DOE/OSTI--3406(Suppl.4)(Add.2)
(DE95005302)
July 1995
Distribution Category UC-814

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FOR FURTHER INFORMATION ON THE CIVILIAN RADIOACTIVE WASTE MANAGEMENT PROGRAM

Contact for the Yucca Mountain Site Characterization Office:

Gregory N. Cook
Director, Public Affairs
Yucca Mountain Site Characterization Office
U.S. Department of Energy
P. O. Box 98608
Las Vegas, NV 89193-8608
(702) 794-7964

Yucca Mountain Site Characterization Project Bibliography

ABOUT THIS BIBLIOGRAPHY

Following a reorganization of the Office of Civilian Radioactive Waste Management in 1990, the Yucca Mountain Project was renamed Yucca Mountain Site Characterization Project. The title of this bibliography was also changed to Yucca Mountain Site Characterization Project Bibliography. Prior to August 5, 1988, this project was called the Nevada Nuclear Waste Storage Investigations.

This bibliography contains information on this ongoing project that was added to the Department of Energy's Energy Science and Technology Database from July 1, 1994, through December 31, 1994.

The bibliography is categorized by principal project participating organization. Participant-sponsored subcontractor reports, papers, and articles are included in the sponsoring organization's list. Another section contains information about publications on the Energy Science and Technology Database that were not sponsored by the project but have some relevance to it.

Earlier information on this project can be found in the first bibliography DOE/TIC-3406, which covers 1977–1985, and its supplements, DOE/OSTI-3406(Suppl.1), DOE/OSTI-3406(Suppl.2), DOE/OSTI-3406(Suppl.3), and DOE/OSTI-3406(Suppl.4), which cover information obtained during 1986–1987, 1988–1989, 1990–1991, and 1992–1993, respectively. More recent information can be found in DOE/OSTI-3406(Suppl.4) (Add.1), which covers January 1994 through June 1994. All entries in the bibliographies are searchable online on the NNW database file. This file can be accessed through the Integrated Technical Information System (ITIS) of the U.S. Department of Energy (DOE).

DOE and DOE contractors can order copies of most Yucca Mountain Site Characterization Project reports and other documents published by the DOE and the principal participant organizations from:

Office of Scientific and Technical Information
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General information and publications on the national program can be obtained through the Office of Civilian Radioactive Waste Management Toll-Free Information System at 1-800-225-NWPA (6972) (or, in Washington, DC, at 488-5513), or by writing to the OCRWM Information Center, P.O. Box 44375, Washington, DC 20026.

Peter M. Stephan, YMP Managing Editor

Office of Scientific and Technical Information
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***Civilian Radioactive Waste Management System, Management & Operating Contractor, Las Vegas.**

Bibliography With Abstracts

YUCCA MOUNTAIN SITE CHARACTERIZATION OFFICE

1 **Multiple event considerations for postclosure seismic hazard evaluations at Yucca Mountain, Nevada.** Lee, R.C. (Science Applications International Corp., Las Vegas, NV (United States)); King, J.L.; Grant, T.A. pp. 76-82 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Postclosure waste canister design requirements suggest the values used for seismic design have less than a 10% chance of being exceeded in a 1,000 year postclosure period. Considerably longer periods (10,000 years) for waste canister design are being considered to take into account potentially longer engineered canister lifetimes and the corresponding potential for a radionuclide barrier with increased performance. Such lengthy design periods may entail engineering design of waste systems that would be exposed to multiple episodes of seismic strong shaking without any benefit of retrofit or repair following each event. Reconnaissance seismic hazard studied conducted for the waste handling facility suggest that repository block waste canister design include consideration for the occurrence of multiple episodes of strong motion if postclosure periods greater than 1,000 years are considered.

2 **Design control overview for the Yucca Mountain Site Characterization Project Exploratory Shaft Facility.** Cikanek, E.M. (Hazard Engineering Co., Las Vegas, NV (United States)); Petrie, E.H. pp. 202-209 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This paper presents an overview of the design control process used for the Exploratory Shaft Facility (ESF) at Yucca Mountain. Design and design control is a complex, often iterative, and a well documented process. Design control is defined as the process of assuring that applicable regulatory requirements and the design basis for applicable structures, systems, and components are correctly translated into specifications, drawings, procedures, and instructions. Elements of the design control process described are: External design input, Quality Assurance (QA) grading, Engineering Plan, internal design input, interface control, design analysis, output documents, progress reviews, design verification, acceptance by the Project Office, field changes, and QA records.

3 **Design considerations for the Yucca Mountain Project Site Characterization.** Bullock, R.L. (Raytheon Services Nevada, Las Vegas, NV (United States)); Grenia, J.D. pp. 216-220 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Site Characterization Facilities (SCF) to be located in volcanic tuff at Yucca Mountain is a challenge to manage, design, and construct. This challenge is a result of a number of factors: This is a first of a kind facility to be planned, characterized, designed and built under the purview of a US nuclear regulatory agency; Stringent regulations inherited from the nuclear power agencies have been adapted and modified to allow design and construction of a surface/underground laboratory for the qualification of a repository site for the possible future storage of nuclear waste; Detailed interface is required between a number of participants to assure licensability of the SCF integration into a future repository; Stringent design and construction procedures; Stringent Quality Assurance and quality control. The regulations and requirements that flow down to the A/E for development of the SCF design are voluminous and unique to this project. The volume of regulations, constraints, and amount of oversite found on this project has no parallel in private sector engineering.

4 **Application of QA grading to Yucca Mountain Site Characterization Project items and activities.** Murthy, R.B. (Dept. of Energy, Las Vegas, NV (United States)); Smith, S.C. pp. 221-228 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Grading is the act of selecting the quality assurance (QA) measures necessary to develop and maintain confidence in the quality of an item or activity. The list of QA measures from which this selection is made are the 20 criteria of the Yucca Mountain Site Characterization Project Quality Assurance Requirements Document.

5 **Design reviews from a regulatory perspective.** Foster, B.D. (Science Applications International Corp., Las Vegas, NV (United States)). pp. 229-234 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This paper presents views on the role of the licensing engineer in the design process with specific emphasis on design reviews and the automated information management tools that support design reviews. The licensing engineer is seen as an important member of a design review team. The initial focus of the licensing engineer during design reviews is shown to be on ensuring that applicable regulatory requirements are addressed by the design. The utility of an automated tool, such as a commitments management system, to support regulatory requirements identification is discussed. The next responsibility of the licensing engineer is seen as verifying that regulatory requirements are transformed into measurable performance requirements. Performance requirements are shown to provide the basis for developing detailed design review criteria. Licensing engineer input during design reviews is discussed. This input is shown to be especially critical in cases where review findings may impact application of regulatory requirements. The use of automated tools in supporting design reviews is discussed. An information structure is proposed to support design reviews in a regulated environment. This information structure is shown to be useful to activities beyond design reviews. Incorporation of the proposed information structure into the Licensing Support System is proposed.

6 **Controlling the description of a high-level radioactive waste isolation system.** Zumba, C.F. (Science Applications International Corp., San Diego, CA (United States)); Shipler, D.B. pp. 235-239 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Control of large, complex, regulation-driven programs using traditional management methods has not been wholly effective. What is needed is a rigorous yet flexible method that is amenable to controlling the design of engineered and natural subsystems while an understanding of the natural subsystem is under investigation. The key to developing such a methodology is controlling the known and predicted model of the system. Regulatory, engineering, and scientific needs can be successfully met and controlled by maintaining a current model of the system as new information is obtained, as new investigative plans are developed, and as physical changes are made to the system.

7 **Yucca Mountain Site Characterization Project waste package plan.** Harrison-Giesler, D.J. (Dept. of Energy, Las Vegas, NV (United States)); Morissette, R.P.; Jardine, L.J. pp. 296-300 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The goal of the US DOE's Yucca Mountain Site Characterization Project (YMP) waste project program is to develop, confirm the effectiveness of, and document a design for a waste package and associated engineered barrier system (EBS) for spent nuclear fuel and solidified high-level nuclear waste (HLW) that meets the applicable regulatory requirements for a geologic repository. The Waste Package Plan describes the waste package program and establishes the technical approach against which overall progress can be measured. It provides guidance for execution and describes the essential elements of the program, including the objectives, technical plan, and management approach. The plan covers the time period up to the submission of a repository license application to the US Nuclear Regulatory Commission (NRC).

8 **Dry drilling and coring development for unsaturated zone studies.** Long, R. (Dept. of Energy, Las Vegas, NV (United States)); Wonderly, D.; Wright, E. pp. 810-815 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Two areas of major difficulty associated with characterization of any unsaturated zone are the conventional drilling and coring processes used to acquire the samples. These processes are inherently contaminating processes if the circulation fluid used and the cuttings generated are not controlled. The Site Characterization Program at Yucca Mountain requires both uncontaminated core for analysis and a "near borehole environment" as close to in-situ conditions as possible for hydrologic testing. As a result, a prototype development program has been initiated to develop drilling and coring processes which allow for acquisition of uncontaminated core and which cause minimal disturbance of in-situ conditions within the formation exposed at the borehole wall.

9 **Geologic sample handling and logging at Apache Leap, Arizona.** Davis, J.H.; Hartley, J.A.; Moyer, J.L.; Sinks, D.J. pp. 816-821 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Early in 1990, the Yucca Mountain Project Office (Project Office; presently the Yucca Mountain Site Characterization Project Office) of the US DOE completed two prototype boreholes at Apache Leap, Arizona, to test dry drilling and coring techniques that will be used during site characterization activities at Yucca Mountain, Nevada. Staff of the Sample Management Facility (SMF), Technical and Management Support Services contractor, used the boreholes to test sample handling and geologic logging procedures. Results of this testing indicate that modifications to approved Project Office procedures will be necessary before site characterization commences. These modifications include reduction of paperwork, verification of drill depths, upgrade of equipment, and enhanced training of SMF field staff.

10 **Monitoring compliance with requirements during site characterization.** Herrington, C.C. (SAIC, Las Vegas, NV (United States)); Jennetta, A.R.; Dobson, D.C. pp. 917-920 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive

waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The question of when a program of Regulatory Compliance should be applied and what it should be applied to, when the subject of compliance is a High Level Radioactive Waste Repository, defies resolution by merely relating to past practices of licensees of the US Nuclear Regulatory Commission (NRC). NRC regulations governing the disposal of High Level Waste include interactions with the potential applicant (US DOE) during the pre-license application phase of the program when the basis for regulatory compliance is not well defined. To offset this shortcoming, the DOE will establish an expanded basis for regulatory compliance, keeping the NRC apprised of the basis as it develops. As a result, the preapplication activities of DOE will assume the added benefit of qualification to a suitable Regulatory Compliance monitoring and maintenance plan.

11 **Test and evaluation of natural barriers at Yucca Mountain, Nevada: Management of the site characterization program.** Blanchard, M.B. (DOE, Las Vegas, NV (United States)); Jones, S.B.; Voegele, M.D.; Younker, J.L. pp. 927-931 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE is responsible for managing a characterization program for the Yucca Mountain site to collect data needed to determine if the site is suitable for recommendation for development as a repository. If found to be suitable, the site will then begin the licensing process with the US NRC. Given the long time period over which this process occurs, it is essential that the data base for the site is systematically documented and updated. Likewise, the records for preliminary performance evaluations are an essential part of that documentation package. A cornerstone of DOE's management approach to site characterization and evaluation are documented and available for scrutiny by oversight groups and the NRC, especially during the licensing process.

12 **Application of QA program for Yucca Mountain Site Characterization Project geologic investigations.** Murthy, R.B. (DOE, Las Vegas, NV (United States)); Smith, S.C. pp. 1214-1219 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The High Level Waste Program requires safe disposal of nuclear waste in a geologic medium for thousands of years. Traditionally, the nuclear industry relies heavily on engineered items. The Mined Geologic Disposal System (MGDS) Program relies equally, if not more, on the natural barriers for containment of radionuclides. As a consequence, a stringent quality assurance (QA) program must be applied to geologic and scientific site suitability investigations.

13 **The last twelve months at Yucca Mountain.** Gertz, C.P. (DOE, Las Vegas, NV (United States)); Robison, A.C. pp. 1314-1318 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE is evaluating Yucca Mountain in Nevada to determine if the site would be a safe location for a high-level radioactive waste repository. As mandated by Congress, the DOE must study the geology, hydrology, environment and other factors to predict whether a geologic repository about 305 meters (1,000 feet) below Yucca Mountain's surface could isolate high-level waste for 10,000 years. Yucca Mountain lies on the western edge of the Nevada Test Site, 177 kilometers (110 miles) northwest of Las Vegas. The Yucca Mountain Site Characterization Project (YMP) has embarked on a broad-based testing program designed to examine all factors that could impact the performance of a repository. While there are several site studies under way, major site investigations have not progressed as planned. The DOE is presently involved in litigation with the state of Nevada, which has refused to issue environmental permits that are required before new site characterization studies can begin. This paper will examine progress made on the YMP during the past year, discuss studies that are planned in the near-term, and will describe the Project's interactions with oversight groups, government entities, and the public.

14 **Perils of project development on public land open to mining.** Jacobs, W.R. (SAIC, Las Vegas, NV (United States)). pp. 1319-1323 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Conducting a government project on public land open to the general mining laws can result in added costs, legal entanglements, schedule uncertainties, and the potential for unanticipated safety issues and concerns due to interactions with mining claimants. Planning for such projects must include a careful assessment of not only land access needs and restrictions, but also possible scenarios for conflict with activities authorized under the general mining laws throughout the life of the project. It is essential to have a thorough knowledge of the applicable mining laws and how they are currently being interpreted and applied by the responsible regulatory authorities and land managers. The Yucca Mountain Project approach to land access, problems encountered with mining claims filed under the Mining Law of 1872, and the lessons learned from these experiences are discussed in this paper.

15 **Being responsive and getting the job done right.** Seidler, P.E. (SAIC, Las Vegas, NV (United States)); Andrews, W.B.; Grassmeier, K.F.; Standish, P.N. pp. 1324-1328 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE, Yucca Mountain Site Characterization Project Office (YMSCPO) has been given the responsibility for characterization of the potential and repository site at Yucca Mountain, Nevada, and the responsibility of informing and working with the Project. In support of these responsibilities, the Project Office has begun a preliminary review of

potential railroad routes to Yucca Mountain for the transportation of high-level radioactive waste. An extensive effort has been undertaken to integrate the route review evaluation with public and local government concerns.

16 **Management of comments on DOE's Site Characterization Plan (SCP) and integration with the planned geotechnical program.** Bjerstedt, T.W. (DOE, Las Vegas, NV (United States)); Gil, A.V.; Baird, F.A. pp. 1336-1342 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE has committed to respond to comments on the SCP throughout the site characterization process. As of January 1990 DOE has received 4,574 comments on both the SCP/Consultation Draft and the statutory SCP. Of these, 2,662 responses have been completed and returned to the originators. Many comments are programmatic in nature and express diverse concerns beyond the scope of the SCP. DOE uses a three-tiered process in responding to comments that integrated technical and management responsibilities. The process defines specific roles in developing, reviewing, and concurring on responses. Commitments or open-items can be generated in DOE responses to comments, which are tracked on a relational database. Major changes reflected in the Secretary of Energy's 1989 reassessment of the high-level waste program were advocated in comments on the SCP. Most DOE commitments, however, deal with consideration of recommendations contained in SCP comments relevant to low-levels of technical planning detail (SCP Study Plans). Commitments are discharged when referred to the appropriate quality-affecting or management process whereupon their merits can be evaluated.

17 **Archaeological program for the Yucca Mountain Site.** Pippin, L.C. (Desert Research Institute, Reno, NV (United States)); Rhode, D. pp. 1444-1448 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Archaeological surveys, limited surface collections and selected test excavations in the Yucca Mountain Project Area have revealed four distinct aboriginal hunting and gathering adaptive strategies and a separate historic Euroamerican occupation. The four aboriginal adaptations are marked by gradual shifts in settlement locations that reflect changing resource procurement strategies. Whereas the earliest hunters and gatherers focused their activities around the exploitation of toolstone along ephemeral drainages and the hunting of game animals in the uplands, the latest aboriginal settlements reflect intensive procurement of early spring plant resources in specific upland environments. The final Euroamerican occupation in the area is marked by limited prospecting activities and travel through the area by early immigrants.

18 **Management and research of desert tortoises for the Yucca Mountain Project.** Rautenstrauch, K.R. (EG&G Energy Measurements, Las Vegas, NV (United States)); Cox, M.K.; Doerr, T.B.; Green, R.A.; Mueller, J.M.; O'Farrell, T.P.; Rakestraw, D.L. pp. 1449-1455 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A program has been developed for the Yucca Mountain Project (YMP) to manage and study the desert tortoise (Gopherus agassizi), a threatened species that occurs at low densities at Yucca Mountain. The goals of this program are to better understand the biology and status of the desert tortoise population at Yucca Mountain, assess impacts on tortoises of site characterization (SC) activities, and minimize those impacts. The first steps we took to develop this program were to compile the available information on the biology of tortoises at Yucca Mountain, ascertain what information was lacking, and identify the potential impacts on tortoises of SC. We then developed a technical design that can be used to identify and mitigate direct and cumulative impacts and provide information on tortoise biology. Interrelated studies were developed to achieve these objectives. The primary sampling unit for the impact monitoring studies is radiomarked tortoises. Three populations of tortoises will be sampled: Individuals isolated from disturbances (control), individuals near major SC activities (direct effects treatment and worst-case cumulative effects treatment), and individuals from throughout Yucca Mountain (cumulative effects treatment). Impacts will be studied by measuring and comparing survival, reproduction, movements, habitat use, health, and diet of these tortoises. A habitat quality model also will be developed and the efficacy of mitigation techniques, such as relocating tortoises, will be evaluated.

19 **Assessing impacts on biological resources from Site Characterization Activities of the Yucca Mountain Project.** Green, R.A. (EG&G Energy Measurements, Las Vegas, NV (United States)); Cox, M.K.; Doerr, T.B.; O'Farrell, T.P.; Ostler, W.K.; Rautenstrauch, K.R.; Wills, C.A. pp. 1456-1460 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

An integrated impact assessment program was developed to monitor the possible effects of Site Characterization Activities (SCA) on the biological resources of the Yucca Mountain area. The program uses control and treatment sites incorporating both spatial and temporal controls. The selection of biotic variables for monitoring was based on their relative importance in the ecosystem and their ability to provide information on potential impacts. All measures of biotic and abiotic variables will be made on the same sample plots to permit linking changes in variables to each other.

20 **The reclamation program for the Yucca Mountain Project.** Ostler, W.K. (EG&G Energy Measurements, Las Vegas, NV (United States)); O'Farrell, T.P.; Winkel, V.K.; Schultz, B.W. pp. 1461-1468 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE is required by law and other regulatory requirements to reclaim disturbances created by site characterization activities at Yucca Mountain. Because of the difficulty of reclaiming arid areas and the lack of site specific information on successful reclamation techniques and procedures, the DOE has developed a comprehensive reclamation program. The program consists of three phase: Planning, operational and research. The planning phase is a continuing process that ensures that program policy, goals, tasks and responsibilities are clearly identified and linked. Three inter-related planning documents have been released by the DOE that establish the program objectives and outline the steps needed to successfully meet those objectives. The operational phase uses best available knowledge to develop and implement reclamation plans that are site-specific for each disturbance. Reclamation activities start prior to any surface disturbance with a survey of each disturbance by trained scientists. The scientists survey the area for the presence of protected species or critical wildlife habitat. They also gather vegetation, landscape, soils and other environmental data that is used to assess the impact of the proposed disturbance. Recommendations can be made to either avoid areas or mitigate impacts. The operational phase includes interim reclamation to protect valuable resources and control erosion prior to final reclamation. Monitoring of reclaimed sites is conducted to correct problem areas and insure that reclamation objectives are achieved. The third phase of the reclamation program is designed to provide site-specific information on effective reclamation techniques through research and field demonstrations. Information on potentially successful techniques will be used to update to improve the effectiveness of the reclamation activities at Yucca Mountain.

21 **Toward linking demographic and economic models for impact assessment.** Williams, C.A. (SAIC, Las Vegas, NV (United States)); Meenan, C.D. pp. 1534-1539 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

One of the objectives of the Yucca Mountain Project, in Southern Nevada, is to evaluate the effects of the development of a high-level nuclear waste repository. As described in the Section 175 Report to the Congress of the US, the temporal scope of this repository project encompasses approximately 70 years and includes four phases: Site characterization and licensing, construction, operation, and closure and decommissioning. If retrieval of the waste were to be required, the temporal scope of the repository project could be extended to approximately 100 years. The study of the potential socioeconomic effects of this project is the foundation for this paper. This paper focuses on the economic and demographic aspects and a possible method to interface the two. First, the authors briefly discuss general socioeconomic modeling theory from a county level view point, as well as methods for the apportionment of county level data to sub-county areas. Next, the authors describe the unique economic and demographic conditions which exist in Nevada at both the state and county levels. Finally, the authors evaluate a possible procedure for analyzing repository effects at a sub-county level; this involves discussion of an interface linking the economic and demographic aspects, which is based on the reconciliation of supply and demand for labor. The authors conclude that the basis for further model development may rely on the interaction of supply and demand to produce change in wage rates. These changes in expected wages should be a justification for allocating economic migrants (who may respond to Yucca Mountain Project development) into various communities.

22 **A decision support system for performance-based site characterization.** Barbour, T.G. (SAIC, Golden, CO (United States)); Lockerd, M.J. pp. 1704-1709 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The complex and dynamic requirements of site characterization present a major management challenge. ParaTrac, a regulatory and technical information system, is described as a valuable tool in assisting managers of such programs. ParaTrac is currently being used on the Yucca Mountain Site Characterization Project to help prioritize site testing based on high-priority regulatory requirements. It has also been used in field activities tracking, MGDS systems analysis, project technical database input, and study plan preparation. The process of planning and implementing a performance-based site characterization program is discussed in general. The questions of "What data are needed?," "How much is enough?," and "How much will it cost?" are addressed. A detailed illustration of how the ParaTrac system can be used to answer these questions is also given. ParaTrac captures the regulatory basis for site characterization and provides a data management system to allow rapid retrieval of related information. These regulatory requirements can be tracked through the entire site characterization process, from parameter information needs to field testing and data collection, and ultimate to various analyses. An example of this process is given for a regulation dealing with ground-water travel time.

23 (CONF-9107280–1) **Thermal and metallurgical considerations of a novel design for the nuclear waste container.** Skaggs, R.; Moujaes, S.; Lei, Y.; Gopal, V.V. Nevada Univ., Las Vegas, NV (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From Nuclear waste packaging focus '91; No City Given, NY (United States); Jul 1991. Order Number DE95000598. Source: OSTI; NTIS; INIS; GPO Dep.

The Departments of Civil and Mechanical Engineering at University of Nevada, Las Vegas are involved in the high level nuclear waste project. Designing containers for long term disposal of spent nuclear fuel and high level radioactive waste, is one of the project tasks. A multi-barrier robust waste containment scheme is being, actively researched, as preliminary work, has shown that, this scheme would better resist the degradation mechanisms set up by phenomena such as geological activity, water immersion, occurrence of mechanical loading, dry oxidizing conditions and wet reducing conditions. The physical configuration of the waste cannister, has an inner shell of copper base alloy, to resist a wet reducing environment, an outer shell of nickel base alloy, to resist dry and oxidizing conditions and a nonconducting oxide barrier to separate the two metallic barriers. Cement concrete is being considered for this role. With 10cm of concrete between the metal alloy shells and the

maximum allowable thermal loads reaching 4740W, the possibility of reaching temperatures, that could be detrimental to concrete is real (i.e., 300C and above). The temperature of the inner shell, to a great degree is a function of the thickness of the oxidic concrete layer. Another possible option being studied is the use of alumina as a sandwich, between the two metal shells. With the 10cm alumina the maximum inner shell temperature will be 230C. To maintain the inner shell at a relatively lower temperature, only a single copper base container will be used at the time of emplacement. After a period of 50 years, the waste is either retrieved for processing or the system is upgraded to a permanent multibarrier system.

24 **'Procurement quality engineering': A measurement driven system to assure quality at each step in the procurement process.** Rinderman, R.R. (Science Applications International Corporation, Las Vegas, NV (United States)). pp. 1151-1155 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The 'Procurement Quality Function' is an element of the Body of Knowledge of Quality Engineering, as defined by the American Society for Quality Control (ASQC). This paper describes the Procurement Quality function which has been installed as an integral part of the Quality Engineering group of the Technical and Management Support Services (T&MSS) contractor to the United States Department of Energy (DOE) Yucca Mountain Site Characterization Project. Each of the elements of the T&MSS Procurement Quality Engineering (PQE) system is discussed along with the measurements obtained. With the installation and development of the PQE system we have attained more meaningful evaluation of supplier capability, reduction of procurement document review reject ratios from 31% to less than 2% per quarter, more effective measurement and control of supplier performance, and the ability to enter into a meaningful teaming effort with T&MSS suppliers.

25 **The MacCSITS database: A tool for curating samples.** Merritt, D.W. (Science Applications International Corporation, Las Vegas, NV (United States)); Lewis, C.; Linden, L.S. pp. 1182-1186 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Geologic samples are a primary source of data for the Yucca Mountain Site Characterization Project (YMP). The collection and study of the samples is regulated by requirements which mandate complete documentation of their identity and history, so that any data submitted in support of site licensing may be traced accurately to their source. Geologic samples are curated at the Sample Management Facility (SMF) located near Yucca Mountain. The MacCSITS database is a tracking and inventory system designed to ease the task of documenting YMP samples.

26 **Progress on the U.S. Department of Energy's issue resolution process: A status report.** Jones, S.B. (Department of Energy, Las Vegas, NV (United States)); VanCamp Gil, A.; Desell, L.J.; Einberg, C. pp. 1236-1239 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy (DOE) is studying Yucca Mountain, Nevada, to determine its suitability for a mined geologic repository for high-level nuclear waste. In addition to identifying, clarifying, and resolving technical issues relative to site characterization, DOE has the responsibility to develop a license application for authorization to construct a geologic repository; the license application would be submitted to the U.S. Nuclear Regulatory Commission. In order to assist in managing the complex licensing interactions required, DOE has developed the Issue Resolution process. Issue Resolution provides a means by which any issue, regulatory or technical, can be addressed and clarified. Eight issues are currently active in this process: Erosion, Calcite-Silica, Volcanism, Seismic Hazards, Engineered Barrier System, Disturbed Zone, Substantially Complete Containment, and Ground Water Travel Time. The Issue Resolution organization includes management and staff members with technical and management experience in relevant areas. The Issue Resolution structure has proven to be useful in focusing resources on those areas within the program that need clarification or interpretation and are critical for successful and timely site characterization and licensing of a potential repository.

27 **Reliability modeling of an engineered barrier system.** Ananda, M.M.A. (Univ. of Nevada, Las Vegas, NV (United States)); Singh, A.K.; Flueck, J.A. pp. 1326-1330 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Weibull distribution is widely used in reliability literature as a distribution of time to failure, as it allows for both increasing failure rate (IFR) and decreasing failure rate (DFR) models. It has also been used to develop models for an engineered barrier system (EBS), which is known to be one of the key components in a deep geological repository for high level radioactive waste (HLW). The EBS failure time can more realistically be modelled by an IFR distribution, since the failure rate for the EBS is not expected to decrease with time. In this paper, we use an IFR distribution to develop a reliability model for the EBS.

28 **Significance of geochemical characterization to performance at Yucca Mountain, Nevada.** Simmons, A.M. (Department of Energy, Las Vegas, NV (United States)). pp. 1482-1489 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. concept for permanent disposal of high-level radioactive waste resembles those of other countries in that it relies upon burial in a deep geologic medium. This concept relies upon multiple barriers to retard transport of radionuclides to the accessible environment; those barriers consist of the waste form, waste container, engineered barrier system (including possible backfill) and retardant properties of the host rock. Because mobilization of radionuclides is fundamentally a geochemical problem, an understanding of past, present, and future geochemical processes is a requisite part of site characterization studies conducted by the

U.S. Department of Energy at Yucca Mountain, Nevada. Geochemical information is needed for evaluating three favorable conditions (the rates of geochemical processes, conditions that promote precipitation or sorption of radionuclides or prohibit formation of colloids, and stable mineral assemblages) and four potentially adverse conditions of the site (groundwater conditions that could increase the chemical reactivity of the engineered barried system or reduce sorption, potential for gaseous radionuclide movement, and oxidizing groundwaters) for key issues of radionuclide release, groundwater quality, and stability of the geochemical environment. Preliminary results of long-term heating experiments indicate that although zeolites can be modified by long-term, low temperature reactions, their beneficial sorptive properties will not be adversely affected. Mineral reactions will be controlled by the aqueous activity of silica in groundwater with which the minerals are in contact. Geochemical barriers alone may satisfy release requirements to the accessible environment for many radionuclides; however, additional site specific geochemical and mineralogical data are needed to test existing and future radionuclide transport models.

29 **Software quality assurance on the Yucca Mountain Site Characterization Project.** Matras, J.R. (SAIC, Las Vegas, NV (United States)). pp. 1643-1647 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Yucca Mountain Site Characterization Project (YMP) has been involved over the years in the continuing struggle with establishing acceptable Software Quality Assurance (SQA) requirements for the development, modification, and acquisition of computer programs used to support the Mined Geologic Disposal System. These computer programs will be used to produce or manipulate data used directly in site characterization, design, analysis, performance assessment, and operation of repository structures, systems, and components. Scientists and engineers working on the project have claimed that the SQA requirements adopted by the project are too restrictive to allow them to perform their work. This paper will identify the source of the original SQA requirements adopted by the project. It will delineate the approach used by the project to identify concerns voiced by project engineers and scientists regarding the original SQA requirements. It will conclude with a discussion of methods used to address these problems in the rewrite of the original SQA requirements.

30 **Qualification of existing data for the Yucca Mountain Site Characterization Project.** Bjerstedt, T.W. (Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States)); Jones, S.B.; Distel, B.W. pp. 1648-1652 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy (DOE) has completed its first effort to qualify existing data using NUREG-1298 'Qualification of Existing Data for High-Level Nuclear Waste Repositories'. A combination of three methods were used: corroboration, equivalent quality assurance program, and peer review. A technical assessment procedure was used to create the documentation to support the qualification process. The technical assessment team compared the procedures in place at the time of the original work to the procedures in use under an approved quality assurance program, the scientific notebooks that recorded the investigations, the geologic samples studied, and the records of a peer review conducted on one part of the work. The team recommended that the data be qualified. This recommendation was accepted by the DOE in September 1992.

31 **Borehole security on the Yucca Mountain project.** Smith, S.C. (Science Applications International Corp., Las Vegas, NV (United States)); Linden, L.S.; Tynan, M.C. pp. 1686-1690 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A borehole security plan was developed and is being implemented to address safety, environmental protection and restoration, waste isolation, and security concerns related to boreholes in the area where site characterization studies are being performed by the U.S. Department of Energy at Yucca Mountain, Nevada. Over 250 boreholes have been drilled to provide geologic, hydrologic, and seismologic data for assessing the suitability of Yucca Mountain for storage of high-level nuclear waste. Approximately 150 additional boreholes are planned for future investigations. In this paper we describe the existing conditions, objectives, and work program use to secure these boreholes.

32 **A variation of the housing unit method for estimating the age and gender distribution of small, rural areas: A case study of the local expert procedure.** Carlson, J.F. (SAIC, Las Vegas, NV (United States)); Roe, L.K.; Williams, C.A.; Swanson, D.A. pp. 1918-1923 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper describes the methodologies used in the development of a demographic data base established in support of the Yucca Mountain Site Characterization Project Radiological Monitoring Plan (RadMP). It also examines the suitability of a survey-based procedure for estimating population in small, rural areas. The procedure is a variation of the Housing Unit Method. It employs the use of local experts enlisted to provide information about the demographic characteristics of households randomly selected from residential units sample frames developed from utility records. The procedure is nonintrusive and less costly than traditional survey data collection efforts. Because the procedure is based on random sampling, confidence intervals can be constructed around the population estimated by the technique. The results of a case study are provided in which the total population, and age and gender of the population, is estimated for three unincorporated communities in rural, southern Nevada.

33 **Current progress in implementing the payments-equal-to-taxes (PETT) program in Nevada.** Lundgaard, E.L. (Department of Energy, Las Vegas, NV (United States)); Ellis, C.B. pp. 1930-1934 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level

radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Nuclear Waste Policy Act of 1982, as amended (NWPA), requires the Secretary of Energy to make Payments-equal-to-Taxes (PETT) to local units of government that are affected by the potential repository at Yucca Mountain, Nevada. The PETT program is designed to provide affected jurisdictions with the revenue they would have received if the potential repository site was being characterized and possibly developed by a private entity rather than the Federal government. A paper presented at last year's conference described how the PETT Program would be implemented in the State of Nevada. This paper describes the current progress in implementing the program as it relates to the PETT associated with property taxes.

34 **IHLW conference paper Yucca Mountain Site Characterization Project Environmental Protection Program.** Dixon, W.R. (Department of Energy, Las Vegas, NV (United States)); McCann, E.W.; Powers, C.D. pp. 1972-1979 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

To ensure the characterization of the Yucca Mountain site is conducted in an environmentally safe and sound manner, the U.S. Department of Energy (DOE) has developed and implemented a comprehensive program that ranges from the acquisition of Federal and State permits to the reclamation of disturbed lands. Among other elements of this program are the following: Identification of relevant environmental regulations, identification of potential environmental impacts, monitoring for potentially significance adverse impacts and mitigation of any impacts that may occur, management of hazardous wastes, waste minimization, and environmental compliance auditing.

35 **Ambient air monitoring to support HLW repository site characterization.** Fransioli, P.M. (Science Applications International Corp., Las Vegas, NV (United States)); Dixon, W.R. pp. 1980-1983 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Site characterization at the Yucca Mountain site includes an ambient air quality and meteorological monitoring program to provide information for environmental and site characterization issues. The program is designed to provide data for four basic purposes: Atmospheric dispersion calculations to estimate impacts of possible airborne releases of radiological material; Engineering design and extreme weather event characterization; Local climate studies for environmental impact analyses and climate characterization; and, Air quality permits required for site characterization work. The program is compiling a database that will provide the basis for analyses and reporting related to the purposes of the program. Except for reporting particulate matter and limited meteorological data to the State of Nevada for an air quality permit condition, the data have yet to be formally analyzed and reported.

36 **Experimental studies to calibrate unsaturated flow models.** Boehm, R. (Univ. of Nevada, Las Vegas, NV (United States)); Krotke, M.; Thota, S.; Xu, Xiang. pp. 2081-2085 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Many aspects of the work related to design and performance assessment of the proposed High Level Nuclear Waste Repository at Yucca Mountain are based upon estimates of moisture migration in the surrounding formations. These estimates are usually made using computer codes that have varying degrees of validation. Since most of the moisture flows are in highly nonhomogeneous media and are unsaturated, the development of experimental data for validating models is a difficult task. Work is described that has been designed to serve as a laboratory calibration of numerical models for unsaturated flow studies. The experiment size is configured large enough that the assumptions applicable to most numerical models should apply, but the size is small enough that the test section can be characterized well and accurately monitored. A large piece of consolidated and fractured medium is used for the main test element. In addition to careful assessment of flows in and out, the moisture content at various locations along the element is monitored. Both electromagnetic and ultrasonic techniques are used in our experiments for the latter estimates. The general experimental method, control system, and data acquisition approach are described.

37 **Functional analysis: The path to effective training.** Rehkop, E.C. (Department of Energy, Las Vegas, NV (United States)); McCarthy, R.A.; Chadwick, P.A. pp. 2133-2137 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The regulatory requirements under which the Yucca Mountain Site Characterization Project (YMP) operates mandate that worker proficiency be achieved and maintained. Individuals performing activities that affect quality should be adequately trained to perform work to a specified standard. Effective training must be structured around the tasks performed and their performance standards which is often an expensive and labor-intensive processing involving many interviews and worker observations. Tasks at YMP include such things as procedure review, data analysis, and test design none of which lend themselves to worker observation. Additionally, budget and time constraints and a small staff of trained job and task analysts have made the analysis process very onerous for everyone. The challenge faced by the YMP training staff was to designed effective initial and continuing training programs for a staff of 700 people filling approximately 550 positions. Crucial to the success of this effort is the collection of valid, sufficiently detailed data on the types of tasks performed and their associated performance standards. This paper describes how the YMP has streamlined the data collection process, cutting the costs and man-hours required while still maintaining the high quality and validity of the data collected.

38 **Project control - the next generation.** Iorii, V.F. (Department of Energy, Las Vegas, NV (United States)); McKinnon, B.L. pp. 2138-2143 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States)

(1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Yucca Mountain Site Characterization Project (YMP) is the U.S. Department of Energy's (DOE) second largest Major System Acquisition Project. We have developed an integrated planning and control system (called PACS) that we believe represents the 'Next Generation' in project control. PACS integrates technical scope, cost, and schedule information for over 50 participating organizations and produces performances measurement reports for science and engineering managers at all levels. Our 'Next Generation' project control too, PACS, has been found to be in compliance with the new DOE Project Control System Guidelines. Additionally, the nuclear utility oversight group of the Edison Electric Institute has suggested PACS be used as a model for other civilian radioactive waste management projects. A 'Next Generation' project control tool will be necessary to do science in the 21st century.

39 (CONF-9402115–1) **Focused mined geologic disposal system (MGDS) repository design for the Yucca Mountain Project.** Brodsky, M.G. (USDOE Nevada Operations Office, Las Vegas, NV (United States). Yucca Mountain Project Office); Bhattacharyya, K.K.; Olguin, L.J. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. From 2. international workshop on design and construction on final repositories; Winnepeg (Canada); 15-17 Feb 1994. Order Number DE95003024. Source: OSTI; NTIS; INIS; GPO Dep.

This paper outlines a refined design process which will successfully manage Yucca Mountain Project repository design efforts while meeting regulatory and programmatic requirements. Pending changes in the program technical baseline as well as limited resources reflect the program's emerging trend to manage technical and programmatic risks associated with the selection of key assumptions. The decision to utilize a Multiple Purpose Canister (MPC), one of many waste package concepts currently being considered, has promulgated a revised Mined Geologic Disposal System (MGDS) design approach. The key elements are: (1) develop MGDs design concepts which fulfills the technical and programmatic requirements; (2) adopt a design approach which uses management assumptions based on available information and expert engineering and scientific judgment now; (3) substantiate the assumptions as the design is developed; and (4) carry alternative design features which are important to safety and/or waste isolation. Advantages and constraints are discussed.

40 (CONF-940553–52) **Investigation of stress in a circular tunnel due to overburden and thermal loading of horizontally placed 21 PWR multi purpose canisters.** Kandalaft-Ladkany, N.; Wyman, R.V. Nevada Univ., Las Vegas, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94012149. Source: OSTI; NTIS; INIS; GPO Dep.

The drift of a High Level Nuclear Waste (HLNW) Repository were subjected to 2-D thermal loading resulting from the horizontal emplacement of 125 Ton Multi-Purpose Canisters (MPC). Ten 2-D temperature profiles, resulting from 57 Kw/acre and 114 Kw/acre thermal loading conditions, were used in a finite element analysis of the drift; in which a quadrant of the drift and surrounding rock ±100m above and below the drift were modeled. Our analysis shows that the 114 Kw/acre thermal loading results in compressive stresses around the drift, 60 years after emplacement, that exceed the unconfined compressive strength of the TSW tuff analyzed. Stresses resulting from a 57 Kw/acre thermal loading are within the acceptable limit in tunnel rock. A parametric analysis of the invert backfill material showed that Young's modulus for the invert backfill should closely match that of the surrounding unconfined rock in the tunnel in order to prevent an unacceptable stress rise in both rock and backfill.

41 (CONF-940553–53) **Simulation of heat transfer around a canister placed horizontally in a drift.** Moujaes, S.; Bhargava, A. Nevada Univ., Las Vegas, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94012152. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is investigating the feasibility of locating a high level radioactive nuclear waste repository at Yucca Mountain, Nevada. The bore hole and the in-drift waste emplacement schemes are under evaluation as potential repository drift geometries. This paper presents a two-dimensional finite element thermal analysis of the nuclear waste canister placed horizontally in a drift. Simulation has been carried out for 1000 years and the peak temperatures at the walls of the drift and at the center of the canister have been determined. The effect of the three modes of heat transfer, conduction, natural convection and radiation, is also discussed.

42 (CONF-940553–57) **Experimental heat transfer and fluid flow over drift-emplaced canisters.** Culbreth, W.G.; Pattisam, S. Nevada Univ., Las Vegas, NV (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94012156. Source: OSTI; NTIS; INIS; GPO Dep.

Drift-emplaced waste canisters are under consideration for the long-term storage of high-level spent fuel in the proposed underground repository at Yucca Mountain. These canisters will be placed on pedestals above the floor of the drifts and exchange heat with the walls of the drift and with air circulating through the repository. To assess the requirements of the repository ventilation system, values of the dimensionless convective heat transfer coefficient and the pressure drop across individual canisters were measured in a experimental model of a drift. The results were curvefitted as functions of the spacing between the canisters and the Reynolds number of the flow. Both natural and forced convection effects were investigated.

43 (DOE/ER/14352–1, pp. 439-442) **Yucca Mountain Site Characterization Project issues in rock mechanics.** Voegele, M.D. (Science Applications International Corp., Las Vegas, NV (United States)). Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The U.S. High Level Waste Disposal Program is investigating a site at Yucca Mountain, Nevada to determine whether or not it is suitable location for the development of a deep mined geologic repository. At this time the U.S. Program is investigating a single site, although the past configuration of the program involved successive screening and comparison of alternative locations. The repository design concept is a mined excavation at a depth of approximately 300 m below the crest of Yucca Mountain and at a distance of approximately 300 m above the regional groundwater table. The site is in volcanic rocks, comprising alternating layers of welded and non-welded volcanic tuffs. The non-welded tuffs underlying the proposed repository horizon are extensively zeolitized. The strategy for disposal safety relies on both engineered and natural barriers to form a defense in depth. The strategy builds upon the aridity of the site, the unsaturated character of the host rock, and the deep regional water table. Rock mechanics issues for the Yucca Mountain Site Characterization Project (YMP) derive from regulatory requirements codified at 10 CFR Part 60, the Nuclear Regulatory Commission's (NRC) licensing criteria for a high-level waste repository. The criteria address safety issues that are embodied in 10 CFR Part 60 as performance objective. These safety issues comprise concerns of repository safety for the time frame prior to permanent closure and for the time frame after permanent closure. For the time frame prior to closure, performance objective deal with issues related to retrieval and worker and public radiological health and safety. For the post closure time frame, the safety issues address concerns related to waste package lifetime, waste package release rate, prewaste emplacement groundwater travel time and compliance with the disposal regulations promulgated by the Environmental Protection Agency (EPA) which are found at 40 CFR 191.

44 (DOE/NV/10872–T124) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site characterization study: Progress report, April 1, 1994–June 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019223. Source: OSTI; NTIS; GPO Dep.

The work performed during this quarter consists of the continuation of the batch studies of the fluorinated benzoic acids and the evaluation of LC/MS for analysis of the fluorinated benzoic acids.

45 (DOE/NV/10872–T132) **Yucca Mountain Site Characterization Project Harry Reid Center Quality Assurance Support: Quarterly report, April 1, 1994–June 30, 1994.** Cross-Smiecinski, A. Nevada Univ., Las Vegas, NV (United States). [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019231. Source: OSTI; NTIS; GPO Dep.

For the cooperative agreement quarters 4/1/94 through 6/30/94, HRC QA staff performed the following: Certification samples were analyzed for inorganics/volatiles, inorganics and inorganics, respectively. The data reports were submitted by HRC to the scoring agencies. Data verification was performed for Fingerprinting and Ground Water Quality Monitoring data. The procedures for data verification and validation are not complete. Field sampling was performed on six well samples and a few more wells were considered as possible sampling sites. Baseline sampling is now complete for the inorganics determinations for all YM-remote accessible sites that were finalized in January 1994.

46 (DOE/NV/10872–T134) **Identification of subsurface microorganisms at Yucca Mountain: 4th Quarterly report, April 1, 1994–June 30, 1994.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019233. Source: OSTI; NTIS; GPO Dep.

This progress report details the identification of bacteria in ground water samples from 29 springs at Ash Meadows and Death Valley at Yucca Mountain.

47 (DOE/NV/10872–T136) **Analytical laboratory and mobile sampling platform: Progress report, April 1, 1994–June 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). [1994]. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94019235. Source: OSTI; NTIS; GPO Dep.

For the cooperative agreement quarters 4/1/94 through 6/30/94, HRC QA staff performed the following: Experimentation on the microwave rock digestion continued during this quarter, however no results from the round robin analyses have been received. Data verification was performed for Fingerprinting and Ground Water Quality Monitoring data. The procedures for data verification and validation are not complete. Field sampling was performed on six well samples and a few more wells were considered as possible sampling sites. The HRC is waiting to hear from AMESH regarding pumping of the C-wells complex and the WT wells for an opportunity to collect ground water samples at near-field sites. Analyses of samples collected in May and June will proceed during July. In addition internal analytical and esternal background data are being compiled.

48 (DOE/NV/10872–T140) **Identification of subsurface microorganisms at Yucca Mountain. Quarterly report, July 1, 1994–September 30, 1994.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95003614. Source: OSTI; NTIS; INIS; GPO Dep.

Bacteria isolated from ground water samples taken from springs at Yucca Mountain during 1993 were collected and processed. Three bacterial genera commonly found in water (Pseudomonas, Hydrogenophaga, and Alteromonas) were selected for extensive review during this quarter. The presence of bacteria representative of these genera in samples from the 18 springs sampled in Ash Meadows and from 14 springs in Death Valley was reviewed. The species level of identification of the three bacterial genera in water samples from the springs were examined by cluster analysis to see how much variation existed within a given species and also to determine if a species with essentially the same FAME pattern was isolated from several springs.

49 (DOE/NV/10872–T141) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain Site Characterization Study. Progress report, July 1, 1994–September 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 20p. Sponsored by USDOE,

Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95003613. Source: OSTI; NTIS; INIS; GPO Dep.

The work performed during this quarter consists of the continuation of the batch studies for the fluorinated benzoic acids and the evaluation of LC/MS for the analysis of these potential tracers. Column studies for these compounds have also been initiated.

50 (DOE/NV/10872–T143) **Analytical laboratory and mobile sampling platform. Progress report, July 1, 1994–September 30, 1994.** Stetzenbach, K. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE95003611. Source: OSTI; NTIS; INIS; GPO Dep.

This report summarizes progress made during the quarter on site characterization studies for the Yucca Mountain Project. Work is continuing on developing a procedure for dissolution of rock, primarily tuff, so that the samples we received from the USGS can be analyzed. The goal of this effort is to provide chemical data that the USGS and the HRC can use to compare the concentration of about 40 elements in ground water and the host rock through which it moves. This work is being coordinated with a similar effort at the NTS to determine if the ground water chemistry can be used to evaluate leakage or mixing between the tuff and carbonate aquifers.

51 (DOE/NV/11417–4) **Great Basin paleoenvironmental studies project: Technical progress report: Fourth quarter, March–May, 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94014166. Source: OSTI; NTIS; GPO Dep.

Examination of the paleoenvironmental and geomorphic records to determine the local and regional impact of past climates will advance the assessment of Yucca Mountain's suitability as a high-level nuclear waste repository. Paleobotanical studies will reconstruct the response of vegetation to climate change at the community and the organismal levels in order to identify periods of mesic climate at Yucca Mountain and the adjacent region during the last 20,000 to 50,000 years. Constructing a history of Great Basin vertebrates, particularly mammals, will provide empirical evidence of past environmental and climatic conditions within the Great Basin. The objective of the geomorphology component of the program is to document the responses of surficial processes and landforms to the climatic changes documented by studies of packrat middens, pollens, and faunal distributions. The goal of the transportation component is to compare the results from three models (FESWMS-2DH, DAMBRK, and FLO-2D) that have been suggested as appropriate for evaluating flood flows on alluvial fans with the results obtained from the traditional one-dimensional, stochastic model used in previous research for the Yucca Mountain Project. Progress on all these tasks is described.

52 (DOE/NV/11417–5) **Great basin paleoenvironmental studies project: Technical progress report first quarter (year 2), June–August 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE95001321. Source: OSTI; NTIS; GPO Dep.

The paleobiotic and geomorphic records are being examined for the local and regional impact of past climates to assess Yucca Mountain's suitability as a high-level nuclear waste repository. The project includes botanical, faunal, and geomorphic components that will be integrated to accomplish this goal Progress reports are presented for: Paleobotenical studies in the Great Basin; Paleofaunas studies in the Great Basin; Geomorphology studies in the Great Basin; and Transportation. The goal of the transportation project is to compare the results from three models (FESWMS-2DH, DAMBRK, and FLO-2D) that have been suggested as appropriate for evaluating flood flows on alluvial fans with the results obtained from the traditional one-dimensional, stochastic model used in previous research performed by DRI for the Yucca Mountain Project.

53 (DOE/RW–0450) **Site characterization progress report: Yucca Mountain, Nevada, October 1, 1993–March 31, 1994.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Oct 1994. 323p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI (Free of Charge); INIS.

This report is the tenth in a series issued at intervals of approximately six months during site characterization of Yucca Mountain as a possible site for a geologic repository for the permanent disposal of spent nuclear fuel and high-level radioactive waste. Also included in this report are descriptions of activities such as public outreach and international programs that are not formally part of the site characterization process. Information on these activities is provided to report on all aspects of the Yucca Mountain studies. The Executive Summary is intended to provide a summary of major decisions, activities, accomplishments, and issues of interest during the reporting period. Chapter 1, Introduction, provides background information to assist the reader in understanding the current status of the program. Chapter 2 provides specific detailed discussions of activities conducted during the current reporting period and has two major divisions. Section 2.1, Preparatory Activities, provides information on select preparatory activities necessary to conduct site characterization and design activities. Sections 2.2 through 2.8 provide specific details on studies and activities conducted during the reporting period and follow the original structure of the Department's 1988 Site Characterization Plan. Chapter 3 contains the current summary schedule, while Chapter 4 provides a description of the program outreach, including activities during the reporting period, in both the international program and public outreach. Chapter 5 presents an epilogue of significant events that occurred after the end of the reporting period.

54 (DOE/YMPO–001) **Final recommendations of the Peer Review Panel on the use of seismic methods for characterizing Yucca Mountain and vicinity.** USDOE Nevada Operations Office, Las Vegas, NV (United States). Yucca Mountain Project Office. 22 Jan 1991. 33p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94014099. Source: OSTI; NTIS; INIS; GPO Dep.

The Peer Review Panel was charged with deciding whether seismic methods, which had been utilized at Yucca Mountain with mixed results in the past, could provide useful information about the Tertiary structure in the Yucca Mountain area. The objectives of using seismic methods at Yucca Mountain are to: (a) obtain information about the structural character of the Paleozoic-Tertiary (Pz-T) contact, and (b) obtain information about the structural and volcanic details

within the Tertiary and Quaternary section. The Panel recommends that a four part program be undertaken to test the utility of seismic reflection data for characterizing the structural setting of the Yucca Mountain area. The Panel feels strongly that all four parts of the program must be completed in order to provide the highest probability of success. The four parts of the program are: (a) drill or extend a deep hole in Crater Flat to provide depth control and allow for the identification of seismic reflectors in an area where good quality seismic reflection data are expected; (b) undertake a full seismic noise test in Crater Flat, test 2D receiver arrays as well as linear arrays; perform an expanding spread test using both P and S wave sources to obtain a quick look at the reflection quality in the area and see if shear wave reflections might provide structural information in areas of unsaturated rock; (c) acquire a P wave seismic reflection profile across Crater Flat through the deep control well, across Yucca Mountain, and continuing into Jackass Flats; and (d) acquire a standard VSP (vertical seismic profiling) in the deep control well to tie the seismic data into depth and to identify reflectors correctly.

55 (EGG–11265-1058) **The terrestrial ecosystem program for the Yucca Mountain Project.** Ostler, W.K.; O'Farrell, T.P. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-940225–112: Waste management '94, Tucson, AZ (United States), 27 Feb - 3 mar 1994). Order Number DE94012670. Source: OSTI; NTIS; INIS; GPO Dep.

DOE has implemented a program to monitor and mitigate impacts associated with site Characterization Activities at Yucca Mountain on the environment. This program has a sound experimental and statistical base. Monitoring data has been collected for parts of the program since 1989. There have been numerous changes in the Terrestrial Ecosystems Program since 1989 that reflect changes in the design and locations of Site Characterization Activities. There have also been changes made in the mitigation techniques implemented to protect important environmental resources based on results from the research efforts at Yucca Mountain. These changes have strengthened DOE efforts to ensure protection of the environmental during Site Characterization. DOE,has developed and implemented an integrated environmental program that protects the biotic environment and will restore environmental quality at Yucca Mountain.

56 (EGG–11265-1066) **Land reclamation on the Nevada Test Site: A field tour.** Winkel, V.K.; Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–5: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94012666. Source: OSTI; NTIS; INIS; GPO Dep.

An all-day tour to observe and land reclamation on the Nevada Test Site was conducted in conjunction with the 8th Wildland Shrub and Arid Land Restoration Symposium. Tour participants were introduced to the US Department of Energy reclamation programs for Yucca Mountain Site Characterization Project and Treatability Studies for Soil Media (TSSM) Project. The tour consisted of several stops that covered a variety of topics and studies including revegetation by seeding, topsoil stockpile stabilization, erosion control, shrub transplanting, shrub herbivory, irrigation, mulching, water harvesting, and weather monitoring.

57 (EGG–11265-1073) **Yucca Mountain Biological Resources Monitoring Program: Progress report, October 1992–December 1993.** EG and G Energy Measurements, Inc., Las Vegas, NV (United States). May 1994. 70p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. Order Number DE94016797. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy (DOE) is required by the Nuclear Waste Policy Act of (as amended in 1987) to study and characterize the suitability of Yucca Mountain as a potential geologic repository for high-level nuclear waste. During site characterization, the DOE will conduct a variety of geotechnical, geochemical, geological, and hydrological studies to determine the suitability of Yucca Mountain as a potential repository. To ensure that site characterization activities do not adversely affect the environment at Yucca Mountain, a program has been implemented to monitor and mitigate potential impacts and ensure activities comply with applicable environmental regulations. This report describes the activities and accomplishments of EG&G Energy Measurements, Inc. (EG&G/EM) from October 1992 through December 1993 for six program areas within the Terrestrial Ecosystem component of the environmental program for the Yucca Mountain Site Characterization Project (YMP): Site Characterization Effects, Desert Tortoises (Gopherus agassizii), Habitat Reclamation, Monitoring and Mitigation, Radiological Monitoring, and Biological Support.

58 (EGG–11265-2036) **Species and community response to above normal precipitation following prolonged drought in the northern Mojave Desert.** Schultz, B.W. (Nevada Univ., Reno, NV (United States). Desert Research Inst.); Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 21p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–7: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94013571. Source: OSTI; NTIS; GPO Dep.

Little information is available on how desert plant communities that are dominated by perennial species respond to normal and above normal precipitation following prolonged drought. Intuitively, one would expect total canopy cover to increase. Whether a concomitant increase in the density of perennial species also occurs is unknown. Even less is known about how individual species respond to above normal precipitation following drought. From 1987 through 1991 a prolonged drought occurred in much of the western United States, including the northern Mojave Desert. In March 1991 the northern Mojave Desert received well above normal precipitation. The following two winters (December–March) also had above normal precipitation (150 to 200 % of normal, unpublished data). Ongoing vegetation characterization studies by the US Department of Energy (DOE) at Yucca Mountain, Nevada, allowed EG&G Energy Measurements to collect data that could be used to infer how both vegetation associations and individual species respond to above normal precipitation following prolonged drought. This paper reports the preliminary results.

59 **Pyritic ash-flow tuff, Yucca Mountain, Nevada.** Castor, S.B. (Univ. of Nevada, Reno NV (United States). Nevada Bureau of Mines and Geology); Tingley, J.V.; Bonham, H.F. Jr. *Economic Geology (and the Bulletin of the*

Society of Economic Geologists) (United States); 89(2): 401-407 (Mar-Apr 1994).

The Yucca Mountain site is underlain by a 1,500-m-thick Miocene volcanic sequence that comprises part of the southwestern Nevada volcanic field. Rocks of this sequence, which consists mainly of ash-flow tuff sheets with minor flows and bedded tuff, host precious metal mineralization in several areas as near as 10 km from the site. In two such areas, the Bullfrog and Bare Mountain mining districts, production and reserves total over 60 t gold and 150 t silver. Evidence of similar precious metal mineralization at the Yucca Mountain site may lead to mining or exploratory drilling in the future, compromising the security of the repository. The authors believe that most of the pyrite encountered by drilling at Yucca Mountain was introduced as pyroclastic ejecta, rather than by in situ hydrothermal activity. Pyritic ejecta in ash-flow tuff are not reported in the literature, but there is no reason to believe that the Yucca Mountain occurrence is unique. The pyritic ejecta are considered by us to be part of a preexisting hydrothermal system that was partially or wholly destroyed during eruption of the tuff units. Because it was introduced as ejecta in tuff units that occur at depths of about 1,000 m, such pyrite does not constitute evidence of shallow mineralization at the proposed repository site; however, the pyrite may be evidence for mineralization deep beneath Yucca Mountain or as much as tens of kilometers from it.

60 **Site characterization at the potential high-level radioactive waste repository site at Yucca Mountain, Nevada.** Gertz, C.P. (DOE, Las Vegas, NV (United States)); Cloke, P.L. *Transactions of the American Nuclear Society (United States);* 69: 58 (1993). (CONF-931160–: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

This paper provides a brief summary of recent site characterization activities at Yucca Mountain, Nevada, located in southern Nevada ~100 miles northwest of Las Vegas. Current and future investigations will supply scientific and technical data for evaluating whether the site is suitable for the disposal of high-level nuclear waste. On July 9, 1991, surface-based testing recommenced following several years devoted to U.S. Nuclear Regulatory Commission (NRC) reviews, development, and implementation of an NRC-accepted quality assurance program and the obtaining of required permits. During the past 16 months, numerous trenches and test pits have been excavated or deepened, and many drill holes have been completed.

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61 **The annotated outlined process for a mined geologic disposal system license application.** Williamson, T.M. (Duke Engineering & Services, Inc., Las Vegas, NV (United States)); VanCamp Gil, A. pp. 1240-1242 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy (DOE) is studying Yucca Mountain, Nevada, as a potential site for a mined geologic repository for high-level nuclear waste. DOE has the responsibility to license the potential repository; if the site is found suitable, a license application would be submitted to the U.S. Nuclear Regulatory Commission (NRC). Current plans are to submit the license application in 2001. To manage development of the license application, DOE has developed the Mined Geologic Disposal System Annotated Outline for License Application (AO). The AO provides a method to verify the site characterization program and to implement the guidance given by the NRC in their draft regulatory guide on the license application. In addition, the AO facilities focused interactions with the NRC and will contribute to the clarification of the regulations. The development of the AO is an interactive process; revisions are produced semiannually, and transmitted to the NRC to provide information and to facilitate NRC's staff guidance to DOE. The AO is an effective method to manage the complex and challenging regulatory and technical information requirements for development of the license application.

62 **Thinking through the 'rethinking report'.** Taylor, E.C. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)). pp. 1259-1262 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Congressional action in late 1992 set aside the existing standards for post-closure safety of a possible repository at Yucca Mountain, Nevada. The Environmental Protection Agency (EPA) must develop new standards based on yet-to-be-completed studies by the National Academy of Sciences. It is not clear when there will be a new standard, and we cannot know what the National Academy studies will reveal. However, we can assess the possible impact by extrapolating a 1990 National Academy position statement that was based on their review of the regulatory features of the high-level radioactive waste disposal program. The analysis here proceeds from basic principles recommended in the position statement, and it develops the implied approach to demonstrating safety. The approach has the desired characteristics proposed in the position statement, but is also depends on and continues what the Department of Energy is already doing at the Yucca Mountain candidate repository site. Its new features are in its approach to organizing the post-closure safety demonstration, and these features are consistent with current planning principles at the Yucca Mountain Site Characterization Project Office. We conclude that if in fact the site is safe, and if the new regulations are consistent with the 1990 National Academy position statement, then these principles can lead to reasonable assurance of safety.

63 **Assessments of system impacts of spent fuel thermal characteristics and emplacement rates.** Rickertsen, L.D. (TRW Environmental Safety Systems Inc., Vienna, VA (United States)). pp. 1372-1376 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Analysis conducted to evaluate the impacts spent fuel thermal characteristics and emplacement rates might have on the thermal conditions in a candidate geologic repository at the Yucca Mountain site are reported here. These analyses considered the effect of the current projections for the burnup of the spent fuel, the variability in waste thermal characteristics, and the sequence *and location of* waste emplacement on the repository temperatures relative to those

predicted for the Yucca Mountain Site Characterization Plan (SCP). The results show that, for the same conceptual design, the temperatures in the repository would be significantly higher than those considered for the SCP. These results could affect the evaluations of alternative thermal loading strategies for the candidate repository.

64 **Integrated test evaluation decision framework for the Yucca Moutain Project.** Judd, B.R. (Decision Analysis Co., Portola Valley, CA (United States)); Hoxie, D.T.; Mattson, S.R.; Younker, J.L. pp. 1623-1632 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

An Integrated Test Evaluation decision framework and computer model were developed to help prioritize site-characterization tests at Yucca Mountain. An initial application of the framework evaluated studies described in the Department of Energy's Site Characterization Plan. Priorities were based on the ability of tests to detect unsuitable site conditions, to demonstrate compliance with regulatory requirements, and to build confidence and support within the scientific community. Testing costs were also considered. Results showed priorities to depend most on estimates of the abilities of tests to build scientific confidence and least on estimates of the ability to detect unsuitable site conditions.

65 **Yucca Mountain Site Characterization Project performance based 'Q' list.** Hulbert, D.I. (TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States)); Blanchard, M.B.; Barton, R.V.; Voegele, M.D. pp. 1653-1656 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In mid-1992, the Yucca Mountain Site Characterization Project (YMP) initiated a performance based 'Q' List development effort. This effort is intended to evolve a 'Q' List based upon the quantitative technical characteristics of the engineered and natural features of the prospective Mined Geologic Disposal System (MGDS). The resulting 'Q' List determinations will replace the existing list which was formulated on a very conservative basis because of the conceptual nature of the initial MGDS designs. The evolved, performance based 'Q' List will enable the selection of the optimum set of controls to be employed during execution of activities associated with natural and engineered items comprising the MGDS.

66 **Detachment faults-regulatory implications for the Yucca Mountain site.** Cline, K.M. (Woodward-Clyde Federal Services, Washington, DC (United States)); Fenste, D.F.; Rogers, R.; Summerson, J.R. pp. 1826-1834 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Site characterization investigations at the Yucca Mountain site, Nye County, Nevada consist of a combination of scientific data collection and analysis, and compliance with regulatory requirements. These investigations include studies to evaluate the presence or absence of detachment faults and their significance to assessing site suitability and complying with NRC regulatory requirements. This paper discusses selected structural/tectonic models proposed for Yucca Mountain and the surrounding region that include detachment faults. The presence of detachment faults and their significance are some of the more controversial aspects of the tectonic models and of the geologic setting of Yucca Mountain. The implications of these models with respect to regulatory compliance is addressed. Based on a preliminary evaluation, and depending on the tectonic model(s) adopted, the presence of detachment faults must be considered as potential pathways for long-term performance evaluations, and as a mechanism for marking buried strike-slip faults and distributed faulting at the surface. The detachment faults recognized in the field thus far have no suggestion of being seismogenic sources.

67 **Yucca Mountain Site Characterization Project exploratory studies facilities construction status.** Allan, J.N. (Morrison Knudsen Corp., Las Vegas, NV (United States)); Leonard, T.M. pp. 2115-2117 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper discusses the progress to date on the construction planning and development of the Yucca Mountain Site Characterization Project (YMP) Exploratory Studies Facilities (ESF). The purpose of the ESF is to determine early site suitability and to characterize the subsurface of the Yucca Mountain site to assess its suitability for a potential high level nuclear waste repository. The present ESF configuration concept is for two main ramps to be excavated by tunnel boring machines (TBM) from the surface to the Topopah Spring Member of the Paintbrush Tuff Formation. From the main ramps, slightly above Topopah Spring level, supplemental ramps will be penetrated to the Calico Hills formation below the potential repository. There will be exploratory development drifts driven on both levels with the Main Test Area being located on the Topopah Spring level, which is the level of the proposed repository. The Calico Hills formation lies below the Topopah Spring member and is expected to provide the main geo-hydrologic barrier between the potential repository and the underlying saturated zones in the Crater Flat Tuff.

68 (DOE/RW/00134–T10) **Calculations supporting evaluation of potential environmental standards for Yucca Mountain.** Duguid, J.O. (INTERA, Inc., Las Vegas, NV (United States)); Andrews, R.W.; Brandstetter, E.; Dale, T.F.; Reeves, M. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States); INTERA, Inc., Las Vegas, NV (United States). Apr 1994. 210p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94015897. Source: OSTI; NTIS; INIS; GPO Dep.

The Energy Policy Act of 1992, Section 801 (US Congress, 1992) provides for the US Environmental Protection Agency (EPA) to contract the National Academy of Sciences (NAS) to conduct a study and provide findings and recommendations on reasonable standards for the disposal of high-level wastes at the Yucca Mountain site. The NAS study is to provide findings and recommendations which include, among other things, whether a health-based standard based on dose to individual members of the public from releases to the accessible environment will provide a reasonable standard for the protection of the health and safety

of the public. The EPA, based upon and consistent with the findings and recommendations of the NAS, is required to promulgate standards for protection of the public from releases from radioactive materials stored or disposed of in a repository at the Yucca Mountain site. This document presents a number of different "simple" analyses of undisturbed repository performance that are intended to provide input to those responsible for setting appropriate environmental standards for a potential repository at the Yucca Mountain site in Nevada. Each of the processes included in the analyses has been simplified to capture the primary significance of that process in containing or isolating the waste from the biosphere. In these simplified analyses, the complex waste package interactions were approximated by a simple waste package "failure" distribution which is defined by the initiation and rate of waste package "failures". Similarly, releases from the waste package and the engineered barrier system are controlled by the very near field environment and the presence and rate of advective and diffusive release processes. Release was approximated by either a simple alteration-controlled release for the high solubility radionuclides and either a diffusive or advective-controlled release for the solubility-limited radionuclides.

69 (DOE/RW/00134–T11) **Review and selection of unsaturated flow models.** Reeves, M. (INTERA, Inc., Las Vegas, NV (United States)); Baker, N.A.; Duguid, J.O. TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States); INTERA, Inc., Las Vegas, NV (United States). 4 Apr 1994. 321p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94015954. Source: OSTI; NTIS; INIS; GPO Dep.

Since the 1960's, ground-water flow models have been used for analysis of water resources problems. In the 1970's, emphasis began to shift to analysis of waste management problems. This shift in emphasis was largely brought about by site selection activities for geologic repositories for disposal of high-level radioactive wastes. Model development during the 1970's and well into the 1980's focused primarily on saturated ground-water flow because geologic repositories in salt, basalt, granite, shale, and tuff were envisioned to be below the water table. Selection of the unsaturated zone at Yucca Mountain, Nevada, for potential disposal of waste began to shift model development toward unsaturated flow models. Under the US Department of Energy (DOE), the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) has the responsibility to review, evaluate, and document existing computer models; to conduct performance assessments; and to develop performance assessment models, where necessary. This document describes the CRWMS M&O approach to model review and evaluation (Chapter 2), and the requirements for unsaturated flow models which are the bases for selection from among the current models (Chapter 3). Chapter 4 identifies existing models, and their characteristics. Through a detailed examination of characteristics, Chapter 5 presents the selection of models for testing. Chapter 6 discusses the testing and verification of selected models. Chapters 7 and 8 give conclusions and make recommendations, respectively. Chapter 9 records the major references for each of the models reviewed. Appendix A, a collection of technical reviews for each model, contains a more complete list of references. Finally, Appendix B characterizes the problems used for model testing.

70 (DOE/RW/00134–T12) **Total System Performance Assessment, 1993: An evaluation of the potential Yucca Mountain repository.** Andrews, R.W.; Dale, T.F.; McNeish, J.A. INTERA, Inc., Las Vegas, NV (United States). Mar 1994. 410p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94015955. Source: OSTI; NTIS; INIS; GPO Dep.

Total System Performance Assessments are an important component in the evaluation of the suitability of Yucca Mountain, Nevada as a potential site for a mined geologic repository for the permanent disposal of high-level radioactive wastes in the United States. The Total System Performance Assessments are conducted iteratively during site characterization to identify issues which should be addressed by the characterization and design activities as well as providing input to regulatory/licensing and programmatic decisions. During fiscal years 1991 and 1992, the first iteration of Total System Performance Assessment (hereafter referred to as TSPA 1991) was completed by Sandia National Laboratories and Pacific Northwest Laboratory. Beginning in fiscal year 1993, the Civilian Radioactive Waste Management System Management and Operating Contractor was assigned the responsibility to plan, coordinate, and contribute to the second iteration of Total System Performance Assessment (hereafter referred to as TSPA 1993). This document presents the objectives, approach, assumptions, input, results, conclusions, and recommendations associated with the Management and Operating Contractor contribution to TSPA 1993. The new information incorporated in TSPA 1993 includes (1) revised estimates of radionuclide solubilities (and their thermal and geochemical dependency), (2) thermal and geochemical dependency of spent fuel waste alteration and glass dissolution rates, (3) new distribution coefficient (k_d) estimates, (4) revised estimates of gas-phase velocities and travel times, and (5) revised hydrologic modeling of the saturated zone which provides updated estimates of the advective flux through the saturated zone.

71 (DOE/RW/00134–T14) **Yucca Mountain Site Characterization Project: Technical Data Catalog (quarterly supplement), June 30, 1994.** TRW, Inc., Fairfax, VA (United States). 30 Jun 1994. 111p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE95002190. Source: OSTI; NTIS; INIS; GPO Dep.

The DOE/NRC Site-Specific Procedural Agreement for Geologic Repository Site Investigation and Characterization Program requires the DOE to develop and maintain a catalog of data which will be updated and provided to the NRC at least quarterly. This catalog is to include a description of the data; the date, place, and method of acquisition; and where it may be examined. The Yucca Mountain Site Characterization Project (YMP) Technical Data Catalog is published and distributed in accordance with the requirements of the Site-Specific Agreement. The YMP Technical Data Catalog is a report based on reference information contained in the YMP Automated Technical Data Tracking System (ATDT). The reference information is provided by Participants for data acquired or developed in support of the YMP. The Technical Data Catalog is updated quarterly and published in the month following the end of each quarter. A complete revision to the catalog is published at the end of each fiscal year. Supplements to the end-of-year edition are published each quarter. These supplements provide information related to new data items not included in previous quarterly updates and data items affected by changes to previously published reference information. The Technical Data Catalog, dated September 30, 1993, should be retained as the

baseline document for the supplements until the end-of-year revision is published and distributed in October 1994.

72 Potential releases of gaseous ^{14}C from Yucca Mountain: A limited role for buoyancy as compared to other flow inducing phenomena. Sullivan, T.M. (Brookhaven National Lab., Upton, NY (United States)); Pescatore, C. *Waste Management (United States);* 14(5): 435-444 (1994).

The issue of gas flow and contaminant transport out of the potential high-level waste (HLW) and spent nuclear fuel repository site at Yucca Mountain, NV, has recently received much attention. An important concern exists over whether or not heating of the rock mass by the waste may generate convective currents resulting from buoyancy. This could significantly reduce (relative to the half-life of the element) the travel time of gaseous contaminants, such as $^{14}CO_2$ (g), to the surface of the mountain. The studies that rely on a full-fledged analysis of the system of coupled equations representing nonisothermal flow in porous media discount the effect of buoyancy; the more simplified analyses do not. To reconcile the contradictory results, the authors have performed a review of the general literature, including studies not directly concerned with flow at Yucca Mountain. The authors conclude that there is convincing theoretical and experimental indications to exclude net mass flows of air to the surface of the mountain resulting only from buoyancy. Therefore, the buoyancy effect, alone, would not cause ^{14}C releases. On the other hand, the authors identify barometric pumping and topographically assisted flow as the most relevant mechanisms for the release of this radionuclide. Coupling between these effects and buoyancy may enhance these surface-driven processes.

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73 Mineralogic alteration history and paleohydrology at Yucca Mountain, Nevada. Levy, S.S. (Los Alamos National Lab., NM (United States)). pp. 477-485 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The importance of paleohydrology to the Yucca Mountain Site Characterization Project derives from the role water will play in radioactive waste repository performance. Changes in hydrologic conditions during the lifetime of the repository may be estimated by investigating past hydrologic variations, including changes in the static water-level position. Based on the distribution of vitric and zeolitized tuffs and the structural history of the site, the highest water levels were reached and receded downward 11.6 to 12.8 myr ago. Since that time, the water level at central Yucca Mountain has probably not risen more than about 60 m above its present position. The history of the high potentiometric gradient running through northern Yucca Mountain may be partly elucidated by the study of tridymite distribution in rocks that have experienced saturated conditions for varying periods of time.

74 Fracture-lining minerals in the lower Topopah Spring Tuff at Yucca Mountain. Carlos, B.A. (Los Alamos National Lab., NM (United States)); Bish, D.L.; Chipera, S.J. pp. 486-493 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Fracture-lining minerals in the lower Topopah Spring Member of the Paintbrush Tuff at Yucca Mountain, Nevada, are being examined to characterize potential flow paths within and away from the candidate repository horizon. Fracture coatings within this interval can be divided into five categories based on rock matrix and type of fracture. Fracture coatings in the densely welded tuff above the basal vitrophyre, near the candidate repository horizon, include (1) those related to lithophysal cavities; (2) mordenite and manganese oxides on nearly planar fractures; (3) later fracture coatings consisting of zeolites, smectite, and calcite. Fracture-coating minerals in the vitrophyre are fine-grained and consist of smectite and a variety of zeolites. The non- to partially-welded vitric and/or zeolitic tuff below the vitrophyre contains fractures mostly lined by cristobalite and clinoptilolite.

75 Radionuclide migration as a function of mineralogy. Triay, I.R. (Los Alamos National Lab., NM (United States)); Mitchell, A.J.; Ott, M.A. pp. 494-498 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The migration of radionuclides is studied as a function of mineralogy utilizing batch sorption and column experiments. The transport behavior of alkaline, alkaline-earth, and transition metals and actinide species is studied in pure mineral separates. The solid phases utilized for these investigations are silicates, alumino-silicates, carbonates, and metal oxides and oxyhydroxides. The results of this effort are utilized to aid in the elucidation of the dominant chemical mechanisms of radionuclide migration; the prediction of radionuclide transport in conditions similar to those expected at the candidate high-level nuclear waste repository site at Yucca Mountain, Nevada; and the identification of materials that act as natural geological barriers or that can be *utilized* as strong sorbers in engineered barriers.

76 Preliminary assessment of clinoptilolite K/Ar results from Yucca Mountain, Nevada, USA: A potential high-level radioactive waste repository site. Wolde-Gabriel, G. (Los Alamos National Lab., NM (United States)); Broxton, D.E.; Bish, D.L.; Chipera, S.J. pp. 457-461 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

At Yucca Mountain, evidence for at least three distinct temporal groups of clinoptilolites can be delineated from the preliminary K/Ar dates (2 - 3 Ma; 4 - 5 Ma; 7 - 11 Ma). The older K/Ar dates that are similar to published illite/smectite ages (9-12 Ma) may be crystallization ages, whereas the younger dates probably represent continued diagenetic reactions of older clinoptilolites with percolating fluids. The K/Ar dates increase with depth, suggesting minimal argon loss

in the deeper samples. internal consistency of the clinoptilolite K/Ar results at different levels within the drill holes suggest that dating of K-rich zeolites may provide useful information for assessing the zeolitization at Yucca Mountain. Variations in the K/Ar dates are probably related to Ar loss during dissolution of older clinoptilolites and to contamination by finely crystalline feldspars. 18 refs., 1 tab.

77 **Precipitation of calcite, dolomite, sepiolite and silica from evaporated carbonate and tuffaceous waters of southern Nevada, USA.** Vaniman, D.T. (Los Alamos National Lab., NM (United States)); Ebinger, M.H.; Bish, D.L.; Chipera, S.J. pp. 687-691 of Water-Rock Interaction: Proceedings. Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Calcite and sepiolite commonly form on evaporation of either carbonate-source or tuff-source waters in southern Nevada. However, dolomite and Mg-smectites precipitate only from carbonate-source waters and silica minerals appear to be more common and less ordered in deposits from tuff-source waters. Thus it may be possible to determine the nature of the source water, based on the deposits left behind after evaporation. Petrographic observations and modeling indicate that in both types of water either calcite or dolomite (or both) precipitate first, followed by sepiolite and ultimately silica phases. Waters from carbonate sources tend to retain dolomite throughout most of their evaporative evolution, whereas waters from silicic igneous sources either do not precipitate dolomite or dissolve their early dolomite precipitates after ~5-10x evaporative increase in the solute/water ratio. The relative proportion of dolomite among the precipitation would lead to formation of opal rather than sepiolite in all waters. However, the common occurrence of sepiolite in deposits from both types of water suggests that silica precipitation is suppressed. The results from modeling indicate that the high terminal silica content of evaporated tuff-source waters may lead to late precipitation of abundant but poorly ordered silica phases (opal-A/opal-CT), unlike the rarer but more ordered silica phases (opal-CT/quartz) precipitated from carbonate-source waters. 12 refs., 2 figs., 1 tab.

78 **Chemical changes associated with zeolitization of the tuffaceous beds of Calico Hills, Yucca Mountain, Nevada, USA.** Broxton, D.E. (Los Alamos National Lab., NM (United States)). pp. 699-703 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

The chemistry of the tuffaceous beds of Calico Hills was examined in samples collected over a 100 km^2 area south of the Timber Mountain-Oasis Valley caldera complex to determine regional geochemical patterns during zeolitization. Samples of 58 vitric and zeolitic tuffs were analyzed for 48 elements by a combination of X-ray fluorescence, atomic absorption spectrophotometry, and neutron activation analysis. Major and trace element concentrations for zeolitic tuffs vary significantly from those for vitric tuffs. Complex, geographically-controlled patterns of elemental enrichment and depletion in the zeolitic tuffs are found for Na, K, Ca, Mg, U, Rb, Sr, Ba and Cs. Vitric and zeolitic tuffs generally have the same SiO_2 contents on an anhydrous basis, but minor net silica gain or loss has occurred in some samples. Zeolitic tuffs from the northern part of the study area, adjacent to the caldera complex, are notably K-rich and Na- and U-poor compared to zeolitic tuffs to the south. The compositions of the K-rich zeolitic tuffs are similar to those found in other areas of the western US where volcanic rocks are affected by potassium metasomatism. Alteration of vitric tuffs took place in an open chemical system and geographic control of major element compositions probably reflects regional variations in ground water chemistry and temperature during alteration. The K-rich zeolitic tuffs in the northern part of the study area were probably altered by moderate-temperature hydrothermal fluids whereas tuffs further south were altered by lower-temperature regional ground waters. 9 refs., 3 figs.

79 **Water-rock interaction and the pH stability of groundwaters from Yucca Mountain, Nevada, USA.** Ebinger, M.H. (Los Alamos National Lab., NM (United States)). pp. 783-786 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Titrations of acidic solutions in waters from the tuff and carbonate aquifers at Yucca Mountain were simulated using the geochemical codes PHREEQE and EQ3/6. The simulations tested pH stability of the waters in the presence of different minerals and in their absence. Two acidic solution, 10^{-4}M HCl and 10^{-4}M $UO_2(NO_3)_2$, were titrated in to the water. Little pH and/or compositional changes resulted in the groundwater when the HCl solution was titrated, but significant pH and CO_2 fugacity changes were observed when $UO_2(NO_3)_2$ was titrated. Water interactions with alkali feldspar, quartz or cristobalite, and Ca-smectite buffered the pH and compositional changes in the carbonate water and decreased the magnitude of pH and compositional changes when small volumes of $UO_2(NO_3)_2$ added to the tuffaceous waters. 5 refs., 3 figs., 2 tabs.

80 **Neptunium retardation with tuffs and groundwaters from Yucca Mountain.** Triay, I.R. (Los Alamos National Laboratory, NM (United States)); Robinson, B.A.; Lopez, R.M.; Mitchell, A.J.; Overly, C.M. pp. 1504-1508 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The retardation of neptunium was studied using batch sorption and column techniques. Pure mineral separates, tuffs and groundwaters from Yucca Mountain were used for these experiments. Our results indicate that Np sorption increases rapidly as the pH of the water increases in cases where surface complexation is thought to be the dominant sorption mechanism. Oxide minerals (such as hematite) sorb Np strongly; therefore, these minerals even at trace levels in Yucca Mountain tuffs can result in significant Np retardation. Neptunium in groundwaters from Yucca Mountain exhibited a significant amount of sorption onto quartz. Neptunium sorption onto quartz is important because of the large quantity of silica in the tuffs. Elution of neptunium solutions in groundwater through columns made of crushed tuff yielded sorption coefficients that agree with the sorption results obtained using batch sorption techniques. Agreement between batch and column experiments indicates a neptunium sorption mechanism that is linear, reversible, and instantaneous.

81 **Dependence of radionuclide sorption on sample grinding surface area, and water composition.** Rogers, P.S.Z. (Los Alamos National Laboratory, NM

(United States)); Meijer, A. pp. 1509-1516 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

In its 1987 technical position paper, 'Determination of Radionuclide Sorption for High-Level Nuclear Waste Repositories', the Nuclear Regulatory Commission (NRC) review panel delineated several studies needed to show that experimental sorption coefficients could accurately model radionuclide sorption behavior along release pathways. In particular, they focused on the potential problems involved with the use of crushed rock samples, stating 'If crushed solids are used, it is essential to show that laboratory experiments involving sorption on crushed solids are relevant to the repository site. The surfaces of crushed material may be significantly different from the surfaces of intact material, both porous and fractured. Grinding may expose the surfaces of solid phases different from those which groundwater would contact in a repository and/or may change the reactivity of the same mineral surfaces with dissolved radionuclides. The surface of crushed mineral scan be enriched in certain elements by factors of two and three relative to the bulk composition...'. The experiments reported here were performed in direct response to the NRC technical position paper. They were designed to quantify the dependence of sorption properties and surface area on the crushed-particle size of the rock samples used in batch sorption experiments. To this end, nine different size fractions of tuff samples, ranging from 2 to 4 mm down to less than 38 μm, were prepared by grinding, sieving, and washing bulk samples. These were reacted with solutions containing three different radioactive sorbers, ^{137}Cs, ^{85}Sr, and ^{237}Np, the solid and solution fractions were separated, and both fractions were gamma counted to determine partitioning of the radioactive sorber. Surface areas of each sample were determined by BET analysis. From this information, the sorption coefficient (Rd) of each tracer on each particle-size fraction, and its correlation with surface area, was calculated.

82 Diffusion of sorbing and non-sorbing radionuclides. Triay, I.R. (Los Alamos National Laboratory, NM (United States)); Birdsell, K.H.; Mitchell, A.J.; Ott, M.A. pp. 1527-1532 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Diffusion is considered one of the most important retardation mechanisms in fractured media. The diffusion experiments conducted involved solid tuff and groundwater from Yucca Mountain. The uptake of radionuclides by the tuff was studied utilizing containers made of tuff in the the form of beakers. The solution containing the radionuclides of interest was placed in the tuff beaker cavity and the uptake of the radionuclides by the tuff was measured as a function of time. Our results indicate that the diffusion coefficient for nonsorbing radionuclides into saturated Yucca Mountain tuff is on the order of 10^{-6} cm^2/s. Large anions, such as pertechnetate are excluded from tuff pores and their diffusion coefficients are on the order of $10^{-7}cm^2/s$. Comparison of the predictions for the uptake of sorbing radionuclides by the tuff with the actual data obtained indicates that conservative transport calculations will result from predicting diffusion using the batch sorption coefficient for the sorbing radionuclide and the diffusion coefficient obtained for tritiated water.

83 Calcite deposits in fractures at Yucca Mountain, Nevada. Vaniman, D.T. (Los Alamos National Laboratory, NM (United States)). pp. 1935-1939 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Calcite is one of the latest-formed minerals within fractures at Yucca Mountain. Petrographic and chemical studies of these calcites have the potential, in conjunction with fluid-inclusion and isotopic studies, of determining the locations of transmissive regions in unsaturated tuffs. Preliminary chemical data for the fracture calcites from Yucca Mountain indicate a common composition for most unsaturated-zone calcites (low abundances of transition elements; chondrite-normalized lanthanide-element patterns with prominent negative Ce and Eu anomalies) that is distinct from most calcites in the saturated zone. Exceptions to this general characterization occur in drill core USW G-4; the reasons for these deviations are as yet unknown, but the rich variety of calcite compositions suggests that much information is to be gained from further studies.

84 Aperture characteristics, saturated fluid-flow and tracer-transports calculations for a natural fracture. Reimus, P.W. (Los Alamos National Laboratory, NM (United States)); Robinson, B.A.; Glass, R.J. pp. 2009-2016 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The overall objective of this study is to conduct tracer-transport experiments in natural fractures in support of the Yucca Mountain Site Characterization Program. We used surface-profile data taken with a noncontact laser profilometer to determine the aperture distribution within a natural fracture and found the surfaces and apertures to be isotropic. The aperture distribution could be described equally well by either a normal or a lognormal distribution, although we had to adjust the standard deviation to 'fit' the data. The aperture spatial correlation varied over different areas of the fracture, with some areas being much more correlated than others. The fracture surfaces did not have a single fractal dimension over all length scales, which implied that they were not-self-similar. We approximated the saturated flow field in the fracture by solving a finite-difference discretization of the fluid-flow continuity tracer breakthrough curves using a particle-tracking method. Comparing the breakthrough curves obtained using both coarse- and fine-resolution aperture data (0.4- and 0.05-mm spacing between points, respectively) over the same subset of the fracture domain suggests that the spacing between the aperture data points must be less than the correlation length to obtain accurate predictions of fluid flow and tracer transport. In the future, we will perform tracer experiments and numerical modeling studies to determine exactly how fine the aperture data resolution must be (relative to the correlation length) to obtain accurate predictions.

85 (DOE/ER/14352–1, pp. 447-450) **Planning and implementation of underground testing in the ESF.** Elkins, N.Z. (Los Alamos National Lab., Albuquerque, NM

(United States)). Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The Exploratory Studies Facility (ESF) is a critical component of the US Department of Energy (DOE) program to identify and characterize a suitable site for licensing and constructing the nation's first geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. As interpreted from the Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987, the mission of the ESF is to conduct subsurface exploration and testing in support of site suitability determination and license application, in a manner that protects the environment and waste isolation capabilities of the site. The Yucca Mountain Site Characterization Project Office (YMPO) is developing a strategic program for subsurface testing that is fully integrated with other scientific efforts and with the design and excavation/construction of the ESF. The major challenge for ESF testing is to sequentially implement a site characterization program that is responsive to Project priorities and objectives and simultaneously ensures that critical, irretrievable data are gathered with minimal impacts to schedule and cost of ESF construction and operation. The guiding strategy for ESF testing is initially focused on determining the site suitability of Yucca Mountain. Prioritized tests and observations underground will be required to complete an early evaluation of site suitability.

86 (LA–12563-MS) **Measured solubilities and speciations from oversaturation experiments of neptunium, plutonium, and americium in UE-25p No. 1 well water from the Yucca Mountain region: Milestone report 3329-WBS1.2.3.4.1.3.1.** Nitsche, H. (Lawrence Berkeley Lab., CA (United States)); Roberts, K.; Prussin, T.; Mueller, A.; Becraft, K.; Keeney, D.; Carpenter, S.A.; Gatti, R.C. Los Alamos National Lab., NM (United States). Apr 1994. 103p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94008790. Source: OSTI; NTIS; INIS; GPO Dep.

Solubility and speciation are important in understanding aqueous radionuclide transport through the geosphere. They define the source term for transport retardation processes such as sorption and colloid formation. Solubility and speciation data are useful in verifying the validity of geochemical codes that are a part of predictive transport models. Results are presented from solubility and speciation experiments of $^{237}NpO_2^+$, $^{239}Pu^{4+}$, and $^{241}Am^{3+}/Nd^{3+}$ in a modified UE-25p No. 1 groundwater (from the Yucca Mountain region, Nevada, which is being investigated as a potential high-level nuclear waste disposal site) at two different temperatures (25° and 60°C) and three pH values (6.0, 7.0, 8.5). The solubility-controlling steady-state solids were identified and the speciation and/or oxidation states present in the supernatant solutions were determined. The neptunium solubility decreased with increasing temperature and pH. Plutonium concentrations significantly decreased with increasing temperature at pH 6 and 7. The concentration at pH 8.5 hardly decreased at all with increasing temperature. At both temperatures the concentrations were highest at pH 8.5, lowest at pH 7, and in between at pH 6. For the americium/neodymium solutions, the solubility decreased significantly with increasing temperature and increased somewhat with increasing pH.

87 (LA–12720-MS) **Calcite deposits in drill cores USW G-2 and USW GU-3/G-3 at Yucca Mountain, Nevada: Preliminary report.** Vaniman, D.T. Los Alamos National Lab., NM (United States). Apr 1994. 28p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94008780. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain is being studied as a potential site for deep geologic disposal of high-level radioactive waste. Should a repository be developed at Yucca Mountain, the preferred location is within the upper unsaturated tuffaceous volcanic rocks. In this location, one factor of concern is the amount and rate of aqueous transport through the unsaturated rocks toward the underlying saturated intervals. Calcite, one of the most recently-formed minerals at Yucca Mountain, is of minor abundance in the unsaturated rocks but is widely distributed. Studies of calcite ages, isotopic systematics, chemistry and petrography could lead to a better understanding of transport processes at Yucca Mountain.

88 (LA–12820-MS) **Actinide(IV) and actinide(VI) carbonate speciation studies by PAS and NMR spectroscopies: Yucca Mountain Project: Milestone report 3031-WBS 1.2.3.4.1.3.1.** Clark, D.L.; Ekberg, S.A.; Morris, D.E.; Palmer, P.D.; Tait, C.D. Los Alamos National Lab., NM (United States). Sep 1994. 62p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94016957. Source: OSTI; NTIS; INIS; GPO Dep.

Pulsed-laser photoacoustic spectroscopy (PAS) and Fourier-transform nuclear magnetic resonance (NMR) spectroscopy were used to study speciation of actinide(IV) and actinide(VI) ions (Np, Pu, Am) in aqueous carbonate solutions vs pH, carbonate content, actinide content, temperature. PAS focused on Pu(IV) speciation. Stability fields on a pH (8.4 to 12.0) versus total carbonate content (0.003 to 1.0 M) plot for dilute Pu(IV) carbonate species ($[Pu]_{tot}$ = 1 mM) were mapped. Four plutonium species, with absorption peaks at 486, 492, 500, and 512 nm were found. Loss of a single carbonate ligand does not account for the difference in speciation for the 486 and 492 nm absorption peaks, nor can any of the observed species be identified as colloidal Pu(IV). NMR data have been obtained for UO_2^{2+}, PuO_2^{2+} and AmO_2^{2+}. This report focuses on results for PuO_2^{2+}. The ligand exchange reaction between free and coordinated carbonate on the $PuO_2(CO_3)_3^{4-}$ systems has been examined by variable temperature ^{13}C NMR spectroscopy. In each of the six different $PuO_2(CO_3)_3^{4-}$ samples, two NMR signals are present, one for the free carbonate ligand and one for the carbonate ligand coordinated to a paramagnetic plutonium metal center. The single ^{13}C resonance line for coordinated carbonate is consistent with expectations of a monomeric $PuO_2(CO_3)_3^{4-}$ species in solution. A modified Carr-Purcell-Meiboom-Gill NMR pulse sequence was used for determining ligand exchange parameters for paramagnetic actinide complexes. Eyring analysis at standard conditions provided activation parameters of $\Delta H \approx 38$ KJ/M and $\Delta S = -60$ J/K for the plutonyl triscarbonate system, suggesting an associative transition state for the plutonyl(VI) carbonate complex self-exchange reaction.

89 (LA-SUB–94-92) **Yucca Mountain Project Integrated Data System (IDS): Final report, October 1, 1989–December 31, 1990.** Los Alamos National Lab., NM (United States); Computer Applications Group, Inc., Carlton, OR (United States). 23 May 1991. 166p. Sponsored by

USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94017052. Source: OSTI; NTIS; INIS; GPO Dep.

This final report for LANL Subcontract 9-XS8-2604-1 includes copies of all formal letters, memorandums, and reports provided by CAG to support the IDS effort in the LANL Test Managers Office, Las Vegas, Nevada from October 1, 1989 through the end of the contract on December 31, 1990. The material is divided into two sections; the Functional Requirements Document (FRD) and other reports, letters, and memorandums. All documents are arranged in chronological order with most recent last. Numerous draft copies of the FRD were prepared and cover sheets for all drafts are included. The complete text of only the last version supplied (July 27, 1990) is included in this document.

90 (LA-SUB–94-109) **1992-93 Results of geomorphological and field studies Volcanic Studies Program, Yucca Mountain Project.** Wells, S.G. Los Alamos National Lab., NM (United States). Oct 1993. 51p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94017065. Source: OSTI; NTIS; INIS; GPO Dep.

Field mapping and stratigraphic studies were completed of the Black Tank volcanic center, which represents the southwestern most eruptive center in the Cima volcanic field of California. The results of this mapping are presented. Contacts between volcanic units and geomorphic features were field checked, incorporating data from eight field trenches as well as several exposures along Black Tank Wash. Within each of the eight trenches, logs were measured and stratigraphic sections were described. These data indicate that three, temporally separate volcanic eruptions occurred at the Black Tank center. The field evidence for significant time breaks between each stratigraphic unit is the presence of soil and pavement-bounded unconformities.

91 (LA-SUB–94-111) **[Characterization of historical infiltration in the unsaturated zone at the Nevada Test Site using chloride, bromide, and chlorine-36 as environmental tracers]: [Final subcontract report].** Los Alamos National Lab., NM (United States); Hydro Geo Chem., Inc., Tucson, AZ (United States). 17 May 1991. 111p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94016570. Source: OSTI; NTIS; INIS; GPO Dep.

This document is an end-of-contract report, prepared by Hydro Geo Chem for Los Alamos National Laboratory under contract number 9-XDD-6329F-1. The ultimate goal of this work is to characterize historical infiltration and unsaturated flow in the Yucca Mountain area of the Nevada Test Site. Work on this contract has focused on using chloride, bromide, stable chlorine isotopes, and chlorine-36 distributions to evaluate the depth of infiltration in the unsaturated zone. Effort in support of this work has included developing analytical procedures, exploring ways in which to separate the. meteoric component from the rock component, and meeting quality assurance requirements.

92 (LA-SUB–94-159) **Progress report on the kinetic measurements of the reactions of the silicates at the Yucca Mountain potential repository site: [Final] report, June 15, 1993–September 30, 1993.** Lasaga, A.C. (Yale Univ., New Haven, CT (United States). Dept. of Geology and Geophysics); Ganor, J. Los Alamos National Lab., NM (United States); Yale Univ., New Haven, CT (United States). Dept. of Geology and Geophysics. [1994]. 28p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE95001752. Source: OSTI; NTIS; INIS; GPO Dep.

Preliminary results are provided on: Synthesis and characterization of analcime and Na-clinoptilolite (Penn State), batch solubility experiments on analcime and clinoptilolite, thermodynamic modelling of solubility data, and kinetic flow-through experiments on analcime and clinoptilolite.

93 (LA-UR–94-640) **Inferences of paleoenvironment from petrographic, chemical and stable-isotope studies of calcretes and fracture calcites.** Vaniman, D.T. (Los Alamos National Lab., NM (United States)); Whelan, J.F. Los Alamos National Lab., NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940553–13: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94007559. Source: OSTI; NTIS; INIS; GPO Dep.

Past research has indicated a genetic connection between calcite formed in calcretes at the surface of Yucca Mountain, Nevada, and calcites deposited in underlying fractures of the unsaturated zone. This common genesis suggests that paleoenvironmental information, as well as the timing and pathways of past recharge episodes, might be obtained from studies of the deposits in both the calcretes and the unsaturated fractures. Chemical and isotopic modification of calcite-precipitating fluids appears to begin at the surface, largely under the influence of plant roots and their decay products. Chemical characteristics of the deeper calcites are either initiated or largely defined within the first few meters of fluid migration into the unsaturated tuffs beneath the calcretes. However, petrographic and isotopic data indicate a very unique low-$\delta^{13}C$ microenvironment that is localized at the upper surfaces of the calcretes. These surfaces form an interface in the soil horizon where infiltration may pond above the underlying carbonate "plug." In order to decipher the chemistry and petrology of past recharge events, it is important to first understand microenvironments such as this that contribute to mineral precipitation/dissolution events in the pedogenic environment.

94 (LA-UR–94-1038) **The transition to a revised quality assurance standard: The Los Alamos experience.** Bolivar, S.L. (Los Alamos National Lab., NM (United States)); Clevenger, M.J.; Gillespie, P.F.; Day, J.L. Los Alamos National Lab., NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940985–1: American Society for Quality Control Energy and Environmental Quality Division conference, Tucson, AZ (United States), 18-21 Sep 1994). Order Number DE94009337. Source: OSTI; NTIS; GPO Dep.

On January 6, 1993 the Los Alamos Yucca Mountain Site Characterization Project (YMP) office received a directive to implement DOE/RW-0333P, Quality Assurance Requirements and Description. This document is a revised quality assurance standard containing the quality assurance requirements for the YMP. Forty-two Los Alamos quality assurance documents were affected by this directive. Our goal was to transition to the revised standard with minimal impact on research activities yet maintain maximum flexibility and efficiency. The process of transitioning to a revised quality assurance standard, in essence replacing an existing quality assurance program with a new program, was a unique

learning experience. Although some problems were anticipated, the magnitude and complexity of problems was, at times, almost overwhelming. The problems encountered include the review process being more complex than anticipated; inconsistencies of much larger magnitude than originally believed; difficulties with electronic data base connections; quality processes being more complex than originally perceived, and administrative bottlenecks. The transition was very stressful and this was in part caused by the magnitude of the change. However, the transition process was enhanced by both a flexible schedule (provided by the customer) and flexibility in being able to revise procedures and modify processes. This allowed for minimal disruption to research activities. The new quality assurance program is better documented, therefore should be better understood by YMP personnel, is tracked electronically, and should provide a better product for the customer.

95 (LA-UR–94-1071) **Late cenozoic evolution of Fortymile Wash: Major change in drainage pattern in the Yucca Mountain, Nevada region during late miocene volcanism.** Lundstrom, S.C. (Geological Survey, Las Vegas, NV (United States)); Warren, R.G. Los Alamos National Lab., NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36 ; AI08-78ET44802. (CONF-940553–27: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009332. Source: OSTI; NTIS; INIS; GPO Dep.

The site characterization of Yucca Mountain, NV as a potential high level nuclear waste repository includes study of the surficial deposits as a record of the paleoenvironmental history of the Yucca Mountain region. An important aspect of this history is an understanding of the evolution of paleogeography leading to establishment of the present drainage pattern. Establishment of drainage basin evolution is needed before geomorphic response to paleoclimate and tectonics can be assessed, because a major change in drainage basin geometry can predominantly affect the sedimentary record. Because alluvial aquifers are significant to regional hydrology, a major change in surface drainage resulting in buried alluvium could have hydrogeologic significance. In this paper, we report on geologic evidence for a major modification in surface drainage pattern in the Yucca Mountain region, resulting in the probable establishment of the Fortymile Wash drainage basin by latest Miocene time.

96 (LA-UR–94-1613) **Iron oxide mineral-water interface reactions studied by AFM.** Hawley, M.E.; Rogers, P.S.Z. Los Alamos National Lab., NM (United States). [1994]. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9405191–1: Scanning microscopy conference, Toronto (Canada), 7-19 May 1994). Order Number DE94014807. Source: OSTI; NTIS; GPO Dep.

Natural iron mineral surfaces have been examined in air by atomic force (AFM) and scanning tunneling (STM) microscopies. A number of different surface features were found to be characteristic of the native surface. Even surfaces freshly exposed by crushing larger crystals were found to have a pebbly surface texture caused by the presence of thin coatings of what might be surface precipitates. This finding is interpreted as evidence for previous exposure to water, probably through an extensive network of microfractures. Surface reactions on the goethite crystals were studied by AFM at size resolutions ranging from microns to atomic resolution before, during, and after reaction with distilled water and 0.IN HCl. Immediate and extensive surface reconfiguration occurred on contact with water. In one case, after equilibration with water for 3 days, surface reprecipitation, etching and pitting were observed. Atomic resolution images taken under water were found to be disordered. The result of surface reaction was generally to increase the surface area substantially through the extension of surface platelet arrays, present prior to reaction. This work is being done in support of the site characterization project at Yucca Mountain.

97 (LA-UR–94-2891) **Simultaneous transport of synthetic colloids and a nonsorbing solute through single saturated natural fractures.** Reimus, P.W. (Los Alamos National Lab., NM (United States)); Robinson, B.A.; Nuttall, H.E.; Kale, R. Los Alamos National Lab., NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-941075–1: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE94018318. Source: OSTI; NTIS; INIS; GPO Dep.

Tracer transport experiments involving colloids that showed little tendency to attach to rock surfaces and a nonsorbing solute (iodide) -were conducted in three different well-characterized natural fractures in tuff. The colloids always arrived earlier in the effluent than the iodide, which we believe is evidence of (1) hydrodynamic chromatography and/or (2) the fact that the colloids experience a smaller effective volume in the fracture because they diffuse too slowly to enter low-velocity regions (dead zones) along the rough fracture walls. The iodide also approached the inlet concentration in the effluent more slowly than the colloids, with the concentration at a given elution volume being greater at higher flow rates. By contrast, the rate of approach of the colloid concentration to the inlet concentration did not vary with flow rate. We attribute this behavior to matrix diffusion of the iodide, with the colloids being too large/ nondiffusive to experience this phenomenon. Dispersion of all tracers was greatest in the fracture of widest average aperture and least in the fracture of narrowest aperture, which is consistent with Taylor dispersion theory. The tracer experiments were modeled/interpreted using a three-step approach that involved (1) estimating the aperture distribution in each fracture using surface profiling techniques, (2) predicting the flow field in the fractures using a localized parallel-plate approximation, and (3) predicting tracer transport in the fractures using particle-tracking techniques. Although considered preliminary at this time, the model results were in qualitative agreement with the experiments.

98 **Complexation of carbonate species at the goethite surface: Implications for adsorption of metal ions in natural waters.** Van Geen, A. (Stanford Univ., CA (United States)); Robertson, A.P.; Leckie, J.O. *Geochimica et Cosmochimica Acta (United States);* 58(9): 2073-2086 (May 1994).

Headspace P_{CO_2} was measured with an infrared gas analyzer over an equilibrated goethite suspension to determine adsorption of carbonate species in the pH range 3 to 8. For a 2 g/L goethite suspension in 0.1 N $NaClO_4$ ($\sim 3\ 10^{-4}$ M surface sites), the fraction of carbonate species adsorbed increased from 0.15 at pH 3 to a maximum of 0.56 at pH 6. In 0.01 N $NaClO_4$, the fraction of carbonate species adsorbed at pH 6 increased to 0.67. The total concentration of CO_2 in the suspension increased from about 0.4 to 0.6 10^{-4} M in

the pH range of these experiments. The development of surface charge at the goethite surface was determined in the pH range 4 to 11 by potentiometric titration under controlled low CO_2 conditions. No hysteresis was observed between the acid and base legs of titrations in 0.10, 0.03, and 0.01 N $NaClO_4$ resulting in a pH_{pzc} of 8.9. The carbonate species adsorption data were modelled using the least squares optimization program FITEQL for the diffuse double-layer model and the triple-layer model using stoichiometries of the type Fe-OCOOH and Fe-$OCOO^-$ for surface bound carbonate species. The model results are consistent with separate experiments showing a significant reduction in chromate adsorption on goethite as the partial pressure of CO_2 was increased from <5 to 450 and 40,000 μatm. The data suggest that mineral oxide surface sites which control solid/solute partitioning of metal ions in natural systems may be largely bound to adsorbed carbonate species.

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99 (ANL/CMT/CP–81910) **Results of drip tests on sludge-based and actinide-doped glasses.** Bates, J.K.; Buck, E.C. Argonne National Lab., IL (United States). [1994]. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-940553–33: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009687. Source: OSTI; NTIS; INIS; GPO Dep.

The reaction of three differs simulated nuclear waste glasses is being evaluated using a test method that slowly drips water onto a glass/metal assembly. The tests have been in progress for up to eight years and are being performed with as-cast and glass aged by reaction with water vapor. Results are presented for the cumulative release of Np, Pu, and Am as a function of time; also reported are the particulate species that have been detected suspended in solution. A significant difference is noted in the suspended species depending on the glass composition, and on whether the glass is aged. With as-cast glass, the radioactivity is associated with the suspended particles, while with the aged glass, the solution has a high initial anion content, and the transuranic elements appear to be dissolved in solution, since they pass through filters with small pore sizes. Examples are given of possible tests to evaluate the interaction between these test solutions and potential engineered barrier components.

100 **Spent fuel waste form characteristics: Grain and fragment size statistical dependence for oxidation response.** Stout, R.B. (Lawrence Livermore National Lab., CA (United States)); Kansa, E.; Buchanan, H.C.; Einziger, R.E.; Thomas, L.E. pp. 103-111 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Yucca Mountain Project of the US DOE is investigating the suitability of a site in the unsaturated zone at Yucca Mountain, NV, for a high level nuclear waste repository. All of the nuclear waste will be enclosed in a container package. Most of the waste form will consist of fragmented UO_2 spent fuel pellets in Zircaloy-clad rods from nuclear reactors. If failure of both the waste containers and the cladding occurs, then the UO_2 fragments will be exposed to oxygen in the air and higher oxides of uranium may form. Some existing microscopic data from low temperature testing indicate that UO_2 oxidizes to U_4O_9 by a phase transformation front that propagates into the fragments. The oxidation state and its extend into the spent fuel fragments may affect the dissolution behavior of spent fuel if it is contacted by water. Thus, a model for this oxidation response of UO_2 spent fuel fragments is necessary to predict the behavior of the exposed waste form in order to assess the performance of any repository with respect to containment of radionuclides. A preliminary model of phase transformation oxidation response of spent fuel is developed that incorporates a statistical dependence on the size distribution of pellet fragments.

101 **Spent fuel waste form characteristics: Grain and fragment size statistical dependence for dissolution response.** Stout, R.B. (Univ. of California, Livermore, CA (United States)); Leider, H.; Weed, H.; Nguyen, S.; McKenzie, W.; Prussin, S.; Wilson, C.N.; Gray, W.J. pp. 112-120 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Yucca Mountain Project of the US DOE is investigating the suitability of the unsaturated zone at Yucca Mountain, NV, for a high-level nuclear waste repository. All of the nuclear waste will be enclosed in a container package. Most of the nuclear waste will be in the form of fractured UO_2 spent fuel pellets in its Zircaloy-clad from electric power reactors. If failure of both the container and its enclosed clad rods occurs, then the fragments of the fractured UO_2 spent fuel will be exposed to their surroundings. Even though the surroundings are an unsaturated zone, a possibility of water transport exists, and consequently, UO_2 spent fuel dissolution may occur. A repository requirement imposes a limit on the nuclide release per year during a 10,000 year period; thus the short term dissolution response from fragmented fuel pellet surfaces in any given year must be understood. This requirement necessitates that both experimental and analytical activities be directed toward predicting the relatively short term dissolution response of UO_2 spent fuel. The short term dissolution response involves gap nuclides, grain boundary nuclides, and grain volume nuclides. Analytical expressions are developed that describe the combined geometrical influences of grain boundary nuclides and grain volume nuclides on the dissolution rate of spent fuel.

102 **Flow and transport around a noncontinuous horizontal layer at Yucca Mountain.** McGraw, M.A. (Pacific Northwest Lab., Richland, WA (United States)); Miley, T.B.; Langford, D.W. pp. 513-519 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC06-76RL01830. From 2. annual American Nuclear Society (ANS) international high

level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Computer simulations were used to examine the effect of a noncontinuous horizontal layer on the flow field and contaminant transport of a simplified conceptual model. The domain consisted of four different material types, where the pinched-out layer had a hydraulic conductivity one order of magnitude less than the other three zones. The boundary conditions were modified for three different simulations. The model results indicate that the boundary conditions used affect the results and are an important consideration in modeling. This implies that one-dimensional modeling is not adequate to represent the system.

103 Unsaturated flow through a variable aperture fracture in Topopah Spring welded tuff. Smoot, J.L. (Pacific Northwest Lab., Richland, WA (United States)); Wurstner, S.K.; Freshley, M.D. pp. 542-546 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC06-76RL01830. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The role of fractures in unsaturated flow through welded and nonwelded tuffaceous rocks is a fundamental question being addressed in performance assessment activities for the Yucca Mountain Project. A computer simulation test case was devised to investigate fracture-matrix interactions for a meter-scale block of Topopah Spring welded tuff. A data set produced by a laser scan of an actual fracture was used to generate the fracture geometry of a three-dimensional model. Simulation results indicate that pulses of water input to the top of the fracture produce gradients of flow down the fracture and into the matrix. The rate and extent of the advance appear to be influenced by the ambient saturation into the matrix. At 90% matrix saturation, an infiltration pulse of 1 cm of water in 1 h increased the pressure head by 250 cm. The wetting front penetrated approximately 8 cm vertically and 2 cm laterally in either direction from the fracture. At 50% matrix saturation, an identical infiltration pulse increased the pressure head by 400 cm. The wetting front penetrated approximately 3 cm vertically and less than 0.5 cm horizontally.

104 Laboratory determined suction potential of Topopah Spring tuff at high temperatures. Daily, W. (Lawrence Livermore National Lab., CA (United States)); Lin, W. pp. 583-588 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The purpose of this work is to experimentally determine the capillary suction potential of Topopah Spring tuff from Yucca Mountain, Nye County, Nevada. This data can be used to help characterize the unsaturated hydraulic properties of the densely welded tuff at this site.

105 Degradation mode surveys of high performance candidate container materials. Gdowski, G.E. (KMI Energy, Livermore, CA (United States)); McCright, R.D. pp. 932-939 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Corrosion resistant materials are being considered for the metallic barrier of the Yucca Mountain Project's high-level radioactive waste disposal containers. Nickel-chromium-molybdenum alloys and titanium alloys have good corrosion resistance properties and are considered good candidates for the metallic barrier. The localized corrosion phenomena, pitting and crevice corrosion, are considered as potentially limiting for the barrier lifetime. An understanding of the mechanisms of localized corrosion and of how various parameters affect it will be necessary for adequate performance assessment of candidate container materials. Examples of some of the concerns involving localized corrosion are discussed. The effects of various parameters, such as temperature and concentration of halide species, on localized corrosion are given. In addition, concerns about aging of the protective oxide layer in the expected service temperature range (50 to 250°C) are presented. Also some mechanistic considerations of localized corrosion are given.

106 An electrochemical approach to predicting corrosion performance of container materials. McCright, R.D. (Lawrence Livermore National Lab., CA (United States)); Farmer, J.C.; Fleming, D.L. pp. 940-944 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The pitting potentials of nickel-rich Alloy 825 are measured in chloride-containing solutions at different temperatures and adjusted to different pH values. The pitting potentials were determined by potentiodynamic polarization of Alloy 825 test specimens from the corrosion potential until a sharp increase in the electrochemical current indicated a breakdown of the protective passive film on the metal surface. Results show that Alloy 825 is susceptible to pitting attach in aggressive electrolytes containing more than 10,000 ppm chloride at 90°C and acicified to a pH value less than 2.5.

107 Variation of permeability with temperature in fractured Topopah Spring tuff samples. Lin, W. (Lawrence Livermore National Lab., CA (United States)). pp. 988-993 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Fractures will play an important role in the near-field hydrology of a nuclear-waste package in a mined repository. Our previous studies showed that the water permeability of fractured Topopah Springs tuff samples decreased by more than three orders of magnitude when the sample's temperature (in the case of a sample under a thermal gradient, the temperature in the hottest zone) increased to 150°C at a constant confining pressure of 5 MPa. When the fractured tuff samples were returned to room temperature the water permeability did not recover. We attributed the permeability

decrease to smoothing of the asperities on the fracture surfaces, which has caused by the dissolution and redeposition of silica minerals as water flowed through the sample. Water permeability of an intact tuff sample did not change significantly under similar experimental conditions.

108 Preliminary calculations of release rates from spent fuel in a tuff repository. Apted, M.J. (Battelle Pacific Northwest Labs., Richland, WA (United States)); Pigford, T.H.; Lee, W.W.L.; O'Connell, W.J.; Lee, K.H.; MacIntyre, A.T.; Ueng, T.S. pp. 1080-1090 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC06-76RL01830 ; W-7405-ENG-48 ; AC03-76SF00098. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Time-dependent release rates of Tc-99, I-129, Cs-135, and Np-237 have been calculated for wet-drip and moist-continuous release modes from the engineered barrier system of a potential nuclear waste repository in unsaturated tuff. We describe the modes of water contact and of release of dissolved radionuclides to be surrounding intact rock, and the corresponding calculational models. We list the parameter values adopted, and then present numerical results, conclusions, and recommendations.

109 Effects of spent fuel aging on repository disposal requirements. McKee, R.W. (Pacific Northwest Lab., Richland, WA (United States)); Johnson, K.I.; Huber, H.D.; Bierschbach, M.C. pp. 1132-1142 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A study has been carried out to analyze the effects of extended spent fuel aging on spent fuel disposal requirements. The analysis considers additional spent fuel aging up to a maximum of 50 years relative to the currently planned 2010 repository startup. As part of the analysis, an equal energy deposition (EED) methodology was developed for determining allowable waste emplacement densities in a tuff geologic repository as a function of spent fuel age and exposure. The method yields virtually identical results to those obtained by a more indirect method referred to as the "equivalent peak temperature rise concept" that has been used by the Yucca Mountain Project. This study demonstrates how this methodology can be used to design both the waste package and the waste emplacement layout to meet more than one thermal goal simultaneously.

110 Yucca Mountain near field environment considerations for engineered barrier system design and performance. Wilder, D.G. (Lawrence Livermore National Lab., CA (United States)). pp. 1366-1374 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The United States DOE is investigating the suitability of Yucca Mountain (YM) as a potential site for the nation's first High-level Nuclear Waste Repository. The focus of this paper is to discuss what is currently known about the Near-Field (NF) environment, particularly those aspects whose interaction with the Engineered Barrier System (EBS) components have significant impacts on the performance of the EBS and its ability to contribute to the isolation of radioactive waste.

111 Effect of ionizing radiation on the waste package environment. Reed, D.T. (Argonne National Lab., IL (United States)); Van Konynenburg, R.A. pp. 1396-1403 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-31109-ENG-38 ; W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The radiolytic production of nitrogen oxides, nitrogen acids and ammonia are discussed in relation to the expected environment in a high-level waste repository that may be constructed at the Yucca Mountain site if it is found to be suitable. Both literature data and repository-relevant data are summarized for air-water vapor systems. The limiting cases of a dry air and a pure water vapor gas phase are also discussed. Design guidelines and recommendations, based solely on the potential consequence of radiation enhancement of corrosion, are given.

112 The constructive use of heat in an unsaturated tuff repository. Ramspott, L.D. (Lawrence Livermore National Lab., CA (United States)). pp. 1602-1607 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract W-7405-ENG-48. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

By designing the engineered barrier system in an unsaturated tuff repository to constructively use heat, the waste containers can be kept dry for hundreds of years. Without water, the aqueous processes that release and transport radionuclides do not operate. In the plans of most international programs, waste is cooled prior to disposal in granite or salt. For these rocks there are technical issues favoring reduced heat. Recently, it has been suggested that the US Program adopt a strategy of cooling nuclear waste prior to disposal. This paper reviews technical issues associated with the role of heat in an unsaturated tuff repository and concludes that the overall effect of heat in such a setting appears to be beneficial to waste isolation.

113 Modeling ion exchange in clinoptilolite using the EQ3/6 geochemical modeling code. Viani, B.E. (Lawrence Livermore National Lab., CA (United States)); Bruton, C.J. pp. 73-77 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Potential disposal of high-level nuclear waste at Yucca Mtn., Nevada requires the means to simulate ion-exchange behavior of clays and zeolites. Vanselow and Gapon convention cation-exchange models have been added to geochemical modeling codes EQ3NR/EQ6, allowing exchange to be modeled for up to three exchangers or a single exchanger with three independent sites. Solid-solution models that are numerically equivalent to the ion-exchange models were derived and also implemented in

the code. The Gapon model is inconsistent with experimental adsorption isotherms of trace components in clinoptilolite. A one-site Vanselow model can describe adsorption of Cs and Sr on clinoptilolite, but a two-site Vanselow exchange model is necessary to describe K contents of natural clinoptilolites. 15 refs., 5 figs., 1 tab.

114 Geochemical modeling of water-rock interactions in the unsaturated zone. Bruton, C.J. (Lawrence Livermore National Lab., CA (United States)); Viani, B.E. pp. 705-708 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

If nuclear waste is buried in unsaturated tuffaceous rocks at Yucca Mountain, nevada, the surrounding environment may be subjected to elevated temperatures and complex patterns of fluid boiling, condensation and flow. Prediction of water-rock interactions is such environments requires evaluating the activity of water and describing activity coefficients of aqueous species in the unsaturated zone, where water is subjected to the effects of capillarity. The activity of water, or relative humidity, can be calculated from soil-moisture characteristic curves. Experimental results from the literature suggest that the Debye-Hueckel activity coefficient model, though developed for saturated systems, is adequate for thermodynamic calculations under ambient conditions in potential repository horizon tuffs. Dynamic geochemical simulations of water-tuff interactions demonstrate the impact of fluid saturation on mineral reaction and fluid chemistry in the unsaturated zone, relative to reaction in the saturated zone. 10 refs., 2 figs.

115 Flow and transport in hierarchically fractured systems. Karasaki, K. (Lawrence Berkeley Laboratory, CA (United States)). pp. 1106-1111 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Preliminary results indicate that flow in the saturated zone at Yucca Mountain is controlled by fractures. A current conceptual model assumes that the flow in the fracture system can be approximated by a three-dimensionally interconnected network of linear conduits. The overall flow system of rocks at Yucca Mountain is considered to consist of hierarchically structured heterogeneous fracture systems of multiple scales. A case study suggests that it is more appropriate to use the flow parameters of the large fracture system for predicting the first arrival time, rather than using the bulk average parameters of the total system.

116 Alternative strategies - a means for saving money and time on the Yucca Mountain Project. Wilder, D.G. (Lawrence Livermore National Laboratory, CA (United States)). pp. 1263-1270 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The United States Department of Energy (DOE) is undertaking studies to determine the suitability of Yucca Mountain (YM) as a potential site for disposal of high-level nuclear waste. Yucca Mountain is located approximately 120 miles northwest of Las Vegas in an arid environment. Many processes that could contribute to mobilization of radionuclides are either absent or minimized in a dry site. Therefore, Yucca Mountain should have the potential of being a very favorable site for disposal of waste. However, the determination of suitability has no precedence, and the characterization of an arid site is complex, requiring intensive studies to determine suitability. The studies undertaken by the Yucca Mountain Site Characterization Project (YMP) are very costly. Unfortunately many people have concluded that the costs are so excessive that the project should not proceed, but rather should be curtailed. The author feels this is unfortunate for two reasons. First, the solution of what to do with nuclear waste is a clear and urgent national need if we are to have a balanced US energy strategy. Second, the excessive cost and lengthy schedule are in part artifacts of the strategy that has been developed for satisfying regulations and providing for isolation of the waste. It is this latter point that will be addressed in this paper.

117 Radionuclide solubility and speciation studies for the Yucca Mountain site characterization project. Nitsche, H. (Lawrence Berkeley Laboratory, CA (United States)); Roberts, K.; Prussin, T.; Keeney, D.; Carpenter, S.A.; Becraft, K.; Gatti, R.C. pp. 1490-1495 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Yucca Mountain, Nevada, U.S.A., is being investigated for its suitability as a potential site for a geologic nuclear waste repository. As part of the site characterization studies, actinide solubilities and speciations were studied at pH 6, 7, and 8.5 at 25° and 60°C in two different groundwaters from the vicinity of Yucca Mountain. The groundwaters differ substantially in total dissolved carbonate concentration, and to a lesser extent in ionic strength. In the waters with higher carbonate content, the solubilities of neptunium(V) decreased, whereas those of americium (III) increased at 25°C and decreased at 60°C. The solids formed were sodium neptunium carbonates and americium hydroxycarbonates. Plutonium solubilities did not significantly change with changing water composition because the solubility-controlling solids were mostly amorphous Pu(IV) polymers that contained only small amounts of carbonate.

118 Large-scale in situ heater tests for hydrothermal characterization at Yucca Mountain. Buscheck, T.A. (Lawrence Livermore National Laboratory, CA (United States)); Wilder, D.G.; Nitao, J.J. pp. 1854-1872 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

To safely and permanently store high-level nuclear-waste, the potential Yucca Mountain repository site must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. Our analysis indicate that the ambient hydrological system will be dominated by repository-heat-driven hydrothermal flow for tens of thousands of years. In situ heater tests are required to provide an understanding of coupled geomechanical-hydrothermal-geochemical behavior in the

engineered and natural barriers under repository thermal loading conditions. In situ heater tests have been included in the Site Characterization Plan in response to regulatory requirements for site characterization and to support the validation of process models required to assess the total systems performance at the site. The success of the License Application (LA) hinges largely on how effectively we validate the process models that provide the basis for performance assessment. Because of limited time, some of the in situ tests will have to be accelerated relative to actual thermal loading conditions. We examine the trade-offs between the limited test duration and generating hydrothermal conditions applicable to repository performance during the entire thermal loading cycle, including heating (boiling and dry-out) and cooldown (re-wetting). For in situ heater tests duration of 6-7 yr (including 4 yr of full-power heating) is required. The parallel use of highly accelerated, shorter-duration tests may provide timely information for the LA, provided that the applicability of the test results can be validated against ongoing nominal-rate heater tests.

119 **Flow visualization and relative permeability measurements in rough-walled fractures.** Persoff, P. (Lawrence Berkeley Laboratory, CA (United States)); Pruess, K. pp. 2033-2041 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Two-phase flow conditions are likely to exist in the rock formations surrounding high level nuclear waste repositories such as Yucca Mountain and WIPP. Two-phase (gas-liquid) flow experiments were done in a natural rock fracture and transparent replicas of natural fractures. Liquid was injected at constant volume flow rate, and gas was injected at either constant mass flow rate or constant pressure. When gas was injected at constant mass flow rate, the gas inlet pressure, and inlet and outlet capillary pressures, generally did not reach steady state by cycled irregularly. Flow visualization showed that this cycling was due to repeated blocking and unblocking of gas flow paths by liquid. Relative permeabilities calculated from flow rate and pressure data show that the sum of the relative permeabilities of the two phases is much less than 1, indicating that each phase interferes strongly with the flow of the other. Comparison of the relative permeability curves with typical curves for porous media (Corey curves) show that the phase interference is stronger in fractures than in typical porous media.

120 **Single fracture aperture patterns: Characterization by slit-island fractal analysis.** Cox, B.L. (Lawrence Berkeley Laboratory, CA (United States)); Wang, S.Y. pp. 2053-2060 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC03-76SF00098. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Fracture aperture surfaces from two different fractures (one crack and one fault) are characterized and compared using geostatistical and fractal methods. Slit-island fractal dimensions of 1.3 and 1.4 are very similar. Cutoff patterns ('indicator maps') are not similar: the crack has a radial pattern and the fault has elongated patterns in the faulting direction. The cuttoff patterns could be used to test the significance of these two different patterns for single fracture fluid flow models. This research has applications for and funding from the Yucca Mountain Site Characterization Project.

121 (CONF-9310102–Vol.2, pp. 822-827) **Seismic design & analysis considerations for high level nuclear waste repositories.** Hossain, Q.A. (Lawrence Livermore National Lab., CA (United States)). Lawrence Livermore National Lab., CA (United States). [1993]. From 4. energy natural phenomena hazards mitigation conference; Atlanta, GA (United States); 19-22 Oct 1993. In *Fourth DOE Natural Phenomena Hazards Mitigation Conference: Proceedings: Volume 2.* 437p. Order Number DE94009267. Source: OSTI; NTIS; INIS.

A high level nuclear waste repository, like the one at Nevada's Yucca Mountain that is being investigated for site suitability, will have some unique seismic design and analysis considerations. These are discussed, and a design philosophy that can rationally account for the unique performance objectives of such facilities is presented. A case is made for the use of DOE's performance goal-based seismic design and evaluation methodology that is based on a hybrid "deterministic" and "probabilistic" concept. How and to what extent this methodology should be modified to adopt it for a potential site like Yucca Mountain is also outlined. Finally, the issue of designing for seismic fault rupture is discussed briefly, and the desirability of using the proposed seismic design philosophy in fault rupture evaluation is described.

122 (LBL–35186) **Phenomenological studies of two-phase flow processes for nuclear waste isolation.** Pruess, K.; Finsterle, S.; Persoff, P.; Oldenburg, C. Lawrence Berkeley Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States);Swiss National Cooperative for the Storage of Nuclear Waste, Baden (Switzerland). DOE Contract AC03-76SF00098. (CONF-940553–47: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94011350. Source: OSTI; NTIS; INIS; GPO Dep.

The US civilian radioactive waste management program is unique in its focus on a site in the unsaturated zone, at Yucca Mountain, Nevada. Two-phase flow phenomena can also play an important role in repositories beneath the water table where gas is generated by corrosion, hydrolysis, and biological degradation of the waste packages. An integrated program has been initiated to enhance our understanding of two-phase flow behavior in fractured rock masses. The studies include two-phase (gas-liquid) flow experiments in laboratory specimens of natural rock fractures, analysis and modeling of heterogeneity and instability effects in two-phase flow, and design and interpretation of field experiments by means of numerical simulation. We present results that identify important aspects of two-phase flow behavior on different space and time scales which are relevant to nuclear waste disposal in both unsaturated and saturated formations.

123 (LBL–35388) **Preliminary analysis of three-dimensional moisture flow within Yucca Mountain, Nevada.** Bodvarsson, G. (Lawrence Berkeley Lab., CA (United States)); Chen, G.; Wittwer, C. Lawrence Berkeley Lab., CA (United States). Mar 1994. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-940553–63: International high-level radioactive waste management conference, Las

Vegas, NV (United States), 22-26 May 1994). Order Number DE94013097. Source: OSTI; NTIS; GPO Dep.

The continuous development of the three-dimensional site-scale model of Yucca Mountain Nevada is described. Three-dimensional moisture flow simulations are conducted, that show how the stratigraphic units and fault offsets and properties at Yucca Mountain create complex three-dimensional flow patterns. Even for a really uniform infiltration rates, these geological complexities result in large lateral flow components and often concentrated flow into the water table. When the major faults are assumed to act as capillary barriers, moisture buildup occurs close to the faults. Conversely, when the faults are assumed to readily absorb water and allow for vertical migration, lateral flow is greatly enhanced and relatively dry conditions are found in the rock matrix adjacent to the faults. These results suggest that careful observations of saturations and rock matrix conditions in rock masses near major faults may help determine the hydrological characteristics of the faults. The site-scale model has been used to predict conditions in wells UZ-16 and other wells, in order to investigate the predictive capabilities of the model. Gas flow and the Geothermal gradient have been incorporated into the model.

124 (LBL–35518) **T2CG1, a package of preconditioned conjugate gradient solvers for TOUGH2.** Moridis, G. (Lawrence Berkeley Lab., CA (United States). Earth Sciences Div.); Pruess, K.; Antunez, E. Lawrence Berkeley Lab., CA (United States). Mar 1994. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE94015159. Source: OSTI; NTIS; INIS; GPO Dep.

Most of the computational work in the numerical simulation of fluid and heat flows in permeable media arises in the solution of large systems of linear equations. The simplest technique for solving such equations is by direct methods. However, because of large storage requirements and accumulation of roundoff errors, the application of direct solution techniques is limited, depending on matrix bandwidth, to systems of a few hundred to at most a few thousand simultaneous equations. T2CG1, a package of preconditioned conjugate gradient solvers, has been added to TOUGH2 to complement its direct solver and significantly increase the size of problems tractable on PCs. T2CG1 includes three different solvers: a Bi-Conjugate Gradient (BCG) solver, a Bi-Conjugate Gradient Squared (BCGS) solver, and a Generalized Minimum Residual (GMRES) solver. Results from six test problems with up to 30,000 equations show that T2CG1 (1) is significantly (and invariably) faster and requires far less memory than the MA28 direct solver, (2) it makes possible the solution of very large three-dimensional problems on PCs, and (3) that the BCGS solver is the fastest of the three in the tested problems. Sample problems are presented related to heat and fluid flow at Yucca Mountain and WIPP, environmental remediation by the Thermal Enhanced Vapor Extraction System, and geothermal resources.

125 (LBL–35560) **Approximating the imbibition and absorption behavior of a distribution of matrix blocks by an equivalent spherical block.** Zimmerman, R.W.; Bodvarsson, G.S. Lawrence Berkeley Lab., CA (United States). Mar 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. (CONF-940553–62: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94013105. Source: OSTI; NTIS; INIS; GPO Dep.

A theoretical study is presented of the effect of matrix block shape and matrix block size distribution on liquid imbibition and solute absorption in a fractured rock mass. It is shown that the behavior of an individual irregularly-shaped matrix block can be modeled with reasonable accuracy by using the results for a spherical matrix block, if one uses an effective radius $\tilde{a} = 3V/A$, where V is the volume of the block and A is its surface area. In the early-time regime of matrix imbibition, it is shown that a collection of blocks of different sizes can be modeled by a single equivalent block, with an equivalent radius of $\langle a^{-1} \rangle^{-1}$, where the average is taken on a volumetrically-weighted basis. In an intermediate time regime, it is shown for the case where the radii are normally distributed that the equivalent radius is reasonably well approximated by the mean radius $\langle a \rangle$. In the long-time limit, where no equivalent radius can be rigorously defined, an asymptotic expression is derived for the cumulative diffusion as a function of the mean and the standard deviation of the radius distribution function.

126 (PNL–9414) **Global ice sheet modeling.** Hughes, T.J. (Univ. of Maine, Orono, ME (United States). Institute for Quaternary Studies); Fastook, J.L. Pacific Northwest Lab., Richland, WA (United States). May 1994. 165p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013744. Source: OSTI; NTIS; INIS; GPO Dep.

The University of Maine conducted this study for Pacific Northwest Laboratory (PNL) as part of a global climate modeling task for site characterization of the potential nuclear waste respository site at Yucca Mountain, NV. The purpose of the study was to develop a global ice sheet dynamics model that will forecast the three-dimensional configuration of global ice sheets for specific climate change scenarios. The objective of the third (final) year of the work was to produce ice sheet data for glaciation scenarios covering the next 100,000 years. This was accomplished using both the map-plane and flowband solutions of our time-dependent, finite-element gridpoint model. The theory and equations used to develop the ice sheet models are presented. Three future scenarios were simulated by the model and results are discussed.

127 (PNL–9416) **Regional forecasting with global atmospheric models: Third year report.** Crowley, T.J. (Applied Research Corp., College Station, TX (United States)); North, G.R.; Smith, N.R. Pacific Northwest Lab., Richland, WA (United States); Applied Research Corp., College Station, TX (United States). May 1994. 328p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013863. Source: OSTI; NTIS; INIS; GPO Dep.

This report was prepared by the Applied Research Corporation (ARC), College Station, Texas, under subcontract to Pacific Northwest Laboratory (PNL) as part of a global climate studies task. The task supports site characterization work required for the selection of a potential high-level nuclear waste repository and is part of the Performance Assessment Scientific Support (PASS) Program at PNL. The work is under the overall direction of the Office of Civilian Radioactive Waste Management (OCRWM), US Department of Energy Headquarters, Washington, DC. The scope of the report is to present the results of the third year's work on the atmospheric modeling part of the global climate studies task. The development testing of computer models and initial results are discussed. The appendices contain several studies that provide supporting information and guidance to

the modeling work and further details on computer model development. Complete documentation of the models, including user information, will be prepared under separate reports and manuals.

128 (PNL–9418) **Global climate change model natural climate variation: Paleoclimate data base, probabilities and astronomic predictors.** Kukla, G. (Columbia Univ., Palisades, NY (United States). Lamont-Doherty Geological Observatory); Gavin, J. Pacific Northwest Lab., Richland, WA (United States); Columbia Univ., Palisades, NY (United States). Lamont-Doherty Geological Observatory. May 1994. 592p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013956. Source: OSTI; NTIS; INIS; GPO Dep.

This report was prepared at the Lamont-Doherty Geological Observatory of Columbia University at Palisades, New York, under subcontract to Pacific Northwest Laboratory it is a part of a larger project of global climate studies which supports site characterization work required for the selection of a potential high-level nuclear waste repository and forms part of the Performance Assessment Scientific Support (PASS) Program at PNL. The work under the PASS Program is currently focusing on the proposed site at Yucca Mountain, Nevada, and is under the overall direction of the Yucca Mountain Project Office US Department of Energy, Las Vegas, Nevada. The final results of the PNL project will provide input to global atmospheric models designed to test specific climate scenarios which will be used in the site specific modeling work of others. The primary purpose of the data bases compiled and of the astronomic predictive models is to aid in the estimation of the probabilities of future climate states. The results will be used by two other teams working on the global climate study under contract to PNL. They are located at and the University of Maine in Orono, Maine, and the Applied Research Corporation in College Station, Texas. This report presents the results of the third year's work on the global climate change models and the data bases describing past climates.

129 (PNL–9788) **Regional forecasting with global atmospheric models: Final report.** Crowley, T.J. (Applied Research Corp., College Station, TX (United States)); Smith, N.R. Pacific Northwest Lab., Richland, WA (United States). May 1994. 138p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94014218. Source: OSTI; NTIS; GPO Dep.

The purpose of the project was to conduct model simulations for past and future climate change with respect to the proposed Yucca Mtn. repository. The authors report on three main topics, one of which is boundary conditions for paleo-hindcast studies. These conditions are necessary for the conduction of three to four model simulations. The boundary conditions have been prepared for future runs. The second topic is (a) comparing the atmospheric general circulation model (GCM) with observations and other GCMs; and (b) development of a better precipitation data base for the Yucca Mtn. region for comparisons with models. These tasks have been completed. The third topic is preliminary assessments of future climate change. Energy balance model (EBM) simulations suggest that the greenhouse effect will likely dominate climate change at Yucca Mtn. for the next 10,000 years. The EBM study should improve rational choice of GCM CO_2 scenarios for future climate change.

130 (PNL-SA–23748) **Interlaboratory comparison of UO_2 dissolution rates.** Gray, W.J. (Pacific Northwest Lab., Richland, WA (United States)); Steward, S.A.; Trait, J.C.; Shoesmith, D.W. Pacific Northwest Lab., Richland, WA (United States). May 1994. 6p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract AC06-76RL01830 ; W-7405-ENG-48. (UCRL-JC–115356; CONF-940553–71: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014413. Source: OSTI; NTIS; INIS; GPO Dep.

Direct disposal of spent nuclear fuel in deep underground geologic repositories (vaults) is being pursued by several countries. Isolation relies on multiple barriers consisting of the site geology, engineered barriers including containers to surround the fuel, and the spent fuel itself. These barriers are intended to inhibit dissolution and transport of radionuclides by groundwater, which is virtually the only mechanism available to release radionuclides from the repository. Performance assessment studies are needed to demonstrate the adequacy of the various repository designs. Essential to this performance assessment is an understanding of the dissolution behavior of the spent fuel. Since the dissolution behavior of spent fuel in an actual repository cannot be adequately approximated in a laboratory, laboratory tests and data must be used to develop a mechanistic model that can predict long-term behavior in a repository. Three different laboratories have performed flowthrough dissolution tests at room temperature on portions of the same batch of unirradiated UO_2 powder, and good agreement was achieved between the different test results. Dissolution rates obtained from electrochemical studies conducted with UO_2 electrodes at Whiteshell Laboratories are compared with the flowthrough test results.

131 (UCRL-ID–116129) **New observations of infiltration through fractured alluvium in Yucca Flat, Nevada Test Site: A preliminary field investigation.** Kao, C.S. (California Univ., Berkeley, CA (United States). Dept. of Civil Engineering); Smith, D.K.; McKinnis, W.B. Lawrence Livermore National Lab., CA (United States). Feb 1994. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94012589. Source: OSTI; NTIS; GPO Dep.

Regional tectonics coupled with the subsurface detonation of nuclear explosives has caused widespread fracturing of the alluvium of Yucca Flat. Fractures deeper than 30 meters have been observed in boreholes. Some of these fractures are large enough to capture significant amounts of runoff during storm events. Evidence of stream capture by fractures and observations of runoff flowing into open fractures give qualitative evidence of infiltration to depths greater than several meters and possibly to the saturated zone. Our field observations contradict the assumption that little infiltration occurs on Yucca Flat. The larger, hydrologically important fractures are associated with geologic faults or the regional stress field. Additional field studies are needed to investigate the impact of fractures on the transport of contaminants.

132 (UCRL-JC–114686-Rev.1) **Technical changes that would contribute to success in the civilian radioactive waste management program: Revision 1.** Ramspott, L.D. Lawrence Livermore National Lab., CA (United States). 1 Oct 1993. 35p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9309295–3-Rev.1: Nuclear as a large-scale global option conference, Oak Ridge, TN (United States), 28-30 Sep 1993). Order Number DE94014059. Source: OSTI; NTIS; INIS; GPO Dep.

This paper briefly reviews the history of the United States program for high-level waste disposal. It then describes the current DOE strategy for licensing and safety for a repository at Yucca Mountain, Nevada. Changes that have occurred since the origin of the program and since publication of the Site Characterization Plan are reviewed. These include changes in external circumstances, changes in technology and new understanding of Yucca Mountain. An alternative approach is then described, based on four key concepts: a simple safety case, reversibility, demonstrability, and decompling operation of a repository from the operation of reactors.

133 (UCRL-JC–114776) **The testing of thermal-mechanical-hydrological-chemical processes using a large block.** Lin, W.; Wilder, D.G.; Blink, J.A.; Blair, S.C.; Buscheck, T.A.; Chesnut, D.A.; Glassley, W.E.; Lee, K.; Roberts, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–22: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008966. Source: OSTI; NTIS; INIS; GPO Dep.

The radioactive decay heat from nuclear waste packages may, depending on the thermal load, create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near-field environment of a repository. A group of tests on a large block (LBT) are planned to provide a timely opportunity to test and calibrate some of the TMHC model concepts. The LBT is advantageous for testing and verifying model concepts because the boundary conditions are controlled, and the block can be characterized before and after the experiment. A block of Topopah Spring tuff of about 3 × 3 × 4.5 m will be sawed and isolated at Fran Ridge, Nevada Test Site. Small blocks of the rock adjacent to the large block will be collected for laboratory testing of some individual thermal-mechanical, hydrological, and chemical processes. A constant load of about 4 MPa will be applied to the top and sides of the large block. The sides will be sealed with moisture and thermal barriers. The large block will be heated with one heater in each borehole and guard heaters on the sides so that a dry-out zone and a condensate zone will exist simultaneously. Temperature, moisture content, pore pressure, chemical composition, stress and displacement will be measured throughout the block during the heating and cool-down phases. The results from the experiments on small blocks and the tests on the large block will provide a better understanding of some concepts of the coupled TMHC processes.

134 (UCRL-JC–114784) **Electrical properties of Topopah Spring tuff as a function of saturation.** Roberts, J.J.; Lin, Wunan. Lawrence Livermore National Lab., CA (United States). Jan 1994. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–76: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014786. Source: OSTI; NTIS; INIS; GPO Dep.

Much attention has been focused on the hydrologic properties of tuff from the potential nuclear waste repository at Yucca Mountain, Nevada. The successful characterization of the near-field environment of the potential repository depends on the ability to understand and predict the movement of water within the matrix and fractures when the rock mass is heated by nuclear waste. This understanding will come only after many combined laboratory experiments, field tests, and model calculations have been performed. Electrical properties, including electrical resistivity and dielectric permittivity, have been utilized in past studies to infer water content in partially saturated rocks. In this study we determine the electrical properties of Topopah Spring tuff from Yucca Mountain (Area 25), and Area 3, Nevada Test Site (NTS), NV, as a function of water content. These results will be used to (1) study the electrical properties of ted rocks as functions of saturation and water chemistry; (2) relate the observed electrical properties to the distribution of water and to the rnicrogeometry of the rock; and (3) to create a database of electrical resistivity (ρ) and relative dielectric permittivity (κ') versus water content (Sw) and temperature for rocks within the potential repository horizon. The database will be used both in laboratory experiments and field tests to determine the moisture content in rocks based on measured electrical properties.

135 (UCRL-JC–114786) **On the benefits of an integrated nuclear complex for Nevada.** Blink, J.A. (Lawrence Livermore National Laboratory, Las Vegas, NV (United States)); Halsey, W.G. Lawrence Livermore National Lab., CA (United States). Jan 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–73: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014753. Source: OSTI; NTIS; INIS; GPO Dep.

An integrated nuclear complex is proposed for location at the Nevada Test Site. In addition to solving the nuclear waste disposal problem, this complex would tremendously enhance the southern Nevada economy, and it would provide low cost electricity to each resident and business in the affected counties. Nuclear industry and the national economy would benefit because the complex would demonstrate the new generation of safer nuclear power plants and revitalize the industry. Many spin-offs of the complex would be possible, including research into nuclear fusion and a world class medical facility for southern Nevada. For such a complex to become a reality, the cycle of distrust between the federal government and the State of Nevada must be broken. The paper concludes with a discussion of implementation through a public process led by state officials and culminating in a voter referendum.

136 (UCRL-JC–115351) **The impact of buoyant gas-phase flow and heterogeneity on thermo-hydrological behavior at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–81: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94019050. Source: OSTI; NTIS; INIS; GPO Dep.

To safety and permanently store high-level nuclear waste, the potential Yucca Mountain repository system must mitigate the release and transport of radionuclides for tens of thousands of years. In the failure scenario of greatest concern, water would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. Our analyses have demonstrated that the only significant source of liquid water is fracture flow from: (1) natural infiltration, (2) condensate drainage generated under boiling conditions, and (3) condensate drainage generated under sub-boiling conditions. The first source of liquid water

arises from the ambient system; the second and third sources are generated by repository heat. Buoyant, gas-phase flow, occurring either on a sub-repository scale or on a mountain scale, may play an important role in generating the second and third sources of liquid water. By considering a wide range in bulk permeability of the fractured rock, we identify a threshold bulk permeability at which buoyant, gas-phase convection begins to dominate hydrological behavior. At 10 times this threshold, convection begins to dominate thermal behavior. These effects can dominate moisture movement in the unsaturated zone on the order of 100,000 yr. We find that the development of a large above-boiling zone suppresses the effects of buoyant vapor flow. Zones of sharply contrasting bulk permeability also influence condensate generation and drainage. Of particular concern are conditions that focus vapor flow and condensate drainage, which could result in persistent refluxing at the repository, causing water to drip onto waste packages. These effects can occur under both sub-boiling and boiling conditions Long-term in situ heater tests are required to diagnose the potential for major repository-heat- driven sources of fractures flow.

137 (UCRL-JC–115352) **Evaluation of thermo-hydrological performance in support of the thermal loading systems study.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States). Earth Sciences Dept.); Nitao, J.J.; Saterlie, S.F. Lawrence Livermore National Lab., CA (United States). Jan 1994. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–82: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE95002404. Source: OSTI; NTIS; INIS; GPO Dep.

Heat generated as a result of emplacing spent nuclear fuel will significantly affect the pre- and post-closure performance of the Mined Geological Disposal System (MGDS) at the potential repository site in Yucca Mountain. Understanding thermo-hydrological behavior under repository thermal loads is essential in (a) planning and conducting the site characterization and testing program, (b) designing the repository and engineered barrier system, and (c) assessing performance. The greatest concern for hydrological performance is source of water that would contact a waste package, accelerate its failure rate, and eventually transport radionuclides to the water table. The primary sources of liquid water are: (1) natural infiltration, (2) condensate generated under boiling conditions, and (3) condensate generated under sub-boiling conditions. Buoyant vapor flow, occurring either on a sub-repository scale or on a mountain scale, any affect the generation of the second and third sources of liquid water. A system of connected fractures facilitates repository-heat-driven gas and liquid flow as well as natural infiltration. With the use of repository-scale and sub-repository-scale models, the authors analyze thermo-hydrological behavior for Areal Mass Loadings (AMLs) of 24.2, 35.9, 55.3, 83.4, and 110.5 MTU/acre for a wide range of bulk permeability. They examine the temporal and spatial extent of the temperature and saturation changes during the first 100,000 yr. They also examine the sensitivity of mountain scale moisture redistribution to a range of AMLs and bulk permeabilities. In addition, they investigate how boiling and buoyant, gas-phase convection influence thermo-hydrological behavior in the vicinity of emplacement drifts containing spent nuclear fuel.

138 (UCRL-JC–115613) **On integrating modeling software for application to total-system performance assessment.** Lewis, L.C. (Lawrence Livermore National Lab., CA (United States)); Wilson, M.L. Lawrence Livermore National Lab., CA (United States). May 1994. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940815–75: International nuclear and hazardous waste management conference, Atlanta, GA (United States), 14-18 Aug 1994). Order Number DE94016361. Source: OSTI; NTIS; INIS; GPO Dep.

We examine the processes and methods used to facilitate collaboration in software development between two organizations at separate locations – Lawrence Livermore National Laboratory (LLNL) in California and Sandia National Laboratories (SNL) in New Mexico. Our software development process integrated the efforts of these two laboratories. Software developed at LLNL to model corrosion and failure of waste packages and subsequent releases of radionuclides was incorporated as a source term into SNLs computer models for fluid flow and radionuclide transport through the geosphere.

139 (UCRL-JC–116147) **What do we mean by a cold repository?.** Halsey, W.G. Lawrence Livermore National Lab., CA (United States). Jan 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–77: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014790. Source: OSTI; NTIS; INIS; GPO Dep.

The topic of thermal loading of a potential repository at Yucca Mountain in Nevada has been the subject of intense discussion within the project technical community. While terms such as "Hot Repository" and "Cold Repository" are frequently used, they have not been clearly defined. In particular, the definition of a cold repository has remained the opinion of each individual. This has led to confusion and misunderstanding. In this paper, a number of observed definitions for a cold repository are discussed along with the technical implications, assumptions and inconsistencies. Finally, a common language is suggested.

140 (UCRL-JC–116315) **Identifying significant uncertainties in thermally dependent processes for repository performance analysis.** Gansemer, J.D.; Lamont, A. Lawrence Livermore National Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–39: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010061. Source: OSTI; NTIS; INIS; GPO Dep.

In order to study the performance of the potential Yucca Mountain Nuclear Waste Repository, scientific investigations are being conducted to reduce the uncertainty about process models and system parameters. This paper is intended to demonstrate a method for determining a strategy for the cost effective management of these investigations. It is not meant to be a complete study of all processes and interactions, but does outline a method which can be applied to more in-depth investigations.

141 (UCRL-JC–116350) **Limitations on scientific prediction and how they could affect repository licensing.** Van Konynenburg, R.A. Lawrence Livermore National Lab., CA (United States). Jan 1994. 9p. Sponsored by

USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–74: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014788. Source: OSTI; NTIS; INIS; GPO Dep.

The best possibility for gaining an understanding of the likely future behavior of a high level nuclear waste disposal system is to use the scientific method. However, the scientific approach has inherent limitations when it comes to making long-term predictions with confidence. This paper examines some of these limiting factors as well as the criteria for admissibility of scientific evidence in the legal arena, and concludes that the prospects are doubtful for successful licensing of a potential repository under the regulations that are now being reconsidered. Suggestions am made for remedying this situation.

142 (UCRL-JC–116357) **Rationale for determining spent fuel acquisitions for repository testing.** Marschman, S.C. (Pacific Northwest Lab., Richland, WA (United States)); Einziger, R.E.; Stout, R.B. Lawrence Livermore National Lab., CA (United States); Pacific Northwest Lab., Richland, WA (United States). Jan 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48 ; AC06-76RL01830. (CONF-940553–48: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94011742. Source: OSTI; NTIS; INIS; GPO Dep.

A rationale for selecting commercial spent nuclear fuels for use as testing materials for the Yucca Mountain Project was developed. A review of experimental data from fuel performance testing was conducted and performance-affecting attributes pertinent to storage and disposal conditions were identified. These were used to form the basis for a fuel-selection strategy designed to ensure adequate and representative samples are available for storage- and disposal-relevant testing.

143 (UCRL-JC–116431) **A large block heater test for high level nuclear waste management.** Lin, W. (and others); Wilder, D.G.; Blink, J.A. Lawrence Livermore National Lab., CA (United States). Jul 1994. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-941075–3: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE95002403. Source: OSTI; NTIS; INIS; GPO Dep.

The radioactive decay heat from nuclear waste packages may, depending on the thermal load, create coupled thermal-mechanical-hydrological-chemical (TMHC) processes in the near-field environment of a repository. A group of tests on a large block (LBT) are planned to provide a timely opportunity to test and calibrate some of the TMHC model concepts. The LBT is advantageous for testing and verifying model concepts because the boundary conditions are controlled, and the block can be characterized before and after the experiment. A block of Topopah Spring tuff of about 3 x 3 x 4.5 m will be sawed and isolated at Fran Ridge, Nevada Test Site. Small blocks of the rock adjacent to the large block will be collected for laboratory testing of some individual thermal-mechanical hydrological and chemical processes. A constant load of about 4 MPa will be applied to the top and sides of the large block. The sides will be sealed with moisture and thermal barriers. The large block will be heated by heaters within and guard heaters on the sides so that a dry-out zone and a condensate zone will exist simultaneously. Temperature, moisture content, pore pressure, chemical composition, stress, and displacement will be throughout the block during the heating and cool-down phases. The results from the experiments on small blocks and the tests on the large block will provide a better understanding of some concepts of the coupled TMHC processes. The progress of the project is presented in this paper.

144 (UCRL-JC–116436) **Groundwater flux, travel time, and radionuclide transport.** Chesnut, D.A. Lawrence Livermore National Lab., CA (United States). Aug 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-941075–4: 18. international symposium on the scientific basis for nuclear waste management, Kyoto (Japan), 23-27 Oct 1994). Order Number DE95002401. Source: OSTI; NTIS; INIS; GPO Dep.

Lawrence Livermore National Laboratory (LLNL) provides the scientific and engineering bases for design and performance analyses of the waste package and other components of the engineered barrier system (EBS) for a potential repository at Yucca Mountain, Nevada. The EBS is an important component of a multi-barrier system designed to isolate radioactive waste until it decays to the point that it is no longer radiologically hazardous to humans or other species. Its performance depends strongly upon the amount, chemical composition, and temperature of liquid water in the "near field" region immediately surrounding the waste packages. For this reason, much of LLNL's Yucca Mountain research has been directed toward understanding flow, transport, and chemical processes in fractured rock under both preemplacement and post-emplacement conditions. Because the radioactive decay heat from a potential repository at Yucca Mountain would dominate the movement of water for thousands of years within the entire repository block and possibly even beyond, the spatial domain of our investigations ranges from the scale of individual fracture apertures (micrometers) to a few kilometers.

145 Near-field diffusion releases through one and two finite planar zones from a nuclear waste package. Ueng, T.S. (Lawrence Livermore National Lab., CA (United States)); O'Connell, W.J. *Nuclear Technology (United States);* 108(1): 80-89 (Oct 1994). DOE Contract W-7405-ENG-48.

For a nuclear waste package emplacement in a potential repository in partially saturated rock, a rock rubble or backfill zone may act more as a barrier than as a pathway for diffusive release of radionuclides. The authors approximate the diffusive transport process using one-dimensional, one- and two-barrier geometries. The one-barrier model suffices when the effective diffusion coefficient in the first zone, the rubble, is substantially lower than that in the second zone, the host rock. For more generally, such as two zones of comparable diffusivities, or for an additional barrier zone, the authors model two barrier zones both of finite extent. They present solutions for three types of radionuclide mobilization at the source: a pulse transient input, a steady input rate, and a constant concentration. The algebraic series form of the solutions aids analysis of sensitivity of break-through times and peak release rates. For the one-zone case, dimensionless parameters allow plotting of the family of transient solutions on a single graph. Comparisons between results of one- and two-zone models and with published results for different geometries and solution methods support verification of the solutions in this study.

146 Behavior of carbon-14 in waste packages for spent fuel in a tuff repository. Van Konynenburg, R.A. (Lawrence Livermore National Lab., CA (United States). Chemistry and Materials Science Dept.). *Waste Management (United States);* 14(5): 363-383 (1994). DOE Contract W-7405-ENG-48.

Light water reactor spent fuel in the US contains only about 37 MBq of carbon-14 per kg U (1 curie per metric ton of initial uranium); however, the potential US repository at Yucca Mountain would be located above the water table, where air is presents. Temperatures might be intentionally elevated by design in order to drive away water. If waste package containment is breached prior to depletion by radioactive decay, C-14 could be released as $^{14}CO_2$ and transported in the gas phase. Since it appears that transport would be rapid relative to radioactive decay, release to the accessible environment would be possible. This paper reviews the evaluation of the inventory of C-14 and what can be projected about its likely behavior. Uncertainties in the containment lifetimes of waste packages, and costs involved in attempting to assure long-term containment, are discussed. Consequences of total release are placed in perspective. An opinion is offered that these consequences are too small to justify the costs of trying to assure that releases would be below the previously prevailing US regulatory limits. The regulations are currently being reconsidered by a committee of the National Academy of Sciences.

SANDIA NATIONAL LABORATORIES

147 Weapons test seismic investigations at Yucca Mountain. Phillips, J.S. (Sandia National Labs., Albuquerque, NM (United States)); Walck, M.C.; Shephard, L.E. pp. 83-90 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Yucca Mountain, located on and adjacent to the Nevada Test Site, is being characterized as part of an ongoing effort to identify a potential high-level nuclear waste repository. This site will be subjected to seismic ground motions induced by underground nuclear explosions. A knowledge of expected ground motion levels from these tests will enable the designers to provide for the necessary structural support in the designs of the various components of the repository. The primary objective of the Weapons Test Seismic Investigation project is to develop a method to predict the ground motions expected at the repository site as a result of future weapons tests. This paper summarizes the data base presently assembled for the Yucca Mountain Project, characteristics of expected ground motions, and characterization of the two-dimensional seismic properties along paths between Yucca Mountain and the testing areas of the Nevada Test Site.

148 Performance assessment in early phases of the repository design process. Blejwas, T.E. (Sandia National Labs., Albuquerque, NM (United States)). pp. 210-215 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Assessments of post-closure performance are an integral part of the design process for a repository for high-level nuclear waste. They provide input to the establishment of design requirements and to the evaluation of designs against these requirements. During early design phases, the assessments are limited by capabilities of analytical models, uncertainties about conceptual models, and a lack of site data. The use of performance assessment in recent design activities for the Yucca Mountain Site Characterization Project, including a study of alternatives for an exploratory shaft facility (ESF), demonstrates the necessity of significant engineering judgment in the interpretation and application of early analyses. Maintaining flexibility for some aspects of repository design is prudent.

149 Mechanical anisotropy of the Yucca Mountain tuffs. Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Boyd, P.J.; Martin, R.J.; Haupt, R.W.; Noel, J.S. pp. 268-271 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Three series of measurements were performed on oriented cores of several Yucca Mountain tuffs to determine the importance of mechanical anisotropy in the intact rock. Outcrop and drillhole samples were tested for acoustic velocities, linear compressibilities, and strengths in different orientations. The present data sets are preliminary, but suggest the tuffs are transversely anisotropic for these mechanical properties. The planar fabric that produces the anisotropy is believed to be predominantly the result of the preferred orientation of shards and pumice fragments. The potential of significant anisotropy has direct relevance to the formulation of constitutive formulation and the analyses of an underground opening within the Yucca Mountain.

150 Predicted thermal and stress environments in the vicinity of repository openings. Bauer, S.J. (Sandia National Labs., Albuquerque, NM (United States)); Hardy, M.P.; Lin, M. pp. 564-571 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

An understanding of the thermal and stress environment in the vicinity of repository openings is important for preclosure performance considerations and worker health and safety considerations for the proposed high-level radioactive waste repository at Yucca Mountain. This paper presents the results of two and three dimensional numerical analyses which have determined the thermal and stress environments for typical repository openings. In general, it is predicted that openings close to heat sources attain high temperatures and experience a significant stress increase. Openings

away from heat sources experience more uniform temperature changes and experience a stress change which results in part from a far-field thermal loading.

151 Research program to develop and validate conceptual models for flow and transport through unsaturated, fractured rock. Glass, R.J. (Sandia National Labs., Albuquerque, NM (United States)); Tidwell, V.C. pp. 977-987 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

As part of the Yucca Mountain Project, our research program to develop and validate conceptual models for flow and transport through unsaturated fractured rock integrates fundamental physical experimentation with conceptual model formulation and mathematical modeling. Our research is directed toward developing and validating macroscopic, continuum-based models and supporting effective property models because of their widespread utility within the context of this project. Success relative to the development and validation of effective property models is predicted on a firm understanding of the basic physics governing flow through fractured media, specifically in the areas of unsaturated flow and transport in a single fracture and fracture-matrix interaction.

152 Mechanical excavator performance in Yucca Mountain tuffs. Ozdemir, L. (Colorado School of Mines, Golden, CO (United States)); Hansen, F.D. pp. 1091-1097 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A research effort of four phases is in progress at the Colorado School of Mines. The overall program will evaluate the cutability of welded tuff and other lithologies likely to be excavated at Yucca Mountain in the site characterization process. Several mechanical systems are considered with emphasis given to the tunnel boring machine. The research comprises laboratory testing, linear drag bit and disc cutter tests, and potentially large-scale lab. demonstrations to support potential use of a tunnel boring machine in welded tuff. Preliminary estimates of mechanical excavator performance in Yucca Mountain tuff are presented here. As phases of the research project are completed, well-quantified estimates will be made of performance of mechanical excavators in the Yucca Mountain tuffs.

153 Performance assessment calculational exercises (PACE-90): Overview and summary. Barnard, R.W. (Sandia National Labs., Albuquerque, NM (United States)); Dockery, H.A. pp. 1189-1197 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

PACE-90 was undertaken by the Yucca Mountain Site Characterization Project in order to develop expertise in computational capabilities and to aid in identification of critical elements and processes necessary for performance assessment. One- and two-dimensional codes simulated groundwater flow and transport of selected radionuclides through Yucca Mountain for a period of 100,000 years. Using an groundwater percolation flux of 0.01 mm/yr and a new interpretation of the hydrostratigraphy, the calculations showed no contamination reaching the water table. However, these results should be interpreted with caution because the calculations were based on unvalidated conceptual models and parameters. In a separate part of the exercise, disturbed-condition problems (human intrusion, climate change, and volcanism) were developed as a basis for future calculations.

154 Estimating geochemical behavior of concretes to be placed at Yucca Mountain. Hinkebein, T.E. (Sandia National Labs., Albuquerque, NM (United States)); Gardiner, M.A. pp. 1404-1409 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The interactions of J-13 water with cementitious materials were examined at 25°C using the geochemical code EQ3NR/EQ6. Results of the modeling suggested the following conclusions: (1) Solution chemistry for calcium-rich concretes was similar to that for silica-rich concretes. (2) Solution pH was strongly buffered by J-13 added concrete. For larger amounts of concrete the pH was dominated by the concrete and typically had values near 12. (3) If ettringite or excess portlandite are present, their decomposition opens the concrete structure. Excess silica reacts with hydrogarnet to tighten the concrete structure. (4) The permeability changes for the limited conditions discussed here are small.

155 Preliminary assessment of the impact of conceptual model uncertainty on site performance. Gallegos, D.P. (Sandia National Labs., Albuquerque, NM (United States)); Pohl, P.I.; Updegraff, C.D. pp. 1469-1479 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Performance assessment modeling for high-level radioactive waste (HLW) disposal incorporates three different types of uncertainty. These include data and parameter uncertainty, modeling uncertainty (conceptual, mathematical, and numerical), and uncertainty associated with predicting future state of the system. In this study, the potential impact of conceptual model uncertainty on the performance of a hypothetical high-level radioactive waste disposal site in unsaturated, fractured tuff has been assessed for a given group of conceptual models. This was accomplished by taking a series of six, one-dimensional conceptual models, which differed only by the fundamental assumptions used to develop them, and conducting ground water flow and radionuclide transport simulations. Complementary cumulative distribution functions (CCDFs) of integrated radionuclide release to the water table indicate that differences in basic assumptions can have a significant impact on the performance of the site. Because each of the conceptual models

employed the same mathematical and numerical models, did not consider future states of the system, changes in the CCDF could be attributed primarily to differences in conceptual modeling assumptions.

156 Scenario evolution: Interaction between event tree construction and numerical analyses. Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Dockery, H.A.; Dunn, E.; MacIntyre, A.T. pp. 1480-1486 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Construction of well-posed scenarios for the range of conditions possible at any proposed repository site is a critical first step to assessing total system performance. Even tree construction is the method that is being used to develop potential failure scenarios for the proposed nuclear waste repository at Yucca Mountain. An event tree begins with an initial event or condition. Subsequent events are listed in a sequence, leading eventually to release of radionuclides to the accessible environment. Ensuring the validity of the scenarios requires iteration between problems constructed using scenarios contained in the event tree sequence, experimental results, and numerical analyses. Details not adequately captured within the tree initially may become more apparent as a result of analyses. To illustrate this process, we discuss the iterations used to develop numerical analyses for PACE-90 using basaltic igneous activity and human-intrusion event trees.

157 A formalism to generate probability distributions for performance-assessment modeling. Kaplan, P.G. (Sandia National Labs., Albuquerque, NM (United States)). pp. 1487-1490 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Estimates of compliance with regulatory criteria for nuclear waste respositories are often based on Monte Carlo simulation, a process which requires that the distribution of the model input parameters be specified. For many parameters there are sparse data available. A formalism is presented for generating probability distributions of parameters used in performance-assessment modeling. The formalism is used when data are either sparse or nonexistent. The appropriate distribution is a function of the known or estimated constraints and is chosen to maximize a quantity known as Shannon's informational entropy. The formalism is applied to a parameter used in performance-assessment modeling. The functional form of the model that defines the parameter, data from the actual field site, and natural analog data are analyzed to estimate the constraints. A beta probability distribution of the example parameter is generated after finding four constraints.

158 Characterization uncertainty and its effects on models and performance. Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States)); Treadway, A.H. pp. 1491-1495 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Geostatistical simulation is being used to develop multiple geologic models of rock properties at the proposed Yucca Mountain repository site. Because each replicate model contains the same known information, and is thus essentially indistinguishable statistically from others, the differences between models may be thought of as representing the uncertainty in the site description. The variability among performance measures, such as ground water travel time, calculated using these replicate models therefore quantifies the uncertainty in performance that arises from uncertainty in site characterization.

159 Uncertainty analysis of preclosure accident doses for the Yucca Mountain repository. Ma, C.W. (Bechtel National Inc., San Francisco, CA (United States)); Miller, D.D.; Zavoshy, S.J.; Jardine, L.J. pp. 1694-1703 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This study presents a generic methodology that can be used to evaluate the uncertainty in the calculated accidental offsite doses at the Yucca Mountain repository during the preclosure period. For demonstration purposes, this methodology is applied to two specific accident scenarios: The first involves a crane dropping an open container with consolidated fuel rods, the second involves container failure during emplacement or removal operations. The uncertainties of thirteen parameters are quantified by various types of probability distributions. The Latin Hypercube Sampling method is used to evaluate the uncertainty of the offsite dose. For the crane-drop scenario with concurrent filter failure, the doses due to the release of airborne fuel particles are calculated to be 0.019, 0.32, and 2.8 rem at confidence levels of 10%, 50%, and 90%, respectively. For the container failure scenario with concurrent filter failure, the 90% confidence-level dose is 0.21 rem.

160 Total-system analyzer for performance assessment of Yucca Mountain. Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Lauffer, F.C.; Cummings, J.C.; Zieman, N.B. pp. 1734 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Total-System Analyzer is a modular computer program for probabilistic total-system performance calculations. The code employs stratified random sampling from model parameter distribution functions to generate multiple "realizations" of the system. The results of flow and transport calculations for each realization are combined into a probability distribution function of the system response as indicated by the performance measure. We give a detailed description of the code and present results for four example problems simulating the release of radionuclides from a proposed high-level-waste repository at Yucca Mountain,

Nevada. The example simulations illustrate the impact of significant variation of percolation flux and sorption on radionuclide releases. We discuss the effects of numerical sampling error and of correlations among the model parameters.

161 A working definition of scenario and a method of scenario construction. Barr, G.E. (Sandia National Laboratories, Albuquerque, NM (United States)); Dunn, E. pp. 1093-1098 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The event-tree method of scenario construction has been chosen for the Yucca Mountain performance assessment. Its applicability and suitability to the problem are discussed and compared with those of the Nuclear Regulatory Commission (NRC) method. The event-tree method is appropriate for an incompletely characterized site, where there must be an evolving understanding, over time, of the processes at work, for a site that may require analysis of details in specific context, and when the scenario functions to guide site characterization. Anticipating the eventual requirement for using the NRC method, we show that the event-tree method can be translated to the NRC format after final scenario screening.

162 Recent developments in stochastic modeling and upscaling of hydrologic properties in Tuff. Rautman, C.A. (Sandia National Laboratories, Albuquerque, NM (United States)); Robey, T.H. pp. 1437-1445 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A set of detailed geostatistical simulations of porosity has been produced for a layered stratigraphic sequence of welded and non-welded volcanic tuffs at Yucca Mountain, Nevada. The simulations are produced using a composite model of spatial continuity and they are highly conditioned to abundant drill hole (core) information. A set of derivative simulations of saturated hydraulic conductivity has been produced, in the absence of conditioning data, using a cross-variable relationship developed from similar data elsewhere. The detailed simulations reproduce both the major stratigraphic units and finer scale layering indicated by the drill hole data. These simulations have been scaled up several orders of magnitude to represent block-scale effective hydrologic properties suitable for use in numerical modeling of groundwater flow and transport. The upscaling process involves the reformulation of a previously reported method that iteratively adapts and initial arbitrary grid to 'homogenize' the detailed hydraulic properties contained within the adjusted cell limits and to minimize the size of cells in highly heterogeneous regions. Although the computation of the block-effective property involves simple numerical averaging, the blocks over which these averages are computed are relatively homogeneous, which reduces the numerical difficulties involved in averaging non-additive properties, such as permeability. The entire process of simulation and upscaling is rapid and computationally efficient compared with alternative techniques. It is thus suitable for the Monte Carlo evaluation of the uncertainty in site characterization as it affects the results of groundwater flow and transport calculations.

163 Characterization of porosity in support of mechanical property analysis. Price, R.H. (Sandia National Laboratories, Albuquerque, NM (United States)); Martin, R.J. III; Boyd, P.J. pp. 1847-1853 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The general applicability of laboratory data for engineering purposes is a prime concern for the design and licensing of a potential repository of high level nuclear waste at Yucca Mountain. In order for the results of experiments to be applicable to the repository scale, the data must be scaled to in situ size and conditions. Previous laboratory investigations of tuff have shown that porosity has a dominant, general effect on mechanical properties. As a result, it is very important for the interpretation of mechanical property data that porosity is measured on each sampled test. Porosity alone, however, does not address all of the issues important to mechanical behavior. Variability in size and distribution of pore space produces significantly different mechanical properties. A nondestructive technique for characterizing the internal structure of the sample prior to testing is being developed and the results are being analyzed. The information obtained from this technique can help in both qualitative and quantitative interpretation of test results.

164 Small-scale behavior of single gravity-driven fingers in an initially dry fracture. Nicholl, M.J. (Sandia National Laboratories, Albuquerque, NM (United States)); Glass, R.J.; Nguyen, H.A. pp. 2023-2032 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Gravity-driven infiltration instability under full-field conditions in initially dry, rough-walled analog fractures and natural fractures in volcanic tuff similar to that found at Yucca Mountain has been demonstrated. Experiments investigating the behavior of individual, gravity-driven fingers in an initially dry, rough-walled analog fracture are presented. Fingers were initiated from constant flow to a point source. Finger structure is described in detail; specific phenomena observed include: desaturation behind the finger-tip bifurcation, and formation of dendritic sub-fingers. Measurements were made of finger-tip velocity, finger width, and finger-tip length. Non-dimensional forms of the measured variables are analyzed relative to the independent parameters, flow rate and gravitational gradient.

165 Modeling gravity-driven fingering in rough-walled fractures using modified percolation theory. Glass, R.J. (Sandia National Laboratories, Albuquerque, NM (United States)). pp. 2042-2052 of High Level Radioactive Waste Management: Proceedings. Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Pore scale invasion percolation theory is modified for imbibition of wetting fluids into fractures. The effects of gravity,

local aperture field geometry, and local in-plane air/water interfacial curvature are included in the calculation of aperture filling potential which controls wetted structure growth within the fracture. The inclusion of gravity yields fingers oriented in the direction of the gravitational gradient. These fingers widen and tend to meander and branch more as the gravitational gradient decrease. In-plane interfacial curvature also greatly affects the wetted structure in both horizontal and non-horizontal fractures causing the formation of macroscopic wetting fronts. The modified percolation model is used to simulate imbibition into an analogue rough-walled fracture where both fingering and horizontal imbibition experiments were previously conducted. Comparison of numerical and experimental results showed reasonably good agreement. This process oriented physical and numerical modeling is a necessary step toward including gravity-driven fingering in models of flow and transport through unsaturated, fractured rock, similar to that found at Yucca Mountain.

166 Wetting front instability in an initially wet unsaturated fracture. Nicholl, M.J. (Sandia National Laboratories, Albuquerque, NM (United States)); Glass, R.J.; Nguyen, H.A. pp. 2061-2070 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 DOE Contract AC04-76DP00789. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Experimental results exploring gravity-driven wetting from instability in a pre-wetted, rough-walled analog fractures such as those at Yucca Mountain are presented. Initial conditions considered include a uniform moisture field wetted to field capacity of the analog fracture and the structured moisture field created by unstable infiltration into an initially dry fracture. As in previous studies performed under dry initial conditions, instability was found to result both at the cessation of stable infiltration and at flux lower than the fracture capacity under gravitational driving force. Individual fingers were faster, narrower, longer, and more numerous than observed under dry initial conditions. Wetting fronts were found to follow existing wetted structure, providing a mechanism for rapid recharge and transport.

167 (DOE/ER/14352–1, pp. 443-446) **Construction monitoring activities in the Yucca Mountain ESF Starter Tunnel.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Costin, L.S.; Brechtel, C.E. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

An underground test facility known as the Exploratory Studies Facility (ESF) is planned as part of the characterization of a site for a potential high-level nuclear waste repository at Yucca Mountain, NV. The first part of the ESF that will be constructed is the North Ramp Starter Tunnel (NRST), which will provide a facility for launching the tunnel-boring machine to be used in the construction of the ESF. Geotechnical monitoring activities are planned for the NRST to provide for the collection of data to confirm design concepts and to enhance safety during construction. This paper describes the activities to be conducted and their objectives. The construction monitoring activities are part of a study defined in the In Situ Design Verification Study Plan. The objectives of this study are to (1) monitor and observe the long-term behavior of openings in a range of ground conditions in the repository host rock, and (2) to observe and evaluate the construction of the ESF with respect to implications for repository construction and performance. Initiating geotechnical monitoring activities in the NRST will allow geotechnical data required to confirm adequate design, construction and long term performance to be collected from the very beginning of underground construction. In addition, the planned monitoring is consistent with standard practice for assuring quality and safety during similar rock excavation for civil construction. The geotechnical monitoring activities addressed by this experiment plan are grouped into three tasks: (1) evaluation of mining methods, (2) monitoring of ground support systems and (3) monitoring drift stability. A general description of each of the tasks is presented below.

168 (DOE/ER/14352–1, pp. 451-454) **Thermal-mechanical analyses for the Yucca Mountain Project.** Jung, J. (Sandia National Labs., Albuquerque, NM (United States)); Ryder, E.E. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

As part of Sandia National Laboratories' (SNL) work in support of the Yucca Mountain Site Characterization Project (YMP), thermal-mechanical analyses are being performed that assist in the design, operations and waste retrieval planning, and performance assessment. In the design area, thermal-mechanical analyses help address safety issues by providing insight into the stability of openings and the related ground support requirements. Also, these analyses help establish thermal design goals for the potential repository. Operationally, predictions of the thermal environment form part of the necessary input for designing the ventilation systems for both emplacement and retrieval operations. In the area of performance assessment, thermal-mechanical models assist in estimating the potential of transporting radionuclides from waste packages. This paper is intended to provide an overview of the thermal-mechanical efforts as SNL in support of the Yucca Mountain Site Characterization Project.

169 (DOE/ER/14352–1, pp. 455-458) **An overview of the Yucca Mountain Site Characterization Project field test program for evaluating seal performance.** Fernandez, J.A. (Sandia National Labs., Albuquerque, NM (United States)); Case, J.B. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Sandia National Laboratories (SNL), a participant in the Yucca Mountain Site Characterization Project, is responsible for implementing the repository sealing program. One aspect of this program is the definition and fielding of tests related to sealing components which comprise the sealing subsystem. The sealing components are identified in the Site Characterization Plan (U.S. DOE, 1988) and Fernandez et al. (1987). These include an anchor-to-bedrock plug, single dams (or single bulkheads with not settlement), general shaft fill, drift backfill, station and shaft plugs, double bulkheads, backfilled sumps, and channels in a backfilled room. The materials used to create these components are cementitious and earthen. Earthen materials will be used for as

many applications as possible to minimize potential degradation of physical properties and potential adverse effects on ground-water chemistry in the repository environment. In places where low strength is acceptable, earthen materials may be used. The most likely application for cementitious materials is where high strength and low deformability may be required. (Hinkebein and Fernandez, 1989). The basis for performing seal component testing is divided into two parts: regulatory requirements and technical requirements. The regulatory requirements are derived primarily from Title 10 Code of Federal Regulations, Part 60 (10 CFR 60) (U.S. Nuclear Regulatory Commission, 1986). The technical requirements are defined by the uncertainties associated with seal performance and seal emplacement. Both categories of requirements are discussed below.

170 (DOE/ER/14352–1, pp. 685-688) **Hydromechanical response of a fracture undergoing compression and shear.** Olsson, W.A. (Sandia National Labs., Albuquerque, NM (United States)); Brown, S.R. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Coupled fluid flow-rock deformation processes can be important in several geotechnical and natural phenomena. Water may flow through rock joints or faults into mined openings or around dams, stress sensitive fractures may affect hydrocarbon reservoir management, or radionuclides may migrate along joints away from underground nuclear waste repositories. The effect of normal stress and closure on fracture flow rates has been much studied. The effect of slip on fracture flow has been estimated theoretically, but there has been little experimental work done on this effect. Olsson combined the rotary shear test with the radial flow geometry to study the effect of joint shear on fracture flow rates for a sawed and ground surface in tuff. In this study, we extend this work to the study of a natural fracture from drill core. We evaluate the effects of normal stress and shear offset on fluid flow rates with predictions from a microscopic theory of surface contact constrained by surface roughness measurements.

171 (DOE/ER/14352–1, pp. 753-756) **The influence of strain rate and sample inhomogeneity on the moduli and strength of welded tuff.** Martin, R.J. III (New England Research, Inc., White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. Wisconsin Univ., Madison, WI (United States). 1993. DOE Contract AC04-76DP00789. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The strength of brittle rock is not a single values function of confining pressure and temperature. Strength is, in fact, a rather ambiguous term and depends on many parameters such as the loading conditions (in particular, rate), the effective pressure, composition of the pore fluid, the distribution of cracks and heterogeneities within the rock, and the scale of the sample under consideration. It is well known that brittle rocks are strongly influenced by the moisture content in the pore space. Water facilitates stress corrosion at the tips of micro-cracks under load. The effect of stress corrosion cracking in brittle rocks is to reduce the strength with increasing partial pressure of water, increasing temperature, and decreasing loading rate. In most cases, it is difficult to document the partial pressure of water within the pore space. Complete water saturation provides the most unambiguous condition. In light of the significance of environmental parameters and strain rate on the strength of rocks, it is important that the functional relation between each of these properties be considered when incorporated into models for the potential nuclear waste repository at Yucca Mountain, Nevada. This report address the effect of strain rate and heterogeneity of the strength and moduli of fully saturated tuff specimens from the potential repository horizon at Yucca Mountain.

172 (SAND–92-0847) **The effect of frequency on Young's modulus and seismic wave attenuation.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States). YMP Performance Assessment Applications Dept.); Martin, R.J. III; Haupt, R.W. Sandia National Labs., Albuquerque, NM (United States). Jul 1994. 57p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94017498. Source: OSTI; NTIS; INIS; GPO Dep.

Laboratory experiments were performed to measure the effect of frequency, water-saturation, and strain amplitude on Young's modulus and seismic wave attenuation on rock cores recovered on or near the site of a potential nuclear waste repository at Yucca Mountain, Nevada. The purpose of this investigation is to perform the measurements using four techniques: cyclic loading, waveform inversion, resonant bar, and ultrasonic velocity. The measurements ranged in frequency between 10^{-2} and 10^{6} Hz. For the dry specimens Young's modulus and attenuation were independent of frequency; that is, all four techniques yielded nearly the same values for modulus and attenuation. For saturated specimens, a frequency dependence for both Young's modulus and attenuation was observed. In general, saturation reduced Young's modulus and increased seismic wave attenuation. The effect of strain amplitude on Young's modulus and attenuation was measured using the cyclic loading technique at a frequency of 10^{-1} Hz. The effect of strain amplitude in all cases was small. For some rocks, such as the potential repository horizon of the Topopah Spring Member tuff (TSw2), the effect of strain amplitude on both attenuation and modulus was minimal.

173 (SAND–93-1157) **Geometric moire method of strain analysis with displacement discontinuities: Yucca Mountain Site Characterization Project.** Brown, S.R. (Sandia National Labs., Albuquerque, NM (United States). Geomechanics Dept.); Hardy, R.D. Sandia National Labs., Albuquerque, NM (United States). Aug 1994. 57p. Sponsored by USDOE, Washington, DC (United States);Department of Defense, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95001114. Source: OSTI; NTIS; INIS; GPO Dep.

Prediction of the deformation behavior of large engineering structures in jointed rock under a specified loading history requires the extensive use of numerical simulation. For example, the evaluation of the stability of the openings for the Exploratory Studies Facility and a potential repository for high-level nuclear waste at Yucca Mountain, Nevada will require computer codes capable of predicting slip on rock joints resulting from changes in thermal stresses. The testing and ultimate validation of these complex finite element computer codes is an important step in their development before their use as a design tool for an engineering structure or for the study of some other practical problem. While field tests may be ultimately necessary, the authors propose

a different and more thorough approach where early tests are done on a bench scale with easily characterized materials and geometries. For these bench-scale tests, the basic approach is to construct a laboratory specimen with a known geometry from an easily characterized material. Digital video imaging combined with the geometric moire fringe method of strain analysis is used to measure and derive the displacements on the sample under load. Here the authors present the method of acquiring and analyzing the moire data and give an analysis of its problems and benefits.

174 (SAND–93-1184) **A strategy to seal exploratory boreholes in unsaturated tuff: Yucca Mountain Site Characterization Project.** Fernandez, J.A. (Sandia National Labs., Albuquerque, NM (United States)); Case, J.B.; Givens, C.A.; Carney, B.C. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 522p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94015043. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents a strategy for sealing exploratory boreholes associated with the Yucca Mountain Site Characterization Project. Over 500 existing and proposed boreholes have been considered in the development of this strategy, ranging from shallow (penetrating into alluvium only) to deep (penetrating into the groundwater table). Among the comprehensive list of recommendations are the following: Those boreholes within the potential repository boundary and penetrating through the potential repository horizon are the most significant boreholes from a performance standpoint and should be sealed. Shallow boreholes are comparatively insignificant and require only nominal sealing. The primary areas in which to place seals are away from high-temperature zones at a distance from the potential repository horizon in the Paintbrush nonwelded tuff and the upper portion of the Topopah Spring Member and in the tuffaceous beds of the Calico Hills Unit. Seals should be placed prior to waste emplacement. Performance goals for borehole seals both above and below the potential repository are proposed. Detailed construction information on the boreholes that could be used for future design specifications is provided along with a description of the environmental setting, i.e., the geology, hydrology, and the in situ and thermal stress states. A borehole classification scheme based on the condition of the borehole wall in different tuffaceous units is also proposed. In addition, calculations are presented to assess the significance of the boreholes acting as preferential pathways for the release of radionuclides. Design calculations are presented to answer the concerns of when, where, and how to seal. As part of the strategy development, available technologies to seal exploratory boreholes (including casing removal, borehole wall reconditioning, and seal emplacement) are reviewed.

175 (SAND–93-1891) **JAC2D: A two-dimensional finite element computer program for the nonlinear quasi-static response of solids with the conjugate gradient method: Yucca Mountain Site Characterization Project.** Biffle, J.H.; Blanford, M.L. Sandia National Labs., Albuquerque, NM (United States). May 1994. 128p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94014302. Source: OSTI; NTIS; INIS; GPO Dep.

JAC2D is a two-dimensional finite element program designed to solve quasi-static nonlinear mechanics problems. A set of continuum equations describes the nonlinear mechanics involving large rotation and strain. A nonlinear conjugate gradient method is used to solve the equations. The method is implemented in a two-dimensional setting with various methods for accelerating convergence. Sliding interface logic is also implemented. A four-node Lagrangian uniform strain element is used with hourglass stiffness to control the zero-energy modes. This report documents the elastic and isothermal elastic/plastic material model. Other material models, documented elsewhere, are also available. The program is vectorized for efficient performance on Cray computers. Sample problems described are the bending of a thin beam, the rotation of a unit cube, and the pressurization and thermal loading of a hollow sphere.

176 (SAND–93-2365) **Laboratory measurements of frictional slip on interfaces in a polycarbonate rock mass model.** Brown, S.R. (Sandia National Labs., Albuquerque, NM (United States). Geomechanics Dept.). Sandia National Labs., Albuquerque, NM (United States). Aug 1994. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95000709. Source: OSTI; NTIS; INIS; GPO Dep.

The evaluation of the stability of the openings for the Exploratory Studies Facility and a potential repository for high-level nuclear waste at Yucca Mountain, Nevada will require computer codes capable of predicting slip on rock joints resulting from changes in thermal stresses. The geometrical method of analysis of moire fringe analysis was used to evaluate the magnitude and extent of frictional sliding in a layered polycarbonate rock mass model containing a circular hole. Slips were observed in confined zones around the hole and micron resolutions were obtained. Unpredicted and uncontrolled uniform slip of several interfaces in the model were observed giving considerable uncertainty in the boundary conditions of the model, perhaps making detailed comparison with numerical models impossible.

177 (SAND–93-2675-Vol.1) **Total-system performance assessment for Yucca Mountain - SNL second iteration (TSPA-1993): Volume 1.** Wilson, M.L. (and others); Gauthier, J.H.; Barnard, R.W.; Barr, G.E.; Dockery, H.A.; Dunn, E.; Eaton, R.R.; Guerin, D.C.; Lu, N.; Martinez, M.J. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 338p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94013818. Source: OSTI; NTIS; INIS; GPO Dep.

Sandia National Laboratories has completed the second iteration of the periodic total-system performance assessments (TSPA-93) for the Yucca Mountain Site Characterization Project (YMP). These analyses estimate the future behavior of a potential repository for high-level nuclear waste at the Yucca Mountain, Nevada, site under consideration by the Department of Energy. TSPA-93 builds upon previous efforts by emphasizing YMP concerns relating to site characterization, design, and regulatory compliance. Scenarios describing expected conditions (aqueous and gaseous transport of contaminants) and low-probability events (human-intrusion drilling and volcanic intrusion) are modeled. The hydrologic processes modeled include estimates of the perturbations to ambient conditions caused by heating of the repository resulting from radioactive decay of the waste. Hydrologic parameters and parameter probability distributions have been derived from available site data. Possible future climate changes are modeled by considering two separate groundwater infiltration conditions: "wet" with a mean flux of 10 mm/yr, and "dry" with a mean flux of 0.5 mm/yr. Two alternative waste-package designs and two

alternative repository areal thermal power densities are investigated. One waste package is a thin-wall container emplaced in a vertical borehole, and the second is a container designed with corrosion-resistant and corrosion-allowance walls emplaced horizontally in the drift. Thermal power loadings of 57 kW/acre (the loading specified in the original repository conceptual design) and 114 kW/acre (a loading chosen to investigate effects of a "hot repository") are considered. TSPA-93 incorporates significant new detailed process modeling, including two- and three-dimensional modeling of thermal effects, groundwater flow in the saturated-zone aquifers, and gas flow in the unsaturated zone.

178 (SAND–93-2675-Vol.2) **Total-system performance assessment for Yucca Mountain - SNL second iteration (TSPA-1993): Volume 2.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Barr, G.E.; Dockery, H.A.; Dunn, E.; Eaton, R.R.; Martinez, M.J.; Gauthier, J.H.; Guerin, D.C.; Lu, N. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 477p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94013819. Source: OSTI; NTIS; INIS; GPO Dep.

Sandia National Laboratories has completed the second iteration of the periodic total-system performance assessments (TSPA-93) for the Yucca Mountain Site Characterization Project (YMP). These analyses estimate the future behavior of a potential repository for high-level nuclear waste at the Yucca Mountain, Nevada, site under consideration by the Department of Energy. TSPA-93 builds upon previous efforts by emphasizing YMP concerns relating to site characterization, design, and regulatory compliance. Scenarios describing expected conditions (aqueous and gaseous transport of contaminants) and low-probability events (human-intrusion drilling and volcanic intrusion) are modeled. The hydrologic processes modeled include estimates of the perturbations to ambient conditions caused by heating of the repository resulting from radioactive decay of the waste. Hydrologic parameters and parameter probability distributions have been derived from available site data. Possible future climate changes are modeled by considering two separate groundwater infiltration conditions: "wet" with a mean flux of 10 mm/yr, and "dry" with a mean flux of 0.5 mm/yr. Two alternative waste-package designs and two alternative repository areal thermal power densities are investigated. One waste package is a thin-wall container emplaced in a vertical borehole, and the second is a container designed with corrosion-resistant and corrosion-allowance walls emplaced horizontally in the drift. Thermal power loadings of 57 kW/acre (the loading specified in the original repository conceptual design) and 114 kW/acre (a loading chosen to investigate effects of a "hot repository") are considered. TSPA-93 incorporates significant new detailed process modeling, including two- and three-dimensional modeling of thermal effects, groundwater flow in the saturated-zone aquifers, and gas flow in the unsaturated zone.

179 (SAND–93-7079) **Effect of boundary conditions on the strength and deformability of replicas of natural fractures in welded tuff: Data analysis.** Wibowo, J. (Colorado Univ., Boulder, CO (United States). Dept. of Civil, Environmental, and Architectural Engineering); Amadei, B.; Sture, S.; Price, R.H. Sandia National Labs., Albuquerque, NM (United States); Colorado Univ., Boulder, CO (United States). Dept. of Civil, Environmental, and Architectural Engineering. Apr 1994. 223p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94013363. Source: OSTI; NTIS; INIS; GPO Dep.

Assessing the shear behavior of intact rock & rock fractures is an important issue in the design of a potential nuclear waste repository at Yucca Mountain Nevada. Cyclic direct shear experiments were conducted on replicas of three natural fractures and a laboratory-developed tensile fracture of welded tuff. The tests were carried out under constant normal loads or constant normal stiffnesses with different initial normal load levels. Each test consisted of five cycles of forward and reverse shear motion. Based on the results of the shear tests conducted under constant normal load, the shear behavior of the joint replicas tested under constant normal stiffness was predicted by using the graphical analysis method of Saeb (1989), and Amadei and Saeb (1990). Comparison between the predictions and the actual constant stiffness direct shear experiment results can be found in a report by Wibowo et al. (1993b). Results of the constant normal load shear experiments are analyzed using several constitutive models proposed in the rock mechanics literature for joint shear strength, dilatancy, and joint surface damage. It is shown that some of the existing models have limitations. New constitutive models are proposed and are included in a mathematical analysis tool that can be used to predict joint behavior under various boundary conditions.

180 (SAND–94-0087C) **Effect of fractures on repository dryout.** Eaton, R.R. Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–64: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014184. Source: OSTI; NTIS; INIS; GPO Dep.

Calculations of water flow through Yucca Mountain show significant dryout and water perching in the vicinity of the proposed nuclear waste repository. These calculations also show that the extent of the dryout and perched water zones is a strong function of the material characteristics which are used to represent the fracture zones. The results show that for 100 μm fracture case appreciable dryout and perched regions exist. When 1 μm fractures are used no dryout or perched regions are calculated.

181 (SAND–94-0155C) **Development of stochastic indicator models of lithology, Yucca Mountain, Nevada.** Rautman, C.A. (Sandia National Labs., Albuquerque, NM (United States)); Robey, T.H. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–66: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014177. Source: OSTI; NTIS; INIS; GPO Dep.

Indicator geostatistical techniques have been used to produce a number of fully three-dimensional stochastic simulations of large-scale lithologic categories at the Yucca Mountain site. Each realization reproduces the available drill hole data used to condition the simulation. Information is propagated away from each point of observation in accordance with a mathematical model of spatial continuity inferred through soft data taken from published geologic cross sections. Variations among the simulated models collectively represent uncertainty in the lithology at unsampled

locations. These stochastic models succeed in capturing many major features of welded-nonwelded lithologic framework of Yucca Mountain. However, contacts between welded and nonwelded rock types for individual simulations appear more complex than suggested by field observation, and a number of probable numerical artifacts exist in these models. Many of the apparent discrepancies between the simulated models and the general geology of Yucca Mountain represent characterization uncertainty, and can be traced to the sparse site data used to condition the simulations. Several vertical stratigraphic columns have been extracted from the three-dimensional stochastic models for use in simplified total-system performance assessment exercises. Simple, manual adjustments are required to eliminate the more obvious simulation artifacts and to impose a secondary set of deterministic geologic features on the overall stratigraphic framework provided by the indictor models.

182 (SAND–94-0261C) **Analyses of releases due to drilling at the potential Yucca Mountain repository.** Barnard, R.W. Sandia National Labs., Albuquerque, NM (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–28: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009282. Source: OSTI; NTIS; INIS; GPO Dep.

Radionuclide releases due to drilling into the potential Yucca Mountain nuclear-waste repository have been evaluated as part of a recent total-system performance assessment. The probability that a drilling event intersects a waste package is a function of the sizes of the drill bit and the waste package, and the density of placement of the containers in the repository. The magnitude of the releases is modeled as a random function that also depends on the amount of decay the radionuclides have undergone. Four cases have been analyzed, representing the combinations of two waste-package designs (small-capacity, thin-wall, vertically emplaced; and large-capacity, thick-wall, horizontally emplaced) and two repository layouts (lower thermal power dissipation, low waste-package placement density; and higher thermal power dissipation, high waste-package placement density). The results show a fairly pronounced dependence on waste-package design and slight dependence on repository layout. Given the assumptions in the model, releases from the larger containers are 4–5 times greater than from the smaller packages.

183 (SAND–94-0278) **Test interference calculations for the Yucca Mountain Project ESF thermomechanical experiments: Yucca Mountain Site Characterization Project.** Holland, J.F. (Technadyne, Albuquerque, NM (United States)); Pott, J. Sandia National Labs., Albuquerque, NM (United States). Oct 1994. 106p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95001856. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Project, managed by the U.S. Department of Energy, is examining the feasibility of siting a repository for high-level nuclear waste at Yucca Mountain on and adjacent to the Nevada Test Site. As part of the site characterization, a series of in situ thermomechanical experiments are planned, which are to be conducted in the Exploratory Studies Facility (ESF). In this report, the results of preliminary analyses of three of the in situ thermomechanical experiments are presented. The major objective of these analyses was to determine the boundaries of the thermally perturbed zones surrounding each of the experiments. The boundaries of the thermal zones needs to be known in order to avoid test interference between the experiments planned for the ESF. A second objective of these analyses was to calculate the displacements and stresses associated with the experiments, in order to advance the planning of the experiments.

184 (SAND–94-0305C) **Text for Mechanical and bulk properties in support of ESF design issues.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Martin, R.J.; Boyd, P.J.; Noel, J.S. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–78: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94015280. Source: OSTI; NTIS; INIS; GPO Dep.

An intensive laboratory investigation is being performed to determine the mechanical properties of tuffs for the Yucca Mountain Site Characterization Project (YMP). Most recently, experiments are being performed on tuff samples from a series of drill holes along the proposed alignment of the Exploratory Study Facilities (ESF) north ramp. Unconfined compression and indirect tension experiments are being performed and the results are being analyzed with the help of bulk property information. The results on samples from five of the drill holes are presented here. In general, the properties vary widely, but are highly dependent on the sample porosity.

185 (SAND–94-0306C) **Relation between static and dynamic rock properties in welded and nonwelded tuff.** Price, R.H. (Sandia National Labs., Albuquerque, NM (United States)); Boyd, P.J.; Noel, J.S.; Martin, R.J. III. Sandia National Labs., Albuquerque, NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940642–6: 1. North American rock mechanics symposium, Austin, TX (United States), 1-3 Jun 1994). Order Number DE94014176. Source: OSTI; NTIS; INIS; GPO Dep.

An integral part of the licensing procedure for the potential nuclear waste repository at Yucca Mountain, Nevada involves accurate prediction of the in situ rheology for design and construction of the facility and emplacement of the canisters containing radioactive waste. The data required as input to successful thermal and mechanical models of the behavior of the repository and surrounding lithologies include bulk density, grain density, porosity, compressional and shear wave velocities, elastic moduli, and compressional and tensile strengths. In this study a suite of experiments was performed on cores recovered from the USW-NRG-6 borehole drilled to support the Exploratory Studies Facility (ESF) at Yucca Mountain. USW-NRG-6 was drilled to a depth of 1100 feet through four thermal/mechanical units of Paintbrush tuff. A large data set has been collected on specimens recovered from borehole USW-NRG-6. Analysis of the results of these experiments showed that there is a correlation between fracture strength, Young's modulus, compressional wave velocity and porosity. Additional scaling laws relating; static Young's modulus and compressional wave velocity; and fracture strength and compressional wave velocity are promising. Since there are no other distinct differences in material properties, the scatter that is present at each fixed porosity suggests that the differences in the observed property can be related to the

pore structure of the specimen. Image analysis of CT scans performed on each test specimen are currently underway to seek additional empirical relations to aid in refining the correlations between static and dynamic properties of tuff.

186 (SAND–94-0326C) **Scaling behavior of gas permeability measurements in volcanic tuffs.** Tidwell, V.C. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–65: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014178. Source: OSTI; NTIS; INIS; GPO Dep.

One of the critical issues facing the Yucca Mountain site characterization and performance assessment programs is the manner in which property scaling is addressed. Property scaling becomes an issue whenever heterogeneous media properties are measured at one scale but applied at another. A research program has been established to challenge current understanding of property scaling with the aim of developing and testing models that describe scaling behavior in a quantitative manner. Scaling of constitutive rock properties is investigated through physical experimentation involving the collection of suites of gas-permeability data measured over a range of discrete scales. The approach is to systematically isolate those factors believed to influence property scaling and investigate their relative contributions to overall scaling behavior. Two blocks of tuff, each exhibiting differing heterogeneity structure, have recently been examined. Results of the investigation show very different scaling behavior, as exhibited by changes in the distribution functions and variograms, for the two tuff samples. Even for the relatively narrow range of measurement scales employed significant changes in the distribution functions, variograms, and summary statistics occurred. Because such data descriptors will likely play an important role in calculating effective media properties, these results demonstrate both the need to understand and accurately model scaling behavior.

187 (SAND–94-0343C) **Thermal and seismic impacts on the North Ramp at Yucca Mountain.** Lin, M. (Agapito (J.F.T.) and Associates, Inc., Grand Junction, CO (United States)); Hardy, M.P.; Jung, J. Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–41: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010389. Source: OSTI; NTIS; INIS; GPO Dep.

The impacts of thermal and seismic loads on the stability of the Exploratory Studies Facility North Ramp at Yucca Mountain were assessed using both empirical and analytical approaches. This paper presents the methods and results of the analyses. Thermal loads were first calculated using the computer code STRES3D. This code calculates the conductive heat transfer through a semi-infinite elastic, isotropic, homogeneous solid and the rafts thermally-induced stresses. The calculated thermal loads, combined with simulated earthquake motion, were then modeled using UDEC and DYNA3D, numerical codes with dynamic simulation capabilities. The thermal- and seismic-induced yield zones were post-processed and presented for assessment of damage. Uncoupled bolt stress analysis was also conducted to evaluate the seismic impact on the ground support components.

188 (SAND–94-0348C) **Construction monitoring activities in the ESF starter tunnel.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Carlisle, S. Sandia National Labs., Albuquerque, NM (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–42: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010386. Source: OSTI; NTIS; INIS; GPO Dep.

In situ design verification activities am being conducted in the North Ramp Starter Tunnel of the Yucca Mountain Project Exploratory Studies Facility. These activities include: monitoring the peak particle velocities and evaluating the damage to the rock mass associated with construction blasting, assessing the rock mass quality surrounding the tunnel, monitoring the performance of the installed ground support, and monitoring the stability of the tunnel. In this paper, examples of the data that have been collected and preliminary conclusions from the data are presented.

189 (SAND–94-0351C) **Some results from the second iteration of total-system performance assessment for Yucca Mountain.** Wilson, M.L. Sandia National Labs., Albuquerque, NM (United States). [1994]. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–45: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010380. Source: OSTI; NTIS; INIS; GPO Dep.

The second preliminary total-system performance assessment for the potential radioactive-waste-repository site at Yucca Mountain has recently been completed. This paper summarizes results for nominal aqueous and gaseous releases using the composite-porosity flow model. The results are found to be sensitive to the type of unsaturated-zone flow, to percolation flux and climate change, to saturated-zone dilution, to container-wetting processes and container-corrosion processes, to fuel-matrix alteration rate and radionuclide solubilities (especially for ^{237}Np), and to bulk permeability and retardation of gaseous ^{14}C. These are areas that should be given priority in the site-characterization program. Specific recommendations are given in the full report of the study.

190 (SAND–94-0414C) **An updated fracture-flow model for total-system performance assessment of Yucca Mountain.** Gauthier, J.H. (Spectra Research Inst., Albuquerque, NM (United States)). Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–68: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94014179. Source: OSTI; NTIS; INIS; GPO Dep.

Improvements have been made to the fracture-flow model being used in the total-system performance assessment of a potential high-level radioactive waste repository at Yucca Mountain, Nevada. The "weeps model" now includes (1) weeps of varied sizes, (2) flow-pattern fluctuations caused by climate change, and (3) flow-pattern perturbations caused by repository heat generation. Comparison with the original weeps model indicates that allowing weeps of varied sizes substantially reduces the number of weeps and the number of containers contacted by weeps. However, flow-pattern perturbations caused by either climate change or repository heat generation greatly increases the number of

containers contacted by weeps. In preliminary total-system calculations, using a phenomenological container-failure and radionuclide-release model, the weeps model predicts that radionuclide releases from a high-level radioactive waste repository at Yucca Mountain will be below the EPA standard specified in 40 CFR 191, but that the maximum radiation dose to an individual could be significant. Specific data from the site are required to determine the validity of the weep-flow mechanism and to better determine the parameters to which the dose calculation is sensitive.

191 (SAND–94-0443C) **Fracture-matrix interaction in Topopah Spring Tuff: Experiment and numerical analysis.** Glass, R.J. (Sandia National Labs., Albuquerque, NM (United States)); Tidwell, V.C.; Flint, A.L.; Peplinski, W.; Castro, Y. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–46: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010754. Source: OSTI; NTIS; GPO Dep.

Fracture-matrix interaction is investigated through combined physical and numerical experimentation. Two slabs of Topopah Spring Tuff are mated to form a vertical saw cut fracture to which water is supplied. X-ray imaging is used to obtain the matrix porosity field and transient saturation fields as water moves from the fracture into the matrix. Porosity, hydraulic conductivity, and pressure/saturation relations of the matrix are measured on small cores taken from adjacent rock. Correlations between hydraulic properties and porosity are developed and modeled. Numerical simulations using TOUGH2 are accomplished with a series of property fields of increasing detail. Property fields are modeled using the measured porosity field divided into 1, 3, 5, 11, and 21 porosity groups with the hydraulic properties assigned from the developed correlations and the average porosity within each group. Comparison with experimental results allows us to begin to evaluate current matrix property measurement techniques, specific matrix property models, property estimation procedures, and effects of matrix property variability.

192 (SAND–94-0668C) **Zeroing in on requirements: Sandia National Laboratories' approach to meaningful program improvement.** Friend, J.C. (MACTEC, Albuquerque, NM (United States)); Richards, R.R.; Jaramillo, C.P. Sandia National Labs., Albuquerque, NM (United States). [1994]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940985–4: American Society for Quality Control Energy and Environmental Quality Division conference, Tucson, AZ (United States), 18-21 Sep 1994). Order Number DE94015738. Source: OSTI; NTIS; GPO Dep.

The necessity to evaluate our participant Quality Assurance (QA) Program for the Yucca Mountain Site Characterization Project (YMP) against the Office of Civilian Radioactive Waste Management (OCRWM) Quality Assurance Requirements and Description (QARD) issued December 1992, presented an opportunity to improve the QA Program. For some time, the SNL YMP technical staff had complained that the QA requirements imposed on their work were cumbersome and inhibited their ability to perform investigations using scientific methods. There was some truth to this, since SNL had over the years developed some procedures with many detailed controls that were far beyond what was required by project QA requirements. This had occurred either as a result of responding to numerous audit findings with a "make the auditor happy" attitude or with an attempt to cover every contingency. Procedures affecting scientific work were authored by the technical staff in an effort to provide them with ownership of the process; unfortunately, there were problems. Procedures were inconsistent because of the varied writing styles and differing perceptions of the degree of QA controls required to implement the program. It was extremely difficult to get all of the technical staff to accept the QA program as it was intended. These issues were endemic to the program and resulted in the QARD, the actual requirements, being written by a team of QA professionals. Once new QARD requirements were issued, an opportunity to evaluate the QA Program and to revise it not only to meet the QARD, but also to make it more plausible and meaningful to the technical staff, was presented. The discussion that follows will describe how the program was changed, will present both the positive and negative experiences observed by SNL personnel during the QARD transition, and will provide some recommendations.

193 (SAND–94-0712C) **Design verification activities in the Exploratory Studies Facility Starter Tunnel at Yucca Mountain.** Pott, J. (Sandia National Labs., Albuquerque, NM (United States)); Grant, J.; Carlisle, S. Sandia National Labs., Albuquerque, NM (United States). [1994]. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9406262–1: North American tunneling conference and exhibition, Denver, CO (United States), 6-9 Jun 1994). Order Number DE94019183. Source: OSTI; NTIS; INIS; GPO Dep.

In situ design verification activities are being conducted in the North Ramp Starter Tunnel of the Yucca Mountain Project Exploratory Studies Facility. These activities include: monitoring the construction blasting, evaluating the damage to the rock mass associated with construction, assessing the rock mass quality surrounding the tunnel, monitoring the performance of the installed ground support, and monitoring the stability of the tunnel. In this paper, examples of the data that have been collected and preliminary conclusions from the data are presented.

194 (SAND–94-1370C) **The effect of stratigraphic uncertainty on repository performance.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Robey, T.H. Sandia National Labs., Albuquerque, NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940815–71: International nuclear and hazardous waste management conference, Atlanta, GA (United States), 14-18 Aug 1994). Order Number DE94015750. Source: OSTI; NTIS; INIS; GPO Dep.

One source of uncertainty in calculating radionuclide releases from a potential radioactive-waste at Yucca Mountain, Nevada, is uncertainty in the unsaturated-zone stratigraphy. Uncertainty stratigraphy results from sparse drillhole data; possible variations in stratigraphy are modeled using the geostatistical method of indicator simulation. One-dimensional stratigraphic columns are generated and used for calculations of groundwater flow and radionuclide transport. There are indications of a dependence of release on hydrogeologic-unit thicknesses, but the resulting variation in release is smaller than variations produced by other sources of uncertainty.

195 (SAND–94-1995) **Mechanical properties of seven fractures from drillholes NRG-4 and NRG-6 at Yucca Mountain, Nevada.** Olsson, W.A. (Sandia National

Labs., Albuquerque, NM (United States). Geomechanics Dept.); Brown, S.R. Sandia National Labs., Albuquerque, NM (United States). Nov 1994. 42p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE95003470. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project has been assigned the task of determining the suitability of the Yucca Mountain site. Among the concerns being investigated, the characterization of the mechanical properties of the fractures present in the host rock had direct relevance to repository design, and the pre- and post-closure performance assessment. Cores from drillholes NRG-4 and NRG-6 containing natural fractures were obtained from the Sample Management Facility at Yucca Mountain, Nevada. Seven selected fracture were sheared at constant normal stress, either 5 or 10 MPa, in the as-received condition (air-dry). Detailed profilometer data was collected from each fracture surface before testing. The tests yielded the normal closure as a function of normal stress, and the shear stress and dilation as a function of shear offset. The constitutive properties resulting from the measurements were: normal stiffness, shear stiffness, shear strength and coefficient of friction, and dilation. Peak friction ranged from 0.89 to 1.11; residual friction ranged from 0.76 to 1.00. The lowest initial dilation angel was found to be 5.29° and the highest was 11.28°. The roughness characteristics of the fracture surfaces agree qualitatively with the simple mathematical model of Brown (1984) derived from fracture data in many other rock types.

196 (SAND–94-2339C) **Stiffness and strength properties of natural fractures from north ramp drill holes.** Olsson, W.A.; Price, R.H.; Brown, S.R. Sandia National Labs., Albuquerque, NM (United States). [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9409238–2: Workshop on rock mechanics, Rockville, MD (United States), 19-20 Sep 1994). Order Number DE95001882. Source: OSTI; NTIS; INIS; GPO Dep.

Cores containing natural fractures were obtained from drillholes UE 25 NRG-4 and USW NRG-6 at Yucca Mountain, Nevada. Seven selected fractures were sheared at constant normal stress, either 5 or 10 MPa, in the air-dry condition. Detailed profilometer data were collected from each fracture surface before testing. The tests yielded the normal closure as a function of normal stress, and the shear stress and dilation as a function of shear offset. The constitutive properties resulting from the measurements were: normal stiffness, shear stiffness, shear strength and coefficient of friction, and dilation. Peak friction ranged from 0.89 to 1.11; residual friction ranged from 0.76 to 1.00. The lowest initial dilation angle was found to be 5.29° and the highest was 11.28°. The roughness characteristics of the fracture surfaces agree qualitatively with the simple mathematical model of Brown (1994) derived from fracture data in many other rock types.

197 **Analysis of releases due to drilling at the potential Yucca Mountain repository.** Barnard, R.W. (Sandia National Labs., Albuquerque, NM (United States)). *Transactions of the American Nuclear Society (United States);* 69: 128-130 (1993). (CONF-931160–: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

Human intrusion into the potential repository at Yucca Mountain, Nevada, was modeled in the Total-System Performance Assessment (TSPA-91) recently completed for the Yucca Mountain Site Characterization Project Office of the U.S. Department of Energy. The scenario modeled assumed that the repository would be penetrated at random locations by a number of boreholes drilled using 20th-century rotary drilling techniques. The probabilities of this scenario occurring depend on several factors. For these analyses, it was assumed that there was a probability of 1.0 that people would be drilling at the site for 10,000 yr.

198 **The influence of strain rate and sample inhomogeneity on the moduli and strength of welded tuff.** Martin, R.J. III (New England Research Inc., White River Junction, VT (United States)); Boyd, P.J.; Noel, J.S.; Price, R.H. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts (United Kingdom);* 30(7): 1507-1510 (1993). Contract DE-AC04-76DP00789. (CONF-930644–: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993).

A series of constant strain rate, unconfined compression experiments was performed on saturated welded tuff specimens collected from Busted Butte near Yucca Mountain, Nevada. Twenty specimens were loaded to failure at strain rates ranging from 10^{-9} s^{-1} to 10^{-3} s^{-1}, under ambient pressure and temperature conditions. The strength of the specimens showed a continuous decrease with decreasing strain rate between 10^{-9} s^{-1} and 10^{-5} s^{-1}. At the highest strain rate, 10^{-3} s^{-1}, strengths were less than those observed at 10^{-5} s^{-1}, likely due to hydrofracturing within the specimen at rapid loading rates. Reduction in strength, corresponding to the decrease in strain rate, is explained in terms of stress corrosion cracking. A detailed examination of six specimens tested at a strain rate of 10^{-9} s^{-1}, using acoustic wave velocities and CT scans, shows a correlation between the nature of the microstructure of the specimens and the observed strengths and elastic moduli. (Author).

199 **Simulation of the arid climate of the southern great basin using a regional climate model.** Giorgi, F. (National Center for Atmospheric Research, Boulder, CO (United States)); Bates, G.T.; Nieman, S.J. *Bulletin of the American Meteorological Society (United States);* 73(11): 1807-1822 (Nov 1992).

As part of the development effort of a regional climate model (RCM) for the southern Great Basin, this paper presents a validation analysis of the climatology generated by a high-resolution RCM driven by observations. Two multi-year simulations were performed over the western United States with the RCM driven by European Centre for Medium-Range Weather Forecasts analyses of observations. This validation analysis is the first phase of a project to produce simulations of future climate scenarios over a region surrounding Yucca Mountain, Nevada, the only location currently being considered as a potential high-level nuclear-waste repository site. Model-produced surface air temperatures and precipitation were compared with observations from five southern Nevada stations located in the vicinity of Yucca Mountain. The seasonal cycles of temperature and precipitation were simulated well. Monthly and seasonal temperature biases were generally negative and largely explained by differences in elevation between the observing stations and the model topography. The model-simulated precipitation captured the extreme dryness of the Great Basin. Average yearly precipitation biases were

mostly negative in the summer and positive in the winter. The number of simulated daily precipitation events for various precipitation intervals was within factors of 1.5-3.5 of observed. Overall, the model tended to overestimate the number of light precipitation events and underestimate the number of heavy precipitation events. At Yucca Mountain, simulated precipitation, soil moisture content, and water infiltration below the root zone (top 1 m) were maximized in the winter. Evaporation peaked in the spring after temperatures began to increase. The conclusion drawn from this validation analysis is that this high-resolution RCM simulates the regional surface climatology of the southern Great Basin reasonably well when driven by meteorological fields derived from observations. 26 refs., 9 figs., 4 tabs.

U.S. GEOLOGICAL SURVEY

200 Volcanic episodes near Yucca Mountain as determined by paleomagnetic studies as Lathrop Wells, Crater Flat, and Sleeping Butte, Nevada. Champion, D.E. (Geological Survey, Menlo Park, CA (United States)). pp. 61-67 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

It has been suggested that mafic volcanism in the vicinity of Yucca Mountain, Nevada, is both recent (20 ka) and a product of complex "polycyclic" eruptions. This pattern of volcanism, as interpreted by some workers at the Lathrop Wells volcanic complex, comprises a sequence of numerous small-volume eruptions that become more tephra-producing over time. Such sequences are thought to occur over timespans as long as 100,000 years. However, paleomagnetic studies of the tephra and lava flows from mafic volcanoes near Yucca Mountain fail to find evidence of repeated eruptive activity over timespans of 10^3 to 10^5 years, even though samples have been taken that represent approximately 95% of the products of these volcanoes. Instead, the eruptions seem to have occurred as discrete episodes at each center and thus can be considered to be "monogenetic." Dates of these episodes have been obtained by the proven radiometric-geochronometer methods of K-Ar or $^{40}Ar/^{39}Ar$ dating.

201 $^{40}Ar/^{39}Ar$ laser fusion and K-Ar ages from Lathrop Wells, Nevada, and Cima, California: The age of the latest volcanic activity in the Yucca Mountain area. Turrin, B.D. (Geological Survey, Menlo Park, CA (United States)); Champion, D.E. pp. 68-75 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

K-Ar and $^{40}Ar/^{39}Ar$ ages from the Lathrop Wells volcanic center, Nevada, and from the Cima volcanic field, California, indicate that the recently reported 20-ka age estimate for the Lathrop Wells volcanic center is incorrect. Instead an age of 119 ± 11 to 141 ± 10 ka is indicated for the Lathrop Wells volcanic center. This age corrected is concordant with the ages determined by two independent isotopic geochronometric techniques and with the stratigraphy of surficial deposits in the Yucca Mountain region. In addition, paleomagnetic data and radiometric age data indicate only two volcanic events at the Lathrop Wells volcanic center that are probably closely linked in time, not as many as five as recently reported.

202 Assessment of fracture-sampling techniques for laboratory tests on core. Severson, G.R. (Geological Survey, Denver, CO (United States)); Boernge, J.M. pp. 285-290 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

As part of the site characterization work to be done at Yucca Mountain in Nye County, Nevada, a candidate site for the first mined-geologic repository for high-level nuclear waste, laboratory tests are proposed to evaluate fluid flow in single fractures. Laboratory and onsite tests were conducted to develop methods for collecting rock-core samples containing single fractures for the subsequent laboratory tests. Techniques for collecting rock cores with axial (parallel to the core axis) and radial (perpendicular to the core axis) fractures are discussed.

203 Evaluation of geographic information systems for three-dimensional ground-water modeling, Yucca Mountain, Nevada. Turner, A.K. (Geological Survey, Denver, CO (United States)); Ervin, E.M.; Downey, J.S. pp. 520-528 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Fully three-dimensional representations of the geologic system at Yucca Mountain have been developed using a Geoscientific Information System, which is an expansion of a traditional Geographic Information System. These advanced, three dimensional, representations of Yucca Mountain are required to adequately evaluate the complex geologic and hydrologic conditions surrounding the site. This Geoscientific Information System will be used to store, analyze, and display site data. The system also will provide a link between geologic and hydrologic data and the numerical ground-water-flow model resulting in more easy testing of hypotheses concerning the conceptual model of the geohydrologic system at Yucca Mountain.

204 Major results of gravity and magnetic studies at Yucca Mountain, Nevada. Oliver, H.W. (Geological Survey, Menlo Park, CA (United States)); Ponce, D.A.; Sikora, R.F. pp. 787-794 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AI08-78ET44802. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

About 4,000 gravity stations have been obtained at Yucca Mountain and vicinity since the beginning of radioactive-waste studies there in 1978. These data have been

integrated with data from about 29,000 stations previously obtained in the surrounding region to produce a series of Bouguer and isostatic-residual-gravity maps of the Nevada Test Site and southeastern Nevada. Yucca Mountain is characterized by a WNW-dipping gravity gradient whereby residual values of -10 mGal along the east edge of Yucca Mountain decrease to about -38 mGal over Crater Flat. Using these gravity data, two-dimensional modeling predicted the depth to pre-Cenozoic rocks near the proposed repository to be about 1,220±150 m, an estimate that was subsequently confirmed by drilling to be 1,244 m. Three-dimensional modeling of the gravity low over Crater Flat indicates the thickness of Cenozoic volcanic rocks and alluvial cover to be about 3,000 m. Gravity interpretations also identified the Silent Canyon caldera before geologic mapping of Pahute Mesa and provided an estimate of the thickness of the volcanic section there of nearly 5 km. Considerable aeromagnetic coverage of southwestern Nevada was obtained in 1978-79 to help characterize Yucca Mountain and vicinity. One significant result is the discovery of a series of circular magnetic anomalies in Crater Flat and the northern Amargosa Desert that suggest the presence of buried volcanic centers there. If this interpretation is confirmed by drilling, the magnetic data can be used to help estimate the total volume of buried volcanic rocks, which, along with radiometric dating, could help provide a better prediction of future volcanism. Elongate magnetic highs and associated lows over Yucca Mountain correlate with mapped faults, some of which are only partially exposed. Thus, the data provide information on the extent and continuity of these faults.

205 Geophysical borehole logging in the unsaturated zone, Yucca Mountain, Nevada. Schimschal, U. (Geological Survey, Denver, CO (United States)); Nelson, P.H. pp. 795-801 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AI08-78ET44802. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Borehole geophysical logging for site characterization in the volcanic rocks at the proposed nuclear waste repository at Yucca Mountain, Nevada, requires data collection under rather unusual conditions. Logging tools must operate in rugose, dry holes above the water table in the unsaturated zone. Not all logging tools will operate in this environment, therefore; careful consideration must be given to selection and calibration. A sample suite of logs is presented that demonstrates correlation of geological formations from borehole to borehole, the definition of zones of altered mineralogy, and the quantitative estimates of rock properties. The authors show the results of an exploratory calculation of porosity and water saturation based upon density and epithermal neutron logs. Comparison of the results with a few core samples is encouraging, particularly because the logs can provide continuous data in boreholes where core samples are not available.

206 An alternative method to Mariotte reservoir system for maintaining constant hydraulic pressure. Thamir, F. (Geological Survey, Denver, CO (United States)). pp. 994-998 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Some studies being done to evaluate the suitability of the Yucca Mountain area as a potential radioactive waste repository require the application of a constant water pressure as a boundary condition to study water flow through porous media. The Mariotte reservoir system is commonly used to supply such a boundary condition. Several problems with the Mariotte reservoir system were discovered when it was used to apply a constant water pressure as a boundary condition for a prolonged period. The constant-pressure boundary condition is required for some lab. experiments to study water flow through porous media. The observed problems were caused by temperature and barometric-pressure fluctuations while the flow rates were very small and caused erroneous water flow-rate measurements. An alternative method was developed and used where the water pressure is controlled by regulating its level by using water-level sensing electrodes. The new method eliminated the effects of temperature and barometric-pressure fluctuations and maintained an acceptable accuracy of the estimated water flow rate without compromising the advantage of the Mariotte reservoir.

207 Pore-water extraction from unsaturated tuffs using one-dimensionsal compression. Mower, T.E. (PRC Environmental Management Inc., Denver, CO (United States)); Higgins, J.D.; Yang, I.C. pp. 999-1006 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

To support the study of the unsaturated-zone hydrochemistry at Yucca Mountain, Nevada, a one-dimensional compression system was developed and tested to extract unaltered and uncontaminated pore-water samples from unsaturated tuff. The major components of the compression system include a high strength steel-alloy corpus ring and nickel-alloy sample sleeve that confine a core sample, and a base platen and piston for application of the axial stress. The base platen and piston are fitted with drainage grooves to alloy pore water to drain during compression. Results obtained using the compression system indicate that pore-water samples could be obtained from nonwelded-tuff cores that had initial moisture contents as small as 8 percent (by weight) and from welded tuff cores that had initial moisture contents as small as 6.5 percent (by weight). For the ambient moisture conditions of tuffs present at Yucca Mountain, the one-dimensional compression system is more effective for extracting pore water than a previously tested triaxial-compression device.

208 Isotopic discontinuities in ground water beneath Yucca Mountain, Nevada. Stuckless, J.S. (Geological Survey, Denver, CO (United States)); Whelan, J.F.; Steinkampf, W.C. pp. 1410-1415 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Analytical data for stable isotopes in ground water from beneath Yucca Mountain, when examined in map view,

show areal patterns of heterogeneity that can be interpreted in terms of mixing of at least three end members. One end member must be isotopically heavy in terms of hydrogen and oxygen and have a young apparent ^{14}C age such as water found at the north end of Yucca Mountain beneath Fortymile Wash. A second end member must contain isotopically heavy carbon and have an old apparent ^{14}C age such as water from the Paleozoic aquifer. The third end member cannot be tightly defined. It must be isotopically lighter than the first with respect of hydrogen and oxygen and be intermediate to the first and second end members with respect to both apparent ^{14}C age and $\sigma^{14}C$. The variable isotopic compositions of hydrogen and oxygen indicate that two of the end members are waters, but the variable carbon isotopic composition could represent either a third water end member of reaction of water with a carbon-bearing solids such as calcite.

209 Distribution of rubidium, strontium, and zirconium in tuff from two deep coreholes at Yucca Mountain, Nevada. Spengler, R.W. (Geological Survey, Denver, CO (United States)); Peterman, Z.E. pp. 1416-1422 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Variations in concentrations of trace elements Rb, Sr, and Zr within the sequence of high-silica tuff and dacitic lava beneath Yucca Mountain reflect both primary composition and secondary alteration. Rb and K concentrations have parallel trends. Rb concentrations are significantly lower within intervals containing zeolitic nonwelded to partially welded and bedded tuffs and are higher in thick moderately to densely welded zones. Sr concentrations increase with depth from about 30 ppm in the Topopah Spring Member of the Paintbrush Tuff to almost 300 ppm in the older tuffs. Zr concentrations are about 100 ppm in the Topopah Spring Member and also increase with depth to about 150 ppm in the Lithic Ridge Tuff and upper part of the older tuffs. Conspicuous local high concentrations of Sr in the lower part of the Tram Member, in the dacite lava, and in unit c of the older tuffs in USW G-1, and in the densely welded zone of the Bullfrog Member in USW GU-3/G-3 closely correlate with high concentrations of less-mobile Zr and may reflect either primary composition or elemental redistribution resulting largely from smectitic alteration. Initial $^{87}Sr/^{86}Sr$ values from composite samples increase upward in units above the Bullfrog Member of the Crater Flat Tuff. The progressive tenfold increase in Sr with depth coupled with the similarity of initial $^{87}Sr/^{86}Sr$ values within the Bullfrog Member and older units to those of Paleozoic marine carbonates are consistent with a massive influx of Sr from water derived from a Paleozoic carbonate aquifer.

210 Strontium isotopes in carbonate deposits at Crater Flat, Nevada. Marshall, B.D. (Geological Survey, Denver, CO (United States)); Futa, K.; Peterman, Z.E.; Stuckless, J.S. pp. 1423-1428 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Strontium isotope studies of carbonates from soils, veins, eolian dust and Paleozoic basement sampled near Crater Flat, southwest of Yucca Mountain, provide evidence for the origins of these materials. Vein and soil carbonates have nearly identical ranges of $^{87}Sr/^{86}Sr$, and eolian material has $^{87}Sr/^{86}Sr$ ratios at the lower end of the pedogenic range. The average $^{87}Sr/^{86}Sr$ of Paleozoic basement from Black Marble Hill is similar to the $^{87}Sr/^{86}Sr$ in the eolian dust, perhaps indicating a local source for this material. Possible spring deposits have generally higher $^{87}Sr/^{86}Sr$ than the other carbonates. These data are compared with similar data from areas east of Yucca Mountain.

211 An evaluation of evidence pertaining to the origin of vein deposits exposed in trench 14, Nevada Test Site, Nevada. Stuckless, J.S. (Geological Survey, Denver, CO (United States)). pp. 1429-1438 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Large vein-like deposits of calcite and opaline silica that infill the Bow Ridge fault are exposed by Trench 14 at the Nevada Test Site. The origin of the deposits has been the center of considerable controversy because the deposits occur on the edge of Yucca Mountain, which is being characterized geologically as a possible site for the nation's first high level nuclear waste repository, and the various proposed modes of origin have differing implications for the performance of a geologic repository. Isotopic data for oxygen, carbon, strontium, and uranium in the carbonates preclude deposition by upwelling waters by any mechanism from either of the regionally extensive aquifers known to exist beneath Yucca Mountain. Data from the adjacent Ash Meadows flow system further suggest that the isotopic compositions of ground water in southern Nevada have not changed markedly during the last 300 to 600 ky, and that therefore, conclusions based on present-day water compositions are probably valid for at least the last 600 ky. Geologic and paleontologic data are inconsistent with a shallow perched water spring origin for the veins, but are consistent with a pedogenic origin. Mineralogic and isotopic data match well with those for pedogenic deposits with perhaps minor modification from entrained or reacted wall rock. Taken as a whole, the data show that the carbonate and opaline silica deposits exposed in Trench 14 must have formed by a pedogenic process. Preliminary results suggest that veins in the sand ramps west of Busted Butte formed by the same mechanism.

212 A hint of recharge at Franklin Lake playa, Inyo County, California, USA. Czarnecki, J.B. (Geological Survey, Denver, CO (United States)); Ronen, D.; Magaritz, M.; Kroitoru, L. pp. 631-634 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

Hydrochemical and hydraulic-head data at a central study site on Franklin Lake playa imply the occurrence of localized recharge caused by intermittent stream flow. The playa is a major discharge area of the ground-water flow system that includes Yucca Mountain, Nevada, the potential site of a high-level nuclear-waste repository. Depth to water at the

study site was 1.7 meters in a fully-screened well in which a multilevel sampler was used to obtain detailed vertical hydrochemical profiles. These profiles showed the occurrence of a relatively fresher-water lens in approximately the top 10 centimeters below the water table which may have resulted from localized recharge. Hydraulic-head data from a 3-piezometer nest indicated a downward hydraulic gradient (-0.10) and a 0.83-meter; rise in the water table in a 3.20-meter-deep piezometer from 1984 to 1989. 3 refs., 4 figs.

213 Isotopic studies of fracture coatings at Yucca Mountain, Nevada, USA. Marshall, B.D. (Geological Survey, Denver, CO (United States)); Whelan, J.F.; Peterman, Z.E.; Futa, K.; Mahan, S.A.; Stuckless, J.S. pp. 737-740 of Water-Rock Interaction: Proceedings. Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

At Yucca Mountain, secondary calcite occurs as fracture coatings, open-space fillings, and replacement cement (in the saturated zone) and has been observed in most of the Tertiary volcanic section. In general, Sr, O and C isotope systematics as well as UV fluorescence suggest that the present depth to water table of ≈500 m is a long-lived feature. Calcite deposition probably reflects a long history of fluid/rock interaction. Calcite $^{87}Sr/^{86}Sr$ ratios and $\delta^{13}C$ values are fairly constant in the lower part of the Tertiary section, reflecting the geochemical signature of the lower carbonate aquifer. Unsaturated zone calcite $\delta^{13}C$ values indicate input of pedogenic C, and $^{87}Sr/^{86}Sr$ increases from shallow ground-water ratios near the water table to pedogenic values near the surface. Calcite $\delta^{18}O$ values are in approximate equilibrium with current ground waters at the present geothermal gradient. 9 refs., 3 figs., 1 tab.

214 A preliminary study of the chemistry of pore water extracted from tuff by one-dimensional compression. Peters, C.A. (Geological Survey, Denver, CO (United States)); Yang, I.C.; Higgins, J.D.; Burger, P.A. pp. 741-745 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

A specially designed and fabricated one-dimensional compression cell is being used to extract water from nonwelded and densely welded tuffs having degrees of saturation greater than 16 and 37 percent respectively. Chemical analyses of pore water obtained at increasing pressures are used to evaluate possible changes in chemistry caused by compression. The extracted pore water varies from a calcium chloride type to a sodium bicarbonate type. The mean concentration of dissolved ions generally decreases during compression. The relative abundance of the major cations varies little with increasing pressure. The relative abundance of the major anion varies moderately with increasing pressure. Possible causes of the pore-water-chemistry changes include: (1) dilution of pore water by low ionic strength adsorbed water from zeolites and clays; (2) dissolution reactions caused by the increase in dissolved carbon dioxide concentrations that may result from pressurization; (3) membrane filtration by zeolites and clays; and (4) ion exchange with the zeolites and clays. 11 refs., 5 figs., 3 tabs.

215 Strontium isotope characterization of the Ash Meadows ground-water system, southern Nevada, USA. Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Stuckless, J.S.; Mahan, S.A.; Marshall, B.D.; Gutentag, E.D.; Downey, J.S. pp. 825-829 of Water-Rock Interaction: Proceedings: Volume 1, Low temperature environments. Kharaka, Y.K.; Maest, A.S. (eds.). A.A. Balkema, Rotterdam (Netherlands) (1992). pp. 884 DOE Contract AI08-78ET44802. From 7. water-rock interaction conference; Park City, UT (United States); 9-23 Jul 1992.

The regional $\delta^{87}Sr$ variation in ground water of the Ash Meadows flow system is consistent with previous work which identifies the Spring Mountains as a major recharge area. $\delta^{87}Sr$ values between -1.06 and 0.79 in water from high springs are indistinguishable from the $\delta^{87}Sr$ values of the Paleozoic carbonate rocks which compose most of the Spring Mountains. The bulk of the discharge at Ash Meadows carries strontium with $\delta^{87}Sr$ values between 4.43 and 4.99. These discharge values require recharge to the system with $\delta^{87}Sr$ values substantially greater than 5. Such waters are identified in the west-central part of the flow system, reflecting a northerly source, and in one spring form the Pahranagat Valley at the northeastern limit of the system. The ultimate source of these large $\delta^{87}Sr$ values may include Tertiary felsic tuffs, Upper Devonian and Mississippian Eleana Formation, or Precambrian clastic rocks. 14 refs., 3 figs.

216 Characterizing the hydrogeologic framework of the Death Valley region, southern Nevada and California. Faunt, C. (Geological Survey, Denver, CO (United States)); D'Agnese, F.; Downey, J.S.; Turner, A.K. pp. 1194-1199 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Three-dimensional (3-D) hydrogeologic modeling of the complex geology of the Death Valley region requires the application of a number of Geoscientific Information System (GSIS) techniques. This study, funded by United States Department of Energy as a part of the Yucca Mountain Project, focuses on an area of approximately 100,000 square kilometers (three degrees of latitude by three degrees of longitude) and extends up to ten kilometers in depth. The geologic conditions are typical of the Basin and Range province; a variety of sedimentary and igneous intrusive and extrusive rocks have been subjected to both compressional and extensional deformation. GSIS techniques allow the synthesis of geologic, hydrologic and climatic information gathered from many sources, including satellite imagery and published maps and cross-sections. Construction of a 3-D hydrogeologic model is possible with the combined use of software products available from several vendors, including traditional GIS products and sophisticated contouring, interpolation, visualization, and numerical modeling packages.

217 Summary of revised potentiometric-surface map for Yucca Mountain and Vicinity, Nevada. Ervin, E.M. (Geological Survey, Denver, CO (United States)); Luckey, R.R.; Burkhardt, D.J. pp. 1554-1558 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The revised map for the potentiometric surface of the uppermost saturated zone in Tertiary volcanic rocks at Yucca

Mountain, Nevada, is based mainly on 1988 water levels. Refinement of the water-level corrections has increased understanding of the area immediately east-southeast and hydrologically downgradient of Yucca Mountain. This small-gradient area is a nearly horizontal surface which corresponds to the likely direction of ground-water flow from Yucca Mountain–east southeast. To the west of Yucca Mountain water levels are approximately 300 m higher than those in the small-gradient area. Water levels are higher to the west of Yucca Mountain apparently because of a barrier to ground-water flow formed by the Solitario Canyon fault and a splay of the fault, and water levels are higher to the north apparently because of a semi-perched ground-water system.

218 Isotopic evidence of complex ground-water flow at Yucca Mountain, Nevada, USA. Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Stuckless, J.S. pp. 1559-1566 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Strontium isotopes (expressed as per mil deviation from mean sea water, $\delta^{87}Sr$) reflect interaction between ground water and the aquifer of the Yucca Mountain region, $\delta^{87}Sr$ values increase from north to south downgradient in the flow system. The largest $\delta^{87}Sr$ values occur in the Amargosa Desert where ground water probably encounters alluvial basin fill derived from Precambrian rocks in the Funeral Range. Similarly, large $\delta^{87}Sr$ values for ground water in the Paleozoic aquifer at the western end of the Spring Mountains also probably reflect an encounter with Precambrian rocks. In several wells into the volcanic rocks, apparent isotopic disequilibrium between ground water and the producing units suggest that the ground water probably integrates over a substantial part of the saturated section in attaining its strontium isotope signature.

219 Late quaternary history and uranium isotopic compositions of ground water discharge deposits, Crater Flat, Nevada. Paces, J.B. (Geological Survey, Denver, CO (United States)); Taylor, E.M.; Bush, C. pp. 1573-1580 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Three carbonate-rich spring deposits are present near the southern end of Crater Flat, NV, approximately 18 km southwest of the potential high-level waste repository at Yucca Mountain. We have analyzed five samples of carbonate-rich material from two of the deposits for U and Th isotopic compositions. Resulting U-series disequilibrium ages indicate that springs were active at 18 ± 1, 30 ± 3, 45 ± 4 and >70 ka. These ages are consistent with a crude internal stratigraphy at one site. Identical ages for two samples at two separate sites suggest that springs were contemporaneous, at least in part, and were most likely part of the same hydrodynamic system. In addition, initial U isotopic compositions range from 2.8 to 3.8 and strongly suggest that ground water from the regional Tertiary-volcanic aquifer provided the source for these hydrogenic deposits. This interpretation, along with water level data from near-by wells suggest that the water table rose approximately 80 to 115 m above present levels during the late Quaternary and may have fluctuated repeatedly. Current data are insufficient to allow reconstruction of a detailed depositional history, however geochronological data are in a good agreement with other paleoclimatic proxy records preserved throughout the region. Since these deposits are down gradient from the potential repository site, the possibility of higher ground water levels in the future dramatically shortens both vertical and lateral ground water pathways and reduces travel times of transported radionuclides to potential discharge sites.

220 Structure of Crater Flat and Yucca Mountain, southeastern Nevada, as inferred from gravity data. Oliver, H.W. (Geological Survey, Menlo Park, CA (United States)); Fox, K.F. pp. 1812-1817 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Existing gravity data in the vicinity of Yucca Mountain and Crater Flat have been examined to determine if these data support only the caldera model or if they support other geologic models such as for a high-angle graben or detachment fault. The west to east isostatic gravity profile reduced for a density of 2.0 g/cm shows a gravity low of about 20 mGal centered only 2 km from the eastern edge of Crater Flat relative to a gravity high over the eastern boundary of Yucca Mountain. In the western part of Crater Flat, isostatic anomalies rise about 50 mGal across the flat, reaching a maximum gradient of 9 mGal/km about 3 km east of the Bare Mountain range-front fault. Computer modeling of these data indicate that a model that consists of a detachment fault that dips to the west at 12° under Yucca Mountain and interacts a 27° east-dipping Bare Mountain fault fits the observed gravity data generally as well as the caldera model.

221 Seismic reflection profiling: Essential geophysical data for Yucca Mountain, Nevada. Hunter, W.C. (Geological Survey, Denver, CO (United States)); Spengler, R.W.; Brocher, T.M. pp. 1835-1839 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Yucca Mountain, Nevada, consists of a thick sequence of ash-flow tuffs and lavas fractured into intact blocks with east-dipping strata, marginal broken zones characterized by dense faulting and brecciation, and intervening down-to-the-west fault zones with locally a typical west-dipping strata. Uncertainty in the structural setting of Yucca Mountain has resulted in multiple interpretations of the role and style of faulting. One interpretation describes steep normal faulting extending to seismogenic depth (10 to 15 km), and an alternate explanation suggests listric faults and a major low-angle detachment between the Tertiary volcanic sequence and the underlying Paleozoic rocks. Resolution of the deep geology is critical to evaluations of the potential tectonic and hydrologic hazards of the site. Seismic reflection profiling will provide essential data for defining the subsurface geometry of Yucca Mountain and for distinguishing between alternate interpretations of the structure of the mountain.

222 Geophysical investigations of buried volcanic centers near Yucca Mountain, Southwest Nevada. Langenheim, V.E. (Geological Survey, Menlo Park, CA (United States)); Kirchoff-Stein, K.S.; Oliver, H.W. pp. 1840-1846 of

High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Several aeromagnetic dipolar anomalies occur over flat, alluvial areas near Yucca Mountain that resemble anomalies typically associated with subaerial basaltic volcanic centers. Detailed gravity and ground magnetic data were collected along a surveyed traverse across an aeromagnetic anomaly in Amargosa Valley, south of Yucca Mountain, Nevada. Modeling of the ground magnetic data collected over the largest of these anomalies, the Lathrop Wells aeromagnetic anomaly, indicates that the top of the causative body, most likely basalt, is less than 250 m below the surface. Gravity data indicate an apparent lack of an associated gravity anomaly and suggest that either the causative body may be tuff rather than basalt, or the volume of the body is small. Both drilling and collection of more magnetic and gravity data are necessary because ages and volumes of buried volcanic centers are important constraints for estimating the probability of potential volcanism near the proposed nuclear waste repository at Yucca Mountain.

223 Isotopic and trace element variability in altered and unaltered tuffs at Yucca Mountain, Nevada. Peterman, Z.E. (Geological Survey, Denver, CO (United States)); Spengler, R.W.; Singer, F.R.; Dickerson, R.P. pp. 1940-1947 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Reference stratigraphic sections near Yucca Mountain, Nevada were established and sampled in outcrop areas where the volcanic rocks have been minimally altered. Isotopic and trace element analysis obtained for these reference sections are baseline data for assessing the degree and extent of element mobility attendant with past zonal alteration of the rock mass. In agreement with earlier studies, zeolitization is shown to have occurred under wholesale open-system conditions. Calcium was increased by two to three times the baseline values and strontium up to twenty times. In contrast, barium displays less variability, and the high-field strength elements zirconium and titanium were the least mobile during zeolitization. The data reported here establish the usefulness of reference sections for assessing past element mobility. The information gained will be helpful in predicting possible future element mobility induced by thermally activated fluids in the near field of a potential repository.

224 Strontium isotopic evidence for a higher water table at Yucca Mountain. Marshall, B.D. (Geological Survey, Denver, CO (United States)); Peterman, Z.E.; Stuckless, J.S. pp. 1948-1952 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

At Yucca Mountain, calcite occurs as open-space fillings and coatings on fractures within much of the host volcanic rocks in both the saturated and unsaturated zones. Strontium isotope analysis of these calcites divide the samples into two groups corresponding to their location in either the saturated or unsaturated zones. The group of samples from the unsaturated zone corresponds very well with pedogenic carbonate samples, indicating that the strontium came from the surface during infiltration events. However, four samples from the unsaturated zone show strontium isotopic ratios similar to present-day ground water. Since these samples are closest to the water table, they are interpreted as the result of a higher water-table stand (≈85 m higher than present-day) in the past.

225 Lead isotopic composition of paleozoic and late proterozoic marine carbonate rocks in the vicinity of Yucca Mountains, Nevada. Zartman, R.E. (Geological Survey, Denver, CO (United States)); Kwak, L.M. pp. 1953-1959 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Paleozoic and Late Proterozoic marine carbonate rocks (limestones, dolomites, and their metamorphic equivalents) cropping out in the vicinity of Yucca Mountain contain lead with an isotopic composition strongly suggesting them to be a major source of the lead observed at Trench 14 in the carbonate phase of carbonate-silica veins and nearby surficial calcrete deposits. Six whole-rock samples of marine carbonate rocks yield $^{206}Pb/^{204}Pb$ = 19.21-29.06, $^{207}Pb/^{204}Pb$ = 15.74-16.01, and $^{208}Pb/^{204}Pb$ = 37.90-39.25, and leachate and residue fractions of the rocks reveal additional isotopic heterogeneity within individual samples. Two samples of eolian dust also have isotopic compositions lying along a 'carbonate' to 'silicate' mixing trend that appears to arise entirely from pedeogenic processes. The tendency for the marine carbonate rocks to evolve highly uranogenic, but not thorogenic, lead results in a distinctive isotopic composition that serves as a tracer in eolian dust and secondary carbonate minerals derived from the marine carbonate rocks.

226 Laboratory study of water infiltration into a block of welded tuff. Thamir, F. (Geological Survey, Denver, CO (United States)); Kwicklis, E.M.; Anderton, S. pp. 2071-2080 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

A laboratory water infiltration experiment through a block of fractured welded tuff measuring 47.5 cm long × 54.3 cm wide × 80.6 cm high was conducted. The purpose of the laboratory experiment was to design an instrumentation and monitoring scheme for an in situ field test to be conducted at Yucca Mountain. The instrumentation design included thermocouple psychrometers and tensiometers to measure water and matrix potentials in fractures or matrix. An infiltrometer was designed to apply constant boundary conditions (pressure or flow rate). The block was drilled with 18 small diameter (12.7 mm) boreholes into which the thermocouple psychrometers and tensiometers were installed. The block was encased in plexiglas to minimize fluctuations in boundary conditions and water evaporation. Sand layers were placed below and above the block. Initial hydraulic testing involved saturating the overlying sand layer and monitoring the redistribution of water from the sand into the block. The final stage of testing involved the application of water to the top sand layer at a constant pressure. Water flow rates into the block at different applied pressures were measured. No outflow of water from the bottom of the block was observed. The instruments and infiltrometer proved to

be adequate to make the desired measurements in both matrix and fractures.

227 (CONF-9309228–10) **Estimation of unsaturated zone liquid water flux at boreholes UZ No. 4, UZ No. 5, UZ No. 7, and UZ No. 13, Yucca Mountain, Nevada, from saturation and water potential profiles.** Kwicklis, E.M. (Geological Survey, Lakewood, CO (United States)); Healy, R.W.; Flint, A.L. Geological Survey, Denver, CO (United States). [1993]. 19p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From Focus 93: site characterization and model validation; Las Vegas, NV (United States); 26-29 Sep 1993. Order Number DE94014223. Source: OSTI; NTIS; INIS; GPO Dep.

The unsaturated zone at Yucca Mountain, Nevada, is being investigated as a potential location for a high-level nuclear waste repository. Characterization of the liquid water flux and its spatial distribution under natural conditions provides estimates of the amount of water that could potentially contact the waste canisters and transport soluble radionuclides to the accessible environment. Estimates of ambient water flux may affect design requirements by indicating the degree to which reliance must be placed on engineered barriers or the waste-generated heat to keep the waste canisters dry.

228 (CONF-9309228–11) **Three-dimensional lithostratigraphic model at Yucca Mountain, Nevada: A framework for fluid transport modeling and engineering design.** Buesch, D.C. (Geological Survey, Las Vegas, NV (United States)); Spengler, R.W.; Nelson, J.E.; Dickerson, R.P. Geological Survey, Las Vegas, NV (United States). [1993]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From Focus 93: site characterization and model validation; Las Vegas, NV (United States); 26-29 Sep 1993. Order Number DE94014850. Source: OSTI; NTIS; INIS; GPO Dep.

A three-dimensional lithostratigraphic model of the central block of Yucca MounEain. Nevada, illustrates how some activities can serve both site characterization and design and construction of the Exploratory Studies Facility (ESF). Site-characterization activities supported bv this model include characterizing the three-dimensional geometry of lithologic units and faults, and providing boundary conditions for geostatistical models and site-scale fluid flow modeling. The model supports the conceptual design as construction efforts for the proposed ramps of the ESF and potential high-level nuclear waste repository.

229 (CONF-940553–67) **Saturation levels and trends in the unsaturated zone, Yucca Mountain, Nevada.** Nelson, P.H. Geological Survey, Denver, CO (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. From International high-level radioactive waste management conference; Las Vegas, NV (United States); 22-26 May 1994. Order Number DE94013978. Source: OSTI; NTIS; INIS; GPO Dep.

The unsaturated zone at Yucca Mountain, Nevada, consists of interstratified nonwelded tuffs, which are locally altered to zeolites and clays, and welded tuffs which have laterally extensive lithophysal and nonlithophysal zones. The vertical heterogeneity and lateral homogeneity in rock types control the physical and hydrological properties. Water content and porosity within the unsaturated zone at Yucca Mountain can be quantified using geophysical logs. A log-based approach offers the advantage of in-situ measurements, continuous throughout a borehole. Water content and porosity can be determined with a pair of geophysical logs, such as the density and dielectric logs, as outlined in this paper.

230 (DOE/NV/10874–T1) **Nevada Test Site flood inundation study: Part of US Geological Survey flood potential and debris hazard study, Yucca Mountain Site for USDOE, Office of Civilian Radioactive Waste Management.** Blanton, J.O. III. Bureau of Reclamation, Denver, CO (United States). [1992]. 50p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017188. Source: OSTI; NTIS; INIS; GPO Dep.

The Geological Survey (GS), as part of the Yucca Mountain Project (YMP), is conducting studies at Yucca Mountain, Nevada. The purposes of these studies are to provide hydrologic and geologic information to evaluate the suitability of Yucca Mountain for development as a high-level nuclear waste repository, and to evaluate the ability of the mined geologic disposal system (MGDS) to isolate the waste in compliance with regulatory requirements. The Bureau of Reclamation was selected by the GS as a contractor to provide probable maximum flood (PMF) magnitudes and associated inundation maps for preliminary engineering design of the surface facilities at Yucca Mountain. These PMF peak flow estimates and associated inundation maps are necessary for successful waste repository design and construction. The standard step method for backwater computations, incorporating the Bernouli energy equation and the results of the PMF study were chosen as the basis for defining the areal extent of flooding.

231 (DOE/NV/10874–T2) **Nevada Test Site probable maximum flood study, part of US Geological Survey flood potential and debris hazard study, Yucca Mountain Site for US Department of Energy, Office of Civilian Radioactive Waste Management.** Bullard, K.L. Bureau of Reclamation, Denver, CO (United States). [1994]. 114p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017189. Source: OSTI; NTIS; INIS; GPO Dep.

The US Geological Survey (USGS), as part of the Yucca Mountain Project (YMP), is conducting studies at Yucca Mountain, Nevada. The purposes of these studies are to provide hydrologic and geologic information to evaluate the suitability of Yucca Mountain for development as a high-level nuclear waste repository, and to evaluate the ability of the mined geologic disposal system (MGDS) to isolate the waste in compliance with regulatory requirements. In particular, the project is designed to acquire information necessary for the Department of Energy (DOE) to demonstrate in its environmental impact statement (EIS) and license application whether the MGDS will meet the requirements of federal regulations 10 CFR Part 60, 10 CFR Part 960, and 40 CFR Part 191. Complete study plans for this part of the project were prepared by the USGS and approved by the DOE in August and September of 1990. The US Bureau of Reclamation (Reclamation) was selected by the USGS as a contractor to provide probable maximum flood (PMF) magnitudes and associated inundation maps for preliminary engineering design of the surface facilities at Yucca Mountain. These PMF peak flow estimates are necessary for successful waste repository design and construction. The PMF technique was chosen for two reasons: (1) this technique complies with ANSI requirements that

PMF technology be used in the design of nuclear related facilities (ANSI/ANS, 1981), and (2) the PMF analysis has become a commonly used technology to predict a "worst possible case" flood scenario. For this PMF study, probable maximum precipitation (PMP) values were obtained for a local storm (thunderstorm) PMP event. These values were determined from the National Weather Services's Hydrometeorological Report No. 49 (HMR 49).

232 (IFE/KR/E–93/007, pp. 83) **Strontium isotope characterization of ground water flow systems at Yucca Mountain, Nevada, USA.** Peterman, Z.E. (U.S. Geological Survey, Denver, CO (United States)); Stuckless, J.S. Institutt for Energiteknikk, Kjeller (Norway). Sep 1993. (CONF-9308236–: 1. international symposium on applied isotope geochemistry (AIG-1), Geiranger (Norway), 29 Aug - 3 sep 1993). In *Proceedings of 1. international symposium on applied isotope geochemistry (AIG-1): Program and abstracts.* 133p. Order Number DE94627117. Source: OSTI; NTIS; INIS.

Short communication. GROUND WATER/isotope ratio; GROUND WATER/rock-fluid interactions; USA/ground water; AQUIFERS; HYDROLOGY; STRONTIUM 86; STRONTIUM 87; TRACER TECHNIQUES; USA

233 (USGS/MAP/I–2201) **Geological map of Bare Mountain, Nye County, Nevada.** Miscellaneous Investigations Series. Monsen, S.A.; Carr, M.D.; Reheis, M.C.; Orkild, P.P. Geological Survey, Denver, CO (United States). Map Div. 1992. 31p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-78ET44802. Source: U.S. Geological Survey, Map Division, Box 25286, Denver Federal Center, Denver, CO 80225.

Bare Mountain comprises the isolated complex of mountain peaks southeast of the town of Beatty in southern Nye County, Nevada. This small mountain range lies between the alluvial basins of Crater Flat to the east and the northern Amargosa Desert to the southwest. The northern boundary of the range is less well defined, but for this report, the terrane of faulted Miocene volcanic rocks underlying Beatty Mountain and the unnamed hills to the east are considered to be the northernmost part of Bare Mountain. The southern tip of the mountain range is at Black Marble, the isolated hill at the southeast corner of the map. The main body of the range, between Fluorspar Canyon and Black Marble, is a folded and complexly faulted, but generally northward-dipping (or southward-dipping and northward-overturned), sequence of weakly to moderately metamorphosed upper Proterozoic and Paleozoic marine strata, mostly miogeoclinal (continental shelf) rocks. The geology of Bare Mountain is mapped at a scale of 1:24,000.

234 (USGS-OFR–92-201) **Water permeability and related rock properties measured on core samples from the Yucca Mountain USW GU-3/G-3 and USW G-4 boreholes, Nevada Test Site, Nevada.** Anderson, L.A. Geological Survey, Denver, CO (United States). 1994. 36p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017959. Source: OSTI; NTIS; INIS; GPO Dep.

Core samples were measured for bulk density, grain density, porosity, resistivity, and water permeability as part of a comprehensive geologic investigation designed to determine the suitability of Yucca Mountain as a site for the containment of high-level radioactive waste products. The cores were selected at the drill sites so as to be representative of the major lithologic variations observed within stratigraphic units of the Paintbrush Tuff, Calico Hills Tuff, Crater Flat Tuff, Lithic Ridge Tuff, and Older Tuffs. Dry and saturated bulk density, grain density, and porosity measurements were made on the core samples principally to establish that a reasonable uniformity exists in the textural and mineral character of the sample pairs. Electrical resistivity measured on sample pairs tended to be lower along the plane transverse to the vertical axis of the drill core herein referred to as the horizontal plane. Permeability values, ranging from virtually zero (<.02 microdarcies) to over 200 millidarcies, also indicate a preferential flow direction along the horizontal plane of the individual tuff units. Permeability decreases with flow duration in all but the non-welded tuffs as unconsolidated particles within the pore network are repositioned so as to impede the continued flow of water through the rock. Reversing flow direction initially restores the permeability of the rock to its original or maximum value.

235 (USGS-OFR–92-458) **Evidence of prehistoric flooding and the potential for future extreme flooding at Coyote Wash, Yucca Mountain, Nye County, Nevada.** Glancy, P.A. USDOE Nevada Operations Office, Las Vegas, NV (United States). 1994. 46p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94018347. Source: OSTI; NTIS; INIS; GPO; GPO Dep.

Coyote Wash, an approximately 0.3-square-mile drainage on the eastern flank of Yucca Mountain, is the potential location for an exploratory shaft to evaluate the suitability of Yucca Mountain for construction of an underground repository for the storage of high-level radioactive wastes. An ongoing investigation is addressing the potential for hazards to the site and surrounding areas from flooding and related fluvial-debris movement. Unconsolidated sediments in and adjacent to the channel of North Fork Coyote Wash were examined for evidence of past floods. Trenches excavated across and along the valley bottom exposed multiple flood deposits, including debris-flow deposits containing boulders as large as 2 to 3 feet in diameter. Most of the alluvial deposition probably occurred during the late Quaternary. Deposits at the base of the deepest trench overlie bedrock and underlie stream terraces adjacent to the channel; these sediments are moderately indurated and probably were deposited during the late Pleistocene. Overlying nonindurated deposits clearly are younger and may be of Holocene age. This evidence of intense flooding during the past indicates that severe flooding and debris movement are possible in the future. Empirical estimates of large floods of the past range from 900 to 2,600 cubic feet per second from the 0.094-square-mile drainage area of North Fork Coyote Wash drainage at two proposed shaft sites. Current knowledge indicates that mixtures of water and debris are likely to flow from North Fork Coyote Wash at rates up to 2,500 cubic feet per second. South Fork Coyote Wash, which has similar basin area and hydraulic characteristics, probably will have concurrent floods of similar magnitudes. The peak flow of the two tributaries probably would combine near the potential sites for the exploratory shaft to produce future flow of water and accompanying debris potentially as large as 5,000 cubic feet per second.

236 (USGS-OFR–93-269) **Characterizing fractured rock for fluid-flow, geomechanical, and paleostress modeling: Methods and preliminary results from Yucca Mountain, Nevada.** Barton, C.C.; Larsen, E.; Page, W.R.; Howard, T.M. Geological Survey, Denver, CO (United States). 1993. 74p. Sponsored by USDOE, Washington, DC

(United States). DOE Contract AI08-78ET44802. Order Number DE94013203. Source: OSTI; NTIS; INIS; GPO Dep.

Fractures have been characterized for fluid-flow, geomechanical, and paleostress modeling at three localities in the vicinity of drill hole USW G-4 at Yucca Mountain in southwestern Nevada. A method for fracture characterization is introduced that integrates mapping fracture-trace networks and quantifying eight fracture parameters: trace length, orientation, connectivity, aperture, roughness, shear offset, trace-length density, and mineralization. A complex network of fractures was exposed on three 214- to 260-m 2 pavements cleared of debris in the upper lithophysal unit of the Tiva Canyon Member of the Miocene Paint-brush Tuff. The pavements are two-dimensional sections through the three-dimensional network of strata-bound fractures. All fractures with trace lengths greater than 0.2 m were mapped and studied.

237 (USGS-OFR–93-369) **Preliminary seismicity and focal mechanisms for the southern Great Basin of Nevada and California: January 1992 through September 1992.** Harmsen, S.C. Geological Survey, Denver, CO (United States). 1994. 213p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94013589. Source: OSTI; NTIS; INIS; GPO Dep.

The telemetered southern Great Basin seismic network (SGBSN) is operated for the Department of Energy's Yucca Mountain Project (YMP). The US Geological Survey, Branch of Earthquake and Landslide Hazards, maintained this network until September 30, 1992, at which time all operational and analysis responsibilities were transferred to the University of Nevada at Reno Seismological Laboratory (UNRSL). This report contains preliminary earthquake and chemical explosion hypocenter listings and preliminary earthquake focal mechanism solutions for USGS/SGBSN data for the period January 1, 1992 through September 30, 1992, 15:00 UTC.

238 (USGS-OFR–93-690) **Preliminary study of lead isotopes in the carbonate-silica veins of Trench 14, Yucca Mountain, Nevada.** Zartman, R.E.; Kwak, L.M. Geological Survey, Denver, CO (United States). 15 Dec 1993. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94013976. Source: OSTI; NTIS; INIS; GPO Dep.

The sub-vertical carbonate-silica veins filling the Bow Ridge Fault, where exposed in Trench 14 on the east side of Yucca Mountain, carry a lead isotopic signature that can be explained in terms of local sources. Two isotopically distinguishable–silicate and carbonate–fractions of lead are recognized within the vein system as well as in overlying surficial calcrete deposits. The acid-insoluble silicate fraction is contributed largely from the decomposing Miocene volcanic tuff, which forms the wall rock of the fault zone and is a ubiquitous component of the overlying soil. Lead contained in the silicate fraction approaches in isotopic composition that of the Miocene volcanic rocks of Yucca Mountain, but diverges from it in some samples by being more enriched in uranogenic isotopes. The carbonate fraction of lead in both vein and calcrete samples resides dominantly in the HCl- and CH_3COOH-soluble calcite. HCl evidently also attacks and removes lead from silicate phases, but the milder CH_3COOH dissolution procedure oftentimes identifies a significantly more radiogenic lead in the calcite. Wind-blown particulate matter brought to the area from Paleozoic and Late Proterozoic limestones in surrounding mountains may be the ultimate source of the calcite. Isotopically more uniform samples suggest that locally the basaltic ash and other volcanic rock have contributed most of the lead to both fractions of the vein system. An important finding of this study is that the data does not require the more exotic mechanisms or origins that have been proposed for the veins. Instead, the remarkably similar lead isotopic properties of the veins to those of the soil calcretes support their interpretation as a surficial, pedogenic phenomenon.

239 (USGS-OFR–94-49) **The Sundance fault: A newly recognized shear zone at Yucca Mountain, Nevada.** Spengler, R.W. (Geological Survey, Denver, CO (United States)); Braun, C.A.; Martin, L.G.; Weisenberg, C.W. Geological Survey, Denver, CO (United States). 1994. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94009403. Source: OSTI; NTIS; INIS; GPO Dep.

Ongoing detailed mapping at a scale of 1:240 of structural features within the potential repository area indicates the presence of several previously unrecognized structural features. Minor north-trending west-side-down faults occur east and west of the Ghost Dance fault and suggest a total width of the Ghost Dance fault system of nearly 366 m (1200 ft). A zone of near-vertical N30° – 40°W – trending faults, at least 274 m (900 ft) wide, has been identified in the northern part of our study area and may traverse across the proposed repository area. On the basis of a preliminary analysis of available data, we propose to name this zone the "Sundance fault system" and the dominant structure, occurring near the middle of the zone, the "Sundance fault." Some field relations suggest left-stepping deflections of north-trending faults along a preexisting northwest-trending structural fabric. Other field observations suggest that the "Sundance fault system" offsets the Ghost Dance fault system in an apparent right lateral sense by at least 52 m (170 ft). Additional detailed field studies, however, are needed to better understand structural complexities at Yucca Mountain.

240 (USGS-OFR–94-54) **Selected ground-water data for Yucca Mountain Region, southern Nevada and eastern California, through December 22.** La Camera, R.J.; Westenburg, C.L. USDOE Nevada Operations Office, Las Vegas, NV (United States). 1994. 169p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94017061. Source: OSTI; NTIS; INIS; GPO Dep.

The U.S. Geological Survey, in support of the U.S. Department of Energy, Yucca Mountain Site-Characterization Project, collects, compiles, and summarizes hydrologic data in the Yucca Mountain region. The data are collected to allow assessments of ground-water resources during studies to determine the potential suitability of Yucca Mountain for storing high-level nuclear waste. Data on ground-water levels at 36 sites, ground-water discharge at 6 sites, ground-water quality at 19 sites, and ground-water withdrawals within Crater Flat, Jackass Flats, Mercury Valley, and the Amargosa Desert are presented. Data on ground-water levels, discharges, and withdrawals collected by other agencies (or as part of other programs) are included to further indicate variations through time at selected monitoring locations. Data are included in this report from 1910 through 1992.

241 (USGS-OFR–94-312) **Streamflow and selected precipitation data for Yucca Mountain Region, southern Nevada and eastern California, water years 1986–90.** Kane, T.G. III; Bauer, D.J.; Martinez, C.M. USDOE Nevada

Operations Office, Las Vegas, NV (United States). 1994. 122p. Sponsored by USDOE, Washington, DC (United States);Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE95001893. Source: OSTI; NTIS; INIS; GPO Dep.

Streamflow and precipitation data collected at and near Yucca Mountain, Nevada, during water years 1986–90 are presented in this report. The data were collected and compiled as part of the studies by the US Geological Survey, in cooperation with the US Department of Energy, to characterize surface-water hydrology in the Yucca Mountain area. Streamflow data include daily-mean discharges and peak discharges at 5 continuous-record gaging stations, and peak discharges at 10 crest-stage, partial-record stations and 2 miscellaneous sites. Precipitation data include cumulative totals at 20 stations maintained by the US Geological Survey and daily totals at 15 stations maintained by the Weather Service Nuclear Support Office, National Oceanic and Atmospheric Administration.

242 (USGS-WRI–93-4144) **Pore-water extraction from unsaturated tuff by triaxial and one-dimensional compression methods, Nevada Test Site, Nevada.** Mower, T.E. (PRC Environmental Management, Inc., Denver, CO (United States)); Higgins, J.D.; Yang, In C.; Peters, C.A. Geological Survey, Denver, CO (United States). 1994. 78p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94015008. Source: OSTI; NTIS; INIS; GPO Dep.

The hydrologic system in the unsaturated tuff at Yucca Mountain, Nevada, is being evaluated for the US Department of Energy by the Yucca Mountain Project Branch of the US Geological Survey as a potential site for a high-level radioactive-waste repository. Part of this investigation includes a hydrochemical study that is being made to assess characteristics of the hydrologic system such as: traveltime, direction of flow, recharge and source relations, and types and magnitudes of chemical reactions in the unsaturated tuff. In addition, this hydrochemical information will be used in the study of the dispersive and corrosive effects of unsaturated-zone water on the radioactive-waste storage canisters. This report describes the design and validation of laboratory experimental procedures for extracting representative samples of uncontaminated pore water from welded and nonwelded, unsaturated tuffs from the Nevada Test Site.

243 (USGS/WRIR–92-4016) **Preliminary hydrogeologic assessment of boreholes UE-25c No. 1, UE-25c No. 2, and UE-25c No. 3, Yucca Mountain, Nye County, Nevada: Water-resources investigations report 92-4016.** Geldon, A.L. Geological Survey, Denver, CO (United States). 1993. 85p. Sponsored by Department of the Interior, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94009943. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this report is to characterize the hydrogeology of saturated tuffaceous rocks penetrated by boreholes UE-25c No. 1, UE-25c No.2, and UE-25c No. 3. These boreholes are referred to collectively in this report as the C-holes. The C-holes were drilled to perform multiwell aquifer tests and tracer tests; they comprise the only complex of closely spaced boreholes completed in the saturated zone at Yucca Mountain. Results of lithologic and geophysical logging, fracture analyses, water-level monitoring, temperature and tracejector surveys, aquifer tests, and hydrochemical sampling completed at the C-hole complex as of 1986 are assessed with respect to the regional geologic and hydrologic setting. A conceptual hydrogeological model of the Yucca Mountain area is presented to provide a context for quantitatively evaluating hydrologic tests performed at the C-hole complex as of 1985, for planning and interpreting additional hydrologic tests at the C-hole complex, and for possibly re-evaluating hydrologic tests in boreholes other than the C-holes.

244 (USGS/WRIR–93-4000) **Revised potentiometric-surface map, Yucca Mountain and vicinity, Nevada: Water-resources investigations report 93-4000.** Ervin, E.M.; Luckey, R.R.; Burkhardt, D.J. Geological Survey, Denver, CO (United States). 1994. 33p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94012059. Source: OSTI; NTIS; INIS; GPO Dep.

This report presents a revised potentiometric-surface map based mainly on the 1988 average water levels at Yucca Mountain and the nearby vicinity extending from Crater Flat to Jackass Flats. Discussion includes an explanation of the revised potentiometric-surface map, an examination of yearly trends in the water levels, and adjustments for temperature and density effects in the deeper wells. Report scope focuses on the potentiometric surface of the uppermost saturated zone in the Tertiary volcanic rocks at Yucca Mountain. Some information, related to the underlying Paleozoic carbonate aquifer, pertinent to the volcanic flow system, is presented.

245 (USGS/WRIR–93-4025) **Precision and accuracy of manual water-level measurements taken in the Yucca Mountain area, Nye County, Nevada, 1988–1990: Water-resources investigations report 93-4025.** Boucher, M.S. Geological Survey, Denver, CO (United States). 1994. 18p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94011023. Source: OSTI; NTIS; INIS; GPO Dep.

Water-level measurements have been made in deep boreholes in the Yucca Mountain area, Nye County, Nevada, since 1983 in support of the US Department of Energy's Yucca Mountain Project, which is an evaluation of the area to determine its suit-ability as a potential storage area for high-level nuclear waste. Water-level measurements were taken either manually, using various water-level measuring equipment such as steel tapes, or they were taken continuously, using automated data recorders and pressure transducers. This report presents precision range and accuracy data established for manual water-level measurements taken in the Yucca Mountain area, 1988–90.

246 **Spatial variability in hydrologic properties of a volcanic tuff.** Istok, J.D. (Oregon State Univ., Corvallis, OR (United States). Dept. of Civil Engineering); Rautman, C.A.; Flint, L.E.; Flint, A.L. *Ground Water (United States);* 32(5): 751-760 (Sep-Oct 1994). DOE Contract AC04-76DP00789 ; AI08-78ET44802.

Spatial variability of hydrologic properties was quantified for a nonwelded-to-welded ash flow tuff at Yucca Mountain, Nevada, the potential site of a high-level, nuclear waste repository. Bulk density, porosity, saturated hydraulic conductivity, and sorptivity were measured on core specimens collected from outcrops on a grid that extended vertically through the entire unit thickness and horizontally 1.3 km in the direction of ash transport from the volcanic vent. A strong, geologically determined vertical trend in properties was apparent that correlated with visual trends in degree of

welding observed in the outcrop. The trend was accurately described by simple regression models based on stratigraphic elevation. No significant horizontal trends in properties were detected along the length of the transect. The validity of the developed model was tested by comparing model predictions with measured porosity values from additional outcrop sections and boreholes that extended 3,000 m north, 1,500 m northeast, and 6,000 m south of the study area. The model accurately described vertical porosity variations except for locations very close to the source caldera, where the model underpredicted porosity in the upper half of the section. The presence of deterministic geologic trends, such as those demonstrated for an ash flow unit in this study, can simplify the collection of site characterization data and the development of site-scale models.

247 Evaluation of measurement scale using imbibition experiments in volcanic tuffs. Flint, A.L. (Geological Survey, Mercury, NV (United States)); Flint, L.E.; Richards, K.A. *Soil Science Society of America Journal (United States);* 58(1): 94-102 (Jan-Feb 1994).

A major issue in the site characterization at Yucca Mountain, Nevada, a potential site for a high-level nuclear waste repository, is the relevance of laboratory-scale measurements on cores to field-scale processes, particularly water flow. Calculation of Philip's sorptivity parameter using imbibition of water into rock was selected as a simple test to describe hydrologic parameters at both laboratory and field scales and to study effects of sample size and spatial variability. Laboratory-scale imbibition experiments were conducted on two sizes of core from two boreholes drilled in layered nonwelded tuff and fractured welded tuff. Laboratory experiments were compared with field experiments in the boreholes using neutron logs and a field-scale Mariotte system. Measured sorptivity for both sizes of core were virtually identical and both could predict field-scale sorptivity if enough samples were used to account for spatial heterogeneity. Core data was less useful in predicting the neutron log data due to the nature of the neutron probe measurement and difficulties in accounting for effects of the unique system geometry. Mean neutron log values could not predict the field results from the welded borehole due to fractures transmitting but not retaining water, and could not predict laboratory results because of scale and sampling volume differences. The mean neutron log data could, however, approximate the large-scale field results in the nonwelded borehole. 19 refs., 6 figs., 3 tabs.

248 Morphology and genesis of carbonate soils on the Kyle Canyon fan, Nevada, U.S.A. Reheis, M.C. (Geological Survey, Lakewood, CO (United States). Federal Center); Taylor, E.M.; Sowers, J.M.; McFadden, L.D.; Harden, J.W. *Geoderma (International Journal of Soil Science) (Netherlands);* 52: 303-342 (1992). DOE Contract AI08-78ET44802.

The physical and chemical properties of soils formed in an arid climate on calcareous alluvium of the Kyle Canyon alluvial fan, southern Nevada, were studied in order to infer the rates and relative importance of various soil-forming processes. These studies included field and microscopic observations and analyses of thin sections, major oxides, extractable iron, and clay minerals. The results are interpreted to reflect five major pedogenic processes: (1) the calcic horizons and calcretes of Kyle Canyon soils form by precipitation of $CaCO_3$, derived from eolian dust and alluvium, as clast coats, matrix cement, and massive layers; (2) the A and uppermost B horizons are essentially dust-derived, for they contain large amounts of detrital material not present in the alluvial parent material, and their major-oxide content is similar to that of modern dust; (3) clay particles are translocated from A into B horizons; (4) iron-bearing minerals in the near-surface B horizons are slowly oxidized; (5) carbonate and aluminosilicate grains are both displaced and replaced by pedogenic $CaCO_3$; the silica released by replacement of aluminosilicates may be locally precipitated as amorphous or opaline silica and (or) incorporated into newly formed palygorskite and sepiolite. Rates of soil development at Kyle Canyon are approximate due to uncertainties in age estimates. Some soil field properties change at rates that are similar to rates for soils formed in rhyolitic parent material near Mercury, Nevada. The rate of accumulation of $CaCO_3$ (3–5 g m^{-2} yr^{-1}) at Kyle Canyon is an order of magnitude faster than that near Mercury, but is comparable to rates calculated for soils in southern New Mexico and Utah. This study is part of the Yucca Mountain Site Characterization Project. 63 refs.

WESTINGHOUSE ELECTRIC CORPORATION

249 Development of preliminary Nevada transportation accident characteristics. Tappen, J.J. (Westinghouse Electric Corp., Las Vegas, NV (United States)); Heitzman, A.; Hill, C.V. pp. 613-617 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The US DOE, Yucca Mountain Site Characterization Project Office (YMSCPO) has been given the responsibility for characterization of the potential repository site at Yucca Mountain, Nevada, and the analysis of repository-related impacts in the State of Nevada. In support of these responsibilities, the YMSCPO initiated a preliminary study to develop background information on the character of the transportation accidents occurring on the highways and raillines in the State of Nevada. The results of this preliminary study shows that while the transportation accidents in Nevada follow national trends, there are some distinct differences between Nevada and the rest of the Nation. This paper summarizes those results.

250 Application of the global positioning system to locating remote sites. Tappen, J.J. (Westinghouse Electric Corporation, Las Vegas, NV (United States)); Bell, S.; Follette, J. pp. 1967-1971 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The location of Near Field (NF) sampling stations, used for the radiological monitoring program portion of the site characterization phase of the Yucca Mountain Project, were determined using the Global Positioning System (GPS). Latitudinal and longitudinal position accuracies on the order of one second were achieved using the differential GPS technique. Acceptance test criteria and results are presented.

Operational criteria for data acceptance and corrected data variability and reproducibility are discussed.

RELATED INFORMATION

251 (ANL–93/45) **Effects of radionuclide decay on waste glass behavior: A critical review.** Wronkiewicz, D.J. Argonne National Lab., IL (United States). Dec 1993. 64p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94010073. Source: OSTI; NTIS; INIS; GPO Dep.

This paper is an extension of a chapter in an earlier report [1] that provides an updated review on the status of radiation damage problems in nuclear waste glasses. This report will focus on radiation effects on vitrified borosilicate nuclear waste glasses under conditions expected in the proposed Yucca mountain repository. Radiation effects on high-level waste glasses and their surrounding repository environment are important considerations for radionuclide immobilization because of the potential to alter the glass stability and thereby influence the radionuclide retentive properties of this waste form. The influence of radionuclide decay on vitrified nuclear waste may be manifested by several changes, including volume, stored energy, structure, microstructure, mechanical properties, and phase separation. Radiation may also affect the composition of aqueous fluids and atmospheric gases in relatively close proximity to the waste form. What is important to the radionuclide retentive properties of the repository is how these radiation effects collectively or individually influence the durability and radionuclide release from the glass in the event of liquid water contact.

252 (ANL–94/14) **Nuclear Waste Programs semiannual progress report, April–September 1992.** Bates, J.K. (and others); Bradley, C.R.; Buck, E.C. Argonne National Lab., IL (United States). May 1994. 39p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94016807. Source: OSTI; NTIS; INIS; GPO Dep.

This document reports on the work done by the Nuclear Waste Programs of the Chemical Technology Division (CMT), Argonne National Laboratory, in the period April–September 1992. In these programs, studies are underway on the performance of waste glass and spent fuel in projected nuclear repository conditions to provide input to the licensing of the nation's high-level waste repositories.

253 (ANL–94/19) **ANL Technical Support Program for DOE Environmental Restoration and Waste Management: Annual report, October 1992–September 1993.** Bates, J.K. (and others); Bourcier, W.L.; Bradley, C.R. Argonne National Lab., IL (United States). Jun 1994. 140p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94017954. Source: OSTI; NTIS; INIS; GPO Dep.

This report is an overview of the progress during FY 1993 for the Technical Support Program that is part of the ANL Technology Support Activity for DOE Environmental Restoration and Waste Management (EM). The purpose is to evaluate, before hot start-up of the Defense Waste Processing Facility (DWPF) and the West Valley Demonstration Project (WVDP), factors that are anticipated to affect glass reaction in an unsaturated environment typical of what may be expected for the candidate Yucca Mountain repository site. Specific goals for the testing program include the following: reviewing and evaluating available data on parameters that will be important in establishing the long-term performance of glass in a repository environment; performing tests to further quantify the effects of important variables where there are deficiencies in the available data; and initiating long-term tests to determine glass performance under a range of conditions applicable to repository disposal.

254 (BNL–49737) **Enumeration and characterization of microorganisms associated with the uranium ore deposit at Cigar Lake, Canada: Informal report.** Francis, A.J.; Joshi-Tope, G.; Gillow, J.B.; Dodge, C.J. Brookhaven National Lab., Upton, NY (United States). Mar 1994. 42p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC02-76CH00016. Order Number DE94016231. Source: OSTI; NTIS; INIS; GPO Dep.

The high-grade uranium deposit at Cigar Lake, Canada, is being investigated as a natural analog for the disposal of nuclear fuel waste. Geochemical aspects of the site have been studied in detail, but the microbial ecology has not been fully investigated. Microbial populations in an ore sample and in groundwater samples from the vicinity of the ore zone were examined to determine their effect on uranium mobility. Counts of the total number of bacteria and of respiring bacteria were obtained by direct microscopy, and the viable aerobic and anaerobic bacteria were assessed as colony forming units (CFUs) by the dilution plating technique. In addition, the population distribution of denitrifiers, fermenters, iron- and sulfur-oxidizers, iron- and sulfate-reducers, and methanogens was determined by the most probable number (MPN) technique.

255 (CEA-CONF–11814) **Elementary migration around the Oklo nuclear reactors. Implications for high level radioactive wastes storage.** Menet-Dressayre, C.; Menager, M.T. CEA Centre d'Etudes de la Vallee du Rhone, 30 - Marcoule (France). Dept. d'Exploitation du Retraitement et de Demantelement. 1993. 10p. (In French). (CONF-9310378–: Oklo Working Group Meeting, Bruxelles (Belgium), 11-12 Oct 1993). Order Number DE95605958. Source: OSTI; NTIS (US Sales Only); INIS.

The study of Uranium and rare earths near the reactors has dispiayed the radioelements transfer in the reactors neighbourhood. The main implications for high level radioactive wastes disposal in geological formations are discussed. 12 refs.

256 (CEA-CONF–11823) **Analysis of colloids from Oklo/Okelobondo and Bangombe waters.** Moulin, V.; Vilarem, J.P. CEA Centre d'Etudes de Cadarache, 13 - Saint-Paul-lez-Durance (France). Dept. Stockage Dechets. 1993. 7p. (CONF-9310364–: Oklo meeting, Brussels (Belgium), 11-12 Oct 1993). Order Number DE95601656. Source: OSTI; NTIS (US Sales Only); INIS.

In the framework of the hydrogeological and hydrogeochemical studies carried out on the Oklo/Okelobondo and Bangombe sites, the nature and physico-chemical characteristics of the colloids present in the waters sampled in these sites have been investigated. Different techniques have been used for this purpose, namely scanning electron microscopy, X-ray microanalysis and photon correlation spectroscopy. Informations on their size, composition and content have thus been obtained. Discussion on the possible origin and formation mechanisms of these colloids is performed. (author). 7 refs., 2 figs., 2 tabs.

257 High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. 891p. American Nuclear Society; American Society of Civil Engineers, New York, New York (United States) (1991). Sponsored by American Society of Civil Engineers, New York, NY (United States);American Nuclear Society, La Grange Park, IL (United States). From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The final disposal of high level radioactive waste (HLW) has been one of the most arduous problems facing the nuclear industry. This issue has many facets, which are addressed in these proceedings. The papers herein contain the most current information regarding the conditioning and disposal of HLW. Most of the needs are technical in nature, such as the best form of the waste, the integrity of storage containers, design and construction of a repository, and characterization of the geology of a repository to provide assurance that radioactive and other hazardous materials will not reach the surrounding environment. Many of the papers discuss non-US programs. Continued international cooperation and technology exchange is essential. There are other concerns that must be addressed before the final emplacement of HLW. Some of the other issues addressed in these proceedings are conformance to regulations, transportation, socioeconomics, and public education. Any impediments in these areas must be resolved along with the scientific issues before final waste disposal. This conference provides a forum for information exchange. The papers in these proceedings will provide the basis for future planning and decisions. Continued cooperation of the technical community will ultimately result in the safe disposal of HLW. Individual abstracts are indexed separately for the data base.

258 Computer-assisted geometric and kinematic analysis of subsurface faulting in the vicinity of Yucca Mountain, Nevada, using balanced geologic cross sections. Young, S.R. (Southwest Research Institute, San Antonio, TX (United States)); Stirewalt, G.L.; Ratliff, R.A. pp. 248-259 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Computer-assisted geological cross section balancing methods are used in the geometric and kinematic analysis of subsurface structures in the vicinity of Yucca Mountain, Nevada, including underlying listric normal fault and detachment fault geometries and their relationships in a linked fault system. Dips of hanging wall fault blocks are directly related to the shapes of underlying curved normal and detachment faults. Arrays of small faults that are pervasively distributed through the hanging wall blocks are interpreted to be the bulk deformation mechanism of the block. As the hanging wall slides over the underlying fault surface, the fault block deforms to accommodate itself to the shape of the fault. Distributed slip on the small fault array is assumed to accomplish this shape change. The deformation is modeled as general simple shear, such that changes in shape of the model fault blocks take place by distributed slip on uniformly oriented slip surfaces that are evenly spaced through the area of the block, replicating the behavior of a deck of cards. Computed listric normal fault trajectories and surface geologic data constrain the range of compatible depths to potential detachment fault zones below Yucca Mountain to between about 3.5 and 6 kilometers. This is at least 1 to 2 kilometers deeper than the contact between the base of the Tertiary volcanics and the Paleozoic section. Preliminary balanced versions of sections A-A′ and B-B′ of Scott and Bonk show that assumption of a vertical simple shear deformation mechanism for fault block distortion will produce geologically reasonable subsurface models of faulting.

259 The development process for unique underground equipment for waste handling. Karhnak, J.M. (UTD Inc., Newington, VA (United States)); Tanious, N.S. pp. 326-333 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The DOE is currently planning to site, construct, and operate a geologic repository at Yucca Mountain, Nevada for the disposal of high-level nuclear waste (HLW). The repository resembles an underground mine, but with a more severe environment due to the radiation and heat given off by the waste. Construction and operation of the repository will require the development of unique equipment for transportation, emplacement, and retrieval of the waste. Reliability will be an important consideration throughout the conception, design, fabrication, and test of the equipment. Creating a plan, staying with it, but knowing when to change requires a blend of knowledge of all the factors that will influence the acceptance and suitability of the new equipment. This paper is based on the authors' experiences in developing unique equipment for mining applications. It reviews the salient points that need to be included in a development plan, with examples of application of these points, and some suggestions for the development plan for equipment for waste handling operations.

260 Correlation of hydraulic conductivity and sonic velocity in water-saturated tuff. Shimo, Michito (Taisei Corp., Yokohama (Japan)). pp. 572-577 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A laboratory study was conducted to investigate the correlation of hydraulic and sonic properties of water-saturated tuff. The hydraulic test used a new rock block testing machine, which has the capability of applying biaxial stresses and pore pressure on a 30 cm cube of rock. The hydraulic conductivity tensor obtained by the cross-hole injection test was clearly anisotropic with principle directions close to those for shear wave velocity to hydraulic conductivity reflects the effect of water bearing voids in retarding the wave propagation. This result suggests that the seismic exploration method may be used for the evaluation of the hydraulic anisotropy of the large volume of rock at the repository site.

261 Unintentional stoppages of trucks hauling high-level nuclear waste in Nevada. Glickman, T.S. (Resources

for the Future, Washington, DC (United States)). pp. 618-625 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Any unintentional stoppage of trucks hauling high-level nuclear waste in Nevada could intensify public concerns about the negative impacts of the Yucca Mountain Project. This paper provides estimates of the expected number and frequency of such stoppages under several alternative scenarios for the routing and volume of the anticipated truck shipments. At least twice as many truck stoppages are expected to occur on freeways as on non-freeways, and at least twice as many are expected to occur in rural areas as in other areas. The expected frequency of such stoppages in the state is estimated to range from about 3 per year to one every 3 1/2 years. About one in every 4 of the stoppages is expected to take place in Las Vegas and 3 out of every 4 are expected to be non-accidents such as mechanical disablements. The minimum duration of the stoppages is expected to be on the order of half an hour for disablements and an hour for accidents.

262 Development of rail access to the proposed repository site at Yucca Mountain. Standish, P.N. (Westinghouse, Las Vegas, NV (United States)); Seidler, P.E.; Andrews, W.B.; Shearin, G. pp. 633-640 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC08-87NV10576. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

In accordance with the Nuclear Waste Policy Amendment Act of 1987, Yucca Mountain was designated as the initial site to be investigated as a potential repository for the disposal of high-level radioactive waste. The Yucca Mountain site is an undeveloped area located on the southwestern edge of the Nevada Test Site (NTS), about 100 miles northwest of Las Vegas. The site currently lacks rail service or an existing right-of-way. If the Yucca Mountain site is found suitable for the repository, rail service is considered desirable by the Office of Civilian Radioactive Waste Management (OCRWM) program because of the potential of rail transportation to reduce (1) costs and (2) number of shipments, relative to highway transportation. Therefore, it is necessary to conduct a study to determine (1) that there are alignments for a potential rail line from existing mainline railroads to Yucca Mountain and (2) that these are consistent with present rail design standards and are acceptable relative to environmental and land access considerations.

263 An approach to evaluate the sufficiency of highway bridges for nuclear spent fuel transportation. Saiidi, M. (Univ. of Nevada, Reno, NV (United States)); Jiang, Y.; Maragakis, E. pp. 641-646 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The transportation of radioactive spent fuel can have a significant impact on bridge structures located on designated routes. Due to the critical nature of the cargo and because of the severe consequences of the failure of a bridge in carrying the vehicles containing the cargo, a careful and systematic examination of bridges along the route needs to be made and the economic impact needs to be determined. This paper presents a relatively general method to undertake these tasks. An actual bridge located in southern Nevada is used as an example to illustrate some of the major steps involved in the process. The need for the development of new limit states for bridges carrying the spent fuel traffic is discussed.

264 Transportation access to Yucca Mountain: Critical issues. Halstead, R.J. (Agency for Nuclear Project, Carson City, NV (United States)); Souleyrette, R.R.; Bartolo, R. di. pp. 647-656 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract FG08-85NV10461. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Transportation planning for a repository at Yucca Mountain is complicated because of uncertainty about the modes and numbers of nuclear waste shipments and because of uncertainty about the routes which will be used. There could be as many as 76,000 truck shipments, or as few as 1,060 dedicated train shipments, during repository operations. The site lacks rail access. Three rail access options currently under study range in length from 120 miles to more than 400 miles. The site is more than 100 miles from the Interstate highway system. The UNLV Transportation Research Center has evaluated three rail and four highway routes using a broad range of impact measures. This preliminary evaluation found that the routing options differ significantly regarding resident and non-resident populations, environmentally sensitive areas, accident rates, and other factors. Crosscutting issues include impacts on Nevada Indian tribes, potential conflicts with US Air Force operations, and future population growth in southern Nevada. Considerable additional analysis will be required prior to environmental impact statement scoping.

265 Political trust's role in explaining Nevada urban resident's perceptions of the proposed Yucca Mountain repository. Dantico, M.K. (Arizona State Univ., Tempe, AZ (United States)); Mushkatel, A.H.; Pijawka, K.D. pp. 748-757 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

This paper examines the key role that political trust plays in explaining repository risk perceptions of urban residents of the Las Vegas metropolitan area. Findings from two surveys of urban residents confirm that very low levels of political trust exist among residents for the federal government and particularly the DOE and the Nuclear Regulatory Commission. Yet, high levels of political trust are found to be strongly related to low risk perceptions of the repository.

266 Development of a structural model to analyze public opinion on a high-level radioactive waste facility.

Flynn, J. (Decision Research, Eugene, OR (United States)); Slovic, P.; Mertz, C.K.; Burns, W. pp. 773-779 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Studies show that Nevada residents and state officials oppose the proposed high-level radioactive waste repository project at Yucca Mountain. Nevada residents view the Yucca Mountain repository as having extremely high risk; nuclear experts, in contrast, feel the risks are very low. These experts have suggested that public risk perceptions may be reduced by better program management, increased trust in the federal government, and/or by increased benefits and compensation for accepting a repository. The model described in this paper is designed to examine the relationship between risk perception and various strategies for risk management using a confirmatory multivariate method known as covariance structure analysis.

267 **Nondestructive testing using borehole and surface seismic techniques to evaluate rock mass damage zones.** Nelson, P.P. (Univ. of Texas, Austin, TX (United States)); Stokoe, K.H. II. pp. 802-809 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

A suite of seismic tests was performed at the U12g tunnel at the Nevada Test Site. The methods include borehole (crosshole and downhole) and surface (Rayleigh wave and refraction) tests. Results indicate that the different methods should be considered complimentary, and that seismic methods can sensitively evaluate magnitudes and variations of in situ rock mass stiffness. In particular, near-surface low velocity (damage) zones are delineated quite well with Rayleigh wave and downhole methods.

268 **Effect of a low-permeability layer on calculated gas flow at Yucca Mountain.** Lu, Ning (Disposal Safety Inc., Washington, DC (United States)); Amter, S.; Ross, B. pp. 853-860 of High Level Radioactive Waste Management: Proceedings of the second annual international conference: Proceedings, Volume 1. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 891 DOE Contract AC04-76DP00789. From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Seasonal flows of air with velocities as high as 3.5 m/s have been observed in deep boreholes at Yucca Mountain. These flows are attributed to convective circulation arising from topographic relief, seasonal temperature variation, and density differences resulting from variation in gas composition. If a repository were built there, heat from the emplaced waste would also contribute to gas flow. Large-scale air flows may be significant to repository performance because they control the movement of carbon dioxide within the mountain and also result in a net flux of water vapor to the surrounding atmosphere. An understanding of the velocity, trajectories, and mixing of the gas in Yucca Mountain, is necessary both as input for a model of the carbon-14 movement in the unsaturated zone and evaluation of the net vapor flux. Amter and Ross developed a model called TGIF (TopoGraphic Induced Flow) to simulate gas flow under Yucca Mountain. This paper describes a systematic sensitivity study that was designed to test several aspects of the TGIF model when used to simulate gas flow under Yucca Mountain. Values of three important inputs to the model were systematically varied to form a matrix of 80 runs. The matrix consisted of five values of permeability contrast between a bedded tuff layer and surrounding welded units (in all cases, bulk permeabilities were used to represent the combined effect of both fractures and matrix permeability), four temperature profiles representing different stages of repository cooldown, and four finite-difference grids.

269 **High Level Radioactive Waste Management: Proceedings, Volume 2.** 895p. American Society of Civil Engineers, New York, NY (United States) (1991). Sponsored by American Society of Civil Engineers, New York, NY (United States);American Nuclear Society, La Grange Park, IL (United States). From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The proceedings of the second annual international conference on High Level Radioactive Waste Management, held on April 28–May 3, 1991, Las Vegas, Nevada, provides information on the current technical issue related to international high level radioactive waste management activities and how they relate to society as a whole. Besides discussing such technical topics as the best form of the waste, the integrity of storage containers, design and construction of a repository, the broader social aspects of these issues are explored in papers on such subjects as conformance to regulations, transportation safety, and public education. By providing this wider perspective of high level radioactive waste management, it becomes apparent that the various disciplines involved in this field are interrelated and that they should work to integrate their waste management activities. Individual records are processed separately for the data bases.

270 **Demonstration of a repository performance assessment capability at the US Nuclear Regulatory Commission.** Codell, R. (Nuclear Regulatory Commission, Washington, DC (United States)); Eisenberg, N.; McCartin, T.; Park, J. pp. 908-916 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

In order to better review licensing submittals for a High-Level Waste Repository, the US Nuclear Regulatory Commission staff has expanded and improved its capability to conduct performance assessments. A demonstration of this capability used the limited data from Yucca Mountain, Nevada to investigate a small set of scenario classes. Models of release and transport of radionuclides from a repository via the groundwater and direct release pathways provided preliminary estimates of releases to the accessible environment for a 10,000 year simulation time. Latin hypercube sampling of input parameters was used to express results as distributions and to investigate model sensitivities. This methodology demonstration should not be interpreted

as an estimate of performance of the proposed repository at Yucca Mountain, Nevada.

271 A model for effective intergovernmental planning. Moore, R.C. pp. 1022-1026 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

Effective intergovernmental planning processes are essential to the resolution of potential affects created by federal projects. Intergovernmental planning for the proposed Yucca Mountain High-level Nuclear Waste Repository has not been effective to date. In this paper, two successful planning efforts are described. The common elements of these processes are analyzed to provide a model that can be used for the resolution of impacts from other projects. Management authorities of the entities involved should establish a working group to conduct the intergovernmental planning. The parties must identify issues that can be resolved through intergovernmental planning. Clear management authority and direction to the staff participating the planning process is essential. Issues which cannot be resolved should not be included in the goals of the working group. Funding to support the planning process is essential.

272 Potential $^{14}CO_2$ releases from spent fuel containers at Yucca Mountain. Pescatore, C. (Brookhaven National Lab., Upton, NY (United States)); Sullivan, T.M. pp. 1066-1073 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The potential release of gaseous $^{14}CO_2$ from small perforations in spent fuel containers has been evaluated as a function of temperature, hole size, effective porosity of corrosion products within the hole, and time, based on the waste package design parameters and environmental conditions described in the Yucca Mountain Site Characterization Report (SCP). The SCP does not specify initial fill gas (argon) pressure and temperature. It is shown that, if significant ^{14}C oxidation takes place during the initial, inert-gas phase, an incentive exists to initially underpressurize the containers. This will avoid large, spiked releases of gaseous $^{14}CO_2$ and will result in delayed, smaller, and more uniform release rates over time. Therefore larger size perforations could be tolerated while meeting the applicable regulations.

273 Forecasting behavioral response to a repository from stated intent data. Easterling, D. (Univ. of Pennsylvania, Philadelphia, PA (United States)); Kunreuther, H.; Morwitz, V. pp. 1540-1547 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

To forecast repository-induced behavior from surveys of behavioral intention, we develop a model of the relation between stated intent and actual propensity. This model relies heavily on the notion of a latent true intent score. We also consider a number of factors that cause true intent to be, on average, a biased indicator of propensity. The forecasting strategy is applied to a survey of convention planners to estimate the proportion of conventions that Las Vegas would lose following various repository scenarios at the Yucca Mountain site.

274 Payments-Equal-To-Taxes (PETT): An interpretation of Sections 116(c) (3) and 118(b) (4) of the Nuclear Waste Policy Act of 1982, as amended. Benson, A. (DOE, Washington, DC (United States)); Moore, W.E.; Lesko, R. pp. 1555-1560 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Payments-Equal-To-Taxes (PETT) program breaks new ground in government interaction by creating a tax-like transfer of funds from the federal government to states and local government. The PETT program is one of the financial assistance provisions of the Nuclear Waste Policy Act of 1982, as amended [42 U.S.C. 10101, et seq.] (NWPAA). The NWPAA charges the US DOE with, among other things, the responsibility for investigation of potential sites and for licensing, constructing, and operating a repository for high-level radioactive waste and spent fuel and an MRS facility. The NWPAA also called for financial assistance to the jurisdictions in which the repository and MRS facility are to be located. One of the financial impacts to the jurisdictions would be loss of tax revenue since the Supremacy clause of the Constitution prohibits jurisdictions from taxing the federal government. The objective of the PETT program is to provide payments that will offset this loss. Since the NWPAA authorizes continued site characterization activities only in the state of Nevada, the focus of this paper will be on the PETT program in Nevada. However, the information presented here generally applied to implementation of the program in other states where site characterization activities have been conducted.

275 Mechanical tunnel excavation in welded tuff. Sperry, P.E. (Tunnel Construction Consultant, Boulder City, NV (United States)). pp. 1642-1645 of High Level Radioactive Waste Management. Proceedings, Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Technical Review Board for the US high-level radioactive waste facility at Yucca Mountain has recommended maximum use of "the most modern mechanical excavation techniques...in order to reduce disturbance to the rock walls and to achieve greater economy of time and cost." Tunnels for the waste repository at Yucca Mountain can be economically constructed with mechanical excavation equipment. This paper presents the results of mechanical excavation of a tunnel in welded tuff, similar to the tuffs of Yucca Mountain. These results are projected to excavation of emplacement drifts in Yucca Mountain using a current state-of-the-art tunnel boring machine (TBM).

276 A first look at roadheader construction and estimating techniques for site characterization at Yucca Mountain, Nevada. Neil, D.M. (Neil and Associates Inc., Aurora, CO (United States)); Taylor, D.L. pp. 1646-1651 of High Level Radioactive Waste Management. Proceedings,

Volume 2. American Society of Civil Engineers, New York, NY (United States) (1991). pp. 895 From 2. annual American Nuclear Society (ANS) international high level radioactive waste management conference; Las Vegas, NV (United States); 28 Apr - 3 may 1991.

The Yucca Mountain site characterization program will be based on mechanical excavation techniques for the mined repository construction and development. Tunnel Boring Machines (TBM's), Mobile Miners (MM), Raiseborers (RB), Blind Hole Shaft Boring Machines (BHSB), and Roadheaders (RH) have been selected as the mechanical excavation machines most suited to mine the densely welded and non-welded tuffs of the Topopah Springs and Calico Hills members. Heavy duty RH in the 70 to 100 ton class with 300 Kw cutter motors have been evaluated and formulas developed to predict machine performance based on the rock physical properties and the results of Linear Cutting Machine (LCM) tests done at the Colorado School of Mines (CSM) for Sandia National Labs. (SNL).

277 **Nuclear Regulatory Commission staff development of the license application review plan for a high-level radioactive waste repository.** Johnson, R.L. (Nuclear Regulatory Commission, Washington, DC (United States)); Holonich, J.J.; Lee, M.P.; Delligatti, M.S. pp. 1243-1247 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Nuclear Regulatory Commission staff has recently started a new initiative to develop the License Application Review Plan (LARP) which the staff will use in its reviews of the U.S. Department of Energy's (DOE's) license application (LA) for a geologic repository for the disposal of high-level radioactive waste (HLW). This paper describes the staff's approach for developing the LARP, the development schedule and current status, the organization and content of the LARP, and the staff's LA review strategy. Therefore, it gives a preview of the draft LARP which will be made available in late 1993. It also describes how the LARP will be used as guidance to the staff in conducting reviews of regulatory and technical issues important to the licensing of a geologic repository. Finally, the benefits to the NRC staff, DOE, and other parties are discussed.

278 **Geologic repository licensing strategy.** Berkowitz, L. (Civilian Radioactive Waste Management System, Washington, DC (United States)); Stern, M.E.; Roberts, J.P.; Desell, L.J. pp. 1248-1251 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The U.S. Department of Energy Office of Civilian Radioactive Waste Management's objective is to characterize and determine the suitability of the Yucca Mountain site and, if this site is found suitable, obtain authorization from the U.S. Nuclear Regulatory Commission to construct, operate, and eventually close a geologic repository at that site. The Department's licensing strategy involves the application of a process, the licensing process, that addresses the achievement of each of the elements of this objective. The applicable laws and regulations with which the Department must comply, including the Nuclear Waste Policy Act, as amended, the Energy Policy Act of 1992, the Atomic Energy Act of 1954, the National Environmental Policy Act, and the administrative Procedure Act, provide insights into what DOE must do if it is to achieve its objective. The Department's licensing strategy, discussed in this paper, is based on these insights.

279 **Modelling adsorption of mixtures of radionuclides by zeolitized tuff.** Rao, M.G. (Howard Univ., Washington, DC (United States)). pp. 1496-1503 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Multi-solute sorption isotherms were measured using 'Nonscents', a zeolited volcanic tuff material from Southeast Arizona. Isotherms for the three constituent binaries, Sr-Co, Cs-Sr and Cs-Co in the ternary system Cs-Sr-Co were obtained using a columnar flow technique. Results clearly show that sorbent-phase selectivity has considerable effect on the sorption process. Presence of cesium in the mixture considerably reduced the expected retardation of solutes Sr and Co in the tuff material. Cobalt is the least favored ion of the ternary system on the sorbent phase. The isotherms were correlated with ion-exchange phase equilibrium model. Equilibrium constants for the three binary pairs, and the sorbent phase ionic activity coefficients were calculated. Triangle rule of the ion exchange phase equilibria has been validated for the Cs-Co-Sr Nonscents system. Sorbent phase selectivities for the ternary system have been successfully predicted for an experimental run.

280 **Research at Howard University on retardation of radionuclides by sorption processes during host rock–ground water interactions.** Rao, M.G. (Howard Univ., Washington, DC (United States)). pp. 1520-1526 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

As stated in a federal law the Nuclear Waste Policy Act, the U.S. Department of Energy (DOE) is responsible for locating a geologic repository for high-level nuclear waste. Among the three sites approved for intensive site characterization studies, many scientists consider the Yucca Mountain, Nevada site more suitable for a nuclear waste repository. A large number of scientists drawn from national laboratories, U.S. Geological Survey, and many private companies are intensively involved in studies that will determine if Yucca Mountain can be recommended as a high-level nuclear waste repository. The DOE is required to prove that the proposed repository will be safe for a period of 10,000 years. Though a multiple barrier approach will be used in the design of the repository, the host rock of the repository itself must provide sufficient retardation to radionuclide migration via sorption processes. To prove the host rock is capable of such retardation, one needs to understand the sorption mechanism of various radionuclides in constituent minerals of the host rock. Mathematical models that describe these sorption processes need to be developed and validated with experimental observations, and these models will be coupled to transport models to demonstrate retardation of radionuclides under flow conditions.

281 **Modeling of saturated zone at Yucca Mountain, Nevada.** Ahola, M.P. (SwRI/CNWRA, San Antonio, TX

(United States)); Sagar, B. pp. 1602-1608 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Contract NRC-02-88-005. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper presents preliminary results of groundwater modeling of the saturated zone in the vicinity of Yucca Mountain. The analysis used both a regional (approximately 250 x 250 km) and subregional (50 x 50 km) finite difference model. Numerical simulations were conducted to determine the impact of various disruptive conditions that might take place over the life span of a potential repository located beneath Yucca Mountain on the saturated groundwater flow field, as well as changes in the watertable elevations. These conditions included increases in precipitation and groundwater recharge within the regional model, changes in permeability of existing hydrogeologic barriers, and the vertical intrusion of volcanic dikes at various orientations through the saturated zone. Based on the regional analysis, the rise in the water-table in the vicinity of Yucca Mountain due to various postulated conditions ranged from only a few meters to over 200 m in certain cases. The increase in evapotranspiration and surface runoff as the water table rises was neglected in this analysis. Results of the subregional model analysis, which was used to simulate intrusive dikes approximately 4 km in length in the vicinity of Yucca Mountain, showed water-table rises ranging from a few meters to as much as 103 m. Dikes oriented approximately north-south beneath Yucca Mountain produced the highest water-table rises. Some of the results from both the regional and subregional analysis are presented in this paper. A more complete discussion of the results and details of the analysis is given in a recent report by Ahola and Sagar.

282 Geometric analysis of alternative models of faulting at Yucca Mountain, Nevada. Young, S.R. (Center for Nuclear Waste Regulatory Analysis, San Antonio, TX (United States)); Stirewalt, G.L.; Morris, A.P. pp. 1818-1825 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Contract NRC-02-88-005. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Realistic cross section tectonic models must be retrodeformable to geologically reasonable pre-deformation states. Furthermore, it must be shown that geologic structures depicted on cross section tectonic models can have formed by kinematically viable deformation mechanisms. Simple shear (i.e., listric fault models) is consistent with extensional geologic structures and fault patterns described at Yucca Mountain, Nevada. Flexural slip models yield results similar to oblique simple shear mechanisms, although there is no strong geological evidence for flexural slip deformation. Slip-line deformation is shown to generate fault block geometrics that are a close approximation to observed fault block structures. However, slip-line deformation implies a degree of general ductility for which there is no direct geological evidence. Simple and hybrid 'domino' (i.e., planar fault) models do not adequately explain observed variations of fault block dip or the development of 'rollover' folds adjacent to major bounding faults. Overall tectonic extension may be underestimated because of syn-tectonic deposition (growth faulting) of the Tertiary pyroclastic rocks that comprise Yucca Mountain. A strong diagnostic test of the applicability of the domino model may be provided by improved knowledge of Tertiary volcanic stratigraphy.

283 Micromechanics of deformation in Topopah Spring tuff, Yucca Mountain, Nevada. Wang, R. (Univ. of Arizona, Tucson, AZ (United States)); Kemeny, J.M. pp. 1873-1879 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Grant MSS9022381. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Samples of Topopah Spring tuff from Yucca Mountain, Nevada have been tested and analyzed. Laboratory tests conducted include standard uniaxial and triaxial compression tests and special 'damage' tests in which samples are loaded to some proportion of their strength and analyzed with SEM microscopy. Based on the SEM analysis of the damaged samples, the micromechanics of rock deformation and failure in Topopah Spring tuff is determined. The results indicate that pores are the major initial microstructures in Topopah Spring tuff. Also, several mechanisms have been found for microcracking under compressive stresses, including pore cracking, the linking of pore cracks, and the formation of en echelon arrays of axial cracks. The macroscopic cracks tend to propagate in the locations with the highest pore density. The final failure of Topopah Spring tuff is due to shear localization near the peak stress. The microbuckling of crack-induced columns has been found to be the major mechanism for inducing shear localization. The heating of Topopah Spring specimens up to 200°C results in no significant microcracking.

284 Core and reaming bit studies in Yucca Mountain tuffs. Gertsch, R.E. (Earth Mechanics Institute, Golden, CO (United States)); McCormick, J.F.; Wright, E.L. pp. 1880-1884 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 Contract YM-92-600. From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

The Site Characterization Project is a major part of the work in determining the suitability of Yucca Mountain as a potential high level waste repository. Over 100 exploratory drill holes for the Project will be drilled in order to limit contamination of the in-situ rock formations. Dry drilling is not a common practice and drill bits suitable for the application need to be developed. To increase penetration rate and bit life, the Department of Energy (DOE) instituted an extensive drilling program at the Colorado School of Mines (CSM) to test and evaluate full sized core and reaming bits. Current test results of the on-going program show that drill bits with aggressive profiles perform best. Stratapac core bits outperform small diamond bits. The gage areas need improvement. Core bits fail first at the outer gage, while the rest of the bit remains relatively intact. Alternating cone reamer designs perform better than designs with all cones facing inward, because they drill the inner gage core hole more effectively.

285 Tourist visitation impacts of the accident at Three Mile Island. Himmelberger, J.J. (Clark Univ., Worcester, MA (United States)); Ogneva-Himmelberger, Y.A.; Baughman, M.L. pp. 1904-1910 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level

radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

This paper analyzes tourist visitation impacts of the March 27, 1979 accident at Three Mile Island. A review of the literature, supplemented with recollections from Pennsylvanian public officials, are used to specify a conventional tourism impact model which holds that depressed 1979 summer tourism season was more influenced by gasoline shortages and possibly other confounding variables (such as rainy local weather conditions and a polio outbreak) than by the nuclear accident. Regression analysis using monthly visitation data for Hershey Chocolate World, Gettysburg National Park, The Pennsylvania Dutch Convention and Visitor Bureau, and several state parks as dependent variables provide support for this model. Potential tourism implications of an accident at Yucca Mountain are briefly discussed in light of our findings.

286 **Assessing fault rapture hazard for the proposed repository at Yucca Mountain, Nevada: Demonstration of a methodology using expert judgements.** Perman, R.C. (Geomatrix Consultants, Inc., San Francisco, CA (United States)); Coppersmith, K.J.; Youngs, R.R.; Shaw, R.A. pp. 2086-2091 of High Level Radioactive Waste Management: Proceedings: Volume 2. American Nuclear Society, Inc., La Grange Park, IL (United States) (1993). pp. 1090 From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

As part of the Electric Power Research Institute's High Level Waste (EPRI HLW) performance assessment, we have developed and demonstrated a methodology to estimate the magnitude and likelihood of earthquake-related fault rupture that could affect the proposed high-level waste repository at Yucca Mountain. A panel of seven earth sciences experts was selected to develop estimates of the probability of fault displacement through the repository, as well as to quantify the uncertainties associated with the assessment. A series of technical workshops focusing on the issues and involving expert judgement elicitation were conducted. Each expert was individually interviewed to elicit his judgement regarding the technical issues and to provide the technical basis for his assessment. The study illustrates a methodology for quantifying uncertainties associated with a complex technical issue that has been the subject of diversity of opinion.

287 (CONF-940815–93) **Incentives and techniques for increasing the capacity of the geologic repository.** Cowell, B.S.; Fontana, M.H.; Michaels, G.E. Oak Ridge National Lab., TN (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. From International nuclear and hazardous waste management conference; Atlanta, GA (United States); 14-18 Aug 1994. Order Number DE94018138. Source: OSTI; NTIS; INIS; GPO Dep.

Estimates of the materials potentially destined for emplacement in Yucca Mountain exceed the statutory repository capacity limit of 70,000 metric tons initial heavy metal. Removal and subsequent burning of the actinides in these materials can dramatically increase the repository capacity, postponing or perhaps eliminating the need for a second repository. The detailed calculations described herein verify portions of a promising actinide removal and waste emplacement concept, HEWEC. Results from heat transfer calculations indicate that more than 2.5 times the material may be emplaced using a combination of optimum geometry and actinide recycle. This optimum geometry includes additional drifts and closer borehole spacing within the drifts. Future work will quantify the additional benefits that may be derived from drift ventilation and staggered emplacement strategies.

288 (DOE/EIS–0203-D-Vol.1-App.F) **Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement: Volume 1, Appendix F, Nevada Test Site and Oak Ridge Reservation Spent Nuclear Fuel Management Programs.** USDOE Idaho Operations Office, Idaho Falls, ID (United States). Jun 1994. 456p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94014155. Source: OSTI; NTIS; INIS; GPO; GPO Dep.

This volume addresses the interim storage of spent nuclear fuel (SNF) at two US Department of Energy sites, the Nevada Test Site (NTS) and the Oak Ridge Reservation (ORR). These sites are being considered to provide a reasonable range of alternative settings at which future SNF management activities could be conducted. These locations are not currently involved in management of large quantities of SNF; NTS has none, and ORR has only small quantities. But NTS and ORR do offer experience and infrastructure for the handling, processing and storage of radioactive materials, and they do exemplify a broad spectrum of environmental parameters. This broad spectrum of environmental parameters will provide, a perspective on whether and how such location attributes may relate to potential environmental impacts. Consideration of these two sites will permit a programmatic decision to be based upon an assessment of the feasible options without bias, to the current storage sites. This volume is divided into four parts. Part One is the volume introduction. Part Two contains chapters one through five for the NTS, as well as references contained in chapter six. Part Three contains chapters one through five for the ORR, as well as references contained in chapter six. Part Four is summary information including the list of preparers, organizations contacted, acronyms, and abbreviations for both the NTS and the ORR. A Table of Contents, List of Figures, and List of Tables are included in parts Two, Three, and Four. This approach permitted the inclusion of both sites in one volume while maintaining consistent chapter numbering.

289 (DOE/ER/14352–1) **Rock mechanics in the 1990s: Proceedings: Volume 2.** Haimson, B. (ed.). Wisconsin Univ., Madison, WI (United States). 1993. 396p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG02-93ER14352. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). Order Number DE94014602. Source: OSTI; NTIS; GPO Dep.

The 34th US Symposium on ROCK MECHANICS was held at the University of Wisconsin-Madison, Madison, WI June 27–30, 1993. Vol 2 contains 98 papers on acoustic emission and failure prediction, YUCCA MOUNTAIN project, numerical methods, constitutive models, role of pore pressure in some rock mechanical processes pertaining to the oil industry, coupled mechanical and hydrologic processes, in-situ stress measurement, rock fractures and joints, coal and metal mining and ground control, and large underground facilities. Individual papers have been entered separately into the data base.

290 (DOE/ER/14352–1, pp. 511-514) **Micromechanical modeling tuffaceous rock for application in underground nuclear waste storage.** Wang, Runqi (Univ. of Arizona, Tucson (United States)); Kemeny, J.M. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Yucca Mountain, Nevada, is currently being considered as a potential site for the underground storage of high-level civilian radioactive wastes. The host rock surrounding the underground repository is Topopah Spring tuff. Previous experimental studies on tuffs have shown that pores are the primary microstructures of Topopah Spring and Apache Leap tuffs (an analog of for Topopah Spring tuff). Tuff is a kind of volcanic ash that has been compressed at high temperature, and pores have been found widely distributed in tuffs. The pores often appear to form at grain boundaries, and are considered an important flaw in initiating microcrack growth. Under compressive loading, microcracking will initiate from sharp corners of the pores and propagate subparallel to the maximum stress direction until interacting with other pores. Further loading may induce pore collapse which is a major contributor to rock deformation and dilatancy in Apache Leap tuff. Large macroscopic fractures in tuff are formed by the processes of crack growth, interaction, and pore linking. The linking crack is almost parallel to the maximum stress direction. The distance between pores in Topopah Spring tuff is 4-6 times the pore diameter. Detailed SEM observations indicate that macroscopic cracks tend to propagate along the path with the highest pore concentrations. Based on the specific micro-mechanisms for deformation in tuffs as described above, micromechanical models have ben developed. The next section of this paper describes these micromechanical models. The third section of the paper describes the use of these models to predict nonlinear rock deformation and failure in tuff under compressive stresses.

291 (DOE/ER/14352–1, pp. 661-664) **Assessment of conventional methodologies for joint roughness coefficient determination.** Hsiung, S.M. (Southwest Research Institute, San Antonio, TX (United States)); Ghosh, A.; Ahola, M.P.; Chowdhury, A.H. Wisconsin Univ., Madison, WI (United States). 1993. Contract NRC-02-88-005. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

A numerical description of rock joint roughness is necessary to describe adequately the pseudostatic and dynamic rock-joint behavior. The most commonly used measure of joint roughness in rock engineering practice is the joint roughness coefficient (JRC), proposed by Barton and adopted by the International Society for Rock Mechanics. Three basic methods for the determination of JRC have been proposed by various investigators - a tilt test on rock joints as proposed by Barton and Choubey, using an average deviation from the center line about which roughness is measured, and using the theory of fractal geometry. These methods are evaluated in this paper to determine their appropriateness for use in the assessment of rock-joint behavior of Apache Leap tuff joints by comparing the estimates using these methods to the JRC values back-calculated from the laboratory direct shear test results.

292 (DOE/ER/14352–1, pp. 745-748) **Design methodology for rock excavations at the Yucca Mountain project.** Alber, M. (Pennsylvania State Univ., University Park (United States)); Bieniawski, Z.T. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

The problems involved in the design of the proposed underground repository for high-level nuclear waste call for novel design approaches. Guidelines for the design are given by the Mission Plan Amendment in which licensing and regulatory aspects have to be satisfied. Moreover, systems engineering was proposed, advocating a top-down approach leading to the identification of discrete, implementable system elements. These objectives for the design process can be integrated in an engineering design methodology. While design methodologies for some engineering disciplines are available, they were of limited use for rock engineering because of the inherent uncertainties about the geologic media. Based on the axiomatic design approach of Suh, Bieniawski developed a methodology for design in rock. Design principles and design stages are clearly stated to assist in effective decision making. For overall performance goals, the domain of objectives is defined through components (DCs) - representing a design solution - satisfy the FRs, resulting in discrete, independent functional relations. Implementation is satisfied by evaluation and optimization of the design with respect to the constructibility of the design components.

293 (DOE/ER/14352–1, pp. 749-752) **In situ flow testing of a cement borehole seal in welded tuff.** Crouthamel, D.R. (Stone & Webster Engineering, Inc., Boston, MA (United States)); Fuenkajorn, K.; Daemen, J.J.K. Wisconsin Univ., Madison, WI (United States). 1993. (CONF-930644–Vol.2: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993). In *Rock mechanics in the 1990s: Proceedings: Volume 2.* 396p. Order Number DE94014602. Source: OSTI; NTIS.

Exploratory boreholes, shafts and tunnels drilled or excavated prior to or during the construction of a subsurface nuclear repository may create direct passages for radionuclide transport to the biosphere. Waste isolation at the Yucca Mountain repository suite will require that penetrations (boreholes, shafts, etc.) of the geological barrier be sealed, primarily to prevent excessive flow of groundwater and/or air into the emplaced wastes and to retard the migration of radionuclides to the accessible environment. Cement is being considered as part of multicomponent seals or plugs for the repository due to its relatively low permeability, high strength, longevity, and swelling capacity. Cement or concrete has long been used as a hydrological barrier in underground mines and in the oil and gas industry. However, insufficient tests data exists about the hydraulic performance of cement plugs under in-situ conditions (i.e. as affected by scale, and field installation and environment), and particularly about their long-term sealing effectiveness. The objectives of the research are to determine the hydraulic conductivities of the cement plug, host stuff, and their interface, and to identify the effects of size and field installation on the borehole plug performance.

294 (DOE/IG–0351) **Report on audit of costs and management of the Yucca Mountain Project.** USDOE Office of Inspector General, Washington, DC (United States).

Capital Regional Audit Office. 23 Jun 1994. 31p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI (Free of Charge).

Report to The Secretary.

The Department of Energy (Department) is responsible for establishing an underground waste repository to store high-level nuclear waste. To carry out this responsibility, the Department of Energy established the Office of Civilian Radioactive Waste Management (Waste Management Office). The Waste Management Office began characterization of the Yucca Mountain site to assess the feasibility of safely storing spent fuel and high level waste for 10,000 years. To date, the Department had spent about $1.5 billion on site characterization activities. The purpose of our audit was to examine how effectively these funds were spent and to examine the costs and management of contracting for the project. Our audit found that if procurement and fund allocation practices were streamlined, significant savings could be achieved over the remaining life of the project. Also, the anticipated reductions in the number of project participants had not materialized, nor had management and integration of the project been effectively implemented. In addition, the Waste Management Office's efforts to make major staffing reductions had not met the original goals, and sound cost reduction ideas advanced by the project's participants were not evaluated and implemented in a timely manner. Management agreed with our recommendations and is in the process of developing a program-wide strategic plan that recognizes funding constraints and has implemented a reorganization of the management structure at the Project Office.

295 (DOE/NV–376) **Waste minimization and pollution prevention awareness plan.** Department of Energy, Las Vegas, NV (United States). Nevada Operations Office. Aug 1994. 68p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94017512. Source: OSTI; NTIS; INIS; GPO Dep.

The primary mission of DOE/NV is to manage and operate the Nevada Test Site (NTS) and other designated test locations, within and outside the United States; provide facilities and services to DOE and non-DOE NTS users; and plan. coordinate, and execute nuclear weapons tests and related test activities. DOE/NV also: (a) Supports operations under interagency agreements pertaining to tests, emergencies, and related functions/activities, (b) Plans, coordinates, and executes environmental restoration, (c) Provides support to the Yucca Mountain Site Characterization Project Office in conjunction with DOE/HQ oversight, (d) Manages the Radioactive Waste Management Sites (RWMS) for disposal of low-level and mixed wastes received from the NTS and off-site generators, and (e) Implements waste minimization programs to reduce the amount of hazardous, mixed, radioactive, and nonhazardous solid waste that is generated and disposed The NTS, which is the primary facility controlled by DOE/NV, occupies 1,350 square miles of restricted-access, federally-owned land located in Nye County in Southern Nevada. The NTS is located in a sparsely populated area, approximately 65 miles northwest of Las Vegas, Nevada.

296 (DOE/RW–0441) **Regulatory guidance document.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). May 1994. 128p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94015371. Source: OSTI; NTIS; INIS; GPO Dep.

The Office of Civilian Radioactive Waste Management (OCRWM) Program Management System Manual requires preparation of the OCRWM Regulatory Guidance Document (RGD) that addresses licensing, environmental compliance, and safety and health compliance. The document provides: regulatory compliance policy; guidance to OCRWM organizational elements to ensure a consistent approach when complying with regulatory requirements; strategies to achieve policy objectives; organizational responsibilities for regulatory compliance; guidance with regard to Program compliance oversight; and guidance on the contents of a project-level Regulatory Compliance Plan. The scope of the RGD includes site suitability evaluation, licensing, environmental compliance, and safety and health compliance, in accordance with the direction provided by Section 4.6.3 of the PMS Manual. Site suitability evaluation and regulatory compliance during site characterization are significant activities, particularly with regard to the YW MSA. OCRWM's evaluation of whether the Yucca Mountain site is suitable for repository development must precede its submittal of a license application to the Nuclear Regulatory Commission (NRC). Accordingly, site suitability evaluation is discussed in Chapter 4, and the general statements of policy regarding site suitability evaluation are discussed in Section 2.1. Although much of the data and analyses may initially be similar, the licensing process is discussed separately in Chapter 5. Environmental compliance is discussed in Chapter 6. Safety and Health compliance is discussed in Chapter 7.

297 (DOE/RW–0448) **OCRWM Bulletin, summer/fall 1994.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). [1994]. 36p. Sponsored by USDOE, Washington, DC (United States). Source: OSTI; INIS; OSTI (Free of Charge).

This publication consists of two parts, OCRWM Bulletin, and Of Mountains & Science which is about the Yucca Mountain project. The OCRWM bulletin provides information about OCRWM activities, program update to Congress, reorganization, training provided on OCRWM database, OCRWM calendar, and exhibit schedule for 1994. Recent activities at the Yucca Mountain project such as the arrival of the tunnel boring machines is presented in layman's term.

298 (INIS-mf–14377) **Alligator Rivers Analogue project - Geologic Setting: Final Report - Volume 2.** Snelling, A.A. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 118p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95606001. Source: OSTI; NTIS (US Sales Only); INIS.

In this volume the author synthesizes the results of the investigations carried over more than 20 years in the Koongarra area. It describes its regional geologic setting, geological evolution and the exploration activities carried out to date. The secondary ore of the Koongarra No. 1 uranium orebody provides a natural analogue suitable for validation of models for radionuclide transport. Although the primary uranium mineralisation occurs as uraninite veins and veinlets in fractures and brecciated zones that cross cut the steeply dipping (55 deg.C) host schists, weathering and dispersion of uranium within the zone of weathered schists has formed this secondary ore. The interaction of the weathering processes with the mineralogy and geochemistry of the unweathered host schists, and the primary hydrothermal alteration halo with and around the primary uranium mineralisation, has also been critical in the development of the secondary ore. This secondary ore natural analogue being

at a shallow depth, plus the availability of open boreholes and drill core/borehole samples, has facilitated groundwater and rock investigations. 49 refs., 4 tabs., 42 figs.

299 (INIS-mf–14378) **Alligator Rivers Analogue project. Geomorphology and paleoclimatic history: Final Report - Volume 3.** Wyrwoll, K.H. (Univ. of Western Australia, Nedlands, WA (Australia)). Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 93p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95606009. Source: OSTI; NTIS (US Sales Only); INIS.

The aim of this volume is to discuss the likely influence of geomorphological and palaeoclimatic controls on the development of the secondary dispersion fan at Koongarra. For the Koongarra area the Phanerozoic was a time of tectonic stability and predominantly subaerial denudation. The structural geology of the region facilitated the erosion of the Kombolgie Formation, setting in train the development of Koongarra Valley. With the removal of the Kombolgie cover the surface of the Cahill Formation could then be eroded. The geochemical controls on the development of the secondary dispersion fan require the orebody to be located in an oxidising weathering environment. Under the present weathering regimes it seems that this implies that the orebody is located at a depth of less than 30 m. From estimates of the present regional denudation rates of the area and wider geomorphological considerations, it is concluded that the top of the orebody would have reached such a depth at some time in the last 1-6 million years. The climates of the Late Quaternary provide some guide to Pleistocene climatic events. The most intense aridity coincided with times of global glacial maxima. There is also evidence that in the Late Cenozoic there were times of elevated rates of chemical weathering. However, the timing, nature and duration of such events is unclear. 171 refs., 4 tabs., 35 refs.

300 (INIS-mf–14379) **Alligator Rivers Analogue project. Geophysics, petrophysics and structure: Final Report - Volume 4.** Emerson, D.W. (Sydney Univ., NSW (Australia). Dept. of Geology and Geophysics); Mills, K.J.; Hallett, M.S.; Cao, L.Q.; Miyakawa, K. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 125p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95606010. Source: OSTI; NTIS (US Sales Only); INIS.

The geophysical and geological field work at Koongarra (including borehole core logging) showed that the site itself is a folded, faulted, variably fractured Precambrian psammitic and pelitic schist sequence with a quasi-horizontal weathered zone superimposed on the steeply dipping rock fabric. The site is flanked by a high resistivity younger sandstone unit to the northwest and by a magnetic amphibolite/ferricrete sequence to the far southeast. The data interpretations elicited the essential structural and broad lithological elements. Gravity, magnetic and electrical laboratory and field studies confirmed a broad folded fractured sequence of dipping layered host rocks weathered in their upper parts and trending in a southwest-northeast direction. Qualitatively interpreted anomalies indicated the trend of the main groundwater movement to the south where dolomites are thought to act as a sink. These drainage features have SP, resistivity and radiometric expression. The roles of the Kombolgie Sandstone as a source of water and the Koongarra Fault as a barrier or otherwise were not established owing to the lack of sufficient samples for testing and also on account of the difficulty of geophysical access over the site's rugged escarpment. 40 refs., 13 tabs., 69 figs.

301 (INIS-mf–14380) **Alligator Rivers Analogue project. Groundwater Chemistry: Final Report - Volume 7.** Edis, R. (Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia)); Waite, D.; Herczeg, A.L.; Sekine, Keiichi; Yanase, Nobuyuki; Seo, Toshihiro. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 185p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605960. Source: OSTI; NTIS (US Sales Only); INIS.

The objective of this volume is to provide an account of the groundwater sampling and analysis program undertaken at Koongarra, as part of the Alligator Rivers Analogue Project. Chemical parameters were investigated in groundwaters at various locations and depths in the vicinity of the Koongarra orebody. Measurements of the pH, redox state, conductivity, and bicarbonate alkalinity provided a starting point for interpreting water chemistry. Groundwater samples were obtained using submersible pumps, or, in a few cases, bailers. The concentrations of major cations and anions, such as magnesium and phosphate, were determined using a variety of standard techniques. Numerous elements were routinely analysed using quantitative or semi-quantitative ICPMS. Uranium series radionuclides and environmental isotopes were measured using radiochemical techniques and mass spectrometry. The distributions of isotopes such as deuterium, tritium, ^{210}Pb, ^{13}C and ^{14}C enabled groundwater mixing and flow-paths to be studied. The occurrence and distributions of major species at Koongarra are presented in this volume, using both cross-sections and contour plans. Chemical and isotopic data for groundwater analyses carried out during the project are included in the Appendices. 47 refs., 16 tabs., 58 figs.

302 (INIS-mf–14381) **Alligator Rivers Analogue project. Weathering and its effects on uranium redistribution: Final Report - Volume 9.** Isobe, H. (Japan Atomic Energy Research Inst., Tokai, Ibaraki (Japan). Tokai Research Establishment); Ohnuki, T.; Yanase, N.; Sato, T.; Kimura, H.; Sekine, K.; Nagano, T.; Edis, R.; Klessa, D.A.; Conoley, C.; Nakashima, S.; Ewing, R.C. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 138p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605961. Source: OSTI; NTIS (US Sales Only); INIS.

In the vicinity of the uranium ore deposit at Koongarra, quartz-chlorite schist, the ore host rock, has been subjected to weathering. Although quartz is resistant to weathering, chlorite has been altered to clays and iron minerals. The chlorite weathering and the uranium association with the weathered minerals are the main topics of this study. In order to clarify the weathering of chlorite and its effects on the redistribution of uranium, the processes, mechanisms, and kinetics of the chlorite weathering, and the uranium concentrations in minerals were examined by various methods: X-ray diffraction analysis, scanning electron microscopy, electron microprobe analysis, transmission electron microscopy, autoradiography, visible spectroscopy, alpha and gamma spectrometry. The observed results were compared to those calculated, based on two different models developed for the present study. Water-rock interactions have resulted in the weathering of chlorite and precipitation and sorption of uranyl from the groundwaters with the weathering products. It is concluded that the chlorite weathering

affects the uranium retardation factor, and thus uranium redistribution at Koongarra. 55 refs., 20 tabs., 120 figs.

303 (INIS-mf–14382) **Alligator Rivers Analogue project. Geochemical Data Bases: Final Report - Volume 10.** Bennett, D.G. (W.S. Atkins Environment, Epsom, Surrey (United Kingdom)); Read, D. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 56p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605962. Source: OSTI; NTIS (US Sales Only); INIS.

The Koongarra uranium deposit in the Northern Territory of Australia is being studied to evaluate the processes involved in the geochemical alteration of the ore body and the formation of the uranium dispersion fan. A broad range of research is being undertaken into the geochemistry and hydrology of the site with the aim of understanding the transport of radionuclides through the system. During the project a range of geochemical and hydrogeochemical models have been developed to account for measured data from the site and with which to predict site evolution. The majority of these models are based on the premise of thermodynamic chemical equilibrium and employ fundamental thermodynamic data to characterise the chemistry of the system. From the differences which exist between the thermodynamic data bases (Appendices I and II) it is possible to gain a view of the level of uncertainty associated with thermodynamic data in each set of calculations. This report gives a brief introduction to the geochemical processes underlying the models, and details the equations used to quantify the more common of these processes (e.g. aqueous speciation and mineral solubility). A description is given of the computer codes (EQ3/6, PHREEQE, MINTEQ) most commonly used during the project for geochemical modelling. Their key features are highlighted and comparisons made. It is concluded that the degree of uncertainty in geochemical modelling studies arising as a result of using one code rather than another is relatively insignificant when compared to that related to differences in the underlying data bases. 73 refs., 3 figs.

304 (INIS-mf–14383) **Alligator Rivers Analogue project. Geochemistry of ^{239}Pu, ^{129}I, ^{99}Tc and ^{36}Cl: Final Report - Volume 15.** Fabryka-Martin, J.T. (Los Alamos Scientific Lab., NM (United States)); Curtis, D.B. Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). 1992. 82p. Sponsored by Nuclear Energy Agency, 75 - Paris (France). Order Number DE95605963. Source: OSTI; NTIS (US Sales Only); INIS.

One objective of this research programme has been to evaluate the applicability of uranium orebodies as natural analogues for testing radionuclide release-rate models used in performance assessment activities. The investigated nuclides included three of the most persistent radioactive constituents of high-level wastes from nuclear fission power reactors: plutonium-239, iodine-129, and technetium-99. The feasibility of uranium minerals as analogues for the behavior of these nuclear reaction products (NRP) in spent fuel relies upon a capability to characterise NRP concentrations in the source minerals. Measured abundances of natural ^{239}Pu, ^{99}Tc and ^{129}I in uranium ores are compared to calculated abundances in order to evaluate the degree to retention of these radionuclides by the ore. This modelling study also shows the extent to which various NRP are correlated, such that one provides a constraint on the production rates of others. Under most conditions, ^{36}Cl, another long-lived neutron-capture product found in uranium ores, is shown to be an ideal in-situ monitor of the ^{235}U fission rate, which is the dominant source term for ^{129}I and possibly a significant one for ^{99}Tc. Similarly, ^{239}Pu/U ratios can be used to establish limits on the ^{238}U neutron-induced fission rate; the ratios measured in this study suggest that ^{238}U induced fission comprises < 4% of the total fissions in most of the ore samples studied and hence can be neglected as a source of ^{129}I and ^{99}Tc. 79 refs., 21 tabs., 18 figs.

305 (INIS-mf–14384) **The effect of weathering on the distribution of uranium and associated elements at Koongarra, Northern Territory, Australia.** Edis, Robert (Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia)). Sydney Univ., NSW (Australia). Mar 1992. 162p. Sponsored by Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW (Australia). Order Number DE95605964. Source: OSTI; NTIS (US Sales Only); INIS.

A thesis submitted to the Faculty of Agriculture of the University of Sydney in fulfilment of the requirements for the degree of Master of Science in Agriculture.

The aim of work described in this thesis was to investigate some aspects of the redistribution of U and other elements, at the Koongarra No.1 U ore deposit in the Northern Territory of Australia. Aspects of the redistribution of U which are considered in this thesis include the spatial patterns of remobilised U; the associations of U with minerals and elements and how these change with weathering, and transport of material by colloids present in the groundwater. The Koongarra No.1 U ore deposit is currently being studied as a natural analogue of a high level radioactive waste repository, as part of the Alligator Rivers Analogue Project. As spent fuel is a proposed waste form for geological burial, the study of uraninite leaching in an ore body makes a very good analogue of a breached repository. Work presented in this thesis was undertaken as part of that study. Aspects of the redistribution considered here include spatial patterns of redistributed U, associations between U, other elements and minerals, and transport of material by groundwater colloids. Techniques employed include:- thin section analyses (optical analysis, autoradiography, electron microprobe, and scanning electron microscopy); mineralogical and chemical analyses (x-ray diffraction, x-ray fluorescence, PIXE-PIGME, neutron activation, and infra-red spectrophotometry); groundwater colloid sampling and concentrating (tangential and stirred cell ultrafiltration); transmission electron microscopy for the examination of colloids and scanning electron microscopy for the examination of prefilters. The redistribution of U during weathering appeared to follow the distribution of Fe oxides. Uranium present in the groundwater responsible for the weathering would then have absorbed onto the freshly precipitated and highly sorptive Fe oxides. Uranium concentrations appeared to be correlative to the degree of weathering, and the corresponding amount of Fe oxides. 339 refs., 36 tabs., 83 figs.

306 (INIS-XN–505) **The International Intraval project: to study validation of geosphere transport models for performance assessment of nuclear waste disposal. Phase 1, summary report.** Nuclear Energy Agency, 75 - Paris (France). Dec 1993. 135p. Order Number DE94629680. Source: OSTI; NTIS (US Sales Only); INIS.

Intraval is an international project that addresses the validation of models of transport of radionuclides through groundwater in the geosphere. Such models are used in assessment of the long-term safety of nuclear waste disposal systems. The present report summarises the results for the test cases and presents some additional remarks.

307 (JAERI-M–94-061) **Status of natural analogue studies: Based on the results obtained by JAERI.** Sekine, Keiichi (Japan Atomic Energy Research Inst., Tokai, Ibaraki (Japan). Tokai Research Establishment). Japan Atomic Energy Research Inst., Tokyo (Japan). Mar 1994. 26p. (In Japanese). Order Number DE94785243. Source: OSTI; NTIS; INIS.

This report is based on the materials for the meeting at the Nuclear Safety Commission of Japan held on September 1993. Details are as follows: Alteration of glass as the study of alteration of natural minerals; alteration of uranium minerals, migration of uranium and thorium series radionuclides, alteration of chlorite, fixation of uranium alteration of minerals and migration of uranium as the study of alligator rivers analogue project held at Koongarra uranium deposit, Australia. (author).

308 (LA-UR–94-2245) **Vadose zone drilling at the NTS.** Efurd, D.W. Los Alamos National Lab., NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94016080. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Project has an opportunity to evaluate possible mobilization and transport of radioactive materials away from the storage horizon in the proposed repository. One scenario by which such transport could occur involves water leaving the storage area and carrying radioactive particulates of colloidal size. The colloids could move along the gas-liquid interface in partially filled fractures within the vadose zone. It should be possible to check the reality of this proposed scenario by examining "anthropogenic analogs" of the repository. These are sites of nuclear tests conducted in unsaturated tuff at the Nevada Test Site (NTS). We propose to drill under one or more such sites to determine if radionuclides have moved from their original confinement in the puddle- glass at the bottom of the cavity. This document examines the characteristics of an ideal test site for such a study, suggests several possible locations that have some of the desired characteristics, and recommends one of these sites for the proposed drilling.

309 (MIC–94-04011/XAB) **Uranium mining developments in northern Saskatchewan: Dominique-Janine extension, McClean Lake project and midwest joint venture: Report.** AEA Environment and Energy, Harwell (United Kingdom). ©1993. 71p. (SSC-EN–106-21/1993E). Source: NTIS Prices: PC E07/MF E02.

Cover title: Dominique-Janine Extension, McClean Lake Project, and Midwest Joint Venture: Report. French ed. : 94-04012/1.

In April 1991, the governments of Canada and Saskatchewan announced a joint federal-provincial environmental assessment review to study uranium mine developments in northern Saskatchewan. To be included in the review were proposals for the Dominique-Janine extension of an existing mine, a proposed new mine at McClean Lake, and a proposed new mine, the Midwest Joint Venture, at South McMahan Lake, as well as proposals for operating mines at McArthur River and at Cigar Lake. This report assessed the acceptability of the first three proposed ventures. It addressed general issues such as the participation of the northern people, biophysical and related concerns, health issues, sustainable development, alternative energy sources, local and global aspects of uranium mining, regulatory agencies, and the nuclear fuel cycle; and the biophysical, socio-economic, and health concerns for each proposed project.

310 (NUREG/CR–6203) **Validation studies for assessing unsaturated flow and transport through fractured rock.** Bassett, R.L. (Arizona Univ., Tucson, AZ (United States). Dept. of Hydrology and Water Resources); Neuman, S.P.; Rasmussen, T.C.; Guzman, A.; Davidson, G.R.; Lohrstorfer, C.F. Nuclear Regulatory Commission, Washington, DC (United States). Div. of Regulatory Applications; Arizona Univ., Tucson, AZ (United States). Dept. of Hydrology and Water Resources. Aug 1994. 210p. Sponsored by Nuclear Regulatory Commission, Washington, DC (United States). Source: OSTI; NTIS; INIS; GPO.

*The objectives of this contract are to examine hypotheses and conceptual models concerning unsaturated flow and transport through heterogeneous fractured rock and to design and execute confirmatory field and laboratory experiments to test these hypotheses and conceptual models. Important new information is presented such as the application and evaluation of procedures for estimating hydraulic, pneumatic, and solute transport coefficients for a range of thermal regimes. A field heater experiment was designed that focused on identifying the suitability of existing monitoring equipment to obtain required data. A reliable method was developed for conducting and interpreting tests for air permeability using a straddle-packer arrangement. Detailed studies of fracture flow from Queen Creek into the Magina Copper Company ore haulage tunnel have been initiated. These studies will provide data on travel time for transport of water and solute in unsaturated tuff. The collection of rainfall runoff, and infiltration data at two small watersheds at the Apache Leap Tuff Site enabled us to evaluate the quantity and rate of water infiltrating into the subsurface via either fractures or matrix. Characterization methods for hydraulic parameters relevant to Weigh-level waste transport, including fracture apertures, transmissivity, matrix porosity, and fracture wetting front propagation velocities, were developed.

311 (PB–94-174133/XAB) **US nuclear waste technical review board report to the US Congress and the Secretary of Energy, January to December 1993.** Nuclear Waste Technical Review Board, Arlington, VA (United States). Dec 1993. 178p. Source: NTIS Prices: PC A09/MF A02; INIS.

Also available from Supt. of Docs. See also NUREG-1046, PB–93-141620 and PB–94-113636.

This report reviews conclusions and recommendations that have resulted from the Board's activities primarily during 1993. In a few cases, activities that took place during 1992 and 1994 also are discussed. Since its last report on the exploratory studies facility, in October 1993, the Board has continued its interactions with the DOE, the state of Nevada, and with others involved in or concerned about the civilian radioactive waste management program. In this report, the Board makes a number of technical recommendations that it believes will aid the DOE in its endeavors to design and implement a safe and efficient radioactive waste disposal system. The report also discusses briefly some of the insights the Board gained during its interactions in June 1993 with experts from high-level waste management programs in Belgium, France, and the United Kingdom.

312 (PNL–9415) **Regional forecasting with global atmospheric models: Fourth year report.** Crowley, T.J. (Applied Research Corp., College Station, TX (United States)); North, G.R.; Smith, N.R. Pacific Northwest Lab., Richland, WA (United States); Applied Research Corp., College Station, TX (United States). May 1994. 60p. Sponsored

by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94013957. Source: OSTI; NTIS; INIS; GPO Dep.

The scope of the report is to present the results of the fourth year's work on the atmospheric modeling part of the global climate studies task. The development testing of computer models and initial results are discussed. The appendices contain studies that provide supporting information and guidance to the modeling work and further details on computer model development. Complete documentation of the models, including user information, will be prepared under separate reports and manuals.

313 **Natural analogue studies in the geological disposal of radioactive wastes.** Studies in Environmental Science, No. 57. Miller, W. (Intera Information Technologies (United Kingdom)); Chapman, N.; Alexander, R.; McKinley, I.; Smellie, J. 401p. Elsevier, Amsterdam (Netherlands) (1994). (NAGRA-NTB–93-03.).

The book deals with the concepts of radioactive waste disposal in Switzerland, Sweden and England, with analogue studies, radionuclide release and transport, applying natural analogue information, and the status of natural analogue studies. It contains descriptions of fourteen natural analogue studies.

314 **Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region.** Akber, R.A. (comp.) (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). 360p. Australian Government Publishing Service, Canberra (Australia) (1992). (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The objectives of the workshop were to review the current knowledge of land application as a technique for disposal of water from mine sites, to assess the for regulation of use of land application in the Alligator River Region, and to specify future information requirements on land application. The paper sessions were followed by two workshops on land application implications for regulation and future information needs. A summary of these sessions is also included in the proceedings. figs., tabs., refs.

315 **Alligator Rivers Region.** pp. 5-13 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

An introduction to the Alligator Rivers Region is presented. It contains general information regarding the physiography, climate, hydrology and mining of the region. The Alligator Rivers Region is within an ancient basin, the Pine Creek Geosyncline, which has an area of approximately 66000 km^2. The Geosyncline has a history of mineral exploitation dating back to 1865, during which time 16 metals have been extracted (silver, arsenic, gold, bismuth, cadmium, cobalt, copper, iron, manganese, molybdenum, lead, tin, tantalum, uranium, tungsten, zinc). Uranium exploration in the Pine Creek Geosyncline was stimulated by the discovery in 1949 of secondary uranium mineralisation near Rum June, 70 km south-east of Darwin. This was followed by a decade of intense exploration activity resulting in the discoveries of economic uranium ore bodies at Rum Jungle and in the upper reaches of the South Alligator River Valley. All the known major uranium deposits of the East Alligator River uranium field have been discovered since 1969. The present known resources of the Geosyncline are approximately 360 000 tonnes of contained U_3O_8. 2 refs., 2 figs., 1 tab.

316 **Land application for disposal of excess water: an overview.** Riley, G.H. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 14-22 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Water management is an important factor in the operation of uranium mines in the Alligator Rivers Region, located in the Wet-Dry tropics. For many project designs, especially open cut operations, sole reliance on evaporative disposal of waste water is ill-advised in years where the Wet season is above average. Instead, spray irrigation, or the application of excess water to suitable areas of land, has been practised at both Nabarlek and Ranger. The method depends on water losses by evaporation from spray droplets, from vegetation surfaces and from the ground surface; residual water is carried to the groundwater system by percolation. The solutes are largely transferred to the soils where heavy metals and metallic radionuclides attach to particles in the soil profile with varying efficiency depending on soil type. Major solutes that can occur in waste water from uranium mines are less successfully immobilised in soil. Sulphate is essentially conservative and not bound within the soil profile; ammonia is affected by soil reactions leading to its decomposition. The retrospective viewpoint of history indicates the application of a technology inadequately researched for local conditions. The consequences at Nabarlek have been the death of trees on one application area and the creation of contaminated groundwater which has moved into the biosphere down gradient and affected the ecology of a local stream. At Ranger, the outcome of land application has been less severe in the short term but the effective adsorption of radionuclides in surface soils has lead to dose estimates which will necessitate restrictions on future public access unless extensive rehabilitation is carried out. 2 refs., 1 tab.

317 **Soils and hydrology of the Ranger uranium mine land application site.** Willett, I.R. (CSIRO, Canberra, ACT (Australia). Div. of Soils); Charters, C.J.; Bond, W.J. pp. 25-42 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper describes the soils and hydrology of an area between Ranger Uranium Mine and Magela Creek, Northern Territory, which is being used for the disposal of retention pond water by irrigation. The soils of an alternative site are also described in less detail. The soil survey of the irrigated area indicated three mapping units differentiated on the basis of texture, colour depth, drainage and the presence of absence of ferricrete. The predominant soils in each unit were yellow earths, red earths and siliceous sands. All the soils had high (20-50%) gravel contents consisting of quartz

and ferruginous materials. The gavel is expected to have little ability to retain solutes and therefore reduces the effectiveness of the bulk soil to retain solutes. The soils are generally low in clay (<20%) and organic matter <1%) and are acidic. The clay minerals were of the low activity types, predominantly kaolinite. Consequently the cation exchange capacities of the soils were very low indicating a limited capacity to retain cations. Preliminary calculations showed that the soils would be unable to retain all the cations in the applied water. In order to assess whether redox reactions are likely to be involved in the retention of radionuclides, the responses of the soils to saturation were tested in a laboratory experiment. The implications of these results for the retention of metals and radionuclides were discussed. All soils were found to have high permeabilities. Preliminary calculations showed that transmission of irrigation water to the water table would be rapid (less than 6 weeks). The soils of the alternative site were generally heavier and contained less gravel than those of the current irrigation site. They are likely to retain more solutes than the soils of the current irrigated area and may be better suited to land disposal of retention pond water. 20 refs., 6 tabs., 5 figs.

318 **General monitoring of soils at Nabarlek and Ranger uranium mines.** Wigston, S.R. (Conservation Commision of Northern Territory, Winnellie, NT (Australia). Land Conservation Unit). pp. 43-69 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper discusses the principles for soil monitoring in the Uranium province as carried out by the Land Conservation Unit of the Conservation Commission of the Northern Territory. It outlines the past and current practices of soil monitoring and indicates the best future direction which should be taken to ensure optimum environmental safeguards. During the discussion, soils of the areas monitored will be referred to in general terms. 11 refs., 4 figs.

319 **Hydrology of Ranger land application area.** McQuade, C.V. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 70-78 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

In 1984 Ranger Uranium Mines (RUM) began assessing the technique of water treatment by land application as a means of reducing the volume of stored water within the Restricted Release Zone. Knowledge of the hydrological characteristics of the treatment site is necessary for optimal day to day and season to season operation of the system and as an input into the assessment of the long-term viability of the site. This paper provides background information on the hydrological requirements for a water treatment site, describes the RUM's water treatment by land application system and summarises the operational statistics and current hydrological knowledge of the site. The general groundwater hydrology of the area comprises a surface soil aquifer overlying a semi-confined aquifer. Drainage of the surface aquifer follows the surface topography along the sandy clays. Vertical permeability ranges between 3 and 12 times greater than horizontal permeability. 7 refs., 2 tabs., 4 figs.

320 **Movement of water and major ions in the Jabiru land application experiment.** Bond, W.J. (CSIRO, Canberra, ACT (Australia). Div. of Soils); Willett, I.R. pp. 79-104 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

A field experiment was conducted to simulate the effects of irrigation with water from Ranger Uranium Mine's Retention Pond 2 on the transport of water, solutes and radionuclides in soil near the minesite. The experiment was generally conducted in accordance with the practices of Ranger Uranium Mine. It was aimed to reproduce these practices under more carefully controlled conditions than those of the actual irrigation area. In particular, the application of water in the irrigation area was observed to be very uneven because of the type of impulse sprinklers used, and because of the obstruction of the sprinkler spray patterns by trees and shrubs. An area that had not been irrigated was selected for the experiment so that the effects of applying RP2 type irrigation water without the effects of previous irrigation could be determined. The main differences between the experimental site and the actual irrigation area were that an area with few trees and shrubs was selected, and the herbage was harvested for analyses. This paper describes the effects of irrigation with RP2 water on water and solute movement in the soil. It describes the effect of irrigation on the storage of water in the soil and on the flow of water through the soil, particularly on the amount of water flowing past the 50 cm depth and potentially entering the groundwater. It also describes the fluxes to the groundwater of major ions dissolved in the water. 10 refs., 5 tabs., 13 figs.

321 **Land application at Ranger uranium mine, northern Australia: six years'review.** Noller, B.N. (Dept. of Mines and Energy, Darwin, NT (Australia). Mines Environment Directorate); Zhou, J.X. pp. 107-112 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This report reviews the six years' practice of land application of waste water at the Ranger Uranium Mine, northern Australia. Elements of significance to the chemical impact on the environment by mining and milling at Ranger are analysed taking into consideration ore petrology and mineralogy, chemical compositions of rocks and ore, relative enrichment of different rock- and ore-forming elements, and the chemicals involved in the milling and extraction processes. Biogeochemistry of land application of waste water as an efficient environmental managing technique is discussed by analysing its biogeochemical cycles, variables which affect the biogeochemical processes, and aqueous chemistry. Data from monitoring of the soils, groundwater, biota, and seepage in the land application area at Ranger are collected and re-organised. A new approach to data presentation and interpretation is made based on the analysis

of the most important variables which may affect the extent of the chemical impact of land application of waste water. The environmental impact of land application of waste water on soils, ground water, biota, and surface water (through seepage) is assessed accordingly. Uranium is retained in the near-surface soil layer while sulfate is present at lower depths. Manganese shows some mobility, appearing in depressions. Radium 226 shows no clear-cut relationship between location of soil sample and level. It is concluded that land application of waste water at Ranger has resulted in minimal environmental impact. 4 refs.

322 Adsorption properties of the soils of the Ranger uranium mine land application area for solutes in water from Retention Pond 2. Willett, I.R. (CSIRO, Canberra, ACT (Australia). Div. of Soils); Bond, W.J. pp. 113-138 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The research reported here aimed to describe the adsorption properties of the soils of Ranger's irrigation area for important constituents of RP2 water. Three kinds of experiments were conducted. For the major ions (Na^+, Mg^{2+}, Ca^{2+}, K^+, SO_4^{2-}, and Cl^-) measurements were made of cation and anion exchange capacities. For the minor solutes (MN^{2+}, U^{238}, and Ra^{226}) which undergo more specific, inner-sphere reactions with soil surfaces, the retention capacities were determined by batch adsorption isotherm methods. Lastly, column experiments were conducted to determine whether the soils could retain U^{238}, Ra^{226} and Pb^{210} when the quantities of each radionuclide were applied in much greater quantities than was possible in the batch adsorption studies, or during the field experiment described earlier at this Workshop (Bond and Willett 1992). It was aimed to obtain information on the retention capacity of the three main soil types of the irrigation area; Unit I, II and III, respectively red earths, yellow earths and siliceous sands, in relation to soil pH. 7 refs., 4 tabs., 13 figs.

323 Fate of radionuclides applied to soil in the Ranger uranium mine land application area. Akber, R.A. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)); Marten, R. pp. 139-165 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper describes the behaviour of the radionuclides ^{238}U, ^{226}Ra and ^{210}Pb within the Ranger Uranium Mine Land Application area. The results presented are based mainly upon the radionuclide analysis of sections of soil core samples recovered from various locations in the land application plot and from a separate experimental plot used to study the fate of solutes during the land application of Ranger Retention Pond 2 water. The results demonstrate that a large proportion of the adsorbed radionuclides is small. An autoradiography study of the soil profile showed that some localised downward movement of radioactivity is possible along pores in the soil structure. 5 refs., 4 tabs., 6 figs.

324 Fate of solutes applied to land application areas. McBride, T.P. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 166-177 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper discusses the fate of major solutes contained in waste waters applied to the Nabarlek and Ranger land application areas. The soils of irrigation plots at Nabarlek and Ranger have limited capacity to retain the major solutes in irradiated waters. At Nabarlek, sulphate (average 5500 mg/L) in irrigated Evaporation Pond 2 (EP2) waters has infiltrated into the soil and is readily transported in groundwater flow. Ammonium (average 1100 mg/L) in irrigated EP2 waters is largely retained by cation adsorption in the soils but is readily oxidised in the aerobic zone to nitrate which can move readily in groundwaters in the same manner as sulphate. Groundwater concentrations of nitrate and sulphate above 500 mg/L and 5000 mg/L respectively have been observed at monitoring bores near the Nabarlek Forest Irrigation Area. At Ranger the sulphate contained in irrigated waters has produced concentrations up to 300 mg/L in groundwaters. Present data suggest that uranium in irrigated waters remains fixed in the top few centimeters of soil in the irrigation area, although the possibility of remobilisation cannot be dismissed because of unexplained high uranium concentrations observed in nearby parts of Magela Creek during the 1991 Wet season. The data presently available do not allow the effects of irrigation-derived solutes on Magela Creek water chemistry to be separated from those of solutes contained in released RP1 and RP4 waters and therefore the amounts of solutes specifically from the irrigation area that have passed down Magela Creek cannot be determined. However, a model developed by OSS for predicting inputs of solutes to Magela Creek from the irrigation area suggests that a significant contribution could be made. Sulphate concentrations in Magela Creek are low and it is uncertain whether most of the major solutes contained in the irrigated waters have moved laterally towards Magela Creek or have continued moving downwards to greater depths. 3 refs., 4 tabs., 9 figs.

325 Critical groups - basic concepts. Carter, M.W. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 181-186 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The potential exposure pathways from the land application site to man are presented. It is emphasised that the critical group is not necessary the population group closest to the source. It could be the group impact by the most significant pathways(s). Only by assessing the importance of each of these pathways and then combining them can a proper choice of critical group be made. It would be wrong to select a critical group on the basis that it seems the most probable one, before the pathways have been properly assessed. A calculation in Carter (1983) suggested that for the

operating mine site, the annual doses to an Aboriginal person, a service worker and a local housewife, were all about the same and were in the range 0.1 to 0.2 mSv per year. Thus it may be that for the land application area, the critical group turns out to be non-Aboriginal rather than the expected Aboriginal group. 6 refs., 3 figs.

326 An Aboriginal perspective on future land use of the land application site of Ranger Uranium Mine. Robotham, F.R.J. (Northern Land Council, Casuarina, NT (Australia)); McLaughlin, D. pp. 187-191 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The Northern Land Council, representing the interests of the traditional owners of the Ranger site, wants the mining site to be restored to its pre-mining condition or as near as possible to it. It is also emphasised that the effective dose equivalent limit to be used for rehabilitation site, including the land application area should be 0.7 mSv per year. Moreover, the land application water should be of such quality that there is no limitation on future land use. 3 refs.

327 Preliminary assessment of radiological conditions at the Ranger land application area. Kavasnicka, J. (Northern Territory Dept. of Mines and Energy, Darwin, NT (Australia)); Bywater, J. pp. 226-240 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Some 18 GBq of uranium and 1.5 GBq of ^{226}Ra were disposed of by land application on the designated disposal area by March 1989. This preliminary study, which is part of a longer-term project, outlines the assessment of external gamma radiation exposures from short-lived gamma-ray emitting decay products of ^{226}Ra and of internal exposures from inhalation of uranium and ^{226}Ra resuspended from the soil surface. The effective dose equivalent from these two exposure pathways for an adult member of the public was calculated to be about 0.05 mSv.y^{-1} (based on a 4 hour per day occupancy of the disposal area). This dose implies a total combined load limit of 490 kBq.m^{-2} of uranium plus 41 kBq.m^{-2} of ^{226}Ra. It is expected that the load limit will be reduced when all pathways and more recent data are taken into the account. 8 refs., 14 tabs., 3 figs.

328 Radiological impact of radionuclide uptake by plants in the land application area. Akber, R.A. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)); Marten, R. pp. 241-251 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Radionuclide concentrations in fruits and foliage of plants can increase as the result of irrigation with effluent water from a uranium mine. The significance of this pathway is discussed with respect to radiological impact from consumption of food and from the generation of ash as a result of bush fires. During the irrigation phase, radionuclide uptake by plants is expected to be via roots only. It is important to make a distinction between the contribution of these two systems, because radiological impact on humans via the vegetation pathways is likely to take place after rehabilitation, when the area could be occupied by humans. This distinction has been achieved through comparison of radionuclide concentrations in the vegetation harvested from an experimental plot, before, during and after irrigation with the simulated Retention Pond 2 (RP2) water of the Ranger Uranium Mine. The consumption of terrestrial food by the Aboriginal people is small and annual land application is likely to result in a dose increment of 3 μSv y^{-1} during future occupancy of the land application area. Bush fires immediately after irrigation may generate ash material 30-40 times more radioactive than the soil material, but subsequent bush fires will produce less radioactive ash. With the exception of uranium in foliage, the measured concentration factors agree within a factor of two with the default values recommended by IAEA. The uranium concentration factor for foliage material was found to be 2-8 times higher than the IAEA default value. 14 refs., 5 tabs., 3 figs.

329 External gamma dose rate survey of the Ranger Uranium Mine land application plot. Marten, R. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 252-266 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Radionuclides, as part of the solutes in retention pond water from a uranium mine, when spray irrigated on land, are adsorbed in the surface 5 to 6 cm layer and impact on the environment in several ways. This survey was conducted to establish the distribution of the external gamma dose rate generated by the applied radionuclide load on the Ranger Uranium Mine land application plot. This paper presents the methodology, the characteristics of the instruments used, and results of investigations of the possible influence of variable background sources, necessary for low level measurements. The final result is compared with results of the analysis of six cores, collected as part of this survey, and with earlier estimates. 2 refs., 3 tabs., 10 figs.

330 Suspension of dust in the vicinity of Ranger Uranium Mine: an estimate for the land application area. Akber, R.A. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 267-286 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520--: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

Suspension of dust in the vicinity of Ranger Uranium Mine is discussed. Estimates of dust loadings are provided through the analysis of two data sets, one covering dust sampling at eight different sites over a six year period and the other an extensive data set for seven different sites sampled for a single Dry season. The Wet season dust loadings average for six years data is 12 $\pm$ 2 μgm^{-3} which

is only half the average value of 24 ± 14 μgm^{-3} for data in a single Dry season. Occasional high dust loadings were observed in the single Dry season data. About 84% of the total dust loading is due to the <10 μm grain size fraction. No correlation exists between the dust loadings and location of sampling sites with respect to the Ranger Uranium Mine and the townships of Jabiru and Jabiru East. The annual average air-borne long-lived alpha radioactivity concentration is 0.13 ± 0.02 mBq^{-3}. High alpha radioactivity concentrations (0.55 ± 0.04 $mBqm^{-3}$) for a sampling site located in the vicinity of an undisturbed uranium orebody were excluded from this average. The seasonal variations of alpha radioactivity concentrations are similar to those of the dust loadings. The corresponding values of the specific radioactivity of dust do not change seasonally which indicates the absence of a strong mine related dust plume associated with the dominant Dry season winds from the mine site to Jabiru East and Jabiru. A resuspension factor 1 x 10^{-8} is recommended for radionuclide loads arising from land application of water from Retention Pond No. 2 at Ranger Uranium Mine. Uncertainties associated with this estimate are discussed. 25 refs., 9 tabs., 3 figs.

331 Effects on native plants of the land application of excess mine water. Ashwath, N. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 289-298 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

The effects arising from land application of excess mine water (Retention Pond 2 (RP2)) on soil, water quality and radiation exposure are well documented at Ranger Uranium Mine. However, the effects on local plants have received very little attention. This paper examines the available data on soil and water quality to identify the possible effects of RP2 water on the health, growth and long-term viability of local native plants. On the basis of these data and on the general responses of crop plants to mineral toxicity, it is speculated that the higher concentrations of Mn and U in RP2 water than in irrigation water may have the potential to affect local plants if the land application of RP2 water is continued until the end of the expected mine life. It is suggested that studies be undertaken on Mn and U uptake of local native plants and on means of reducing litter accumulation on the land application site. In addition, the development of a sound physiologically oriented vegetation monitoring program is proposed to assess the impact of RP2 water on local native plants. 17 refs., 5 tabs., 1 fig.

332 Ecological effects occurring outside the land application sites. McBride, T.P. (Office of the Supervising Scientist for the Alligator Rivers Region, Sydney, NSW (Australia)). pp. 316-326 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

At Nabarlek the impacts of remobilised salts from the irrigation areas are observable in Gadjerigamundah Creek where the waters contain additional solutes, including ammonium (1991 average 3.6 mg N/L), sulphate (1991 average 73 mg/L and nitrate (1991 average 66 mg N/L) and have low pH (1991 observed minimum 4.4). The existence of biological impacts in Gadjerigamundah Creek is suggested by changes in fish community structure observed in a multi-year study commissioned by Queensland Mines Pty. Ltd. Because of high dilution, mining attributable effects on Cooper Creek water chemistry are scarcely detectable and effects on its biota are not expected to be observable. At Ranger increased concentrations of magnesium (up to 4.3 mg/L), sulphate (up to 17 mg/L) and uranium (up to 1.7 μg/L) have been observed in Magela Creek at site GS8210009 during the 1990-91 Wet season and salts derived from irrigation possibly contributed to these values. However the monitoring data presently available do not allow the effects of irrigation-derived solutes on Magela Creek water chemistry to be separated from those of solutes contained in released Retention Pond 1 (RP1) and Retention Pond 4 (RP4) waters. A model developed by OSS for predicting transport of solutes from the irrigation area to Magela Creek suggests that the irrigation area has the capacity to be significant source of additional solutes. Although no monitoring has taken place in Magela Creek to detect biological impacts in Magela Creek caused specifically by irrigation, sensitive procedures used to monitor waste water releases have not detected any impacts on biota. 3 refs., 4 tabs., 9 figs.

333 Regulation and monitoring of land application. McGill, R.A. (Northern Territory Dept. of Mines and Energy, Darwin, NT (Australia)). pp. 329-337 of Proceedings of the workshop on land application of effluent water from uranium mines in the Alligator Rivers Region. Akber, R.A. (comp.). Australian Government Publishing Service, Canberra (Australia) (1992). pp. 360 (CONF-9109520–: Workshop on the land application of effluent water from uranium mines in the Alligator River Region, Jabiru (Australia), 11-13 Sep 1991).

This paper describes the objectives and regulation of, and the monitoring of the effects of, land application of surplus waters from the uranium mine sites in the Alligator Rivers Region. As a result of past problems, no further permission to use land application has been given at Nabarlek. The land application at Ranger is restricted to those days when runoff is unlikely in the prevailing climatic and soil moisture conditions. The monitoring schedule covers routine analysis of the irrigation water and water from observation bores and seepage sites around the land application area. Soil core samples are also analysed on an annual basis. On areas that are not to be used for mining operations, the most suitable method of land application depends on the chemistry and volume of the water to be irrigated and on the soil types of the irrigation area. However, on stockpiles and areas that are to be mined in the future, such considerations can be ignored. 1 tab., 1 fig.

334 Episodic caldera volcanism in the Miocene southwestern Nevada volcanic field. Revised stratigraphic framework, $^{40}Ar/^{39}Ar$ geochronology, and implications for magmatism and extension. Sawyer, D.A. (Geological Survey, Denver, CO (United States)); Hudson, M.R.; Fleck, R.J.; Lanphere, M.A.; Warren, R.G.; Broxton, D.E. *Geological Society of America, Bulletin (United States);* 106(10): 1304-1318 (Oct 1994). DOE Contract AI08-91NV11040.

The middle Miocene southwestern Nevada volcanic field (SWNVF) is a classic example of a silicic multicaldera volcanic field in the Great Basin. More than six major calderas formed between >15 and 7.5 Ma. We summarize major

revisions of the SWNVF stratigraphy that provide for correlation of lava flows and small-volume tuffs with the widespread outflow sheets of the SWNVF. New laser fusion $^{40}Ar/^{39}Ar$ isotopic ages are used to refine and revise the timing of eruptive activity in the SWNVF. The use of high-sensitivity mass spectrometry allowed analysis of submilligram-sized samples with analytical uncertainties of ~0.3% (1 σ), permitting resolution of age differences as small as 0.07 Ma. These results confirm the revised stratigraphic succession and document a pattern of episodic volcanism in the SWNVF. 95 refs., 6 figs., 3 tabs.

335 But why doesn't anybody know what to do about the waste?. Rossin, A.D. *Bezpecnost Jaderne Energie (Czech Republic);* 1(8-9): 294-309 (Aug-Sep 1994). (In Czech). (CONF-930906--: '93 international conference on nuclear waste management and environmental remediation, Prague (Czech Republic), 5-11 Sep 1993).

English translation available from Nuclear Information Center, 156 16 Prague-Zbraslav, Czechoslovakia, at USD 10.- per typewritten page.

A thorough and instructive description is given of the history of nuclear power and nuclear waste issues in the U.S. Special attention is devoted to the impacts of the President Carter's policy, to the Acts of the U.S. Congress, and to the problems connected with the design and construction of the Yucca Mountain repository. Major challenges facing the U.S. nuclear energy policy are recapitulated. 26 refs.

336 Yucca Mountain reviews a waste of time. Wamsted, D. *Energy Daily (United States);* 22(25): 3 (8 Feb 1994).

The author of this article contends that two proposed reviews of Yucca Mountain are a waste of time. Further reviews will not eliminate opposition. What is needed is real action on the issue, such as studying the safety and suitability of the proposed waste site.

337 Board seeks major changes in DOE's Yucca Mountain Program. Wamsted, D. *Energy Daily (United States);* 22(38): 3 (28 Feb 1994).

Seeking to keep the heat on the Department of Energy, the Nuclear Waste Technical Review Board urged the department to make several fundamental changes in its high level radioactive waste program. In particular, the board said DOE currently directs too much funding toward overhead and infrastructure and not enough to on-site characterization activities. In addition to these changes, the board called on O'Leary to convene an independent review of the waste program's management and organizational structure. Such a review, which the board said would complement the secretary's current financial review of the program, is particularly important in light of the department's proposal to boost funding for the program in fiscal 1995.

338 Long-term C-14 source term for a high-level waste repository. Ahn, T.M. (Nuclear Regulatory Commission, Washington, DC (United States)). *Waste Management (United States);* 14(5): 393-408 (1994).

This paper evaluates the possibility of long-term Carbon-14(C-14) releases from spent fuels and containers in the anticipated environments of the proposed Yucca Mountain high-level waste repository. Long-term degradation mechanisms of spent fuel matrices, cladding, and containers are evaluated. Under dry conditions, formation of higher oxides, such as U_3O_8, may lead to significant C-14 releases from the spent fuel matrix. It is unclear whether there will be significant C-14 releases from lower oxidation to $UO_{2.4}$ or from the unoxidized matrix. Under aqueous dissolution conditions, C-14 releases from the spent fuel matrix can be significant. Under aqueous dissolution or dry conditions, it is unlikely that there will be significant C-14 releases from cladding, unless severe localized corrosion takes place. In considering containers and cladding as metallic barriers, the authors discuss qualitatively various factor governing total C-14 containment inside metallic barriers. C-14 releases can be delayed, even by the formation of small through-wall pits in metallic barriers. Although the authors do not have completely definitive information yet, it is clear that the spent fuel matrix, cladding, and containers can serve as important barriers to C-14 releases from waste packages in a repository environment.

339 Simulation of gas phase transport of carbon-14 at Yucca Mountain, Nevada, USA. Lu, N. (Disposal Safety Inc., Washington, DC (United States)); Ross, B. *Waste Management (United States);* 14(5): 409-420 (1994). DOE Contract AC04-76DP00789.

The authors have simulated gas phase transport of Carbon-14 at Yucca Mountain, Nevada. Three models were established to calculate travel time of Carbon-14 from the potential repository to the mountain surface: a geochemical model for retardation factors, a coupled gas-flow and heat transfer model for temperature and gas flow fields, and a particle tracker for travel time calculation. The simulation used three parallel, east-west cross-sections that were taken from the Sandia National Laboratories Interactive Graphics Information Systems (IGIS). Assuming that the repository is filled with 30-year-old waste at an initial areal power density of 57 kw/acre, the authors found that repository temperatures remain above 60 C for more than 10,000 years. For a tuff permeability of 10^{-7} cm^2, Carbon-14 travel times to the surface are mostly less than 1,000 years, for particles starting at any time within the first 10,000 years. If the tuff permeability is 10^{-8} cm^2, however, Carbon-14 travel times to the surface range from 3,000 to 12,000 years, for particle starting within the 10,000 years.

340 NWTRB: YM project needs overall strategy. *Nuclear News (La Grange Park, Illinois) (United States);* 36(15): 58-59 (Dec 1993).

The eighth report on Underground Exploration and Testing at Yucca Mountain was released by the Nuclear Waste Technical Review Board (NWTRB) on October 15. The report, directed to the US Congress and the Secretary of Energy, says that although the board has seen some improvements over the last four years in the Department of Energy's plans for exploration and testing at the site, it is concerned that important technical decisions about the design and approach to excavating the exploratory facility are being made "without sufficient analysis" in order to comply with overly optimistic schedules. The board fears that this could extend, rather than shorten, program schedules, as well as increase costs.

341 The Cigar Lake uranium deposit, Saskatchewan (Canada). Pagel, Maurice (Centre de Recherches sur la Geologie de l'Uranium (CREGU), 54 - Vandoeuvre-les-Nancy (France)); Ruhlmann, Francois; Bruneton, Patrice. *Canadian Journal of Earth Sciences (Canada);* 30(4): 651-652 (Apr 1993). (In English, French).

This brief preface introduces a special section devoted to Cigar Lake. Discovered by Cogema, the deposit has estimated reserves of 154 600 tonnes of uranium with an

average grade of 7.9%. The other eight articles in this section have been abstracted separately.

342 Geological environment of the Cigar Lake uranium deposit. Bruneton, P. (Cogema/ branche Uranium, Departement des recherches minieres, Velizy-Villacoublay (France)). *Canadian Journal of Earth Sciences (Canada);* 30(4): 653-673 (Apr 1993).

The Cigar Lake uranium deposit occurs within the Athabasca Basin of northern Saskatchewan, Canada. Like other major uranium deposits of the basin, it is located at the unconformity separating Helikian sandstones of the Athabasca Group from Aphebian metasediments and plutonic rocks of the Wollaston Group. The Athabasca Group was deposited in an intra-continental sedimentary basin that was filled by fluviatile terrestrial quartz sandstones and conglomerates. The group appears undeformed, and its actual maximum thickness is about 1500 m. On the eastern side of the basin, the detrital units correspond to the Manitou Falls Formations where most of the uranium deposits are located. The lower Pelitic unit of the Wollaston Group, which lies directly on the Archaean basement, is considered to be the most favourable horizon for uranium mineralization. On the Waterbury Lake property, the Manitou Falls formation is 250-500 m thick and corresponds to units MFd, MFc, and MFb. The conglomeratic MFb unit hosts the Cigar Lake deposit. However, the basal conglomerate is absent at the deposit, wedging out against an east-west, 20 m high, pre-Athabasca basement ridge, on top of which is located the orebody. Despite the presence of the orebody, large areas of the Waterbury lake property remain totally unexplored and open for new discoveries. 45 refs., 23 figs., 4 tabs.

343 Petrography and mineralogy of alteration halos around the Cigar Lake deposit and their relation to the mineralization. Pacquet, A. (Cogema. Groupe des sciences de la Terre, Razes (France)); Weber, F. *Canadian Journal of Earth Sciences (Canada);* 30(4): 674-688 (Apr 1993). (In French).

Around the Cigar Lake orebody, the present zoneography of alteration halos reflects several alteration episodes, some of which are anterior to and others coeval with the mineralizing events and have a regional extension. In the main pod, the uraninite mineralization was dated 1341 $\pm$ 12 Ma. In the sandstones, it is surrounded by ferromagnesian chlorites with a variable sudoitic character. This proximal alteration halo grades into a more distal envelope, visible in the sandstone and in the basement, that is composed of magnesium sudoite and 3T hydromuscovite. During this mineralizing event, dravite crystallized in the form of urchin-like clusters in the basement and xenotime overgrowth, around altered zircon, and apatite formed in the sandstones. Around the main pod and in some perched orebodies, an alteration zone of vanadium-bearing ferrikaolinite and iron-bearing 3T hydromuscovite, crosscut by a later siderite, surrounds the pitchblende dated 323 $\pm$ 4 Ma. Coffinite and an aluminous hydromuscovite crystallized during a later fracture event. The aluminous hydromuscovite also appears, with a silica-carbon-uranium complex, in perched mineralizations. Kaolinization and iron-sulfide oxidation into iron hydroxides occurred in perched orebodies that were more exposed to meteoric alteration. 19 refs., 12 figs., 11 tabs.

344 Clay mineralogy and isotope geochemistry of the alteration halo at the Cigar Lake uranium deposit. Percival, J.B. (Geological Survey of Canada, Ottawa, ON (Canada). Mineral Resources Division); Bell, K.; Torrance, J.K. *Canadian Journal of Earth Sciences (Canada);* 30(4): 689-704 (Apr 1993).

Geological Survey of Canada Contribution 48590.

The clay-size fraction of the alteration halo associated with the Cigar Lake uranium deposit consists of illite with subordinate kaolinite, sudoite (Al-chlorite), Fe-chlorite, hematite, and traces of an illite-chlorite mixed-layer mineral. The Kuebler Index of illite crystallinity ranges from 2.0 to 6.7; the most-altered samples average 4.0. These data indicate that high-grade diagenetic to anchizonal conditions have been reached within the alteration halo. Intensity ratios of the 002 and 001 illite reflections (I(002)/I(001)) are generally greater than 0.4, the phengite-muscovite boundary, reflecting aluminum-rich illites; illite composition approaches hydromuscovite. K-Ar dates for illite-rich samples, from 1255 to 1148 Ma, could reflect variable resetting of the K-Ar system during hydrothermal fluid circulation after or during main-stage ore formation. The sudoite-illite assemblage from an altered basement sample yield a date of 815 Ma, unlike the clay-rich ore sample which contains no radiogenic argon. The younger date of the basement sample and the lack of radiogenic ^{40}Ar in the ore sample may result from alteration. Average δD and $\delta^{18}O$ values for illite-rich samples are -82 and +10, respectively. Samples that contain sudoite are enriched in D, but the ore sample containing Fe-chlorite is depleted in D and ^{18}O relative to the illite-rich samples. 72 refs., 12 figs., 6 tabs.

345 Metallographic study of the different mineral associations and chemical characterization of the uraniferous minerals of Cigar Lake deposit (Saskatchewan, Canada). Reyx, Jean (Cogema/ branche Mine, Departement des recherches minieres, Velizy (France)); Ruhlmann, Francois. *Canadian Journal of Earth Sciences (Canada);* 30(4): 705-719 (Apr 1993). (In French).

The Cigar Lake deposit, discovered in 1981, represents one of the richest uranium occurrences known in the province of Saskatchewan. Being located at the unconformity between the Aphebian metasediments and the Helikian sandstone cover, this deposit is classified in the group of deposits spatially related to the Proterozoic unconformity. The metallographic study of the mineralizations in the main ore body, hosted in the basement, and the so-called 'perched' mineralization in the cover rocks, led to the definition of three major mineralizing stages, which contributed in varying degrees to ore deposition. A major stage is characterized by the association of U-Ni-Co-As-S $\pm$ Mo-Bi-Cu-Zn-Pb and reflects the polyphased nature of this hydrothermal stage. This early deposition of the uraniferous phase (massive, botryoidal and euhedral uraninite) was followed, on one hand, by a phase precipitating nickel-cobalt and iron arsenides and sulfoarsenides, and on the other hand, by a phase exclusively of sulfides. The age of emplacement of this stage is 1341 Ma. The second stage appears only in the metamorphic units of the Aphebian basement. It is represented by a uraninite-sulfide paragenesis, the uraninite being characterized principally by the presence of thorium and, as well, a lead content lower than that in the uranous oxide stage. The third mineralizing stage affects the basement rocks, the main orebody, and the cover rocks with their perched mineralization. It is a simple pitchblende - iron or iron-nickel sulfide and (or) hematite paragenesis with an age of emplacement of 323 Ma. 23 refs., 19 figs., 3 tabs.

346 Formation and evolution of the Cigar Lake uranium deposit based on U-Pb and K-Ar isotope systematics. Philippe, S. (Montpellier-2 Univ., 34 (France));

Lancelot, J.R.; Clauer, N.; Pacquet, A. *Canadian Journal of Earth Sciences (Canada);* 30(4): 720-730 (Apr 1993).

A systematic geochronological study was conducted on the Cigar Lake uranium deposit. U-Pb and Pb-Pb systematics were applied to different types of uranium ore, and various associated sheet silicates were dated by the K-Ar method. These two approaches define a widespread retrograde metamorphic event in the basement, which occurred at about 1780 Ma during the Hudsonian orogeny, and a four-stage evolutionary model for the ore deposit. This model is compatible with the history of other unconformity-type uranium deposits in the Athabasca Basin. The first stage in the evolution of the Cigar Lake uranium deposit is marked by uraninite crystallization at 1341 $\pm$ 17 Ma, which, in association with arsenides and sulfarsenides, constitutes the mineralization of economic interest (main orebody). The second stage, characterized by a Fe-kaolinite and Fe-illite paragenesis, occurred locally at about 900 Ma. The third stage involved uranium mobilization at about 325 Ma and is characterized by (i) preferential loss of radiogenic lead from primary uraninite and crystallization of pitchblende at the rims of uraninite grains and (ii) formation of pitchblende associated with Fe sulfides or hematite in the main and perched orebodies. The last stage is characterized by recent alteration and coffinitization which have affected all ore types. 40 refs., 8 figs., 3 tabs.

347 Sm-Nd, Pb-Pb, and Rb-Sr systematics of the basement in the Cigar Lake area, Saskatchewan, Canada. Pagel, Maurice (Centre de Recherches sur la Geologie de l'Uranium (CREGU), 54 - Vandoeuvre-les-Nancy (France)); Juteau, Martine; Michard, Annie; Turpin, Laurent. *Canadian Journal of Earth Sciences (Canada);* 30(4): 731-742 (Apr 1993).

The Sm-Nd, Pb-Pb, and Rb-Sr isotope geochemistry of graphitic metapelitic gneisses and their altered equivalents from the Cigar Lake area (Saskatchewan, Canada) has been investigated. Some granitic gneisses were also analyzed for Pb-Pb and Rb-Sr. Sm-Nd data show that the metapelitic gneisses are composed of detritus from heterogeneous, mainly mantle-derived Archean rocks (2.5-2.6 Ga) and that the Sm-Nd system has not been significantly perturbed during subsequent alteration and metamorphic events. The Pb-Pb age for samples of the less altered graphitic metapelitic gneisses is 1.77 $\pm$ 0.03 Ga. The crustal common Pb is located on the Pb-Pb isochron, but there are different zones with high and variable U/Pb ratios (μ 15-280). The Pb-Pb age for the granitic gneisses is 1.79 $\pm$ 0.11 Ga. The Pb isotope data show that there has been no major uranium redistribution in the basement after the Hudsonian orogeny. However, there has been a strong perturbation of the U-Pb system in the regolithic zone beneath the Athabasca cover. In some samples, uranium was added during the mineralizing event. The Rb-Sr system in the graphitic metapelitic gneisses was also affected. The $^{87}Sr/^{86}Sr$ ratio in pitchblende is 0.709. At 1.3 Ga, there is a strong contrast between the $^{87}Sr/^{86}Sr$ ratio in the Athabasca sandstones (0.706-0.710) and the $^{87}Sr/^{86}Sr$ ratio in the metapelitic gneisses from the basement (0.725-0.775). The upper zone of the regolith is characterized by a low $^{87}Sr/^{86}Sr$ ratio (0.705-0.707). The Pb-Pb and Pb-Sr data are consistent with the circulation of a fluid with a low $^{87}Sr/^{86}Sr$ ratio, derived from sedimentary cover; this fluid passed through the most permeable zones of the basement rocks, especially the regolith. The mineralizing fluid had a $^{87}Sr/^{86}Sr$ value typical of a fluid in equilibrium with the Athabasca sandstones. 36 refs., 9 figs., 6 tabs.

348 Characterization of graphite alteration and bitumen genesis in the Cigar Lake deposit (Saskatchewan, Canada). Landais, Patrick (Centre de Recherches sur la Geologie de l'Uranium (CREGU), 54 - Vandoeuvre-les-Nancy (France)); Dubessy, Jean; Dereppe, Jean-Marie; Philp, R.P. *Canadian Journal of Earth Sciences (Canada);* 30(4): 743-753 (Apr 1993).

Bitumens collected in the east zone of the Cigar Lake deposit have been analyzed by ^{13}C nuclear magnetic resonance, pyrolysis - gas chromatography, Rock-Eval, and elementary analysis. Carbon and hydrogen isotopic compositions and uranium contents have been determined. Results indicate that the bitumens consist mainly of aromatic structure, and have undergone a late oxidation process. Similarities in carbon isotopic composition between barren bitumens and graphite collected in the basement gneisses, as well as evidence for progressive disorganization of graphite along a basement profile, suggest a genetic relationship between graphite and bitumens from the mineralized areas. The presence of amorphous carbon in pit structures inside graphite flakes close to the unconformity supports this assessment. Significant differences in geochemical and isotopic characteristics of Cigar lake barren bitumens and the Cluff Lake mineralized bitumens suggest that there are two possible mechanisms for their formation. Barren ^{13}C-enriched bitumens could have formed directly by hydrogenation of amorphous carbon, whereas mineralized, isotopically light bitumens from Cluff Lake may result from the polymerization of light hydrocarbons around uraninite grains. 41 refs., 9 figs., 5 tabs.

349 Geochemistry of the waters associated with the Cigar lake uranium deposit (Saskatchewan, (CA)) and their uranium and lead isotope contents as guides for prospecting. Toulhoat, Pierre (CEA Centre d'Etudes de Fontenay-aux-Roses. Dept. Stockage Dechets, Fontenay-aux-Roses CEDEX (France)); Beaucaire, Catherine. *Canadian Journal of Earth Sciences (Canada);* 30(4): 754-763 (Apr 1993). (In French).

The primary objective of this study is to understand the chemical evolution of the waters crossing the Cigar Lake (Saskatchewan, Canada) uranium ore deposit, then to investigate the behavior of the lead and uranium isotopes, and to test their use as guides in exploration. The underground waters around the Cigar Lake ore deposit were sampled by pumping boreholes or by air lifting. Isotopic analyses of U and Pb and chemical analyses of the major elements and of some trace elements (Ba, Ra, U) were completed. Based on these results, a model is proposed to explain the genesis and evolution of the waters, and also to account for the water-minerals equilibria. 37 refs., 8 figs., 4 tabs.

350 Draft report uges DOE to consider second waste repository. Lane, E. *Energy Daily (United States);* 21(33): 4 (19 Feb 1993).

The permanent nuclear waste repository planned for Yucca Mountain, Nevada, cannot hold the projected spent fuel that will be generated by future nuclear plants and defense facilities so the Energy Department should consider a second repository now, according to an annotated outline of a draft report to Congress from the Office of Civilian Radioactive Waste Management discussed at a public meeting Wednesday. The report, required under Section 803 of the

Energy Policy Act of 1992, is supposed to determine the adequacy of spent nuclear fuel and high-level radioactive waste management plans for future waste generation. The report is scheduled for completion Oct. 24.

351 Relationship of Superfund risk assessments to repository performance assessments. Avci, H.I. (Argonne National Lab., IL (United States)). *Transactions of the American Nuclear Society (United States);* 69: 43-44 (1993). (CONF-931160--: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

There has been little or no interaction among the scientists performing risk assessments for Superfund sites and those conducting performance assessments for geologic repositories; however, there are enough similarities between the two types of assessments that it is worthwhile to examine how the repository performance assessments can benefit from the Superfund risk assessments. The evolving regulations for the repositories to be built and operated in the United States make the cross-over between the two assessments particularly apparent. In this paper, similarities and differences between the two types of assessments are examined, and suggestions are provided to improve communication among the analysts performing them.

352 The Department of Energy's approach to high-level waste standards. Brocoum, S. (DOE, Washington, DC (United States)); Dyer, J.R. *Transactions of the American Nuclear Society (United States);* 69: 86-87 (1993). (CONF-931160--: American Nuclear Society (ANS) winter meeting, San Francisco, CA (United States), 14-18 Nov 1993).

The U.S. Department of Energy (DOE) has the legal responsibility to (a) characterize the Yucca Mountain site to evaluate its suitability for a high-level radioactive waste repository and (b) develop and operate a repository if the site is suitable, if the recommendation of the site is approved by the President, and if the U.S. Nuclear Regulatory Commission (NRC) issues a construction authorization and a license to operate the repository and permanently dispose of waste. The DOE, as implementing agency, will bear the burden of proof in demonstrating compliance with the standards established by the US Environmental Protection Agency (EPA) and incorporated in the NRC's implementing rules and the DOE's siting guidelines.

353 Micromechanical modeling of tuffaceous rock for application in nuclear waste storage. Wang, R. (Arizona Univ., Tucson, AZ (United States). Dept. of Mining and Geological Engineering); Kemeny, J.M. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts (United Kingdom);* 30(7): 1351-1357 (1993). Grant NSFSGP MSS9022381. (CONF-930644--: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993).

This paper describes the development of micromechanical models for tuffaceous rock. In particular, laboratory tests have been conducted on Topopah Spring tuff from Yucca Mountain, Nevada and Apache Leap tuff from Superior, Arizona. Topopah Spring tuff is the host rock for the proposed underground nuclear waste repository at Yucca Mountain, and Apache Leap tuff is an analog for the host rock. Based on SEM microscopy of the damaged rock specimens, the specific micro-mechanisms for deformation in tuffs have been determined. Micromechanical models based on fracture mechanics theory are then developed for these specific mechanisms. The micromechanical models are able to predict the nonlinear stress-strain behaviour of tuff, including strain-hardening, strain-softening, triaxial strength, and dilatation. (Author).

354 In situ flow testing of a cement borehole seal in welded tuff. Crouthamel, D.R. (Stone and Webster Engineering Corp., Boston, MA (United States)); Fuenkajorn, K.; Daemen, J.J.K. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts (United Kingdom);* 30(7): 1503-1506 (1993). (CONF-930644--: 34. US symposium on rock mechanics, Madison, WI (United States), 27-30 Jun 1993).

The experimental determination of the hydraulic conductivities of cement borehole plugs in welded tuffs and the effects of field installation and in-situ environment is described. The field results are compared with those from related laboratory experiments which give hydraulic conductivity values nearly two orders of magnitude lower. This improved performance in sealing characteristics is brought about by the controlled installation procedures and conditions in the laboratory. Seal performance can be improved in the field by developing controlled emplacement techniques and careful evaluation of site conditions preparation prior to installing the plug. (4 figures, 1 table, 14 references) (UK).

355 Fluid density and gravitational variations in deep boreholes and their effect on fluid potential. Oberlander, P.L. (Pacific Northwest Lab., Richland, WA (United States)). *Ground Water (United States);* 27(3): 341-350 (May-Jun 1989).

As depth below the water table increases, there can be significant spatial variations in fluid density. Fluid density is a function of fluid temperature, total dissolved solids and gases content, fluid compressibility, and the force of gravity. Variations in fluid density can affect the applicability of measured water levels to represent fluid pressure at depth and the existence of a scalar fluid potential. Where ground water is sufficiently heterogeneous, fluid pressure and fluid density must be known spatially to properly determine the three-dimensional impelling force per unit mass $E = -[g_k + (1/\rho) \nabla P]$. Assuming that the water-level elevation in deep boreholes represents a fluid potential may result in significant errors in determining flow direction and quantities under conditions of a variable density fluid and low hydraulic gradients. Boreholes constructed to investigate the feasibility of deep geologic disposal of nuclear waste have penetrated to depths greater than 1,500 m below the Earth's surface. In these deep boreholes, fluid density variations may need to be considered as a part of the hydrologic analysis. Fluid density variations with depth, predicted as general cases based on simple models, indicate the relative importance of temperature, compressibility, and gravity variations at three potential high-level nuclear waste repository locations. Fluid density generally decreases with depth for sites where geothermal gradients are greater than 20° C/km, and thermal expansion can offset the effects of fluid compressibility.