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Office of Civilian Radioactive Waste Management

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Science and Technology Program Work at the Peña Blanca Natural Analogue Site

Presented to:
U.S. Nuclear Waste Technical Review Board Panel on the Natural System

Presented by:
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Peña Blanca Analogue Team

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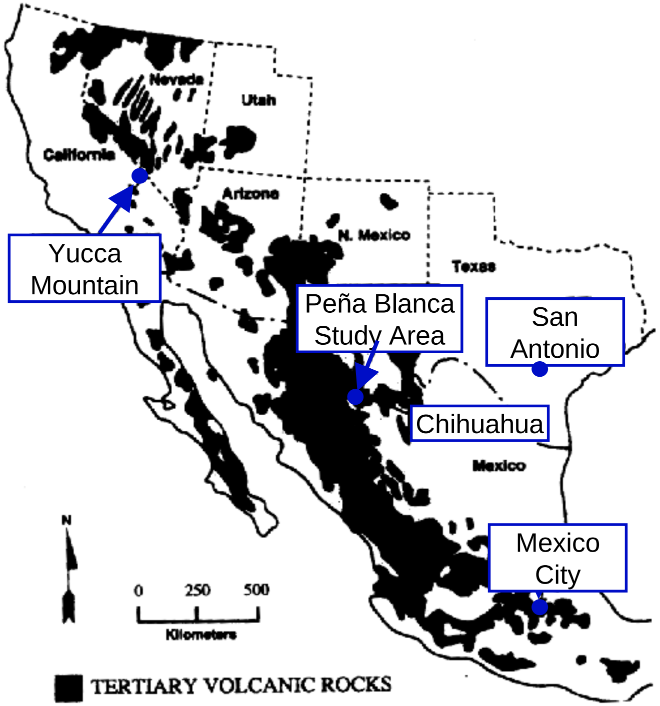
Outline

- Background and results to date
- Objectives of Science and Technology (S&T) Project
- Subprojects
- Timeline and deliverables

Background - History of the Nopal I Uranium Deposit at Peña Blanca

- **Tuff … *44 Ma***
- **Uraninite deposit … *8±5 Ma***
- **Oxidation … *3 Ma***
- **Uranium transport … *400 Ka***
- **Opal deposits … *50 Ka***
- **Mining … *1960-1985***

Peña Blanca U deposit similar to Yucca Mountain - rhyolitic tuff, unsaturated zone, semi-arid climate



Previous Work

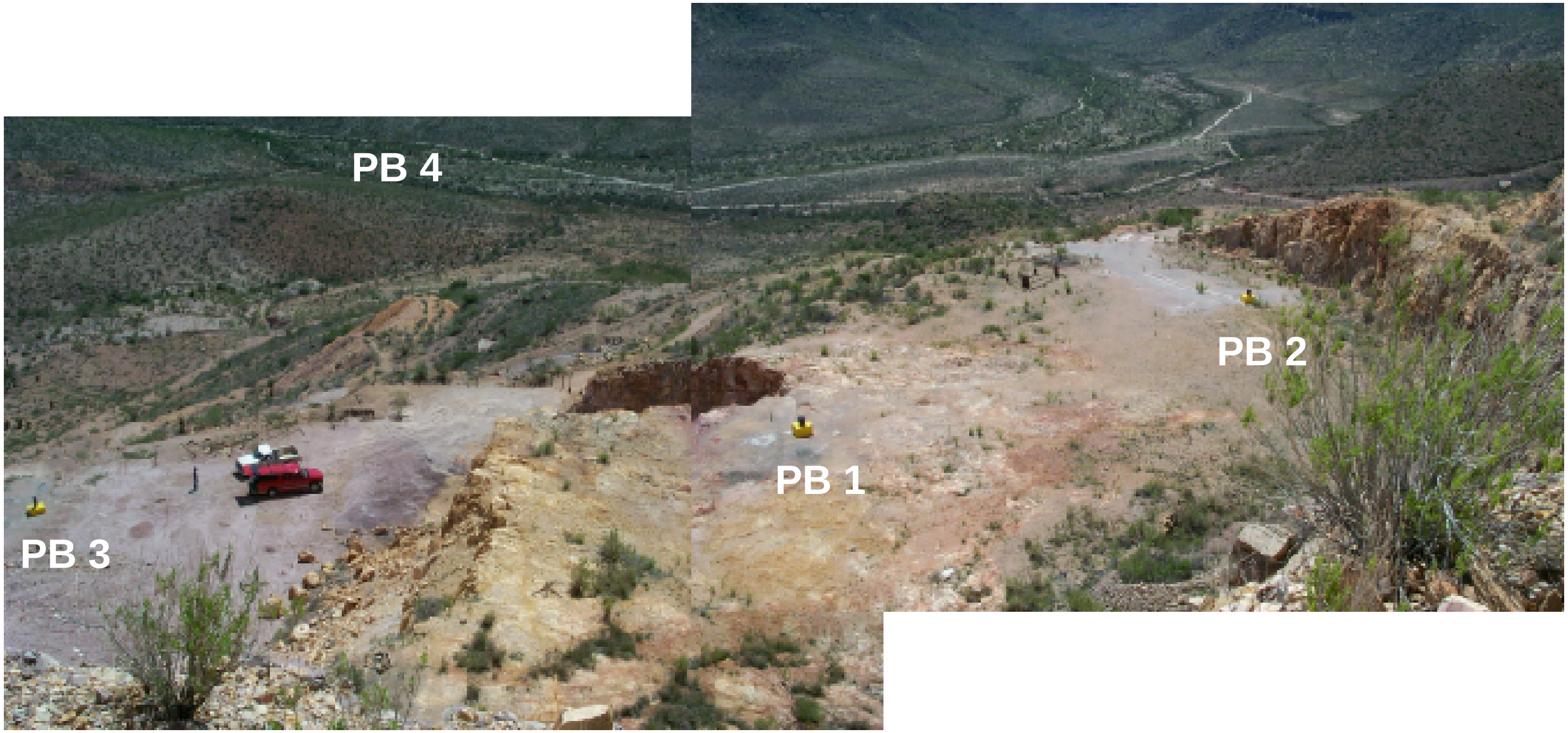
- **Previous U-series studies have shown that U, Pa, and Th have remained undisturbed in fractures in the unsaturated zone (UZ) near the deposit for at least the past 200,000 years, whereas Ra shows recent (< 8,000 y) open-system behavior**
- **UZ water ^{226}Ra concentrations correspond to large activity excesses relative to ^{238}U, ^{234}U, and ^{230}Th. Relative order of mobility of Ra>>U>>Th, in agreement with the fracture data**
- **In contrast, limited Ra data for saturated zone (SZ) waters indicate that ^{226}Ra/^{238}U activity ratios are less than 1, suggesting a relative order of mobility in this environment of U>Ra>>Th**
- **This change in Ra mobility between unsaturated and saturated conditions may be due to differences in Ra solubility/complexation or kinetic effects over long transport distances**
- **Groundwater U concentrations are generally greatest for samples near the deposit**

2003 Developments at Peña Blanca

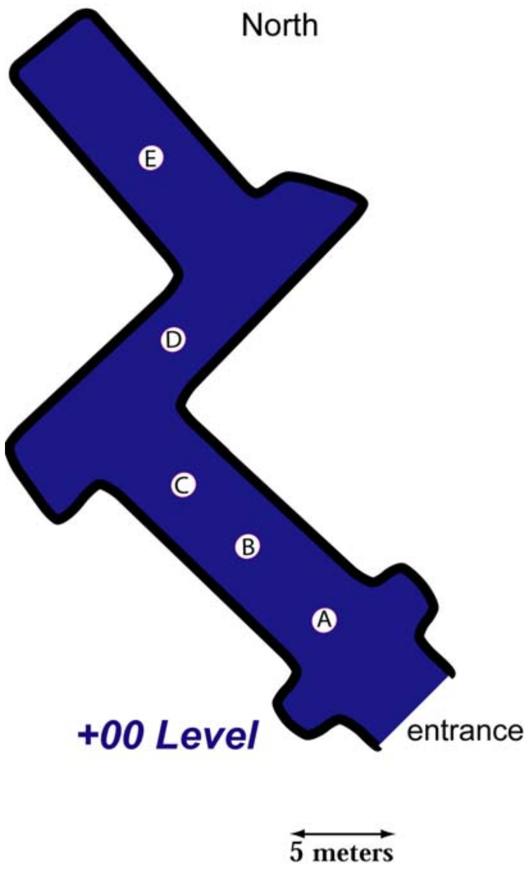
- Three new wells drilled, with core, cuttings, and water samples collected
- Geophysical logs obtained from wells
- PB-1 core described
- Rock samples selected for characterization

CFE drilling rig at PB-1

Panoramic View of Groundwater Wells



Unsaturated Zone Water Samples from Adit



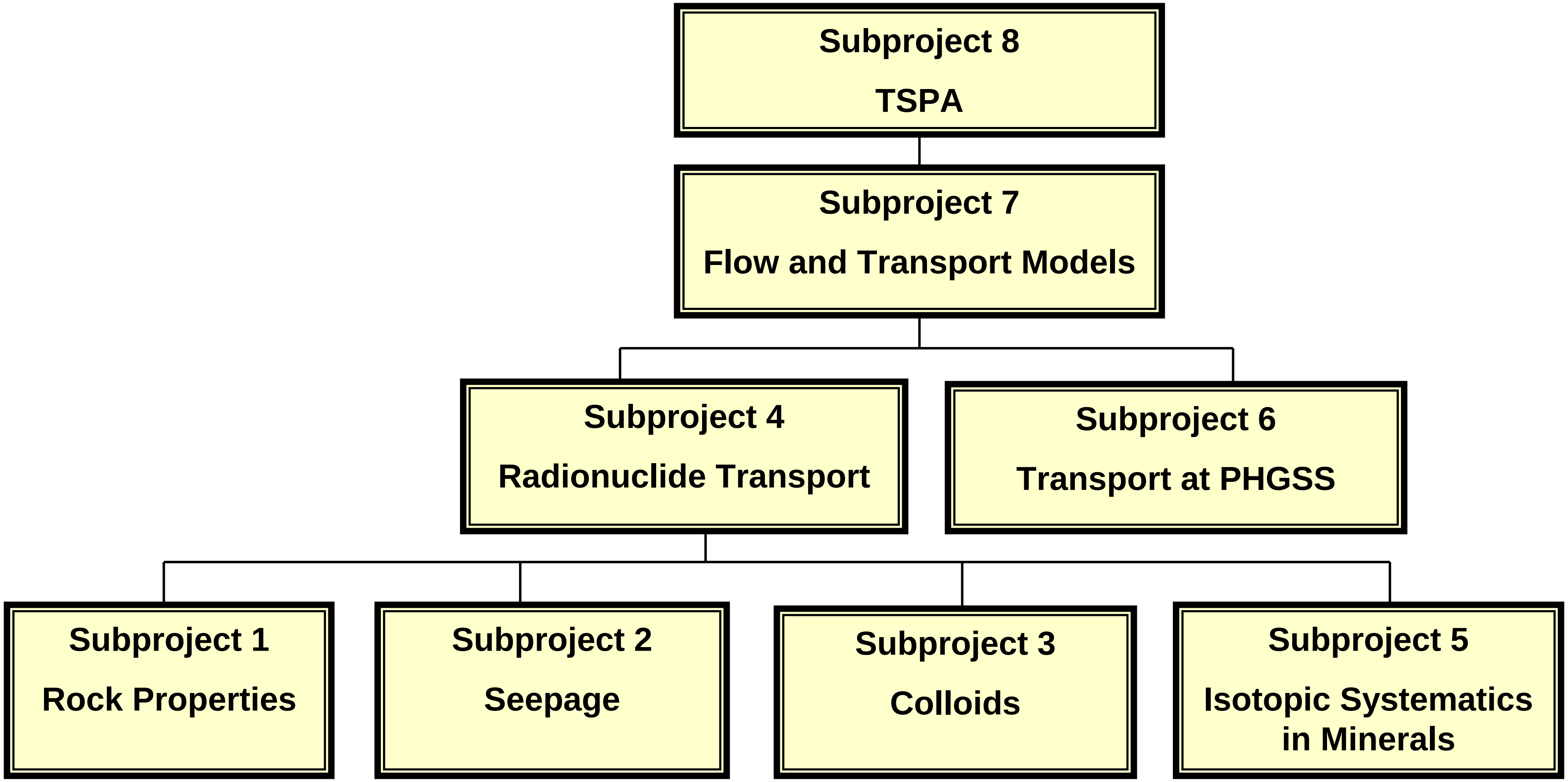
Objectives

- Evaluate the Yucca Mountain Project-Total System Performance Assessment (YMP-TSPA) model by testing against field observations and process model results from the Peña Blanca analogue site
- 3-D conceptual model
- Test both positive and negative lines of evidence
- Targeted Yucca Mountain (YM) questions:
  - Active fractures and fracture-matrix interaction
  - Transport behavior associated with adits and drifts
  - Colloid transport (presence and changes in concentration downgradient)

Subprojects

- Characterization of rock and hydrologic properties
- Seepage
- Colloids
- Radionuclide transport
- Isotopic systematics in minerals
- Assessment of transport at the prior high-grade stockpile site (PHGSS)
- Flow and transport modeling
- TSPA modeling

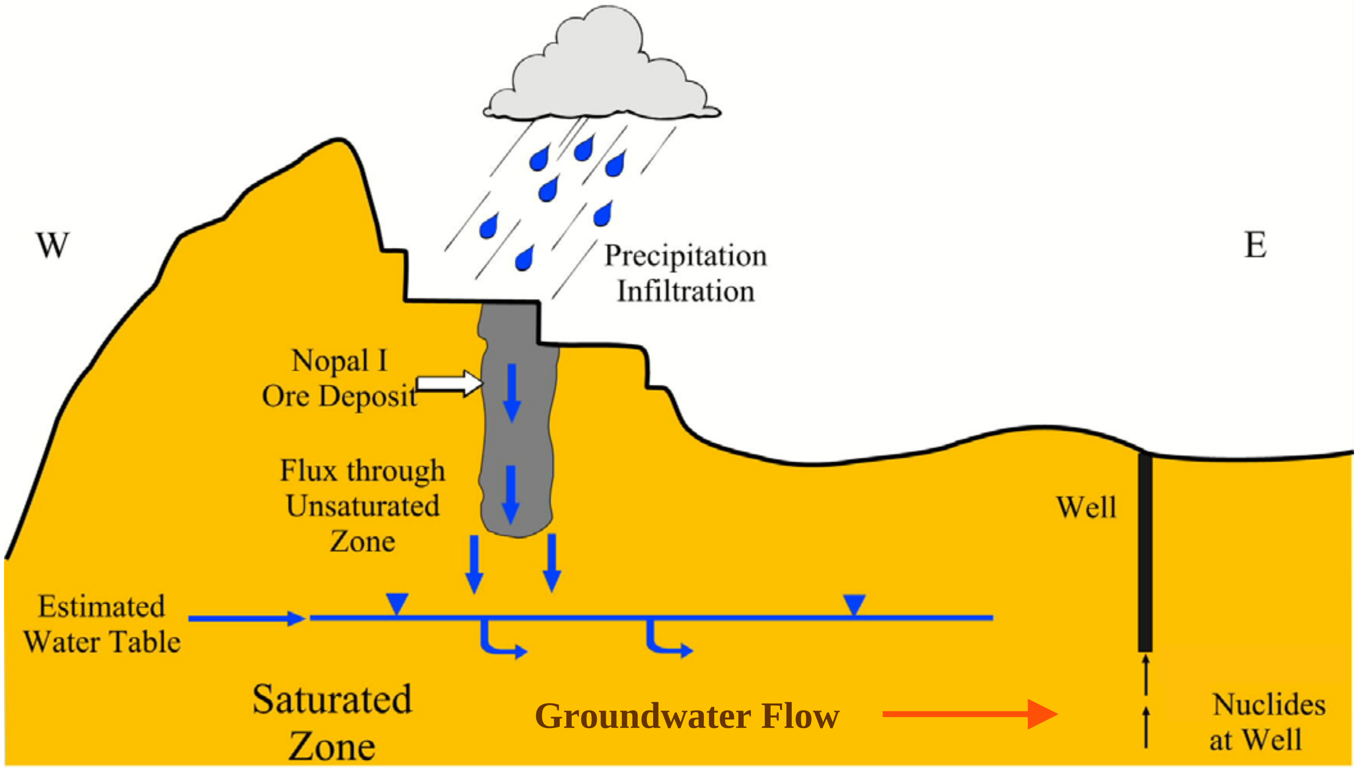
Relation of Subprojects to TSPA Model



Peña Blanca Total System Performance Assessment Analysis

- **Goal**: Use model to attempt to predict uranium and Tc-99 transport at Nopal I
- Utilize ground truth
- Calibrate model to Nopal I
- Evaluate sensitivity to uranium solubility, infiltration/flow rate, dissolution area, and K_d
- **Results**: Scale results to Yucca Mountain and compare to improve confidence in YMP-TSPA predictions of fate of uranium species and Tc-99

Conceptual Model of the Nopal I Mine



Peña Blanca Total System Performance Assessment Analysis - Process

- Estimate precipitation input to the land surface of the ore deposit
- Estimate radionuclide inventory
- Flow through the ore body to the unsaturated zone
- Release of radionuclides from the ore deposit
- Estimate groundwater gradient from water-level data
- Groundwater flow of contaminants through the saturated zone to receptor wells. Set up a Nopal I simulation code in GoldSim
- Predict transport of Tc-99
- Analyze water samples from the 4 wells for Tc-99
- Compare analytical results to model simulation and calibrate as necessary
- If successful, repeat analysis for other radionuclides

First Year Timeline for Three-Year Study

- Characterization of rock and hydrologic properties
- Initial seepage modeling and experimental design
- Analysis of water for colloids and initial design of colloid tracer experiment
- Measurement of long-lived U-series isotopes in water, fractures, and colloids
- Measurement of short-lived U-series isotopes in water
- Measurement of Sr, Ba, stable isotopes, major elements in rock and water samples
- Characterization of primary and secondary minerals, obtain ages
- PHGSS - site characterization
- Water table monitoring
- Compilation of data for transport model
- Construction of TSPA model

Project Deliverables

- Annual status reports
- 1 peer-reviewed journal publication per subproject plus integrative papers
- Rock and fracture properties data set
- Archive of water and rock analyses
- Standards for mapping U-series elements in minerals
- 3-D gamma spectroscopy map of PHGSS
- Hydrologic gradient and potentiometric map
- TSPA analysis

Backup

Characterization of Rock and Hydrologic Properties

- **Objective: Develop hydrogeologic framework for flow and transport models**
- **Obtain fracture data from core and televiewer logs**
- **Determine permeability, porosity, and grain density properties for each lithologic unit**
- **Determine primary and secondary mineralogy of matrix and fracture minerals**
- **Develop potentiometric surface map**
- **Construct conceptual model of Peña Blanca hydrogeologic system**

Tasks - Seepage Studies

- Develop conceptual and numerical models for seepage in adit system
- Conduct seepage tests with various injection rates and tracers to evaluate fracture-matrix interaction and seepage threshold
- Evaluate effect of surface roughness and fractures on localization of seeps
- Develop revised conceptual and numerical models

Tasks - Colloids

- Collect water samples from wells at Peña Blanca and characterize colloids
- Identify secondary minerals in fractures that may act as colloidal particles affecting radionuclide transport
- Develop model for colloidal transport as part of integrated hydrogeological flow and transport model

Hematite-goethite vein in Nopal tuff

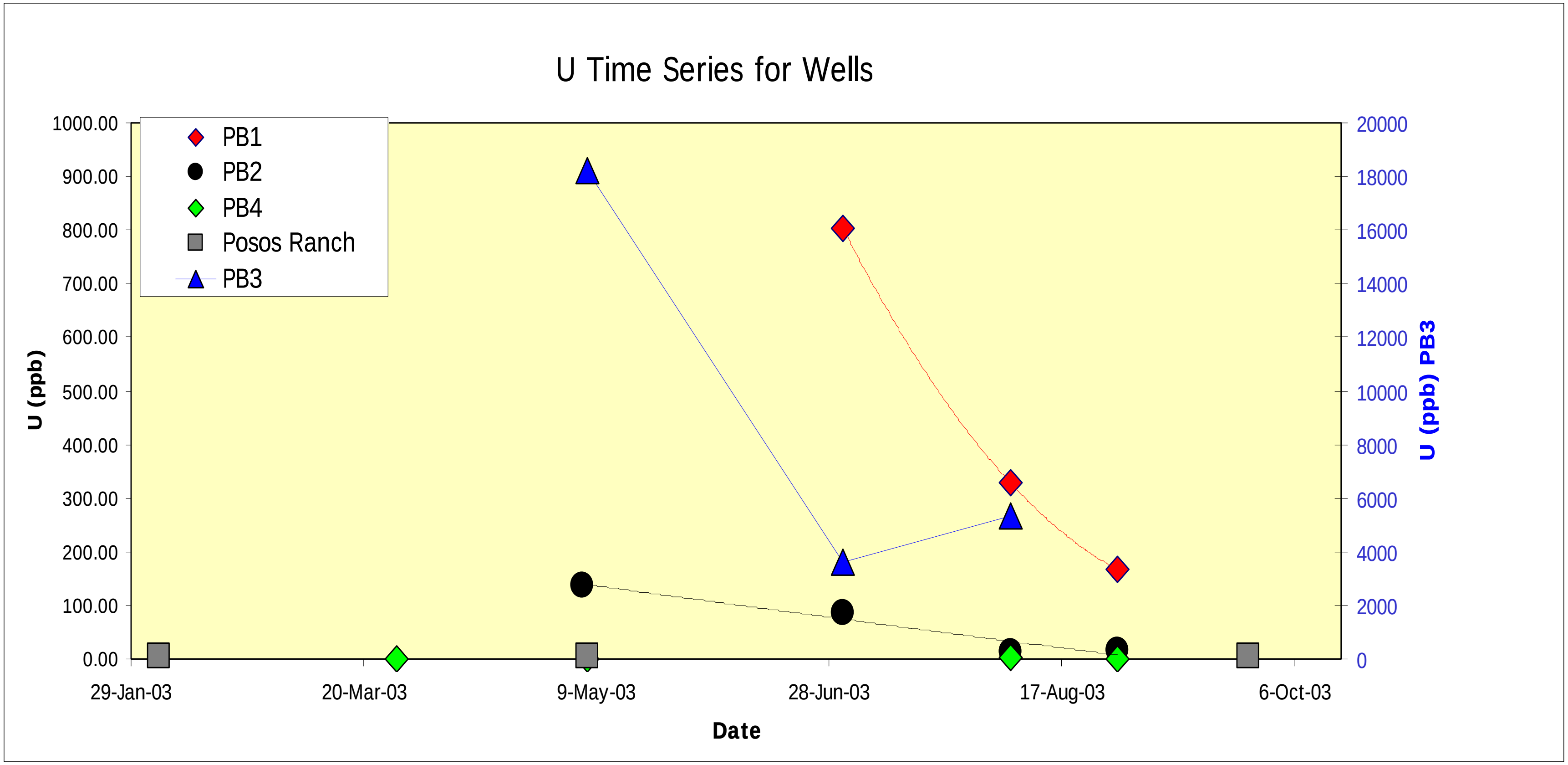
Radionuclide Transport

- **Use uranium deposit to evaluate the behavior of actinides and their daughters in the natural environment - stability of spent fuel**
- **Evaluate the net transport of uranium and its daughters for use in performance assessment**
- **Long-and short-lived uranium - series disequilibria in fracture samples**
- **Long-and short-lived uranium - series disequilibria in seasonal water collections (UZ and SZ)**
- **Long-and short-lived uranium - series disequilibria in colloid samples**
- **Tracer tests in wells (SF6)**
- **Radioisotope transport modeling**

Features of Modeling

- Develop and test a model based on naturally occurring U- and Th-series disequilibria for characterization of the in situ migration of actinide nuclides in and around Nopal I
- Will allow estimates to be made of the rates of sorption-desorption (hence retardation factors) and dissolution-precipitation of the isotopes over a range of time scales in both the UZ and SZ
- Interpret and model results in terms of transit times and fluid transport rates
- Incorporate results into kinetic radioisotope model results

Drilling as a Tracer Study



Limited mixing across 100 meters over last 6 months.

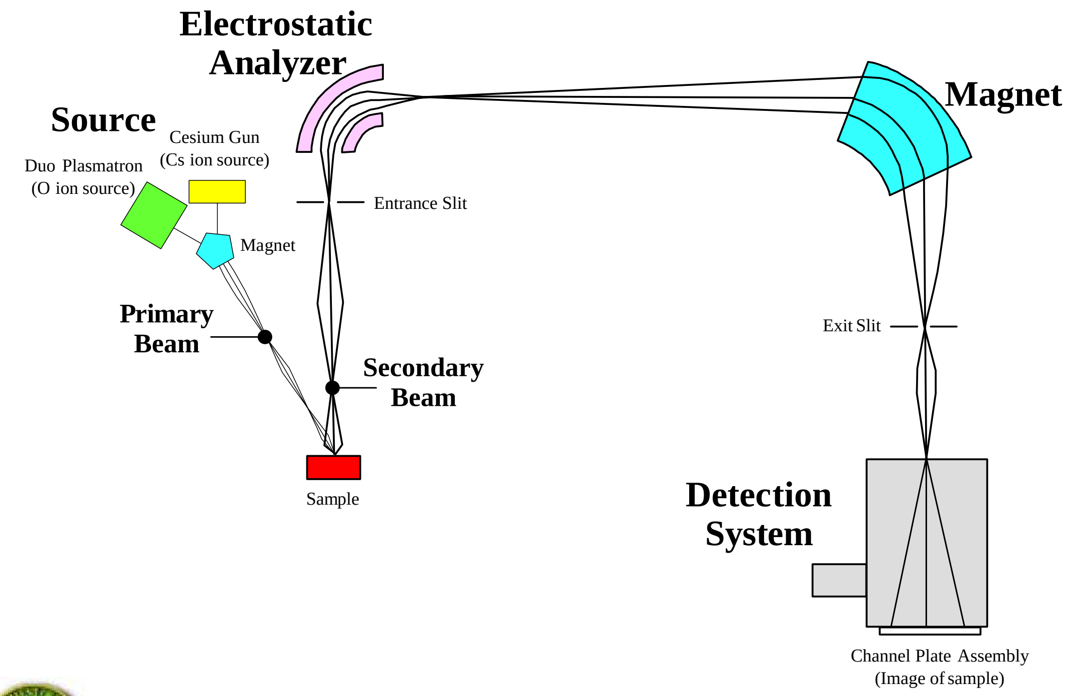
No U elevation seen in other wells.

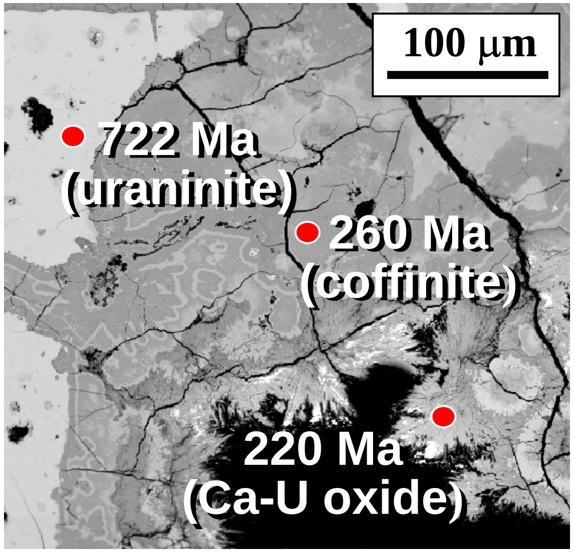
Isotopic Analysis of Minerals by Secondary Ion Mass Spectrometry

- Objectives: to determine the physiochemical characteristics and source of oxidizing fluids and to link fluids that interacted with the uranium minerals to specific geologic events
- Characterization of primary and secondary uranium minerals:
  - Paragenesis and structure (i.e., extent of oxidation) of uranium minerals
  - Chemical composition and element mass balance (e.g., trace element distribution)
- Source of fluids:
  - O and H isotopic composition of uranium minerals are sensitive indicators of fluid type
- Linking fluids to specific geological events:
  - The age of primary and secondary uranium minerals using U-Pb and U-Th isotope systematics

Why Secondary Ion Mass Spectrometry?

Obtaining ages of minerals and isotope ratios from 10-20 mm spots, in situ from a microscope slide, allows analyses to be placed in context with textures and other imaging techniques.





Example: secondary Ion Mass Spectrometry (SIMS) analysis spots and ages of uranium minerals superimposed on a back-scattered electron image of a sample from the unconformity-type deposits (e.g., Cigar Lake), Athabasca Basin, Canada.

Radionuclide Transport at the Prior High-Grade Stockpile Site and Water Table Characterization

Objectives: Determine the rate of migration of radionuclides from former high-grade stockpile at Peña Blanca and characterize the regional water table through monitoring of water table elevations in 11 wells around Peña Blanca

- **Characterize former high-grade stockpile site**
- **Determine 3-D distribution of radionuclides via sample analysis and gamma spectroscopy**
- **Regularly measure water table elevations in PB-1, PB-2, PB-3, PB-4, and other regional wells**
- **Create baseline piezometric map for area**

Former high-grade stockpile site, Peña Blanca

Development of Numeric Flow and Transport Models

- **Objective: Using data obtained from the Peña Blanca S&T studies, develop detailed conceptual and numerical flow and transport models, with a focus on radionuclide transport, and evaluate YM TSPA model. Compile data for flow and transport model at Peña Blanca**
- **Conduct 2-D and 3-D numerical simulations**
- **Compare simulation results to observed radionuclide concentrations in well samples**
- **Conduct sensitivity studies to identify key areas of uncertainty**
- **Evaluate ability of YMP-TSPA model to predict radionuclide transport at Peña Blanca**