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France-Wallonie-Vlaanderen
UNION EUROPÉENNE
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RISSC

with the support of the European Regional Development Funds

Avec le soutien de la
Wallonie

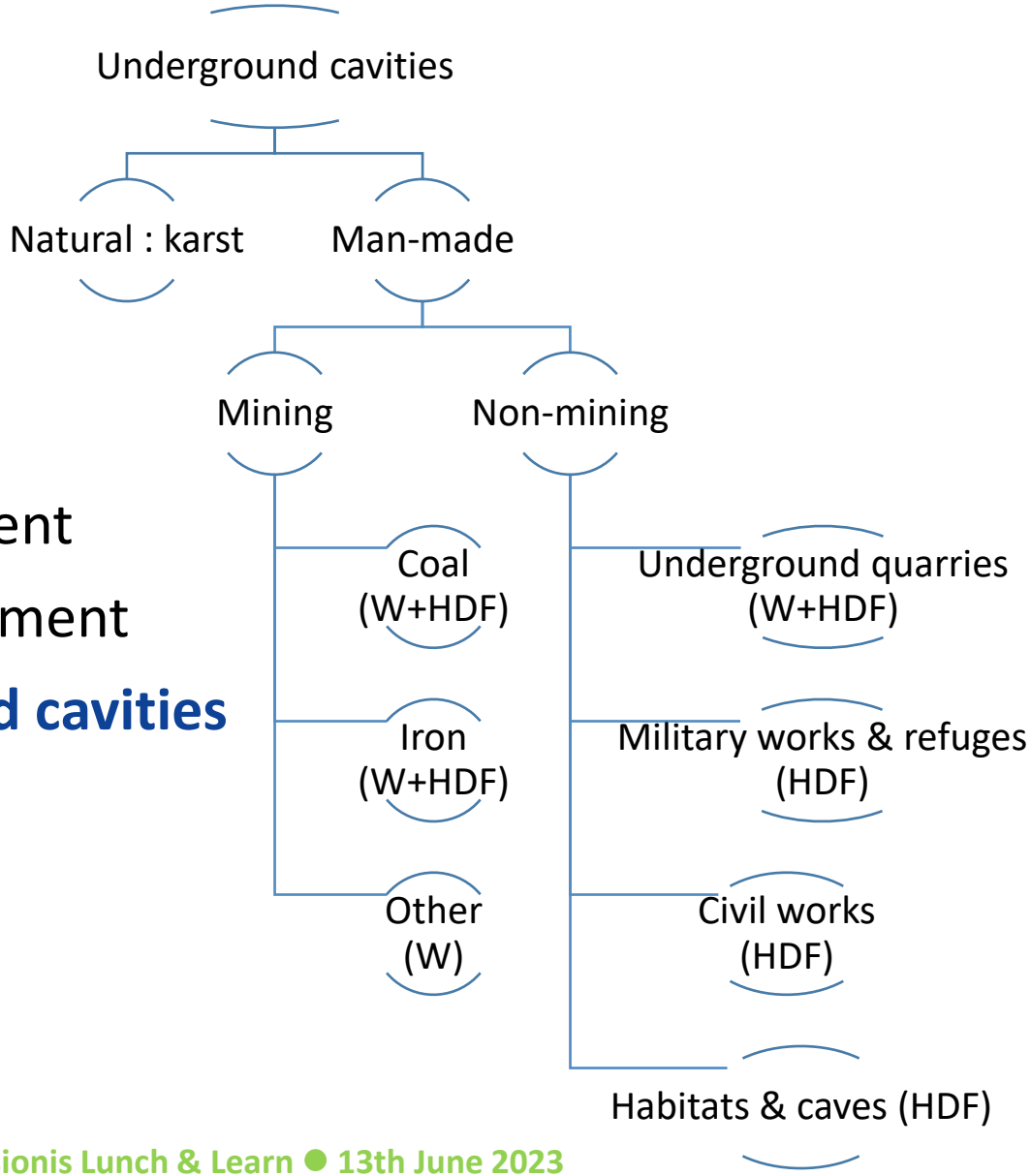
Characterisation of the cavity risk and influence of underlying mining works

Fanny Descamps, Temenuga Georgieva, Jean-Pierre Tshibangu
UMONS

A few words about the RISSC project

RISSC RIsques Sous-Sol Cavités

Cross-border improvement of prevention and management of risks related to **underground cavities**



A few words about the RISSC project

Ere	Systeme	Geodynamique	Paysages	Structures tectoniques	Roches/minerais exploites	Cavites remarquables
Cenozoïque	Quaternaire	Sismicité Eustatisme Incision vallées Loess-Karst	Plateforme continentale	Joints NW-SE	(Argiles !) Grès	
	Neogene	Volcanisme (Nord-Est)	Erection	Joints NE-SW E-W	Calcaire lutétien	Laon Senlis
	Paleogene	Inversion tertiaire Z.C.N.A.	Apport éolien terrigène Monts de l'Artois		Calcarénite	
Mesozoïque	Cretace	Inversion alpine Extension	Mer de la craie	Cisaillement Extension NE-SW	Craie phosphatée Craie blanche + silex (Argiles)	Malogne Spiennes, Arras, Mimoyecques
	Jurassique	Karst	Marécages	Failles normales synsédimentaires Diaclases Flexure		
	Trias	Pénéplanation-érosion	Début Bassin de Paris	Fracturation hydroplastique		
Paleozoïque	Permien	Front varisque Raccourcissement hercynien	Montagne hercynienne	Plis varisques cylindriques		
	Carbonifere	Dépôt houiller (grès, schistes, charbon) Dépôt calcaire	Mer épicontinentale	Failles régionales + filons	Charbon-houille-grès Calcaire Pierres ornementales	Bassin houiller (Douai, Borinage, Centre, Charleroi, Liège) Mazy, Soignies, Tournai
	Devonien	Plateforme en extension	Mer dévonienne	Failles normales, diaclases	Plomb-zinc-galène-fer	Calestienne Karst (Han-sur-Lesse) Vielsalm-Lierneux
	Silurien	Raccourcissement calédonien	« Monts calédoniens »	Schistosité	Ardoises	
	Ordovicien	Dépôt terrigène	Océan	Clivage + filons	Coticule	
	Cambrien			Discordance		

Vandycke (2022)

A few words about the RISSC project

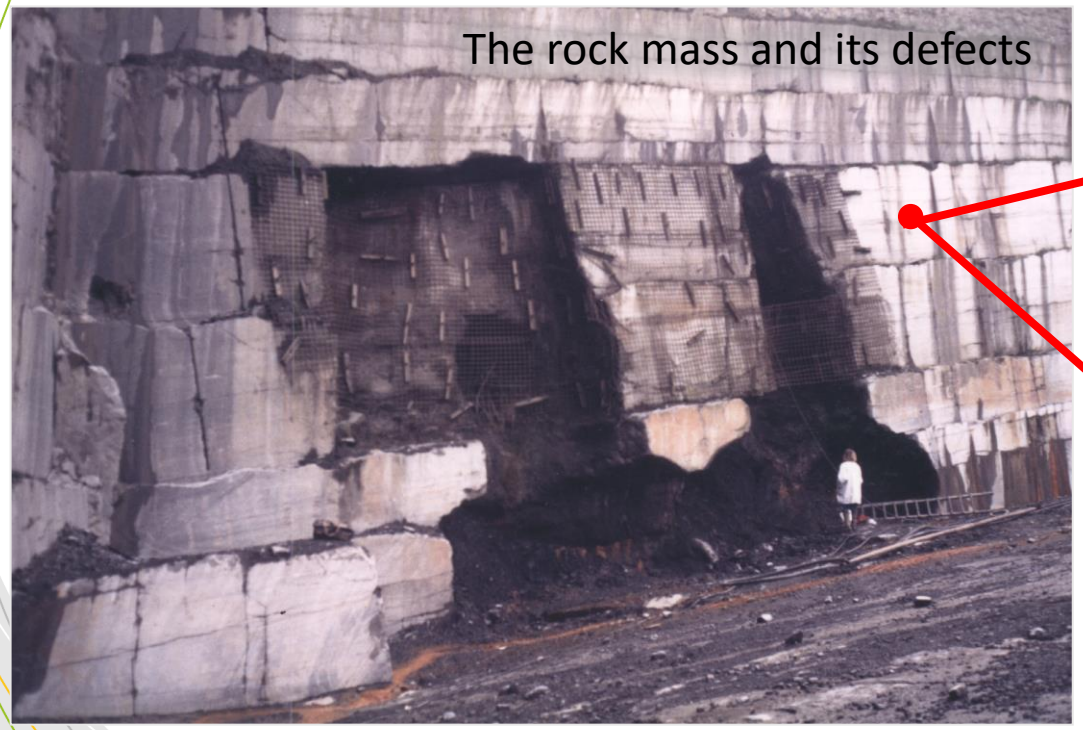
RISSC

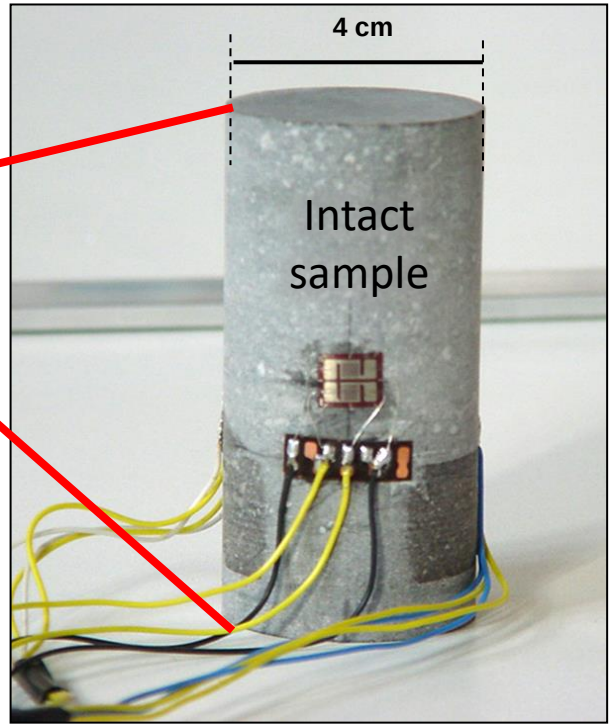
1. Characterisation of underground objects and threats, in particular:
   - Understanding failure mechanisms: testing, modelling, interpretations
   - Influence of underlying mining areas
2. Local solutions for reducing the risk
3. Technical support for local actors and populations

Work achieved in the framework of Temenuga GEORGIEVA's thesis at UMONS

Overall methodology

- Characterisation : in situ and in laboratory
- Identification of the mechanical behaviour of geomaterials





→ Constitutive law

Overall methodology

- Characterisation : in situ and in laboratory
- Identification of the mechanical behaviour of geomaterials
- Geomechanical numerical models to investigate failure mechanisms
- Particular case of underlying mining influence

Test site : Malogne underground quarries (Mons)

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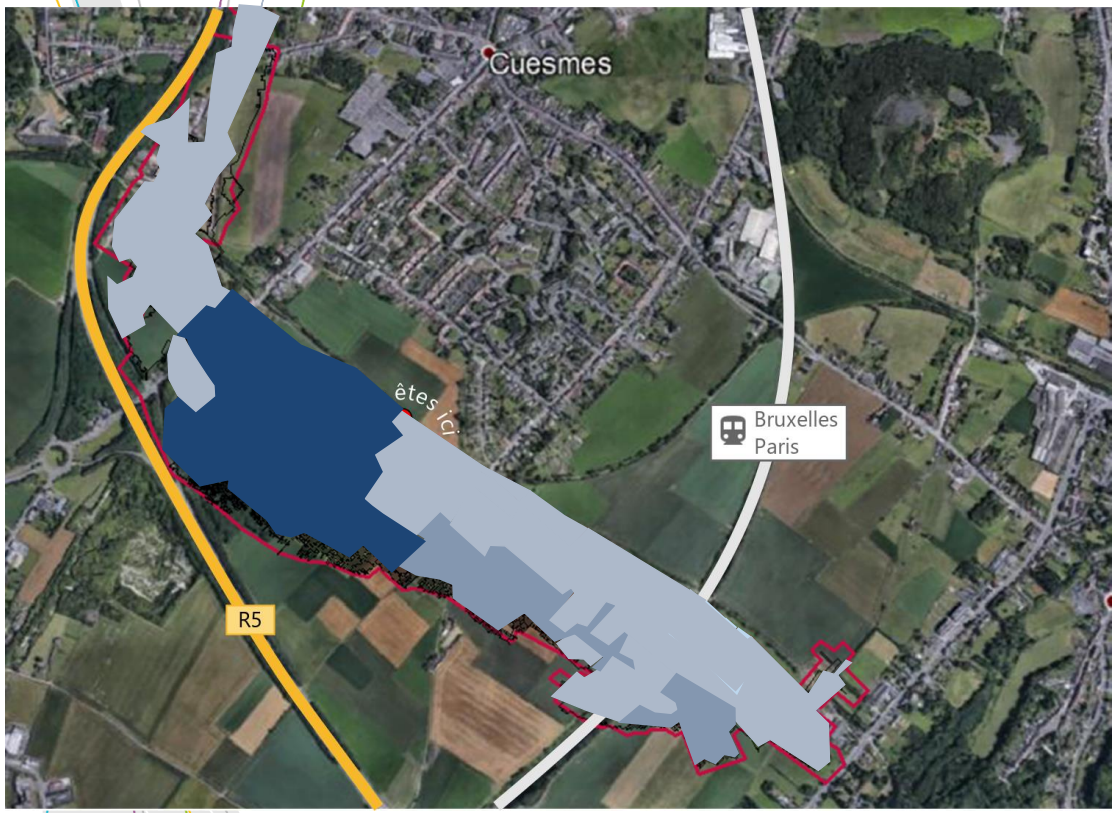

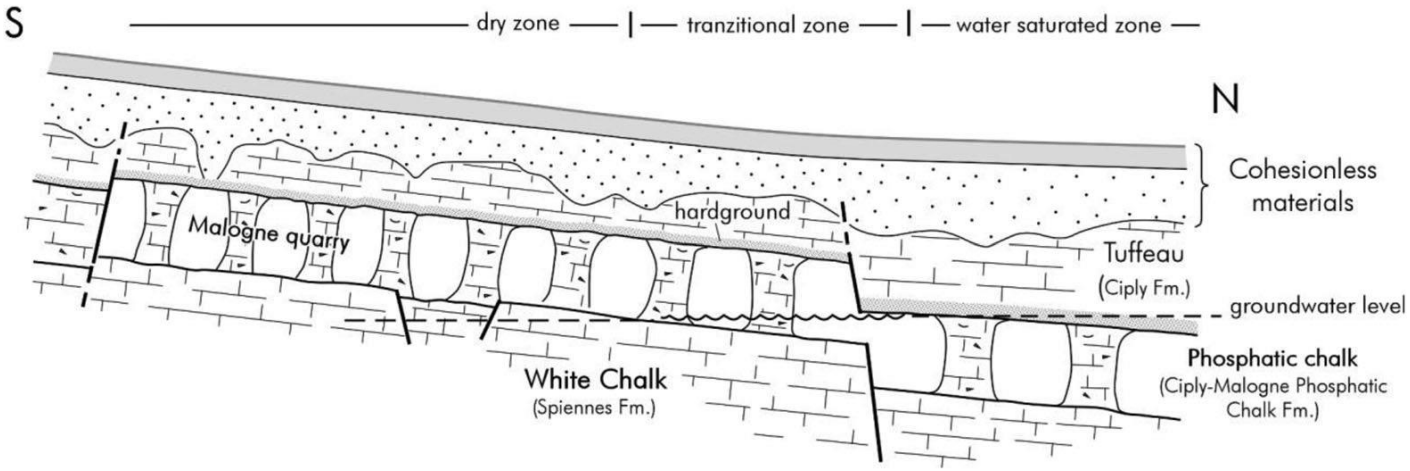

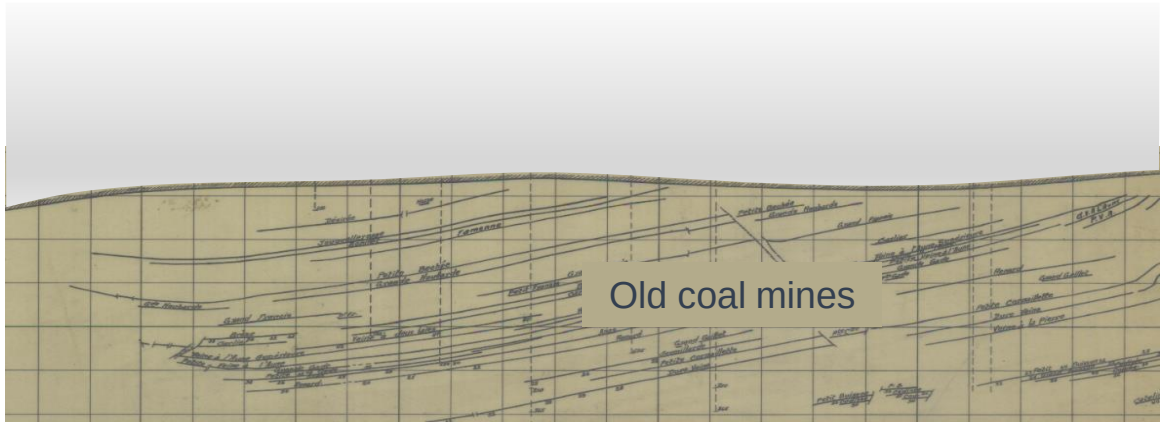

Test site : Malogne underground quarries (Mons)

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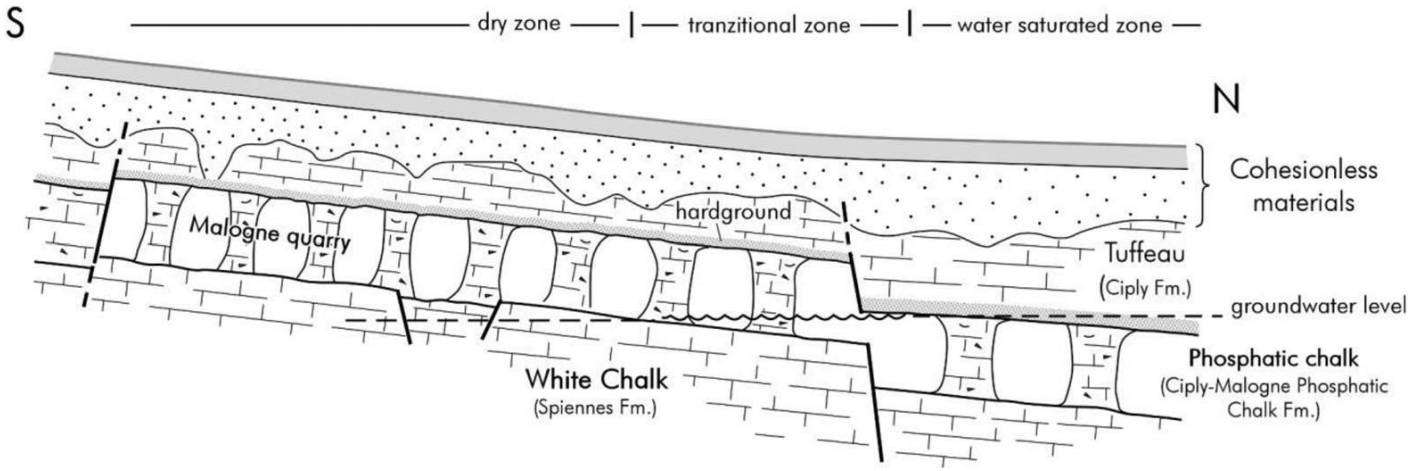
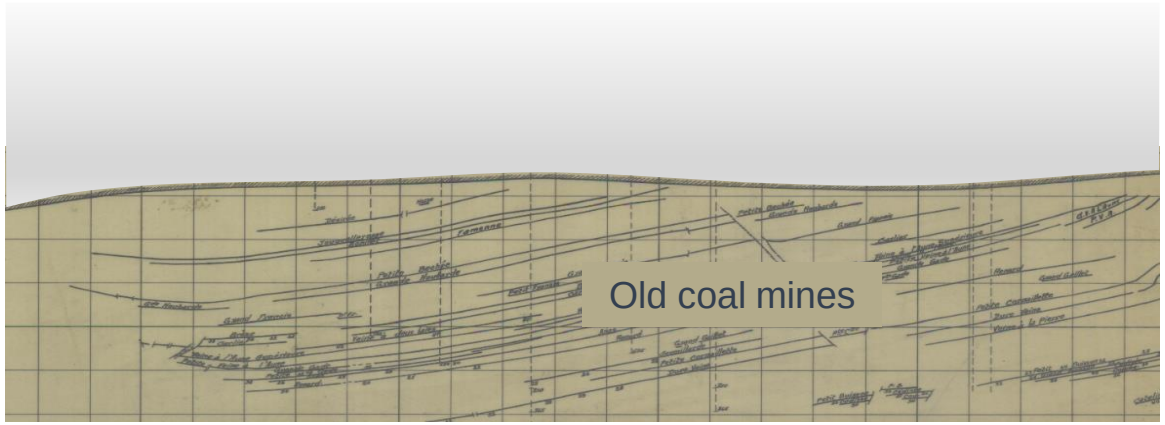
- 1860-1963 : coal mining
  - 24 seams
  - Depth : about 200 to 840m
  - Mined out thickness: up to 15m (4-8m in the studied area)
- 1877-1925: phosphatic chalk quarrying
  - Room and pillar method (67ha)
  - Depth : 13-25m
  - Geology : Mons Basin, extension tectonics





Overview of the site

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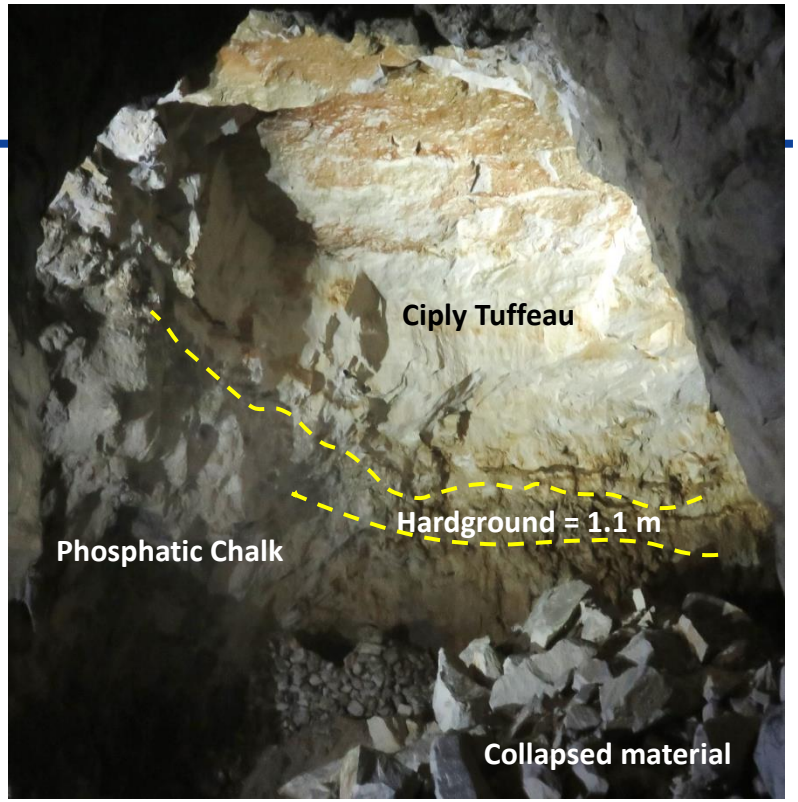
- Large and well documented
- Variety of phenomena:
  - Fall of roof
  - Splitting of pillars
  - Diabolo pillars
  - Karstification & oxydation

Mapping



Generalised collapse in 2015

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Photo : CACEff, 2015

Mining subsidence

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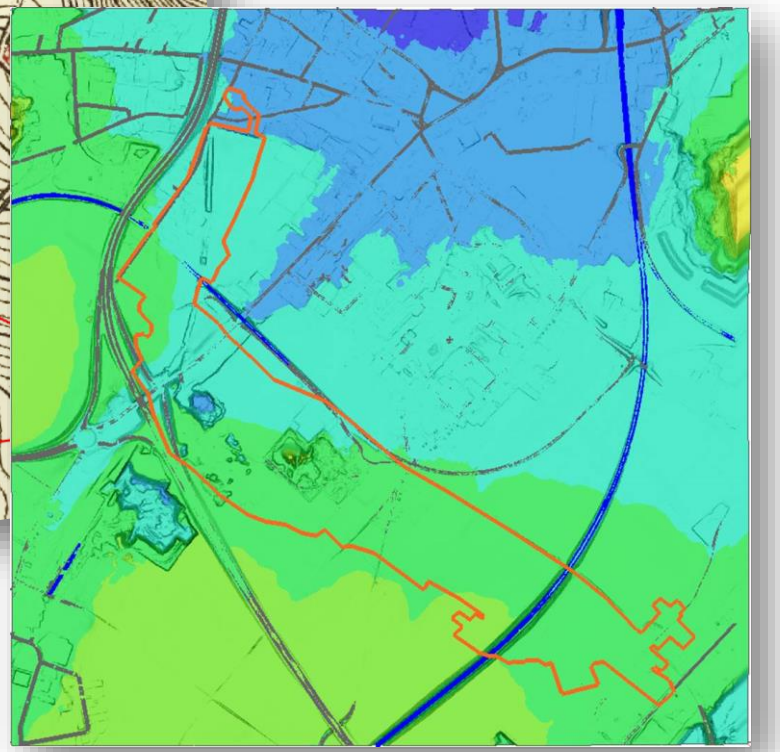
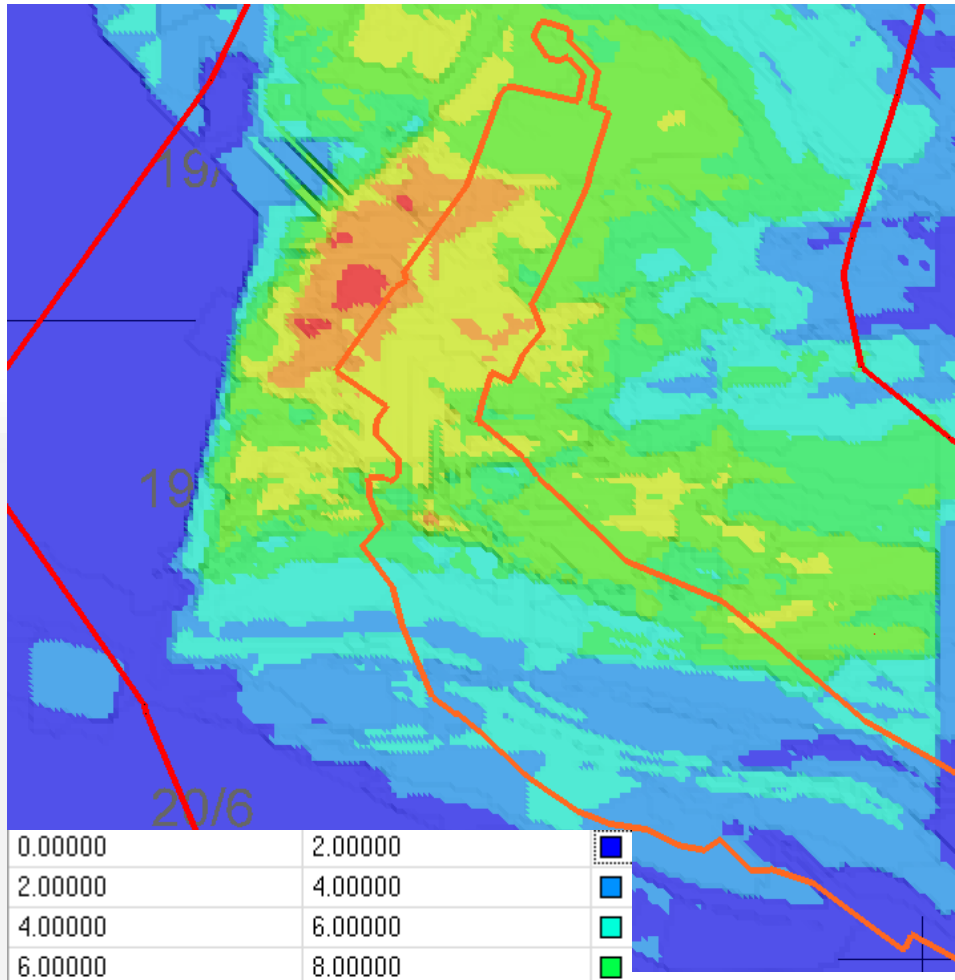
Initial topography
- Map « dépôt de la guerre » (1865-1880)
- // start of coal mining

Current topography
- MNT 2013-2014

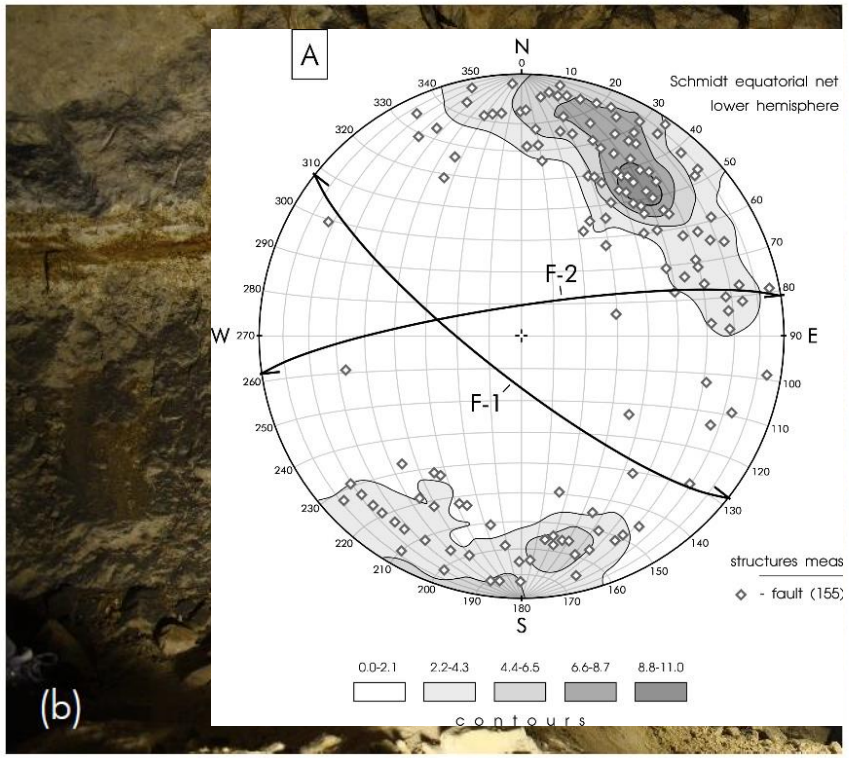




0.00000	2.00000	
2.00000	4.00000	
4.00000	6.00000	
6.00000	8.00000	
8.00000	10.00000	
10.00000	12.00000	
12.00000	14.00000	
14.00000	16.00001	

Rock mass characterisation

- Structural survey in order to identify discontinuities
  - 2 sets of faults F1 and F2
  - 2 sets of joints



Collaboration SPW

Rock mass characterisation

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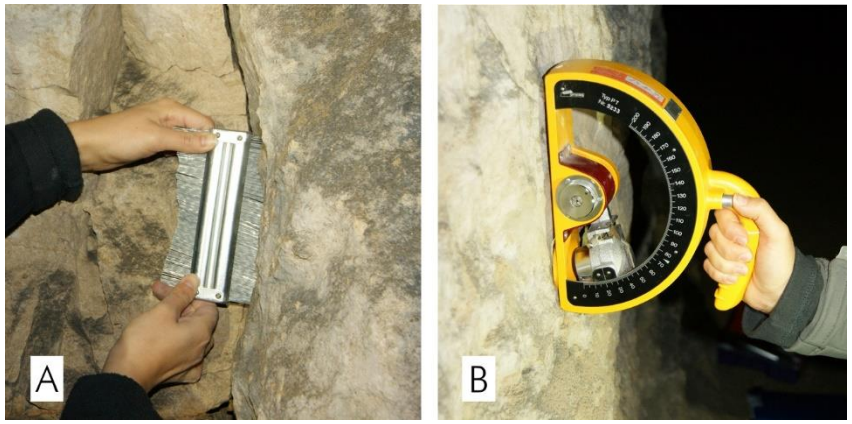
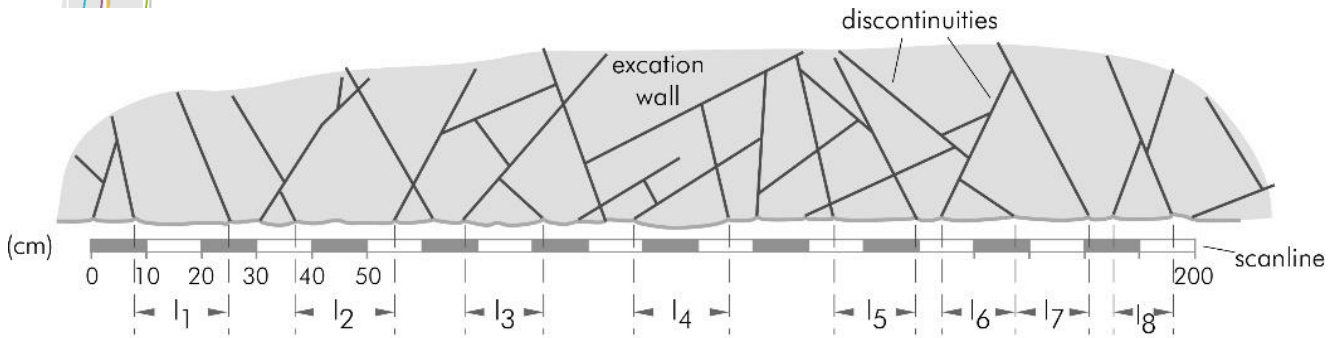
- Rock mass quality indices (RQD, RMR, GSI)

  to account for:
  - Discontinuity spacing
  - Rock strength (Schmidt hammer measurements)
  - Nature of joints (roughness)
  - Water conditions

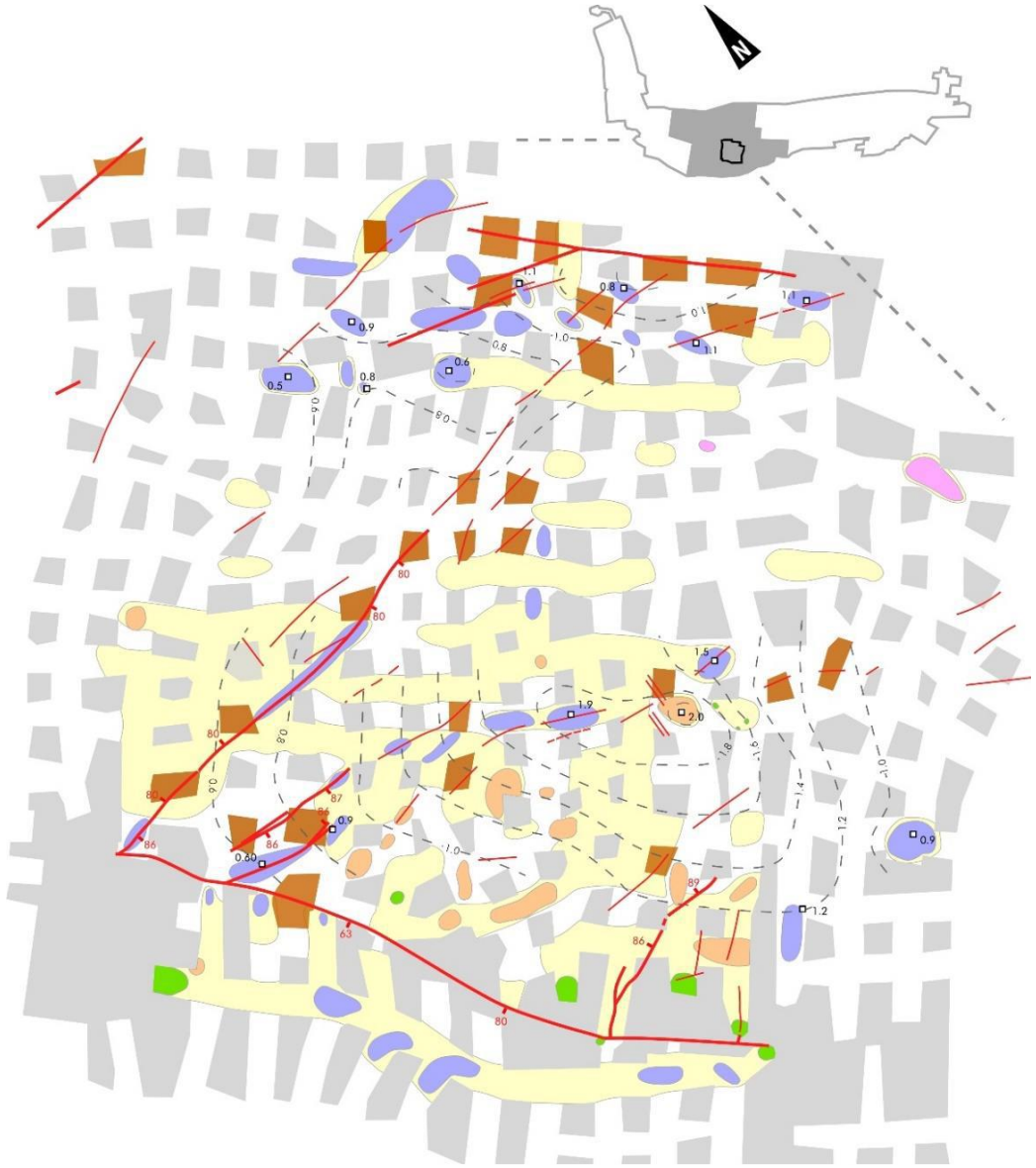




$$RQD_w = \frac{l_1 + l_2 + \ldots + l_8}{\text{scanline lenght}} \times 100\ (\%)$$

Rock mass characterisation

RISSC



Mining layout

- pillar

Lithology

- oxidation
- hardground measurement point
- hardground thickness isoline

0 5

Instability features

- damaged pillar
- roof slabbing
- roof scaling
- dome-shape structure
- sand pocket (paleokarstification)

Structural data features

- normal fault
- joint

Rock mass characterisation

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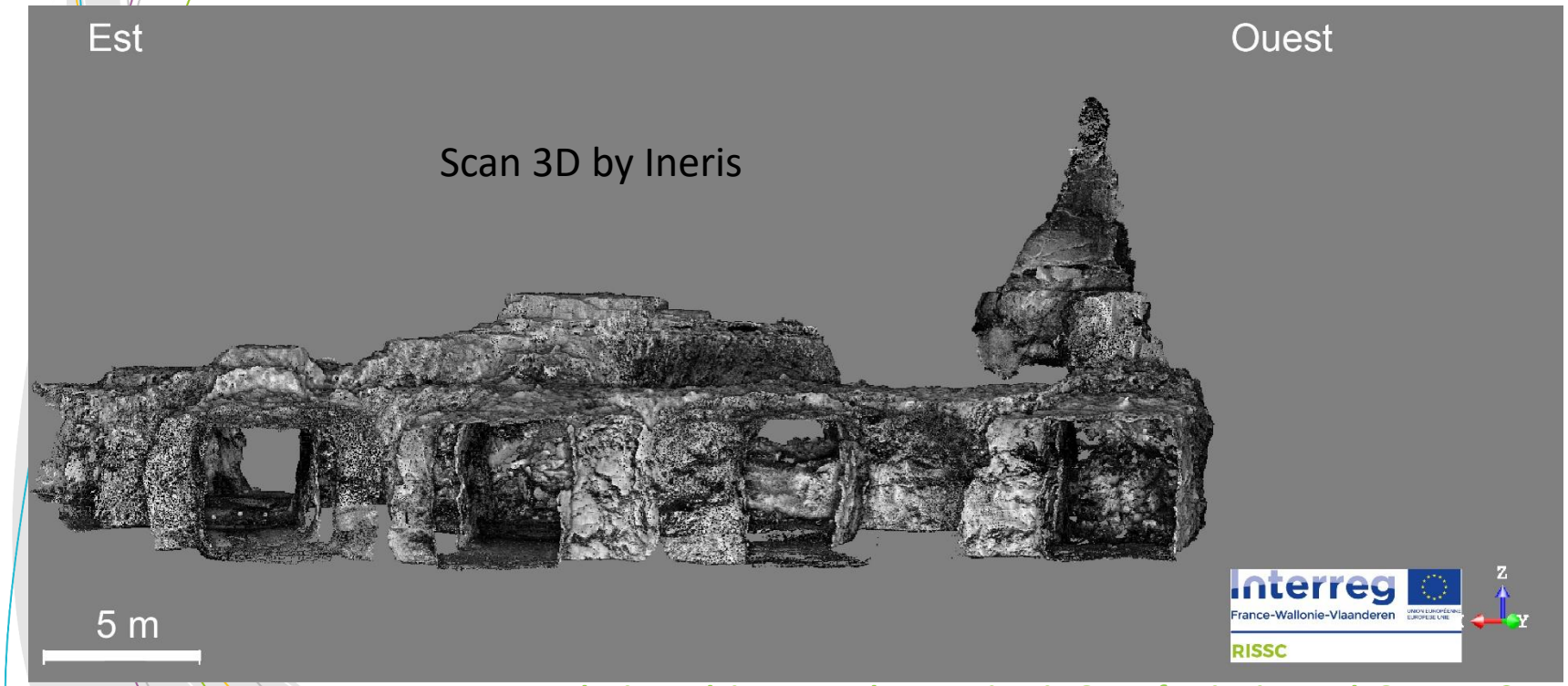
- Other techniques sometimes used, mainly for monitoring purpose in RISSC :
  - Photogrammetry
  - Scan 3D



Laboratory testing

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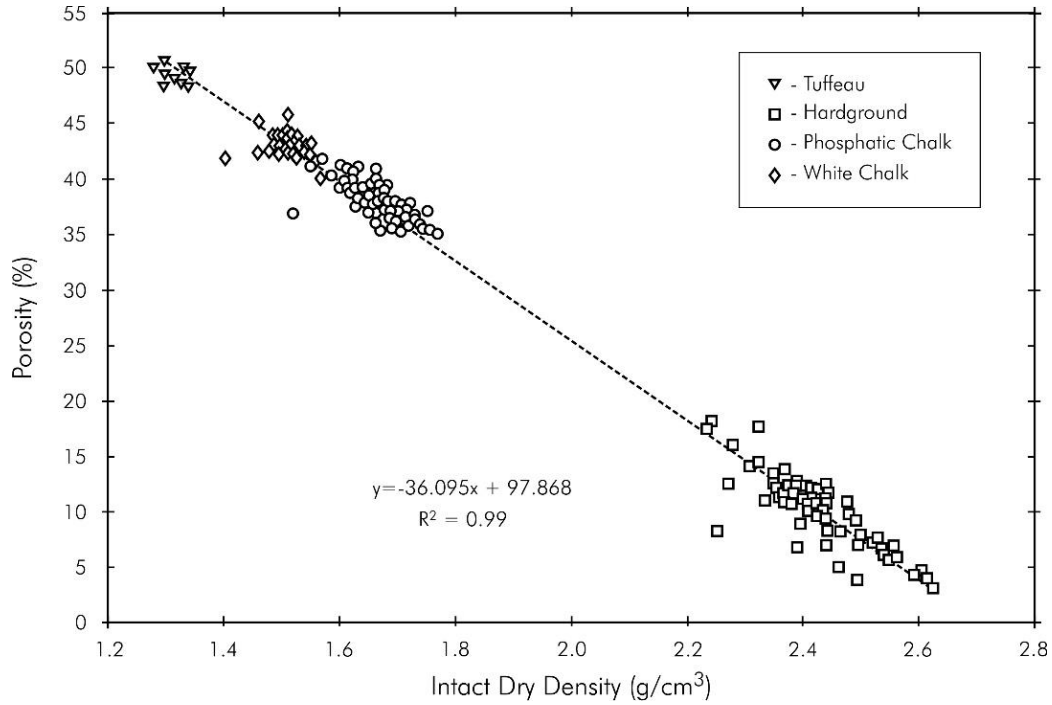
- Studied rocks
  - Phosphatic Chalk
  - Hardground
  - White Chalk
  - Tuffeau

HG PhosC WC

- Petrophysics
  - Density
  - Porosity
  - Sonic



Laboratory testing

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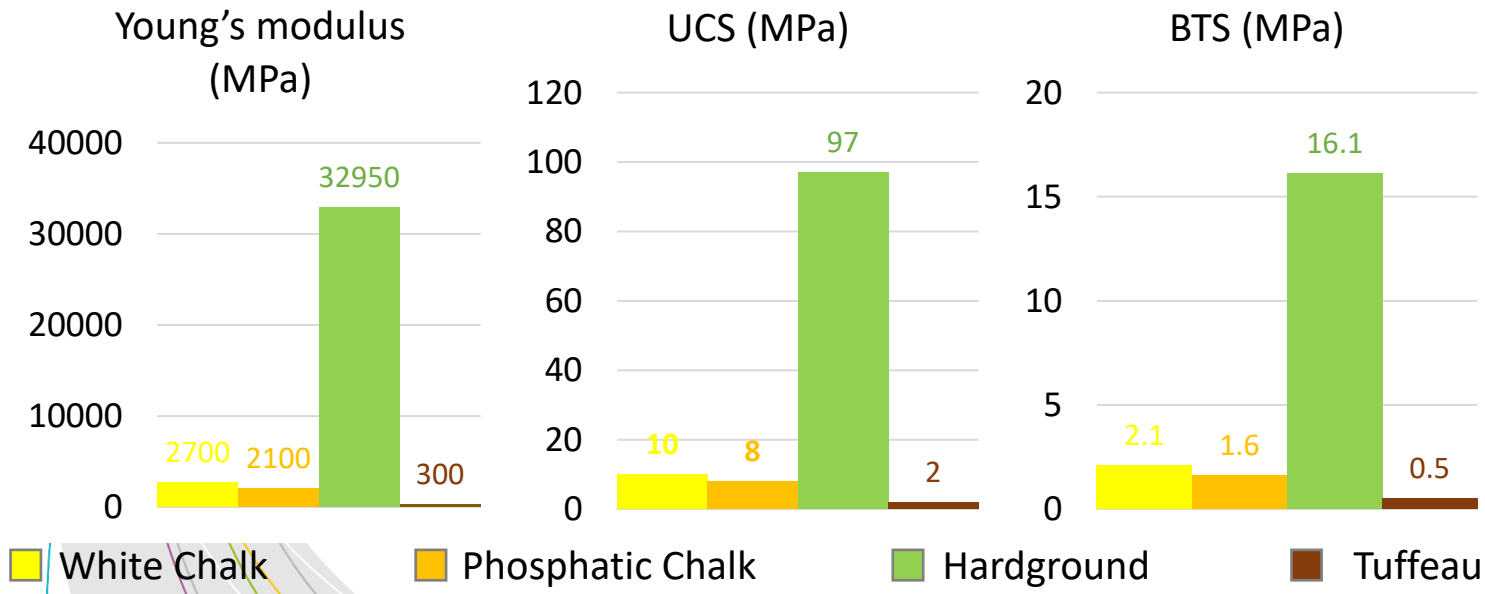
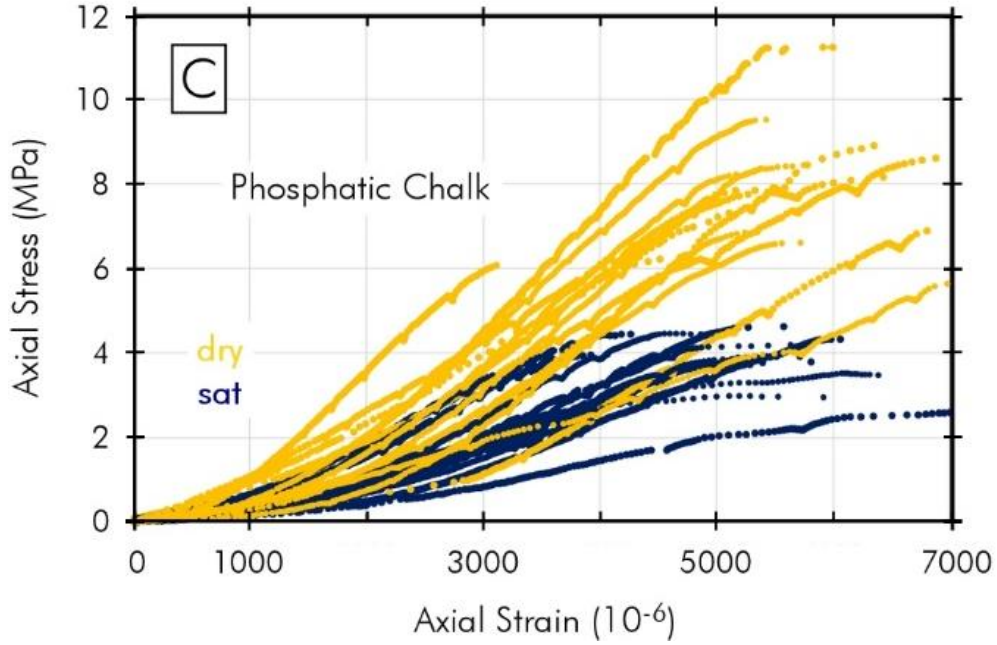
- Mechanical tests
  - Unconfined compression (UCS)
  - Brazilian tension (BTS)
  - True triaxial (hardground only)

Purpose :

Describe the mechanical behaviour under sollicitations by a mathematical model

- Stress-strain relationships
- Elastic domain – Yield/failure locus

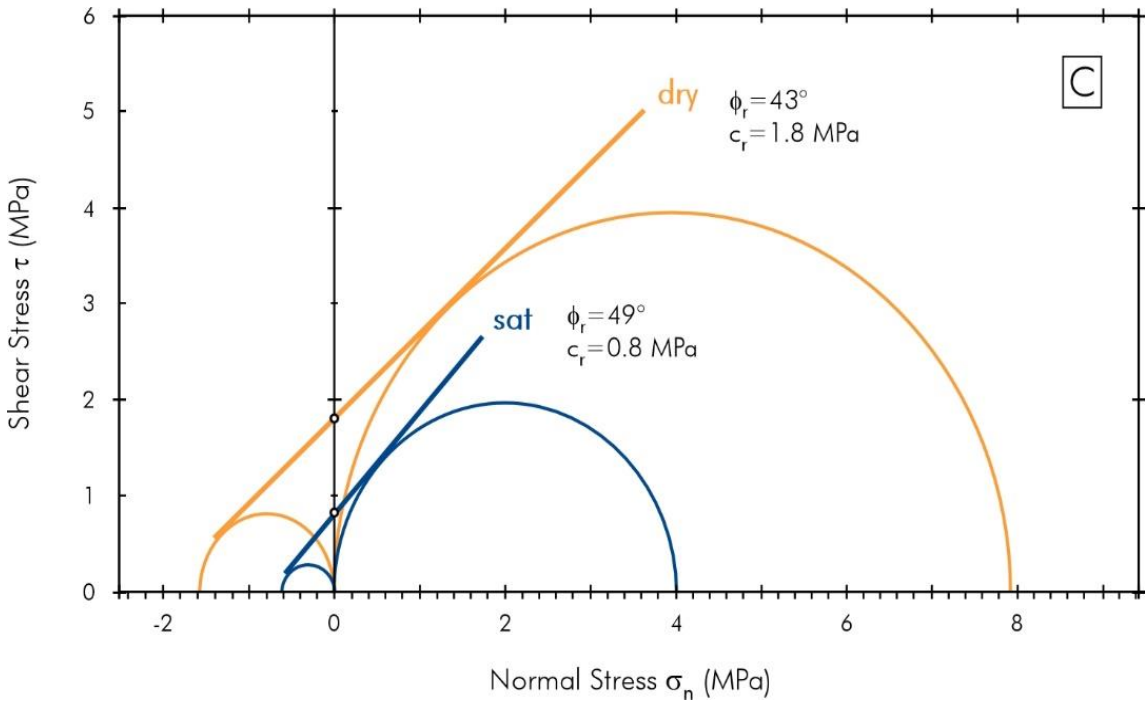




Mechanical behaviour

- Data : in situ + labo + literature
- Model: isotropic, elastic perfectly plastic behaviour with Mohr-Coulomb criterion

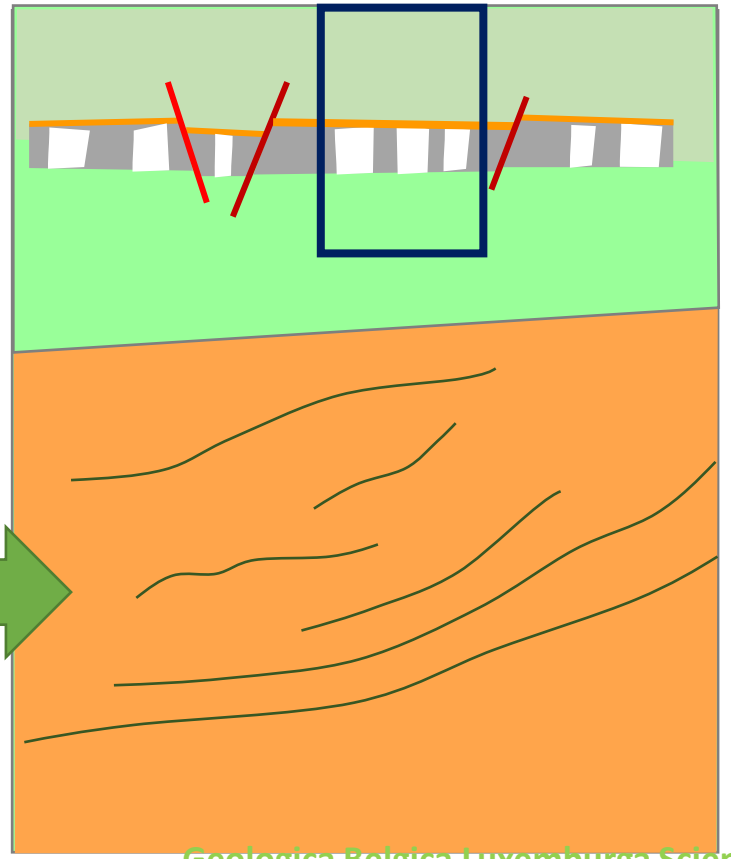
Material	E (MPa)	ν	R_t (MPa)	C (MPa)	φ (°)
Cohesionless	20	0.33	0	0	30
Ciply Tuffeau	160	0.2	0.01	0.1	30.4
Hardground	16 600	0.11	0.7	5.4	30.4
Phosphatic Chalk	1 140	0.23	0.06	0.4	30.4
White Chalk	1 400	0.25	0.07	0.54	30.4
Coal host rock (sandstones and shales)	17 000	0.15	4.8	5.2	41
Coal	3 000	0.3	1.5	1.9	48
Compacted goaf	7 750	0.1	1.5	1.7	21



Construction of a numerical model

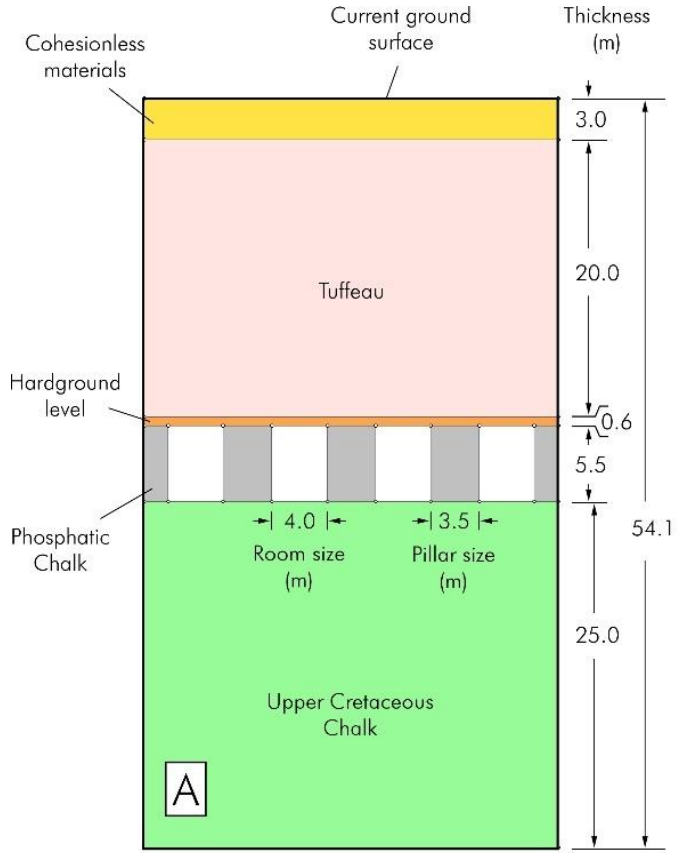
1. Large model with phosphatic chalk quarry and coal seams

How to model coal mining works?



Boundary conditions

2. Local model with parametric study of instabilities



Influence of underlying coal mines

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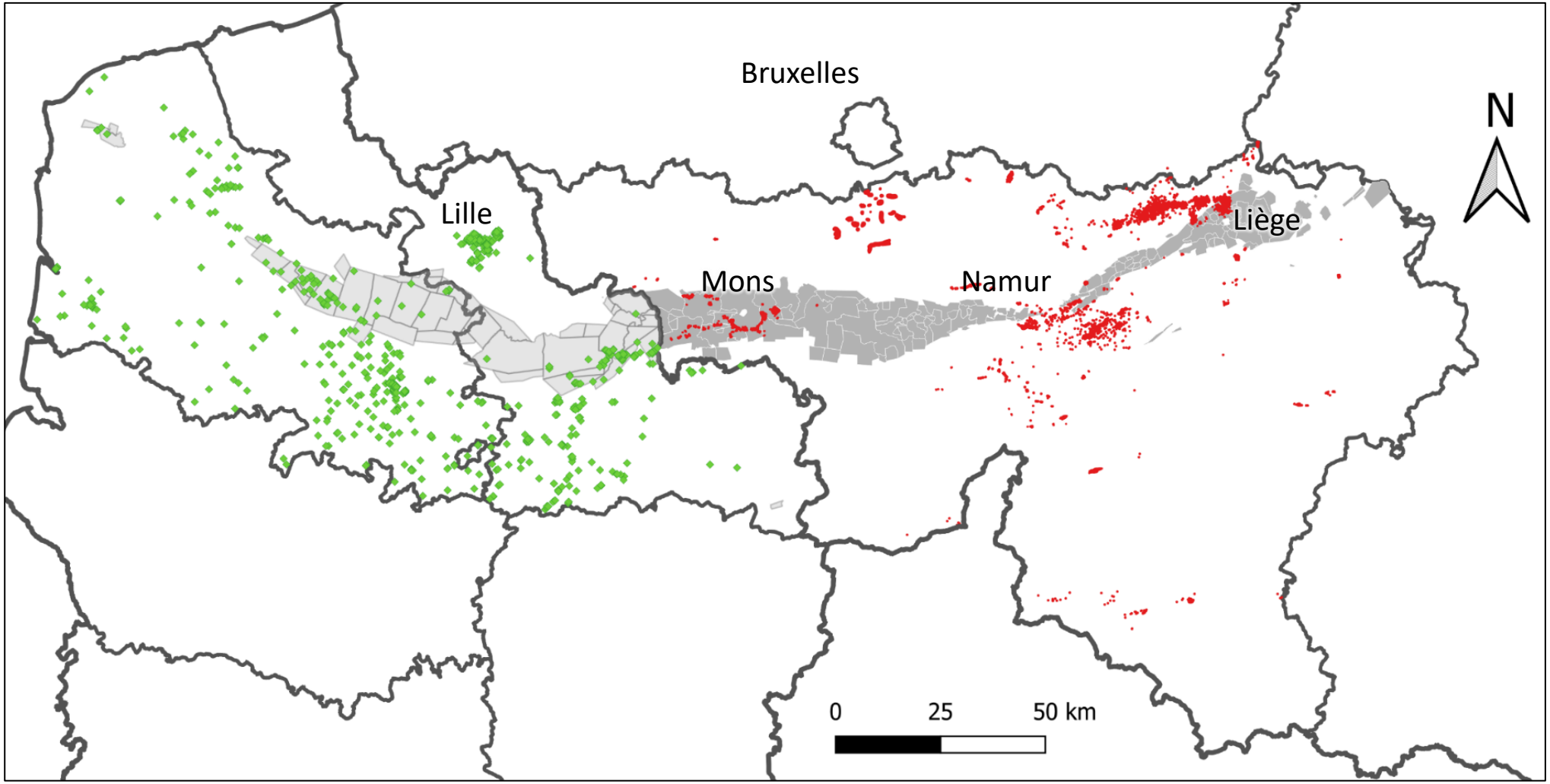


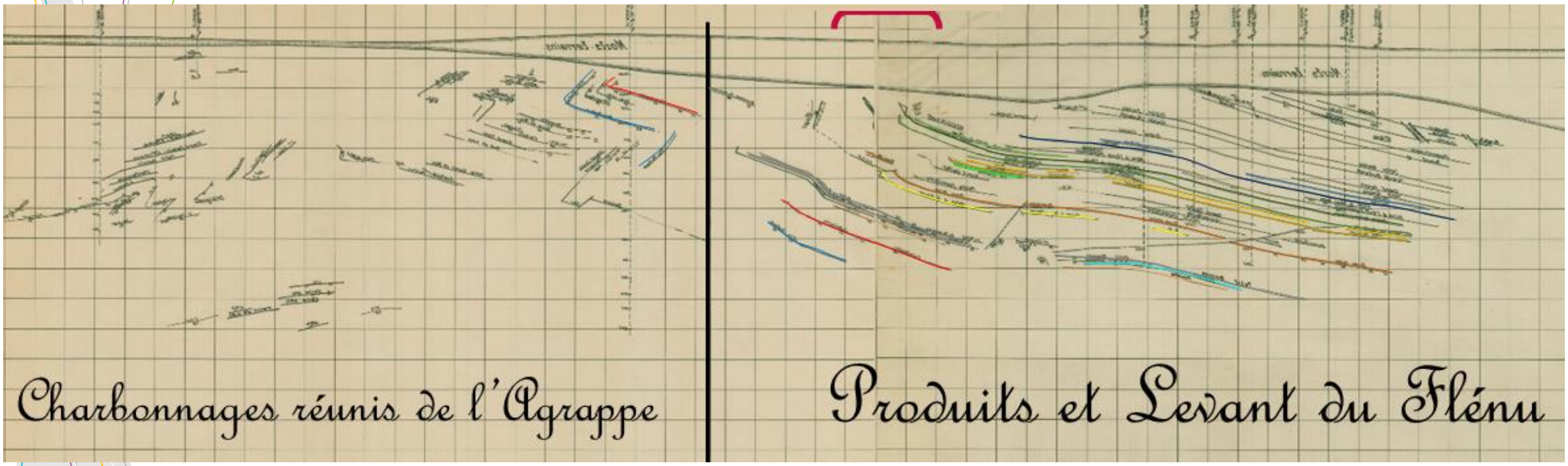
Underground quarries of Wallonia, Nord and Pas-de-Calais and coal concessions

Vertical cross-section

S

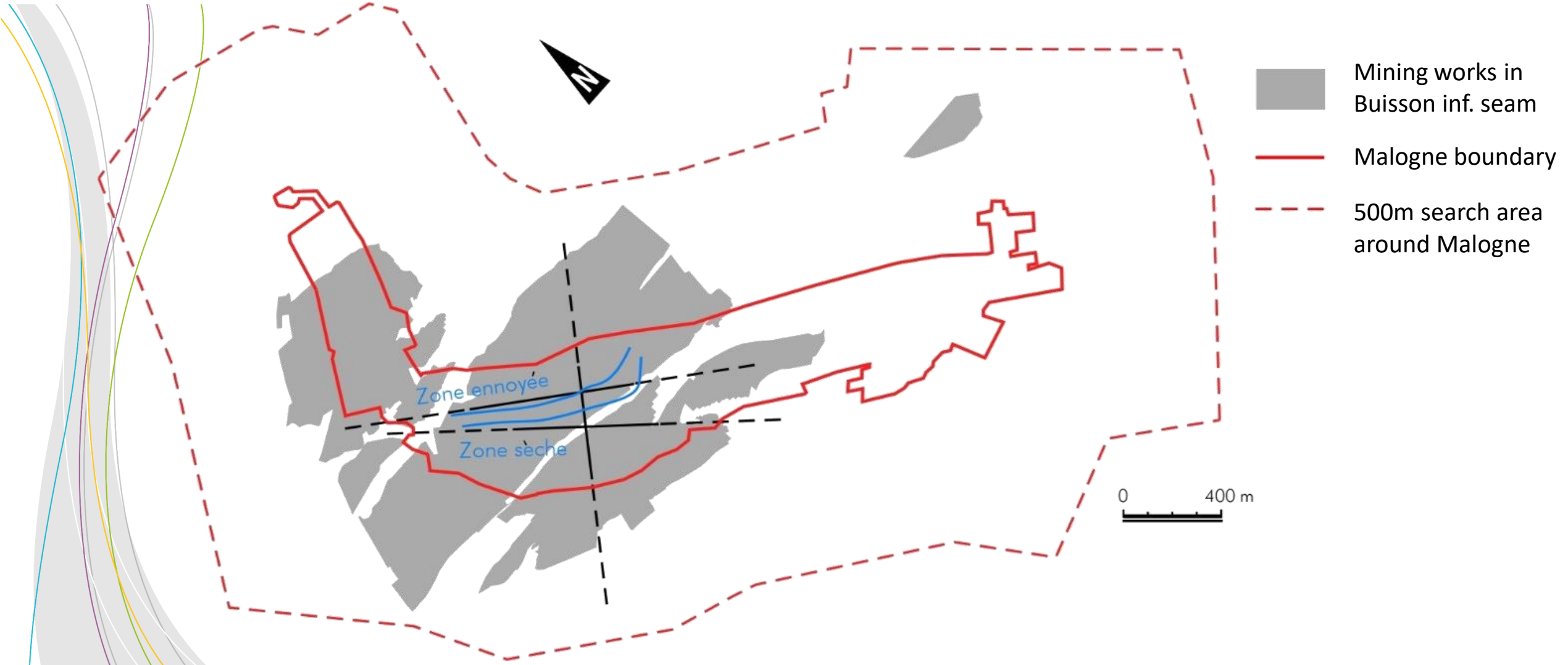
Malogne

N



How to model coal mining works?

RISSC



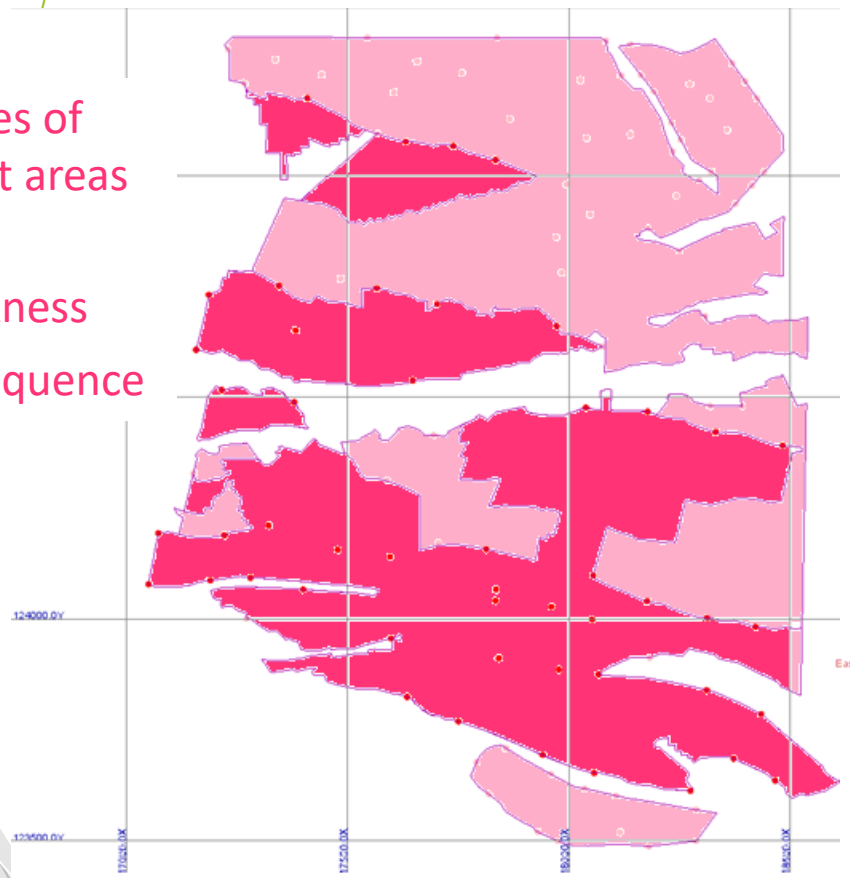
How to model coal mining works?

RISSC

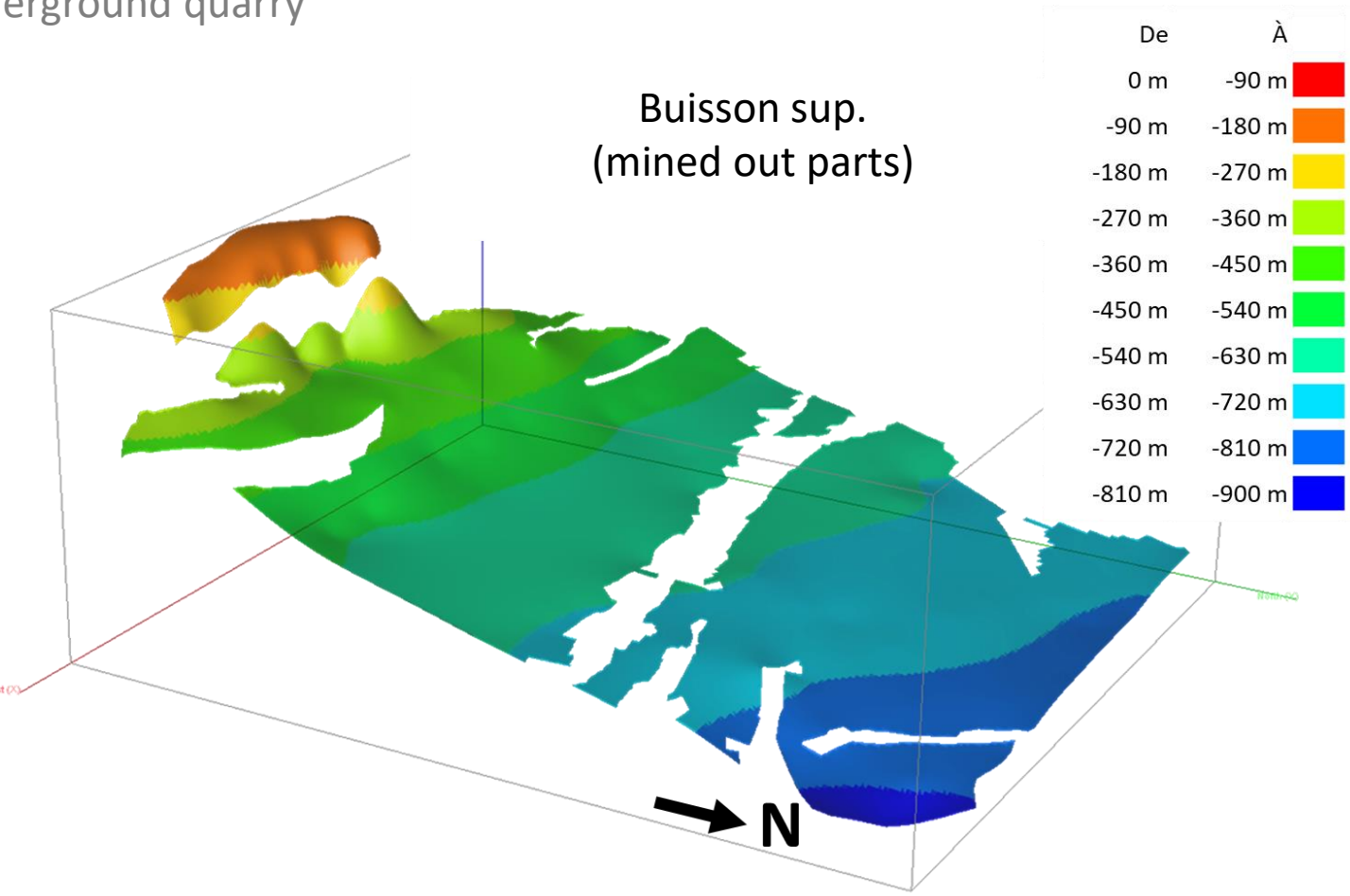
Coal mining

- Mining maps at 1:1000
- 500m around the underground quarry

- Boundaries of mined out areas (3D)
- Coal thickness
- Mining sequence

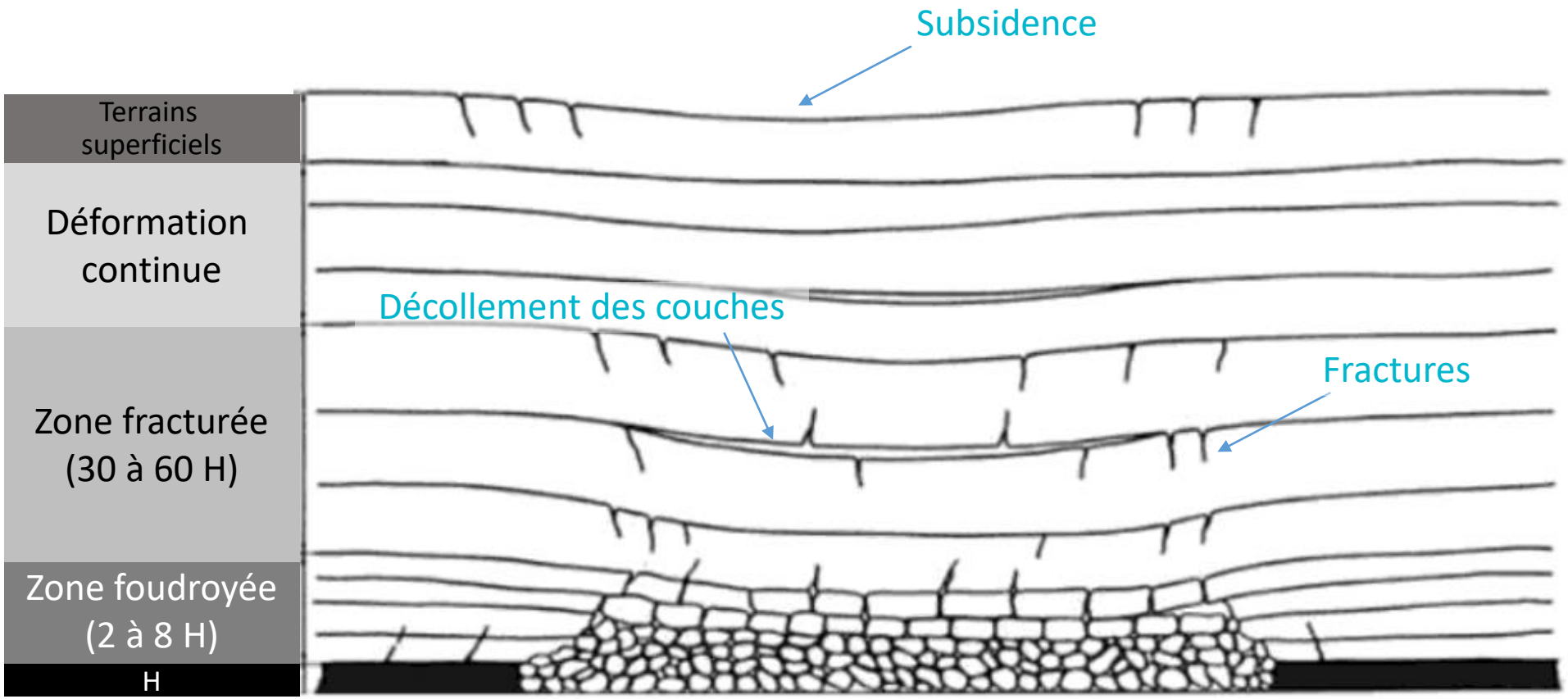


Buisson sup.
(mined out parts)



Collaboration ISSeP

Effects of longwall mining

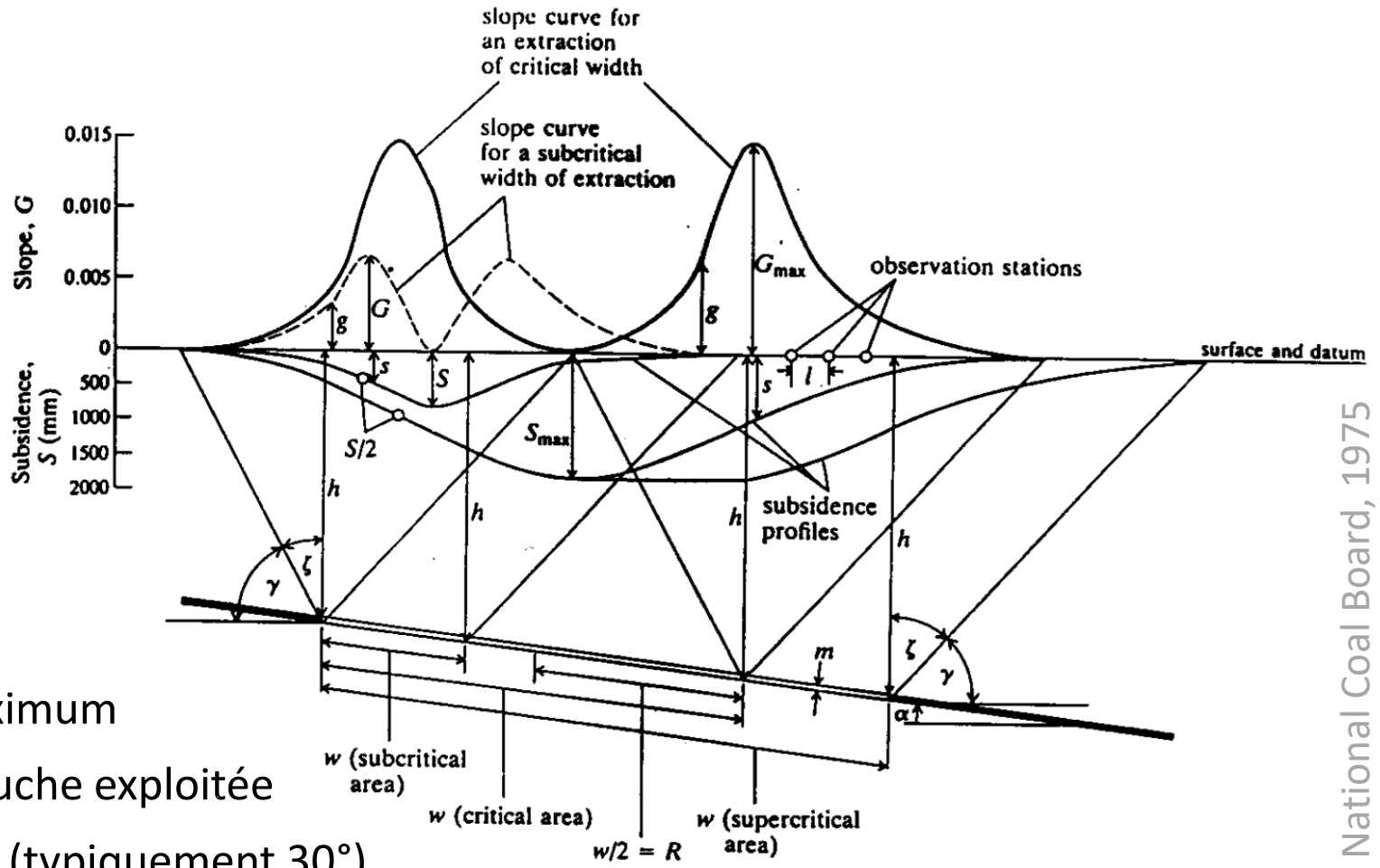


Panneau de longue taille

Assessing continuous subsidence

s, subsidence
= déplacement vertical d'un point en surface

S, subsidence max. pour un profil



National Coal Board, 1975

- S_{max}, affaissement maximum
- h, profondeur de la couche exploitée
- ζ, angle d'affaissement (typiquement 30°)
- W_c, largeur critique

$$W_c = 2h \tan \zeta$$

FEM analysis

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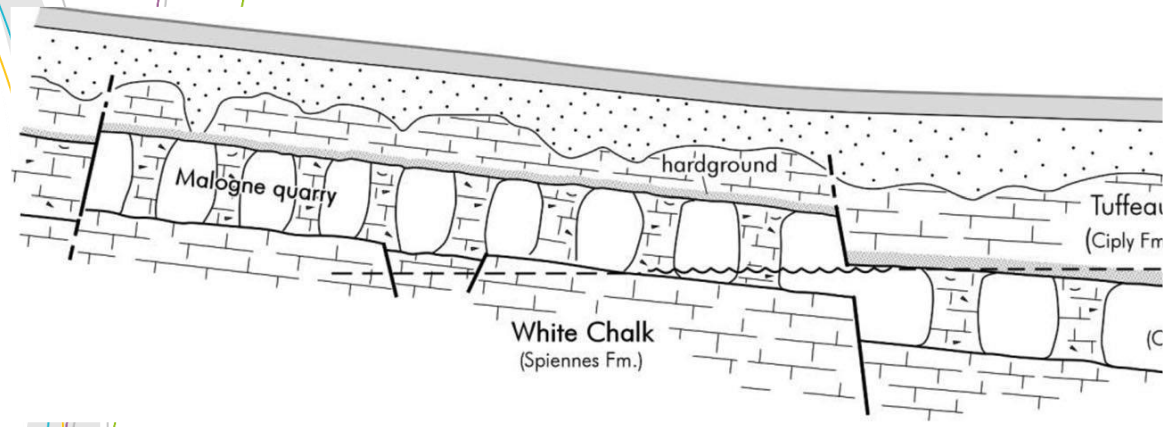

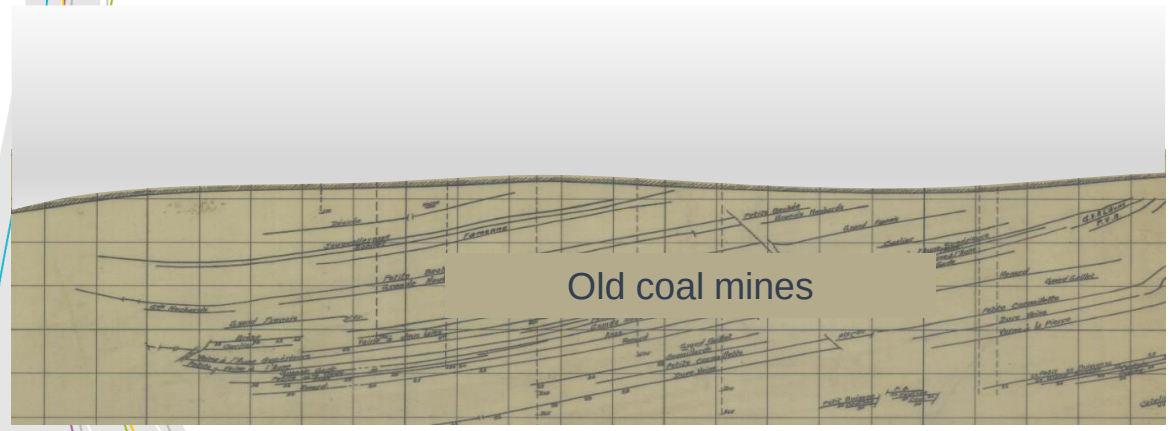

- From reality to conceptualisation
- Various underground works
- In situ observations
- Which failure mechanism is likely to occur?
- How can phenomena trigger and propagate?

FEM analysis

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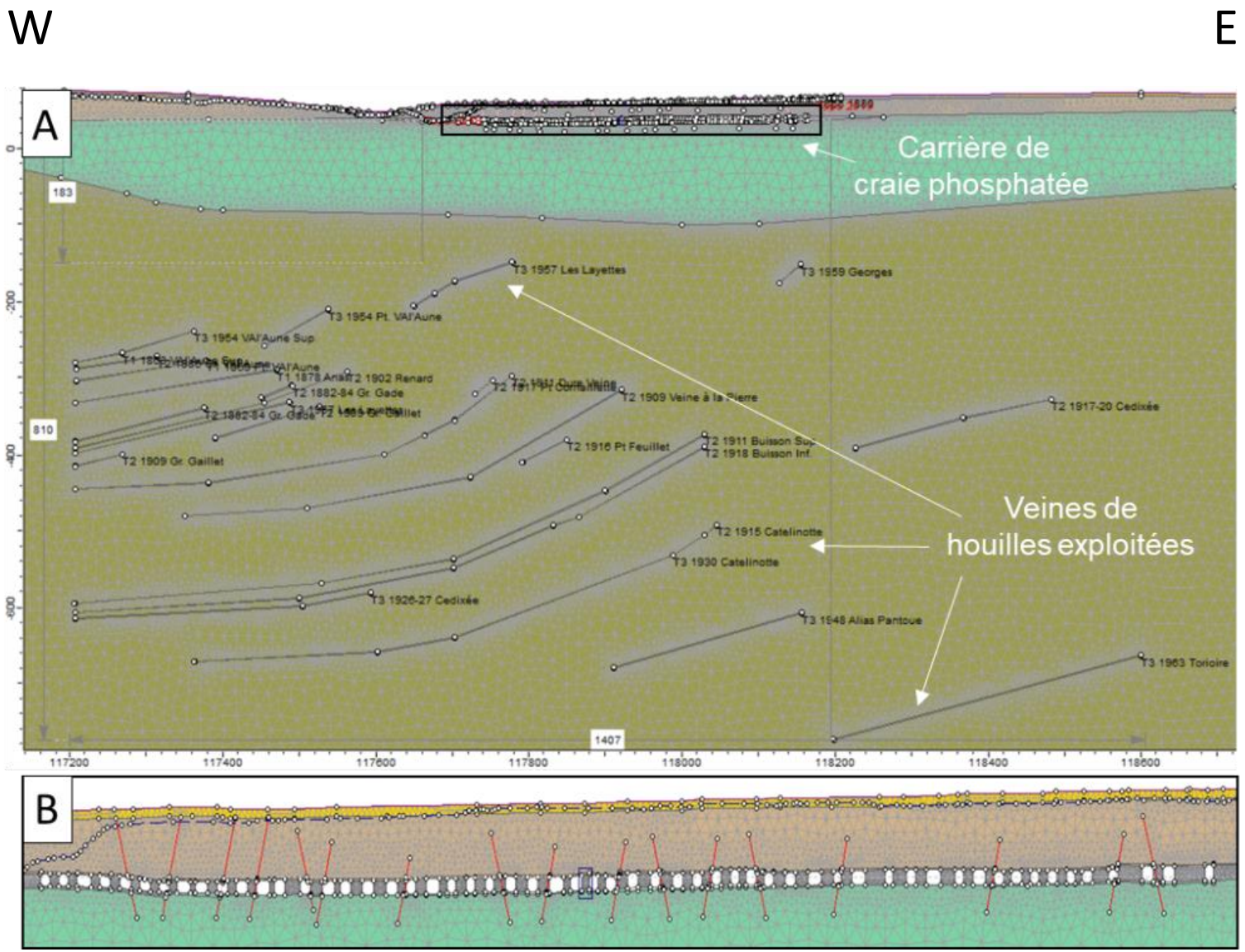
- Drillholes, maps
- Units :

Cohesionless materials
Ciply Tuffeau
Hardground
Phosphatic Chalk
White Chalk
Coal host rock (sandstones and shales)
Coal
Compacted goaf

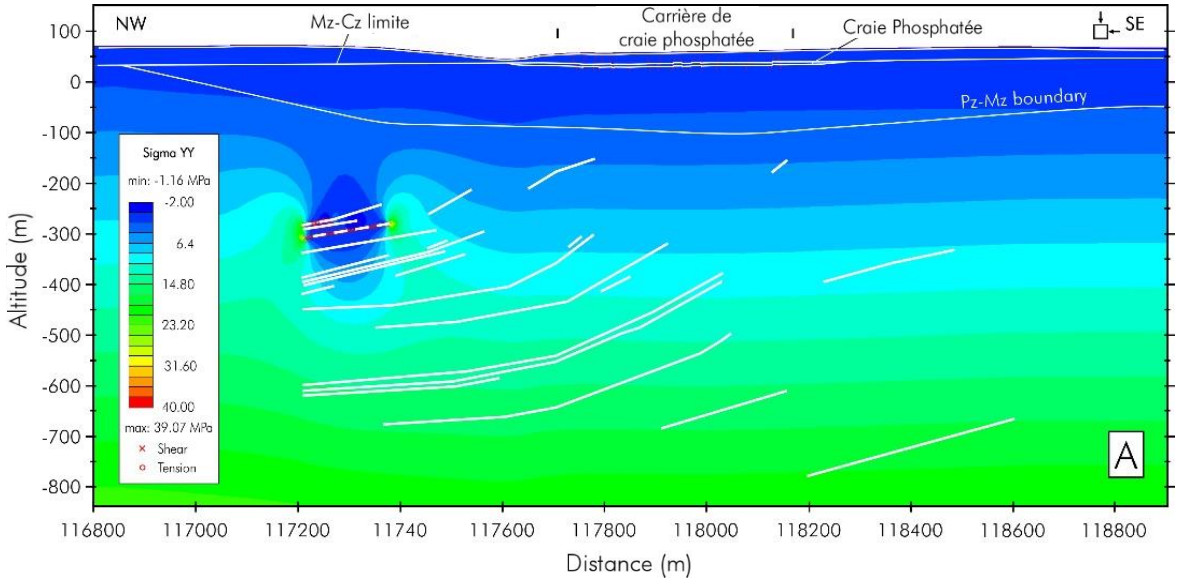
- Accounting for discontinuities

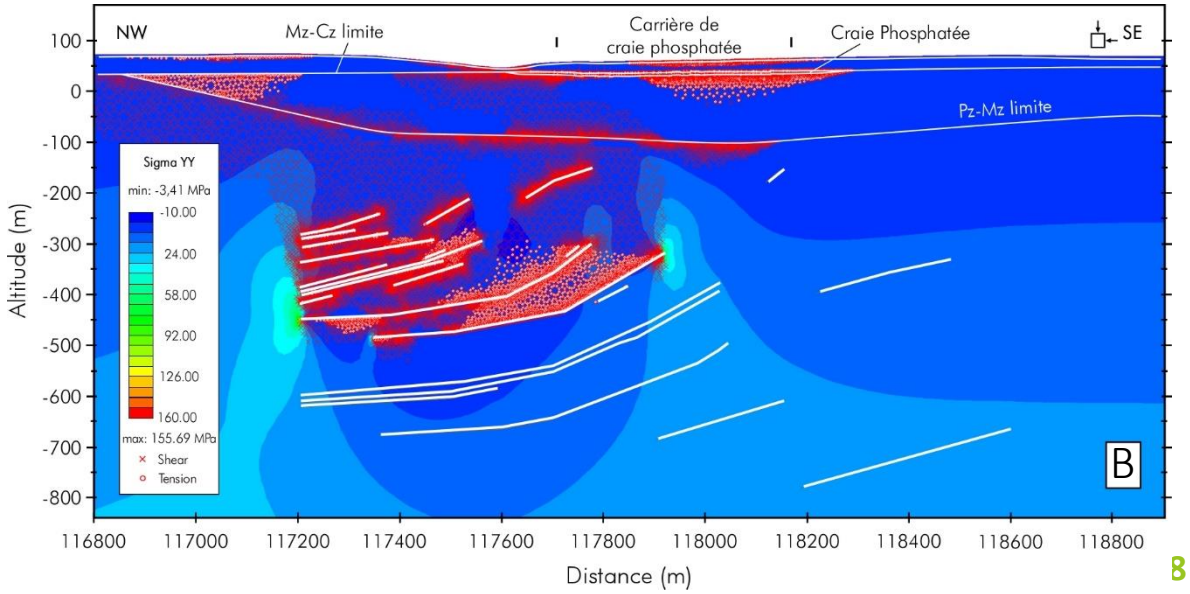


FEM analysis

RISSC

- **T1 : coal mining based on mining maps sequence (1860-1877)**
  - Creation of voids then replacement by a material « compacted goaf »
  - Stress redistribution
  - Mainly affects Cenozoic rocks
  - Limited effect on surface
- **T2 : mining of coal and chalk (1877-1925)**
  - Unknown sequence in chalk
  - Conceptualised in 3 steps
  - Failure initiates and propagates in the roof of the seams, through the interburden (caving)
  - Plastic zones in the interburden
  - Effects propagate into chalk



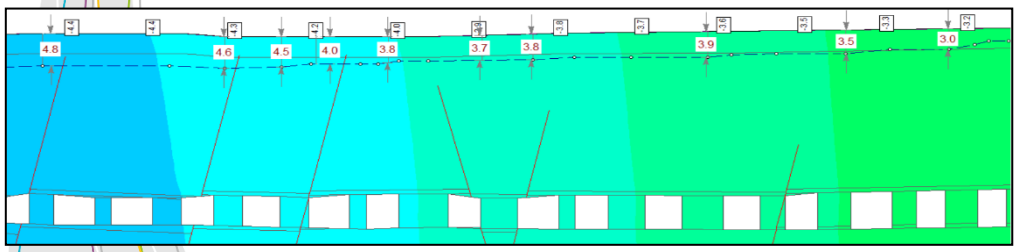


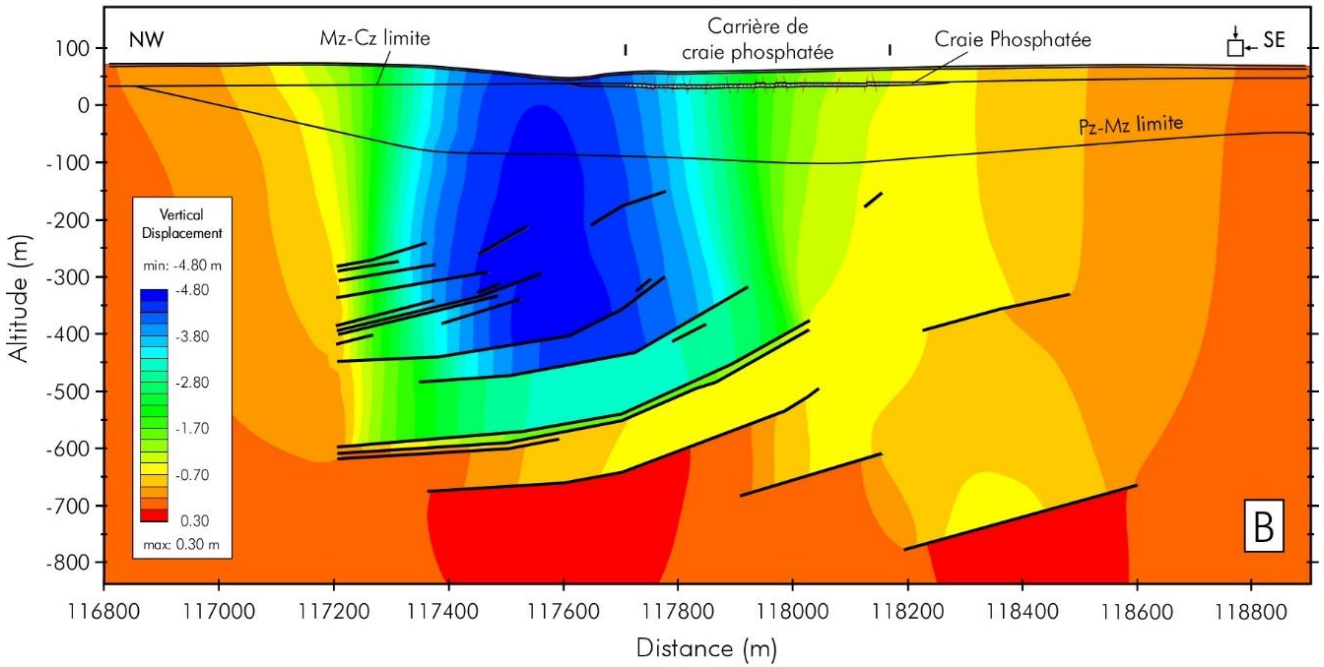
FEM analysis

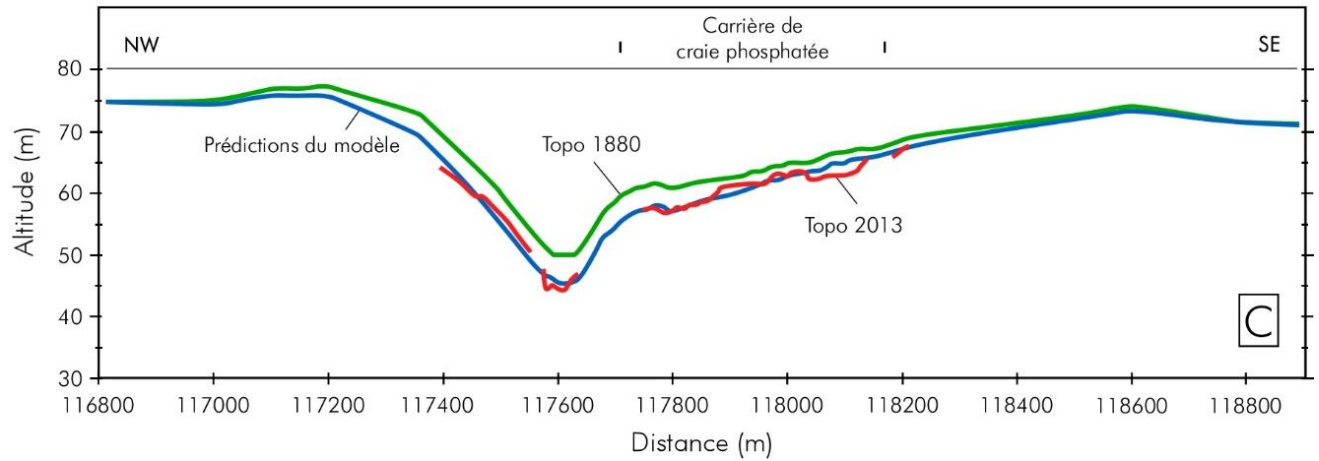
RISSC

- **T3 : coal mining**
- **End of mining:**
  - Asymetric subsidence profile
  - Subsidence max. 4.8 m
  - // cumulated thickness of mined-out coal
  - Not right below the underground quarry

Zoom on the phosphatic chalk quarry

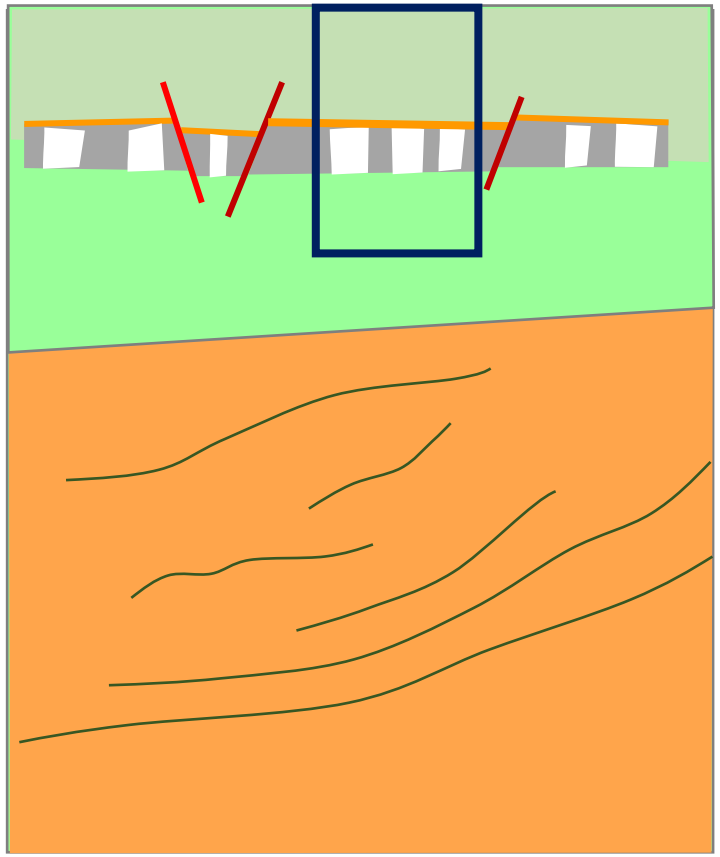






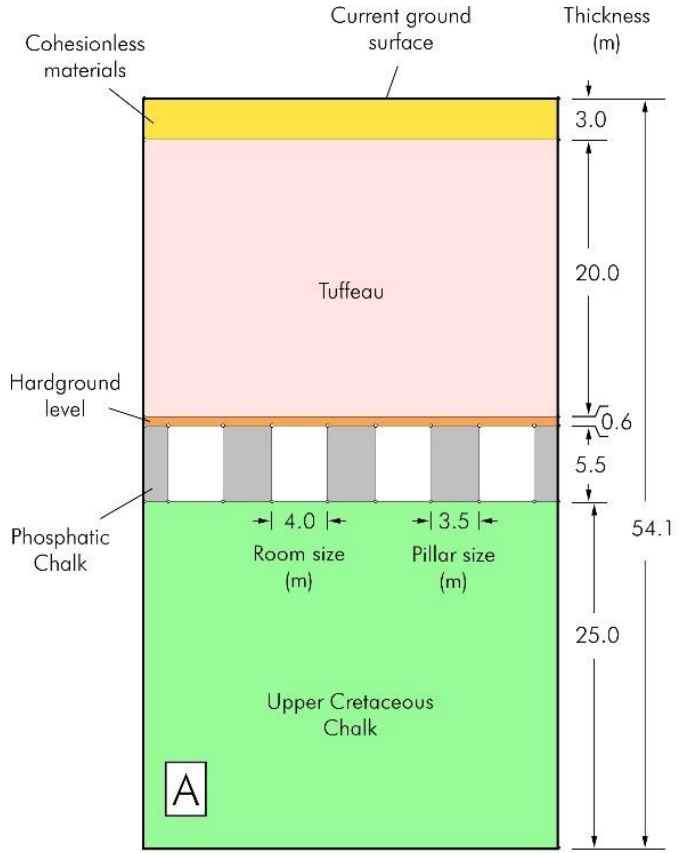
At a local scale

1. Large model with the phosphatic chalk quarry and coal seams



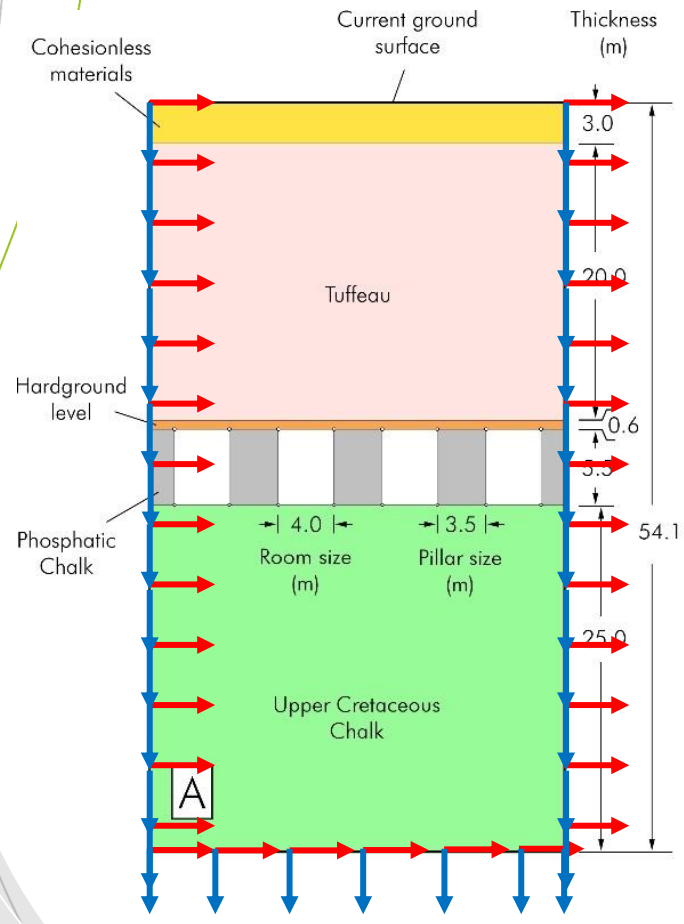
Boundary conditions

2. Local model with parametric study of instabilities



At a local scale

RISSC



Previous models provide the boundary conditions in terms of :

- ↓ Vertical displacement : -2.5 to -3m depending on the profile
- → Horizontal displacement : -1.3 to +0.6m depending on the profile

Influence of several parameters

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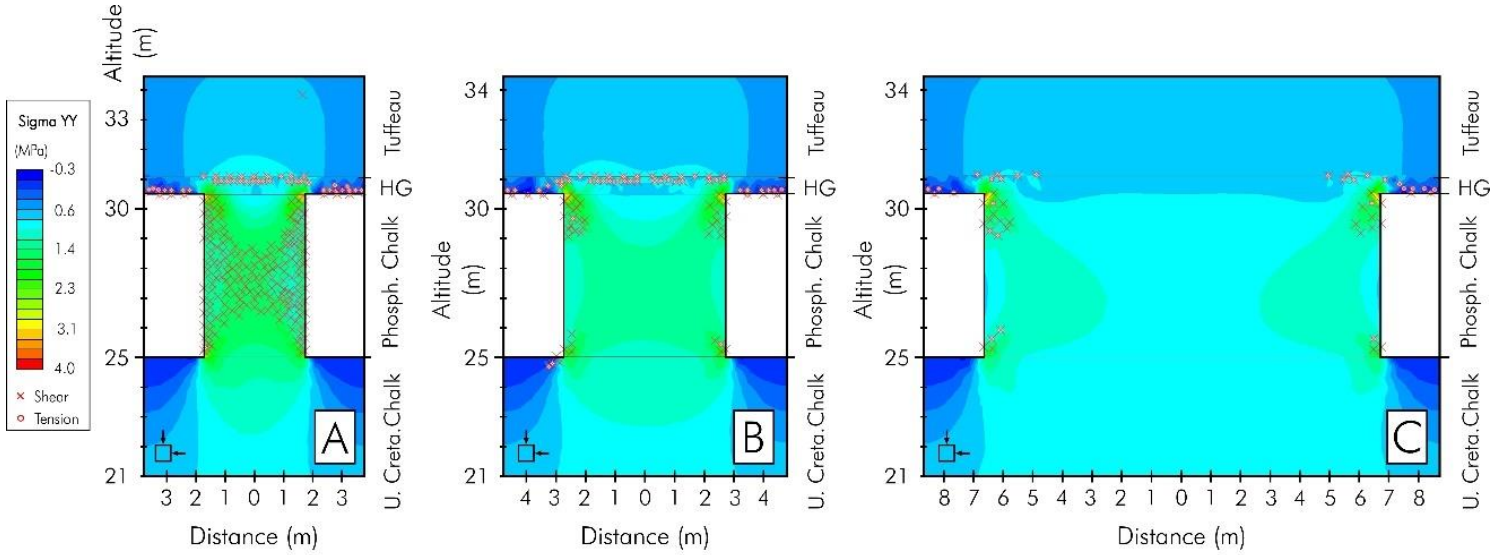
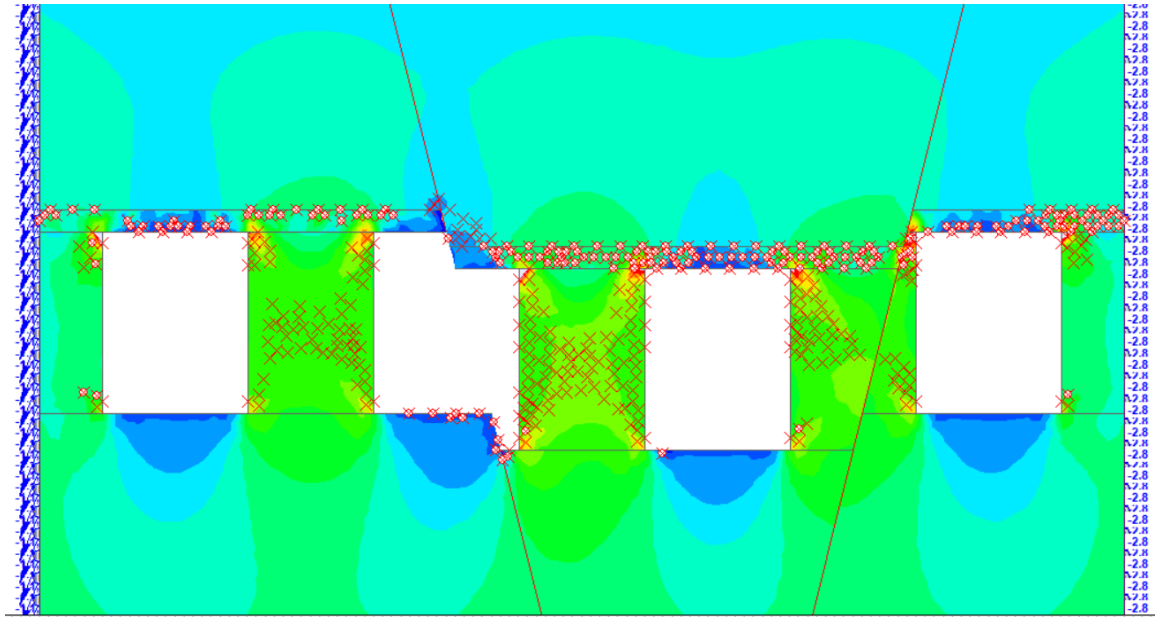
- Size of pillars
- Lithology (hardground)
- Discontinuities
- Combined effects





Conclusions

- Integrated approach from in situ and laboratory characterisation to the numerical modelling of the behaviour of underground cavities
- Better understanding of failure mechanisms
- Coal mines in HDF and Wallonia → huge effects on surface and on subsurface cavities
- FEM:
  - For a given rate of coal extraction, instabilities are triggered in subsurface cavities
  - Instabilities propagate to surface
  - Locally, several factors play a role on the stability of cavities

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