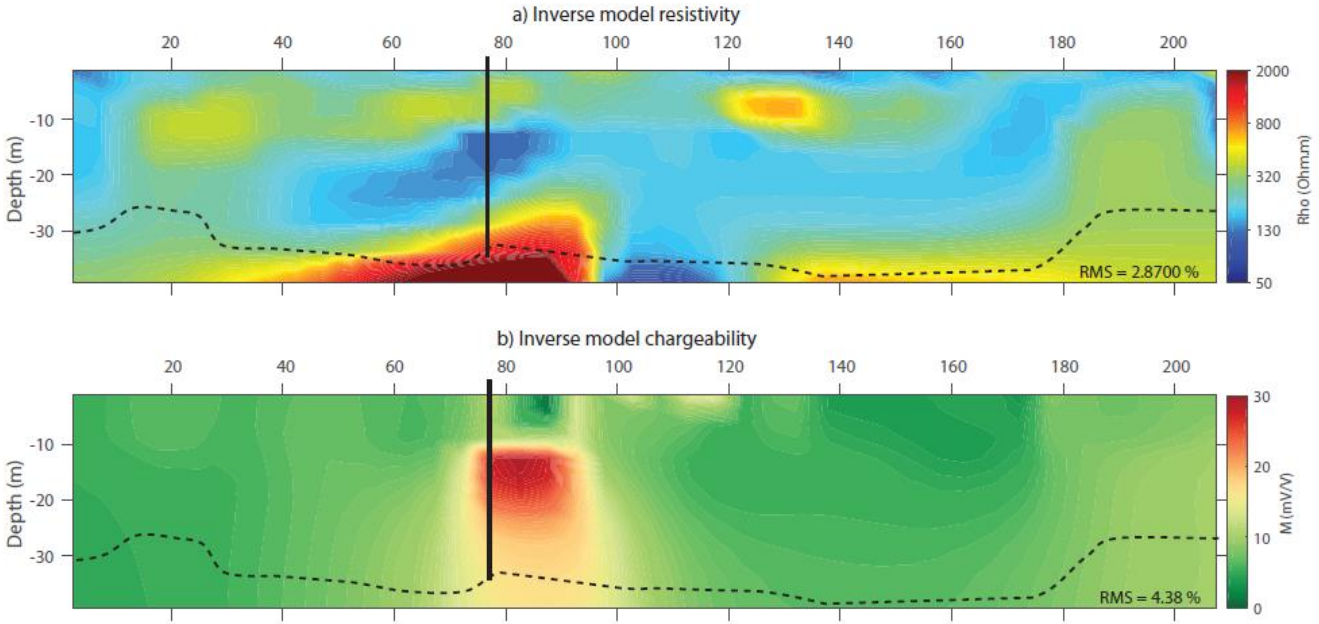


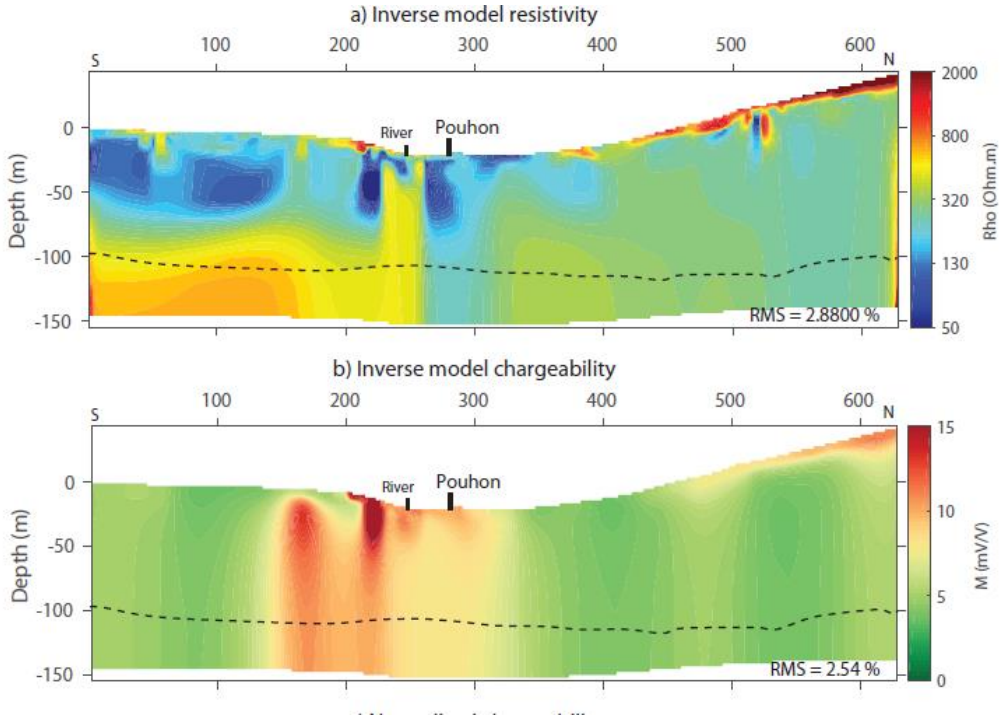
Resistivity and chargeability values measured at the springs location are similar to the one commonly accepted for metallic minerals in the literature…

Which tends to confirm the hypothesis of iron hydroxides precipitation at shallow depths as a signature of the presence of CO2-rich groundwater.

More details in : Defourny, A.; Nguyen, F.; Collignon, A.; Jobé, P.; Dassargues, A.; Kremer, T. **Induced Polarization as a Proxy for CO_2-Rich Groundwater Detection—Evidences from the Ardennes, South-East of Belgium**. *Water* **2020**, *12*, 1394. *https://doi.org/10.3390/w12051394*

Other results





Question is:
Can we find a similar signature at other locations where there is no spring?
Or does this signature exist at that precise location because of a contact with oxygen ?

Defourny et al. (2020). Induced Polarization as a Proxy for CO2-Rich Groundwater Detection—Evidences from the Ardennes, South-East of Belgium. *Water*

Conclusions and further research

Natural mineral waters rich in dissolved CO_2

Where does the CO_2 comes from ?

Combination of $\delta^{13}C$ and ^{3}He isotopic values

Where can we find them ?

Combination of ERT and IP measurements

Thank you for your kind attention…

… and keep it sparkling !