STUDY PLAN

for

STUDY 8.3.1.17.3.1:

RELEVANT EARTHQUAKE SOURCES

Rev 1

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U. S. GEOLOGICAL SURVEY

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
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PREFACE

This study plan revises and updates the plan for Study 8.3.1.17.3.1, Relevant Earthquake Sources, Rev 0 dated November 18, 1991. This revision (Rev 1) reflects the current U.S. Department of Energy approach to seismic hazard assessment as described in Topical Report, "Methodology to Assess Vibratory Ground Motion and Fault Displacement Hazards at Yucca Mountain" (U.S. Department of Energy, 1994). The revision also addresses comments on the Site Characterization Plan (U.S. Department of Energy, 1986) by the Nuclear Regulatory Commission (U.S. Nuclear Regulatory Commission, 1987), and takes into account NRC guidance on fault identification (McConnell and others, 1992). In particular, it drops the concept of a cumulative slip earthquake and evaluates the maximum magnitude for identified seismic sources based on estimates of the physical dimension of future fault rupture.

The U.S. Department of Energy's updated methodology (U.S. Department of Energy, 1994) relies on a probabilistic analysis to assess seismic hazards at Yucca Mountain. The probabilistic analysis, which considers the contribution to vibratory ground motion and fault displacement hazards at the site from all significant sources, will be used as the basis for determining design basis earthquakes and to support assessment of the performance of a potential repository with respect to radioactive waste containment. The updated approach, therefore, requires identification of all seismic sources with a potential to contribute significantly to the hazard at the site, and evaluation of the recurrence rates and maximum magnitudes of each source. This study plan addresses that aspect of seismic hazard assessment.

The earlier study plan (Rev 0) relied on the idea of the 10,000-year Cumulative Slip Earthquake (CSE) in order to characterize the magnitudes of relevant earthquake sources. The CSE technique utilizes long-term fault slip rates to estimate magnitudes that are appropriate for the design of preclosure facilities that are important to safety. In contrast, this revised study plan addresses expected and maximum magnitudes based on the dimensions and displacements of Quaternary faults consistent with current practices of seismic source characterization (e.g., Schwartz, 1988; Coppersmith, 1991; Reiter, 1991).

Revision 1 presents a methodology that relies on a variety of geologic, seismologic, and geophysical data in an effort to characterize the locations, geometries, maximum magnitudes, and recurrence rates of relevant seismic sources. The approach separates the rate-related source parameters (slip rate, recurrence interval) from the time-independent parameters (fault length, fault width, slip per event). Silvio K. Pezzopane and David P. Schwartz are members of the DOE Seismic Hazards Working Group and are the authors of Revision 1. Portions of this study plan follow directly from Revision 0.

ABSTRACT

Implementation of Study 8.3.1.17.3.1 will identify and characterize those earthquake sources that are relevant to seismic hazard analyses of the Yucca Mountain site. The first of two activities is designed to identify and characterize the locations, potential for activity, and geometries of potentially relevant earthquake sources in the site area and the region. The second activity will characterize the maximum magnitudes and recurrence rates of the relevant earthquake source. For fault specific sources, maximum earthquake magnitudes are based on estimates of source dimensions such as maximum fault rupture length, subsurface rupture area, and maximum displacement per event. Empirical regressions between earthquake magnitude and the fault rupture parameters are used in a cross-checking technique to find the maximum magnitude. Recurrence rates of the seismic sources are based on fault-specific studies that establish earthquake recurrence intervals and fault slip rates from the geologic record of Quaternary faulting. The paleoseismic record of surface-rupturing earthquakes is used together with the historic seismicity record to establish recurrence rates that encompass both the preclosure and postclosure time intervals. For non-fault specific sources, maximum magnitude will be determined on the basis of seismic and tectonic observations within the Basin and Range and similar tectonic regimes. Recurrence rates will be evaluated using the available seismic and geologic record.

The seismic sources, along with their potentials for activity, maximum magnitudes, and recurrence rates, and the uncertainties in these values, all serve as input to Study 8.3.1.17.3.6 (Probabilistic analyses of vibratory ground motion and fault displacement at Yucca Mountain). That study, in turn, forms the basis for determining seismic design earthquakes and supports the performance assessment of the potential repository.

TABLE OF CONTENTS

[Figures are at end of report]

FIGURES

FIGURE

STUDY 8.3.1.17.3.1: RELEVANT EARTHQUAKE SOURCES

Study 8.3.1.17.3.1 consists of two activities:

- 8.3.1.17.3.1.1 - Identify relevant earthquake sources
- 8.3.1.17.3.1.2 - Characterize relevant earthquake sources

The study is part of the preclosure tectonics program; it is one of a series of related studies that collect and synthesize information about earthquake sources in the site region in order to estimate the fault displacement and vibratory ground motion hazards to the proposed repository (fig. 1-1).

1. PURPOSE AND OBJECTIVES OF THE STUDY

The objectives of this study are to identify and characterize those earthquake sources that are relevant to seismic hazard analyses of the site -- i.e., those sources that could be active -- and, if active, could cause fault displacement or severe ground shaking at the site. Primary emphasis is on the identification of those faults that are considered capable of generating an earthquake with the equivalent of 0.1g or greater ground acceleration, and/or significant displacement, at the location of the potential repository.

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

Information for identifying potentially relevant earthquake sources will be supplied mostly by the data collection and synthesis activities in Investigation 8.3.1.17.4 (Preclosure tectonics data collection and analysis). The information items to be synthesized in this study (8.3.1.17.3.1) are:

- Maps and cross sections of earthquake locations determined from historical and instrumental earthquake data.
- Maps showing Quaternary faults with lengths greater than about 20 km within 100 km of the site and Quaternary faults with lengths greater than about 1 km within 10 km of the site.
- Maps of gravity-, magnetic-, and heat-flow anomalies, both regional and local.

- Local and regional paleoseismic data concerning the ages and displacements per event, recurrence intervals, and the fault styles and slip rates of Quaternary faulting.
- Local and regional evidence of neotectonic deformation or stability.
- Regional and local seismic reflection data.
- Information on local and regional crustal stresses.
- Local and regional tectonic models.

These combined data will be used to identify and characterize potentially relevant earthquake sources. Identification will include evaluation of source locations, depths, geometries, potentials for activity, and dependencies. Characterization will include evaluation of maximum magnitudes and recurrence rates. Uncertainties for all parameters will also be assessed. The results of the study will provide input to Study 8.3.1.17.3.6 (Probabilistic analyses of vibratory ground motion and fault displacement at Yucca Mountain).

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 performance measures are discussed in sections 1.2; 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

Information from this study will be applied toward designing the repository in accordance with tentative design goals for predicting the performance of the repository, and for measuring the predicted performance against tentative goals associated with performance measures. In general, information from the study is needed to improve confidence levels in all parameters related to potential fault displacement and vibratory ground motion used to assess repository design and performance. More specifically, information on potential earthquake sources that may control ground motion at frequencies within the range of engineering significance are needed to design repository facilities to withstand the effects of vibratory ground motions. In addition, the information serves 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. The information to be obtained is also needed to satisfy certain regulatory requirements, as described below.

Design Issue 4.4
(Technologies for repository construction, operation, closure, and decommissioning)

For preclosure design issue 4.4 (U.S. Department of Energy, 1988; Site Characterization Plan (SCP) section 8.3.2.5), information from this study is needed to satisfy the tentative goals associated with two performance measures: (1) the locations of surface facilities important to safety (FITS) and (2) the ability to continue preclosure operations and retrieve waste (see SCP tables 8.3.2.5-1 and 8.3.2.5-2). The goals for those performance measures deal with the locations of underground and surface facilities important to safety (see SCP tables 8.3.1.17-5b, -5a, -6b, -6a; 8.3.2.5-1 and -2).

For both goals, the study will contribute information pertaining to the locations, geometries, magnitudes, and recurrence rates of:

- potential earthquake sources in the controlled area
- potentially relevant earthquake sources within 100 km of the site

In general, this information will be used to support design and performance parameters needed to aid in (1) the development of a seismic design-basis for repository facilities that are important to safety and (2) the identification of credible accidents that might be initiated by seismic events and lead to the release of radioactive materials. Specifically, this information will be used to support development of design-basis ground motion and, if required, fault displacement loading inputs for surface and subsurface facilities. Vibratory ground motions will be characterized by peak values, response spectra, and time histories covering the frequency range of engineering interest for design basis earthquake(s). Fault displacement design values, if required, will be characterized by the location, amount, and direction of offset. Design basis ground motion and fault displacement values will be based on the results of a seismic hazard assessment incorporating contributions from all seismic sources identified by this study.

Finally, information from this study will contribute indirectly to the resolution of performance issues 1.1, 1.8, 1.9, and 1.11 (SCP sections 8.3.5.13, 8.3.5.17, 8.3.5.18 and 8.3.2.2, respectively) through its contributions to the postclosure tectonics program.

2. Rationale for selecting the study

The two activities in this study were chosen as complementary means for obtaining the required information on potentially relevant seismic sources within the Yucca Mountain area. Potential seismic sources include Quaternary faults, areal-source zones (for fault specific or background seismicity), and underground nuclear explosions relevant to fault displacements or ground motions at the site. Activity 8.3.1.17.3.1.1 will identify potentially relevant earthquake sources through a synthesis of the types of information listed in section 1.1. The assessment of the relevance of an identified seismic source requires an assessment of the magnitude of the source and the rate of occurrence of different magnitude events. Activity 8.3.1.17.3.1.2 will assess the magnitude of the sources based on measured or assessed fault parameters including maximum rupture lengths, subsurface rupture areas, and displacements per event. Recurrence relations will be developed using information on the timing of past events, slip rates, and seismicity. Activity 8.3.1.17.3.1.2 will also evaluate fault sources with respect to their potential for generating vibratory ground motion of 0.1 g or more at the site, consistent with the investigation suggested in Section 3.3(6)(a) of NUREG-1451 (McConnell et al., 1992). Activities in this study will thus be performed concurrently and iteratively with information on ground-motion (attenuation) relationships developed in Activity 8.3.1.17.3.5.2 (Characterize ground motion from the controlling seismic events) and determined site effects developed in Study 8.3.1.17.3.4 (Effects of local site geology on surface and subsurface motions). Determination of frequencies of engineering interest will consider parameters and revisions to parameters needed for seismic design and design analysis. A catalog of seismological sources will be defined and compiled for use in a probabilistic assessment of vibratory ground motion and fault displacement hazards at the Yucca Mountain site (Activity 8.3.1.17.3.6.2).

2.1 Activity 8.3.1.17.3.1.1 Identify relevant earthquake sources

2.1.1 Rationale for the selected test

A single test--identify relevant earthquake sources--will be conducted to achieve the objective of this activity. The planned work can be divided into four major elements:

- Compiling, from published sources and from other SCP activities, information on mapped surface faults, buried faults, seismic activity, and relevant supporting information.

- Examining and synthesizing the compiled information on potentially relevant seismic sources.

- Updating the compilation as new studies of faults and earthquakes in the site characterization program are completed.

- Assessing iteratively, based on the maximum magnitude earthquake and closest source-to-site distance, the potential for each source identified in Activity 8.3.1.17.3.1.2 to generate vibratory ground motion of 0.1 g or more at the site.

All relevant earthquake sources that can reasonably be identified or inferred will be determined by this planned method. There are no alternatives that would provide the amount, kind, and quality of data needed to adequately identify these features.

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

2.1.2.1 Number

The number of potentially relevant seismic sources that will be identified depends on the number of Quaternary faults recognized, attenuation of ground motion, and the spatial variation of seismicity that must be represented by areal sources. Preliminary evaluation by the principal investigator indicates that about 50 known or suspected Quaternary faults are of sufficient size and proximity to be important in seismic hazard analysis (Figs. 2-1 and 2-2).

2.1.2.2 Location

The location of the study area is dictated by the need to assess vibratory ground motion at frequencies of engineering interest, which is dependent on the distance from the site location to the source, the potential earthquake magnitude of the source, and the site-response characteristics of the site location. Although specific boundaries cannot be drawn, virtually all of the documented geologic structures, or significant portions of them, that are considered relevant to seismic hazard analysis, occur within 100 km of the potential site. However, other sources potentially capable of large earthquakes may exist or extend beyond a 100 km radius of the repository site and need to be included in order to evaluate their contribution to ground-motion at frequencies of engineering interest.

2.1.2.3 Duration and timing

The duration and timing for this activity is dependent upon information from other activities, and the need to provide information from this activity to other studies (see secs. 4 and 5).

2.1.3 Constraints: factors affecting selection of tests

The choice of the test method for this activity was not affected by the following factors: impacts on the site; simulation of repository conditions; limits and capabilities of analytic methods; timing; scale and applicability of measurements; and interference with the exploratory shaft. It employs standard compilation practices appropriate to the information requirements for the activity (see sec. 2.1.1). Regarding possible interference with other tests, it should be noted that other studies and activities in the preclosure tectonics program will use data from this activity to achieve their specific objectives.

2.2 Activity 8.3.1.17.3.1.2 Characterize relevant earthquake sources

2.2.1 Rationale for the selected test

The test for this activity--characterize relevant seismic sources identified in Activity 8.3.1.17.3.1.1--will provide essential data in determining the potential for fault displacement and vibratory ground motions at the repository site. The test consists primarily of two parts: (1) determine the maximum magnitude of each relevant earthquake source, based on evaluation of rupture dimensions and/or seismotectonic analysis; and (2) determine the rate of occurrence for various size earthquakes for each of the sources, based on slip rates, recurrence interval data, historical seismicity and paleoseismic activity. Rationale for part (1) is that earthquake magnitudes correlate with rupture dimension, and for part (2) the rationale is that earthquake recurrence is constrained by slip rate, hence past recurrence rates tend to predict future recurrence rates.

A key assumption in seismic hazard analysis is that each seismic source is associated with a maximum magnitude earthquake (also called an "upper-bound magnitude") (e.g., Reiter, 1991). The maximum earthquake is considered to be the magnitude of the largest possible earthquake that can be associated with a specific source or source zone, given the current tectonic regime.

Seismologic theory as well as measurements of historic fault ruptures indicate that the magnitude (or seismic moment) of an earthquake is related to dimensions of the rupture (length, downdip extent, and surface area) and the amount of fault displacement or slip (e.g., Aki and Richards, 1980; Schwartz et al., 1984). Empirical data from surface-rupturing earthquakes show strong statistical correlations between these rupture dimensions and earthquake magnitude. The empirical relationships have been refined and updated (e.g., Bonilla et al., 1984; Wells and Coppersmith, 1994), along with relationships between seismic moment and moment magnitude (e.g., Hanks and Kanamori, 1979; Kanamori, 1983), and together serve as the basis for establishing maximum earthquake magnitudes. Currently, the most comprehensive and up-to-date empirical regressions are by Wells and Coppersmith (1994), which probably will be the relationships used for magnitude assessments in this study. The regressions improve those of previous studies through an approach that is based on moment magnitude (M_w or just M) rather than surface wave magnitude (M_s). Moment magnitude is the only scale that is related to physical properties of the source (rupture dimensions and displacement), and is the preferred parameter for characterizing earthquake size because of its widespread use and unambiguous attributes.

Maximum earthquake magnitude is related to fault geometry and fault behavior through an assessment of the maximum dimensions of a single rupture. Fault segmentation models will be used to identify portions of faults that are likely to rupture during individual earthquakes. For many faults, the locations of fault segments and the boundaries between segments appear to be structurally controlled (e.g., Schwartz and Coppersmith, 1986; Schwartz, 1988). Multiple approaches have been employed to develop criteria for evaluating segmentation, including paleoseismic investigations (e.g., Schwartz, 1988) and observations of historical surface ruptures (e.g., Knuepfer, 1989). Paleoseismic data regarding the timing of past events, displacements per event, displacement distributions along the faults, and slip rates are critical for defining rupture segments and for modeling earthquake recurrence (e.g., Schwartz, 1988). Also significant changes in fault strike, fault trace complexity, the cumulative amount and sense of slip, the lithology across the fault, and the presence of transverse geologic structures can be used to recognize fault segments (e.g., Knuepfer, 1980). Segmentation models provide a physical basis for the selection of rupture lengths that can be used in the calculation of maximum magnitudes.

Quaternary faults in the vicinity of Yucca Mountain are spaced within a few kilometers of each other in map view (Scott and Bonk, 1984). This closeness of faults, as compared to other regions of the Basin and Range Province, presents the possibility that two or more faults could coalesce into a master fault at seismogenic depth. In this case, an earthquake on the master fault could propagate ruptures to the surface along several faults. Paleoseismic data will be used to evaluate the displacements and simultaneous timing of events among the various faults.

Maximum magnitudes will be developed from the paleoseismic measurements and mapped fault lengths using relationships between the fault dimensions, displacement per event, and the seismic moment. For cases in which two or more faults are assumed to rupture simultaneously, the estimates of magnitude will be based on the length of the combined fault zone.

Maximum earthquake magnitudes in this study will be calculated using the empirical magnitude-rupture parameter regressions and the estimates of rupture dimensions and displacements developed from geologic, paleoseismic, and historic seismicity data (Studies in 8.3.1.17.4). Several estimates of rupture dimensions will be used in a cross-checking technique to lend stability to the magnitude estimates. Uncertainties in the rupture parameters will be defined from the paleoseismic data and incorporated with uncertainties inherent in the empirical regressions to encompass the range of possible magnitudes and determine confidently the maximum earthquake magnitude.

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

2.2.2.1 Number

The number of maximum magnitude and recurrence rate determinations will depend on the number of relevant seismic sources identified in Activity 8.3.1.17.3.1.1.

2.2.2.2 Location

The locations of maximum magnitude and recurrence rate determinations will depend on the locations of the relevant seismic sources identified in Activity 8.3.1.17.3.1.1.

2.2.2.3 Duration and timing

The discussion in section 2.1.2.3 is applicable to this section.

2.2.3 Constraints: factors affecting selection of tests

The discussion in section 2.1.3 is applicable to this section.

3. DESCRIPTION OF TESTS AND ANALYSES

3.1 Activity 8.3.1.17.3.1.1 Identify relevant earthquake sources

The objective of this activity is to identify relevant earthquake sources.

3.1.1 General approach

The identification of relevant seismic sources follows an iterative procedure whereby potentially relevant seismic sources, including faults and areal source zones, will be initially identified, compiled and evaluated according to existing geological, geophysical and seismological information (see listing in sec. 1.1) and according to existing parameters needed for seismic design (SCP, section 8.3.2.5.1) and design analysis (SCP, section 8.3.2.5.7). As investigations of faults and earthquakes -- primarily from studies in Investigation 8.3.1.17.4, Preclosure tectonics data collection and analysis, and other studies in Investigation 8.3.1.17.3, Studies to provide required information on vibratory ground motion that could affect repository design or performance -- are completed, updating the inventory of, and the information on potentially relevant sources is necessary. If parameters for seismic design and design analysis change, it is possible that the then current assessments on seismic source relevancy will also change, depending on the seismic characterization of each of the sources.

Information on depths, dimensions, and geometries of relevant seismic sources from other activities will constrain source size in three dimensions in the crust so that areas and volumes, appropriate to planar and volumetric sources, respectively, can be estimated. The kinds of information (based primarily on the designated parameters for this activity, which are listed in sec. 1.1) to be compiled for each source includes source location and length, likely source penetration depth, source orientation, and likely style of faulting (see sec. 3.1.7). The work will be performed concurrently with the effort to define maximum earthquakes for relevant earthquake sources in Activity 8.3.1.17.3.1.2 (see sec. 3.2).

Uncertainty of buried source locations, of source geometries at depth, and possible interconnections of sources at depth, will be described by a range of interpretations illustrating the preferred, closest and farthest approach of the source to the site.

3.1.2 Test method and procedures

Tabulations of relevant sources will be produced iteratively, considering refined information on potentially relevant sources as studies of faults and earthquakes are completed in other activities, considering information and changes in information developed on ground-motion attenuation in Activity 8.3.1.17.3.5.2, on site effects in Study 8.3.1.17.3.4, and on parameters and revisions to parameters needed for seismic design and design analysis.

3.1.3 QA level assignment

Quality assurance requirements will be specified in a Yucca Mountain Project QA Grading Report which will be issued as a separate document.

3.1.4 Required tolerances, accuracy, and precision

No explicit requirements for tolerance, accuracy, or precision have been specified for this activity. As indicated earlier, the final selection of relevant earthquake sources is based on those faults whose characteristics (e.g., rupture length and area, amount and timing of movements, slip rates, recurrence interval) suggest a capability for significant fault displacements or for generating 0.1 g or greater ground acceleration at the potential repository site (see McConnell et al., 1992). For most such faults, however, uncertainties exist in many of the important parameters needed for quantifying seismic risk. As a consequence, hazard analyses are subject to a range of interpretations (of the available fault data) expressed in terms of the annual probabilities that various levels of ground motion or fault displacement will be exceeded at a given locality. Documentation of the uncertainties and the resulting probabilistic analyses of seismic hazards are being conducted in Study 8.3.1.17.3.6 (Probabilistic analyses of vibratory ground motion and fault displacement at Yucca Mountain).

3.1.5 Range of expected results

Quaternary fault studies (e.g., Swadley et al., 1984; F.W. Simonds, U.S. Geological Survey, written commun., 1995) suggest that individual scarps expressed in alluvium are commonly a few hundred meters to about 4 km in length in the site area. Faults or fault zones associated with these scarps may be found to be continuous at depth, perhaps on the order of a one kilometer length to 15 or more kilometers. Potentially relevant sources will include those identified Quaternary fault sources with lengths greater than about 1 km within 10 km of the site. Such sources are presently expected to be the dominant contributors to high frequency ground-motion hazard. Low frequency ground- motions are generally dominated by larger magnitude earthquakes occurring at greater distances from the site. Accordingly, smaller sources at greater distances are less relevant to the ground-motion hazard at the site. Information about individual faults beyond 10 km of the site will be compiled if evidence exists to indicate that such faults by themselves, or as extensions or genetically related groupings, could contribute significantly to the hazard at the site. Area-source representations of earthquake epicenters not associated with known geologic structures but considered representative of random strain-release in a volume of the brittle crust are expected to have variable magnitudes, recurrence rates, levels of activity, and physical dimensions, all of which are constrained by the distribution of seismicity in time and space, various seismotectonic characteristics, and geophysical properties.

3.1.6 Equipment

Equipment to be used in the compilation, analysis, and archiving of the information compiled will be:

- Hand-held calculator and drafting tools
- Computer and associated standard peripherals
- Word processing software
- Database management software
- Graphics software

3.1.7 Data-reduction techniques

In this activity, standard techniques will be used to compile and synthesize available information on potentially relevant earthquake sources into a computerized data base using standard data base software. Reduction of field information to maximum, minimum, average, or preferred slip rates on faults; locations, sizes and focal mechanisms of earthquakes, with uncertainties; and local and regional stress tensors will have been performed by the original investigators of the contributing studies. Tabulations of the compiled data will include (1) fault name and minimum distance from the site; (2) fault length, estimated maximum magnitude, and uncertainties; (3) evidence of Quaternary movement; (4) amounts of displacement (Quaternary, accumulative); (5) slip rates and recurrence intervals; (6) style of faulting; and (7) estimates of ground motion acceleration. Such compilation techniques have been used to document data and slip-rate estimates of faults of the San Andreas fault system and California in general (Clark, et al., 1984).

3.1.8 Representativeness of results

The information obtained in this activity is expected to be representative of potentially significant seismic sources in the site area and in the region. The test method for this activity is designed to yield information with which to make accurate conclusions concerning potential vibratory ground motions and fault displacements at the site in seismic hazard assessments. All Quaternary faults identified or inferred in contributing activities will be addressed in this activity. Data gaps and uncertainties from contributing activities are expected and will be accounted for through probabilistic analyses in Study 8.3.1.17.3.6. Area-source representations of earthquake epicenters not associated with known geologic structures but considered representative of random strain-release throughout a volume of the brittle crust will be compiled to account fully for the observational earthquake data and be suitable for use in a probabilistic ground motion assessment. In large part, representativeness of results will depend upon the representativeness of the data input from contributing geological and seismological studies that are referred to in section 3.1.1.

3.1.9 Relations to performance goals and confidence levels

The uses of the information from this activity for measuring the performance of the repository against the tentative goals for applicable performance measures are discussed in section 1.2.

3.2 Activity 8.3.1.17.3.1.2 Characterize relevant earthquake sourcesy

The objective of this activity is to characterize the earthquake source parameters for each of the relevant fault and areal sources identified in the previous activity (see section 2.2.1). The location, geometry, maximum magnitude, and recurrence rates of potential earthquakes are to be established based on the seismogenic properties of the potentially relevant sources compiled in Activity 8.3.1.17.3.1.1.

3.2.1 General approach

This activity will produce estimates of maximum magnitude and recurrence rates of earthquakes for identified Quaternary faults in the site area (within 5 km of Yucca Mountain; Fig 2-2) and faults and areal source zones in the region (generally those within 100 km of Yucca Mountain , Fig. 2-1; see section 2.1.2.2). The characterization of areal source zones will rely on the existence of relatively uniform seismotectonic domains. The maximum magnitudes and recurrence rates for such zones will be evaluated on the basis of the historical seismicity record and on empirical observations of the size distribution of earthquakes that are not associated with surface displacement. The estimates will be based on the following kinds of information:

- Regional and local Quaternary fault maps
- Structural geologic cross-sections
- Seismic reflection profiles across crustal faults
- Fault segmentation interpretations
- Empirical correlations between rupture dimensions and earthquake moment magnitudes
- Alternative tectonic models
- Historical seismicity epicenters and hypocenters
- Cumulative and individual-event fault displacements
- Fault slip rates
- Paleoseismic earthquake recurrence intervals
- Fault style and sense of slip

The characterization of individual Quaternary faults and areal source zones will follow an iterative procedure whereby initial estimates and their associated uncertainties will be made according to the available information from contributing studies. As geological, geophysical and paleoseismic investigations of faults (performed in other studies and activities) are completed, updating the earthquake magnitude and recurrence estimates will be necessary.

3.2.2 Test method and procedures

Earthquake magnitude and recurrence estimates for Quaternary faults will be produced iteratively as studies of these faults are completed in other activities. Derivation of such estimates will use standard mathematical procedures. Maximum earthquake magnitudes and recurrence rates will be estimated from available geologic, geophysical, and seismologic data described in section 3.2.1.

Earthquake magnitudes will be calculated using empirical regressions and the rupture lengths, rupture areas, and the maximum and average displacements estimated from geologic and paleoseismic data. Uncertainties in the fault rupture parameters will be documented in terms of the geologic basis for preferred and alternative values. Maximum magnitude determinations will employ multiple approaches consistent with the available data. Determinations will be weighted on the basis of uncertainty associated with input values and the assessed relative merits of the approaches. A distribution of maximum magnitudes will be developed for each source that incorporates the uncertainties in the source parameters and alternative interpretations.

Earthquake recurrence distributions will be characterized for each relevant seismic source and will be based on all available geologic and paleoseismic data related to earthquake recurrence intervals and slip rates. If supported by the data, recurrence models will be designed to incorporate the time elapsed since the most recent event and evidence for either temporal clustering or quasi-periodic recurrence if it is apparent. Regional recurrence rates will be assessed from an evaluation of historical seismicity catalogs. Uncertainties in the recurrence estimates and alternative recurrence or magnitude distribution models will be evaluated and their relative merits and shortcomings described.

3.2.3 QA level assignment

Quality Assurance requirements will be specified in a Yucca Mountain Project QA Grading Report which will be issued as a separate document.

3.2.4 Required tolerances, accuracy, and precision

The statements in section 3.1.4 are applicable to this section.

3.2.5 Range of expected results

Maximum magnitudes determined for local and regional fault sources will likely range from M 6-7 for short faults near the site to M 7-8 for longer faults at regional distances, such as the Death Valley-Furnace Creek fault. For areal sources, the maximum magnitude will be based on the observed magnitudes of historical earthquakes that did not rupture the surface.

Earthquake recurrence intervals for maximum magnitude events on most of the site faults are expected to be in the range of 10^4 to 10^6 years. It is expected that the recurrence rates for local faults will be highly variable and perhaps temporally clustered, so that an average recurrence interval may be less representative than the median or mode. Some of the larger and more significant sources at regional distances, however, are expected to have recurrence rates in the range of 10^3 to 10^5 years, and it is these sources that are important to ground motions at lower frequencies (or longer periods) of engineering significance.

3.2.6 Equipment

The list of equipment in section 3.1.6 applies to this section.

3.2.7 Data-reduction techniques

In this activity, standard mathematical and computational techniques will be used to establish the maximum magnitude and recurrence rates of earthquakes on local and regional sources using a computerized data base developed in Activity 8.3.1.17.3.1.1. Data reduction of field information will have been performed by the original investigator of the contributing activity.

3.2.8 Representativeness of results

The test method for this activity is designed to yield magnitude and recurrence estimates of earthquakes for potentially relevant earthquake sources. The values are expected to be representative because they are based on empirical regression relations. However, such estimates are subject to any limitations (uncertainties) on interpretations regarding individual fault movement and the Quaternary tectonic history of the site area and region as determined in contributing fault studies. Representativeness of results is therefore determined, in large part, by the representativeness of the data input from contributing geological studies. Alternative characterizations of magnitude and recurrence potential of relevant seismic sources are addressed in Study 8.3.1.17.3.6, Probabilistic hazard analysis.

3.2.9 Relations to performance goals and confidence levels

The uses of the information from this activity for measuring the performance of the repository against the tentative goals for applicable performance measures are discussed in section 1.2.

4. APPLICATION OF RESULTS

Information on relevant earthquake sources will be used as direct input to the probabilistic vibratory ground motion and fault displacement hazard analyses being conducted in Study 8.3.1.17.3.6. The data will also contribute indirectly to Study 8.3.1.8.2.1 (Tectonic effects: evaluations of changes in the natural and engineered barrier systems resulting from tectonic processes and events), especially for evaluating the effects of potential fault displacements on waste packages, water table elevation, and local fracture porosity and permeability.

5. SCHEDULE AND MILESTONES

Study 8.3.1.17.3.1 is scheduled for completion in FY 1996, with preparation of a final report on relevant earthquake sources for use in Study 8.3.1.17.3.6 (Probabilistic analyses of vibratory ground motion and fault displacement at Yucca Mountain). Interim reports in the form of preliminary tabulations of fault data will be made available as needed in FY 1995.

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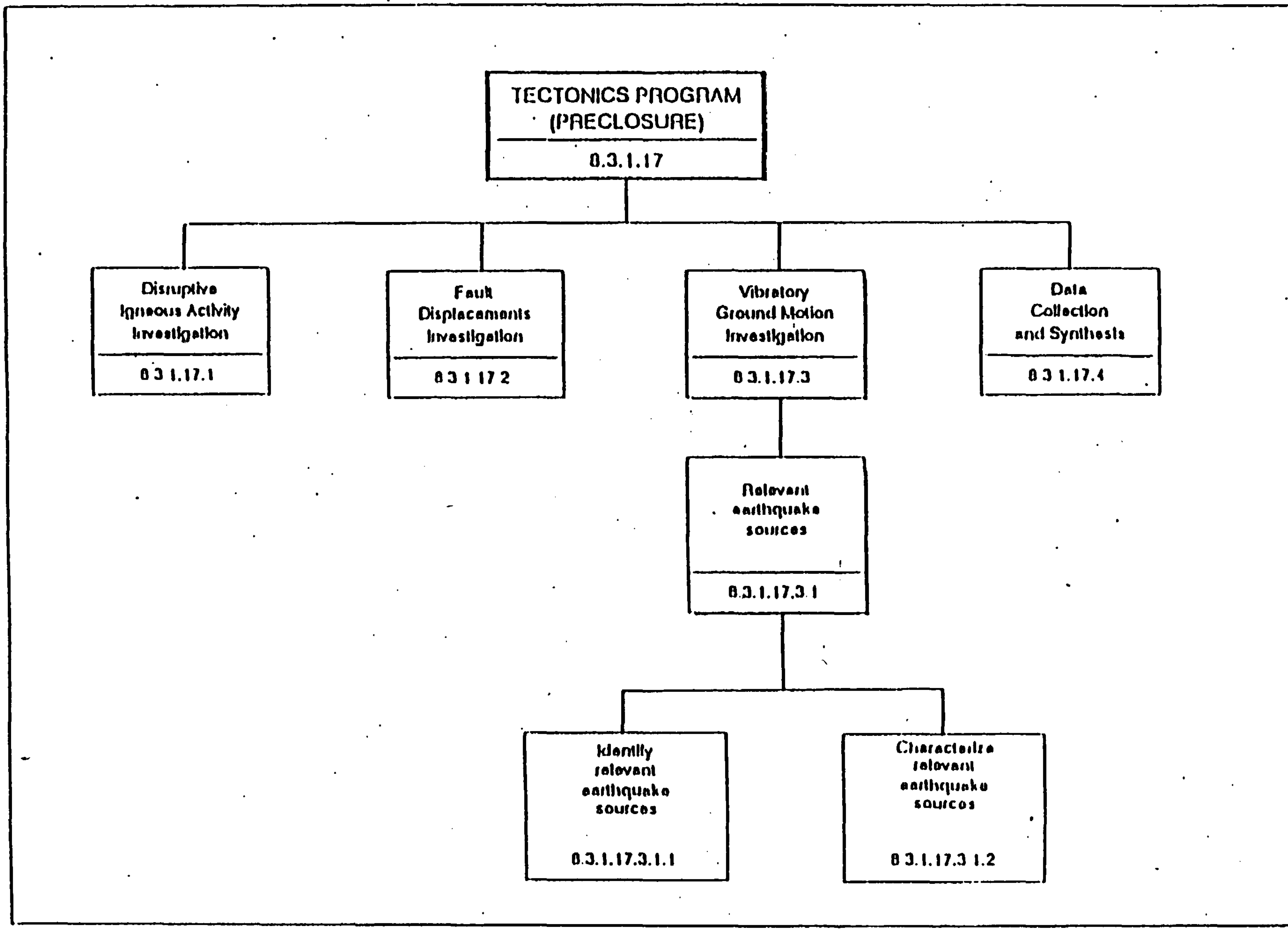


Figure 1-1. Relation of Study 8.3.1.17.3.1 to the preclosure tectonics program.

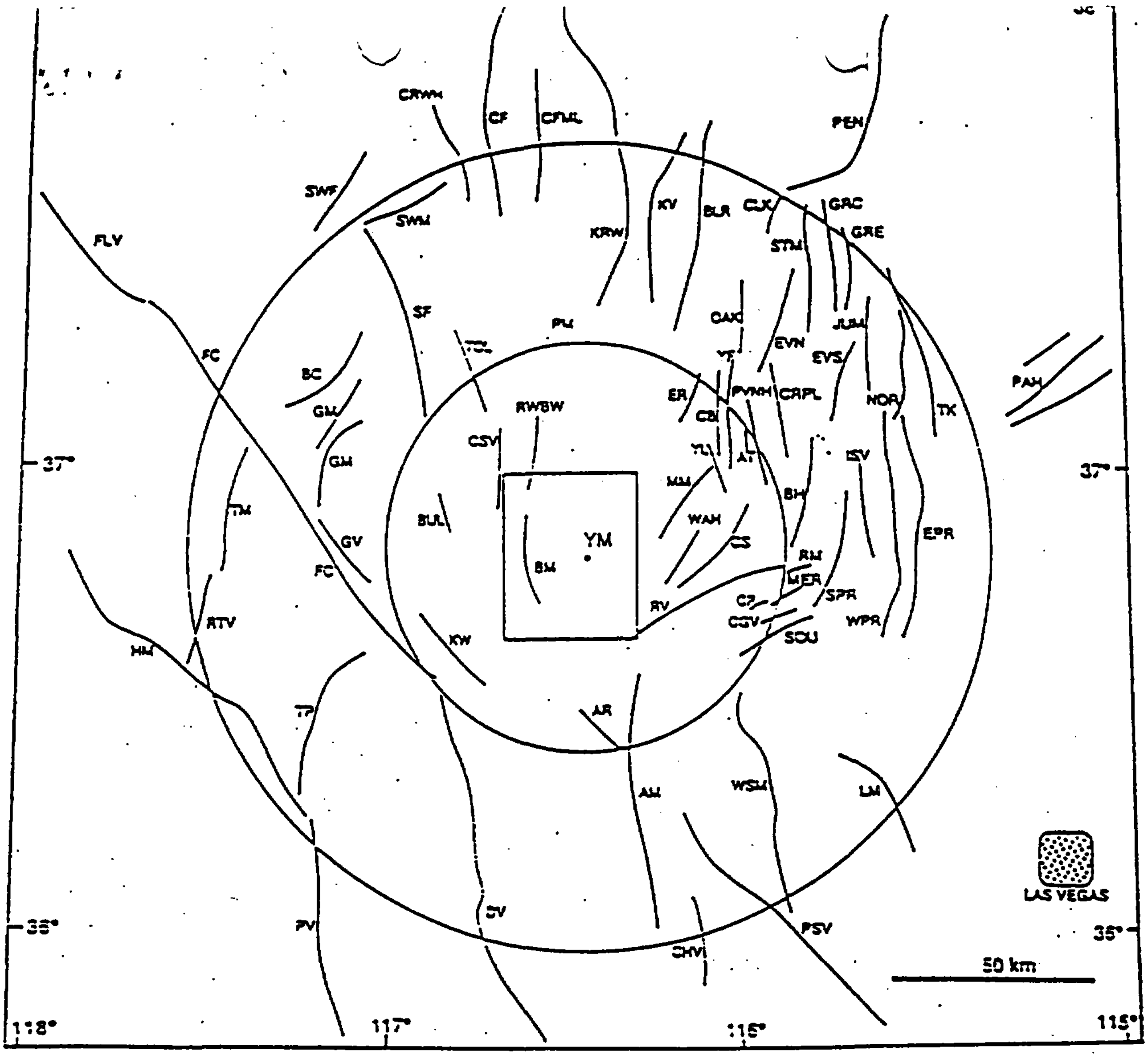
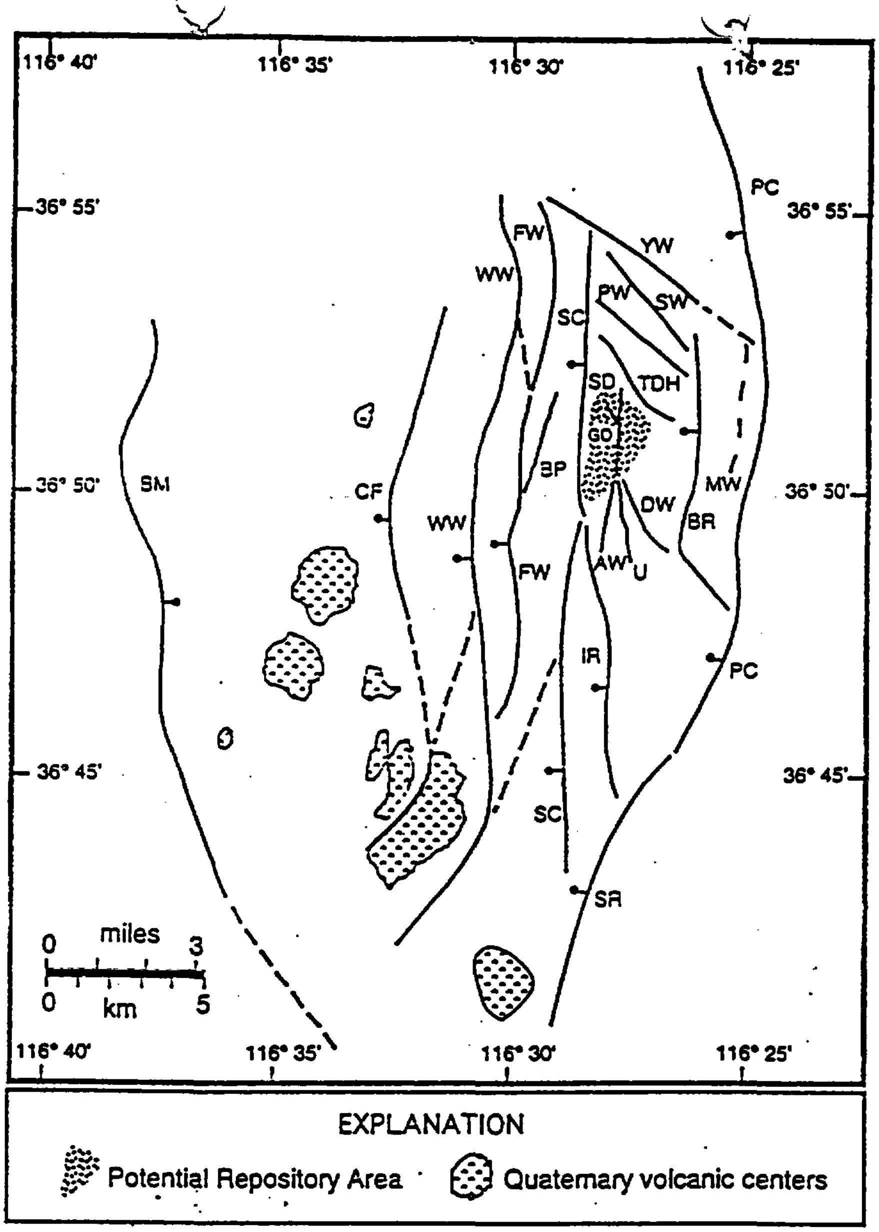


Figure 2-1. Index map of potential relevant earthquake sources in the Yucca Mountain region (based on L.C. Piety, U.S. Bureau of Reclamation, written commun., 1995). Circles are 50 and 100 km radii from Yucca Mountain (YM). Rectangle is area of Figure 2-2. Faults are identified as follows:

AM - Ash Meadow
AR - Amargosa River
AT - Area Three
BC - Bonnie Claire
BH - Buried Hills
BLR - Belted Range
BM - Bare Mountain
BUL - Bullfrog Hills
CB - Carpetbag
CF - Cactus Flat
CFML - Cactus Flat-Mellan
CGV - Crossgrain Valley
CHV - Chicago Valley
CLK-Chalk Mountain
CP - Checkpoint Pass
CRPL - Cockeyed Ridge-Papoose Lake
CRWH - Cactus Range-Wellington Hills
CS - Cane Spring
DV - Death Valley
EPR - East Pintwater Range
ER - Eleana Range
EVN - Emigrant Valley North
EVS - Emigrant Valley South
FC - Furnace Creek
FLV - Fish Lake Valley
GM - Grapevine Mountains
GRC - Groom Range Central
GRE - Groom Range East
GV - Grapevine
HM - Hunter Mountain
ISV - Indian Springs Valley
JUM - Jumbled Hills
KRW - Kawich Range West
KV - Kawich Valley
KW - Keane Wonder
LM - La Madre
MER - Mercury Ridge
MM - Mine Mountain
NDR - North Desert Range
OAK - Oak Spring Butte
OSV - Oasis Valley
PAH - Pahranagat
PEN - Penoyer
PM - Pahute Mesa
PSV - Pahrump-Stewart Valley
PV - Panamint Valley
PVNH - Plutonium Valley-North Halfpint Range
RM - Ranger Mountains
RTV - Racetrack Valley
RV - Rock Valley
RWBW - Rocket Wash-Beatty Wash
SF - Sarcobatus Flat
SOU - South Ridge
SPR - Spotted Range
STM - Stumble
SWF - Stonewall Flat
SWM - Stonewall Mountain
TK - Tikaboo Valley
TM - Tin Mountain
TOL - Tolecha Peak
TP - Towne Pass
WAH - Wahmonie
WPR - West Pintwater Range
WSM - West Springs Mountain
YF - Yucca Flat
YL - Yucca Lake



FAULT SYMBOLS			
Abbreviation	Fault Name	Abbreviation	Fault Name
AW	Abandoned Wash	PC	Paintbrush Canyon
BM	Bare Mountain	PW	Pagany Wash
BP	Boomerang Point	SC	Solitario Canyon
BR	Bow Ridge	SD	Sundance
CF	Crater Flat	SR	Stagecoach Road
DW	Dune Wash	SW	Sever Wash
FW	Fatigue Wash	TDH	Teacup-Drill Hole Wash
GD	Ghost Dance	U	unnamed
IR	Iron Ridge	WW	Windy Wash
MWV	Midway Valley (buried fault)	YW	Yucca Wash

Figure 2-2. Index map of known and suspected Quaternary faults at and near Yucca Mountain. Simplified from Scott and Bonk (1984), F.W. Simonds (U.S. Geological Survey, written commun., 1995), and W.C. Day (U.S. Geological Survey, written commun., 1995).