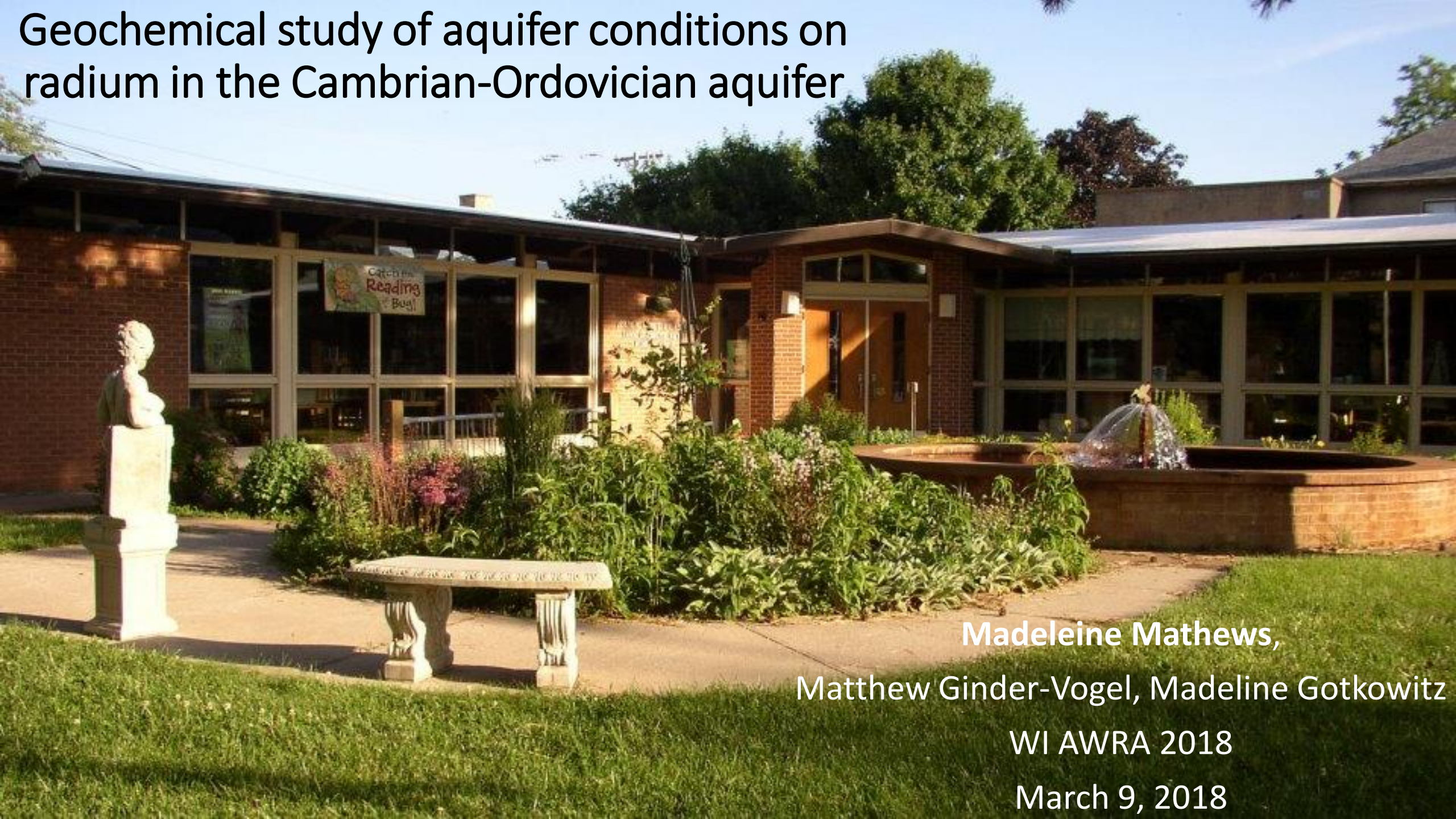
Geochemical study of aquifer conditions on radium in the Cambrian-Ordovician aquifer



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WI AWRA 2018

March 9, 2018

The US EPA has set a Maximum Contaminant Level for radium in drinking water

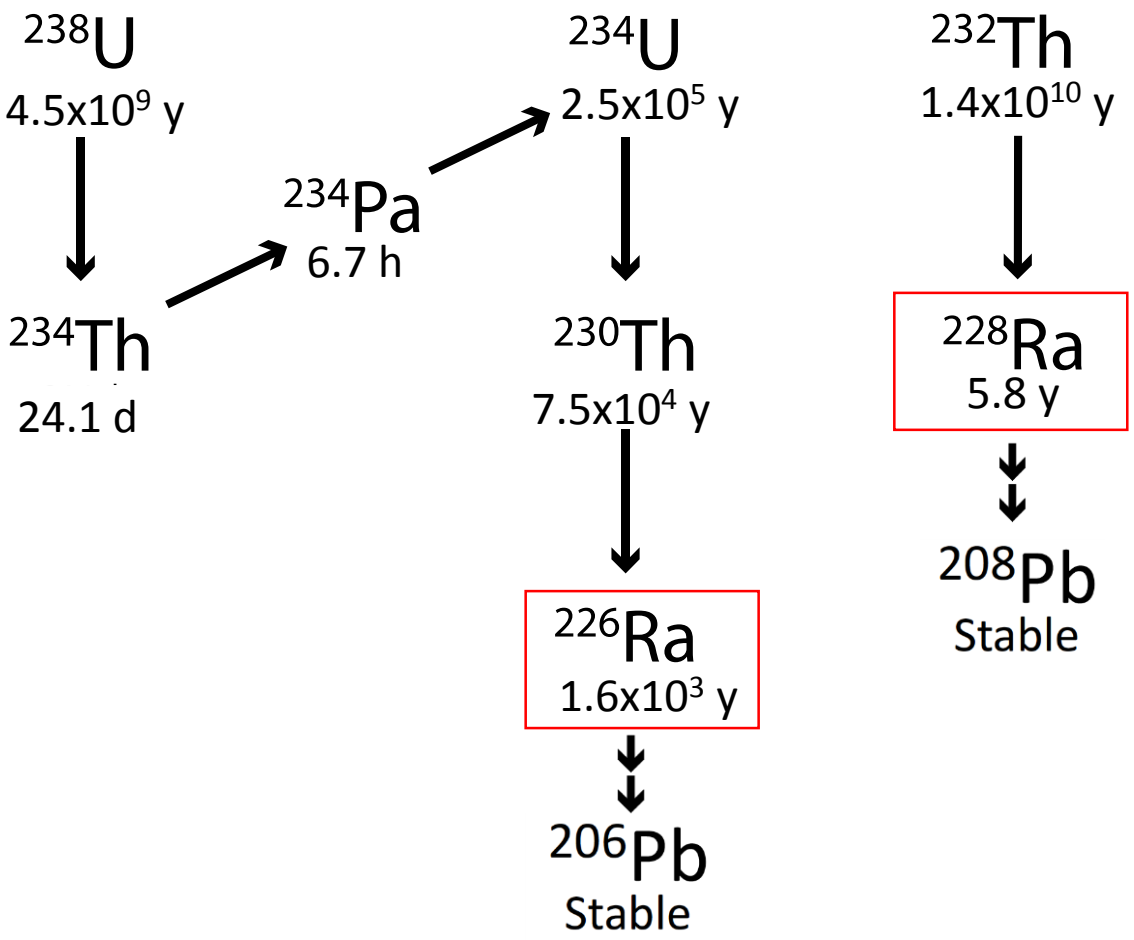
Regulated Radionuclide	Maximum Contaminant Level (MCL)
Total Radium (^{226}Ra + ^{228}Ra)	5 pCi/L
Gross Alpha Particle	15 pCi/L
Uranium	30 µg/L

- Ingestion of radium through drinking water
- Risk for osteosarcoma and other bone disease

The MCL is defined as the combined activity of the two major radium isotopes

U - Uranium
Th - Thorium
Pa - Protractinium
Ra - Radium

β-decay
α-decay

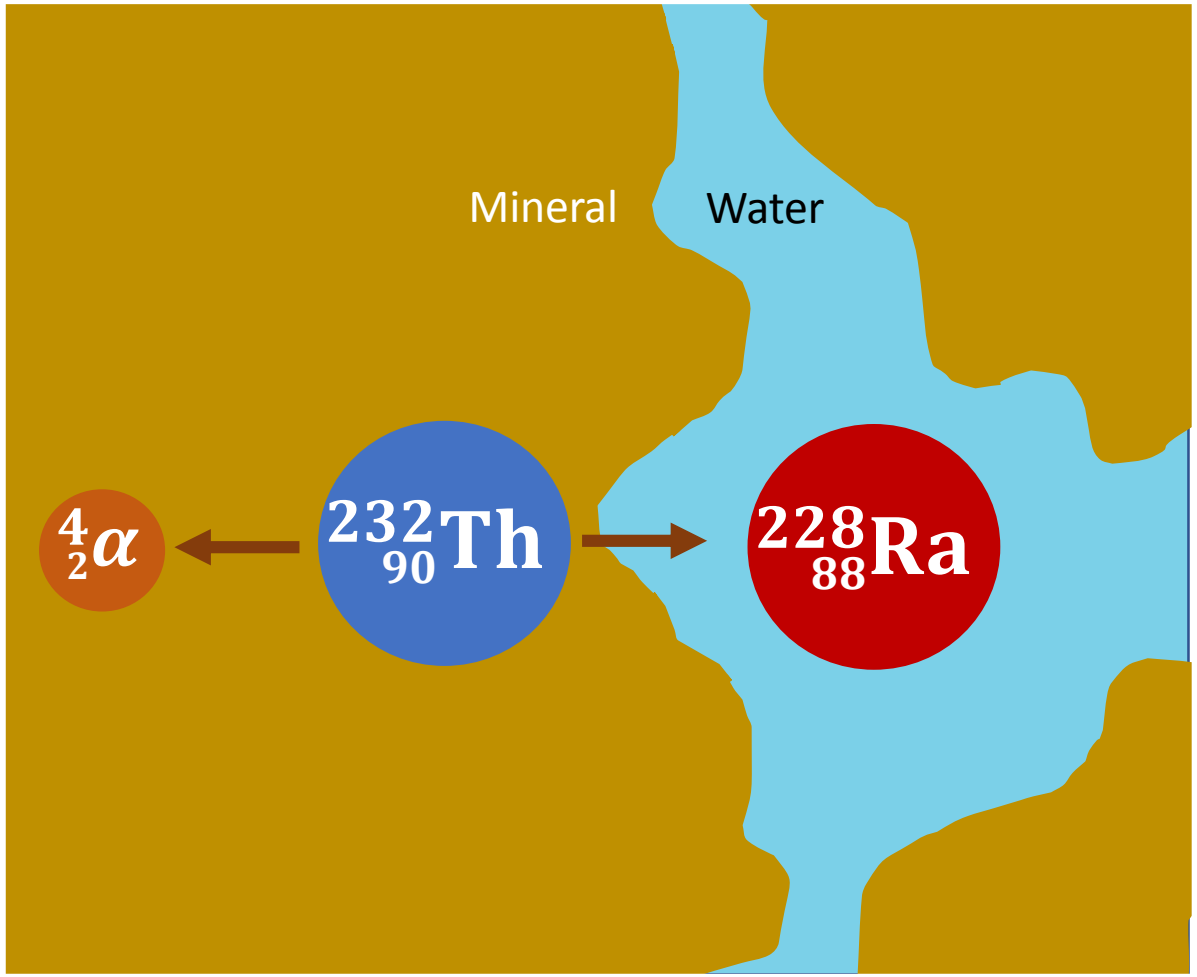


Radium isotopes can be emitted into aquifer systems from parent isotope radioactive decay

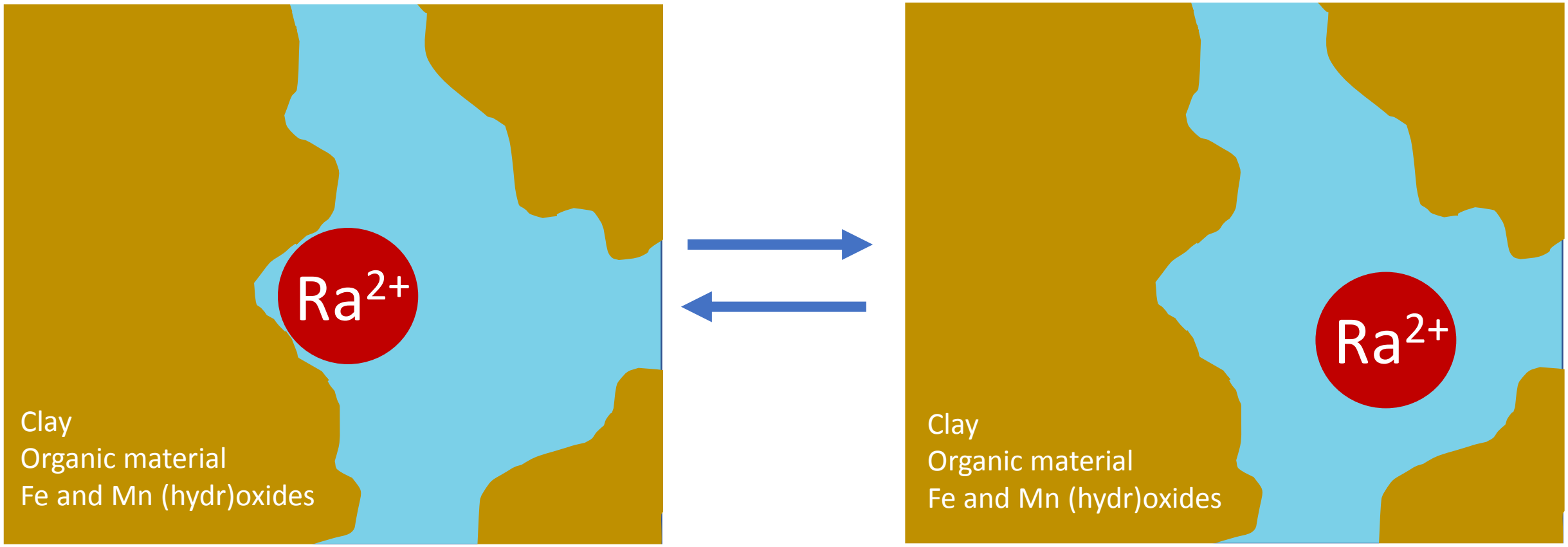
- Alpha Decay

  Example:

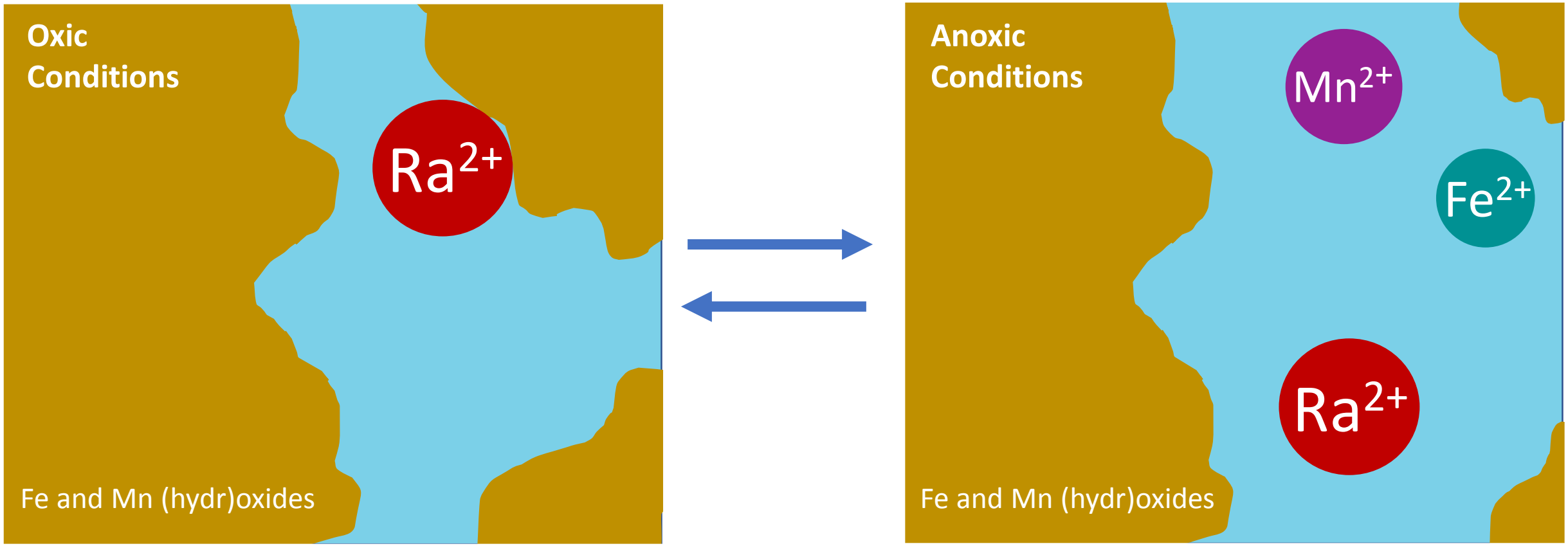
  $$^{232}_{90}\mathrm{Th} \rightarrow {}^{228}_{88}\mathrm{Ra} + {}^{4}_{2}\alpha$$



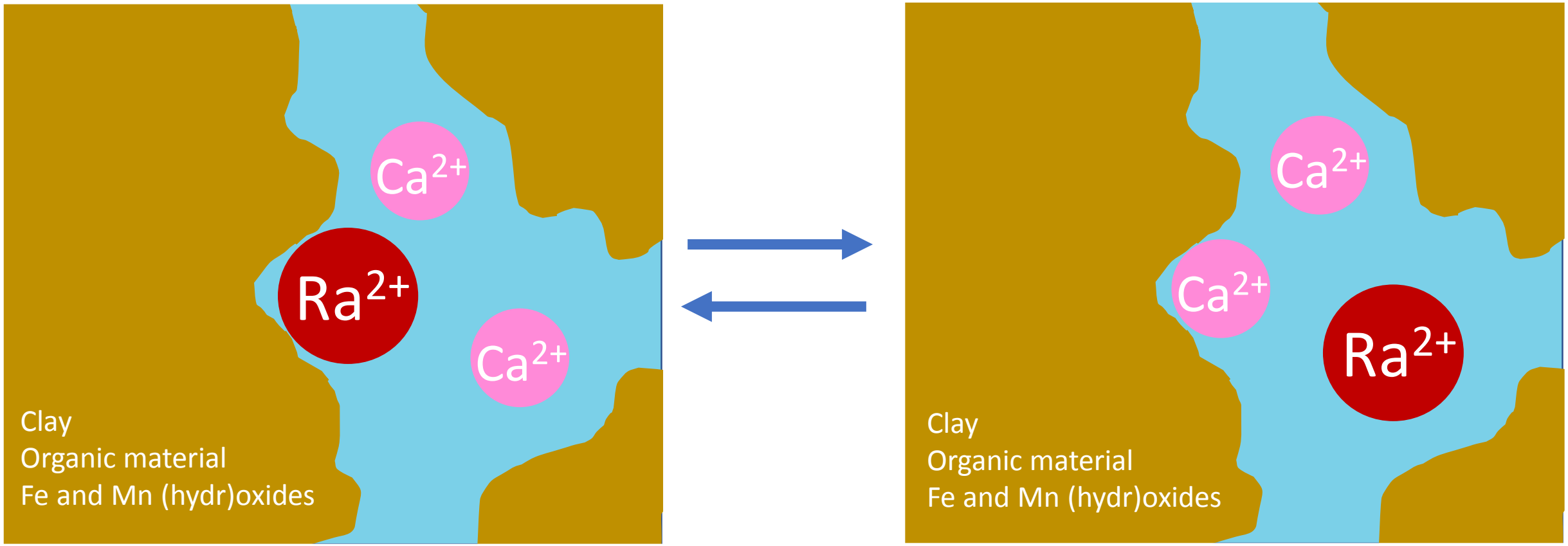
Radium sorbs readily to aquifer solids



Anoxic conditions can result in loss of mineral sorption sites



Elevated total dissolved solids can result in sorption site competition

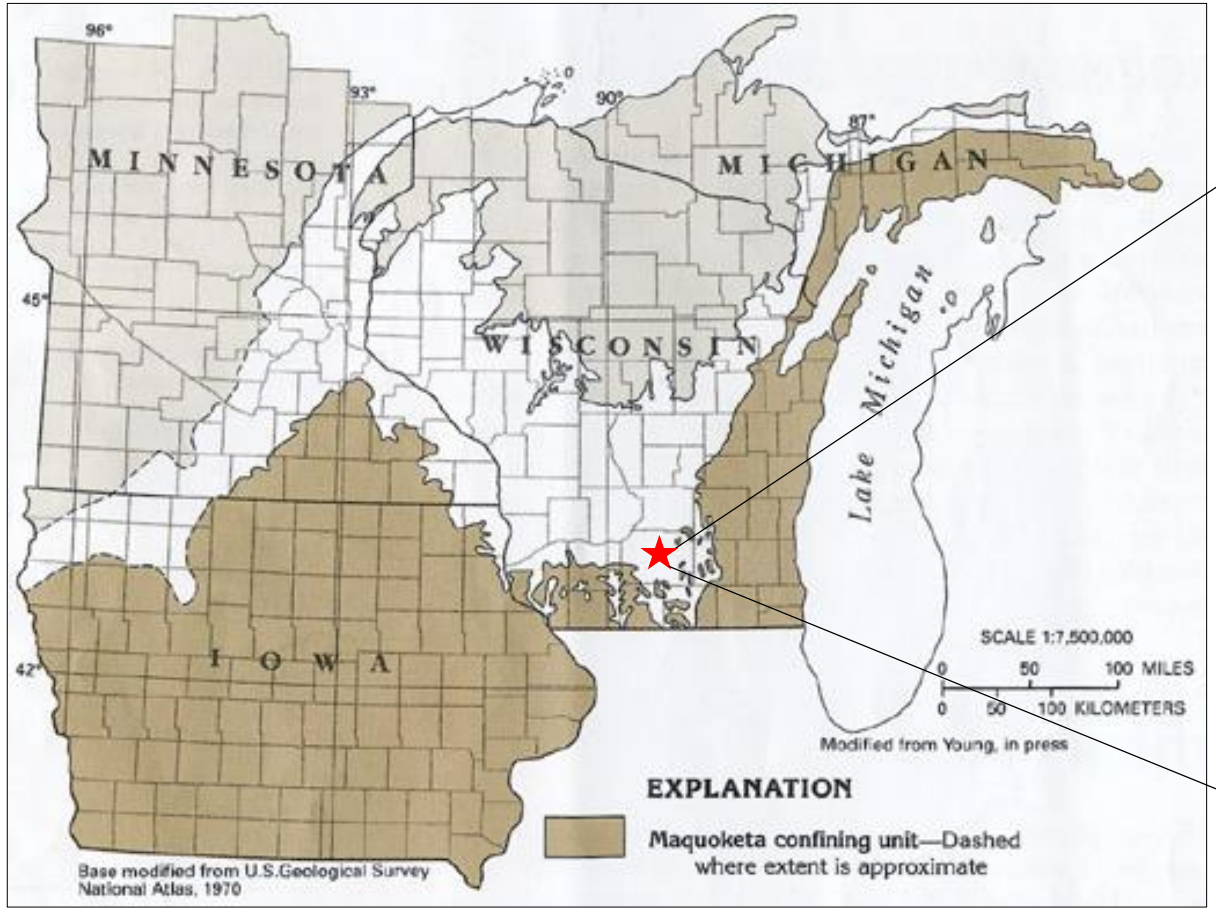


MAIN QUESTIONS

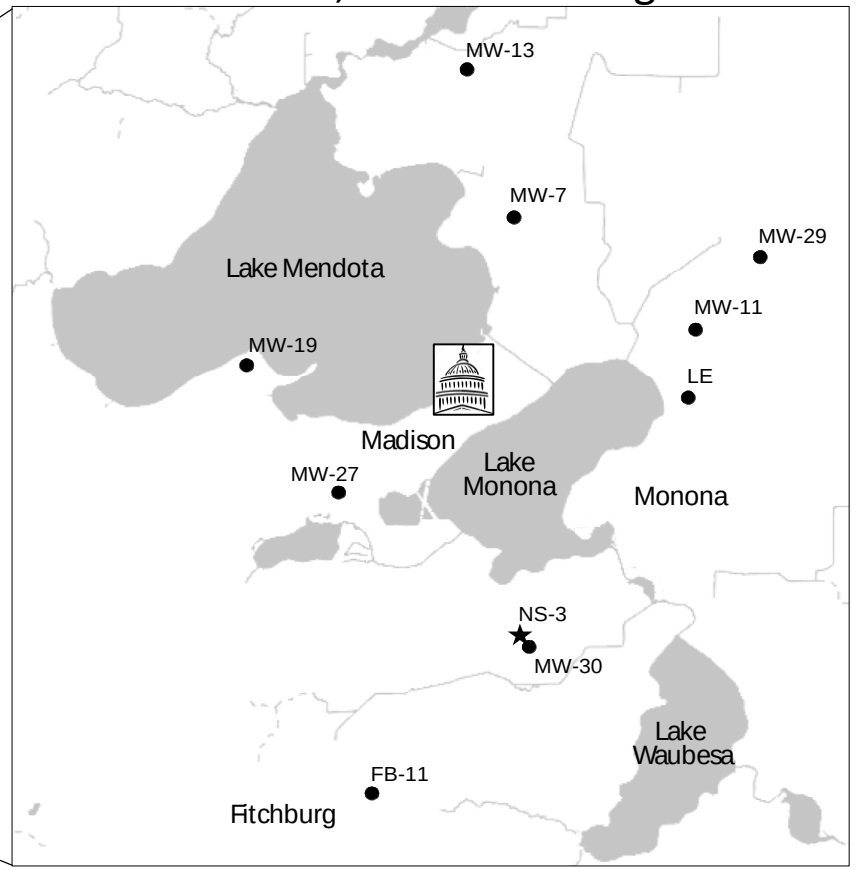
1. What are the sources of radium in the Midwestern Cambrian-Ordovician aquifer?

2. How do geochemical conditions affect radium concentrations?

The study site is located in the Midwestern Cambrian-Ordovician groundwater system



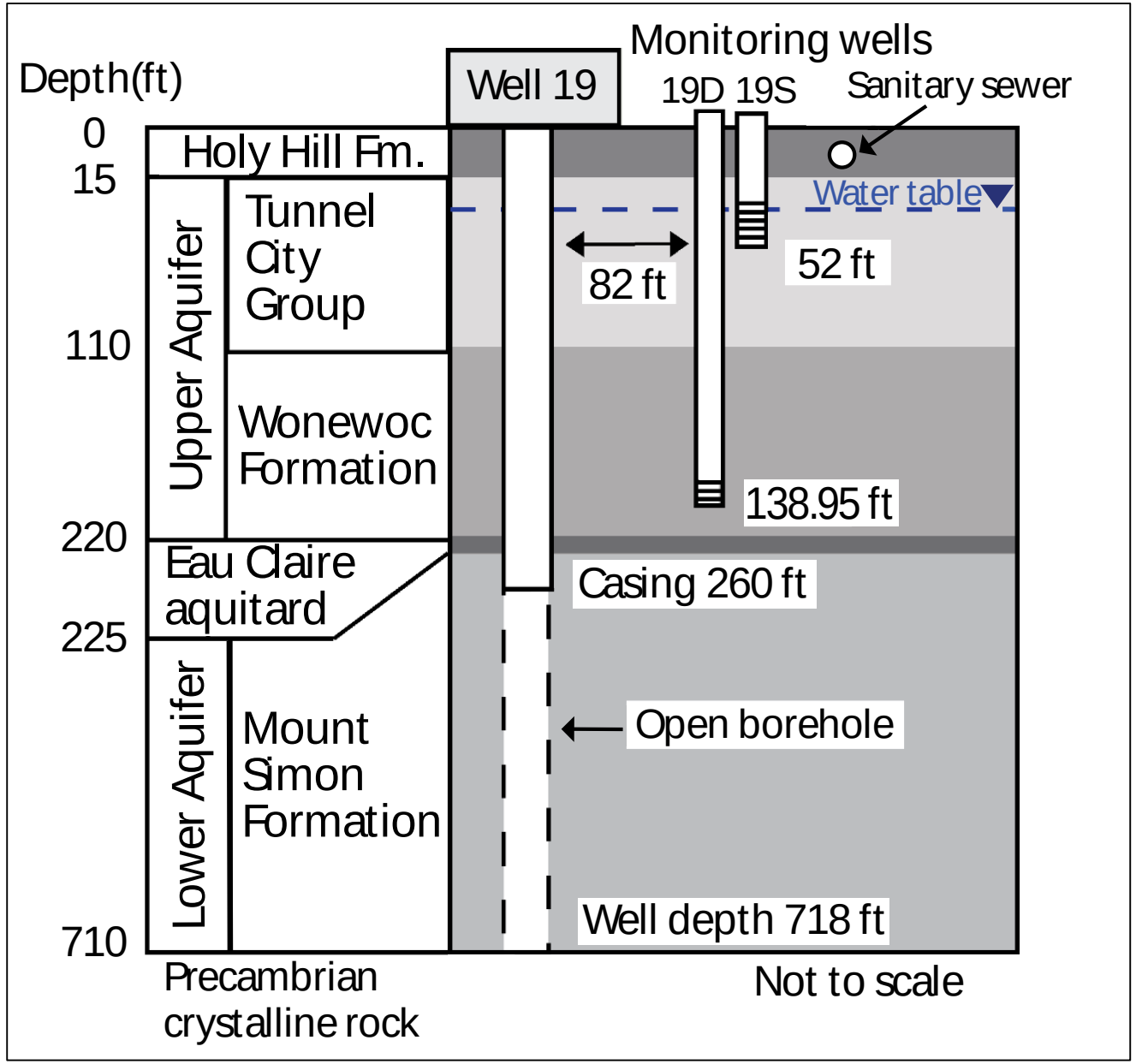
Madison, WI: Monitoring Wells



Cambrian-Ordovician Aquifer System. In *Ground Water Atlas of the United States: Iowa, Michigan, Minnesota, Wisconsin. HA 730-J*; USGS.

Madison hydrostratigraphy and well construction

- Twenty-two short-screened monitoring wells



Groundwater Characterization

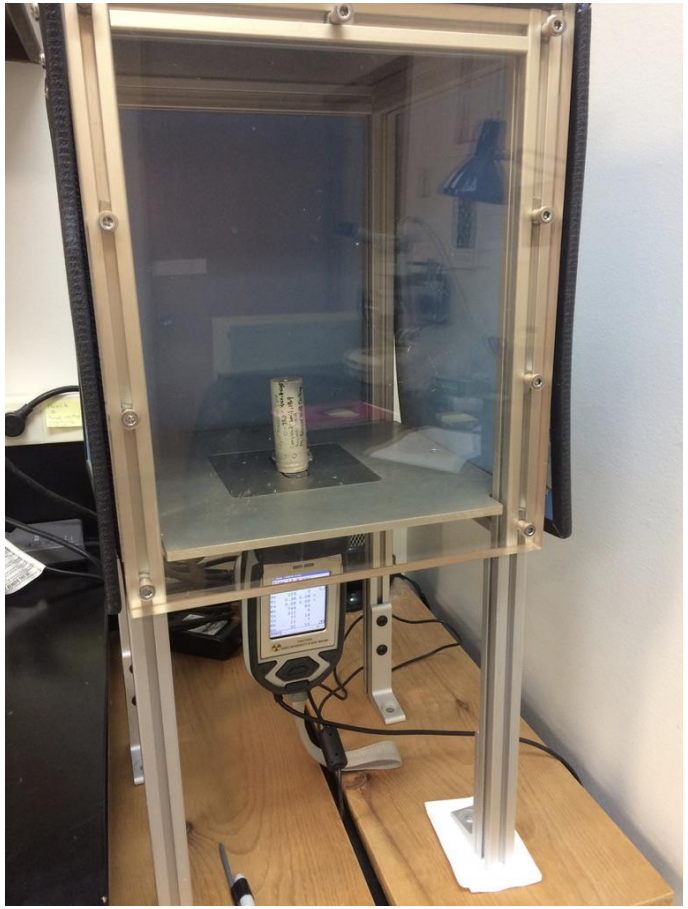
- Aqueous analysis:
  - pH, temperature, specific conductance, dissolved oxygen (DO)
  - ^{226}Ra and ^{228}Ra analysis
  - ^{238}U and ^{232}Th analysis
  - Nitrate, sulfate, chloride (Ion chromatography)
  - Ba, Ca, Fe, Mg, Mn, Na, Si (Inductively-coupled plasma optical emission spectroscopy)

Sampling at 22 monitoring wells

Aquifer solids across hydrostratigraphic units were characterized for elemental composition by X-ray spectroscopic techniques

WGNHS Core Repository

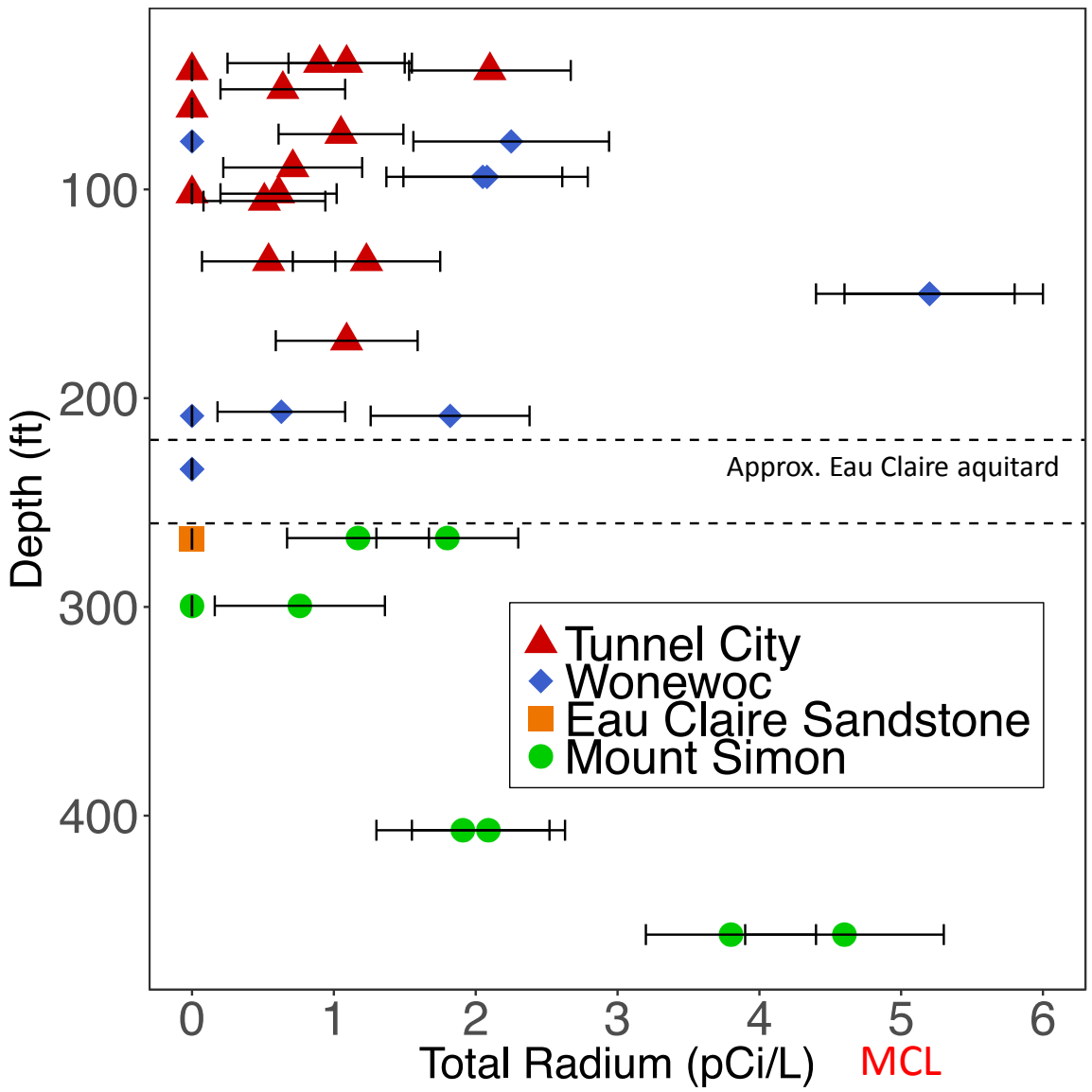
Well borehole cuttings



Portable X-ray Fluorescence (pXRF)

Radium concentrations in the aquifer system

- **Monitoring wells**
- Total Ra concentration from sampling in 2016-2017



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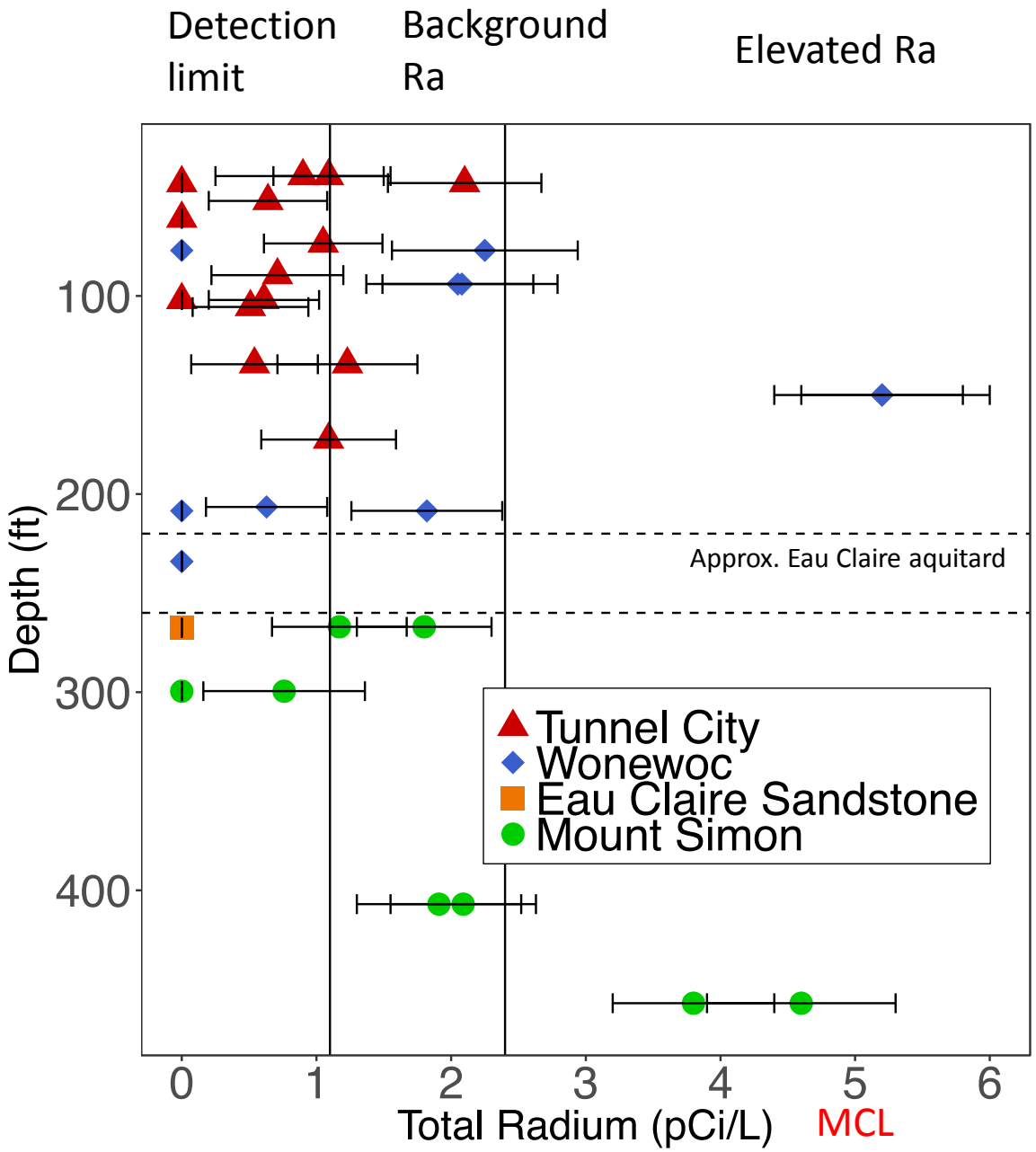
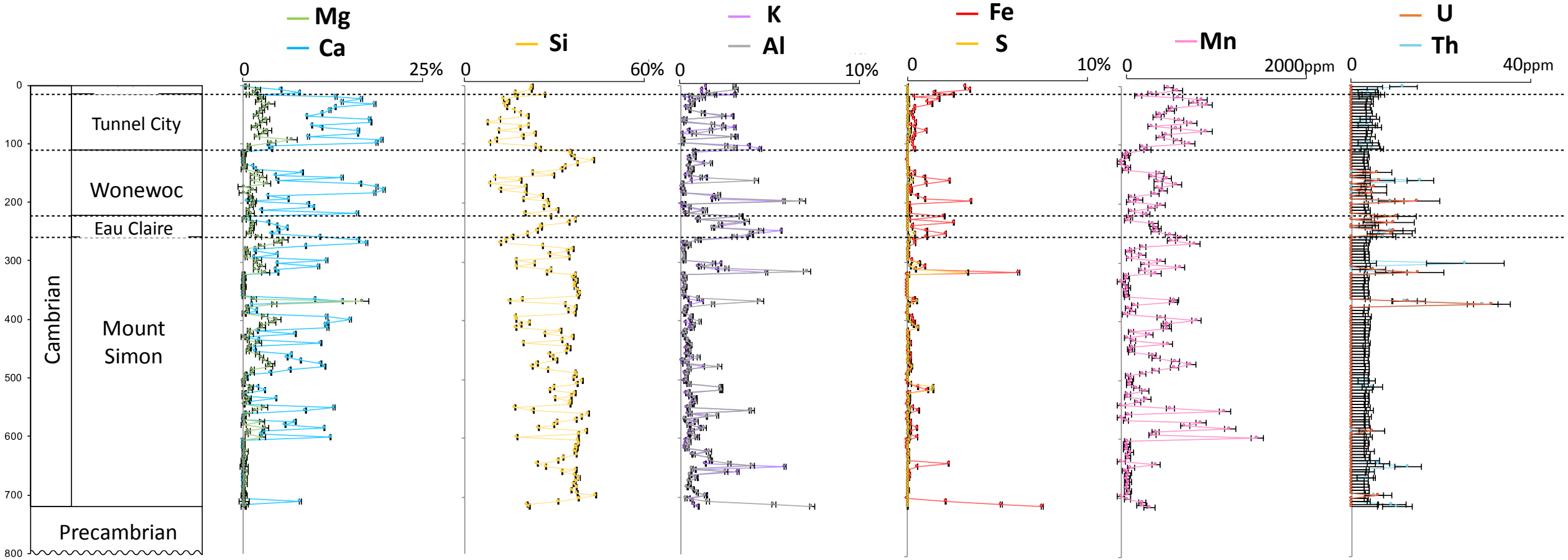


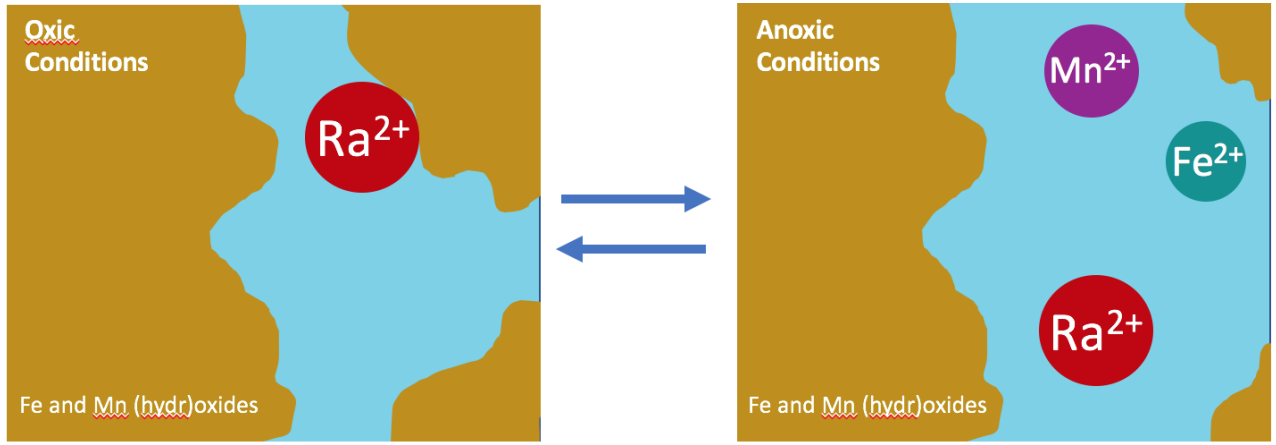
Parent isotopes can be found in shaley facies or coatings on sand grains

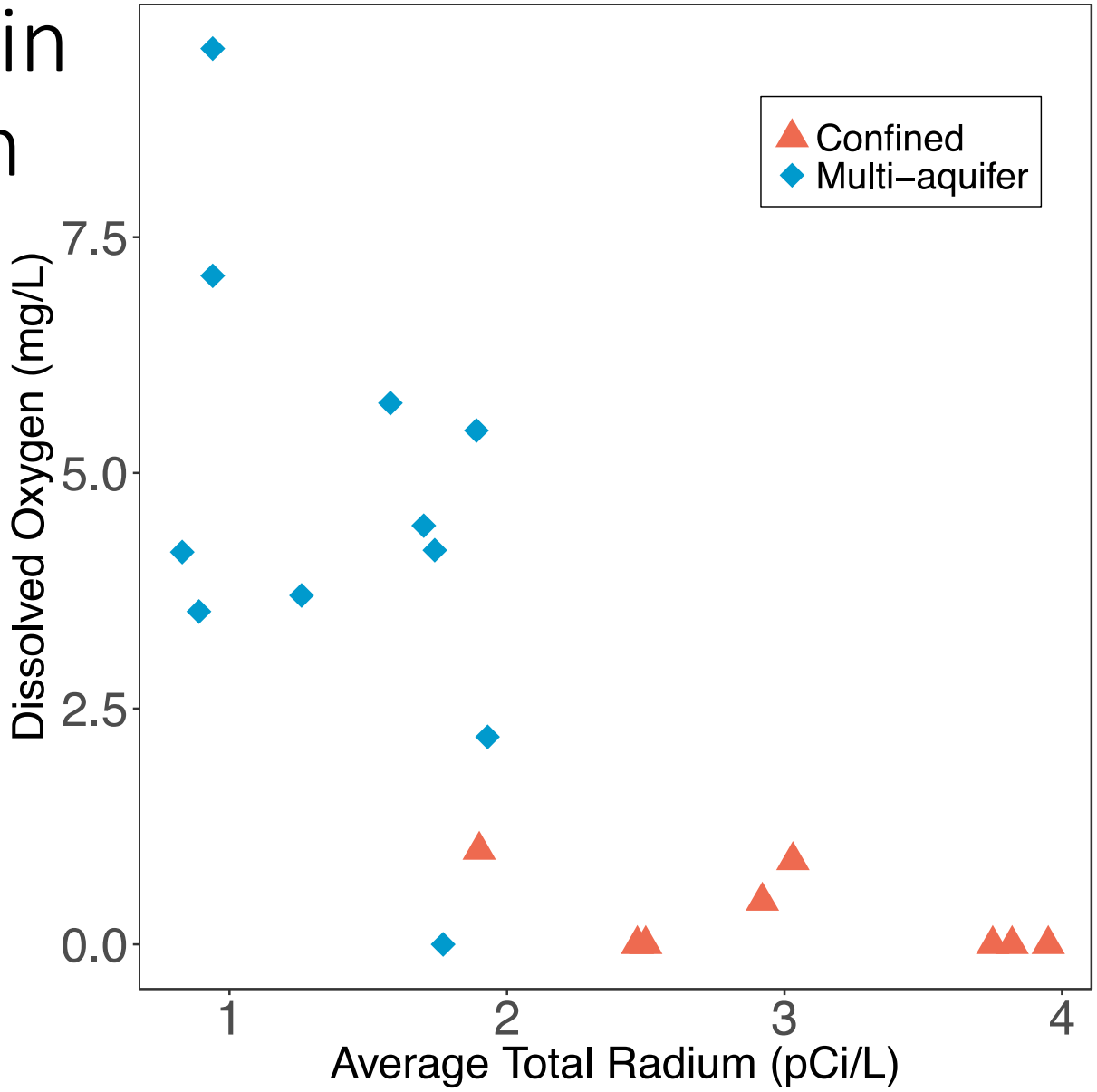


Solid-phase elemental composition from pXRF

Madison municipal wells contain greater total Ra concentration

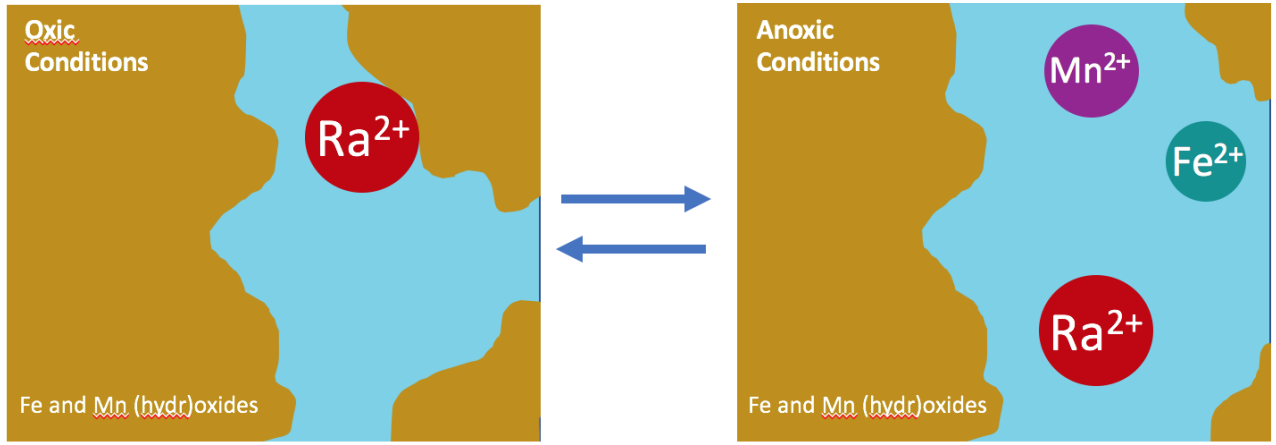
- **Municipal wells**
- Ave. total Ra in 19 municipal wells in Madison, WI
- DO sampled in 2017

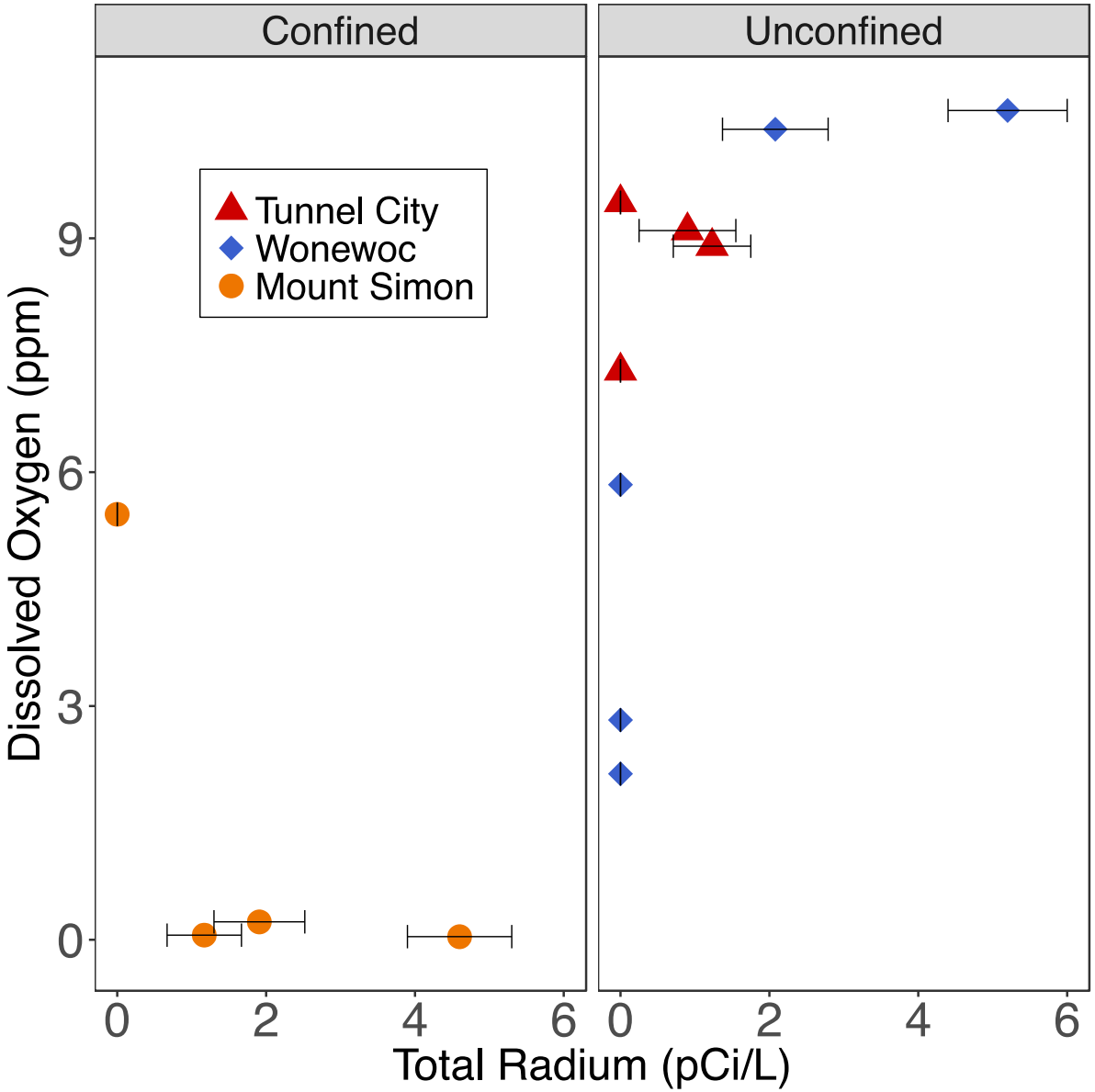




Anoxic conditions contribute to increased radium concentration in monitoring wells

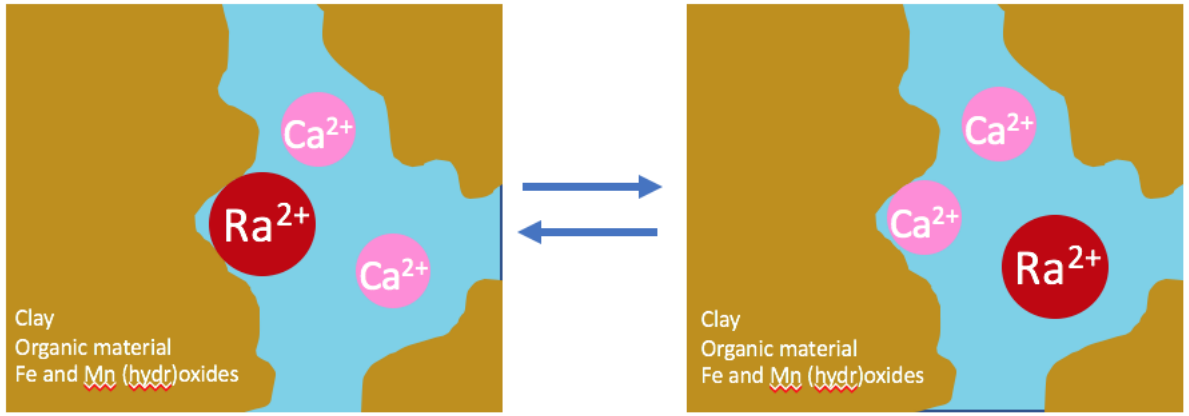
- **Monitoring wells**
- Dissolution of minerals due to anoxic conditions

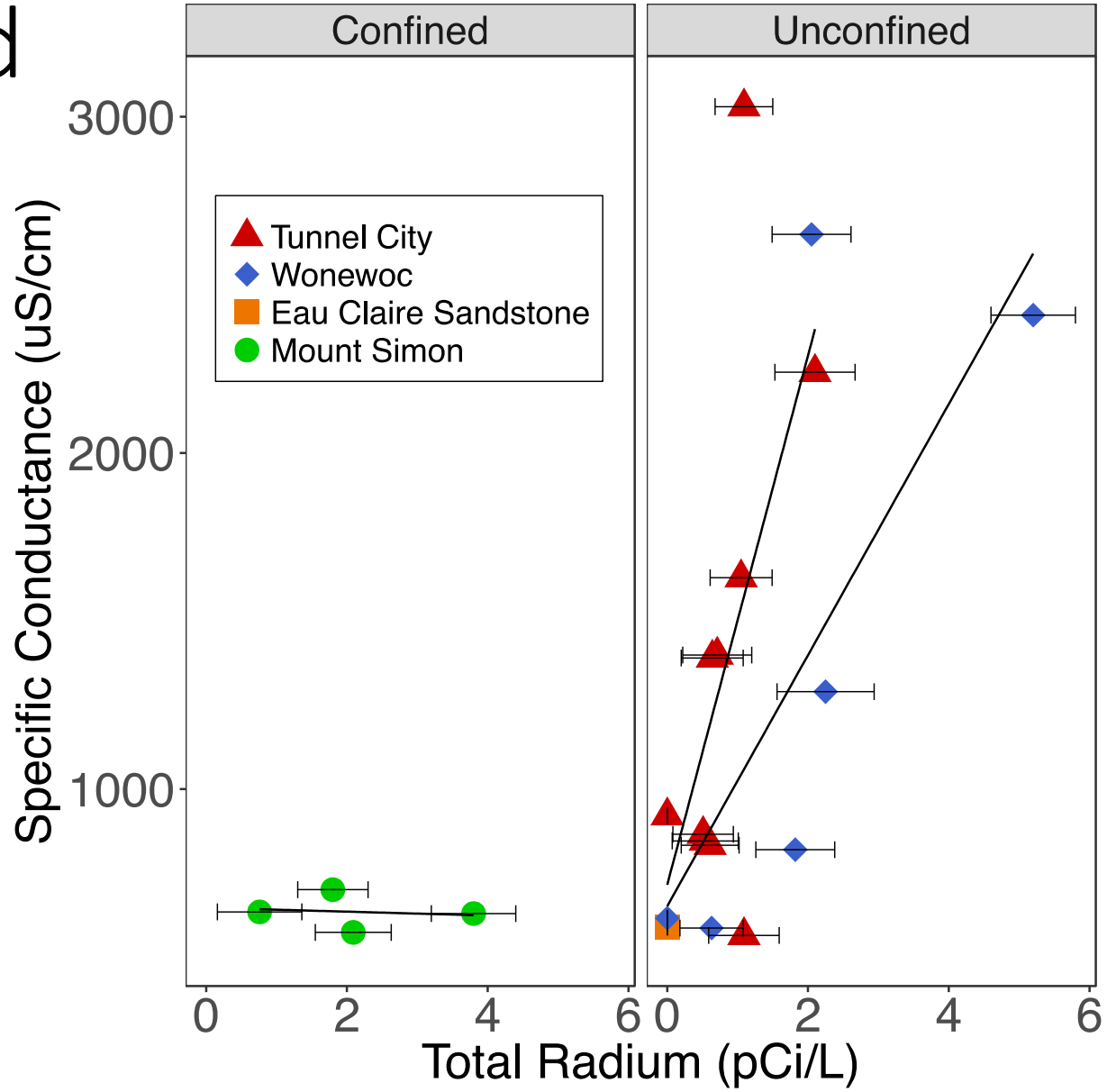




Shallow wells have elevated total dissolved solids

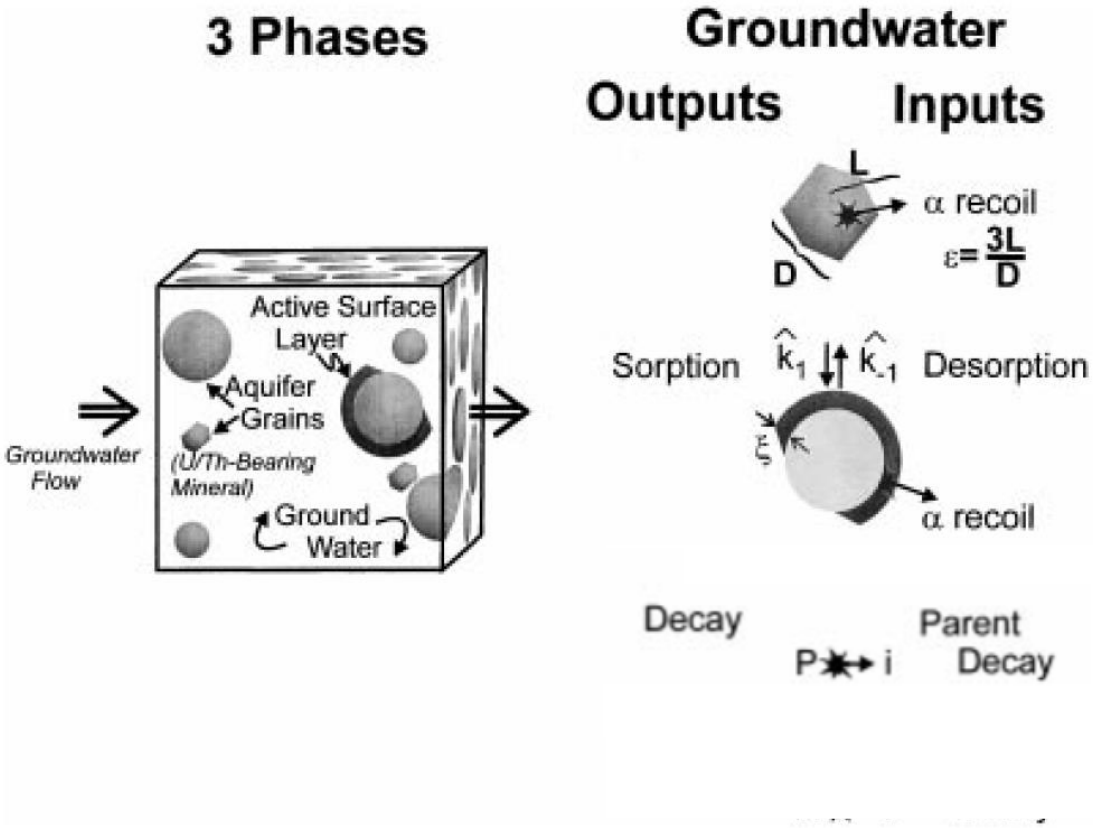
- **Monitoring wells**
- Fewer available sorption sites
- Confined and unconfined conditions





Conclusions – the effect of geochemical conditions on radium in the Cambrian-Ordovician aquifer

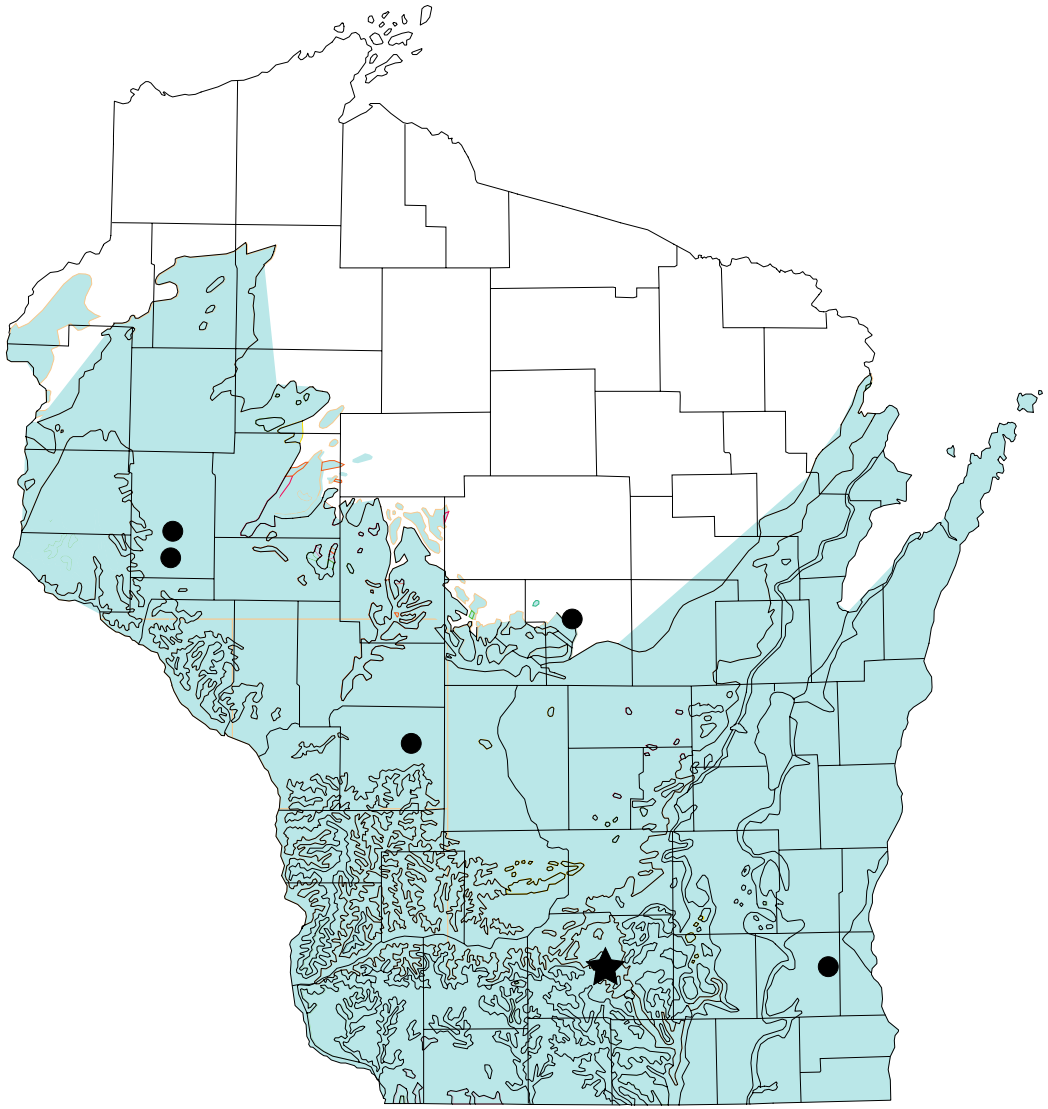
- Ra in C-O aquifer
- Confined systems: anoxic conditions may contribute to elevated Ra
- Unconfined systems: elevated dissolved solids may contribute to elevated Ra



Adapted from: Tricca, A.; Porcelli, D.; Wasserburg, G. J. Factors controlling the groundwater transport of U, Th, Ra, and Rn. *J. Earth Syst. Sci.* **2000**, *109* (1), 95–108.

Future studies

- Isotopic signature of Ra in Cambrian-Ordovician aquifer for potential solid-phase sources
- Quantify potential solid-phase sources (speciation, dissolution, sorption potential)
- Geochemical modeling of Ra leaching via MODFLOW reactive transport models to look at contribution by stratigraphy



Examples of elevated Ra across WI

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