

# **THE CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES Southwest Research Institute®**

## **Overview, Licensing Role, and Geochemistry Activities**

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# Introduction to the Center for Nuclear Waste Regulatory Analyses

- **Fall 1987:** Center for Nuclear Waste Regulatory Analyses (CNWRA) established as Federally Funded Research and Development Center at SwRI, supporting the U.S. Nuclear Regulatory Commission (NRC)
  - Charter expanded in 1992 to pursue work for clients outside NRC
  - Geosciences and Engineering Division organized in 2005, comprising CNWRA and a Department of Earth, Material, and Planetary Sciences
- **Staff**
  - 61 technical
  - 23 support
- **Organization**
  - Hydrogeology
  - Geochemistry
  - Geology and Geophysics
  - Corrosion Science and Process Engineering
  - Mining, Geotechnical, and Facility Engineering
  - Performance Assessment

Elements integrated across disciplines to effectively solve client problems



## Areas of Support to the NRC

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- Principal area of support is to the High-Level Waste Repository Safety Program
- The CNWRA performs work for NRC areas outside the HLW program:
  - Uranium mining and mill tailings
  - Site decommissioning
  - Waste reprocessing
  - Spent fuel storage
  - Environmental Impact Assessment
  - Waste Incidental to Reprocessing
  - Nuclear Reactor Research

## Other Programs

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- In addition to the NRC, other Geosciences and Engineering Division clients include
  - Oil, gas, and mining industries
  - Manufacturing and chemical processing plants
  - Foreign government agencies (Sweden, Switzerland, France, Australia, Canada, UK)
  - International waste management companies
  - U.S. and Caribbean water authorities
- CNWRA staff are active participants in the SwRI Internal Research and Development program

## Areas of Technical Expertise

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- Geochemistry/Radiochemistry
- Hydrology/Climatology
- Material Sciences
- Mechanical Engineering
- Computer Sciences
- Performance and Risk Assessment
- Rock Mechanics
- Mining Engineering
- Structural Geology
- Health Physics
- Nuclear Engineering
- Volcanology

# We Use a Systems Approach to Resolving Regulatory and Technical Issues

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**Computer Modeling**

**Laboratory Investigations**

**Field Studies**

***A risk-informed performance-based systems  
approach in support of the NRC***

# Computer Modeling Capabilities

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- Modeling activities in
  - Performance/Risk Assessment
  - Hydrology and Transport
  - Volcanism
  - Structural Geology, Seismicity
  - Geochemistry
  - Rock Mechanics/Mine Design



# Laboratory Facilities

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- Rock Mechanics
- Geochemistry/Radiochemistry
- Hydrology
- Materials Testing
- Structural Geology
- Access to other SwRI laboratories, including Hot Cell

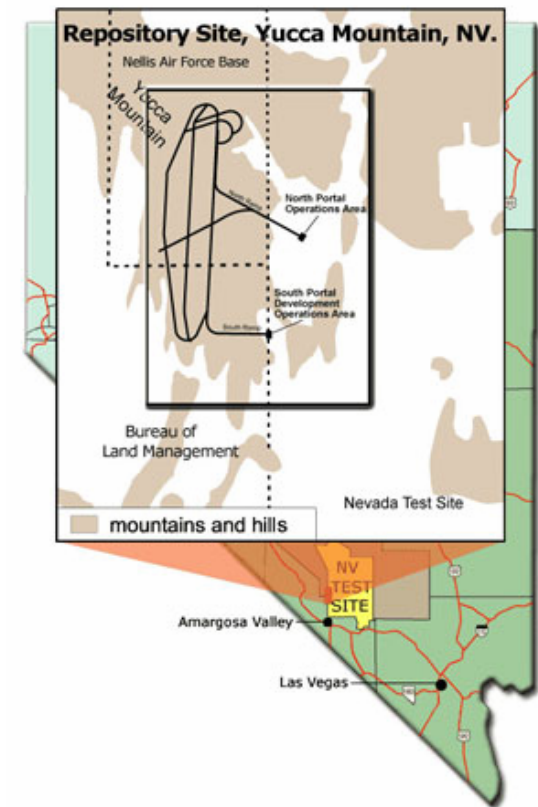
## Field Investigations

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- Geological/Geophysical Investigations
  - Basin and Range Province, Western U.S.
  - Yucca Mountain, Nevada
  - Bare Mountain, Nevada
  - Indonesia
  - Gulf of Mexico
  - Mekong Delta, Vietnam
  - Caribbean Basin
  - Middle East; Persian Gulf
  - Lake Baikal, Siberia
  - San Antonio, Texas
- Natural Analog Sites
  - Santorini archaeological site, Mediterranean Sea
  - Parícutin volcano, Mexico
  - Peña Blanca uranium deposit, Chihuahua, Mexico
  - Cerro Negro volcano, Nicaragua
  - Tolbachik volcanic field, Kamchatka, Russia
- Hydrologic Investigations
  - Vegetation/infiltration studies, Yucca Mountain, Nevada
  - Watershed analysis, Solitario Canyon, Nevada
  - Edwards Aquifer, Texas

# U.S. High-Level Radioactive Waste Program

- President recommended Yucca Mountain site in 2002
- Would contain commercial and defense spent nuclear fuel and other U.S. Department of Energy (DOE) high-level waste
- NRC staff will review any license application DOE submits to build and operate



[http://www.ocrwm.doe.gov/ym\\_repository/quick/index.shtml](http://www.ocrwm.doe.gov/ym_repository/quick/index.shtml)

## **CNWRA Role in U.S. High-Level Radioactive Waste Program**

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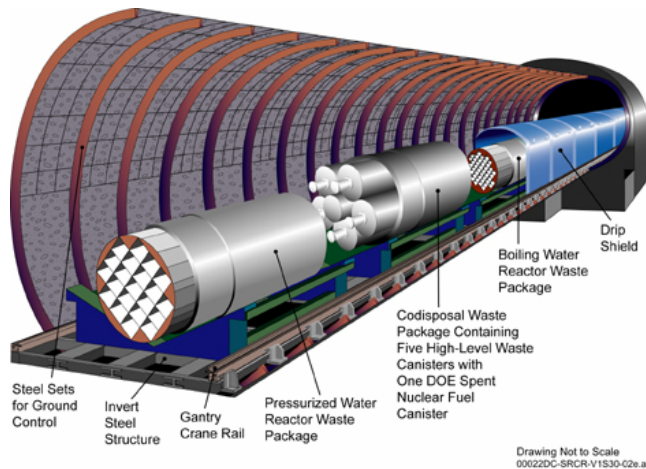
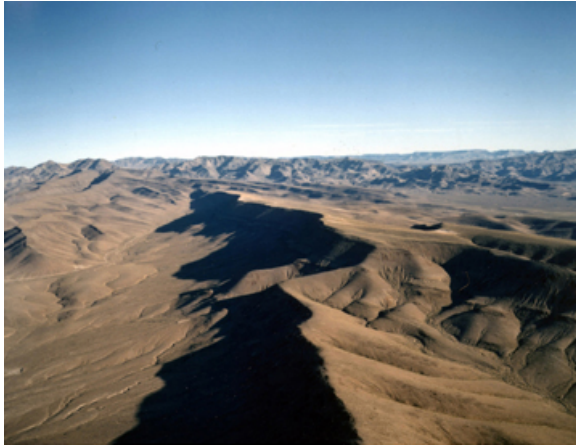
- As an independent contractor, the CNWRA has provided technical assistance to NRC during the prelicensing period
  - Maintaining understanding of DOE plans and models that would support a license application
  - Interacting with DOE to better understand their technical approach to particular issues
  - Conducting independent scientific and engineering analyses relevant to waste disposal at the potential Yucca Mountain repository
- Once NRC receives a license application, the CNWRA will
  - Perform technical reviews of documents related to the application
  - Support preparation of any NRC documents (e.g., safety evaluation report)
  - Provide hearing support, if necessary
  - Continue relevant technical activities
  - Stay informed on continuing DOE technical activities

## **CNWRA Role in U.S. High-Level Radioactive Waste Program (cont.)**

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- NRC will decide whether or not to
  - Accept the license application for docketing
  - Approve a license authorizing DOE to construct a repository at Yucca Mountain
- If construction is authorized, a later license will be required to receive and possess waste at the repository
- The CNWRA plans to continue providing technical assistance to the NRC high-level waste program, whether or not a Yucca Mountain license is granted

# Factors Affecting Repository Performance



- Environmental Processes
  - Climate and meteorology
  - Disruptive events
- Geological Systems
  - Features and processes
  - Disruptive events
- Engineered Designs
  - Repository excavations and support systems
  - Waste packages
  - Waste forms
- Biosphere Attributes

[http://www.ocrwm.doe.gov/info\\_library/newsroom/photos/index.shtml](http://www.ocrwm.doe.gov/info_library/newsroom/photos/index.shtml)

# Total System Performance Assessment and Related Support

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- Environmental Impact Assessments
  - EIS adoption decision
- Performance Assessment
  - Review models and data
  - Evaluate system integration
- Regulatory Support
  - Develop effective regulations
  - Prepare regulatory compliance review strategies

## **Current Geochemistry-Oriented Projects at the CNWRA**

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- **High-Level Waste (NRC)**
  - Quantity and Chemistry of Water Contacting Engineered Barriers and Waste Forms
  - Radionuclide Release Rates and Solubility Limits
  - Radionuclide Transport in the Unsaturated Zone
  - Radionuclide Transport in the Saturated Zone
  - Support other areas, such as Total System Performance Assessment and Integration
- **Waste Incidental to Reprocessing (NRC)**
  - Analyses to support Non-High-Level Waste Determinations: Cementitious materials and waste forms

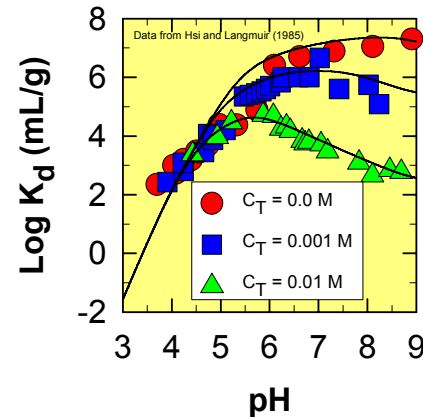


## Recent Geochemistry-Related Modeling Activities

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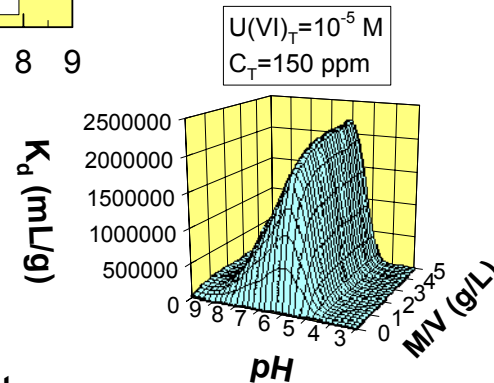
- Total-system Performance Assessment (TPA) abstractions of radionuclide release and transport
  - Model development
  - Parameter development
  - User guide preparation
- Process models
  - Colloid-facilitated transport, including effects of kinetic sorption-desorption on effectiveness of colloids in enhancing radionuclide transport
  - Transport effects of temporal changes in water chemistry and spatial heterogeneity of  $K_d$ s
  - Assessment of existing matrix diffusion models
  - Participation in NEA sorption modeling effort
  - Chemistry of water in contact with engineered barrier system and in-package components
  - Coupled reactive transport in the unsaturated zone (MULTIFLO)

# Modeling Important Geochemical Processes

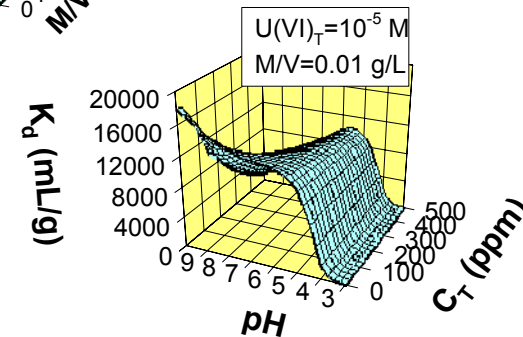


(a) Model Calibration

(b) Predicted Effects of pH, M/V



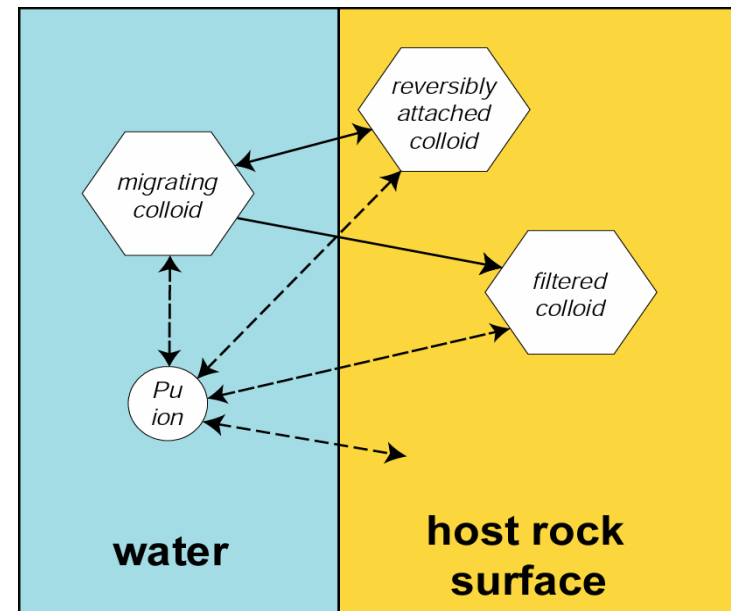
(c) Predicted effects of pH,  $C_T$



- Geochemical models used to calculate radionuclide transport parameters
- Representation of effects of geochemistry in performance assessment

# Colloids in Performance Assessment

- Simplified abstractions of colloid-facilitated release and transport (poster at Migration '07)
- Reversible and irreversible attachment of radionuclides to colloids
- Competitive sorption onto steel corrosion products; irreversible Pu and Am attachment
- Reversible model during transport: equilibrium among radionuclide dissolved, sorbed to host rock, and sorbed to colloids
- Supported by process modeling work

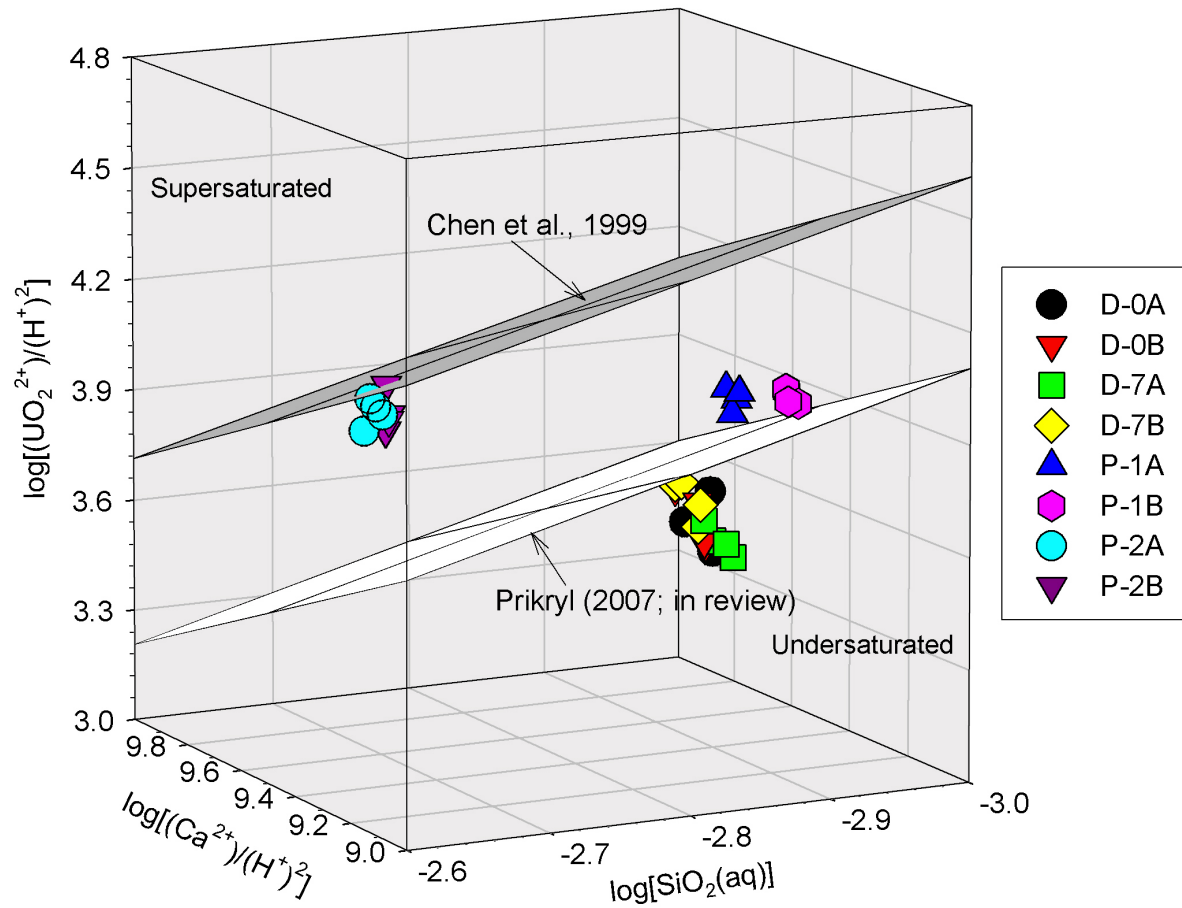


## Recent Geochemistry Laboratory Studies

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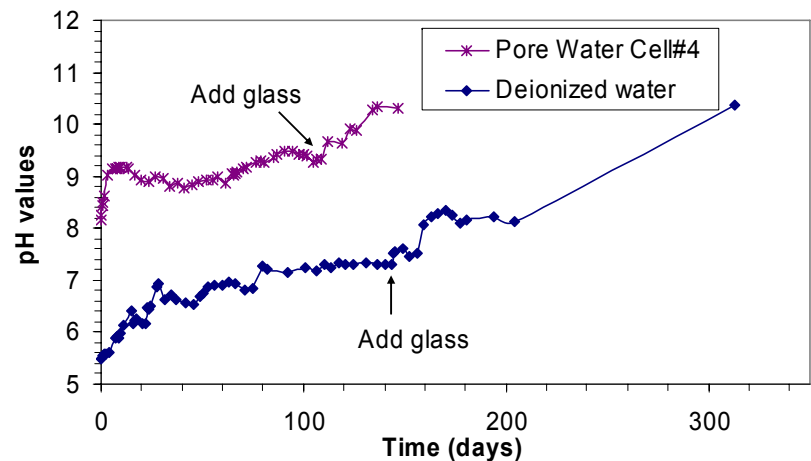
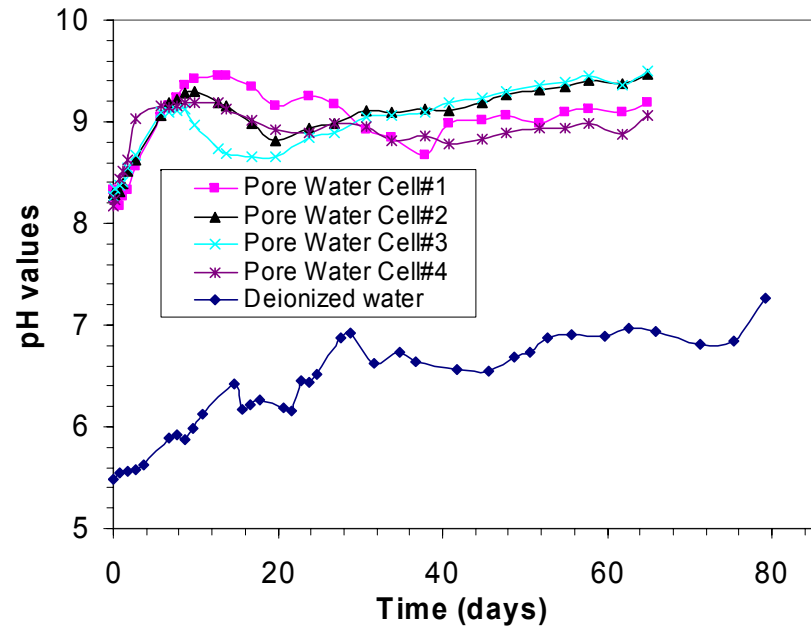
- Uranophane solubility (*Geochimica et Cosmochimica Acta* paper in press)
- Chemistry during steel and glass corrosion
- Neptunium sorption on steel corrosion products
- Deliquescent properties of salt mixtures
- Colloid work being planned

# Uranophane Solubility



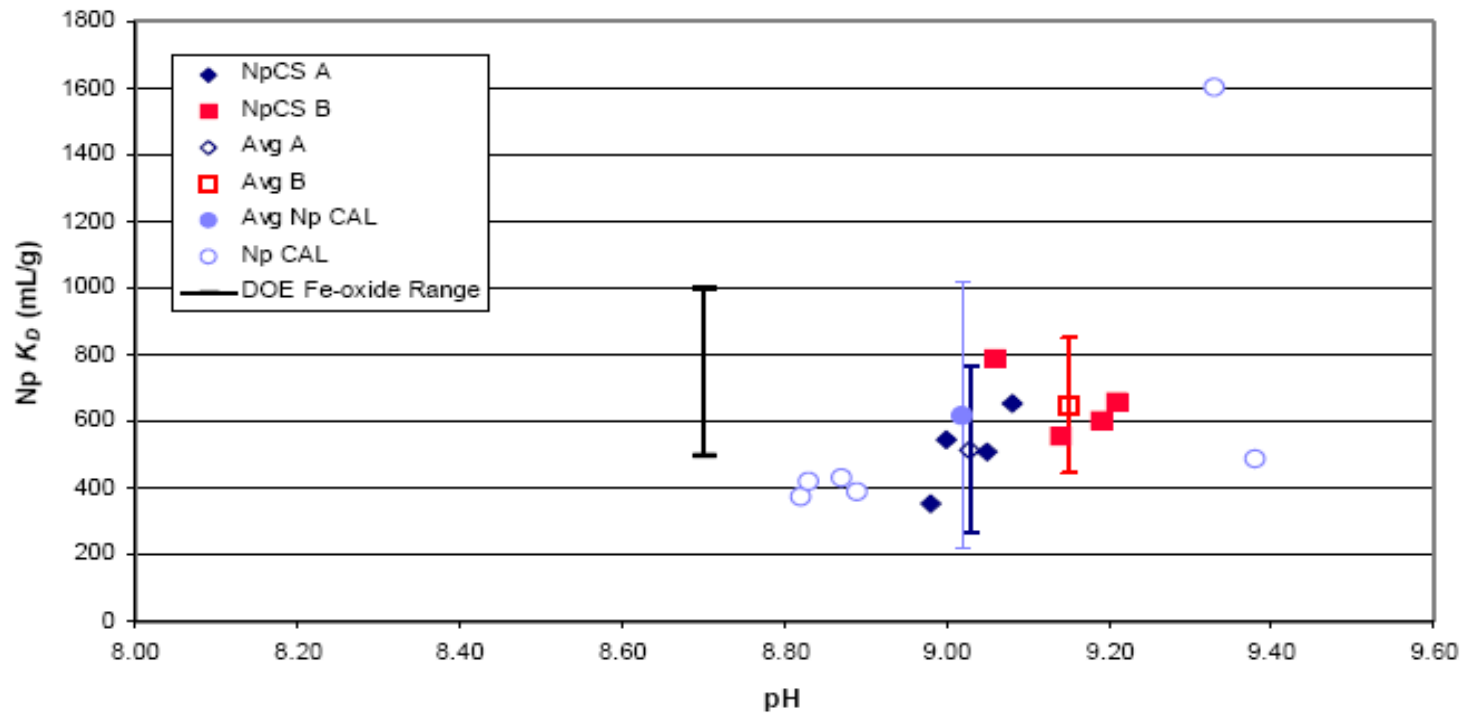
# In-Package Chemistry: pH During Carbon Steel Corrosion in Simulated Pore Water

- High pH (>9) seen in simulated pore waters; moderate pH in deionized water
- In both cases, the pH values were higher than predicted by equilibrium chemical models
- Addition of glass increased the pH further



# Neptunium Sorption to Steel Corrosion Products

Np  $K_D$  for Carbon Steel Corrosion Products and Calcite-Bearing Alluvium



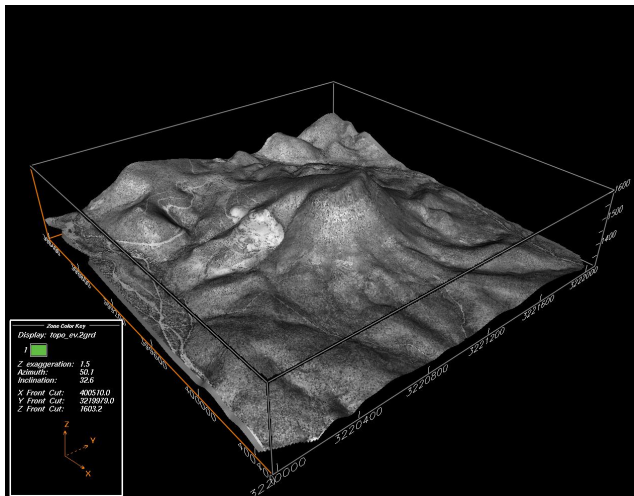
# Colloid Experiments Under Development

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- Quantify effect of colloid composition and water chemistry on the magnitude of radionuclide sorption onto colloids to better constrain colloidal source term and transport. Conduct batch sorption experiments on prepared colloidal suspensions.
- Quantify effect of radionuclides competing for sorption sites on colloids through literature, models, and extension of current laboratory experiments.
- Equipment recently obtained
  - ZetaPALS w/ 90Plus Analyzer. Characterization of colloid surface chemistry and particle size distributions.
  - Lambda 950 UV/VIS/NIR Spectrometer. Quantification of colloid concentrations.

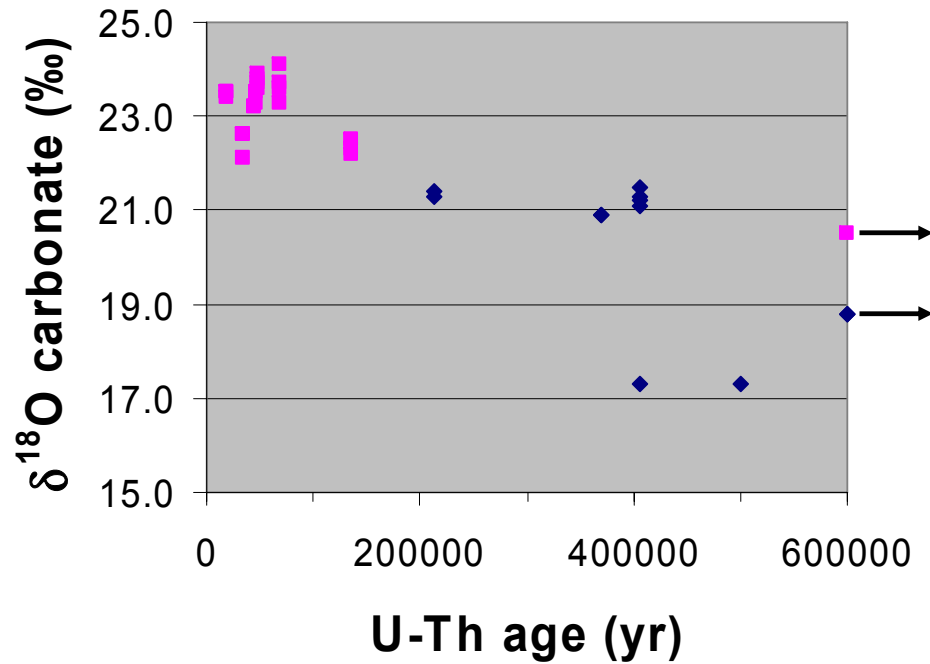


# Natural Analog Field Studies at Peña Blanca, Mexico



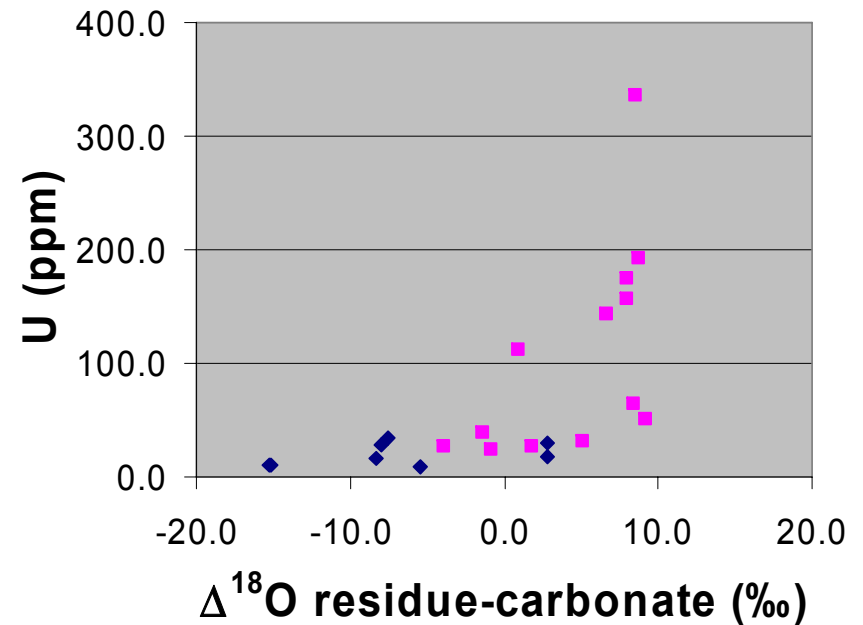
- Uranium deposit near Chihuahua, Mexico
- Geologic/climate/hydrologic setting similar to Yucca Mountain, Nevada
- ~8 Ma uraninite deposit
- Uranium analog to oxidation and dissolution of spent nuclear fuel
- Transport of uranium from deposit analogous to radionuclide transport from HLW geologic repository
- Supports alternative radionuclide release model in performance assessment

## Recent Isotopic Studies at Nopal I



- U-rich caliches (squares) and U-poor calcites (diamonds) around Nopal I
- Suggests recent, low-temperature deposition of U-rich authigenic carbonate and silicate

Pickett & Leslie, 2005 Annual Meeting,  
Geological Society of America



## CONCLUSIONS

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- Independent capability essential for an effective regulatory program
- Exceptional laboratory, field, and numerical modeling facilities
- CNWRA supports multiple NRC program areas, as well as other clients
- Long-term, independent, conflict-of-interest-free technical staff
- Active geochemistry program focused on nuclear waste repository geochemical environment and radionuclide release and transport

## Acknowledgment

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