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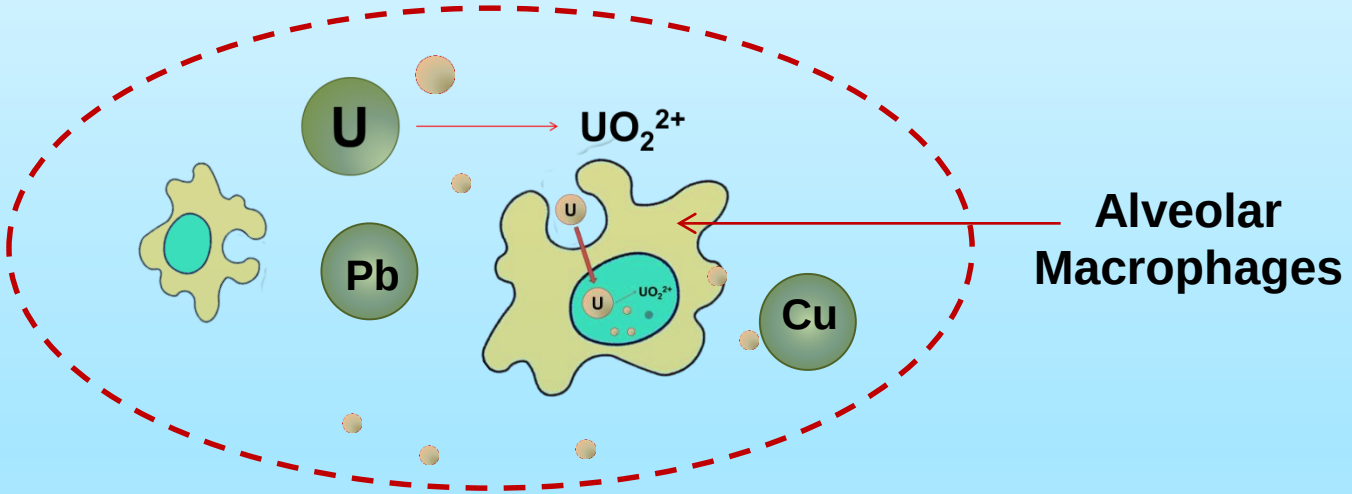
Mineralogy Controlled Dissolution of Inhaled Uranium in Simulated Bodily Fluids



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New Mexico INBRE
IDeA Networks of Biomedical Research Excellence

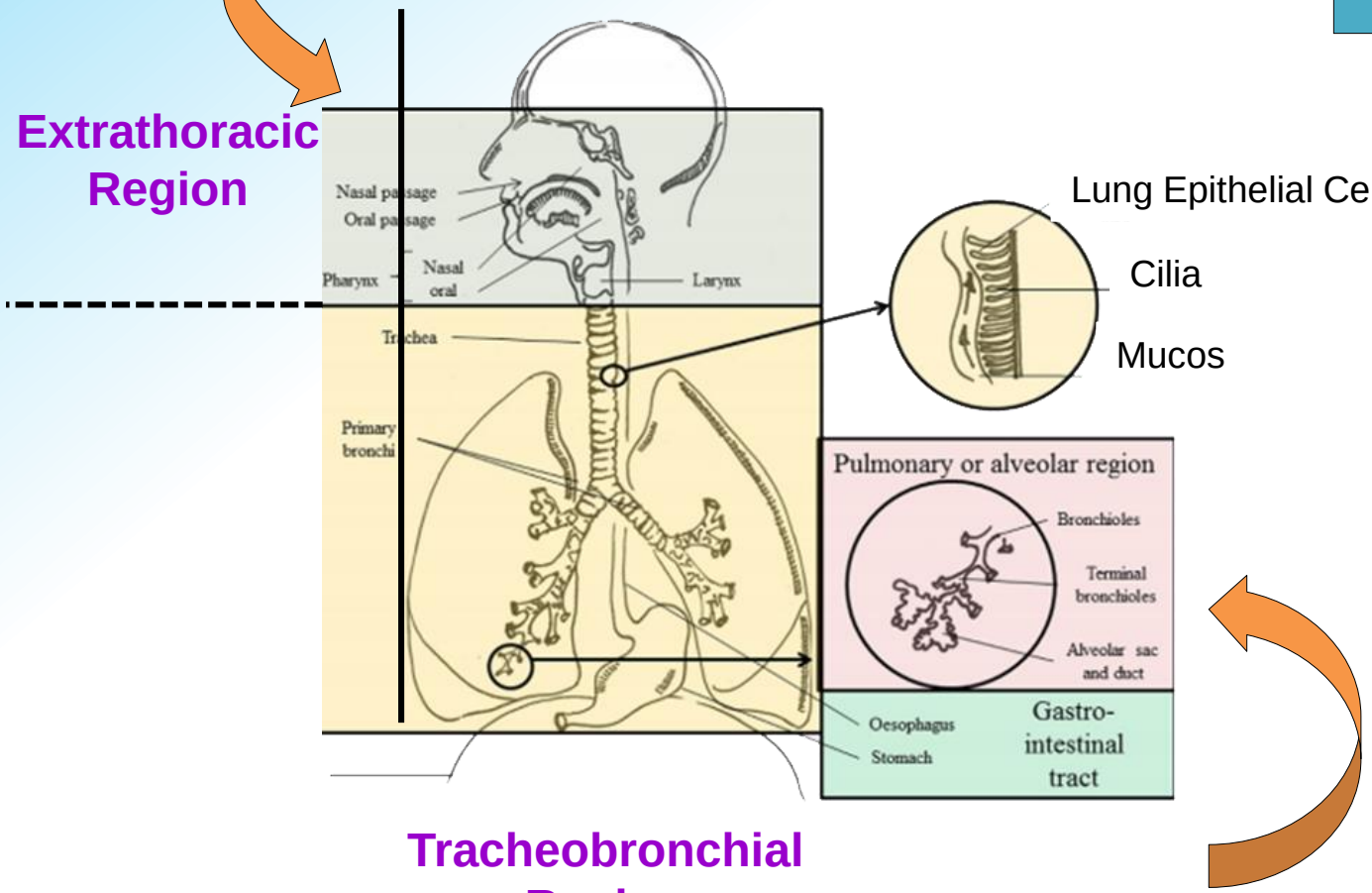
New Mexico EPSCoR

Respirable Particles

Bigger particles more than 10 μm cleared to gastro intestinal tract

Bigger Particles can Interact with Gastric and Intestinal fluids

Extrathoracic Region



Lung Epithelial Cells

Cilia

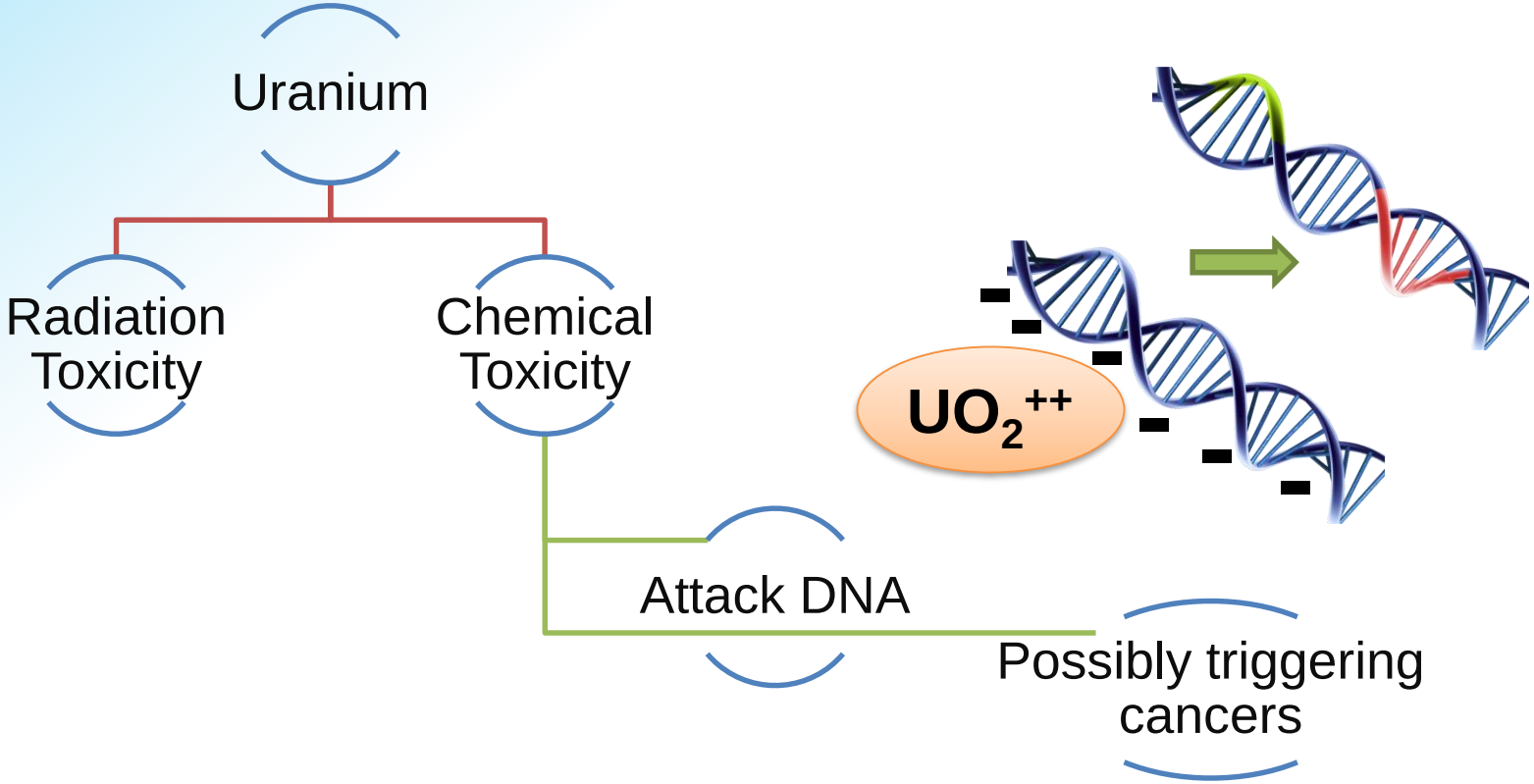
Mucos

Tracheobronchial Region

Smaller particles less than 5 μm enters the alveolar region

Hoffmann (2011)

Why Uranium is Bad to Inhale?



Evidences from Mice and Rat Studies

DNA strand break in lung cells, kidney cells

Macrophages death

Histological alterations

Asic et al., (2017), Stearns et al., (2005)

Why Uranium is Bad to Inhale?

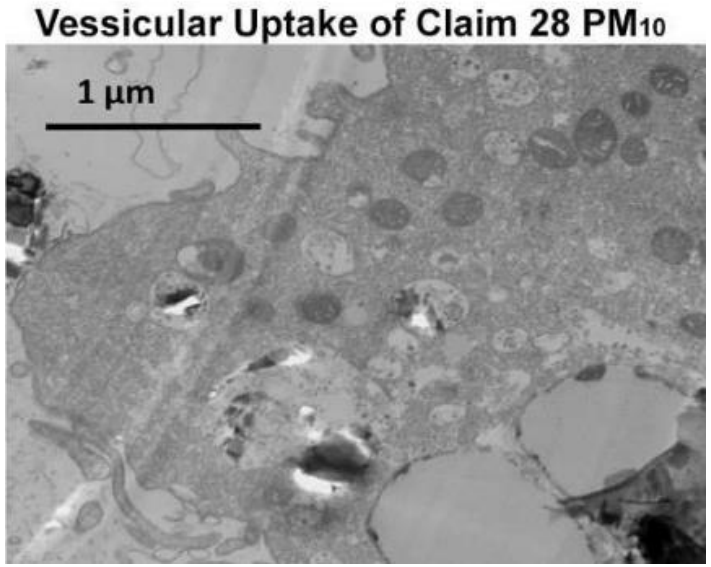
Cardiovascular and metabolic diseases

Proximity to the Uranium Mines

Are uranium in respirable dust responsible?

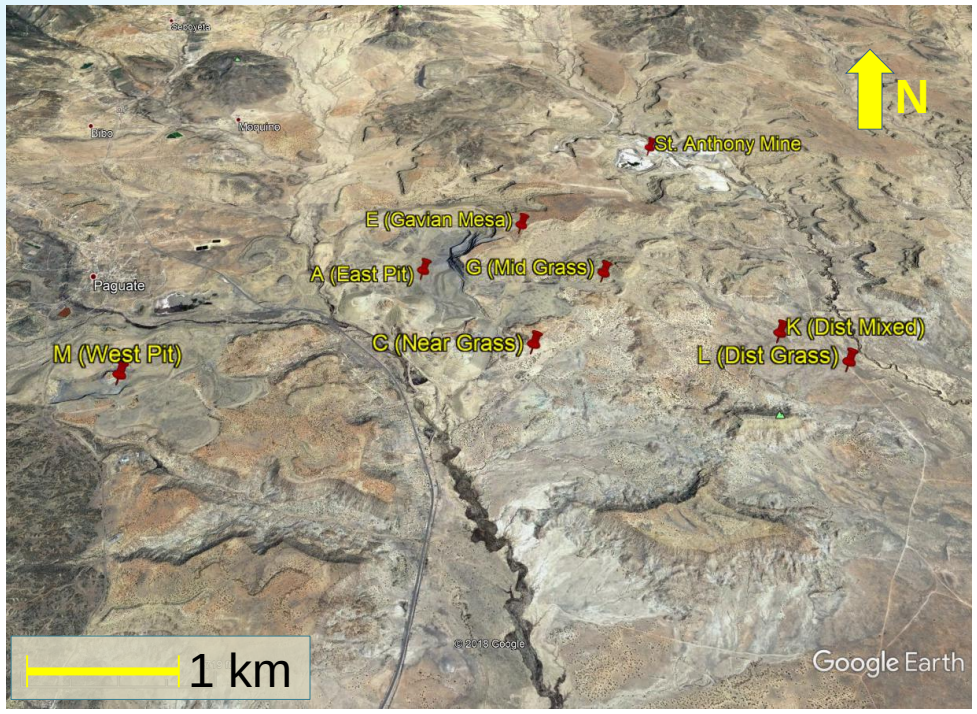
How does Uranium affect?

Chemistry behind the Uranium toxicity?

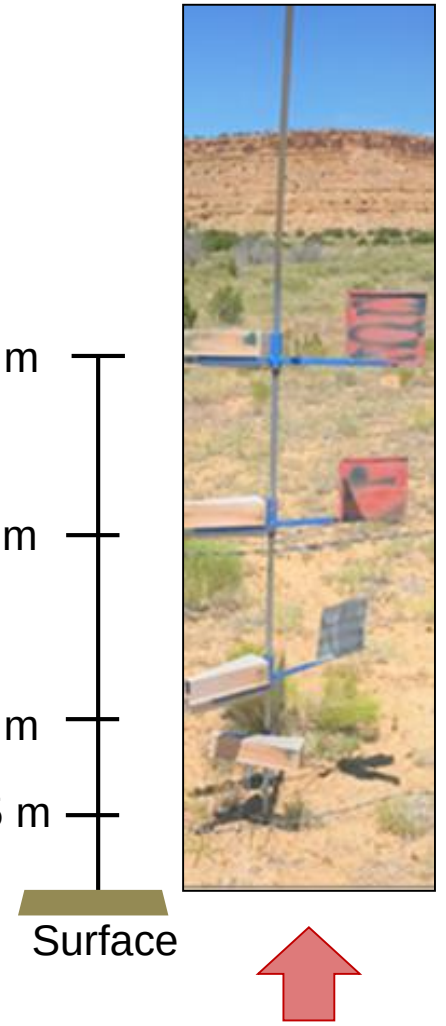


Zychowski et al., (2018)

Locations of the Collected Dusts

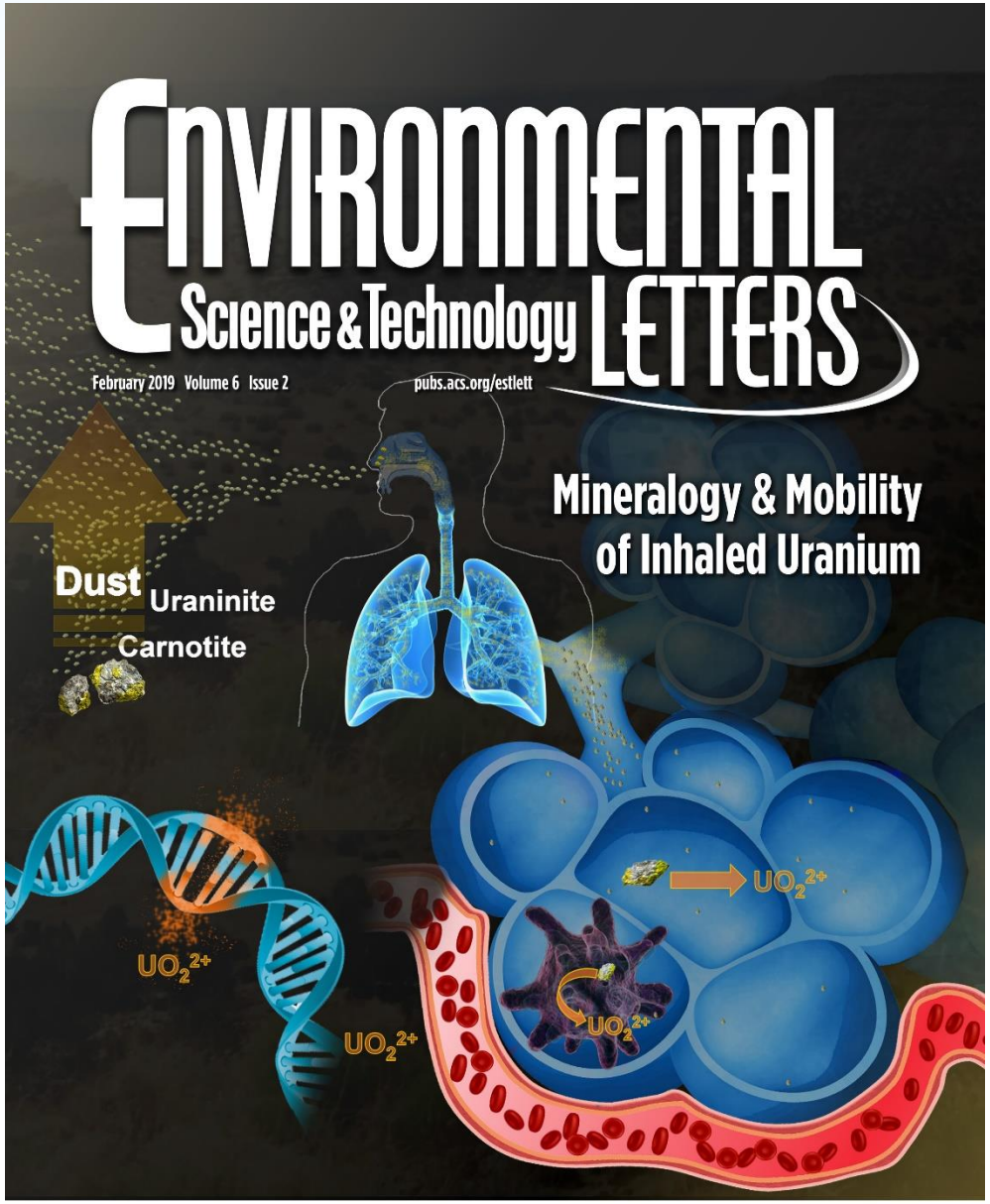


Dusts Deposited at or Above 1.5 m from Surface was Collected during the 2017 Summer and 2018 Fall used for Analysis

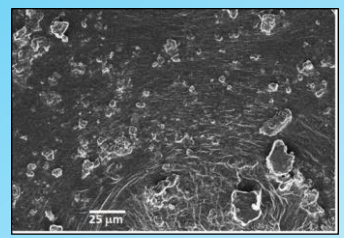


Four Big Spring Number Eight Passive Dust Collectors at Four Sampling Heights

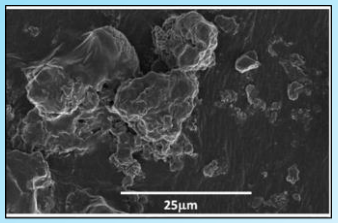
Fate of 4μm or Less Sized – (PM_4) Particles in the Lungs



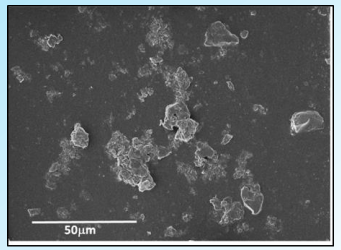
Particle Size Distribution



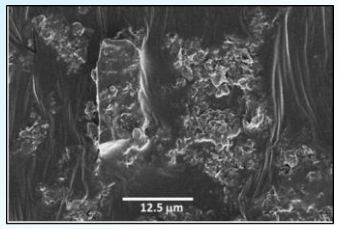
Site A



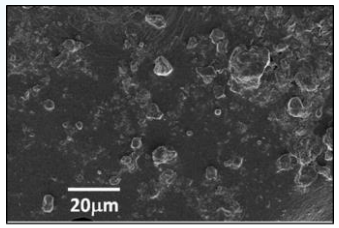
Site C



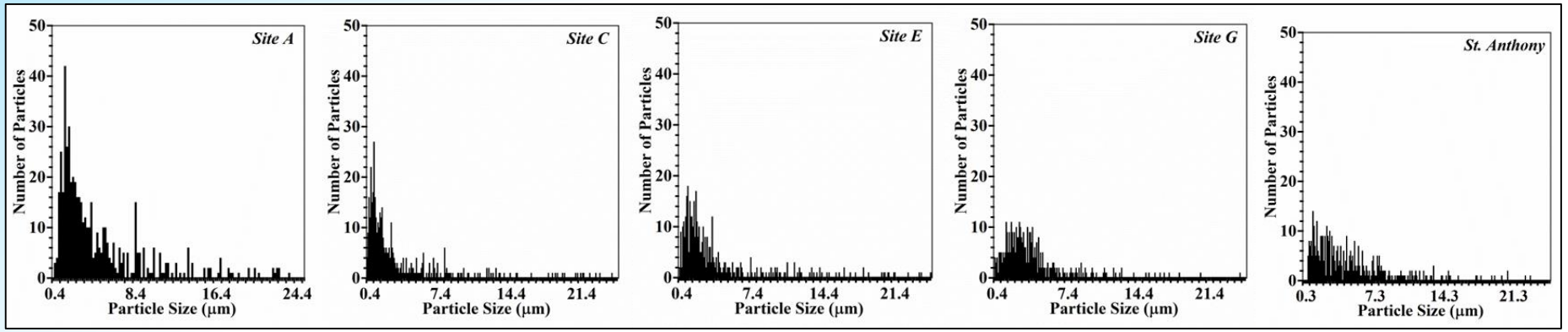
Site E



Site G



St. Anthony



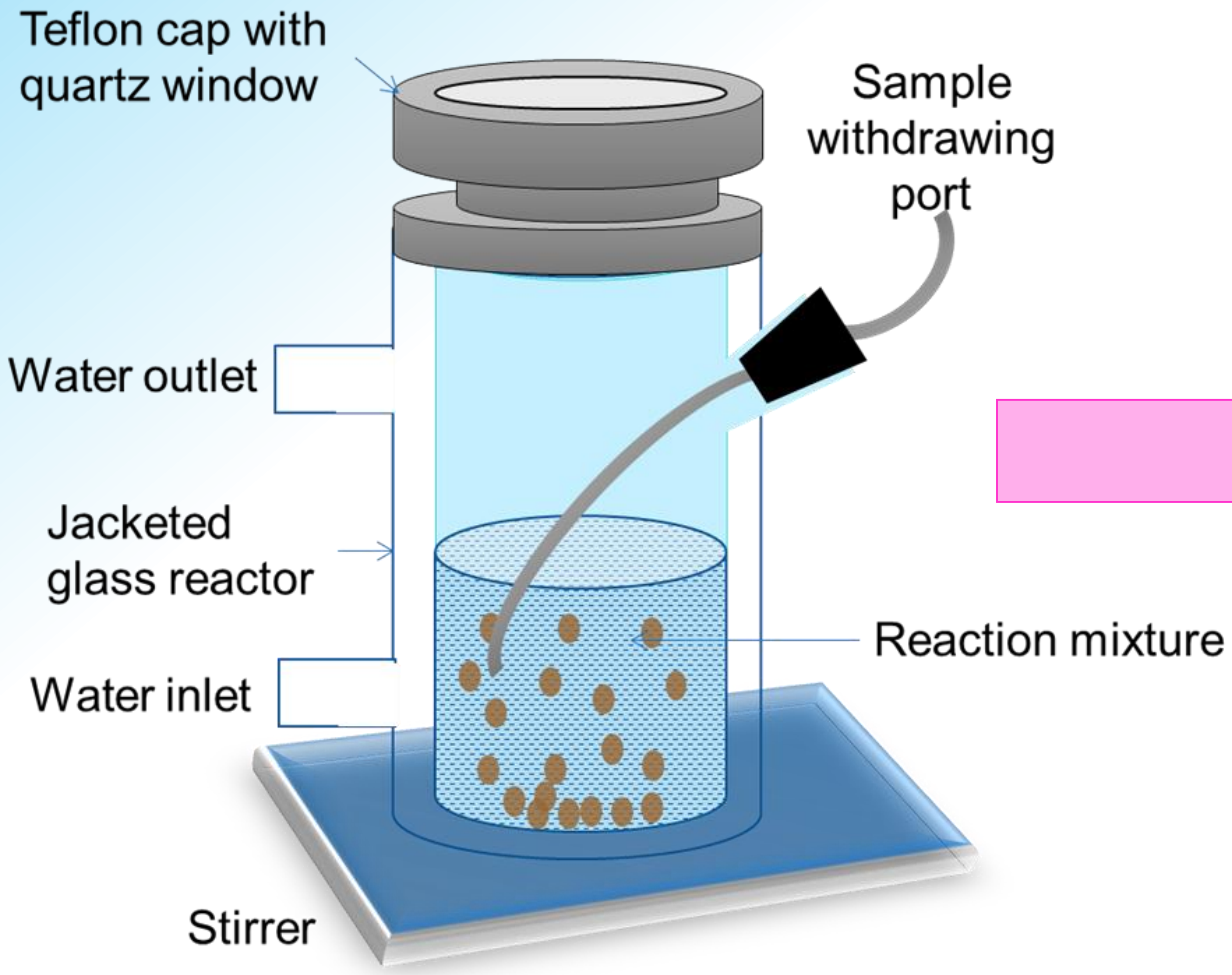
Particle Size Analysis of the Dusts; ImageJ

Sample	# of Particles Analyzed	Average Length (µm)	PM_{10}	PM_4
A	520	4.7±4.6	88%	61%
C	421	3.4±4.6	92%	75%
E	418	4.0±4.8	89%	74%
G	380	3.9±3.3	94%	69%
St. Anthony	424	4.6±4.0	90%	57%

Specific Surface Area & U Percentage

Sample	7 Points N_2 BET Surface Area (m^2/g)	%U (w/w)
St. Anthony Sediment	1.61±0.08	0.87
Site A	2.10±0.09	0.23
Site C	0.77±0.14	0.14
Site E	14.5±1.0	0.18
Site G	1.77±0.59	0.23

Batch-Reactor Dissolution Studies in Simulated Lung Fluids



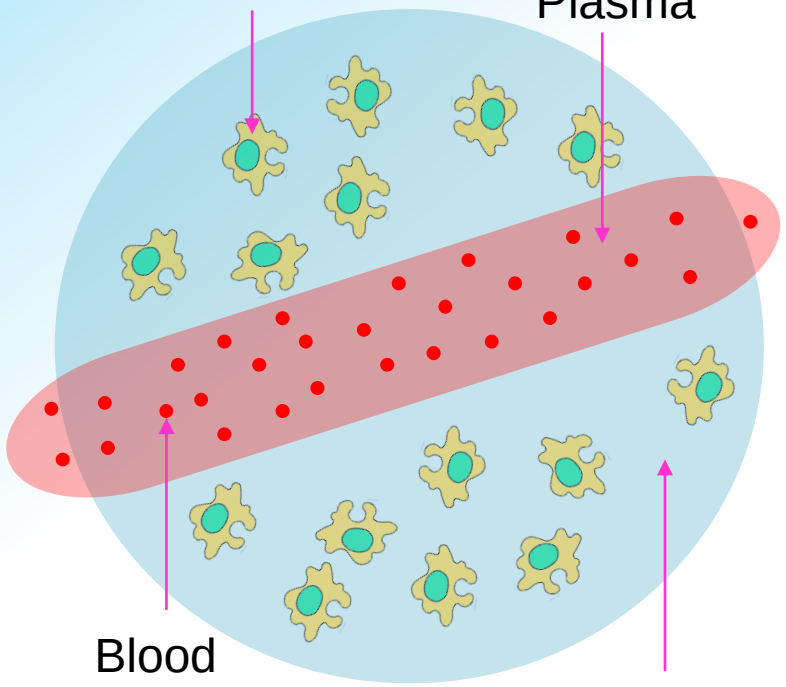
ICP – MS Analysis

Maintained at 37 °C, Inside a Dark Room

Simulated Lung Fluids (SLFs)

Mimics using ALF

Intracellular Fluid in macrophages - (ICF)



Mimics using Gambel's (GS)

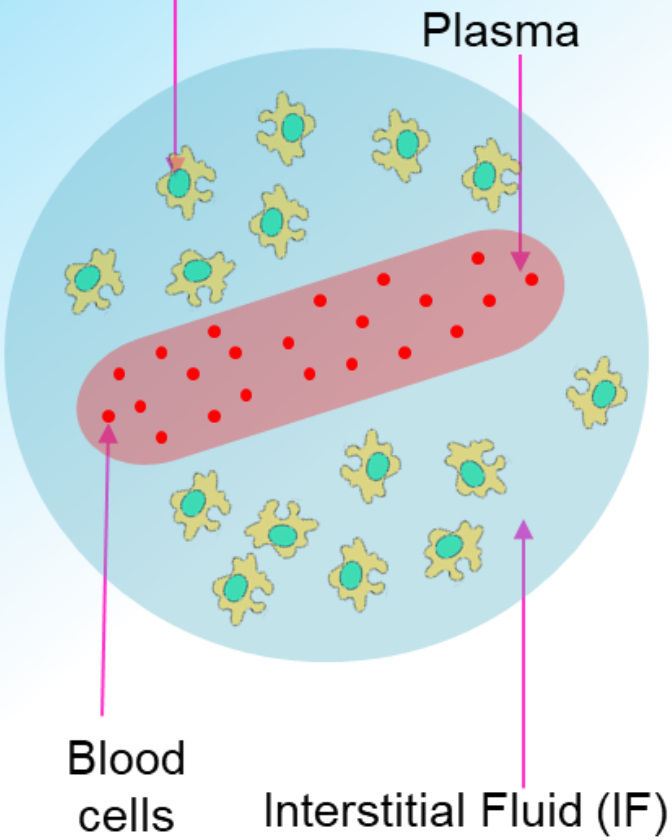
Composition ($g \cdot L^{-1}$)	Gamble	ALF
NaCl	6.779	3.21
Na_2HPO_4		0.071
$NaHCO_3$	2.268	
Trisodium citrate dihydrate	0.055	0.077
NH_4Cl	0.535	
Glycine	0.375	0.059
NaH_2PO_4	1.872	
L-cysteine	0.121	
NaOH		6.0
Citric acid		20.8
$CaCl_2 \cdot 2H_2O$	0.026	0.128
Na_2SO_4		0.039
$MgCl_2 \cdot 6H_2O$		0.05
Disodium tartrate		0.09
Sodium lactate		0.085
Sodium pyruvate		0.172
Properties		
pH	7.3 ± 0.1	4.5 ± 0.1
Ionic strength ($mol \cdot L^{-1}$)	0.17	0.34

Pelfrêne et al., (2017)

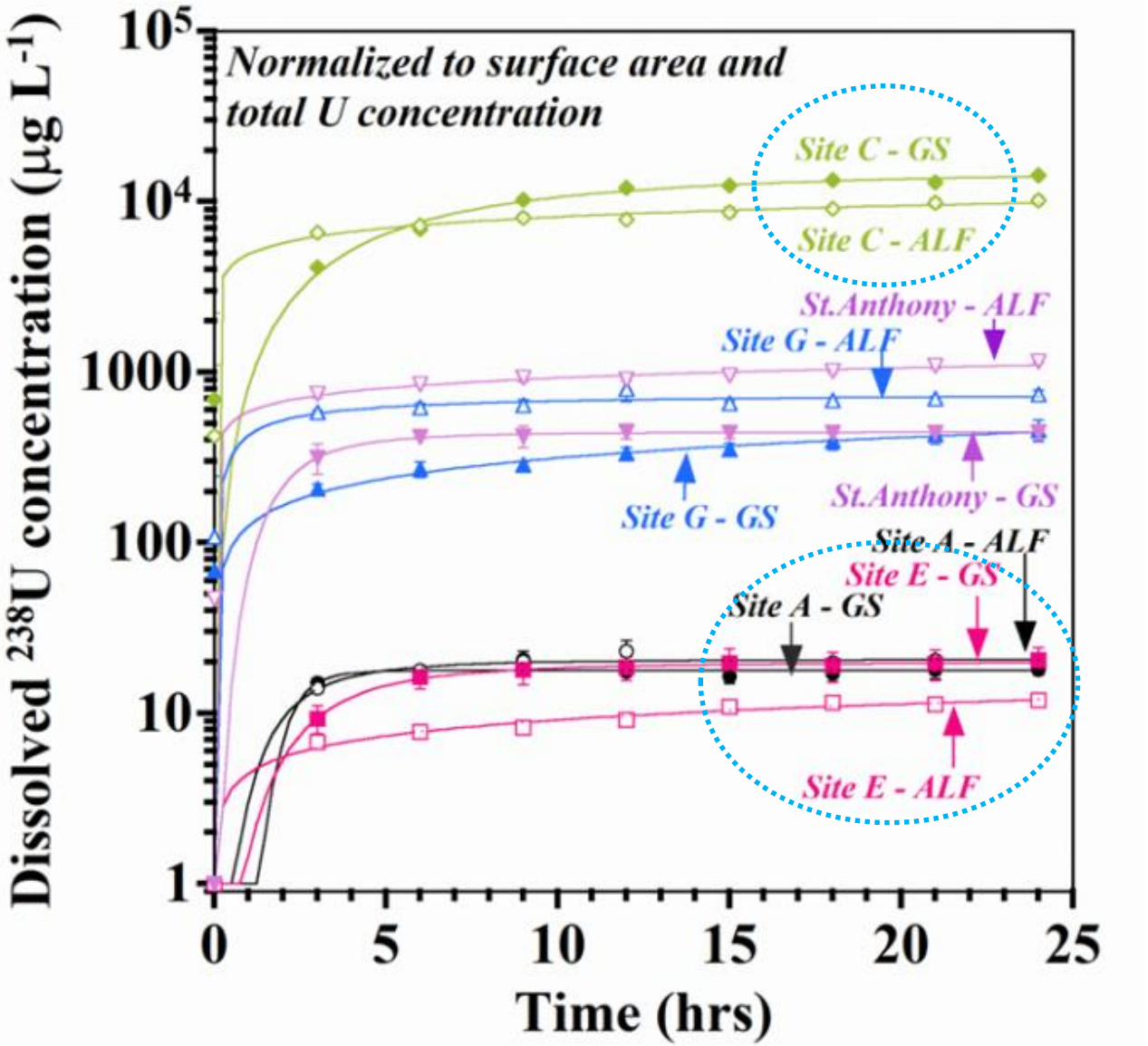
Dissolution of U from the Dusts

Mimics using ALF

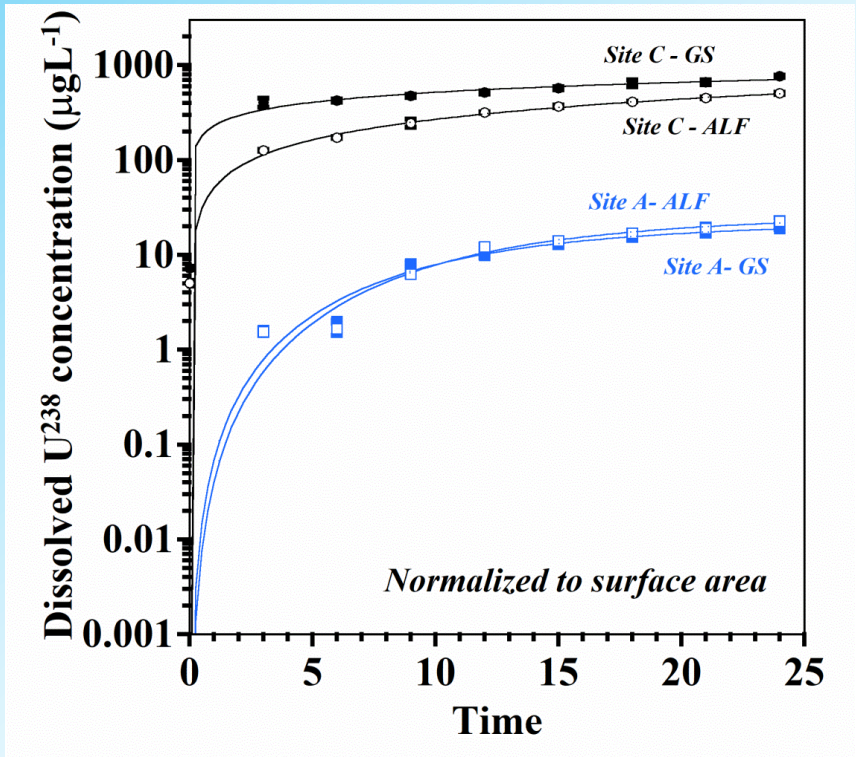
Intracellular Fluid in macrophages - (ICF)



Mimics using Gambel's (GS)



Persistence with Seasons



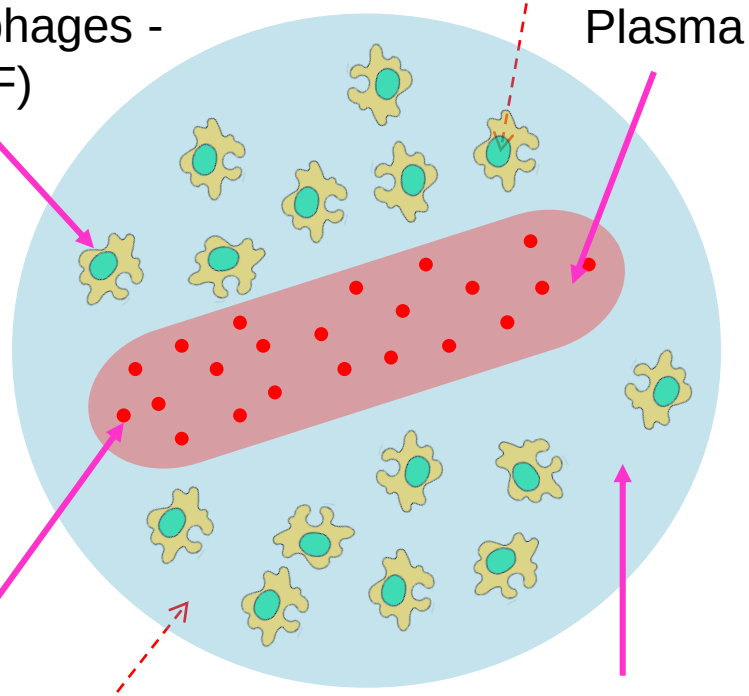
Winter 2017, Dusts were Collected 4 Months After the First Collection

Uranium from Sites A, G and St. Anthony would more mobilize

Mimics using ALF

Intracellular Fluid in macrophages - (ICF)

Plasma



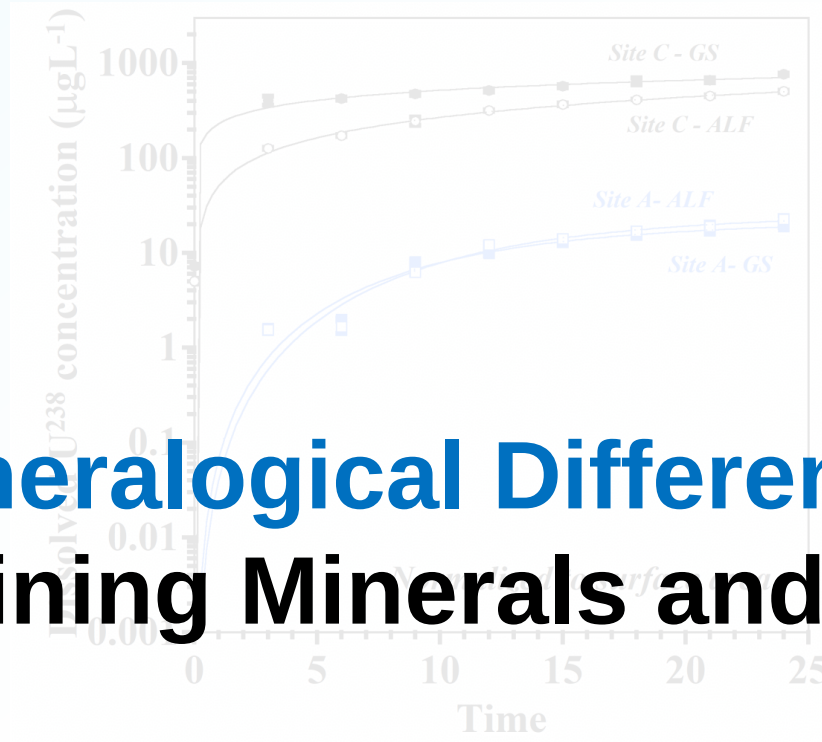
Blood cells

Interstitial Fluid (IF)

Mimics using Gambel's (GS)

Uranium from Sites C and E would become more mobilize

Persistence with Seasons



Winter 2017, Dusts were Collected 4 Months After the First Collection

Uranium from Sites A, G and St. Anthony would more mobilize

Mimics using ALF
Intracellular Fluid in macrophages - (ICF)

Plasma

Blood cells

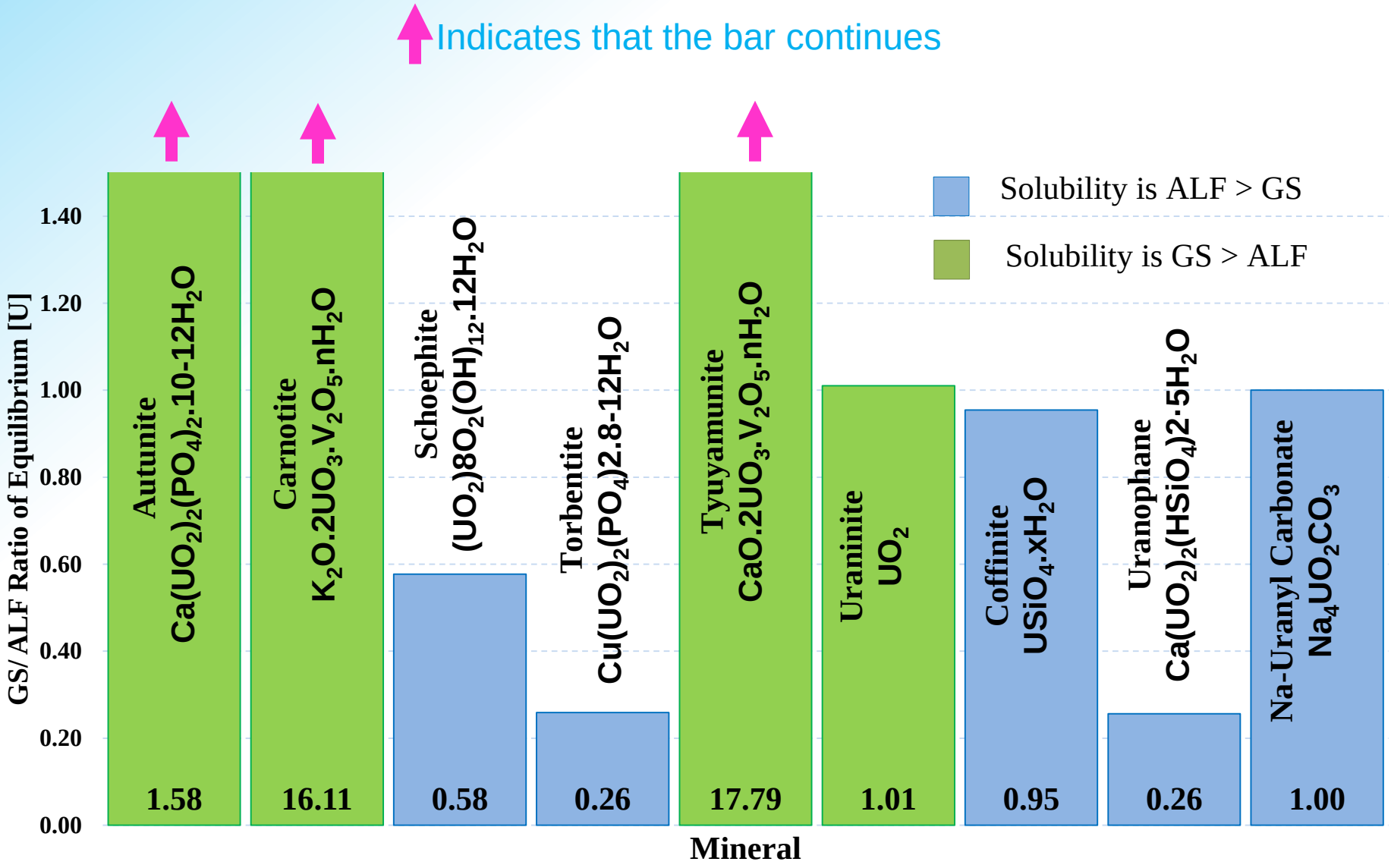
Interstitial Fluid (IF)

Mimics using Gambel's (GS)

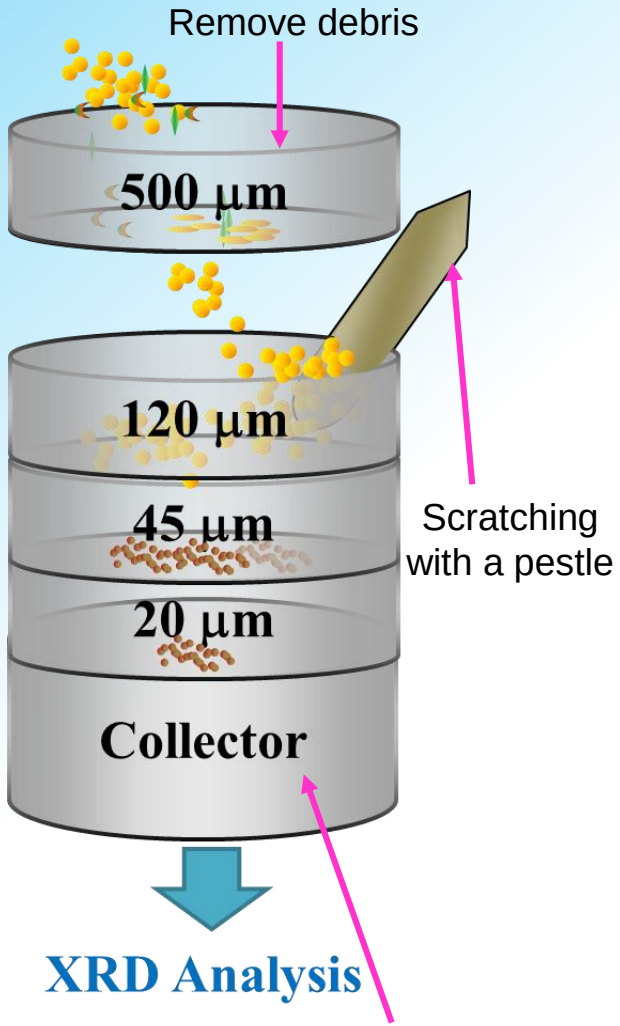
Uranium from Sites C and E would become more mobilize

Mineralogical Differences of both Uranium Containing Minerals and Other Existing Minerals

Single Uranium Mineral Study – PHREEQC 3.3.8.



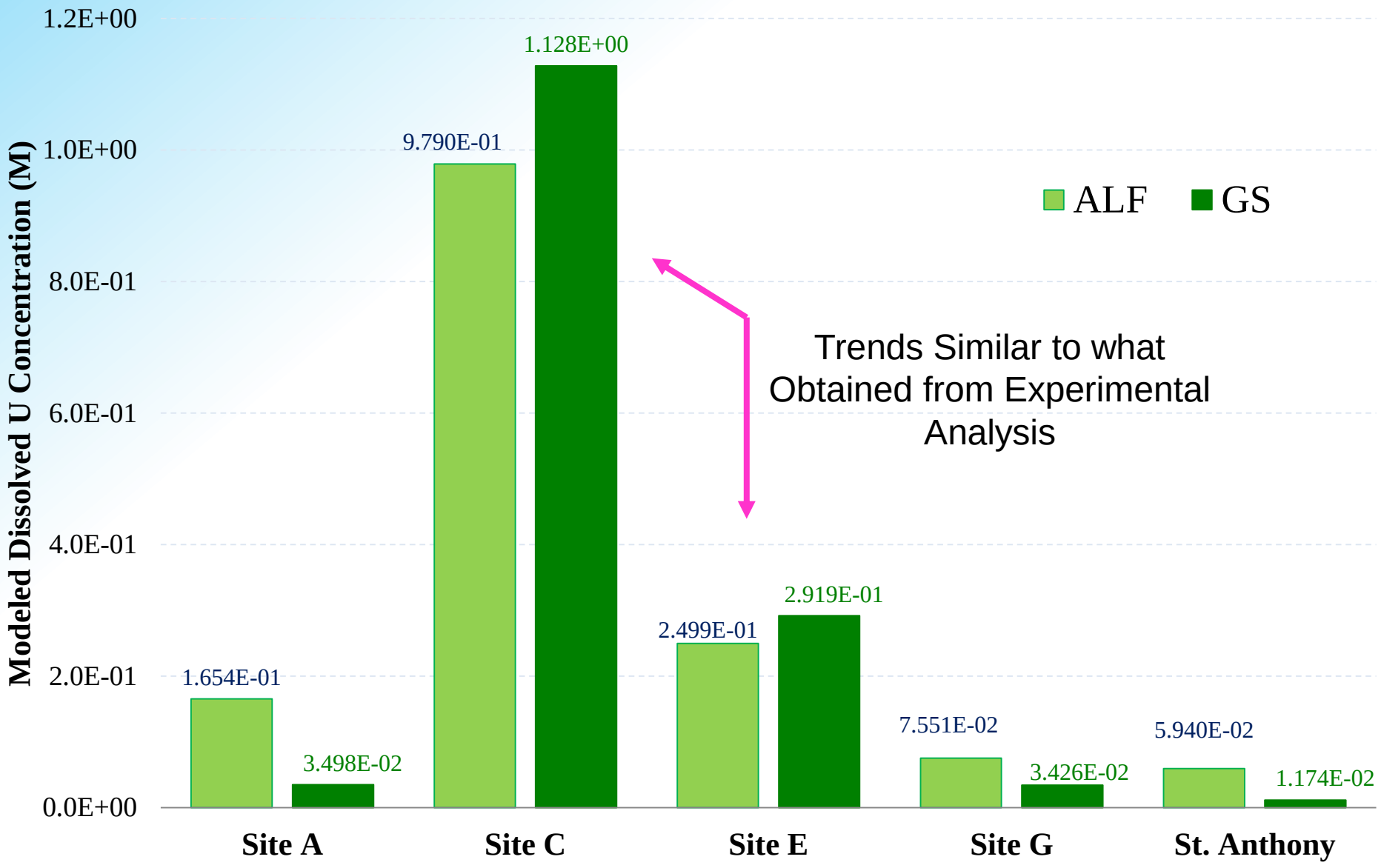
Mineralogy of Dusts



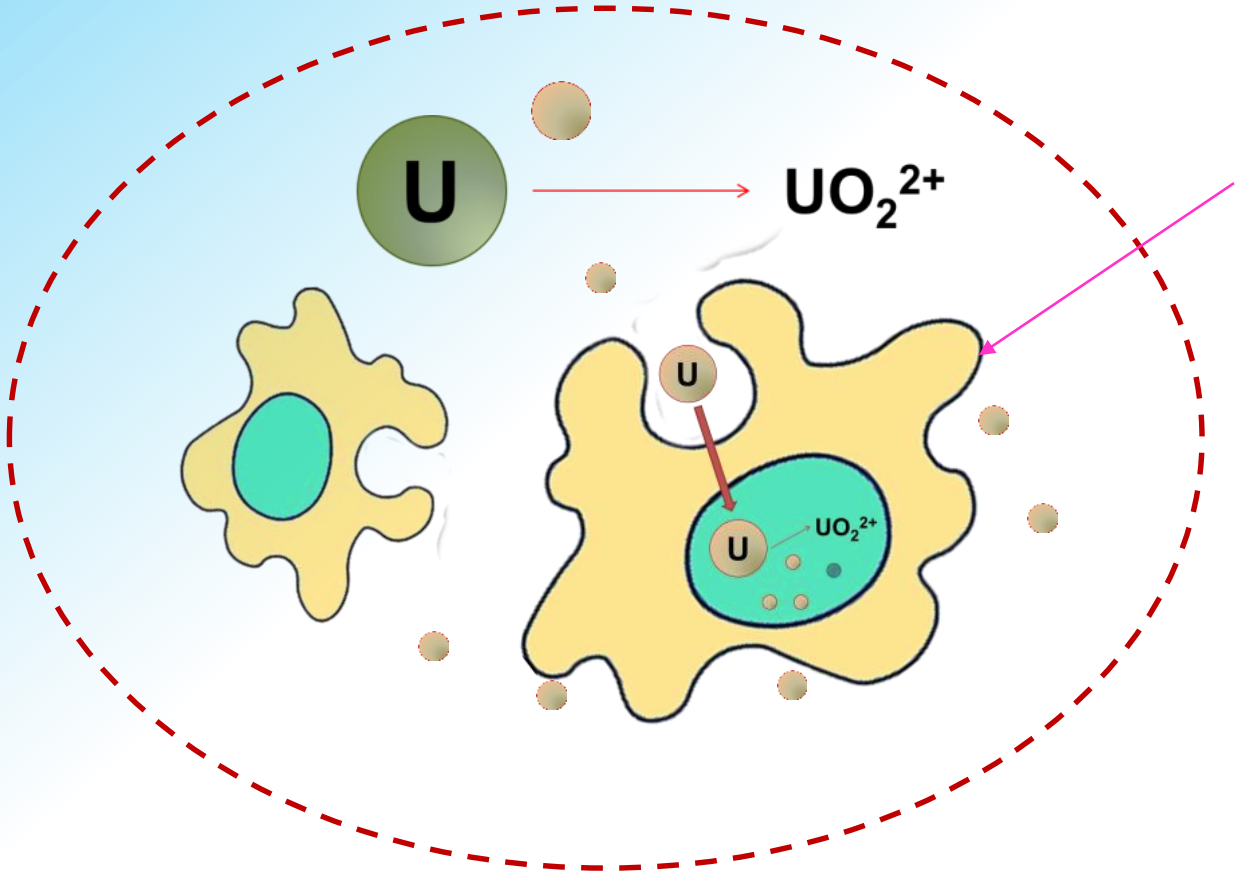
Dissolution of U is higher in GS

Sample	St. Ant.	Site A	Site C	Site E	Site G
Quartz	√	√	√	√	√
Dolomite	√	√	√	√	√
Microcline	--	√	√	√	√
Kaolinite	√	√	--	--	√
Calcite	--	--	√	√	√
Rutile	√	--	--	--	--
Uraninite	√	--	√	√	√
Coffinite	√	--	√	√	√
Andersonite	--	--	√	√	√
Torbentite	--	√	--	√	√
Tyuyamunite	--	--	--	--	√
Carnotite	--	--	√	√	--
Uranophane	√	--	--	--	--
Schoephite	√	--	--	--	--
Atunite	√	√	√	√	√

Simulating the Dust



Dissolved Uranium Species



Alveolar Macrophages

Curcumin-TritonX Method thru
Colorimetry & Fluorescence Quenching
Confirms the Primary Dissolved Species is UO_2^{2+}

Orange Coloration and
Absorbance Maxima at 430 nm
Indicates the Presence of UO_2^{2+}

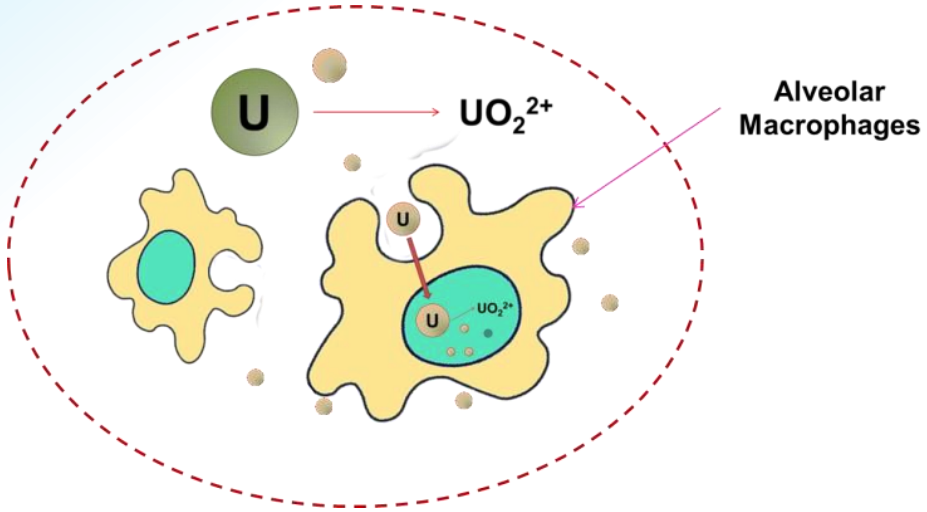
Method is from Zhu et al., (2016)

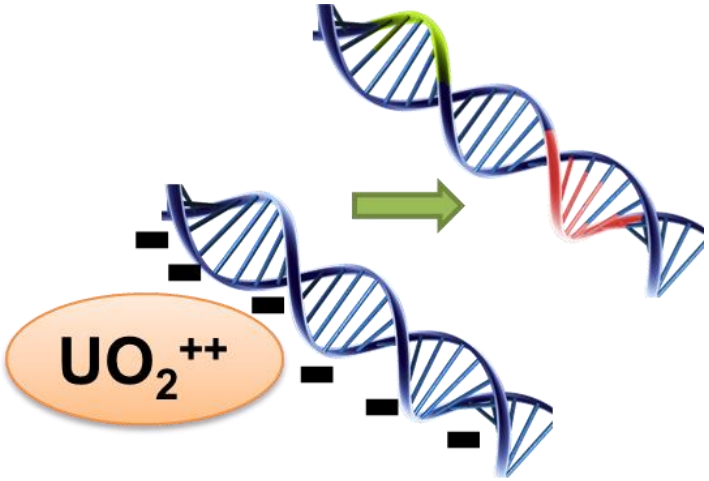
Health Implications

- Uranium in the air-born dusts can be inhalable
- After inhalation, they become soluble in the lung fluids primarily producing UO_2^{2+}
- Extent of dissolution is controlled by the mineralogy of dusts

- Carnotite, Autunite, Thyuyamunite and Uraninite likely to dissolve more in interstitial fluid
- Schoephite, Torbenite, Coffinite, Uranophane and Uranyl carbonates likely to dissolve more in alveolar macrophages
- non-uranium minerals such as calcite, kaolinite affects on the uranium dissolution

- The toxicological assessments on these mining lands should be site-specific rather than applied generally





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