

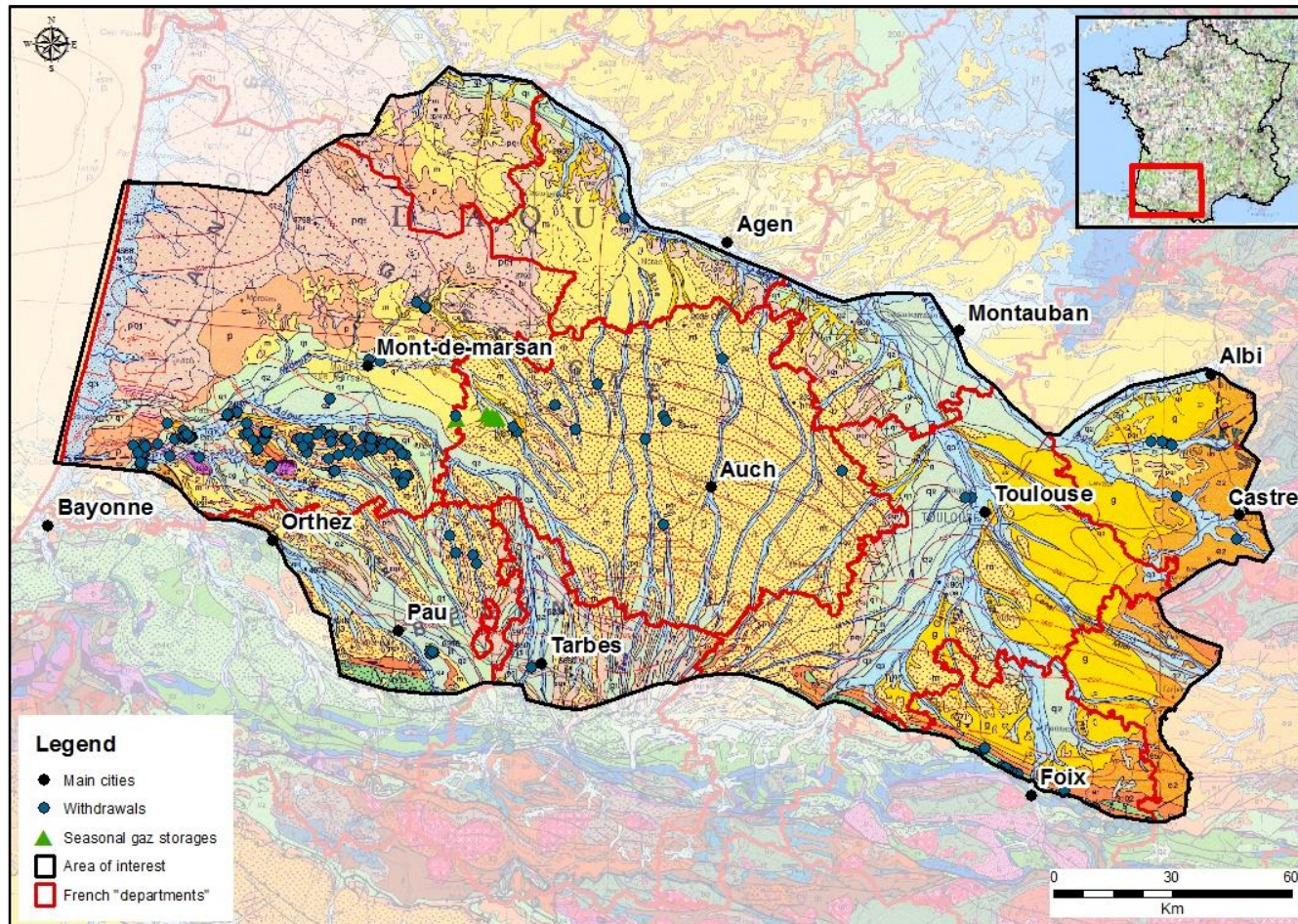


**THE GAIA-PROGRAM: A
SCIENTIFIC APPROACH
DEDICATED TO THE
UNDERSTANDING OF THE DEEP
GROUNDWATER CIRCULATIONS
IN THE SOUTH AQUITAINE
BASIN.**

Arnaud Willeumier, Nicolas Pedron, David Malet

Hydrogeological context

So called “deep aquifers” (Eocene to upper Cretaceous) of the south Aquitaine Basin are used for multiple uses: **drinking water, thermal and geothermic applications, irrigation and seasonal gas storage**



Area : 32 000 km²

*Depth to aquifers:
0-3000m*

*About 200
exploitation
boreholes for a
cumulated volume
reaching
25 to 30 Mm³/yr*

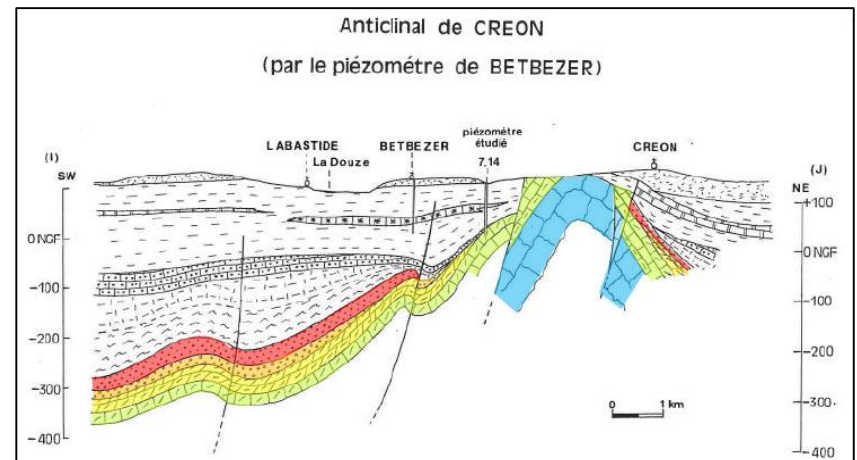
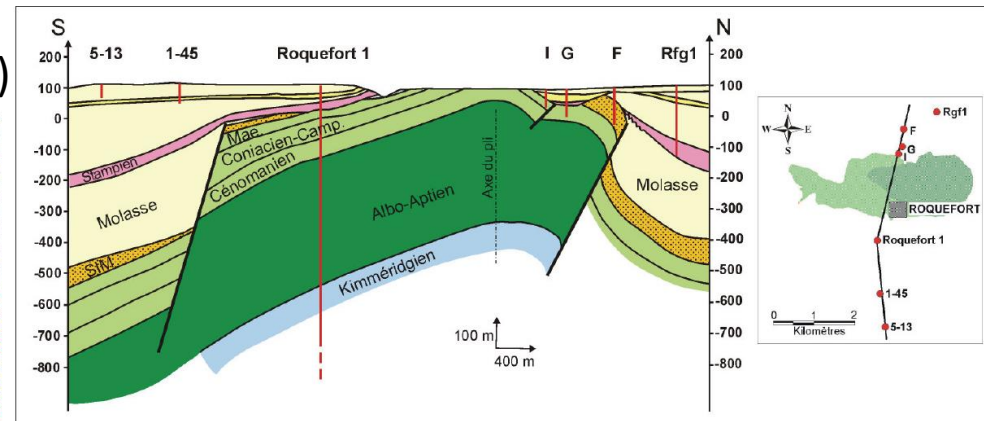
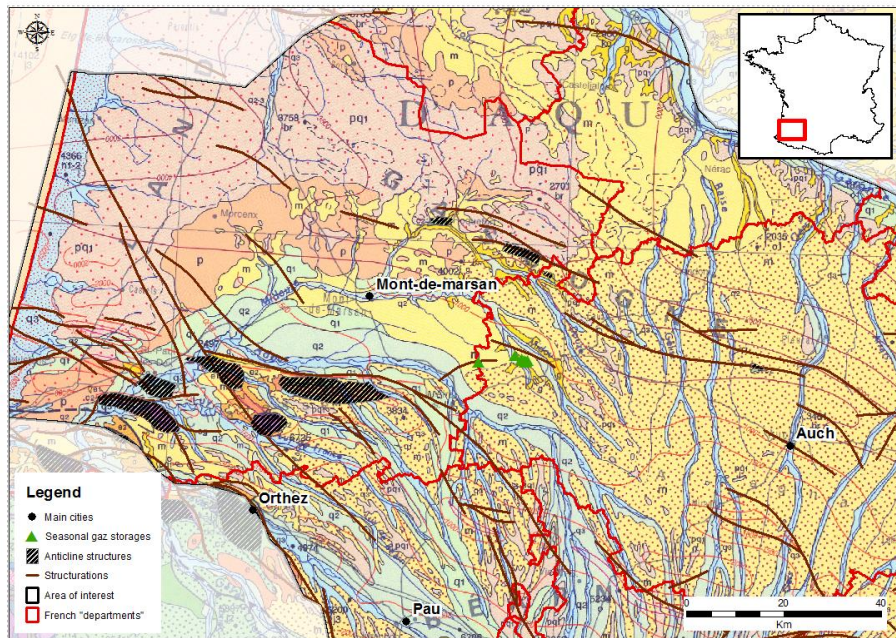
*Uneven
distribution of the
boreholes*

A complex aquifer system

Specificity of the area: **compression features** inducing faults and folding, synclines and anticlines, as well as localized diapirism

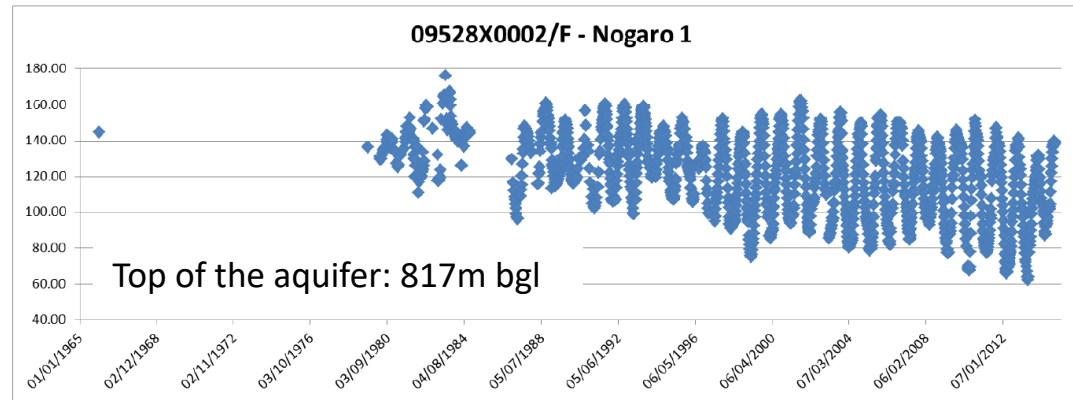
Deep confined aquifers are **connected at a local scale** (anticlinal structures) and **at a more regional scale** for two of them (Under-Molassic Sands and underlying Paleocene aquifer)

(Douez, 2007)



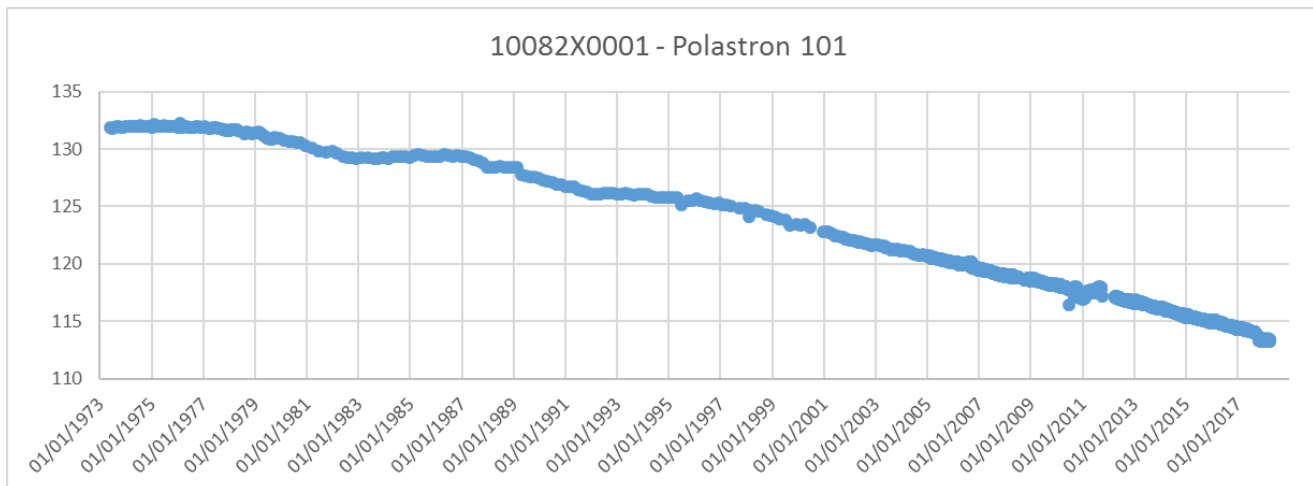
The main aquifer: the UMS

The **Under-Molassic Sands** (extension: about 15 000 km²) is the most solicited (12 Mm³/yr) and the siege of the gas storages that strongly influence the confined groundwater Piezometric level (tenth of kilometers)



Annual fluctuations:
almost 80m

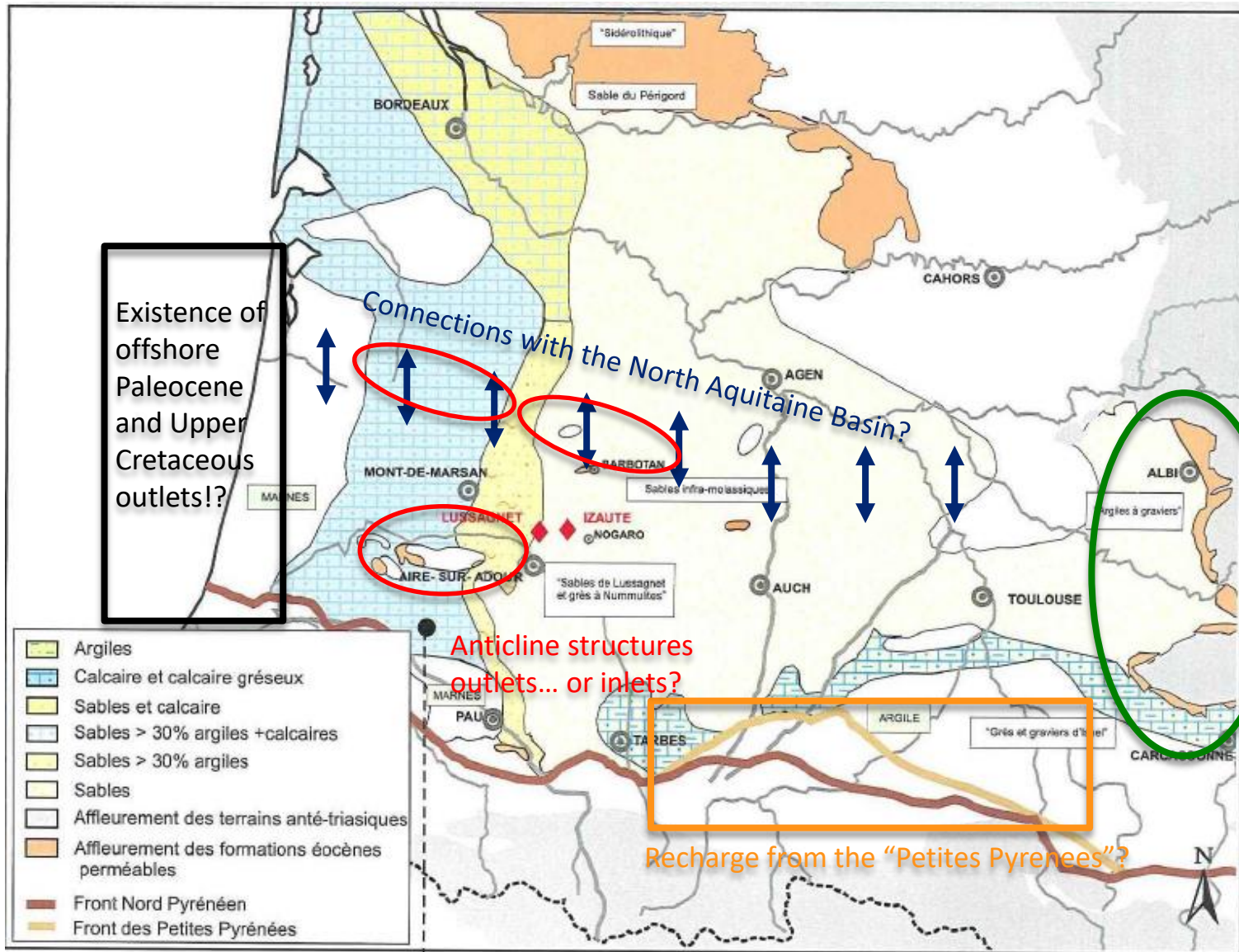
A **decrease in the Piezometric level** is recorded almost since the beginning of the monitoring (late 1960s), inducing disappearing of artesianism in some areas and the drying of thermal springs



=> Water authorities expressed their need for a groundwater management model and a private company its interest for a better understanding

The main hydrogeological issues of the GAlA project

=> Geometry and water budget



Map from Elf Gaz de France and Aquila Conseil, 2001

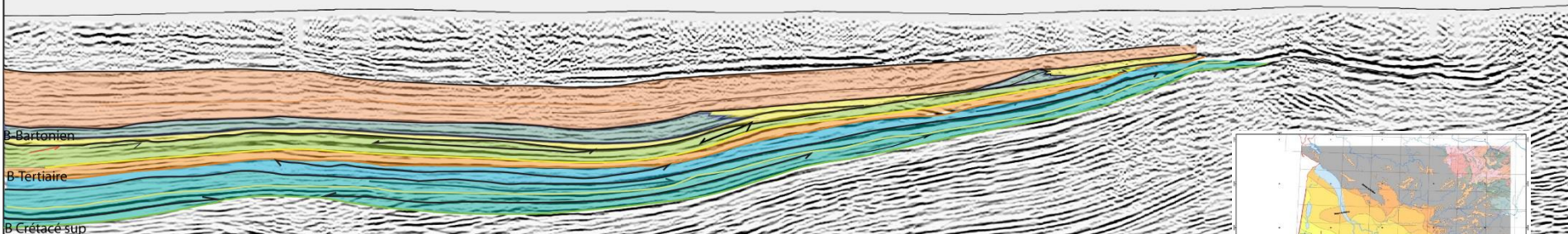
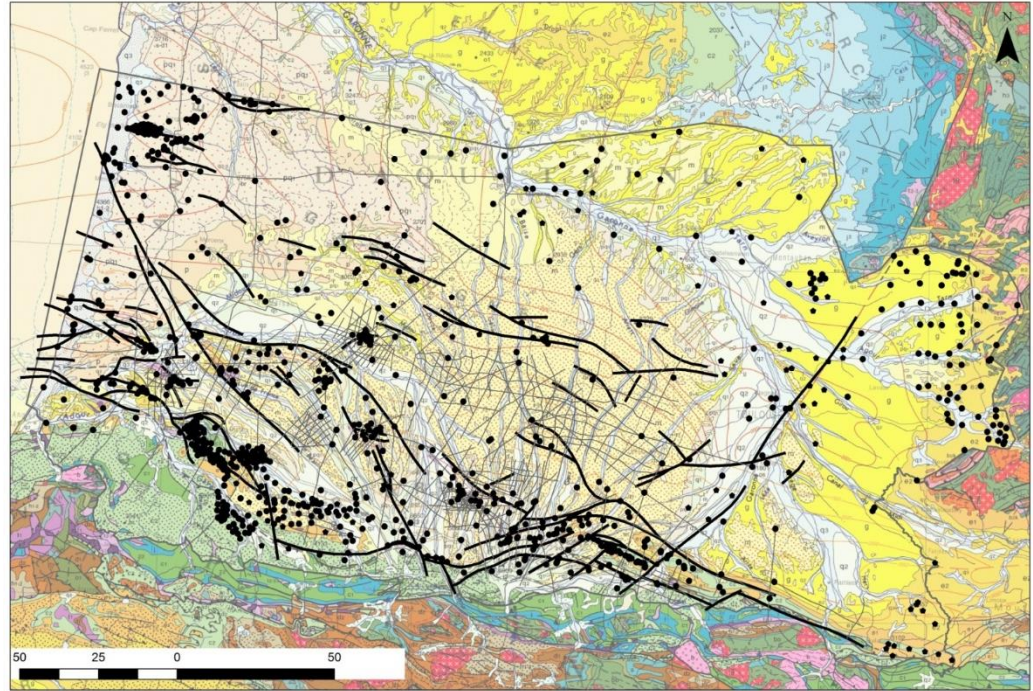
Recharge from the "Massif Central" and "Montagne Noire" foothills?

Geological data to build 3D geometry

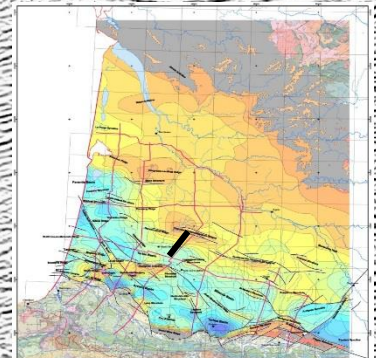
Geological database

- 1050 re-interpreted deep boreholes.
- More than 1300 boreholes.
- More than 5000 km of seismic profiles.

(Lasseur et al, 2017)

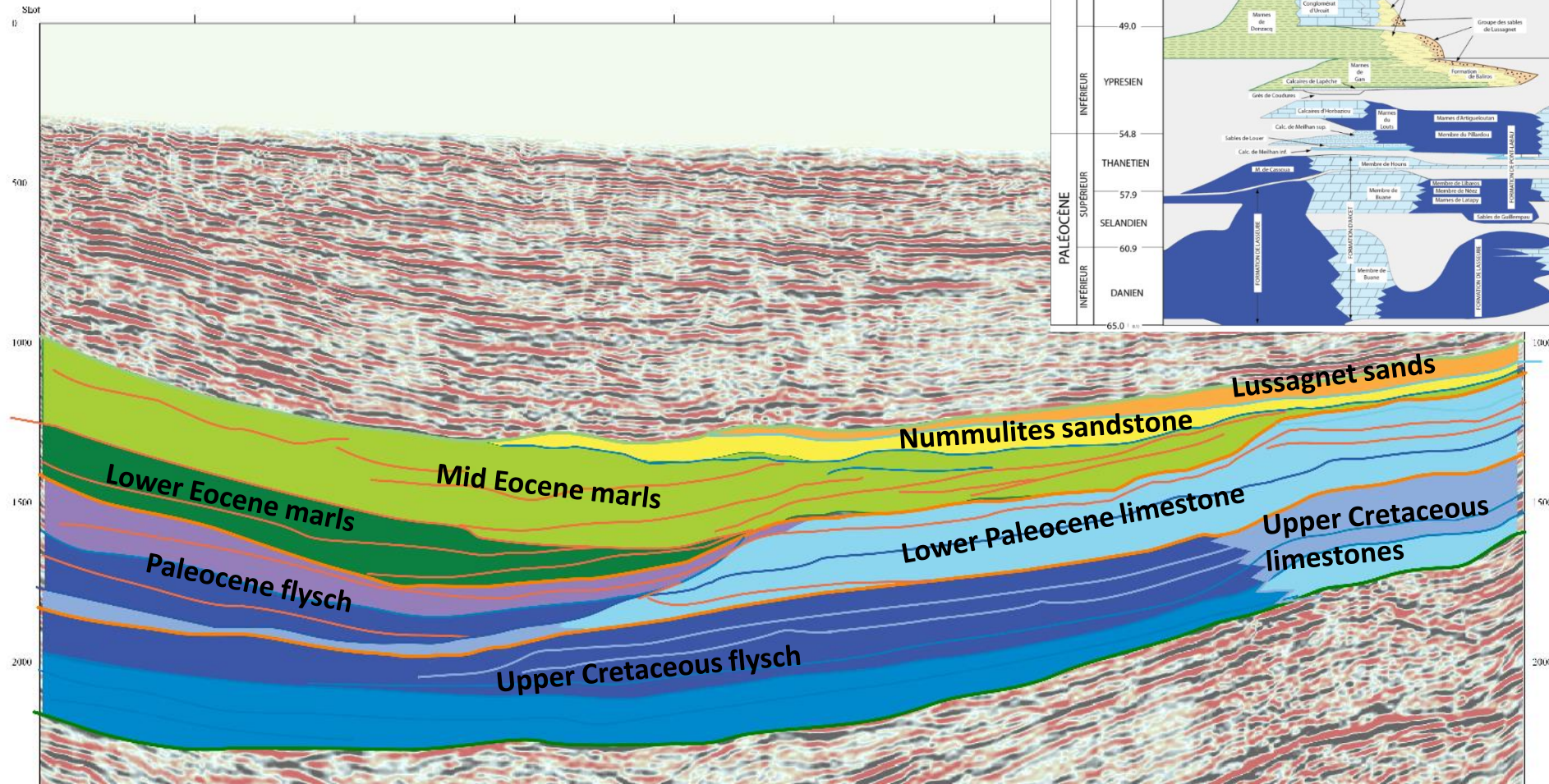


Shrinking of the tertiary and cretaceous formations towards the so-called “Celtaquitaine bend”
=> N/S Disconnections of the Eocene sands



Towards a 3D geological model

Based on the cross-sections and the constitution of litho-stratigraphic schemes, elaboration of a simplified representation of the aquifer system



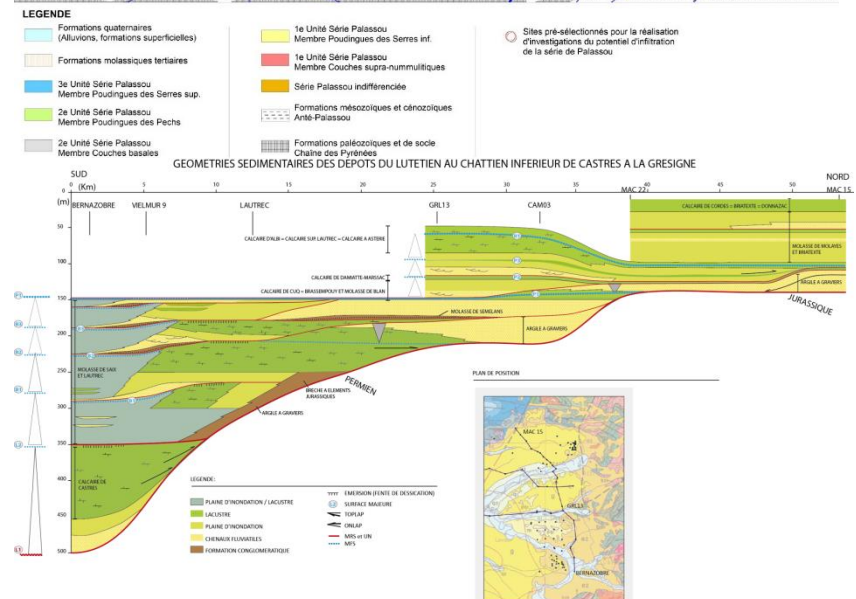
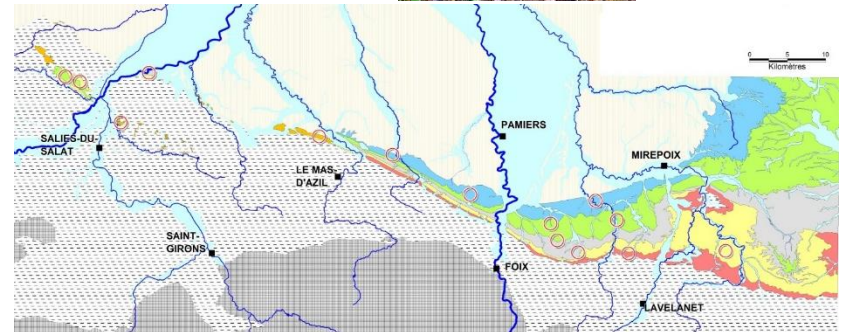
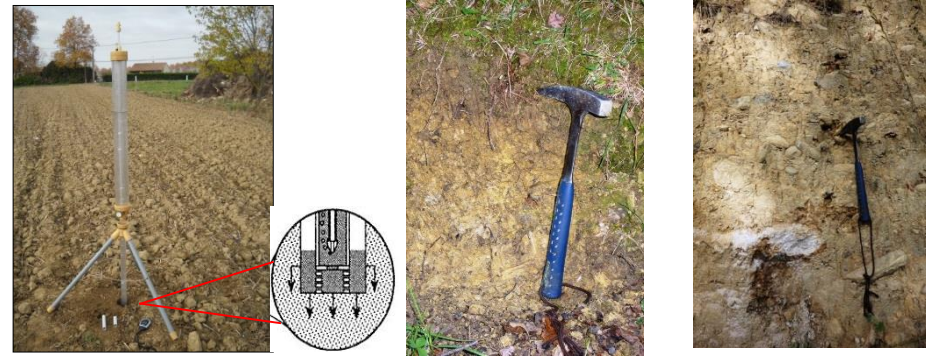
Hydrogeological investigations - Recharge

Recharge does not occur directly into the UMS but is transferred into it through **bridging-formations**: so-called “gravel clays” and the Palassou conglomerate, both **heterogeneous**

Permeability tests were performed in the field, showing for instance a $9 \cdot 10^{-5}$ to $2 \cdot 10^{-7}$ m/s permeability for the “gravel clays”

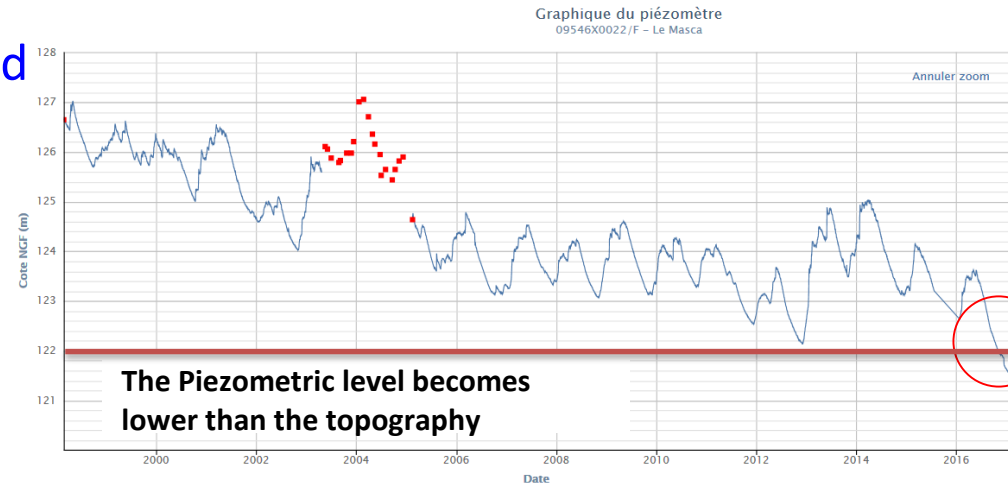
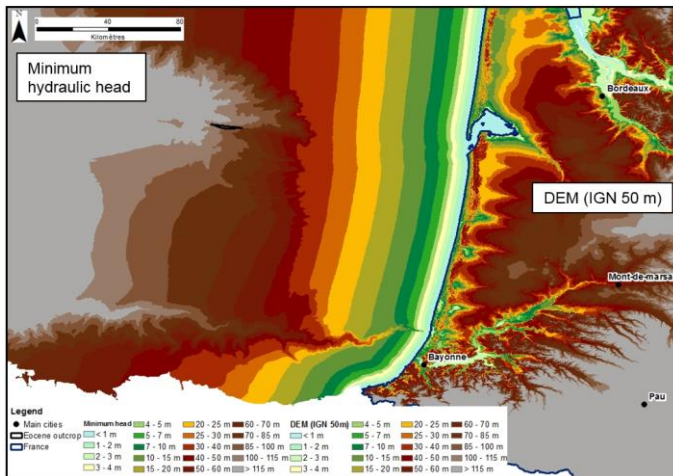
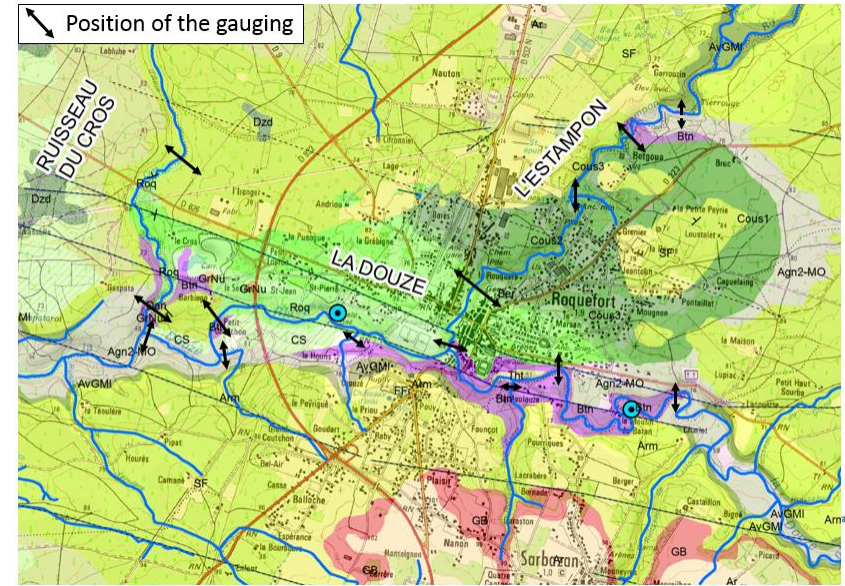
Upstream-downstream gauging are performed during low-flow periods in order to identify river recharge

Recharge pathways are inferred from litho-stratigraphic cross-sections



Hydrogeological investigations - Outflows

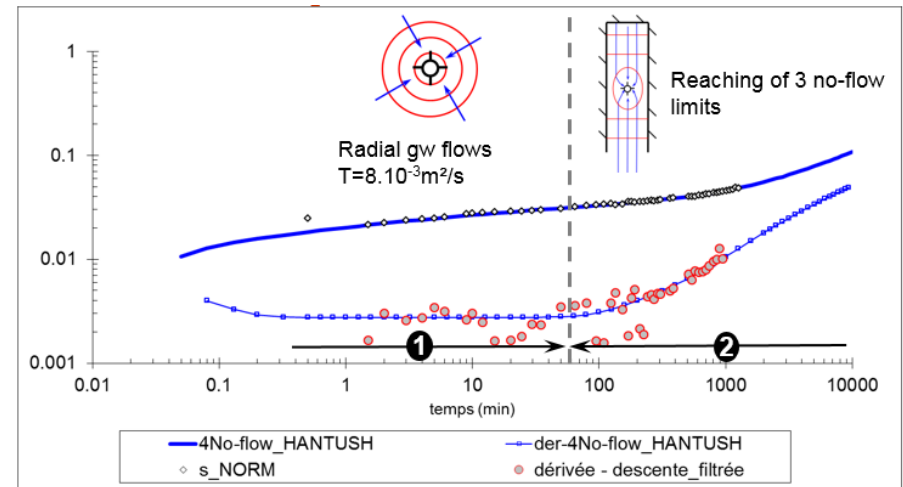
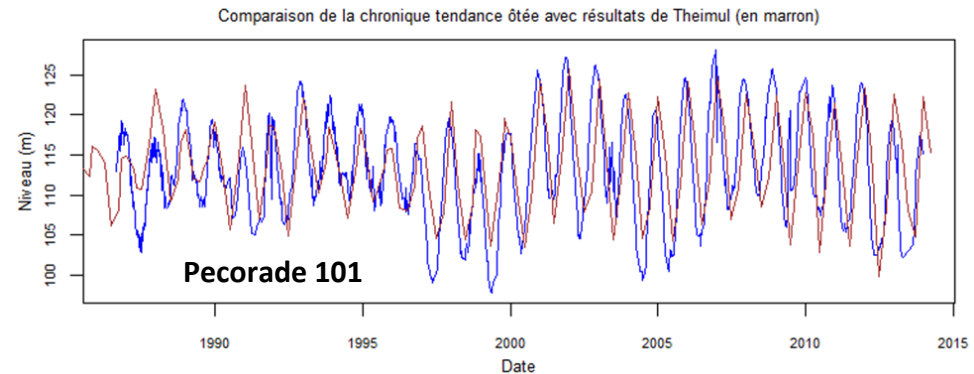
- Study of anticline structures: Piezometric and chemistry analyses, Upstream-downstream gauging
- Modification of the hydrodynamic behavior as the groundwater level drops: springs dry out and what was an outlet becomes a recharging area. Diminution of the groundwater age, change in the water chemistry
- Off-shore outflows have been considered regarding feasibility and divers observations



(Wuilleumier, n°EGU2018-7622)

Hydrogeological investigations – hydrodynamic properties

- Exploitation of the propagation of the pressure wave from the gas storages through the UMS aquifer to infer storage coefficient and transmissivity over large areas (tenth of km)
- Re-interpretation of old pumping test data using the drawdown derivative method (Bourdet, 1983) in order to get a diagnosis of the groundwater circulations around the borehole before modeling the pumping test. => to infer local transmissivity



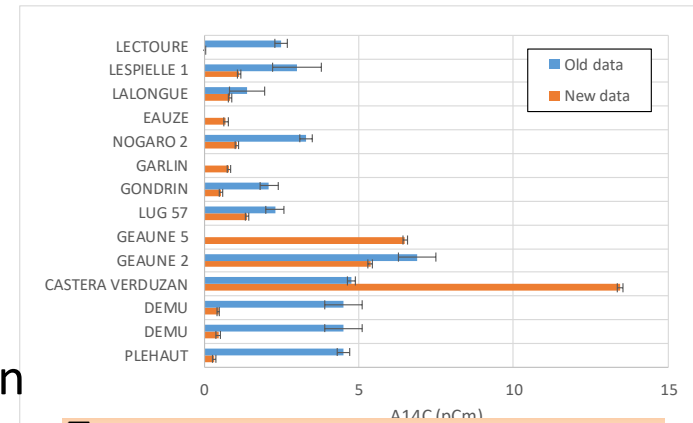
Groundwater age

^{14}C measurements have been made over 14 boreholes, using a specific sampling method to ensure a perfect isolation of the water from the atmosphere during the sampling period.

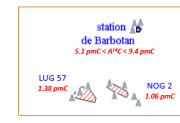


^{14}C activities are almost always lower than the ones determined in previous investigations and correspond to ages older than 30,000 years.

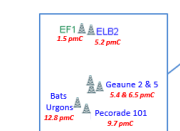
Considering the scarcity of hydrogeological data in some areas, groundwater ages are useful tools to identify pathways and build hypotheses for establishing a conceptual hydrogeological model



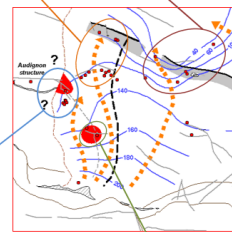
5 Interpretations



• Mixing of deep waters with youngest ones close to the Barbotan emergences



Specific hydrogeochemical behavior close to the limits of the permeable aquifer
Potential mixing with youngest waters



- Origin of water different in the North of the Celt-Aquitaine structure (Lectoure)
- Mixing of young waters with deep waters close to the structure correlated with an increase in carbonate content (Castéra-Verduzan)
- Very low ^{14}C activities elsewhere

- Ages of waters higher than 30,000 years
- Local stagnation close to the Garlin deep structure

(André et al, n°EGU2018-7811)

How to get reliable data from low-productive wells?

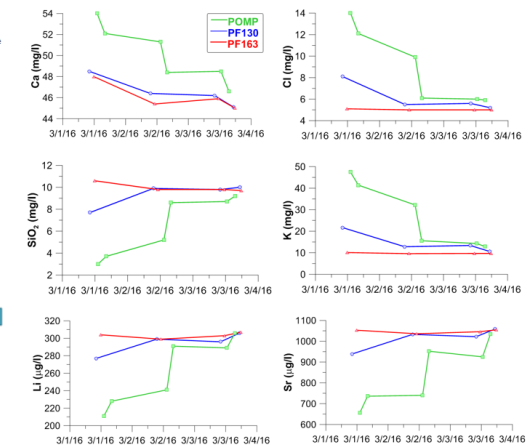
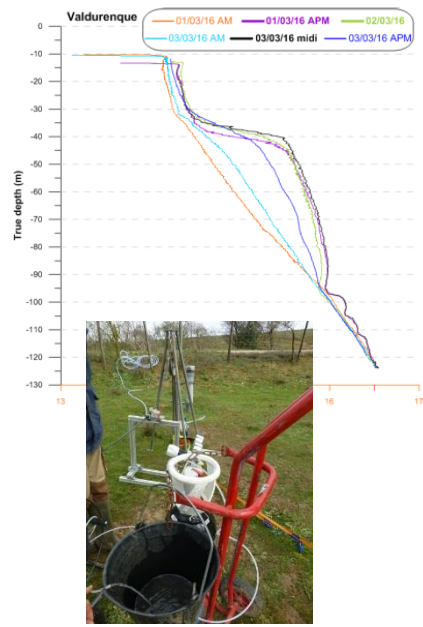
✓ Part of the piezometers are former hydrocarbon exploration wells (>4000m) plugged to a certain depth and converted by perforating their casings (over a tenth of meters).

✓ => generally low-productive, do they provide reliable data?

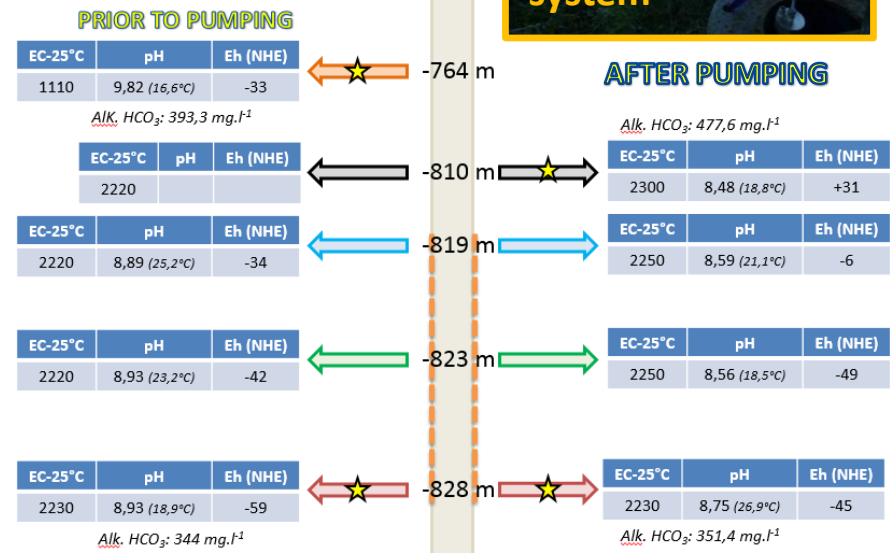
✓ Cyclic investigations were made in deep boreholes: well logging, deep sampling at selected depths, borehole stimulation by pumping, deep sampling again.

=> deep samplings, performed at the right depth, provides reliable data

(Gal et al, n°EGU2018-7116 and 7172)



Example of Polastron



Conclusions

Understanding groundwater circulations in deep aquifers which are characterized by few access opportunities need to **combine investigations methods**, using the different fields of the earth sciences

It reinforces our abilities to understand groundwater circulations and provides useful **objective constraints** to calibrate the future groundwater model solicited by the water authorities

All investigations made in the frame of the GAIA project are reported into **public technical reports** and available online (<http://infoterre.brgm.fr>)

More investigations complete the full-picture of the project, in the frame of geology, hydrogeology and hydrogeochemistry

a.wuilleumier@brgm.fr



THANK YOU
FOR
YOUR ATTENTION
