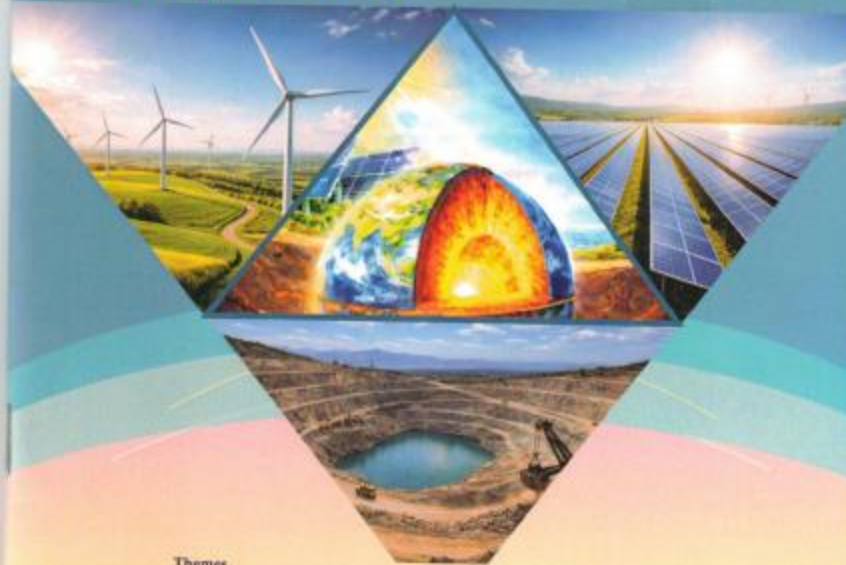




ISCMRDET 2026

Proceedings

International Symposium on
Sustainable **Critical Mineral Resource** Development
for **Energy Transition**



Themes

1. Critical mineral resources and their significance for energy transition
2. Geology and potential of critical mineral resources
3. Sustainable mining, processing, recovery of critical minerals

Hanoi, Vietnam April 20, 2026

10:00 – 11:45: General session: Critical Mineral Resources and Their Significance for Energy Transition

Chair: Prof. Raman Paranjape (Regina)

10:00 – 10:30: Dr. Phillip Choi (UoR): Energy Transition and Design of Collectors for Minerals Processing

10:30 – 11:00: Prof. Tran Thanh Hai (HUMG): Strategic mineral resources: are they the key to 21st-century bloodline of the World and how important they are for Vietnam's future?

11:00 – 11:30: Prof. Takashi Sasaoka (Kyushu University): Environmentally Friendly Mining System for Seabed Mineral Resources

11:30 – 11:45: Questions and Answers

11:45 – 13:00: Lunch

13:00 – 15:00: Symposium 1: Geology and potential of critical mineral resources

Chair: Prof. Tran Thanh Hai (HUMG)

13:00 – 13:20: M.Sc. Tran Thi Huong; Assoc. Prof. Dr. Nguyen Hoang (Institute of Earth Sciences, Vietnam Academy of Science and Technology): The controlling factors on the mineralization in the Tram Tau felsic volcanic formation (Tu Le Basin, North Vietnam)

13:20 – 13:40: Dr. Bui Thanh Tinh (HUMG): Development of REE mineralization in the Dong Pao deposit, Lai Chau, Viet Nam: insights from mineralogy, fluid inclusions, and trace-element geochemistry

13:40 – 14:00: Vu Anh Dao (HUMG): Fluvial geomorphology and weathering crust controls on ion-adsorption rare earth element mineralization in Northwestern Vietnam

14:00 – 14:20: Prof. Raman Paranjape (UoR): Magnetic Confinement of Dust Particles for Mining Applications: A Summary

14:20 – 14:40: Dr. To Xuan Ban (HUMG): The erosion and accretion at Day River mouth, Vietnam

14:40 – 15:00: Questions and Answers

15:00 – 15:30: Coffee break

Development of REE mineralization in the Dong Pao deposit, Lai Chau, Viet Nam:
insights from mineralogy, fluid inclusions, and trace-element geochemistry

*Tinh Thanh BUI**

* Hanoi University of Mining and Geology, Vietnam

*Corresponding author: Tinh Thanh Bui (buihanhtinh@hmg.edu.vn)

Abstract

Rare-earth Dongpao deposit is estimated as a top resource of rare earth element (REE) in Vietnam with around 4.38 million tons of total REE oxide. REE-bearing ores can be distinguished into primary and weathered ores. The primary ores comprise carbonatite and vein-type ores exhibit high REE concentrations (vein-type ore), the weathered ores comprise weathered syenite and weathered vein-type ore. The vein-type ore samples show that the main REE-bearing mineral is bastnasite with high REE concentration from 39,700 to 131,188 ppm. While the carbonatite samples show that the main REE-bearing mineral is synchysite, the REE concentration is from 9,122 to 15,048 ppm. The weathered vein-type ore commonly occurs on the outcrop of the Dongpao area; these samples have REE concentrations from 31,832 to 33,786 ppm and contain predominant oxidized REE minerals. The REE concentration in the weathered syenite is much lower from 1,892 to 2,656 ppm. But the heavy rare earth element concentration is higher (668 - 919 ppm) compared to that of the weathered vein-type ore (284 - 288 ppm). Barite and fluorite are the principal gangue minerals associated with REE in the primary and weathered vein-type ores. Mineralization is principally enriched by hydrothermal processes, and then the primary vein-type ore was weathered to become friable ore. Weathering of REE carbonate minerals can lead to diverse pathways, including precipitation of hydrated carbonates such as Lanthanite under CO₂-rich, near-neutral to alkaline conditions, incorporation into phosphates like Florencite in the presence of available P and Al, and oxidation of Ce to form Cerianite, producing a Ce anomaly. They remain in the ore veins or are transported and partly redistributed in the weathered layers.

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SUSTAINABLE MINING AND CRITICAL MINERAL PROCESSING FOR ENERGY TRANSITIONS SYMPOSIUM

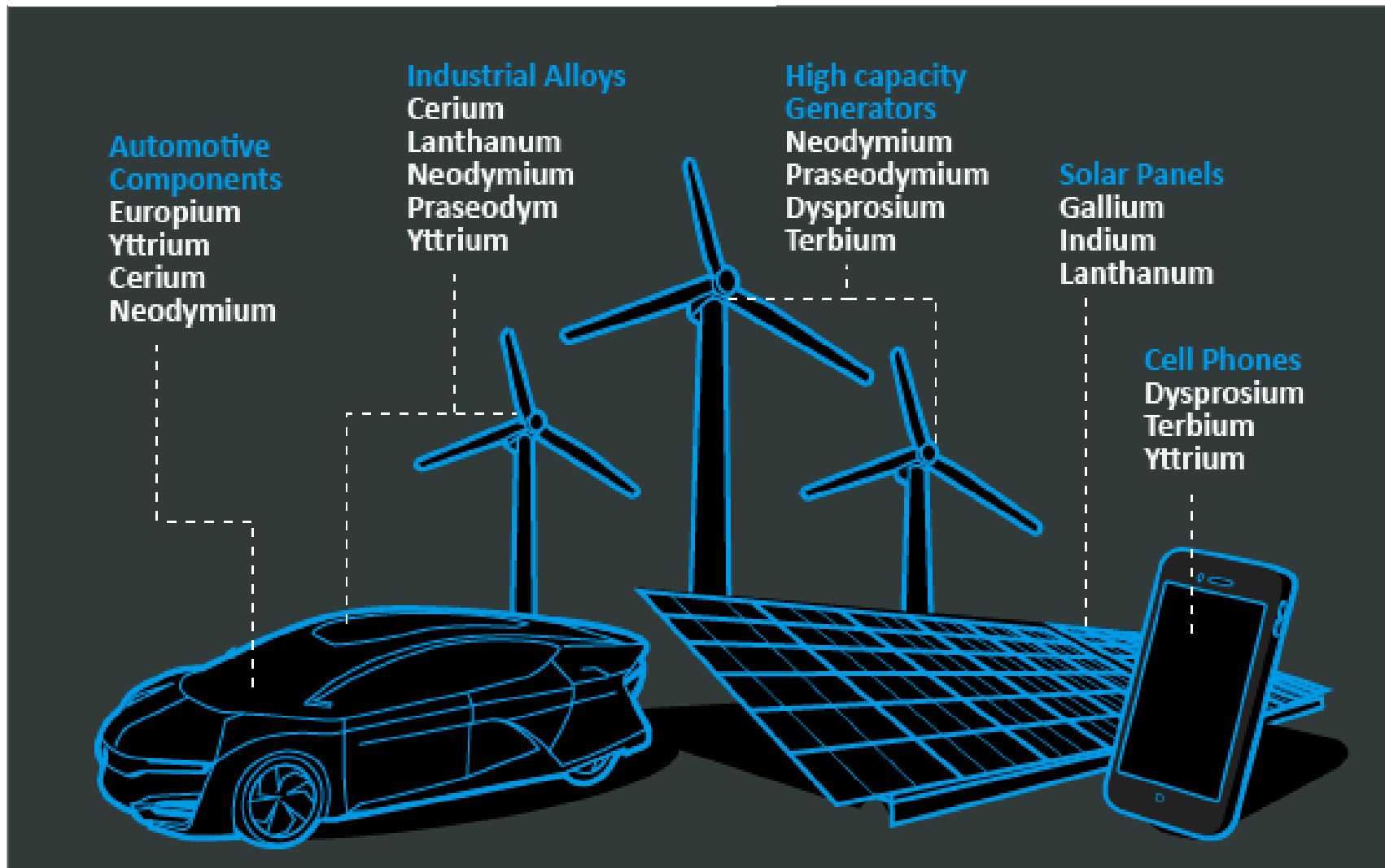
DEVELOPMENT OF REE MINERALIZATION IN THE
DONG PAO DEPOSIT, LAI CHAU, VIET NAM: INSIGHTS FROM
MINERALOGY, FLUID INCLUSIONS, AND
TRACE-ELEMENT GEOCHEMISTRY

PhD. Bui Thanh Tinh

Hanoi, 2026

1. Introduction

REE applications



The global demand for rare earth elements (REE) is growing because they are essential for a variety of applications such as permanent magnets and renewable energy technology.

Fig 1. REE and their associated applications

1. Introduction

Global REE reserves



Fig 2. Distribution of major rare earth reserves by country as of 2022.

1. Introduction

REE deposits in Vietnam

- There are 18 known REE deposits in Vietnam
- Magmatic-related deposits are in the North.
- Placer deposits distributed along the coastal line.



Fig 3. Distribution of REE deposits in Vietnam. Resource data is based on Bui, T. H., and Trinh, D. H. (2017); Khang, L. Q. (2002)

1. Introduction

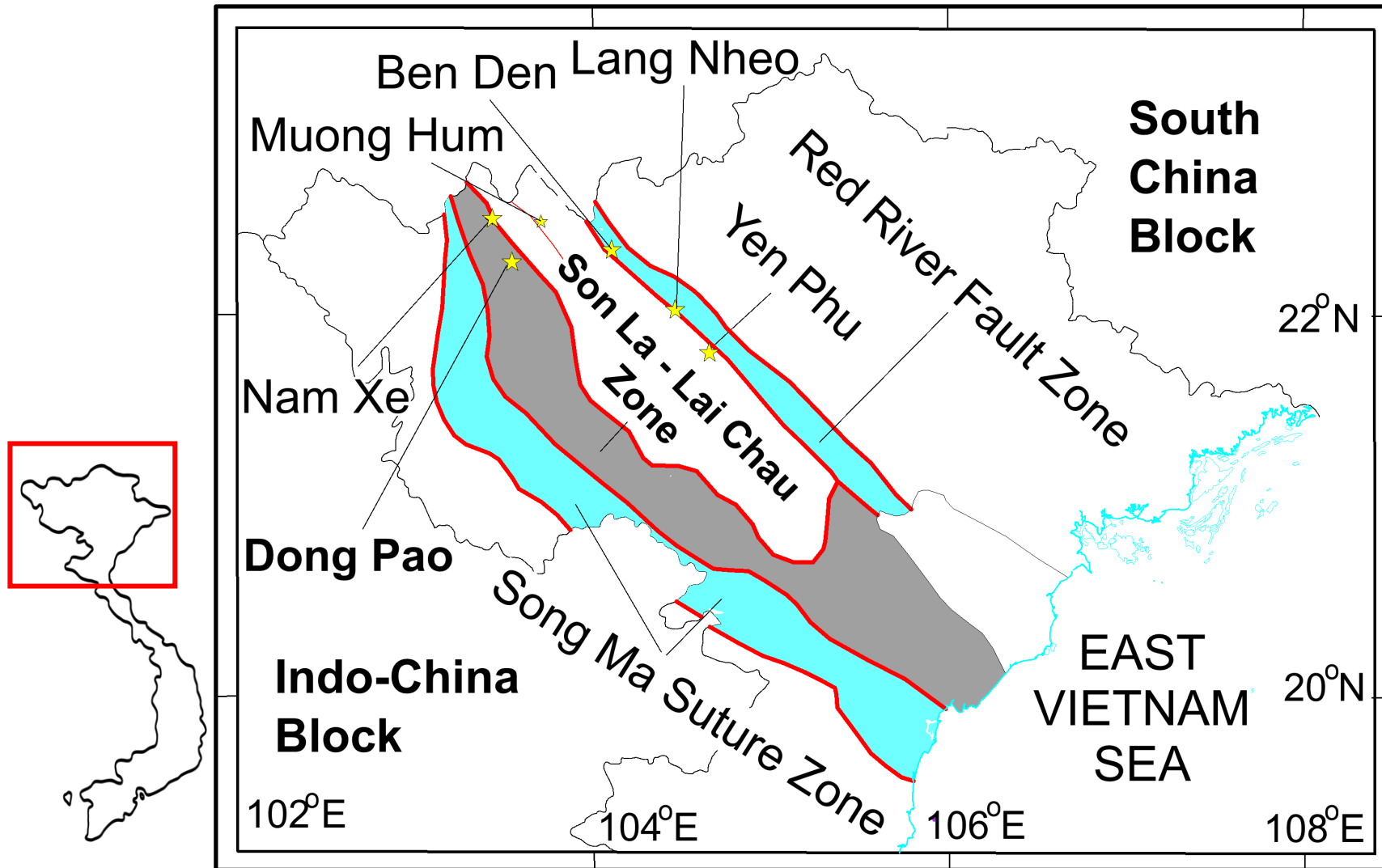


Fig 4. The outcrop in the north of the Dong Pao deposit, Vietnam.

History of exploration in the Dong Pao deposit

- Dong Pao deposit was discovered in 1959 (Vlaxov I.Ia et al, 1960).
- Conducting exploration projects in 1980s (Hirano et al., 1996); 2000s (Fujii et al., 2010). ; 2010 (Nguyen, 2010).
- REE mineralization is reported to be hosted in syenite, carbonatite, metasomatized limestone (country rocks), and weathered profile on the top of the units.
- The latest exploration reports showed seven promising orebodies with a total REO resource of > 4.7 Mt, >24.5 Mt barite, and >13.7 Mt fluorite (Nguyen, 2010).

2. Geology



Geology of northern Vietnam

The Don Pao deposit is located in the north of Vietnam, in the Son La-Lai Chau Zone (geologically between the Red River Fault Zone and Song Ma Suture Zone)

The Son La – Lai Chau zone is an extensional region formed during Cenozoic strike-slip tectonics between the south China and Indochina blocks (Chung et al., 1997).

Fig 5. Geological setting of north Vietnam showing the tectonic location of Son La – Lai Chau Zone

2. Geology

Geology of The Dong Pao deposit

- The alkaline rocks of Dong Pao includes syenites, and carbonatites emplaced at ca. 51Ma (Li et al 2023)
- The alkaline rocks are surrounded by limestone
- 60 orebodies are located in the Dong Pao area named F1, F2 – F60
- F3 is the richest orebody (Fujii et al. 2010; Li et al. 2023)

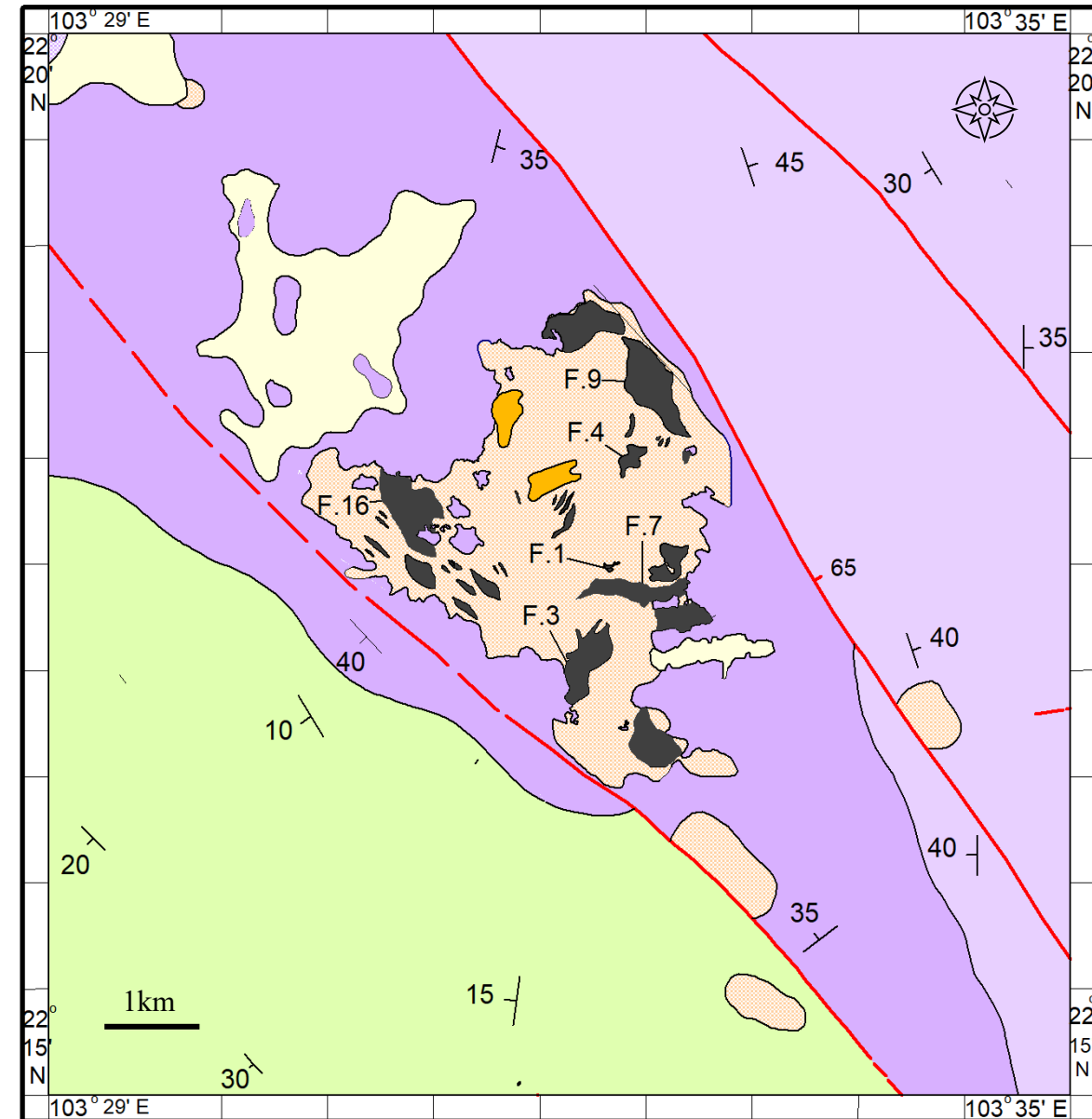


Fig 6. Geological map of the Dong Pao deposit

2. Geology

Geology of the Dong Pao deposit

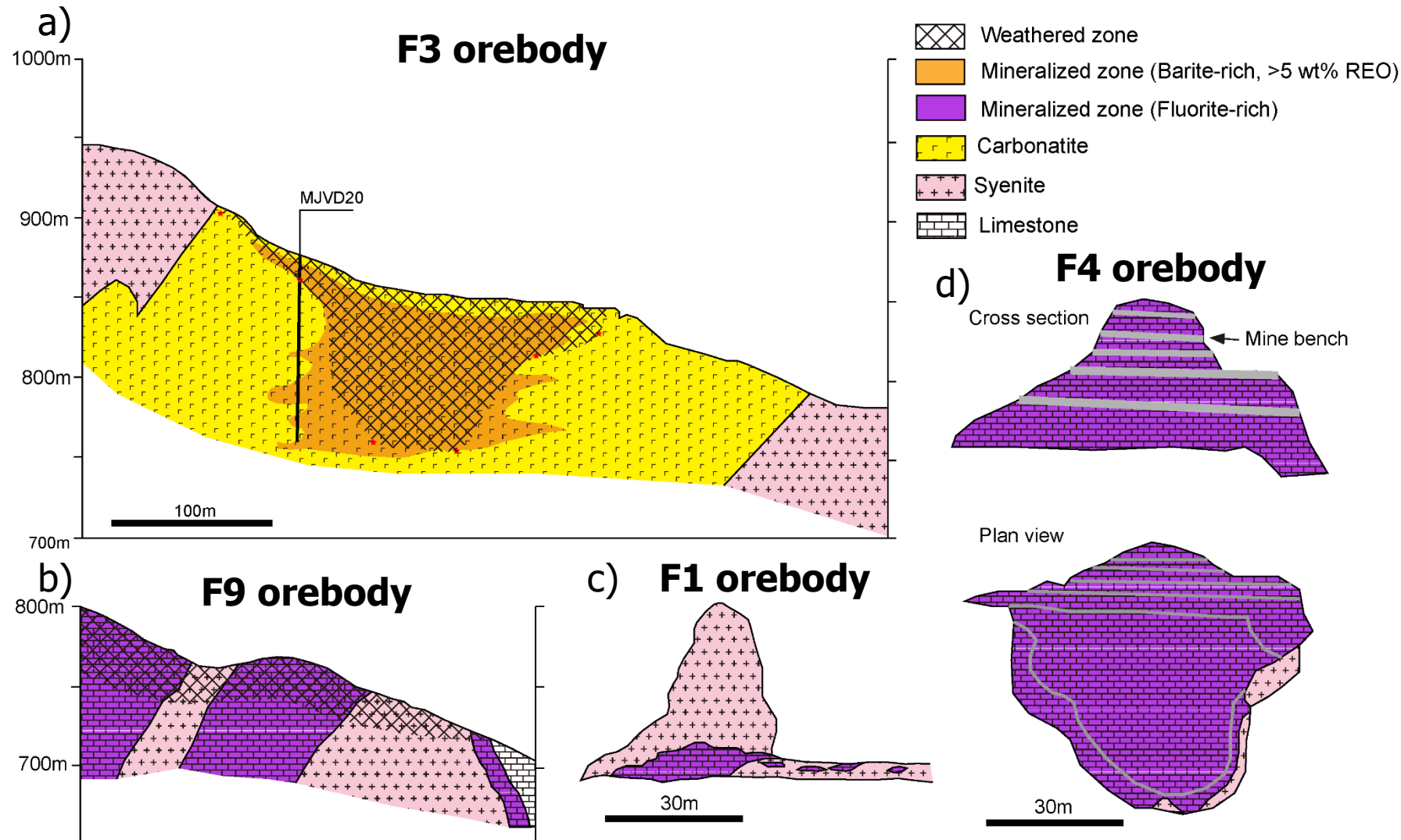


Fig 7. Occurrence of REE orebodies in the Dong Pao deposit.

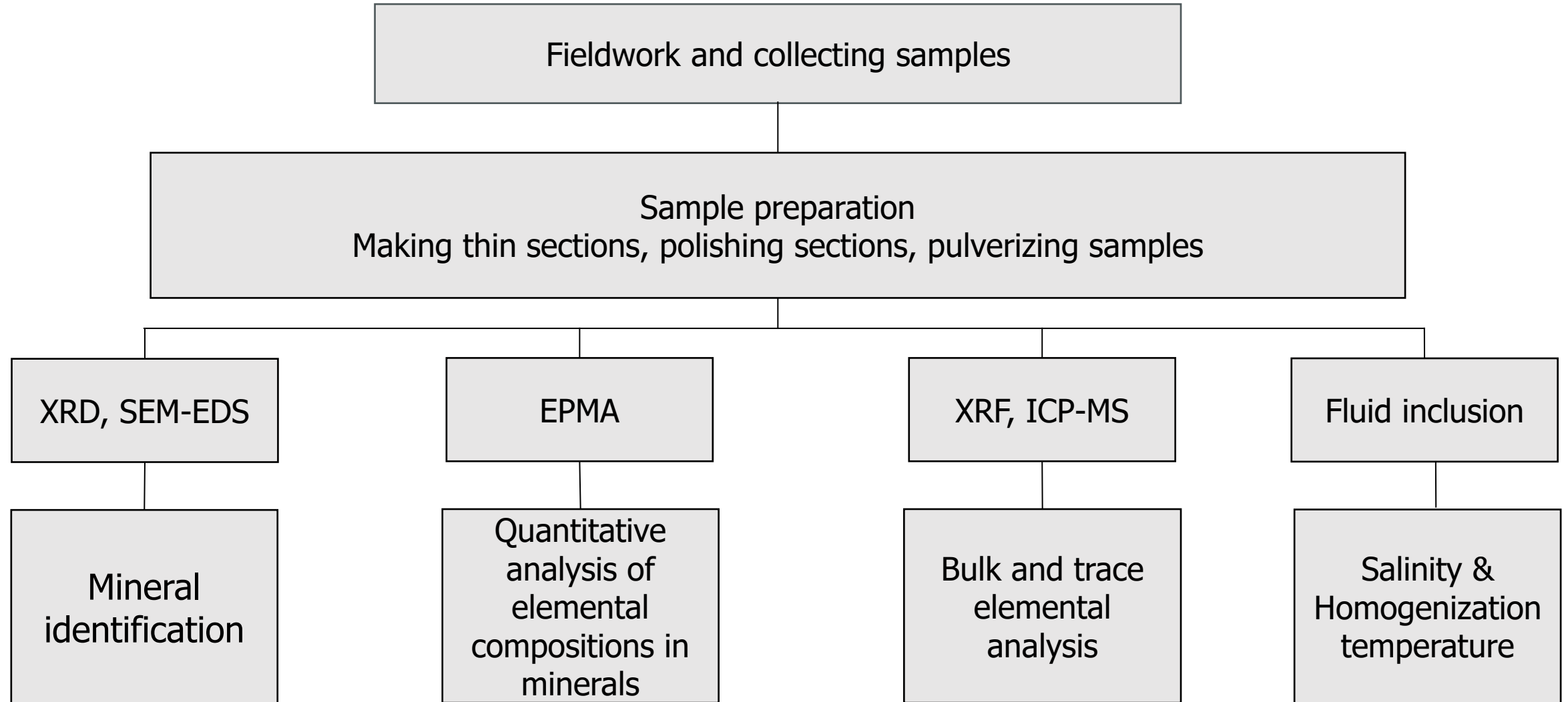
a) A cross-section of F3 orebody modified from JICA & MMAJ (2002). MJVD20 drill hole location is shown.

b) A cross-section of F9 orebody (This study).

c) A sketch of F1 orebody (JICA & MMAJ, 2002).

d) A sketch of F4 orebody (JICA & MMAJ, 2002).

Methods



3. Results-Rock description

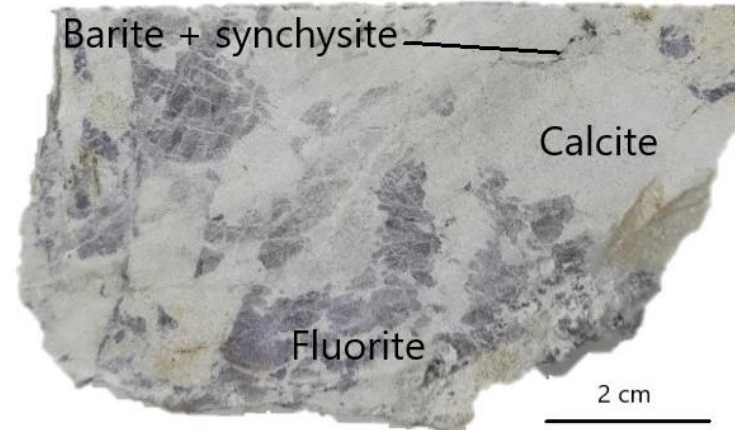
carbonatite

a)



Fresh carbonatite (F3)

b)



Metasomatized carbonatite (F3)

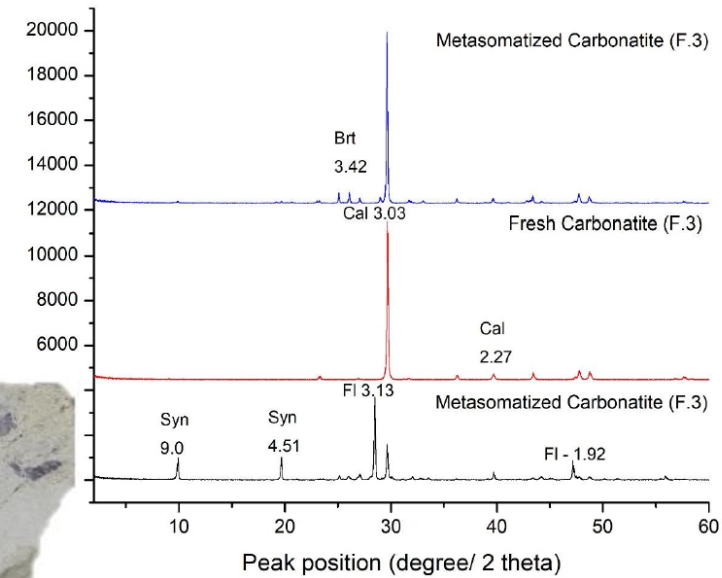
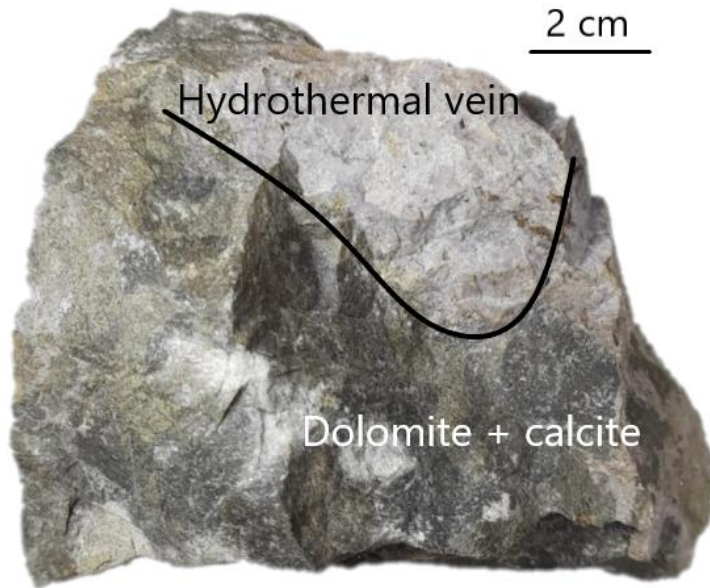


Figure 8. Hand-specimen photos of a) Calcite carbonatite and b) Metasomatized calcite carbonatite rich in fluorite.

3. Results-Rock description

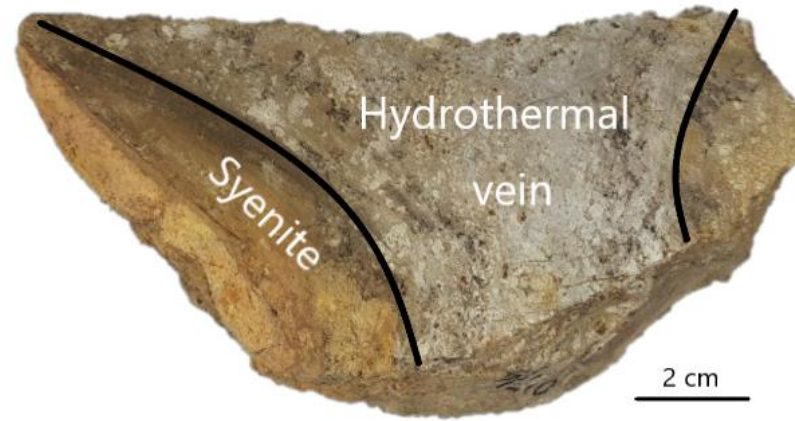
Limestone

a)



Metasomatic rock –
dolomite + calcite (F9)

b)



Outcrop Hydrothermal vein (F9)

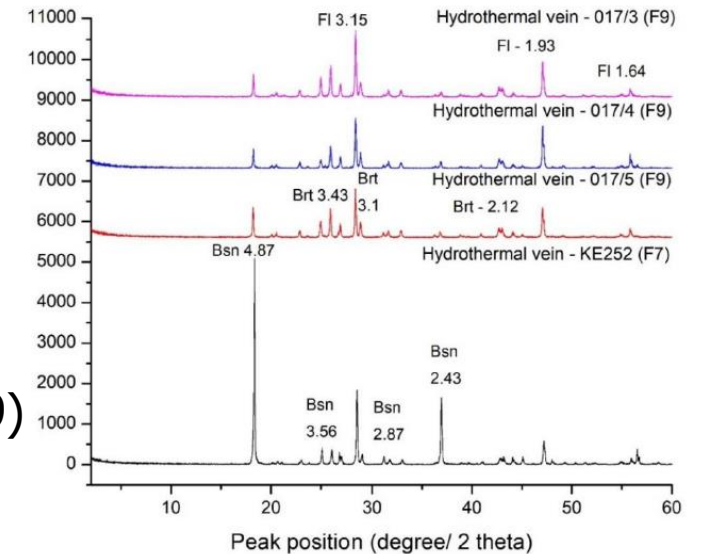
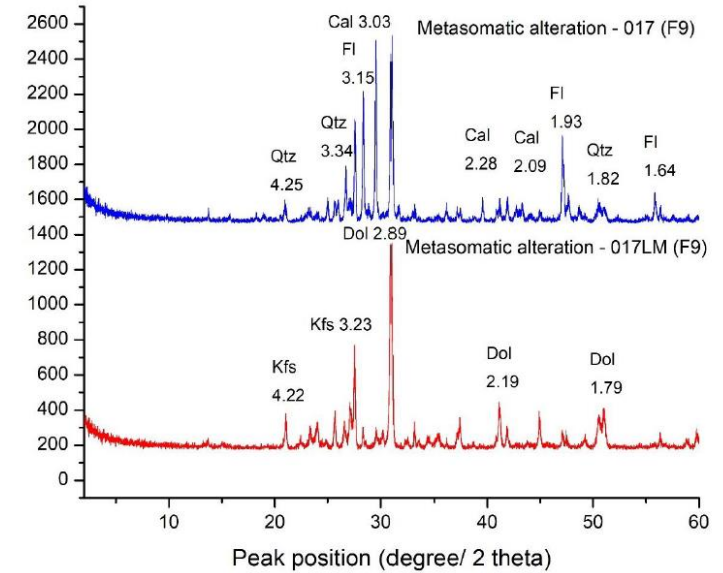


Figure 9. Hand-specimen photos of a) altered limestone, b) hydrothermal vein consisting of fluorite, barite, and REE minerals.

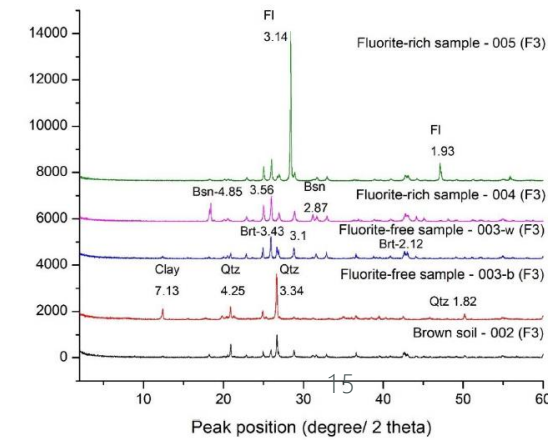
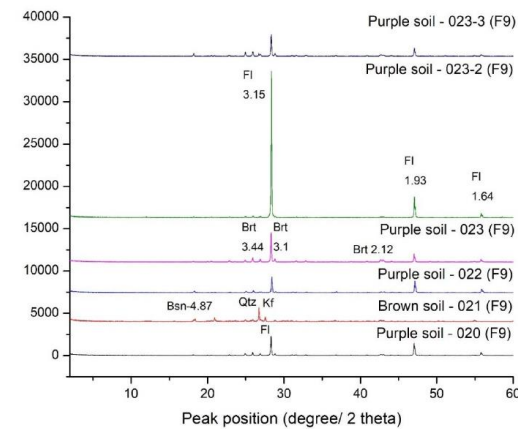
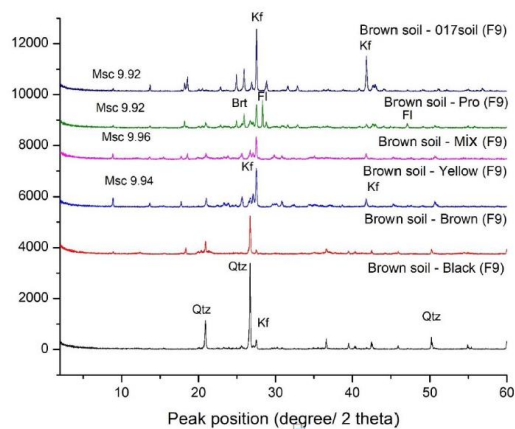
4. Results-Rock description

Weathered profile

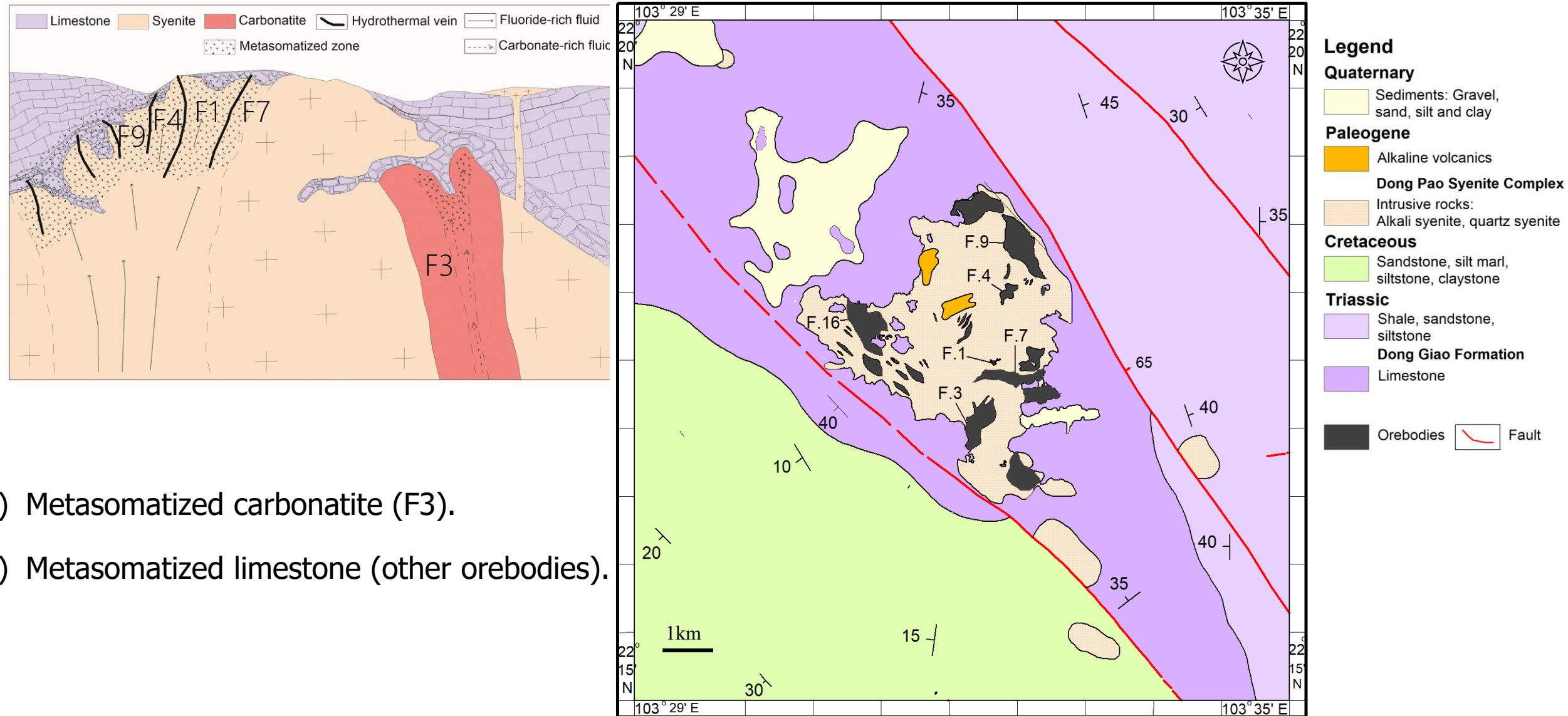
Weathered soil on top of syenite (F9)
(Brown soil)

Fluorite-rich soil (F9)
(Purple soil)

Weathered
carbonatite (F3)



3. Results - Rare earth mineralization styles and Genesis of the REE Dong Pao deposit



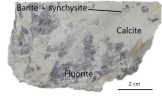
- 1) Metasomatized carbonatite (F3).
- 2) Metasomatized limestone (other orebodies).

Figure 11. A schematic sketch outlining the genesis of the Dong Pao deposit.

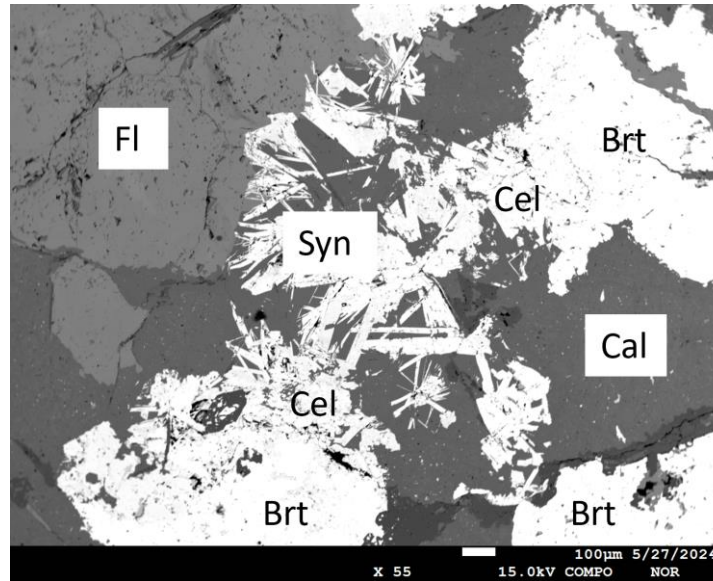
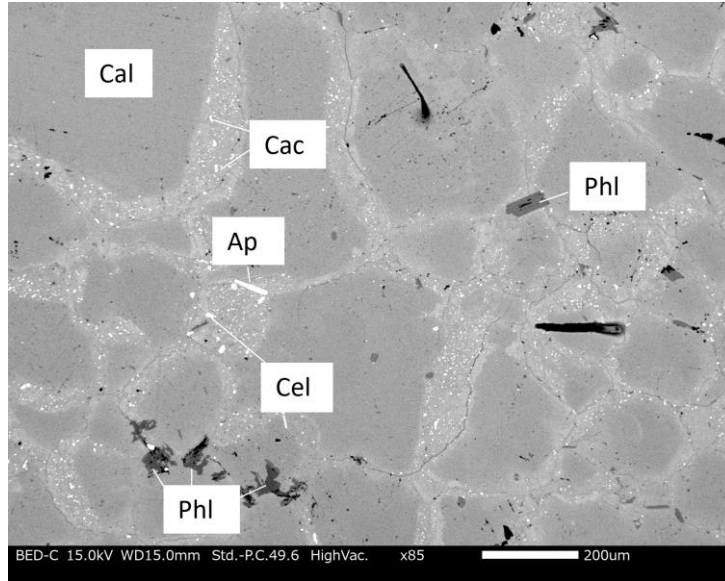
3. Results - Metasomatized carbonatite (F3)



Fresh carbonatite

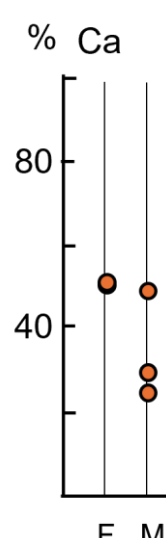
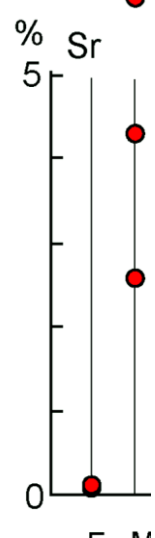
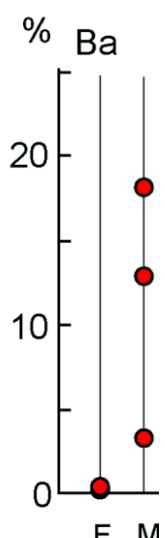
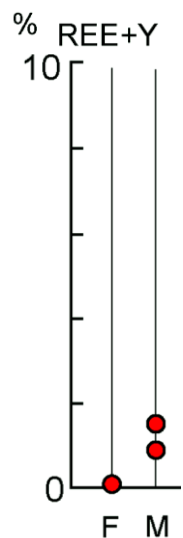


Metasomatized carbonatite



Apatite (Ap), $[\text{Ca}_5(\text{PO}_4)_3\text{F}]$
Carbocernaite (Cac) $[\text{Ca}(\text{Sr},\text{Ba},\text{REE})(\text{CO}_3)_2]$,
Strontianite (Str) $[\text{SrCO}_3]$,
Phlogopite (Phl) $[\text{KMg}_3(\text{Si}_3\text{Al})\text{O}_{10}(\text{F},\text{OH})_2]$

The metasomatized carbonatite is characterized by the replacement of calcite by barite (Brt) $[\text{BaSO}_4]$, fluorite (Fl) $[\text{CaF}_2]$, Celestine (Cel) $[\text{SrSO}_4]$, and rare earth carbonate minerals such as synchysite-(Ce) $[\text{Ca}(\text{Ce},\text{La})(\text{CO}_3)_2\text{F}]$.

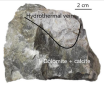


F: Fresh

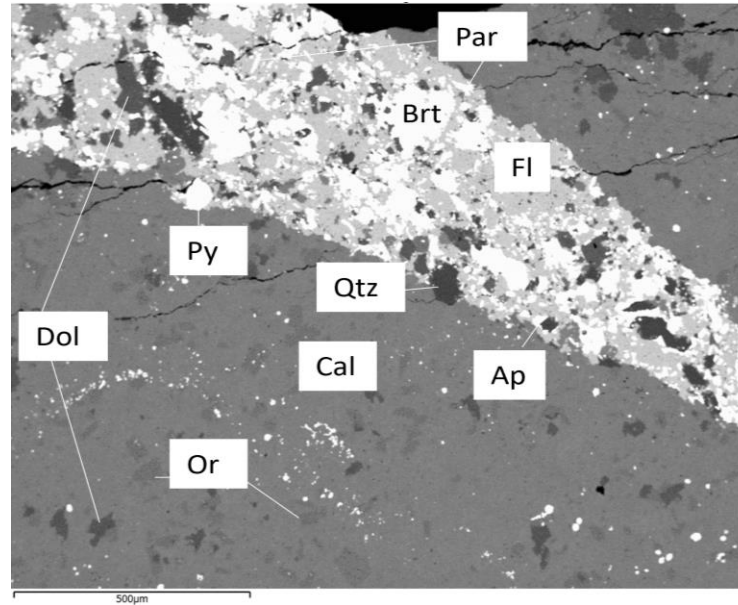
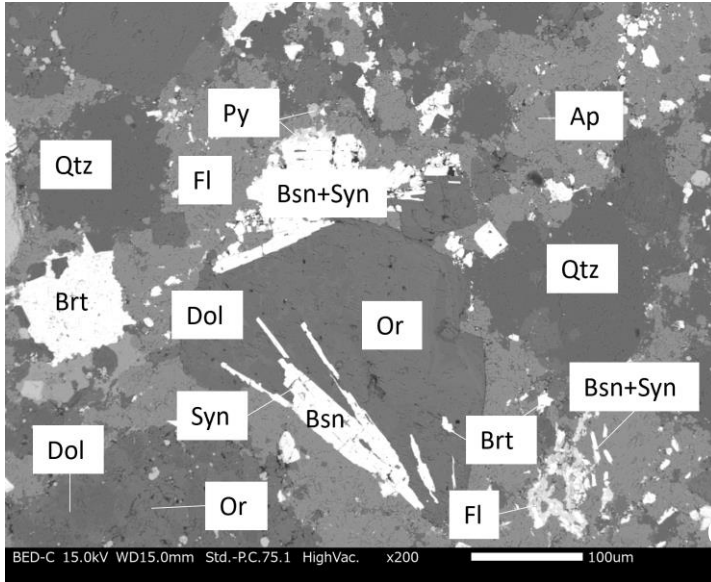
M: Metasomatized

Carbonatite-derived late-stage fluids are responsible for the formation of Ba-Sr-REE mineralization in carbonatite complexes (Zaitsev et al., 1998; Wall et al., 2001; Giebel et al., 2017; Mitchell and Gittins 2022; Louvel et al., 2022; Bhattacharjee et al., 2024).

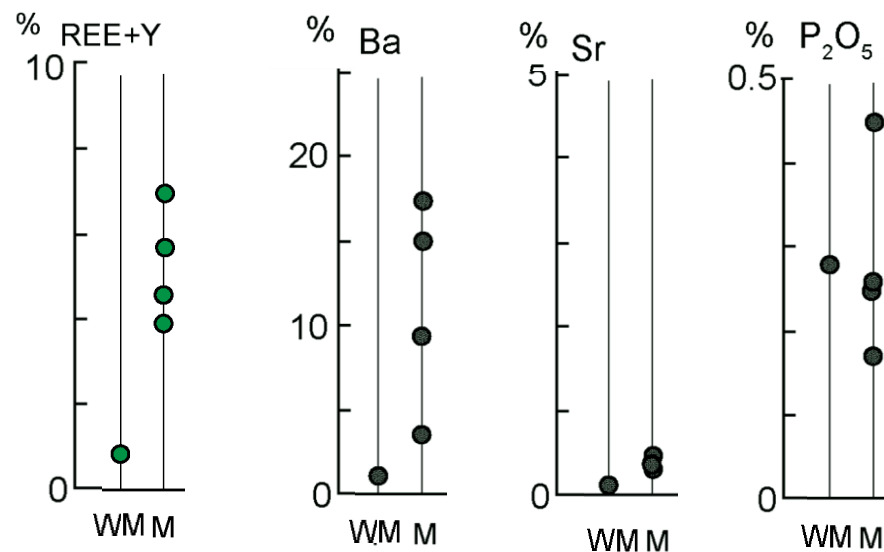
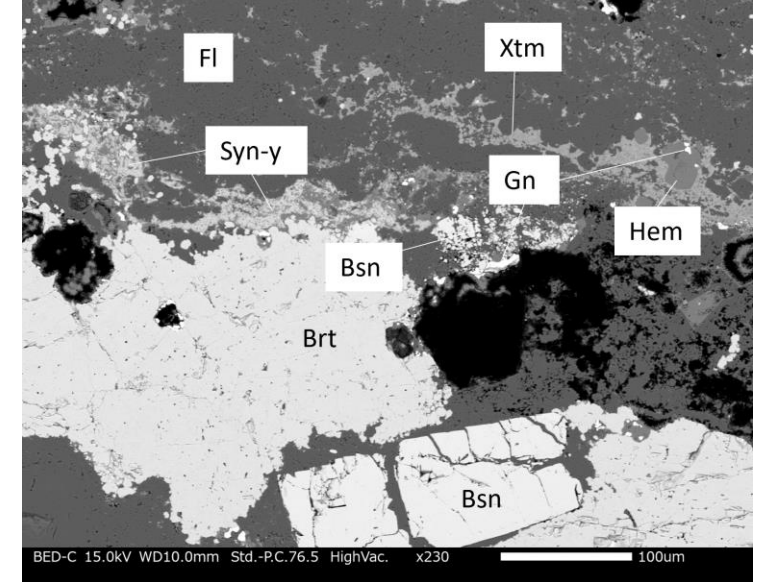
3. Results - Metasomatized limestone (other orebodies)



Metasomatized limestone



Hydrothermal Vein



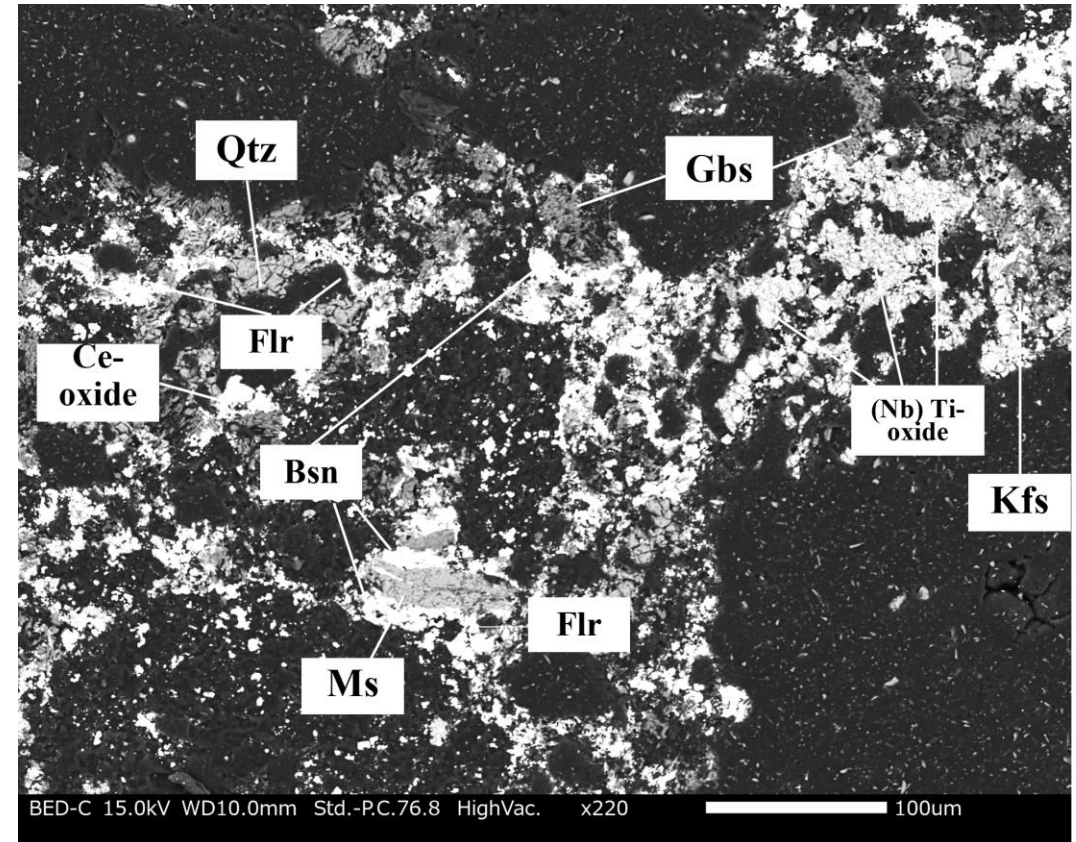
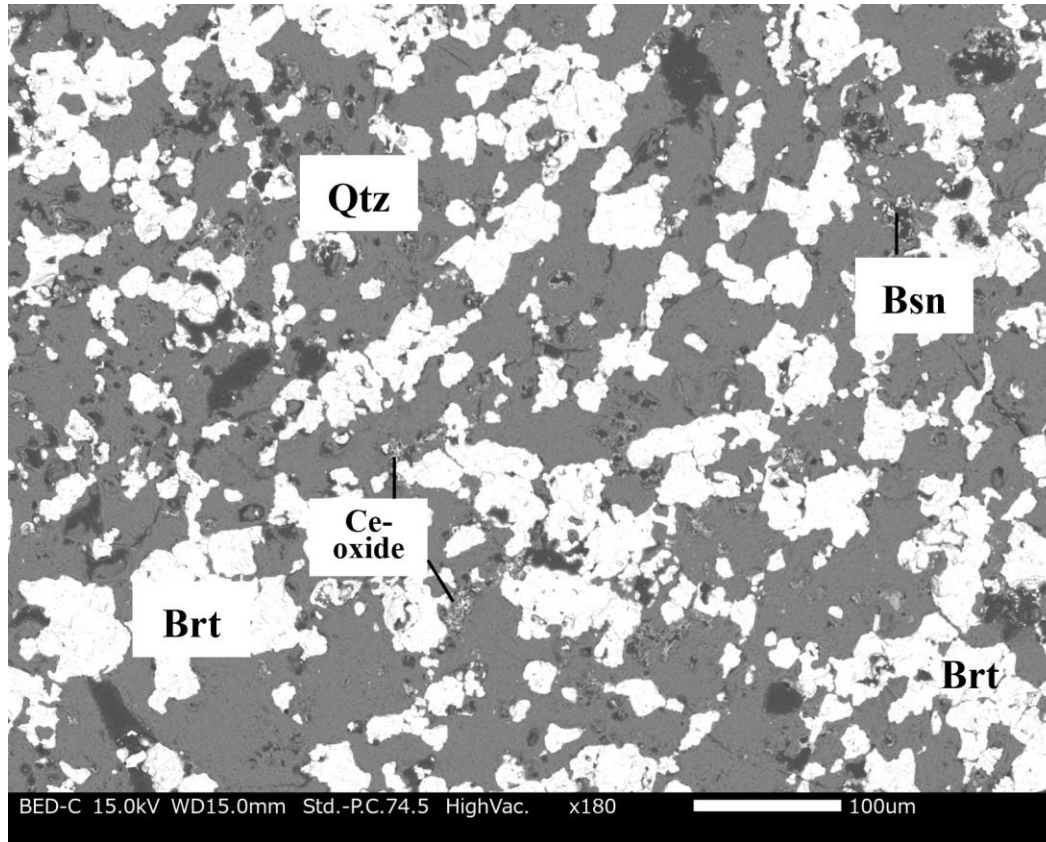
WM: Weakly Metasomatized

M: Metasomatized

- The limestone is heavily metasomatized to form metasomatized limestone contains dolomite overprinted by the assemblage of barite, fluorite, bastnäsite-(Ce) (Bsn), [(Ce,La)(CO₃)F], parasite-(Ce) [Ca(Ce,La)₂(CO₃)₃F₂].
- The metasomatic limestone is intruded by hydrothermal veins, which contain fluorite, barite, bastnäsite-(Ce), xenotime [Y(PO₄)].

3. Results - Mineralogy description

Weathered carbonatite (F3)

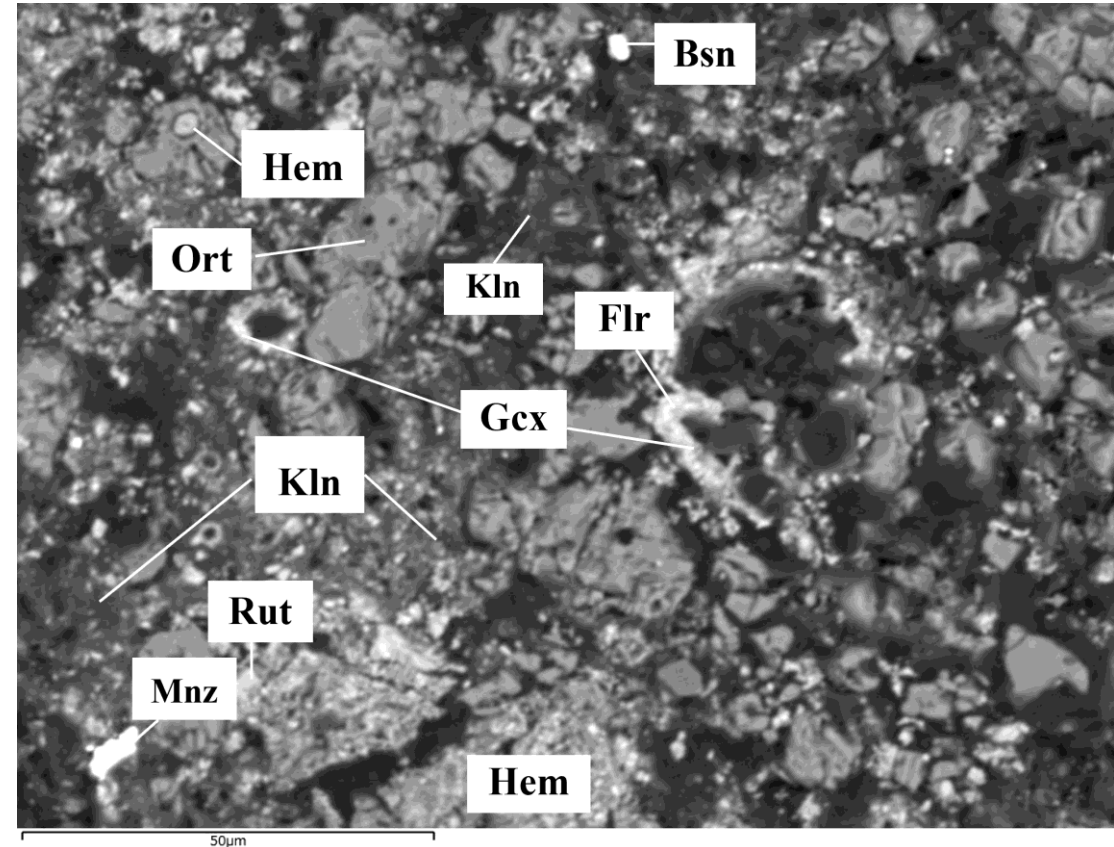
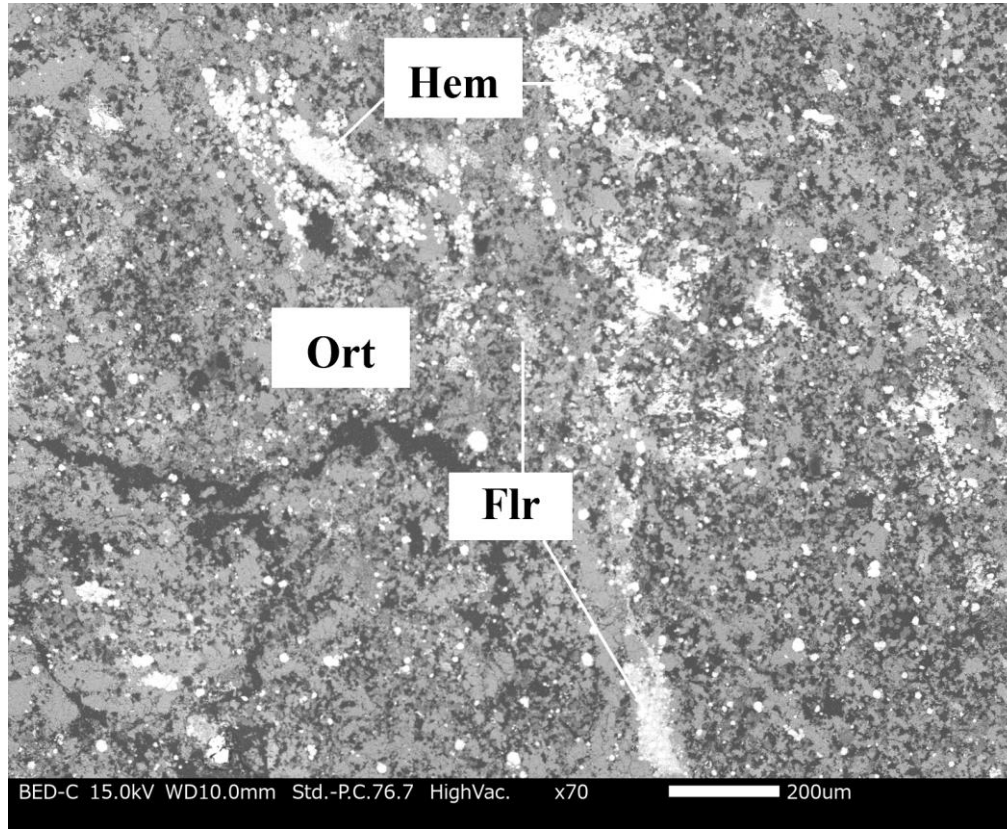


Back-scattered electron images of weathered carbonatite (F3) in the Dong Pao deposit. Barite (Brt) quartz (Qtz), muscovite (Ms), gibbsite (Gbs).

Bastnäsite (Bsn), $[\text{REE}(\text{CO}_3)\text{F}]$; Cerianite (Ce-oxide), $[\text{Ce}^{4+}, \text{Th})\text{O}_2]$; Florencite (Flr), $[\text{CeAl}_3(\text{PO}_4)_2(\text{OH})_6]$.

3. Results - Mineralogy description

Weathered soil on top of syenite (F9) (Brown soil)



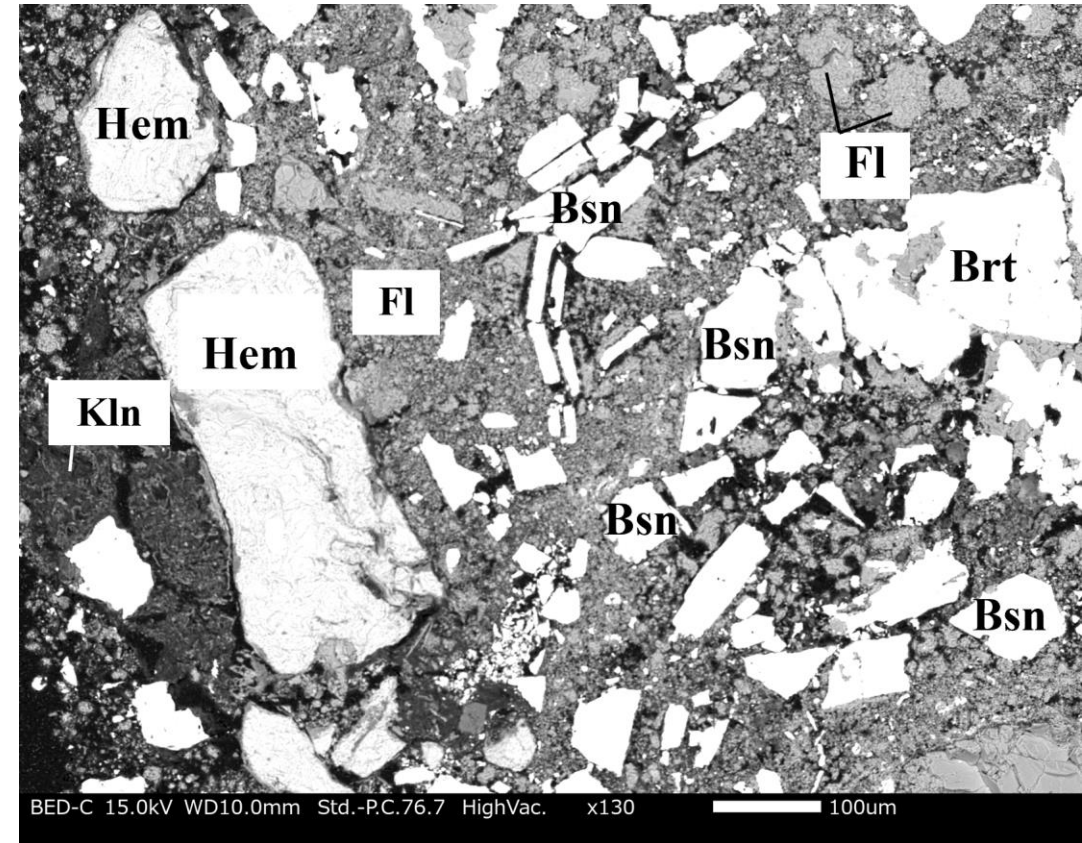
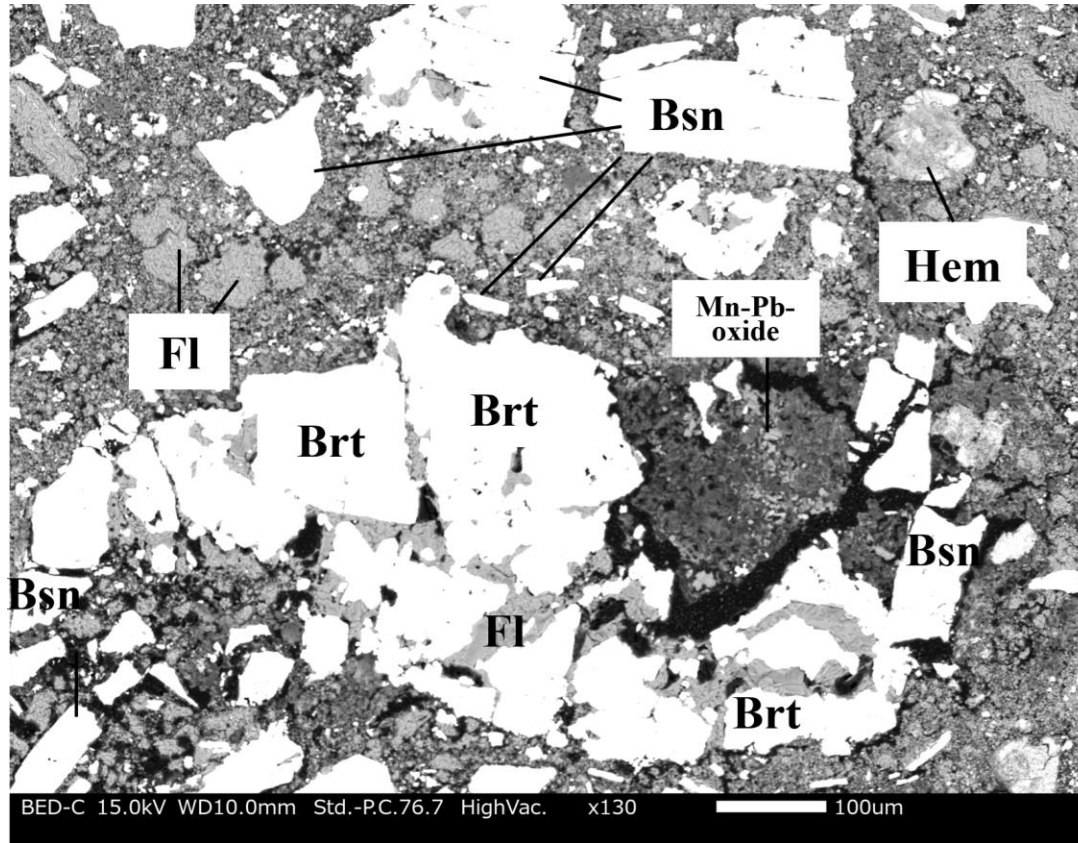
Back-scattered electron images of weathered soil on top of syenite (F9) in the Dong Pao deposit.

Bastnäsite (Bsn), $[\text{REE}(\text{CO}_3)\text{F}]$; cerianite (Ce-oxide), $[\text{Ce}^{4+}, \text{Th})\text{O}_2]$; florencite (Flr), $[\text{CeAl}_3(\text{PO}_4)_2(\text{OH})_6]$.

Gorceixite (Gcx) $[\text{BaAl}_3(\text{PO}_4)(\text{PO}_3\text{OH})(\text{OH})_6]$; Monazite (Mnz), $[\text{REE}(\text{PO}_4)]$.

3. Results - Mineralogy description

Fluorite-rich soil (F9) (Purple soil)

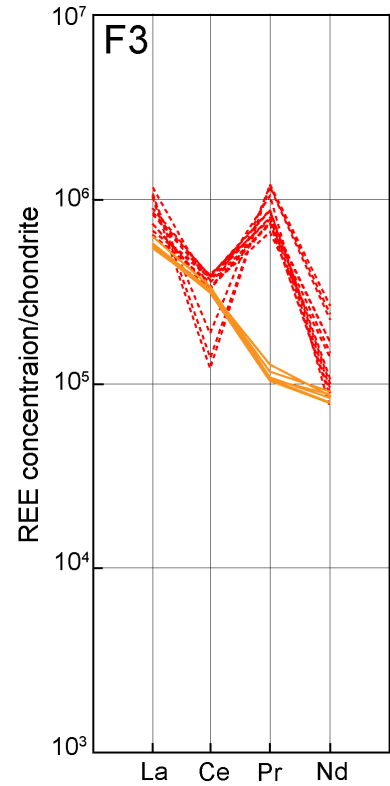


Back-scattered electron images of fluorite-rich soil (F9) in the Dong Pao deposit.

Barite (Brt), bastnäsite (Bsn) $[\text{REE}(\text{CO}_3)\text{F}]$, fluorite (Fl), hematite (Hem) and manganese oxides (Mn-Pb-oxide).

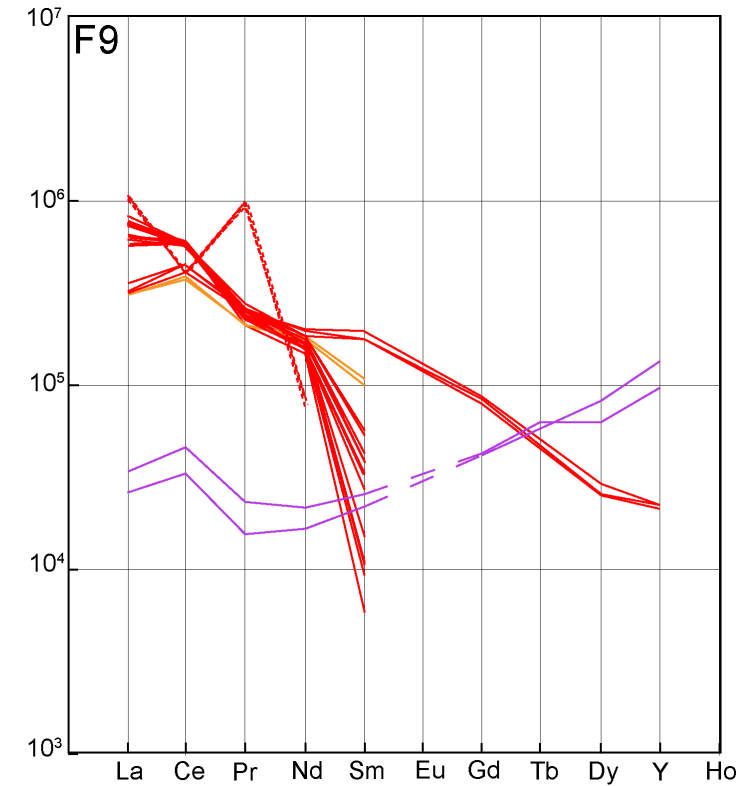
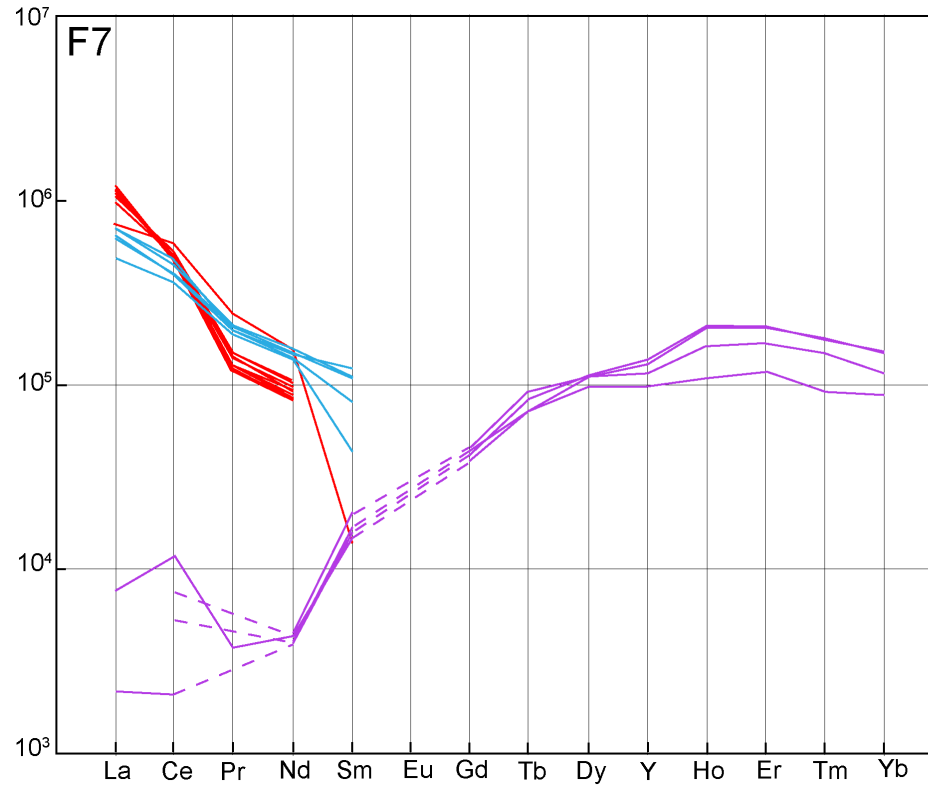
3. Results - Mineral chemistry

Carbonatite hosted



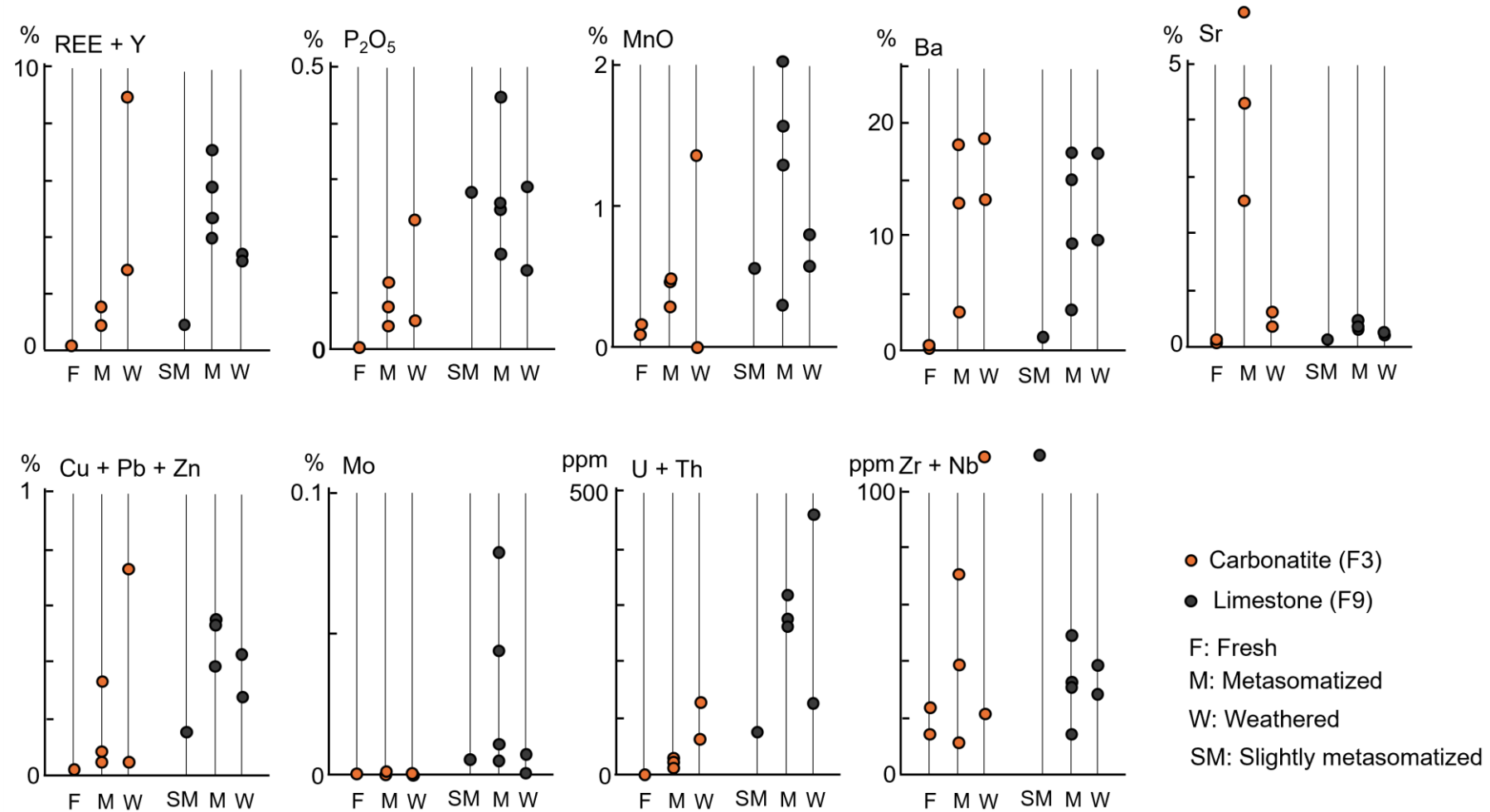
— Bastnasite — Synchysite — Monazite — Xenotime - - - - - Bastnasite in surface weathered sample

Metasomatized limestone zone hosted



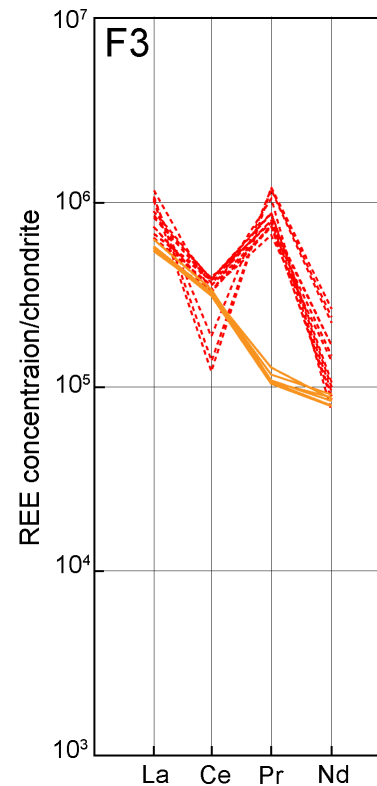
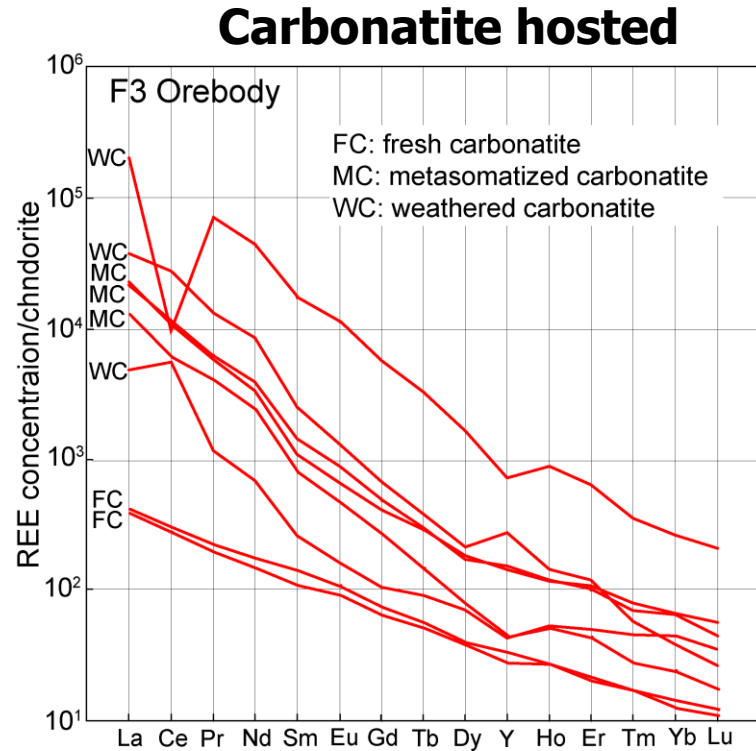
Chondrite-normalized REE patterns of REE minerals in F3, F7 and F9 orebodies of the Dong Pao deposit. The data is based on EPMA analysis and normalized after McDonough and Sun (1995).

3. Results - Geochemistry



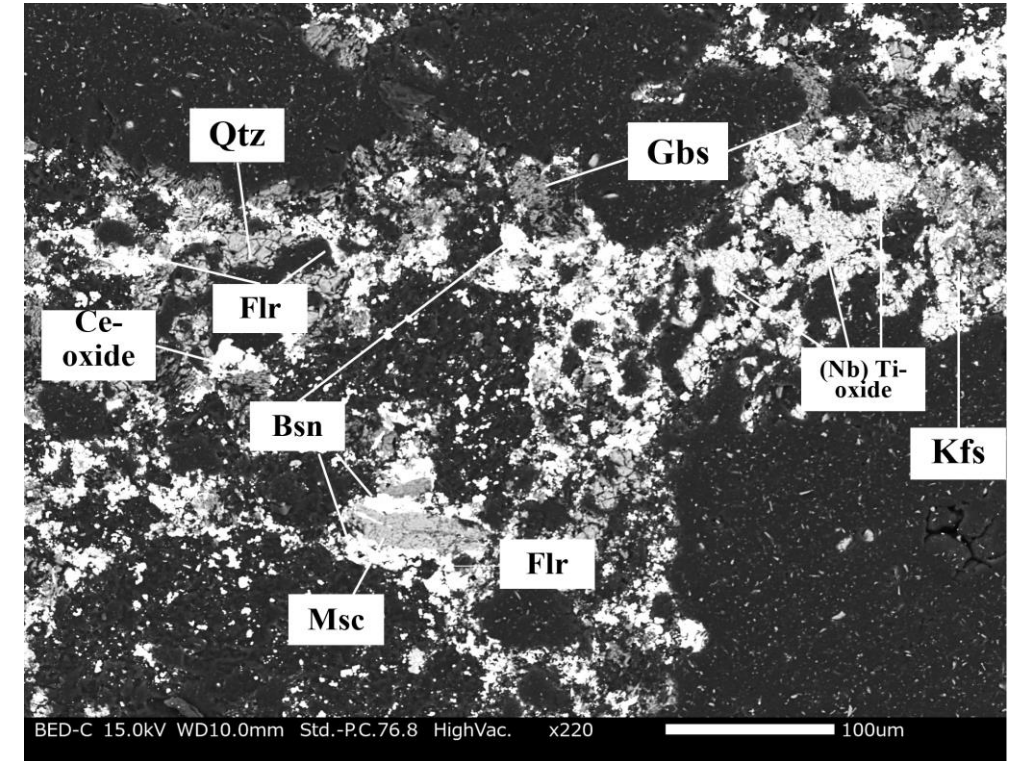
Elemental distribution between the metasomatized rock and carbonatite type mineralization in the Dong Pao deposit.

3. Results - Weathering effect



— Synchysite Bastnasite in surface weathered sample

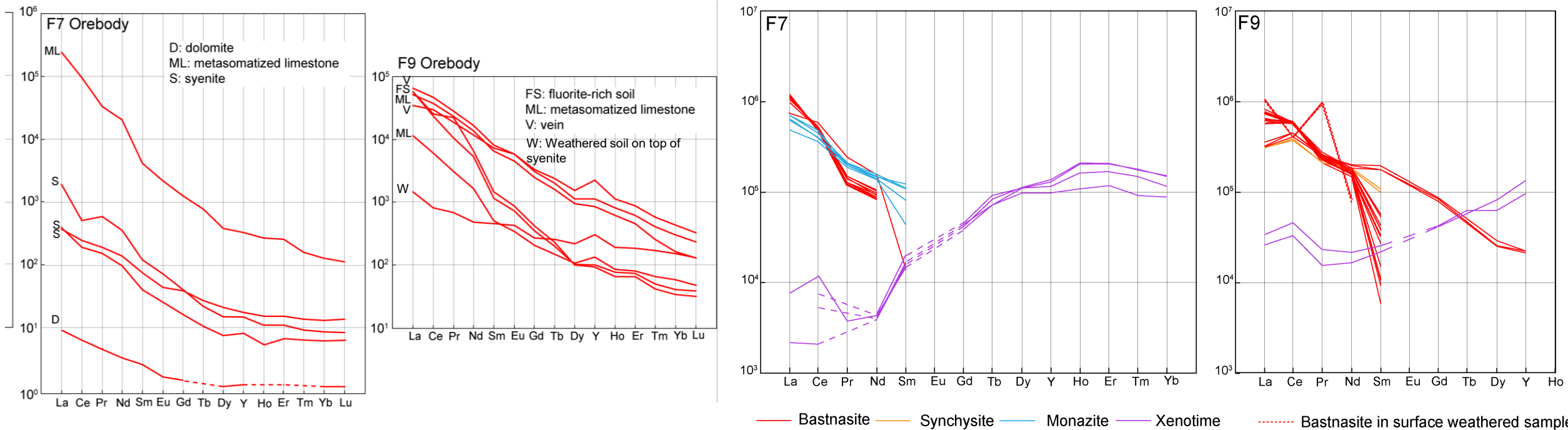
Weathered carbonatite (F3)



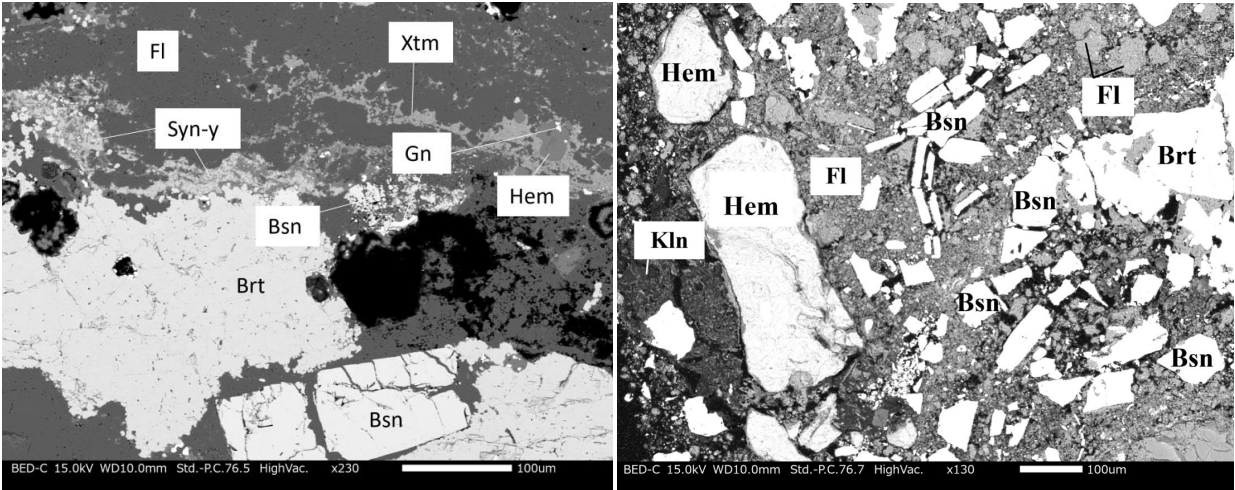
This material contains Ce-rich minerals such as cerianite $[\text{Ce}^{4+}, \text{Th})\text{O}_2]$; florencite (Ce) $[\text{CeAl}_3(\text{PO}_4)_2(\text{OH})_6]$, and bastnäsite-(Ce) $[(\text{Ce}, \text{La})(\text{CO}_3)\text{F}]$, although some bastnäsite is enriched in La [bastnäsite-(La)] $[\text{La}(\text{CO}_3)\text{F}]$.

3. Results - Weathering effect

Metasomatized limestone hosted

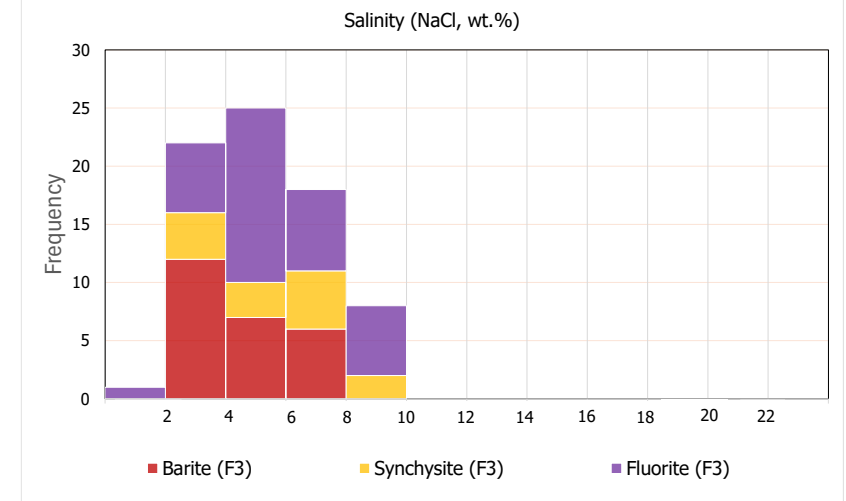
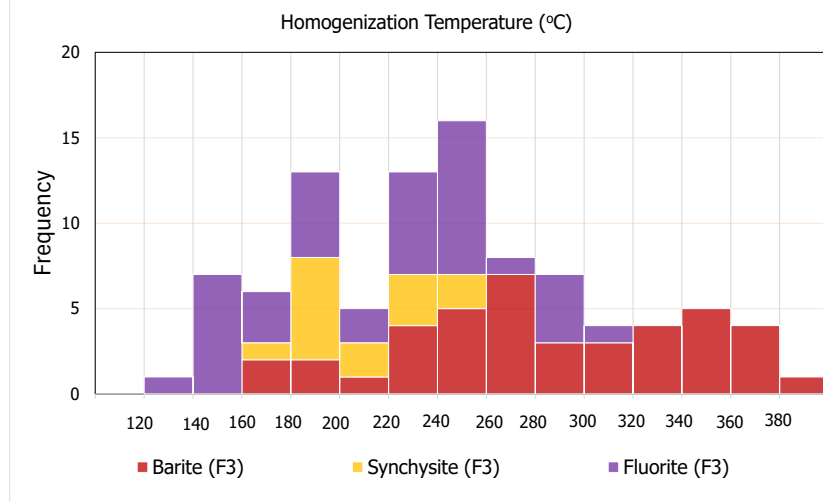
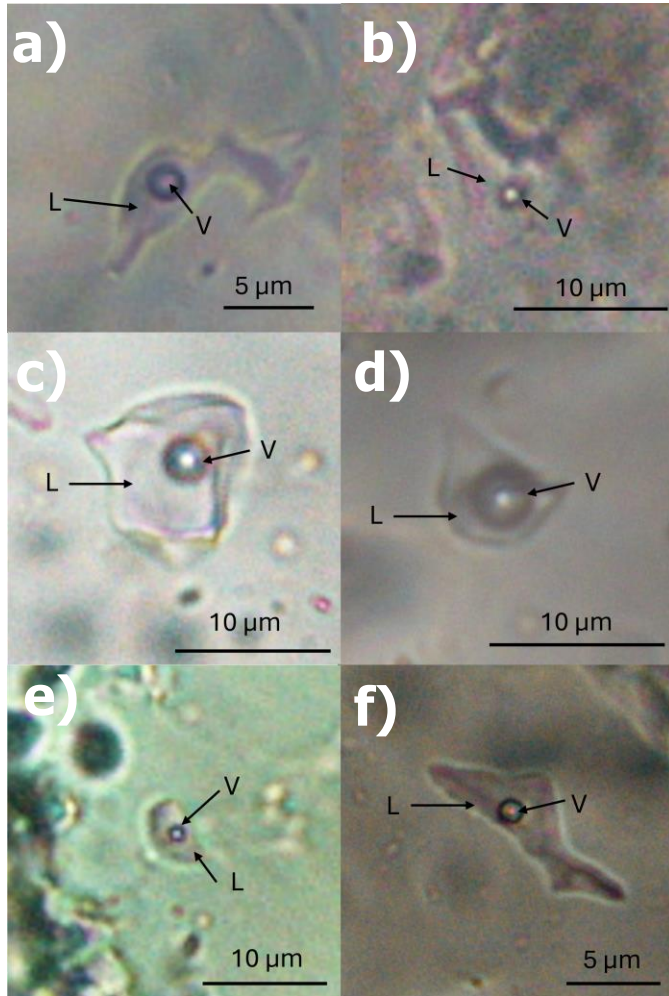


Hydrothermal vein (F9) →

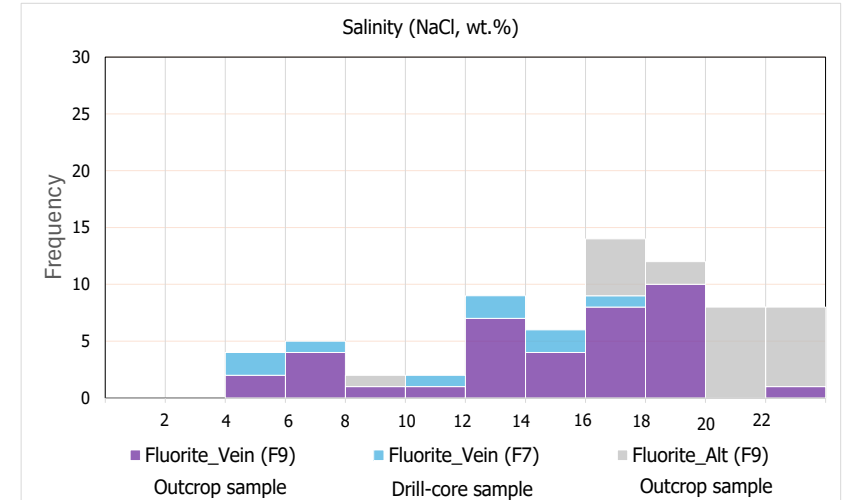
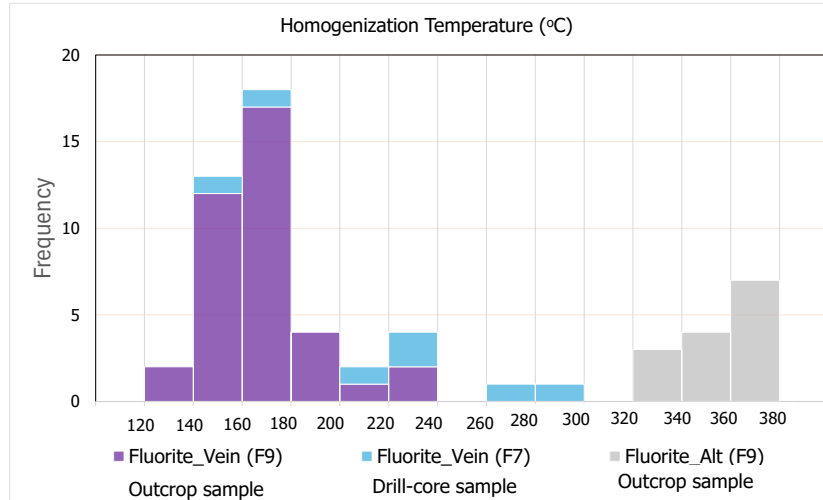


Fluorite-rich soil (F9)

3. Results – Fluid inclusion



Metasomatized carbonatite



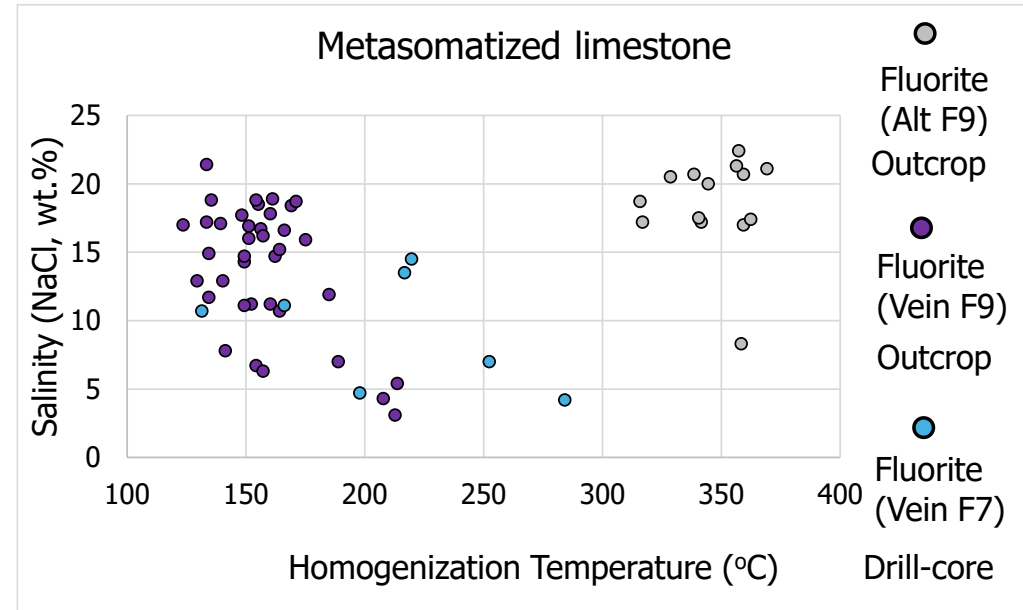
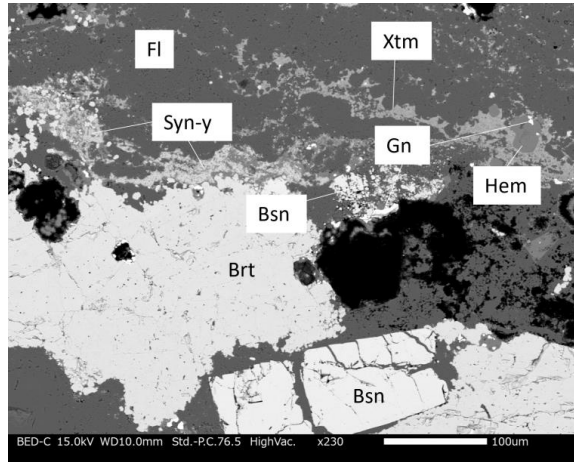
Metasomatized limestone

Fluid inclusions with irregular, polygonal, round, elongated, and prismatic shapes in

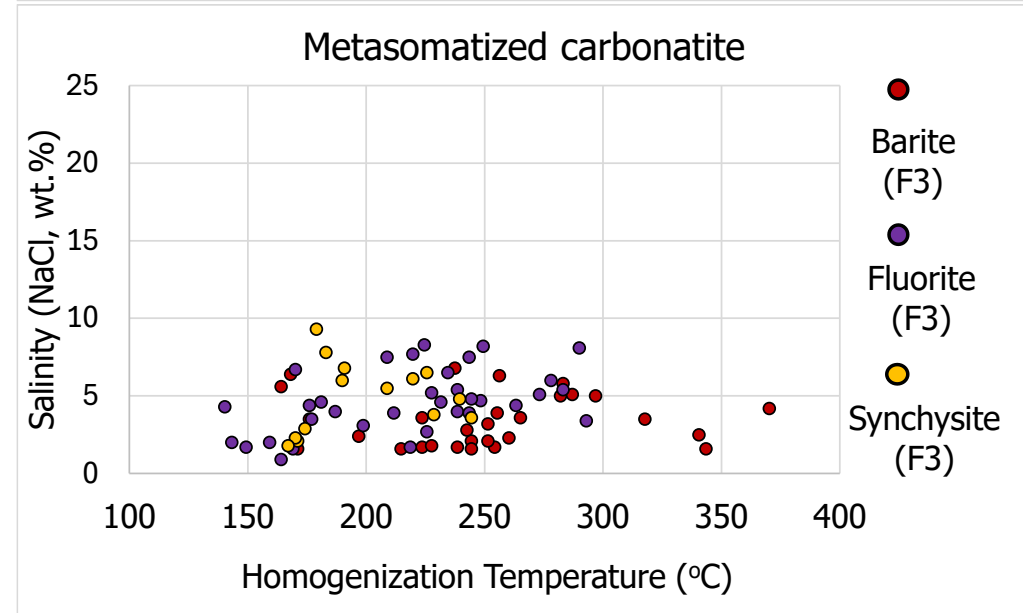
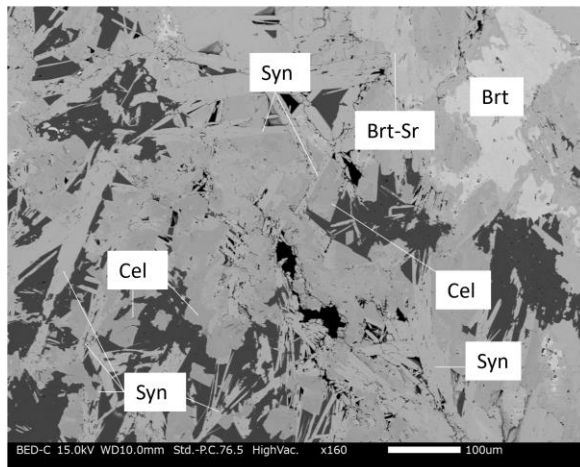
a) synchronite in metasomatized carbonatite (F3), b) barite in metasomatized carbonatite (F3), c) fluorite in metasomatized carbonatite (F3), d) fluorite in the hydrothermal vein (F9), e) fluorite in the hydrothermal vein (F7), f) fluorite in the metasomatic rock (F9).

3. Origin of metasomatic fluids

Fluorine-rich fluid



Carbonate-rich fluid



4. Contribution

- The Dong Pao deposit features two distinct styles of rare earth element (REE) mineralization:
 1. Metasomatized limestone: This mineralization style results from the interaction of fluorine-rich fluids with limestone. It is characterized by abundant lenticular orebodies situated between syenite and limestone (as seen in F9) and serves as an analogue to skarn deposits.
 2. Metasomatized carbonatite: This style arises from the interaction of carbonate-rich fluids with carbonatite, it occurs within calciocarbonatites that intrude the syenite (in F3).
- Weathering processes have played a significant role in upgrading the REE ore and redistributing REE concentrations within the weathering profile on top of orebodies.
- The study clarifies the mineralogical composition of each REE mineralization type, providing a foundation for mineral processing, mining operations, and deposit management in the Dong Pao.
- This study confirmed the high REE prospectivity of the Dong Pao deposit (up to 13% TREO), and the occurrence of HREE in the metasomatized limestone mineralization (4,958 ppm) and in the weathering profile on the top of orebodies (up to 919.5 ppm).

THANK
YOU

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