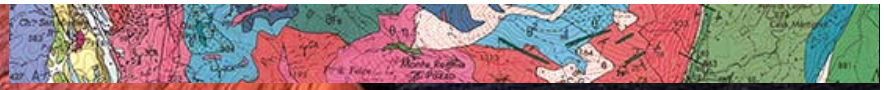

# MODELING GYPSUM THICKNESS : APPLICATION IN EVALUATION OF COLLAPSE HAZARD IN PARIS AREA


**BOURGINE Bernard and BADINIER Guillaume (BRGM)**

**KREZIAK Charles (CEREMA)**

**CAPOU Olivier (ADEME)**


INSTITUT CARNOT brgm

Géosciences pour une Terre durable

brgm

# OVERVIEW

## INTRODUCTION (PROBLEMATIC / OBJECTIVES)

## GEOLOGICAL CONTEXT

## METHODOLOGY

## RESULTS - CONCLUSION

# INTRODUCTION

## PROBLEMATIC : Gypsum dissolution can induce collapses

ORIGIN of dissolution : natural or due to human activities (leak of water in the city water network or during/after a well drilling, ….) :





HAZARD is higher when :

- Thickness is important
- Gypsum is near the surface

# INTRODUCTION

**OBJECTIVE** : **Edit regulation maps for the French Ministry of Ecological Transition (MTES)**

WHY ? : geothermal drilling activities are developing in France ➡ French regulation for little or moderate drillings (“Géothermie de Minime Importance”) has been revised in 2015.

Geothermal drilling (BRGM - Orléans)

# INTRODUCTION

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WHY ? : geothermal drilling activities are developing in France ➡ French regulation for little or moderate drillings (“Géothermie de Minime Importance”) has been revised in 2015.

FUNDING INSTITUTIONS (except BRGM) :

- The **DRIEE Ile-de-France** (Environment and Energy Region and Interdepartmental Direction)
- The **ADEME** (French Environment and Energy Management Agency)

IMPLICATED ORGANISM :

- The **CEREMA** (Risk and Environment Study Center)

# INTRODUCTION

**OBJECTIVE** : **Edit regulation maps for the French Ministry of Ecological Transition (MTES)**

DELIVERABLES :

- **1 - Gypsum thickness maps** (this work) for 3 depth intervals : 10-50, 10-100 and 10-200m

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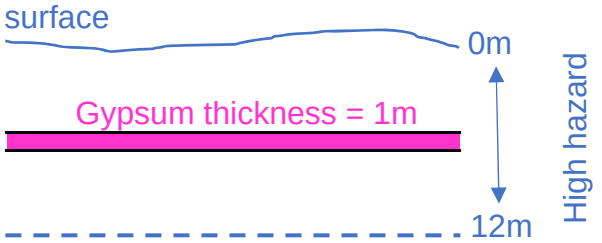
- **1 - Gypsum thickness maps** (this work) for 3 depth intervals : 10-50, 10-100 and 10-200m

- **2 - Hazard maps** : INERIS* methodology :

*** INERIS :** RISk and industrial Environment National Institute

High hazard if : $\frac{\text{gypsum thickness}}{\text{depth to surface}} > 1/12$



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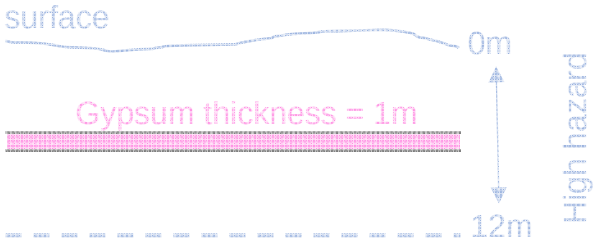
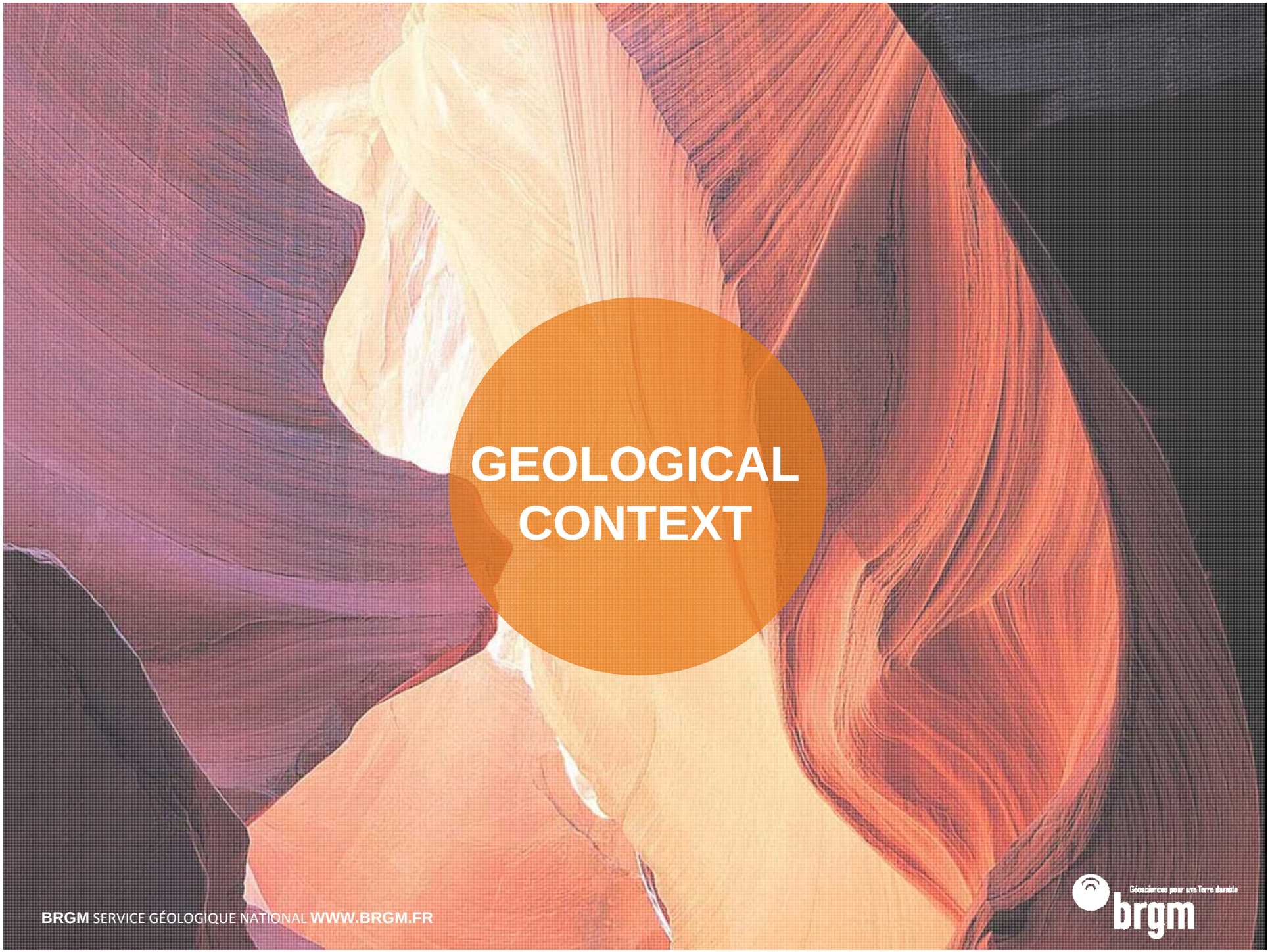


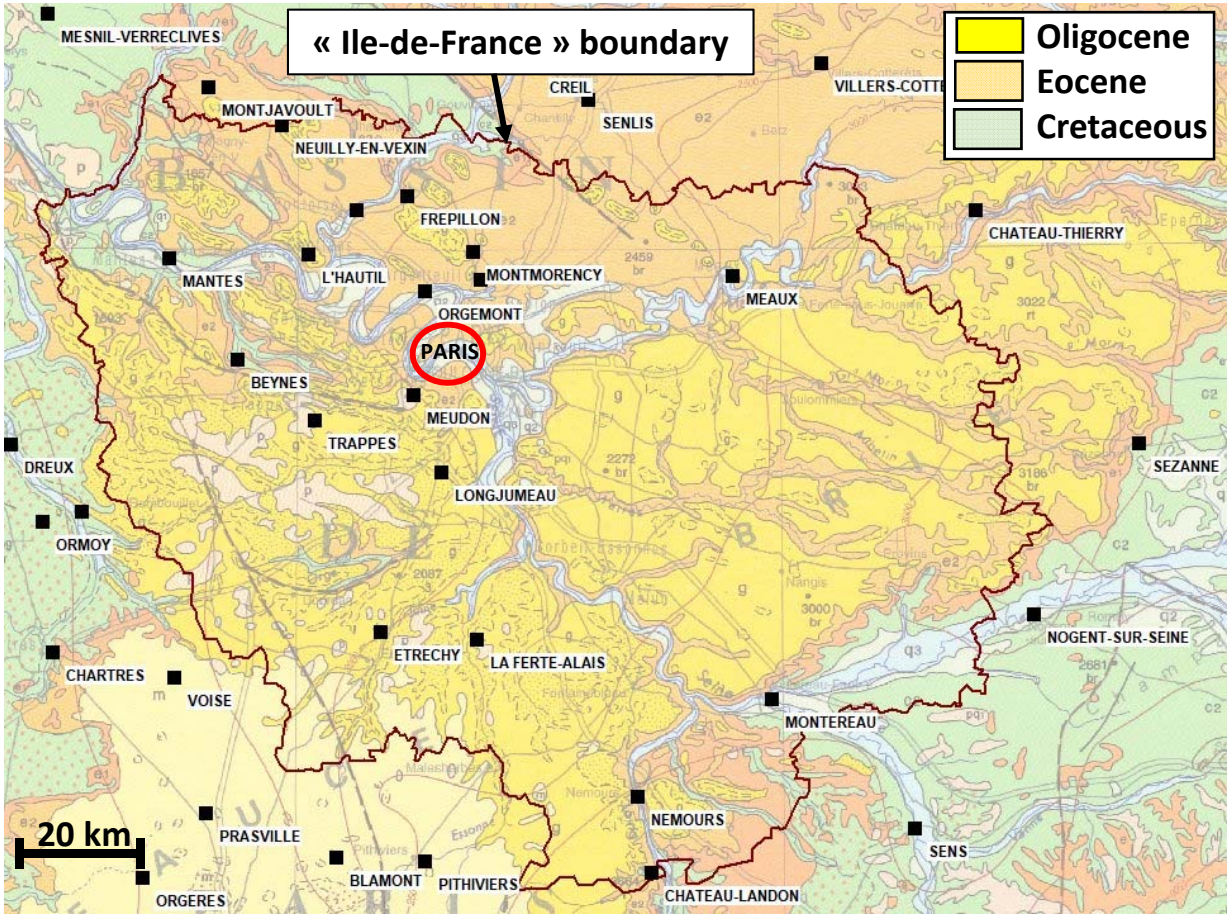

- **3 - Regulation maps** : addition of gypsum hazards maps + other hazards due to geothermal drillings (aquifers connection, other collapses, etc…) : not yet published


GEOLOGICAL
CONTEXT

# GEOLOGICAL CONTEXT

"Ile-de-France" (12000 km²) : - Located in the Paris basin

- Outcrops of Quaternary to Cretaceous formations

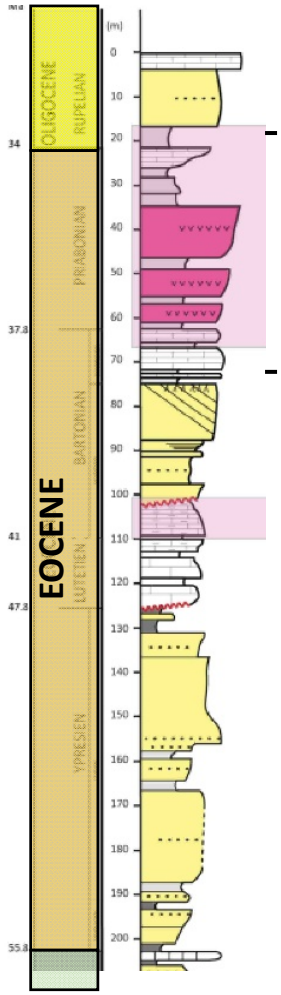


# GEOLOGICAL CONTEXT

Gypsum in “Ile-de-France” : mainly in 2 set of Eocene formations :

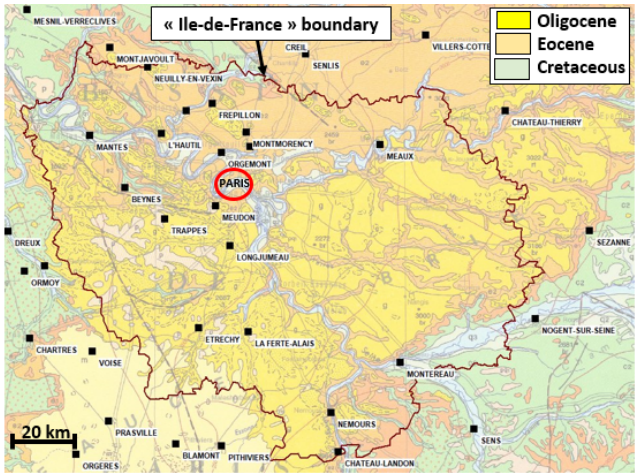
=> **LUDIAN**

**Synthetical Log (Briais, 2015)**




ARGILES VERTES (Sannoisian)
MARNES DE PANTIN (Ludian)
MARNES BLEUES ARGENTEUIL (Ludian)
MASSES DE GYPSE (Ludian and Marinesian)
MARNES A PHOLADOMYA (Ludian)

≈ **LUDIAN**
**(lagunal deposits)**



# GEOLOGICAL CONTEXT

Gypsum in “Ile-de-France” : mainly in 2 set of Eocene formations :

=> **LUDIAN** and **LUTETIAN/BARTONIAN**

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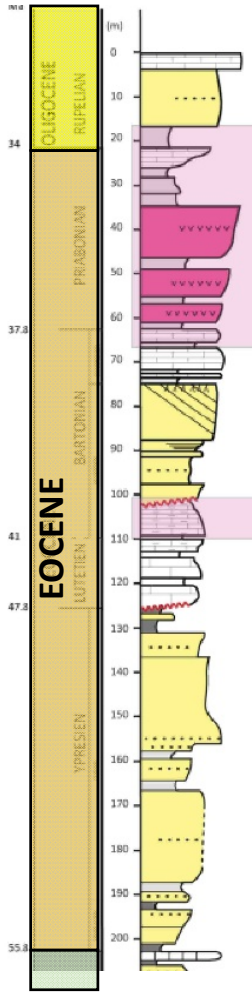


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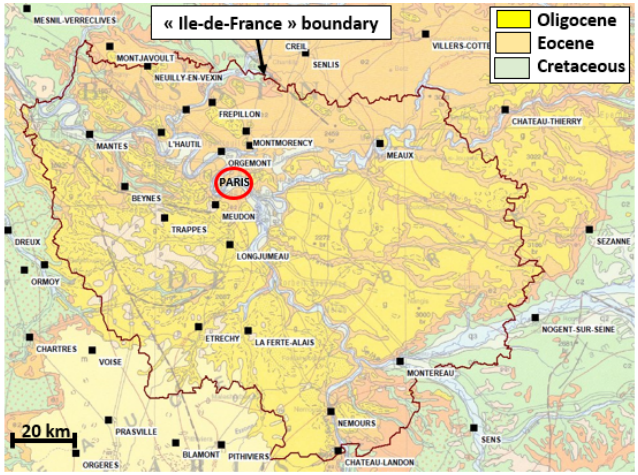
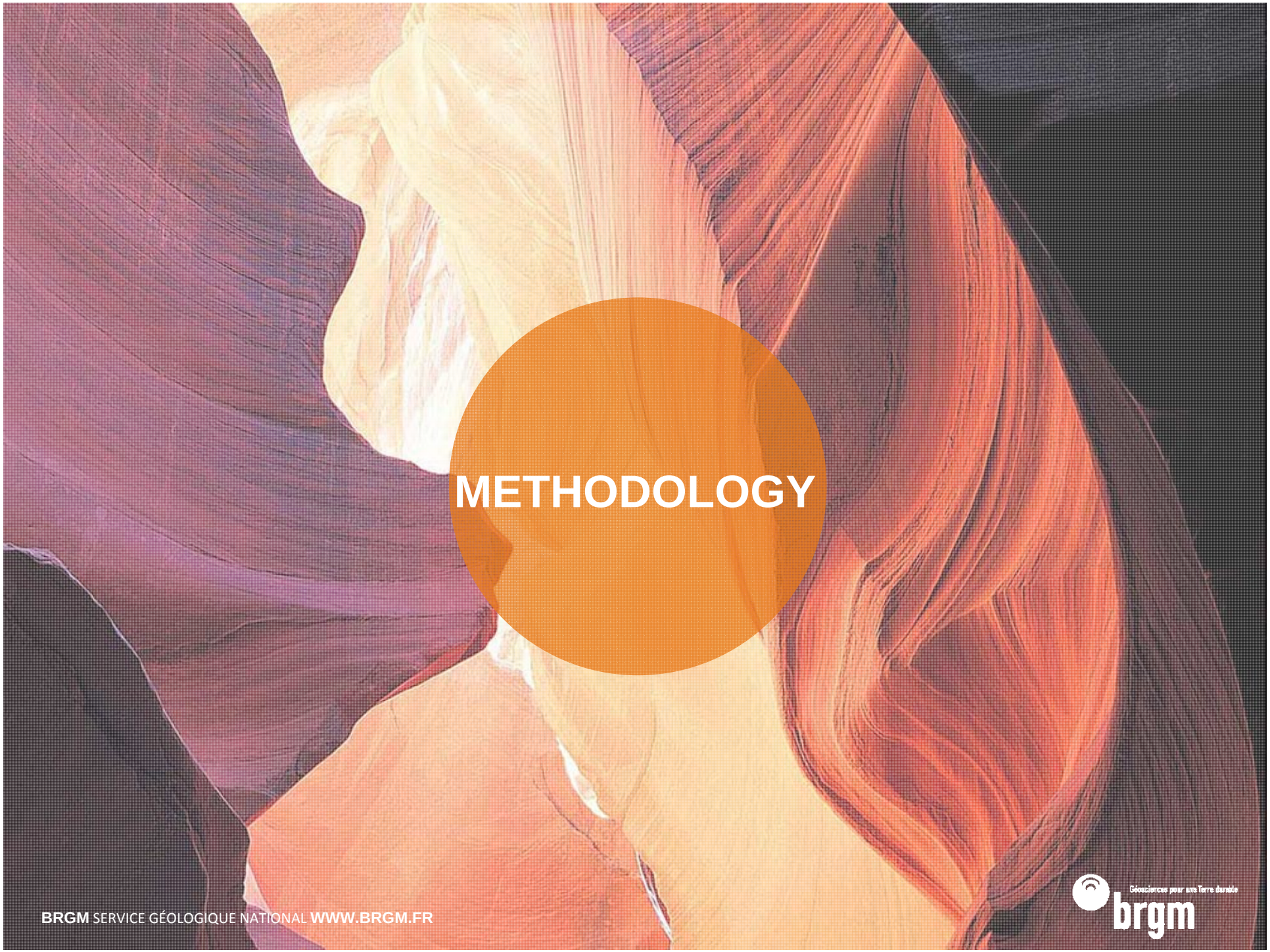
MARNES ET CAILLASSES

**LUTETIAN/BARTONIAN (lagunal deposits)**




METHODOLOGY

# METHODOLOGY : 4 STEPS

## STEP 1: DEFINE REFERENCE HOLES DATASET

➔ 300 high quality holes (PhD Thesis, Briais, 2015)

➔ First 3D geological model of gypsiferous formations

# METHODOLOGY : 4 STEPS

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**STEP 2: INCREASE REFERENCE HOLES DATASET BY ADDING PROGRESSIVELY OTHER AVAILABLE HOLES**

➔ **After cross validation / reinterpretation of other available holes (5 000)**

➔ **Improved stratigraphic 3D model**

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**STEP 3: COMPUTE GYPSUM THICKNESS ALONG HOLES**

➔ **Select gypsum facies between top/base of gypsiferous layers**

➔ **Cumulate thicknesses in each depth interval**

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➔ Cumulate thicknesses in each depth interval

**STEP 4: INTERPOLATE GYPSUM THICKNESS**

**➔ Thickness maps for each layer and for each depth intervals**

# METHODOLOGY : 4 STEPS

## STEP 1: DEFINE REFERENCE HOLES DATASET

## STEP 2: INCREASE REFERENCE HOLES DATASET BY ADDING PROGRESSIVELY OTHER AVAILABLE HOLES

## STEP 3: EXTRACT GYPSUM OCCURENCES

## STEP 4: INTERPOLATE GYPSUM THICKNESS

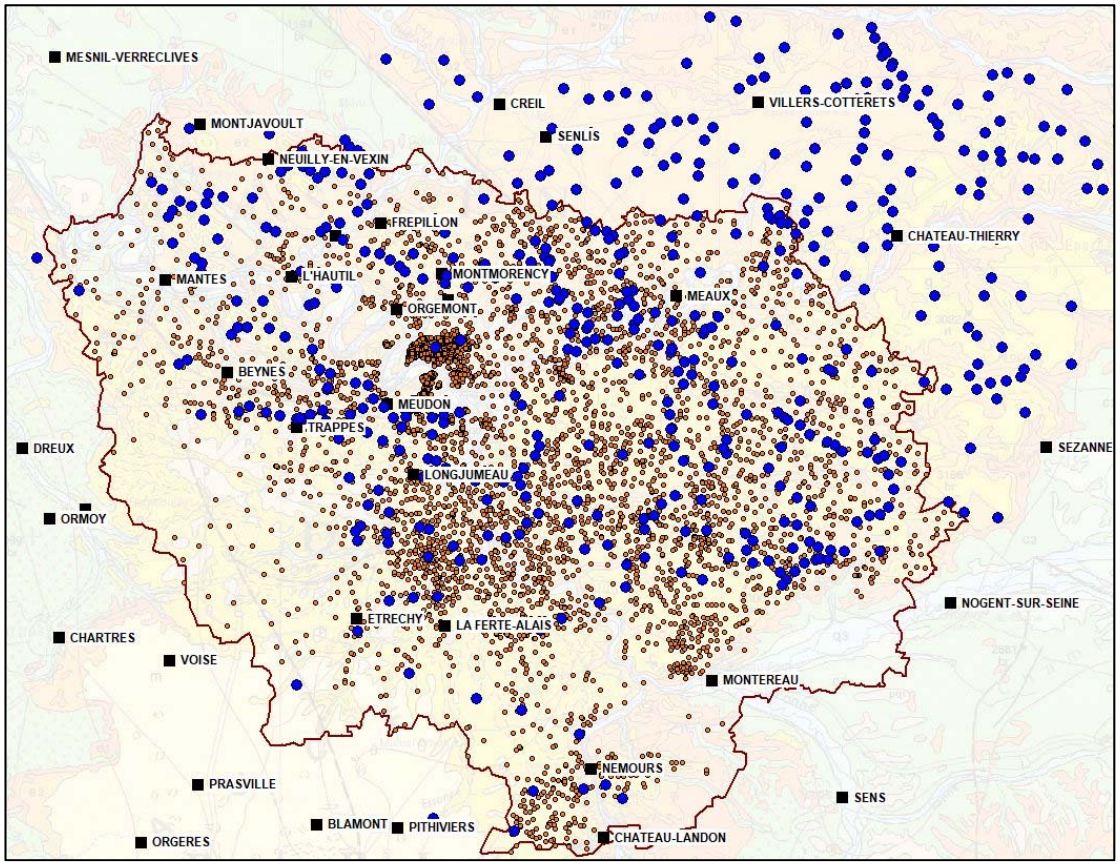
**GDM® software (BRGM)**

- Holes database management
- Geostatistical analysis, interpolation
- Automatic map/cross sections showing inconsistencies
- 1D/2D/3D view
- Building 3D model

# METHODOLOGY

## STEP 1: DEFINE REFERENCE HOLES DATA SET

- 300 high quality drill holes (with Gamma-Ray log) in IDF




**Reference holes (PhD Briais, 2015)**

**Other available wells to test (5000)**

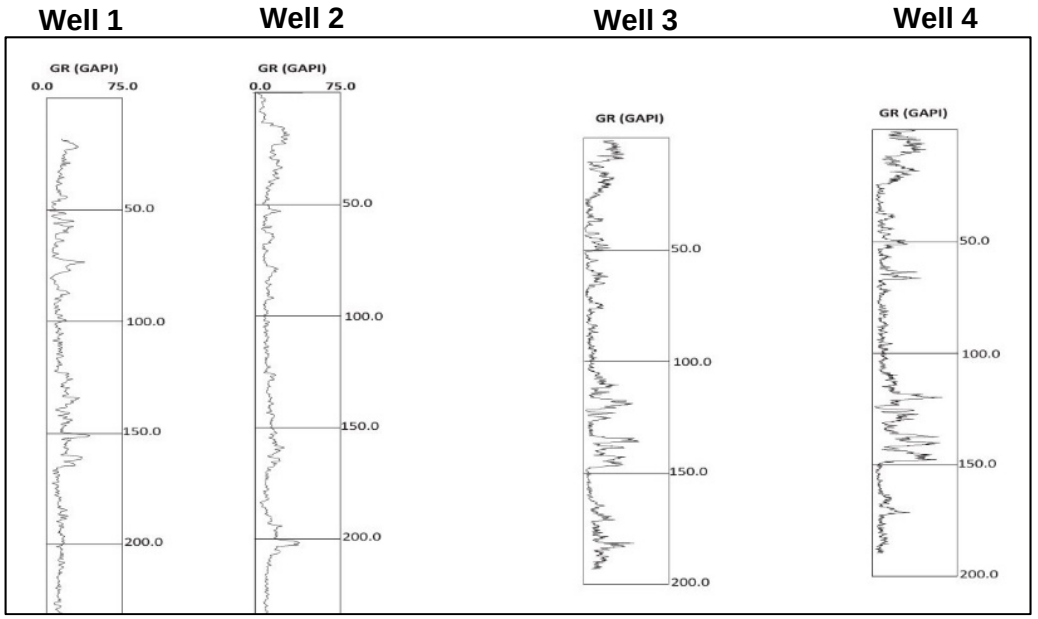
# METHODOLOGY

## STEP 1: DEFINE REFERENCE HOLES DATA SET

- 300 high quality drill holes (with Gamma-Ray log) in IDF
- Sequence stratigraphy concepts *(Briais 2015, Phd thesis) :*

**GAMMA-RAY CORRELATIONS**

**(not lithologic approach) :**



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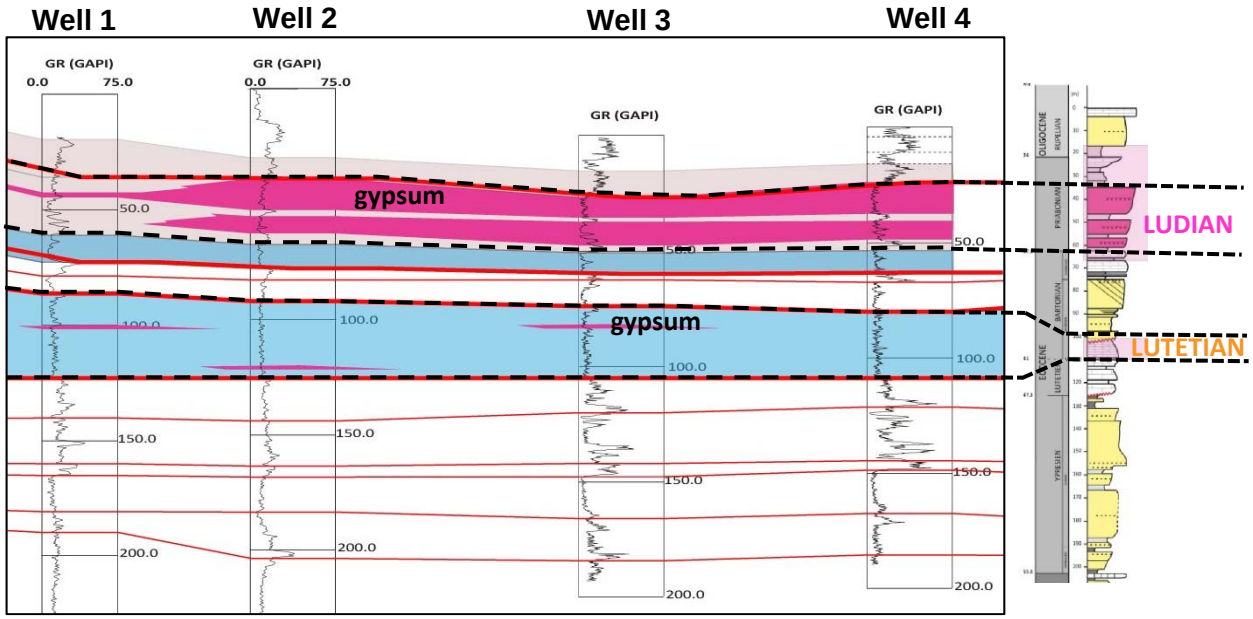



**TOP AND BASE INTERPRETATION**

**geostats**

**3D MODEL** of reference geological surfaces, including top and base of Ludian and Lutetian formations

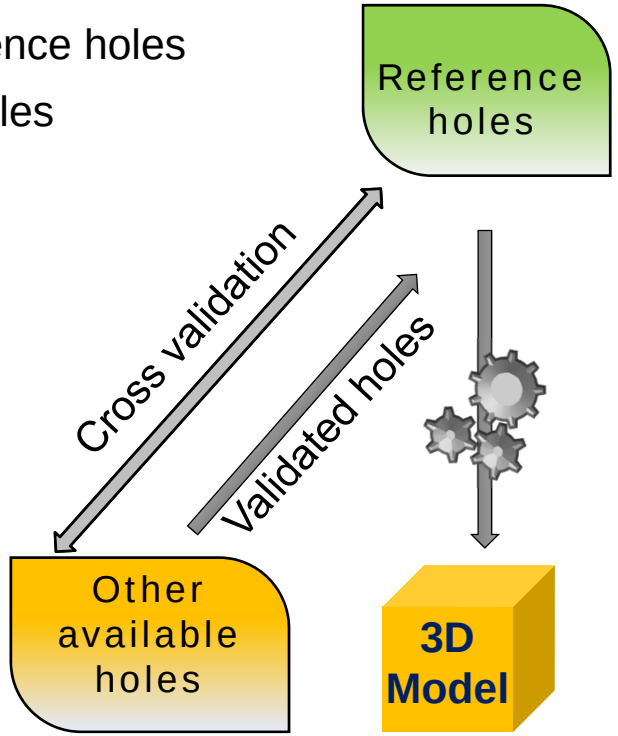
*("LOGISEQ" methodology – BRGM : Bourgine et al., 2017)*

# METHODOLOGY

## STEP 2: INCREASE REFERENCE HOLES DATASET BY ADDING PROGRESSIVELY OTHER AVAILABLE HOLES

***Iterate following steps:***

- Geostatistical cross validation of “other available holes” against “reference holes”
- “Other available holes” re-interpreted
- Validated holes added to reference holes
- 3D model updated with new holes




*Bourgine et al., 2017*

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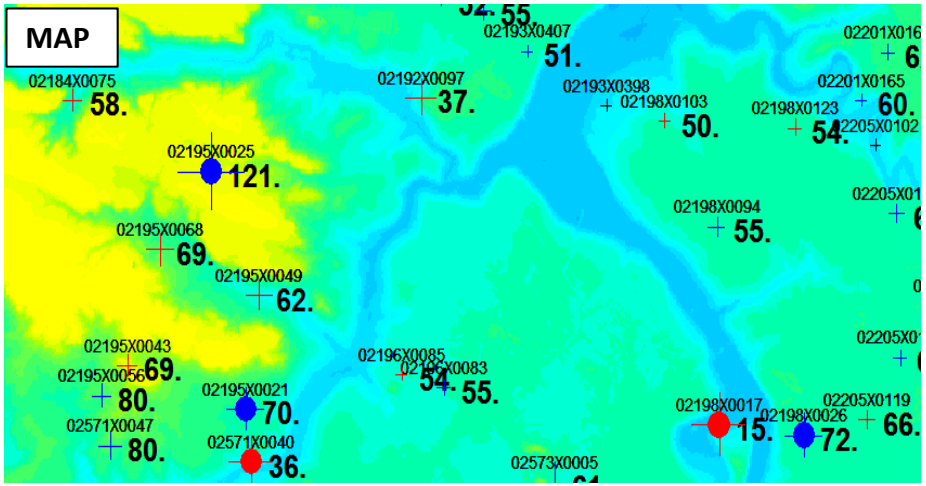
- 3D model updated with new holes

***Results***

- 400 re-interpreted holes
- 4600 consistent holes
- Updated model of top and base of Ludian and Lutetian formations.

# METHODOLOGY

## STEP 2: MAP & CROSS SECTIONS HIGHLIGHTING HOLES TO BE CHECKED




Elevation of the top of Ludian :

- « Too HIGH » compared to the model
- « Too LOW » compared to the model

**GDM Software (BRGM)**

# METHODOLOGY

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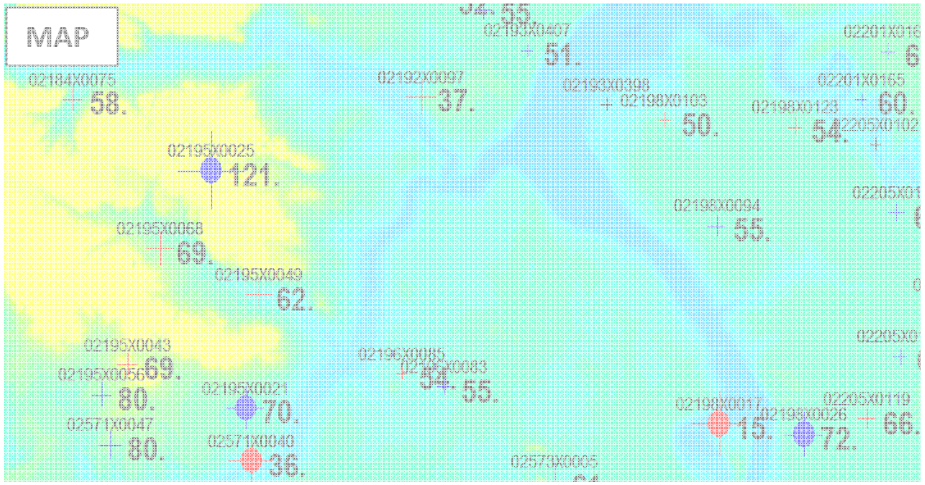


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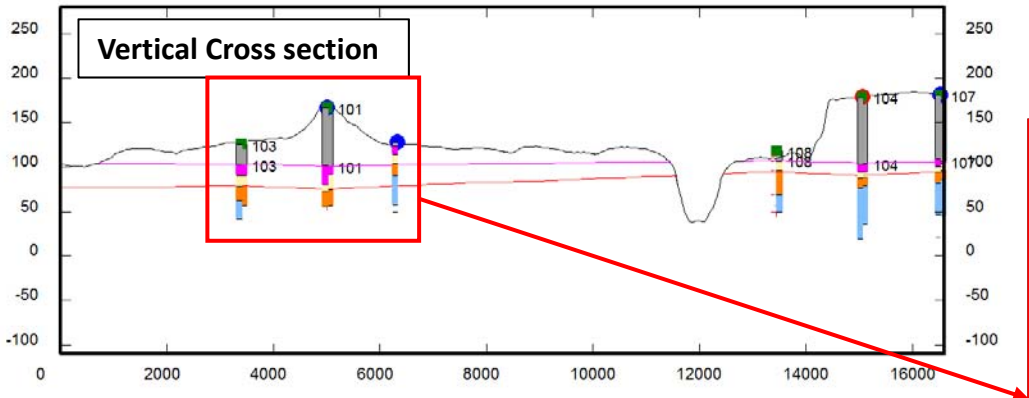
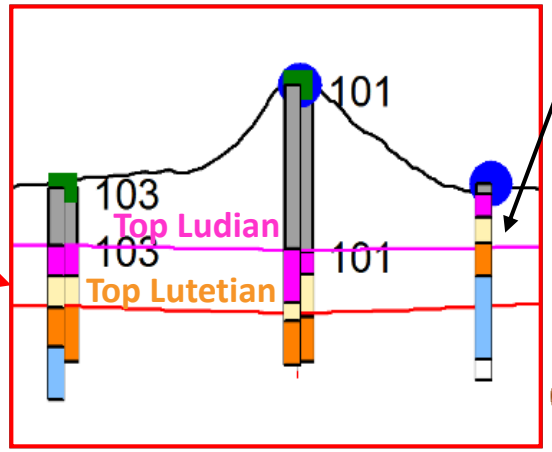



« Suspicious hole »
→ to be verified



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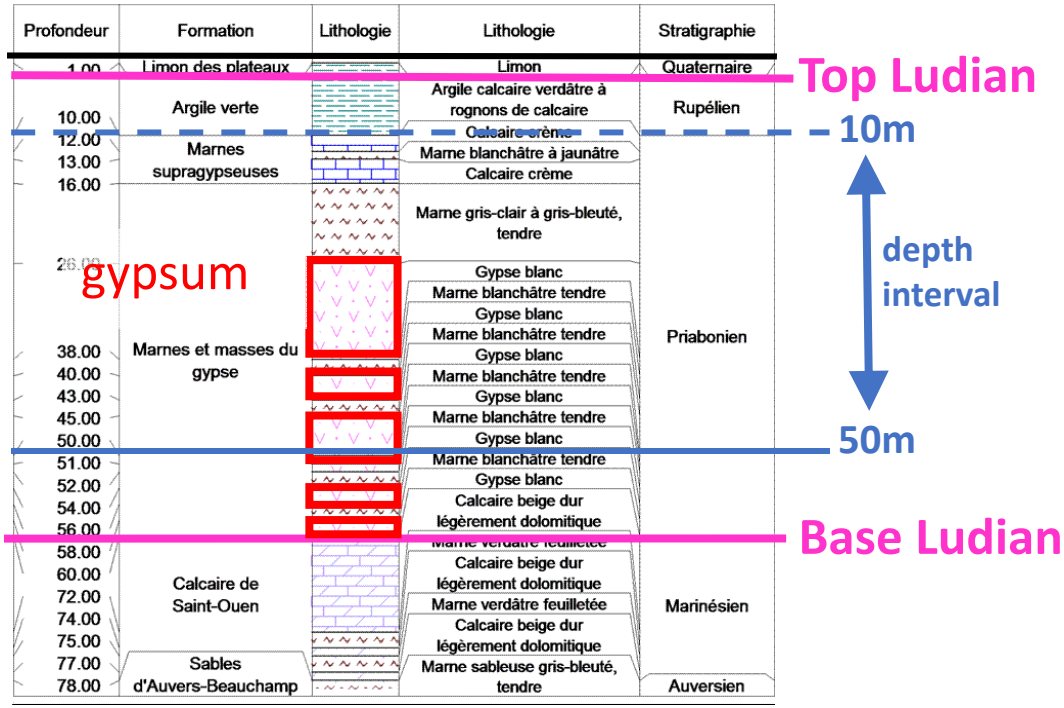
# METHODOLOGY

## STEP 3: COMPUTE GYPSUM THICKNESS ALONG HOLES

- between top and base of the two main gypsiferous formations
- in given depth interval: 10-50m, 10-100m and 10-200m
- using the full set of holes (approx. 5000)

Example of hole 01842X0163 (10-50m depth interval) :



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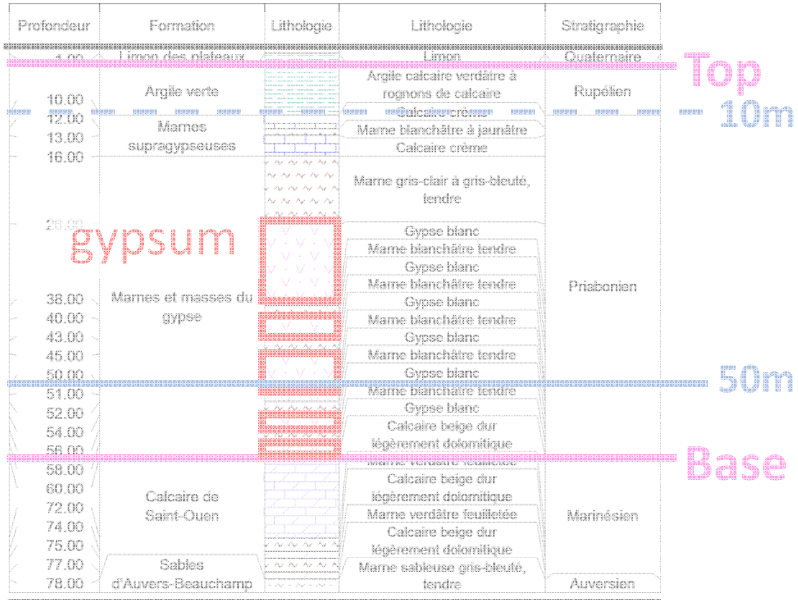
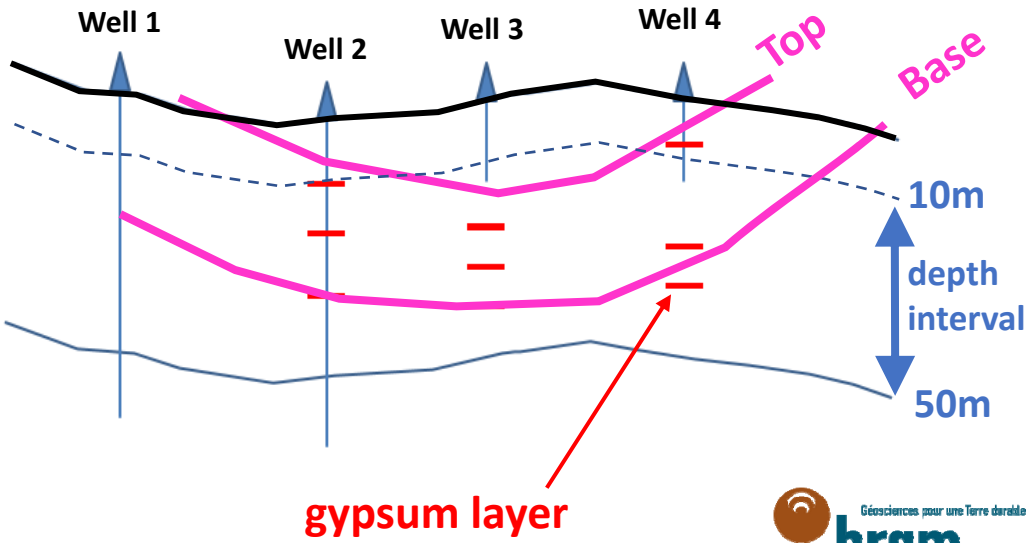
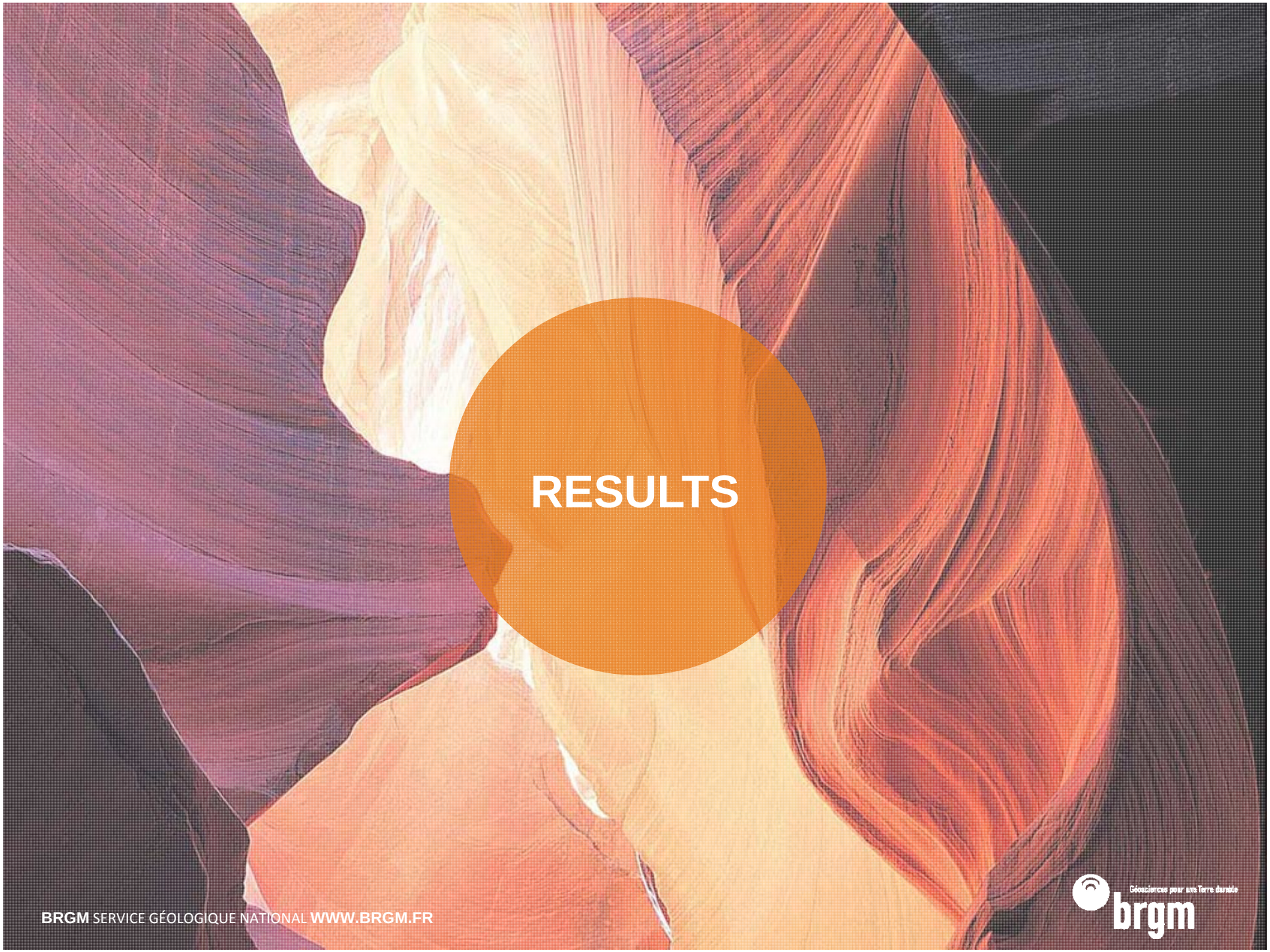
⚠ Drill holes not crossing the whole depth interval !



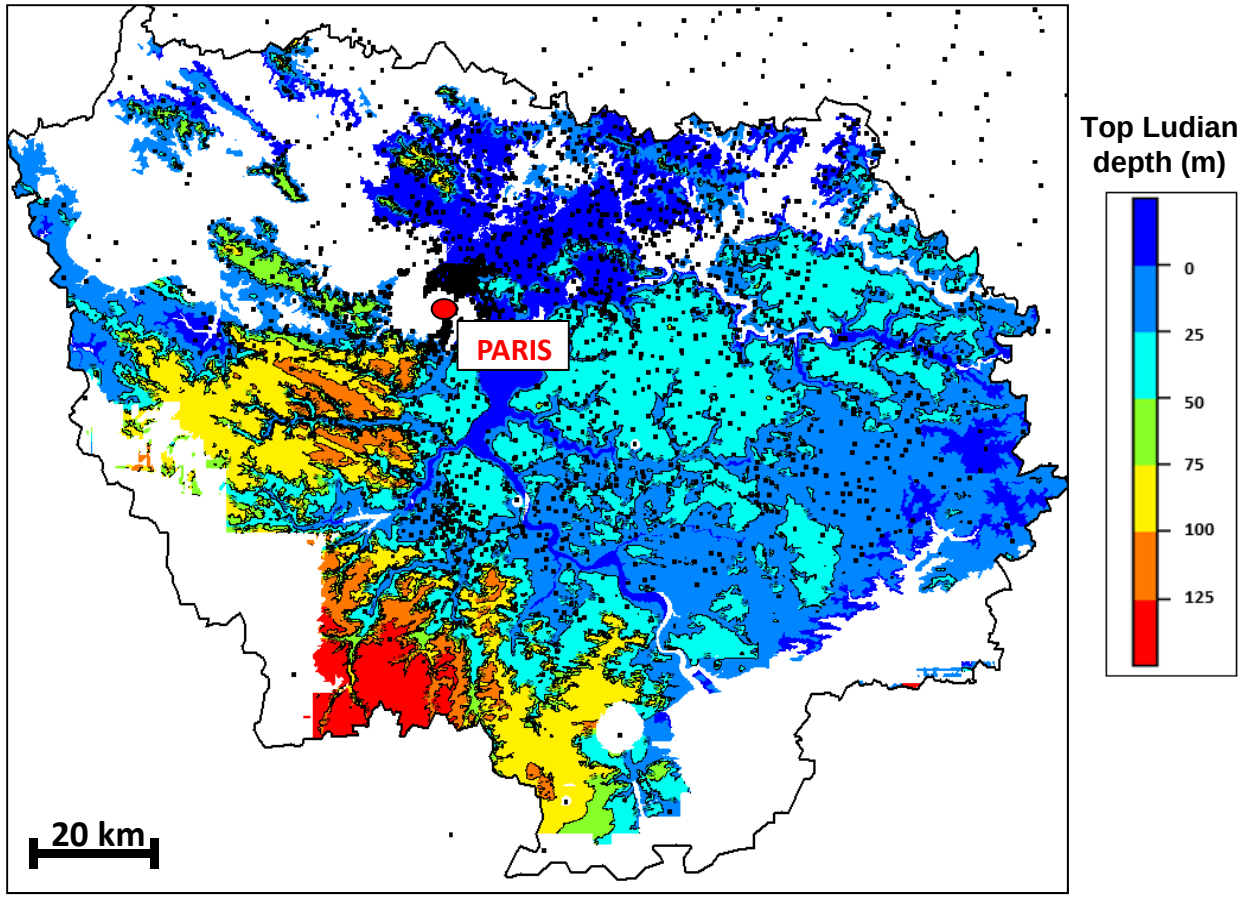




RESULTS

# RESULTS

## TOP LUDIAN DEPTH MAP :

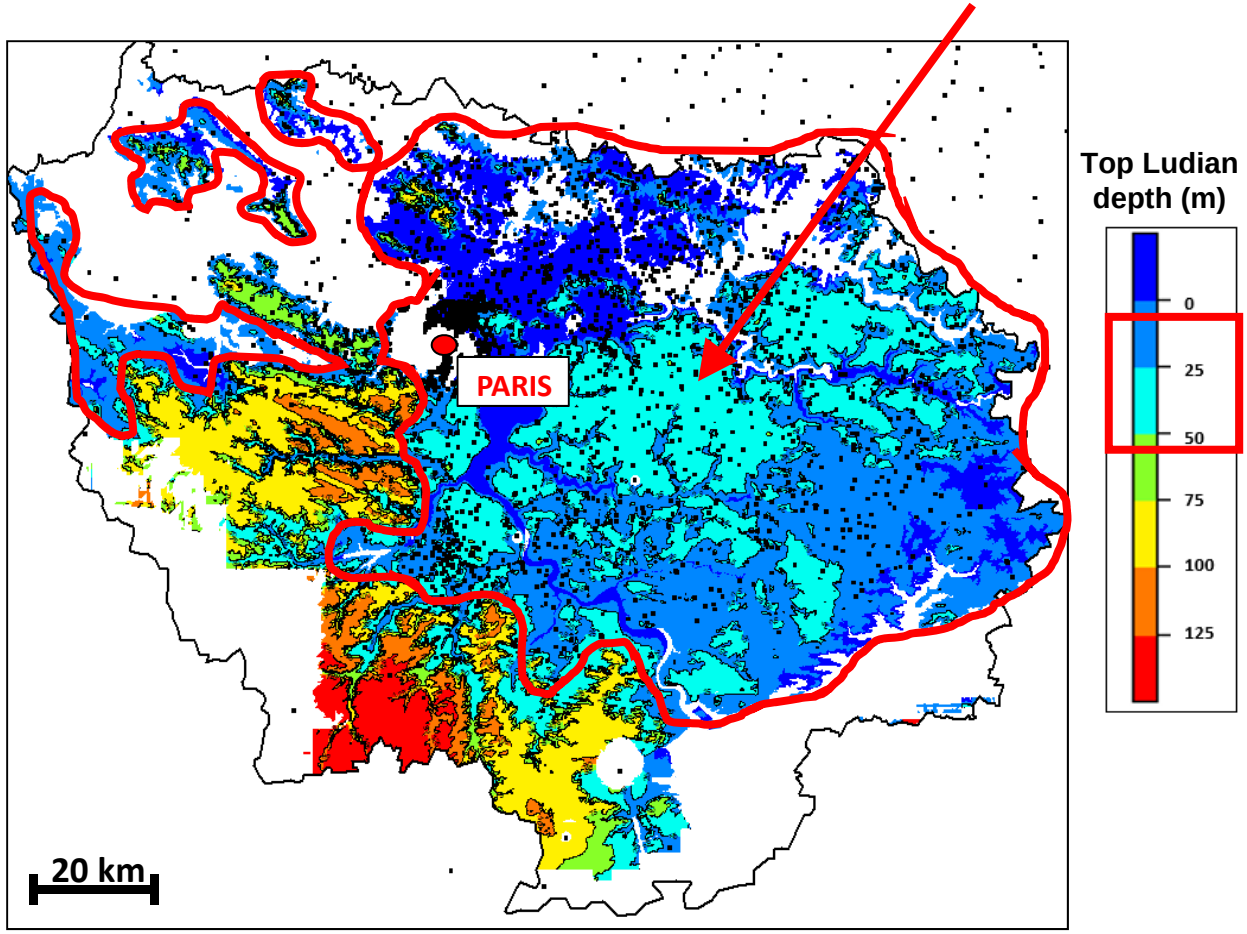
→ 10-50, 10-100 and 10-200m potential gypsum hazard areas



# RESULTS

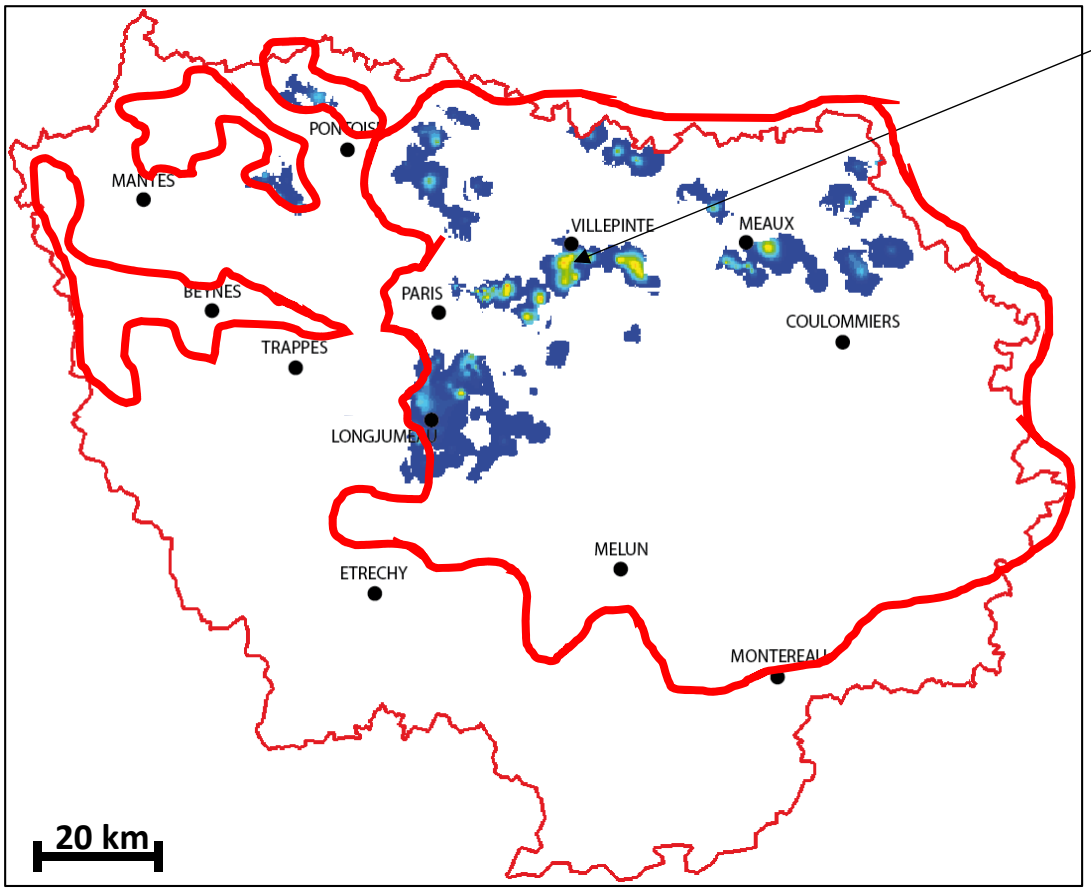
## TOP LUDIAN DEPTH MAP :

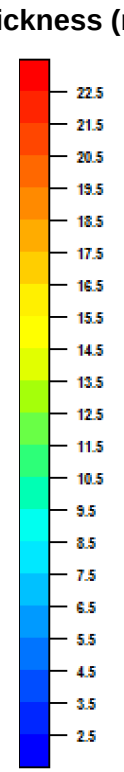
Ludian gypsum < 50m depth (blue colors) can be encountered in the North, Center and East of IDF



# RESULTS

## LUDIAN GYPSUM THICKNESS (10-50M DEPTH) :




**SEVRAN, 2017**
**(source : CEREMA)**

# RESULTS

## HAZARD AND REGULATION MAPS :

Quantification of hazard level as a function of gypsum thickness / gypsum depth

| Thickness/Depth | HAZARD LEVEL | |
|---|---|---|
| t/d = 0 | Null | 0 |
| t/d < 1/12 | Low | 1 |
| 1/12 < t/d < 0.2 | Medium | 5 |
| t/d > 0.2 | High | 7 |

Hazard high if ratio t/d > 1/12

INERIS methodology (report DRS13-130829-04972B)

# RESULTS

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<u>Regulation maps</u>
(not yet published) :

Gypsum hazard maps

+

Other hazards due to geothermal drillings

+

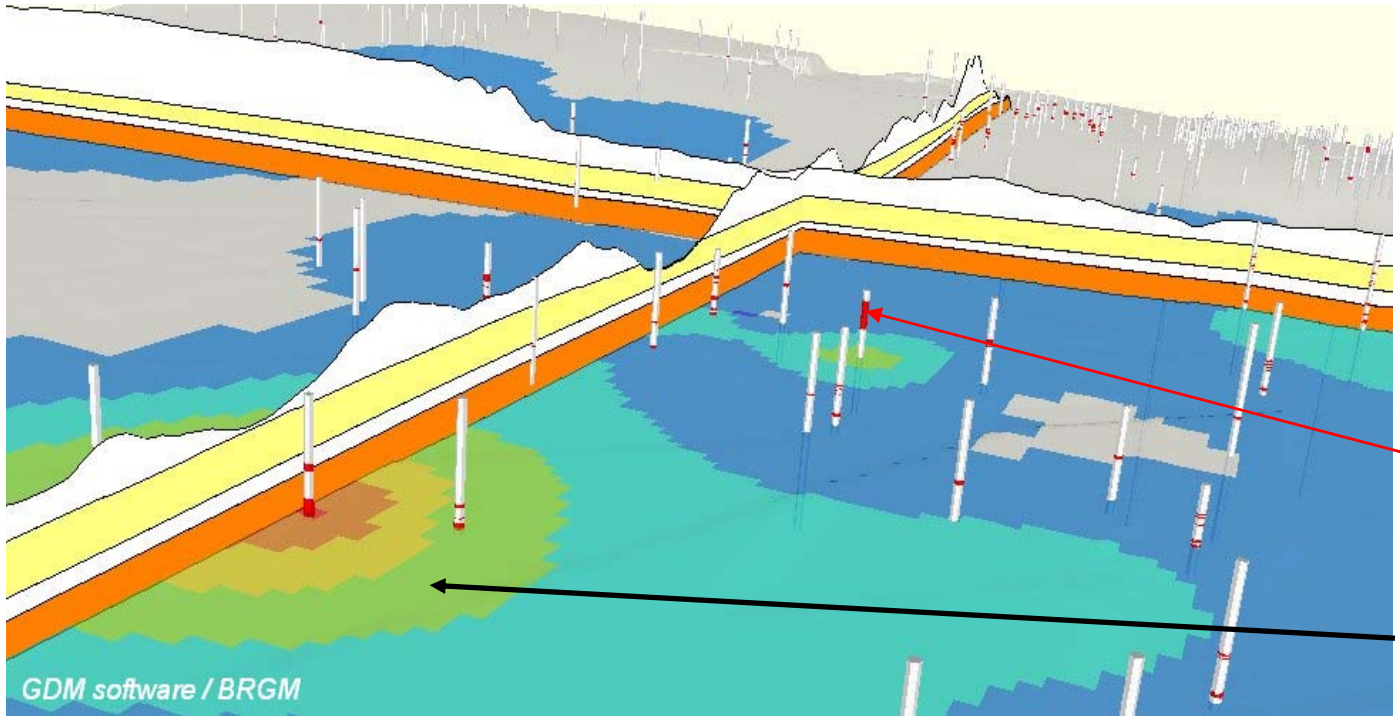
Type of geothermal drilling

(simple, double)

# CONCLUSION

## THE METHODOLOGY HAS BEEN SUCCESSFULY APPLIED

- Takes advantage of sequence stratigraphy concepts
- Helps to validate other available holes
- Use of geostatistics to assess the quality of the model
- Use of GDM software to automate processing and check data in 2D/3D




Ludian Layer

Lutetian Layer

gypsum facies along holes

interpolated gypsum thickness

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## COULD BE APPLIED TO OTHER APPLICATIONS

- Aquifer characterization
- Calculate properties (facies thickness, geochemical property, pollutant content) within given depths intervals *(example : poster n°20, Le Guern et al., 2018)*


REFERENCES :

- **INERIS report (2014)** : rapport d'étude DRS13-130829-04972B.
- **Briais J. (2015) – PhD thesis**: Le Cénozoïque du bassin de Paris : un enregistrement sédimentaire haute résolution des déformations lithosphériques en régime de faible subsidence. Université de Rennes 1, 450p.
- **Bourgine B. et al. (2017)** Building a Geological Reference Platform Using Sequence Stratigraphy Combined with Geostatistical Tools. In: Gómez-Hernández J., Rodrigo-Ilarri J., Rodrigo-Clavero M., Cassiraga E., Vargas-Guzmán J. (eds) Geostatistics Valencia 2016. Quantitative Geology and Geostatistics, vol 19. pp 865-877. Springer, Cham