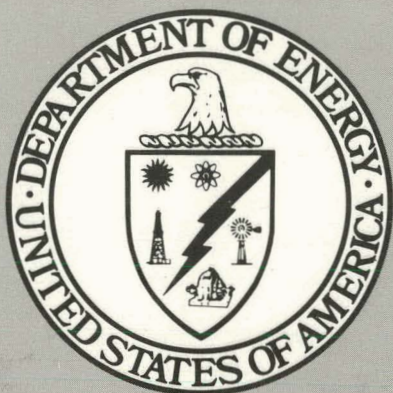


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NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

Quarterly Report for the Period October—December 1981

March 1982

Nevada Operations Office
Las Vegas, Nevada

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NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

— QUARTERLY REPORT —

OCTOBER THROUGH DECEMBER 1981

MARCH 1982

— UNITED STATES DEPARTMENT OF ENERGY —
— NEVADA OPERATIONS OFFICE — LAS VEGAS, NEVADA —

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INTRODUCTION

The Nevada Nuclear Waste Storage Investigations (NNWSI) are investigating and determining whether specific underground rock masses are suitable for permanently disposing of highly radioactive wastes, studying and determining whether the Nevada Test Site (NTS) would qualify as a suitable repository site, and developing and demonstrating the capability to safely handle and store commercial spent reactor fuel and high-level waste. The NNWSI are being conducted in support of the National Waste Terminal Storage (NWTS) Program, and are being managed by the Nevada Operations Office (NV) of the U.S. Department of Energy (DOE). The principal Project participants are: Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL), Westinghouse Electric Corporation (WEC), and the U.S. Geological Survey (USGS). The Project organization chart is shown in Figure 1.

This document is a compilation of the technical progress of the principal Project participants of the NNWSI in meeting the objectives described in the draft FY 1982 NNWSI Project Plan and revised planning documentation during the first quarter of FY 1982. The NNWSI Project Work Breakdown Structure (WBS) for FY 1982 is comprised of eight tasks which form the main sections of this document.

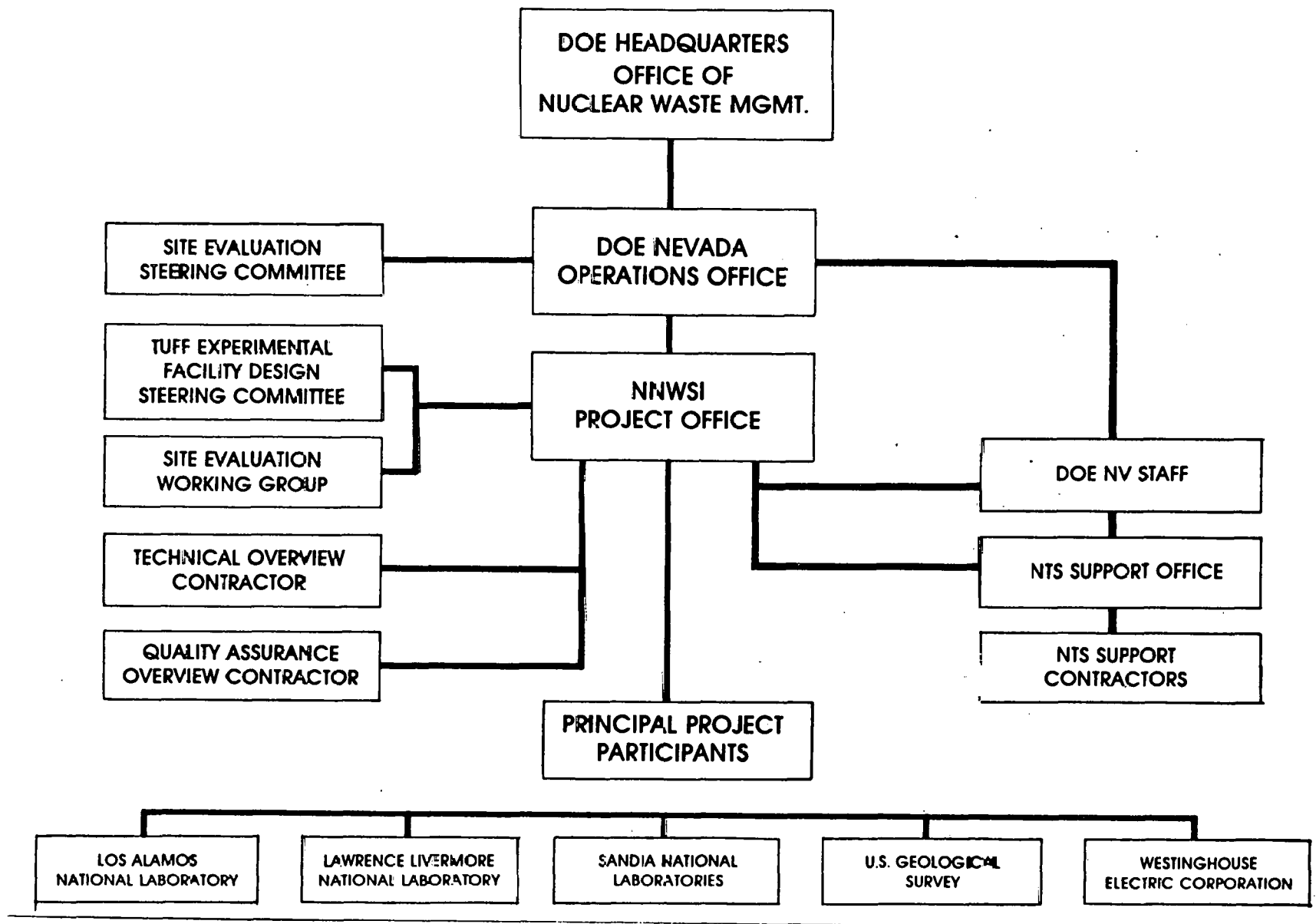


Figure 1. NNWSI Organization Chart

HIGHLIGHTS

- Scenarios for the release of radionuclides from a repository in alternate rock types occurring in the southwest NTS area were ranked by probabilities.
- Revision 1 of NVO-196-24, "Bibliography of the Published Reports, Papers, and Articles on the Nevada Nuclear Waste Storage Investigations," was compiled and published.
- Hydraulic conductivity measurements were made in G-Tunnel to characterize potential locations for the Nuclide Migration Field Experiments in welded tuff.
- Modifications to the tracer injector assemblies were made to permit their use in radial flow fields developed in near-vertical faults or joints.
- The granite radionuclide migration experiments were cancelled in November and a termination plan was developed that will allow the technical community to take advantage of the research conducted.
- Examination of tuffs in thin-section generally shows large round pores; however, the permeability of tuffs is lower than would be expected probably because the large pores are connected by a discontinuous network of small channels that constrict fluid flow.
- Mineralogic and petrologic studies of USW-G1 and USW-G2 drill hole core samples show that sorptive zeolites are abundant in restricted zones above the water table in USW-G2 and that the depth distributions of zeolites are much shallower in USW-G2 than in USW-G1.
- The drilling, logging, and hydrologic testing of USW-G2 were completed at Yucca Mountain; static water level checks are continuing.
- Detailed mapping of Yucca Mountain in the vicinity of the proposed repository has been completed.
- Analysis of data from 60 wells in and around the NTS, including 16 in the Yucca Mountain area, are nearing completion. Variations in heat flow are attributable primarily to hydrologic processes. Apart from indicating a general downward movement of water of a few milliliters per year, the results from Yucca Mountain are as yet inconclusive.
- Teleseismic residual data have been inverted using a linear inversion technique to produce general three-dimensional pressure-wave velocity models for the NTS and surrounding region.
- Geologic mapping has been completed of the volcanic and alluvial deposits of the Big Dune 15-minute quadrangle which is generally located between southern Crater Flat and the Funeral Mountains. No faulting of definite Quaternary age has been found in this area.

- A computerized data recording and earthquake detection system that is more efficient at detecting and locating earthquakes was made operational.
- A series of 55 evaluations of repository locations in the screening area was performed; the Site Evaluation Working Group is identifying the sets of evaluations which are appropriate for adequately representing the screening activity and reviewing the assumptions regarding attribute weights which were used in the evaluations.
- A review has been completed covering the likelihood of creep failure in a tuff repository.
- The possible cases for locating a repository within the Yucca Mountain stratigraphy at various inclinations with different waste packages were recorded and will be ranked according to their respective favorability for the development of a Test and Evaluation Facility/Repository.
- A study of natural ventilation for a repository under Yucca Mountain was completed and it was concluded that natural ventilation should be used in conjunction with mechanical ventilation in an operating repository.
- The second Spent Fuel Test--Climax exchange of a spent fuel canister was successfully carried out in late October.
- A land withdrawal plan for siting a commercial high-level waste repository on the NRDA and/or contiguous Nellis AFB and BLM land was prepared and forwarded to the DOE/HQ in November.

WORK BREAKDOWN STRUCTURE

1.1 SYSTEMS

Objective: To plan, document, and evaluate the performance of the Project and to identify modeling techniques to evaluate the performance of the overall waste package, site, and the repository containment and isolation systems.

1.1.1 PROGRAM BASELINE

Objective: To evaluate the performance of the Project.

The TPOs and the TOC worked with the Project Manager, LANL, LLNL, SNL, USGS, WEC, contractors, and subcontractors in planning, coordinating, reviewing, documenting, and implementing a balanced technical project. This activity has no reportable progress.

1.1.2 SYSTEMS ANALYSIS

(No NNWSI work funded this fiscal year.)

1.1.3 SOCIOECONOMIC ASSESSMENT

(No NNWSI work funded this fiscal year.)

1.1.4 ALTERNATE DISPOSAL CONCEPTS

(No NNWSI work funded this fiscal year.)

1.1.5 PERFORMANCE ASSESSMENT

Objective: To assess the performance of the overall waste containment and isolation systems.

Scenarios for the release of radionuclides from repositories in alternate rock types in the southwest NTS area were ranked by probabilities. These probabilities were used to revise the scope of the draft report on release scenarios for repositories located in the southwest NTS area. A presentation on the scenario development methods was given at the NWTS Annual Information Meeting in Columbus.

1.2 WASTE PACKAGE

Objective: To integrate the development of a waste package for tuff with the NWTS Program and to design, construct, and qualify waste packages which allow for the safe handling, storage, and containment of the waste and which permit safe retrieval of the waste package, i.e., everything placed into the repository emplacement hole.

1.2.1 WASTE PACKAGE BASELINE

(No NNWSI work funded this fiscal year.)

1.2.2 WASTE FORM

(No NNWSI work funded this fiscal year.)

1.2.3 BARRIER MATERIALS

(No NNWSI work funded this fiscal year.)

1.2.4 DESIGN AND DEVELOPMENT

Objective: To provide design drawings and specifications for waste package components and to develop package fabrication equipment specifications.

1.2.4.1 Tuff Waste Package Development

Objective: To integrate the development of a waste package for tuff with the NWTS Program for emplacement in a repository on or near the NTS.

In addition to the Principal Investigator (A. Rothman), the present work at LLNL on the waste package (WP) consists of: corrosion metallurgy (D. McCright), backfill geochemistry (V. Oversby), performance modeling (D. Gregg), systems analysis (W. Sutcliffe), thermal modeling (D. Montan), and nuclear chemistry/miscellaneous (H. Tewes). All but the principal investigators are part-time people, and additional time and people are planned as the program progresses this FY, consistent with our yearly budget plan.

Thermal calculations on temperature distribution in a tuff WP are continuing for various backfill thermal conductivities, for various water inflow times, and for several backfill thicknesses. Detailed results will be reported later.

The literature is being studied to determine the suitability of bentonite or other materials for backfill based on stability and thermal properties. A report will be issued shortly by V. Oversby.

A document is being prepared on materials research and development needs for a tuff-specific waste package. A draft was submitted to NV for review. Copies

also have been circulated to ONI, ONWI, PNL, and W/AESD for comment. A meeting was held at Columbus on November 19, 1981, with ONI, ONWI, PNL, W/AESD, and Sandia to discuss some of the issues raised by the document. Action was taken to provide PNL with NTS J-13 groundwater for initial corrosion tests and steps were initiated to obtain tuffs representative of potential repository sites for WP materials tests at PNL and at LLNL.

LLNL personnel met with W/AESD personnel on conceptual WP design for a tuff repository on November 17 and November 19, 1981, at Columbus. Also in attendance were Sandia, ONI, and ONWI. Questions were raised by Westinghouse and answers were requested from NNWSI Project people. Most replies have been received and a document is being prepared for Westinghouse which will be sent shortly.

Several personnel (Sutcliffe, Rothman, Gregg) attended a meeting of the Package Standards Compliance Working Group at Columbus, November 18. A subsequent meeting is planned for Livermore on January 7, 1982. Sutcliffe will be the representative on the working group.

Sorption of Anions on Possible Backfill Components

The results of the sorption of technetium on graphite were obtained with the R_d values for sorption of I^- for comparison. There was essentially no change in pH during the experiment.

1.3 SITE

Objective: To characterize the southwest NTS area to identify and technically qualify a possible site for the construction and operation of a mined geologic repository for radioactive waste.

1.3.1 SITE BASELINE

Objective: To establish the requirements for conducting the Site task and to ensure that the objective of the Site task will be met.

This task has no reportable progress.

1.3.2 EARTH SCIENCES

Objective: To develop the data base and methodology necessary to characterize the geologic system and understand its physical-chemical interactions.

1.3.2.1 Nuclide Migration Field Experiments

Objective: To develop the experimental, instrumental, and safety techniques necessary to conduct controlled small-scale, at-depth nuclide migration experiments in the field.

1.3.2.1.1 Nuclide Migration Field Experiments in Tuff

Objective: To develop and use in situ nuclide migration assessment techniques in the tuffaceous media of G-Tunnel for predicting radionuclide transport under field constructions.

Management Summary

Fiscal support for technical activities in FY 1982 was reduced, causing most work scheduled for this quarter to be terminated. Options for completely terminating these experiments were developed in October in an attempt to accomplish as many of the experimental objectives as possible before the end of FY 1982. However, the lack of any firm FY 1982 budget figure resulted in stopping almost all work by the end of November. During December 1981, data from the experiment-site characterization activities were reviewed in preparation for drafting the experiment-site selection report, and for defining less expensive field designs for the G-Tunnel experiments. Preliminary design modifications, based on the best available laboratory and field data and transport modeling, were submitted in late December. These modifications reflect the need to change the technical approach used if credible fracture-flow, radionuclide transport experiments are to be safely and successfully conducted in G-Tunnel.

Preparation of two topical reports supporting experiment-site characterization and selection continued during this quarter. The first report will present the mineralogic and petrographic examination and comparison of bedding planes

in the nonwelded tuff in G-Tunnel done by K. Keil and J. Conolly (UNM). The second report summarizes the field techniques used to measure the hydraulic conductivities of intact rock, bed contacts, joints, and faults in the nonwelded tuff in G-Tunnel. Results of these field tests will also be compared with laboratory permeability measurements on core taken for experiment-site characterization. Both reports are expected to be released by April 1982.

Technical Summary

Technical progress during the first quarter of FY 1982 was greatly constrained by the loss of funding mentioned above. The progress made during this quarter and the current status of activities will be presented below for three major areas:

- a. Field activities.
- b. Equipment design and development.
- c. Transport modeling and analyses.

Field Activities

Hydraulic conductivity measurements were made in G-Tunnel to characterize potential experiment locations. The hydraulic conductivity of the beds above and below contact GT5-80 was measured using five different exploratory holes cored from VDH#5. Sandia's field test equipment, designed specifically for the NNWSI tuff radionuclide migration and rock mechanics experiments in G-Tunnel, was used. Test intervals were straddle packed and single-hole, steady-state, and shut-in measurements were made. In addition, two hole-to-hole, steady-state conductivity measurements in the pair RNM-ED 80/4 and 80/5 were conducted.

The goal of these tests was to determine the effective apertures of contact GT5-80 and of near-vertical joints and faults crossing the contact. This information would be used to describe potential experimental flow-fields in these fractured tuffs as input to the site selection process. Before funds were cut off for these studies in November 1981, enough data had been collected to confirm expectations that contacts between the beds of nonwelded tuff in that area of G-Tunnel are not primary conduits for groundwater. The specific hydraulic conductivities of the contacts tested were equivalent to that of the rock matrix itself, limiting any effective apertures at the contact to less than about 2 micrometers (assuming the cubic law relating volumetric flow rate to fracture aperture is valid). However, some of the near-vertical faults tested accepted water at flow rates of up to 600 ml/hr at a 0.71 MPa injection pressure. In addition to these test data, observation of groundwater flow through many of the vertical faults and/or joints in this region of G-Tunnel strongly suggests that these fractures again be considered for use in the tuff radionuclide migration field experiments. (These and other reasons for this suggestion will be given in the experiment site characterization report now in preparation.)

At the present time, the field test equipment has been removed from G-Tunnel and placed in storage. Data from completed tests are being evaluated and compared to type-flow curves from theoretical models. Results of these tests will be reported in coming months, depending on the availability of funds to support the completion of analyses.

Other fieldwork completed in October or early November was (a) mapping and surveying in VDH#5 and HF23, (b) exploration drilling to the northeast of HF23, and (c) the drilling of three 55-cm-diameter cores (containing vertical fractures) from HF23 for tracer injector experiments to be conducted at Sandia. At present, no additional fieldwork is planned because of lack of funds.

Equipment Design and Development

Modifications to the tracer injector assemblies were made to permit possible use in radial flow fields developed in near-vertical faults or joints. At present, all work on the WATIS and WATCS equipment and on the full-scale test block has been stopped; equipment is presently stored at Sandia.

Transport Modeling and Analyses

Only a minimum effort was supported in this quarter to provide modeling and analyses. In the laboratory, a series of experiments was started to confirm predicted sensitivities of radionuclide transport to changes in (1) fracture aperture and (2) groundwater flow rate. These parameters were identified in an earlier design report as having strong modelable influence on the migration of radionuclides through any fractured rock.

Other analyses completed this quarter were the mercury-intrusion, pore symmetry analyses, and mineralogic and petrographic studies of the shallow core samples taken for the systematic screening of bedding planes.

Preparation of Rock-Treated Water

The experiment for preparing 200-l of G-Tunnel rock-treated water was essentially completed after the water from well J-13 had been contacted with muck from G-Tunnel for 28 days, filtered, contacted with fresh muck for 24 days, and filtered again. Final membranes in both filtrations were 0.05-micrometer Nuclepore polycarbonate filters. Aliquots of the water were removed at frequent intervals during the contacts and filtered through 0.05-micrometer Nuclepore membranes. A portion of each aliquot was acidified for determination of cations and silicon by emission spectroscopy. Concentrations of anions were determined by ion chromatography on nonacidified samples.

The average experimental normalities of the rock-treated water are 3.17 meq/l for cations and 2.68 meq/l for anions. The average values for well J-13 water are 2.85 meq/l for cations and 3.22 meq/l for anions. The differences of normalities for cations and anions of 18 percent and 12 percent for these two waters are slightly higher than differences of 1 percent to 15 percent typically observed by the USGS in water analyses. Part of the differences in

normalities of anions and cations may be due to loss of CO_2 , and therefore HCO_3^- , from the solutions. This possibility is being investigated with determination of alkalinity by titration with acid. For groundwaters, such as that from well J-13, in the range of pH 8 to 9, the principal component of alkalinity should be HCO_3^- because basic constituents such as phosphate have not been detected.

The pH of the water varied less than 0.08 unit during preparation of the rock-treated water. The average value is 8.32 ± 0.03 .

Development and Characterization of Water Tracers

Methods are being developed for the separation and identification of potential groundwater tracers. Initial work with water tracers and the basic means for their separation was done at the University of Arizona. A class of compounds consisting of various fluorinated benzoic acids was selected because of desirable nonsorbing tracer qualities. As a preliminary measurement, the melting points of five available compounds were determined to assess their general purity.

A high-performance liquid chromatograph, which will be used as the instrument to separate and identify the tracer compounds, was installed and is operational. The analytical methods developed are being adapted at the University of Arizona for our water samples and instrument. To be useful as water tracers, the above acids, which have low solubilities in water, must be converted to soluble salts. Such a salt was prepared from 3-trifluoromethyl benzoic acid (3-TFMBA) by two methods. The first involves forming the salt by adding concentrated sodium carbonate solution to the acid over a steam bath; CO_2 evolves and escapes by effervescence. The product was diluted with water, filtered, and evaporated to dryness. Later, a solution was made by dissolving a weighed portion of the salt in water. In the second method (S. Jensen, University of Arizona, personal communication, September 1981), 0.01M NaOH is added to a weighed amount of 3-TFMBA, and the solution stirred. The resulting solution was diluted and filtered. The two salt solutions were examined on a Hewlett-Packard UV-VIS spectrometer for comparison. Although the spectra were generally similar, the fine structure between 200 and 240 nm differed. A large UV absorption band appeared in the spectra of both NaOH- and Na_2CO_3 -formed salts near 230 nm, corresponding to benzene-ring absorption. The pH of the NaOH-formed salt solution was 7.16; that of the Na_2CO_3 -formed salt was 5.47. At present, the chromatographic procedure is not well enough developed to distinguish the two types of salt.

Sorption of U(VI)

Because of the current unavailability of ^{237}U tracer, which was used in past uranium sorption experiments, a new procedure for uranium determination was developed. Normal uranyl nitrate is used as tracer; neutron activation followed by delayed-neutron counting is used for the quantitative determination of uranium.

The first experiment with this technique was with G-Tunnel rock using solutions, the initial pH values of which were adjusted with hydrochloric acid or sodium hydroxide. The results were unexpected. Sorption ratios much higher than those previously reported with tuff were obtained. Our previous sorption experiments with ^{237}U tracer generally gave R_d values less than 10 ml/g. In addition, it should be noted that the previous experiments were performed with solutions in which dried tracer had been dissolved in the appropriate groundwater rather than with pH-adjusted solution as in this experiment.

The difference in sorption ratios with pH may be due to differences in species of uranium present. For example, Langmuir has shown a variety of species at 10^{-2} atm CO_2 ranging from UO_2^{2+} in acid solution through a series of neutral and anionic complexes to $\text{UO}_2(\text{CO}_3)_4^{4-}$ in the pH range studied. Also, unusual speciation problems have been observed in our studies when americium and plutonium tracers were added in acid solution to the groundwaters and the pH of the resultant solution was adjusted.

A set of experiments with dried normal uranyl nitrate tracer similar to those with the ^{237}U tracer was repeated with sample JA-37. The results from the two methods are in good agreement, indicating that both methods of tracing with uranium for sorption experiments give the same results.

Experiments with G-Tunnel matrix material from hole RNM-9 were also performed using dried uranyl nitrate dissolved in groundwater. The observed sorption ratios obtained were low but are somewhat higher than sorption ratios for U(VI) and for other zeolitized tuffs under ambient conditions.

Crushed-Rock Column Studies

The crushed-rock column experiment utilizing fracture-fill material from G-Tunnel was stopped after 242 days. The column was sectioned to locate the strontium, cesium, barium, and europium activities that had not been eluted. Although most of the technetium had been eluted earlier, giving an R_d value* between 0.2 and 1.5 ml/g, 2.6 percent of the technetium loaded was still on the column, all in the last half. Approximately 20 percent of the ^{85}Sr , ^{137}Cs , and ^{133}Ba , and greater than 50 percent of the ^{151}Eu had moved away from the load point.

Fracture Flow: Block Experiments

A sample of ash fall tuff from a 10 cm core from drill hole S80-4 in G-Tunnel, containing a natural fracture, was cut into a rectangular block for future flow experiments. The block was cut with a wire saw using rock pretreated groundwater as a lubricant so that the chemistry of the rock would not be altered by the cutting operation. The sides of the block were sealed with

*The R_d of technetium could not be determined exactly because the sample volumes taken were too large to accurately obtain the volume at 50 percent elution.

Uralane,* a two-component polyurethane sealant. Plexiglas injection and sampling ports were sealed to the ends of the block. This block will not be submitted to stress to simulate lithostatic pressure because a previous experiment showed that tuff fractures tend to seal under stress. Water was pumped into the fracture. The polyurethane sealant proved ineffective because it did not penetrate the rock and, therefore, blistered and leaked when wet. The polyurethane seal was then coated with a 0.5-cm coating Beuhler epoxy. The epoxy coating successfully sealed the block, and the block is now being equilibrated with pretreated groundwater.

1.3.2.1.2 Nuclide Migration Field Experiments in Granite

Objective: To develop in situ nuclide migration assessment techniques in the granitic media of the Climax facility.

Engineering and design work proceeded as planned until November when word was received that the granite RNM project was to be cancelled. During October, the fabrication drawings for the cart system were completed and the laboratory testing of the pumps, sampling units, and on-line beta detector was started. In November, all work was stopped with the exception of the laboratory core sorption experiments and the groundwater characterization activities which require a limited amount of additional work to bring them to a reportable status. A termination plan was developed that will allow the technical community to take advantage of the research conducted in the past year and a half. By the end of the quarter, final documentation of completed work had begun. Seven reports are planned, including the final draft of the Engineering Test Plan.

Project personnel prepared for and participated in an internal design review of the Engineering Test Plan at LLNL in early December. The review comments will be addressed when the Engineering Test Plan is revised following the formal peer review to be held in Las Vegas sometime in February. Only a few minor changes were recommended by the reviewers. Project personnel also participated in a QA review at LLNL December 16-18, 1981.

Dana Isherwood presented a summary of our research findings entitled "Site Characterization for Field Radionuclide Migration Studies in Climax Granite" (UCRL-86194) at the Materials Research Society in Boston on November 16, 1981. The final version of this paper has been forwarded to the symposium editor for publication in Scientific Basis for Nuclear Waste Management (Vol. 4). Dana Isherwood also participated in the French-U.S. bilateral meeting on radionuclide migration in Paris, France, October 22-23, 1981. Prior to the meeting, she visited the Stripa Mine in Sweden and the KBS offices in Stockholm. On October 26-27, 1981, she toured the site of the Swiss underground facility at Grimsel Pass in the Swiss Alps and the Institute for Reactor Research (EIR) outside Baden, Switzerland. A detailed trip report is available.

*A trademark of Furane Plastics Company.

Site Characterization

The boreholes TT7-TT8 and the extensions of boreholes TT5-TT6 were visually logged with the borescope in October. Fourteen high-angle fractures were identified in the top borehole (TT8) and ten fractures in the bottom borehole (TT7). Two fractures seen at approximately 12.1 m and 7.5 m in TT8 and TT7 appear to be likely candidates for initial hydrologic testing. The other fractures could not be visually correlated between the two boreholes based on appearance and orientation. In the extensions of boreholes TT5-TT6, a candidate fracture was identified at 14.3 m in TT5 and 14.6 m in TT6.

Groundwater Characterization

The borehole groundwater collection system was installed in the Pilcdriver drift in October. The assembly was inserted in an NX borehole drilled vertically in the ceiling of the drift near the location of the previous water collector. The packer is a mechanically expandable type (Cobbs Engineering Company). The packer was maintained in place using about 1,100 psi of nitrogen gas. The oxygen probe, which is mounted on the end of the packer, is part of a slightly modified Leeds and Northrup Model 7931 dissolved-oxygen monitor system (Clack and Taylor, 1981). The design of this probe is based on an internal generation of oxygen that balances the external sample oxygen. This balanced, or null, approach obviates the need for sample stirring. The probe is sealed so that it could operate entirely submerged in the water; its electrical connection to the external meter was sheathed in heat-shrinkable Teflon tubing. The pH electrode is an HNU Systems Model ISE-45-02-00 combination probe, and the Eh electrode is a Beckman Instruments platinum-inlay redox electrode. The latter was cleaned initially by immersion in hot, concentrated hydrochloric acid. The pH and Eh measurements were made with an Orion Model 601A ion analyzer--the Eh potentials by connection to the Ag-AgCl reference half-cell of the pH probe. The pH and Eh probes are mounted in an acrylic plastic flow chamber by means of Swagelok fittings. The metal parts of the packer to which the water was exposed are chromium plated. All other materials in contact with the water (valves, tubing, and fittings) are inert plastics (Teflon, Viton, and Polyethylene).

When first installed, the water outlet to the pH-Eh electrode flow cell was closed and the 3-way valve was switched so that the water level could rise to the top of the vent tube and then overflow continuously to the outside. During this time, the dissolved oxygen concentration was monitored and was found to decline slowly as the water filled borehole and displaced the trapped air. The flow rate of water entering the collector and the total capacity for collected fluid were estimated to be 0.25 l/h (0.066 gal/h) and 9.7 liters (2.6 gal), respectively. The indicated dissolved oxygen level reached 1.0 mg/l (ppm) after 9 days, 0.10 mg/l after 14 days, and was less than 0.02 mg/l (the detection limit) after 16 days. Water temperature was 19-20°C. To confirm the low level of dissolved oxygen, samples from the water outlet were also analyzed by the Hach Winkler/azide method and found to be less than 0.14 mg/l.

Because in this case the measurements indicated that the groundwater was virtually anoxic, high purity nitrogen was selected as the feed gas to replace

the volume of fluid removed from the collector during sampling. To obtain water samples for further analysis and to perform pH and Eh measurements, the 3-way valve was switched to the nitrogen at a pressure of 3 psi. The valves in the water outlet line were opened to allow flow chambers to fill; the chamber was inverted several times to remove all gas bubbles; and then the water was flowed through it until steady pH and Eh readings were obtained. At the completion of water sampling, the outlet valves were closed and the 3-way valve again switched to allow the groundwater to refill the collector and overflow through the vent.

It is possible that equilibration of the water with the displacement gas may change the composition of the water; however, the small surface-to-volume ratio of this configuration and lack of water agitation would minimize this effect. Prompt analysis of the first samples from the full collector are advisable. In special cases where the water chemistry is more complex than here, gas mixtures that would not alter the chemistry of the water, such as those employed by Lecomte et al. (1981), could be used.

Samples from the borehole collector were obtained twice in November and once in December. Preliminary results indicate that with the exception of the oxygen content, this water is identical in chemical composition to the water collected from the seeps on the drift crown. A groundwater characterization report which will include a compilation of the analytical results for the various Climax waters is being prepared.

1.3.2.2. Tuff Studies

Objective: To determine the geochemical, mineralogical, and petrological properties of tuff.

1.3.2.2.1 Geochemistry

Objective: To determine the geochemical properties of tuff as a basis for predicting the migration of radionuclides to the accessible environment.

Kinetic Sorption Experiments on Wafers

Sorption experiments with ^{85}Sr , ^{137}Cs , and ^{133}Ba on G1-1982 and G1-1883 wafers were terminated. The sorption ratios for G1-1883 and G1-1982 wafers are comparable to those obtained by batch measurements on crushed, washed, and sieved ($\geq 38 \mu\text{m}$) samples of G1-1883 and G1-1982 tuff.

The sorption of ^{131}I on wafers of G1-1436 tuff was repeated. From preliminary measurements, it appeared that about 66 percent of the ^{131}I was sorbed on the wafer in 600 hours. However, the counting statistics were quite poor because of the decay of the ^{131}I , so the experiment was repeated with a larger amount of ^{131}I . At 721 hours, no sorption was observed, and about 96 percent of the water in the pretreated (saturated) rock apparently had exchanged with the water that was traced with ^{131}I .

The only wafers now being studied are the Climax Stock and Stripa granites, G-Tunnel tuff, and G1-1436 tuff (all for sorption of ^{95m}Tc), and G-Tunnel tuff for the desorption of ^{85}Sr , ^{133}Ba , ^{137}Cs , and ^{152}Eu . No sorption of technetium has been observed on any of the wafers. With batch and column measurements on Climax Stock granite, the sorption of technetium was quite high; however, sorption occurred only in the smallest fraction studied, 106 to 150 micrometers. It can be postulated that sorption of technetium may follow reduction of TcO^{-4} by hematite. Perhaps in the larger fractions (and in the wafers), the hematite is encased by other mineral(s), which makes it unavailable to reduce TcO^{-4} , and this coating is destroyed by crushing below 106 micrometers. It does seem likely either that the iron present in the granite, which probably causes sorption of technetium by first reducing pertechnetate, is not available in the intact rock wafers and is available after grinding or that the crushed granite was contaminated with iron during grinding because the pulverizing was done in an iron system. The latter possibility, where the total iron concentration in a less than 75-micrometer fraction prepared with an agate grinding system, was compared with larger size fractions from an iron pulverizer. The percent of Fe_2O_3 was 2.32 in the agate system and 2.88 to 2.33 in the other. These values were not considered to be appreciably different. These results suggest that any sorption of technetium observed in crushed tuff samples may be caused by minerals not normally accessible in intact rock.

Experiments directed toward a comparison of actinide sorption measurements using batch, circulating system, and crushed-rock column methods and some results for americium and neptunium measurements were reported earlier.

Because neptunium sorption values tend to be small, activity in the liquid trapped in the solid portion of the sample becomes more important in calculating R_d values from data. Neptunium values have been recalculated to correct for such contribution to the activity observed in the "solid" samples.

The R_d values measured for neptunium for G-Tunnel sample U12G-RNM9 by the circulating system method are virtually the same as those determined by the batch technique. The same traced feed solution was used for both sets of measurements. The R_d values for neptunium vary with the mineralogy ranging from 6.5 ml/g for sorption on the devitrified tuff to about 36 ml/g for sorption on the zeolitized sample from G-Tunnel. As is frequently observed, the desorption R_d values tend to be higher than those for sorption.

Batch sorption measurements in air and in a controlled atmosphere (nitrogen, less than 0.2 ppm oxygen, less than 20 ppm carbon dioxide) using a neptunium-traced feed solution are in progress. Tuffs from U12G-RNM9, as well as tuffs YM-22 (devitrified characterization) and YM-38 (zeolitized characterization), are being studied.

Preliminary results suggest that there may be factor-of-two differences between the controlled-atmosphere measurements and those made in air for the zeolitized tuffs YM-38 and U12G-RNM9, with sorption under reduced-oxygen conditions being greater. Duplicate samples were run where possible and, as can be seen from the standard deviations of the numbers, agreements are fairly good.

Plutonium batch and circulating system sorption and desorption contacts have been completed; however, sample counting is still in progress. In the batch experiments, a number of the crushed-tuff samples were pretreated with ground-water for longer periods than the routine two or three weeks to investigate possible differences in sorption resulting from self-grinding of the crushed rock before start of sorption. The results are inconclusive; the majority of data for 20- and 132-day pretreatment times are in agreement. Where this is not true, the short treatment time appears to give anomalously high values, which is inconsistent with other experiments relating sorption and particle size.

The average R_d values from batch measurements are consistent with those measured previously with tuffs having similar mineralogies. The devitrified tuffs G1-1883, YM-54, and YM-22 gave R_d values (standard deviations) of 76(12), 84(17), and 140(40), respectively. The R_d values of 180(20) and 300(90) for the zeolitized tuffs YM-49 and U12G-RNM9 are comparable to the earlier measurement of 250(90) for tuff YM-38.

Sorption results obtained from batch and circulating system measurements with plutonium were compared. The initial concentrations of plutonium in the feed solutions for this series of experiments were $3.1 \times 10^{-12}M$ for YM-49, $4.1 \times 10^{-12}M$ for JA-37, $4.1 \times 10^{-12}M$ for G1-1883, and $4.8 \times 10^{-12}M$ for U12G-RNM9. To eliminate any variation resulting from the preparation of the feed solutions, the same traced solution was used for both batch and circulating system contacts for a given rock. One of the initial reasons for comparing batch and circulating system results was to determine whether fine particles that were produced during pretreatment shaking of the rock in the batch procedure were leading to higher observed sorption ratios. The differences in results from the two techniques cannot readily be explained in this manner. The batch R_d value for the JA-37 tuff, which is relatively high in montmorillonite, appears to be higher than the value obtained with the circulating system: 510(100) vs 290(30) ml/g. This could be a result of the higher accessibility of the clays in the batch samples; however, the zeolitized samples YM-49 and U12G-RNM9 show somewhat lower sorption with the batch method although the accuracy of the data is poor. No large particle-size effects have been observed for sorption on zeolitized tuffs in other experiments.

Batch studies of the dependence of plutonium sorption on concentration have been repeated using tuffs YM-22 and YM-49 as before. As nearly as possible, the feed solutions for the new experiments were prepared as were those for the earlier measurements. Variations in the "added" plutonium concentrations were mostly a result of differences in isotopic composition of the ^{237}Pu used and the amount of decay that occurred prior to the start of the feed preparation. Within the accuracy of our results there appears to be little correlation between sorption ratio and element concentration in the range studied.

Microautoradiography Studies

A series of 14 filters from the preparation of feed solutions containing both ^{237}Pu and ^{239}Pu of five different concentrations were studied by microautoradiography (MAR). The solutions had been passed first through 0.4 micrometer

Nuclepore polycarbonate filters and then through 0.05 micrometer filters. The differences in plutonium concentration did not affect the results obtained. All the 0.4 micrometer filters contained mainly colloidal or aggregated species, as well as most of the activity removed by filtering. Only one of the 0.05 micrometer filters contained any aggregated species, but it showed predominantly single tracks. All the other 0.05 micrometer filters contained single tracks only. The first 0.4 micrometer filter was, therefore, effective in removing essentially all aggregated plutonium species greater than 0.05 micrometer.

Dependence of Sorption Ratio on Particle Size

Batch sorption ratio measurements are in progress to determine whether very small particles (less than 38 micrometers) of tuff have significantly different sorptive properties from larger particles. These experiments address the question whether small particles that are present in fractions such as the less than 500-micrometer fraction contribute significantly to the observed sorption ratios. It was anticipated that the results of these experiments would be pertinent to the interpretation of the observed differences between sorption ratios from batch and column experiments. In the latter, all material was greater than 35 micrometers because of the size of the frits used.

The batch sorption experiments were done in duplicate with three different particle sizes: less than 38 micrometers, 38 to 106 micrometers and 106 to 500 micrometers. Each fraction was washed prior to treatment on or through the appropriate sieves with water from well J-13. Six tuff samples were selected for these experiments: G1-2363, G1-2289, G1-1883, G1-3658, YM-38, and YM-54. The tracers were ^{137}Cs , ^{85}Sr , ^{133}Ba , and ^{152}Eu . Contacts were for three weeks at ambient temperature under atmospheric conditions. Samples of each fraction of each rock are being analyzed by X-ray diffraction.

Available results of these experiments for samples G1-2363 and G1-1893 both nonzeolitized tuffs, sorption ratios are higher by a factor of two to four for the smaller (less than 38 micrometers) particle size. Such a difference between particle sizes has usually been the observed difference in sorption ratios measured by batch (less than 500 micrometers) and by column experiments for nonzeolitized tuffs.

For the zeolitized tuffs, G1-2289 and YM-38, the effect of very small particles (less than 38 micrometers) on the sorption ratios is not so noticeable as for the nonzeolitized tuffs. Sorption ratios for cesium, strontium, and barium on sample G1-2289 are very high, which is consistent with previously observed relationships between sorptive behavior and mineralogy.* In any case, sorption ratios for cesium, strontium, barium, and europium are high for zeolitized tuffs, and differences in values are more difficult to observe.

*Prior data obtained from sample G1-2289 showed rather low sorption ratios for those elements. It cannot be explained at this time why these low values were obtained.

Results of the X-ray diffraction analyses for some fraction sizes indicate there is very little difference in mineralogic composition between the very small and the larger fractions. It seems then that the observed difference in sorption ratios for nonzeolitized tuffs is due to some factor other than mineralogic composition. It was observed though that for tuff G1-2363 there was a noticeable difference in the types of feldspars in the coarse and fine fractions. Further investigations will have to be performed to determine the effects of fine particles on the sorption of radionuclides.

Crushed-Rock Column Studies

In earlier comparisons of batch and column data, it has been noted that, particularly for devitrified tuffs, R_d values calculated from column data are generally several times smaller than those obtained by batch techniques. When batch measurements were repeated with washed fractions of sample G1-1982, the R_d values obtained were significantly smaller (for all fractions greater than 38 micrometers) than earlier measurements on unwashed fractions. Similar measurements on sample G1-1883 and G1-2363 also gave lower R_d values. The results from the batch measurements of the greater than 38-micrometers, washed fractions are in much better agreement with those from the columns than were the results of earlier comparisons. The average ratio of R_d values from batch measurements to those from column experiments for six samples is 1.1 ± 0.1 . Batch R_d values for two fractions (less than 38 micrometers and less than 500 micrometers) containing fines also agree fairly well with each other, thus indicating that the fines present in the less than 500-micrometer sample contribute substantially to the measured sorption ratios. Sorption ratios for wafers of G1-1883 and G1-1982 tuff are similar to those on the greater than 38 micrometer washed fractions and significantly lower than the batch R_d values reported for the less than 500-micrometer fraction.

The reason for the large effect from less than 38 micrometer particles is not known. The X-ray diffraction analyses of the various fraction sizes indicated no differences in mineralogy such as, a concentration of clay in the fine fractions.

An experiment with a crushed-rock column, 8-cm long by 0.5-cm in diameter, of G1-1436 tuff, which is highly zeolitized, has been completed. Solutions of HTO and $^{131}\text{I}^-$ were passed through the column at a flow rate of about 11 m/yr to investigate the effect of a very slow flow rate on the elution of I^- . There was a distinct effect. The $^{131}\text{I}^-$ had a larger apparent migration velocity than the HTO. "Anion exclusion" by materials with high cation exchange capacities whose negative charges cause an early breakthrough of the migrating anion has been reported. This experiment should be repeated to verify the results; the elutions of HTO and I^- were identical for a number of other columns with flow rates about two to three orders of magnitude faster.

A column of YM-5 tuff, with the approximate composition of 70 percent glass, 10 percent clay, 15 percent alkali feldspar, and 5 percent quartz, was prepared. After elution of ^{131}I , the column was loaded with ^{85}Sr , ^{137}Cs , and ^{133}Ba . This is the second glassy tuff run as a crushed-rock column. The first, G1-1292 tuff, a vitrophyre, gave the only broad elution curve yet observed for ^{85}Sr .

The other crushed-rock column prepared recently was from JA-18 tuff. Elution of ^{131}I was completed, and an experiment with ^{241}Am will be started.

Although work with crushed-granite columns is not directly related to the NNWSI, some of the results are reported here because the inferences on possible sorption mechanisms may indeed have a bearing on tuff. The flow of two granite columns was stopped, and the columns were sectioned and counted. One of the columns, CS-7#1, which had been loaded with ^{85}Sr , ^{137}Cs , and ^{133}Ba 2.69 a year previously, still retained 65.5 percent of the ^{137}Cs and 17 percent of the barium. The rest (34.5 percent) of the ^{137}Cs had been eluted in a very broad band whose peak corresponded to an R_d value of 289 ml/g. Of the cesium remaining on the column, 66 percent was still at the load point, and the rest was distributed in decreasing amounts between the load point and the exit. No cesium was detected on any of the column fittings or tubing. Cesium was not being eluted at the time the column was stopped which implies that there is more than one mechanism for the exchange of cesium between the rock and groundwater and its subsequent elution. Of the 17 percent of the barium which had not been eluted and remained on the column, the majority appeared to be irreversibly sorbed; 74 percent was still at the load point.

The other granite column that was terminated had been loaded with ^{95m}Tc and ^{152}Eu . After the column had been run at a flow rate of 22 m/yr for 284 days, neither ^{95m}Tc nor ^{152}Eu had been detected in the effluent. After the column was sectioned and counted, the distribution coefficients were inferred from the point at which 50 percent of the activities were detected. Technetium had an R_d value of 610 ml/g, and the R_d for europium was 759 ml/g. The batch R_d values for europium were 211 to 1,960 ml/g. The batch R_d values for technetium ranged from 32 to 160 ml/g on a 106- to 150-micrometer fraction. Larger-size fractions gave 0 ml/g. The fraction size used in the column was 38 to 106 micrometers.

Whole-Core Column Studies

Of the 22 whole-core tuff columns that were prepared for running at low pressure with a syringe or peristaltic pump, only seven are flowing fast enough (0.1 to 0.9 ml/g day) to be useful. Those seven are cores of G1-2410, G1-2233, G1-2854, G1-2901, G1-2698, G1-2289, and G-Tunnel tuffs. Columns G1-2698, G1-2901, G1-2854 (fracture), G1-2233, and G-Tunnel were loaded with 5-microliter spikes of ^{85}Sr , ^{137}Cs , and ^{133}Ba and have been running for about 200 days. None of the nuclides have been detected in the effluents. This result is not surprising for the G-Tunnel, G1-2698, and G1-2233 cores, which all contain significant amounts of zeolites. The free-column volumes of these cores were determined using ^{95m}Tc and ^{131}I . A whole-core column of YM-54 tuff is running slowly, but may be used anyway for comparison because a large number and type of experiments were done with that particular welded tuff from the Bullfrog Member of the Crater Flat Tuff. Free-column volumes for cores G1-2410 and G1-2289 are now being measured with ^{131}I and HTO.

Dependence of the Distribution Coefficient on the Freundlich Isotherm

The effects of nonlinear isotherms on sorption phenomena are being explored. Equations and computer programs to solve the diffusion equations with nonlinear isotherms are being developed. In the course of this activity, some simple relations have been derived that can explain the dependence of the distribution coefficient (K_d) on the solution-to-solid ratio. The results of experiments in which the solution-to-solid ratio was varied can be directly compared with the results of measurements in which the tracer concentration was varied (isotherm determinations).

Matrix Diffusion: Diffusion with Nonlinear Sorption

The isotherm measurements on tuff YM-22 show that sorption of simple cations of strontium, cesium, and barium give Freundlich isotherm exponents of less than 1.0. A nonlinear isotherm complicates the equations for matrix diffusion by giving the diffusion coefficient a concentration dependence, thus rendering the differential equations nonlinear.

The Freundlich isotherm presents special problems in the solution of the diffusion equations because, for a Freundlich isotherm parameter less than one, the K_d is infinity for a concentration of zero and the apparent diffusion coefficient is zero. In a finite-difference analysis of the problem, no diffusion can occur unless the initial concentration in the rock is greater than zero. This means that either an arbitrary cutoff must be given to the Freundlich isotherm, below which it becomes linear, or the initial conditions must be altered to arrive at a solution. This problem does not exist for the Langmuir isotherm. The applicability of the Langmuir isotherm to our data is now being investigated.

Another phenomenon that leads to a nonlinear diffusion equation is fixation, where some fraction of the ions are irreversibly fixed in the matrix. This problem is nearly identical to that presented by Crank for simultaneous diffusion with a bimolecular reaction.

A computer program utilizing the finite difference method is being developed to apply some of the mechanisms to matrix diffusion. The program will eventually be incorporated into a transport model so that a more realistic model can be developed.

Matrix Diffusion and Related Solute Transport Properties of Fractured Tuff

Pore-size distribution measurements have been completed on 10 tuff samples using mercury infusion porosimetry. The pore-size measurements were made for pores with theoretical diameters (based on the Washburn equation) ranging from 10^{-1} cm to 10^{-5} cm.

In order to summarize the porosimetry data, the volume of mercury intruded at each pressure was divided by the total volume intruded at the maximum porosity pressure (approximately 2,000 psi). The fractional volume intruded for each sample was then multiplied by 100 to obtain the cumulative percent of the porosity for pores with diameters greater than 10^{-5} cm. The Washburn equation was then used to compute the theoretical pore diameter corresponding to each measured pressure.

Nearly all of the porosity in these samples is due to pores less than 10^{-2} cm in diameter. In most of the samples, over 50 percent of the porosity is due to pores less than 10^{-4} cm (1 micrometer) in diameter. Possibly half of the samples contain a large fraction of their porosity in pores less than 10^{-5} cm in diameter.

Measurements of grain density are in progress for the tuff samples for which the pore-size distributions were determined. Until the grain density measurements have been completed, the total porosity of these samples cannot be completed and construction of total pore-size distribution curves cannot be done. A preliminary evaluation of the extent to which the pore volumes determined from the porosimetry approach the total pore volumes of the samples can be made, however, by comparing the apparent grain densities computed from the porosimeter measurements to grain densities for other tuffs from the NTS determined by Manger; Manger reported that grain powder densities for samples of the Paintbrush Tuff ranged from 2.2 to 2.5 g/cm³ with an average of approximately 2.33 g/cm³. If one assumes that the grain powder density of the grains composing the tuffs at the NTS is relatively uniform, then the apparent grain densities give an indication of the portion of the pore volume that could not be measured on our porosimeter.

Fracture Flow: Laboratory Experiments With Isolated Fractures

The elution of ⁸⁵Sr and ¹³⁷Cs was observed in flow through two fractured tuff samples taken from cores from the USW-G1 drill hole at the NTS. The tuff samples, G1-2335 and G1-2840, are welded tuffs from the Bullfrog and Tram Members, respectively. The cores are 2.54-cm in diameter by 4.76-cm long and contain tensile fractures (artificial fractures). Forty-milliliter "slugs" of groundwater traced with ⁸⁵Sr and ¹³⁷Cs were passed through the fractures.

The breakthrough curves were compared with the curves predicted by the analytic solution to flow through a one-dimensional fracture coupled to diffusion into the matrix. The fracture volume and the fracture aperture, in particular, were determined using Darcy's law. The tuff samples were not placed under confining pressure because the samples were found to seal under moderate pressure (about 1,000 psi), whereupon the fracture permeability was reduced to the same magnitude as the matrix permeability.

The flow through the fracture was straight flow, enabling direct comparison with the one-dimensional calculations. The theoretical curves were calculated using the R_d values from batch measurements (called "batch K_d values" in this section) for the K_d value in the calculations and using a lower value to get a closer fit to the experimental results.

The results of the fracture-flow experiments with tuff samples from cores G1-2335 and G1-2840 were not in agreement with the calculation if the batch K_d values were used. The K_d values which gave the best fits to the breakthrough portion of the strontium elution were 30 ml/g and 16 ml/g for samples G1-2335 and G1-2840, respectively. The batch measurements yielded 148 ml/g and 160 ml/g for samples G1-2335 and G1-2840, respectively. A general trend that has been observed in sorption experiments on tuff is that batch measurements

yield K_d values that are three to five times larger than the K_d values that are determined by column experiments. These experiments were consistent with that trend. In addition, the shape of the elution calculated for the tuffs is not in agreement with the observed elution. The activity desorbs more slowly than would be expected for reversible, diffusion-controlled sorption. This observation is also consistent with previous measurements of sorption on tuff. In general, the K_d values determined by desorbing activity from tuff are considerably larger than those determined from the sorption process. The cesium runs could not be fit by simply lowering the K_d values. When the batch K_d values were used, the expected peak arrival time was off-scale with respect to the experimental peak. Lowering the K_d values, however, brought the peak arrival time closer to the experimental, but the area under the curve became much greater than the experimental curve. In conclusion, a satisfactory fit to the experimental elution curves for cesium could not be achieved using the simple matrix diffusion model.

Behavior of Pu(IV) Polymer

The migration of radiocolloids through geologic media is of interest because a number of fission-product and transuranic species can exist in polymeric forms or as pseudocolloids. A study of Pu(IV) polymer was initiated with the ultimate goal of investigating its interaction with tuff and its potential for migrating through porous and fractured tuff. The immediate goal of this study was to characterize the behavior of dilute Pu(IV) polymer solutions using the techniques of centrifugation, filtration, and microautoradiography.

A stock solution of Pu(IV) polymer, about 5×10^{-3} M in Pu(IV) and about 4×10^{-2} M in HClO_4 , which was provided by T. W. Newton, had been purified on a cation exchange column, and its characteristic absorption spectrum had been verified. For most of the work reported below, this stock solution was diluted with 4×10^{-2} M HClO_4 to a Pu(IV) concentration in the 10^{-6} M range. Centrifugations were done at 12,000 rpm (28,000 g) for a period of one hour. Filtrations utilized 13-mm-diameter Nuclepore polycarbonate filters with pore sizes of 0.4 micrometers and 0.05 micrometers. Kodak NTB-3 nuclear track emulsion was employed in the microautoradiography and was applied either to glass slides on which the Pu(IV) solution had been dried or to filters which had contacted the plutonium aqueous phase. The presence of aggregated species in aqueous phases or on filters was indicated by "stars" and dense spots on the autoradiographs. These aggregates may include polymeric species, colloids, and pseudocolloids.

The following observations were made concerning Pu(IV) polymer in 0.04 M HClO_4 :

- a. Neither the 0.4-micrometer nor the 0.05-micrometer polycarbonate filters appeared to be effective in removing the polymer from the aqueous phase. Plutonium was sorbed on these filters to some extent as indicated by numerous single tracks in the autoradiographs, but the general absence of stars showed that effective removal did not take place.
- b. Centrifugation at 28,000 g removed a large fraction of the polymeric material. Treatment of the centrifuged material in an ultrasonic bath caused it to be redispersed in approximately its original concentration.

- c. The conditions under which solutions are dried may affect the appearance of autoradiographs. In general, a solution containing polymers dried on glass gives rise to more and larger stars than does that solution dried on a polycarbonate filter.

The observation with respect to the inefficiency of the filters is in agreement with work by Lloyd and Haire who reported that 95 percent of plutonium colloids formed in a nitrate solution passed through 0.01 micrometer Millipore filters. Other workers, however, have reported the successful use of filters with Pu(IV) colloids. Neither of these groups examined the filters with microautoradiography.

The observed efficiency of high speed centrifugation for removing substantial amounts of polymeric Pu(IV) corresponds with literature reports. An "order-of-magnitude" calculation based on our centrifuge geometry and the assumption of a colloid particle density of about 6 g/cm^3 indicates that particles of diameter $\geq 5 \times 10^{-3}$ micrometers were removed during centrifugation.

The use of microautoradiography to identify the presence of polymers can be extremely useful. However, as this study illustrates, one must be careful that the stars found in the autoradiographs are not artifacts caused by aggregates produced in the solution drying process. Our efforts are continuing to develop techniques for quantifying dilute radiocolloids.

Plutonium Chemistry in Near-Neutral Solutions: The Plutonium(IV) Polymer

The existence of bright green suspensions of Pu(IV) polymer has been known for a long time. The Pu(IV) polymer is of interest for environmental reasons and also because it is probably related to the nonreactive Pu(IV) that was observed to form in very dilute solutions.

Suspensions of the polymer were prepared by diluting Pu(IV) in HCl-HClO₄ mixtures, rather than by using nitric acid as previously described. The formation of polymer was observed to be much slower than reported for nitric acid solutions, but after ionic species were removed with a cation exchange resin, the spectra of our preparations were essentially the same as those reported. In a second method of preparing the polymer, Pu(VI) in HClO₄ was partially neutralized with an NaOH solution, followed by heating to 90 °C for 30 minutes. The spectrum of the suspension prepared in this way and treated with a cation exchange resin agreed with published spectra.

Storage Capacity and Permeability

The method of measuring permeability has been modified so that the storage capacity as well as the permeability of a specimen can be determined. Storage capacity is the additional volume of fluid that can be stored in a unit volume of rock by a unit increase in pore fluid pressure. The storage capacity is a function of both the porosity and the compressibility of the pores. When the fluid pressure in the pores is increased, the amount of fluid stored is increased by compression of the fluid and enlargement of the pores.

Analysis of the measurements of various tuff samples is still being refined; however, the values of both permeability and storage capacity are surprisingly low when compared to granitic rocks. The values for tuff and granite are nearly equal although those for tuff tend to be slightly higher. This result is surprising because granitic rock porosities are typically 1 percent or less, and tuff porosities are generally in the 10 to 40 percent range. Further, in a given rock, permeability varies roughly as the cube of the porosity. Clearly, the pore structures of granites and tuffs differ considerably.

The similarity in storage capacity is also surprising. Almost all the storage capacity of a granite is a result of the compressibility of the pores; it has very little pore volume in which to store fluid by compression. Approximately half the storage capacity of a typical tuff arises from fluid compression. The pore compressibility is roughly equal for the two rock types. While increasing the effective confining pressure on a granite from 0 to 30 MPa may decrease the porosity a factor of two, the effect of such a change on a tuff would be negligible.

Examination of tuff in thin-section generally shows large round pores. This is clearly the nature of most of the porosity of tuff. However, if channels the size of the pores existed through the tuff, the permeability of the tuff would be much higher than is observed. There must be, rather than continuous large channels, large pores connected by a network of small channels that constrict the fluid flow. Further, to account for the low pore compressibility, the large pores in particular, and perhaps even the small channels, must be rather round in cross section.

Refinement of a model for the pore structure of tuff will not only enhance understanding of its permeability, but will aid in understanding diffusion into the bulk rock. Very preliminary evidence indicates that the observed permeability may be a function of the distance over which permeation occurs. Relating this observation to the pore structure may indicate whether or not such a dependence can be expected in diffusion coefficients.

Anion Analyses of Groundwaters

Refinement of parameters for ion chromatography continued. The detector response above approximately 30 mg/l carbonate is not linear. Nonlinearity is especially troublesome in comparing samples from a controlled atmosphere with air-exposed samples. Because the carbonate solution peak is broad, greater sensitivity in distinguishing concentration differences can be obtained by running diluted samples at a comparatively high instrumental sensitivity setting.

An HP-3390A integrator was connected to the ion chromatograph for digitizing the detector output for anions of strong acids. In general, instrumental conditions have now been determined that will permit both detection of usually low-level components, such as nitrate and phosphate, to concentrations as low as 1 mg/l and also detection of higher level, higher response components such as chloride and sulfate. Because the chloride peak is strong in comparison to

the peaks of other anions, samples with chloride concentrations ≥ 20 mg/l have to be rerun for chloride alone at a lower sensitivity setting or be diluted. If not, a signal overrun is flagged on the integrator. So, in some cases, dilutions and multiple injections of samples must be made for optimum sensitivity of both types of components.

Groundwater Analysis

Water samples have been taken at two different times separated by 35 days of pumping from well UE25b-1 at Yucca Mountain. These samples were returned to Los Alamos for chemical analysis.

At the time of sampling on August 7, 1981, water from the well was also introduced into a closed stirred cell where the Eh, pH, $E_{S^{2-}}$, temperature, and oxygen content were measured.

The -75 MV output of the sulfide electrode indicates the concentration of S^{2-} or HS^- is $< 10^{-10}$ M and probably is due to the sulfide in the electrode's membrane. The relationship between Eh and $E_{S^{2-}}$, however, may be a useful measure of oxygen poisoning and should be about 180 MV if the electrodes are not poisoned and oxygen is absent. Our Eh- $E_{S^{2-}}$ value of 295 MV is too large, so perhaps the Eh electrode was poisoned by air. On the other hand, it is reasonable to have a positive Eh value indicating an oxidizing water because the water from the well was still foaming, indicating that all the drilling fluids, which originally contained air, had not been eliminated from the water in the well. Similar measurements were not made during the later sampling because the well water was still foaming.

It has been shown previously that unfiltered waters or even waters filtered through 0.45-micrometer membranes contain suspended iron solids that can be removed on further filtration through 0.05-micrometer Nuclepore membranes. As expected, the filtering step through 0.05-micrometer Nuclepore membranes reduced the iron content drastically for both of the water samples collected 35 days apart. No other large differences between samples were noted due to this filtration step.

The acidification step after filtration appeared to result in a slight increase in the concentration of virtually all the cations. Whether or not this is reproducible is not known at this time. The increased cation content, however, is not from the acid itself because J. T. Baker Ultrex HNO_3 was used. Metallic impurities in this acid are all less than 30 ppb and only 2 ml of acid was used in 50 ml of solution.

Two large changes can be noted in cation concentration with length or time of pumping. The lithium content decreased greatly, as expected. Lithium chloride had been added during the well drilling to serve as a tracer to show when the well had been pumped enough to infer that formation water was being pumped from the well. However, the lithium content after more than 13 million gallons had been pumped was still not down to background levels of approximately 0.050 mg/l. The manganese content also decreased drastically between the two pumpings. No reason for this can be offered at this time.

Modeling of Groundwater Interactions

The results of a preliminary search for free-energy data at 25°C for some of the mineral phases found during exploratory drilling at or near Yucca Mountain were obtained. The reactions of primary interest are the formation of the minerals from aqueous species. Equilibrium-constant or free-energy data were obtained for these formation reactions from a particular basis set of aqueous species. Data were found for silica (crystalline and amorphous forms), alkali feldspars, some clays, and one zeolite (analcime). No data were found for three other zeolites observed at Yucca Mountain: clinoptilolite, heulandite, and mordenite. Free-energy data were estimated for these minerals by three different techniques. Many of the minerals of interest actually exist as solid solutions; however, few thermodynamic data are available for solid solutions.

1.3.2.2.2 Mineralogy/Petrology

Objective: To determine the major mineral phases present in strata encountered in the drilling exploration program and to determine their relative abundances, textural relationships, chemical properties, and stability relations where appropriate.

Studies of Drill Cores from USW-G2 and UE25b-1h

Drill hole USW-G2 was recently completed to a depth of 6,000 feet at a spot north of the exploration block in Yucca Mountain; also, drill hole UE25b-1h was completed to a depth of 4,000 feet, just north of the previous shallower drill hole UE25a-1. Samples from both of these new drill holes recently became available and our detailed mineralogic and petrologic studies of these samples will be completed during the second quarter of FY 1982. Therefore, a much more thorough discussion of these cores will be presented in the next quarterly report. However, the X-ray diffraction studies of cores from both of the new drill holes are complete and the results can now be presented.

The results of the X-ray diffraction studies of USW-G2 and UE25b-1h are significantly different from the previous study of USW-G1. Some of the outstanding differences involve the distribution of zeolite minerals critical to the naturally sorptive barriers proposed in most tuff-based repository models. Unlike USW-G1, and unlike the previously studied drill holes at Yucca Mountain, USW-G2 contains a prominent zeolitized horizon well above the present water table. This horizon is marked by 10 to 90 percent clinoptilolite-rich tuff at depths of 548 feet to 762 feet in USW-G2. These depths include most of the Pah Canyon Member and the uppermost Topopah Spring Member of the Paintbrush Tuff. It is possible that the densely welded zone high in the Topopah Spring Member may have acted as a local aquitard, creating a perched water table that would cause extensive zeolitization this high in the section. The suggestion of a perched aquitard is reinforced by the absence of abundant zeolites from 770 feet to 1,536 feet below the zone described and including almost the entirety of the central Topopah Spring Member which is somewhat less welded and should be readily zeolitized if saturated.

Clinoptilolite again occurs in abundance at 1,634 feet in USW-G2, and remains abundant to a depth of 2,430 feet. This depth interval includes the lowermost Topopah Spring Member, and most of the bedded tuff of Calico Hills. This is also a zone of abundant mordenite mineralization (1,691 feet to 2,667 feet). Below this interval is a gap of approximately 300 feet of unzeolitized tuff corresponding to welded zones within the Prow Pass Member of the Crater Flat Tuff. Dense zeolitization again occurs in the lowermost 200 feet of the Prow Pass Member (3,067 feet in depth to 3,250 feet in depth). The last abundant occurrence of clinoptilolite in USW-G2 is at 3,250 feet in depth, and the last abundant occurrence of mordenite is at 3,578 feet in depth. These final occurrences are at the base of the Prow Pass Member and at the base of the Bullfrog Member (Crater Flat Tuff), respectively.

The deepest occurrences of the sorptive zeolites clinoptilolite and mordenite is shallow in USW-G2 compared with USW-G1. In drill hole USW-G1 clinoptilolite last occurs at 3,850 feet, which is below the Tram Member of the Crater Flat Tuff. In USW-G1 the last abundant occurrence of mordenite is at 2,622 feet. Thus, there are at least two major differences between the zeolite distributions in USW-G2 and USW-G1: zeolites are abundant in restricted zones above the water table in USW-G2, and the depth distributions of zeolites are much shallower in USW-G2 than in USW-G1.

In UE25b-1h the last occurrence of clinoptilolite in abundance is at 3,092 feet (upper Tram Member), and the last occurrence of mordenite in abundance is at 2,919 feet which is also within the upper Tram Member. Thus the deepest occurrences of abundant highly sorptive zeolites are shallowest in UE25b-1h, almost as shallow in USW-G2, and deepest in USW-G1.

The less sorptive zeolite analcime can occur through the breakdown of more hydrous zeolites (for example, clinoptilolite) under the effect of increased temperature. Such alterations could lead to the facies-like overlapping assemblages of clinoptilolite-mordenite tuff and analcime tuff in USW-G1 and USW-G2. In UE25b-1h, however, there is a 200-foot gap between the last appearance of the more hydrous zeolites (clinoptilolite at 3,092 feet) and the first appearance of analcime (3,298 feet). This gap may be significant in evaluating conflicting hypothesis concerning the origins of zeolites at Yucca Mountain: either the zeolites may form in a system relatively closed to solution exchange but under a high thermal gradient, or the zeolites may form in an open system of downward-percolating cation-charged waters under a lower thermal gradient. This question will be dealt with in the forthcoming LANL report on USW-G2.

Clay minerals are almost ubiquitous throughout USW-G2, as in other drill cores obtained from other drill holes at Yucca Mountain. Swelling clays (smectites) are present in most samples but are generally scarce in the bedded tuffs of Calico Hills. The swelling capacities of the smectites undergo a transition at 3,500 feet where they pass from Na-saturation to K-saturation with a concomitant collapse and decrease of swelling capacity. Kaolinites appear below 3,500 feet in USW-G1 (3,362 feet in UE25b-1h), and chlorite appears below 5,500 feet in USW-G2 (UE25b-1h extends only to 4,000 feet).

Several fractures were examined in detail for the study of UE25b-1h. The fractures are of interest because they provided pathways for element movement in the geologic past. Fractures may also provide pathways for future waste element movement, particularly if the fractures are not completely sealed. The fractures in UE25b-1h commonly contain calcite in addition to the minerals in the fracture matrix. However, two fractures contain fluorite in substantial amounts. Also, a fracture with a brown band cutting the calcite contained todorokite, a manganese oxide hydrate common in marine deposits.

1.3.3 GEOLOGIC CHARACTERIZATION

Objective: To determine the geologic and hydrologic characteristics of candidate repository locations and to evaluate the feasibility of developing a mined repository.

1.3.3.1 Geologic Investigations

Objective: To locate and characterize rock masses on or near the NTS to determine their suitability for hosting a nuclear waste repository.

The USW-G1 drill-hole report, entitled "Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW-G1, Yucca Mountain, Nye County, Nevada," by R. W. Spengler and others, has been sent to the printer.

USW-G2 drilling, logging, and hydrologic testing have been completed except for static water-level checks; a total depth of 1,830.8 m was reached. The drill hole penetrated rhyolitic to rhyodacitic lava flows and flow breccia from 1,485.6 to 1,718.2 m with tuffaceous sediments at the base between 1,718.2 and 1,723.0 m. A thin ash-flow tuff is present at the base of the tuffaceous sediments at 1,723.0 to 1,728.4 m. A dacite lava flow and flow breccia were penetrated from 1,728.4 to 1,793.9 m with tuffaceous sediments at the base between 1,793.9 and 1,811.3 m. A thin ash flow is intercalated with the tuffaceous sediments at 1,804.8 m to 1,807.4 m. This thin ash-flow tuff could be equivalent to the upper part of the "older tuffs" penetrated in USW-G1. These "older tuffs" occur from 1,811.3 m to the total depth of the hole. Measurements of the fluid levels were made on November 18, 30, and December 9, 1981, at 521.5, 522.7, and 523.0 m, respectively.

The drill-hole report, entitled "Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW-G2, Yucca Mountain, Nye County, Nevada," by Florian Maldonado and others is being drafted.

The geologic map of the southwest quadrant of the NTS (nine 7 1/2-minute quadrangles) compiled by Florian Maldonado has been transmitted to the Technical Reports Unit after colleague review.

Drilling has been terminated at hole UE29a-2 at 421.5 m due to hole instability and related technical difficulties. After penetrating hydrothermally altered and silicified rhyolitic lavas at about 335 m, argillized tuffs were encountered in the tuffaceous beds of the Calico Hills. Hydrologic tests are now being conducted.

The USW-G3 and USW-H3 drill sites have been relocated along the crest of Yucca Mountain at the southern tip of the proposed repository boundaries. Site-criteria meetings for USW-G3 were attended by G. L. Dixon, R. W. Spengler, and R. B. Scott on December 4, and for USW-H3 by R. W. Spengler and F. E. Rush on December 14.

Detailed mapping of Yucca Mountain in the vicinity of the proposed repository has been completed by R. B. Scott and R. W. Spengler. Use of detailed stratigraphic zonation within the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff has allowed recognition of previously unrecognized minor, but abundant, normal faults in the southeastern portion of the proposed repository. In that area, closely spaced northwest-trending fractures, seen in the field and on aerial photographs as lineaments, are parallel to these faults. The pervasive fractures and lineaments are also present further to the north in the central part of the repository; although stratigraphic control is sufficient to recognize that larger faults are not associated with the fractures, this control cannot discount offsets less than 1 m. These faults and fractures may only represent surficial brittle behavior that does not affect more ductile rocks at greater depths and confining pressures; drill holes USW-G3 and USW-H3 will determine the depths of fracture and fault penetration.

Frank M. Byers (who has retired from the Survey, effective December 31, 1981) and R. B. Scott have finished thin-section petrography of samples from USW-G2.

A risk analysis was made for a TEF for the Yucca Mountain site (coupled and uncoupled) by G. L. Dixon, F. M. Byers, D. L. Hoover, R. W. Spengler, and R. B. Scott.

1.3.3.2 Geophysical Investigations

Objective: To determine the surface distribution and configuration of geologic structures, rock units, and rock physical properties on or near the NTS.

Gravity

The following report was released to distribution:

Ponce, D. A., and Oliver, H. W., 1981, Charleston Peak Gravity Calibration Loop: U.S. Geological Survey Open-File Report 81-985.

An abstract, "Gravity Interpretations of Yucca Mountain, Nye County, Nevada, and Its Implications for Southern Nevada Structure," by D. B. Snyder was published in EOS.

A report by D. A. Ponce and W. F. Hanna documenting gravity and magnetic studies at Syncline Ridge is in technical review.

Six of seven planned detailed gravity profiles across Fortymile Wash have been completed. A Bouguer gravity map within a radius of 100 km of Yucca Mountain at 1:500,000 has been generated by computer techniques.

Magnetics

Three of seven planned detailed magnetic profiles across Fortymile Wash were completed in November. A station spacing of 30 feet was employed and the profiles coincide with the previously obtained gravity data. The combined data should help resolve synclinal versus fault structures proposed to be related with Fortymile Wash.

Heat Flow

Analysis of data from 60 wells in and around the NTS, including 16 in the Yucca Mountain area, is nearing completion. Thermal conductivity measurements on tuffs from the Pahute Mesa, Oak Springs, and Yucca Mountain regions are also nearing completion. Formal estimates of heat flow indicate considerable variation on both regional and local scales. The variations are attributable primarily to hydrologic processes involving interbasin flow with a vertical component of velocity of a few millimeters per year. Apart from indicating a general downward movement of water of a few millimeters per year, the results from Yucca Mountain are as yet inconclusive.

Teleseismic Residual Studies

Teleseismic residual data have been inverted using a linear inversion technique to produce several three-dimensional P-wave velocity models for the NTS and surrounding region in southern Nevada.

In the three-dimensional inversion, the section of the earth under study is divided into blocks. Velocities in the blocks are perturbed until the observed residuals fit one or more of the models in a least-squares sense. The salient features of the model(s) are the following:

Upper Crust (0-15 km in depth)--A low-velocity body, 50 km long and 30 km wide, in which there is a maximum velocity decrease of about 6 percent (relative to surroundings) is observed in the northwest corner of the NTS. A smaller body with a 4 percent velocity decrease is located in the southwest corner of the NTS. These anomalies are part of a 200 km long, north-trending, low-velocity feature passing through most of the western half of the NTS. To the east and west of these features, velocities increase and then decrease again.

Lower Crust (15-30 km in depth)--In the lower crust, the velocity perturbations are of much lower magnitude. In general, the pattern is dominated by north-south trending features.

Upper Mantle (30-230 km in depth)--This region, covered by three layers in the inversion procedure, show in general, north-south trending bands of highs and lows with maximum velocity variations of about 5 percent.

1.3.3.3 Hydrologic Investigations

Objective: To determine the present and past hydrologic regimes of the NTS and surrounding area as a basis for predicting future hydrologic regimes and the potential for hydrologic transport of nuclear wastes to the accessible environment.

Hydrology of Candidate Areas

The manuscript describing the results of hydrotesting in well USW-VH1 has been completed and is being prepared for transmittal to the DOE in January 1982.

Two activities continue on well USW-H1: (1) Data interpretation and report writing, and (2) planning for the reentry of the well for hydraulic head monitoring. Water-level monitoring in the well indicates that the hydraulic head has stabilized at about 572.1 m below ground level.

Results of the pumping tests using wells UE25b-1 and UE25a-1 are being analyzed and will be incorporated into a report. The water level in UE25a-1 has stabilized at 469.3 m below ground level.

Water level in well USW-G2 was still declining as indicated by measurements throughout the quarter. The last measurement, made on December 7, 1981, showed a depth to water of 522.9 m below ground level. Measurements will continue on a semimonthly basis until static conditions are reached. A site has been staked for well USW-H3, and drilling and testing criteria have been written. For this well and several subsequent wells, emphasis has been changed from coring and detailed testing and sampling of a single well to a two-phase program involving four wells: (1) drilling and reconnaissance testing within a 60-day period for each well to provide a smaller initial data base at several well sites and (2) a proposed detailed testing and sampling program for selected wells to follow completion of the reconnaissance drilling and testing. Drilling of USW-H3, the first of these wells, should start in January 1982; completion of drilling and reconnaissance testing is scheduled for March 1982.

Hydrologic Modeling

Drill hole UE29a-2 was drilled to a depth of 421.6 m with strings of casing set to depths of 11.9, 48.8, 86.9, and 247.2 m. The hole subsequently caved and the present depth is approximately 355.1 m. All strings of casing are cemented to the surface except for the 27.3 cm casing that is set to 247.2 m. The hole was underreamed from 247.2 to 355.1 m to a diameter of 38 cm so that the 7.0-cm casing could be lowered. While trying to fit the casing, the casing was pulled apart at a depth of 57.9 m and the rig was damaged. Drilling was suspended and plans for testing the hole were made. Briefly, these included: (1) pumping and sampling UE29a-1 (drilled to a depth of 65.5 m but bridged at approximately 45.7 m); (2) pumping and sampling UE29a-2 from 247.2 to 355.1 m; (3) perforating the casing from 86.9 to 213.4 m and setting a bridge plug within the casing at 245.4 m; and (4) pumping and sampling from 86.9 to 213.4 m.

Depth to water in UE29a-1 is approximately 24.4 m; it is approximately 32 m in UE29a-2 (open below 247.2 m), indicating there is potential for downward movement of water. Pumping of UE29a-1 in early December indicated that the transmissivity of the hole from 24.4 to 45.7 m is low; this is in agreement with observations during drilling that the hole produced little water until a depth of 57.9 m was reached. Pumping of UE29a-2 between depths of 247.2 m and 355.1 m on December 23 and 25 indicate that the well should sustain pumping rates of 31.54 to 37.85 liters per second.

The high head (approximately 1,188.7 m above sea level), compared to heads in wells J-12, J-13, UE25b-1, and USW-H1 (approximately 731.5 m) may be caused by one or more of at least three possible explanations: (1) a block of low-permeability Eleana argillite extending outward from Calico Hills occurs between the Area 29 holes and J-13; (2) low-permeability volcanic rocks may be present between the Area 29 wells and J-13; and (3) recharge in upper Fortymile Canyon may have occurred recently enough (perhaps on the time scale of 10 to thousands of years) to have resulted in the high heads measured in the Area 29 wells. The chemical samples may provide data that will help answer this question.

1.3.3.4 Tectonics, Seismicity, Volcanism

Objective: To assess the potential for faulting, damaging earthquakes, volcanic activity, and accelerated erosion to affect long-term repository performance.

Tectonics

Geologic mapping has been completed of the volcanic and alluvial deposits of the Big Dune 15-minute quadrangle, which is located generally between southern Crater Flat and the Funeral Mountains. No faulting of definite Quaternary age has been found in this area. Several silicic ash beds were found in the alluvium; these may help to further refine the ages of the enclosing materials. The northern half of the quadrangle is being incorporated into the geologic map of the southwestern NTS area for the Site Characterization Report (SCR).

A report on the Plio-Pleistocene stratigraphy of the Lake Tecopa Basin, done for the project by J. W. Hillhouse of the Geological Survey, was received and reviewed. The Lake Tecopa Basin, about 80 km south of the NTS on the Amargosa River drainage system, is an area of important and well-exposed Pleistocene stratigraphy, which contains several dated silicic ash beds. Relations between alluvial units being mapped at the NTS, and dated lakebeds, are also well exposed. In general, the deposits of the Lake Tecopa Basin are younger than those upstream in the Amargosa Valley, and represent an important link in the geohydrologic history of the Amargosa drainage system.

The review and revision of a report on the interpretation of gravity of southwestern NTS by D. Snyder and W. Carr have been completed.

A reasonably firm correlation has been made by G. Izett and W. Carr of three occurrences of an ash bed in drill holes in Searles Lake and Frenchman Playas

and in a pit in the Amargosa Valley. This bed has been dated at about 3 million years, which yields rough rates of tectonic subsidence for the three areas of: Searles Lake basin, 0.7 feet per 1,000 years; Frenchman Flat basin, 0.2 feet per 1,000 years; and Amargosa Valley, essentially zero. These rough figures fit well with other evidence for rates of relative tectonic activity in these areas. Frenchman Flat is one of the most active basins at the NTS.

Planning for and working on the SCR has occupied much project time during the last part of the report period.

Seismicity

The principal zones of seismicity were the Rock Valley fault system, the Yucca Flat area, Sarcobatus Flat, and a region along the California-Nevada border west of Gold Mountain. One earthquake was located near Calico Hills just east of Yucca Mountain. The only focal mechanism obtainable from these data was a composite mechanism for two magnitude 2.7 events in the Sarcobatus Flat area that indicates right-lateral strike-slip on a north-northeast trending fault or a left-lateral strike-slip on an east-northeast trending fault.

At the end of this quarter, a computerized data recording and earthquake detection system was made operational. This system is much more accurate and efficient at detecting and locating earthquakes than human operators and will permit data processing to be kept up to date or, at most, two to three days behind recording time.

Volcanism Studies

A talk on "Strombolian Eruptive Sequences" was presented at the fall meeting of the American Geophysical Union. Data presented in the talk suggest a relatively low rate of magma rise (0.1 to 0.5 m sec^{-1} , bubble free regime) for Quaternary basalt eruption in the NTS region. Eruptive sequences preserved in the NTS region can be explained by variations in the mass eruption rate with time and by the history of bubble coalescence from the time of bubble exsolution to the time of bubble coalescence.

A draft of a paper "Calculation of the Probability of Volcanic Disruption of a High-Level Radioactive Waste Repository within the Nevada Test Site Region, USA" has been completed. It will receive final editing early in the next quarter and be submitted to the NNWSI to fulfill a program milestone. The paper develops a probability model for the occurrence of a volcanic disruptive event.

The probability of a disruptive event (p) is a/A where a is the area of a repository (for basaltic volcanism in the NTS region) and A is some minimal area that encloses the repository and the volcanic events used to describe λ . A computer program has been developed for determining A based on the distribution of volcanic center in the NTS region. The parameter λ can be determined through two procedures, either rate of magma production with time, or core counts of volcanic events over time.

Final revisions of a paper on "Aspects of Potential Magmatic Disruption of a High-Level Radioactive Waste Repository, Nevada Test Site" have been completed. The paper will be submitted to an outside journal for publication. Several new sources of data have been added to the paper. Final lithic fragment abundance calculations have been completed for scoria cones of the NTS region and the San Francisco Volcanic Field. Literature surveys and field studies were completed to establish cone:sheet ratios of Strombolian eruptive centers. A conservative ration of 4.5:1 was assigned for disruptive scenarios. Using this ratio the magmatic volume of all Quaternary basalt centers of the NTS region have been calculated. Finally, thin-section studies have been completed of lithic fragments in cone scoria. These data indicate a relatively shallow depth of derivation (less than 200 m) of fragments indicating incorporation during magma fragmentation (the point at which the bubble/magma ratio reaches 0.75).

1.3.3.5 Geochronology

Objective: To provide potassium-argon, fission-track, uranium-trend, and uranium-series ages on geologic samples for use in determining the history of geologic events and conditions in the NTS area.

Potassium-Argon Dating

During the last three months, no completed K-Ar ages were determined; only potassium determinations from analytical laboratories are being awaited to calculate final ages on eight basalt samples.

Uranium-Series Dating

Dating two samples of calcite filling in drill core from USW-G2 of welded tuff at Yucca Mountain has been attempted using the uranium-series method. The analytical data of these samples were submitted by W. J. Carr and F. Maldonado.

The first sample of coarse-grained calcite in a cavity at 343-m depth contained an unusually low uranium concentration (0.073+0.006 ppm) and a rather low $^{234}\text{U}/^{238}\text{U}$ activity ratio (1.02+0.03) as compared to the previously reported results on a series of samples of calcite-filling fractures in drill core from UE25a-1 (1-9 ppm of uranium and 1.17-1.47 of $^{234}\text{U}/^{238}\text{U}$, respectively). The cavity-filling calcite at 343-m depth has yielded a uranium-series age of 142,000+20,000 years B.P.

The second calcite sample filling fractures in drill core at 893-m depth contains somewhat higher uranium concentration (0.30+0.15 ppm) than the first sample and about the same $^{234}\text{U}/^{238}\text{U}$ activity ratio within limits of error (1.02+0.06). Because only about 0.2 g of clean calcite crystals were recovered from the fractures, the thorium analyses could not be carried out and no age could be calculated.

1.3.3.6 Drilling Plans and Engineering

Objective: To provide Project participants with technical support from the NTS contractors.

These support requirements are reported in the various task activity sections to which they are applicable.

1.3.3.7 Field Geology and Core Library Support

Objective: To provide and maintain a cadre of Fenix & Scisson geologists to support the Project participants, to provide and maintain core library facilities at the NTS for handling and storing rock samples, and to provide general NNWSI Project support to the USGS.

Fenix & Scisson geologists provided support to: (1) Subtask 1.3.3.1, for fracture/fault frequency, distribution of core from USW-G2, and detailed geologic mapping of the Yucca Mountain area; (2) Subtask 1.3.3.2, for compilation of geophysical field data; (3) Subtask 1.3.3.3, for monitoring and hydrologic testing of UE29b-2; and (4) Subtask 1.3.3.4, for continued field mapping of Quaternary deposits.

1.3.3.8 Weapons Test Seismic Investigations

Objective: To measure weapons-test-induced ground motion for determining its changes with distance, depth, and yield and to obtain site-specific ground motion data for evaluating potential repository sites.

SAND82-9174, "Effects of Repository Depth on Ground Motion-The Pahute Mesa Data," was sent to DOE/NV the last week in December. The following are the conclusions from the report:

The Weapons Test Seismic Investigation project has a net of ground motion measurement stations at seven locations where measurements were made on the surface and at an available depth. Depths at which measurements were made ranged from 61 m to 762 m. Measurements were made at some of the seven locations on several different Pahute Mesa weapons tests. This data set provides a base from which the effects of depth of measurement on ground motion can be assessed. The assessment made use of ratios (top/bottom) single peak vector accelerations, velocities, and displacements, averages of multiple peaks of the same parameters, and top/bottom ratios of PSRVs. Also, waveforms of the individual vertical, radial, and tangential components of the same three parameters were compared at top and bottom.

The amount of change between surface and a given depth is strongly dependent on the geology at the site of the measurements. Motions at depth relative to

those at the surface are little different at the site of the Climax granite pluton, but are quite different, especially in the horizontal components, at Rainier Mesa where topography appears to have exerted a greater influence than geology.

In spite of these relatively large site-dependent differences, an exponential least-squares fit to the ratios (top/bottom) was calculated. For single peak vector ratios:

Acceleration	$R = 1.479e^{-0.000867d}$	$r^2 = 0.282$
Velocity	$R = 1.059e^{-0.00163d}$	$r^2 = 0.494$
Displacement	$R = 1.082e^{-0.00118d}$	$r^2 = 0.322$

where R is the ratio of the peak vector value at the surface to that at the bottom, d is the depth to the bottom, and r^2 is the coefficient of determination.

Next, the peaks in the vector wavetrain were listed in order from the largest to the smaller ones. Then, the averages of a specified number of peaks was calculated and the ratio of the average (top/bottom) was determined. The number of peaks specified were 5, 10, 15, 20, and 25. Most of the change in ratio occurred for 5 and 10 peaks. Increasing the number of peaks from 15 to 25 produced relatively little change.

Where the average of the 15 largest peaks was used:

Acceleration	$R = 1.325e^{-0.00125e}$	$r^2 = 0.495$
Velocity	$R = 1.067e^{-0.00158d}$	$r^2 = 0.516$
Displacement	$R = 0.995e^{-0.00137d}$	$r^2 = 0.424$

PSRV (Psuedo Relative Response Velocity) plots were made for the vector values at the surface and at depth, and the ratio (top/bottom) plotted over a frequency range from 0.1 to 100 Hz. A mean value of the ratio over that frequency range was calculated and used as an index of the effect of depth.

Where these ratios are used:

$$R = 1.327e^{-0.000119d} \quad r^2 = 0.546$$

Using multiple peak values improves the coefficients of determination, and using the PSRV ratios improves them even more. While scatter in the ratios from one event to another is one cause of small coefficients, an even larger cause is the very strong effect of the local geology at the points of measurements. Ratios from the Climax granite are always smaller than those given by the fits listed above, and ratios from Rainier Mesa are always larger. No effect of yield on changes in ground motion with depth were discernable. A pronounced difference between motion at the surface and that at shallow depths

was seen for acceleration and PSRV ratios. This is evidenced by the fact that the constants in the fits listed above are well above 1.

Comparison of waveforms at the top with those at the bottom for acceleration, velocity, and displacement shows that for the depths examined there is relatively little change in the surface wave portions of the vertical motion, while the two horizontal components change markedly. Body wave portions of the wavetrain attenuate rapidly with depth.

1.3.4 HYDROLOGIC CHARACTERIZATION

(These task activities are included in Task 1.3.3.)

1.3.5 ENVIRONMENTAL CHARACTERIZATION

Objective: To perform the area-to-location screening and to inventory and analyze existing environmental information relevant to potential repository locations within the screening area.

1.3.5.1 Area-to-Location Screening

Objective: To develop the approach and to perform the area-to-location screening of potential repository rock units.

A series of 55 evaluations of repository locations in the screening area was performed. Seventeen of these were presented to the SEWG for review at a meeting in Albuquerque. The SEWG was asked to identify which sets of evaluations are appropriate for adequately representing the screening activity in the final recommendation report and to review the assumptions regarding attribute weights which were used in the evaluations. Work progressed on documenting the report data and objectives. The SEWG concurred that a series of five separate documents will be prepared to document the screening activity, allowing the recommendation report to be kept to a brief synopsis of pertinent results while four supporting documents detail, respectively, the method, input data and associated favorability graphs, objectives, and computer programs. Computer algorithms were developed for (1) accentuating the effects of low favorability attributes on the rating of otherwise favorable locations and (2) assessing the sensitivity of location ratings to the statistical variance contained in average weights assigned to the objectives. A presentation on the NNWSI Screening Activity was made at the NTS Annual Information Meeting in Columbus.

1.3.5.2 Environmental Area Characterization

Objective: To prepare an Environmental Area Characterization Report (EACR) that will be the initial data base for subsequent environmental impact analyses and to identify environmental factors and information significant for area-to-location screening.

Fieldwork planning meetings were held with the DRI Atmospheric Sciences Center and EG&G. Two DRI meteorologists were given a tour of Yucca Mountain along

with H. Church, SNL, who will be Technical Monitor for the meteorologic and air quality work. The WSNSO staff was briefed on the project.

Draft task descriptions were received from DRI/ASC and EG&G. Both will be finalized and work initiated early in January. Archaeologic study design has been delayed awaiting the seismologic study location definition. The archaeologic work will be initiated as soon as all potentially impacted areas are identified.

EG&G delivered a field report, "Survey of Yucca Mountain, Forty-Mile Canyon, and Jackass Flats in Nye County, Nevada, for Desert Tortoise, Gopherus agassizii." Tortoises were found between 3,400 to 3,800 feet in the eastern foothills of the mountain and along and south of the road to drill hole USW-G1.

A paper entitled "Status of NEPA Activities in the NNWSI Project" was presented at the NWTS Program Information Meeting in Columbus.

1.3.5.3 Horizon Selection Activity

Objective: To review and organize the technical information for evaluating, ranking, and selecting an at-depth horizon for further exploratory investigation.

1.3.6 SOCIOECONOMIC EVALUATION

(No NNWSI work funded this fiscal year.)

1.3.7 PERFORMANCE EVALUATION

Objective: To determine if new site performance evaluation techniques and/or more detailed data must be developed, particularly for basaltic volcanism, and to perform sensitivity evaluations in support of site characterization and performance evaluation.

A report of the radiological consequences of basaltic volcanism was reviewed and revised for early 1982 NV review.

1.4 REPOSITORY

Objective: To establish the technological basis for repository development necessary to assure adequate repository and waste package containment and isolation capabilities.

1.4.1 REPOSITORY BASELINE

(No NNWSI work funded this fiscal year.)

1.4.2 REPOSITORY DATA BASE DEVELOPMENT

Objective: To develop the information needed to support the development of an adequate repository design.

1.4.2.1 Tuff Investigations

1.4.2.1.1 Laboratory and Modeling

Objective: To investigate several long-term effects of repository conditions on tuff.

Model Development

A report documenting benchmark room-and-pillar calculations completed with a ubiquitous jointed material model is scheduled to be completed by Sandia and RE/SPEC in mid-January.

Computation tools for predicting flows through porous media containing regions which are not necessarily fully saturated (referred to as "partially saturated") have been developed using the existing COYOTE and MARIAH codes. The approach taken was the following:

- a. Modify the time-dependent, finite element, heat conduction code COYOTE to make it applicable for calculating isothermal flow of water through partially saturated porous media. This code will be referred to as COYOTE/UNSAT.
- b. Extend the finite element code MARIAH, which was originally written to calculate mass and thermal transport through saturated porous rock, to a code which is applicable for analyzing heat and mass transport through porous material with regions which are partially saturated. This code will be referred to as MARIAH/UNSAT.

Both of these revisions of the codes are based on the Richards flow equation and have two-dimensional capabilities (axisymmetric or planar). Motivation for developing the computational capabilities within Sandia are two-fold: (1) Assure compatibility between our partially saturated computation studies and associated thermal and stress calculations done within Organization 5500, and (2) In-house development will make it possible to combine the statistical

fracture work currently being done by D. Gartling, 5511, and B. Thomas, 5521, with the partially saturated flow model.

The number of codes existing with similar capabilities is very limited. One such code is the one-dimensional finite-element code developed by Baca and King. The equations solved in both the Baca Code and MARIAH/UNSAT are similar. However, the Baca Code uses a log transformation for the pressure which results in the code being inapplicable to completely saturated regions. This restriction is seldom significant for doing near-surface calculations in arid site vadose zones; the region for which the Baca Code was written. This restriction could be limiting for analyzing regions in tuff where both fully saturated and unsaturated rock are found.

Rock Physics Studies

A review has been completed that covers the likelihood of creep failure in rock types that might be selected for a high-level nuclear waste repository. This review will appear in the Proceedings of the Workshop on Near-Field Phenomena in Geologic Repositories for Radioactive Waste under the title "Importance of Creep Failure of Hard Rock in the Near Field of a Nuclear Waste Repository." Although damage resulting from slow creep deformation may seem unlikely for a hard rock, experiments and models indicate that time-dependent microcracking and water-induced stress corrosion can lead to significant reductions in rock strength. Model extrapolations under dry conditions at 20 MPa confining pressure suggest small failure zones in the rib of the model repository room in hard rock during the first few years of operation. However, at 30 to 100 years the modeled failure zone grows dramatically to completely encompass the near field of the room. Such a situation would be likely to prevent access being maintained.

Failure problems may be exacerbated under hydrous conditions. Extrapolations from existing experimental data suggest a 30 percent to 50 percent reduction in the compressive strength of granite over the 100-year time range critical to a repository under water-saturated conditions. This estimate is based on extrapolations; the data for tuff are even less complete but suggest weakening comparable to that in water-saturated granite.

The review concludes that, contrary to intuition, creep deformation will occur under nuclear waste repository conditions, and this deformation can cause design problems. Coupled phenomena make this conclusion even stronger. For instance, dilatant microcracking can cause a decrease in thermal conductivity leading to higher rock temperatures than those predicted by current models. A thorough laboratory investigation of hard rock creep deformation, particularly in tuff under repository conditions, must be developed.

1.4.2.1.2 Rock Mechanics Field Experiments in Tuff

Objective: To develop and implement test plans for determining and evaluating the in situ physical, chemical, and mechanical properties of welded tuff under simulated repository conditions.

The rock mechanics activities related to nonwelded tuff were added during the first quarter of FY 1982. They were added for two reasons. First, the NNWSI Horizon Selection process is considering a horizon in nonwelded tuff and initial field experience and data can support this process. Second, the slightly dipping beds of Yucca Mountain suggest that the most economical repository layout may be achieved if parts of some of the rooms extend into stratigraphically different layers, which might include some nonwelded tuff. Generic field testing in G-Tunnel that emphasizes the thermomechanical aspects can facilitate the materials characterization and design efforts. It is planned that the Small Diameter Heater Experiment being repeated in nonwelded tuff during FY 1982 and the other Nonwelded Tuff Experiment Development activities will be developed during this period.

NTS Facilities Preparation

A revised plan view of the G-Tunnel Underground Facility (GTUF) incorporates space for the Nonwelded Tuff Experiment Development activities. Various test areas are named for reference.

Drift Mining--The instrumentation and Small Diameter Heater No. 1 alcoves were completed during the first quarter. The leveling of the floor of the Small Diameter Heater Alcove No. 1 using a method to minimize surface disturbance was accomplished by using the Alpine miner. The Experiment Drift was mined using the heading and bench method. The heading was advanced to the terminal distance of 30.2 m by the end of December.

Experiment Drilling--Two holes were drilled in the Small Diameter Heater Alcove No. 1 for the experiment in welded tuff. The holes are 3.2 m deep.

Welded Tuff Experiment Preparation

A paper entitled, "Tuff Rock Mechanics Testing, G-Tunnel at Nevada Test Site," by R. M. Zimmerman, W. C. Vollendorf, and L. D. Tyler, SAND81-2166A, was presented at the 1981 National Waste Terminal Storage Program Information Meeting in Columbus, Ohio, On November 18, 1981.

Small Diameter Heater--The heater unit for this experiment was designed and fabricated. The parts are to be assembled and the first phase of testing is scheduled to commence in the next quarter. Software and data acquisition system details have been defined and are being completed to meet this schedule.

Unit Cell-Canister Scale--The preliminary design of the central and guard heaters has been completed by Los Alamos Technical Associates. Stress and

displacement measuring instrumentation has been ordered. This is the same instrumentation that is being used with the Heated Block Experiment and procedures are being instituted to calibrate and install the sensors using the same procedures. Science Applications, Inc. (SAI) is providing support in these areas.

Heated Block--Primary efforts have been devoted to the design and fabrication of the fixtures required to calibrate and proof test various components of the instrumentation system. In particular, apparatuses for the multiple-point borehole extensometers (MPBX), U.S.B.M. borehole deformation gauge (BDG), the CSIRO Strain Cells and the borehole piezometers have been fabricated. Twelve MPBXs and ten CSIROs have been received at SNL and are to be shipped to SAI for this testing. The preliminary design of the structural frame to be used to guide the percussion bits during the drilling of the slots around the block has been completed.

The test matrix for the heated block experiment has been redefined to emphasize testing in near saturated and unsaturated conditions. Modeling codes are being prepared to define the thermal fluxes required to allow testing during these phases.

Rocha Slot--A contract has been granted to Foundation Sciences, Inc., to propose slot cutting methods and flatjack designs in order to achieve the objectives of this experiment. The experiment was originally intended for welded tuff, but it has applications for nonwelded tuff and the design of the nonwelded tuff experiments--mechanical and thermomechanical--is being considered. In this case, the mechanical experiment would be a pressurized slot type and the thermomechanical experiment would be a heated slot type.

Miniature Heater--The evolution of the thermal probe experiment into the miniature heater experiment resulted during the preliminary design phase. The thermal probe was to be an experiment emphasizing the transient line source technique to measure in situ thermal conductivity, with an emphasis on joint effects. Analyses have shown that the joint effects can be better defined with auxiliary thermocouples in nearby holes. Thus, the experiment becomes a miniature heater and is so named.

1.4.2.1.3 Yucca Mountain Evaluation

Objective: To define, characterize, and evaluate the tuff strata underlying Yucca Mountain to determine their relative desirability and suitability for hosting a repository.

Thermal Conductivity

During this quarter, emphasis was placed on thermal conductivity of the Topopah Springs Member of the Paintbrush Tuff. Five new measurements of conductivity from this unit were received. Three measurements from the densely welded devitrified portion of the unit in Hole USW-G2 back-calculate to a zero porosity conductivity of 2.624 ± 0.143 W/m°C compared with an average of 2.453 ± 0.090 W/m°C for three previous measurements from Holes USW-G1 and

UE25a-1. The difference probably is not real. The average of the six measurements for densely welded devitrified Topopah is 2.539 ± 0.142 W/m°C. Assuming 0.10 porosity, which is representative of the densely welded Topopah, use of this zero porosity conductivity and geometric-means formalism predicts a saturated conductivity of intact material of 2.20 W/m°C, and a fully dehydrated conductivity of 1.87 W/m°C compared to a measured value of 1.85 ± 0.02 W/m°C. These results indicate that the zero porosity conductivity of the Topopah is independent of depth and location.

The first two measurements of conductivity in the lithophysal portions of the Topopah were also received. Measurements were made in the dehydrated condition only. One sample, containing an estimated 0.11 lithophysal void space in addition to the matrix porosity has a reported average conductivity of 1.41 W/m°C. The other with an estimated 0.17 lithophysal void space has a conductivity of 1.23 W/m°C. If 1.89 W/m°C is taken as the conductivity of the intact (nonlithophysal) portions of these samples, the calculated thermal conductivities are 1.38 and 1.17 W/m°C for the two samples, respectively. Thus, initial measurements of thermal conductivity in the lithophysal portions of the Topopah are consistent with simple extrapolation of the geometric means formalism to the larger voids. This extrapolation requires that the lithophysal void space be included and with the assumption that no new thermal processes are involved in heat transfer in this material, at least in low thermal gradients. If it is assumed that the matrix is fully saturated in the lithophysal zones, the calculated thermal conductivities at the two lithophysal void volumes analyzed here are 1.60 and 1.34 W/m°C, respectively.

Conductivity results were also received for six samples of the welded Grouse Canyon Member of the Belted Range Tuff, from Hole RMP-1 in G-Tunnel. This hole penetrates the depth interval of interest for initial heater tests in this welded tuff. Porosities range from 0.12 to 0.18, and grain densities from 2.60 to 2.63, both values being slightly higher than for similar material from the Topopah. The zero-porosity conductivity of the six new samples is 2.190 ± 0.092 W/m°C; saturated and dehydrated conductivities average 1.798 ± 0.062 and 1.439 ± 0.122 W/m°C, respectively. The zero-porosity conductivities are consistent with those calculated from previous measurements made in a more porous portion of the unit (2.145 ± 0.144 W/m°C on three samples). Thus, while the porosities and mechanical properties of the Grouse Canyon are quite similar to those in nonlithophysal portions of the Topopah, the thermal conductivities of the two tuffs are consistently different. The zero-porosity conductivities of the Topopah and Grouse Canyon Member are 2.54 and 2.19 W/m°C, respectively.

Mechanical Testing

During this quarter, the initial round of mechanical testing of the Tuffaceous Beds of Calico Hills was completed. In order to develop a formalism useful in screening potential respository/TEF horizons, emphasis was placed on unconfined compression tests with a supporting effort on determination of confining pressure, temperature, saturation, and strain-rate effects. At present, the only unit remaining to be tested below the Topopah Springs is the Tram Member of the Crater Flat Tuff. This testing has begun; as soon as

possible after its completion, a summary report on the basic mechanical properties of all tuffs but the Topopah Springs will be written.

Most recent results have been obtained on the Tuffaceous Beds of Calico Hills from Hole USW-G1. Forty unconfined tests were run on material from this unit at a strain rate of 10^{-5}sec^{-1} in the saturated state. Samples were selected from four of the five nonwelded ash flows in the unit, as well as from the zone of bedded/reworked tuffs at the base. Approximately thirty additional tests at confining pressure and variable strain rates have also been performed, and are undergoing evaluation, but are not described further here.

The unconfined tests were run in quadruplicate--two tests being performed at each depth at both Sandia and Terra Tek. Reported porosities in the nonwelded ash flows range from 0.37 to 0.43, and average unconfined compressive strengths from 18.3 to 39.3 MPa. There is no apparent correlation between porosity and strength over this narrow porosity interval. The tests generally are slightly more variable than previous results, the average standard deviation in compressive strength being 7.3 MPa, about 25 percent of the average strength.

Samples were tested from two depth intervals within the bedded/reworked zone at the base of the unit. At a depth of 1,741 to 1,742 feet ($\phi = 0.36$) an average strength of 50.5 MPa was measured. At 1,784 to 1,785 feet ($\phi = 0.29$), the strength was 18.0 MPa.

The results from the Tuffaceous Beds of Calico Hills, taken together, appear to indicate that: (1) unconfined strengths may vary considerably within the unit by a factor of about 2, independent of porosity; (2) the mechanical properties of bedded/reworked zones may be quite variable; and (3) it is not reasonable to think of this unit as being homogeneous.

Based on previous testing of zeolitized materials from the Bullfrog, it was suggested that the unconfined strength of zeolitic tuffs could be estimated as a function of porosity by the relation $C_0 = 4.786 \times 10^5(\phi^{-2.735})$, where porosity is taken in percent. If the new data from the Tuffaceous Beds of Calico Hills are included, the overall correlation function is changed to $C_0 = 5.781 \times 10^4(\phi^{-2.126})$. At porosities of 10 to 20 percent, the older function estimates significantly higher strengths. However, between porosities of 25 and 40 percent, the old and new predictive curves agree to within 15 percent. In a situation in which individual measurements on the same sample can vary by an average of 20 percent, agreement to within 15 percent between two predictive curves is considered to be good agreement.

Work has begun on development of a simple constitutive model to predict the mechanical response of material from the Topopah Springs as a function of percent lithophysal void space. USGS personnel are presently logging the Topopah from Hole USW-G2 in considerable detail. It is anticipated that this logging will be completed by the end of January. At that time, sample selection for initial testing of lithophysal material will be made based on the results of the USGS logging effort.

1.4.2.1.4. Horizon Performance Analysis and Geotechnical Evaluation

Objective: To select, on the basis of geotechnical considerations, a tuff horizon or zone at Yucca Mountain that is the most favorable for the development of a TEF/Repository and to perform the follow-up detailed geotechnical evaluation of the selected horizon.

Thermal/Mechanical/Analysis

Several meetings and discussions were conducted both within Sandia and outside of Sandia including one meeting at RE/SPEC (12/16/81) and one Mine Design Study Working Group meeting (11/3-81). The information below is a result of these meetings and discussions.

All of the possible cases (different locations of the repository within the Yucca Mountain stratigraphy, possible different inclinations of the repository, and different waste packages) were recorded. A subset of these cases was chosen for the first-round thermomechanical horizon performance analysis and evaluation of the room-and-pillar and far-field domains. For the first round, the room-and-pillar and far-field calculations will be completed using SP with a CTL of 50 kW/acre. Several different thermomechanical calculations will be completed with these conditions in order to satisfy the objective of the first round, i.e., to determine a preliminary ranking of possible repository locations within the stratigraphy of Yucca Mountain.

The first work packages distributed to the modelers were room-and-pillar calculations using the above conditions.* One work package included average material properties for the zeolitized tuffs and the other for the devitrified tuffs below the water table. Both work packages included four different joint variables (none, 0°, 90°, 0° & 90°). A ubiquitous jointed rock mass model is to be in those calculations that include joints.

The statistical method to be used in the future horizon performance analysis has been discussed. This method will be used in the next room-and-pillar calculations. These calculations will be the same subset of cases as in the first work package but the material properties and in situ stress will be treated in input variables with defined ranges. The statistical method to be used includes the following steps: (1) the input variable will be sampled within the defined ranges and various calculations defined using the Latin Hypercube technique; (2) the calculations will be completed and various repository conditions (stress, temperature and factor of safety for a given set of variables determined for certain regions; and (3) the repository conditions will be analyzed statistically to determine sensitivity of the conditions to the various defined variables and to develop a polynomial which can predict a specific repository condition for a range of horizon properties. This polynomial will allow some flexibility. If new properties are acquired

*In order to complete the first assigned work package, RE/SPEC and Sandia are adding the ability to handle a nonlinear joint failure envelope.

within the originally defined variable ranges, the repository conditions can be quickly estimated by using the polynomial. Also, if the repository depth is varied within a specific horizon, repository conditions can be estimated by using the polynomial. Thus, the fraction of a certain horizon which is unsuitable, according to some criteria, may be determined. This information could be used in the horizon evaluation and ranking.

Thermal Sensitivity Analysis

An analysis of the thermal response of the repository to changes in input parameters has been organized and begun. The ARRAYF code, described in SAND80-0440, will be used to make the calculations because it is inexpensive to use while maintaining reasonable accuracy. The thermal input parameters to be varied include: initial thermal energy output per canister, the extraction ratio, the gross thermal loading, tuff conductivity and heat capacity, and backfill conductivity and thickness. The particular cases to be evaluated numerically will be determined using the Latin Hypercube sampling technique and the results will be analyzed using the STEPWISE regression code. The results of this statistical analysis will indicate the relative sensitivity of the temperature to the input parameters. Polynomials also will be generated which allow the temperature, at a particular time and location, to be determined as a function of the thermal parameters.

1.4.3 EQUIPMENT DEVELOPMENT

(No NNWSI work funded this fiscal year.)

1.4.4 INSTRUMENTATION DEVELOPMENT

(No NNWSI work funded this fiscal year.)

1.4.5 REPOSITORY SEAL DEVELOPMENT

Objective: To develop and test repository sealing methods for an underground repository located in tuffaceous media on or near the NTS.

1.4.5.1. Repository Sealing

Objective: To develop repository sealing concepts for tuff, including the seal material requirements, specifications, and emplacement techniques which will ensure that repository integrity will not be breached as a result of the sealing method employed, and to perform field testing of the concepts developed.

Initial Review and Recommendation for Detailed Study of Sealing Effectiveness History at the NTS

The initial review of the availability and applicability of information relating to seals and containment structures used in the nuclear testing program to the NNWSI repository sealing activity has been completed. Formal information is limited to the Construction Summary Reports prepared for

specific nuclear tests. The majority of knowledge on stemming and containment, however, resides with the individuals participating in the nuclear tests. Three areas in which investigations will continue include: (1) the applicability of existing weapons effects testing seals to the repository program of in situ testing; (2) the experience and capability to produce specific physical properties in cement and grout mixtures; and (3) NTS experience in emplacing cement and grout seals.

Shaft and Borehole Plugging Criteria

A response to a D'Appolonia request for NNWSI-generated information has been prepared. Interest was expressed in the following areas: reference repository design, reference stratigraphy, reference repository horizon, reference hydrology, and reference geochemistry. Investigations into the availability of this data indicated that little information is currently available which would satisfy D'Appolonia's needs as it applies to shaft and borehole plugging as information becomes available in the NNWSI program, it will be forwarded to D'Appolonia.

1.4.6 GENERIC REPOSITORY ENGINEERING

(No NNWSI work funded this fiscal year.)

1.4.7 REPOSITORY CONCEPTUAL DESIGN

Objective: To develop a conceptual repository design which will serve as the basis for a Title I design.

1.4.7.1 Preliminary Data Package Development

Objective: To prepare data and analysis summaries and to perform systems analyses of geotechnical information and computer models to be used for developing the design guidelines for a test and evaluation facility and conceptual repository design.

Preliminary Data Package Development

The RE/SPEC "Forced Ventilation Analysis of a Commercial High-Level Nuclear Waste Repository in Tuff," Topical Report RSI-0175 (SAND81-7206) has been given a technical review by SNL Division 4531 (NNWSI Engineering Projects Division and 5511 (Fluid Mechanics and Heat Transfer Division). The comments have been taken to RE/SPEC for incorporation into the final draft prior to publication of the report.

1.4.7.2. Conceptual Design

Objective: To develop a conceptual repository design for a specific repository horizon which will serve as the basis for the Title I design and which will provide direction for the locations of the Exploratory Shaft and the design of the Test and Evaluation Facility.

Loss of Drilling Fluid

Mud records, hole histories, and graphic lithologic and structural data for Hole USW-G1 have been processed for use with the Applicon computer graphics system. Initial graphic results are being corrected for use in correlation studies in an attempt to define permeability parameter distribution in the hole.

Hole USW-G1 core shows little evidence of fracture and is believed to be outside the fracture patterns running parallel with and inside Drillhole Wash. USW-G1 geology is thought to be representative of the block south of Drillhole Wash.

All hydrologic testing has been within the saturated zone. No data has been obtained for the unsaturated zone with the possible exception of mud data from drilling records. Drilling in and through the Topopah Springs Member almost always results in lost circulation.

Repository Conceptual Design

A preliminary repository surface layout has been entered in the Applicon system. The facilities are located north of an east-west drift that connects a possible early shaft (ES) on the west with a Test and Evaluation Facility (TEF) shaft on the east. The buildings are sited to take advantage of natural drainage. During the time of repository operation, the ES might be renamed the construction ventilation shaft, and the TEF shaft might be renamed the man and materials shaft.

Our original repository underground layout consists of six panels at 115 acres/panel with 39,000 feet of storage drift/panel (688 acres total).

Our second underground layout has essentially the same areas and lengths as the original but is made with the rooms in a chevron configuration. The 45° entry and exit angles minimize the ventilation pressure losses and ease the turning requirements for the emplacement equipment.

Our third underground layout is an eight-panel version of the original and provides a total storage area of 918 acres. One ventilation shaft has been moved to the top of the ridge to enhance natural ventilation.

Our fourth underground layout is a 16-panel configuration with 57 acres/panel, 17,200 feet of storage drift/panel, and a total area of 918 acres.

Our fifth underground layout is an eight-panel layout with five subpanels/panel. The subpanel is 930 feet by 900 feet (19.2 acres) with 7,440 feet of storage drift/subpanel. This configuration, the storage drifts are oriented north/south which is parallel to the strike.

These underground layouts are all stored in our Applicon system and can be graphically modified as work progresses on advantages and disadvantages of these configurations.

Natural Ventilation Investigation

A study of natural ventilation for the repository in Yucca Mountain was completed. The topography is such that several hundred feet of natural head can be obtained if the air inlets and outlets are well chosen. The conclusions from our short study follow:

- a. Since natural ventilation fluctuates, it cannot be relied upon solely for mine air conditioning.
- b. The natural driving force created by the various surface and subsurface ambient conditions must be considered as an auxiliary pressure source to mechanical ventilation.
- c. Augmenting the powered ventilation system with natural ventilation can reduce the procurement and operating costs significantly.

1.4.8 PERFORMANCE EVALUATION

(No NNWSI work funded this fiscal year.)

1.5 REGULATORY AND INSTITUTIONAL

Objective: To assess and document the safety and environmental characteristics of a repository system in a manner which meets anticipated NRC licensing requirements and the requirements of the National Environmental Policy Act (NEPA).

1.5.1 REGULATORY BASELINE

Objective: To ensure that NNWSI licensing assumptions and plans are consistent with NWTS assumptions and plans.

NNWSI concerns about 10CFR60 draft technical criteria were provided for inclusion in the DOE consolidated NWTS review position statement on the criteria.

1.5.2 LICENSING APPLICATIONS

Objective: To plan and coordinate the preparation of licensing-related documentation.

A rationale for identifying licensing issues was discussed with TPOs in early December, and plans for formulating a complete listing of such issues should be available in February. The plan defines licensing issues and provides a means of recommending, discussing, and finalizing them so that a uniform and integrated set will be available. The listing of licensing issues is an important step in producing the NNWSI SCR--especially Part C.

1.5.3 NEPA DOCUMENTS

Objective: To plan and coordinate the preparation of the NEPA documentation.

This task has no reportable progress.

1.5.4 COMMUNITY AND INSTITUTIONAL LIAISON

Objective: To inform and coordinate appropriate NNWSI activities with the affected community and government institutions.

This task has no reportable progress.

1.6 TEST FACILITIES

Objective: To ensure the availability of test facilities and equipment necessary to support the research, development, and demonstration activities of the NWTS Program.

1.6.1 SALT FACILITIES

(Not applicable to the NNWSI.)

1.6.2 GRANITE FACILITIES

1.6.2.1 Climate Test Facility

Objective: To provide the support services needed to operate and maintain the Climax Test Facility.

Fuel Canister Handling Operations

The second exchange of a spent fuel canister was successfully carried out during the two-week period of October 19-30, 1981. The first week involved preparation for spent fuel retrieval and replacement; these activities were executed October 26 and October 28, respectively. The spent fuel assembly in CEH07 was exchanged, rather than the one in CEH11 as was previously planned, at the request of R. Cash of HEDL (SFT 81-155, October 21, 1981). Assembly S/N D06 was returned to the E-MAD lag storage pit and replaced with S/N D09.

Overall, this exchange was conducted in a very efficient and well coordinated manner. The exercise of the canister handling systems and operating personnel once again demonstrated our continuing capability to retrieve the fuel assemblies from the test array when required. It also pointed up the need for periodic exercise to maintain the capability, and identified some shortcomings in the mothballing and periodic maintenance procedures.

During the dosimeter exchange, five floor plugs were removed. Examination of the plugs and pit areas exposed no additional evidence of moisture condensation or corrosion beyond that noted in January 1981. This is consistent with the hypothesis of "drying out" the rock and concrete in the immediate vicinity of the storage holes during the first few months of the test and no additional free water being added to the region.

The minimal pull over dead weight required to hoist the canister assembly from the storage hole after 17 months again confirmed the graphite shim operation.

Detectable traces of radon were again noted in gas samples drawn from two liner-rock annuli during this period. A very small increase (about 100 dpm) in gamma activity was noted during a survey of the CEH 7 liner while the fuel canister was removed. This may indicate some slight neutron activation of liner components (carbon steel), but may also be due to radiation from the

fuel assembly in an adjacent hole. This matter will receive further investigation during the next exchange when the fuel assembly will be removed from CEH 16 which is located between two electrical simulators.

The fuel exchange operation and related activities required a total of 146 man-days of LLNL and EG&G field effort; Westinghouse and REECo support is not included. The field manpower levels during the two-week period ranged from 7 to 18 people/day.

In view of the recent indications that the SFT-C is very likely to be a five-year duration test with the attendant attrition and turnover of project personnel and the general aging of equipment, LLNL strongly reiterates the recommendation of last January that we continue to schedule these activities on a nominal eight to ten month frequency for the duration of the test. LLNL tentatively plans the next exchange operation for July 1982.

Thermal and Thermomechanical Modeling

Several thermal calculations were performed this quarter in support of development of data reduction algorithms. Instruments such as extensometers measure apparent displacements which result from thermal expansion of instrument components. Since measurements of component temperatures can be made at only a few points, it is necessary to use these few measurements to calculate the average component temperature. The results obtained from temperature measurements can be compared with a more exact solution based on calculated temperature profiles for the instrument components. Thus, a determination of thermally induced instrument errors can be made.

Field Instrumentation

Field instrumentation activities continued to constitute a major part of the SFT-C this quarter. Specific topics are discussed in the following paragraphs.

Repeatability and Recalibration--The spent fuel exchange required removal and replacement of three sets of instruments. First, 19 thermistors which are used to document the canister-drift-air thermal regime were removed to permit UTV operations and have been replaced without incident. Second, two through-hole wire extensometers and 12 convergence wire extensometers were also removed to permit UTV operation. Offsets introduced during this procedure range from 6 to 556 micrometers and average about 59 micrometers. Markedly larger errors occur in the long through-hole units (THE) where significant catenaries develop. Third, recalibration of the six thermocouples associated with the canister in CEH07 was performed to 0°C and 150°C. All are within the ISA standard. Interestingly, 9 of the 12 calibration temperatures exhibited smaller errors in the recalibration than in the original calibration, some 17 months later, after operating in a temperature range of 120-150°C and an intense radiation field (about 10^4 R/hr). This speaks well of the Type K thermocouples employed throughout the test array.

Acoustic Emissions--Acoustic emissions (AE) activity increased in the October to December 1981 period over the previous activity in the spring and summer of 1981. The peak in AE activity occurred during the week of a canister change. Twelve AE events were recorded on days 299 and 300. The events were distributed uniformly in time (not swarm-type) and occurred at times when there was no human activity at the test level. The events were discrete in nature with impulsive onsets with clearly defined P and S waves. All of the activity was located in the north pillar between stations AE 2,5, 11, and 3. Because the peak in activity occurred during the time of peak human activity (a canister change) and the events were located well within the rock mass, it does raise questions relating to the triggering of events. The zone of activity has always been active during the length of the project. The events may be triggered due to loading of the canister transport vehicle. Whatever the case, there seems to be a zone of weakness on which either thermal or mechanical stresses can trigger events.

Observations of the S/P wave ratio are being made as a function of time. Three paths have been monitored using the calibration source in AE 13. These paths are AE 13-AE 5, AE 13-AE 3, and AE 13-AE 19; the last path serves as a reference path. Both AE 5 and AE 3 have shown a systematic increase in the S- to P-wave ratio. The P and S waves are clearly defined and should, therefore, provide reliable data. Although both paths show an increase in the S/P wave amplitudes, the time at which the maximum value occurs is worth noting. The maximum for AE 5 occurred in mid-1981. However, the maximum value for AE 3 seems not to have been reached yet. Assuming that the S/P wave ratio increases as a function of temperature, the effects of the peak heat pulse may be moving away from the heat source; i.e., the path AE 13-AE 3 is now feeling the maximum effect of heating while the effects of AE 13-AE 5 has reached a maximum and is decreasing.

Neutron Dosimetry--Measurements of neutron flux from the spent fuel assemblies utilized in the exchange were made by EG&G-Santa Barbara personnel under contract to LLNL. Three sets of activation foils were attached to the STV cask at the fuel assembly axial centerline, about 120° apart radially. Total exposure time was slightly less than 40 hours. A report on these measurements will be prepared when the data have been analyzed.

Instrument Failure and Replacement--A final test was completed this quarter, closing out the investigation of the failure of linear potentiometers on rod extensometers at the SFT-C. One failure mechanism which was suggested early in the investigation was migration of acetic acid (generated by the curing of Silastic sealing compound used in the extensometer assemblies) into the potentiometers. A potentiometer was placed in a bell jar and subjected to vapors from glacial acetic acid for a period of over 25 days. During this time, the total resistance of the unit increased from 5066 to 6293 ohm--over 24 percent. Subsequent to removal from the bell jar, the resistance decreased to 5408 ohm. Although total resistance is still nearly 7 percent above the original value, the test demonstrates that damage produced by acetic acid is at least partially reversible. Since reversible damage was not observed in the failed potentiometers recovered from the SFT-C, it is unlikely that acetic acid was the sole cause of the observed failures.

Formal documentation of rod extensometer potentiometer and stressmeter failures was completed this quarter and submitted to NV for review. This report gives a detailed account of the identification and evaluation of observed failures and discusses the remedial actions taken.

Installation of 48 transducers within the GBE and GCE series rod extensometers was completed. Four types of transducers were installed: Bourns and Vernitron rectilinear potentiometers, Schaevitz LVDTs, and Kaman electromagnetic proximeters. All units were calibrated in the laboratory, prior to fielding, and in situ, after installation on the extensometers.

During laboratory calibration, the LVDTs were found to be out of specification and were returned to the manufacture for repair. These units have now been accepted and installed. In an effort to improve the quality of the data obtained from the LVDTs, extra measures are being taken to reduce the electrical noise in the system.

Stressmeter Calibration--A contractor report on the "Calibration Characteristics of IRAD Gauge Vibrating Wire Stressmeters at Normal and High Temperature" has been received and reviewed at LLNL. The report documents laboratory tests of the stressmeter in four materials (Climax granite, Barre granite, aluminum, and lucite) under three stress conditions (uniaxial, biaxial, and triaxial) over a temperature range of 23°C to 100°C. Many important factors are investigated. These include reproducibility and hysteresis, gauge preload, initial stress field, loading geometry and cross-sensitivity, temperature, and rock inhomogeneities. The report should be useful not only in work at the SFT-C but also in other waste insolation and geomechanics investigations.

Additional Instrumentation--In developing algorithms to compensate for the adverse impact that thermal effects have on the quality of displacement and stressmeter data, LLNL personnel have identified a need for additional temperature measurements on several devices. As a result, a total of 33 thermocouples will be installed on rod extensometer head assemblies and fracture monitors in late January.

A four-wire resistance measurement device is currently being developed and tested for deployment on convergence wire extensometers. This system would utilize the temperature coefficient of resistance of the wire to determine the change in average temperature of the wire. If testing proceeds as planned, the four-wire systems could be deployed in late January or early February.

Laboratory Testing--A series of tests has been started to study two phenomena which will be examined in the posttest analysis of rock core taken in the vicinity of the canister emplacement holes. Results of these tests will be used in establishing a rationale for posttest sampling which is part of the test termination plan slated for completion this fiscal year.

The first tests call for loading 15 irradiated and 15 unirradiated samples of Climax stock quartz monzonite to failure in a Brazilian tensile test geometry. These tests have been completed and data are being analyzed. No adverse effects of gamma radiation have been observed.

The second tests will evaluate the effects of gamma radiation on uniaxial compressive strength and the elastic moduli. Thirty samples are presently being prepared for this activity.

The third tests are aimed at evaluating the extent of damage induced by drilling the canister emplacement holes. These data are necessary to be able to subtract out the drilling damage from damage seen in the posttest cores; the resultant being damage induced by heating alone or heating plus irradiation. The basic technique to be applied is counting and characterizing microfractures detected on scanning electron microscope images.

Data Acquisition System--During the quarter, the overall system availability was 94.6 percent. A total of four hardware failures occurred: one 64K memory board and three peripheral interface boards. All were replaced and additional spares were purchased.

Operation and maintenance of the system continued as a routine activity. The 11-P operating system revision (2126) was installed in October and was found to contain several "bugs" which caused problems in the intercomputer link, and caused one CPU to suspend. This problem was corrected.

Design and fabrication of a "switch" to permit either CPU to acquire data from all instruments in the event of a hardware failure has been completed. This switch will be tested and installed in January. It is designed to operate under software control, either automatically or operator-initiated remotely.

Installation of a data-quality leased line to Livermore is in progress and scheduled for completion in late January. This is expected to rectify our problems with remote communications mentioned last quarter. A similar arrangement is being considered for improving the Area 15 CP40 alarm terminal circuit and will be implemented if the Livermore link is successful.

Data Management System

Data Processing--In processing SFT-C data tapes, 8 of 39 magnetic tapes were found to contain major errors in the form of parity errors and "garbage" which could not be read by the binary read program (BREAD) used in processing the tapes. New copies have been made which can be processed. The technique which produced the faulty copies is no longer in use so the problem should not recur.

The current version of BREAD has been used to reprocess all 39 tapes through a prescribed series of steps. This procedure is employed to ensure that high quality data is available for reduction and analysis. BREAD output statistics document the number of data points processed and the numbers and types of faulty records encountered in processing each tape. Just under 4×10^6 data points are now available for further processing and analysis.

The output of BREAD processing is one or two files each of which contain data from all instruments over a short interval of time--typically 20 days. To facilitate plotting data for longer time periods, it is necessary to merge

these files. Since the file containing all instruments for all time is excessively long, a directory system was developed which has a file for each instrument containing all data on it. The output of BREAD processing was reformatted to expedite the merging operation.

The file directory system through which data sets are stored and retrieved is cross-indexed. Data are added to each file in alphabetical order of the instrument license plate. Data are retrieved from the files according to its logical relationship to the test; for example, a subdirectory allows the user to view data from all thermocouples associated with a particular canister emplacement hole.

Status of Data for Analysis--Work continued on the development of algorithms for performing final conversion of acquired raw data. Analysis of two-point and three-point thermocouple calibrations indicates that the errors associated with individual thermocouples is small. Nearly all errors fall within a $\pm 0.15^{\circ}\text{C}$ error band at 0°C and 50°C calibration temperatures. This compares well with the $\pm 0.11^{\circ}\text{C}$ theoretical limit of precision for the system electronics and is well within the ANSI special limits of error of $\pm 1.1^{\circ}\text{C}$. Given these results, it is unnecessary to perform additional conversions of the thermocouple data. Analyses of thermocouple data will begin early next quarter.

Data from stressmeters and the various types of extensometers require correction for the effects of thermal expansion of instrument components. Appropriate algorithms are under development at this time but reconversion of all field data for these instruments is required before analyses can be begun. One exception is manually recorded data from the tape extensometer. These data have been corrected, based on one-point temperature measurements acquired at the time the tape is read. A separate data reduction routine has been applied to this data set and the data are now ready for plotting and analysis.

Working Group Meeting on Geotechnical Instrumentation

A working group session on the application of geotechnical instrumentation in radioactive waste isolation was held in Denver on December 2-3, 1981. Project members were on the executive committee and participated in presentations and discussions. In addition to benefitting the NWTS and NNWSI geotechnical instrumentation programs, the working group provided a forum for discussing specific successes and failures observed at the SFT-C. A report of the proceedings of this meeting is in preparation and will be presented at the April 1982 ASCE Geotechnical Conference and Exposition in Las Vegas, Nevada.

Technical Reporting and Public Information Activities

Reports in publication progress:

"Heater Test No. 1, Climax Stock Granite, NTS," D. N. Montan and W. B. Bradkin, UCRL, in preparation.

"Excavation and Drilling Activities Associated with a Spent Fuel Test Facility in Granitic Rock," W. C. Patrick and M. C. Mayr, UCRL-53201, in preparation.

"Fracture Mapping at the Spent Fuel Test--Climax," J. Yow, D. Wilder, UCRL-53201, in preparation.

"Instrumentation #1: Specifications, Design, Calibration Installation of Instrumentation for an Experimental High-Level Nuclear Waste Storage Facility," W. C. Patrick, UCRL, in preparation.

"Thermoluminescence for Self Dosimetry in Climax Stock Quartz Monzonite," UCRL-86627, in preparation.

"Thermal Calculations for the Design, Construction, Operation, and Evaluation of the Spent Fuel Test--Climax, NTS," UCRL-53238, in preparation.

"Instrumentation #2: Identification, Evaluation, and Remedial Actions Related to Transducer Failures at the Spent Fuel Test--Climax," W. C. Patrick, UCRL, in preparation.

Reports published:

"Preliminary Report on Radiation-Induced Thermoluminescence in Climax Stock Quartz Monzonite," R. C. Carlson and L. Page, UCID-19229.

"As-Built Mechanical and Thermomechanical Calculations of a Spent Fuel Test--Climax Stock Granite," T. R. Butkovich, UCRL-53198.

"Climax Spent Fuel Dosimetry Progress Report, September 1980-September 1981", UCRL-15419, EG&G-Goleta.

"Calibration Characteristics of IRAD Gage Vibrating Wire Stressmeters at Normal and High Temperatures," (Volume 1 and 2), UCRL-15426.

Conducted 28 tours on 19 separate days for approximately 260 people.

1.6.3 BASALT FACILITIES

(Not applicable to the NNWSI.)

1.6.4 TUFF FACILITIES

1.6.4.2 Exploratory Shaft

Objective: To provide access to and to further define potential repository horizons in tuff.

Design

The draft Conceptual Design Report for the Exploratory Shaft (ES) was completed on schedule. This report will be updated and issued as a final report following appropriate policy review.

A preliminary study evaluating the advantages and disadvantages of mining or drilling the ES show that either technique is a viable option and a final decision probably will not be made until the shaft depth has been selected. Assuming that the ES is drilled, procurement orders must be placed for two items this fiscal year if the purchase option is to be exercised rather than leasing these items or using NTS equipment. These two items are a drill rig, with a 18-month delivery time and the power casing tongs, with a 12-month delivery time. Currently, no capital equipment funds are authorized in FY 1982 for these items.

Assistance has been provided in scoping a surface excavation to evaluate the unsaturated zone rather than drill a vertical borehole. One approach would be to construct an adit into a Topopah Spring outcropping where various in situ experiments can be conducted.

Experiment Test Plan

The objective of this task is to develop an experiment test plan that will assess the in situ thermomechanical, hydrologic/geochemical, and geologic characteristic of a tuffaceous target horizon in Yucca Mountain to determine its suitability for a Test and Evaluation Facility (TEF) and a repository. The planning for this activity has been initiated.

The test plan is to be developed according to the following guidelines: (1) Development of the test plan is to be a joint endeavor with active participation from appropriate NNWSI participant organizations, and with invited participation from other organizations as needed. Development of the data requirements should not be limited to those areas of investigation in which a given organization is currently involved in the NNWSI; (2) Development of the test plan should benefit and draw heavily from experience gained elsewhere in the NWTs Program. Specifically, the test plans for basalt and salt should be utilized extensively and the format for the tuff test plan document should parallel those documents as appropriate to facilitate comparisons of the test plan; (3) Los Alamos is responsible for planning and coordinating the development of the test plan. This includes scheduling and controlling delivery of individual topics and subtopics to be included in the test plan, as well as compilation and completion of the draft test plan; and (4) The draft test plan should be subjected to extensive internal NNWSI review. External review of the tuff test plan should include comment by BWIP (basalt) and ONWI (salt) reviewers knowledgeable of their respective test plans.

The approach to be taken to develop the ES test plan will be to first define the data required for each step of the exploration (see below). Ranges of acceptable and unacceptable results must be identified and criteria and methods by which suitability is to be judged must be defined. A ranking or priority will be assessed to each set of required data. This will allow greatest emphasis to be placed on the most needed data sets. Only after the above data sets have been identified can the tests be selected to obtain the required data.

The testing program will proceed in a series of steps, with each subsequent step dependent upon favorable results obtained from the previous series of tests. As currently defined, the test plan will include the following exploration steps: Step (1) Conformatory borehole; Step (2) Phase I (TEF site verification) during shaft construction or in completed shaft; Step (3) Phase I (TEF site verification) for characterization of horizon of interest; Step (4) Phase II (repository site verification); and Step (5) at-depth testing (repository design verification).

1.6.4.3 Test and Evaluation Facility (TEF)

Objective: To develop and operate an in situ Test and Evaluation Facility in a potential repository unit in tuff to characterize the unit and to predict repository performance.

No report.

1.6.5 SUPPORT FACILITIES

1.6.5.1 E-MAD Facility

Objective: To ensure the availability of the E-MAD Facility and to maintain and develop the capabilities to meet programmatic requirements.

No report.

1.6.5.1.2. E-MAD Facility Operations and Capability Maintenance

Objective: To maintain the readiness of both personnel and equipment at the E-MAD Facility to meet programmatic requirements.

No report.

1.7 LAND ACQUISITION

Objective: To acquire land for possible future use as a repository.

A land withdrawal plan for siting a commercial high-level waste repository on the NRDA and/or contiguous Nellis AFB and BLM land was prepared and forwarded to the DOE/HQ in November 1981.

1.8 PROGRAM MANAGEMENT

Objective: To direct and assure coordination of all activities to fulfill the goals and objectives of the Project and to coordinate the Project with the NWTS Program.

1.8.1 PROGRAM MANAGEMENT

Objective: To provide the management interfaces between the participating organizations.

This task has no reportable progress.

1.8.2 PROJECT CONTROL

Objective: To monitor the fiscal and technical accomplishments of the Project.

This task has no reportable progress.

1.8.3 INTERFACE ACTIVITIES

Objective: To implement technical interfaces between NWTS Projects.

This task has no reportable progress.

1.8.4 QUALITY ASSURANCE

Objective: To provide the necessary planned and systematic actions and administrative controls to assure all NNWSI activities which affect quality, safety, reliability, or maintainability are conducted in accordance with established Project requirements.

Quality Assurance Overview Contractor

In October, QA Overview submitted the projected schedule of FY 1982 Project Office audits to complete the deliverable schedule for October 30, 1981.

QA Overview developed a proposal for a tracking system called "Action Item Reporting" (AIR) System in October. The AIR system provides a means of identifying and tracking significant ongoing NNWSI activities to satisfactory completion. Activities tracked by the AIR system could be either technical or quality assurance related. The proposal is being reviewed by Technical Overview. Additionally, this proposal responds to one of the observations in the September 1981 Project Office audit of Technical Overview and QA Overview.

QA Overview distributed two internal Sandia procedures in October. One was an audit procedure that was revised in response to one of the observations in the Project Office audit of QA Overview. The other procedure was a newly developed procedure defining inspection activities.

A draft version of the NNWSI Record Management Plan (QMP-17-01) was completed in November. The revision provides a definition of records to be stored at the Project Record Center that better reflects the needs of the NNWSI. Records are generally categorized as resulting from site-specific investigations or from generic/regional investigations. A full set of records will be stored for site-specific activities, while only summary level records will be stored for generic/regional activities. This approach will provide the NNWSI with the records needed for the Site Characterization Report and license application, but still keep the volume of records storage at the Project Record Center at a reasonable level.

QA Overview has been using this categorization of records in working with NNWSI organizations to finalize their lists of records to be forwarded to the Project Record Center. QA Overview contacted all NNWSI organizations in this finalization process during the quarter. QA Overview received updated lists of records to be stored in the NNWSI Project Record Center from Westinghouse and Fenix & Scisson. These lists were quite good, and QA Overview has told these organizations to begin sending records to the Project Record Center. QA Overview suggested a list of records for direct Project Office submittal to the Project Record Center. QA Overview is awaiting Project Office response to this proposal.

QA Overview reviewed the criterial letter for USW-G3, and provided comments on the review to the Project Office. A QA Overview representative attended the drilling meeting for USW-G3 on December 4, 1981. This drilling meeting and the Technical Integration Group (TIG) meeting on December 8, 1981, highlighted areas where there were still questions of QA program sufficiency. QA Overview accepted a TIG action item to define a large scale procedure or outline to containing QA requirements to be met from criteria generation through debriefing or summary of drilling operations. A first draft of these QA requirements has been developed and will be discussed with NV personnel in January 1982.

The process of establishing adequacy of the NNWSI Quality Assurance Program to 10CFR50, Appendix B, and AMSI/ASME NQA-1 has begun. QA Overview reviewed the Holmes & Narver Quality Assurance Manual and provided comments to them. QA Overview attended the December meeting of site contractor QC Managers to support the NV QA Manager in establishing 10CFR50, Appendix B and ANSI/ASME HQA-1 as the quality assurance program requirements for NNWSI activities. This initiated the updates necessary to get adequate contractor quality assurance programs for NNWSI activities.

The audit activities this quarter were:

- a. QA Overview prepared the response to the September 1981 Project Office audit of Technical Overview and QA Overview. The response was coordinated with Technical Overview, and was jointly issued on October 22, 1981, by Department Managers responsible for both organizations.
- b. QA Overview completed the report for Audit 81-9 conducted at USGS in late September. The report was submitted to the Project Office in early October.

- c. QA Overview reviewed the LANL actions responding to the findings in Audit 81-8. The actions taken were good, and the audit was closed in December when LANL provided a copy of the procedure they committed to revise.
- d. QA Overview let Project Office audit teams on two audits in December.
 - Audit 82-1 conducted a Lawrence Livermore National Laboratory from December 15-18, 1981.
 - Audit 82-2 conducted at Sandia National Laboratories, Albuquerque from December 9-11, 1981

These audits had dual purposes of assessing adherence of each organization to their QA program documentation and establishing adequacy of existing QA programs to meet requirements in 10CFR50, Appendix B, and ANSI/ASMR NQA-1-1979. The results of these audits will be in reports now being prepared.

- e. Audit 81-3 conducted at SNL in March 1981 is still open. Sandia has not provided a Mine Design Study Working Group charter, and in a recent letter, SNL stated that the Mine Design Study Working Group has completed its activities and a charter would not be written. The audit team does not agree with this action, and M. P. Kunich has agreed to inform SNL that a charter is still required to define Mine Design Study Working Group activities and close the audit.

Continuing efforts by QA Overview by direct liaison with REECO quality assurance is leading toward resolution of the problem regarding calibration and calibration identification of flow meters being used during drilling activities at the drill sites. On November 23, 1981, a letter was forwarded to WMPO/NV by QA Overview requesting that drilling activities on UE29a-2, which had already been suspended for other reasons, be suspended until it could be verified that instrumentation was properly calibrated and labeled, and that a calibration program was in operation to assure continued calibration. Later discussions with WMPO/NV resulted in more information being furnished concerning REECO QA program requirements and calibration activities. WMPO/NV discussions with NTS personnel on this subject had the result of assurances that the meters in question were calibrated and were not identified in accordance with the REECO QA program requirements. It was agreed that our objectives in this case were pretty well satisfied--even though not verified as yet--and that future criteria should be careful to specify equipment needs and accuracies required.

The above problems was brought to light and information was furnished through the NTS monitoring activities on behalf of QA Overview. They also were on hand to monitor the dry run of the Surface Transporter at Climax and the Westinghouse AESD maintenance activities in preparation for the spent fuel exchange.

U.S. Geological Survey

Participated in criteria meetings for drill hole USW-G3 held in Las Vegas.

Submitted review of USGS/NNWSI Project QA Program status to USGS Administration.

Participated in Audit 81-9 of USGS/NNWSI Project QA Program held September 22-24 in Denver.

Approved a Unit Task Procedure and seven Detailed Technical Procedures for Hydrologic Investigations.

Drafted a Unit Task Procedure for Geologic Investigations.

Presented a paper on the status of geologic investigations of the NNWSI at ONWI national meeting held in Columbus, Ohio.

Procedure NWM-USGS-MDP-1, The Identification, Handling, Storage, and Disposition of Drill Hole Core and Samples, was approved and distributed. The Gravity Measurements and Data Reduction Procedure, NWM-USGS-GPP-01, was revised by Menlo Park personnel and approvals are being obtained. Approval signatures were secured on six hydrology procedures and on a heat flow geophysics procedure. A Unit Task Procedure for the Geologic Investigations was drafted.

Westinghouse Electric Corporation

In accordance with the new DOE Directives NE 5840, "Quality Assurance Policy for Nuclear Energy," and 5700.6A, "Quality Assurance," AESD-Nevada Operations Quality Assurance issued eight Quality Methods and Procedures (QMPs) which address and implement quality assurance criteria provided in ANSI/ASME NQA-1-1979, "Quality Assurance Program Requirements for Nuclear Power Plants." These QMPs with those presently contained in the AESD-Nevada Operations Quality Assurance Manual provide the necessary systematic and administrative controls to assure AESD-Nevada Operations activities that affect quality, safety, reliability, and maintainability during design, procurement, fabrication, inspection, shipment, testing, and storage are conducted in accordance with applicable requirements. Additional QMPs are presently being written and shall be issued in accordance with an established QMP schedule.

AESD-Nevada Operations and REECo worked to develop a Memorandum of Understanding which defines the use of the existing REECo Major Equipment and Supply Acquisition (MESA) Procedure for REECo procurements of AESD-Nevada Operations requisitioned items. The Memorandum of Understanding was issued in December 1981 and documents the AESD-Nevada Operations and REECo interfaces when procuring items which require adherence to the MESA Procedure. Particular concern to AESD-Nevada Operations was in the areas of approval of suppliers

for technical and quality capabilities (as required by NQA-1, "Quality Assurance Program Requirements for Nuclear Power Plants") prior to placement of an order, supplier surveillance during order processing, and receipt inspection activities. These areas are now adequately defined and controlled.

Issued a revised AESD-Nevada Operations Quality Assurance Record Types List which incorporated minor Sandia Quality Assurance Overview comments to the original list. The initial package of AESD-Nevada Operations Quality Assurance Records was prepared for transmittal to the NNWSI Project Record Center at the Nevada Test Site. This transmittal shall be accomplished by February 5, 1982.

Conducted AESD-Nevada Operations Quality Assurance internal audits of AESD-Nevada Operations activities in the areas of "Control of Measuring and Test Equipment," "Handling, Storage, and Shipping," "Corrective Actions," and "Non-conforming Items." Actions required to resolve deficiencies noted during the audits are being monitored by AESD-Nevada Operations Quality Assurance to verify timely and adequate resolutions. The December 1981 AESD-Nevada Operations Quality Assurance Corrective Action Status Report was issued to AESD-Nevada Operations management to identify those items which require corrective action as a result of audits performed in CY 1981.

The Sandia Quality Assurance Overview/DOE audit of the AESD-Nevada Operations quality assurance function has been rescheduled from March 1982 to June 1982, at which time the Climax Fuel Exchange is scheduled to occur.

Provided quality assurance input for the proposed Test Evaluation Facility (TEF) and Generic Packaging Facility (GPF). Process flow charts, manpower, equipment requirements, and schedules were prepared. The packaging activities for the TEF are to be conducted in a manner which would not prohibit future licensing of the TEF. The quality assurance tasks and manpower requirements were planned accordingly.

Provided quality assurance support during equipment and systems calibration and maintenance in addition to dry runs and operator qualification/certification activities at the E-MAD Facility.

Los Alamos National Laboratory

The Los Alamos NNWSI Organization Chart and the Quality Assurance Program Plan were revised but approved signatures have not yet been secured. Personnel certifications for ESS-division were prepared and put on file. CNC Division personnel certifications were prepared and are being approved. An indoctrination and training session for new project personnel is being developed.

The Sorption Coefficient and Migration Measurements Work Plan was revised. The revision completes the July audit by DOE.

The Exploratory Shaft Work Plan is being revised and three design procedures were written for the Exploratory Shaft work.

Lawrence Livermore National Laboratory

Aubrey Miller, former Project Quality Engineer for NNWSI projects, has retired. Holly Miller assumed this position as of October 1, 1981. A large portion of the total QA effort this quarter has been spent becoming familiar with the QA system, organizing new QA files, and reorganizing old QA files in addition to preparing for a NNWSI quality assurance audit of December 16-18, 1981.

A QA Surveillance file was created informally documenting monthly review of NNWSI projects by the project quality engineer. The findings from these reviews are written up in the form of a monthly "memo to file" with copies sent to the Task Leaders.

Minor changes were made to the SFT-C Nonconformance Correction Procedure, QP-08-03, to more clearly define the guidelines for generation of nonconformance disposition records. There is still some question as to the effectiveness and clarity of this procedure. The issue will be addressed during the preparation of a new umbrella QA Plan. Revision 11 of the SFT-C QA Plan has been deferred in lieu of efforts to write this umbrella plan for all Waste Isolation Projects at LLNL. Work continues on this plan with a projected completion date of April 1982.

The project quality engineer also took part in the October spent fuel exchange, reviewing procedures and observing the operation. The task was successfully accomplished and it was concluded that all those involved performed their functions with a high regard for quality.

While at the NTS for the fuel-exchange, visits were made to the USGS Core Library and to the H&N Project Record Center. Touring these facilities gave an understanding of their function and how they affect quality in the NNWSI projects they support.

As mentioned, Waste Isolation Projects: Spent Fuel Test--Climax, Granite Field Radionuclide Migration, and laboratory testing were the subject of an extensive quality assurance audit conducted by the Sandia QA Overview Group December 16-18, 1981. Those performing as auditors were Frank Muller, Gerry Rudolfo and Mitch Kunich. John Rinaldi and John Dronkers were also present as observers. The audit was productive in that it indicated our relative strengths and weaknesses and identified a number of areas where changes should be made.

Sandia National Laboratories

An internal audit of SNL Division 4531 on Section 10 (inspection) of the QPP was conducted on December 12, 1981. The audit covered activities during the period of March 1981 through November 1981. The division activities complied with the requirements of Section 10.

An audit was conducted by the NNWSI QA Overview Contractor to determine SNL Division 4531 and 4537 compliance to ANSI/ASME NQA-1-1979. NQA-1-1979 has become the guiding QA document for the entire NNWSI Project.

1.8.5. SPECIAL SUPPORT

Objective: To provide special technical support to the NWTS Program.

The following four abstracts were presented at the 1981 National Waste Terminal Storage Program Information Meeting in Columbus, Ohio, on November 16-19, 1981:

"Tuff Rock Mechanics Testing in G-Tunnel at Nevada Test Site," by R. M. Zimmerman, W. C. Vollendorf, and L. D. Tyler, SAND81-2166A.

"Analysis of the Thermal Environment on a Waste Package in Tuff," by J. K. Johnstone, W. D. Sundberg, and J. L. Krumhanal, SAND81-2165A.

"Development of the Data Base for Tuffs at Yucca Mountain, Nevada Test Site," by A. R. Lappin, SAND81-2167A.

"Thermomechanical Evaluation of Potential Repository Horizons," by B. S. Langkopf, L. D. Tyler, A. R. Lappin, R. L. Johnson, and D. Parrish, SAND81-2184A.