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Title: Career highlights at Los Alamos National Laboratory

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Putnam, Robert Lee

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Los Alamos
NATIONAL LABORATORY

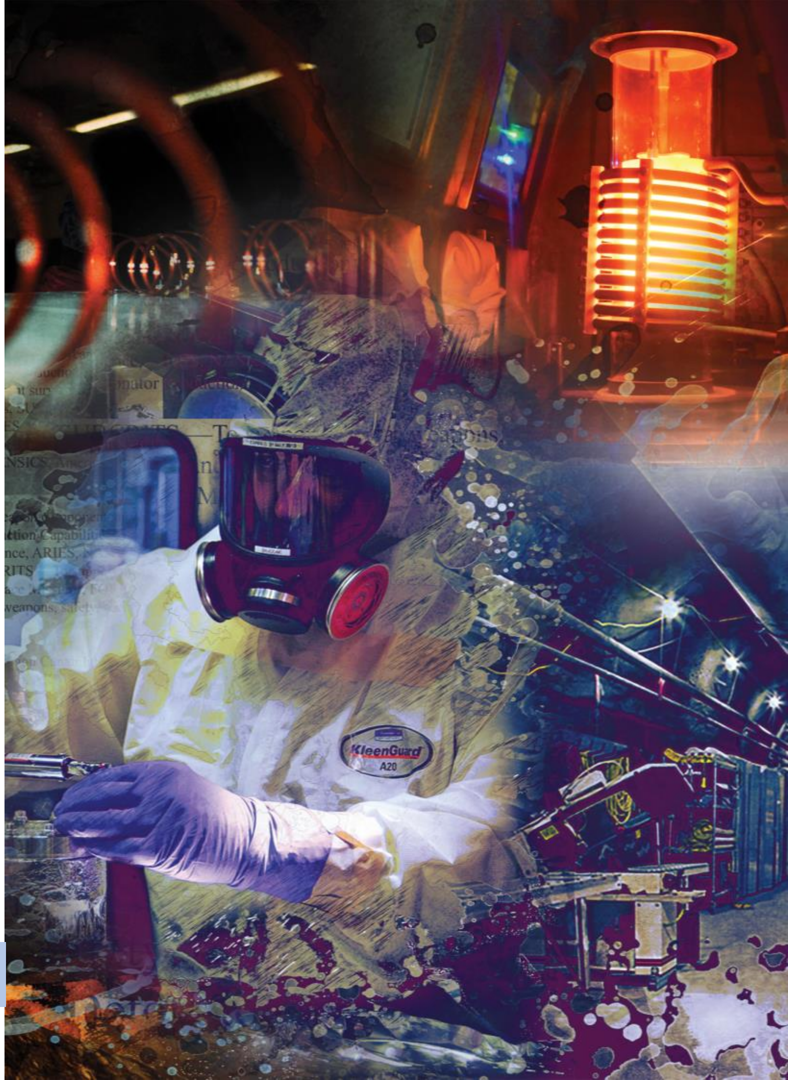
Career highlights at Los Alamos National Laboratory

March 13, 2023
Dr. Robert L Putnam, Chief Production Scientist, LANL ALDWP-TAO
Dr. Chelsea Neil, Scientist, LANL EES-16
Dr. Sarah Hickam, Scientist, LANL MST-16

LA-UR-23-#####

Today’s agenda

- Los Alamos National Laboratory mission and history
- Dr. Putnam – career and highlights
- Dr. Neil – career and technical research
- Dr. Hickam – career and technical research
- Questions and Discussion



Mosaic of actinide nuclear activities at LANL

The Laboratory Mission & Objectives

Mission
To solve national security challenges through simultaneous excellence.

Vision
To be trusted by our nation, emulated by our peers, and respected by the world.

Culture
How we do our work is as important as what we do.

Strategic Objectives

Nuclear Deterrent
Lead the nation in evaluating, developing, and ensuring effectiveness of our nuclear deterrent, including the design, production, and certification of current and future nuclear weapons.

Threat Reduction
Anticipate persistent and emerging threats to global security; develop and deploy revolutionary tools to detect, deter, and respond proactively.

Technical Leadership
Deliver scientific discoveries and technical breakthroughs to advance relevant research frontiers and anticipate emerging national security risks.

Trustworthy Operations
Consistently demonstrate and be recognized by diverse stakeholders for trusted and trustworthy operations.

Our Values

Service
Serving our nation, our partners, our community, and each other.

Integrity
Demonstrating honesty, ethical conduct, accountable stewardship, and individual responsibility.

Teamwork
Achieving our best by respecting diverse opinions and backgrounds, exploring alternatives, and collaborating with colleagues and partners.

Excellence
Ensuring safe and secure mission delivery in nuclear security; science, technology, and engineering; operations; and community relations.

LANL by the numbers

As of July 2022

40
size of the site, in square miles

3,500
telework or hybrid employees

$2B
planned procurements in FY22

15,000
total workforce

49%
staff who identify as minority

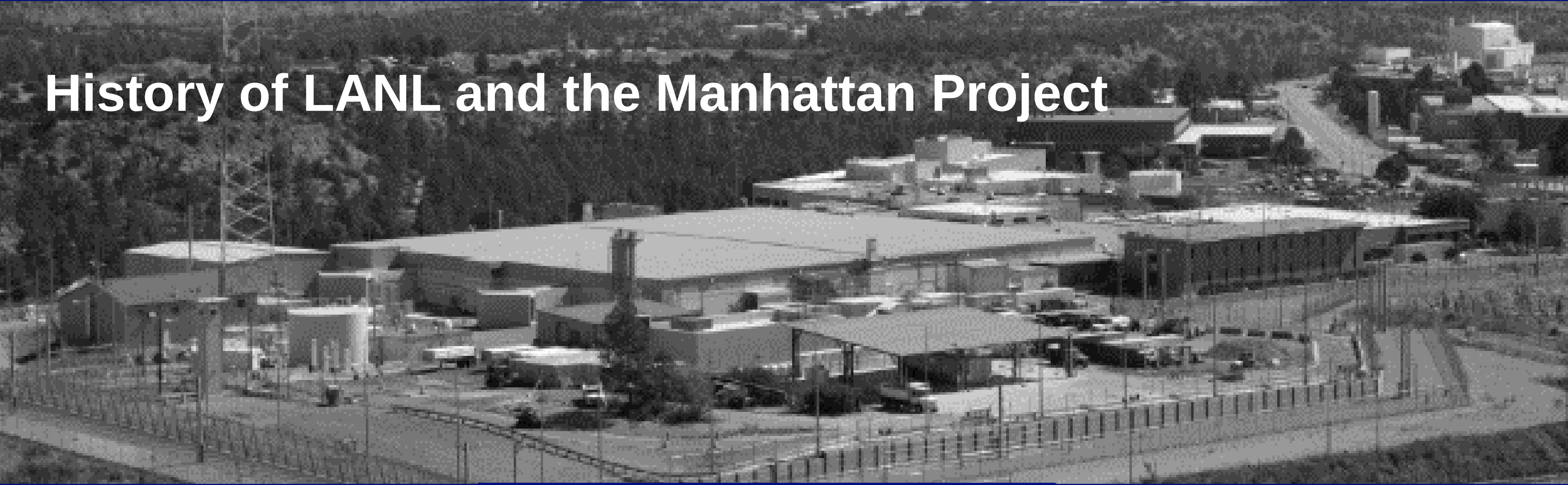
$1.3B
payroll

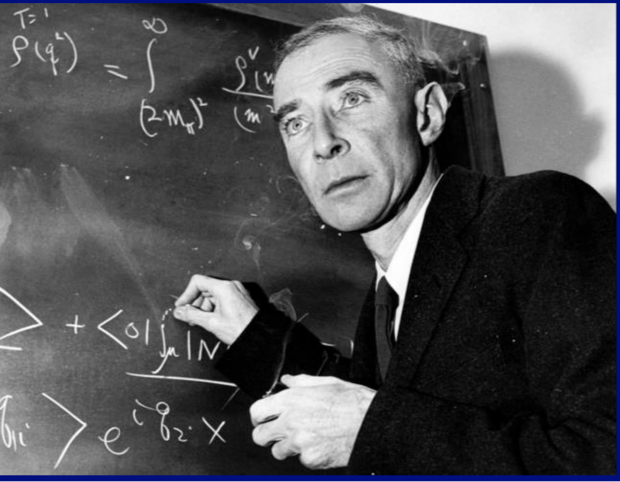
Up to **2,000**
planned hires for FY22

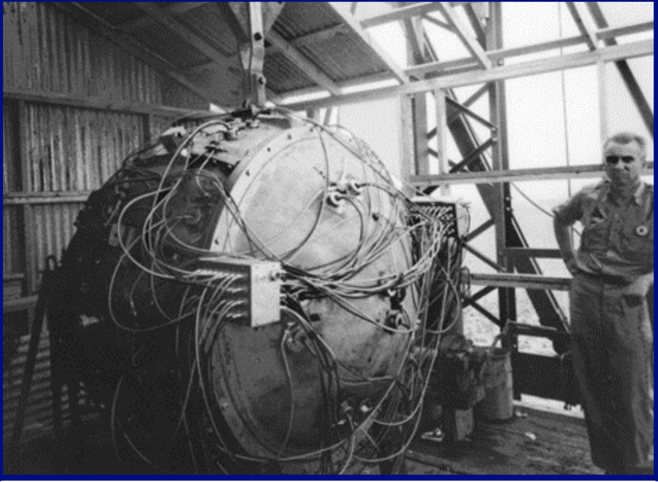
33/67
staff who ID as female/male

$103K
average starting salary

History of LANL and the Manhattan Project

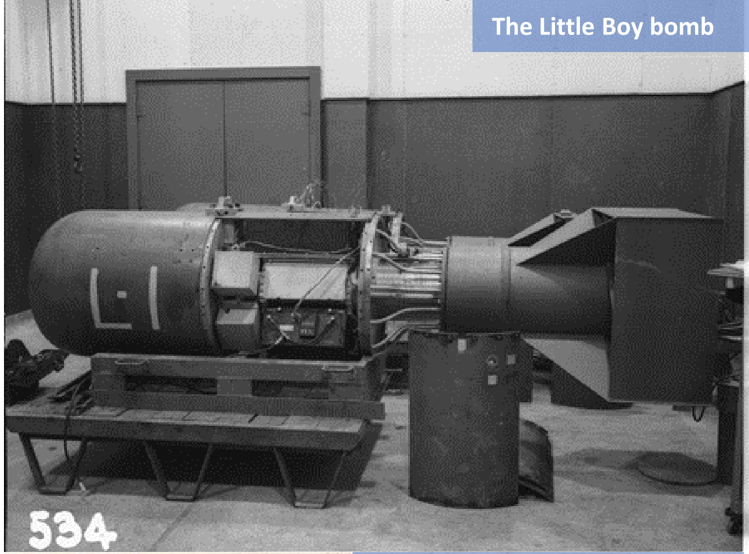




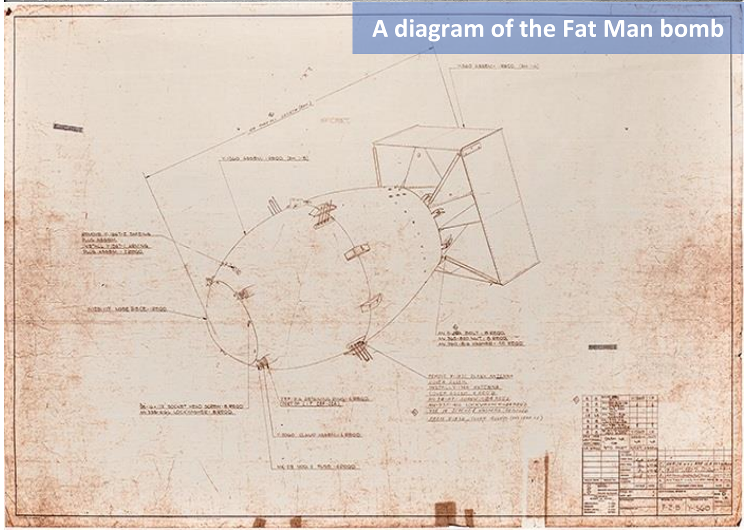


Our history with weapons production

- The Laboratory began in 1943, a few years after the start of World War II, for a single purpose: to design and build an atomic bomb.
- On July 16, 1945, the world's first atomic bomb was detonated 200 miles south of Los Alamos at Trinity Site.
- Two types of nuclear weapons were developed at the Los Alamos wartime lab in an effort to help end World War II. Both would be released above Japan just days apart, in August 1945.
    - Little Boy was a uranium, gun-type weapon
    - Fat Man was a plutonium, implosion-style weapon



The Little Boy bomb


A diagram of the Fat Man bomb

A career in support of national security

Dr. Robert L Putnam

Chief Production Scientist, LANL ALDWP-TAO

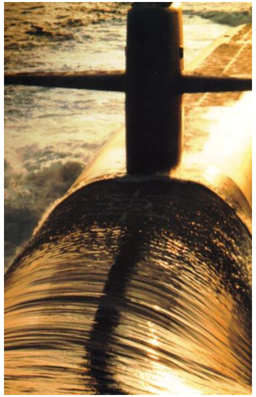
Dr. Robert L. Putnam

- B.S. Chemistry – Brigham Young University (BYU) (1992)
- M.S. Physical Chemistry – BYU (1995)
  - *Thesis: Thermodynamic Study of Lyophilized Yeast Cells. Construction of an Automated Micro-scale Adiabatic Calorimeter for Measurement of Heat Capacities of Solid Samples from 13K to 325 K and Data Acquisition Software for use with the Brigham Young University Cryogenic Adiabatic Calorimeters.*
- M.A. Geosciences – Princeton (PU) (1998)
- PhD. Geosciences – PU (1999)
  - *Dissertation: Formation energetics of ceramic waste materials for the disposal of excess weapons plutonium.*
- Post Doc – Los Alamos National Laboratory (LANL) (1999-2001)
- M.A. Program and Project Management – George Washington University (2005)
- Staff / manager at LANL (2001 – present)

Highlights of a LANL career

- Department of Energy National Nuclear Security Administration (DOE/NNSA) – led the restoration of pit manufacturing capability to the United States of America after 19 years without (2007)
- Department of Defense – Senior Policy Advisor for Nuclear Defense in GSA/CWMD (2011-2014)
  - Post Fukushima response and recovery
  - NATO CWMD
  - Siria Chemical Weapons
- DOE/NNSA – NA-10 Science Council Member (2014-2016)
- Chief Production Scientist, LANL plutonium facility, and director of the Technical Applications Office

- W76 – Submarine Launched Ballistic Missile



- W88 – Submarine Launched Ballistic Missile

- B61 – nuclear gravity bomb

- W78 – Intercontinental Ballistic Missile

Career Advice

- The more you work interdisciplinary problems with teams the more effective and valuable you are at a National Laboratory such as LANL
- Do not hesitate to branch out and learn new things and skills
- Collaborate and network
- Have fun and do something good/worthwhile

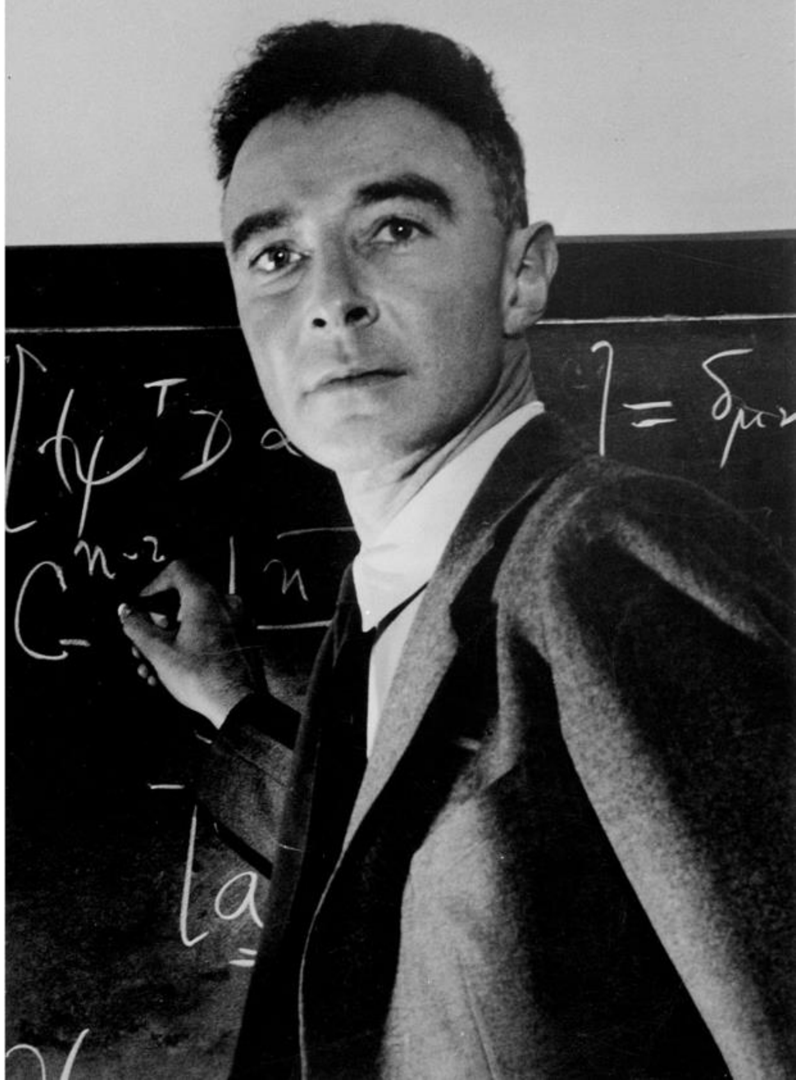
Today is a good day in National Nuclear Deterrence

Thank you from LANL

“There must be no barriers for freedom of inquiry. There is no place for dogma in science.

The scientist is free, and must be free, to ask any question, to doubt any assertion, to seek for any evidence, to correct any errors.”

–J. Robert Oppenheimer

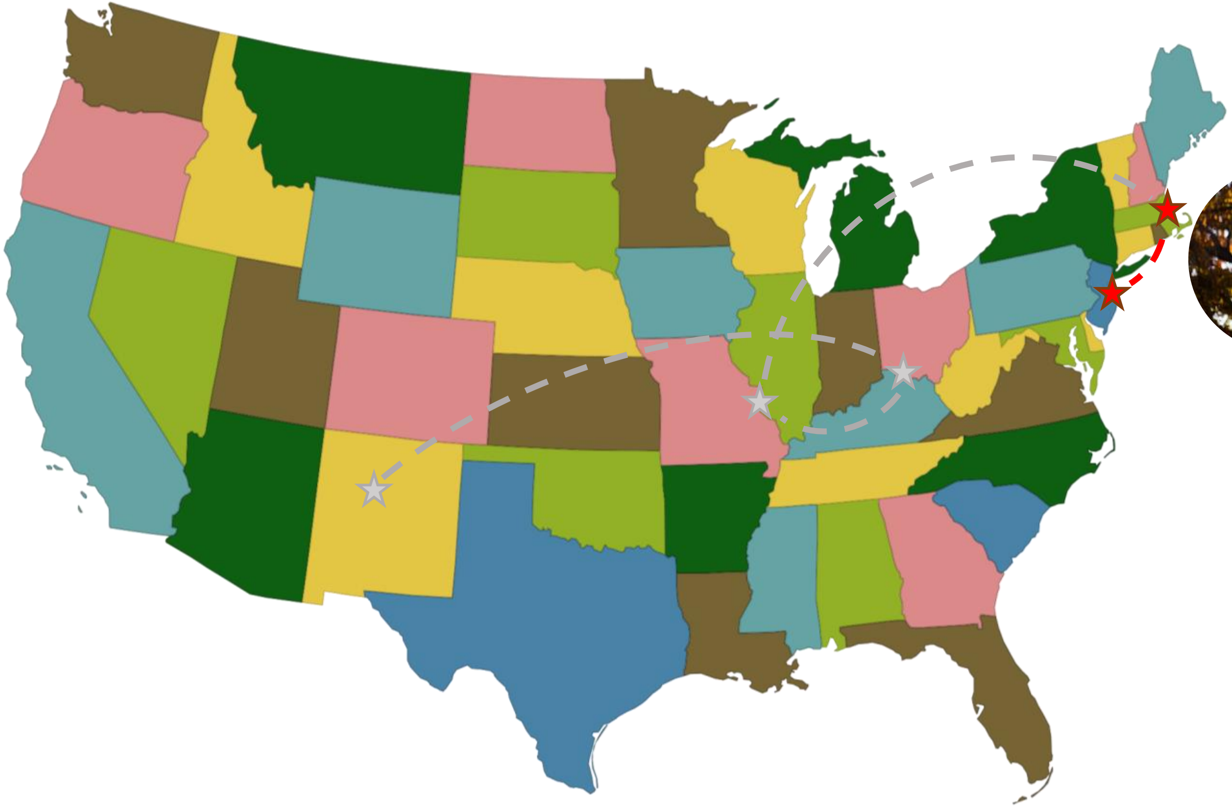


Geochemistry to support LANL's national and energy security missions

Dr. Chelsea Neil

Earth and Environmental Sciences Division, EES-16

The road so far…

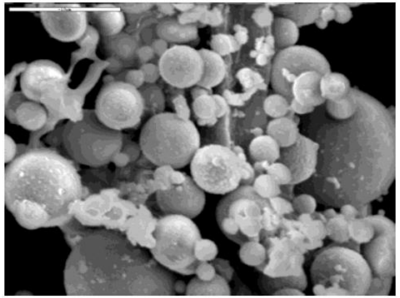


Tufts University
Medford, MA
B.S., Chemical Engineering

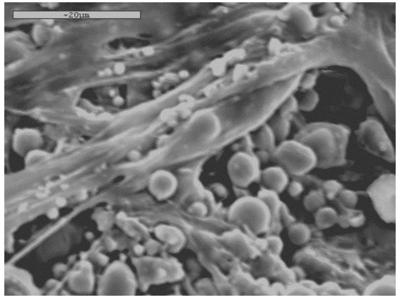
Tufts University

Tufts University
Medford, MA
B.S., Chemical Engineering

- B.S. in Chemical Engineering
  - Department of Chemical and Biological Engineering
- Began research through the Tufts Summer Scholars program working with Dr. Chris Swan in the Civil and Environmental Engineering Department
- Led to a senior honors thesis on toxin leaching from coal fly ash

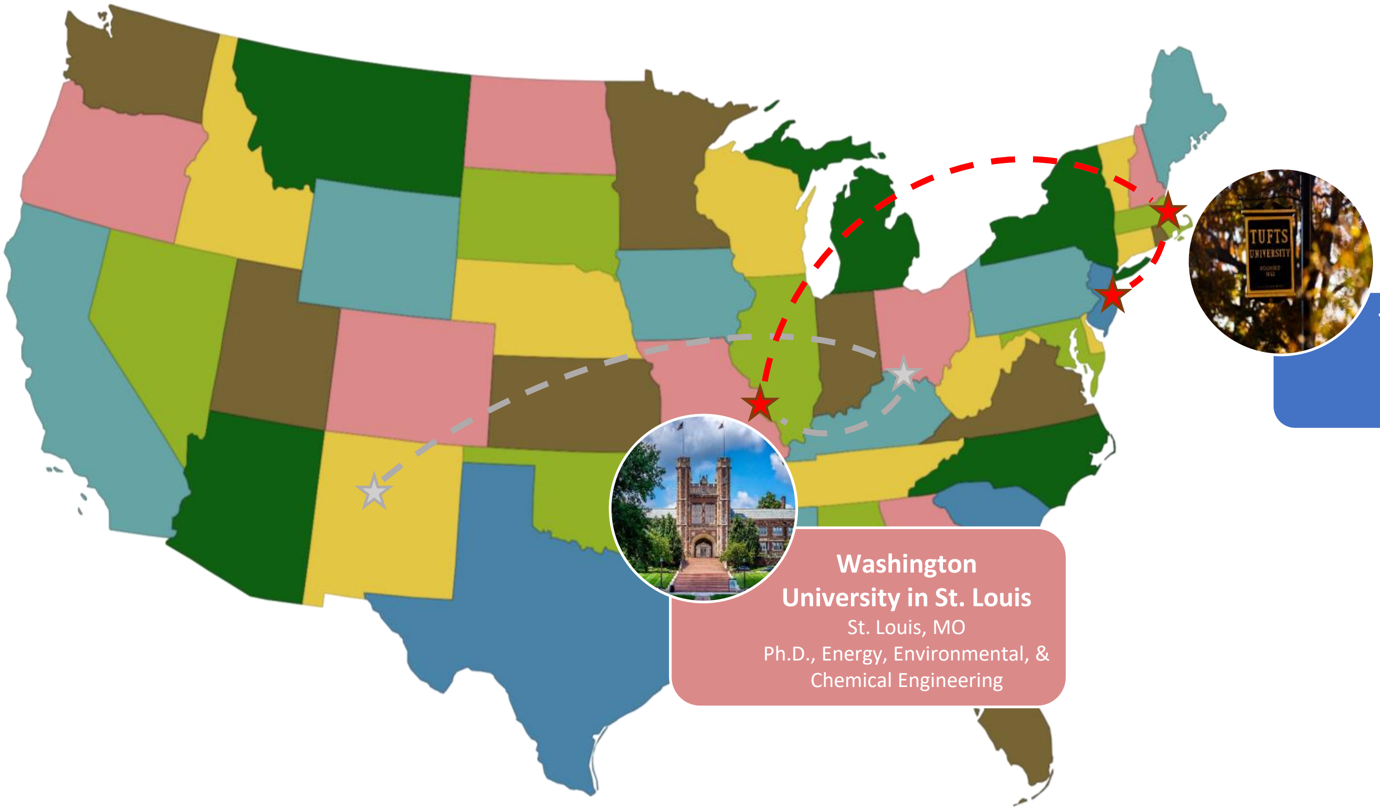


Free fly ash



Fly ash bound with waste plastic to form synthetic aggregates

The road so far…



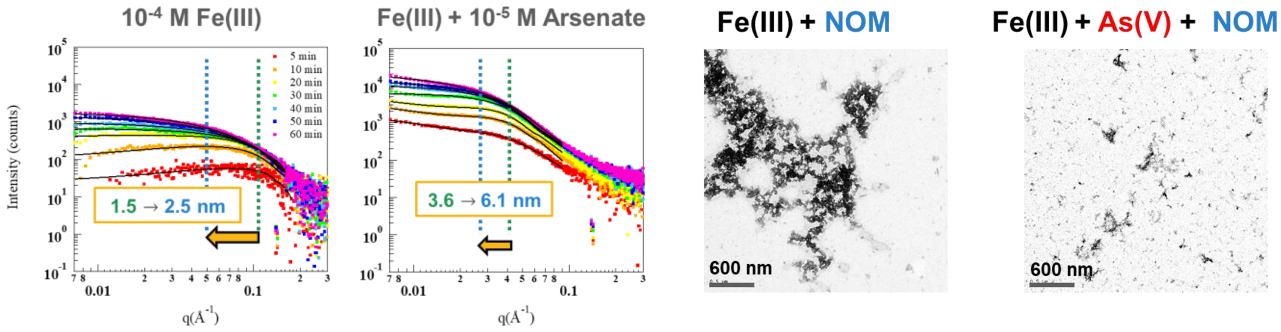
Tufts University
Medford, MA
B.S., Chemical Engineering

Washington University in St. Louis
St. Louis, MO
Ph.D., Energy, Environmental, & Chemical Engineering

Washington University in St. Louis

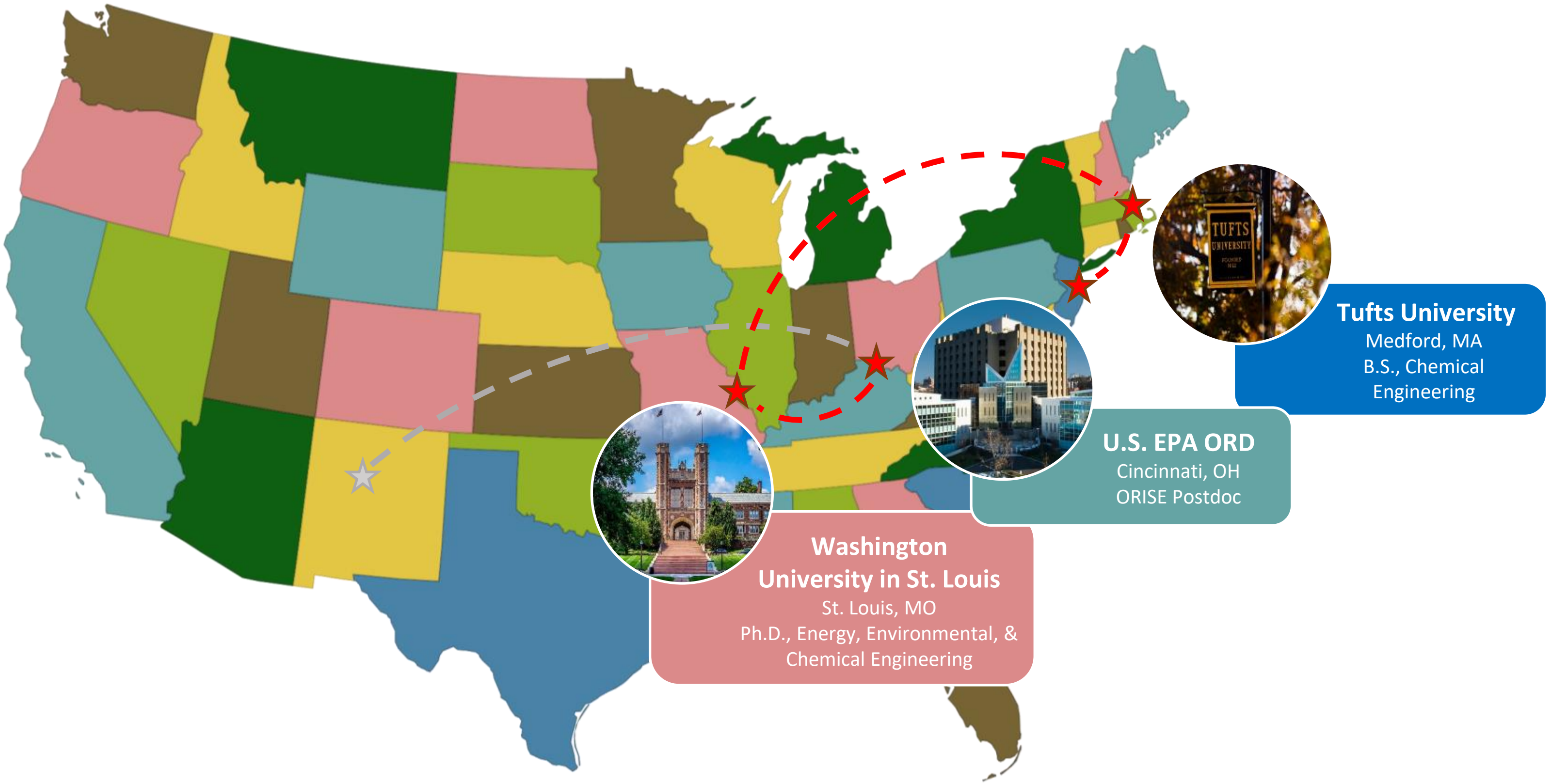
Washington University in St. Louis
St. Louis, MO
Ph.D., Energy, Environmental, & Chemical Engineering

- Joined Environmental NanoChemistry Laboratory (ENCL)
  - Advisor Dr. Young-Shin Jun
- Dissertation: “Understanding the Nano- and Macro-scale Processes Impacting Arsenic Mobilization during Managed Aquifer Recharge”
- First experiences in geochemistry and using synchrotron X-ray techniques



Incorporation of As in Fe hydroxide precipitates affects size and aggregation.

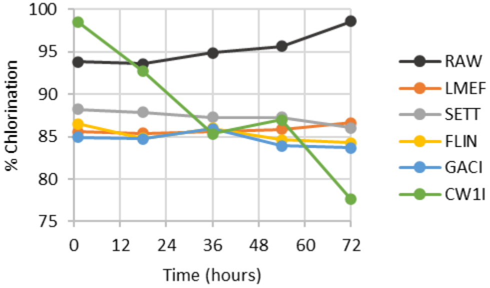
The road so far…



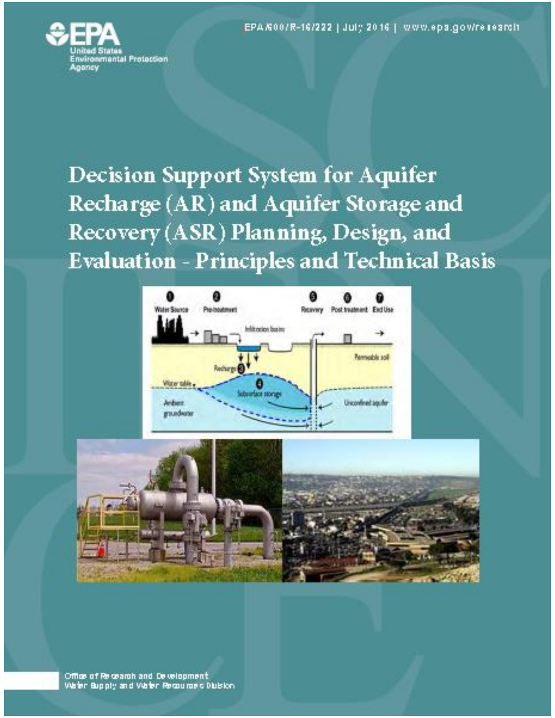
U.S. Environmental Protection Agency

U.S. EPA ORD
Cincinnati, OH
ORISE Postdoc

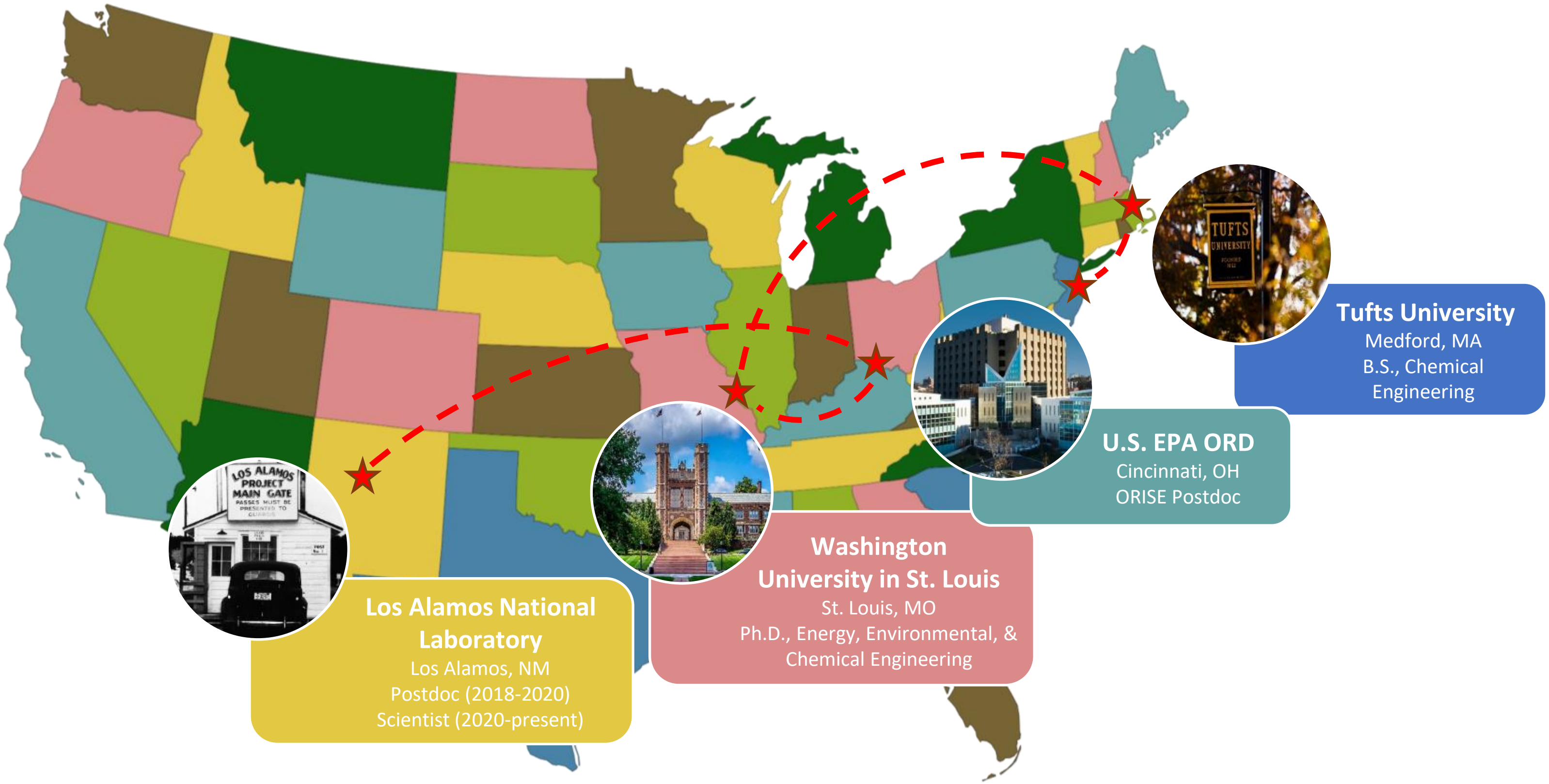
- Took ORISE postdoc position with Dr. Jeff Yang
- Worked primarily on two projects:
  - Developing a decision support system for aquifer recharge implementation
  - Studying disinfection byproduct formation during a storm event



More brominated DBPs from carbon remaining post GAC treatment (CW1I)



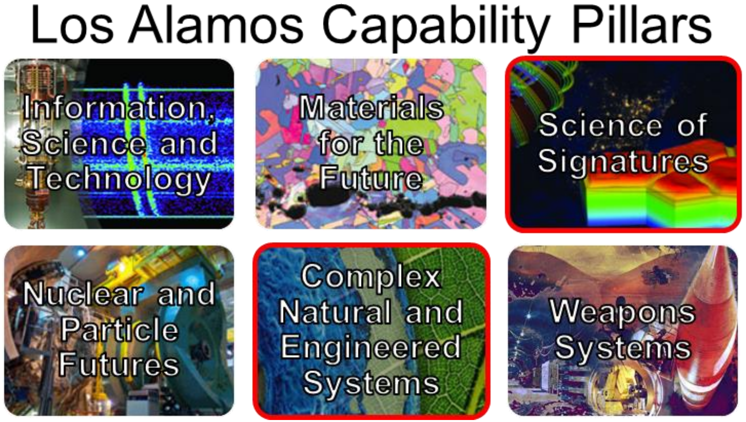
The road so far…



Los Alamos National Laboratory

- Joined the Earth and Environmental Sciences Division in 2018
  - Member of the Radionuclide Geochemistry team
- Research primarily falls under two LANL mission critical areas
  - Science of Signatures (**National Security**)
  - Complex Natural and Engineered systems (**Energy Security**)

Radionuclide Geochemistry team



Geochemistry for National and Energy Security

- National Security
  - Noble gas transport
  - Hydrothermal iodine chemistry
  - Fission product-glass melt partitioning
- Energy Security
  - Hydrocarbon recovery from shale
  - Geologic carbon sequestration
  - Geologic hydrogen storage

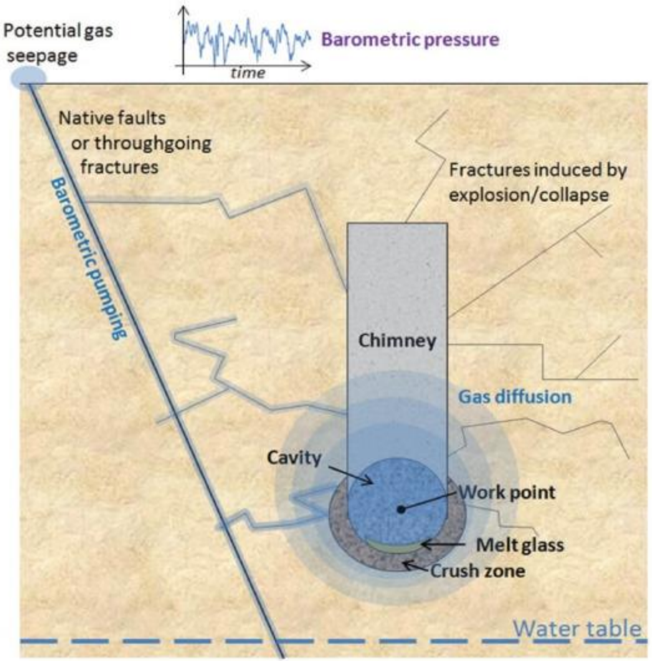
National Security

Noble gas transport

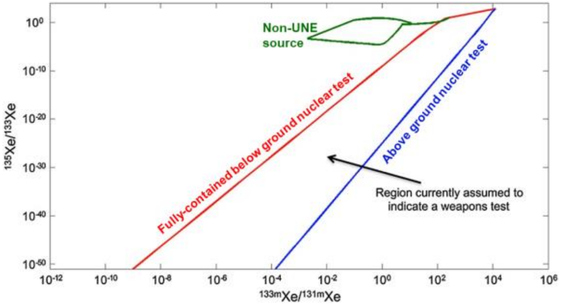
Geochemistry for National Security

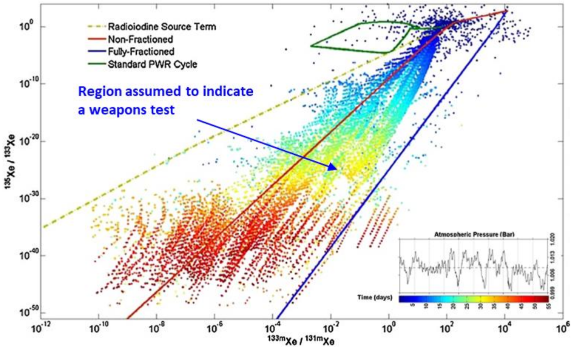
Nonproliferation detection from underground nuclear explosions (UNEs)

- Detected radionuclide signatures are a smoking gun for nonproliferation detection
- Attribution is only possible with a complete understanding of signature transport



Bourret et al. *Journal of Environmental Radioactivity*, 222, (2020)





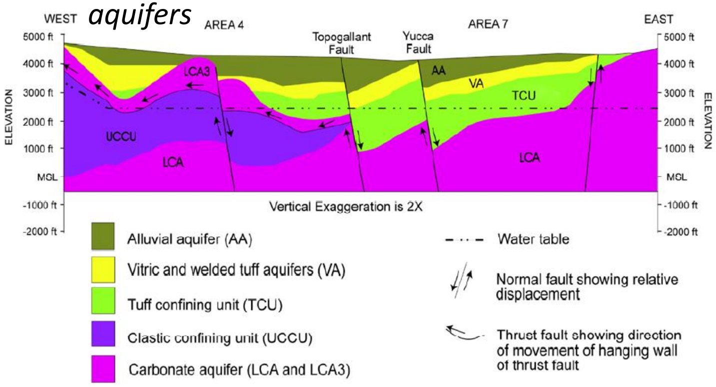
Lowrey et al. *Geophysical Research Letters*, 40(1), (2013)

Geochemistry for National Security

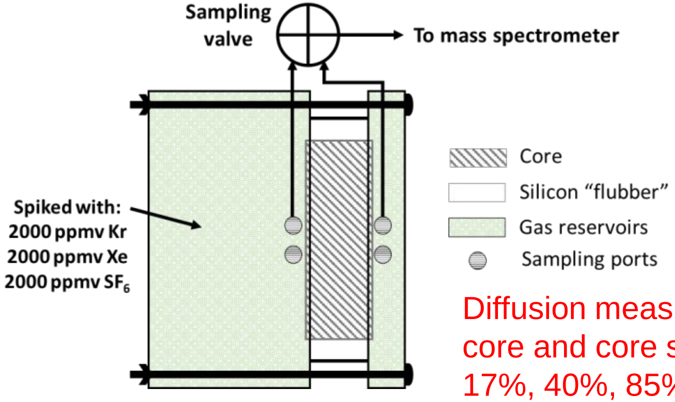
Laboratory measurement of gas diffusion through zeolitic tuff

Hydrostratigraphy of Yucca Flat (NNSS)

Zeolitic tuff confining units and volcanic aquifers



Experimental set-up



Diffusion measured on dry core and core saturated to 17%, 40%, 85% and 100% of total saturation

- *Diffusion cell use for gas transport study through zeolitic tuff from NNSS*
- *Zeolitic tuff can sorb noble gases (Feldman et al., 2020)*
- ***Role of sorption and saturation on transport not known***

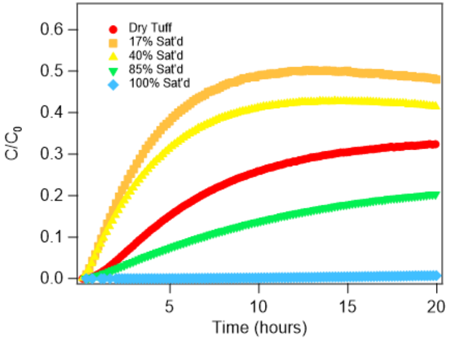
Feldman et al. *Journal of Environmental Radioactivity*, 220, (2020) National Security

Noble gas transport

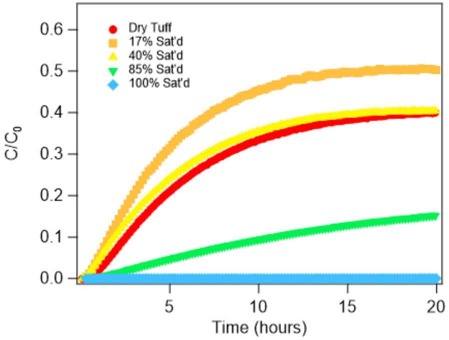
Geochemistry for National Security

Saturation shortens gas breakthrough times for Kr, Xe, and SF_6

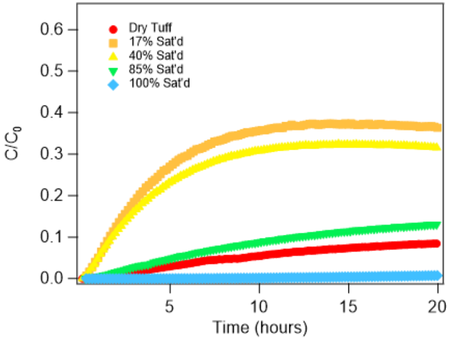
Krypton (Kr)



Sulfur hexafluoride (SF_6)



Xenon (Xe)



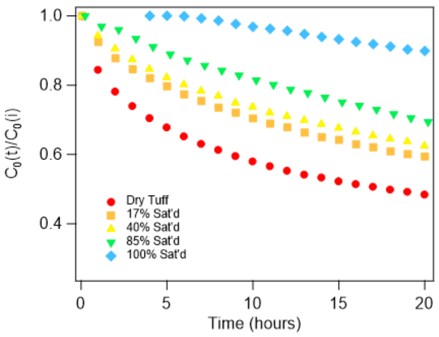
- *Breakthrough is **gas dependent***
- *Fastest breakthrough at lowest partial saturation (17% saturated).*
- *Other than 100% saturation, s**lowest breakthrough for Xe in dry tuff***

Neil, C.W., et al., 2022. *Journal of Environmental Radioactivity*, *250*, p.106905.

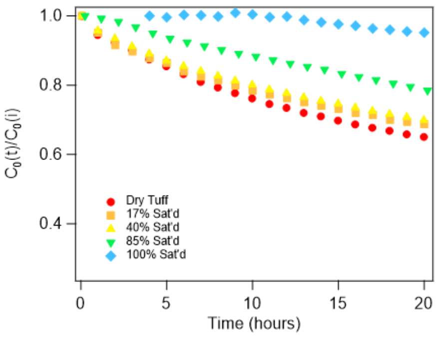
Geochemistry for National Security

Water blocks zeolite sorption of noble gases

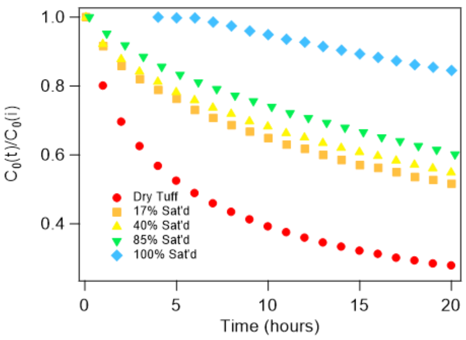
Krypton (Kr)



Sulfur hexafluoride (SF_6)



Xenon (Xe)



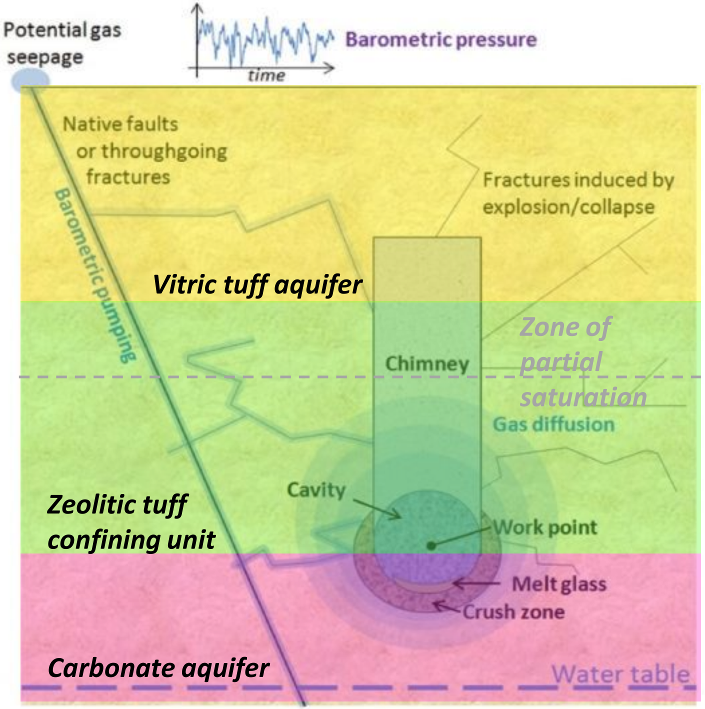
- Largest drop in C_0 in dry system for Xe, with significant increase between dry and 17%
- **Sorption of tracer gases in the rock (Xe > Kr > SF_6)** explains why breakthrough is so slow, especially for Xe – sorption decreasing with increasing saturation is the driving force for diffusion

Neil, C.W., et al., 2022. *Journal of Environmental Radioactivity*, *250*, p.106905.

Geochemistry for National Security

National Security → Noble gas transport

Improving model interpretation of detected UNE signatures

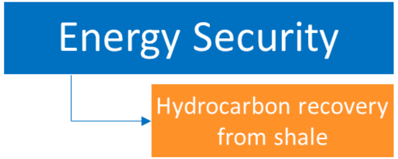


Bourret et al. *Journal of Environmental Radioactivity*, 222, (2020)

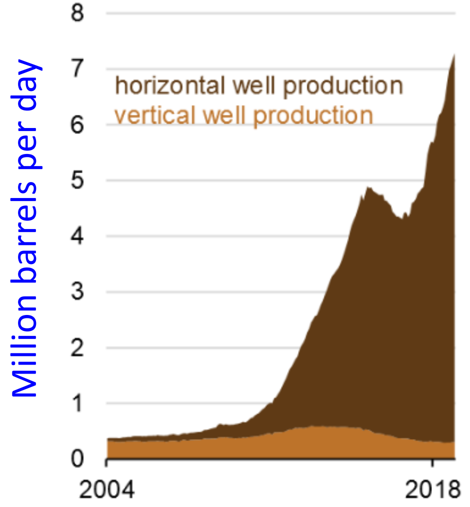
Identified critical new factors impacting signal fractionation

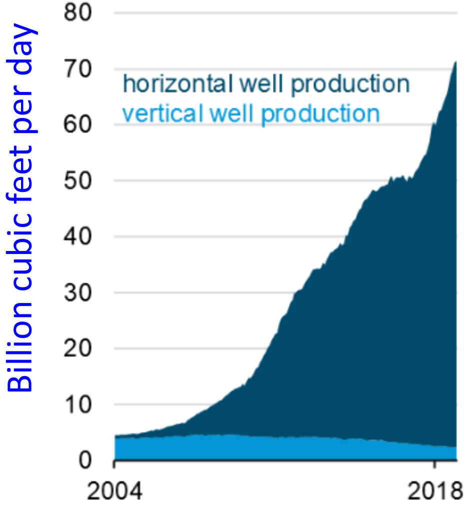
1. Zeolite content of overlying rock
2. Partial saturation of rock above the water table

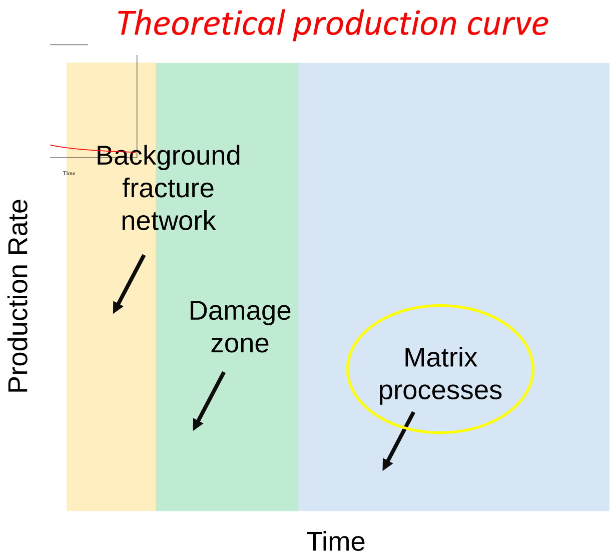
Geochemistry for Energy Security



Hydrocarbon recovery from tight shale limited by matrix processes







Current hydrocarbon recovery rates are extremely low (<10% for oil and ~20% for gas)

U.S. Energy Information Administration, Annual Energy Outlook 2019

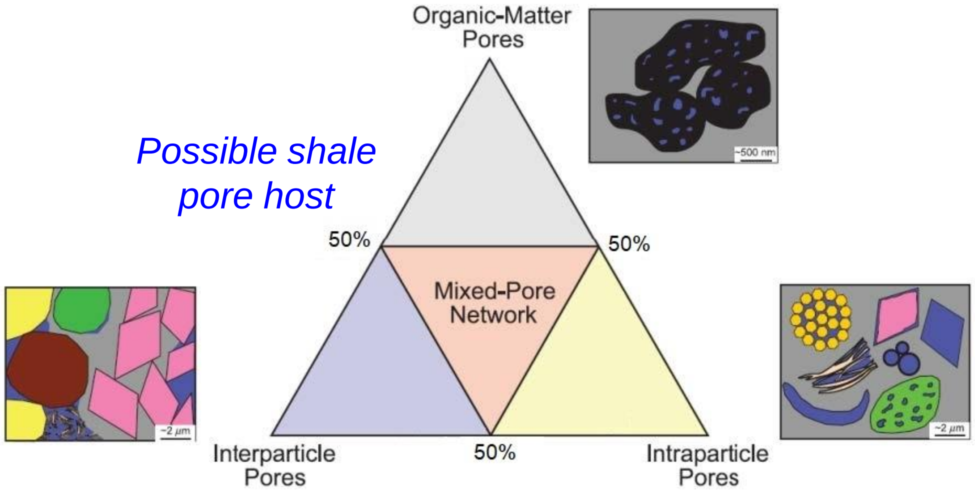
Energy Security

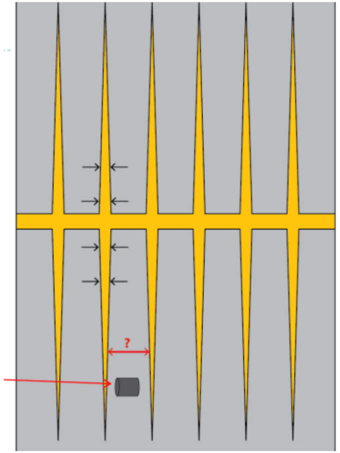
Hydrocarbon recovery from shale

Geochemistry for Energy Security

Heterogeneous shale nanopores will influence fluid transport

Possible shale pore host





Matrix-fracture fluid transfer

- Shale pore network is intrinsically heterogeneous, consists primarily of small pores
  - Organic vs. inorganic porosity, open vs. closed pores
- Recovery will depend on hydrocarbon transport out of matrix and into fracture network

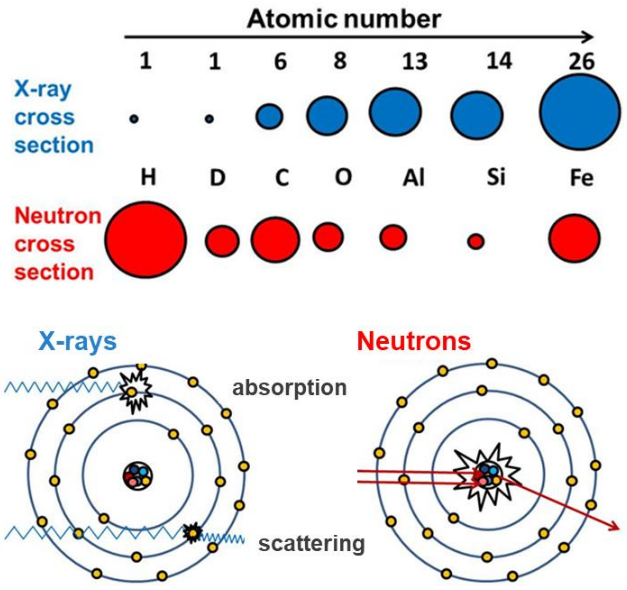
Energy Security

Hydrocarbon recovery from shale

Geochemistry for Energy Security

Why neutrons?

- Unlike X-ray scattering, neutron scattering does not scale with atomic number, Z
  - Can measure lighter fluids/gases such as H_2O, methane and hydrocarbons
  - Sensitive to isotopes
- Neutral charge of neutrons results in large penetration depths
  - Allows for pairing neutron techniques with high pressure environmental cells



X-ray and neutron interactions with atoms

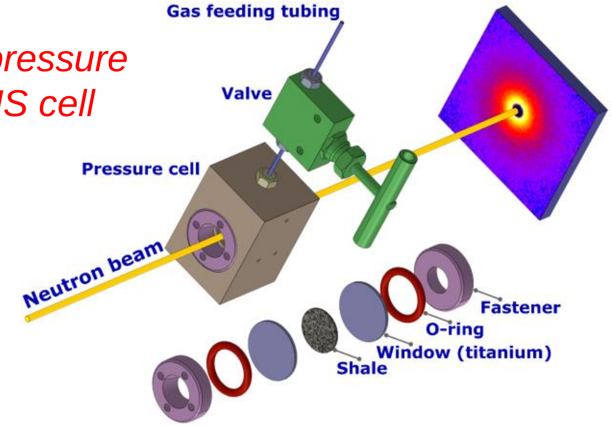
http://worldsciencereport.blogspot.com/

Geochemistry for Energy Security

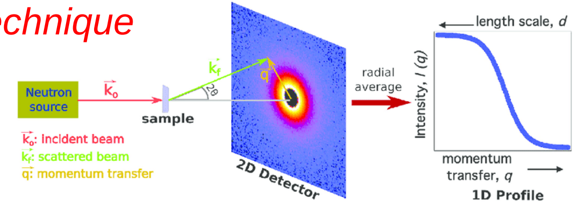
In situ, high pressure small-angle neutron scattering (SANS)

- Small-angle neutron scattering (SANS) can measure **fluid behavior in pores ranging from 1 to 100 nm**
  - Measures the difference in scattering between the rock and pore space, i.e. the contrast
  - Adding/removing fluid from nanopores changes this contrast
- Through observing changes in intensity upon pressure cycling, one can **quantify fluid removal from pore spaces**

High-pressure SANS cell



SANS technique



$$Q = \frac{4\pi}{\lambda} sin\theta \quad \lambda = 2dsin\theta \quad d = {}^{2\pi}/_{Q}$$

Castellanos, M., et al. *Comput. Struct. Biotechnol. J.* 15 (2017): 117-130.

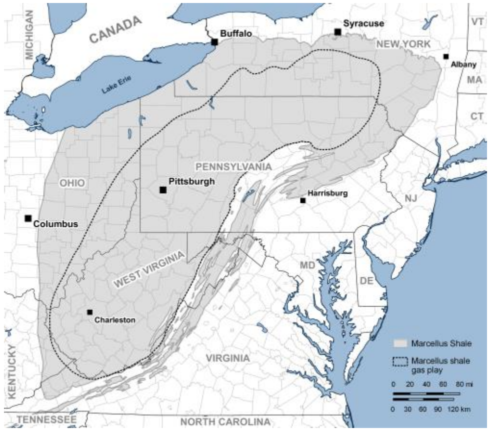
Energy Security

Hydrocarbon recovery from shale

Geochemistry for Energy Security

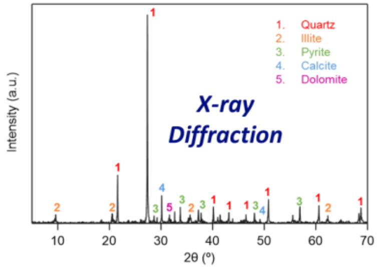
Marcellus shale pressure cycling experiments

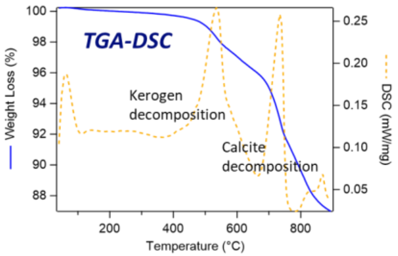
- USGS estimates that the Marcellus Shale Play contains 42.954 to 144.145 trillion cubic feet of recoverable natural gas
- **Pressure management** is a key means to increase recovery based on operational parameters
- During SANS, Marcellus shale was put through two pressure cycles to understand peak pressure controls on methane recovery



Marcellus Shale Gas Play

http://pubs.er.usgs.gov/publication/ofr20061237





Cycle 1: Peak pressure of 3,000 psi (20.7 MPa)
Cycle 2: Peak pressure of 6,000 psi (41.4 MPa)

Neil, C.W *et al*., 2020. *Communications Earth & Environment*, *1*(1), pp.1-10.

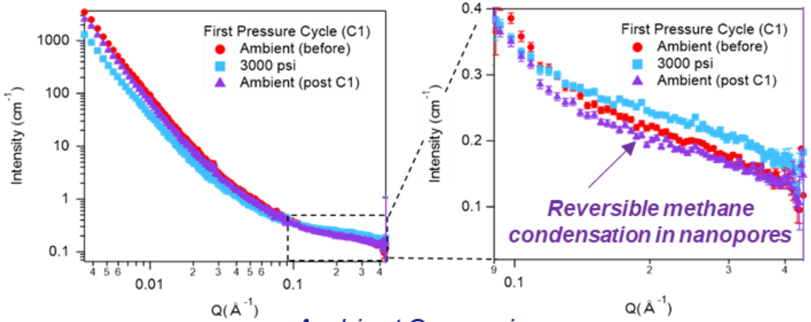
Energy Security

Hydrocarbon recovery from shale

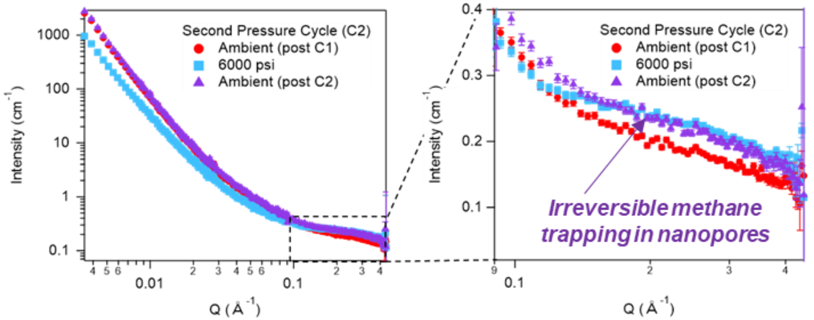
Geochemistry for Energy Security

SANS spectra post pressure cycles 1 & 2

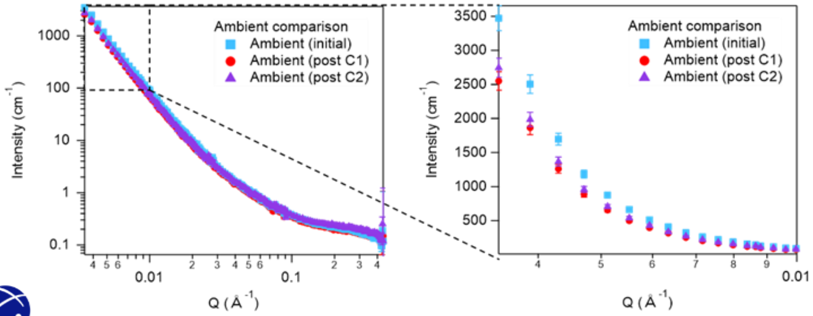
First Pressure Cycle



Second Pressure Cycle



Ambient Comparison



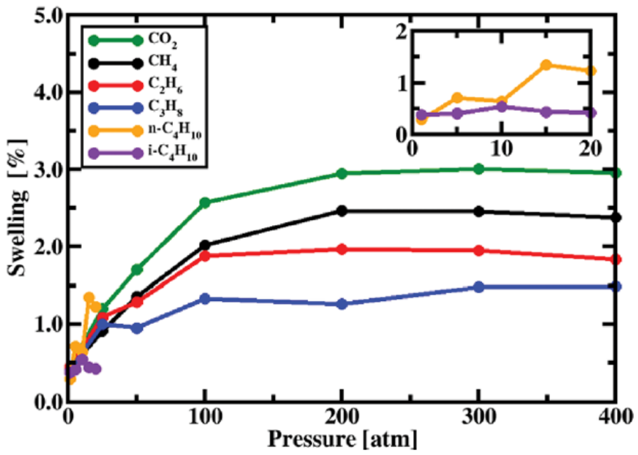
Q is inversely related to pore radius.

- More methane retention in small pores (high Q) for high peak pressure (Cycle 2)
- More methane retention in large pores (low Q) for low peak pressure (Cycle 1)

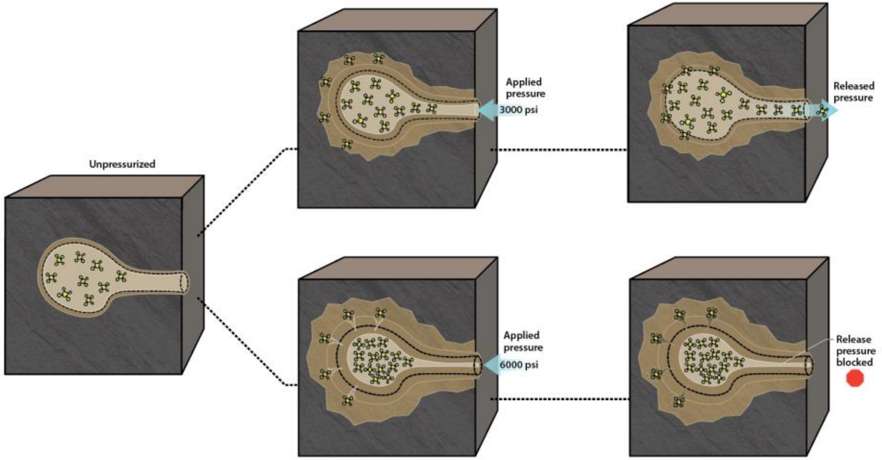
Neil, C.W *et al.*, 2020. *Communications Earth & Environment*, *1*(1), pp.1-10.

Geochemistry for Energy Security

Proposed mechanism for observed methane trapping in nanopores



MD simulations show kerogen swelling up to 3,000 psi (200 atm) and then shrinking at P up to 6,000 psi (400 atm) due to deformation



Pressure management is key for improving recovery—models must account for matrix nanopore effects!

Neil, C.W *et al*., 2020. *Communications Earth & Environment*, *1*(1), pp.1-10.

Tesson, S. and Firoozabadi, A., 2019. *The Journal of Physical Chemistry C*., *123*(48), pp. 29173-29183

Geochemistry for National and Energy Security

- National Security
  - Noble gas transport
  - Hydrothermal iodine chemistry
  - Fission product-glass melt partitioning
- Energy Security
  - Hydrocarbon recovery from shale
  - Geologic carbon sequestration
  - Geologic hydrogen storage

Thank you!

Questions or comments?

Collaborators:

Rex Hjelm, Marilyn Hawley, Erik Watkins, Hongwu Xu, Qinjun Kang, Hari Viswanathan, Mohamed Mehana, Yimin Mao

Hakim Boukhalfa, Doug Ware, John Ortiz, Sofia Avendaño, Dylan Harp, Scott Broome, Robert Roback, Pat Brug, Philip H Stauffer

Dr. Chelsea W. Neil

Email: cwneil@lanl.gov

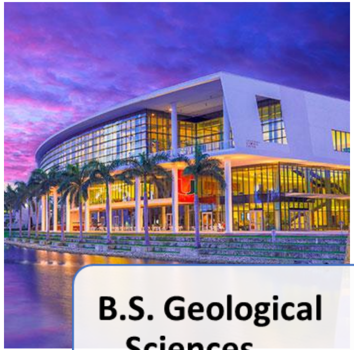
Acknowledgements

Early career in nuclear materials science

Dr. Sarah Hickam

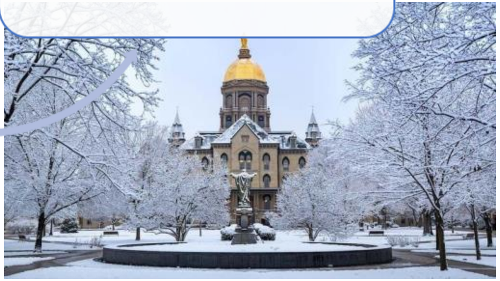
Nuclear Materials Science group (MST-16)

Career Timeline



B.S. Geological Sciences
University of Miami
2014

2014
Started Ph.D.
University of Notre Dame, actinide chemistry focus



LANL Internship
2018

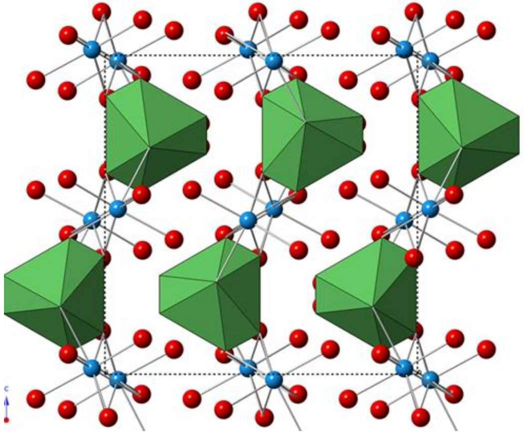
2019
Finished Ph.D./
Started **LANL Postdoc**

Converted to **Scientist**
2021

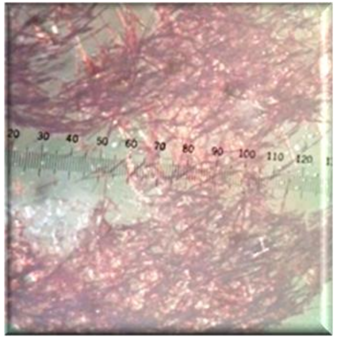
Graduate Research Focus

- Synthesis of inorganic, U and Np-based compounds
- Dissolution of U-based materials (UO_2, UN, UC) in alkaline, peroxide-rich conditions

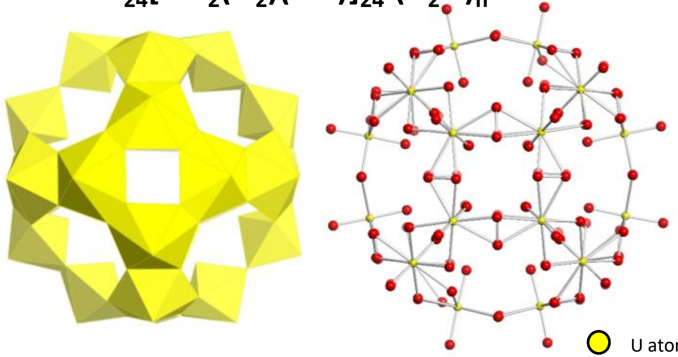
$Ca_2[NpO_2(O_2)_3]\cdot 9H_2O$



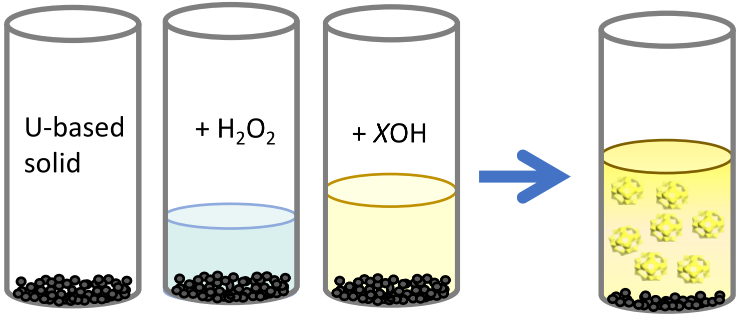
Np polyhedra   Ca atoms   O atoms



$Li_{24}[UO_2(O_2)(OH)]_{24}\cdot(H_2O)_n$



U atoms
O atoms

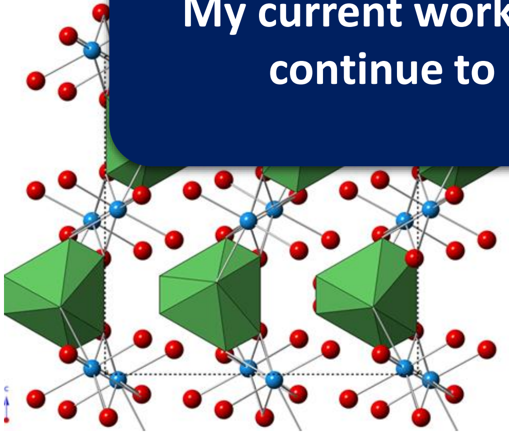


Graduate Research Focus

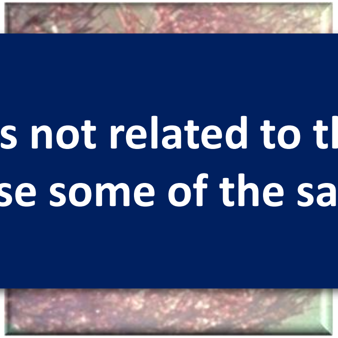
- Synthesis of inorganic, U and Np-based compounds
- Dissolution of U-based materials (UO_2, UN, UC) in alkaline, peroxide-rich conditions

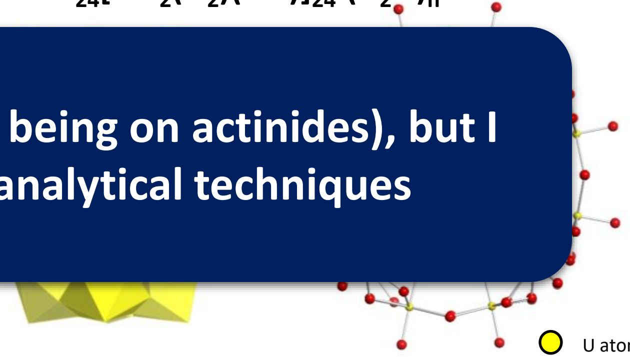
$Li_{24}[UO_2(O_2)(OH)]_{24}\cdot(H_2O)_n$

My current work is not related to this (other than being on actinides), but I continue to use some of the same or related analytical techniques

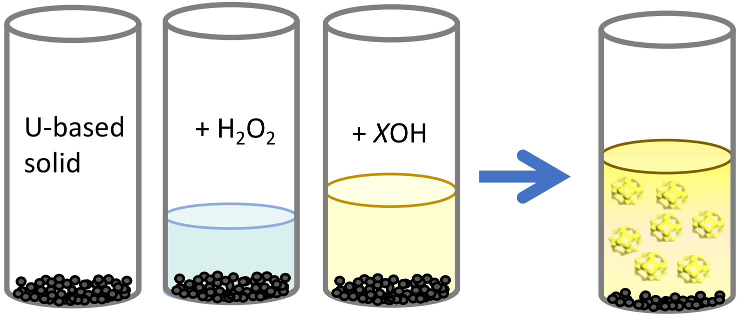


Np polyhedra Ca atoms O atoms





U atoms
O atoms



LANL Internship Experience

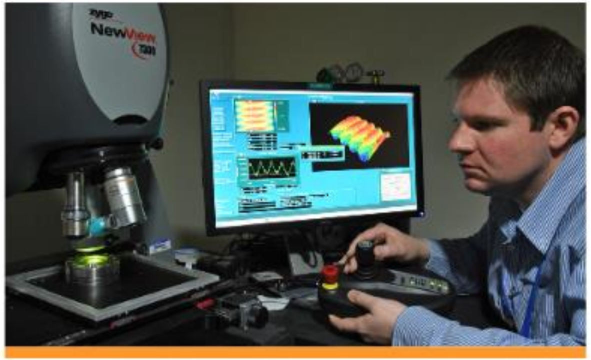
Interned in the Chemistry-Actinide Analytical Chemistry (C-AAC) group for 6 months

- Worked on small project to optimize precipitation of dilute actinide-containing solutions
- I was paired with a mentor for glovebox training. This was my first hands-on experience with Plutonium at LANL!



Postdoc in Nuclear Materials Science (MST-16)

- I met my post-doc advisor in person while doing my internship at LANL
- Project: characterize plutonium materials using X-ray Absorption Spectroscopy (XAS) for nuclear forensics research
- MST-16 engages in fundamental research and programmatic work. Best of both worlds!



From *Modernizing the nation's stockpile: Plutonium Surface Science Lab*, LA-UR-18-26998.

Converted to scientist in May 2021

- As a postdoc, I joined other efforts that were happening in my team:
  - Installed new equipment
  - Learned new techniques
  - Helped with logistics to aid other projects

In my opinion, these things helped me be successful in my postdoc and were a large part of my conversion to a scientist.

Current work

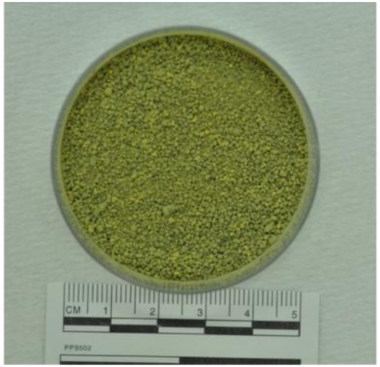
- Surface science of plutonium metal
- Molten salt studies
- X-ray absorption spectroscopy studies

Local structure and distribution of impurities in PuO_2: forensic signatures of formation conditions

Sarah Hickam

Example analytical plan for nuclear forensics

Interdicted nuclear material



E. Keegan et al. Forensic Science International 240 (2014) 111–121

Analysis

Radiochemical, age dating, trace elements, x-ray diffraction, grain size and shape, etc.

Interpretation

-Source

-Processing history

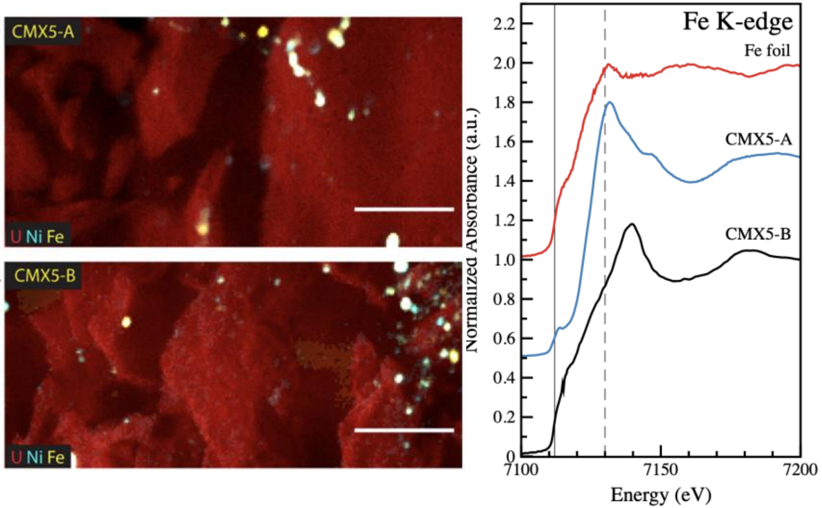
Rocky Flats Plant, Pu Pit Manufacturing for Nuclear Weapons, Courtesy of David Clark

Czech Republic, Nuclear Reactor, Courtesy of Britannica.com

Case development, attribution, and response

XAS for nuclear forensics

- **Motivation:** need to rapidly locate and identify signatures for particle samples
- **Goal:** enhance current nuclear forensics analytics by developing *X-ray Absorption Spectroscopy (XAS)* techniques to identify signatures in support of attribution



Analysis

Radiochemical, age dating, trace elements, x-ray diffraction, grain size and shape, **+ XAS**

Interpretation

-Source

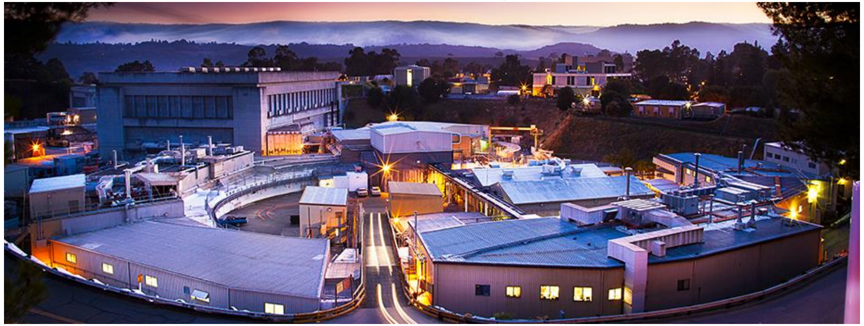
-Processing history

van Veelen, A.; Hickam, S.; Edwards, N.P.; Webb, S.M.; Clark, D.L.; Wilkerson, M,P.; Pugmire, A.L.; Bargar, J. *Analytical Chemistry* **2022** *94* (19), 7084-7091

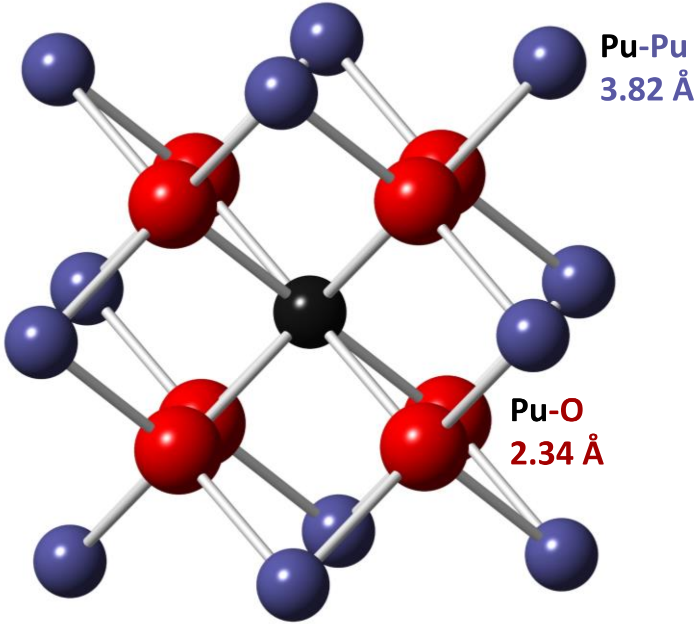
XAS for nuclear forensics

- X-ray absorption spectroscopy (XAS) provides **local structure** and **oxidation state** information, is **element specific**, and has **low detection limits** (~1 ppm)
- Experiments are typically done at a synchrotron: high flux, tunable and wide-range of x-ray energies
- This was a new technique for me!

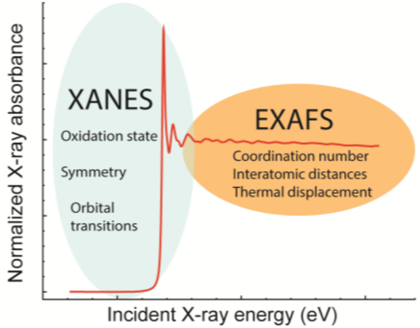
SSRL at SLAC National Accelerator Laboratory
Menlo Park, CA



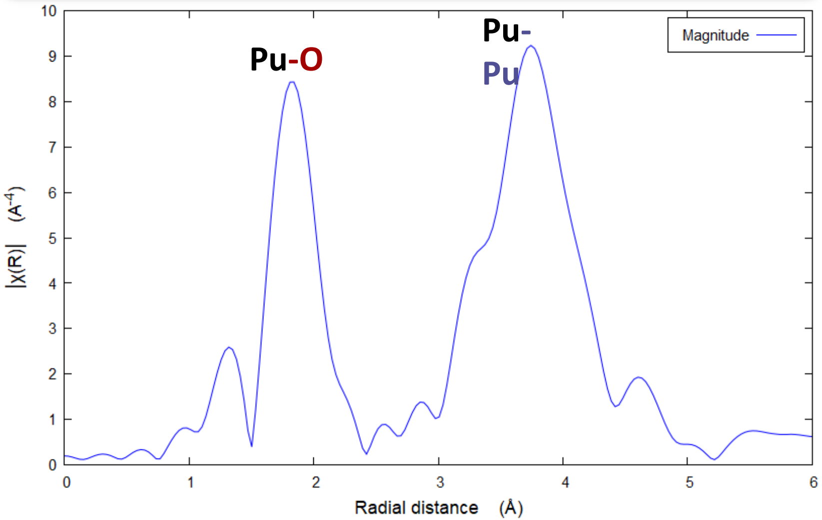
XAS for nuclear forensics



Absorbing Pu atom
Pu
O



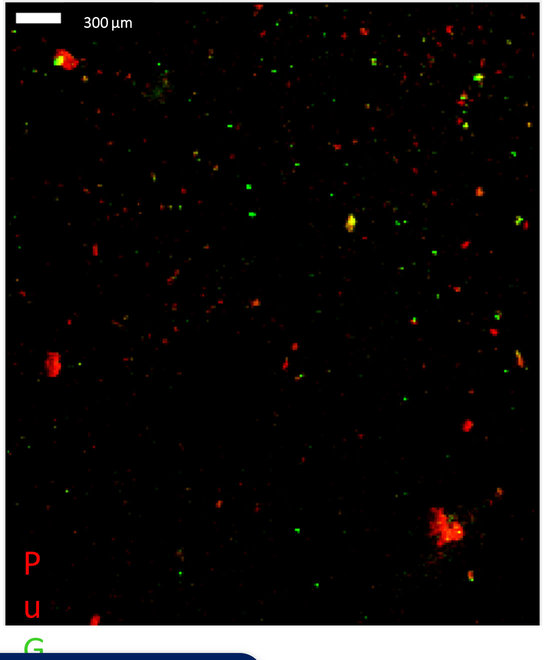
EXAFS: distances, coordination number



XAS for nuclear forensics

- XAS studies of **PuO_2** at the Pu L_{III}-edge are numerous and show significant differences in local structure. <u>Impurities have not been well-studied.</u>

- X-ray fluorescence + μ-XAS provides allows rapid identification and location of elements + local structure information

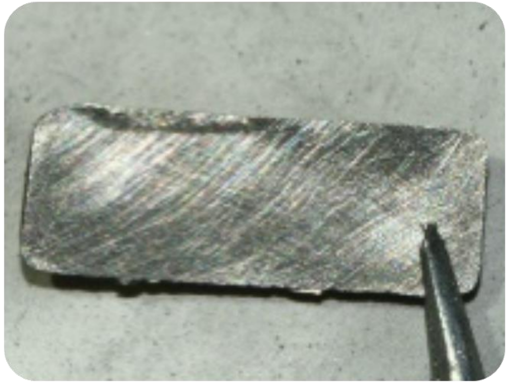


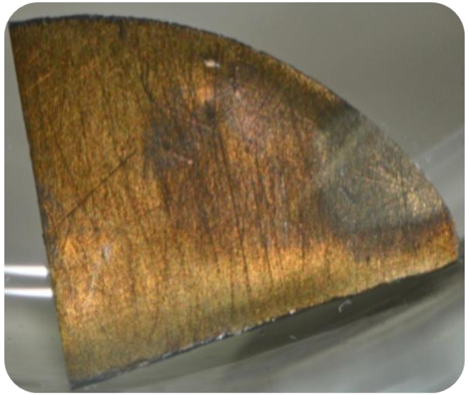
The combination of actinide + impurity distribution and local structure may provide unique signatures

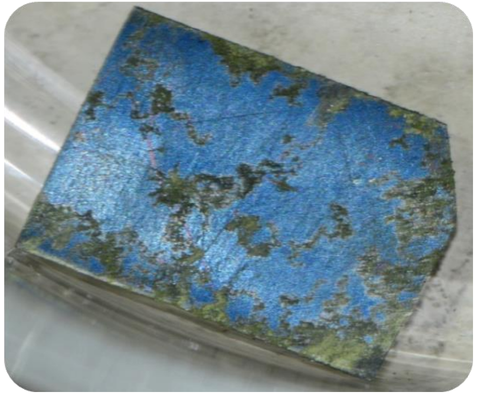
PuO_2 sample set

- **Corrosion** of Pu^0 during storage
- **ARIES:** Advanced Recovery and Integrated Extraction System
  − Conversion of excess Pu to PuO_2 for long term storage
- PuO_2 from Pu oxalate

Increasing oxidation







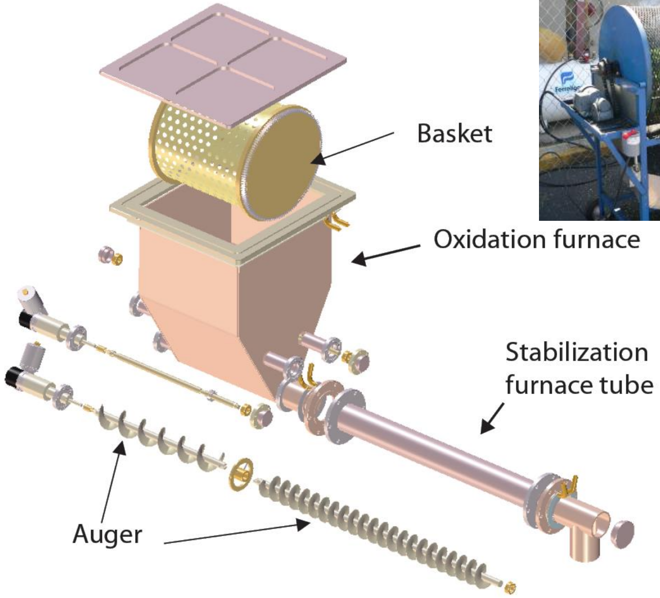
Courtesy of Alison Pugmire, LANL

ARIES processing

Muffle Furnace (Room Air)

Samples: Muffle Furnace 500°C
Muffle Furnace 965°C

Direct Metal Oxide (DMO) Furnace (75% O_2, / 25% Ar)

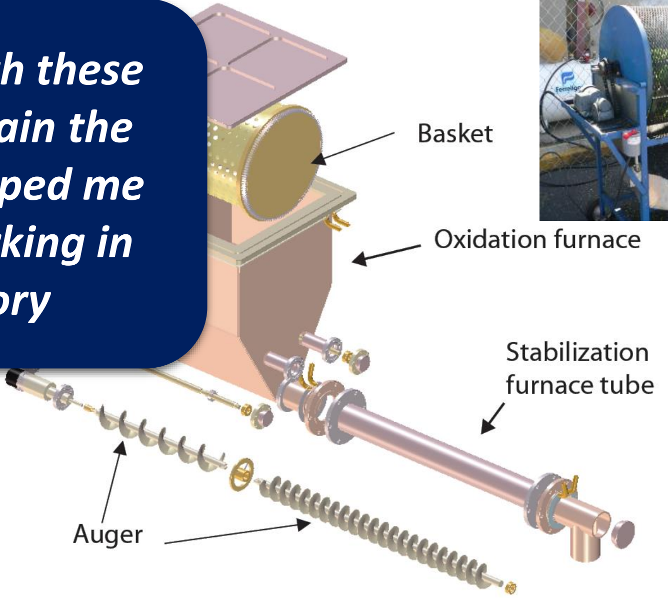


ARIES processing

Muffle Furnace (Room Air)

Direct Metal Oxide (DMO) Furnace (75% O_2, / 25% Ar)

I had to work with these programs to obtain the samples. This helped me meet others working in the Laboratory



Samples: Muffle Furnace 500°C
Muffle Furnace 965°C

DMO 950-1040°C

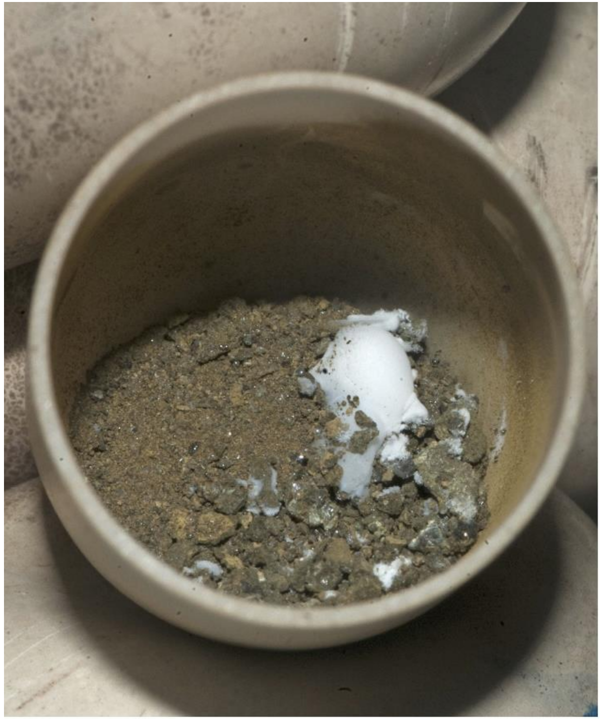
Gallium local structure in PuO_2 powders

- Phase stabilizer for δ-Pu^0

- Question: what is the local structure and distribution of Ga in PuO_2 powders and does it change with PuO_2 history?

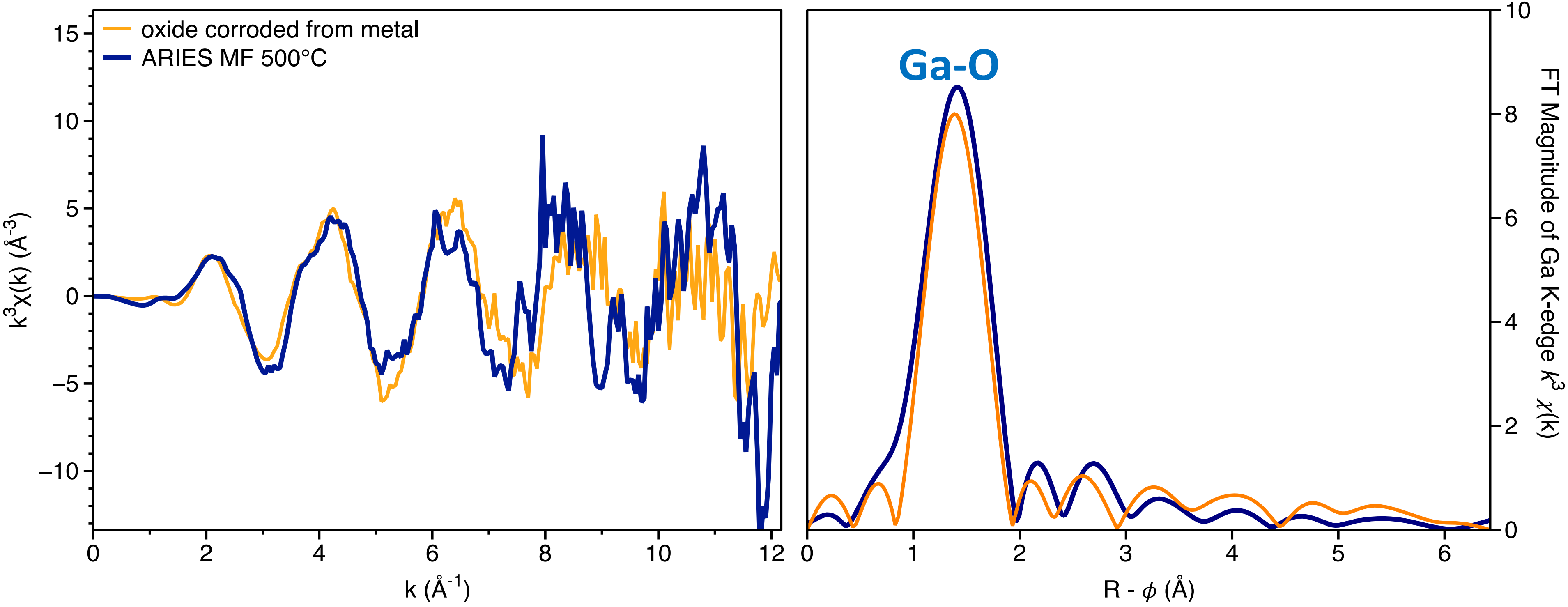
ARIES PuO_2:

- After thermogravimetric analysis of oxides, white powders thought to be Ga_2O_3 were observed

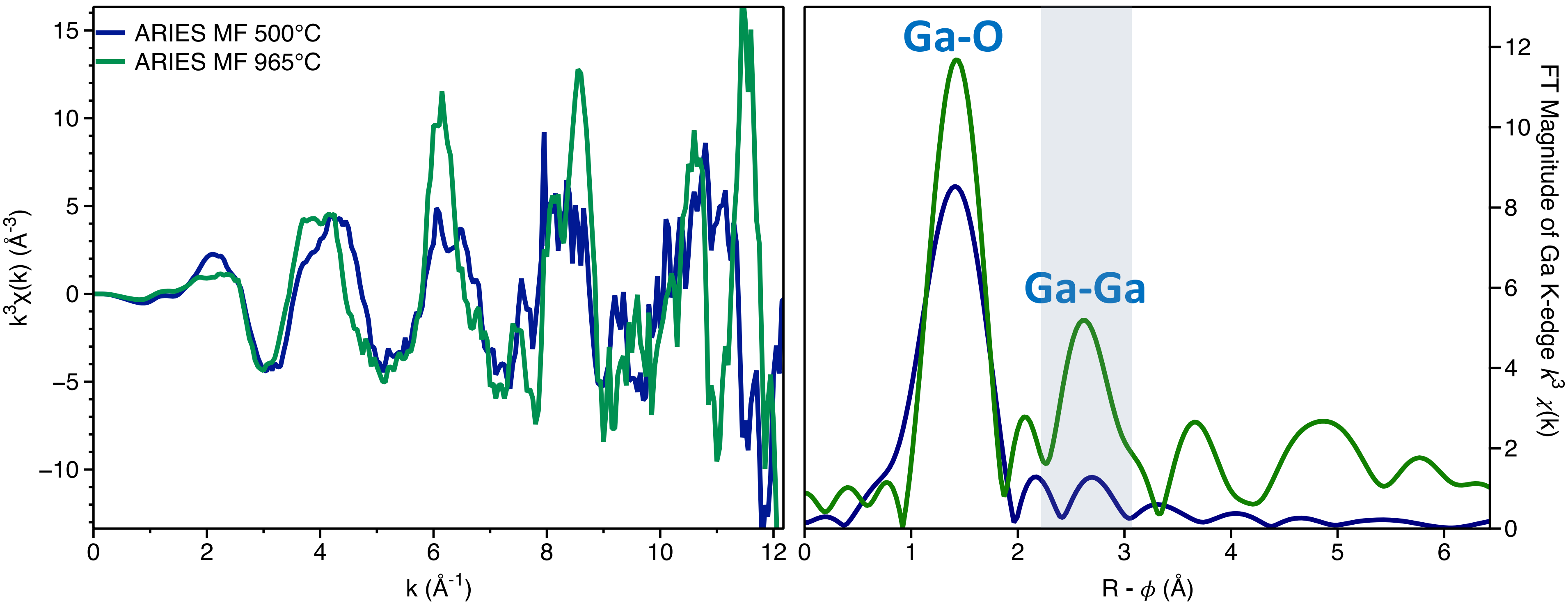


Berg, J. M. et al. *Thermal stabilization tests on direct metal oxidation product at temperatures from 650 to 950 °C*; LA-UR-13-20802. LANL: 2013.

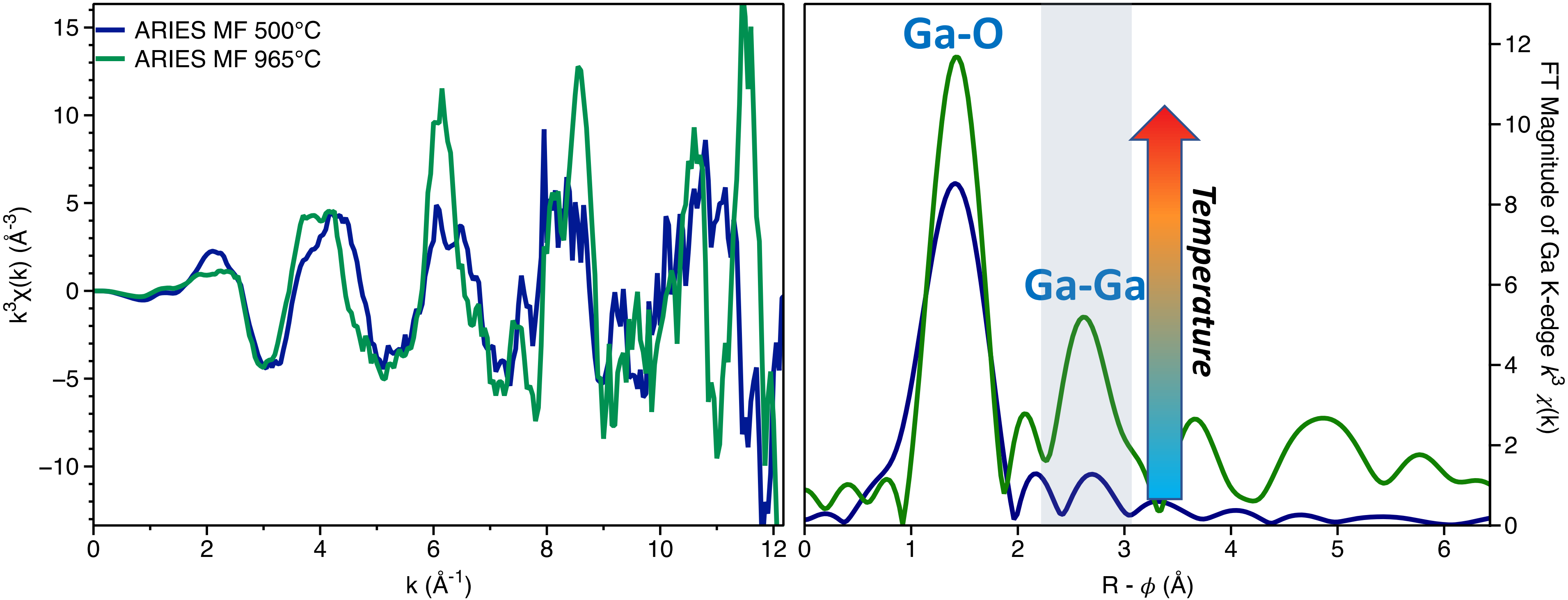
Bulk ARIES Ga EXAFS



Bulk ARIES Ga EXAFS



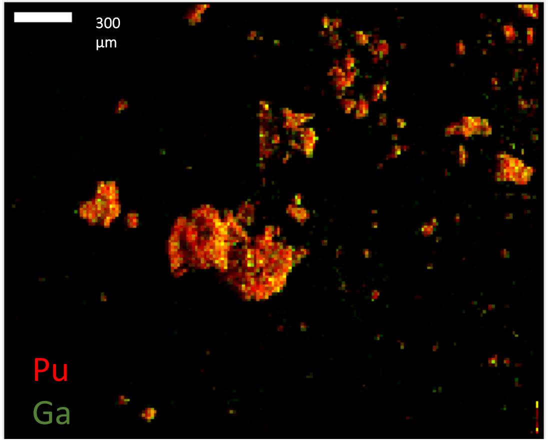
Bulk ARIES Ga EXAFS



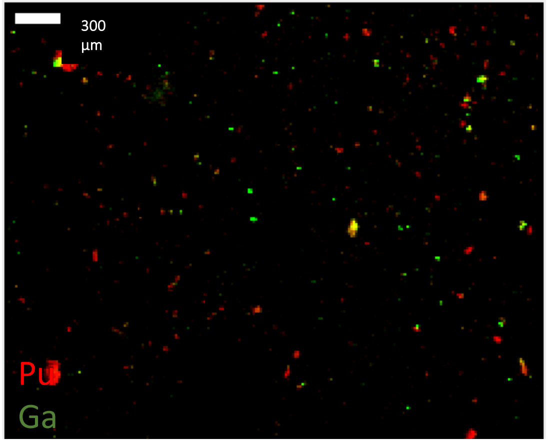
Ga becomes more well-ordered and forms β-Ga_2O_3 at higher processing temperatures

Identifying Processing Signatures

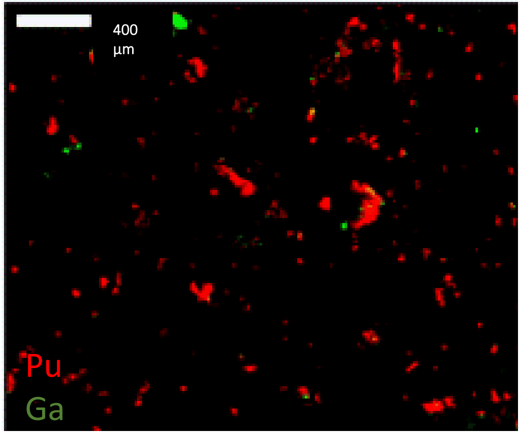
Corroded δ-Pu



Muffle Furnace 500°C

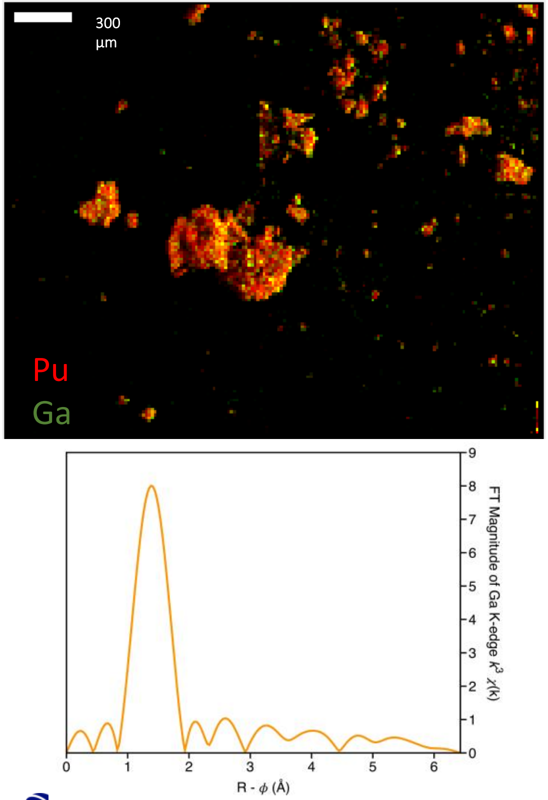


Muffle Furnace 965°C

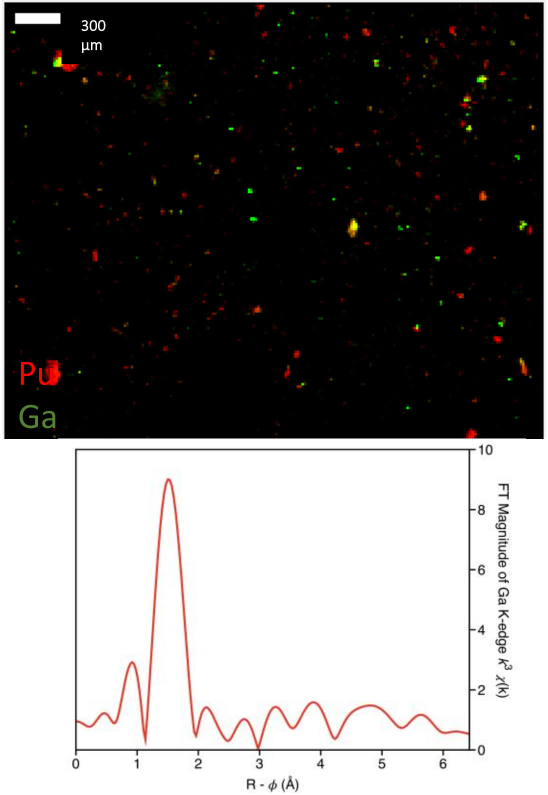


Identifying Processing Signatures

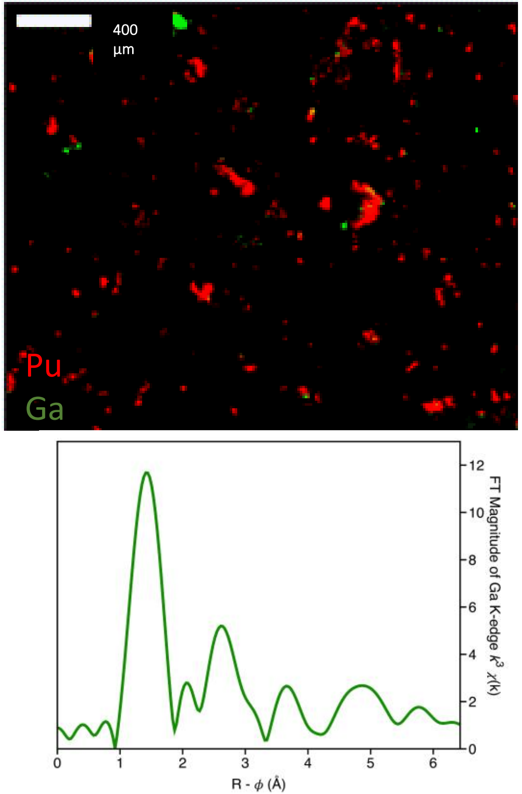
Corroded δ-Pu



Muffle Furnace 500°C

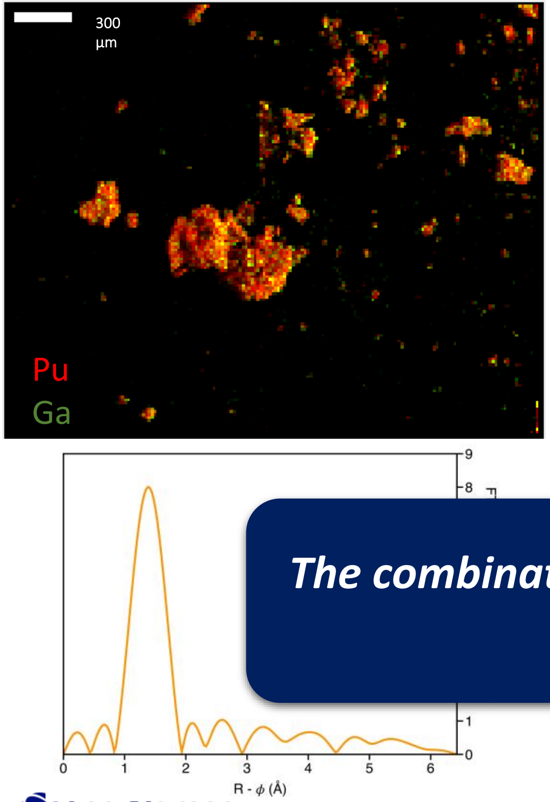


Muffle Furnace 965°C

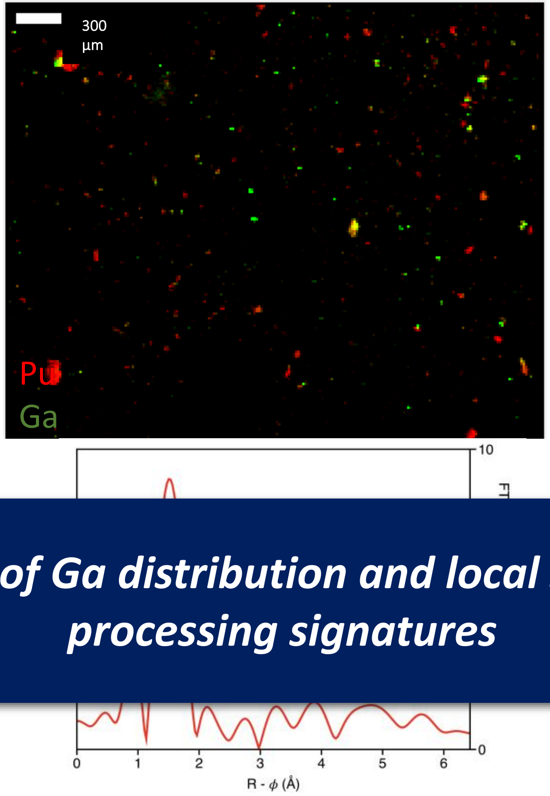


Identifying Processing Signatures

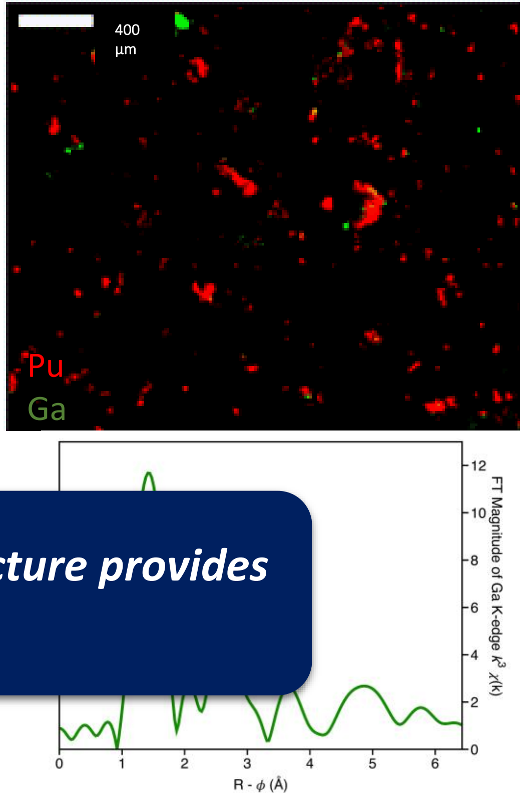
Corroded δ-Pu



Muffle Furnace 500°C



Muffle Furnace 965°C



The combination of Ga distribution and local structure provides processing signatures

This work and my early career goals

This project is only a small percentage of the work I do now, but it helped me in several ways:

- Expanded my knowledge of Plutonium science and skillset
- Allowed me to engage in fundamental research with an application in mind
- Became a gateway to programmatic work
- I am now acknowledged as the LANL technical lead for this project

Thank you!

Collaborators

Kasey Hanson
Dan Olive
Jared Stritzinger
Kyle Gardner
Robert Sykes

Tomas Martinez
Carlos Archuleta
Chris Cordova

Acknowledgments

U.S. Department of Energy, National Nuclear Security Administration, Office of Defense Nuclear Nonproliferation Research and Development under Contract No. DE-AC02-76SF00515.

Stanford Synchrotron Radiation Lightsource. Use of the Stanford Synchrotron Radiation Lightsource, SSRL, is supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract No. DE-AC02-76SF00515.

Backup Slides

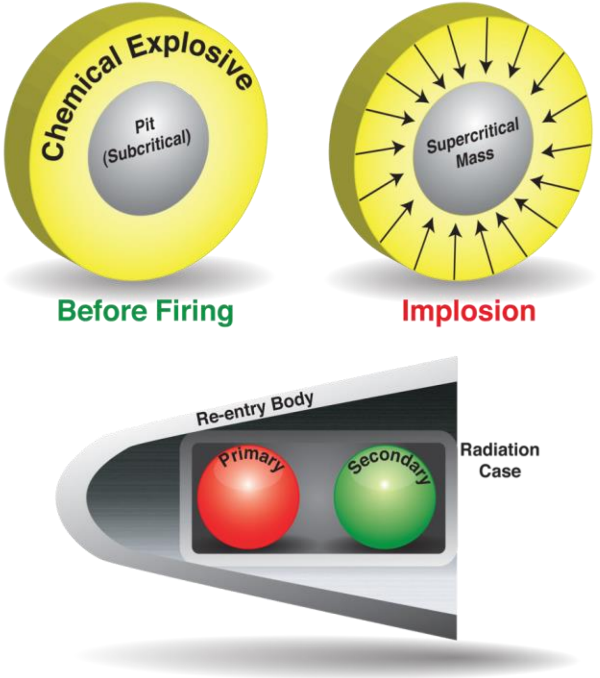
What is plutonium?

- Plutonium is the 94th element in the periodic table and was first separated by Glenn Seaborg (right) and his team in 1941
- Primary applications
  - Use in nuclear explosives
  - Use as a fuel for nuclear reactors
- Any reactor that contains uranium will create plutonium as a byproduct

As long as nuclear explosives and nuclear reactors exist, the U.S. will need to maintain the capability to handle, store, process, and produce plutonium-bearing materials

We currently have the only capability in the nation to manufacture plutonium pits

- A plutonium pit is the core of a nuclear weapon
- We are ramping up to product at least 30 pits per year (ppy) by 2026 to support the nation’s nuclear stockpile
    - These pits will replace existing aging pits in the stockpile; they are not adding new weapons to stockpile numbers
- We are currently in the development phase, producing R&D pits that don’t go into the stockpile
- The 30PPY mission also involves significant infrastructure and equipment upgrades in process by our sister ALD, Plutonium Infrastructure



Unclassified diagram of pits within a nuclear weapon.

We are the Nation’s Plutonium Center of Excellence

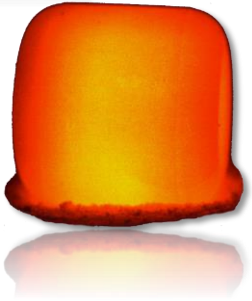
Pu Manufacturing

Pit Certification

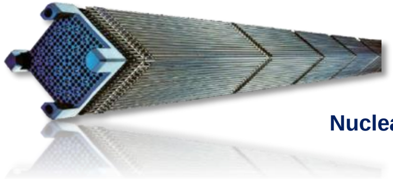
Plutonium Storage

The Cornerstone: Plutonium Facility, PF-4
(Mission Operations and Supports)

Materials Disposition



Pu-238



Nuclear Energy