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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Workshop VI: Flow and Transport through Unsaturated Fractured Rock (Account No. 20-5704-002).

DATE AND PLACE: January 25-28, 1993. Tucson, Arizona.

AUTHORS: A. B. Gureghian, W. M. Murphy, R. T. Green, R. C. Bagtzoglou, S. Mohanty, R. G. Baca, and B. Sagar

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PERSONS PRESENT:

See Attendance List (Attachment 1).

BACKGROUND AND PURPOSE OF TRIP:

The purpose of this trip was to attend and participate in Workshop VI: Flow and Transport through Unsaturated Fractured Rock. The workshop was organized by the University of Arizona (UA), the U.S. Nuclear Regulatory Commission (NRC), and the Center for Nuclear Waste Regulatory Analyses (CNWRA), and was hosted by the UA. It was attended by approximately 70 scientists representing universities, U.S. Department of Energy (DOE), the U.S. Geological Survey (USGS), United States Environmental Protection Agency (EPA), NRC, CNWRA, U.S. Department of Agriculture (USDA) Salinity Lab, and various national laboratories, such as Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratories (LLNL), Lawrence Berkeley Laboratory (LBL), and Sandia National Laboratories (SNL). The workshop consisted of some 20 formal presentations, including a video tape session on Thursday, January 26, 1993, covering the instrumentation and the drilling approach utilized at the Apache Leap Test Site (ALTS), and the instrumentation status at the Las Cruces Trench Site. Randy Bassett (UA) and Tom Maddock (UA) opened the workshop and provided the key note address.

SUMMARY OF PERTINENT POINTS:

Technical Session I: Opening.

B. Sagar (CNWRA) presented an overview paper entitled "Role of PA in the Site Characterization Process." The various requirements for assessing performance were highlighted; mathematical models, data analysis, geologic evolution and scenarios. This speaker also raised some questions regarding the role of performance assessment (PA) in the site characterization program.

R. Bassett, University of Arizona, Hydrology and Water Resources (UA/HWR), presented a paper on "Solute and Gas Transport Studies at the Apache Leap Sites." This speaker described the various isotopic and chemical data for water collected at the ALTS, including ^{14}C . The completion of the nine boreholes at the site and the future testing and gas sampling schedule was also reported. Perched water was found at the suspected level in the new slant borehole. A possible connection between the perched water and absence of clay minerals was noted. A plan is to extract water samples from the core samples using the

squeezing technology developed by A. Yang. An emphasis is on isotopic analyses as constraints on the hydrologic system.

A. Guzman (UA/HWR) presented a paper on "Multi-Scale Permeability Determinations in Fractured Tuff." Measurements of large-scale pneumatic permeability tests of variably saturated, fractured rock at different scales were reported. Because permeability data was observed to vary in space with a scale dependent mean, this researcher concluded that multi-scale tests are thus necessary, in order to avoid the risk of generating ambiguous permeability estimates. This speaker also reported that geostatistical analysis of ALTS pneumatic data enabled him to generate semivariograms yielding the variance and the spatial correlation scales of the data as function of the scale of measurement.

T. Rasmussen, University of Georgia (UG), discussed the water budget issue over large watersheds. Infiltration and runoff data collected over a two-year period were reported, including correlation curves of runoff versus rainfall, as well as probability density function's (PDF's) for each of these water budget components. J. Long (LBL) presented a paper entitled "Report on the Activities of the Characterization and Fluid Committee." An emphasis was placed on the role of fractures in fluid flow.

T. Nicholson (NRC) presented a progress report on INTRAVAL. The speaker reviewed the various activities and scientific benefits resulting from the four-year long U.S. participation in this international forum dedicated to code validation. Apparently INTRAVAL activities will be terminating by the end of the current year.

Technical Session II: Apache Leap Research Site.

This session consisted of a sequence of video and slide presentations focused on site descriptions, drilling methodologies, core handling, neutron log data, geophysical instrumentation, and recorded data.

G. Davidson (UA/HWR) discussed the sampling process of air and water collected in the unsaturated zone. He hinted to the fact that studies were under way to find a correlation between fracture position along core and surface observation. P. Wierenga, University of Arizona, Soil and Water Science (UA/SWS), presented a video session of the Las Cruces Trench, followed by a discussion on the instrumentation needs to understand small scale basic processes (e.g., chemical and microbiological), and techniques for measuring *in situ* soil properties.

Technical Session III: Physical and Hydraulic Properties of Fractured Unsaturated Rock Obtained from Core Material, Borehole Measurements, and Laboratory Studies.

J. Rousseau (USGS) reported on some recent results of unsaturated zone instrumentation prototype testing. His studies are focused on the Hydrologic Research Facility, at the Nevada Test Site. He reported that the Ghost Dance Fault is a series of faults with a dip of 80°. He also shared some of his experimental experiences with unsaturated zone measuring equipment and commented on the extremely long time it takes for equilibrating them (6 to 18 months). J. Rousseau described sophisticated psychrometers and accurate down-hole monitoring technology. Grouting of the equipment with hydrated calcium sulfate was identified as a possible complication. The high solubility of gypsum raises questions of resulting osmotic effects on the local water distribution. It is unclear that gypsum can equilibrate at the water activity (suction pressure) of the Yucca Mountain environment.

F. Paillet (USGS) gave a presentation on the use of acoustic and televiwing techniques for fractured rock. He emphasized that it is very difficult to relate information from core data and remote methods to the "big picture" of how the fractures extend over large (km) scales.

A. Flint (USGS) discussed findings from his modeling studies to assess the influence of long term climate change at Yucca Mountain. For an assumed net infiltration rate of 0.1 mm/yr his results showed that a depth of 250 to 320 meters is the most likely place for perched zone (high saturation) development. He also reported that the saturation profiles are influenced only by the fracture volume fraction. He further made a comment on the existence of alluvium strata at the top of the Mountain, which have to be saturated fully before any fracture flow is initiated. It was also suggested that the fault zones may act as conduits, capable of draining the perched water table zones.

R. Glass (SNL) made a presentation based on his laboratory studies regarding gravity-driven fingering in unsaturated rough-walled fractures. He reported that when the water flux is stopped, gravity dominates and fingers develop. He also reported that the moisture profiles are smoother when higher fluxes are present. He suggested that this observation may have some implications and corroborating arguments for the existence of a percolation threshold behavior as it pertains to effective property calculations.

R. Green (CNWRA) made a presentation on the application of similitude analysis for scaling up results obtained through heat and fluid flow laboratory-based experiments. Results of laboratory-scale experiments conducted at CNWRA were compared to results of a field heater test conducted by LLNL at G-tunnel and compared using dimensional analysis. Preliminary analysis suggests the laboratory-scale experiment is more closely an analog of a cool repository, whereas the G-tunnel heater experiment more closely approximated a hot-repository.

Technical Session IV: Chemical and Isotopic Composition of Gas and Fluid and the Relationship to Flow Path and Travel Time.

A. Yang (USGS) described gas sampling technology and gas chemistry data from Yucca Mountain, material mainly prepared for his upcoming presentation at the International High Level Radioactive Waste Meeting. D. Thorstenson (USGS) presented data on CO₂ content of gases and C isotope data from Yucca Mountain. He presented a diffusion model for ¹⁴C transport from the surface into the mountain.

W. Murphy (CNWRA) presented diffusion modeling nearly identical to that of Thorstenson, and went on to interpret the apparent diffusivity in the context of porosity, tortuosity, gas-liquid equilibria, and dispersion (e.g., due to barometric pumping). He also presented results of reaction path modeling of gas-water-rock interactions at Yucca Mountain, material from the second 1992 CNWRA Semiannual research report.

J. Fabryka-Martin (LANL) presented ³⁶Cl and Cl/Br data from unsaturated boreholes at Yucca Mountain.

Technical Session V: Scaling Issues Related to Geophysical Geochemical and Hydraulic Data.

S. Neuman (UA) reported on his findings regarding the existence of a universality of permeability variation with correlation and data-support scales. He discussed the self-affine nature of the semivariogram, and commented on the anti-persistence observed in permeability fields at the ALTS. He also suggested that the macro-dispersion observed in fractured systems (superimposed on stochastic matrix) should be less than the one observed in stochastic matrix fields.

S. Mohanty (CNWRA) presented results obtained under the Stochastic Project on the use of efficient methodologies for the calculation of effective properties for unsaturated fractured media.

T. Doe (Golder Associates) made a presentation on the integration of field data and discrete fracture modeling. He gave a report on the activities of the Stripa validation project, and a preliminary discussion of the work conducted at the Kamaishi mine in Japan. He also reported that some of his results suggest that permeability is not so much a material property, but is depending more on the geometry of the system, the applied pressure, and the preferential pathways. He emphasized that the accuracy of the flow simulation is closely related to the accuracy of the pathway geometry description. He finally implied that discrete fracture modeling should be recommended due to the fact that it is very easy to apply constraints on data information.

C. F. Tsang (LBL) reported on his results supporting the concept of scale dependence of tracer transport in fractured rocks. He stated that tracer transport is extremely sensitive on heterogeneity, and presented some results showing that the tracer peak arrival time is strongly influenced on the applied flow rates.

R. van Genuchten (USDA) presented his results on the application of a dual porosity model for flow and transport in structured media. These results are (very recently) published in the Water Resources Research journal.

D. Chesnut (LLNL) gave an informal presentation on the effects of scaling heterogeneity on PA models.

Notes on CNWRA/UA Collaboration Meeting

A meeting was held on January 28, 1993 to discuss possible collaboration between the UA and CNWRA on ALTS activities. The meeting was coordinated by Tom Nicholson (NRC). An agenda listed six or seven potential collaborative efforts. Individuals involved in each topic gave brief descriptions of technical aspects, with some group discussion of science and logistics of collaboration. Although mutual technical interests were clearly exhibited, aspects of collaboration remained poorly defined. The meeting concluded with the general proposal that parties with mutual interests should communicate with one another.

SUMMARY OF ACTIVITIES:

See Agenda (Attachment 2).

IMPRESSIONS/CONCLUSIONS:

This workshop provided an excellent opportunity to the participants to become cognizant with the progress accomplished in the areas of field experiments designed to estimate air and water permeability of unsaturated fractured rock, scaling effects, and various modeling aspects of unsaturated fractured media.

PROBLEMS ENCOUNTERED:

None.

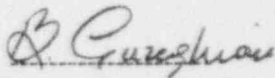
PENDING ACTIONS:

None.

RECOMMENDATIONS:

None.

SIGNATURES:



A. B. Gureghian
Principal Scientist

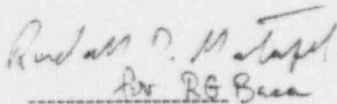
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ATTACHMENTS:

1. Attendance List.
2. Agenda for Technical Exchange.

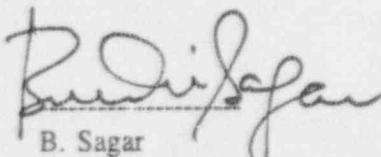
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for R.G. Baca

R. G. Baca, Manager
Performance Assessment
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2/23/93

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B. Sagar
Technical Director

2/25/93

Date

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WORKSHOP VI:
FLOW AND TRANSPORT THROUGH UNSATURATED FRACTURED ROCK

January 25-28, 1992, Tucson, Arizona
Raddison Hotel

- Workshop Coordinators:** Randy Bassett and Dan Evans
Department of Hydrology and Water Resources
University of Arizona
- Workshop Organizing Committee:** Bob Baca - CNWRA
Randy Bassett - UA/HWR
Dan Evans - UA/HWR
Tom Nicholson - NRC
Rex Wescott - NRC
- Workshop Program Coordinator:** Dennis Scheall
- General Theme:** The Use of Borehole Measurements and Core Analysis Data to Interpret Hydrologic and Chemical Characteristics of Fractured Unsaturated Tuff.

MONDAY - JANUARY 25, 1993	
<u>TECHNICAL SESSION I: OPENING</u> (Located in SALON 8)	
11:00 - 1:00	REGISTRATION
1:00 pm	Opening Remarks - Randy Bassett (UA/HWR) Tom Maddock (UA/HWR - Acting Department Head)
1:15 pm	Budhi Sagar (CNWRA): <i>Role of Performance Assessment in the Characterization Process.</i>
2:00 pm	Randy Bassett (UA/HWR): <i>Solute and Gas Transport Studies at the Apache Leap Research Sites.</i>
2:40 - 2:55	BREAK
2:55 - 3:00	Opening Remarks - Associate Dean William Cosart (UA/College of Engineering and Mines)
3:00 pm	Amado Guzman (UA/HWR): <i>Multi-Scale Permeability Determinations in Fractured Tuff.</i>
3:30 pm	Todd Rasmussen (UGa): <i>Laboratory Investigations of Fluid Flow through Unsaturated Fractured Rock</i>
4:00 pm	Jane Long (LBL): <i>Report on the Activities of the Characterization and Fluid Flow Committee</i>
4:30 pm	Tom Nicholson (NRC): <i>Progress Report on INTRAVAL</i>

WEDNESDAY - JANUARY 27

TECHNICAL SESSION IV: CHEMICAL AND ISOTOPIC COMPOSITION OF GAS AND FLUID AND THE RELATIONSHIP TO FLOWPATH AND TRAVEL TIME.

	Session Chairman - Randy Bassett (UA/HWR)
1:00 pm	Opening Remarks - R. Bassett
1:10 pm	Albert Yang (USGS): <i>Preliminary Isotopic Data from Boreholes of Apache Leap, Arizona and Yucca Mountain, Nevada.</i>
1:40 pm	Don Thorstenson (USGS): <i>Geochemistry of CO₂ and Carbon Isotopes from Open Boreholes at Yucca Mountain, Nevada.</i>
2:10 pm	William Murphy (CNWRA): <i>Transport and Distribution of Carbon at Yucca Mountain, Nevada.</i>
2:40 pm	--OPEN DISCUSSION--
3:10 pm	BREAK
3:20 pm	June Fabryka-Martin (LANL): <i>Chlorine-36 in Shallow Boreholes at Yucca Mountain.</i>
3:50 pm	--OPEN DISCUSSION--
5:00 pm	ADJOURN

THURSDAY - JANUARY 28

TECHNICAL SESSION V: SCALING ISSUES RELATED TO GEOPHYSICAL GEOCHEMICAL AND HYDRAULIC DATA

	Session Chairman - Art Warrick (UA/SWS)
8:00 am	Opening Remarks - Art Warrick
8:10 am	Shlomo Neuman (UA/HWR): <i>Universal Rules for Permeability Variation with Correlation and Support Scales: Validation Against World-Wide Crystalline Rock and Apache Leap Fractured Tuff Data.</i>
8:40 am	A.C. Bagtzoglou and S. Mohanty (CNWRA): <i>Theoretical Prediction and Numerical Determination of the Effective Hydraulic Conductivity of Unsaturated Porous Media.</i>
9:10 am	Tom Doe (Golder Associates): <i>Integration of Field Data Collection and Discrete Fracture Modelling.</i>
9:40 am	--OPEN DISCUSSION--
10:10 am	BREAK
10:20 am	Chin Fu Tsang (LBL): <i>Scale Dependence of Tracer Transport in Fractured Rocks.</i>
10:50 am	Rien van Genuchten (USDA/ARS): <i>Flow and Transport Models for Structured Media.</i>
11:20 am	--OPEN DISCUSSION--
12:00 pm	WORKSHOP SUMMARY AND ADJOURN