ELECTRICAL SIGNATURE OF CO_2-RICH GROUNDWATER SYSTEMS

APPLICATION IN THE ARDENNES, SOUTH-EAST OF BELGIUM

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CONTEXT

CO_2-rich mineral groundwaters have been exploited for centuries for both bottling and thermal activities. They often trigger a strong economic activity in the areas where they are present. CO_2-rich mineral groundwater systems usually involve three elements:

Groundwater

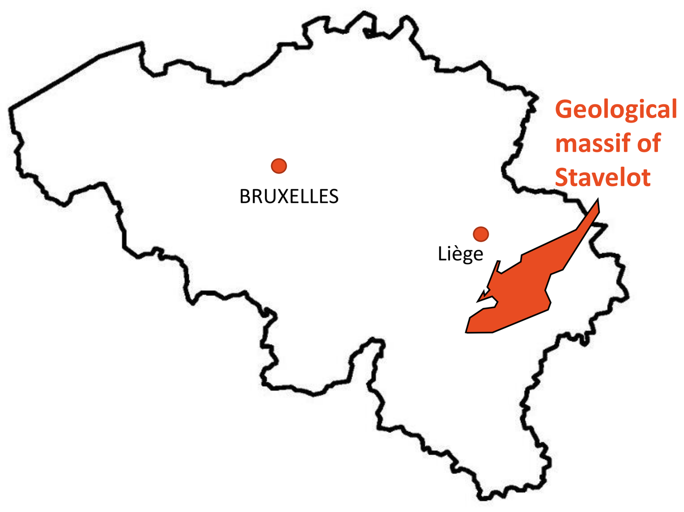
A source of geogenic gaz
Either from organic, sedimentary or juvenile origin

A network of fractures
Enabling the contact between gaz and groundwater and the upflow of groundwater to the surface

Geophysical prospection is crucial to help in the detection **of productive areas** to :

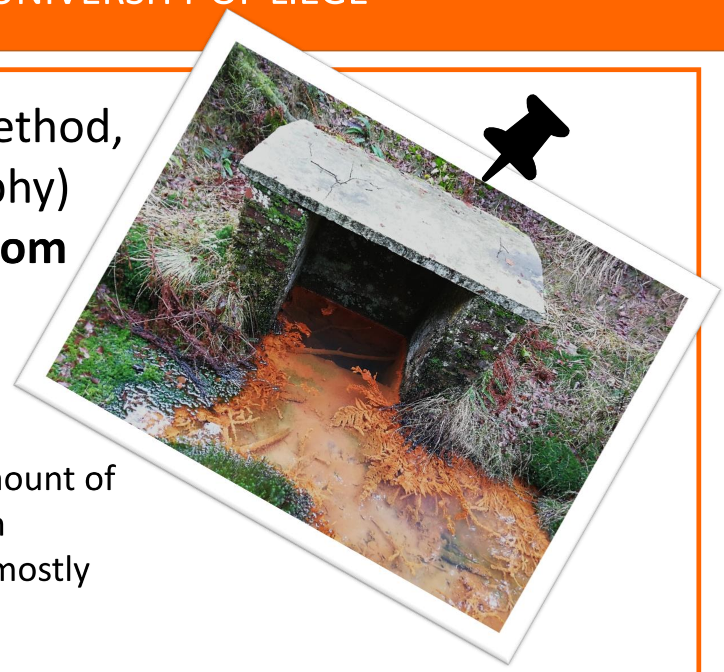
- Address the corresponding uncertainties **before drilling operations**
- Understand the resource to **ensure its sustainable exploitation**
- **Secure future supply**

The study takes place in Belgium, in the geological massif of Stavelot, where CO_2 rich springs are numerous. 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.**



OBJECTIVE

Assess the ability of **IP** (induced polarization) method, **combined to ERT** (electrical resistivity tomography) method, to **distinguish CO_2-rich groundwater from non carbogaseous groundwater**.



CO_2-rich groundwater, made quite acidic with its high content in dissolved CO_2 (**pH ranges between 4 and 6**), contains a large amount of **dissolved iron (up to 7 mg/l)** lixiviated from the host rock. When reaching the surface, **iron precipitates under hydroxide forms** (mostly goethite) giving to the spring a typical color.

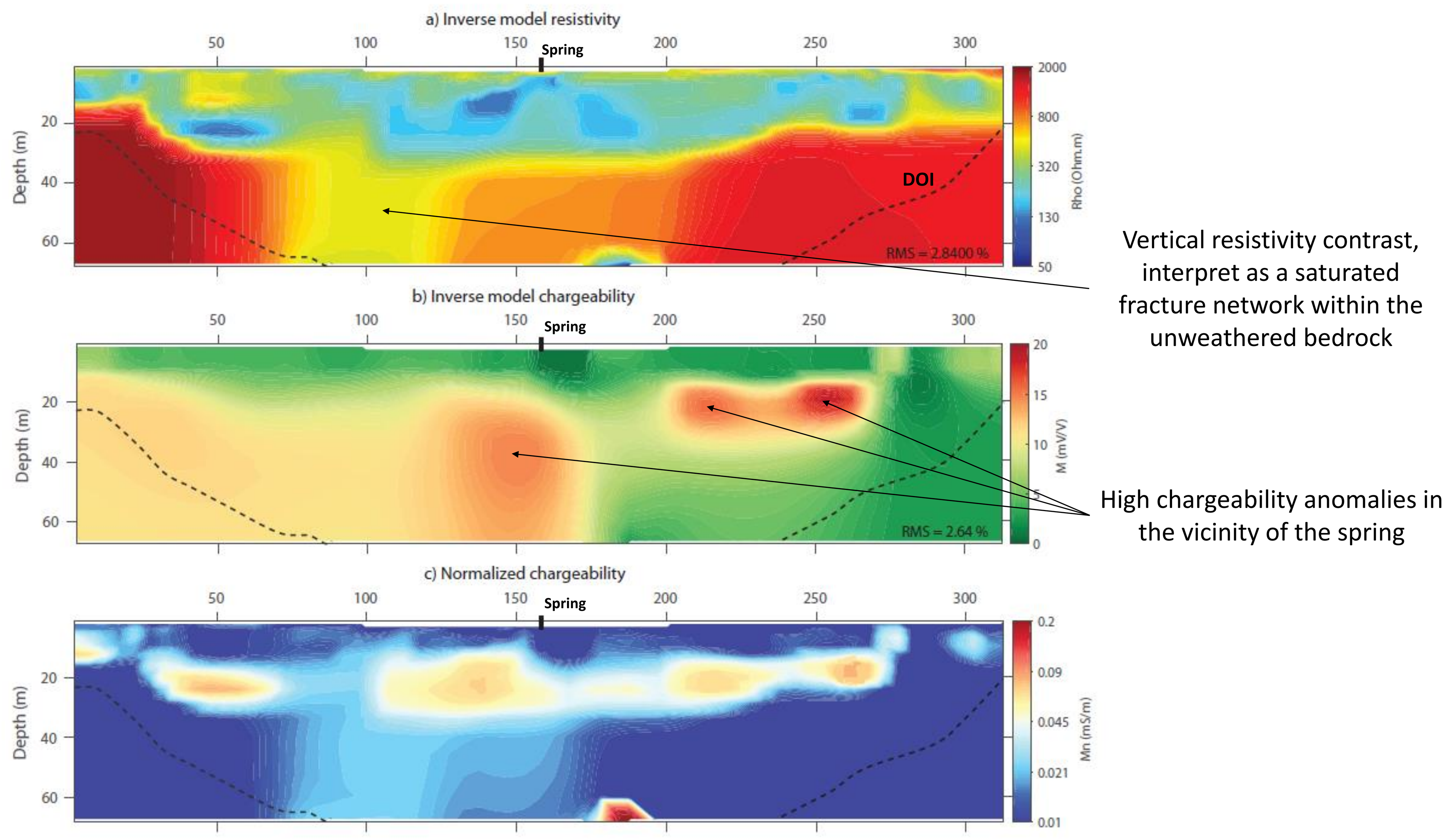
Our hypothesis is that these precipitation processes occuring at the surface only represents the tip of the iceberg. We expect that, **at shallow depths** where groundwater upflows through a fractured network, **precipitation could also occur** due to the combined effect of:

- Groundwater **conditions evolving from reducing to oxidizing**
- **Degassing of CO_2** from groundwater as the pressure decreases, moving pH towards less acidic values

To highlight theses phenomena, the following parameters have been studied

- **Resistivity - R** [Ω.m] : assessing the faulting of the medium
- **Chargeability – M** [mV/V] : detecting the presence of polarizable minerals in the subsurface (supposingly iron hydroxides)
- **Normalized chargeability - Mn** [mS/m]: expressed as **M/R**, showing the areas in which the **medium is both fractured and polarizable** i.e. possibly uplift zones.

RESULTS



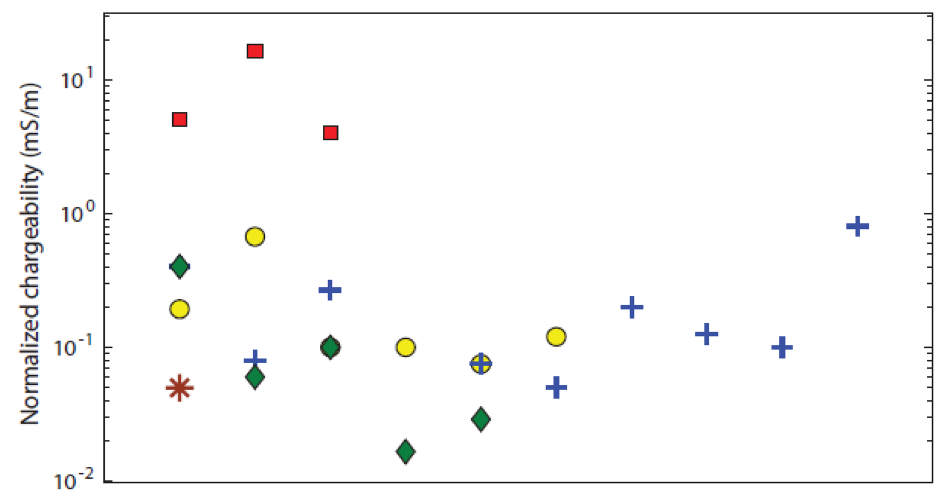
Combined ERT & IP profile realized straight upon a CO_2-rich groundwater spring.

Several combined ERT/IP **profiles** were **performed** directly **above CO_2-rich groundwater springs or abstraction wells. Results are similar for all profiles**: a **low resistivity contrast** seems to **indicate water uplift areas** and **high chargeability anomalies** are present every time in the vicinity of the groundwater source. For comparison, a **profile** was also **performed above an abstraction well producing non-carbogaseous groundwater**. If a **vertical resistivity contrast was observed** as expected, no **striking feature appeared for the chargeability distribution**, confirming the importance of this parameter of the detection of CO_2-rich groundwater.

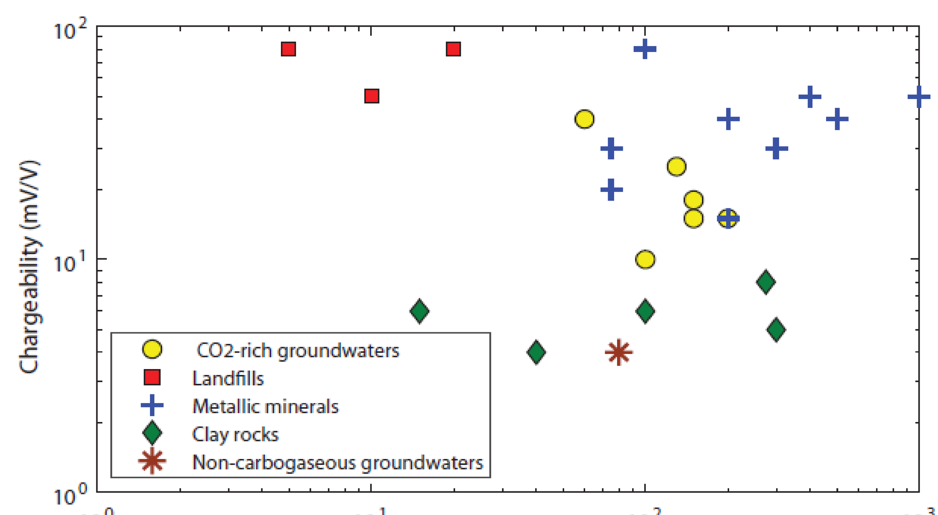
The computation of the normalized chargeability enables the combination of both the resistivity and chargeability features into one unique representation and is likely to be a pertinent parameter to indicate the presence of CO_2-rich groundwater. However, normalized chargeability values must be examined with caution because different resistivity and chargeability values can lead to identical normalized chargeability ratios.

INTERPRETATION

The following figures gather chargeability and resistivity values observed in ERT/IP studies related to different contexts, combined with the values from our study.



Normalized chargeability appears to be a striking observable for the presence of CO_2-rich groundwater, as it combines information from resistivity and chargeability domains. The only value of normalized chargeability **however does not allow a distinction regarding the cause of the anomalies** i.e. if it is due to polarizable clay rocks, to metallic minerals or to another source.



Representing **theses anomalies in a Resistivity vs Chargeability space** allows to **make this distinction**. It can be observed that the values corresponding to CO_2-rich groundwaters are gathered with values from metallic minerals, **supporting the hypothesis** that high chargeability value signature is due to precipitated iron hydroxides.

CONCLUSIONS

The combination of **IP** and **ERT** measurements provides a **new proxy** for **detection of CO_2-rich groundwater.**

R and M distribution yield specific markers of the presence of groundwater and of precipitated iron minerals, respectively

Mn anomalies are the most **striking parameter**

We propose to **examine anomalies values within a chargeability-resistivity space**

FUTURE

Test the setup and analyze the results in a different geological context

Evolve to 3D and develop the setup for bigger scales

Introduction to chemistry in the multivariate analysis and development of a full hydrogeochemical model

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