



# Cartographie de l'exposition au retrait-gonflement des argiles

Mapping exposure to clay shrinkage and swelling



# RISK

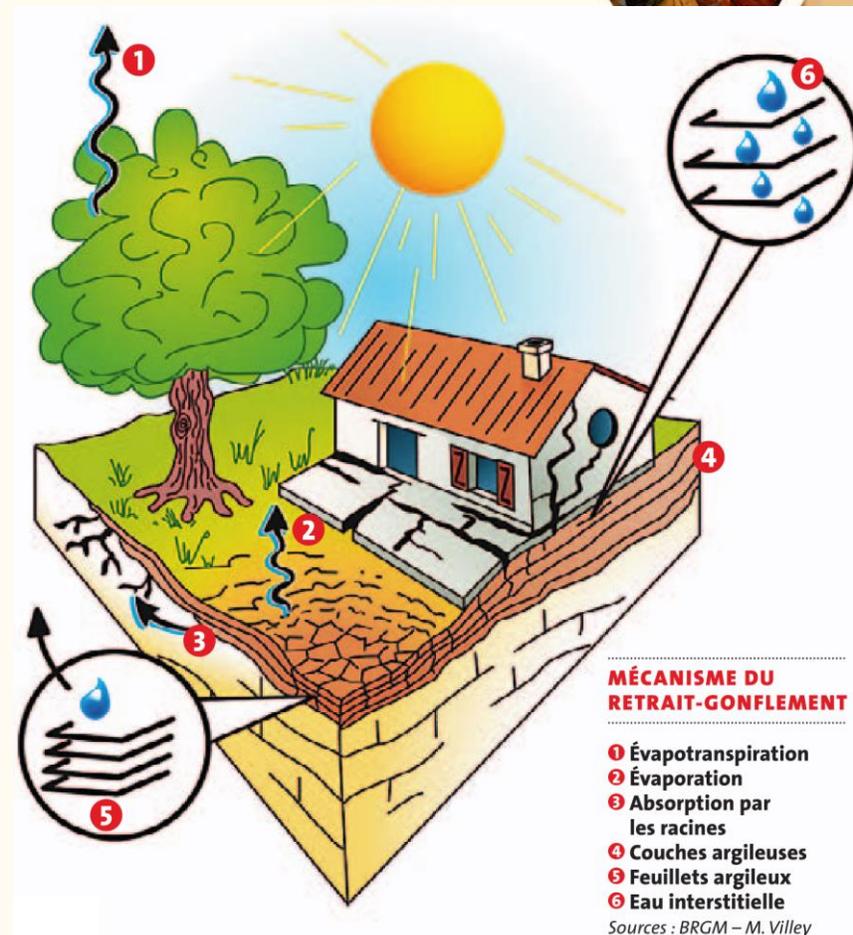
Summer  
School  
2024



## Ground movement

- Volume change of clay minerals
- Change in water content
- Hydration → swelling
- Desiccation → shrinkage
- Heterogeneous variations in water content

## Differential settlement



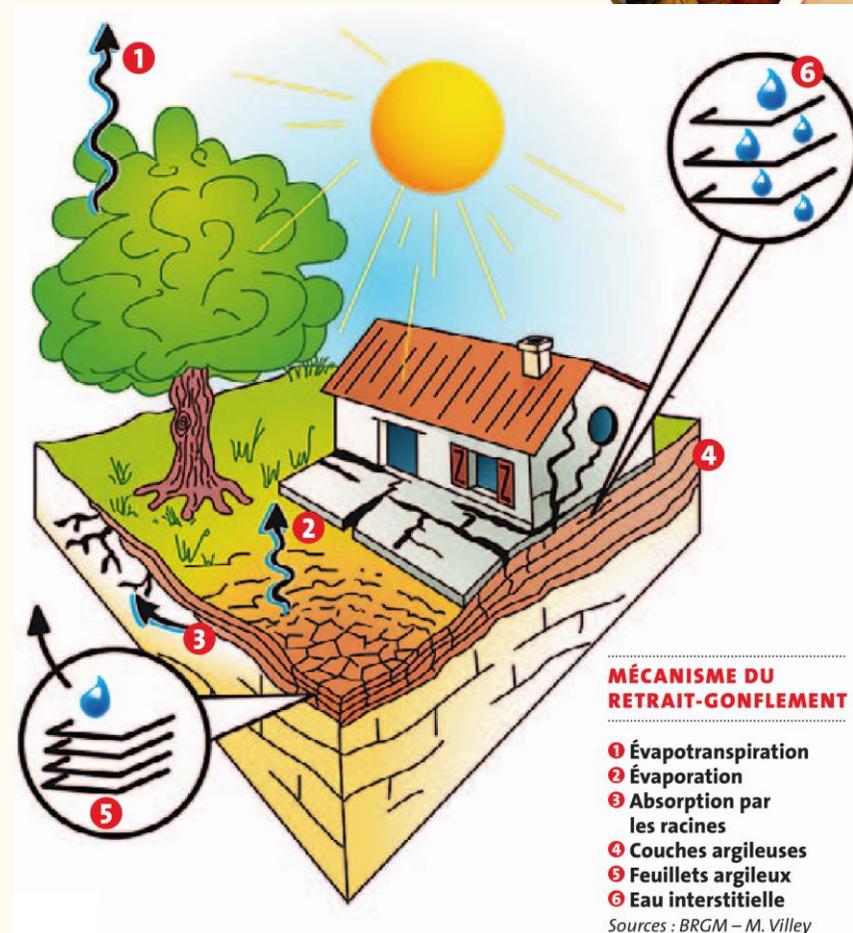
## Predisposing factors

### Nature of soils

- Clay content
- Thickness
- Clay minerals

### Geomorphology

- Slope
- Water nearby
- Vegetation



## Triggering factors

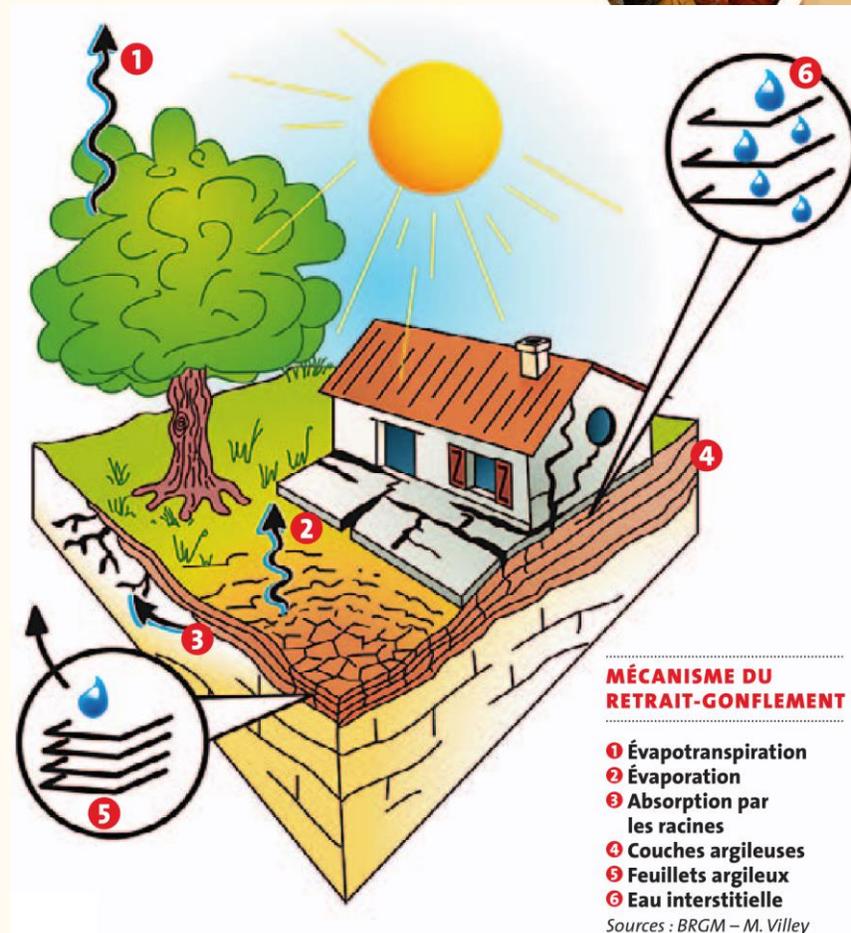
### Drought

- High temperature
- Rainfall deficit

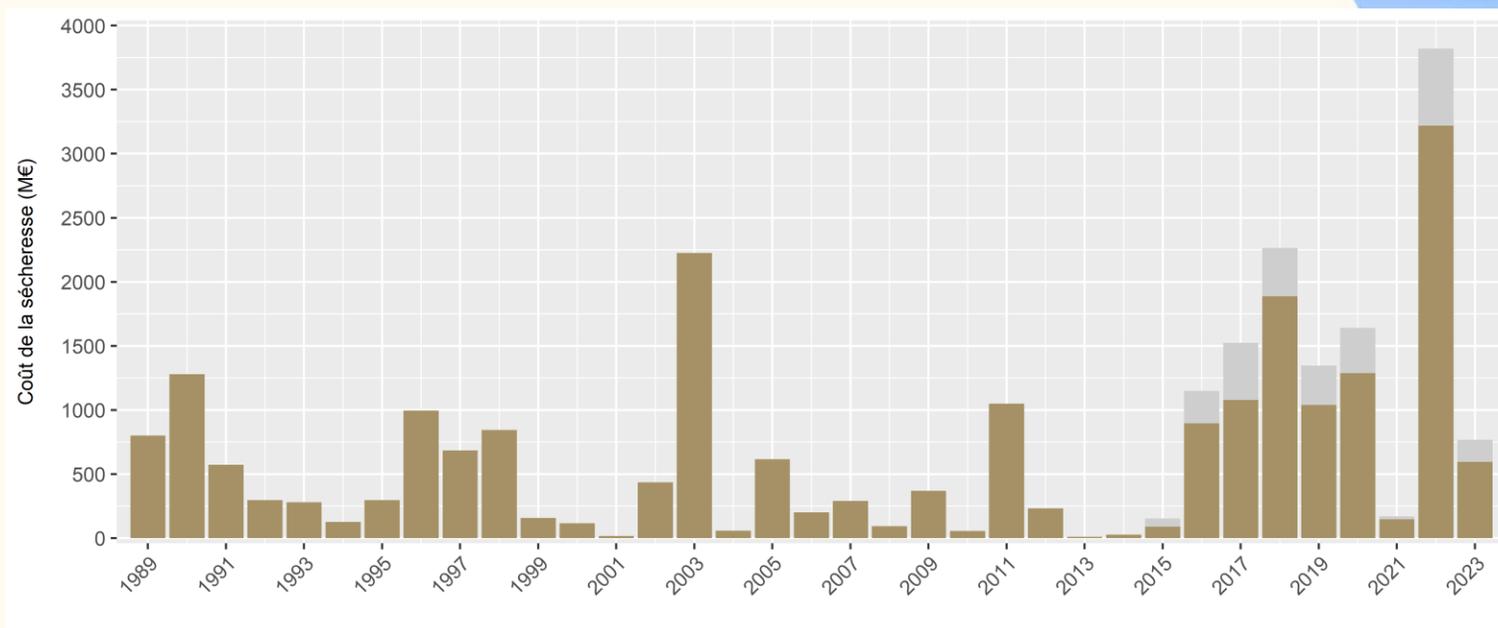
### Climate history

- Multi-year cumulative rainfall
- Winter/Summer contrast

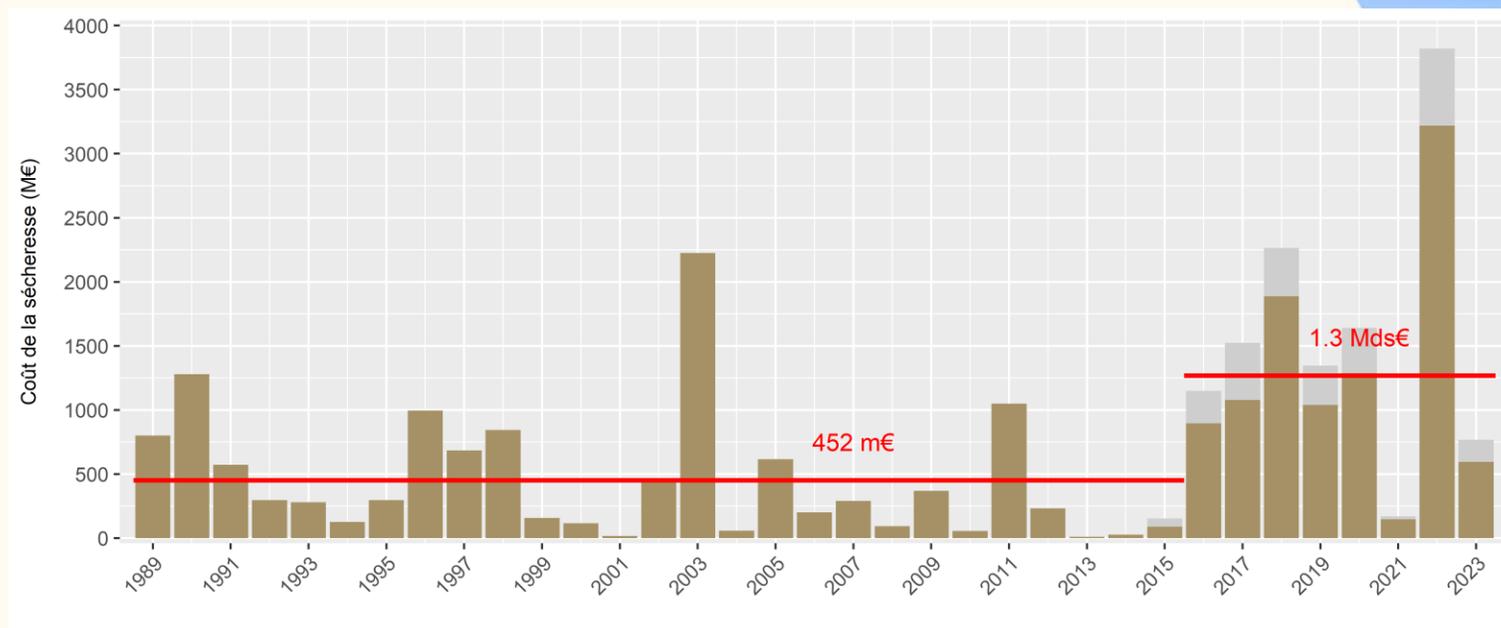
### Anthropogenic factors



- 22,3 Bn€ between 1989 and 2023 (CCR)
- 40% of municipalities impacted
- More than 60,000 natural disaster decrees since 1989



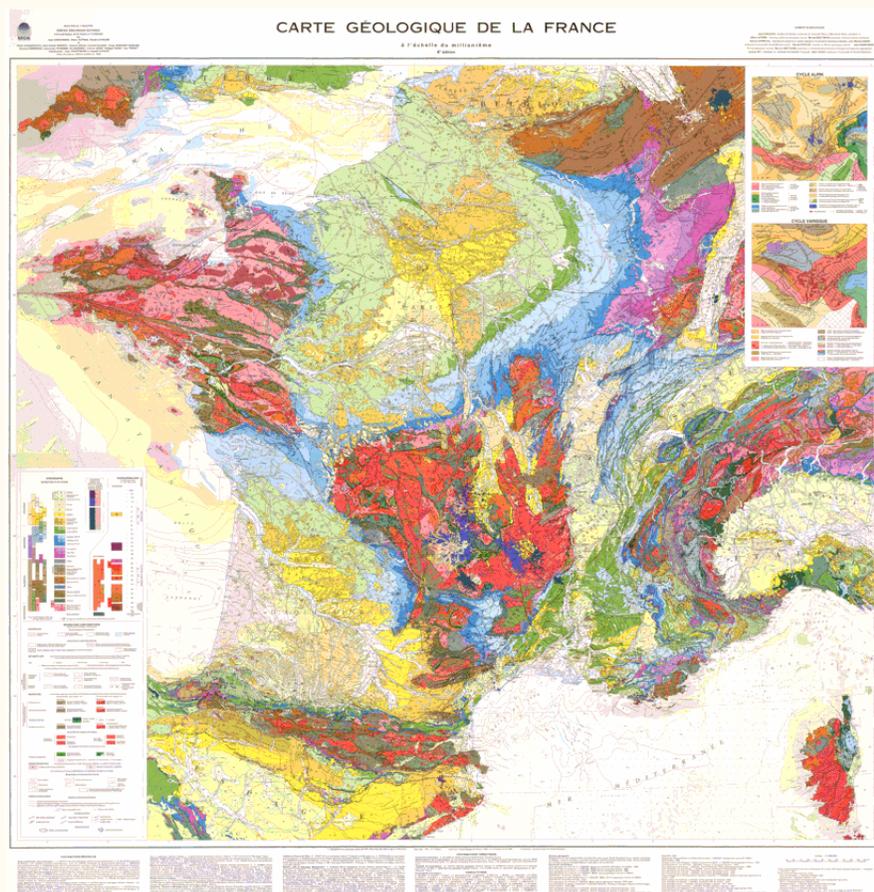
- 22,3 Bn€ between 1989 and 2023 (CCR)
- 40% of municipalities impacted
- More than 60,000 natural disaster decrees since 1989



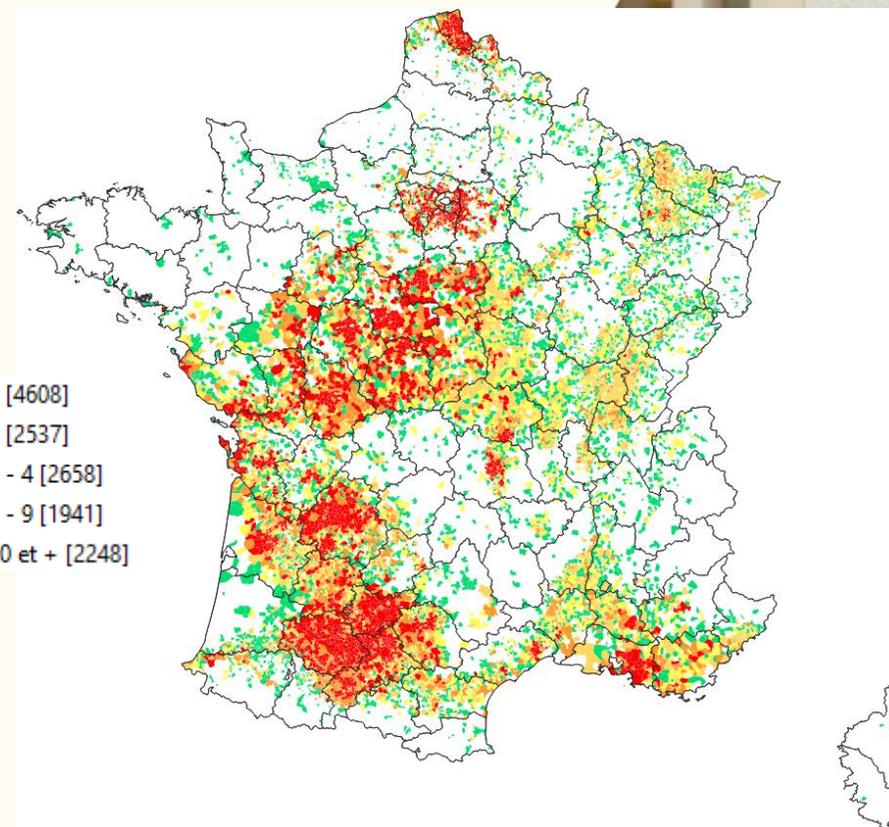
- ~ 30,000 damaged houses / y
- Average cost: 24,000€
- 12 droughts in top 20 climate events
- 2<sup>nd</sup> most costly phenomenon after floods

Rang	Exercice	Événement	Coût assuré actualisé en euros 2023	Nombre de communes reconnues au 31/03/2024	Nombre de départements touchés
1	2022	Sécheresse	[3,3 Md€, 3,8 Md€]	6719	92
2	2017	IRMA	2,5 Md€	2	2
3	2018	Sécheresse	[1,9 Md€, 2,3 Md€]	4060	76
4	2003	Sécheresse	2,19 Md€	4357	70
5	2017	Sécheresse	[1,1 Md€, 1,5 Md€]	2106	59
6	2003	Inondations du Rhône	1,40 Md€	1522	29
7	2002	Inondations du Gard	1,32 Md€	418	7
8	1990	Sécheresse	1,29 Md€	4007	69
9	2016	Inondations de mai-juin	1,27 Md€	2133	43
10	2019	Sécheresse	[1,1 Md€, 1,35 Md€]	2918	62
11	2016	Sécheresse	[1 Md€, 1,2 Md€]	983	31
12	2020	Sécheresse	[1 Md€, 1,2 Md€]	2607	61
13	2011	Sécheresse	1,06 Md€	2249	68
14	2010	Inondations consécutives à Xynthia	1,01 Md€	1451	12
15	1996	Sécheresse	1,01 M€	2863	67
16	1995	Inondations du Nord en janvier/février	930 M€	3385	40
17	1998	Sécheresse	852 M€	1688	56
18	1989	Sécheresse	809 M€	3791	66
19	2010	Inondations du Var	771 M€	61	2
20	1999	Inondations de l'Aude	760 M€	442	5

## Good correlation btw damages and geology

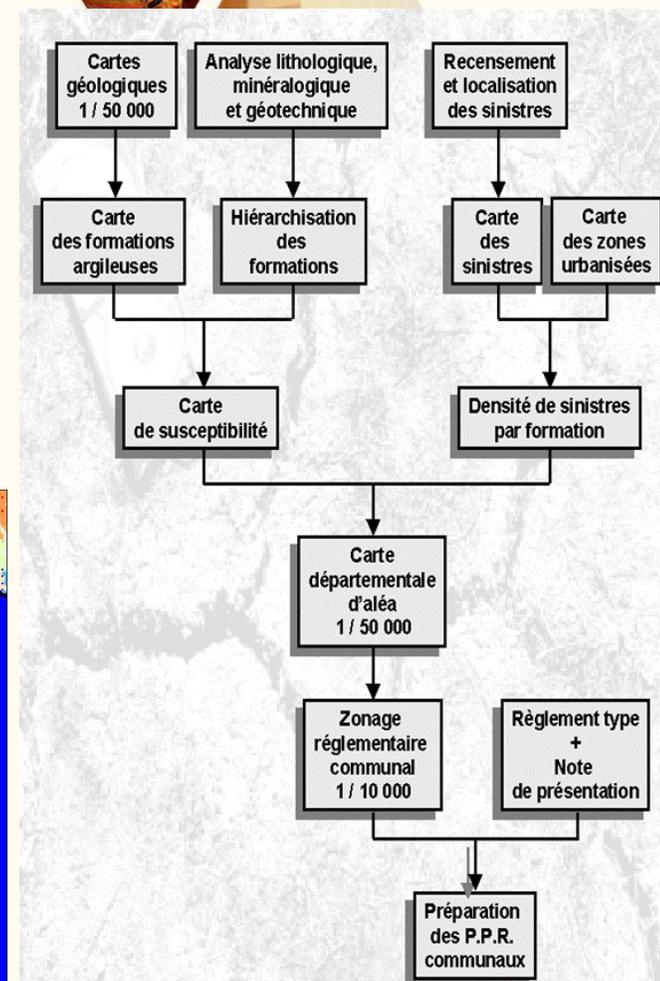
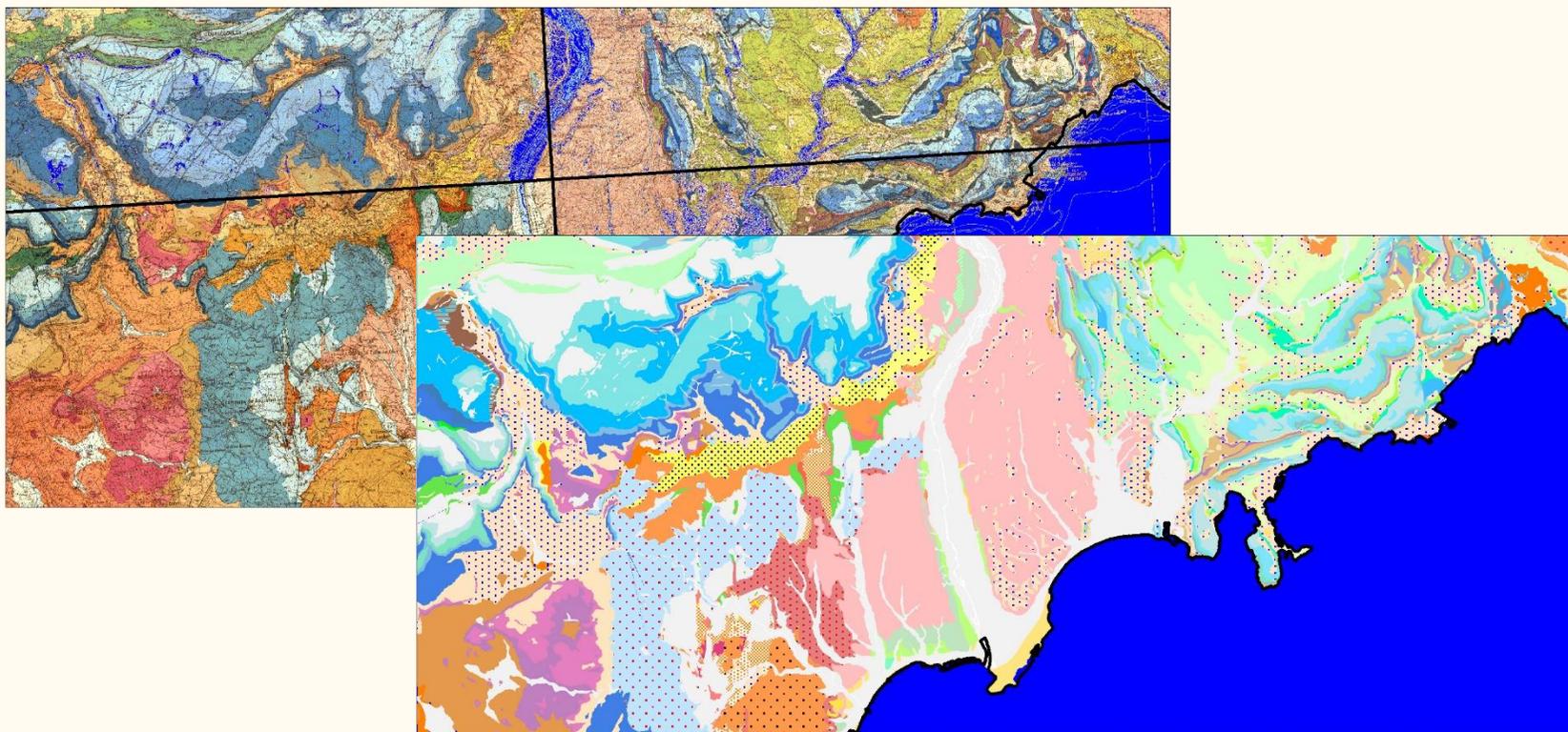


- ✓ 1 [4608]
- ✓ 2 [2537]
- ✓ 3 - 4 [2658]
- ✓ 5 - 9 [1941]
- ✓ 10 et + [2248]



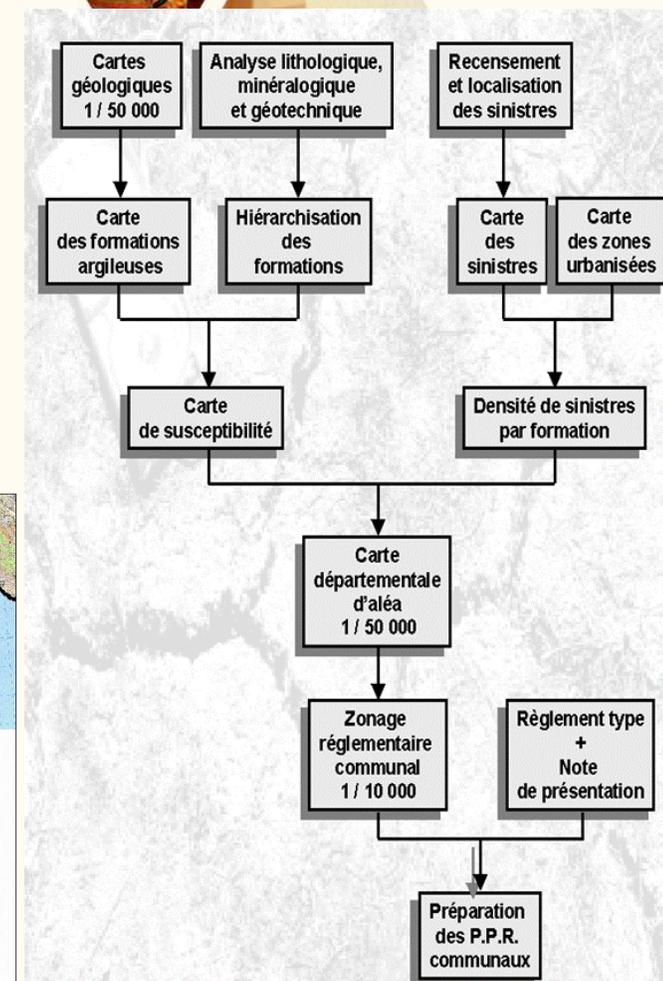
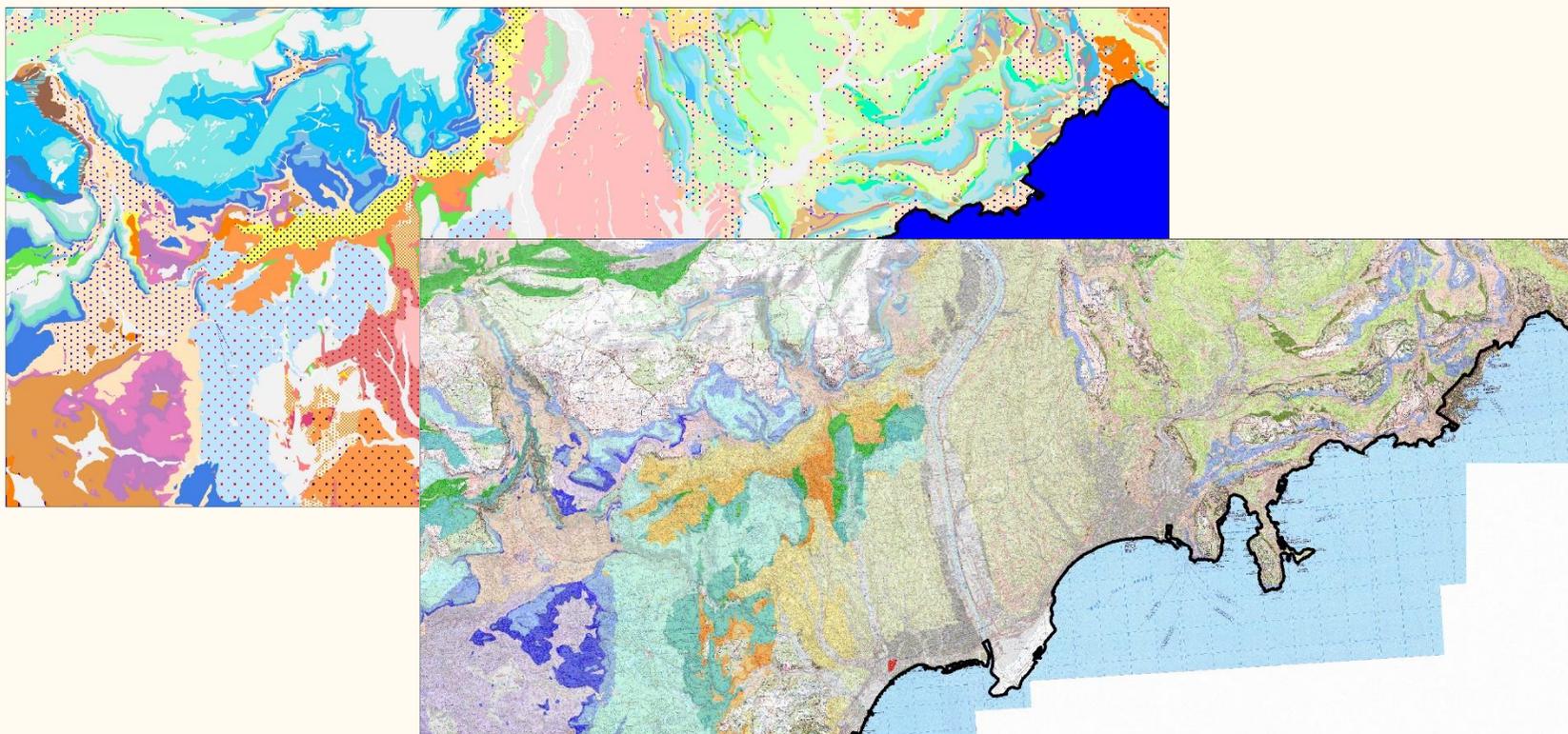
## From geological map sheets to Harmonized department geological map

- 1,127 sheets / 96 departments



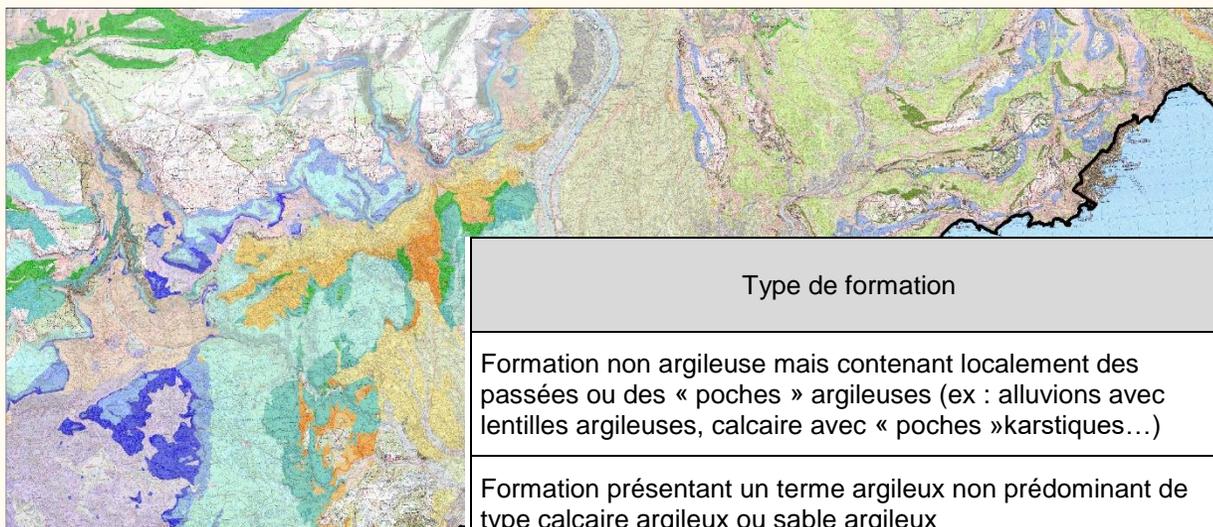
## From Harmonized department geological map to clay formation map

- More than 2,000 clay formations

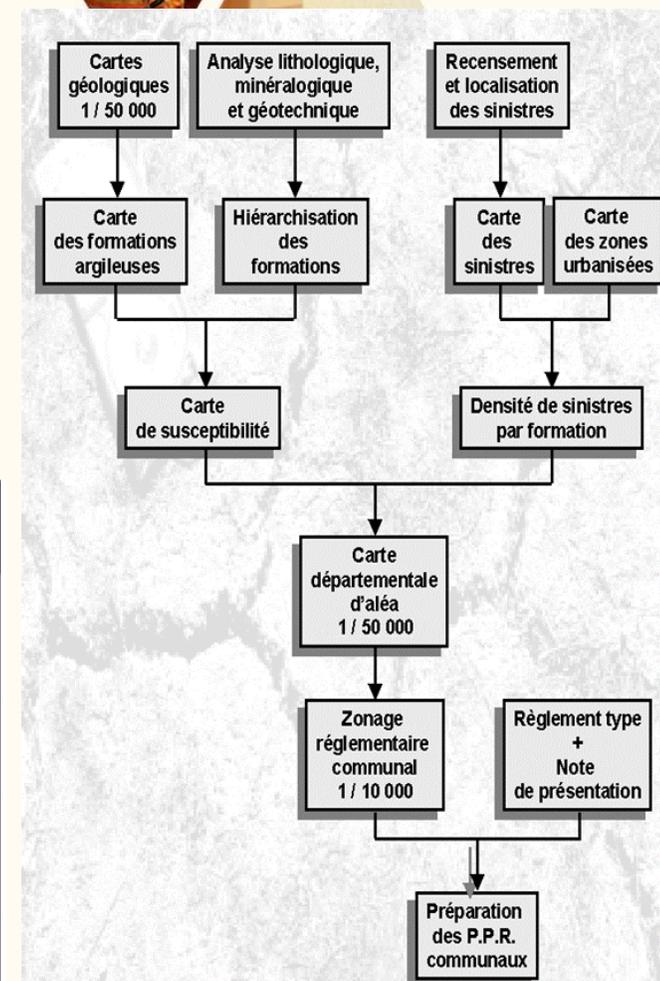


## Clay formations hierarchy Lithology

- Clay content, thickness, continuity

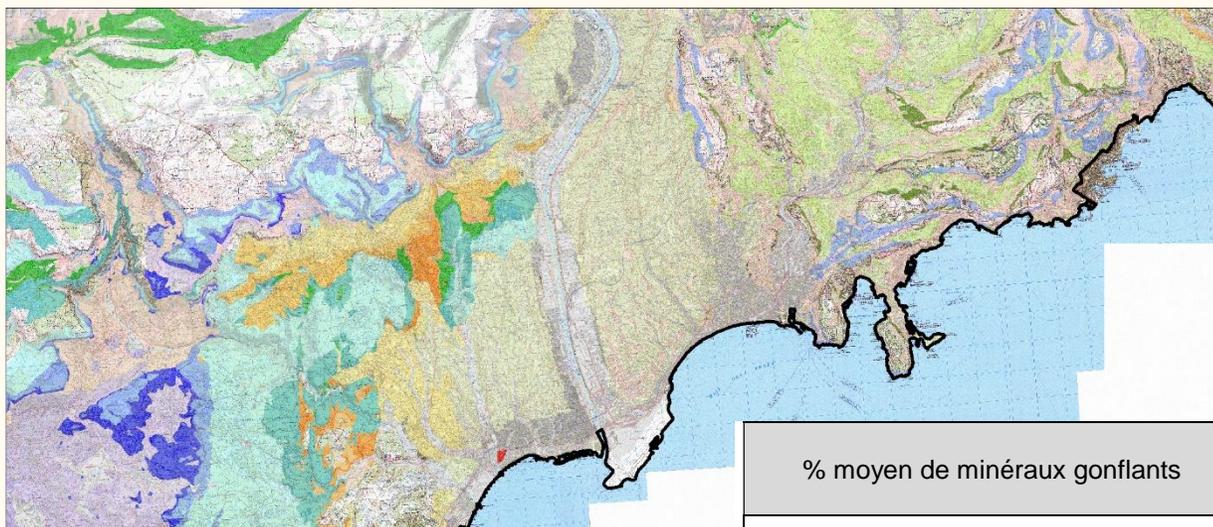


Type de formation	Susceptibilité	Note lithologique
Formation non argileuse mais contenant localement des passées ou des « poches » argileuses (ex : alluvions avec lentilles argileuses, calcaire avec « poches » karstiques...)	faible	1
Formation présentant un terme argileux non prédominant de type calcaire argileux ou sable argileux	moyenne	2
Formation à dominante argileuse, présentant un terme ou une passée non argileuse (ex : alternance marno-calcaire ou sablo-argileuse) ou très mince (moins de 3 m)	forte	3
Formation essentiellement argileuse ou marneuse, d'épaisseur supérieure à 3 m et continue	très forte	4

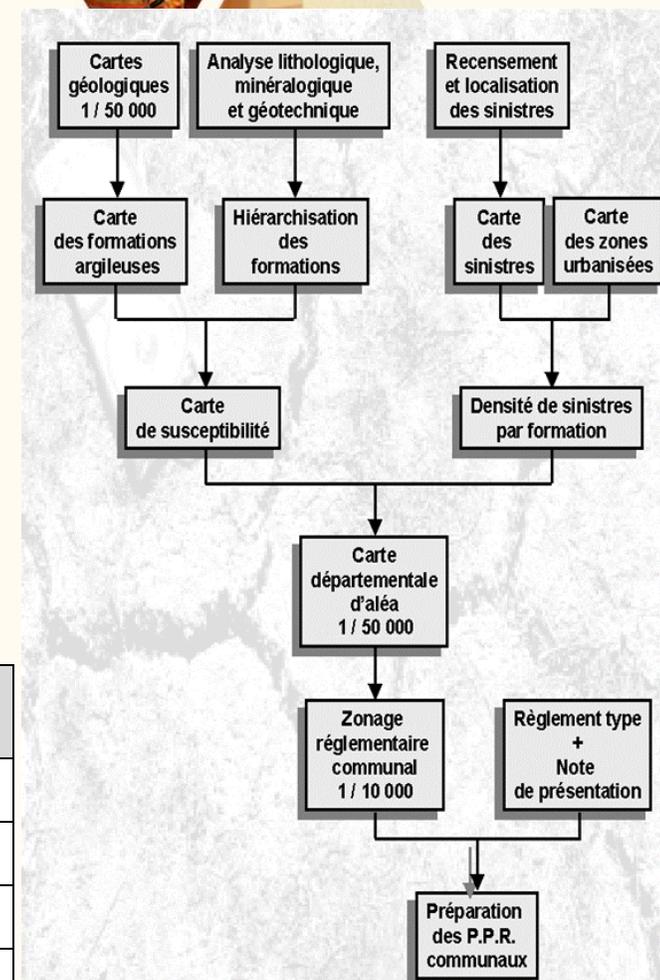


## Clay formations hierarchy Mineralogy

- Clay minerals, more or less prone to shrink/swell

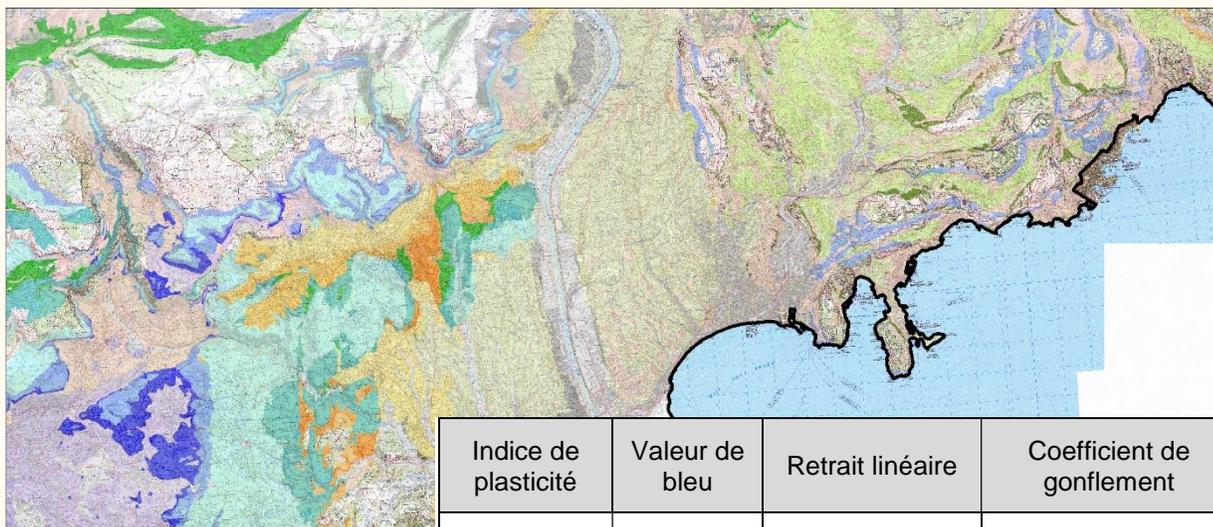


% moyen de minéraux gonflants	Susceptibilité	Note minéralogique
< 25 %	faible	1
25 à 50 %	Moyenne	2
50 à 80 %	Forte	3
> 80 %	très forte	4

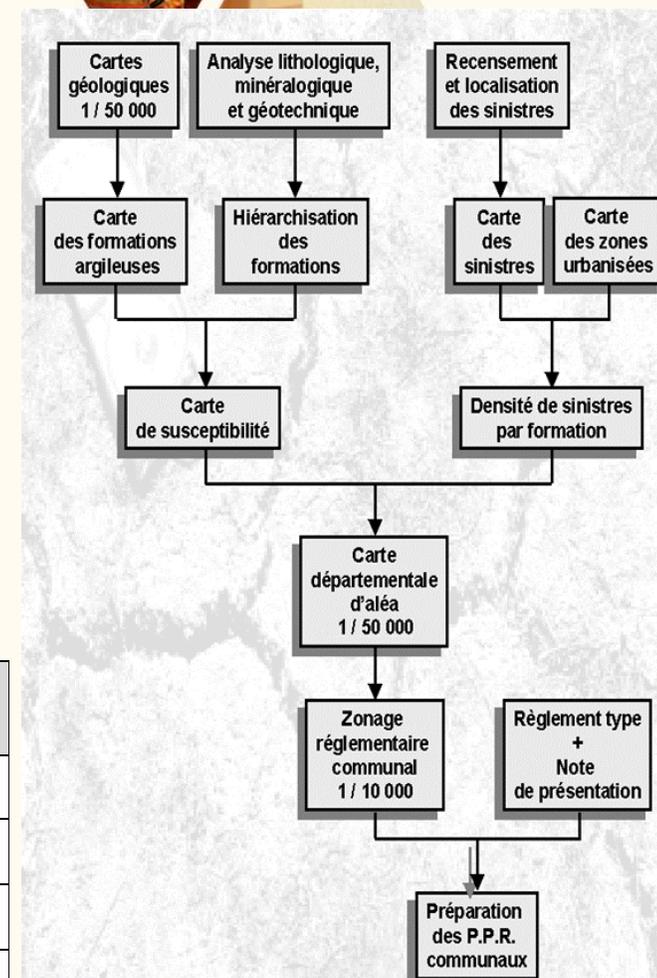


## Clay formations hierarchy Geotechnical parameters

- Plasticity Index, Methylene Blue, Oedometer Test

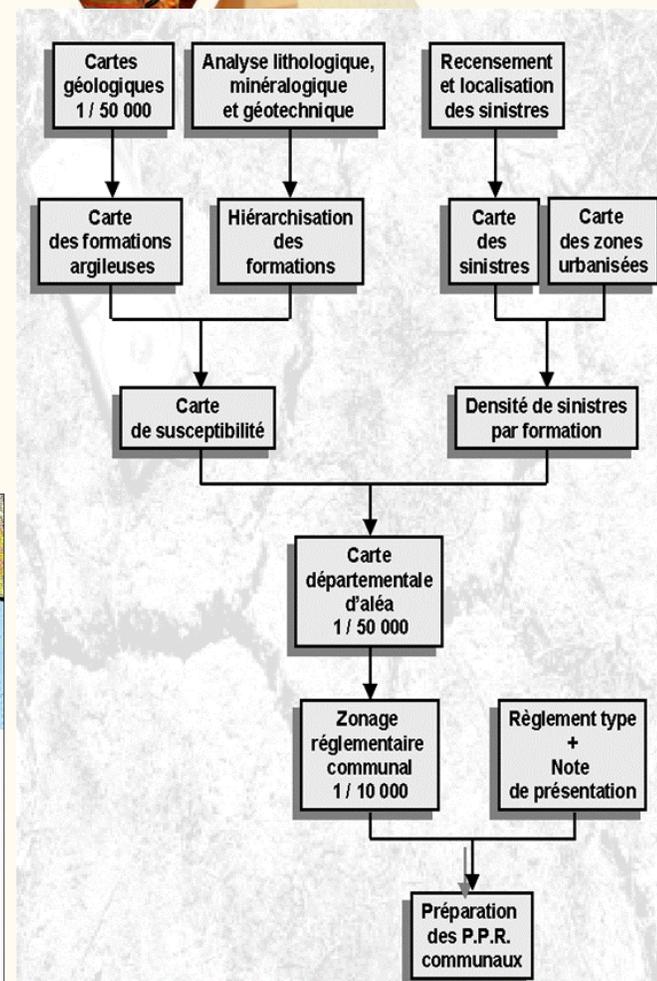
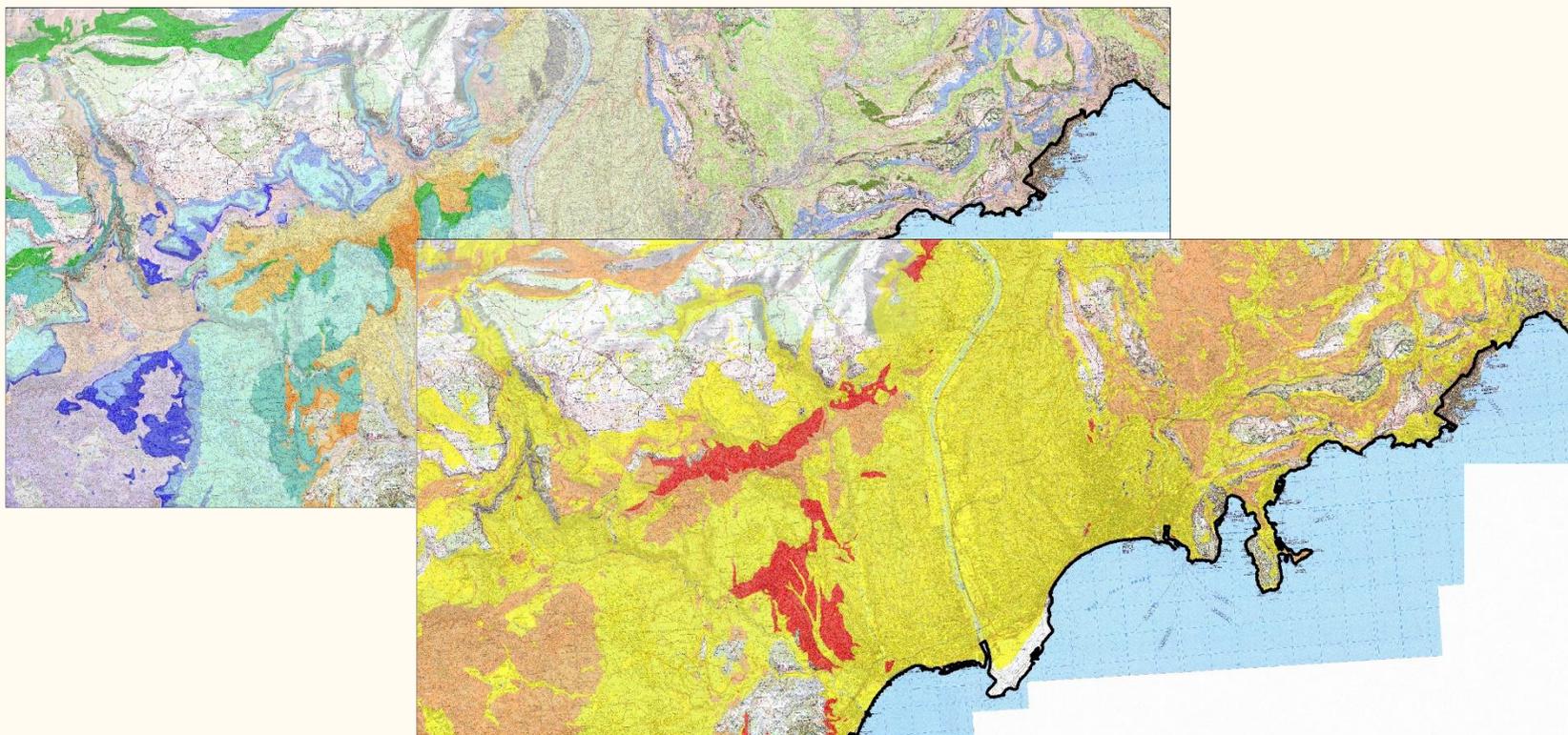


Indice de plasticité	Valeur de bleu	Retrait linéaire	Coefficient de gonflement	Susceptibilité	Note géotechnique
$IP < 12$	$< 2,5$	$RI < 0,4$	$C_g < 0,025$	faible	1
$12 \leq IP < 25$	2,5 à 6	$0,4 \leq RI < 0,65$	$0,025 \leq C_g < 0,035$	moyenne	2
$25 \leq IP < 40$	6 à 8	$0,65 \leq RI < 0,75$	$0,035 \leq C_g < 0,055$	forte	3
$IP \geq 40$	$> 8$	$RI \geq 0,75$	$C_g \geq 0,055$	très forte	4



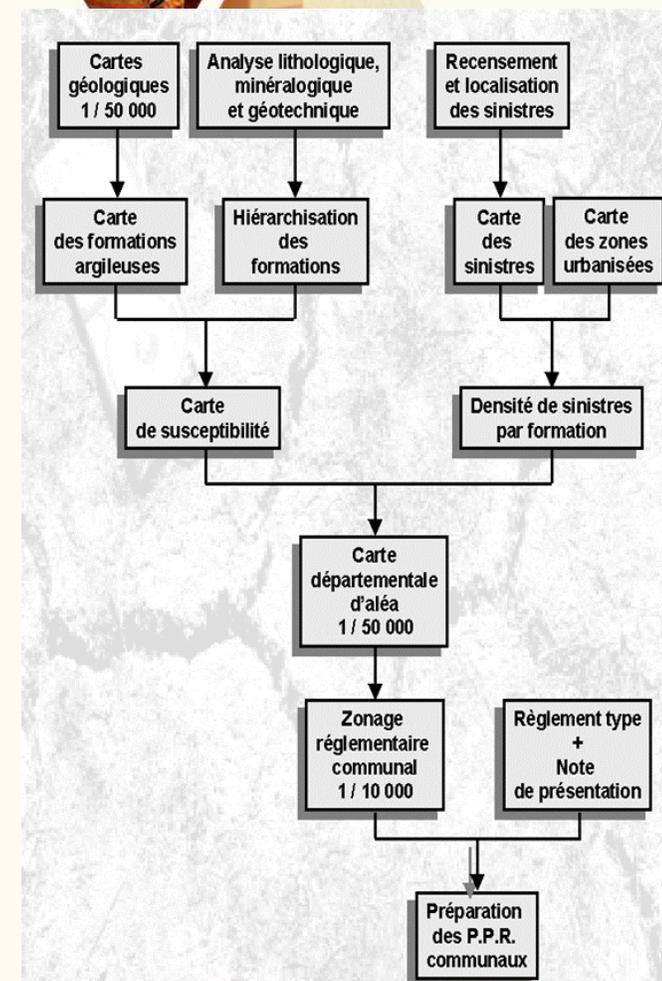
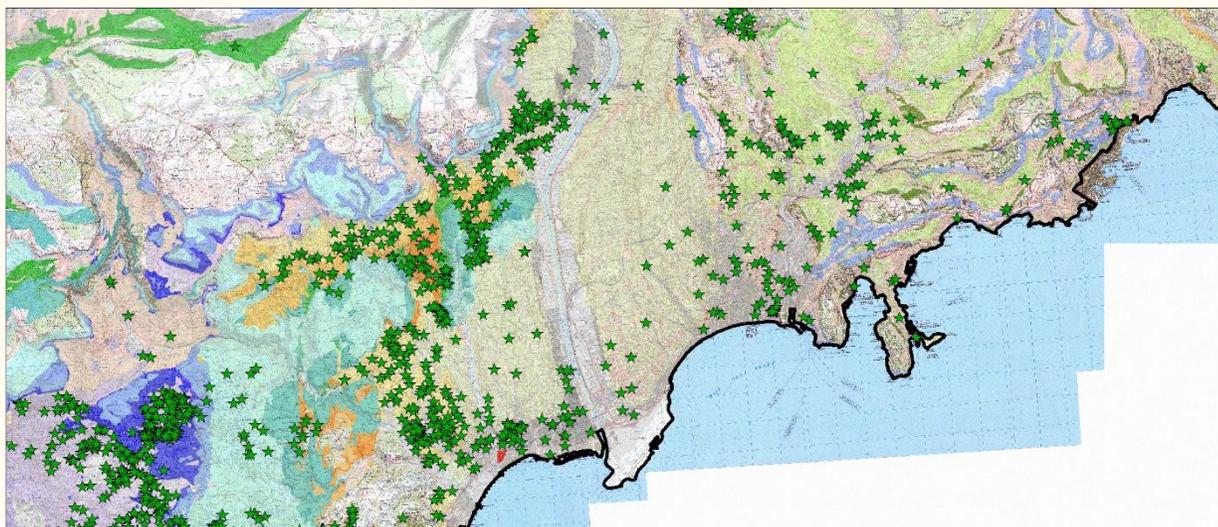
## Susceptibility Map

- Average of 3 criteria



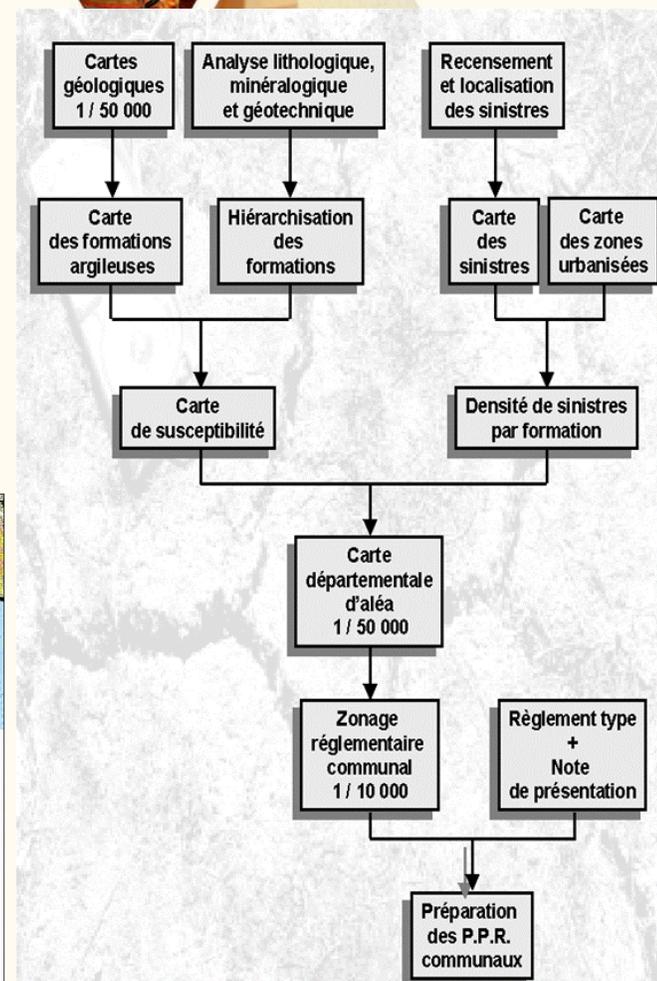
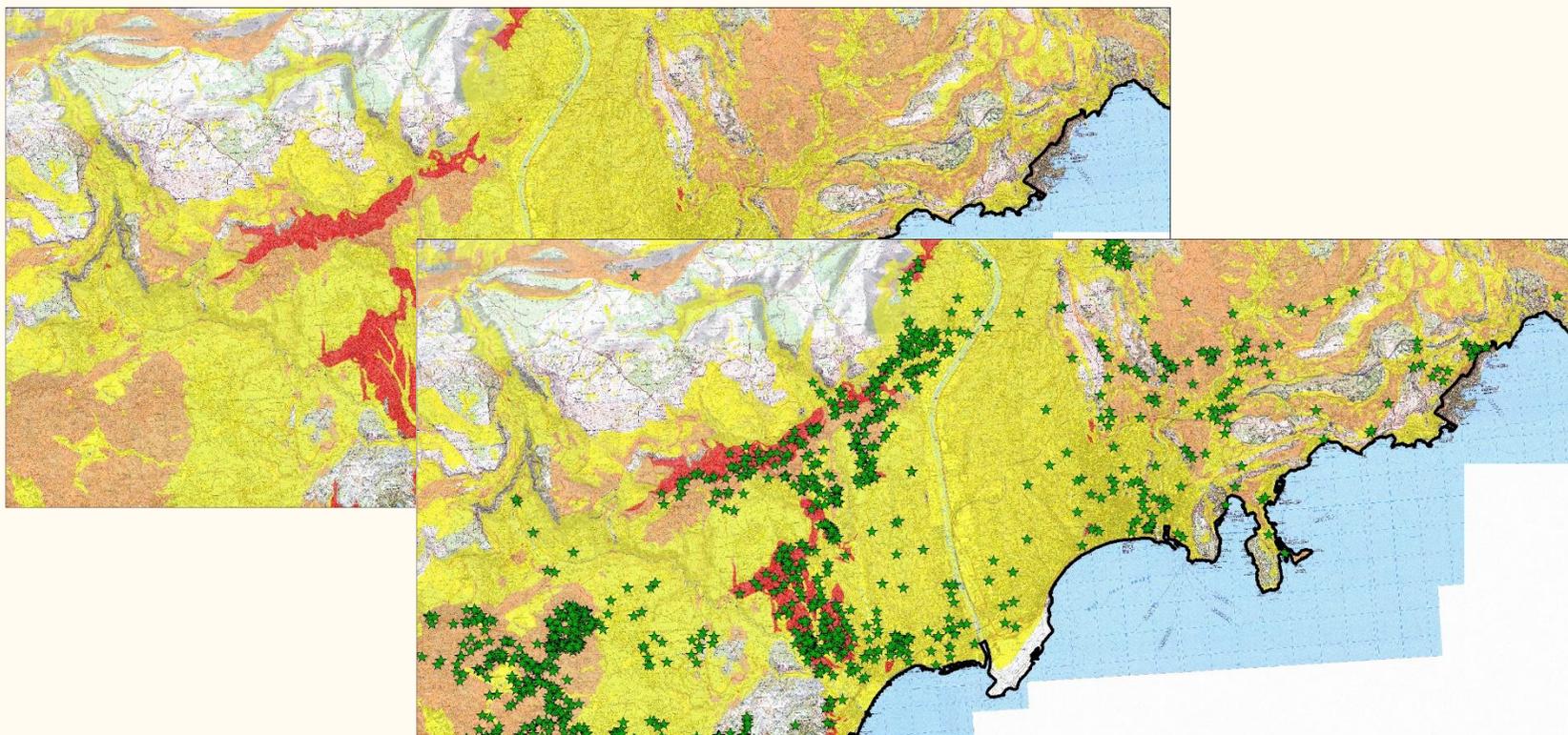
## Damages density mapping

- Number of damages per km<sup>2</sup> of urban area



## Susceptibility Map X Damages Map

- Exposure



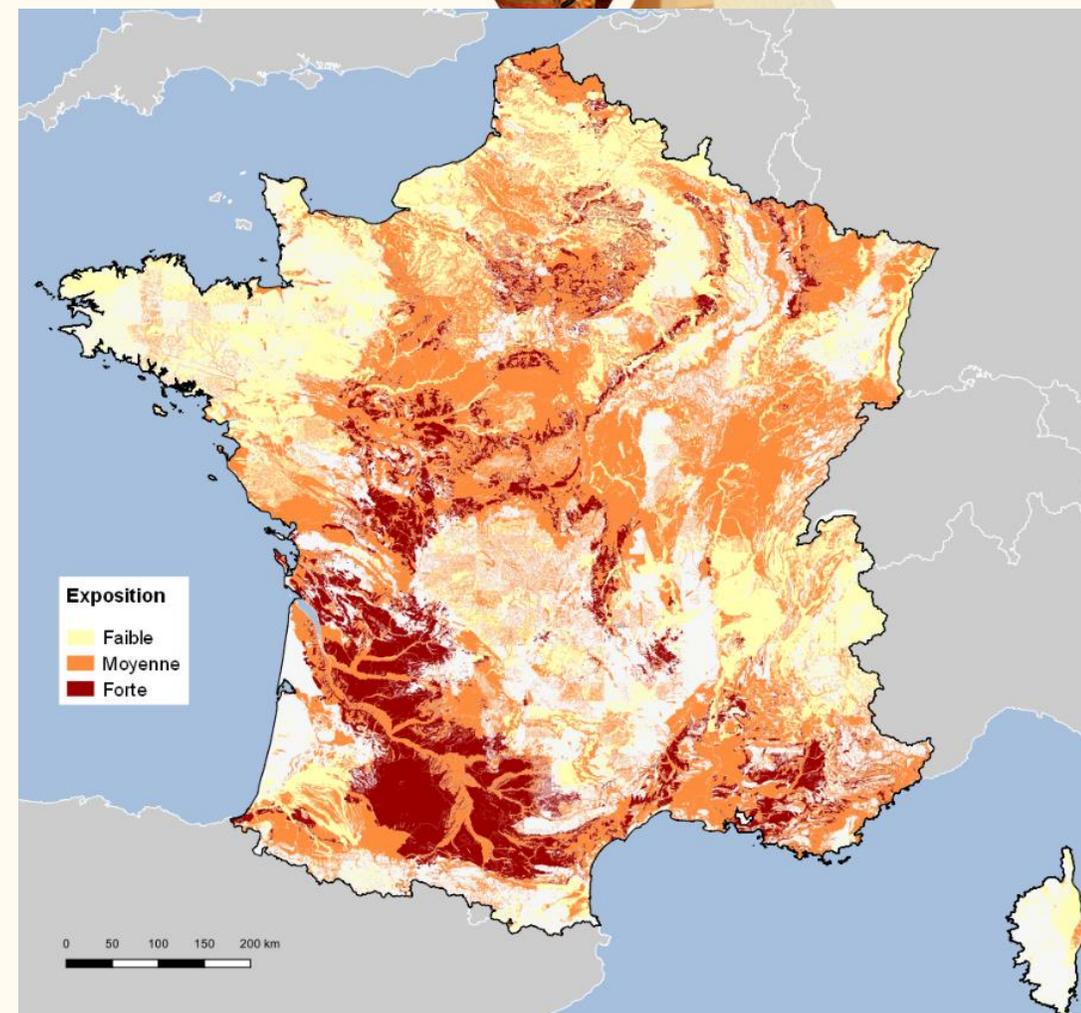
## Exposure Map

### 4 levels of exposure

- No clay (at 1/50k scale)
- Low (yellow)
- Medium (orange)
- High (red)

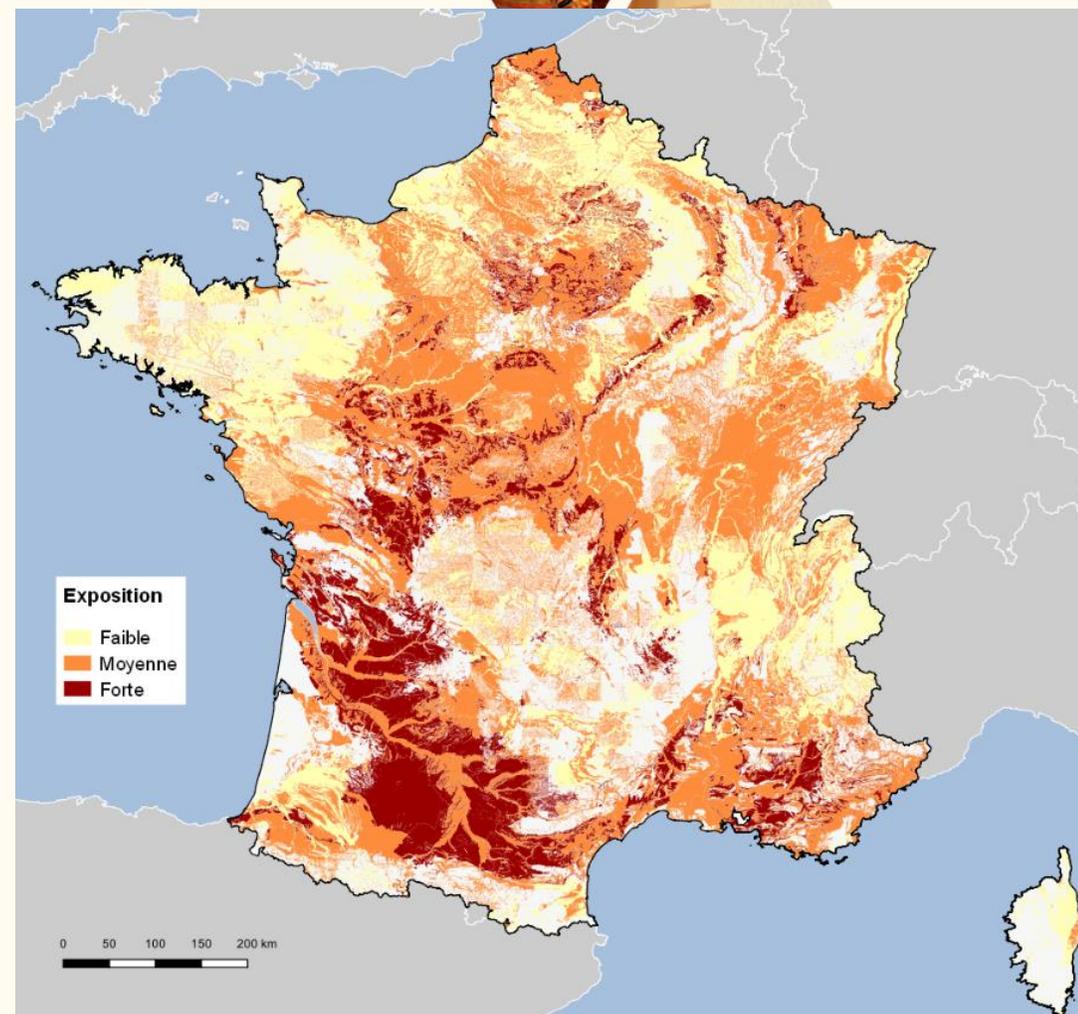
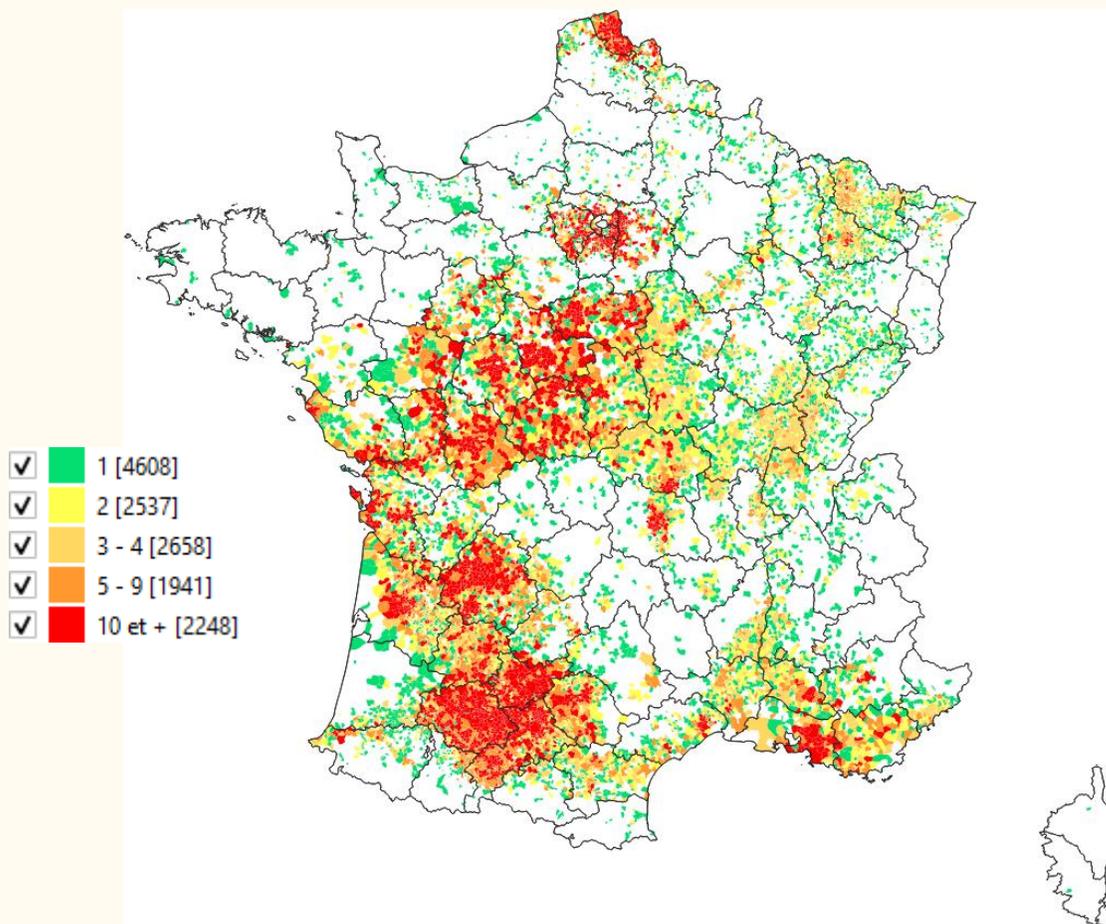
### Medium + High

- 48% of french territory
- 93% of damages





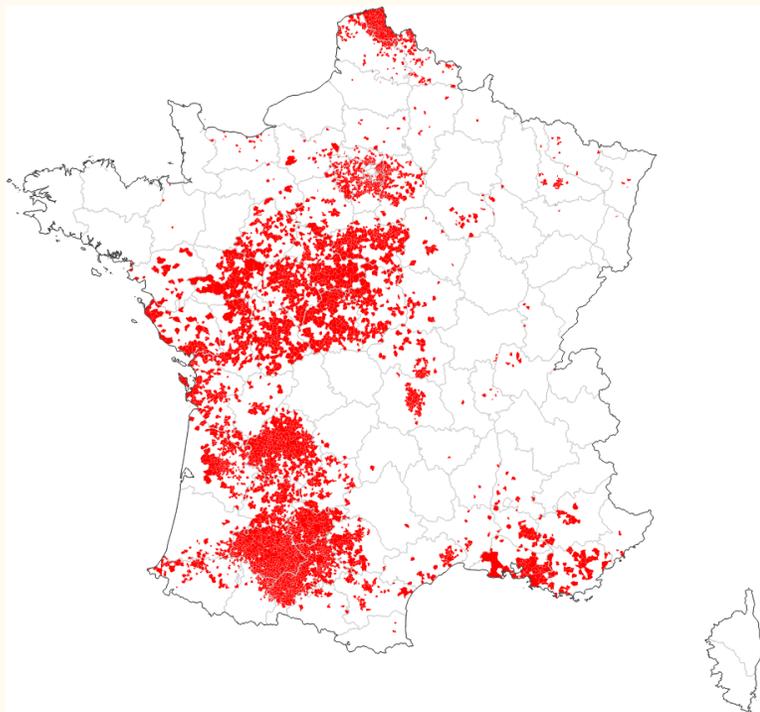
## Exposure Map vs. Claims



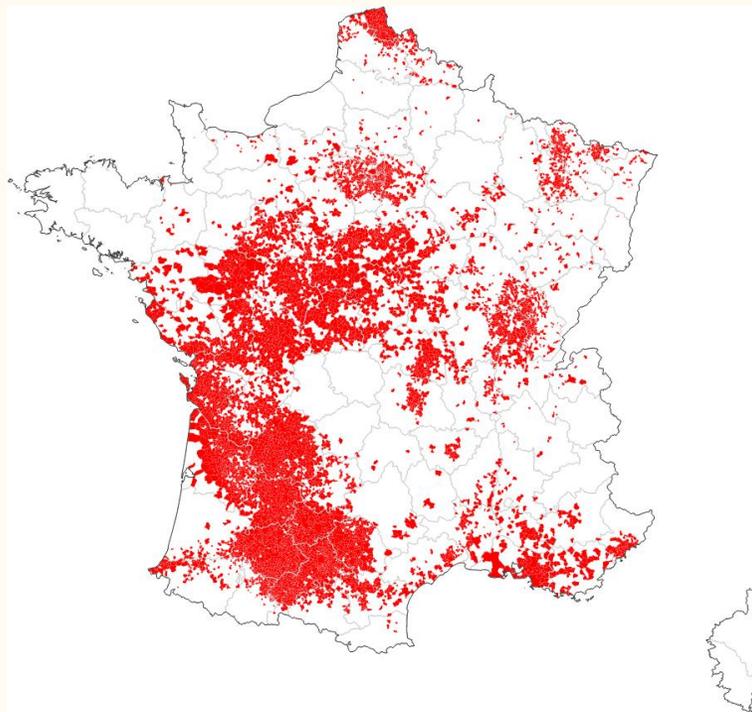


# RISK

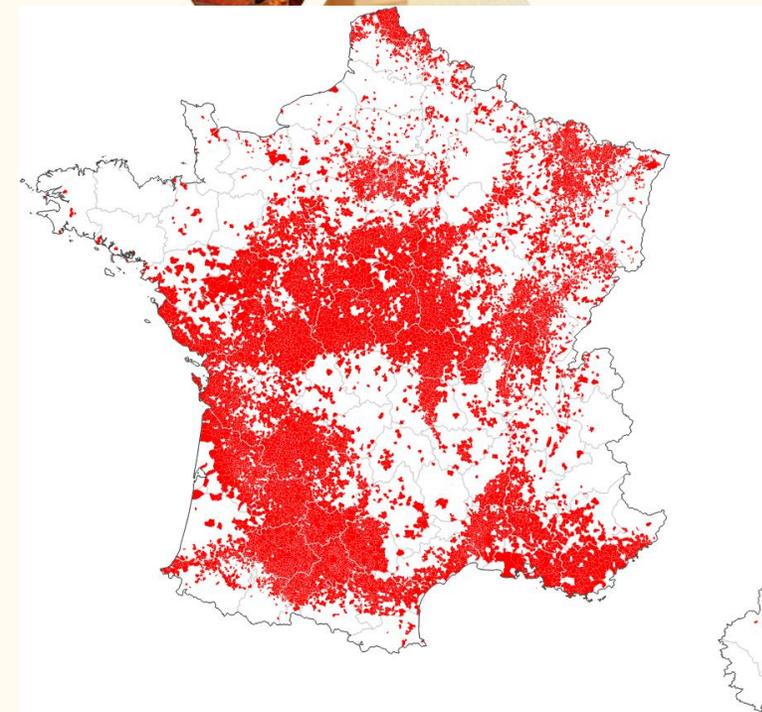
Summer  
School  
**2024**



1989-2002  
14% municipalities  
490 M€/y



2003-2015  
24% municipalities  
410 M€/y



2016-2022  
40% municipalities  
1,3 B€/y

**Thank You**

