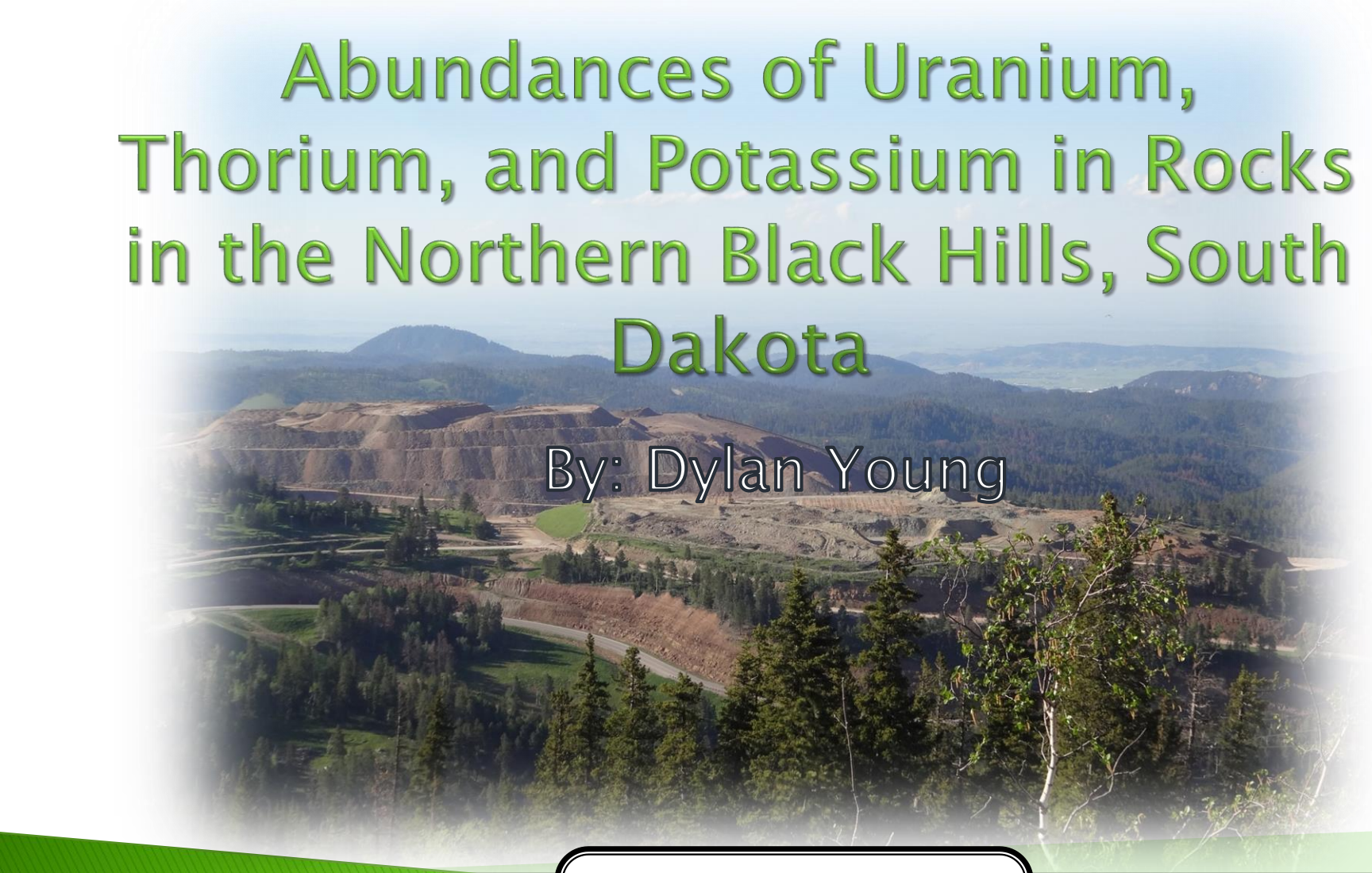
# Abundances of Uranium, Thorium, and Potassium in Rocks in the Northern Black Hills, South Dakota



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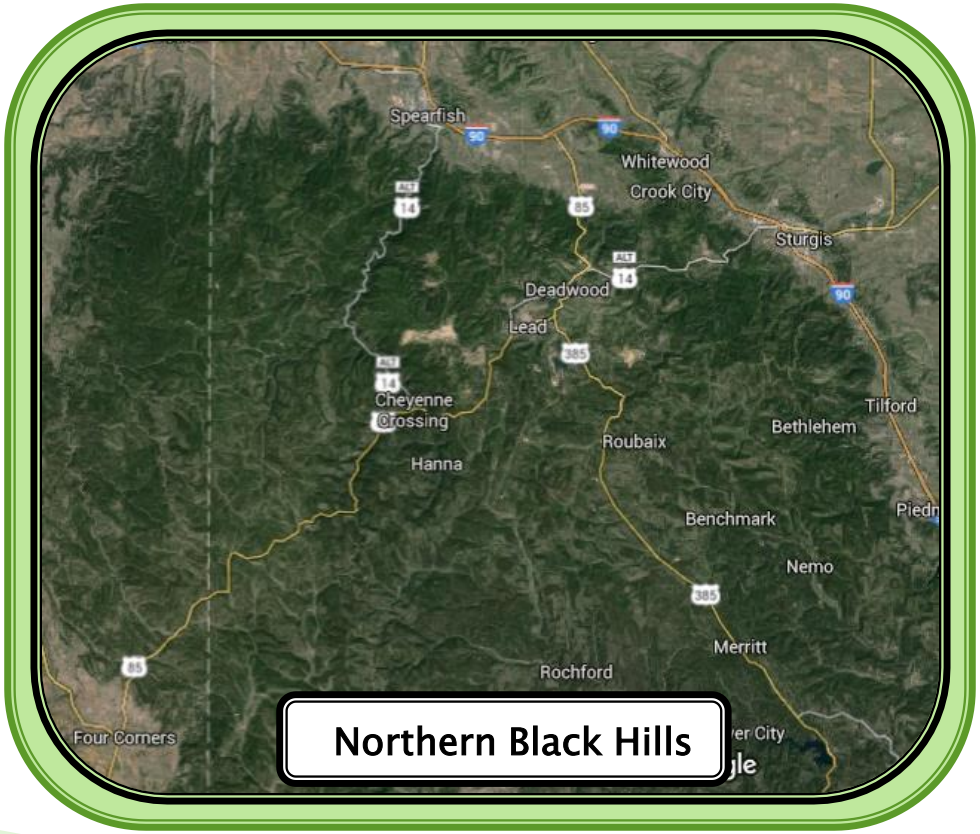
# Outline

- Introduction
- Geology of Northern Black Hills
- Methods
- Discussion
- Conclusion and Further Research



# Homestake Mine and the Sanford Underground Laboratory

- Homestake Mine was converted to Sanford Underground Laboratory (SUL) in 2006
- A new research project, the Long Baseline Neutrino Experiment (LBNE), is currently in designing stage
- The purpose is to track neutrino particles as they pass through Earth
- Plans presently are to construct an antineutrino (geoneutrino) detector in the Homestake mine

# Purpose of Research

- Natural radioactive decay of $^{235}U$, $^{232}Th$ and $^{40}K$ are present across Earth, which also generates antineutrinos
- Present across Earth and surrounding the Black Hills and the Homestake Mine
- Uncertainties are present on the content and contribution of radioactivity

# Geology of the Black Hills

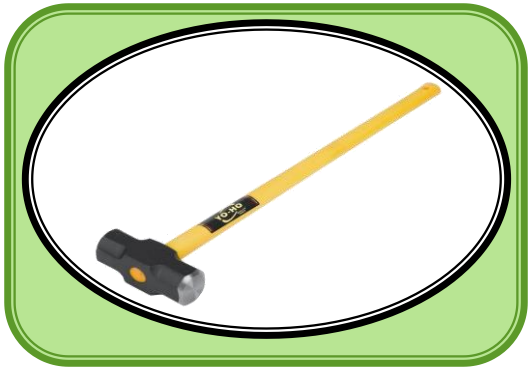
- Most of the metamorphic rocks present are from the Precambrian
- Sedimentary rocks vary with age
  - Deadwood Formation – Cambrian
  - Whitewood Limestone (LS)– Ordovician
  - Englewood and Pahasapa LS – Mississippian
- Ore deposits are found in Deadwood, Whitewood and Pahasapa Formations
- Igneous Rocks– Paleozoic, Mesozoic and Tertiary

# Importance

- Tertiary igneous rocks from the Northern Black Hills of importance
  - Rhyolite
  - Porphyritic Rhyolite
  - Monzonite
  - Phonolite
- Hydrothermal activity associated with ore deposits (gold and silver)
- Occurrences of Thorium and Uranium bearing minerals in the region directly associated

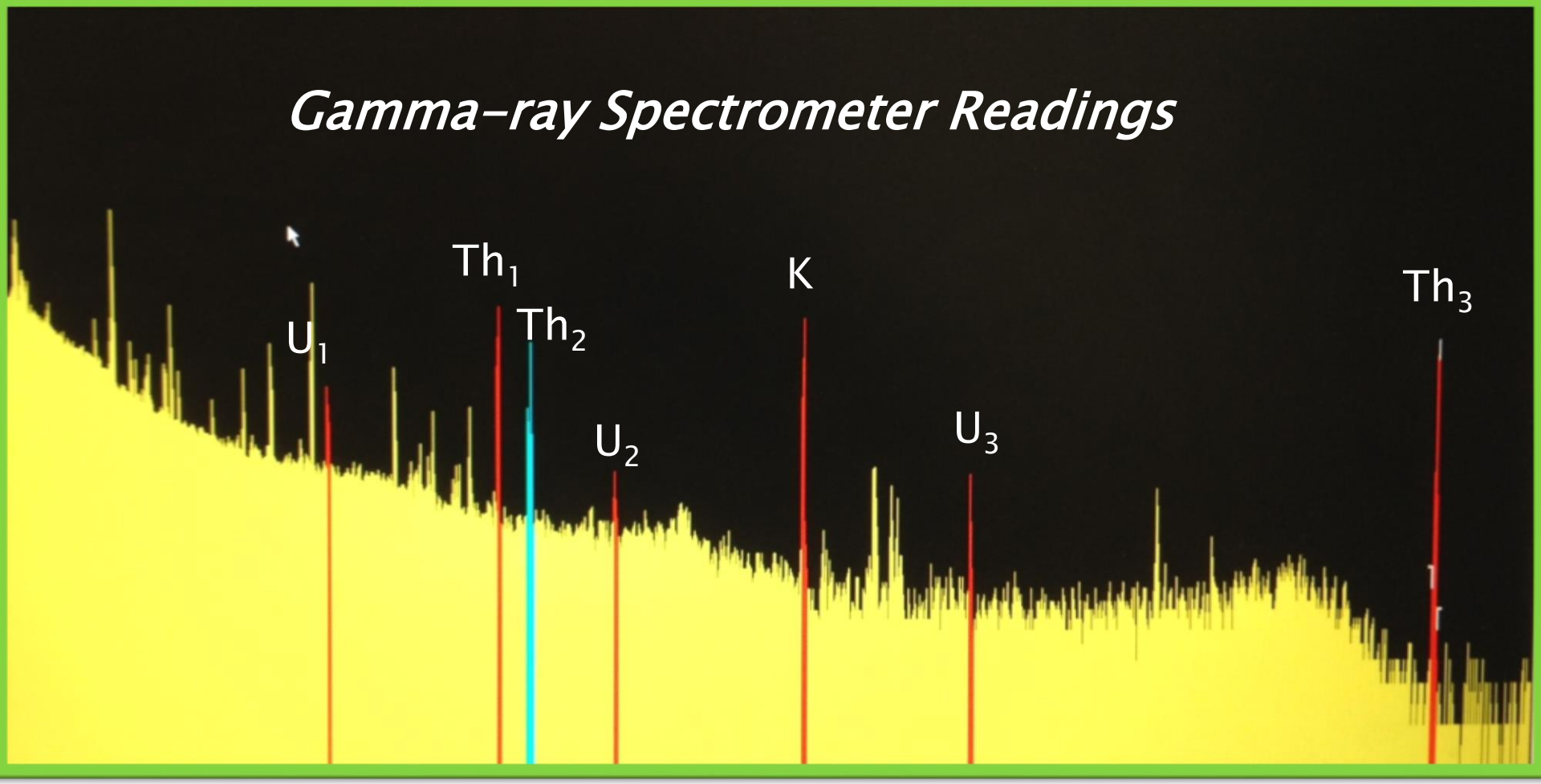
# Methods

- Sampling and collecting



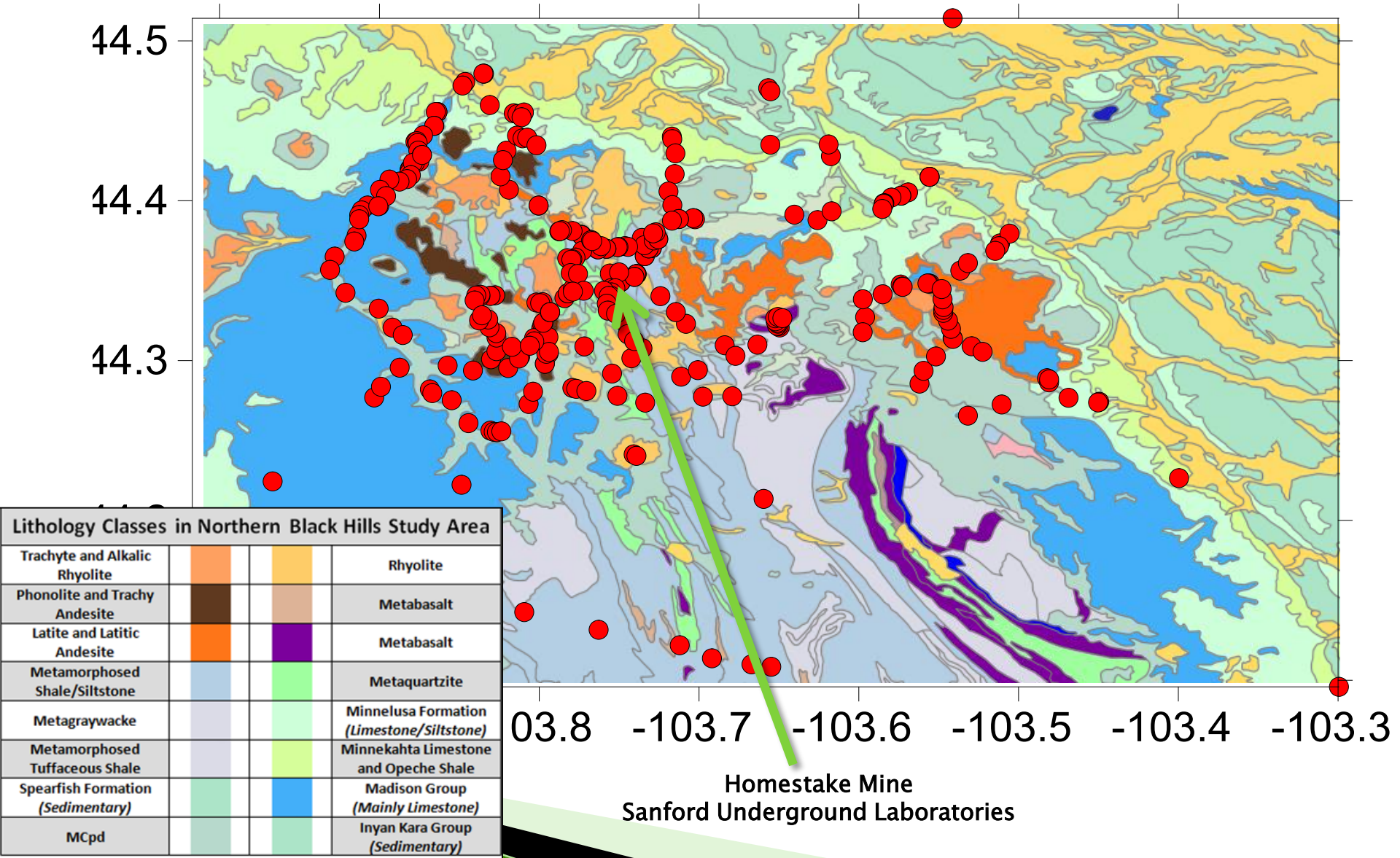
- Sample Preparation
- Gamma-ray Spectrometry

- Mapping and Statistical Analysis
- Continued research

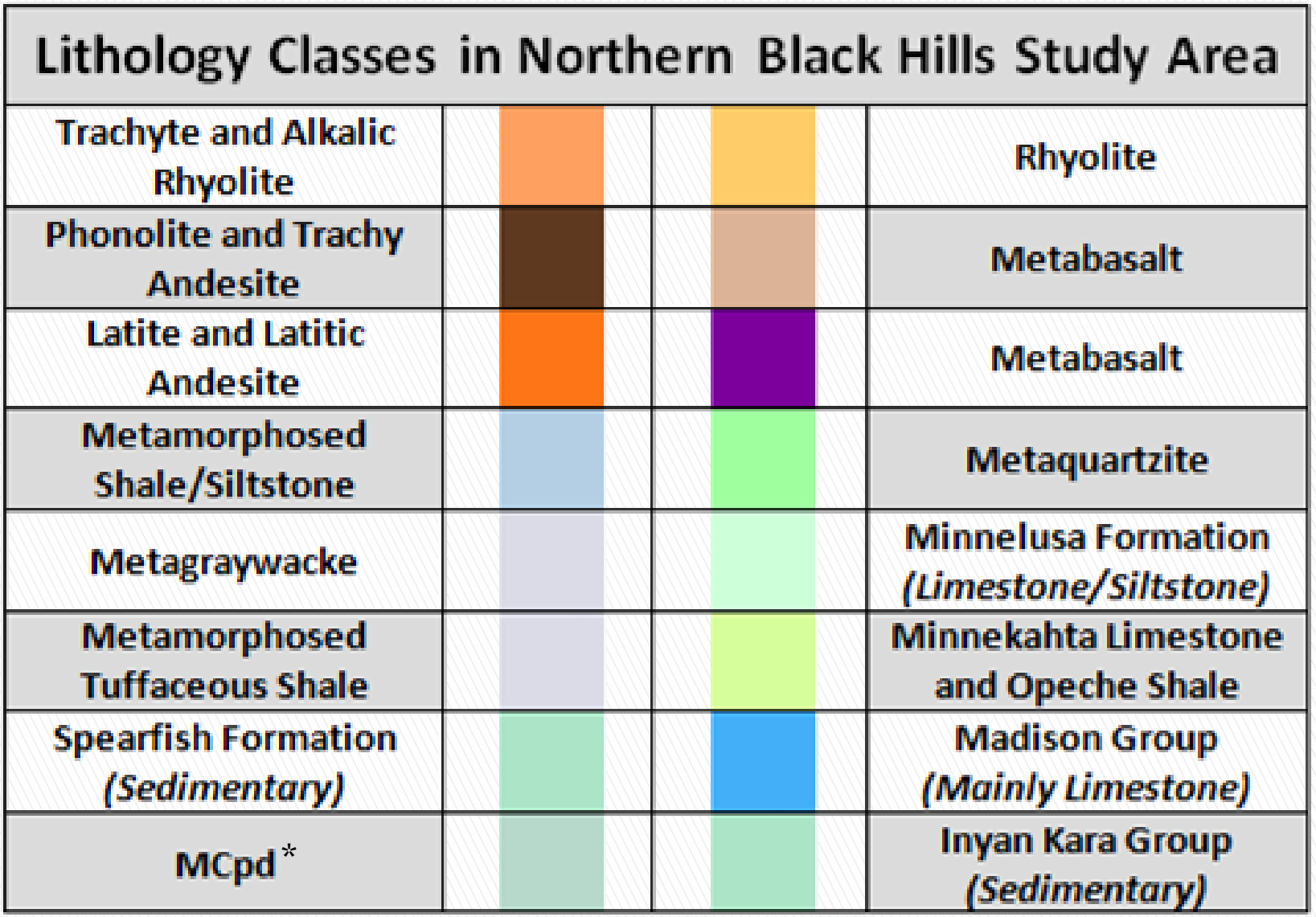



**251 B - Element Concentrations:** 95.88 Th (µg/L)
(Sample wt: 750.2g) 0.00 U
2.88 K

# Overview of Northern Black Hills

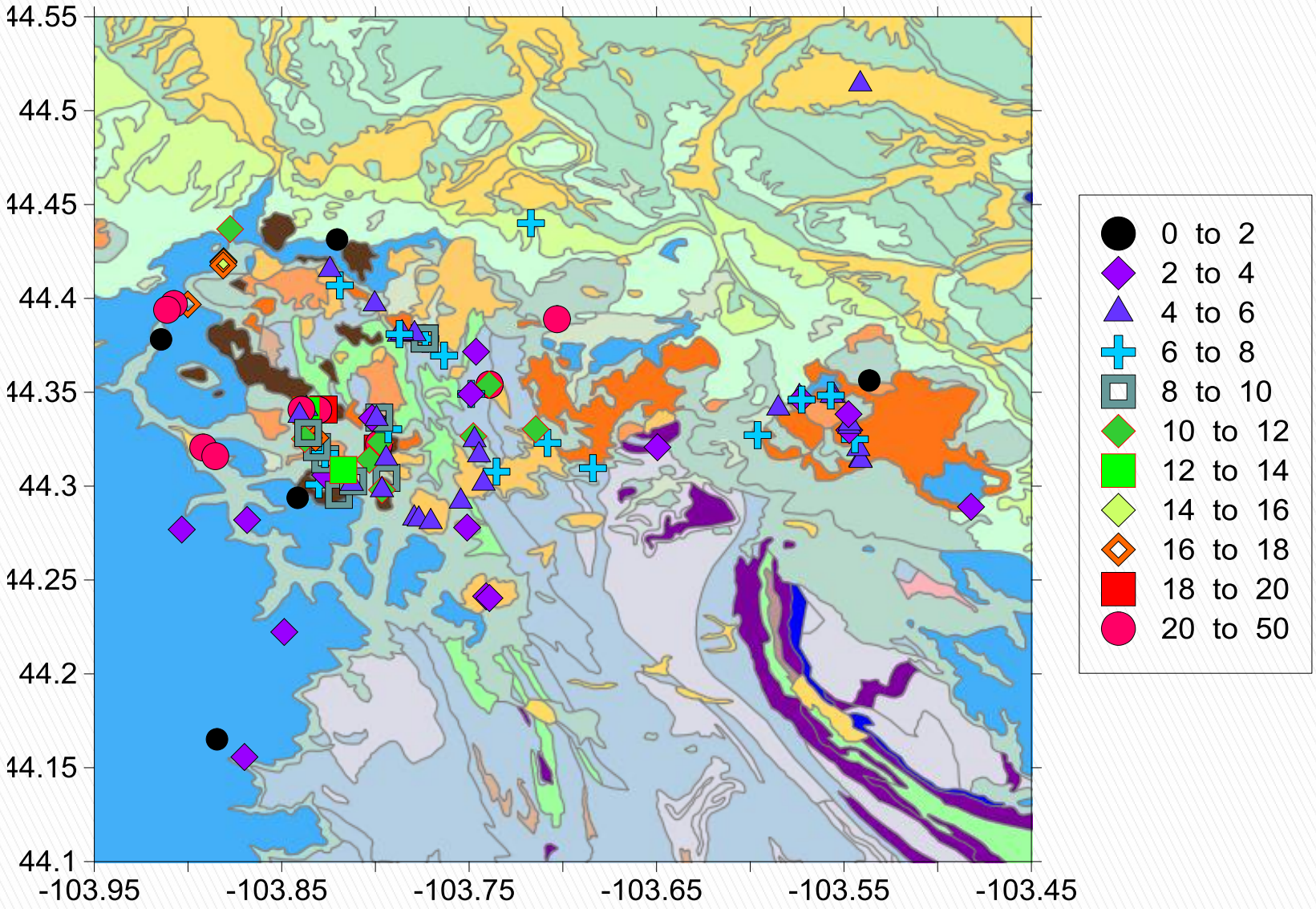



| Lithology Classes in Northern Black Hills Study Area | | | |
|---|---|---|---|
| Trachyte and Alkalic Rhyolite | | | Rhyolite |
| Phonolite and Trachy Andesite | | | Metabasalt |
| Latite and Latitic Andesite | | | Metabasalt |
| Metamorphosed Shale/Siltstone | | | Metaquartzite |
| Metagraywacke | | | Minnelusa Formation *(Limestone/Siltstone)* |
| Metamorphosed Tuffaceous Shale | | | Minnekahta Limestone and Opeche Shale |
| Spearfish Formation *(Sedimentary)* | | | Madison Group *(Mainly Limestone)* |
| MCpd | | | Inyan Kara Group *(Sedimentary)* |

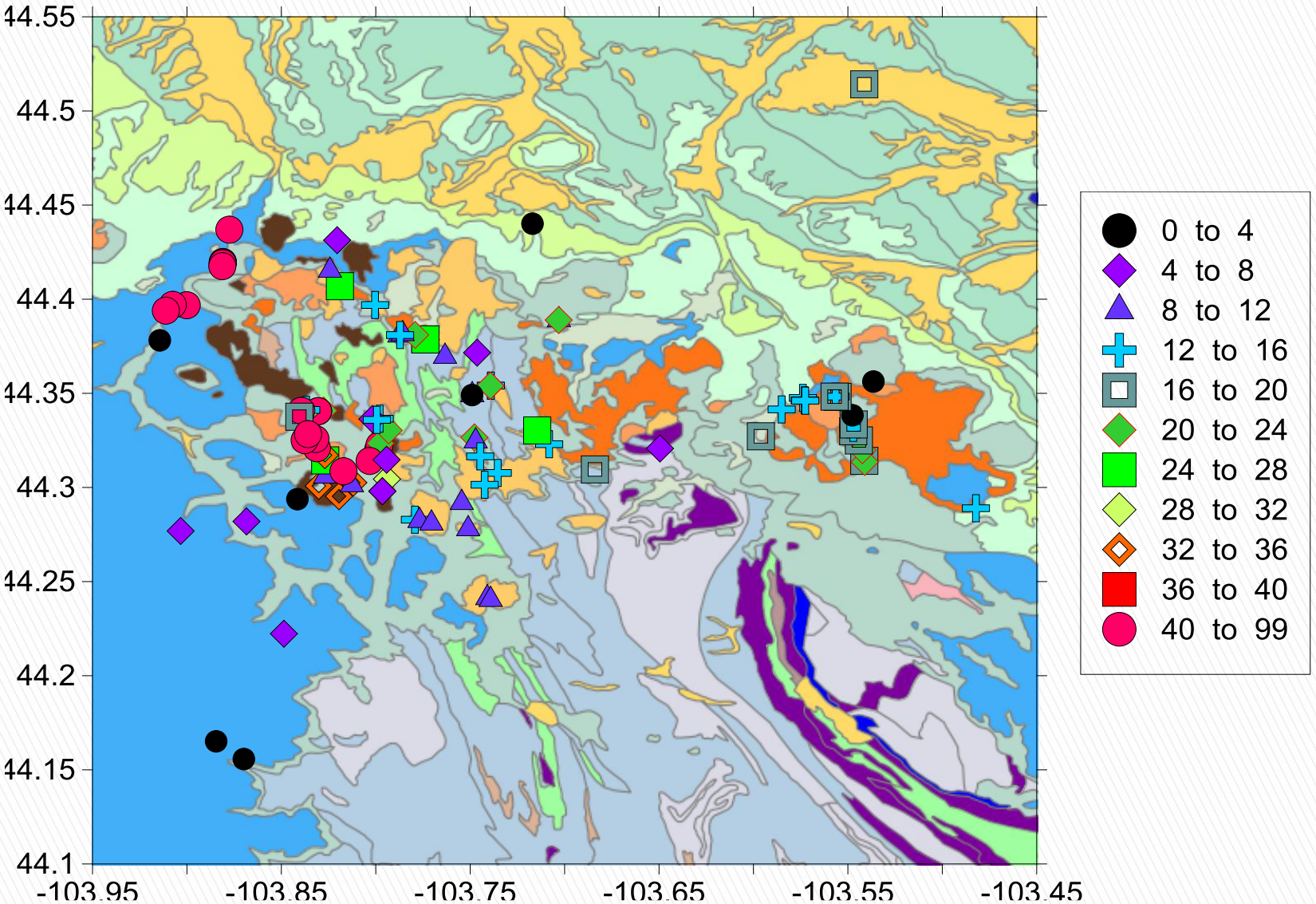



*MCpd: Consists of Pahasapa Limestone, Englewood Formation, Whitewood Limestone, Winnipeg Formation and the Deadwood Formation

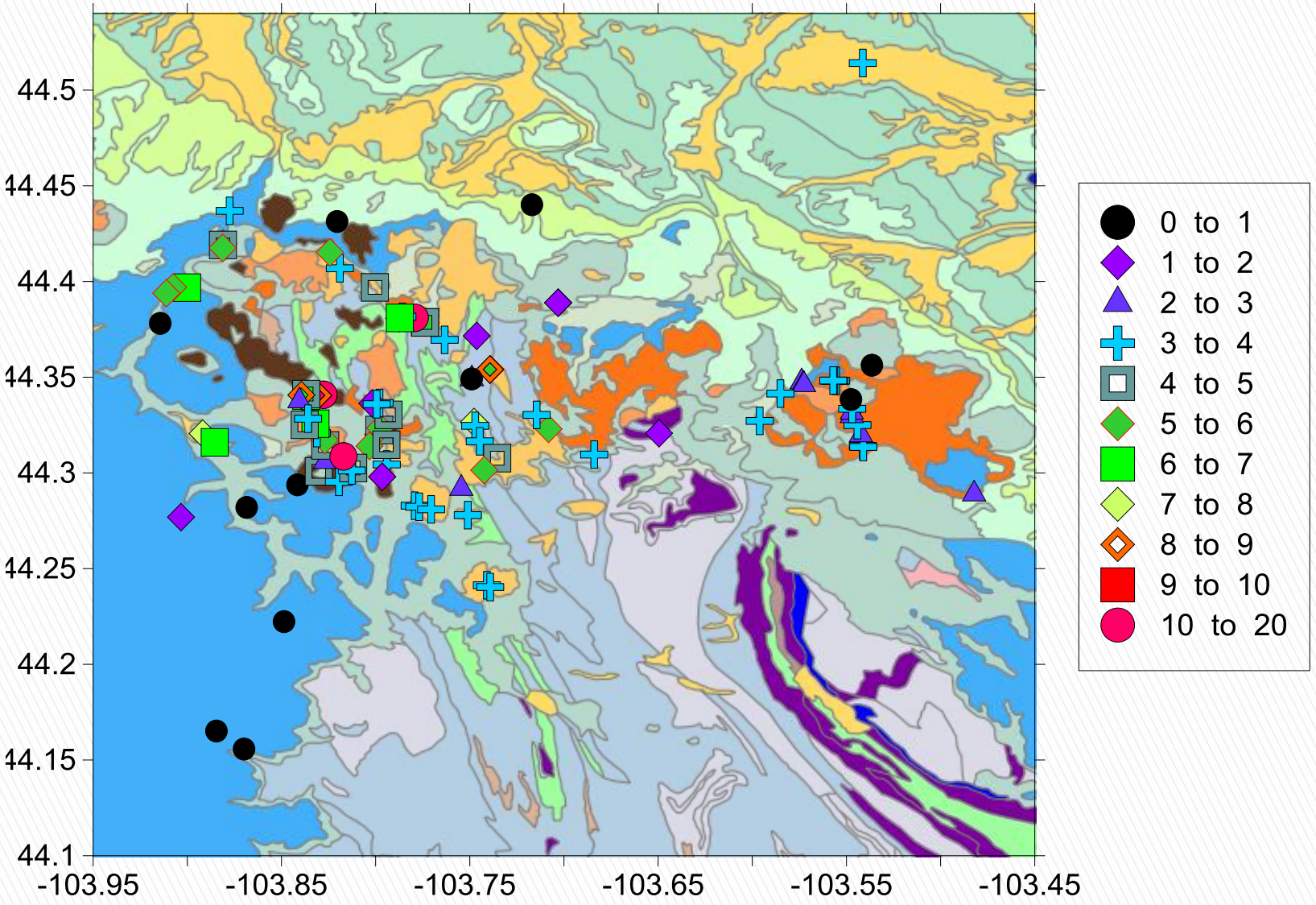
# Igneous Rocks Uranium



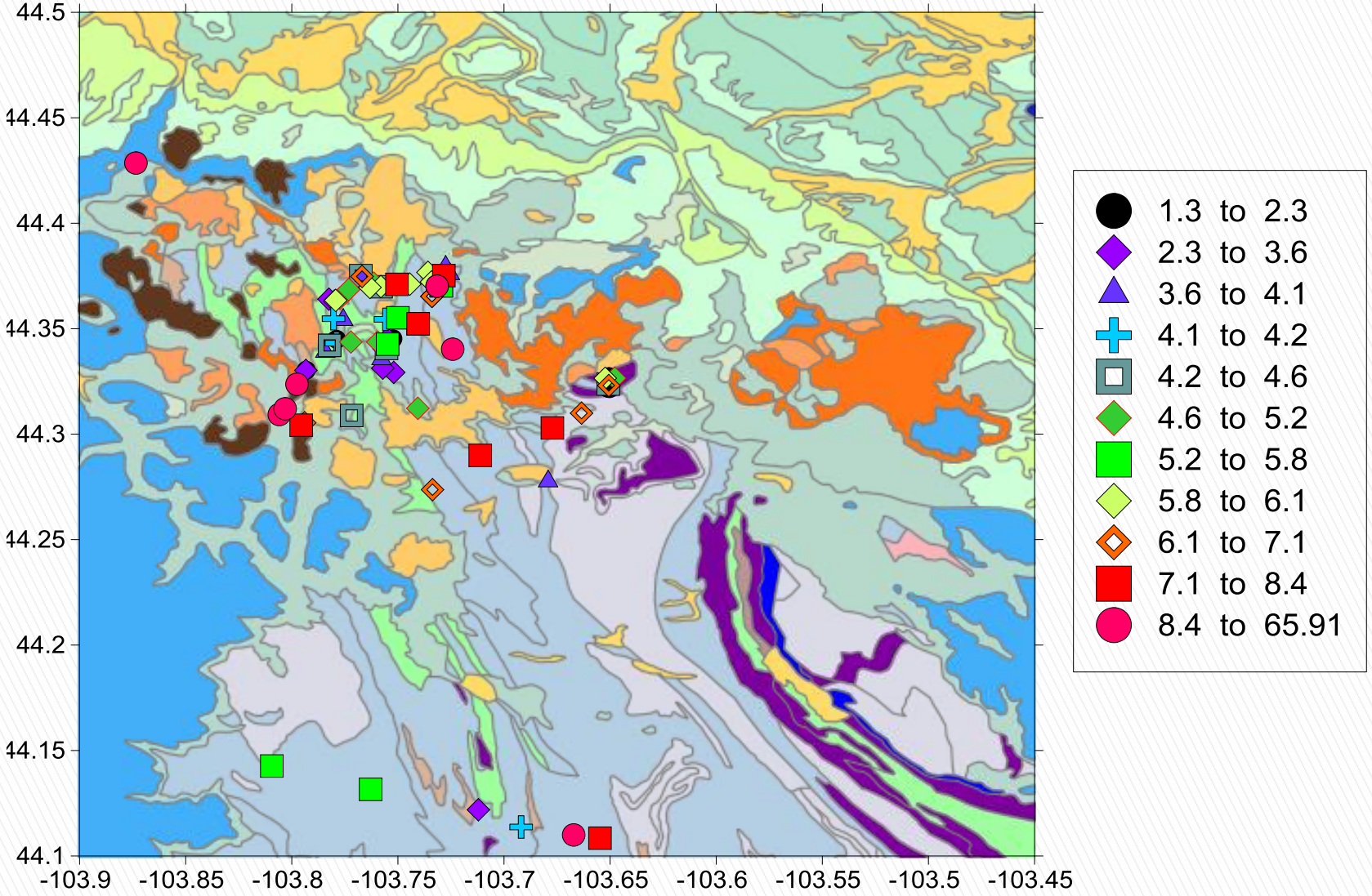
# Igneous Rocks Thorium



# Igneous Rocks Potassium



# Metamorphic Rocks Uranium



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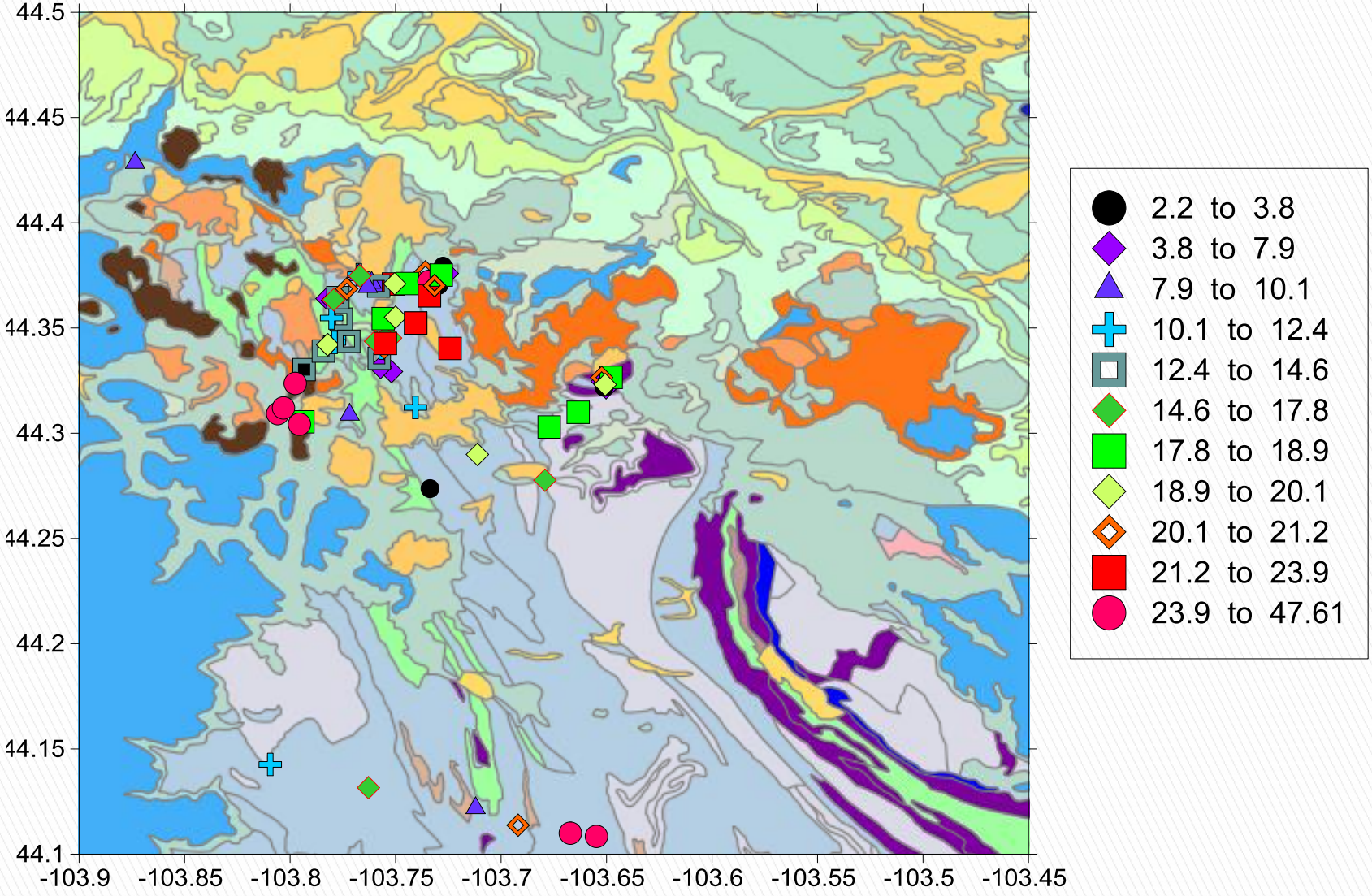
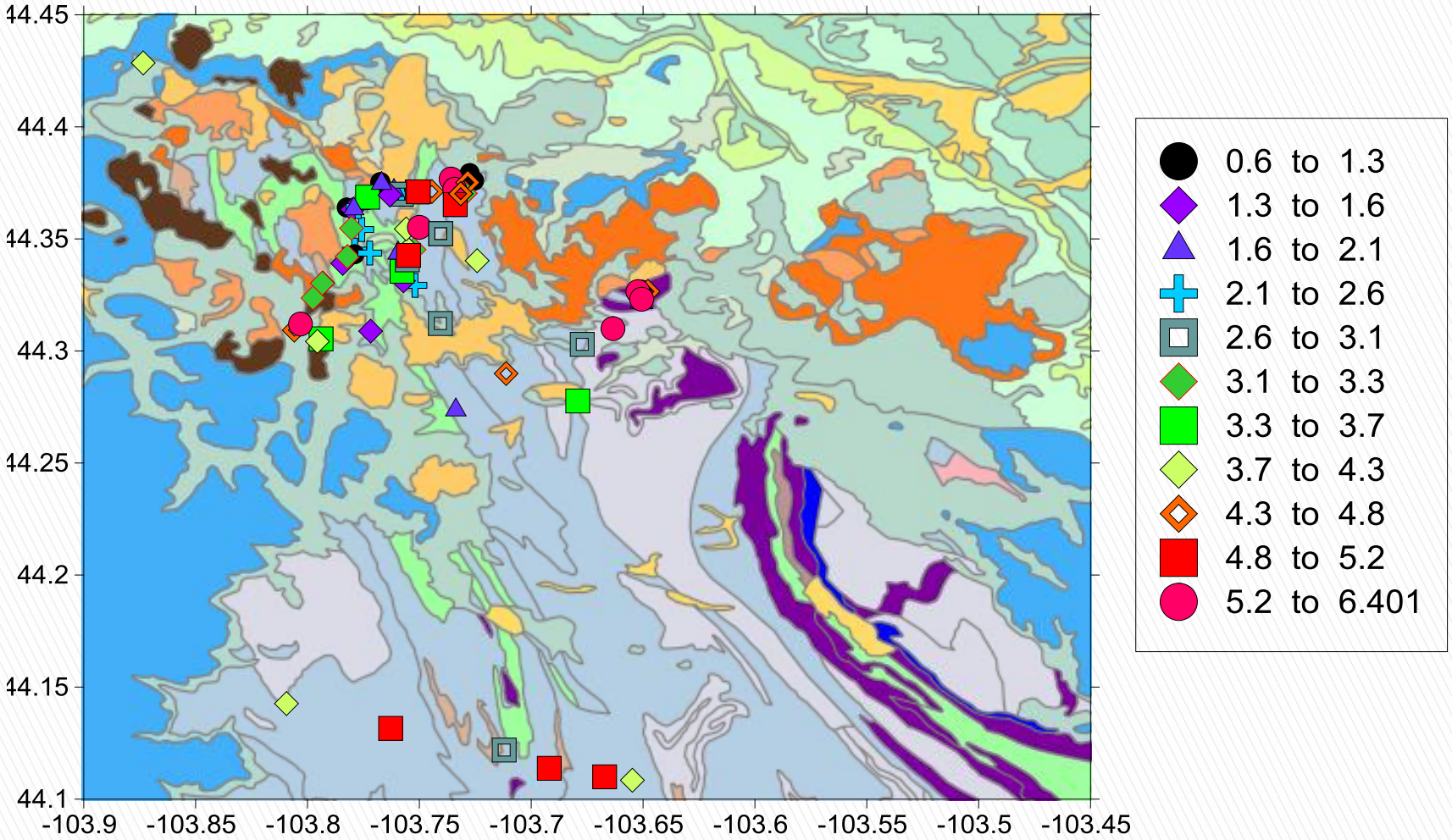
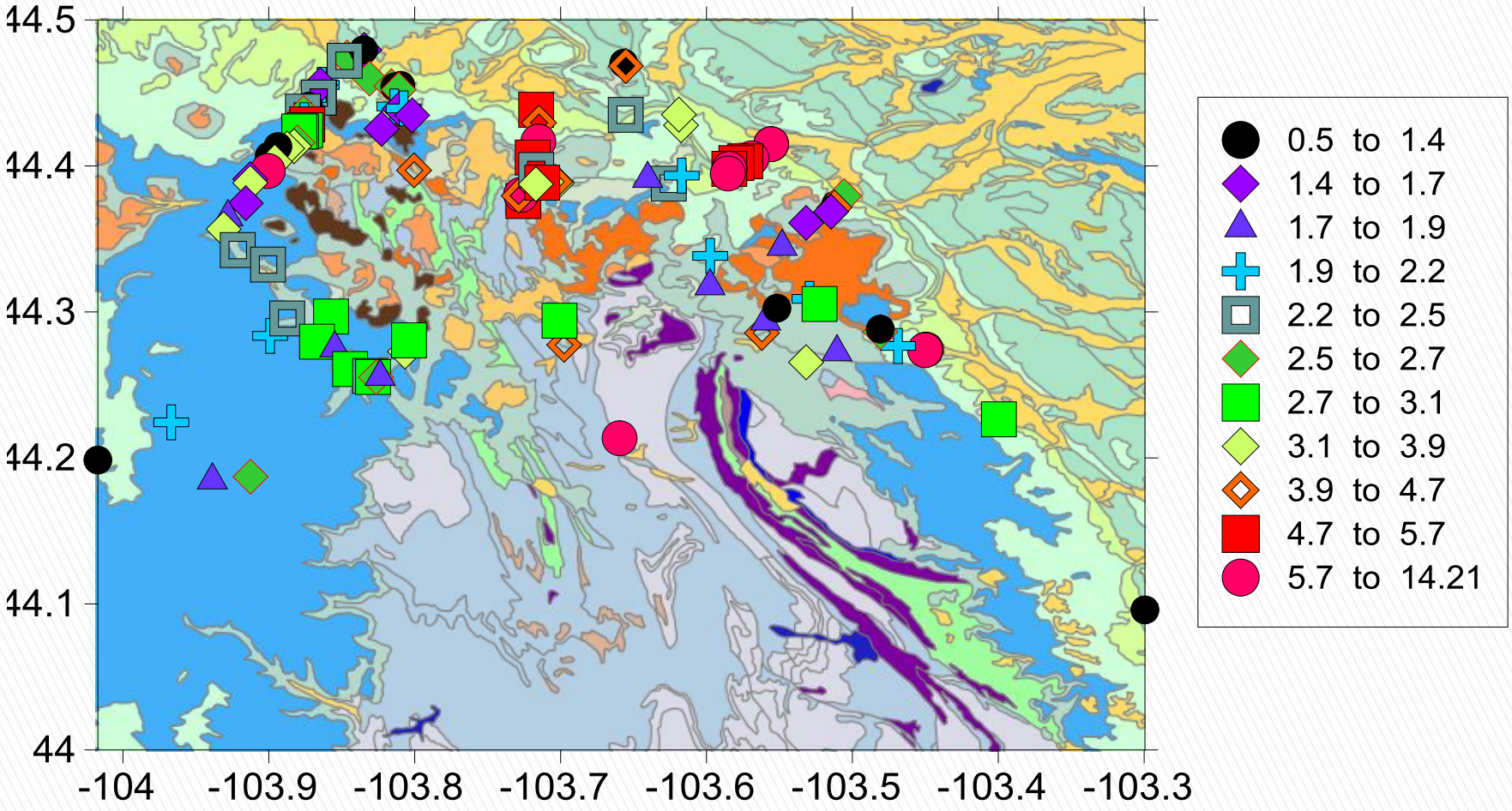


# Metamorphic Rocks Potassium

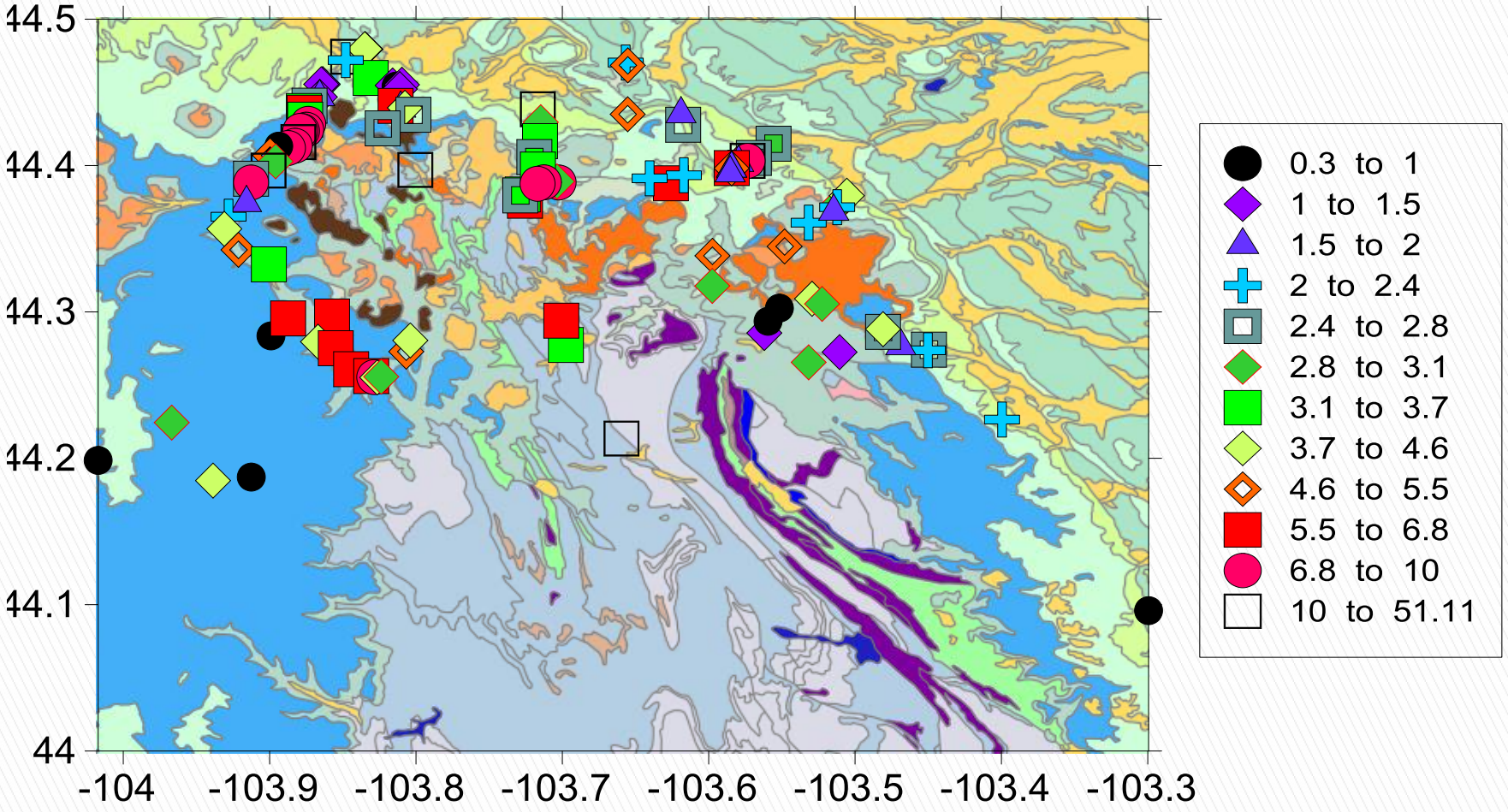


# Sedimentary Rocks Uranium




*Some high levels can be associated with greywacke deposits

# Sedimentary Rocks Thorium

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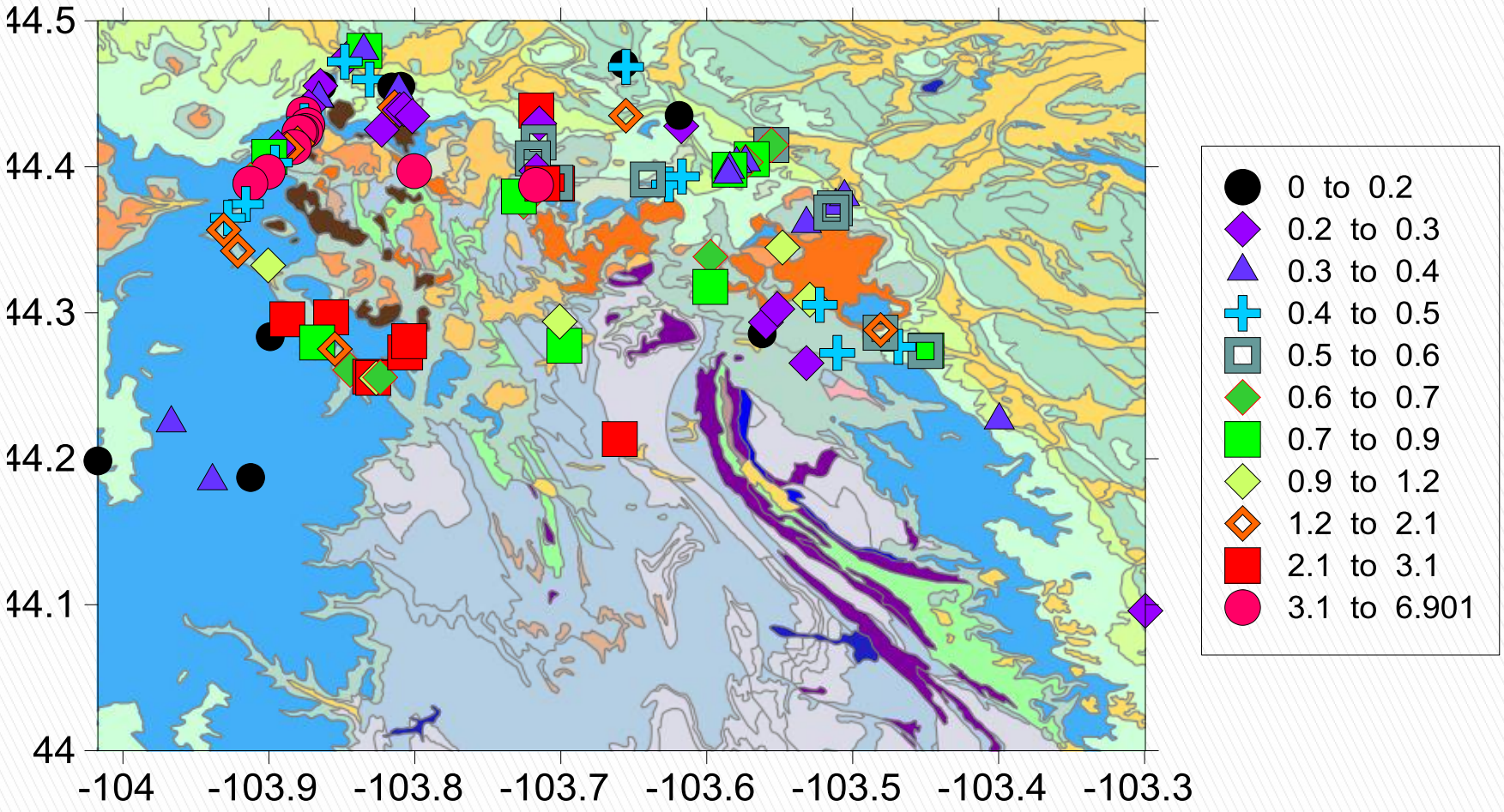
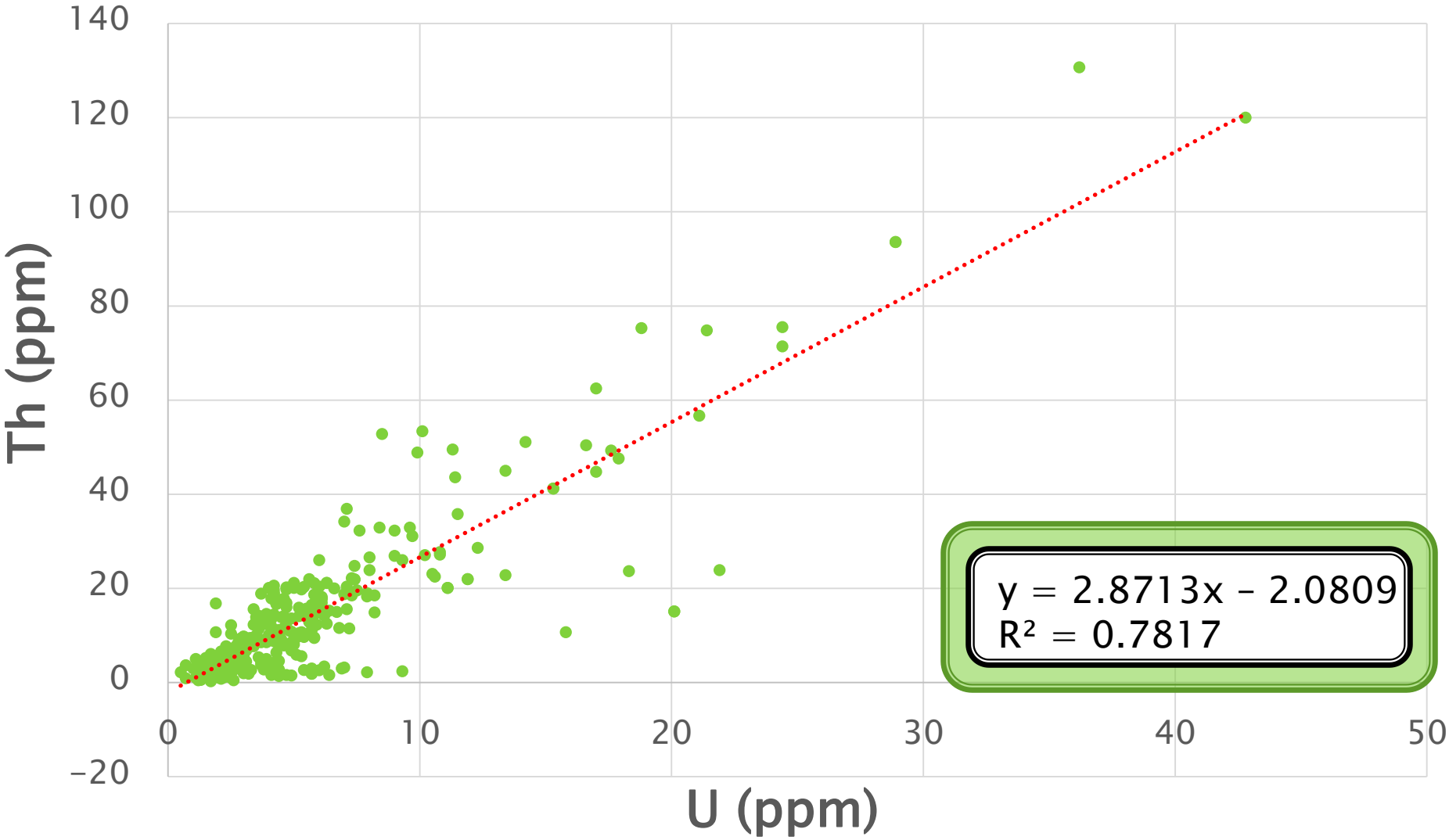
# Sedimentary Rocks Potassium

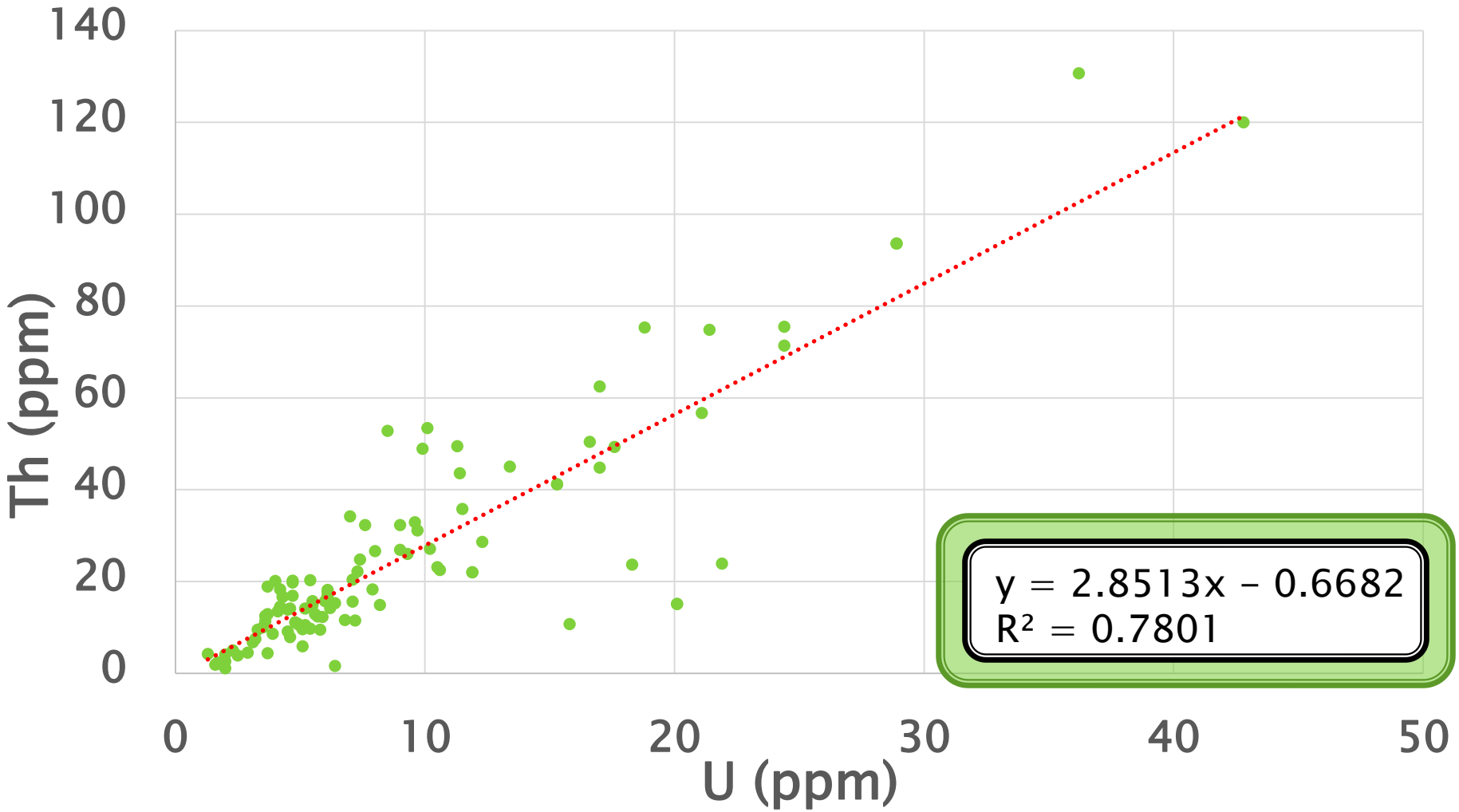


# Composite Uranium/Thorium Ratio

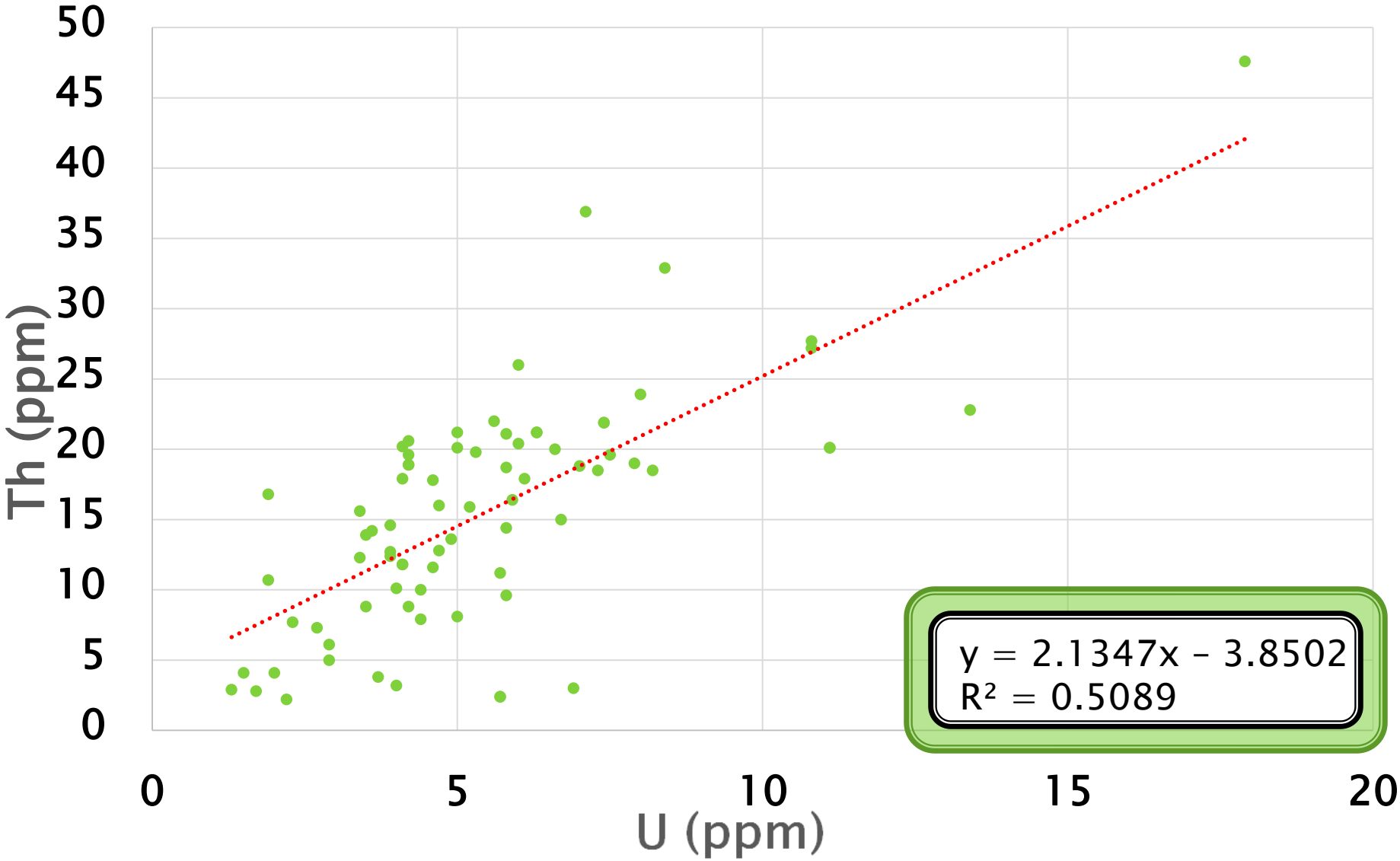



* Includes data from every sample

# Igneous Uranium/Thorium Ratio



# Metamorphic Uranium/Thorium Ratio



# Statistical Results

| Average Th/U Ratio |
| --- |
| 2.42 |

| Black Hills Background Radioactivity | | | |
| --- | --- | --- | --- |
| | U (ppm) | Th (ppm) | $K_2O$ (pct) |
| **Minimum** | 0.50 | 0.30 | 0.00 |
| **Maximum** | 65.90 | 130.70 | 13.80 |
| **Average** | 6.00 | 14.54 | 2.61 |
| **Median** | 4.30 | 9.60 | 2.40 |
| **Standard Deviation** | 6.46 | 17.71 | 2.24 |
| **Variance** | 41.76 | 313.55 | 5.03 |
| **Count** | 300 | 300 | 300 |
| ***2 Std. Dev. Above Avg.*** | 18.92 | 49.96 | 7.10 |

# Statistical Results

| Average Th/U Ratio |
| --- |
| 3.83 |

| Black Hills Igneous Rock Radioactivity | | | |
| --- | --- | --- | --- |
| | U (ppm) | Th (ppm) | $K_2O$ (pct) |
| **Minimum** | 1.30 | 1.10 | 0.2 |
| **Maximum** | 42.80 | 130.70 | 13.80 |
| **Average** | 5.89 | 25.18 | 4.02 |
| **Median** | 6.10 | 16.70 | 3.70 |
| **Standard Deviation** | 6.25 | 24.33 | 2.43 |
| **Variance** | 56.78 | 591.74 | 5.89 |
| **Count** | 105 | 105 | 105 |
| ***2 Std. Dev. Above Avg.*** | 18.38 | 73.83 | 8.87 |

# Statistical Results

| Average Th/U Ratio |
| --- |
| 2.47 |

| Black Hills Metamorphic Rocks Radioactivity | | | |
| --- | --- | --- | --- |
| | U (ppm) | Th (ppm) | $K_2O$ (pct) |
| **Minimum** | 1.30 | 2.20 | 0.60 |
| **Maximum** | 65.90 | 47.60 | 6.40 |
| **Average** | 6.22 | 15.37 | 3.15 |
| **Median** | 5.00 | 15.28 | 1.48 |
| **Standard Deviation** | 7.42 | 8.28 | 2.20 |
| **Variance** | 55.06 | 68.56 | 2.20 |
| **Count** | 77 | 77 | 77 |
| ***2 Std. Dev. Above Avg.*** | 21.06 | 31.93 | 6.12 |

# Statistical Results

| Average Th/U Ratio |
| --- |
| 1.44 |

| Black Hills Sedimentary Rocks Radioactivity | | | |
| --- | --- | --- | --- |
| | U (ppm) | Th (ppm) | $K_2O$ (pct) |
| Minimum | 0.50 | 0.30 | 0.00 |
| Maximum | 14.20 | 51.10 | 6.90 |
| Average | 3.12 | 4.50 | 0.99 |
| Median | 2.60 | 3.00 | 0.50 |
| Standard Deviation | 1.92 | 5.29 | 1.28 |
| Variance | 3.68 | 27.95 | 1.64 |
| Count | 117 | 117 | 117 |
| *2 Std. Dev. Above Avg.* | 6.96 | 15.07 | 3.55 |

# Conclusion

- Understanding the background radioactivity across Northern Black Hills is of importance
  - To accurately calibrate the antineutrino detector that is currently being designed
- The average Th/U ratio trends in the Black Hills are much lower than the standard Bulk Silicate Earth (BSE) model
  - Composite: 2.42, Igneous: 3.83, Metamorphic: 2.47, and sedimentary: 1.44
- Previous studies are not very accurate due to sparse and broadly widely sampling

# Special Thanks to:

Harney Peak, South Dakota

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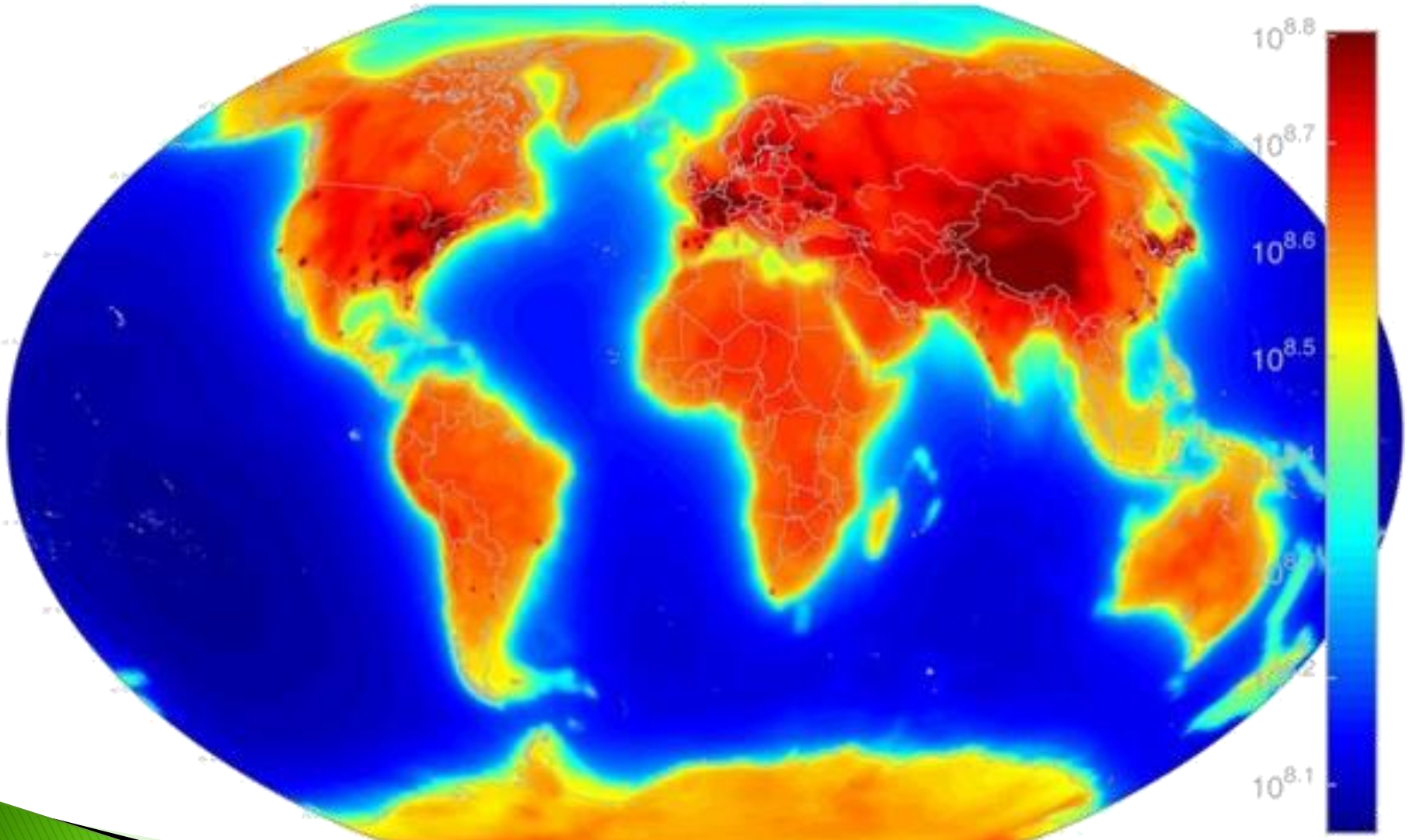
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