YUCCA MOUNTAIN PROJECT
STUDY PLAN APPROVAL FORM

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Study Plan Number 8.3.1.17.4.6

Study Plan Title Quaternary Faulting Within the Site Area

Revision Number 0

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PREFACE

This study plan summarizes and extends the discussions of Study 8.3.1.17.4.6 in the SCP (Site Characterization Plan). Sections 1, 4, and 5 are drawn from the statutory SCP and from related Project documents; those sections show the study in the context of the SCP. Sections 2 and 3 discuss the bases for the planned tests and the plans themselves in detail beyond that in the SCP. Because the study plan incorporates the most recent planning for the study, it occasionally departs from the statutory SCP, reflecting modifications that have been accommodated through the Project change-control process (Interim Revision Notices).

Sections 1, 4, and 5 of this plan were written mainly by Frances R. Singer, sections 2 and 3 by Ralph R. Shroba. K.F. Fox, Jr. was the primary reviewer of the plan. W.R. Keefer and David Schleicher shared in writing and review of the plan.

ABSTRACT

Study 8.3.1.17.4.6 will gather information on Quaternary faults in an area of about 240 km^2 surrounding Yucca Mountain. To do so, one of the two activities in the study will prepare detailed (1:20-scale) maps of trenches along and across faults on which Quaternary movement is known or suspected; those maps will provide information on the time, direction, and amount of Quaternary movement. The other activity will incorporate information from the trench maps and from other studies into a 1:24,000-scale map of all Quaternary faults identified in the site area; the map will show the amounts, directions, and times of Quaternary displacement on those faults.

The information from this study is needed to improve confidence levels in fault parameters used to predict repository performance. The information will be used in the preclosure tectonics program to assess the likelihood of fault displacements and seismic ground motion that could affect the design or performance of the repository. It will be used in the postclosure tectonics program to assess the effects of future faulting on the waste package and on erosion, geochemistry, and hydrology.

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FIGURE

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STUDY 8.3.1.17.4.6

QUATERNARY FAULTING WITHIN THE SITE AREA

Study 8.3.1.17.4.6 consists of two activities (hereinafter termed simply *Activity 1* and *Activity 2*):

- 8.3.1.17.4.6.1: Evaluation of Quaternary geology and potential faults at Yucca Mountain
- 8.3.1.17.4.6.2: Evaluation of age and recurrence of movement on suspected and known Quaternary faults

The study is part of the preclosure tectonics program (fig. 1-1); it is one of a series of related studies that gather and synthesize information needed to assess future fault displacements and vibratory ground motions in the region surrounding Yucca Mountain.

1 PURPOSE AND OBJECTIVES OF THE STUDY

The objectives of this study are to identify and characterize Quaternary faults--

- that intersect or project toward the surface facility, the repository, or the controlled area;
- whose length or recurrence rate (hereinafter termed recurrence interval) suggest a potential for future earthquakes with magnitudes such that associated ground shaking could affect design or performance of the waste facility.

Such faults will be studied in the site area, here defined as a rectangular area of about 240 km^2 (90 mi^2) generally centered on the repository and encompassing the controlled area and much of Yucca Mountain (fig. 1-2).

Objectives specific to each activity in the study are discussed in sections 3.1 and 3.2.

1.1 Information to be obtained and how that information will be used

This study will produce a 1:24,000-scale map of Quaternary faults within the site area and greatly detailed (about 1:20-scale) maps of trenches excavated across those faults. The study will incorporate information from other activities to interpret the subsurface extension, geometry, and possible segmentation of Quaternary faults, to constrain the locations and ages of Quaternary faulting, and to identify areas that may contain concealed Quaternary faults. In addition, the study will gather information on--

- the surface location, orientation, length, width, segmentation, and possible interconnections of all Quaternary faults that can be identified within the site area;

- the location, amount, direction, and time of Quaternary movement on these faults.

The amount and time of Quaternary movement will be used to determine recurrence intervals and slip rates.

This information will be gathered through detailed geologic mapping of faults with known or suspected Quaternary movement, trenching of fault zones, and dating of Quaternary deposits and surfaces that are offset by, or that overlap, the faults in the site area.

The information from the study will be used to determine the directions, amounts, rates, and recurrence intervals of Quaternary faulting as a basis for predicting the likely locations, timing, and magnitudes of future faulting and earthquake events that could impact the design or performance of the waste facility. The information will also be used in modeling the effects of faults on fluid flow--hence, the potential movement of radionuclides--in the unsaturated zone.

The specific information to be obtained in each activity is discussed in sections 3.1.1 and 3.2.1. Specific uses of the information for measuring repository performance against goals for performance measures are discussed in sections 1.2, 3.1.9, and 3.2.9; uses of the information for supporting other studies are discussed in section 4.

1.2 Rationale and justification for the information to be obtained: why the information is needed

This section explains why information from this study is needed to design the repository in accord with tentative design goals and to predict the performance of the repository and measure the predicted performance against tentative goals associated with performance measures. In general, information from the study is needed to improve confidence levels in all fault parameters used to assess repository design and performance. More specifically, the information is needed as a basis for assessing the likelihood of fault movement or seismic ground motion that could directly or indirectly affect the surface or underground facilities both during operation of the repository and after closure (figs. 1-3, 1-4; table 4-1). Although no Federal, State, or other regulations explicitly call for the study, the information to be obtained is needed to satisfy regulatory requirements, as described below.

Information from the study is needed to decide whether the repository will satisfy the tentative goals associated with two performance measures for design issue 4.4 (SCP sec. 8.3.2.5; this study plan, fig. 1-3), which deals with the technical feasibility of constructing, operating, closing, and decommissioning the repository. The goals for those performance measures deal with (1) the locations of the underground facilities and (2) the locations of surface facilities important to safety. For the first goal, the study will identify--

- faults within the repository block that have more than 1 m of Quaternary offset, and the surface locations of those faults;

- faults that would intersect the underground facilities and that have inferred Quaternary slip rates of more than 0.005 mm/yr, and the surface locations of those faults (if such faults exist).

That information is needed to reduce the likelihood that the underground facilities will be located in areas of potentially active faults (see SCP tables 8.3.1.17-4(b), 8.3.1.17-4(a), and 8.3.2.5-2), so that the repository and its engineered barriers will comply with 10 CFR 60 and 10 CFR 960. For the second goal, the study will contribute to identifying and characterizing potentially significant Quaternary faults within 5 km of facilities important to safety (along with the other studies shown in SCP fig. 8.3.1.17-4). That information is needed to reduce the likelihood that such facilities will be located over potentially active geological structures (see SCP tables 8.3.1.17-3(b), 8.3.1.17-3(a), and 8.3.2.5-1).

For design issue 1.11 (SCP sec. 8.3.2.2; this study plan, fig. 1-4), this study will contribute information on Quaternary faults that intersect the repository; that information will be used in measuring the repository design against the general goal that the area available for the repository substantially exceed the area needed to store the equivalent of 70,000 metric tons of uranium.

For design issue 2.7 (SCP sec. 8.3.2.3; this study plan, fig. 1-3), information from this study will contribute to the assessment of the frequency and magnitude of fault movement within the repository as a means of measuring the predicted performance of the repository against one or more of the eleven stated performance goals. For resolving performance issues 2.3 and 2.4 (SCP secs. 8.3.5.5 and 8.3.5.2; this study plan, fig. 1-3), information from the study will contribute to assessing the potential for seismic ground motion or for movement on faults intersecting the surface or underground facilities.

Information from this study will also contribute to the resolution of performance issues 1.1, 1.8, and 1.9 (SCP secs. 8.3.5.13, 8.3.5.17, and 8.3.5.18; this study plan, fig. 1-4) through its contributions to the postclosure tectonics program and to the three-dimensional geologic model and the rock-characteristics model of the site area. Although not shown in figure 1-4, Study 8.3.1.17.4.6 assists indirectly in the resolution of issue 1.12 by data input through the postclosure tectonics program.

2 RATIONALE FOR SELECTING THE STUDY

Section 2 discusses the bases for the tests planned for this study. The SCP (sec. 8.3.1.17) discusses the bases for the study in the context of the preclosure tectonics program.

The two activities in this study were chosen as complementary means for obtaining the required information on Quaternary faulting within the site area. One of the activities (Activity 2) will provide detailed information from trenches on known and suspected Quaternary faults. The other activity (Activity 1) will synthesize that information (as well as information from other studies) and present it in a map of Quaternary faults in the site area. The bases for selecting the types of tests that are planned for each activity are discussed below. The test plans themselves are discussed in section 3.

2.1 Activity 8.3.1.17.4.6.1 Evaluation of Quaternary geology and potential faults at Yucca Mountain

2.1.1 Rationale for the types of tests selected

The choice of the SCP test method (sec. 3.1.2) was dictated by the ability of the method to provide the information (SCP parameters) required for issue resolution (see sec. 1.2) and for input to other studies (see sec. 4) with the required degree of accuracy and confidence. The planned method--mapping Quaternary faults in the site area--is the standard, conventional method for mapping Quaternary faults; it has five major components or "submethods":

- compiling, from published sources, information on faults along which Quaternary movement is known or suspected
- detecting possible Quaternary faults through the interpretation of aerial photographs
- examining and mapping all known and suspected Quaternary faults in the field
- incorporating relevant information from other planned activities
- updating the map as other studies of relevant faults are completed

In its early stages, the activity will assemble data that are readily available from published sources and from the mapping of those fault traces discernible on aerial photographs in available data bases. These preliminary data will be used to guide the subsequent fieldwork. As relevant information becomes available from other studies, it will be updated and incorporated, probably in the later stages of the activity. If existing aerial photography is not adequate for the needs of this study, acquisition of new photography may be necessary, coordinated through DOE.

Perhaps half of the total effort in the activity will be devoted to fieldwork (the third submethod listed above), because direct observation offers the only available means for accurately identifying and characterizing potentially significant Quaternary faults. The remaining half of the effort will be roughly equally divided among the other four submethods.

There are no reasonable alternatives to the planned method for producing a synoptic presentation of the information required of the study. The five components of the method probably encompass the full range of possible alternative methods. Accordingly, the only alternatives to the planned method as a whole are various modifications of the amount of effort devoted to each component. However, no modification that would reduce the planned emphasis on fieldwork is considered to be a reasonable alternative, inasmuch as no other single component of the method would provide the amount, kind, and quality of information needed to adequately characterize Quaternary faulting throughout the site area. Similarly, increasing the amount of fieldwork at the expense of the other components would not correspondingly increase the quality of the information.

2.1.2 Rationale for selecting the number, location, duration, and timing of tests

2.1.2.1 Number

The number of tests (measurements and observations) is dictated by the number of faults on which Quaternary movement is currently known or suspected and by the number of additional faults on which Quaternary movement is subsequently demonstrated (see sec. 3.1.1). The number of field observations will further depend on the number and quality of exposures, the number of office measurements and observations, and the availability and quality of data from other sources. The number of individual tests cannot be quantified, but a few person-years will probably be required to prepare the 1:24,000-scale map that is to be the primary product of this activity. That scale was chosen as adequate for reliably showing (1) the locations of faults within that part of the area within 5 km of surface facilities important to safety that is included in the site area and (2) the length of faults, fault segments, and possible interconnections between faults.

2.1.2.2 Location

The location of the study area is dictated by the need to determine the surface locations of faults that are likely to intersect the underground facilities and that have >1 m of Quaternary offset, and by the need to identify and characterize the major known potentially significant Quaternary faults within 5 km of facilities important to safety. (See the discussion of issue 4.4 in sec. 1.2.) The location of the field observations is dictated by the locations of such faults and by the locations of natural exposures where field observations can be made to complement the trench studies of Activity 2.

2.1.2.3 Duration and timing

The duration and timing for this activity are dictated by the need to incorporate information from other activities into this activity (see table 3.1-1) and to provide information from this activity to other studies and to Mission Plan milestones prescribed by the Project integrated schedule (see secs. 4 and 5). The scheduled duration and timing are based on the anticipated number of trenches, the expected complexity of the features in the trenches, and the staff, budget, and support resources planned to study the faults.

2.1.3 Constraints: factors affecting selection of tests

The choice of the SCP test method for this activity was unaffected by the following factors: impacts on the site; simulation of repository conditions; limits and capabilities of analytical methods; timing; scale and applicability of measurements; and interference with other tests or the exploratory shaft. Because this activity consists of data compilation and geologic mapping, it will have no effect on other tests, on the design and construction of the exploratory shaft, or on the ability of the site to isolate the waste (see SCP, sec. 8.4.3.3). The activity does not attempt to simulate repository conditions. It employs a balance of standard geologic mapping and compilation practices appropriate to the information requirements for the activity (see sec. 2.1.1); hence, reasonable alternative balances of these practices are unlikely to have significantly different accuracy. Although the activity draws on data from other sources, it does not draw on analyses whose limitations might have affected the choice of the test method. Similarly, the choice was not affected by analytical methods to be used in other studies that will draw on the results of this activity. Alternatives to the planned method would offer modest advantages in timing and cost but would result in an unacceptable reduction of data quality. Finally, selection of the test method was not affected by considerations of the scale of the geologic features to be mapped or of the applicability of the test method: the equipment to be used has no alternatives that can measure the required parameters with markedly greater accuracy or representativeness (see secs 3.1.4, 3.1.8); and the concept of applicability is not relevant because the activity is to be conducted mainly in the field.

2.2 Activity 8.3.1.17.4.6.2 Evaluation of age and recurrence of movement on suspected and known Quaternary faults

2.2.1 Rationale for the types of tests selected

The choice of test methods (sec. 3.2.2; table 3.2-3) was dictated by the ability of these methods to provide the information (SCP parameters) required for issue resolution (see sec. 1.2) and for input to other studies (see sec. 4) with the required degree of accuracy and confidence. Of the eight SCP test methods, two involve dating of Quaternary datums and fracture fillings and correlation and dating of Quaternary volcanic ash. Of the remaining six test methods, five involve trenching, mapping, and dating of the five individual faults on which Quaternary movement is currently known or suspected, and the sixth involves trenching, mapping, and dating of other suspected and possible Quaternary faults in the site area. The test method for studying each fault has three major components or "submethods":

- mapping of faults and associated surficial deposits exposed in trench walls
- dating of Quaternary datums (e.g., surficial deposits, soils, and volcanic ashes) exposed in trench walls by numerical, relative, or correlative methods
- determining the amounts, directions, and times of Quaternary faulting

The greater part of the effort in these five test methods--perhaps 50-80 percent--will be devoted to trench-wall mapping, the second submethod listed above.

The activity employs a combination of standard current field and laboratory practices for studying faults in trenches and for identifying and dating the relevant Quaternary datums. For the activity as a whole, no reasonable alternatives to actually mapping the faults in trenches and dating the Quaternary datums would provide reliable information on the locations, amounts, directions, and times of Quaternary movement. For identifying the locations, amounts, and directions of movement, the alternatives of studying the faults only in natural exposures (rather than trenches) or of merely sketching the trench walls (rather than mapping them in detail) would fail to provide the required information. Similarly, for determining times of movement, there are no reasonable alternatives to (1) correlation of relevant datums with materials of known age, (2) numerical dating of such datums and fracture fillings by the uranium-series, uranium-trend, and cation-ratio procedures, and (3) dating of those volcanic ashes that are intercalated in Quaternary deposits and that contain minerals suitable for determining age by potassium-argon and fission-track techniques. The alternatives of estimating the ages or of determining only the relative ages of relevant datums would not provide specific information on the timing of fault movement. Although numerical dating methods will be employed when appropriate, materials suitable for numerical age determinations are commonly absent; therefore, considerable emphasis will be placed on relative-age determinations and on correlation with surficial deposits of known age.

2.2.2 Rationale for selecting the number, location, duration, and timing of tests

2.2.2.1 Number

The number of trenches (sec. 3.2.1) is dictated mainly by the number and the lengths of faults on which Quaternary movement is known or suspected and by the number of locations along a fault that are favorable for geologic studies and that are suitable for trenching (see sec. 2.2.2.2). Major faults will typically be trenched at two to four different sites along their lengths and possibly at one or two additional sites if deemed necessary. The dimensions of the trenches (sec. 3.2.1) are dictated by the nature of the fault and by the age and physical characteristics of the surficial deposits at each of the potential trench sites, as well as by experience gained from observing relevant features in existing trenches. The number of laboratory analyses is dictated chiefly by the number of trenches and by the complexity of the structural features and the number of surficial deposits and volcanic ashes exposed in the trenches. The numbers of trenches and laboratory analyses are further dictated by the need to attain the confidence levels specified for the three characterization parameters tied to this activity, as shown in SCP tables 8.3.1.17-3(b) and 8.3.1.17-4(b).

2.2.2.2 Location

The locations of the trenches are dictated by the surface locations of faults having known or suspected Quaternary movement and by the presence of surficial deposits of different ages that record the location, amount, and direction of Quaternary movement on these faults. The locations of the trenches are dictated by the need to identify areas--

- where the trace of the fault can be determined or reasonably inferred prior to trenching (e.g., through study of aerial photographs)
- that are accessible and amenable to trenching
- that are most likely to have sequences of deposits on both sides of the fault that--
  - constrain the times of fault movement
  - are suitable for either numerical, relative, or correlative age determinations
  - have physical properties that facilitate the
    - identification of structural features
    - determination of the number of faulting events
    - measurements of the amount and direction of movement

Trench sites that meet these criteria will be identified through detailed interpretation of aerial photographs and comprehensive field observations.

2.2.2.3 Duration and timing

The duration and timing for this activity are dictated by the need to incorporate information from other activities into this activity (see table 3.2-1) and to provide information from this activity to Activity 1 and to other studies according to the Project integrated schedule (see secs. 3.2.1, 4, and 5). The scheduled duration and timing are based on the anticipated number of trenches, the expected complexity of the features in the trenches, and the staff, budget, and support resources available to study the faults.

2.2.3 Constraints: factors affecting selection of tests

Because this activity generates data from mapping of shallow trenches and from age determinations of materials from these trenches, it will have no effect on the design and construction of the exploratory shaft. Section 8.4 of the SCP discusses potential impacts of site activities on the waste isolation characteristics of the site and presents analyses to demonstrate that such studies do not adversely impact the site. In particular, section 8.4.2.2.2.1 discusses the assumed dimensions of trenches; section 8.4.3.2.1.1 discusses the analysis which was used to evaluate whether surface excavation such as trenches could impact hydrologic conditions at the site; and section 8.4.3.2.5.1 discusses potential impacts and concludes that surface activities such as trenching will not adversely impact the site. As part of this determination, trenching must be less than or equal to the dimensions assumed in the analysis. As such, Sandia National Laboratory has developed criteria letters which are used to dictate the dimensions of trenches, and are used to ensure that the dimensions will not exceed those assumed for the analysis of site impacts. If it is determined that larger trenches are needed, additional analysis may be necessary to demonstrate that no adverse site impacts will occur. Accordingly, the choice of the SCP test methods for this activity (as for Activity 1) was affected neither by those factors nor by the need to simulate repository conditions, the limits and capabilities of analytical methods, timing, or scale and applicability of measurements, for the reasons presented in section 2.1.3.

3 DESCRIPTION OF TESTS AND ANALYSES

This section summarizes the tests that are planned for the two activities in this study. The bases for selecting the types of tests planned for each activity are discussed in section 2.

3.1 Activity 8.3.1.17.4.6.1 Evaluation of Quaternary geology and potential Quaternary faults at Yucca Mountain

The objectives of this activity are--

- to synthesize and evaluate data on--
  - the location, orientation, length, width, and recurrence interval of Quaternary faults within the site area
  - the location, amount, and nature of movement on these faults
- to identify previously unrecognized Quaternary faults in the site area.

3.1.1 General approach

This activity will produce a 1:24,000-scale map of all Quaternary faults identified within the area delineated in figure 1-2 (the "site area"). The map, associated text, and tables of analytical data will show--

- the location, orientation, and extent of all identified Quaternary faults and of fault scarps and significant lineaments expressed in surficial deposits;
- the ages of fracture fillings and of the youngest offset Quaternary datums (e.g., surficial deposits, soils, and volcanic ashes);
- the locations, amounts, directions, and times of displacement of Quaternary datums;
- the slip rates and recurrence intervals, where possible, for Quaternary faulting.

The planned map will be based on data both from this activity and from other activities. This activity will provide data on the surface traces of known, suspected, and possible Quaternary faults in the site area by compilation of existing fault mapping and by new field mapping and study of all known, suspected, and possible Quaternary faults. This activity will also incorporate data from other activities (table 3.1-1) on--

- the subsurface extension, geometry, and possible segmentation (as defined by Schwartz and Coppersmith, 1986) of Quaternary faults as interpreted from standard geophysical surveys;
- the location and age constraints on Quaternary faulting and the identification of areas that may contain concealed Quaternary faults as inferred from the distribution, surface characteristics, and ages of the surficial deposits within the site area.

In preparing the Quaternary fault map of the site area, the following kinds of information (equivalent to the SCP parameters and characteristics) will be collected:

- location, length, orientation, areal pattern, and width of Quaternary faults
- location, length, orientation, inclination, and height of fault scarps
- magnetic and gravity expression of faults
- location, length, and orientation of lineaments expressed in surficial deposits
- location, amount, and direction of displacement of Quaternary datums
- ages of fault scarps and of Quaternary datums that are displaced by or that overlap Quaternary faults and of volcanic ashes, mineral coatings, and fracture fillings within the fault zones
- evidence for segmentation and interconnections of faults

The number of observations of Quaternary faults will depend on the number of such faults identified in the site area. This activity will initially focus on the mapping and study of four faults in the site area on which Quaternary movement is known (Windy Wash, Solitario Canyon, Bow Ridge, and Paintbrush Canyon) and on a fifth fault (Ghost Dance) on which movement is suspected based on its proximity and similarities with the known Quaternary faults. In addition, a few previously unrecognized Quaternary faults might be revealed through the mapping of surficial deposits (Activity 8.3.1.5.1.4.2) and of known Quaternary faults (this activity). Any newly discovered Quaternary faults will be studied in much the same manner and detail as the known Quaternary faults, depending on their orientation and proximity to the waste facility. Observations in this activity will complement those made in Activity 2 in trenches excavated across the fault zones. In this activity, about 1 person-year will be spent observing natural exposures along each fault, evaluating and synthesizing relevant information from published reports and from other activities, and compiling the required information onto the 1:24,000-scale map that is to be the primary product of this activity.

3.1.2 Test method and procedure

This activity will use a single SCP method--Quaternary fault mapping of Yucca Mountain--defined by one technical procedures (table 3.1-2). The activity will use standard, current geologic practices for--

- locating, depicting, and characterizing the surface features of faults with Quaternary movement and of lineaments expressed in surficial deposits;
- synthesizing and presenting relevant information from other activities.

The map of Quaternary faults will be produced by compiling fault data from existing geologic maps (e.g., Swadley and others, 1984; Scott and Bonk, 1984, from Activity 8.3.1.4.2.2.1); by delineating previously unrecognized Quaternary faults through examination of available remote-sensing images and aerial photographs (including both high- and low-sun-angle photographs of scale 1:12,000 or larger) and through new field studies in the site area; by examining each of the faults to determine the age of the youngest Quaternary datum that is offset; by incorporating information on rates of movement and recurrence intervals from the detailed trench studies of Activity 2 (see sec. 3.2); and by incorporating information on fault orientation from the geophysical surveys in Studies 8.3.1.17.4.3 and 8.3.1.17.4.7 (table 3.1-1). Other geophysical surveys, such as ground-penetrating radar (which will be evaluated in Study 8.3.1.17.4.2) will be considered for inclusion in this activity. The map will be updated as new information on Quaternary faults in the site area becomes available. Details of the method to be used in this activity are spelled out in the technical procedure shown in table 3.1-2.

3.1.3 QA requirements

QA grading packages will be prepared for this activity before work begins (App. A).

3.1.4 Required tolerances, accuracy, and precision

No requirements for tolerance, accuracy, or precision have been explicitly specified for the tests in this activity (see. sec. 3.1.1). However, tentative goals have been established for design or performance parameters corresponding to the characterization parameters for the activity; these goals suggest accuracies desired for some of the parameters to be measured in the activity. The following discussion compares the accuracies specified in those goals with the accuracies expected of the tests. Related discussions in section 3.1.8 consider the representativeness and uncertainties of the results.

Characterization parameter: identification and characterization of potentially significant Quaternary faults within 5 km of facilities important to safety

Tentative goal for related design or performance parameter: to determine the existence of such faults within that part of the area within 5 km of facilities important to safety that lies in the study area with high confidence

Expected accuracy: the map of Quaternary faults produced in the activity will identify the five faults in the site area on which Quaternary movement can currently be demonstrated or is currently suspected (fig. 1-2); in addition, the map will identify most of the hitherto-unrecognized Quaternary faults that can be detected through state-of-the-art-technology--that is, faults that show well-expressed offset of Quaternary datums and that are detectable through examination of aerial photographs, areal mapping, studies in trenches (Activity 2), and evidence from geophysical surveys (Studies 8.3.1.17.4.3, 8.3.1.17.4.7). Identification of such faults is subject to the uncertainties discussed in section 3.1.8.

Characterization parameter: surface locations of faults in the repository block with more than 1 m of Quaternary offset

Tentative goals for related design or performance parameters (all with high confidence):

to classify those faults according to standard practice

to locate the faults within 5 m (SCP table 8.3.1.17-4(a)) or 20 m (SCP table 8.3.2.5-2) to measure their surface orientation within 10°.

Expected accuracy: The planned mapping is expected to classify those faults and to show their locations and orientations as accurately as current technology and the available geologic data permit. The locations of the faults will be plotted to standard map accuracy--within 1 mm on the 1:24,000 base map, hence, within 24 m on the ground. Locations of well-expressed faults will be plotted within a few tenths of a millimeter on the 1:24,000-scale map of this activity (i.e., within about 5 m on the ground) at those points where accurate information is available from related activities, such as the trench-wall mapping of Activity 2 (see sec. 3.2.4) and the exploratory trenching in Midway Valley (Activity 8.3.1.17.4.2.2). The orientations of the faults, where natural exposures permit, will probably be measured within 5-10°; in the trench-wall mapping of Activity 2 and of Activity 17.4.2.2, orientations may be measured within a degree or two if fault relations are clearly displayed on the trench walls.

Characterization parameter: surface locations of faults intersecting the underground facilities and having more than 0.005 mm/yr of Quaternary slip rate (SCP table 8.3.1.17-4(b))

Tentative goals for related design or performance parameters (both with high confidence):

to determine the existence of such faults (SCP table 8.3.1.17-4(a))

to locate such faults (SCP table 8.3.1.17-4(a))

Expected accuracy: The accuracies expected for these measurements are discussed above.

3.1.5 Range of expected results

Previous studies (e.g., Swadley et al., 1984) in the Yucca Mountain area suggest the following ranges of expected results.

The surface traces of Quaternary faults in the site area are likely to be a few hundred meters to perhaps 20 km in length. These faults trend generally north, but locally they trend northeast or northwest. The Quaternary faults are likely to dip steeply near the surface. Near the surface, observed offsets on individual faults are likely to be confined to zones of displacement that are generally less than 15 m wide. Zones of subsidiary fractures may extend a few meters to several tens of meters or more outward from the zones of displacement. Some of the major fault zones may contain two or more separate segments (as defined by Schwartz and Coppersmith, 1986). Fault scarps expressed in surficial deposits are likely to be about a few hundred meters to about 5 km in length, about 0.3-5 m high, and less than 100,000 yr old. Lineaments expressed in surficial deposits are likely to be generally less than a few kilometers in length and have trends that range from northwesterly to northeasterly. Amounts and directions of displacement, times of latest movement, rates of displacement, and recurrence intervals of Quaternary faults in the site area are discussed in section 3.2.5.

3.1.6 Equipment

This activity will use a variety of conventional field and office equipment for mapping the Quaternary faults in the site area. Typical equipment is listed in table 3.1-3.

3.1.7 Data-reduction techniques

In this activity, standard data-reduction techniques will be used to synthesize and compile the field observations. In this process, observations made on the ground surface, in natural exposures, and on aerial photographs will be compiled onto scale-stable topographic base maps; stereographic techniques will be used where appropriate.

3.1.8 Representativeness of results

The information obtained in this activity is expected to be as representative of Quaternary faults in the site area as current technology permits, because all known and suspected Quaternary faults will be studied comprehensively and in detail. The activity is designed to yield comprehensive information on all known and suspected Quaternary faults and to result in the identification and characterization of hitherto unrecognized faults that cut Quaternary deposits in the site area. Accordingly, the information to be obtained for the characterization parameters explicitly tied to this activity is expected to be representative of--

- potentially significant Quaternary faults within that part of the area within 5 km of facilities important to safety that is included in the site area.
- faults in the proposed repository block that offset Quaternary materials more than 1 m,
- faults that potentially intersect the underground facilities and that have Quaternary slip rates greater than 0.005 mm/yr.

The information obtained in this activity is not intended to be extrapolated outside the site area shown in figure 1-2. Similarly, this activity will not extrapolate the information into the future; it will, however, provide the bases for such extrapolations to be done in Investigations 8.3.1.17.2, 8.3.1.17.3, and elsewhere in Investigation 8.3.1.17.4 (e.g., 8.3.1.17.4.12) (see section 4). Study 8.3.1.17.4.2 (Location and recency of faulting near prospective surface facilities) will contribute information on Quaternary faulting within that part of the site area included within Midway Valley. Study 8.3.1.17.4.3 (Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane) will contribute information on Quaternary faulting for those parts of the area within 5 km of facilities important to safety that lie outside the site area.

Because conditions are seldom ideal, some data gaps and uncertainties are likely to occur and to impose limitations on the ability to recognize and characterize Quaternary faults in the site area--particularly those of limited extent and little offset or those that lack discernible surface expression or a distinguishable geophysical signature. This is especially true for small amounts of strike-slip movements which are not expressed by visible offsets the ground surface or in the trenches of Activity 2. Such uncertainties, however, are expected to have only a minimal effect on the representativeness of the information required from this activity.

In summary, the degree to which all Quaternary faults can be detected, mapped, and characterized depends on--

- quality and extent of natural exposures and degree to which faults and evidence for fault movements are expressed in surficial deposits
- strategic placement of trenches (Activity 2) and clarity of fault relations exposed on trench walls
- extent to which aerial photographs reveal linear features and fault scarps
- capability of geophysical surveys (Study 8.3.1.17.4.7) to identify subsurface faults that may project upward to the surface

3.1.9 Relations to performance goals and confidence levels

This activity will directly address the first three characterization parameters listed in table 4-1 by providing information on the location and offset of Quaternary faults. This information is required to establish high confidence in the goals noted in section 3.1.4. Slip rates are provided by the second activity. This activity will also indirectly address postclosure performance concerns such as the effect of tectonic activity on the regional ground-water system (Investigation 8.3.1.8.3) as shown in figures 1-3 and 1-4. The scope of this activity and scale of mapping are designed to establish the required confidence in the asociated performance and design goals.

3.2 Activity 8.3.1.17.4.6.2 Evaluation of age and recurrence of movement on suspected and known Quaternary faults

The objectives of this activity are--

- to determine, through trenching and trench-wall mapping--
  - the surface location, orientation, length, and width
    - of the Windy Wash, Solitario Canyon, Ghost Dance, Bow Ridge, and Paintbrush Canyon faults and
    - of other suspected or possible Quaternary faults within the site area
  - the location, time, amount, nature, and recurrence interval of Quaternary movement on these faults
- to evaluate the characteristics and history of Quaternary movement on the Bow Ridge and possibly other fault systems in the context of data from other studies (e.g., 8.3.1.5.2.1.5) on the age, nature, and origin of fracture coatings and fissure fillings along this fault system.

3.2.1 General approach

This activity will produce detailed (scale about 1:20) trench-wall maps at selected locations across Quaternary faults in the area delineated in figure 1-2; the maps will show--

- faults, fractures, and other structural features;
- width of fault zones;
- distribution and ages of Quaternary datums (e.g., surficial deposits, soils, and volcanic ashes) that are displaced by or that overlap Quaternary faults;
- locations, amounts, and directions of displacement of Quaternary datums.

Structural features and associated surficial materials that are intersected by or that overlap Quaternary faults will be mapped and studied in detail in trench excavations, and they will be analyzed in the laboratory by appropriate geochronologic and chemical methods. These methods will provide information needed to evaluate Quaternary faulting in the site area. Information from other studies will be used as indicated in table 3.2-1.

The kinds of information (equivalent to the SCP parameters and characteristics) to be collected in the site area in this activity include:

- location, orientation, length, and width of Quaternary faults
- width and character of rupture zones, including the fabric of sheared material
- character of fracture surfaces

- location, amount, and direction of displacement of Quaternary datums
- ages of Quaternary datums that are displaced by or that overlap Quaternary faults and of volcanic ashes, mineral coatings, and fracture fillings within the fault zones
- age, lateral extent, morphology, and height of fault scarps
- evidence for segmentation and interconnections of faults

Observations will be made in trenches excavated across five known or suspected Quaternary fault zones (Windy Wash, Solitario Canyon, Ghost Dance, Bow Ridge, and Paintbrush Canyon); in addition, observations will also be made on an unknown number (perhaps three to five) of other Quaternary faults in the site area if such faults are discovered during the mapping in Activity 1 (see sec. 2.2.2.2). Each of the faults will be studied in one or more trenches that are excavated across the fault zone. At present, there are about 25 trenches across the five fault zones (fig. 1-2). These trenches will be reexamined for any previously unrecognized evidence of Quaternary faulting and will be remapped if necessary. Perhaps 15-20 additional trenches may be deemed necessary; these trenches will typically be about 20-50 m long, 2-5 m deep, and 4-5 m wide. At sites where geologic conditions warrant more extensive excavation, trench dimensions may exceed these values, but they will remain within the limits discussed in SCP section 8.4. In addition, subsidiary trenches will be excavated along selected fault zones, on one or both sides of the main trench, to determine the direction and amount of strike-slip movement; these subsidiary trenches will be perpendicular to the main trenches and will probably be 5-10 m long, 2-4 m deep, and 4-5 m wide. Trench-wall mapping and preparation of the final maps for each main trench may require as much as the equivalent of one person-year; for each subsidiary trench, as much as a half person-year. A technique involving stereographic photography for use in mapping trench walls may substantially reduce the mapping time.

Table 3.2-2 shows the types and numbers of laboratory analyses to be carried out in this activity. The numbers of individual analyses are estimates because they depend on conditions that will remain unknown until new trenches are excavated, some of the existing trenches are extended, and the structural features and displaced materials in these trenches can be examined and evaluated. Appropriate numerical dating methods (table 3.2-3) will be applied, as needed--chiefly

- U-series for vein material
- U-trend for surficial deposits
- varnish cation-ratio dating for geomorphic surfaces

Deposits and surfaces of unknown age will be dated where they are displaced by or overlap Quaternary faults in the site area and where they can be correlated with stratigraphic units of known age elsewhere in the Beatty 1:100,000 quadrangle. In order to cross-check the results of the above dating methods, uranium-trend and varnish cation-ratio dating methods will be applied to deposits and surfaces of known age within the general region (within about 200 km of Yucca Mountain) that can be used as time calibration for these dating methods. Methods for identification, correlation (of tephra), and dating (chiefly, fission-track and potassium-argon) will be applied to volcanic ash intercalated in deposits that are cut by or that overlap Quaternary faults within the site area.

3.2.2 Test methods and procedures

The activity consists of eight SCP methods (table 3.2-3), which fall into three main classes:

- mapping and evaluation of offset of Quaternary datums in trenches and outcrops along--
  - the Windy Wash fault zone
  - the Solitario Canyon fault zone
  - the Ghost Dance fault zone
  - the Bow Ridge fault zone
  - the Paintbrush Canyon fault zone
  - other suspected and possible fault zones
- numerical dating of Quaternary datums, vein materials, and fracture fillings
- correlation and dating of Quaternary volcanic ash

The test methods for this activity are defined by the technical procedures shown in table 3.2-3. The activity will use current, standard geologic and geochronologic procedures (e.g., those discussed in Hatheway and Leighton, 1979, and Pierce, 1986) for--

- mapping of trench walls and measurement of offset Quaternary datums
- determination of the numerical ages of vein material deposited in fissures along fault zones through isotopic analyses
- determination of the numerical ages of surficial deposits and geomorphic surfaces that are cut by or that overlap faults through isotopic, radiogenic, and chemical analyses
- determination of the relative ages of such surficial deposits through stratigraphic correlation
- identification, correlation, and numerical age determination of volcanic ash interbedded with surficial Quaternary deposits or filling fractures, through isotopic, radiogenic, and chemical analyses

These procedures will provide the information needed for determining timing, recency, slip rates, and recurrence intervals for Quaternary faulting. Recurrence intervals will be based on field evidence for the number of faulting events and on numerical age control for the timing of the events.

The direction and amount of total displacement (slip) will be determined where suitable planar or linear stratigraphic features can be identified on both sides of the fault, as detailed in the SCP (pp. 8.3.1.17-158, 8.3.1.17-159). Photography will be carried out with a metric camera that will take overlapping stereographic photographs that have surveyed control points. Stratigraphic contacts and structural features observed in the trench walls and on the corresponding contact diapositive prints will be depicted on detailed digitized maps that will be prepared with the aid of an analytical plotter.

3.2.3 QA requirements

QA grading packages will be prepared for this activity before work begins (App. A).

3.2.4 Required tolerances, accuracy, and precision

No requirements for tolerance, accuracy, or precision have been explicitly specified for the tests in this activity (see. sec. 3.2.1). Section 3.1.4 discusses the tentative goals established for design or performance parameters (those goals correspond to the characterization parameters for this activity and suggest accuracies desired for some of the parameters to be measured in the activity). The following discussion considers the accuracies expected of the measurements of each parameter for this activity.

Ground locations of trench sites will be determined within a few meters (±5) by accurate surveying instruments. The trench locations will be plotted within 1 mm (24 m actual ground distance) on the 1:24,000 base map to be used in Activity 1. Well-expressed structural features and datums cut by or overlapping faults will be located as accurately as definition of the feature allows (typically, within a few millimeters to a few centimeters); they will typically be plotted within 2 mm on the very large scale (about 1:20) trench-wall maps (i.e., within 4 cm on the actual trench walls). Accordingly, the locations and displacements of such faults will probably be measured within a few centimeters. Because faults in surficial materials are typically nonplanar and poorly expressed, the orientation of most faults will probably be measured within 10°.

Accuracy of numerical-age determinations of surficial deposits of unknown age cannot be determined because of a lack of independent age control. Precision given with numerical age determinations by the methods planned for this activity is generally within 10 to 50 percent of the indicated age.

There is no standard methodology for quantifying the accuracy of ash identification and correlation, because the accuracy of identification and correlation depends on several factors, including the type of instruments used for the analyses, instrumental detection limits, the specific procedures implemented, sample size, and sample preparation techniques. Precision of K-Ar and fission-track ages of volcanic ash are given with the age determination. They are generally within 5 to 40 percent of the indicated age. The accuracy of K-Ar and fission-track ages can be evaluated with respect to the correlated age of the volcanic ash based on equivalence to independently dated volcanic ash elsewhere in the Western United States. Precision of the various numerical dating methods will be evaluated by performing separate analyses of subsamples of selected samples. For an indepth discussion of the application of dating methods to Quaternary tectonism refer to Pierce (1986).

3.2.5 Range of expected results

Ranges of values expected for the length, width, orientation, and possible segmentation of Quaternary faults in the site area are given in section 3.1.5. On the basis of the limited information currently available (e.g., Swadley et al., 1984, and unpublished field observations), other parameters are expected to fall within the following ranges:

- Fault movements--chiefly dip-slip, but locally strike- or oblique-slip
- Net displacements--from a few centimeters in the past few thousand years to a few meters in the past 130,000 yr
- Recency of movement and recurrence intervals for individual faults--from a few thousand years to a few hundred thousand years
- Ages of surficial deposits that are displaced by or that overlap faults--from a few thousand years to 1-2 million yr
- Ages of volcanic ashes most likely to be found intercalated with surficial deposits or incorporated into fissure fillings within the fault zones--

  Ashes from the Lathrop Wells volcanic center--probably about 80,000-10,000 yr old. The most widespread ash is probably about 80,000-50,000 yr old. The youngest ash could be as young as about 5,000 yr old

  Bishop Ash from the Long Valley caldera--740,000 yr old, based on correlation and dating of equivalent tephra in the Western United States

  Ash from Red Cone or Black Cone in Crater Flat could be as young as 600,000 yr

Other possible ashes may have come from Long Valley, Sleeping Butte, and Yellowstone.

3.2.6 Equipment

This activity will require a great variety of field and laboratory equipment. Most comprises conventional, off-the-shelf items (table 3.2-4). Exceptions include some of the custom-made vacuum chambers used for U-series and U-trend dating, gas spectrometers used for potassium-argon dating, and Teflon boards used for fission track dating.

3.2.7 Data-reduction techniques

In this activity, observations made of trench walls in fault zones or of photographs of these trench walls will be recorded on scale-stable trench maps. Standard data-reduction techniques (technical procedures GP-08 and GCP-01; table 3.2-3) will be used for data generated for numerical dating of Quaternary datums, fissure fillings, and fracture coatings and for data generated for the correlation and dating of Quaternary volcanic ashes.

3.2.8 Representativeness of results

The discussion of section 3.1.8 applies to this activity as well as to Activity 1. Here again, some uncertainties are likely to remain despite the detail of the trench-wall mapping and the related supporting activities.

Numerical dating of Quaternary faulting events is subject to direct and indirect limitations imposed both by the local geology and by the analytical procedures used to determine the time of faulting. These limitations include-

- the distinct likelihood that the time of faulting cannot be determined directly; thus, the need to bound the time of a faulting event by determining the ages of the materials that most closely predate and postdate the event
- the common lack of uncontaminated materials within relevant materials that are suitable for numerical dating
- the common lack of alternative numerical dating methods to cross check the reliability of the numerical age determined for a given material
- the error inherent in the analytical procedures used to determine the age of the materials

Because of these limitations, it may not be possible to place close bounds on the times of faulting during the Quaternary; similarly, it may not be possible to make exact determinations of derivative parameters such as rates of displacement and recurrence intervals. Despite these limitations, the numerical age determinations performed on suitable materials in this activity will provide the best obtainable limits for constraining the times, rates of displacement, and recurrence intervals for Quaternary faulting.

3.2.9 Relations to performance goals and confidence levels

This activity will directly address the third characterization parameter in table 4-1 by providing information on the locations and slip rates of Quaternary faults that might intersect the underground facilities. This information is required to establish high confidence in the goals noted in section 3.2.4. This activity will also indirectly address postclosure performance concerns such as the effect of tectonic activity on the regional ground-water system (Investigation 8.3.1.8.3) as shown in figures 1-3 and 1-4. The scope of this activity and scale of mapping are designed to establish the required confidence in the asociated performance and design goals.

4 APPLICATION OF RESULTS

This section identifies other studies that will use the information obtained in the present study. The description is summarized from information in the statutory SCP. Related discussions in section 1.2 draw on section 8.3.5 of the SCP to consider the uses of information from the study in the context of issue resolution and performance goals.

Information from this study will be used both in the preclosure tectonics program (Program 8.3.1.17) and in the postclosure tectonics program (Program 8.3.1.8). Figures 1-3 and 1-4 and table 4-1 show what information from the study will be used and how that information will be used in specific studies in those programs. In the following, the discussion of where the information will be used is summarized from the SCP discussion of each activity.

In the preclosure tectonics program (fig. 1-3; table 4-1), information from this study will be used--

- to assess the probability of 5 cm of offset at locations proposed for facilities important to safety (Activity 8.3.1.17.2.1.1)
- to assess the probability of 7 cm of offset in 100 yr on any fault that intersects areas proposed for waste emplacement (Activity 8.3.1.17.2.1.2)
- to identify earthquake sources that could generate severe ground motions at the site, to determine rates for earthquake recurrence as a function of magnitude, and to characterize 10,000-yr cumulative-slip earthquakes (Studies 8.3.1.17.3.1, 8.3.1.17.3.5, and 8.3.1.17.3.6)

In the postclosure tectonics program (fig. 1-4; table 4-1), information from this study will be used--

- to assess the likelihood that the waste package will be ruptured by fault movement (Study 8.3.1.8.2.1)
- to analyze the effects of future faulting--
    - on local fracture permeability and effective porosity (Study 8.3.1.8.3.3)
    - on erosion (Study 8.3.1.6.3.1)
    - on hydrologic flux rates (Study 8.3.1.8.3.1)
    - on the elevation of the water table (Study 8.3.1.8.3.2)
    - on rock geochemical properties (Study 8.3.1.8.4.1)

The information from this study will also be used to complement the geologic mapping of structural features in the site area both at the surface and in the exploratory shaft and drifts (Study 8.3.1.4.2.2), by determining the attitudes, lengths, displacements, and other near-surface characteristics of Quaternary faults and fault zones.

5 SCHEDULE AND MILESTONES

Figure 5-1 shows the principal milestones for this study and all direct scheduling ties to other studies. This information is abstracted from the most current and complete Project schedule network (2/21/89).

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Hatheway, A.W., and Leighton, F.B., 1979, Trenching as an exploratory method, *in* Hatheway, A.W., and McClure, C.R., Jr., eds., Geology in the siting of nuclear power plants: Geological Society of America, Reviews in Engineering Geology, v. IV, pp. 169-195.

Pierce, K.L., 1986, Dating methods, ch. 13 *in* Active tectonics (Studies in geophysics): Washington, D.C., National Academy Press, pp. 195-214.

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Scott, R.B., and Bonk, Jerry, 1984, Preliminary geologic map of Yucca Mountain, Nye County, Nevada, with geologic sections: U.S. Geological Survey Open-File Report 84-494.

Swadley, W C, Hoover, D.L., and Rosholt, J.N., 1984, Preliminary report on late Cenozoic faulting and stratigraphy in the vicinity of Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-788, 42 pp.

APPENDIX A: APPLICATION OF QA CRITERIA

The extent that QA criteria are applicable to this study will be specified in Quality Assurance Grading Reports that are completed and approved in accordance with YMP Administrative Procedure (AP) -5.28Q before work begins. These QA Grading Reports will be issued as a separate document. Table A-1 shows the criteria from NQA-1 that apply to this study and procedures and other documents that satisfy those criteria.

Table A-1.--Applicable NQA-1 criteria for Study 8.3.17.4.6 and how they will be satisfied

NQA-1 criteria	Documents that satisfy those criteria
1. Organization and interfaces	The organization of the OCRWM program is described in the Mission Plan (DOE/RW-005, June 1985) and further described in section 8.6 of the SCP. Organization of the USGS-YMP is described in the following: QMP-1.01 (Organization Procedure)
2. Quality assurance program	The Quality Assurance Programs for the OCRWM are described in YMP-QA Plan-88-9 and OGR/83, for the Project Office and HQ respectively. The USGS QA Program is described in the following: QMP-2.01 (Management Assessment of the YMP-USGS Quality Assurance Program) QMP-2.02 (Personnel Qualification and Training Program) QMP-2.05 (Qualification of Audit and Surveillance Personnel) QMP-2.06 (Control of Readiness Review) QMP-2.07 (Development and Conduct of Training) Each of these QA programs contains Quality Implementing Procedures further defining the program requirements. An overall description of the QA Program for site characterization activities is described in section 8.6 of the SCP.

3. Scientific investigation control and design	This study is a scientific investigation. The following QA implementing procedures apply: QMP-3.02 (USGS QA Levels Assignment [QALA] On Hold) QMP-3.03 (Scientific and Engineering Software) QMP-3.04 (Technical Review of YMP-USGS Publications) QMP-3.05 (Work Request for NTS Contractor Services (Criteria Letter) QMP-3.06 (Scientific Investigation Plan) QMP-3.07 (Technical Review Procedure) QMP-3.09 (Preparation of Draft Study Plans) QMP-3.10 (Close-out Verification for Scientific Investigations) QMP-3.11 (Peer Review)
4. Administrative operations and procurement	QMP-4.01 (Procurement Document Control) QMP-4.02 (Acquisition of Internal Services)
5. Instructions, procedures, plans, and drawings	The activities in this study are performed according to the technical procedures listed in section 3.2 of this study plan, and the QA administrative procedures referenced in this table for criterion 3 QMP-5.01 (Preparation of Technical Procedures) QMP-5.02 (Preparation and Control of Drawings and Sketches) QMP-5.03 (Development and Maintenance of Management Procedures)
6. Document control	QMP-6.01 (Document Control)
7. Control of purchased items and services	QMP-7.01 (Supplier Evaluation, Selection and Control)

8. Identification and control of items, samples, and data	QMP-8.01 (Identification and Control of Samples) QMP-8.03 (Control of Data)
9. Control of processes	Not applicable
10. Inspection	Not applicable
11. Test control	Not applicable
12. Control of measuring and test equipment	QMP-12.01 (Instrument Calibration)
13. Handling, shipping, and storage	QMP-13.01 (Handling, Shipping, and Storage of Instruments)
14. Inspection, test, and operating status	Not applicable
15. Control of nonconforming items	QMP-15.01 (Control of Nonconforming Items)
16. Corrective action	QMP-16.01 (Control for Corrective Action Reports) QMP-16.03 (Trend Analysis)
17. Records management	QMP-17.01 (YMP-USGS Records Management) QMP-17.02 (Acceptance of Data Not Developed Under the YMP QA Plan)
18. Audits	QMP-18.01 (Audits) QMP-18.02 (Surveillance)

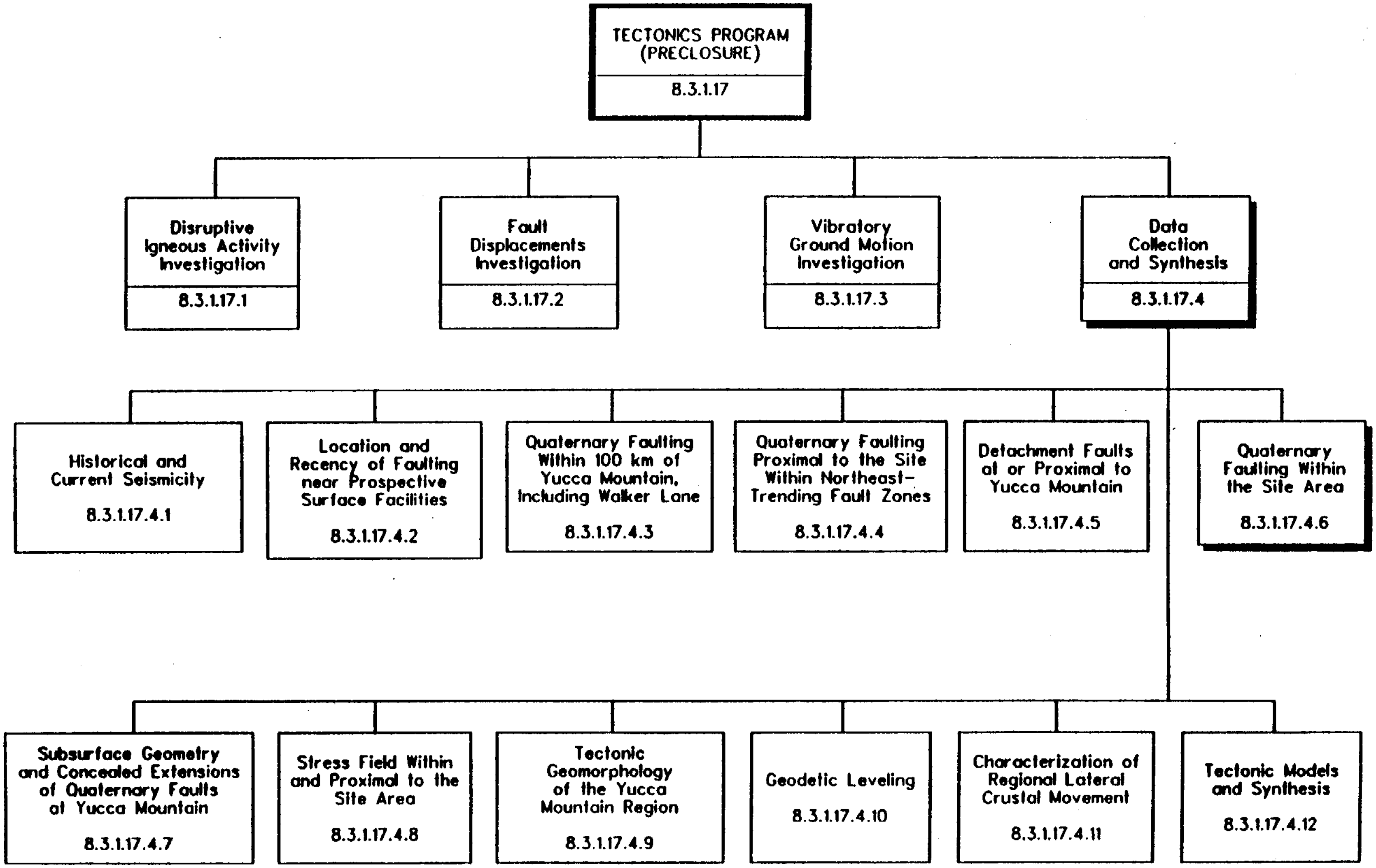


Figure 1-1.--Relation of Study 8.3.1.17.4.6 to the preclosure tectonics program

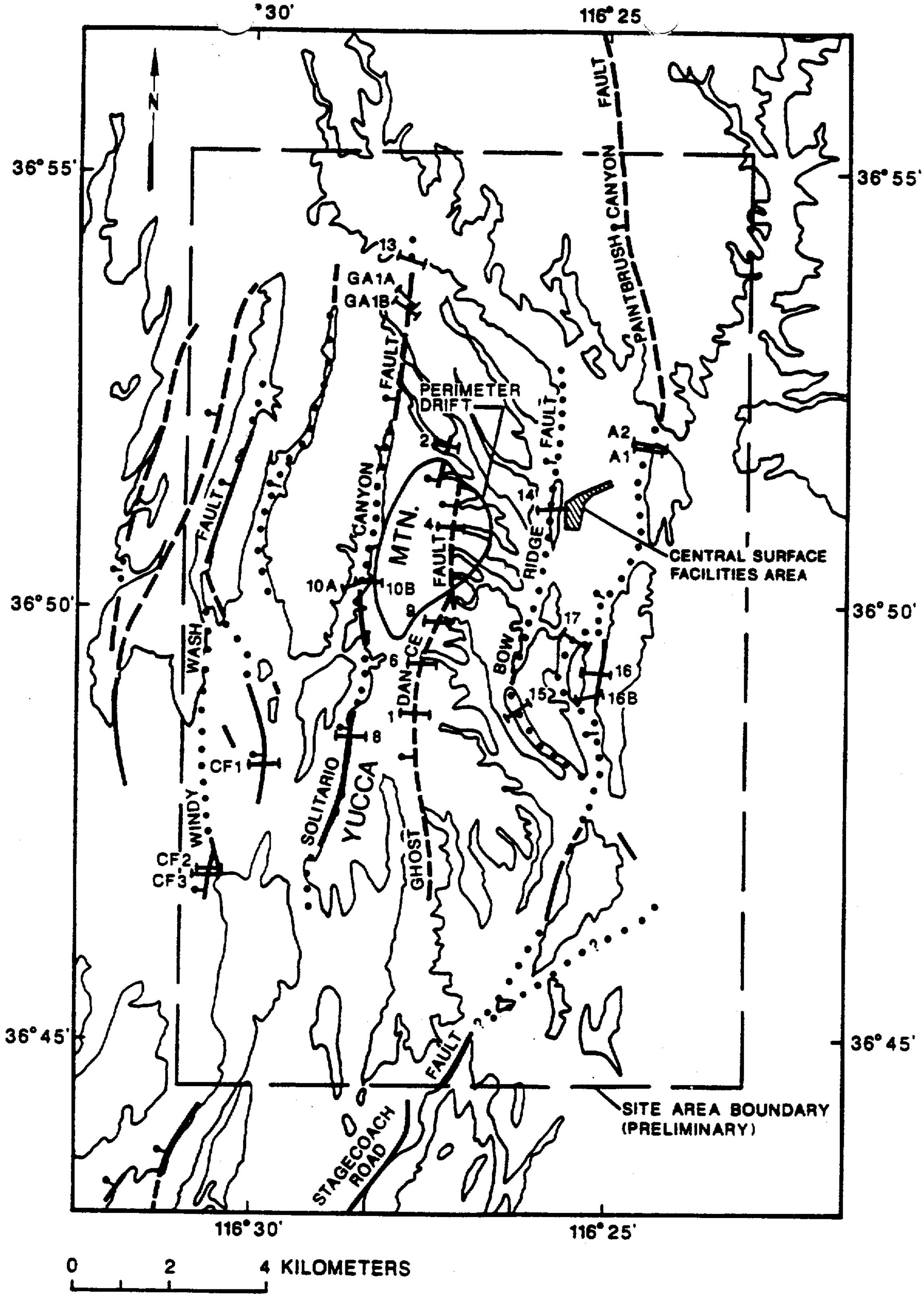
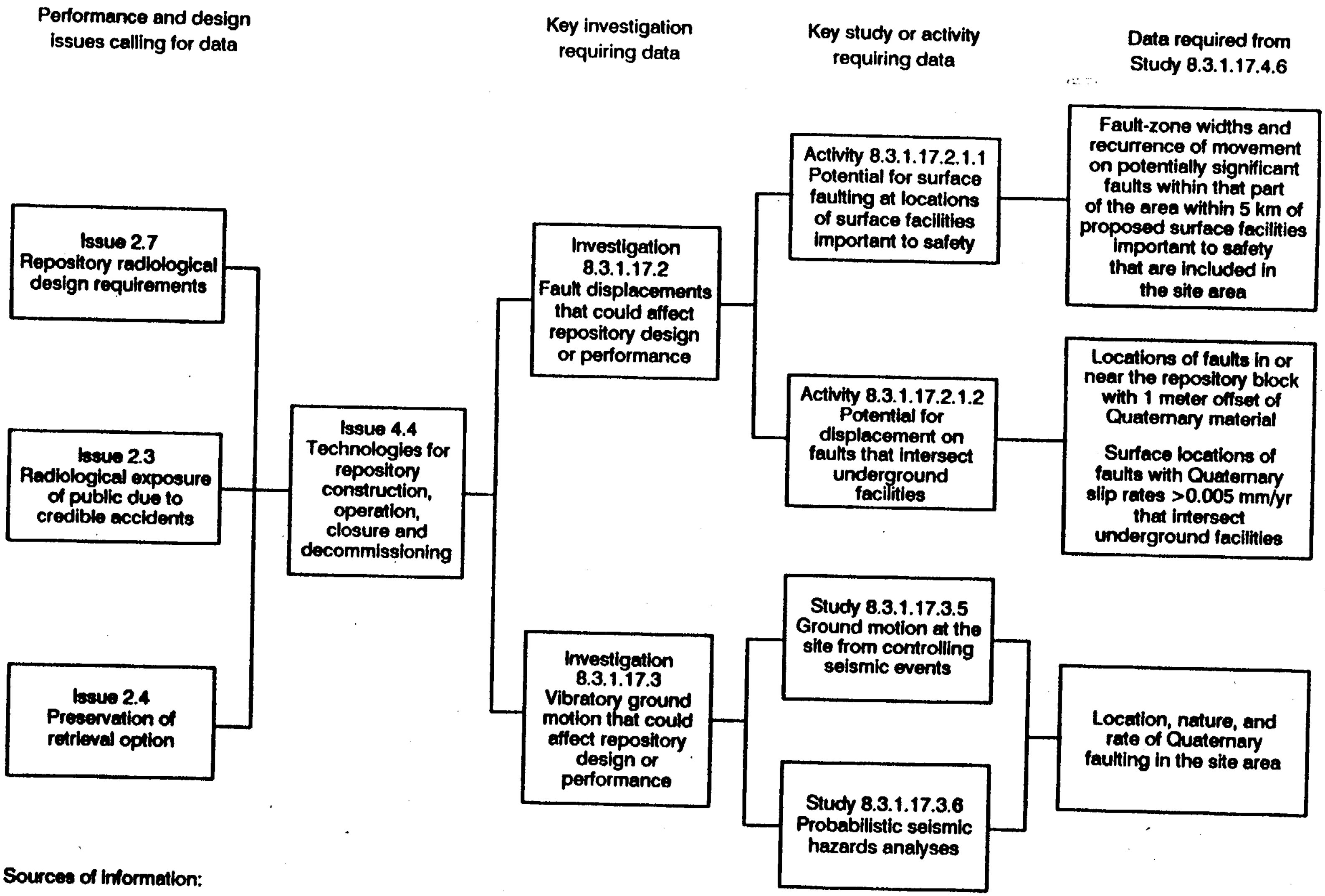


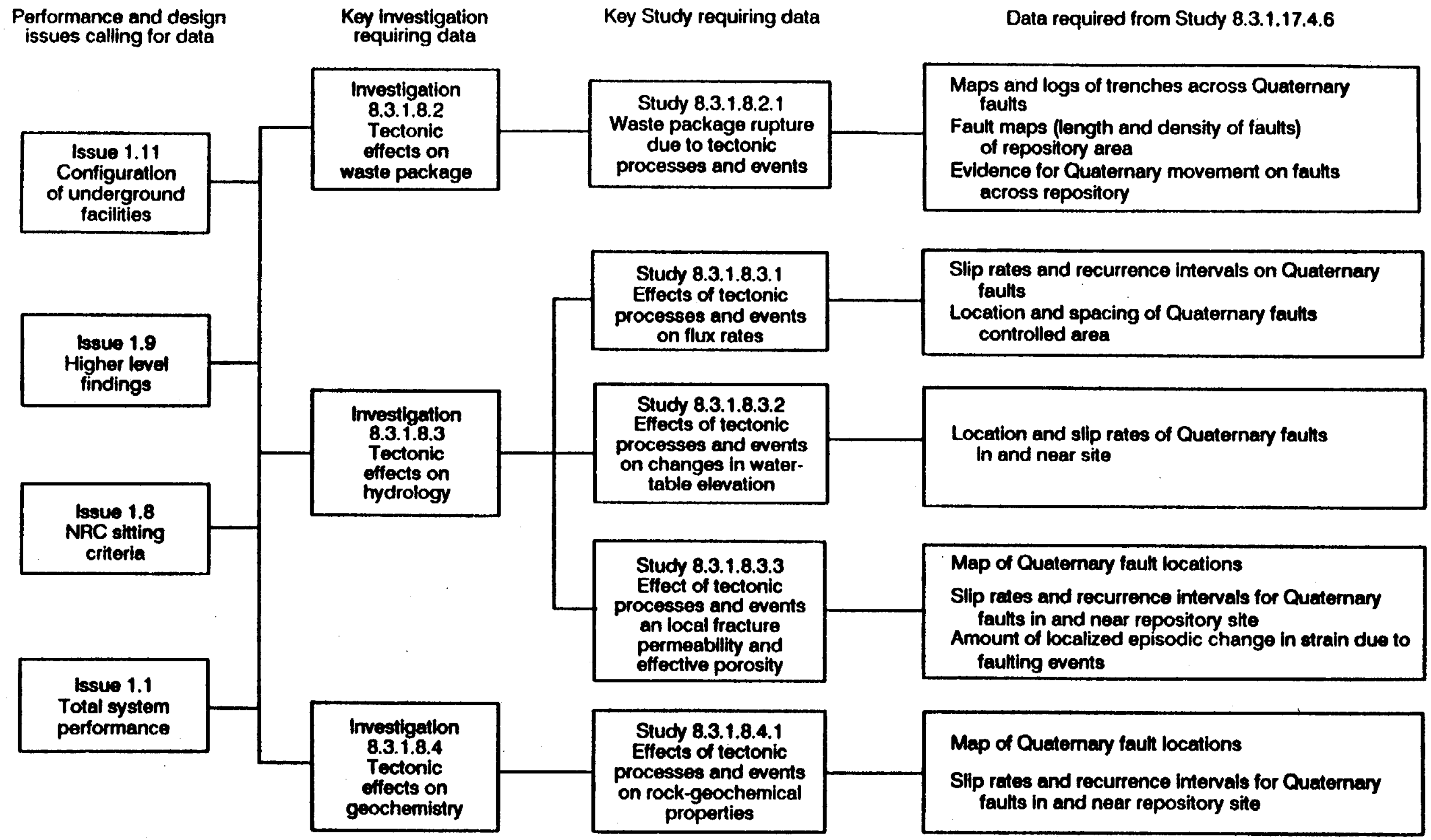
Figure 1-2.--Generalized map of Yucca Mountain site area, showing major known and suspected Quaternary faults and locations of trenches excavated across those faults as of April 1985. Other faults on which Quaternary movement is suspected (e.g., northwest-trending faults in the northern part of the site area) are not shown because of scale. Modified from Swadley and others, 1984



Sources of information:

for Investigation 8.3.1.17.2, modified from SCP Figures 8.3.1.17-1, 8.3.1.17-4;
for Investigation 8.3.1.17.3, modified from SCP Figures 8.3.1.17-1 and 8.3.1.17-5.

Figure 1-3.--Information required from Study 8.3.1.17.4.6 for issue resolution through studies in the preclosure tectonics program



Sources of information:

Investigation 8.3.1.8.2, modified from SCP Figure 8.3.1.8-1 and Figure 8.3.1.8-4;
for Investigation 8.3.1.8.3, modified from SCP Figures 8.3.1.8-1, 8.3.1.8-5, 8.3.1.8-6, and 8.3.1.8-7;
for Investigation 8.3.1.8.4, modified from SCP Figure 8.3.1.8-1 and Figure 8.3.1.8-8;

Figure 1-4.--Information required from Study 8.3.1.17.4.6 for issue resolution through studies in the erosion and postclosure tectonics program

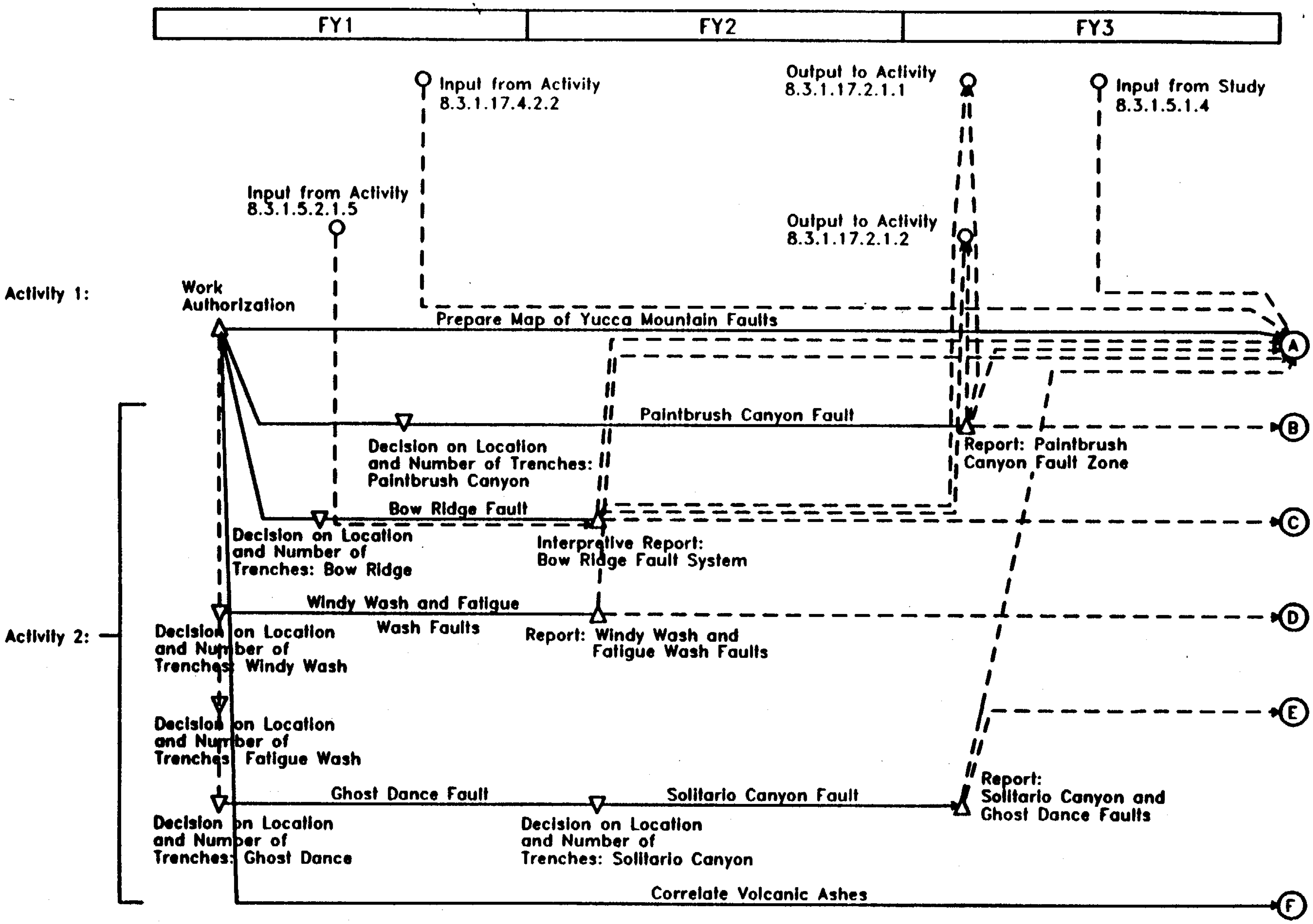
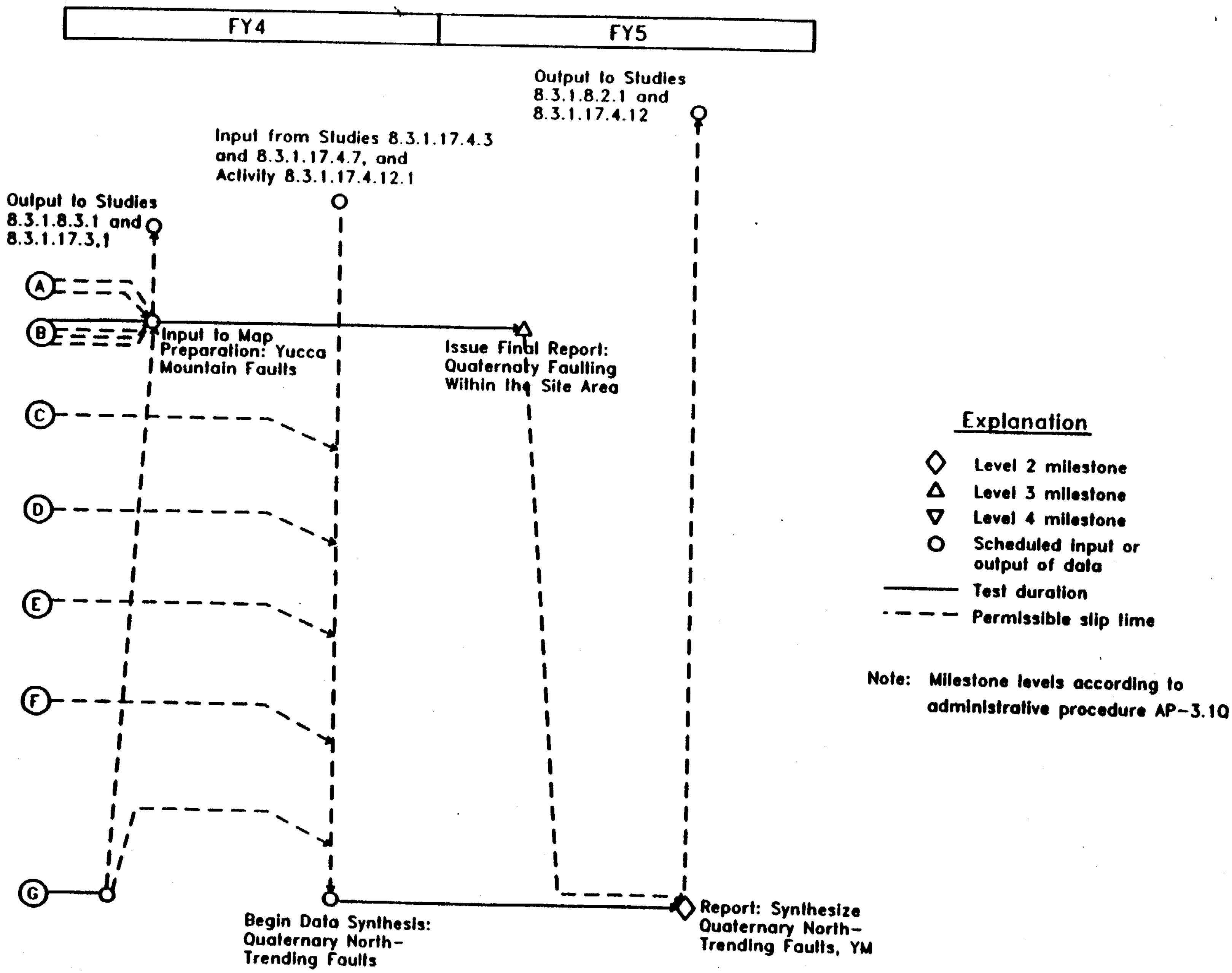


Figure 5-1.--Schedule for Study 8.3.1.17.4.6



Study 8.3.1.17.4.6: Quaternary faulting within the site area
Rev 0 May 17, 1989

Studies and activities that directly provide information to Study 8.3.1.17.4.6 or that directly use information from Study 8.3.1.17.4.6

8.3.1.5.1.4: Analysis of the paleoenvironmental history of the Yucca Mountain region

8.3.1.5.2.1.5: Studies of calcite and opaline silica vein deposits

8.3.1.8.2.1: Analysis of waste package rupture due to tectonic processes and events

8.3.1.8.3.1: Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository

8.3.1.17.2.1.1: Assess potential for surface faulting at locations of surface facilities important to safety

8.3.1.17.2.1.2: Assess potential for displacement on faults that intersect underground facilities

8.3.1.17.3.1: Relevant earthquake sources

8.3.1.17.4.2.2: Conduct exploratory trenching in Midway Valley

8.3.1.17.4.3: Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane

8.3.1.17.4.7: Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain

8.3.1.17.4.12: Tectonic models and synthesis

Figure 5-1 (cont'd).--Schedule for Study 8.3.1.17.4.6

Table 3.1-1.--Information to be provided to Activity 8.3.1.17.4.6.1 by other activities

Information to be provided	Source of information[1]	Use of information
Gravity, magnetic, and shallow-reflection data	[2]8.3.1.17.4.7	To determine subsurface continuity of fault segments observed at the surface
Deep refraction data	[2]8.3.1.17.4.3.1	To evaluate the subsurface expression of Quaternary faults
Distribution of surficial deposits	8.3.1.5.1.4.2	To identify areas that may contain concealed Quaternary faults and to help constrain the times of movement of known Quaternary faults
Location, amounts, directions, rates, and recurrence intervals of Quaternary faulting	8.3.1.17.4.6.2 8.3.1.17.4.2.2	To identify spatial variations in the nature and chronology of Quaternary faulting

[1]Study or activity from which information will be obtained

8.3.1.5.1.4.2: Surficial deposits mapping of the Yucca Mountain area

8.3.1.17.4.2.2: Conduct exploratory trenching in Midway Valley

8.3.1.17.4.3.1: Conduct and evaluate deep geophysical surveys in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane

8.3.1.17.4.6.2: Evaluate age and recurrence of movement on suspected and known Quaternary faults

8.3.1.17.4.7: Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain

[2]Seismic lines are tentative, pending Project decision

Table 3.1-2.--Technical procedures to be used in Activity 8.3.1.17.4.6.1

Abbreviated name	Number (NWM-USGS-)
Geologic mapping	GP-01, R0

Table 3.1-3.--Typical equipment to be used in Activity 8.3.1.17.4.6.1

Abney level
Brunton compass
Jacob's staff

brushes
camera, film, etc.
field notebook
hand lens
pick
rock hammer
shovel
sampling bags
whisk broom

measuring tape
labeling materials
pencils and other standard drawing materials

aerial photographs
scale-stable topographic base maps
stereoscope
mechanically operated stereographic plotter

Table 3.2-1.--Information to be provided to Activity 8.3.1.17.4.6.2 by other activities

Information to be provided	Source of information[1]	Use of information
Age, nature, origin of fracture coatings and fissure fillings	8.3.1.5.2.1.5	To evaluate tectonic features in the Bow Ridge fault zone
Ages of soils and surficial deposits that are cut by or that overlap Quaternary faults; locations of faults	8.3.1.5.1.4.1 8.3.1.5.1.4.2, 8.3.1.17.4.3.2	To establish the recency, rates, and recurrence intervals of Quaternary faulting

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[1]Study or activity from which information will be obtained

8.3.1.5.1.4.1: Modeling of soil properties in the Yucca Mountain region

8.3.1.5.1.4.2: Surficial deposits mapping of the Yucca Mountain area

8.3.1.5.2.1.5: Studies of calcite and opaline silica vein deposits

8.3.1.17.4.3.2: Evaluate Quaternary faults within 100 km of Yucca Mountain

Table 3.2-2.--Types and numbers of laboratory analyses in Activity 8.3.1.17.4.6.2

Types of analyses	Numbers of datums, ashes, and surficial deposits to be analyzed
Numerical dating of Quaternary datums by[1]	
Uranium series	10-20
Uranium trend	10
Varnish-cation ratio	25-35
Numerical dating of Quaternary volcanic ashes by	
Potassium-argon	5
Fission-track	5
Numerical dating of Quaternary surficial deposits of known age by	
Uranium-trend	5-10
Varnish cation-ratio	10-20
Chemical characterization of volcanic ashes by[2]	
Microprobe analysis	5
Instrumental neutron-activation analysis	5
X-ray fluorescence analysis	5

[1]Other numerical dating methods, such as thermoluminescence and electron-spin resonance, will be considered as possible dating methods after adequate testing, evaluation, and verification

[2]May be required for tephra correlation

Table 3.2-3.--SCP test methods and technical procedures to be used in Activity 8.3.1.17.4.6.2

SCP test method[1]								Abbreviated name	Technical procedure
WW	SC	GD	BR	PC	SP	ND	VA		Number (NWM-USGS-)
[X indicates technical procedures to be used in SCP test method]									
X	X	X	X	X	X			Geologic mapping	GP-01, R0
X	X	X	X	X	X			Fabric of sheared material	[2]TBD
X	X	X	X	X	X			Geologic trenching studies	GP-07, R0
X	X	X	X	X	X			Photography of trench walls	[2]TBD
X	X	X	X	X	X			Photogrammetric mapping of trench walls	[2]TBD
X	X							Geodimeter	[2]TBD
X	X	X	X	X	X			Soils	GP-17, R0
X	X	X	X	X	X	X		U-series dating	GCP-03, R1
X	X	X	X	X	X	X		U-trend dating	GCP-04, R1
X	X	X	X	X	X	X		Gamma-ray spectrometry	GCP-05, R1
X	X	X	X	X	X	X		Sampling of rock varnish	[2]TBD
X	X	X	X	X	X	X		Cation-ratio dating of rock varnish	[3]DP-114, R0
X	X	X	X	X	X	X	X	Age data bank	GCP-01, R1
X	X	X	X	X	X	X	X	Sample control	GCP-02, R1
X	X	X	X	X	X	X	X	Spike calibration	GCP-09, R0
X	X	X	X	X	X	X	X	Mineral separation	GCP-07, R1
X	X		X				X	Correlation of tephra	GP-08, R0
X	X		X				X	[4]Microprobe analysis	[3]DP-07, R2
X	X		X				X	[4]Instrumental neutron activation analysis	[2]TBD
X	X		X				X	[4]X-ray fluorescence analysis	[2]TBD
							X	Potassium-argon dating	GCP-06, R0
							X	Fission-track dating	GCP-08, R0

[1]WW, Windy Wash fault zone; SC, Solitario Canyon fault zone; GD, Ghost Dance fault zone; BR, Bow Ridge fault zone; PC, Paintbrush Canyon fault zone; SP, other suspected and possible fault zones; ND, numerical dating; VA, volcanic ash correlation and dating

[2]To be determined: technical procedure not yet approved. Work according to procedure will not be started until procedure has been approved by DOE

[3]Los Alamos National Laboratory procedure TWS-ESS-

[4]May be required for tephra correlation

Table 3.2-4.--Typical equipment to be used in Activity 8.3.1.17.4.6.2

Field equipment
Rock hammer, hand lenses, Brunton compass, scale-stable topographic base map, aerial photographs, stereoscope, field notebooks, Abney level, Jacob's staff, sample bags and containers, labeling materials, bulldozer, backhoe, pick, shovel, broom, whisk broom, scale-stable base, pencils and other standard drawing materials, nails, rope, brushes, knife, water bottle, acid bottle, soil description sheets, soil-color charts, measuring tape, trench-wall photographs, camera, light meter, and other standard photographic equipment
Laboratory equipment
Computer, computer software, analytical stereographic plotter, magnetic discs, standard mineral-separation equipment, standard chemical-laboratory equipment, rock crusher, rock pulverizer, ball mill, magnetic separator, dielectric separator, ion-exchange columns, anion-exchange columns, vacuum chambers, heat lamp, teflon plating apparatus, platinum and stainless steel counting discs, mass spectrometer, alpha spectrometer, gas spectrometer, flame photometer, petrographic microscope and associated equipment, FEP teflon, NBS glass standards, irradiation containers, scanning electron microscope equipped with an energy-dispersive X-ray analyzer or a particle-induced X-ray emission analyzer, electron microprobe, nuclear reactor and associated equipment, gamma spectrometer, energy-dispersive X-ray spectrometer

Table 4-1.--Information to be provided to other studies by Study 8.3.1.17.4.6

Information to be obtained from this study	Where information will be used[3]	How information will be used
[1,2]Fault-zone widths and recurrence of movement on potentially significant faults within 5 km of proposed surface facilities that are important to safety	8.3.1.17.2.1.1	To assess the probability of 5 cm of fault offsets at locations proposed for surface facilities important to safety
[1]Locations of faults in or near the repository block with 1 m offset of Quaternary material [1]Surface locations of faults with Quaternary slip rates >0.005 mm/yr that intersect underground facilities	8.3.1.17.2.1.2	To assess the probability of 7 cm of offset occurring in 100 yr on any fault that intersects underground areas proposed for waste emplacement
Maps and logs of trenches across Quaternary faults Length and spacing of faults in repository area Evidence for Quaternary displacement on faults over repository Slip rates on faults in and near the repository	8.3.1.8.2.1	To calculate the number of waste packages that a fault penetrating the repository would intersect To summarize and evaluate data on slip rates and recurrence intervals on faults in and near the controlled area To assess the probability of faulting in waste emplacement boreholes, and effects on waste package lifetime To assess expected ground motion at the repository horizon in a 1,000-yr period

Table 4-1.--Information to be provided to other studies by Study 8.3.1.17.4.6 (cont'd)

Information to be obtained from this study	Where information will be used[3]	How information will be used
Locations of Quaternary faults	8.3.1.8.3.1.3	To estimate the slip rates, recurrence intervals, and probable cumulative offset in 10,000 yr on Quaternary faults in and near the controlled area
Slip rates and recurrence intervals on Quaternary faults	8.3.1.8.3.1.5	To assess the probability that average percolation flux rates at the top of the Topopah Spring welded unit at Yucca Mountain would be significantly affected by future fault activity
	8.3.1.8.3.2.6	To assess the probability that fault offset will result in significant changes in the elevation of the water table or potentiometric surface, changes in the hydraulic gradient, the creation of discharge points, or the creation of perched aquifers in the controlled area in 10,000 yr
	8.3.1.8.3.3.2	To assess the probability that movement on faults could result in significant local changes in saturated fracture permeability and fracture effective porosity along the fault that could affect the regional ground water flow system
	8.3.1.8.3.1.4	To estimate the effects that the creation of scarps, the diversion of drainage, the change in the dip of beds, or the juxtaposition of beds due to fault offset would have on average percolation flux at the top of the Topopah Spring welded unit
	8.3.1.8.4.1.2	To assess the probability that local distribution coefficients will be significantly altered along faults in 10,000 yr by displacement events
	8.3.1.8.4.1.3	To assess the possibility that offsets occurring on faults in 10,000 yr in the controlled area will divert radionuclides to travel pathways with significantly different distribution coefficients or water chemistry
Location, nature, and rate of Quaternary faulting in the site area	8.3.1.1.17.3.1, 8.3.1.17.3.5, 8.3.1.17.3.6	To identify and characterize those earthquake sources that could generate severe earthquakes at the site

[1]This information corresponds to the three characterization parameters directly tied to this study in SCP tables 8.3.1.17-3(b) and 8.3.1.17-4(b).

[2]For those parts of the area within 5 km of facilities important to safety that fall outside of the site area, this information will be provided by Study 8.3.1.17.4.3 (Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane).

[3]Studies or activities in which information will be used:

8.3.1.8.2.1: Analysis of waste package rupture due to tectonic processes and events

8.3.1.8.3.1.3: Faulting rates, recurrence intervals and probable cumulative offset in 10,000 yr

8.3.1.8.3.1.4: Effects of faulting on average flux rates

8.3.1.8.3.1.5: Assessment of the effect of faulting on flux rates

8.3.1.8.3.2.6: Assessment of the effect of faulting on water-table elevation

8.3.1.8.3.3.2: Assessment of the effects of faulting on local fracture permeability and effective porosities

8.3.1.8.4.1.2: Assessment of the degree of mineral change along fault zones in 10,000 yr

8.3.1.8.4.1.3: Assessment of the effects of fault offset on travel pathway

8.3.1.17.2.1.1: Assess potential for surface faulting at locations of surface facilities important to safety

8.3.1.17.2.1.2: Assess potential for displacement on faults that intersect underground facilities

8.3.1.17.3.1: Relevant earthquake sources

8.3.1.17.3.5: Ground motion at the site from controlling seismic events

8.3.1.17.3.6 Probabilistic seismic hazards analyses