# Expanding the provenance toolkit beyond detrital zircon dating: a test case from the Merrimack River

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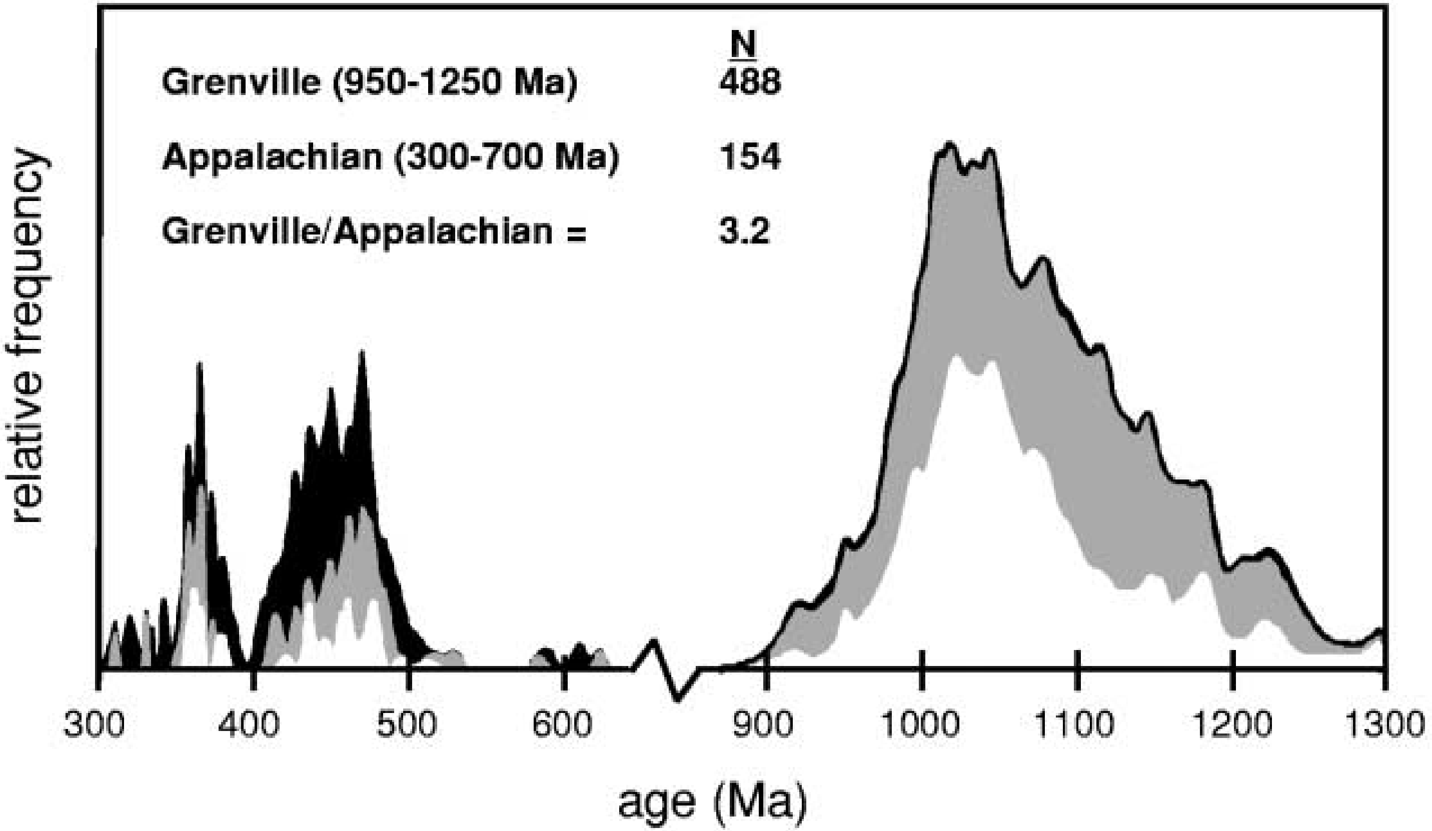
# Limitations of detrital zircon geochronology in provenance analysis

- Strong bias towards felsic magmatism (especially Zr-rich plutons)
- Little info on metamorphic history

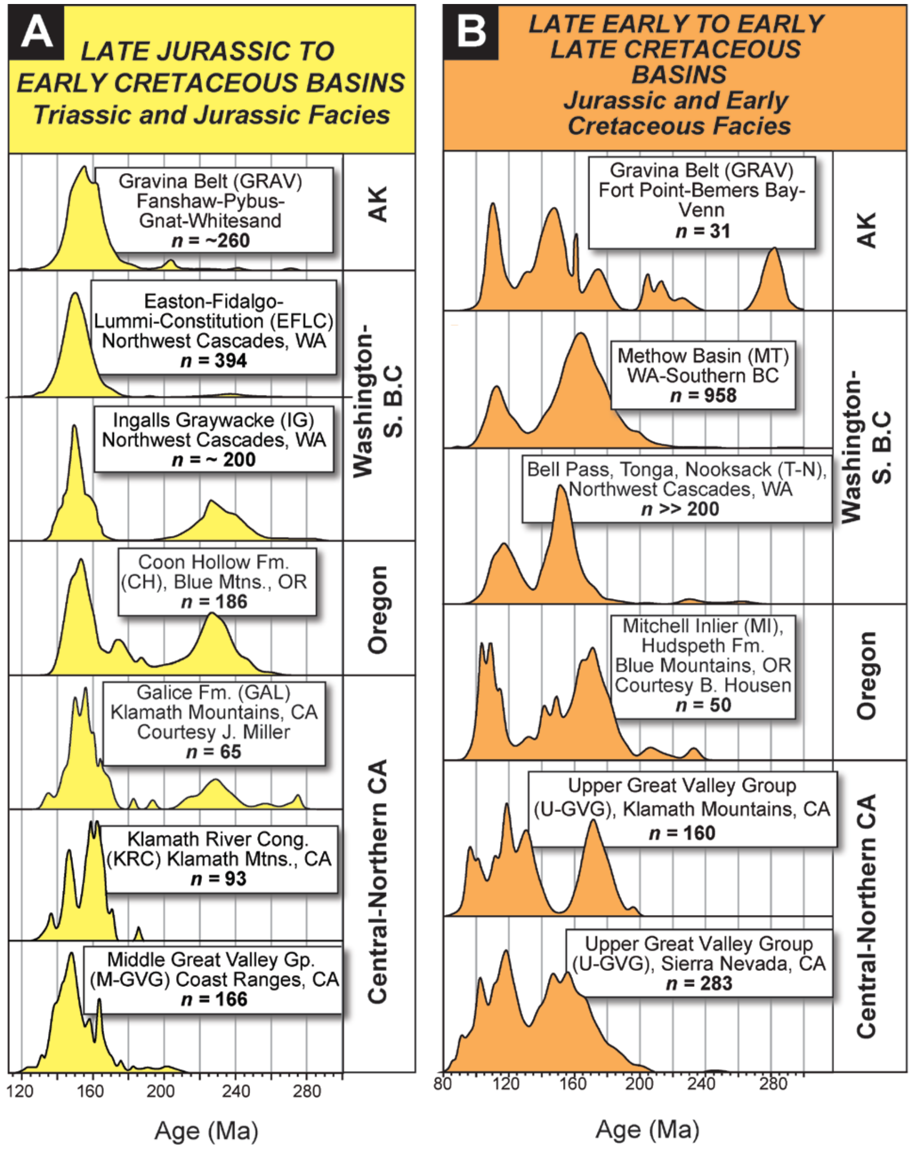



From Eriksson et al (2003)

*- Alien geologists sampling detrital zircons from the major Appalachian rivers might assume that Appalachians formed mostly between 1.0 and 1.1 Ga and would completely miss Alleghanian orogeny*

# Limitations of detrital zircon geochronology in provenance analysis

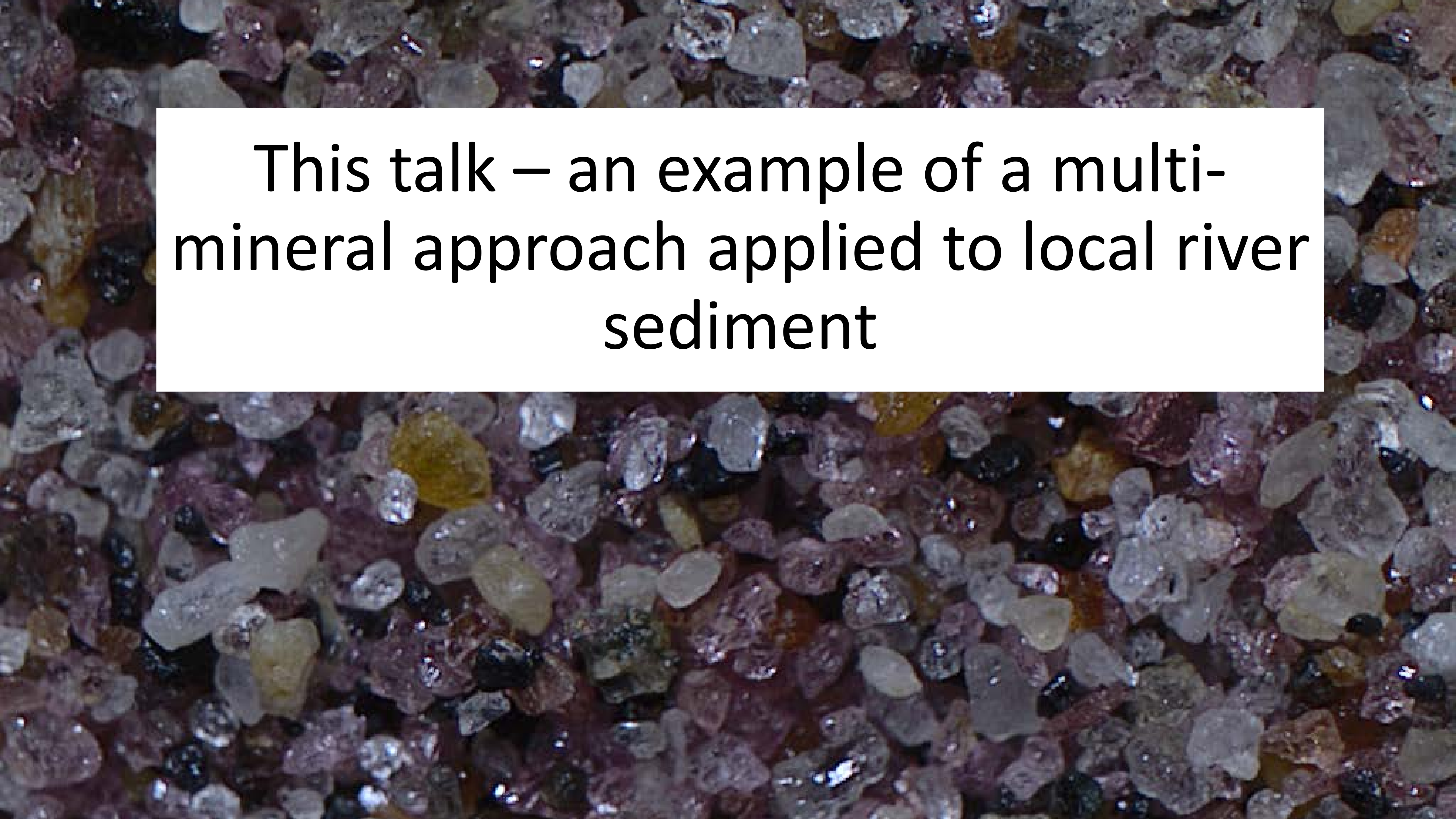
- Zircon age spectra are often non-unique
- As LaMaskin (2012) noted, coeval Cordilleran sediments have very similar age populations from California to Alaska



# Limitations of detrital zircon geochronology in provenance analysis

- Survivability means that it is often recycled from older sediments

- We cannot say much about tectonic setting of these zircon source rocks from U-Pb ages alone

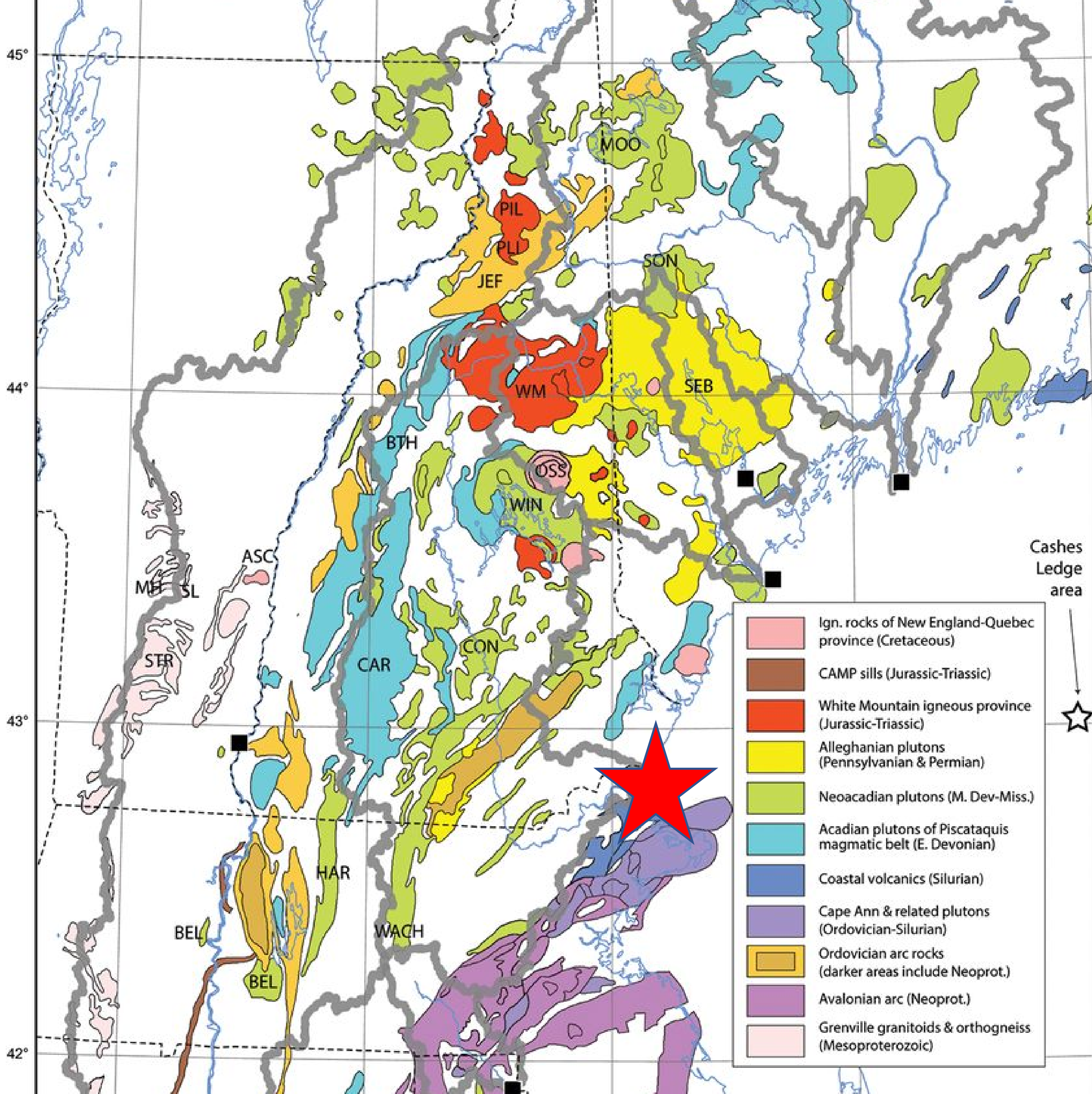


# This talk – an example of a multi-mineral approach applied to local river sediment

# The sample

- Garnet-rich sand from mouth of Merrimack River
  - River flows out of Mesozoic White Mtns province through various Paleozoic pluton and metasedimentary belts

*From Bradley et al. (2015) ->*



# Proxies used here

- Zircon (old reliable)
  - U-Pb ages - track major episodes of intermediate to felsic magmatism
  - Trace elements - may distinguish source rock type (e.g., Belousova et al., 2002; Grimes et al., 2015)

# Proxies used here

- Monazite
  - U-Th-Pb ages – records metamorphism in variety of rock types; occasional igneous phase
  - Trace elements - may distinguish source rock type (e.g., Itano et al., 2016)

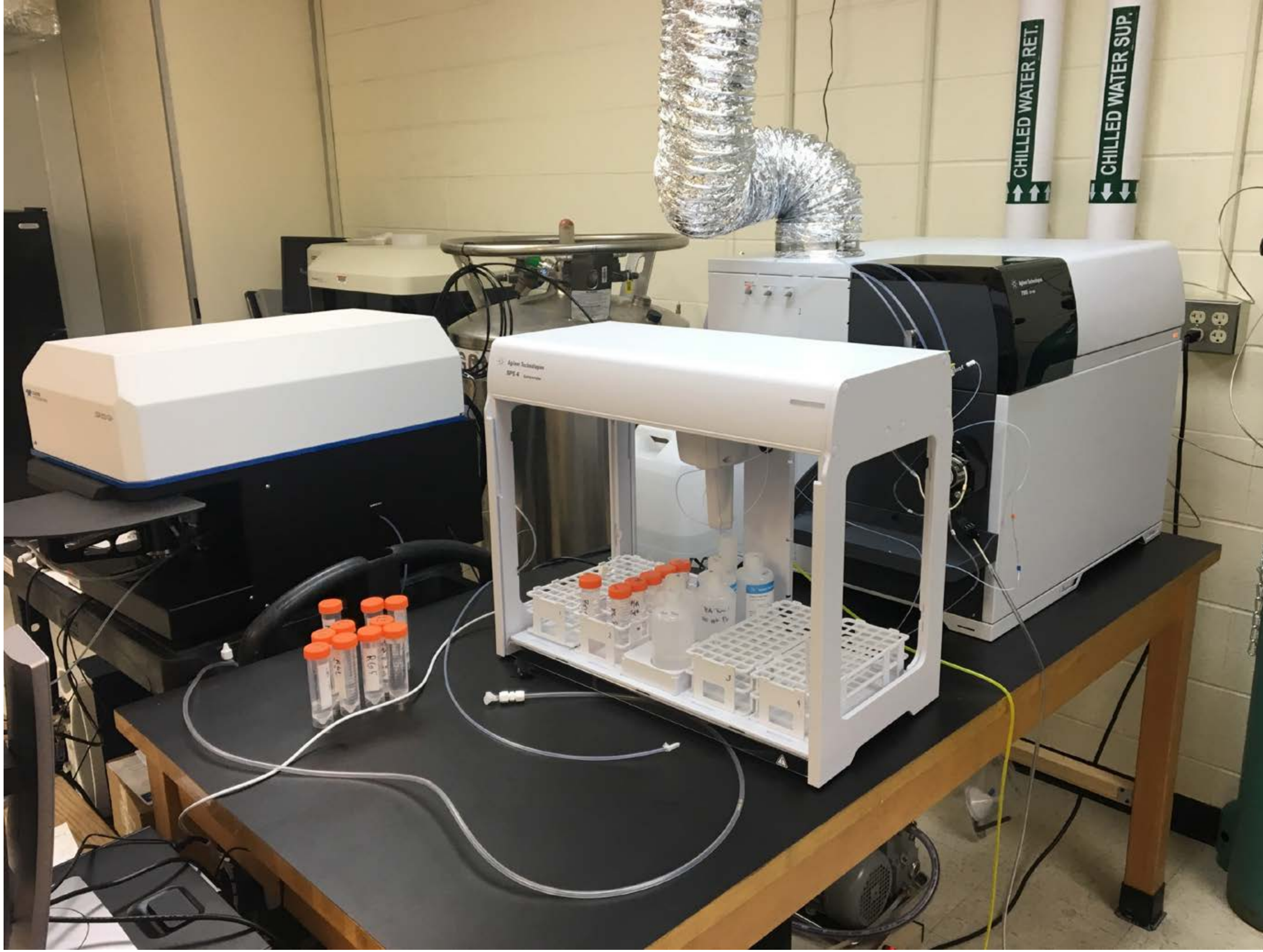
# Proxies used here

- Rutile
  - U-Pb ages – records metamorphism in variety of rock types
    - If exhumation is slow, ages will reflect cooling rather than peak metamorphism
  - Trace elements - may distinguish source rock type (e.g., Triebold et al., 2007)
    - Zr concentration is temperature dependent (Zack et al., 2004)

# Proxies used here

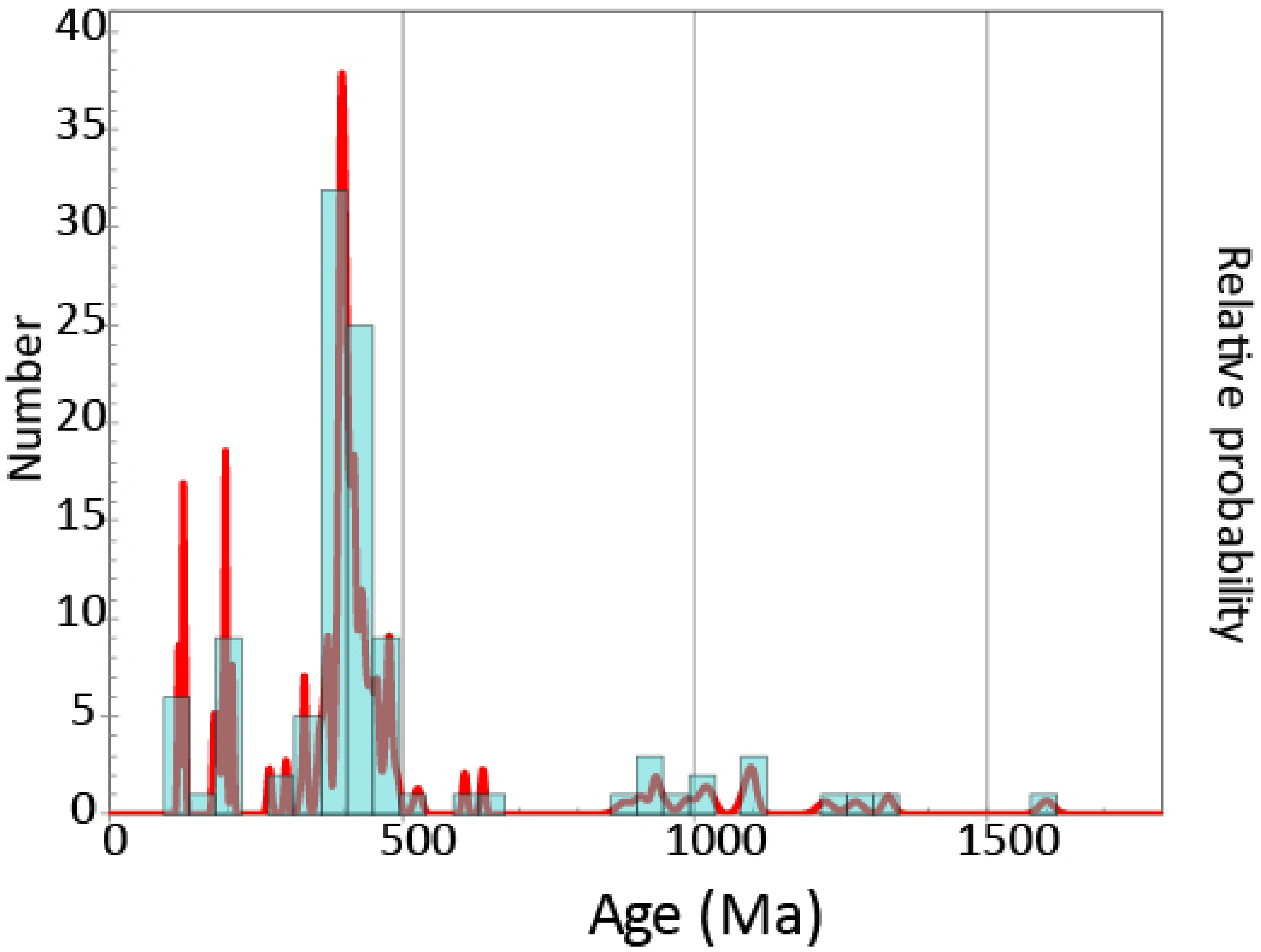
- Titanite
  - U-Pb ages – Common in many igneous rock types; also forms in several metamorphic environments
  - Trace elements - may distinguish source rock type (e.g., Aleinikoff et al., 2002)

- All analyses conducted at UMass Lowell with CETAC LSX-213 G2+ laser and Agilent 7900 Q-ICP-MS



# Zircon age results

- Major peak 400 Ma and lesser peaks at 200 and 120
- Identical to Bradley et al (2015)



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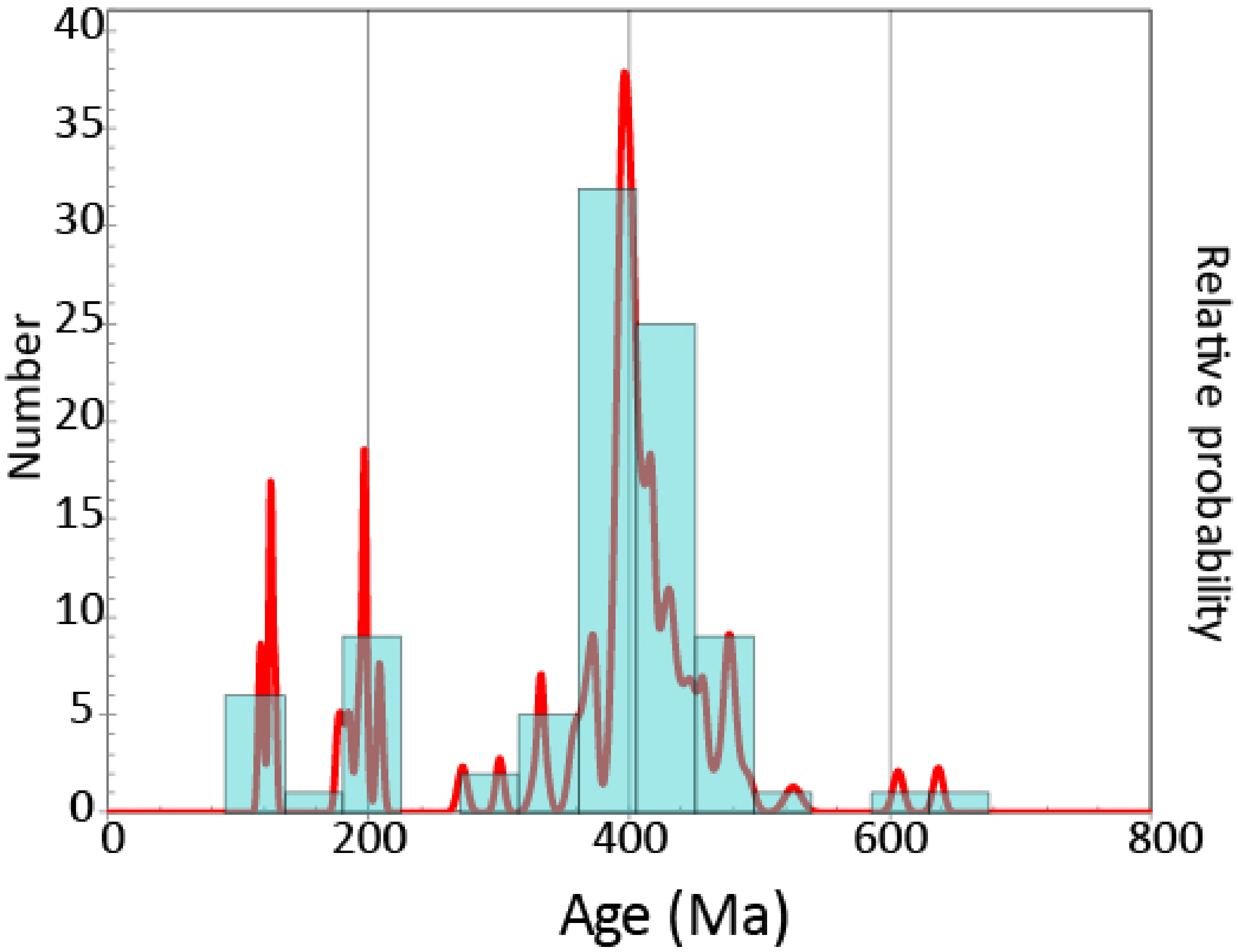
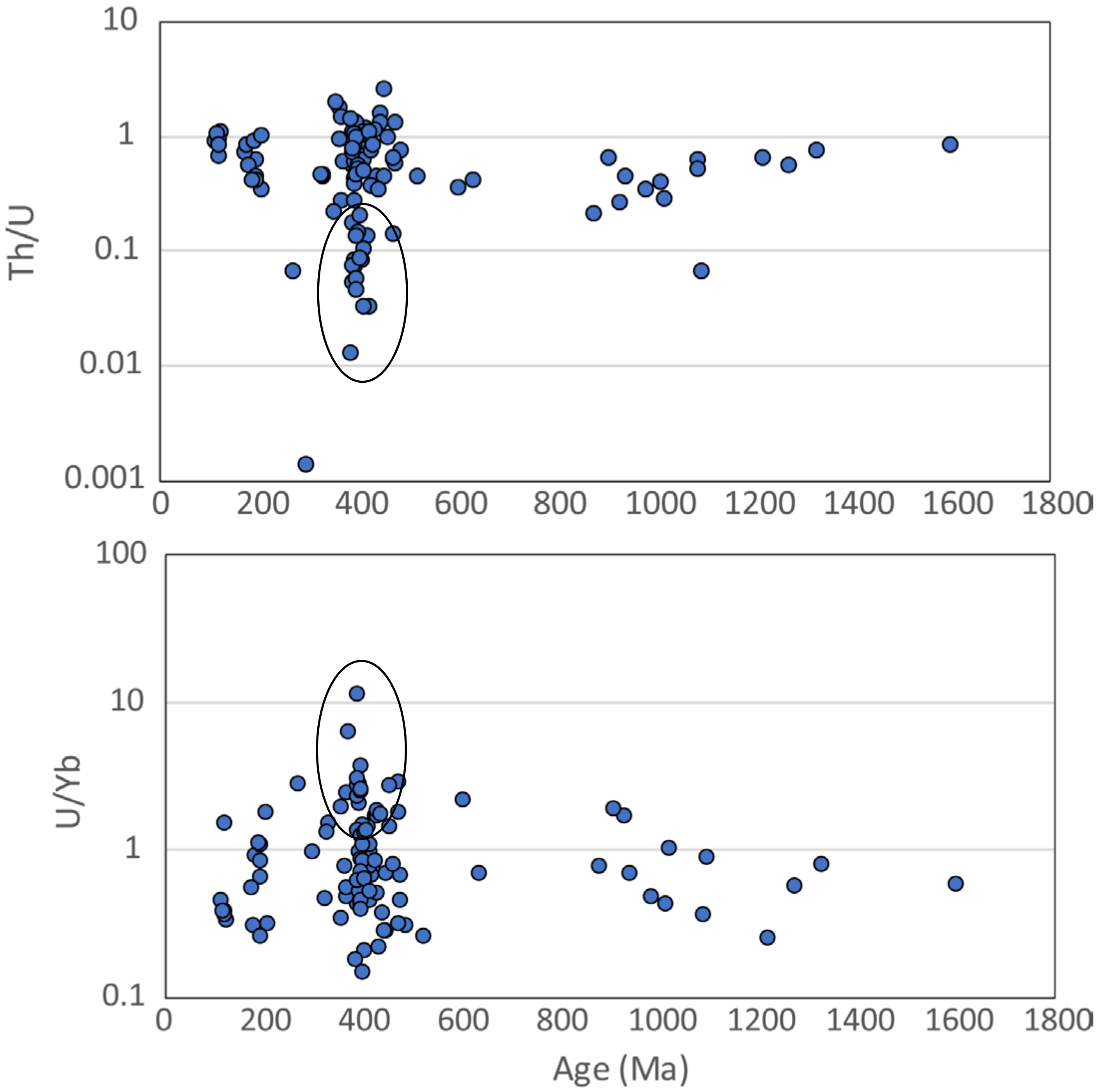
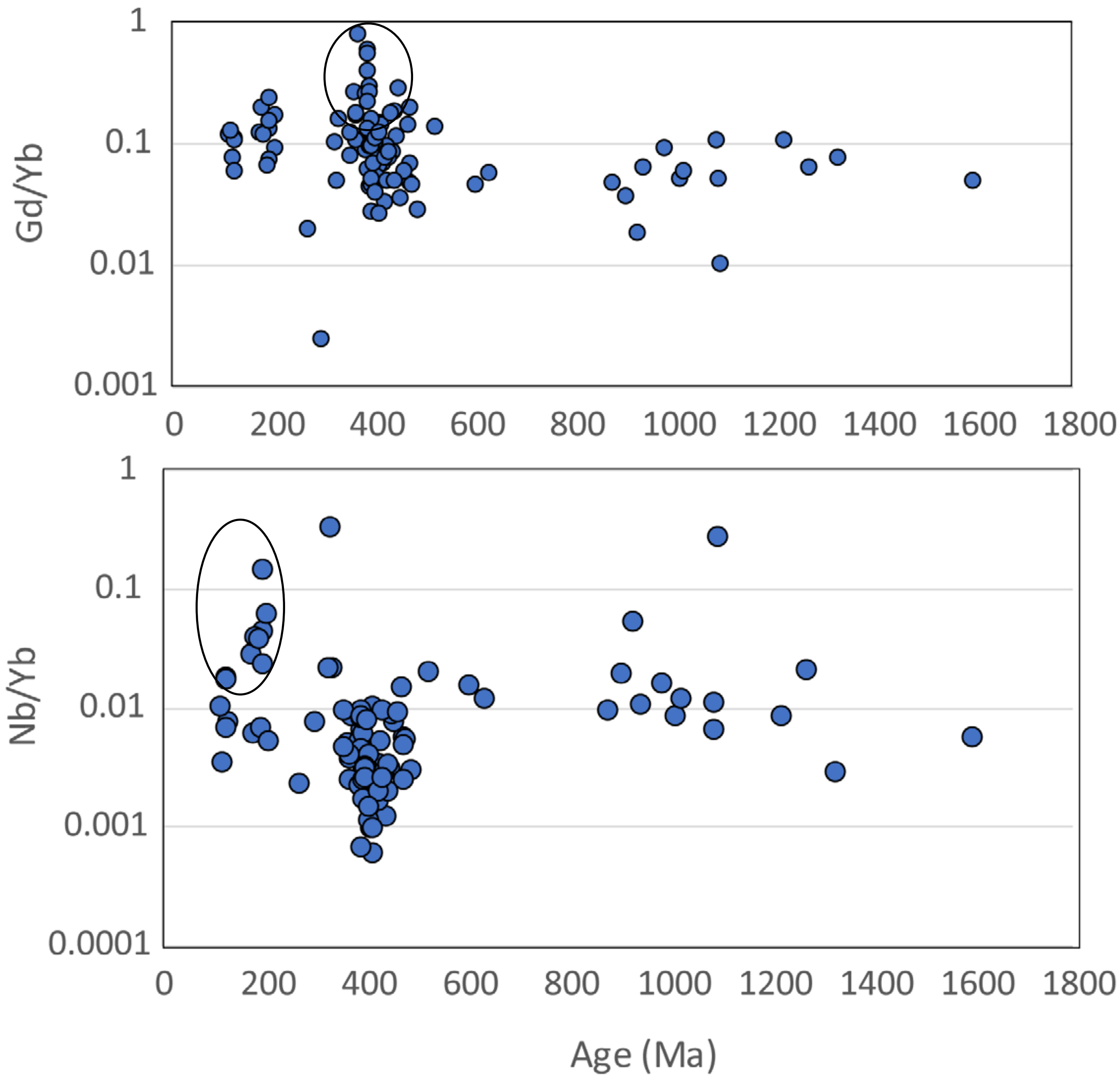


- ~400 Ma population has significant subgroup with low Th/U and high U/Yb
  - Suggests crystallization from peraluminous and crustally derived magma



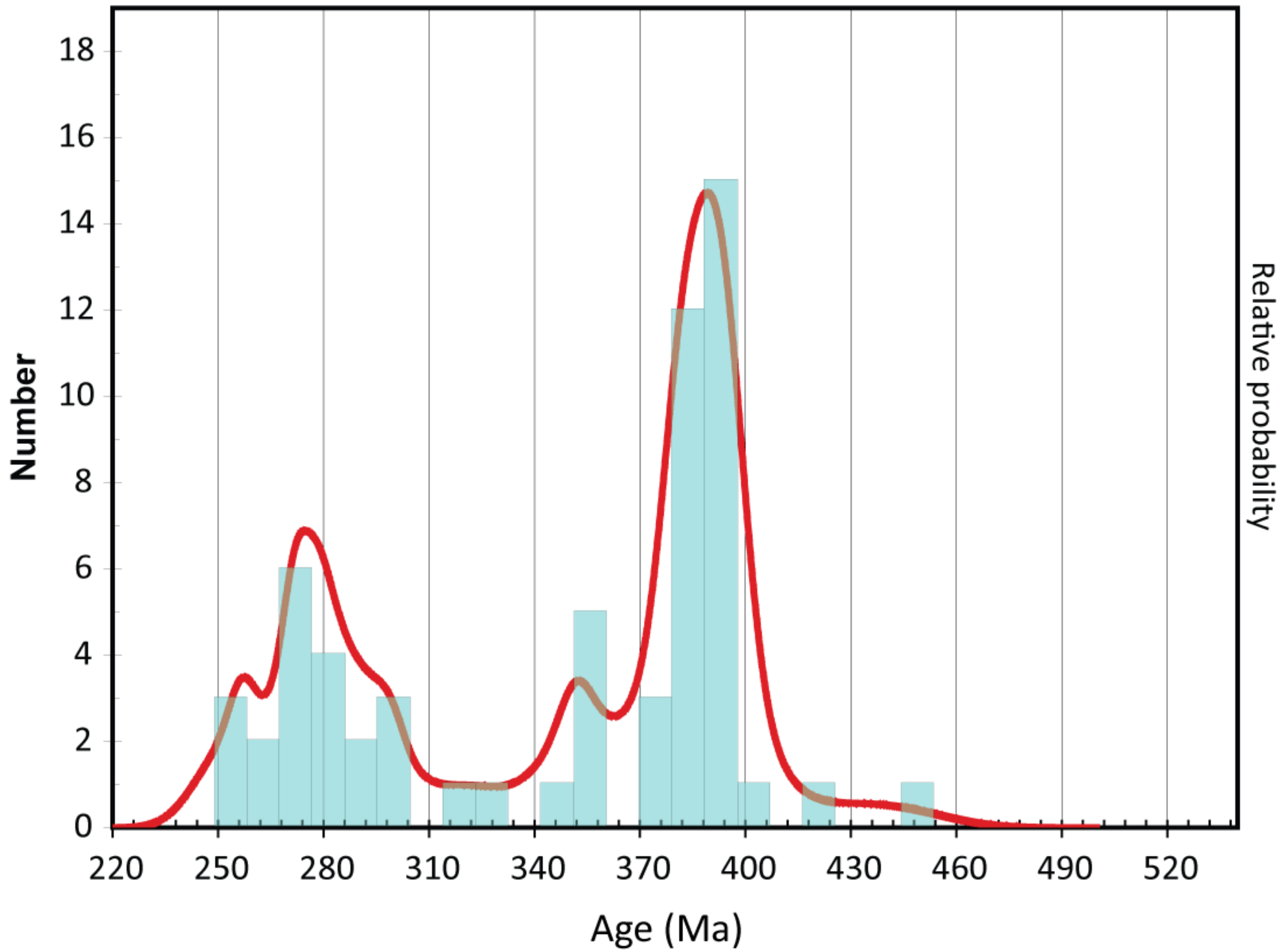
- Spike in Gd/Yb at 400 Ma is consistent with melting in thickened crust

- Spike in Nb/Yb at 200 Ma consistent with alkalic A-type granites

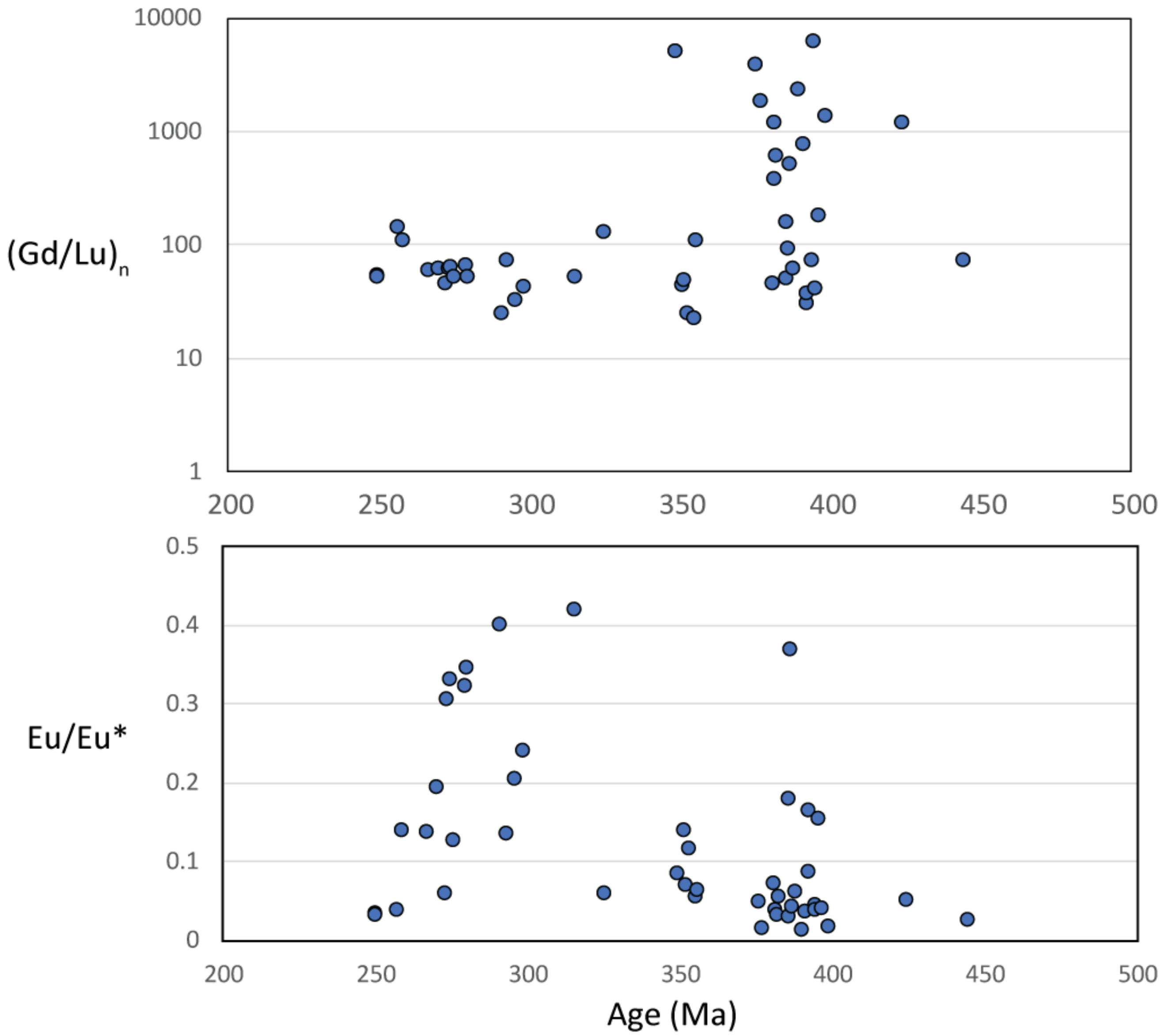


# Monazite age results

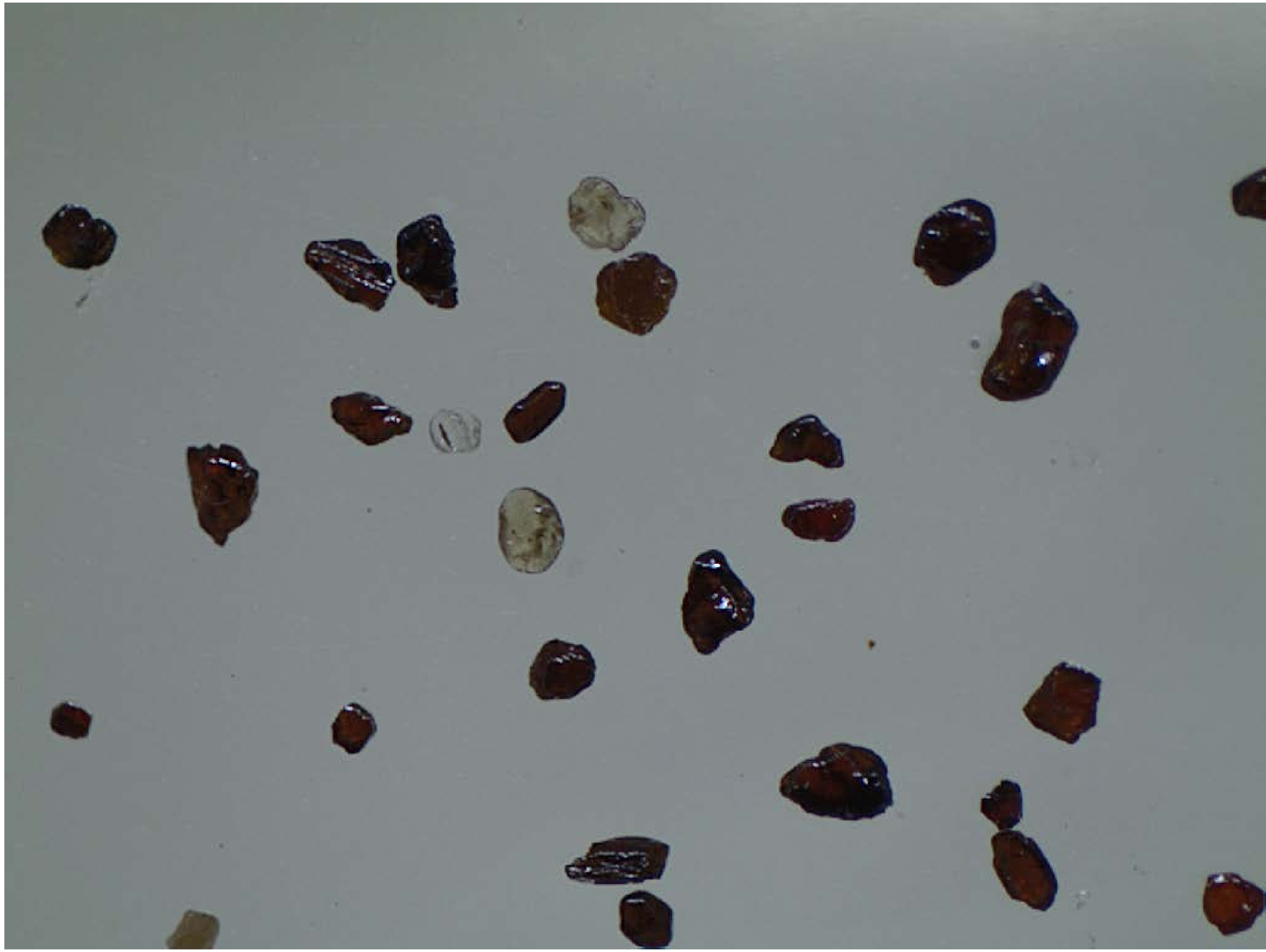
- Peaks at 389, 277, and 347 Ma
  - 389 Ma peak is slightly younger than main zircon age peak
  - 277 Ma peak is *absent* from zircon age spectra
- No Precambrian ages



- Many of the oldest monazites grew in equilibrium with garnet and feldspar
- Itano et al. (2015) monazite discriminants would suggest that many of these are igneous monazites…
  - But one would expect to see zircons of same age in detrital record if true

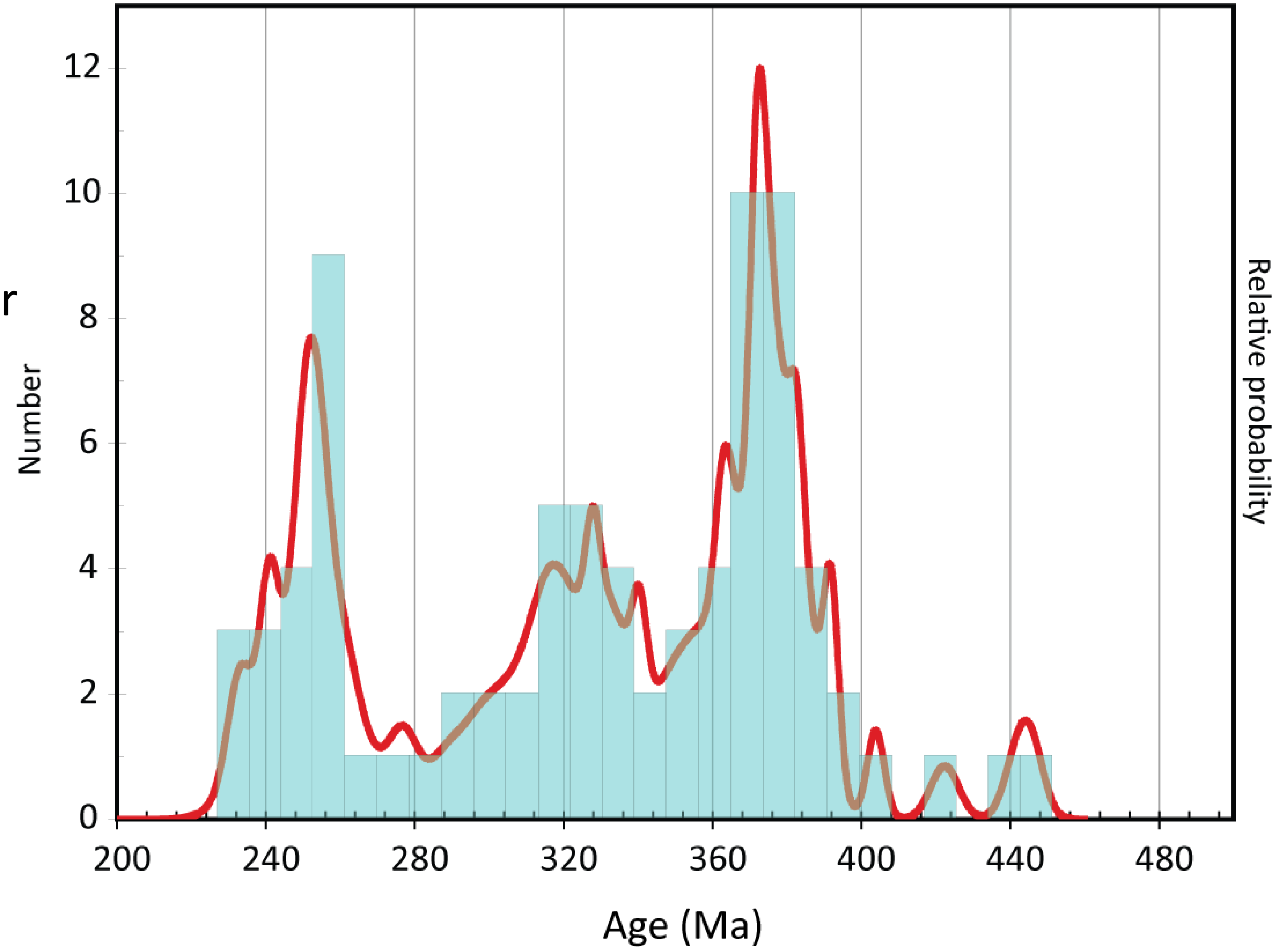


# Rutile age results



# Rutile age results

- Hmm… Looks similar to monazite pattern
  - Except each rutile peak is offset by 10 to 20 years
  - This likely reflects the lower closure temperature of rutile (~500-550°), indicating slow cooling/exhumation



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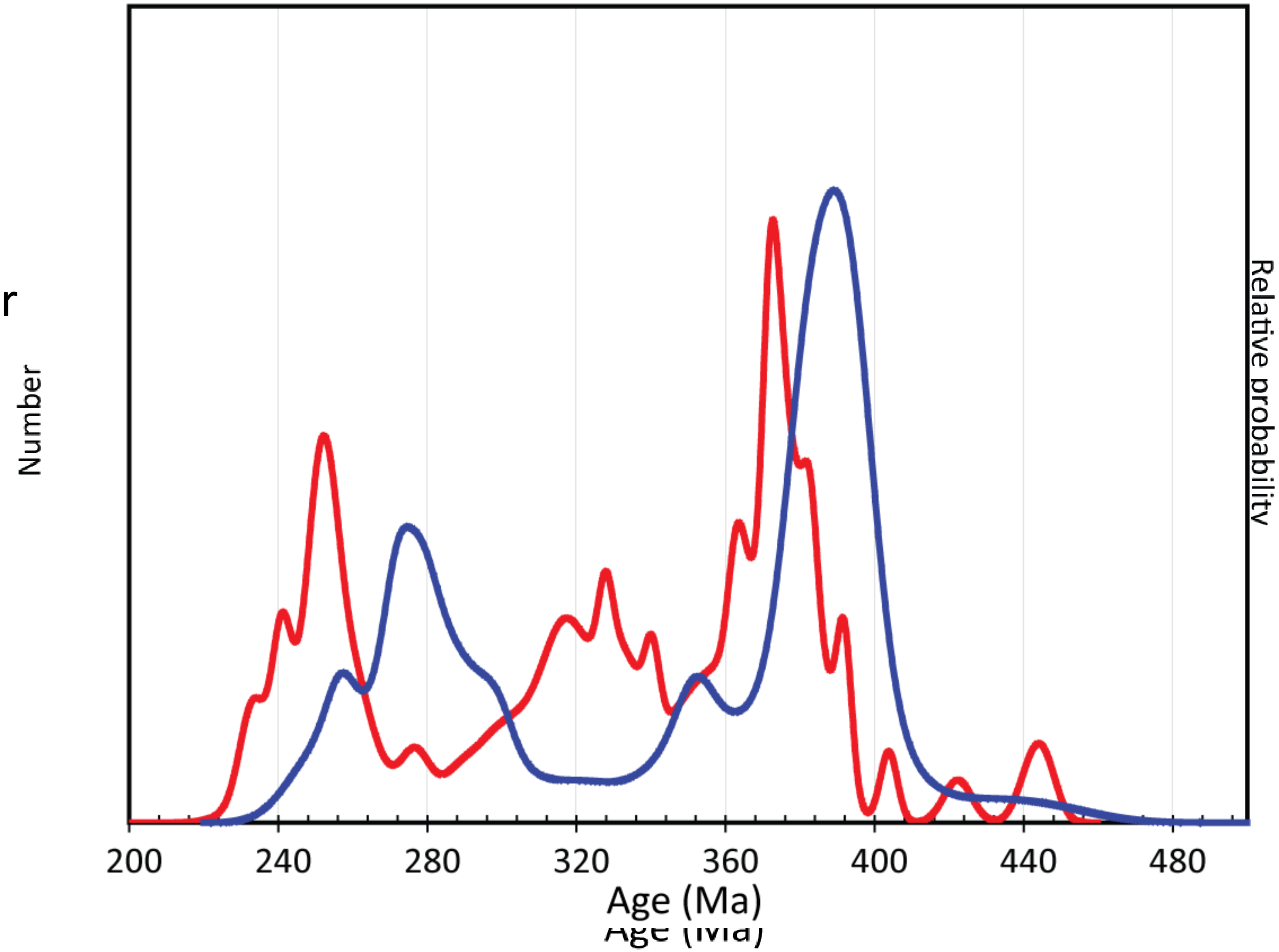
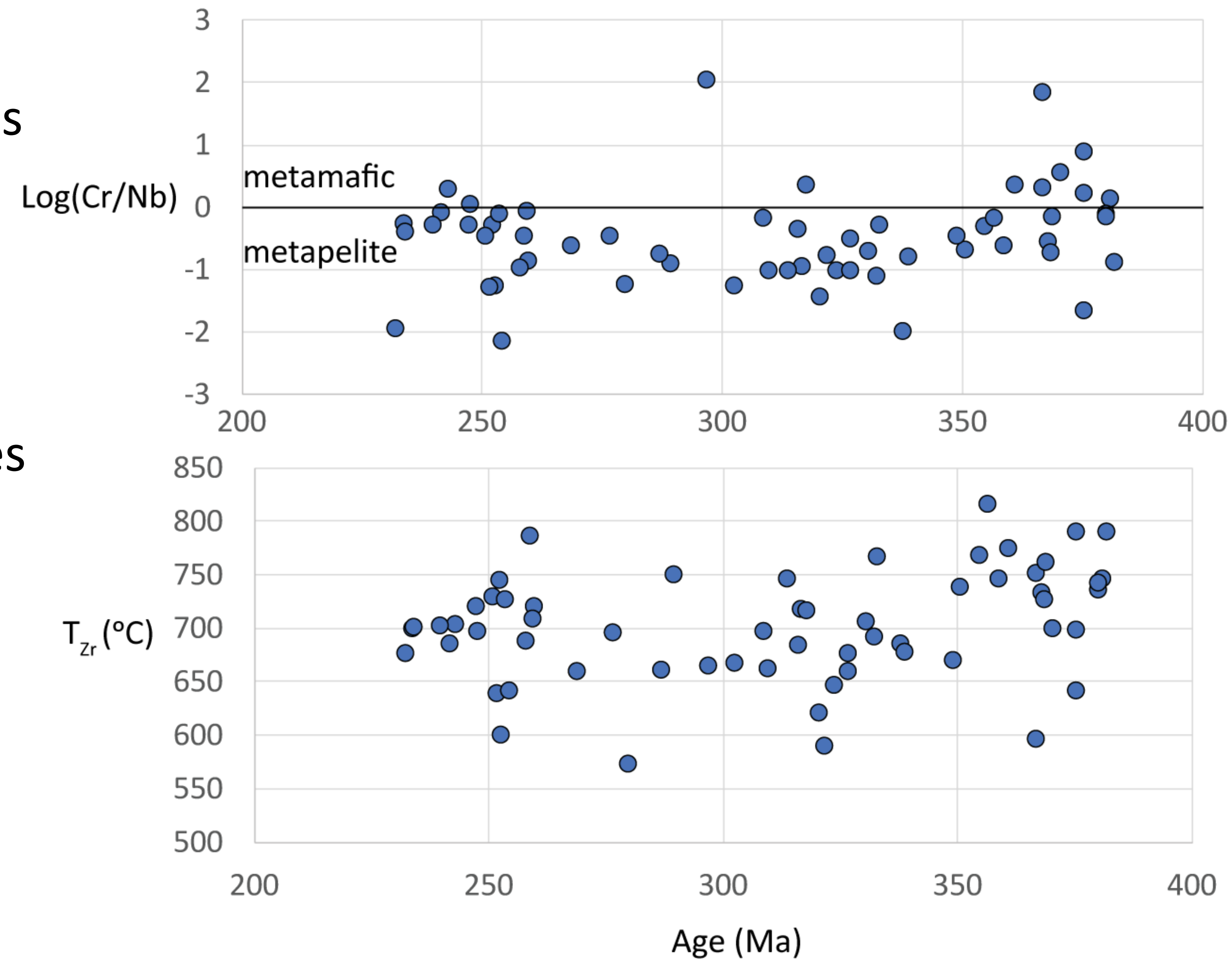


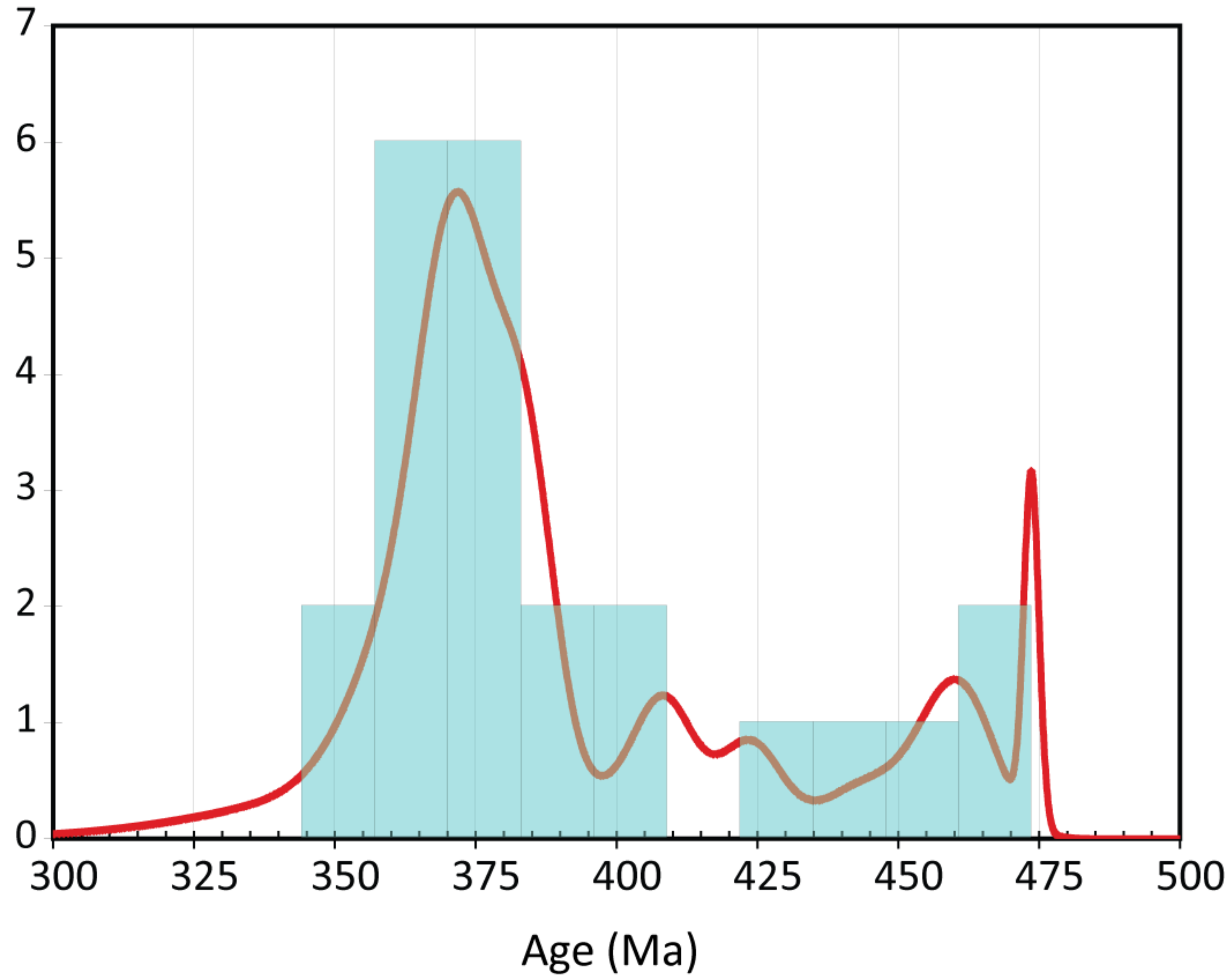
- Cr and Nb concentrations indicate mostly metasdimentary source rocks

- Zr thermometer indicates temperature in upper amphibolite to granulite conditions of growth

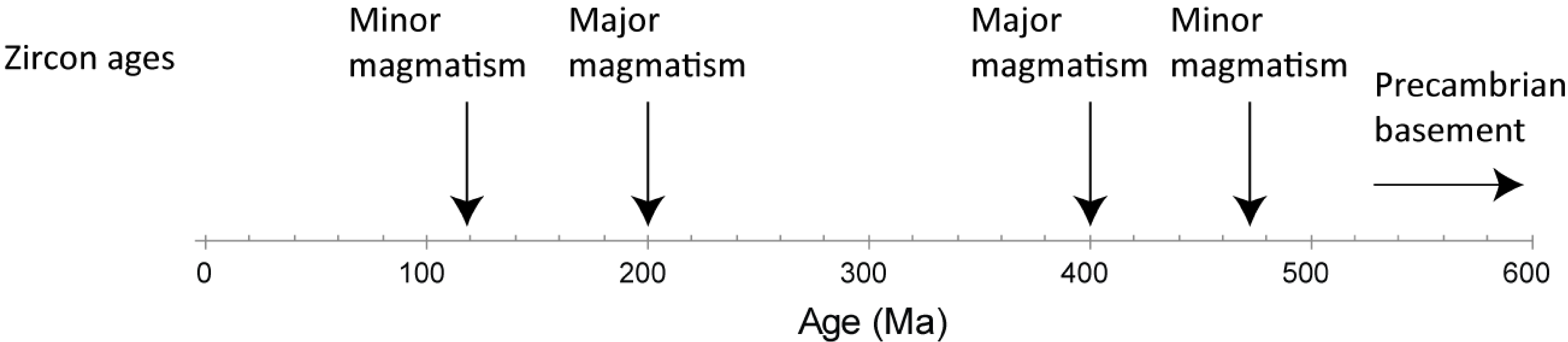


# A few titanites

- Al and Fe content indicate magmatic origin
- Ages line up with minor zircon age peaks, reflecting more limited magma compositional range that crystallizes titanite



# Back to the alien geologists



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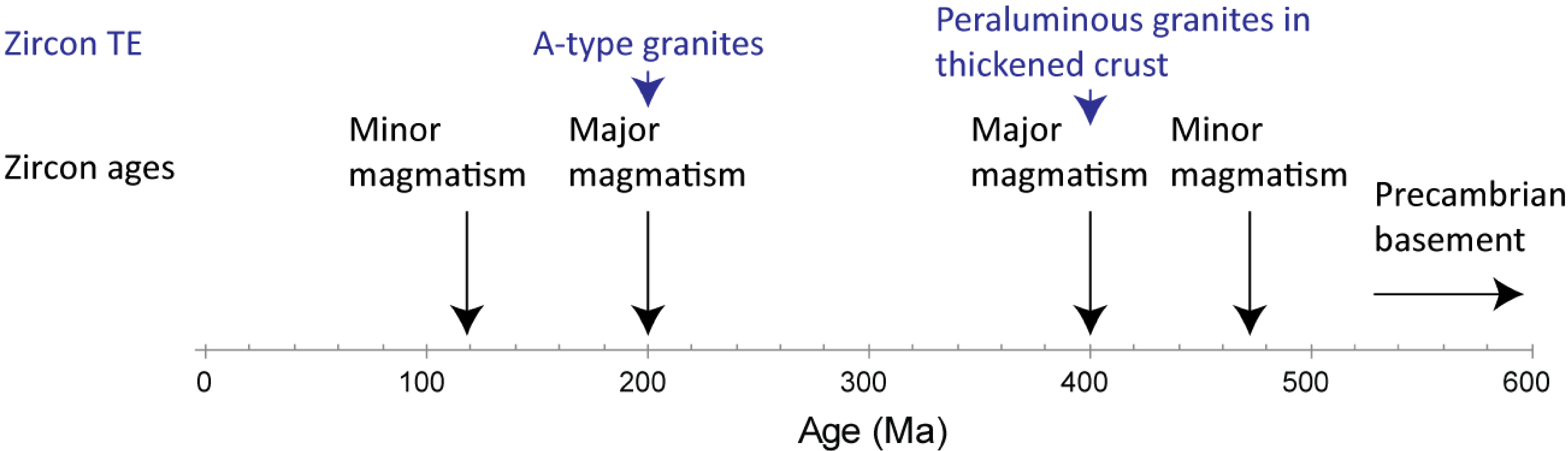

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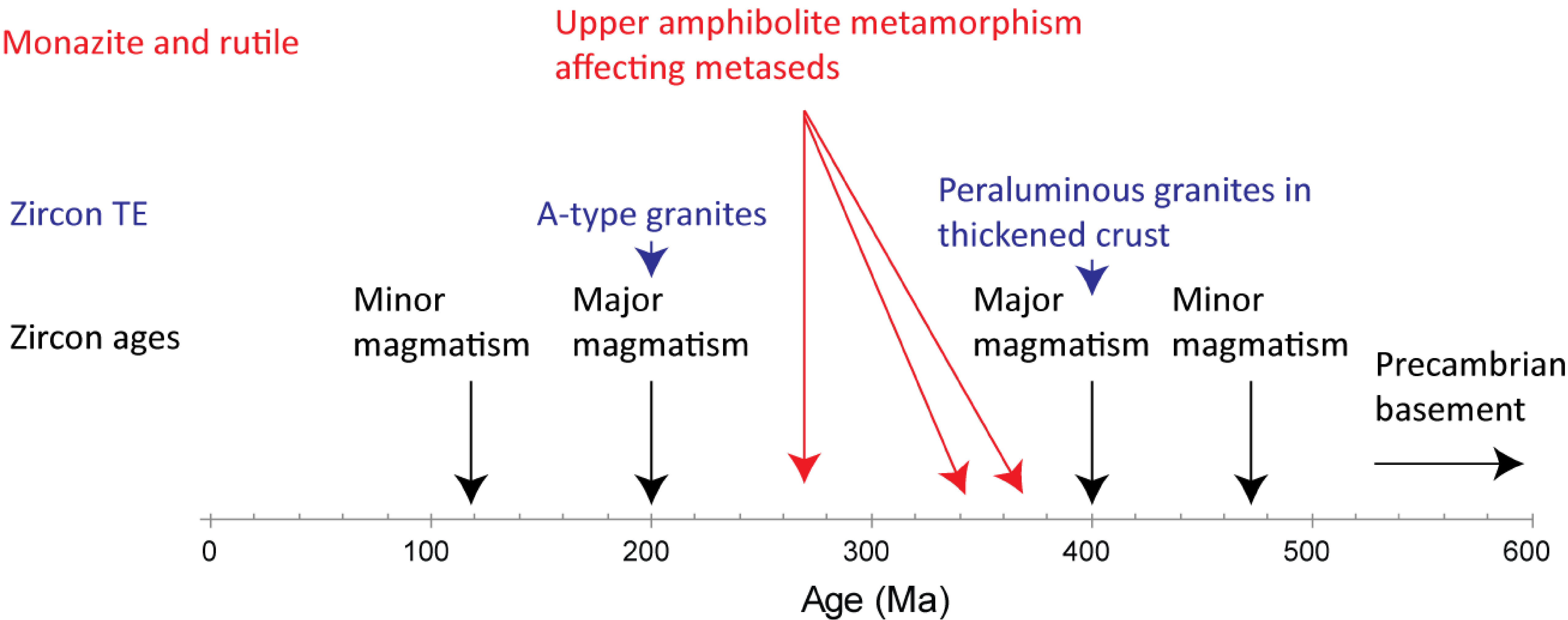

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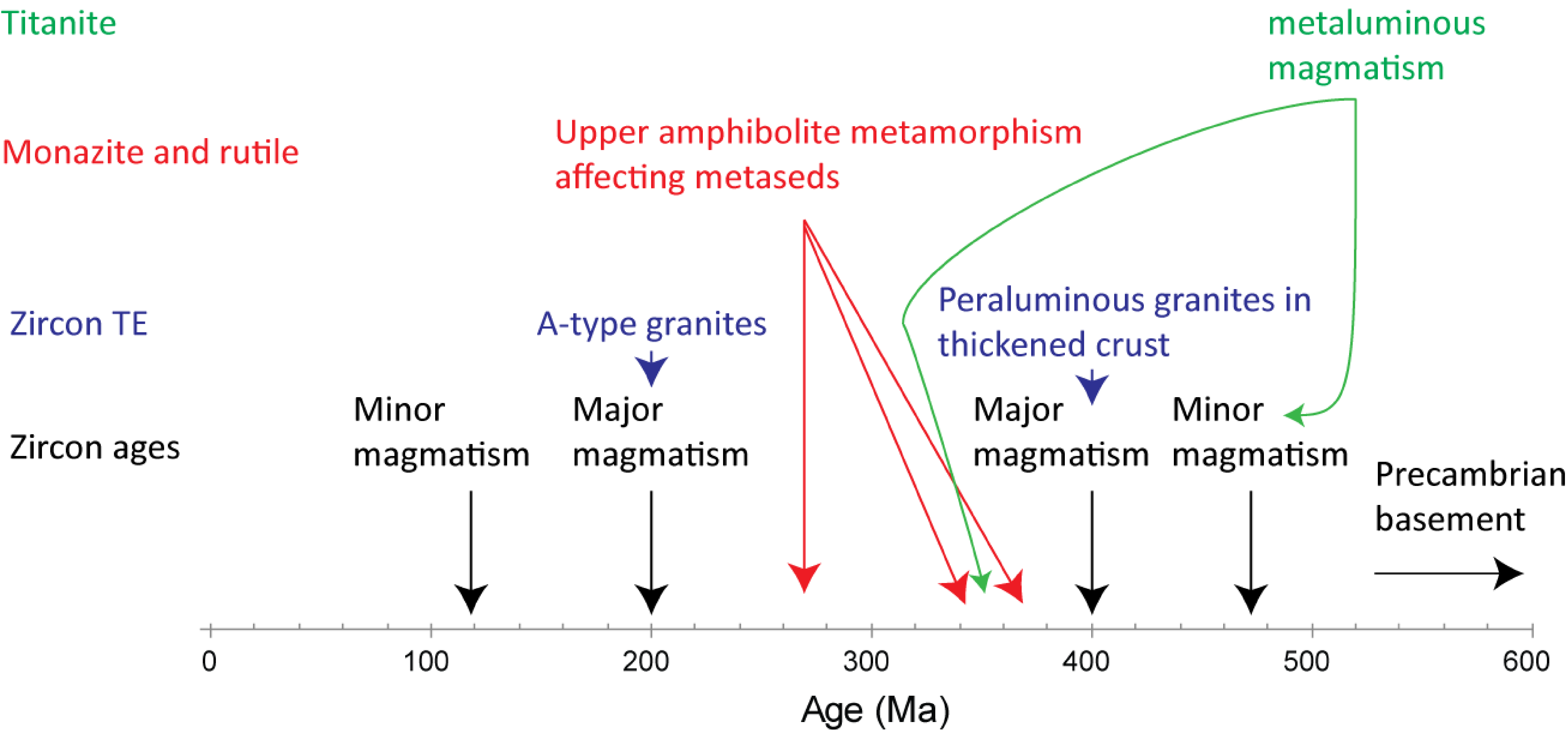

# Conclusions

- Dating of detrital monazite, rutile, and titanite in conjunction provides crucial information on sedimentary provenance that is missed when dating only zircon
- In the case of the Merrimack River sands, multiproxy approach provides record of high-grade Alleghanian and later Acadian metamorphism that zircon dating alone misses
- Trace elements in zircon provide clues to tectonic settings of source rocks