Genèse et particularités des roches marneuses et argileuses

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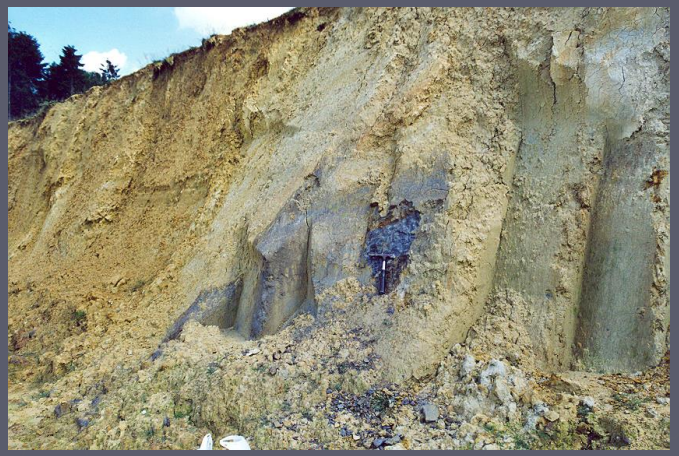
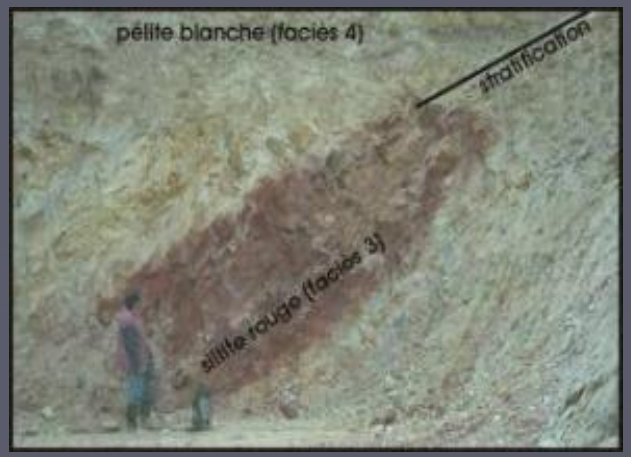
Quelques altérites sur roches marneuses/argileuses en Belgique





Processus d'altération météorique (exemple: Ardenne)

ERA		Age (Ma)	tectonism
CENOZOIC	IV		Alpine
	Neog.	23.5	
	Paleog.	65	
MESOZOIC	Cretac.	135	
	Juras.	205	
	Trias.	245	
PALAEOZOIC	Pm	295	Hercynian
	Carb.	360	
	Dev.	410	
	Early		Caledonian

pedogenèse

incision des vallées

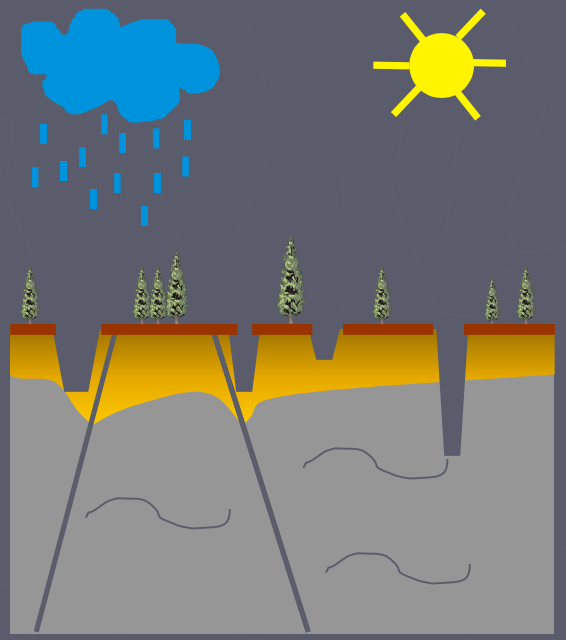
altération météorique

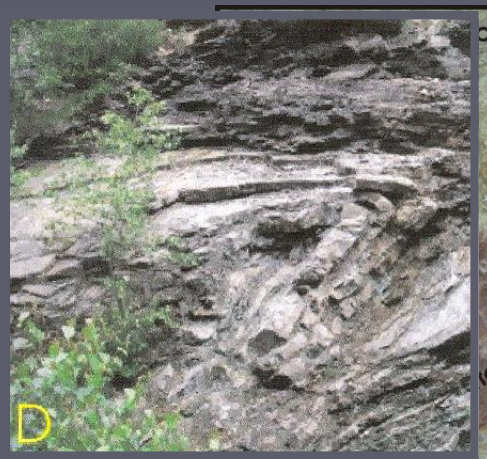
per descensum
contact
atmosphere-lithosphere

Paramètres
Protolithe (roche-mère)
Fracturation - géodynamique
(climat)

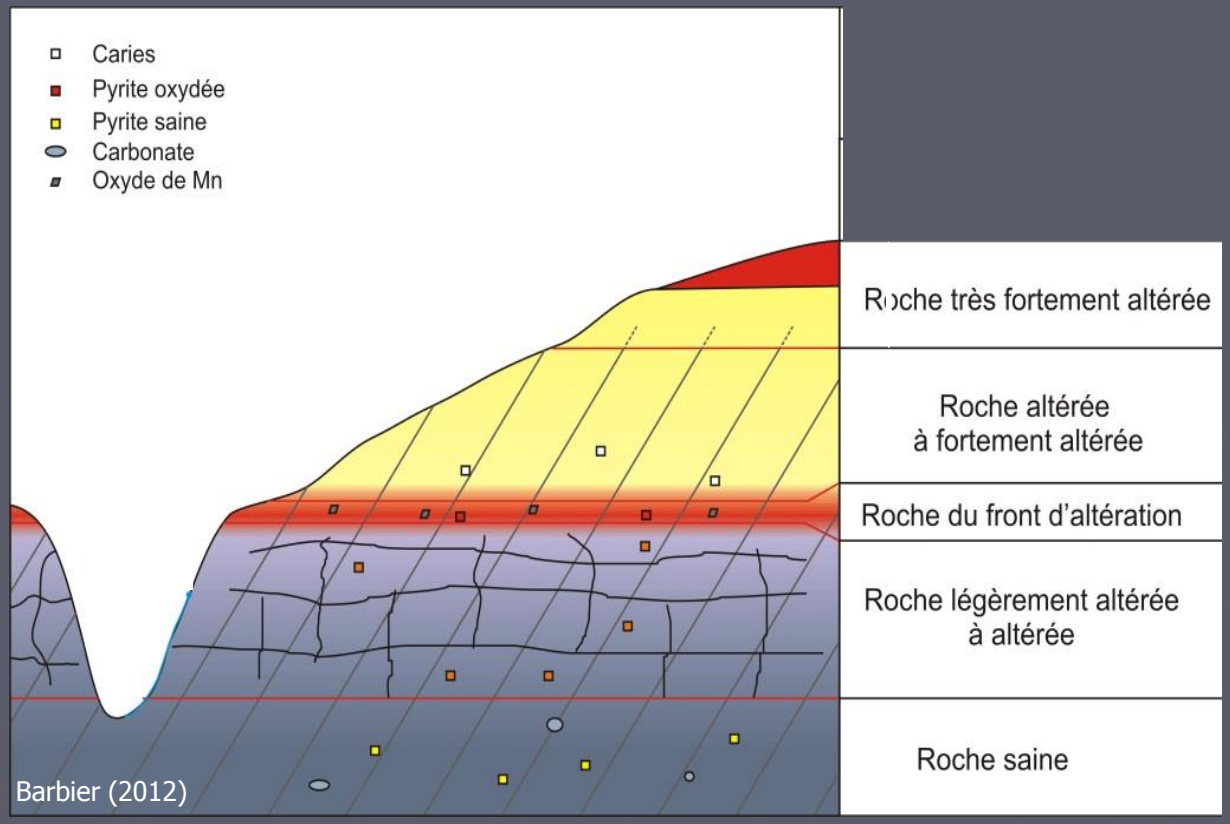
tectonique

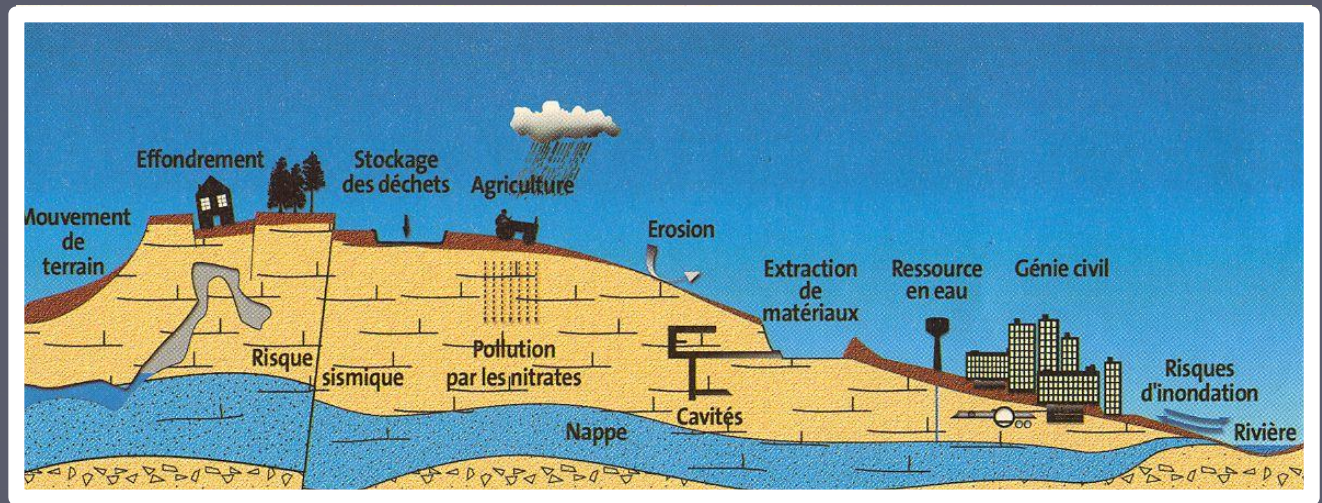
sédimentation



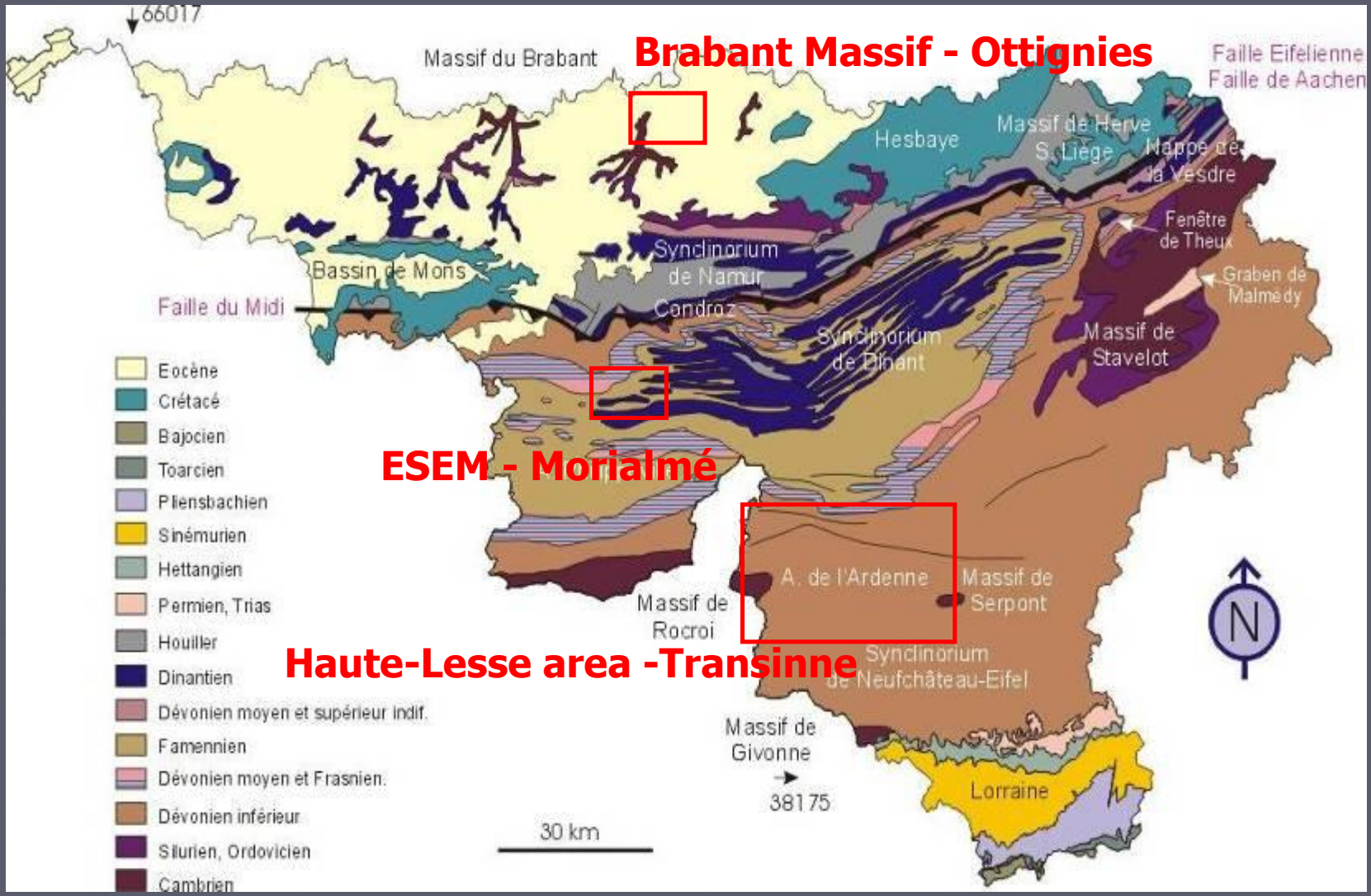


Intérêts de l'étude des roches altérées wallonnes





Différentes régions sur "socle argilo-marneux" => altération météorique variable



Haute-Lesse

Paramètres :
Protolithe (pH)
Fracturation - géodynamique (climat)

Acidification

Acide carbonique

$H_2O + CO_2 = H_2CO_3$

$H_2CO_3 = H^+ + (HCO3)^-$

Acide sulfurique

$FeS_2 + 15/4\ O_2 + 7/2\ H_2O$
$\rightarrow Fe(OH)_3 + 2\ H_2SO_4$

$FeS_2 + 14\ Fe^{3+} + 8\ H_2O$
$\rightarrow 15\ Fe^{2+} + 2\ (SO_4)^{2-} + 16\ H^+$

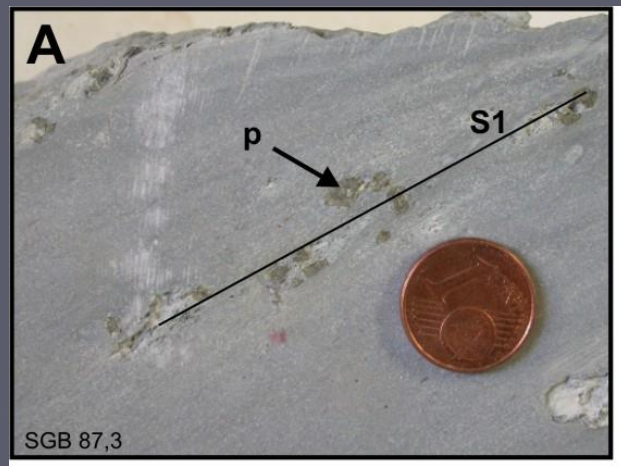
environnement supergène :

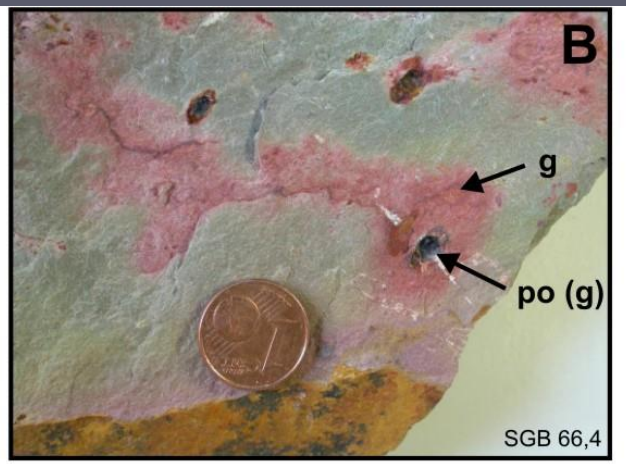
$Fe^{2+} + 5/2\ H_2O + ¼\ O_2$
$\rightarrow Fe(OH)_3 + 2\ H^+$

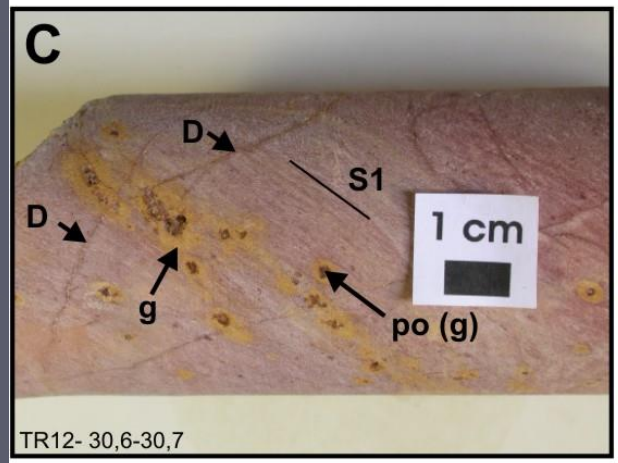
Matière organique ?

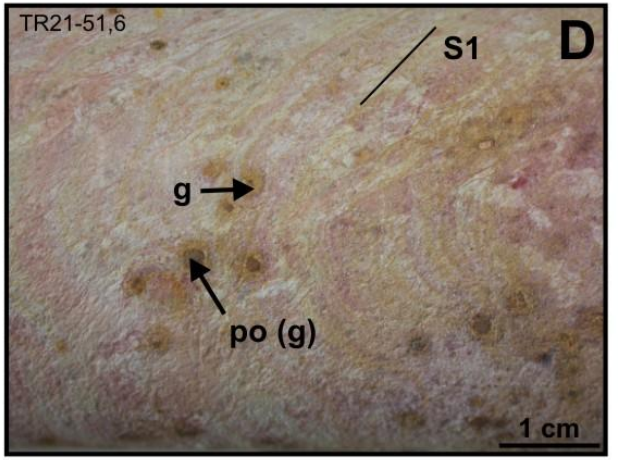
$RCH_2OH + O_2 + H_2O$
$\rightarrow RCOOH$
$\rightarrow RCOO^- + H^+$
Groupement organique

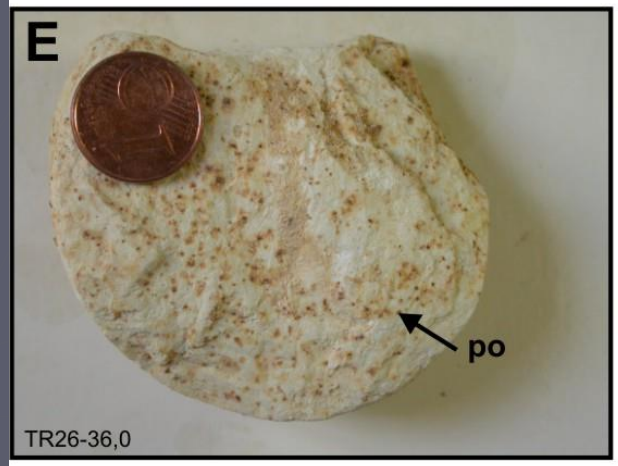
$NH_4^+ + 2O_2$
$\rightarrow H_2O + 2H^+ + NO_3^-$

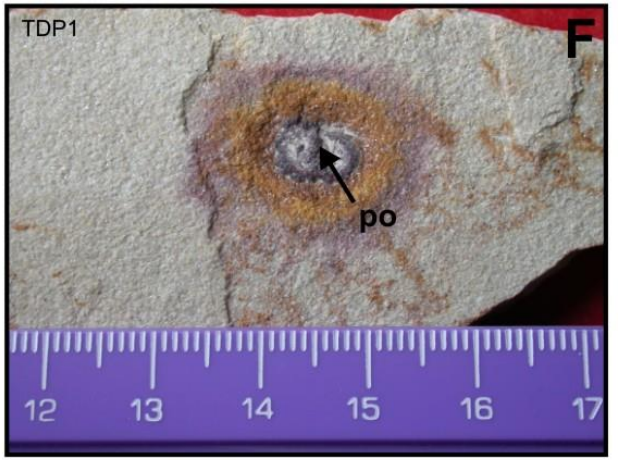












Neutralisation

Neutralisation par les carbonates

$CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO^{3-}$
$HCO^{3-} + H^+ \rightarrow H_2O + CO_2$

Neutralisation par la chlorite

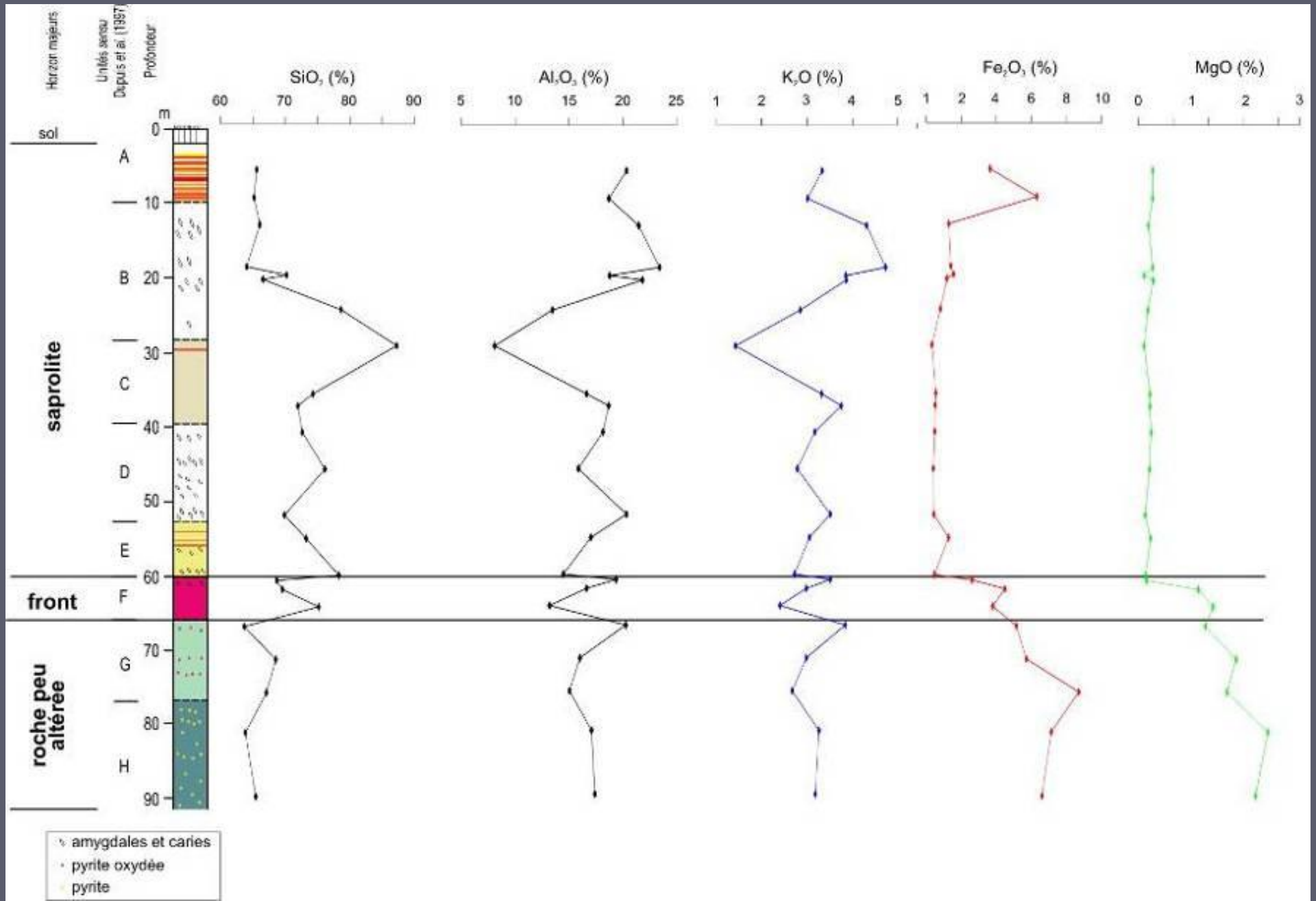
$Mg_{2,2}\ Fe_{2,2}\ Al_{2,4}\ Si_3O_{10}\ (OH)_8$ (chlorite)
$+ 0{,}1(Na^+, K^+) + 3{,}7\ H^+ + 0{,}1O_2$
$\rightarrow$ (Na, K) 0,1 $MgFe^{2+}\ (Fe^{3+})_{0,5}\ Al_{2,0}\ Si_{2,6}\ O_{10}(OH)_2$
nH_2O (smectite) + 1,2 Mg^{2+} +0,7 Fe^{2+}
+ 0,2 $Al_2Si_2O_5\ (OH)_2$ (kaolinite) + (4,5-n) H_2O

ou plus simplement,
chlorite + $2x\ H^+ \rightarrow$ smectite/kaolinite clay
+ $x\ (Mg^{2+}, Fe^{2+}) + nH_2O$

$$CaAl_2Si_2O_8 + 2\ H_2SO_4 + H_2O \rightarrow Ca^{2+} + 2\ HSO_4^- + Al_2Si_2O_5(OH)_4$$

$$4\ KAlSi_3O_8 + 6\ H_2O + 4\ CO_2 \rightarrow Al_4Si_4O_{10}(OH)_8 + 8\ SiO_2 + 4K^+ + 4\ HCO_3^-$$

Chimie


Horizon majeurs
Unités sensu Dupuis et al (1997)
Profondeur
SiO2 (%)
Al2O3 (%)
K2O (%)
Fe2O3 (%)
MgO (%)
m
sol
saprolite
front
roche peu altérée
A
B
C
D
E
F
G
H
amygdales et caries
pyrite oxydée
pyrite

Indice d'altération

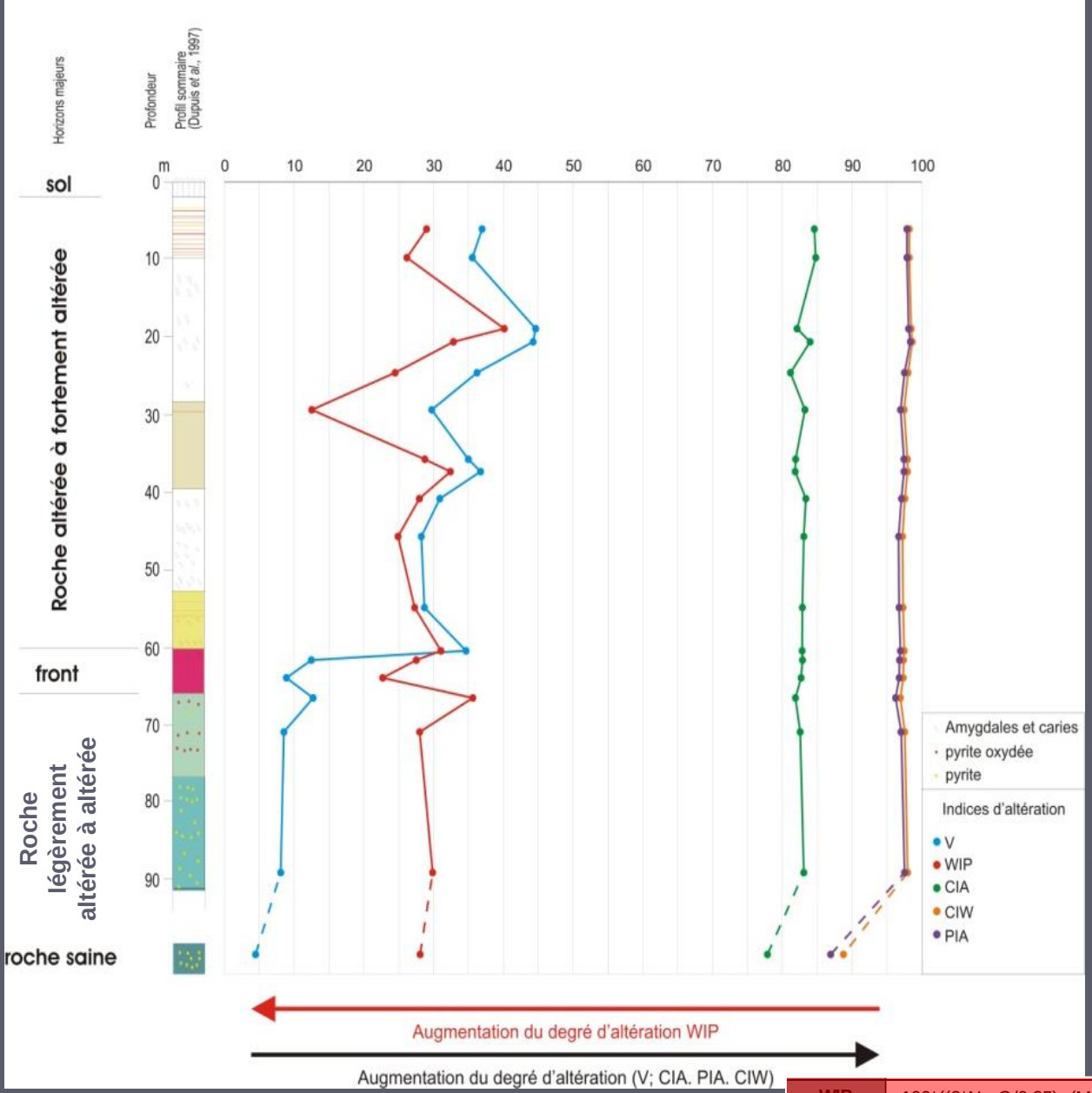
- Quantification du degré d'altération météorique
- Mobilité éléments chimiques majeurs (Al, Na, Mg, K, Ca)

Summary of weathering indices (if calculated using molecular proportions of elements oxides) evaluated in this study

Index	Formula	Optimum fresh value	Optimum weathered value	Ideal trend of index up-profile (increase in weathering)	Allows Al mobility	Reference
R	SiO_2/Al_2O_3	>10	0	Negative	No	Ruxton (1968)
WIP	$(100)[(2Na_2O/0.35)+(MgO/0.9)+(2K_2O/0.25)+(CaO/0.7)]$	>100	0	Negative	Yes	Parker (1970) (see also Table 1 of Harnois, 1988)
V	$(Al_2O_3+K_2O)/(MgO+CaO+Na_2O)$	<1	Infinite	Positive	No	Vogt (1927) (see also Roaldset, 1972)
CIA	$(100)[Al_2O_3/(Al_2O_3+CaO+Na_2O+K_2O)]$	≤ 50	100	Positive	No	Nesbitt and Young (1982)
CIW	$(100)[Al_2O_3/(Al_2O_3+CaO+Na_2O)]$	≤ 50	100	Positive	No	Harnois (1988)
PIA	$(100)[(Al_2O_3-K_2O)/(Al_2O_3+CaO+Na_2O-K_2O)]$	≤ 50	100	Positive	No	Fedo et al. (1995)
STI	$(100)[(SiO_2/TiO_2)/((SiO_2/TiO_2)+(SiO_2/Al_2O_3)+(Al_2O_3/TiO_2))]$	>90	0	Negative	No	de Jayawardena and Izawa (1994)

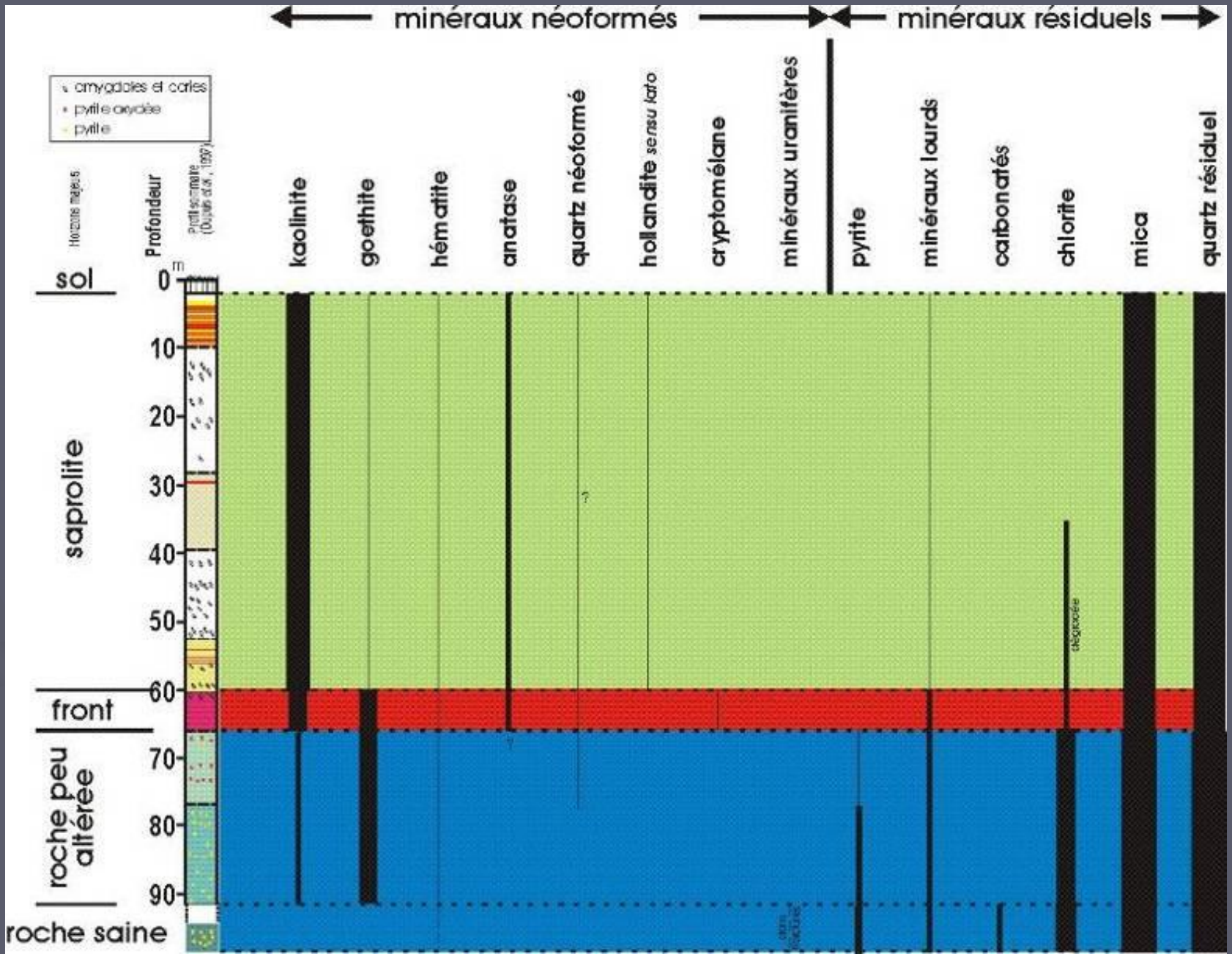
For the weathering of silicate rocks, the CaO must be restricted to that derived from silicate minerals.

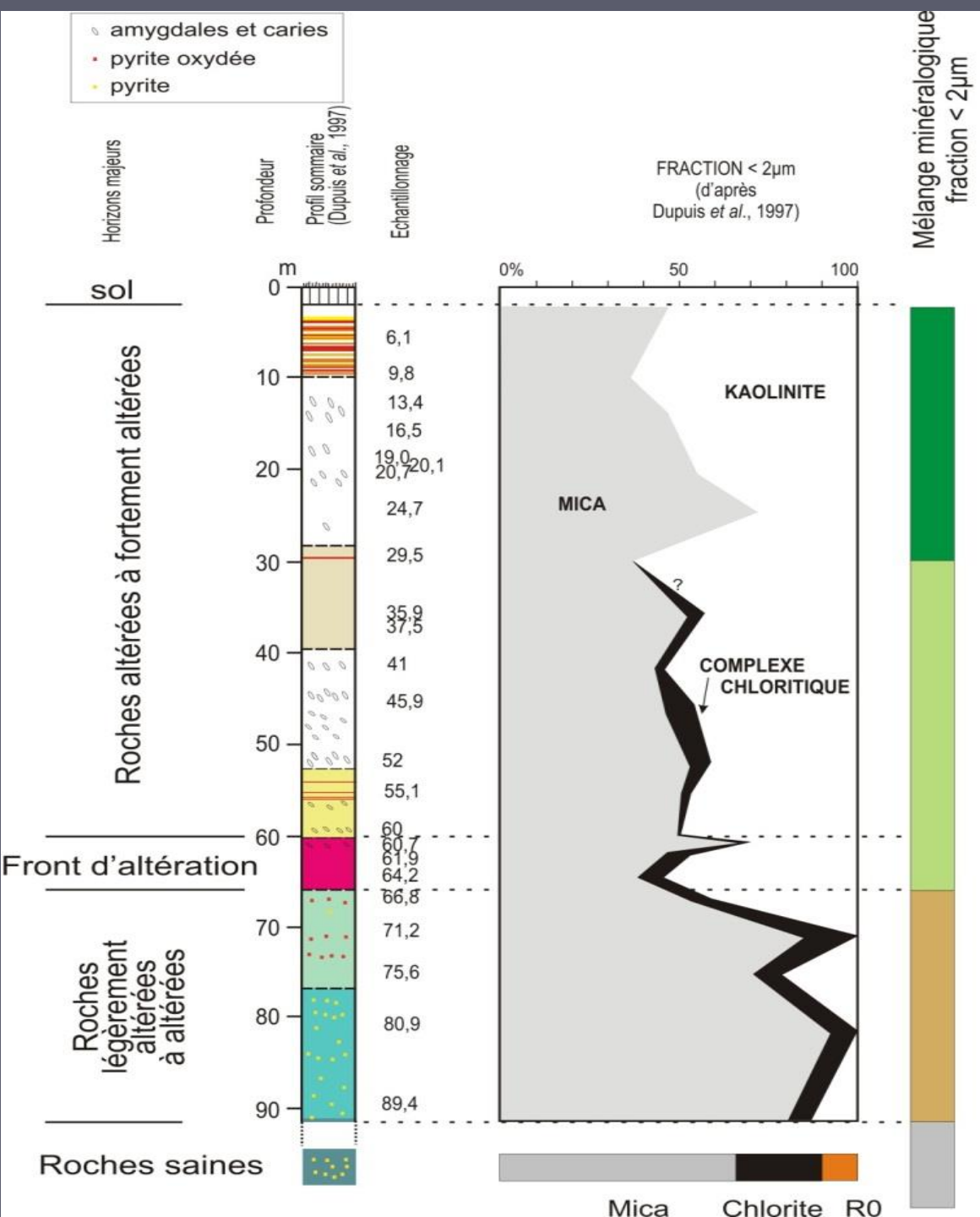
Indice		*Formule*	*référence*
WIP	Weathering index of Parker	$100*((2*Na_2O/0.35)+(MgO/0.9)+(2*K_2O/0.25)+(CaO/0.7))$	Parker ,1970
V	Vogt's Residual Index	$(Al_2O_3+K_2O)/(MgO+CaO+Na_2O)$	Vogt, 1927
CIA	Chemical Index of Alteration	$100*(Al_2O_3/(Al_2O_3+CaO+Na_2O+K_2O))$	Nesbitt et Young, 1982
CIW	Chemical index of weathering	$100*(Al_2O_3/(Al_2O_3+CaO+Na_2O))$	Harnois, 1988
PIA	Plagioclase Index of Alteration	$100*((Al_2O_3-K_2O)/(Al_2O_3+CaO+Na_2O-K_2O))$	Fedo *et al*., 1995



WIP	$100*((2*Na_2O/0.35)+(MgO/0.9)+(2*K_2O/0.25)+(CaO/0.7))$	Parker ,1970
V	$(Al_2O_3+K_2O)/(MgO+CaO+Na_2O)$	Vogt, 1927
CIA	$100*(Al_2O_3/(Al_2O_3+CaO+Na_2O+K_2O))$	Nesbitt et Young, 1982
CIW	$100*(Al_2O_3/(Al_2O_3+CaO+Na_2O))$	Harnois, 1988
PIA	$100*((Al_2O_3-K_2O)/(Al_2O_3+CaO+Na_2O-K_2O))$	Fedo *et al*., 1995

Minéralogie





Kaolinite = $Al_2Si_2O_5(OH)_4$

Chlorite = $Mg_{2,2}Fe_{2,2}Al_{2,4}Si_3O_{10}(OH)_8$

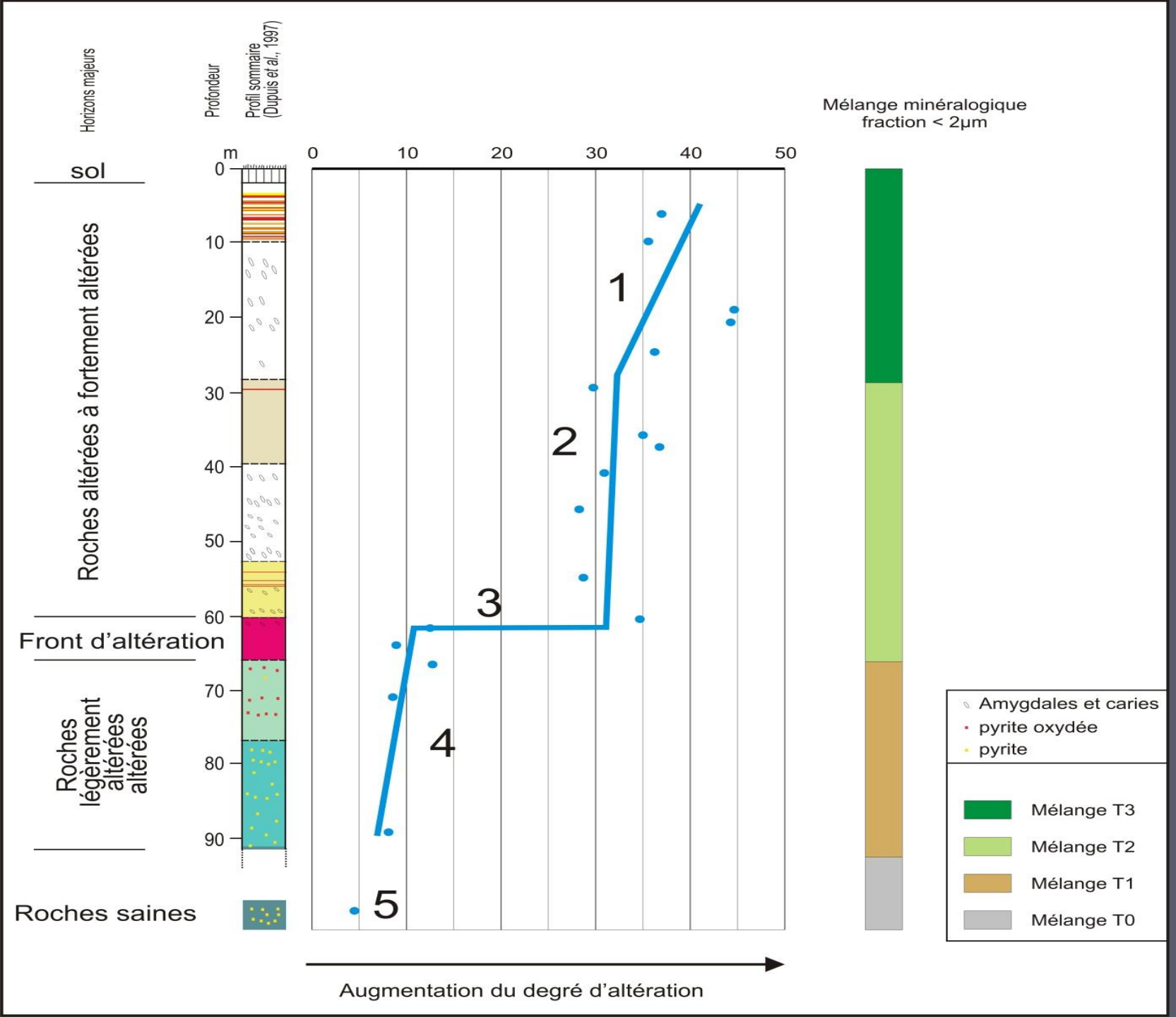
Illite = $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$

T 3 : illite (++) - kaolinite (++)

T 2 : illite (++) - kaolinite (++) complexe chloritique (+)

T 1 : illite (+++) - complexe chloritique (++) - kaolinite (+)

T 0 : illite (+++) - chlorite (++) - interstratifiés (+)


Horizons majeurs
Profondeur
Profil sommaire (Dupuis et al., 1997)
m
0
10
20
30
40
50
sol
Roches altérées à fortement altérées
Front d'altération
Roches légèrement altérées altérées
Roches saines
0
10
20
30
40
50
60
70
80
90
1
2
3
4
5
Mélange minéralogique fraction < 2µm
Amygdales et caries
pyrite oxydée
pyrite
Mélange T3
Mélange T2
Mélange T1
Mélange T0
Augmentation du degré d'altération

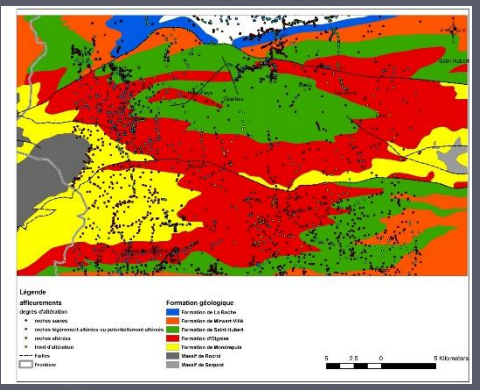
Outils de cartographie

Méthodes directes

Tarières

Affleurements

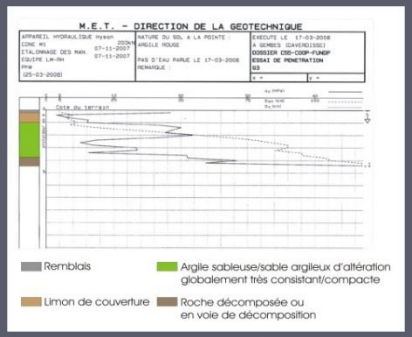
BD-Topographie



Forages

Méthodes indirectes

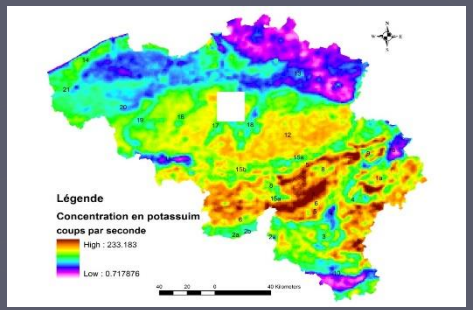
"Essais de sol "



Tomographie électrique

Profil sismique

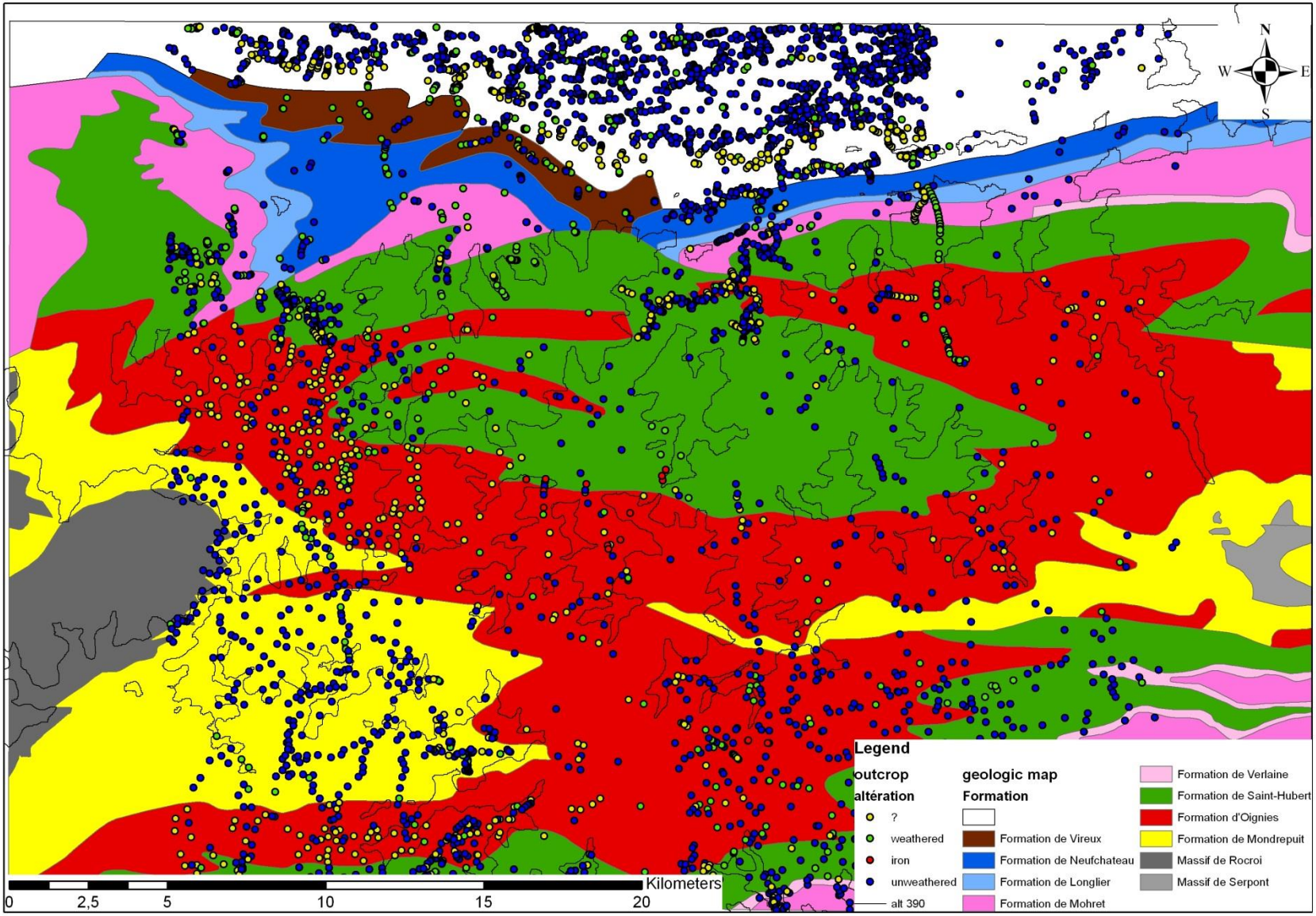
Radiométrie aéroportée



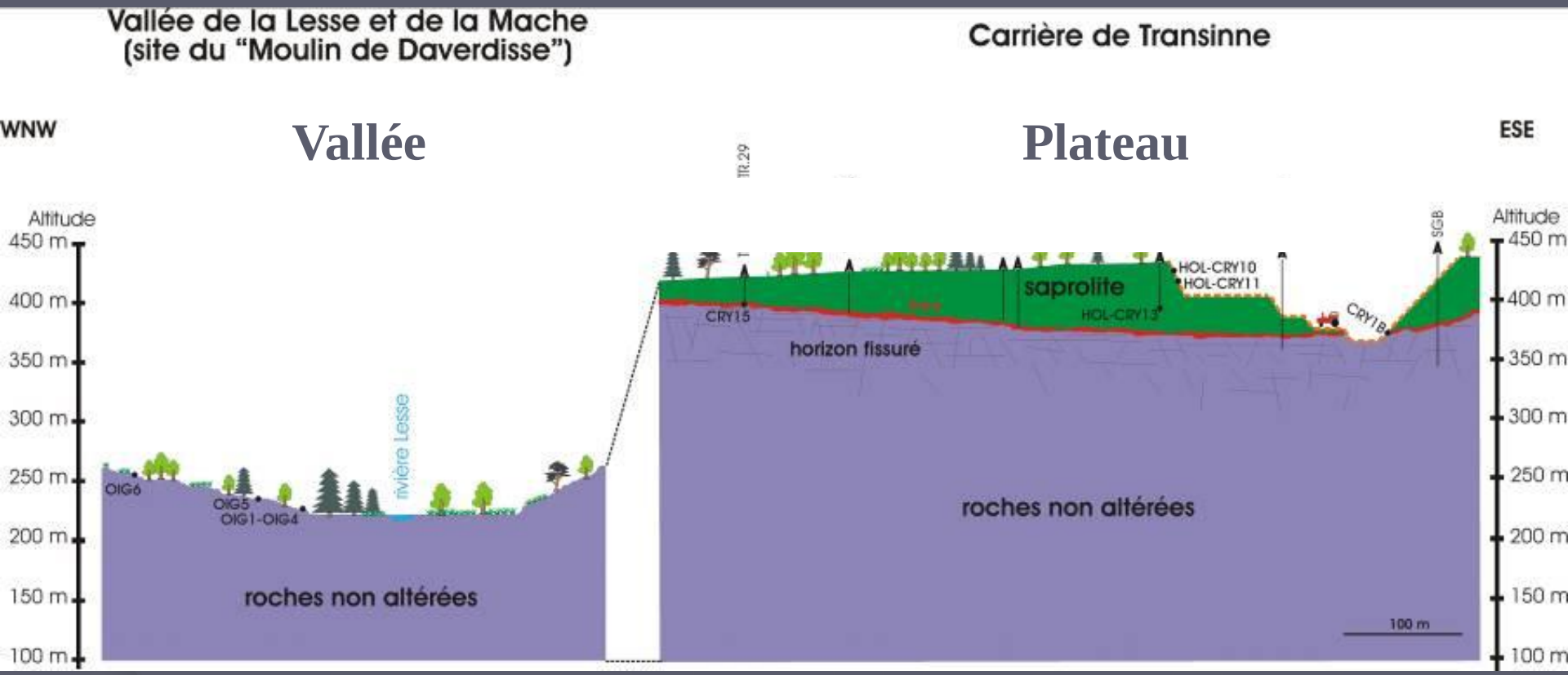
Terrain

- Affleurements
- Tarières

Terrain

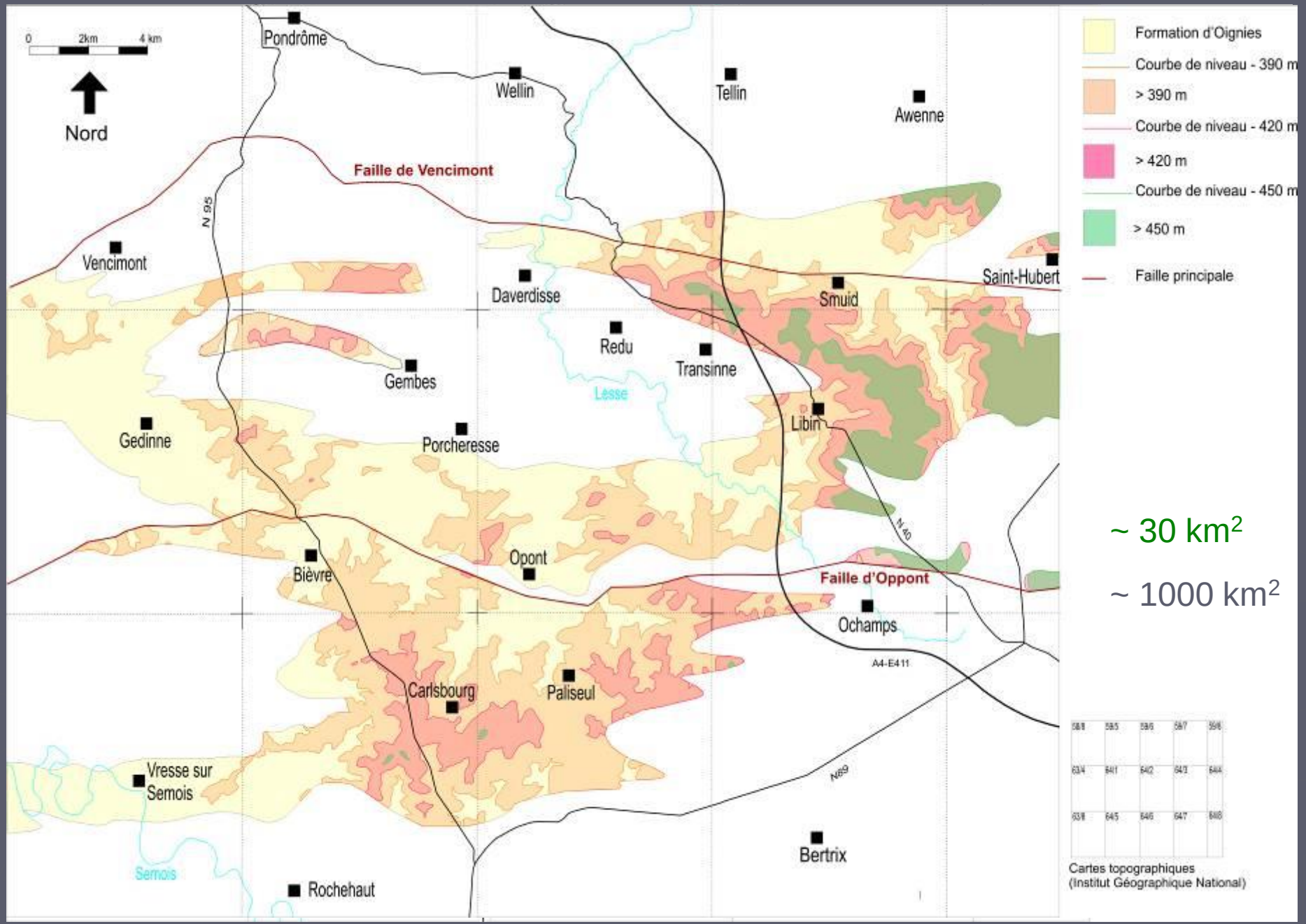

N
W
E
S
Legend
outcrop
altération
?
weathered
iron
unweathered
alt 390
geologic map
Formation
Formation de Vireux
Formation de Neufchateau
Formation de Longlier
Formation de Mohret
Formation de Verlaine
Formation de Saint-Hubert
Formation d'Oignies
Formation de Mondrepuit
Massif de Rocroi
Massif de Serpont
Kilometers
0
2,5
5
10
15
20

Topographie



Roches altérées (Haute-Lesse)

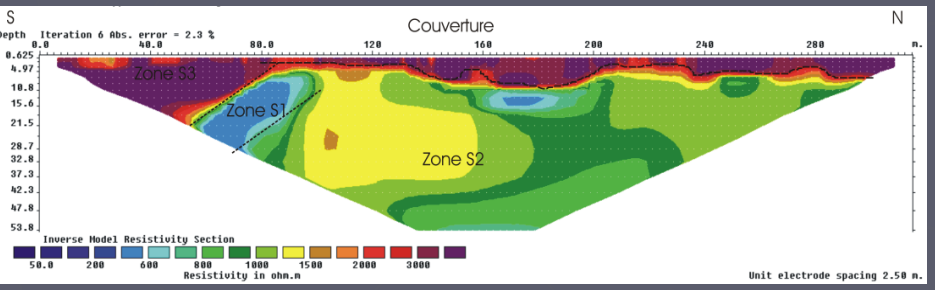
- Formation d'Oignies (Mirwart *sensu* SGW)
- altitude > 390 mètres


0 2km 4 km
Nord
Pondrôme
Wellin
Tellin
Awenne
Faille de Vencimont
N 95
Vencimont
Daverdisse
Saint-Hubert
Smuid
Redu
Transinne
Gembes
Lesse
Libin
Gedinne
Porcheresse
N 40
Opont
Bièvre
Faille d'Oppont
Ochamps
A4-E411
Carlsbourg
Paliseul
N89
Vresse sur Semois
Semois
Bertrix
Rochehaut
Formation d'Oignies
Courbe de niveau - 390 m
> 390 m
Courbe de niveau - 420 m
> 420 m
Courbe de niveau - 450 m
> 450 m
Faille principale
~ 30 km2
~ 1000 km2
Cartes topographiques
(Institut Géographique National)

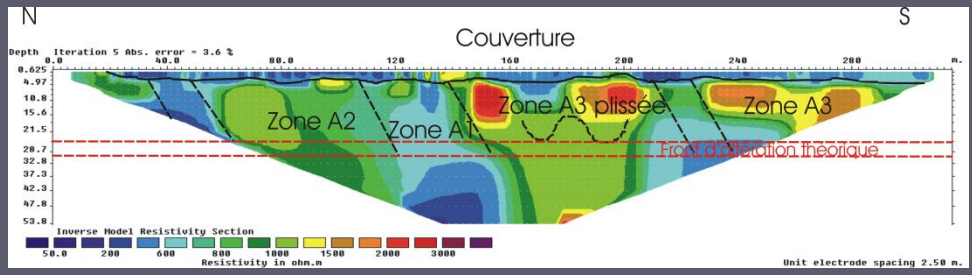
Géophysique

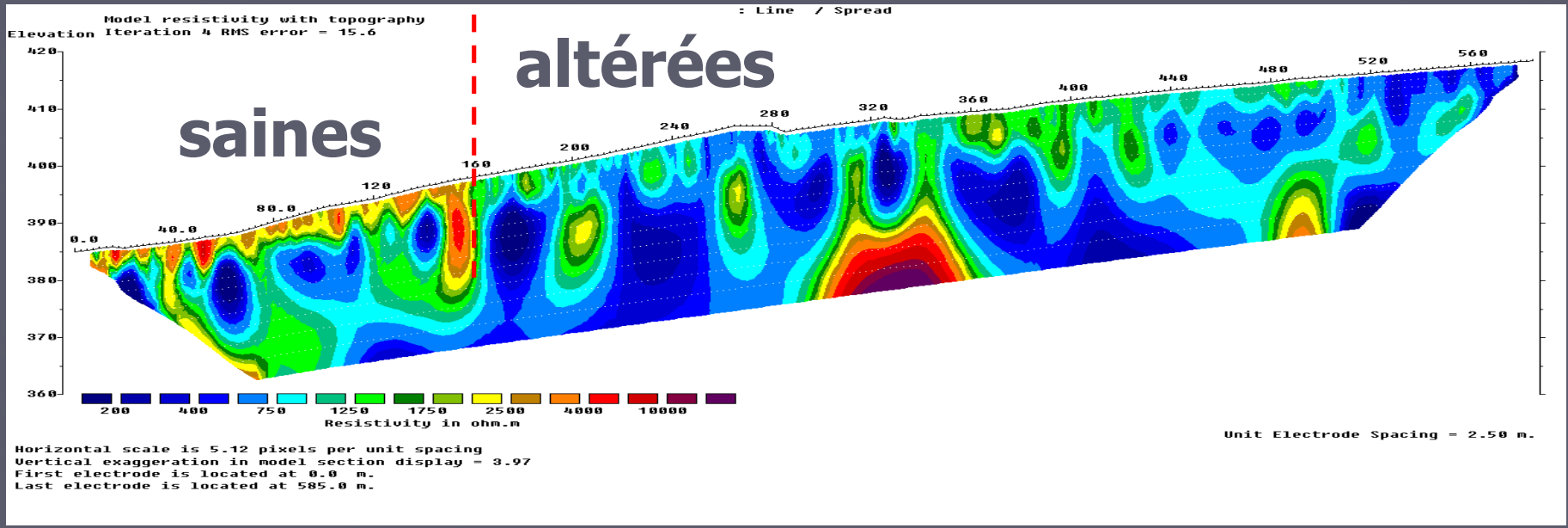
- Tomographie électrique éprouvée par forages et tarières

Roches saines



Roches altérées





Brabant Massif (Ottignies)

162 m

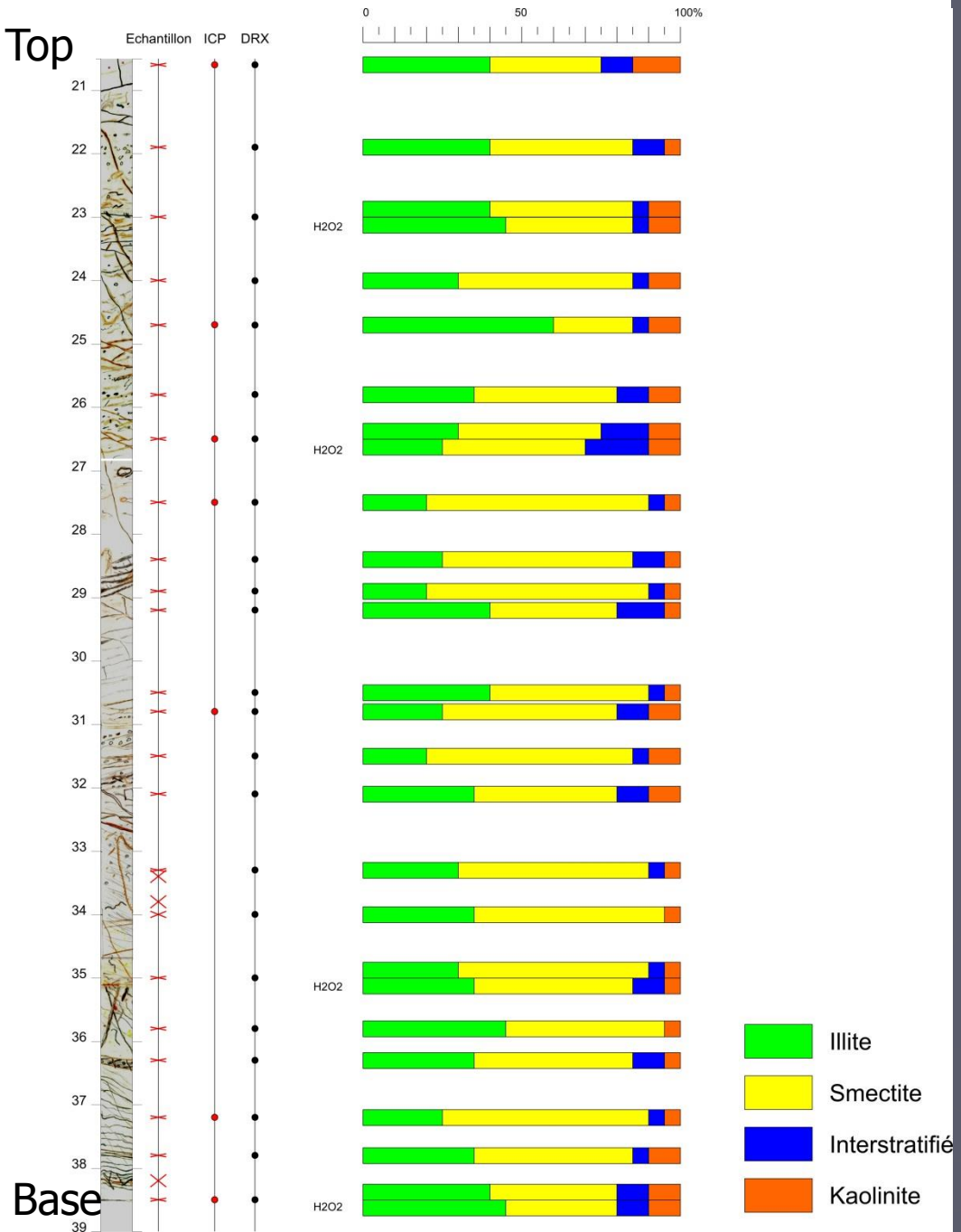
247 m

Plus profond

165 m

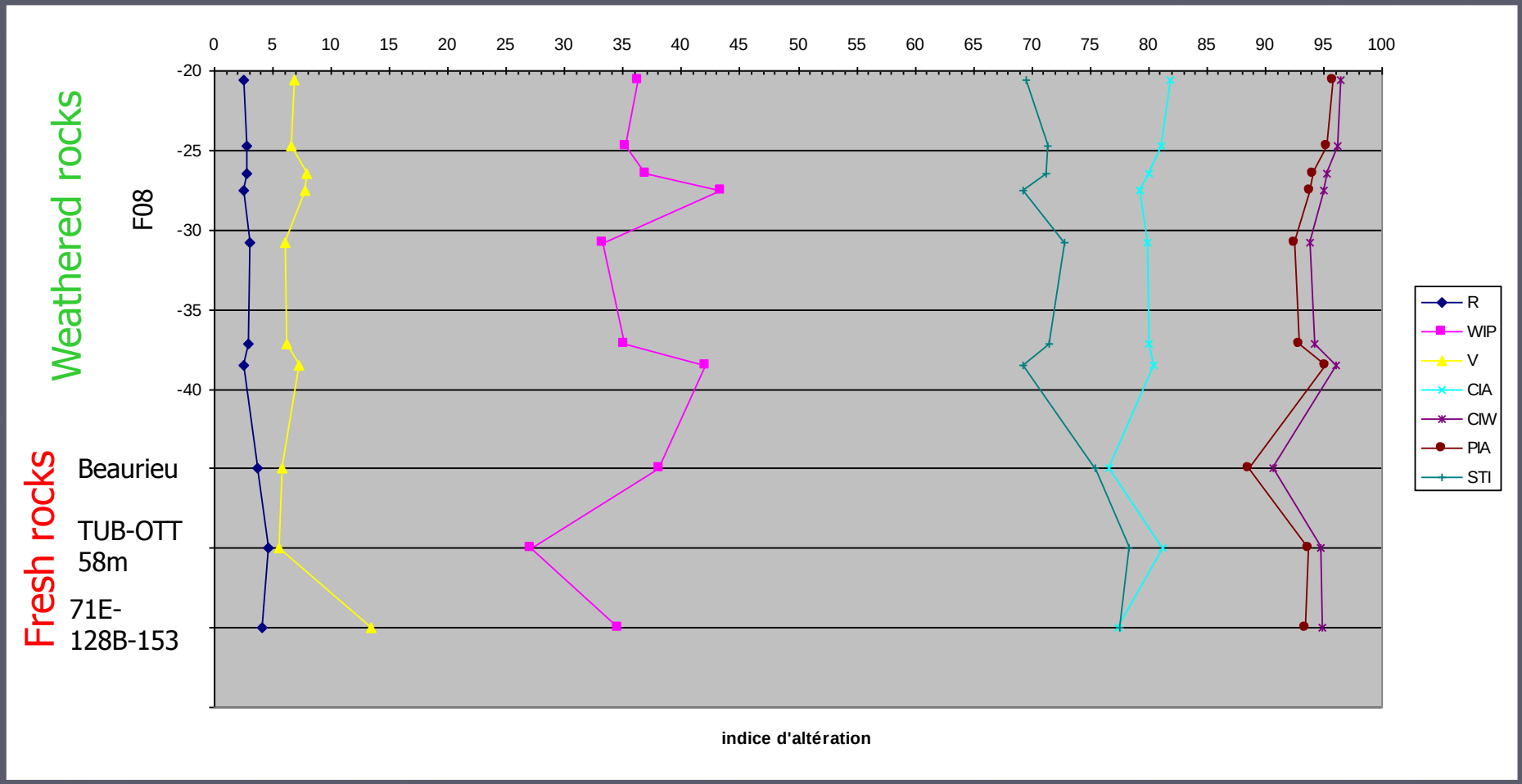
264 m

Minéralogie



Barbier (2012)

Indice d'alteration météorique

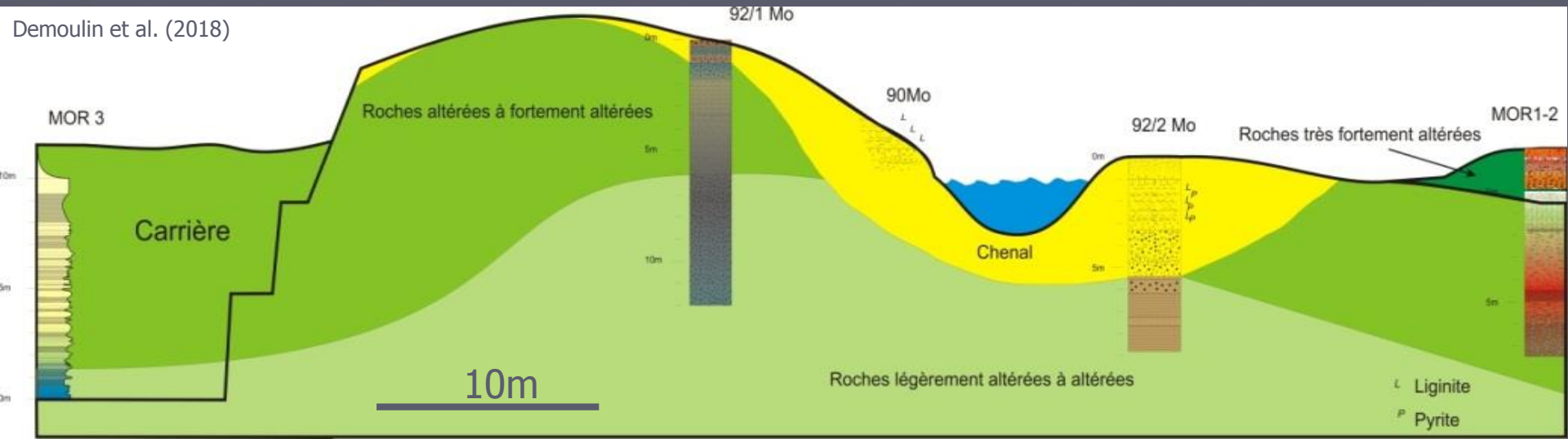


Barbier (2012)

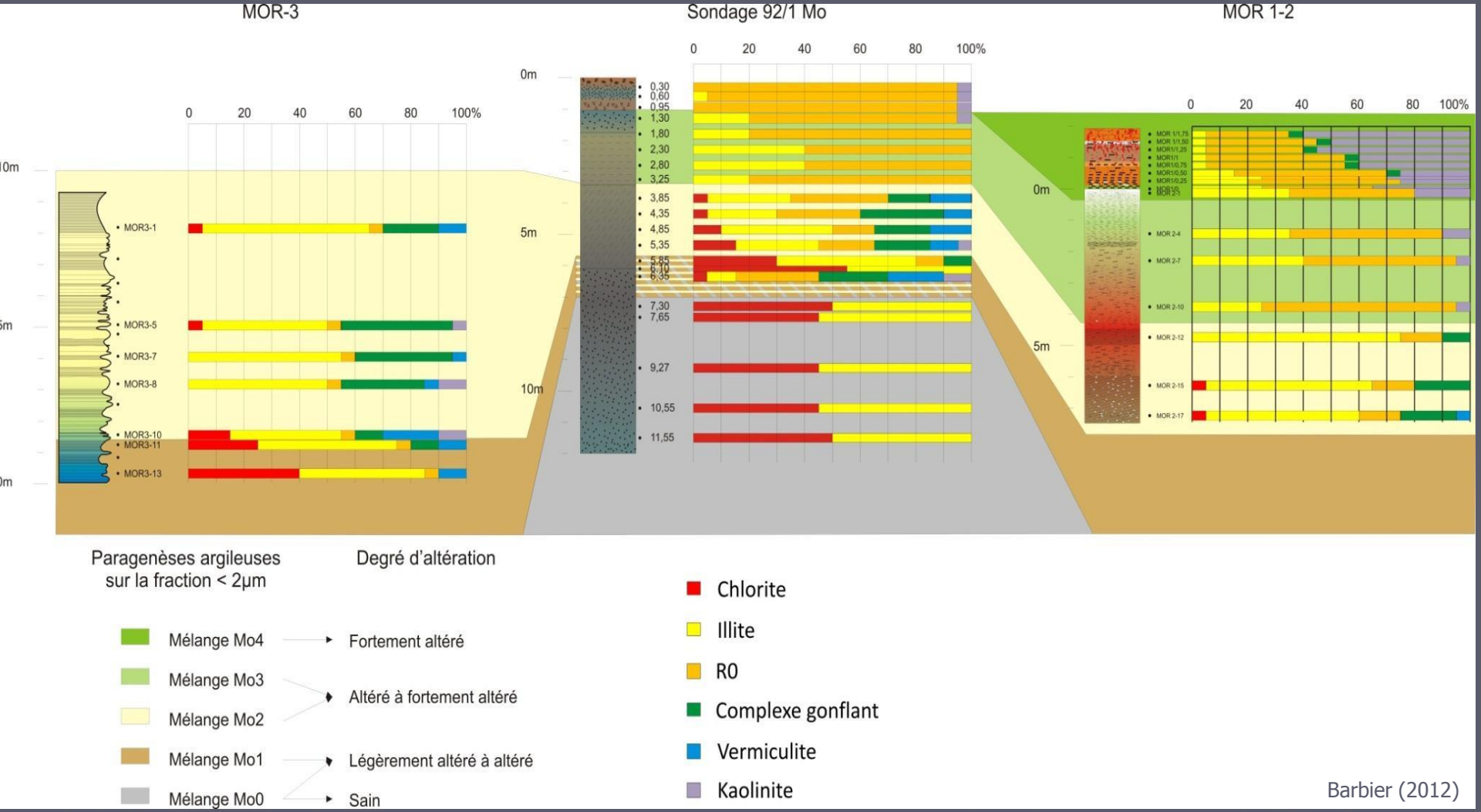
Paramètres :
Protolithe
Fracturation - géodynamique (climat)

ESEM (Morialmé)

Demoulin et al. (2018)



Minéralogie



Barbier (2012)

Mo4 : illite (+) interstratifié (++) kaolinite (++)
Mo3 : illite (++) interstratifié (+++) kaolinite (+)
Mo2 : chlorite (+) illite (++) interstratifié (+) complexe chloritique/gonflant (++)
Mo1 : chlorite (+) illite (+++) interstratifié + complexe chloritique/gonflant (+)
Mo0 : chlorite (+++) illite (+++)

Conclusions

- Genèse - caractérisation (en Belgique)
  - Protolithe (sulfures - carbonates - silicates)
  - Indice d'alteration (*Weathering Index*)
  - Fracturation ?
- Cartographie
  - Terrain
  - Topographie
  - Tomographie électrique