Study Plan for
Study 8.3.1.17.4.4

Quaternary Strike-Slip Faulting Proximal to the Site Within Northeast-Trending Fault Zones

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PREFACE

This study plan summarizes and extends the discussion of Study 8.3.1.17.4.4 in the Site Characterization Plan (SCP). Sections 1, 4, and 5 are drawn from the SCP and related Yucca Mountain Project documents; these sections show the study in the context of the Site Characterization Program. Sections 2 and 3 discuss the methods and procedures for the planned activities, tests, and analyses generally in more complete detail than are described in the SCP.

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ABSTRACT

Study 8.3.1.17.4.4 is designed to provide information on the past and potential activity of strike-slip faults within northeast-trending fault zones near the potential repository site at Yucca Mountain. The results of these fault studies will be one of the major sources of data to be used in characterizing the tectonic regime of the region, and for predicting the likely locations, timing, and magnitudes of future earthquakes that could impact the design or performance of the potential waste facility.

The primary objective of the study is to evaluate the potential for ground motion resulting from future movement on Quaternary left-lateral (?) strike-slip faults within the Rock Valley, Mine Mountain, and Cane Spring fault zones which lie east and south of Yucca Mountain. Field and laboratory investigations will focus on: (1) spatial dimensions of the fault zones -- length, width, orientation, segmentation; (2) age, lateral extent, and height of fault scarps and related ground surface breaks; (3) location, amount, and sense of displacement of Quaternary deposits and horizons; (4) age and nature of Quaternary deposits and horizons displaced by, or which cover, Quaternary fault planes; and (5) structural attitudes and deformation styles adjacent to and within the fault planes. Information bearing on these fault parameters, as a basis for predicting the likelihood of renewed activity within the northeast-trending fault zones during the next 100, 10,000, and 100,000 years, is needed in order to safeguard the potential repository from tectonic events which could cause or lead to unacceptable contamination of the accessible environment.

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QUATERNARY STRIKE-SLIP FAULTING PROXIMAL TO THE SITE WITHIN NORTHEAST-TRENDING FAULT ZONES

INTRODUCTION

The preclosure tectonics program (Program 8.3.1.17) comprises several investigations designed to develop a comprehensive understanding of the tectonic history of the Yucca Mountain region and to identify those tectonic processes that could impact potential repository structures, systems, or components. Among the tectonic processes that could affect repository design or performance are fault displacements and earthquake ground motions. Investigation 8.3.1.17.4 (Preclosure tectonics data collection) includes several studies that are designed to satisfy the data requirements of the preclosure tectonics program related to faulting and earthquake activity (fig. 1-1). Study 8.3.1.17.4.4 (this study) is intended to provide information on past and potential activity of strike-slip faults near the site, and to be a data source for tectonic syntheses and characterization of the tectonic regime of the Yucca Mountain region.

The SCP (p. 8.3.1.17-132-143) lists four activities for Study 8.3.1.17.4.4:

8.3.1.17.4.4.1 -- Evaluate the Rock Valley fault zone

8.3.1.17.4.4.2 -- Evaluate the Mine Mountain fault zone

8.3.1.17.4.4.3 -- Evaluate the Stagecoach Road fault zone

8.3.1.17.4.4.4 -- Evaluate the Cane Spring fault zone

With regard to the 3rd listed activity above, geologic mapping by Scott (1990) and Quaternary neotectonic studies by Whitney and Muhs (1991) have demonstrated that the Stagecoach Road fault is a southern extension of the Paintbrush Canyon fault system (fig. 1-2) which is being investigated as part of Study 8.3.1.17.4.6 (Quaternary faulting within the site area). Accordingly, the activity involving the Stagecoach Road fault is no longer considered to be a part of this study, and the activity formerly designated as 8.3.1.17.4.4.4 (Evaluate the Cane Spring fault zone) is renumbered as Activity 8.3.1.17.4.4.3 in this study plan. Previously, the Stagecoacn Road fault was interpreted by Maldonado (1985) to be part of a fault projected southwest from the Calico Hills and Shoshone Mountain (see fig. 8.3.1.17-13, SCP). However, the linkage between the mapped fault segments was inferential and there was no evidence of left-lateral displacement. Nevertheless, these fault segments will be reconnoitered, and the intervening areas examined on air photos to ascertain the field relationships.

1. PURPOSE AND OBJECTIVES OF THE STUDY

The fundamental purpose of this study is to evaluate the history of strike-slip faulting in the three identified northeast-trending fault zones near the potential repository site (fig. 1-2) in order to predict whether (and how) future fault activity might affect performance of the potential repository. The objectives are to (1) determine the amount and nature of Quaternary displacements on faults within northeast-trending zones; and (2) provide data to estimate the probability, magnitudes and dynamic behavior of potential future earthquakes on faults within the northeast-trending zones.

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

The study will address three fundamental aspects of the fault geology: 1) location and physical features of the faults, determined by detailed mapping; 2) structural setting and tectonic style, determined by detailed site investigations; 3) history of fault activity, determined by detailed dating techniques. Information will be obtained on the following parameters:

- Spatial dimensions of the fault zones: length, width, orientation, segmentation
- Planimetry of fault strands within the fault zones
- Age, lateral extent, and height of fault scarps and related ground surface breaks
- Location, amount, and sense of displacement of Quaternary deposits and horizons
- Age and nature of Quaternary deposits and horizons displaced by or covering Quaternary fault planes within the zones
- Structural attitudes and deformation styles adjacent to and within the fault planes

Information on the faults and adjacent stratigraphic and geomorphic features will be gathered from four principal sources: (1) published or archived data (particularly review and summary of the body of published data that has been collected on the Mine Mountain fault system); (2) examination and interpretation of aerial photographs and other remote sensing imagery; (3) geophysical investigations; and (4) detailed field work (including trenching) accompanied by appropriate laboratory analyses (geochemical and petrographic analyses and radiometric age dating). Supporting data on subsurface geometry of the faults will be provided by Activity 8.3.1.17.4.7.8 (Evaluate shallow seismic reflection (mini-sosie) methods and, if appropriate, conduct surveys of selected structures at and proximal to the site area). Mapping of fault traces will be augmented, if possible, by methods evolved from Activities 8.3.1.17.4.7.6 (Evaluate methods to detect buried faults using gamma-ray measurements, and plan potential application of these methods within the site area), 8.3.1.17.4.7.7 (Evaluate thermal infrared methods and plan potential applications of these methods within the site area). Additional data on Quaternary expression of faults in Jackass Flats will be gathered by Activity 8.3.1.17.4.3.2 (Evaluate Quaternary faults within 100 km of Yucca Mountain). The potential for activity on the faults will be assessed in light of the results of study 8.3.1.17.4.8.(Stress field within and proximal to the site area).

Projections of rates of tectonic processes into the future are to be based, in accordance with 10CFR60.122 and 10CFR960.4-2-7(a), on forward extrapolation of the measured rates at which these processes operated during the Quaternary. Data used to estimate rates come from 3 types of sources: (1) contemporary instrumental measurements, (2) written historical records, and (3) field observations of evidence of Quaternary movements. Information on pre-Quaternary tectonic processes may be relevant where it supplies context useful in evaluating the Quaternary processes and rates. These data will be integrated with other data relevant to Quaternary faulting proximal to the site (fig. 1-3) to develop tectonic models.

The information to be obtained for each activity is discussed in section 3. 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

Determination of directions, amounts, rates, and recurrence intervals of Quaternary faulting proximal to the site within northeast-trending fault zones is needed as a basis for predicting the likely locations, timing, and magnitudes of future earthquakes and fault displacements that could impact the design or performance of the potential waste facility. Information bearing on the specific location and rates at which these processes are likely to operate during the next 100, 10,000, and 100,000 years is needed in order to safeguard the potential repository from tectonic events which could cause or lead to unacceptable contamination of the accessible environment.

The information to be gathered by this study (and by studies of seismicity (8.3.1.17.4.1), in-situ stress (8.3.1.17.4.8), and lateral crustal movement (8.3.1.17.4.11)) is needed to estimate the locations and rates at which tectonic processes, including faulting, folding, uplift and subsidence, operated at Yucca Mountain and its environs during Holocene and late Quaternary time (fig. 1-3). This body of information is needed to provide reasonable assurance that damage to the potential repository and surface facilities due to faulting and seismic ground shaking will be avoided or is within design limits. Figures 1-4 and 1-5 show the relationships of data-gathering activities to issue resolution.

2. RATIONALE FOR SELECTING THE STUDY

Yucca Mountain is located near the intersection of the northwest-trending Walker Lane belt and the northeast-trending Mine Mountain-Spotted Range belt (Carr, 1984; fig. 2-1). The Walker Lane belt appears to be a zone of transition between terrain to the north and east characterized by predominantly dip-slip (normal) faulting and terrain to the south and west characterized by both dip-slip faulting and right-lateral strike-slip faulting. The Walker Lane belt thus defines the diffuse eastern limit of the zone of northwest-striking right-lateral faults within the western margin of the North American plate which distribute movement of the Pacific Plate inland. Prominent members of this family of faults near Yucca Mountain include the Pahrump-Stewart Valley fault to the south, the Death Valley-Furnace Creek fault to the west, and the fault(s) within the central Walker Lane to the north. The Mine Mountain-Spotted Range structural belt is defined by a cluster of northeast to east-northeast striking, left-lateral (?) strike-slip faults that lie athwart the northwest-trending Walker Lane belt. Faults that are part of this belt to the east and south of Yucca Mountain include the Mine Mountain, Cane Spring, and Rock Valley fault zones (fig. 1-2). Lateral faulting thus appears to be an important element of the complex tectonic setting of Yucca Mountain.

The tectonic styles of Quaternary faulting in this complex region form the primary basis for organization of studies of faulting in the site characterization program. This study of left-lateral (?) strike-slip faulting is thus complemented by regional studies of high-angle normal faulting and right-lateral strike-slip faulting, and those concerned with detachment faulting.

An additional basis for organization of the faulting investigations is that the nature and detail of information required varies with respect to distance from the site and design criteria (fig. 2-2). Three areas have been defined: (1) the site area, (2) the Midway Valley part of the site area, and (3) the area within a 100 km radius of Yucca Mountain exclusive of the site area.

The site area forms a rectangle (fig. 1-2) encompassing the potential site of the repository, Midway Valley, and the major structural blocks at Yucca Mountain and their bounding faults. This area includes several major apparently high-angle Quaternary faults that are of potential significance to the repository (e.g. Windy Wash, Solitario Canyon, Bow Ridge, and Paintbrush Canyon-Stagecoach Road faults); these faults are being studied as part of Study 8.3.1.17.4.6 (Quaternary faulting within the site area). Information pertaining to Quaternary faulting in the site area is needed to evaluate possible adverse effects of this tectonic process on the ground water flow system, to define locations where ground rupture is possible, and to estimate the magnitude of ground shaking that is possible due to earthquakes.

Midway Valley, lying within the northeast sector of the site area, is the potential location of surface facilities (fig. 1-2). Study 8.3.1.17.4.2 (Location and recency of faulting near prospective surface facilities) has accordingly been organized to characterize the presence or absence of late Pleistocene and Holocene faulting within Midway Valley.

The potential adverse effects of faulting on containment are greatest within the site area, and diminish with increasing distance from the site area. It is considered unlikely, therefore, that faulting processes occurring beyond 100 km from Yucca Mountain could directly affect waste containment at the potential repository site. However, ground shaking and strain associated with earthquakes on major faults within 100 km of the site (e.g. Rock Valley, Bare Mountain, and Death Valley-Furnace Creek faults) could adversely affect regional groundwater flow systems and both surface and subsurface facilities and thus should be taken into account. It is also possible that some major faults present within the 100 km radius could project into the subsurface beneath the potential site area (e.g. right-lateral faults of the Walker Lane belt and suspected detachment faults). Studies, including this study of left-lateral (?) strike-slip faulting within northeast-trending zones, will therefore provide information on some of the Quaternary faulting processes within the 100 km region (fig. -2-2).

2.1 Activity 8.3.1.17.4.4.1 Evaluate the Rock Valley fault zone

2.1.1 Rationale for the selected test

This activity consists of applying geological mapping techniques and analyses to features of the Rock Valley fault zone in order to provide the information (SCP parameters) necessary for issue resolution (sec. 1.2) and for input, with the required degree of accuracy and confidence, to other studies (secs. 4 and 5) in the site characterization program. Detailed descriptions of the procedures and techniques are given in section 3.1.

The Rock Valley fault zone is the southernmost of the northeast-trending strike-slip zones that are the subject of this study (fig. 1-2). The zone lies about 20 km east and south of Yucca Mountain and is separated from it by Skull Mountain; segments of the fault zone may extend south of Yucca Mountain into the Amargosa Valley. Because Quaternary movement is known on several individual faults within this Zone (Barnes et al., 1982; Swadley, 1983; Yount et al., 1987; Swadley and Huckins, 1989), it is anticipated that Quaternary displacement will be discovered on other fault segments during the course of this investigation. Although faulting in this zone may not directly affect the potential repository site, fault movements within the zone are important to understanding the systematic structural development of the northeast-trending zones and their overall role in the tectonic setting of the Yucca Mountain region. An adequate understanding of the displacement history and the relationship of the northeast-trending faults to other tectonic features proximal to the potential site requires an evaluation of the Rock Valley fault zone to an extent equivalent to the other fault-related studies.

Study 8.3.1.17.4.4 Quaternary Strike-Slip Faulting Proximal to the Site Within Northeast-Trending Fault Zones

The main focus of the activity is to evaluate the rate of Quaternary displacement within the Rock Valley fault zone, and the nature and characteristics of displacement along the fault zone. At least one quarter of the total effort will be devoted to field work, primarily trenching and geophysical surveys, sampling, and annotation of deformation features on the ground. Study will be conducted along (1) the main trace of the fault zone lying generally north of U.S. Highway 95, and (2) the possible southern extension of the fault zone lying south of Amargosa Valley (fig. 2-3). The remainder of the effort will be devoted to interpretation of published geologic mapping, geophysical data, conventional and low sun-angle aerial photographs, and satellite imagery, data reduction and compilation, and trench wall map preparation.

With the exception of the seismic surveys, there are no reasonable alternatives to the planned standard procedures (described in sec. 3) for producing a synoptic presentation of the information required from the study. The standard procedures probably encompass the full range of possible alternative methods (see sec. 3). Accordingly, the only alternatives to the planned method, as a whole, are various modifications of the amount of effort devoted to each procedure. However, no modification that would reduce the planned emphasis on field work is considered to be a reasonable alternative, inasmuch as no other single procedure would provide the amount, kind, and quality of information needed to adequately characterize Quaternary faulting along the Rock Valley fault zone. Similarly, increasing the amount of field work at the expense of the other components would not correspondingly increase the quality of the information.

Initial results from very shallow refraction surveys in the Yucca Mountain area (Rodriguez and Yount, 1988) suggest that the widespread calcrete horizons developed in near-surface deposits are strong refractors that are easily mapped in the subsurface by refraction methods. Shallow refraction profiles were employed in an investigation of the Beatty scarp to determine whether or not it is fault-controlled; techniques, application, and results are described by Swadley, et al (1988). It should be emphasized, however, that there is a variety of erosional hydrologic, and pedogenic processes that could terminate a calcrete horizon without faulting. Similarly, faulting could juxtapose two different calcrete horizons in a manner such that a seemingly continuous horizon could be mapped. Therefore, the seismic refraction method will be used in conjunction with other methods to assist in identifying those areas where faulting may be present. Very shallow seismic reflection surveys have also been carried out in the Yucca Mountain area with successful results reported by Harding (1988), giving credence to that technique as a way to locate near-surface faulting. Serious consideration may be given to imaging techniques such as thermal IR imaging, passive microwave radiometry, and ground-penetrating radar imaging as a means of detecting buried faults. These methods may be used to help trace fault segments covered by alluvial deposits or are otherwise obscured at the surface. Thermal IR methods will be given first consideration because of the well established, relatively simple technology, and because of the ready interpretability of survey data. The thermal IR scanning technique is moisture-sensitive and takes advantage of the fact that near-surface buried fractures tend to retain moisture beneath an otherwise uniform reflective surficial. cover;

application at optimum times of year may overcome some conventional observational limitations. This survey will be flown at a time when subsurface moisture content is likely to be relatively high. Depending on results obtained in Activity 8.3.1.17.4.6, gamma ray measurements may also be applied to mapping precise locations of buried faults.

2.1.2 Number, location, duration, and timing

2.1.2.1 Number

The number of measurements and observations necessary to evaluate the Rock Valley fault zone will depend upon the number of individual faults on which Quaternary movement is currently known or suspected and by the number of additional faults or lineaments identified during the present study. The number of field observations will further depend on the number and quality of exposures, as well as the number of faults and lineaments identified during the preliminary review and synthesis of published data and the examination and interpretation of aerial photographs, which will then be followed by field investigations. Although accurate estimates of these numbers cannot be made at present, data collected at localities selected for initial field study will include, if possible, (1) scarp height, (2) scarp form, (3) traceable length of fault line, (4) datums cut by a fault and overlapping a fault, (5) width and character of shear zone (including subsidiary fractures), (6) fabric of sheared material, (7) character of fault and fracture surfaces, and (8) fault attitudes.

Following initial field evaluation, seismic refraction profiles may be generated across known or suspected fault traces and the selection of trench sites will be made. Alternatively, seismic profiling may be reconducted if fault data obtained from trenching is inconclusive, or if scarps suggest the presence of a fault zone that may or may not be amenable to trenching. Thus, two main criteria for reflection profiling are: (1) need for auxiliary (confirmatory) data, and (2) need for information to assist in selecting trench sites. The number of such profiles will depend on the number of scarps that, on the basis of geological evidence, seem to represent recent faulting. Sufficient trenches will be excavated across faults of the Rock Valley fault zone to permit adequate characterization of the fault zone.

Determination of net fault displacement depends on finding and (or) exposing concealed intersections of faults with Quaternary datums (piercing points). If suitable points or horizons are found, the direction and amount of fault slip can then be calculated. Because these features are irregularly distributed, their discovery is to a degree fortuitous. Thus, it is not expected that all trenches will reveal Quaternary datums or stratigraphic features that would permit calculation or measurement of total fault displacement. It thus may be necessary to excavate additional trenches at certain localities.

Samples of surficial materials exposed by trenching will be collected for age-dating. The number of samples is dependent on the quality of exposures and the extent of trenching, the suitability of the materials available for appropriate analyses, and the sample size required by standard analytical procedures to obtain valid results.

2.1.2.2 Location

This activity will be confined to the 8 to 13-km wide zone of northeast-trending faults that comprise the Rock Valley fault zone, which extends from the southern end of Frenchman Flat southwest for a distance of approximately 60 km (figs. 1-2 and 2-3). Locations of seismic profiles and of trenches have not yet been determined as indicated in the above section. However, the selection of some sites will depend on the need to determine the presence of faulting at locations where surface investigations have proven inconclusive. It is expected that some of the preferred locations will be at extreme ends of the fault zone, and near its center, in order to determine changes in style, age, or displacement from northeast to southwest. The area extending into the Amargosa Desert south of Amargosa Valley (fig. 1-2) is not well known; a special attempt will be made to determine whether or not faulting continues into this area.

2.1.2.3 Duration and timing

It is expected that field investigations, excavations, and mapping of trench walls, conducting seismic surveys, collecting samples for age determinations, and synthesizing and evaluating data for map compilation will take approximately two person-years to accomplish. The timing and duration of the activity will be planned so as to coordinate with other studies and activities (see sec. 5 and fig. 5-1), both to acquire input from and to deliver data to the other studies and activities in a timely fashion.

2.1.3 Constraints: factors affecting test selection

The Rock Valley fault zone lies 20 km or more east and south of Yucca Mountain (fig. 1-4); thus, the selection of the test for this activity was unaffected by its impact on the potential repository site, simulation of repository conditions, and interference with other tests or the construction and design of the exploratory studies facility. With regard to accuracy and precision, limits and capability of analytical methods, and the scale of phenomena to be measured, the planned work involves conventional methods and techniques designed to provide (1) reliable data and measurements within the designated parameters for the activity (see sec. 1.1), and (2) essential data that can be used to assess the potential for future vibratory ground motions in the vicinity of the potential site resulting from displacement along left-lateral (?) northeast-trending faults of the Rock Valley fault zone.

Determination of lateral displacement along faults in very shallow-dipping, non-indurated strata is extremely difficult; therefore, no single mapping technique or procedure is likely to provide meaningful or reliable results everywhere along the fault zone. Accordingly, emphasis will be placed on those technique(s) that hold promise for yielding the most reliable data at different locations and at different scales of observation. This approach will analyze features ranging in scale from gouge striae to antithetic splays to displaced landform elements.

It is desirable to link mapped fault segments into an integrated fault-trace network in order to assess the regional deformation pattern proximal to the site. However, tracing of fault strands is likely to be a significant problem in the alluvial valleys, and special procedures such as thermal IR imaging, passive microwave radiometry, and ground-penetrating radar imaging, may be employed as mentioned in section 2.1.1.

Alternative procedures may be used for calculation of total displacement, including the strike-slip component, provided that both the dip-slip component and the direction of fault slip are known. The direction can, in rare cases, be inferred from orientation of slickenlines or, less precisely, from orientation of elongate pebbles and cobbles that have been rotated by shear within the fault zone. Slickenlines are rarely present on fault surfaces within the surficial deposits; however, they are common on bedrock fault surfaces. These approaches to determine total displacement are thus of limited utility. Offset of small stream channels and other geomorphic features intersected by Quaternary faults may provide a cruder but more obvious measure of strike-slip displacement.

2.2 Activity 8.3.1.17.4.4.2 Evaluate the Mine Mountain fault zone

2.2.1. Rationale for the selected test

The area between the Mine Mountain fault zone and the Rock Valley fault zone is marked by above average seismic activity. However, focal plane solutions generally indicate right-lateral movement on north-trending faults, rather than left-lateral movement parallel to the northeast to east-northeast-trending faults. Previous geologic mapping along the Mine Mountain fault zone at Mid Valley (figs. 1-2, 2-4) has revealed substantial dip-slip displacements, with some of the movement probably having occurred during the last million years (McArthur and Burkhard, 1986). This activity will be conducted to verify the reported faulting of Quaternary deposits in Mid Valley and to determine if there is a strike-slip component. Mapping also suggests that the fault zone extends, beneath alluvial cover, southwestward from Mid Valley into Jackass Flats (Maldonado, 1985), to within 20 km of Yucca Mountain, but displacements of Quaternary deposits have not yet been recognized there. The activity will examine surficial deposits along the projected trace of the fault zone into Jackass Flats for any evidence of Quaternary activity.

Study 8.3.1.17.4.4 Quaternary Strike-Slip Faulting Proximal to the Site Within Northeast-Trending Fault Zones

As with the other activities described in this study plan, this activity is designed to provide reliable information on the nature and extent of Quaternary movement along the named fault zone, and hence, to determine its potential for producing vibratory ground motion at Yucca Mountain. Larger objectives seek answers to the following questions concerning local tectonic activity: (1) is the Mine Mountain fault zone an active or potentially active element of a left-lateral strike slip system? (2) has Quaternary displacement occurred at the southwestern projection of the zone near the site area? (3) what is the structural relationship of this fault zone to the Rock Valley fault zone and to the Stagecoach Road fault (being studied in Study 8.3.1.17.4.6). Because of these objectives, there are no reasonable alternatives to direct observation and measurement of features in natural or in newly excavated exposures that would provide the number, type, and quality of data needed for proper evaluation.

2.2.2 Number, location, duration, and timing

2.2.2.1 Number

The discussion in section 2.1.2 is applicable to this section. The initial stage of the planned work will entail review and synthesis of the published data, and interpretation of conventional and low sun-angle air photos and satellite imagery. These work elements will guide field investigations to locate and evaluate previously unmapped lineaments and scarps indicative of Quaternary displacements in Jackass Flats. If evidence of Quaternary movement is detected, trenching will be undertaken. A minimum of two trenches will be dug and mapped in an effort to determine the age, slip rate, and style of faulting, and to provide samples for age dating purposes if active fault strands are recognized. Supplementary data on subsurface geometry of the possible projection of the fault into Jackass Flats and toward Amargosa Valley may be provided by Activity 8.3.1.17.4.7.8 (Evaluate shallow seismic reflection (mini-sosie) methods and, if appropriate, conduct surveys of selected structures at and proximal to the site area). The number of seismic profiles and the decision to employ seismic profiling at any given site will be guided by the objectives outlined in 2.1.2.1.

2.2.2.2 Location

The Mine Mountain fault zone occupies a relatively narrow (~1.5 km), northeast-trending corridor to the east and northeast of Yucca Mountain (figs. 1-2, 2-4). It is believed to extend southwest from Mid Valley for a distance of approximately 25 km to Jackass Flats. Field investigations and related studies will be conducted along the entire length and breadth of the fault zone. Particular attention will be paid to the southwestern end to determine its spatial relationship to the nearby, and nearly parallel, Stagecoach Road fault (fig. 1-2).

2.2.2.3 Duration and timing

It is estimated that the work for this activity will take a minimum of one person-year; the actual time involved is largely dependent on how many occurrences indicative of Quaternary fault movements are found, particularly in the extensive areas covered by surficial deposits in and northeast of Jackass Flats, and on the need for trenching and trench wall mapping. The timing and duration of the activity will be planned so as to coordinate with other studies and activities (see sec. 4 and fig. 5-1), both to acquire input from and to deliver data to the other studies and activities in a timely fashion.

2.2.3 Constraints: factors affecting test selection

The discussion in section 2.1.3 is applicable to this section. At this time, no special conditions or constraints that might influence the test procedures are anticipated . Because of the possible spatial relationships of the Stagecoach Road fault and the faults parallel with the Mine Mountain fault zone (Maldonado, 1985), close coordination with field operations of study 8.3.1.17.4.6 is anticipated.

2.3 Activity 8.3.1.17.4.4.3 Evaluate the Cane Spring fault zone

2.3.1 Rationale for the selected test

The Cane Spring fault zone consists of several parallel, northeast-trending faults that form a zone less than a kilometer wide and 10 km long, lying some 20 km east of Yucca Mountain (figs. 1-2, 2-5). Significant left lateral movement along some of the faults took place during late Tertiary time, as indicated by offsets in bedrock; there is also evidence that displacement may have occurred in Quaternary times (Poole and others, 1965). Detailed mapping and study of surficial deposits along the fault traces is needed to evaluate this evidence so that the potential of the Cane Spring fault zone to produce moderate to large earthquakes in the future can be evaluated. Much of the discussion in section 2.1.1 is directly applicable to this section. Again, detailed field observation and sampling is required to document the past behavior and physical results of the reported faulting, so that estimates of potential future effects can be made.

2.3.2 Number, location, duration and timing

2.3.2.1 Number

Much of the discussion in section 2.1.2.1 is applicable to this section. Lineaments (vegetative and physiographic) will be examined for evidence of Quaternary fault control. If strong evidence is found, then selected fault traces will be trenched. Ambiguous results may be resolved by seismic profiling and (or) trenching. The numbers of trenches and shallow seismic refraction surveys cannot be estimated until the initial stages of study (evaluation of published data, interpretation of air photos and satellite imagery, and field reconnaissance) are completed.

2.3.2.2 Location

The northeast-trending Cane Spring fault zone lies between the Rock Valley and Mine Mountain fault zones and is bounded by Skull Mountain on the west and Frenchman Flat on the east (fig. 1-2). Field investigations and related studies will be conducted throughout the 10-km long zone, with particular attention given to linear physiographic and vegetation features that occur in surficial deposits toward the northeast end of the fault zone (fig. 2-5). The Cane Spring fault zone projects southwest toward its intersection with the Rock Valley fault zone south of Skull Mountain (fig. 1-2). This area will be examined in detail to determine, if possible, the nature of the fault zone intersections. Information on fault zone interaction is valuable in assessing systematic tectonic behavior among groups of faults.

2.3.2.3 Duration and timing

The discussion in section 2.1.2.3 is applicable to this section. The planned work is expected to take between one and one and one-half person years. The projected time allocated to this activity varies because of the question of trenching; trench siting, excavation, mapping, and sampling will require at least a third of the total projected time, especially if the need for trenching is specifically indicated near the fault zone intersection where considerable complexity is anticipated.

2.3.3 Constraints: factors affecting test selection and procedure

The discussion in section 2.1.3 is applicable to this section.

3. DESCRIPTION OF TESTS AND ANALYSES

The three activities in Study 8.3.1.17.4.4 are virtually identical in their objectives and parameters. Accordingly, descriptions of the planned tests and analyses can be given on a study-wide basis rather than on an activity-by-activity basis. If there are differences in some aspects of the work elements between activities, specific mention is made of those variations in the following sections.

The common objective for each of the activities in this study is to determine the location, spatial orientation, length, and width of Quaternary fault traces, and the amount, rate, and recurrence of Quaternary movement of the fault system being studied. Also common to each of the activities are the six parameters listed in section 1.1. The planned work elements to investigate the three fault systems, as discussed in the following sections, are designed to provide the kinds and quality of data required to meet the stated objectives for the study and to satisfy the designated parameters.

3.1 General approach

The methods to be used in evaluating northeast-trending fault systems proximal to Yucca Mountain are outlined as follows:

- Preliminary phase
  - (a) Review and evaluate published data
  - (b) Examine and interpret air photos and other remote sensing data
  - (c) Compile and tabulate data
  - (d) Prepare maps and other materials to guide reconnaissance field study phase
- Reconnaissance field study phase
  - (a) Map and document natural exposures
  - (b) Collect samples for analysis
  - (c) Edit and expand map database

(d) Revise reconnaissance map (prepared in the preliminary phase)

(e) Tabulate field observations and measurements to form a digital data base

- Detailed field investigation phase

(a) Coordinate activities with Study 8.3.1.17.4.6 (Quaternary faulting with the site area).

(b) Conduct seismic surveys and annotate seismic profiles (coordinate, as necessary, with Activity 8.3.1.17.4.7.8, Evaluate shallow seismic reflection (mini-sosie) methods and, if appropriate, conduct surveys of selected structures at and proximal to the site area).

(c) Possibly conduct microwave/IR scanning and gamma-ray surveys of suspected faults, and interpret results

(d) Excavate trenches and map trench walls

(e) Collect samples

(f) Compile and interpret sample analytical data

(g) Revise detailed field map

- Data synthesis phase

(a) Coordinate with Study 8.3.1.17.4.1 (Historical and current seismicity)

(b) Coordinate with Study 8.,3.1.17.4.3 (Quaternary faulting within 100 Km of Yucca Mountain, including the Walker Lane)

(c) Coordinate with Study 8.3.1.17.4.8 (Stress field within and proximal to the site area)

(d) Revise and edit fault map

(e) Assemble all data from previous investigative phases of this study and the results of other coordinative studies

(f) Digitize data base

(g) Characterize and summarize parameters for each fault zone

(h) Prepare data output for Study 8.3.1.17.4.12 (Tectonic models and synthesis)

3.1.1 Preliminary phase

The preliminary phase of investigation involves two initial tasks: (1) review of published maps and analyses, and (2) interpretation of aerial photos and other remote sensor data. The objective is to create a preliminary base map consisting of one or more sheets at 1:12,000. The map(s) will be compiled from previously published maps and from interpretations of remote sensing data, including conventional and low sun-angle stereo air photos, (at scales ranging from 1:12,000 to 1:80,000), SLAR mosaics, and 10-m SPOT Pan images. The map(s) will show bedrock, surficial units, mapped structural features, and interpreted linear features ranked according to type of ground expression and recognition confidence.

The map(s) will be keyed to a tabulated compilation of published fault-related data (e.g. strand lengths, widths, strike, dip, scarp relief, datums, ages), which will in turn be keyed to a bibliography. The compilation will be created in order to facilitate data management and exchange, hypothesis testing, and final synthesis.

3.1.2 Reconnaissance field study phase

This work will consist of two main tasks: (1) mapping and documenting natural exposures on 1:12,000 topographic base maps, and (2) editing and expanding the map database. This will be mainly a field phase of operations. Faults located during the preliminary phase of study will be walked out and scrutinized for locations, amounts, directions, and times of displacement of Quaternary datums, and linear features identified by remote sensing will be checked for evidence of fault origin. Sites that show evidence of Quaternary displacement will be documented and, if feasible, sampled for age dating analysis. Site occupation will entail documenting locations and making standard field measurements, (see parameters listed in sec. 1.1), and providing interpreted ages of the youngest offset Quaternary datums (e.g. surficial deposits, soils, volcanic ashes). This phase of work is expected to be time-consuming because of the large area that must be covered by foot traverses and the large numbers of measurements to be made and samples to be collected. One time-saving approach that may be evaluated during this phase is use of hand-held Global Positioning Satellite (GPS) receivers and an altimeter to spot site locations to within 15m accuracy. Locations can be recorded in the field as well as logged digitally for later plotting in a Geographic Information System (GIS) at any desired scale or projection.

Additionally, it may be feasible to bar-code certain standard parameters or field labels for samples and observations in order to maximize data consistency and accession. This technique is not meant to be a substitute for detailed note taking or field sketching, but rather a means to automate the recording of certain conventional class-related parameters, such as color, texture, lithology, sample identification and type, slope characteristics, and the location, orientation, and extent of faults, fault scarps, and lineaments. Hand-held digital scanning ("digital photography") of field sites may be attempted also as a convenient and inexpensive substitute for film-based photography. The objective of these techniques is to provide the most complete and consistent documentation possible, with maximum data access and flexibility for analysis and report generation.

Each field station will be plotted on the fault maps and structural data will be shown by appropriate symbols. The data will be uploaded, scanned, or keyed into a digital database. Each field station will then be a point for a scale-independent, plottable, interrelated data set that can be displayed graphically as overlaid map symbology, or as a digital file (spreadsheet) that can be expanded or modified through subsequent data acquisition, and manipulated for statistics. As relevant data become available from other studies in the site characterization program, they will be merged with the digital database. All data thus acquired will be linked to appropriate source references.

3.1.3 Detailed field investigation phase

This phase of operations will be the most time-consuming. It will involve detailed investigation of at least two sites in each fault zone to acquire the most detailed, quantitative evidence for Quaternary displacement and style of deformation. It will also involve coordination with other studies for technical guidance and interpretive support. In particular, mapping along the Mine Mountain fault zone will entail data-sharing with Study 8.3.1.17.4.6 (Quaternary faulting within the site area).

Two major tasks will be undertaken in this phase of the planned work:

1) <u>Seismic profiling:</u> Seismic profiling will be done in cooperation with, or following advice from, Activity 8.3.1.17.4.7.8 (Evaluate shallow seismic reflection (mini-sosie) methods and, if appropriate, conduct surveys of selected structures at and proximal to the site area). Seismic profiles ideally will be sited along lines normal to the selected fault trace where results are anticipated to provide a more certain interpretation of subsurface fault structure. Locations of seismic profiles will be chosen on the basis of evidence of fracturing or faulting, scarps or lineaments. Seismic profiling will be employed mainly toward the western ends of the fault zones where the need to resolve structural and tectonic ambiguities is greatest because of the proximity to Yucca Mountain and the potential repository.

Two kinds of profiling will be considered: refraction (bison type) and reflection (mini-sosie type). At this time, selection of seismic line field parameters cannot be defined. Review of the results of previous surveys in the area and noise trials will be required to determine offsets, array lengths, geophone spacing, group intervals, etc. The shallow refraction technique will be applied nominally to kilometer-long lines to detect fault breaks. The shear wave method, using 12 or more geophones with 3 m spacing and a sledgehammer energy source, is capable of detecting 30 cm offsets in surficial deposits. Maximum penetration depth of about 100 m is desirable. The shallow reflection (mini-sosie) method will be applied to resolve shallow stratigraphy and structure, within 100 m of the ground surface, along 1-5 km lines. Energy will probably be provided by hand-operated tampers. Interpretive seismic profiles will be prepared for inclusion with the detailed maps. Discussions of techniques, applications, and results are presented in Oliver et al (1990), Swadley et al (1988), and Harding (1988).

2) Trenching: Trenching will be undertaken at sites most likely to provide measurable, datable Quaternary displacements. The main objective of trenching is to assess the amount of fault displacement and to determine, by dating Quaternary datums, when faulting occurred.

At each site, an initial trench 20-50 m long and 2-5 m deep will be excavated by back hoe, normal to the fault plane. Direct measurement of lateral displacement within nearly flat layers of alluvium is difficult because of the scarcity of distinctive features such as linear channels, that can be matched across the fault plane. Special effort will be made to find offset features. To evaluate strike slip, subsidiary trenches will be excavated parallel and adjacent to the main fault plane exposed by the initial trench. The fault plane itself will be hand-excavated in order to expose evidence of shear (hence net slip) in the fault plane. Amount of strike slip will be measured by offset datums as may be exposed in the subsidiary trench walls. The trenches will be mapped and, if possible, progressively deepened and mapped, thus providing a detailed three-dimensional representation of Quaternary structure and stratigraphy within each trench.

The distribution and relative positions of Quaternary datums, shear zones, fractures and fracture fills will be mapped and photographed and/or scanned, and will provide stratigraphic constraints for the proper interpretation of radiometric age data. Datums will be sampled, using conventional sampling procedures, and their ages determined, if possible, through appropriate procedures (e.g., Uranium-trend, Uranium-series, soil development, ash correlation, and thermoluminescence techniques). Suitable clastic and residual organic material, if present, will be dated by radiocarbon or cation ratio methods. A detailed chronostratigraphy will be developed from the completed data. This stratigraphy is important to an accurate determination of the timing and amounts of successive displacements on the mapped faults. Fracture fillings will be analyzed by geochemical and mineralogical techniques. Where materials suitable for numerical age determinations are not present, emphasis will be placed on relative-age determinations based on correlations with surficial deposits of known age elsewhere in the general region surrounding Yucca Mountain. This will be done in coordination with Activity 8.3.1.17.6.2 (Evaluation of age and recurrence of movement on suspected and known Quaternary faults) and Study 8.3.1.5.1.4 (Analysis of the paleoenvironmental history of the Yucca Mountain region). Data from three trenches previously mapped in the Rock Valley fault zone (Yount, unpub. data) will also be incorporated.

Trench maps will show the following features at an appropriate display scale (e.g., 1:20):

- faults, fractures and other disruptive structures
- widths of shear zones and shear features
- distribution and ages of Quaternary datums (e.g. surficial deposits, soils, and volcanic ashes displaced by or that overlap Quaternary faults)
- locations, amounts, and directions of displacement of Quaternary datums in directions out of the trench wall plane

Summary reports for each fault zone will be prepared following trench investigations. Results of sample analyses will be compiled within the database and will be interpreted to elucidate late Quaternary stratigraphy. A detailed chronostratigraphy is important as it provides the timing and amount of late Quaternary fault movements. The field map will be revised to the extent that data from trenching and from geophysical surveys provide more certain definition of faults and fault history.

3.1.4 Data synthesis phase

This will be the most complex phase as it will bring together laboratory results and findings from other studies and previous phases of investigation in order to make the predictive assessments required of this study. Three tasks are planned:

1) Coordination and data sharing with Studies 8.3.1.17.4.3 (Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane); 8.3.1.17.4.8 (Stress field within and proximal to the site area); 8.3.1.17.3.4 (Relevant earthquake sources); 8.3.1.17.4.1 (Historical and current seismicity), and interpreting results.

2) Merging of all analytical, geophysical and detailed observational data into the digital database, and creation of a synthesis map at 1:24,000 that shows the northeast-trending

fault zones, sites of most recent disruption, sense of motion along faults, relationship to all known proximal fault systems, and areas of most likely future activity.

3) Summarizing the parameters for each fault zone in a report that:

- characterizes Quaternary fault behavior
- evaluates tectonic relationships among the three fault zones.
- relates the faults in the northeast-trending zones to the regional tectonic framework

3.2 Test methods and procedures

Technical procedures for the methods and procedures for Study 8.3.1.17.4.4 are provided by QMP or Technical Procedure documents that are presently in effect, in preparation, or to be determined.

3.3 QA requirements

Quality Assurance (QA) requirements will be specified in a Yucca Mountain Project QA Grading Report which will be issued as a separate document. All applicable procedures will be identified on the basis of the findings in the Grading Report and will be prepared in accordance with applicable QA requirements.

3.4 Required tolerances, accuracy, and precision

It is a requirement of the present study of the northeast-trending fault zones to identify faults that have had demonstrable Quaternary movement and thus have the potential for producing future ground motions. None of the fault zones considered by this study intersect the potential repository block, nor do any of them lie closer than 5 km to facilities important to safety (fig. 2-1); however, there are no SCP-designated requirements to measure Quaternary displacements and slip rates within certain specified limits as are required for the Quaternary fault studies in Study 8.3.1.17.4.6 (Quaternary faulting within the site area). The planned tests are expected to locate individual faults on the ground within standard map accuracies (± 12 m at 1:12,000 map scale), and to locate faults in trench wall exposures to within a few centimeters of their actual positions. Orientations of faults, where natural exposures permit, will probably be measured within 5-10 degrees; fault orientations clearly displayed along trench walls will probably be measured within 1-2 degrees. Planimetric location of lineaments is expected to be at the same level of accuracy as for faults mapped on the ground.

Accuracies to be achieved in determining amounts and ages of Quaternary movements are difficult to estimate, being entirely dependent upon the clarity of the relationships exhibited in natural exposures and trenches, on the quality of material available for radiometric age determinations, and the resolution and accuracy of the techniques used to estimate ages. If ideal conditions exist with respect to these factors, the various dating techniques will provide age data with precision ranging from 2 to 75% for ages within the last 100,000 years (Colman and Pierce, 1991). Radiocarbon dates are the most reliable, commonly providing ages with precision of a few hundred years for materials less than 20,000 years old and up to a few thousand years as the limit (40,000 to 50,000 years) for radiocarbon resolution is approached.

3.5 Range of expected results

Previous field work (Rock Valley fault zone: Swadley, 1983; Swadley and Huckins, 1989; Yount et al., 1987; Mine Mountain fault zone: Orkild, 1968; MacArthur and Burkhard, 1986; Cane Spring fault zone: Poole, 1965) gives some indication of the range of results that may be expected from this study. Traces of Quaternary faults in the northeast-trending fault zones are likely to be a few hundred meters to 1 km long (lengths as great as 5 km are reported from the Rock Valley fault zone). Lineaments expressed in surficial deposits are generally less than a few km in length. Fault scarps in surficial deposits are generally 0.3 to 5 m high and a few hundred meters to 1 km long; scarps range in age from less than 100,000 yr to as much as 1,000,000 yr.

Zones of shear are expected to be less than 5 m wide along most faults. Subsidiary fractures may extend a few meters to several tens of m outward from the shear zones.

Few determinations of Quaternary slip rates within the northeast-trending fault zones have been made because of the difficulty in obtaining reliable measurements of net fault displacement, and the lack of conclusive evidence as to the timing of faulting. Previous study suggests that displacement within the Rock Valley fault zone occurred at least once within the last 28,000 years (Yount et al., 1987).

3.6 Equipment

The study will employ mostly conventional USGS-issue field equipment for the reconnaissance and detailed field investigation phases. A scanning stereoscope will be employed in the study of stereo images. Operation of specialized or heavy equipment (i.e. seismic profiling, airborne scanning, trenching equipment) will likely be done on a contract basis.

If certain field-related data gathering activities are automated (see sec. 3.1.2), the necessary equipment will include: two portable GPS receivers, heavy-duty portable bar code scanner, bar coding software, digital camera and viewing device, and lap top computer. Use of this specialized equipment also entails digital mapping hardware and software in order to create and manage a database-linked digital map and to pursue map data analysis. Such equipment includes: graphics support computer, digitizing table or tablet, flat-bed scanner, plotter, GIS software for mapping, and interactive database manager.

3.7 Data-reduction techniques

Standard data-reduction techniques will be used to synthesize and compile the results of this study. Faults, lineaments, and fault-related deformation features will be graphically and symbolically represented on scale-stable base maps at 1:12,000 using, wherever possible, conventional geological map symbology and explanations. Sample sites will be given appropriate symbols, as will locations of trenches and seismic profiles. Data from the trenches and profiles will be used to produce interpretive structural cross sections that will show, at a minimum, fault attitudes, deformation features, and age and character of offset or overlapping units.

Seismic reflection data will be reproduced as conventional reflector amplitude/travel-time profiles that will be annotated to show key reflections, structure, acoustic noise, two-way travel time scale, vertical exaggeration, and bar scale. Profiles will be keyed to mapped fault traces or to lineaments.

Seismic refraction data will be reproduced as time-distance profiles that show P-wave velocities of subsurface layers and intercept times along reversal refraction lines. The P-wave velocities corresponding to subsurface layers will be correlated with stratigraphic units exposed in trenches, if applicable, or otherwise mapped and (or) documented.

Trench wall maps will be plotted at a scale of 1:20 (or other appropriate scale) to show, at a minimum, structure, stratigraphy, sample sites, and wall photos. The wall maps will be keyed to mapped faults and sample tables.

All data (field observations, sample logs, sample analysis results, results of previous studies, references) will be entered into a computer database. Each item of information will be linked to a numbered field site which will be encoded as a pair of map coordinates. The field sites can then be plotted, and the data retrieved in any combination for tabulated display or printout, or for further analysis. The database may also include scanned images, drawings, and links to digital data acquired by other site studies wherever such linkage is feasible.

3.8 Representativeness of results

The planned tests are designed to yield comprehensive information on the most tectonically significant northeast-trending faults (with respect to the potential repository) within the study area, and to lead to the identification and characterization of hitherto unrecognized faults in this area. The complete data set is expected to provide an accurate representation of those Quaternary strike-slip faults that may have potential to produce vibratory ground motions from future movements within the three northeast-trending fault zones.

The degree to which all Quaternary strike-slip faults can be detected, mapped, and characterized depends mainly on two factors: (1) the quality and extent of natural exposures and the degree to which faulting is expressed on the ground, and (2) the effectiveness of geophysical and geochemical techniques in furnishing diagnostic information. Analysis of fault activity also depends on strategic placement of trenches and on the clarity of fault relations exposed in trench walls, and on the availability of suitable materials for radiometric age determinations. Because of these contingencies, some data gaps and uncertainties are likely to occur as indicated in earlier sections.

3.9 Relations to performance goals and confidence levels

Performance goals for Study 8.3.1.17.4.4 are targeted to three major elements required for developing hypotheses of tectonic activity in and around the potential repository site: (1) fault geometry and mechanics, (2) faulting rates, and (3) fault-rupture patterns. Data relative to these elements must satisfy performance parameters with medium to high confidence levels. The performance goals are as follows:

- Identify the existence of northeast-trending Quaternary strike-slip faults in zones proximal to the site (including fault classification and surface location and orientation).
- Determine the geometry of displacement and the nature of the deformation
- Determine the number, timing, and amount of displacement associated with individual events during Quaternary time

The methods of study discussed in this study plan are considered adequate to address satisfactorily these performance goals and to ensure that such goals will be met with quantitative data leading to high confidence levels. However, it should be emphasized that not all faults are likely to yield data that are completely unambiguous with regard to their age and amounts of displacement during Quaternary time, as discussed in section 3.8.

Section 1.2 addresses the topic of issue resolution.

4. APPLICATION OF RESULTS

This section identifies other studies that will use the information obtained in the present study; related discussions in section 1.2 draw on section 8.3.5 of the SCP to consider the uses of this information in the context of issue resolution and performance goals. Information from this study will be used in the preclosure tectonics program (Program 8.3.1.17) and will contribute indirectly to the postclosure tectonics program (Program 8.3.1.8), as shown on figures 1-4 and 1-5, and table 4-1. The following discussions are summarized from the SCP.

Data from the present study will be synthesized and evaluated in Activity 8.3.1.17.4.12.1 (Evaluate tectonic models). This synthesis will, in turn, contribute to the definition of an applicable tectonic model (or models) that describes the way in which forces and bodies in the Yucca Mountain region interact to produce the geologic and tectonic framework of the potential repository. Information from this study will also be used to supply data requirements needed to (a) assess fault displacements that could affect repository design or performance (Investigation 8.3.1.17.2) and (b) provide required information on vibratory ground motion that could affect repository design or performance (Investigation 8.3.1.17.3).

In the postclosure tectonics program (fig. 1-5; table 4-1), information from this study will be integrated with information from other studies or activities to assist in predicting the likely locations, timing, and magnitude of future faulting and earthquake events that could impact the design or performance of the potential repository.

5. SCHEDULE AND MILESTONES

Figure 5-1 shows the principal milestones for this study and all direct scheduling ties to other studies. Additional schedule information is provided in Table 5-1. This information is abstracted from the most current and complete schedule network.

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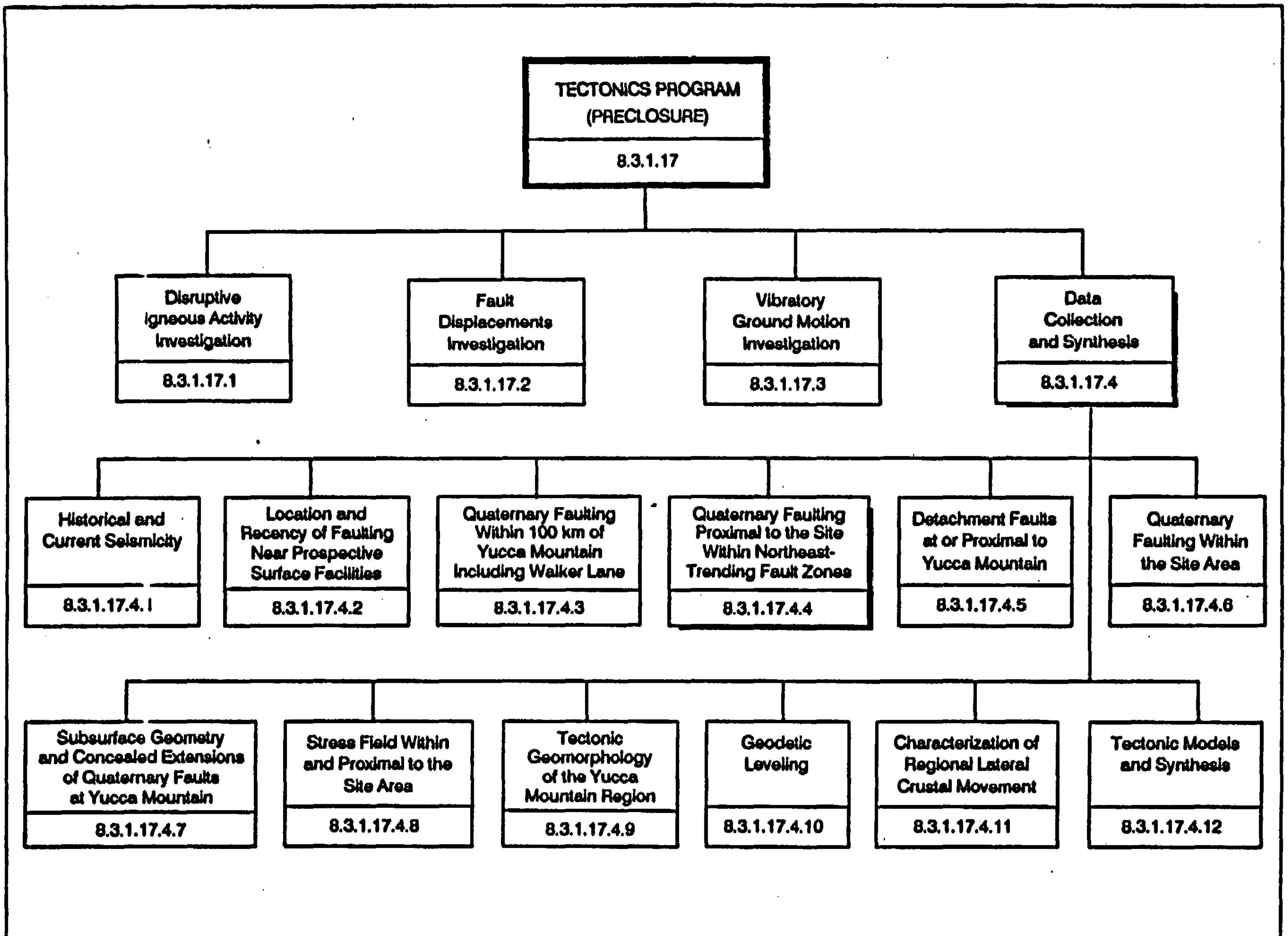


Figure 1-1. Relation of Study 8.3.1.17.4.4 to the preclosure tectonics program.

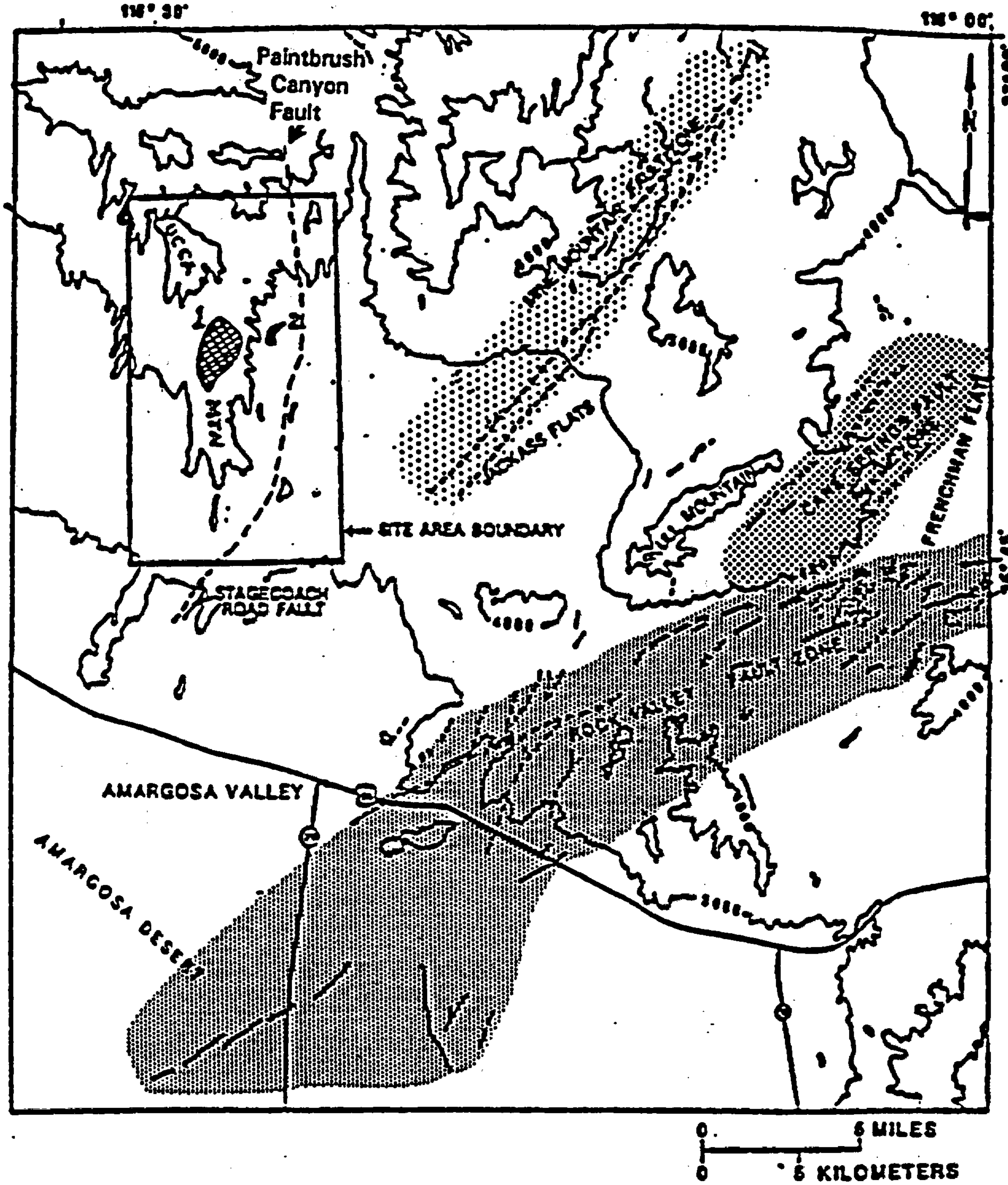
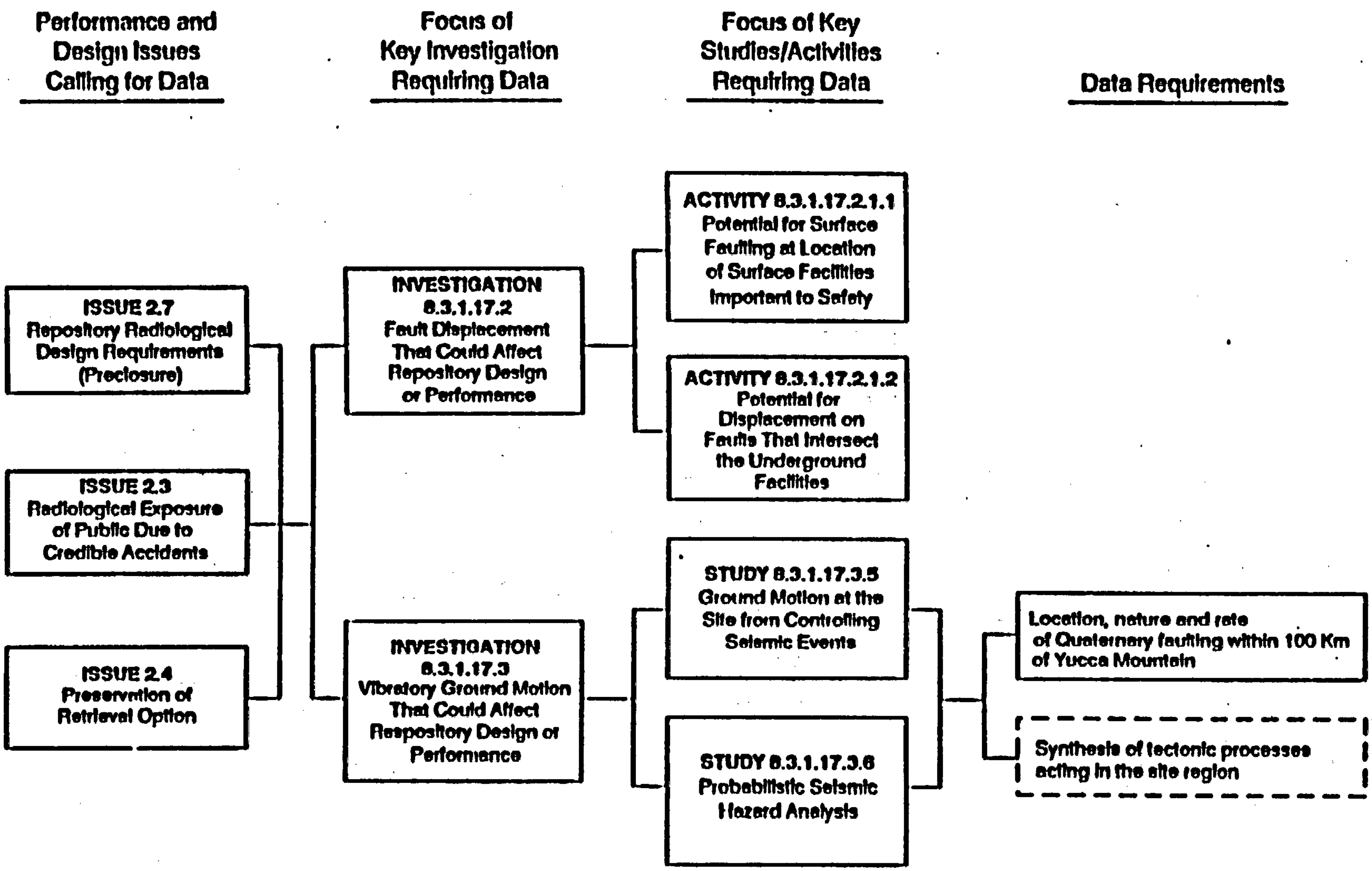


Figure 1-2. Index map showing location of the three northeast-trending fault zones being evaluated in Study 8.3.1.17.4.4. Numbered localities are: 1 - perimeter drift of potential repository site (cross hatch); 2 - proposed location of surface facilities. Stagecoach Road fault also shown.

		TECTONIC PROCESS		
		Uplift and Subsidence	Faulting	Folding
Quaternary	Contemporary and Historical Time	Study 8.3.1.17.4.10 (Geodetic Leveling)	Study 8.3.1.17.4.10 (Geodetic Leveling) Study 8.3.1.17.4.1 (Historical and Current Seismicity) Study 8.3.1.17.4.8 (Stress Field Within and Proximal to the Site Area) Study 8.3.1.17.4.11 (Characterization of Regional Lateral Crustal Movement)	
	Holocene (Prior to Historical Time) and Pleistocene	Study 8.3.1.17.4.9 (Tectonic Geomorphology of the Yucca Mountain Region)	Study 8.3.1.17.4.2 (Location and Recency of Faulting Near Prospective Surface Facilities) Study 8.3.1.17.4.3 (Quaternary Faulting Within 100 km of Yucca Mountain, Including Walker Lane) Study 8.3.1.17.4.4 (Quaternary Faulting Proximal to the Site Within Northeast-Trending Fault Zones) Study 8.3.1.17.4.5 (Detachment Faults at or Proximal to Yucca Mountain) Study 8.3.1.17.4.6 (Quaternary Faulting Within the Site Area) Study 8.3.1.17.4.7 (Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain)	Study 8.3.1.8.5.3 (Investigation of Folds in Miocene and Younger Rocks of the Region)

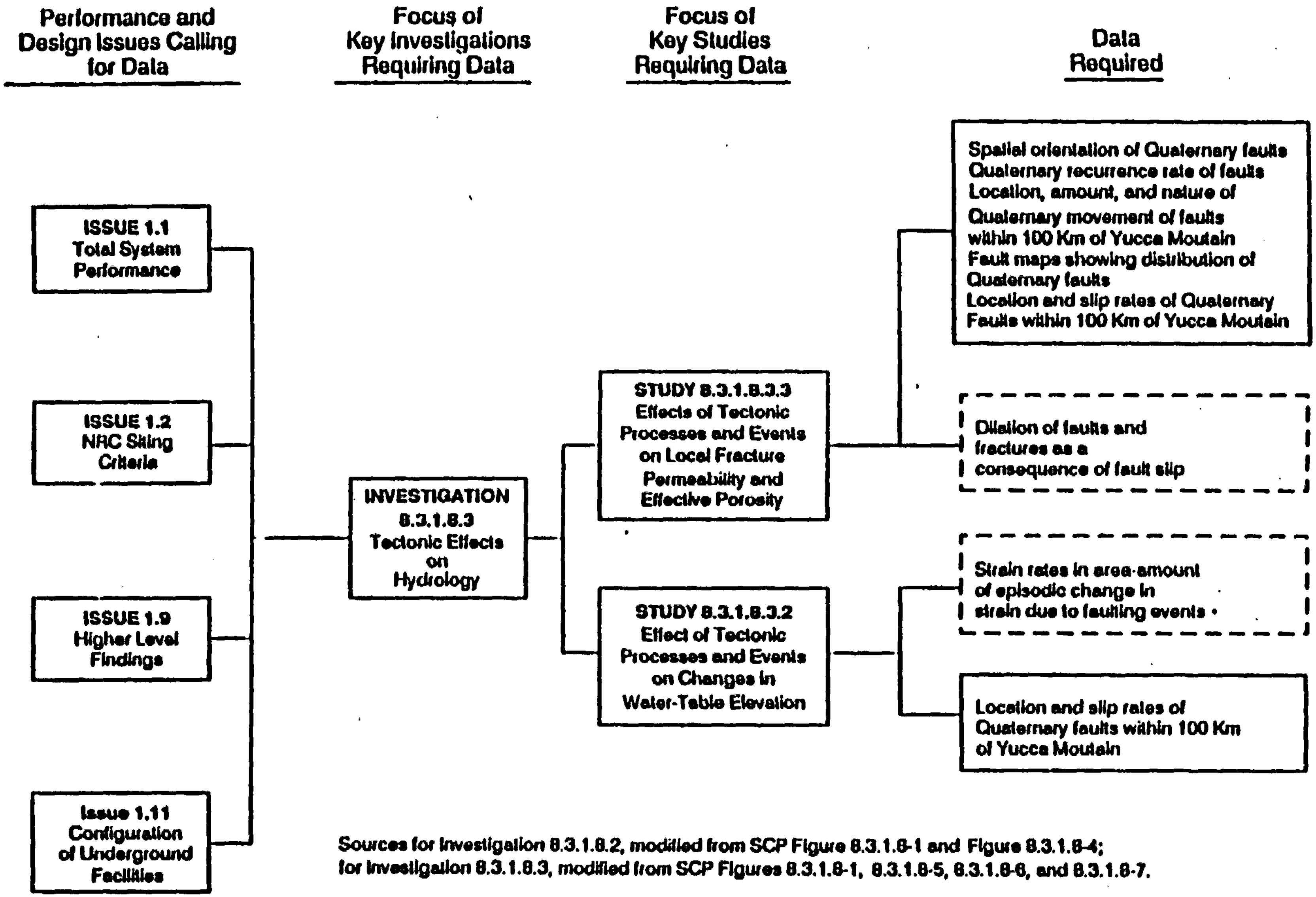
Figure 1-3. Logic diagram, showing area of responsibility of this study in the investigation of the location and rates of tectonic processes operating during the Quaternary.



Sources 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, 8.3.1.17-5.

Note: Dashed box indicates data requirement supplied indirectly through contribution to Study 8.3.1.17.4.12, Tectonic Models and Synthesis.

Figure 1-4. Required data supplied (in part) by Study 8.3.1.17.4.4 for issue resolution through studies in the preclosure tectonics program



Sources for 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.

Note: Dashed box indicates data requirement supplied indirectly through contribution to Study 8.3.1.17.4.12, Tectonic Models and Synthesis.

Figure 1-5. Required data supplied (in part) by Study 8.3.1.17.4.4 for issue resolution through studies in the postclosure tectonics program.

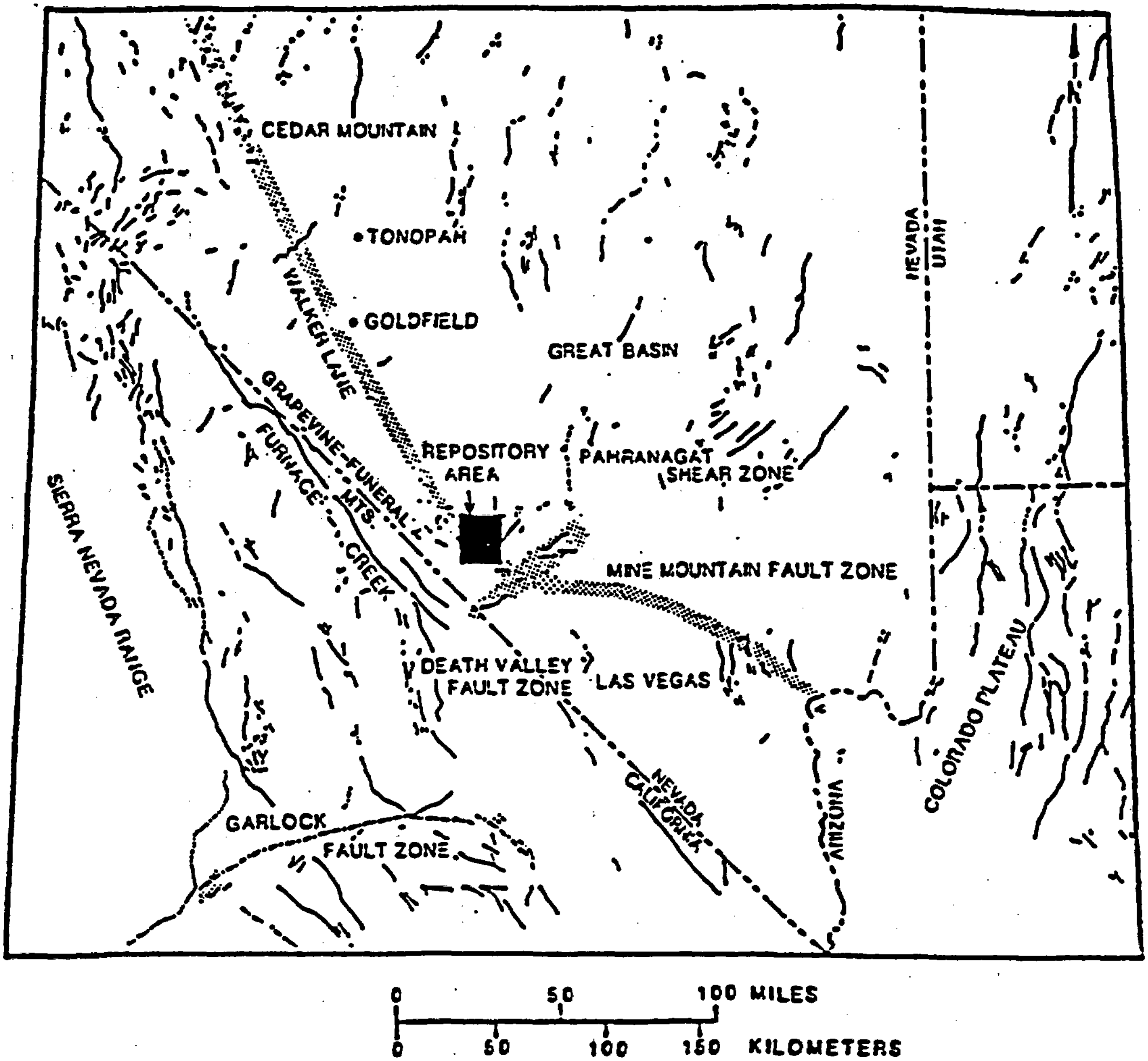


Figure 2-1. Regional structure map, showing location of major structural features.

	REQUIRED INFORMATION				
Area (and designated study(ies))	Verification of rupture-free area(s)	Potential locations of ground rupture	Source and magnitude of ground shaking (earth-quakes)	Potential effects of faulting on hydrology	Kinematics and nature of faulting (input to study of Tectonic Models)
Site of facilities in Midway Valley (Study 8.3.1.17.4.2: Location and recency of faulting near prospective surface facilities)	Yes	No	No	No	No
Site Area (including Midway Valley) (Study 8.3.1.17.4.6: Quaternary faulting within the site area) (Study 8.3.1.17.4.7: Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain) (Study 8.3.1.17.4.4: Quaternary faulting proximal to the site within northeast-trending fault zones) [This study]	No	Yes	Yes	Yes	Yes
Area within 100 km of Yucca Mountain, exclusive of Site Area (Study 8.3.1.17.4.3: Quaternary Faulting within 100 km of Yucca Mountain, including the Walker Lane belt) (Study 8.3.1.17.4.4: Quaternary faulting proximal to the site within northeast-trending fault zones) [This study] (Study 8.3.1.17.4.5: Detachment faults at or proximal to Yucca Mountain)	No	No	Yes	Yes	Yes

Figure 2-2. Information on faulting required within the proposed site of surface facilities in Midway Valley, the Site Area, and the area within 100 km of Yucca Mountain

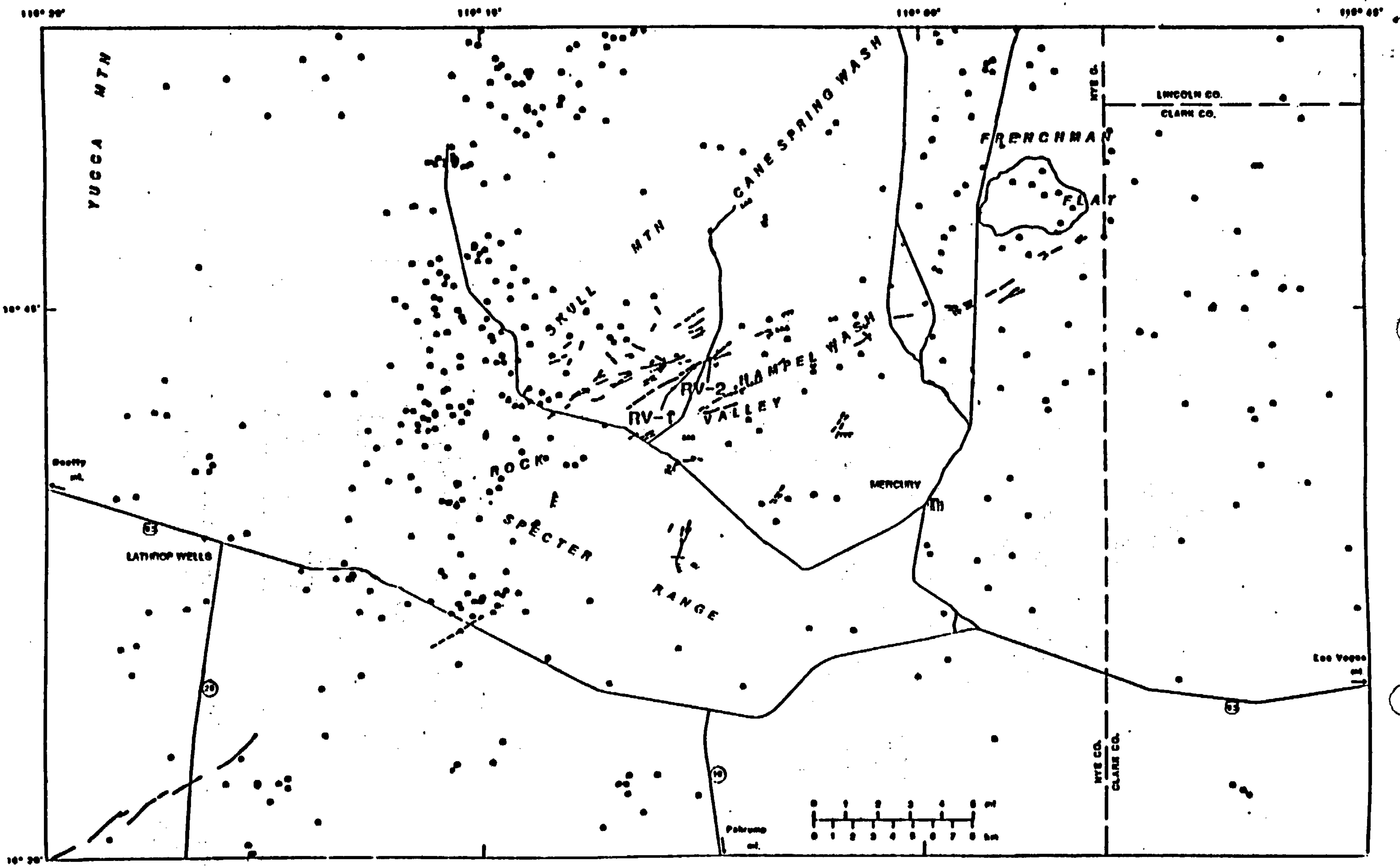


Figure 2-3: Map of the Rock Valley fault system. Solid lines, faults in Quaternary alluvium; dashed lines, suspected faults in Quaternary alluvium; hachured lines, scarps in Quaternary alluvium; gray filled circles, earthquake epicenters.

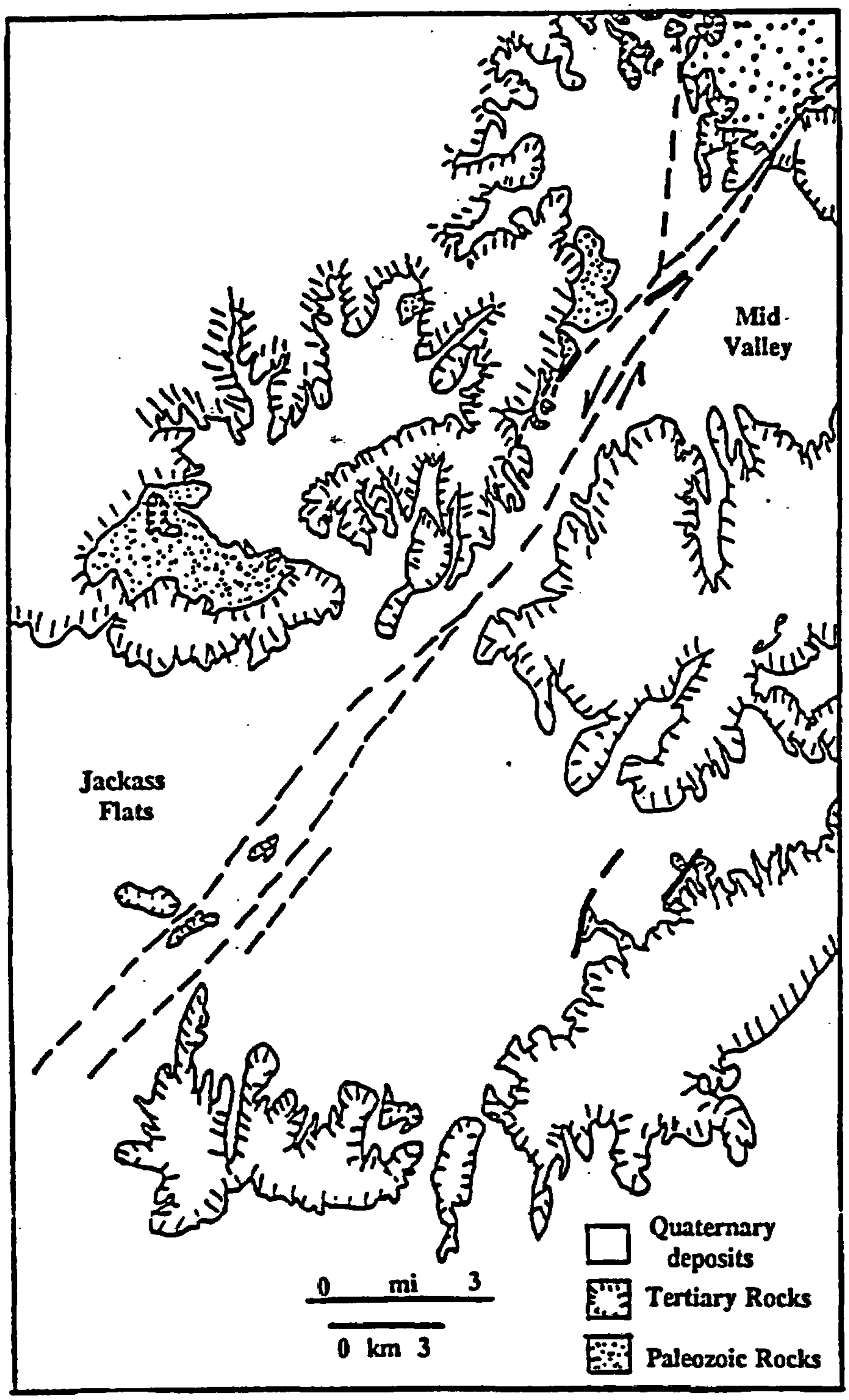


Figure 2-4: Map of the Mine Mountain fault system. Solid lines, faults in Quaternary alluvium; dashed lines, approximate projections of faults beneath Quaternary alluvium. Geology generalized from Maldonado, 1985.

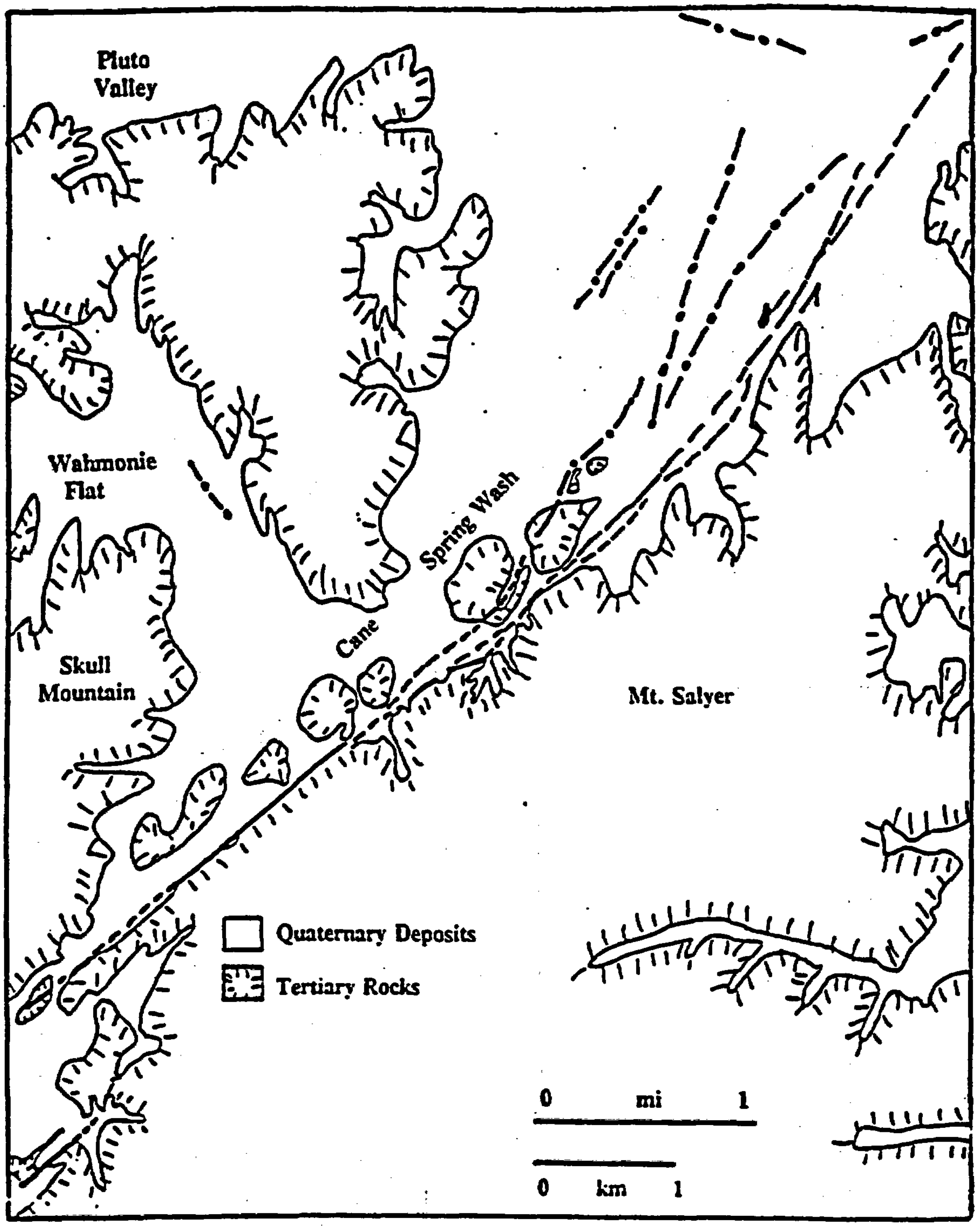


Figure 2-5: Map of the Cane Spring fault system. Solid line, fault in Quaternary alluvium; dashed line, fault concealed beneath Quaternary alluvium, dot-dashed line, brush line or other linear feature possibly indicating fault in Quaternary alluvium. Geology generalized from Poole and others, 1965.

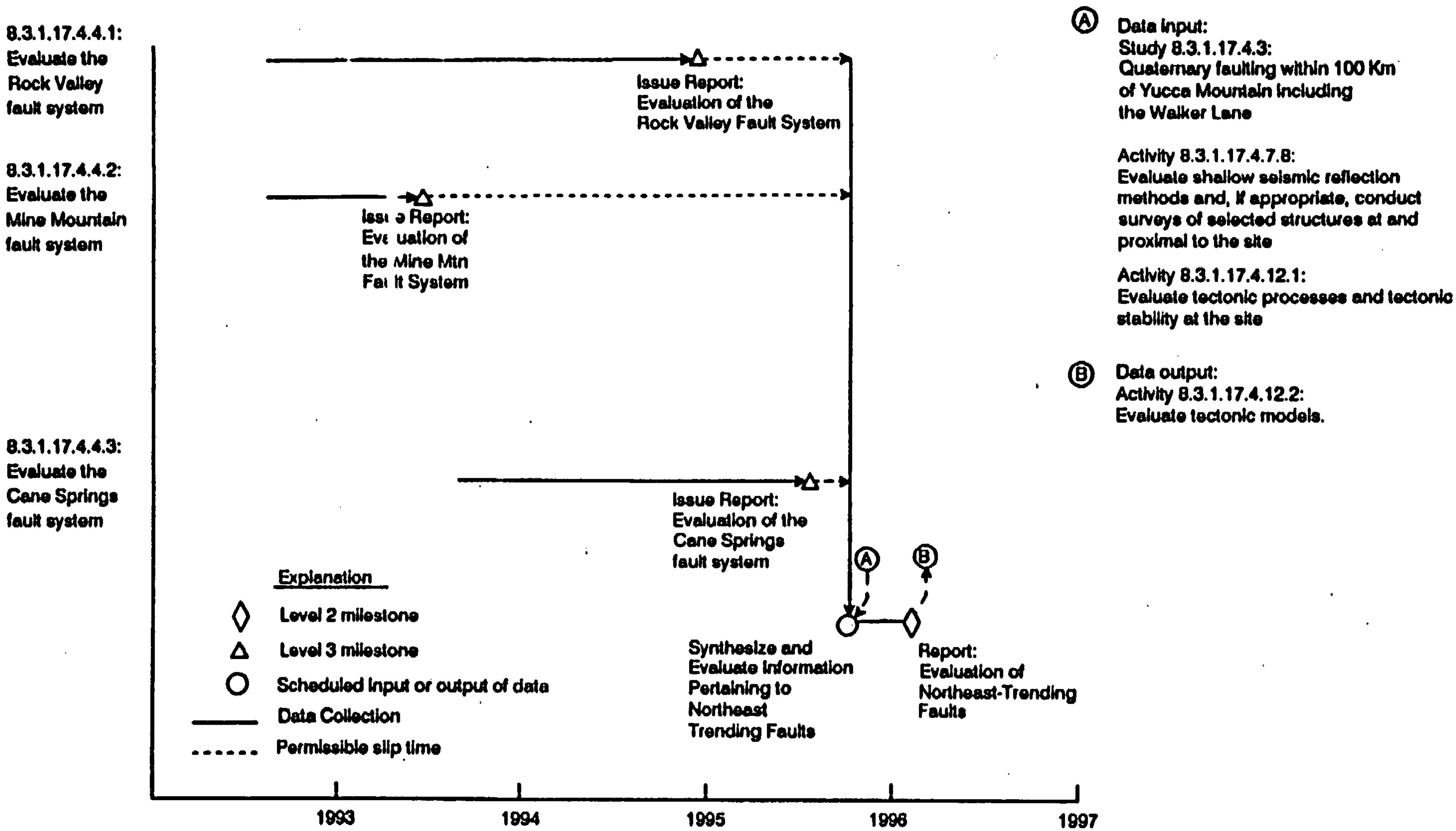


Figure 5-1. Schedule for Study 8.3.1.17.4.4

Table 4-1. Information to be provided to other studies by Study 8.3.1.17.4.4

Information to be obtained from this study	Where information will be used[1]	How information will be used
Location, distribution, geometry displacement rate, and age of faults within northeast-trending fault zones proximal to Yucca Mountain; geologic times	8.3.1.17.3	To be incorporated with information from other studies to predict the likely locations, timing, and magnitudes of future faulting and earthquake events that could impact the design or performance of the waste facility.
	8.3.1.8.3.3.2*	To be integrated with information from other activities to summarize and evaluate data on slip rates and recurrence intervals on faults in and near the controlled area.
	8.3.1.8.3.1.3 8.3.1.8.3.3.2*	To be integrated with information from other studies to estimate slip rates, recurrence intervals, and possible cumulative offset in 10,000 years on Quaternary faults in and near the controlled area.
	8.3.1.8.3.2.3* 8.3.1.8.3.3.3*	To be integrated with information from other studies to estimate magnitude and location of strain associated with possible future movement of Quaternary faults.

[1] Investigations, studies, or activities in which information will be used:

8.3.1.8.3.1.3:	Faulting rates, recurrence intervals, and probable cumulative offset in 10,000 years
8.3.1.8.3.2.3:	Assessment of the effect of strain changes on water table elevation.
8.3.1.8.3.2.5:	Effects of faulting on water table elevation.
8.3.1.8.3.2.6:	Assessment of the effects of faulting on water table elevation.
8.3.1.8.3.3.2:	Assessment of the effect of faulting on local fracture permeability and effective porosities.
8.3.1.8.3.3.3:	Assessment of the effects of stress or strain on hydrologic properties of the rock mass.
8.3.1.17.3:	Vibratory ground motion that could affect repository design or performance.

* Information from Study 8.3.1.17.4.4 will be used indirectly in this Study/Activity.

SP 8.3.1.17.4.4, R0