

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

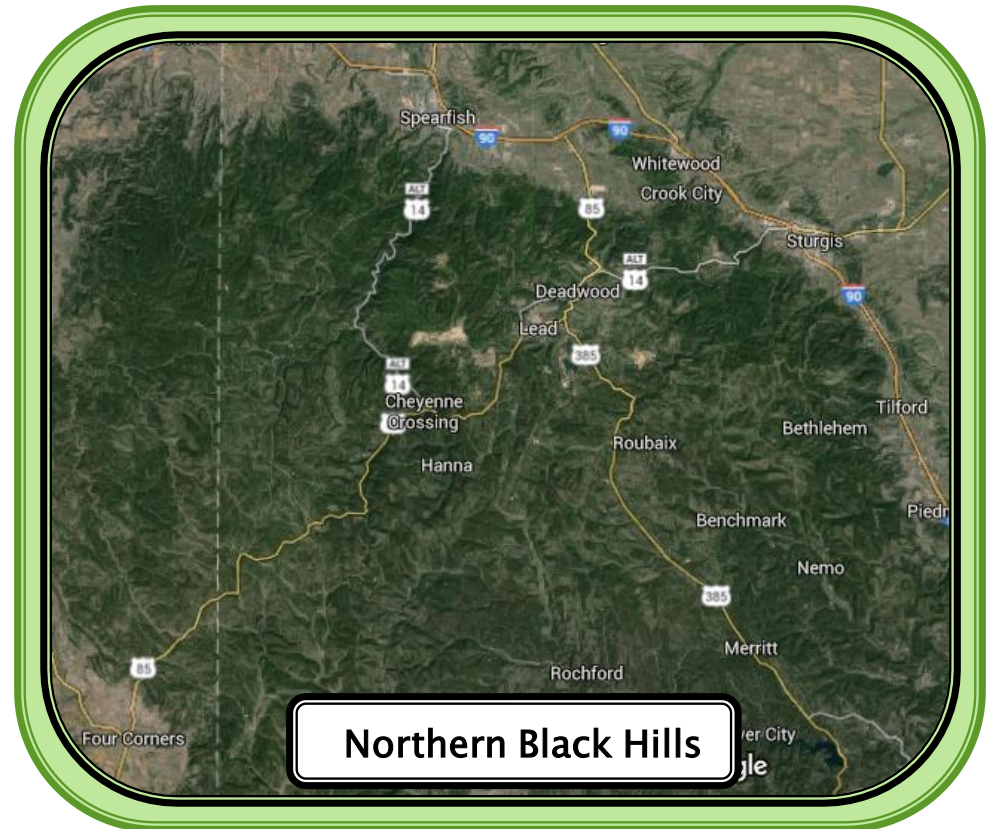
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 **UND Geothermal
Laboratory**
The University of North Dakota


school of geology
and geological engineering

Outline

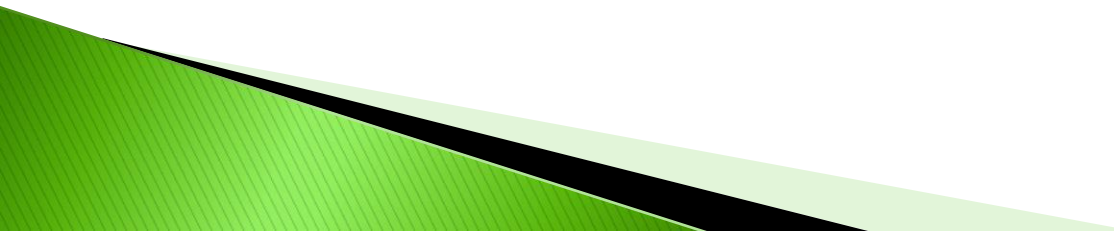
- ▶ Introduction
- ▶ Geology of Northern Black Hills
- ▶ Methods
- ▶ Discussion
- ▶ Conclusion and Further Research



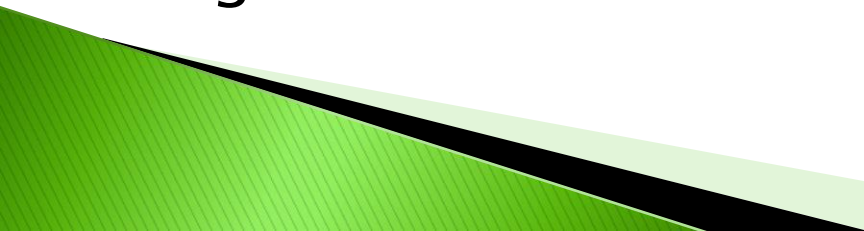
Homestake Mine and the Sanford Underground Laboratory

- ▶ 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
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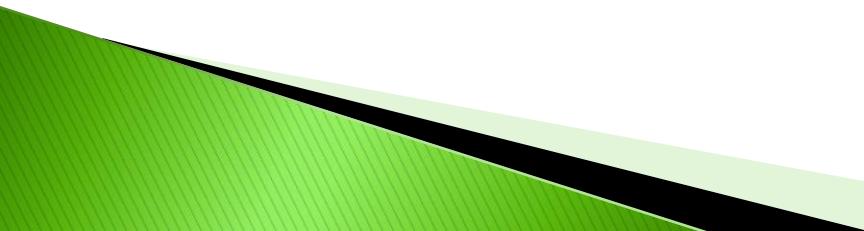
Purpose of Research

- ▶ 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
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Geology of the Black Hills

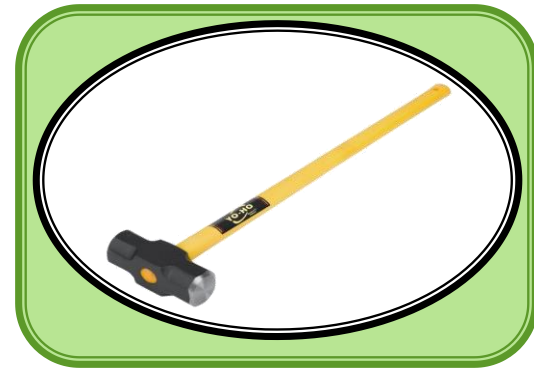
- ▶ Most of the metamorphic rocks present are from the Precambrian
 - ▶ Sedimentary rocks vary with age
 - Deadwood Formation – Cambrian
 - Whitewood Limestone (LS)– Ordovician
 - Englewood and Pahasapa LS – Mississippian
 - ▶ Ore deposits are found in Deadwood, Whitewood and Pahasapa Formations
 - ▶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

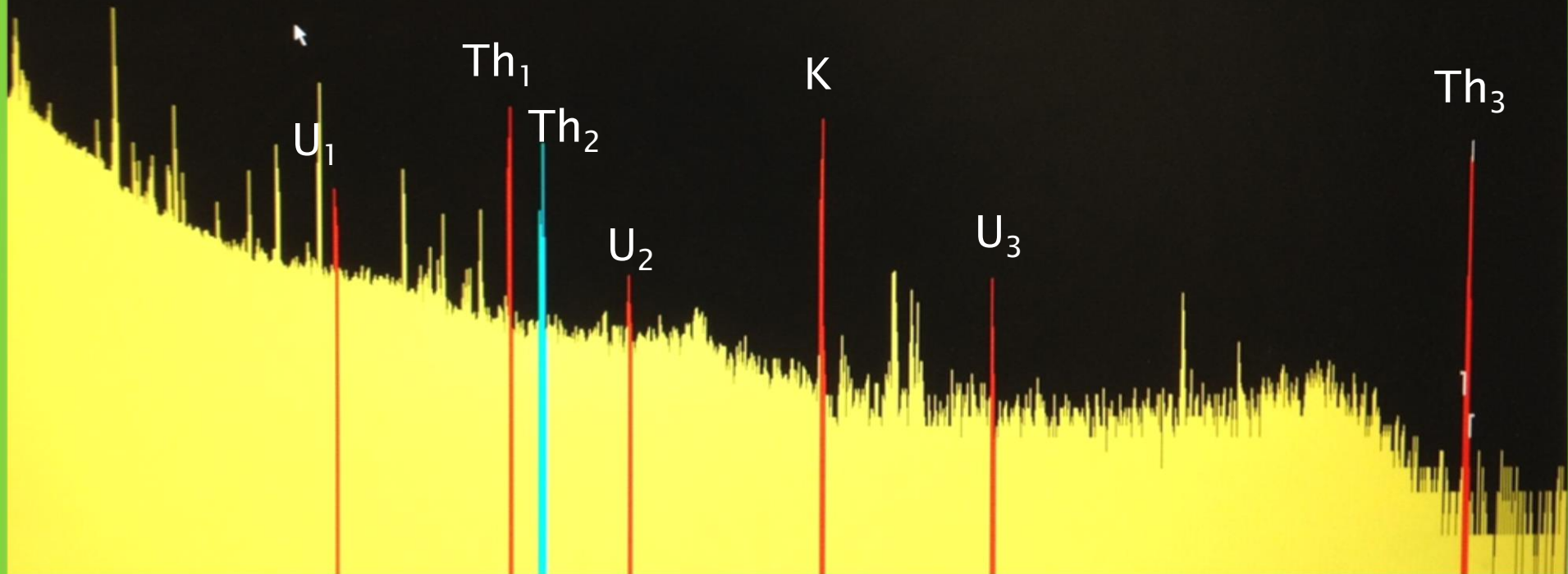
- ▶ Tertiary igneous rocks from the Northern Black Hills of importance
 - Rhyolite
 - Porphyritic Rhyolite
 - Monzonite
 - Phonolite
 - ▶ Hydrothermal activity associated with ore deposits (gold and silver)
 - ▶ Occurrences of Thorium and Uranium bearing minerals in the region directly associated
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Methods

- ▶ Sampling and collecting
- ▶ Sample Preparation
- ▶ Gamma-ray Spectrometry
- ▶ Mapping and Statistical Analysis
- ▶ Continued research

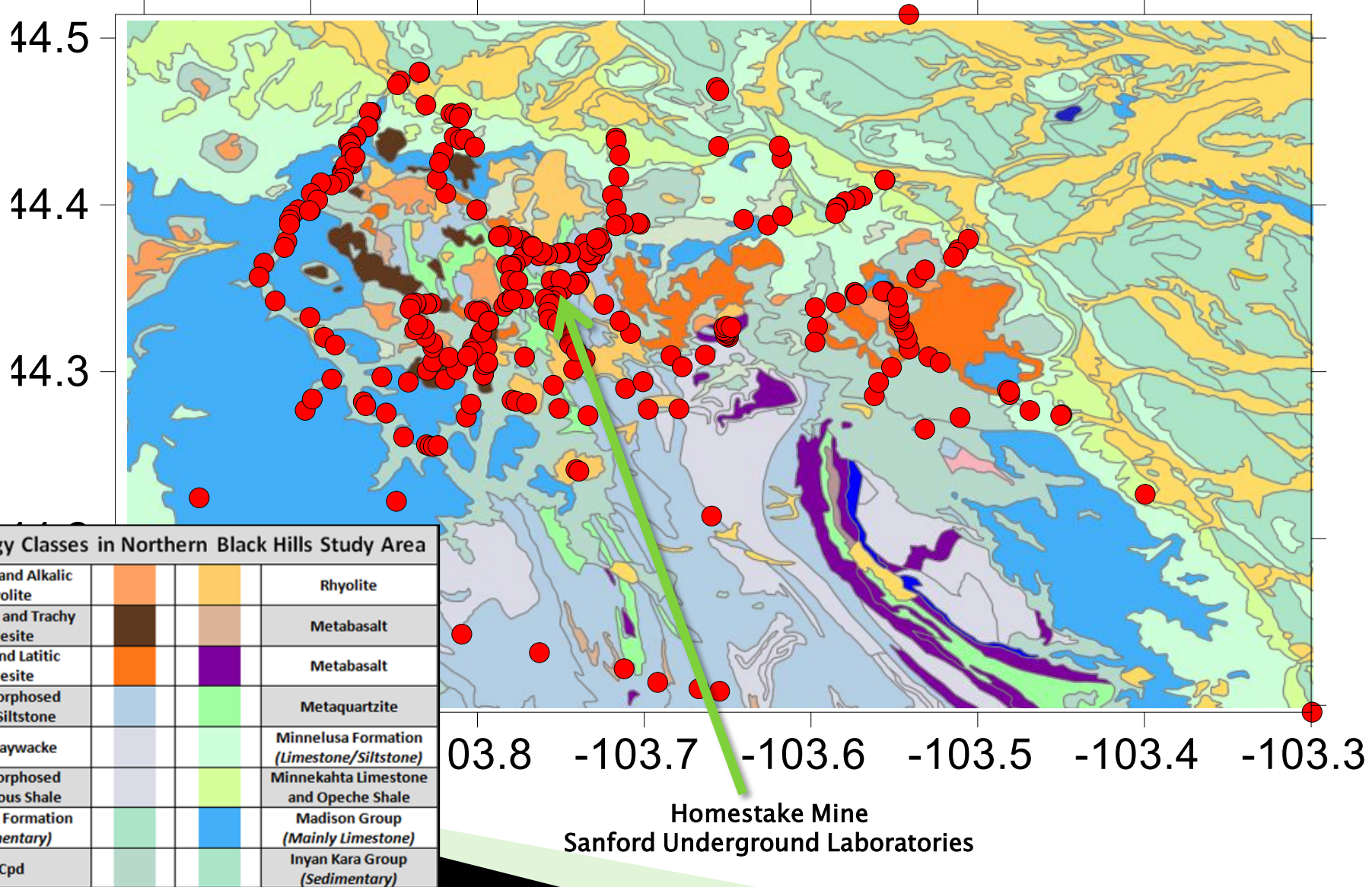





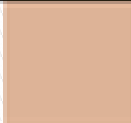


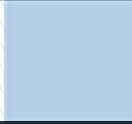



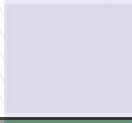
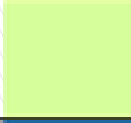


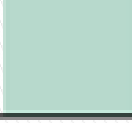
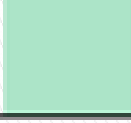
Gamma-ray Spectrometer Readings



251 B – Element Concentrations: 95.88 Th ($\mu\text{g/L}$)
(Sample wt: 750.2g) 0.00 U
2.88 K

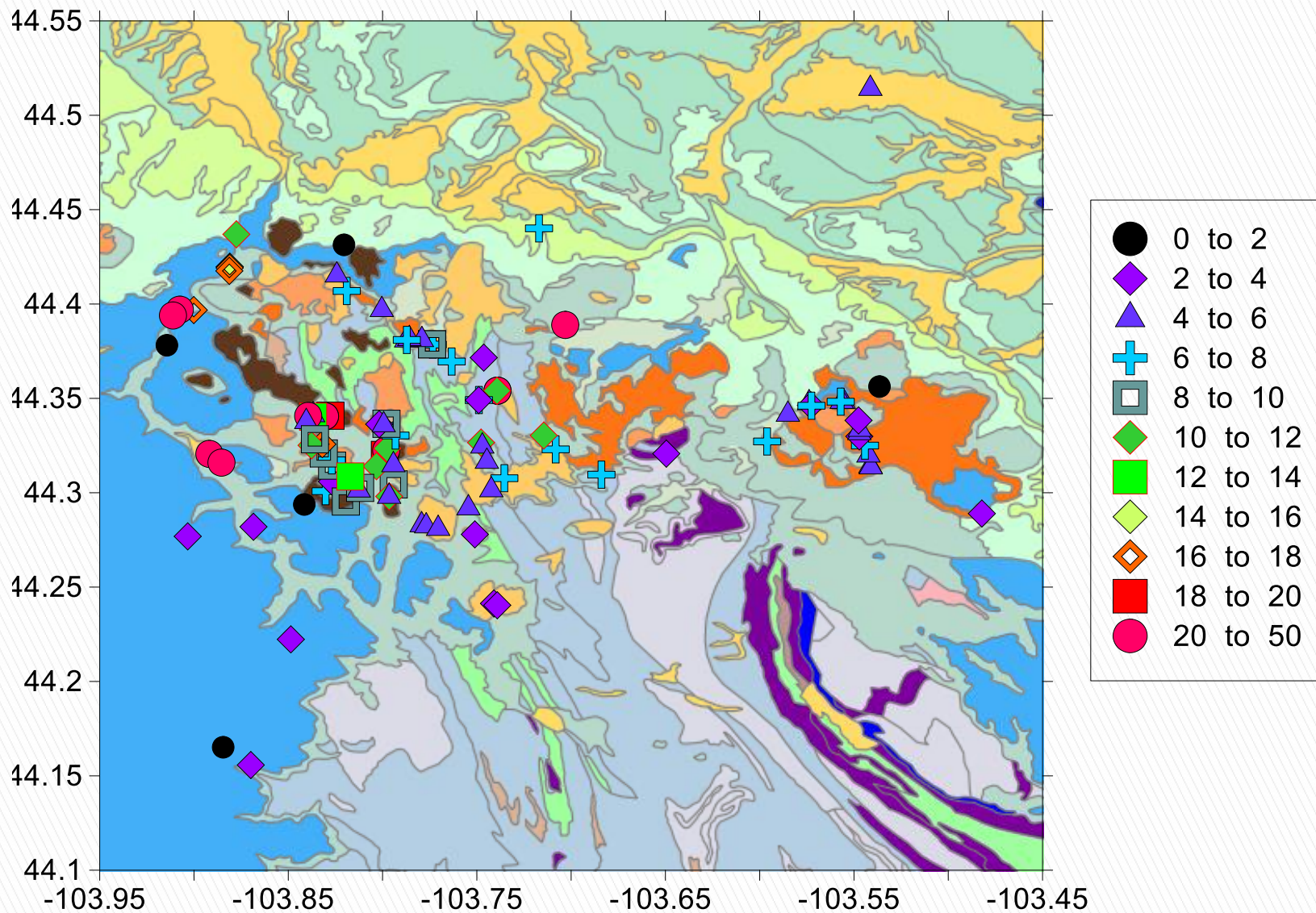
Overview of Northern Black Hills



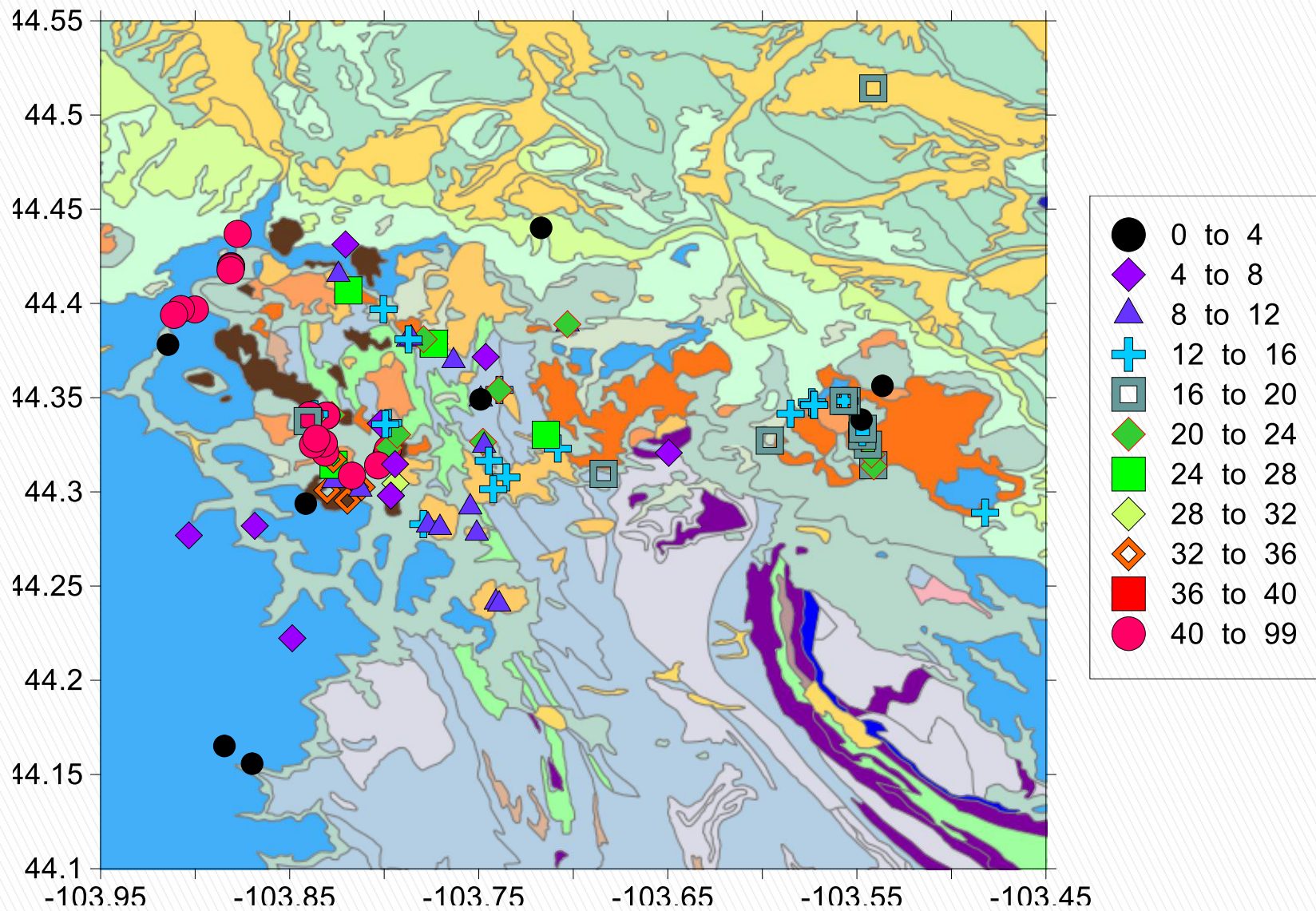
Lithology Classes in Northern Black Hills Study Area			
Trachyte and Alkalic Rhyolite			Rhyolite
Phonolite and Trachy Andesite			Metabasalt
Latite and Latitic Andesite			Metabasalt
Metamorphosed Shale/Siltstone			Metaquartzite
Metagraywacke			Minnelusa Formation (Limestone/Siltstone)
Metamorphosed Tuffaceous 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

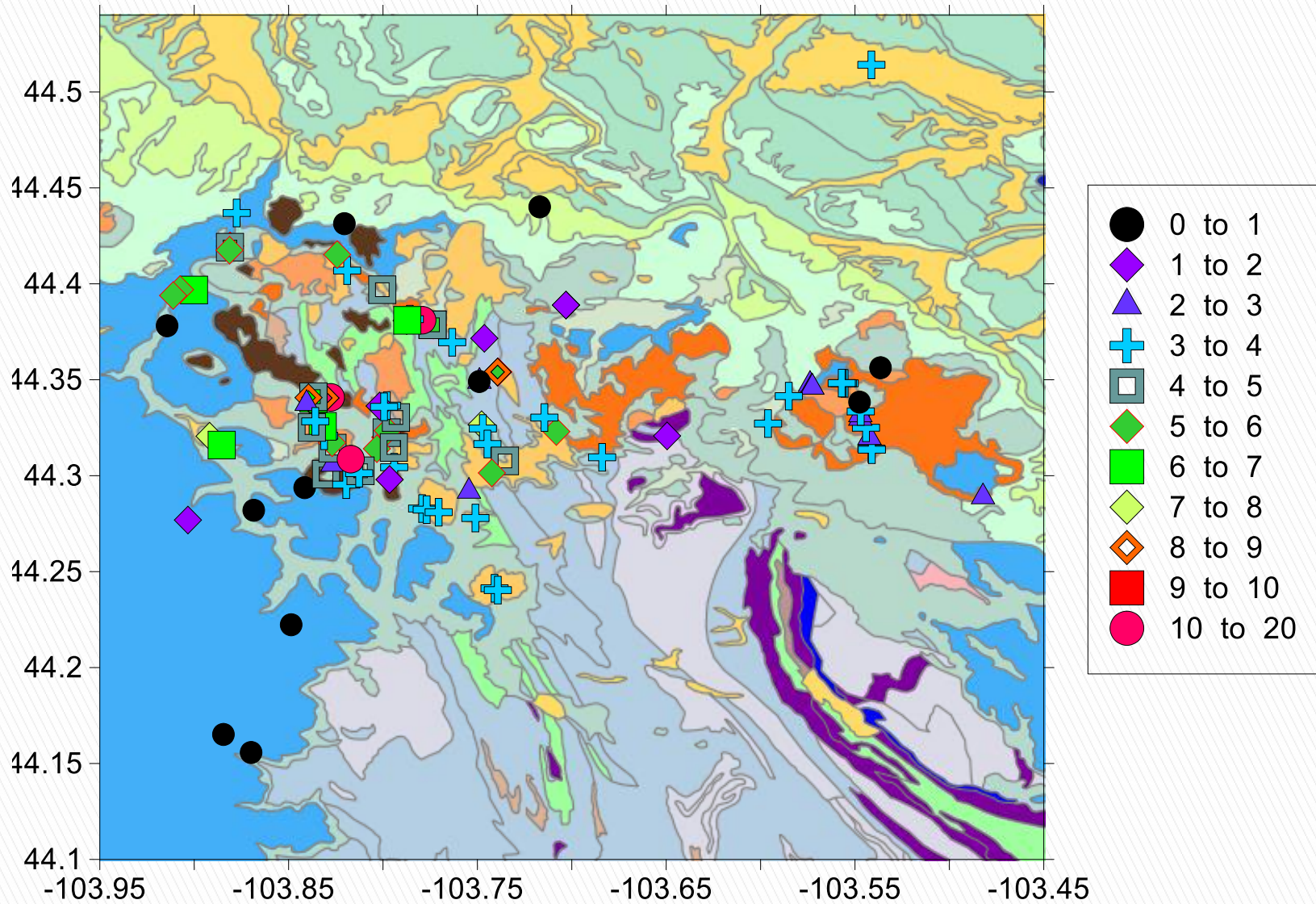
Igneous Rocks Uranium



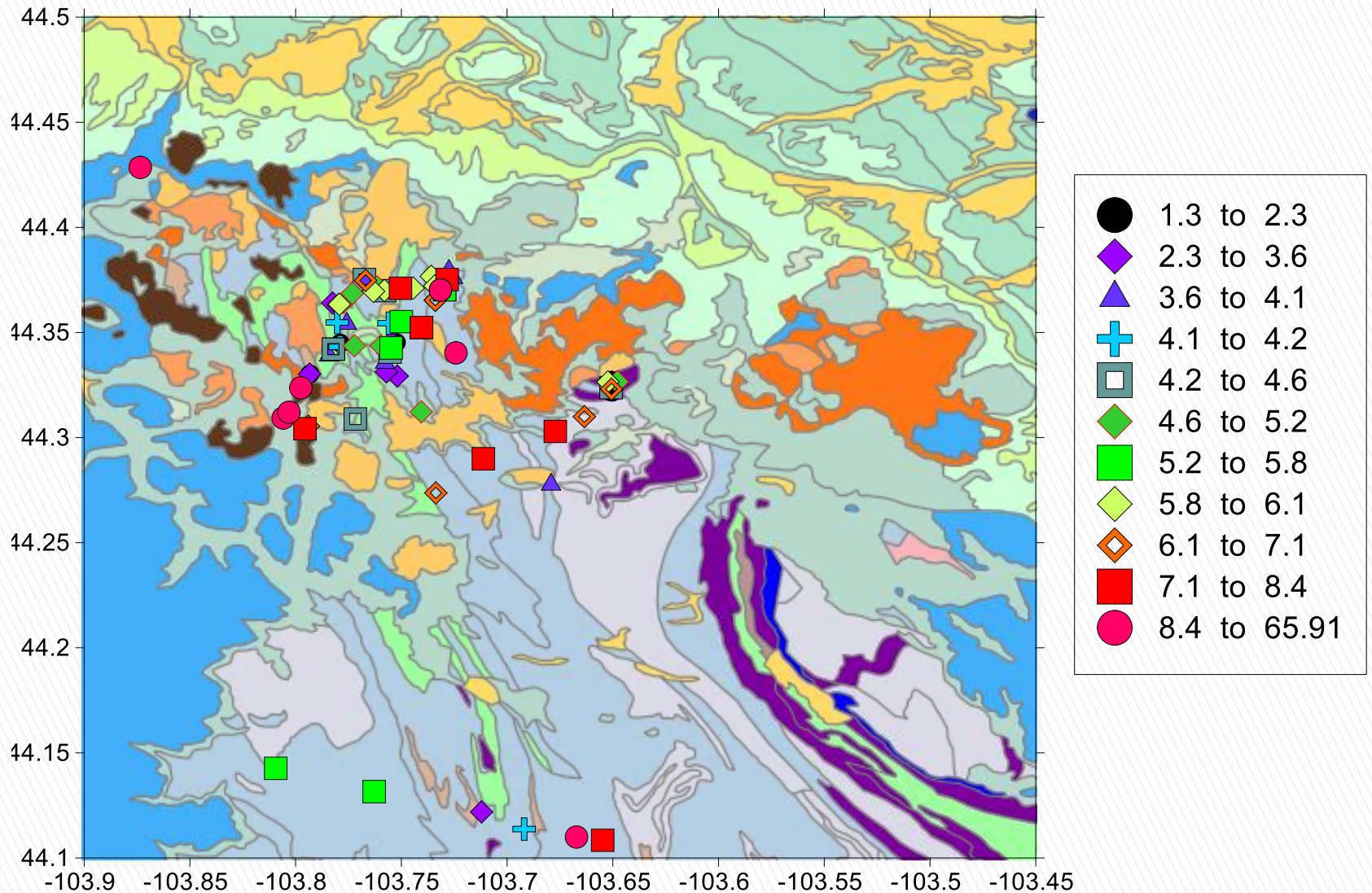
Igneous Rocks Thorium



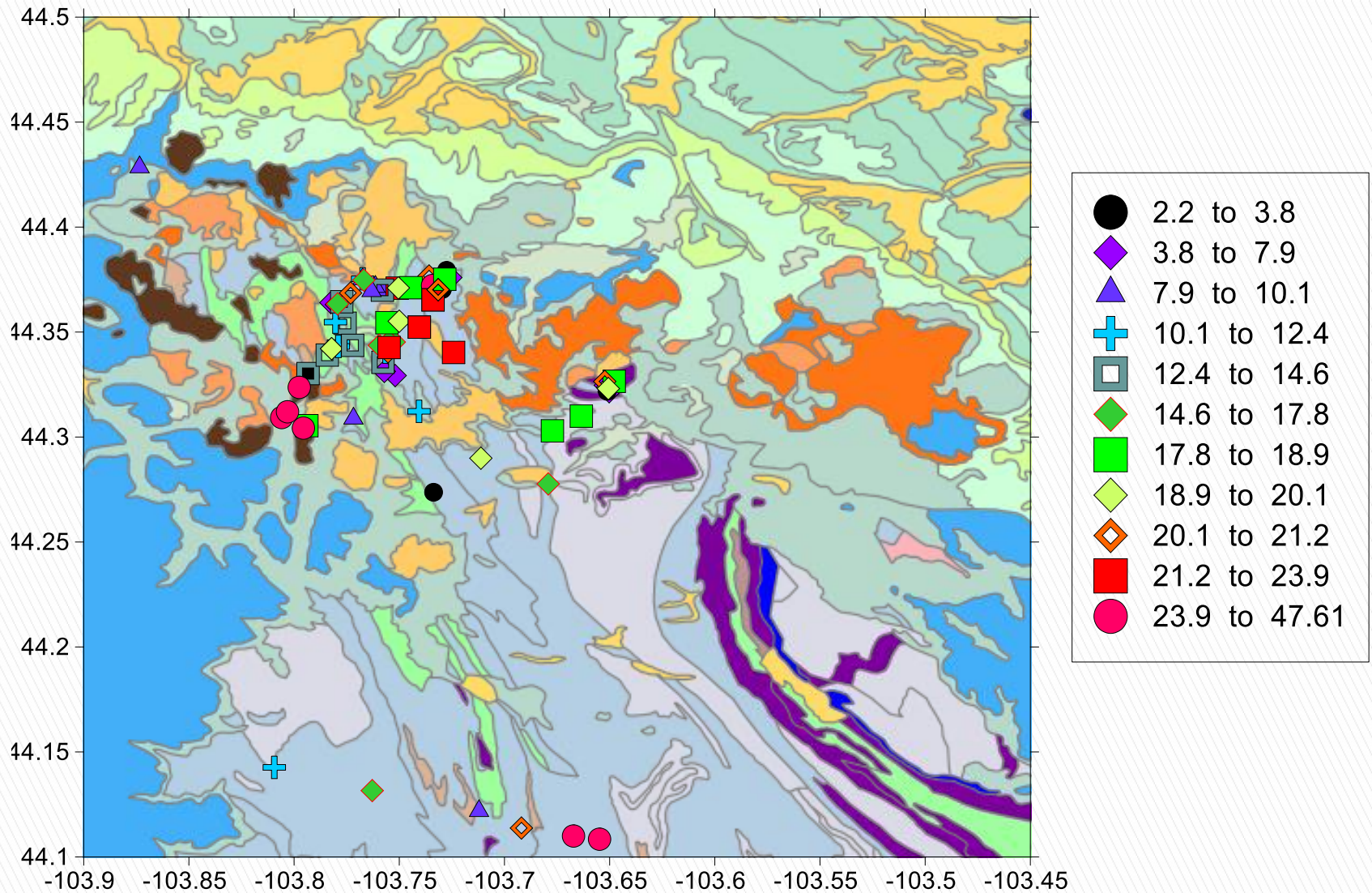
Igneous Rocks Potassium



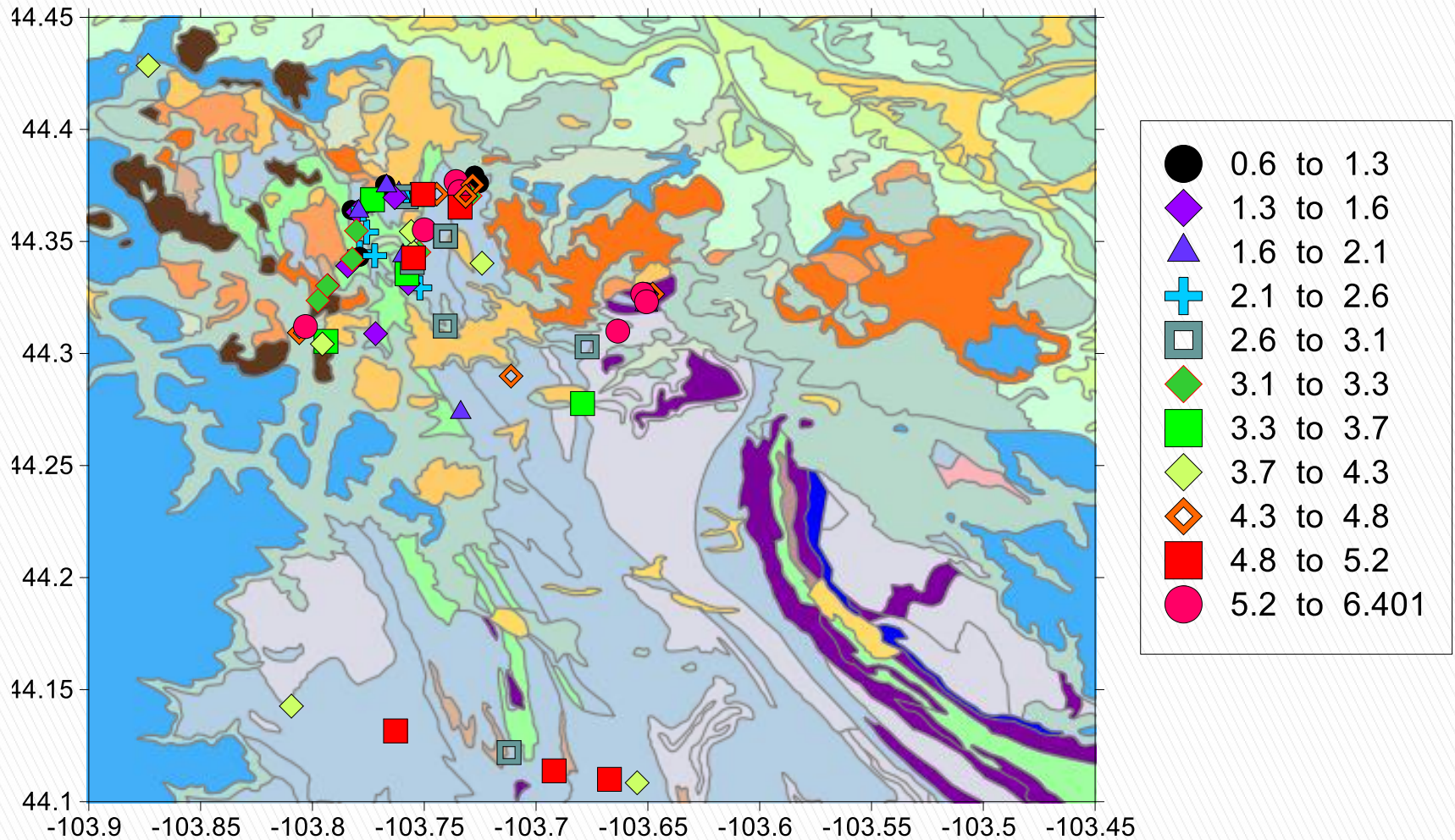
Metamorphic Rocks Uranium



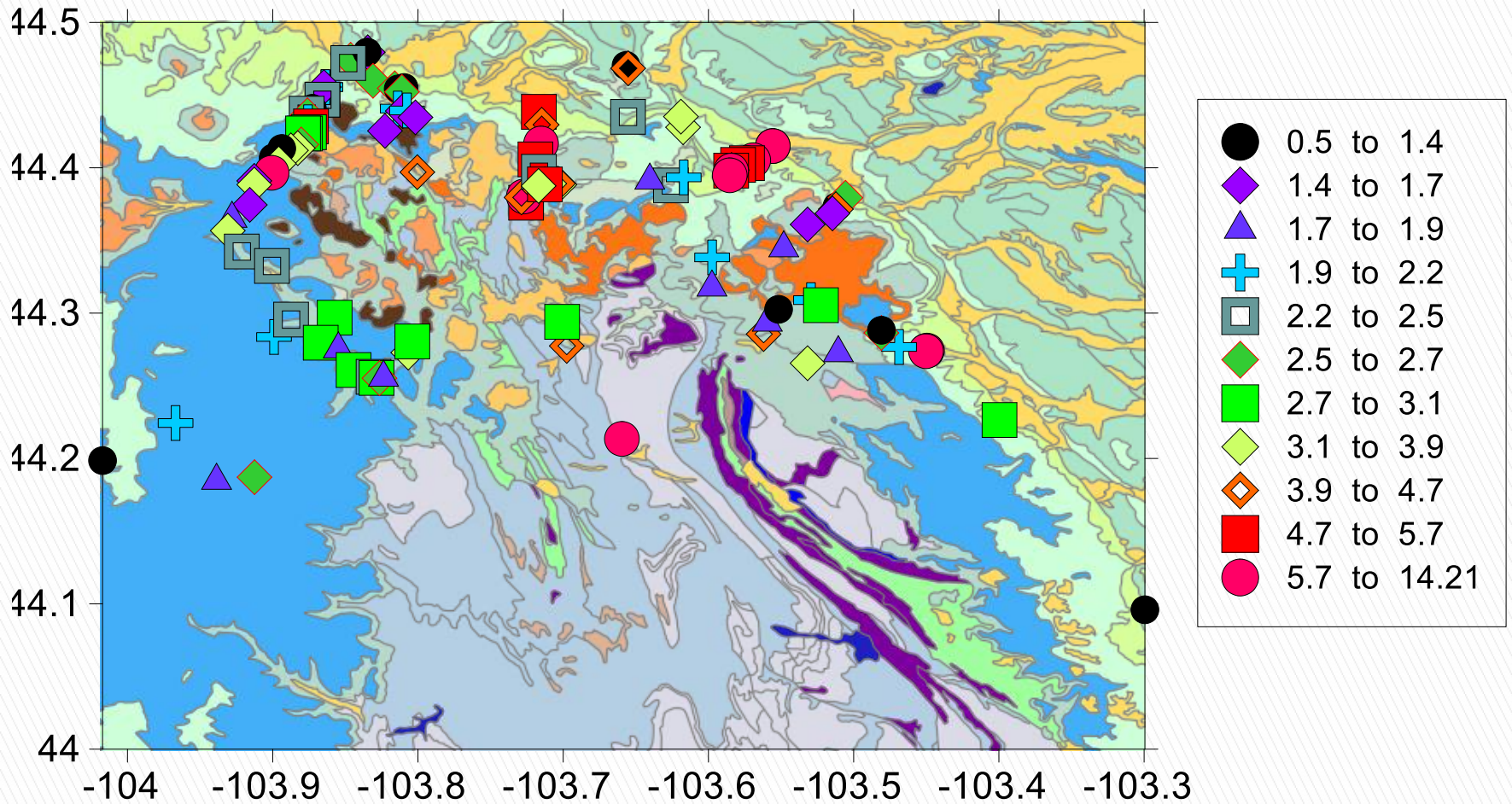
Metamorphic Rocks Thorium



Metamorphic Rocks Potassium

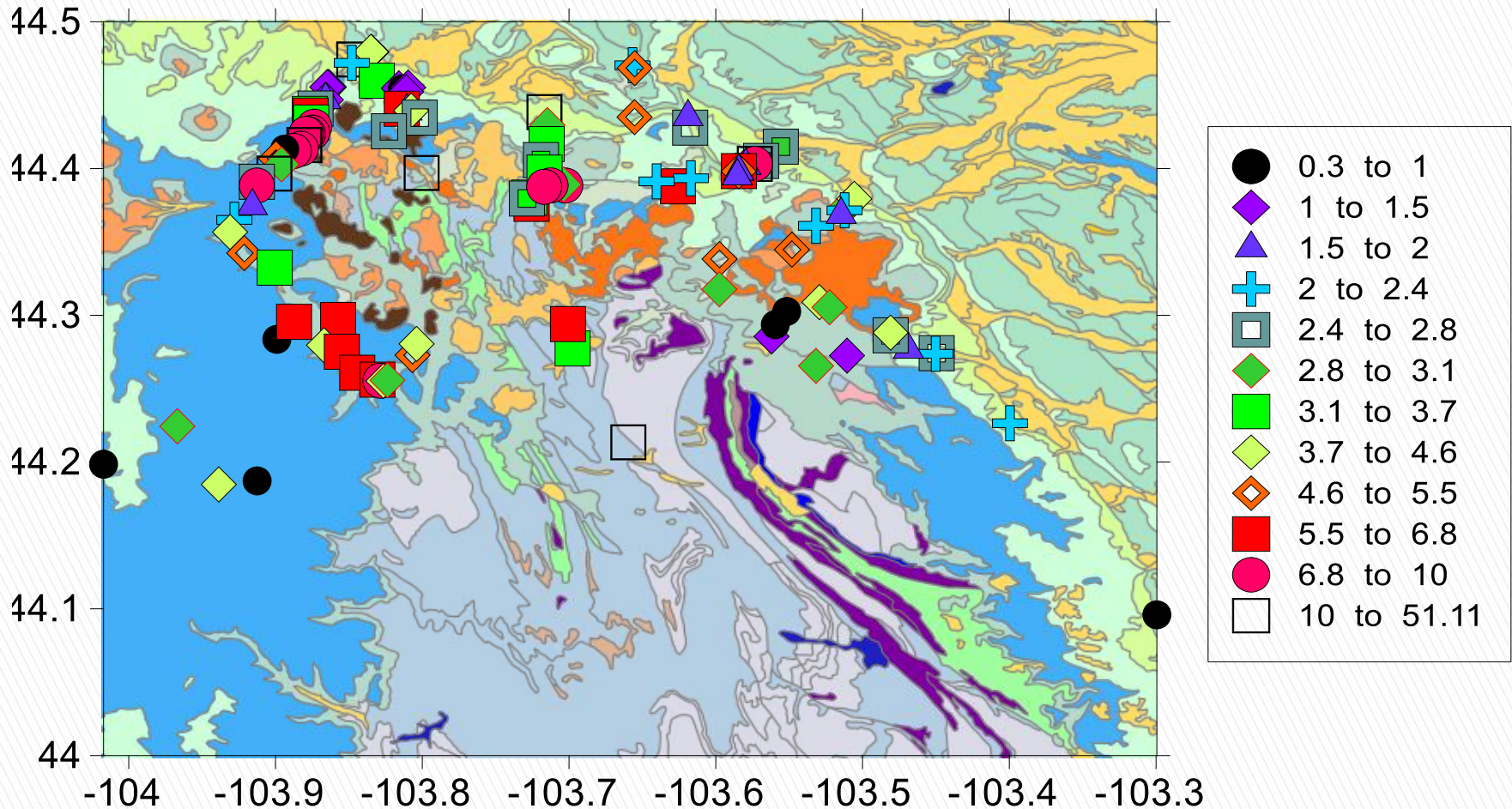


Sedimentary Rocks Uranium



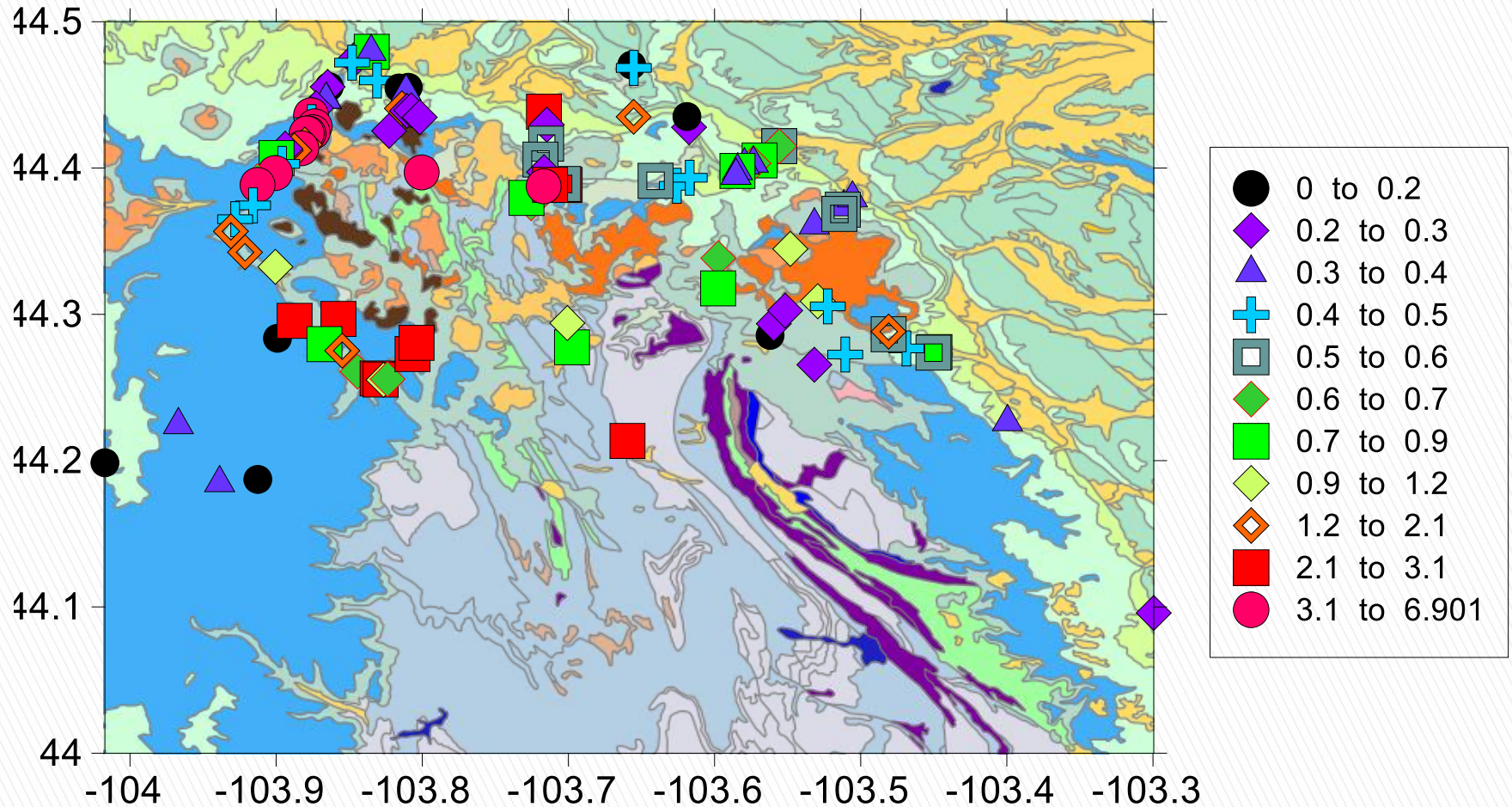
*Some high levels can be associated with greywacke deposits

Sedimentary Rocks Thorium

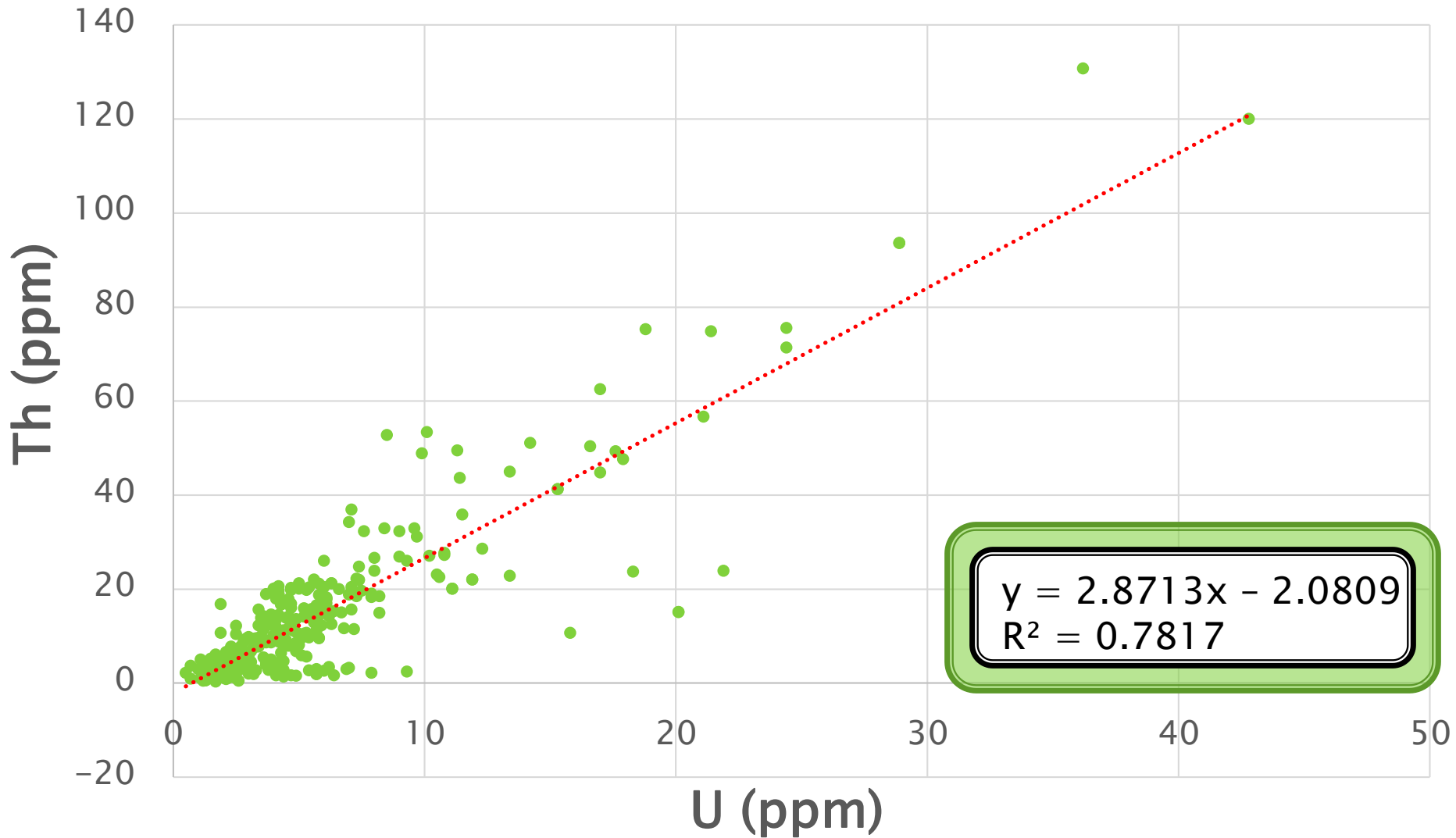


*Some high levels can be associated with greywacke deposits

Sedimentary Rocks Potassium

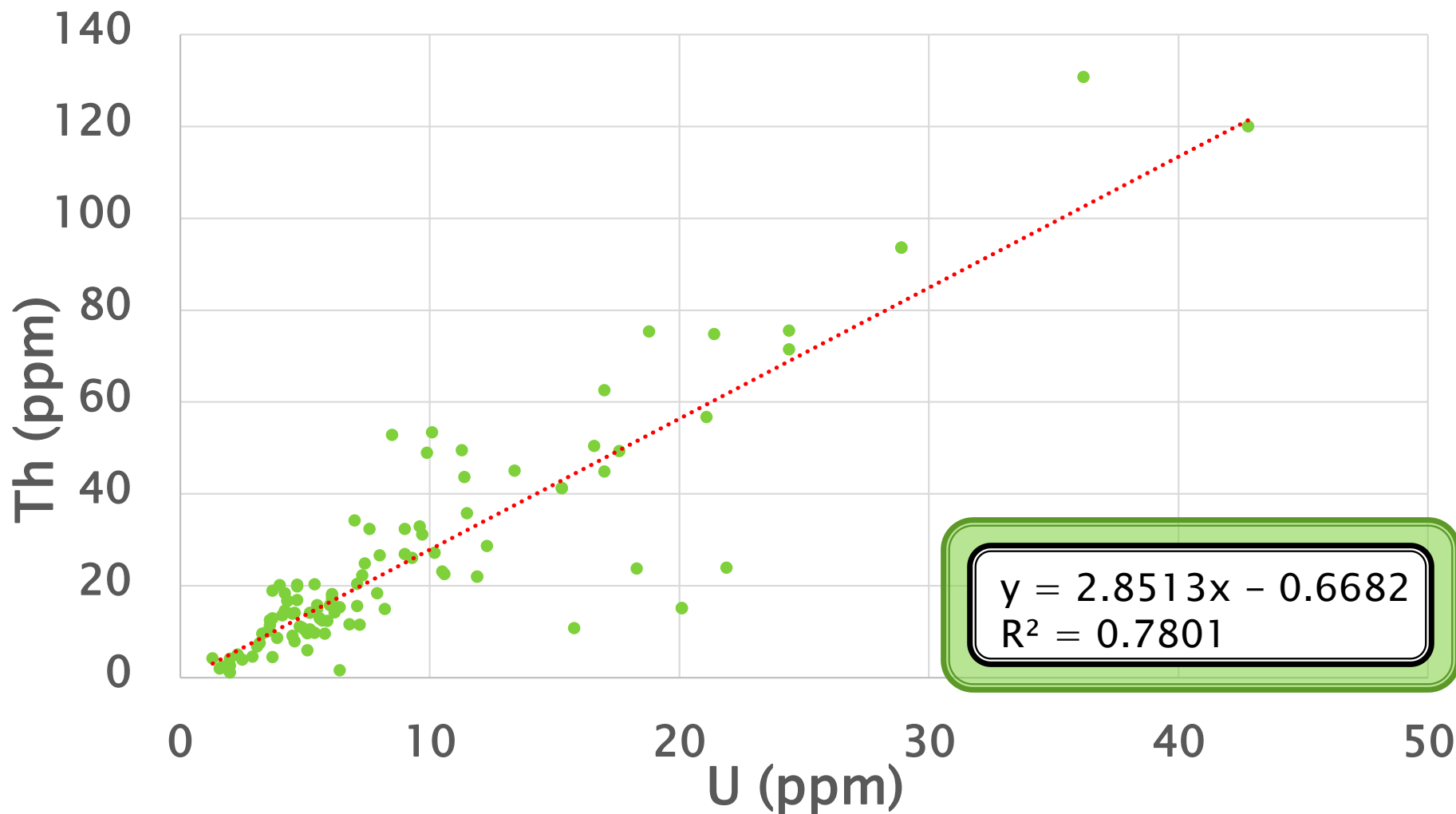


Composite Uranium/Thorium Ratio

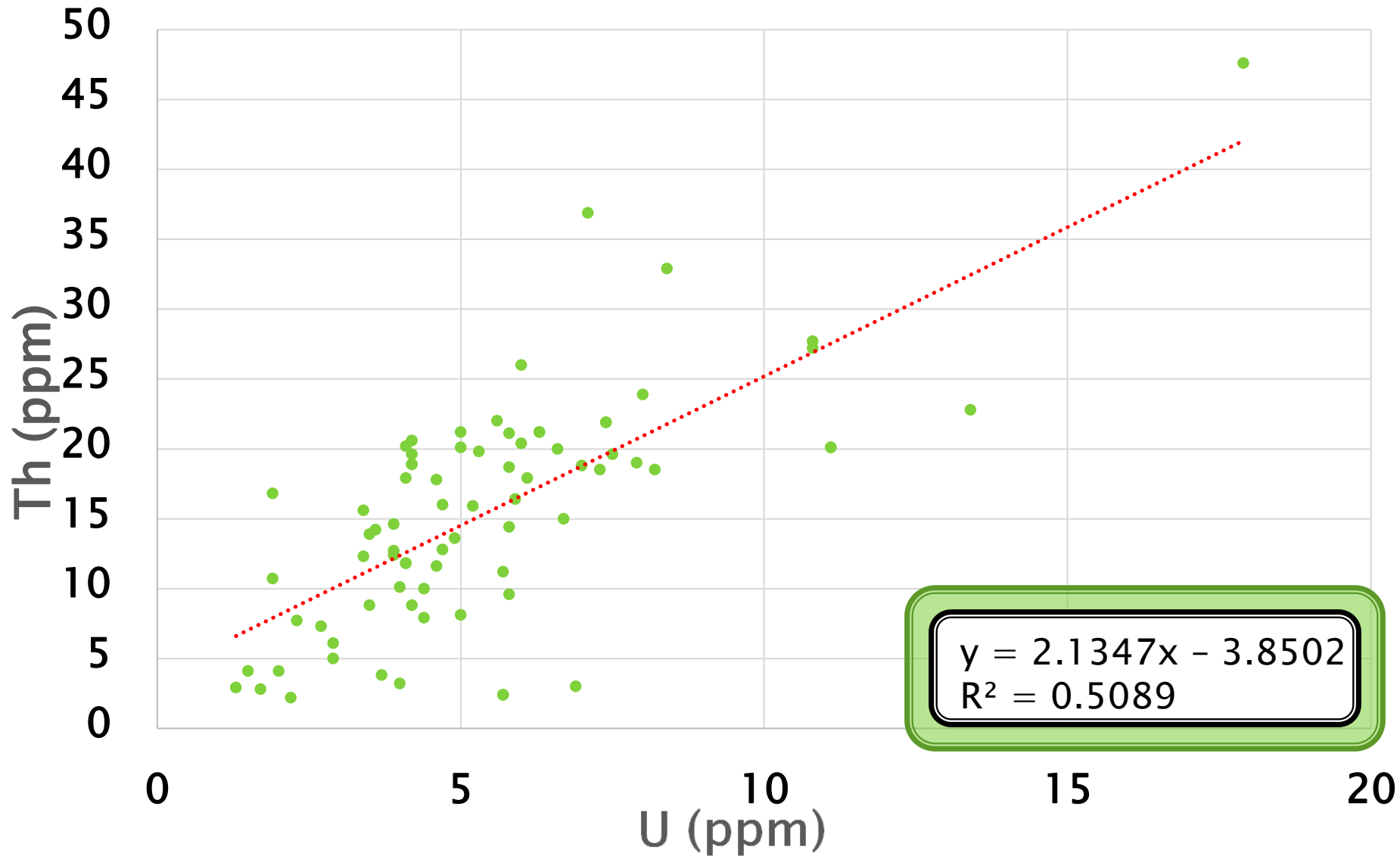


* Includes data from every sample

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 ₂ O (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
<i>2 Std. Dev. Above Avg.</i>	18.92	49.96	7.10

Statistical Results

Average Th/U Ratio

3.83

Black Hills Igneous Rock Radioactivity			
	U (ppm)	Th (ppm)	K ₂ O (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
<i>2 Std. Dev. Above Avg.</i>	18.38	73.83	8.87

Statistical Results

Average Th/U Ratio

2.47

Black Hills Metamorphic Rocks Radioactivity			
	U (ppm)	Th (ppm)	K ₂ O (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
<i>2 Std. Dev. Above Avg.</i>	21.06	31.93	6.12


Statistical Results

Average Th/U Ratio

1.44

Black Hills Sedimentary Rocks Radioactivity			
	U (ppm)	Th (ppm)	K ₂ O (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
<i>2 Std. Dev. Above Avg.</i>	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
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Special Thanks to:

Harney Peak, South Dakota



