DiSTAR Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Geological investigation and exploration targeting of Critical Raw Materials

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The Team of Economic Geology and Mineral Deposits

- Profs:
  - Nicola Mondillo
  - Francesco Putzolu
  - Giuseppina Balassone
- Research fellow
  - Anna Sorrentino
- Ph.D. students:
  - Francesca Corrado
  - Sebastiano Coticelli
  - Germano Solomita

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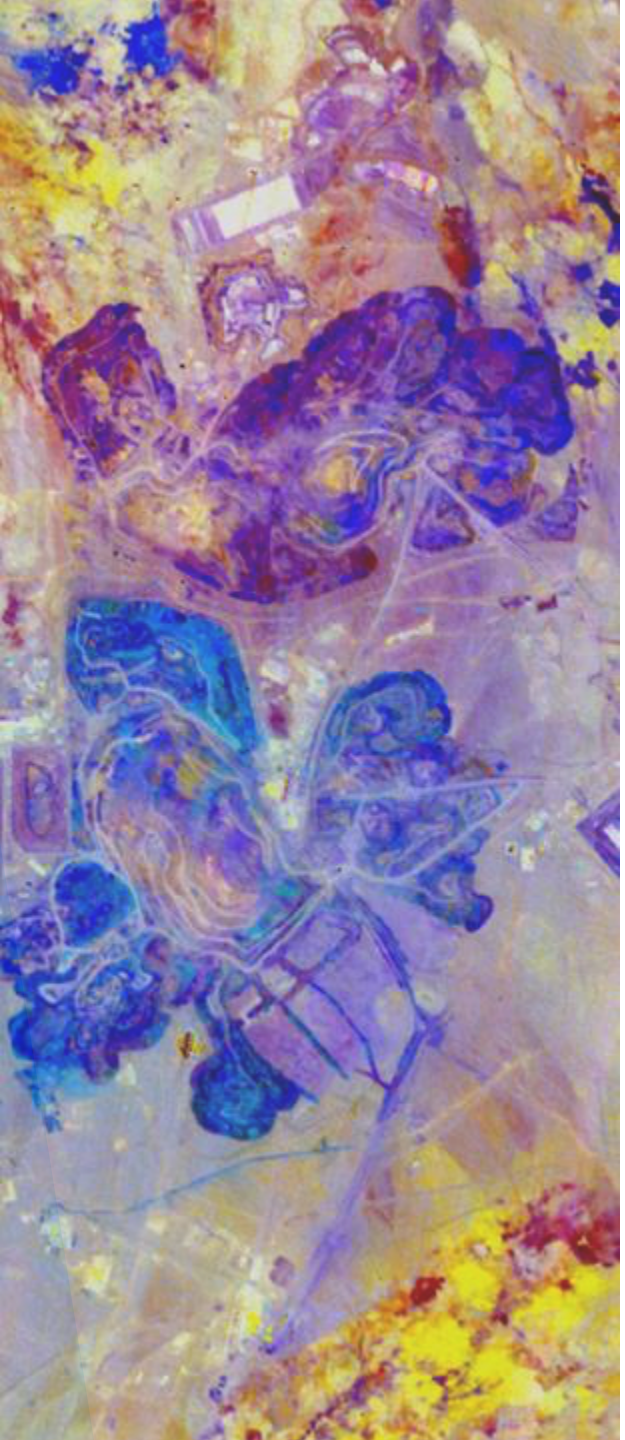


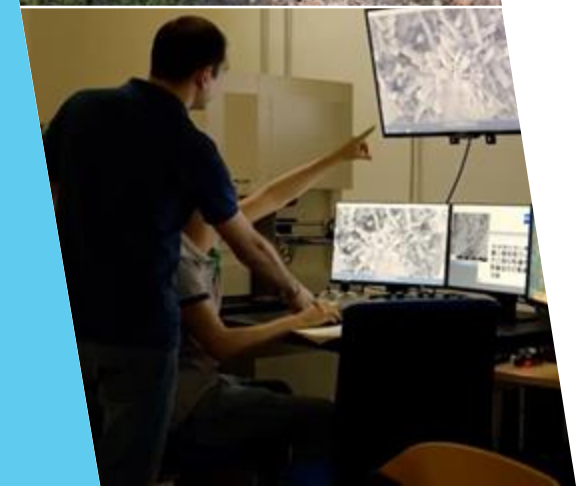
Research topics

Comprehensive characterization of mineral deposits:

- Development of **genetic models** (i.e., formation mechanisms in the frame of regional geology).
- Optimization of the **mineral production** (better knowledge of the mineralized facies, the deportment of major commodities and trace elements, etc).

Deposit types and Related CRMs:

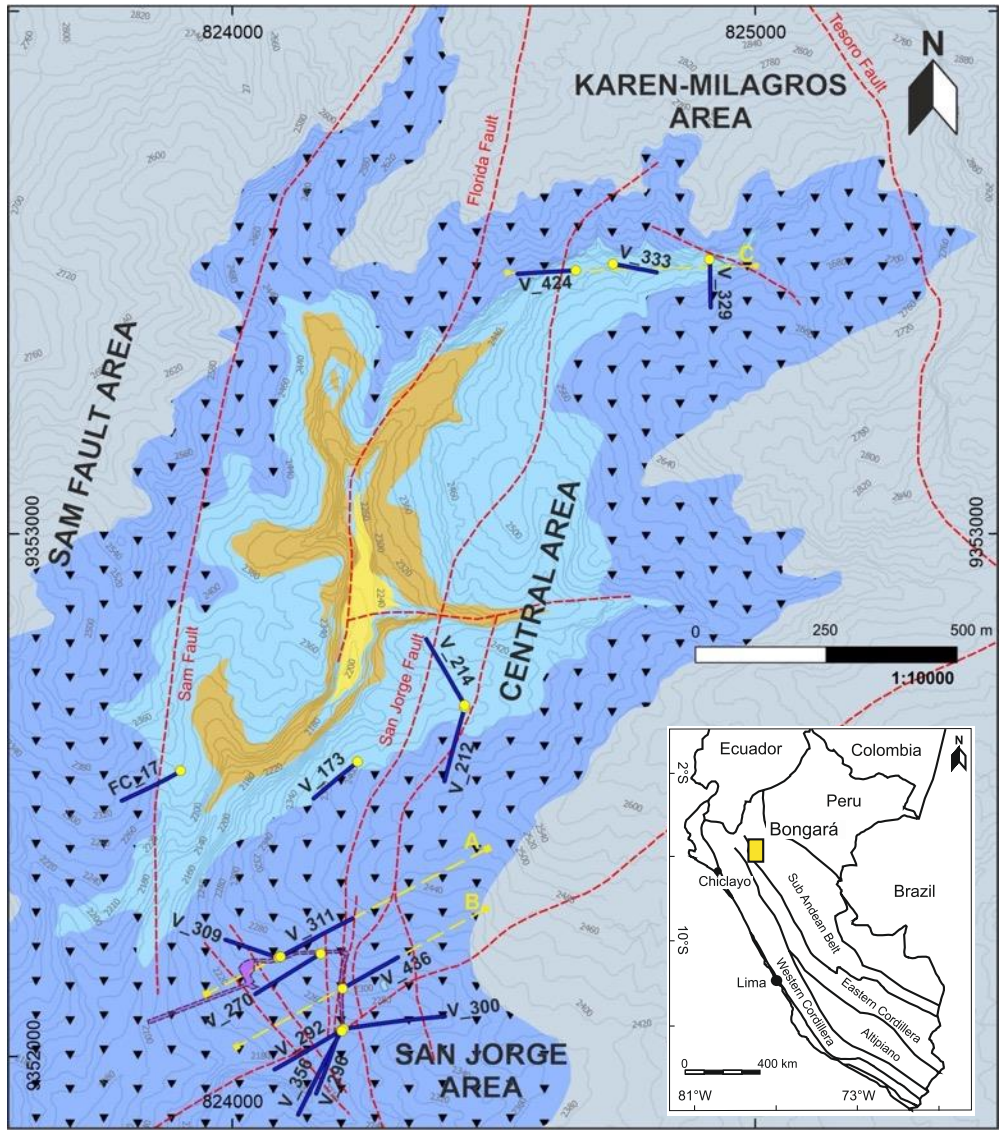
- **Zn-Pb(Ge)** and **V** deposits (sulfides and oxidized ores)
- Bauxite (**Al-REE-Sc-Ga**) and **Ni-Co-Sc** laterite deposits
- Volcano-sedimentary **Li-B** deposits
- Granite-pegmatite **Li-Rb-Cs** deposits
- Clay-hosted mineral systems
- Porphyry-**Cu** and epithermal systems
- Hydrothermal vein systems (**F-Ba-REE**)



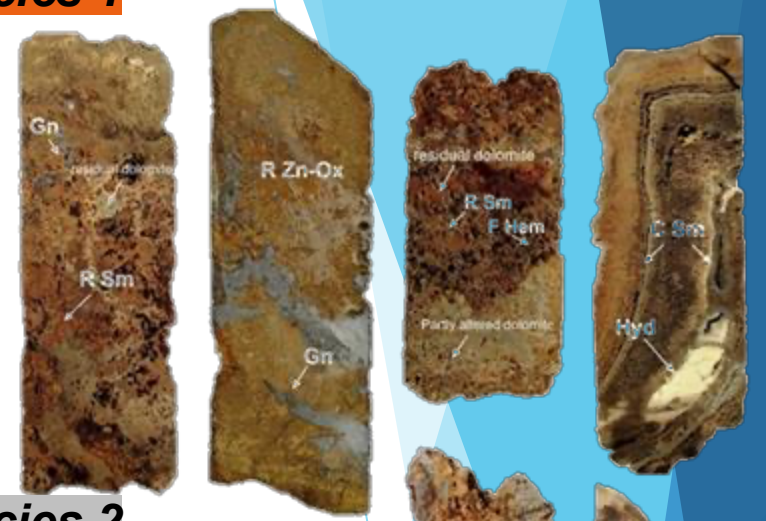
Research workflow

- Geological survey and sampling (with the support of portable instruments)
- Mineralogical and geochemical analyses (in-house facilities: XRD, ICP-OES, SEM-EDS, Mass. Spec., etc)
- Modelling of multiple source data
- Development of genetic models
- Identification of targeting features for the requested scopes (e.g., significant element association, mappable mineral assemblage)

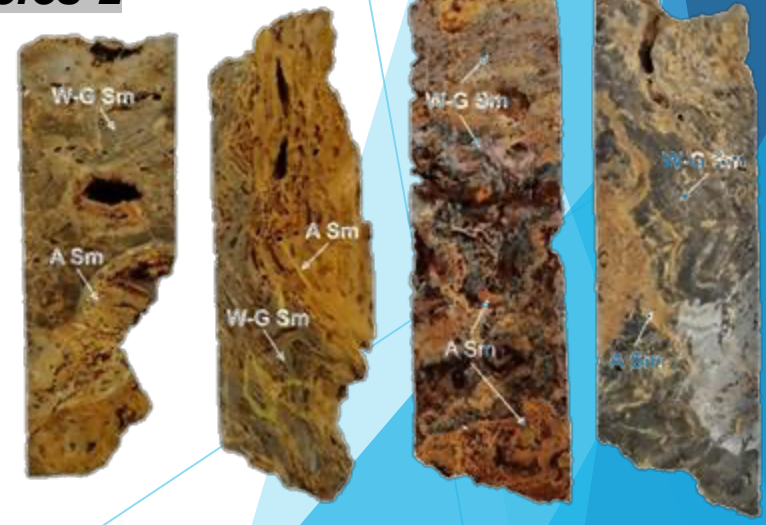
Germanium in the Zn-Pb Florida Canyon project (Peru)



Facies 1



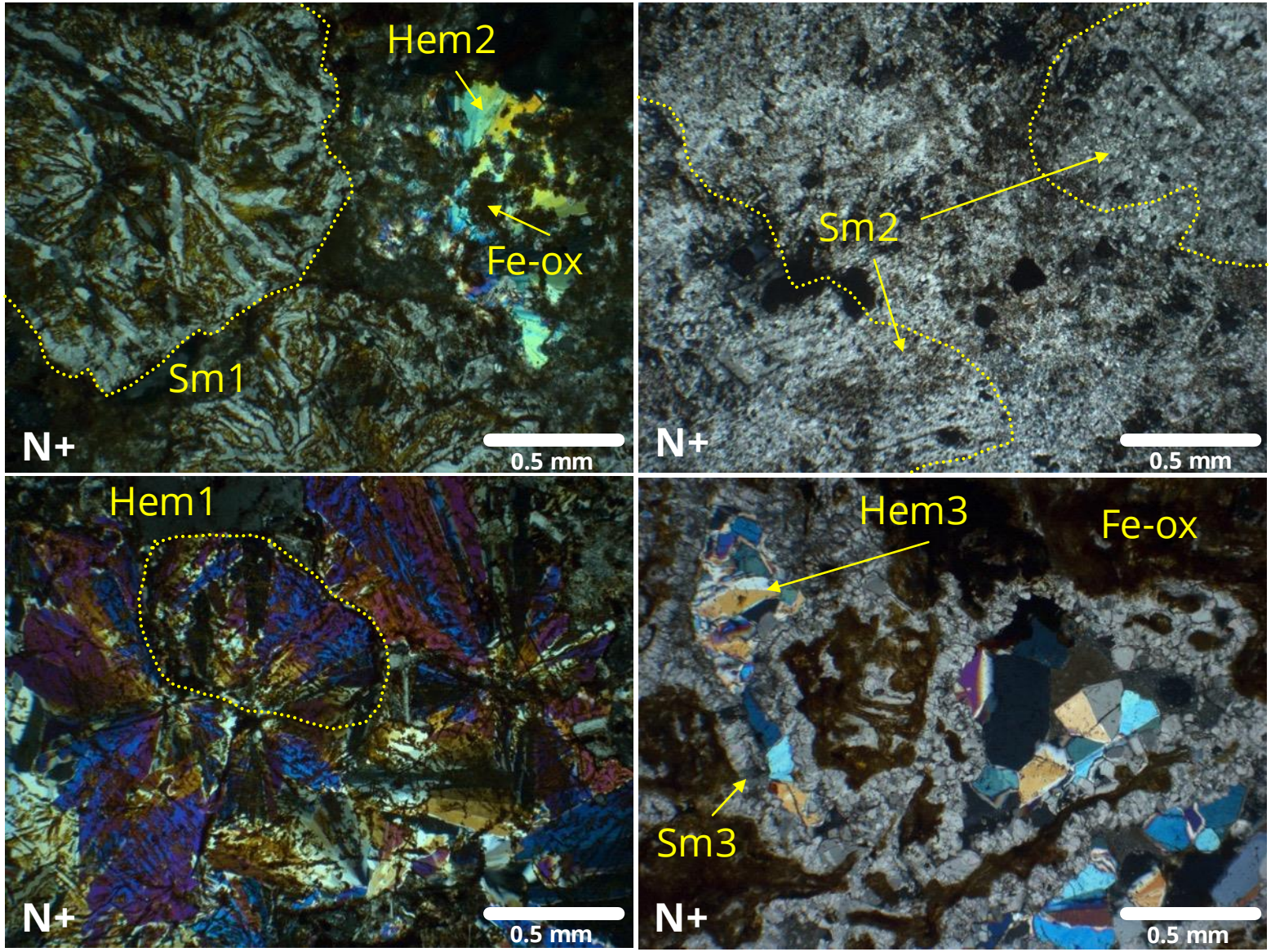
Facies 2



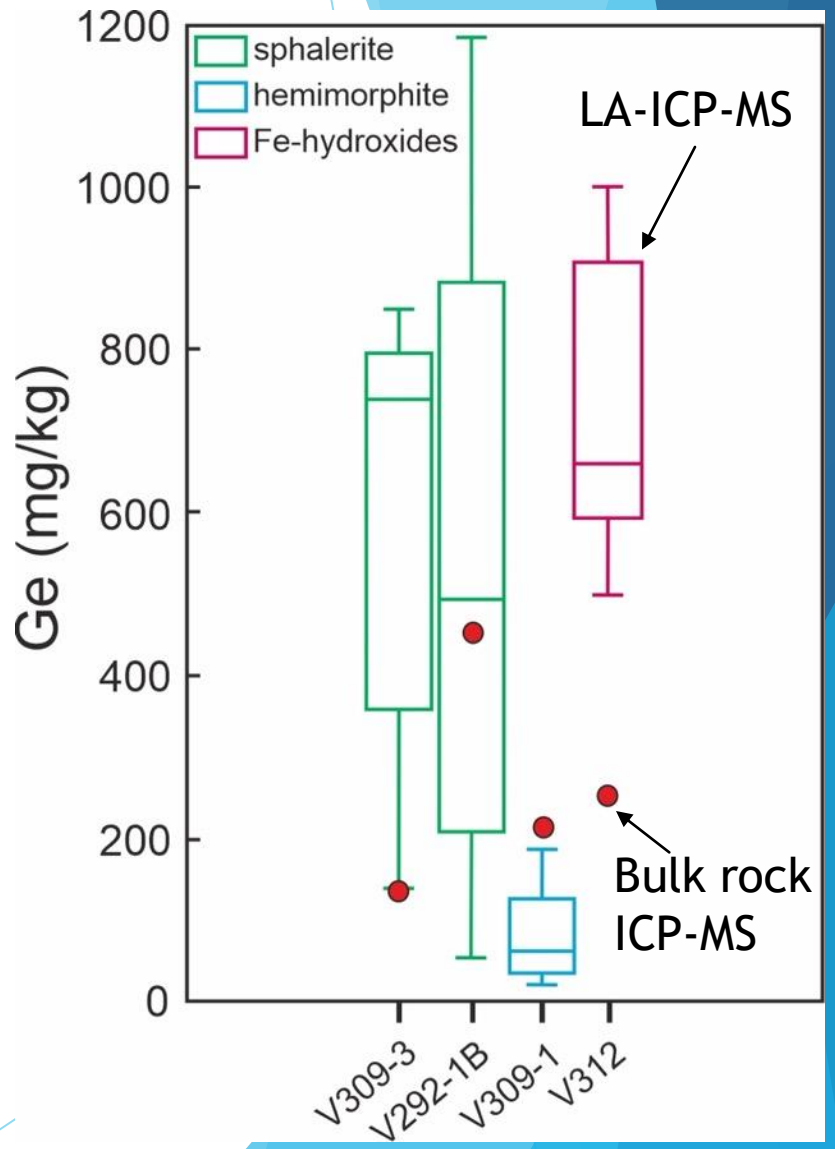
R Sm: replacive smithsonite; **R Hem**: replacive hemimorphite; **C Sm**: concretionary smithsonite; **F Sm**: open space filling smithsonite; **F Hem**: open space filling hemimorphite; **W-G Sm**: White-to-grey smithsonite; **Dol3**: hydrothermal dolomite; **Qtz**: quartz; **Sph**: sphalerite; **Py**: pyrite

https://riperu.nexaresources.com/

Germanium in the Zn-Pb Florida Canyon project (Peru)



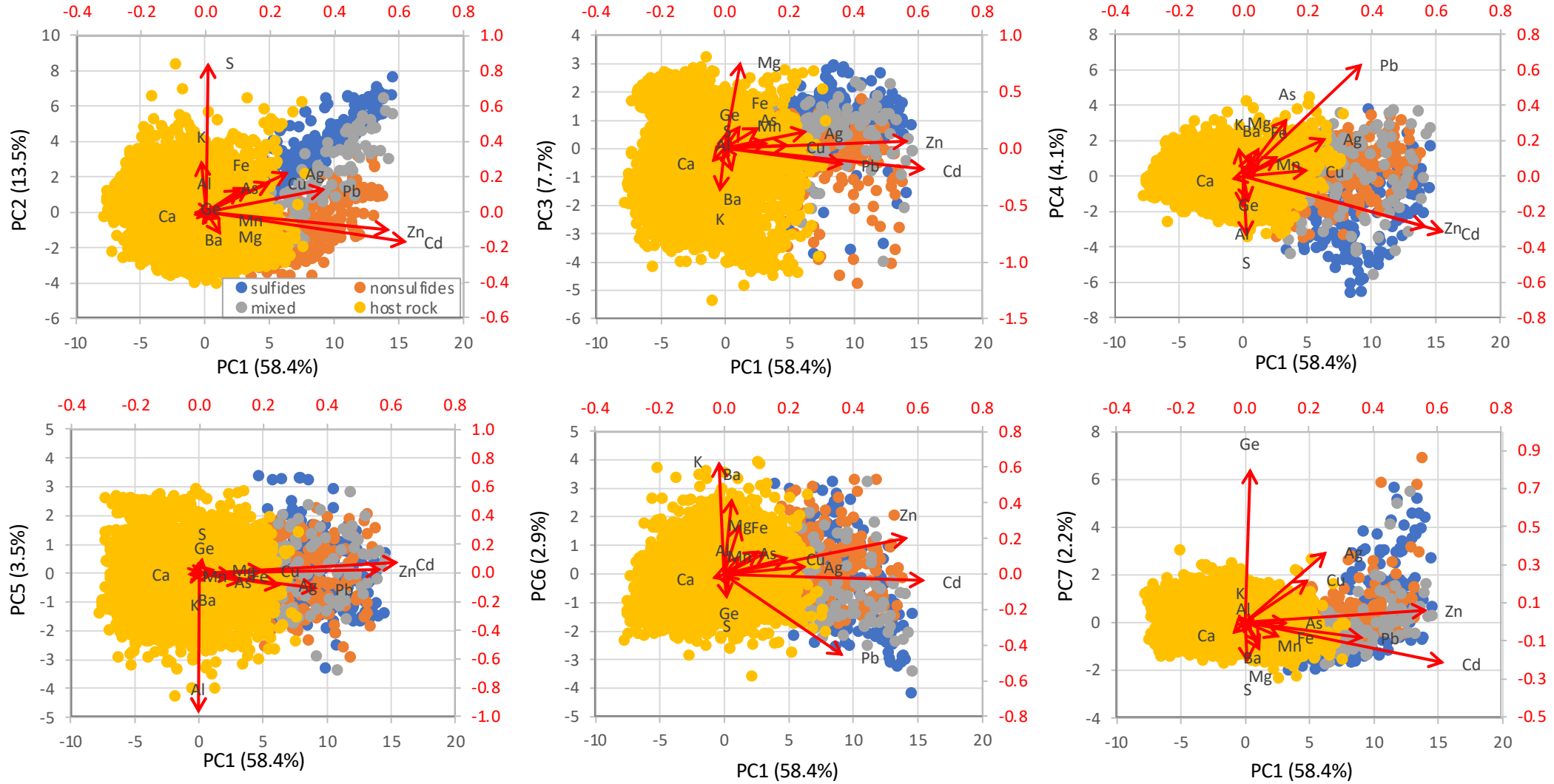
Mineralogy and textures of the Zn-ore minerals (optical microscopy).



(Chirico et al. 2022)

Germanium in the Zn-Pb Florida Canyon project (Peru)

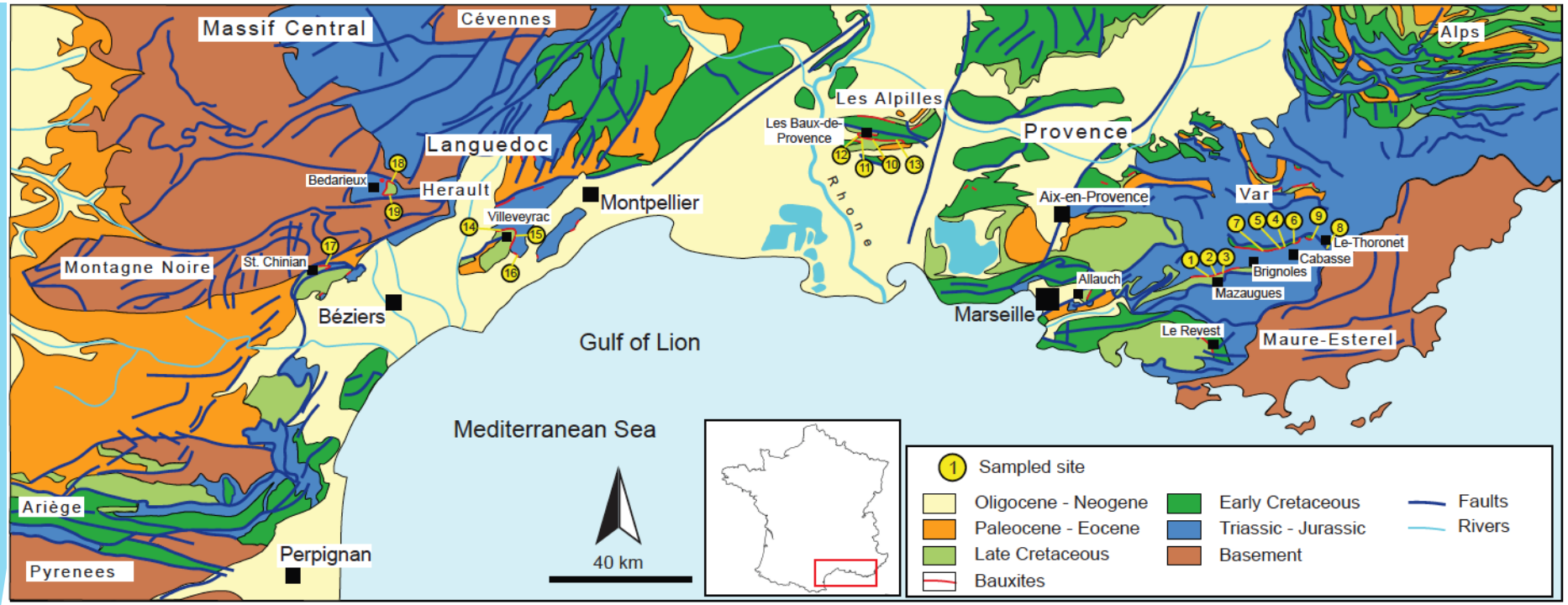
Principal Component Analysis on 4632 samples from 70 drill cores.
Variables: Pb, Zn, Fe, As, Ba, Ca, Cd, Ge, Mg, Mn, K, S, Al, Ag and Cu

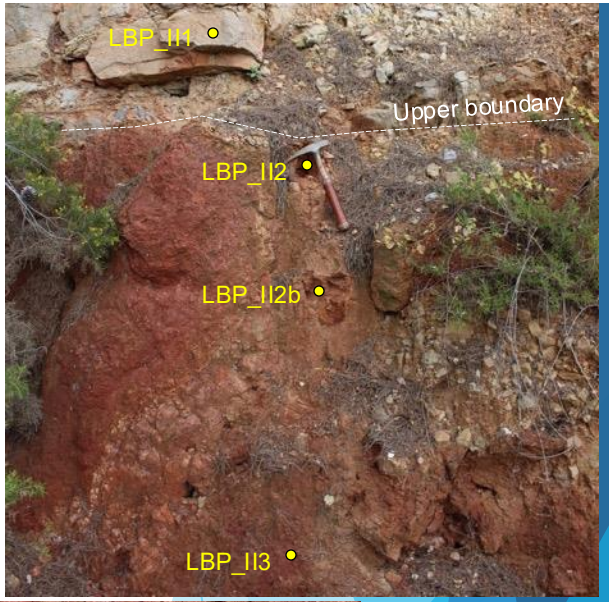


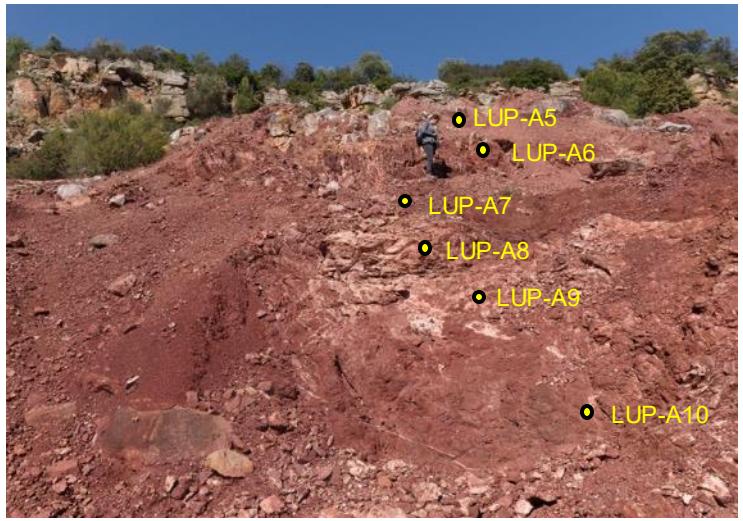
Ge was not significantly distributed with oxidized facies.

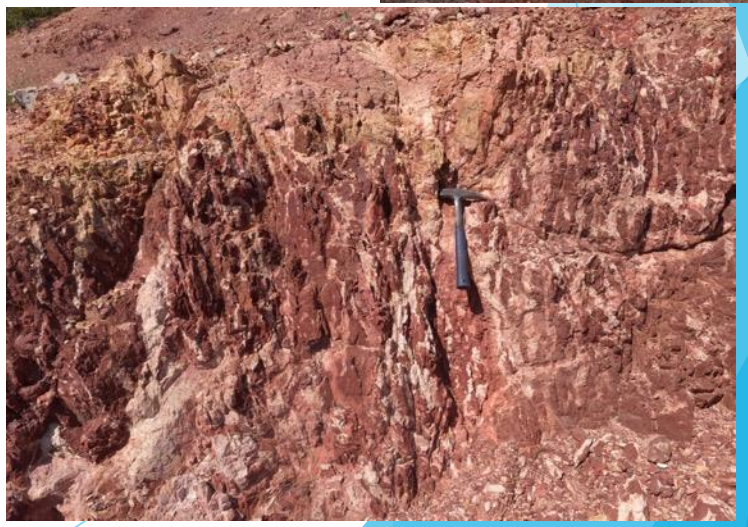
(Chirico et al. 2022)

Rare Earth Elements in the southern France bauxite deposits





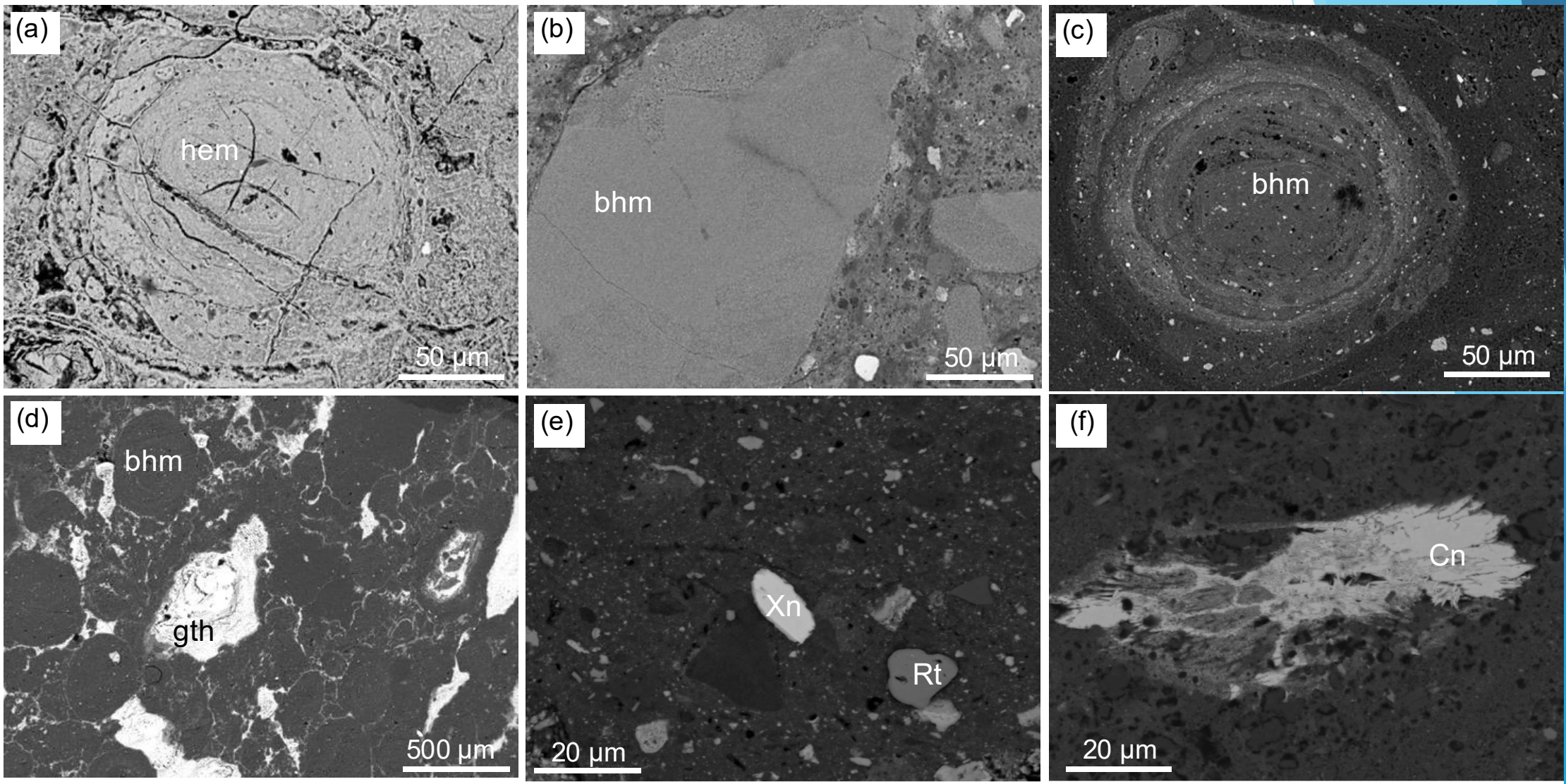




(Mondillo et al. 2025)

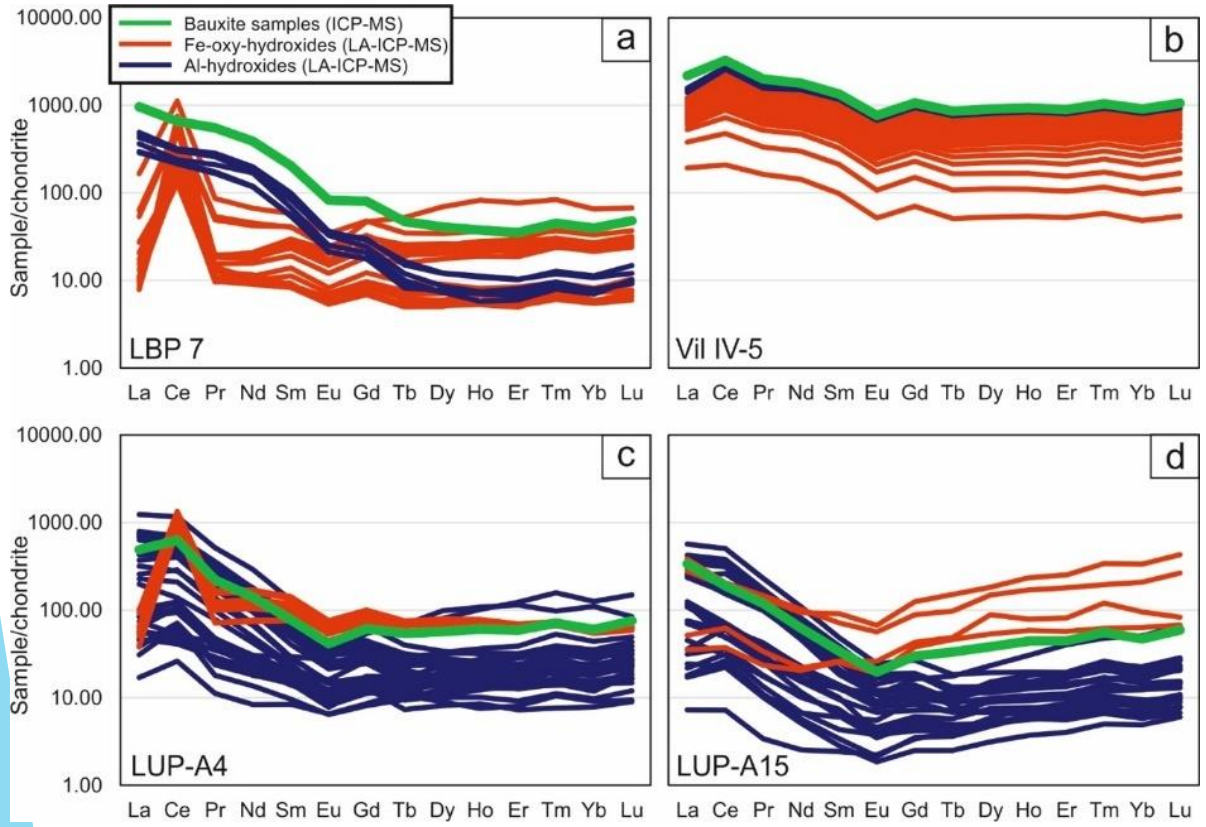
Rare Earth Elements in the southern France bauxite deposits

Mineralogy at SEM-EDS

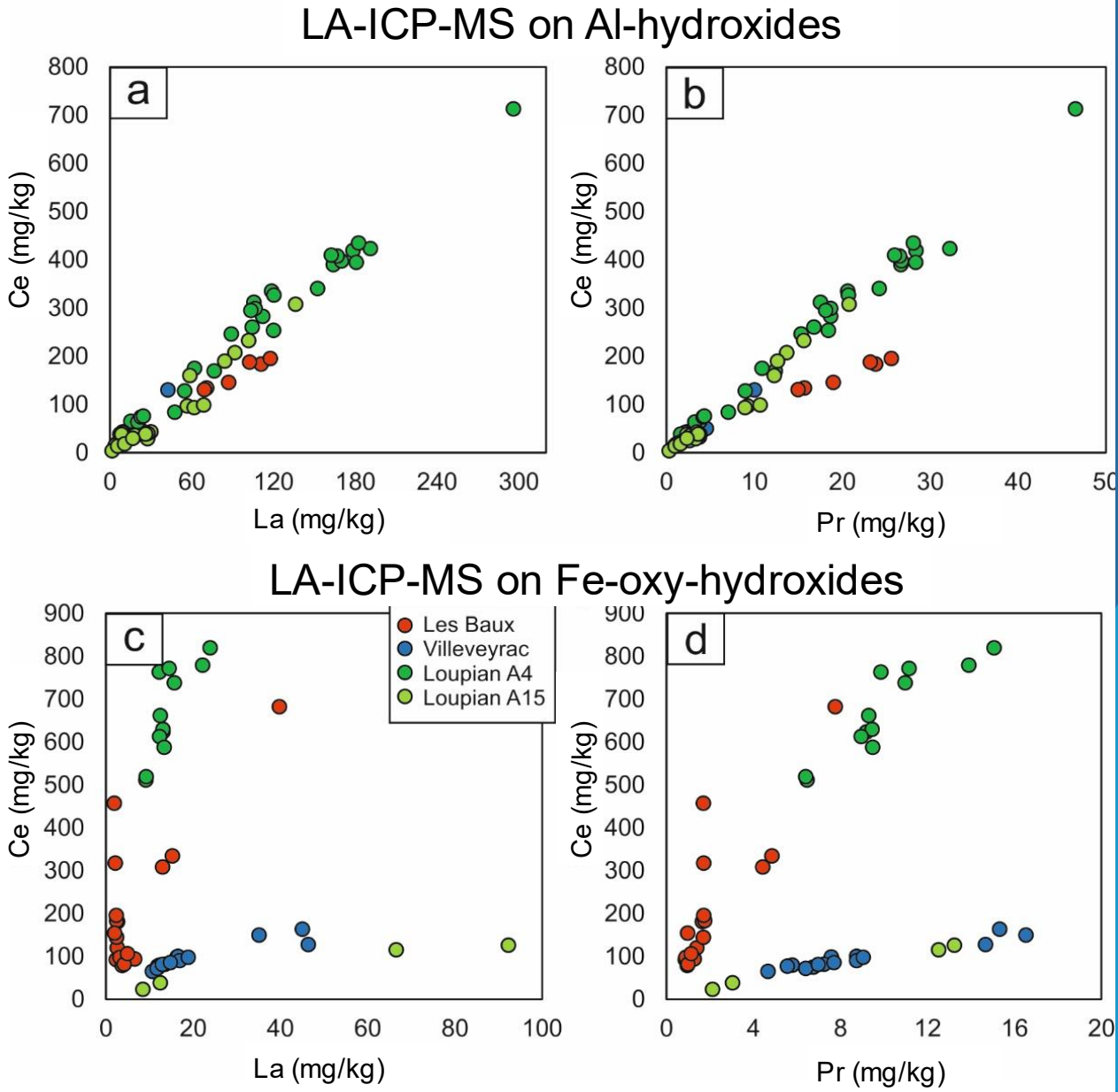


(**a**) nucleus of a hematitic oolite, (**b**) boehmite-rich clasts, (**c**) boehmite oolite, (**d**) goethite crusts and dendrites (bright) between the Al-hydroxides oolites (dark), (**e**) detrital xenotime and rutile, (**f**) authigenic cerianite.

Rare Earth Elements in the southern France bauxite deposits



REE concentrations obtained on bulk bauxite samples and *in-situ* LA-ICP-MS analysis of Al- and Fe-(oxy)-hydroxides normalized to chondrite.



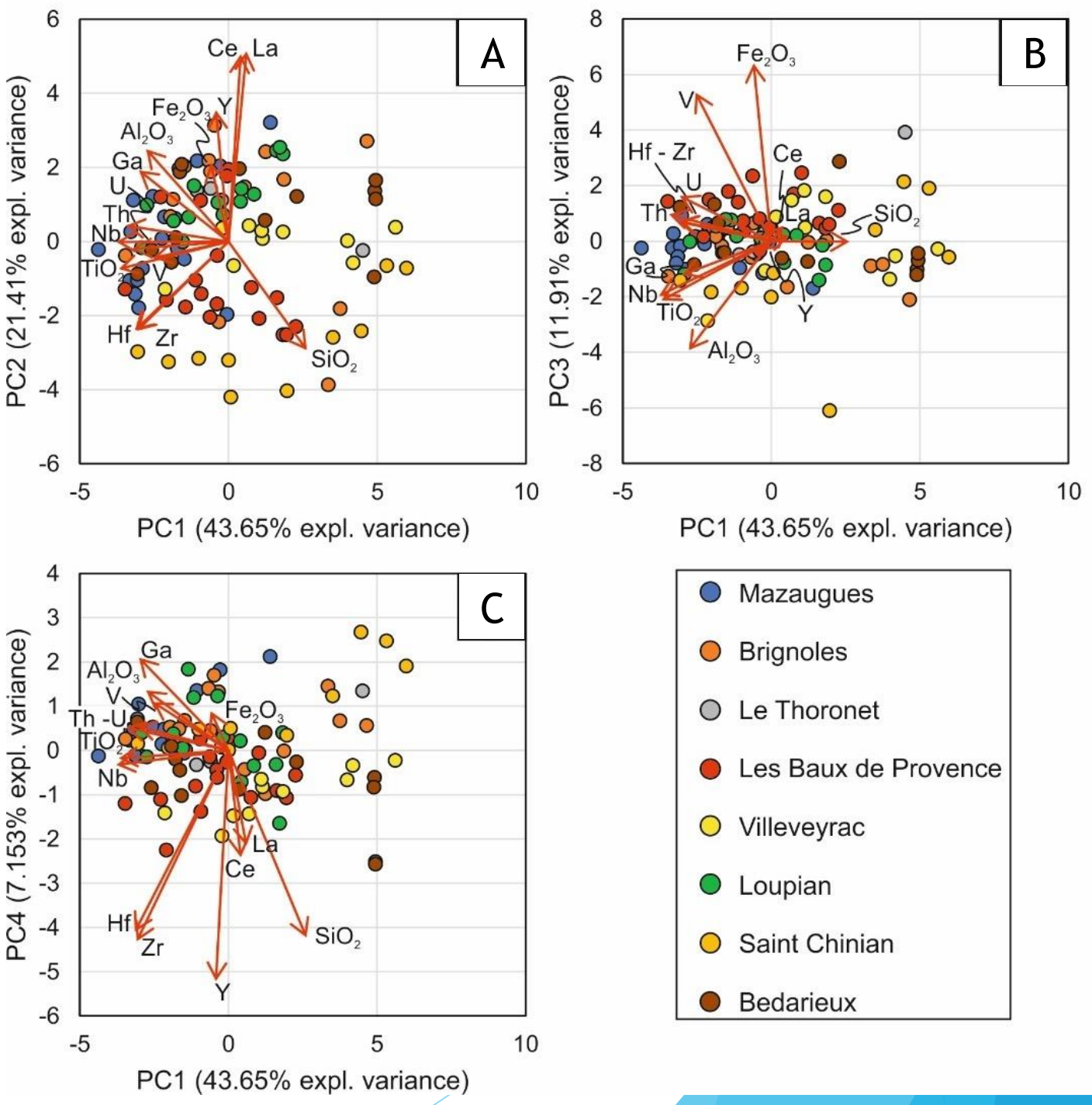
Rare Earth Elements in the southern France bauxite deposits

- **Bulk-rock chemical analysis** on 115 samples from several localities in Provence and Languedoc,
- Major, minor and trace elements,
- Target: determining REE deportment through **multivariate statistics**.

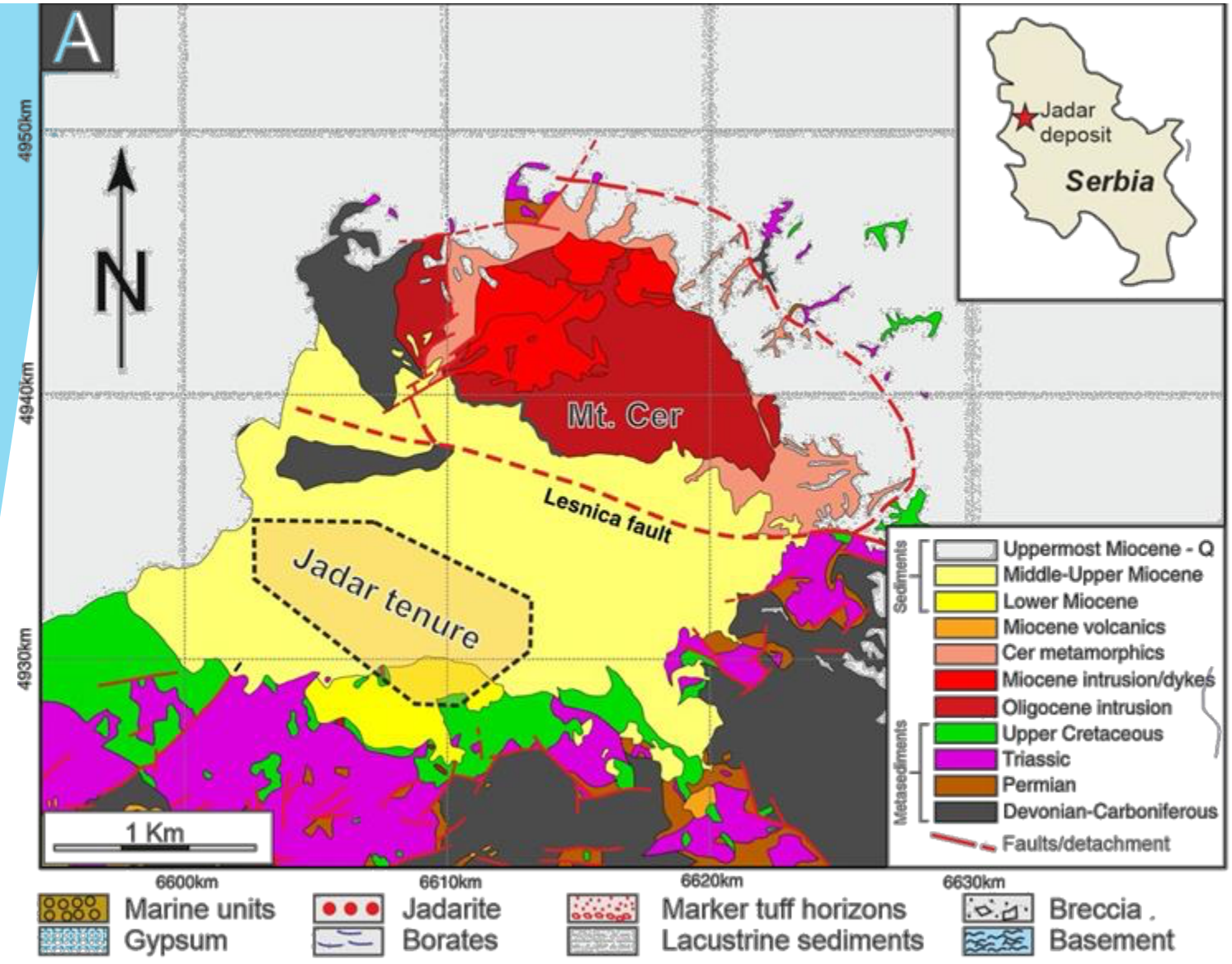
REEs deport with Fe+Al in PC2 =>
authigenic distribution

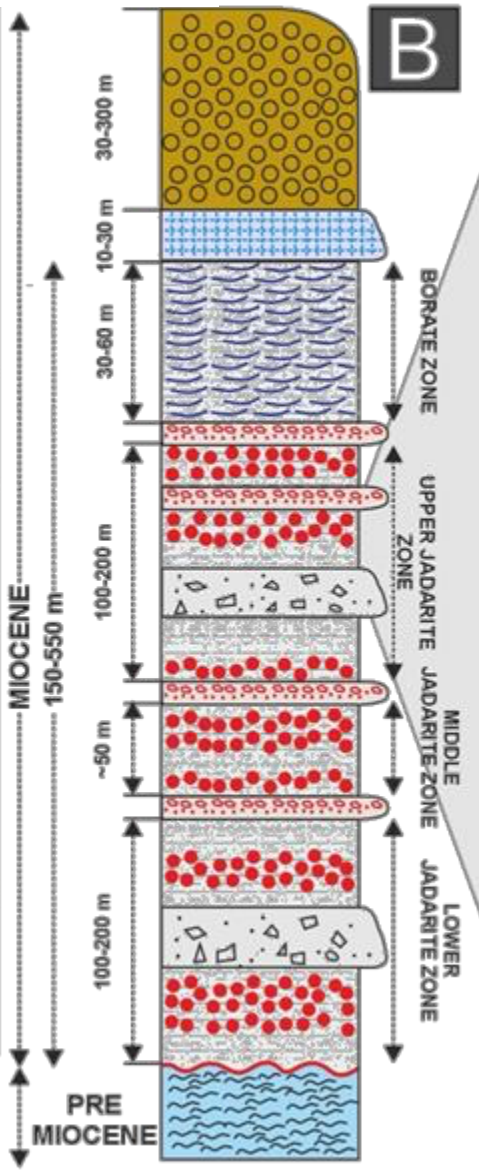
REEs deport with Zr in PC4 =>
detrital component

(Mondillo et al. 2025)



Lithium in volcano-sedimentary deposits: The Jadar project (Serbia)

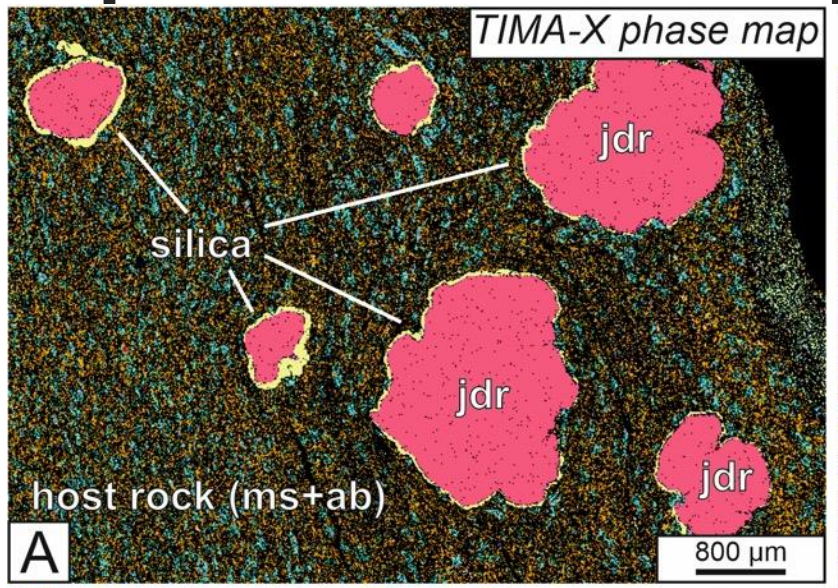


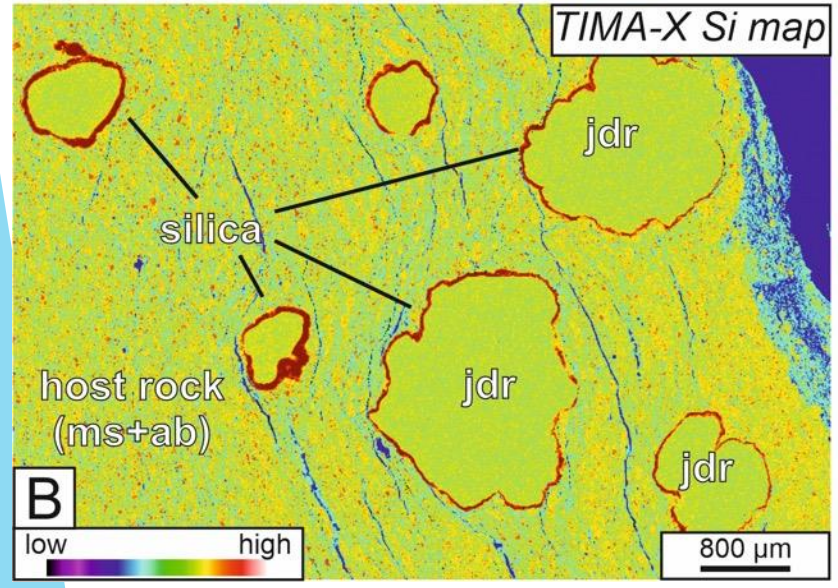


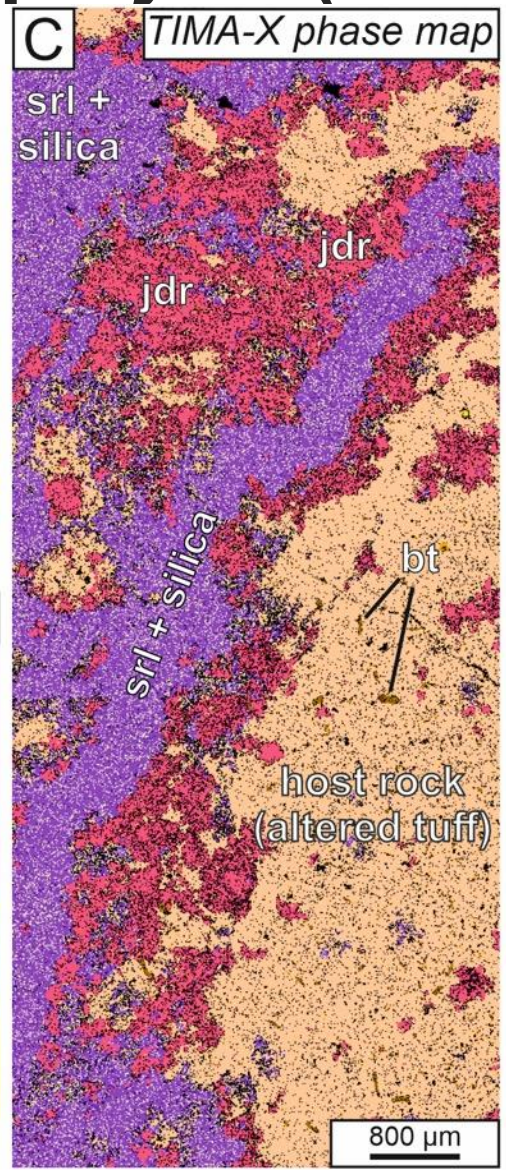
Geology and features of the Jadar lithium deposit (Putzolu et al., 2025)

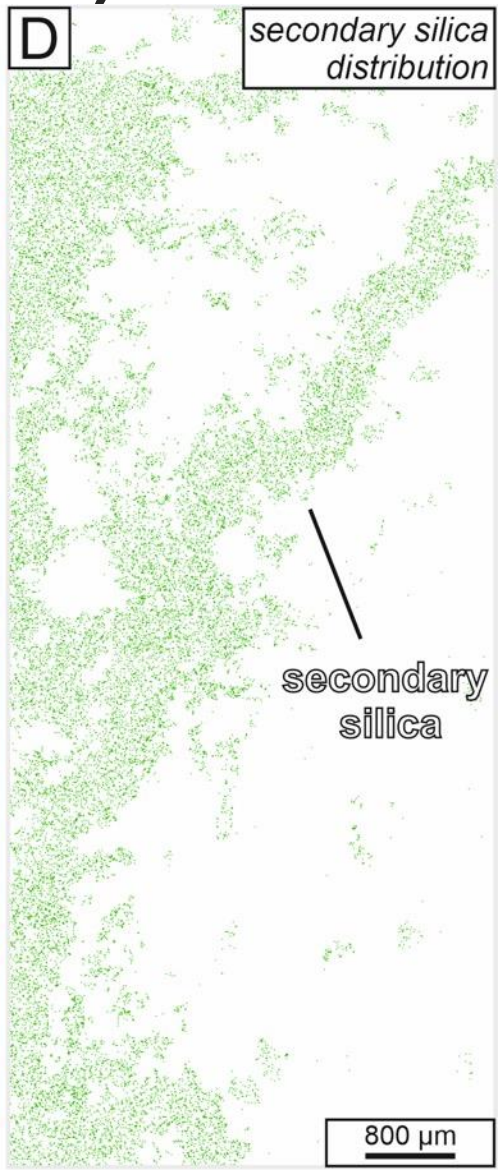
https://www.riotinto.com/en/operations/projects/jadar

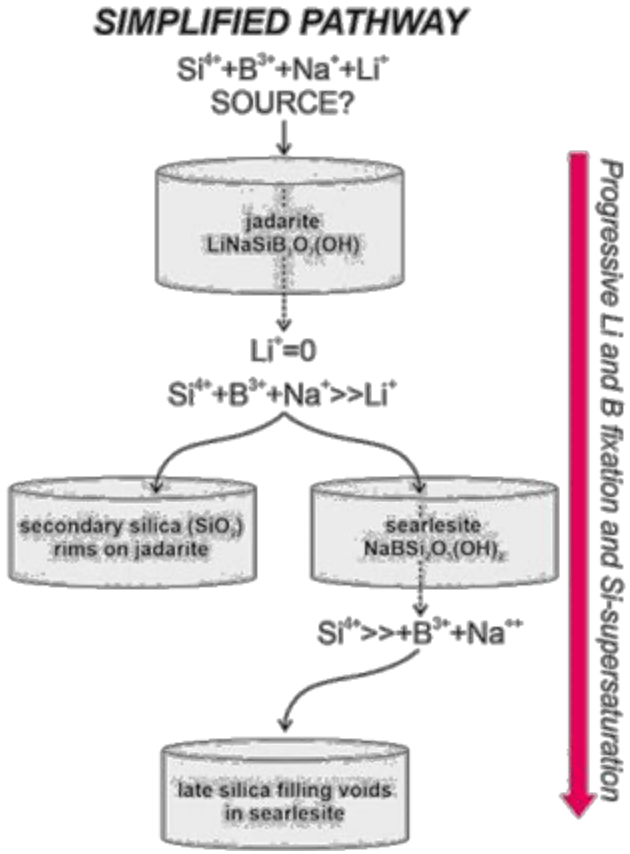
Lithium in volcano-sedimentary deposits: The Jadar project (Serbia)







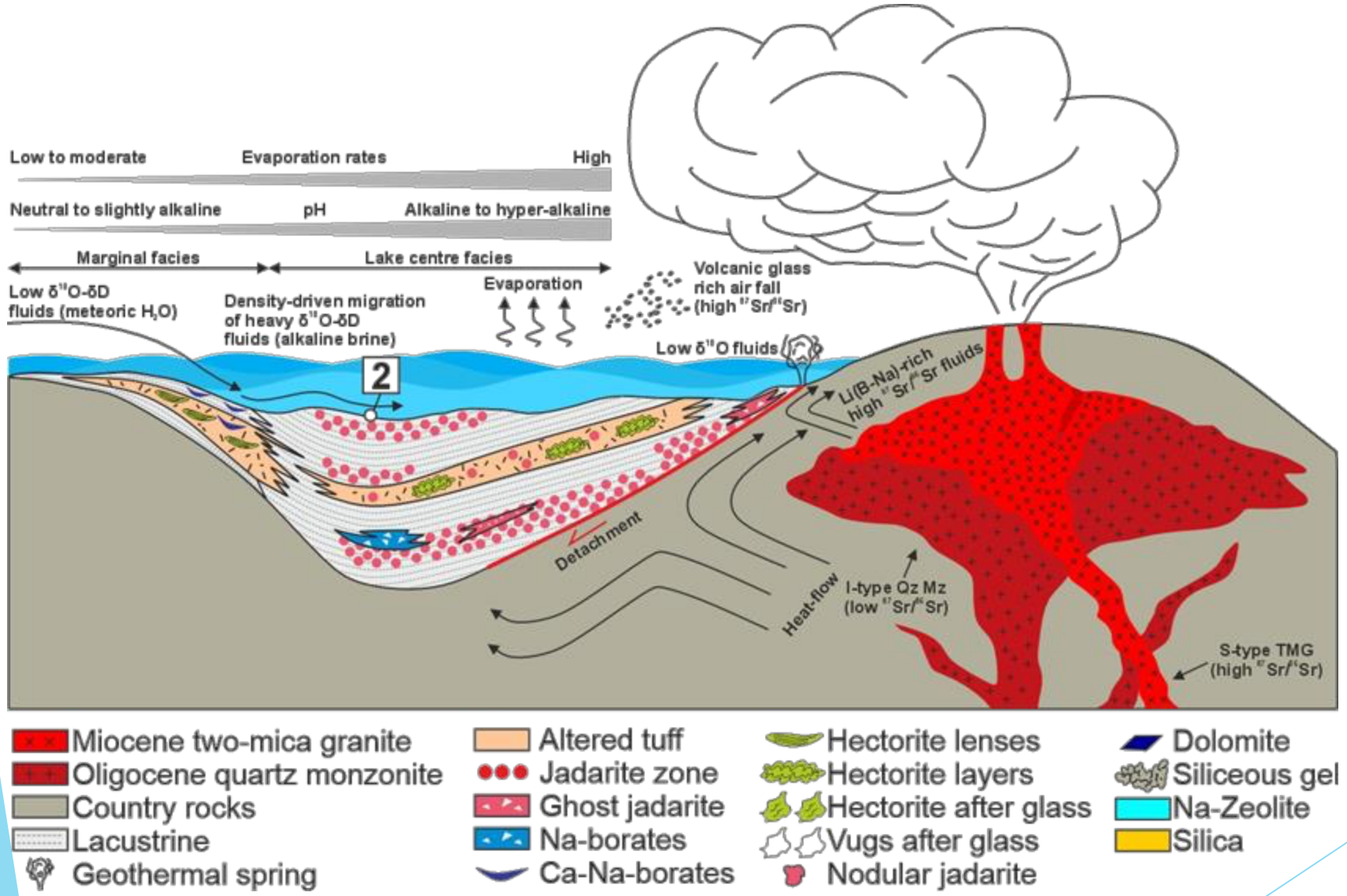


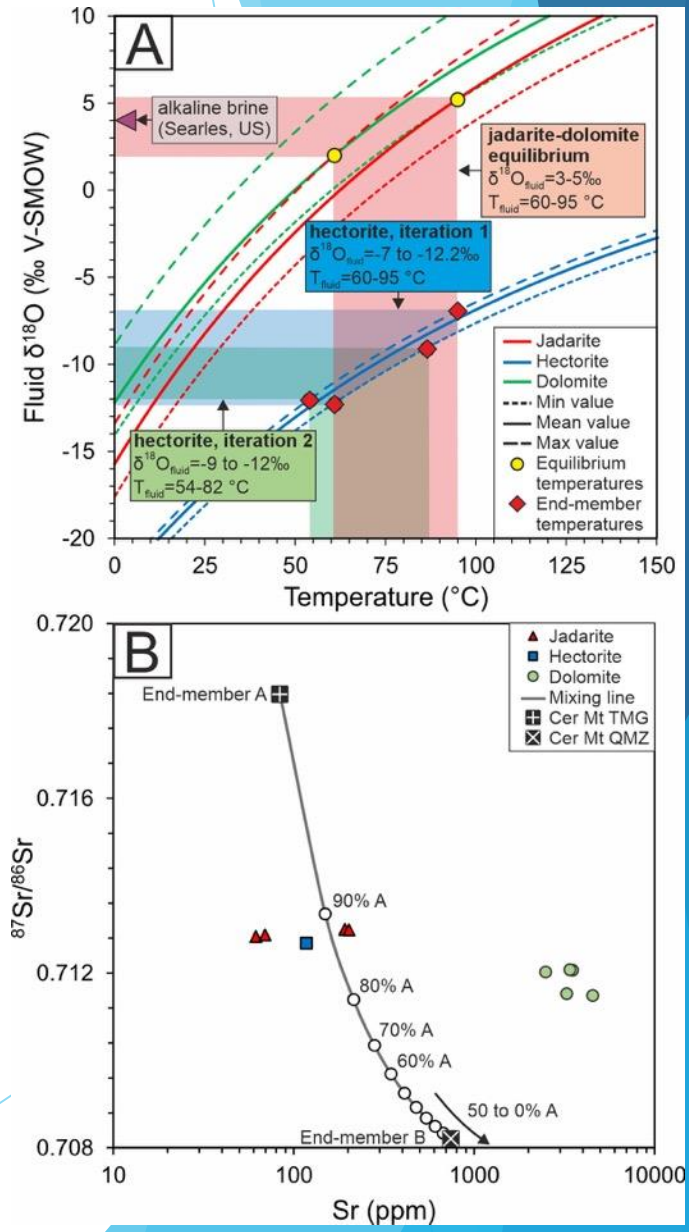


Abbreviations
Jdr= jadarite
Ms= muscovite
Ab = albite
Srl = searlesite
Bt = biotite

Genetic pathway of jadarite (Putzolu et al., 2025)

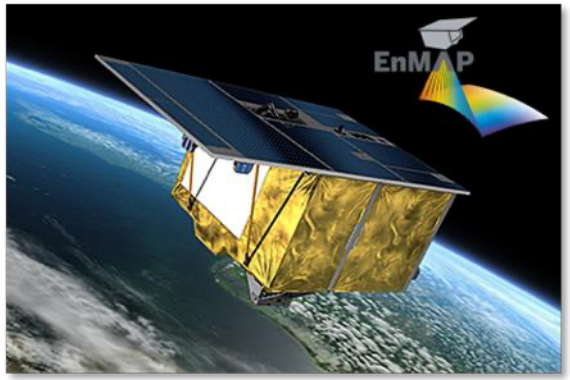
Lithium in volcano-sedimentary deposits: The Jadar project (Serbia)





Isotopic and geological model of the Jadar lithium deposit (Putzolu et al., 2025)

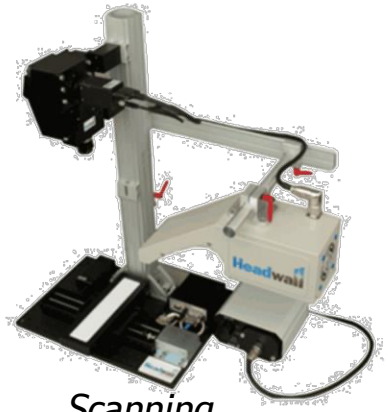
Multiscale hyperspectral remote sensing applied at mineral deposits



	PRISMA	EnMAP
Launch Year	2019	2022
Spectral range	400 – 2500 nm (VNIR-SWIR)	400 – 2500 nm (VNIR-SWIR)
Spectral resolution	11 nm (VNIR) – 15 nm (SWIR)	6.5 nm (VNIR) – 10 nm (SWIR)
Spectral band	234	224
Signal-to-Noise Ratio	≥200:1 (VNIR) >100:1 (SWIR2)	≥400:1 (VNIR) ≥250:1 (SWIR)
Spatial resolution	30m/pixel	30m/pixel
Swath Width	30 km	30 km

Satellite to in-situ and laboratory-based data acquisition

Increasing spatial and spectral resolution



Scanning

Point probe (1 mm)

NaturaSpec Spectroradiometer

Application at:

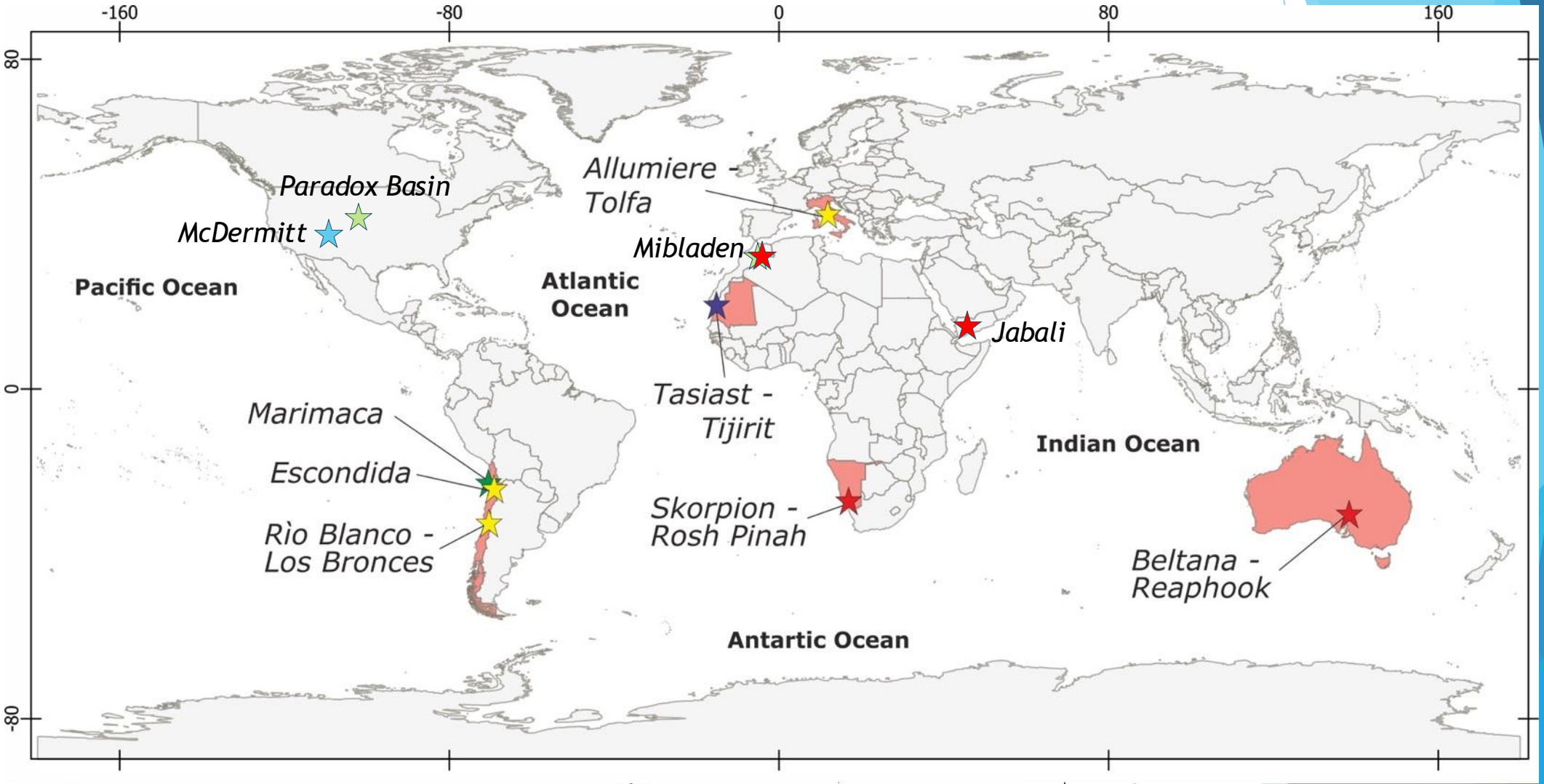
- **Mineral Exploration**
- **Mining Operations**

Headwall Photonics

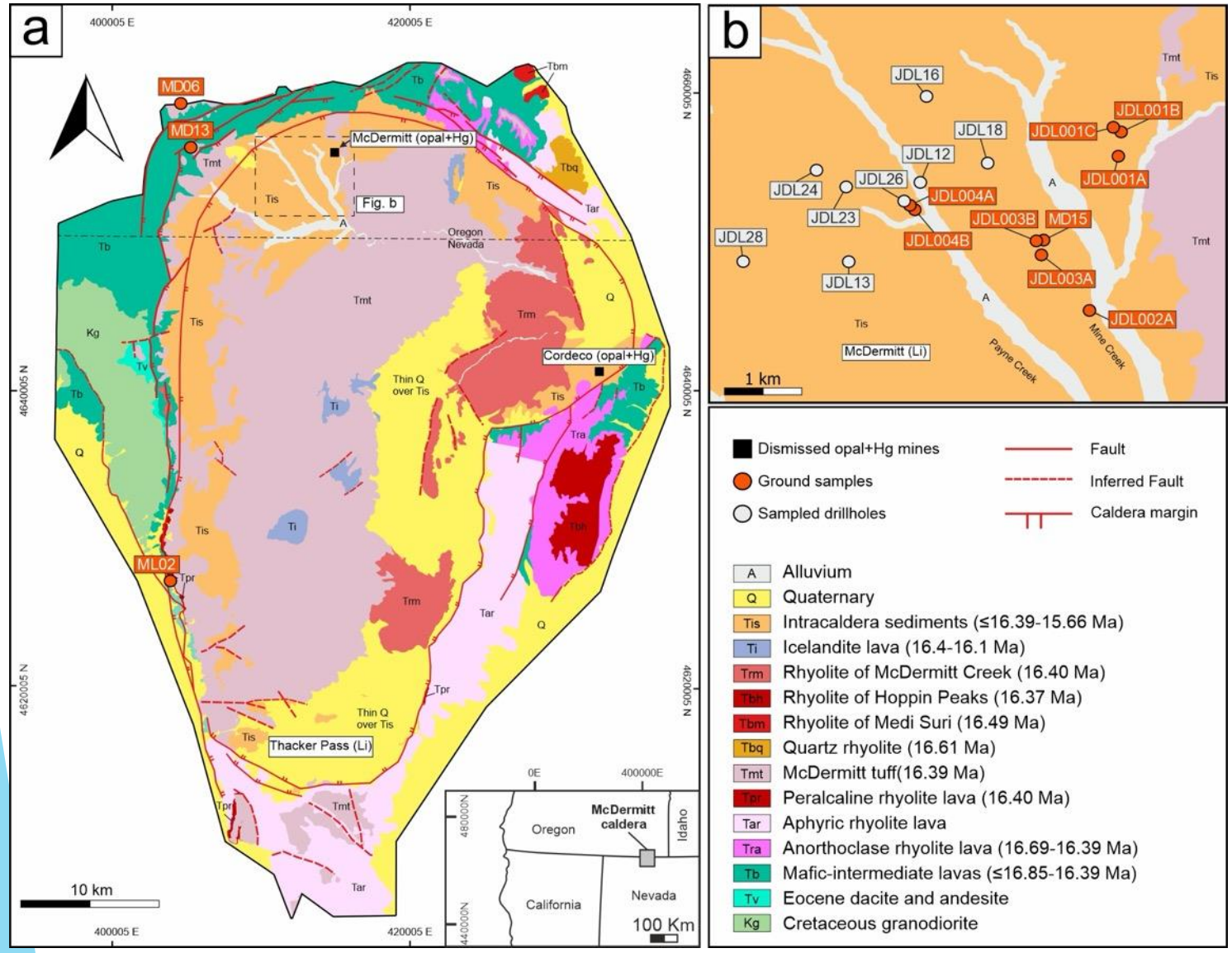
	Nano-Hyperspec	Micro-Hyperspec
Acquisition level	Field/Lab	Field/Lab
Wavelength range	400 - 1000 nm	900 - 2500 nm
Spectral bands	273	170
Spectral resolution	2 nm	10 nm

	NaturaSpec™
Acquisition level	Lab
Wavelength range	350 - 2500 nm (continuous)
Spectral bands	2151
Spectral resolution	2.7nm@700nm 5.5nm@1500nm 5.8nm@2100nm

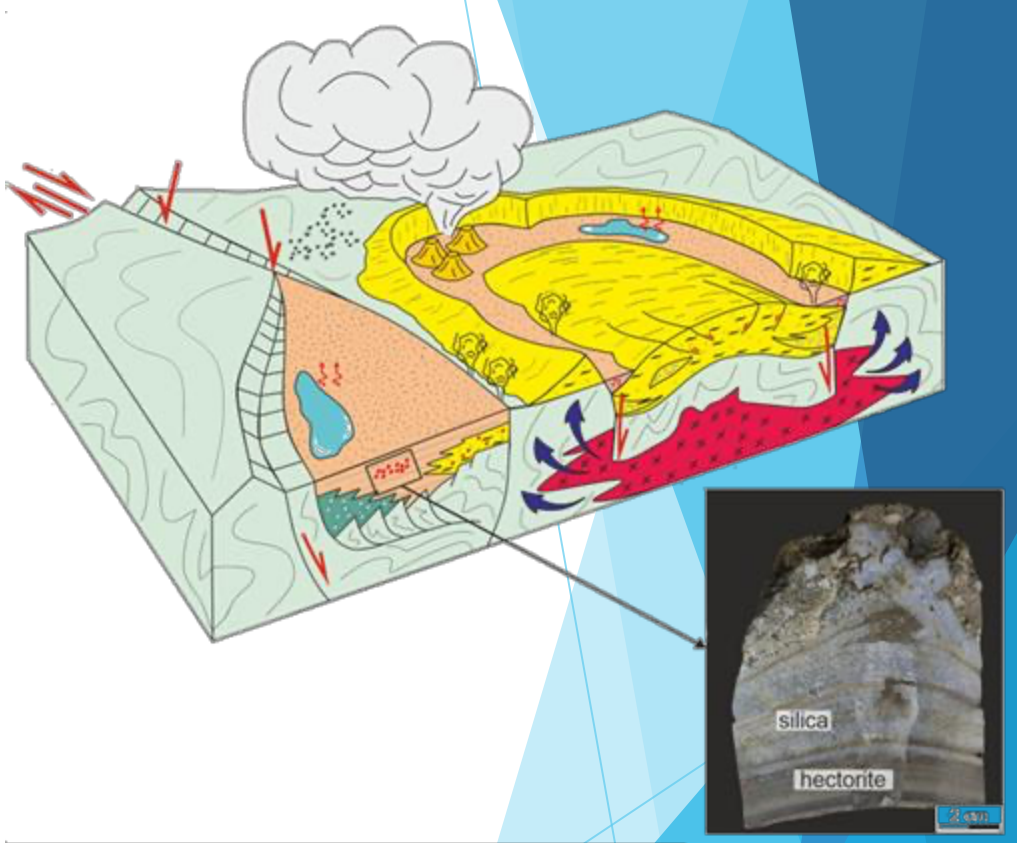
Multiscale hyperspectral remote sensing applied at mineral deposits



Exploration tools for volcano-sedimentary lithium deposits: The McDermitt project (USA)



Geological map of the McDermitt caldera (Corrado et al., 2025).



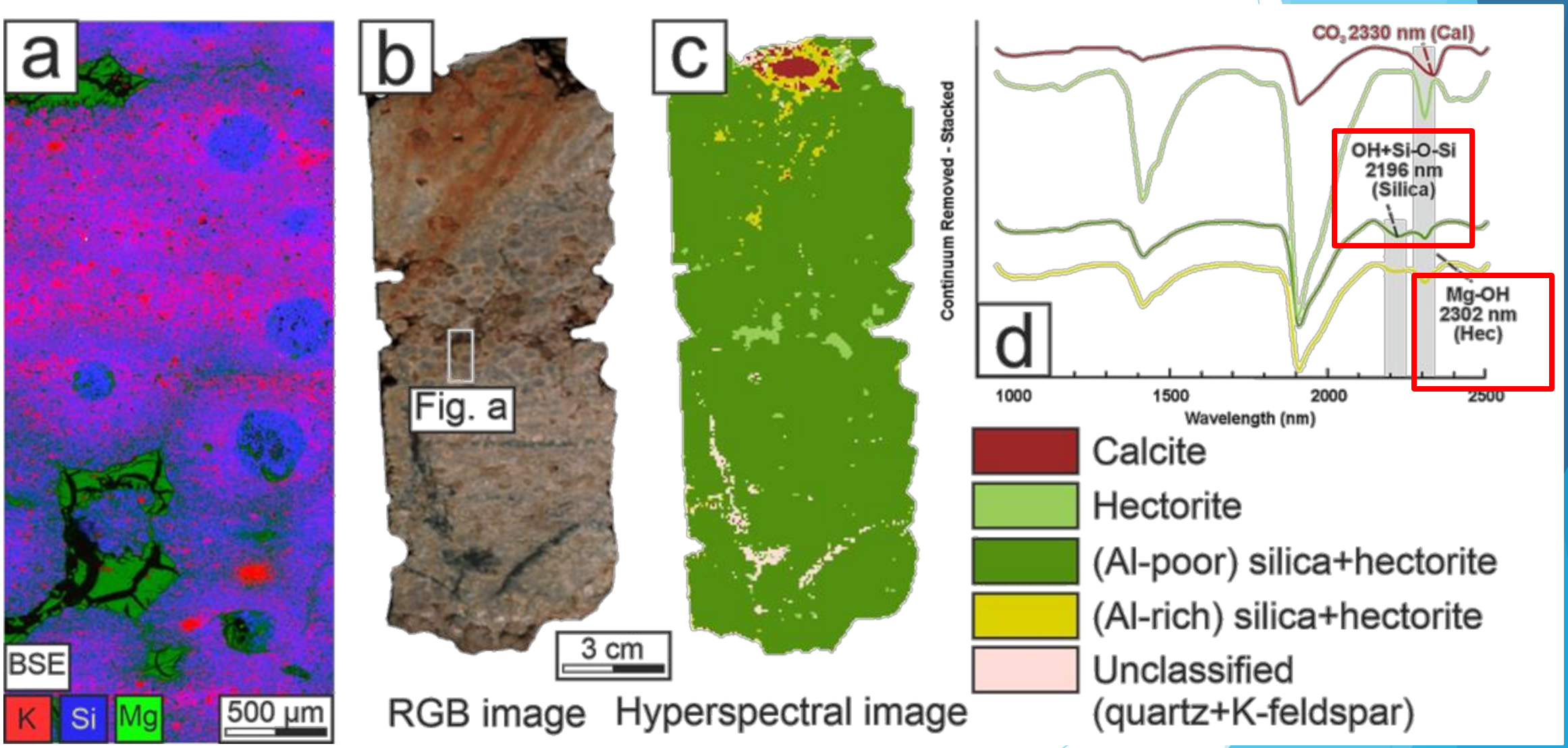
Li-bearing volcanic glass (ca. 70 wt% SiO_2) + high pH fluids

↓

hectorite (ca. 55 wt% SiO_2) + ca. 15 wt% SiO_2 excess (amorphous silica)

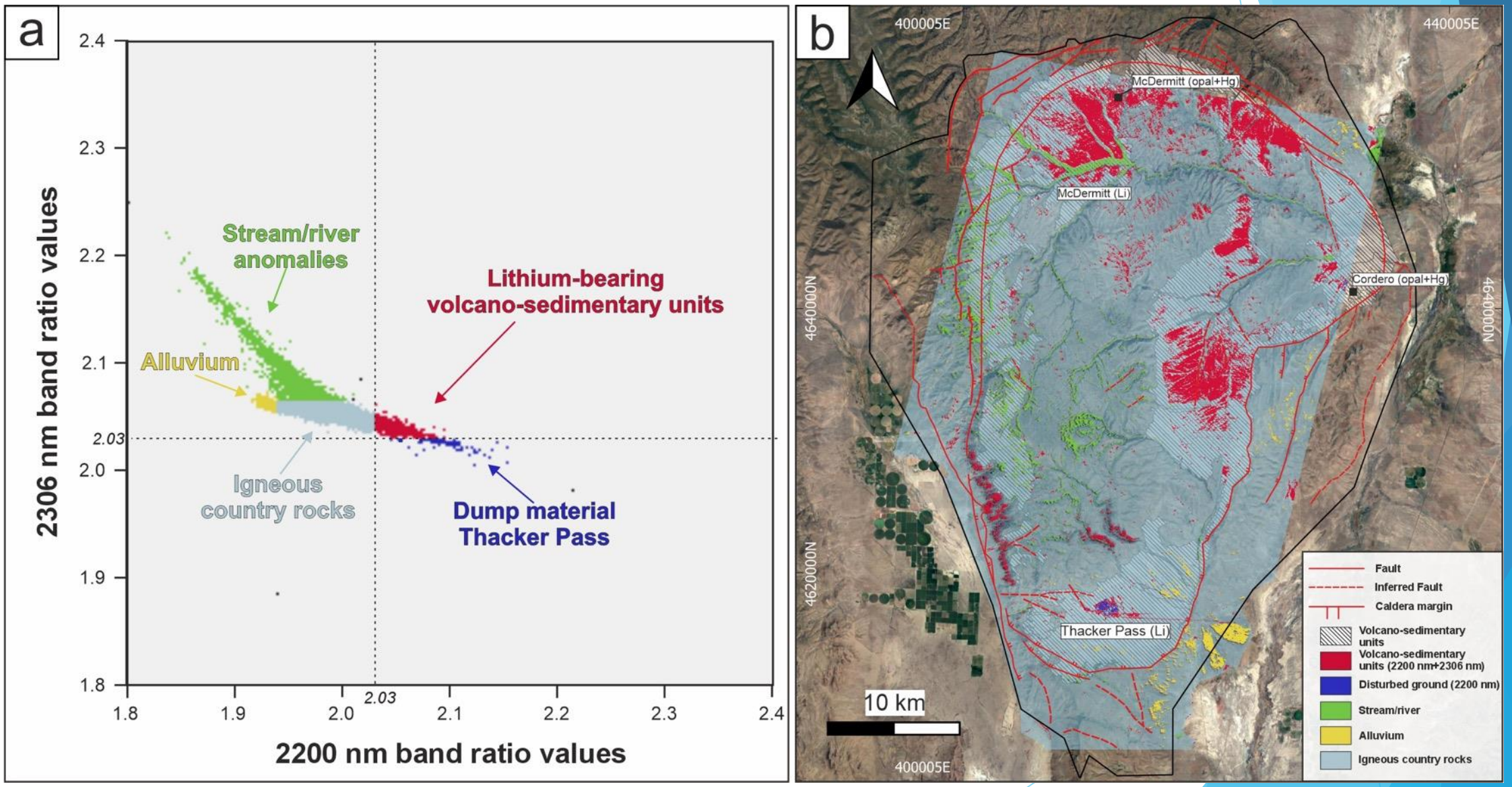
Sketch of a volcano-sedimentary lithium system (Putzolu et al., 2025)

Exploration tools for volcano-sedimentary lithium deposits: The McDermitt project (USA)



Results of mineralogical analysis and proximal hyperspectral characterization (Corrado et al., 2025)

Exploration tools for volcano-sedimentary lithium deposits: The McDermitt project (USA)



Results of the satellite hyperspectral analysis (Corrado et al., 2025)

Funded by the European Union
NextGenerationEU

MUR
Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

PNRR Project - GeoSciences IR

un'Infrastruttura di Ricerca per la Rete Italiana dei Servizi Geologici

https://geosciences-ir.it

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Sistema Nazionale per la Protezione dell'Ambiente

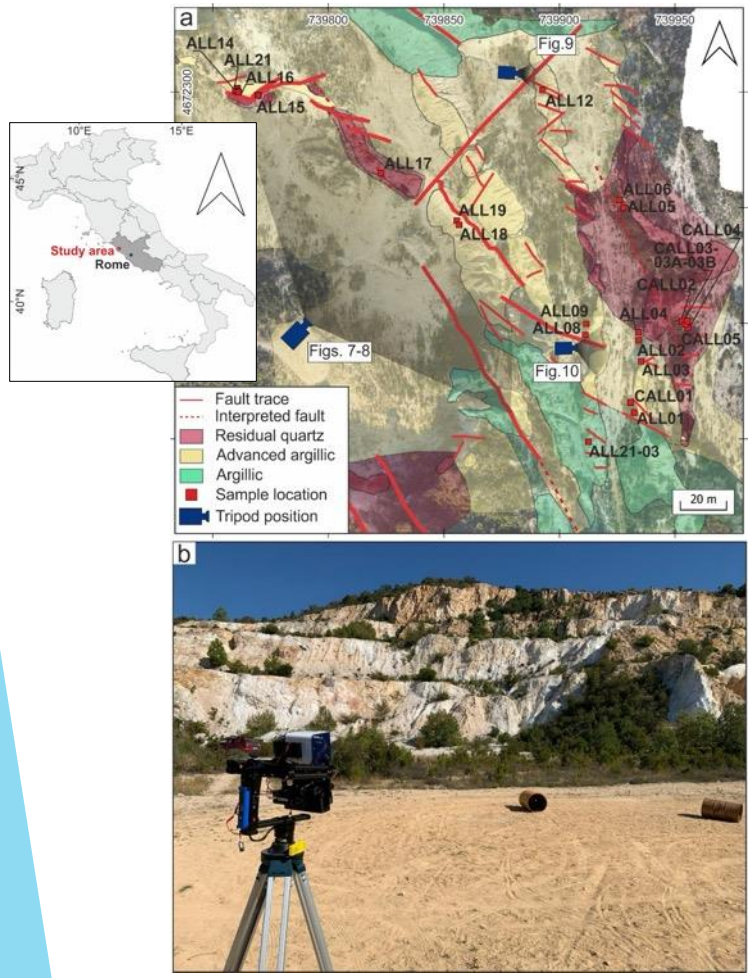
WP5 «Georesources and land monitoring»

Main aims:

- To produce **e-learning courses** on mineral deposits for public administrations
- To develop **innovative approaches** supporting mining operations

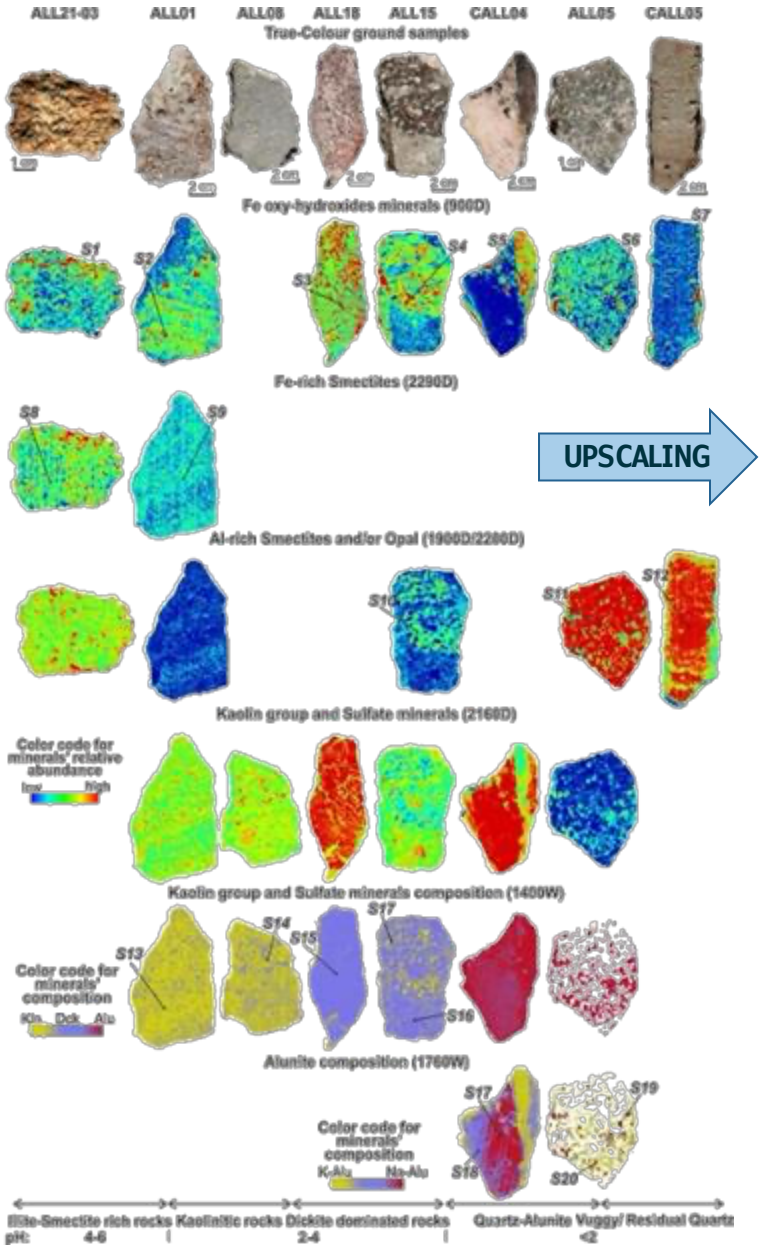
In-situ hyperspectral mapping of hydrothermal minerals

PNRR Project - GeoSciences IR



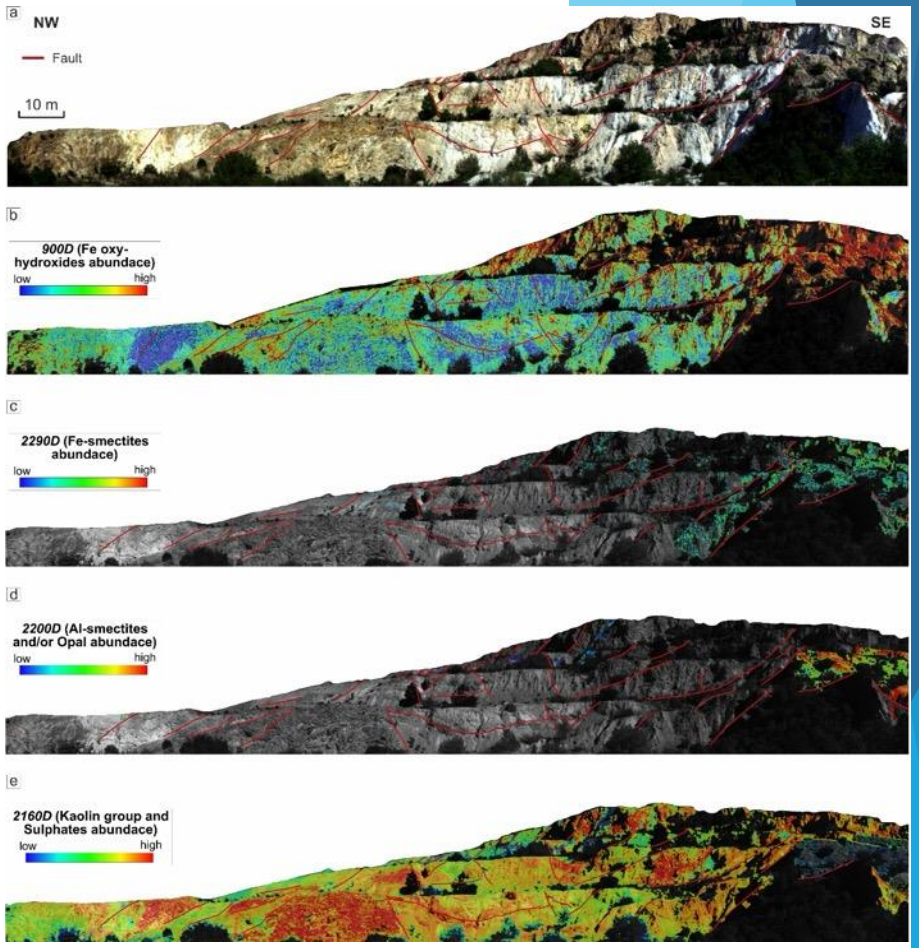
- ✓ **24 samples** collected across the entire Allumiere quarry
- ✓ **Imaging and Point-based reflectance spectroscopy**

(Sorrentino et al., 2025)



UPSCALING

ALLUMIERE QUARRY (Italy)
Close-range investigation



Minimum wavelength mapping allowed to identify:

- Kaolinite and Dickite polytypes
- Alunite chemical composition (Na/K ratio)
- Al-smectites and/or Opaline silica & Fe-smectites
- Fe oxy-hydroxides

In-situ hyperspectral mapping of hydrothermal minerals

PNRR Project - GeoSciences IR

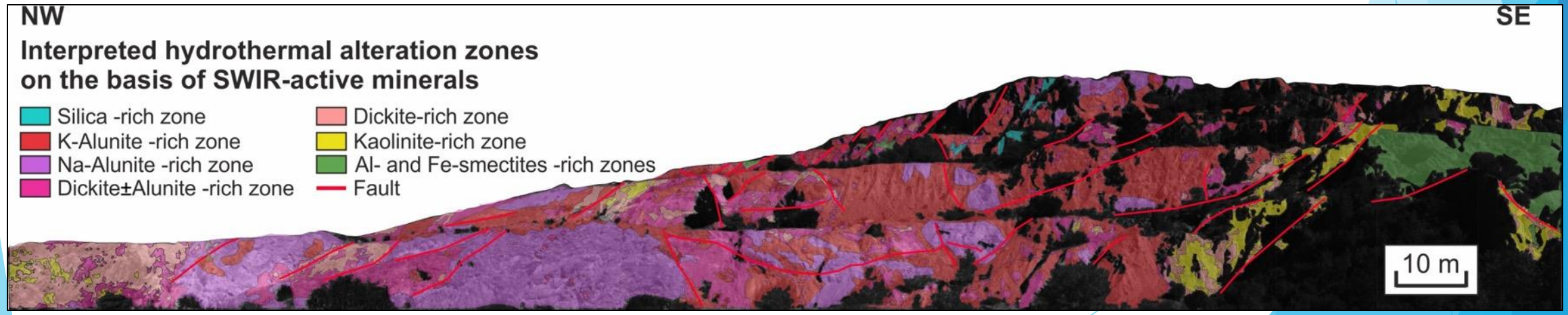
ALLUMIERE QUARRY (Italy) 3D modelling

✓ **Peripheral Zones**
Dominated by Al-/Fe-rich (illite-)smectites, associated with near-neutral pH (4–6) and lower temperatures

✓ **Transitional Zones**
Gradual shift to advanced argillic alteration, following traditional zonation schemes (e.g., Hedenquist and Arribas, 2022)

✓ **Towards the Core Zone**
Mineralogical zonation pattern from Kaolinite to Dickite to Dickite+Alunite to K-Alu and Na-Alu, reflecting a decreasing pH (5 → 2) and increasing temperature conditions

✓ **Silicified Core**
High-temperature (~ 250 °C) and extremely H_2SO_4 and H_2S-rich acidic solutions



(Sorrentino et al., 2025)

Industrial minerals and CRMs in Quaternary volcanic rocks of the Campania region (Italy)

PROGRAMMA NAZIONALE DI ESPLORAZIONE

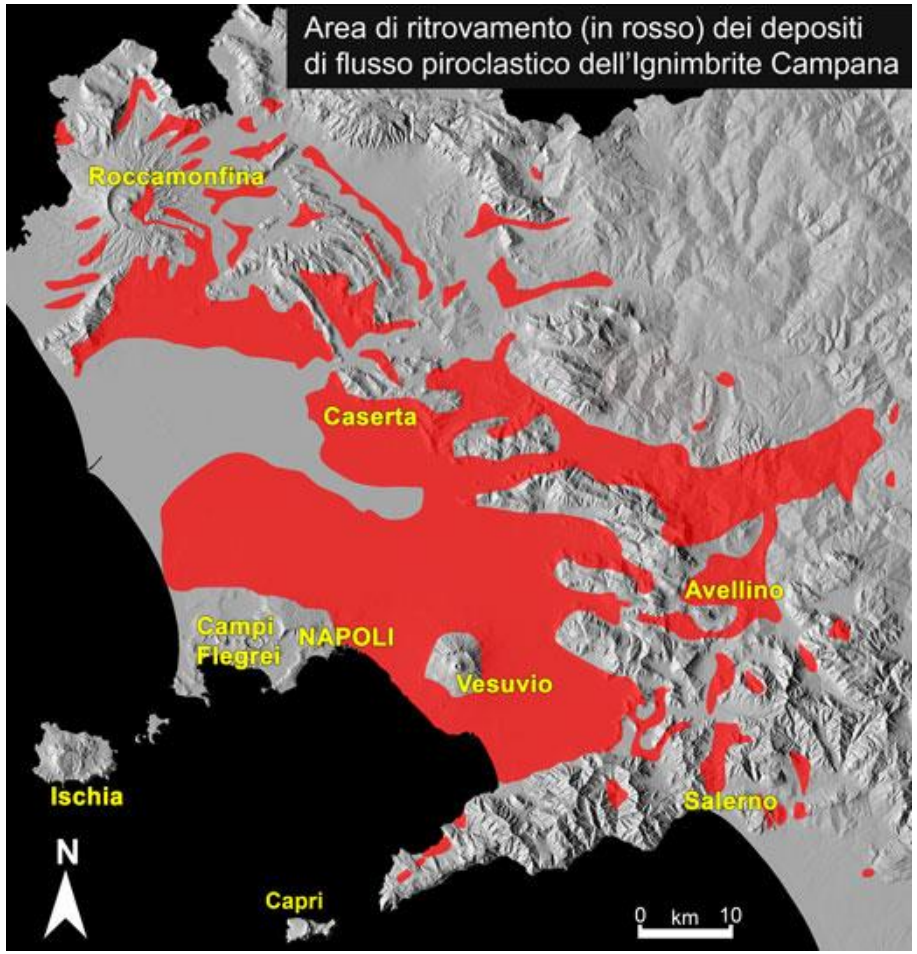
Art.10, DL n. 84/2024

ISPRA

Ready to start…

The WP aims at understanding the current mining potential in the basin.

- Economic Raw Material: **zeolite**
- Possibly associated Critical Raw Material: **feldspar**
- Hypothetical Strategic Raw Materials: **REE, lithium**



(PNE program, 2024; ISPRA; INGV)

Conclusions

Comprehensive knowledge of mineral deposits is fundamental for critical mineral targeting.

Multivariate statistical analyses applied at the evaluation of mineral deportment can be useful but must be supported by data obtained through standard mineralogical methods.

New hyperspectral satellite and proximal sensors produce data much more accurate than older systems, also allowing to detect chemical variations in specific mineral phases/groups.

It is always necessary to validate the data with control samples.

A solid knowledge of the minerogenetic model is required for the correct interpretation of the data.

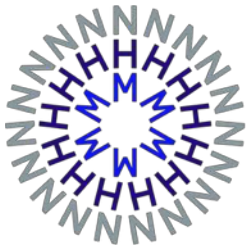
Research partners

Università degli Studi di Padova

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

INGV

OSSERVATORIO VESUVIANO
SEZIONE DI NAPOLI



Natural History Museum

UNIVERSITY OF OXFORD

JINDALEE LITHIUM

srk consulting

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RioTinto

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Thanks for the attention

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Extended literature at:

https://www.distar.unina.it/en/research-macroarea-1/economic-geology-and-mineral-deposits/