Study Plan for
Study 8.3.1.3.2.1

Study Plan for Mineralogy, Petrology, and Chemistry of Transport Pathways

Revision 0

June 1989

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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YUCCA MOUNTAIN PROJECT

Study Plan Number 8.3.1.3.2.1

Study Plan Title Study Plan for Mineralogy, Petrology and Chemistry of Transport Pathways

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Prepared by:

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Date:

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MINERALOGY, PETROLOGY, AND CHEMISTRY OF TRANSPORT PATHWAYS

Los Alamos National Laboratory

ABSTRACT

The mineralogy, petrology and chemistry of pathways test is designed (1) to determine the three-dimensional distribution of mineral types, compositions, abundances, and petrographic textures within the potential host rock, and (2) to determine the three-dimensional distribution of mineral types, composition, and abundances in rocks beyond the host rock that provide pathways to the accessible environments. This study will provide input into the assessment of retardation by sorption, and to the geologic framework of Yucca Mountain. [The analysis of mineral types, abundances, and distributions beneath Yucca Mountain is required by each of these information needs and investigations.] There are three activities within this study: petrologic stratigraphy of the Topopah Spring member, mineral distributions between the host rock and the accessible environment, and fracture mineralogy.

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CONTENTS (cont'd.)

STUDY PLAN FOR MINERALOGY, PETROLOGY, AND CHEMISTRY OF TRANSPORT PATHWAYS

1. PURPOSE AND OBJECTIVES OF STUDIES

1.1 Purpose

The geochemical environment of Yucca Mountain may affect the long-term performance of the repository by retarding the transport of radionuclides by groundwater. The purpose of this Study is to characterize the mineralogy, petrology, and chemistry along potential groundwater flow paths leading from the repository to the accessible environment. Data gathered in this Study will provide information about the types, abundances, distributions, compositions, and textural relationships of minerals along potential groundwater pathways. This information will be used in conjunction with data from sorption experiments (SCP Investigation 8.3.1.3.4) to evaluate radionuclide retardation by sorption processes along flow paths to the accessible environment. Calculational models (SCP 8.3.5.13.3) will use radionuclide retardation factors based on sorption experiments and mineralogic data from this Study to resolve Performance Issue 1.1.6 (probabilistic estimates of radionuclide releases to the accessible environment considering anticipated and unanticipated scenarios).

Groundwater flow paths at Yucca Mountain are not well defined for either present or future hydrologic conditions. These flow paths must be determined to address the performance objective for pre-waste-emplacement groundwater travel time as required by 10 CFR 60.113 and will be defined in SCP activity 8.3.1.2.2.10.3 for the unsaturated zone and activity 8.3.1.2.3.3.3 for the saturated zone. Therefore, at present, this Study must characterize the rock-matrix and fracture-lining minerals along all possible flow paths between the repository and the accessible environment. Our Study will characterize the mineralogy, petrology, and chemistry of rocks occurring along the following types of potential groundwater transport pathways:

- In the unsaturated zone, downward porous matrix flow of groundwater from the repository to the water table.
- In the unsaturated zone, downward transport of groundwater by fracture flow from the repository to the water table.
- In the saturated zone, lateral transport of groundwater by porous matrix flow.
- In the saturated zone, lateral transport of groundwater by fracture flow.

This Study Plan is based upon section 8.3.1.3.2.1 of the Site Characterization Plan (SCP) and includes all three activities discussed in that section. These activities are: 1) Petrologic stratigraphy of the Topopah Spring Member (8.3.1.3.2.1.1), 2) mineral distributions between the host rock and accessible environment (8.3.1.3.2.1.2), and 3) fracture mineralogy (8.3.1.3.2.1.3). This Study Plan is intimately tied to SCP activity 8.3.1.3.2.2 (alteration history), and together both Study Plans define a methodology for identifying the important mineralogic and geochemical properties in the candidate host rock and along groundwater flow paths at Yucca Mountain.

1.2 Rationale and Justification

Collection of these data is required to meet the requirements of 40 CFR Part 191, 10 CFR Part 60, and 10 CFR Part 960; these data will play an important role in resolving Issue 1 (will the mined geologic disposal system at Yucca Mountain isolate the radioactive waste from the accessible environment after closure?). In addition, the data collected in this Study will be used to evaluate the Yucca Mountain site in terms of the siting guidelines outlined in 10 CFR Part 960 and siting criteria in 10 CFR Part 60. In particular, Issue 1.8 (can the demonstrations for favorable and potentially adverse conditions be made as required by 10 CFR 60.122?) and Issue 1.9 (can the higher level findings required by 10 CFR Part 60 be made for qualifying conditions on the postclosure guideline and the disqualifying and qualifying conditions on the technical guidelines for geohydrology, geochemistry, rock characteristics, climate changes, erosion, dissolution, tectonics, and human interference; and can the comparative evaluations be made by 10 CFR 960.3-1-5?) require geochemical information provided by this study for their resolution. Specifically, this Study and the closely-related Study of Alteration History (SCP 8.3.1.3.2.2.1) will provide data to evaluate the following favorable conditions:

1. The nature and rates of geochemical processes operating in the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

2. Geochemical conditions that promote precipitation or sorption of radionuclides.

3. Mineral assemblages that, when subjected to the anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

Potentially adverse conditions will be evaluated by identifying geochemical processes that would reduce sorption of radionuclides, result in the degradation of rock strength, or adversely affect the performance of the engineered barrier.

The data gathered under this Study Plan will be used in conjunction with sorption data (SCP 8.3.1.3) to calculate chemical retardation factors for each species of radionuclides. Chemical retardation factors are required performance parameters for assessing the following performance allocation scenarios: 1) the nominal case for release of radionuclides, 2) failure of unsaturated zone barriers, and 3) failure of saturated zone barriers (SCP Tables 8.3.5.13-8 and -9). The sorptive behavior of radionuclides in tuffs is largely controlled by the mineralogy, petrology, and chemistry of the rocks. Only a limited number of sorption experiments can be conducted on tuffs in the time available before license application; these experiments will characterize the average sorptive behavior for each radionuclide as a function of whole-rock mineralogy and chemistry. Sorptive retardation factors will be calculated for potential groundwater transport pathways by using the mineralogic, petrologic, and chemical data in this Study as a framework for extrapolating the results of sorption experiments performed with a limited number of samples to a three-dimensional distribution of sorption behavior across the site (activity 8.3.1.3.7.1.2; geochemical/geophysical model of Yucca Mountain and integrated geochemical transport calculations).

Data gathered under this Study Plan will also support other SCP investigations, studies, and activities. Application of the results of this Study are described in Section 4.0 of this Study Plan.

This Study is based on examination of samples from the drill holes (SCP 8.4.2.2), samples from outcrops, and samples from the Exploratory Shaft Facility. Section 2.4 of this Study Plan gives general guidelines about the locations of drill holes to be studied and the numbers of samples to be collected. However, we intend our sampling plan to be an iterative process with data collected from early drill holes providing a basis for modifying and improving drilling and sampling plans for later drill holes. The statistical techniques that will be used to evaluate the adequacy of drill hole and sample data are described in Section 3.5 of this Study Plan. The number of samples will also vary among the various analytical methods employed (e.g., x-ray diffraction, electron microprobe, x-ray fluorescence); our goal is to provide a statistically-valid data base for each of the analytical methods used.

2. RATIONALE

2.1 Approach

This Study will examine the mineralogic and chemical variability of rocks in the unsaturated and saturated zones with particular emphasis placed on the repository host rock and on those units occurring along potential groundwater paths to the accessible environment. To accomplish this task, we have reorganized the activities presented in the SCP into the activities shown in Table I. These activities were reorganized for the purposes of this Study Plan so that suites of samples that will undergo similar types of analyses are grouped together. For example, all samples examined under the activity "Internal Stratigraphy of the Candidate Host Rock" will be subjected to modal analysis by optical microscope techniques. Samples examined under the section "Quantitative Mineralogy of the Host Rock and Underlying Rocks along Transport Pathways" will be analyzed by x-ray diffraction. Brief descriptions of the activities in this Study are as follows:

- Quantitative Mineralogy of the Host Rock and Underlying Rocks Along Transport Pathways. The purpose of this activity is to determine the abundance and distribution of minerals occurring in the fractures and matrix of the host rock and in deeper stratigraphic units along potential groundwater flow paths from the repository to the accessible environment (SCP Sections 8.3.1.3.2.1.1, 8.3.1.3.2.1.2 and 8.3.1.3.2.1.3).

- Internal Stratigraphy for the Candidate Host Rock. This activity will define mappable stratigraphic subdivisions within the Topopah Spring Member based on vertical and lateral variations of microscopic groundmass textures, modal phenocryst abundances, mineralogy, and mineral chemistry (SCP 8.3.1.3.2.1.1).

- Chemical Variability in the Host Rock and Along Transport Pathways. This part of the Study examines chemical variations in the candidate host rock and in rocks and radionuclide-sorbing minerals along transport pathways. These data will support all three activities in SCP Sections 8.3.1.3.2.1.1 and 8.3.1.3.2.1.2.

- Role of Fractures and Faults as Past Transport Pathways and Evidence for Paleo-water Table(s). This activity includes textural relationships, chemistry, and relative ages of fracture-lining minerals to determine past transport pathways, depositional conditions, and maximum elevations of paleo-water table(s) (SCP Section 8.3.1.3.2.1.3).

- Statistical Evaluation of Mineralogic, Petrographic, and Chemical Data. This part of the Study is a statistical analysis of mineralogic, petrographic, and chemical data from Yucca Mountain to establish levels of confidence at which data can be extrapolated between widely spaced drill holes (SCP Sections 8.3.1.3.2.1.1 and 8.3.1.3.2.1.2).

These activities, when used in conjunction with results from sorption experiments (SCP activity 8.3.1.3), directly support performance assessment by providing the chemical and mineralogic framework for assigning sorption retardation factors to rock units at Yucca Mountain. Because of the known variations in the chemistry and mineralogy of rocks, sorption retardation factors are expected to vary as a function of vertical and lateral position beneath the site.

TABLE I. CORRELATION OF ACTIVITIES IN THIS STUDY TO ACTIVITIES IN THE SITE CHARACTERIZATION PLAN

Study Plan Activity	Site Characterization Plan Activity	
Quantitative Mineralogy of the Host Rock Along Transport Pathways	8.3.1.3.2.1.1	Petrologic Stratigraphy of the Topopah Spring Member
	8.3.1.3.2.1.2	Mineral Distributions Between the Host Rock and Accessible Environment
	8.3.1.3.2.1.3	Fracture Mineralogy
Internal Stratigraphy for the Candidate Host Rock	8.3.1.3.2.1.1	Petrologic Stratigraphy of the Topopah Spring Member
Chemical Variability in the Host Rock Along Transport Pathways	8.3.1.3.2.1.1	Petrologic Stratigraphy of the Topopah Spring Member
	8.3.1.3.2.1.2	Mineral Distributions Between the Host Rock and Accessible Environment
Role of Fractures and Faults as Past Transport Pathways and Evidence for Paleo-Water Tables	8.3.1.3.2.1.3	Fracture Mineralogy
Statistical Evaluation of Mineralogic, Petrographic, and Chemical Data	8.3.1.3.2.1.1	Petrologic Stratigraphy of the Topopah Spring Member
	8.3.1.3.2.1.2	Mineral Distributions Between the Host Rock and Accessible Environment

These activities also support the activity "History of Mineralogic and Geochemical Alteration at Yucca Mountain" (SCP Section 8.3.1.3.2.2.1) by providing the mineralogic and chemical data that describe the present-day alteration mineral assemblages at Yucca Mountain. The temperature and chemical conditions under which these mineral assemblages formed can be constrained by the mineral species present, their chemistry, their abundances, their textures, and their distribution.

2.2 Types of Measurements and Determinations to be Made

The measurements and determinations that will be made include:

- mineral identifications, abundances, and distributions in bulk rocks and fractures by x-ray diffraction,
- major, minor, and trace element chemistry of whole rocks, mineral separates, and fracture coatings by x-ray fluorescence, atomic absorption spectrophotometry, and neutron activation analysis,
- mineral chemistry by electron microprobe analysis,
- groundmass textural variations by modal petrography, and
- textural relationships of minerals in fractures by scanning electron microscope.

Analytical methods to be used for each activity are discussed in the appropriate methods sections under that activity. Not all methods will be used for each sample.

2.3 Rationale for Choosing Types of Measurements Made

X-ray diffraction (XRD) provides an unambiguous identification of mineral phases present at levels above detection limits and gives a quantitative estimate of mineral abundances. In cases where mineral identifications are ambiguous because abundances are close to detection limits, additional methods such as optical petrography and electron microprobe analysis can be used to complement XRD analyses. XRD is the only technique suitable for determinations of mineral species and abundances, particularly for the fine-grained groundmass and fracture-lining minerals that are of interest to the Project.

X-ray fluorescence (XRF) is one of several techniques available for determining major-, minor-, and trace-element concentrations in bulk-rock samples. The suite of elements to be analyzed by XRF includes SiO_2, TiO_2, Al_2O_3, FeO (total), CaO, MgO, Na_2O, K_2O, MnO, P_2O_5, Ba, Rb, Sr, V, Cr, Ni, Zn, Y, Zr, and Nb. We have chosen XRF over other techniques such as emission spectroscopy and atomic absorption spectroscopy because, although all of the methods have acceptable levels of accuracy and precision, XRF analyses are rapid and samples are readily archived. Neutron-activation analysis (NAA) will be used for additional major-, minor and trace-element analysis (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Zr, Mo, Ag, In, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Dy, Yb, Lu, Hf, Ta, W, Au, Hg, and Th. Uranium concentrations will be determined by delayed neutron counting. NAA is a nondestructive, sensitive, and precise analytical method that complements the analytical suite done by XRF, particularly for trace elements. Fluorine and chlorine will be determined by atomic absorption spectrophotometry, a method that is both sensitive and cost-effective. The applications of these data are described in Section 3.3 of this Study Plan.

Electron microprobe analysis is the only practical technique for determining compositions of primary and secondary minerals in the groundmass and fractures. The electron beam can be focused on areas ranging from 1-25 microns square, and therefore quantitative compositions can be determined for most minerals. Other techniques, such as liquid separation of individual phases or analysis by standard bulk-rock techniques, are not cost-effective and offer no substantial improvement in precision and accuracy for major chemical components.

Modal petrography by optical microscopy complements the data collected by the techniques described above by allowing investigators to determine the distribution and textural relations of fracture and groundmass minerals. Microscopy is also useful in choosing samples for bulk-rock chemical analyses and for determining suitable mineral grains for electron microprobe analysis. We are investigating the use of image analysis as a technique for quantifying groundmass textures; however, this analysis is not fully developed at the present time.

Scanning electron microscope (SEM) inspection of samples, particularly open fractures, allows determination of textural relations at a much finer scale than can be achieved by either binocular microscope (open fractures) or petrographic microscope (thin sections of closed fractures). Qualitative chemical analyses useful for mineral identification can be made on grains that are too small for quantitative electron microprobe analysis or on open fracture surfaces that cannot be studied in thin sections.

2.4 Sampling

An important goal of this Study is to characterize accurately and completely the rocks along potential transport pathways; our ability to define the mineralogy and chemistry along pathways is directly linked to our knowledge of the locations of these pathways. The extent of this knowledge is a significant constraint on this Study. We are therefore attempting to obtain a knowledge of the vertical and lateral variations in mineralogy and chemistry along all likely groundwater flow paths between the host rock and the accessible environment so that our results are not significantly limited by our ability to define flow paths. Thus, this constraint will require numerous analyses of rocks and minerals within the controlled area boundary (Fig. 2).

2.4.1 Location of Drill Holes

Samples collected from surface-based drill holes will allow us to evaluate the lateral changes in mineralogy, chemistry, and petrography at Yucca Mountain by providing an areally extensive suite of subsurface samples from the exploration block (Fig. 1) and the surrounding controlled area (Fig. 2). The sampling program for the unsaturated zone will emphasize characterization of rock units beneath the exploration block, particularly between the candidate host rock and the water table. Characterization of the saturated zone requires that samples be collected beneath the exploration block and along potential groundwater flow paths to the accessible environment; emphasis will be placed on characterizing down-gradient groundwater flow paths to the south and east.

Drilling activities providing samples for this study include the systematic drilling program (SCP 8.3.1.4.3.1.1), geologic (G) core holes (SCP 8.3.1.4.2.1.1), unsaturated zone (UZ) drill holes (SCP 8.3.1.2.2.3.2), and water-table (WT) holes (SCP 8.3.1.2.3.1.2). Additional descriptions of these drill holes can be found in section 8.4.2.2 of the SCP. Most of the samples supporting this Study will come from the systematic drilling program.

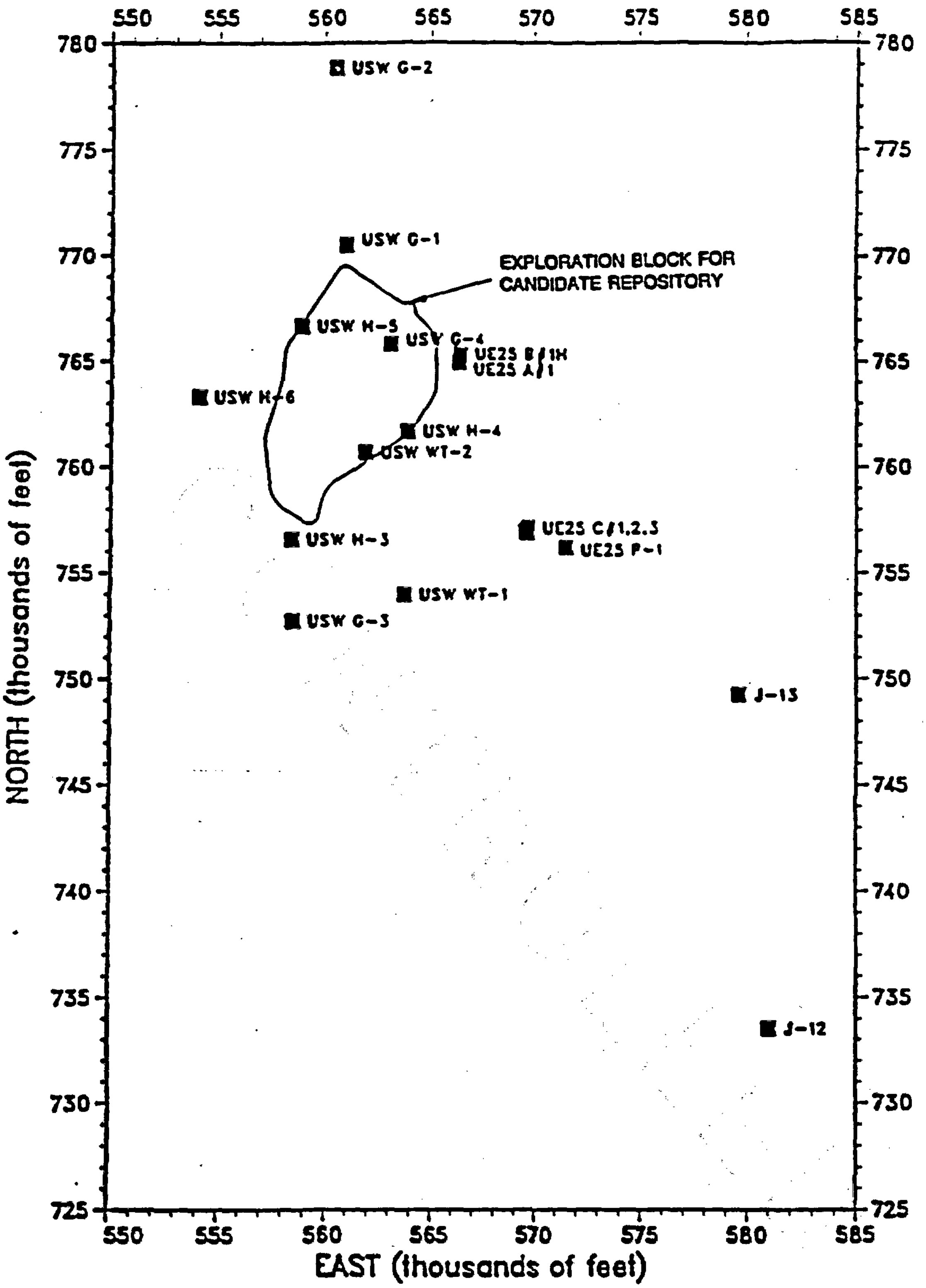

Figure 1. Location map of existing drill holes used in this study.

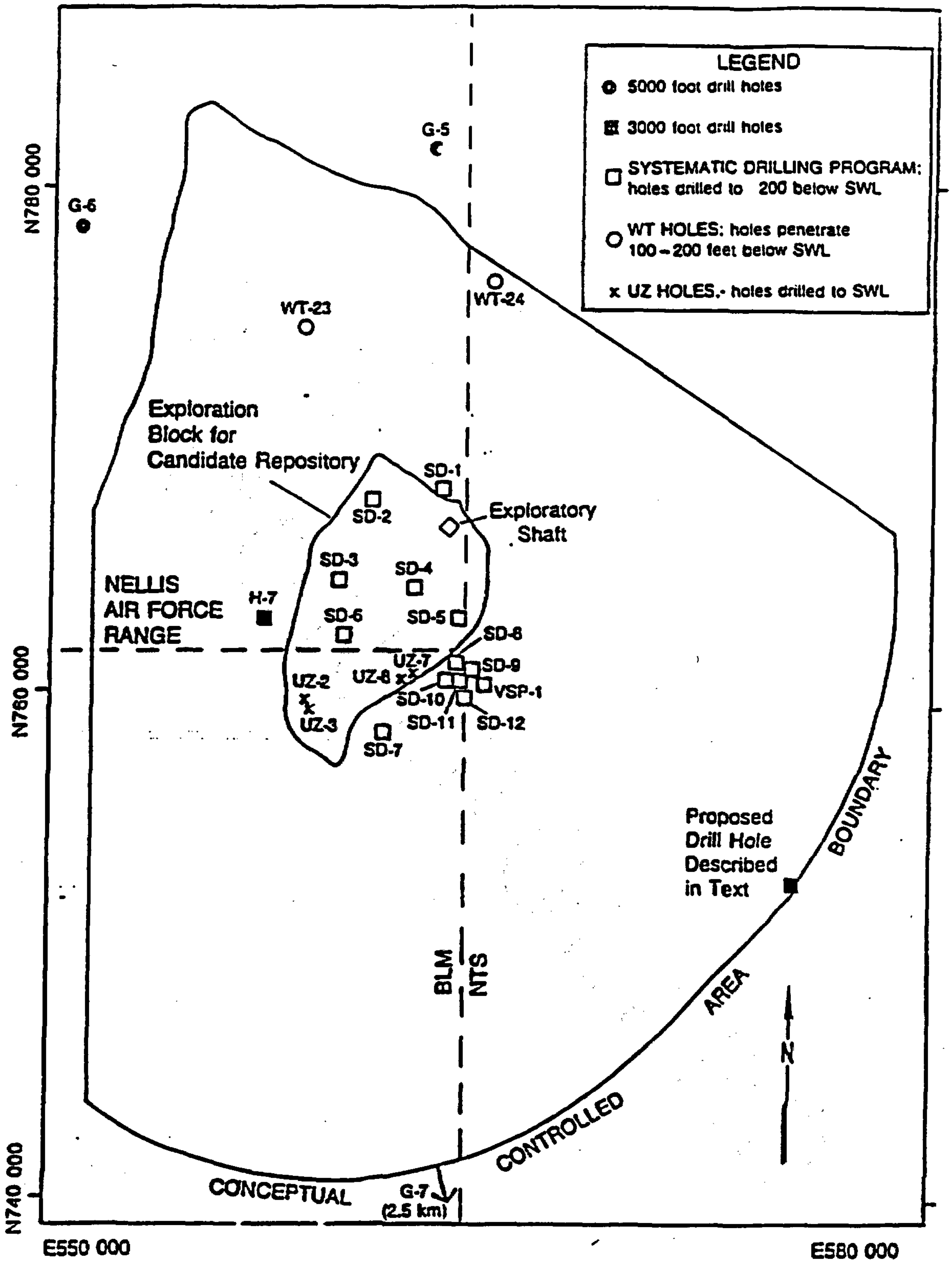

Figure 2. Drill holes that will provide samples for this study.

The systematic drilling program at Yucca Mountain (SCP 8.3.1.4.3.1.1) will take place in two discrete phases. During the first phase, holes will be distributed at various spacings to assess the effects of drill hole density on the extrapolation of geologic information across the exploration block. Section 3.5 of this Study Plan describes the extrapolation techniques that will be applied to mineralogic, chemical, and petrographic data. The second-phase drilling will be designed to complete the characterization of the exploration block and of potential groundwater pathways to the accessible environment. The optimization of drill hole densities during the second phase will take place under SCP activity 8.3.1.4.3.1.1 and will depend on 1) the intrinsic variability of rock units at the site, 2) the sensitivity of radionuclide transport models to uncertainties in characterizing these parameters, and 3) an economic cost analysis for completing the drilling program.

Analyses have been already performed on core and cuttings from holes drilled for early investigations; therefore, the distribution of the holes was determined by those investigations. The location of these existing holes is shown in Figure 1.

The drilling program planned for site characterization will allow improved accuracy in a predictive model of mineralogy and chemistry across the candidate repository block and out to the accessible environment. For purposes of characterization of potential transport pathways, the holes used need to be fully cored and extend to the first major laterally transmissive zone below the water table. As this has not been well defined as yet, our working boundary for characterization is the base of the Crater Flat Tuff and its underlying flow breccia in the northern part of the exploration block. This choice is based on hydrologic data showing several transmissive zones in the Crater Flat Tuff in most holes (Benson et al., 1983; Lobmeyer, 1986). Three drill holes (USW G-5, USW G-6, and USW G-7) are planned that will penetrate the older volcanic units beneath the Crater Flat Tuff and its underlying flow breccia. We plan to characterize the mineralogy, chemistry, and petrography of these units where these units are penetrated.

Our requirements for deep drill holes (approximately 3000 feet total depth) are not incorporated into the present version of the SCP. These requirments will be addressed in the next SCP update.

The drill holes that we plan to use in this Study for site characterization are shown in Figure 2. In addition, a hole to be located between J-13 and UE-25p#1 (approximate location shown by an open box in Figure 2) would provide important information on mineralogic and chemical variability along saturated flow paths and on the Topopah Spring Member under saturated conditions. The locations of drill holes proposed for this Study may change as the drilling program for surface-based testing changes. Samples from the ES and drifts will provide information on the Paintbrush Tuff and will be used extensively in activity 8.3.1.3.2.1.1 of the SCP (Petrologic Stratigraphy of the Topopah Spring Member). Outcrop samples may also be used in the activity. Cuttings from additional hydrology holes may be used to provide supplemental data for this Study if needed. The locations of outcrop and drill cuttings samples will be determined as the requirements are developed for these types of samples.

2.4.2 Sample Distribution Within Drill Holes

Sampling along a drill core is done in such a way as to assure that each lithologic unit and each fracture coating type is sampled. The results of prototype testing will be used to determine sample sizes and sample densities to be used during site characterization. We anticipate a maximum sampling interval of approximately 50 ft, but samples may be taken more frequently as required for adequate characterization of the core. The sample locations will be determined by the investigator after inspection of the core; geological logs provided by the U.S. Geological Survey (USGS) will provide information to guide sample selection. During the first phase of the systematic drilling program, we anticipate collecting approximately 1000 samples to characterize the mineralogy of whole rock samples. Splits of about 150 of these mineralogic samples will be analyzed for major- and trace-element chemistry. Petrographic thin sections will be prepared for all of the mineralogic samples; mineral-chemical data will be collected for secondary minerals in approximately 100 of the thin sections. Approximately 800 samples will be collected to characterize the fracture mineralogy of the site during first-phase drilling. The number and distribution of samples collected during the second phase of the systematic drilling program will be determined after the results of first-phase drilling have been evaluated.

2.4.3 Statistical Analysis of Sample Distribution

The question of the number and spacing of samples required to characterize adequately the rocks and minerals along groundwater transport pathways at Yucca Mountain is addressed by the activity described in Section 3.5 of this Study Plan. Additional holes cannot provide additional reliability of a calculational model for predicting releases to the accessible environment (SCP 8.3.5.13.3) if the small-scale variability (measured in many cores by the within-hole variance of the observations) is not significantly smaller than the variability between holes drilled at the maximum feasible density. A preliminary study by Campbell (1988), kriging existing XRD data using a technique described in Section 3.5.1 of this Study Plan, strongly suggests that local variability of mineralogy may be substantial. However, this analysis used data which are not of QA Level I, and many more such computations using data from the holes proposed above will be made before the adequacy of this sampling plan can be assessed. If, when data collection is completed on the holes proposed during the first phase of the systematic drilling program, greater accuracy in the predictive model is found to be both attainable and also needed to satisfy requirements for licensing, additional data collection in the existing drill holes will be proposed. If the distribution of the first-phase drill holes provides inadequate characterization of the site, additional drill holes will be proposed (second phase) to provide the necessary information.

Existing fracture-mineral data are not as complete as rock matrix data, and core from several drill-holes shown in Figure 1 must be examined before the distribution of fracture coatings can be determined and any statistical methods employed to determine the number and spacing of samples required to develop a predictive model for Yucca Mountain.

2.5 Additional Factors for Consideration

2.5.1 Impact on Site

The analyses necessary for this Study should have minimal impact on the site because most samples necessary for the Study will be obtained from cores from existing and planned drill holes or from surface outcrops. Much of the data on the internal stratigraphy of the candidate host rock and on the mineralogy of fractures and faults will be acquired using samples from the exploratory shaft. Sampling procedures for the exploratory shaft samples are being developed as part of the prototype test plan and are not part of this Study Plan.

2.5.2 Required Accuracy and Precision and Limits of Methods

Results from this Study will provide an understanding of the vertical and lateral variability of the mineralogy and chemistry of rocks at and in the vicinity of Yucca Mountain. Data with known and predictable error will provide estimates and bounds on effective mineralogy used in calculating overall retardation by sorption and will provide stratigraphic control during repository construction. This Study will provide highly accurate determinations of the presence or absence of phases in the rocks and fractures. The detection limits, accuracy and precision of x-ray diffraction, x-ray fluorescence, microprobe, and petrographic analyses are sufficient for the needs of this study; techniques are described in detail by Bish and Chipera (1986), Broxton et al. (1986), and Byers and Moore (1987).

Statistical studies will address the uncertainties associated with sample inhomogeneity, density, and distribution. The prototype test for sample collection procedures (WBS 1.2.6.9.4.1.3) will examine inhomogeneities in the candidate host rock on the microscopic, hand-specimen, and outcrop scale. In addition, statistical methods for interpolating data between widely spaced and unevenly distributed drill holes are being developed under Section 3.5 of this study plan. All of the above studies will be used to determine uncertainties associated with sample collection. Sampling procedures for fracture studies will be developed in the prototype test for sample collection procedures (WBS 1.2.6.9.4.1.3).

Accuracies and precisions for individual analytical methods are given in sections 3.1.2, 3.2.2, and 3.3.2 of this Study Plan.

2.5.3 Capability of Methods to Support Study

The techniques employed in this Study are standard techniques with known reliabilities. The methods used for analyzing the data are also standard for the most part. Minor variations in the analytical procedures are described in Sections 3.1, 3.1.2, 3.3.1, and 3.4.1. The techniques are sufficient for the requirements of this Study.

2.5.4 Time Required Versus Time Available

We anticipate that this Study will be completed in time to support the license application given existing schedules for the exploratory shaft and integrated drilling program.

2.5.5 Interference with Other Studies

This Study is not expected to interfere with any other studies or tests.

2.5.6 Quality Assurance Requirements

The activities in this Study Plan have been assigned as Quality Level I in accordance with paragraph 5.2.1d in procedure TWS-MSTQA-QP-18. These data may be used in assessing radionuclide migration which hss a direct bearing on site assessments concerning waste isolation to be used in the license application. The criteria from NQA-1 that apply to this study are shown in Appendix A and the procedures that will satisfy these criteria are shown in Appendix A and in sections 3.1.1, 3.2.1, 3.3.1, and 3.4.1 of this Study Plan. The Quality Level Assignment Sheets for this Study are included in Appendix B.

The software used to support licensing will be verified and validated according to the LANL Software QA plan.

3. DESCRIPTION OF MEASUREMENTS AND ANALYSES

The following description of measurements and analyses contains a more detailed discussion of work being performed in support of Investigation 8.3.1.3.2.1 of the SCP. Section 2.1 of this Study Plan shows how each of the following sections relates to activities in the SCP.

3.1 Quantitative Mineralogy of the Host Rock and Along Transport Pathways

The quantitative mineralogy of the host rock and of the rock matrix along transport pathways at Yucca Mountain will be determined by analyzing core, outcrop, and exploratory shaft material using x-ray powder diffraction.

These analyses will be performed on homogenized powdered samples and will provide accurate and unambiguous determination of the phases present. The use of standards of all the minerals present in the tuffs plus a corundum internal standard permits determination of the amounts of all phases present. X-ray diffraction patterns of samples with a corundum internal standard will be recorded for all whole-rock samples analyzed. Analyses will be performed on samples from core and from the exploratory shaft samples whenever changes in lithology are apparent so that complete mineralogical data are available for all lithologies.

The mineralogy of fracture- and fault-lining minerals will be determined by analyzing scraped samples of fracture coatings. Whenever sufficient material is available, quantitative analysis will be performed as for whole rock samples. Because many fractures have thin and/or discontinuous coatings, it is not always possible to obtain enough sample for an XRD powder with an internal standard; in these cases semi-quantitative analyses must be performed on smear samples with an external standard. The purpose of the analyses is mineral identification, thus samples will be chosen to provide the thickest covering of representative minerals. Therefore, the relative proportions of minerals in a given sample may not be representative of the actual proportions over a larger area of the fracture. Once mineral identifications are established, visual estimates of fracture-surface coverage will be made for each mineral phase. These estimates will be compared to the semi-quantitative XRD results.

Fibrous zeolites in the host rock matrix and fractures will be identified and quantified to allow assessment of possible health risks to workers inhaling dust containing these minerals during construction of the repository. Study of fibrous minerals supports SCP Study 8.3.1.15.1.8, which is examining constraints on the ventilation of the underground repository facilities imposed by such minerals.

3.1.1 Methods

Analyses will be performed on powdered samples using x-ray powder diffraction. The methods to prepare samples and to perform quantitative analysis of rocks using x-ray powder diffraction data are those described by Bish and Chipera (1986) and in the procedures listed below. Additional methods for data analysis may employ fitting of the whole diffraction pattern (Bish and Howard, 1987) and simultaneous linear equations methods combining x-ray diffraction data with x-ray fluorescence chemical analyses. If needed, these procedures will be developed 30-60 days before their use in tests. The only modification anticipated in our sample preparation procedure may be the eventual addition of a spray dryer to prepare samples with little or no preferred orientation. This modification is dependent upon the development in industry of a suitable spray dryer. The methods used to prepare and analyze smear samples of fracture minerals are described in Carlos (1987).

These analyses will provide data used in predicting the long-term performance of the site and, as such, are classified as Quality Level I. The work will be performed in accordance with the Los Alamos National Laboratory (LANL) Quality Assurance Program Plan for the Yucca Mountain Project. The following technical procedures will also apply:

1. Siemens X-Ray Diffraction Procedure, TWS-ESS-DP-16.
2. Clay Mineral Separation and Preparation for X-Ray Diffraction Analysis, TWS-ESS-DP-25.
3. Nevada Test Site Fracture-Filling Studies Procedure, TWS-ESS-DP-28.
4. Pulverizing, Using the SPEX 8500 Shatterbox, TWS-ESS-DP-53.
5. Crushing, Operating of 50-Ton Hydraulic Press, TWS-ESS-DP-54.
6. Rock Splitting, Operating of 50-Ton Hydraulic Press, TWS-ESS-DP-55.
7. Brinkman Automated Grinder Procedure, TWS-ESS-DP-56.
8. Quantitative Analysis by X-Ray Powder Diffraction, TWS-ESS-DP-116.
9. X-Ray Fluorescence Weighing Procedure, TWS-ESS-DP-51.
10. Fusing, Using the Junior Orbit Shaker, TWS-ESS-DP-52.
11. Procedure for X-Ray Fluorescence Analysis, TWS-ESS-DP-111.

3.1.2 Required Accuracy and Precision

This activity requires high accuracy in identification of minerals present in tuffs, but high precision on individual amounts is not required for most minerals. X-ray powder diffraction routinely provides unambiguous qualitative determinations of the presence or absence of minerals in tuffs above the minimum detection limits. Detection limits are a function of what mineral is being determined and of experimental conditions but are generally 1-5% of the rock. Precision of determinations of individual minerals in pressed powder samples is a function of the mineral being determined. Future advances in data reduction should improve precisions to at least ±5% of the determined amount for bulk samples. At present, precision in oriented smear samples used in fracture studies is probably no better than ±25% of the determined amount. That number will be improved somewhat by use of similarly prepared standards in the data reduction, but the primary purpose of the analysis of fracture coatings remains identification of minerals in fractures, not quantification of amount. We expect ranges in mineralogical compositions similar to those reported in Bish and Chipera (1986) for bulk-rock samples and similar to those reported by Carlos (1985, 1987) for fracture minerals.

The accuracy of input required for transport modeling has not been determined yet, therefore the accuracy of results needed in this activity cannot be defined. For use in modeling functional stratigraphy, we have set as our limit of accuracy in predicting zeolitic versus nonzeolitic as 20 m, which is 10% of the average thickness of the Calico Hills Tuff. A tuff is considered to be zeolitic if it contains more than 20% zeolites.

3.1.3 Equipment Required

Most equipment required for this activity is presently available at Los Alamos, including equipment used for sample preparation (rock crusher, shatterbox, and automated grinder) and analytical equipment, such as the Siemens D-500 x-ray diffractometer and the Rigaku x-ray fluorescence spectrometer. All computer hardware necessary for data reduction is also available. When available on the market, an appropriate spray dryer will be purchased for use in eliminating preferred orientation effects in x-ray powder diffraction analyses.

3.1.4 Data Reduction and Analysis

The program QUANT5 will be used initially to reduce all intensity data obtained on the Siemens x-ray diffractometer to determine weight percents of individual minerals. QUANT5 performs either internal or external standard analyses using standard data collected on the Siemens diffractometer. Integrated intensity data used as input to QUANT5 will be obtained using software provided with the Siemens diffractometer. X-ray fluorescence data will be reduced using the program XRF-11 written by Criss Software, Largo, MD. Future enhancements in XRD data reduction may incorporate Rietveld methods and/or simultaneous linear equation methods coupled with XRF chemical data.

QUANT5 and XRF-11 will be documented, used, and controlled in accordance with the LANL YMP procedure for configuration management (TWS-QAS-QP-3.11) and the procedures for software control (TWS-QAS-QP-3.12 and QP-3.13).

3.1.5 Representativeness of the Tests and Limitations and Uncertainties

Prototype tests for the collection of samples are presently underway to address the representativeness of core, shaft, and outcrop samples. The results of these prototype tests will be used to guide the methodologies for collection of samples in this Study. These analyses will provide representative data to the extent that the analyzed core is representative of the rock and fractures being studied. Approximately 1000 whole-rock samples and 800 fracture-filling samples will be analyzed from core holes, drill holes, and the exploratory shaft and drifts during the first phase of the drilling program. Typically we are able to collect, analyze, and report whole-rock data for a 6,000-ft drill hole in one man-year. Sampling densities vary according to the lithologic complexity of the rock units, but in the past we have collected approximately one sample/50 ft of lithologically uniform drill core. This density may change in future work based upon the results of ongoing statistical studies (Section 3.5 and WBS 1.2.6.9.4.1.3).

Fracture minerals are nonuniformly distributed in drill cores. Based on past experience with Yucca Mountain cores, we expect to collect an average of four fracture coatings per 100 feet of core. Actual sample densities will vary depending on fracture frequencies with different stratigraphic intervals. Ultimately, sample densities will be determined by the principal investigator after examination of the core. Collection, analysis, and reporting of fracture-mineral data for a 6,000-ft drill hole generally takes 1.5-2 man-years.

Data for core, shaft, and outcrop samples collected over a large area will be used to determine the vertical and lateral variability of minerals at Yucca Mountain. The use of these data will be limited by the number of samples that can be analyzed and by the frequency of sampling. For example, the more samples analyzed from a given area, the better our knowledge will be for that area. As outlined above, our ability to define the mineralogy along potential groundwater pathways from the repository to the accessible environment will ultimately be limited by our ability to predict the locations of these pathways, not by our ability to obtain mineralogic data for the site.

3.2 Internal Stratigraphy for the Candidate Host Rock

The Topopah Spring Member consists of a thick layer of rhyolitic rock overlain by a relatively thin quartz latite caprock (Lipman el al., 1966). The potential repository workings will be within the rhyolitic portion of the Topopah Spring Member, which is homogeneous in chemical composition (Lipman et al., 1966; Zielinski, 1983) but is variable in textural and phenocryst petrography (Byers, 1985; Byers and Moore, 1987) and in mineralogy (Bish and Vaniman, 1985).

Petrographic data from drill cores show that textural features can be used to determine stratigraphic position to within 50-100 ft within the densely-welded interior of the Topopah Spring Member. There are four major stratigraphic subdivisions between the quartz latitic caprock and basal vitrophyre of the Topopah Spring Member. These subdivisions, which define the internal stratigraphy of the Member, include in ascending order: 1) the lower nonlithophysal zone, 2) the lower lithophysal zone, 3) the middle nonlithophysal zone, and 4) the upper nonlithophysal zone. Petrographic studies have been important in developing the internal stratigraphy of the Topopah Spring Member in the vicinity of the exploration block (Byers and Moore, 1987). Petrographic studies will be extended to new drill core, to shaft samples, and to outcrop samples to refine stratigraphic subdivisions within the tuff.

We will also examine the feasibility of computerized image analysis of thin sections to determine if this new technique has potential for quantifying the amounts of some textural features such as spherulitic/microlitic groundmass, granophyre, cryptocrystalline groundmass, amygdules, and phenocrysts that are now measured by point-counting methods. If image analysis studies are successful, the results will be compared to observations from petrographic studies. We are also considering the feasibility of image analysis to examine large-scale welding and crystallization features in rock slabs; rock staining techniques may be used to enhance the discrimination of these features.

3.2.1 Methods

Samples will be collected from outcrop, drill core, or underground workings by procedures developed from the prototype test for sample collection for the exploratory shaft (WBS 1.2.6.9.4.1.3). Outcrop or underground samples from a massive solid exposure of Topopah Spring rhyolite will consist of oriented samples with the top, a north arrow and a horizontal plane marked with indelible felt-tip pen. For core samples, thin sections will be cut with the long dimension of the slide vertical and with the down direction marked on the slide in accordance with QA procedure TWS-ESS-DP-04. Muck samples are not oriented.

These thin sections will be point counted to determine percentages of the different grain-size groundmass textures and phenocrysts in order to estimate the stratigraphic position as described in Byers (1985). For this examination the thin sections will be counted in transmitted light, using a research polarizing microscope and an automated point counter. Results will be tabulated and shown graphically in a manner similar to Figure 2 of Byers (1985) and similar to Figures 2 through 5 of Byers and Moore (1987).

The following procedures will be used in sampling, thin-sectioning, and modal counting of textures and phenocrysts in thin section:

1. Sample Identification and Control for Mineralogy-Petrology Studies, TWS-ESS-DP-101.

2. Nevada Test Site Core Petrography Procedure, TWS-ESS-DP-03.

3. Thin Section Preparation Procedure, TWS-ESS-DP-04.

4. Procedure for Determination of Volume Percent of Constituents in Thin Sections of Topopah Spring Member and Similar Rhyolites, TWS-ESS-DP-102.

3.2.2 Required Accuracy and Precision

Petrographic modal analyses generate quantitative phenocryst mineral percentages. Doubtful identifications of microphenocrysts in a fine-grained volcanic rock can be resolved by the electron microprobe when necessary. For most petrographic work, an occasional misidentified microphenocryst (<0.2 mm) would not significantly affect the overall percentages. Modal analyses of textures, however, are at best only semi-quantitative and more prone to operator variance. It remains to be determined whether image analysis can quantify textures and thus increase the speed, efficiency, and reproducibility of this method.

To be useful in determining stratigraphic intervals during construction of a repository, it is necessary to be able to identify a sample to within 25 m of its stratigraphic position. A resolution of 25 m should provide enough control to ensure that the closest approach of the repository to the underlying basal vitrophyre of the Topopah Spring Member is no less than 50 m. It is desirable to keep the minimum separation between the repository and the vitrophyre at least 50 m because of potential thermal stability problems arising in secondary minerals associated with the vitrophyre at temperatures above 100°C. To minimize alteration of glass and secondary minerals in the vitrophyre, the closest desired approach of the repository to the vitrophyre is 50 m (based on temperature profiles developed in Sinnock et al., 1984).

3.2.3 Equipment Required

All necessary standard field equipment for surface-outcrop sampling involving measured sections of the Topopah Spring is available at LANL. This equipment includes a Polaroid camera, 35-mm camera, rock picks, sledge hammers, cold chisels, steel tapes, Jacob staff (measuring pole), Abney levels, Brunton compasses, tally recorder, and rock marking and sample bagging supplies. Similar equipment would also be used for underground sampling. Drill core will be marked for sampling; current procedures require that core library personnel take core samples.

Required laboratory equipment includes that in the LANL thin-section laboratory (TWS-ESS-DP-04): a polarizing microscope, an electrically driven automated point counter, and a computerized image analyzer.

3.2.4 Data Reduction and Analysis

The data will be stored in a computer data base, and standard graphic packages will be used for producing binary and ternary phenocryst plots, histograms, and bar graphs plotted with respect to stratigraphic position (Byers, 1985). The data will also be subjected to discriminant statistical analyses (Byers and Moore, 1987). The amount of variance arising from one petrographer making multiple point counts on one thin section and from two petrographers counting the same thin section will also be assessed. This operator variance test will help us determine what levels of variance are acceptable for this activity.

3.2.5 Representativeness of the Analyses and Limitations and Uncertainties

The analyses will generate data that will be representative of the internal stratigraphy of the Topopah Spring Member. A 20- x 30-mm thin section contains 5,000-12,000 modal point counts in which phenocrysts and textures are identified (Byers, 1985; LANL Procedure TWS-ESS-DP-102). Assuming all material under the cross hairs (point counts) is correctly identified and no constituent is less than 2% of the thin section area, the thin section is representative of the specimen and probably of the adjoining rock. These assumptions about the representativeness of thin sections will be examined in detail during prototype testing. Multiple thin sections will be analyzed where sample representativeness must be demonstrated. The principal source of error in these tests is the consistency between operators in identification of textures.

3.3 Chemical Variability in the Host Rock and Along Transport Pathways

The whole-rock and mineral-chemical data will be used in conjunction with the mineralogic data to characterize the site, providing a basis for correlating sorption and other laboratory tests to the conditions at Yucca Mountain. In addition, the whole-rock and mineral-chemical data will be used to support XRD methods under development (see Section 3.1.1 of this Study). These new XRD methods combine mineralogic data with chemical data to provide constraints on the compositions of individual mineral phases, particularly for those mineral too fine-grained to be analyzed by electron microprobe. Determination of Fe^{2+}/Fe^{3+} will be used to identify rock units that might change the oxidation/reduction potential of groundwaters that come into contact with these rocks. Fluorine and chlorine within the tuffs in the unsaturated zone are incompatible elements that could be concentrated in late stage crystallization products (e.g., vapor phase minerals); these minerals might interact with vadose water to produce weak acids that could have prolonged contact with waste canisters. Mineral-chemical data for zeolites, clays, and manganese oxides will be collected because the sorption potential and mineral stability of these minerals is determined in part by their compositions. Although conditions of analysis are not optimized for many elements of economic interest, many of the chemical analyses (e.g., U, Th, Au) for whole-rock samples will be of sufficient quality for use in the mineral resources evaluation of the site (SCP 8.3.1.9.2). Additionally, the whole-rock chemical data, particularly for trace elements, can contribute to stratigraphic studies of the volcanic units at the site (SCP 8.3.1.4.2.1). The whole-rock chemical data collected in this Study also will be used to support investigations of alteration history of tuffs at Yucca Mountain (SCP 8.3.1.3.2.2.1). Comparison of devitrified, vitric, and zeolitic tuffs will allow us to determine the past mobility of various major-, minor-, and trace-elements during alteration of the tuffs at Yucca Mountain and thus will provide information about expected future alteration.

The chemistry of tuffs and of their matrix minerals will be determined by XRF, NAA, AA, and electron microprobe analysis. Samples will include drill core, outcrop samples, and material from the exploratory shaft. X-ray fluorescence analyses will be used to determine major-, minor-, and some trace-element constituents of whole-rock samples. Samples will be homogenized and fused into glass disks for analysis. We will obtain quantitative chemical analyses by calibrating our sample suite against well-characterized standards with similar chemical compositions. Ferrous iron concentrations will be determined titrametrically; however, we have not yet decided whether these analyses will be determined in-house or contracted to an outside laboratory. Fluorine and chlorine will be determined by atomic absorption spectrophotometry. Neutron activation analysis will be used to determine trace elements not readily detectable by XRF for whole-rock samples. NAA will also provide independent determination of some major, minor and trace elements determined by XRF.

The chemical compositions of rock-matrix and fracture-lining minerals, including zeolites, clays, secondary feldspars, and manganese- and iron-oxide minerals, will be determined by electron microprobe analyses. Trace element compositions for individual mineral phases can be determined by analyzing mineral separates by XRF and NAA as needed. Microprobe samples will normally consist of polished thin sections. We will use silicate mineral standards to calibrate the electron microprobe during the analyses of silicate minerals; oxide standards will be used when possible to calibrate the electron microprobe during the analysis of oxides. In most cases, we will coordinate the selection of samples for chemical analyses with those collected for XRD so that the mineral chemistry and mineralogy of the alteration assemblages can be compared. When the minerals to be analyzed occur in thin coatings on open fractures, thin sections cannot be made. Minerals on these fracture faces may be analyzed by microprobe using polished epoxy mounts or by analyzing flat fracture surfaces directly.

3.3.1 Methods

Major-, minor-, and trace-element compositions in bulk-rock samples will be determined by XRF. Samples will be prepared by powdering and homogenizing 15-20 g of material in a shatterbox. Duplicate 1- to 2-g sample splits will be heated to 1,000°C for one hour to destroy zeolite and clay crystal structures, thus eliminating gross weighing errors introduced by the rapid rehydration of these minerals upon cooling. Loss on ignition (LOI) in the samples will be determined by the difference in sample weight before and after the heating treatment. The samples will then be ground in an agate grinder and the material prepared for fusion with a fluxing agent. Elemental concentrations will be determined on a Rigaku wavelength-dispersive x-ray fluorescence spectrometer. The spectrometer will be calibrated by running standard reference materials at the time of sample analysis. The standard reference materials, which consist of National Bureau of Standards (NBS), United States Geological Survey (USGS), and other certified rock materials, will be selected to be as similar in composition to the samples as possible. Correction for interelement x-ray matrix effects for major elements are performed by a fundamental parameters method. Matrix corrections for trace elements are made by ratioing the elements' net intensity to the net Rh-Compton intensity.

Because the drying procedure described above results in significant sodium loss in samples with abundant hydrous minerals (Broxton et al., 1986), splits of all samples will be analyzed for sodium by NAA or AA. Other volatile elements such as fluorine and chlorine will be determined by AA. A procedure for AA analyses will be prepared.

Neutron activation analysis will be used to determine major, minor, and trace-element concentrations in whole-rock samples and, if needed, in mineral separates. Approximately 4 g of sample is irradiated in a thermal neutron flux of ~6 X 10^{12} neutrons/cm^2/s at the Los Alamos Omega West research reactor. Uranium concentrations are determined by delayed-neutron counting (DNC). The samples are then entered into the NAA sequence. The full DNC/NAA sequence for each sample is 20-s irradiation, 10-s delay, 30-s DNC analysis, 20-min delay, 475-s gamma-ray count for short-lived radionuclides, 500-s re-irradiation, 4- to 7-day delay, 1-hr gamma-ray count for intermediate-lived radionuclides, 3-wk delay, and finally a 2-hr count for long- lived radionuclides. Gamma-ray counting is done by lead-shielded Ge (Li) detectors. Detectors are set at distances of 40 cm, 5 cm, and on contact, respectively, when short, intermediate, and long counts are done. The

4096-channel gamma-ray data are recorded and subsequently analyzed by computer. Neutron activation procedures are described in detail in Minor et al. (1982).

Mineral and glass compositions will be determined on polished thin sections by an automated Cameca electron microprobe operated at 15 keV and 13- to 20-nA beam currents. Calibration standards for silicate minerals will include feldspars, amphiboles, and pyroxenes. Calibration standards for oxide minerals include oxides, barite, silicate minerals and glass. Wavelength dispersive x-ray counts for major elements will be counted for 15-20 s or less if 10,000 counts are acquired. Minor elements may be counted for as long as 120 s. Sodium will be counted first during analysis because it tends to migrate from the region excited by the electron beam. When analyzing hydrous minerals or glass, we will use as large a rastered beam as possible (5-25 microns on an edge) and, if possible, move the sample beneath the electron beam to minimize the migration of sodium and the dehydration of the sample.

We are developing electron-microprobe methods for the analysis of minerals on open fracture surfaces, on both polished epoxy mounts and natural surfaces.

The following procedures will be used in XRF, NAA, and electron microprobe analyses:

1. Thin Section Preparation Procedure, TWS-ESS-DP-04.
2. Operating Instructions for DV-502 Vacuum Evaporator for Carbon Coating Samples, TWS-ESS-DP-06.
3. Microprobe Operating Procedure, TWS-ESS-DP-07.
4. Nevada Test Site Fracture-Filling Studies Procedure, TWS-ESS-DP-28.
5. X-Ray Fluorescence Weighing Procedure, TWS-ESS-DP-51.
6. Fusing, Using the Junior Orbit Shaker, TWS-ESS-DP-52.
7. Pulverizing, Using the SPEX 8500 Shatterbox, TWS-ESS-DP-53.
8. Crushing, Operating of 50-Ton Hydraulic Press, TWS-ESS-DP-54.
9. Rock Splitting, Operating of 50-Ton Hydraulic Press, TWS-ESS-DP-55.
10. Procedure for X-Ray Fluorescence Analysis, TWS-ESS-DP-111.
11. Procedure for Neutron Activation Analysis, TWS-ESS-DP-117.
12. Procedure for Atomic Absorption Analysis, estimated completion date December, 1989.

3.3.2 Required Accuracy and Precision

Previous work by Los Alamos has shown that the whole-rock and mineral-chemical compositions at Yucca Mountain are variable (Broxton et al., 1986 and 1987). For fracture-lining minerals, the expected ranges of compositions should be similar to those reported in Carlos (1985, 1987), except for Mn-oxides above the water table for which mineral compositions have not yet been published.

These earlier investigations provide estimates for the expected range of compositions of rocks and minerals at Yucca Mountain. Based on these earlier investigations, the analytical errors for XRD, NAA, and microprobe analysis are acceptably small compared to the compositional variations found in the rocks and minerals.

XRF analyses generally have relative precisions of better than 5% for major chemical constituents and 20% for minor and trace constituents. These errors can exceed 100% as detection limits are approached. For microprobe analyses, minimum detection limits and errors in calculated weight percents are determined for each analysis from counting statistics. In general, precisions for microprobe analyses are similar to those for XRF. Neutron activation analysis typically has relative errors of 10% or less when elemental concentrations are one order of magnitude above the detection limits (Garcia et al., 1982).

3.3.3 Equipment Required

All of the equipment required for this activity is presently available. Complete laboratories are available for splitting and homogenizing rock samples; for fusing glass disks for XRF studies; and for cutting and polishing thin sections for electron microprobe studies. Analytical hardware such as the Rigaku x-ray fluorescence spectrometer and Cameca automated electron microprobe are available for use. Facilities are also available for irradiation and analysis of neutron activation samples.

3.3.4 Data Reduction and Analysis

X-ray fluorescence data will be reduced using the program XRF-11 written by Criss Software, Largo, MD. This program calculates elemental concentrations by comparing measured x-ray intensities to a library of intensities for rock standards of known compositions. The rock standards used for calibration are similar in composition to the tuffs being analyzed. The program uses fundamental parameters to make matrix corrections for x-ray absorption and fluorescence effects.

Electron microprobe data will be collected and processed using the Sandia TASK8 (Chambers, 1985). This system incorporates the empirical Bence and Albee (1968) method for correcting mineral compositions for differential matrix effects. ZAF (atomic number, adsorption, and fluorescence) data reduction (Duncumb and Shields, 1966) is also available for the microprobe.

Data from the neutron activation analysis will be processed using the program RAYGUN, a variant of the program GAMANAL (Gunnick and Niday, 1972) This program determines a background, gamma-ray peak areas, and gamma-ray energy for each input spectrum. It then assigns gamma rays by energy to radionuclides in a gamma-ray library, apportioning all gamma-ray intensities to specific radionuclides. Intensities are converted to elemental concentrations using irradiation, detector, and decay constants. Corrections for room background and fission product activity are also performed by RAYGUN.

All computer software will be developed, documented, used and controlled in accordance with the LANL YMP procedure for configuration management (TWS-QAS-QP-3.11) and the procedures for software control (TWS-QAS-QP-3.12 and QP-3.13).

3.3.5 Representativeness of Tests and Limitations and Uncertainties

This activity will provide representative chemical compositions of tuffs and their constituent authigenic minerals in both matrix and fractures for major lithologic and stratigraphic units at Yucca Mountain. Samples will be collected from drill holes, from outcrops, and from the exploratory shaft. These samples should provide an extensive data base with which to examine vertical and lateral chemical variability at Yucca Mountain. The limitations on this data set include the number and distribution of drill holes available for study. The effects of these limitations will be addressed by statistical studies as described in section 3.5 of this report. Manpower resources places another limitation on the number of samples that can be examined. In general, a 6,000-ft continuously cored drill hole requires 1 man-year for us to collect, analyze, and report data for whole rock samples and 1.5-2 man-years for fracture-lining minerals.

3.4 Role of Fractures and Faults as Past Transport Pathways and Evidence for Paleo-Water Table(s)

The role of fractures and faults as past transport pathways will be examined by analyzing the minerals that occur in fractures and faults and determining their sequence of deposition. Several episodes of deposition of fracture-lining minerals have occurred at Yucca Mountain, and the abundance and distribution of these minerals vary both with depth and with lateral position across the mountain. Fracture-lining minerals will be identified using binocular microscopy, XRD analysis, and scanning electron microscopy. Open fractures will be examined by binocular microscope and SEM to determine the depositional relationships of fracture-lining minerals. Thin sections will be examined with a petrographic microscope and also with the SEM if greater magnification is required. Minerals in fractures will be compared to the minerals present in the rock matrix to determine if the species of fracture-lining minerals deposited are controlled by wall-rock mineralogy. Chemical data will be obtained on the minerals to provide information on the nature of source fluids and conditions of deposition. Evidence for paleo-water table(s) may be found in the mineral morphology and/or composition and in the relationship of fracture-lining minerals to rock matrix and changes in that relationship with depth. The interpretive aspects of this subtask directly support the Study "History of Mineralogic and Geochemical Alteration at Yucca Mountain" (SCP Section 8.3.1.3.2.2.1) and the Calcite-Silica Study (SCP Section 8.3.2.5.2.1) by providing information about the deposition of minerals in fractures and faults at Yucca Mountain. Isotopic data obtained on fracture-lining minerals by the Calcite-Silica Study (8.3.1.5.2.1) and fluid inclusion data obtained in the Alteration History Study (8.3.1.3.2.2.1) will be integrated with the results of this activity to interpret mineral paragenesis.

3.4.1 Test Methods

Samples will first be examined under the binocular microscope and a fragment of the fracture surface will be prepared for SEM studies if appropriate. Most of the remainder of the fracture surface will be scraped with a tungsten carbide scraper to obtain a sample for XRD analysis. X-ray diffraction analyses will be performed as described in Section 3.2. Because of problems in obtaining representative samples, XRD of fracture-lining minerals is used primarly to identify the minerals present rather than quantifying their amount. A discussion of the problems encountered in quantifying the amounts of minerals present on fracture surfaces is given in Carlos (1987). Additional XRD analyses may be performed on clay separates. When the amounts of material are small, as is often the case for fracture coatings, the sample is suspended in water in a container and the clay fraction is siphoned off and stored for later XRD analysis. This results in an impure clay separate, but XRD of a glycolated clay sample still permits identification of clay minerals. Heulandite and clinoptilolite are two structurally related zeolites that occur as common fracture-lining minerals in the unsaturated zone. To distinguish between heulandite and clinoptilolite, the sample is heated and reanalyzed by XRD as described by Mumpton (1960).

Examination by binocular microscope shows the extent of surface coverage by each mineral. The morphology and relationships of the coatings can be observed by using the SEM. Fragments representative of the fracture coating are broken off the core and mounted on aluminum stubs. The samples are then gold coated and examined with the ISI DS-130 SEM. Energy dispersive spectra are taken to identify the elements present. The data obtained are not quantitative because of the low atomic weight of the major elements, the gold coat on the sample, and the topography of the sample surface. The size of the grains, which may be only a few microns, can be determined. Open fracture samples intended for microprobe analysis may be carbon coated and examined in the SEM, but the image is not as sharp as with a gold coat. Thin sections may also be examined using the SEM. These are carbon coated, and quantitative analysis is possible using standards, but this method has not been employed because the electron microprobe (wavelength dispersive) is preferable. The high magnification (up to 10,000X on the lower stage) permits identification of thin layers in multiple-layered coatings.

The chemistry of the minerals will be determined by electron microprobe analysis of thin sections (Section 3.3) where possible, and of epoxy mounts or by direct analysis of fracture surfaces if necessary. For fibrous minerals, we will adapt the method described by Smith and Norem (1986) for microprobe analysis of palygorskite in a colloidal carbon paste. Neutron activation analysis (Section 3.3) may be used on mineral separates if more detailed trace chemistry would provide additional information on depositional conditions and if sufficient material is available for analysis.

Cathodoluminescence may also be used to examine different generations of fracture-lining minerals. The usefulness of cathodoluminescence will depend on the types and amounts of trace elements in the fracture-lining minerals. Procedures will be developed for this analytical method as it applies to fracture minerals if it appears that the method is feasible and will provide needed information on mineral paragenesis.

The following procedures will be used in the examination of chemistry and paragenesis of fracture minerals to determine the role of fractures and faults as past transport pathways:

1. Thin Section Preparation Procedure, TWS-ESS-DP-04.

2. Operating Instructions for DV-502 Vacuum Evaporator Used in Carbon Coating Samples, TWS-ESS-DP-06.

3. Microprobe Operating Procedure, TWS-ESS-DP-07.

4. Siemens X-Ray Diffraction Procedure, TWS-ESS-DP-16.

5. Clay Mineral Separation and Preparation for X-Ray Diffraction Analysis, TWS-ESS-DP-25.

6. Nevada Test Site Fracture-Filling Studies Procedure, TWS-ESS-DP-28.

7. Sputter Coater Operating Procedure for Gold Coating Samples, TWS-ESS- DP-50.

8. Operating Instructions for International Scientific Instruments Model DS-130 Scanning Electron Microscope and Tracor Northern Series II X-Ray Analyzer, TWS-ESS-DP-112.

9. Procedure for Neutron Activation Analysis, TWS-ESS-DP 117.

3.4.2 Required Accuracy and Precision

The methods used in this activity are the same and have the same precisions and accuracies as those described in sections 3.1.2 and 3.3.2 of this Study Plan. This activity requires accurate identification of minerals present in fractures, but high precision on individual amounts is not necessary because of the problems of sample representativeness described above. For the purposes of this Study, the precision and accuracy of electron microprobe analyses are considered adequate for mineral identification when used in conjunction with XRD analysis. The precision and accuracy are also adequate for determining the chemical variability of fracture-lining minerals laterally and with depth. Textural relationships are determined by visual inspection of cross-cutting relationships and of superimposition of mineral phases; these observations will be made using both a microscope and an SEM. Using the combination of methods employed in this study, the experienced geologist familiar with these instruments will be readily able to identify minerals and textural relationships. Examination of many samples yields patterns of fracture filling and eliminates the possibility of a single atypical sample leading to erroneous conclusions.

3.4.3 Equipment Required

All of the equipment required for this activity is presently available at Los Alamos. The thin section laboratory is capable of making any kind of mount required for microprobe or SEM analysis. Analytical equipment, such as microscopes, Siemens D-500 x-ray diffractometers, Cameca automated electron microprobe, and an ISI model DS130 SEM, is available for use. Facilities exist for irradiation and analysis of neutron activation samples and for cathodoluminescence examination of rock fragments and thin sections.

3.4.4 Data Reduction and Analysis

X-ray diffraction data will be reduced as described in Section 3.1.4; electron microprobe data will be collected and processed as described in Section 3.3.4. SEM data are qualitative and consist of peak identification performed by the Tracor Northern IDENT program on energy dispersive data.

3.4.5 Representativeness of Tests and Limitations and Uncertainties

Because of the nonuniform distributions and amounts of fracture-lining minerals at Yucca Mountain, the results obtained for this activity can be representative of the repository block only if a large suite of samples is examined. For this reason samples will be collected from all available cored holes and from the exploratory shaft and drifts. Identification and chemical analysis of some minerals may not be possible because of the limited amount of material available in the fractures. Exploratory shaft and drift samples will have more fracture surface area available for sampling so the role of fractures and faults in past transport will be best characterized for these samples. The prototype test for sample collection (WBS 1.2.6.9.4.1.3) will address sample-collection procedures for fracture studies in the exploratory shaft and drifts. Interpretations of evidence for paleo-water table(s), for the role of fractures as transport pathways at depth, and for the lateral variation in past transport through fractures will be based on data for samples collected within drifts of the exploratory shaft and on data for samples collected from surface based exploratory drill holes. The collection and interpretation of data will be limited by the number and distribution of drill cores and by the time and budget constraints on the number of samples we are able to analyze.

3.5 Statistical Evaluation of Mineralogic, Petrographic, and Chemical Data

Statistical analyses of mineralogic and modal petrographic data will consist of probabilistic modeling and statistical extrapolation of mineralogic, modal, and chemical data from the drill holes in Section 2.4.1 of this Study Plan. Probabilistic analysis of mineralogic data will be used to (1) detect lateral and vertical trends in mineralogy; (2) correlate mineralogic and modal petrographic data with the internal stratigraphy of the repository host rock; and (3) detect outliers, possible measurement or reporting errors, and other anomalies in the data. Geostatistical extrapolation will be used to extrapolate mineralogic and petrologic contacts between drill holes where probabilistic modeling indicates the presence of lateral trends.

Based on the work above and on a review of other basic statistical considerations, recommendations will be made for optimizing drill-hole densities and distributions. Recommendations will also be made to optimize the design of sampling activities within drill holes and in the exploratory shaft to ensure that the field and laboratory data collected are representative of the site and that the variance in probabilistic models is minimized.

The optimization of drill-hole densities and within-hole sampling is properly a function not only of the variability of mineralogic, petrographic, and chemical parameters within the site, as discussed in Section 2.4.3, but also of 1) the sensitivity of results of activities described in SCP 8.3.1.3.7.1 and elsewhere to uncertainties in these parameters, and 2) economic cost analysis for drilling, sampling, and analysis programs. The development of this information is outside the scope of this Study Plan, but to the extent that it is available it will be used to modify recommendations based on statistical models of intrinsic variability in the data. As discussed in SCP section 8.4.2.2, drill holes will be chosen so as to provide a statistically valid set of samples for various site investigations including activities in this Study. Purely statistical recommendations will be based on data from existing drill core, data from prototype sampling, and data from the new drill holes (Section 2.4.1 of this Study Plan) as they become available. Reports will be periodically issued to evaluate the adequacy of the proposed drilling plan (SCP Section 8.4.2.2) for characterization of the mineralogy, chemistry and petrography of rocks at Yucca Mountain (see milestone list in Section 5).

3.5.1 Methods

The methods used in the probabilistic modeling will consist of standard statistical analyses, including: (1) the use of histograms, bivariate scatter plots, and other exploratory data-analysis tools to evaluate data; (2) analysis of variance and multiple regression to determine between-hole variability and to estimate significant lateral and vertical trends; and (3) canonical correlation and analysis of variance to investigate the relationship between mineralogy and stratigraphy. Log-ratio models (Aitchison, 1986) will be employed.

Statistical extrapolation will employ kriging to extend the mineralogic and petrologic data from a limited number of drill holes into a three-dimensional mineralogic model of Yucca Mountain. Use of kriging assumes that the data can be usefully modeled as observations from a nonstationary stochastic process, which is an intrinsic random function (Matheron, 1973; Journel, 1986). The method is extensively documented in the literature (e.g., Clark, 1979). The sensitivity of results to selection of a kriging model will be investigated. Sample reuse techniques, such as cross-validation and bootstrapping, will be used to exploit the data as fully as possible and to verify error estimates.

Commercial statistics computer programs, such as SAS (1982), will be used to make basic statistical calculations wherever possible. A technical document describing the use of these commercial computer programs with log-ratio models will be prepared.

Kriging techniques are being implemented at Los Alamos by in-house programming. Cross-validation and bootstrap (Campbell, 1987) methods are also being programmed in-house.

All data analyses in this section are Quality Level I activities; therefore, both the in- house and the commercial computer codes used in this study will be subject to outside peer review for validation.

3.5.2 Data Input Requirements

The input data required for probabilistic modeling and geostatistical extrapolation consist of mineralogic, modal, and chemical data for samples collected from drill holes and outcrops. Drill-hole locations and sample depths are also required as input parameters. Statistical requirements for additional drill hole data can be determined only after sensitivity analysis requirements (SCP Section 8.3.1.3.7.1) for the potential repository are known.

3.5.3 Expected Data Output and Accuracy of the Analysis

The output from the statistical analyses described above are probabilistic models of mineral and chemical distributions and variability. In addition, anomalous data can be identified for further study or reanalysis. Significant trends in the mineral and chemical data may indicate the need for a formal extrapolation procedure for the construction of a three-dimensional mineralogic model.

Kriging will provide an estimate of the expected value of a parameter at a point conditional on the observations and the conditional estimation error. These results depend on the choice of a model for the generalized covariance function of the process, which must usually be estimated from the same data. We will evaluate various functional forms. The most important factor affecting accuracy is the variability inherent in the input data and the density of available observations.

3.5.4 Representativeness of Approach

The representativeness of the models produced ultimately depends on the representativeness of the available data. Some of the drill holes to be studied have been located to sample anomalous surface or subsurface features (e.g., USW G-5 and USW G-6). The remaining drill holes selected for this study provide areal coverage of the exploration block and of the surrounding area. These latter drill holes are representative by definition. Data from feature-sampling holes will be compared to data from the representative holes to assess the representativeness of the former. The representativeness of individual samples will be assessed by statistical outlier detection techniques (Beckman and Cook, 1983).

The geostatistical extrapolation technique described above provides some guidance for the desirable distribution and density of drill holes to achieve the desired level of accuracy in extrapolation. A report will be issued that will contain recommendations about lateral and vertical sample densities to minimize the variance of probabilistic models and to ensure representativeness of the resulting models.

4. APPLICATION OF RESULTS

The information derived from the activities described in this Study Plan will be used in the following issues, investigations, and information needs:

Issue, Investigation, or Information Need	Subject
SCP 8.3.1.2.3.1	Mineralogic data from this Study will be used in the design and interpretation of infiltration and tracer flow tests done for geohydrology.
SCP 8.3.1.3.2.2	Mineral-chemical and mineralogic studies will aid investigations of thermal stability, expansion/contraction behavior, and hydration/dehydration behavior in zeolites, clays, and glasses proximal to the disturbed zone.
SCP 8.3.1.3.2.2.1	The mineralogic, chemical, and petrographic data from this Study will provide information about the alteration history of tuffs at Yucca Mountain.
SCP 8.3.1.3.3	Mineralogic and chemical data from this study will identify the mineral species and glass compositions of interest for studies of mineral and glass stability.
SCP 8.3.1.3.4	The mineralogic and chemical data gathered in this Study Plan will identify the mineral species and rock compositions appropriate for use in investigations of radionuclide retardation by sorption. The mineralogic and chemical data also provide a basis for assigning sorption retardation factors to potential groundwater flow paths at Yucca Mountain.
SCP 8.3.1.3.7.1 and 8.3.1.3.7.2	Secondary minerals are highly sorptive of many important radionuclides, and the distribution and abundance of these minerals in fractures and bulk rocks at Yucca Mountain will strongly influence radionuclide retardation by sorption processes along flow paths to the accessible environment. The mineralogic data will constrain both the quantitative models of Section 8.3.1.3.7 and performance assessment calculations for Issue 1.1. In order to consider all potential flow paths to the accessible environment, the mineralogic and chemical data must be extrapolated between widely spaced drill holes. The statistical studies in this study plan will identify the uncertainties resulting from these extrapolations.
SCP 8.3.1.4.1	The study of the internal stratigraphy of the Topopah Spring Member will aid repository construction by ensuring that working elevations can be determined should faults of uncertain amount and sense of displacement be crossed during mining operations.
SCP 8.3.1.4.2.1	The whole-rock chemical data can contribute to stratigraphic studies of the volcanic units at the site.
SCP 8.3.1.5.2.1.5	The fracture mineralogy activity will provide information about the composition and paragenesis of fracture-lining minerals at Yucca Mountain that will be used in interpretation of near-surface calcite-silica deposits.

Issue, Investigation, or Information Need	Subject
SCP 8.3.1.9.2.1.1	The whole-rock chemical data collected in this Study can be used to supplement other data collected for the geochemical assessment of Yucca Mountain in relation to the potential for mineralization.
SCP 8.3.1.15	Mineralogic data will be used in the design and interpretation of tests done on the physical properties of rocks.
SCP 8.3.1.15.1.8	Mineralogic studies o: ʻractures and bulk rocks will provide information on the abundance and distribution of fibrous zeolites (erionite and mordenite) that may be hazardous to the health of workers during construction of the repository.
SCP 8.3.4.2	Mineralogic and chemical data from this study will be used in design and interpretation of investigations of chemical stability of the waste package and repository components.
SCP 8.4.2.2	The statistical information produced in this Study will be used to evaluate the adequacy of the proposed integrated drilling program to characterize the mineralogy, chemistry, and petrogrpahy of Yucca Mountain for performance and design issues.
Issues 1.6.3 and SCP 8.3.1.3.2	All tests in this study plan are important components in the accurate description of paths from the disturbed zone to the accessible environment. Statistical studies of the mineralogic and chemical data will identify the uncertainties in our description of these paths.

5. SCHEDULE

The schedule and milestones are presented below. Only major milestones are noted on the schedule chart represented in Figure 3.

Milestones

R603	Issue progress report on image analysis for Topopah petrographic database.
R597	Complete compilation of petrographic and mineralogic data for peer reviewers and comparison with available outcrop.
R623	Issue report on manganese minerals in USW G-4 fractures.
M335	Issue report on summary of three dimensional mineralogic variation along transport pathways.
M337	Issue report on the precision, accuracy, and alternative interpretation for models of mineralogy along transport pathways.
New*	Optimization of core and shaft sampling based on prototype sampling.
M334	Issue report on petrographic stratigraphy within the Topopah Spring Member with evaluation of lateral variability within the candidate repository horizon.
R757	Issue report on the comparison of fracture mineralogy between drill cores at Yucca Mountain.
R701	Update report on the mineralogic evaluation of transport pathways at Yucca Mountain.
New	Preliminary evaluation of adequacy of proposed drilling plan for characterization of mineralogy, chemistry, and petrography of Yucca Mountain.
R548	Issue summary report on quantative x-ray diffraction data for mineralogy along transport pathways at Yucca Mountain.
M339	Issue report on statistical evaluation of Topopah Spring exploratory shaft samples, contrasted with core samples relevant to the exploration block at Yucca Mountain.
New	Update report evaluating adequacy of proposed drilling plan for characterization of mineralogy, chemistry, and petrography of Yucca Mountain.
R702	Issue update report on mineralogic evaluations of transport pathways at Yucca Mountain.

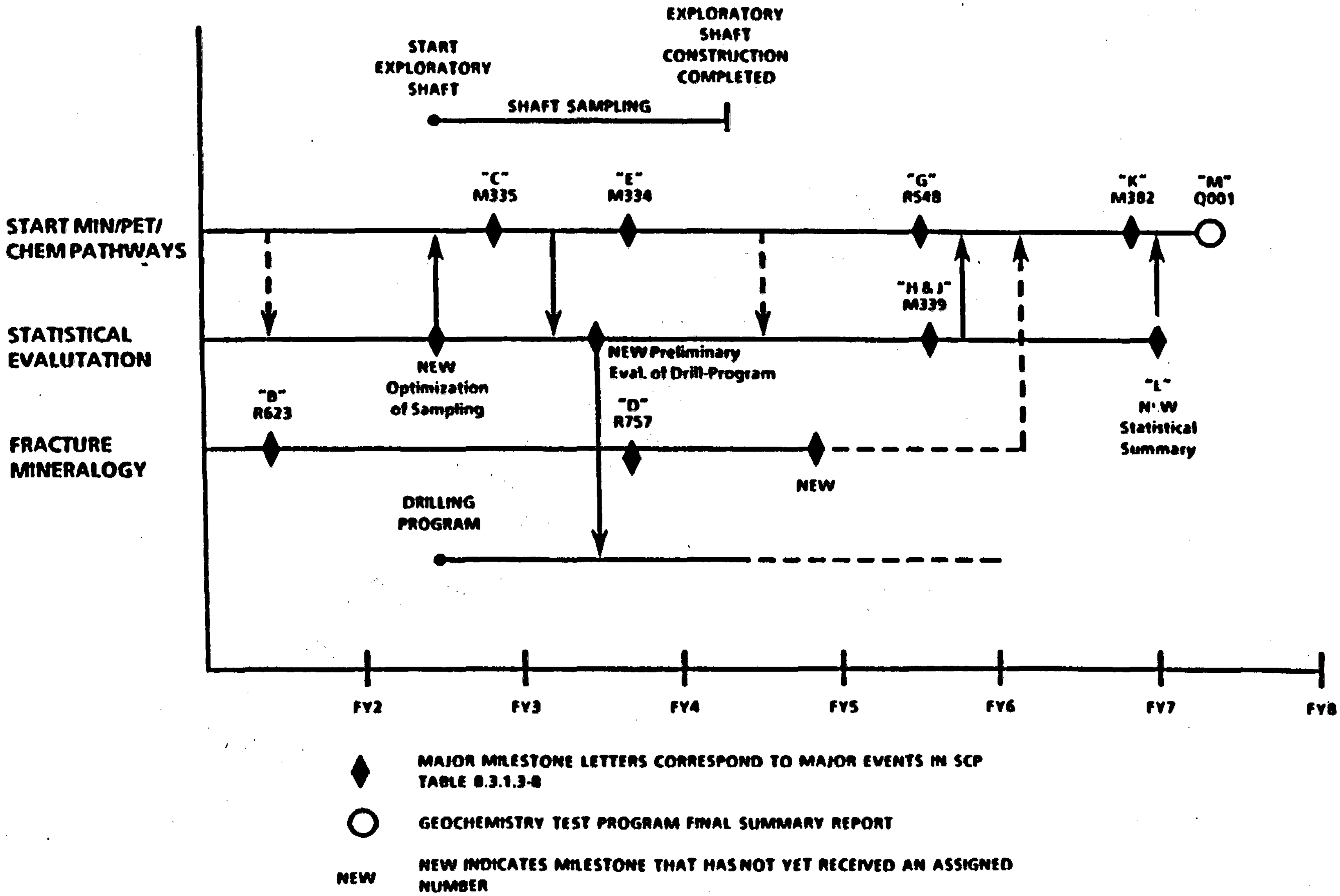

Figure 3. Milestones for Studies on Mineralogy, Petrology, and Chemistry of Transport Pathways

M382 Complete mineralogic evaluation of transport pathways at Yucca Mountain.

New Statistical summary for extrapolating mineralogic, chemical, and petrographic data between drill holes.

Q001 Issue report on the summary of results defining the geochemical characterization (mineralogy/petrology, mineral stability, and water chemistry) at Yucca Mountain.

* New indicates milestone which had not been assigned a milestone number at the time this Study Plan was prepared.

Additional information on schedules and milestones can be found in SCP Sections 8.5.1.5 and 8.5.6. All activities in this study plan and the study plan for alteration history (SCP Section 8.3.2.3.2.2.1) can be conducted in parallel.

Most of the activities in this study plan are based upon subsurface samples. Therefore, schedules and milestones are constrained by sample availability, which is tied to the drilling schedule, construction of the exploratory shaft, and the operation of the core library. A drilling schedule is being prepared at this time (SCP Section 8.4.2.2). If a significant number of new holes are drilled, and additional numeralogic and petrologic characterization is found to be necessary, the work outlined in this study plan would sharply increase. The timing of construction of the exploratory shaft will also have a major impact on schedules and milestones. SCP Section 8.3.1.3.2.4 describes how milestones will be affected by delays in the start of the exploratory shaft. In particular, milestones addressing mineralogic evaluation of transport pathways (R548, R701, R702, and M382) will be significantly affected by delays in the exploratory shaft and in the drilling schedule. The milestone in which statistical evaluations of lateral variability in mineralogy will be made for the candidate host rock (M334) is based upon data provided by the milestones addressing mineralogic evaluation of transport pathways. Delays in the earlier milestones will affect the completion dates for the statistical studies. The summary of results of the geochemical characterization at Yucca Mountain (milestone M382) will be based in large part on data produced under this Study Plan. Delays in the exploratory shaft and in the drilling program could seriously delay the milestones leading to the completion of M382.

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APPENDIX A

QUALITY ASSURANCE SUPPORT DOCUMENTATION

Table A-1 lists the applicable NQA-1 criteria for this study and explains how they will be satisfied.

TABLE A-1

APPLICABLE NQA-1 CRITERIA FOR SCP STUDY 8.3.1.3.2.1
AND HOW THEY WILL BE SATISFIED

NQA-1 Criterion	Documents Addressing These Requirements		Anticipated Date of Issue
1. Organization	The organization of the Office of Civilian Radioactive Waste Management (OCRWM) program is described in Section 8.6 of the SCP. The LANL QA program is described in the LANL-YMP-QAPP and includes a program description addressing each of the NQA-1 criteria. The LANL QA program contains quality administrative procedures (QP) further defining the program requirements.		
	TWS-QAS-QP-01.1	Interface Control	1/31/89
	TWS-QAS-QP-01.2	Stop Work Control	1/31/89
	TWS-QAS-QP-01.3	Conflict Resolution	2/21/89
2. QA Program	The LANL QA program is described in the LANL-YMP-QAPP and includes a program description addressing each of the NQA-1 criteria. An overall description of the YMP QA program for site characterization activities is described in Section 8.6 of the SCP.		
	TWS-QAS-QP-02.1	Personnel Selection, Indoctrination, and Qualification	1/31/89
	TWS-QAS-QP-02.2	Personnel Training	1/31/89
	TWS-QAS-QP-02.3	Readiness Review	5/31/89
	TWS-QAS-QP-02.4	Management Assessment	5/31/89
	YMP AP-5.4Q	Assignment of Quality Assurance Level	1/24/89
3. Design and Scientific Investigation Control	This study is a scientific investigation. The following QPs apply:		
	TWS-QAS-QP-03.1	Software QA Plan	4/30/89
	TWS-QAS-QP-03.2	Technical and Policy Review	4/30/89
	TWS-QAS-QP-03.3	Preparation of SCP Study Plan	5/31/89
	TWS-QAS-QP-03.5	Documenting Scientific Investigation	2/29/89
	TWS-QAS-QP-03.6	IDS Design and Interface Control	5/31/89
	TWS-QAS-QP-03.7	Peer Review	5/31/89

TABLE A-1

APPLICABLE NQA-1 CRITERIA FOR SCP STUDY 8.3.1.3.2.1
AND HOW THEY WILL BE SATISFIED
(continued)

NQA-1 Criterion	Documents Addressing These Requirements		Anticipated Date of Issue
	TWS-QAS-QP-03.8	IDS Technical Assessment Review	5/31/89
	TWS-QAS-QP-03.11	Software Configuration Management	6/16/89
	TWS-QAS-QP-03.12	Scientific and Engineering Software and Software Libraries	6/16/89
	TWS-QAS-QP-03.13	Auxiliary, Commercial, and Utility Software	6/16/89
	TWS-QAS-QP-03.14	Design Input for ESF	2/3/89
	TWS-QAS-QP-03.15	TMO Design and Interface Control	5/31/89
4. Procurement Document Control	TWS-QAS-QP-04.1	Procurement	12/14/88
	TWS-QAS-QP-04.2	Acceptance of Procured Services	1/31/89
	TWS-QAS-QP-04.3	Qualification of Suppliers	1/31/89
5. Instructions, Procedures, and Drawings	TWS-QAS-QP-05.1	Preparation of QPs	12/14/88
	TWS-QAS-QP-05.2	Preparation of DPs	12/14/88
6. Document Control	TWS-QAS-QP-06.1	Document Control	1/31/89
7. Control of Purchased Material, Equipment, and Services	Applicable parts of this criterion are covered in Item 4 (see above).		
8. Identification and Control of Materials, Parts and Samples	TWS-QAS-QP-08.1	Identification and Control of Samples	5/31/89
	TWS-QAS-QP-08.2	Control of Data	5/31/89
9. Control of Special Processes	This criterion has been determined to be inapplicable to the scope of work of the LANL YMP.		
10. Inspection	This criterion has been determined to be inapplicable to the scope of work of the LANL YMP.		
11. Test Control	This criterion has been determined to be inapplicable to the scope of work of the LANL YMP.		

TABLE A-1

APPLICABLE NQA-1 CRITERIA FOR SCP STUDY 8.3.1.3.2.1
AND HOW THEY WILL BE SATISFIED
(concluded)

NQA-1 Criterion	Documents Addressing These Requirements		Anticipated Date of Issue
12. Control of Measuring and Test Equipment	The control of instrument calibration and data collection is described in the technical procedures referenced in Section 3 of this plan. The following QPs also apply:		
	TWS-QAS-QP-12.1	Measuring and Test Equipment	5/31/89
	TWS-QAS-QP-12.2	Control of Operator-Calibrated Equipment	5/31/89
13. Handling, Storage and Shipping	TWS-QAS-QP-13.1	Handling, Shipping, and Storage	3/17/89
14. Inspection, Test and Operating Status	This criterion has been determined to be inapplicable to the scope of work of the LANL YMP.		
15. Nonconforming Materials, Parts or Components	TWS-QAS-QP-15.1	Nonconformances	12/14/88
16. Corrective Action	TWS-QAS-QP-16.1	Corrective Action	4/28/89
	TWS-QAS-QP-16.2	Trending	5/31/89
17. Quality Assurance Records	TWS-QAS-QP-17.1	Resident File	12/14/88
	TWS-QAS-QP-17.2	Records Processing Center	12/14/88
18. Audits	TWS-QAS-QP-18.1	Audits	4/28/89
	TWS-QAS-QP-18.2	Surveys	3/17/89
	TWS-QAS-QP-18.3	Auditor Qualification	3/31/89

QUALITY ASSURANCE LEVEL ASSIGNMENT SHEET (QALAS)

AND

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET (QLACS)

SIP No. 86/4.2

Rev. 0

Activity Mineralogy/Petrology

Tasks: Fracture Mineralogy

Alteration History

Mineralogy of Transport Pathways

The Quality Assurance Level Assignments (QALAs) included in this appendix were approved in 1986. Revised QALAs are currently being developed using new procedures that implement NUREG-1318. When these QALAs are approved, they will supersede the 1986 QALAs and will be provided through controlled distribution as a revision to the Study Plan.

QUALITY ASSURANCE LEVEL ASSIGNMENT SHEET (QALAS)

NNWSI QUALITY ASSURANCE LEVEL ASSIGNMENT			
Items/Activities	QA Level	QA Requirements	Technical Justification
Alteration and Fracture Mineralogy	I	1,2,3,4,5,6,7,8, 10,11,12,13,15, 16,17,18 See attached QLALS	NNWSI SOP-02-02: para.5.2.1bA (activity will provide site characterization data), and Step 2 of QA Level Assignment Checklist Only those items and sub-activities that directly control the quality of quantitative data will be considered Level I.

APPROVALS (Signature and Date)

PI [signature] 6-26-86 TPO [signature] 6-26-86

QAL [signature] 6-26-86 WMPO(TECH) [signature] 7-14-86

QAIM [signature] 6/26/86 WMPO(PQM) [signature] 7/14/86

PI FINAL REVIEW [signature] 10/9/86

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET (QLACS)

SIP No. 86/4.2

Rev. 0

Activity: Mineralogy/Petrology

Task: Fracture Mineralogy

PI: D. T. Vaniman D. T. Vaniman, HD DO

QA Criterion	Applies	Does not Apply	Comments
1. QA Organization	x		
2. QA Program	x		
3. Design and Scientific Investigation Control	x		Only scientific investigation requirements apply
4. Procurement Document Control	x		
5. Instructions, Procedures, and Drawings	x		
6. Document Control	x		
7. Control of Purchased Material, Equipment, and Services	x		
8. ID and Control of Materials, Parts, Components, and Samples	x		
9. Control of Processes		x	Activities performed under this WBS are not considered to be special processes as per definition in Appendix A SOP-02-01
10. Inspection	x		Applicable for surveillance requirements only
11. Test and Experiment/Research Control	x		
12. Control of Measuring and Test Equipment	x		

QA Criterion	Applies	Does not Apply	Comments
13. Handling, Shipping, and Storage	x		
14. Inspection, Test, and Operating Status		x	No hardware generated in this task
15. Control of Nonconformances	x		
16. Corrective Action	x		
17. QA Records	x		
18. QA Audits	x		

QUALITY ASSURANCE LEVEL ASSIGNMENT SHEET (QALAS)

NNWSI QUALITY ASSURANCE LEVEL ASSIGNMENT

Items/Activities	QA Level	QA Requirements	Technical Justification
Mineralogy of Transport Pathways	I	1,2,3,4,5,6,7,8, 10,11,12,13,15, 16,17,18 See attached QLACS	NNWSI SOP-02-02: para.5.2.1bA (activity will provide site characterization data), and Step 2 of QA Level Assignment Checklist Only those items and sub-activities that directly control the quality of quantitative data will be considered Level I.

APPROVALS (Signature and Date)

PI [signature] 6-26-86 TPO [signature] 6-26-86

QAL [signature] 6-26-86 WMPO(TECH) [signature] [illegible]

QAIM [signature] 6/26/86 WMPO(PQM) [signature] 7/14/86

PI FINAL REVIEW [signature] 10/9/86

QUALITY LEVEL ASSIGNMENT CRITERIA SHEET (QLACS)

SIP No. 86/4.2
Rev. 0
Activity: Mineralogy/Petrology
Task: Mineralogy of Transport Pathways
PI: D. T. Vaniman DTV Lwm FY, DO

	QA Criterion	Applies	Does not Apply	Comments
1.	QA Organization	x		
2.	QA Program	x		
3.	Design and Scientific Investigation Control	x		Only scientific investigation requirements apply
4.	Procurement Document Control	x		
5.	Instructions, Procedures, and Drawings	x		
6.	Document Control	x		
7.	Control of Purchased Material, Equipment, and Services	x		
8.	ID and Control of Materials, Parts, Components, and Samples	x		
9.	Control of Processes		x	Activities performed under this WBS are not considered to be special processes as per definition in Appendix A SOP-02-01
10.	Inspection	x		Applicable for surveillance requirements only
11.	Test and Experiment/Research Control	x		
12.	Control of Measuring and Test Equipment	x		

QA Criterion	Applies	Does not Apply	Comments
13. Handling, Shipping, and Storage	x		
14. Inspection, Test, and Operating Status		x	No hardware generated in this task
15. Control of Noncon-formances	x		
16. Corrective Action	x		
17. QA Records	x		
18. QA Audits	x		

The following number is for Office of Civilian Radioactive Waste Management Records Management purposes only and should not be used when ordering this document:

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