



# U-series Geochronology and the Age of Steep Cone

Sentinel Meadows, Yellowstone National Park

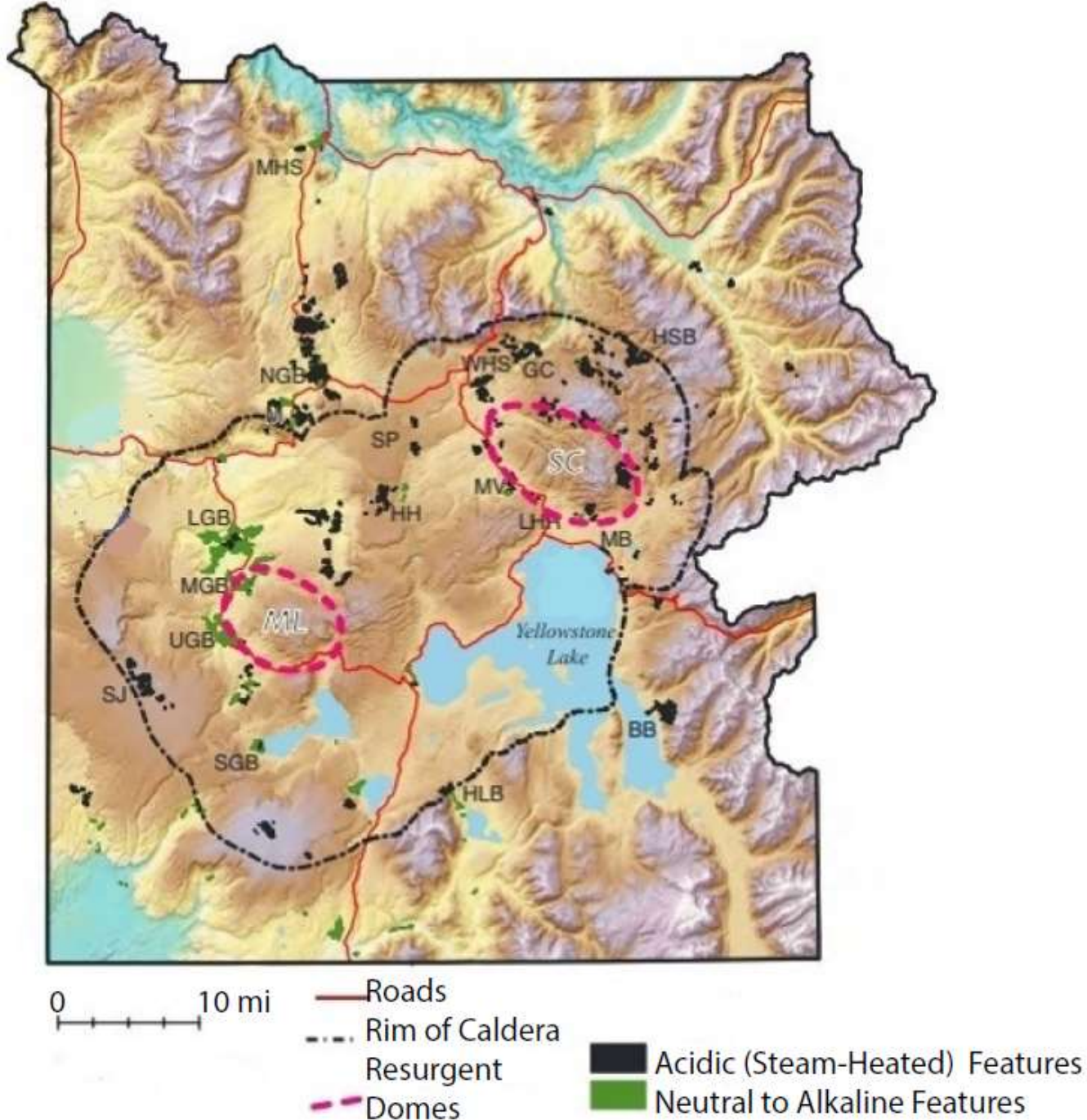
Shauna Bladt

# Overview

- **Hypothesis:** *Either, Steep Cone developed after the end of the Pleistocene Pinedale glaciation and thus formed within a period of no greater than 15,000 years, or its formation began before the recession of the glaciers in northwestern Wyoming.*
  - Steep Cone is a hydrothermal silica-sinter dome in the Sentinel Meadows region of the park
  - Hypothesis tested by dating the deposition of Steep Cone's silica sinter using U-series isotope radiometric methods

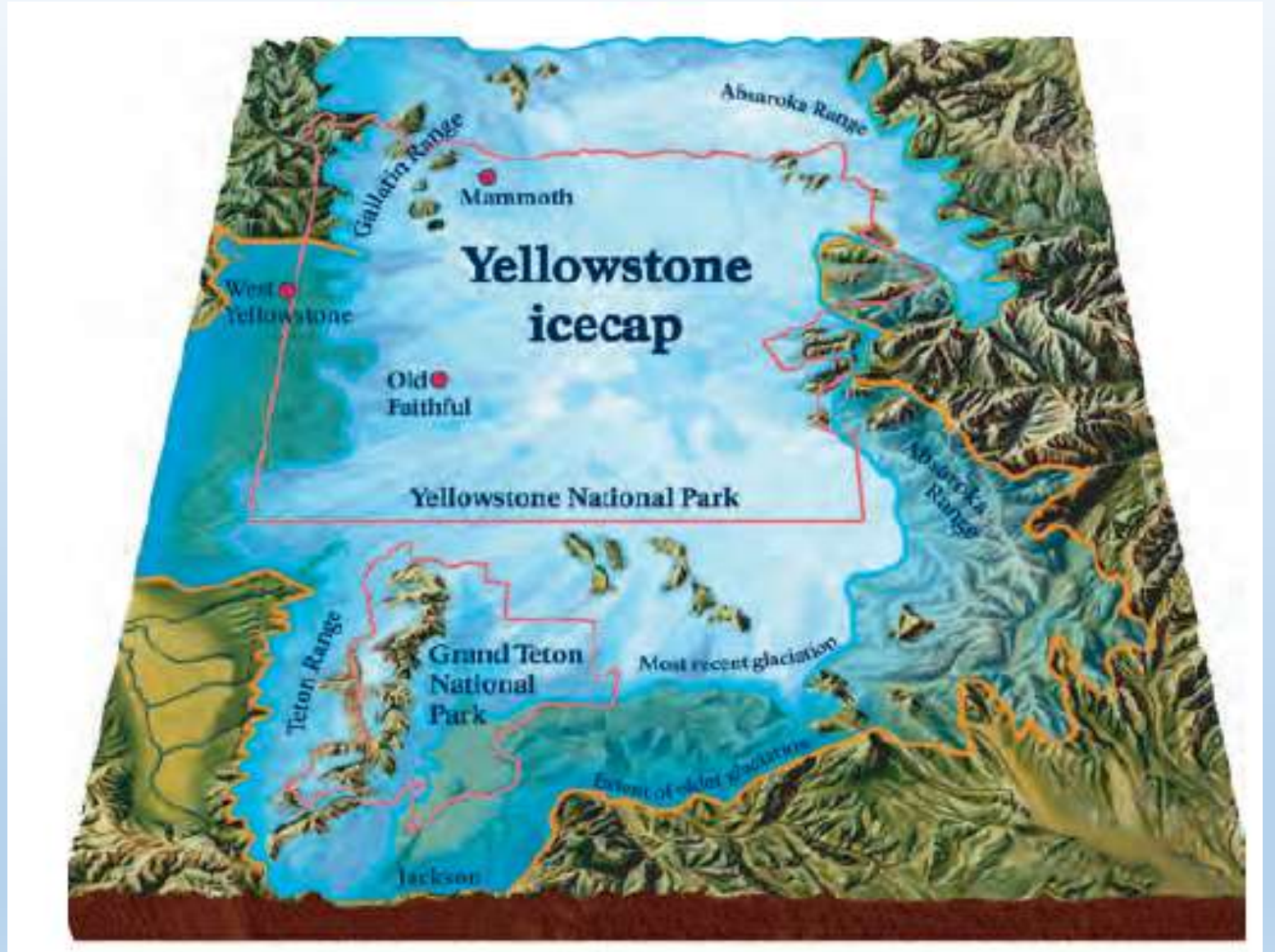
# The Yellowstone Hydrothermal System

- Composed of more than 10,000 hydrothermal features
- Features cluster along the caldera's ring fracture zone and around Yellowstone's two resurgent domes
- Two major classes of hydrothermal features: hot water and vapor dominated systems
- Supplied with heat and volatiles by underlying magma reservoir



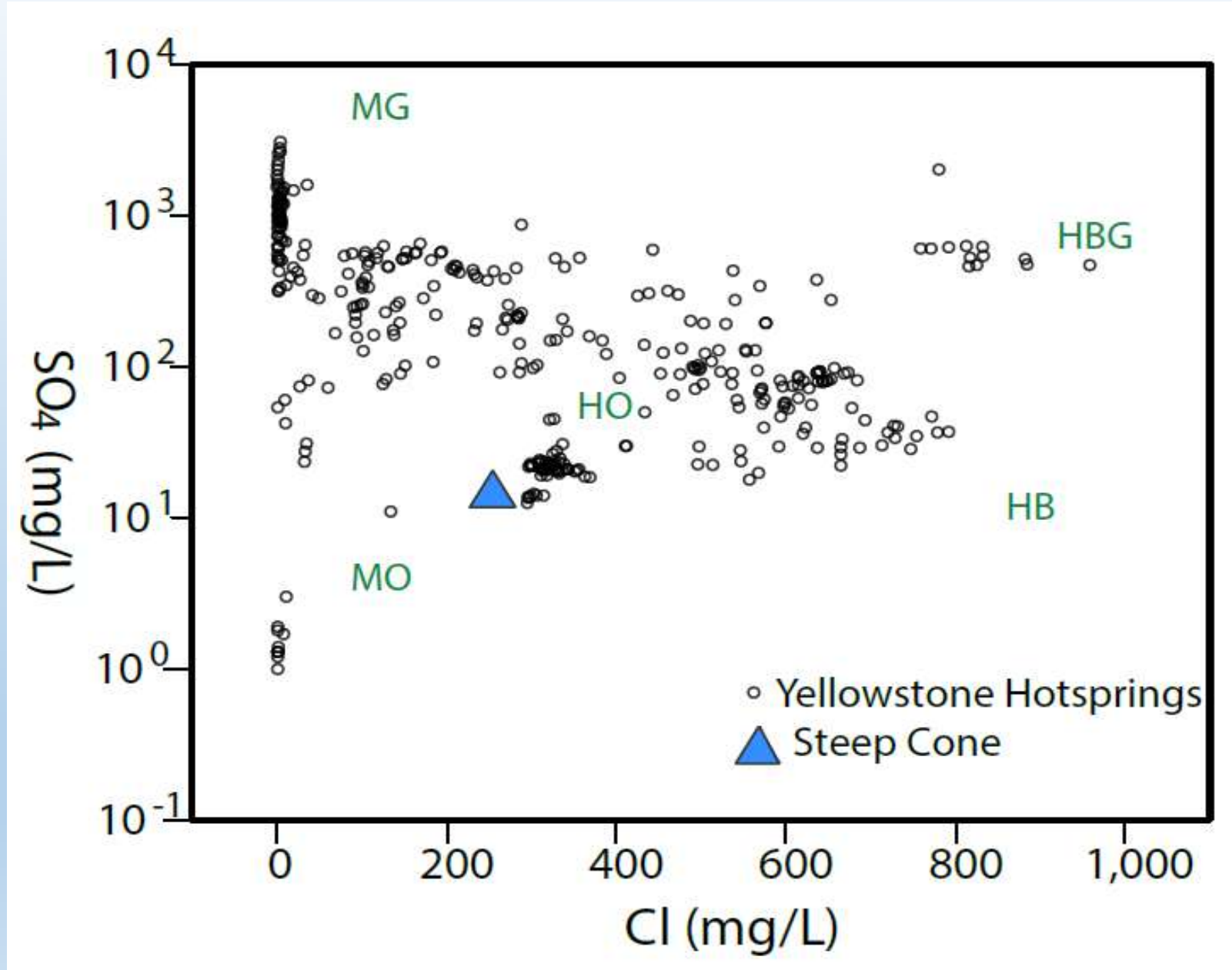
# Pleistocene Glaciation in Yellowstone

- Two major glaciation periods during the Pleistocene
- Bull Lake glaciation (older event): 200 ka to 130 ka
- Pinedale glaciation (most recent event): 30 ka to 15 ka



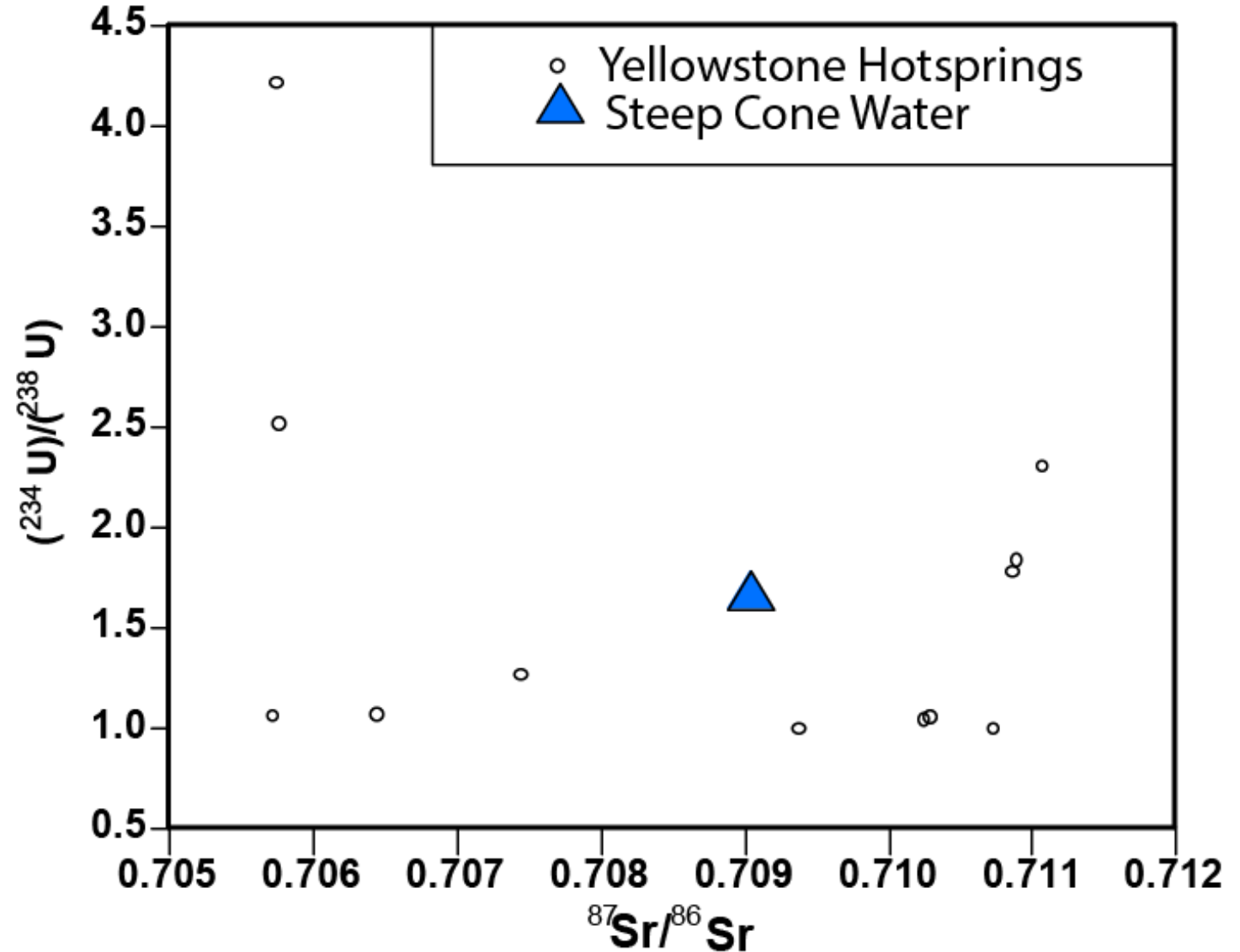
# How does Steep Cone water compare chemically to other Yellowstone hot springs?

- End members (shown in green) classify waters by their source (hydrothermal or meteoric) and composition
- Steep Cone appears to be a mixture of meteoric and deep-sourced hydrothermal waters with little to no subsurface boiling or gas discharge.

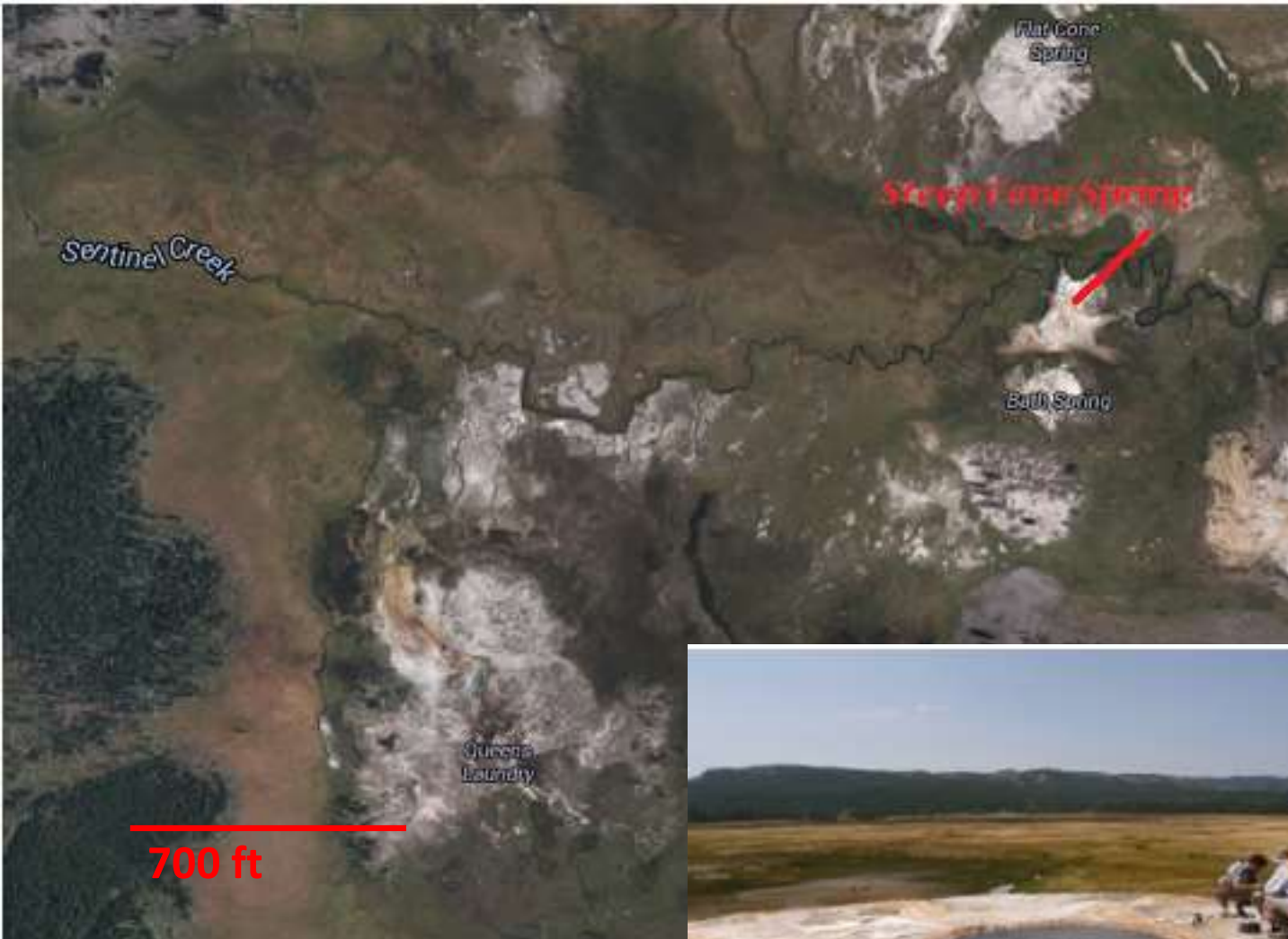


# How does Steep Cone water compare isotopically to other Yellowstone hot springs?

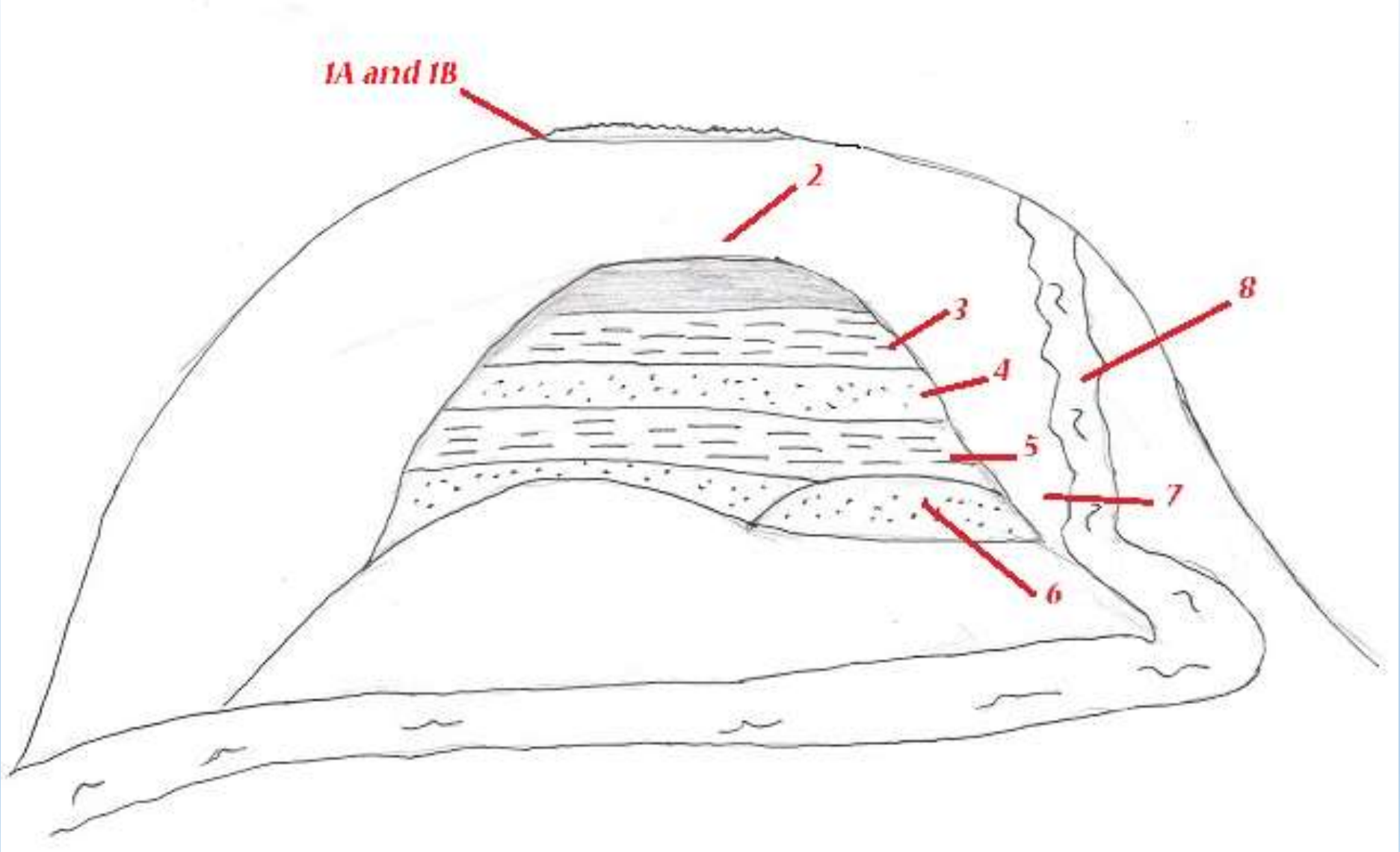
- $(^{238}\text{U})/(^{234}\text{U})$  ratio in water indicates its residence time in Steep Cone's underground reservoir
- $^{87}\text{Sr}/^{86}\text{Sr}$  ratio yields clues to the composition of the reservoir's host rock
- Steep Cone water has a relatively low  $(^{238}\text{U}/^{234}\text{U})$  and a mid-range  $^{87}\text{Sr}/^{86}\text{Sr}$ , which suggests
  - a long residence time
  - a host rock with a mixture of volcanic and sedimentary origins



# Sentinel Meadows and Steep Cone



# Steep Cone Schematic and Sample Collection Sites



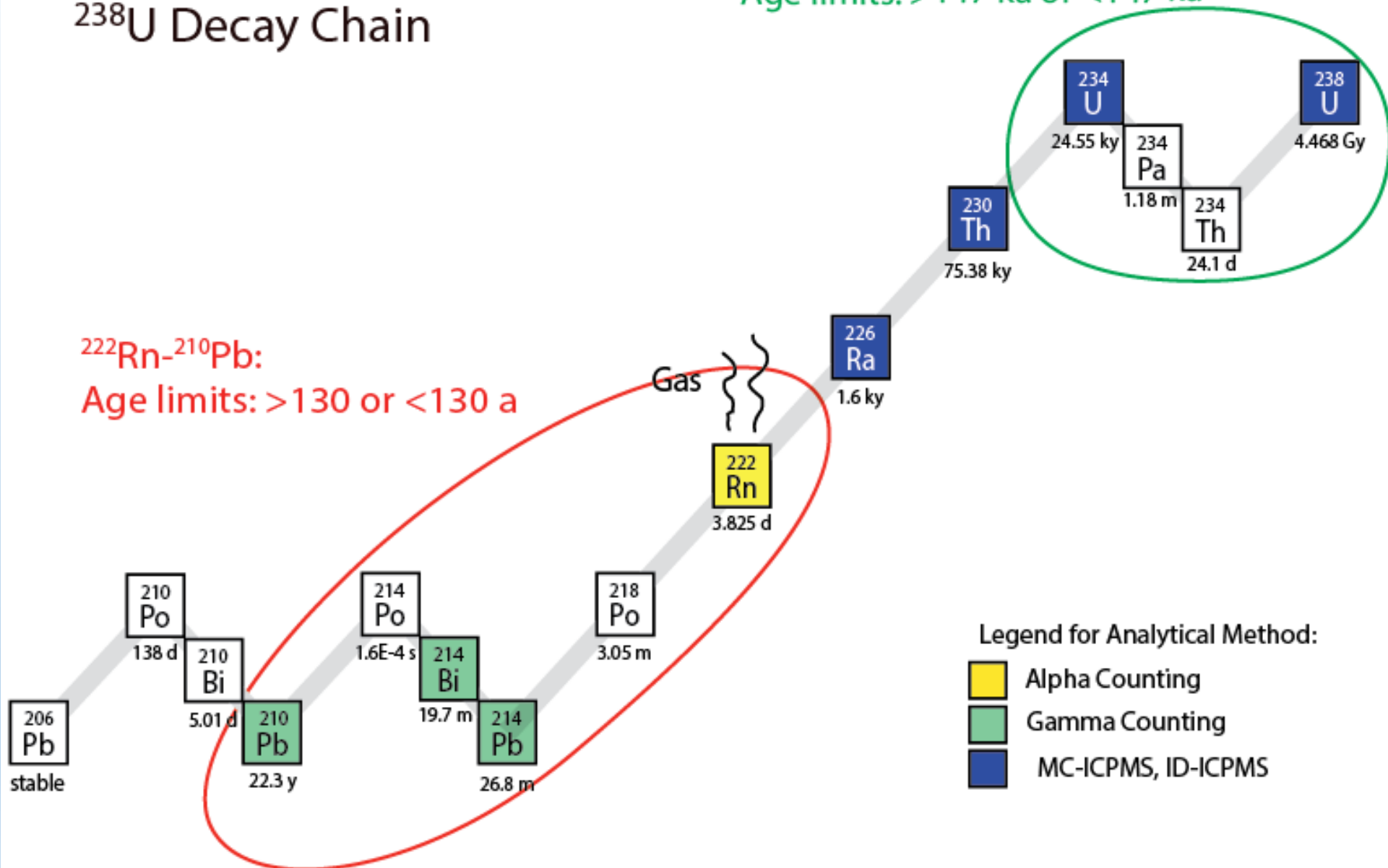
# The Basics of U-series Isotope Dating

- The **half-life** of an isotope is the time it takes for the abundance of that isotope to be reduced by half. **Decay constant ( $\lambda$ )** =  $\ln(2)/t^{1/2}$
- **Activity** =  $\lambda N$  (decay constant \* abundance of isotope)
- When the activities of all the radioisotopes in a system are equal, that system is in **secular equilibrium**.
- **Fractionation** occurs when a natural process (such as precipitation of dissolved matter) disrupts equilibrium and changes isotopic activity ratios within the system
- After fractionation, a parent-daughter isotope system returns to secular equilibrium after six half-lives of the daughter isotope have passed.

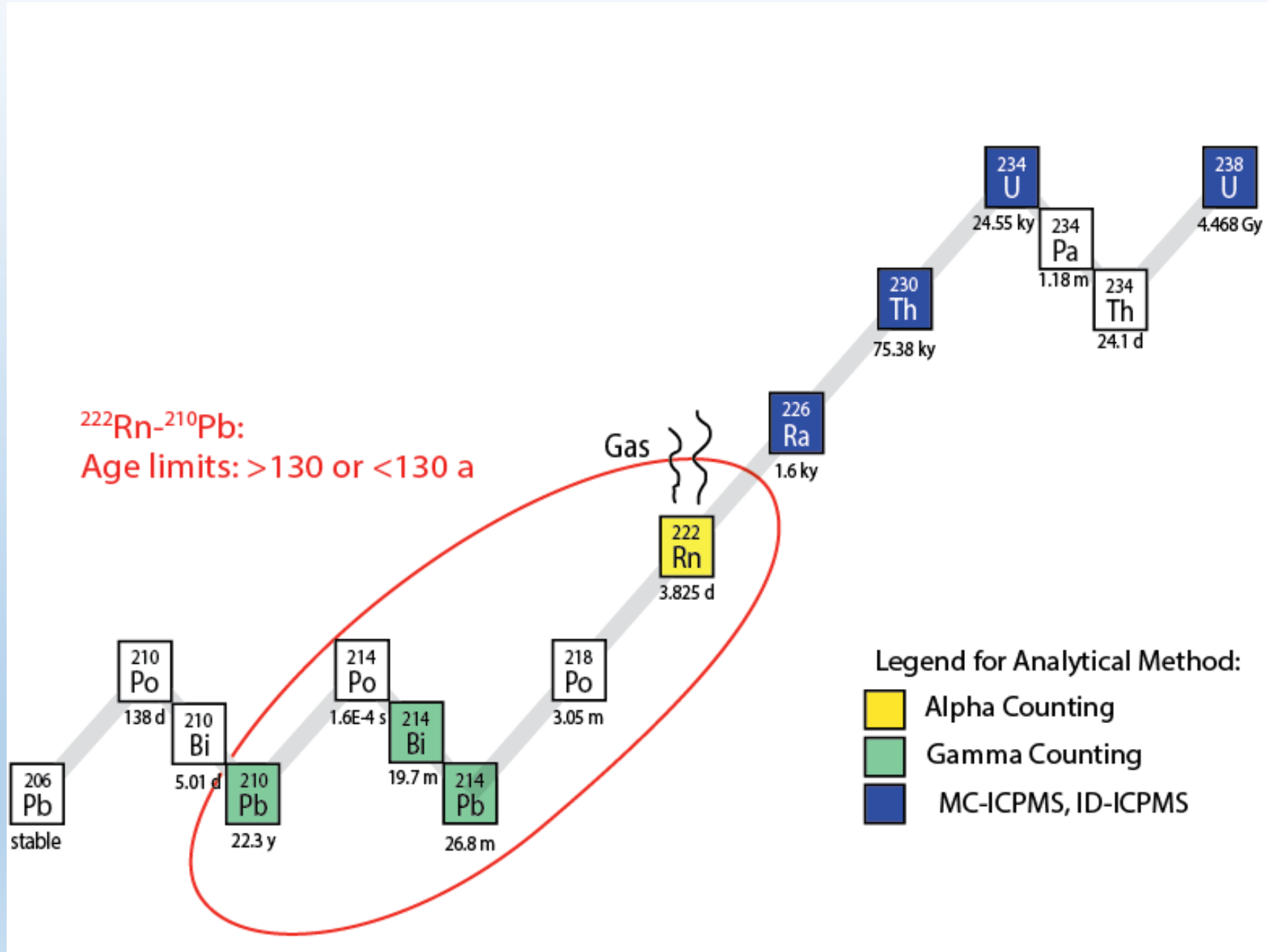
# $^{238}\text{U}$ Decay Chain

$^{238}\text{U}$ - $^{234}\text{U}$ :

Age limits: >147 ka or <147 ka

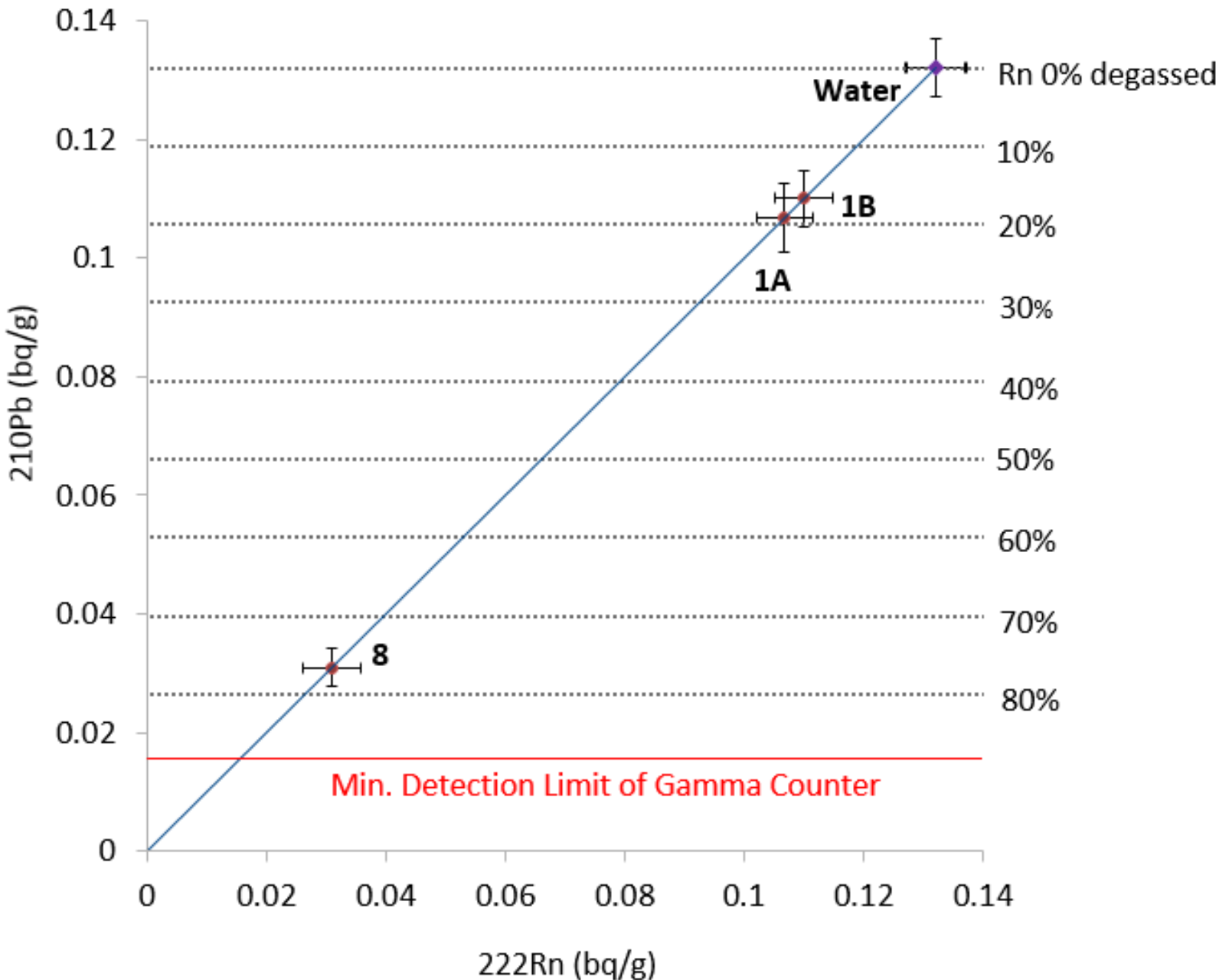


# The $^{222}\text{Rn} \rightarrow ^{210}\text{Pb}$ system



- Isotope activities of Steep Cone samples measured using gamma ray spectrometry
- $^{226}\text{Ra}$  activity below detection limit in both sinters and water
- $^{210}\text{Pb}$  activity measurable in the three youngest sinter samples, below detection limit in remaining seven
- High  $^{222}\text{Rn}$  activity measured in water

## 210Pb in Sinter vs. 222Rn in Water

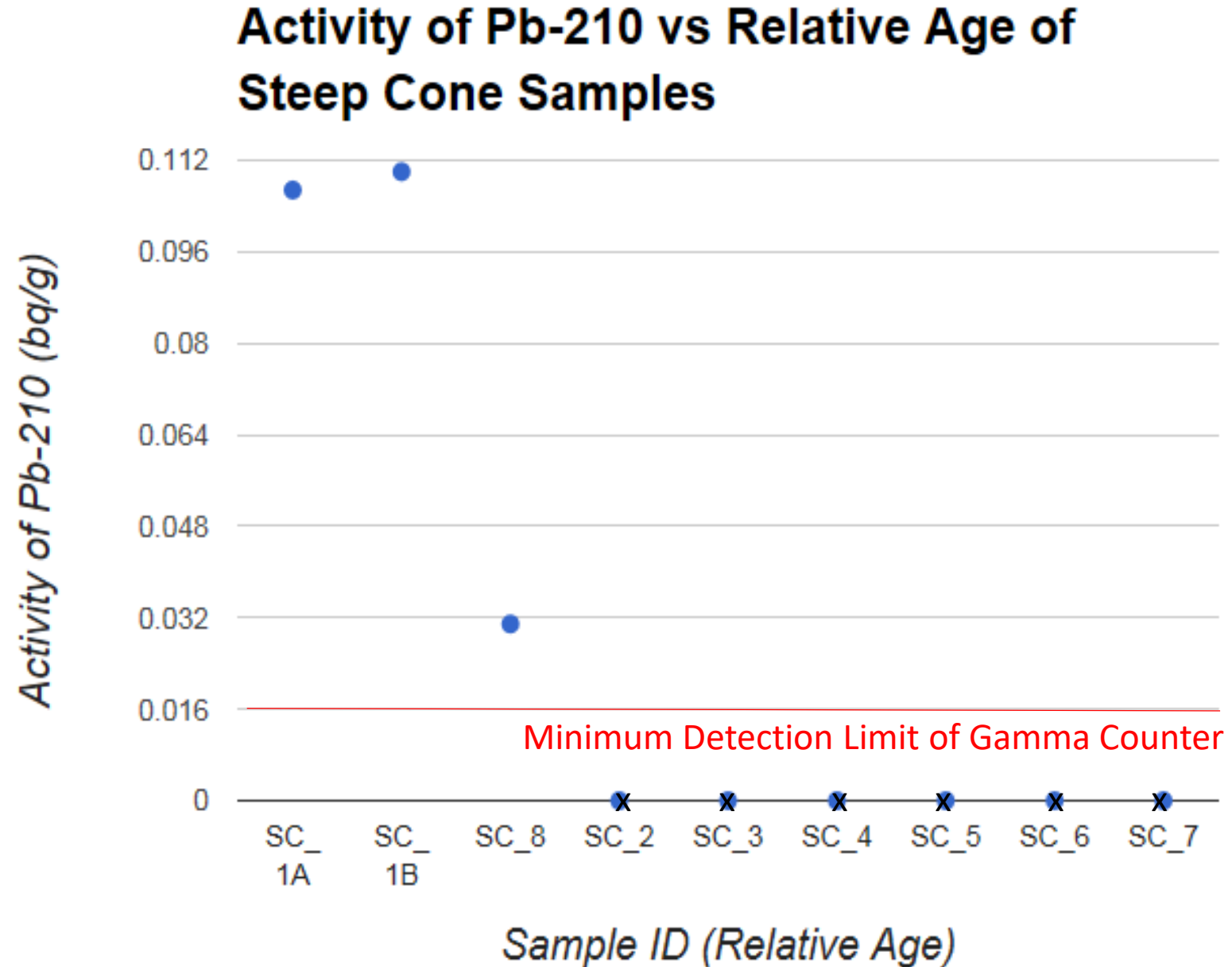


What can we hypothesize based on this  $^{226}\text{Ra}$ ,  $^{222}\text{Rn}$ , and  $^{210}\text{Pb}$  data?

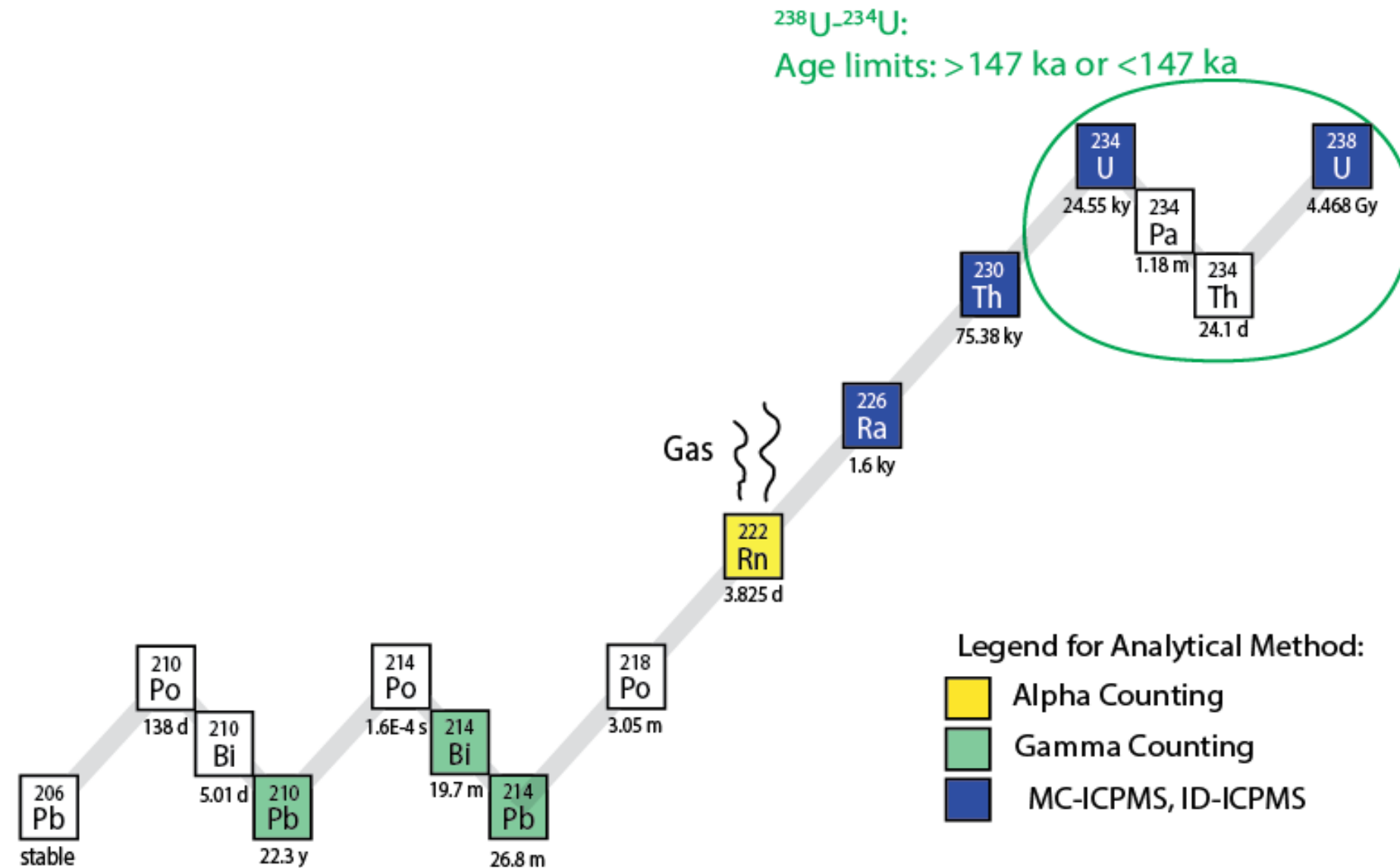
- $^{222}\text{Rn}$  degasses from the water as it flows away from the outlet
- $^{230}\text{Th}$  and  $^{226}\text{Ra}$  are not soluble in Steep Cone waters
- Water has a long residence time in Steep Cone's reservoir

# $^{210}\text{Pb}$ establishes a constraint on Steep Cone's age.

- $^{210}\text{Pb}$  is unsupported
- It takes 3 half-lives of  $^{210}\text{Pb}$  for ( $^{210}\text{Pb}$ ) in 1A and 1B to decay to an activity below detection limit
- **The old samples (below detection limit) are all at least 65 years old.**



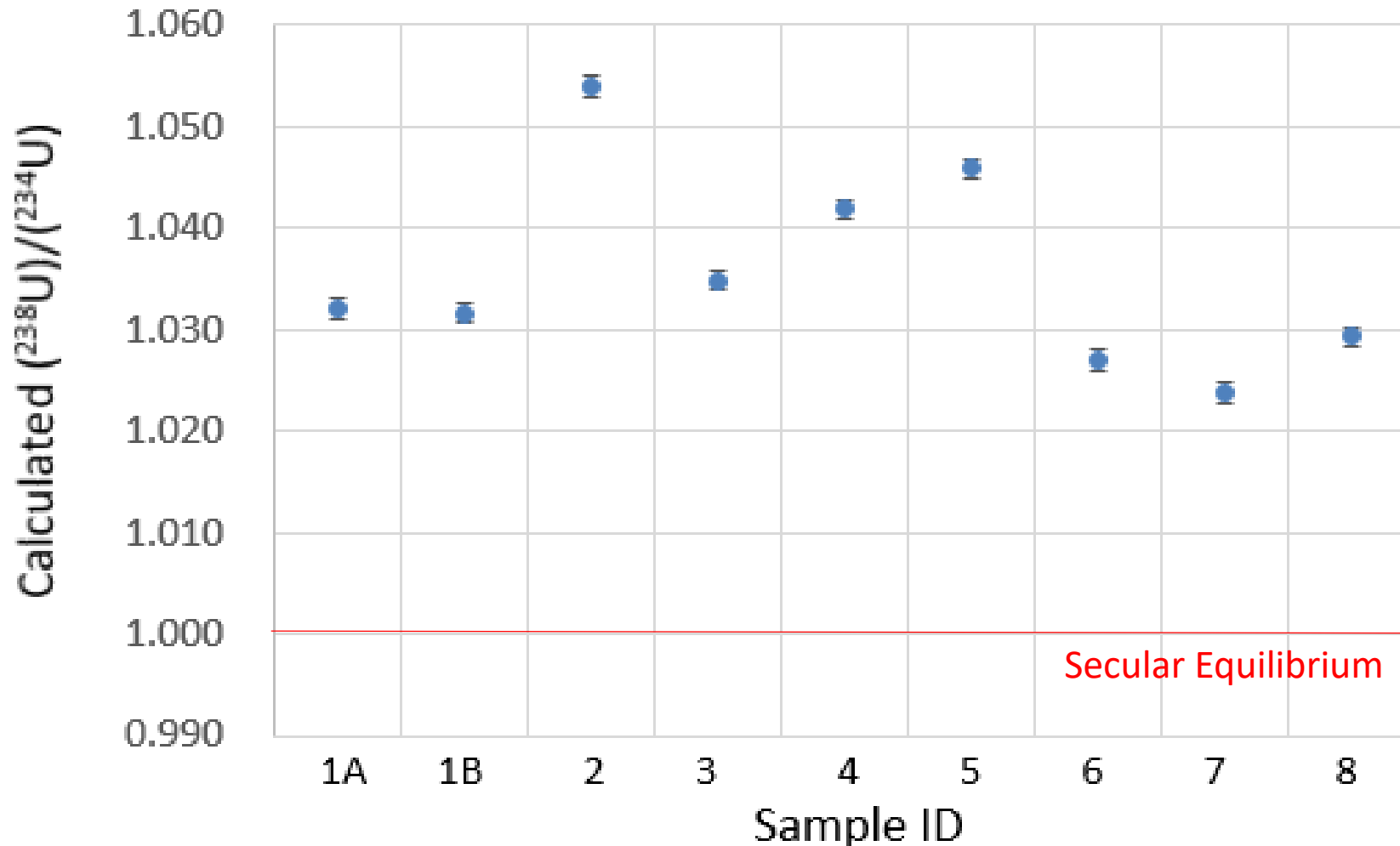
# The $^{238}\text{U} \rightarrow ^{234}\text{U}$ system



U-isotope abundances of Steep Cone samples measured with multi-collector inductively coupled plasma mass spectrometry.

# The $^{238}\text{U}/^{234}\text{U}$ activity ratio provides another constraint on Steep Cone's age.

## Measured Sample $^{238}\text{U}/^{234}\text{U}$ Equilibrium



- $^{238}\text{U}/^{234}\text{U}$  activity too close to equilibrium to be from Steep Cone alone
- Samples probably contaminated with dust from nearby Central Plateau Member rhyolite flows
- The dust must be in equilibrium (CPM rhyolites are 0.75 My old)
- Therefore, samples must not yet be in equilibrium. **They are less than 147 ky old.**

# Recap

- Hypothesis: *Either, Steep Cone developed after the end of the Pleistocene Pinedale glaciation and thus formed within a period of no greater than 15,000 years, or its formation began before the recession of the glaciers in northwestern Wyoming.*
- So far we have not yet established Steep Cone's age relative to the Pinedale glaciation. However, lead and uranium abundances and ratios give us a minimum age of 65 y and a maximum age of 147 ky.
- A possible next step: Look for  $^{230}\text{Th}$  and  $^{226}\text{Ra}$  on the mass spectrometer

# Acknowledgements

Many thanks to...

- Dr. Ken Sims, Professor of Geology and Geochemistry and my faculty mentor
- Geology graduate students Sean Scott and Bram Role, who spent many hours guiding me through sample prep, data collection and analysis on the gamma ray spectrometer (Bram) and the MC-ICPMS (Sean)