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Yucca Mountain Site Characterization Project Bibliography

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FOR FURTHER INFORMATION ON THE CIVILIAN RADIOACTIVE WASTE MANAGEMENT PROGRAM

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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 January 1, 1994, through June 30, 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. 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:

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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.

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***Civilian Radioactive Waste Management System, Management & Operating Contractor, Las Vegas.**

Bibliography With Abstracts

YUCCA MOUNTAIN SITE CHARACTERIZATION OFFICE

1 (CONF-930205–82) **Carbon-14 releases from an unsaturated repository: A senseless but expensive dilemma.** Pflum, C.G. Science Applications International Corp., Las Vegas, NV (United States). [1993]. 6p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-87NV10576. From Waste management '93; Tucson, AZ (United States); 28 Feb - 4 mar 1993. Order Number DE94000976. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of the US Environmental Protection Agency (EPA) Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR Part 191 or standards) is to protect public health and safety. The 1985 rule was developed on the basis of the assumption that the repository would be located in a geologic formation that lies below the water table. It is appropriate to examine gaseous releases and transport of pollutants in order to determine site adequacy. When the provisions of the 1985 standard are applied to Yucca Mountain, specifically the limits for carbon-14, we can release in 10,000 years no more than 7,000 curies of carbon-14 in the form of carbon dioxide. Meanwhile, the US Department of Energy (DOE) and others indicate that the repository may release about 8,000 curies of carbon-14 dioxide, an amount that exceeds the standard by 10 to 20 percent. The original basis of the 1985 standards was that, in a site below the water table, the limit for carbon-14 was technically achievable. It was not a standard based on a release level that would prevent a danger to public health. If we examine the danger to public health of the release of 8,000 curies of carbon-14 dioxide during and 8,000-year period, this release would not a pose a significant threat to the average individual. Industry and natural sources release many times this amount of carbon-14 dioxide each year. The question therefore becomes: is it appropriate to spend an additional $3.2 billion on waste packages when the expenditure does not measurably improve the public health?

2 (CONF-9303214–1) **Rural migration in southern Nevada.** Mosser, D.; Soden, D.L. Nevada Univ., Las Vegas, NV (United States). [1993]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. From National Social Science Association meeting; San Francisco, CA (United States); 31 Mar - 3 apr 1993. Order Number DE93018976. Source: OSTI; NTIS; INIS; GPO Dep.

This study reviews the history of migration in two rural counties in Southern Nevada. It is part of a larger study about the impact of a proposed high-level nuclear waste repository on in- and out-migration patterns in the state. The historical record suggests a boom and bust economic cycle has predominated in the region for the past century creating conditions that should be taken into account by decision makers when ascertaining the long-term impacts of the proposed repository.

3 (DOE/NV/10872–T91) **Identification and characterization of conservative organic tracers for use as hydrologic tracers for the Yucca Mountain site characterization project: Quality Assurance Project Plan, Revision 1: Quarterly progress report, October 1, 1993–December 31, 1993.** Stetzenbach, K.J. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. 13 Dec 1993. 52p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94007777. Source: OSTI; NTIS; INIS; GPO Dep.

The purpose of this work is to identify and characterize candidate conservative organic tracers for use as hydrologic tracers for experiments to be conducted at the Yucca Mountain C-well complex. During this quarter the main effort was directed towards rewriting the quality assurance program in preparation for a review and audit by the USGS. However, due to budget constraints the review and audit were not carried out. The tracer QA plan and standard operating procedures (SOPs) were revised and copies are included in the report. Instrumental problems were encountered and corrected with the addition of new integration and sample control software. In the sampling, there was an unexplained peak in the chromatograms of the tracers being tested in the light tuff. This was not correctable and these experiments will be repeated in the next quarter.

4 (DOE/NV/10872–T94) **Identification of subsurface microorganisms at Yucca Mountain: Second quarterly report, October 1, 1993–December 31, 1993.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1993]. 14p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94007780. Source: OSTI; NTIS; GPO Dep.

The primary effort of this past quarter was to develop a procedure where accumulated data files could be evaluated to determine the naming consistency and inter-relationships of the various species which have been identified by the Microbial Identification System (MIDI) system. This involved a series of steps, including the clustering of similarly named organisms in a dendrogram format to determine how closely similarly named isolates are related. The experience of other researchers using the MIDI system has shown that clusters which are joined at a Euclidian distance of 10 or less belong to the same species. Strains which are very similar cluster at less than 6 Euclidian units and clusters below two units have nearly identical fatty acid patterns. When the dendrograms derived from the springs were scrutinized, some organisms were found which did not match the pattern of their named group. Then a decision was made whether to rename the isolates and exclude them from the group or redefine the group. This decision was assisted by plotting the principal components derived from an analysis of the fatty acid composition of members of the genus. Each species can be examined by the same procedure to determine group homogeneity. In these 2-dimensional plots members of the same species are roughly bounded by a box of 100

squared units while closely related strains are grouped more tightly together. The 2-dimensional plot of isolates of Micrococcus luteus demonstrates the presence of three identifiable sub-species.

5 (DOE/NV/10872–T103) **Rural migration in Nevada: Lincoln County. Phase 1, 1992–1993.** Soden, D.L.; Carns, D.E.; Mosser, D.; Conary, J.S.; Ansell, J.P. Nevada Univ., Las Vegas, NV (United States). Southwestern Social Science Research Center. [1993]. 206p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94011946. Source: OSTI; NTIS; INIS; GPO Dep.

The principal objective of this project was to develop insight into the scope of migration of working age Nevadans out of their county of birth; including the collection of data on their skill levels, desire to out or in-migrate, interactions between families of migratory persons, and the impact that the proposed high-level nuclear waste repository at Yucca mountain might have on their individual, and collective, decisions to migrate and return. The initial phase of this project reported here was conducted in 1992 and 1993 in Lincoln County, Nevada, one of the counties designated as "affected" by the proposed repository program. The findings suggest that a serious out-migration problem exists in Lincoln County, and that the Yucca mountain project will likely affect decisions relating to migration patterns in the future.

6 (DOE/NV/10872–T110) **Identification of subsurface microorganisms at Yucca Mountain: Third quarterly report, January 1, 1994–March 31, 1994.** Stetzenbach, L.D. Nevada Univ., Las Vegas, NV (United States). Harry Reid Center for Environmental Studies. [1994]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-90NV10872. Order Number DE94011953. Source: OSTI; NTIS; INIS; GPO Dep.

Bacteria isolated from ground water samples taken from 31 springs during 1993 were collected and processed according to procedures described in earlier reports. These procedures required aseptic collection of surface water samples in sterile screw-capped containers, transportation to the HRC microbiology laboratory, and culture by spread plating onto R2A medium. The isolates were further processed for identification using a gas chromatographic analysis of fatty acid methyl esters (FAME) extracted from cell membranes. This work generated a presumptive identification of 113 bacterial species distributed among 45 genera using a database obtained from Microbial ID, Inc., Newark, Delaware (MIDI). A preliminary examination of the FAME data was accomplished using cluster analysis and principal component analysis software obtained from MIDI. Typically, bacterial strains that cluster at less than 10 Euclidian distance units have fatty acid patterns consistent among members of the same species. Thus an organism obtained from one source can be recognized if it is isolated again from the same or any other source. This makes it possible to track the distribution of organisms and monitor environmental conditions or fluid transport mechanisms. Microorganisms are seldom found as monocultures in natural environments. They are more likely to be closely associated with other genera with complementary metabolic requirements. An understanding of the indigenous microorganism population is useful in understanding subtle changes in the environment. However, classification of environmental organisms using traditional methods is not ideal because differentiation of species with small variations or genera with very similar taxonomic characteristics is beyond the capabilities of traditional microbiological methods.

7 (DOE/OSTI–3406-(Suppl.3)(Add.3)) **Yucca Mountain Site Characterization Project bibliography, January–June 1993. An update.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN (United States). Nov 1993. 31p. Sponsored by USDOE, Washington, DC (United States). Order Number DE93015389. Source: OSTI; NTIS; INIS; GPO Dep.

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 January 1, 1993, through June 30, 1993. 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.

8 (DOE/RW/00134–T7) **Yucca Mountain Site Characterization Project Technical Data Catalog.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States). 30 Sep 1993. 428p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94005462. Source: OSTI; NTIS; INIS; GPO Dep.

The March 21, 1993, Department of Energy (DOE)/ Nuclear Regulatory Commission (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 time (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 (this edition), should be retained as the baseline document for the supplements until the end-of-year revision is published and distributed in October 1994.

9 (DOE/RW/00134–T9) **Yucca Mountain Site Characterization Project: Technical Data Catalog quarterly supplement.** USDOE Yucca Mountain Site Characterization Project Office, Las Vegas, NV (United States).

31 Mar 1994. 300p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94010427. Source: OSTI; NTIS; INIS; GPO Dep.

The March 21, 1993, Department of Energy (DOE)/ Nuclear Regulatory Commission (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 time (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.

10 (DOE/RW–0434) **Site characterization progress report: Yucca Mountain, Nevada, April 1, 1993–September 30, 1993, No. 9.** USDOE Office of Civilian Radioactive Waste Management, Washington, DC (United States). Feb 1994. 362p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94008654. Source: OSTI; NTIS; INIS; GPO Dep.

Prepared in accordance with Nuclear Waste Policy Act (Section 113).

In accordance with requirements of Section 113(b)(3) of the Nuclear Waste Policy Act of 1982, as amended, and 10 CFR 60.18(g), the U.S. Department of Energy has prepared this report on the progress of site characterization activities at Yucca Mountain, Nevada, for the period April 1, 1993, through September 30, 1993. This report is the ninth 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 high-level radioactive waste. Also included in this report are 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.

11 (EGG–11265-2029) **Effects of soil quality and depth on seed germination and seedling survival at the Nevada test site.** Blomquist, K.W.; Lyon, G.E. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–3: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94006476. Source: OSTI; NTIS; INIS; GPO Dep.

The Nuclear Waste Policy Act, as amended in 1987, directs the US Department of Energy (DOE) to study Yucca Mountain, in southern Nevada, as a potential site for long-term storage of high-level nuclear waste. DOE policy mandates the restoration of all lands disturbed by site characterization activities and DOE has developed an environmental program that is to be implemented during site characterization activities at Yucca.Mountain. DOE is currently conducting reclamation feasibility trials as part of this environmental program. No topsoil was saved on disturbances during early site investigation and minimal soil remains at existing disturbances on Yucca Mountain. A study was developed to test the effects of soil quality and depth on seedling emergence and survival. A series of plots was established and two treatments were tested. The first treatment compared native topsoil to subsoil imported from a borrow pit. The second treatment compared four different depth ranges of both soil types. All plots received identical seeding treatments. Seedling density was measured after emergence. Overall seedling densities were low, averaging 10.3 ± 8.8 (SD) plants/m^2. Statistical analysis revealed a significant interaction between the two treatment factors. The subsoil had increasing densities from the deep soil depths to the shallow depths while the topsoil had increasing densities from the shallow soil depths to the deep depths. The cause of this interaction may have resulted from the bedrock being close to the soil surface of the shallow plots.

12 (EGG–11265-2030) **The influence of annual species composition and density on perennial seedling density in four plant communities in the Northern Mojave Desert.** Hall, P.F. (EG and G Energy Measurements, Inc., Las Vegas, NV (United States)); Angerer, J.P.; Ostler, W.K.; Schultz, B.W. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–1: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94006475. Source: OSTI; NTIS; GPO Dep.

According to the Nuclear Waste Policy Act of 1982 (as amended in 1987), the US Department of Energy (DOE) must study and characterize Yucca Mountain as a potential site for long-term underground storage of high-level nuclear waste. Part of the overall site characterization program is to monitor potential impacts on the biological resources at Yucca Mountain. A part of the biological monitoring program, assessed vegetation parameters included density of annual and perennial seedlings. This data was used to evaluate: (1) seed germination and seed survival; and (2) if annual plant species density and cover influence perennial seedling survival. Twelve permanent 200 × 200-m ,study plots were established in each of four vegetation associations present in the Yucca Mountain Project area. During the spring of 1992, 20 to 60, 1-m^2 randomly-located quadrats per study plot were measured for perennial seedling density, annual species density, and annual species composition. Perennial seedlings found in 1992 were relocated in the spring of 1993, and survival determined. Cover was measure in the spring of 1992. Annual plant density and cover was greatest in the Larrea-Lycium-Grayia vegetation association, and lowest in the Larrea-Ambrosia vegetation association. Annual seedling density had a negative exponential relationship with perennial seedling density in 1992. However, non-linear regression analysis indicated that 1992 annual seedling density had a greater impact on survival of pernnial seedlings from 1992 to 1993.

13 (EGG–11265-2031) **Plant succession on disturbed sites in four plant associations in the Northern Mojave Desert.** Gabbert, W.D.; Schultz, B.W.; Angerer, J.P.; Ostler, W.K. EG and G Energy Measurements, Inc., Las Vegas, NV (United States). [1993]. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-93NV11265. (CONF-9310276–2: 8. wildland shrub and arid land restoration symposium, Las Vegas, NV (United States), 19-21 Oct 1993). Order Number DE94006482. Source: OSTI; NTIS; GPO Dep.

The US Department of Energy (DOE) is characterizing Yucca Mountain Nevada, as a potential site for long-term underground storage of high-level nuclear waste. DOE is committed to reclaim all lands disturbed by the project, and return them to a stable ecological state, with a composition and productivity similar to predisturbance conditions. A study was implemented to assess plant species which naturally invade disturbed sites in the Yucca Mountain Project Area. In 1991 and 1992 study plots were established on disturbed sites. Sites were characterized by disturbance type (i.e., road, drill pad, etc.), disturbance severity, vegetation association, time since abandonment, and topographic placement. Density of all perennial plant species was measured on disturbed and undisturbed plots. The species with the highest density in disturbed sites was Chrysothamnus teretifolia. This species was not a major contributor in undisturbed sites. In the undisturbed sites Ambrosia dumosa had the highest density of perennial plant species but was also high in density in the disturbance sites. Total species density was higher in undisturbed sites compared to disturbed sites. Plant species density analysis compared disturbed and undisturbed vegetation associations. Results will be used to design reclamation field trails and to finalize the Yucca Mountain Project Reclamation Implementation Plan.

14 (LBL–30043, pp. 148-183) **A mechanical model for repeated slip events along normal faults in the basin and range: Applications to Yucca Mountain, Nevada.** Kemeny, J.M. Lawrence Berkeley Lab., CA (United States). Dec 1990. DOE Contract AC03-76SF00098. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

A mechanical model has been developed to calculate the effects of repeated slip events along pre-existing normal faults in the Basin and Range. The model calculates the aseismic and seismic deformation due to the propagation of slip along the normal fault, and the moment and energy release associated with seismic motion. Also, the model calculates regional stress changes associated with a slip event, from which changes in the level of the water table are estimated. The model is used to predict the effects of a slip event on normal faults in the vicinity of Yucca Mountain, Nevada, which is the proposed site for underground nuclear waste storage.

15 (LBL–35381) **Thermal modeling for a potential high-level nuclear waste repository at Yucca Mountain, Nevada.** Pruess, K. (Lawrence Berkeley Lab., CA (United States). Earth Sciences Div.); Tsang, Y. Lawrence Berkeley Lab., CA (United States). Mar 1994. 83p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Order Number DE94011016. Source: OSTI; NTIS; INIS; GPO Dep.

Repository performance models based on numerical simulation of fluid and heat flows have recently been developed by several different groups. Model conceptualizations generally focus on large-scale average behavior. This comparison finds that current performance assessment (PA) models use generally similar approximations and parameters. Certain differences exist in some performance-relevant parameters, especially absolute permeabilities, characteristic curves, and thermal conductivities. These reflect present uncertainties about the most appropriate parameters applicable to Yucca Mountain and must be resolved through future field observations and laboratory measurements. For a highly heterogeneous fractured-porous hydrogeologic system such as Yucca Mountain, water infiltration through the unsaturated zone is expected to be dominated by highly localized phenomena. These include fast channelized flow along preferential paths in fractures, and frequent local ponding. The extended dry repository concept proposed by the Livermore group is reviewed. Predictions of large-scale drying around the repository on the average for large thermal loads cannot be taken to indicate that waste packages will not be contacted by liquid water, and that aqueous-phase transport of contaminants is not possible. Specifically, the authors find that modest water infiltration, on the order of a few millimeters per year, would be sufficient to overwhelm the vaporization capacity of the repository heat and inundate the waste packages within a time frame of a few thousand years. A preliminary analysis indicates that channelized flow of water may persist over large vertical distances. The vaporization-condensation cycle has a capacity for generating huge amounts of ponded water. A small fraction of the total condensate, if ponded and then episodically released, would be sufficient to cause liquid phase to make contact with the waste packages.

CRWMS M&O, LAS VEGAS

16 (DOE/RW/00134–T5) **Site characterization plan thermal goals reevaluation.** TRW Environmental Safety Systems, Inc., Las Vegas, NV (United States). 8 Sep 1993. 50p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94004175. Source: OSTI; NTIS; INIS; GPO Dep.

The Site Characterization Plan (SCP) (DOE, 1988) attempted to define surrogate criteria that could be used to establish potential repository performance. These criteria or SCP thermal goals were developed from knowledge existing at the time and, as a reference case, emphasized performance for waste emplacement in a vertical borehole. Since that time, new knowledge has become available and some additional analyses of thermal loading have been performed. Additionally, other emplacement modes such as in-drift emplacement are being considered to accommodate larger waste packages. New concepts such as "extended hot" are also being considered as possible methods to achieve improved waste isolation. Thus it became clear that the thermal goals established in the SCP should be reevaluated. A Working Group was formed to reassess the SCP thermal goals to determine whether each goal was still valid, if there were goals that needed to be added, and what if any effort was needed to reduce the uncertainty associated with a particular goal. The objectives of the effort were to: (1) provide thermal goals that would support the FY 1993 Thermal Loading Systems Study; (2) help focus the planned testing and analysis efforts; and (3) acquire data that potentially could be used to initiate a change to the project technical baseline. Sixteen thermal goals were evaluated; fifteen were

from various sections of the SCP; one goal was added, and another was split into two to include in-drift emplacement. The group's findings and recommendations are presented.

17 (DOE/RW/00134–T6) **Review and selection of unsaturated flow models.** INTERA, Inc., Las Vegas, NV (United States). 10 Sep 1993. 288p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94004174. Source: OSTI; NTIS; INIS; GPO Dep.

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 ground-water flow models; to conduct performance assessments; and to develop performance assessment models, where necessary. In the area of scientific modeling, the M&O CRWMS has the following responsibilities: To provide overall management and integration of modeling activities. To provide a framework for focusing modeling and model development. To identify areas that require increased or decreased emphasis. To ensure that the tools necessary to conduct performance assessment are available. These responsibilities are being initiated through a three-step process. It consists of a thorough review of existing models, testing of models which best fit the established requirements, and making recommendations for future development that should be conducted. Future model enhancement will then focus on the models selected during this activity. Furthermore, in order to manage future model development, particularly in those areas requiring substantial enhancement, the three-step process will be updated and reported periodically in the future.

18 (DOE/RW/00134–T8) **Yucca Mountain Site Characterization Project Technical Data Catalog (Quarterly supplement).** TRW, Inc., Fairfax, VA (United States). 31 Dec 1993. 71p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-91RW00134. Order Number DE94008425. Source: OSTI; NTIS; GPO Dep.

The March 21, 1993, Department of Energy (DOE)/ Nuclear Regulatory Commission (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 time (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.

LOS ALAMOS NATIONAL LABORATORY

19 (LA–12411-SR) **Status report on ESF-related prototype testing.** Oliver, R.D.; Kalia, H.N. (comps.). Los Alamos National Lab., NM (United States). Dec 1992. 316p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94008703. Source: OSTI; NTIS; INIS; GPO Dep.

This report provides information on the Prototype Testing performed in the G-Tunnel on the Nevada Test Site by the Yucca Mountain Project form April 1988 to November 1989. The Testing Program was implemented to ensure that the Exploratory Shaft Facility (ESF) tests can be completed in the time available and to develop instruments, equipment, and procedures so the ESF tests can collect reliable and representative site characterization data. This report summarizes the ESF prototype tests and presents preliminary results.

20 (LA–12596-MS) **Measurement of unsaturated hydraulic conductivity and chemical transport in Yucca Mountain Tuff: Milestone Report 3044-WBS1.2.3.4.1.4.1.** Conca, J.L. (Washington State Univ., Richland, WA (United States)). Los Alamos National Lab., NM (United States). Dec 1993. 28p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94004880. Source: OSTI; NTIS; INIS; GPO Dep.

Hydraulic conductivities, K, were experimentally determined as a function of volumetric water content, θ, in tuff from the Yucca Mountain site. In addition, the retardation factor, R_f, in Yucca Mountain tuff with respect to selenium, as the selenite species, was measured under unsaturated conditions. These data were used to determine the feasibility of applying a new unsaturated flow technology (UFA) to further hydrologic studies at Yucca Mountain. The UFA directly measures $K(\theta)$ rapidly in Yucca Mountain tuff and is shown to agree well with traditional methods. Hysteresis does not appear important during this testing. Hydraulic steady-state is achieved fastest during desaturation from a saturated state. Imbibition into dry tuff requires a long time for steady-state to occur because of slow filling of the diffusion porosity which can take a few weeks. The existing UFA is a prototype, and a new design of the next generation UFA is completed that eliminates some of the earlier problems. These preliminary investigations demonstrates that the UFA is a useful investigate technique that should be used to compliment existing techniques for hydrogeochemical characterization at Yucca Mountain and other arid sites.

21 (LA–12652-MS) **Mineralogy and clinoptilolite K/Ar results from Yucca Mountain, Nevada, USA: A potential high-level radioactive waste repository site.** WoldeGabriel, G.; Broxton, D.E.; Bish, D.L.; Chipera, S.J. Los Alamos National Lab., NM (United States). Nov 1993. 44p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94005018. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is investigating Yucca Mountain, Nevada, as a potential site for a high-level nuclear waste repository. An important aspect of this evaluation is to understand the geologic history of the site including the diagenetic processes that are largely responsible for the present-day chemical and physical properties of the altered tuffs. This study evaluates the use of K/Ar geochronology in determining the alteration history of the zeolitized portions of Miocene tuffs at Yucca Mountain.

Clinoptilolite is not generally regarded as suitable for dating because of its open structure and large ion-exchange capacity. However, it is the most abundant zeolite at Yucca Mountain and was selected for this study to assess the feasibility of dating the zeolitization process and/or subsequent processes that may have affected the zeolites. In this study we examine the ability of this mineral to retain all or part of its K and radiogenic Ar during diagenesis and evaluate the usefulness of the clinoptilolite K/Ar dates for determining the history of alteration.

22 (LA–12703-SR) **Los Alamos National Laboratory Yucca Mountain Site Characterization Project 1992 quality program status report.** Bolivar, S.L. (and others); Burningham, A.; Chavez, P. Los Alamos National Lab., NM (United States). Mar 1994. 126p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94007726. Source: OSTI; NTIS; INIS; GPO Dep.

This status report summarizes the activities and accomplishments of the Los Alamos Yucca Mountain Site Characterization Project's quality assurance program for calendar year 1992. The report includes major sections on Program Activities and Trend Analysis. Program Activities are discussed periodically at quality meetings. The most significant issue addressed in 1992 has been the timely revision of quality administrative procedures. The procedure revision process was streamlined from 55 steps to 7. The number of forms in procedures was reduced by 38%, and the text reduced by 29%. This allowed revision in 1992 of almost half of all implementing procedures. The time necessary to complete the revision process (for a procedure) was reduced from 11 months to 3 months. Other accomplishments include the relaxation of unnecessarily strict training requirements, requiring quality assurance reviews only from affected organizations, and in general simplifying work processes. All members of the YMP received training to the new Orientation class Eleven other training classed were held. Investigators submitted 971 records to the Project and only 37 were rejected. The software program has 115 programs approved for quality-affecting work. The Project Office conducted 3 audits and 1 survey of Los Alamos activities. We conducted 14 audits and 4 surveys. Eight corrective action reports were closed, leaving only one open. Internally, 22 deficiencies were recognized. This is a decrease from 65 in 1991. Since each deficiency requires about 2 man weeks to resolve, the savings are significant. Problems with writing acceptable deficiency reports have essentially disappeared. Trend reports for 1992 were examined and are summarized herein. Three adverse trends have been closed; one remaining adverse trend will be closed when the affected procedures are revised. The number of deficiencies issued to Los Alamos compared to other participants is minimal.

23 (LA–12780-MS) **Molecular models for actinide speciation.** Clark, D.L.; Watkin, J.G.; Morris, D.E.; Berg, J.M. Los Alamos National Lab., NM (United States). Jun 1994. 32p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. Order Number DE94012370. Source: OSTI; NTIS; INIS; GPO Dep.

Much effort has been devoted to the development of sensitive spectroscopic techniques for the study of actinide speciation based on the sensitivity of f-f electronic absorption bands to oxidation state and ligation of the actinide ions. These efforts assume that data obtained in such studies will be interpretable in terms of changes in complexation of the metal center. However, the current understanding of 5f electronic structure is based on data from solid state doped single crystals. In those studies, the local coordination geometry about the central actinide ion is maintained in an almost perfect high-symmetry environment and will have little relevance for species in solution where deviations from perfect high symmetry tend to be the rule rather than the exception. The authors have developed a vigorous research program in the systematic preparation and spectroscopic characterization of synthetic actinide complexes (Th, U, Np, and Pu) in which they can control nuclearity, oxidation state, and molecular structure. These complexes have been used to determine how observable electronic transitions are perturbed in response to structural changes in the complex in solution. From the spectra obtained for these model complexes, the authors have found that the f-f transitions naturally fall into obvious groupings by coordination number and symmetry by which they can now differentiate between monomeric, dimeric, and trimeric species in solution. The study of radionuclide speciation is fundamentally important to the determination of radionuclide solubility in the groundwater at Yucca Mountain.

24 (LA-UR–93-3691) **Natural alteration in the cooling Topopah Spring tuff, Yucca Mountain, Nevada, as an analog to a waste-repository hydrothermal regime.** Levy, S.; Valentine, G. Los Alamos National Lab., NM (United States). [1993]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9309228–5: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE94002699. Source: OSTI; NTIS; INIS; GPO Dep.

Studies of natural hydrothermal alteration in the cooling Topopah Spring tuff suggest a useful "self-analog" predictor of fluid-rock interactions within the thermal regime imposed by a potential nuclear waste repository at Yucca Mountain. This tuff has the advantages of representative rock types and appropriate spatial distribution of lithologic features. The cooling history of the tuff spanned the temperature range for any proposed repository thermal load, and the unsaturated-zone hydrologic conditions of the natural alteration would have been similar to existing conditions. A site at northeastern Yucca Mountain, with a prominent vertical fracture zone, has been selected for natural analog studies. The cooling of the tuff and the movement of water in the fracture zone and adjacent matrix will be modeled with the finite element code FEHNM, capable of simulating flow through porous and fractured media using a dual porosity-dual permeability continuum model, with heat transfer and two-phase (vapor and liquid) processes fully accounted for.

25 (LA-UR–93-3699) **Role of magma-water interaction in very large explosive eruptions.** Valentine, G.A. Los Alamos National Lab., NM (United States). [1993]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9310222–1: Seminar on physics of vapor explosion, Tomakomai (Japan), 25-29 Oct 1993). Order Number DE94002698. Source: OSTI; NTIS; GPO Dep.

An important class of explosive eruptions, involving large-scale magma-water interaction during the discharge of hundreds to thousands of cubic kilometers of magma, is discussed. Geologic evidence for such eruptions is summarized. Case studies from New Zealand, Australia, England, and the western United States are described, focusing on inferred eruption dynamics. Several critical problems that need theoretical and experimental research are identified.

These include rates at which water can flow into a volcanic vent or plumbing system, entrainment of water by explosive eruptions through lakes and seas, effects of magma properties and gas bubbles on magma-water interaction, and hazards associated with the eruptions.

26 (LA-UR-93-3992) **The Nevada Test Site: An analog for a nuclear repository.** Thompson, J.L. Los Alamos National Lab., NM (United States). [1993]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-931201-3: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993). Order Number DE94003956. Source: OSTI; NTIS; INIS; GPO Dep.

The United States proposes to store high level nuclear wastes underground; a site at Yucca Mountain in southern Nevada is currently under evaluation. A major concern is that radioactive materials may dissolve in the groundwater and be transported to the accessible environment. At the Nevada Test Site (NTS) adjacent to Yucca Mountain underground nuclear tests have been conducted for over 30 years. Radionuclides (unreacted fissile material, activation products, fission products) from these tests remain underground with no confinement by engineered barriers. The US Department of Energy has supported studies since 1973 designed to measure the distribution of these radionuclides and to evaluate the processes by which they might be transported by groundwater. The authors describe here some of what they have learned about how radionuclides are distributed around nuclear test cavities and how they interact with groundwater.

27 (LA-UR-94-921) **The Quality Council in the scientific arena.** Day, J.L. (Los Alamos Technical Associates, Inc., NM (United States)); Gillespie, P.F.; Bolivar, S.L. Los Alamos National Lab., NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940538-3: 48. annual quality congress, Las Vegas, NV (United States), 24-26 May 1994). Order Number DE94009358. Source: OSTI; NTIS; GPO Dep.

Communication between 12 separate Los Alamos National Laboratory (Los Alamos) research-and-development organizations (9 located in Los Alamos, NM, and 3 located in different areas of the United States) performing work on Los Alamos Yucca Mountain Site Characterization Project (YW or the Project) have improved significantly since the Los Alamos YNT Quality. Council was tonned in 1991. The Quality Council has also been instrumental in improving communications between Los Alamos scientists and the Los Alamos quality assurance (QA) organization and between Los Alamos YNT and the US Department of Energy (DOE) management. This paper describes the evolution of Los Alamos YNT's Quality Council and the resulting benefits.

28 (LA-UR-94-925) **Selenite transport in unsaturated tuff from Yucca Mountain.** Conca, J.L. (Washington State Univ., Richland, WA (United States)); Triay, I.R. Los Alamos National Lab., NM (United States). [1994]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-940553-31: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009360. Source: OSTI; NTIS; INIS; GPO Dep.

Direct measurements of unsaturated selenite retardation coefficients and unsaturated hydraulic conductivity were obtained on two tuff samples from Yucca Mountain using the UFA™ technology. The retardation factor for the selenite species was only 2.5 in both Yucca Mountain vitric member at 62.6% saturation and zeolitized nonwelded tuff from G-tunnel at 52.8% saturation with respect to J-13 well water from the Nevada Test Site contaminated with selenium at 1.31 mg/l (ppm). In batch tests on the same material using 1.2 mg/l (ppm), the average K_d was determined to be 13, giving retardation factors higher than the UFA column breakthrough tests by an order of magnitude. The difference could result from preferential flow paths in the UFA column as might occur in the field or differences in residence times between the two types of test. The unsaturated hydraulic conductivities during the experiments were 2.49×10^{-8} cm/s for the Yucca Mountain vitric member and 1.16×10^{-8} cm/s for the zeolitized nonwelded tuff.

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29 (ANL-92/48) **Test plan for reactions between spent fuel and J-13 well water under unsaturated conditions.** Finn, P.A.; Wronkiewicz, D.J.; Hoh, J.C.; Emery, J.W.; Hafenrichter, L.D.; Bates, J.K. Argonne National Lab., IL (United States). Jan 1993. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94008702. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is evaluating the long-term performance of a high-level nuclear waste form, spent fuel from commercial reactors. Permanent disposal of the spent fuel is possible in a potential repository to be located in the volcanic tuff beds near Yucca Mountain, Nevada. During the post-containment period the spent fuel could be exposed to water condensation since of the cladding is assumed to fail during this time. Spent fuel leach (SFL) tests are designed to simulate and monitor the release of radionuclides from the spent fuel under this condition. This Test Plan addresses the anticipated conditions whereby spent fuel is contacted by small amounts of water that trickle through the spent fuel container. Two complentary test plans are presented, one to examine the reaction of spent fuel and J-13 well water under unsaturated conditions and the second to examine the reaction of unirradiated UO_2 pellets and J-13 well water under unsaturated conditions. The former test plan examines the importance of the water content, the oxygen content as affected by radiolysis, the fuel burnup, fuel surface area, and temperature. The latter test plant examines the effect of the non-presence of Teflon in the test vessel.

30 (ANL-93/37) **Nuclear waste programs: Semiannual progress report, October 1991-March 1992.** Bates, J.K. (and others); Bradley, C.R.; Buck, E.C.; Dietz, N.L.; Ebert, W.L.; Emery, J.W.; Feng, X.; Finn, P.A.; Gerding, T.J.; Hoh, J.C. Argonne National Lab., IL (United States). Nov 1993. 33p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94011227. 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 October 1991-March 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

31 (ANL/CMT/CP–81047) **Disposition of actinides released from high-level waste glass.** Ebert, W.L.; Bates, J.K.; Buck, E.C.; Gong, M.; Wolf, S.F. Argonne National Lab., IL (United States). [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. (CONF-940416–7: 96. annual meeting of the American Ceramic Society (ACS), Indianapolis, IN (United States), 25-28 Apr 1994). Order Number DE94011474. Source: OSTI; NTIS; INIS; GPO Dep.

A series of static leach tests was conducted using glasses developed for vitrifying tank wastes at the Savannah River Site to monitor the disposition of actinide elements upon corrosion of the glasses. In these tests, glasses produced from SRL 131 and SRL 202 frits were corroded at 90°C in a tuff groundwater. Tests were conducted using crushed glass at different glass surface area-to-solution volume (S/V) ratios to assess the effect of the S/V on the solution chemistry, the corrosion of the glass, and the disposition of actinide elements. Observations regarding the effects of the S/V on the solution chemistry and the corrosion of the glass matrix have been reported previously. This paper highlights the solution analyses performed to assess how the S/V used in a static leach test affects the disposition of actinide elements between fractions that are suspended or dissolved in the solution, and retained by the altered glass or other materials.

32 (ANL/CMT/PP–71628) **Repository relevant testing applied to the Yucca Mountain Project.** Bates, J.K.; Woodland, A.B.; Wronkiewicz, D.J.; Cunnane, J.C. Argonne National Lab., IL (United States). Oct 1990. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94008476. Source: OSTI; NTIS; INIS; GPO Dep.

The tuff beds of Yucca Mountain, Nevada, are currently being investigated as a site for the disposal of high-level nuclear waste in an underground repository. If this site is found suitable, the repository would be located in the unsaturated zone above the water table, and a description of the site and the methodology of assessing the performance of the repository are described in the Site Characterization Plan (SCP). While many factors are accounted for during performance assessment, an important input parameter is the degradation behavior of the waste forms, which may be either spent fuel or reprocessed waste contained in a borosilicate glass matrix. To develop the necessary waste form degradation input, the waste package environment needs to be identified. This environment will change as the waste decays and also is a function of the repository design which has not yet been finalized. At the present time, an exact description of the waste package environment is not available. The SCP does provide an initial description of conditions that can be used to guide waste form evaluation. However, considerable uncertainty exists concerning the conditions under which waste form degradation and radionuclide release may occur after the waste package containment barriers are finally breached. The release conditions that are considered to be plausible include (1) a "bathtub" condition in which the waste becomes fully or partially submerged in water that enters the breached container and accumulates to fill the container up to the level of the breach opening, (2) a "wet drip" or "trickle through" condition in which the waste form is exposed to dripping water that enters through the top and exits the bottom of a container with multiple holes, and (3) a "dry" condition in which the waste form is exposed to a humid air environment.

33 (ANL/CMT/PP–71738) **Leaching patterns and secondary phase formation during unsaturated leaching of UO_2 at 90°C.** Wronkiewicz, D.J.; Bates, J.K.; Gerding, T.J.; Veleckis, E.; Tani, B.S. Argonne National Lab., IL (United States). Nov 1991. 56p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE94008483. Source: OSTI; NTIS; INIS; GPO Dep.

Experiments are being conducted that examine the reaction of UO_2 with dripping oxygenated ground water at 90°C. The experiments are designed to identify secondary phases formed during UO_2 alteration, evaluate parameters controlling U release, and act as scoping tests for studies with spent fuel. This study is the first of its kind that examines the alteration of UO_2 under unsaturated conditions expected to exist at the proposed Yucca Mountain repository site. Results suggest the UO_2 matrix will readily react within a few months after being exposed to simulated Yucca Mountain conditions. A pulse of rapid U release, combined with the formation of dehydrated schoepite on the UO_2 surface, characterizes the reaction between one to two years. Rapid dissolution of intergrain boundaries and spallation of UO_2 granules appears to be responsible for much of the U released. Differential release of the UO_2 granules may be responsible for much of the variation observed between duplicate experiments. Less than 5 wt % of the released U remains in solution or in a suspended form, while the remaining settles out of solution as fine particles or is reprecipitated as secondary phases. Subsequent to the pulse period, U release rates decline and a more stable assemblage of uranyl silicate phases are formed by incorporating cations from the ground water leachant. Uranophane, boltwoodite, and sklodowskite appear as the final solubility limiting phases that form in these tests. This observed paragenetic sequence (from uraninite to schoepite-type phases to uranyl silicates) is identical to those observed in weathered zones of natural uraninite occurrences. The combined results indicate that the release of radionuclides from spent fuel may not be limited by U solubility constraints, but that spallation of particulate matter may be an important, if not the dominant release mechanism affecting release.

34 (ESTSC–000324SUN0003) **EQ3/6 V7.2A: Geochemical Modeling of Aqueous Systems.** Wolery, T.J. (Lawrence Livermore National Lab., CA (United States)). Lawrence Livermore National Lab., CA (United States). 14 Sep 1992. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Source: ESTSC; Lawrence Livermore National Lab.

Description: SUN; UNIX; ANSI FORTRAN 77; UNIX interface software, C-shell UNIX; 2 3.5 Diskettes. EQ3NR input files end in .3i, EQ6 input files end in .6i. This is a recommended convention, and it is required in order to run these codes using the UNIX interface software. The data *file* names have the form exemplified by data0.comR22. Here com is one of the five data file descriptors and R22 is a stage number (a configuration control identifier). The main code FORTRAN source files end in .fsc. The EQLIB library package supports the EQPT, EQ3NR, and EQ6 codes. This library is included with the package.

EQ3/6 is a software package for geochemical modeling of aqueous systems. This description pertains to version 7.2A. It addresses aqueous speciation, thermodynamic equilibrium, disequilibrium, and chemical kinetics. The major

components of the package are EQ3NR a speciation-solubility code and EQ6, a reaction path code. EQ3NR is useful for analyzing groundwater chemistry data, calculating solubility limits, and determining whether certain reactions are in states of equilibrium or disequilibrium. It also initializes EQ6 calculations. EQ6 models the consequences of reacting an aqueous solution with a specified set of reactants (e.g. minerals or waste forms). It can also model fluid mixing and the effects of changes in temperature. Each of five supporting data files contains both standard state and activity coefficient-related data. Three support the use of the Davies or B-dot equations for the activity coefficients; the other two support the use of Pitzer's equations. The temperature range of the thermodynamic data on the data files varies from only 25 degrees C to 0-300 degrees C.

35 (UCRL-ID–114739) **The role of multiple barriers in assuring waste package reliability: Yucca Mountain Project.** Bradford, R.M. Lawrence Livermore National Lab., CA (United States). Aug 1993. 16p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94007845. Source: OSTI; NTIS; INIS; GPO Dep.

Yucca Mountain in southwestern Nevada is being studied as a potential repository site for the permanent storage of high-level nuclear waste. Regulators have set performance standards that the potential repository must meet in order to obtain regulatory approval. Nuclear Regulatory Commission (NRC) regulations state that containment of radioactivity must be "substantially complete" for the first 1000 years after closure of the facility. Thereafter, the acceptable annual limit on releases is 1/100,000 of each radionuclide remaining in the inventory after 1000 years. To demonstrate that the potential facility is in compliance with the regulations, it is necessary to obtain some understanding of the probability distribution of the cumulative quantity of releases by certain time points. This paper will discuss the probability distribution of waste container lifetimes and how the understanding of this distribution will play a role in finding the distribution of the release quantities over time. It will be shown that, for reasonable assumptions about the process of barrier failure, the reliability of a multiple-barrier container can be achieved and demonstrated much more readily than a container consisting of a single barrier. The discussion will focus primarily on the requirement of substantially complete containment for the first 1000 years.

36 (UCRL-JC–114790) **Dispersivity in heterogeneous permeable media.** Chesnut, D.A. Lawrence Livermore National Lab., CA (United States). Jan 1994. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–15: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94007870. Source: OSTI; NTIS; INIS; GPO Dep.

When one fluid displaces another through a one-dimensional porous medium, the composition changes from pure displacing fluid at the inlet to pure displaced fluid some distance downstream. The distance over which an arbitrary percentage of this change occurs is defined as the mixing zone length, which increases with increasing average distance traveled by the displacement front. For continuous injection, the mixing zone size can be determined from a breakthrough curve as the time required for the effluent displacing fluid concentration to change from, say, 10% to 90%. In classical dispersion theory, the mixing zone grows in proportion to the square root of the mean distance traveled, or, equivalently, to the square root of the mean breakthrough time. In a multi-dimensional heterogeneous medium, especially at field scales, the size of the mixing zone grows almost linearly with mean distance or travel time. If an observed breakthrough curve is forced to fit the, clinical theory, the resulting effective dispersivity, instead of being constant, also increases almost linearly with the spatial or temporal scale of the problem. This occurs because the heterogeneity in flow properties creates a corresponding velocity distribution along the different flow pathways from the inlet to the outlet of the system. Mixing occurs mostly at the outlet, or wherever the fluid is sampled, rather than within the medium. In this paper, we consider the effects. of this behavior on radionuclide or other contaminant migration.

37 (UCRL-JC–114791) **The impact of repository heat on thermo-hydrological performance at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Sep 1993. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9309228–7: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE94004349. Source: OSTI; NTIS; INIS; GPO Dep.

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 (WP), accelerate its failure rate, and eventually transport radionuclides to the water table. These analyses have demonstrated that the only significant source of liquid water is nonequilibrium fracture flow from: (1) meteoric sources, (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 vapor flow, occurring either on a sub-repository scale or on a mountain scale, may play an important role in the generation of the second and third sources of liquid water. By considering a wide range in bulk permeability, k_b, the authors identify the threshold k_b (called k_b^{hyd}) at which buoyant, vapor convection begins to dominate hydrological behavior, and the threshold k_b (called k_b^{th}) at which this convection begins to dominate thermal behavior. They find that k_b^{th} is generally an order of magnitude larger than k_b^{hyd} and that the development of a large above-boiling zone suppresses the effects of buoyant vapor flow. Of particular concern are conditions that promote the focusing of vapor flow and condensate drainage, which could result in persistent two-phase conditions (often referred to as the heat-pipe effect) in the vicinity of WPs. The results of this study underscore the need for in situ heater tests to help diagnose the potential for the major repository-heat-driven sources of fracture flow.

38 (UCRL-JC–115230) **Integrated modelling of near field and engineered barrier system processes.** Lamont, A.; Gansemer, J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–35: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009909. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Integrating Model (YMIM) is an integrated model of the Engineered barrier System has been developed to assist project managers at LLNL in identifying areas where research emphasis should be placed. The model was designed to be highly modular so that a model of an individual process could be easily modified or replaced without interfering with the models of other processes. The modules modelling container failure and the dissolution of nuclides include particularly detailed, temperature dependent models of their corresponding processes.

39 (UCRL-JC–115734) **Science and licensing: Let's get off the collision course.** Van Konynenburg, R.A. Lawrence Livermore National Lab., CA (United States). Oct 1993. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-931108–94: Fall meeting of the Materials Research Society (MRS), Boston, MA (United States), 29 Nov - 3 dec 1993). Order Number DE94008688. Source: OSTI; NTIS; INIS; GPO Dep.

Our best possibility for gaining an understanding of the likely future behavior of a high level nuclear waste disposal system is use of the scientific method. However, science has inherent limitations when it comes to making long-term predictions with confidence. This paper examines 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 were binding until recently. Suggestions are made for remedying this situation.

40 (UCRL-JC–115798) **The impact of repository heat on hydrological behavior at Yucca Mountain.** Buscheck, T.A.; Nitao, J.J. Lawrence Livermore National Lab., CA (United States). Jan 1994. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–9: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94006658. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes the role of radioactive heat-of-decay in the the performance of the Yucca Mountain Facility. Waste package and waste form degradation due to water contact is described.

41 (UCRL-MA–111991) **CNGBOCHS: An integrated Ingres-Interleaf system for processing change requests associated with GEMBOCHS, EQ3/6, and other research groups.** Daveler, S.A.; Lundeen, S.R.; Johnson, J.W. Lawrence Livermore National Lab., CA (United States). Jun 1993. 21p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94008701. Source: OSTI; NTIS; GPO Dep.

Over the years, users of the GEMBOCHS thermodynamic database (GEMBOCHS is an acronym for Geologic and Engineering Materials: Bibliography Of CHemical Species) and the EQ316 software package have periodically forwarded suggestions for improvement to the GEMBOCHS and EQ316 research groups. These correspondences typically report database or software errors that have been discovered during application, solicit the inclusion of additional or improved thermodynamic data, or suggest incorporation of new or alternate algorithms for performing various geochemical calculations. Traditionally, these suggestions have been made in person, over the phone, or via surface mail, and their resolution has often required additional correspondence. Hence, it has been difficult to maintain a complete, readily-accessible database of such transactions. This difficulty has been eliminated by development of the CNGBOCHS software package (CNGBOCHS is an acronym for ChaNGe Bibliography Of CHemical Species). This system permits GEMBOCHS and EQ316 users to submit suggestions for improvement using the standard electronic mail system (hereinafter referred to as email); facilitates timely review, status notification, and resolution of these suggestions; and greatly simplifies the task of maintaining a comprehensive change-request database that can be relationally searched and selectively printed in rapid fashion. The purpose of this document is to describe the procedure for submitting email change requests to CNGREQ and to present a succinct summary of the CNGBOCHS-CNGREQ interface: its local access, operation, and run-time options.

42 **Implications of episodic nonequilibrium fracture-matrix flow on repository performance.** Nitao, J.J. (Lawrence Livermore National Lab., CA (United States). Earth Sciences Dept.); Buscheck, T.A.; Chesnut, D.A. *Nuclear Technology (United States);* 104(3): 385-402 (Dec 1993). DOE Contract W-7405-ENG-48.

Some of the possible water transport mechanisms through fractured rock in the unsaturated zone at Yucca Mountain are studied to analyze the performance of a high-level nuclear repository at the potential Yucca Mountain site. Analysis shows that water can flow in fractures as opposed to flow through the rock matrix if the incoming flux and the fracture aperture size exceed critical values. The rock matrix does not have to be nearly saturated for fracture flow to occur because the fractures and matrix can be in capillary disequilibrium during transient episodic infiltration events. As an example, the type of flow, fracture or matrix, is calculated for vertical fractures in the hydrogeologic units at Yucca Mountain. The results affect such issues as natural and total system performance, site characterization activities, and site suitability determination. Also, the important differences between an unsaturated an a saturated site are pointed out. The traditional concepts of near-field, far-field, and disturbed zone become blurred when talking about the unsaturated zone. The heat of decay may have beneficial aspects for an unsaturated site. Current regulations containing such concepts such as "groundwater travel time" are not consistent with some of the physical processes inherent in an unsaturated system.

43 **Repository-heat-driven hydrothermal flow at Yucca Mountain, Part 1: Modeling and analysis.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J. *Nuclear Technology (United States);* 104(3): 418-448 (Dec 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. Analyses have demonstrated that (a) the ambient hydrological system will be dominated by repository-heat-driven hydrothermal flow for tens of thousands of years and (b) the only significant source of liquid water is from nonequilibrium fracture flow, driven either by meteoric sources or by the condensation of repository-heat-driven flow of water vapor. For sub-boiling conditions, the infiltration of meteoric water and condensate drainage are controlled by the highly heterogeneous distribution of hydrological properties, while for above-boiling conditions, they are largely determined thermodynamically. In a concept called

the "extended-dry repository," the heat of radioactive decay generates a region of above-boiling temperatures around the repository, thereby extending the time before liquid water can contact a waste package. It is also found that the magnitude of repository-heat-driven, buoyant, liquid-phase convection in the saturated zone is more dependent on the total mass of emplaced spent nuclear fuel (SNF) than on the details of SNF emplacement, such as the areal power density (expressed in kilowatts per acre) or SNF age.

44 **Repository-heat-driven hydrothermal flow at Yucca Mountain, Part II. Large-scale in situ heater test.** Buscheck, T.A. (Lawrence Livermore National Lab., CA (United States)); Nitao, J.J.; Wilder, D.G. *Nuclear Technology (United States);* 104(3): 449-471 (Dec 1993). DOE Contract W-7405-ENG-48.

In situ heater tests are needed to provide an understanding of coupled geomechanical-hydrothermal-geochemical behavior in the engineered and natural barriers under repository thermal loadings and to support the validation of related numerical and conceptual models. Hypothesis testing can help focus characterization, modeling, and testing activities required to support model validation and build robust site suitability and licensing arguments. In situ heater tests can address the following hypotheses: (a) repository-driven heat flow is dominated by heat conduction; (b) a region of above-boiling temperatures surrounding the repository corresponds to the absence of liquid water at the waste package environment; (c) fracture density and connectivity are sufficient to promote rock dryout due to boiling and condensate shedding; (d) rewetting of the dryout zone lags significantly behind the end of the boiling period; and (e) large-scale, buoyant, gas-phase convection may eventually dominate moisture movement in the unsaturated zone. Because of limited time, some of the in situ tests will have to be accelerated relative to actual thermal loading conditions. The tradeoffs between the limited test duration and generating hydrothermal conditions applicable to repository performance during the entire thermal loading cycle are examined, including heating (boiling and dryout) and cooldown (rewetting). For in situ heater tests to be applicable to actual repository conditions, a minimum heater test duration of 6 to 7 yr (including 4 yr of fullpower heating) is required. The parallel use of highly accelerated, shorter duration tests may also provide timely information for the license application.

SANDIA NATIONAL LABORATORIES

45 (SAND–91-1653) **Scenarios constructed for basaltic igneous activity at Yucca Mountain and vicinity: Yucca Mountain Site Characterization Project.** Barr, G.E. (Sandia National Labs., Albuquerque, NM (United States)); Dunn, E.; Dockery, H.; Barnard, R.; Valentine, G.; Crowe, B. Sandia National Labs., Albuquerque, NM (United States). Aug 1993. 186p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94001779. Source: OSTI; NTIS; INIS; GPO Dep.

Basaltic volcanism has been identified as a possible future event initiating a release of radionuclides from a potential repository at the proposed Yucca Mountain high-level waste repository site. The performance assessment method set forth in the Site Characterization Plan (DOE, 1988) requires that a set of scenarios encompassing all significant radionuclide release paths to the accessible environment be described. This report attempts to catalogue the details of the interactions between the features and processes produced by basaltic volcanism in the presence of the presumed groundwater flow system and a repository structure, the engineered barrier system (EBS), and waste. This catalogue is developed in the form of scenarios. We define a scenario as a well-posed problem, starting from an initiating event or process and proceeding through a logically connected and physically possible combination or sequence of features, events, and processes (FEPs) to the release of contaminants.

46 (SAND–92-0119) **An experimental comparison of laboratory techniques in determining bulk properties of tuffaceous rocks: Yucca Mountain Site Characterization Project.** Boyd, P.J. (New England Research, Inc., White River Junction, VT (United States)); Martin, R.J. III; Price, R.H. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 53p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94011000. Source: OSTI; NTIS; INIS; GPO Dep.

Samples of tuffaceous rock were studied as part of the site characterization for a potential nuclear waste repository at Yucca Mountain in southern Nevada. These efforts were scoping in nature, and their results, along with those of other investigations, are being used to develop suitable procedures for determining bulk properties of tuffaceous rock in support of thermal and mechanical properties evaluations. Comparisons were made between various sample preparation, handling, and measurement techniques for both zeolitized and nonzeolitized tuff in order to assess their effects on bulk property determinations. Laboratory tests included extensive drying regimes to evaluate dehydration behavior, the acquisition of data derived from both gas and water pycnometers to compare their suitability in determining grain densities, a comparison of particle size effects, and a set of experiments to evaluate whole core saturation methods. The results affirm the added complexity of these types of measurements where there is a zeolite component in the sample mineralogy. Absolute values for the bulk properties of zeolitized tuff are immeasurable due to the complex nature of their dehydration behavior. However, the results of the techniques that were investigated provide a basis for the development of preferred, consistent methods for determining the grain density, dry and saturated bulk densities, and porosity of tuffaceous rock, including zeolitic tuff in support of thermal and mechanical properties evaluations.

47 (SAND–92-0449) **Fracture analysis and rock quality designation estimation for the Yucca Mountain Site Characterization Project: Yucca Mountain Site Characterization Project.** Lin, M. (Agapito (J.F.T.) and Associates, Inc., Grand Junction, CO (United States)); Hardy, M.P.; Bauer, S.J. Sandia National Labs., Albuquerque, NM (United States). Feb 1993. 127p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-76DP00789. Order Number DE94008700. Source: OSTI; NTIS; INIS; GPO Dep.

Within the Yucca Mountain Site Characterization Project, the design of drifts and ramps and evaluation of the impacts of thermomechanical loading of the host rock requires definition of the rock mass mechanical properties. Ramps and exploratory drifts will intersect both welded and nonwelded tuffs with varying abundance of fractures. The rock mass mechanical properties are dependent on the intact rock properties and the fracture joint characteristics. An understanding of the effects of fractures on the mechanical

properties of the rock mass begins with a detailed description of the fracture spatial location and abundance, and includes a description of their physical characteristics. This report presents a description of the abundance, orientation, and physical characteristics of fractures and the Rock Quality Designation in the thermomechanical stratigraphic units at the Yucca Mountain site. Data was reviewed from existing sources and used to develop descriptions for each unit. The product of this report is a data set of the best available information on the fracture characteristics.

48 (SAND–92-2248) **Estimations of the extent of migration of surficially applied water for various surface conditions near the potential repository perimeter: Yucca Mountain Site Characterization Project.** Sobolik, S.R.; Fewell, M.E. Sandia National Labs., Albuquerque, NM (United States). Dec 1993. 105p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94006117. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is studying Yucca Mountain in southwestern Nevada as a potential site for a high-level nuclear waste repository. Site characterization includes surface-based and underground testing. Analyses have been performed to support the design of site characterization activities so to have minimal impact on the ability of the site to isolate waste, and on tests performed as part of the characterization process. Two examples of site characterization activities are the construction of an Exploratory Studies Facility, which may include underground shafts, drifts, and ramps, and surface-based testing activities, which may require borehole drilling, excavation of test pits, and road watering for dust control. The information in this report pertains to two-dimensional numerical calculations modeling the movement of surficially applied water and the potential effects of that water on repository performance and underground experiments. This document contains information that has been used in preparing recommendations for two Yucca Mountain Site Characterization Project documents: Appendix I of the Exploratory Studies Facility Design Requirements document, and the Surface-Based Testing Field Requirements Document.

49 (SAND–92-2333) **The effect of sliding velocity on the mechanical response of an artificial joint in Topopah Spring Member tuff: Yucca Mountain Site Characterization Project.** Olsson, W.A. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94009248. Source: OSTI; NTIS; INIS; GPO Dep.

A smooth artificial joint in Topopah Spring Member tuff was sheared at constant normal stress at velocities from 0 to 100 μm/s to determine the velocity-dependence of shear strength. Two different initial conditions were used: (1) unprimed – the joint had been shear stress-free since last application of normal stress, and before renewed shear loading; and (2) primed – the joint had undergone a slip history after application of normal stress, but before the current shear loading. Observed steady-state rate effects were found to be about 3 times lager than for some other silicate rocks. These different initial conditions affected the character of the stress-slip curve immediately after the onset of slip. Priming the joint causes a peak in the stress-slip response followed by a transient decay to the steady-state stress, i.e., slip weakening. Slide-hold-slide tests exhibit time-dependent strengthening. When the joint was subjected to constant shear stress, no slip was observed; that is, joint creep did not occur. One set of rate data was collected from a surface submerged in tap water, the friction was higher for this surface, but the rate sensitivity was the same as that for surfaces tested in the air-dry condition.

50 (SAND–92-2625) **A computational model for three-dimensional jointed media with a single joint set: Yucca Mountain Site Characterization Project.** Koteras, J.R. Sandia National Labs., Albuquerque, NM (United States). Feb 1994. 49p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94007582. Source: OSTI; NTIS; INIS; GPO Dep.

This report describes a three-dimensional model for jointed rock or other media with a single set of joints. The joint set consists of evenly spaced joint planes. The normal joint response is nonlinear elastic and is based on a rational polynomial. Joint shear stress is treated as being linear elastic in the shear stress versus slip displacement before attaining a critical stress level governed by a Mohr-Coulomb faction criterion. The three-dimensional model represents an extension of a two-dimensional, multi-joint model that has been in use for several years. Although most of the concepts in the two-dimensional model translate in a straightforward manner to three dimensions, the concept of slip on the joint planes becomes more complex in three dimensions. While slip in two dimensions can be treated as a scalar quantity, it must be treated as a vector in the joint plane in three dimensions. For the three-dimensional model proposed here, the slip direction is assumed to be the direction of maximum principal strain in the joint plane. Five test problems are presented to verify the correctness of the computational implementation of the model.

51 (SAND–93-0817C) **Using an Augmented Lagrangian Method and block fracturing in the DDA method.** Lin, C.T. (Colorado Univ., Boulder, CO (United States). Dept. of Civil Engineering); Amadei, B.; Sture, S.; Jung, J. Sandia National Labs., Albuquerque, NM (United States). [1994]. 6p. Sponsored by USDOE, Washington, DC (United States);National Science Foundation, Washington, DC (United States). DOE Contract AC04-76DP00789. Grant MS-9215397. (CONF-940506–3: 8. international conference on computer methods and advances in geomechanics, Morgantown, WV (United States), 22-28 May 1994). Order Number DE94005270. Source: OSTI; NTIS; INIS; GPO Dep.

This paper presents two extensions to the Discontinuous Deformation Analysis (DDA) method orginally proposed by Shi for modeling the response of blocky rock masses to mechanical loading. The first extension consists of improving the block contact algorithm. An Augmented Lagrangian Method is used to replace the Penalty Method orginally proposed. It allows Lagrange multipliers to be introduced without increasing the number of equations that need to be solved and thus, block contract forces can be calculated more accurately. A block fracturing capability based on a three-parameter Mohr-Coulomb criterion represents the second extension. It allows for shear or tensile fracturing of intact blocks and the formation of smaller blocks.

52 (SAND–93-0852) **The appropriateness of one-dimensional Yucca Mountain hydrologic calculations: Yucca Mountain Site Characterization Project.** Eaton, R.R. Sandia National Labs., Albuquerque, NM (United States). Jul 1993. 51p. Sponsored by USDOE, Washington,

DC (United States). DOE Contract AC04-94AL85000. Order Number DE94003314. Source: OSTI; NTIS; INIS; GPO Dep.

This report brings into focus the results of numerous studies that have addressed issues associated with the validity of assumptions which are used to justify reducing the dimensionality of numerical calculations of water flow through Yucca Mountain, NV. it is shown that, in many cases, one-dimensional modeling is more rigorous than previously assumed.

53 (SAND–93-1182) **Evaluation of the effects of underground water usage and spillage in the Exploratory Studies Facility: Yucca Mountain Site Characterization Project.** Dunn, E.; Sobolik, S.R. Sandia National Labs., Albuquerque, NM (United States). Dec 1993. 60p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94005956. Source: OSTI; NTIS; INIS; GPO Dep.

The Yucca Mountain Site Characterization Project is studying Yucca Mountain in southwestern Nevada as a potential site for a high-level radioactive waste repository. Analyses reported herein were performed to support the design of site characterization activities so that these activities will have a minimal impact on the ability of the site to isolate waste and a minimal impact on underground tests performed as part of the characterization process. These analyses examine the effect of water to be used in the underground construction and testing activities for the Exploratory Studies Facility on in situ conditions. Underground activities and events where water will be used include construction, expected but unplanned spills, and fire protection. The models used predict that, if the current requirements in the Exploratory Studies Facility Design Requirements are observed, water that is imbibed into the tunnel wall rock in the Topopah Springs welded tuff can be removed over the preclosure time period by routine or corrective ventilation, and also that water imbibed into the Paintbrush Tuff nonwelded tuff will not reach the potential waste storage area.

54 (SAND–93-2507C) **Towards a realistic approach to validation of reactive transport models for performance assessment.** Siegel, M.D. Sandia National Labs., Albuquerque, NM (United States). [1993]. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9309228–8: Focus 93: site characterization and model validation, Las Vegas, NV (United States), 26-29 Sep 1993). Order Number DE94005249. Source: OSTI; NTIS; INIS; GPO Dep.

Performance assessment calculations are based on geochemical models that assume that interactions among radionuclides, rocks and groundwaters under natural conditions, can be estimated or bound by data obtained from laboratory-scale studies. The data include radionuclide distribution coefficients, measured in saturated batch systems of powdered rocks, and retardation factors measured in short-term column experiments. Traditional approaches to model validation cannot be applied in a straightforward manner to the simple reactive transport models that use these data. An approach to model validation in support of performance assessment is described in this paper. It is based on a recognition of different levels of model validity and is compatible with the requirements of current regulations for high-level waste disposal. Activities that are being carried out in support of this approach include (1) laboratory and numerical experiments to test the validity of important assumptions inherent in current performance assessment methodologies,(2) integrated transport experiments, and (3) development of a robust coupled reaction/transport code for sensitivity analyses using massively parallel computers.

55 (SAND–93-2675) **Total-system performance assessment for Yucca Mountain – SNL second iteration (TSPA-1993): Executive summary.** Wilson, M.L. (Sandia National Labs., Albuquerque, NM (United States)); Barnard, R.W.; Gauthier, J.H. Sandia National Labs., Albuquerque, NM (United States). Apr 1994. 67p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94012995. 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). 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. 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. Probabilistic analyses are performed for aqueous and gaseous flow and transport, human intrusion, and basaltic magmatic activity. Results of the calculations lead to a number of recommendations concerning studies related to site characterization. Primary among these are the recommendations to obtain better information on percolation flux at Yucca Mountain, on the presence or absence of flowing fractures, and on physical and chemical processes influencing gaseous flow. Near-field thermal and chemical processes, and waste-container degradation are also areas where additional investigations may reduce important uncertainties. Recommendations for repository and waste-package design studies are: (1) to evaluate the performance implications of large-size containers, and (2) to investigate in more detail the implications of high repository thermal power output on the adjacent host rock and on the spent fuel.

56 (SAND–93-3903C) **Modeling infiltration into a tuff matrix from a saturated vertical fracture.** Ho, C.K. Sandia National Labs., Albuquerque, NM (United States). [1993]. 23p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–26: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008953. Source: OSTI; NTIS; INIS; GPO Dep.

Saturation profiles resulting from TOUGH2 numerical simulations of water infiltration into a tuff matrix from a saturated vertical fracture have been compared to experimental results. The purpose was to determine the sensitivity of the infiltration on local heterogeneities and different representations of two-phase characteristic curves used by the model. Findings indicate that the use of simplified (linearized) capillary pressure curves with rigorous (van Genuchten) relative permeability curves resulted in a more computationally efficient solution without a loss in accuracy. However, linearized forms of the relative permeability functions produced poor results, regardless of the form of the capillary pressure function. In addition, numerical simulations revealed that the presence of local heterogeneities in the tuff caused nonuniform saturation distributions and wetting fronts in the in matrix.

57 (SAND–93-4002C) **Paleoclimate validation of a numerical climate model.** Schelling, F.J. (Sandia National Laboratories, Las Vegas, NV (United states)); Church, H.W.; Zak, B.D.; Thompson, S.L. Sandia National Labs., Albuquerque, NM (United States). [1994]. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–30: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009287. Source: OSTI; NTIS; INIS; GPO Dep.

An analysis planned to validate regional climate model results for a past climate state at Yucca Mountain, Nevada, against paleoclimate evidence for the period is described. This analysis, which will use the GENESIS model of global climate nested with the RegCM2 regional climate model, is part of a larger study for DOE's Yucca Mountain Site Characterization Project that is evaluating the impacts of long term future climate change on performance of the potential high level nuclear waste repository at Yucca Mountain. The planned analysis and anticipated results are presented.

58 (SAND–93-4045C) **Studies of non-isothermal flow in saturated and partially saturated porous media.** Ho, C.K.; Maki, K.S.; Glass, R.J. Sandia National Labs., Albuquerque, NM (United States). [1993]. 27p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–44: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94010395. Source: OSTI; NTIS; INIS; GPO Dep.

Physical and numerical experiments have been performed to investigate the behavior of nonisothermal flow in two-dimensional saturated and partially saturated porous media. The physical experiments were performed to identify non-isothermal flow fields and temperature distributions in fully saturated, half-saturated, and residually saturated two-dimensional porous media with bottom heating and top cooling. Two counter-rotating liquid-phase convective cells were observed to develop in the saturated regions of all three cases. Gas-phase convection was also evidenced in the unsaturated regions of the partially saturated experiments. TOUGH2 numerical simulations of the saturated case were found to be strongly dependent on the assumed boundary conditions of the physical system. Models including heat losses through the boundaries of the test cell produced temperature and flow fields that were in better agreement with the observed temperature and flow fields than models that assumed insulated boundary conditions. A sensitivity analysis also showed that a reduction of the bulk permeability of the porous media in the numerical simulations depressed the effects of convection, flattening the temperature profiles across the test cell.

59 (SAND–93-4097C) **Appropriateness of one-dimensional calculations for repository analysis.** Eaton, R.R. Sandia National Labs., Albuquerque, NM (United States). [1994]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–5: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94005588. Source: OSTI; NTIS; INIS; GPO Dep.

This paper brings into focus the results of numerous studies that have addressed issues associated with the validity of assumptions which are used to justify reducing the dimensionality of numerical calculations of water flow through Yucca Mountain, NV. It is shown that in many cases, one-dimensional modeling is more rigorous than previously assumed.

60 (SAND–93-7116C) **Development of methods to evaluate uranium distribution coefficients in unsaturated media.** Sautman, M.T. (Massachusetts Inst. of Tech., Cambridge, MA (United States). Dept. of Nuclear Engineering); Simonson, S.A. Sandia National Labs., Albuquerque, NM (United States). [1993]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-9309146–7: 5. annual American Chemical Society (ACS) Industrial and Engineering Chemistry (I&EC) Division special symposium on emerging technologies for hazardous waste management, Atlanta, GA (United States), 27-29 Sep 1993). Order Number DE94004694. Source: OSTI; NTIS; INIS; GPO Dep.

To date, batch sorption and dynamic column experiments have been performed for many elements as part of site characterization programs. These experiments were often conducted with samples having relatively high liquid/solid ratios (in some cases the solid volume was much smaller than the solution volume). The development of methods for measuring sorption parameters at low liquid/solid ratios was undertaken to attempt to judge whether or not results of saturated experiments are valid for use in performance assessments of sites located in unsaturated rocks. The amount of hydrologic saturation can affect the ionic strength, pH, and redox potential which can in turn affect sorption. In addition, the presence of the gas phase may affect the amount of wetting occurring on the solid's surface. This paper describes experimental procedures which were developed to evaluate the sorption of uranium by silica sand at predetermined levels of unsaturation.

61 (SAND–94-0185) **Modeling heterogeneous unsaturated porous media flow at Yucca Mountain.** Robey, T.H. (Spectra Research Inst., Albuquerque, NM (United States)). Sandia National Labs., Albuquerque, NM (United States). [1994]. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–18: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008612. Source: OSTI; NTIS; INIS; GPO Dep.

Geologic systems are inherently heterogeneous and this heterogeneity can have a significant impact on unsaturated flow through porous media. Most previous efforts to model groundwater flow through Yucca Mountain have used stratigraphic units with homogeneous properties. However, modeling heterogeneous porous and fractured tuff in a more realistic manner requires numerical methods for generating heterogeneous simulations of the media, scaling of material properties from core scale to computational scale, and flow modeling that allows channeling. The Yucca Mountain test case of the INTRAVAL project is used to test the numerical approaches. Geostatistics is used to generate more realistic representations of the stratigraphic units and heterogeneity within units is generated using sampling from property distributions. Scaling problems are reduced using an adaptive grid that minimizes heterogeneity within each flow element. A flow code based on the dual mixed-finite-element method that allows for heterogeneity and channeling is employed. In the Yucca Mountain test case, the simulated volumetric water contents matched the measured values at drill hole USW UZ-16 except in the nonwelded portion of Prow Pass.

62 (SAND–94-0207C) **Constraining local 3-D models of the saturated-zone, Yucca Mountain, Nevada.** Barr, G.E.; Shannon, S.A. Sandia National Labs., Albuquerque, NM (United States). [1994]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. (CONF-940553–20: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94008956. Source: OSTI; NTIS; INIS; GPO Dep.

A qualitative three-dimensional analysis of the saturated zone flow system was performed for a 8 km × 8 km region including the potential Yucca Mountain repository site. Certain recognized geologic features of unknown hydraulic properties were introduced to assess the general response of the flow field to these features. Two of these features, the Solitario Canyon fault and the proposed fault in Drill Hole Wash, appear to constrain flow and allow calibration.

U.S. GEOLOGICAL SURVEY

63 (USGS-OFR–92-450) **Geodetic leveling data used to define historical height changes between Tonopah Junction and Las Vegas, Nevada.** Gilmore, T.D. Geological Survey, Menlo Park, CA (United States). 1992. 133p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94003605. Source: OSTI; NTIS; INIS; GPO Dep.

This report documents geodetic leveling data for a survey route following US Highway 95 from Tonopah Junction, approximately 50 km west of Tonopah, Nevada, to Las Vegas, Nevada. The survey route passes immediately south of the potential site for a high-level nuclear waste repository at Yucca Mountain in southern Nevada. Comparisons among the results of the several repeated levelings along this survey route provide a partial basis for evaluating contemporary crustal deformation patterns in the vicinity of the Yucca Mountain site and the relation between any such deformation and geologic structures known or suspected to have been active during Quaternary time.

64 (USGS-OFR–93-60) **Geohydrologic data from test hole USW UZ-6s, Yucca Mountain, Nye County, Nevada.** Loskot, C.L. Geological Survey, Denver, CO (United States). 1993. 25p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94008084. Source: OSTI; NTIS; INIS; GPO Dep.

As part of the investigation of Yucca Mountain, Nevada, as a potential site for storing high-level radioactive wastes in an underground mined geologic repository, the US Geological Survey, in cooperation with the US Department of Energy, in 1982, began drilling a series of test holes in and near the southwestern part of the Nevada Test Site to determine the geologic and hydrologic characteristics of the area. Test hole USW UZ-6s is part of that series of test holes, and this report presents data obtained from test hole USW UZ-6s. The data includes those from drilling operations, lithology, coring, and laboratory analyses of hydrologic properties, which include gravimetric water content, water potential, and bulk- and grain-density values. The gravimetric water content of the densely welded section of the Tiva Canyon Member of the Paintbrush Tuff averages 0.027 gram per gram for test hole USW UZ-6s; water potential averages −7,200 kilo-pascals; gravimetric water content of the moderately to densely welded tuffs range from 0.054 gram per gram for the Tiva Canyon Member of the Paintbrush Tuff to 0.027 gram per gram for the Topopah Spring Member of the Paintbrush Tuff; and water potentials range from −6,700 to −3,400 kilopascals. Gravimetric water content for the partially welded to unnamed bedded tuffs average 0.123, 0.106, and 0.085 gram per gram for the Tiva Canyon Member, the unnamed bedded tuffs, and the Topopah Spring Member in test hole USW UZ-6s; average water potentials for these units are −1,700, −480, and −820 kilopascals.

65 (USGS-OFR–93-651) **Meteorological, stream-discharge, and water-quality data for 1986 through 1991 from two small basins in central Nevada.** McKinley, P.W.; Oliver, T.A. Geological Survey, Denver, CO (United States). 1994. 167p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AI08-92NV10874. Order Number DE94009861. Source: OSTI; NTIS; U.S. Geological Survey, Open-File Reports Section, MS 517, Box 25286, Denver Federal Center, Denver, CO 80225; GPO Dep.

The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, is investigating the volcanic tuffs of Yucca Mountain, Nevada, for their suitability as storage sites for nuclear waste. Two small basins, measuring less than 2 square miles, were studied to determine the volume of precipitation available for recharge to the ground water. The semiarid 3 Springs Basin is located to the east of Kawich Peak in the Kawich Range east of Tonopah, Nevada. Stewart Basin is a subalpine drainage basin north of Arc Dome in the Toiyabe Range north of Tonopah, Nevada. This publication presents the meteorological, stream-discharge, and water-quality data collected during the study. Meteorological data collected include air temperature, soil temperature, solar radiation, and relative humidity. Stream-discharge data were collected from the surface-water outlet of each basin. Water-quality data are chemical analyses of water samples collected from surface- and ground-water sources. Data were collected throughout the two basins. Each basin has a meteorological station located in the lower and upper reaches of the basin. Hydrologic records include stream-discharge and water-quality data from the lower meteorological site and water-quality data from springs within the basins. Meteorological data are available from the lower sites from the winter of 1986 through the fall of 1991. Periods of data collection were shorter for additional sites in the basin.

66 (USGS-WRI–92-4065) **An estimate of the roughness length and displacement height of Sonoran Desert vegetation, south-central Arizona.** Claassen, H.C. (Geological Survey, Denver, CO (United States)); Riggs, A.C. Geological Survey, Denver, CO (United States); Geological Survey, Reston, VA (United States). 1993. 20p. Sponsored by USDOE, Washington, DC (United States);Geological Survey, Reston, VA (United States). DOE Contract AI08-92NV10874 ; AI08-78ET44802. Order Number DE94003606. Source: OSTI; NTIS; GPO; U.S. Geological Survey, Books and Open-File Reports Section, Box 25425, Mail Stop 517, Federal Center, Denver, CO 80225-0425; GPO Dep.

A somewhat unconventional technique using a tethered balloon was used to estimate the roughness length for momentum (z_m) and displacement height (d) for typical Sonoran Desert vegetation. It has been suggested that measurements of the meteorological fluxes of momentum, sensible heat, and latent heat are best done at heights above ground level determined by either the roughness length (z_m) or the size and shape of vegetation. Therefore, estimates of z_m

and vegetation characteristics are a desirable prerequisite to developing a flux-measurement protocol. Because the literature contains little information on z_m for Sonoran Desert vegetation, it is desirable to measure z_m and the displacement height (d) associated with Sonoran Desert vegetation.

67 **Relict colluvial boulder deposits as paleoclimatic indicators in the Yucca Mountain region, southern Nevada.** Whitney, J.W. (Geologic Survey, Denver, CO (United States)); Harrington, C.D. *Geological Society of America, Bulletin (United States);* 105(8): 1008-1018 (Aug 1993).

Six colluvial boulder deposits from Yucca Mountain, Nye County, Nevada, were dated by cation-ratio dating of rock varnish accreted on boulder surfaces. Estimated minimum ages of these boulder deposits range from 760 to 170 ka. Five additional older deposits on nearby Skull and Little Skull Mountains and Buckboard Mesa yielded cation-ratio minimum-age estimates of 1.38 Ma to 800 ka. An independent cosmogenic chlorine-36 surface exposure date was obtained on one deposit, which confirms an estimated early to middle Quaternary age. These deposits have provided the oldest age estimates for unconsolidated hillslope deposits in the southwestern United States. We suggest that the colluvial boulder deposits were produced during early and middle Pleistocene glacial/pluvial episodes and were stabilized during the transition to drier interglacial climates. By comparison to modern periglacial environments, winter minimum monthly temperatures of -3 to -5 °C were necessary to initiate freeze-thaw conditions of such vigor to physically weather relatively large volumes of large boulders from the upper hillslopes of the Yucca Mountain area. These conditions imply that early and middle Pleistocene glacial winter temperature were at least 1 to 3°C colder than existed during the last Pleistocene glacial episode and 7 to 9°C colder than present. 53 refs., 9 figs., 3 tabs.

RELATED INFORMATION

68 **High Level Radioactive Waste Management: Proceedings: Volume 1.** 1115p. American Nuclear Society, Inc., La Grange Park, IL 60525 (United States) (1993). Sponsored by American Society of Civil Engineers, New York, NY (United States);American Nuclear Society, La Grange Park, IL (United States). From 10. international high-level radioactive waste management conference; Las Vegas, NV (United States); 25-29 Apr 1993.

Individual papers are processed separately for the databases. The theme of the 1993 International High Level Radioactive Waste Management (IHLRWM) Conference, "Sharing Technologies for a Common Need" characterizes the objective of the entire conference series. The common need for all who are involved in high-level radioactive waste management is to find a technically and institutionally acceptable solution for the disposition of spent fuel and high-level waste that protects the public and the environment. High-level radioactive waste management is a multinational concern where every country can benefit from sharing its technology. Each year, the international community becomes more involved in this conference. This year, the fourth IHLRWM conference has 42 participating organizations and 50 papers approved for presentation. Of these, 16 of the organizations and 70 of the papers are from outside of the United States. As more and more of the world's electricity is generated by nuclear power plants, there is a greater need for information exchange and cooperative among countries and various international agencies. Through such cooperation, nations can share information, technology, and experience and a consensus to improve confidence in the safety of each nation's approach to solving its high-level waste management problems. Commenting the signing of two new international agreements in 1992, the former director of the US Department of Energy (DOE) Office of Civilian Radioactive Management (OCRWM), said, "As nuclear waste issues continue to be addressed in numerous countries, international cooperative research and development becomes an increasingly important way to maximize limited resources, build consensus on issues in the radioactive waste management and broaden our technical and institutional knowledge base."

69 (DOE/EA–0532) **Environmental assessment for the Groundwater Characterization Project, Nevada Test Site, Nye County, Nevada: Revision 1.** USDOE Nevada Operations Office, Las Vegas, NV (United States). Aug 1992. 156p. Sponsored by USDOE, Washington, DC (United States). Order Number DE94004388. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy (DOE) proposes to conduct a program to characterize groundwater at the Nevada Test Site (NTS), Nye County, Nevada, in accordance with a 1987 DOE memorandum stating that all past, present, and future nuclear test sites would be treated as Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (Memorandum from Bruce Green, Weapons Design and Testing Division, June 6, 1987). DOE has prepared an environmental assessment (DOE/EA-0532) to evaluate the environmental consequences associated with the proposed action, referred to as the Groundwater Characterization Project (GCP). This proposed action includes constructing access roads and drill pads, drilling and testing wells, and monitoring these wells for the purpose of characterizing groundwater at the NTS. Long-term monitoring and possible use of these wells in support of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, is also proposed. The GCP includes measures to mitigate potential impacts on sensitive biological, cultural and historical resources, and to protect workers and the environment from exposure to any radioactive or mixed waste materials that may be encountered. DOE considers those mitigation measures related to sensitive biological, cultural and historic resources as essential to render the impacts of the proposed action not significant, and DOE has prepared a Mitigation Action Plan (MAP) that explains how such mitigations will be planned and implemented. Based on the analyses presented in the EA, DOE has determined that the proposed action is not a major Federal action significantly affecting the quality of the human environment, within the meaning of the National Environmental Policy Act of 1969 (NEPA). Therefore, preparation of an environmental impact statement is not required and the Department is issuing this FONSI.

70 (DOE/FTR–94002466) **Travel to France and Switzerland to collaborate on radioactive waste storage: Foreign trip report, June 15–20, 1993.** Dockery, H.A. Sandia National Labs., Albuquerque, NM (United States). 28 Oct 1993. 47p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-76DP00789. Order Number DE94002466. Source: OSTI; NTIS (US Sales Only); GPO Dep.

The purpose of the visit to the Bureau de Recherches Geologiques et Minieres (BRGM) on June 16 was to determine if there might be common areas of interest of radioactive waste storage and isolation and to initiate contact between the Sandia National Laboratories (SNL) and BRGM in those areas. The informal visit included presentations about several of BRGM's activities. Of particular interest was information on the BRGM hydrologic and geochemical modeling effort for waste-disposal projects. The traveler made a presentation on Yucca Mountain total-system performance-assessment activities and applications for staff from both BRGM and ANDRA. On June 17 and 19, he attended a meeting of a working group to develop an international database of features, events, and processes (FEPs) to be considered in scenario development at the NEA offices in Paris, France. The primary result of the working group was to propose construction of a database of FEPs that would be of general use to the international community for both projects involved with high-level radioactive waste, as well as hazardous waste. The member countries will be working over the next year to incorporate all previously assimilated information into a joint database. The last part of the trip was made to visit NAGRA in Switzerland on June 22 and 23. The main purpose of that trip was to present information on Sandia's Total-System Performance-Assessment activities. The presentation was well received by the audience. The comment was made that the European community was not aware of the large amount of progress that had been made in the area of total-system performance assessment and that further exchanges of this nature would be welcomed.

71 (DOE/FTR–94006304) **Report on the nuclear waste program in Sweden: Foreign trip report, December 12–16, 1993.** Shephard, L.E. Sandia National Labs., Albuquerque, NM (United States). 27 Jan 1994. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94006304. Source: OSTI; NTIS (US Sales Only); GPO Dep.

Dr. Shephard is one of two US representatives for the Scientific Advisory Committee (SAC) that has been formed by the Svensk Kaernbranslehantering AB (SKB) to provide review and advice on the technical program being planned or implemented at the Aespoe Hard Rock Laboratory (HRL), Oskarshamn, Sweden. The fifteenth meeting of the SAC was convened in Forsmark, Sweden, December 14 and 15, 1993 (Attachment 1 contains a list of participants). Several components of the HRL technical program were discussed (see Attachment 2: Agenda) including: (1) plans for initiating an evaluation of repository construction techniques comparing both drill and blast and tunnel boring machine construction approaches, (2) the results of a pre-investigation study that predicted conditions prior to construction of the HRL, (3) the status of a small-scale prototype repository simulation experiment (DOABLE), (4) important elements and characteristics of HRL conceptual models, and (5) preliminary modelling results and plans for the multi-well tracer experiment. Each of these discussion topics contained components with direct application to the Yucca Mountain Project.

72 (DOE/NV/10630–28-Add.2) **Addendum to Environmental Monitoring Plan, Nevada Test Site and Support Facilities: Addendum 2.** Reynolds Electrical and Engineering Co., Inc., Las Vegas, NV (United States). Nov 1993. 95p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-89NV10630. Order Number DE94005932. Source: OSTI; NTIS; INIS; GPO Dep.

This 1993 Addendum to the "Environmental Monitoring Plan Nevada Test Site and Support Facilities – 1991," Report No. DOE/NV/10630-28 (EMP) applies to the US Department of Energy's (DOE's) operations on the Continental US (including Amchitka Island, Alaska) that are under the purview of the DOE Nevada Operations Office (DOE/NV). The primary purpose of these operations is the conduct of the nuclear weapons testing program for the DOE and the Department of Defense. Since 1951, these tests have been conducted principally at the Nevada Test Site (NTS), which is located approximately 100 miles northwest of Las Vegas, Nevada. In accordance with DOE Order 5400.1, this 1993 Addendum to the EMP brings together, in one document, updated information and/or new sections to the description of the environmental activities conducted at the NTS by user organizations, operations support contractors, and the US Environmental Protection Agency (EPA) originally published in the EMP. The EPA conducts both the offsite environmental monitoring program around the NTS and post-operational monitoring efforts at non-NTS test locations used between 1961 and 1973 in other parts of the continental US. All of these monitoring activities are conducted under the auspices of the DOE/NV, which has the stated policy of conducting its operations in compliance with both the letter and the spirit of applicable environmental statutes, regulations, and standards.

73 (DOE/NV/11417–1) **Great Basin paleoenvironmental studies project: Technical progress report: First quarter (January–August 1993).** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1993]. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94004562. Source: OSTI; NTIS; INIS; GPO Dep.

Project goals, project tasks, progress on tasks, and problems encountered are described and discussed for each of the studies that make up the Great Basin Paleoenvironmental Studies Project for Yucca Mountain. These studies are: Paleobotany, Paleofauna, Geomorphology, and Transportation. Budget summaries are also given for each of the studies and for the overall project.

74 (DOE/NV/11417–2) **Great Basin paleoenvironmental studies project: Technical progress report, second quarter, September–November, 1993.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1993]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94004563. Source: OSTI; NTIS; GPO Dep.

Progress is described in the four tasks associated with this project. Task 1, Paleobotanical studies in the Great Basin, has as its objective the reconstruction of the response of vegetation to climate in order to identify periods of mesic climate at Yucca Mountain during the last 20,000 to 50,000 years. Past extremes in infiltration rates are expected to serve as estimates of climate that may be expected during the next 10,000 years at Yucca Mtn. Task 2, Paleofaunas, will construct a history of Great Basin vertebrates that will provide empirical evidence of past environmental and climatic conditions. The objective of Task 3, Geomorphology, is to document the responses of surficial processes and landforms to the climatic changes documented by studies of packrat middens, pollen, and faunal distributions. The goal of Task 4, Transportation, is to compare the results from three models 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 Yucca Mountain. This research looked at three alluvial fans with rail transportation alignments crossing them.

75 (DOE/NV/11417–3) **Great Basin paleoenvironmental studies project: Third quarterly technical progress report, December 1993–February 1994.** Nevada Univ., Reno, NV (United States). Desert Research Inst. [1994]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC08-93NV11417. Order Number DE94009652. Source: OSTI; NTIS; GPO Dep.

Examination of the paleolithic and geomorphic records to determine the local and regional impact of past climates will advance assessment of Yucca Mountain's suitability as a high-level nuclear waste repository. The project includes the integration of botanical, faunal, and geomorphic components to accomplish this goal. Paleobotanical studies will reconstruct the response of vegetation to climate change at the community and the organismal levels by integrating data obtained from nearly continuous sediment records of pollen, plant macrofossils, and stable isotopes from fossil woodrat middens. The goal of the paleofaunas study is to construct a history of Great Basin vertebrates, particularly mammals, that will provide empirical evidence of past environmental and climatic conditions within the Great Basin as it is recorded by the animals. Taxonomic composition of archaeological and paleontological faunas from various areas within the Great Basin and morphological change within individual mammalian taxa at specific localities are being investigated to monitor faunal response to changing environmental conditions. The objective of the geomorphology component of the paleoenvironmental program is to document the responses of surficial processes and landforms to the climatic changes documented by studies of packrat middens, pollen, and faunal distributions. The project will focus on: (1) stratigraphic relationships between lake deposits and aeolian or fluvial sediments and landforms; (2) cut and fill sequences in floodplain and river-channel deposits; (3) identification of periods of dune mobility and stability; (4) documentation of episodes of alluvial fan and terrace development and erosion; and (5) correlation of (3) and (4) to climatically driven lake-level fluctuation as revealed by shoreline features such as strandlines and beach ridges. Accomplishments for this period are presented for these studies.

76 (DOE/RW/00286–3) **Public involvement in radioactive waste management decisions.** Council of State Governments, Lombard, IL (United States). Midwestern Office. Apr 1994. 32p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC01-94RW00286. Order Number DE94011159. Source: OSTI; NTIS; INIS; GPO Dep.

Current repository siting efforts focus on Yucca Mountain, Nevada, where DOE's Office of Civilian Radioactive Waste Management (OCRWM) is conducting exploratory studies to determine if the site is suitable. The state of Nevada has resisted these efforts: it has denied permits, brought suit against DOE, and publicly denounced the federal government's decision to study Yucca Mountain. The state's opposition reflects public opinion in Nevada, and has considerably slowed DOE's progress in studying the site. The Yucca Mountain controversy demonstrates the importance of understanding public attitudes and their potential influence as DOE develops a program to manage radioactive waste. The strength and nature of Nevada's opposition – its ability to thwart if not outright derail DOE's activities – indicate a need to develop alternative methods for making decisions that affect the public. This report analyzes public participation as a key component of this openness, one that provides a means of garnering acceptance of, or reducing public opposition to, DOE's radioactive waste management activities, including facility siting and transportation. The first section, Public Perceptions: Attitudes, Trust, and Theory, reviews the risk-perception literature to identify how the public perceives the risks associated with radioactivity. DOE and the Public discusses DOE's low level of credibility among the general public as the product, in part, of the department's past actions. This section looks at the three components of the radioactive waste management program – disposal, storage, and transportation – and the different ways DOE has approached the problem of public confidence in each case. Midwestern Radioactive Waste Management Histories focuses on selected Midwestern facility-siting and transportation activities involving radioactive materials.

77 (EUR–14877) **Oklo working group meeting.** Von Maravic, H. (Commission of the European Communities, Brussels (Belgium)). Commission of the European Communities, Luxembourg (Luxembourg). 1993. 199p. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). Source: OSTI; NTIS (US Sales Only); INIS.

Natural analogue studies have been carried out for several years in the framework of the European Community's R and D programme on radioactive waste; and within its recent fourth five-year programme on 'Management and storage of radioactive waste (1990-94)' the Community is participating in the Oklo study, natural analogue for transfer processes in a geological repository. The Oklo project is coordinated by CEA-IPSN (F) and involves laboratories from several CEA directorates (IPSN, DTA and DCC) which collaborate with other institutions from France: CREGU, Nancy; CNRS, Strasbourg and ENSMD, Fontainebleau. Moreover, institutes from non-EC member States are also taking part in the Oklo study. The second joint CEC-CEA progress meeting of the Oklo Working Group was held in April 1992 in Brussels and gave the possibility of reviewing and discussing progress made since its first meeting in February 1991 at CEA in Fontenay-aux-Roses. About 40 participants from 15 laboratories and organizations coming from France, Canada, Gabon, Japan, Sweden and the USA underline the great interest in the ongoing research activities. The meeting focused on the different tasks within the CEC-CEA Oklo project concerning (i) field survey and sampling, (ii) characterization of the source term, (iii) studies of the petrographical and geochemical system, and (iv) studies of the hydrogeological system and hydrodynamic modelling. (author) 17 papers are presented.

78 (EUR–14877, pp. 9-14) **Oklo, natural analogue for transfer processes in a geological repository: an overview.** Chapuis, A.M. (CEA Centre d'Etudes de Fontenay-aux-Roses, 92 (France). Inst. de Protection et de Surete Nucleaire); Blanc, P.L. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The uranium ore body in Oklo is a unique subject in the world, as natural fission reactions occurred there two billion years ago. It provides opportunities for the study of natural analogy with deep radioactive waste disposal, specially radionuclide mass transfer processes to the surface. The

ongoing program is co-funded by the CEC, and it involves several directorates in the CEA, that is to say the IPSN, plus DTA and DCC. Other, non-CEC agencies also take part in the studies, such as SKB (Sweden), AECL and ONTARIO-HYDRO (Canada). It can be subdivided into several different tasks: (1) In situ sampling, in close collaboration with the mining company (C.O.M.U.F., Compagnie des Mines d'Uranium de Franceville, Mounana, Gabon). (2) Study and characterization of the source term (mostly in CEA laboratories). (3) Studies on the geochemical systems ruling the migrations, implying collaboration between CEA laboratories and other institutions: CREGU (Centre de Recherches sur la Geologie des matieres premieres minerales et energetiques, formerly "de l'Uranium", Nancy), Centre de Geochimie de la Surface (CNRS, Strasbourg), and Ecole Nationale Superieure des Mines de Paris (ENSMP, Centre de Geologie Generale et Miniere and Centre d'Informatique Geologique, Fontainebleau). (4) Modelling: Part of the modelling will take place in each laboratory involved, but the final coupling of models will be the responsibility of IPSN and ENSMP. (author). 1 fig.

79 (EUR–14877, pp. 15-24) **The reaction zones and the rock sampling in Oklo-Okelobondo.** Peycelon, H. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Since 1972, 16 reaction zones have been discovered. Eleven of those are located in the Oklo open pit and are mined out. Nowadays the interesting zones for the natural analogue project are located underground and had been identified as zones 10, 13 and 16 in the mining works of Oklo and in the borehole OK 84 at Okelobondo. The sampling had been picked up in the reaction zones and in their peripheric areas. Far from the reaction zones fractures, falts, organic matters and dolerite have also been sampled. The aim of the sampling was to find rocks which shows fluid circulation evidence. Particular attention has been paid to: 1- The limits of layers. 2- The interlayers: pelitic and fine black sandstones where little veins of calcite was frequently found. 3- The fractures, falts and hydraulic fracturated rocks. Less systematically and to complete the sampling some samples have been taken in the layers and are representative of the common uranium ore. (author). 6 figs., 2 refs.

80 (EUR–14877, pp. 25-35) **Geochemical and isotopic characterization of the reaction zones (uranium, transuranium, lead and fission products).** Holliger, P. (CEA Centre d'Etudes de Grenoble, 38 (France)). Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

New in-situ isotopic studies have been carried out on polished sections from the Oklo nuclear reactor zones. Interpretations of U - Fission Products (F.P) analyses allow to calculate the main nuclear reaction parameters (fluence, neutron spectrum, conversion factor, fission proportion of ^{235}U, ^{238}U and ^{239}Pu, lifetime of the reactors,...) of the newly discovered reactor zones. U-Pb measurements on uranium oxides and galenas show that 1.95 billion years is the primary age of the Oklo uranium deposit and 750 million years is the time of an episodic disturbance with U and Pb local isotopic homogenization and redistribution. This major episode of U and Pb migration was probably caused by the intrusion of a dolerite dyke which cuts across the Oklo deposit near to the reactor zone 13. Samples from parts of reactor zones 10 and 13, located in sandstone and massive uraninite respectively, were studied in order to examine the stability of fission products relative to uranium. Ion microprobe images show a good retention of numerous FP (e.g Rare Earth Elements) and transuranium elements in the UO_2 matrix and the existence of tiny inclusions containing Ru, (Tc), Rh, Pd, Mo and Te together with Pb, As and S. (author). 4 refs., 6 figs., 3 tabs.

81 (EUR–14877, pp. 37-44) **Migration of radioelements around the new nuclear reactors at Oklo: petrological and geochemical results.** Menet-Dressayre, C. (CEA Centre d'Etudes de la Vallee du Rhone, 30 - Marcoule (France). Direction du Cycle du Combustible); Menager, M.T. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Samples from a new natural reactor of Oklo (zone 10) have been investigated with the aim of specifying possible elemental migrations into its close surroundings. The mineralogy demonstrates the occurrence of a redox front at the boundary of the reactor. We show first that significant migration of rare earths and uranium took place on a decimetric scale around the reactor and that secondary phases (both clay minerals, carbonates filling fissures and accessory minerals such as zircon) are responsible for their subsequent immobilization within the rock. (author). 2 refs., 1 fig., 3 tabs.

82 (EUR–14877, pp. 45-55) **Geochemistry of apatites, pyrites and galenas in near- and far-field veins and sandstones around the Oklo fossil reactors (Gabon): identification of ancient hydrothermal circulations.** Raimbault, L. (Ecole Nationale Superieure des Mines, 77 -Fontainebleau (France). Centre d'Informatique Geologique). Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The identification and the modelling of fission-product transfer from reactor cores to near-and far-field surrounding rocks, are a prerequisite to the use of the Oklo fossil reactors as a natural analogue of radioactive waste disposal. It is thus necessary to characterize the different hydrothermal circulation stages which occurred in the deposit, for their ability to carry away radionuclides to be assessed. The problems to be solved are as follows:(1) to identify each stage, (2) to constrain the chemical composition of these fluids as precisely as possible, (3) to determine fluid pathways, and if possible, (4) to assign the source(s) of matter carried by each fluid, and the source of energy needed for fluid convection. This paper presents the geochemistry of apatites, pyrites and galenas. (author). 3 refs., 4 figs., 2 tabs.

83 (EUR–14877, pp. 57-65) **Dating of the Francevillian sedimentary series and mineralogic and isotopic (Sm, Nd, Rb, Sr, K, Ar, U, O and C) characterization of the gangue of the reactors 10 and 13.**

Preliminary report. Gautier-Lafaye, F. (Centre National de la Recherche Scientifique (CNRS), 67 - Strasbourg (France). Centre de Sedimentologie et Geochimie de la Surface); Stille, P.; Bros, R.; Taieb, R. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

This paper summarizes the various ages reported for the diagenetic events in the Francevillian sedimentary series (Precambrian era) and the fission reactors of Oklo. Obviously, differences exist between the ages obtained on the silicate minerals and the ages obtained on the Uranium ores and on the reactors. Clay minerals which crystallized during the fission reactions yield younger ages than the reactors themselves. Similarly, the diagenetic clays (1870 Ma) show younger ages than the Uranium ores (2000 Ma). This is in contrast to mineralogical and field evidence indicating that Uranium mineralization occurred during diagenesis of the Francevillian sediments. These antithetical results give rise to several questions. Does the age obtained on the diagenetic clays date a late thermal event or does the age of the Uranium mineralization reflect a multistage U-Pb history. This work tries to bring answers with the help of new isotopic analysis and studies mineralogy of the gangue of reactors and isotopic compositions in Uranium ores. 8 refs., 4 figs.

84 (EUR–14877, pp. 67-70) **Natural analogues of bitumen matrices in a deep repository.** Petit, J.C. (CEA, 75 - Paris (France)); Landais, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Bitumens are used for the solidification of low-activity alpha-containing wastes and their long-term behaviour in geological conditions remain questionable. It is thus proposed in this work to gain some understanding on this issue by studying natural analogues of technological bitumens which have been poorly investigated, from this viewpoint, until now. In particular, we intend to characterize the organic matter associated with the Oklo nuclear reactors (Gabon) and to estimate the specific consequences of radiation damages, notably radiolytic effects, by comparison with organic matter collected outside the reaction zones and having variable uranium concentrations. The work will concentrate on two distinct aspects: firstly, the structural and chemical modifications induced by the radiation damages in the organic matter; secondly, the changes in the leaching behaviour of various elements (e.g. U, REE, etc.) possibly deriving from these radiation-induced alterations. The Oklo reactors are a priori favourable, as natural analogues, because of the long time scale involved, the association of bitumen and uraninite (UO_2), the presence of daughters of fission products and transuranium elements generated by the nuclear reactions which induced various radiation effects. (author).

85 (EUR–14877, pp. 71-80) **Hydrogeology of the Oklo-Okelobondo site.** Gurban, I. (Ecole Nationale Superieure des Mines, 75 - Paris (France)); Ledoux, E.; Blanc, P.L.; Escalier des Orres, P.; Bourguet, L. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

This study gives an account of all the hydrogeological data from the Oklo-Okelobondo site obtained so far. This hydrogeological overview has led to the proposal of a hydrodynamic flow pattern for the system and the choice of a study area as a basis for a preliminary modelling of groundwater flow and solute transport in the far field. (author). 5 refs., 4 figs.

86 (EUR–14877, pp. 81-99) **Far field hydrogeochemistry in the Oklo reactor area (Gabon).** Toulhoat, P. (CEA Centre d'Etudes de Cadarache, 13 - Saint-Paul-lez-Durance (France). Dept. Stockage Dechets); Gallien, J.P.; L'Henoret, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

In the frame of a general study of the Oklo natural reactor, which takes into account the natural analogue aspect, a complete hydrogeological and hydrogeochemical study is undertaken. The partners of this study are the following: - Section de geochimie, CEA (France): P. Toulhoat, J.P. Gallien, P. L'Henoret, V. Moulin (groundwater chemistry and colloids). - Ecole des Mines de Paris (CIG, Fontainebleau) E. Ledoux, I. Gurban (hydrogeology and modelling) - SKB and Conterra AB (Sweden) J.A.T. Smellie, A. Winberg (hydrogeology, isotope geochemistry). The aim of this study is to try to understand and to characterize the possible mobilization of elements or isotopes when groundwaters come in contact with nuclear reaction zones. The first step of the study is presented here, which comprises a general geochemical and hydrodynamical characterization of the site. In this presentation, the site of Bagombe is also mentioned as it has been confirmed as sector in which nuclear fission reactions occurred as in Oklo. (author). 10 refs., 6 figs., 6 tabs.

87 (EUR–14877, pp. 101-116) **Analysis of waters from the Oklo reactor area: preliminary results on the content of organic substances and colloids.** Moulin, V. (CEA Centre d'Etudes de Cadarache, 13 - Saint-Paul-lez-Durance (France). Dept. Stockage Dechets); Vilarem, J.P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The migration of radionuclides, in a nuclear waste disposal in geological formation, depends in part on the physico-chemical forms of the radioelements present in the natural aquifer. In particular, the presence of colloids (entities defined as dispersed particles with size of 1 nm-1 μm) may alter the speciation of radioelements and hence, change their behaviour. Their mobility may be enhanced or decreased by sorption or complexation reactions. These colloids may be inorganic particles (silicates, silico-aluminates, metallic hydroxides, etc) or organic particles (such as humic substances constituted by humic and fulvic acids). Moreover, these colloids may exist in different natural systems (e.g. surface, marine and groundwaters) often associated with humic substances. The evaluation of the importance of colloids in the dissemination of radioactivity necessitates, in particular, the determination of their concentration in the

waters sampled on the site, and their characterization (composition, size). In the framework of a general study of the Oklo natural reactor, a complete hydrogeochemical and hydrogeological study is undertaken. Preliminary studies on the colloid content of different water samples from the Oklo reactor area have been performed to complete the study of the groundwater chemistry presented by Toulhoat et al. (1991, 1992). These complementary studies have, as objectives, to evaluate: - the occurrence of colloids by scanning electron microscopy (after ultrafiltration) and by photon correlation spectroscopy, -the occurrence of organic materials by the analysis of the total organic carbon content. (author). 4 refs., 8 figs.

88 (EUR–14877, pp. 117-129) **A first attempt at modelling groundwater flow and mass transport in the far field.** Gurban, I. (Ecole Nationale Superieure des Mines, 75 - Paris (France)); Ledoux, E.; Raimbault, I.; Blanc, P.L.; Escalier des Orres, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

The purpose of this study is to identify and then to model the present transfer of groundwater which might set in motion elements produced in the reaction zone. Consequently, the first stage of this study consisted of a hydrochemical overview of the Oklo-Okelobondo site into which all previous and current information, gathered during missions in September 1990 and June 1991 was integrated. In the second stage of the study, a preliminary hydrodynamic model was built. In a plausible context and based on the collected data, the study area, the drainage of the domain and the aquifer layers were defined and a conceptual hydrogeological flow pattern proposed. The data made it possible to begin the hydrodynamic modelling of current migration basing it on a pattern of groundwater circulation and bearing in mind the morphology of the soil surface and of the geological strata and taking into account the first results of the hydrochemical analyses. (author). 7 refs., 1 tab.

89 (EUR–14877, pp. 131-141) **Swedish activities in the Oklo natural analogue project.** Smellie, J.A.T. (Conterra AB, Uppsala (Sweden)); Winberg, A.; Karlsson, F. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Presently, many countries are concerned about the need for a safe method to dispose of high-level nuclear wastes. The various national regulatory agencies involved generally require quantitative predictions for at least the first 10^4 years after disposal, and qualitative predictions of repository safety performance for up to 10^6 years. Predicting what this future behaviour will be can be considerably facilitated by comparison with the evolution of parallel natural geochemical systems, particularly those rich in radioelements. Such natural systems provide a unique opportunity to test, by observation and measurement, many of the geochemical processes that are expected to influence the predicted reliability of high-level radioactive waste containment deep in the bedrock for long periods of geological time, providing direct and indirect validation support for some of the models and data used in performance assessment. Oklo, by virtue of representing a fossil natural reactor which achieved criticality some 2 000 Ma ago, provides a unique opportunity to show whether the stable nuclear fission end-products have remained, in the near-vicinity of the reactor zone subsequent to fission. Furthermore, the materials found in the Oklo reactors resemble closely important waste forms such as spent nuclear fuel and bitumised residue and have been subject to extreme geochemical reactions and radiolysis when related to expected site disposal conditions, and for a much longer time. In order to study such effects, not only do the reactor zones require further detailed mineralogical, geochemical and radiochemical study, but equally the geological setting and hydrological environment of the reactor zones also need to be understood. For this reason SKB are interested to study the spatial distribution of the reactor zones at Oklo, Okelobondo and Bagombe in the context of the large-and small-scale groundwater hydraulics of the host sedimentary rocks. (author). 7 refs., 1 fig.

90 (EUR–14877, pp. 143-152) **Oklo stable isotopes.** Jakubick, A.T. (Ontario Hydro Research Lab., Toronto, ON (Canada)); O'Neill, J.A.; Gnoyke, R.; Thomas, G.F. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204265–: Migration of radionuclides in the geosphere meeting, Brussels (Belgium), 9-10 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

It is generally accepted that the fission reactions at Oklo resulted in convective circulation of the water heated up in the reactor zones. These convective currents were likely the main cause for the redistribution of some of the uranium of the reactor zones and most of the migration of the fission products possibly occurred at this stage. In order to derive generic conclusions applicable to the problems of nuclear waste disposal one has to identify the pattern of circulation of the convective currents and relate the observed distribution of elements around the reactor zones to the patterns left behind by the paleohydrogeological regime. The objective of this project is to discern and delineate the pathways of elemental migration by determining the deuterium and oxygen signature in the rocks confining the reactor zones. Furthermore the stable isotope analysis provides insights regarding water-rock interaction. In pursuit of this objective the Toronto team is concentrating on measurements of deuterium while F. Gauthier-Lafaye of Strasbourg is responsible for the analysis of the oxygen isotopes. In the final synthesis of the results beyond the main objective we intend to evaluate the differences in migration between the various members of the decay chains by means of a semi-analytical 3 dimensional model. (author). 8 refs., 1 fig., 1 tab., 2 appendices.

91 (EUR–14877, pp. 153-166) **X-ray photoelectron spectroscopic study of a sample from a natural fission reactor at Oklo, Gabon.** Sunder, S. (Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Nuclear Research Establishment); Sargent, F.P.; Miller, N.H. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

X-ray photoelectron spectroscopy (XPS) was used to study a sample from a natural fission reactor, reaction zone number 13, at Oklo (Gabon). Peaks due to uranium, oxygen, carbon, lead, silicon, calcium, aluminum, sulfur thorium

and bismuth were seen in the XPS spectra. High-resolution spectra were recorded for the U, Pb, O, and C bands to determine the chemical state of these elements. The oxidation state of uranium in the sample is predominantly U^{4+}, with a U^{6+}/U^{4+} ratio of about 0.11. Lead was in the +2 oxidation state. The carbon signal indicated the presence of organic carbon, while the oxygen bands indicated the presence of water. The significance of the results for nuclear fuel waste management is discussed. (author). 27 refs., 7 figs., 2 tabs.

92 (EUR–14877, pp. 167-175) **Geochemical behaviour of fissiogenic Rb, Sr, Cs and Ba in SF84 (zone 10).** Hidaka, H. (Tokyo Metropolitan Univ. (Japan)); Holliger, P. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

In order to estimate the geochemical behaviour of fission products in the Oklo reactor and to determine the various characteristics of the reactor, isotopic measurements of many elements (Rb, Sr, Zr, Mo, Ru, Pd, Ag, Cd, In, Sn, Te, Ba and REE) are being carried out with thermal ionization mass spectrometer. Our attention in this report is focused only on alkali and alkaline earth elements from SF84 (Zone 10) samples. Until now, some isotopic studies have been performed to search for fissiogenic Rb, Sr, Cs and Ba of Oklo samples, but with little success. The extremely low retentivity in the reactor and the presence of high abundances of natural elements make the isotopic compositions of Rb, Sr and Ba little anomalous. (author). 7 refs., 3 figs., 2 tabs.

93 (EUR–14877, pp. 177-188) **Heterogeneity and alteration of uraninite from the natural fission reactor 10 at Oklo, Gabon.** Ewing, R.C. (New Mexico Univ., Albuquerque, NM (United States). Dept. of Geology); Janeczek, J. Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

A mineralogical study of uranium ore from reactor zone 10 revealed that uraninite in the natural reactors at Oklo, Gabon, has been altered through partial dissolution, Pb loss, and replacement by coffinite, $USiO_4.nH_2O$. The dissolution occurred during formation of the clay mantle surrounding the ore body and was probably caused by hydrothermal saline solutions under reducing conditions. The loss of lead (up to 11 wt%) from uraninite occurred approximately one billion years after the operation of the reactors. As a result, there are two generations of uraninite in the reactor zone that differ in chemical composition and unit cell parameters [a_1 = 0.5495(2) and a_2 = 0.5455(2) nm]. Minor coffinitization of uraninite has also occurred. Thus, the Oklo deposit has been altered since the event of nuclear criticality. This provides several distinct geochemical environments in which one may analyze the corrosion of uraninite and the subsequent retention or migration of fission products. (author). 20 refs., 3 figs., 1 tab.

94 (EUR–14877, pp. 189-194) **Effects of organic matter on the containment of uranium and fissiogenic isotopes in the Oklo natural reactors.** Nagy, B. (Arizona Univ., Tucson, AZ (United States). Dept. of Geosciences). Commission of the European Communities, Luxembourg (Luxembourg). 1993. (CONF-9204280–: 2. Joint CEC-CEA Progress Meeting of the Oklo Working Group, Brussels (Belgium), 6-7 Apr 1992). In *Oklo working group meeting.* 199p. Order Number DE94612684. Source: OSTI; NTIS (US Sales Only); INIS.

Several of the Proterozoic natural fission reactors at Oklo in the Republic of Gabon contain abundant organic matter. Organic petrography including reflectance measurements, Rock-Eval pyrolysis, microfocused-laser Raman spectrometry, pyrolysis-gas chromatography-organic mass spectrometry, pyrolysis-high resolution organic mass spectrometry, ion microprobe and thermal ionization isotope mass spectrometry, backscattered scanning electron microscopy and electron microprobe analyses were used to characterize the organic matter and its associated minerals in and in the vicinity of the organic-rich reactors 7-9. Non-uraniferous organic samples distant from the reactors were also examined by most of these analytical techniques. There are two types of organic matter in the natural reactors and in the distant sedimentary rocks: solid bitumen and kerogen. Both of these organic substances consist of a condensed aromatic hydrocarbon macromolecular matrix which contains dispersed fine-grain size, cryptocrystalline graphite. Liquid bitumen was generated during criticality through reaction mechanisms involving water at elevated temperatures. Later the liquid bitumen became a solid. The liquid bitumen helped to reduce U(VI) to U(IV) from aqueous solutions, resulting in the precipitation of uraninite which incorporated fissiogenic isotopes. These uraninite crystals were coated and enclosed in bitumen, which held them immobile after its solidification. This mechanism prevented ^{235}U and fission product losses for long periods of time. Organic matter in the natural reactors and uranium ores have a less tightly bound macromolecular matrix than organics in the non-uraniferous and distant sedimentary rocks, but the looser molecular matrix did not hinder ^{235}U and fission product retention. (author). 19 refs., 2 tabs.

95 (IAEA-TECDOC–732, pp. 119-128) **United States high-level radioactive waste management program: Current status and plans.** Williams, J. (Department of Energy, Washington, DC (United States). Office of Civilian Radioactive Waste Management). International Atomic Energy Agency, Vienna (Austria). Feb 1994. (CONF-9308225–: Regular advisory group meeting on spent fuel management: Current status and prospects, Vienna (Austria), 31 Aug - 3 sep 1993). In *Spent fuel management: Current status and prospects 1993: Proceedings of a regular advisory group meeting held in Vienna, 31 August-3 September 1993.* 131p. Order Number DE94623709. Source: OSTI; NTIS (US Sales Only); INIS.

Over 20% of the electricity generated in the United States is produced by 108 commercial nuclear reactors. U.S. commercial nuclear utilities are currently storing spent nuclear fuel at the reactor sites. Spent fuel is stored in fuel pools at 70 sites around the country, in addition to several utility at-reactor dry storage installations. To date, the total quantity of spent fuel accumulated at reactor sites is approximately 24,000 metric tons of heavy metal (MTHM). According to current projections, by the time the last license for the current generation of nuclear reactors expires, the estimated total quantity of spent fuel requiring disposal will reach about 86,000 MTHM. We have been conducting a program directed at developing a waste-management system consisting of a geologic repository, with a projected start date of 2010; a monitored retrievable storage facility (MRS); and a

transportation system to support storage and disposal operations. Until the Federal system starts to accept spent fuel for storage and disposal, commercial utilities are responsible for managing their spent fuel. To facilitate spent-fuel management at reactor sites and in the Federal system, we are evaluating the development and use of multipurpose canisters. These metal canisters would be used with appropriate overpacks for (1) storage, at reactor sites or at a Federal facility; (2) transportation; and (3) permanent disposal. Our repository program remains focused on the scientific investigations needed to determine whether the candidate site (Yucca Mountain in Nevada) is suitable. For the MRS, we remain optimistic that a volunteer site will be found through the efforts of the Nuclear Waste Negotiator. With a conceptual design completed, we are deferring major new MRS activities until a site has been identified. Our transportation strategy is directed at being able to transport spent fuel as soon as a storage facility is ready to accept it. (author).

96 (INIS-mf–13846, pp. 2.51-2.61) **Nuclear waste disposal and the environment.** Torgerson, D.F. (Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Nuclear Research Establishment); Soonawala, N.M. Canadian Nuclear Association, Toronto, ON (Canada). 1990. 245p. (CONF-900621–: 30. annual conference of the Canadian Nuclear Association and the 11th annual conference of the Canadian Nuclear Society, Toronto (Canada), 3-7 Jun 1990). In *Proceedings of the 30. Annual Conference of the Canadian Nuclear Association.* Order Number DE94622203. Source: OSTI; NTIS (US Sales Only); INIS.

The Canadian Nuclear Fuel Waste Management Program, under which research has been carried out for more than a decade, is assessing the concept of deep geological disposal of nuclear fuel waste. The quantity of used fuel produced after a century of nuclear power production will be comparable to the uranium content of a large uranium ore body. The research has assessed engineered and natural systems for containing and retarding radionuclides that may be released from the vault. The geology of Precambrian rocks has been studied in detail. Extensive hydrogeological research has been carried out to study the flow and chemistry of groundwater up to a kilometer below the surface. Studies have been carried out on the behaviour of radionuclides in the surface waters, soils, the atmosphere, and the food chain. Mathematical modelling is being carried out to assess the environmental impact and safety of the disposal system. Studies of natural analogs, such as the uranium ore body at Cigar Lake have provided information on important processes over very long times. These results will be submitted for review under the federal Environmental Assessment and Review Process. Acceptance and implementation of the concept for nuclear fuel waste disposal would demonstrate final closure of the nuclear fuel cycle. 15 refs.

97 (INIS-mf–13849, pp. 113-135) **Design considerations at the Cigar Lake project.** Peebles, G.A. (Cigar Lake Mining Corporation, Cigar Lake, Saskatchewan (Canada)). Canadian Nuclear Association, Toronto, ON (Canada). 1988. 413p. (CONF-880662–: 28. annual conference of the Canadian Nuclear Association and the 9. annual conference of the Canadian Nuclear Society, Winnipeg (Canada), 12-15 Jun 1988). In *Proceedings of the Canadian Nuclear Association 28. annual conference.* Order Number DE94622204. Source: OSTI; NTIS (US Sales Only); INIS.

The Cigar lake uranium deposit in northern Saskatchewan is the largest high grade uranium deposit in the world with a total reserve of 385 million pounds U_3O_8. The main section of the deposit has a total geological reserve of 285 million pounds at an average grade of 14% U_3O_8. This paper describes the geological characteristics of the deposit and the development of the test mining program.

98 (JAB–10733-TM12) **Processed seismic motion records from earthquakes (1982–1993): Recorded at Scotty's Castle, California.** Lum, P.K.; Honda, K.K. URS/John A. Blume and Associates, Engineers, San Francisco, CA (United States). Oct 1993. 311p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC08-89NV10733. Order Number DE94001371. Source: OSTI; NTIS; GPO Dep.

As part of the contract with the US Department of Energy, Nevada Operations Office (DOE/NV), URS/John A. Blume & Associates, Engineers (URS/Blume) maintained a network of seismographs to monitor the ground motion generated by the underground nuclear explosions (UNEs) at the Nevada Test Site (NTS). The seismographs were located in the communities surrounding the NTS and the Las Vegas valley. When these seismographs were not used for monitoring the UNE generated motions, a limited number of seismographs were maintained for monitoring motion generated by other than UNEs (e.g. motion generated by earthquakes, wind, blast). Scotty's Castle was one of the selected earthquake monitoring station. During the period from 1982 through 1993, numerous earthquakes with varied in magnitudes and distances were recorded at Scotty's Castle. The records from 24 earthquakes were processed and included in this report. Tables 1 and 2 lists the processed earthquakes in chronological order and in the order of epicentral distances, respectively. Figure 1 shows these epicenters and magnitudes. Due to the potential benefit of these data for the scientific community, DOE/NV and the National Park Service authorize the release of these records.

99 (LA-UR–93-4253) **Radionuclide releases from natural analogues of spent nuclear fuel.** Curtis, D.B. (Los Alamos National Lab., NM (United States)); Fabryka-Martin, J.; Dixon, P.; Aguilar, R.; Rokop, D.; Cramer, J. Los Alamos National Lab., NM (United States). [1993]. 12p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-931201–6: 4. international conference on chemistry and migration behavior of actinides and fission products in the geosphere, Charleston, SC (United States), 12-17 Dec 1993). Order Number DE94004989. Source: OSTI; INIS; NTIS; GPO Dep.

Measures of ^{99}Tc, ^{129}I, ^{239}Pu and U concentrations in rock samples from uranium deposits at Cigar Lake and Koongarra have been used to study processes of radionuclide release from uranium minerals. Rates of release have been immeasurably slow at Cigar Lake. At Koongarra release rates appear to have been faster, producing small deficiencies of ^{99}Tc, and larger ones of ^{129}I. The inferred differences in radionuclide release rates are consistent with expected differences in uranium mineral degradation rates produced by the differing hydrogeochemical environments at the two sites.

100 (LBL–30043, pp. 19-32) **Geoscience technical support for nuclear waste geologic repositories.** Mangold, D.C.; Tsang, C.F. Lawrence Berkeley Lab., CA (United States). Dec 1990. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

The Geoscience Technical Support activities in the Geologic Repository Project (GRP) at LBL covered a range of reports and reviews in FY89, particularly reviews of Study Plans of the Yucca Mountain site and their associated Comment Resolution Workshops. LBL sought to be responsive and active in meeting DOE's need for geoscience technical support for nuclear waste repositories. In addition, in consultation with DOE/HQ, the authors investigated and presented DOE with well-considered scientific inputs to program directions and new areas of needed work. This included the development of a white paper and proposed work plan on preclosure monitoring and performance confirmation that grew out of a request made by DOE to LBL to consider such studies for a repository in the unsaturated zone. This year also saw the beginning of a quality assurance program for GRP.

101 (LBL–30043, pp. 33-41) **Radionuclides in hydrothermal systems as indicators of repository conditions.** Wollenberg, H.A.; Flexser, S.; Smith, A.R. Lawrence Berkeley Lab., CA (United States). Dec 1990. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

Hydrothermal systems in tuffaceous and older sedimentary rocks contain evidence of the interaction of radionuclides in fluids with rock matrix minerals and with materials lining fractures, in settings somewhat analogous to the candidate repository site at Yucca Mountain, NV. Earlier studies encompassed the occurrences of U and Th in a "fossil" hydrothermal system in tuffaceous rock of the San Juan Mountains Volcanic Field, CO. More recent and ongoing studies examine active hydrothermal systems in calderas at Long Valley, CA and Valles, NM. At the Nevada Test Site, occurrences of U and Th in fractured and unfractured rhyolitic tuff that was heated to simulate the introduction of radioactive waste are also under investigation. Observations to date suggest that U is mobile in hydrothermal systems, but that localized reducing environments provided by Fe-rich minerals and/or carbonaceous materials concentrate U and thus attenuate its migration.

102 (LBL–30043, pp. 100-113) **Mass transport with chemical reactions in a varying thermal field.** Carnahan, C.L. Lawrence Berkeley Lab., CA (United States). Dec 1990. DOE Contract AC03-76SF00098. In *Geotechnical support and topical studies for nuclear waste geologic repositories: Annual report, fiscal year 1989.* 186p. Order Number DE94003377. Source: OSTI; NTIS; INIS.

The work described here is part of a task to theoretically and numerically analyze effects of varying thermal fields on transport of radionuclides and ground water components in fracture filling materials in the near field at Yucca Mountain, and to numerically estimate the sensitivity of the effects to magnitudes of controlling parameters. A computer program, THCVP, simulates coupling between advective/diffusive solute transport and chemical reactions, coupling of the reactions to heat transport, and feedback from precipitation/dissolution reactions to fluid flow. A simple simulation of transport of dissolved silicic acid along a gradient of temperature shows how precipitation of quartz at low temperatures can drastically reduce advective transport of all solution components including trace contaminants.

103 (PB–94-113636/XAB) **Underground exploration and testing at Yucca Mountain: A report to Congress and the Secretary of Energy.** Nuclear Waste Technical Review Board, Arlington, VA (United States). Oct 1993. 38p. Source: NTIS Prices: PC A03/MF A01; INIS.

Also available from Supt. of Docs. See also DE88009788.

Underground exploration and testing are major components of the DOE's site-characterization efforts at Yucca Mountain, Nevada. During the past four years, the DOE's plans for exploration and testing in an underground facility have evolved substantially, and many improvements have been made. The report reviews the status of the DOE's underground exploration and testing project at Yucca Mountain, Nevada; it suggests strategies to improve both the exploration and testing program and the approach to designing and excavating the exploratory facility. The Board makes several recommendations it believes will speed progress and improve cost-effectiveness. The Board believes the changes it is recommending can and should be made without slowing the momentum of important site-characterization activities currently under way at Yucca Mountain.

104 (PB–94-116886/XAB) **NWTRB special report to congress and the Secretary of Energy.** Nuclear Waste Technical Review Board, Washington, DC (United States). Mar 1993. 28p. Source: NTIS Prices: PC A03/MF A01; INIS.

The Nuclear Waste Technical Review Board (the Board) was created by Congress in 1987 to review the scientific and technical validity of the Department of Energy's (DOE) civilian radioactive waste management program. The goal of the DOE's program is to design and develop a system to manage and safely dispose of the spent nuclear fuel being produced at the nation's 108 commercial nuclear power plants along with some high-level reprocessing wastes from defense-related activities. During its review of the program, the Board has witnessed considerable progress, especially in site characterization and data collection at Yucca Mountain, and, given existing data, this NWTRB Special Report to Congress and the Secretary of Energy briefly outlines three of the Board's major concerns: (1) the program's unrealistic deadlines, (2) the need for an integrated overall waste management plan, and (3) the effectiveness of program management. The Board believes that these concerns should be addressed immediately, concurrent with ongoing site-characterization work, to ensure that the program has a strong technical and scientific base and to facilitate program progress.

105 (PNL–8659) **AREST model description.** Engel, D.W.; McGrail, B.P. Pacific Northwest Lab., Richland, WA (United States). Nov 1993. 87p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94004566. Source: OSTI; NTIS; INIS; GPO Dep.

The Office of Civilian Radioactive Waste Management and the Power Reactor and Nuclear Fuel Development Corporation of Japan (PNC) have supported the development of the Analytical Repository Source-Term (AREST) at Pacific Northwest Laboratory. AREST is a computer model developed to evaluate radionuclide release from an underground geologic repository. The AREST code can be used to calculate/estimate the amount and rate of each radionuclide that is released from the engineered barrier system (EBS) of the repository. The EBS is the man-made or disrupted area of the repository. AREST was designed as a system-level models to simulate the behavior of the total repository by combining process-level models for the release from an individual waste package or container. AREST contains primarily analytical models for calculating the release/transport

of radionuclides to the lost rock that surrounds each waste package. Analytical models were used because of the small computational overhead that allows all the input parameters to be derived from a statistical distribution. Recently, a one-dimensional numerical model was also incorporated into AREST, to allow for more detailed modeling of the transport process with arbitrary length decay chains. The next step in modeling the EBS, is to develop a model that couples the probabilistic capabilities of AREST with a more detailed process model. This model will need to look at the reactive coupling of the processes that are involved with the release process. Such coupling would include: (1) the dissolution of the waste form, (2) the geochemical modeling of the groundwater, (3) the corrosion of the container overpacking, and (4) the backfill material, just to name a few. Several of these coupled processes are already incorporated in the current version of AREST.

106 (PNL–8853) **Software requirements specification document for the AREST code development.** Engel, D.W. (Pacific Northwest Lab., Richland, WA (United States)); McGrail, B.P.; Whitney, P.D.; Gray, W.J.; Williford, R.E.; White, M.D.; Eslinger, P.W.; Altenhofen, M.K. Pacific Northwest Lab., Richland, WA (United States). Nov 1993. 54p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. Order Number DE94004586. Source: OSTI; NTIS; INIS; GPO Dep.

The Analysis of the Repository Source Term (AREST) computer code was selected in 1992 by the U.S. Department of Energy. The AREST code will be used to analyze the performance of an underground high level nuclear waste repository. The AREST code is being modified by the Pacific Northwest Laboratory (PNL) in order to evaluate the engineered barrier and waste package designs, model regulatory compliance, analyze sensitivities, and support total systems performance assessment modeling. The current version of the AREST code was developed to be a very useful tool for analyzing model uncertainties and sensitivities to input parameters. The code has also been used successfully in supplying source-terms that were used in a total systems performance assessment. The current version, however, has been found to be inadequate for the comparison and selection of a design for the waste package. This is due to the assumptions and simplifications made in the selection of the process and system models. Thus, the new version of the AREST code will be designed to focus on the details of the individual processes and implementation of more realistic models. This document describes the requirements of the new models that will be implemented. Included in this document is a section describing the near-field environmental conditions for this waste package modeling, description of the new process models that will be implemented, and a description of the computer requirements for the new version of the AREST code.

107 (SAND–92-0984) **Measuring the dynamic compression and release behavior of rocks and grouts associated with HYDROPLUS.** Furnish, M.D. Sandia National Labs., Albuquerque, NM (United States). Oct 1993. 162p. Sponsored by USDOE, Washington, DC (United States);Department of Defense, Washington, DC (United States). DOE Contract AC04-94AL85000. Order Number DE94003312. Source: OSTI; NTIS; GPO Dep.

Gas-gun impact tests were performed on twelve rocks and rock simulants pertinent to the HYDROPLUS nuclear yield measurement program: A variety of tuffs, rhyolites, carbonates, grouts, an epoxy-alumina mixture and quartzite permafrost samples recovered in an apparently preserved frozen state from northern Canada. The present report presents results for all of these materials except for the carbonates. Two classes of impact techniques were employed for measuring equation-of-state properties for these materials. Both use velocity interferometry diagnostics. One, employing a sample-in-projectile geometry, provides high-precision Hugoniot data and continuous release trajectories for dry or water-saturated materials. The majority of the experiments were performed with this geometry. The other, employing a sample-in-target geometry, provides loading path and Hugoniot data as well as limited release data. Uncertainties in the results have been estimated by analyzing the effects of errors in observables and ancillary material properties.

108 (SAND–93-2240C) **Using performance assessment for radioactive waste disposal decision making – implementation of the methodology into the third performance assessment iteration of the Greater Confinement Disposal site.** Gallegos, D.P. (Sandia National Labs., Albuquerque, NM (United States)); Conrad, S.H.; Baer, T.A. Sandia National Labs., Albuquerque, NM (United States). [1993]. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC04-76DP00789. (CONF-940553–8: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94006583. Source: OSTI; NTIS; INIS; GPO Dep.

The US Department of Energy is responsible for the disposal of a variety of radioactive wastes. Some of these wastes are prohibited from shallow land burial and also do not meet the waste acceptance criteria for proposed waste repositories at the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain. These have been termed "special-case" waste and require an alternative disposal method. From 1984 to 1989, the Department of Energy disposed of a small quantity of special-case transuranic wastes at the Greater Confinement Disposal (GCD) site at the Nevada Test Site. In this paper, an iterative performance assessment is demonstrated as a useful decision making tool in the overall compliance assessment process for waste disposal. The GCD site has been used as the real-site implementation and test of the performance assessment approach. Through the first two performance assessment iterations for the GCD site, and the transition into the third, we demonstrate how the performance assessment methodology uses probabilistic risk concepts to guide affective decisions about site characterization activities and how it can be used as a powerful tool in bringing compliance decisions to closure.

109 (SKB-TR–93-17) **Oxidation of uraninite.** Janeczek, J. (Univ. of New Mexico, Albuquerque, NM (United States). Dept. of Earth and Planetary Science); Ewing, R.C. Swedish Nuclear Fuel and Waste Management Co., Stockholm (Sweden). Jun 1993. 30p. Order Number DE94620288. Source: OSTI; NTIS; INIS.

Samples of uraninite and pitchblende annealed at 1200 degrees C in H_2, and untreated pitchblende were sequentially oxidized in air at 180-190 degrees C, 230 degrees C, and 300 degrees C. Uraninite and untreated pitchblende oxidized to the U_4O_9-type oxide, and their x-ray symmetry remained isometric up to 300 degrees C. Reduced pitchblende, after oxidation to UO_{2+x} and U_4O_9-type oxides, transformed into α-U_3O_8 at 300 degrees C. Two major mechanisms control uraninite and untreated pitchblende stability during oxidation: 1. Th and/or lanthanide elements

maintain charge balance and block oxygen interstitials near impurity cations; 2. the uraninite structure saturates with respect to excess and radiation-induced oxygen interstitials. Untreated pitchblende during oxidation behaved similarly to irradiated UO_2 in spent nuclear fuel; whereas, reduced pitchblende resembled non-irradiated UO_2. An analysis of the data in the literature, as well as our own efforts (XRD, EMPA, SEM, AEM) to identify U_3O_7 in samples form Cigar Lake, Canada, failed to provide conclusive evidence of the natural occurrence of tetragonal αU_3O_7. Most probably, reported occurrences of U_3O_7 are mixtures of isometric uraninites of slightly different compositions, 45 refs.

110 (SKB-TR–93-21) **Development of 'CHEMFRONTS' a coupled transport and geochemical program to handle reaction fronts.** Baeverman, C. (Royal Inst. of Tech., Stockholm (Sweden). Dept. of Chemical Engineering). Swedish Nuclear Fuel and Waste Management Co., Stockholm (Sweden). Oct 1993. 254p. Order Number DE94621512. Source: OSTI; NTIS; INIS.

A computer program to calculate coupled mass transport and fluid rock interactions has been developed. The program, CHEMFRONTS, is based on the quasi-stationary state approximation and uses a kinetic expression for the mineral dissolution and precipitation coupled to a transport model. It is adapted to handle sharp reaction fronts. Such fronts evolve in the ground and typical examples are redox fronts and dissolution and precipitation fronts. CHEMFRONTS calculates the chemical reactions for one-dimensional advective flow through a porous medium. Reactions between the water and the solid phase such as dissolution and precipitation are included in the model. In the water phase, complexation and redox reactions are also computed. To verify the program, comparisons have been made with results obtained with other computer programs, CHEQMATE, PHASEQL/FLOW, and DYNAMIX. Natural analogues, such as Pocos de Caldas and Cigar Lake, are also studied. The results from the simulations and comparisons are encouraging. 37 refs.

111 (UCRL-ID–116122) **Preliminary on the isotope hydrology investigations at the Nevada test site: Hydrologic resources management program: FY 1992–1993.** Davisson, M.L.; Kenneally, J.M.; Smith, D.K.; Hudson, G.B.; Nimz, G.J.; Rego, J.H. Lawrence Livermore National Lab., CA (United States). Jan 1994. 83p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. Order Number DE94011538. Source: OSTI; NTIS; GPO Dep.

A comprehensive isotope data base of the NTS groundwaters collected during FY 92-93 is presented with preliminary interpretations. Multiple samples were collected from over 30 sites on pumped wells and open-holes by wireline bailing. Field water level measurements indicate essentially a bimodal distribution separated by water levels at higher elevations (e.g. Pahute Mesa) from water levels of lower elevations (e.g. Yucca and Frenchman Flats). Down hole temperature measurements have confirmed anomalous temperature gradients in the eastern Yucca Flat area and on Pahute Mesa, where horizontal temperature gradients up to 0.33°F/100ft are found. Consistent with previous reports by others, the major ion geochemistry of the NTS groundwater are dominated by Na-K-HCO_3 and Ca-Mg-HCO_3 water types, where the Na-rich water appears to be related to dissolution in the volcanic tuffs and the Ca-rich water to the Paleozoic carbonates. Increases in dissolved Si also seems to be indicative of groundwater that resides in the volcanic tuffs. Processes controlling the Na/Ca ratios are complex and may include ion exchange reactions with clays, evaporative concentration in the vadose zone, and lithological heterogeneities in addition to simple differential dissolution between the volcanic tuffs and the Paleozoic carbonates. Apparent ^{14}C ages range between 4000 and 38,000 years for groundwaters at the NTS. The uncertainty is large for exact age determinations at this time. The ^{14}C abundance decreases with increased dissolved HCO_3, and ^{13}C suggests dissolution of the "dead" Paleozoic carbonates significantly influence the ages, but more work is needed to investigate the influence of vadose zone carbonate.

112 (UCRL-JC–114686) **Technical changes that would contribute to success in the civilian radioactive waste management program.** Ramspott, L.D. Lawrence Livermore National Lab., CA (United States). 1 Oct 1993. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9309295–3: Nuclear as a large-scale global option conference, Oak Ridge, TN (United States), 28-30 Sep 1993). Order Number DE94007381. Source: OSTI; NTIS; INIS; GPO Dep.

Many changes have taken place since the SCP safety strategy was formulated; it needs to be revised or replaced. Four concepts would aid in the shift from a rigid, ecelctic, schedule-driven, all-or-nothing program to an incremental, evolving, and experimental but integrated program. These are a simple safety case, reversability, demonstrability, and decoupling operations of a repository from operation of reactors. A simple safety case based on containment can be made for a repository at Yucca Mountain. This containment strategy is based on the dryness of openings at Yucca Mountain, Extended Dry heat management, and long-lived containers. Reversibility is technically believable at Yucca Mountain because of extended retrievability and drift emplacement, if an MRS were co-located with the repository. Because the rock is unsaturated, extended retrievability is technically feasible at Yucca Mountain. Demonstrability could be improved at Yucca Mountain by planning for incremental progression toward operation and closure of a repository, possibly including a shift to underground retrievable storage. Demonstrability can also be improved by using natural analogs. Repository operation can be decoupled from reactor operation by use of an unconstrained MRS facility or at-reactor dry storage and multipurpose storage canister/casks.

113 (UCRL-JC–115255) **Seismic design and analysis considerations for high level nuclear waste repositories.** Hossain, Q.A. Lawrence Livermore National Lab., CA (United States). 30 Sep 1993. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9310102–42: 4. energy natural phenomena hazards mitigation conference, Atlanta, GA (United States), 19-22 Oct 1993). Order Number DE94005817. Source: OSTI; NTIS; INIS; GPO Dep.

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.

114 (UCRL-JC–116349) **A performance goal-based seismic design philosophy for waste repository facilities.** Hossain, Q.A. Lawrence Livermore National Lab., CA (United States). Feb 1994. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-940553–23: International high-level radioactive waste management conference, Las Vegas, NV (United States), 22-26 May 1994). Order Number DE94009105. Source: OSTI; NTIS; INIS; GPO Dep.

A performance goal-based seismic design philosophy, compatible with DOE's present natural phenomena hazards mitigation and "graded approach" philosophy, has been proposed for high level nuclear waste repository facilities. The rationale, evolution, and the desirable features of this method have been described. Why and how the method should and can be applied to the design of a repository facility are also discussed.

115 **High level radioactive waste management: Proceedings: Volume 2.** 748p. American Nuclear Society, La Grange Park, IL (United States) (1990). Sponsored by USDOE, Washington, DC (United States). (CONF-900406–: 1. international topical meeting on high-level radioactive waste management, Las Vegas, NV (United States), 8-12 Apr 1990).

The technical program for this meeting is designed to meet two major objectives: provide forums for major technical disciplines to (a) discuss current technical issues related to the full spectrum of international high level radioactive waste management activities, and (b) discuss the general contributions that they make to society and the approaches they use in defining and addressing issues related to high level radioactive waste management. The program includes disciplines related to social, institutional, and regulatory technologies for which data must be collected and evaluated in order to reach conclusions or to make decisions. Full papers are produced here so that appropriate, quality data and results are fully described. Topics covered include: natural systems, exploratory shaft design, intraplate seismotectonics and volcanology, transport processes, regulations, public involvement, intergovernmental issues, transportation operations and routing, total system performance, waste packages, cask system design, social issues, hydrology, site characterization, geochemistry, engineered barriers, systems modeling, system engineering, cask materials, waste producers, Yucca Mountain hydrology, rock mass characterization and testing, vitrification, environmental and health effects, climatology, waste management facilities, and spent fuel materials performance. Individual papers are indexed separately.

116 **The nuclear negociator and public acceptance: the United States experience.** Leroy, D.H. pp. 14-21 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608–: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

In 1987, the United States Congress created the Office of the Nuclear Waste Negotiator. The task of the Office was to seek volunteer host locations for either a temporary storage facility or a permanent repository for spent fuel from the Nation's 110 commercial nuclear reactors. This paper details the organization, operating principles, history and significant findings of the Office since its commencement of activities in September of 1990.

117 **The USA approach to address the issue of the safety of final waste repository.** Bernero, R.M. pp. 103-113 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608–: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

In the United States, the approach to address the issue of safety for high-level nuclear waste repositories is not a simple approach. It involves three agencies of the Federal Government (Department of Energy) (DOE), Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) which have assumed responsibilities for the safe disposal of high-level radioactive wastes. DOE has received through a number of actions including legislation such Nuclear Waste Policy Act of 1982 and the Low-Level Radioactive Waste Policy Amendments Act of 1985, the responsibility for constructing and operating a high-level radioactive wastes repository. NRC is responsible for licensing and regulating the receipt and possession of high-level radioactive wastes. Its requirements governing the disposal of high-level radioactive wastes in a geologic repository are contained in 10 CFR Part 60 and cover pre-licensing activities, construction authorization, receipt and possession of spent fuel or high-level radioactive wastes. With respect to EPA, its responsibilities are to establish generally applicable standards governing releases of radioactivity. These regulations are found in 40 CFR Part 191 and set the environmental standards for the management and disposal of transuranic and high-level radioactive wastes.

118 **United States high-level radioactive waste repository program.** Barrett, L.H. (USDOE, Washington, DC (United States)). pp. 199-207 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608–: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

Ten years have now passed since the United States established a national policy and process for developing a waste management system for spent nuclear fuel and high-level radioactive waste. Of those ten years, the last two years have marked the greatest progress in studying a site for development of a geologic repository. This paper will discuss the United States program underway for developing the waste management system, with particular emphasis on our recent progress at Yucca Mountain, Nevada – the site designated by the United States Congress for detailed site characterization to determine whether or not it is suitable for development of a repository.

119 **Technical and political aspects for site characterization, evaluation and acceptance.** Kuehn, K. (Gesellschaft fuer Strahlen- und Umweltforschung mbH Muenchen, Braunschweig (Germany). Inst. fuer Tieflagerung). pp. 299-311 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608–: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

All countries which use nuclear energy - have to solve the problem how and where to dispose of the radioactive

wastes which are generated by application of nuclear energy. Within these radioactive wastes we can differentiate three categories with regard to their disposal: Irradiated fuel elements if they are declared waste. This is the case in the United States, in Canada, Spain, Sweden, and Finland. Some strong trends into this direction can also be observed in Germany. High-level heat-generating wastes which are generated by vitrification - of liquid wastes produced by reprocessing irradiated fuel. This is true for France, United Kingdom, Japan, Germany, Switzerland, Belgium and the Netherlands. But this is also true for those five countries which possess and/or produce nuclear weapons, namely the United States, the former USSR, China, France, and United Kingdom. Low- and intermediate-level radioactive wastes which are mainly produced by operating nuclear power and reprocessing plants but also by other nuclear fuel cycle facilities and through application of radionuclides in industry, medicine and research. Most countries have decided to dispose of these wastes by shallow land burial, like the United States, Canada, Japan, France, and United Kingdom. Some other countries, like Germany, Sweden, Finland, and Switzerland, will dispose of these wastes in underground repositories too. Because of the difficult problem of public acceptance, site selection for a radioactive waste repository is not a pure technical and scientific task. On the contrary, it is mainly a political one. Two examples where possible sites were selected more because of political than of technical reasons are Yucca Mountain in the United States and Gorleben in Germany. There do exist, however, also approaches to select a site on technical and scientific grounds like in Canada, France, or Sweden.

120 Site characterizations and evaluations U.S. policies and approaches for public interactions. Saltzman, J. (USDOE, Washington, DC (United States)). pp. 336-343 of Safe Management and disposal of nuclear waste. Volume 1. Societe Francaise d'Energie Nucleaire, Paris (France) (1993). pp. 448 (CONF-930608--: Safewaste '93: the final disposal of nuclear waste, Avignon (France), 13-18 Jun 1993).

The Nuclear Waste Policy Act of 1982 (NWPA) established the Office of Civilian Radioactive Waste Management within the U.S. DOE to develop a waste disposal system for spent nuclear fuel from civilian nuclear power plants and high-level radioactive waste from the Nation's defense programs. The Act authorizes construction of one geologic repository in which the waste would be permanently isolated and specifies the process for evaluating and siting a repository. In 1987, the Act was amended to instruct DOE to focus all site characterization efforts on Yucca Mountain, Nevada, in order to determine whether or not it is suitable for the development of the Nation's first geologic repository. If site characterization indicates that the Yucca Mountain site is suitable for a repository, DOE will recommend it to the President for construction of a repository. If the President approves, the recommendation will be submitted to Congress. To ensure the complete coverage of all aspects of the program, a set of strategic principles was established to guide through decisions and actions. The first step in developing these principles was the identification of critical issues. Many of the issues identified recognized the importance of full participation in the program by all affected and interested parties. Next meetings were held with external parties to obtain their views on the strategic principles and the future of the program. The input received from the participants of these workshops contributed substantially to the final strategic principles. Some of these relevant strategic principles include: consider public trust and confidence in program decisions; provide for the involvement of affected governments, interested parties, and the public in decision making; work cooperatively with affected governments and interested parties; share information and data; provide for outside review; and evaluate socioeconomic issues in cooperation with affected governments.

121 Photoacoustic absorption spectroscopy on plutonium(IV) in varying bicarbonate concentrations. Ekberg, S.A. (Los Alamos National Laboratory, NM (United States)); Tait, C.D.; Morris, D.E.; Palmer, P.D. pp. 452, Paper TECH 24 of 205th ACS national meeting. American Chemical Society, Washington, DC (United States) (1993). pp. 1951 (CONF-930304--: 205. American Chemical Society national meeting, Denver, CO (United States), 28 Mar - 2 apr 1993).

This talk will begin with a brief discussion of what photoacoustic Absorption Spectroscopy (PAS) is, and what YMP means. To understand the solubility and speciation studies of potential contaminants must be understood. With this in mind, PAC experiments have been performed on samples with a constant Pu(IV) concentration of 250 nM in varying $NaHCO_3$ concentrations from 1.0M to 0.003M. This work was supported by the Yucca Mountain Site Characterization Project Office as part of the Civilian Radioactive Waste Management Program managed by the U.S. Department of Energy, Yucca Mountain Site Characterization Project Office.

122 State of solutions to high level nuclear waste management. Tang, Y.S. (Tang (Y.S.), Bethel Park, PA (United States)). pp. 2.175-2.179 of Proceedings of the 28th intersociety energy conversion engineering conference. Volume 2--Environmental impact, energy systems, new technology for energy utilization, policy issues, renewable energy sources, stirling cycles. American Chemical Society, Washington, DC (United States) (1993). pp. 1005 (CONF-930804--: 28. intersociety energy conversion engineering conference, Atlanta, GA (United States), 8-13 Aug 1993).

This paper summarizes the current status of the solution to High Level Waste (HLW) management in the US. It addresses all aspects of handling and disposal of HLW from reactor pool storage to final permanent disposal. Each problem area is discussed under the headings of issues, recommended solutions, and current status. Among the issues discussed, the public acceptance and siting obviously are the overriding issues to be solved. After much delay, the site characterization work at the Yucca Mountain potential site are now in progress.

123 Environmental monitoring for uranium and neptunium at Yucca Mountain using epithermal neutron activation analysis. Riggle, K.J. Missouri Univ., Columbia, MO (United States). 1992. 109p. Source: University Microfilms, P.O. Box 1764, Ann Arbor, MI 48106 (United States). Order No. 93-07,452.

Epithermal Neutron Activation Analysis (ENAA) is investigated as an analysis method for uranium and neptunium in environmental samples from Yucca Mountain. The design and construction of a facility for this technique are described. Theoretical improvement in sensitivity for ENAA over thermal NAA (TNAA) is discussed and compared to experimental results for different sample types. Uranium is analyzed in eight different sample matrices, including samples from Yucca Mountain. Neptunium has been studied only in AGV-1 Granite. As predicted by theory, uranium

shows a high experimental sensitivity improvement factor (average = 7.76), while neptunium has a factor of only 0.49. Detection limits for uranium using ENAA range from 6 to 52 ppb by weight (2.6 to 17 ng in sample) for the different matrices. Neptunium shows a detection limit of 57 ppb by weight (6.2 ng in sample) in AGV-1 Granite using ENAA. Using TNAA, neptunium can be analyzed to 35 ppb by weight (3.4 ng in sample).

124 Gabon's natural reactors: nature shows how to contain radioactive waste. Nagy, B. (Arizona Univ., Tucson, AZ (United States). Lab. of Organic Geochemistry). *Nuclear Engineering International (Incorporates Nuclear Power) (United Kingdom);* 39(475): 30-31 (Feb 1994).

When the Okla "natural" fission reactors were discovered in 1972, investigators were soon surprised at how little several of the fission products or U-235 had moved in the two billion years since they were active. Studies underway in several countries are seeking to determine whether these ancient reactors can serve as time-tested analogs for the modern processes needed for a nuclear waste repository. (author).

125 Managing nuclear waste from power plants. Keeney, R.L. (Univ. of Southern California, Los Angeles, CA (United States)); Winterfeldt, D. von. *Risk Analysis (United States);* 14(1): 107-130 (Feb 1994). Grant SES-8919502.

National strategies to manage nuclear waste from commercial nuclear power plants are analyzed and compared. The current strategy is to try to operate a repository at Yucca Mountain, Nevada, to dispose storage at a centralized facility or next to nuclear power plants. If either of these is pursued now, the analysis assumes that a repository will be built in 2100 for waste not subsequently put to use. The analysis treats various uncertainties: whether a repository at Yucca Mountain would be licensed, possible theft and misuse of the waste, innovations in repository design and waste management, the potential availability of a cancer cure by 2100, and possible future uses of nuclear waste. The objectives used to compare alternatives include concerns for health and safety, environmental and socioeconomic impacts, and direct economic costs, as well as equity concerns (geographical, intergenerational, and procedural), indirect economic costs, as well as equity concerns (geographical, intergenerational, and procedural), indirect economic costs to electricity ratepayers, federal government responsibility to manage nuclear waste, and implications of theft and misuse of nuclear waste. The analysis shows that currently building an underground repository at Yucca Mountain is inferior to other available strategies by the equivalent of $10,000 million to $50,000 million. This strongly suggests that this policy should be reconsidered. A more detailed analysis using the framework presented would help to define a new national policy to manage nuclear waste. 36 refs., 3 figs., 17 tabs.

126 Oxidation of uraninite: does tetragonal U_3O_7 occur in nature?. Janeczek, J. (Dept. of Earth Sciences, Silesian Univ., Sosnowiec (Poland)); Ewing, R.C.; Thomas, L.E. *Journal of Nuclear Materials (Journal des Materiaux Nucleaires) (Netherlands);* 207: 177-191 (Dec 1993).

Samples of uraninite and pitchblende annealed at 1200 C in H_2, and untreated pitchblende were sequentially oxidized in air at 180-190 C, 230 C, and 300 C. Uraninite and untreated pitchblende oxidized to the U_4O_9-type oxide, and their X-ray symmetry remained isometric up to 300 C. Reduced pitchblende after oxidation to UO_{2+x} and U_4O_9-type oxides transformed into α-U_3O_8 at 300 C. Two major mechanisms control uraninite and untreated pitchblende stability during oxidation: (1) Th and/or REE maintain charge balance and block oxygen interstitials near impurity cations; (2) the uraninite structure saturates with respect to excess oxygen and radiation-induced oxygen interstitials. Untreated pitchblende during oxidation behaved similarly to irradiated UO_2 in spent nuclear fuel; whereas, reduced pitchblende resembled nonirradiated UO_2. An analysis of the data in the literature, as well as our own efforts to identify U_3O_7 in samples from Cigar Lake, Canada, failed to provide conclusive evidence of the natural occurrence of tetragonal α-U_3O_7. Most probably, reported occurrences of U_3O_7 are mixtures of isometric uraninites of slightly different compositions. (orig.)

127 Petrography and paragenesis of organic matter associated with the natural fission reactors at Oklo, Republic of Gabon: a preliminary report. Mossman, D.J. (Mount Allison University, Sackville, NB (Canada). Dept. of Physics); Nagy, B.; Rigali, M.J.; Gauthier-Lafaye, F.; Holliger, P. *International Journal of Coal Geology (Netherlands);* 24(1/4): 179-194 (Dec 1993). (CONF-9205398–: Symposium on advances in organic petrology and geochemistry, Wolfville (Canada), 25-27 May 1992).

Sixteen known uranium-rich pockets in the sediment-hosted uranium ore deposits in the Oklo area became nuclear fission reactors 1968±50 Ma ago and operated as such for up to 1 Ma. Nuclear criticality was caused by unique and fortuitous geological environments and events. These included the localized high concentrations of uranium in small pockets in the ore bodies, the fact that the relative abundance of the fissile ^{235}U isotope was five times greater in uranium ~2 Ga ago than present, the presence of water which acted as a moderator in the natural reactors and the absence of neutron poisons, which are elements that can prevent nuclear chain reactions. Organic matter has been studied in natural reactors 7 to 9 and at locations at various distances from these reactors. Bitumen in the Oklo reactors is the predominant organic phase. It is now solid bitumen. Its immediate precursor was liquid bitumen, generated from syngenetic kerogen in organic-rich sedimentary rocks in the Francevillian Basin of Gabon and in the natural reactors themselves by hydrous reaction mechanisms prior to, during, and after nuclear criticality. A preliminary paragenesis of organic matter at Oklo is defined. 36 refs., 3 figs., 1 tab.

128 Effects of environment on localized corrosion of copper-based, high-level waste container materials. Sridhar, N. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses); Cragnolino, G.A. *Corrosion (Houston) (United States);* 49(12): 967-976 (Dec 1993).

Effects of environmental factors on localized corrosion of copper (Cu)-based materials that are candidates for use in high-level nuclear waste containers were examined. Effects of bicarbonate (HCO_3^-), chloride (Cl^-), and sulfate (SO_4^{2-}), which are present in the ground water near the proposed Yucca Mountain site for a high-level waste repository, were studied. Localized corrosion was observed only at low temperatures in environments involving combinations of high HCO_3^- with high Cl^- or high SO_4^{2-}. Uniform corrosion was observed at low concentrations of HCO^-_3 (< ~2,000 ppm), especially when Cl^- or SO_4^{2-} concentration was high. A passive behavior without localized corrosion was observed at high HCO_3^- concentrations at temperatures > 80 C, irrespective of the Cl^- and SO_4^{2-} concentrations. Localized corrosion observed in the Cu-based alloys was much

shallower than in stainless steels and nickel (Ni)-based alloys and tended to broaden with time under potentiostatic conditions. Oxygen-free Cu (CDA-102, UNS C10200) exhibited a greater tendency toward localized corrosion than a 70% Cu-30% Ni alloy (CDA-715, UNS C71500).

129 Studies of colloids and suspended particles, Cigar Lake uranium deposit, Saskatchewan, Canada. Vilks, P. (Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Labs.); Cramer, J.J.; Bachinski, D.B.; Doern, D.C.; Miller, H.G. *Applied Geochemistry (United Kingdom);* 8(6): 605-616 (Nov 1993).

The Cigar Lake U deposit located in the eastern part of the Athabasca Sandstone Basin, consists of a high-grade ore body (up to 55% U) located at a depth of ≈ 430 m. As part of a study to evaluate the analog features of this deposit with respect to a disposal vault for waste nuclear fuel, colloids (1-450 nm) and suspended particles (> 450 nm) in groundwater have been investigated to evaluate their effect on element transport. The results show that particle compositions are similar to the composition of minerals in the sandstones and ore body, suggesting that particles in groundwater are generated by the erosion of fracture-lining minerals and concentrations are affected by the integrity of the host rock. The observed colloid and suspended particle concentrations in the deep groundwaters are too low to have a significant impact on radionuclide migration, provided that radionuclide sorption is reversible. If radionuclides are irreversibly sorbed to particles they cannot sorb to the host rock and their migration can only be evaluated with an understanding of particle mobility. The data for dissolved and particulate U, Th and Ra were used to calculate field-derived distribution ratios (R_d) between particles and groundwater. The wide range of observed R_d values indicates that these radionuclides in particulate form are not in equilibrium with groundwater. U-series isotope data indicated that most of the U and Ra on particles was derived from groundwater. Some particles could have retained their U for as long as 8000 a. The U and Ra contents of particles in the ore and surrounding clay zones are significantly higher than in particles from sandstone, suggesting that the clay has been an effective barrier to particle migration. (author).

130 Okulo natural reactors: Recent findings and their significance on geologic disposal of high level radioactive waste. Yamakawa, Minoru (Power Reactor and Nuclear Fuel Development Corp., Tokyo (Japan)). *Nippon Genshiryoku Gakkai-Shi (Journal of the Atomic Energy Society of Japan) (Japan);* 35(11): 978-984 (Nov 1993). (In Japanese).

French CEA has reported in 1972 that natural nuclear reactors existed in Okulo uranium deposit in Gabon in Africa, that caused nuclear fission chain reaction (Okulo phenomena) spontaneously two billion years ago. The fission products and transuranic elements produced by the natural reactors have been preserved in strata without movement while subjected to geological phenomena for such very long years. 16 zones of the natural reactors have been discovered so far. The geological features of the Okulo uranium deposit are explained. The total amount of ^{235}U lost by the chain reaction was estimated to be about 6t, and the fission products were about 6t. The Okulo phenomena offered the valuable results of the synthetic formation disposal test that the nature has carried out for such long years. The significance of the study on natural analog is discussed. Organic substances and the mechanism of holding and movement of uranium and fission nuclides, the stability of uraninite and the age measurement of the deposit by Nd-Sm process are reported as the main results. (K.I.).

131 The Nevada initiative: A risk communication Fiasco. Flynn, J. (Decision Research, Eugene, OR (United States)); Solvic, P.; Mertz, C.K. *Risk Analysis (United States);* 13(5): 497-502 (Oct 1993).

The U.S. Congress has designated Yucca Mountain, Nevada as the only potential site to be studied for the nation's first high-level nuclear waste repository. People in Nevada strongly oppose the program, managed by the U.S. Department of Energy. Survey research shows that the public believes there are great risks from a repository program, in contrast to a majority of scientists who feel the risks are acceptably small. Delays in the repository program resulting in part from public opposition in Nevada have concerned the nuclear power industry, which collects the fees for the federal repository program and believes it needs the repository as a final disposal facility for its high-level nuclear wastes. To assist the repository program, the American Nuclear Energy Council (ANEC), an industry group, sponsored a massive advertising campaign in Nevada. The campaign attempted to assure people that the risks of a repository were small and that the repository studies should proceed. The campaign failed because its managers misunderstood the issues underlying the controversy, attempted a covert manipulation of public opinion that was revealed, and most importantly, lacked the public trust that was necessary to communicate credibly about the risks of a nuclear waste facility. This article describes the advertising campaign and its effects. The manner in which the ANEC campaign itself became a controversial public issue is reviewed. The advertising campaign is discussed as it relates to risk assessment and communication. 29 refs., 2 tabs.

132 GAO report recommends review of goals, objectives. *Nuclear News (La Grange Park, Illinois) (United States);* 36(9): 50-51 (Jul 1993).

This article highlights a recent GAO study titled Nuclear Waste: Yucca Mountain Project Behind Schedule and Facing Major Scientific Uncertainties. The study was undertaken at the request of the former chairman of the Subcommittee on Nuclear Regulation, the predecessor of the current Subcommittee on Clean Air and Nuclear Regulation of the Senate Committee on Environment and Public Works. The report concludes that the level of funding DOE is requesting is not adequate to complete the goals of the project within the established timeline, and questions whether the changes being recommended by DOE to streamline the project will save money at the cost of safety. The GAO report recommends that the Secretary of Energy "...review the program's goals and objectives in the context of the program's priority for funding." It also recommends that Congress not consider any funding changes until the Secretary's report is in and an independent review by the Nuclear Waste Technical Review Board is also available.

133 Permeability of Apache Leap Tuff: Borehole and core measurements using water and air. Rasmussen, T.C. (Univ. of Arizona, Tucson, AZ (United States)); Evans, D.D.; Sheets, P.J.; Blanford, J.H. *Water Resources Research (United States);* 29(7): 1997-2006 (Jul 1993). Contract NRC-04-86-114.

Characterization data for water and air properties of variably saturated rocks are required for evaluation of the candidate high-level nuclear waste disposal site at Yucca

Mountain, Nevada, as well as for municipal, toxic, and hazardous waste sites situated in variably saturated fractured rock elsewhere. Field and laboratory methods for estimating and interpreting parameters obtained from field borehole and laboratory core experiments are examined using permeability data interpreted from air and water injection tests in variably saturated fractured tuff at the Apache Leap Tuff Site in central Arizona. The tuff at the field site has a matrix porosity of approximately 17.5% and contains numerous near-vertical fractures at an average spacing of 1.3 m. More than 270 m of 6.4-cm-diameter oriented core were collected from boreholes. Laboratory estimates of absolute permeabilities using air and water as the test fluids were acquired at a range of matric potentials for 105, 5-cm-long core segments extracted at approximately 3-m intervals containing no obvious fractures. Field scale estimates of fractured rock permeabilities using air and water as test fluids were obtained at ambient matric suctions and water saturated conditions, respectively. The field tests were conducted along 3-m intervals within boreholes with the intervals centered on core sampling positions. Permeabilities measured in boreholes using air are shown to provide good estimates of permeabilities measured using water into initially unsaturated, fractured rock at the Apache Leap Tuff Site.

134 Technetium in nature and age of the solar system. Kuroda, P.K. *Radiochimica Acta (Germany);* 63: 9-18 (1993). (CONF-9303140–: Topical symposium on the behavior and utilization of technetium '93, Sendai (Japan), 18-20 Mar 1993).

The age of discovering new elements by artificial means began in 1937 when element 43, technetium, was discovered. It so happened, however, that technetium was found to occur in certain stars in 1952 and ^{99}Tc produced by the spontaneous fission of ^{238}U was found to occur in uranium-bearing minerals and ores such as pitchblende, in 1961. When the Oklo phenomenon was discovered in 1972, it became also apparent that a large quantity of ^{99}Tc existed in nature approximately 1,700 million years ago, when the pre-Fermi reactors were operating on the earth. Results from recent studies on the occurrences of technetium and another man-made element, plutonium, in nature indicate that the solar system began to form about 5,000 million years ago. (orig.)

135 Geochemical behaviour of ^{99}Tc in the Oklo natural fission reactors. Hidaka, Hiroshi (Dept. of Chemistry, Faculty of Science, Tokyo Metropolitan Univ. (Japan)); Shinotsuka, Kazunori; Holliger, P. *Radiochimica Acta (Germany);* 63: 19-22 (1993). (CONF-9303140–: Topical symposium on the behavior and utilization of technetium '93, Sendai (Japan), 18-20 Mar 1993).

Ru isotopic ratios of five Oklo uranium ore samples were determined by inductively coupled plasma mass spectrometry (ICP-MS). We found fissiogenic Ru enriched metallic micro-inclusions in the samples, so in-situ isotopic measurements were performed by secondary ion mass spectrometry (SIMS). From the isotopic abundances of fissiogenic ^{99}Ru, the geochemical behaviour of ^{99}Tc in the Oklo natural reactors could be inferred. More ^{99}Ru has been enriched in metallic inclusions of the samples than in matrix uraninite grains. (orig.)

136 Effects of evaporation and solute concentration on presence and composition of water in and around the waste package at Yucca Mountain. Walton, J.C. (Southwest Research Inst., San Antonio, TX (United States). Center for Nuclear Waste Regulatory Analyses). *Waste Management (United States);* 13(4): 293-301 (1993).

For the proposed repository at Yucca Mountain, the amount, timing, and expected composition of water contacting the waste package are major concerns. In the presence of thermal loading from radioactive decay, a flow system is set up with water leaving as vapor and returning as liquid flowing through the matrix and fractures. A hypothesis is developed suggesting that most water in the vicinity of the waste package evaporates, leaving behind a scale deposit and concentrated solution. The vapor pressure lowering caused by the brine solution maintains a water film on the rock and waste package materials even in the presence of a dry environment with thermal gradients. The chemical environment within which container corrosion and spent fuel alteration occur is anticipated to be an initial period of concentrated brine, followed by solutions of lower ionic strength as the repository cools. The specific environment and timing could vary widely between different waste packages and within individual waste packages subsequent to container failure.

137 Can you say 'N'? NIMBY, NWPA and nuclear Preemption. *Natural Resources Journal (United States);* 33(2): 493-506 (Spr 1993).

In Nevada v. Watkins, the Ninth Circuit Court of Appeals upheld the constitutionality of the 1987 NWPA amendments, which enabled the continued site characterization of Yucca Mountain and thwarted Nevada's attempt to ban nuclear waste within its borders. The Watkins court ruled that Nevada's statute, which banned nuclear waste, was preempted by NWPA. Nevada, like many states has passed laws that limit the storage, transportation or disposal of nuclear waste within its state boundaries. These statutes will meet the same fate as the one struck down in the Watkins decision - that is, until states rights in the area of nuclear energy are clarified. This note examines Watkins' application of the preemption doctrine, as well as general preemption principles, to determine what avenues may still be open to states seeking to regulate the disposal of nuclear waste. The Watkins decision neither discussed the fully authority of NWPA nor defined the extent of the federal government's preemption of state regulation of nuclear waste disposal. However, Watkins seems to solidify the rationale of other recent court decisions holdings that Congress has occupied the nuclear-energy field. This interpretation could effectively eliminate any state regulatory power over the nuclear-energy field, including nuclear-waste disposal.

138 Canada remains Western World's leading uranium supplier. *Canadian Energy News (Canada);* 7(23): 182-183 (1 Dec 1992).

Canada is the leading producer-exporter of uranium in the Western World, and hosts a significant portion of the global uranium exploration. Estimates of known uranium resources were 459,000 tU at the start of 1992, down over 20% from 1991. The decrease is mainly due to mine closures at Elliot Lake. Total shipments in 1991 approached 8,200 tU, valued at over $500 million. Actual exports were 7,810 tU. A major part of the $ 44 million spent on exploration in 1991 is accounted for by underground geotechnical testing at Cigar Lake.