Time-lapse ERT monitoring of changes in groundwater content and flows in an epikarst system : implementation and challenges

Arnaud WATLET[1], Michel VAN CAMP[2] and **Olivier KAUFMANN[3]**

Department of Geology and Applied Geology, Faculty of Engineering, University of Mons (UMONS)
Rue du Houdain 9, B-7000 Mons, Belgium

[1] PhD student at UMONS - arnaud.watlet@umons.ac.be [2] Dr. at Royal Observatory of Belgium [3] Prof. Ir. at UMONS

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1. Presentation of Karst Aquifer Research by Geophysics Project

KARAG project aims at investiging water dynamics of a karst system throug the use of a time-lapse ERT monitoring system and other geophysical methods. We present here a state of progress of the project focusing on the implementation of such a monitoring system at the Rochefort Cave Laboratory field site (Belgium).

Present knowledge of karst systems has evidenced the importance of the unsaturated zone on the water dynamics. However, this zone is the lesser known part in the karst water balance. For a better understanding of the infiltration processes within the epikarst, a continuous monitoring of spatial and temporal changes in the water content is necessary. An electrical resistivity tomography (ERT) monitoring system is needed to image, at least on a daily basis, the spatial variability of resistivities due to the complex geometry of the epikarst.

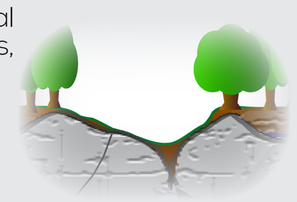
Onsite ERT response have been tested during a preliminary survey by achieving different 2D profiles and 3D panels. This has evidenced some potential areas of water infiltration from the epikarst through the unsaturated zone.

2. Karst system Introduction

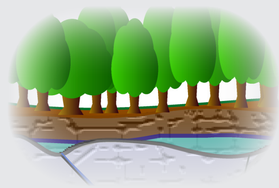
Unsaturated Zone

The epikarst shows typical morphological characteristics, such as :

- Dolines or sinkholes
- Swalow holes
- Springs

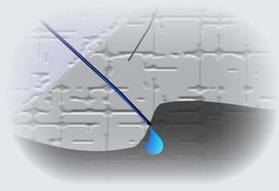


In subsurface, weathered rocks (i.e. limestones) shows a high potential of water storage.



Infiltration of water through fractures and bedding joints have complex dynamics :

- Heterogeneous features
- Several sub-systems :
  - Caves & conduits
  - Fissures & porous matrix
- Unknown connections
- Highly non-linear dynamics
- Time dependent geometry

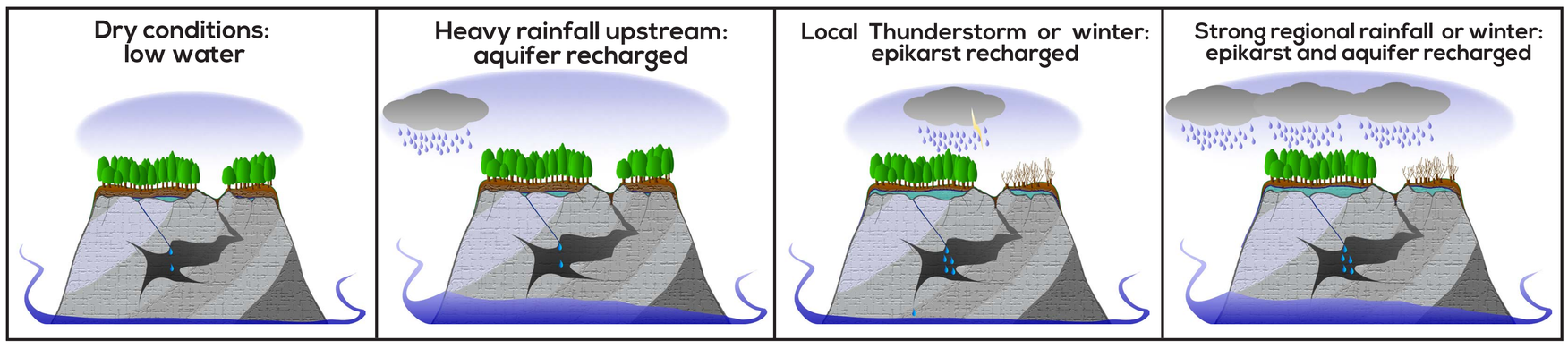


Saturated Zone

At depth, the aquifer corresponds to the saturated zone. In the case of karst systems it can consists in an underground river which is falling in a sinkhole and goes through karstic formations to a resurgence.

3. Water storage variations in karst systems due to hydrogeological and climatic conditions

4 stages of groundwater content are excpected to occur in a karst system. The purpose of the research is to identify these steps onsite using geophysical tools and beter understand their dynamics.



4. Rochefort Cave Laboratory Field Site

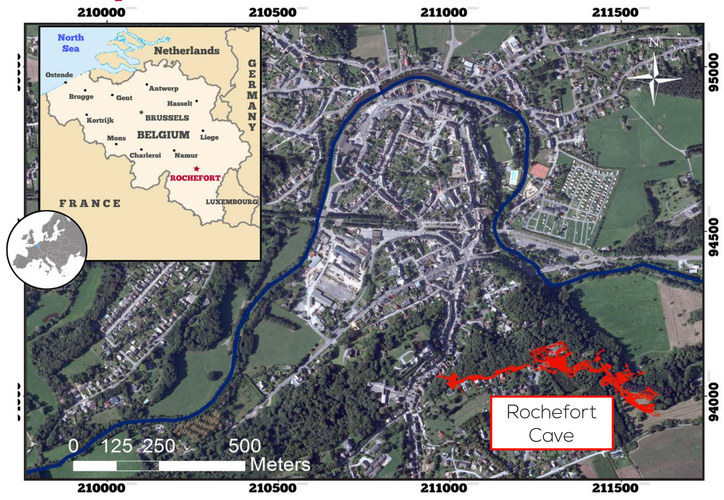
The Rocheort cave is located in the southern part of Belgium within a band of limestones and belongs to a hydrogeological system constituted by a complex meander cut-off of the Lomme river. It is formed by a network of large galleries with a diameter of several meters. The underground laboratory covers an area of 100x100 meters in the northern part of the cave, at a depth of about 30 meters.

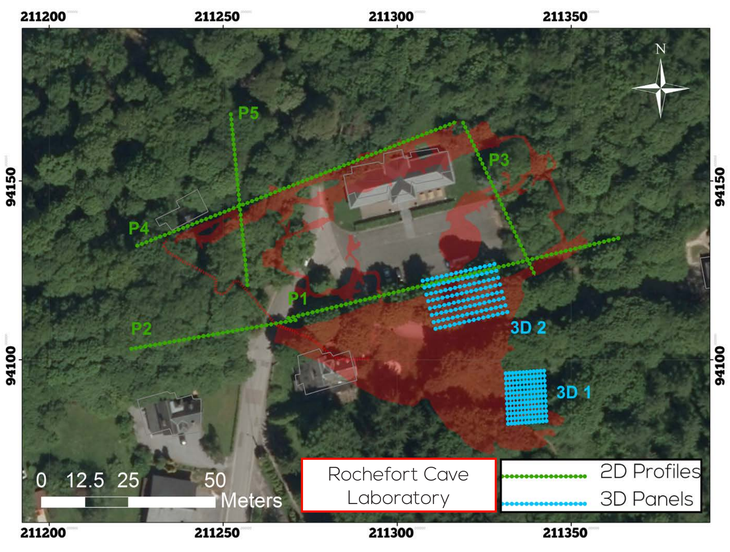
On the surface, there is an average rate of urbanization as well as some woods (desiduous trees). A large doline gives acces to the cave while some other sinkholes have been backfilled many years ago

The laboratory was created in the 90's to monitor active faulting inside the cave. Since then, extensiometers, high resolution thermometers, a seismometer and drip counters have been installed.

Gravimetric monitoring has also been done in a surface laboratory next to the entrance of the cave.

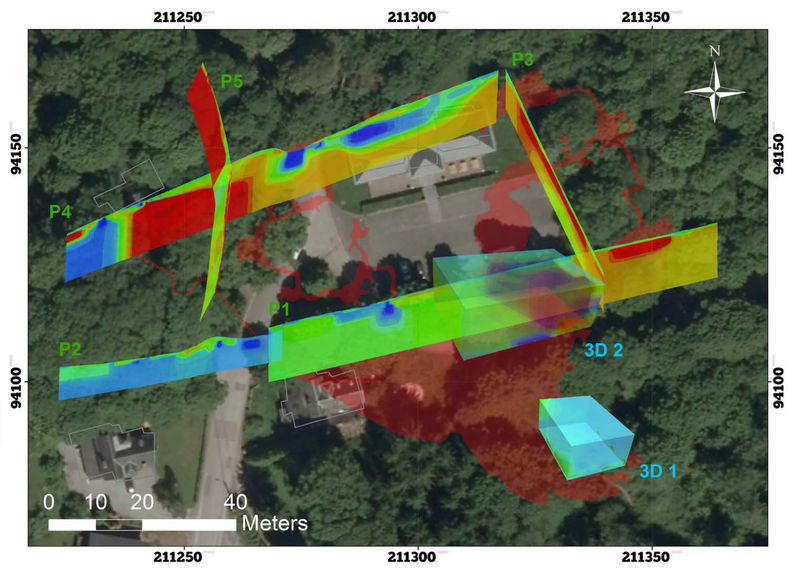
KARAG project benefit from this infrastucture and will continue developping the laboratory to enhance calibrating geophysical data using direct measurements on water flows.





5. ERT survey on site

During the first months of the project, the area was investigated by ERT using an Iris Syscal Pro acquisition system. The geoelectrical response of the subsurface allowed us to indentify the most interesting zones in terms of water storage and infiltration in order to set up a permanent ERT monitoring system.



5 ERT Profiles

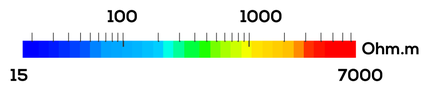
5 profiles were achieved following this configuration:

Profiles	1	2	3	4	5
Number of electrodes	96	48	48	96	48
Interspace	1 meter				
Type of arrays	Dipole - Dipole (with reciproques) Wenner-Schlumberger				

Results of Wenner-Schlumberger arrays using a robust inversion are shown on the left. It highlights high dichotomy of the subsurface:

- low resistivities in the epikarst,
- high resistivities in fresh limestones.

Very conductive areas are expected to be related to a «salt effect» along roads due to salt spreading in winter.

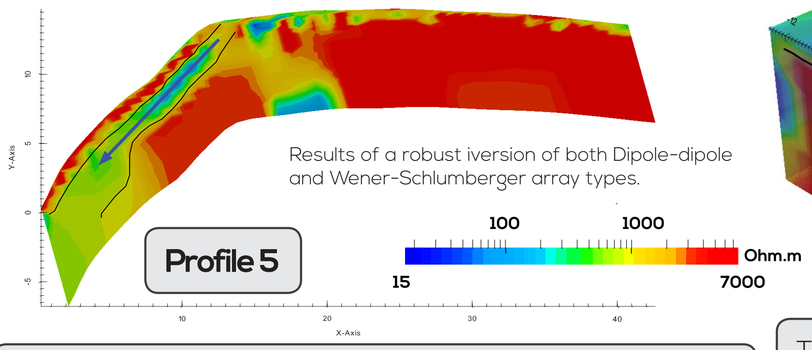


2 ERT 3D Panels

3D panels have been realised in order to investigate more broadly the field site. The first panel shows very low resistivities as it stands on an old backfilled doline. The second shows more interesting variations that we have interpreted as epikarstic features.

Panels	1	2
Number of electrodes	192	96
Interspace	1 meter	2 meters
Type of arrays	Dipole - Dipole Pole-dipole (with one infinite electrode) Wenner-Schlumberger Equatorials	

6. Evidences of infiltration

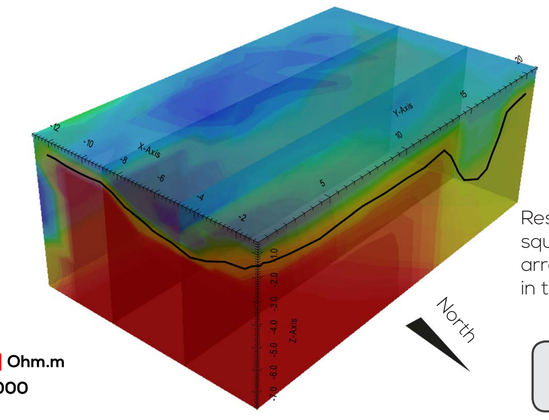


Results of a robust iversion of both Dipole-dipole and Wener-Schlumberger array types.

Profile 5

100 1000 Ohm.m
15 7000

Profile 5 is located at the entrance of the cave along a side of the dolline. Electrodes were set following a stratigraphic unit. It is one of the most interesting site as it shows a low resistivity layer that appears to be related to water infiltrations through bedding joints.
The conductive zone in the middle of the profile might be an artifact coming from burried wires.
High resistivities at the right side are in the range of non-weathered limestones.



Results of a least-squares inversion of all array types mentionned in the table.

3D Panel 2

The second 3D panel reads as follow:

1. The thikness of the epikarstic zone varies from 0 to 3 meters. . Consequently, the first 3 meters might store groundwater.

2. There is an increase of conductivity in the western part of the panel in agreement with the results of P1, P2 and P3. It may refer to a more fracturated or weathered zone that could be a preferential pathway for water stored in the epikarst.

This area is particularly important as it is located just over a zone of high dripping rate in the cave.

7. Conclusions and perspectives

Onsite survey has shown zones that may host the permanent ERT monitoring system of KARAG research project.

This system will be installed in early 2014.

We are also planning to test an implementation of electrodes inside the cave or through a borehole. This is to better focus on the unsaturated zone of the karst system and to investigate the advantage of having recourse to uncommon ERT arrays.

Additional monitoring tools will be set up as well. A network of buried temperature sensors is needed to correct for thermal effects on resistivities. Flow recorders inside the cave are useful to monitor discharge, temperature and conductivity of the water that percolate throughout the epikarst. The ground moisture will be monitored locally through a network of time domain reflectometry (TDR) and water conductivity probes. Gravimetric measurements will also provide insights on changes in the groundwater content.