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# Bottled Water's Hydrogeochemical characteristics and Health Promotion Effect in Europe

Jean-Christophe Maréchal

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# Bottled Water's Hydrogeochemical characteristics and Health Promotion Effect in Europe

Jean-Christophe Maréchal

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The 10th Jeju Water World Forum (2018)

# Presentation Plan

- **Water and health**
- Bottled water market and legislation in Europe
- Natural mineral water field characteristics, hydrogeological processes and quality
- Hydrogeological approaches for better knowledge
- Examples of NMW protection strategies
- Conclusion

# Water and health

## Facts:

- Water is an essential nutrient and plays a key role in the human body.
- Water is the basic element of living beings: they could not have appeared and could not survive without it.
- Water has several crucial functions for the health of human people.
- In the reference man, 60% of body weight (BW - about 45 l) is represented by total body water (TBW)

## Water intake guidelines

The European Food Safety Authority (EFSA) recommends a daily water intake of **1.6 litres for women** or **2.0 litres for men** (assuming that food contributes on average 20% of the total water intake).

EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA); Scientific Opinion on Dietary reference values for water. EFSA Journal 2010; 8(3):1459. [48 pp.]. doi:10.2903/j.efsa.2010. 1459. Available online: [www.efsa.europa.eu](http://www.efsa.europa.eu)

# National Health Guidelines for Drinking Water

The importance of drinking adequate amounts of water is also acknowledged by national governments, public health institutes and agencies.

## **Flemish Institute for Health Promotion**



*Drink water above all, 1.5 liter/day*

**German Nutrition Society** *Water is essential to life. Make sure your daily fluid intake is approximately 1½ litres. Rather choose water, carbonated or noncarbonated, and other beverages low in calories.*



## **National Research Institute for Food and Nutrition**



*Drink plenty of water every day, to be healthy it is important to drink a lot, at least 6 – 8 glasses, of water. Anticipate thirst, drinking 1.5 – 2 litres per day.*

## **Swiss Nutrition Society**



*Drink 1–2 litres of unsweetened beverages per day, preferably water.*

# Water quality classification

**Dry residues at 180°C** (total salts in grams after evaporation of 1 l mineral water at 180°C):

- waters with a very low mineral content (dry residues < 50 mg/l),
- waters low in mineral content (50 < dry residues < 500 mg/l),
- waters with a medium mineral content (500 < dry residues < 1500 mg/l),
- waters rich in minerals (dry residues > 1500 mg/l).

**Quantity of free carbon dioxide:**

- fizzy waters (also called carbonic or acidic)
- still waters

**Predominant ionic composition:**

- bicarbonate waters,
- sulfate waters,
- salt waters,
- bicarbonate–sulfate waters...

**Biological activity:**

- diuretic mineral waters;
- cathartic waters
- reconstituent waters (arsenical-ferrous waters)...

# Water quality and health

A water can be drunk only if the concentration of constituents is within the limits set by special regulations taking into account long-term maximum daily intake, the nature of the contaminating agent and its possible degree of toxicity

## **A few examples:**

- Waters with a low mineral content have diuretic effects, and are indicated in urinary stones
- Bicarbonate waters may neutralize acid secretion, accelerate gastric emptying, provoke the release of gastric peptides (like gastrin and endorphins)
- Sulfate waters stimulate intestinal motility and are mainly indicated in chronic primitive constipation,
- Sulfurous and bicarbonate waters are indicated in diabetes
- Chloride-sodium waters (salt waters) stimulate intestinal peristalsis and intestinal secretion of water and electrolytes. They are used in primitive constipation, irritable colon, biliary pathology.
- Mineral waters rich in calcium are indicated when calcium requirements are increased (children, pregnant women, menopause, old age, osteoporosis)
- Magnesium waters are mainly cathartic; studies indicate that they may prevent atherosclerosis.
- ... see Petraccia et al. 2006

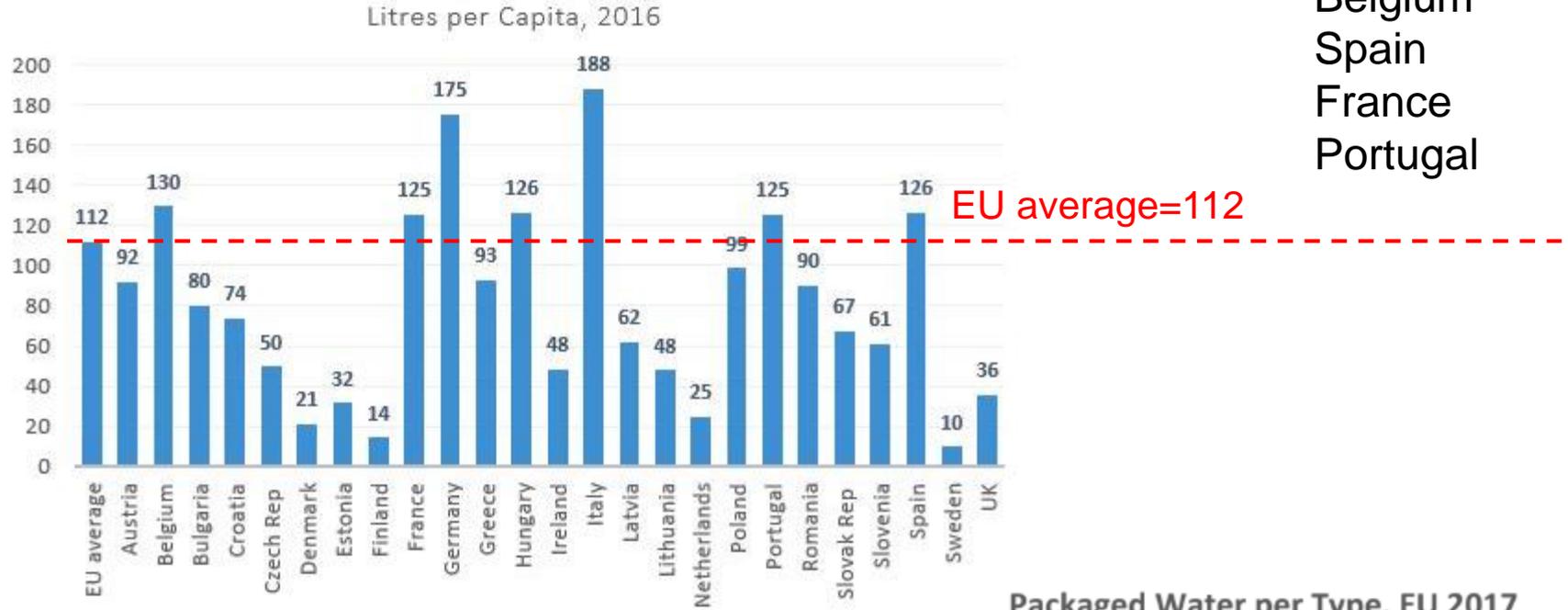
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- Water and health
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- Hydrogeological approaches for better knowledge
- Examples of NMW protection strategies
- Conclusion

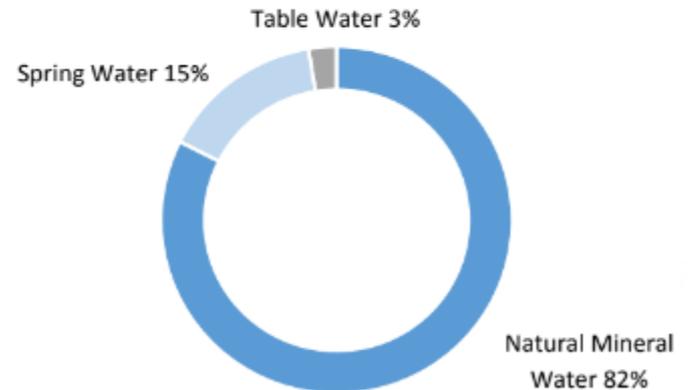
# Bottled water consumption in Europe

52 billion litres

Italy  
Germany  
Belgium  
Spain  
France  
Portugal

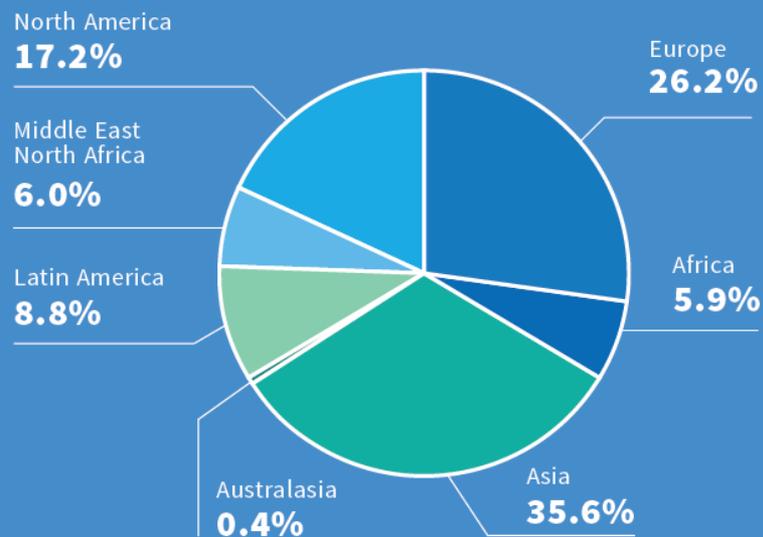


Packaged Water per Type, EU 2017



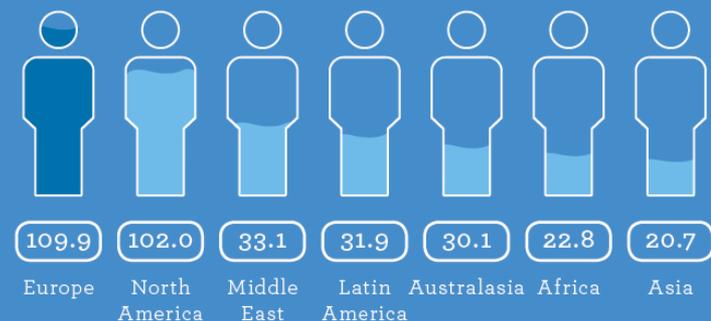
# Bottled water: Europe and the World

## Global bottled water consumption



Source: Canadean

## Packed water litres per capita yearly consumption



Source: Canadean

Europe has the highest per capita consumption in the world

# Bottled water classification

Characteristics	Filtrated water	Spring water	Natural mineral water
Origin	Multiple	Groundwater (multiple)	Groundwater (single)
Natural protection	Not required	Mandatory	Mandatory
Treatment	Partial filtration or disinfection	No disinfection treatment	No disinfection treatment
Mineral content	Variable	Known, low fluctuations	Stable
Effect on health			Healing effect

Natural mineral water and spring waters must be bottled directly at source

# Natural mineral water definition in Europe

1) **Natural mineral water** means microbiologically wholesome water, originating in an underground water table or deposit and emerging from a spring tapped at one or more natural or bore exits.

Natural mineral water can be clearly distinguished from ordinary drinking water:  
(a) by its nature, which is characterized by its **mineral content, trace elements or other constituents and, where appropriate, by certain effects;**  
(b) by its **original purity**, both characteristics having been preserved intact because of the underground origin of such water, which has **been protected from all risk of pollution.**

2) The characteristics referred to in point 1, which may give natural mineral water properties favourable to health, shall have been assessed.

3) The **composition, temperature and other essential characteristics of natural mineral water shall remain stable** within the limits of natural fluctuation; in particular, they shall not be affected by possible variations in the rate of flow

Mineral water can be put on the market and/or exploited for healing purposes only after the recognition by the Ministry of Health.



Géosciences pour une Terre durable

European Parliament (2009). Directive 2009/54/EC of 18 June 2009 on the exploitation and marketing of natural mineral waters. *Official Journal of the European Union*, (26/06/2009) 45-58

# EU Legislation on Bottled Waters

## Natural Mineral Water

- Directive **2009/54/EC** on the exploitation and marketing of natural mineral waters

## Spring Water

- Regulated partly by Directive **2009/54/EC** on the exploitation and marketing of natural mineral waters
- Directive **98/83/EC** on the quality of water intended for human consumption.

## Bottled Drinking Water

- Directive **98/83/EC** relating to the quality of water intended for human consumption.

# Europe: land of sources

More than 2000 natural mineral waters  
have been recognized in the EU



Each natural mineral water in Europe must receive official recognition from the State's competent authority. The list of recognised natural mineral waters is published in the Official Journal of the European Union and available on the European Commission's website.

*From EFBW Industry Report*

# Natural Mineral Water in France



# Thermalism and thermal cures

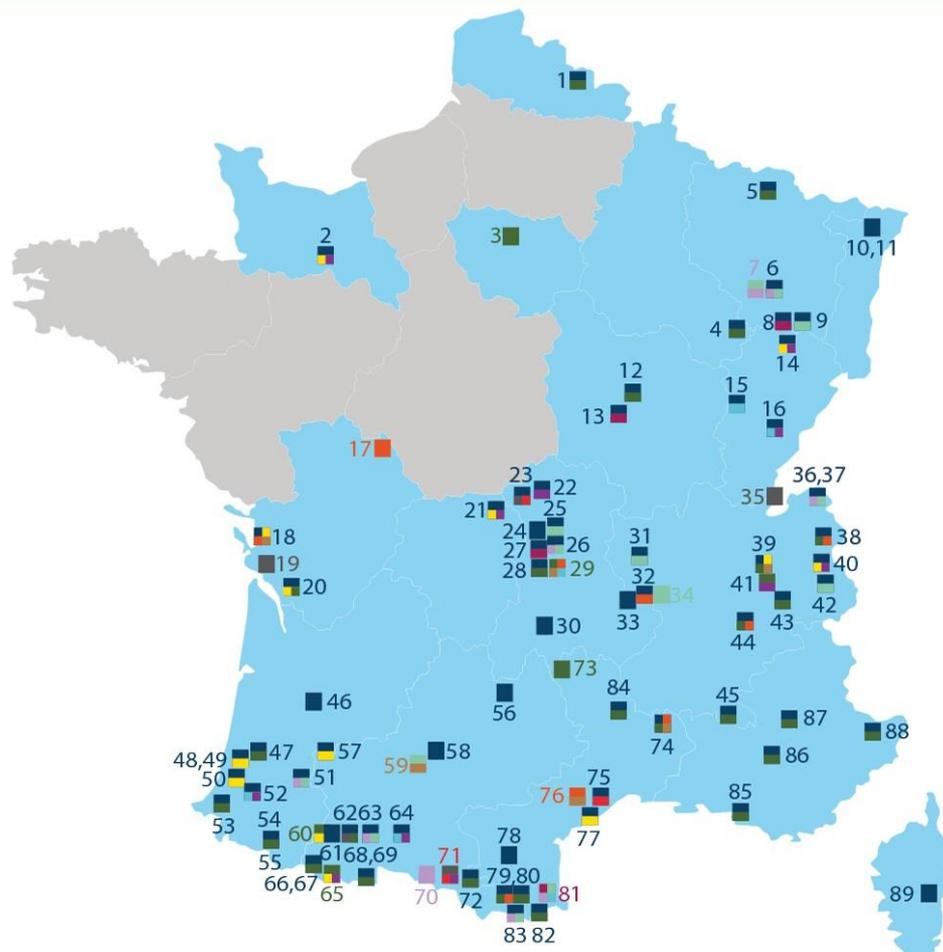
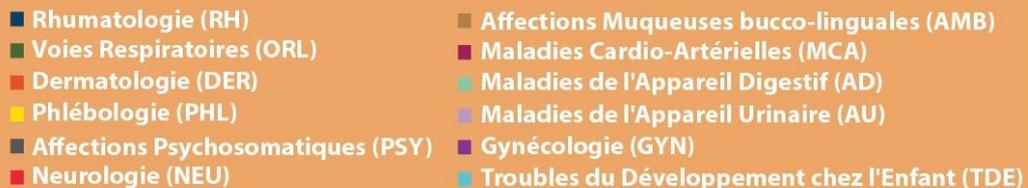
The mechanisms of action of the thermal cures are related to the geological peculiarities of the natural thermal products used, but also to the environment proposed in the thermal establishments.

Thermal products are based on **thermal waters** and come in many forms: water, vapors, sludge or gas.

According to their natural chemical composition and their administration (in external care, in the form of massage, baths, showers ...), they act on the pains, the muscular relaxation, the articular and dermic suppleness, the respiratory system or the overall health mental and physical.

If the thermal cure is prescribed by a doctor, the cares are reimbursed by health insurance. The reimbursement varies according to personal resources or personal situation and the disease of the patient.

# Thermalism for health recovery



Medical care:

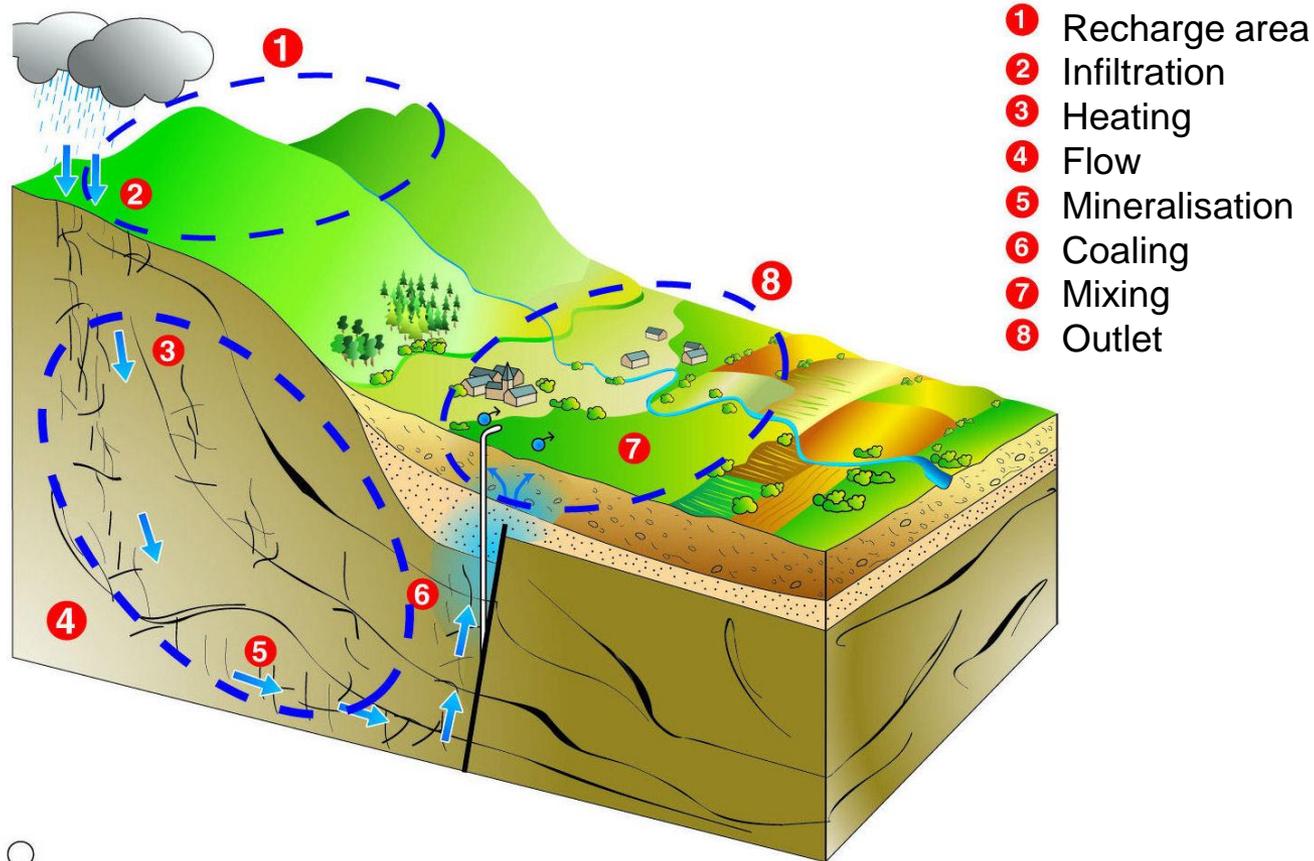
- Rheumatology
- Respiratory
- Dermatology
- Phlebology
- Psychosomatic affection
- Neurology
- Bucco-lingual mucosa
- Cardio-arterial disease
- Digestive disease
- Urinary tract disease
- Gynecology
- Children development trouble

# Presentation Plan



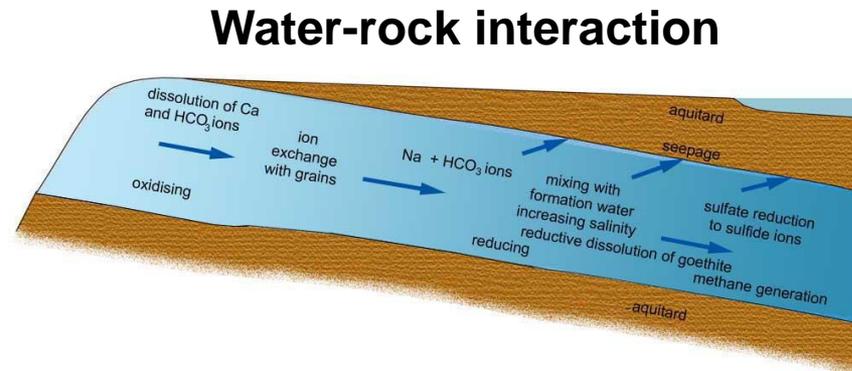
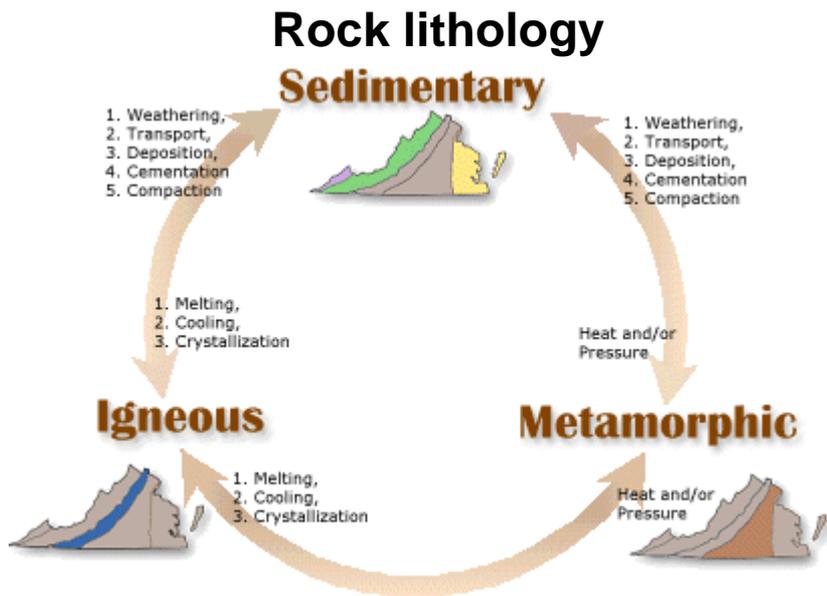
- Water and health
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# Quality acquisition

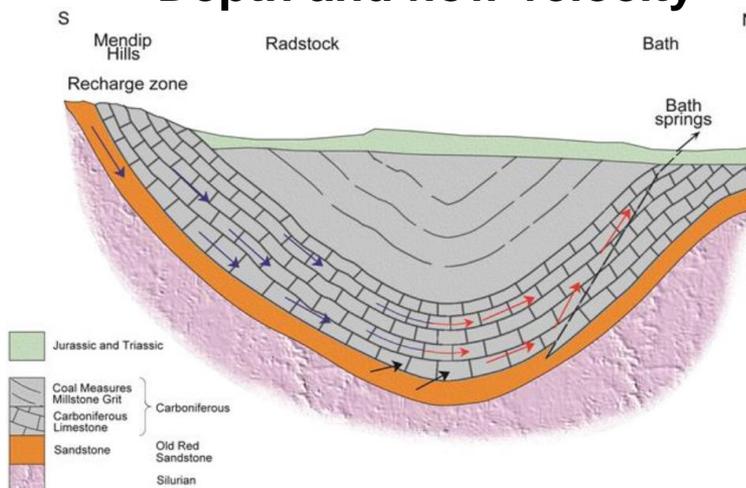


Characteristics of mineral water are dependant on water-rock interaction, temperature and pressure at depth and transit time : they determine the **mineralization and quality of water**

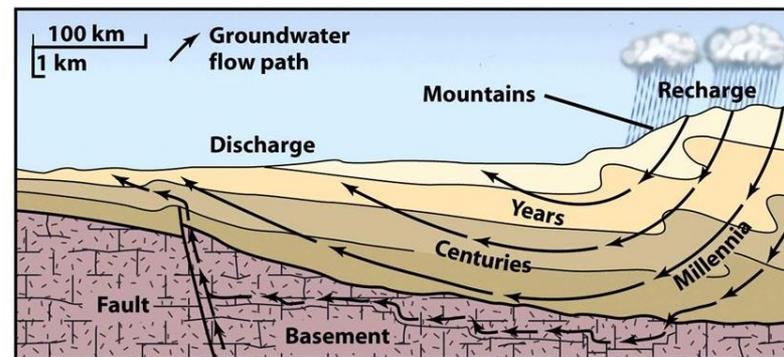
# Groundwater quality acquisition



## Depth and flow velocity



## Transit time



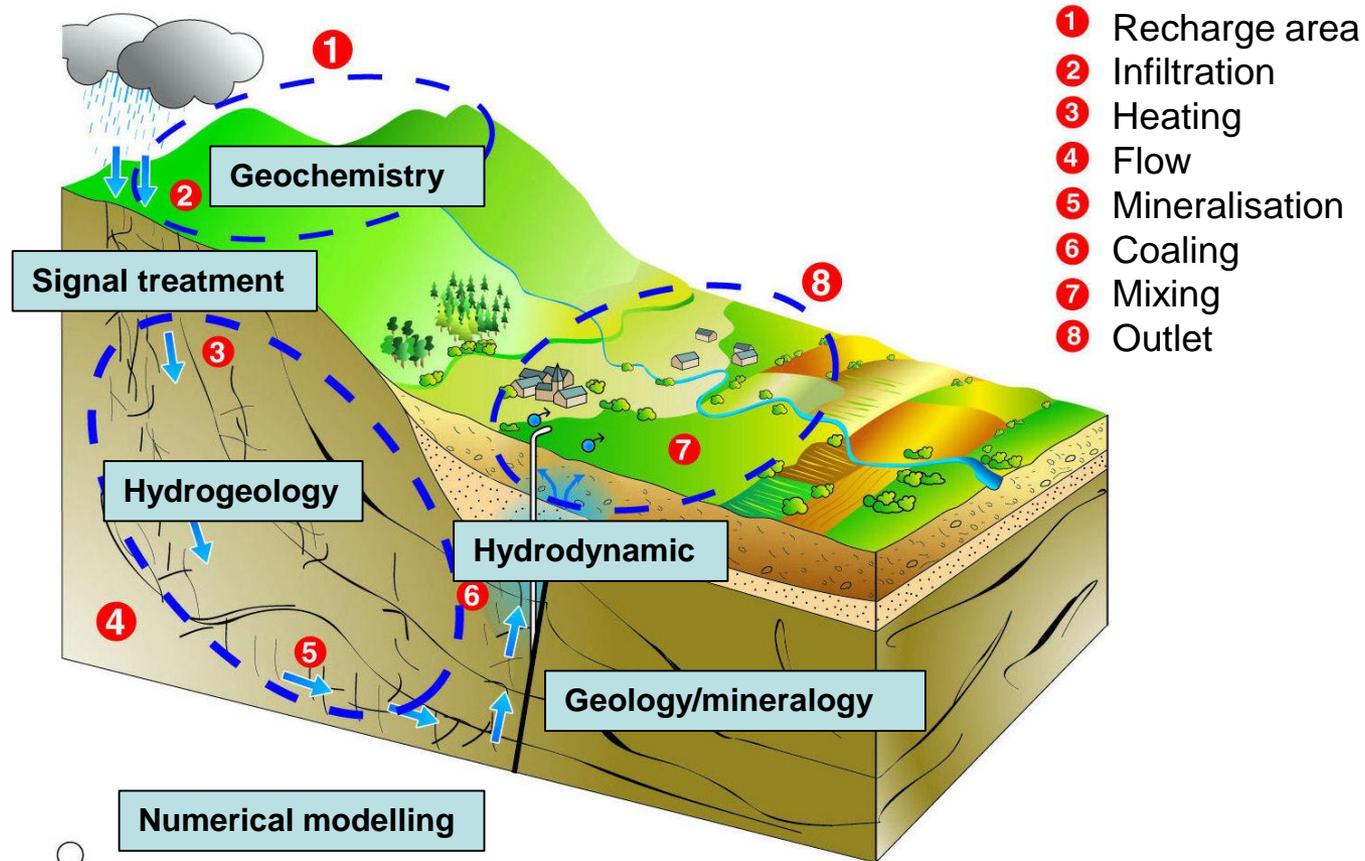
Earth: Portrait of a Planet, 3<sup>rd</sup> edition, by Stephen Marshak

Chapter 19: A Hidden Reserve: Groundwater

# Presentation Plan

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# Multidisciplinary approach

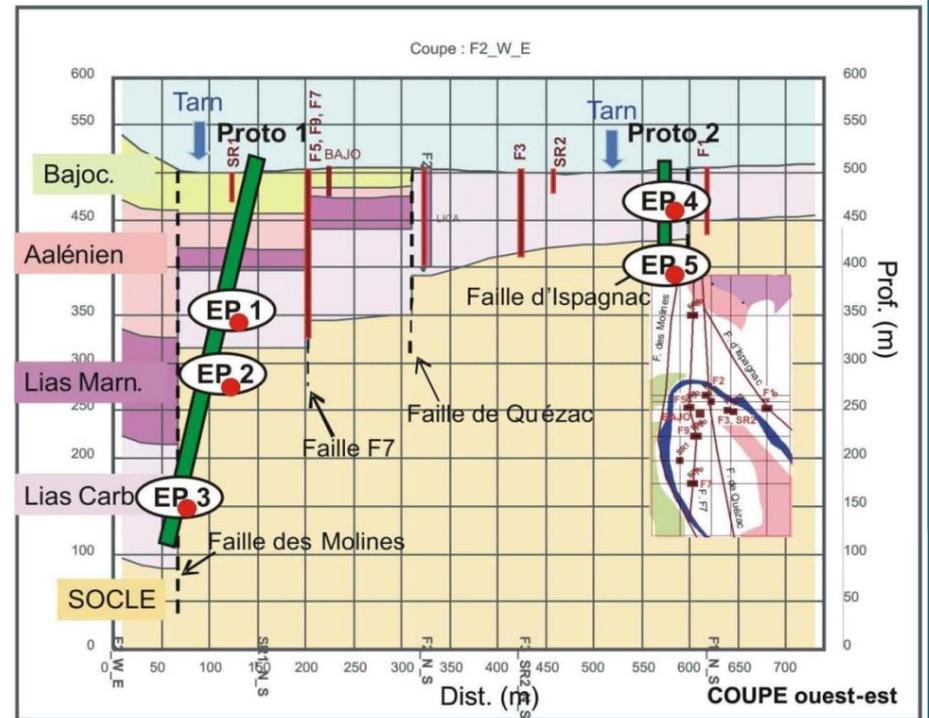
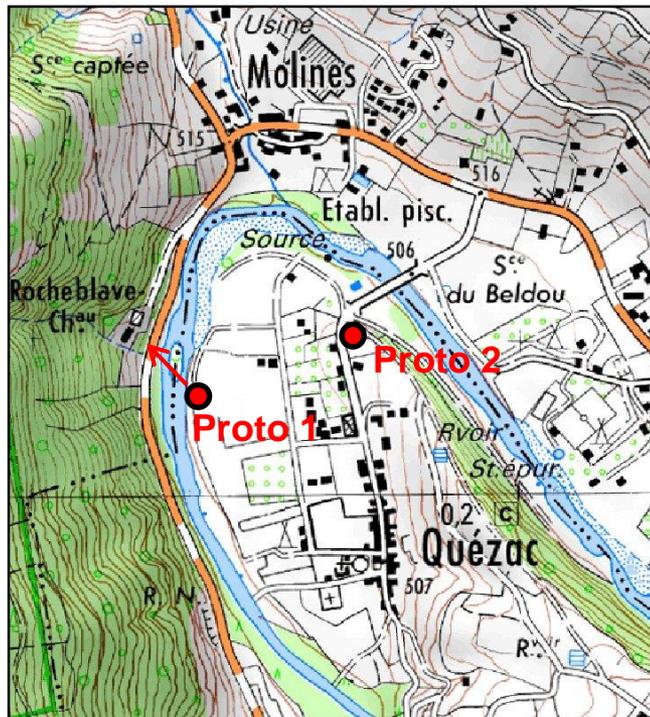


# Geology and mineralogy

**Objective: reservoir lithology and geometry characterization**

**Methods:**

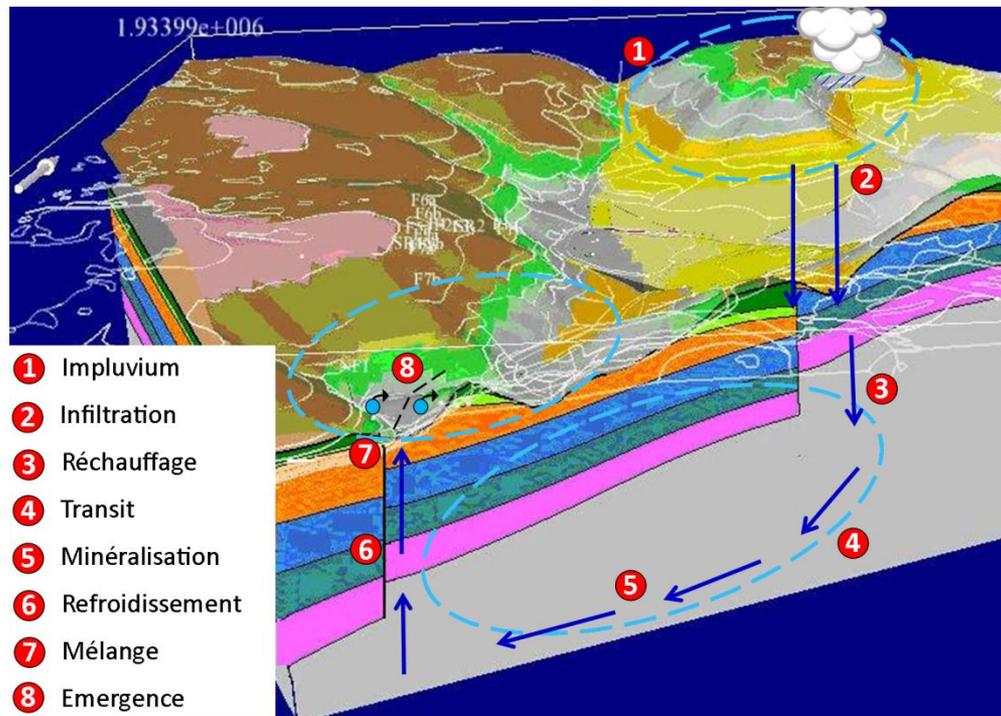
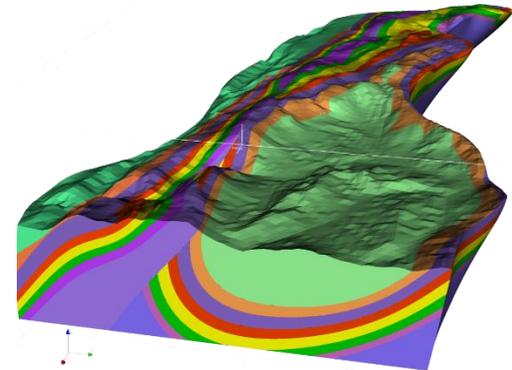
- Geological mapping, structural analysis, geophysical investigations, borewells drilling...



# 3D Geological Model

## Objective:

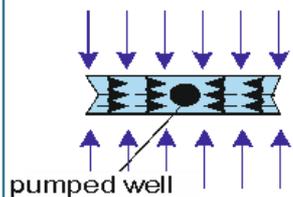
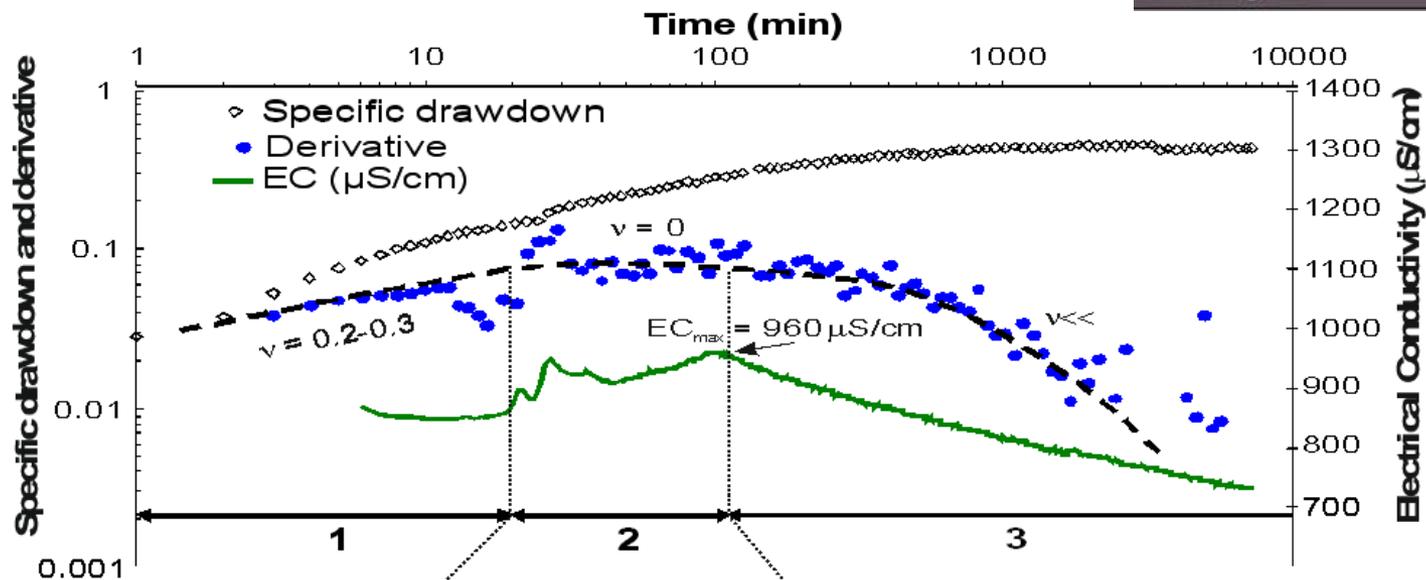
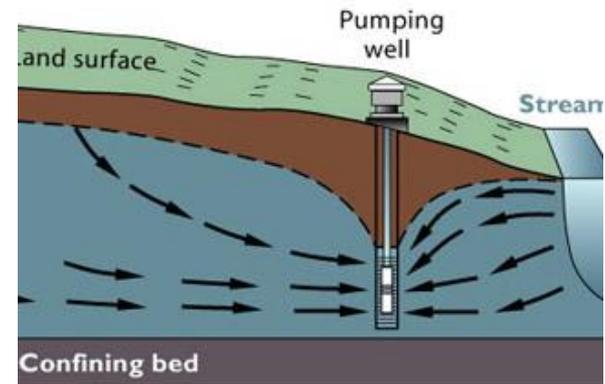
- Identify aquifer layers,
- Characterize their geometry,
- Locate groundwater reservoirs,
- Locate recharge areas....



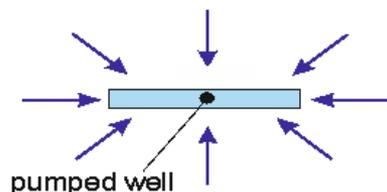
# Hydraulic tests in wells

## Objective:

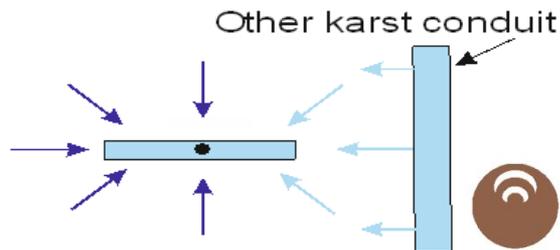
- Characterize the reservoir hydrodynamic characteristics



**Bilinear flow**



**Pseudo-radial flow**



**Pseudo-radial flow with a fixed head boundary**



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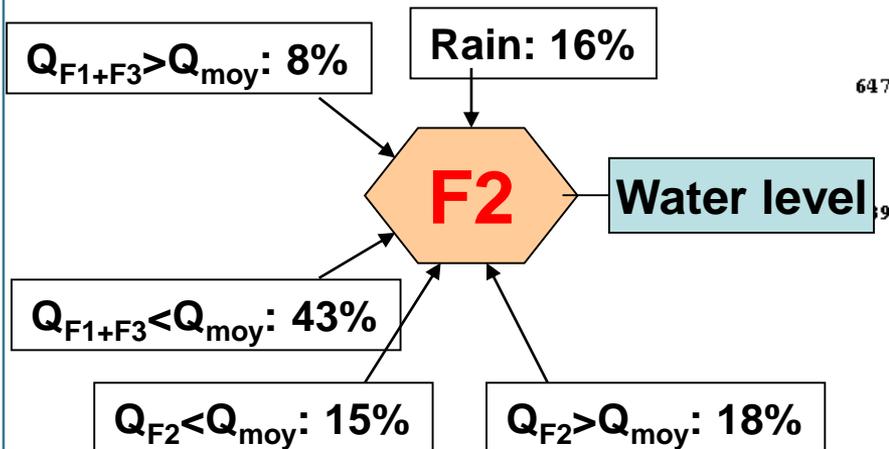
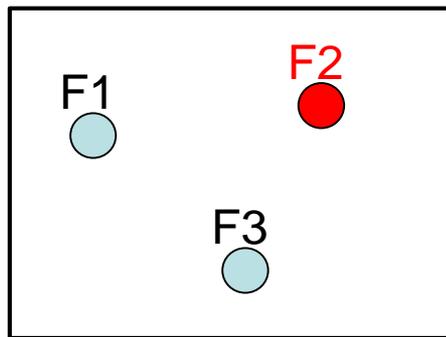
**brgm**

# Signal treatment

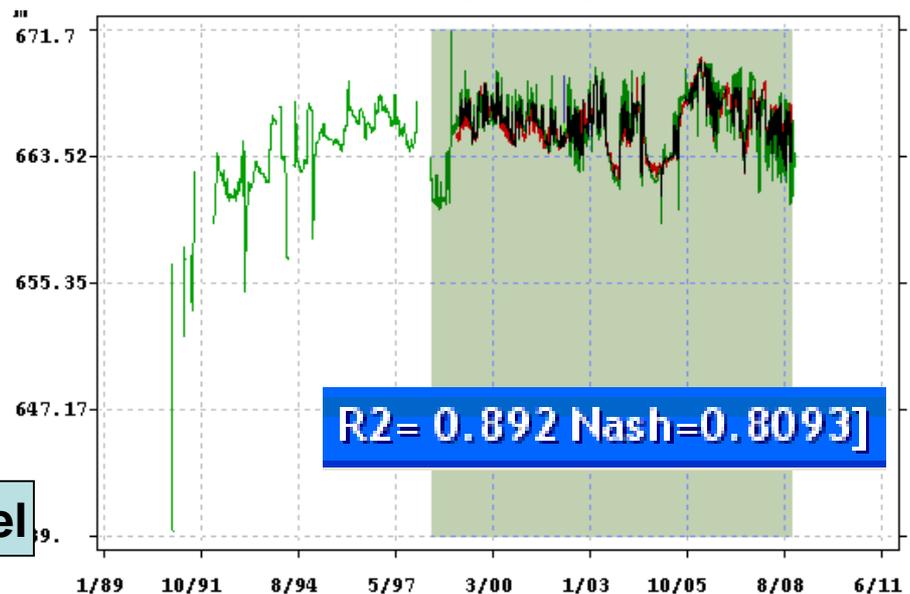
## Objective:

- Understand the reservoir dynamics
- Identify the main external parameters (precipitation, pumping rate, surface water dynamics) driving the quantity and quality of groundwater

### Abstraction field



### F2 water levels



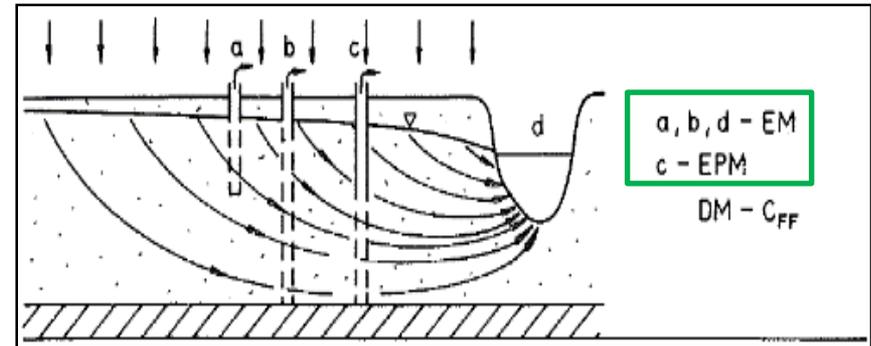
# Transit time analysis

## Objective:

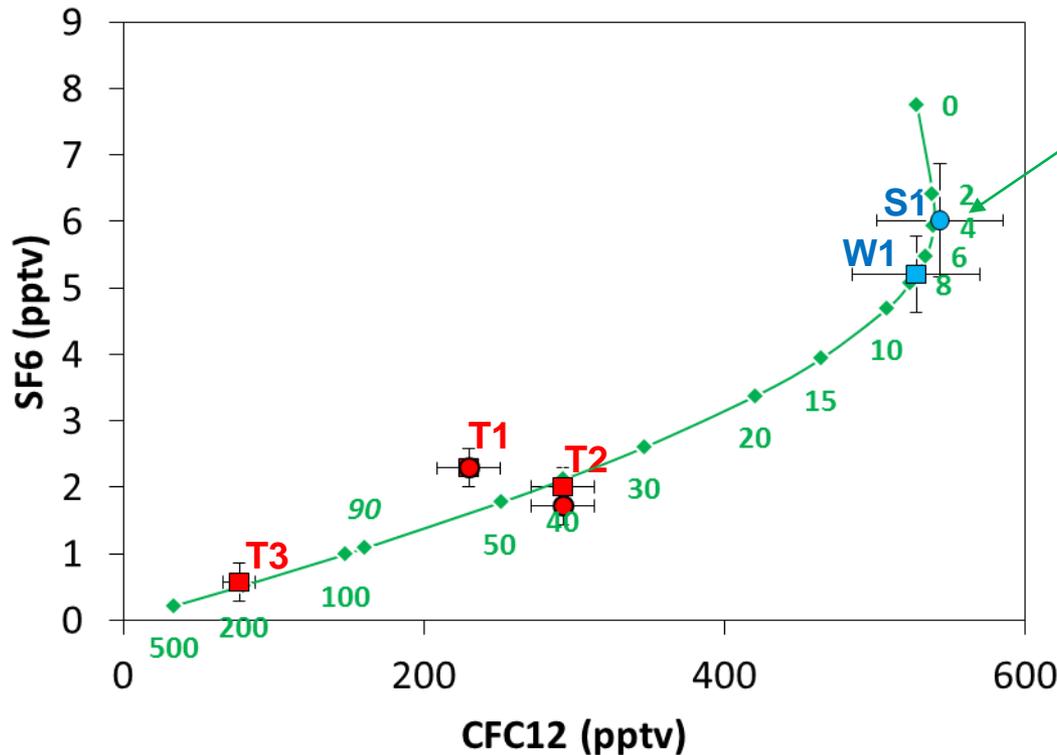
- Evaluate the transit time of NMW

## Method:

- Isotopes: tritium, SF6, CFC...



(Maloszweski and Zuber, 1982)

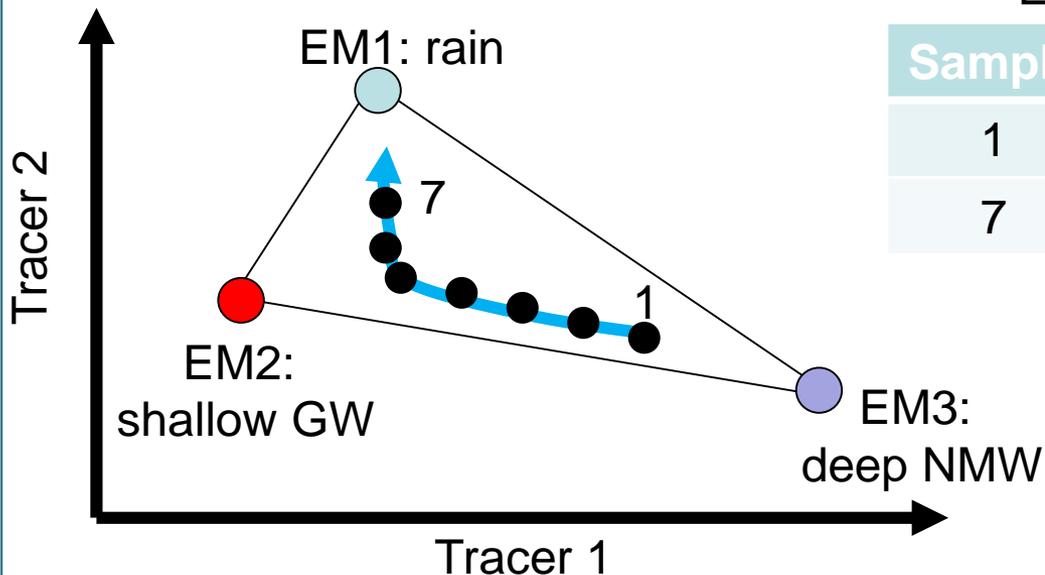


In green,  
age of NMW

# Geochemistry

## Objective:

- Identify the origin of water,
- Characterize the type of mineralization (water-rock interaction),
- Quantify mixing processes
- Estimate transit times
- Estimate maximum depth of groundwater flow path (geothermometers)
- ...

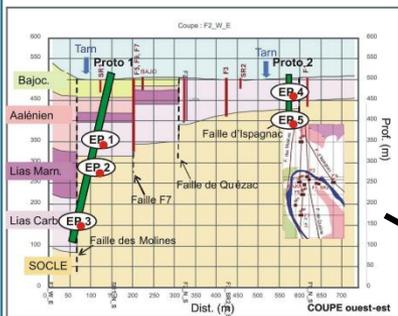


End-member mixing analysis

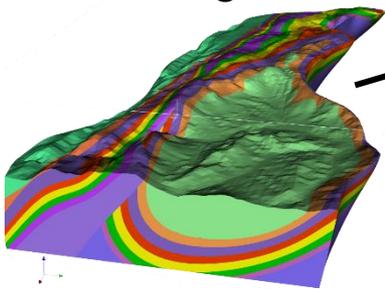
Sample	EM1	EM2	EM3
1	5%	25%	70%
7	45%	40%	15%

# Multi-disciplinary approach

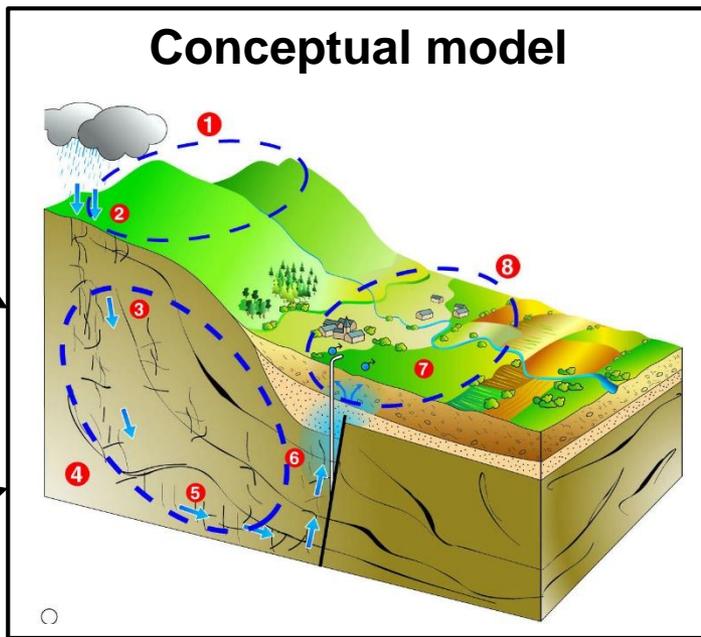
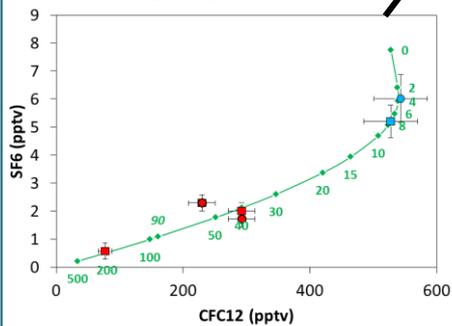
Geology: wells drilling



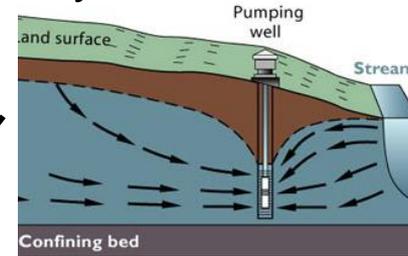
3D Geological Model



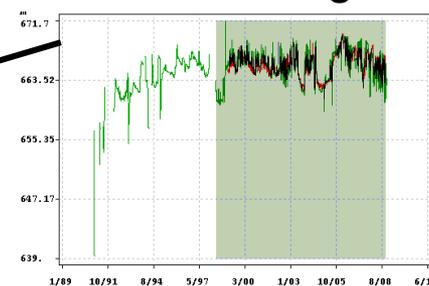
Transit time



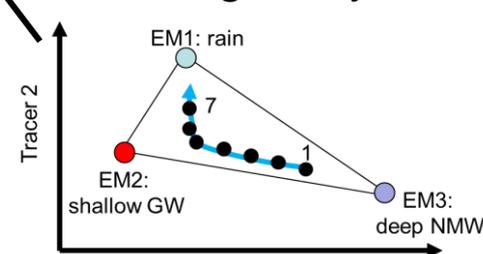
Hydraulic tests



Treatment signal



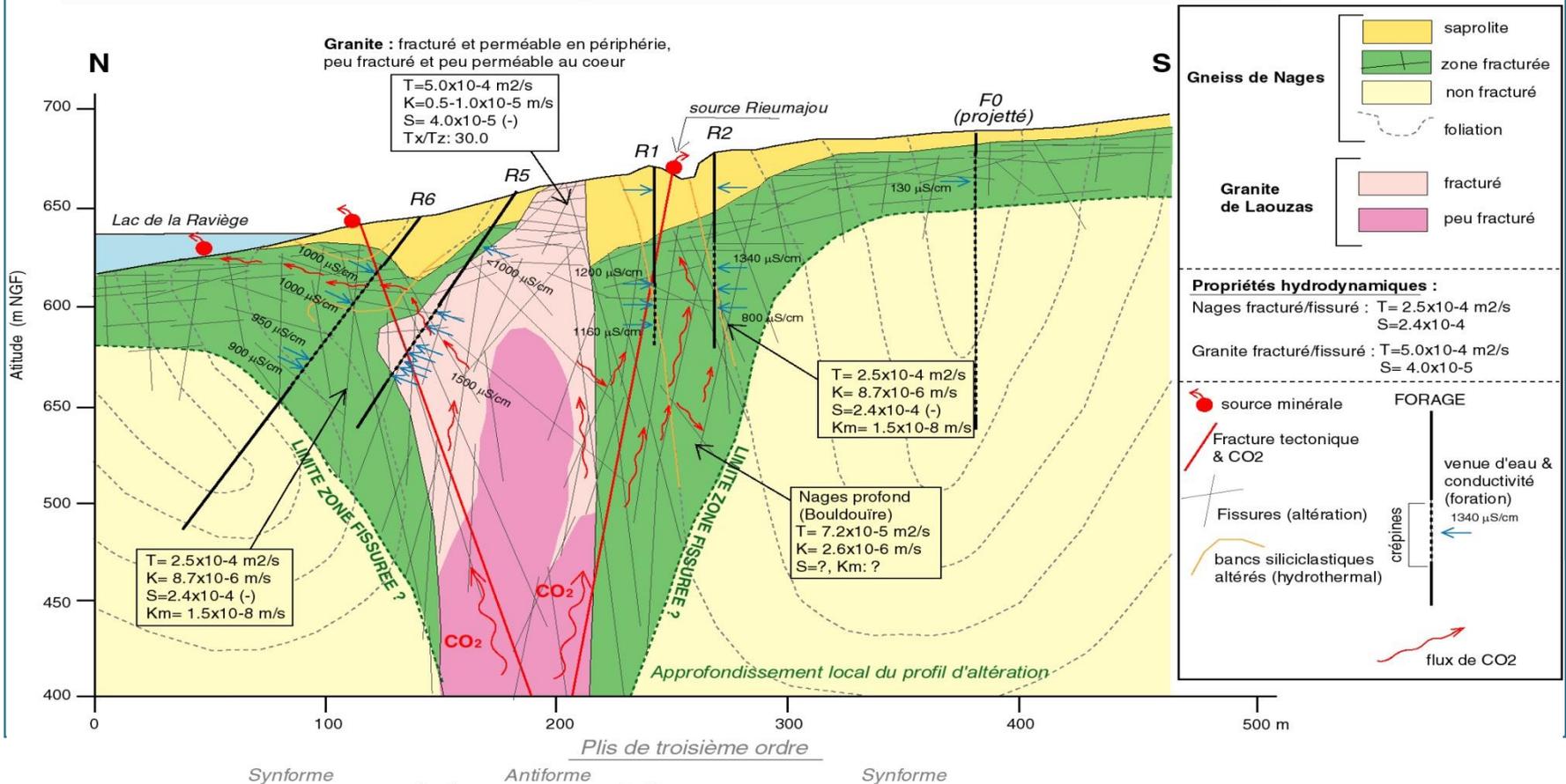
Mixing analysis



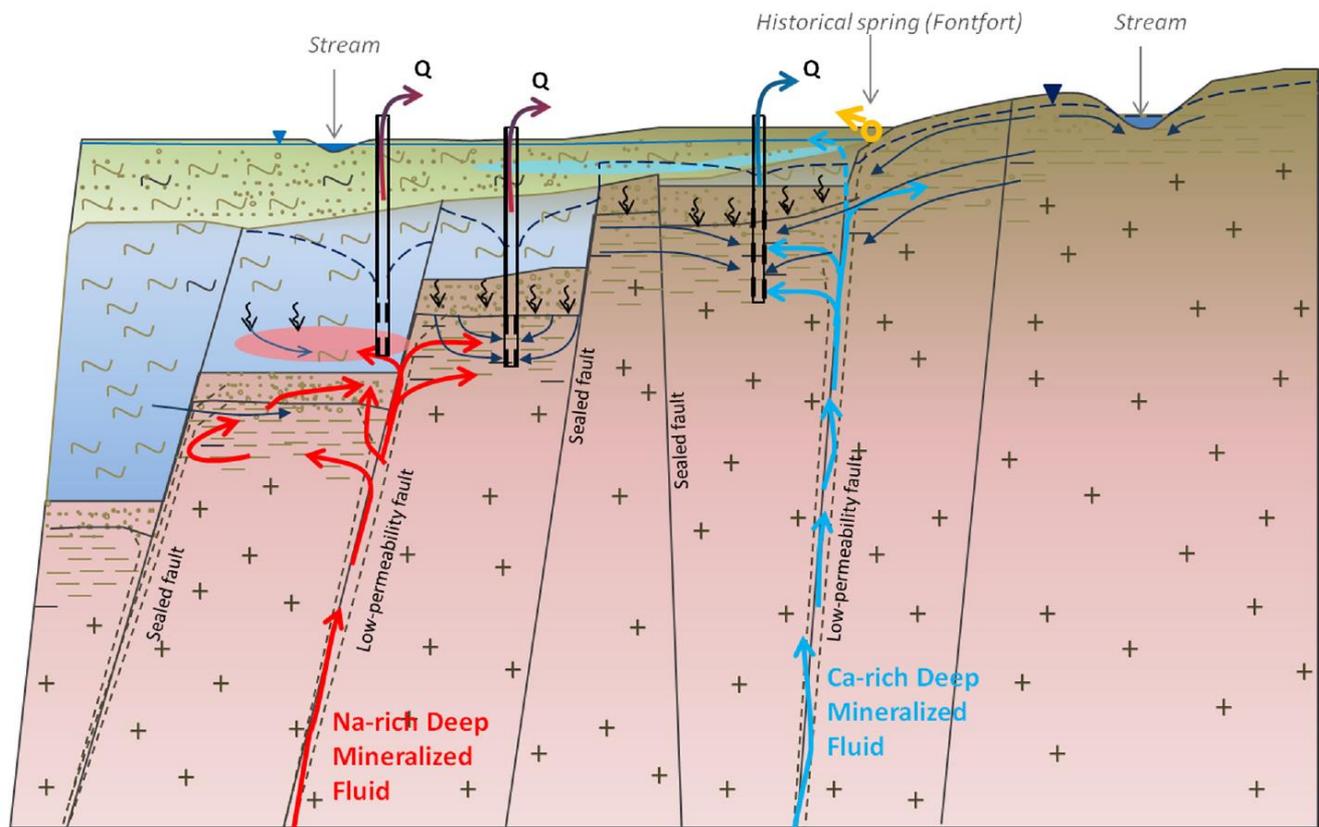
# Salvetat: reservoir identification and modelling



- Regional Geology - reservoirs
- Hydrogeological role of deep faults, granite intrusion
- Hydrauliques tests
- Water sampling
- Role of weathered crystalline basement
- New isotopes in carbo-gaseous field



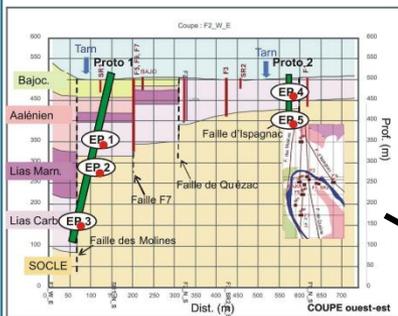
# Badoit: complex reservoir characterization



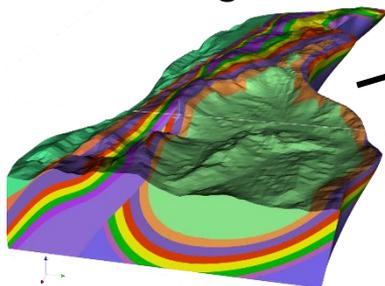
	Saprolite		Syn-rift clayey sedimentary deposits		Piezometric level of the granite aquifer				Upward flux of deep mineralized fluid
	Fissured layer		Post-rift sandy clayey sedimentary deposits		Piezometric level in superficial formations				
	Unweathered Granite				Leakage/interformational flow				Sedimentary deposits invaded by deep mineralized fluid
					Groundwater flow (not mineralized)				

# Numerical modelling

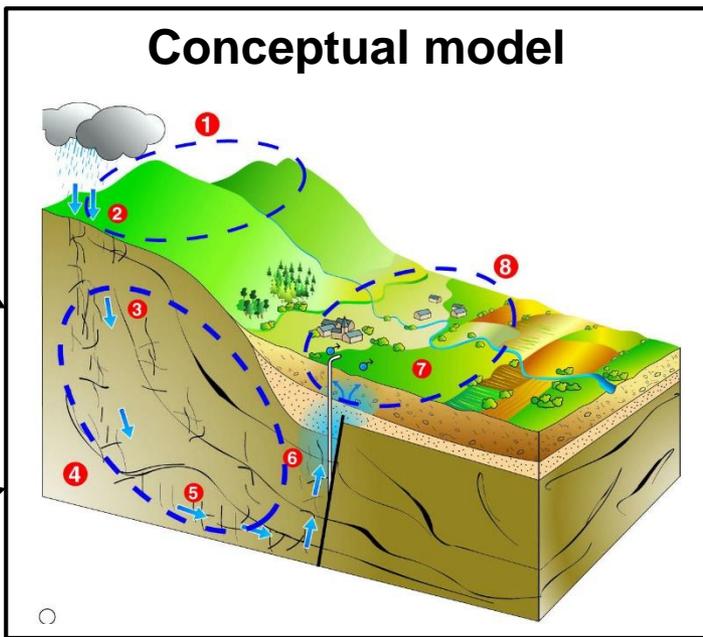
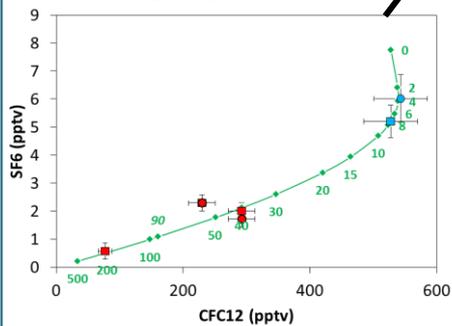
Geology: wells drilling



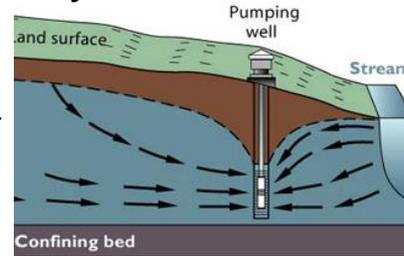
3D Geological Model



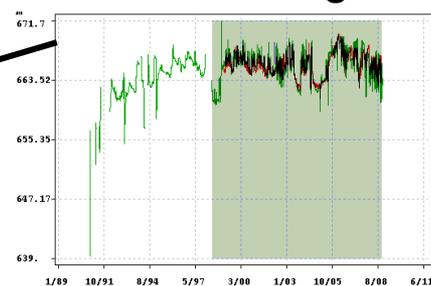
Transit time



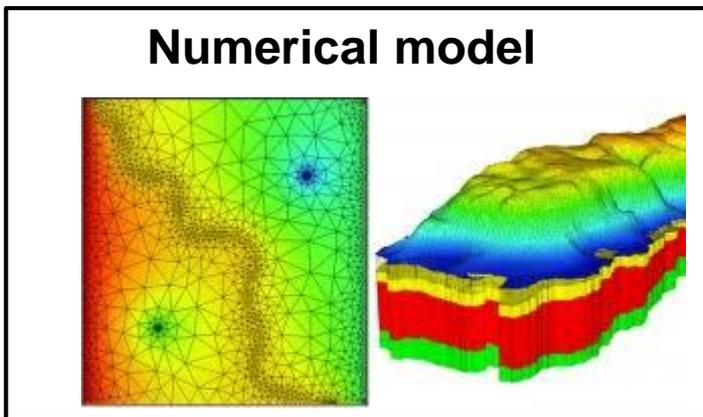
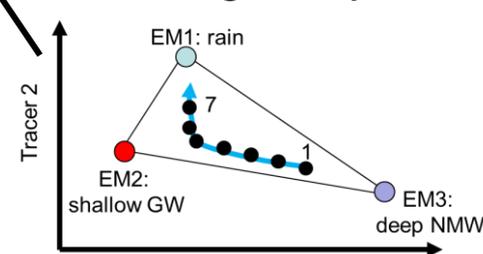
Hydraulic tests



Treatment signal



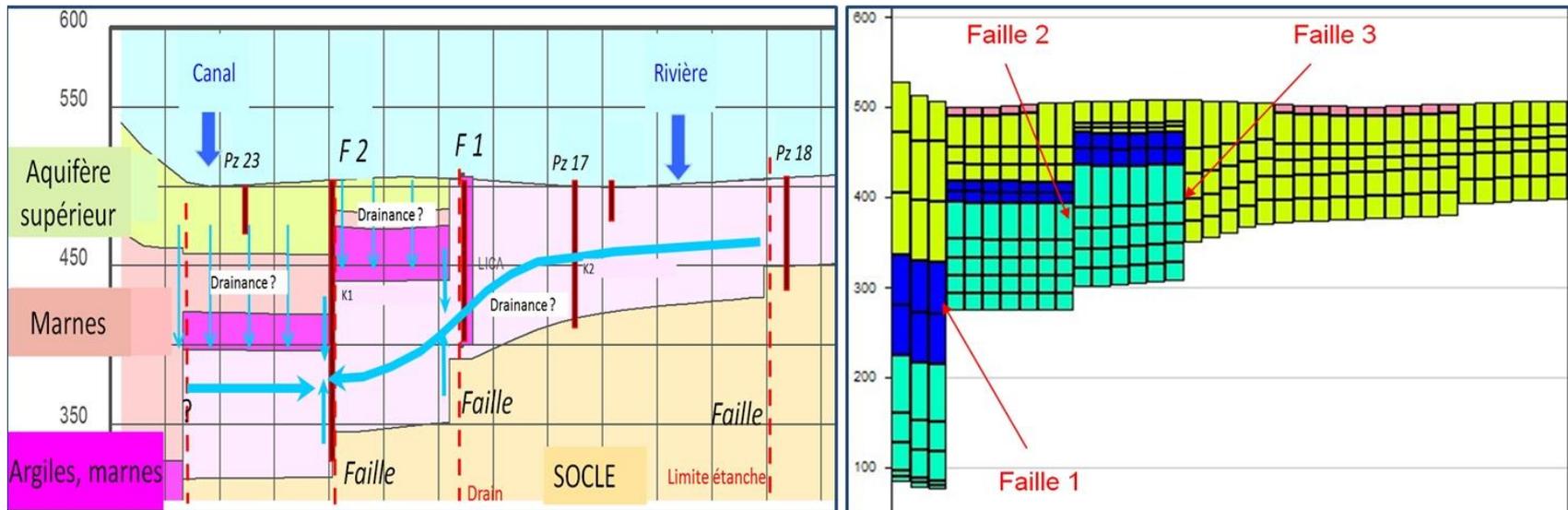
Mixing analysis



# Numerical modelling

## Objective :

- Improve the management of the NMW field
- Optimize pumping rates
- Improve resource protection



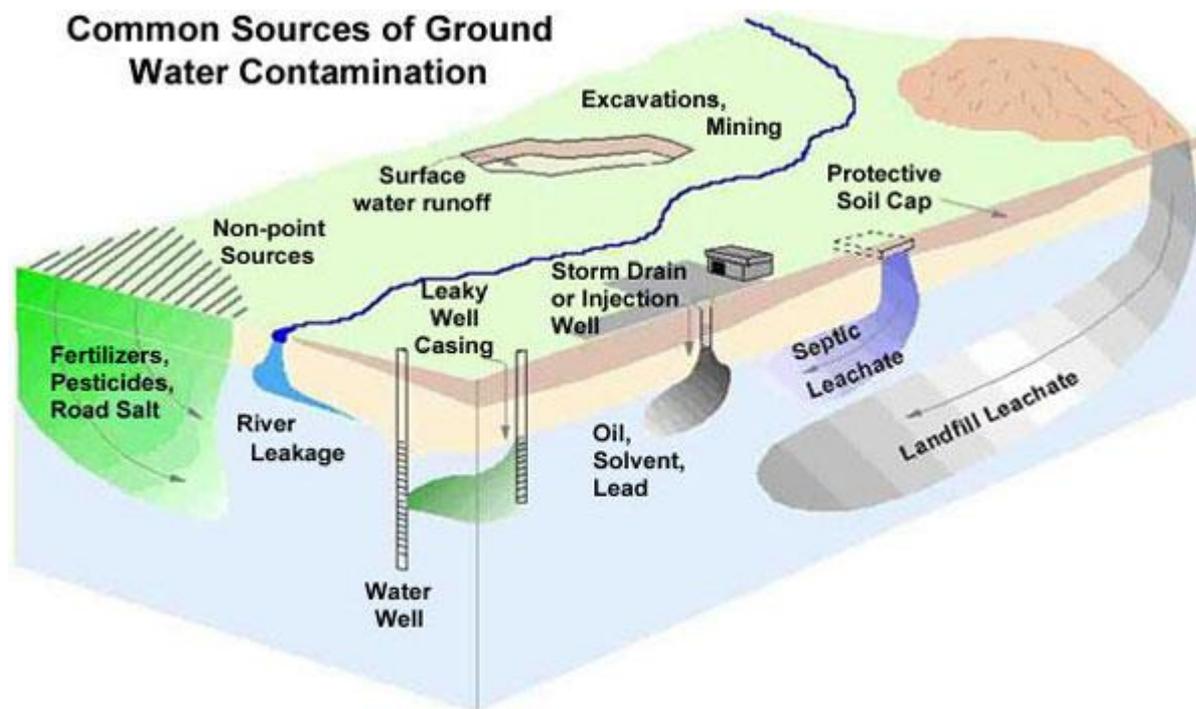
## Methods:

- Water levels and groundwater flow
- Temperature
- Water quality

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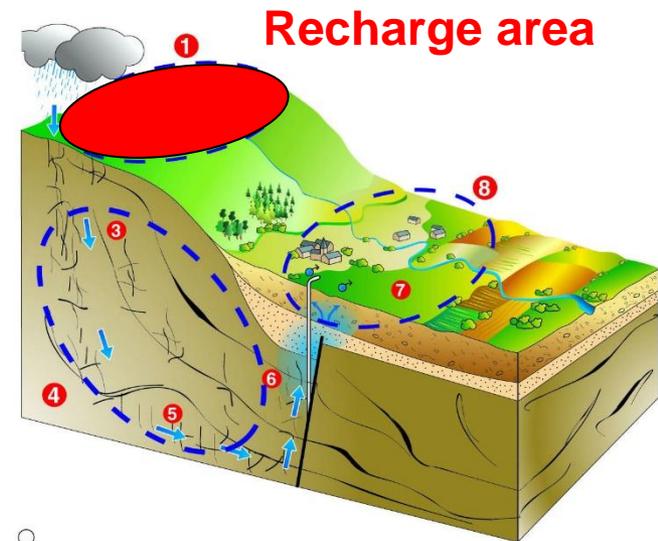
# Groundwater contamination of the recharge area



# Strategy for protecting the recharge area

Under certain conditions of feasibility, bottlers can acquire all or part of the land located in the recharge area of the water reservoir to preserve it. Initiatives in partnership, initiated and financed in part by the mineral water producers, bring together the various local actors (municipalities, farmers, authorities, etc.) to promote sustainable management of activities and ecosystems:

- **With the farmers**, non-polluting activities can be promoted concerning the use of phytosanitary, manure and manure, or the bringing to the standards of the buildings of breeding
- **With the municipalities**, the accent is put on the risks of occasional pollution related to the defective sanitation networks or the modification of the hydrological cycle resulting from demographic evolution and urbanization.



# Perrier mineral water

- Nature: naturally carbogaseous
- Low mineralisation : 480 mg/l
- Production: > 1.2 billions/yr



## Agriculture, vineyard



Nestlé Waters France decided to protect the lands from the fertilizers and pesticides, harmful for the ground and the aquifers of mineral water because of the excess of nitrates that they generate

# Perrier : actions son the recharge area

In order to protect land, Nestlé Waters France has established a protection zone around the source and, since 1993, has started a land acquisition program. Farming contracts have been signed with farmers interested in **organic farming**.

In exchange for an advantageous provision of agricultural land, the latter must comply with precise specifications: the strict observation of low quantities of nitrates and the absence of synthetic pesticides.



# Perrier: actions on the recharge area

In 1994, the winery of Vergèze wine cooperative (also known as the Vineyard of the Voie d'Héraclès) is born. Thanks to a better management of the vine and natural preventive treatments, the cooperative produces 50,000 hectoliters of organic wines every year and occupies an essential place in the wine-growing world of the region. It has become the biggest organic winery in France.



# Volvic mineral water

- Nature: carbo- calcic-sodic
- Very low mineralisation : 130 mg/l
- Production: > 1.4 billions liters/yr



Created in 2006, the CEPIV (Environmental Protection Committee for the Volvic recharge area) has the mission of developing a concerted policy of protection of the recharge area. It relies on the expertise of NGOs such as the League for the Protection of Birds (LPO), the National Forest Office (ONF) or the Conservatory of Natural Spaces of Auvergne (CENA).

This public / private partnership is carrying out several missions, such as the weeding of railways without the use of chemical products in partnership with SNCF, the evaluation and control of the risks related to the presence of human activity, the preservation of ecological and hydrological areas (CENA, LPO) or the implementation of good breeding practices. It ensures, for example, the ecological maintenance of streams: it allowed the restoration of the Lambertèche Creek, which had been degraded by the trampling of cattle in the watercourse, through the development of watering zones on the banks. promoting good forest management practices

# Volvic : forest and protection strategy

This recharge area of Volvic NMW is currently wooded for 52% of its surface area ; it was therefore considered necessary to develop a NMW resource protection sectorial policy in the area of forestry, within the framework of the CEPIV.



Recently (2009-2013), the Life+ SEMEAU project ([www.life-semeau.eu](http://www.life-semeau.eu)) was thus defined and set up, mainly to contribute to the design and initial applications of this type of sectorial policy on the Volvic recharge area.

The project showed that forest cover plays an important quantitative role with regards to the watershed's water budget and that continued increase of the forest cover will reduce the groundwater and NMW recharge, and thus the springs' discharge. water resources uses on the Volvic impluvium are multiple: NMW bottling, with the deepest component of the hydrogeological cycle (about 15% of the total resource), tap-water (more than 35%), and fish-farming, irrigation, and leisure among other activities downstream of the spring.

# Evian mineral water

- Nature: calcic
- Low mineral content : 345 mg/l
- Production: > 1.5 billions liters/yr



The recharge area of the Gavot plateau, which feeds the Evian springs, became protected by the Association for the Protection of the Recharge Area of Evian Natural Mineral Water (APIEME) in 1992..

This recharge area (area of 35 km<sup>2</sup>) contains mostly forests and natural meadows, and some natural wetlands.

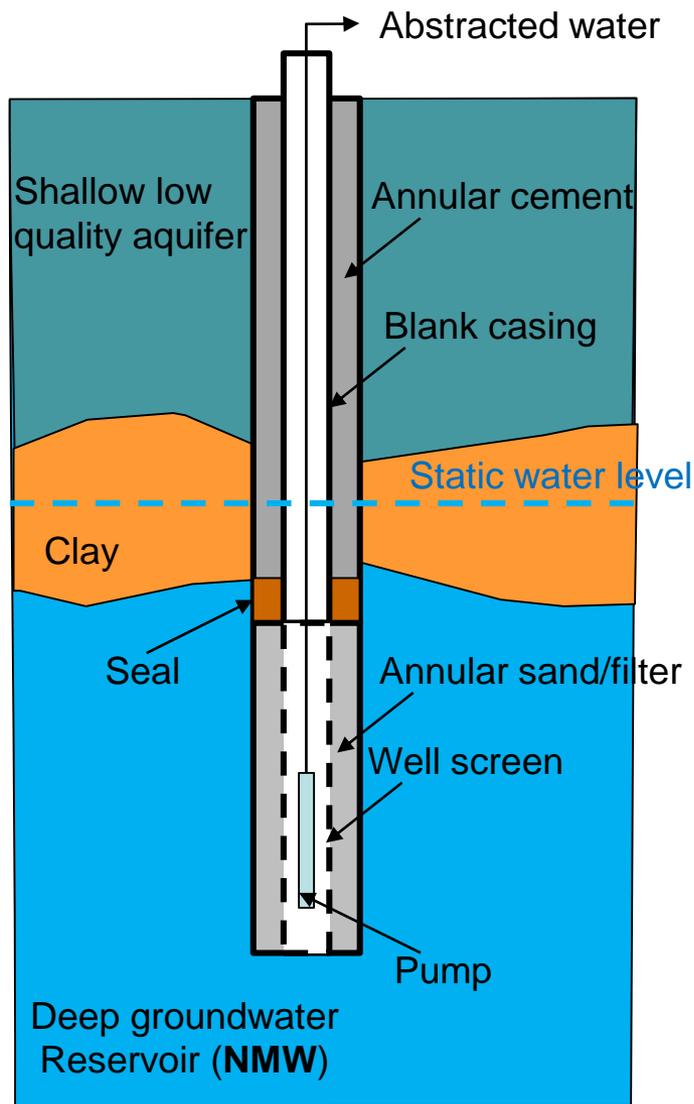
The cost of the protection of the recharge area is shared between the Evian Company (2/3), and the cities (1/3) where the Evian springs are located (Evian, Publier, Neuvecelle and Maxilly). Several types of actions are used, among which: protection by local development programmes, such as the building of a wastewater treatment plant and extending the sewer network, and measures to incite farmers to improve their agricultural practices while raising their income

Lachassagne & al. 2011, Beley et al. 2016

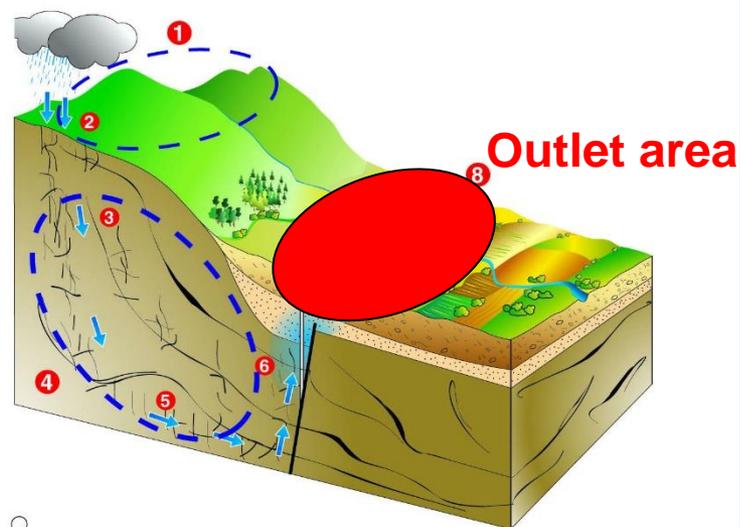
APIEME is constituted by:

- the nine municipalities located on the recharge area;
- the four municipalities with mineral water springs;
- the Evian company

# Strategy for protecting the outlet area



Abstract water using well-designe well in order to avoid mixing of NMW with low quality shallow groundwater



# Protection: for which results?

*Le Coadou, L., et al. (2016)*

**Method:** extensive survey on the potential presence of a large amount of emerging contaminants in 40 French bottled waters, including parent compounds and metabolites

**Sampling population:** 70% of the French bottled water market in volume.

Six classes of compounds were investigated, most of them being unregulated in bottled waters: pesticides and their transformation products (118), pharmaceutical substances (172), hormones (11), alkylphenols (APs) (8), phthalates (11) and perfluoroalkyl substances (PFAS) (10)

**Limits of quantification (LOQ) :** very low and reliable 87% were below 10 ng/L



*Le Coadou, L., et al. (2016)*

# Protection: for which result?

## Results:

- Among the 14,000 analyses performed, 99.7% of the results < LOQ
- None of the hormones, pharmaceutical substances and phthalates were quantified
- Nineteen compounds out of the 330 investigated were quantified in 11 samples. Eleven were pesticides including 7 metabolites, 6 were PFAS and 2 were APs.
- The presence of a majority of pesticide metabolites suggested a former use in the recharge areas of the exploited aquifers

## Conclusion:

This study confirmed that the groundwater aquifers exploited for bottling were well-preserved from chemicals, as compared to less geologically protected groundwater, and also underlined the need to pursue the protection policies implemented in recharge areas in order to limit the anthropogenic pressure.

# Conclusion (1/2)

- Water is an essential nutrient and plays a key role in the human body
- EFSA recommends a daily water intake of 1.6 litres (women) or 2.0 litres (men)
- According to their chemical content, waters can help in healing various diseases
- Characteristics of mineral water are dependent on water-rock interaction, temperature and pressure at depth and transit time : these parameters determine the mineralization and quality of water
- To preserve the quality of groundwater, it is necessary to avoid polluting activities on the recharge area and insure a well-designed and safe abstraction system at the outlet
- For that purpose, it is necessary to apply multidisciplinary approaches in order to properly understand the NMW field and manage and protect it

## Conclusion (2/2)

- Several French water bottling companies have initiated public/private
- partnerships in order to protect their NMW fields in a win-win relationship
- Groundwater aquifers exploited for bottling are well-preserved from chemicals, as compared to less geologically protected groundwater
- Need to pursue the protection policies implemented in recharge areas in order to limit the anthropogenic pressure
- The major mineral water producers have well understood this point and they draw from these acquired scientific data the elements of communication that make it possible to show that NMW is unique and shows all the attentions so that tomorrow it is always healthy

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Thank you  
for your attention



...do not forget: tap water is  
generally of good quality

