Retrospective of U.S. Nuclear Regulatory Commission Efforts on Natural Analogs and the Peña Blanca Uranium District

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The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of a license application for a geologic repository at Yucca Mountain.

Natural Analog: Regulatory Perspective

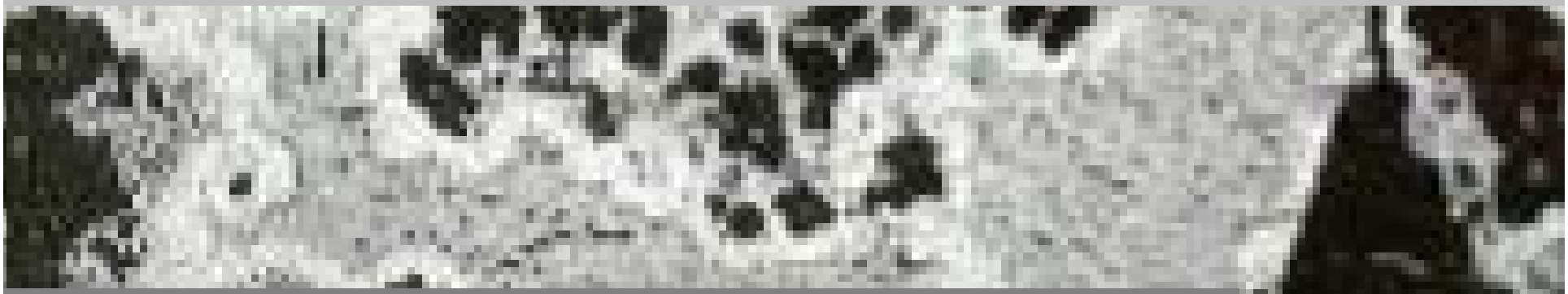
Natural analog studies are independently used by the NRC to:

1. **Understand the limitations for using natural analog information to support models used to demonstrate repository performance**

2. **Identify processes and events likely to occur in a repository over time, thus assisting in evaluation of conceptual models used for estimating potential repository performance**

Peña Blanca Natural Analog: Background

In 1989, the NRC Office of Research identified the Peña Blanca Uranium District in Chihuahua, Mexico as being a potential natural analog site to study the processes and events relating to uranium migration in an unsaturated, fractured tuff. (Murphy, Pearcy, & Goodell, 1991)



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Peña Blanca Natural Analog Objectives

Better understand potential performance of a tuff-hosted repository by:

- **Characterizing oxidative alteration processes of uraninite (source term)**
- **Characterizing processes related to radioelement migration through a fractured tuff**
- **Modeling processes important to uraninite oxidation and radioelement migration**

Uranium Minerals and Oxidative Alteration

Uranium minerals at Nopal I

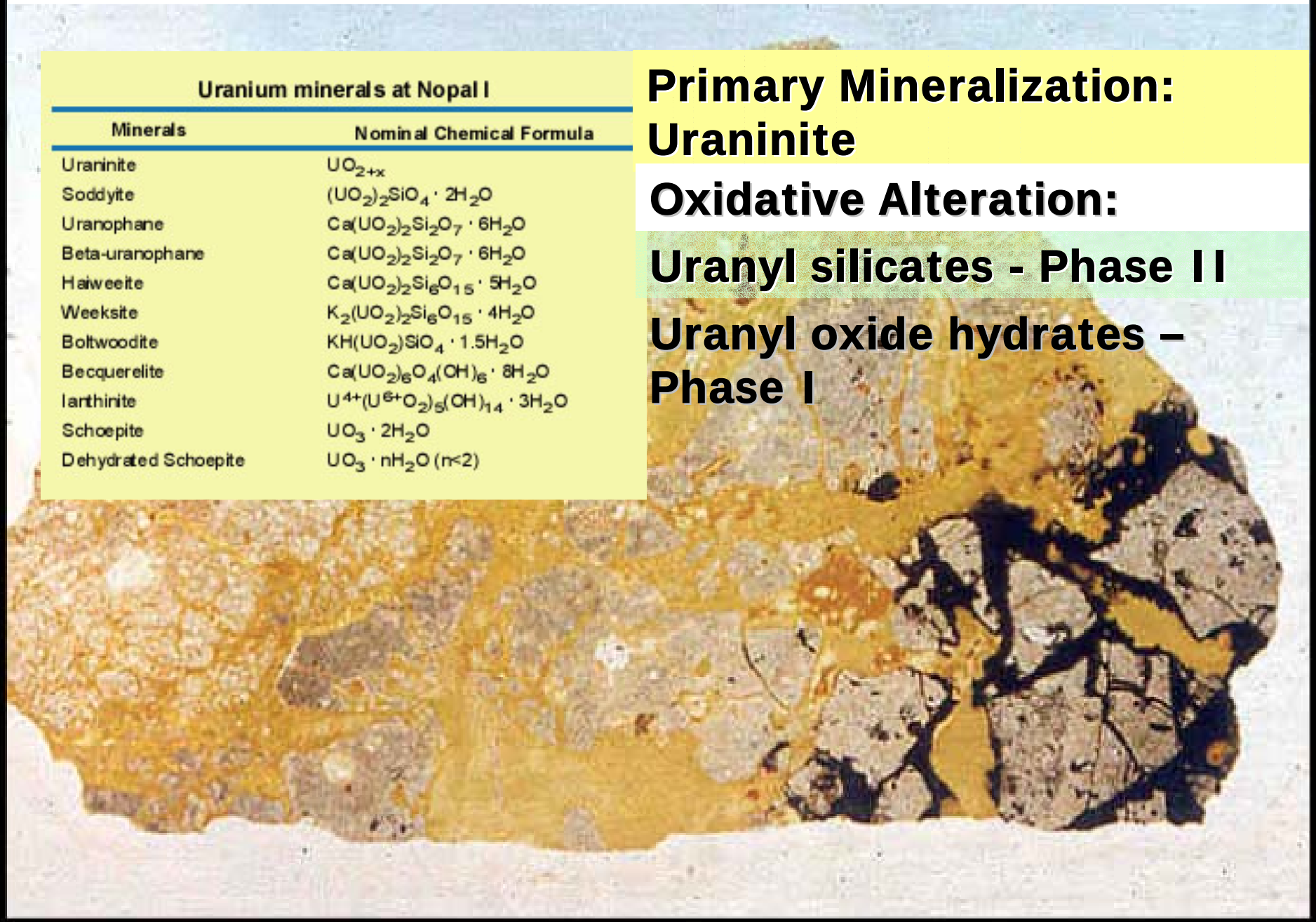
Minerals	Nominal Chemical Formula
Uraninite	UO_{2+x}
Soddyite	$(UO_2)_2SiO_4 \cdot 2H_2O$
Uranophane	$Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$
Beta-uranophane	$Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$
Haiweeite	$Ca(UO_2)_2Si_6O_{15} \cdot 5H_2O$
Weeksite	$K_2(UO_2)_2Si_6O_{15} \cdot 4H_2O$
Boltwoodite	$KH(UO_2)SiO_4 \cdot 1.5H_2O$
Becquerelite	$Ca(UO_2)_6O_4(OH)_6 \cdot 8H_2O$
Iarthinite	$U^{4+}(U^{6+}O_2)_5(OH)_{14} \cdot 3H_2O$
Schoepite	$UO_3 \cdot 2H_2O$
Dehydrated Schoepite	$UO_3 \cdot nH_2O$ (n<2)

Primary Mineralization: Uraninite

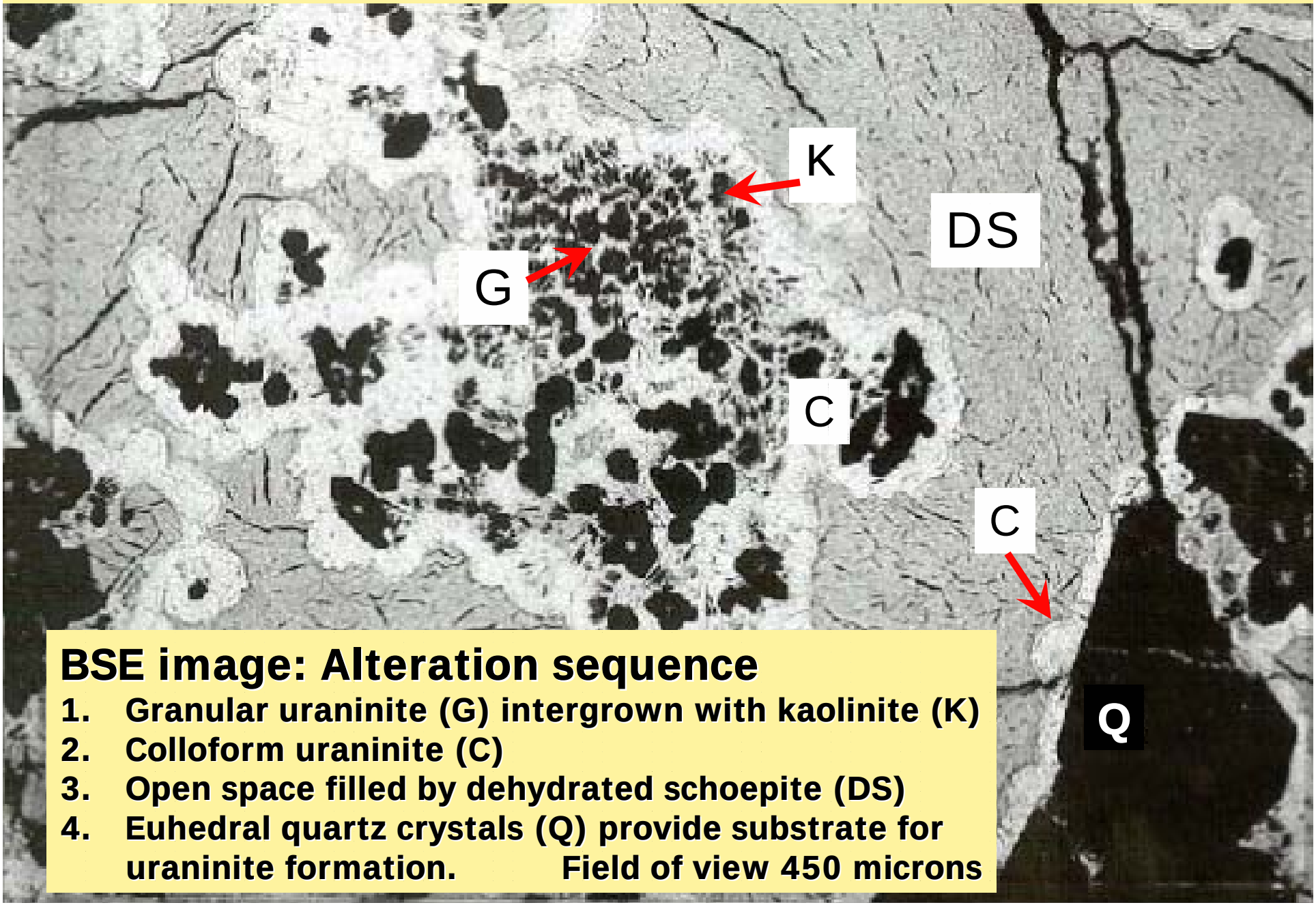
Oxidative Alteration:

Uranyl silicates - Phase II

Uranyl oxide hydrates – Phase I



Uranium Mineral Paragenesis

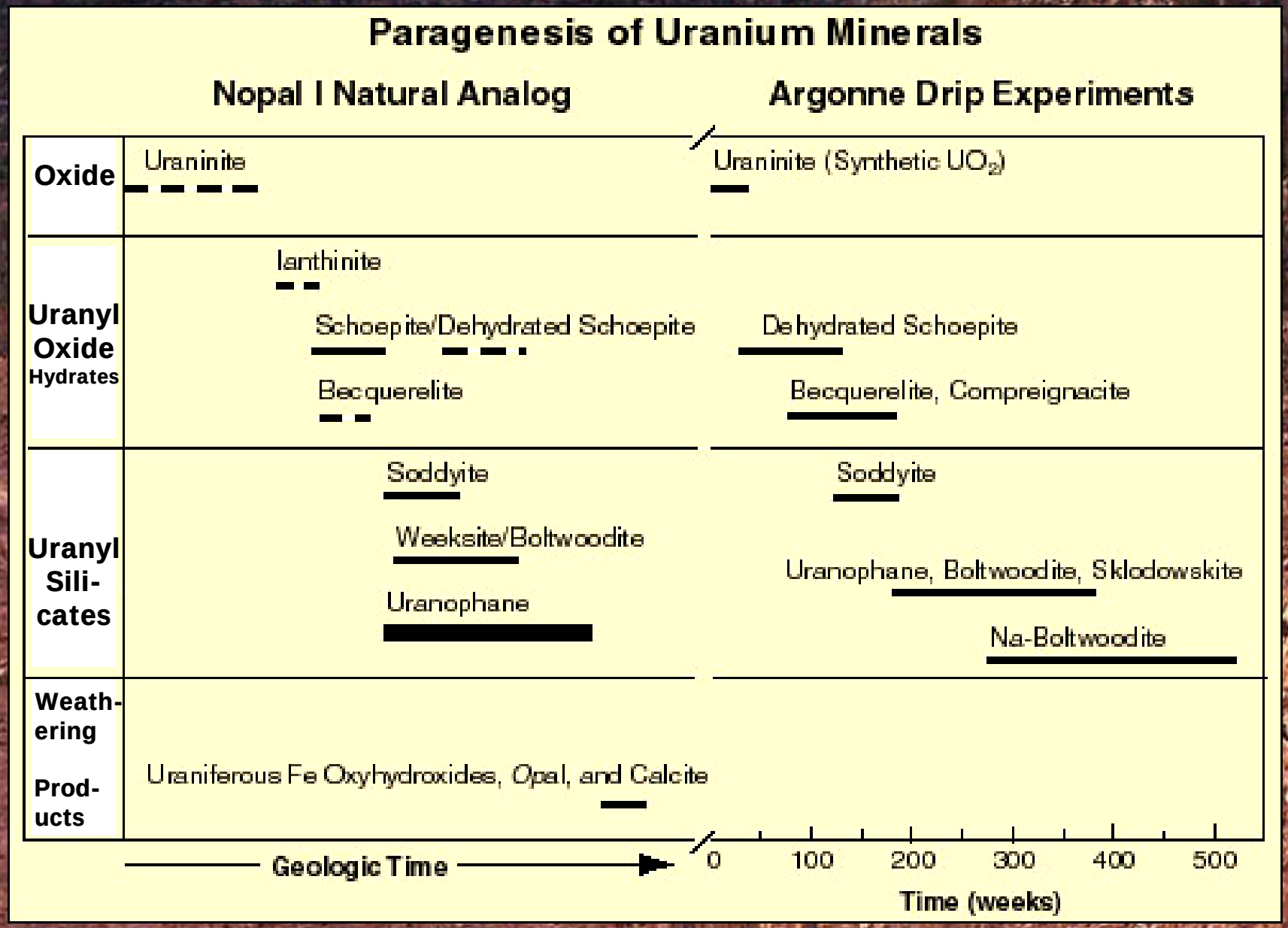


BSE image: Alteration sequence

1. Granular uraninite (G) intergrown with kaolinite (K)
2. Colloform uraninite (C)
3. Open space filled by dehydrated schoepite (DS)
4. Euhedral quartz crystals (Q) provide substrate for uraninite formation.

Field of view 450 microns

Comparison of Uranium Mineral Paragenesis

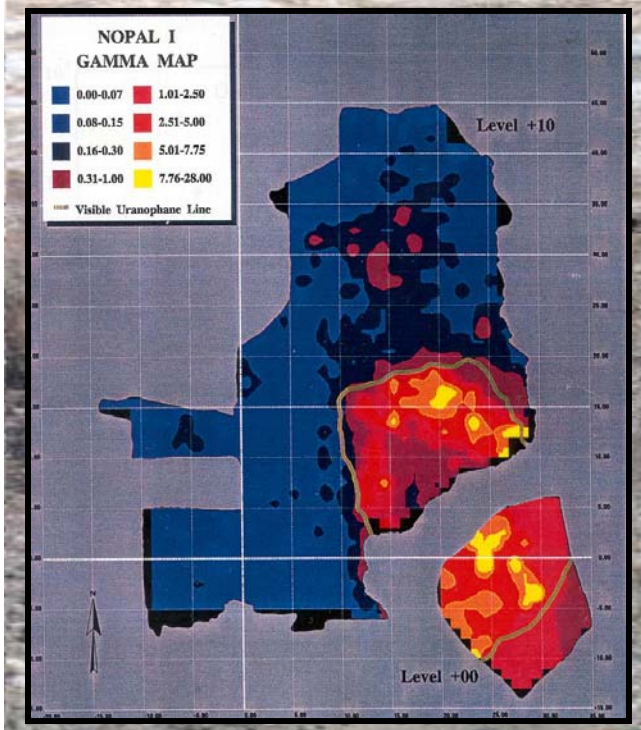


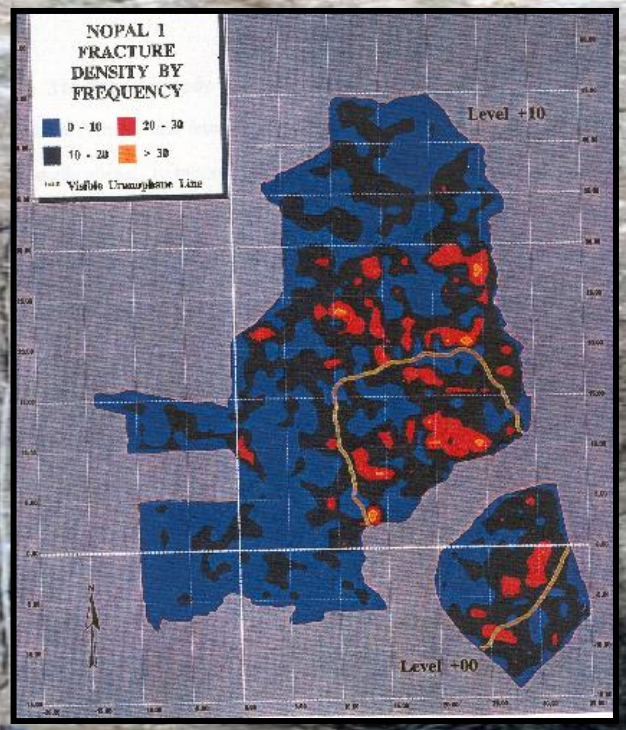
Source Term and Migration Analogy

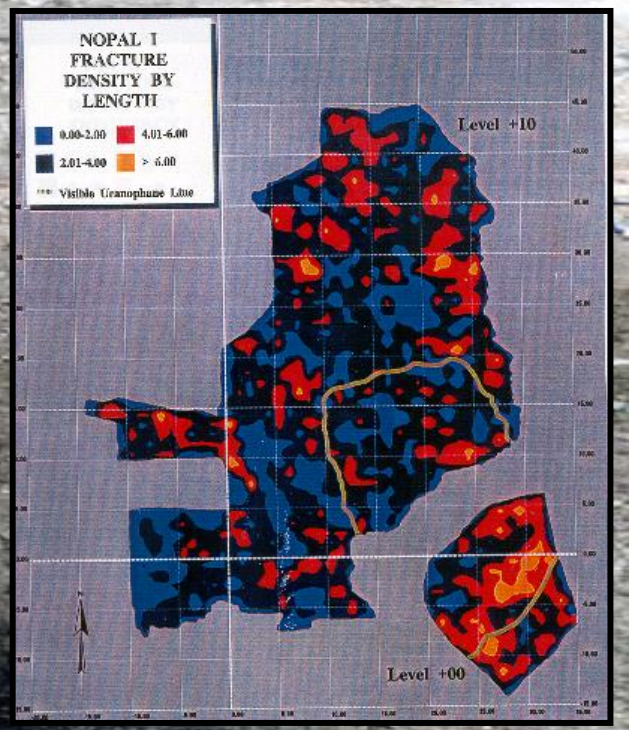
Measured U distribution on Levels 0 and +10

Measured fracture density, orientation, and length

Measured U along and perpendicular to fractures

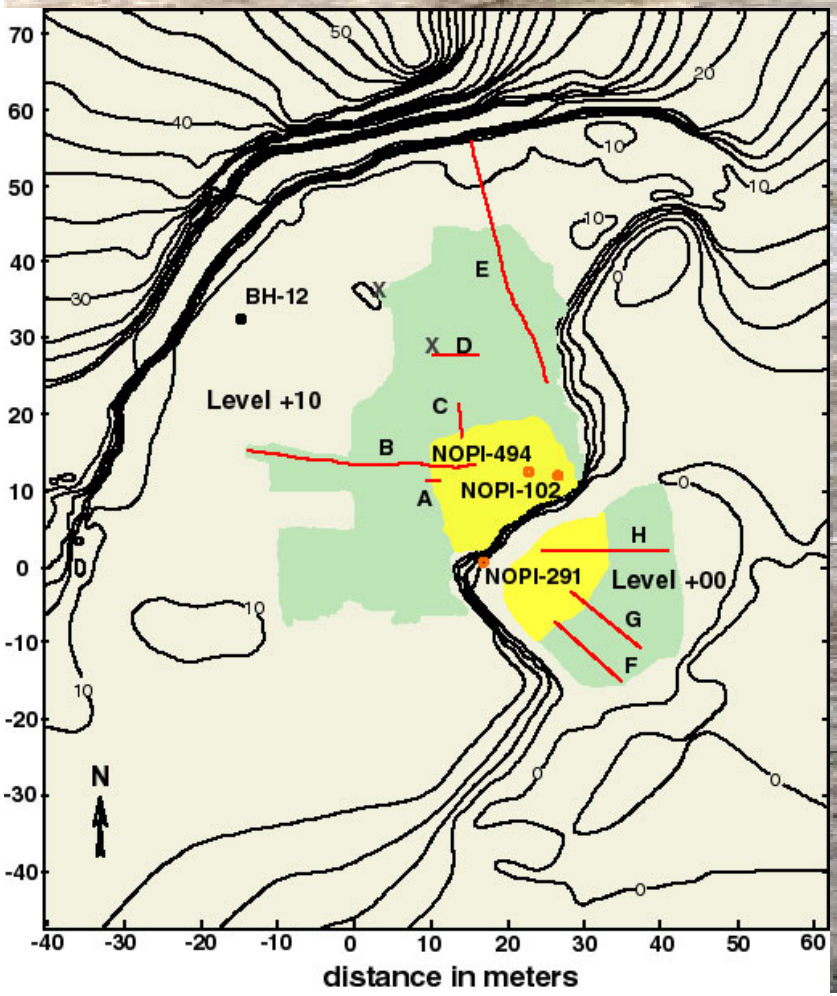


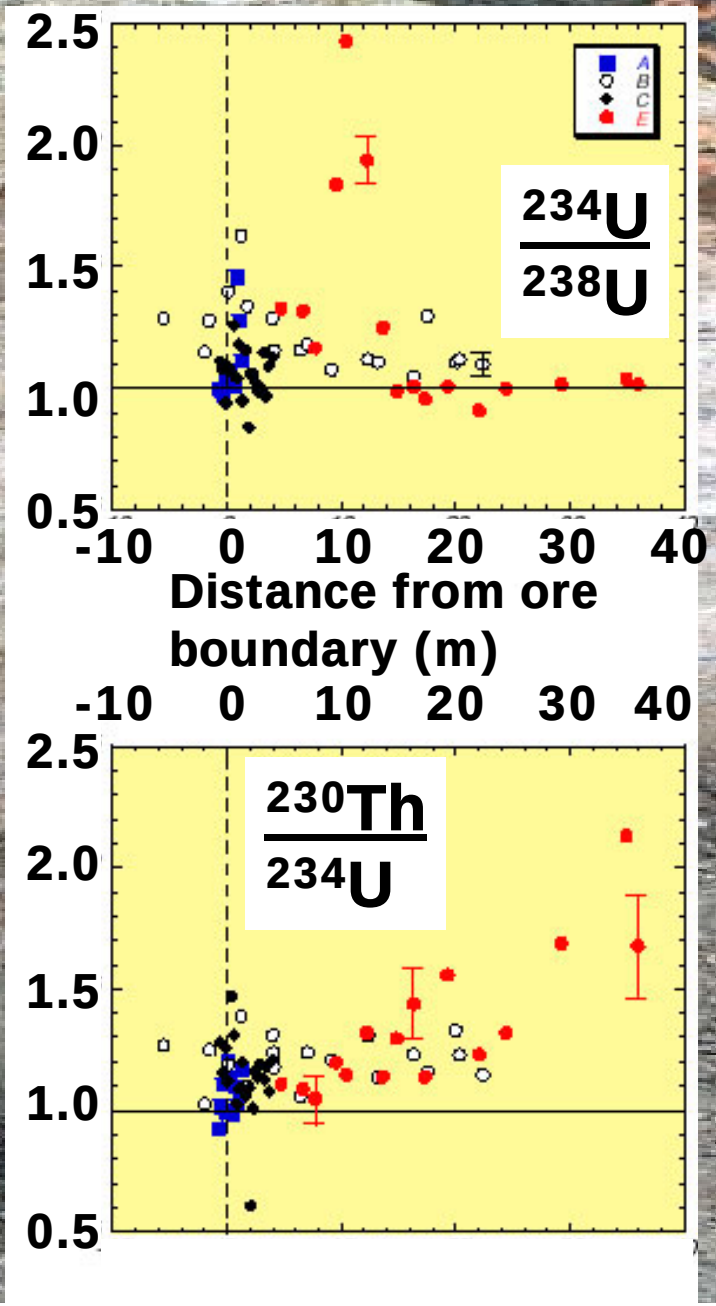




Peña Blanca Analog: Uranium Migration

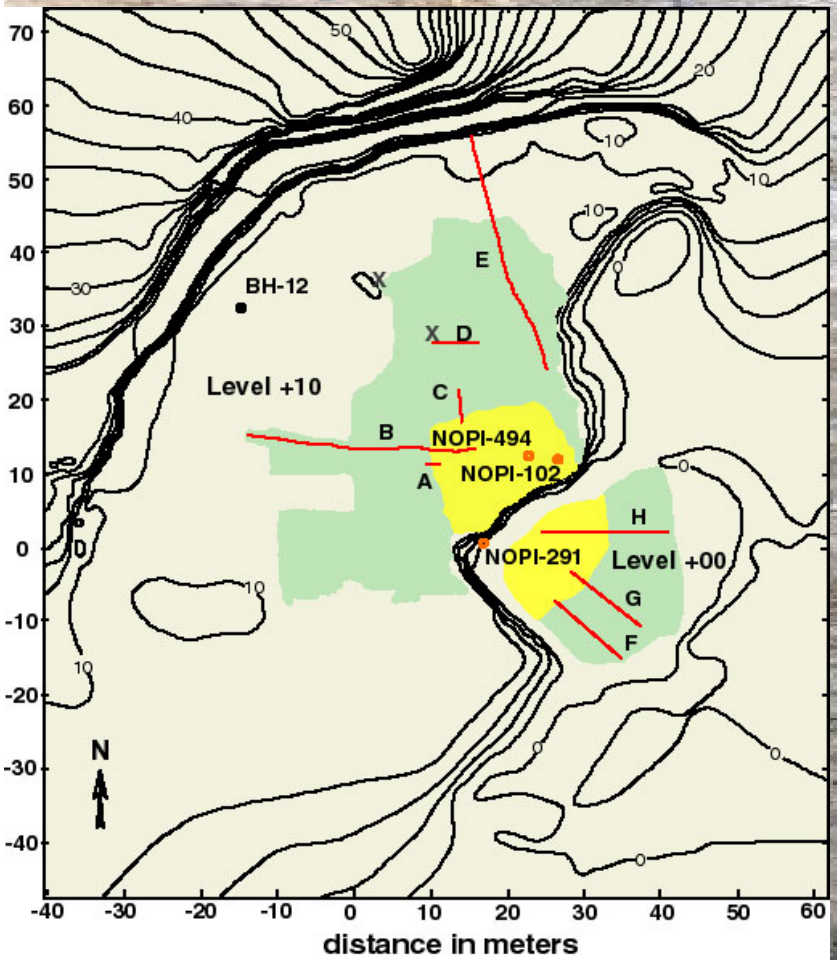
Measured U along fractures for transport studies



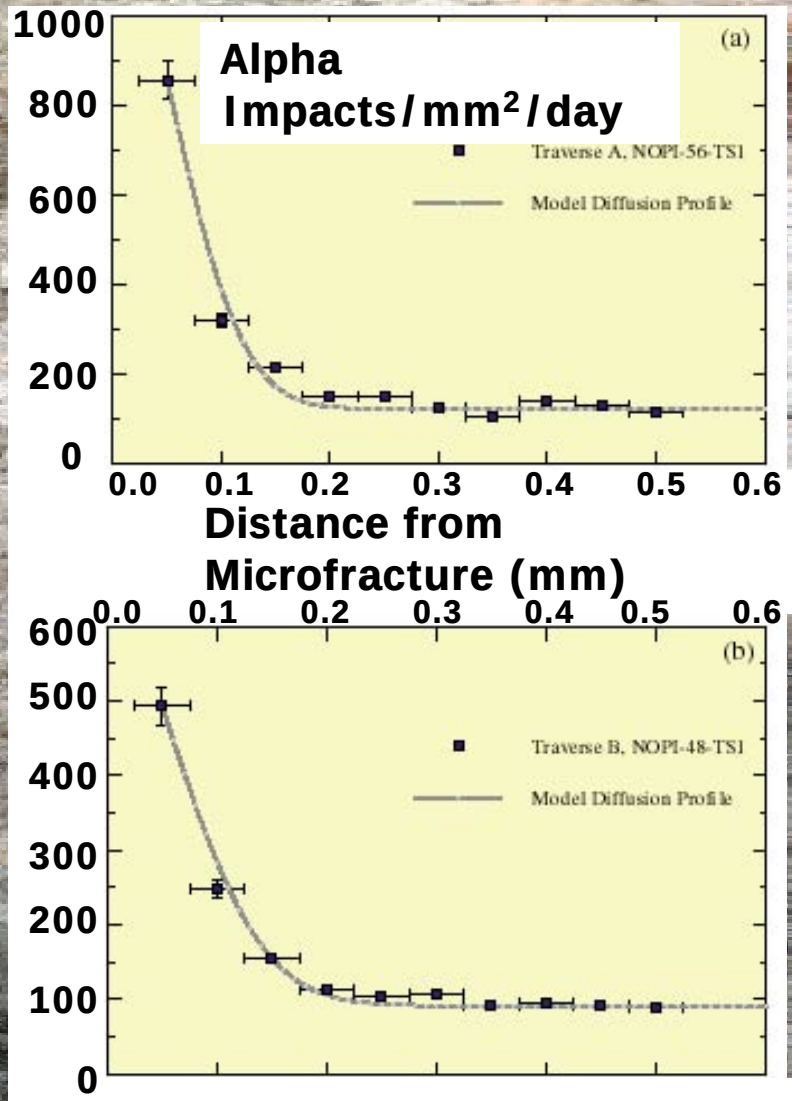


Peña Blanca Analog: Uranium Migration

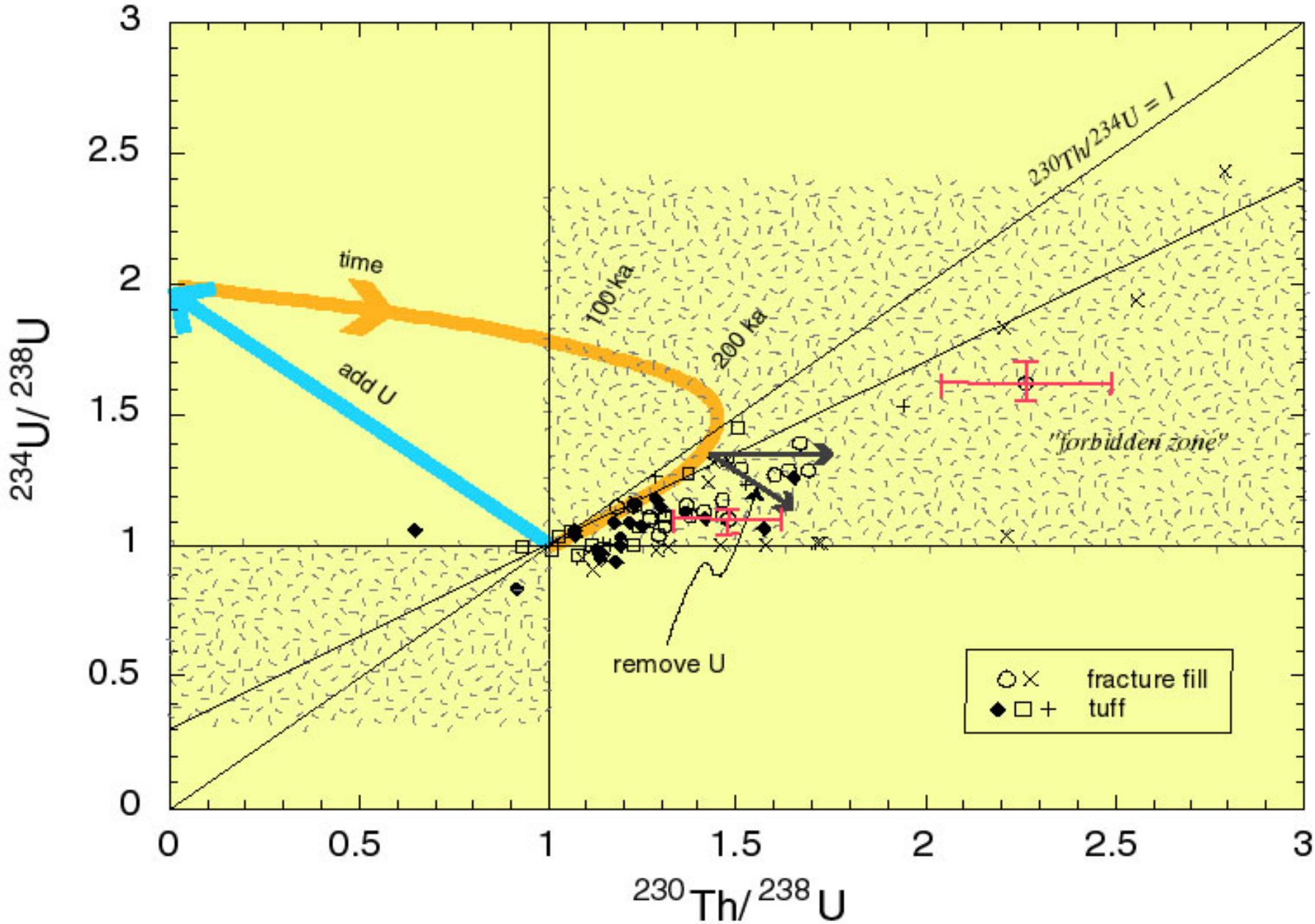
Measured U perpendicular to fractures for transport studies



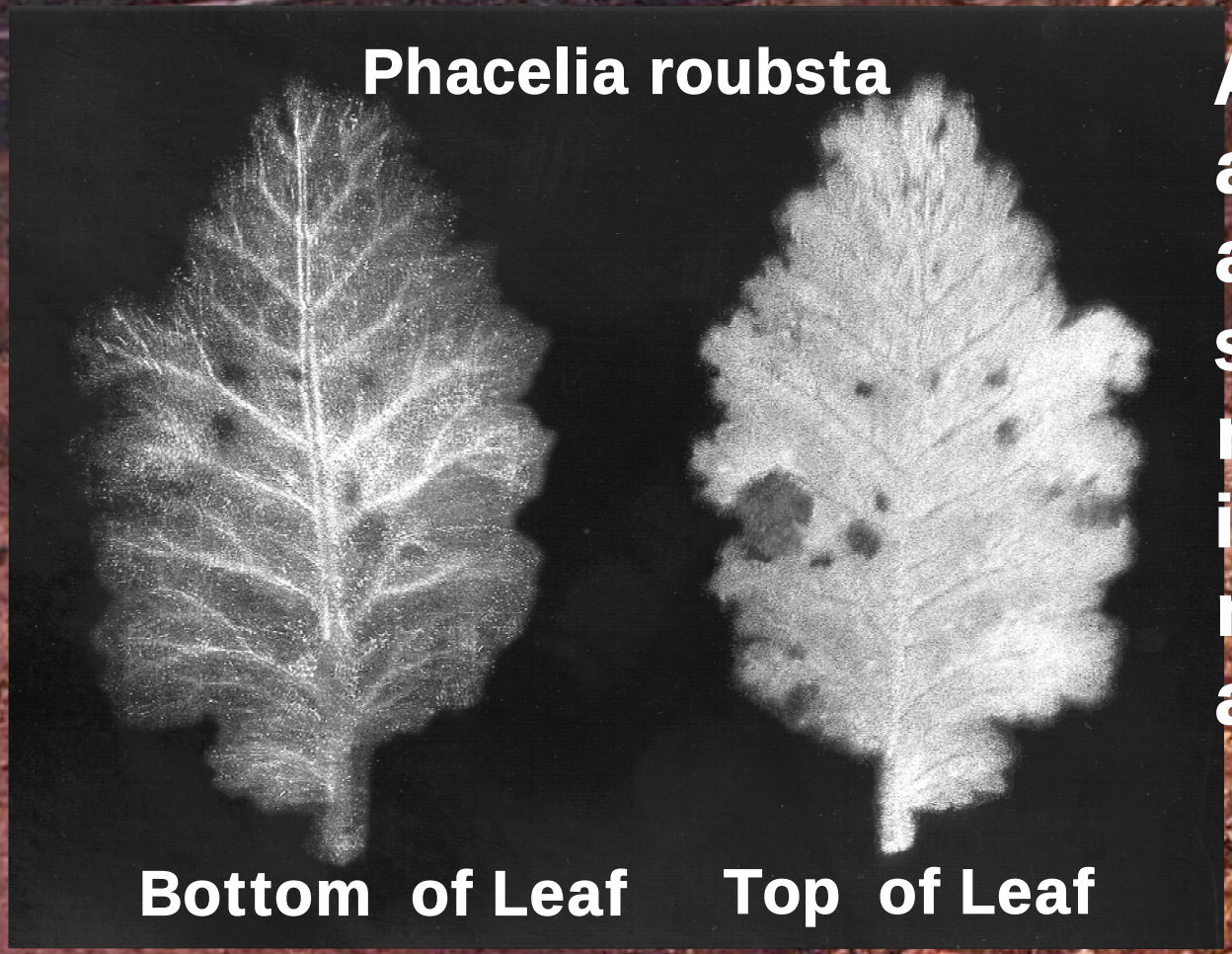
Matrix Diffusion



Uranium Migration - Isotopic Study of Rocks



Vegetation-Derived Insights on Mobilization



Alpha autoradiography and uranium series isotopes measurements indicate radium mobility on annual basis

(Leslie, Pickett, and Pearcy, 1999)

Source Term and Migration Analogy - Summary

- Reasonable analogy to oxidative alteration at Yucca Mountain
- Minor uranium mobility along fractures
- Minor migration of uranium into matrix perpendicular to fractures
- System is open to radionuclide release and transport under current conditions

Peña Blanca Natural Analog: Conclusions

NRC studies at Peña Blanca have been used:

1. **To understand the limitations of using natural analog information to support models, such as source term models, used to demonstrate repository performance**

2. **To identify processes and events likely to occur in a repository over time, thus assisting NRC in reviewing conceptual models used for estimating potential repository performance**