Integration of proxy data for a better comprehension of naturally sparkling mineral groundwater in the Stavelot massif (south-east of Belgium)

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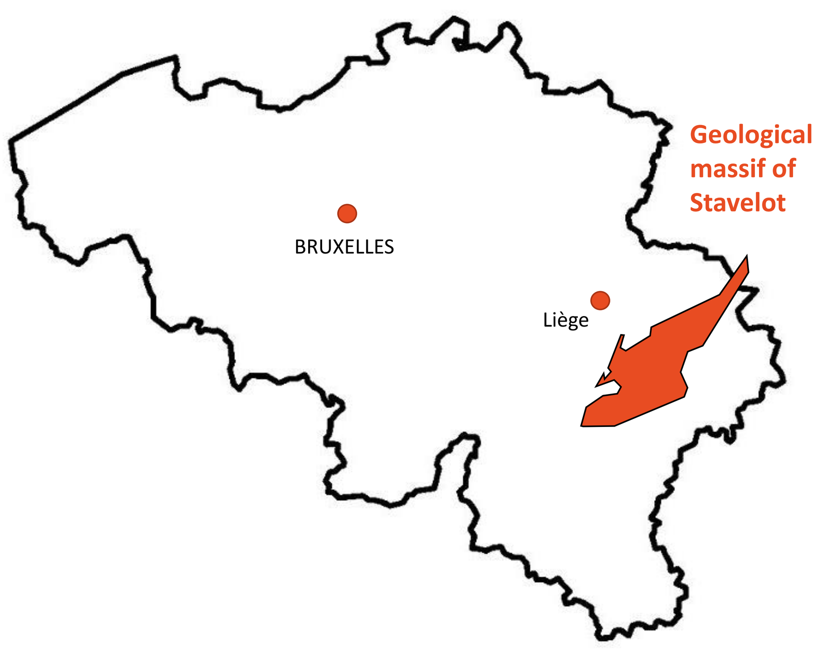
CONTEXT

In the south eastern part of Belgium are found tens of **natural springs of CO2-rich groundwater**. These springs are recognized for their **extreme pureness** and healing properties and have driven a strong **economic** and touristic **development of the area**.



These springs are found in the geological massif of Stavelot. Two folding events occurred in the area, resulting in the presence of many **thrust faults** and normal fractures. These **structural features enable the uplift of deep carbonated groundwater to the surface**.

A better understanding of the resource is needed to

- Ensure a **sustainable exploitation**
- Guarantee its **protection**
- Map and estimate the **potential reserves**
- Enhance the global knowledge of the local and regional geology

What is to be clarified

- The **origin of the CO2**
- The **circulation and uplift network** and the extend of the connection existing between the different areas of the massif
- The origin of its **particular composition**

OBJECTIVE

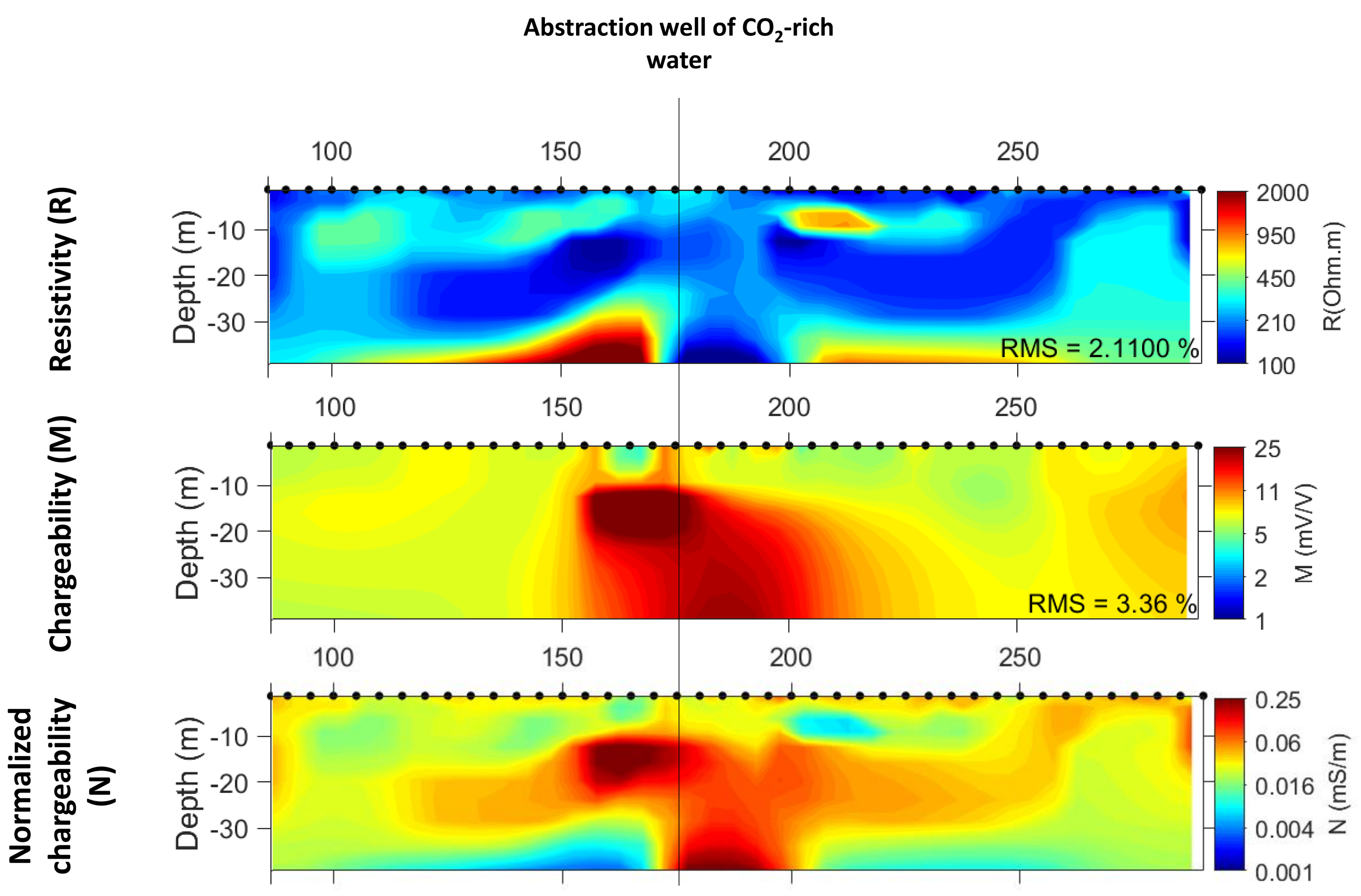
Develop an **integrated method** for the comprehension of naturally sparkling groundwater by **combining different proxy data**:

- **Geological features**: Use of an actualized geological map and new interpretation of the local fault network
- **Geophysics**: ERT & IP methods to spot the particular signature of upwelling zones
- **Hydrochemistry**: Equilibrium of carbonates and indicator elements of deep groundwater pathways
- **Isotopes**: Carbon isotopes for the discrimination of the origin of CO2
- **Rare gazes**: Combined with water isotopes, to assess groundwater residence time in the aquifer

GEOPHYSICS

Combination of ERT and IP methods for the detection of uplift zones. Three parameters are interesting to considered:

- **Restistivity - R** [Ω.m] : informing on the faulting of the medium ;
- **Chargeability – M** [mV/V] : informing on the presence of polarizable minerals in the subsoil (in our case, supposinlgy iron oxides) ;
- **Normalized chargeability - N** [mS/m]: expressed as **M/R**, showing the areas in which the **medium is both fractured and polarizable** i.e. possibly uplift zones.



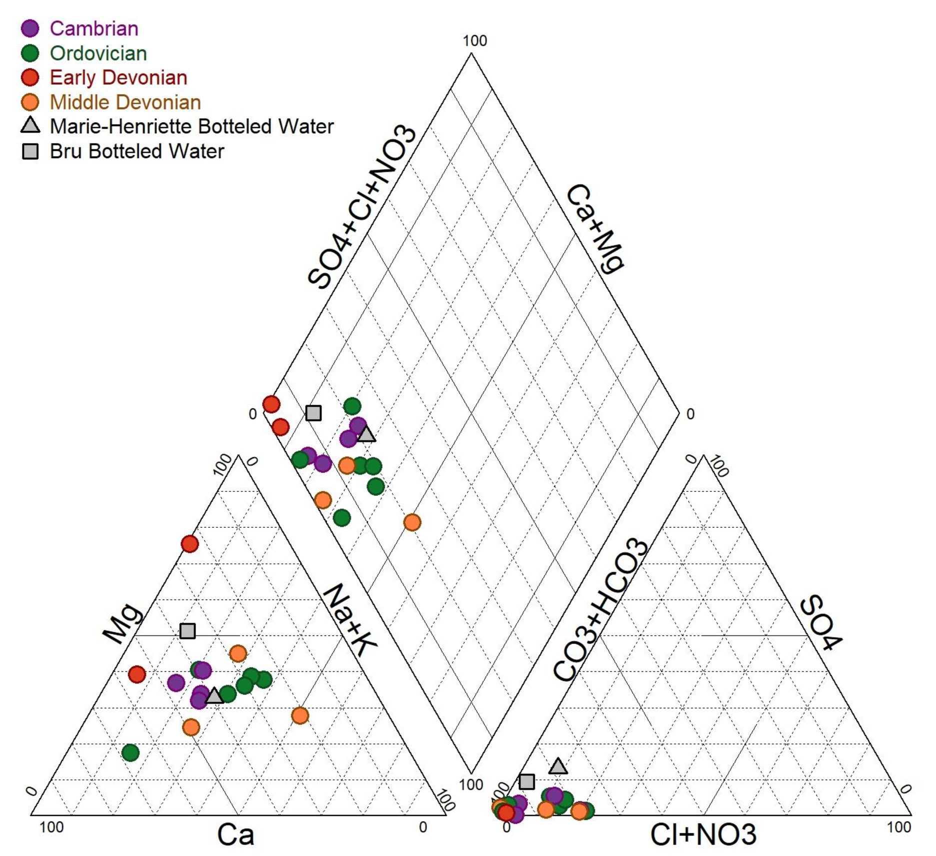
Combined ERT & IP profile realized straight upon an abstraction well producing carbonated water.

HYDROCHEMISTRY

Groundwater from the springs is a bicarbonate-calcic water, with a **low pH** and a **high iron content**. The water is however **moderately mineralized** with an average total dissolved solid content (TDS) between 80 and 160 mg/l. The **composition is quite variable** from one area to the other and some slight differences also exist between springs within the same area. **CO_2 concentration** in groundwater ranges **between 1 and 4 g/l**, depending on the spring.

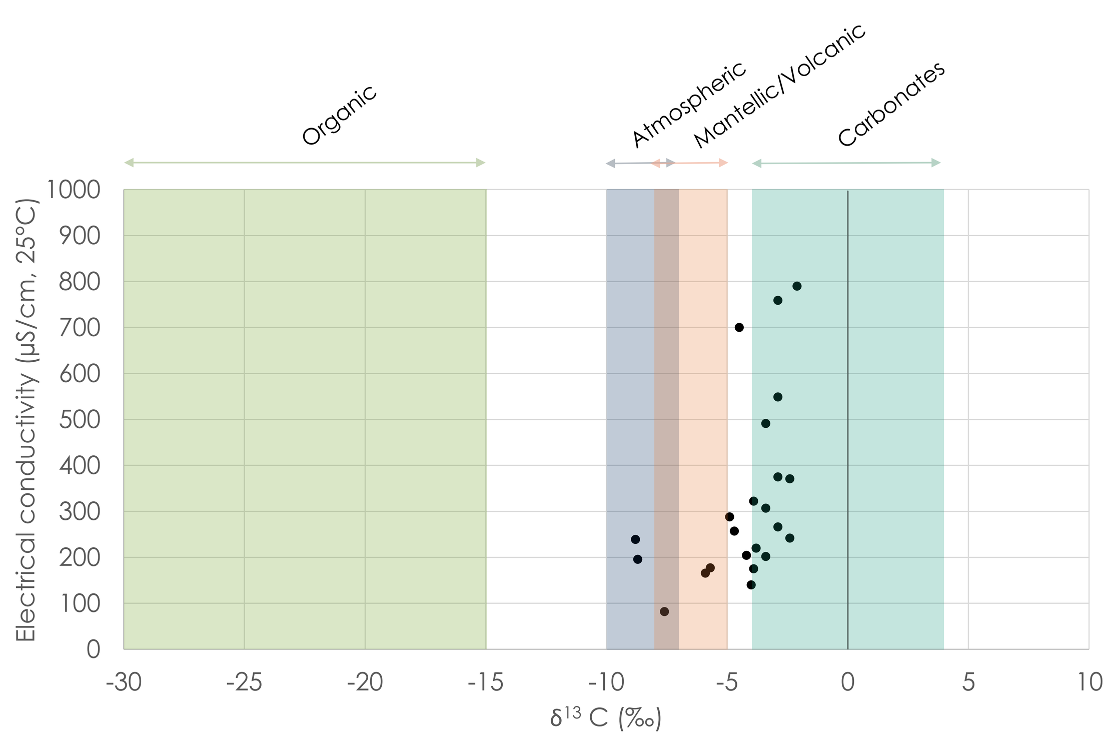
Average* composition of groundwater from natural springs	
Ca (mg/l)	43
Na (mg/l)	30
Mg (mg/l)	22
K (mg/l)	3
HCO_3 (mg/l)	308
SiO_2 (mg/l)	22
Fe (mg/l)	14
Mn (mg/l)	1.2
CO_2 (g/l)	**1.9**
pH (-)	5.8
EC (µS/cm)	540

**Mean computed on 15 samples from different natural springs*



Piper diagram of 15 samples from different natural springs and link with the geology

ISOTOPES



[13]C isotopic ratio for 23 groundwater samples in the area, in comparison with isotopic composition of four possible carbon sources

$\delta^{13}C$ of groundwater sampled in the area ranges from **-9 to -2 ‰.** Compared to the isotopic ratios of possible sources, it appears that the most likley origin of the CO_2 in groundwater is either (or a combination of both):

- the **dissolution of carbonates** rocks and an enrichment of the water in HCO_3^-
- a **direct contribution** of CO_2 from **mantellic/volcanic origin.**

FURTHER RESEARCH

Collect and gather more data → Process data with **self-organizing machine learning algorithm** → **Categorize** points and **recognize** proxy-data that are signature of CO_2-rich groundwaters → Probabilistic **mapping of the reserves** area

- **SCIENCE**
  Understanding of the hydro-geo-dynamic phenomenon responsible for the existence and circulation of CO_2-rich groundwaters
- **TECHNOLOGY**
  Application of machine learning algorithms to data from different areas of geoscience
- **BUSINESS**
  Ease the prospection and the evaluation of the reserves and thus help in the protection, the management and the exploitation of the resource

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LET'S KEEP IN TOUCH !

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