U-Pb geochronology of zircon, monazite, xenotime and allanite at the Music Valley REE deposit: Implications for mineralization and fluid-related alteration

S. Tyson McKinney, John M. Cottle, Graham W. Lederer

The University of California, Santa Barbara

Department of Earth Science

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USGS

science for a changing world

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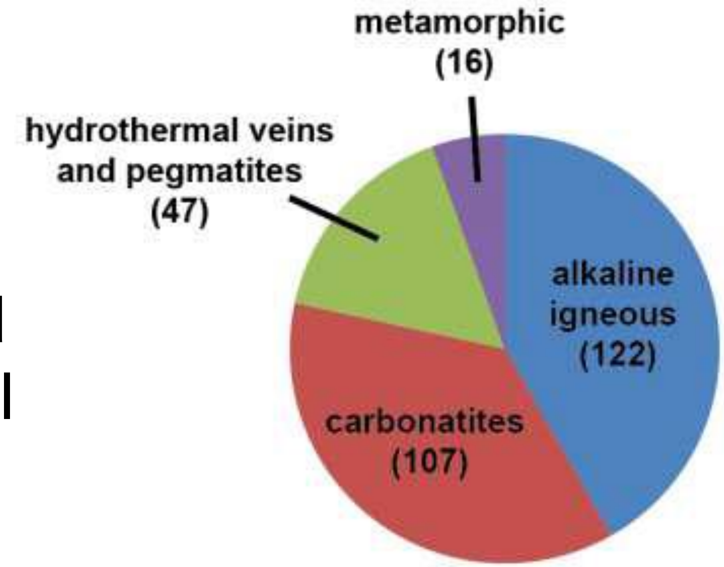
LET THERE BE LIGHT

Motivation



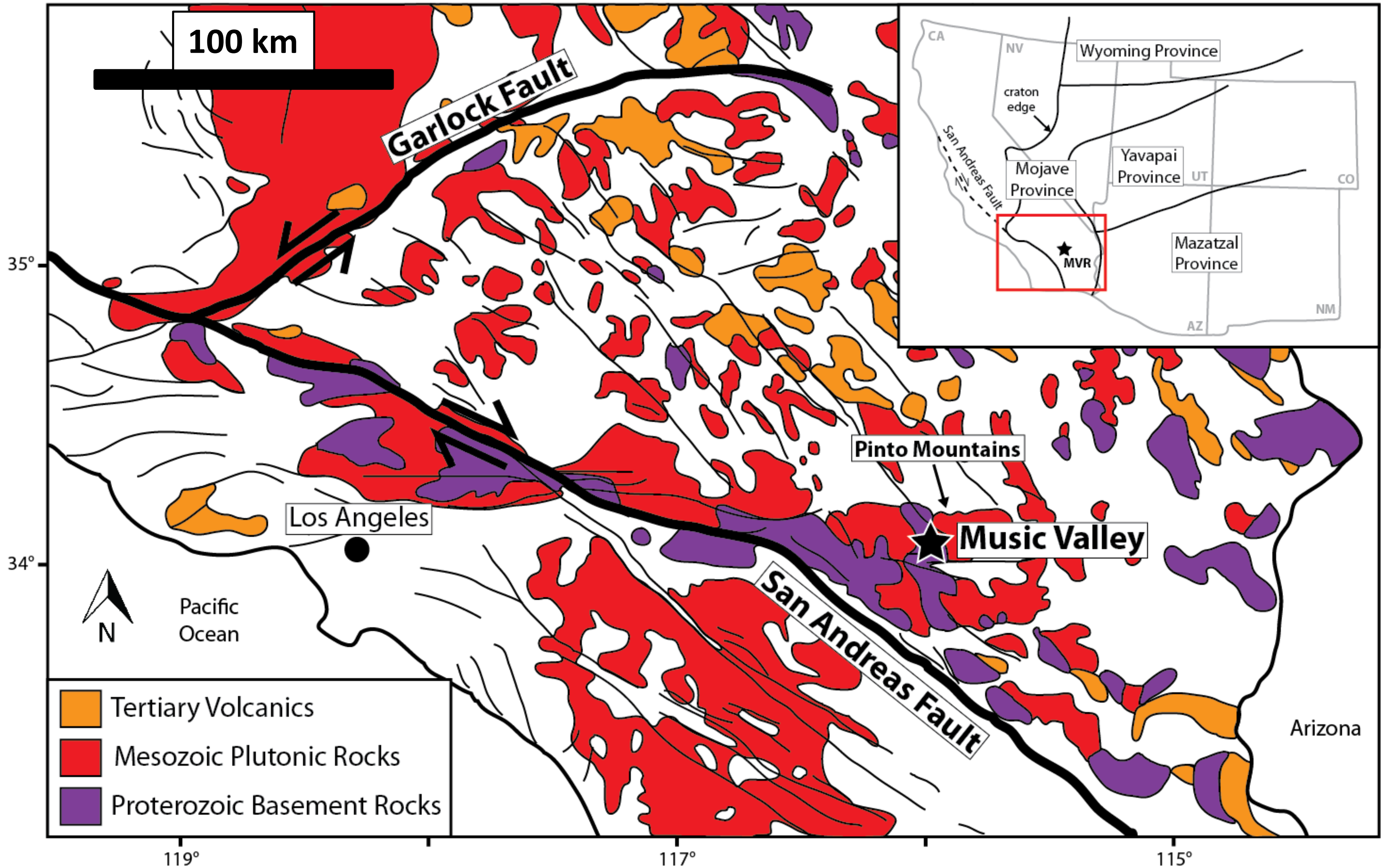
(after Orris & Grauch, 2002)

- REE deposits broadly divided into primary (REE concentrated by igneous and/or hydrothermal means) and secondary (REE concentrated by sedimentary processes and weathering)

- Alkaline intrusive systems and carbonatites are relatively well understood, metamorphic-type deposits are not

- Music Valley REE Deposit
  - monazite and xenotime hosted in a Proterozoic biotite gneiss
  - potentially important domestic REE occurrence

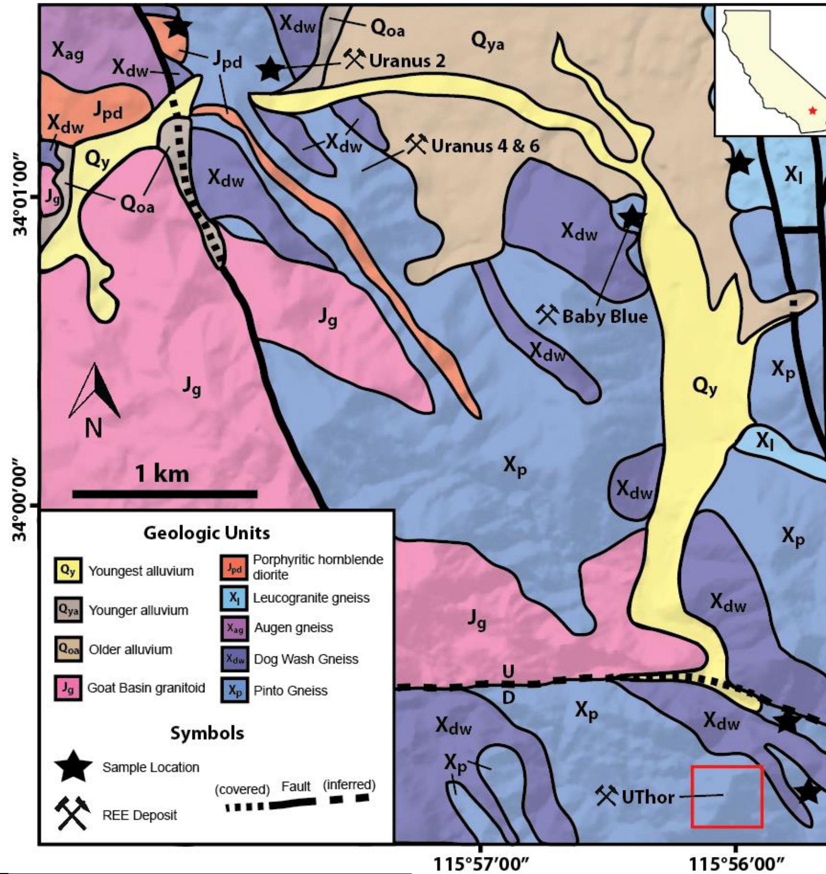
Music Valley



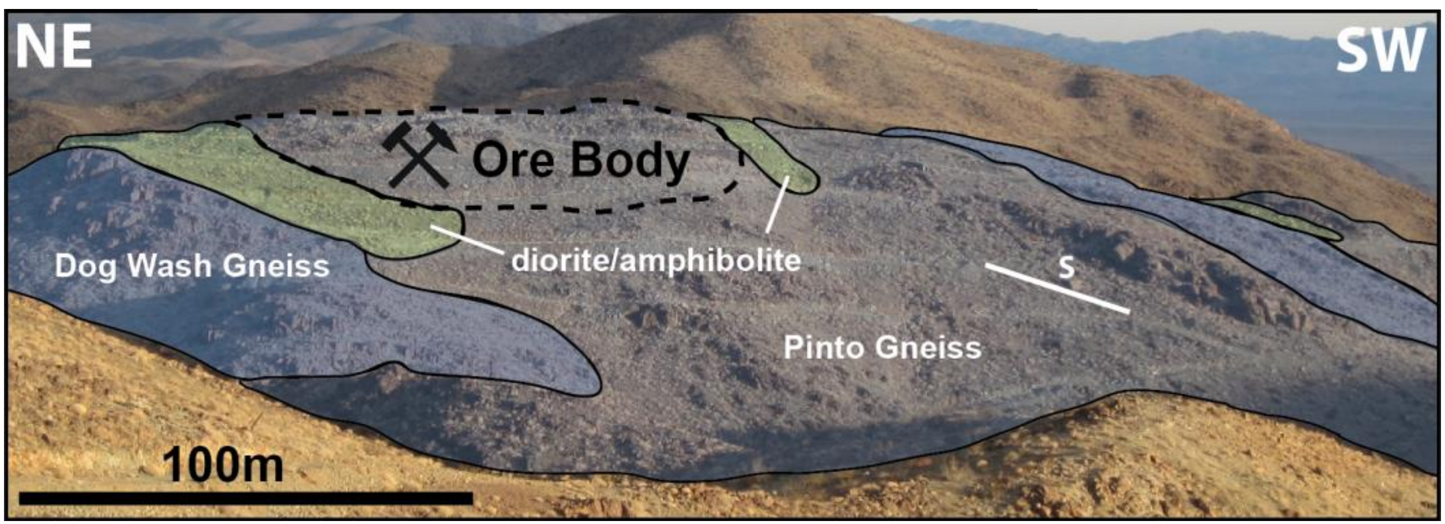
(modified after Jennings et al., 2010 and Coleman et al., 2002)

Music Valley REE

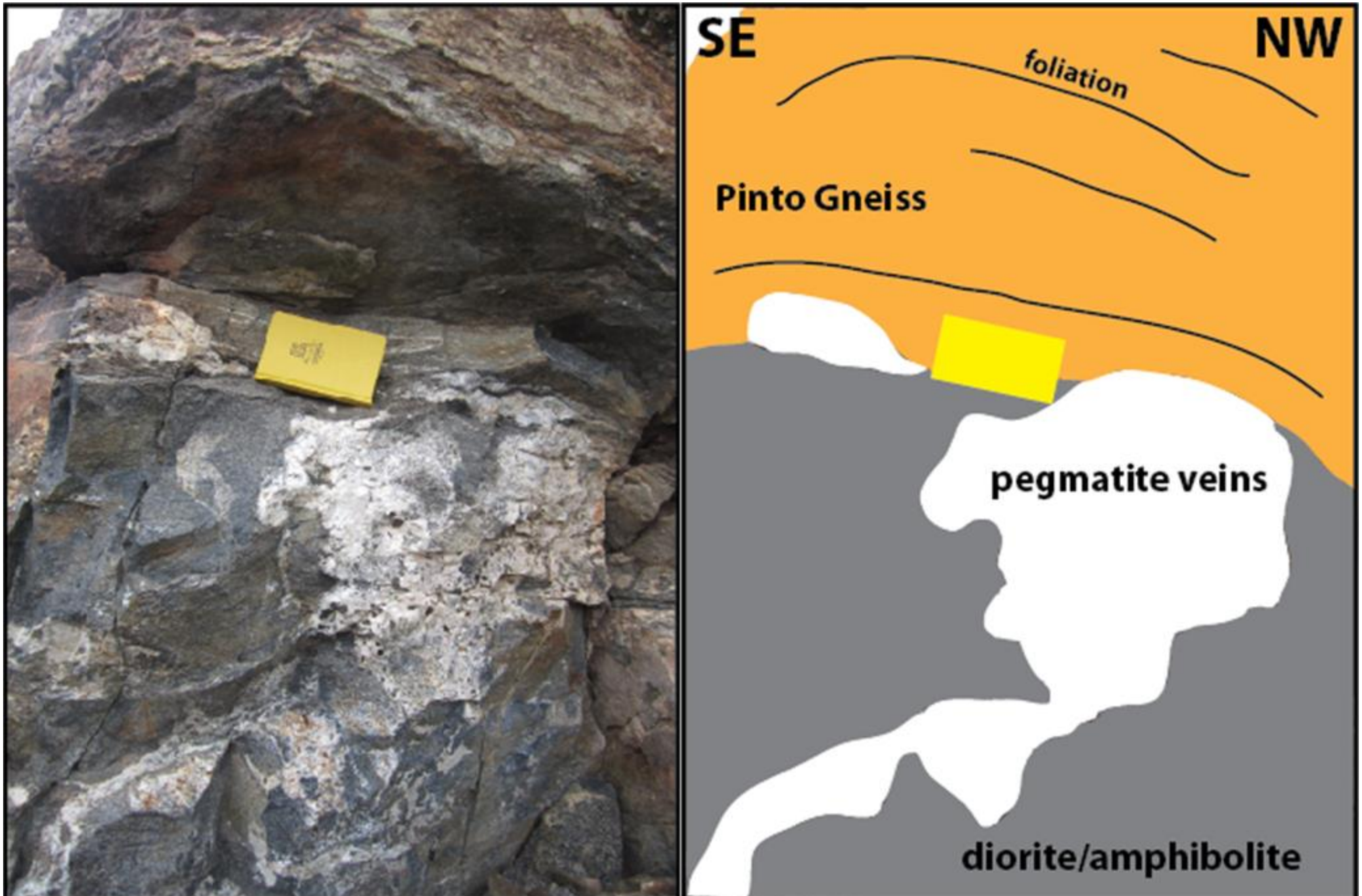
- Host rock: Pinto Gneiss
- Main deposit = UThor
- Previous interpretation (Evans, 1964) → monazite and xenotime are detrital in origin



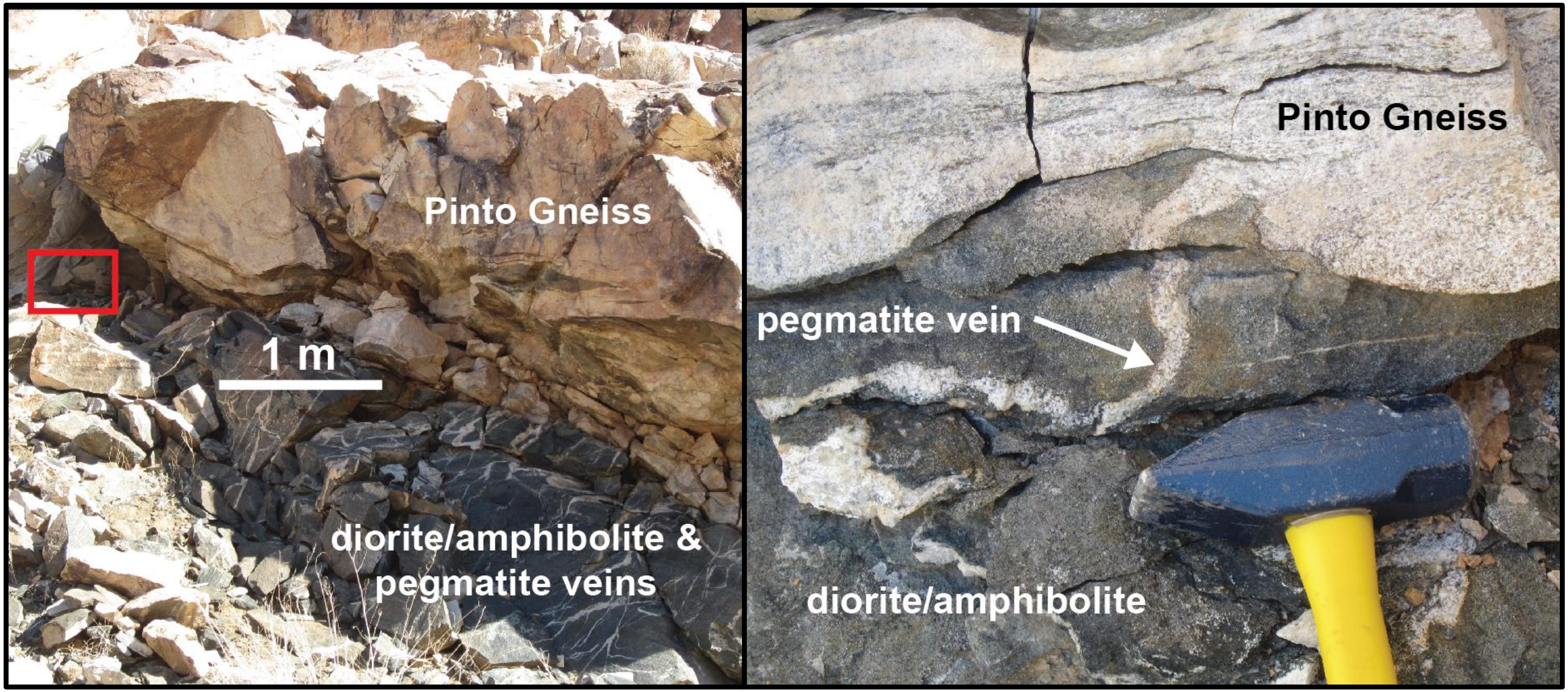
(modified after Howard et al., 2013 and Dibblee, 2008)



Petrologic Relationships



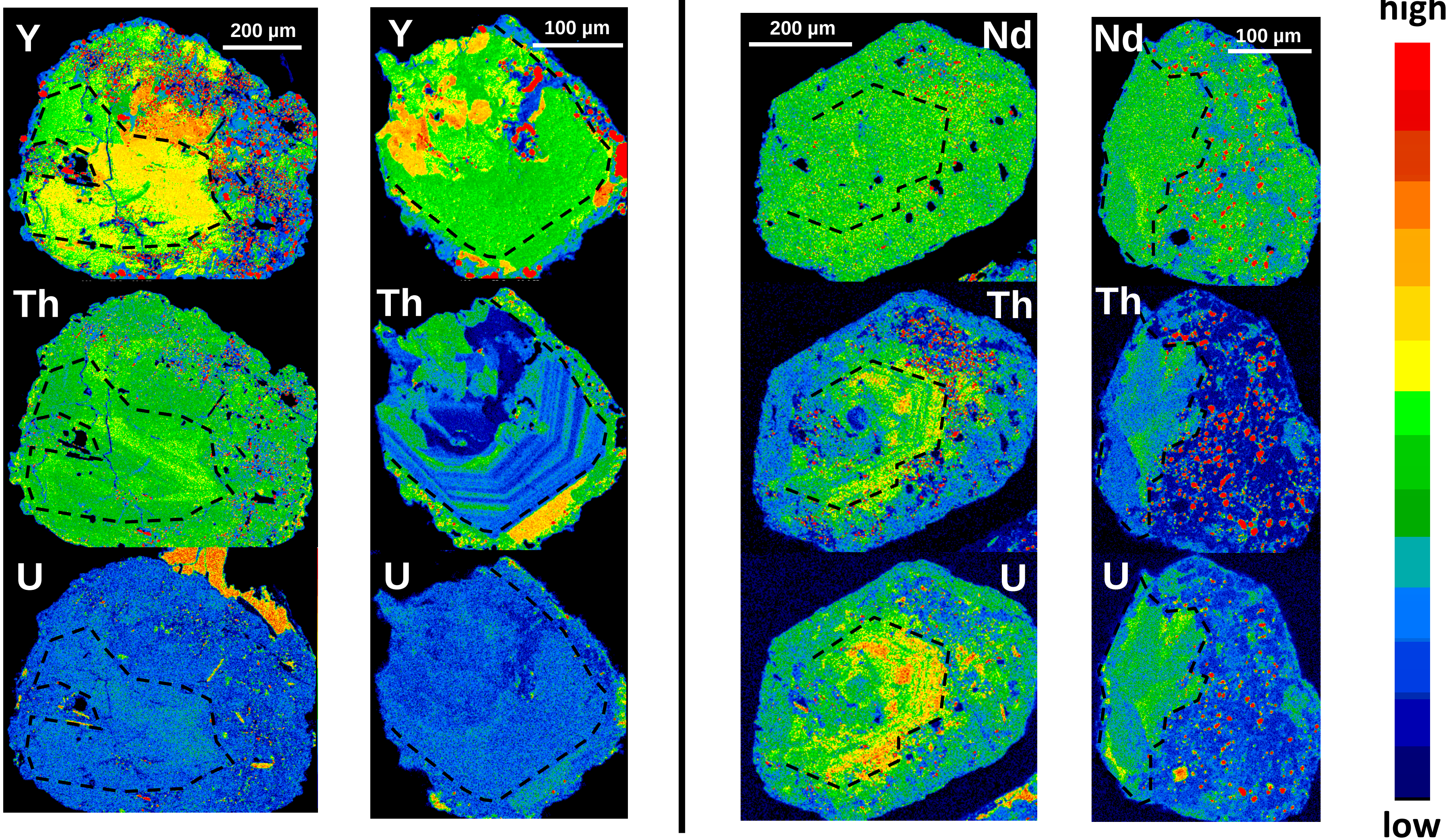
Petrologic Relationships



Textural Domains

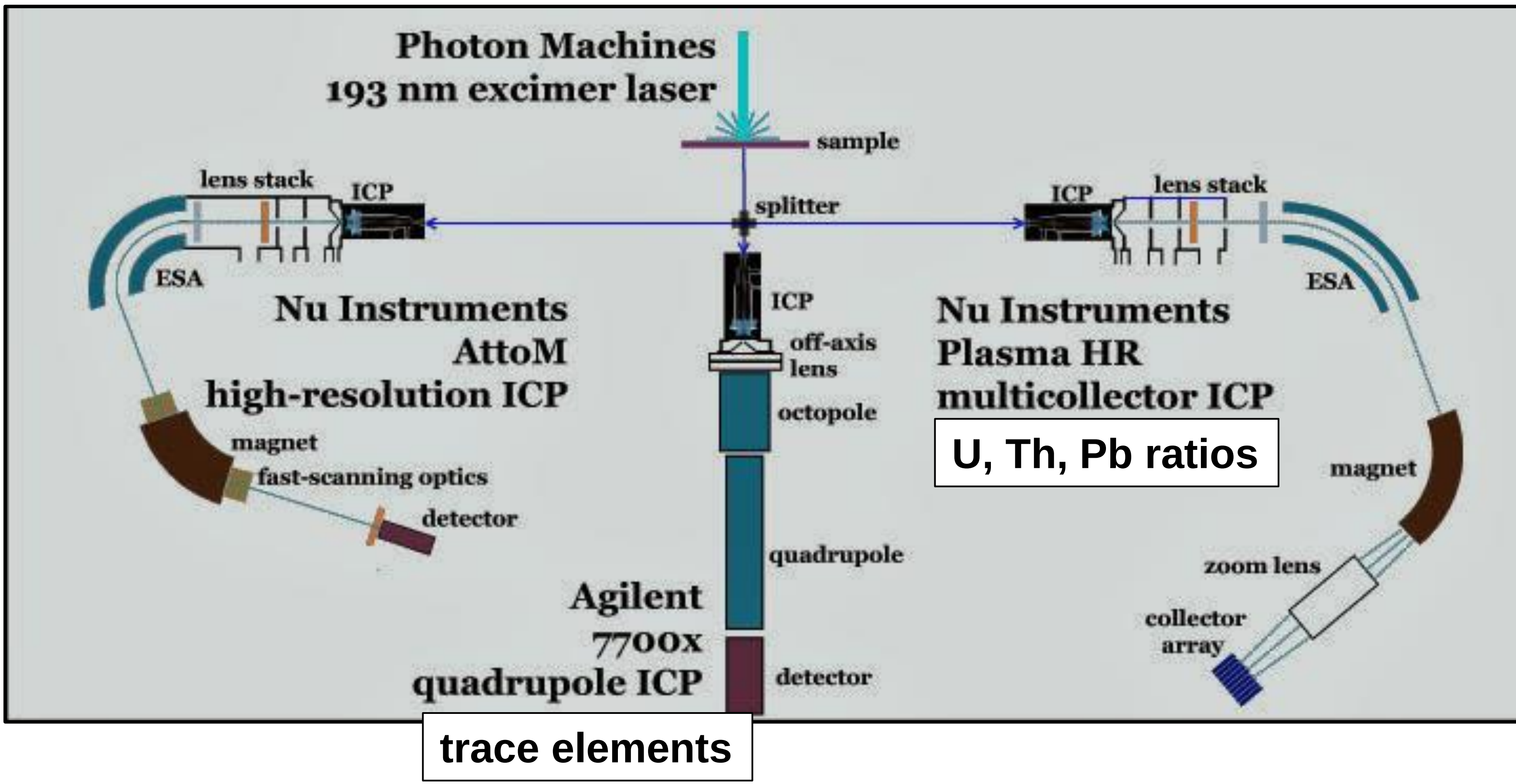
Monazite

Xenotime

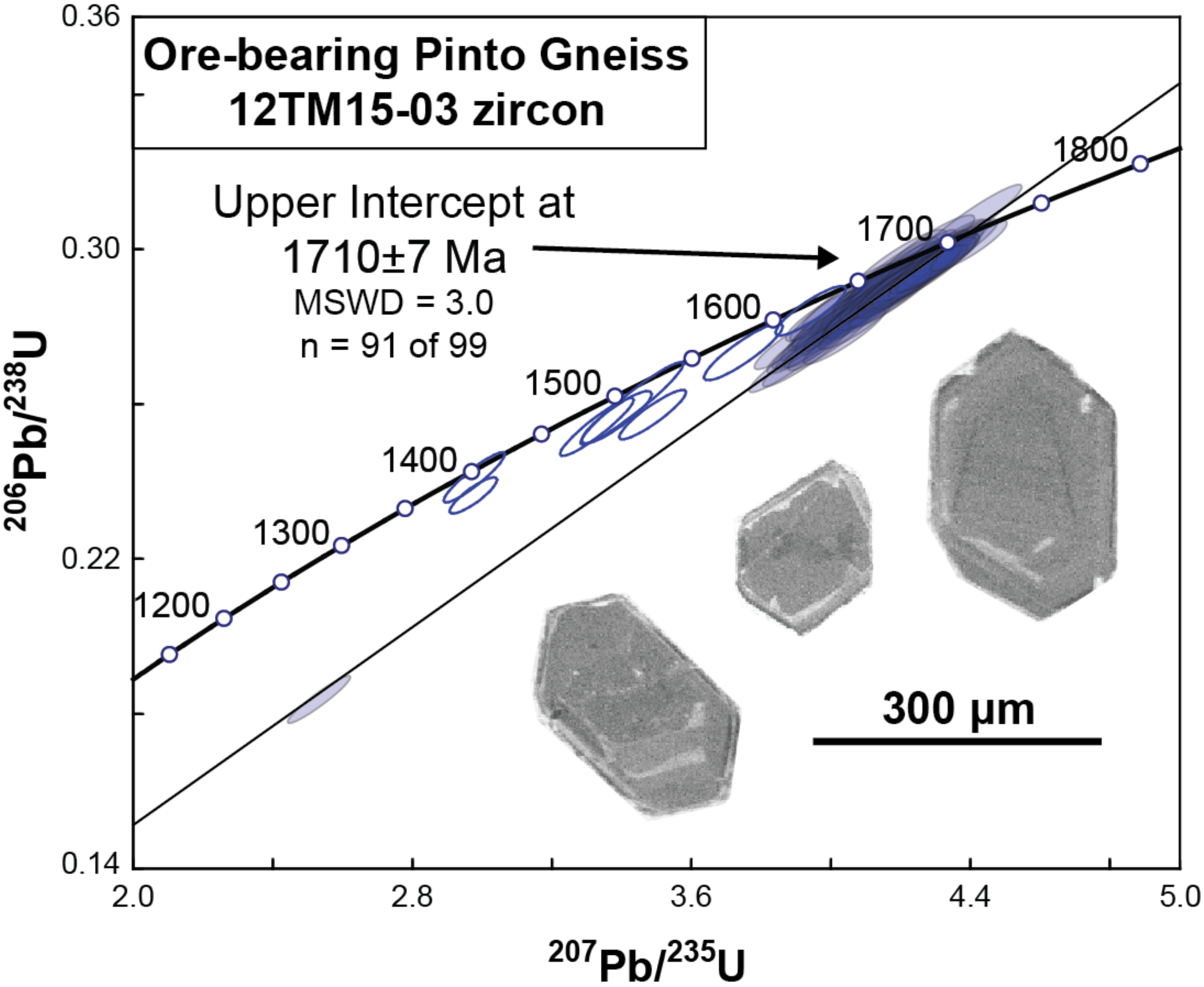


LASS ICP-MS Geochronology

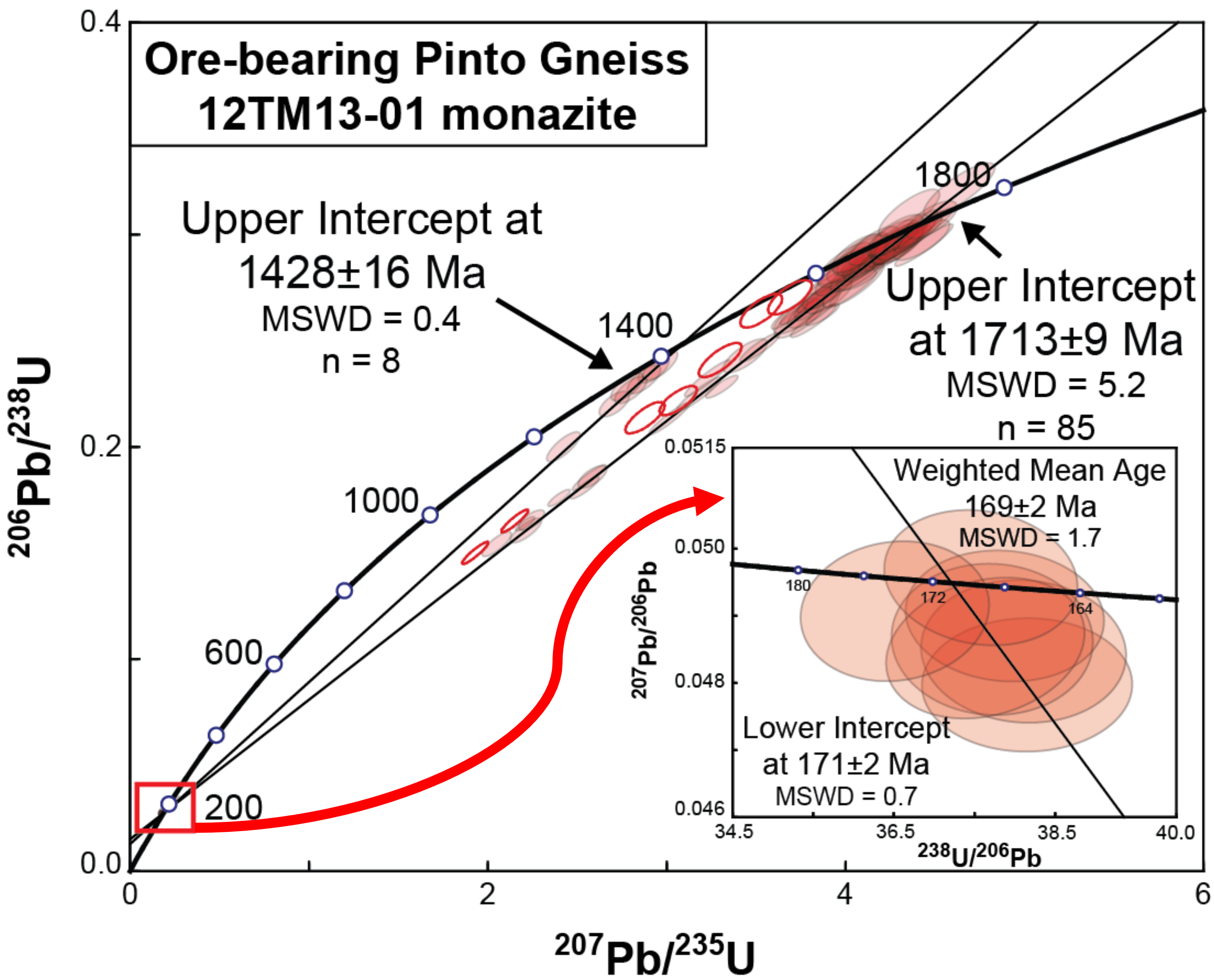
UC Santa Barbara Department of Earth Science



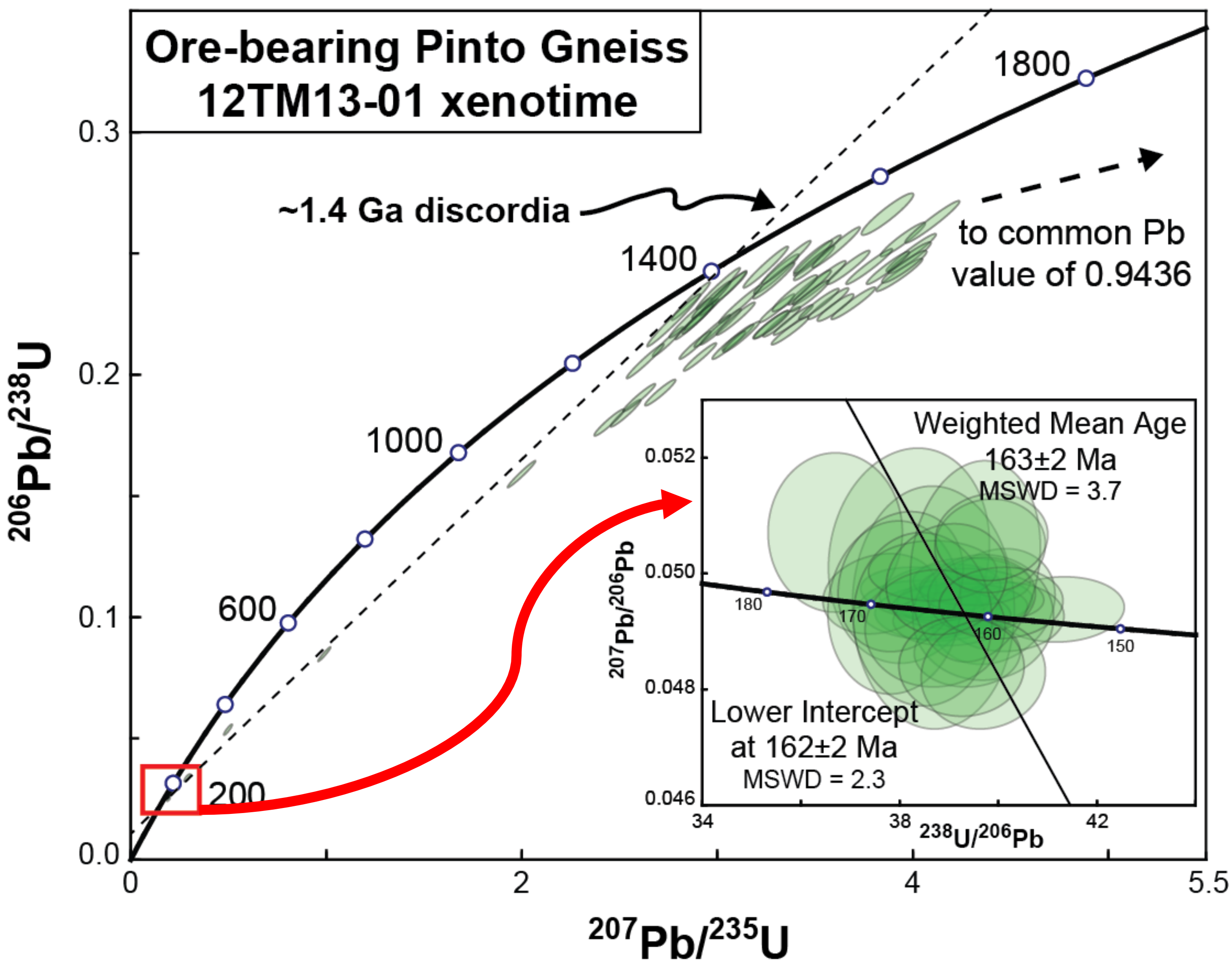
Zircon (Pinto Gneiss)



Monazite (Pinto Gneiss)



Xenotime (Pinto Gneiss)



Summary of Pinto Gneiss Geochronology

c. 1.71 Ga (zircon/monazite)

→ emplacement of igneous protolith to Pinto Gneiss

→ timing of ore formation

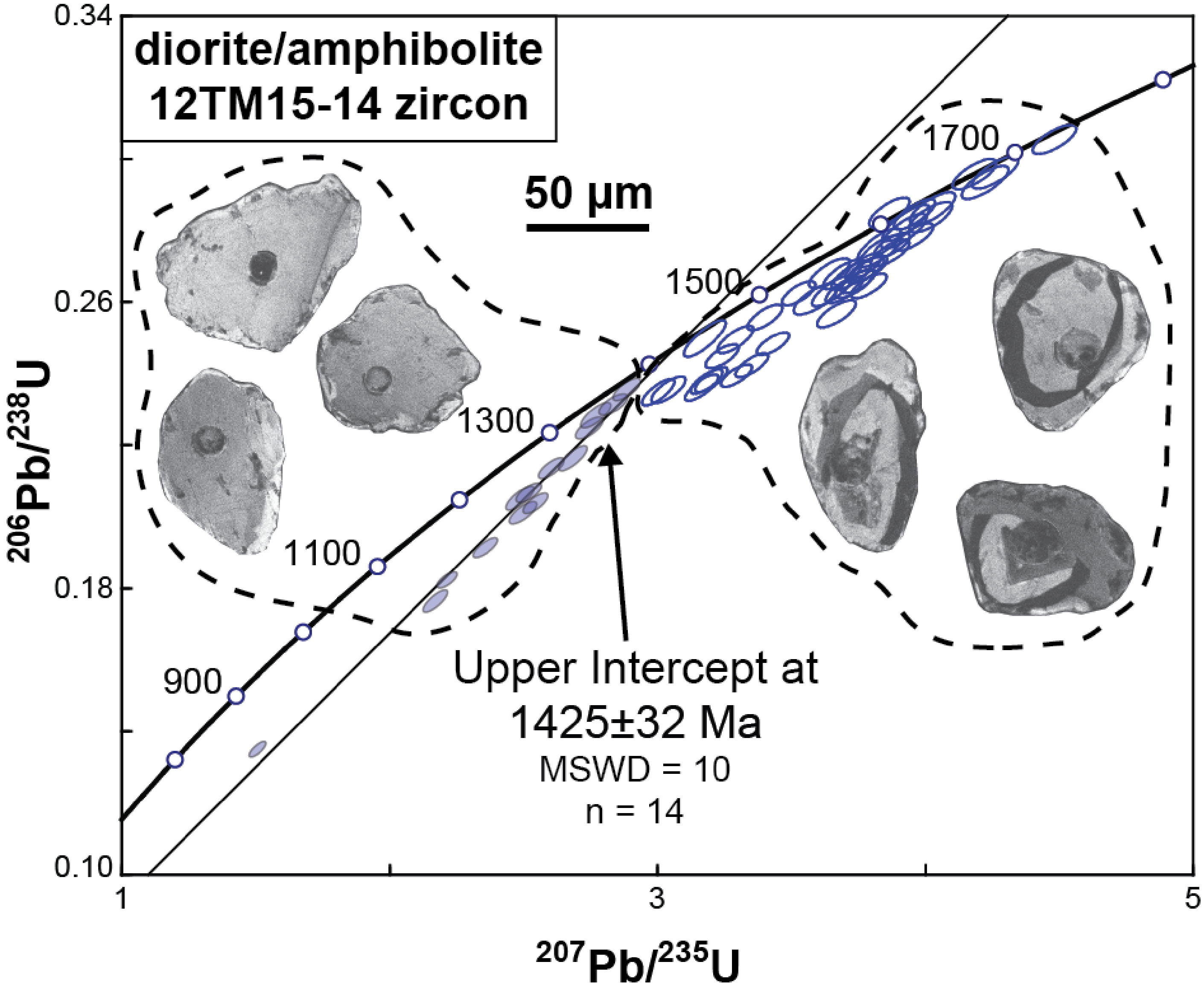
c. 1.4 Ga (zircon/monazite/xenotime)

→Pb loss and/or recrystallization of all three phases

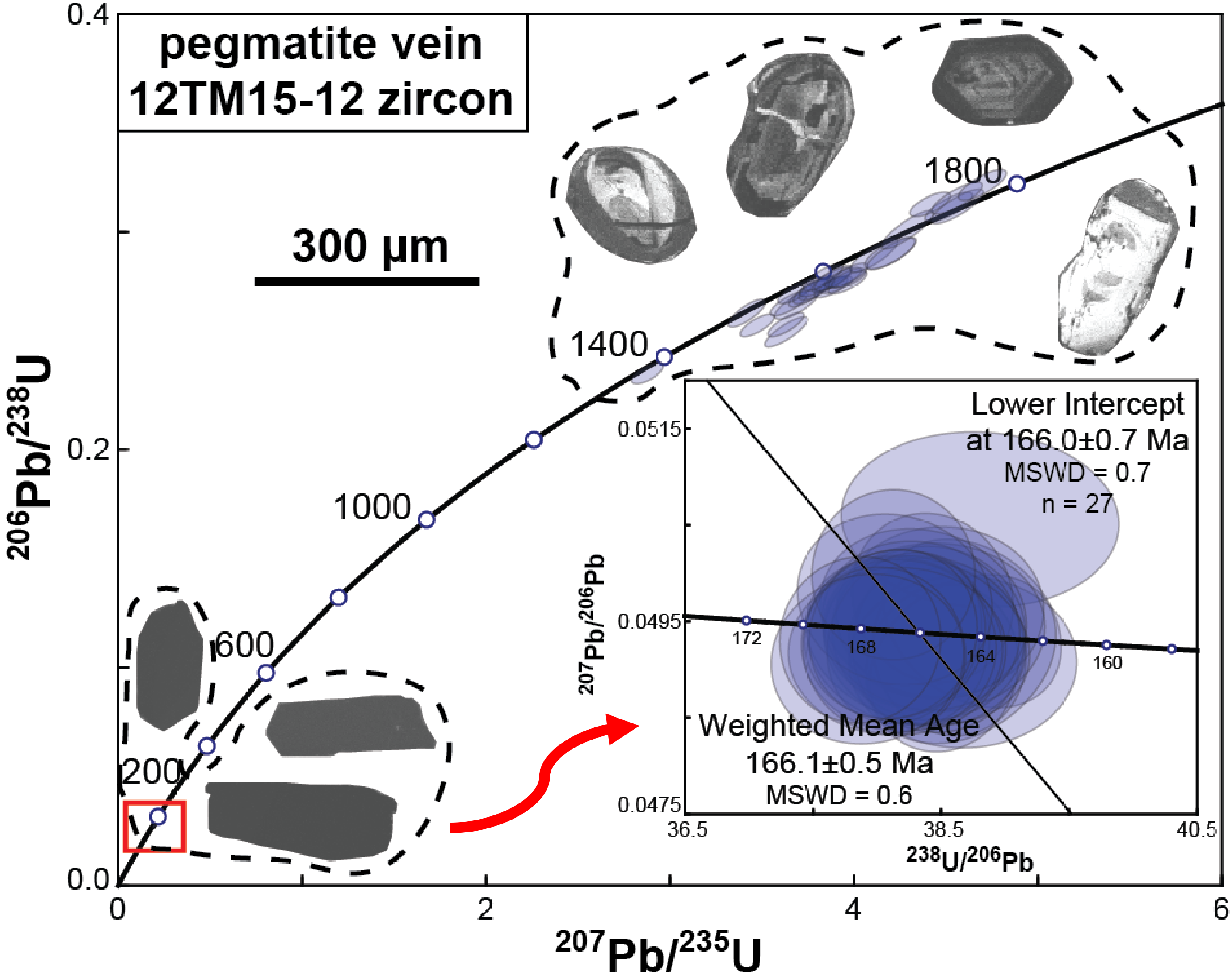
c. 160-170 Ma (monazite/xenotime)

→ Pb loss and/or recrystallization of monazite and xenotime

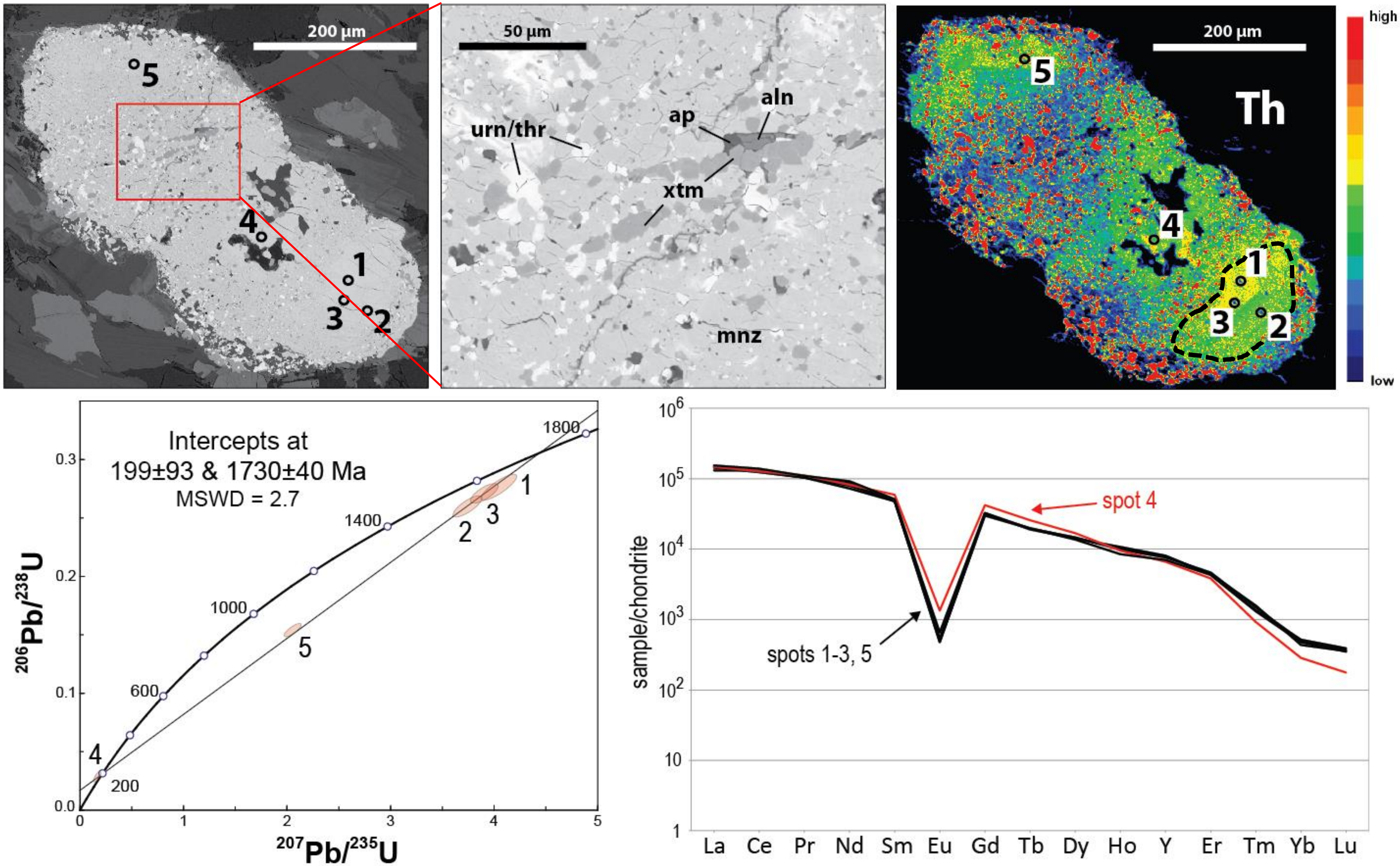
Zircon (diorite/amphibolite)



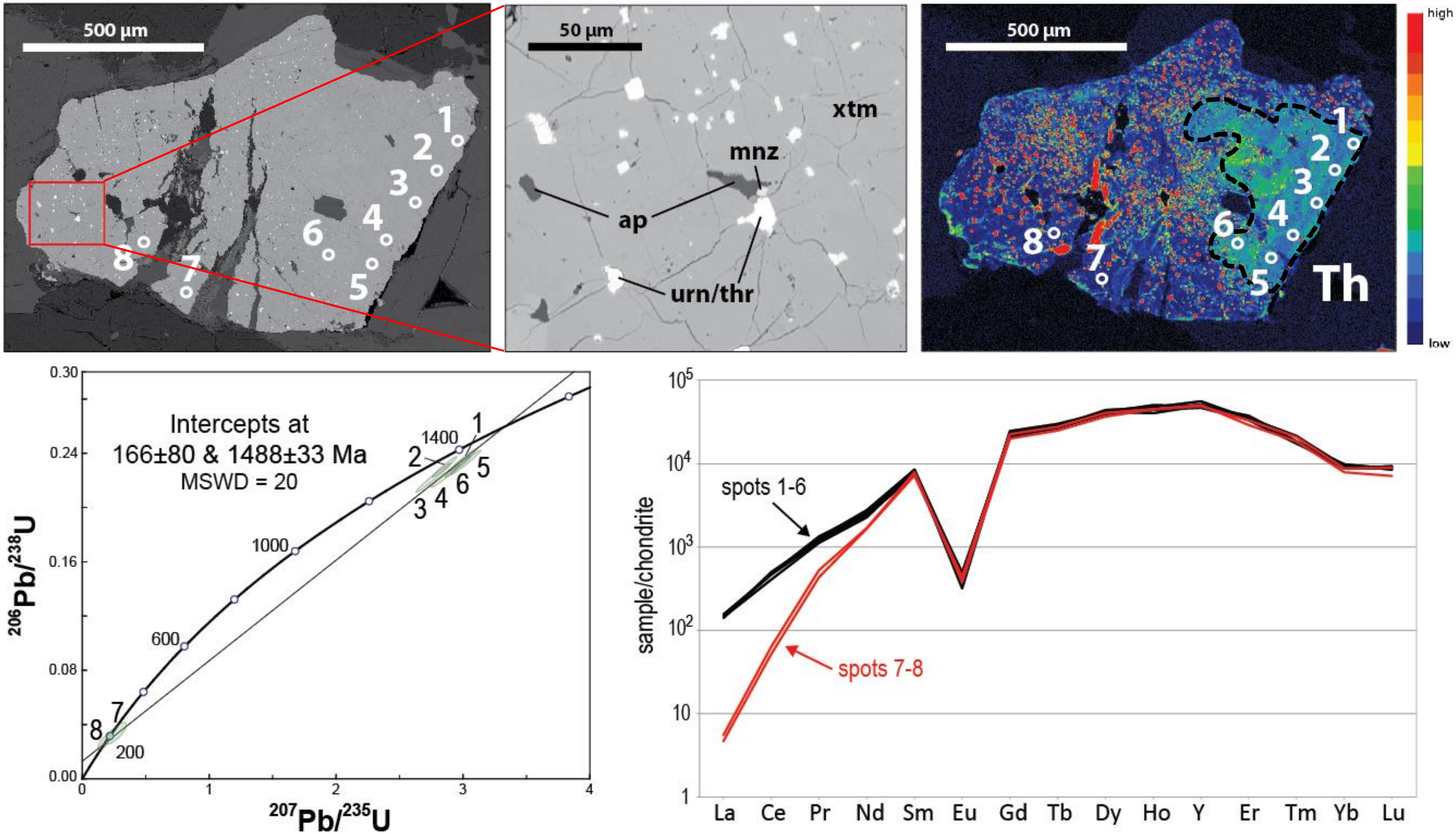
Zircon (pegmatite veins)



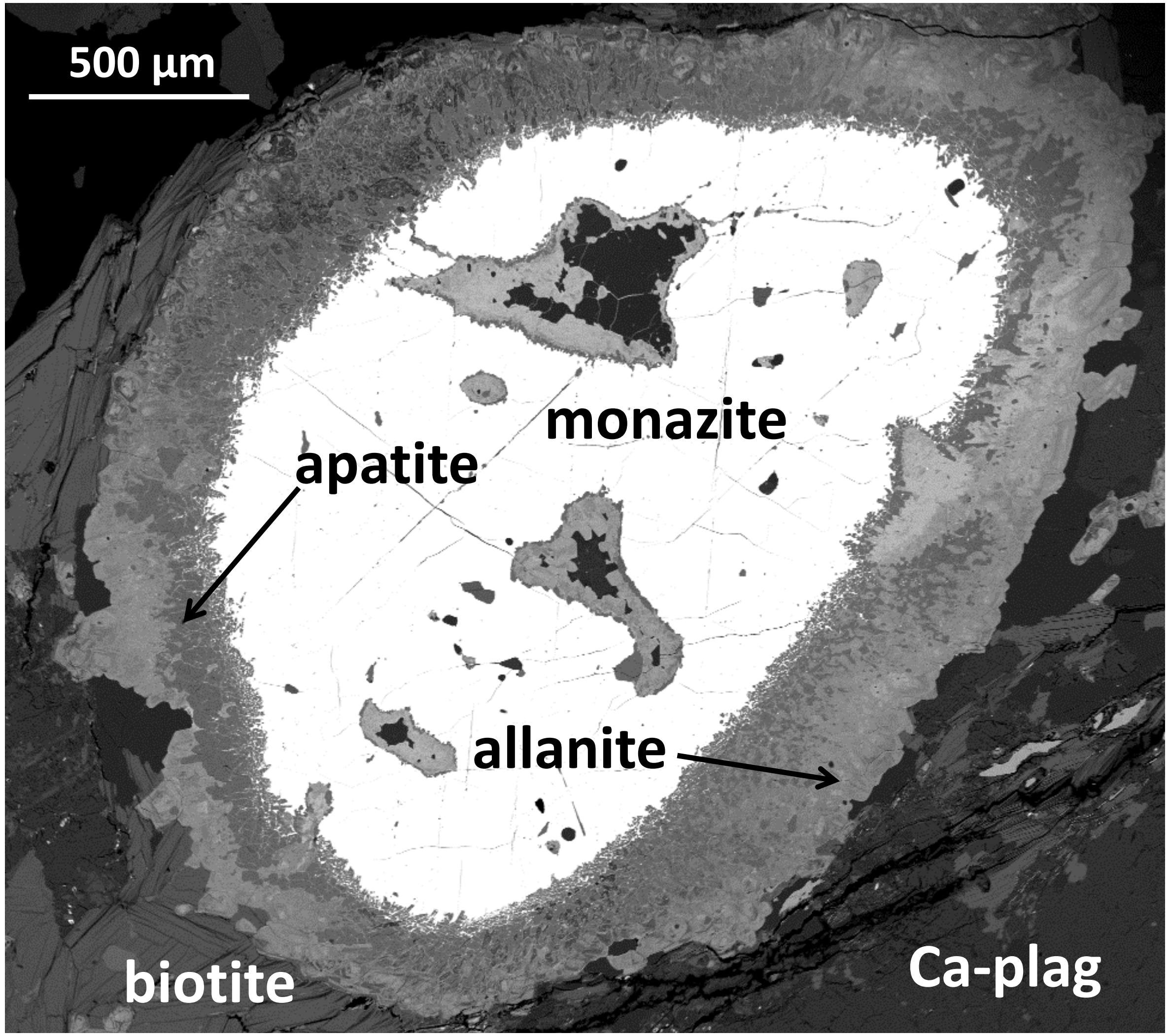
REE Mineral Alteration Geochronology



REE Mineral Alteration Geochronology



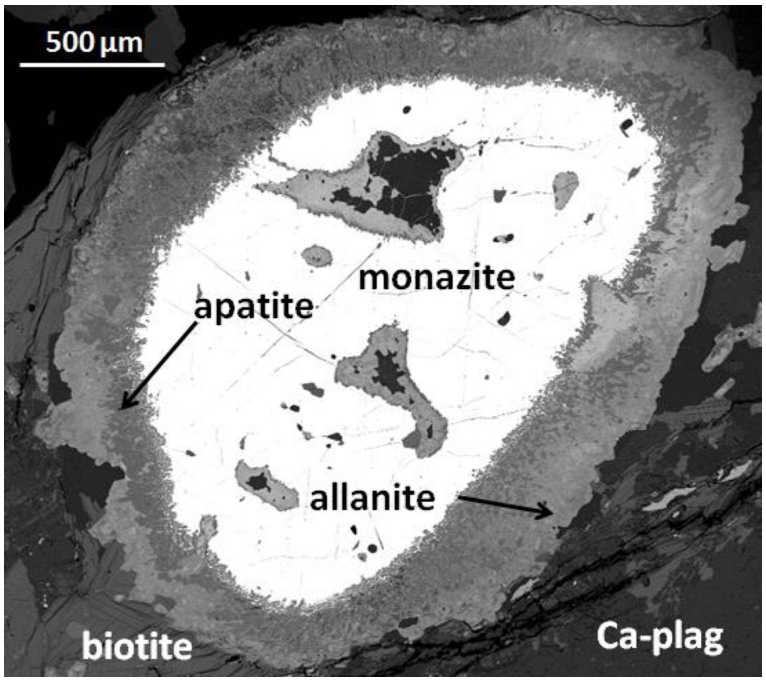
Monazite Breakdown Reaction (Pinto Gneiss)

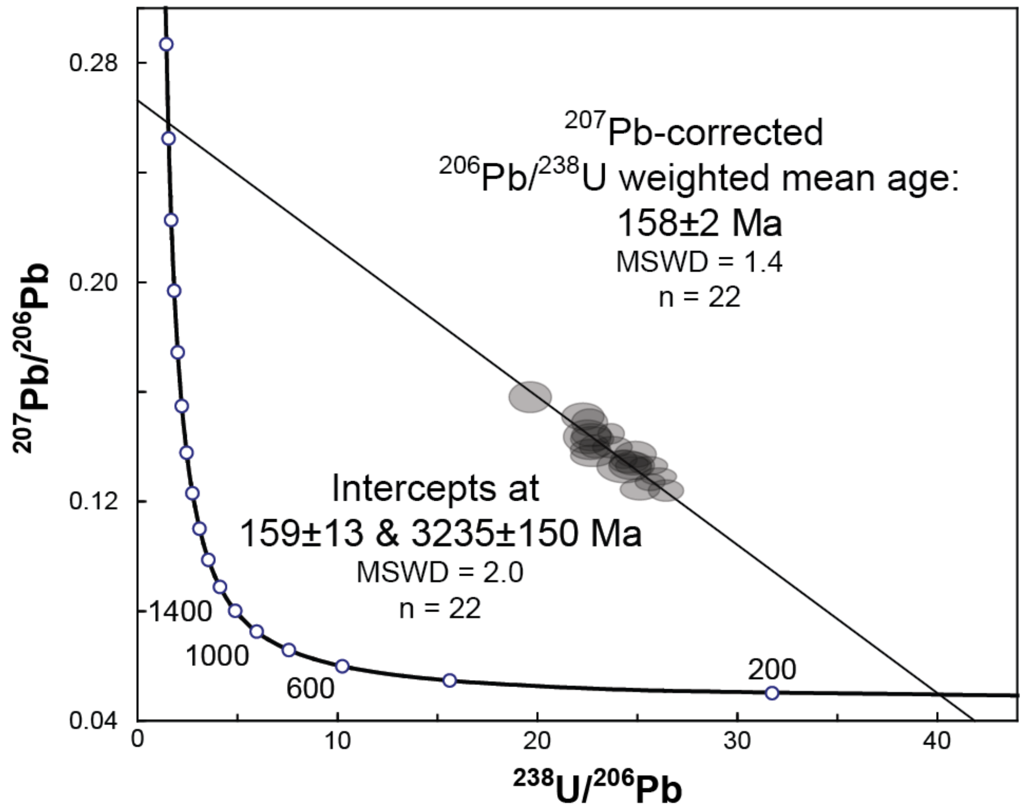


monazite + Ca-plag + biotite → apatite + allanite (+ H_2O + kspar?)

monazite	Ca-plag	biotite	apatite	allanite	kspar?
REE phosphate	Ca,Al silicate	K,Fe,Mg silicate (also OH, F)	Ca phosphate	Fe,Ca,REE silicate	K silicate

Geochronology – Allanite (Pinto Gneiss)

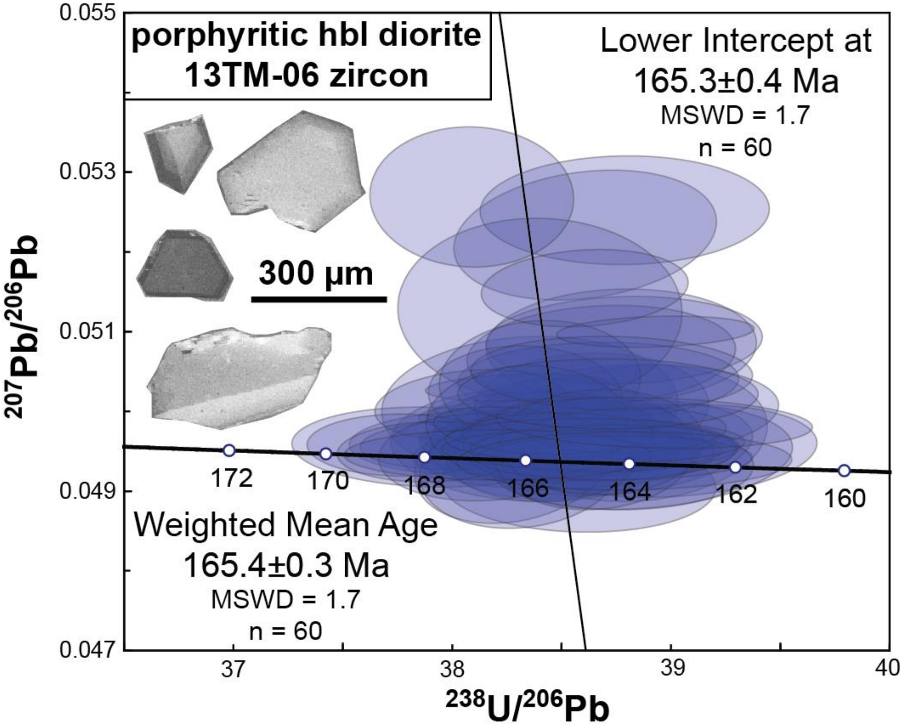




monazite + Ca-plag + biotite → apatite + allanite (+ H_2O + kspar?)

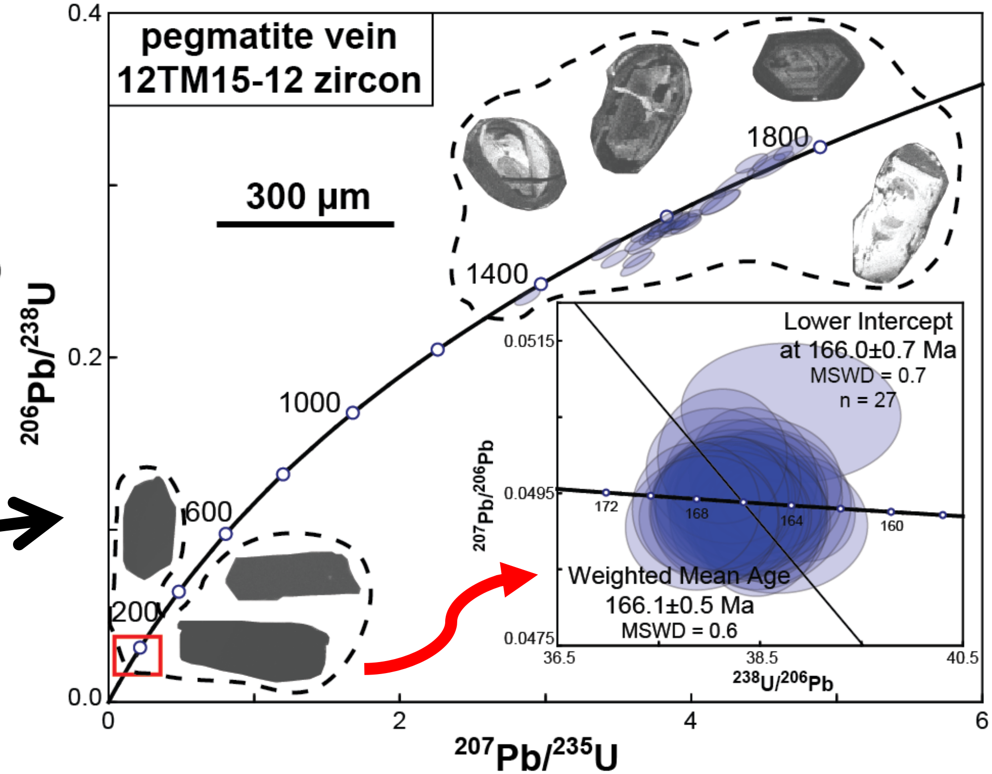
monazite	Ca-plag	biotite	apatite	allanite	kspar?
REE phosphate	**Ca,Al silicate**	**K,Fe,Mg silicate (also OH, F)**	**Ca phosphate**	**Fe,Ca,REE silicate**	**K silicate**

Fluid Alteration Coincides With…



emplacement of porphyritic hornblende diorite

genesis of pegmatite veins



Summary of Fluid-Related Alteration Geochronology

- Emplacement of the porphyritic hornblende diorite at ~166 Ma was associated with fluids that caused:
  1. partial melting of the Pinto Gneiss to form pegmatite veins
  2. dissolution re-precipitation of monazite and xenotime in the Pinto Gneiss
  3. monazite breakdown to form apatite and allanite in the Pinto Gneiss

Conclusions

- A multi-chronometer approach can be useful for understanding rocks that have experienced a complex geologic history

- The split-stream analytical technique can be a powerful tool for understanding phases with multiple age and/or textural domains

BONUS SLIDES

Pinto Gneiss - Monazite & Xenotime

Pinto Gneiss - Monazite & Xenotime

Geochemistry

monazite + annite + anorthite + quartz + fluid → apatite + allanite + muscovite (or K-feldspar)

$$3(LREE)PO_4 + KFe_3(Si_3AlO_{10})(OH,F)_2 + 4CaAl_2Si_2O_8 + 3SiO_2 + 4Ca^{2+} + 4H^+ \rightarrow Ca_5(PO_4)_3(OH,F) + 3Ca(LREE)FeAl_2Si_3O_{12}(OH,F) + KAl(Si_3AlO_{10})(OH)_2$$

Broska, I., and Siman, P., 1998. The breakdown of monazite in the west-Carpathian Veporic Orthogneisses and Tatric Granites. *Geologica Carpathica*, **49:3**, 161-167.

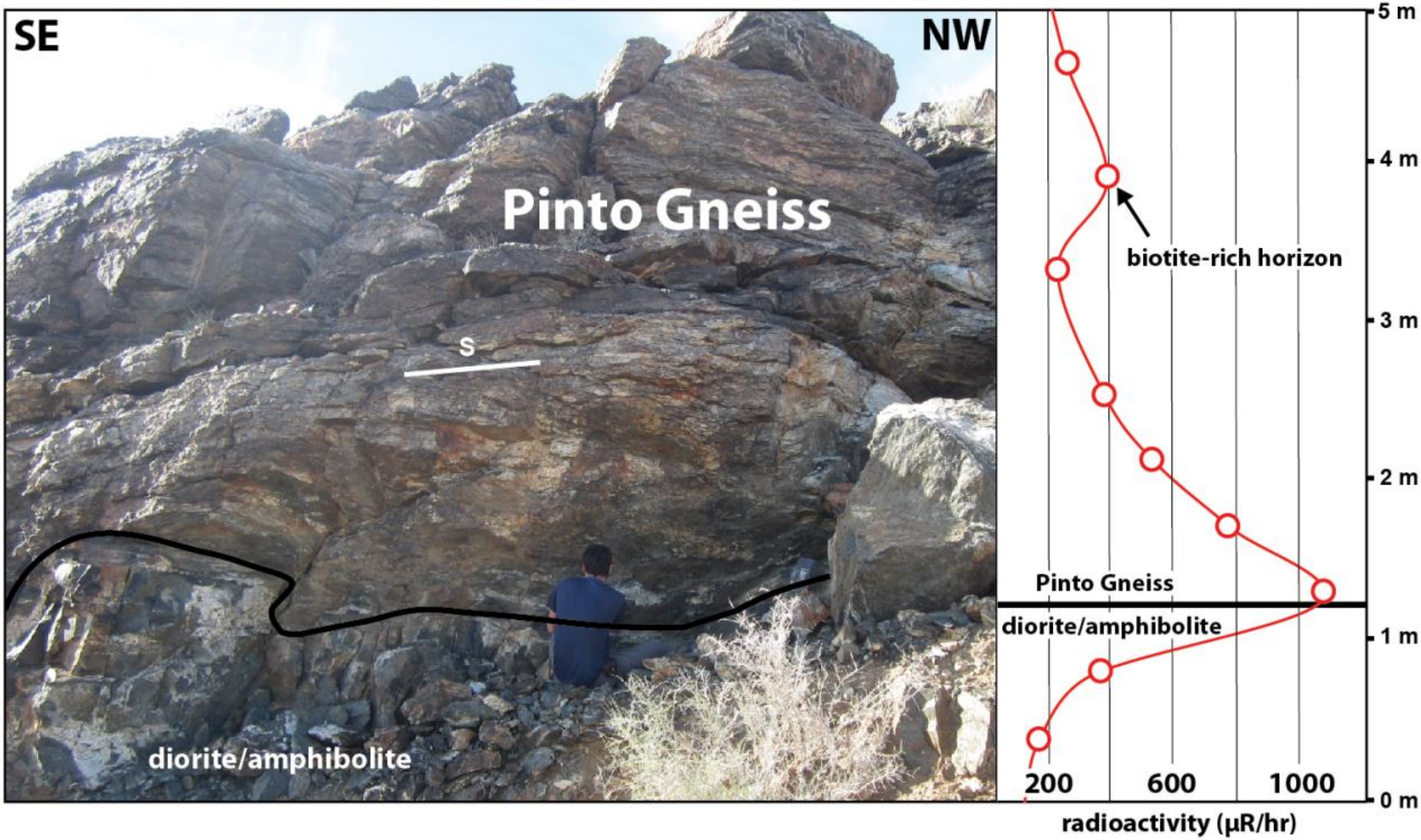
Geochemistry

External parameters controlling Th, U and LREE behavior during fluid/rock interaction (various references):

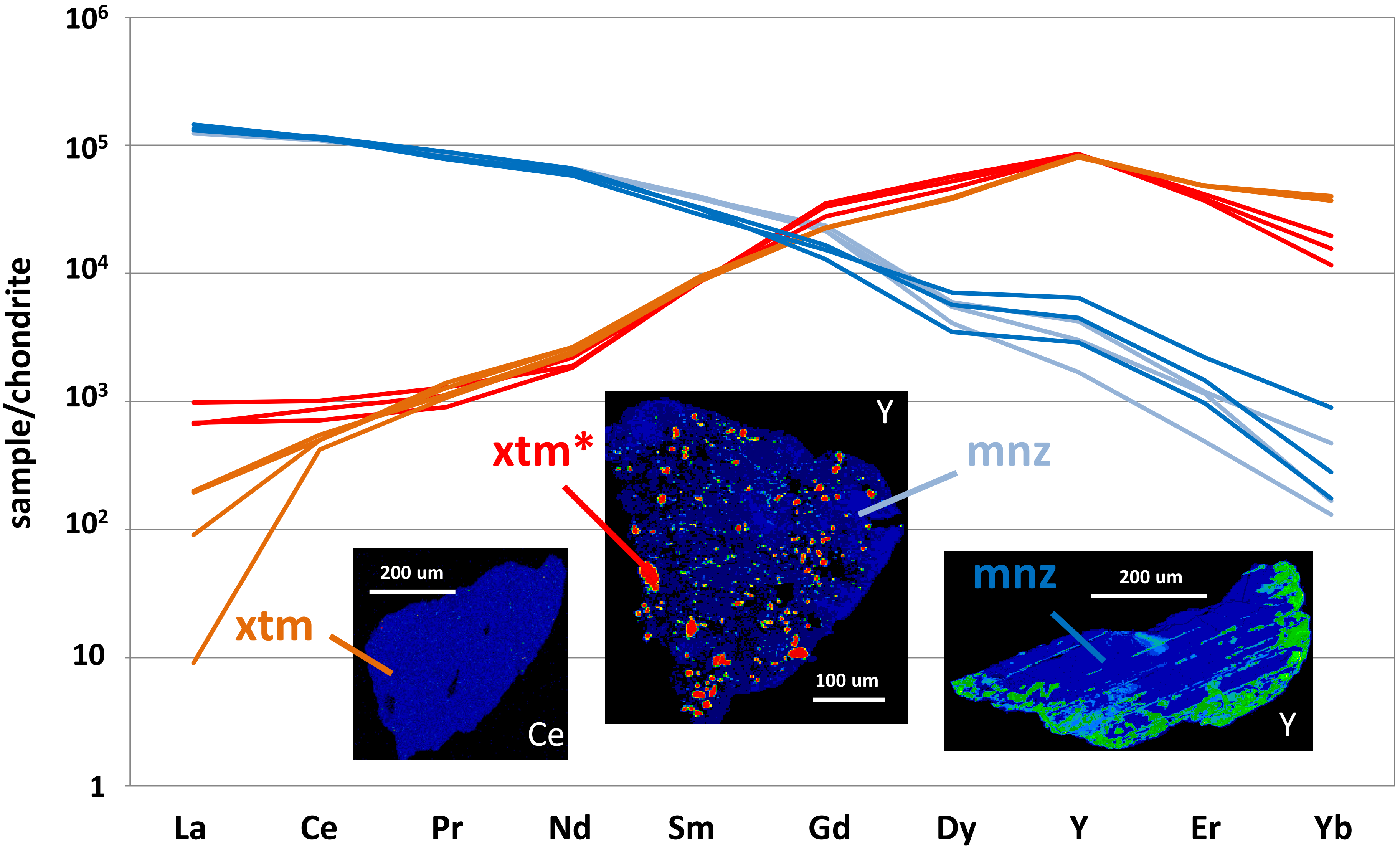
1. temperature
2. fluid composition
3. pH and redox conditions
4. ligand species and stability of REE, Th- and U- rich phases
5. initial composition of the monazite

Didier et al., 2013. Disturbance versus preservation of U-Th-Pb ages in monazite during fluid-rock interaction: textural, chemical and isotopic in situ study of microgranites. *Contrib Mineral Petrol*, **165**, 1051-1072.

Radiation Profile



Geochemistry



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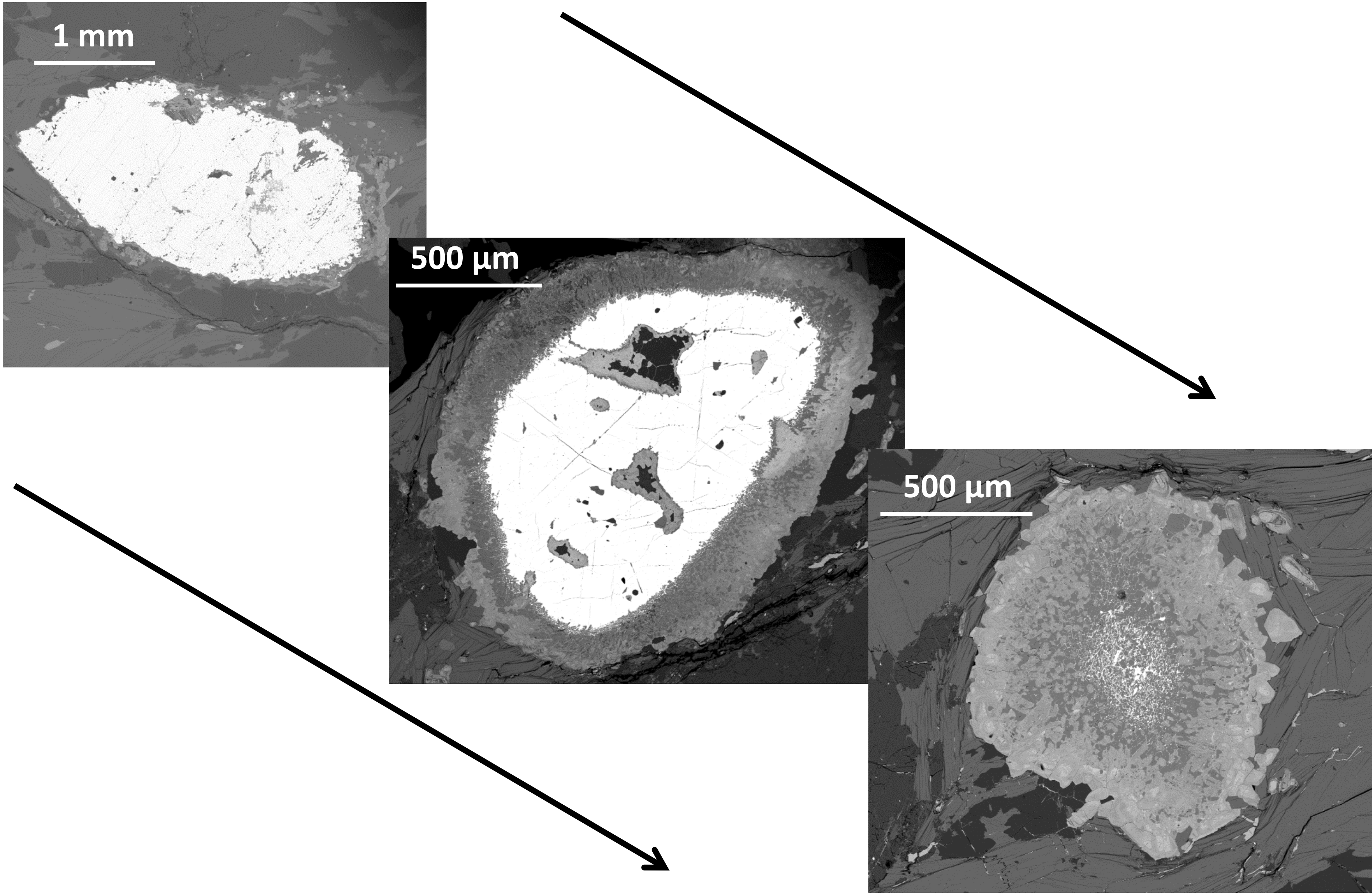

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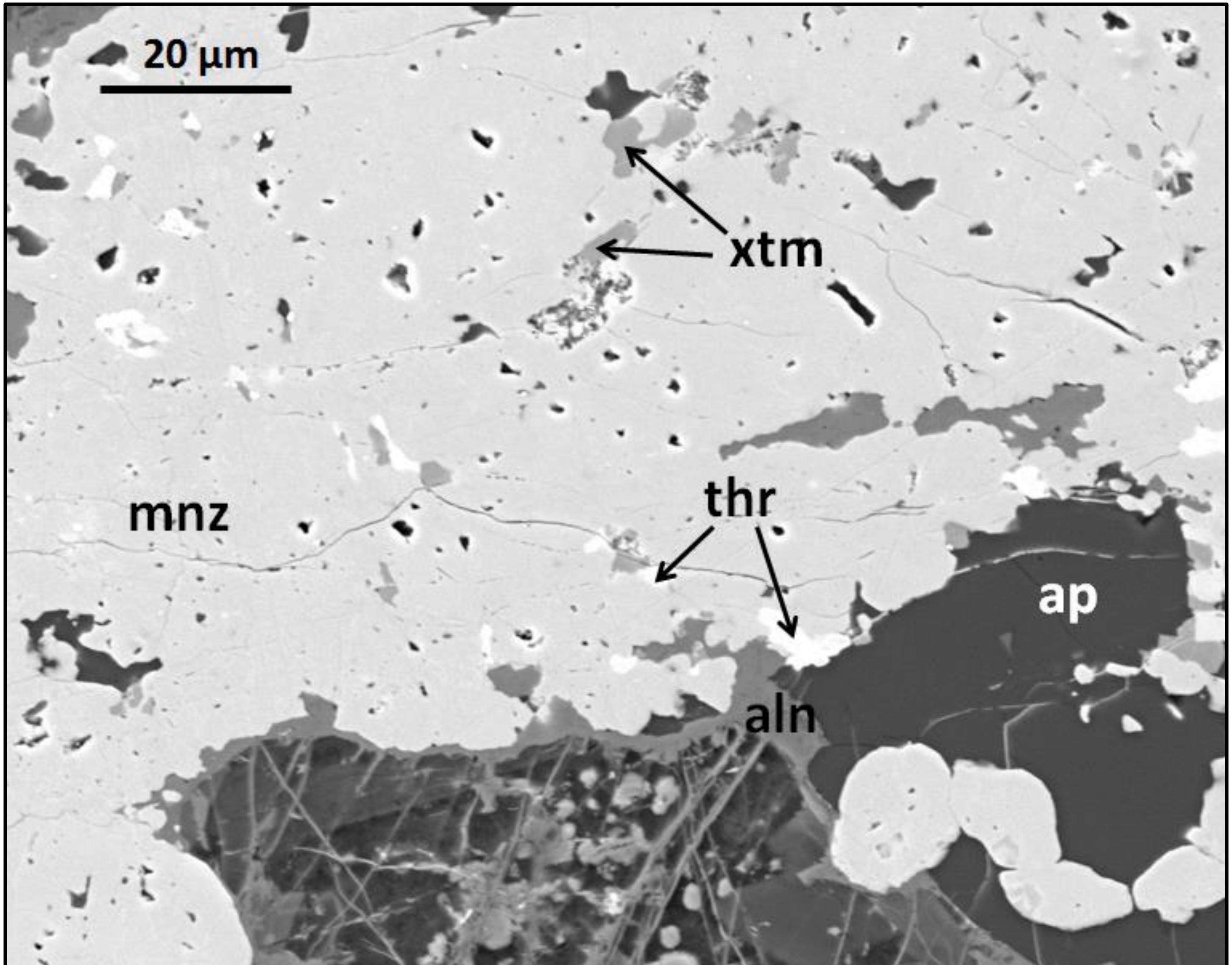

Results – Geochemistry