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A hybrid geophysical-geomorphological approach as the basis for a geological model of the Chaîne des Puys

Cyril Aumar, Philippe Labazuy, Olivier Merle, Solène Buvat, Lydie-Sarah Gailler, Charley Merciecca

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Geological modeling of a volcanic watershed in a crystalline basement context using a hybrid geological-geophysical method

Côme watershed (Chaîne des Puys, France)

Cyril Aumar⁽¹⁾, Philippe Labazuy⁽¹⁾, Olivier Merle⁽¹⁾, Solène Buvat⁽¹⁾, Charley Merciecca⁽¹⁾

*Réunion des Sciences de la Terre
Rennes, 03 novembre 2023*



Établissement public de mission chargé du développement durable



Laboratoire
Magmas &
Volcans



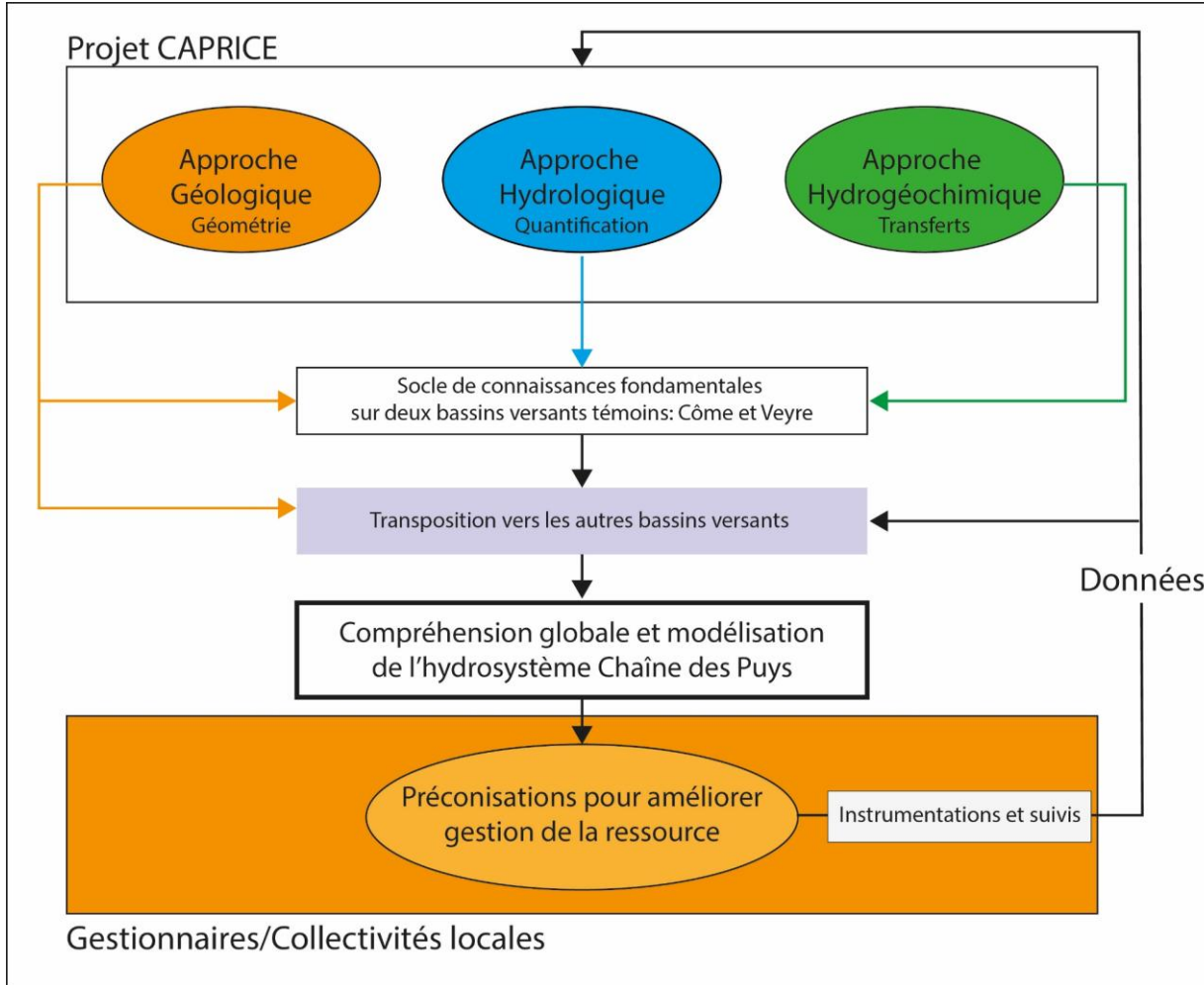
**UNIVERSITÉ
JEAN MONNET**
SAINT-ÉTIENNE



Une école de l'IMT

Study context:

CAPRICE : Approche Pluridisciplinaire pour la Caractérisation des Ressources en Eau de la Chaîne des Puys



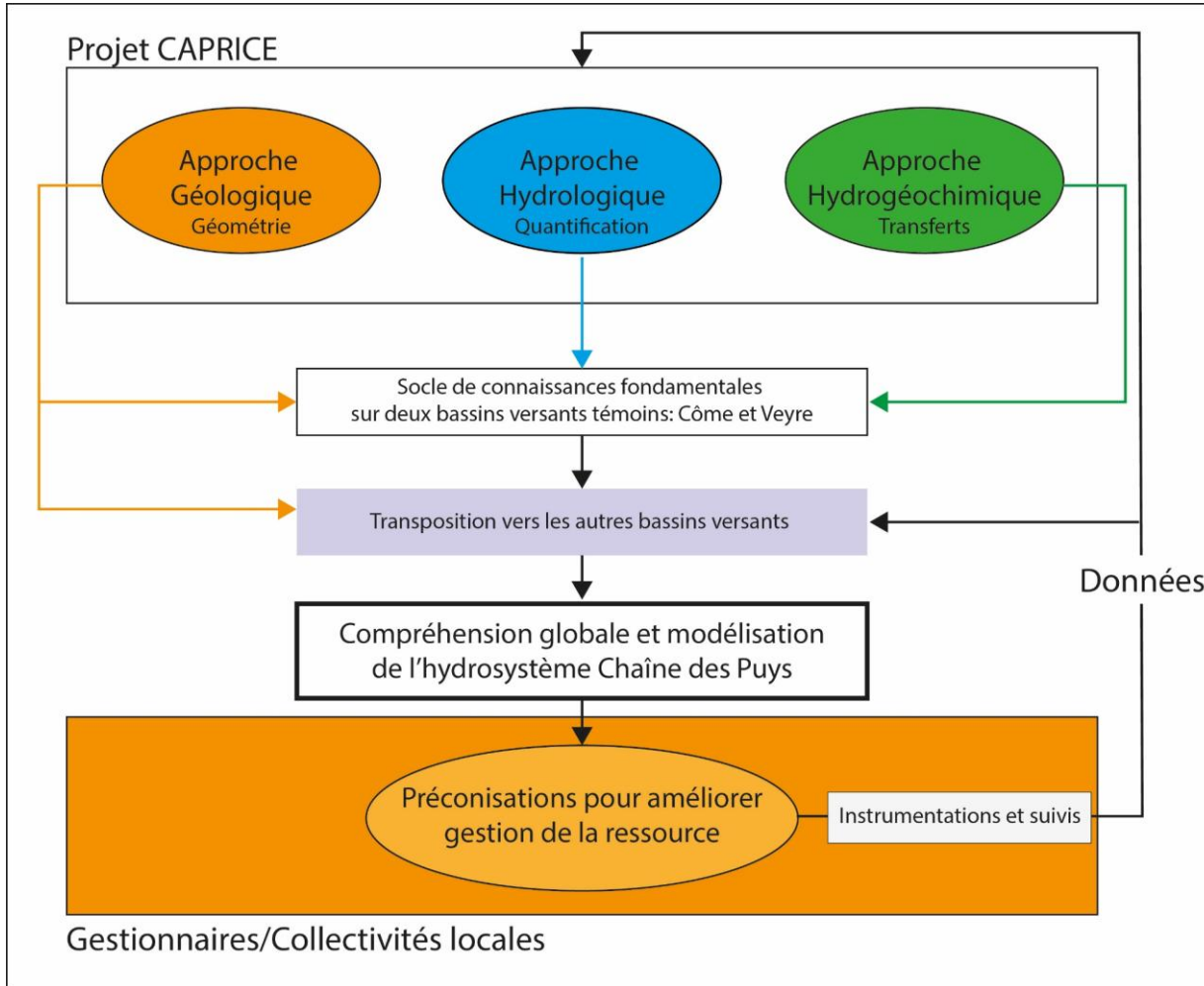
Projet funding:



Établissement public du ministère chargé du développement durable

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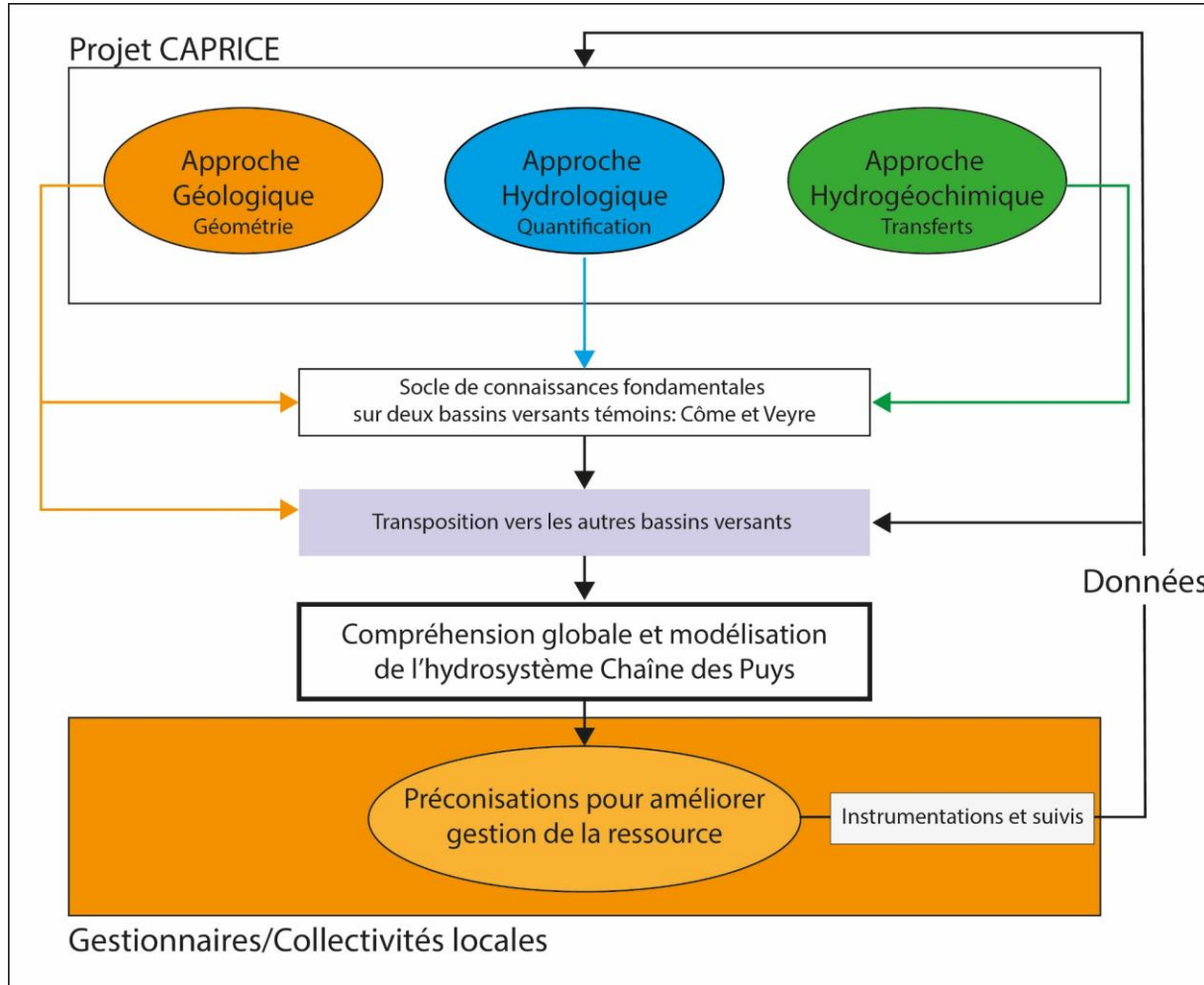
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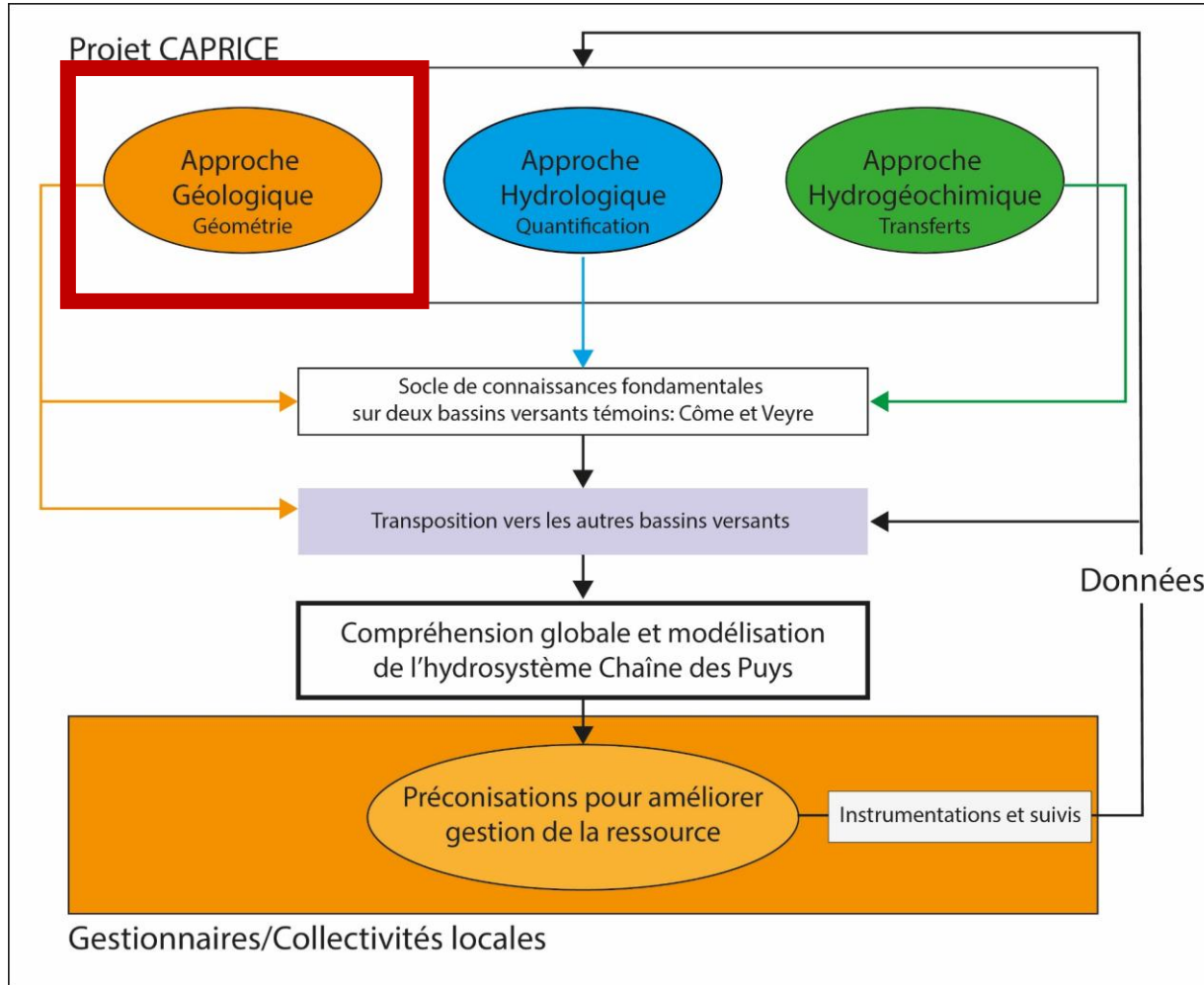
Scientific collaboration:



Une école de l'IMT

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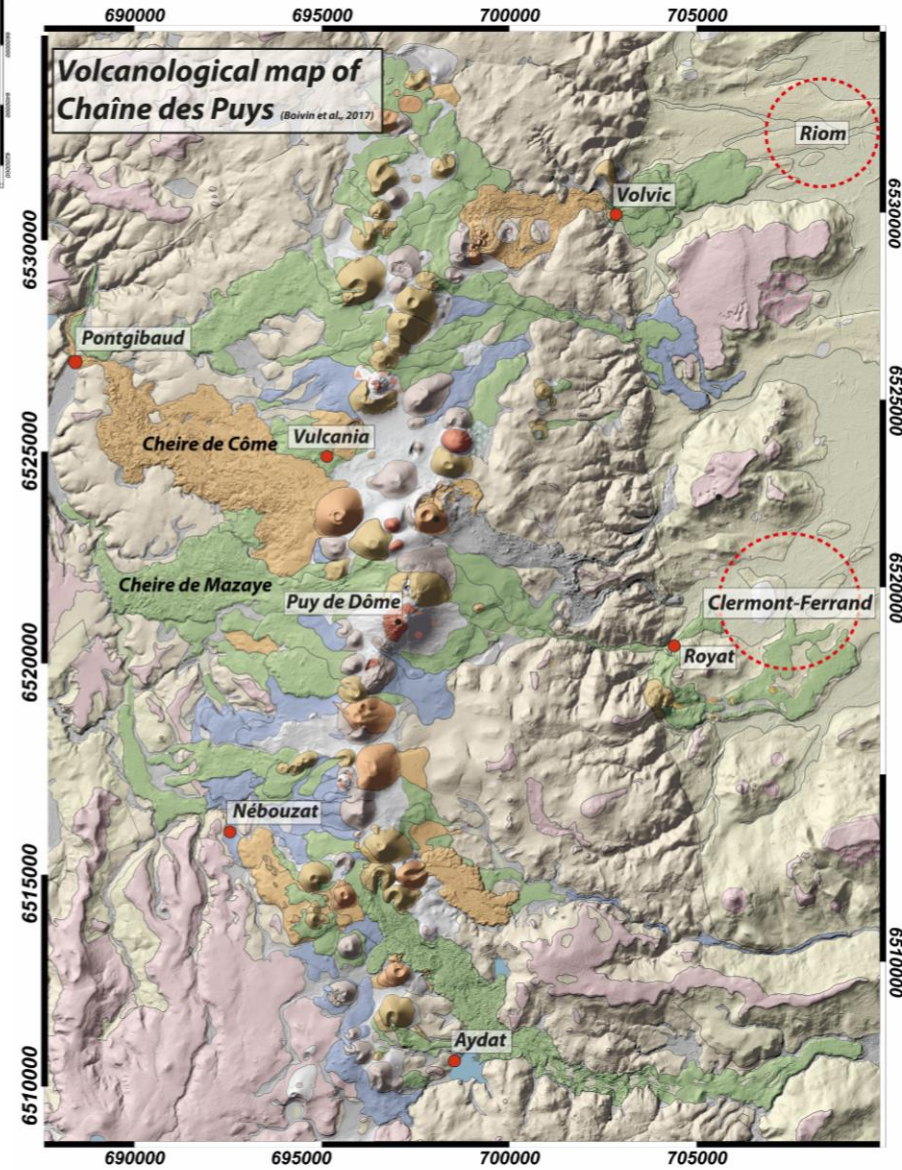
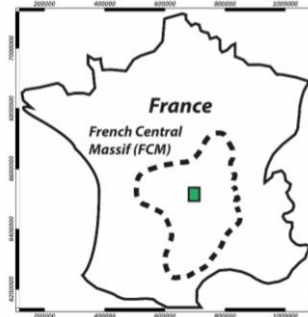


Scientific collaboration:



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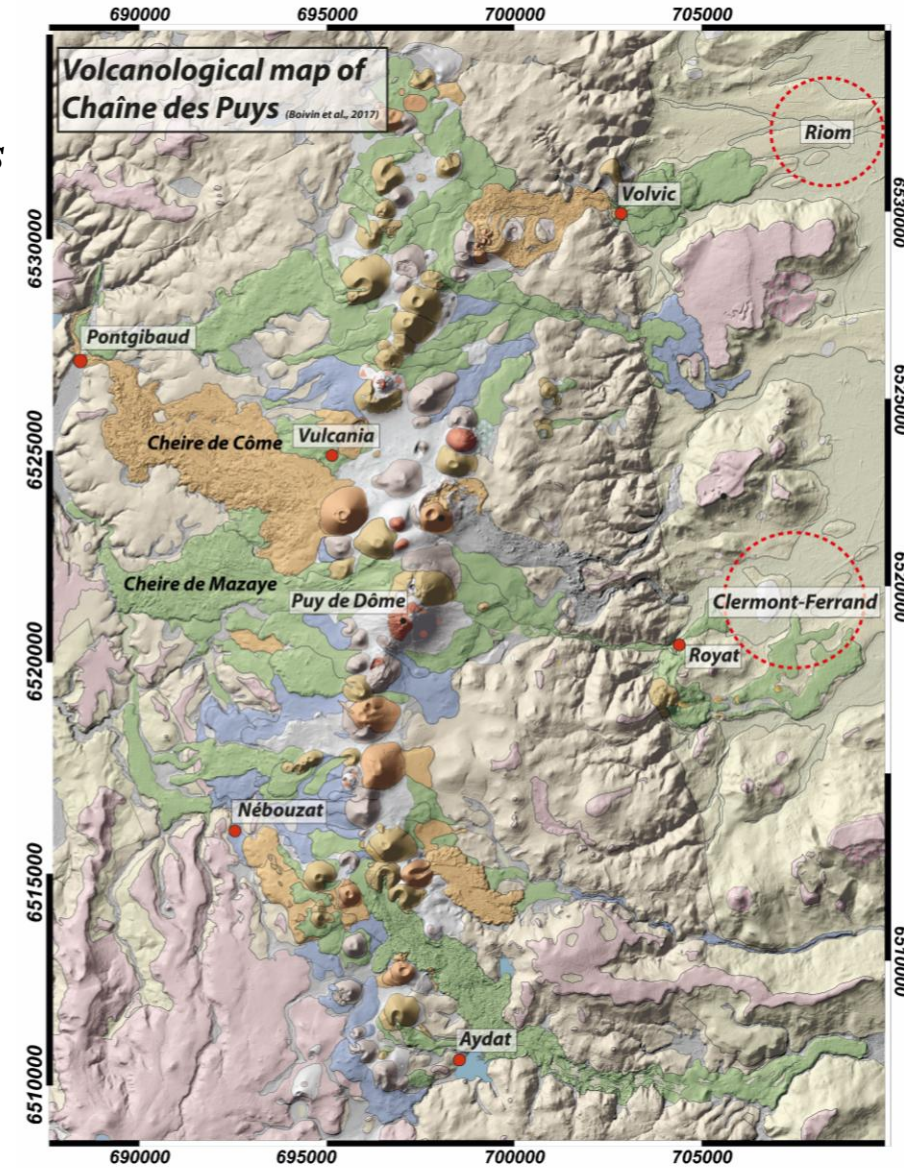
Study context:



Study context:

Drinking water supply in the Chaîne des Puys:

- 350.000 users
- 12 Water resource manager
- 50 catchments
- 10 Watersheds



Study context:

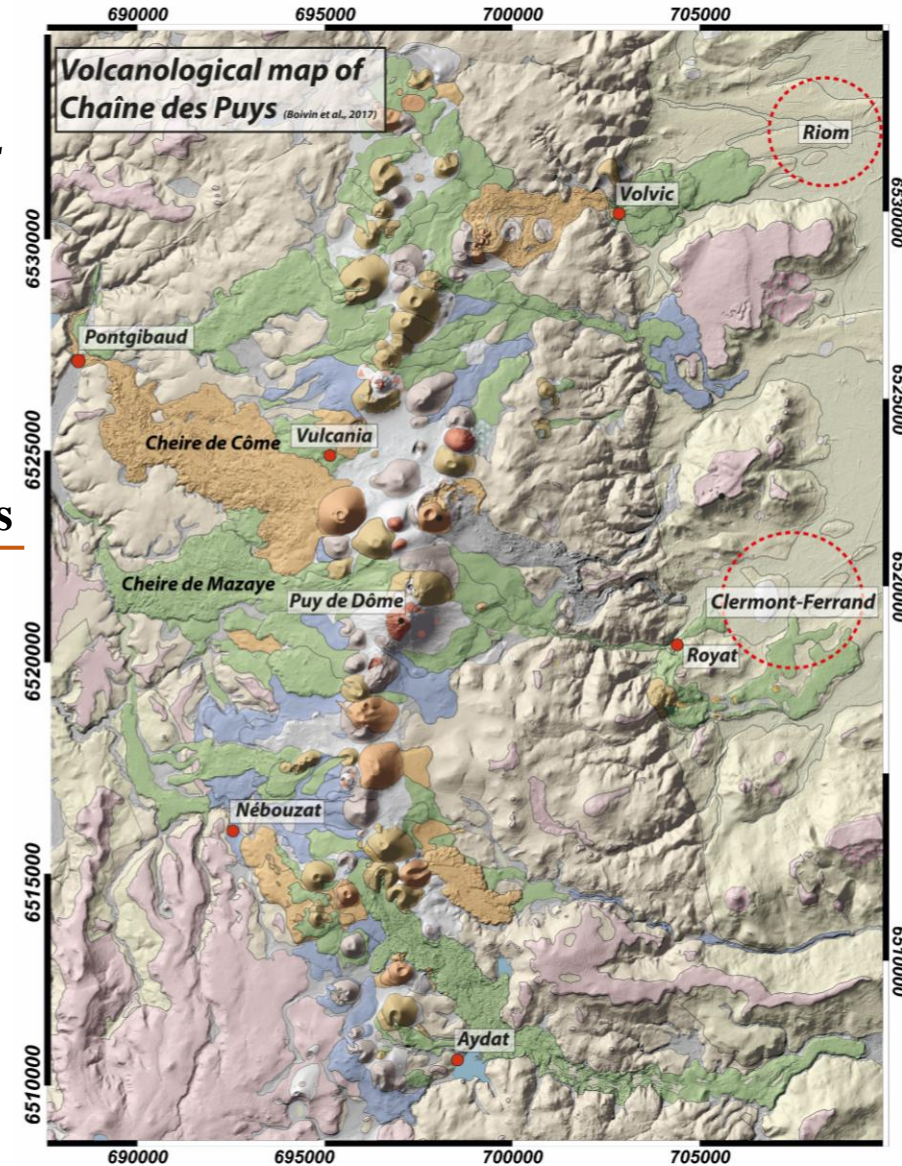
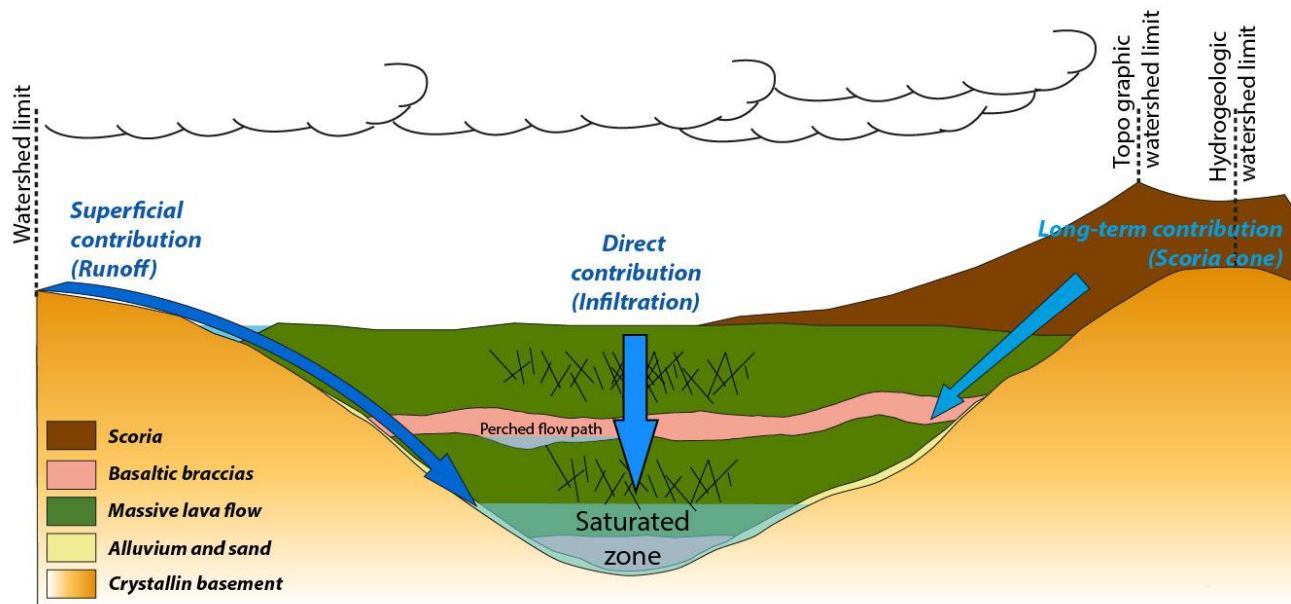
Drinking water supply in the Chaîne des Puys:

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Hydrogeological functioning:

- Aquifers are located along the axis of filled **paleovalleys**
- Flow velocities depend on the type of volcanic formation
- Topographic watersheds are meaningless

Bedrock topography controls flow axes and size of hydrogeological catchments



Côme Watershed :

Geological context

■ *50.000 users*

■ *2 catchments*

■ *Catchment area of 35 km²*

Côme Watershed :

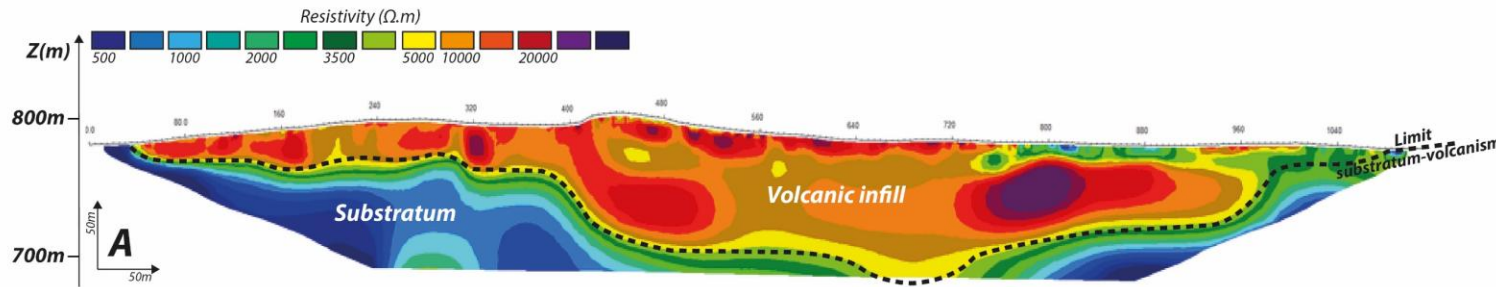
Geological context

■ 7 lava flows

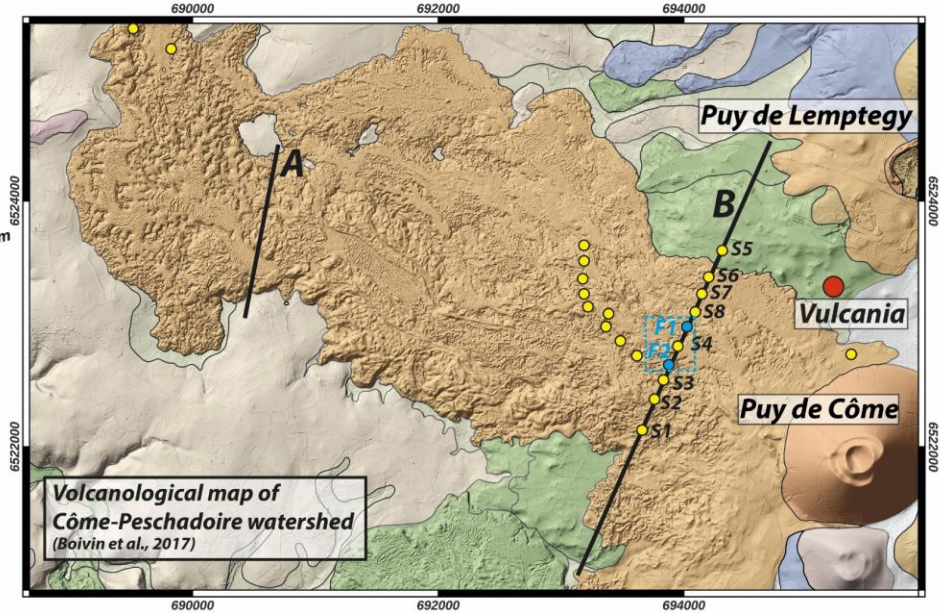
■ 28 boreholes

■ 150 m of thickness

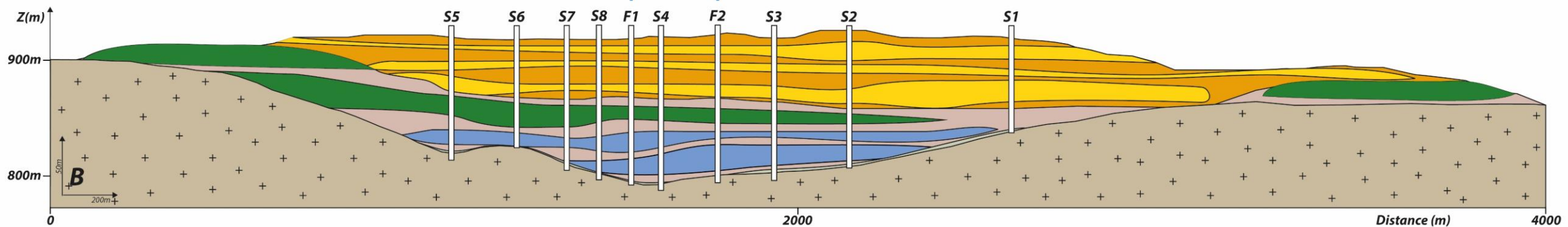
Geological survey of the Côme upstream part



Map and cross-section caption :



Côme wells



Côme Watershed :

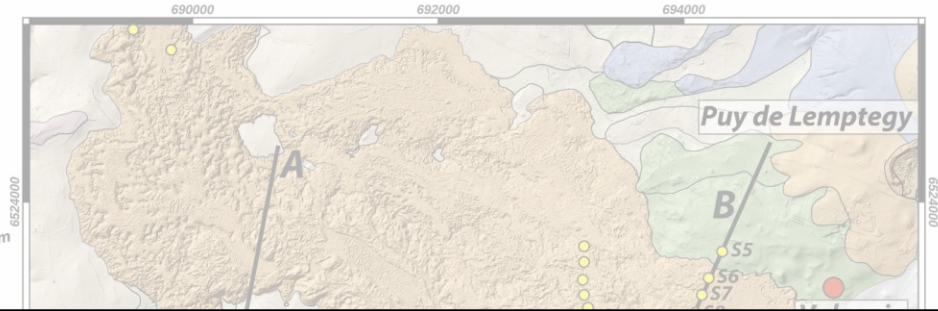
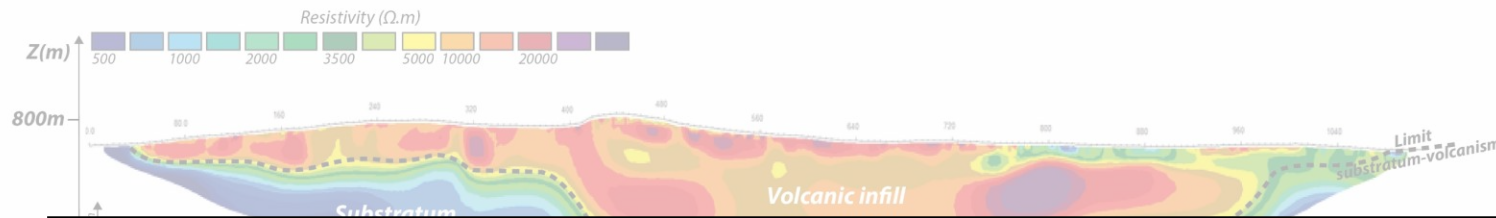
Geological context

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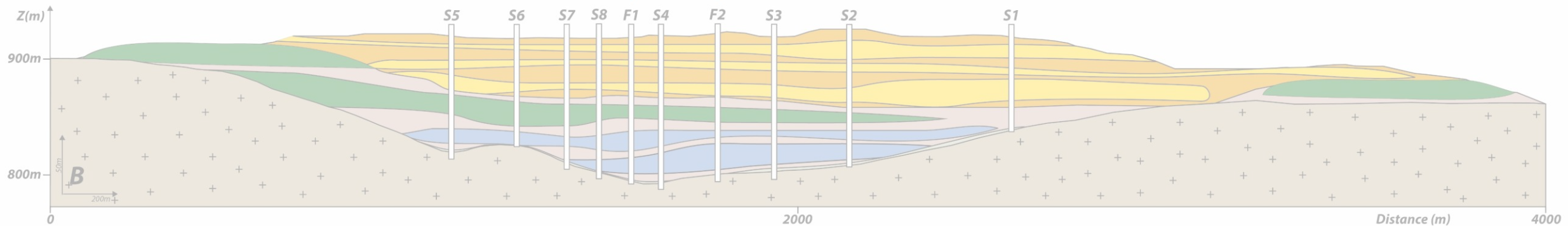
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Geological survey of the Côme upstream part

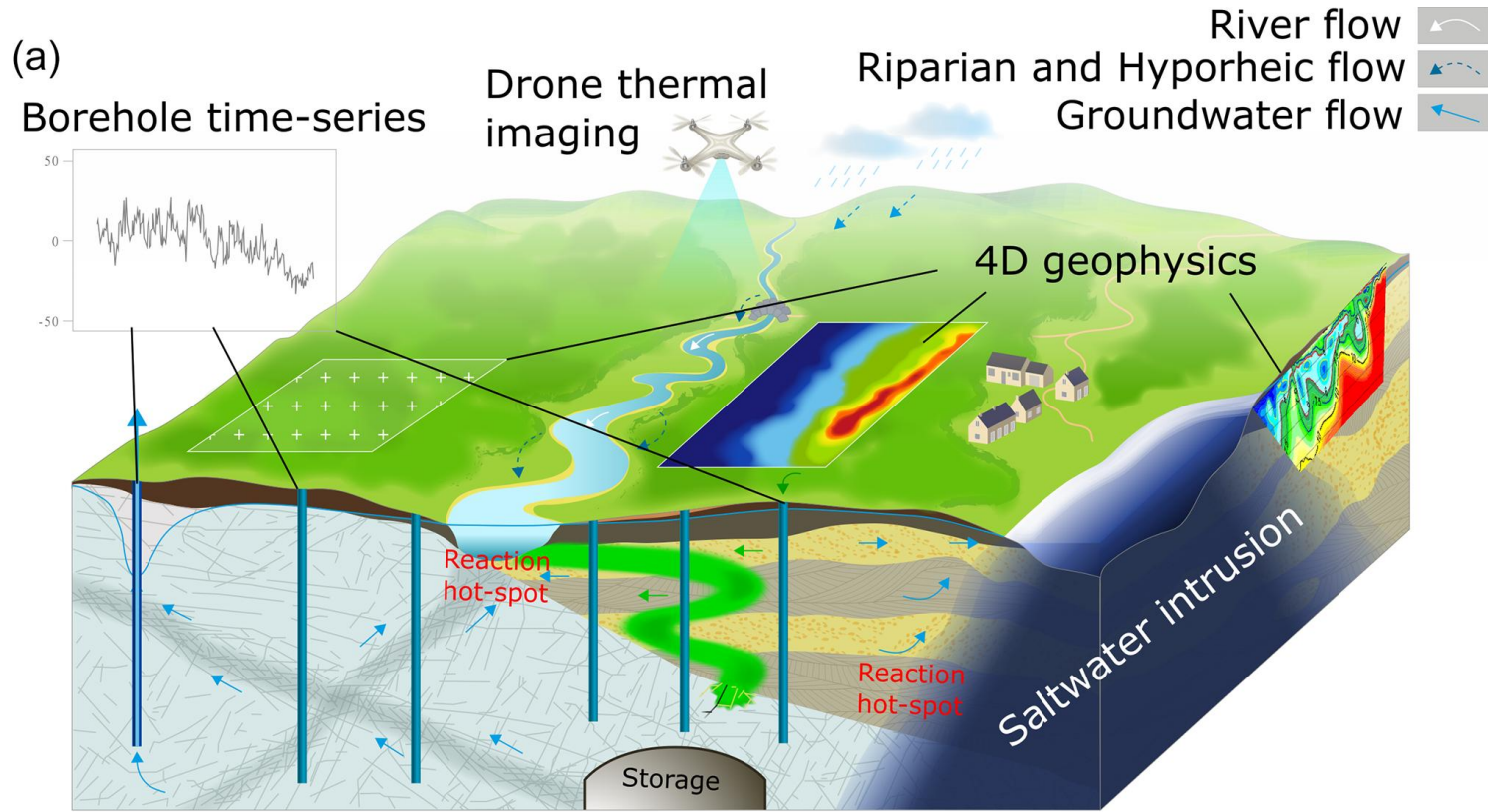


How to reconstruct the pre-volcanic topography in order to map groundwater flows in volcanic structures ?



Geophysical survey:

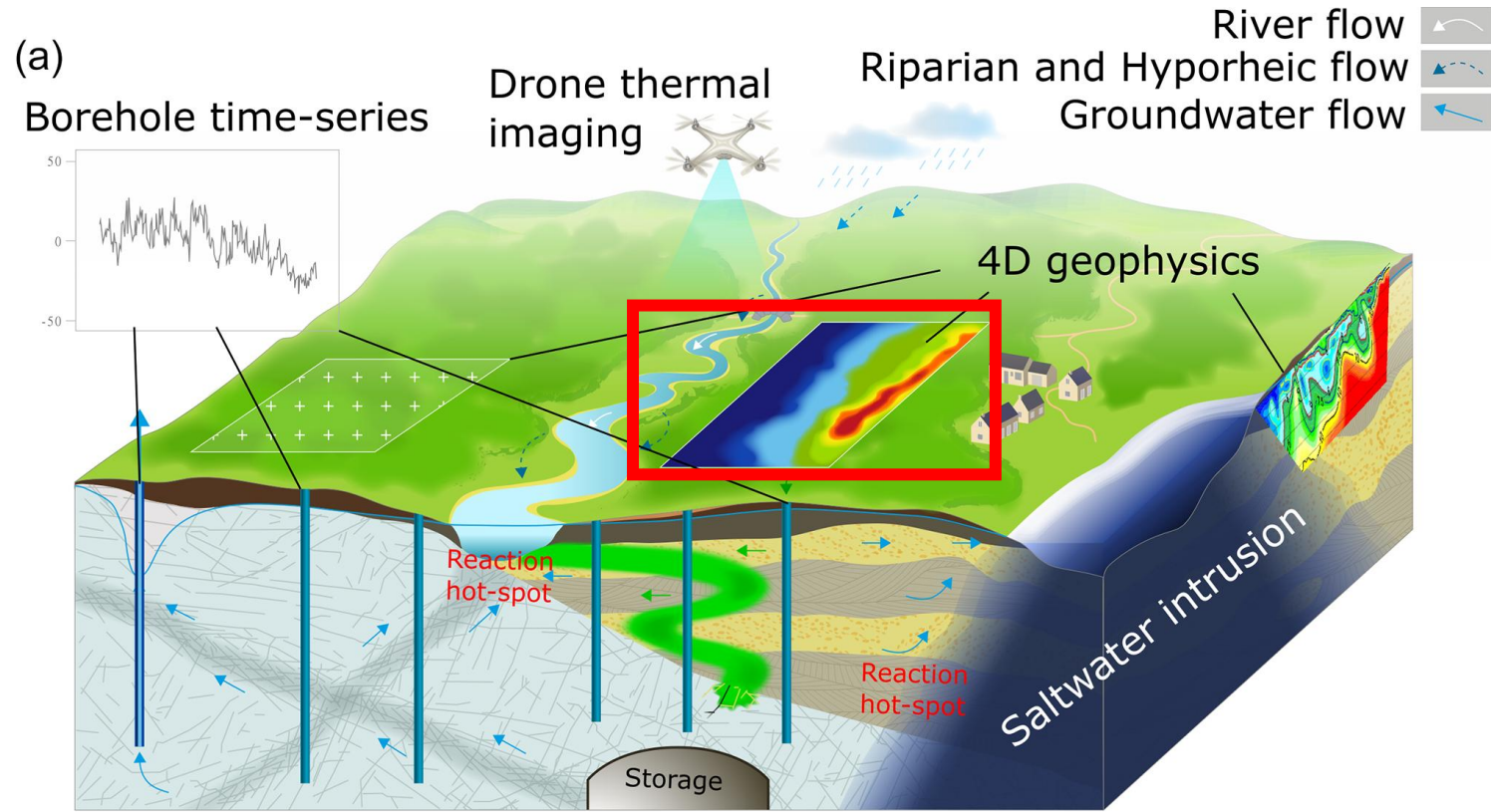
Self potential method (SP)



Hermans et al. (2023)

Geophysical survey:

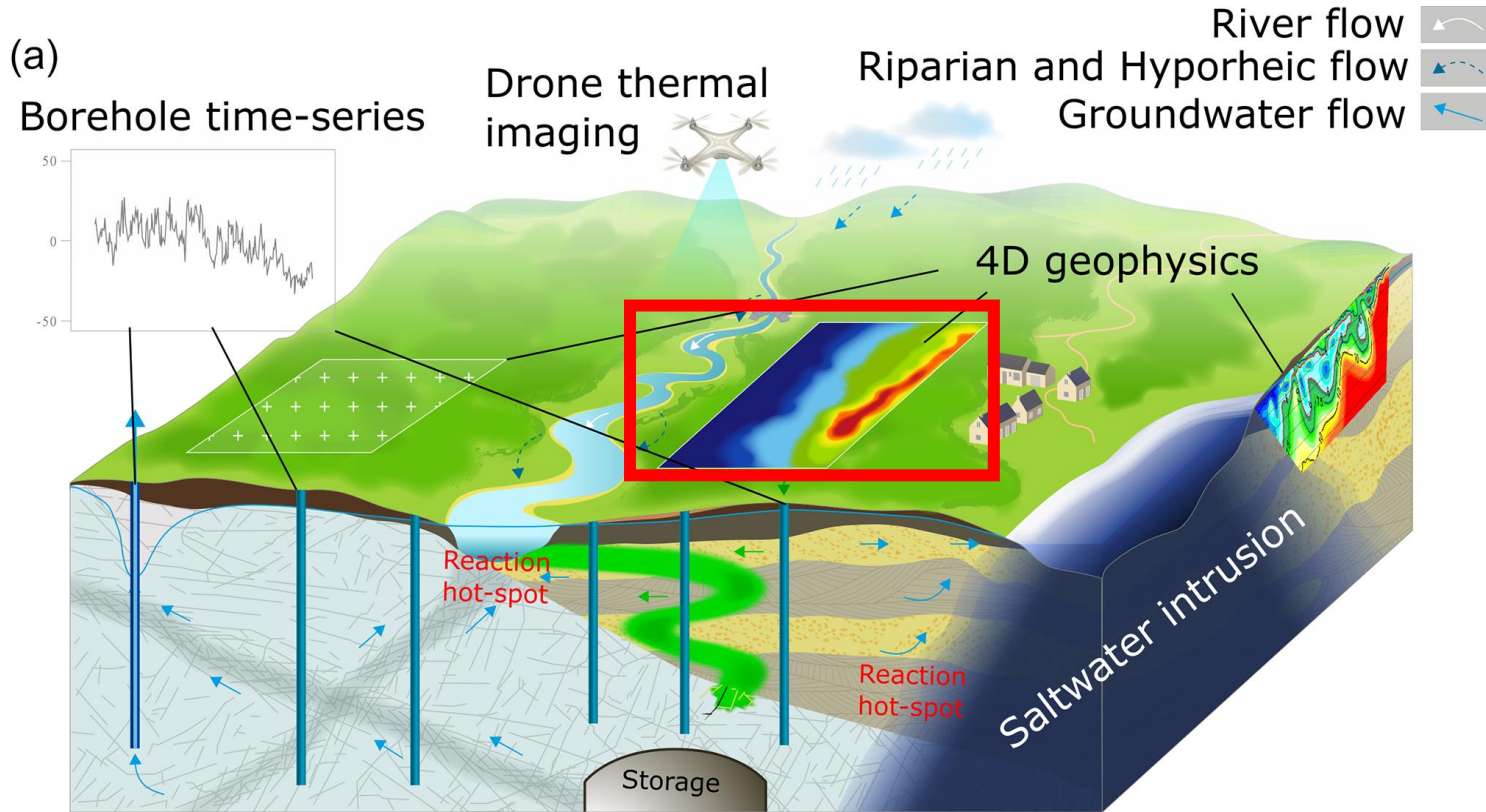
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Hermans et al. (2023)

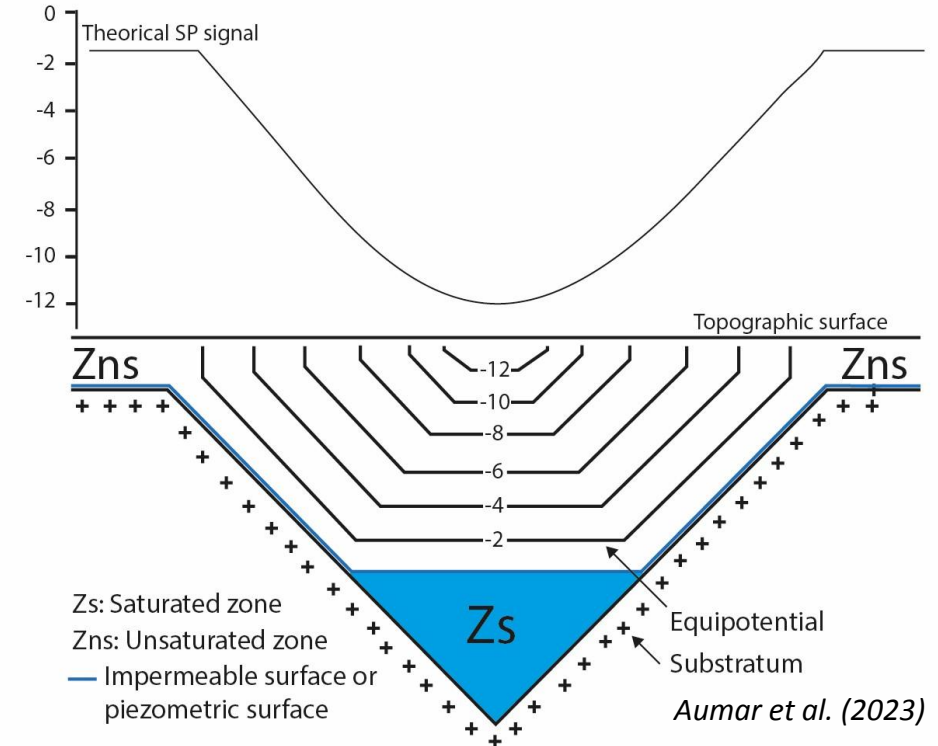
Geophysical survey:

Self potential method (SP)



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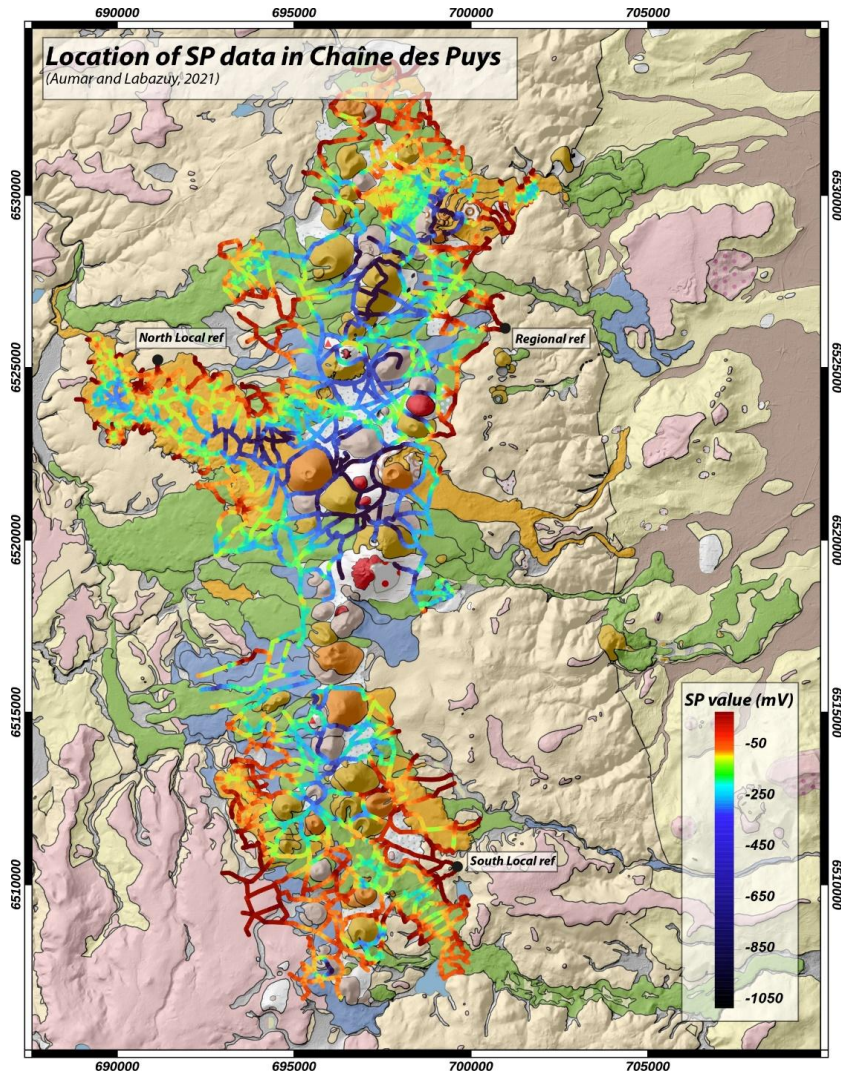
A : Simple paleovalley filling by volcanic formations



- Self potentials correspond to naturally generated potential differences in the subsurface.
- In the Chaîne des Puys, the phenomenon of streaming potential may explain the SP signals.
- **Spatial variations in SP signal are interpreted as fluctuations in bedrock or water table depth.**

Geophysical survey:

Self potential method (SP)



Aumar et al. (2023)

These data can be downloaded in open access on Data OPGC :

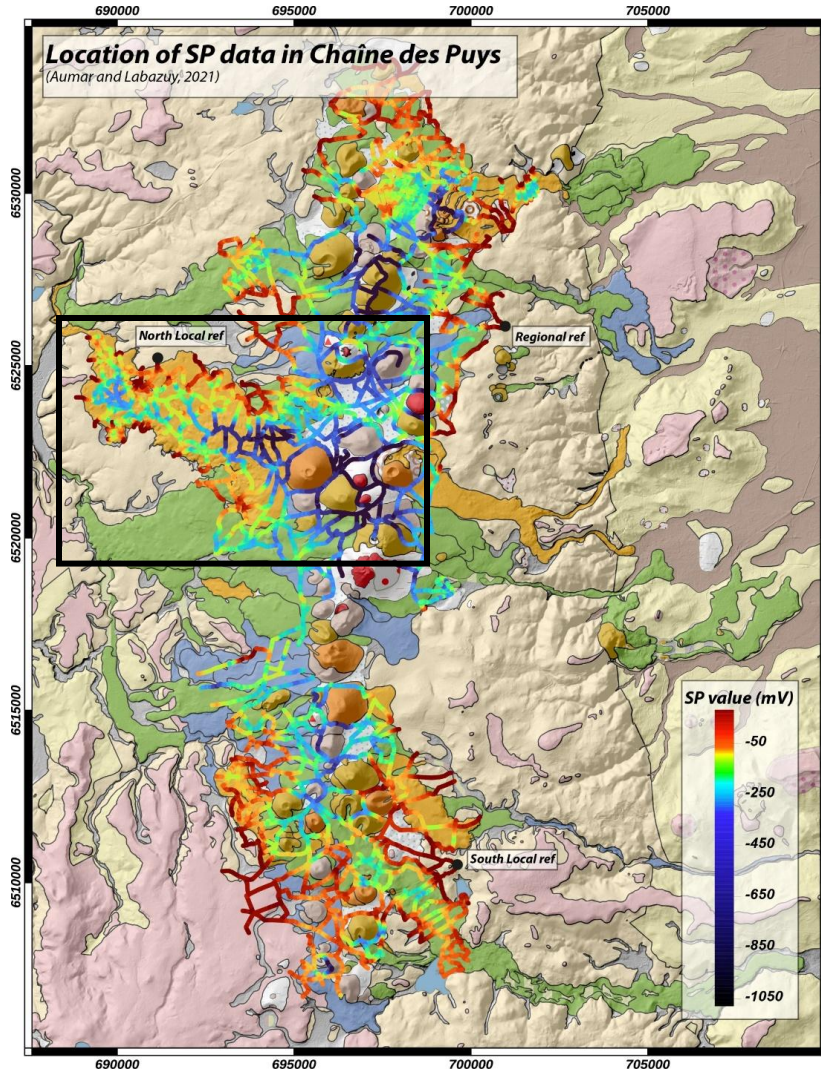
Aumar, C., & Labazuy, P. (2021). *Self Potential database on the Chaîne des Puys [Data set]*. OPGC, LMV. <https://doi.org/10.25519/ZGHC-N543>

These data have been published in a data paper (Data in Brief) :

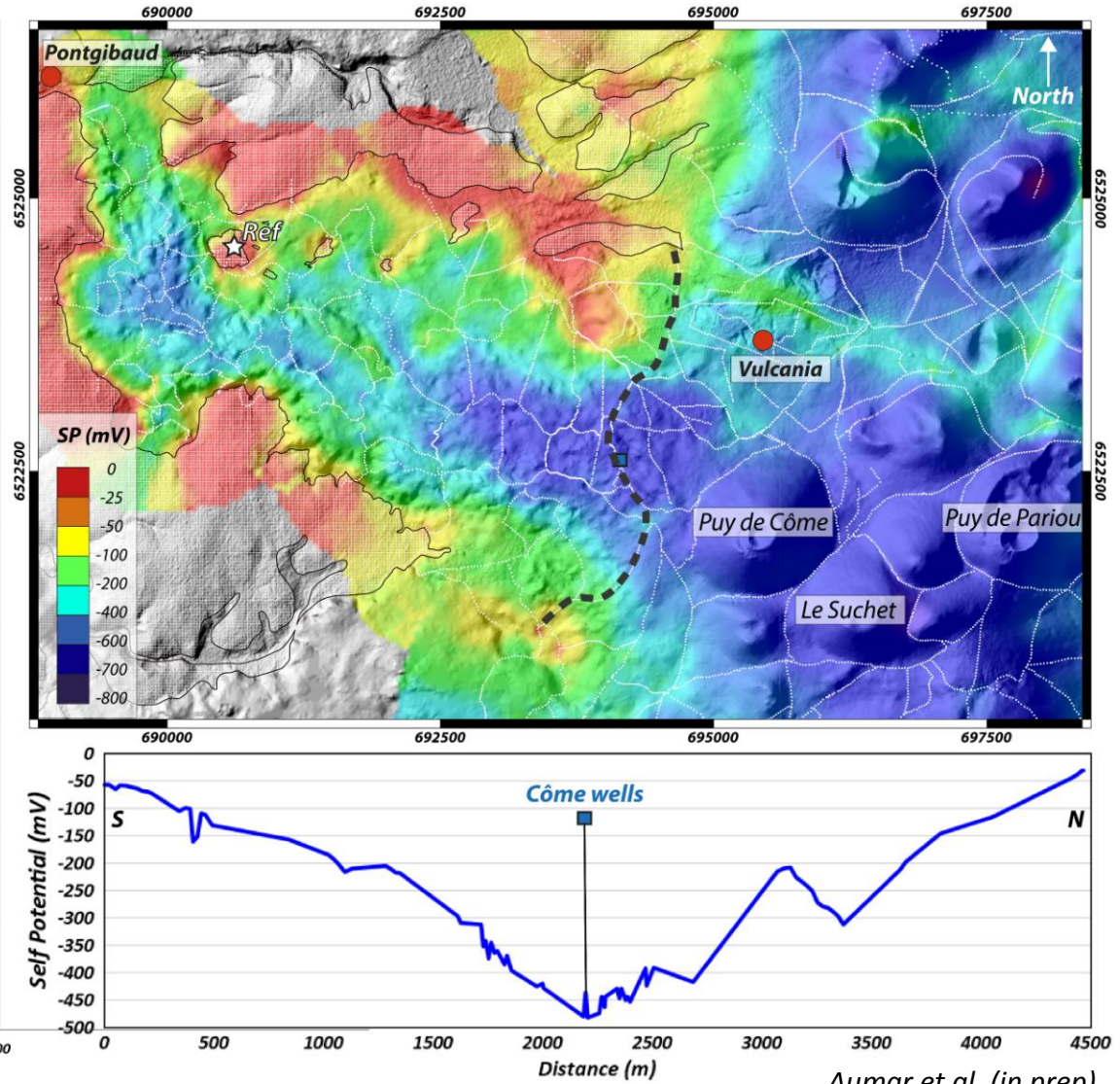
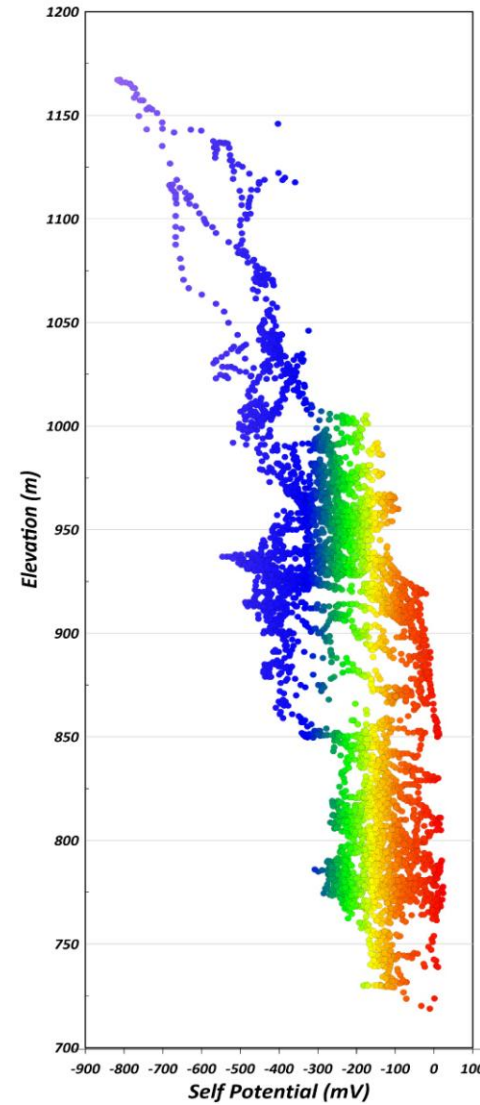
Aumar, C., Labazuy, P., Buvat, S., Delage, E., (2023). *Self-potential dataset for mapping groundwater flow patterns in the Chaîne des Puys (Auvergne, France)* <https://doi.org/10.1016/j.dib.2023.109533>

Geophysical survey:

Self potential method (SP)



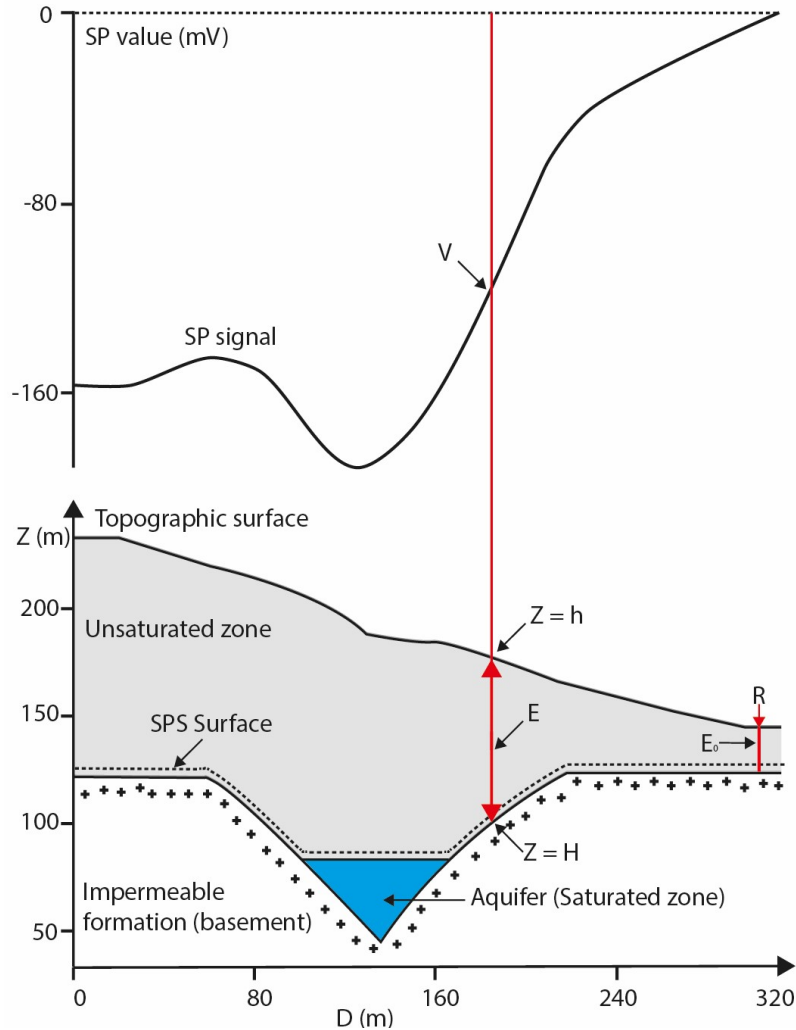
Aumar et al. (2023)



Aumar et al. (in prep)

Geophysical survey:

Self potential method (SP)



In Aumar et al. (2023) according to Aubert et al. (1991)

SPS modeling:

- Semi-empirical modeling based on a linear relationship :

$$Z_{sps}(x, y) = z(x, y) - \frac{V(x, y)}{K}$$

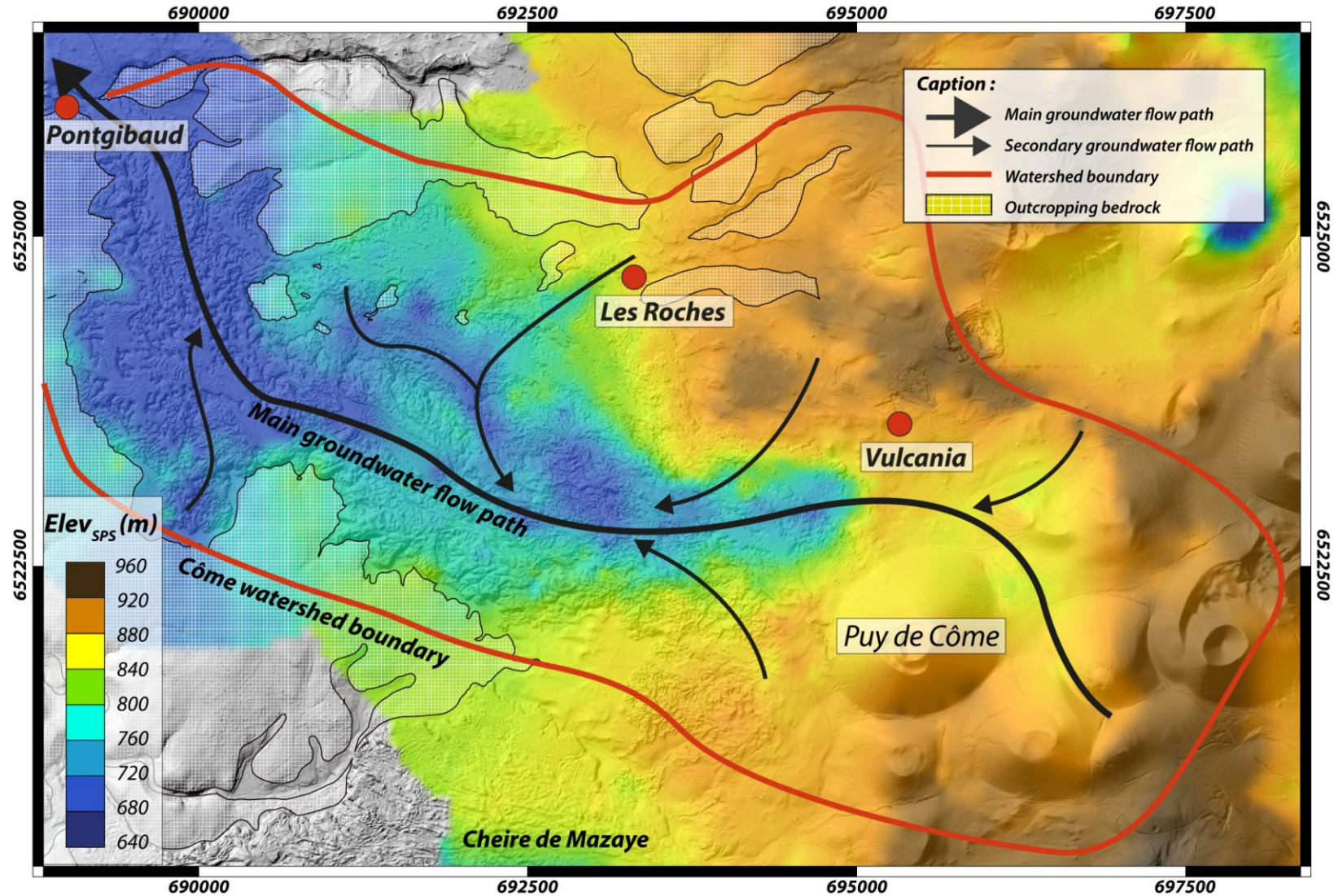
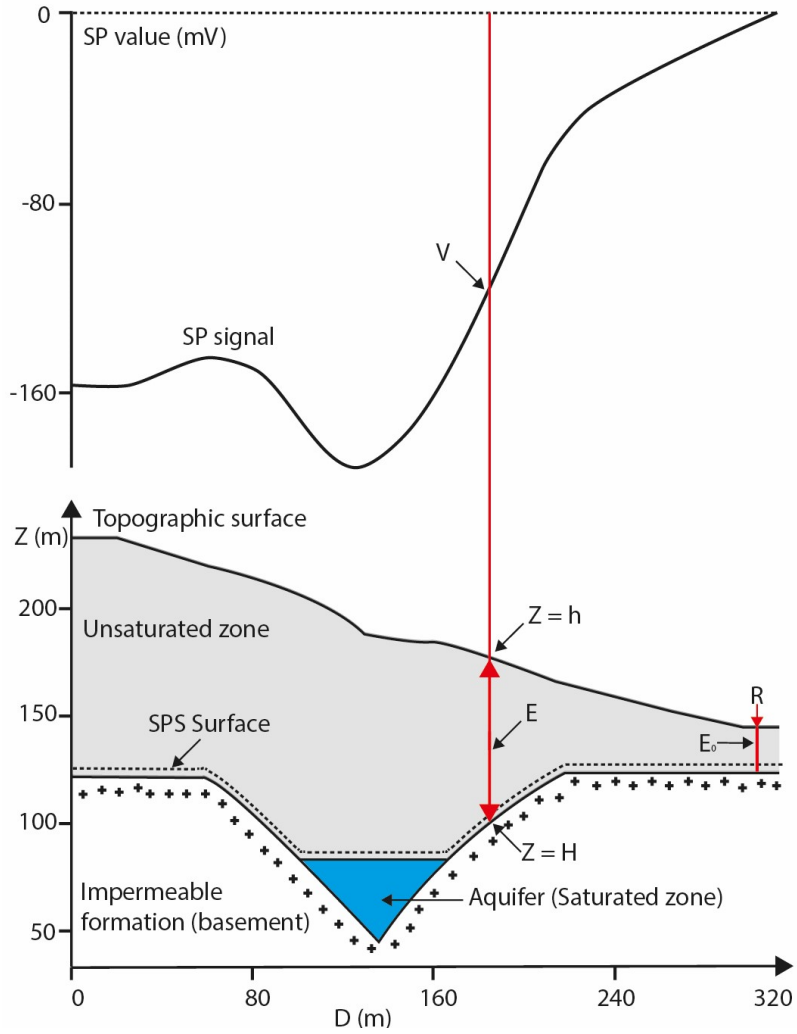
- The SPS surface represents the altitude of the roof of the first conductive terrain, which in the context of the Chaîne des Puys corresponds to :

The bedrock-volcanism interface **OR** The piezometric surface.

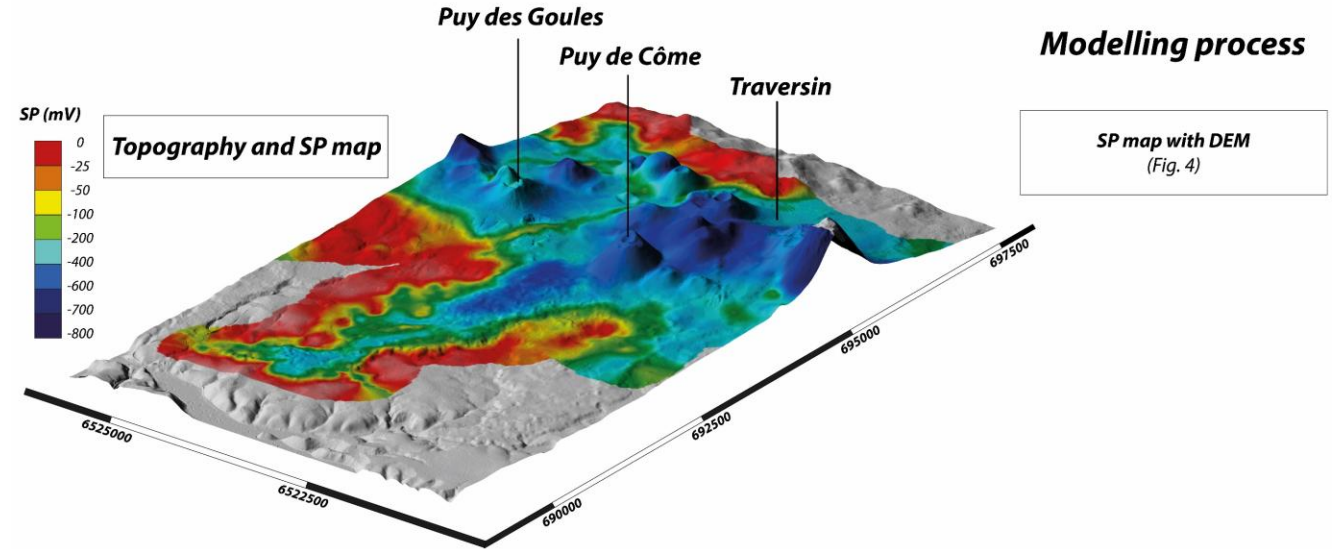
- The K coefficient incorporates the hydrodynamic and geological characteristics of the volcanic pile.

Geophysical survey:

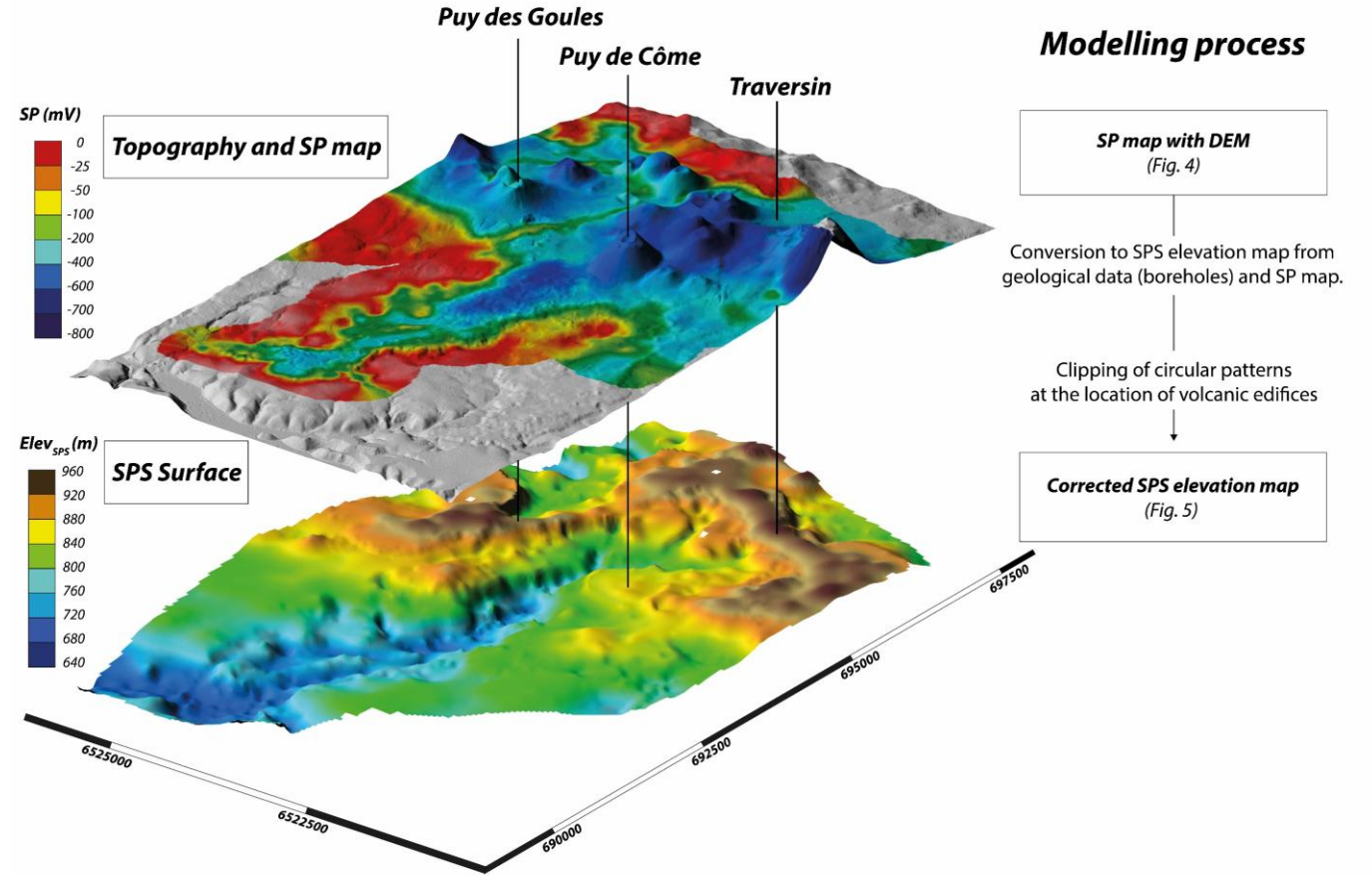
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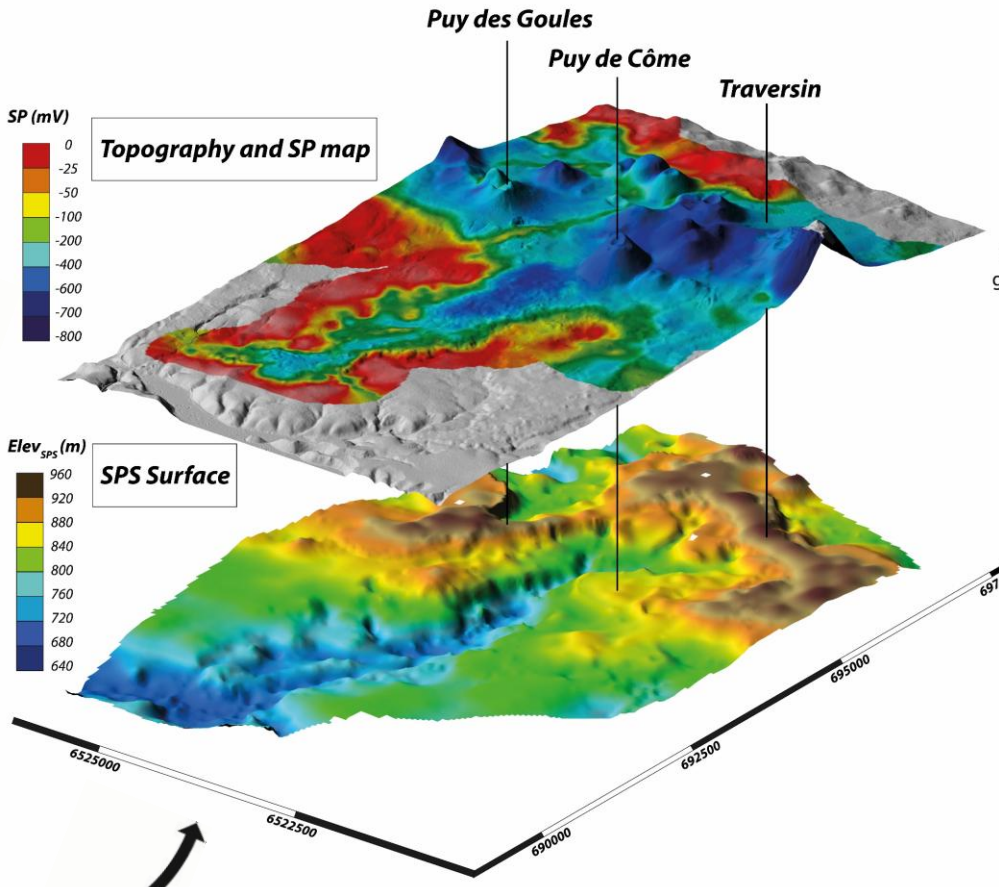
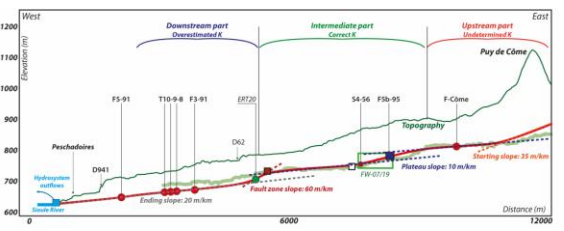
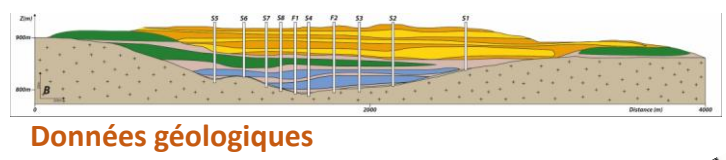
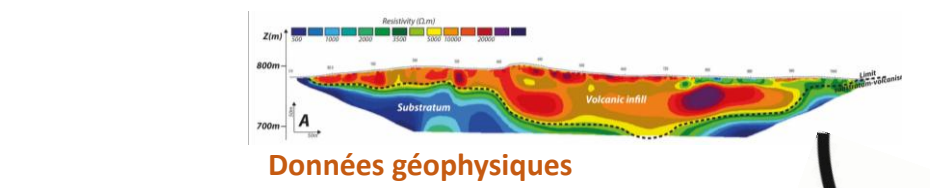
Coupling geophysics and geomorphology:



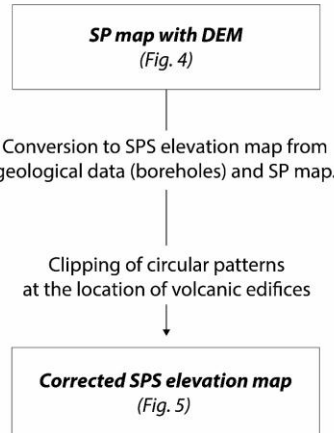
Coupling geophysics and geomorphology:



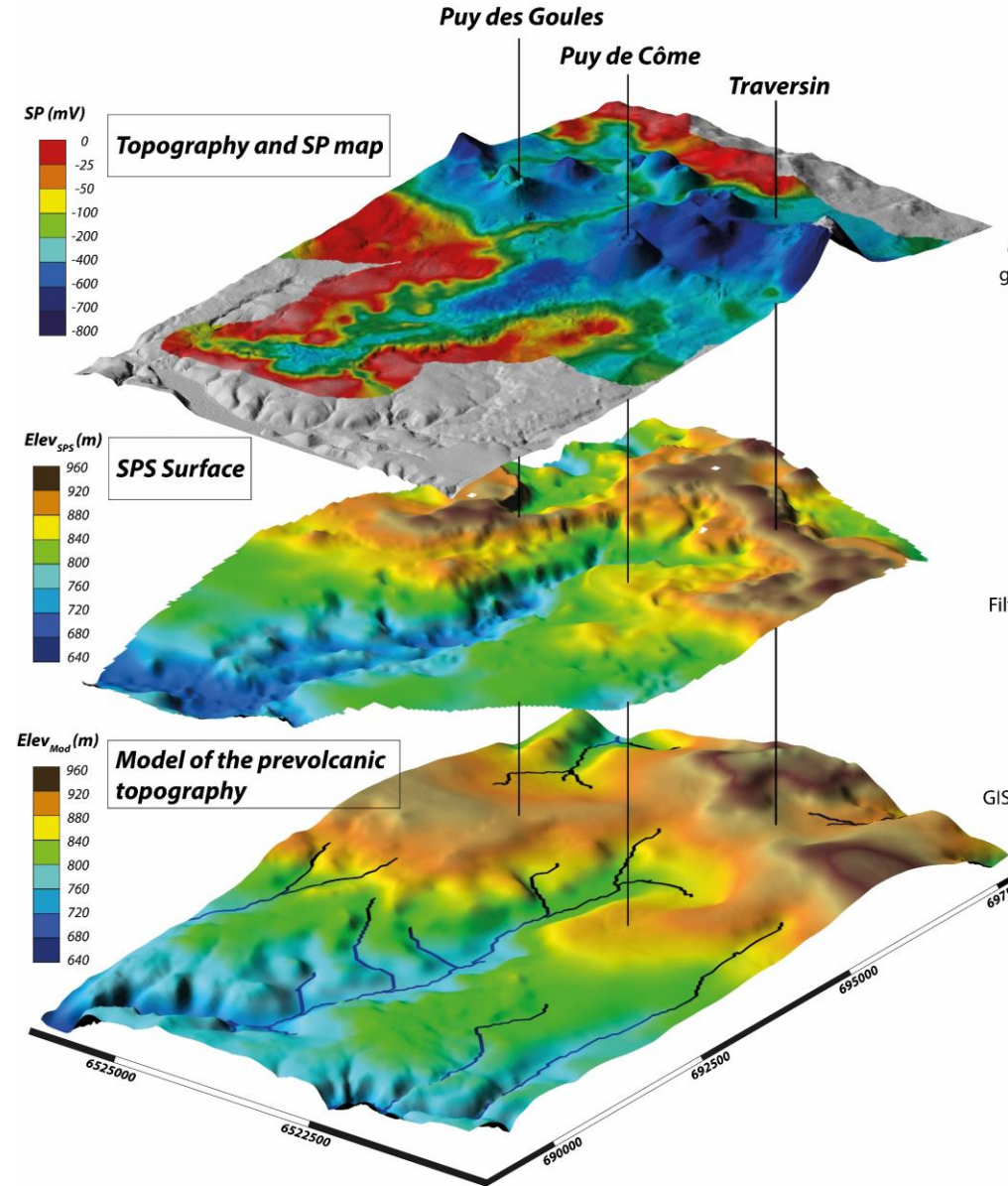
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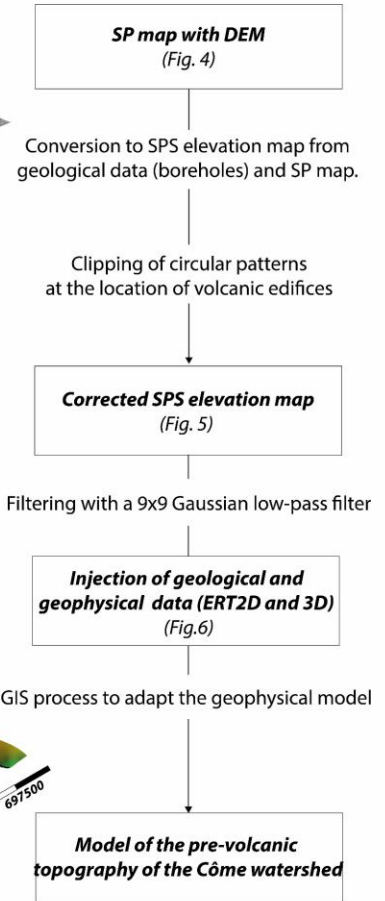
Modelling process



Coupling geophysics and geomorphology:

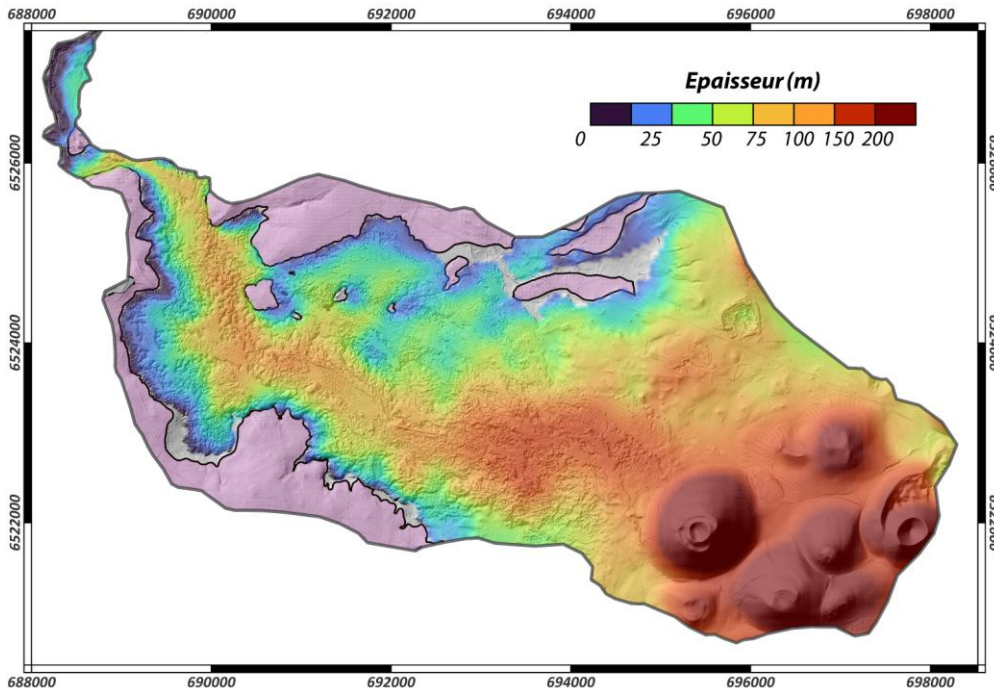


Modelling process

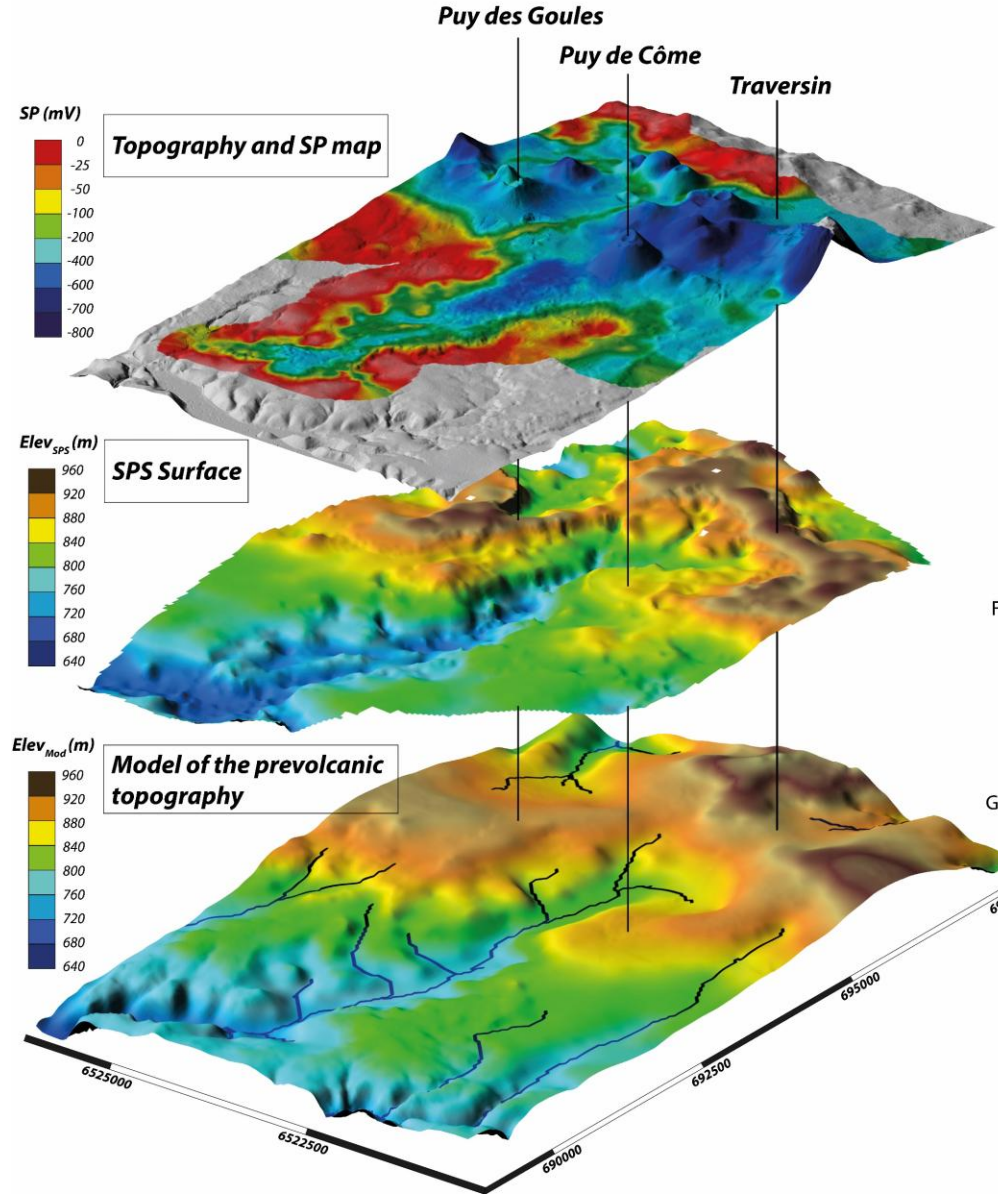


Coupling geophysics and geomorphology:

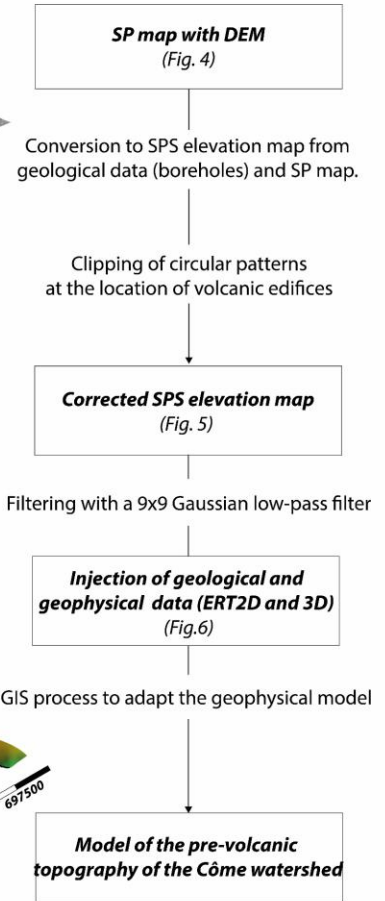
Thickness and volume of volcanic formations



- Volume of volcanic formations: **2,74 km³**
- Volume of water in Côme aquifer: **0,33 km³**
- Renewal time: **20 ans**

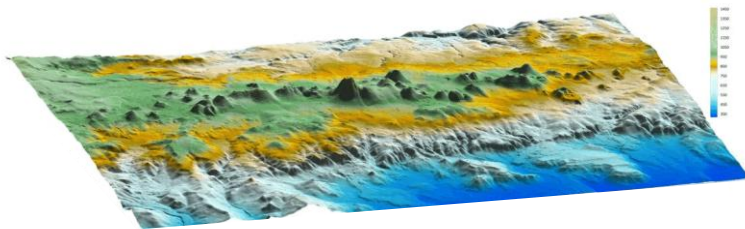


Modelling process



Conclusions

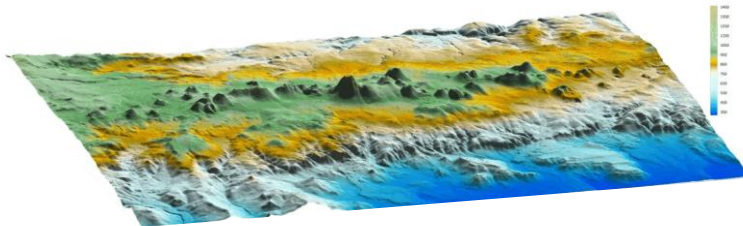
- *Data acquisition on a large scale*
- *With a multi-method approach*
- *Major contribution to the identification of groundwater flow in the Chaîne des Puys watersheds*
- *Useful for water balance, hydrogeological modeling or political decision*



Geological modeling at the volcanic field scale

Conclusions

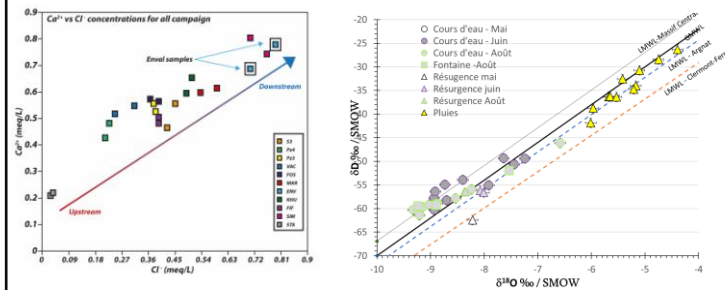
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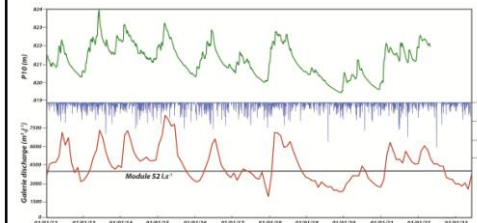
Geological modeling at the volcanic field scale

Crossing methods

- Compare methods to validate hydrogeological functioning
- Estimate water flows and volumes
- Parameterize hydrogeological models for routine use to improve resource management



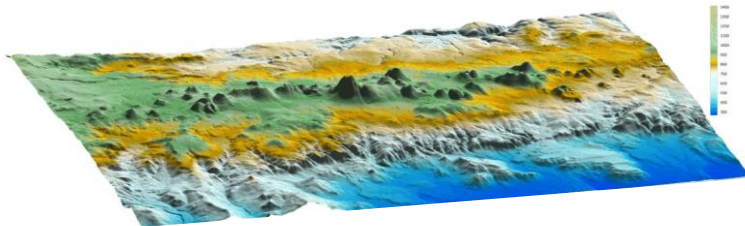
Chemical, isotopic and environmental tracers



Piezometric and flow rate data

Conclusions

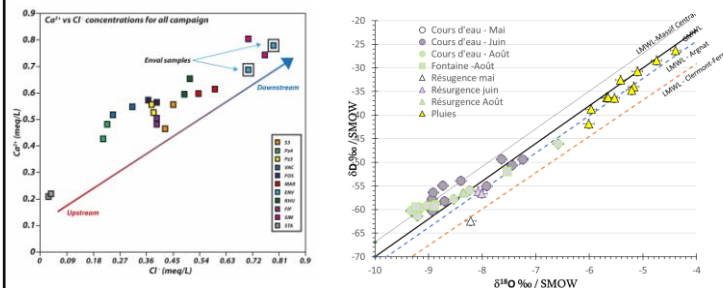
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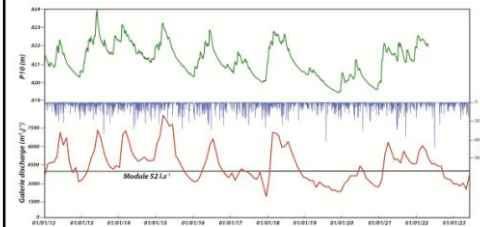
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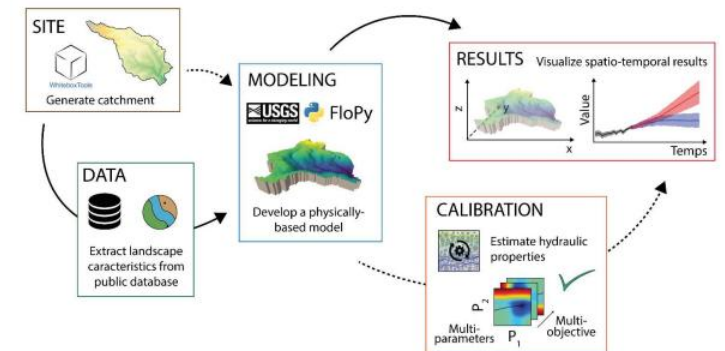
Chemical, isotopic and environmental tracers



Piezometric and flow rate data

Hydrogeological modeling

- Integrate all existing data (volume, residence time, hydrological monitoring, rainfall, etc.)
- Model operation at watershed scale (permeability/porosity calibration)
- Projection based on short- and medium-term climate scenarios for operational purposes



Merci pour votre attention

