Spectroscopy and Microscopy Study of Abandoned Uranium Mine Wastes on Navajo Nation in Northeastern Arizona

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Abandoned Uranium Mine Wastes

- More than 1,000 abandoned mine waste sites on the Navajo Nation, many with only interim reclamation or no remedial actions.
- Rural communities, particularly Native American, live in close proximity of these sites.
- Human health risks associated with metal exposure in these sites remain poorly understood.
- Fundamental understanding about the fate and transport of metals is necessary.

Blue Gap-Tachee Site, Northeastern AZ

Navajo Nation Blue Gap-Tachee mines

- 16779.7 tons
- 4181 tons (Claim 28)
- **Uranium and Vanadium mining (1950s-1980s)**
- **Several families still live at base of cliff next to Claim 28 wastes**

Research Objective

Determine the co-occurrence of U and other metals in abandoned mine wastes using spectroscopy and microscopy.

Research Questions

- In what chemical species are U and co-occurring metals present in abandoned mine wastes in Blue Gap-Tachee Chapter of the Navajo Nation in northeastern Arizona?
- How do these metals move in the environment?

Materials: Field Samples in Blue Gap-Tachee

- Soil (solid/dirt) from surface:

Sample name	Gamma Rad (uR/hr)	Sampling Date
Undisturbed soil	13	January, 2014
Mine Waste 1	320	January 2014
Mine Waste 2	401	June 2014

- Water (sampling date: June 2014):
  - **Seep** in Claim 28 site
  - **Spring** (~0.3 miles away from mine waste).

Water Quality Analyses

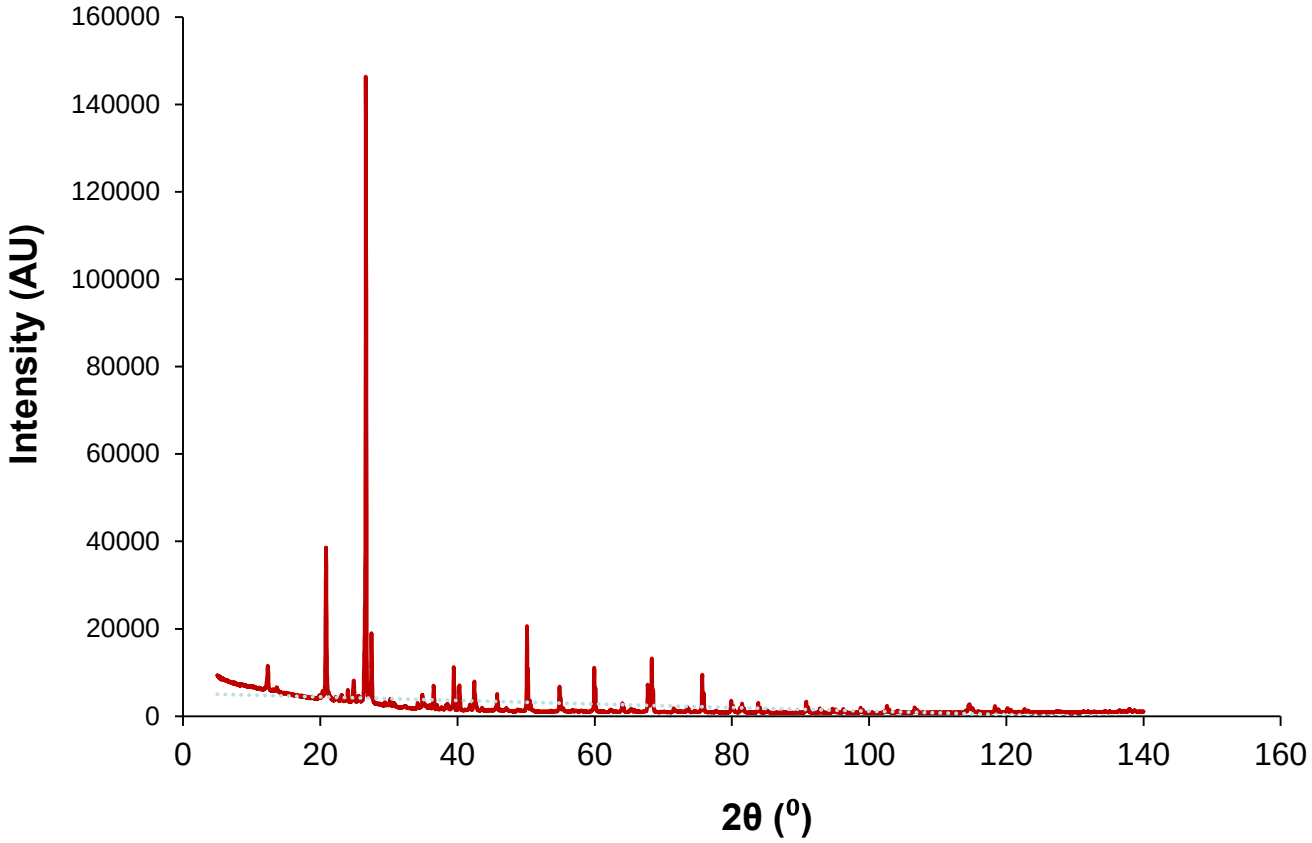
Metals analyzed with ICP-MS*

Sample	Parameter		
	U (µg/L)	As (µg/L)	pH
Spring	163.2	5.7	7.4
Seep	135.4	9.6	3.8
MCL**	30	10	6.5-8.5

*ICP-MS = Inductively coupled plasma mass spectrometry

**MCL = Maximum Contaminant Level, or drinking water standard

X-ray Diffraction (XRD)



Semi-quantitative analyses indicate that:

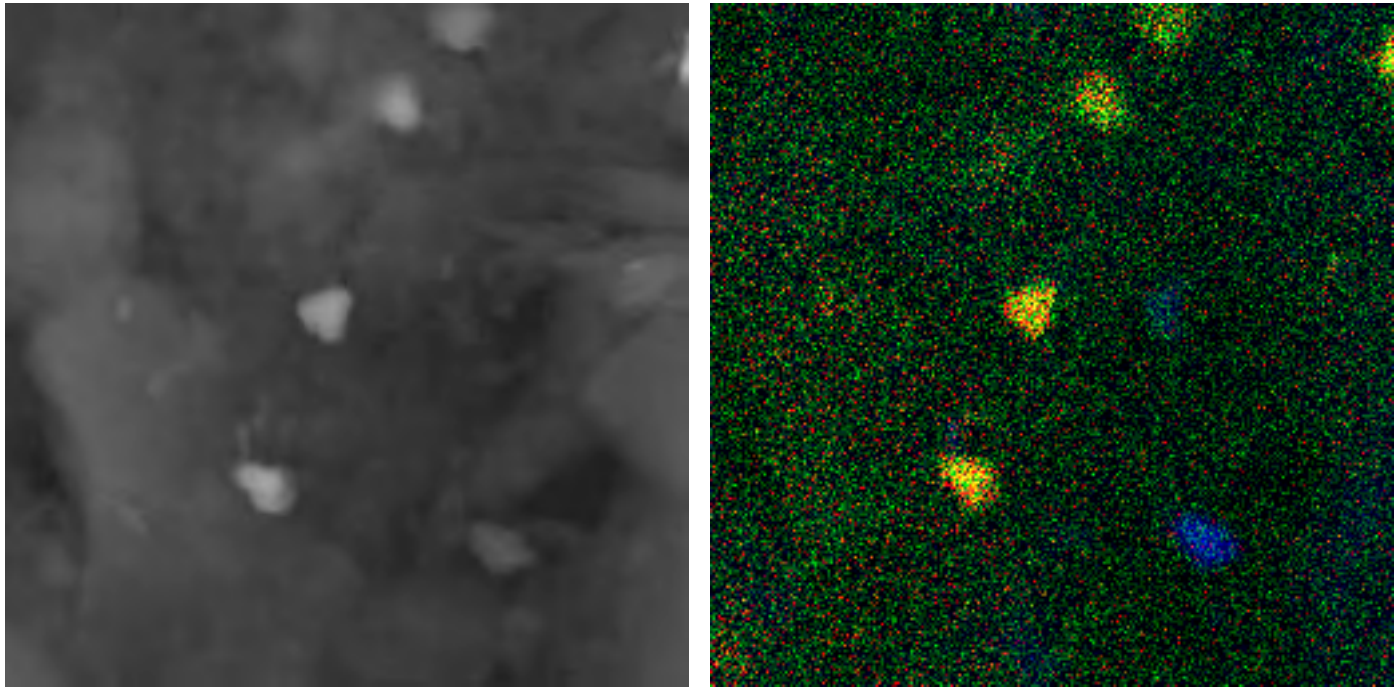
- 59 % quartz
- 34% potassium feldspar
- 7% kaolinite

X-ray Fluorescence (XRF) on Mine Wastes

	Elemental Content, ug g^{-1}							
	Si	**S**	**Al**	**Fe**	**Mg**	**U**	**V**	**Ca**
Undisturbed Soil	241,950	1,339	52,129	26,739	3,068	BDL*	BDL*	16,441
Mine waste1	235,563	223	69,533	15,259	181	2,248	15,814	855
Mine waste2	243,703	1,834	59,730	3,511	405	6,614	4,328	3,293

- Abandoned mine waste solid samples were acid digested (HCl + HF + HNO_3) determine elemental content of 20-40 ug g^{-1} As.
- ug g^{-1} = part per million

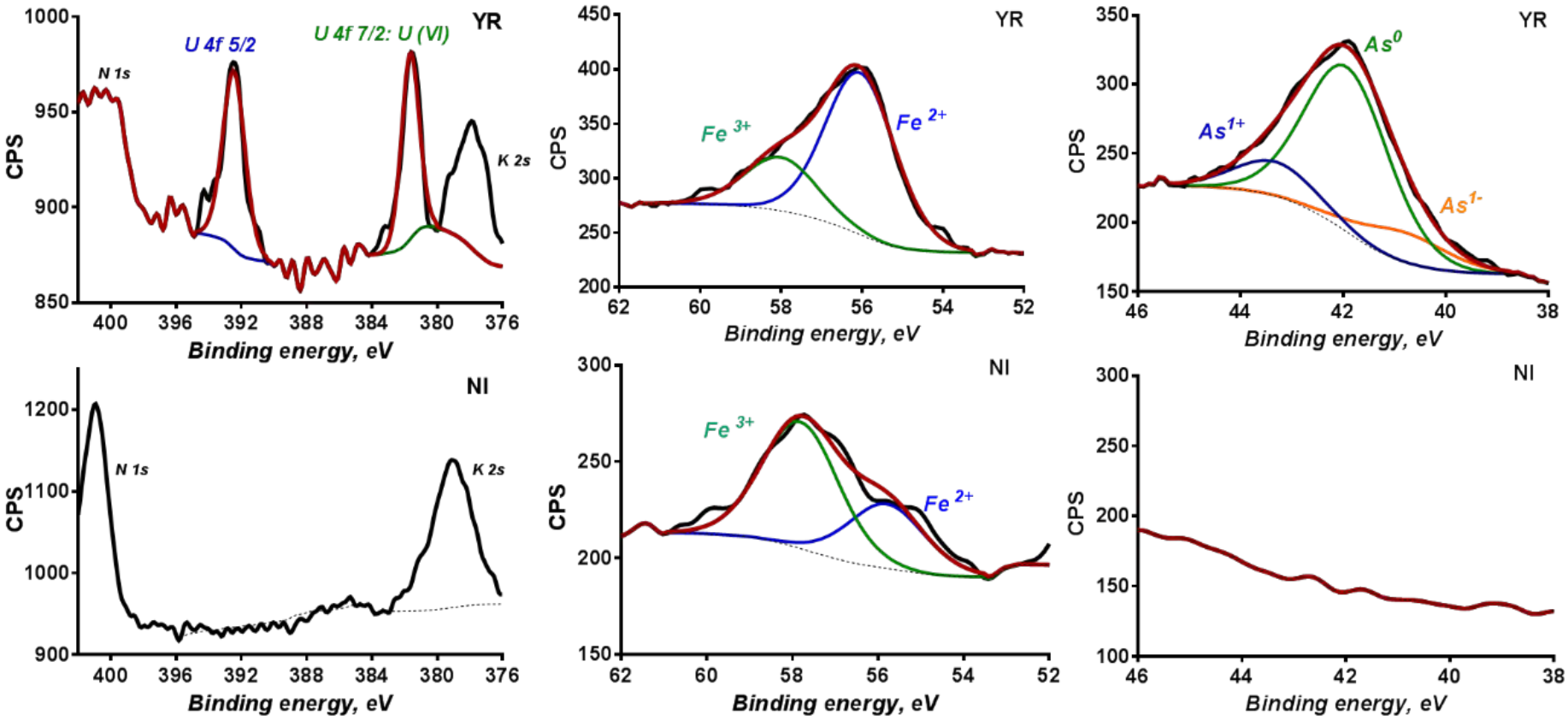
Scanning Electron Microscopy (SEM)



a) Back scattered-electron (BSE) SEM image.

b) Uranium(red) - Vanadium(green) - Iron(blue) composite BSE map. Yellow reflects combined U and V.

X-ray Photoelectron Spectroscopy (XPS)



- ~74% Fe(III) and 26% Fe(II) in undisturbed soils
- ~26% Fe(III) and 74% Fe(II) when U(VI), V(V), and As (0,I) are present.

Batch Chemical Extraction Experiments

Water Quality Data

Sample	Parameter		
	U (µg/L)	As (µg/L)	pH
Spring	163.2	5.7	7.4
Seep	135.4	9.6	3.8

In 50 mL plastic vials loaded with 1g of sediment:

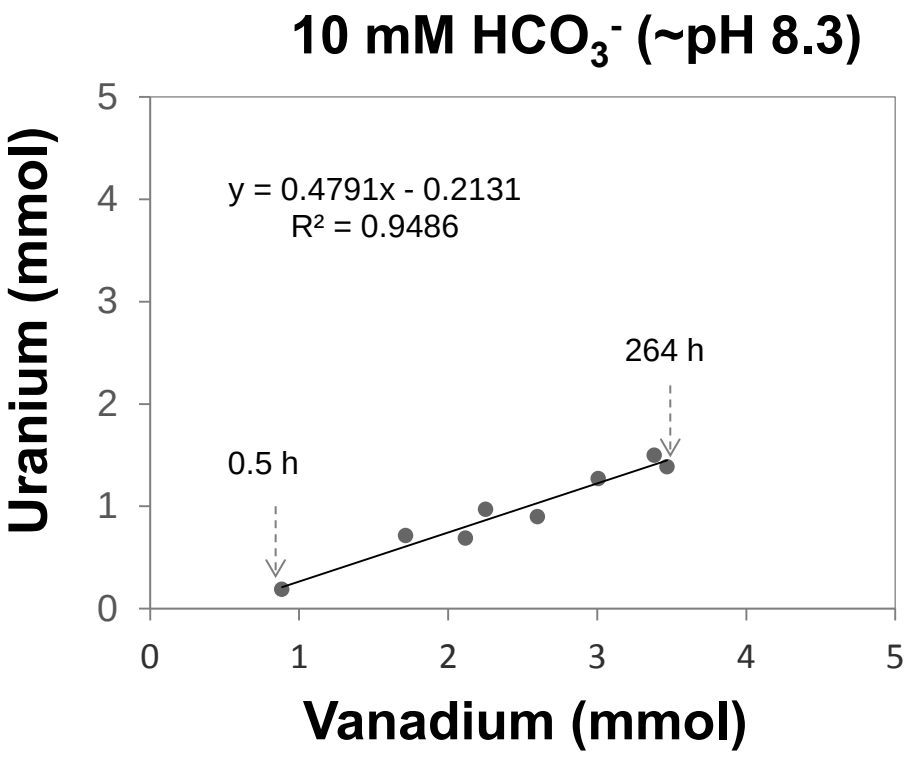
- 10mM HCO_3^- (~pH 8.3)
- 10 mM ascorbic acid, $C_6H_8O_6$ (~pH 3.8).

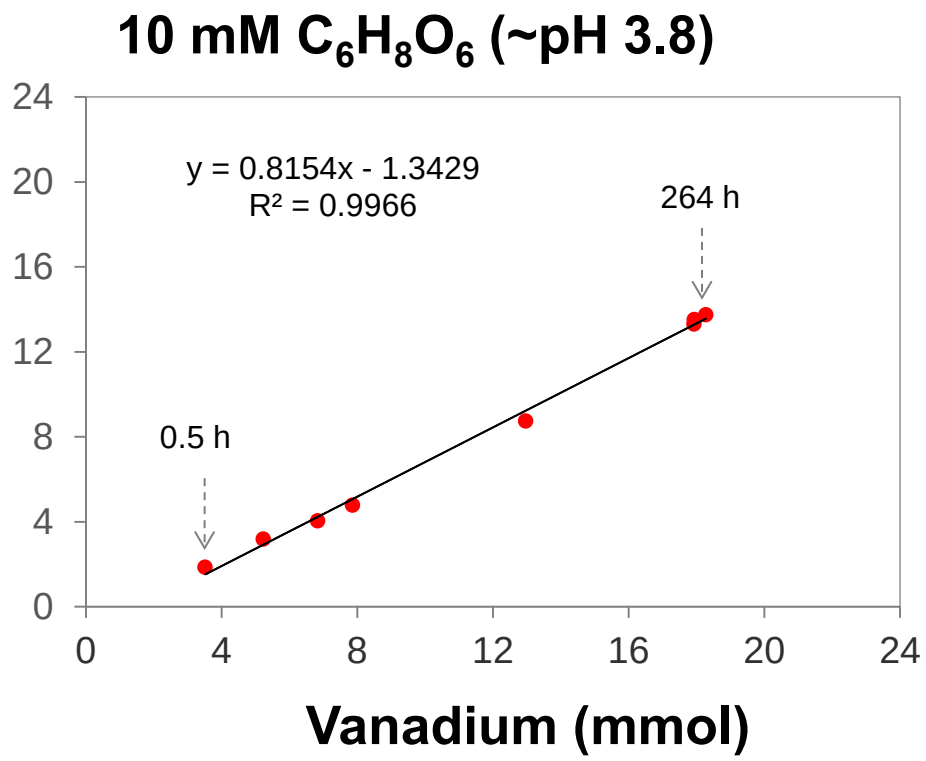
Total Reaction Time = 264 hours. Samples collected at:
0.5, 1, 1.5, 2, 6, 24, 48, 96, 264 hours.

Filtered through 0.22 µm filter membrane, acidified (2% HNO_3).

Measurements of aqueous concentrations with ICP-MS.

Batch Experiments: U vs. V

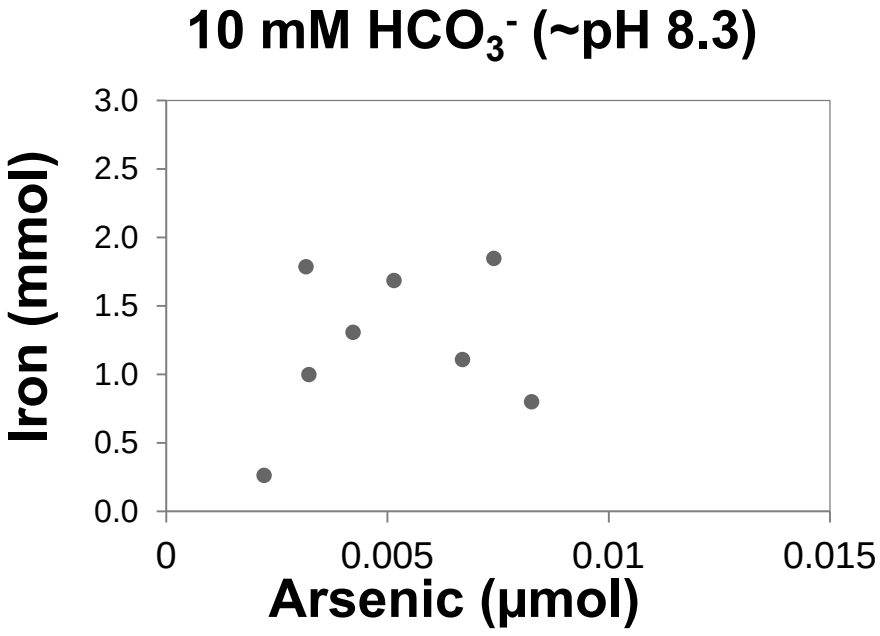


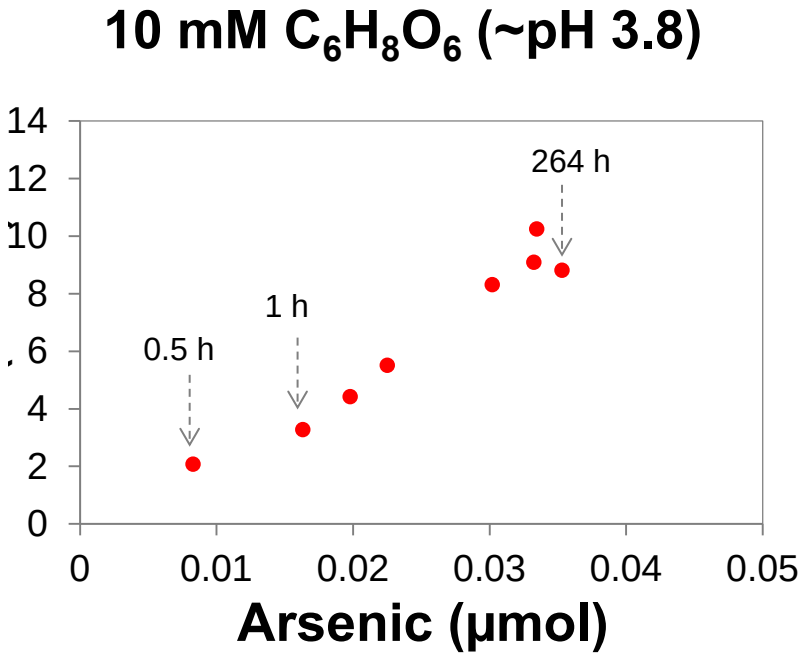


- Release of U was ~ 10 times lower with HCO_3 than with $C_6H_8O_6$.
- Release of V was ~ 5 times lower with HCO_3 than with $C_6H_8O_6$.
- Linear relationship between U and V release.

Reference:
carnotite [$K_2(UO_2)_2V_2O_8$]

Batch Experiments: As vs. Fe





- ~ 25% of As is released at pH 8.3 (no clear correlation with Fe).
- ~ 46% of As released at pH 3.8 in 1 hours.
- Some correlation is observed between As and Fe release after 1 hour of reaction of mine waste with 10 mM $C_6H_8O_6$ (pH 3.8).

Conclusions

- U-V phase present in abandoned mine wastes.
- U and As in mine waste can be released into water under environmentally relevant conditions.
- Release of U is 10 times higher at pH 3.8 compared with 7.4.

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Questions?

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