

# *Proterozoic fluorbritholite-bearing REE-rich hydrothermal pods and veins from near Jamestown, CO*



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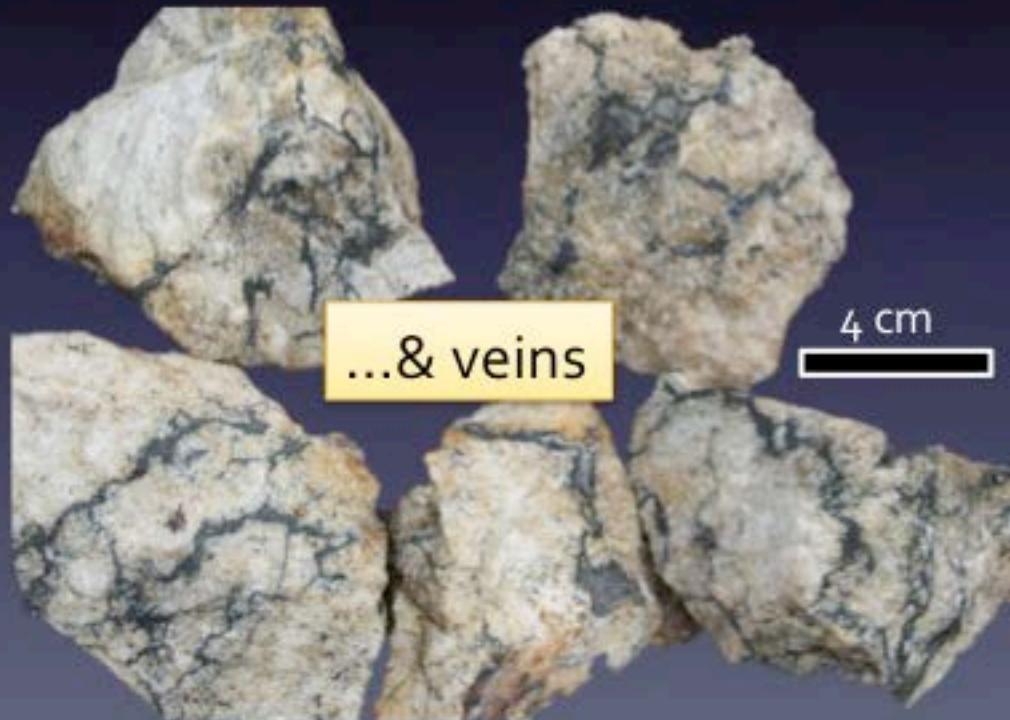
*Markus B. RASCHKE*<sup>2</sup>



*GSA annual meeting  
Denver, CO  
October 29<sup>th</sup> 2013*

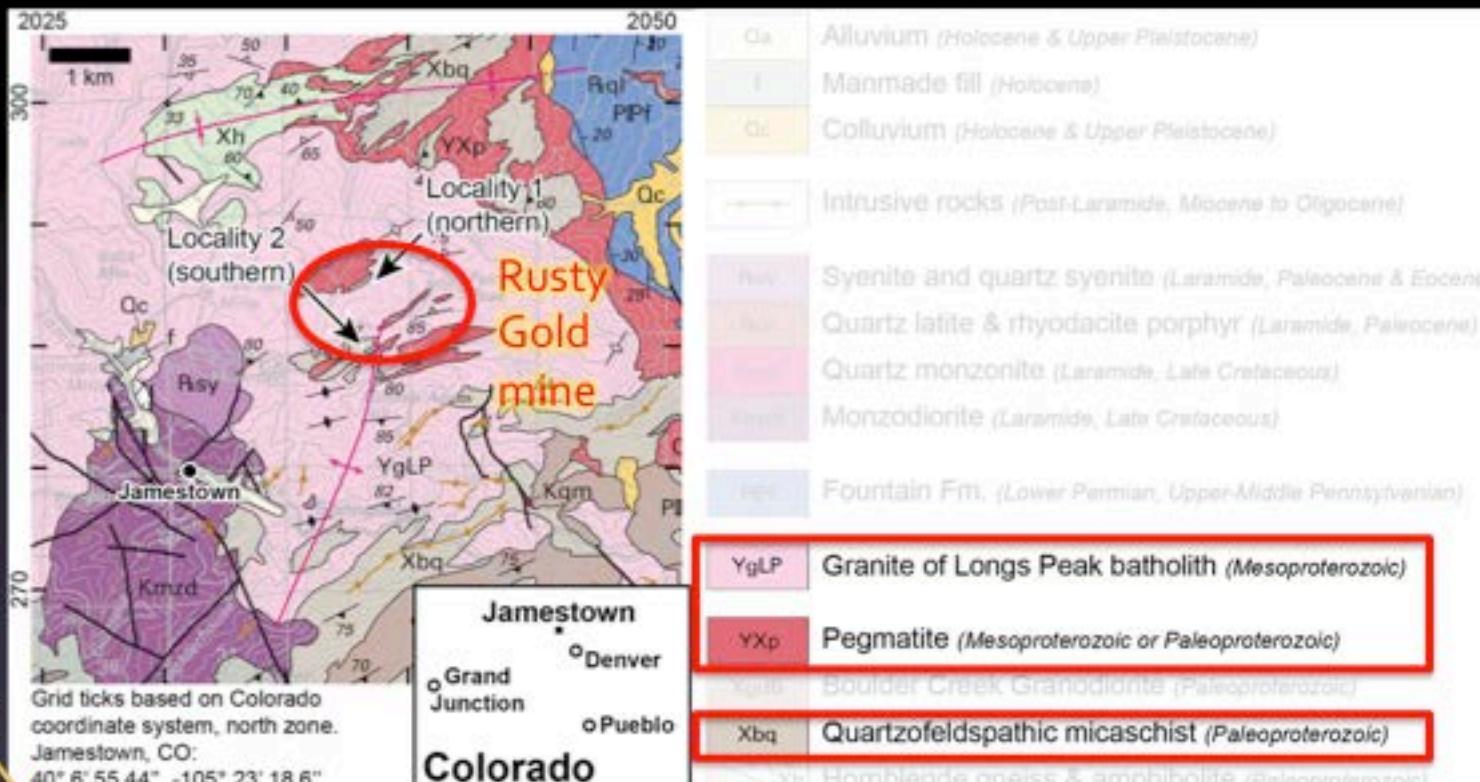
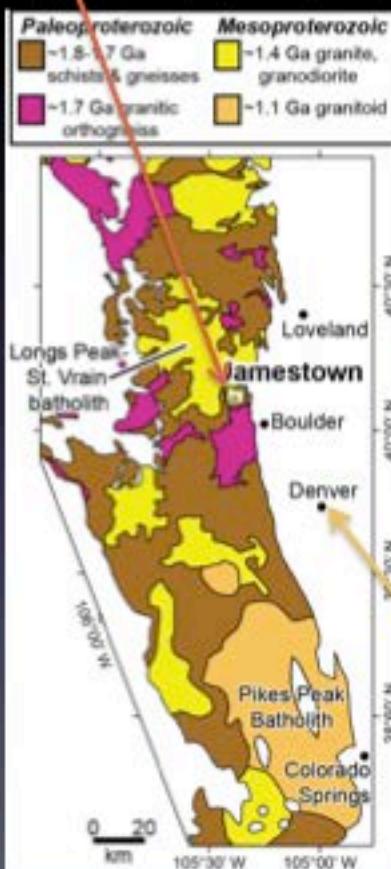
# REE mineralization near Jamestown, CO...

- Introduction
- Geochemistry
- Mineral assemblages
- Mineral analyses
- Geochronology & formation



# Geological setting

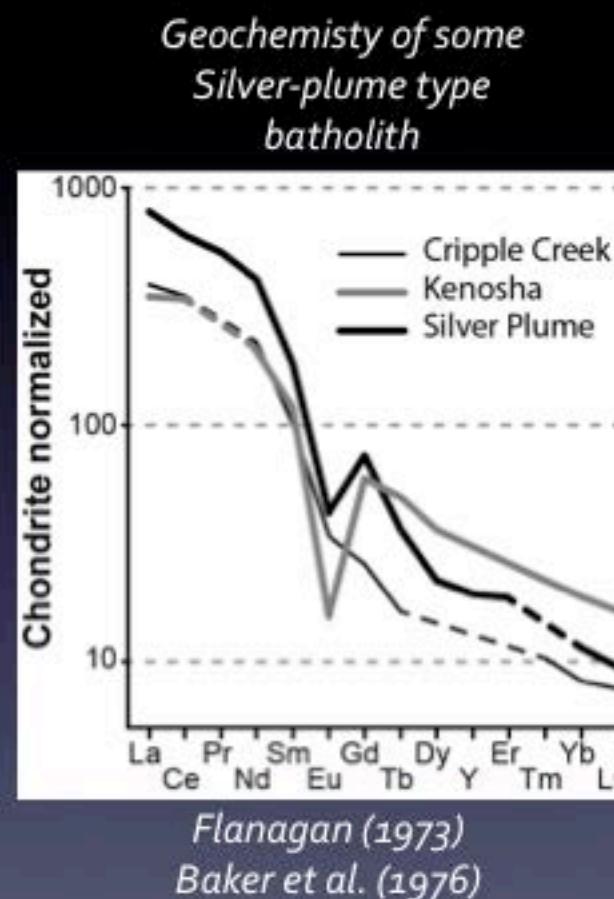
## Studied area



## You are here!

# Longs Peak - St. Vrain granite

- **Peraluminous “anorogenic” granite** ( $A/CNK > 1$ ); enriched in K and lithophile (Rb, Ba, REE, U, Th), depleted in Na, Ca, Mg, Sr (Anderson & Thomas, 1985)
- Mineralogy: Kfs, Qtz, Pl, Bt, Ms  
Accessory: Mgt, Ap, Zrn, Sil, Aln, Mnz (?)
- Intrude Paleoproterozoic schist and Boulder Creek granodiorite (~1.8 – 1.7 Ga)
- “Silver Plume” age ~1.43 Ga  
(Peterman et al., 1968)
- **Rare pegmatite & aplite** (low water content)
- **Strong fractionation of LREE to HREE**



# Why studying this area?

## THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 25

JUNE, 1940

No. 6

### DEPOSITS OF RADIOACTIVE ~~CERITE~~ NEAR JAMESTOWN, COLORADO\*

EDWIN N. GODDARD AND JEWELL J. GLASS,  
*U. S. Geological Survey, Washington, D.C.*

Two studies in  
1940 & 1941,  
since then  
nothing...

### Fluorbritholite!

*American Mineralogist 26 (2), 1941*

COLORADO ~~CERITE~~

ROSS A. HANSON\* AND D. W. PEARCE, *Dept. of Chemistry,  
Purdue University, W. Lafayette, Indiana.*

### Motivation for this study:

- Claim for **cerite\***, but it's NOT...
- Mineral assemblage & composition?
- Extension of mineralization?
- Relation with 1.4 Ga granite / pegmatite / aplite?

\*Cerite = Fe-bearing ( $\pm$ Al, Mg) hydrous silicate of REE

# Outcrop

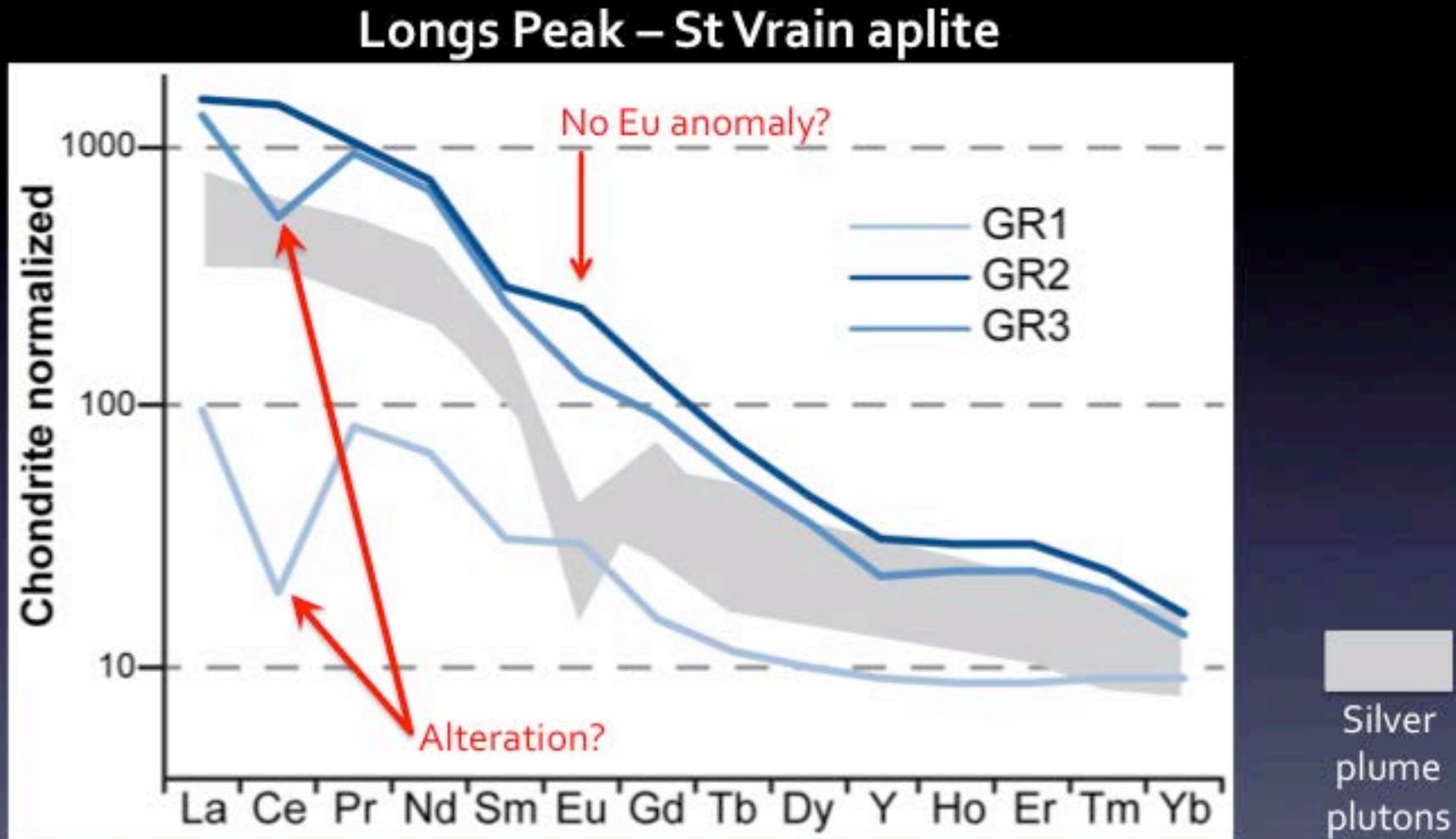


Common cm-sized pods and thin veins within aplite



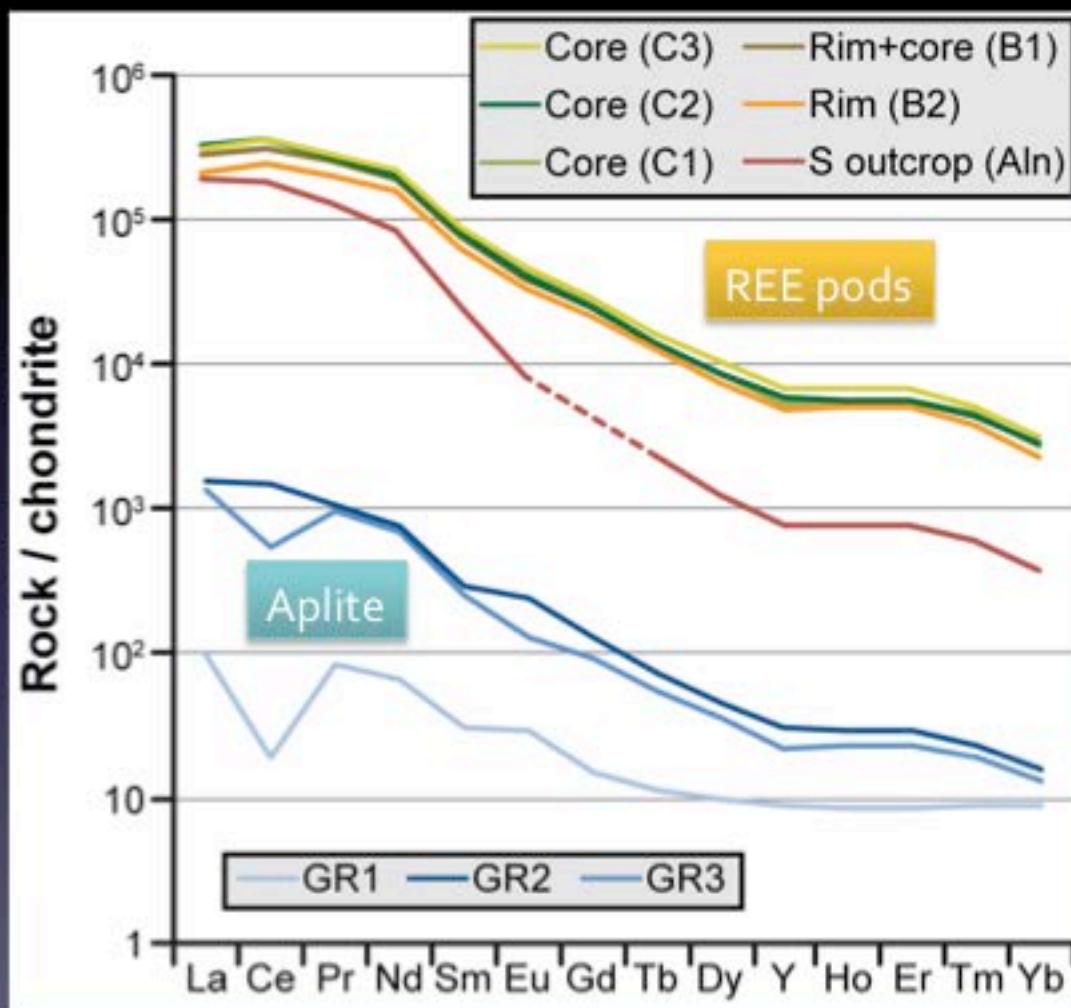
Dark rim in pods & isolated vein = allanite

# Rock geochemistry (*aplite*)



Aplite enriched in (L)REE compare to Silver plume plutons  
(presence of allanite in matrix)

# REE pods/veins geochemistry



Extreme enrichment in REE in pods compare to aplite

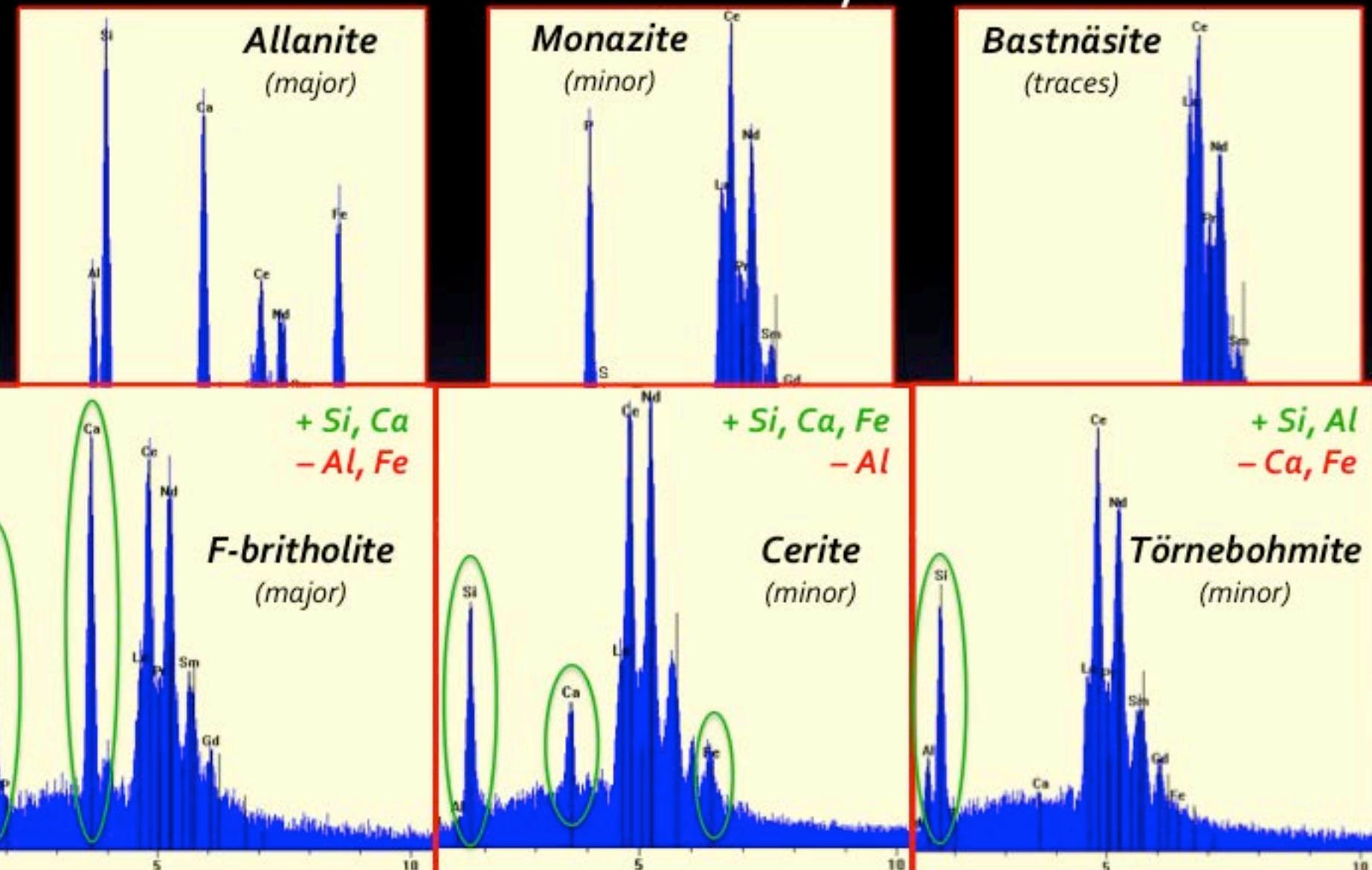
Significant enrichment in heavy REE and U from rim to core

- **Rim ~ 25.2 wt-% REO**  
(~0.3 wt-% HREE)  
(~0.55 wt-% Th, ±U, Pb)
- **Core ~49.0 wt-% REO**  
(~2.5 wt-% HREE)  
(~0.93 wt-% U, Th, ±Pb)

# REE pods mineralogy



# EMP - EDS analyses



...and "rare" REE minerals (silicates) in the core of the mineralization

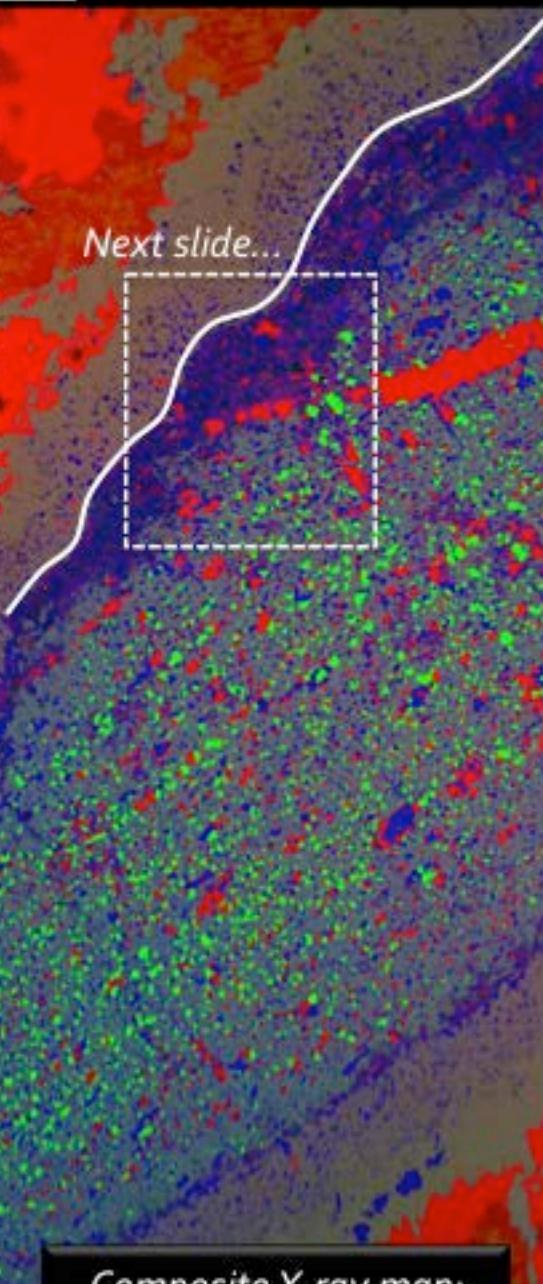
# F-britholite, cerite & törnebohmite

- Hydrous to fluorine-rich silicate of LREE
- **Fluorbritholite:**  $(\text{Ca}, \text{REE})_5 (\text{SiO}_4)_4 \text{PO}_4)_3 (\text{F}, \text{OH})$
- **Cerite:**  $(\text{Ca}, \text{REE})_9 (\text{Al}, \text{Fe}, \text{Mg}) (\text{SiO}_4)_6 [(\text{SiO}_3)(\text{OH})] (\text{OH}, \text{F})_3$
- **Törnebohmite:**  $(\text{REE})_2 (\text{Al}, \pm \text{Fe}) (\text{SiO}_4)_2 (\text{OH})$
- Rare occurrence worldwide, especially fluorbritholite:



6 other localities: **Mont St-Hilaire** (Canada; Sørensen, 1997), **Sweden** (Norr Kärr [2x] & Norberg, Sweden; Holtstam and Andersson, 2007) and **Nâm Nâm Xe** (Vietnam)

1 mm



Composite X-ray map:  
*R=Si, G=Ca, B=La*

# Mineralogy

Quartz / Kfsp

Plagioclase

Allanite

Monazite

REE-carbonate

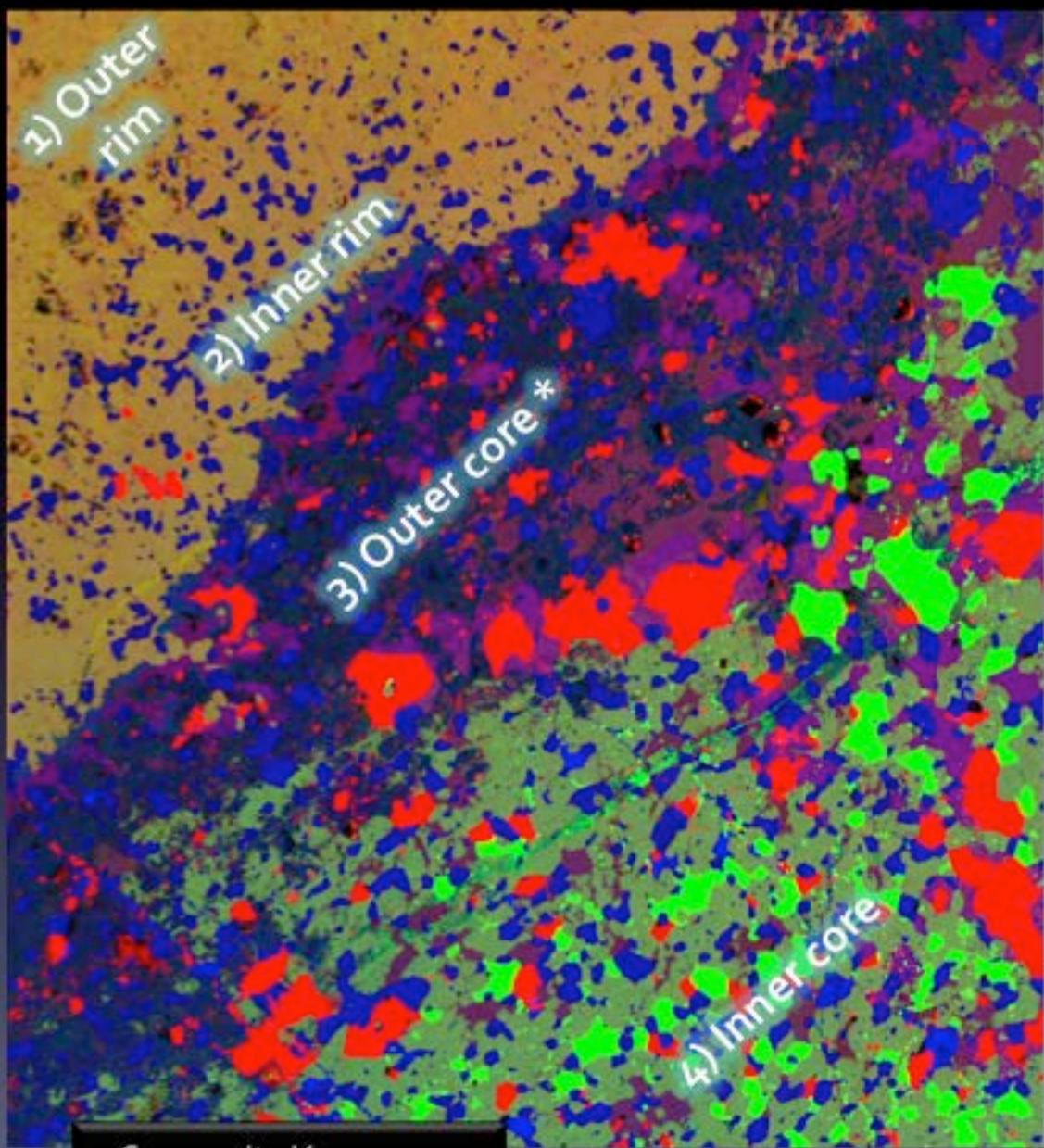
Törnebohmite & cerite

Fluorite

F-britholite

+ Uraninite in core  
(5-10  $\mu\text{m}$  grain)

0.5 mm



Composite X-ray map:  
R=Si, G=Ca, B=La

# Rim - Core

Quartz

Mineral ZONE... 1 2 3 4

Allanite X x - -

Monazite - x X X

REE-carbonate - - X ±

Cerite - - X ±

Törnebohmite - - X ±

Fluorite - - - X

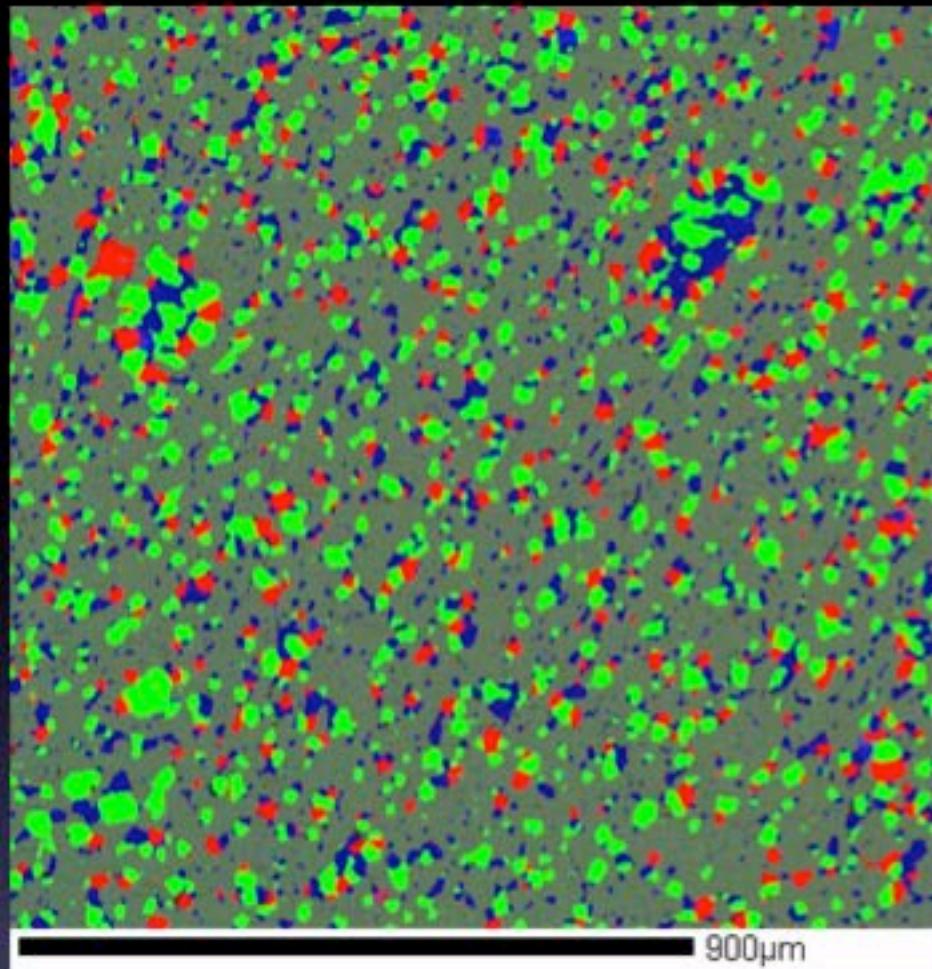
F-britholite - - - X

R=Si

G=Ca

B=La

\* Not always present



Composite X-ray map:  
R=Si, G=Ca, B=La

Purple fluorite give the purplish color of core (coloration due to x-ray radiation from uraninite)

# Core

F-britholite (69.6%)

Fluorite (13.4%)

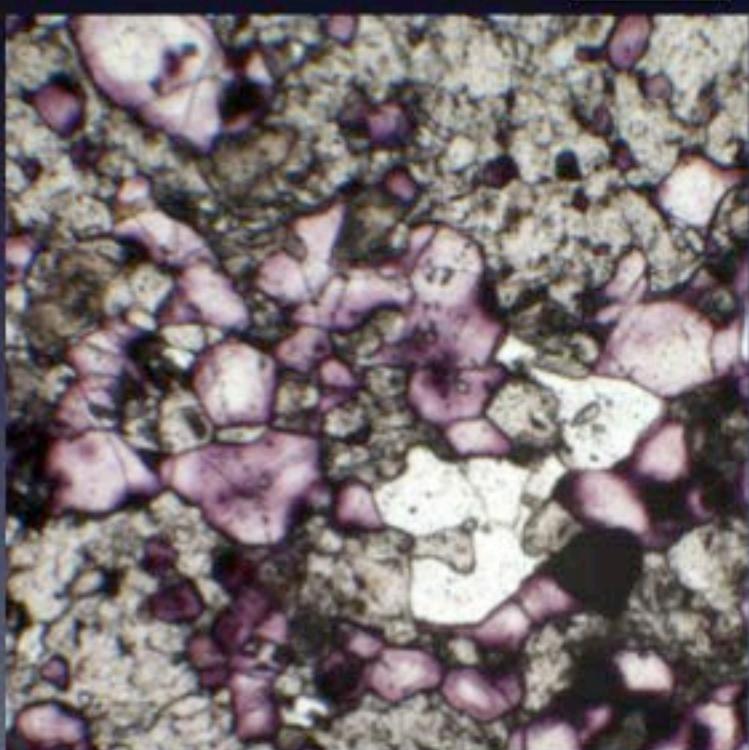
+ *Uraninite*  
(0.5%)

Monazite (12.4%)

Quartz (4.2%)

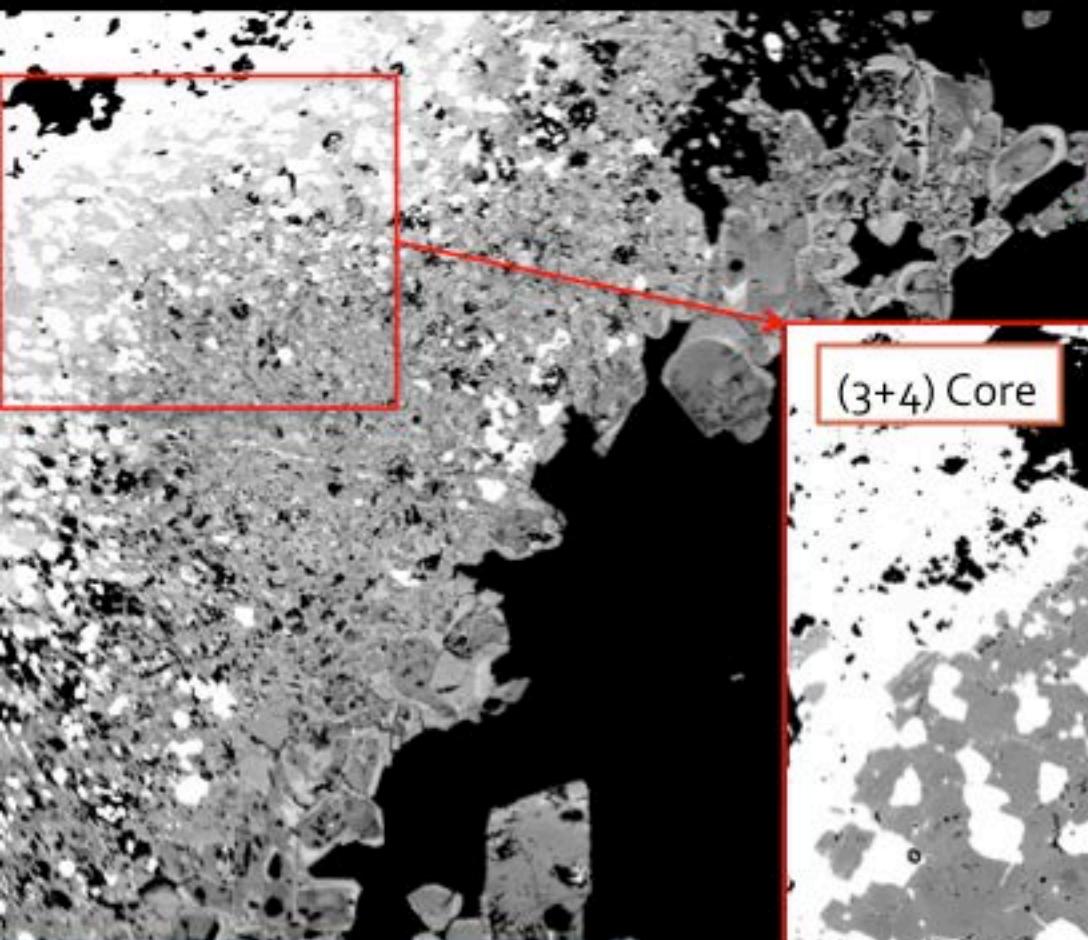
REE-carbonate (0.1%)

~50 μm



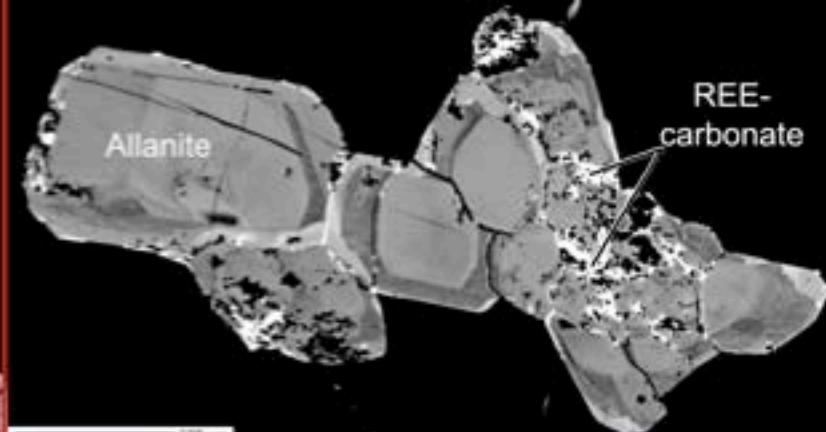
# Allanite zoning

The only REE-mineral with a significant zoning...

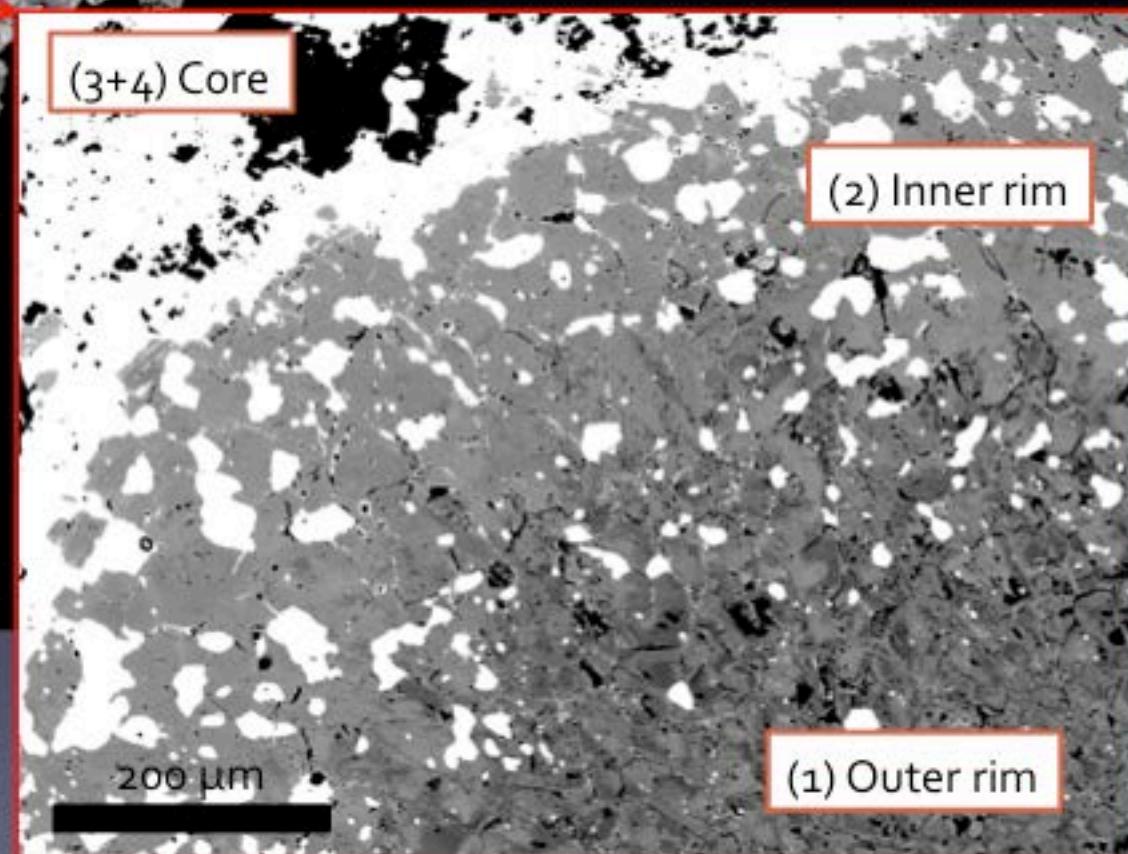


0.5 mm

(BSE images)



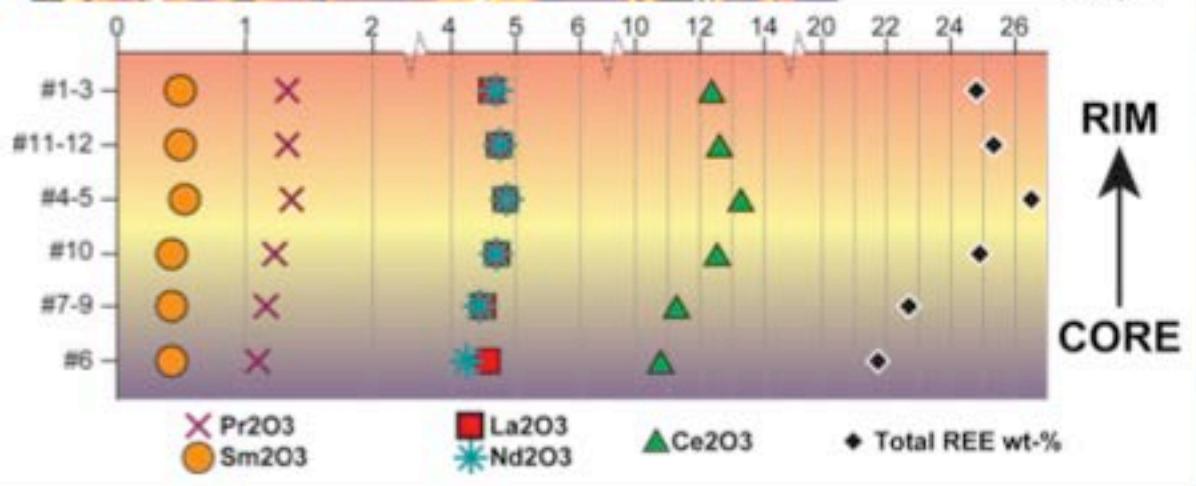
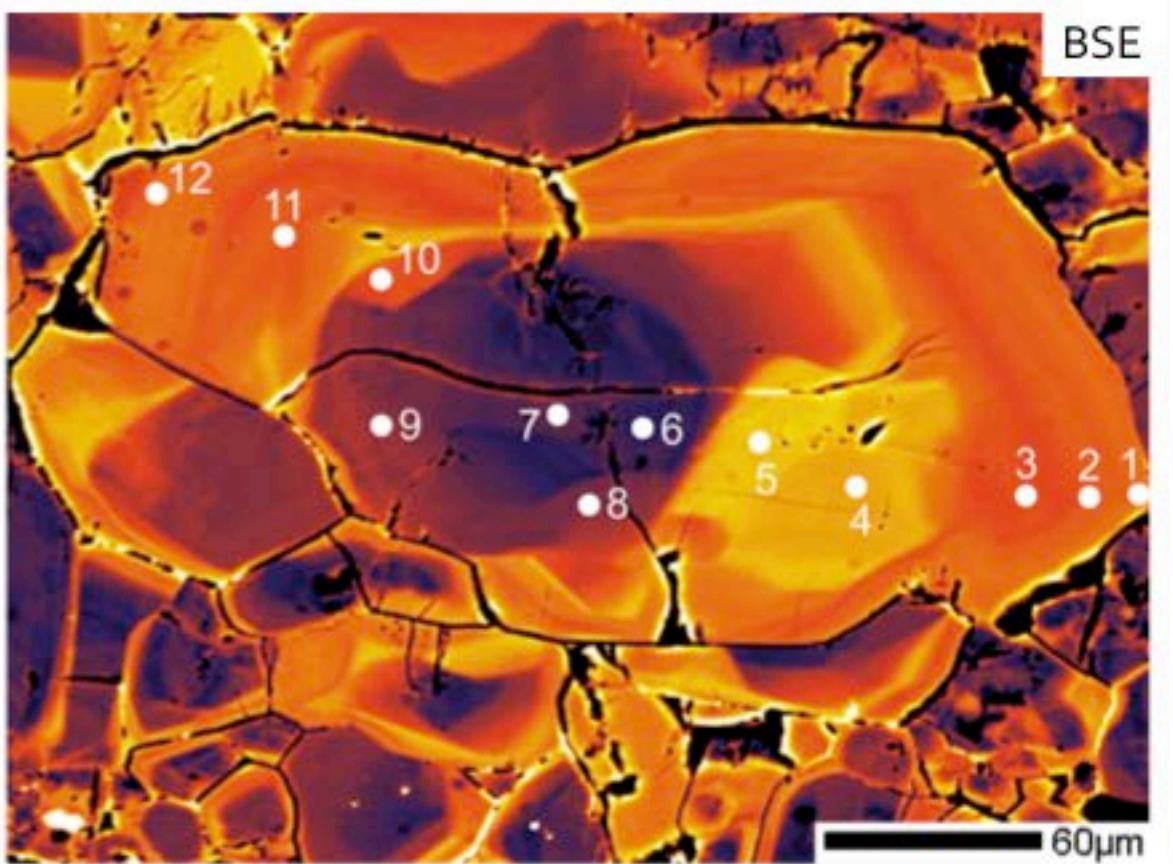
Isolated matrix allanite



(1) Outer rim

(2) Inner rim

(3+4) Core

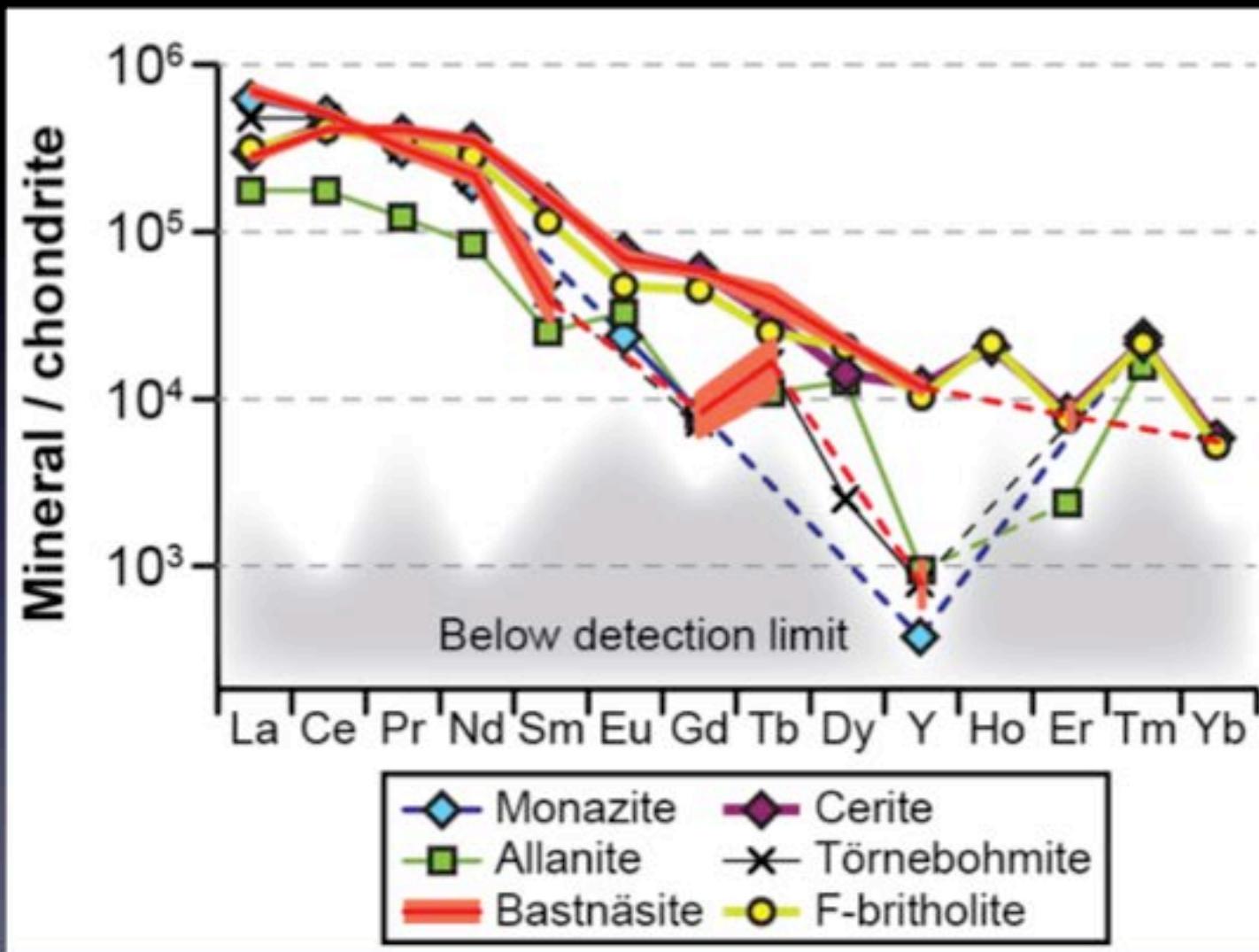


# Allanite zoning

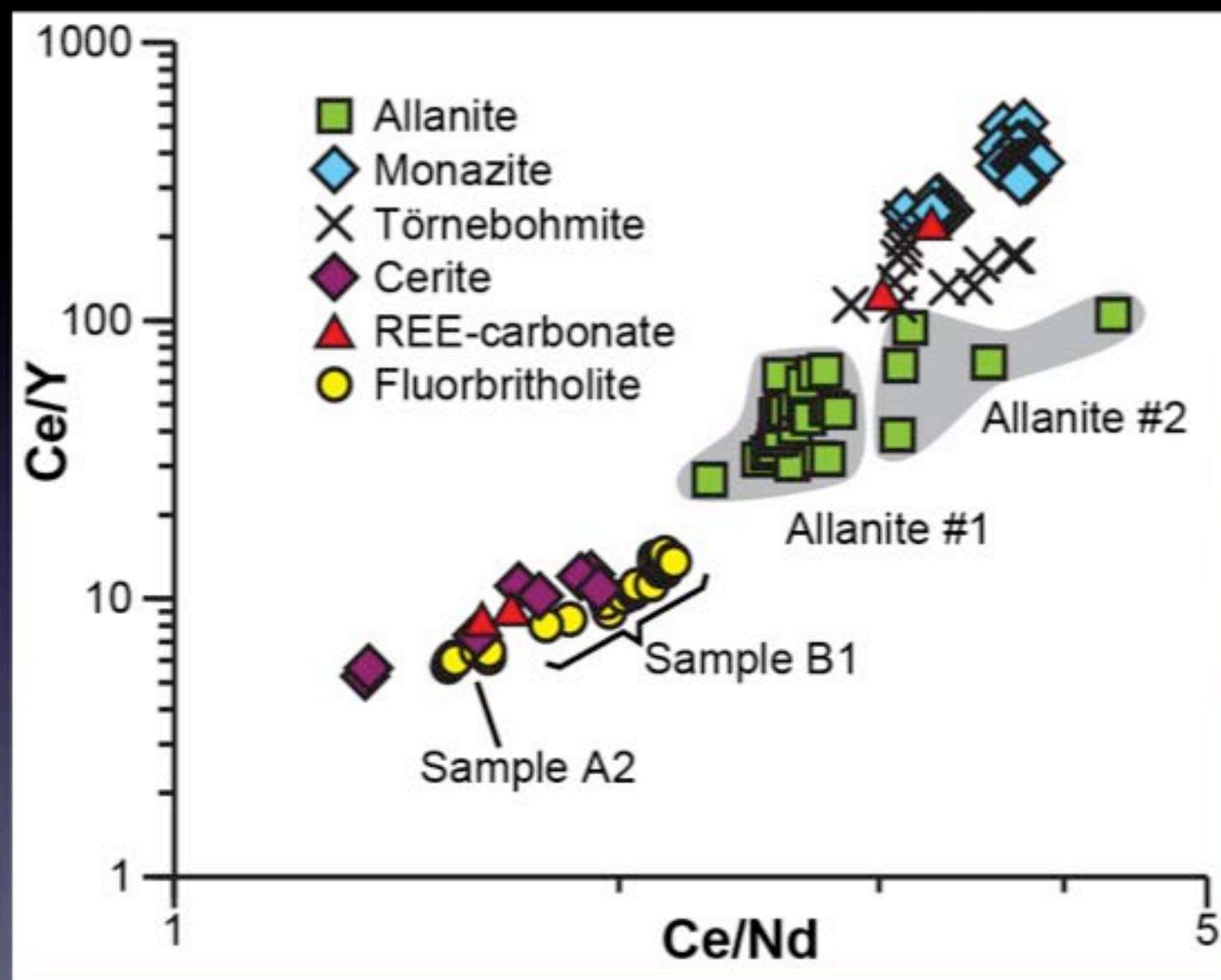
Increase of REE-content at rim, slight drop at very rim  
*(onset of monazite crystallization?)*

*REE-richest  
near inner rim  
of the vein*

# Summary WDS analyses

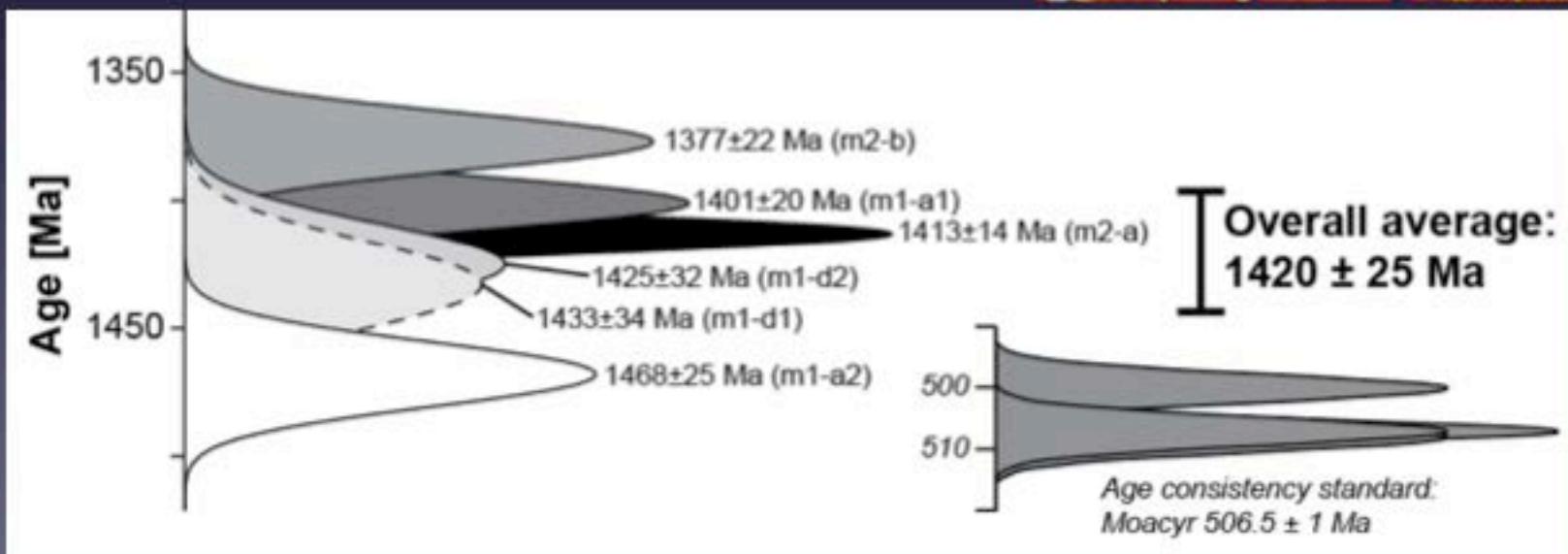
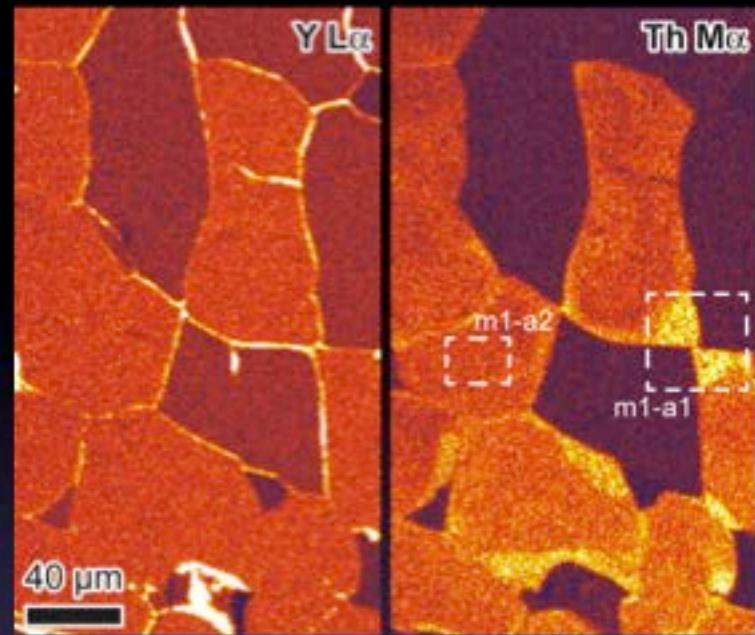


# Summary WDS analyses



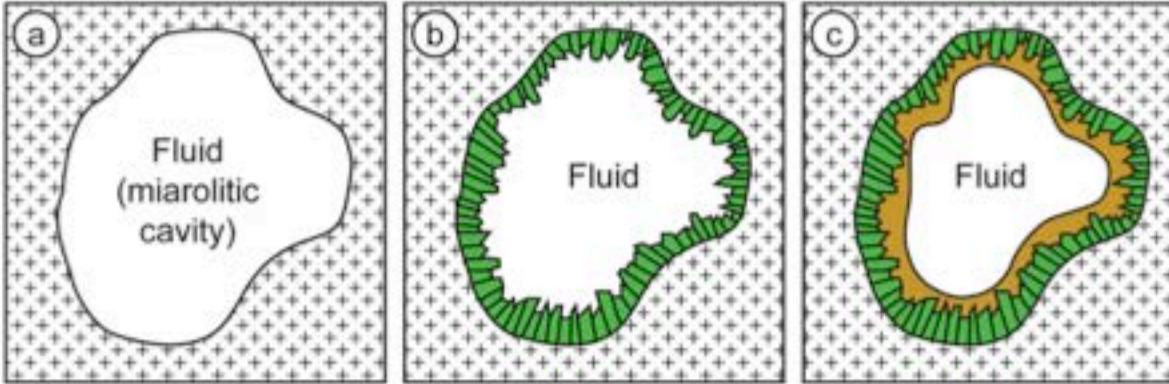
# Monazite dating

- Actinide poor
  - 0.4-1.7 wt-% ThO<sub>2</sub>
  - ~0.1 wt-% UO<sub>2</sub>
- U-Th-Pb<sub>total</sub> electron microprobe dating (*UMass Amherst, SX-100 "Ultrachron"*)
- ***1420 ± 25 Ma, identical to pluton intrusion***

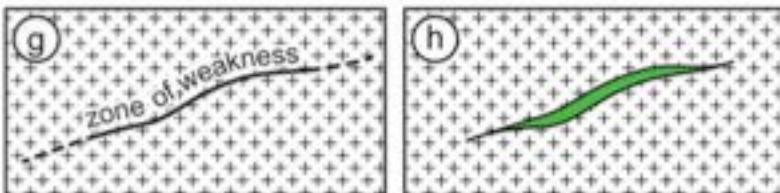


# Pods & veins formation

Type I: miarolitic cavities

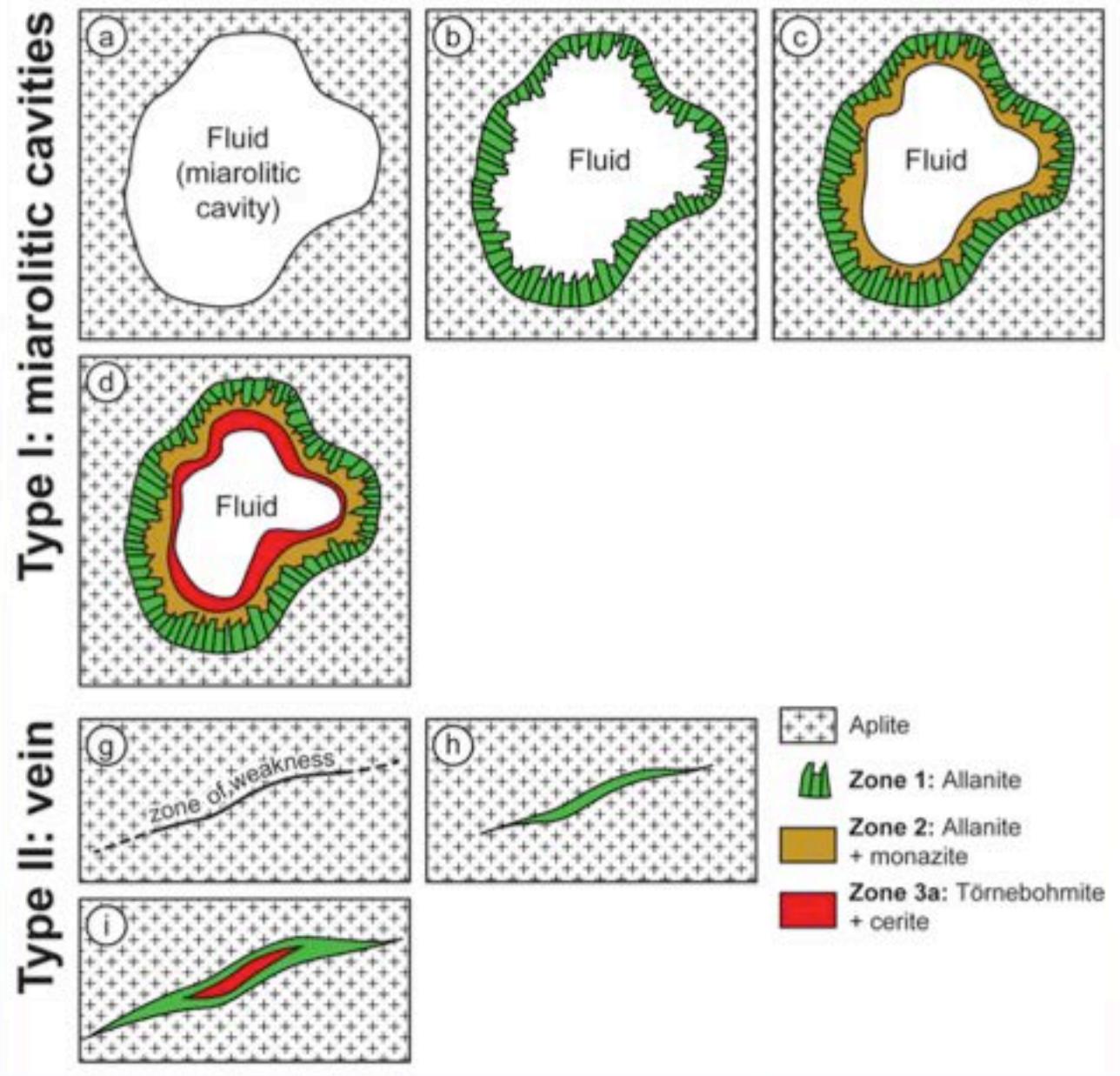


Type II: vein



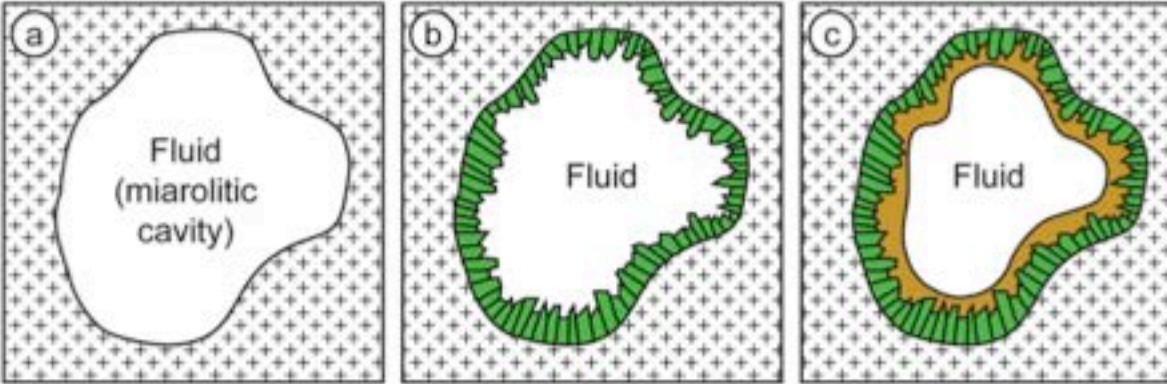
- Aplite (cross-hatched)
- Zone 1: Allanite (green)
- Zone 2: Allanite + monazite (yellow)

# Pods & veins formation

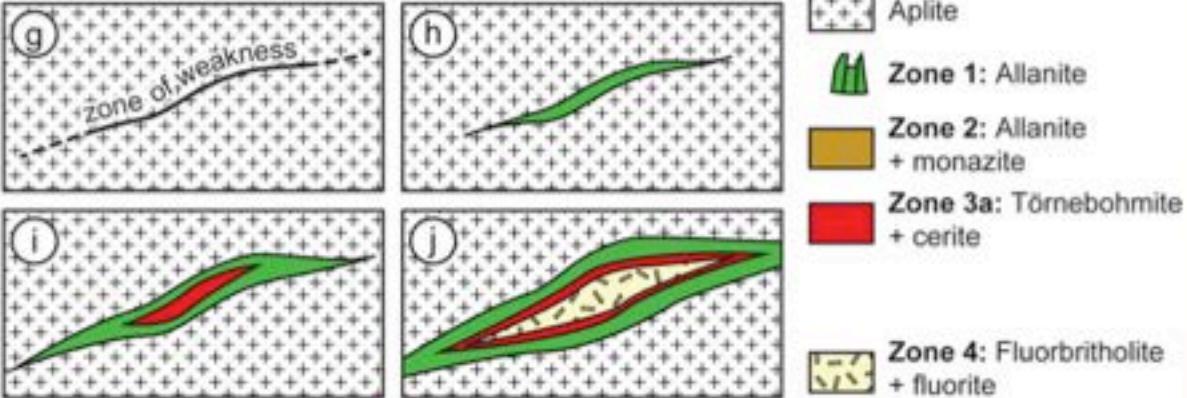


# Pods & veins formation

## Type I: miarolitic cavities

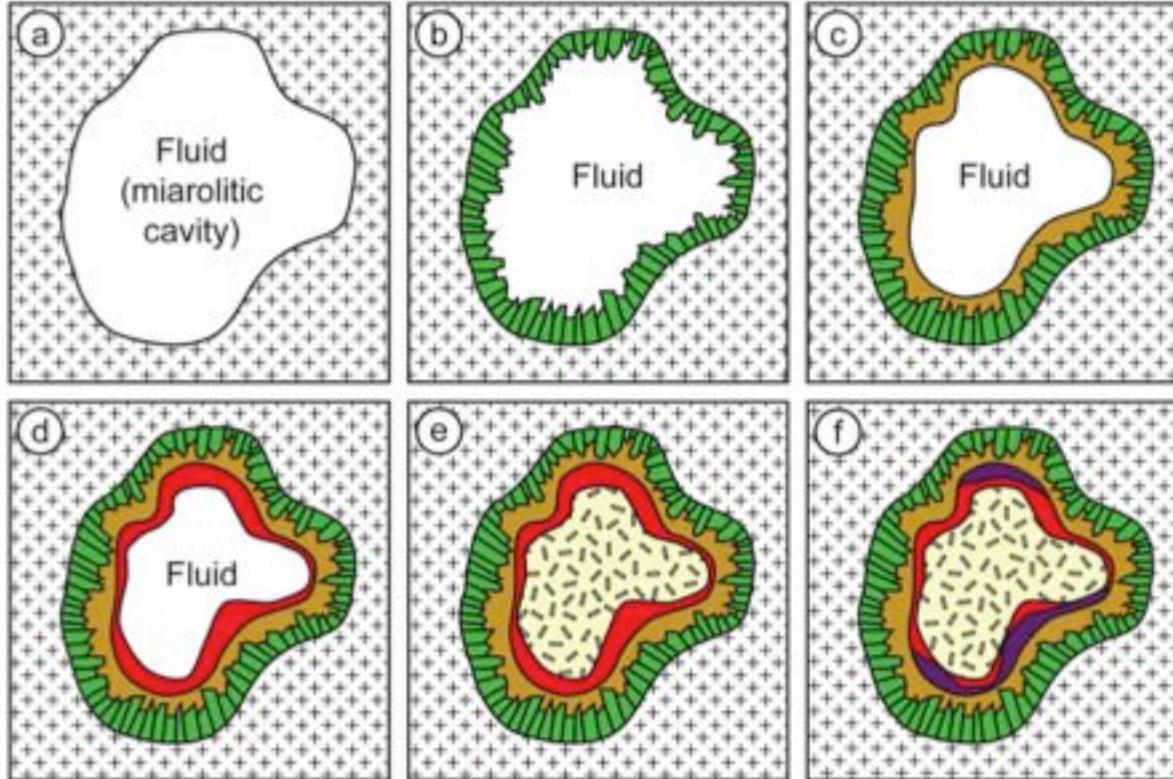


## Type II: vein

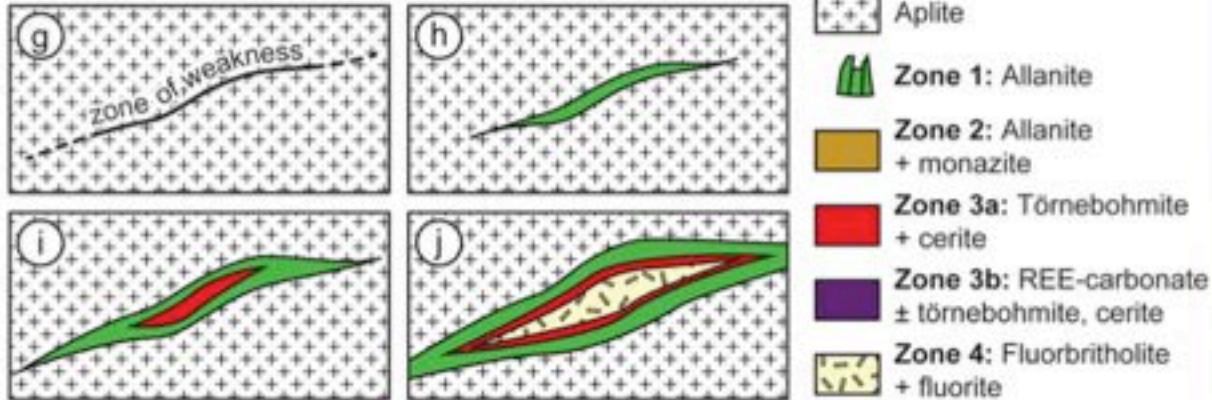


# Pods & veins formation

Type I: miarolitic cavities

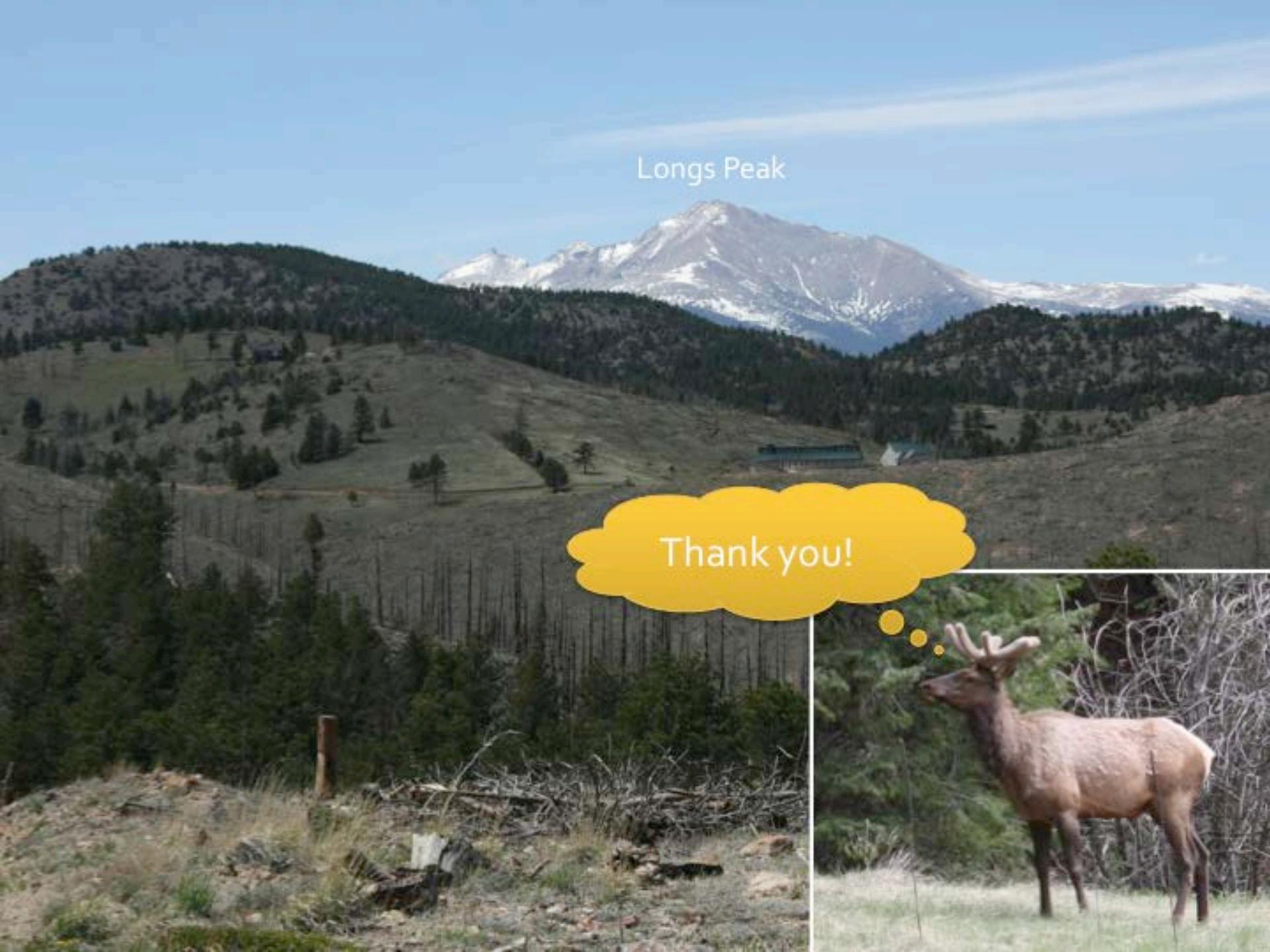


Type II: vein



# Conclusion

- Mineralization occurs shortly after crystallization of Longs Peak - St. Vrain pluton (~1.43 Ga)
- Initial enrichment of REE in granite => late magmatic fluids strongly enriched in REE => REE-mineral precipitation
- Concentric zoning of REE-mineral assemblage depicting evolution of F-rich fluid from pegmatite
- Late reaction forming Bastnäsite (breakdown of allanite, cerite, törnebohmite and/or fluorbritholite) => late CO<sub>2</sub> fluid
- *Remaining questions: condition of formation & fluid composition, explanation for mineral zone, extension of mineralization, REE-speciation...*



Longs Peak

Thank you!

