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Isabelle Duhamel-Achin, Blandine Gourcerol, Maxime Picault

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FRENCH METROPOLITAN MINING POTENTIAL REAPPRAISAL OF SELECTED CRITICAL METALS

Isabelle Duhamel-Achin i.duhamelachin@brgm.fr
Blandine Gourcerol b.gourcerol@brgm.fr
Maxime Picault m.picault@brgm.fr

LOCAL CHAPTER EAGE PARIS

EAGE Local Chapter PARIS - June 22nd 2021

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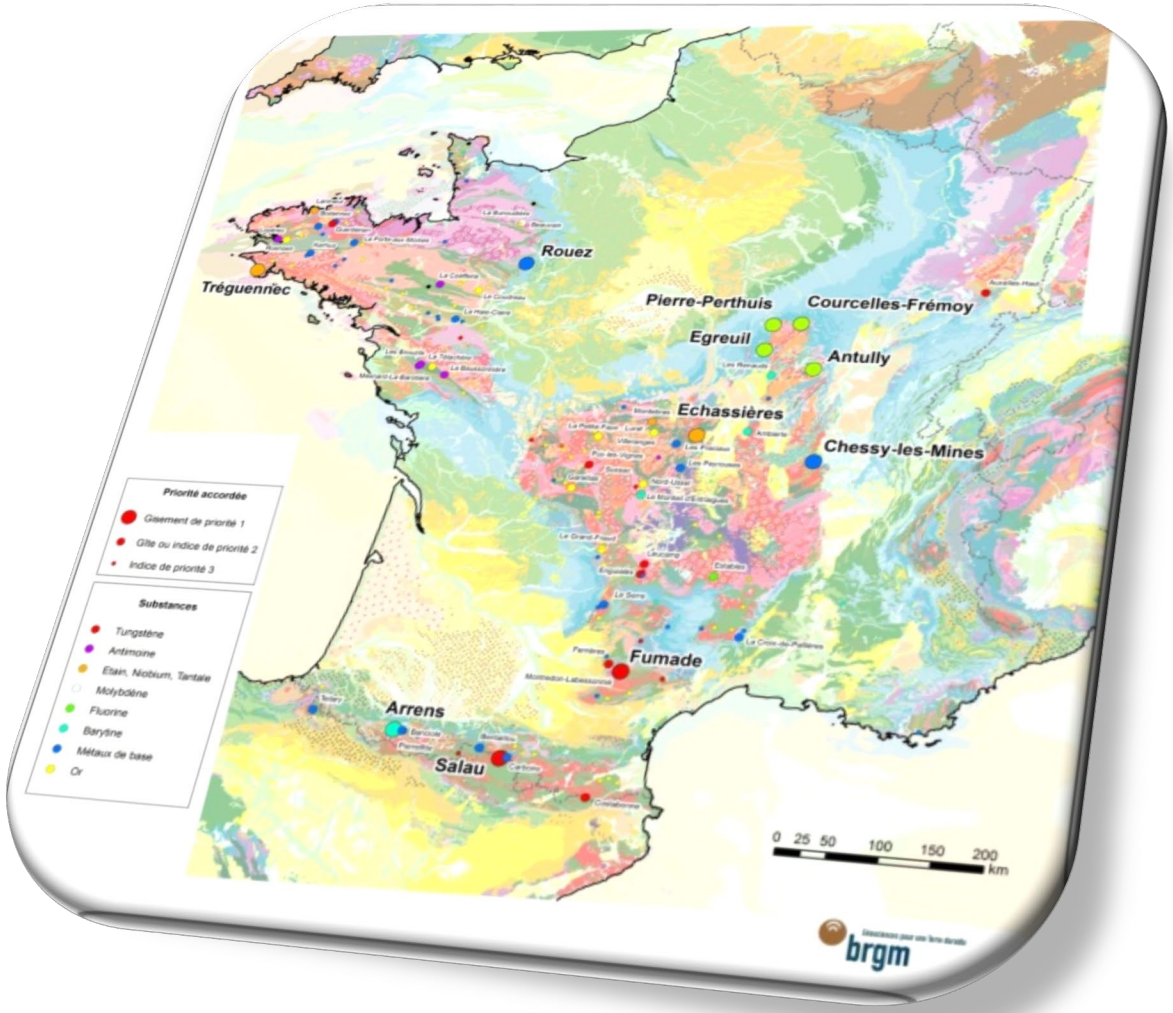
Outline

Historical exploration program conducted by BRGM and the first inventory of mineral resources in France

Criticality assessment of raw materials for France

Potential for selected critical metals in metropolitan France

- Tungsten
- Antimony
- Tin
- Lithium



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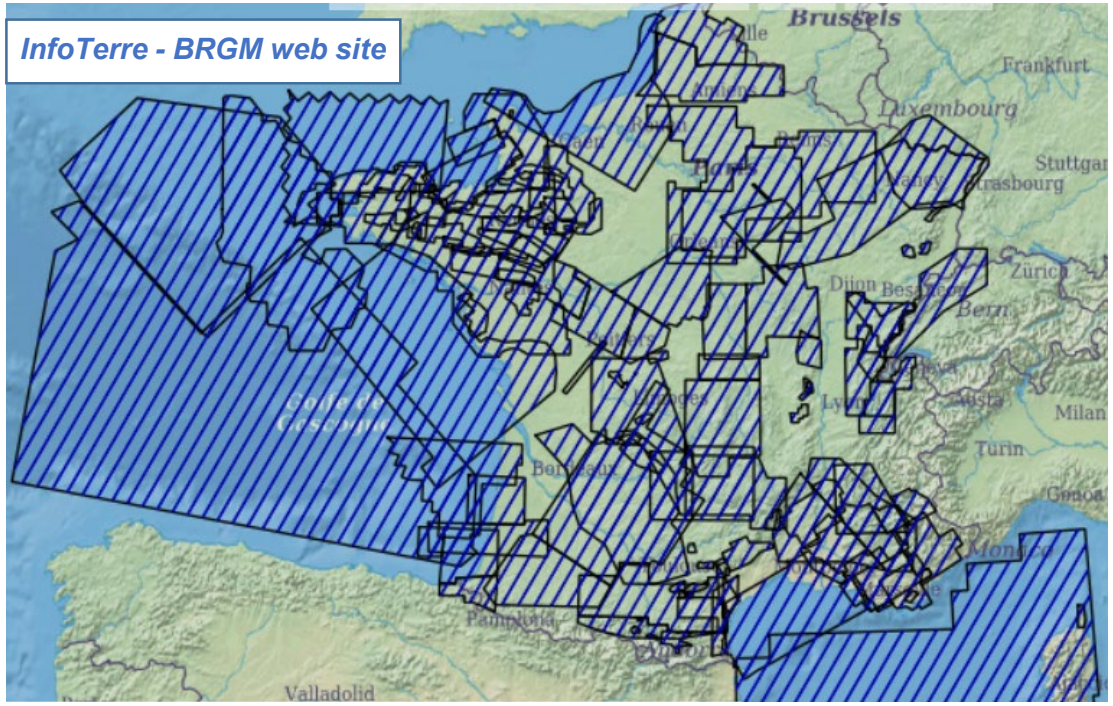
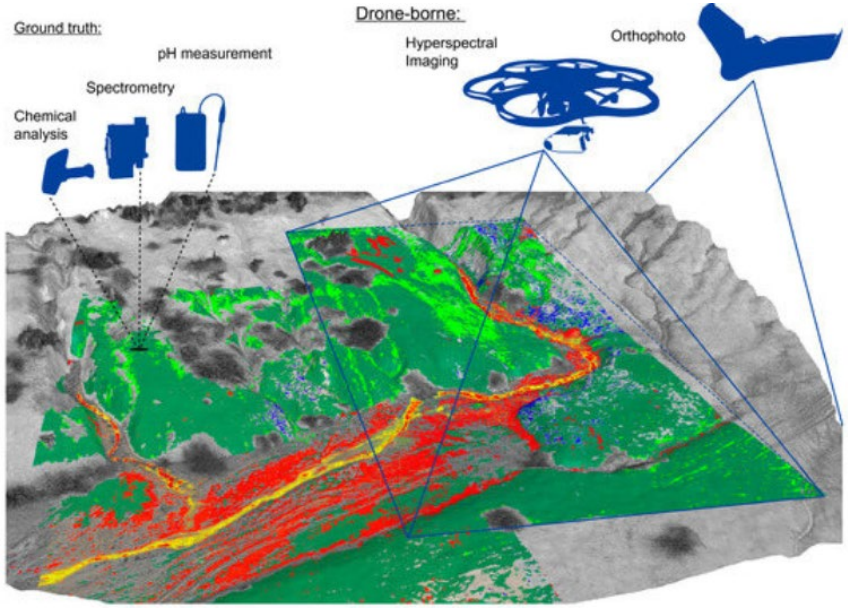
Geophysical aerial survey of France

- Geophysical airborn surveys dedicated to mining prospection are outdated (conducted from the end of 60's to 80's)
- >1990's surveys were dedicated to natural risks diagnosis, deep water research or prospection of construction material



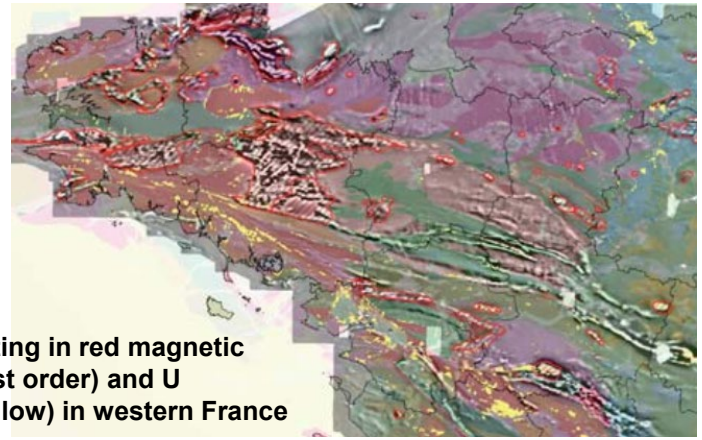
Surface covered by historical MAG airborn geophysical surveys over metropolitan France



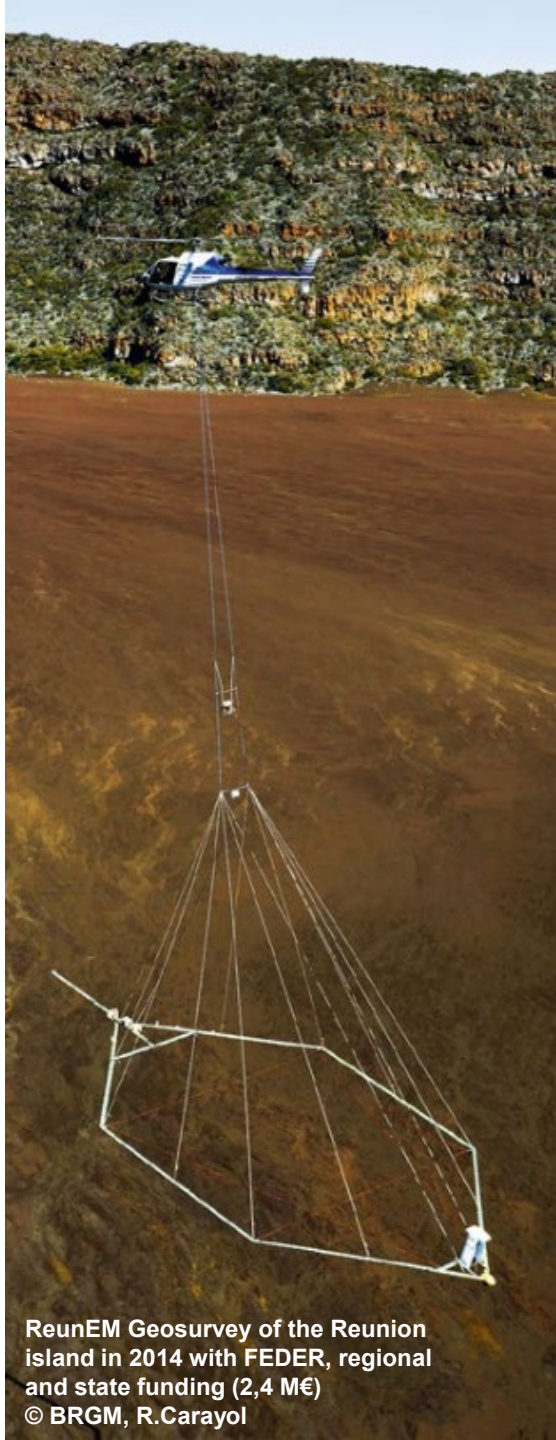
Source : Jackisch et al. (2018)
https://doi.org/10.3390/rs10030385

- More recent methods with higher resolution exist to explore and refine underground mining potential

⇨ See following presentation by Elodie Willard (Orano Mining)



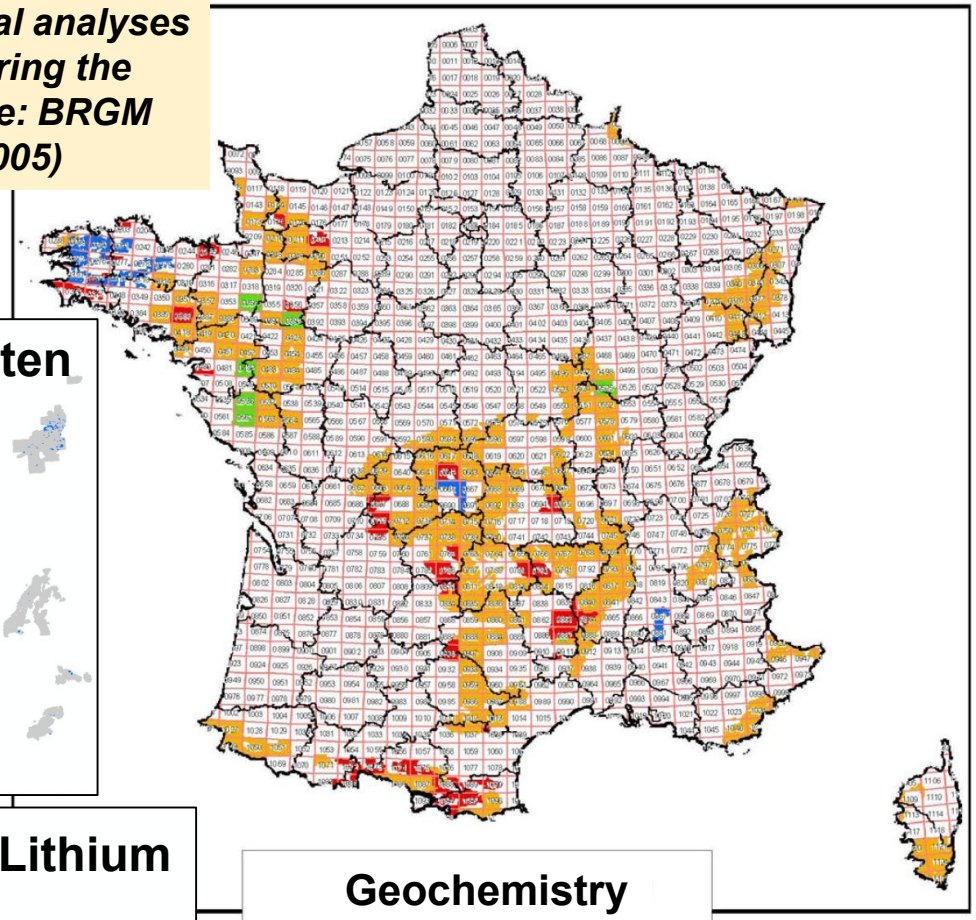
Map representing in red magnetic anomalies (first order) and U anomalies (yellow) in western France



ReunEM Geosurvey of the Reunion island in 2014 with FEDER, regional and state funding (2,4 M€)
© BRGM, R.Carayol

French exploration national program and the mineral resources inventory

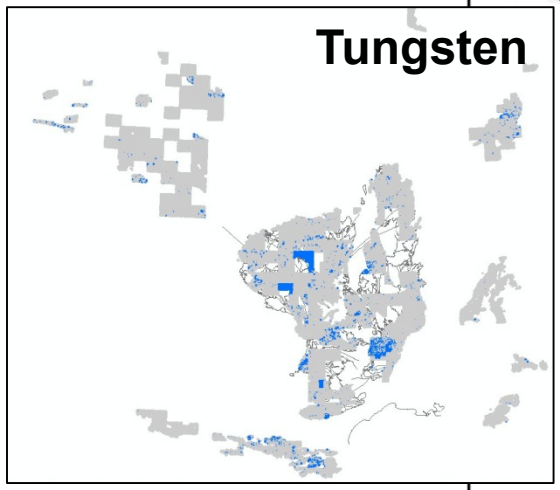
French cover of geochemical analyses on stream sediments during the national inventory (Source: BRGM report RP53546FR 2005)

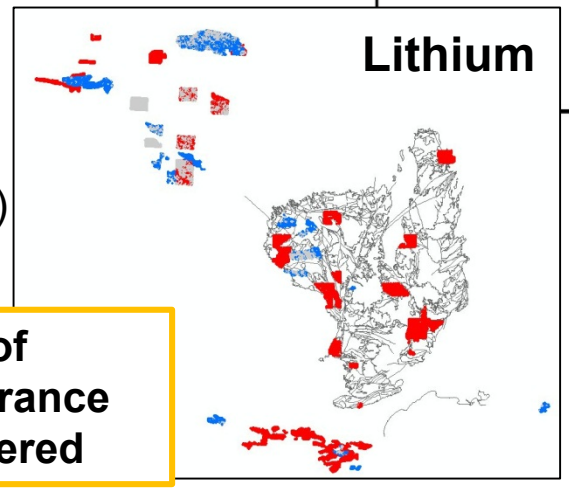


Oil shock in 1973 → Government inquiry into the supply of raw materials for French industry

The Ministry of Industry assigned the **BRGM**, as part of its public service mission, to realize an "**Inventory of Mineral Resources in the National Territory**" (1975-1991 metropolitan ⇨1995 in some overseas territories as French Guiana):

- Assess the **French raw material potential**
- **Promote** mineral exploration and production





Geochemistry

BRGM		
	DCP	234 379 éch
	ICP	34 999 éch
	Quanto	10 122 éch
	3 à 7 élém.	4 935 éch
	Total	284 435 éch
	Number of samples	

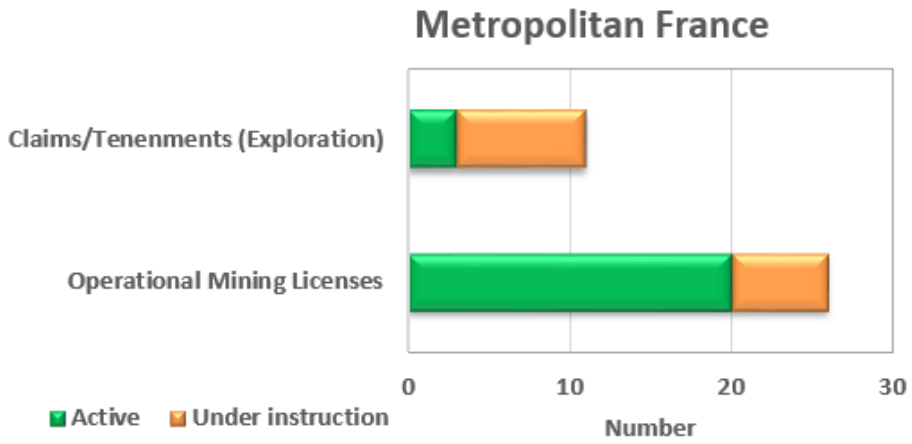
- Strategic prospecting campaigns
  - "Stream sediments" (~285,000 samples over 102,000 km^2)
  - "Alluvial" complementary surveys (97,000 samples)

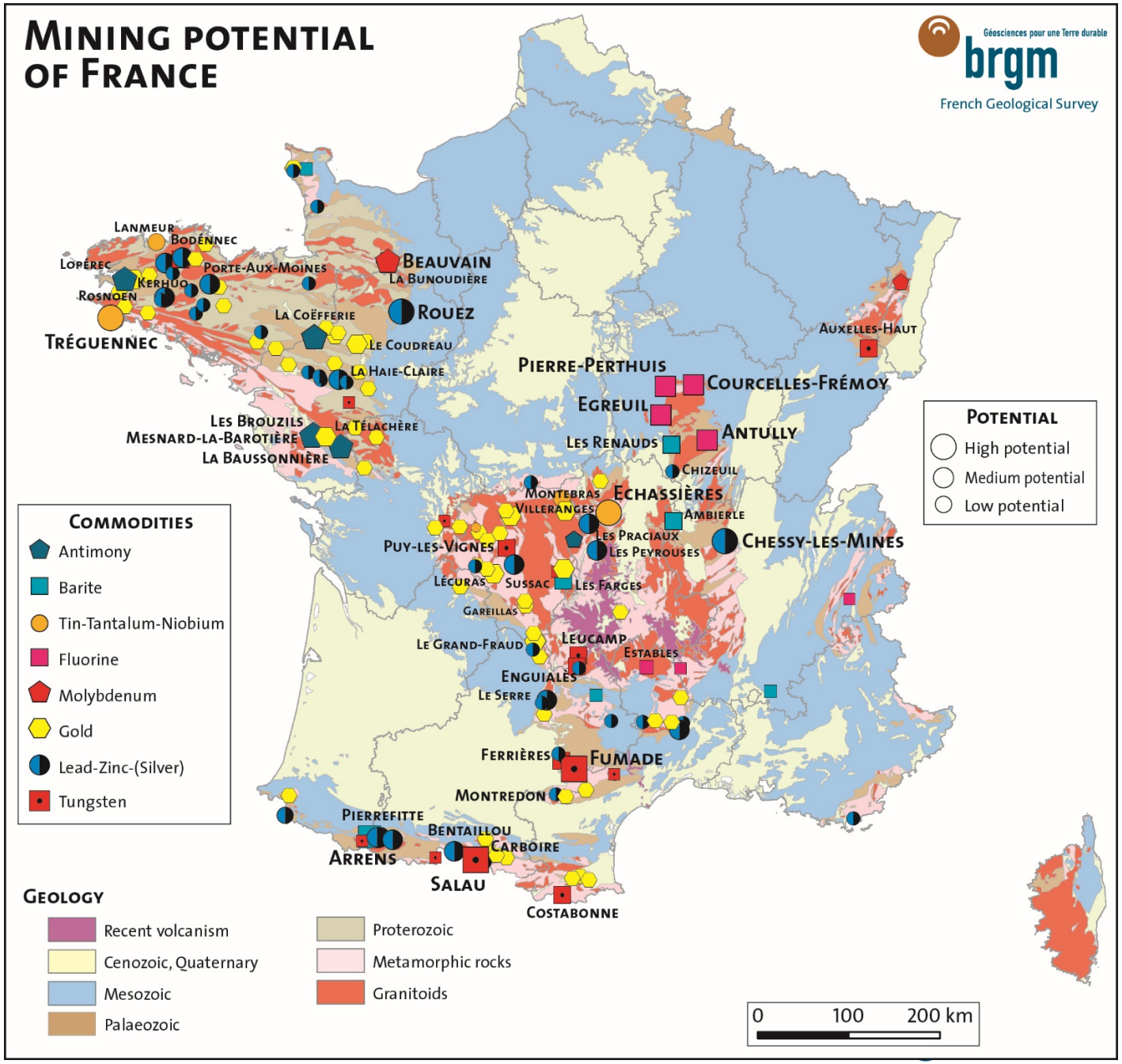
⇨ **Discovery of 2,000 new occurrences**

Only 20% of metropolitan France has been covered

Mining potential of Metropolitan France

- 176 licenses in France (metropolitan+overseas)
- **20 active mining licenses in metropolitan currently valid and/or in operation** (salts, bauxite, fluorine, bituminous carbonate schists)





Source: www.mineralinfo.fr/page/lactivite-miniere-en-france and camino.beta.gouv.fr (data consulted on 15/06/2021)

Criticality assessment for France

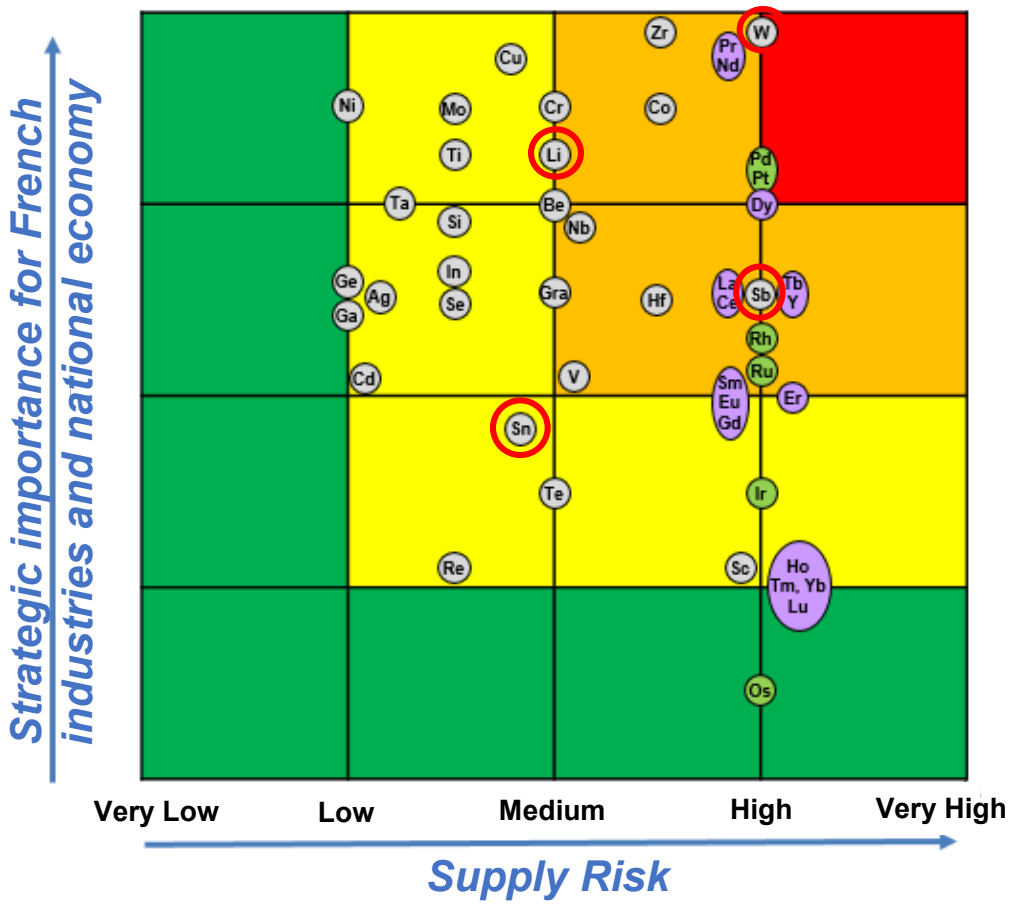
- **34 commodities** studied since 2015 for the **French National Comity for Strategic Metals (COMES)**

comes
Comité pour les métaux stratégiques

Key factors:

- ***Supply Risk Analyses***:
  - Identified reserves of primary resources and location of deposits
  - World production (mining and metallurgy : producers and processors with their strengths and weaknesses)
  - Risk factors (industrial, environmental, geopolitical and societal)
- ***Analysis of demand:***
  - Global consumption (uses and user industries)
  - Mapping industrial channels and positioning of the players (partnerships, competition, monopolies, etc.)
  - Assessment of a companies' exposure to risks (fluctuation of raw materials' prices, regulations, government policies, etc.)
  - Recent market developments and impacts on users (substitutions, technological changes, new markets, recyclability…)

BRGM, criticality assessment for France updated in december 2020



Source: http://www.mineralinfo.fr

Critical Raw Materials are both of high **economic importance** for the considered state/sector/industry and have a **high risk of supply disruption**

minéralinfo
LE PORTAIL FRANÇAIS DES RESSOURCES MINÉRALES NON ÉNERGÉTIQUES

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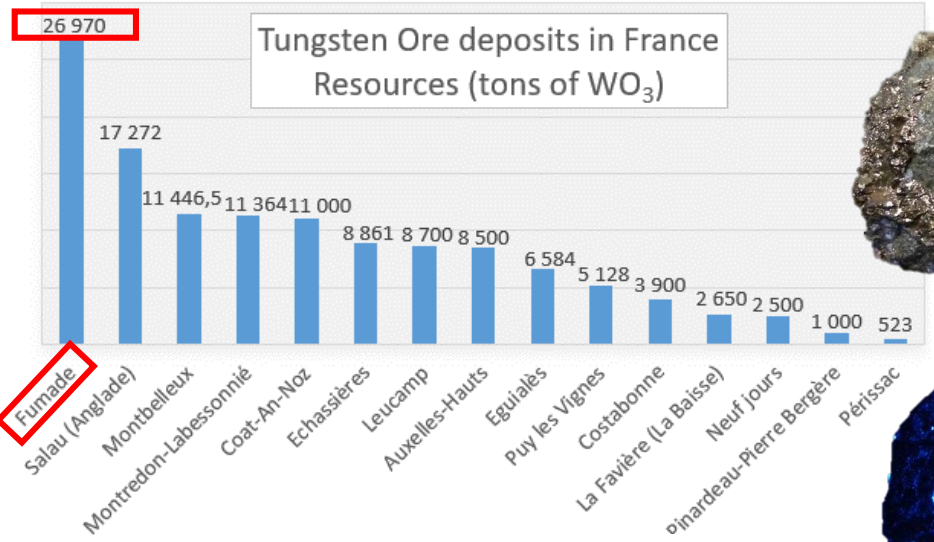
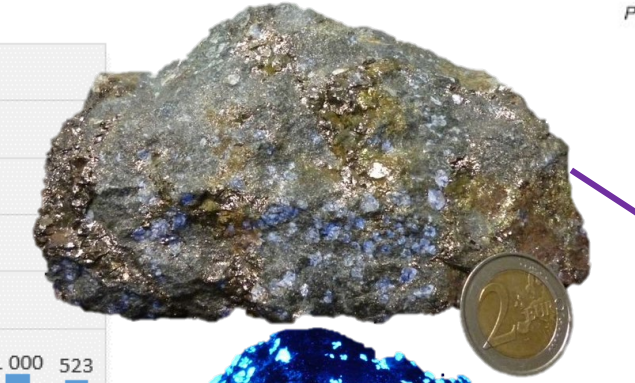
Potential for some selected critical metals in metropolitan France

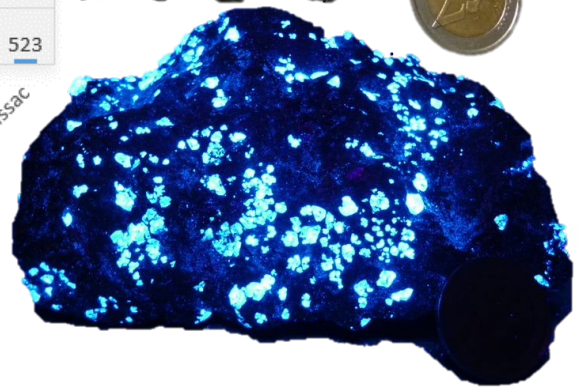
Tungsten (W) in France

- Uses: hard metals/cemented carbides in steels, superalloys and wear-resistant (drilling and cutting tools, automotive components and aerospace/defense)
- Many known resources in FR (but almost no prospection since 1990)
- 2 distinct deposit types
  - Skarns
  - Quartz-Wolframite veins
- 2 distinct bearing minerals:
  - Scheelite ($CaWO_4$)
  - Wolframite $(Fe,Mn)WO_4$
- Past production: 25 361 t WO_3 (12 415 t Salau)

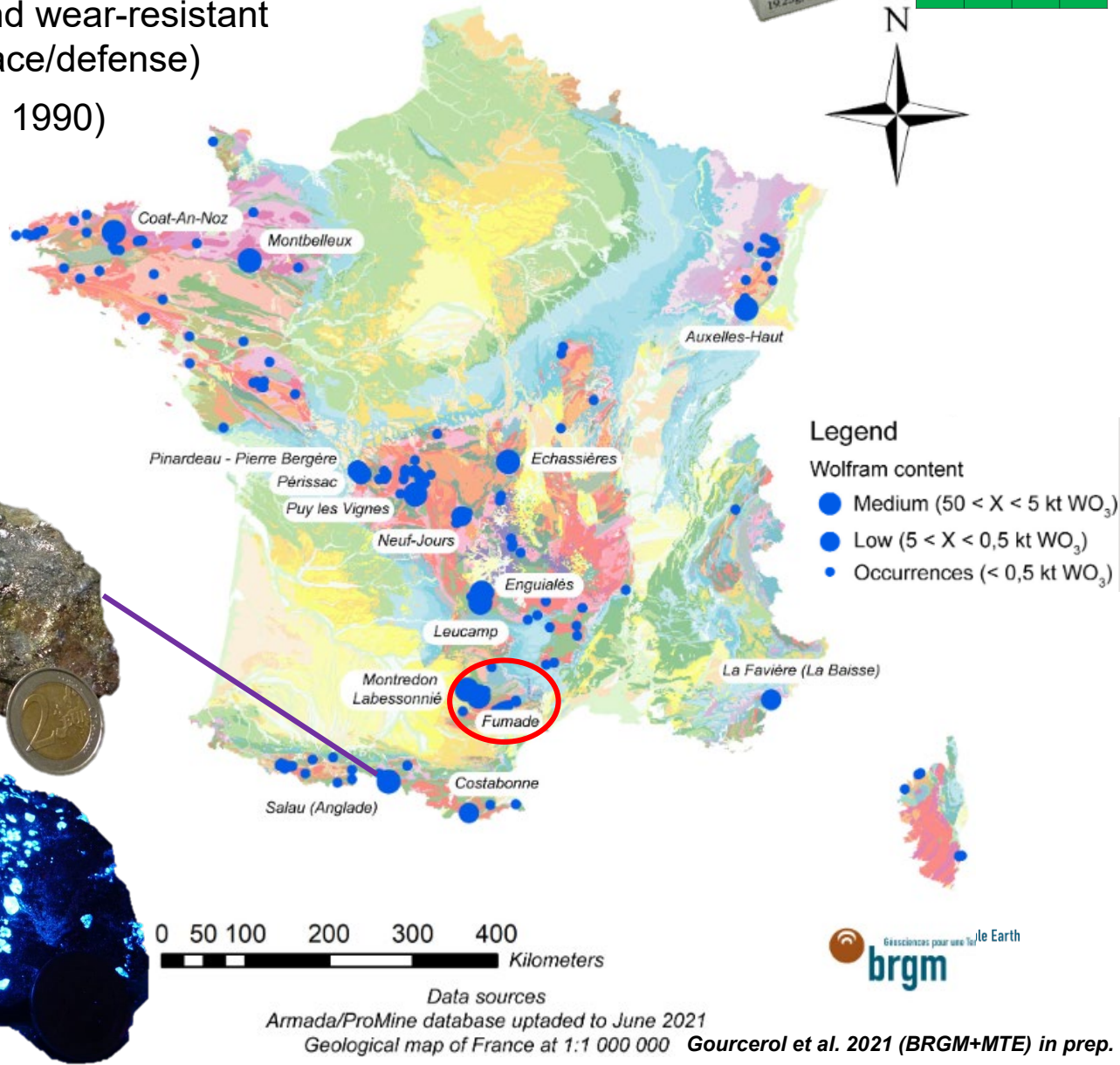
France was an important producer: 3rd in Europe until 1986





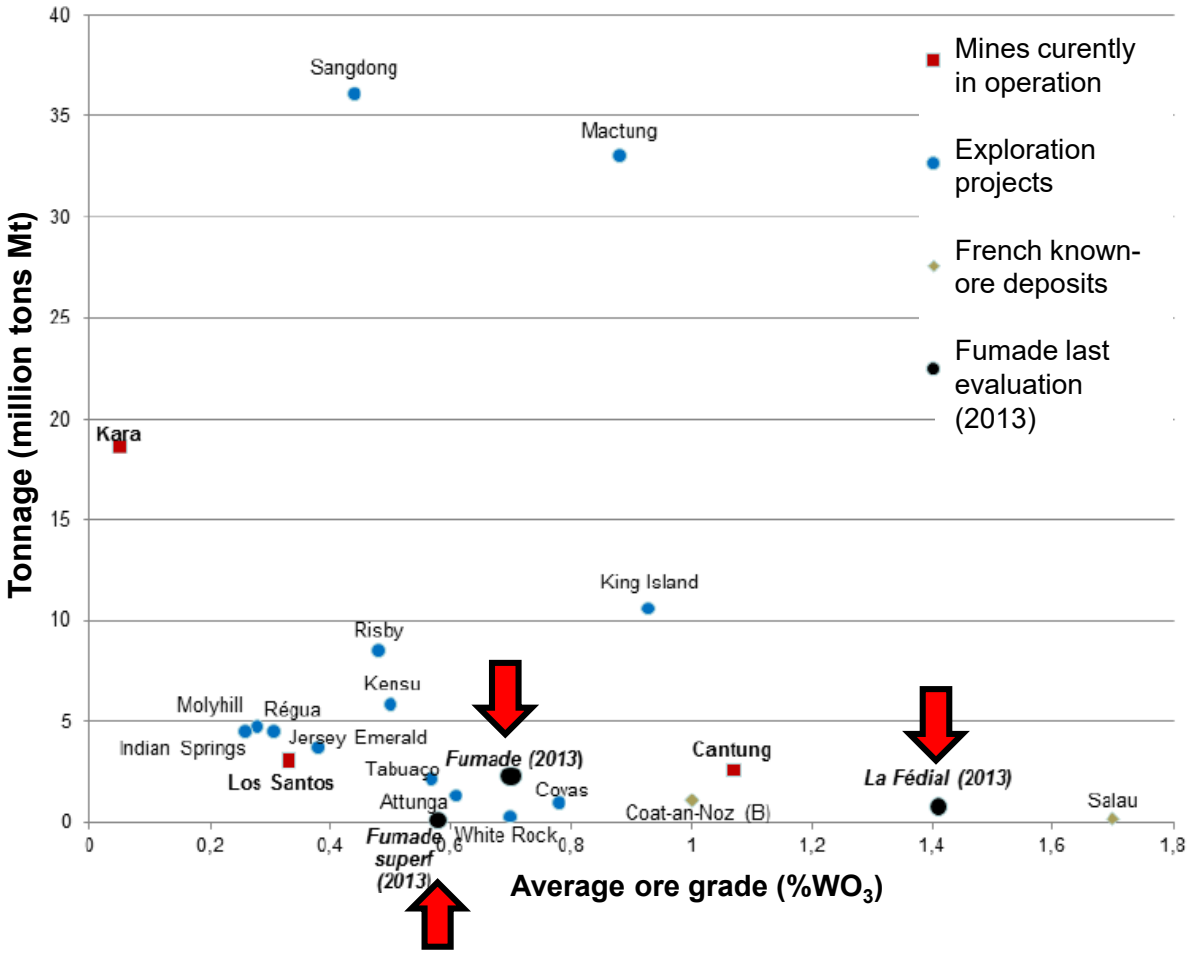


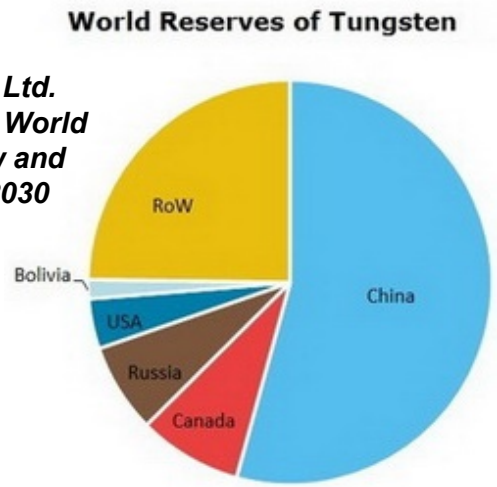
Scheelite ore under UV from Salau deposit © Picault M.



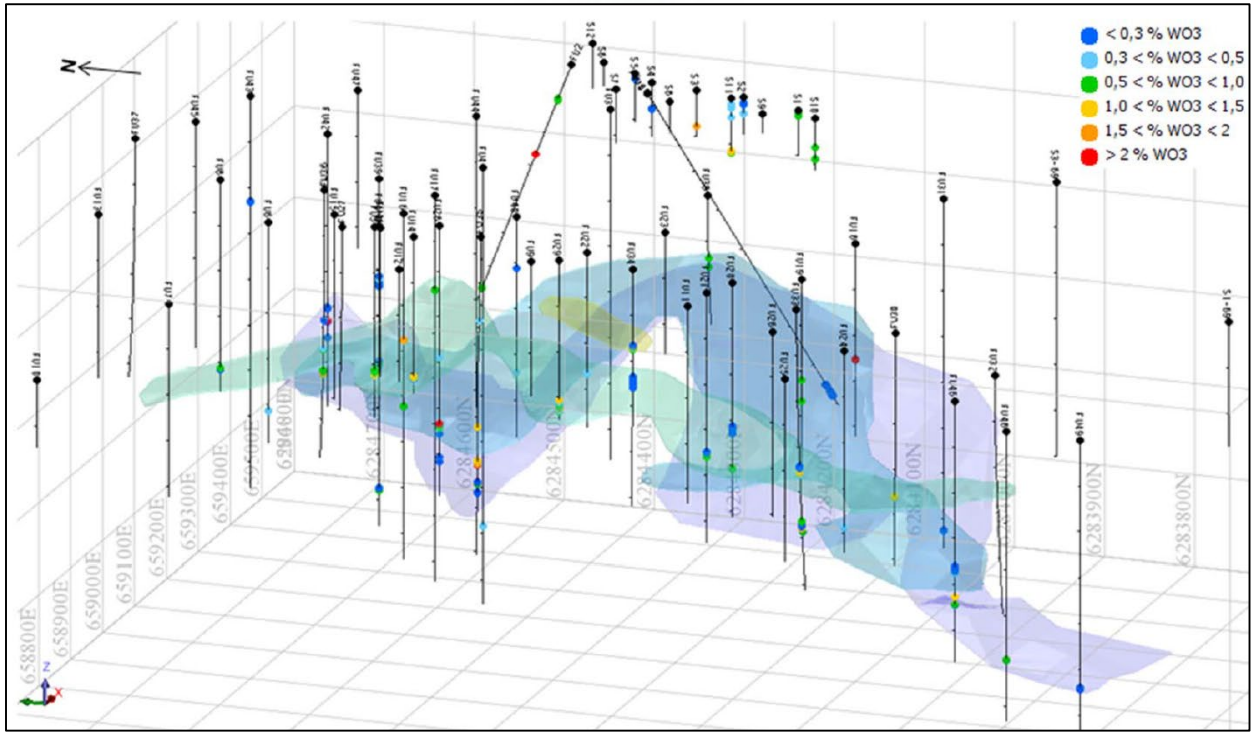
Gourcerol et al. 2021 (BRGM+MTE) in prep.

- **Fumade W skarn deposit in Tarn department:** ore grades vs. tonnage and comparison with other skarn deposits (Audion, 2013 ; BRGM/RP-62718-FR)





Source: MRC Ltd. Tungsten: 2021 World Market Review and Forecast to 2030



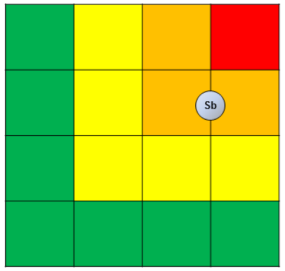
Fumade 3D-modeling of mineralisation zones with respective average grades (%WO_3) and historical drillholes-collar traces

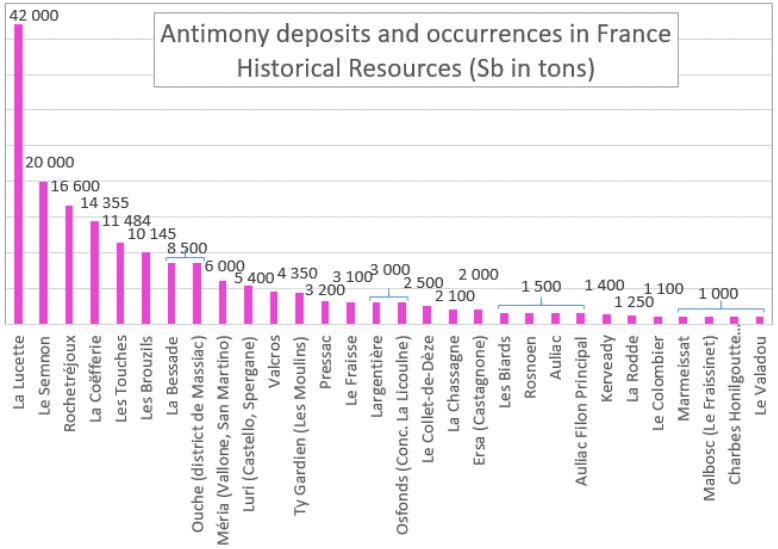
Antimony (Sb) in France

- Uses : flame retardant materials, batteries Pb-Sb, insulating sheathing, plasturgy additive…

- 3 main deposit types:
  - Quartz-Stibnite veins
  - By-product of Pb-Zn stratiform deposits
  - Disseminated in Carbonates
- 2 distinct minerals:
  - Stibnite (Sb_2S_3)
  - Berthierite ($FeSb_2S_4$)
- Past production: 125 203 t Sb (42 000 t Sb for La Lucette)

https://aureole.brgm.fr/



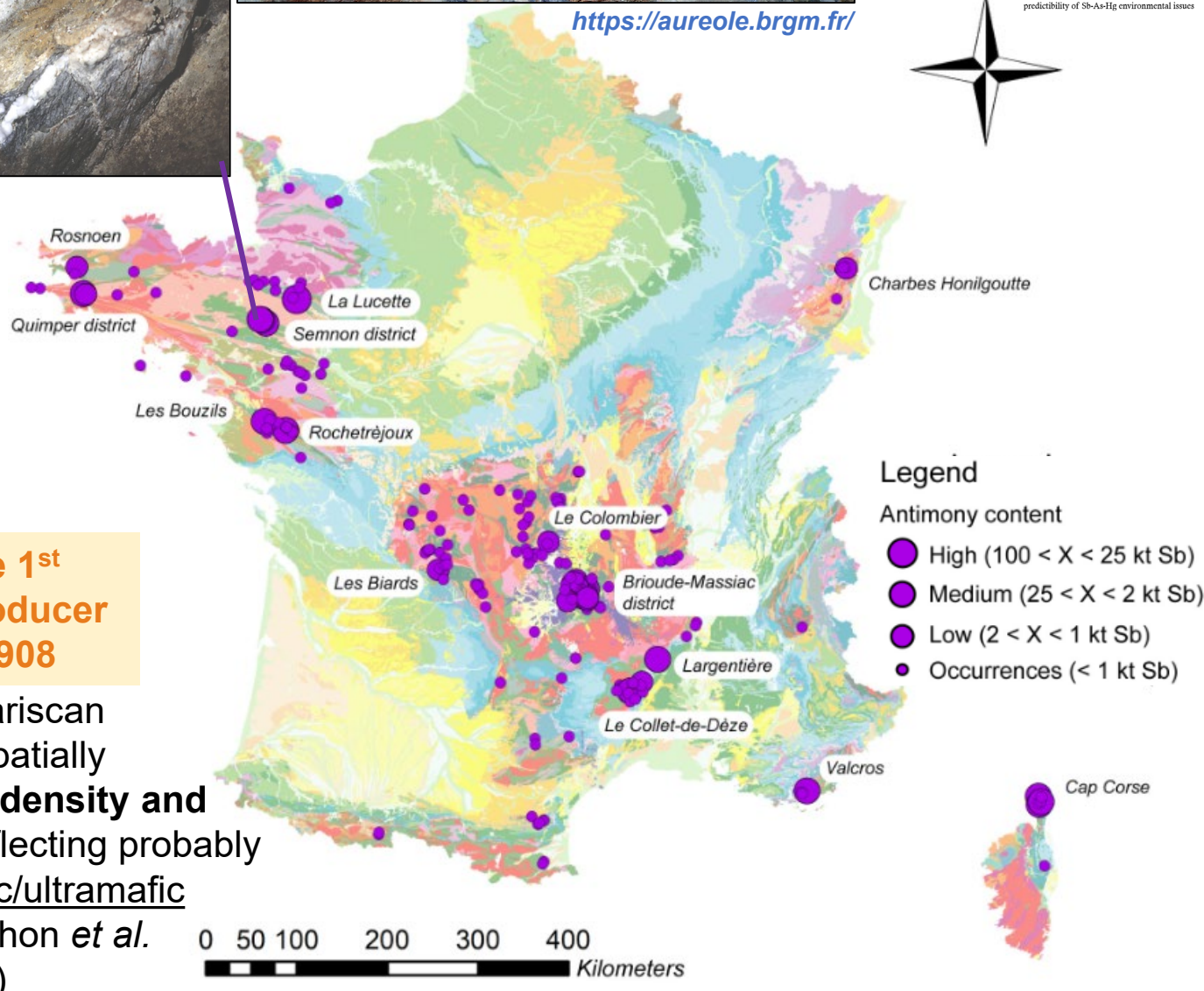


BRGM — FRENCH NATIONAL GEOLOGICAL SURVEY

France was the 1st leading World producer from 1890 to 1908

Sb deposits in the Variscan Armorican belt are spatially correlated with **high-density and magnetic zones**, reflecting probably the presence of mafic/ultramafic bodies at depth (Pochon *et al.* 2016, *Terra Nova 28*)

⇨a **key for Sb prospecting** in deformation belts



Gourcerol et al. 2021 (BRGM+MTE) in prep.
Data sources
Armada/ProMine database uptaded to June 2021
Geological map of France at 1:1 000 000

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

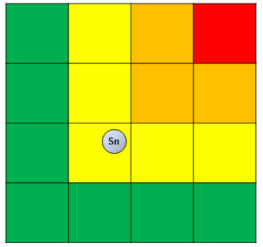
brgm Géosciences pour une Terre durable

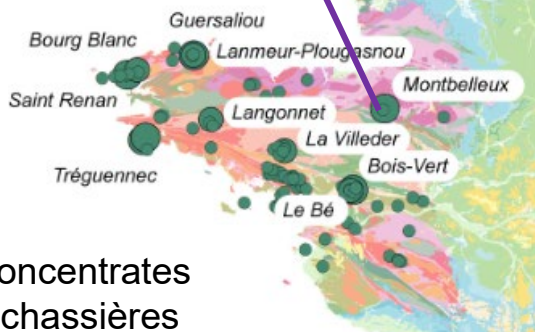
Tin (Sn) in France

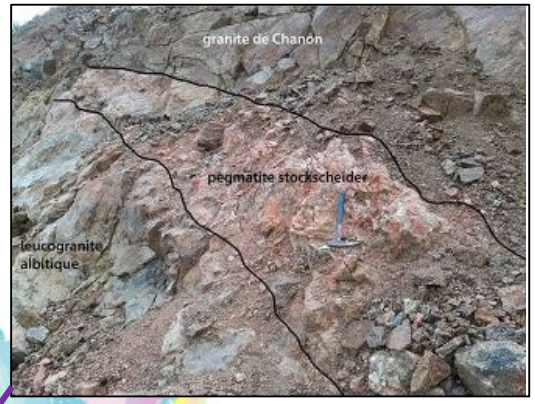
- Uses: electronic welding, semi-conductors, alloying, coatings and powder applications
- Deposit types:
  - Qtz-veins stockwerks or pegmatites-hosted cassiterite (SnO_2) related to emplacement of peraluminous granites
  - Stockscheiders
  - Greisens (Sn-W)

IMERYS CERAMICS FRANCE produces few tonnes of Sn-Ta concentrates (cassiterite-tantalite) as by-products of kaolins in the quarry of Echassières

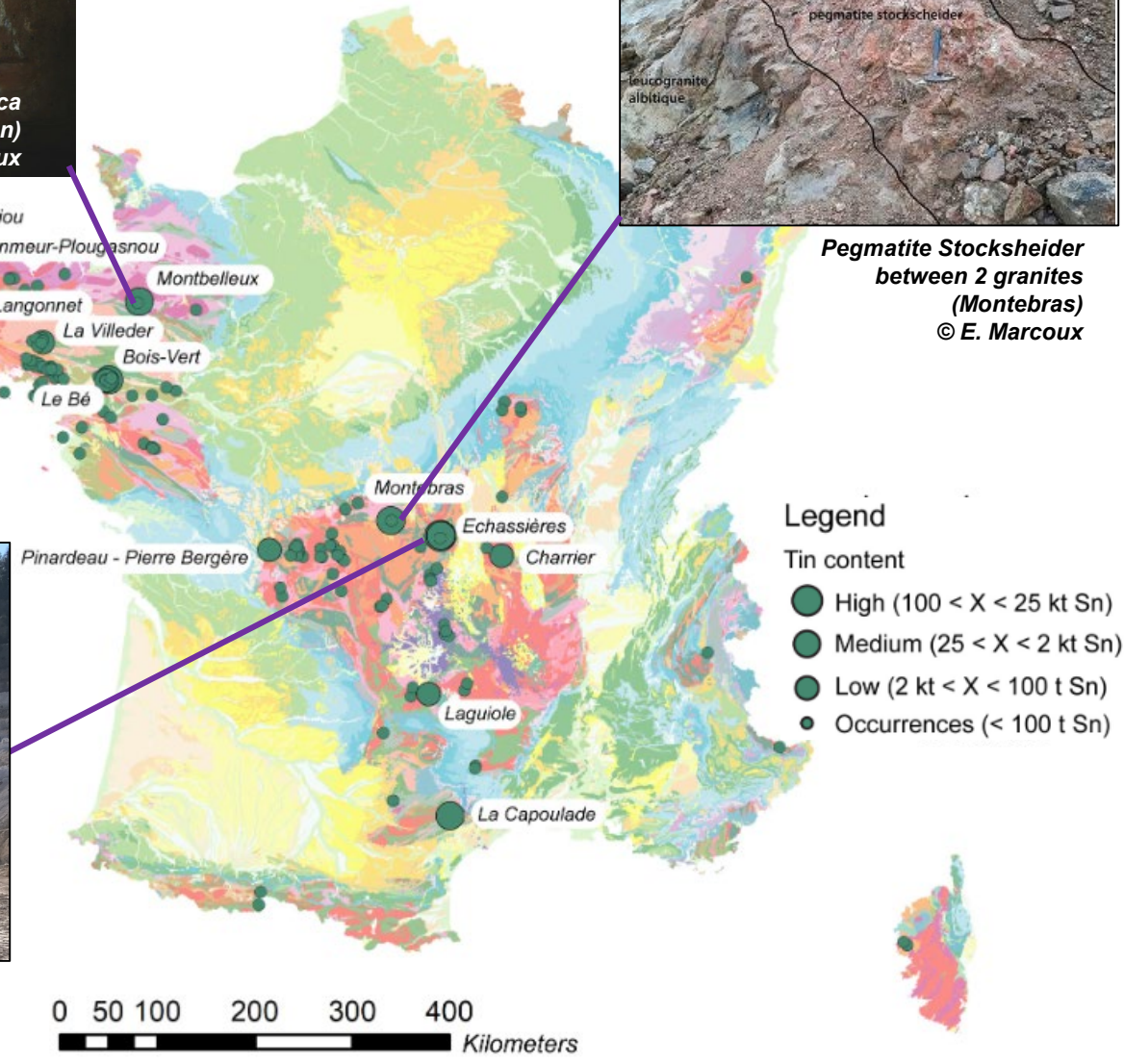
Cassiterite in silica (La Villeder, Morbihan) © BRGM - Urbain de Cayeux

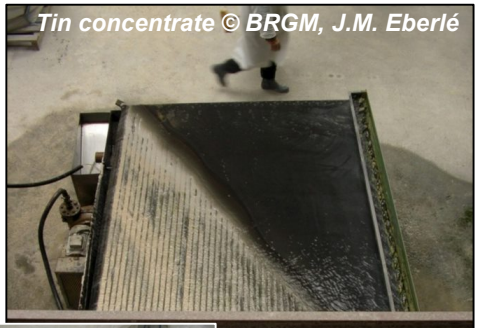






Pegmatite Stocksheider between 2 granites (Montebras) © E. Marcoux





Tin concentrate © BRGM, J.M. Eberlé

Echassières quarry © BRGM, I.Duhamel-Achin

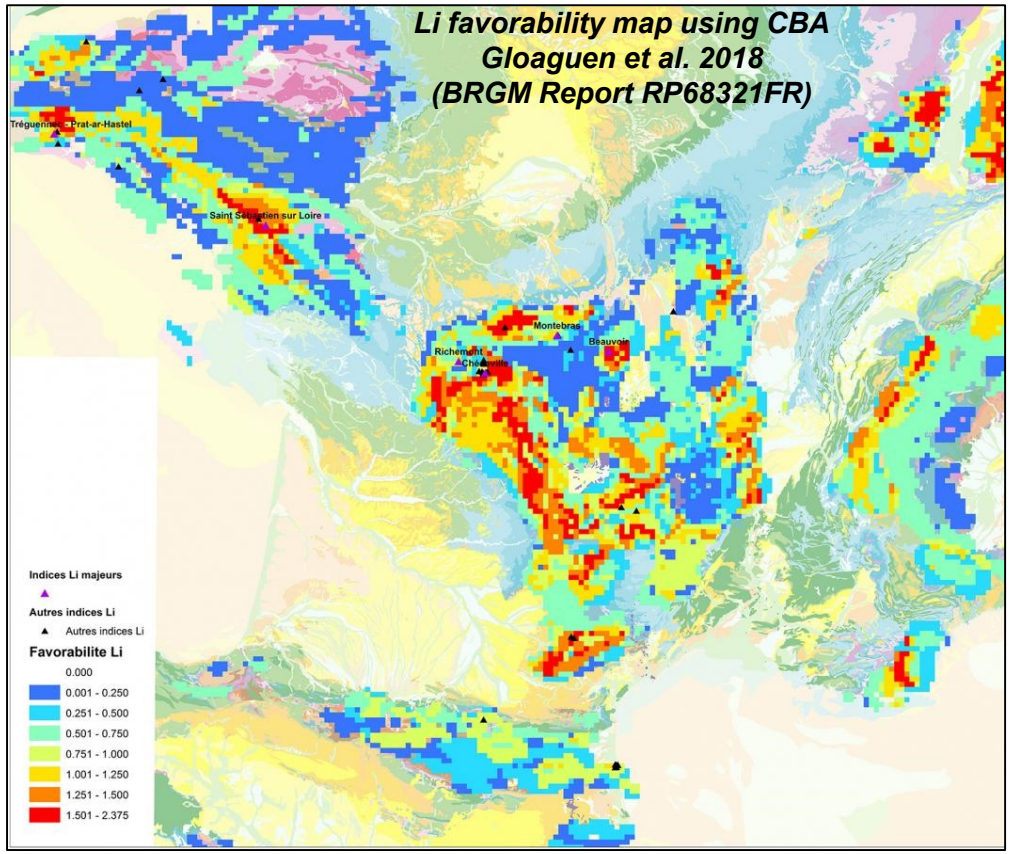
Stockwerk of Qtz-W-Sn veins La Bosse-Echassières (Gloaguen et al. 2018 BRGM/RP-67620-FR)

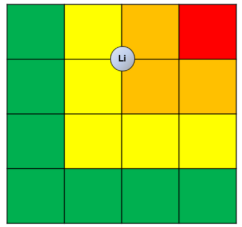
Lithium (Li) in France

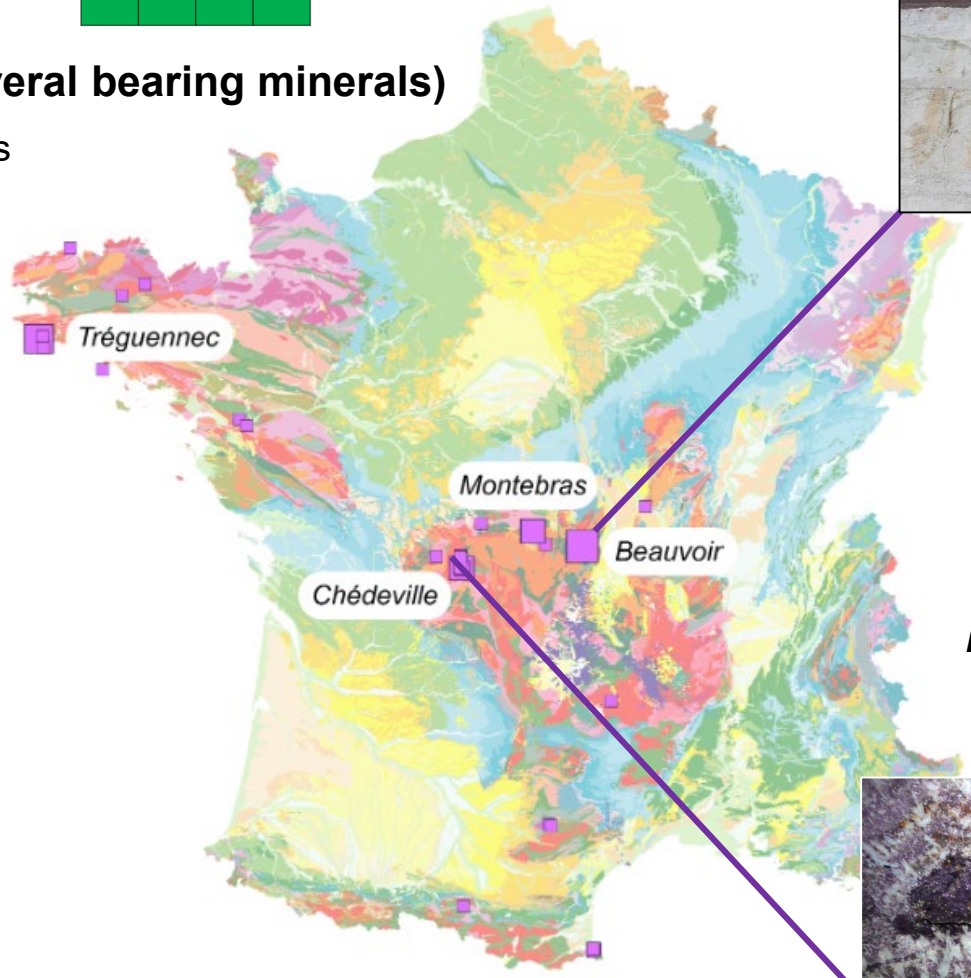
- Uses: Li-ion batteries, ceramics and glasses, metallurgy…
- Main deposit types: ▪ **Hard-rock deposits (with several bearing minerals)**

Predictive Li potential assessment in hard-rocks using BRGM's CBA method FR ⇨ EU (Gourcerol *et al.*, 2019, Ore Geology Reviews Vol.109)

IMERYS CERAMICS FRANCE explores Li in rare metal granites (Beauvoir deposit)







Legend

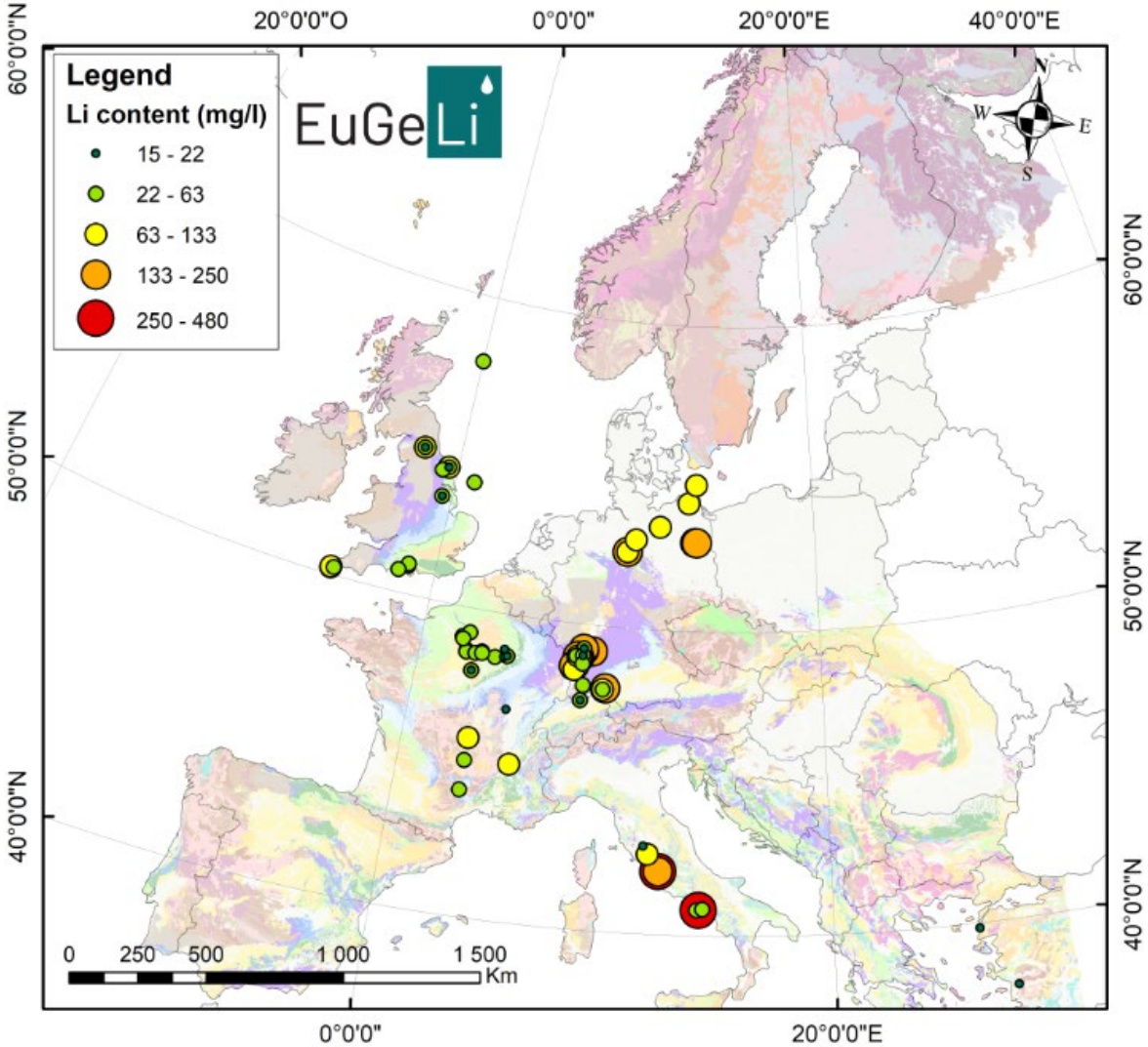
Lithium content

- High (1 000 < X > 100 kt Li_2O)
- Medium (100 < X > 50 kt Li_2O)
- Low (50 < X > 5 kt Li_2O)
- Occurrences (< 5 kt Li_2O)

Petalite ($LiAlSi_4O_{10}$)
Lepidolite
($K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$)
LCT-Pegmatite swarms, Chédeville, Monts d'Ambazac
(Limousin department, France)
© BRGM, Eric Gloaguen

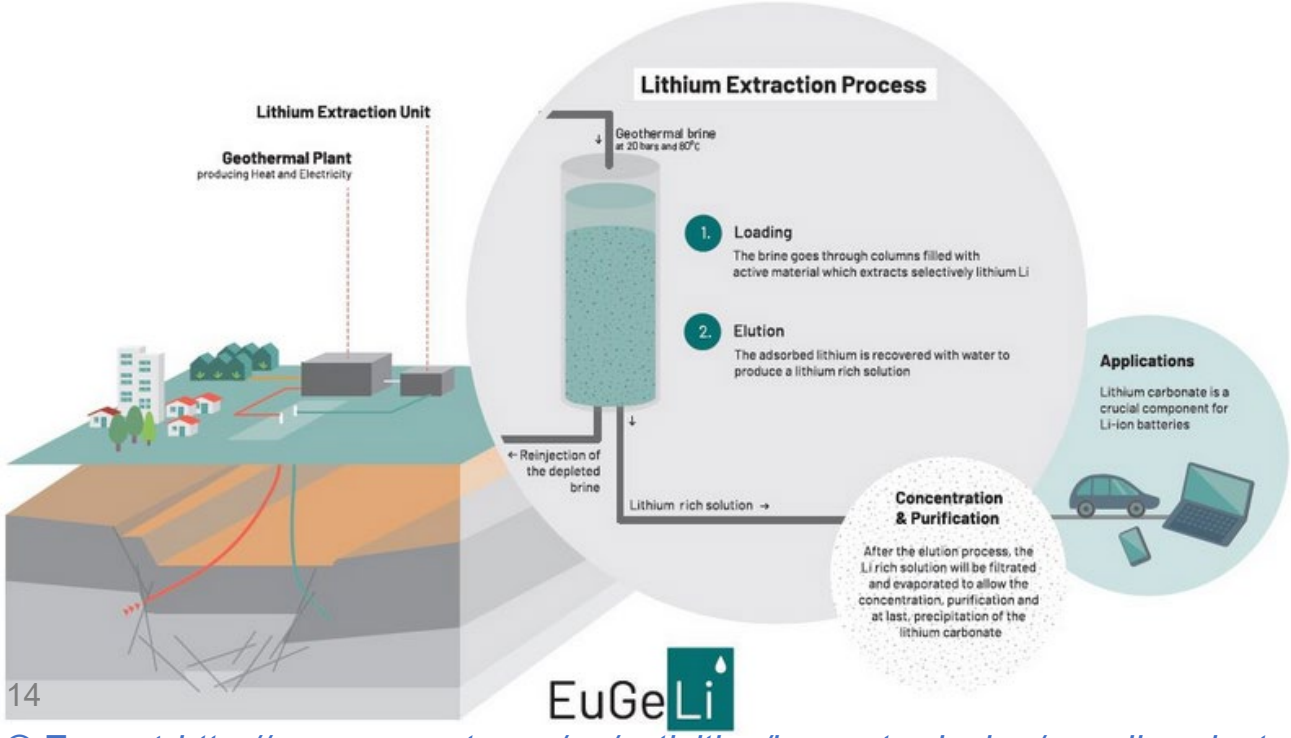
- **Deep geothermal brine deposits**

EIT Raw Materials EuGeLi project coordinated by ERAMET (Millot *et al.*, AGU 2020) + following presentation by Clio Bosia for Lithium de France)



Gourcerol et al. 2021 in prep.

The Soultz-sous-Forêts site in Bas-Rhin, France
© BRGM - Albert Genter



Source : © Eramet http://www.eramet.com/en/activities/innovate-design/eugeli-project

Outlooks

Weaknesses Strengths and Future Opportunities?

- **Evolving interest in metals** regarding technological innovation and end-uses driving consumption
  - Relatively old aerial geophysical surveys over metropolitan France for mining exploration/deep potential
  - Limited historical data on CRMs in past mineral resource inventories
  - No systematic multi-elemental geochemical analyses during exploration campaigns
  - Evolution of geological knowledge and ore genetic models

⇨ **Importance of maintaining research and exploration in France**

⇨ **Reprocessing mining wastes and tailings from old historical mining sites with more efficient technologies**

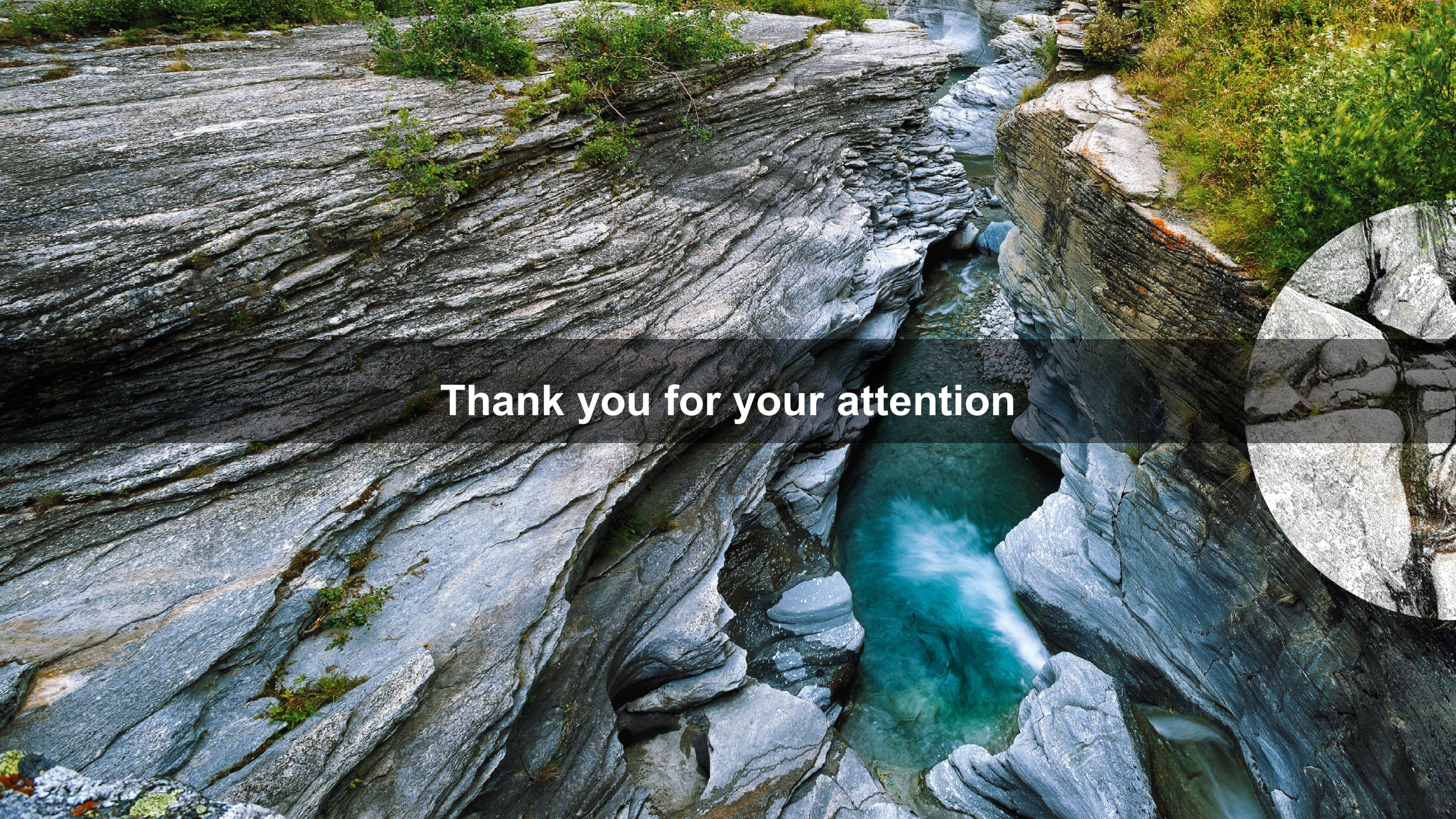
- **Supply risk disruption evolves, especially with the pandemic context** (pressure on market, variability of prices and demand, new protection policies, transport restrictions, increase of operational costs…)

- Evolution of the state's strategy according to **economic importance** and **industrial dependency**

⇨ **relocation of primary production and value chains for some very critical commodities ?**

- **Reappraisal of the French metropolitan potential in selected critical metals is essential and promising**:
  - W, Sb, Sn in Variscan orogenic belts (Armorican and Central Massives)
  - Li in hard rocks and geothermal brines

- Legal mining **framework policy** is **currently reassessed** by the French Government (2021)



Thank you for your attention