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Las Vegas, NV
International High-Level Waste Management Meeting

At:
Lawrence Berkeley National Laboratory

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Presented by:

Thrust Overview
and International, National, and International, National, and Technology
Office of Science and Technology

OSTI
Natural Barriers Projects

Participating Organizations in Targeted Thrust Areas

Targeted Thrusts and Natural Barriers
Natural Barriers (NB) Objectives

- Components
  - Determine feasibility of eliminating certain engineered
  - Reduce costs
  - View of NB Thrust Lead
    - Standard
  - Stretch goal is to determine whether there is solid scientific
    - Repository performance
  - Demonstrate natural system can make large contributions to
    - Beyond the expected occurrence of peak dose
    - Strengthen the NB analysis for periods up to and
  - Enhance understanding of the natural system

OSTI
Natural Barriers Performance Factors

- Sorption
- Matrix diffusion
- Transport
- Shadow zone
- Invert
- Radionuclide release
- Chemical environment
- Natural ventilation and thermal convection
- Evaporation/condensation
- In-diff environment
  - Capillary barrier
  - VapORIZATION/barrier
- Seepage
- Climate / infiltration / percolation / flow patterns
2005 Proposal Call

- Proposal call issued in January 2005 ($1,200k)
- 55 proposals (12 from universities)
- Two main topics:
  - Unsaturated Zone Near-Field Coupled Processes (30)
  - Saturated Zone Flow and Transport (25)
- Four proposals funded 4th quarter of FY2005
  - Three from universities
Proposal Review Process

• Justification of the selection of projects for consideration for funding to OCRWM S&T
• Discussion with Office of Repository Development

- Benefit, etc.
- Innovation, project size, likelihood of achieving the pragmatic
- Scientific significance and technical merit
- Balancing the portfolio in terms of areas of interest, extent of
  - Programmatic merit
- Thrust Area Lead Review
  - Independent technical experts
  - Comprehensive evaluation
  - Solicitation

- Completeness of information, page number (15 pages), responsiveness to

Compliance Review
- Pore Connectivity, Episodic Flow, and Unsatuated Diffusion (Oral)
- Matrix/Fracture Flow in Subsidiary Units (Oral)
- Perla Blanca Natural Analogue (Oral, also in Natural Analogue Session)
- Enhanced Retardation of Radionuclides in Fractured Rock (Oral)

Unsaturated Zone (UZ) Transport

- Experiments (Oral, Parallel Session)
- Testing the Concept of Drift Shadow with X-Ray Absorption Imaging
- Testing the Concept of Drift Shadow (Oral, Parallel Wed AM Session)
- Nature of Drift Shadows at Analogue Sites (Oral)

Drift Shadow

- Drift Shadow Chemistry (not presented at IHLWM)
- An Integrated In-Drift/Neel Field Flow and Transport Model with Reactive
  (at IHLWM)

- Affecting Drift Performance: Laboratory and Modeling Studies (not presented
- Integrated Assessment of Critical Chemical and Mechanical Processes
- Coupled In-Drift, Near-Field, and Mountain-Field Fluid and Heat Flow

Natural Barriers Projects (1)
Natural Barriers Projects (Cont.)

- Large-Scale (2 km) Natural Gradient Tracer Test (not presented at IHLM)
- Saturated Zone Plumes in Volcanic Rocks (Orel)
- Carbon-14 Groundwater Analyses (not presented at IHLM) and Aluminim (Orel)
- Improved Characterization of Radiochemical Retardation in Volcanics Presented at IHLM
- Radiocative Solutes and Colloids, Using Chemical Analogues (not
  Field Studies for the Determination of Transport Properties of
  Mobility of Nuclear Waste (not presented at IHLM)
- Determining the Redox Properties of Yucca Mountain-Related
  Saturated Zone (SZ) Transport
Drift Seepage

Thermal seepage

- Impact of coupled processes in rocks and drifts on coupled THMC processes
- Advanced modeling along with laboratory studies of seepage under non-ambient conditions

OST84 Emphasis
Coupled In-drift, Near-Field, and Mountain-Scale Fluid and Heat Flow Processes (Danko et al.)

(a) Boiling Phase: Heated Drift Section Above Boiling Temperature

(b) Sub-Boiling Phase: Heated Drift Section Below Boiling Temperature

Natural ventilation and convection can greatly reduce seepage into drift.
Integrated Assessment of Critical CM Processes Affecting Drift Performance (Elsworth et al.)

Approach: Laboratory Experiments and associated modeling

THMC processes: Pressure Solution and Precipitation

Hydro-Mechanical

Hydro-Chemical

Constitutive Models

Modeling/Upscaling
multiple accounting of water to dissolve radionuclides
- Full mass balance obtained from the couple model avoids
  brines
  multiphase (liquid and gas) equilibrium of concentrated
  Rigorous thermodynamic framework to describe the
  rocks
  and solute transport in both the drifts and the near-field
  Fully integrated THC model that couples heat, water, gas,
An Integrated In-Drift/Near-Field Reactive Flow and Transport Model (Spycher et al.)

Near-field and in-drift seepage water chemistry from coupled THC model
Dehydration From Dust Salts

Relative Humidity

Mass per WP Surface (mg/cm²)

Brine Formed

Water Absorbed

NaCl+KNO₃

NaCl+KNO₃+N₂H₄NO₃

Eutectic
Radionuclide release to the UZ from downward percolating water significantly delays to validate that the region below the drift that is sheltered.

- Laboratory Studies
- Field Studies at analog site
- Studies in ESF and ECRB at Yucca Mountain
- Studies to demonstrate the drift shadow concept

OST81 Emphasis

Drift Shadow
Seepage simulation for percolation to be 10% of saturated fracture permeability.

- Double drifts can be a possible design criteria.
- Drift shadows in the upper drifts mitigate seepage into the lower waste emplacement drift.
Testing the Concept of Drift Shadow (Faces et al.)
250 μm aperture fracture

- Design for multi- and in-plane fracture system
- Capillary fringe at the bottom of the test cell for tests with higher flow rates (experimental design needs to be improved)
- Tracer being diverted around the drift and not under the drift

Testing the Concept of Drift Shadow with X-Ray Absorption Imaging Experiments (Altman et al.)
Unsaturated Zone and Saturated Zone Transport
Fracture Rock (Liu et al.)
Enhanced Retardation of Radionuclide Transport in
Scale Dependence of Effective Matrix Diffusion: Evidence and Preliminary Interpretation
than groundwater movement.

Isotopes are three to six orders of magnitude slower than groundwater movement.

Modeling the Ra-222, Pb-210, and Po-210 contents of well-water samples indicates that migration rates of the well-water system in Nopital +00 adit, collecting data since April 2005.

Design, construction, and installation of seepage collection systems are three to six orders of magnitude slower than groundwater movement.

An advection-dispersion model yielded estimations of saaturated zone groundwater velocities (1-20 m/yr) and dispersion coefficients (10-5 to 10-3 cm/s).

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Uranium concentrations and isotopic activity ratio of uranium concentration and isotopic activity ratio of uranium concentrations and isotopic activity ratio of uranium concentrations and isotopic activity ratio of uranium concentrations.

Rock samples for mineral parageneses.

Spectroscopic and electron microscopy analysis of the rock samples for mineral parageneses.

Near surface transport: spectral gamma-ray measurements of samples from a block of high-grade ore and from soil downslope of the block.

Studies at Peña Blanca provide a wealth of data and understanding on radioactive transport processes and the overall system behavior, a small subset is as follows:

Peña Blanca Natural Analogue (Levy, Dobson, et al.)
Long-term in situ K\(^+\) U concentration data allowed estimation of higher levels within the UZ indicating the presence of U transported from

- All pore water samples and rock leachates are \(^{234}\)U-enriched (\(^{234}\)U/\(^{238}\)U from 1.1 to 5.2).

That may enhance retardation that may enhance retardation

- The superposition units remain a viable process and that matrix flow through the zeolitized tuff implies similar amounts of water/rock interaction rock powders from fracture surface rubble core (zones of higher permeability) and samples of untraced core (rock matrix).

- Similar ranges of \(^{234}\)U/\(^{238}\)U AR values for measured in USW SD-9 and U-series isotopic compositions are mineral abundances and whole-rock chemical

Matrix/Fracture Flow in Superposition Units (Neymark et al.)
Diffusion in Fractured Tuff (Hu et al.)

Pore Connectivity, Episodic Flow, and Unsaturated

Interacting imbibition-diffusive-sorption processes leading to radionuclide retardation under fracture-dominant flow.

Ambitious, integrated, and rigorous tests

Pore-scale network modeling

Synchrotron microtomography

Transport

Episodic fracture flow and tracer

Water imbibition and tracer transport

Gas diffusion

Sample acquisition and processing components

Experimental and modeling research
Groundwater (Cizdziel et al.)

Determining the Redox Properties of Ybr Related

- Measure concentrations with ICP-MS
- Use ion chromatography (IC) to separate metal/metalloid species
- Flash frozen (liquid N₂) to preserve redox speciation
- Collect groundwater under inert atmosphere (e.g., argon, N₂)

Yucca Mountain: As, Se, Cr, Mn, Fe, Cu, Mo, V, W, Re,

Alternative to Pt Eh probe: Determine the principal redox

- Disequilibrium
- Irreversibility or slow kinetics of many redox couples
- Some redox couples cannot be determined with Pt electrode

for measuring Redox conditions in groundwater

- Traditional platinum electrode Eh probe not always reliable

Reducing environments can greatly restrict the mobility of some radionuclides in the saturated zone
Most Nye County wells contain more Ar (V) than Cr (VI), more oxidizing environment.

Data to Date:

Project Objective: "Map of Redox Conditions in SZ"
Field Studies: Transport Properties of Radioactive Solutes and Colloids Using Chemical Analogues (Fretfield et al.)
- Predictive modeling using results of first batch tests

- Modeling

- Design and conduct next suite of sorption/desorption studies

- Perform analyses on sorption tests already conducted

- Lab

- Inject Reactive Tracer—July 2006

- Transport study—April 2006

- Conduct conservative tracer test (data used to design reactive

- Borehole completion with U-tube samplers—Feb 28

- Borehole geophysical logging, conductivity logging

- Drilling NC-EWDP-24PA—February 15

Field

FY06 Work—LBNL, USGS, LANL, NWPAO
Improving Characterization of Radiocurie Retardation in Volcanics and Alluvium (Remus et al.)
Carbon 14 Water Analysis (Thomas, Patterson et al.)

- Historic groundwater age estimates based on dissolved inorganic carbon (DIC) isotopes
  - Significant Age Corrections needed (20,000 to 2,000 ybp)
- New groundwater age estimates based on dissolved organic carbon (DOC) isotopes
  - DOC age independent of DIC reactions
- Developed method for carbon isotope analysis of low DOC groundwaters (<1 mg/L) for C-13 and C-14
- Results to date
  - All DOC C-14 values are smaller than DIC C-14 values
  - DOC C-14 times are similar to or less than DIC C-14 corrected ages (average travel time)
  - DOC and corrected DIC groundwater ages in the Yucca Mountain-Amargosa Valley area indicate mostly Holocene recharge
  - Groundwater travel times range from modern to 10,200 ybp except for one sample
location planned in remainder of FY06 to consolidate plans and assign tasks.

Two-day meeting of project participants in Amargosa Valley, near selected testing site.

- Injection will be designed to impose a tracer cloud of several tens of meters in the formation, so as to intersect multiple wells. Flow paths in the formation, introduction of tracer processes (advection, dispersion, and matrix diffusion)

- The formation cannot be assessed, rather, project can place bounds on transport of several (2) kilometers characteristic of Yucca Mountain over distances from hundreds of meters to

- This project aims to design and execute a tracer test with no forcing, and associated with the C-hole complex, under forced hydraulic gradient conditions testing to date are conducted over relatively short distances (~30-65 meters)

Umari, Reimus and others

Large Scale Natural Gradient Tracer Test (Shapiro,
The Site-Scale Saturated Zone Base-Case Transport Model predicts very thin radionuclide plumes

- Thin plumes obviate benefits of sorption characteristics of Yucca Mountain volcanic rocks

Project initiated in FY05 3rd quarter to determine if narrow plumes are characteristic of volcanic rocks worldwide

- Literature review of Snake River-INL, Oak Ridge, Hanford show larger dispersivity than that at Yucca Mountain
Quarterly and annual reports to OSTI director
Projects follow QA procedures
Personal as well as new participants from universities
Great enthusiasm among both the veteran national lab
Large attendance

• NB Thrust Review (February 13, 2006)
• NB Thrust Review (March 16, 2005)

Evaluated projects, research direction, and emphasis

Steve Yabuuchi
Richard Parizek
Rien van Gennuchten
Saboda Garb

Panel:
Proposed Yucca Mountain repository

Enhance our ability to predict the performance of the

UZ as pH changes from near-drift to below-drift

Field Studies to investigate radionuclide precipitation in the

at Yucca Mountain

Whether irreversible sorption is possible or even reversible
demonstrate enhanced performance

Cultivate alternative approaches that may

Current projects implement this long-range goal

View of Natural Barriers Thrust Lead

the regulatory standard

scientific basis for the natural system alone meeting

Stretch goal: determine whether there is a solid

Long-Term Strategy
Second-largest contributor to overall dose, after Tc-99m Mountain (TSPA shows that Pu-239 colloids are the significant reduction of colloid transport at Yucca. Indirect evidence of trapped colloids at water/air interfaces at an analogous site may imply potential values for several important radionuclides. One or more orders-of-magnitude increase in $K^0$. Diffusion within both the UZ and SZ. Several orders-of-magnitude enhancement in matrix. Detrapsibility and greater transparency and enhancement in-dirt models, leading to potential performance. Materials Performance Thrusts in developing unified integration of natural barriers, source term and findings to date.