Chantier Pyrénées

Journées RGF 05 avril 2018

Mobilité hydrothermale des métaux stratégiques (Ge) associés aux minéralisations Pb-Zn lors de l'histoire tectono-métamorphique des Pyrénées

Alexandre Cugerone, 2ème année

***Directrice de thèse**: Cenki-Tok[1]B.,*

***Collaborateurs**: Chauvet[1]A., Oliot[1]E, Salvi S.[2], Béziat[2] D., Kouzmanov[3] K., Le Goff[4] E., Munoz[1]M.*

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[3] Université de Genève

[4] BRGM

Mine de Bentaillou, Ariège

Photo:

ARSHAL, Lafage B.

Trois problématiques

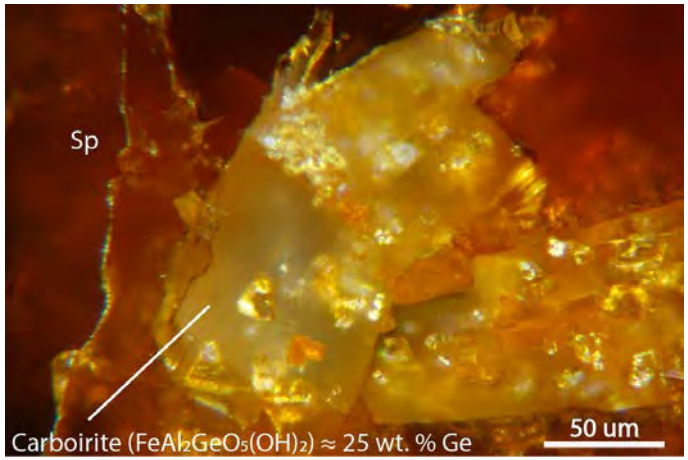
1 – Quelle est la genèse des minéralisations Pb-Zn-(Ge) dans la Zone axiale des Pyrénées?

- Nouveau modèle

2 – Quelle est la localisation et le mécanisme de concentrations du Ge?

- Remobilisation du Ge

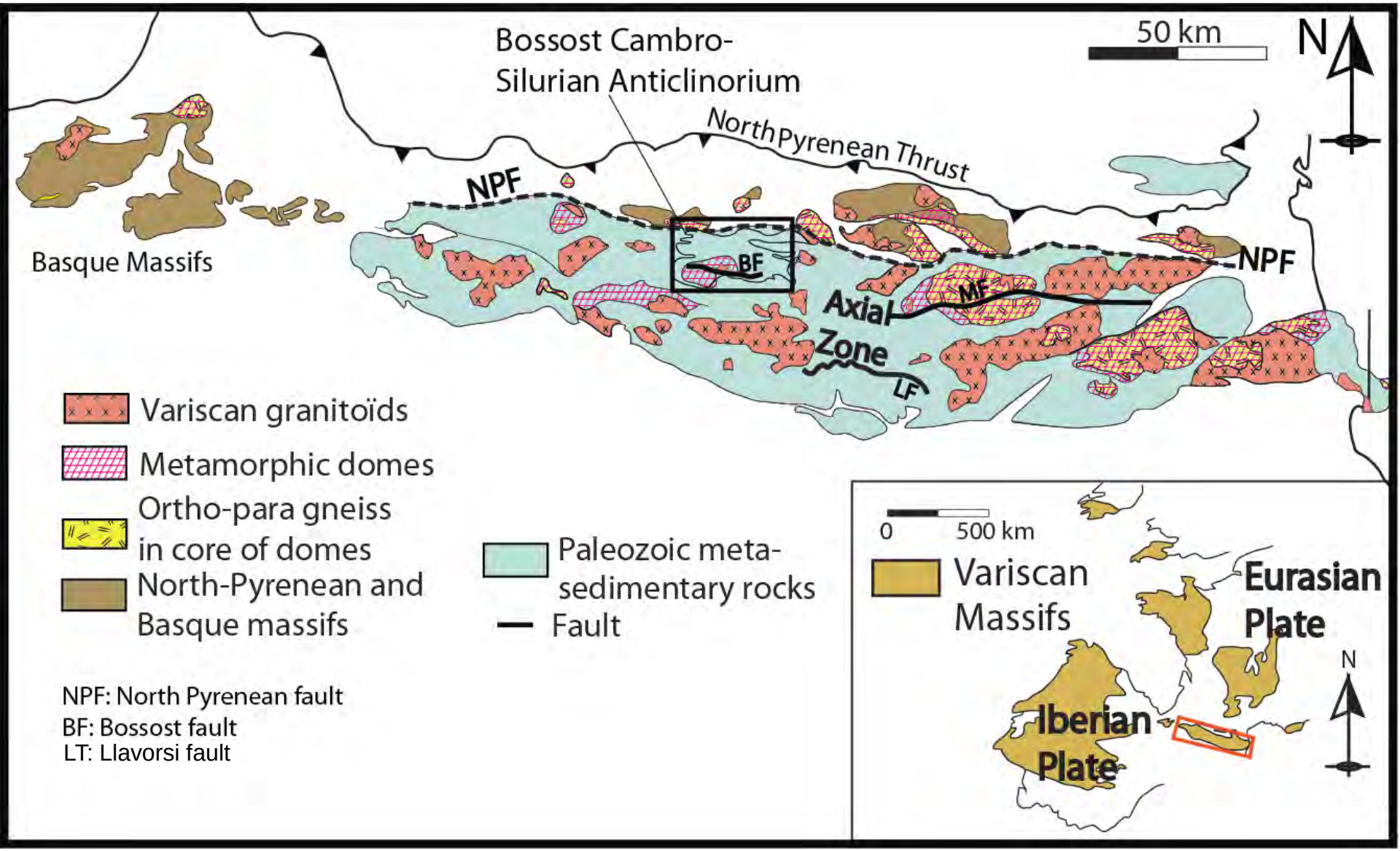
Sp : sphalerite (ZnS)



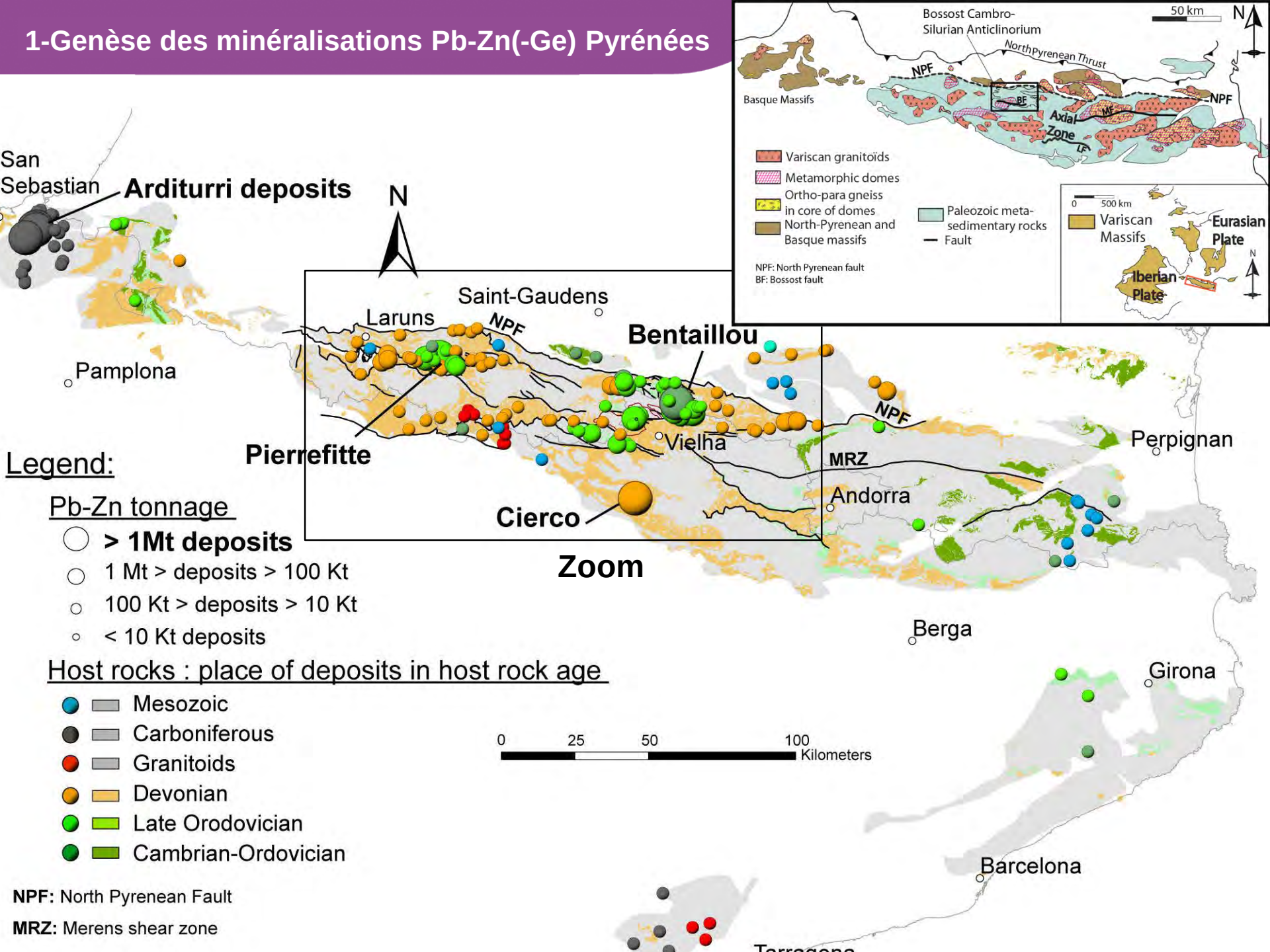
3 – Quelle sont les fluides minéralisateurs (type, composition,…)?

- A venir

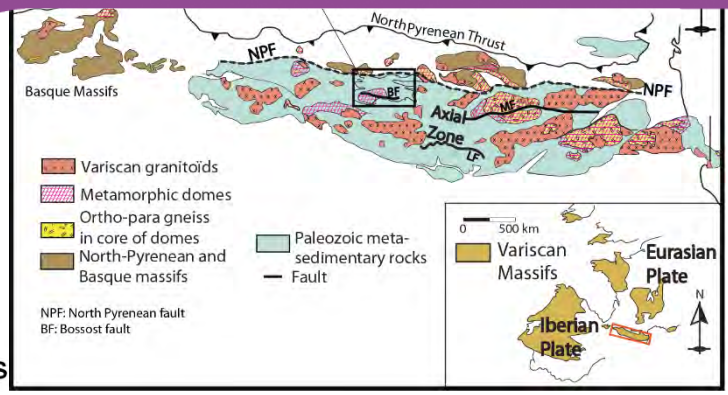
1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



Pb-Zn studied deposits:

1-Arre	7-Estibère	13-Pale Bidau
2-Anglas-Uzious	8-Crabioules	14-Liat
3-Arrens	9-Victoria	15-Bentaillou
4-Estaing	10-Margalida	16-Urets
5-Pierrefitte	11-Argut	17-Carboire
6-Nerbiou	12-Pale de Rase	18-Aulus

Pierrefitte anticlinorium

Saint-Gaudens

Laruns

NPF

EAT

Bossost anticlinorium

Bagnères de Luchon

BF

GT

Vielha

MRZ

LT

Andorra

Lys anticlinorium

Pallaresa anticlinorium

Pb-Zn tonnage

- > 1Mt deposits
- 1 Mt > deposits > 100 Kt
- 100 Kt > deposits > 10 Kt
- < 10 Kt deposits

N

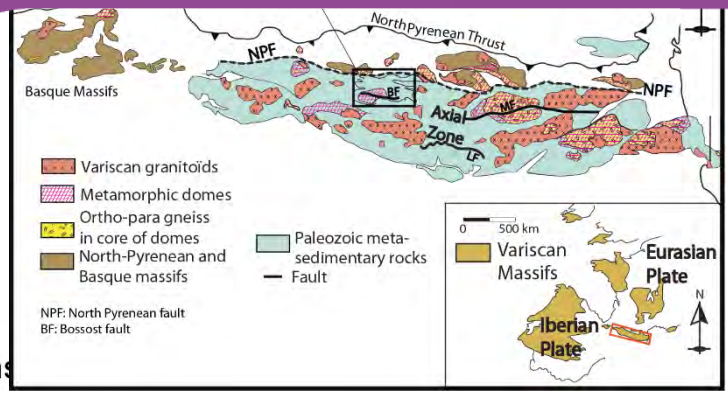
0 10 20 40 Kilometers

Age of rocks and deposits:

- Devonian
- Late Ordovician
- Ordovician inferior-middle
- Other Paleozoic rocks
- Mesozoic
- Granitoids

NPF: North Pyrenean Fault
BF: Bossost Fault
GT: Gavarnie Thrust
LT: Llavorsi Thrust
EAT: Eaux-Chaudes Thrust

1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



Pb-Zn studied deposits:

1-Bentaillou
2-Victoria
3-Pale Bidau
4-Arre

Pierrefitte anticlinorium

Saint-Gaudens

NPF

Laruns

EAT

4

Bossost anticlinorium

3

1

Bagnères de Luchon

BF

2

Vielha

NPF

GT

Pb-Zn tonnage

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0 10 20 40

Kilometers

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MRZ

Andorra

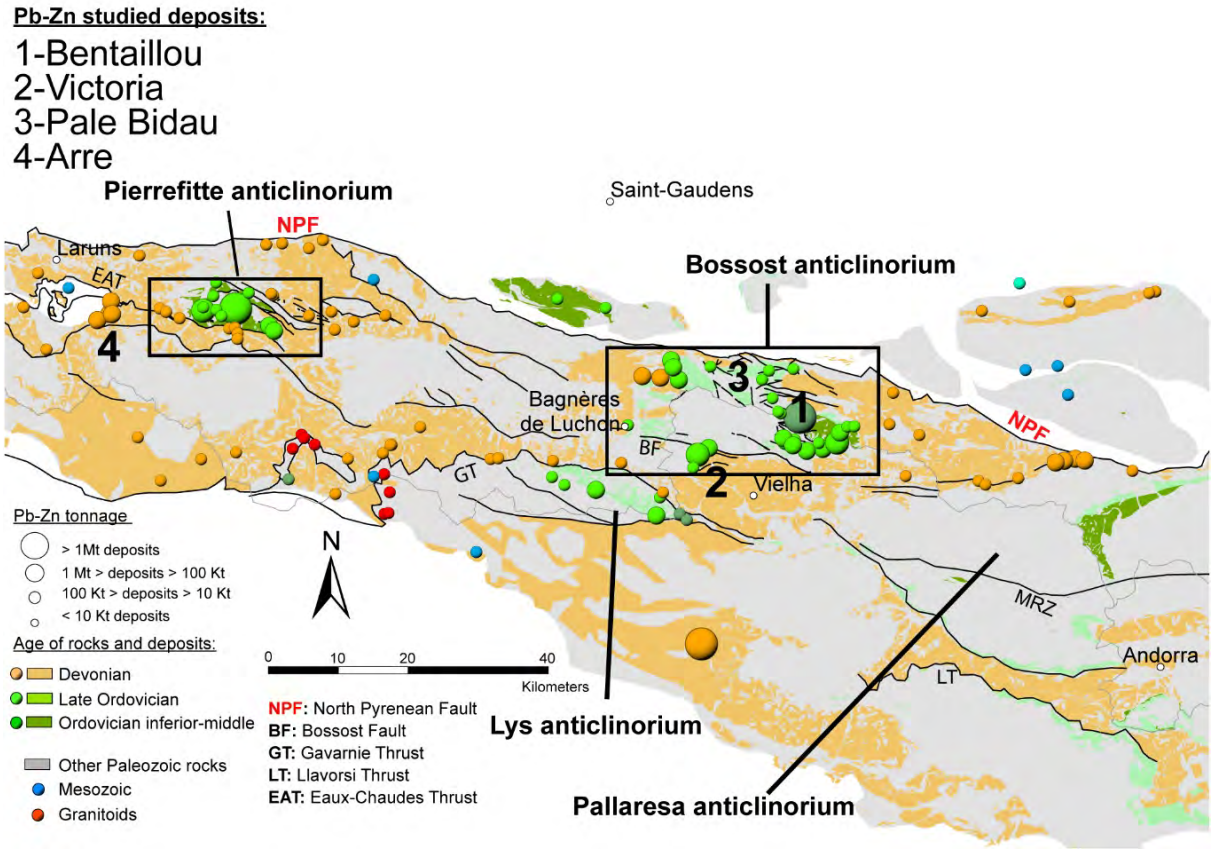
LT

Lys anticlinorium

Pallaresa anticlinorium

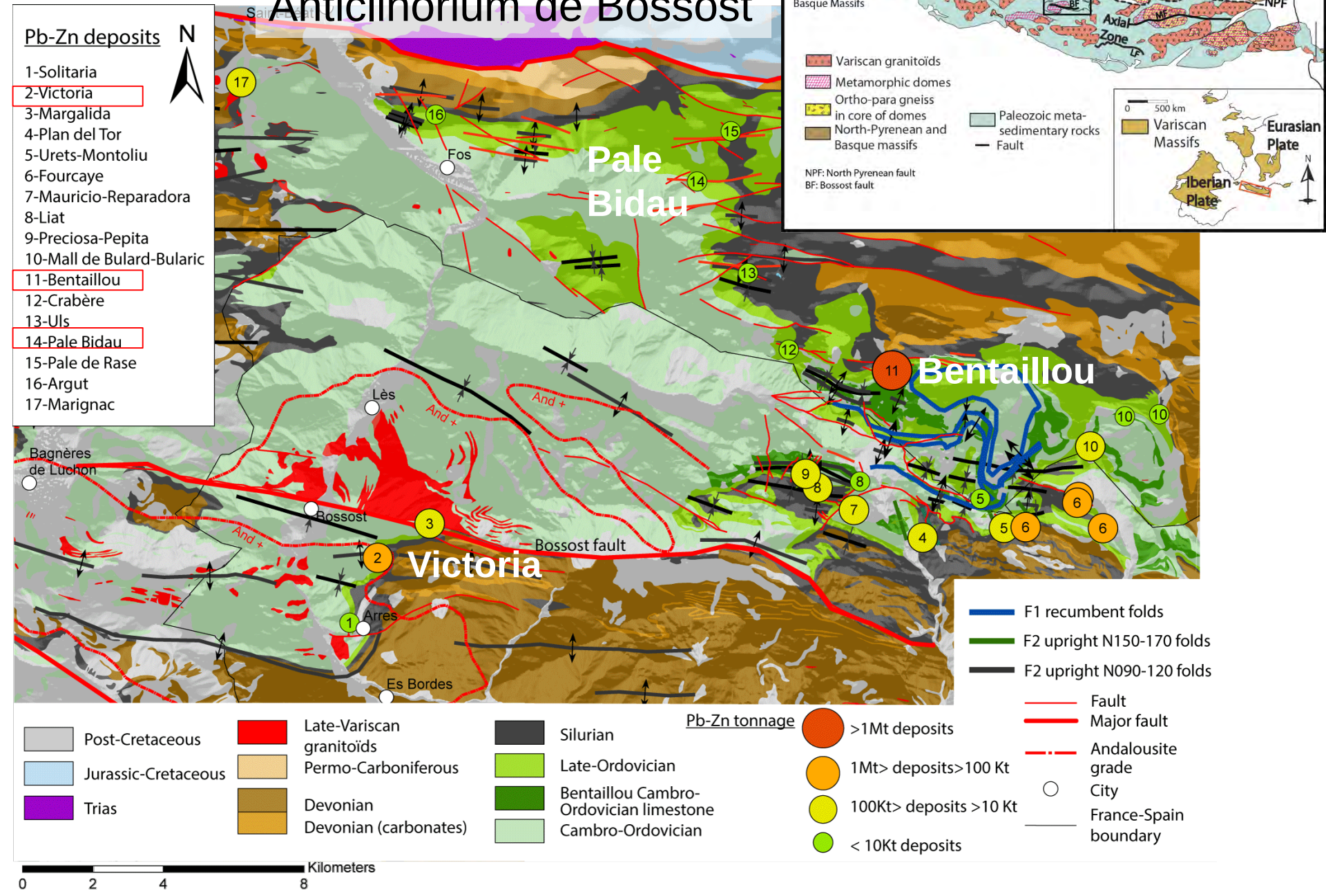
1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées

Gites	Zone	Encaissant		
		age	Roche	Metamorphisme
Bentaillou	Bossost	Cambro-Ordovicien	Marbres-schistes	-
Victoria		Cambro-Ordovicien Sup	schistes	++
Pale Bidau		Ordovicien Sup	calcschistes	-
Arre	Pierrefitte	Dévonien	calcaire	-



1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées

Anticlinorium de Bossost



Genèse des minéralisations Pb-Zn-(Ge): PROBLEMATIQUE

Ore Geology Reviews 95 (2018) 1–19

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Relationships between the occurrence of accessory Ge-minerals and sphalerite in Variscan Pb-Zn deposits of the Bossost anticlinorium, French Pyrenean Axial Zone: Chemistry, microstructures and ore-deposit setting

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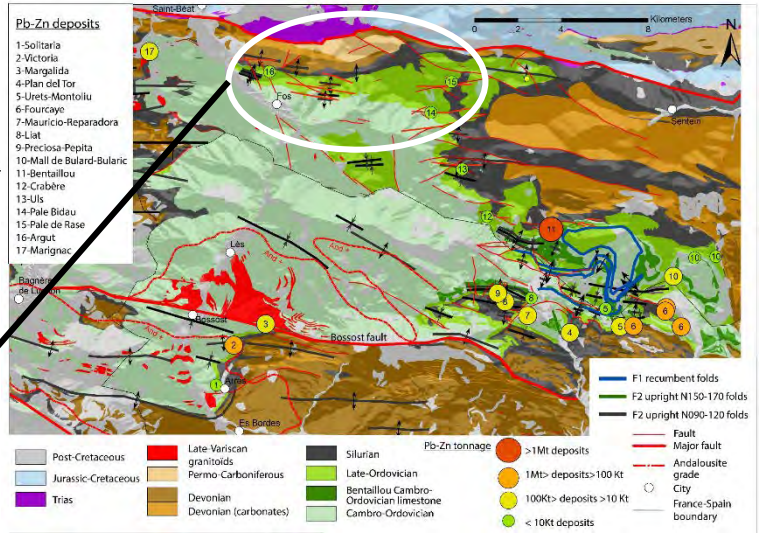
[b] BRGM, Bureau de Recherches Géologiques et Minières, Territorial Direction Languedoc-Roussillon, 1039 Rue de Pinville, 34000 Montpellier, France
[c] BRGM, Bureau de Recherches Géologiques et Minières, 3 Avenue Claude Guillemin, BP 36009, 45060 Orléans Cedex 2, France



Trois gites Pb-Zn étudiés:

→Minéraux à Ge dans sphalerite (ZnS) recristallisée/déformée

→Post-Ordovicien, probablement Varisque →épigénétique

Genèse des minéralisations Pb-Zn-(Ge): PROBLEMATIQUE

Minéralisations déposées en même temps que l'encaissant = syngénétique

-->Ages de mise en place ordovicien ou dévonien?

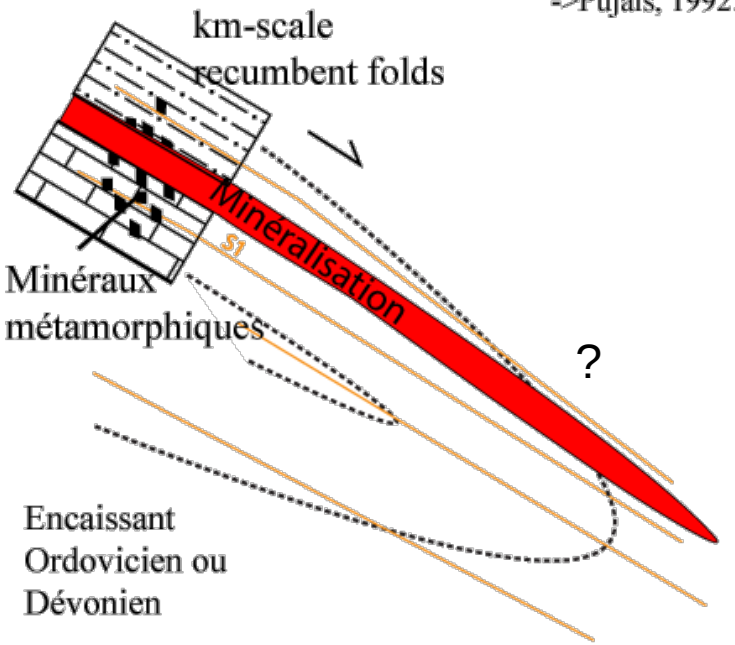
->Pouit & Bois (1980's): Pierrefitte, Bossost

->Pesquera & Velasco, 1989: Pb-Zn massifs basques

->Pujals, 1992: Pb-Zn Bossost (Sud)

ET/OU

Minéralisations post-sédimentations = épigénétiques



--> Ages de mise en place Varisque?

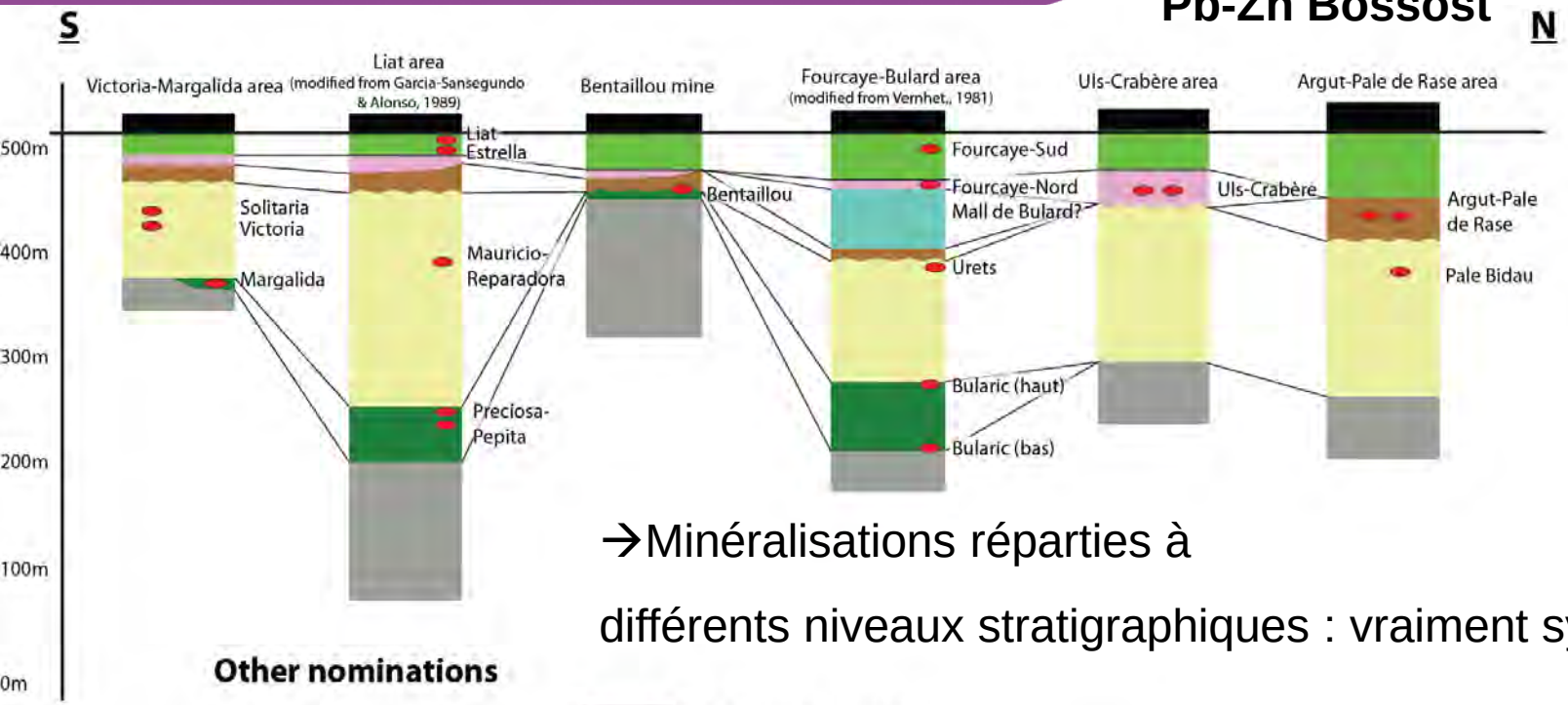
->Nicol, 1997: Pierrefitte

->Reyx, 1973: Anglas-Arre

->Alonso, 1979: Pb-Zn Bossost (Sud)

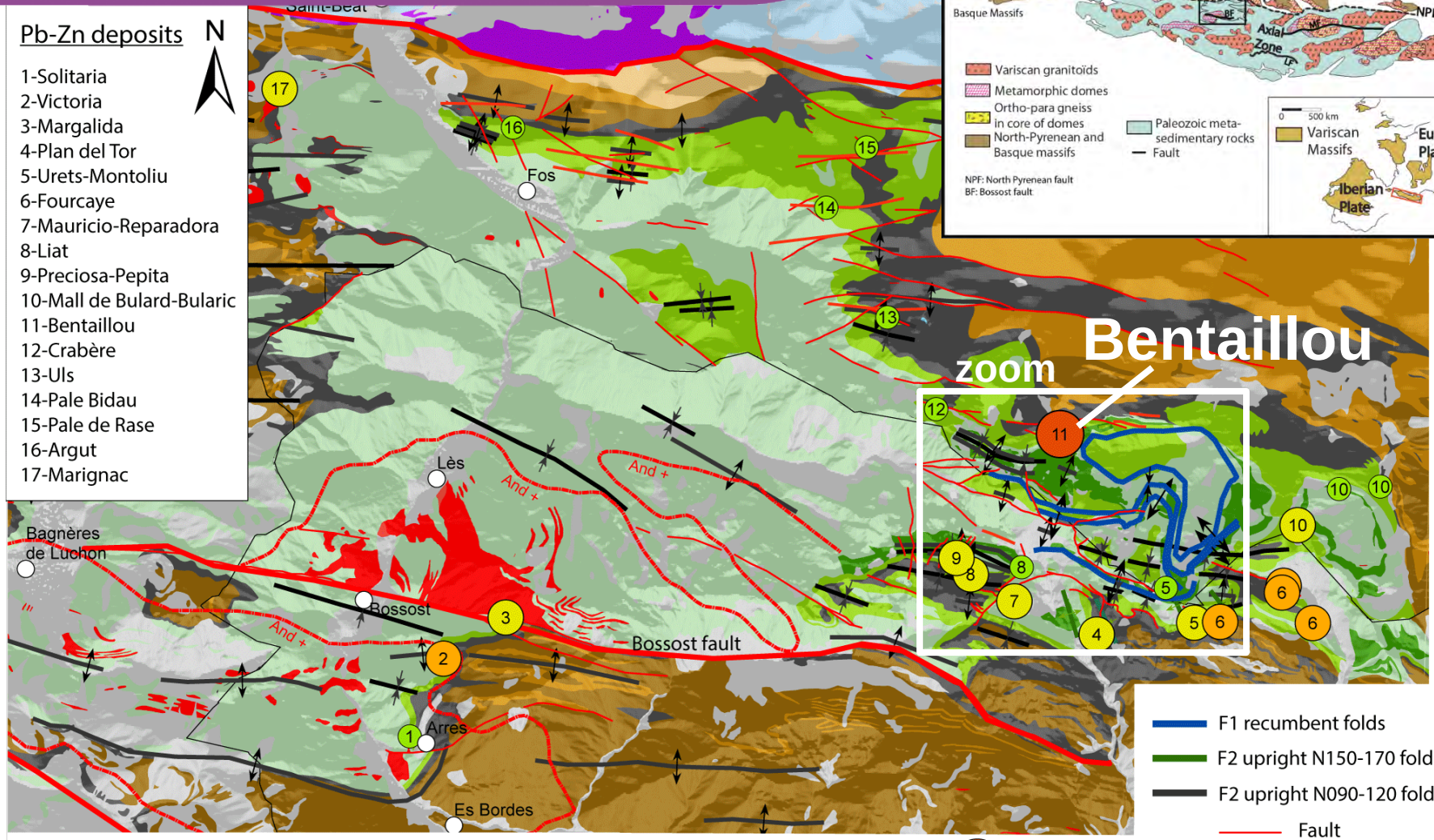
->Cugerone et al., 2018: Bossost (Nord)

Pb-Zn Bossost

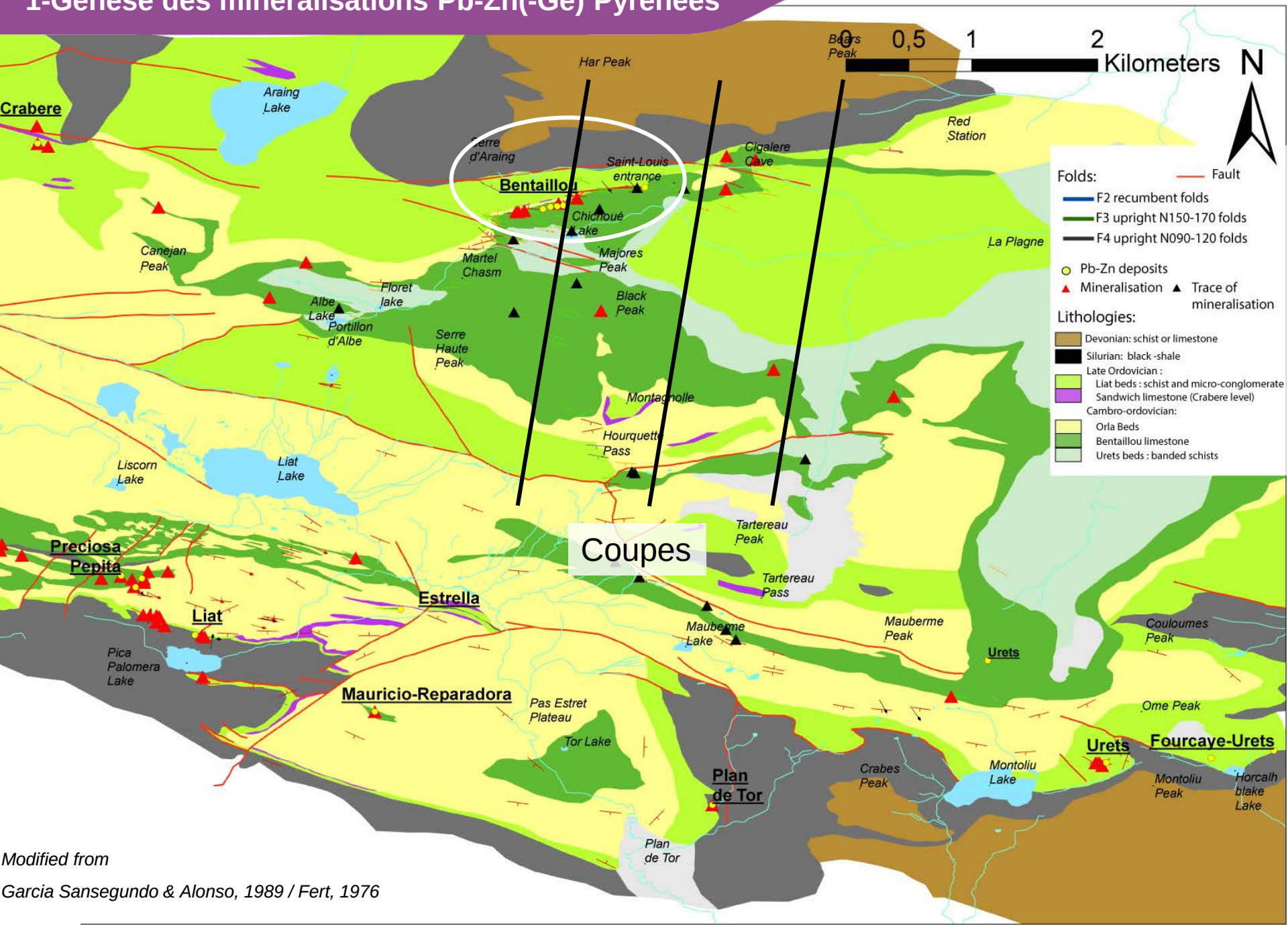


→Minéralisations réparties à différents niveaux stratigraphiques : vraiment syngénétique?

1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



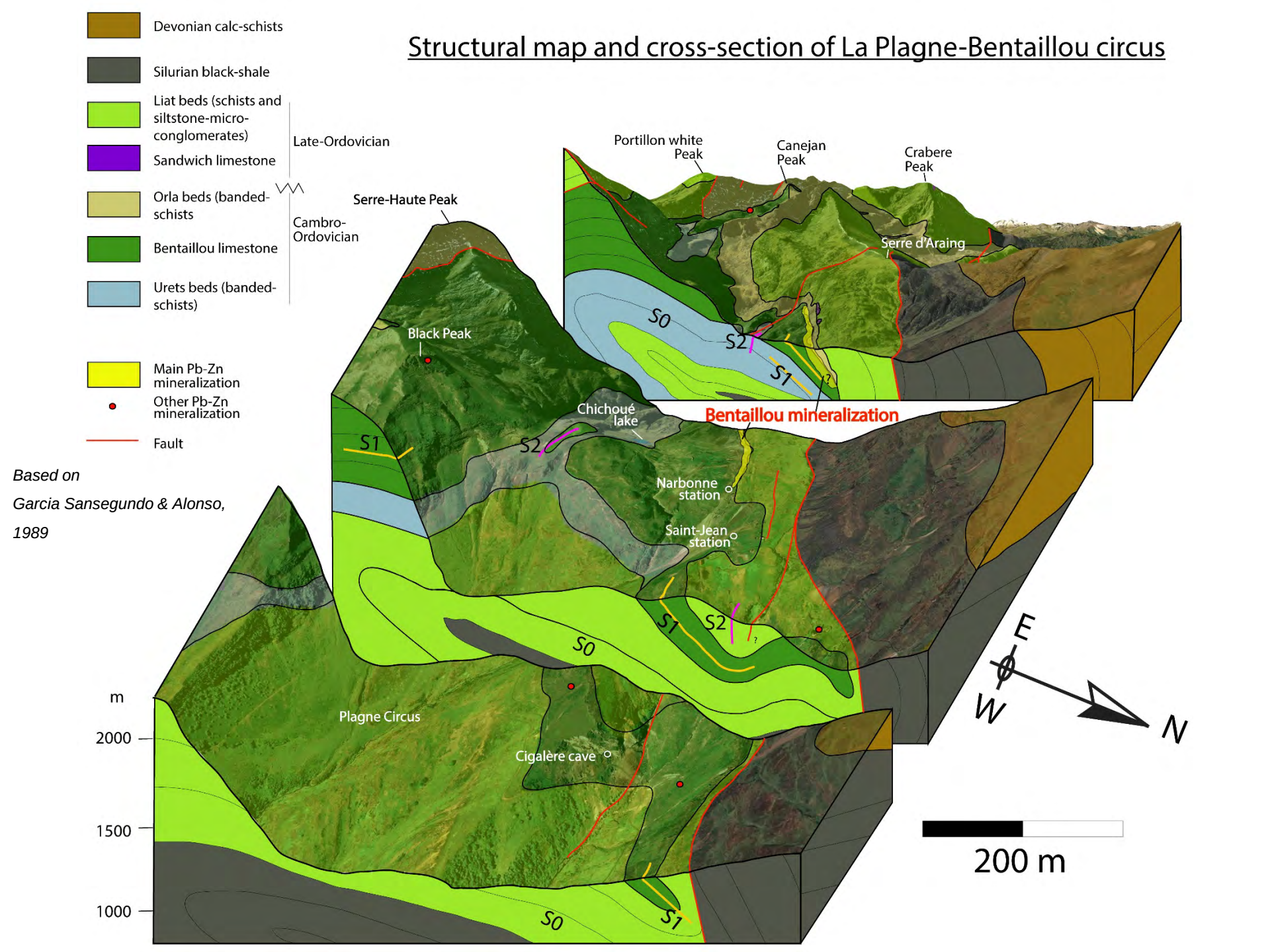
1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



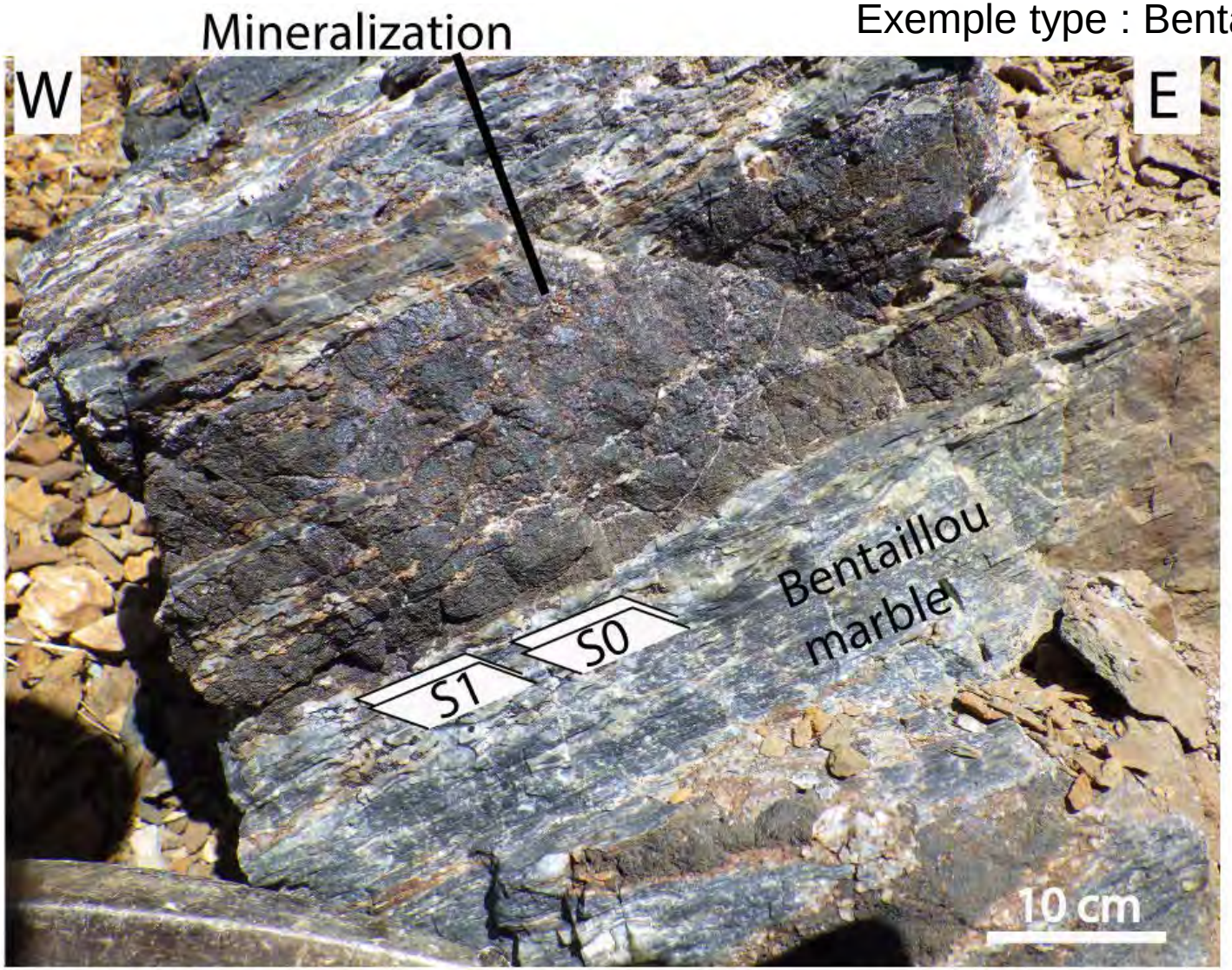
Modified from

Garcia Sansegundo & Alonso, 1989 / Fert, 1976

Structural map and cross-section of La Plagne-Bentaillou circus

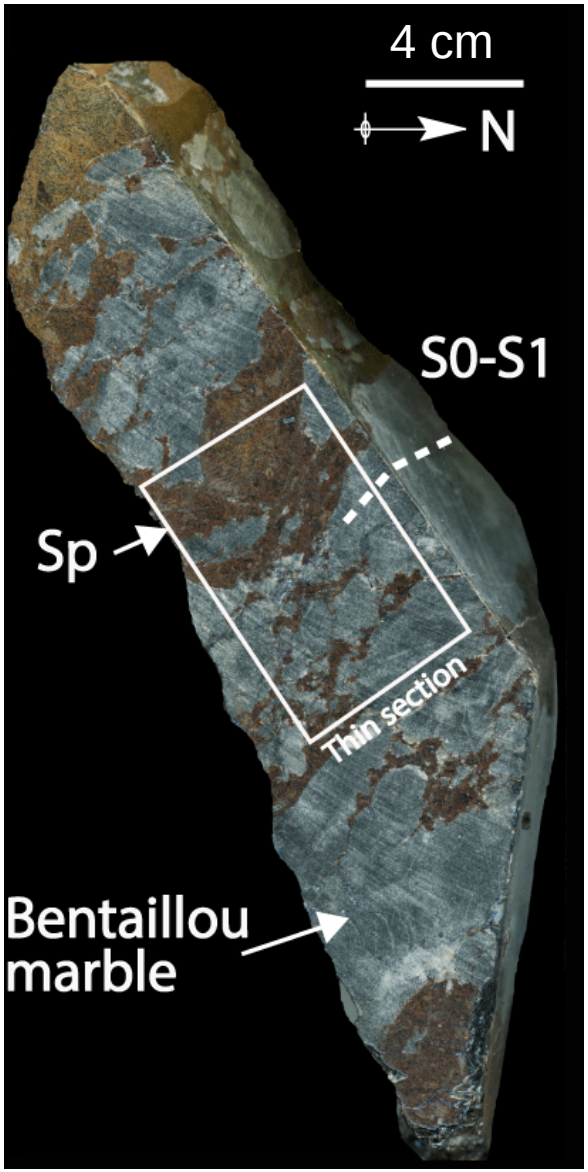


Exemple type : Bentaillou (Ariège)

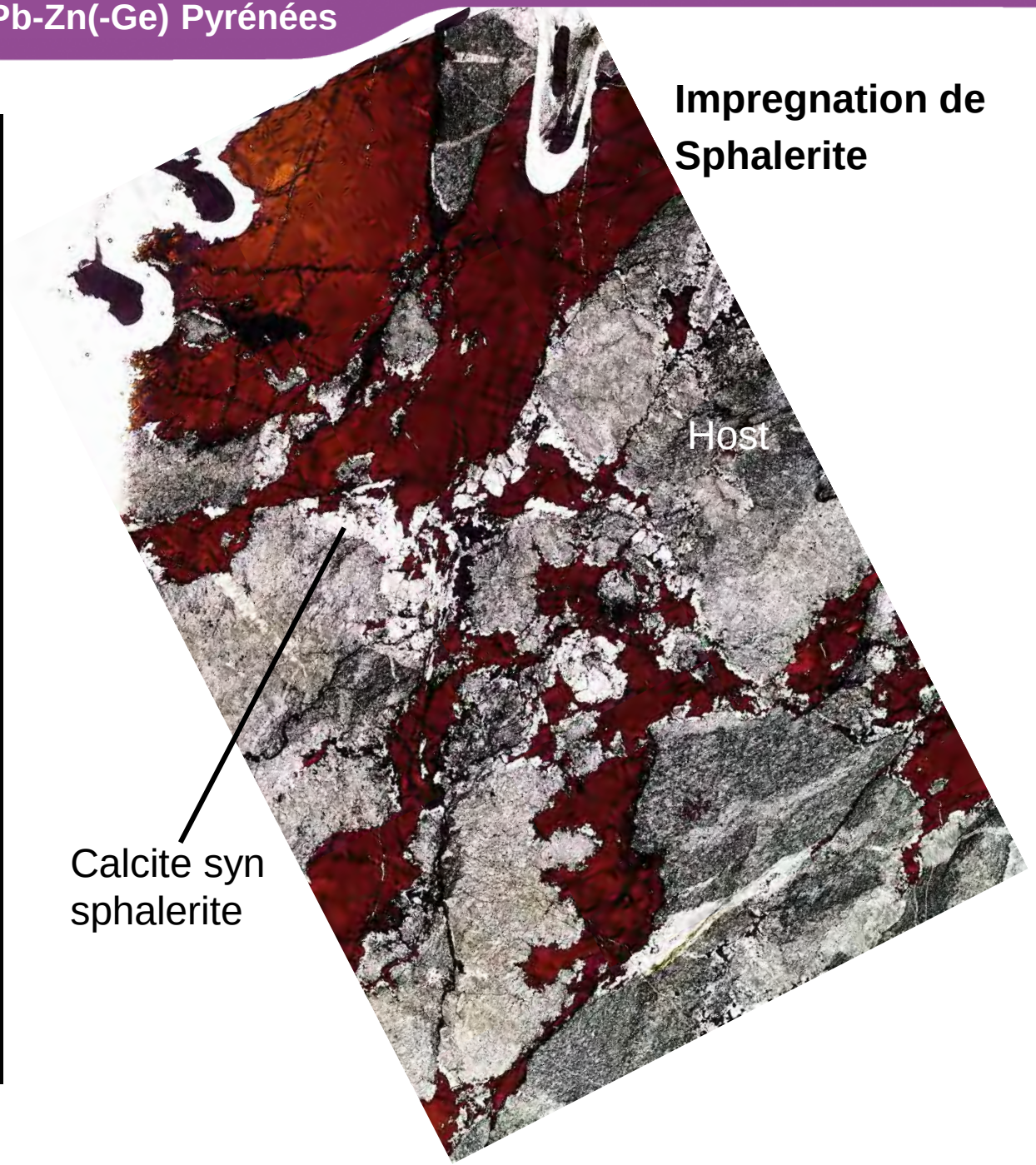


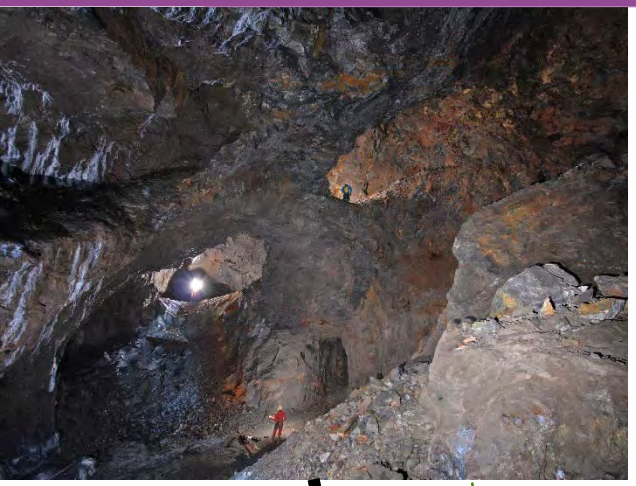
Minéralisation semble stratiforme à première vue même si toutes les structures semblent parallèles

Texture de la minéralisation

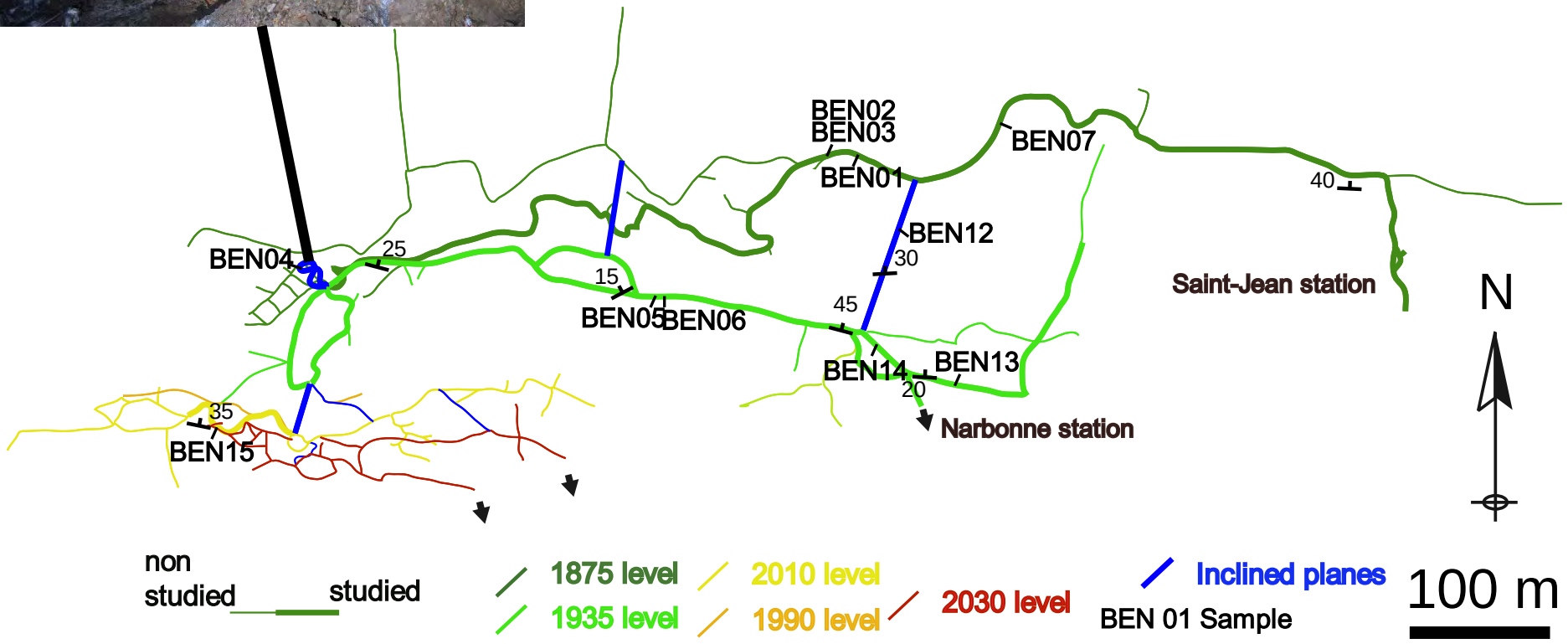


Impregnation de Sphalerite



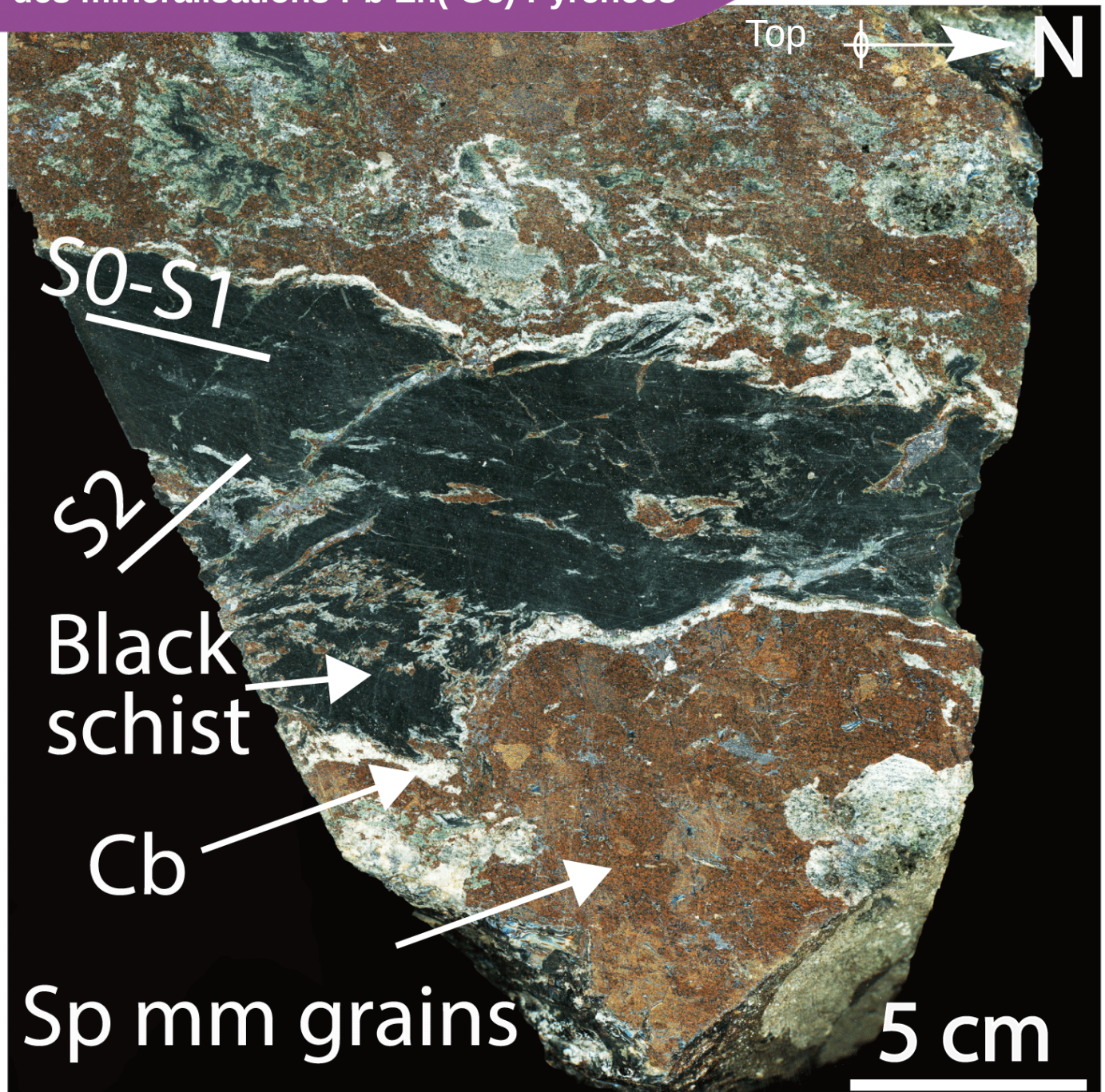


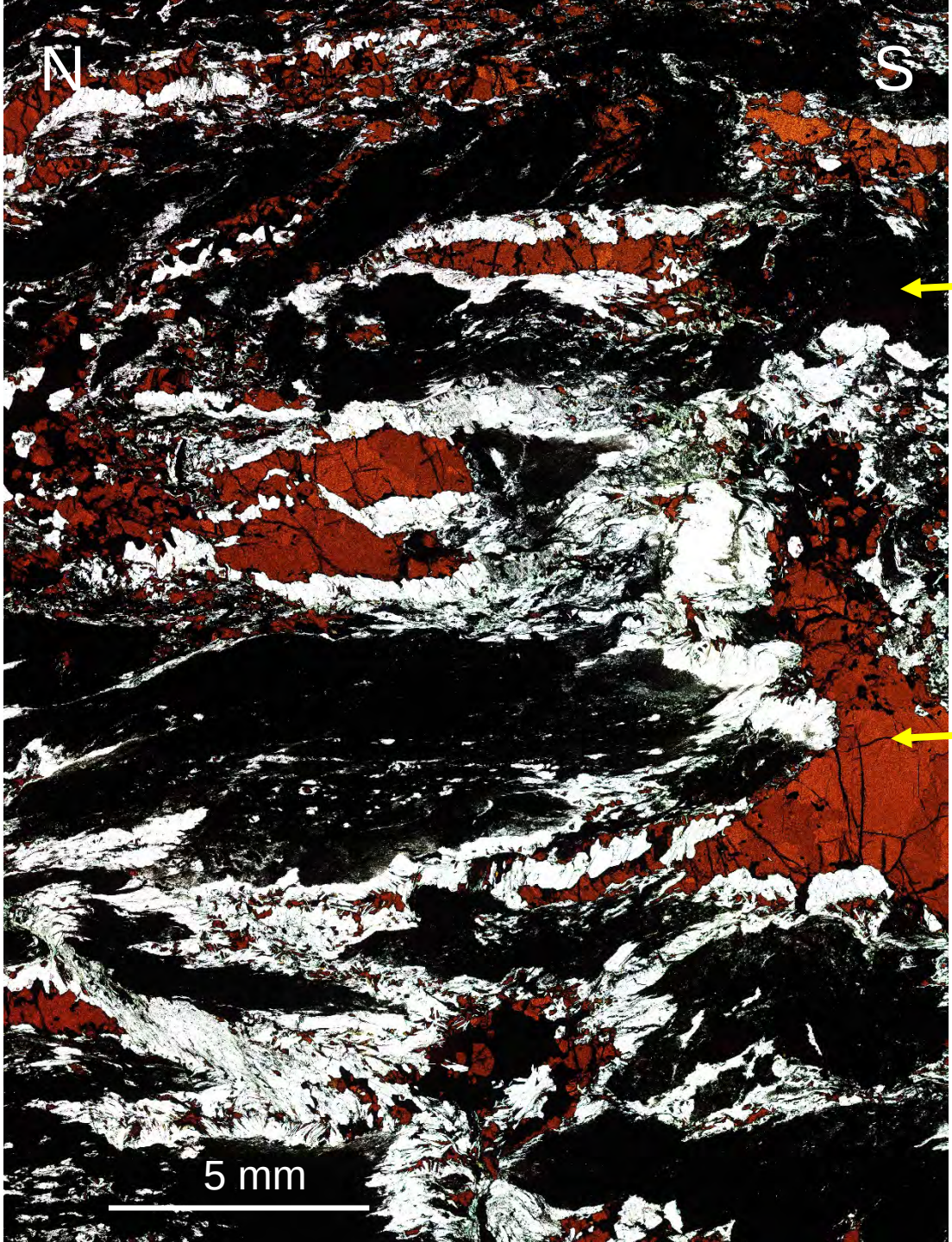
Bentaillou : plan partiel des galeries souterraines



Plan de base: Arshal-B.Lafage, De Pazzis L.


Bentaillou
E
W
schists
S0-S1
Mineralization
10 cm


Top
N
S0-S1
S2
Black schist
Cb
Sp mm grains
5 cm

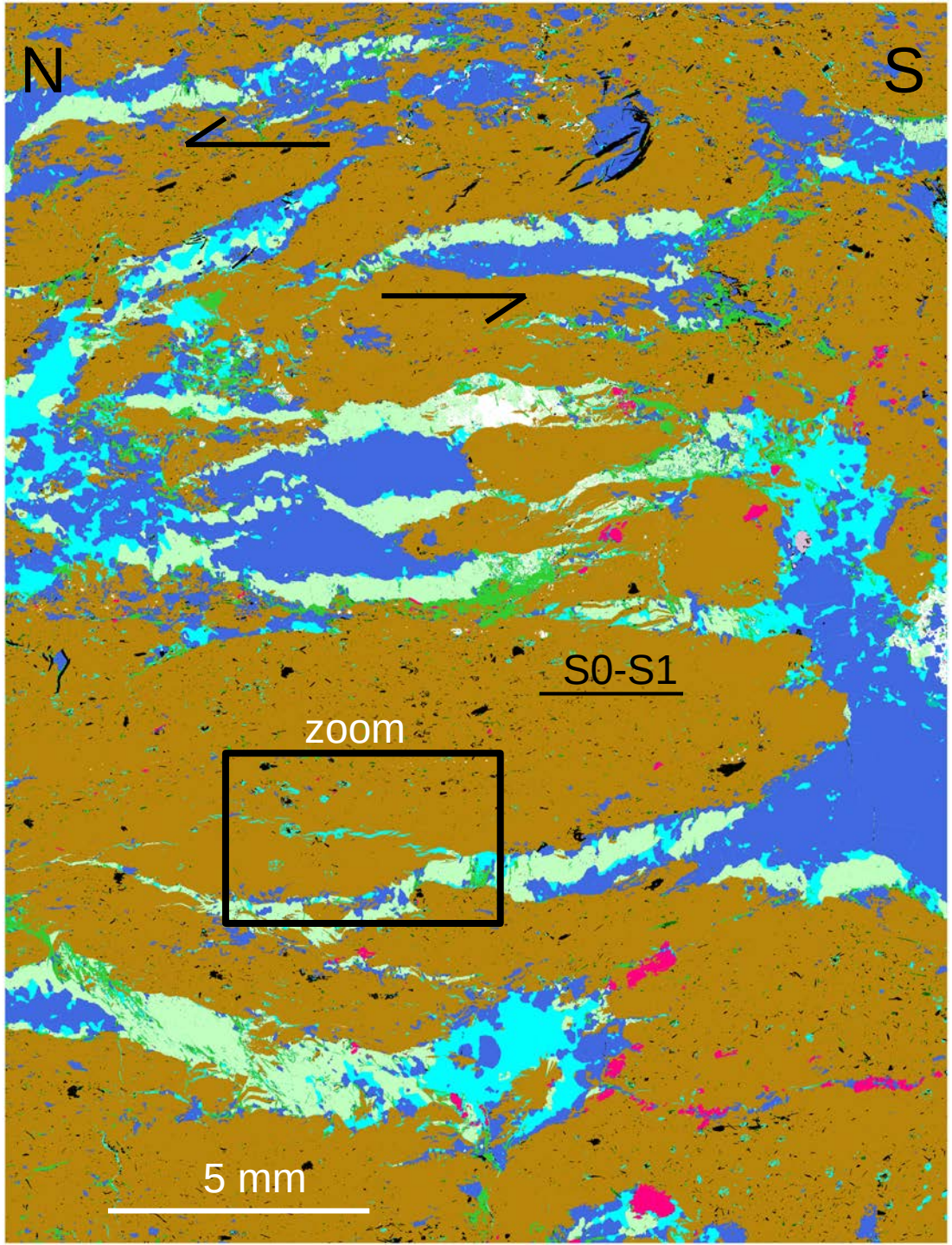


Thin section
(Lum.naturelle)

Schistes
noirs

Sphalerite

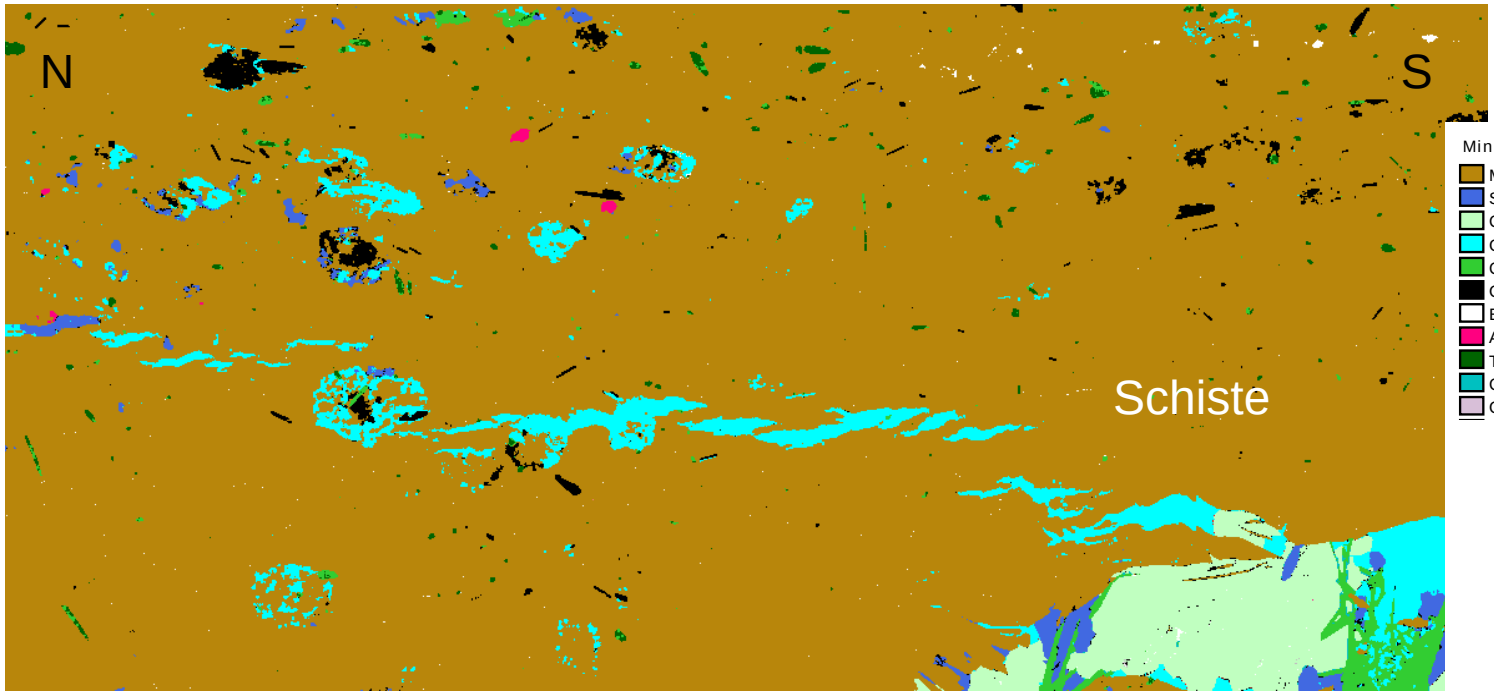
Gite Pb-Zn de Bentaillou



Mineral Name	Composition
Muscovite	64.5590
Sphalerite general	16.6998
Calcite	7.4369
Galena	5.8158
Chlorite	2.6292
Others	1.6777
Background	0.6559
Apatite	0.5085
Tourmaline	0.4145
Ca-Fe-Mg_carbonate	0.1762
Quartz	0.0335

Qemscan

Gite Pb-Zn de Bentaillou



Zoom

Mineral Name	
Muscovite	64.5590
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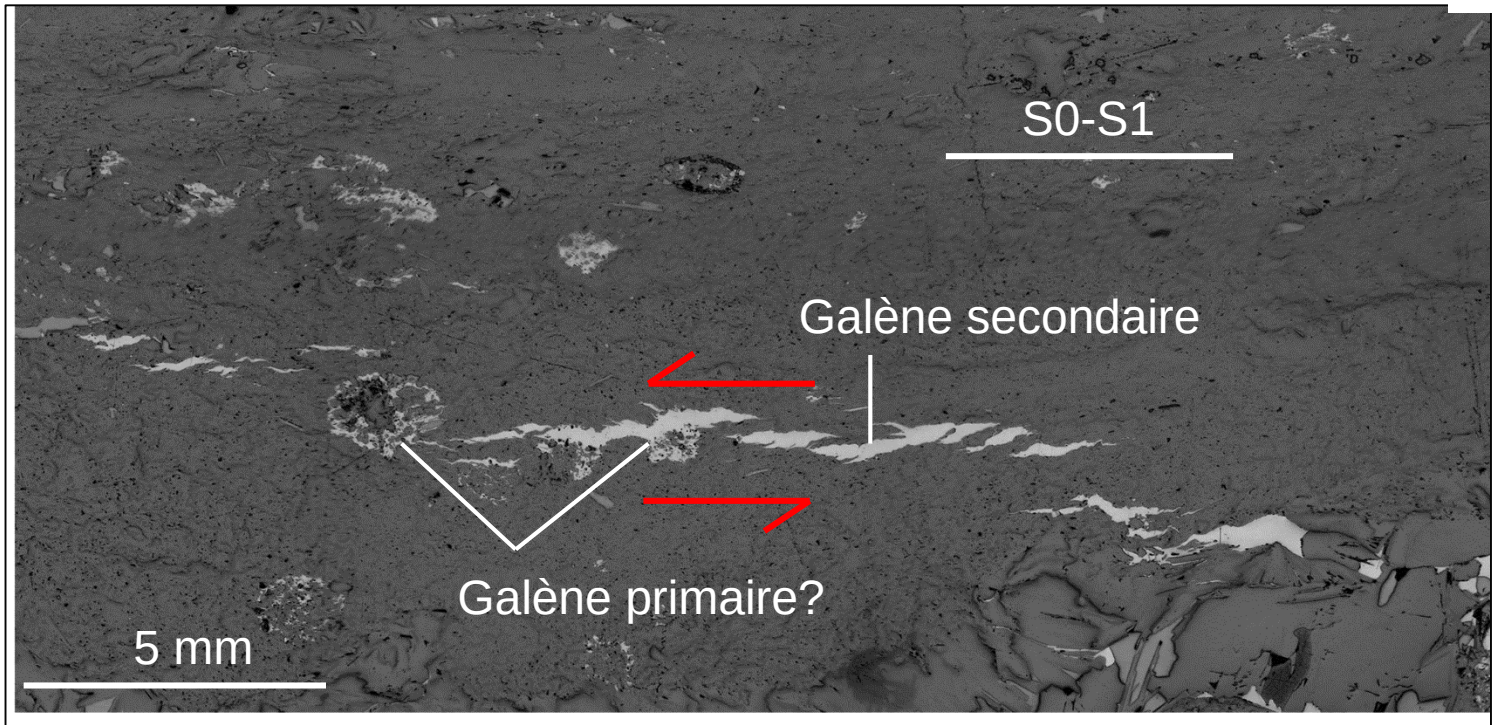
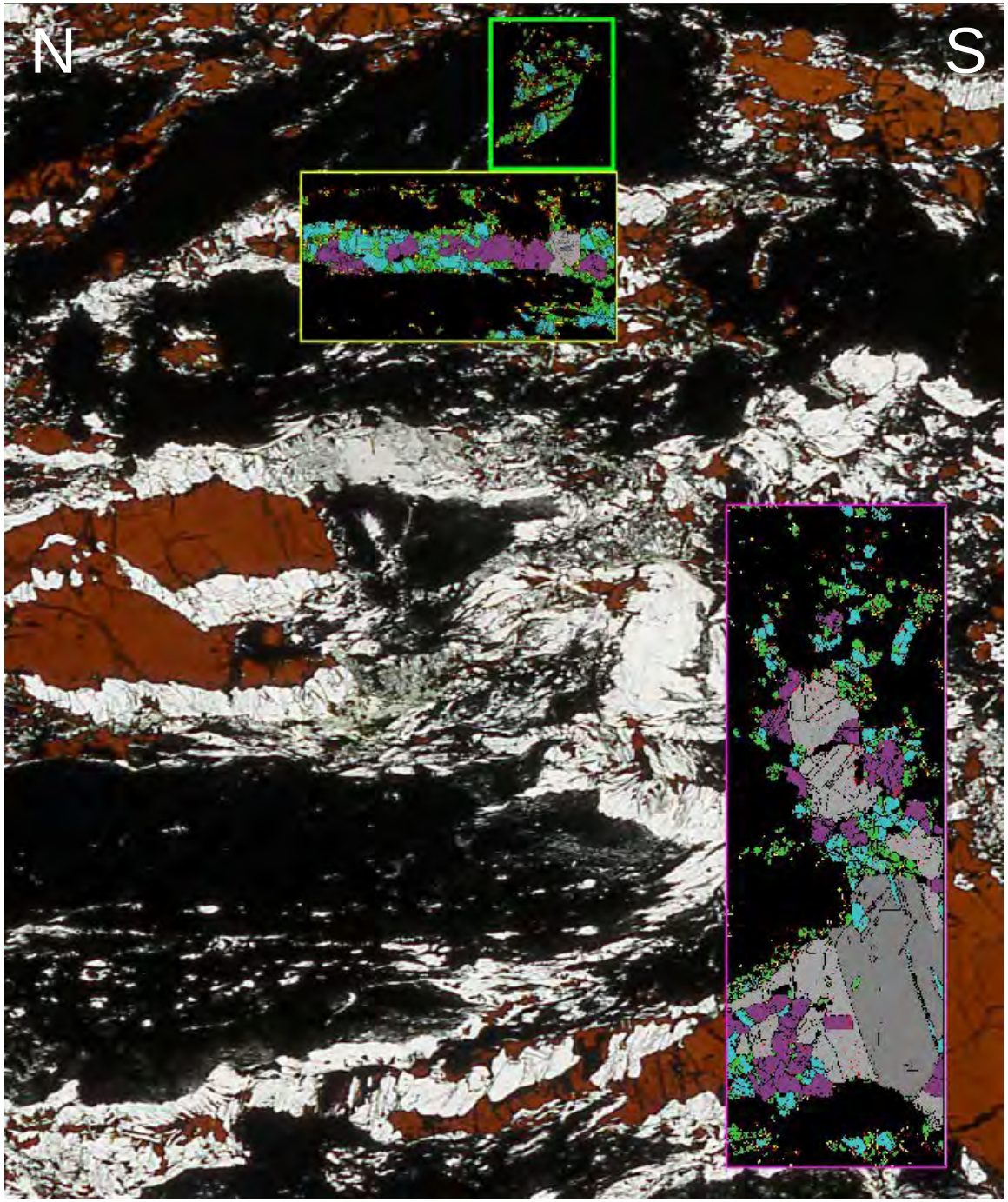


Gite Pb-Zn

de Bentaillou



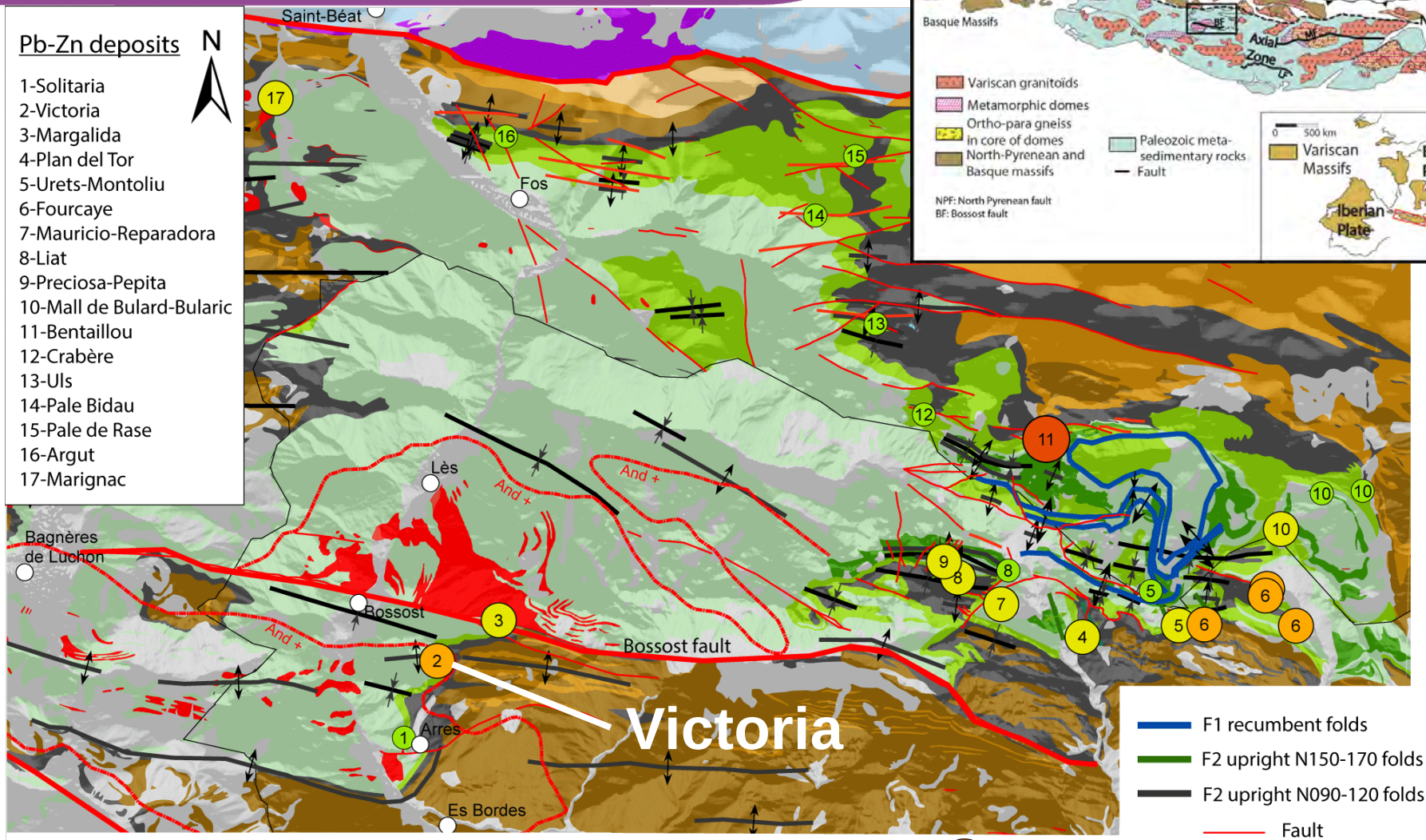
1-25um
25-50 um
50-150 um
150-300 um
300-500 um
500-1500 um
>1500 um

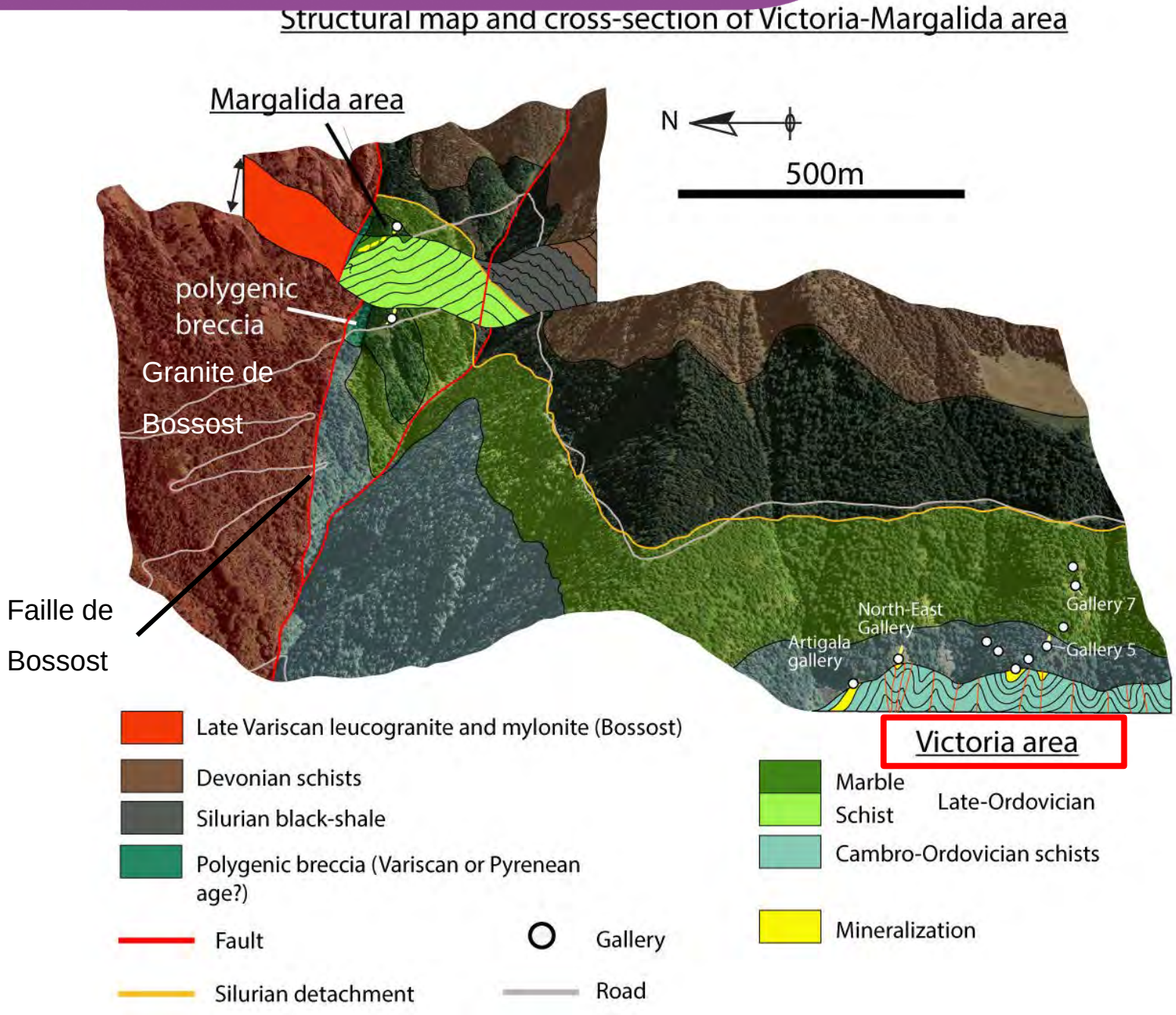
EBSD

Texture grossière et peu déformée de la sphalérite

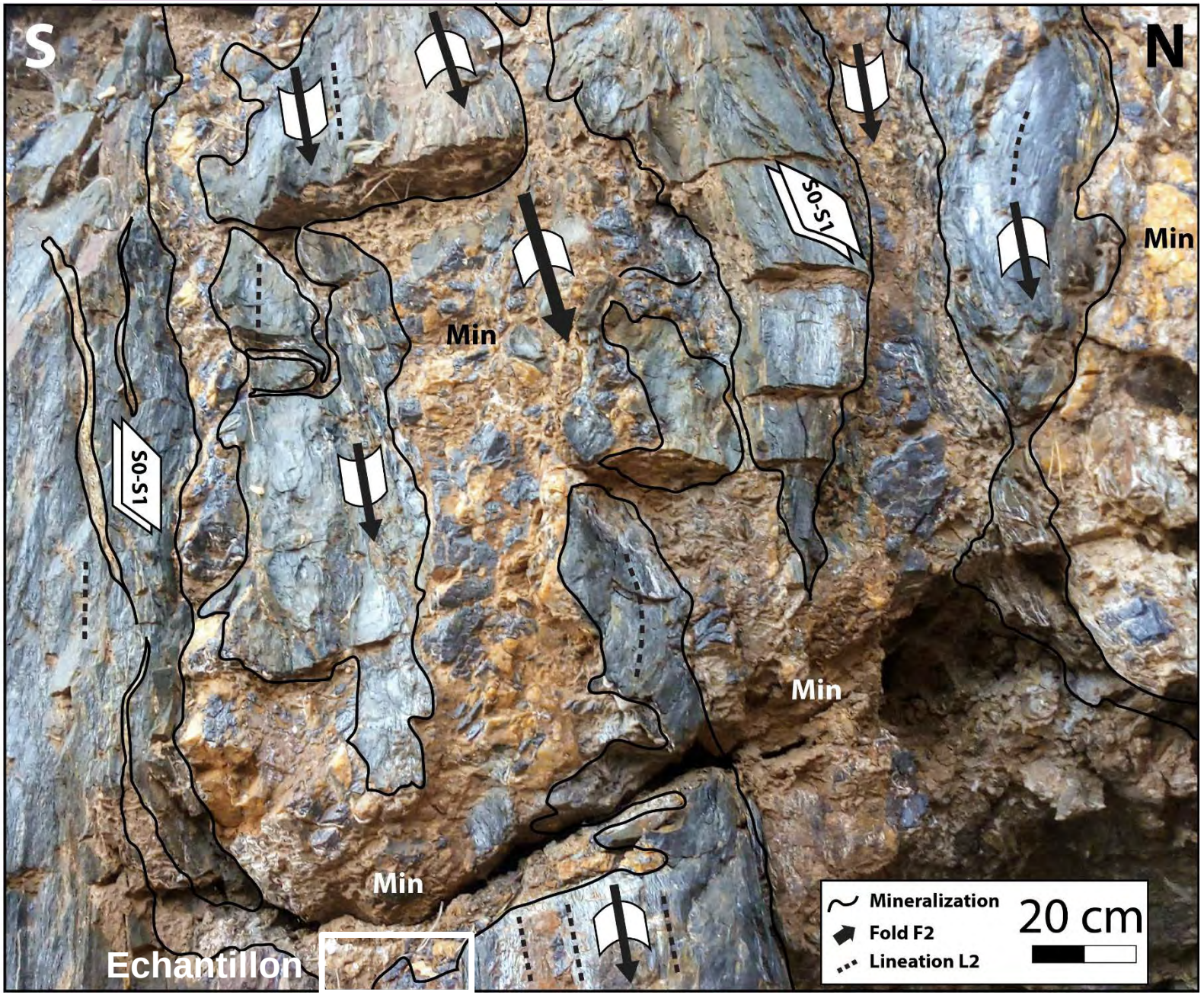
Gite Pb-Zn de Bentaillou

1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



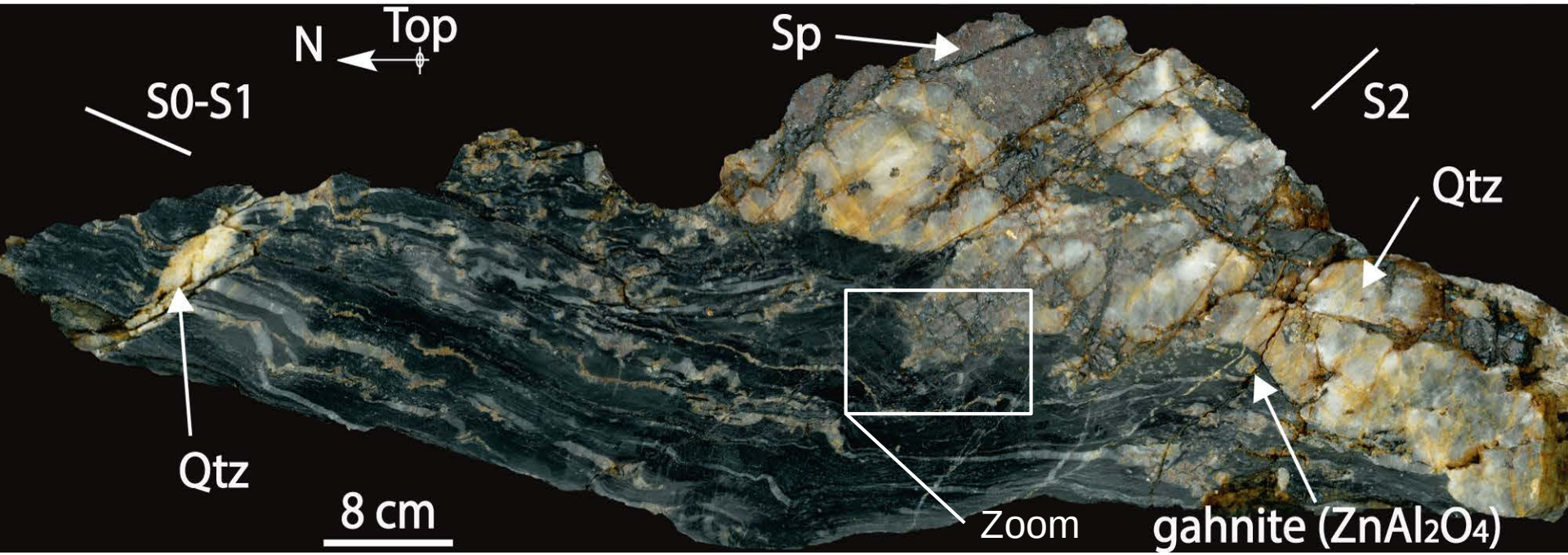

Structural map and cross-section of Victoria-Margalida area
Margalida area
N
500m
polygenic breccia
Granite de Bossost
Faille de Bossost
North-East Gallery
Artigala gallery
Gallery 7
Gallery 5
Victoria area
Late Variscan leucogranite and mylonite (Bossost)
Devonian schists
Silurian black-shale
Polygenic breccia (Variscan or Pyrenean age?)
Fault
Silurian detachment
Gallery
Road
Marble
Schist
Late-Ordovician
Cambro-Ordovician schists
Mineralization

North East gallery (Victoria)



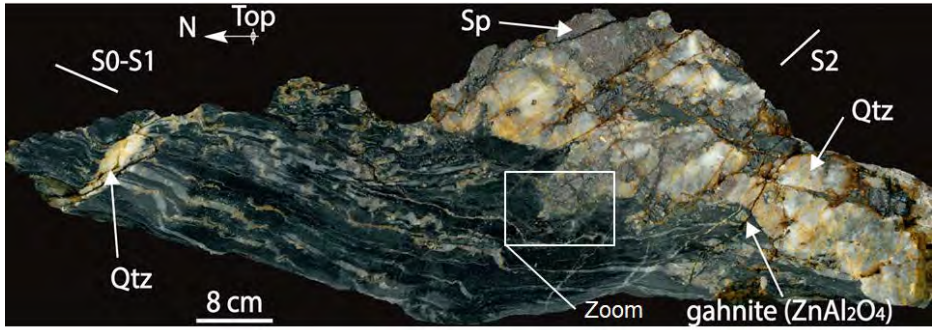
North East gallery (Victoria)

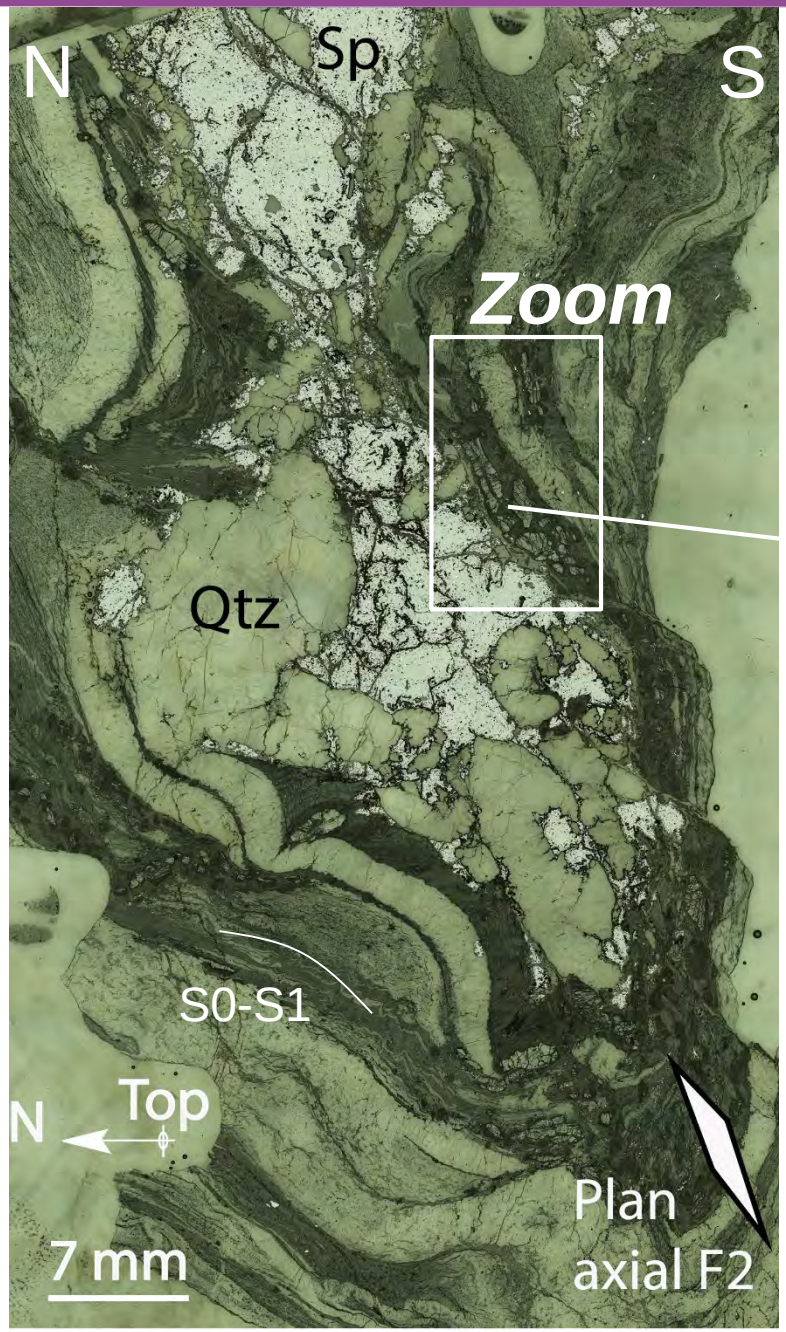
Victoria: minéralisation globalement // à S0 et S1 / plissé par F2



Relation avec minéraux métamorphiques?

North East gallery (Victoria)





Gahnite

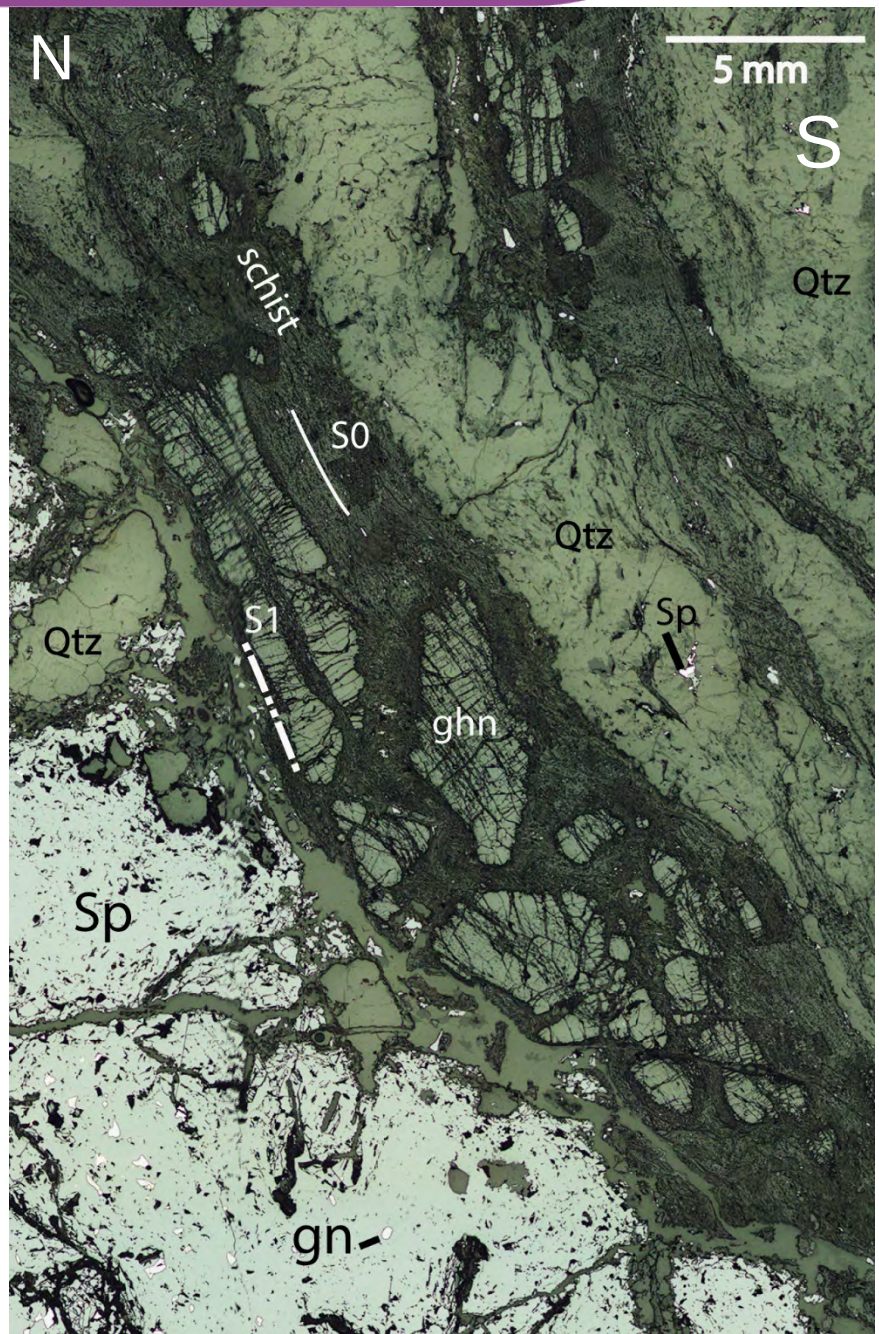
North East gallery (Victoria)

Victoria

Gahnite (ghn) :

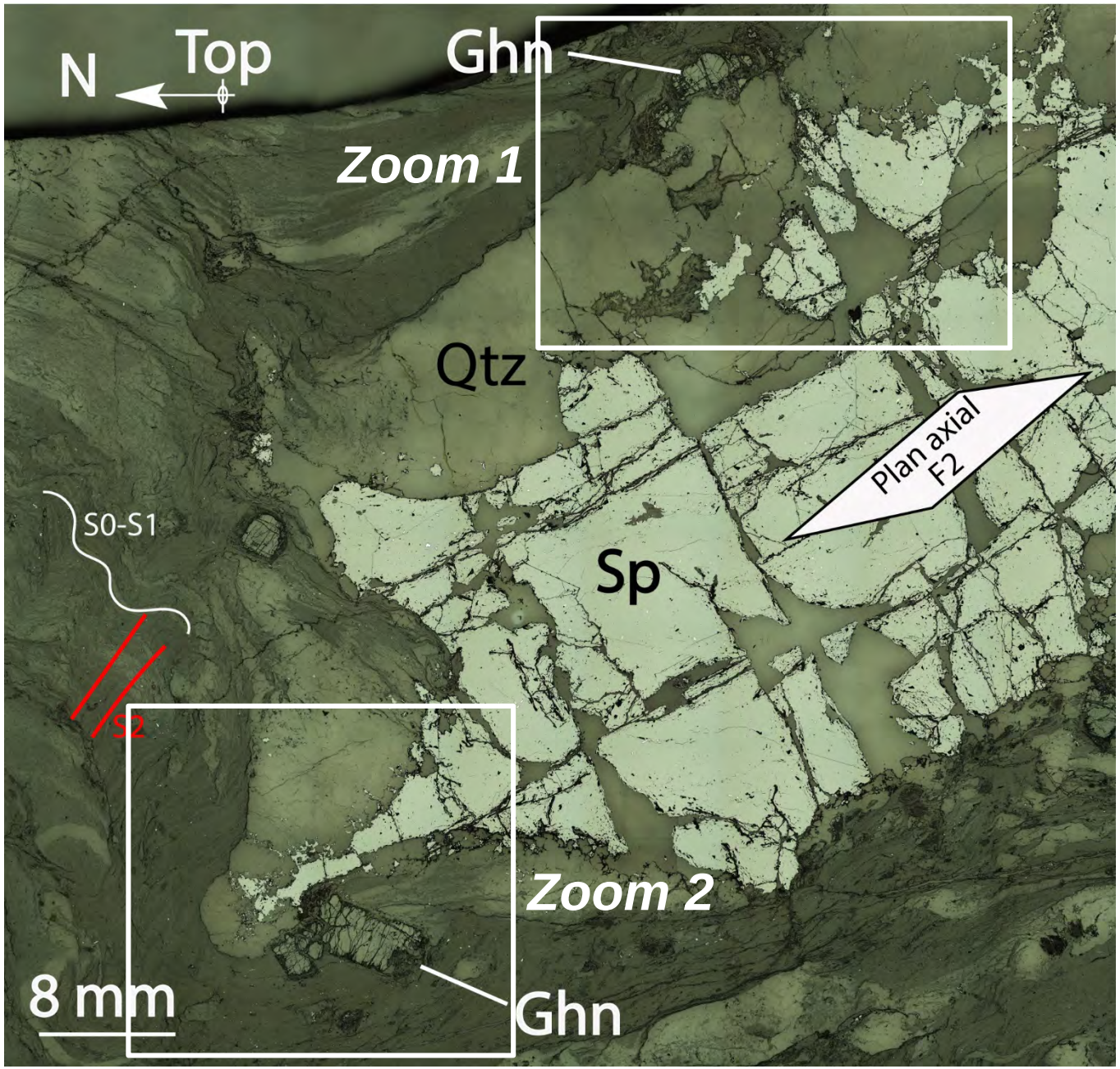
$ZnAl_2O_4$

Spinelle de HT°



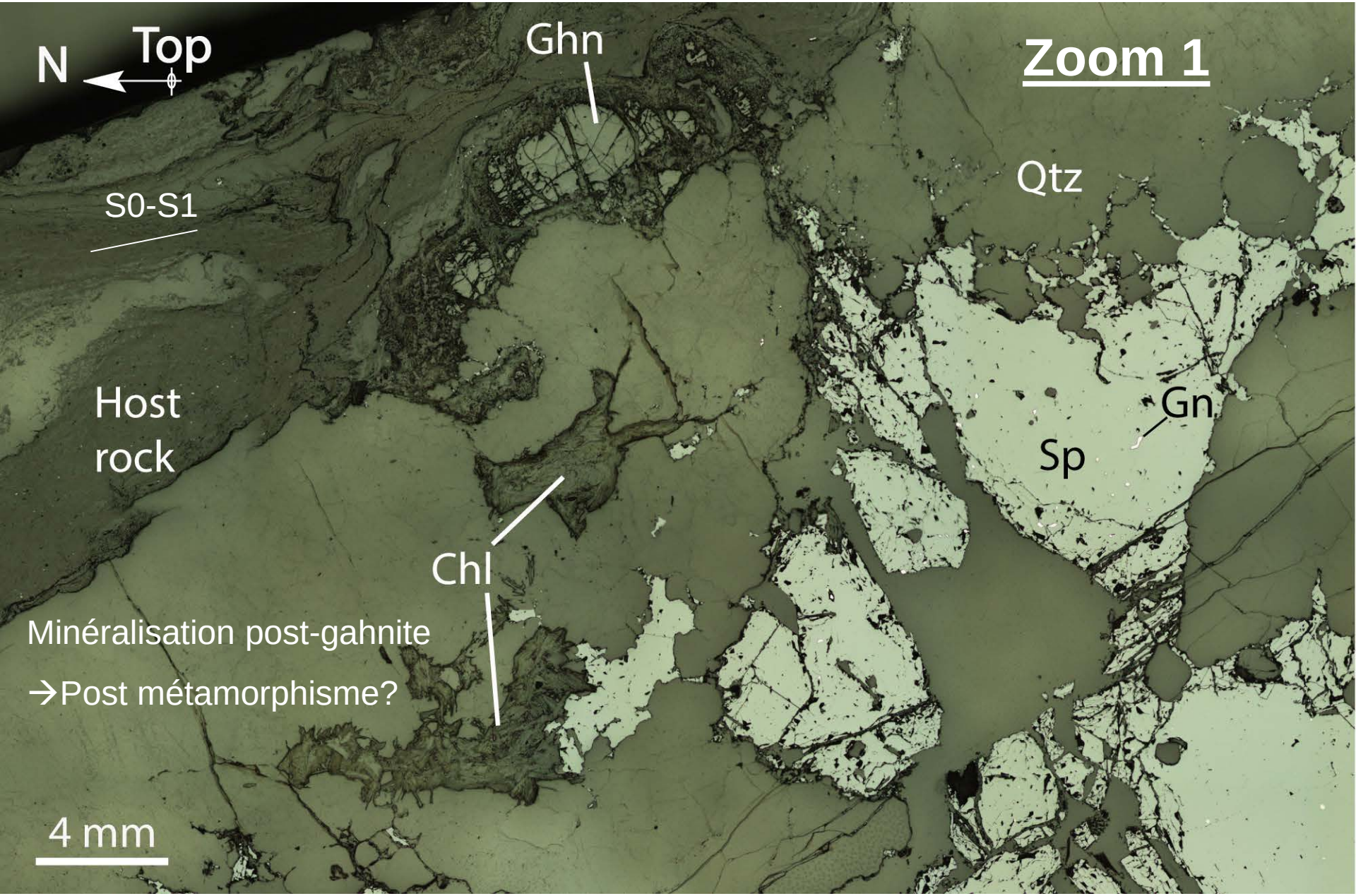
→Marqueur d'une minéralisation primaire à sphalerite pré-métamorphique

→Gahnite anté ou syn S1

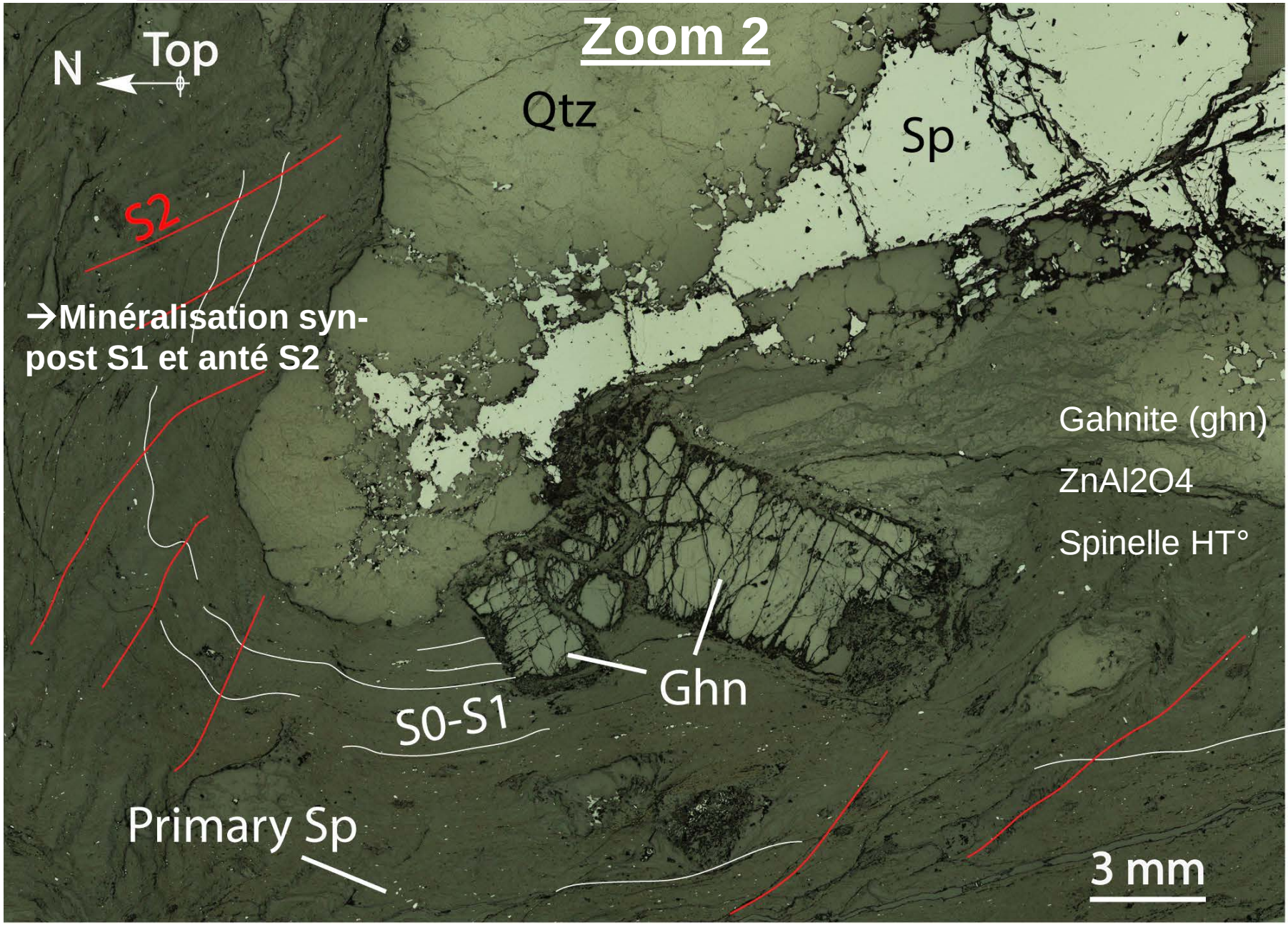


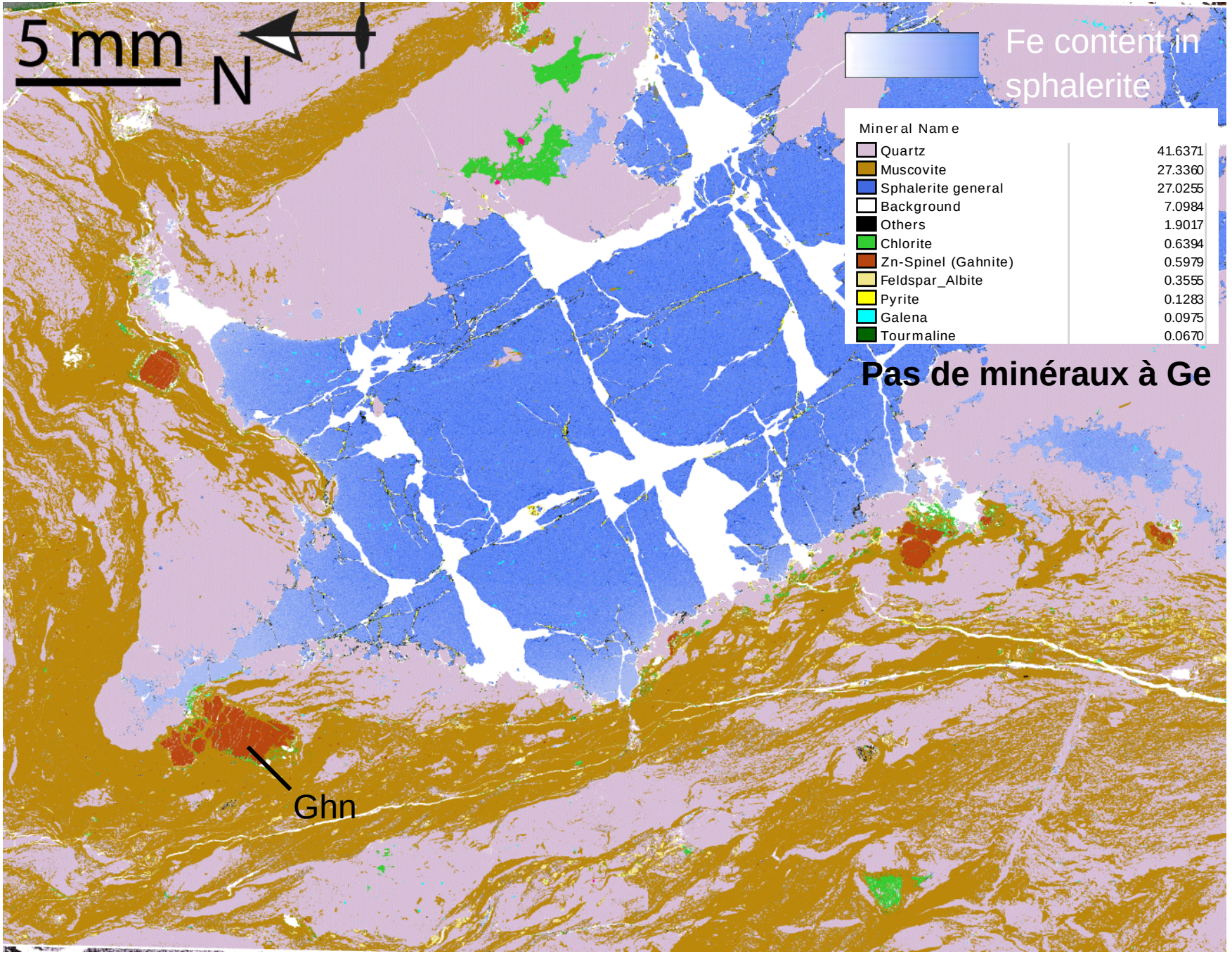
Zoom

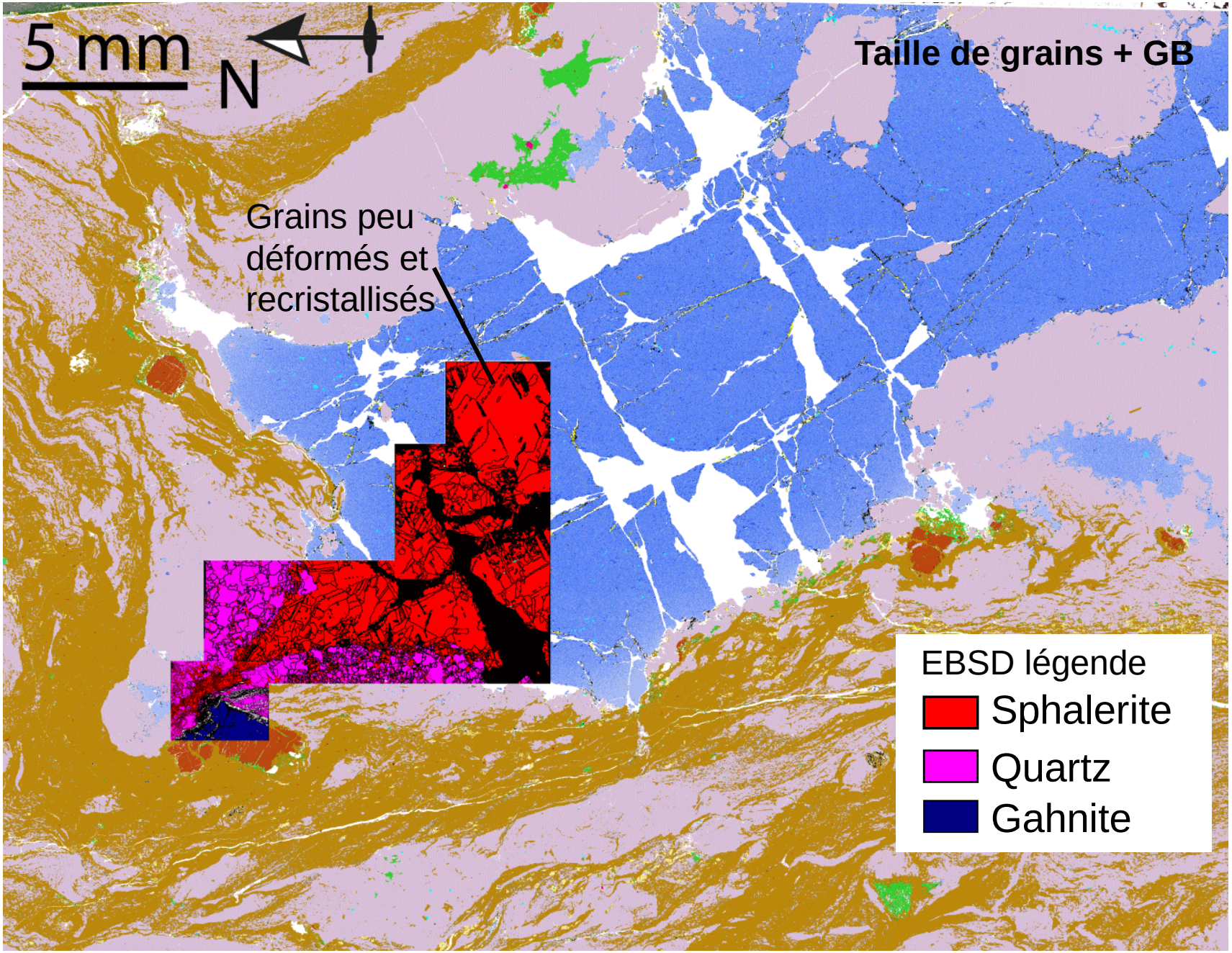
Ghn : gahnite ; Sp: sphalerite



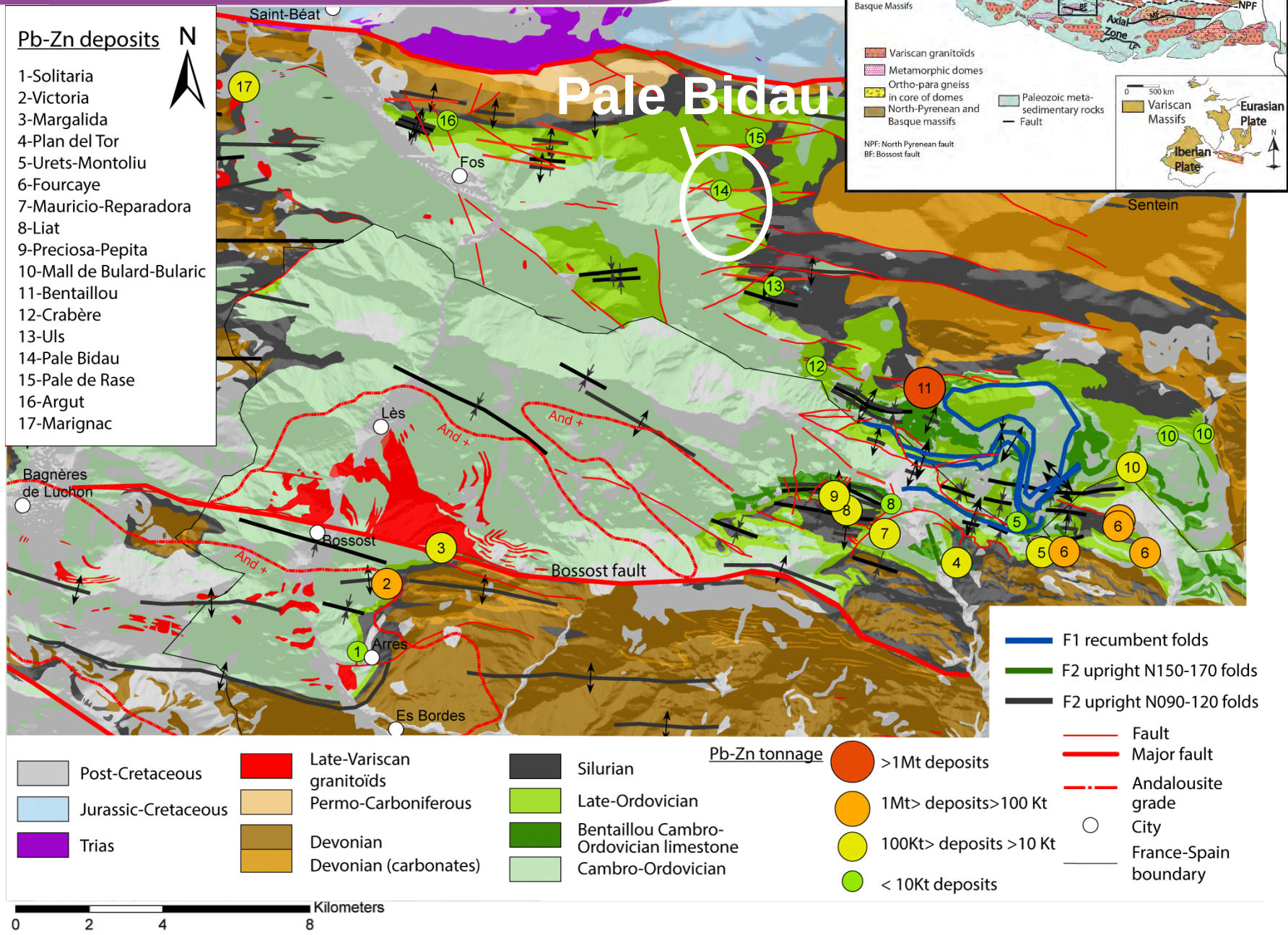
Ghn : gahnite ; Sp: sphalerite

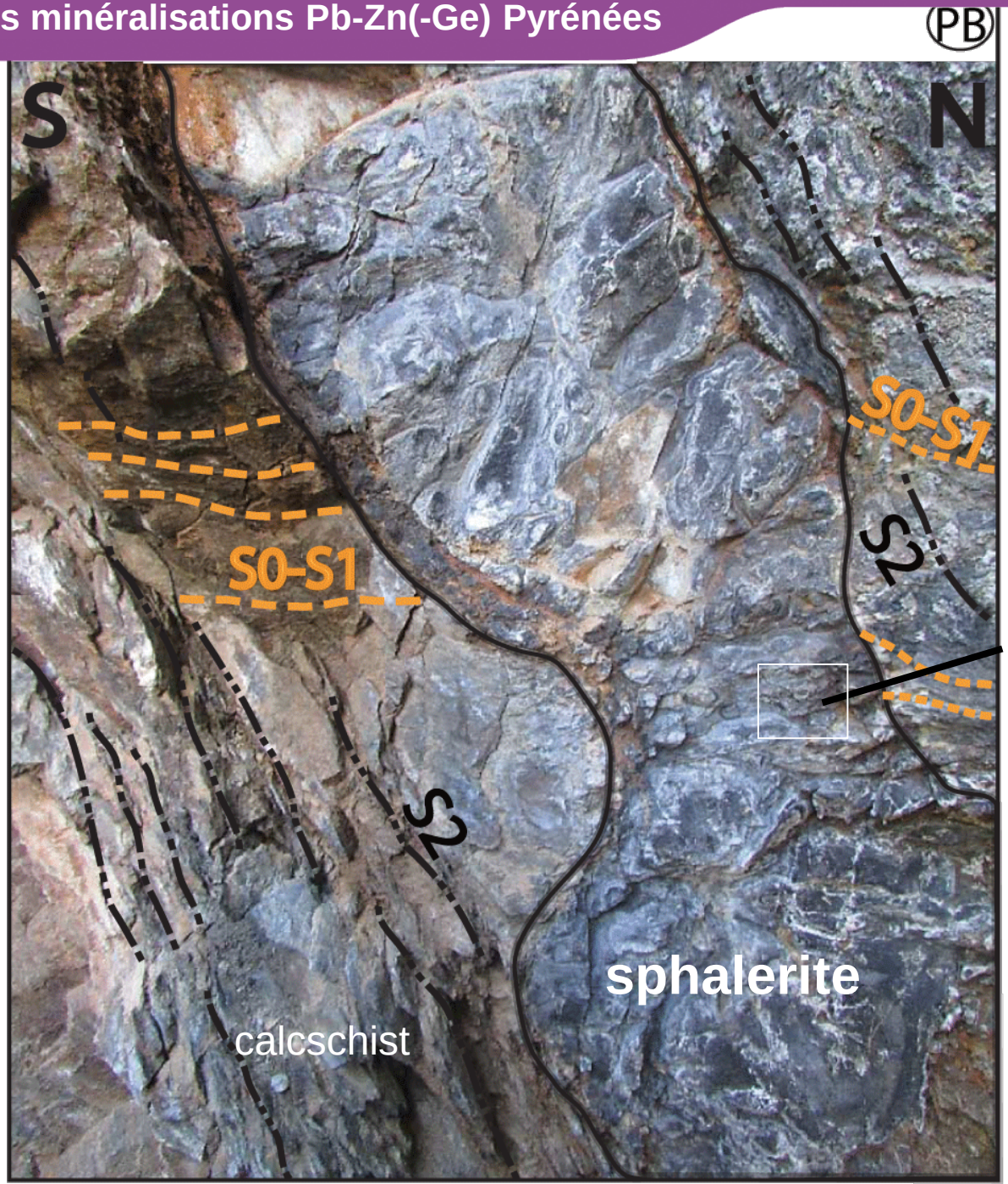



5 mm
N
Fe content in sphalerite
Mineral Name
Quartz 41.6371
Muscovite 27.3360
Sphalerite general 27.0255
Background 7.0984
Others 1.9017
Chlorite 0.6394
Zn-Spinel (Gahnite) 0.5979
Feldspar_Albite 0.3555
Pyrite 0.1283
Galena 0.0975
Tourmaline 0.0670
Pas de minéraux à Ge
Ghn

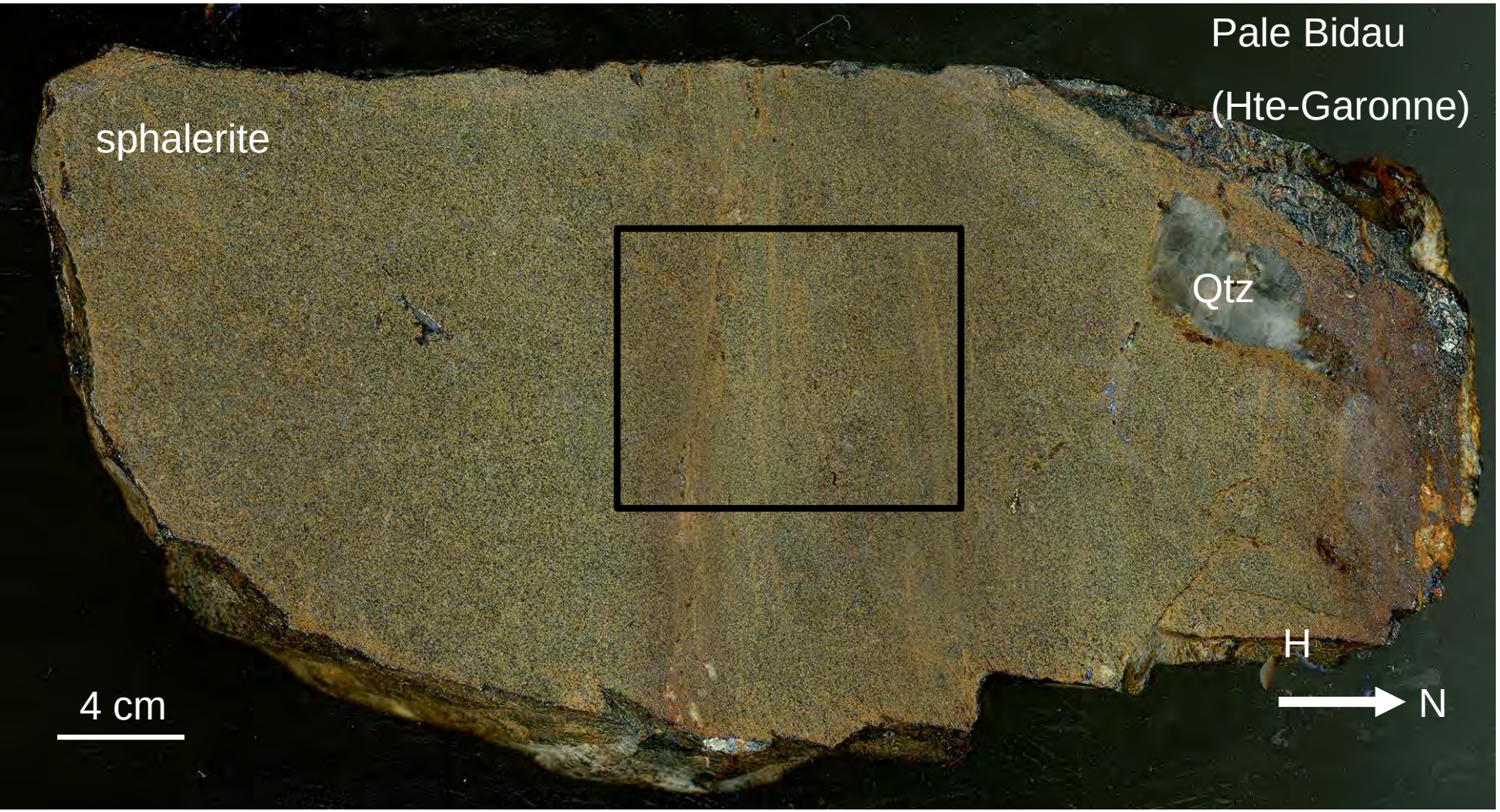

5 mm
N
Taille de grains + GB
Grains peu déformés et recristallisés
EBSD légende
Sphalerite
Quartz
Gahnite

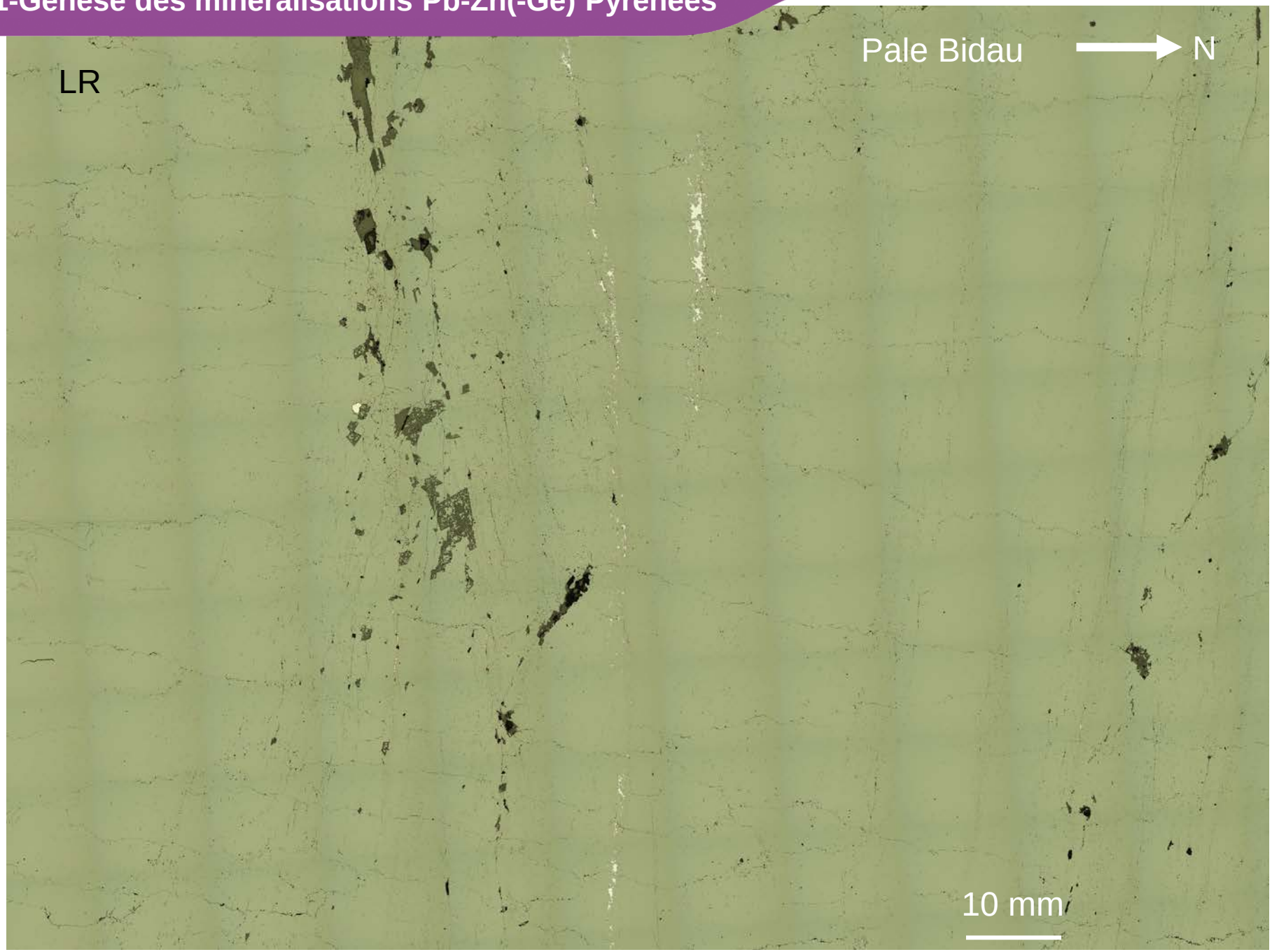
1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées



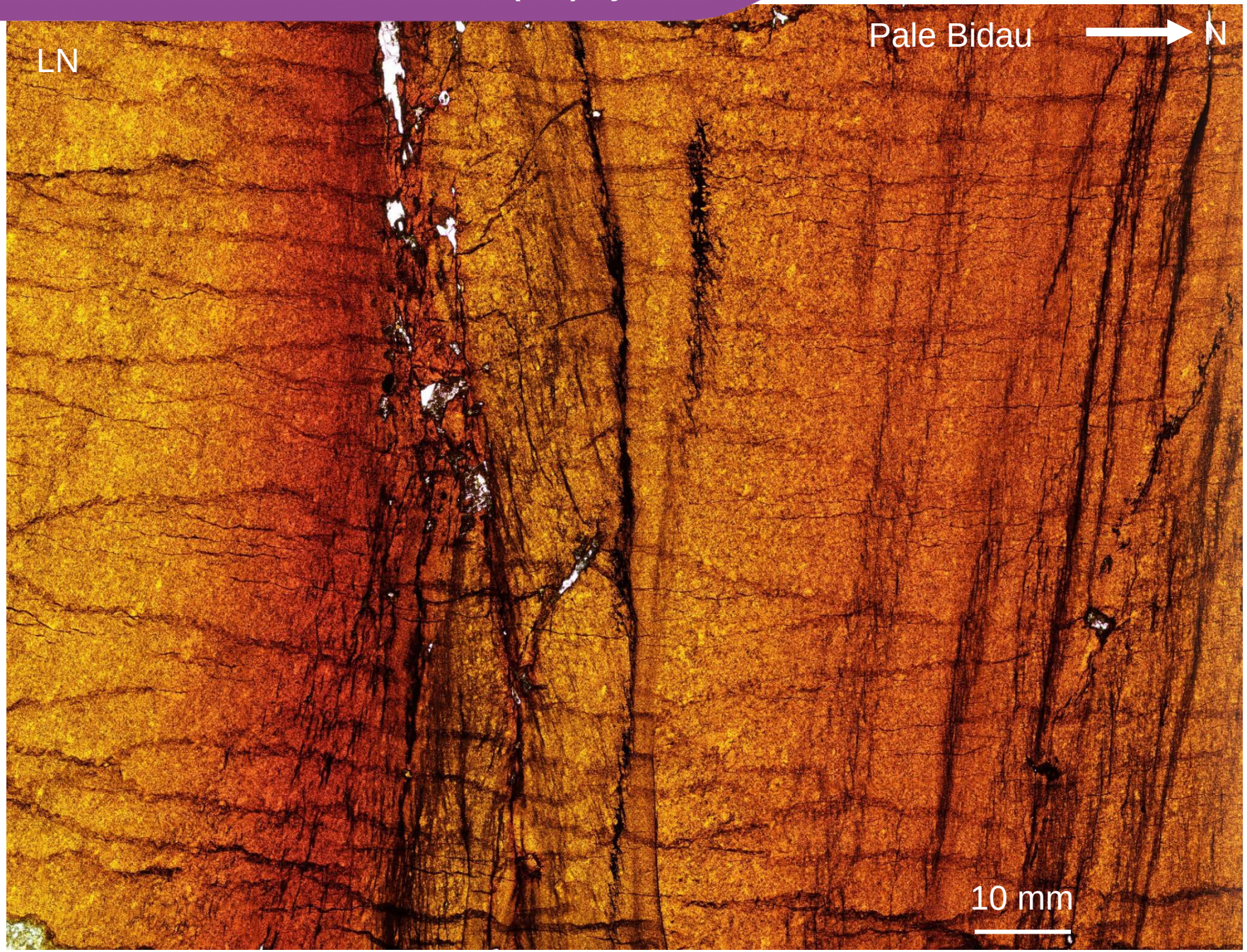

PB
S
N
S0-S1
S2
S0-S1
S2
sphalerite
calcschist
Echantillon

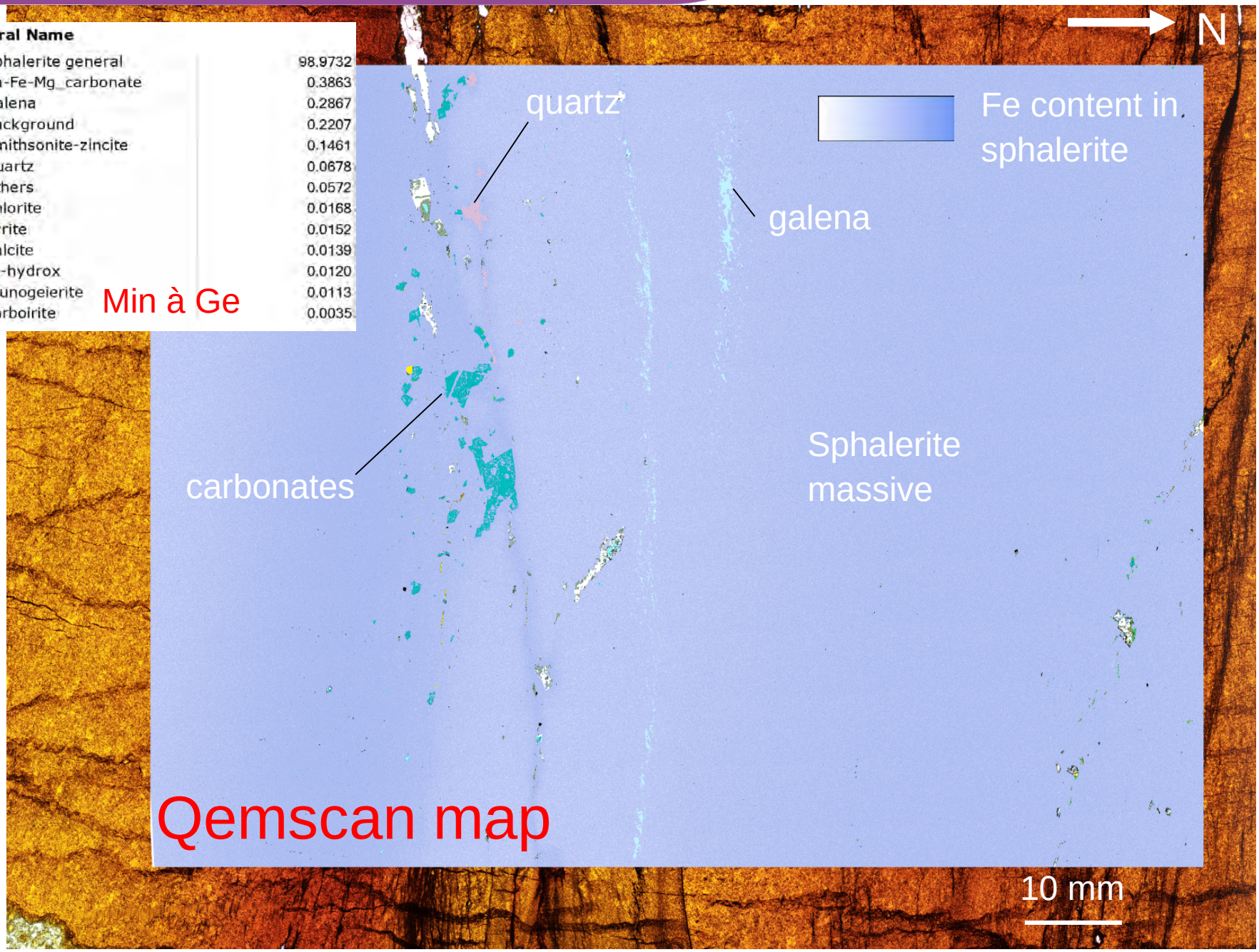
Echantillon

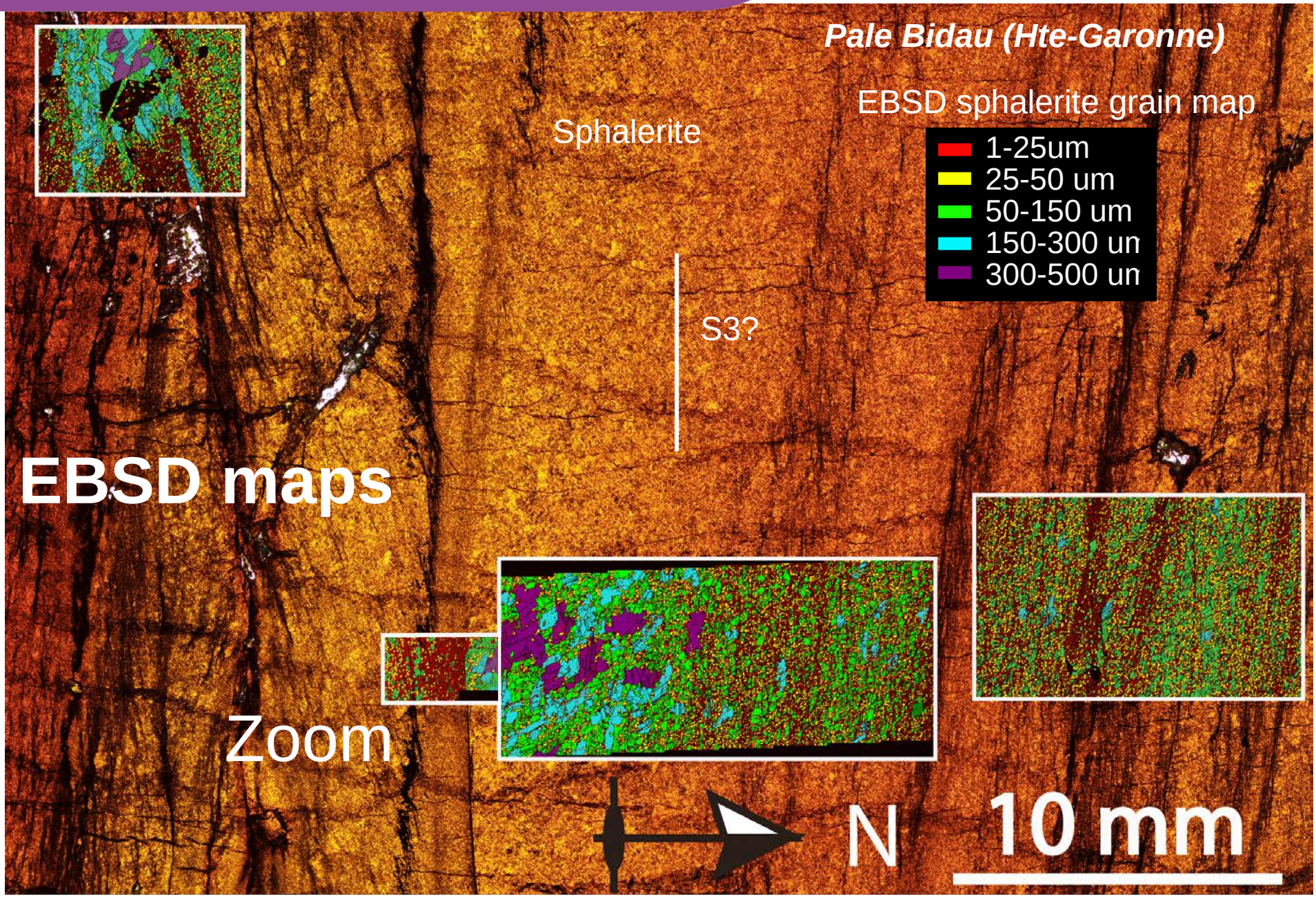



LR
Pale Bidau
N
10 mm

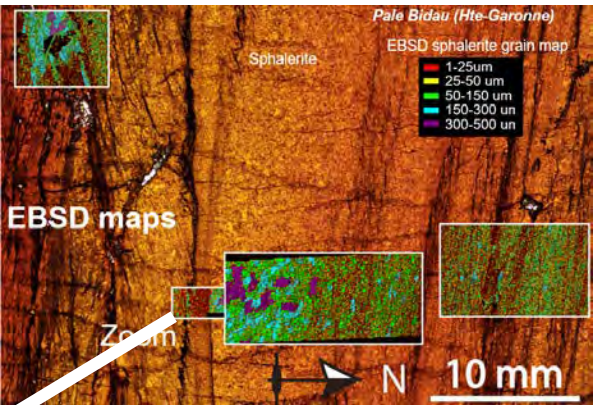
1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées




Mineral Name
Sphalerite general 98.9732
Ca-Fe-Mg_carbonate 0.3863
Galena 0.2867
Background 0.2207
Smithsonite-zincite 0.1461
Quartz 0.0678
Others 0.0572
Chlorite 0.0168
Pyrite 0.0152
Calcite 0.0139
Fe-hydrox 0.0120
Brunogeierite 0.0113
Carboirite 0.0035
Min à Ge
N
quartz
Fe content in sphalerite
galena
carbonates
Sphalerite massive
Qemscan map
10 mm


Pale Bidau (Hte-Garonne)
EBSD sphalerite grain map
1-25um
25-50 um
50-150 um
150-300 un
300-500 un
Sphalerite
S3?
EBSD maps
Zoom
N
10 mm

1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées

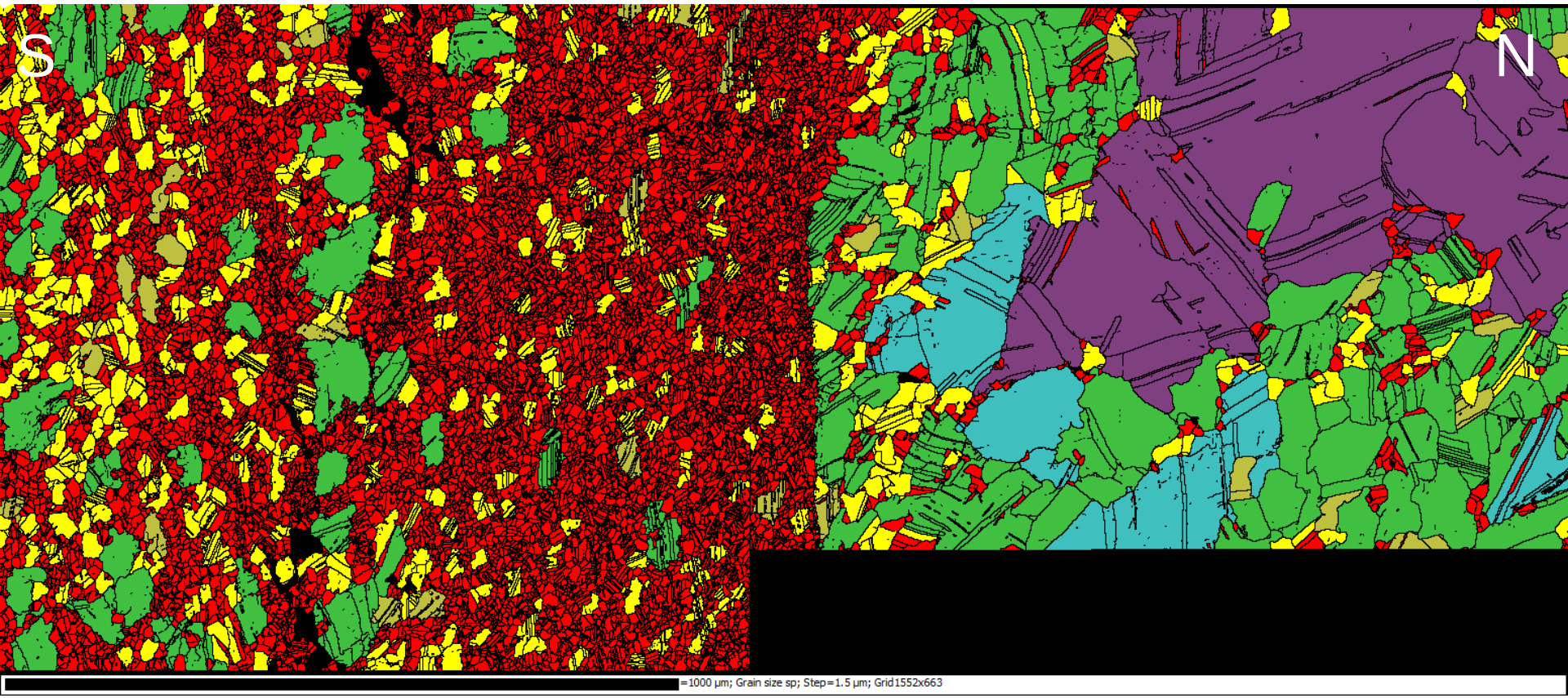


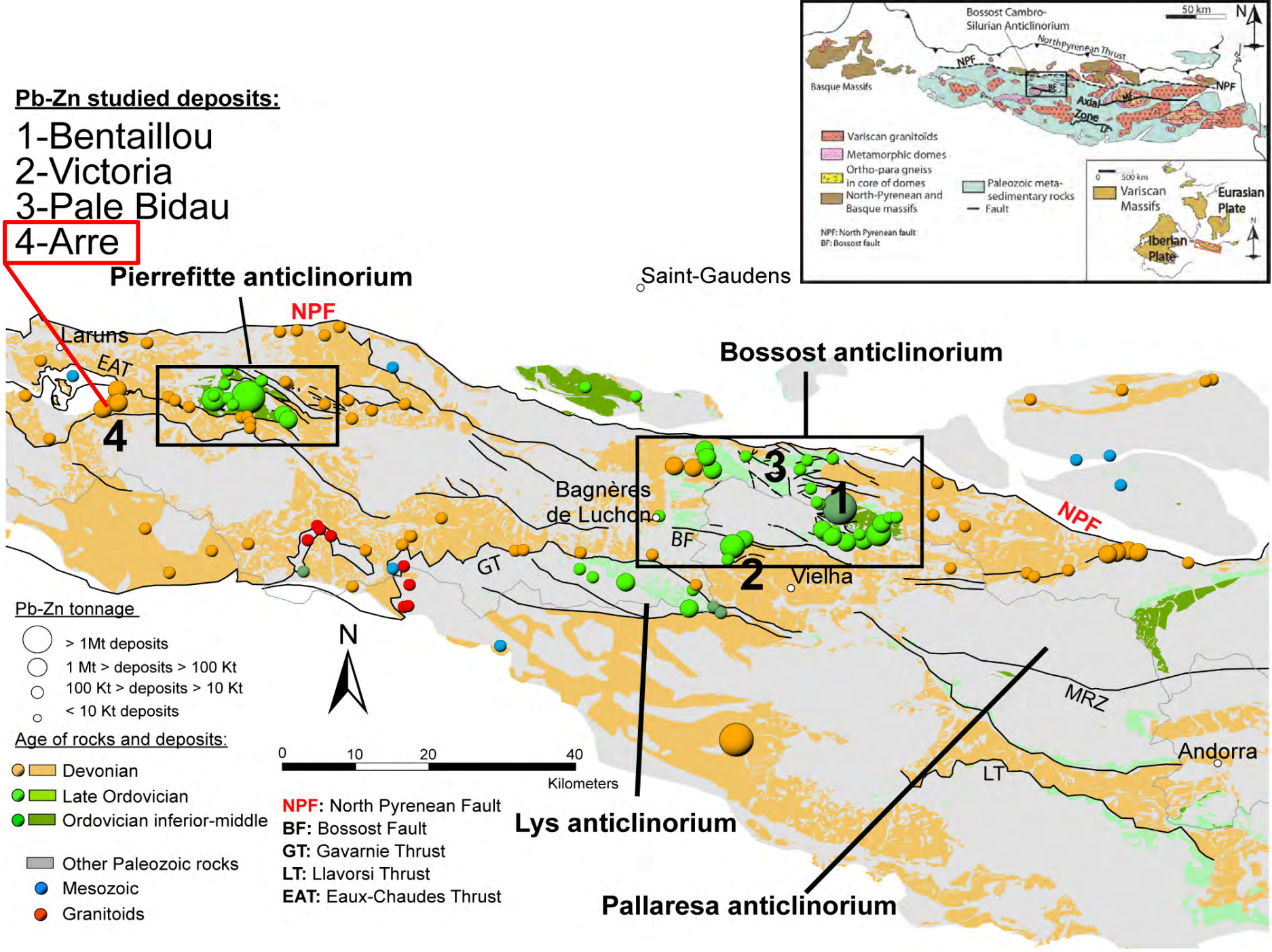
EBSD: Carte taille de grains

Pale Bidau

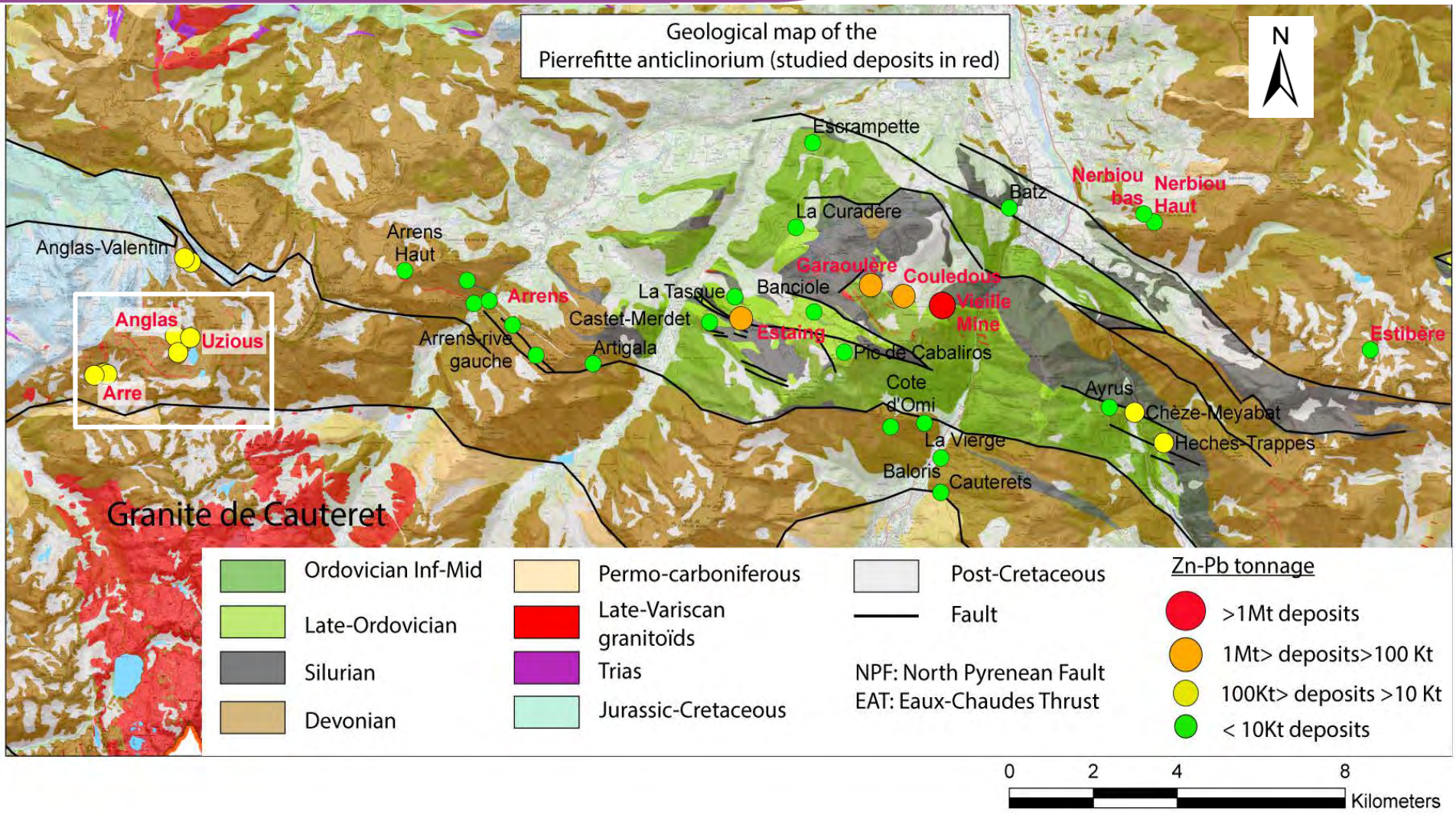
1-25um
25-50 um
50-150 um
150-300 un
300-500 un

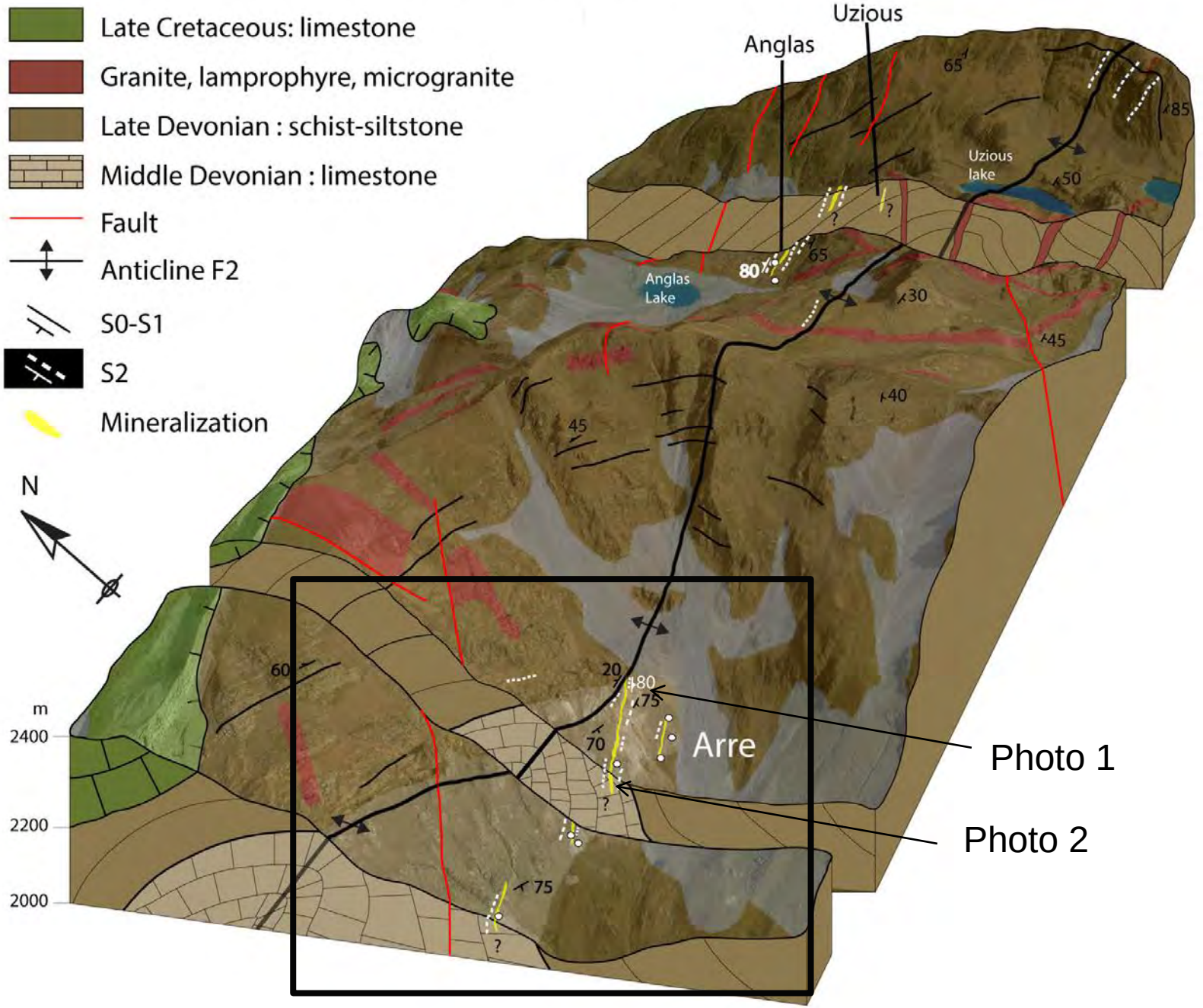
Zoom 2




Pb-Zn studied deposits:
1-Bentaillou
2-Victoria
3-Pale Bidau
4-Arre
Pierrefitte anticlinorium
Saint-Gaudens
NPF
Laruns
EAT
4
Bossost anticlinorium
3
1
Bagnères de Luchon
BF
2
Vielha
GT
NPF
MRZ
Andorra
LT
Lys anticlinorium
Pallaresa anticlinorium
Bossost Cambro-Silurian Anticlinorium
North Pyrenean Thrust
Basque Massifs
Axial Zone
Variscan granitoïds
Metamorphic domes
Ortho-para gneiss in core of domes
North-Pyrenean and Basque massifs
Paleozoic meta-sedimentary rocks
Fault
NPF: North Pyrenean fault
BF: Bossost fault
Variscan Massifs
Eurasian Plate
Iberian Plate
Pb-Zn tonnage
> 1Mt deposits
1 Mt > deposits > 100 Kt
100 Kt > deposits > 10 Kt
< 10 Kt deposits
Age of rocks and deposits:
Devonian
Late Ordovician
Ordovician inferior-middle
Other Paleozoic rocks
Mesozoic
Granitoids
N
0 10 20 40
Kilometers
NPF: North Pyrenean Fault
BF: Bossost Fault
GT: Gavarnie Thrust
LT: Llavorsi Thrust
EAT: Eaux-Chaudes Thrust

1-Genèse des minéralisations Pb-Zn(-Ge) Pyrénées




Structural map and cross-section of Arre-Anglas area
Late Cretaceous: limestone
Granite, lamprophyre, microgranite
Late Devonian : schist-siltstone
Middle Devonian : limestone
Fault
Anticline F2
S0-S1
S2
Mineralization
N
m
2400
2200
2000
Anglas
Uzious
Uzious lake
Anglas Lake
Arre
Photo 1
Photo 2

Filon d’Arre

Filon Arre 1

Photo 1

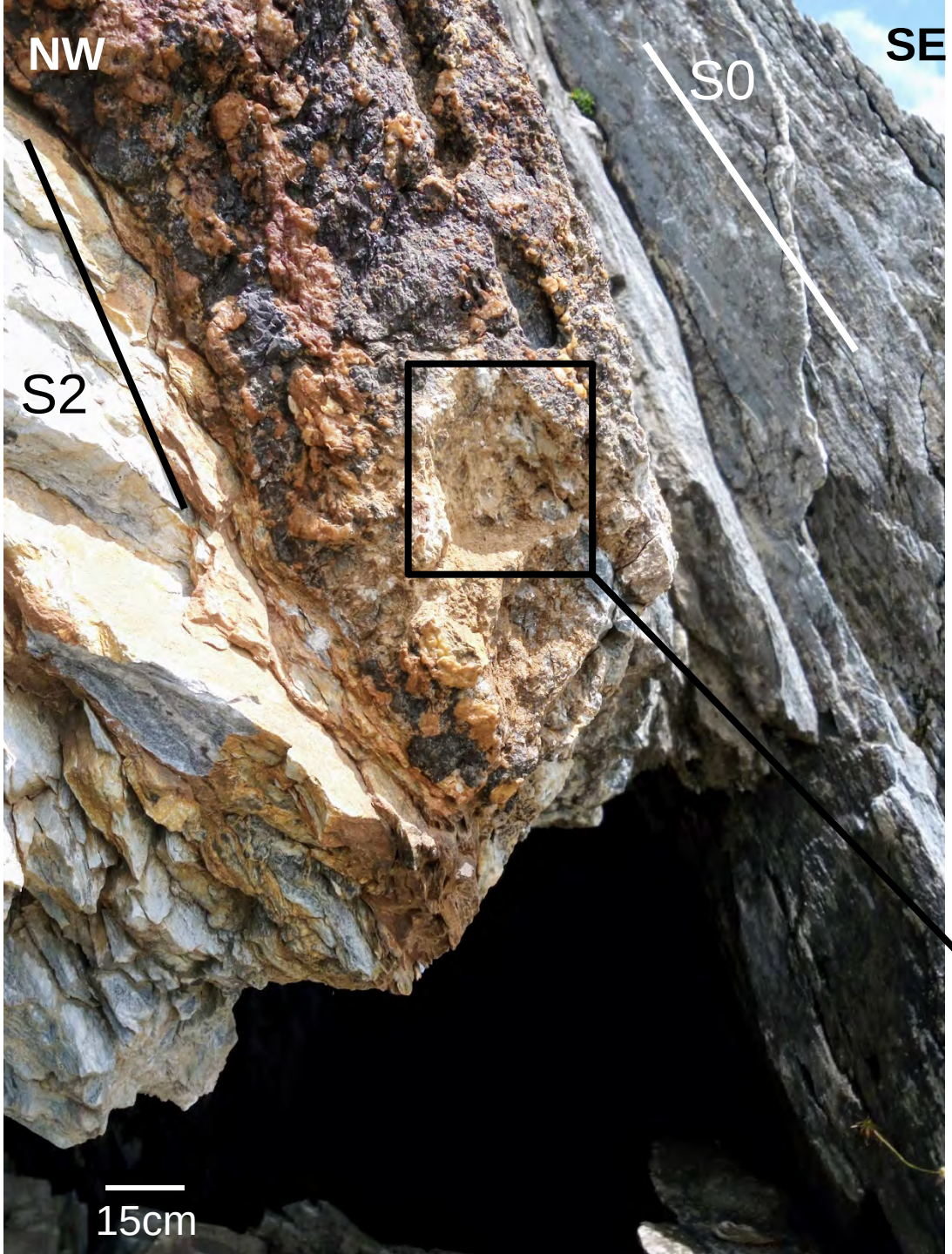
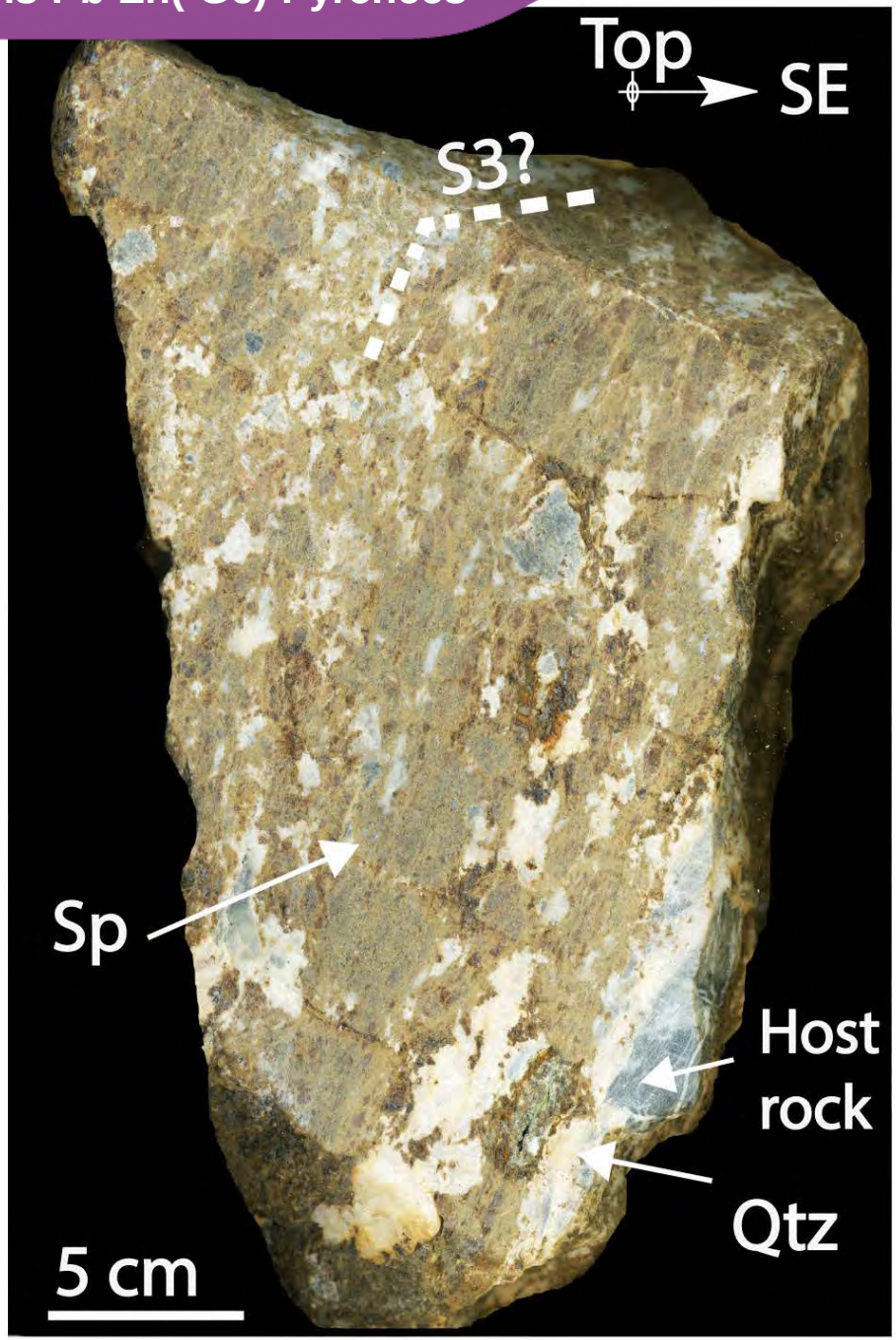
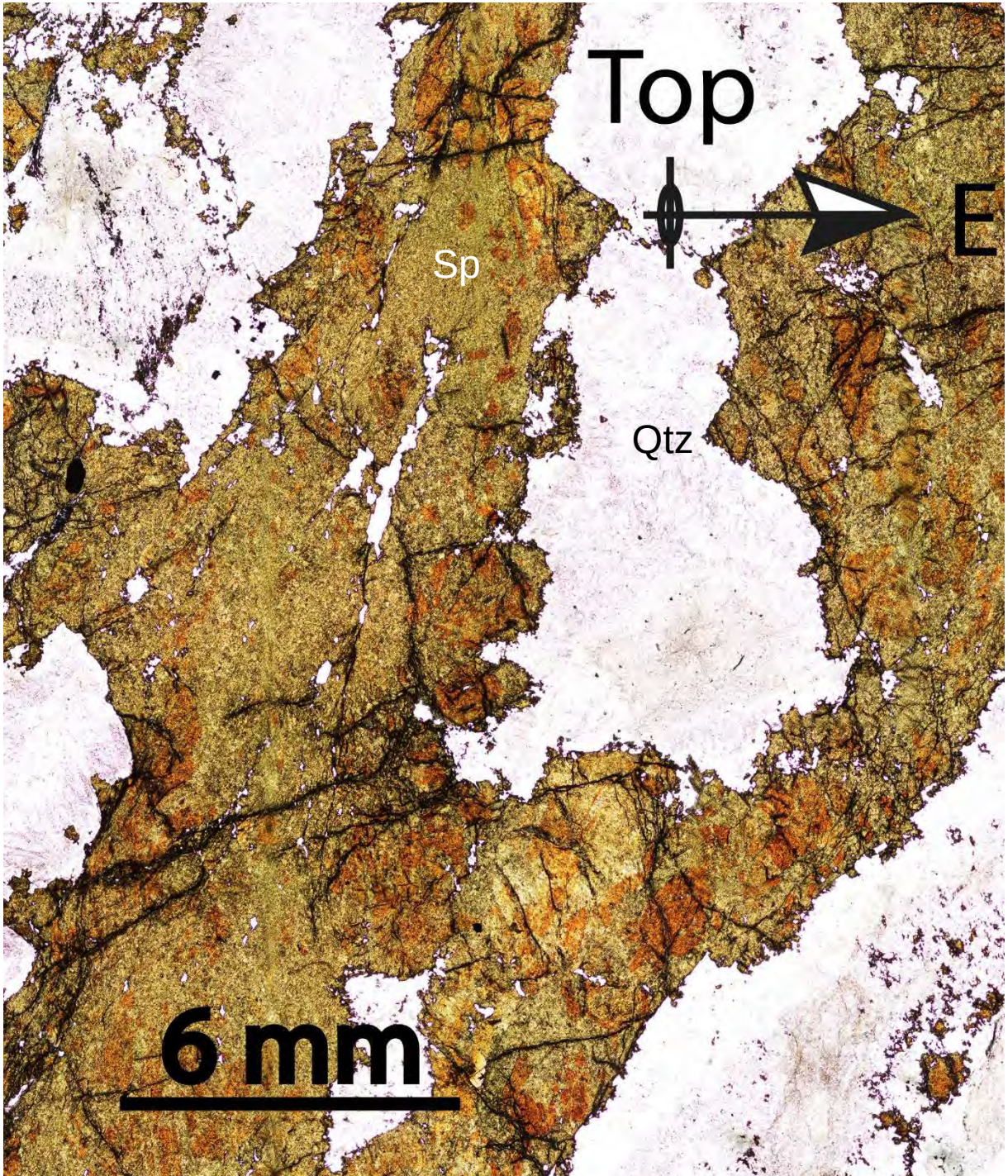


Photo 2

Minéralisation dans filon N040

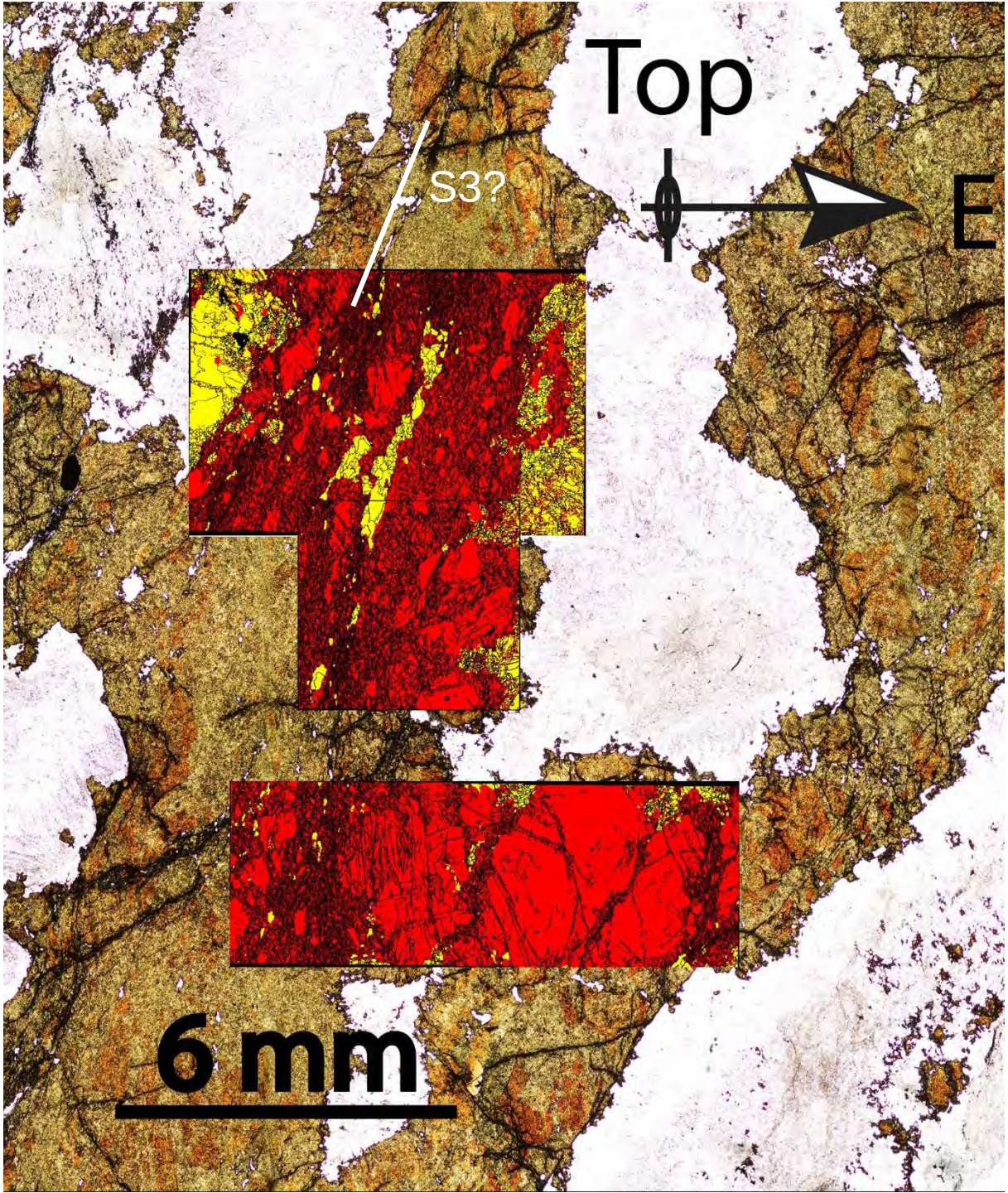
Echantillon


Top
SE
S3?
Sp
Host
rock
Qtz
5 cm


Top
E
Sp
Qtz
6 mm

Phase+

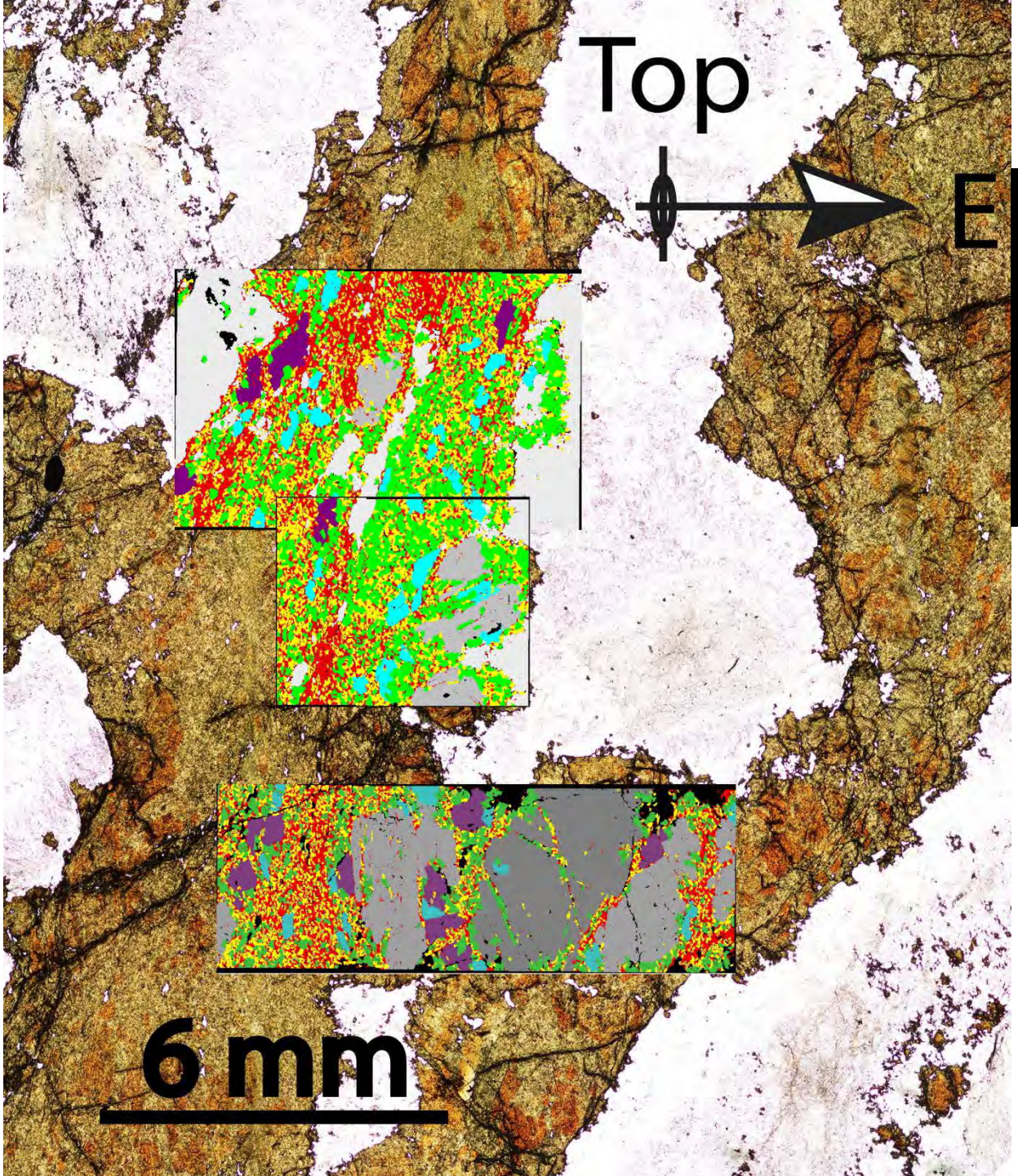
Limite de grains



Zoom

Sphalerite

Quartz



Taille de grains

- 1-25um
- 25-50 um
- 50-150 um
- 150-300 um
- 300-500 um
- 500-1500 um
- >1500 um

1 – Genèse des minéralisations Pb-Zn-(Ge) dans la Zone axiale des Pyrénées?

La minéralisation principale exploitée s'est mise en place au Varisque

→Probable remobilisation/reconcentration de niveaux à sulfures du Cambro-Ordovicien-Sup?

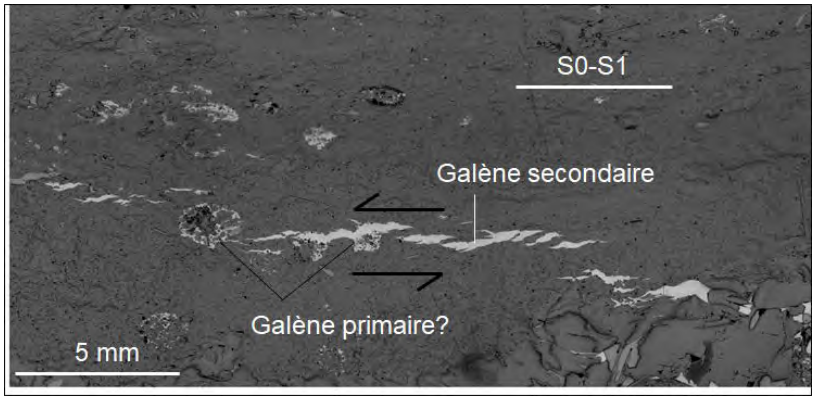
Les principales minéralisations se présentent dans des pièges structuraux:

Bentaillou: contact lithologique-pli couché F1

Victoria: charnières de pli F2

Pale Bidau: zone de faiblesse (S2↗)

Arre: extrados de pli F2



Deux sous-types de minéralisations épigénétiques Varisques:

Type1 (Bentaillou-Victoria)

→Post-metamorphique, syn-post S1 mais anté S2

Type 2 (Pale Bidau-Arre)

→ Post (ou syn) S2

2 –Mécanisme concentrations du Ge?

Dans quels gites Pb-Zn se concentrent les minéraux à Ge?

	Zone	Encaissant			Minéralisation
		age	Roche	Metamorphisme	
Bentaillou	Bossost	Cambro-Ordovicien	Marbres-schistes	Peu métamorphique	//S0-S1
Victoria		Cambro-Ordovicien Sup	schistes	Métamorphique	//S0-S1
Pale Bidau		Ordovicien Sup	calcschistes	Peu métamorphique	//S2
Arre	Pierrefitte	Dévonien	calcaire	Peu métamorphique	//S2

2 –Mécanisme concentrations du Ge?

Sphalerite

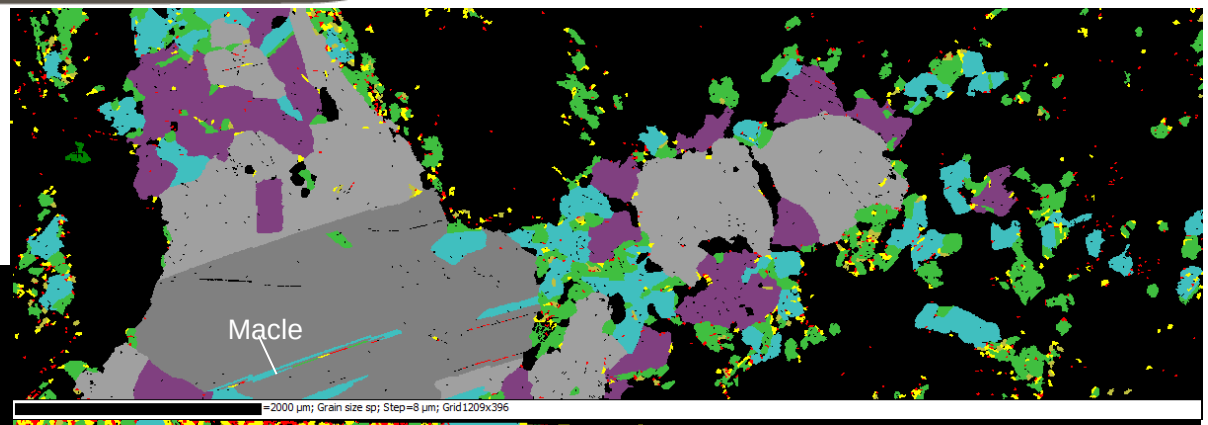
Bentaillou

Même texture pour Victoria

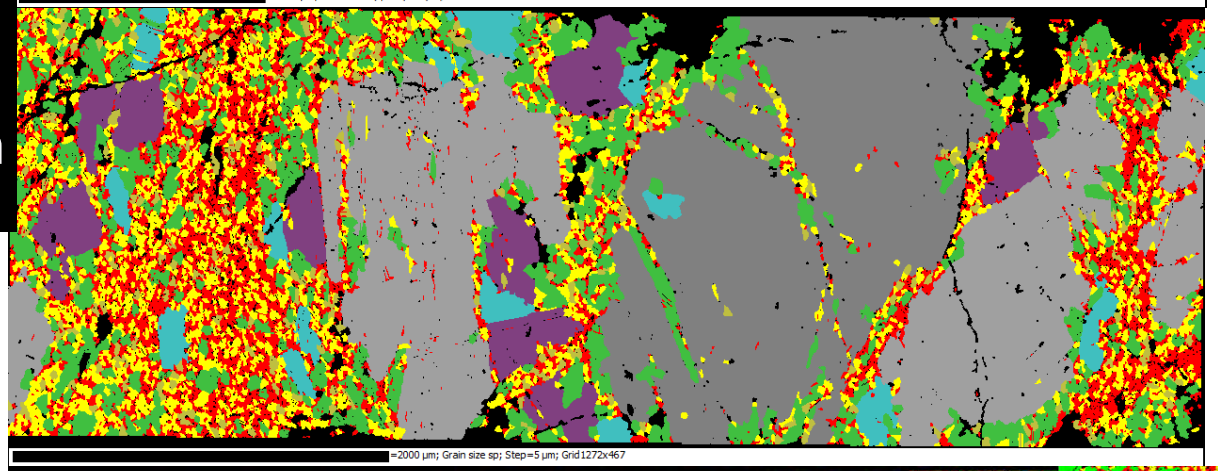
EBSD:

taille de grains

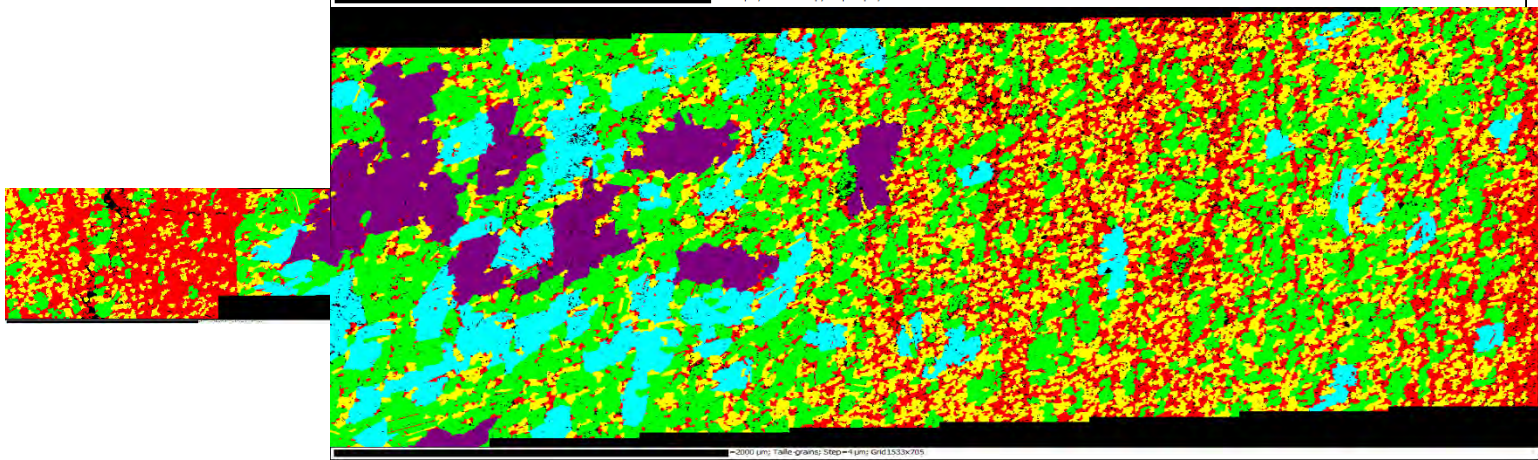
1-25um
25-50 um
50-150 um
150-300 um
300-500 um
500-1500 um
>1500 um



Arre



Pale-Bidau



2 –Mécanisme concentrations du Ge?

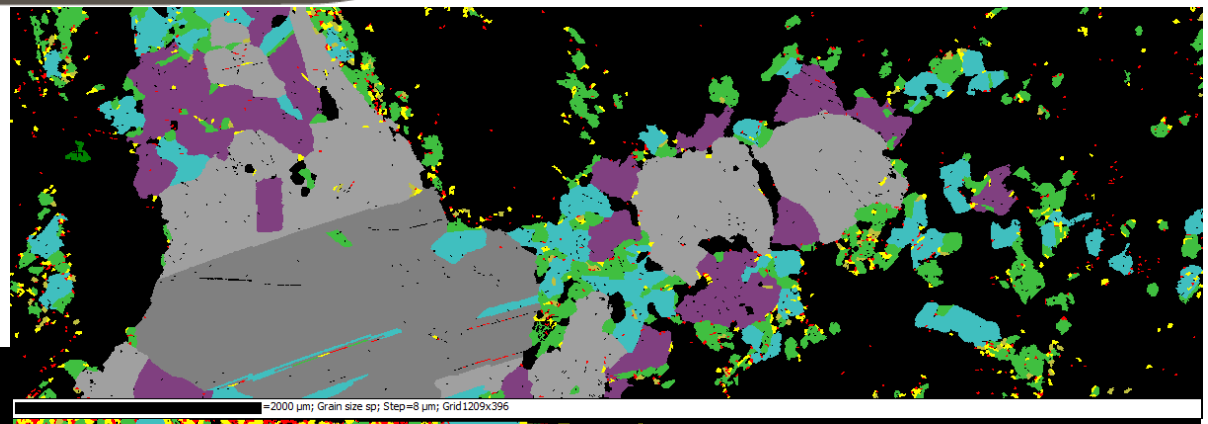
Sphalerite

Bentaillou

Même texture pour Victoria

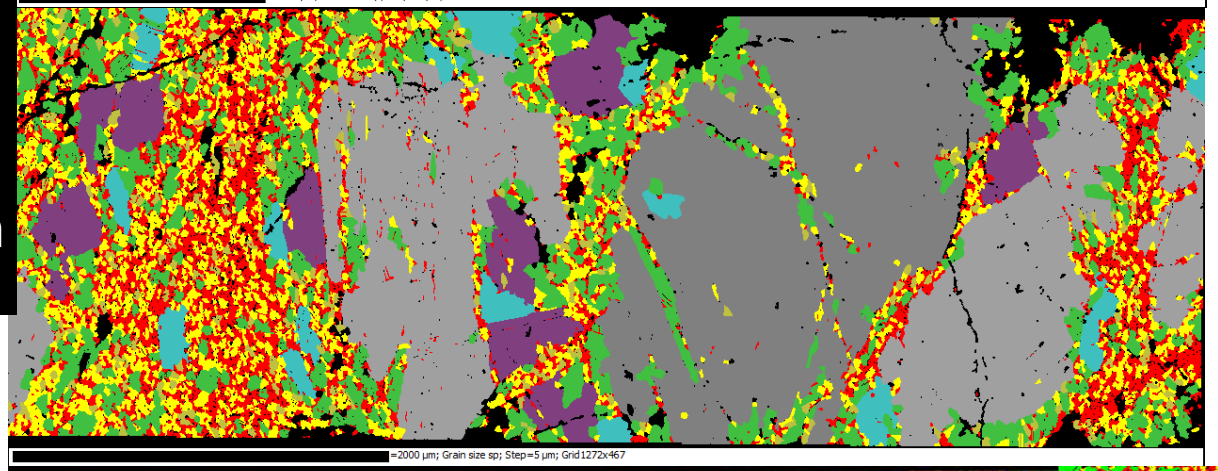
Pas de Ge

1-25um
25-50 um
50-150 um
150-300 um
300-500 um
500-1500 um
>1500 um



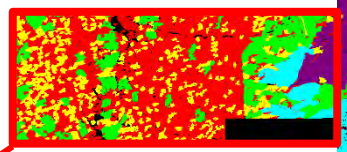
Arre

Minéraux à Ge

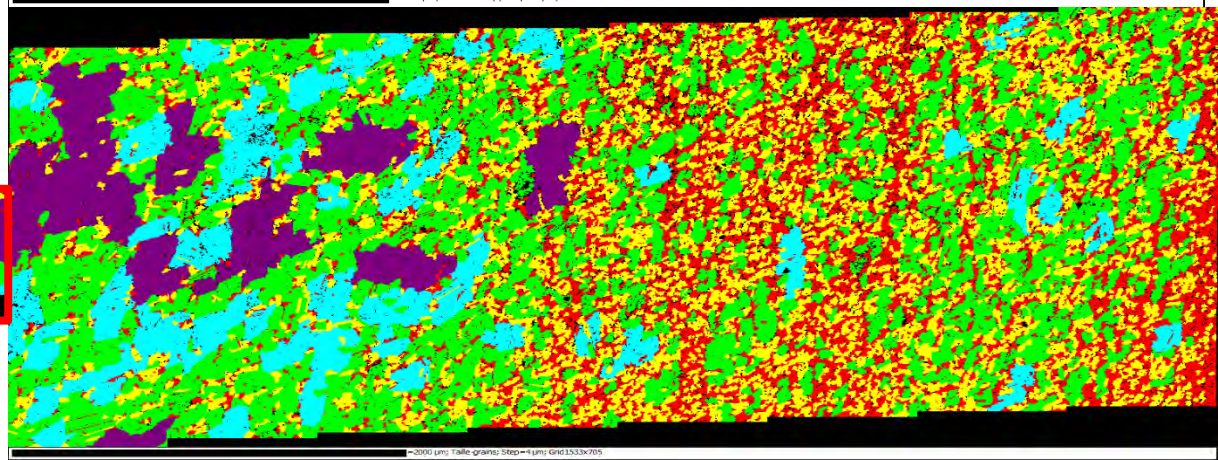


Minéraux à Ge

Pale-Bidau

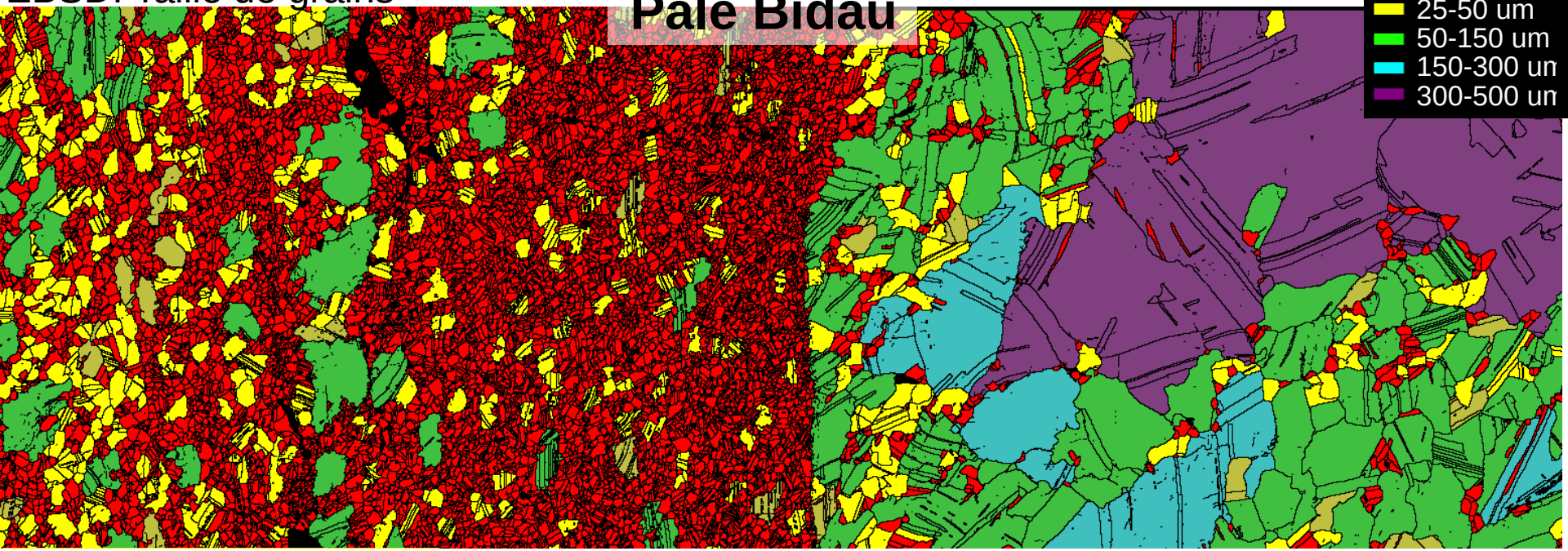


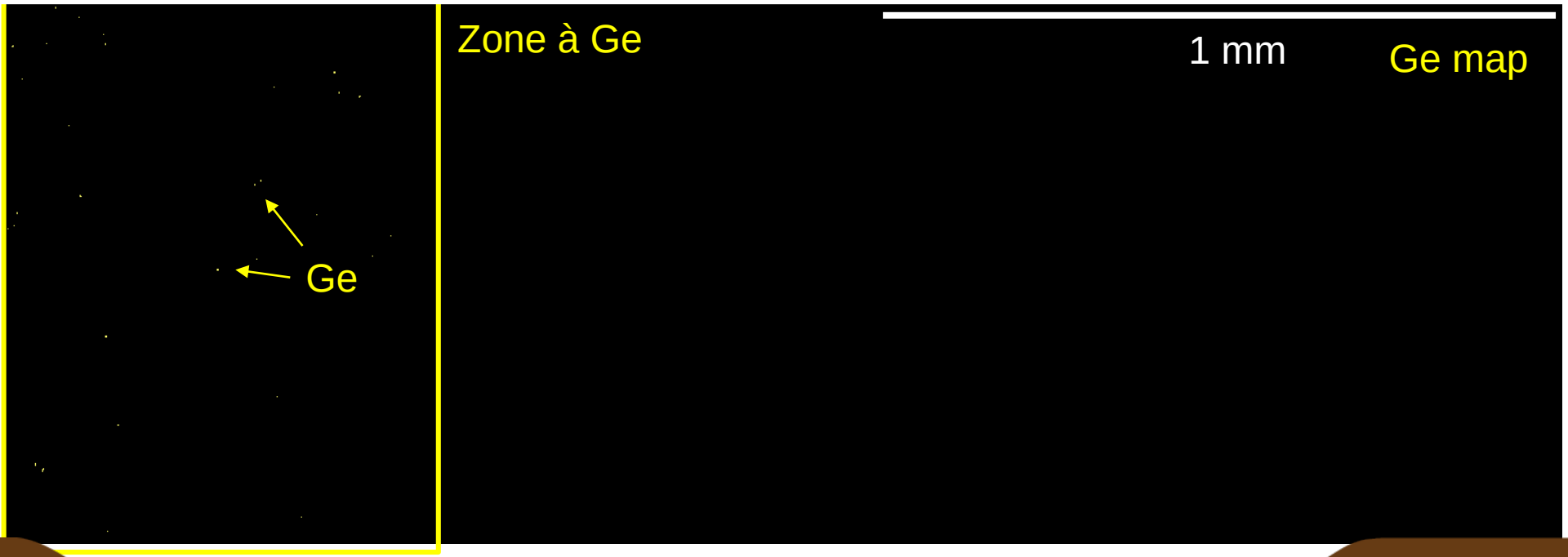
Zoom



EBSD: Taille de grains

Pale Bidau

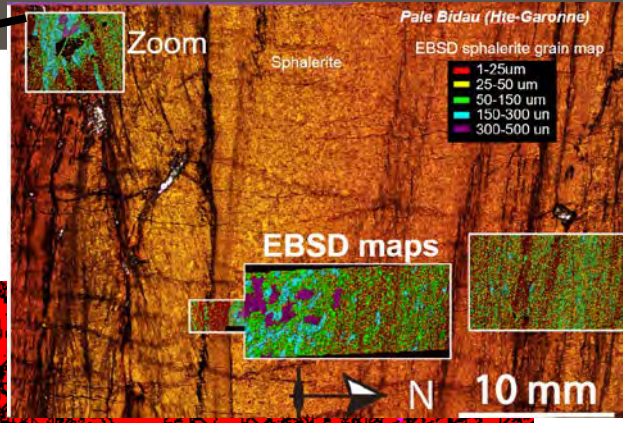




2 –Mécanisme concentrations du Ge?

Zoom

Pale Bidau



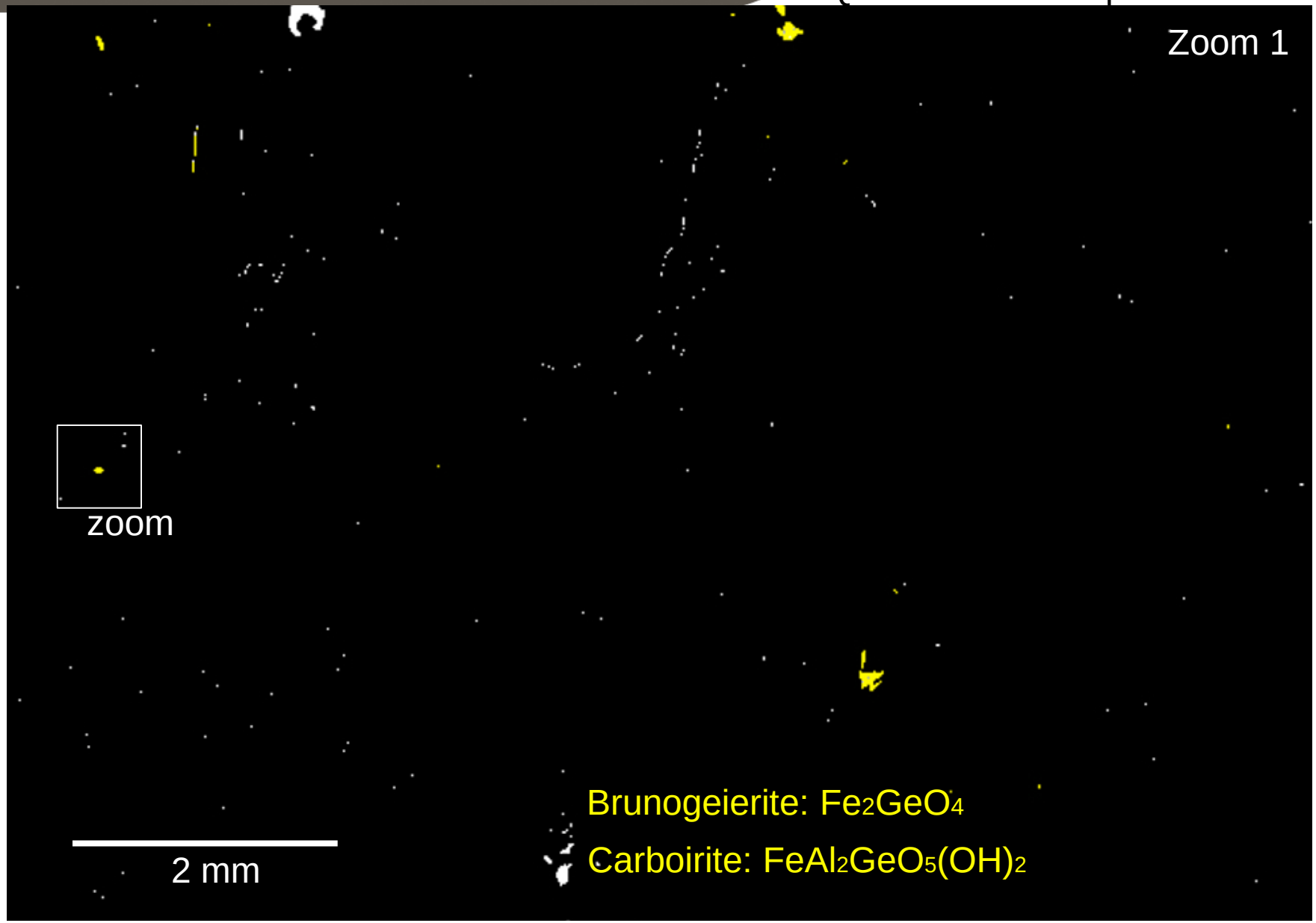
Sphalerite
Pyrite
Calcite
Quartz
Dolomite
Galena

500 um

EBSD: Phase map + grain boundaries

2 –Mécanisme concentrations du Ge?

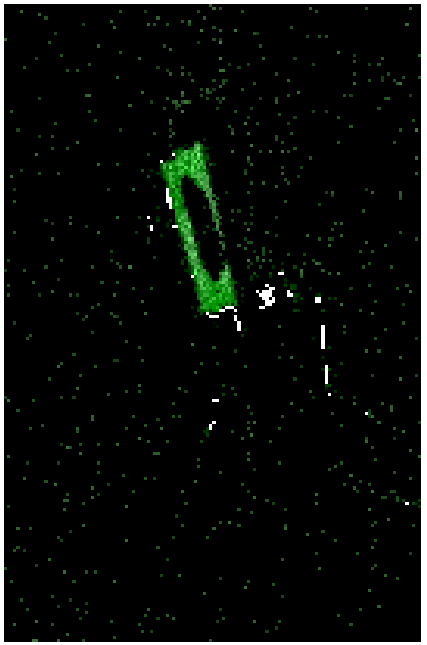
Qemscan : chimique Ge

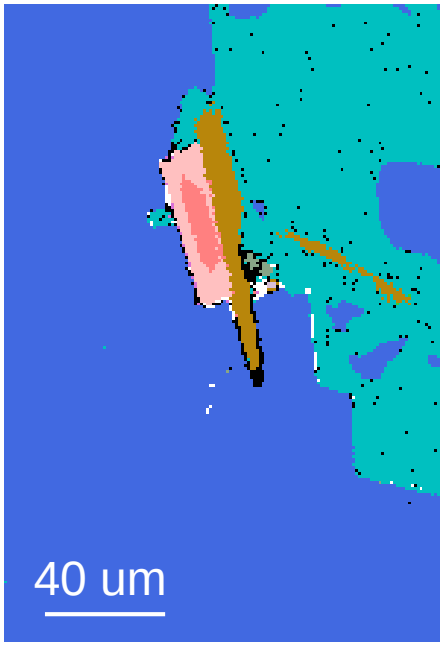


2 –Mécanisme concentrations du Ge?

Analyse QEMSCAN de la carboirite

Qemscan map: concentrations qualitatives





Ge map

\+

Al Map

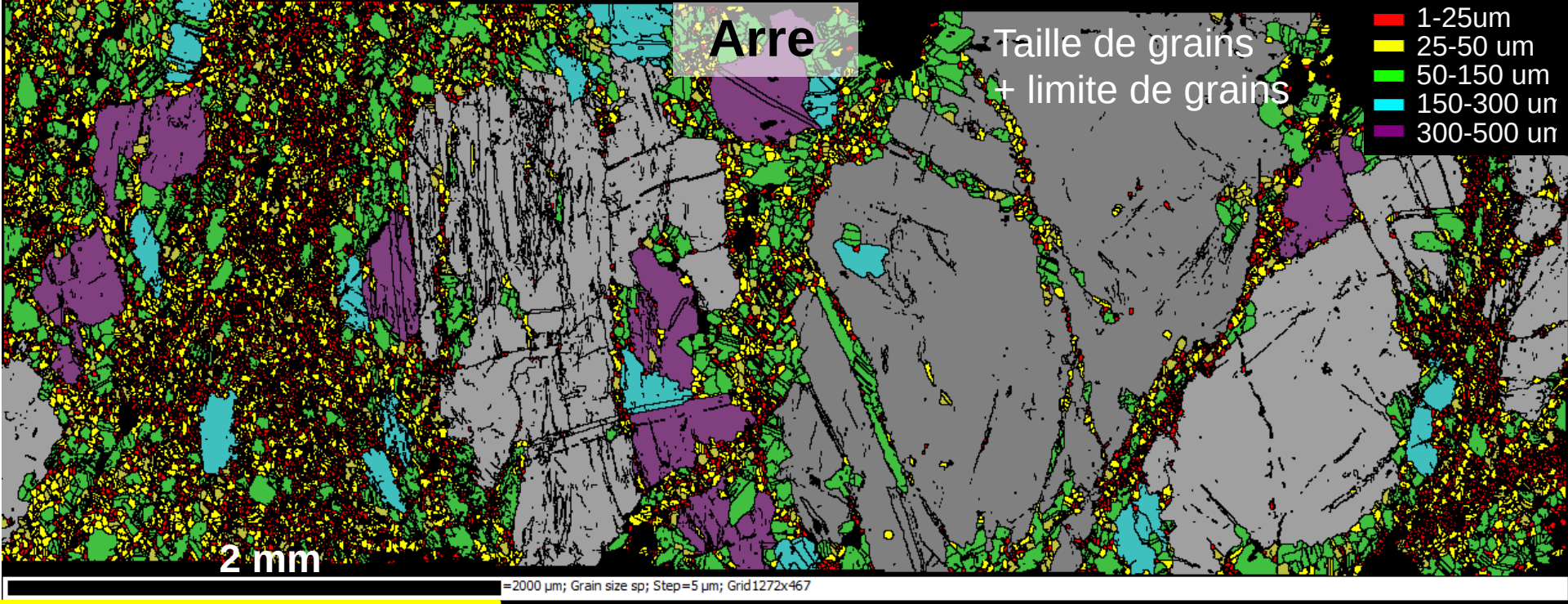
\+

Cl map

\+

- Ge-micas noirs-lépidomélane?
- Carboirite
- Muscovite
- Sphalerite
- Calcite

Carboirite: $FeAl_2GeO_5(OH)_2$


Arre
Taille de grains
+ limite de grains
1-25um
25-50 um
50-150 um
150-300 un
300-500 un
2 mm
=2000 µm; Grain size sp; Step=5 µm; Grid1272x467


Zone à Ge
Ge map
Ge

2 –Mécanisme concentrations du Ge?

Type1 (Bentaillou-Victoria)

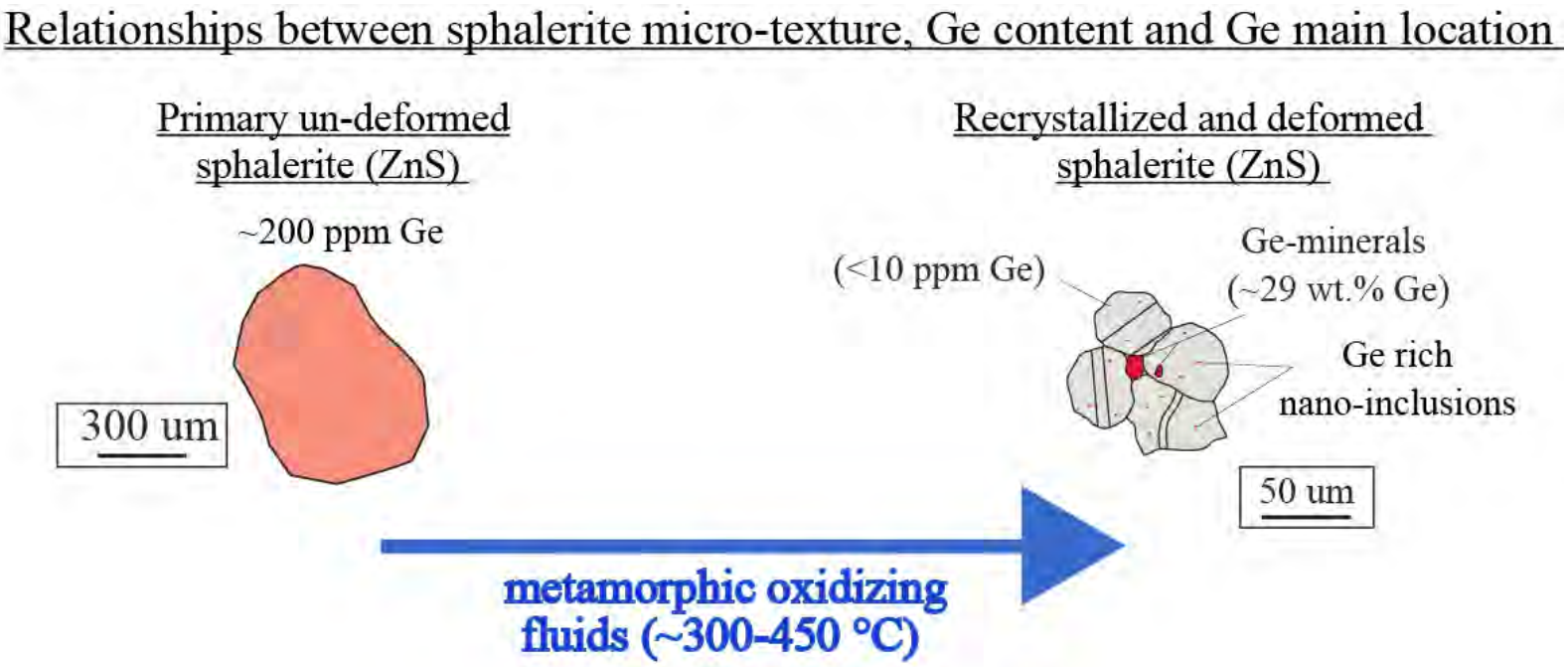
→Post-métamorphique et anté S2

→**Pas de minéraux à Ge**.

Type 2 (Pale Bidau-Arre)

→ Post (ou syn) S2

→ **Minéraux à Ge** (dans les zones déformées-recristallisées de la sphalérite)



Cugerone et al., 2018

Conclusion

Type1 (Bentaillou-Victoria)

→Post-métamorphique et anté S2

→**Pas de minéraux à Ge**.

Type 2 (Pale Bidau-Arre)

→ Post (ou syn) S2

→ **Minéraux à Ge** (dans les zones déformées-recristallisées de la sphalérite)

Perspectives 2eme-3eme années

Deux types de fluides différents ?

→Inclusions fluides (quartz et sphalerite)

Chimie des sphalérites des deux types – Grains reliques/recristallisés

→Analyse LA-ICPMS des concentrations en éléments traces dans la sphalerite (couplé EBSD) et dans les minéraux à Ge.

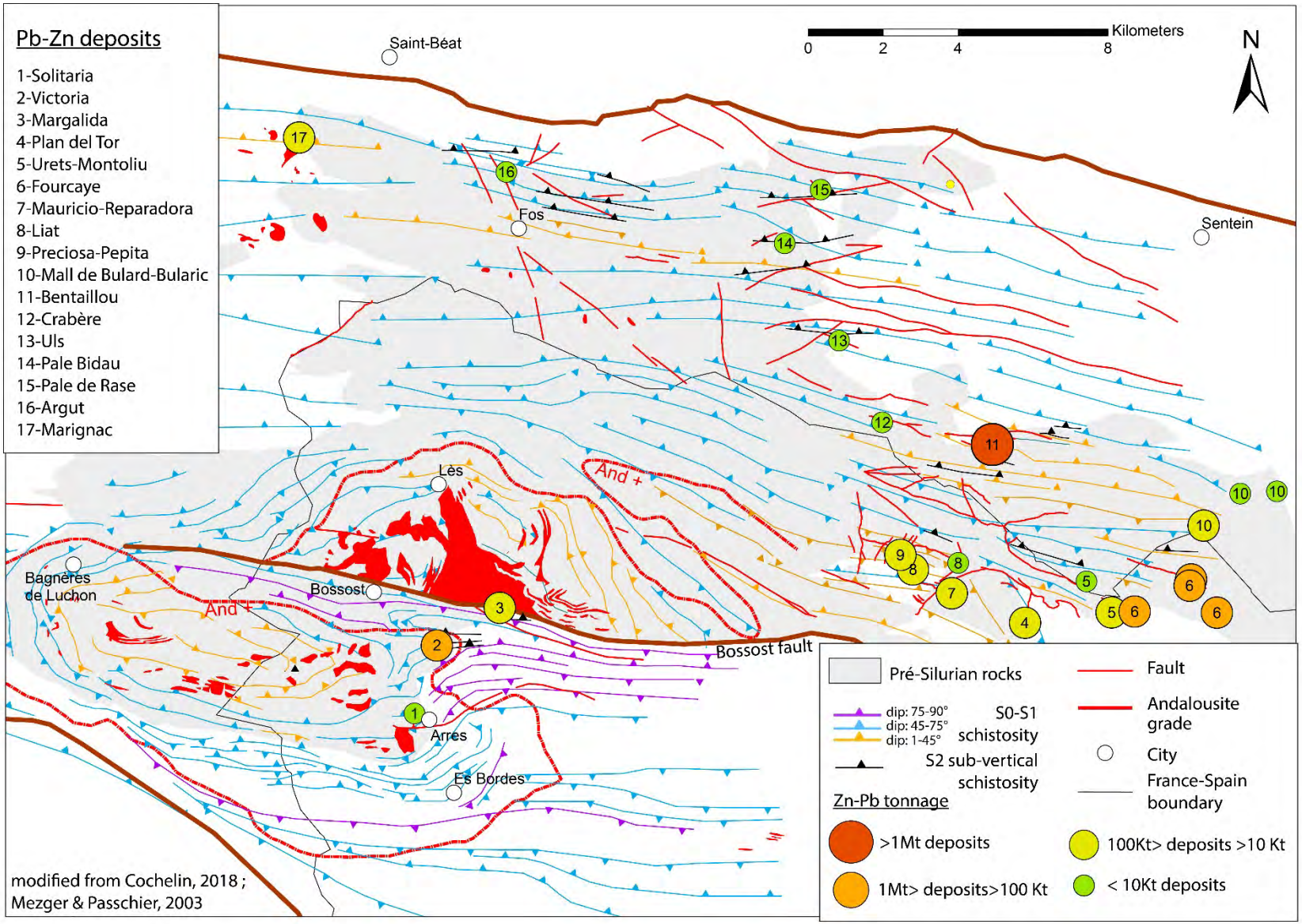
Merci

Mine de Bentaillou, Ariège

Photo:

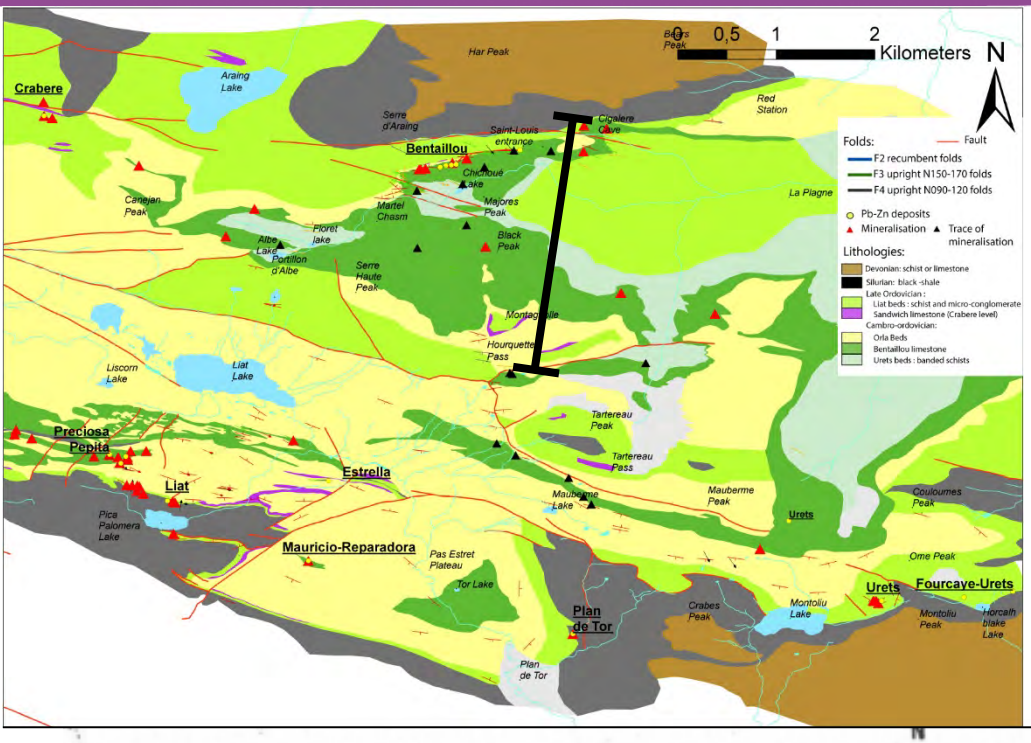
ARSHAL, Lafage B.

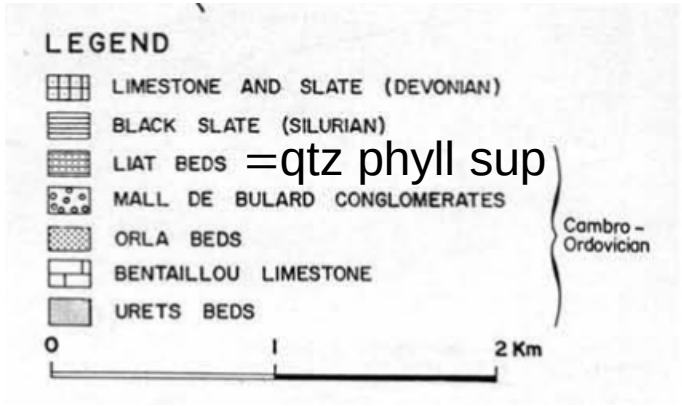
Pb-Zn-(Ge) des Pyrénées



Bossost anticlinorium

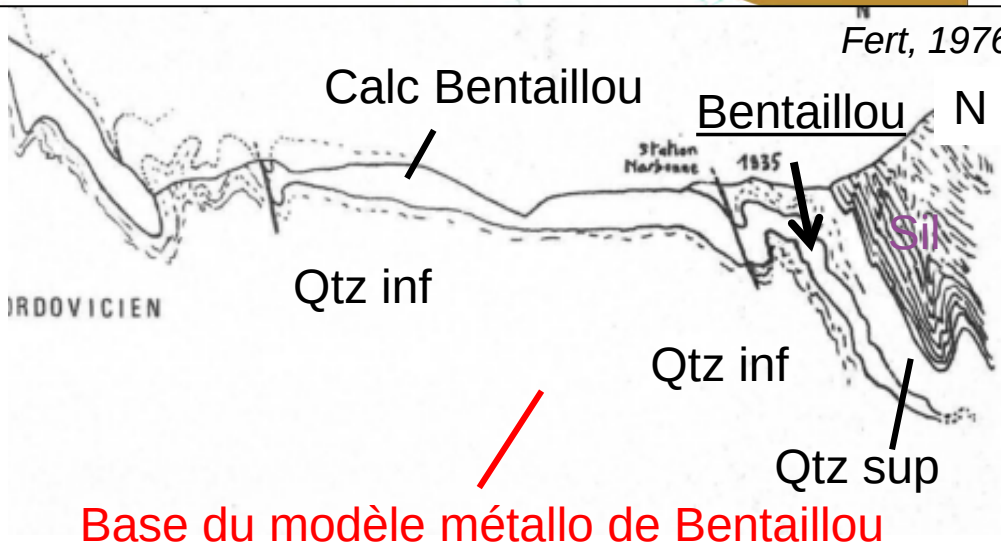
Pb-Zn-(Ge) des Pyrénées



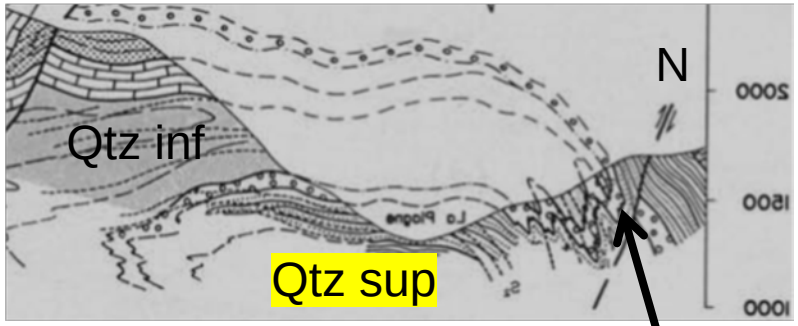


Garcia-Sansegundo, 1989

Fert, 1976

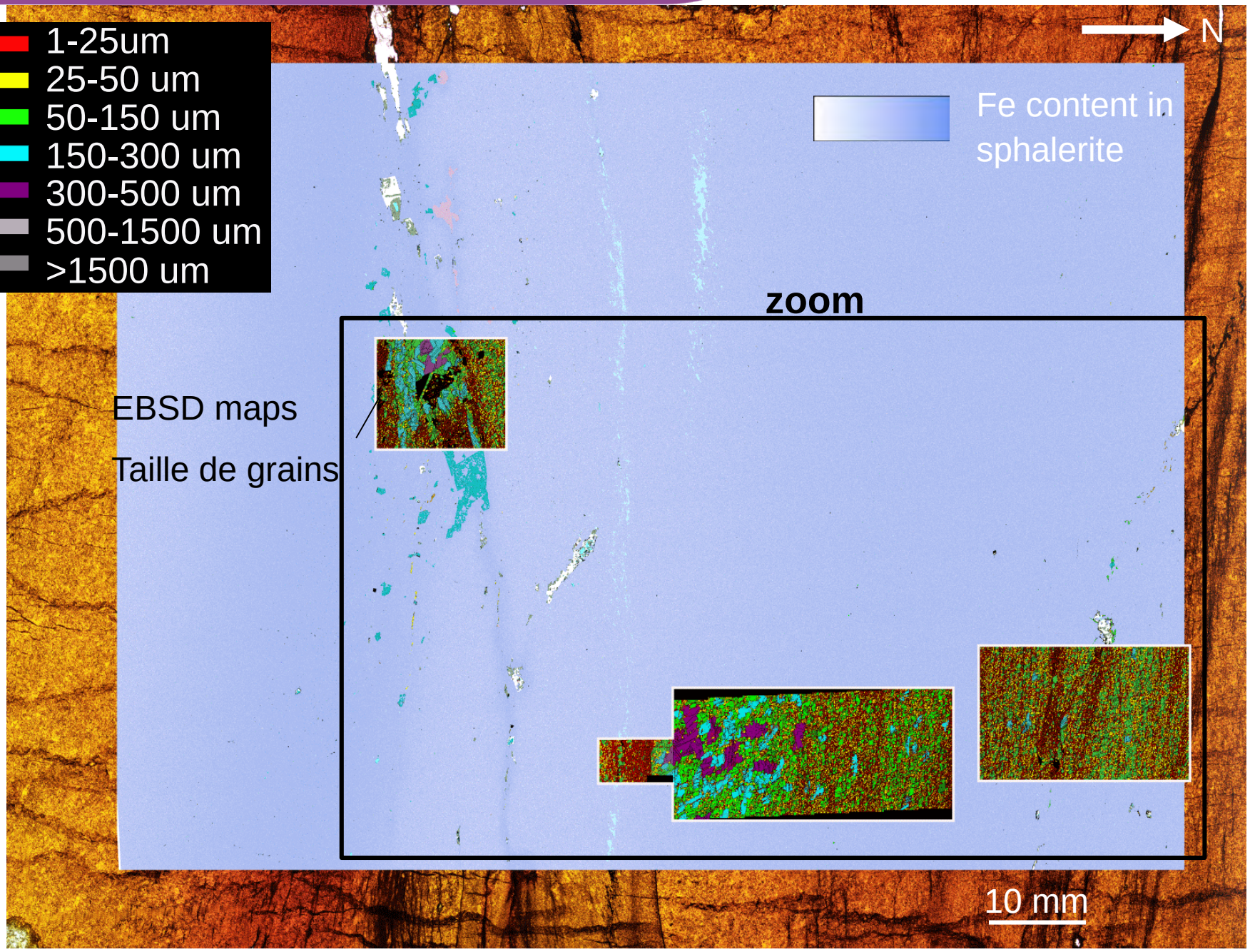


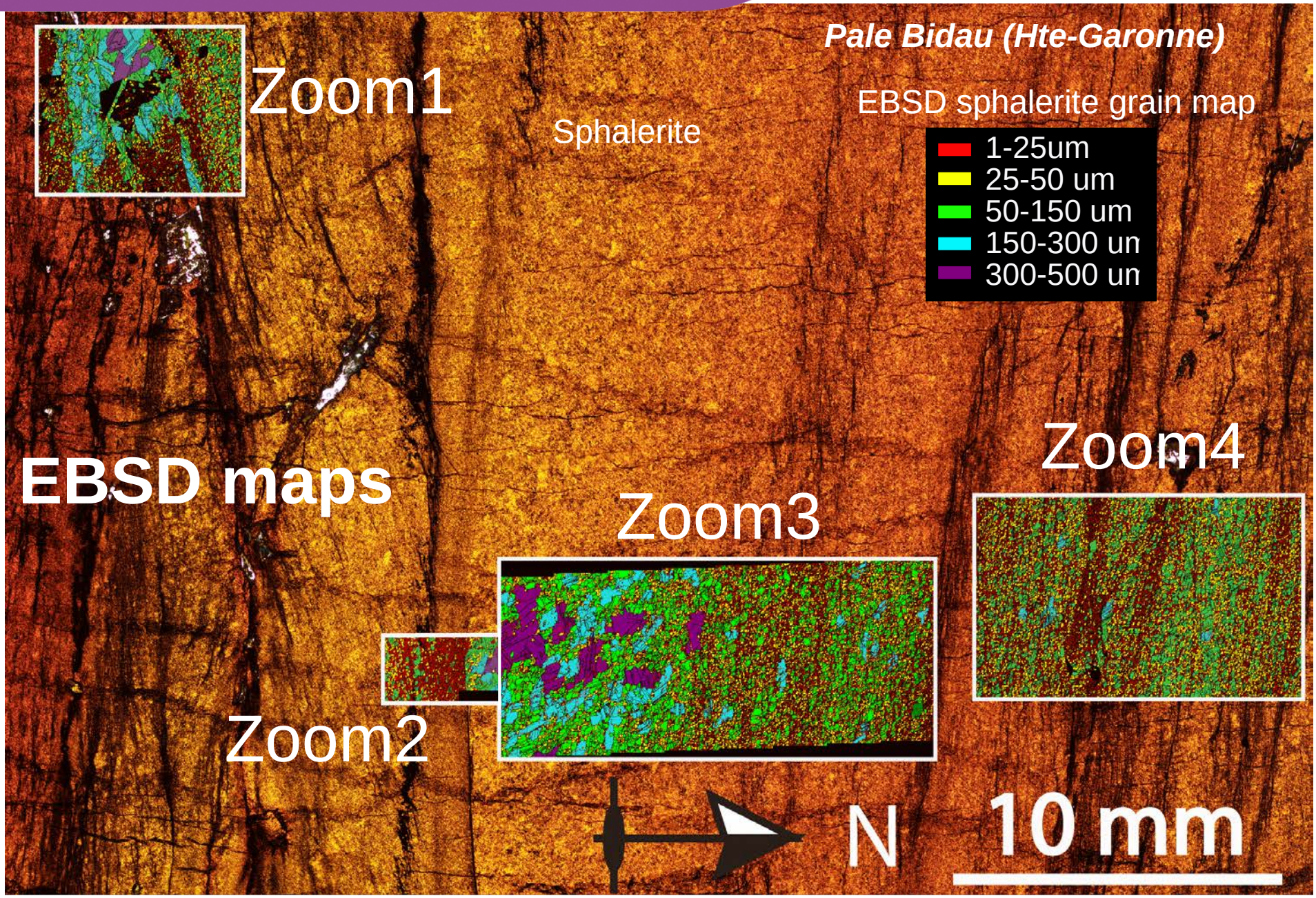
Base du modèle métallo de Bentaillou

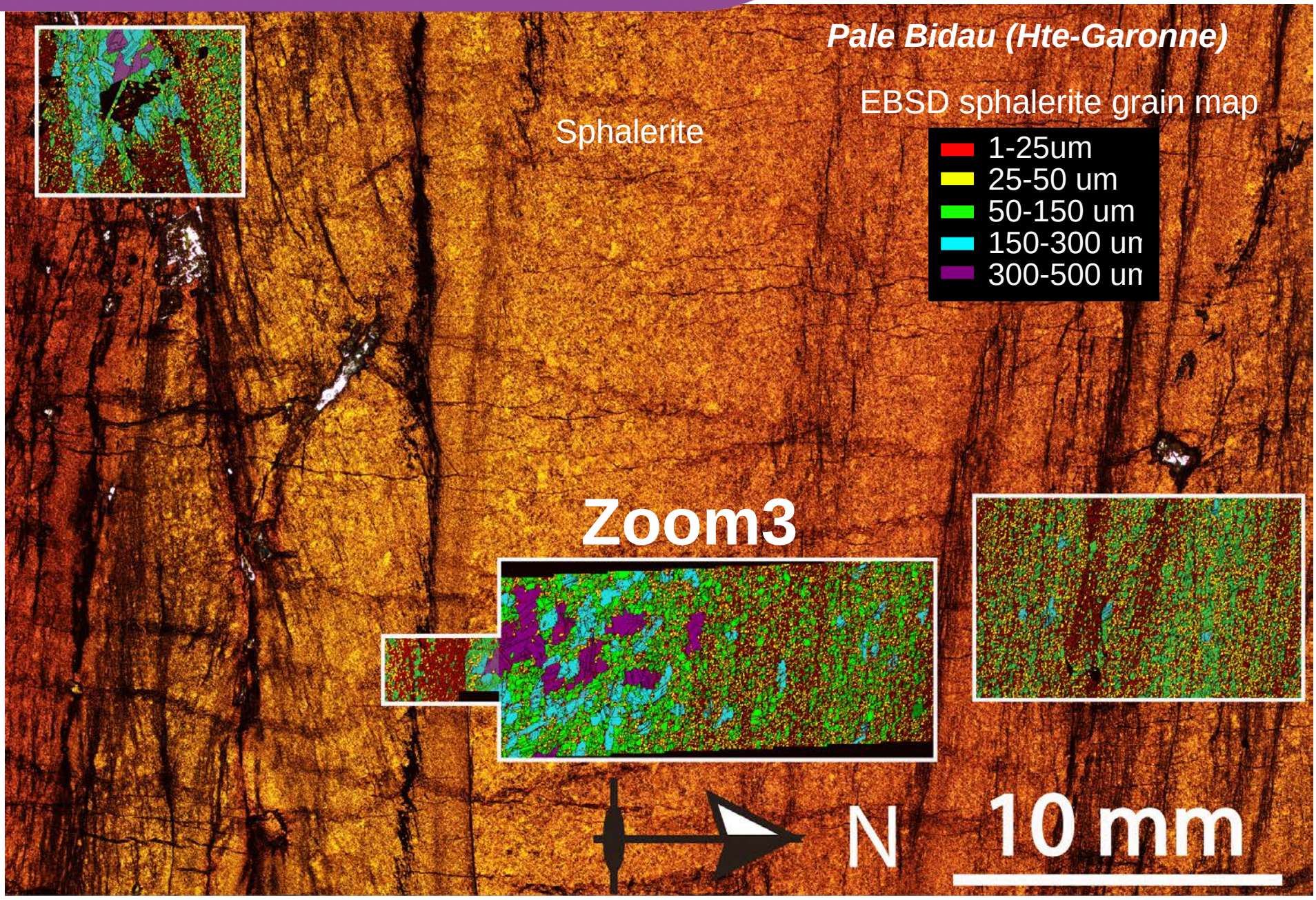


Qtz phyll sup et non
Qtz phyll inf dans cette
coupe →plis couchés km

Bentaillou

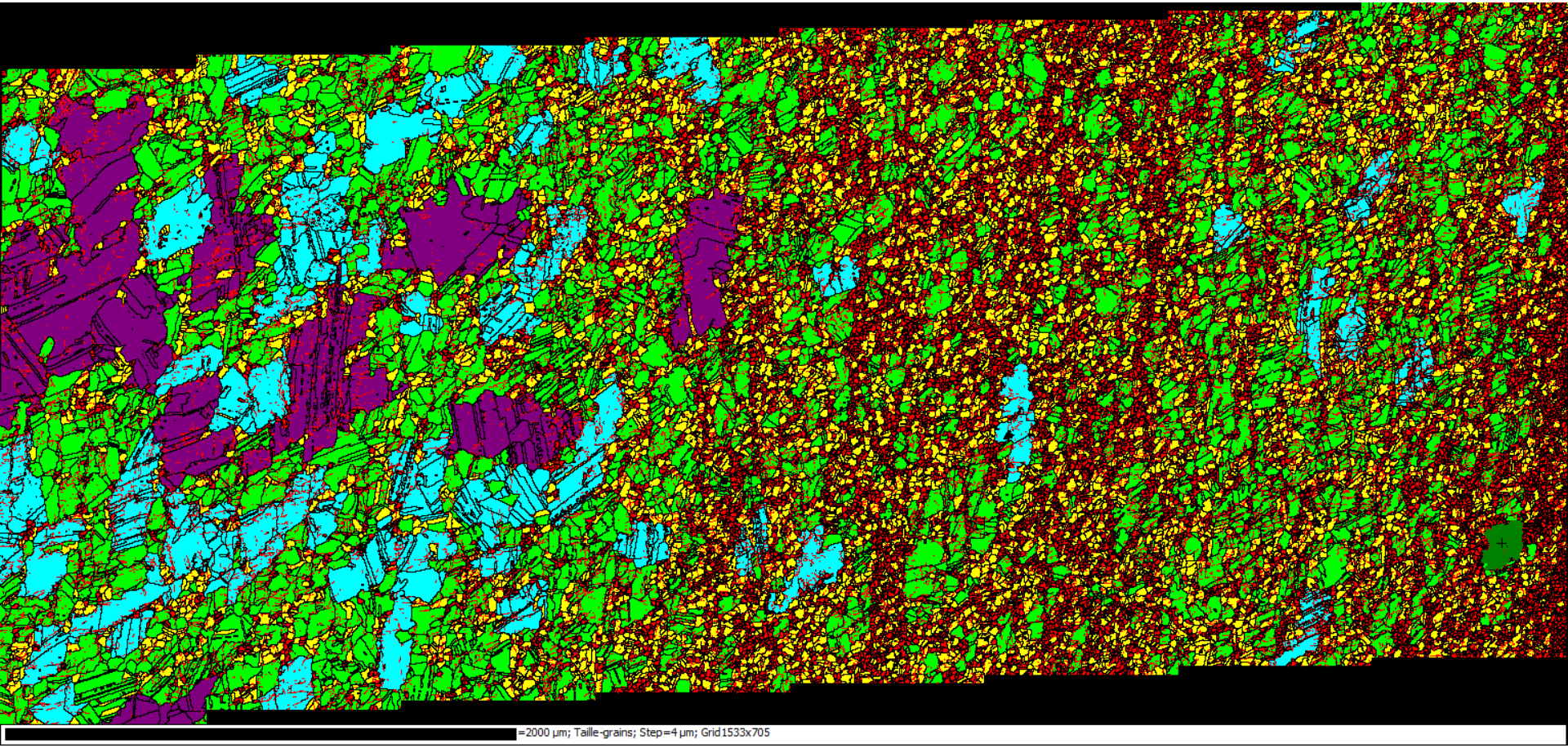

1-25um
25-50 um
50-150 um
150-300 um
300-500 um
500-1500 um
>1500 um
N
Fe content in sphalerite
zoom
EBSD maps
Taille de grains
10 mm


Pale Bidau (Hte-Garonne)
EBSD sphalerite grain map
1-25um
25-50 um
50-150 um
150-300 un
300-500 un
Zoom1
Sphalerite
EBSD maps
Zoom4
Zoom3
Zoom2
N
10 mm


Pale Bidau (Hte-Garonne)
EBSD sphalerite grain map
1-25um
25-50 um
50-150 um
150-300 un
300-500 un
Sphalerite
Zoom3
N
10 mm

EBSD : Taille de grains

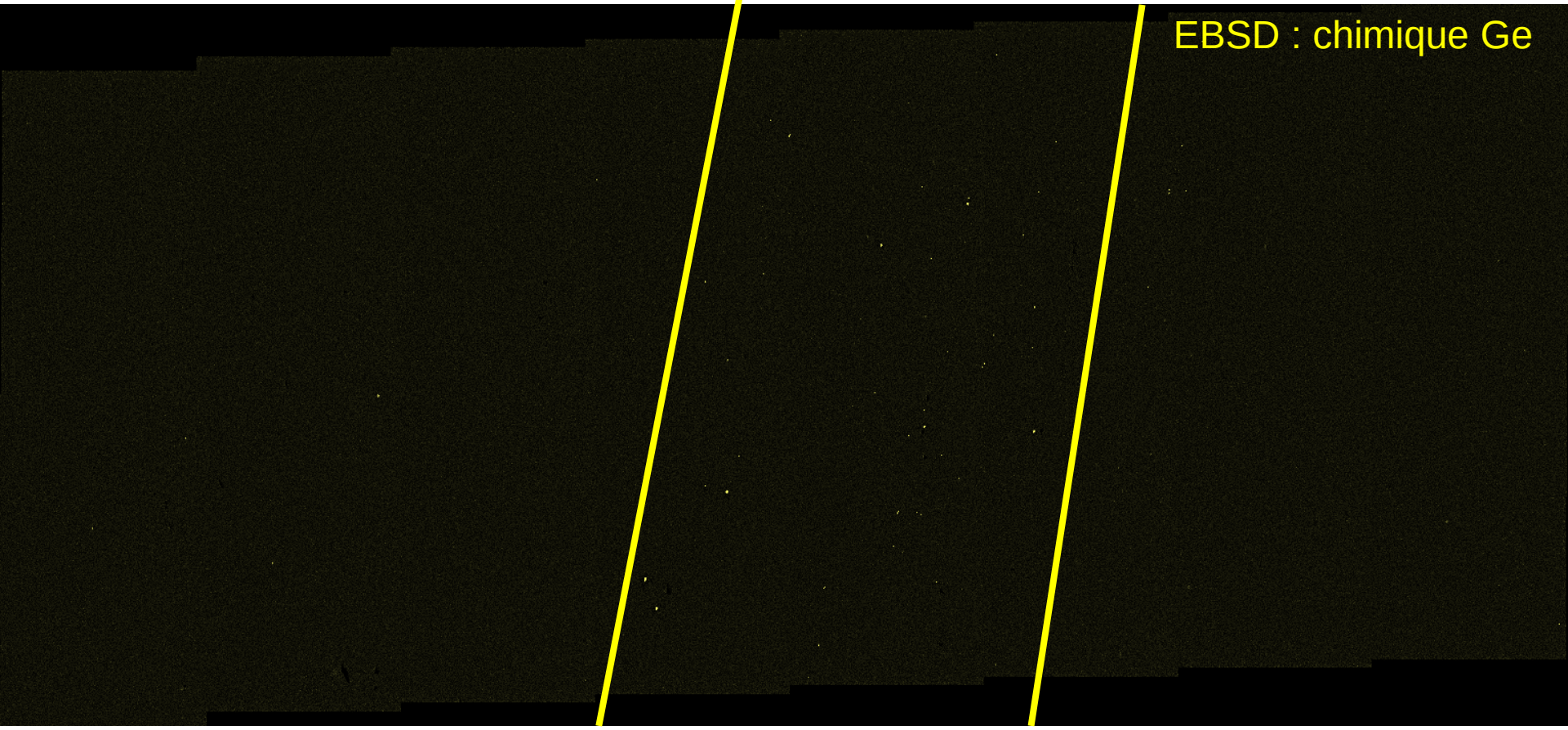
Zoom3



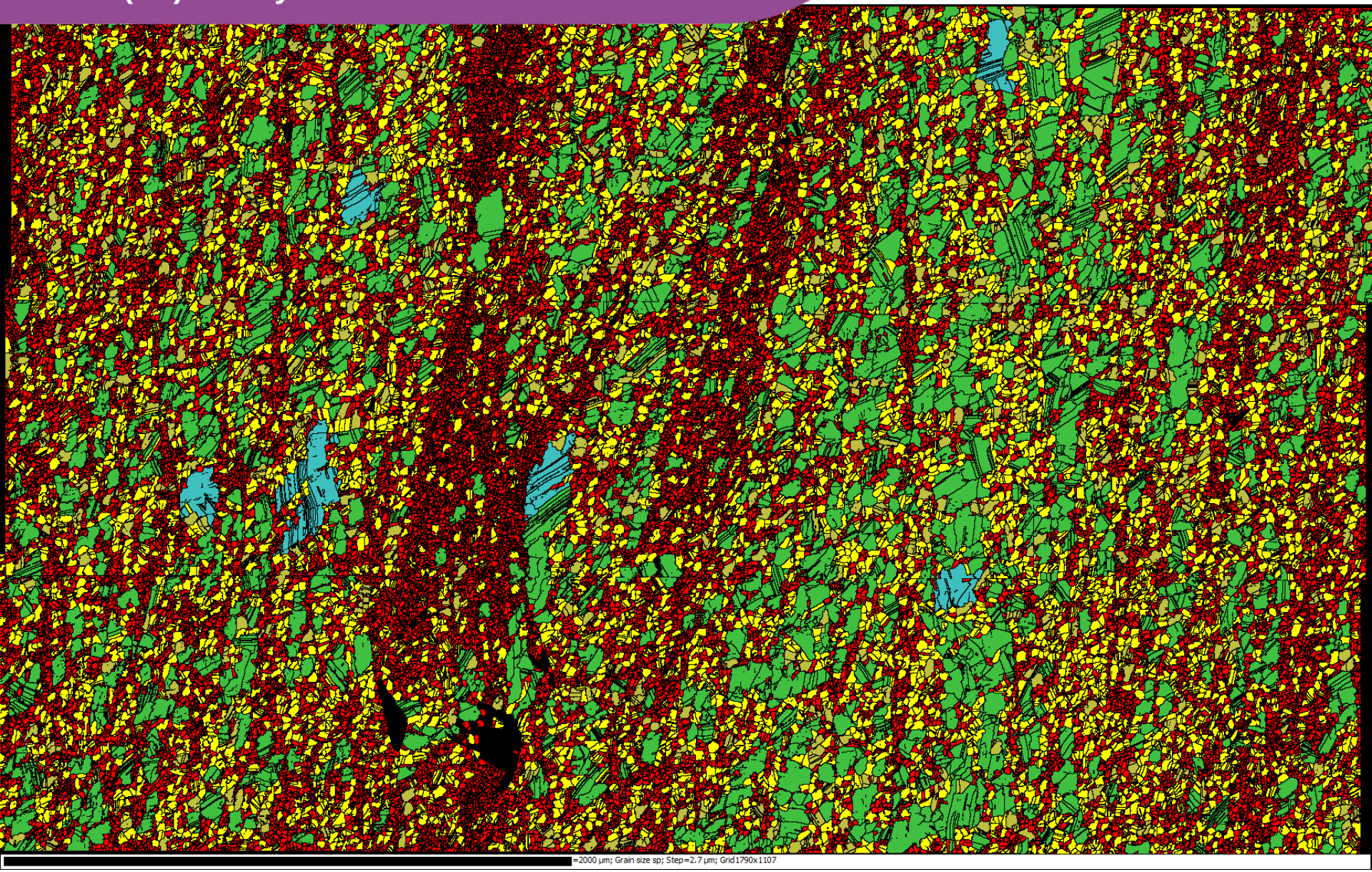
2 mm

1-25um
25-50 um
50-150 um
150-300 un
300-500 un

Zoom3

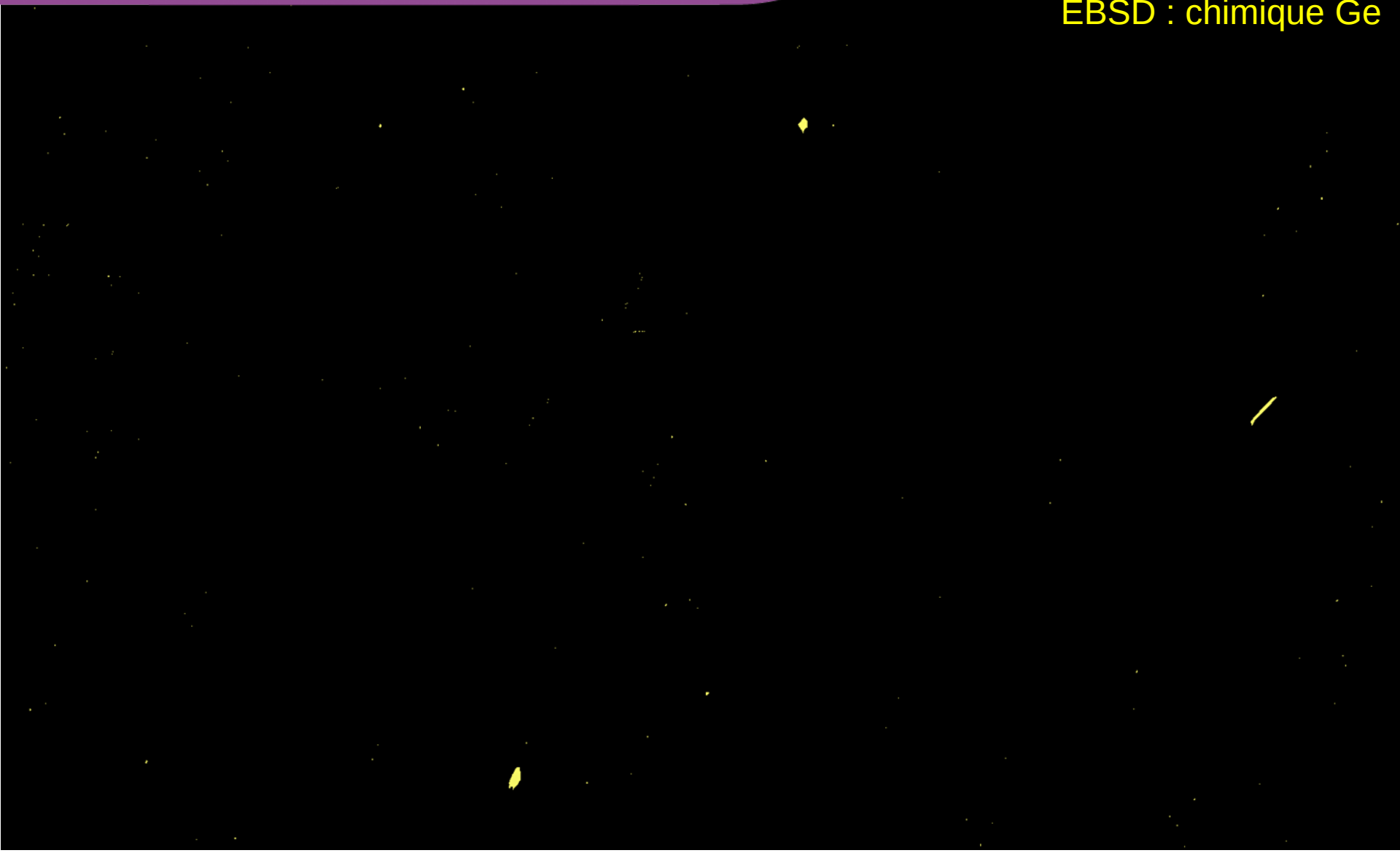


Pb-Zn-(Ge) des Pyrénées



2 mm

Zoom4



2 mm

Zoom4

Méthodes

- Terrain dans 15 gites Pb-Zn différents (environ 2 mois cumulés)

  →Travail en galeries et sur affleurements ;

  Etude structurale,

  Echantillonnage orienté

  - Minéralogie et microstructurale: QEMSCAN, EBSD

  - Etude des fluides minéralisateurs: Inclusions fluides gangue et sphalerite

  - Etude quantitative des mineurs/traces dont Ge: LA-ICP-MS couplé EBSD

A venir