



RESEARCH & INNOVATION PROGRAMME
ON RAW MATERIALS
TO FOSTER CIRCULAR ECONOMY



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of the European Union



<https://aureole.brgm.fr>

ERA-MIN2 AUREOLE project : tArgeting eU cRitical mEtals (Sb, W) and predictability of Sb-As-Hg envirOnmentaL issuEs – Oct. 2019 – Sep. 22

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Why Antimony ?

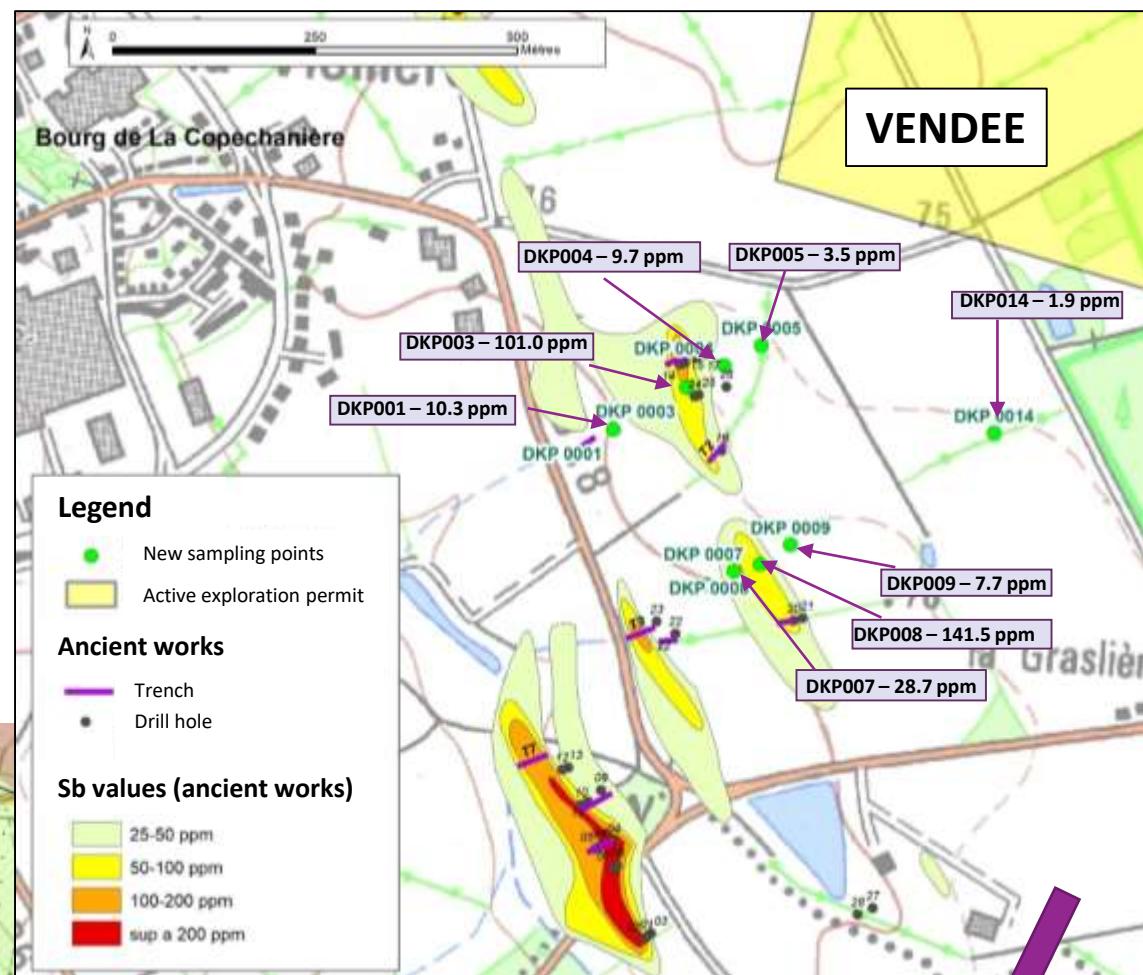
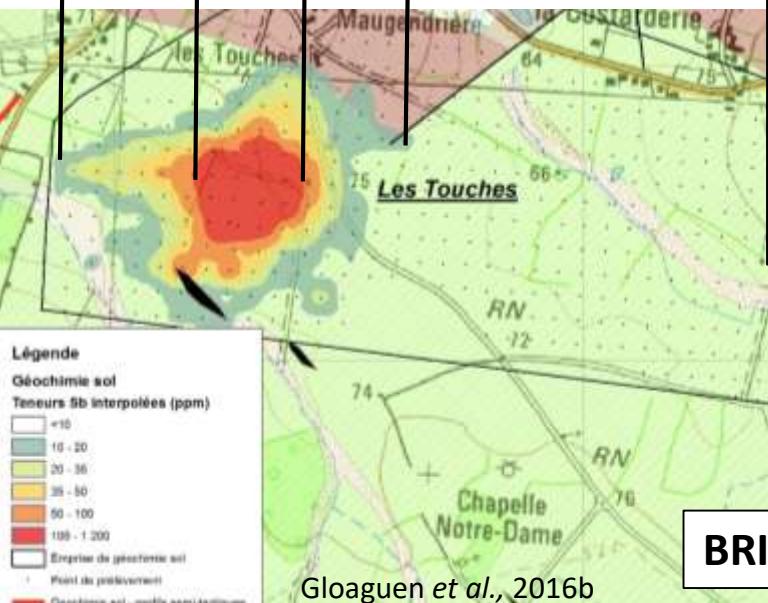
- **Antimony & tungsten** are classified as **critical metals for EU** (European Commission 2017 com. 490)
 - Antimony deposits are common in Europe
 - Au, W, Hg, As are frequently associated with Sb deposits at various grades.
- The **toxicity** of Sb, As, Hg being **more and more recognized**, it is now essential to **establish environmental hazard maps at belt scale**.
- A better knowledge of EU areas of high potential for discoveries of Antimony deposits could limit the effect of possible future Chinese quotas on supplies
 - The **geological processes that control Sb ore deposits distribution are poorly constrained**
 - The **geological processes that control co-products grades**, for example, W as scheelite up to 1 wt %, Au, Hg, etc are presently **unknown**.
- The **Variscan belt** was the first world producer at the begining of XX century and **show a strong potential for Sb-type ore deposits**
 - The **Armorican – Iberian arc as study area**

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General concept

Geochemical haloes associated to Sb mineralisation at the earth surface are **strongly localised**

760m >10ppm Sb
230m
>100ppm Sb



Mafic dykes (black)

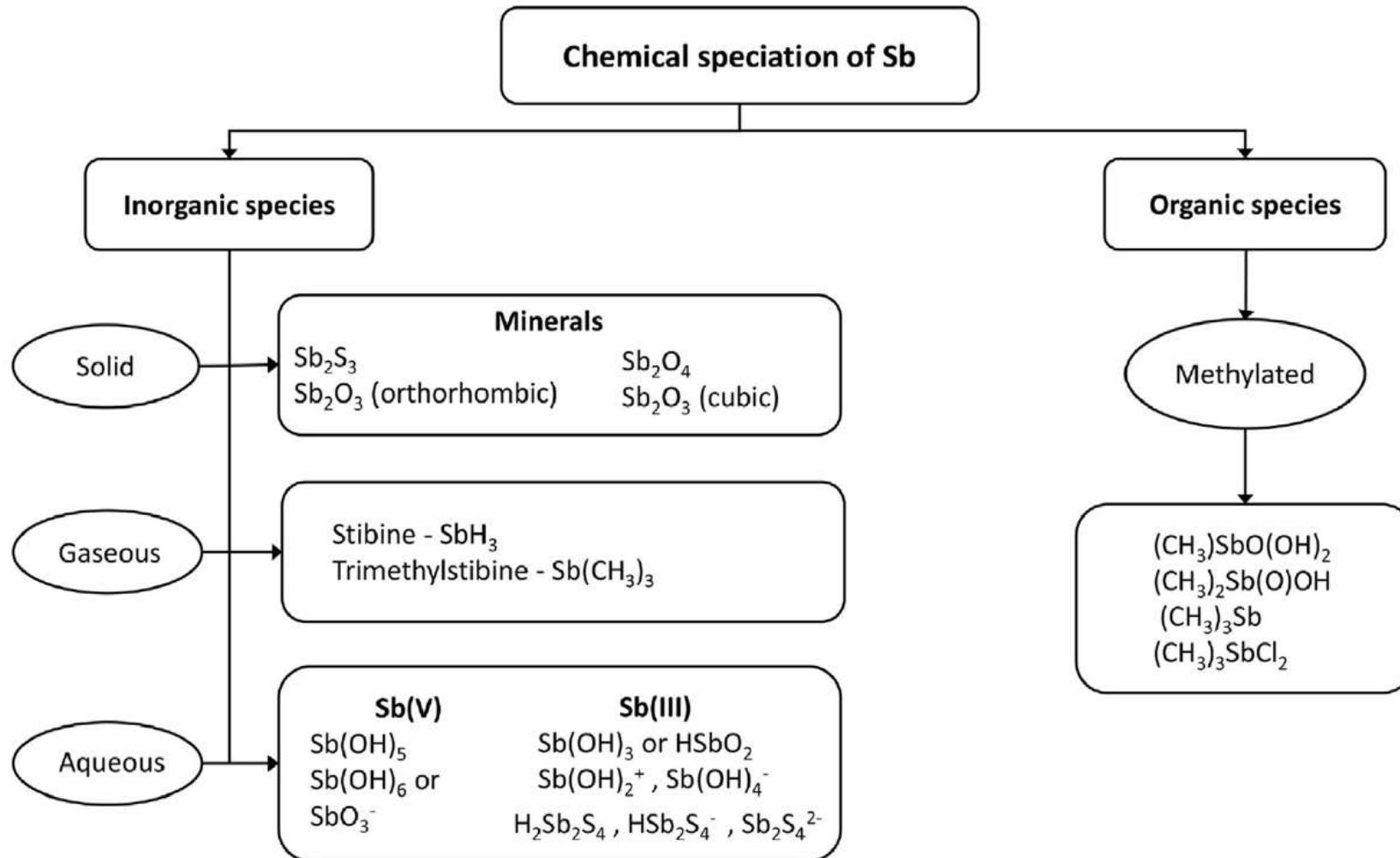
BRITTANY

West of France



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Sb: a metalloid presenting multiple species in environment



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Sb: a metalloid presenting multiple species in environment

- Mobilization from host mineral phases:

Oxyde : $\text{Sb}_2\text{O}_3(\text{s}) + 3 \text{H}_2\text{O}(\text{l}) = 2 \text{Sb(OH)}_3 \text{ aq}$ - low solubility ($10^{-5} \text{ mol.L}^{-1}$, $3 < \text{pH} < 9$, Baes and Mesmer, 1976)

Sulfide : $\text{Sb}_2\text{S}_3(\text{s}) + 6 \text{O}_2 + 2 \text{H}_2\text{O} = 2\text{Sb(OH)}_3 \text{ aq} + 3 \text{H}_2\text{SO}_4 \text{ aq}$ - acidic and aerobic conditions

Sulfide : $\text{Sb}_2\text{S}_3(\text{s}) + 6 \text{H}_2\text{O}(\text{l}) = 2\text{Sb(OH)}_3 \text{ aq} + 3 \text{H}_2\text{S} \text{ aq}$ - alkaline conditions $\text{pH} > 9$ (Hu et al., 2016)

- In presence of hydrogen sulfide and neutral – high pH: formation of thio-Sb soluble complexes
- Acidic and anaerobic conditions + hydrogen sulfide: stability and/or precipitation of Sb sulfide

Toxicity SbIII > SbV but mobility SbIII < SbV in neutral pH condition

Sb mobility is higher with reducing conditions, associated to Fe²⁺

Adsorption of Sb onto oxides, clay and natural organic matter

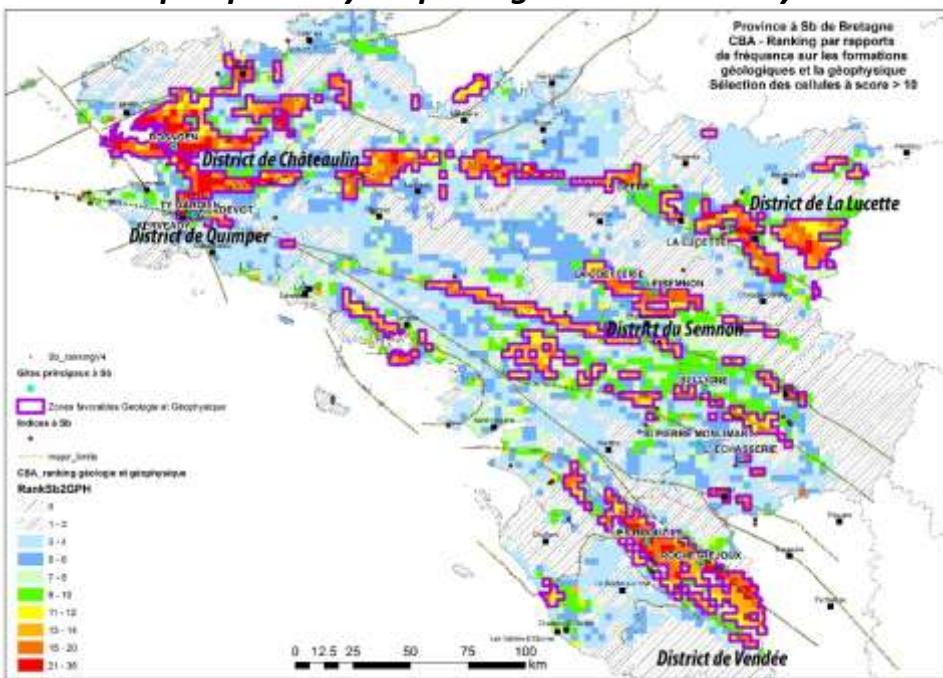
Geo and bioavailable chemical species (Sb, Hg, As, etc) have a mobilization controlled by surface physico-chemical and bacterial processes associated with local specificities (rainfall, temperature, morphology, supergene weathering, etc)

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General concept

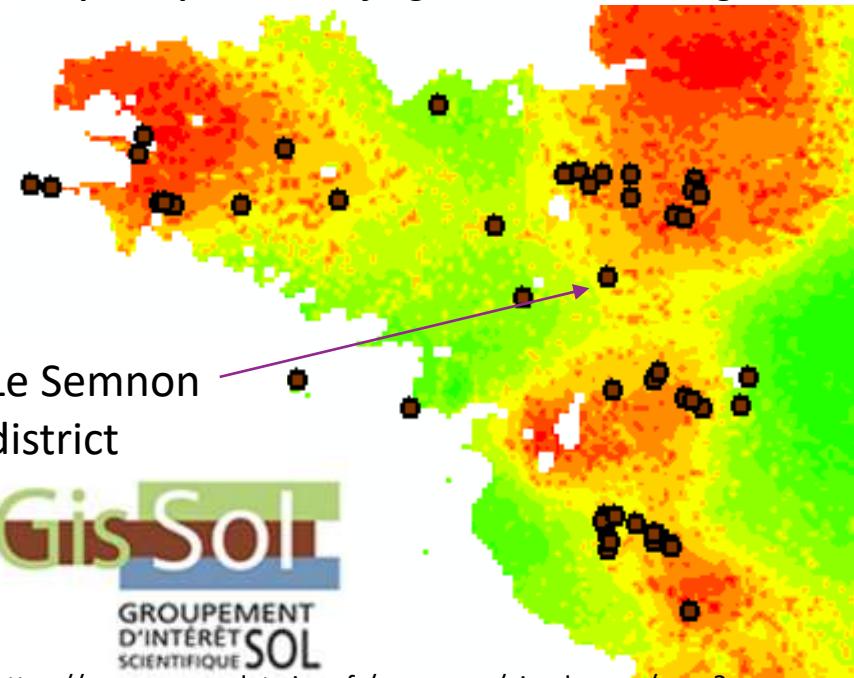
- **Improvement of spatial prediction for Sb, Hg and As in soils (for both mineral exploration and to prevent health issues) is required.**
- It can be achieved only by focusing high definition soil survey on prospective areas highlighted by mineral prospectivity methods based on the understanding of processes that control ore location and chemical element mobilization or immobilisation at the surface

Sb mineral prospectivity map using Cell-Based Analysis method



Gloaguen et al., 2016a

Spatial prediction of Hg in soils 16 x 16km grid



https://agroenvgeo.data.inra.fr/geoserver/gissol_rmqw/wms?

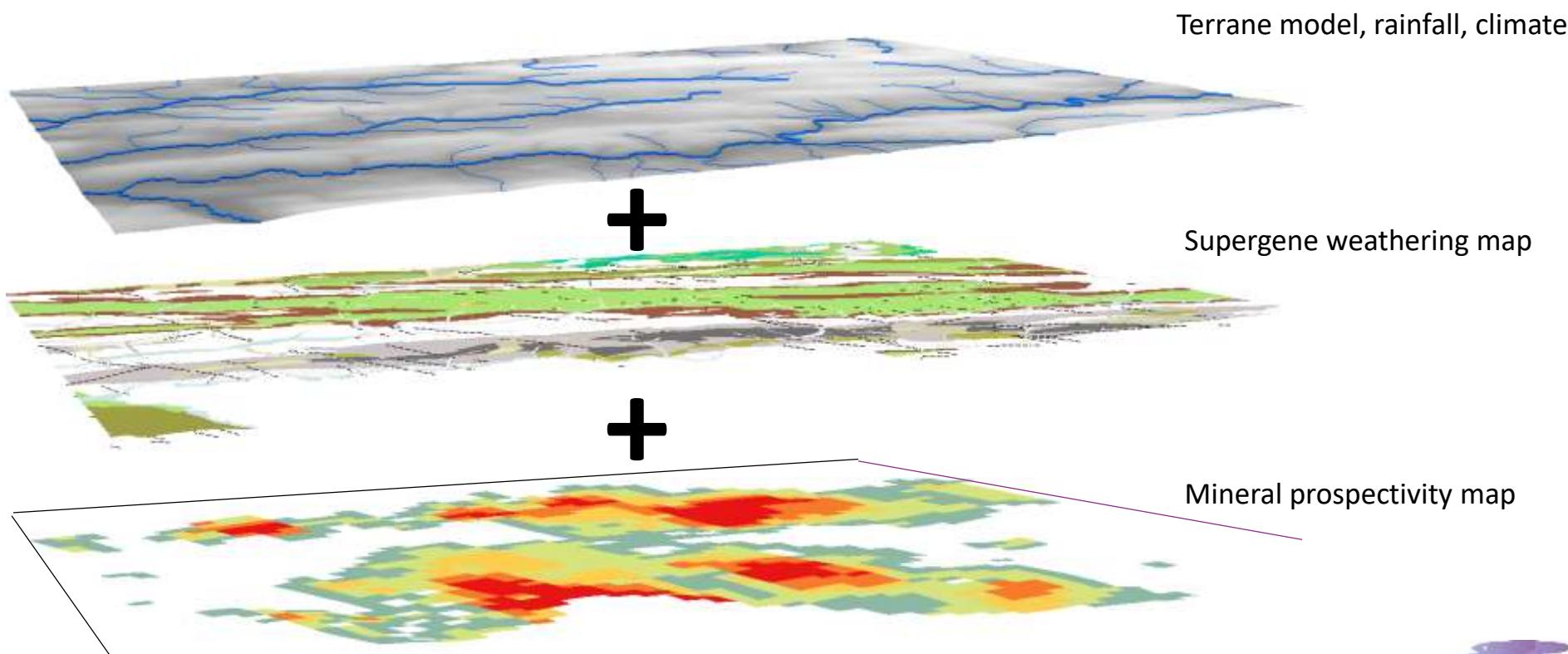
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General concept

The aim is to provide :

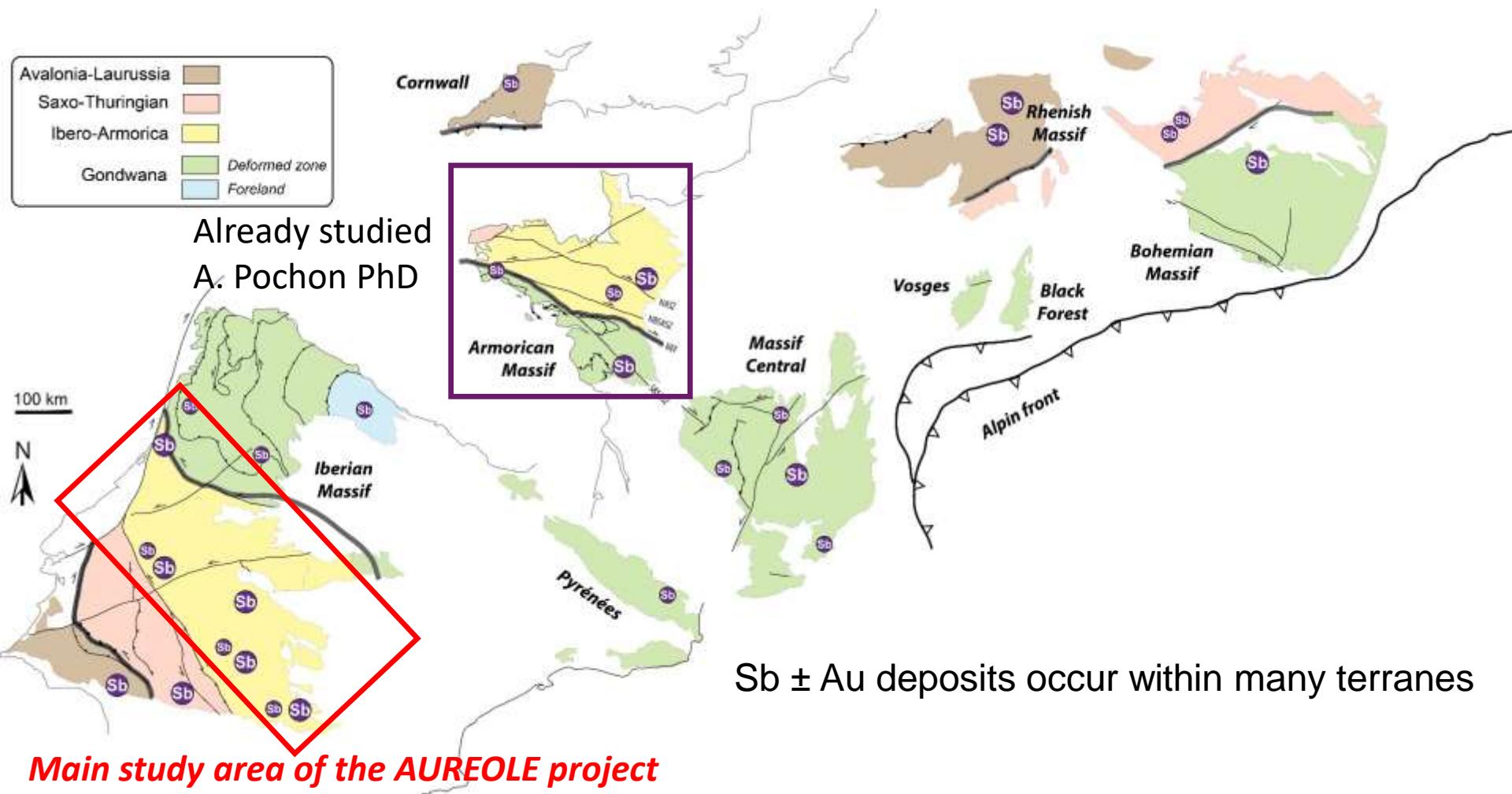
- ✓ **Risk assessment maps for environmental issues**
- ✓ **Mineral prospectivity maps for Mineral exploration**

Both based on a new metallogenical model and a better constraint of parameters that control metals/metalloids behavior at the earth surface



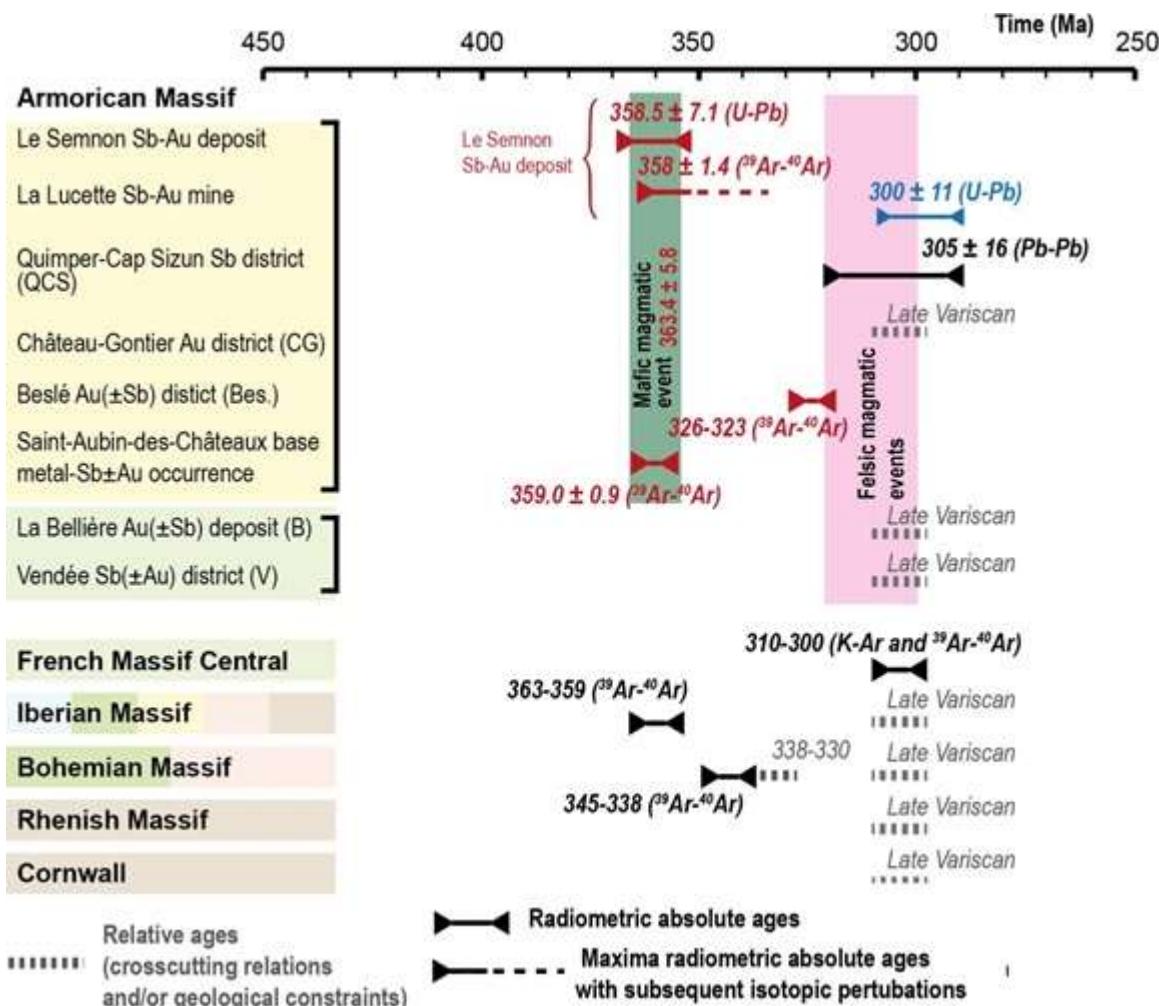
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Sb ± Au occurrences in the European Variscan belt



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Sb ± Au occurrences in the European Variscan belt

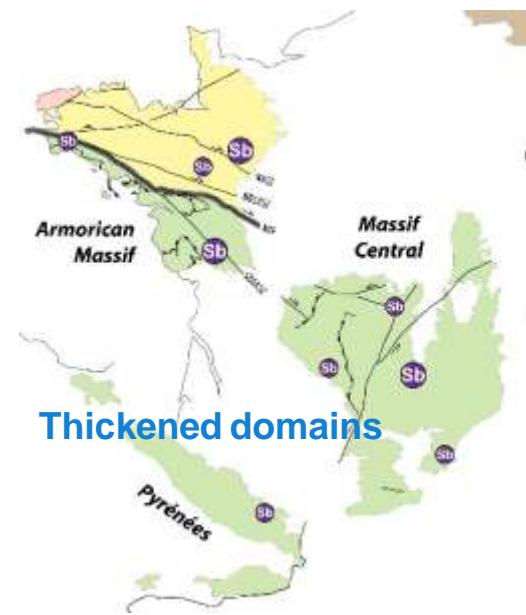


- Variscan Sb deposits are associated at least with 2 events
- Remobilisation from the ca 360Ma event or new events?

Modified from Pochon et al (2019)

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Metallogenetic Model: Sb mineralisation genetically related to the “Or 300 Ma” event



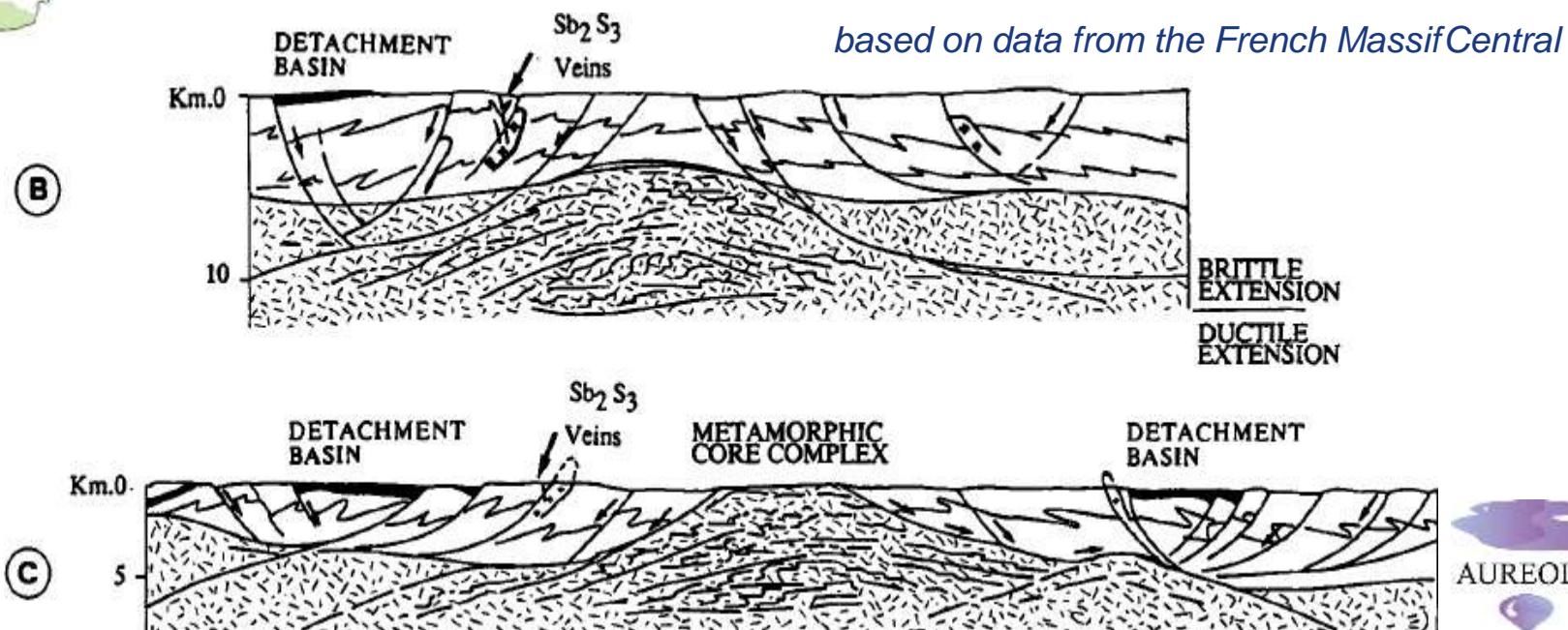
TERRA RESEARCH

The massive stibnite veins of the French Palaeozoic basement: a metallogenetic marker of Late Variscan brittle extension

Marguerite Munoz, Pierre Courjault-Radé and Francis Tollon

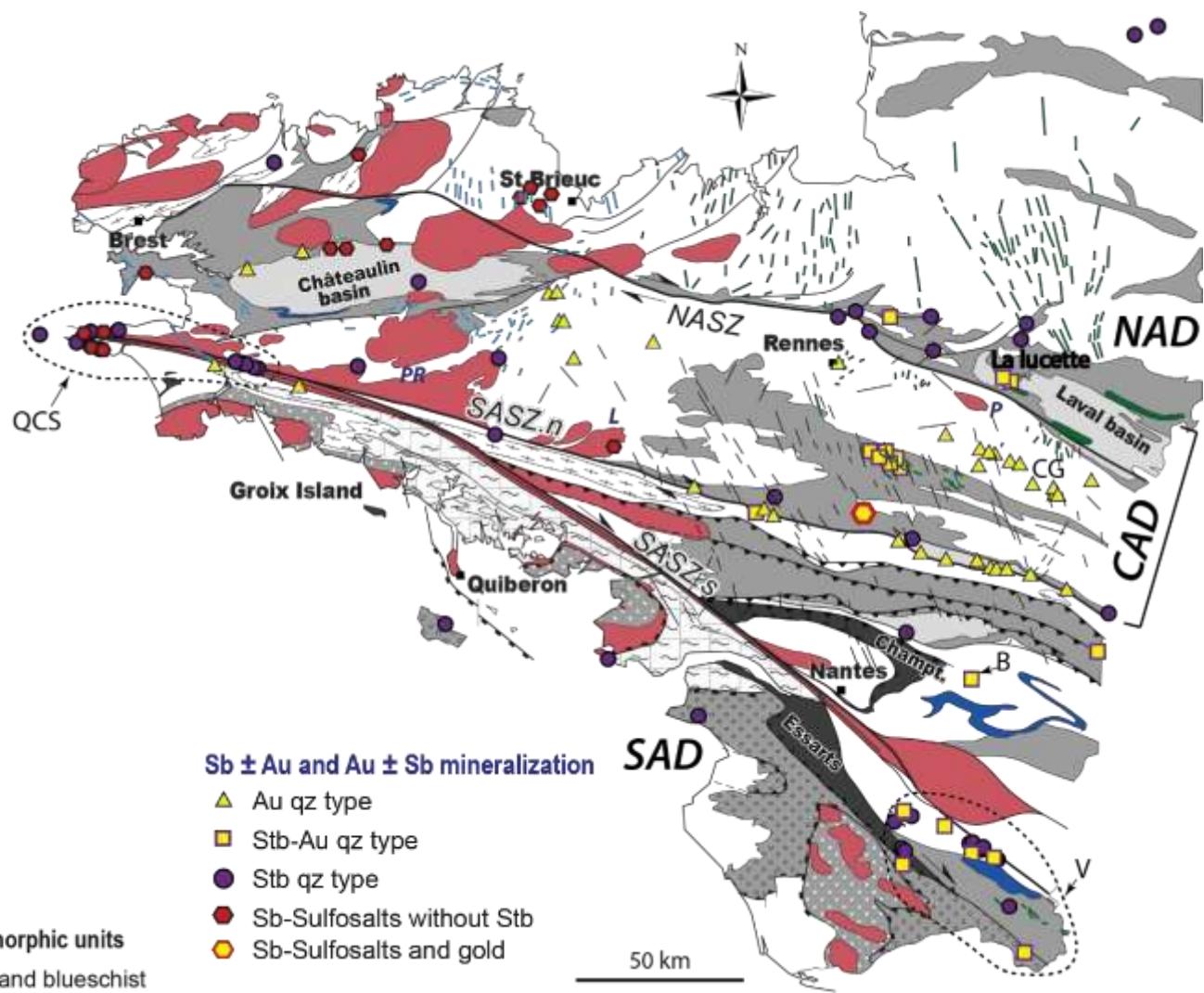
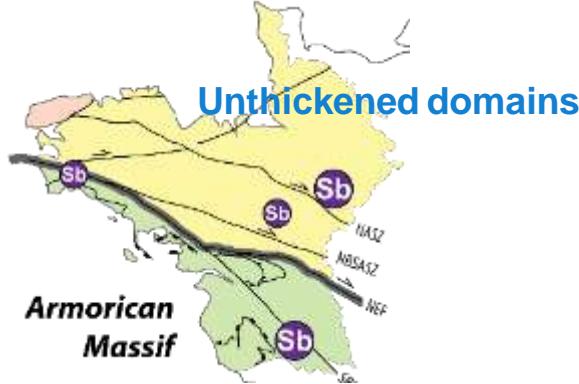
Laboratoire de Minéralogie (U.R.A. n° 067, CNRS), 39, Allées J. Guesde, F-31000 Toulouse, France

Munoz et al. 1992



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Sb ± Au occurrences in the European Variscan belt



Pochon et al. 2019



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Spatial statistical analysis

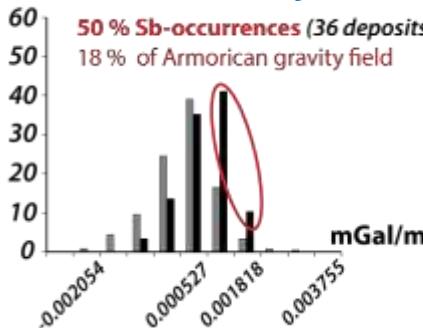
High density zones

Geophysical evidence of mafic rocks at depth
(locally outcropping)

Geophysical signatures of outcropping eclogites

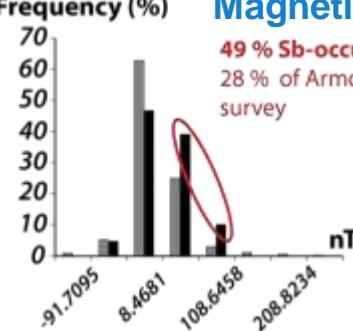
- Undifferentiated Sb-occurrences

Frequency (%) Gravity field

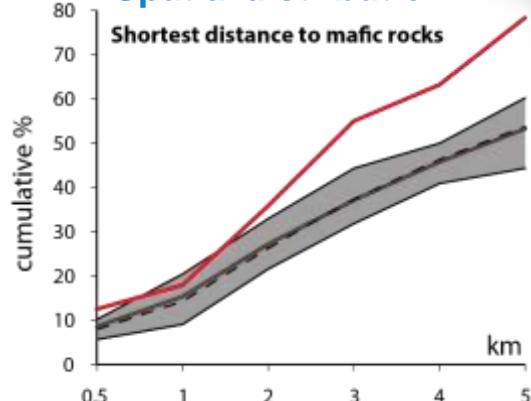


Magnetic field

49 % Sb-occurrences (35 deposits)
28 % of Armorican aeromagnetic survey

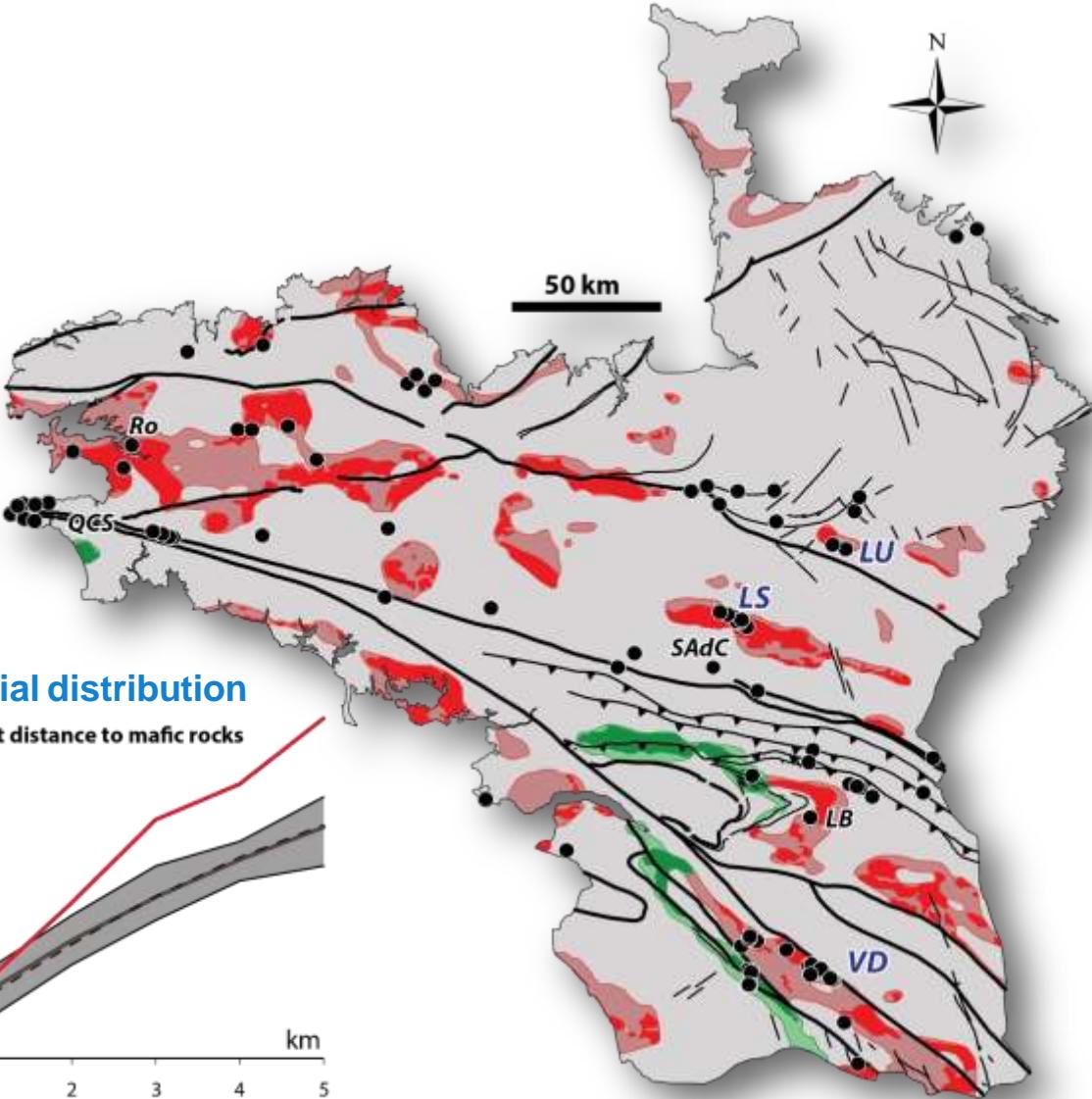


Spatial distribution



Spatial correlation between Sb occurrences and:

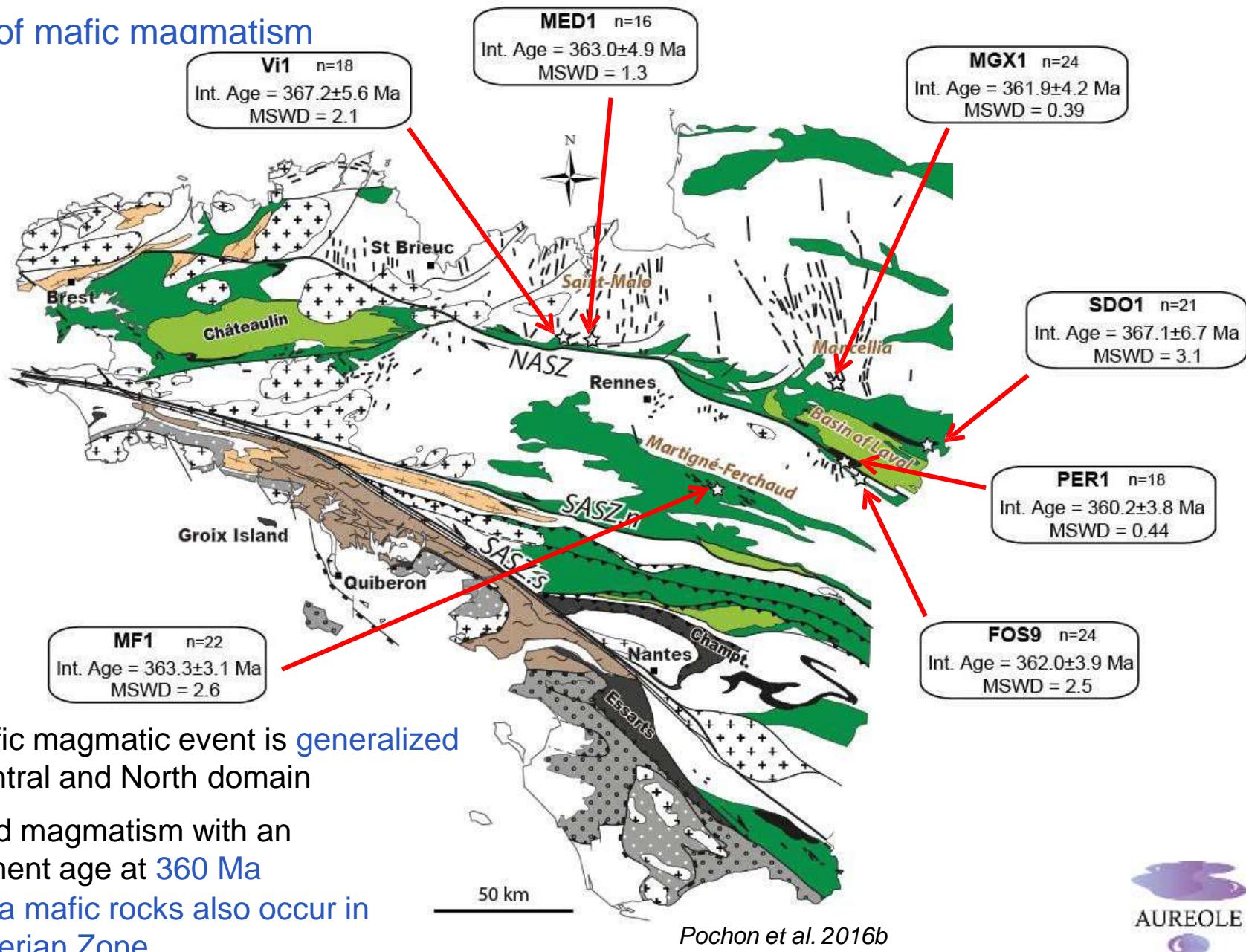
- High density and magnetic zones
 - Outcropping mafic rocks
 - Faults
- **Spatial link between mafic magmatism and Sb**
→ **Under investigation for the Central Iberian Zone**



Pochon et al. 2016a

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Timing of mafic magmatism



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Timing of Sb event

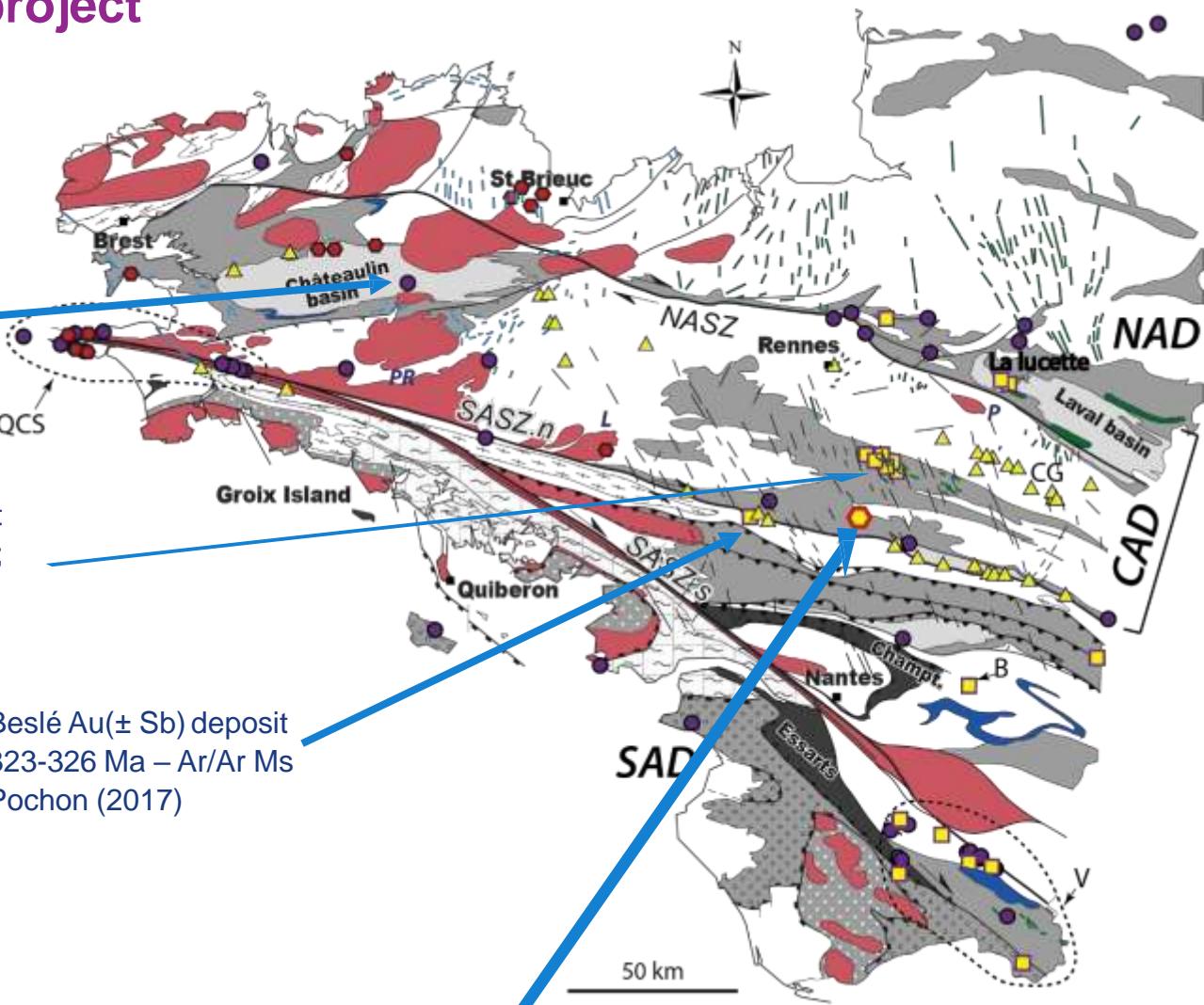
Scubériou Sb occurrence:
Viséan to post-Viséan age

Le Semnon Sb deposit
 358.5 ± 7.1 Ma – U-Pb;
 358 ± 1.4 Ma - Ar/Ar
Pochon et al (2018)

- Variscan Sb deposits are associated at least with 2 events, 360 & 325-300Ma
- Remobilisation from the ca 360Ma event or new events?

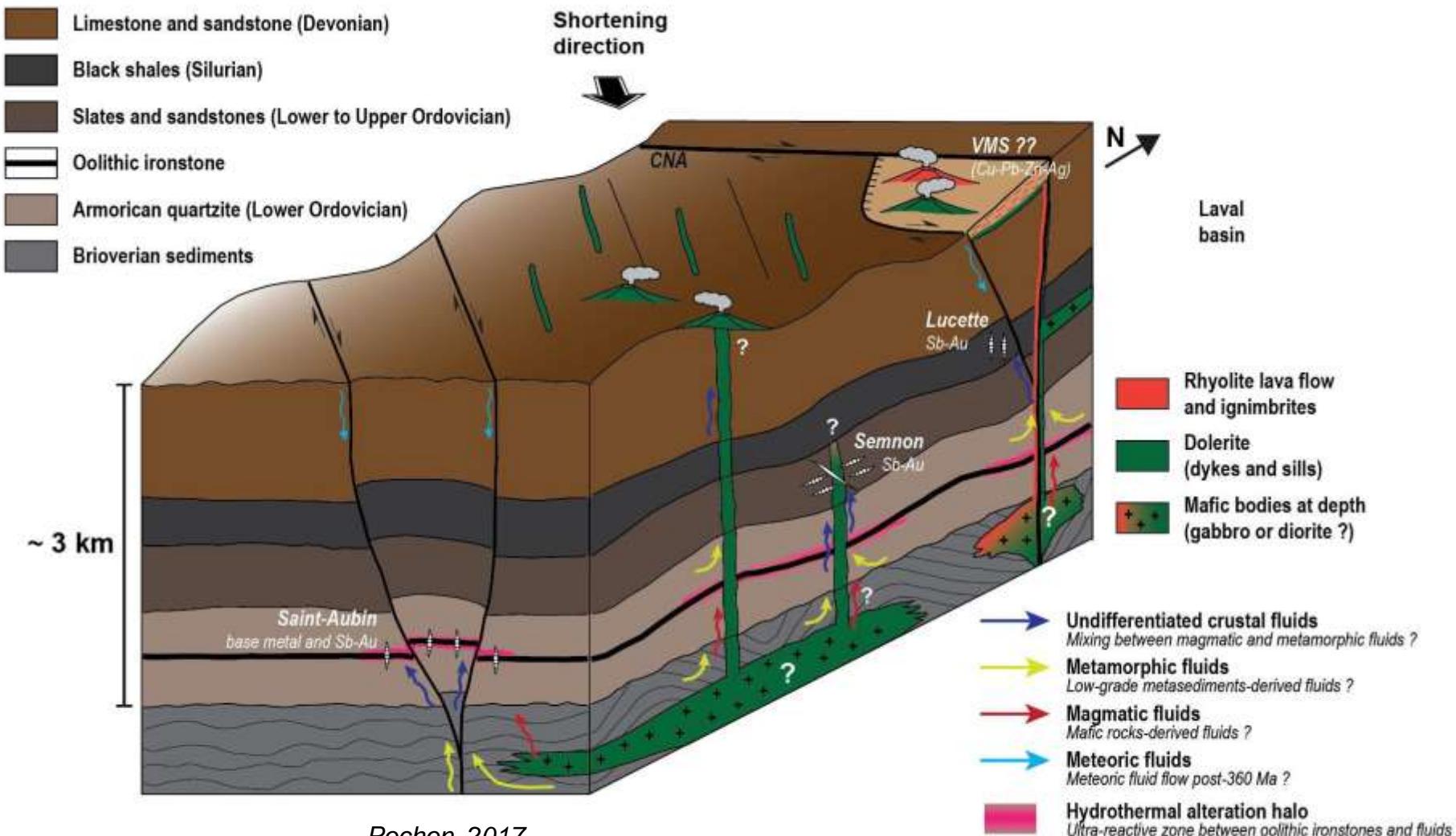
Beslé Au(± Sb) deposit
323-326 Ma – Ar/Ar Ms
Pochon (2017)

Saint-Aubin-des-Châteaux Sb-Au occurrence
 358 ± 1.4 Ma - Ar/Ar
Pochon et al (2019)



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Metallogenical model



Pochon, 2017

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General concept & challenges

The **main challenges** of this project will be: 1) To **extend/update the metallogenetic model in Iberia**

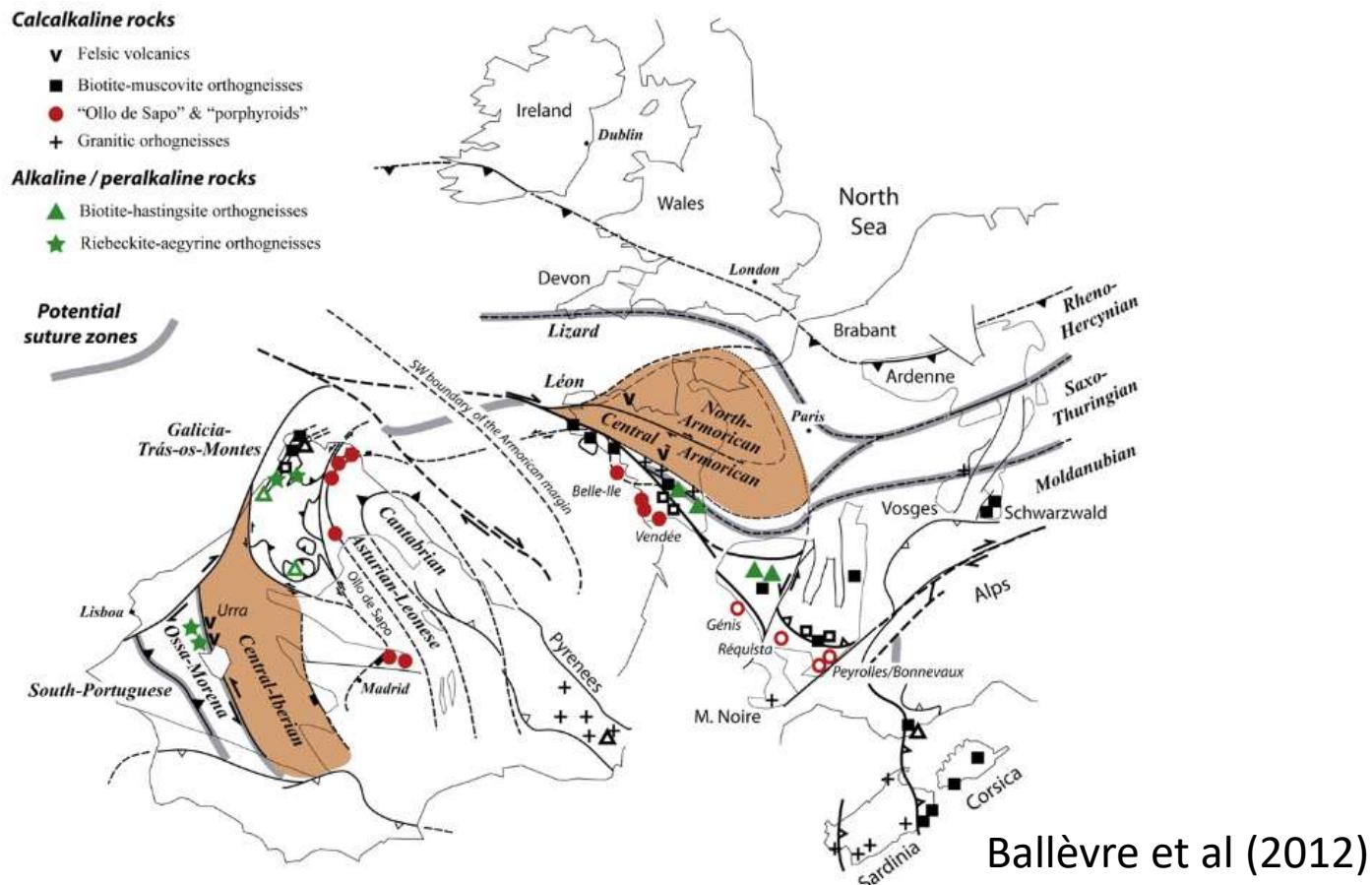
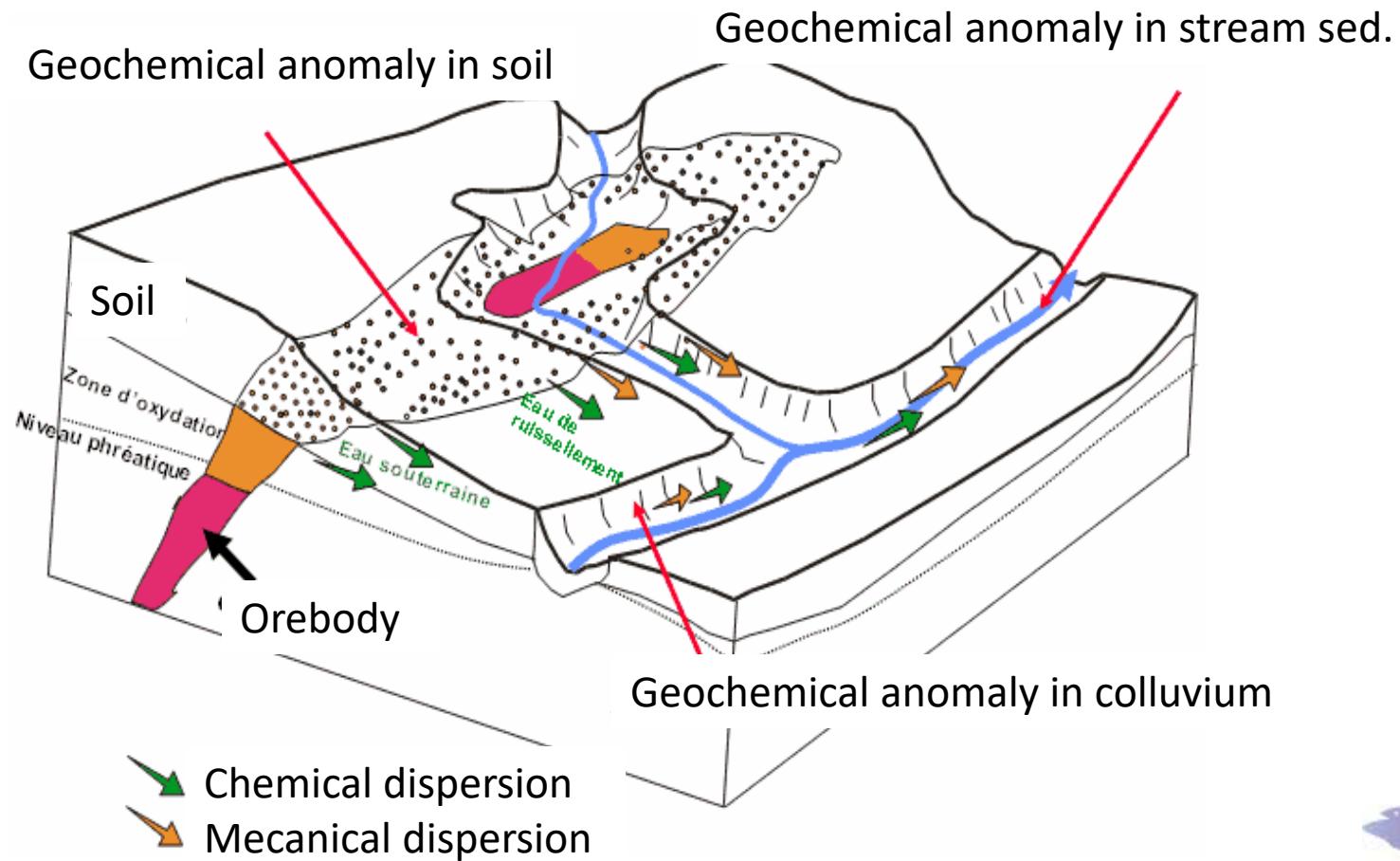


Fig. 12. Sketch of the western part of Europe with emphasis on the Ibero-Armorian Arc, showing the distribution of the volcanics/plutonics with reliable (filled symbols) and probable (open symbols) Early Ordovician (485 ± 15 Ma) ages.

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General concept & challenges

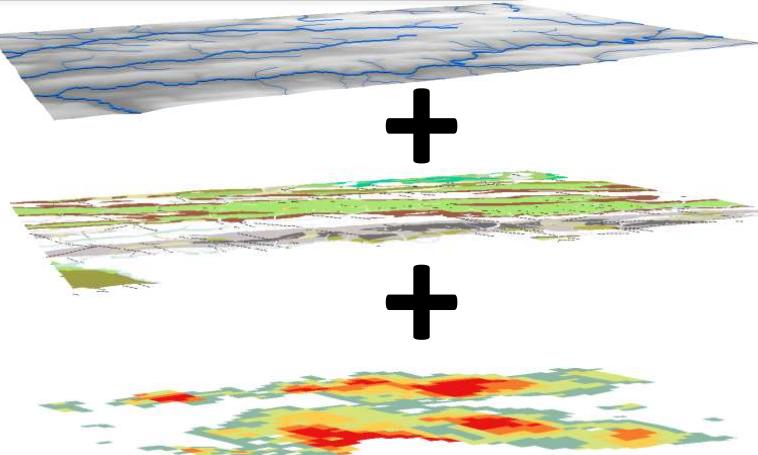
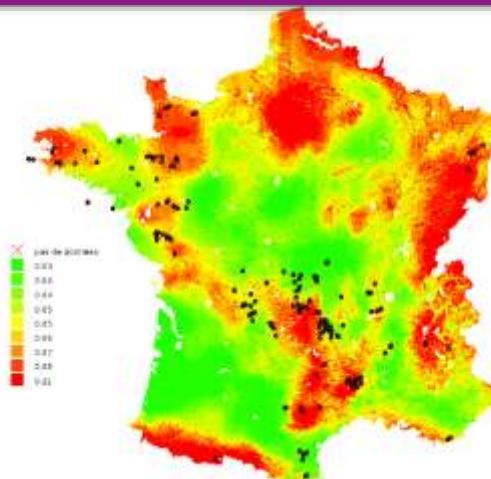
The **main challenges** of this project will be: 2) To constrain all the processes that control the mobility/immobility of metals & metalloids



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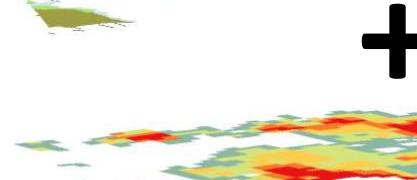
General concept & challenges

WP3 – Mineral prospectivity and risk assessment maps



Terrane model,
rainfall, climate

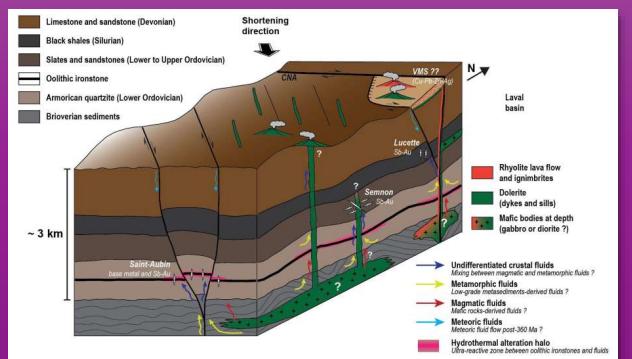
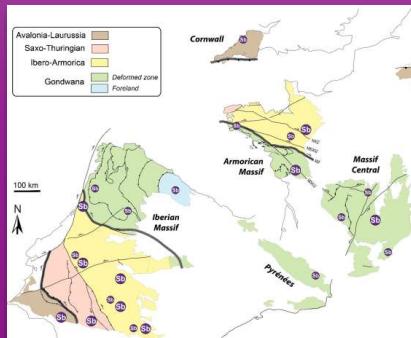
Supergene
weathering
map



Mineral
prospectivity
map

- ✓ Risk assessment maps for environmental issues
- ✓ Mineral prospectivity maps for Mineral exploration

WP1- Geological processes that controls location and feature of Sb ore deposit



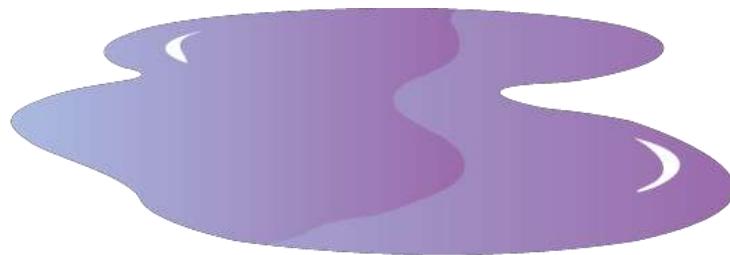
WP2 – Physical, organic and bacterial processes that control mobilization and transport of metals/metalloids

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More information on our website

<https://aureole.brgm.fr>

Thank you for your attention



AUREOLE



Targeting European Critical Metals (Sb, W) &
predictability of Sb-As-Hg environmental issues



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