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STATE OF NEVADA COMMENTS

ON THE

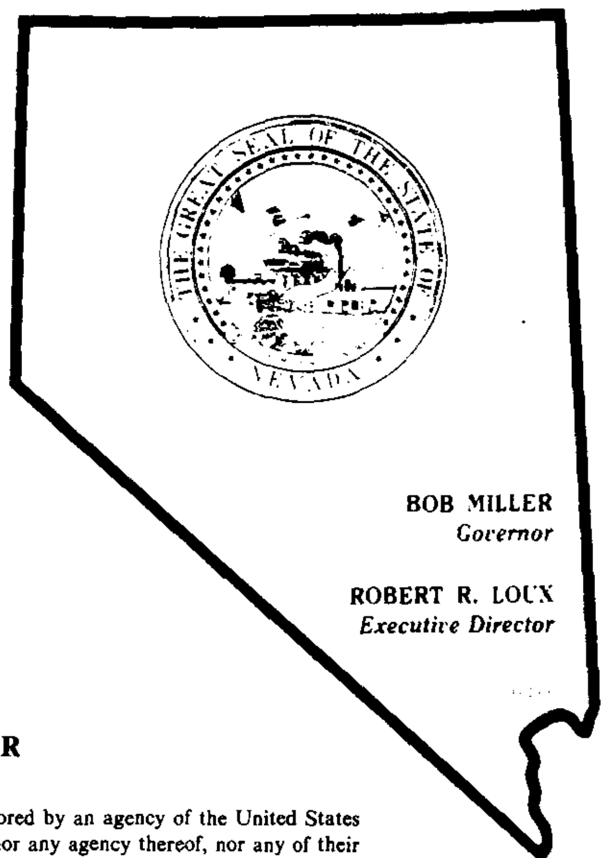
U.S. DEPARTMENT OF ENERGY

SITE CHARACTERIZATION PLAN

YUCCA MOUNTAIN SITE

NEVADA

VOLUME IV



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COMMENTS OF

CENTER FOR NEOTECTONIC STUDIES,

MACKAY SCHOOL OF MINES,

UNIVERSITY OF NEVADA - RENO

Critical Review
of the
Department of Energy's

Site Characterization Plan

by personnel of the

Yucca Mountain Project

in the

Center for Neotectonic Studies,

Seismological Laboratory,

and the

Nevada Bureau of Mines and Geology,

Mackay School of Mines

University of Nevada - Reno

June 30, 1989

Summary

by

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The following document comprises a critical evaluation of the DOE's Site Characterization Plan (SCP). The comments address a number of issues related to the scientific methods involved in the proposed procedures of site characterization, the suitability and integration of the methods, and the validity of the approach taken by the DOE in the context of the NRC regulations.

The SCP contains many improvements of the Draft Environmental Assessment (DEA) and the Environmental Assessment (EA), and fewer improvements of the SCP Consultation Draft. An obvious attempt has been made to address topics that were regarded in these previous reviews as deficiencies in the study program. For example, the activity and seismogenic potential of the Quaternary faults at Yucca Mountain are treated much more realsitically than originally proposed by the DOE, even though published data has not increased significantly since the DEA and EA were released. Water is now recognized as a resource, and faults and fault breccias are recognized as potential hosts for epithermal mineralization. There has, in addition, been considerable effort to incorporate a number of alternative conceptual models (involving both cross sections of Yucca Mountain and regional tectonic models) into the realm of tectonic hypotheses. There is a little doubt that the SCP proposes an exhaustive and wide-ranging scope of investigations for the purpose of site characterization, and that many of these investigations have been included by the DOE in response to critical reviews by external groups (such as the NRC and various State of Nevada agencies).

Nevertheless, there are a number of significant shortcomings in the SCP that, if not corrected, will surely render the attempt at site characterization poorly focused, inadequate, and far more time-consuming than planned by the DOE. Not least among these is the difficulty encountered in attempting a critical review of the Plan. The SCP, as was the case with the CDSCP, is overwhelmingly long, complicated, and confusing; so much so that it contains internal inconsistencies and contradictions, as well as fundamentally incorrect information. This is a view held by virtually every reviewer of the SCP in this document, and it belies the basic flaws of the SCP that form our major concerns. These are as follows.

1. **The SCP mistakenly approaches the problem of characterization as a purely engineering project rather than one of scientific nature, and yet many of the scientific questions require basic research programs using yet-to-be-developed and state-of-the-art methods.** In making this statement, we are assuming that, due to the

unprecedented nature of the problem at hand, site characterization and repository construction require more care than might be acceptable for less important structures. In particular, we assume that respository construction should not proceed based on unverified critical assumptions with the belief or hope that if any of these assumptions turn out to be incorrect, relatively simple or inexpensive modifications can be made to compensate for any changes required. Design and construction must at all critical points be based on verified knowledge.

Because of the above requirements it is necessary to obtain a high level understanding of both physical and chemical processes involved, a level which can only be obtained by a competent basic research effort to attack the major uncertainties relating to, for example, tectonics, earthquakes, volcanic activity, seismic site effects, and geotechnical behaviour of the rockmass and foundation materials. By all accounts, it appears that many critical problems will have to be approached with a basic research effort at the beginning of site characterization. That is, the basic knowledge about processes involved will have to be developed while the site characterization studies are carried out. Unfortunately, this means that in many cases site characterization activities will address the wrong issues or fail to address important issues. This could only be avoided if site characterization were driven by basic research programs and timetables, rather than by a schedule determined by political timetables.

The plethora of investigations proposed in the SCP represents a shotgun approach to the problem of site characterization. And yet the great number of investigations are largely unrelated, despite the fact that the SCP is littered with cross-references between studies, investigations, and activities. Cross-referencing does not by itself make an integrated project, and if ever there was a need for such an integrated approach it is surely the Yucca Mountain project. The approach of throwing technology at a problem in the hope of a correct answer falling out is, moreover, inefficient in terms of manpower and money. If carried out as planned, site characterization will be far more expensive and time-consuming than planned by the DOE. In this sense, the time-table is unrealistic.

The approach taken by the DOE appears to be driven by engineering concerns, and implicitly assumes that the scientific problems are essentially solved or can be easily solved. This is particulary apparent in the location of the various shafts and drifts. It appears that the requirements to best investigate the repository block have been usurped by the needs to position the shafts where they best serve the operational requirements of the repository.

The site characterization program is not geared toward the discovery of fatal flaws in the site. Rather it assumes no such flaws exist, and that given a reasonable amount of time and money the site will be characterized and ready for licensing.

2. **Results of probabilistic analyses will be of little value since the decision that enough relevant quality data has been acquired is wholly subjective.** In many instances, probabilistic analyses will ultimately yield the hard numbers required for engineering and design purposes. The validity of probabilistic analyses relies completely on the quality or accuracy of the data base and to some degree on its completeness. In the SCP the quality of the data and the judgment of its sufficiency (close enough to completeness) is to be judged by wholly unknown but apparently subjective procedures and unknown personnel. For example, Tables 8.3.1.8 - 1b and-2b relate tentative parameter goals (in terms of an exceedence probability) and their characterization parameter to the confidence in current and required estimates of the parameter. Levels of confidence are given as low, medium, or high. Nowhere is it stated what low, medium, or high actually means, or who makes the decision! The SCP states (p. 8.3.1.8. - 24):

> " . . . . the feasibility of planned or potential activities will be evaluated to determine if the activities will reasonably increase the level of confidence in the parameters that describe the process or not. If it is not feasible to increase the level of confidence, then no additional studies will be performed and the site performance will be evaluated on the basis of available data."

This approach represents a significant problem insofar as it allows DOE legitimately to halt studies when it suits the judgement of an unknown person using unknown criteria. Thus, site characterization will be dependent on the philosphies and methodology adopted by the DOE rather than by the investigation program outlined in the SCP.

3. **Probabilistic analyses rely on input data that is qualitative by nature and that is associated with errors of unknown magnitude. Therefore, the potential errors in the probabilistic analyses will be unknown.** Errors in the input data - where these data comprise observations, inferences, and interpretations about geological processes - are imprecisely known and can at best be estimated in subjective and qualitative terms. These unknown errors will necessarily carry through to the results of any probabilistic analyses, and yet this error is never discussed in the SCP. Further errors of unknown magnitude will be introduced by using an inadequate data base. The obvious example involves the analysis of seismic hazard. Seismic hazard analyses are critically dependent on the completeness of the seismic record. In this respect, instrumental seismic records are well known to be too short in virtually every tectonic environment, particularly in regions of continental deformation where both temporal and spatial clustering almost certainly occurs and where the temporal clustering may occur in "cycles" between hundreds and thousands of years. It is unclear if the proposed investigations in the SCP of regional Quaternary faults are detailed enough to provide enough qualitiy data for a seismic hazard analysis. In addition, the application of established seismic hazard analyses to a region of distributed deformation may not be appropriate. That is, for example, it may not be appropriate to consider the slip rate on any one fault for a

particular analysis but it may be better to consider the cumulative slip rate of a distributed set of faults.

Probabilistic seismic hazard analyses are still in the early stages of development and are being developed in very different tectonic environments from that of Yucca Mountain. The use of such analyses in the Yucca Mountain region represents a new and untested process. This view is not expressed in the SCP.

4. **The concept of the 10,000 year cumulative slip earthquake (CSE) is unacceptable.** This type of seismic source characterization is unconventional, unrealistic, misleading, and nonconservative. Prorating slip over a 10,000 year period creates artificial, watered-down earthquake size estimates; recall that the recurrence interval of some of the faults in and near Yucca Mountain may greatly exceed 10,000 years. Moreoever, the CSE is applied to only one fault at a time at Yucca Mountain, rather than to the collective suite of faults, which may be more appropriate. The concept of the CSE appears to be a vehicle for making sure that the controlling displacements on faults at or near Yucca Mountain are suitably low for DOE purposes.

5. **Regional studies are neglected or misunderstood. Geological interpretations of Yucca Mountain must be consistent with that of the region. Yucca Mountain can not be studied in isolation.** This is a further example of the engineering (rather than scientific) approach adopted in the SCP. Regional studies of deep inactive structures and, to a lesser extent, of potentially active regional structures are either completely missing from the SCP or inadequate in scope. Only regional studies can provide the background from which particular aspects of the geology of Yucca Mountain can be recognized as anomalous. This is particularly critical when evaluating, for example, the potential for hydrocarbons or mineralization at Yucca Mountain. Regional studies will also provide the data base necessary for an accurate seismic hazard analysis (see # 3).

6. **The Quaternary tectonics portions of the SCP do not address anticipated an unanticipated events.** These events are required by 10 CFR 60 to be defined and utilized in modeling repository performance. The 10 CFR 60 definitions of these terms seem to be straight-forward, but the SCP has avoided relating proposed investigations to these events.

7. **Who are the personnel responsible for the scientific work and decisions described in the SCP?** The SCP describes an enormous scope of work, yet no indication is given of the personnel responsible for it. In many cases, the necessary work involves state-of-the-art techniques and methodology (see #1) and involves basic research; the quality of this work will depend on the personnel performing and directing it. In addition, the decisions on whether enough quality data has been collected, or whether a process is sufficiently understood, is wholly dependent on the person who makes that decision. Is this person a DOE manager or a scientist?

Without knowing more about the personnel involved in directing the critical stages of research, the quality of the SCP is impossible to evaluate.

These seven points form our main criticisms, and represent the types of general comments which individual reviewers regarded as most significant. The remainder of the document contains a significantly larger number of comments, each significant but pertinent to particular aspects of the SCP.

TASK 1

SUMMARY
REVIEW OF SITE CHARACTERIZATION PLAN
YUCCA MOUNTAIN SITE

Task 1 Quaternary Tectonics Comments

Principal Investigator: John W. Bell
Co-investigators: Craig M. dePolo and Alan R. Ramelli

The Site Characterization Plan (SCP) outlines a very detailed program of study that addresses most, but not all, important Quaternary tectonics issues relevant to the suitability of the Yucca Mountain site. It covers most of the deficiencies previously noted in the Environmental Assessment (EA), and proposes studies of critical elements necessary for developing multiple tectonic models. Although the program as a whole addresses most of the important questions, the adequacy of specific studies is difficult to assess without the study plans, most of which have not yet been released.

The addition of tables outlining alternative hypotheses provides much needed clarification of the Department of Energy's (DOE) current preferred representations and their view of alternate possibilities. However, these tables were inserted into the SCP at the last minute in response to one of the Nuclear Regulatory Commission's (NRC) comments. They are thus poorly integrated with the rest of the document and require more detailed explanation and justification.

It is not clear that the proposed level of assessment will, or even can, be carried out due to either unrealistic schedules or DOE methodology. Schedules presented in the current (December, 1988) version of the SCP indicate that various aspects of the program that rely on specific studies will draw upon these studies at specified points in time. These milestones, usually placed at the issuance of draft reports, require rapid completion of some activities. Any delays in specific studies could delay dependent aspects. Also, any changes made subsequent to the draft reports could require changes in a whole sequence of related topics. The SCP outlines an extremely ambitious research program that would be difficult to accomplish, even in a realistic time frame.

The Quaternary tectonics portions of the SCP do not address anticipated and unanticipated events. These events are required by 10 CFR 60 to be defined and utilized in modeling repository performance. The 10 CFR 60 definitions of these terms seem to be straight-forward, but the SCP has avoided relating proposed investigations to these events.

There is an apparent conflict in approach of the SCP, based primarily on the interpretation of the existing data base. On the one hand, the SCP states in numerous places that the present tectonics data base is inadequate to fully assess the earthquake and volcanic hazards, while on the other hand there are numerous statements implying a low probability and rare occurrence of tectonic activity. The conflict arises because the position appears to have already been adopted that significant faulting has a low probability of occurrence, as it was in the EA.

We seriously object to the concept and use of the "10,000 year cumulative-slip earthquake." This is a specially defined event that incorrectly incorporates a predetermined level of risk into the earthquake hazard analysis. Instead, we recommend that a "maximum magnitude" or "maximum credible" earthquake be utilized. Based on existing data, the most likely "anticipated event" during the post-closure period is a magnitude 7+ earthquake occurring on Yucca Mountain faults. Use of the 10,000 year cumulative slip earthquake could greatly underestimate this potential.

The proposed studies of the local and regional Quaternary tectonics issues are fairly comprehensive, but there are some elements of these studies with which we have concerns:

- Although the Quaternary stratigraphic and geomorphic investigations are relatively detailed, the scale of mapping to be done in the site area is inadequate for delineating surficial geologic and fault relationships. A scale of 1:24,000 is planned; for a site investigation of this nature, the scale should be at least as large as 1:12,000.

- The studies planned for the tectonic relationships within the site area are extensive. However, some proposed goals appear to be unrealistic based on the level of uncertainty known to be associated with the collection of data of this nature. In addition, we are concerned that not enough emphasis has been placed on evaluating complex faulting (including volcanic) events, on young faulting along the Fatigue Wash fault, on strike-slip faulting, or on considering faulting and tectonics in the drilling program.

Finally, the comment is made in the SCP that, " . . . the feasibility of planned or potential activities will be evaluated to determine if the activities will reasonably increase the level of confidence in the parameters that describe the process or not. If it is not feasible to increase the level of confidence, then no additional studies will be performed and the site performance will be evaluated on the basis of available data." This approach could be used by DOE to suspend studies that they deem likely to provide unfavorable results, and suggests that DOE may still only be superficially addressing the technical data base. This potential problem is difficult to completely assess, but it suggests that site characterization may not necessarily revolve around the detailed investigation program outlined in the SCP, as much as it will be dependent upon the philosophies and methodologies adopted by the DOE.

REVIEW OF SITE CHARACTERIZATION PLAN YUCCA MOUNTAIN SITE

Task 1 Quaternary Tectonics Comments

Principal Investigator: John W. Bell
Co-investigators: Craig M. dePolo and Alan R. Ramelli

Introduction

The following comments are related to Quaternary tectonics issues contained in the current (December, 1988) version of the Site Characterization Plan (SCP) for the Yucca Mountain Site for a proposed high-level nuclear waste repository. The bulk of this review was originally submitted on the Consultation Draft of the SCP (CDSCP; January, 1988). The comments as presented here have been revised to reflect updates in the current version. The sections reviewed here focus on, but are not limited to:

Chapter 1 Geology
- 1.1 Geomorphology
- 1.2 Stratigraphy and Lithology
- 1.3 Structural Geology and Tectonics
- 1.4.2 Seismology of Yucca Mountain
- 1.5 Long-term Regional Stability with Respect to Tectonic and Geological Processes
- 1.8.1 Summary of Significant Results

Chapter 8 Site Characterization Program
- 8.3.1.6 Erosion
- 8.3.1.8 Post-closure Tectonics
- 8.3.1.17 Pre-closure Tectonics

Each section was reviewed by Task 1 for scientific credibility, applicability to the siting criteria for high-level nuclear waste repositories (10 CFR 60), and consistency with established and state-of-the-art knowledge in the area of Quaternary geology and active faulting. Unfortunately, it is difficult to completely evaluate the proposed characterization program in the absence of detailed study plans, most of which have not yet been released. Most proposed studies listed in the SCP present only a summary of the activities.

The current version of the SCP was reviewed for consistency with the CDSCP and to determine whether any of the original criticisms or concerns had been addressed. Most of the previous comments remain unchanged, but Quaternary tectonics issues in the SCP have been revised to include alternative conceptual models (ACM). Although this revision has not been comprehensively integrated into the text, being contained solely within the new series of ACM tables, it is regarded as a major concession by the Department of Energy (DOE). The full range of alternatives is still incomplete, some preferred models may be unrealistic, and much additional clarification or justification is needed, but several significant changes are evident. For example, the local tectonic model now has no preferred representation for fault geometry and mechanisms, or for fault pattern geometry (pp. 8.3.1.8-33, 36). Similarly, the regional tectonics model now has no preferred representation for regional faulting mechanism, or for frequency and distribution of events (pp. 8.3.1.8-41, 43).

This review begins with an overview of both the positive and negative aspects of the local and regional Quaternary tectonics and stratigraphy, and is then divided into segments which rank our comments on the basis of our level of concern: General Objections-- major disagreements or flaws; General Concerns-- Significant disagreements; and Specific Comments and Questions-- Remarks directed at specific statements in the SCP.

General Overview

On the positive side, the SCP outlines a very detailed scope of work for the site characterization phase which will address many Quaternary tectonics issues which were raised in earlier reviews of the 1984 Draft Environmental Assessment (Bell, 1985) and the 1986 Environmental Assessment (Bell, 1986). An obvious attempt has been made in the SCP to address topics which were regarded in these previous reviews as deficiencies in the study program; in fact, one is struck by the effort that has been made to include activities which are designed to satisfy our original concerns. For example, the activity and seismogenic potential of the Quaternary faults at Yucca Mountain are treated much more realistically than originally proposed by DOE, even though the published data base has not changed significantly since the DEA and EA were released. This suggests that the DOE has become more receptive to legitimate scientific concerns regarding the conceptualization of fault models for Yucca Mountain.

In addition, the list of proposed activities designed to assess pre- and post-closure tectonics issues is impressive. Although not completely addressing all of our present concerns, these proposed activities cover many of the major elements necessary for developing multiple tectonic models. The recognition of the need for modeling the linkage between the regional Walker Lane system, a possible detachment system, and the site-specific faulting, for example, indicates that consideration will probably be given to a range of models.

On the negative side, it is not clear that the proposed level of assessment will, or even can, be carried out due to either unrealistic characterization schedules or to DOE methodology. The revised time schedules now have shifted many of the milestones for the tectonics programs. These shifts effectively compress much of the work into the last part of the program, coming in some cases after the completion of the advanced conceptual design and after the initiation of, and well into, the license application design. The schedules indicate that various aspects of the program will draw upon specific studies at designated points in time. These points, usually placed at the issuance of draft reports, require rapid completion of some activities. Any delays in specific studies could delay dependent aspects. Also, any changes made subsequent to the draft reports could require changes in a whole sequence of related topics. The SCP outlines an extremely ambitious research program that would be difficult to accomplish, even in a realistic time frame.

In addition, there appears to be a question as to how the DOE intends to pursue the characterization program. The SCP, for example, states (p. 8.3.1.8-24):

> "... the feasibility of planned or potential activities will be evaluated to determine if the activities will reasonably increase the level of confidence in the parameters that describe the process or not. If it is not feasible to increase the level of confidence, then no additional studies will be performed and the site performance will be evaluated on the basis of available data."

This approach could be used by DOE to suspend studies that they deem likely to provide unfavorable results, and suggests that they may still only be superficially addressing the technical data base, as was done in the DEA and EA documents. This potential problem is difficult to completely assess, but it suggests that site characterization may not necessarily revolve around the detailed investigation program outlined in the SCP as much as it will be dependent upon the philosophies and methodologies adopted by the DOE. This is supported by the apparent conflict in scientific approach encountered in a number of places throughout the SCP.

Apparent Conflict in Approach

The SCP states in numerous places, in particular in Chapter 1, that the present tectonics data base is inadequate to fully assess the earthquake and volcanic hazards at Yucca Mountain (p. 1-5). This sort of disclaimer is consistently repeated:

> "The present tectonic model is a preestablished fault system in which recurrent Quaternary and some Holocene movement has been demonstrated and which is favorably oriented in the existing stress field for future movement ... The present data base allows some conclusions about locations and orientations, offsets, relative importance, and ages of movement of some of the faults at and near Yucca Mountain. However, it is insufficient to reliably gauge future tectonic effects on seismicity and on the hydrologic regime." (p. 1-340).

> "In general, additional work is necessary to better document the recurrent nature of faults near the site" (p. 1-206).

> "It is difficult to assess accurately the probability of faulting because little is known about expected earthquake magnitudes or the recurrence intervals and displacement for faults in the southern Great Basin, and at Yucca Mountain in particular ... Slip rates on seismogenic faults in the Great Basin are considered to be nonuniform in both space and time (Wallace, 1985)" (p. 1-207 & 1-208).

> "In determining the probability of faulting at Yucca Mountain, once sufficient paleoseismic data are available, it may not be correct to assume a uniform stress release model as a basis for probability calculations ... " (p. 1-208).

In contradiction to these disclaimers, there are numerous statements implying a low probability and rare occurrence of tectonic activity at Yucca Mountain throughout Chapters 1 and 8.

" An outline of our current perception of the effects from faulting is presented in DOE (1986) and summarized here. It appears unlikely that faulting would lead to radionuclide releases to the accessible environment during the first 10,000 yr following closure of the repository" (p. 1-207).

" Even if new fractures formed, they are not expected to significantly alter ground water flow conditions because the area already is strongly fractured" (p. 1-207).

" Because these faults (such as the Windy Wash and Paintbrush Canyon) have very low slip rates, it is anticipated that the demonstration can be made that the occurrence of 5 cm of displacement in 1,000 yr on even these longer, more significant faults is a very low probability event" (p. 8.3.1.8-27).

" During the Quaternary, tectonic and volcanic processes in the Yucca Mountain area have included . . . slow (less than 3 cm/1000 yr) relative vertical tectonic adjustment . . . The effect of these intermittent and localized constructional processes on the late Quaternary landscape of the Yucca Mountain area has been limited . . . Comparable tectonic and volcanic activity over the next 10,000 yr would likely induce a comparably limited effect on the (late Quaternary) landscape of the Yucca Mountain area" (p. 1-30).

" Quaternary deposits are offset or fractured by 32 faults in the 1,100 km^2 area . . . 23 of them moved 1.2 to 2 million yr ago, four of them about 1 million yr ago, and at least five of them during the past 270,000 yr" (p. 1-128)

" If the average offset per event (on the Windy Wash fault) was about 10 cm, each event had a magnitude (Ms) of about 6 to 6.5 . . . The rate of offset averaged over the past 270,000 yr has been about 0.0015 mm/yr which is "extremely low" in the classification scheme of Slemmons and dePolo (1986)" (p. 1-132 & 1-133).

" The (Solitario Canyon) fault shows no evidence of movement during the past 270,000 yr but does show evidence of movement about 1.2 million yr ago" (p. 1-133).

" Considering the length and nature of this (Paintbrush Canyon) fault, it could have been the source of moderate earthquakes (M 6.5) in the past, although such events would appear to be rare based on the low rate of movement" (p. 8.3.1.17-30).

" . . . the annual probability for the controlling earthquake is expected to be low (less than about 10^{-4}, assuming the Paintbrush Canyon fault is controlling) . . . (p. 8.3.1.17-37).

This conflict arises because the impression is given that the position has already been adopted that significant faulting has a low probability of occurrence, as it was in the EA. One could easily speculate that this dichotomy is one based on the different approaches taken by the USGS and the DOE.

Local Quaternary Tectonic Studies

For the most part, the program outlined in the SCP for evaluation of local tectonics is quite extensive and describes lofty goals. This program calls for collection of an enormous amount of information. As outlined in sections 8.3.1.17.4.6.1 Activity: "Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain" and 8.3.1.17.4.6.2 Activity: "Evaluate age and recurrence of movement on suspected and known Quaternary faults", the "parameters" to be obtained in order to evaluate local tectonics include;

* Length, location, and spatial orientation of faults
* Segmentation within individual faults
* Width of faults
* Age and nature of Quaternary deposits and Quaternary surfaces displaced by or covering Quaternary faults within the site area
* Location, amount, and direction of displacement of Quaternary deposits and Quaternary surfaces
* Age, lateral extent, and height of fault scarps
* Age of soils overlapping or displaced by faults
* Age of volcanic ashes intercalated in surficial deposits that overlap or are displaced by faults, or that have filled fissures within the fault zones

This information is to be obtained primarily through Quaternary mapping, exploratory trenching, and associated dating of Quaternary materials. We consider this to be an appropriate approach, but feel that it is not made clear that these goals can be reasonably achieved. Several of these issues involve data that are not easy to obtain and that usually have fair to high levels of uncertainty (e.g., age estimates, strike-slip displacements, locations and orientations of buried faults, ages of compound fault scarps). In particular, given the complex, anastomosing nature of the Yucca Mountain fault system, we do not believe it will be possible to make an adequate interpretation of fault segmentation, at least with regard to discrete rupture segments. It is not made clear in the SCP that these problems are appreciated, nor how uncertainties will be incorporated.

<u>Regional Quaternary Tectonics Studies</u>

We feel the SCP correctly assesses the need for and relative importance of regional Quaternary tectonics studies:

> "The first important object of the tectonic studies is to describe the location, nature, amount, and probability of potential fault movement at the proposed Yucca Mountain repository. Accomplishing this requires integrating results from regional and site-specific studies. Among the required data will be 1) slip rates and recurrence rates of movements on Quaternary faults, 2) probability of future faulting on different styles of faults, 3) character of the regional stress field, and 4) probabilities from the tectonic scenarios" (p. 1-349 & 1-350).

The proposed regional tectonics data collection program is described in the pre-closure tectonics section 8.3.1.17.4. Geological and geophysical evidence of large-scale

Quaternary faulting within 100 km of the site will be assessed in order to determine the potential for fault displacement that could affect repository design or performance. The activities planned for site characterization include:

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

* Evaluate Quaternary faults within 100 km of Yucca Mountain

* Evaluate the Cedar Mountain earthquake of 1932 and its bearing on wrench tectonics of the Walker Lane within 100 km of the site

* Evaluate the Bare Mountain fault zone

* Evaluate structural domains and characterize the Yucca Mountain region with respect to regional patterns of faults and fractures

* (Evaluate) Quaternary faulting proximal to the site within northeast-trending fault zones

* (Evaluate) detachment faults at or proximal to Yucca Mountain

Based on the principle that the regional studies should be relevant to the design and performance of the repository, we endorse the activities listed above; we are, however, somewhat concerned with some of the planned sub-activities based either on relevance or on level of detail. Given the apparent schedule constraints and resource limitations, and the fact that some additional studies in the site area are lacking, we are not certain that the levels of detail proposed for all of these regional activities are necessary.

Quaternary Geology Studies

Quaternary stratigraphic and geomorphic studies are critical for constraining the recency and frequency of faulting at Yucca Mountain; discussions of the approach and planned activities are given in Chapter 1 and in section 8.3.1.17.4 of the pre-closure tectonics investigations in Chapter 8. Separate studies are planned for the surface facilities area in Midway Valley (section 8.3.1.17.4.2) and for the site area as a whole (section 8.3.1.17.4.6).

The activities outlined for Midway Valley appear consistent with the level of detail necessary for delineating fault activity critical to the surface handling facility. These activities include mapping surficial deposits at 1:5,000-scale, differentiating and trenching Quaternary faults, and identifying those faults that have Quaternary slip rates exceeding 0.001 mm/yr or that measurably offset materials less than 100,000 yr old.

The Quaternary geology studies for the site area are contained within the investigations designed to identify and characterize Quaternary faults that either intersect the repository or that have a potential for generating ground shaking that could impact design or performance of the repository. Planned activities (Activities 8.3.1.17.4.6.1 & 8.3.1.17.4.6.2) include:

* Mapping surficial deposits of Yucca Mountain

* Compiling a Quaternary fault map of Yucca Mountain

* Mapping and analysis of offset of Quaternary datums in trenches and outcrop for the Paintbrush Canyon, Bow Ridge, Windy Wash, Ghost Dance, and Solitario Canyon faults

* Conducting uranium-trend, uranium-series, and rock varnish cation ratio dating of Quaternary deposits

* Analyzing Quaternary volcanic ash

The outlined study program is comprehensive in that it addresses all areas of major importance, but we are concerned that the level of detail may not be totally adequate for the Quaternary stratigraphic framework, or the scale of surficial and Quaternary fault maps. We also object to the lack of attention given to the Fatigue Wash fault.

Probabilistic Studies

Probabilistic analyses need to be used carefully and appropriately, and not be used to either mask a lack of data or in lieu of gathering additional data. We have serious concerns regarding the arbitrary use of data in probabilistic studies. In particular, we object to the concept and use of the "10,000 year cumulative slip earthquake," a specially "designed" earthquake unique to the Yucca Mountain site investigation. This earthquake was originally referred to as the "exceptional earthquake" in an earlier (August, 1987) version of the SCP, but this term has now been removed from nearly all parts of the current version of the SCP.

The Quaternary tectonics portions of the SCP do not address anticipated and unanticipated events. These events are required by 10 CFR 60 to be defined and utilized in modeling repository performance. The 10 CFR 60 definitions of these terms appear to be straight-forward, but the SCP appears to have avoided relating any proposed investigations to these events; in particular, there is no indication as to how the probabilistic assessments will contribute to identifying these events.

Alternative Conceptual Models

The DOE has responded in an ambitious and significant manner to the Nuclear Regulatory Commission (NRC) request to provide complete listing of alternative conceptual models (ACM's). Four tables outline the current DOE position on preferred and alternative hypotheses:

Table 8.3.1.8-7 Local model for postclosure tectonics;
Table 8.3.1.8-8 Regional model for postclosure tectonics;
Table 8.3.1.17-7 Local model for preclosure tectonics;
Table 8.3.1.17-8 Regional model for preclosure tectonics.

These tables are the principal new additions to the SCP.

Although the ACM tables provide much needed clarification of several issues and of DOE positions, they were interjected into the SCP at the last minute in an attempt to satisfy NRC's request. There has thus been little or no outside review of, or input into, the various issues as outlined. Because the ACM tables are new and unreviewed, there are a number of cases of incomplete listing of ACM's, internal inconsistencies, and/or flawed logic. Also, many of the positions presented require more extensive discussion and justification than can be provided in table form. If backing statements are included elsewhere in the SCP, the ACM tables should include references to appropriate sections.

Comments on Alternative Hypotheses Tables

Table 8.3.1.8-7 Postclosure Tectonics ACM's (local model)

Additional Alternative Hypotheses Needed

Model element	Additional alternative hypotheses
Faulting rates	Slip rates could be higher because of high degrees of uncertainty and errors in methods of age-estimation (Swadley and others, 1988; Rosholt and others, 1988; Dorn and others, 1988)
Fault rupture pattern	The north-trending faults move in response to transitory stress changes induced by basaltic intrusion
Rate of volcanism	Differences in volumes of Plio-Quaternary basalts are insignificant. The 3 m.y. cycle has a greater volume than the 1 m.y. cycle, but the present cycle (Lathrop Wells cone) is not complete, so its total volume is unknown.

Additional Discussion and/or Justification Needed

Driving forces/processes

A low level of uncertainty is indicated for the preferred model of mechanically driven processes, as opposed to thermally driven processes or a combination of the two. Does the indication that existing data support the preferred model imply no data exist that are at least suggestive of thermally driven processes? Or are certain data being selectively used to support the preferred model? This is one of the better examples of the need for additional discussion and/or justification.

Effects on groundwater flow (volcanic or igneous effects)

Justification for low uncertainty in the current estimate and the need to reduce uncertainty is based solely on arguments of time needed to develope thermal effects; it does not address the "physical barriers" aspect of the alternative hypothesis, which could change during a single eruptive episode.

Effects on groundwater flow (tectonic effects/flux rates)

Comment that " . . . subsurface effects due to faulting...are not likely to be great enough to influence flux rates" indicates a high level of understanding of potential for changes in pathways along fault zones. What studies have been accomplished to achieve this level of confidence?

Effects on groundwater flow (tectonic effects/fracture properties)

Fracture dilation could occur over a matter of a few seconds during a faulting event. Is this recognized? (Related to above comment).

Table 8.3.1.8-8 Postclosure Tectonics ACM's (regional model)

Additional Discussion and/or Justification Needed

Physical domain

The justification, "regional processes outside model domain unlikely to affect site design or performance," is used to argue for a low uncertainty in the current estimate. This type of logic should be reserved for the "Need to reduce uncertainty," because it says nothing about the actual validity or correctness of the model.

Driving forces/processes

Same comment as for Table 8.3.1.8-7.

Internal Contradictions

For the model element "Distribution of volcanism" (p. 8.3.1.8-45), the Death Valley - Pancake Range zone (DVPRZ) is interpreted in the current representation as "a significant feature controlling the occurrence of volcanism in the domain," but for other model elements (System geometry and Nature of volcanism), the DVPRZ is not included in current representations. If the DVPRZ is not thought to have a thermal effect on the crust (incipient rift), what is its significance thought to be for distribution of volcanism?

Table 8.3.1.17-7 Preclosure Tectonics ACM's (local model)

Additional Alternative Conceptual Models Needed

Model element	Add'l Alternative hypotheses
Faulting rates	Same as for Table 8.3.1.8-7
Faulting rupture pattern	Same as for Table 8.3.1.8-7
Distribution of seismic potential	Local earthquakes are potentially complex, large magnitude events that involve crustal penetrating structures and multiple faults in the shallow crust, and would overshadow the interpretation of "moderate" local events.

Additional Discussion and/or Justification Needed

Driving forces/processes
Same comment as for Table 8.3.1.8-7.

Table 8.3.1.17-8 Preclosure Tectonics ACM's (regional model)

Additional Discussion and/or Justification Needed

Physical Domain
Same comment as for Table 8.3.1.8-8.

Driving forces/processes
Same comment as for Table 8.3.1.8-7.

General Objection

Objection 10,000 Year Cumulative Slip Earthquake

The concept and use of the 10,000 year cumulative slip earthquake are unacceptable. This type of seismic source characterization is unconventional, unrealistic, misleading, and nonconservative. Prorating slip over a 10,000 year period creates artificial, watered-down earthquake size estimates. This is an attempt to incorporate a risk factor into estimates of seismic sources, which we consider an inappropriate approach. For such a critical facility, the widely used and accepted maximum or maximum credible earthquake methodology would be preferable to the proposed 10,000 year cumulative slip earthquake. The use of other conventional methodologies (e.g., estimating characteristic earthquakes) may also be acceptable.

As defined in the SCP, the 10,000 year cumulative slip earthquake is "an earthquake that, occurring every 10,000 years, would produce the observed or estimated average Quaternary slip rate on a fault." It is proposed to use this type of estimate in seismic design for the preclosure period. Although it is not explicitly stated as being used for the postclosure period, it is quite implicit (e.g., Table 8.3.1.8-2(b), p. 8.3.1.8-8, Tentative parameter goal - "Annual probability less than 10^{-4} of faulting with displacement over 5 cm" and Activity 8.3.1.8.3.1.3, p. 8.3.1.8-84, " . . . cumulative offset in 10,000 yr."

The 10,000 year cumulative slip earthquake is considered to be an attempt to combine deterministic and probablistic hazard analyses. It is stated to be a deterministic method, because it provides an estimate of a specified magnitude for a specified seismic source. However, it incorporates a probabilistic aspect in that it downgrades the expected event size in consideration of the (perceived) infrequency of event occurrence.

The SCP presents three arguments in support of the 10,000 year cumulative slip earthquake that will be addressed here:

First, the SCP states that the 10,000 year event "can be determined with greater confidence than a true maximum magnitude" p. 8.3.1.17-36). This is incorrect, because additional input parameters and associated uncertainties are involved in the estimation of the 10,000 year event as compared to a maximum earthquake estimate. There are considerable uncertainties associated with the estimation of ages and displacements, which are used to produce the 10,000 year cumulative slip earthquake. By necessity, experimental dating techniques are used in estimation of ages of Quaternary deposits and surfaces. The reliabilities of these techniques have not yet been firmly established. Preliminary work using soils development and radiocarbon rock varnish dating suggests that ages may currently be grossly overestimated (Peterson, 1988; Dorn and others, 1988). Uncertainties in estimates of displacement are also quite large, due to an undetermined contribution from lateral slip. Displacement uncertainties will affect any methodology used, but the 10,000 year cumulative slip earthquake is particularly sensitive to variations in slip estimates, as its name implies.

The 10,000 year event methodology does not include theoretical or practical concepts of characteristic earthquakes (i.e., events to occur in the future will be similar to those seen in the geologic record). We feel that these uncertainties are greater than the data and procedures used in conventional deterministic analyses of maximum earthquakes for known sources.

The SCP states (p. 8.3.1.17-36):

> "Because large earthquakes occur infrequently, few observational data are available for calibrating the maximum seismogenic potential of individual faults. This is particularly true for faults of the type found in the southern Great Basin, where recurrence intervals for large earthquakes appear to range from about 10,000 to 100,000 yr. Therefore, conventional methods for determining maximum earthquake magnitudes from the physical characteristics of local faults appear to be subject to larger uncertainties than for the more active faults associated with plate motions."

Conventional methods may have larger uncertainties in analyzing faults with longer recurrence intervals relative to plate margin faults, but this has little bearing on what kind of seismic hazard analysis should be conducted for the Yucca Mountain facilities. Recent research has shown that short-term slip rates and recurrence intervals are greatly different than long-term behavior for some faults. For example, the Meers fault in Oklahoma has been the site of multiple large late Holocene earthquakes, despite very low long-term average rates (Swan, 1989). The evidence of Holocene activity at Yucca Mountain may be more significant than the low long-term rates.

Second, the SCP states, "low slip rates suggest that the use of fault length or displacement to develop deterministic estimates of magnitude for a given fault are misleading . . . " (p. 8.3.1.17-72). As discussed above, the analysis of faults with low slip rates (or longer recurrence intervals) may incur larger uncertainties, but this does not render the analysis meaningless or "misleading." Recent studies suggest that faults with lower slip rates may be associated with earthquakes of higher stress drops and moments, (Kanamori and Allen, 1986; Cao and Aki, 1986). Thus, prudent and conservative deterministic and probabilistic analyses may be even more appropriate for faults in the Yucca Mountain region.

Third, the SCP states that, "Use of slip rate data (to constrain recurrence times) in conjunction with more conventional fault data provides added assurance that adequately conservative assessments of the local seismogenic potential will be accomplished" (p. 8.3.1.17-36). This is a somewhat fuzzy statement, but it is assumed in this review that "adequately conservative assessments" implies that the use of maximum earthquakes is overly conservative.

The 10,000 year event is considered nonconservative for two additional reasons. First, slip rates can and do vary through time. Recent work has shown that fault activity in the Basin and Range province and other regions commonly exhibits spatial and temporal clustering of events (Wallace, 1985; Pearthree and Wallace, 1988). Averages and recurrence intervals over short-term periods (e.g., 10 ka) can be greatly different than those over the long term. For example, an order-of-magnitude difference in slip rate on the Windy Wash fault can be estimated by using data presented in the SCP (Table 1-8). From these data, a slip rate of 0.002 mm/yr would be estimated for the last 270,000 years, while the slip rate over the last 3,000 to 6,500 years would be estimated at 0.015 to 0.033 mm/yr. It should be noted that either or both of these estimates could be low if there is a significant component of strike-slip displacement or if age-estimates are in error. Although it is not specifically spelled out in the SCP, it is presumed that, whenever possible, long-term averages will be used in the 10,000 year event estimation. The evidence for Holocene activity may indicate that Yucca Mountain is currently within a more active cycle than long-term rates would suggest.

Also, the 10,000 year cumulative slip earthquake methodology treats only single fault ruptures, whereas evidence exists for complex rupture of multiple faults at Yucca Mountain (Ramelli and others, 1988). Most large historical Basin and Range earthquakes have involved several faults, rather than a single, discrete fault. A seismic source estimation of a single fault, such as the Paintbrush Canyon fault, may significantly underestimate potential seismic hazards.

> Note on Sample Calculation of 10,000 year event In the sample calculation (p. 8.3.1.17-73), an estimated magnitude of 6.6 is derived for a 10,000 year cumulative slip earthquake. Using the figures and assumptions presented in this calculation, magnitude values can be estimated for various recurrence intervals (assuming uniform behavior). For a recurrence interval of 70,000 years, average slip per event would be 0.72 m (maximum 2.16 m), and a magnitude 7.2 would be estimated, using the same relation from Bonilla and others (1984). If such a "characteristic" event were to occur, its magnitude could be expected to exceed the 10,000 yr cumulative slip event by more than 1/2 of a magnitude.

The artifical nature of the 10,000 year cumulative slip earthquake will make it difficult or impossible to accurately estimate the uncertainty or conservatism of the estimate. Maximum or characteristic earthquake analyses are direct methods, and uncertainties can be incorporated into the analysis. Considering different earthquake scenarios, the sensitivities of input parameters can be judged and more meaningful estimates of conservatism can be made.

In short, the 10,000 year cumulative slip earthquake is felt to be a nonconservative estimate for seismic hazard considerations of facilities important to safety.

A seismic source analysis of the site should include deterministic maximum, maximum credible, and/or characteristic earthquake estimates for the known and speculated sources and probabilistic maximum or maximum credible earthquake estimates to represent unknown and new faults. Multiple estimation methods and uncertainties should be utilized to understand the sensitivity and conservatism of the estimates. Nevada's historical earthquake record also needs to be considered in the analysis. For example, several similarities have been noted between the Yucca Mountain and the Cedar Mountain areas, suggesting a 1932 Cedar Mountain type of event should be considered in the seismic analysis (Bell, 1985; Bell and others, 1987). The 1932 Cedar Mountain earthquake was a complicated, multiple fault event, yielding an $M_s = 7.2$.

The NRC has expressed they believe the use of Appendix A of 10 CFR Part 100 for the period through permanent closure is conservative and appropriate (Trapp and Coplan, 1986). Trapp and Coplan comment that, "Appendix A of 10CFR100 has become a standard against which nuclear facilities other than power plants have been evaluated." Two of the projects reviewed by NRC are the Independent Spent Fuel Storage facilities and the proposed Monitored Retrievable Storage facility. These facilities are regulated by 10 CFR Part 72, which states "west of the Rocky Mountain front (west of approximately 104° west longtitude), and in other areas of known potential seismic activity, seismicity will be evaluated by the techniques of Appendix A of Part 100 of this chapter (10 CFR 100)." Appendix A calls for "determining the earthquakes of greatest magnitude related to the faults." This is also supportive of using maximum or maximum credible earthquakes in the seismic considerations for Yucca Mountain.

The Yucca Mountain site lies within a tectonically active area, with many potential seismogenic sources lying immediately adjacent to it. A consequence of this is that conventional maximum or maximum credible earthquake analyses would yield high seismic design values for this site. High design values are viewed as appropriately characterizing the site, rather than being overly conservative. The seismic hazards of the site need to be characterized correctly, similar to other critical facilities located in areas with numerous local, capable faults. The 10,000 year cumulative slip earthquake falls far short of that goal.

General Concerns

Concern Consideration of complex faulting events

Considerations of disruptive scenarios involving faulting generally consider the possibility of rupture along only a single fault. This applies to analyses of both ground motion and rupture of waste packages. The possibility of complex events, with distributed rupture on multiple faults is not adequately considered, even though existing evidence indicates this may have occurred in the past. Evidence from Yucca Mountain (basaltic ash in fault fractures and close spacing [< 2 km] of surface faults) suggests an intimate interrelationship between the surface faults and emplacement structures of the Crater Flat basalts/Lathrop Wells Cone. Combined with observations of historical earthquakes in the Basin and Range, this indicates that complex events are quite possible. Faulting at Yucca Mountain might involve rifting and dike intrusion in the lower- to mid-crust, with extrusion of basalts and/or distributed rupture across several faults in the upper-crust and at the surface. Rupture of multiple structures could produce large magnitude events. Failure to allow for this could cause the effects of seismic events to be seriously underestimated.

Applicable sections:
8.3.1.8; p. 8.3.1.8-27; . . . a throughgoing fault . . .
8.3.1.8.2.1.2 Activity: . . . packages intersected by a fault . . .
8.3.1.8.2.1.4 Activity: . . . package rupture due to faulting . . .
8.3.5.13 Item 2) . . . selection of release-scenario classes . . .
Applicable tables:
8.3.1.8-2(b); p. 8.3.1.8-7 Number of waste packages . . .
8.3.5.13-1. Potentially significant scenarios

Concern Study of the Fatigue Wash fault

In the SCP, both discussions and plans for study of north-south trending faults in the site vicinity usually refer to the Paintbrush Canyon, Bow Ridge, Solitario Canyon, and Windy Wash faults. Mention is rarely made of the Fatigue Wash fault. This fault has geomorphic expression similar to the others, and it is an integral part of the complex fault system at Yucca Mountain. Due to the anastomosing nature of this system, inferring extensions of individual faults can be very subjective. For example, the fault trace cut by trench CF-1 could more reasonably be called the Fatigue Wash fault than the Windy Wash fault, as has been done. The Fatigue Wash fault is an integral part of this system, but it has not yet been studied. While this fault will probably not control design parameters for the initial waste emplacement area, it bounds one of the principal areas considered in early discussions of expansion areas (Environmental Assessment).

For example:
p. 8.3.1.17-28 Review of local tectonic environment
Section 8.3.1.17.4.6.2 Activity: Evaluate age and recurrence . . .

Concern Strike-slip displacements

Even though it is acknowledged in the SCP (p. 8.3.1.17-30, paragraph 1) that strike-slip displacements on some of the Quaternary faults can not yet be ruled out, all estimates of displacements and slip rates are based solely on vertical displacements. In fact, strike-slip displacement is implied to be insignificant (p. 8.3.1.17-58; Technical rationale for investigation) even if it exists.

Although no direct evidence of strike-slip displacement has been recognized, at least some circumstantial evidence has been observed (e.g., patterns of faults exposed in trenches along the Windy Wash and the Bow Ridge faults, and focal mechanisms derived from regional earthquakes). For any faults that have a significant amount of Quaternary strike-slip displacement, the observed vertical displacements could be considerably less than the net displacement. Since so much is being based on slip rates, failing to account for strike-slip displacements could result in greatly underestimated magnitudes and displacements through waste packages.

Concern Seismic hazard of the Paintbrush Canyon fault

The SCP states (p. 8.3.1.17-37) that the Paintbrush Canyon fault "capable of producing a moderate earthquake (M about 6.5) with a recurrence interval greater than ten thousand years." Selecting a magnitude prior to investigations is a premature and extremely nonconservative approach. A magnitude 6.5 earthquake is on the order of a random earthquake for the Basin and Range Province, and could occur nearly anywhere in this province, regardless of the specific tectonic setting. Based on what we know of the Yucca Mountain site faults, and the historical earthquake record of Nevada, larger earthquakes should be anticipated.

Several moderate-sized historical earthquakes in the Basin and Range Province have produced limited surface rupture and fracturing (e.g. 1934 Excelsior Mountains, 1935 Helena, 1948 Verdi, 1966 Boca Valley, 1980 Mammoth Lakes earthquakes). The 1986 Chalfant earthquake was an $M_L = 6.4$ event and occurred on a secondary or splay fault that does not have a clear surface expression. Surface fracturing from this earthquake was scattered over a wide area, was on the order of a millimeter to a few centimeters, and is already poorly preserved. The historical record suggests that a moderate earthquake (magnitude 6 to 6 ½) should be considered as a floating or random earthquake, which can occur on secondary as well as main faults.

The second part of this statement regarding the recurrence interval of a moderate event, is misleading because the data are too incomplete to determine this.

Concern Uncertainties of values used in risk assessment

Throughout the SCP, there is considerable emphasis placed on the precise determination of various parameters that can not be estimated without considerable uncertainty. For example, it is intended to use slip-rate values to define earthquake hazards. Slip rates normally have a great deal of inherent uncertainty, due to such factors as paucity of datable materials or geomorphic features, the combined uncertainties of age-estimates of Quaternary materials, age-bracketing as opposed to direct age-estimates, and unknown amounts of strike-slip displacement. It is not made clear that this problem is understood and how these uncertainties will be conservatively dealt with. Another example; it is stated that determining displacement on faults in the subsurface will be "nearly impossible" (Sec. 8.3.1.17.2.1.2), but plans call for identification of faults in the subsurface with a "probability of greater than 10^{-4} for displacing more than 7 cm" (e.g., p. 8.3.1.17-34). In the "current estimates" it is evident that values will be assumed to meet the desired goals, unless demonstrated otherwise. It thus appears that when data are "nearly impossible" to obtain, values will be assumed to be favorable.

Levels of uncertainty should be clearly stated and carried through into estimates that rely on data with large uncertainties.

Concern Estimation of annual probabilities

The SCP estimates annual probabilities of seismic events on given faults by inverting the estimated recurrence intervals (p. 8.3.1.17-37). These probability estimations are misleading for several reasons: they do not account for the elapsed time since the last event; they do not consider uncertainties in the estimates; they do not include a sophisticated examination of the earthquake history of the source (e.g., if the most recent event on a fault was smaller than previous events, this event may have released only part of the stress); and they do not consider a random probability of earthquake clustering and contageous interactions with other faults.

The estimates and procedure of estimating annual probabilities used in the SCP are misleading and inappropriate for use in analyses or decisions.

Concern Probability "precedent" from nuclear power plants

The SCP states on p. 8.3.1.17-35 that:

> "An important precedent is provided by nuclear power plants where annual probabilities for exceeding the design-basis motions have been found to be on the order of 10^{-3}/yr to 10^{-4}/yr for several operating plants (Reiter and Jackson, 1983)."

It is important to place this "precedent" in context. The broad range of "on the order of 10^{-3}/yr to 10-4/yr" corresponds to the estimated return periods of probabilistically derived spectra which are similar to spectra derived using Appendix A of 10 CFR Part 100 for several nuclear power plants (Reiter and Jackson, 1983; L. Reiter, 1988, pers. comm.). These plants are located in the central and eastern United States, were constructed before the implimentation of Appendix A, and were undergoing reanalysis for seismic hazards. Reiter and Jackson (1983) report these values as "implicitly accepted by NRC in recent licensing decisions," because these values correspond to the Appendix A type analysis for these facilities. The final review memorandum contained in Reiter and Jackson (1983) states, "Application of this study and its review recommendations to other sites or other programs should be examined on a case by case basis." Thus this report is not meant as an ubiquitous precedent for nuclear power plants and facilities.

Significant differences exist between these central and eastern United States sites and the Yucca Mountain site. The Yucca Mountain site has several capable faults in the immediate area, and a similar analysis would probably yield greater corresponding return periods (lower corresponding annual probabilities).

The SCP also appears to misuse this broad range of annual probabilities in subsequent citations. The term "on the order of 10^{-3}/yr to 10^{-4}/yr" is a fuzzy range, and it means the actual values reviewed may have been a little higher or lower than the reported values (L. Reiter, 1988, pers. comm.). The SCP uses this range, however, rigidly defining goals, decisions, and estimations of conservatism.

Concern Quaternary stratigraphy

The stratigraphic scheme of Swadley and others (1984) will be used for mapping surficial deposits (section 1.2.2.3, and p. 8.3.1.17-94). As discussed in previous reviews of the DEA and EA, this scheme is not entirely adequate for delineating surficial deposits in the degree of detail necessary for constraining timing of fault activity. The results of the study by Whitney and others (1986) on the Windy Wash fault and our on-going soil-geomorphic studies in Crater Flat also support this conclusion; the stratigraphic sequence may be adequate for mapping on a regional scale, but the late Quaternary stratigraphic relationships of Yucca Mountain are sufficiently complex to warrant a more detailed scheme for site investigation purposes. A scheme should be used which subdivides and further defines Swadley and others' units into finer divisions commensurate with the level of present knowledge.

Concern Scale of mapping

The scale of mapping proposed for the site area does not appear to be adequate for delineating and constraining Quaternary fault activity. Section 8.3.1.17.4.6.1 indicates that the surficial deposits and Quaternary faults will be mapped at a scale of 1:24,000 for the site area (91 mi^2). Our concern is that this scale is not adequate for a site investigation of this nature; a scale of 1:24,000 is considered to be a reconnaissance level. At a minimum, the scale for mapping in the site area should be 1:12,000. The original bedrock mapping of the site area by Scott and Bonk (1984) is 1:12,000, and there is now complete 1:12,000-scale aerial photography available for the site area. Consequently, the surficial and Quaternary fault mapping should be integrated with the mapping of Scott and Bonk (1984) so that a comprehensive, detailed geologic map of the site area can be produced.

Similarly, the scale of the Quaternary fault map for the site area should be large scale so that subtle details of fault and related fracture patterns are displayed. The ability to analyze detailed fault patterns is particularly important in interpreting the evidence for strike-slip faulting.

Concern Cane Springs fault zone

Studies of northeast-trending fault zones proximal to the site are necessary for constraining the recency and recurrence of activity of these structures in that they are regarded as conjugate features within a northwest-trending Walker Lane system. As they relate to characterizing the faults at the site, however, we regard the Rock Valley and Mine Mountain fault zones as the most important, and the Cane Springs fault zone as less important. The Rock Valley and Mine Mountain fault zones appear to be structurally linked to the Yucca Mountain fault system, whereas the Cane Springs fault zone is once-removed from this system. The detailed surficial geology studies planned for the Cane Springs fault zone could be reduced, especially if they are at the expense of additional work needed on the local fault systems.

Concern Detachment faults

An evaluation of the presence of detachment faults at and proximal to Yucca Mountain is proposed because detachment faults could represent a significant seismogenic source or they could conceal a significant seismogenic source at depth (p. 8.1.3.17-144). We agree in general with the need for detachment fault studies, but are somewhat concerned with the level of detailed studies planned on a regional basis. The question of a detachment fault beneath Yucca Mountain may have limited significance as far as seismogenic sources are concerned. The presence of Quaternary basalts in the area indicates the existence of crustal-penetrating structures.

We are concerned somewhat with the level of detailed bedrock mapping planned for the Paleozoic and Tertiary rocks in the Beatty, Specter Range, Camp Desert Rock, and Sheep Range areas, and the extensive age dating planned for the Amargosa Desert core complex. The level of effort placed on these activities appears rather ambitious given the data necessary for delineating the presence of a regional detachment fault.

The presence or absence of a detachment fault beneath Yucca Mountain is important for modeling fault geometry and tectonic interrelationships, understanding seismic potential, and interpreting subsurface stratigraphy, and studies should be directed primarily toward these purposes.

Concern Supporting bases for parameters

Supporting bases for various parameters are often not given. Examples include: "significantly large" offsets of 2 m during the postclosure period (p. 8.3.1.8-60 and 8.3.1.8-73); a 5 km radius to assess the possibility of sympathetic displacements (p. 8.3.1.17-46), even though sympathetic rupture is known to have occurred in response to events at much greater distances than this; and a cutoff of 1 m of Quaternary displacement or 100 m of Tertiary displacement (p. 8.3.1.17-50), potentially excluding Holocene/late Pleistocene displacements of less than a meter and excluding the Ghost Dance fault. Since DOE has established "goals" for themselves that they claim will provide an adequately conservative assessment of the site, they should provide clearly stated bases for goals and parameters to demonstrate that these are in fact appropriate numbers.

Concern Carry-through of studies into risk assessment

There is a lack of carry-through of planned studies or activities into disruption scenarios and risk assessment. For example, an assessment of tectonic interrelationships of Quaternary faults is stated as planned, but disruptive scenarios treat faults as acting independently and call for evaluation of the effects of rupture along only a single fault. This makes the SCP appear to be an unintegrated document, and therefore raises significant concern that studies, even if accomplished, will be lost and not incorporated into risk assessment.

Concern Ash-fall potential

The analysis of ash-fall potential (Section 8.3.1.17.1.1) considers only silicic volcanic sources in the western Great Basin, even though it is known (p. 8.3.1.17-159) that ash-fall from other sources (e.g., Cascades and Yellowstone) have occurred at the site in the past. This could greatly affect the results of probability analyses, which are being used. It could also affect the potential particle density and size distribution at the site, since ash from more distant sources would probably have a finer average particle size.

Also, the same logic as the 10,000 year earthquake (see above objection) is used in the form of a 1,000 year ash-fall. Such events, if they were to occur, would probably exceed these watered down values.

Concern Input of tectonics into the drilling program

The manner in which the systematic drilling program is outlined (Section 8.3.1.4.3.1.1) expresses little concern for providing information on faults, even though the "parameters" to be provided by the drilling program include locations and characteristics of faults. Throughout sections on faulting in the SCP, it is stated that drill-hole data will provide the needed information on down-dip fault location and geometry. However, little indication is given that the drilling program will be tailored to provide such information. The problem is reflected in the proposed distribution of first phase core holes (Figure 8.3.1.4-11a). For example, no holes appear to be located in order to intersect the Solitario Canyon fault at depths greater than a few hundred feet.

Also, no indication is given as to how conflicts will be resolved regarding reasoning for differing locations of drill-holes (e.g., it would be advantageous to move drill-hole SD-6 approximately 500 meters to the east for study of the Ghost Dance fault, but perhaps not for groundwater study).

As the drilling program is outlined, it is quite difficult to evaluate whether it will be sufficient to fulfill the stated objectives.

Concern Waste package spacing

There seems to be a philosophy for waste package spacing that results in the hottest, most hazardous materials being placed in the most questionable areas. This concerns statements in the SCP that spacing of packages will be flexible enough to allow questionable areas (e.g., fracture zones or perched water) to be avoided and that spacing will vary, depending on heat output of individual packages, which will vary by up to an order-of-magnitude. The conclusion that can be reached from this is that the hottest waste will be placed adjacent to questionable areas, since these will have the lowest spacing. This also applies to the statement that one possibility for evenly distributing the heat is to have a closer packing of waste packages at the outer edges of the repository (in other words, next to the main fault zones).

Applicable sections

8.3.2.2.3 Design concepts . . . ;
Product 1.11.3-2 Usable area and flexibility evaluation;
Product 1.11.3-5 Criteria for contingency plan;
8.3.2.2.6 Repository thermal loading . . . ;
Product 1.11.6-2 Borehole spacing;
Product 1.11.6-4 Stategy for containment enhancement.
8.3.2.2.6.2 Design Activity 1.11.6.2 Borehole spacing strategy

Applicable tables

8.3.2.2-7 Parameters . . . to satisfy Info. Need 1.11.3;

Specific Comments/Questions

Comment Age of basaltic volcanism

Section 1.2.1.2.2, paragraph 1, p. 1-49; This discussion states that the most recent period of basaltic volcanism "occurred from 3.7 to . . . 0.1 million yr before present." This implies inactivity, which is obviously not the case, especially in light of the evidence that Lathrop Wells Cone is younger than 20,000 yr old (Wells et al, 1988). Even if the youngest eruptions were 0.1 million yr old, we would still probably be within this volcanic cycle, given the apparent recurrence rate of these eruptions.

Comment Age of calcite deposits

Section 1.2.2.2.10, p. 1-73; It is stated that "a correlation with even the younger ash is consistent with a relatively old age for the calcite deposits." This is not necessarily true, especially in light of recent evidence that Lathrop Wells Cone is younger than 20,000 yr old (Wells and others, 1988). Also, no evidence is presented that excludes the possibility of calcite formation postdating the ash.

Comment Fault lengths and earthquake magnitude

It is stated that "Because the entire mapped fault length is assumed to rupture, the estimate of maximum magnitude is conservative" (p. 1-193). In light of several historical earthquakes in the western Basin and Range province (e.g., 1915 Pleasant Valley, 1932 Cedar Mountain, and 1954 Fairview Peak-Dixie Valley earthquake sequences) and comments by Blume and Associates (1987, page 16), ruptures along individual traces often extend well beyond mapped lengths and overall rupture zones may have lengths several times that of individual traces. There is considerable uncertainty in whether a seismic event will extend beyond the mapped trace of a single fault; therefore, assuming ruptures will be confined to mapped fault lengths is not conservative.

Comment Effects of igneous intrusion

In table 8.3.1.8-3(b), p. 8.3.1.8-11, a current estimate of the trend of source structures for basaltic intrusions is given as about N30E. This would be the trend of the Lathrop Wells Cone projected into the surface facilities area. An igneous intrusion immediately adjacent to the repository block could greatly affect percolation flux rates. Despite the importance of this, DOE feels their "confidence" in the current estimate matches their perceived "needed" confidence level (i.e., both are "moderate") and "no new activities are planned" with regard to this subject.

Comment Estimation of slip rates

We are concerned that elementary level procedures are being used to determine the slip rates of faults (p. 8.3.1.17-30). Estimating the slip rate of a fault for seismogenic purposes is often one of the most difficult and uncertain tasks in neotectonics. Several problems often have to be addressed, such as: how much surface distortion has occurred?; is the slip distributed?; is this slip-rate estimation representative of the entire fault (a point problem)?; how accurately can offset units be measured?; have slip rates varied through time?; what is the true sense of displacement of the fault? These potential uncertainties, which are unknown if unaddressed, would be propagated into other estimates derived from slip rates, such as estimates of recurrence intervals and magnitude.

Comment Use of time/magnitude/slip rate graph

We are concerned that the time/magnitude/slip rate graph presented in Slemmons and dePolo (1986) is being misused to estimate recurrence intervals (p. 8.3.1.17-30). The input information used is premature and not based on data. The magnitude of 6.5 is extremely nonconservative (see comment on seismic hazard of the Paintbrush Canyon fault) and the slip rate used does not consider distributed slip and the percentage of strike-slip component, etc. (see comment on estimation of slip rates).

The graph being used was developed from a data set of dominantly strike-slip faults from plate boundary settings. The recurrence behavior of earthquakes in the Basin and Range province is likely somewhat different than plate boundary settings. Perhaps specific relationships developed from the Basin and Range province would be more applicable for use at the Yucca Mountain site.

The value estimated-- "50,000"-- for these input parameters (M6.5, 0.01 mm/yr) is technically misestimated from the graph. The corresponding value to these input parameters from the graph is 40,000.

Question 1,000 year period in fault analysis

Where does the widespread use of a 1,000 yr period for faulting come from? Is there a basis specifically stated for deviating from the 10,000 year period? Might not the 1,000-10,000 year period be more critical, since the waste will have cooled, allowing more groundwater to reach the packages?

Question Air gap

What is the level of confidence that the air gap (Sec. 8.4.3.2.4) will be maintained, allowing 7 cm of slip to be accommodated before rupturing the packages? Significant spalling seems likely, given the high temperatures imposed by the waste and the vibratory ground motion that would accompany a near-field seismic event.

Question Folding or distributed shear

Why do all the discussions of "folding or deformation from distributed shear" drop consideration of the latter in current estimates (i.e., "folding has not occurred in the last 10 million years"), when we know that deformation from distributed shear has occurred? (For example; Table 8.3.1.8-2(b), p. 8.3.1.8-8).

Summary

The SCP outlines a very detailed scope of work which addresses most, but not all, important Quaternary tectonics issues relevant to the suitability of the Yucca Mountain site. On the positive side, the SCP covers nearly all of the deficiencies noted in the DEA and EA, and it proposes studies of critical elements necessary for developing multiple tectonic models. On the negative side, it is not clear whether the proposed level of investigation will, or can, be carried out. There is an apparent conflict in approach based primarily on the interpretation of the existing data base; on the one hand, the SCP indicates that much data needs to be collected before assessing fault hazards, while on the other hand it also indicates that anticipated hazard is expected to be low.

We seriously object to the concept and use of the "10,000 year cumulative-slip earthquake." This methodology incorrectly incorporates a predetermined level of risk into the earthquake hazard analysis. Instead, we recommend that a maximum magnitude, maximum credible, and/or characteristic earthquake methodology be utilized. Based on existing data, the most likely "anticipated event" is a magnitude 7+ earthquake occurring on Yucca Mountain faults during the post-closure period.

The proposed studies of the local and regional Quaternary tectonics issues are fairly comprehensive, but there are several elements of these studies with which we have concerns.

Although the Quaternary stratigraphic and geomorphic investigations are relatively detailed, the scale of mapping to be done in the site area is inadequate for delineating surficial geologic and fault relationships. A scale of 1:24,000 is planned; for a site investigation of this nature, the scale should be at least 1:12,000.

The studies planned for the fault and tectonic relationships within the site area are extensive. However, some proposed goals appear to be unrealistic based on the level of uncertainty known to be associated with the collection of data of this nature. In addition, we are concerned that not enough emphasis has been placed on considering complex faulting (including volcanic) events, on young faulting along the Fatigue Wash fault, on strike-slip faulting, or on considering faulting and tectonics in the drilling program.

The regional Quaternary tectonic studies are also comprehensive, but we are concerned that a couple of the planned activities may be too detailed given the resource and time constraints of the characterization program. Based on the principle that the regional studies should be relevant to the design and performance of the repository, we question the need for detailed study of the Cane Springs fault zone and the need for the ambitious program outlined for detachment faulting.

Principal Recommendations

* The use of the 10,000 year cumulative slip earthquake should be abandoned and maximum or maximum credible earthquakes used in the seismic hazard analysis. Based on existing information, we feel that a reasonably conservative seismic analysis will include a large magnitude earthquake, with complex, distributed rupture, similar to the 1932 Cedar Mountain earthquake ($M_s=7.2$), as an "anticipated event".

* A study of the Fatigue Wash fault should be initiated.

* Mapping of Quaternary deposits and faults in the site vicinity should be done at a scale of at least 1:12,000.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Section 8.3.1.17.3.1.2.	10,000 Year Cumulative Slip Earthquake The concept and use of the 10,000 year cumulative slip earthquake are unacceptable. This type of seismic source characterization is unconventional, unrealistic, misleading, and nonconservative. Prorating slip over a 10,000 year period creates artificial, watered-down earthquake size estimates. This is an attempt to incorporate a risk factor into estimates of seismic sources, which we consider an inappropriate approach. For such a critical facility, the widely used and accepted maximum or maximum credible earthquake methodology would be preferable to the proposed 10,000 year cumulative slip earthquake. The use of other conventional methodologies (e.g., estimating characteristic earthquakes) may also be acceptable. As defined in the SCP, the 10,000 year cumulative slip earthquake is "an earthquake that, occurring every 10,000 years, would produce the observed or estimated average Quaternary slip rate on a fault." It is proposed to use this type of estimate in seismic design for the preclosure period. Although it is not explicitly stated as being used for the postclosure period, it is quite implicit (e.g., Table 8.3.1.8-2(b), p. 8.3.1.8-8, Tentative parameter goal - "Annual probability less than 10^{-4} of faulting with displacement over 5 cm" and Activity 8.3.1.8.3.1.3, p. 8.3.1.8-84, ". . . cumulative offset in 10,000 yr." The 10,000 year cumulative slip earthquake is considered to be an attempt to combine deterministic and probablistic hazard analyses. It is stated to be a deterministic method, because it provides an estimate of a specified magnitude for a specified seismic source. However, it incorporates a probabilistic aspect in that it downgrades the expected event size in consideration of the (perceived) infrequency of event occurrence.

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Section 8.3.1.17.3.1.2.	The SCP presents three arguments in support of the 10,000 year cumulative slip earthquake that will be addressed here: First, the SCP states that the 10,000 year event "can be determined with greater confidence than a true maximum magnitude" p. 8.3.1.17-36). This is incorrect, because additional input parameters and associated uncertainties are involved in the estimation of the 10,000 year event as compared to a maximum earthquake estimate. There are considerable uncertainties associated with the estimation of ages and displacements, which are used to produce the 10,000 year cumulative slip earthquake. By necessity, experimental dating techniques are used in estimation of ages of Quaternary deposits and surfaces. The reliabilities of these techniques have not yet been firmly established. Preliminary work using soils development and radiocarbon rock varnish dating suggests that ages may currently be grossly overestimated (Peterson, 1988; Dorn and others, 1988). Uncertainties in estimates of displacement are also quite large, due to an undetermined contribution from lateral slip. Displacement uncertainties will affect any methodology used, but the 10,000 year cumulative slip earthquake is particularly sensitive to variations in slip estimates, as its name implies. The 10,000 year event methodology does not include theoretical or practical concepts of characteristic earthquakes (i.e., events to occur in the future will be similar to those seen in the geologic record). We feel that these uncertainties are greater than the data and procedures used in conventional deterministic analyses of maximum earthquakes for known sources.

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Section 8.3.1.17.3.1.2.	The SCP states (p. 8.3.1.17-36): "Because large earthquakes occur infrequently, few observational data are available for calibrating the maximum seismogenic potential of individual faults. This is particularly true for faults of the type found in the southern Great Basin, where recurrence intervals for large earthquakes appear to range from about 10,000 to 100,000 yr. Therefore, conventional methods for determining maximum earthquake magnitudes from the physical characteristics of local faults appear to be subject to larger uncertainties than for the more active faults associated with plate motions." Conventional methods may have larger uncertainties in analyzing faults with longer recurrence intervals relative to plate margin faults, but this has little bearing on what kind of seismic hazard analysis should be conducted for the Yucca Mountain facilities. Recent research has shown that short-term slip rates and recurrence intervals are greatly different than long-term behavior for some faults. For example, the Meers fault in Oklahoma has been the site of multiple large late Holocene earthquakes, despite very low long-term average rates (Swan, 1989). The evidence of Holocene activity at Yucca Mountain may be more significant than the low long-term rates. Second, the SCP states, "low slip rates suggest that the use of fault length or displacement to develop deterministic estimates of magnitude for a given fault are misleading . . . " (p. 8.3.1.17-72). As discussed above, the analysis of faults with low slip rates (or longer recurrence intervals) may incur larger uncertainties, but this does not render the analysis meaningless or "misleading." Recent studies suggest that faults with lower slip rates may be associated with earthquakes of higher stress

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Section 8.3.1.17.3.1.2.	drops and moments, (Kanamori and Allen, 1986; Cao and Aki, 1986). Thus, prudent and conservative deterministic and probabilistic analyses may be even more appropriate for faults in the Yucca Mountain region. Third, the SCP states that, "Use of slip rate data (to constrain recurrence times) in conjunction with more conventional fault data provides added assurance that adequately conservative assessments of the local seismogenic potential will be accomplished" (p. 8.3.1.17-36). This is a somewhat fuzzy statement, but it is assumed in this review that "adequately conservative assessments" implies that the use of maximum earthquakes is overly conservative. The 10,000 year event is considered nonconservative for two additional reasons. First, slip rates can and do vary through time. Recent work has shown that fault activity in the Basin and Range province and other regions commonly exhibits spatial and temporal clustering of events (Wallace, 1985; Pearthree and Wallace, 1988). Averages and recurrence intervals over short-term periods (e.g., 10 ka) can be greatly different than those over the long term. For example, an order-of-magnitude difference in slip rate on the Windy Wash fault can be estimated by using data presented in the SCP (Table 1-8). From these data, a slip rate of 0.002 mm/yr would be estimated for the last 270,000 years, while the slip rate over the last 3,000 to 6,500 years would be estimated at 0.015 to 0.033 mm/yr. It should be noted that either or both of these estimates could be low if there is a significant component of strike-slip displacement or if age-estimates are in error. Although it is not specifically spelled out in the SCP, it is presumed that, whenever possible, long-term averages will be used in the 10,000 year event estimation. The evidence for Holocene activity may indicate that Yucca Mountain is currently within a more active cycle than long-term rates would suggest.

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Section 8.3.1.17.3.1.2.	Also, the 10,000 year cumulative slip earthquake methodology treats only single fault ruptures, whereas evidence exists for complex rupture of multiple faults at Yucca Mountain (Ramelli and others, 1988). Most large historical Basin and Range earthquakes have involved several faults, rather than a single, discrete fault. A seismic source estimation of a single fault, such as the Paintbrush Canyon fault, may significantly underestimate potential seismic hazards. Note on Sample Calculation of 10,000 year event In the sample calculation (p. 8.3.1.17-73), an estimated magnitude of 6.6 is derived for a 10,000 year cumulative slip earthquake. Using the figures and assumptions presented in this calculation, magnitude values can be estimated for various recurrence intervals (assuming uniform behavior). For a recurrence interval of 70,000 years, average slip per event would be 0.72 m (maximum 2.16 m), and a magnitude 7.2 would be estimated, using the same relation from Bonilla and others (1984). If such a "characteristic" event were to occur, its magnitude could be expected to exceed the 10,000 yr cumulative slip event by more than 1/2 of a magnitude. The artifical nature of the 10,000 year cumulative slip earthquake will make it difficult or impossible to accurately estimate the uncertainty or conservatism of the estimate. Maximum or characteristic earthquake analyses are direct methods, and uncertainties can be incorporated into the analysis. Considering different earthquake scenarios, the sensitivities of input parameters can be judged and more meaningful estimates of conservatism can be made.

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Section 8.3.1.17.3.1.2.	In short, the 10,000 year cumulative slip earthquake is felt to be a nonconservative estimate for seismic hazard considerations of facilities important to safety. A seismic source analysis of the site should include deterministic maximum, maximum credible, and/or characteristic earthquake estimates for the known and speculated sources and probabilistic maximum or maximum credible earthquake estimates to represent unknown and new faults. Multiple estimation methods and uncertainties should be utilized to understand the sensitivity and conservatism of the estimates. Nevada's historical earthquake record also needs to be considered in the analysis. For example, several similarities have been noted between the Yucca Mountain and the Cedar Mountain areas, suggesting a 1932 Cedar Mountain type of event should be considered in the seismic analysis (Bell, 1985; Bell and others, 1987). The 1932 Cedar Mountain earthquake was a complicated, multiple fault event, yielding an $M_s = 7.2$. The NRC has expressed they believe the use of Appendix A of 10 CFR Part 100 for the period through permanent closure is conservative and appropriate (Trapp and Coplan, 1986). Trapp and Coplan comment that, "Appendix A of 10CFR100 has become a standard against which nuclear facilities other than power plants have been evaluated." Two of the projects reviewed by NRC are the Independent Spent Fuel Storage facilities and the proposed Monitored Retrievable Storage facility. These facilities are regulated by 10 CFR Part 72, which states "west of the Rocky Mountain front (west of approximately 104° west longitude), and in other areas of known potential seismic activity, seismicity will be evaluated by the techniques of Appendix A of Part 100 of this chapter (10 CFR 100)." Appendix A calls for "determining the earthquakes of greatest magnitude related to the faults." This is also supportive of using maximum or maximum credible	

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Section 8.3.1.17.3.1.2.	earthquakes in the seismic considerations for Yucca Mountain. The Yucca Mountain site lies within a tectonically active area, with many potential seismogenic sources lying immediately adjacent to it. A consequence of this is that conventional maximum or maximum credible earthquake analyses would yield high seismic design values for this site. High design values are viewed as appropriately characterizing the site, rather than being overly conservative. The seismic hazards of the site need to be characterized correctly, similar to other critical facilities located in areas with numerous local, capable faults. The 10,000 year cumulative slip earthquake falls far short of that goal.

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Pg. 8.3.1.8-27 Sec. 8.3.1.8.2.1.2 Sec. 8.3.1.8.2.1.4 Sec. 8.3.5.13	Consideration of complex faulting events Considerations of disruptive scenarios involving faulting generally consider the possibility of rupture along only a single fault. This applies to analyses of both ground motion and rupture of waste packages. The possibility of complex events, with distributed rupture on multiple faults is not adequately considered, even though existing evidence indicates this may have occurred in the past. Evidence from Yucca Mountain (basaltic ash in fault fractures and close spacing [< 2 km] of surface faults) suggests an intimate interrelationship between the surface faults and emplacement structures of the Crater Flat basalts/Lathrop Wells Cone. Combined with observations of historical earthquakes in the Basin and Range, this indicates that complex events are quite possible. Faulting at Yucca Mountain might involve rifting and dike intrusion in the lower- to mid-crust, with extrusion of basalts and/or distributed rupture across several faults in the upper-crust and at the surface. Rupture of multiple structures could produce large magnitude events. Failure to allow for this could cause the effects of seismic events to be seriously underestimated.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Pg. 8.3.1.17-28 S. 8.3.1.17.4.6.2	<u>Study of the Fatigue Wash fault</u> In the SCP, both discussions and plans for study of north-south trending faults in the site vicinity usually refer to the Paintbrush Canyon, Bow Ridge, Solitario Canyon, and Windy Wash faults. Mention is rarely made of the Fatigue Wash fault. This fault has geomorphic expression similar to the others, and it is an integral part of the complex fault system at Yucca Mountain. Due to the anastomosing nature of this system, inferring extensions of individual faults can be very subjective. For example, the fault trace cut by trench CF-1 could more reasonably be called the Fatigue-Wash fault than the Windy Wash fault, as has been done. The Fatigue Wash fault is an integral part of this system, but it has not yet been studied. While this fault will probably not control design parameters for the initial waste emplacement area, it bounds one of the principal areas considered in early discussions of expansion areas (Environmental Assessment).

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Pg. 8.3.1.17-37	Estimation of annual probabilities The SCP estimates annual probabilities of seismic events on given faults by inverting the estimated recurrence intervals (p. 8.3.1.17-37). These probability estimations are misleading for several reasons: they do not account for the elapsed time since the last event; they do not consider uncertainties in the estimates; they do not include a sophisticated examination of the earthquake history of the source (e.g., if the most recent event on a fault was smaller than previous events, this event may have released only part of the stress); and they do not consider a random probability of earthquake clustering and contageous interactions with other faults. The estimates and procedure of estimating annual probabilities used in the SCP are misleading and inappropriate for use in analyses or decisions.

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S. 8.3.1.17.2.1.2 Pg. 8.3.1.17-34	<u>Uncertainties of values used in risk assessment</u> Throughout the SCP, there is considerable emphasis placed on the precise determination of various parameters that can not be estimated without considerable uncertainty. For example, it is intended to use slip-rate values to define earthquake hazards. Slip rates normally have a great deal of inherent uncertainty, due to such factors as paucity of datable materials or geomorphic features, the combined uncertainties of age-estimates of Quaternary materials, age-bracketing as opposed to direct age-estimates, and unknown amounts of strike-slip displacement. It is not made clear that this problem is understood and how these uncertainties will be conservatively dealt with. Another example; it is stated that determining displacement on faults in the subsurface will be "nearly impossible" (Sec. 8.3.1.17.2.1.2), but plans call for identification of faults in the subsurface with a "probability of greater than 10^{-4} for displacing more than 7 cm" (e.g., p. 8.3.1.17-34). In the "current estimates" it is evident that values will be assumed to meet the desired goals, unless demonstrated otherwise. It thus appears that when data are "nearly impossible" to obtain, values will be assumed to be favorable. Levels of uncertainty should be clearly stated and carried through into estimates that rely on data with large uncertainties.

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Pg. 8.3.1.17-37	<u>Seismic hazard of the Paintbrush Canyon fault</u> The SCP states that the Paintbrush Canyon fault "may be capable of producing a moderate earthquake (M about 6.5) with a recurrence interval greater than ten thousand years." Selecting a magnitude prior to investigations is a premature and extremely nonconservative approach. A magnitude 6.5 earthquake is on the order of a random earthquake for the Basin and Range Province, and could occur nearly anywhere in this province, regardless of the specific tectonic setting. Based on what we know of the Yucca Mountain site faults, and the historical earthquake record of Nevada, larger earthquakes should be anticipated. Several moderate-sized historical earthquakes in the Basin and Range Province have produced limited surface rupture and fracturing (e.g. 1934 Excelsior Mountains, 1935 Helena, 1948 Verdi, 1966 Boca Valley, 1980 Mammoth Lakes earthquakes). The 1986 Chalfant earthquake was an $M_L = 6.4$ event and occurred on a secondary or splay fault that does not have a clear surface expression. Surface fracturing from this earthquake was scattered over a wide area, was on the order of a millimeter to a few centimeters, and is already poorly preserved. The historical record suggests that a moderate earthquake (magnitude 6 to 6 ½) should be considered as a floating or random earthquake, which can occur on secondary as well as main faults. The second part of this statement regarding the recurrence interval of a moderate event, is misleading because the data are too incomplete to determine this.

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Pg. 8.3.1.17-30 Pg. 8.3.1.17-58	Strike-slip displacements Even though it is acknowledged in the SCP that strike-slip displacements on some of the Quaternary faults can not yet be ruled out, all estimates of displacements and slip rates are based solely on vertical displacements. In fact, strike-slip displacement is implied to be insignificant even if it exists. Although no direct evidence of strike-slip displacement has been recognized, at least some circumstantial evidence has been observed (e.g., patterns of faults exposed in trenches along the Windy Wash and the Bow Ridge faults, and focal mechanisms derived from regional earthquakes). For any faults that have a significant amount of Quaternary strike-slip displacement, the observed vertical displacements could be considerably less than the net displacement. Since so much is being based on slip rates, failing to account for strike-slip displacements could result in greatly underestimated magnitudes and displacements through waste packages.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Pg. 8.3.1.17-35	Probability "precedent" from nuclear power plants

The SCP states on p. 8.3.1.17-35 that:

> "An important precedent is provided by nuclear power plants where annual probabilities for exceeding the design-basis motions have been found to be on the order of 10^{-3}/yr to 10^{-4}/yr for several operating plants (Reiter and Jackson, 1983)."

It is important to place this "precedent" in context. The broad range of "on the order of 10^{-3}/yr to 10-4/yr" corresponds to the estimated return periods of probabilistically derived spectra which are similar to spectra derived using Appendix A of 10 CFR Part 100 for several nuclear power plants (Reiter and Jackson, 1983; L. Reiter, 1988, pers. comm.). These plants are located in the central and eastern United States, were constructed before the implimentation of Appendix A, and were undergoing reanalysis for seismic hazards. Reiter and Jackson (1983) report these values as "implicitly accepted by NRC in recent licensing decisions," because these values correspond to the Appendix A type analysis for these facilities. The final review memorandum contained in Reiter and Jackson (1983) states, "Application of this study and its review recommendations to other sites or other programs should be examined on a case by case basis." Thus this report is not meant

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Pg. 8.3.1.17-35	as an ubiquitous precedent for nuclear power plants and facilities. Significant differences exist between these central and eastern United States sites and the Yucca Mountain site. The Yucca Mountain site has several capable faults in the immediate area, and a similar analysis would probably yield greater corresponding return periods (lower corresponding annual probabilities). The SCP also appears to misuse this broad range of annual probabilities in subsequent citations. The term "on the order of 10^{-3}/yr to 10^{-4}/yr" is a fuzzy range, and it means the actual values reviewed may have been a little higher or lower than the reported values (L. Reiter, 1988, pers. comm.). The SCP uses this range, however, rigidly defining goals, decisions, and estimations of conservatism.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Sec. 1.2.2.3 Pg. 8.3.1.17-94	Quaternary stratigraphy The stratigraphic scheme of Swadley and others (1984) will be used for mapping surficial deposits (section 1.2.2.3, and p. 8.3.1.17-94). As discussed in previous reviews of the DEA and EA, this scheme is not entirely adequate for delineating surficial deposits in the degree of detail necessary for constraining timing of fault activity. The results of the study by Whitney and others (1986) on the Windy Wash fault and our on-going soil-geomorphic studies in Crater Flat also support this conclusion; the stratigraphic sequence may be adequate for mapping on a regional scale, but the late-Quaternary stratigraphic relationships of Yucca Mountain are sufficiently complex to warrant a more detailed scheme for site investigation purposes. A scheme should be used which subdivides and further defines Swadley and others' units into finer divisions commensurate with the level of present knowledge.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
S. 8.3.1.17.4.6.1	<u>Scale of mapping</u> The scale of mapping proposed for the site area does not appear to be adequate for delineating and constraining Quaternary fault activity. Section 8.3.1.17.4.6.1 indicates that the surficial deposits and Quaternary faults will be mapped at a scale of 1:24,000 for the site area (91 mi^2). Our concern is that this scale is not adequate for a site investigation of this nature; a scale of 1:24,000 is considered to be a reconnaissance level. At a minimum, the scale for mapping in the site area should be 1:12,000. The original bedrock mapping of the site area by Scott and Bonk (1984) is 1:12,000, and there is now complete 1:12,000-scale aerial photography available for the site area. Consequently, the surficial and Quaternary fault mapping should be integrated with the mapping of Scott and Bonk (1984) so that a comprehensive, detailed geologic map of the site area can be produced. Similarly, the scale of the Quaternary fault map for the site area should be large scale so that subtle details of fault and related fracture patterns are displayed. The ability to analyze detailed fault patterns is particularly important in interpreting the evidence for strike-slip faulting.	

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S. 8.3.1.17.4.4.4	Cane Springs fault zone Studies of northeast-trending fault zones proximal to the site are necessary for constraining the recency and recurrence of activity of these structures in that they are regarded as conjugate features within a northwest-trending Walker Lane system. As they relate to characterizing the faults at the site, however, we regard the Rock Valley and Mine Mountain fault zones as the most important, and the Cane Springs fault zone as less important. The Rock Valley and Mine Mountain fault zones appear to be structurally linked to the Yucca Mountain fault system, whereas the Cane Springs fault zone is once-removed from this system. The detailed surficial geology studies planned for the Cane Springs fault zone could be reduced, especially if they are at the expense of additional work needed on the local fault systems.	

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Sec. 8.3.1.17.4.5	Detachment faults An evaluation of the presence of detachment faults at and proximal to Yucca Mountain is proposed because detachment faults could represent a significant seismogenic source or they could conceal a significant seismogenic source at depth (p. 8.1.3.17-144). We agree in general with the need for detachment fault studies, but are somewhat concerned with the level of detailed studies planned on a regional basis. The question of a detachment fault beneath Yucca Mountain may have limited significance as far as seismogenic sources are concerned. The presence of Quaternary basalts in the area indicates the existence of crustal-penetrating structures. We are concerned somewhat with the level of detailed bedrock mapping planned for the Paleozoic and Tertiary rocks in the Beatty, Specter Range, Camp Desert Rock, and Sheep Range areas, and the extensive age dating planned for the Amargosa Desert core complex. The level of effort placed on these activities appears rather ambitious given the data necessary for delineating the presence of a regional detachment fault. The presence or absence of a detachment fault beneath Yucca Mountain is important for modeling fault geometry and tectonic interrelationships, understanding seismic potential, and interpreting subsurface stratigraphy, and studies should be directed primarily toward these purposes.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
GENERIC	Apparent Conflict in Approach

The SCP states in numerous places, in particular in Chapter 1, that the present tectonics data base is inadequate to fully assess the earthquake and volcanic hazards at Yucca Mountain (p. 1-5).. This sort of disclaimer is consistently repeated:

> " The present tectonic model is a preestablished fault system in which recurrent Quaternary and some Holocene movement has been demonstrated and which is favorably oriented in the existing stress field for future movement . . . The present data base allows some conclusions about locations and orientations, offsets, relative importance, and ages of movement of some of the faults at and near Yucca Mountain. However, it is insufficient to reliably gauge future tectonic effects on seismicity and on the hydrologic regime." (p. 1-340).

> " In general, additional work is necessary to better document the recurrent nature of faults near the site" (p. 1-206).

> " It is difficult to assess accurately the probability of faulting because little is known about expected earthquake magnitudes or the recurrence intervals and displacement for faults in the southern Great Basin, and at Yucca Mountain in particular . . . Slip rates on seismogenic faults in the Great Basin are considered to be nonuniform in both space and time (Wallace, 1985)" (p. 1-207 & 1-208).

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GENERIC	" In determining the probability of faulting at Yucca Mountain, once sufficient paleoseismic data are available, it may not be correct to assume a uniform stress release model as a basis for probability calculations . . . " (p. 1-208). In contradiction to these disclaimers, there are numerous statements implying a low probability and rare occurrence of tectonic activity at Yucca Mountain throughout Chapters 1 and 8. " An outline of our current perception of the effects from faulting is presented in DOE (1986) and summarized here. It appears unlikely that faulting would lead to radionuclide releases to the accessible environment during the first 10,000 yr following closure of the repository" (p. 1-207). " Even if new fractures formed, they are not expected to significantly alter ground water flow conditions because the area already is strongly fractured" (p. 1-207). " Because these faults (such as the Windy Wash and Paintbrush Canyon) have very low slip rates, it is anticipated that the demonstration can be made that the occurrence of 5 cm of displacement in 1,000 yr on even these longer, more significant faults is a very low probability event" (p. 8.3.1.8-27).

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
GENERIC	" During the Quaternary, tectonic and volcanic processes in the Yucca Mountain area have included . . . slow (less than 3 cm/1000 yr) relative vertical tectonic adjustment . . . The effect of these intermittent and localized constructional processes on the late Quaternary landscape of the Yucca Mountain area has been limited . . . Comparable tectonic and volcanic activity over the next 10,000 yr would likely induce a comparably limited effect on the (late Quaternary) landscape of the Yucca Mountain area" (p. 1-30). " Quaternary deposits are offset or fractured by 32 faults in the 1,100 km^2 area . . . 23 of them moved 1.2 to 2 million yr ago, four of them about 1 million yr ago, and at least five of them during the past 270,000 yr" (p. 1-128) " If the average offset per event (on the Windy Wash fault) was about 10 cm, each event had a magnitude (Ms) of about 6 to 6.5 . . . The rate of offset averaged over the past 270,000 yr has been about 0.0015 mm/yr which is "extremely low" in the classification scheme of Slemmons and dePolo (1986)" (p. 1-132 & 1-133). " The (Solitario Canyon) fault shows no evidence of movement during the past 270,000 yr but does show evidence of movement about 1.2 million yr ago" (p. 1-133). " Considering the length and nature of this (Paintbrush Canyon) fault, it could have been the source of moderate earthquakes (M 6.5) in the past, although such events would appear to be rare based on the low rate of movement" (p. 8.3.1.17-30).

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
GENERIC	" . . . the annual probability for the controlling earthquake is expected to be low (less than about 10^{-4}, assuming the Paintbrush Canyon fault is controlling) . . . (p. 8.3.1.17-37). This conflict arises because the impression is given that the position has already been adopted that significant faulting has a low probability of occurrence, as it was in the EA. One could easily speculate that this dichotomy is one based on the different approaches taken by the USGS and the DOE.	

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COMMENT NO.:	1-14	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Pg. 8.3.1.8-60 Pg. 8.3.1.8-73 Pg. 8.3.1.17-46 Pg. 8.3.1.17-50	Supporting bases for parameters Supporting bases for various parameters are often not given. Examples include: "significantly large" offsets of 2 m during the postclosure period (p. 8.3.1.8-60 and 8.3.1.8-73); a 5 km radius to assess the possibility of sympathetic displacements (p. 8.3.1.17-46), even though sympathetic rupture is known to have occurred in response to events at much greater distances than this; and a cutoff of 1 m of Quaternary displacement or 100 m of Tertiary displacement (p. 8.3.1.17-50), potentially excluding Holocene/late Pleistocene displacements of less than a meter and excluding the Ghost Dance fault. Since DOE has established "goals" for themselves that they claim will provide an adequately conservative assessment of the site, they should provide clearly stated bases for goals and parameters to demonstrate that these are in fact appropriate numbers.

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COMMENT NO.:	~~xxx~~ 1-15	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
GENERIC	<u>Carry-through of studies into risk assessment</u> There is a lack of carry-through of planned studies or activities into disruption scenarios and risk assessment. For example, an assessment of tectonic interrelationships of Quaternary faults is stated as planned, but disruptive scenarios treat faults as acting independently and call for evaluation of the effects of rupture along only a single fault. This makes the SCP appear to be an unintegrated document, and therefore raises significant concern that studies, even if accomplished, will be lost and not incorporated into risk assessment.	

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COMMENT NO.:	~~xxx~~ 1-16	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Sec. 8.3.1.17.1.1 Pg. 8.3.1.17-159	<u>Ash-fall potential</u> The analysis of ash-fall potential (Section 8.3.1.17.1.1) considers only silicic volcanic sources in the western Great Basin, even though it is known (p. 8.3.1.17-159) that ash-fall from other sources (e.g., Cascades and Yellowstone) have occurred at the site in the past. This could greatly affect the results of probability analyses, which are being used. It could also affect the potential particle density and size distribution at the site, since ash from more distant sources would probably have a finer average particle size. Also, the same logic as the 10,000 year earthquake (see above objection) is used in the form of a 1,000 year ash-fall. Such events, if they were to occur, would probably exceed these watered down values.

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SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
Sec. 8.3.1.4.3.1.1 Fig. 8.3.1.4-11a	<u>Input of tectonics into the drilling program</u> The manner in which the systematic drilling program is outlined (Section 8.3.1.4.3.1.1) expresses little concern for providing information on faults, even though the "parameters" to be provided by the drilling program include locations and characteristics of faults. Throughout sections on faulting in the SCP, it is stated that drill-hole data will provide the needed information on down-dip fault location and geometry. However, little indication is given that the drilling program will be tailored to provide such information. The problem is reflected in the proposed distribution of first phase core holes (Figure 8.3.1.4-11a). For example, no holes appear to be located in order to intersect the Solitario Canyon fault at depths greater than a few hundred feet. Also, no indication is given as to how conflicts will be resolved regarding reasoning for differing locations of drill-holes (e.g., it would be advantageous to move drill-hole SD-6 approximately 500 meters to the east for study of the Ghost Dance fault, but perhaps not for groundwater study). As the drilling program is outlined, it is quite difficult to evaluate whether it will be sufficient to fulfill the stated objectives.

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COMMENT NO.:	xxxx 1-18	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Sec. 8.3.2.2.3 Sec. 8.3.2.2.6 Sec. 8.3.2.2.6.2 Sec. 8.3.2.2-7	Waste package spacing There seems to be a philosophy for waste package spacing that results in the hottest, most hazardous materials being placed in the most questionable areas. This concerns statements in the SCP that spacing of packages will be flexible enough to allow questionable areas (e.g., fracture zones or perched water) to be avoided and that spacing will vary, depending on heat output of individual packages, which will vary by up to an order-of-magnitude. The conclusion that can be reached from this is that the hottest waste will be placed adjacent to questionable areas, since these will have the lowest spacing. This also applies to the statement that one possibility for evenly distributing the heat is to have a closer packing of waste packages at the outer edges of the repository (in other words, next to the main fault zones).

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COMMENT NO.:	1-19	CHAPTER NO. 1
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Sec. 1.2.1.2.2	<u>Age of basaltic volcanism</u> Section 1.2.1.2.2, paragraph 1, p. 1-49; This discussion states that the most recent period of basaltic volcanism "occurred from 3.7 to . . . 0.1 million yr before present." This implies inactivity, which is obviously not the case, especially in light of the evidence that Lathrop Wells Cone is younger than 20,000 yr old (Wells et al, 1988). Even if the youngest eruptions <u>were</u> 0.1 million yr old, we would still probably be within this volcanic cycle, given the apparent recurrence rate of these eruptions.	

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Sec. 1.2.2.2.10	Age of calcite deposits Section 1.2.2.2.10, p. 1-73; It is stated that "a correlation with even the younger ash is consistent with a relatively old age for the calcite deposits." This is not necessarily true, especially in light of recent evidence that Lathrop Wells Cone is younger than 20,000 yr old (Wells and others, 1988). Also, no evidence is presented that excludes the possibility of calcite formation postdating the ash.

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COMMENT NO.:	1-21	CHAPTER NO. 1
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Pg. 1-193	Fault lengths and earthquake magnitude It is stated that "Because the entire mapped fault length is assumed to rupture, the estimate of maximum magnitude is conservative" (p. 1-193). In light of several historical earthquakes in the western Basin and Range province (e.g., 1915 Pleasant Valley, 1932 Cedar Mountain, and 1954 Fairview Peak-Dixie Valley earthquake sequences) and comments by Blume and Associates (1987, page 16), ruptures along individual traces often extend well beyond mapped lengths and overall rupture zones may have lengths several times that of individual traces. There is considerable uncertainty in whether a seismic event will extend beyond the mapped trace of a single fault; therefore, assuming ruptures will be confined to mapped fault lengths is not conservative.	

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COMMENT NO.:	1-22	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-3(b)	<u>Effects of igneous intrusion</u> In table 8.3.1.8-3(b), p. 8.3.1.8-11, a current estimate of the trend of source structures for basaltic intrusions is given as about N30E. This would be the trend of the Lathrop Wells Cone projected into the surface facilities area. An igneous intrusion immediately adjacent to the repository block could greatly affect percolation flux rates. Despite the importance of this, DOE feels their "confidence" in the current estimate matches their perceived "needed" confidence level (i.e., both are "moderate") and "no new activities are planned" with regard to this subject.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Pg. 8.3.1.17-30	Estimation of slip rates We are concerned that elementary level procedures are being used to determine the slip rates of faults (p. 8.3.1.17-30). Estimating the slip rate of a fault for seismogenic purposes is often one of the most difficult and uncertain tasks in neotectonics. Several problems often have to be addressed, such as: how much surface distortion has occurred?; is the slip distributed?; is this slip-rate estimation representative of the entire fault (a point problem)?; how accurately can offset units be measured?; have slip rates varied through time?; what is the true sense of displacement of the fault? These potential uncertainties, which are unknown if unaddressed, would be propagated into other estimates derived from slip rates, such as estimates of recurrence intervals and magnitude.

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COMMENT NO.:	1-24	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Pg. 8.3.1.17-30	<u>Use of time/magnitude/slip rate graph</u> We are concerned that the time/magnitude/slip rate graph presented in Slemmons and dePolo (1986) is being misused to estimate recurrence intervals (p. 8.3.1.17-30). The input information used is premature and not based on data. The magnitude of 6.5 is extremely nonconservative (see comment on seismic hazard of the Paintbrush Canyon fault) and the slip rate used does not consider distributed slip and the percentage of strike-slip component, etc. (see comment on estimation of slip rates). The graph being used was developed from a data set of dominantly strike-slip faults from plate boundary settings. The recurrence behavior of earthquakes in the Basin and Range province is likely somewhat different than plate boundary settings. Perhaps specific relationships developed from the Basin and Range province would be more applicable for use at the Yucca Mountain site. The value estimated-- "50,000"-- for these input parameters (M6.5, 0.01 mm/yr) is technically misestimated from the graph. The corresponding value to these input parameters from the graph is 40,000.	

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-25	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
GENERIC	1,000 year period in fault analysis Where does the widespread use of a 1,000 yr period for faulting come from? Is there a basis specifically stated for deviating from the 10,000 year period? Might not the 1,000-10,000 year period be more critical, since the waste will have cooled, allowing more groundwater to reach the packages?

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DOCUMENT TITLE: Site Characterization Plan		
COMMENT NO.:	1-26	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Sec. 8.4.3.2.4	<u>Air gap</u> What is the level of confidence that the air gap will be maintained, allowing 7 cm of slip to be accommodated before rupturing the packages? Significant spalling seems likely, given the high temperatures imposed by the waste and the vibratory ground motion that would accompany a near-field seismic event.	
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COMMENT NO.:	1-27	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Tab. 8.3.1.8-2(b)	Folding or distributed shear Why do all the discussions of "folding or deformation from distributed shear" drop consideration of the latter in current estimates (i.e., "folding has not occurred in the last 10 million years"), when we know that deformation from distributed shear has occurred? (For example; Table 8.3.1.8-2(b), p. 8.3.1.8-8).

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DOCUMENT TITLE: Site Characterization Plan			
COMMENT NO.:	1-28	CHAPTER NO.	8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-7	Additional Alternative Hypothesis Needed For the model element, Faulting rates, the following additional alternative hypothesis is possible and should be included: Slip rates could be higher because of high degrees of uncertainty and errors in methods of age-estimation (Swadley and others, 1988; Rosholt and others, 1988; Dorn and others, 1988).

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-29	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-7	<u>Additional Alternative Hypothesis Needed</u> For the model element, <u>Fault rupture pattern</u>, the following additional alternative hypothesis is possible and should be included: The north-trending faults move in response to transitory stress changes induced by basaltic intrusion.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-30	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-7	Additional Alternative Hypothesis Needed For the model element, Rate of volcanism, the following additional alternative hypothesis is possible and should be included: Differences in volumes of Plio-Quaternary basalts are volcanism insignificant. The 3 m.y. cycle has a greater volume than the 1 m.y. cycle, but the present cycle (including Lathrop Wells cone) is not complete, so its total volume is unknown.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1-31 CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-7	Additional Discussion and/or Justification Needed For the model element, Driving forces/processes, additional discussion and/or justification is needed: A low level of uncertainty is indicated for the preferred model of mechanically driven processes, as opposed to thermally driven processes or a combination of the two. Does the indication that existing data support the preferred model imply no data exist that are at least suggestive of thermally driven processes? Or are certain data being selectively used to support the preferred model? This is one of the better examples of the need for additional discussion and/or justification.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-32	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-7	Additional Discussion and/or Justification Needed For the model element, Effects on groundwater flow (volcanic or igneous effects), additional discussion and/or justification is needed: Justification for low uncertainty in the current estimate and the need to reduce uncertainty is based solely on arguments of time needed to develope thermal effects; it does not address the "physical barriers" aspect of the alternative hypothesis, which could change during a single eruptive episode.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-33	CHAPTER NO.	8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-7	Additional Discussion and/or Justification Needed For the model element, Effects on groundwater flow (tectonic effects/flux rates), additional discussion and/or justification is needed: Comment that " . . . subsurface effects due to faulting...are not likely to be great enough to influence flux rates" indicates a high level of understanding of potential for changes in pathways along fault zones. What studies have been accomplished to achieve this level of confidence?

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DOCUMENT TITLE: Site Characterization Plan			
COMMENT NO.:	1-34	CHAPTER NO.	8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT		
Table 8.3.1.8-7	<u>Additional Discussion and/or Justification Needed</u> For the model element, <u>Effects on groundwater flow (tectonic effects/fracture properties)</u>, additional discussion and/or justification is needed: Fracture dilation could occur over a matter of a few seconds during a faulting event. Is this recognized?		
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DOCUMENT TITLE:	Site Characterization Plan		
COMMENT NO.:	1-35	CHAPTER NO.	8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-8	Additional Discussion and/or Justification Needed For the model element, Physical domain, additional discussion and/or justification is needed: The justification, "regional processes outside model domain unlikely to affect site design or performance," is used to argue for a low uncertainty in the current estimate. This type of logic should be reserved for the "Need to reduce uncertainty," because it says nothing about the actual validity or correctness of the model.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-36	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Table 8.3.1.17-7	<u>Additional Alternative Hypothesis Needed</u> For the model element, <u>Faulting rates,</u> the following additional alternative hypothesis is possible and should be included: Slip rates could be higher because of high degrees of uncertainty and errors in methods of age-estimation (Swadley and others, 1988; Rosholt and others, 1988; Dorn and others, 1988).	

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COMMENT NO.:	1-37	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Table 8.3.1.8-8	Internal Contradiction For the model element "Distribution of volcanism" (p. 8.3.1.8-45), the Death Valley - Pancake Range zone (DVPRZ) is interpreted in the current representation as "a significant feature controlling the occurrence of volcanism in the domain," but for other model elements (System geometry and Nature of volcanism), the DVPRZ is not included in current representations. If the DVPRZ is not thought to have a thermal effect on the crust (incipient rift), what is its significance thought to be for distribution of volcanism?	

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COMMENT NO.:	1-38	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.8-8	Additional Discussion and/or Justification Needed For the model element, Driving forces/processes, additional discussion and/or justification is needed: A low level of uncertainty is indicated for the preferred model of mechanically driven processes, as opposed to thermally driven processes or a combination of the two. Does the indication that existing data support the preferred model imply no data exist that are at least suggestive of thermally driven processes? Or are certain data being selectively used to support the preferred model?

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DOCUMENT TITLE: Site Characterization Plan		
COMMENT NO.:	1-39	CHAPTER NO.
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
Table 8.3.1.17-7	Additional Alternative Hypothesis Needed For the model element, Fault rupture pattern, the following additional alternative hypothesis is possible and should be included: The north-trending faults move in response to transitory stress changes induced by basaltic intrusion.	
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COMMENT NO.:	1-40	CHAPTER NO.

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.17-7	Additional Alternative Hypothesis Needed For the model element, Distribution of seismic potential, the following additional alternative hypothesis is possible and should be included: Local earthquakes are potentially complex, large magnitude events that involve crustal penetrating structures and multiple faults in the shallow crust, and would overshadow the interpretation of "moderate" local events.

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COMMENT NO.:	1-41	CHAPTER NO.

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.17-7	Additional Discussion and/or Justification Needed For the model element, Driving forces/processes, additional discussion and/or justification is needed: A low level of uncertainty is indicated for the preferred model of mechanically driven processes, as opposed to thermally driven processes or a combination of the two. Does the indication that existing data support the preferred model imply no data exist that are at least suggestive of thermally driven processes? Or are certain data being selectively used to support the preferred model?

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COMMENT NO.:	1-42	CHAPTER NO.

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.17-8	Additional Discussion and/or Justification Needed For the model element, Physical domain, additional discussion and/or justification is needed: The justification, "regional processes outside model domain unlikely to affect site design or performance," is used to argue for a low uncertainty in the current estimate. This type of logic should be reserved for the "Need to reduce uncertainty," because it says nothing about the actual validity or correctness of the model.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1-43	CHAPTER NO.

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.17-8	Additional Discussion and/or Justification Needed For the model element, Driving forces/processes, additional discussion and/or justification is needed: A low level of uncertainty is indicated for the preferred model of mechanically driven processes, as opposed to thermally driven processes or a combination of the two. Does the indication that existing data support the preferred model imply no data exist that are at least suggestive of thermally driven processes? Or are certain data being selectively used to support the preferred model?

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TASK 2

Summary of SCP Review, Task 2--Geochemistry, FWD & MPL

1. Few substantial changes compared to Draft SCP.
2. Changes
   a. Took "Timetable and Milestones" out of most sections and incorporated it in an expanded Table and Graphs toward the end of sections.
   b. Modified "Adsorption" sections. Showed new awareness of some factors important in measuring adsorption and applying results to Yucca Mountain.
   c. New section, under "Analogue Studies" in which predictions on retardation are tested, first at the laboratory scale, then at intermediate scale in caissons, and then in the field.
3. Comment on changes.
   a. Direction of changes was appropriate, made research plans more realistic.
   b. Changes did not satisfactorily remedy some problems having to do with the overall planning, implementing, coordinating, and applying to the field situation.
   c. These comments numbered, e.g., "2-5".
4. General comments.
   a. General Comments are numbered, e.g., "Task 2, Gen. 13".
   b. These have to do with problems concerning overview, coordination, impracticality of accomplishing stated research activities, lack of recognition of coupled processes (better to use "integrated" than "coupled"), confusion on basic thermochemistry, specific problems of measuring and applying adsorption data, incognito institutions and researchers, lack of maturation in research process.

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	CHAPTER NO. 8.3.1.3
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2-1	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 3, 10	New. Approach used to satisfy performance and design requirements. New section on geochemical barrier, development of models, quantifying retardation factor, site performance.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2-2	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 12, 21, 22, 23	New recognized desireability to use geochemistry to evaluate validity of site concepts, relation to hydrology, kinds of flow, gaseous pathways, rock/water reactions, modelling.

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COMMENT NO.: 2-3 | CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 28	Reworked. First paragraph summarizes expected work in absorption. Enormous. Get "retarda-factors for each species known to be chemically absorbing and for each rock unit in the saturated and unsaturated zone in the controlled area under the range of water and rock chemical conditions expected for each unit."

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COMMENT NO.:	2-4	CHAPTER NO. 8.3.1.3

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
p. 36	Purpose and objectives... 1st paragraph. Removed was a statement on the usefulness of groundwater chemistry only if sorption were were important, and inserted was: 'support and be integrated with other modeling efforts....' An indication of uncertainty was removed and replaced by a more certain one. Last sentence says that groundwater compositions at Yucca Mountain and the surrounding area have been determined for the saturated zone. Is this true?

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COMMENT NO.:	2-5	CHAPTER NO. 8.3.1.3
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
p. 37, 38	Study: Groundwater chemistry model. Objectives rewritten. Removed sentence, "Could compromise waste package." The new expression is more certain.	

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2-6	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 39	Last sentence, first paragraph. "Further work on the characterization of the satured zone water chemistry. This disagrees with the earlier statement on p. 36.

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COMMENT NO.:	2-7	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Sec. no. 8.3.1.3.2.	Describes planned 3-dimensional work on minerals, rocks. Obviously will need more access to cores than presently available.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2-8	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 46	On Activity: Mineral distributions Measure of work involved in the statement that sampling will be done every 20 meters (to me, a very large interval), which means for a 1000-meter hole only 50 samples are used to to characterize the entire section.

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COMMENT NO.: 2-9	CHAPTER NO. 8.3.1.3
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 56	The Technical Rationale states that stable assemblages can form through experimentation (true) but that thermodynamic data gained from certain reactions will be used to calculate the kinetics (even more difficult).

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COMMENT NO.:	2-10	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 59	The work proposed in this section, "Kinetics and thermodynamics of mineral evolution," is monumental.

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COMMENT NO.:	2-11	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 65-68	On Radionuclide retardation by sorption processes: The section under Parameters lists 8 gross factors that could be involved in measuring sorption coefficients. No experimental tree or box was attempted but the amount of work was recognized to be formidable. This is the only section to explicitly state these problems.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 2-12 CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 69	On Batch Sorption. Parameters. Reference to Well J13 waters removed. Evidently this is a recognition of problems involved in using a "standard water."

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COMMENT NO.:	2-13	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 71	The third paragraph gives a rare mention of the number of tests needed: 200.

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COMMENT NO.:	2-14	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
Table 8.3.1.3-3 p. 72	The table lists 10 "elements" and 5 "solid phases." A recurring problem running through geochemistry is the persistent use of "element" rather than solution species. Uranium, for example, can occur as U^{0}, U^{2+}, U^{3+}, U^{4+}, U^{6+}; it forms complexes with various substances; it allies with oxygen to make UO_2^{2+} cations. Using the element as a designation makes descriptions simple but it is misleading.

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COMMENT NO.:	2-15	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 74-76	On: Sorption as a function of sorbing element concentrations. Even here, where there is no question about the actual use of solution species, elements are listed, not ion species. New is a discussion on K_D values and use at Yucca Mountain, although the suggestion of K_D contour maps for the different stratigraphic units seems to require more information than is available or obtainable on 3-dimensional characteristics of the rock sequence.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 2-16	CHAPTER NO. 8.3.1.3
SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
p. 86	Section on precipitation processes along flow paths. Purpose and objectives: The 2nd paragraph recognizes that radionuclides may transport as dissolved species and in colloids.

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COMMENT NO.:	2-17	CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 86	Section on Technical rationale concerning precipitation processes along flow paths. The first sentence, "It is not practical to measure solubilities of all waste elements that may exist in radioactive wastes under all conditions that may occur at the repository or along flow paths to the environment. The statement is accurate and honest. The section following describes ways of reducing the number of factors and variables. But once again, the use of elements as a term rather than the solid phases in which they occur, which is thermodynamically required, cloaks specifically what is to be done. Solubility in physical chemistry has a precise meaning: it is the level of dissolved substances in solution in equilibrium with a solid phase.

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COMMENT NO.: 2-18	CHAPTER NO. 8.3.1.3
SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
p. 89	Section on solubility measurements, parameters. First and only mention that "Identity of solids controlling solubility" is important.

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COMMENT NO.: 2-19	CHAPTER NO. 8.3.1.3
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 90	Section on Solubility Measurements Description. Last sentence, "Solubilities experiments are not planned for technetium, cesium, iodine of strontium. Although radionuclides of these elements make important contributions to the of waste, they have high solubilities under conditions at Yucca Mountain, thus solubilities might not limit their transport. Again confusion is introduced by not referring to the solid phases in which the elements are located. But inserting phases does not clean up the sentence. Because one says they <u>may</u> have high solubilities is not a reason to avoid studying them.

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COMMENT NO.: 2-20	CHAPTER NO. 8.3.1.3
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 90	Solubility measurements, cont. 2nd paragraph staes that attempts will be made to approach steady state from both undersaturation and oversaturation. Oversaturation runs will provide and indication of the solids that may precipitate. These solids would then be used later to react with solution and to approach the steady state. This way they do not have to specify the solid involved. Approaching a "steady state" from oversaturation in silicate systems is fraught with kinetic difficulties. One may never get the equilibirum solid phase because of kinetic hindrances. A simple case is silica. Generally, quartz is the stable silica phase under the crustal conditions at Yucca Mountain. Reacting quartz with water slowly and carefully eventually will get to a "steady state" or true solubility of 7 ppm at 25°C. However, stirring the quartz-solution will cause the silica concentration to go up smoothly past 7 ppm, to about 100 ppm. Allowing the solution to stand, eventually amorphous silica will separate, in the presence of the stable phase quartz. But what does the experiment tell us? Only that the kinetic behavior or a "simple" system can be complex and unpredictable.

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COMMENT NO.: 2-21 | CHAPTER NO. 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
p. 127	On Demonstration of the applicability of laboratory data to repository transport calculations. Much of this section is new. The research is important because it tests in the laboratory and in the field predicted transport behavior. New is a "natural analogues" study, which will be informative if a sufficiently close analogue can be found.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: Task 2, Gen. 1 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	<u>Need for Supervision and Coordination of the Research</u> Some major difficulties in the SCP stem from the absence of a cooordinated plan, clearly conceived before the research began, aimed at ensuring in-context closely coordinated research by qualified persons, stepwise evaluation of results, systematic application to the problems, and arrival at consciously known check-points at which go-no go decisions are made. Chapter 8 mentions no agency that oversees, actively supervises or coordinates. the presented planning is more an exercise in form than reality.

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COMMENT NO.: Task 2, Gen. 2 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Need for Effective DOE Overview. The geochemical research is supported by DOE funds made available to research organizations on the basis of submitted proposals; these organizations are mainly the U.S. Geological Survey, Denver Office; Los Alamos National Laboratory; Sandia National Laboratories; Lawrence Livermore National Laboratory; and Argonne National Laboratory. Excellent researchers with modern facilities have studied various aspects of the needed work, with the relevancy of one project to the other and its place in the decision-making sequence being the responsibility of DOE. Unfortunately, DOE does not present a convincing case that someone in the system has the breadth of view and the operational insights to ensure sound progress.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: Task 2, Gen. 3 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Need for Vertically Directed Coordination The geochemical and related research that has been done is a set of projects organized without guidance and evaluation by a central responsible group. It is a horizontal organization into which research funds have been dropped to splatter and run to the edges of the agencies, much as mercury dropped on the laboratory floor runs to the corners of the room. My opinion is that DOE will find it difficult to be successful in meeting technical criteria required by NRC and requested by the State of Nevada, if the present organizational system is used.

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COMMENT NO.: Task 2, Gen. 4 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Inherent Complexity and Magnitude of Geochemical Work Plans do not seem to recognize the extreme amount of work required to answer at a reasonable level of certainty even simple geochemical questions. The SCP refers in an almost off-hand manner to various measurerments to be made to answer some geochemical questions; e.g., an important question is whether rocks contacted by groundwaters in a leaky repository will reach and precipitate radionuclides from solution. To solve this question requires data on solution reactions over the temperatures, pressures, and concentrations at Yucca Mountain, solid phase physical and thermodynamic data, absorption isotherms, solubilities of solids and gases in groundwaters, the radiolysis effect, influence of microbial organization, and effects of canister and backfill materials. Existing data on these factors is incomplete. Equilibrium data proposed to be gathered in the laboratory is costly, time-consuming, and not possible in some instances. Disequilibrium data on reaction kinetics are even more difficult because reactions of silicate-water systems below 300°C are unpredictable, hard to establish empirically, and lacking in theoretical bases.

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COMMENT NO.: Task 2, Gen. 5 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Interactive Systems in Nature A surprising aspect of the SCP is the low level of understanding of the importance of interactive effects. Geologists are accustomed to the idea that any set of rocks is an integrated result of physical, chemical and biological interactions during and after the original formation of the rocks. The oceans and the atmosphere have compositions that are the result of integrated processes of many kinds. The continental crust is the result of long sustained cyclic processes that mixed and sorted inorganic and organic matter, which led to the low density, silica-rich rocks that float as a crust on top of denser mantle rocks. For practical reasons, to study such complex systems the approach used must be simplified, but it must always be kept in mind that the applications of such work to concrete crustal problems may or may not be reasonable. Nature follows interactive paths, over millions of years, in her own ways, not necessarily those deduced from simplified studies.

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COMMENT NO.: Task 2, Gen. 6 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Metastable Problems in the Laboratory

Metastable Problems in the Laboratory

As an example, let us consider the reaction of a glass-crystal mixture of rhyolite with dilute groundwater. The crystals are mostly quartz and K-feldspar. One could measure the solubility of each phase in turn over the range of temperature, pressure and solution composition. The solubility of quartz is controlled by temperature and pressure:

$$SiO_2^{\circ} + H_2O \rightarrow Si(OH)_4 \text{ or } H_4SiO_4$$

The H_4SiO_4 molecule in solution ionizes:

$$H_4SiO_4 \Leftrightarrow H^+ + HSiO_4^-$$

thus making an acid solution.

Sanidine, the high-temperature form of K-feldspar, can react:

$$KAlSi_3O_8 \Leftrightarrow K^+ + Al^{+++} + 3Si(OH)_4$$

From the equilibrium point of view, the K-feldspar that can coexist with aqueous solutions at low temperatures is microcline, not sanidine. Microcline forms slowly in rocks, taking millions of years. The reaction is also pH or acidity dependent. Al^{+++} tends to react with H_2O:

$$Al^{+++} + 2H_2O \Leftrightarrow HAlO_2 + 3H^+$$

precipitating metastable diaspore ($HAlO_2$) and liberating H^+.

Metastable reactions such as these are difficult to anticipate or characterize.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: Task 2, Gen. 7 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Interactive Systems, cont. The SiO_2 content of solution will adjust to both quartz and K-feldspar. However, the back reaction of SiO_2 in solution to make quartz is slow, and the SiO_2 concentration can build up beyond the quartz solubility. This high SiO_2 then promotes the appearance commonly of SiO_2-rich metastable solid phases as opal or zeolites. Once formed, the metastable silica-rich phases maintain a high concentration of dissolved silica, thus making more difficult the appearance of truly stable minerals. Kinetics of breakdown of zeolite to stable phases is not well known and is difficult to measure. Meanwhile, unstable volcanic glass reacts step-wise with solution, feeding it with a flood of released constituents, which then enter the solution and affect reactions. The point is that Yucca Mountain reactions involve coupled step reactions of stable and metastable phases. Little is known from first principles. These interactions are recognized by geochemists to be troublesome. To predict interactions with other subsystems in geology, geophysics, and biology poses even greater problems.

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COMMENT NO.: Task 2, Gen. 8	CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Unanticipated Interactive Systems A good illustration of unanticipated coupled effects is Szymanski's proposal that kinetic and heat energy propagate upward, affect water chemistry, and horizontal-vertical movements of groundwater. DOE was caught by surprise by Szymanski, and it is predictable that they will, likewise, be subjected to a series of such surprises as the work proceeds and further insights are developed. However, the seriousness of the problem will most likely not be realized until some future time when efforts are made to use the data to assess repository performance. By then, much money and time will have been expended inefficiently.

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COMMENT NO.: Task 2, Gen. 9 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Experimental Problems in Adsorption The behavior of natural solids and solutions are complex functions of many factors, including the presence of other ions that compete for surface sites. Adsorption behavior of single and multiple solution species is needed to judge retardation. Many experiments have been done on adsorption of invidual solution species on solids analogous to minerals of high surface areas, generally at low temperatures and 1 bar pressure. One may use groundwater or simplified analogue solutions. Adsorption is only partly an equilibrium phenomenon; a given solution constituent reacts with the solid to form steady states achieved over the time of the experiment. The fine-grained solid is highly reactive, and can coarsen or transform to another phase given enough time. The best that that can be done is to establish empirically absorption ratios as a function of temperature, solution composition and time, for known solution species and characterizable solids. The effects caused by the presence in solution of other absorbed species would then need to be worked out. They cannot be calculated on the basis of existing knowledge.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: Task 2, Gen. 10 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Example of Experimental Problems in Adsorption If enough is known about the nature and concentrations of solution species, the reaction can be treated according to principles of solution chemistry. For example, copper species formed when chloride dissolves in solution are Cu^{+}, Cu^{++} (dependiing on redox) or as complex ions, $CuCl^{+}$, $CuCl_2^{o}$, or $CuCl_3^{-}$, etc. The absorption behavior of a metallic ion or complex ion depends stronly on charge, and is quite different for a positive charge compared to a zero charge and/or a negative charge. The equilibrium ratios of the concentrations of dissolved species at a given temperature and pressure depends therefore on the stabilities of ions and is a function of total metallic and Cl^{-} concentrations, ionic strength, hydrogen ion concentration, and oxygen fugacity. To experimentally cover the range of conditions for one dissolved substance on a particular substrate is a great deal of work.

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COMMENT NO.: Task 2, Gen. 11 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Adsorption, Cont. Suppose that the absorption behavior of copper species has been determined satisfactorily. Of course, many other species are in natural solutions that are capable of interacting with copper, but the chloride complexes are likely to be the most important. But let's look at another factor, the presence of other metallic substances, such as compounds of uranium and vanadium in which the valence can range from +6 to +1, and various oxy-compounds can form. Radioactive waste contains many compounds of different nuclides. Each with sufficient effort can be worked out. At some stage, then, a large amount of empirical data on each solution component is on hand. How can this be used?

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COMMENT NO.: Task 2, Gen. 12 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Adsorption, cont. The need for adsorption data is to estimate rate of transport problems in the worst case scenario of canister rupture at the thermal maximum in the presence of oxygenated flowing groundwater. The nature and levels of radionuclide compounds injected into solution, let's say, can be estimated. A problem immediately arises: to evaluate the sorption by materials in the site region, one must know the appropriate behavior of the individual radionuclide components <u>in the presence of all the other dissolved species</u>. That is, the various ions and complexes in solution will naturally interact with each other, with the solution, and with the solids. To deduce effects in a mixed system from data on individual solution species requires fundamental understanding of the reaction kinetics, which does not exist and which is not likely to be generated in any finite time.

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COMMENT NO.: Task 2, Gen. 13 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Evidence on Overall Coordination The documents are mute on the identity of persons and institutions that have overall responsibility for the work. Presumably, the future efforts will be done the same way as in the past and as are going on now, that is, in bite-sized packages allocated to researchers on the basis of proposals, invited or uninvited. Will the overall assessment at the close of the program be done in a similar way? If so, strong objections should be lodged.

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COMMENT NO.: Task 2, Gen. 14 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Maturation. Difficulties with the SCP do not lie in whether the persons and institutions are capable of doing the research. Many high quality individuals are doing excellent work. The work eventually is published in internal documents, at which point the researchers go on to their next project, which may or not be related to Yucca Mountain. This generates alternating intense focus and inattention, which results in a lack of maturation in the scientific work. Researchers who can stay with the research and who are responsible for interpretations and applications commonly go through stages of development of understanding and insights. Many leads have to be followed, some without positive results, but overall progress is made and insights deepened. Connections with other research eventually can be perceived and applied. The situation aparently stems from the belief by DOE that geological research can be done in an engineering fashion. Break the work up into identifiable bits, make sure that capable people are assigned the correct tasks, and simply wait for results. But for this approach to work, some agency early on would have to make planning decisions.

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COMMENT NO.: Task 2, Gen. 15 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Geochemical Research Projects in SCP Geochemical sections in Chapters 4 and 8 have been organized to meet NRC and EPA criteria for performance. Discussions were made of areas in which substantial progress has been made, notably in the chemistry, mineralogy and petrology of Yucca Mountain, mostly by the U.S. Geological Survey and Los Alamos National Laboratory. Three dimensional distributions have been worked on, but the lack of bore holes spaced to detect important structures that are deep enough to bottom in basement rocks has handicapped researchers. The nature and distributions of pore fluids above and below the groundwater table have not been completely characterized, which is an important goal of the proposed research. In general, the importance of geochemistry to site characterization was recognized. Research was planned to answer the various process questions by using a battery of field and laboratory studies. The studies were outlined to show sequential activities, uses in the program and relationships to other studies. The geochemical problem areas were discussed and the research formulations designed to solve these problems. So far as general approaches in geochemistry are concerned, the research plan was thorough and in general, relevant.

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COMMENT NO.: Task 2, Gen. 16 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
General	Specific Research Projects in Geochemistry A major problem is in implementing the research. The agencies and individuals to be involved are not specified. The time sequence of planned events is presented in linear fashion with a quantitative scale. Relationships, uses, and dependence on other research areas are mentioned. No clear statement was made as to how the objectives were to be achieved, who was in charge of what, and who, if anybody, was responsible for overviews and integration of all work. The conclusion can be drawn that future work will be done in a manner similar to past work, by isolated individuals and agencies, without an overall plan.

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COMMENT NO.: Task 2, Gen. 17 | CHAPTER NO. 4, 8.3.1.3

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
General	Magnitude of Research Projects in Geochemistry An operational problem is the general lack of awareness of the overwhelming amount of work required to achieve research activities mentioned in an off-hand manner in the Site Characterization Plan. To actually do the work described would require many years of effort at a cost which would make the characterization not practical. Any experimenter who has worked with silicate-fluid systems at 300°C and below is aware of the painfully slow progress made if the work is to stand up to ordinary critical review by one's peers. The DOE work not only must meet standards of colleagues but also of the NRC, EPA, interveners, and State agencies.

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TASK 3

Site Characterization Plan Review

Summary Comments

Task 3: Volcanic Geology and Mineral Deposits

L. T. Larson, D. C. Noble and S. I. Weiss

June 8, 1989

In general, most of our summary comments of May, 1988, on the Consultation Draft, remain applicable to the Site Characterization Plan of December, 1988. Although writing and organization are better, relatively few substantive improvements have been incorporated in the current version: for example, water is now recognized as a natural resource currently being exploited in the area and there now appears to be recognition of the importance of faults and breccias in localizing possible epithermal mineralization. Major deficiencies in the current SCP greatly outweigh the relatively minor improvements and must be of continuing concern to the State.

Of foremost concern is the *fait accompli* attitude that permeates the SCP. Implicit assumptions that Yucca Mountain is suitable for the repository are numerous and indicate prejudiced conclusions and a desire during site characterization to collect only those data needed to support those conclusions. This clearly prejudiced characterization program is not likely to result in scientifically sound or comprehensive identification and evaluation of potentially disqualifying or adverse conditions that may exist.

The "evaluation" of mineral and hydrocarbon resource potential given in sections 1.7 and 1.8 is built on incomplete, outdated, often inaccurate and/or misleading information and remains largely inadequate. The assumptions, interpretation, discussion and analysis given in sections 1.7 and 1.8 are not data (facts), although they remain unacceptably misrepresented as such in Chapter 8 and elsewhere. Sections 1.7 and 1.8 do not recognize or consider important recent mineral deposit discoveries in nearby areas that reflect increased and successful mineral exploration in the region and render hydrothermal systems of the southern part of the southwestern Nevada volcanic field much more attractive to explorationists than is recognized in the SCP. Similarly, the SCP omits a variety of important data on mineral deposits and mining that have become available since 1984, resulting in a marked underrepresentation of the present level of mining activity and probable future mineral interest in southwestern Nevada.

Sections 1.7, 1.8 and studies proposed within Chapter 8 reflect a flawed and compartmentalized understanding of the regional volcanic and mineral deposits geology, and of epithermal mineral deposits and the relationships of mineral deposits to volcanic centers of the collapse-caldera type. In particular, the proposed geochemical assessment is likely to be inconclusive without much greater subsurface sampling density and a much greater understanding of the vertical and lateral distribution and mineralogic variation of the subsurface hydrothermal alteration of Yucca Mountain. There continues to be no appreciation of the possibility of mineral deposition in the Paleozoic strata or volcanic rocks *prior* to deposition of the Topopah Spring Member. Furthermore, analogue comparisons are entirely unrealistic without substantially greater subsurface data and access to information that may be unavailable for pertinent analogue areas.

We take particular issue with the specious statement given in section 1.8.1.7.1 that the site represents an unattractive locality for mineral exploration because of the relative lack of alteration exposed at the surface and the lack of past mining activity. Being surrounded on both sides by nearby mineral districts that host at least one World-class gold deposit puts Yucca Mountain in the midst of what is commonly termed "elephant country" by explorationists. Having extensive subsurface alteration permissive of hydrothermal mineral deposits and being within "elephant country" is indeed attractive for eventual exploration. It is also well documented (e.g. Carlin and Battle Mountain areas) that when in "elephant country" explorationists are much more likely to test even the areas with the least promising surface characteristics, especially during times of favorable metal prices.

The proposed borehole drilling program is totally inadequate to evaluate the resource base in and near Yucca Mtn. and thus completely inadequate to provide data which will keep the likelihood of future human interference at a minimum. Future drilling must include boreholes (several) in the site proper and about it, and these must penetrate completely the Tertiary section and provide samples from a representative section of the underlying Paleozoic rocks. Several boreholes must also directly test faults, intersections of faults, breccia zones and highly fractured zones for evidence of hydrothermal mineralization. The hydrocarbon potential will also remain untested without deep drilling (20,000 - 25,000 feet) in the controlled area or the repository block. Such a deep borehole would yield important geologic, geophysical and regional structural information.

The SCP has within it technical procedures and methods that make use of of almost every conceivable geologic, geochemical, geophysical tool known to man. One gets the distinct impression that the DOE attitude and thought process is one that given a problem they don't understand, their answer is to 'throw' technology at the problem and hope the answer will 'fall' out; a classic example of the 'shotgun' approach. Cost or likely time for completion appear to be of very little concern. What further concerns us in this regard is that we believe that some of the proposed methods are likely to be ill-used, misapplied or under-utilized. For example, proposed surface geophysics is not at all to be focussed on potential resources at depth and geochemistry sampling is only at surface or repository levels-- not in holes in rocks which underlie the proposed repository unit and would likely be the target of future exploration efforts.

The SCP refers to the need to map and interprete 'small scale' structures (etc.) and they propose that the largest scale of mapping to be used is 1:12,000(one inch = 1000 feet), or twice that of a of a 7.5 minute topographic quadrangle. This scale is much too small for 'detail' unless DOE defines detail differently than do we. Certainly structures significant to the localization of ore in many mines throughout the World cannot be depicted on such a scale.

Two other items are not logically supported and deserve criticism here. One is the use in section 1.6.4 of a 10 km boundary around the proposed site, beyond which underground mines and excavations are excluded from consideration.

Where did this arbitrary 10 km boundary come from? What is the rationale behind this distance? A distance of 20 km would include active mines and prospects of Bare Mountain. Why 10 km? In section 1.7, a 1 km depth is mentioned as the maximum depth evaluated in standard mineral resource assessments. Does this mean that in the extremely nonstandard case of Yucca Mountain only possible resources within 1 km of the surface will be evaluated? If so, this would be wholly unacceptable. What is the basis of this important limit? Mining at depths below 1 km in North America is not unusual when warranted by grade-tonnage-price considerations. Such unsupported and arbitrary boundaries seem to us to be an example of the fox being allowed to decide how to best guard the hen house.

Finally, we reiterate our first summary comment of May, 1988, because it remains applicable to the current SCP. It is our opinion that the proposed activities will *not* provide geologic, volcanological, geochemical, geochronological, tectonic, or geophysical information required to appropriately evaluate the mineral/energy potential of Yucca Mountain and the lands about the potential site. If only the presently planned activities are carried out we will have only a very marginally better idea of the size and value of possible resources at depth below Yucca Mountain in either the volcanic rocks or the underlying Paleozoic strata. It appears to us that DOE continues not to take seriously concerns of resource potential.

Steven I. Weiss, Research Associate, Task 3

SUMMARY COMMENTS

References to Chapter 1 being "data", or to "data" of Chapter 1 are misleading and should be removed because most of Chapter 1 is obviously *not* data and should not be referenced as such. In my opinion, to refer to interpretations, assumptions and discussion as data (FACTS) is wholly incorrect; the authors and editors of this document lose credibility by such references.

In Chapter 1 and Chapter 8, much more emphasis should be placed on the importance of structural control on localization of ore mineralization in hydrothermal mineral deposits. Evidence of economically important mineralization within hydrothermal mineral deposits is obvious throughout the region (e.g., Bullfrog Hills, Bare Mountain, Mine Mountain(?) Calico Hills(?) and numerous areas within Nellis AFB&GR to the north). In the Bullfrog Hills (e.g., Original Bullfrog, Gold Bar Mine, Bond-Bullfrog Gold's Ladd Mountain) ore-grade Au-Ag mineralization has been, is presently, and will in the near future be exploited where it is largely hosted by faults that are of probable extensional nature in rocks of the Timber Mountain-Oasis Valley caldera complex. Hydrothermal alteration of the type associated with epithermal mineralization is clearly evident in the sparse published data from the subsurface of Yucca Mountain, yet almost no mention is made of any plans or intent to identify and test the fault and fracture structures within and beneath the site for mineralization. This surely reflects either a lack of understanding and technical expertise concerning epithermal ore deposits, or a predetermined opinion on resource potential and site suitability more easily supported by absence of key information.

I found no mention of plans to directly test hydrocarbon potential of the Paleozoic section beneath the site. In the context of the proposed investigations, activities, studies etc., the issue will likely remain unresolved without a direct test with a deep drillhole (~20,000 ft ??) within the controlled area. Such a test would also provide important information on the deep structural geology.

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-1; pg. 1 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.3.2.2.1 p. 8.3.1.3-49	History of mineralogic and geochemical alteration of Yucca Mountain

Objectives. Para. 1 sentence 1, I can't figure out what this objective is.

REVIEWER: L.T. Larson

L. T. Larson JR

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 8, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-2; pg. 2 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.3.2.2.1 **History of mineralogic and geochemical alteration of Yucca Mountain**

p. 8.3.1.3-49

Para. 2, sent. 1- makes an unevidenced and to my knowledge unknown statement. This whole paragraph is totally spectulative and what they have apparently done is take the shotgun approach of throwing everything at the problem in the fond hopes that something will work. They really have no idea.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson Jr.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE TECHNICAL REVIEW COMMENT FORM	
DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-3; pg. 3 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.3.2.2.1 History of mineralogic and geochemical alteration of Yucca Mountain

p. 8.3.1.3-49

Parameters. 1. such as? what authigenic mineralsand in what unit(s)? 4/5. Here again we pre- suppose the correct hydrologic flow models.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson L.R.	DATE: June 8, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-4; pg. 4 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.3.2.2.1	History of mineralogic and geochemical alteration of Yucca Mountain
p. 8.3.1.3-49	

An understanding of the nature, distribution and timing of hydrothermal alteration will be critical to, and bear directly on, efforts to evaluate the potential for undiscovered epithermal mineralization. Why is there no mention of a connection between this activity and those concerned with evaluating possible mineral resources?? This is a reflection of DOE's uninformed and compartmentalized thinking concerning ore deposits geology and exploration.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 8, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-5; pg. 5 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.3.2.2.1 p. 8.3.1.3-50	History of mineralogic and geochemical alteration of Yucca Mountain

X-ray diffraction will not detect phases that are present at less than about 5 vol% of the samples. This could result in inaccurate identification of phase assemblages and lead to incorrect assumptions and interpretations. Thin-section petrography must be done in conjunction with XRD.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 8, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-6; pg. 6 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.3.2.2.1 p. 8.3.1.3-50,51	History of mineralogic and geochemical alteration of Yucca Mountain

Use of these experimental dating techniques, especially with no mention of calibration schemes, will likely result in ambiguous information and will have an extremely high level of uncertainty. Why not use established dating techniques?? The 250 proposed samples for all this work will *not* give a representative picture of the paleohydrothermal system(s) for such a large volume of rock, especially since the present and proposed drill hole distribution is so limited and unrepresentative of the subsurface of Yucca Mtn. Also, contrary to the statement in the text, 6 of the 8 Technical Procedures for this Activity are *not* given.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 8, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-7; pg. 7 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.2	Investigation: Geologic framework of the Yucca Mountain site
p. 8.3.1.4-28	Fundamental OBJECTION/Concern

As written, the SCP tacitly assumes that the fundamental geologic framework of the region within which the Repository Site is situated is adequately known. This assumption is simply not correct. It is well known, for example, that there are important and fundamental questions concerning the presence or absence, age, etc., of detatchment faults. In addition, there are questions of equal or greater practical importance concerning a number of fundamental aspects of the Neogene (late Cenozoic) volcano-tectonic evolution repository region. These questions include, for example, aspects of volcanic stratigraphy, the location of calderas and relation to known ash-flow sheets, the relative and absolute age of various lava units and their relation to caldera systems, the timing of hydrothermal activity and mineralization and its relation to magmatic/caldera system(s), etc., etc., etc.

During their preliminary investigations, the Task 3 group has recognized a number of uncertainties in the basic volcano-tectonic framework of the southwestern Nevada volcanic field. These questions include the nature, age, and(or) ash-flow sheet assignments of a number of features of the Timber Mountain-Oasis Valley-Crater Flat caldera complex, the timing of initiation of magmatic activity of the southwestern Nevada volcanic field, and the probable identification of a new caldera of the southwestern Nevada volcanic field. Work carried out a few years ago (e.g., Noble et al., 1984, Jour. Geophys. Res., v. 89, p. 8593) showed that there were fundamental errors that had existed for *decades* concerning the stratigraphy and source assignments of ash-flow sheets of the *youngest and best preserved caldera centers.* Major revisions in basic geology have not been restricted to our group; for example, Warren et al. (1988, Geol. Soc. America Abs. with Programs, v. 20, p. 240) have made fundamental revisions in the stratigraphy, age and caldera assignment of a number of units of lava situated only a few miles north of the repository site. It is therefore highly unlikely that DOE's current understanding of the older, less well exposed or preserved volcanic geology is substantially complete and without similar errors.

REVIEWER: D.C. Noble D. C. Noble J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-8; pg. 8 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site

p. 8.3.1.4-28 Fundamental OBJECTION/Concern

Certain fundamental aspects of the volcanic/caldera geology have been essentially ignored for decades. Although Smith and Bailey, in their classic 1968 paper on resurgent cauldrons, explicitly recognized a late, post-collapse stage of hydrothermal activity, only very recently has work been begun on understanding the nature, timing, mineralogical, chemical, and metallization effects of hydrothermal activity and its relation to the various caldera and other volcanic centers of the southwestern Nevada volcanic field (e.g., Aronson and Bish, 1987, abs. of presentation at Clay Minerals Society, Socorro, NM; Bish, LANL Rept. LA-10667-MS; Jackson et al., 1988, Geol. Soc. America Abs. with Programs, v. 20, p. 171). See also our discussion of 8.3.1.8.5.1.2 Activity: Geochronology studies.

REVIEWER: D.C. Noble

D. C. Noble j.R.

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-9; pg. 9 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.4.2.1.1 Activity: Surface and subsurface stratigraphic studies of the host rock and surrounding units
p. 8.3.1.4-32

The work proposed in this section appears reasonably comprehensive. The detailed studies of the Topopah Spring Member outlined on pages 8.3.1.4-39 -42 are desirable, but it should be emphasized that such work does not take the place of the fundamental studies of the Cenozoic geologic setting as discussed in the previous comments.

REVIEWER: D.C. Noble D. C. Noble J.R	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-10; pg. 10 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys
p. 8.3.1.4-41

The program is nothing if not comprehensive. Certain of the studies appear desirable, for example the vertical seismic profiling, the paleomagnetic studies, and the commerically available logs. Certain other proposed work has the appearance to the geophysical layman of overkill.

REVIEWER: D.C. Noble D. C. Noble rk	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-11; pg. 11 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys
p. 8.3.1.4-41

General Comment: Objectives. The objectives are vastly incomplete. Given the limited drilling proposed to depths we must also have much more geophysical data in order to evaluate mineral potential at depth. Just to improve the confidence in stratigraphic models is totally insufficient.

REVIEWER: L.T. Larson L. T. Larson J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-12; pg. 12 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys
p. 8.3.1.4-41

Description. 1. Para. 3 Assumes there are marker horizons with 'sufficient' contrast . . .. Who says?? 2. Para 4 DOE does not provide any reason for the proposed survey locations and they are not obvious. 3. Table 8.3.1.4-4 The techniques proposed are exhaustive but a) how will they 'combine' with existing surveys (not at all I think) and b) how many many years are we looking at. Also, here again is the shotgun approach. They don't know if any of them will work so they will try them all. And still we will have almost no information useful to evaluation of potential mineral resources.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-13; pg. 13 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys
p. 8.3.1.4-41

General Comment: This comment is also appropiate to other sections of the SCP. No indication of man-year effort is given. Must this all be done in time for a proprosed 2000 AD (or whatever) opening of the repository? If so, it will never happen. The people who prepared this are not realists-they have simply taken the 'do everything' approach and have made little effort beyond logic diagrams to integrate work..

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson J.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-14; pg. 14 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.2.2 p. 8.3.1.4-65	Characterization of the structural features within the site area

General/specific comments: 1. para. 2. Detailed geologic mapping of zonal features in ash-flow tuffs . . .. will provide necessary stratigraphic control for identifying 'small scale' faults. Comment: That depends entirely on extent and consistency and presence of zonal features not presently known and also on what is meant by 'small scale'.

2. A mapping scale of 1"12,000 is not for detail. Small faults (widths of inches and lengths of meters or 10's of meters) and joint sets (widths of cm's) cannot be indicated on this proposed scale. Scale should be at least 10X larger and preferably even larger.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson L.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-15; pg. 15 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.2.2.1 p. 8.3.1.4-66	Geologic mapping of zonal features in the Paintbrush Tuff

General Comment: SCP indicates that such mapping is complete. Are they referring to Scott's?? -but that it will be extended W and S as shown in Fig. 8.3.1.4-9 on page 8.3.1.4-67. They will then assess need for 1:2400 mapping. I can forsee absolute need right now!!-if, as they say, they want detail.

REVIEWER: L.T. Larson L. T. Larson LTL	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-16; pg. 16 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.5.2.1.5 p. 8.3.1.5-110	Studies of calcite and opaline silica veins.

It would appear that this is yet another of the 'shotgun' approaches that exist throughout this draft SCP. DOE proposes almost all possible techniques to answer the question are these veins formed by ground waters going down or hydrothermal waters going up? What they do not appear to have done is to consider these possibilities in any sort of broader context (regional geologic significance??). Do the veins presently exposed in Trench 14 presage a broad-scale, post volcanic, hydrothermal event at or near Yucca?? Such are known elsewhere-witness the Golconda, Nv. deposits of manganese-tungsten and silver hosted in Quaternary valley alluvium and the slightly older but clearly post-volcanic Sulfur, Nv. gold deposits. What possibilities do these sorts of considerations open?

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson Jr.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-17; pg. 17 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.5.2.1.5 p. 8.3.1.5-110	Studies of calcite and opaline silica veins.

The nature and origin of the various calcite-silica veins and fracture fillings bear directly on questions concerning the extent and character of paleohydrothermal system(s) present beneath Yucca Mtn. It is critical that this group of activities be integrated with studies concerning past alteration (8.3.1.3.2.2) and potential for undiscovered mineral deposits. The geochemical, textural and petrographic information obtained in these studies should be part of the information base of the mineral resource studies, regardless of whether the information is of economic interest or not. It is disturbing to see this type of non-integrated approach so late in the DOE's program.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-18; pg. 18 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.5.2.1.5 Studies of calcite and opaline silica veins.
p. 8.3.1.5-110

The SCP outlines methods and technical procedures that utilize almost every conceivable laboratory - petrographic, chemical, isotopic, etc., procedure to characterize the vein deposits. The principal weakness in their approach is geological, and reflects an inadequate consideration of the importance of a thorough and quantitative understanding of the late Cenozoic paleohydrothermal history of the region within which the southwestern Nevada volcanic field is situated.

Specifically, the veins would be of much greater significance to the potential for disruption or flooding of the Repository if it could be shown that important hydrothermal activity had taken place in the region in latest Neogene (late Pliocene and/or Quaternary) time, than if this period, during which their was very little or no silicic igneous activity, was a time when no major hydrothermal/geothermal systems had developed in the region. This is particularly true if, as we suspect, it will not be possible to accurately date the veins by radiometric or other methods.

A *regional* understanding of the space-time distribution of hydrothermal activity is thus required. Moreover, it should be noted that there are several localities in Nevada (e.g., Sulfur, McGinniss) where there has been important hydrothermal activity, which in one case deposited economic precious-metal mineralization and in the other deposited Au and Ag, but in subeconomic amounts, well after the cessation of known Cenozoic volcanic activity!

REVIEWER: D.C. Noble D. C. Noble J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-19; pg. 19 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.5.2.1.5 Studies of calcite and opaline silica veins.
p. 8.3.1.5-111

OBJECTION: Last paragraph states mapping from another activity will be used to determine the location and areal distribution of the calcite-opaline silica deposits, which will establish an important datum and critical point for modeling. The cited activity (8.3.1.5.1.4.2) appears to deal only with mapping of surficial deposits and thus the calcite-silica deposits within bedrock will apparently not be included. This is completely unacceptable; the datum will be meaningless without consideration of the deposits in bedrock as well.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-20; pg. 20 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8	Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues
p.8.3.1.8-1	

General Concern: the complexity of the language, sentence structure and nomenclature used throughout this section render an intelligent evaluation of the content almost impossible. One of the central problems is that references are repeatedly made to some of the 13 (and possibly 17?) "investigation"s shown in Figure 8.3.1.8.1, but exactly to which of these "investigations" are they referring? Several times the "investigation" is not specified and the reader is left guessing and unable to follow the argument(s).

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-21; pg. 21 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 p.8.3.1.8-1	Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues

OBJECTION: As shown on pages 8.3.1.8-3 through 8.3.1.8-21, the levels of confidence needed, available in current estimates and needed in final values appear totally unsupported. Is this section going to be referenced later as "data" ?--Nonsense.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-22; pg. 22 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 p.8.3.1.8-1	Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues

General Comments: Summary. Overview covers most approaches and possibilities but leaves some serious gaps in thinking.

1. In their table on pages 8.3.1.8-3 thru -21 they select 'goals' and 'measurements' and 'needed confidence levels' etc.- Who makes these decisions and on what bases? It seems a circular path-one where the fox may well be deciding how many chickens are to be in the hen house.

2. None of the siting issues or probabilities referred to in the lengthy tables addresses what I consider two important igneous or volcanic aspects. To wit: a) Basaltic volcanism is most likely, agreed, and I agree it is likely to be structurally controlled - but present basaltic volcanism in Crater Flats is along a structure leading into or very near to the repository. Reactivation of this structure and its attendant volcanism is inadequately addressed. b) Much thought is given to intrusive interrupting the repository but I think zero thought has been given to a total system whereby the waste is dissipating heat through the rock- creating heat flow outward from repository while at the same time an intrusive at depth or laterally (and present higher heat gradiant in G-3 near caldera edge evidences this possibility) is also giving off heat outwards-this time toward repository waste. Thus normal heat flow gradiant is disrupted and heat might 'pond'-thus elevating ambient heat to unacceptable levels in repository during post closure period. This in turn could cause a chain of undesireable events such as moisture drive off,mineralogic changes, etc.

3. Item 8.3.5.18 in table 8.3.1.8-2(a). Ground motion causes spalling and closes air gap around waste package. Fault to do this is not necessary because Topopah Spgs has an abrupt failure mode and character when unconfined and once this rock is open to air it will spall readily-thus, just by the nature of the rock, it will at least partially close the air gap about the waste packages. Needs consideration.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson Jr.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.2 Activity: Geochronology studies
p.8.3.1.8-112

General comment: 1. Fascinating new methods proposed. Really state-of-the-art. Truely experimental. So I doubt if any two will agree and if this is so, which does one believe?? Also, how many years or decades do we have for the work?? Is this another example of the DOE shotgun approach??

REVIEWER: L.T. Larson L. T. Larson	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-23; pg. 23 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 p.8.3.1.8-24	Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues

Approach. - page 8.3.1.8-24. NNSWI will base its analysis of performance measures on a projection of Quaternary rates . . . at and proximal to the site. Here they are saying the lasat 2 million years where elsewhere they refer to the past 4 million years. Also, what is considered "proximal". Is Crater Flat proximal; is Timber Mtn., Bare Mtn? What?

REVIEWER: L.T. Larson L. T. Larson J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-24; pg. 24 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 p.8.3.1.8-26	Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues

para. 3. More refined data is needed as stated but also beyond the immediate site area on basaltic volcanism and also on such volcanism not penetrating repository but otherwise affecting it-see previous general comments.

REVIEWER: L.T. Larson L. T. Larson JR.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-25; pg. 25 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.1 p.8.3.1.8-108	Activity: Volcanism drillholes

1. Holes only 1000 foot deep to test magma sources that are estimated to be present by aeromagnetics?? Nonsense!!-might as well not drill at all. And, what was rationale for picking 330 meters? Why not 500 or 1000 or ???

2. All the sophisticated things on p. 8.3.1.8-108 are completely irrelevant if they don't hit something and in 1000 feet it appears to me unlikely that they will!

REVIEWER: L.T. Larson L. T. Larson Jr.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-26; pg. 26 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.1 p.8.3.1.8-108	Activity: Volcanism drillholes

General Concern: Drilling the anomalies to test for subsurface volcanic features is a good idea. However, the choice of 330m depth for the holes seems arbitrary and probably insufficient to adequately test the anomalies. The drillhole depths should be more flexible if they are serious about a real test here. This is particulary important for testing the available geophysical data; we know from past experience (e.g., drillhole UE25a-3, Calico Hills) how valuable such drilling is for testing data on the location and geometry of even large subsurface plutons.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-27; pg. 27 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.1 p.8.3.1.8-110	Activity: Volcanism drillholes

OBJECTION: first paragraph: Obtaining estimates of volumes of buried volcanic centers presumes the holes will penetrate *through* the inferred volcanic rocks, a terribly unrealistic presumption for such few and shallow holes. Such estimates will likely be laughable in their level of uncertainty. What is unexcuseable though, is the reference in the 4th sentence to such estimates (if they become available) as data!! ESTIMATES ARE NOT DATA (FACTS)!! Incredible that such propositions can be printed by people alluding to a scientific study. Such potential garbage will not refine probability calculations or anything else.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-28; pg. 28 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.1 Activity: Volcanism drillholes
p.8.3.1.8-110

First paragraph: No K-Ar ages will be obtainable from the inferred buried centers unless the holes penetrate the inferred rocks and materials suitable for dating are recovered. Where will such a likely possibility leave the proposed tectonic model and tests of patterns of basaltic volcanism in the NTS region?? I have strong doubts about the ability of this activity to meet such important objectives.

Key Technical Procedures for this activity do not yet exist.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-29; pg. 29 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1 Study: Characterization of volcanic features
p.8.3.1.8-107

OBJECTION: Judging from the information and descriptions given in Chapter 1, the work is far from completed and is not likely to refine risk assessment. If the relation of basaltic volcanism and intrusion to structural features is important, then much valuable information available by cost-effective mapping and radiometric dating is being ignored by not including the Quaternary mafic volcanism of the Sleeping Butte area in this study.

The proposed study seems also to ignore the need to test/resolve the questions of the volcanic and structural nature and significance of Crater Flat (c.f., Carr, 1988, GSA Abstr. v. 20, p. 148) Is Crater Flat a volcanic feature or tectonic feature, combination, what??

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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COMMENT NO.: 3-30; pg. 30 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.2 Activity: Geochronology studies
p.8.3.1.8-112

Objectives. What chronology is it that has been established for the >8 Ma basalts in the region?? Where is this *established* chronology available and how and by whom has it been established?? I question this assertion.

Also, why the focus on Black Mtn.? What reason is there for this and if Black Mtn. is considered to be the youngest silicic center of the region, the authors here show an important lack of knowledge of the volcanic geology and chronology of the southwestern Nevada volcanic field.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-31; pg. 31 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.2 Activity: Geochronology studies
p.8.3.1.8-112

Parameters. Much of the information for parameter #1 is to be obtained from Activity 8.3.1.8.5.1.3. However, Activity 8.3.1.8.5.1.3 is focussed on the young centers and is largely on a reconnaissance basis. How will detailed information necessary for establishing field relations and detailed stratigraphic information (needed for interpreting the age determinations) become available?? As written, it appears that such necessary information is not likely to be obtained in this activity.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.2 Activity: Geochronology studies
p.8.3.1.8-113

Description; third paragraph: The statement is incorrect that the Black Mtn. center is the youngest silicic volcanic center in the Yucca Mtn. region. Noble et al., 1984 (JGR v. 89, B10, p. 8593-8602) and Weiss and Noble, 1989 (JGR v. 94, B5, p. 6059-6074) have demonstrated that ash flow units of the Stonewall Mtn. center postdate and locally overlie rocks of the Black Mtn. center. The age cited from Kistler (1968) in this paragraph is from an ash-flow sheet of the Stonewall center, not from Black Mtn. as thought at the time of Kistler's paper. The authors lose credibility by not recognizing that important stratigraphic reassignments have been made in the past 5 years.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.2 Activity: Geochronology studies
p.8.3.1.8-114

top of page, paragraph continued from p. 113: It seems imprudent to use developmental techniques. What if the very strong possibility of inconsistent results occurs?? I also note that technical procedures for 4 of the important dating techniques do not yet exist, and can not exist until the techniques have been developed and applied to the objectives of this activity. Seems to be a lot of crucial information and resulting interpretaion and inference is riding on something that may not work.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-35; pg. 35 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.2 Activity: Geochronology studies
p.8.3.1.8-112

This section provides additional examples that the individuals who prepared the SCP do not possess thorough and current knowledge and understanding of the late Tertiary volcanic and tectonic evolution of the southwestern Nevada volcanic field. For example, on page 8.3.1.8-113, the youngest K-Ar age for the Black Mountain volcanic center (caldera) is given as 6.5 Ma after Kistler. (Actually, Kistler's age is 6.2 Ma, which recalculates to 6.3 Ma using presently acceptable constants.) Noble et al. (1984, Jour. Geophys. Res, v. 89 p. 8593) show that the unit dated, the Spearhead Member of the Stonewall Flat Tuff (formerly termed the Labyrinth Canyon Member of the Thirsty Canyon Tuff), is from the Stonewall Mountain volcanic center to the northwest. Ages available for the Thirsty Canyon Tuff (Kistler, 1968; Weiss et al., Jour. Geophys. Res. v. 94, B5, p. 6075) are older, ranging from 7.5 to 7.8 Ma.

Furthermore, it is incorrect to state that K-Ar ages on Na-rich sanidines are suspect. A number of replicate ages, for example on the Stonewall Flat Tuff, show that ages obtained on such materials are both precise and accurate.

Rather, the radiometric ages on the basalts must be suspect, and are probably too old. Further work is required on dating the basalts that have yielded ages in the 8 to 9 Ma range. Any errors most probably do not lie in the analytical procedures applied but rather in the selection and/or preparation of materials for radiometric dating.

Finally, the focus of dating the youngest silicic volcanism in the region should not be on the Black Mountain. Rather, the most likely candidates for young silicic volcanism are various domes and flows of rhyolite exposed west and northwest of the Timber Mountain-Oasis Valley caldera complex.

REVIEWER: D.C. Noble D. C. Noble J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-36; pg. 36 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.3 Activity: Field geologic studies
p.8.3.1.8-116

This section provides further evidence that the individuals who prepared the SCP do not possess thorough and current knowledge and understanding of the late Tertiary volcanic and tectonic evolution of the southwestern Nevada volcanic field.

REVIEWER: D.C. Noble	ORGANIZATION: Univ. Nevada-Reno
D. C. Noble J.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-37; pg. 37 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.8.5.1.3 Activity: Field geologic studies
p.8.3.1.8-116

Objectives. That most of the work is completed is is simply not correct. Recent information (e.g. Wells et al., 1988, GSA Abstr. v. 20, p. 242) shows important assumptions and interpretations contained in Chapter 1 to very likely be wrong, and at the very least requiring considerable further basic geologic study. Though basalts >6 Ma have been delineated in the quadrangle mapping of the NTS, very little is known, and less is published, concerning their eruptive history, evolution of eruptive centers, etc., etc. In particluar this is the case for the large areas of the southwestern Nevada volcanic field which have been mapped at only the county scale or were mapped at 15 minute scale before stratigraphic relations and ages of the major ash-flow sheets and caldera complexes were established.

We also know from a DOE-NRC-CVTS-NWPO field trip in spring, 1989, that DOE's detailed mapping of some (or all??) of the post- 6 Ma basaltic centers simply does not exist. Such assertions should not be included in the SCP, a document that the uninformed public relies on for accuracy and faithful representation of facts.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-38; pg. 38 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9 p. 8.3.1.9-1	Overview of human interference program

General Comments: 1. nowhere in this section does DOE address the very real (judging from present day human activities) problem of random vandalism and curiosity of humans about something that may have been 'locked' away 000's of years ago. 2. The entire effort seems to disregard NRC regulations that "require that resources at the site with current markets be identified and described in terms of net and gross values" and that it must "be demonstrated that the site is located in an area such that natural resources at or near the site are not likely to give rise to interference activities. On page 8.3.1.9-3 DOE goes on to say that intrusion by exploratory drilling for resources can be the most severe intrusion scenario . . .. Taking these items in keeping with what they propose to do to ascertain mineral resource potential in and near the site it is evident that the program they propose is totally inadequate in terms of geology, drilling, geophysics, etc. In particular, great gaps are present and apparently will remain present, in our knowledge of possible mineralization in the Paleozoics below Yucca tuffs. Also, just how near do you have to be to be revelant in terms of mineralization. Calico??, Wahmonie??, Mine Mtn??Bare Mtn? Camp Transvaal?? Where??? On page 8.3.1.9-3 the DOE says "current information and new data acquired from site activities will be employed to assess the natural resource potential of Yucca Mtn." They have laid out very little effort directed specifically toward mineral potential determinations. What they have done is ill-conceived and ill-integrated.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson L.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-39; pg. 39 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9 p. 8.3.1.9-2,3	Overview of human interference program

The basic assumptions of the approach laid out on p. 8.3.1.9-2 and 8.3.1.9-3 are probably unrealistic, particularly in not-so-distant-future economic situations when available energy and mineral resources are likely to be much more limited and consequently much more valuable. The incompatability of resource exploration and extraction in a given area has historically not been sufficient to over-ride favorable (or potentially favorable) economic factors, which provide the only real controls on resource exploration and extraction.

If future human activities are unpredictable and DOE is serious about the human interference issue, how will it be possible for "professional judgement" to determine the likleyhood of future human intrusion resulting from resource exploration or extraction?? Who exactly will these "professionals" be who will be able to determine the unpredictable?? Professional scientists?? Professional athletes?? Professional engineers?? Professional fortune tellers?? Who?? This approach and the thinking behind it are seriously flawed, if not absurd.

What "current information and new data" are they referring to in the last paragraph of p. 8.3.1.9-3?? The SCP is utterly deficient and lacking in much important current information concerning the mining, ore deposits geology, hydrothermal alteration/mineralization history and current resource exploration in the accessible portions of the southwestern Nevada volcanic field and withdrawn areas of the NAFBGR and NTS. The proposed studies (see following comments) are not likely to add significantly to the little that DOE knows now and must know if they are serious about any resource potential assessment.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-40; pg. 40 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9 p. 8.3.1.9-11	Overview of human interference program

first paragraph at top of page and second paragraph on p. 8.3.1.9-12: *How* will such estimates be made and *whose* "professional and expert opinion" are they referring to here?? I do not think DOE has a satisfactory way to resolve the natural resource issue so they are hoping it falls out (magically) of site characterization and can then be lain on someone else (presumeably of their choosing) down the road. Are they proposing to use *my* professional and expert opinion?? How about mining industry people who are experts in the local area?? I think not. The whole thing sounds suspicious to me.

second to last paragraph p. 8.3.1.9-11: The present assessment given in Chapter 1, particularly for precious metals resource potential, is wholly inadequate and is based on incomplete and out-of-date information together with inappropriate and misleading emphasis, interpretation and inference. This is particularly accute in regards to possible undiscovered resources.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-41; pg. 41 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2 Investigation: Studies to provide information required on present and future value of energy, mineral, land and groundwater resources

p. 8.3.1.9-22-23

Technical Rationale. 1. Their statement that the scarcity of vegetation, wildlife and water has historically precluded using the land for recreational purposes - I take exception to. Look at Sand Mtn. Nv. and others. Much greater recreational use would have been made had not most of the land been withdrawn into NTS and Nellis.

2. Their statement that probability that natural resources occur at Yucca is a required input parameter for evaluating the probability that future exploratory drilling will occur is true. BUT, it is also true that it is required to define the presence or absence of resources which, if present, is an NRC disqualifier. They do not address this little item here. Also they say 'in the vicinity' of Yucca Mtn. Just what is vicinity?? They do not define.

REVIEWER: L.T. Larson L. T. Larson S.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-42; pg. 42 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2	Investigation: Studies to provide information required on present and future value of energy, mineral, land and groundwater resources
p. 8.3.1.9-21	

OBJECTION: The preliminary assessment presented in the environmental assessment (DOE, 1986b) was so inadequate that it should not be considered a credible reference. Sections 1.7 and 1.8 of the SCP do provide additional information, but in no way should these be considered a bonafide "evaluation" of anything.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-43; pg. 43 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2	Investigation: Studies to provide information required on present and future value of energy, mineral, land and groundwater resources
p. 8.3.1.9-23	

Land use (middle of page) This whole line of reasoning based on historical use is suspicious at best. Historically there was no large, affluent population in nearby regions with recreational time and technology until after WW II that was able to access the area; but by then most of the area was already withdrawn from public access.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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COMMENT NO.: 3-44; pg. 44 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2 Investigation: Studies to provide information required on present and future value of energy, mineral, land and groundwater resources

p. 8.3.1.9-23

Second to last paragraph: second sentence refers to an "expert panel" who will evaluate the calculated probability of natural resources. Who will be on this panel? When will this evaluation occur? What type and how much authority, if any, will this panel have? And just what *is* a "subjective probability"?? Will this "subjective probability" be used to calculate some other probability or rate or be used to "demonstrate" something??--Nonsense.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-45; pg. 45 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2 Investigation: Studies to provide information required on present and future value of energy, mineral, land and groundwater resources

p. 8.3.1.9-25

Table 8.3.1.9-3: The current representation is not correct and does not allow for the possible presence of undiscovered resources, particularly between drillholes or beneath the many shallower holes of the *non-representative* domain that has been drilled. There is abundant evidence from the limited drilling and regional and local geology that is *permissive* of significant ore forming processes having occurred. There is nothing to exclude the possibility of significant hydrothermal mineral deposits beneath the repository!!

The levels of uncertainty given (column 3) are incorrect and are both highly uncertain based on both the available information and the absence of much crucial geologic information.

Seventh column: Subtle evidence of hydrothermal mineralization *does* exist in the subsurface based on chemical and petrographic information available in the published literature. Also, the existing drillholes and published information are not, and should not be considered, *representative* of the subsurface of Yucca Mtn or the volume of rock beneath the proposed repository. So in essence, we really do not know much about what is, or is not, down there.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-46; pg. 46 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1 p. 8.3.1.9-27	Study: Natural resource assessment of Yucca Mountain

Fundamental concern: The possibility of economic and(or) potentially economic mineral resources within and in the general vicinity of the Yucca Mountain Repository Site is a much more serious issue than has been considered by DOE as is presently represented in the SCP. The following examples provide clear evidence of the mineral potential of the region surrounding Yucca Mountain and of the rock units of the Repository Site.

The Beatty-Bullfrog-Bare Mountain area, which based on certain structural interpretations may within the past 10 million years have been appreciably closer to Yucca Mountain, is presently extremely active with regard to mineral production, mine construction, and mineral exploration. At the Gold Bar mine gold is presently being produced from ore hosted by *welded ash-flow tuff of the Paintbrush Tuff.* At Ladd Mtn., about one mile south of the Montgomery-Shoshone, mine reserves of 3.2 million ounces of gold have recently been announced by Bond-Bullfrog (Dallhold, Inc.), and a world-class mine is presently in the early stages of production. The host rocks for this mine are welded *ash-flow tuffs of the Timber Mountain-Oasis Valley caldera complex.* Reserves of 0.15 million ounces of gold have recently been announced by GEXA Gold at the Telluride district directly northeast of Bare Mountain, and active drilling continues. Radiometric dating by Task 3 has shown that hydrothermal activity is related to activity of the Timber Mountain-Oasis Valley caldera complex and other volcanic centers of the southwestern Nevada volcanic field. The Transvaal district, underlain by *welded ash-flow tuff of the Timber Mountain-Oasis Valley caldera complex*, is presently the subject of negotiations with major mineral companies with respect to options for mineral exploration. Other mines (e.g., Mayflower and Pioneer) and prospects are also hosted in volcanic rocks of the southwestern Nevada volcanic field.

The northern part of Yucca Mountain clearly would be explored/sampled/evaluated for precious-metal mineral deposits if it were open to the public. In view of these and other available information, particularly published information from drill holes at Yucca Mountain, a comprehensive study of the mineral resources of the region based on the acquisition of a wide range of geologic, mineralogic, geochemical, isotopic, geophysical data and other data through *new* field and laboratory work is essential.

REVIEWER: D.C. Noble D. C. Noble J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-47; pg. 47 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1 p. 8.3.1.9-27	Study: Natural resource assessment of Yucca Mountain

Fundamental concern:The review of mineral deposits presented in Section 1 clearly demonstrates that the DOE lacks scientific personnel who are qualified to evaluate the mineral deposit geology and mineral resource potential of the Yucca Mountain Repository Site Area. The dicussion reads like a major term paper written by an industrious but inexperienced graduate student. A lack of knowledge of the most recent literature and cutting-edge thought as well as a lack of knowledge of and contact with the exploration and mining industry in the region is obvious.

REVIEWER: D.C. Noble D. C. Noble J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-48; pg. 48 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2.1 Study: Natural resource assessment of Yucca Mountain
p. 8.3.1.9-27

Fundamental concern: The amount of work proposed to evaluate mineral resources is completely and utterly inadequate. At least an order of magnitude more work will be required to provide an adequate understanding of the probability of mineral resources at depth in the region of the Yucca Mountain Site. Based on the effort proposed in the SCP for evaluating various tectonic, hydrologic, cultural, and other factors, the effort devoted to evaluting mineral resource potential should be two orders of magnitude greater than that outlined here.

The nature and balance of the work proposed by DOE in the SCP to evaluate mineral deposits potential is largely improper. Specificially, no systematic, comprehensive and detailed geologic investigations and ancillary support petrographic, geochemical, isotopic, radiometric dating, etc., studies are proposed of the many areas of hydrothermal alteration, known and potential mineralization, and other pertinent areas! The work of Task 3 to date has clearly demonstrated that the knowledge presently available is totally inadequate. To remedy this a Geologic Studies Program must be set up to evaluate mineral potential and related problems in volcanic stratigraphy, caldera geology, structural geology, etc.

REVIEWER: D.C. Noble D. C. Noble Jr.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-49; pg. 49 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1 p. 8.3.1.9-27	Study: Natural resource assessment of Yucca Mountain

This section promises a great deal but delivers very little. For example, in the last paragraph of p. 8.3.1.9-27, what models of mineral resource generation are there that are considered characteristic of the region?? Why not tell us which ones they are referring to or that they will consider?? This looks like putting of the cart before the horse.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-50; pg. 50 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1 p. 8.3.1.9-28	Study: Natural resource assessment of Yucca Mountain

Fundamental concern: last paragraph this page; There is no basis for the implicit assumption (first sentence) that future mineral exploration drilling and/or mining will be shallow. Deep activities will occur if warranted by price-grade attractiveness. Deep drilling or mining could conceivably pass *through* the repository in pursuit of possible (or perceived) resources beneath the repository. This would surely not result in diminishing the potential for interacting with the waste. This paragraph appears ill thought out.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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COMMENT NO.: 3-51; pg. 51 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2.1 Study: Natural resource assessment of Yucca Mountain
p. 8.3.1.9-29

Last paragraph on this page is internally inconsistent because it states that information in this Study will allow calculation of tonnage, grade, etc., of *undiscovered* resources that may have value in the future. Surely the information needed for such a calculation will require the actual *discovery* of any such undiscovered resources; a rather large undertaking if they are truly serious. This paragraph should be revised for clarity.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-52; pg. 52 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-30	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

General Comment: a) This appears to be thought of as a separate item and it should not be-- it should be a part of geologic assessment. b) No mention is made of depth dimension. You certainly will not be able to assess all potential mineralization from surface studies.

REVIEWER: L.T. Larson L. T. Larson Jr.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-53; pg. 53 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-30	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

Parameters. To list of elements given in silicic tuffs I think one could easily add Fl, Be, Al (alunite), Mo (Valles Caldera)... (others??).

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson J.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-54; pg. 54 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-31	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

1. They state that adjacent areas with surface and subsurface anomalies (e.g. Wahmonie, etc.) would prove more likely. Probably this is true but should one not consider these within the affected area??

2. Their statement that samples will also be collected and analyzed from N Yucca Mtn, Calico and Wahmonie. Should they also not include Camp Transvaal, and Mine Mtn.??

REVIEWER: L.T. Larson L. T. Larson J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-32	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

They state that sample spacing in the controlled area will be between 250 and 750 feet for geochemistry. Specific spacing should be based upon sizes of analog systems - which I am sure will be at their narrowest much smaller than 250 feet. That is if they are talking about mineralization.

DOE says subsurface program will be carried out in a similar manner. A representative number of drillhole cores will be selected that uniformily.... Comments on this are that this is not a sufficient statement. Specifically: a) no comment on depth feature. How deep the holes? To the Paleozoic? How many will do this?? Not clear. b) no uniformly spaced holes now exist and none are evidenced on their borehole program. c) core will be sampled at 50-300 foot intervals?? Really!! they should be sampled much closer and specific samples should be premised upon geology.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson J.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-56; pg. 56 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-33	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

DOE indicates that specifically excluded elements are Cr, Co and Pt-group because they are known only to be associated with mafic and ultramafics. This is not in general true for cobalt and while generally true for Cr and Pt-group exceptions to exist-such as Goodsprings, Nv etc.

The DOE statements in the Table - that all geochemical sampling plan, analytical methods and field methods are "To Be Determined"- leaves one with little basis for evaluation.

REVIEWER: L.T. Larson

L. T. Larson J.R.

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-57; pg. 57 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization
p. 8.3.1.9-30	

Fundamental concern: The most important criticism of the activity is that the proposed geochemical work is completely divorced from, and not under the guidance of, a geological study team. The geochemical assessment is improperly administratively structured; it is presently set up as effectively a separate activity independent of detailed geologic (and geophysical) work. Instead, it should be one portion of (and under the scientific and administrative control of) an intensive, and fundamentally geologic, program of evaluation of mineral potential as stated in section 3, above.

REVIEWER: D.C. Noble	ORGANIZATION: Univ. Nevada-Reno
D. C. Noble J.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-58; pg. 58 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-30	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

Fundamental concern: No discussion is given of several important geological features that bear directly on the use of geochemical data to evaluate the mineral potential of the Yucca Mountain area. Specifically, no mention is made of the definite possibility that mineralization *occurred* before the deposition of the Topopah Spring Member of the Paintbrush Tuff, and thus that a potential ore deposit could be very effectively shielded from surface detection by geochemical sampling methods. Secondly, no indication is given that in many epithermal Au-Ag systems both economic elements and pathfinders are largely - or completely - restricted to a rather limited vertical range, and that in some systems there is little or no chemical or mineralogical signature spatially above ore at depth.

REVIEWER: D.C. Noble D. C. Noble Jr.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-59; pg. 59 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-30	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

Fundamental concern: Finally, and perhaps most important: Mineral systems - including areas of hydrothermal alteration and enrichment in pathfinder elements - commonly are appreciably smaller than the area of the Repository block. Without a systematic program of deep drilling within the actual Repository area it will be impossible to determine the possible presence of economic mineralization within and/or below the Repository. Evaluation of those portions of the SCP dealing with studies involving drilling, etc., show that very few, if any drill holes are planned that will penetrate the repository horizon, not to mention rocks beneath the horizon.

REVIEWER: D.C. Noble D.C. Noble J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-60; pg. 60 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2.1.1 — Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

p. 8.3.1.9-30

Specific comments include the omission of Be as an element that occurs in a volcanic setting (e.g., Spor Mountain, Utah) and the omission of Tl, Te, NH_4^+ (ammonium), Mo and W as common pathfinders. In particular, the omission of thallium shows that the individual(s) who prepared this section are unfamiliar with modern knowledge of the trace-element associations of epithermal precious-metal systems. A closer sampling grid than that proposed is probably desirable, although the major criticisms of the plan of investigation relate to the conceptual design of the study.

REVIEWER: D.C. Noble	ORGANIZATION: Univ. Nevada-Reno
D. C. Noble f.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-61; pg. 61 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-31	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

OBJECTION: Description, 1st paragraph; Drilling *is* a type of exploration and may be likely, but not necessarily, based on favorable surface chemistry. Certainly there are examples of drilling programs conducted without elevated values at the surface (e.g., Ladd Mtn., mineralized structures at depth at Creede, CO discovered by Homestake, etc.). As written, the next sentence implies that Sections 1.7 and 1.8 comprise the currently available data and regional comparisons. This is simply not correct; they are neither current nor complete. Furthermore, "confidence" is not needed to comply with 10 CFR 60, but solid, *representative* and conclusive information is required.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-62; pg. 62 of 91	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2.1.1 Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

p. 8.3.1.9-31

Description, 2nd paragraph; comparison of Yucca Mtn breccias with analogue breccias known to carry mineralization is a good idea. Such comparisons should include as many *analagous* breccias as can be found associated with mineralization in southwestern Nevada.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

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NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-65; pg. 65 of 91	CHAPTER NO.: 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2.1.1 Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

p. 8.3.1.9-32

2nd to last paragraph: Just what "average elemental values found in silicic tuffs" are they refering to here?? Name *one* reference in the professional literature that gives reliable background or average values for precious metals and(or) pathfinder elements such as Sb, As, Hg, Mo, Tl, etc. Such baseline information will surely have to be generated prior to any comparison.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-66; pg. 66 of 92 | CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.1 p. 8.3.1.9-33	Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

The statement that methods and technical procedures are given in the following table is not correct. Only the methods are given. In such an important activity one should have a way to evaluate the proposed methods, but none seem to exist. Why not cite the appropriate technical procedures for some of the same analytical methods proposed in other activities?? Such a lack of procedures casts additional doubt on the adequacy of the activity.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-67; pg. 67 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.2 p. 8.3.1.9-33	Activity: Geophysical/Geologic appraisal of the site relative to mineral resources.

1. The parameter section is a paragraph full of "may's" which will allow them to do or not do exactly what they wish. And just what is 'qualitative' evaluation?? Merely looking at? How does this fit their directive to define resources by tonnage and grade?? 2. They don't propose to do anything new at all. Merely look at existing data. This clearly indicates that they do not take their charge seriously as far as resources go.

REVIEWER: L.T. Larson L. T. Larson LR.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-68; pg. 68 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.2.1.2 Activity: Geophysical/Geologic appraisal of the site relative to mineral resources.

p. 8.3.1.9-33

It is stated in the section Methods and technical procedures: "There are no procedures for Activity 8.3.1.9.1.2. Existing data will be used." In a similar manner to our evaluation of section 8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site, we believe that the present geologic and geophysical data base is insufficient to adequately evaluate the mineral resources potential of Yucca Mountain site and environs. The geophysical data presently available is largely of a character inappropriate for evaluating mineral potential. A program of appropriate geophysical support should be set up within the geological program; it should not be administratively under a separate geophysical or seismological group.

REVIEWER: D.C. Noble	ORGANIZATION: Univ. Nevada-Reno
D. C. Noble Jr.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-69; pg. 69 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.2 p. 8.3.1.9-33	Activity: Geophysical/Geologic appraisal of the site relative to mineral resources.

General Concern: As proposed, this activity is not integrated with the mineral resource testing program. Existing data is too regional in scope and scale and is unlikely to have resolution needed to detect mine-scale structures or mineralized zones. Remote sensing is not at all appropriate for the most important aspect of the activity: attempting to detect and map subsurface structures and hydrothermal alteration.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-70; pg. 70 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.2 p. 8.3.1.9-34	Activity: Geophysical/Geologic appraisal of the site relative to mineral resources.

Parameters: Possible zones of hydrothermal alteration (exposed at surface) will not be identified with any type of myopia, thematic or otherwise. The proposed technique sounds more like a disease than a remote sensing tool.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-71; pg. 71 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.4 p. 8.3.1.9-37	Activity: Assessment of hydrocarbon resources at and near the site

1. Again at the site they intend to use only UE25p#1 since it was the only one to hit Paleozoics. This is clearly and obviously inadequate for appraisal of anything . Further, how far did it penetrate Paleozoics and what variety were encountered?? 2. Finallly, many more specifics on units and locations away from Yucca which are to be sampled is needed. 3. The table on page 8.3.1.9-39 is very difficult to evaluate since everything is TBD.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson Jr.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-72; pg. 72 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.4 p. 8.3.1.9-37	Activity: Assessment of hydrocarbon resources at and near the site

General Concerns: As written, this activity is unlikely to provide the required information. Unless the regional structural geometry becomes well known, it is unrealistic to assume that the planned tests will be of sufficient value to substantially improve our knowledge of the hydrocarbon potential beneath the Site. Specifically, without a deep drill-hole (~20,000 feet) through the Site, it is unlikely that the objectives of the activity will be acheived. Also, Section 1.7.2.2.1 is referenced as if it were a bonafide literature reference; indeed it is not and should not be presented as such.

REVIEWER: S.I. Weiss	ORGANIZATION: Univ. Nevada-Reno
Steven I. Weiss	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-73; pg. 73 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.5 p. 8.3.1.9-39	Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration

<u>General concern</u>: We reiterate that the D.O.E proposed Site Evaluation Procedures (Activities 8.3.1.9.2.1.1, -.2, etc.) do *not* provide adequate fundamental geologic and other data necessary to evaluate mineral, etc., potential of the Yucca Mountain Site. In addition, we note that it will in all likelihood be impossible, or a best unfeasible, to calculate "tonage, or other amount, grade, and quality". Rather, only a probabilistic estimate can be given as to the mineral, etc., potential of the Site and environs.

REVIEWER: D.C. Noble D. C. Noble f.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-74; pg. 74 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.5 p. 8.3.1.9-39	Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration

General Concerns: The objectives of this activity are unlikely to be acheived without systematic drilling of mineralized structures. Such structures, if they exist, will need to be discovered accidentally by unrelated drilling or excavation because the proposed geological, chemical and geophysical studies do not appear oriented towards identification of structures likely to host epithermal mineralization that may be present.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-75; pg. 75 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.5 p. 8.3.1.9-41	Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration

General concern: As written, it seems unlkely that a final assessment of mineral resources at the site, qualitative or otherwise, can be made from this activity. How can the present value or potential for future exploration of *undiscovered* resources be credibly calculated, assessed, or evaluated without discovery of the resource(s)?? This activity promises a great deal but...

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

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COMMENT NO.: 3-76; pg. 76 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2.1.5	Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration
p. 8.3.1.9-41	

The analog selection parameters seem reasonable to me. Should , however, include the New Mexico Valles system, the San Juan system, the New Zealand systems, and probably Fiji and Peru???? I must ask, however, where they are going to get the data to make reasonable comparisons if they don't drill and explore in all ways the Yucca situation more thoroughly than they have proposed.

REVIEWER: L.T. Larson	ORGANIZATION: Univ. Nevada-Reno
L. T. Larson J.R.	DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-77; pg. 77 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.3 p. 8.3.1.9-45	Investigation: Studies to provide information required on potential effects of exploiting natural resources on hydrologic, geochemical, and rock characteristics

General comment: 1. At this time this section pertains only to ground water. Why? It would appear to me more than appropiate-indeed essential to model effects of other possible occurrences based on analogs. 2. Fig. 8.3.1.9-4 logic diagram. This diagram, in common with essentially all of their logic diagrams tends to separate tasks into discrete activities which, at the level the work is to be done, are not mutually supporting and should be. For example, how can 8.3.1.9.2.1.5 -mineral and energy assessment-be done at all without 8.3.1.9.1.1.1 Geochemical, and 8.3.1.9.1.1.2 -Geophysical/geological assessment??

REVIEWER: L.T. Larson L. T. Larson JR	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-78; pg. 78 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.3 p. 8.3.1.9-45	Investigation: Studies to provide information required on potential effects of exploiting natural resources on hydrologic, geochemical, and rock characteristics

OBJECTION: Again, The Environmental Assessment (DOE, 1986b) and Section 1.7 of the SCP should not be considered satisfactory evaluations or data sets. Estimates, assumptions and interpretations are referred to as data (e.g., p. 8.3.1.9-45), this is incorrect and misleading and should be removed so that it does not become accepted by less-informed readers.

REVIEWER: S.I. Weiss Steven I Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-79; pg. 79 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.9.3 **Investigation: Studies to provide information required on potential effects of exploiting natural resources on hydrologic, geochemical, and rock characteristics**

p. 8.3.1.9-45

General Concerns: The "panel of experts" is likely to be used as a public relations gimmic unless their authority and appointments to this panel come from outside of DOE. If they are to have *no* authority, why bother at all?? As written the investigation does not address the impact that *perceived* resources would have on exploration and attempts at extraction.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-80; pg. 80 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.3.1 p. 8.3.1.9-46	Study: Evaluation of data needed for assessment of the likelihood of future inadvertant human intrusion at Yucca as a result of exploration and/or extraction of natural resources

General Comment: Here, how can you evaluate data need and predict drilling intensity over the next 10K years unless you have a very good and documented idea of what is present - and not just at or near the surface. They simply do not have any such idea and they will not with what they propose to do in the mineral resource evaluation.

REVIEWER: L.T. Larson L. T. Larson J.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-81; pg. 81 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.3.1.1 p. 8.3.1.9-48	Activity: Compilation of data to support the assessment calculation of the potential for inadvertent human intrusion at Yucca Mountain

General Concerns: The 2 objectives seem unrealistically ambitious, particularly regarding expected drilling density, depth and frequency; *how* will the needed parameters be obtained or evaluated? What kind of data do they intend to compile that is likely to provide such information? The fact that methods and technical procedures are to be determined sometime in the future is not reassuring to the reader considering the complexity and importance of this activity.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-82; pg. 82 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.3.3 p. 8.3.1.9-51	Application of results

General concerns: Again, here we see the whole thing is to eventually rest on the use of a panel of experts to use their "professional judgement" to estimate the bounds of some probability. As written, this is absurd. Who will be on the panel?? By whom will they be appointed?? How long will they have to evaluate the information given to them?? Last sentence: To imply that these "estimated bounds" obtained through use of "professional judgement" will be *data* and state that such can be used in calculating total system releases is wishful hogwash, of no scientific basis and wholly unacceptable!!

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-83; pg. 83 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.3.3 p. 8.3.1.9-51	Application of results

OBJECTION: Third sentence: What if significant resources *are* found in Yucca Mountain? How can this be demonstrated if the information to be obtained does not support this predetermined idea? This is another example of drawing conclusions *before* doing the study. Why bother if only the desired information is to be collected and(or) considered?

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-84; pg. 84 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.11 p. 8.3.1.11-2	Overview of land ownership and mineral rights program

General Comment: 1. page 8.3.1.11-2. Their statement in paragraph 1 that "prior investigations have identified no mineral rights in the immediate vicinity of Yucca" is not true. Until May of 1989 there existed mineral claims on BLM land right up to the Nellis boundary. Unless, of course, this is not considered "immediate vicinity". Just what is immediate vicinity anyhow?? We understand that in May, 1989, the claim owner agreed to sell his claims to DOE and settled for nearly $250,000. This provides another disturbing example of DOE's lack of current information concerning the site or worse, an effort to not present the facts completely.

REVIEWER: L.T. Larson L. T. Larson L.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-85; pg. 85 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.14.2.3.3 p. 8.3.1.14-59	Geophysical field measurement.

General Comment: Here once again zero consideration is given to the defining of mineral resource potential at depth. This section is representative of what I believe the attention DOE has placed on this requirement. They simply don't want to know and are not going to employ a program which will truely find out.

REVIEWER: L.T. Larson L. T. Larson	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-86; pg. 86 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.1 p. 8.3.1.17-51	Investigation: Studies to provide required information on volcanic activity that could affect repository design or performance

General Comment: 1. All that is being done is a survey of existing literature-no new research indicated. They clearly either are uninformed or do not wish to really understand problem. 2. Thinking in this section is that such volcanic activity will not be a fatal flaw for the site but merely give data to change engineering design. It is typical of the "fait accompli" thinking and mentality which permeates this entire SCP.

REVIEWER: L.T. Larson

L. T. Larson S.R.

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-87; pg. 87 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4.5.1 p. 8.3.1.17-145	Activity: Evaluate the significance of the Miocene-Paleozoic contact in the Calico Hills area to detachment faulting in the site area

Geologic mapping at 1:12,000 and compliation at 1:24,000 may be insufficient in that not enough detail can be accurately recorded to clearly show possible detachment.

REVIEWER: L.T. Larson L. T. Larson L.R.	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-88; pg. 88 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4.5.1	Activity: Evaluate the significance of the Miocene-Paleozoic contact in the Calico Hills area to detachment faulting in the site area
p. 8.3.1.17-145	

This is one of the most concisely written and doable activities so far, and is the type of fundamental, cost-effective geologic study needed most desperately in the site characterization program. Compilation of mapping at 1:24,000 may not be appropriate for the level of detail they may want to show.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-89; pg. 89 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.17.4.5.2 Activity: Evaluate postulated detachment faults in the Beatty-Bare Mountain area

p. 8.3.1.17-147

Sounds like the fundamental type of geologic study necessary to the program.

REVIEWER: S.I. Weiss

Steven I. Weiss

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-90; pg. 90 of 92 | CHAPTER NO.: 8

SEC. NO.
PAGE NO.
DRWG. NO.

COMMENT

8.3.1.17.4.5.2 Activity: Evaluate postulated detachment faults in the Beatty-Bare Mountain area

p. 8.3.1.17-147

Specific Comment: Here as in Calico Hills, a 3rd objective should be to see if such detachments are relevant in any way to mineralization control or displacement in the area. There is a reasonable body of opinion at present that recent Au discoveries at Ladd Mtn ,perhaps Gold Bar, and certainly the old Original Bullfrog are in structures relateable to detachments.

REVIEWER: L.T. Larson

L. T. Larson f.R.

ORGANIZATION:
Univ. Nevada-Reno

DATE: June 9, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 3-92; pg. 91 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.17.4.5.3 Activity: **Evaluate the potential relationship of breccia within and south of Crater Flat to detachment faulting**

p. 8.3.1.17-149

Specific Comment: **No real new work proposed. How do they propose to determine relevance of this to the tectonic development and volcanic activity and potential mineralization processes with the work they propose to do (or not to do??)?**

REVIEWER: **L.T. Larson**	ORGANIZATION: **Univ. Nevada-Reno**
L. T. Larson Jr.	DATE: **June 9, 1989**

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3-92; pg. 92 of 92	CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT

8.3.1.17.4.5.3 Activity: Evaluate the potential relationship of breccia within and south of Crater Flat to detachment faulting

p. 8.3.1.17-149

The proposed work sounds reasonable and doable.

REVIEWER: S.I. Weiss Steven I. Weiss	ORGANIZATION: Univ. Nevada-Reno DATE: June 9, 1989

TASK 4

SUMMARY OF THE YUCCA MOUNTAIN SCP

JAMES N. BRUNE

The particular topics of the SCP I have reviewed include those relating to seismology, geophysics, tectonics, and geology, with a more specific review of the proposed rock mass characterization.

General Considerations

I am approaching review of the SCP from the point of view of a Professor of Geophysics and a research seismologist, with experience in seismic hazard, seismic engineering problems, and testimony before a number of NRC hearings related to the San Onofre and Diablo Canyon nuclear power plants. Thus the main focus of my review relates to the basic scientific understanding required, first, to adequately evaluate the SCP, secondly, to judge whether or not the tremendous amount of work implied by the SCP can be carried out in a timely manner, given present or achievable scientific manpower and knowledge, and thirdly, what the probabilities are that the proposed site characterization will verify that the site is acceptable or not acceptable, or will require extensive further study unanticipated in the SCP, or will conclude that the site can be made acceptable only with an unanticipated great increase in cost. Implicit in the approach I will take is the assumption that site characterization and repository construction require more care than might be acceptable for less important structures, in particular that repository construction should not proceed based on unverified critical assumptions with the belief or hope that if any of these assumptions turn out to be incorrect, relatively simple or inexpensive modifications can be made to compensate for any changes required. Design and construction must at all critical points be based on verified knowledge.

Because of the above requirements it is necessary to obtain a high level understanding of physical and chemical processes involved, a level which can only be obtained by a competent basic research effort to attack the major uncertainties relating to, for example, tectonics, earthquakes, volcanic activity, seismic site effects, and geotechnical behavior of the rockmass and foundation materials. Based on the reported (in the SCP) preliminary efforts to obtain a general understanding of these, on the severely limited efforts of the USGS, on the lack of understanding evidenced by the lack of verified scientific results in the SCP, it appears that many critical problems will have to be approached with a basic research effort at the beginning, i.e. the basic knowledge about processes involved will have to be developed while the site characterization studies are carried out. Unfortunately this means that in many cases site characterization activities will address the wrong issues or fail to address important issues. This could only be avoided if the site characterization activities were driven by basic research programs and timetables, rather than by a schedule determined by political time tables. In the vast labyrinth of activities outlined in the SCP it is almost certain that many of them will take unexpected turns and require much backtracking and result in much wasted effort. The SCP is fundamentally lacking in not providing a clear program of basic research to understand the basic physical processes involved, and to understand the great amount of data which will be collected.

A particularly important question has to do with the availability of manpower to competently carry out the activities outlined in the SCP, and especially to carry out the required associated basic research. When the data required begins flowing in, who will be available to digest it, analyze it, draw important conclusions, and thereby redirect future activities? It might be months or years before it is realized that a certain effort is going the wrong way, collecting the wrong data, or collecting faulty data. No amount of QA can substitute for a basic understanding of whats going on. There is no evidence in the SCP that the scientific and engineering personnel required now exist, or can be trained under programs outlined in the SCP.

Since I have been involved in graduate education most of my career I can testify to the difficulty of educating scientists and engineers to the level required for a project of this type. The vague generalities of the SCP suggest that the required scientific and engineering personnel do not now exist in the DOE and its contractors and consultants. How does DOE propose to obtain such personnel, especially at a time when the nation as a whole is having difficulty in producing adequately trained scientists and engineers? Especially important is the requirement for high level scientists and engineers capable of supervising, critically reviewing, and re-directing the activities of the various tasks. Attempting to proceed with unqualified personnel will result in tremendous inefficiencies in activities, and consequent uncertainties in the final results. I believe that the SCP is fundamentally lacking in this regard, and should include an extensive description of the type and availability of personnel required, and the educational program required to provide these personnel.

A similar question arises with regard to the facilities required for research, data analysis, and testing activities suggested in the SCP. The SCP does not give confidence that such facilities now exist or can be developed in a timely manner, and I believe the SCP should be expanded in this regard.

The uncertainties outlined above, along with the great uncertainties in understanding the basic geophysical facts make review of the SCP difficult. The hundreds of pages of generalized descriptions, charts, and the labyrinth of organizational charts, box diagrams, etc., gives an initial appearance of comprehensiveness. However, in attempting to follow the logic of any particular aspect, so many unanswered questions come up at each stage, that in the end one is left with great uncertainty about what actually is going to occur. In most research proposals this type of uncertainty is to a certain extent compensated for by the qualifications and track record of the institutions and principal investigators carrying out the research. The question of the qualifications, competence, an track record of the institutions responsible for the research is fundamental to a critical review of the SCP, but is almost totally lacking. One is forced to resort to answering only hypothetical questions such as: If the basic knowledge, qualified personnel, facilities, and institutions existed to carry out the type of scientific and engineering research required, would the SCP document as it now stands provide a comprehensive and clear indication of what is likely to actually occur? Even to this very restricted question I would have to say, I doubt it. The best one can say is that the document may be extensive, general, and vague enough to encompass what is likely to eventually occur. There is no reason in principal why the SCP can not be carried out and yield a clear conclusion as to the suitability of the site, and to the engineering requirements for construction and safe operation of the repository.

What actually does happen will depend on the knowledge, personnel, facilities, and organizations developed during the SCP, and these cannot be critically judged at this time. It is quite likely that site characterization will require extensive further study unanticipated in the SCP, or will conclude that the site can be made acceptable only with an unanticipated great increase in cost.

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1	CHAPTER NO. 1 and 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
	REVIEW OF THE YUCCA MOUNTAIN SCP JAMES N. BRUNE Introduction The particular topics of the SCP I have reviewed include those relating to seismology, geophysics, tectonics, and geology, with a more specific review of the proposed rock mass characterization.
1.0	General Considerations
8.0 8.1 8.2 8.3.1 8.3.1.1 8.3.1.8 8.3.1.17	I am approaching review of the SCP from the point of view of a Professor of Geophysics and a research seismologist, with experience in seismic hazard, seismic engineering problems, and testimony before a number of NRC hearings related to the San Onofre and Diablo Canyon nuclear power plants. Thus the main focus of my review relates to the basic scientific understanding required, first, to adequately evaluate the SCP, secondly, to judge whether or not the tremendous amount of work implied by the SCP can be carried out in a timely manner, given present or achievable scientific manpower and knowledge, and thirdly, what the probabilities are that the proposed site characterization will verify that the site is acceptable

REVIEWER: James Brune Print James N Brune Signature	ORGANIZATION: University of Nevada Reno Seismological Lab DATE: June 15, 1989

Form 3.4.1

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1 | **CHAPTER NO.** 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.0 8.1 8.2 8.3.1 8.3.1.1 8.3.1.8 8.3.1.17	or not acceptable, or will require extensive further study unanticipated in the SCP, or will conclude that the site can be made acceptable only with an unanticipated great increase in cost. Implicit in the approach I will take is the assumption that site characterization and repository construction require more care than might be acceptable for less important structures, in particular that repository construction should not proceed based on unverified critical assumptions with the belief or hope that if any of these assumptions turn out to be incorrect, relatively simple or inexpensive modifications can be made to compensate for any changes required. Design and construction must at all critical points be based on verified knowledge. Because of the above requirements it is neccessary to obtain a high level understanding of physical and chemical processes involved, a level which can only be obtained by a competent basic research effort to attack the major uncertainties relating to, for example, tectonics, earthquakes, volcanic activity, seismic site effects, and geotechnical behavior of the rockmass and foundation materials. Based on the reported (in the SCP) preliminary efforts to obtain a general understanding of these, on the severely limited efforts of the USGS, on the lack of understanding evidenced by the lack of verified scientific

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.0 8.1 8.2 8.3.1 8.3.1.1 8.3.1.8 8.3.1.17	results in the SCP, it appears that many critical problems will have to be approached with a basic research effort at the beginning, i.e. the basic knowledge about processes involved will have to be developed while the site characterization studies are carried out. Unfortunately this means that in many cases site characterization activities will address the wrong issues or fail to address important issues. This could only be avoided if the site characterization activities were driven by basic research programs and timetables, rather than by a schedule determined by political time tables. In the vast labarynth of activities outlined in the SCP it is almost certain that many of them will take unexpected turns and require much backtracking and result in much wasted effort. The SCP is fundamentally lacking in not providing a clear program of basic research to understand the basic physical processes involved, and to understand the great amount of data which will be collected. A particularly important question has to do with the availability of manpower to competently carry out the activities outlined in the SCP, and especially to carry out the required associated basic research. When the data required begins flowing in, who will be available to digest it, analyze it, draw important conclusions, and thereby redirect future activities? It might be months or years

REVIEWER: James Brune **Print** James N Brune **Signature**	**ORGANIZATION:** University of Nevada Reno Seismological Lab **DATE:** June 15, 1989

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.0 8.1 8.2 8.3.1 8.3.1.1 8.3.1.8 8.3.1.17	before it is realized that a certain effort is going the wrong way, collecting the wrong data, or collecting faulty data. No amount of QA can substitute for a basic understanding of whats going on. There is no evidence in the SCP that the scientific and engineering personnel required now exist, or can be trained under programs outlined in the SCP. Since I have been involved in graduate education most of my carreer I can testify to the difficulty of educating scientists and engineers to the level required for a project of this type. The vague generalities of the SCP suggest that the the required scientific and engineering personnel do not now exist in the DOE and its contractors and consultants. How does DOE propose to obtain such personnel, especially at a time when the nation as a whole is having difficulty in producing adequately trained scientists and engineers? Especially important is the requirement for high level scientists and engineers capable of supervising, critically reviewing, and re-directing the activities of the various tasks. Attempting to proceed with unqualified personnel will result in tremendous inefficencies in activities, and consequent uncertainties in the final results. I beleive that the SCP is fundamentally lacking in this regard, and should include an extensive description of the type and availability of
REVIEWER: James Brune Print James N Brune Signature	ORGANIZATION: University of Nevada Reno Seismological Lab DATE: June 15, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.0 8.1 8.2 8.3.1 8.3.1.1 8.3.1.8 8.3.1.17	personnel required, and the educational program required to provide these personnel. A similar question arises with regard to the facilities required for research, data analysis, and testing activities suggested in the SCP. The SCP does not give confidence that such facilities now exist or can be developed in a timely manner, and I beleive the SCP should be expanded in this regard. The uncertainties outlined above, along with the great uncertainties in understanding the basic geophysical facts make review of the SCP difficult. The hundreds of pages of generalized descriptions, charts, and the labyrinth of organizational charts, box diagrams, etc., gives an initial appearance of comprehensiveness. However, in attempting to follow the logic of any particular aspect, so many unanswered questions come up at each stage, that in the end one is left with great uncertainty about what actually is going to occur. In most research proposals this type of uncertainty is to a certain extent compensated for by the qualifications and track record of the institutions and principal investigators carrying out the research. The question of the qualifications, competence, an track record of the institutions responsible for the research is fundamental to a critical review of the SCP.

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
8.0 8.1 8.2 8.3.1 8.3.1.1 8.3.1.8 8.3.1.17	but is almost totally lacking. One is forced to resort to answering only hypothetical questions such as: If the basic knowledge, qualified personnel, facilities, and institutions existed to carry out the type of scientific and engineering research required, would the SCP document as it now stands provide a comprehensive and and clear indication of what is likely to actually occur? Even to this very restricted question I would have to say, I doubt it. The best one can say is that the document may be extensive, general, and vague enough to encompass what is likely to eventually occur. There is no reason in principal why the SCP can not be carried out and yield a clear conclusion as to the suitability of the site, and to the engineering requirements for construction and safe operation of the repository. What actually does happen will depend on the knowledge, personnel, facilities, and organizations developed during the SCP, and these cannot be critically judged at this time. It is quite likely that site characterization will require extensive further study unanticipated in the SCP, or will conclude that the site can be made acceptable only with an unanticipated great increase in cost.	

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DATE: June 15, 1989

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT
	Specific Comments. I have reviewed those parts of the SCP which relate to seismology, geophysics, tectonics, and geology, and have read earlier reviews of the CDSCP by members of the Seismological Laboratory staff. The above comments reflect a general review of these parts of the SCP. I have made a more detailed review of the following sections of the SCP.

REVIEWER: James Brune
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ORGANIZATION:
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Seismological Lab

DATE: June 15, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2	CHAPTER NO. 2,6 and 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
2.1 2.2 2.3 2.4 2.9.1 2.9.3 6.1.2.3 8.3.1.4 8.3.1.4.3 8.3.1.15	Characterization of Rock Mass The overall plan for rock mass characterization is based on measurements made on small scale tests, both in the lab and in-situ, and use of the results to extrapolate to larger scales, using numerical programs. These extrapolations include use of estimates of joint and fault behavior. This technique has not been validated by actual emperical studies for the type of structure being proposed. It is true that the structure qualifies as a mined structure of the type for which there is considerable experience. Nevertheless for such an important structure we should not rely on questionable extrapolations from mining experience in other types of rock and other situations, but should determine in detail the mass properties of the actual in-situ rock. The detail provided in sections 8.3.1.4 and 8.3.1.17 are not sufficient to give confidence that the proposed plans for rock characterization and understanding of long term behavior will work. The geophysical and geothechnical methods briefly mentioned in the SCP are not demonstated to be effective. The SCP should either document the proposed studies better, or expand the SCP to include more extensive experiments to establish the rock behavior.

REVIEWER: James Brune Print James N Brune Signature	ORGANIZATION: University of Nevada Reno Seismological Lab DATE: June 15, 1989

Form 3.4.1

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2	CHAPTER NO. 2,6 and 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
	Similar comments to those above for characterizing the undisturbed rock mass also apply to characterization of the structure after excavation and heating, and backfill. There is little justification that the proposed methods can be expected to work.

REVIEWER: James Brune
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DATE: June 15, 1989

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	3	CHAPTER NO. 1,2 and 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
1.3.2.3 1.8.3.3.3 2.6 2.6.2 8.3.1.15	An important aspect of the rock mass characterization is the potential response to a stress field favorable to fault slippage(2.3.2.1 and 1.3.2.3). Given preliminary indications that such conditions may exist, and the seriousness of such a possibility, the SCP is totally deficient in outlining the type of extensive program that should be carried out to verify, eliminate, or mitigate against such conditions. The frictional properties of faults in the rock mass should be throughly understood. If the rock mass is near failure, detailed determination of the effects of possible triggering mechanisms should be carried out (e.g. from nuclear explosions, nearby earthquakes, atmospheric loading, and ground water loading).
2.2.2	In general the rock mass characterization plan does not adequately describe how the existence of larger fractures, joints, and especially faults, both in and near the repository, will effect the overall behavior. Considerable fundamental research is probably required in estimating these effects.
8.3.1.4 8.3.1.4.2.3 8.3.1.17.4.8 8.4	The SCP generally lacks documentation of the extensive stress, strain, and seismic monitoring which should be carried out, both before, during and after construction, to verify that the rock mass is behaving as

REVIEWER: James Brune Print James N Brune Signature	ORGANIZATION: University of Nevada Reno Seismological Lab DATE: June 15, 1989

SUMMARY OF THE YUCCA MOUNTAIN SCP

BILL PEPPIN

I find that the SCP, as presented, is an unsatisfactory mechanism for accomplishing site characterization of Yucca Mountain. I cite 4 justifications for this statement: (1) the document cannot be critically reviewed, (2) it places overmuch emphasis on the engineering versus the scientific aspects of site characterization, (3) the SCP authors consistently fail to impress the reader in proposing leading edge studies to address critical questions, and (4) make uncomfortably numerous misleading, contradictory, or downright incorrect statements. These are discussed in subsequent paragraphs.

Critical Review Impossible The SCP as written proposes an enormous amount of work covering a vast range of topics. Yet, as we read this document and look into the proposed studies, a reviewer has no idea if the goals stated are attainable, because at no place is it mentioned what individuals will do the work (or are likely to do the work) and at no place are given manpower estimates for accomplishing the various studies. If this were done, I believe the fundamental flaw in this whole approach would stand out very clearly for all to see: the stated goals are probably not at all realistic. The SCP is able to be quite direct in its approach to the problem of satisfying the various regulations governing site characterization. The structure of the SCP reflects an attack of the regulatory issues one by one. As a result, essentially every study is weighted equally. What is needed is an effort to be far more selective, especially in the identification of those areas which could disqualify the site at an early time and render all the other studies moot. Once these hurdles are properly cleared, then move over into the myriad of regulatory issues which can be easily addressed individually (but which, in toto, are a very large burden indeed).

Engineered Approach. The SCP treats the site characterization problem as one which can be solved by more-or-less standard methods, presupposing that this is little more than a problem like designing a bridge or a dam. In fact, we have heard researchers point out many areas in which such a judgment is premature. In spite of words to the contrary in the SCP, competent hydrologists have stated time and again that the behavior of the unsaturated tuff to act as a barrier to the transmission of radionuclides is a problem that is not capable of being treated with any precision using state-of-the-art technology (nonlinear equations; requirement of too much detailed knowledge of the medium; vast uncertainty on the role of fractures), and moreover, that the tuff is likely to be unable to perform this function. Geologists make a point that the repository site might very well be underlain by a detachment fault which could be active. Geochemists have stated that claims about the sorptive behavior of the various minerals, acting to buffer and retard the transmission of radionuclides, are not based on sufficient facts and are not grounded on state-of-the-art information. Engineers have stated that the problem of engineered rock barriers, a critical part of the strategy to retard movement of radionuclides, will fail the first time an earthquake happens which produces moderate shaking underground (which is certainly quite likely in even 1,000 years time), and that the metal selected for the canisters was the worst possible choice from the point of view of waste isolation (Tom Devine at recent NWPO contractors' meeting in Carson City.) These are scientific, not engineering problems. At the present time, we have no idea if they can be resolved given any level of effort at Yucca Mountain, nor can we

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	expected. The SCP should include a more extensive description of how the performance of the structure will be monitored in general.	

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assess the odds that any findings we might make would disqualify the site. Thus, from the scientific point of view, detailed plans to characterize the site following the appropriate regulations seems premature at this time.

Lack of Originality in Proposed Research. We have heard many specialists criticize the SCP for omitting studies at the cutting edge of their disciplines, and in my area of expertise, seismology, the same holds true (see my other specific comments on this aspect of the SCP). This is inauspicious for the success of site characterization for two reasons. First, a number of these cutting-edge research proposals could lead to new, critical information for site characterization. Second, in a research program in which hundreds of millions of dollars are to be spent, the fact that so few innovative proposals are given reduces one's confidence in the people who put together the SCP (whoever they are). We are dealing with an effort comparable to the Manhattan Project in scale, but we can see no illustrious scientists who have committed to oversee the project, which is what made the Manhattan project a success.

Misleading, Contradictory, and/or Incorrect Statements The SCP is replete with statements which are misleading, contradictory, or incorrect, and some of these will be the specific target of detailed comments to follow this one. I present a number of these taken from the SCP Overview, an important document as it provides essentially the only access to the SCP by the interested lay-public which is comprehensible. Consider the following statements:

1: It is believed that there is little percolation of water downward through the unsaturated rocks above the water table (SCP Overview, page 15)

2: Measurements made since 1978 show that within about 6 miles of the proposed repository the release of seismic energy has been 100 or 1000 lower than that in the surrounding region (SCP Overview, page 22)

3: Present estimates of the time for ground-water travel from the proposed repository to the underlying water table range from 9,000 to 80,000 years (SCP Overview, page 28)

4: There would be no hydrostatic pressure [at the repository site] because it would be located above the water table (SCP Overview, page 49)

5: The current evidence suggests that the time of ground-water travel from the candidate repository through the unsaturated units is longer than 10,000 years (SCP Overview, page 86)

Now consider comments 1,3 and 4. Each of these reads as though the matter is essentially settled, and incapable of drastic revision on study. However, competent hydrologists have consistently challenged these points. Thus, they are misleading in that the reader is not made aware that these are scientific points, vital to the qualification of Yucca Mountain as a geologic repository, whose resolution is far from clear. For example, If (Point 4) the repository will be located above the water table for the next 10,000 years, then why are studies being directed at understanding climatic changes (which could possible cause the water table to reach the repository), and toward possible upward movement of the saturated zone resulting from a large earthquake? Consider comments 3 and 5: these are in direct contradiction. Consider comment 2: this is incorrect. it can be made correct and far less misleading if written as follows: "Microseismic recording since 1978 has revealed very few earthquakes within 10 km of the repository; this scarce seismicity represents energy release which is 100 to 1000 times less (ergs/km) than the average energy release for the surrounding region. However, this regional average is strongly controlled by the occurrence of rather widely-scattered larger events, and should not be taken as significant evidence for lower levels of seismicity near Yucca Mountain as compared with this regional average."

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

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I find that the SCP, as presented, is an unsatisfactory mechanism for accomplishing site characterization of Yucca Mountain. I cite 4 justifications for this statement: (1) the document cannot be critically reviewed, (2) it places overmuch emphasis on the engineering versus the scientific aspects of site characterization, (3) the SCP authors consistently fail to impress the reader in proposing leading edge studies to address critical questions, and (4) make uncomfortably numerous misleading, contradictory, or downright incorrect statements. These are discussed in subsequent paragraphs.

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DOCUMENT TITLE: Site Characterization Plan			
COMMENT NO.:	1 of 29	CHAPTER NO. (general summary)	
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2: Measurements made since 1978 show that within about 6 miles of the proposed repository the release of seismic energy has been 100 or 1000 lower than that in the surrounding region (SCP Overview, page 22)

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	be located above the water table for the next 10,000 years, then why are studies being directed at understanding climatic changes (which could possible cause the water table to reach the repository), and toward possible upward movement of the saturated zone resulting from a large earthquake? Consider comments 3 and 5: these are in direct contradiction. Consider comment 2: this is incorrect. it can be made correct and far less misleading if written as follows: "Microseismic recording since 1978 has revealed very few earthquakes within 10 km of the repository; this scarce seismicity represents energy release which is 100 to 1000 times less (ergs/km) than the average energy release for the surrounding region. However, this regional average is strongly controlled by the occurrence of rather widely-scattered larger events, and should not be taken as significant evidence for lower levels of seismicity near Yucca Mountain as compared with this regional average."	

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COMMENT NO.:	2 of 29	CHAPTER NO. 1
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Section 1.3.1.2 page 1-82	In the third paragraph is stated that, "[Tectonic] province and subprovince boundaries typically coincide with large strike-slip faults," with the implication that frequently (usually?) tectonic character changes when one crosses such a boundary. The statement implies a significance to the fact that these boundaries are artificially drawn when none may exist. This is quite important, because Chapter 1 argues that the Holocene faulting in Death Valley, a few tens of km west of Yucca Mountain, is in a different tectonic province, and therefore, the higher rates of seismic energy release there does not apply to the repository site. In the absence of any clear model to show these regions are in the same province, it may later be necessary to presume (for the conservatism in the absence of better information) that the Death Valley seismicity rates are more representative.	

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Section 1.3.2.3 page 1-139	In the third paragraph it is stated that, "...it is assumed that on a regional scale two of the principal stresses are approximately horizontal and the third is approximately vertical," following the work of Zoback and Zoback (1980, see SCP references Chapter 1) on stress regionalization. However, in the context of the stress regime at Yucca Mountain, it may be unwise to make such an assumption: knowledge of the exact orientation of the principal stresses could be of vital importance in assessing the possible susceptibility of existing fractures at the repository to dike intrusion from a volcanic source. For example, would the tectonic stress impede the opening of these cracks, or promote their opening? If we discard this information a priori, we may have lost a vital opportunity to obtain information critical to siting. This discussion at this point in the SCP should address this possibility.

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COMMENT NO.:	4 of 29	**CHAPTER NO.**	1
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Section 1.3.2.3 page 1-140	At the top of the page it is stated that, "The average direction of Sh [the smaller horizontal principal stress] is approximately west - northwest, except for southern Nevada..." This statement is not correct for one of the areas of highest seismicity in the Basin and Range, the Mammoth Lakes - Bishop region, where it trends ENE to E, see "Variation of the Regional Stress Tensor at the Western Great Basin Boundary from the Inversion of Earthquake Focal Mechanisms," by Ute R. Vetter, University of Nevada - Reno (submitted). This paper presents new information about the stress regime in the Basin and Range, and needs to be included in this discussion. One significant point pertinent to Yucca Mountain from this paper is the following. In the vicinity of Mammoth Lakes, we see that the principal stresses change from dominantly strikeslip in and just east of the Sierra Nevada to oblique - normal faulting to the east in central Nevada. However, the situation is reversed in the southern Sierra, where normal-faulting earthquake give rise to strikeslip events as we move east toward Yucca Mountain. It is possible that the postulated "east - west seismic zone" which trends through southern Nevada including Yucca Mountain is related to this change from strikeslip to normal in the Sierra and from normal to strikeslip in the Basin and Range.		

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Section 1.3.2.3 page 1-145	On this page is described a measurement of in situ stress using hydrofracturing. it is stated that, "44,000 barrels of drilling fluid were lost to the formations below the casing." This reader would appreciate a discussion on how this observations bears on the postulated ability of the Topopah Springs tuff to contain the radioactive waste for 10,000 years. Does DOE claim that this particular drill hole USW G-1, just on the northern boundary of the repository, does not represent the unfractured tuff of the repository horizon? Is 44,000 barrels an insignificantly small amount of fluid loss? What if the fluid loss was through fractures, wouldn't this be a significant result?	

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AGENCY FOR NUCLEAR PROJECTS
NUCLEAR WASTE PROJECT OFFICE
QUALITY ASSURANCE PROCEDURE

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COMMENT NO.:	6 of 29	CHAPTER NO. 1
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Section 1.3.2.3 page 1-146	The information here indicated an inconsistency between the geodetic observations near Yucca Mountain (showing NE compression) with indicators based on geology, earthquake focal mechanisms, and hydrofracturing measurements, which indicated NW extension. And yet, there is not study proposed to address this apparently significant finding, nor is any hypothesis suggested to explain the discrepancy. I believe that these matters must be clearly understood before any claim can be made that the regional tectonics are well understood.	

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Section 1.3.2.2.2, pages 1-117 to 1-1-135	Evidence given in this section, based on analysis of slikensides and other data, shows for faults with known slip in the vicinity of Yucca Mountain, including within the repository block, that a strong component of normal-fault motion is observed. On the other hand, the data from focal mechanisms of earthquakes shows dominantly strikeslip, even for the considerable tectonic release accompanying large underground nuclear explosions (Wallace, T.C. and others, 1983, 1985, see Chapter 1 references). Therefore, there is an outstanding discrepancy between observed strain release accompanying present-day earthquakes and what is expected from the geologic and geodetic evidence, just as there is in the vicinity of Mammoth Lakes - Bishop, also in the Basin and Range province, to the northwest. This is another point which is of direct importance to establishing, with any confidence, a conceptual model for the tectonics of the Yucca Mountain region. I can find no explicit mention of this problem in the text. A study is proposed (8.3.1.8) which addresses a more detailed investigation of slikensides and paleostress, but the above-mentioned discrepancy is not brought out clearly, as I believe it should be.

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Section 1.4.1 page 1-155	It is stated here that, "Since August 1978 a high-quality seismographic network has operated in support of the Yucca Mountain project...", mentioning the 47-station network covering 80,000 square km. Because these instruments are essentially all high-gain vertical instruments, and because the information is transmitted to the recording site using narrow-band standard USGS telemetry, the dynamic range is quite limited. As a result, essentially the only information that one can extract from the network is P and S wave onset times, with S-wave spectral information available from very few horizontal components. Therefore, this is not what seismologists would call a "high-quality" array. The University of Nevada Seismological Laboratory proposed several years ago to install an array of continuously-telemetered wideband 3-component digital stations which would have provided "high-quality" seismic coverage of Yucca Mountain; however, reviewers should be aware that the existing network data, even though in digital form, offers not much information which will be of assistance in providing data for modern waveform analyses of southern Nevada earthquakes in the vicinity of Yucca Mountain.	

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Section 1.4.1 page 1-159	Given are estimates of typical estimated standard errors of hypocenters determined using the SGB seismic array; these are 0.5 km in horizontal distance and 1.0 km in focal depth. However, at this point the text should mention that the accuracy of the focal depths determined is not likely to be anything like so small as 1.0 km, because this quantity is susceptible to considerable error when using a network with station spacing of 25 km or more and only P observations. No discussion is given of attempts to provide some sort of estimates of hypocentral accuracy in this report, aside from the claim that various layered models were run in a sensitivity study. Quite a few options are available along these lines, especially considering that precisely-known sources on Nevada Test Site are available.	

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Section 1.4.1 page 1-159f	Here is given a discussion of the precision with which focal mechanisms of earthquakes can be determined from first-motion data. It is stated that part of the contribution to the error in such determinations is the uncertainty in focal depth and in the velocity model. The text should mention here that, because most of the earthquake mechanisms determined are almost pure strikeslip, these uncertainties will have essentially no effect on the determination of the focal planes, because for such mechanisms the determinations are essentially independent of the takeoff angles of the seismic waves leaving the source, which is definitely not the case for normal-faulting events.	

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Section 1.4.1 page 1-160	It is stated that the southern Great Basin catalog is complete for earthquakes of magnitude 1.0 or more since 1978. Work by Martha Savage (University of Nevada Seismological Laboratory, submitted to the Nevada Waste Project Office 1988) shows that this is almost certainly not true. A response on this point should appear at this place in the text.		

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Section 1.4.1 page 1-163 and accompanying discussion	Figure 1-57 is presented to support the view that seismicity in the vicinity of Yucca Mountain is quite a bit lower than in the surrounding region. If given without qualification, then such a result would have important consequences for the assessment of seismic hazard at the repository sit. However, the figure is completely misleading, as rather cursory analysis will show. The text states that 2,800 earthquakes were located since 1978 in the 80,000 square km region surrounding Yucca Mountain, so that if the earthquakes were distributed randomly over the region then we expect approximately ten earthquakes of any magnitude within a circular region 20 km across. Therefore, a circle of such size placed anywhere in the southern Great Basin will almost always show the low level of energy release given in this figure. The only time it will not is when the circle happens to include one of the larger earthquakes (of which there are a fairly small number). Therefore, a diagram like Figure 1-57 will result when the analysis is centered almost anyplace in southern Nevada: no special significance to the repository site can be given.	

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Section 1.4.1.1.2 page 1-168	Reference is made to a "broad, diffuse seismic belt crossing southern Nevada from east to west." It is unclear that the seismicity in this belt is any different than it is north and south of this so-called "belt of activity". The text should note that not all seismologists agree that the seismicity in this belt is truly different from the surrounding regions.		

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SEC. NO. PAGE NO. DRWG. NO.	**COMMENT** 1 of 2
Section 1.4.1. 1.2 page 1-168	Figure 1-58 is presented to show the distribution of focal depths for computer hypocenters, and attention is drawn to the lack of occurrence of earthquakes at about a depth of 4 km. This is unlikely to be a true result, because the focal depth resolution of the network is probably much greater than the formal precision of the estimates coming out of the location programs (1.0 km. see Comment 9). The discussion about tests performed to verify the existence of this minimum are not convincing to me: calculations I made and submitted to the Nevada Waste Project office two years ago form the basis for this assessment using actual data from the southern Great Basin network. However, having pointed out this feature, no explanation of it is offered, and contradictory statements are given in the third paragraph. On the one hand the authors state that, "Rogers et al. (1987) have performed an extensive series of computation experiments that show that the peaks in the distribution [of focal depths] are not artifacts of data processing, hypocenter location algorithm, velocity model used, or distribution of depth errors..." Then, later in the paragraph is stated that, "Extensive tests, conducted to study the effects of the variation-of-velocity-model on hypocenters in Rogers et al. (1987) were inconclusive and do not rule out the possibility that bimodal depth distribution is a model-dependent feature." As this is potentially an important datum pertinent, for example, to
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	the existence of possible active detachment surfaces beneath Yucca Mountain, this point ought to be addressed specifically, and the potential significance pointed out.	

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Section 1.4.1.2 page 1.175	Table 1.12 and Figure 1-57 are discussed here. The text should here explain the method used to estimate seismic energy release from the earthquake catalog.	

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AGENCY FOR NUCLEAR PROJECTS
NUCLEAR WASTE PROJECT OFFICE
QUALITY ASSURANCE PROCEDURE

QAP-3.4
REVISION 0
JANUARY 20, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
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Section 1.4.1.2.12 page 1.187	Attempts were made to correlate seismicity from the catalog with known structures. It is stated that, "...the frequent association of nodal planes [from earthquake focal mechanisms] with an alignment of earthquakes or with mapped structural grain in the surrounding surficial rocks imparts greater confidence that the faults that define the structural grain at the surface are active and do reflect the general structural pattern at seismogenic depths. On this basis, the data suggest that north- to east-northeast-striking faults should be considered potentially seismogenic." This statement makes a number of assumptions that are, in my opinion, not clearly demonstrated. First, it is assumed that northeasterly alignment of epicenters truly occurs, and is not an artifact of the location procedure, which (Peppin, 1987, review submitted to Nevada Waste Project Office) is debatable at the very least, but is quite possible incorrect. Second, it is assumed that alignments of very small earthquake do indeed bear on the kinds of tectonic generalizations that the authors are hoping to make from the patterns of seismicity that have found. Work at the University of Nevada in areas of sparse seismicity in the Great Basin, specifically the Excelsior Mountains and Mammoth Lakes region, shows that, like the Yucca Mountain region, earthquakes tend to cluster in volumes, and are not clearly correlated with observed structures. The authors of the SCP at this point evidently	

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did not appreciate that this is an outstanding obstacle restricting the interpretation of seismicity patterns in the Great Basin, as evidence by the fact that no study of this problem is suggested in Chapter 8.

The authors note at page 1-171 that, "...the closest correlations between seismicity and known faults have been for aftershocks of nuclear tests on Pahute Mesa and for the Massachusetts Mountain earthquake (Cane Springs fault system)". This overlooks another important fault on which large displacement occurred associated with a test, the Carpetbag fault in Yucca Valley. This and the Boxcar fault, which ruptured during the BENHAM test and was reactivated by the JORUM test, are north-trending faults whose general trend matches the numerous north-south nodal planes shown for focal mechanisms in this chapter. In the context of the discussion given at this point in the SCP, I believe the omission of a thorough discussion of the faulting accompanying nuclear testing on Nevada Test Site is a serious oversight, as it certainly bears on potential faulting at Yucca Mountain.

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Section 1.4.1.3 page 1.188	The text here refers to Table 1-8 which summarizes the known (possible active) faults in the near vicinity of Yucca Mountain. Neither the table nor the text at this point mentions postulated active detachments passing underneath Yucca Mountain. Some discussion of this phenomenon should appear at this point in the text.	

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Section 1.4.1.5 page 1.190	In estimating the return period at Yucca Mountain for large earthquakes, two models are addressed which give return periods for a magnitude 6 earthquake in 10,000 square km of 26.3 and 172.4 years, respectively (Models A and B). The text goes on to say that, "Based on the lack of historic M = 6 earthquakes within 100 km of the [Yucca Mountain] site, Model B would appear to be preferred." On such an important question, this is dangerously specious reasoning. In California, we have seen magnitude 6 earthquake occur time and again in places where historic seismicity shows no such thing and where the geologic evidence was not compelling for such before the fact (the Oroville earthquake being one of the best examples). With equally valid logic, one can turn this around and postulate that Yucca Mountain is in a "seismic gap" and therefore more likely to produce a M = 6 earthquake than other regions nearby which have already had theirs. This is a poor commentary on the level of thinking by the preparers of the SCP. In the absence of any clear reason to select between the two models above, conservatism would require preferring Modal A, not Model B.		

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Section 1.4.2.1 page 1-195	One of the proposed activities (8.3.1.8) includes "purging the catalog of aftershocks [induced by nuclear explosions]". If the existing catalogs are examples of such effort, then this reader is not impressed, as we pointed out in our comments to Nevada Waste Projects Office two years ago. The catalog contains after events of nuclear explosions known to be hole collapses, and yet listed as nuclear explosion afterhsocks. This is quite important for the assessment of seismic hazard at Yucca Mountain, because the tectonic aftershocks of nuclear explosions comprise the bulk of the seismic energy release near the site. Therefore, correctly identifying multiple collapse events, such as the large after events of JORUM on 16 September 1969 at 1544, 1623, and 1731 GCT, is an effort well worth careful consideration.

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Section 8.3.1.17 general comments	This section of the SCP describes activities in support of the assessment of tectonic activity in the first 100 years of the repository ("pre-closure tectonics"). The main issues of concern here are the estimation of the "controlling" earthquakes (those likely to produce the highest accelerations which could interfere with surface facilities or sub-surface emplacement of the waste) and, deriving from this, estimates of the character of ground motion specific to the critical facilities sites associated with repository. This section includes a mass of proposed studies which cover these topics daily thoroughly. My fairly general criticism is that not all of the activities have estimates of how much time it will take to complete, and no manpower estimates are given. This starts to be a consideration of some moment when one reads, at page 8.3.1.17-27 for example, that "...all final results for volcanic, faulting, and ground-motion events will be evaluated using probabilistic methods (1) to ensure that adequate consideration is given to the full range of potential tectonic processes and to their associated uncertainties, and (2) to help identify those processes that are key to characterizing the geologic hazards at the site." In this one sentence is given a description of an activity that could take anywhere from 1 to 100 man-years or more. Therefore, the reader has no idea if this goal can be attained in the time constraints of the site

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	characterization process (about 10 years).	

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Section 8.3.1.17.3.1.2 page 8.3.1.17-72	Here is given a rationale for use of the "10,000-year cumulative slip earthquake" as a means to determine the amount of slip to use on faults near the repository. The authors of the SCP are quite aware that this is a concept that has not been previously accepted by the Nuclear Regulatory Agency, not is it likely to be accepted for the repository, especially given the requirement that the waste be isolated for such a long period of time. The reason why this will not be accepted follows from common sense. In Chapter 1 of the SCP descriptions are given of the various faults in the vicinity of the repository (Solitario Canyon; Paintbrush; Bare Mountain, etc), and it is documented there that recurrence times on these faults are very likely to exceed 10,000 years, maybe reaching 100,000 years or more. Therefore, it is not likely that the controlling earthquake, about which we worry, is going to occur every 10,000 years on one of these faults. Rather, if the event occurs, it will occur once every 50,000, or 100,000 years, and will therefore produce a slip that is 5 or ten times what will be computed using the "10,000-year cumulative slip earthquake." Therefore, this concept can only be a vehicle for making sure that the controlling displacements to occur on faults close to Yucca Mountain will be "small enough" not to disqualify the site: I can think of no other reason for such a definition. The discussion in the test at this point, which specifically addresses the rationale	

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	for doing this, in unconvincing to me.	

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Section 8.3.1.17.4.1.1 page 8.3.1.17-88	Reviewing catalogs of southern Nevada seismicity presented by the USGS, it appears that as a seismologist I would have chosen to do this work differently. This difference in philosophy is highlighted at this point in the text. There is listed a number of parameters which will be measured on the seismic network, and what is given does not include the arrival times of the seismic phases! While this is presumed, it reflects an attitude held by them which I don't share concerning the importance of this information. I am specifically concerned about the use of S waves by the USGS in doing locations. Numerical experiments which I performed using data from one of the swarms near Yucca Mountain including and excluding S waves convinced me that, with an array as sparse as that in southern Nevada, depth control of the events would depend critically on careful use of this phase in locations. I see no evidence anyplace that S waves have been used in any way excepting quite routinely, or that any effort has been made to use proper master-event location methods to determine the hypocenters of the events. In summary: as a seismologist I am disturbed to find at no place in this lengthy document a discussion of S waves and how they can be used to improve hypocentral determinations.
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Section 8.3.1.17.4.1.2 page 8.3.1.17-91	Here is described a portable array of about 30 channels for use in "special studies" to augment the continuous coverage of the southern Nevada network. Efforts involving portables are quite expensive to run, and therefore one should have quite a definite idea on toward what such an intensive effort will be directed. Here the text provides only some generalities about the uses of this array: "...[to obtain] high-dynamic-range data that are suitable for calculating earthquake source parameters, obtaining accurate aftershock locations, monitoring microseismicity in the vicinity of suspect tectonics features, or measuring local site effects on ground motion." What will be learned from spectral source parameters? How will the hypocenter locations be improved, given that the stated precision from the regional network is 0.5 km horizontally and 1.0 km vertically (i.e., how much more precision does one need?) I happen to agree with the use of a deployable digital network, but I can think of several specific experiments and specific scientific objectives, and these do not appear at this point in the text.	

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Section 8.3.1.17.4.1.2 page 8.3.1.17-92	It is stated that, "The catalog of southern Great Basin earthquakes will be examined to determine if significant changes in rates of occurrence of earthquakes are detectable following nuclear tests at NTS..." At least two papers have been published on this point in the last 15 years with results resoundingly dismissing alteration of the seismicity by underground nuclear explosions beyond about 10 km from ground zero. Thus, can this activity be set aside?	

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Section 8.3.1.17.4.3 page 8.3.1.17-97	Here is discussed tectonics between Death Valley and Yucca Mountain and is stated that, "the southwestern boundary [of the Walker Lane belt including Yucca Mountain] is formed by the Death Valley-Furnace Creek fault zone (Carr, 1984)" This would seem to be a key point for the evaluation of seismic risk at the repository site, and is indirectly the focus of a major proposed activity (8.3.1.17.4.3.1). It seems to me that we really don't know right now whether or not the extremely active Holocene faulting in Death Valley couldn't jump over into Yucca Mountain in the next 10,000 years, which is why the SCP proposes detailed geophysical surveys of the region between Death Valley and Yucca Mountain. If these two areas really are in different "seismogenic provinces," it would seem that a prime objective of the above-proposed activity would be to determine the nature of this transition. If resolvable, this point may require a knowledge of movement in the upper mantle beneath Death Valley and Yucca Mountain (perhaps using analysis of anisotropy in S waves for example). My concern is that this outstanding problem is not specifically discussed in the text, but rather the existence of a tectonic boundary placing Death Valley and Yucca Mountain in different provinces is taken as given.

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Section 8.3.1.17.4.8 page 8.3.1.17-179	This is a proposed study of the present-day stress field acting within and proximal to the repository site. I believe that this is a worthwhile endeavor. However, as I pointed out in Comment 3, if we are really going to understand which of the faults at Yucca Mountain have favorable orientations for this stress, we will have to drop the assumption that the principal axes of stress comprise one perpendicular to the surface and two in the horizontal plane (stated as an assumption in Chapter 1, see Comment 3). I am told by people at the University of Nevada who study present-day tectonics that these principal stresses can depart significantly from this assumption in several cases which are plausible at Yucca Mountain. This and related studies need to take note of this point and address it carefully.	

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Section 8.3.1.8, Table 8.3.1.8-1b	A performance parameter given on page 2 of this table is the effects of volcanic eruption penetrating the repository, with a performance goal to show that less than 0.1% of the repository will be disrupted with a conditional probability of being exceeded in 10,000 year of less than 0.1. Although this is not in my discipline, I cannot image how any such estimate could be made. This is a more striking example from the SCP of a goal that appears on common sense to be unattainable at almost any level of confidence.	

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Section 8.3.1.8.1.1.3 magma bodies	This activity discusses exploration for magma bodies in and near Yucca Mountain, but fails to include a recent, evidently successful new method using seismic tomography. Evans and coworkers at the USGS in Menlo Park have recently presented results on the three-dimensional structure underneath Newberry Crater in central Oregon and Medicine Lake in northern California. This work, which uses active seismological methods and gives resolution of the order of a km, detected possible zones of magma under these structures. These experiments, which cost several hundred thousand dollars each to run, can be completed in about six month's time including experimental design, instrument deployment, data collection, and data reduction. This is quite likely the best method to use in the search for crustal magma bodies near Yucca Mountain. I suggest that Activity 8.3.1.8.1.1.3 be modified to include this technique, not only near Yucca Mountain, but near the Crater Flats cinder cones, with a specific goal of trying to detect a northeast-trending low-velocity zone at depth in the crust extending from the cones to the repository site.	

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Section 8.3.1.8 Post-closure tectonics	This is one area of study that is not considered directly in the SCP involving assessment of the tectonic stress in the vicinity of Yucca Mountain. The nuclear testing program has led to a very large amount of strain release in the vicinity of the tests, and a sequence of authors (most recently Wallace and others, 1985, see SCP references) has shown clearly that the amount of stress released by these explosions as "tectonic" strain release, is diminishing. Therefore, the weapons testing program affords an opportunity to provide a quite quantitative estimate of the stress stored in the vicinity of Yucca Mountain in the shallow crust. The testing appears to release a large percentage (most?) of the stored strain energy; the SCP in Chapter 1 documents fairly thoroughly that the occurrence of these events is known apart from identification of hole collapses; therefore, we can assume that the strain energy release (ergs/km) of the explosion afterevents in sections of Pahute Mesa gives a reasonable upper bound for possible strain release near Yucca Mountain. A special study should be directed at developing this point. In general, authors of the SCP seem to shy away from making greater use of the enormous data set available on explosions and their afterevents, which seems to me a valuable gift to seismic assessment of the repository site both in terms of energy release and in terms of ground-motion characterization. I have direct experience that ground-motion characterization		

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	using explosions has been accepted by the NRC: see "Seismic Confirmatory Program Virgil C. Summer Nuclear Station Unit 1 OL No. 1. NPF-12," South Carolina Electric and Gas Company, February, 1983.		
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Review of the Yucca Mountain Consultation Draft Site Plan-
Geophysical Structural Determination Related to Rock Characterization

Keith Priestley

Summary

Compliance with performance and design criteria for a geologic high level radioactive worth repository requires information on the rock characteristics both within the immediate area of the site, and in the region about the site. The required information includes information about the stratigraphy and structure both local to the site and in the wider region about the site, the properties of the rock units occurring at the site, and the temperature and stress conditions before excavation of the underground openings. This information can be used directly in the design of the underground facilities to evaluate the site performance related to ground-water travel time, waste package(?) lifetime and radionuclide release to the environment. Information gained from geophysical structural determination is important in regional studies including improvement in earthquake location, identification of concealed faults, evaluation of ground motion attenuation etc.

Discussion of geophysical structural determination are permanently contained in two sections of the consultation draft of the site characterization plan, section 8.3.1.4 Rock Characteristics and section 8.3.1.17 Preclosure Tectonics. The results of studies in section 8.3.1.17 Preclosure Tectonics are also applicable to studies in section 8.3.1.8 Postclosure Tectonics.

General Comments

Whereas the Site Characterization Plan should be a coherent document describing a well-defined, logical approach towards understanding the Yucca Mtn. site, the existing document is discontinuous, generally vague, and extremely hard to follow. It appears that the approach the preparers of the SCP chose was to prepare a list of all possible geologic, geophysical, and hydrological research topics in hopes that something was not missed. Should the site characterization proceed as presented in the SCP there undoubtedly will be a great deal of research conducted which is irrelevant to the suitability of the site as a high level nuclear waste repository.

A more suitable approach may have been (and probably still is) to spend more effort in understanding the fundamental physical problems confronting the projects and once these are well defined, address them specifically. In fact this approach may have been followed more than the haphazard form of the existing document demonstrates. The present form of the SCP does not give an outside reviewer confidence that the preparer understand the specific problems which used to be dealt with and hence the best procedures to follow in characterizing the size.

Specific Comments on Section of the SPC

Because of the length and complexity of the SCP, it is extremely hard to be critical about details of the research plan for the site characterization. Related issues seem to be scattered throughout the document and in a few weeks review it is impossible to be sure that something which seems to have been missed in one section of the document, may not actually be covered in some other reviewer's connected portion of the document. The document does not instill confidence in at least this reviewer that the multiple preparers of the SCP are aware of the interrelated parts of the research. The problem in the end may not be that a significant measurement is not made, but that interrelationship between various bits of the research will not be taken into account.

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COMMENT 1 of 6

Review of the Yucca Mountain Consultation Draft Site Plan-
Geophysical Structural Determination Related to
Rock Characterization

Introduction

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once these are well defined, address them specifically. In fact this approach may have been followed more than the haphazard form of the existing document demonstrates. The present form of the SCP does not give an outside reviewer confidence that the preparer understand the specific problems which used to be dealt with and hence the best procedures to follow in characterizing the size.

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Evaluation of Geophysical Structural Studies

Seismic refraction and reflection, seismic tomography, gravity, magnetic, and electric analysis provide data for several investigations in the site characterization plan (SCP) for Yucca Mountain geologic repository. The work discussed, primarily in section 8.3.1.17.4.3.1 is comprehensive in scope, however, the presentation of the details of the work is vague or nonexistent. Because of this vague presentation, it is not possible to critically evaluate the details of the plan of study. Some of the studies discussed in the SCP are underway. For example, many of the longer seismic refraction lines were recorded between 1980 and 1984 by the U.S. Geological Survey, however, more lines are planned for the future. As stated in several places throughout the SCP, many of the geophysical methods proposed have not been tried at Yucca Mountain and much preliminary testing is planned. Almost all data collection efforts discussed in the SCP are qualified as to location, stating that the final choice of the data collection site awaits further preliminary studies. In addition, many of the methods proposed are qualified by statements that preliminary work will be done to determine the usefulness of a particular geophysical method. For example, seismic reflection results for the Yucca Mountain area have been disappointing to

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date, and further preliminary work is planned. In the SCP there is no discussion of variations in the data gathering techniques or variations in data processing techniques to improve the abilities of the various geophysical method should standard data collection techniques or processing prove ineffective. Also, should some of the methods prove ineffective, there is no discussion of alternative methods. Virtually all geophysical methods for determining earth structure, seismic, gravity, magnetic, electrical, will be employed for both local studies (scale of 100 meters) and regional studies (scale of 10 to 100 k). One additional method not discussed should be considered. In some areas, shallow radar imaging has proven useful for identifying locations for trending, for mapping continuity between trenches, and for mapping shallow fault features. This should be considered along with shallow seismic refraction and reflection in trench identification and evaluation studies.

Data gained from geophysical structural determinations are important to investigation 8.3.1.17 - studies to provide required information on vibratory ground motion that could affect repository design or performance including studies 8.3.7.17.3.1 identification and characterization of earthquake sources that are relevant to a deterministic seismic hazard analysis of the

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	site, and 8.3.1.17.3.4 documentation of systematic effects on surface and subsurface ground motion from local site geology;and to investigation 8.3.1.17.4 - Preclosure Tectonic data collection and analysis including studies 8.3.1.17.4.3 identification and characterization of Quaternary faulting within 100 km of the site, and 8.3.1.17.4.7 subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain.

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8.3.1.17.4.2	Identification of relevant earthquake sources Relevant earthquake sources will be identified through a synthesis of information including geophysical structural information. Important to this activity are the location and potential activity of burial faults. Model site effects using the wave properties of the local geology -Theoretical site-effect models will be developed based on measurements of the velocity, attenuation and density structure of the soil and bedrock to a depth of at least 1 km, particularly under Midway Valley. The data for these studies will primarily be supplied by the data-collection activities in Investigation 8.3.1.17.4 as outlined in Figure 8.3.1.17-5. Location and recency of faulting near the prospective surface facility includes two activities, the identification appropriate trench locations in Midway Valley and exploratory trenching in Midway Valley. The identification of appropriate trench locations will be made primarily using geologic mapping. Areas of supported Quarternery faulting may also be investigated using shallow seismic refraction and reflection profiling. To this	

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	should be added shallow radar profiling. Studies have shown this to be a valuable and economic method for identifying appropriate locations for trenching and for mapping the subsurface continuation of structures between trenches.

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8.3.1.17.4.3.1	Conduct and evaluate deep geophysical surveys in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane. A variety of geophysical studies are planned at different locations and scales including deep and shallow seismic reformation; deep, intermediate and shallow seismic reflection; and gravity, magnetic and electrical surveys of the region and the site. These studies are summarized Tables 8.3.1.17-7 and 8.3.1.17-8. These data collection experiments include: a) Deep refraction surveys with shot point spacing of 8 to 20 km in the region of Yucca Mountain. The results from this work to date provide detailed velocity control only to about 12 to 15 km depth. b) Shallow refraction and reflection surveys of 250-500 m long profiles in the immediate vicinity of Yucca Mountain. The maximum depth of penetration will be 100 m The number and location of these profiles will be decided on the basis of geologic mapping. c) A deep reflection survey across Yucca Mountain to image large scale features in the crust. Previous work of this type in the region of Yucca Mountain has produced	

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8.3.1.17.4.7	data of marginal quality and the decision to proceed on this study will be made after the evaluation of preliminary test.	

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8.3.1.17.4.7	Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain. Evaluate intermediate depth (2-3 km) reflection and refraction methods and plan potential application of these methods within the site area. This is a planning activity only and the decision to proceed with actual application of these methods will await the review of the preliminary test. Detailed gravity survey of the site area to infer the location of faults and continuity of rock units within the site. Detailed aeromagnetic survey of the site area to infer from this information the location of fault and continuity of rock units within the site. Detailed ground magnetic survey of specific features within the site to infer the location of faults and continuity of rock units in the vicinity of the shaft and surface facilities. Evaluate surface geoelectric methods and plans potential applications of these methods within the site	

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	area to evaluate this method and if useful, plan future activities.	

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8.3.1.4	Rock Characteristics	

Rock Characteristics

The studies of Rock Characteristics described in section 8.3.1.4 provide important information for developing three dimensional models of the physical properties of the site. The objective of the three dimensional models is to provide a computer-based representation of the physical properties of the rocks of the Yucca Mountain Site. The data base for the model will contain the distribution of parameters within the rock units of the site. An important function of the computer based model will be to provide input for numerical computer analysis that involves hydrological, thermal, thermomechanical and geochemical processes.

Data gained from geophysical structural determination are important to several rock characterization investigations of the Yucca Mountain Site, including 8.3.1.4.1.1 development of an integrated drilling program; 8.3.1.4.2.1 characterization of the vertical and internal distribution of stratigraphic units within the site area; and 8.3.7.4.2.2 characterizations of the structural features within the site area. In addition, these type of investigations are important for sections 8.3.1.17 Preclosure Tectonics and 8.3.1.8 Postclosure Tectonics.

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Develop positions on drilling issues that pertain to site characterization.

In the evaluation of drill hole and other subsurface data for the purpose of citing additional drill holes, the bore holes geophysical method, and surface geophysical methods will play an important role.

Characterization of the vertical and lateral distribution of stratigraphic units within the site area.

Surface-based geophysical surveys will be used to help define the lateral and vertical distribution of stratigraphic units and lithostratigraphic subunits of the Yucca Mountain tuff. Table 8.3.1.4-4 summarized the geophysical studies for program 8.3.1.4.

Borehole geophysical surveys will be conducted to aid the definition and refinement of the location and character of lithostratigraphic units and contact between units and to determine the distribution of rock properties within lithostratigraphic units. A suite of commercially available geophysical logs will be obtained in future drillholes and additional experimental geophysical logs will be obtained.

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	Seismic tomographical vertical seismic profiling methods will be evaluated and if successful will be used for studying subsurface fracture networks in the region between the surface, boreholes, and underground workings; and to calibrate and relate the seismic propagation characteristics of the host rocks to the fracture patterns observed in boreholes and underground workings, and to extrapolate the observed fracture patterns to the surrounding regions.	

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SUMMARY OF COMMENTS ON THE YUCCA MOUNTAIN SCP

MARTHA KANE SAVAGE

SECTIONS PERTINENT TO SEISMOLOGY

This summary of my comments of the SCP is divided into two sections. First, I comment on changes between last year's SCPCD and the SCP. In accordance with the reccomended QA format, the detailed comments are addressed only to the problems present in the SCP and do not contain comparisons with last year's SCPCD. The second section of this summary reviews the major comments from the detailed comment sections to follow.

General Comments on changes between the SCPCD and the SCP

Many of the changes seem to be superficial. Some problem points have been addressed in some sections, but left out in others. This is particularly bothersome when the points are ignored in summary sections or in sections describing the proposed activities in detail (see comments 1, 10 and 11): it is not clear if the points will really be considered during the investigation. The major problems identified in the SCPCD and the difference for the SCP are detailed below:

1) Difficult and confusing organization: The SCP is worse if anything, because offending sections were not removed, but problems were addressed in separate tables or sections, or by adding a few sentences that contradicted previous sentences. The result is that it is not clear what points will be included in various investigations.

2) No discussion of timing, personnel, or budget, and lack of "proposal quality" work: No change.

3) Implicit assumption of Yucca mountain as an accepted site: No change.

4) Scientific issues not addressed in any clear, well-focussed fashion: No change.

5) Use of the extremely non-conservative 10,000-yr cumulative slip earthquake instead of accepted maximum magnitudes: unchanged, except for more words added in attempted justification.

6) Coupled-process studies: Addressed more clearly in several tables and sections, but not in key sections such as identification of earthquake sources or probabilistic hazard analysis.

7) Misuse of qualitative data and assumptions: somewhat better--justifications are added in the new tables but still left out in the old tables.

8) Reliance on numerical and probabilistic studies when input parameters are poorly understood: unchanged.

9) Inadequacy of regional studies: some attempts have been added to correct this.

10) Inadequate database: not much change.

Summary of Detailed Comments

Admittedly, the task of determining safety over a 10,000 year period is formidable and it is doubtful that anybody or any group of people could make such assurances. Just the process of organizing the studies is obviously very difficult. Nonetheless, the SCP does not give confidence that the task will be completed anywhere near as well as it could be, and in particular, the organization is so poor as to lose the confidence of any careful reviewer.

The summary chapter on geology gives an example of the flaws present in the rest of the SCP as well. It is disorganized, with related topics repeated in several different sections, sometimes with one section contradicting another section, (See comments 1, 10 and 11) and even at times with one sentence in a paragraph in direct contradiction to another in the same paragraph. In particular, the remarks in the summary sections repeat misleading statements that are acknowledged as such in earlier sections. These contradictions seem to reflect a lack of understanding of basic problems, questioning the ability of the authors of the SCP to carry out work described in later sections.

The major criticism of the SCP is that it is impossible to evaluate whether the planned projects will be carried out successfully. The proposed projects are generally vague, with little discussion of specific methods to be used. Although sections exist detailing project durations, there is no discussion of how many people or which people will be in charge of the various projects, or which tasks will receive more emphasis. It is therefore difficult to determine whether the project could really be completed in the allotted time. The schedule for completion appears almost totally unrealistic. Some study plans have apparently already been approved, without waiting for our comments, other public comments, or for those from the NRC. Tasks that appear similar have widely different schedules, and in some cases, tasks that are needed as a basis for other tasks are scheduled to be completed after those tasks. With such poor coordination in planning it is doubtful that coordination in carrying out the research will be any better, and it seems unlikely that a comprehensive evaluation will be achieved.

The structure of the report is difficult to follow. Related topics are scattered throughout the report, and confusion is generated. The problem seems to arise from the approach taken of designing separate studies for each parameter deemed necessary to satisfy regulatory conditions, with little obvious coordination between studies. A better way would have been to design scientific studies to answer basic questions, and in a later section show which parameters will come from which studies.

There are no disqualifying conditions to meet the disqualifying conditions in the regulations. Presumably some values of parameters would disqualify the site completely, either by a hazard that would be impossible to engineer against, or by requiring a complete redesign of the facilities such that the expense would be higher than is presently allowed. If so, some method of stopping the expense of the characterization program is needed for the case that such a condition is found.

Qualitative performance goals are too vague. The resolution of the goals will be a matter of opinion and will need to be documented more rigorously. The qualitative nature of the needed confidence in the performance characteristics is too vague. For each parameter, the reasoning must be stated as to why a particular parameter has been given a low, medium, or high confidence or need for confidence. This is important because it is stated that the goals are to be used to direct research priorities. In particular, according to the current system apparently no further study will go into projects for which the confidence in the present figures have the same confidence as the needed confidence.

It is encouraging that the DOE has started to address the concept of alternative conceptual models, as seen in their new tables. I am particularly pleased with the columns that give justifications for the qualitative assigned confidence and needed confidences. Such columns should also have been added to the earlier tables. However, the detailed descriptions of key activities, such as characterizing relevant earthquake sources and deterministic and probabilistic hazard analysis still ignore the alternative conceptual models, and it is not clear how they intend to incorporate them in the analysis.

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Sec. 1.4, 1.5.2.1, 1.5.2.2, 1.5.2.3, 1.8.1.4, 1.8.1.5 pg. 1-151 through 1-213, 1-335 through 1-340	The summary chapter on geology gives an example of the flaws present in the rest of the SCP as well. It is disorganized, with related topics repeated in several different sections, sometimes with one section contradicting another section, and even at times with one sentence in a paragraph in direct contradiction to another in the same paragraph. (See comments 1, 10 and 11.) In particular, the remarks in the summary sections repeat misleading statements that are acknowledged as such in earlier sections. These contradictions seem to reflect a lack of understanding of basic problems, questioning the ability of the authors of the SCP to carry out work described in later sections.

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Overview, all pages; Chapter 1, all pages; Chapter 8, pp. 8.0-1 through 8.0-10; 8.1-1 through 8.1-11; 8.2.1-8.2-60; 8.3.1.8, all pages; 8.3.1.17, all pages, 8.3.2.1-24	The major criticism of the SCP is that it is impossible to evaluate whether the planned projects will be carried out successfully. The proposed projects are generally vague, with little discussion of specific methods to be used. Although sections exist with project durations (e.g., Sec. 8.3.1.8.6, p. 8.3.1.8-131 through 8.3.1.8-139 and Sec. 8.3.1.17.5, p. 8.3.1.17-207 through 8.3.1.17-226), there is no discussion of how many people or which people will be in charge of the various projects, or which tasks will receive more emphasis. It is therefore difficult to determine whether the project could really be completed in the allotted time.	

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same as comment 2	The structure of the report is difficult to follow. Related topics are scattered throughout the report, and confusion is generated. The problem seems to arise from the approach taken of designing separate studies for each parameter deemed necessary to satisfy regulatory conditions, with little obvious coordination between studies. A better way would have been to design scientific studies to answer basic questions, and in a later section show which parameters will come from which studies.	

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same as comment 2, but particularly tables 8.3.1.8-through 8.3.1.8-6 and 8.3.1.17-1 through 8.3.1.17-6, pages 8.3.1.8-3 through 8.3.1.8-21 and 8.3.1.17-3 through 8.3.1.17-25.	There are no disqualifying conditions to meet the disqualifying conditions in the regulations. Presumably some values of parameters would disqualify the site completely, either by a hazard that would be impossible to engineer against, or by requiring a complete redesign of the facilities such that the expense would be higher than is presently allowed. If so, some method of stopping the expense of the characterization program is needed for the case that such a condition is found.

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same as comment 4	Qualitative performance goals are too vague. The resolution of the goals will be a matter of opinion and will need to be documented more rigorously. The qualitative nature of the needed confidence in the performance characteristics is too vague. For each parameter, the reasoning must be stated as to why a particular parameter has been given a low, medium, or high confidence or need for confidence. This is important because it is stated that the goals are to be used to direct research priorities. In particular, according to the current system apparently no further study will go into projects for which the confidence in the present figures have the same confidence as the needed confidence.	

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Section 1.4.1.1.2, pg. 1-168, paragraph 3, in particular table 8.3.1.8-5b, p. 8.3.1.8-18, Section 8.3.1.8	General comment on parameter goals and characterization parameters: On many occasions, a needed confidence in a parameter goal is stated as "high" but the "needed confidence in final values" of the only listed characterization parameter is listed as "moderate". If the confidence in the parameter used to characterize the goal is only "moderate", then the confidence in the parameter goal cannot be higher than "moderate". For an example, see p. 8.3.1.8-18, Table 8.3.1.3-5b, "Effects of fault motion on local fracture permeabilities and effective porosities".	

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8.3.1.17, pp. 8.3.1.17-1 through 8.3.1.17-226 In particular activity 8.3.1.17.3.1.2, p. 8.3.1.17-72 and many other sections	The concept of the "10,000 year cumulative slip event" is extremely non-conservative. As stated on page 8.3.1.17-36, recurrence intervals for earthquakes in the target area are 10,000 to 100,000 years. Therefore, the total slip released in an earthquake would have been accumulating for 10,000 to 100,000 years, and the "10,000 year cumulative slip event" yields a **minimum** magnitude for occurrence on the given fault. A more realistic and conservative approach would be to use a 100,000 year cumulative slip earthquake, or to use the maximum earthquake that could be produced by the fault. The recurrence interval could be included in probabilistic calculations, but the **magnitude** of the event should be based on a truly conservative estimate of the probable magnitude. Using a 100,000 year earthquake would require increasing all values that use slip rates to determine magnitudes of cutoff displacement by a factor of 10.

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Section 8.3.1.17.5 Table 8.3.1.17-11. pp 8.3.1. 17-207 through 226.	The schedule for completion appears almost totally unrealistic. Some study plans have apparently already been approved, without waiting for our comments, other public comments, or for those from the NRC (e.g., studies 8.3.1.17.1.1 and 8.3.1.17.4.10 had the study plan approved 1/89, and studies 8.3.1.17.3.2, 8.3.1.17.4.2, and 8.3.1.17.4.3 had the study plan approved 3/89). In addition to not knowing who is going to complete which tasks, or which ones will be given priority, tasks that appear similar have widely different schedules, and in some cases, tasks that are needed as a basis for other tasks are scheduled to be completed after those tasks. For example, in table 8.3.1.17-11, p. 8.3.1.17-212, 214, and 215. Task 8.3.1.17.3.1, identification of relevant earthquake sources, is to have complete earthquake magnitude estimates by 9/92, and task 8.3.1.17.3.5, evaluation of ground motions at the site from controlling events, is to identify controlling events by 3/93. However, task 8.3.1.17.3.6, Probabilistic seismic hazard

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analysis, is to complete the earthquake source evaluation by 11/91 and to have a report available on the probabilistic ground motion assessment by 12/92. The earthquake source evaluation for probabilistic hazard analysis will be completed more than a year before that for deterministic hazard analysis, in spite of the statement in section 8.3.1.17.3.6.1, on page 8.3.1.17-83 that in comparison to the deterministic hazard analysis, "The scope of this [evaluation of earthquake sources for probabilistic hazard analysis] is more comprehensive in that more seismic sources will be characterized, multiple interpretations of seismic sources will most likely be retained and their relative likelihoods judged, any dependencies in the interpreted existence of source zones (e.g., perfect dependence or mutual exclusiveness of some sources) must be specified, and maximum magnitudes must be estimated explicitly."

Similarly, Study 8.3.1.17.4.11.1, analyze lateral component of crustal movement, and study 8.3.1.17.4.12, development and synthesis of tectonic models- won't be ready until 9/93.

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	These studies are necessary to constrain the horizontal strain and to determine maximum magnitudes of earthquakes and faulting probabilities, yet they will be completed after the probabilistic hazard analysis is finished. With such poor coordination in planning it is doubtful that coordination in carrying out the research will be any better, and it seems unlikely that a comprehensive evaluation will be achieved.	
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Tables 8.3.1.8-7, 8.3.1.8-8, 8.3.1.17-7, 8.3.1.17-8, pages 8.3.1.8-31 through 8.3.1.8-45 and 8.3.1.17-38 through 8.3.1.17-42.	It is encouraging that the DOE has started to address the concept of alternative conceptual models, as seen in their new tables. I am particularly pleased with the columns that give justifications for the qualitative assigned confidence and needed confidences. Such columns should also have been added to the earlier tables, 8.3.1.8-1 through 8.3.1.8-6 and 8.3.1.17-1 through 8.3.1.17-6. However, the detailed descriptions of key activities, such as characterizing relevant earthquake sources and deterministic and probabilistic hazard analysis (Sections 8.3.1.17.3.1, 8.3.1.17.3.5, 8.3.1.17.3.6, 8.3.1.17.4.2, 8.3.1.17.4.3) still ignore the alternative conceptual models, and it is not clear how they intend to incorporate them in the analysis. For example, a simple alternative model that is highly plausible is that some of the faults presently considered to be separate are actually connected at depth and may slip together in a large earthquake, with consequent motion much larger than the motion expected on any one particular fault. However, the method of excluding earthquakes less than 20 km long from consideration in section	

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	8.3.1.17.3.1.1 (Identify relevant earthquake sources; p. 8.3.1.17-69) may keep such possibilities from consideration.	
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Sections 1.4.1.1.1, 1.4.1.1.3, 1.4.1.2, 1.4.1.2.1, 1.4.1, 1.8.1.4.1 Fig. 1-55, p. 1-161, 1-165, 1-170, 1-175, 1-335.	The discussion of spatial variation of energy release (p.1-165, 1-175) is superfluous and the attempt to show low energy release near Yucca Mountain is misleading. In their method, they average earthquake energy release over progressively larger areas as they get further from the central point (Yucca Mountain). Naturally, greater variation in average energy release will be observed in the closer bands that have smaller areas over which to average. If this technique were applied elsewhere in the region, I would expect to find some areas with lower-than-average nearby energy release, and as in their analysis, the values tend toward the regional average in the further bands which contain broader areas and hence more earthquakes. Moreover, these values would change with time as new clusters began in previously quiescent areas. This latter point was acknowledged on p. 1-170, sec. 1.4.1.1.2, in which they stated "As the SGBSN continues to monitor seismicity...Therefore, it is likely that new patterns of activity, spatial and temporal, will become evident in areas that had previously been quiescent". Finally, figure 1-55 on p. 1-161 shows that when the whole historic record is

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	included, Yucca Mountain is not in a particularly low area of energy release. In spite of their own acknowledgement of the constantly changing seismicity patterns, the authors repeat the misleading statement about low energy release in the summary sections (1.4.1.1.3, p. 1-170; 1.8.1.4.1, p. 1-335; Overview, p. 22 and 23).	

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Section 1.4.1.1.2, p. 1-168 paragraph 3.	The SCP states "Rogers et al. (1987) have performed an extensive series of computational experiments that show that the peaks in the distribution are not artifacts of data processing, hypocenter location algorithm, velocity model used, or distribution of depth errors". Several sentences later, they contradict it by saying "Extensive tests, conducted to study the effects of the variation-of-velocity model on hypocenters in Rogers et al. (1987), were inconclusive and do not rule out the possibility that the bimodal depth distribution is a model-dependent feature." The bimodal nature is again stated as a fact in Section 1.8.1.4, p. 1-335.	

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Sec. 1.4.2.1, 1.5.2.3, p. 1-193, 1-212	Section 1.4.2.1 states that the design criterion for acceleration will be 0.4 g, but section 1.5.2.3 discusses the effects for a repository designed for acceleration of 0.75g to show that ground motion from nearby nuclear tests will not affect the repository.	
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Section 1.4.2, p. 1-193, Section 1.4.1.3 p. 1-187.	Rogers et al. (1977) study of earthquake potential is used to estimate maximum magnitude. They state that "Because the entire mapped fault length is assumed to rupture, the estimate of maximum magnitude is conservative". But in the nearby 1932 Cedar Mountains M=7.2 earthquake, surface expressions of faults were much smaller than the inferred extent at depth. (Molinari, 1984). It is assumed that the surface rupture was a case of distributed faulting. Therefore, using just one mapped fault length is not conservative, since faults may be connected at depth but not at the surface. Similarly, in the Mammoth Lakes area, magnitude 6+ earthquakes have occurred with no prior surface expression of faults (Cockerham and Corbett, 1987; Hill et al., 1985). References: Molinari, M.P., 1984, Late Cenozoic geology and tectonics of the Stewart and Monte Cristo Valleys, west-central Nevada [M.S. thesis]: University of Nevada, Reno, NV, 124 pp. Cockerham, R.S. and Corbett, E.S.1987, The July 1986 Chalfant Valley, California, Earthquake Sequence: Preliminary Results, Bull. Seismol.

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Soc. Am., 77, p. 280-289.

Hill, D.P., R.A. Bailey, and A.S. Ryall, 1985. Active tectonic and magnetic processes beneath Long Valley caldera, eastern California; J. Geophys. Res., 90, p. 11,111-11,120.

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Section 1.3.2.5.3., p. 1-159.	Location uncertainties for the SGBSN network locations are given as 0.5 km horizontal and 1.0 km in depth. These estimates do not include errors from the velocity models, which will make the location errors much larger.	

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Section 1.4.1.5 and 1.4.2.1, pp. 1-189 through 1-196.	The suggestion is made that calculating the regional hazard is best done by excluding the Nevada-California seismic belt. Since there is no established seismic or tectonic theory that explains why the Nevada-California seismic belt happens to be more seismic at present than adjacent areas, it is reasonable to suppose that adjacent areas might at some point exhibit the same increase in seismicity, and therefore the region should not be excluded from a conservative analysis that must predict the next 10,000 years.		

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Section 1.5.2.2, p. 1-208.	The report states "It is likely that any future faulting at Yucca Mountain would occur along pre-established faults". Nearby areas have shown that earthquakes greater than magnitude 6 have occurred on unmapped faults that do not penetrate the surface. (See comment 13).	

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Section 8.3.1.17.2, p. 8.3.1.17-57.	Goal 2 of fault displacement beneath FITS states that the study will consist of "Identification and characterization of faults within 100 m of FITS that have apparent Quaternary slip rates > 0.001 mm/yr or that measurably offset materials that are less than 100,000 yr old". Faults may have recurrence intervals greater than 100,000 years. Wallace (1981) describes a "County Dump" fault in New Mexico that has recurrence intervals of 90,000-190,000 years, with 4 fault events at 20,000, 120,000, 310,000 and 400,000 years ago. If such a fault is in the area it may have last broken more than 100,000 years ago and still have a probability of breaking in the next 100 or 1,000 years. A fault with recurrence interval of 100,000 years and a slip rate of the given 0.001 mm/yr could slip 10 cm, more than the 5 cm considered for FITS in a 100 year period or for the waste package rupture over 1,000 years. All faults within 100 m of FITS should be identified, characterized, and trenched. REFERENCE: Wallace, R.E., 1981. Active faults, paleoseismology, and earthquake hazards in the		

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	western United States, in Earthquake Prediction, and International Review, edited by D.W. Simpson and P.G. Richards, American Geophysical Union, Washington, D.C., 209-216.		

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Section 8.3.1.17.2, p. 8.3.1.17-57.	For characterization parameters related to waste retrieval, Goal 3 is to "Estimate total probability of exceeding 7 cm displacement on any fault in the area of emplaced waste, considering known and possibly concealed faults and the tectonic interrelationships among local faults". Goal 2 is to find "Surface and subsurface locations of any faults that intersect prospective underground facilities and that have average Quaternary slip rates greater than 0.005 mm/year. If such a fault had a 100,000 year recurrence interval, then 50 cm of slip could be released in one episode, well above the 7 cm of displacement. Such a fault should be considered in the probabilistic calculation, not ignored.	

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Section 8.3.1.17.3 p. 8.3.1.17-69	The study to provide required information on vibratory ground motion that could affect repository design or performance uses magnitudes of 10,000 year cumulative slip earthquakes on local sources. This is nonconservative and may underestimate ground motion by a factor of 10. See also comment 7.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT 1 of 3		
Section 8.3.1.17.3, p. 8.3.1.17-70	The following statement is made: "The likelihood of a buried fault being active will be evaluated considering the spatial correlation of the fault with historical seismicity, the orientation of the feature with respect to measured or inferred crustal stress orientations ...". As stated in chapter 1.4, historical seismicity is very poorly located. Even since the advent of the SGBSN network in 1978, locations are not known well enough to rule out the correlation of earthquakes with faults (See chapter 1.4). Therefore, the lack of direct correlation of a fault with an earthquake does not mean that the fault is not active, but may merely mean that the earthquake was not well located. The stated accuracy of 0.5 km horizontal and 1.0 km in depth on p. 1-159 is unreasonably small and most likely does not include errors from velocity models or location procedures. A systematic approach to determining better earthquake locations, through using S waves that are currently ignored, and through using three-dimensional velocity models or master-event location techniques is in order. For example, earthquakes in California align much more closely		

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with faults when 3-D variation in velocity is taken into account, or when a master-event type technique is used to locate the events (e.g., Thurber, 1983). Often aftershock studies don't line up on fault planes until detailed investigations using master-event techniques are conducted (e.g., Lide and Ryall, 1984). In Hawaii, locations and focal mechanisms were much better constrained when three-dimensional velocity structures were used to locate the events (Thurber, 1987). The Basin and Range province obviously does not have a simple layer-cake geometry as is used to locate the events with the HYPO71 program, or even a linear-gradient model such as is used in the Hypoinverse program. In an analogous area in the Basin and Range province, Jones (1987) has shown that the assumption of horizontal layers while locating earthquakes in the Basin and Range province leads to location errors greatly in excess of the parameters that come directly from the HYPO71 program that they have used. Therefore, a thorough analysis of the effects of 3-dimensional structure on the locations is needed before lack of correlation of earthquakes with faults can be used as arguments that the faults are inactive.

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and before any tectonic interpretation is made from the apparent depth distributions of the earthquakes.

REFERENCES:
Jones, C.H., 1987. A Geophysical and Geological Investigation of Extensional Structures, Great Basin, Western United States. PhD thesis, Massachusetts Institute of Technology, 226 pp.

Lide, C.S. and A.S. Ryall, 1985. Aftershock distribution related to the controversy regarding mechanisms of the May 1980, Mammoth Lakes, California, Earthquakes. J. Geophys. Res., 90, 11,151-11,154, 1985.

Thurber, C.H., 1983. Earthquake locations and three-dimensional crustal structure in the Coyote Lake area, Central California, J. Geophys. Res., 88, 8226-8236.

Thurber, C.H., 1987. Seismic structure and tectonics of Kilauea Volcano, Hawaii. in Hawaiian Volcanism, USGS Professional Paper 1350,

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8.3.1.17.3.6.2 p. 8.3.1.17-84 through 85	In evaluating ground motion probabilities, parameters needed should also include site effects from activity 8.3.1.17.3.4.1, p. 8.3.1.17-78, since the ground motion probabilities of import are those at the sites affected.	

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8.3.1.17.4.1.1, p. 8.3.1.17-88	In compiling historical earthquake records, errors in location procedure or velocity model are not included in the uncertainty estimates that are returned from standard location programs. Therefore, in order to evaluate how well an earthquake is located, some indication of the method of location should be given in addition to the hypocenter uncertainty estimate, so that the true uncertainty can be evaluated. Similarly, the additional parameters for the larger earthquakes should include references to how the parameters were determined.	

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8.3.1.17.4.1.2 p. 8.3.1.17-89	Monitoring current seismicity. As in Comment 22, compiled parameters ought also to include references to velocity model, location and magnitude method, and station corrections used. Similarly, the additional parameters for the larger earthquakes should include references to how the parameters were determined. In addition, as described above (Comment 19), careful systematic relocation of events and examination of station residuals should be performed to distinguish whether seismicity patterns observed are real or artifacts of the present location procedures and velocity models.	

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Section 8.3.1.17.4.1.3, p. 8.3.1.17-92	In evaluating the potential for induced seismicity at the site, the possibility that the extra heating from the radioactivity could induce cracking that would then induce earthquakes ought to be considered. In addition, activities include surveys of literature on seismicity induced by the impoundment of Lake Mead and on mining-induced seismicity, but not for surveys of literature on seismicity induced by nuclear explosions. We note that several hole collapses (Magnitude up to 4.6) that are discussed in the literature (McEvilly and Peppin, 1972) are reported as earthquakes in the present historical catalog (Meremonte and Rogers, 1981) that is to be used as the basis for most activities. Before this catalog alone is used in the studies, this situation should be corrected by a thorough literature search as a starting point. Reference: McEvilly, T.V. and W.A. Peppin, 1972. Source characteristics of earthquakes, explosions and afterevents. Geophys. J. R. astr. Soc. 31, 67-82.

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Section 8.3.1.8.2.1.6 and 8.3.1.8.2.1.7, pages 8.3.1.8-71 and 72 and 8.3.1.8-82.	The SCP considers active folding to affect only the changes in dips of beds. In several places (Coalinga, California; Whittier, California; El Asnam, Turkey) surface folding is accomplished by thrust earthquakes at depth. While the evidence is that most faulting in the Basin and Range is strike-slip or normal, such a possibility should also be considered for any observed folding, as thrust faulting would affect the seismic hazards.	

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Section 8.3.1.17. p. 8.3.1.17-27	The 3rd paragraph reads: "Because source events that will be postulated are not likely to change as more refined fault data become available, the resulting motions are expected to provide a stable basis for use in design." There is still controversy about the ages and recurrence intervals of many of the faults: therefore, the source events may well be changed in the future and work using source events should perhaps be postponed until a thorough understanding of all the possible earthquakes is carried out.		

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Section 8.3.1.17 p. 8.3.1.17-35	For consideration of vibratory ground motion, design-basis ground motions are to be characterized for frequencies significant to facilities important to safety such that there is less than a 10% chance of being exceeded during 100 yr. That does not seem conservative. It implies that if ten such facilities are built, then we expect one of them to experience ground motion in excess of the design parameters.		

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Section 8.3.1.17.4.1.2 p. 8.3.1.17-90	The SCP states: "A local accelerograph array will be installed at the site as described in activity 8.3.1.17.4.1.2". This is the section to which they refer, but they do not describe the array in any detail at all, and later it states "This activity will only synthesize and compile data collected by other activities".	

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TASK 5

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GENERAL STATEMENT

Compared with the Consultation Draft, there have been many significant changes and improvements in the SCP. In particular, alternative hypotheses have been explicitly incorporated into the analysis, mainly in the form of "hypothesis-testing tables." In addition, many "activities" (parts of "studies", which themselves are parts of "investigations") have been added and others have been described in more detail than in the Consultation Draft. Clearly, much additional attention has been given to details within the overall scheme of organization.

Unfortunately, no attention seems to have been given to the overall structure of the Site Characterization Plan. As in the Consultation Draft, the overall organization scheme is "overwhelmingly long, complicated, and confusing, so much so that it contains countless internal inconsistencies and contradictions" (see my comments on SCP-CD). Although DOE officials have insisted in many public meetings that the plan is flexible and can be changed at any time, it appears that the overall structure of the plan is rigid, fragmented, and will take a hopelessly large amount of time and money to implement, much less modify and improve. As it stands, it

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is unlikely that this Site Characterization Plan will enable the DOE to provide the critical information required to decide site suitability. Numbers will be generated by innumerable small "activities", each operating in a vacuum, and no amount of organization tables, hypothesis-testing charts, and logic diagrams will result in a coherent or realistic picture of the required detail of Yucca Mountain. DOE has created a monster in this SCP, and will now be controlled by it for the next 5 to 10 years.

The State of Nevada, on the other hand, will probably be kept at bay for years arguing or discussing details of one interpretation or activity or another, most of which has little chance of clarifying the actual questions of whether the Yucca Mountain site is capable of isolating waste from the environment during the Preclosure and Postclosure periods, and whether the is significant potential for mineral or petroleum resources. General comments below are followed by specific comments on the major sections I have reviewed.

GENERAL COMMENTS

1. My general comments on the SCP-CD still stand.

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Signature: Richard A. Schweickert

DATE: June 10, 1989

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2. Chapter 1 has seen little change, and my old comments still stand.

3. The Pre- and Post-closure tectonics programs seem to have been designed on the basis of disruption scenarios or initiating events, without any sense of the overall scientific problems that have to be faced, e.g. regional and local patterns of faults, history of faulting and extension, fault activity, volcanism, folding, etc.

4. There is no focus on regional structure (except for Quaternary faults), or on deep structures. Studies and investigations proposed will not address deep faults of various ages or the structure of Paleozoic rocks at depth beneath the site.

<u>There exist problems of</u>

<u>a) Mesozoic thrust structures, having both east and west vergence.</u>
<u>b) pre-Middle Miocene extensional faults or detachments.</u>
<u>c) pre-Middle Miocene strike-slip faults, and Middle Miocene caldera-related faults.</u>
<u>These structures, some of which definitely exist,</u>

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others of which are probable, are important to

a) seismic hazard if reactivated,
b) understanding of boundary conditions of groundwater flow,
c) assessment of mineral potential, and
d) assessment of hydrocarbon potential.

5. **The Site Characterization Program is not geared for discovery of fatal flaws in the site. Rather, it explicitly assumes no fatal flaws exist.** The program should instead focus on

a) identification of the types of fatal flaws that could exist, and
b) programs to determine whether or not such fatal flaws exist

rather than assuming "hypotheses" that there are no fatal flaws.

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COMMENT NO.: 5-2; pg. 1 of 1 | CHAPTER NO.: 8

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8.3.1.4 pg. 8.3.1.4-1 to 108	Some changes have been made, but overall focus is the same. Geologic framework and Geologic model do not seem to be integrated into the logic diagrams, and appear to be add-ons.

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SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.4 pg. 8.3.1.4-19 to 23 8.3.1.4-2	Table 8.3.1.4-2: Alternative hypotheses 1. In several cases, reasons for choice of "current representation" over "alternatives" are not clear, except, possibly that the most optimistic cases are preferred. 2. Current representation of the geologic domain is an assumption, not a hypothesis. 3. Logic is faulty in some places: "alternative hypotheses" in several cases are either known to be wrong or are unrelated to current representation. 4. Hypotheses about structure only consider shallow, exposed faults; the possibility of deeper, concealed (buried or blind) faults is not even mentioned. 5. Hypotheses listed under "rock characteristics", current representation, seem contradictory; exact alternatives are unclear.

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8.3.1.8 pg. 8.3.1.8-1 to 141	Postclosure tectonics: Significant revisions have been made to this program . Many new investigations and activities have been added. However, numerous organizational and logical problems exist. All investigations seem to be designed and driven by various "initiating events", and thus seem to have little coherence to them.

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COMMENT NO.: 5-5; pg. 1 of 1 | CHAPTER NO.: 8

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8.3.1.8.5 pg. 8.3.1.8-105 to 131	Investigation 8.3.1.8.5, "Postclosure tectonics data collection and analysis" is a confusing collection of unrelated studies, including volcanic features, igneous intrusive features, and folds. There is no logic diagram because there is no logic to this scheme of organization.

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SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.8.5.3.1 pg. 8.3.1.8-130-131	Under 8.3.1.8.5.3.1, Evaluation of folds in Neogene rocks of the region, note that existing maps are inadequate for the study of folds in Neogene rocks.

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COMMENT NO.: 5-7; pg. 1 of 2 | CHAPTER NO.: 8

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8.3.1.8 pg. 8.3.1.8-31 to 39 8.3.1.8-7	Table 8.3.1.8-7--hypotheses for local model for post-closure tectonics: a. Table is mislabeled, "preclosure" tectonics b. Choices of "current representation" are commonly unjustified, and highly speculative; in several instances the alternatives are much more reasonable or prudent. c. Several key alternatives are not listed or considered. d. Combination of thermal and mechanical driving forces is more reasonable than mechanical forces alone. e. Under boundary conditions, "regional controls that affect distribution of strain in the region" are completely unknown, and provide no boundary conditions. f. Under system geometry, an alternative not listed is a brittle crust modified by thermal inputs from magmatic bodies within the crust. g. Faulting geometry and mechanisms are seriously incomplete(this also goes for tables 8.3.1.8-8, 8.3.1.17-7, and 8.3.1.17-8): only shallow, exposed faults are considered. **Several other alternatives that need to be considered include concealed faults such as Mesozoic thrusts (both west and east vergence), pre-Middle Miocene detachment faults, pre-Middle Miocene strike-slip faults, and Middle Miocene**

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caldera-related faults.

h. Under fault rupture patterns, the three alternatives listed are not independent, but may be closely interrelated.

i. Under controls on volcanism, the second and third alternatives listed are not independent alternatives, but again are interrelated.

j. Under rate of volcanism, there are actually two independent alternatives listed rather than one.

k. Under effects on ground water flow, there is no justification for choosing the current representations; a much more prudent approach would be to adopt the alternatives for testing.

l. Comment k above also applies to chemical properties along flow paths.

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8.3.1.8 pg. 8.3.1.8-40 to 45 8.3.1.8-8	Table 8.3.1.8-8--hypotheses for the regional model for postclosure tectonics a. Most statements under comment 5.7 apply here. b. Under driving forces, intraplate forces and stresses must also be considered, together with forces produced by thermal input from magmatic bodies within the crust. c. Under regional faulting mechanisms, other alternatives include reactivation of buried or blind faults. This is not an either/or situation, since the tectonic setting is neither pure extension nor pure strike-slip. d. Under extension rate and distribution, although extension may be <u>concentrated</u> in local zones, it clearly does not occur <u>exclusively</u> in those local zones. e. There is little or no consideration of coupled processes in this table.

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COMMENT NO.: 5-9; pg. 1 of 1 | CHAPTER NO.: 8

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8.3.1.17 pg. 8.3.1.17-1 to 226	Preclosure tectonics: Significant revisions have also been made in this program since the SCP-CD. However, once again this program has little coherence since most of the key studies are lumped together in a catchall investigation, 8.3.1.17.4, Preclosure tectonics data collection and analysis. The other investigations are again predicated mainly upon certain disruption scenarios and prejudged data needs. No studies or investigations address the existence of Mesozoic thrusts, and pre-Middle Miocene detachment and strike-slip faults, or Middle Miocene caldera-related faults in the region or at the site. **This is a very serious oversight in planning.**

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COMMENT NO.: 5-10; pg. 1 of 1 | CHAPTER NO.: 8

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8.3.1.17.4.3.2 pg. 8.3.1.17-119 to 127	Investigation 8.2.1.17.4, Activity 4.3.2: This includes a very comprehensive and important series of tasks, each of which should be an "activity" in its own right.

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8.3.1.17.4.3.3 pg. 8.3.1.17-127 to 128	Activity 4.3.3: This is a fairly minor task, and should be a subactivity.

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SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.17.4 pg. 8.3.1.17-132 to 153	Studies 4.4 and 4.5 are said to be largely complete in several activities, suggesting little additional work will be necessary. Yet there still are very large uncertainties about the Rock Valley fault system and about detachment faults, making further studies essential.

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8.3.1.17 pg. 8.3.1.17-38 to 44 8.3.1.17-7	Table 8.3.1.17-7--hypotheses for local model for preclosure tectonics: a. specific comments on Table 8.3.1.8-7 (comment 5-7) apply here. b. Under distribution of seismic potential, another alternative that needs to be addressed is events on buried or blind faults. c. Under adequate seismic design basis, how can the model of the10,000-yr cumulative slip earthquake be justified? d. Choices of current representations are highly speculative in several cases.

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8.3.1.17 pg. 8.3.1.17-45 to 49 8.3.1.17-8	Table 8.3.1.17.8--hypotheses for regional model for preclosure tectonics: a. All comments for Table 8.3.1.8-8 (comment 5-13) apply here.

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8.3.1.4, 8.3.1.8, and 8.3.1.17

Various generic types of research in tectonics are highly fragmented in the SCP and are poorly integrated. For example, consider Fault-related studies, Volcanism studies, and Folding studies. Because even these generic types of studies are highly fragmented and are not even integrated into a regional tectonics program, there is little chance that relations between possibly coupled processes will be clarified:

1. Fault-related studies

a. Only Quaternary faults are considered; no studies are planned to address geometry, location, seismic potential, and significance to groundwater flow of i) Mesozoic thrusts, ii)pre-Middle Miocene detachments, iii) pre-Middle Miocene strike-slip faults, iv) Middle Miocene caldera-related faults.

b. Regional studies include:

8.3.1.17.4.3
4.3.1
4.3.2
4.3.3
4.3.4
4.3.5

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8.3.1.17.4.4
4.4.1
4.4.2
4.4.3
4.4.4
8.3.1.17.4.5
4.5.1
4.5.2
4.5.3
4.5.4
4.5.5

c. Site studies of faults include:
8.3.1.17.4.2
8.3.1.17.4.6
4.6.1
4.6.2
8.3.1.17.4.7
4.7.1
4.7.2
4.7.3
4.7.4
4.7.5
4.7.6
4.7.7

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4.7.8
8.3.1.4.2
2.2
2.3
8.3.1.8.2
2.1.3
8.3.1.8.3.1.3
3.1.4
3.2.6
3.3.2

c. Volcanism studies include:
8.3.1.8.5.1
5.2
8.3.1.17.1.1
1.1.1
1.1.2
1.1.3

d. Studies of folding include:
8.3.1.8.2.1.6
8.3.1.8.5.3.1

In short, relations between folding and faulting or between faulting and volcanism, if any, will be very difficult to determine from this program.

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All General:

The contents of Chapter 1 represent a relatively thorough review of the geological literature as it pertains to the Yucca Mountain region. Some mention is made of almost all tectonic models and the various hypotheses proposed to explain the development of the southern Great Basin (SGB). Nevertheless, Chapter 1 is still out-dated; significant advances have been made in both our understanding of the SGB and in the amount of data gathered. It is unreasonable to expect the SCP to be completely up to date for two reasons: 1) The SGB represents a breeding ground of new ideas and models, and these ideas are being continually published in the scientific literature. 2) The SCP has taken a long time to be assembled (preliminary work began in the early 1980's), and with all the various reviews and careful screening of the document, it cannot be expected to represent a state-of-the-art review.

Nevertheless, due to the significance of the project at hand it is essential that scientists working for the DOE are aware of the latest ideas and data, and that they are allowed to respond to them. In this respect, I am disturbed by the rigid and piecemeal structure of the SCP (in particular, Chapter 8); no indication is made that scientists will have the flexibility to respond to new data or ideas beyond those generated by the various studies planned in the SCP.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
All	Throughout the SCP (as in the CDSCP) there is a considerable mix of qualitative and quantitative data and measures. This is unavoidable in the earth sciences. In order to go from the geology to engineering parameters for design and construction purposes it is necessary to perform probabilistic analyses. **Probabilistic analyses yield reasonable results if and only if the data base is relatively complete and accurate.** This is an extremely important point that is never emphasized in the SCP. From this point of view, it is very difficult to have any confidence in any seismic hazard analyis of the Yucca Mountain area simply because the plans to evaluate the paleoseismicity are inadequate. No attempt, for example, is made to evaluate the potential for spatial or temporal clustering, nor is any attempt made to consider a distributed seismic event at Yucca Mountain, nor to incorporate multiple-fault slip rates into probabilistic analyses.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
All	Chapter 8 represents an ambitious plan to characterize the Yucca Mountain site. It is difficult to evaluate the extent to which the various studies, activities, and investigations are interrelated, if at all. Certainly, each study, activity, etc., is cross referenced to other studies, etc., but this does not represent a coordinated plan of attack. I am left with the impression that Chapter 8 is a collection of studies, etc. that are being thrown *en masse* toward Yucca Mountain in the hope that they will provide the required answers. It is more important to take care in posing the right questions before planning a scientific attack on the problem.

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COMMENT NO.: 4 CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8-3	This comment is concerned with Table 8.3.1.8 - 1b and -2b. These tables address various performance parameters, tentative goals, testing bases, and so on, for processes related to postclosure tectonics. The tentative parameter goals are cast in terms of the probability of exceedance of a particular performance parameter. That is, what are the chances that a particular geologic process will affect the repository in a particular way? Such probabilities will ultimately be used in engineering applications and will (presumably) translate to equipment and building or electrical material specifications. And yet the testing basis that determines the required amount of further investigation is apparently quite subjective and qualitative; current and required confidences in the various estimates are judged to be low, medium, or high. Who decides what is low, medium or high? And what do any of these measures mean? This mix of quantitative analysis (probabilistic analysis) and qualitiative measures is a recurrent theme in the SCP, this table being but one example, which disturbs me greatly.

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8.3.1.8-7

In Table 8.3.1.8-2b, the confidence in the characterization parameter, "Orientation of faults in and near the repository block", is given as moderate, and the needed confidence also as confident. Presumably this means that no more studies need be done to clarify this parameter.

It is complete nonsense to imagine that the orientations (in 3-D) of the active or inactive faults at and near Yucca Mountain are known with any degree of confidence. They may be listric and low-angle, planar and high-angle, distributed and anastomosing, etc.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8-31	In Table 8.3.1.8-7: Nowhere is there a scenario involving temporal and spatial seismic clustering, yet such clustering is almost certain to exist in the Basin and Range province (noted by R. Wallace, USGS, 1984, BSSA) as it does in the modern deformation of continental blocks elsewhere in the world (Ambraseys, 1989, Geophy. J.).

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8-144	In Study 8.3.1.17.4.5, "Detachment faults . . .", a further question applicable to the significance of detachment faults is: What is their role in the hydrologic system? (Do they act as flow pathways or barriers?) This question is apparently neglected in this part of the SCP.

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8.3.1.17-97	Study 8.3.1.17.4.3 "Quaternary faulting . . . " represents the attempt to evaluate the regional modern deformation via faulting or seismic events. The main objective of the Study is to "characterize those faults capable of future earthquakes with magnitude such that associated ground shaking could impact design or affect performance of the waste facility." This is clearly an important objective, but represents only part of the correct objective which is to evaluate the paleoseismicity in the region to provide a thorough database for any probabilistic seismic hazard analysis. By neglecting faults within 100 km of Yucca Mountain that would not directly affect the mountain the DOE will not be able to properly evaluate the paleoseismicity, and will therefore not be able to construct a worthwhile seismic hazard map of the region that includes YM. Moreover, in order to evaluate the paleoseismicity it will ne necessary to examine Quaternary faults within the "tectonic region", which must include the southern Great Basin from Owens Valley to the Colorado Plateau. This is not the impossible task it may seem.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4.3 8.3.1.17-101	It is stated that two potential seismic source zones exist within a 100 km radius of YM, 1) a concealed Walker Lane structure, and 2) the northern Death Valley-Furnace Creek fault zone. A number of significant Quaternary faults are not included: The 50km (plus) Stateline fault system is ignored; this fault comes within 50 km of YM. The Panamint fault system, approximately 90km away at its most proximal site. Faults of unknown character to the northeast within the Bombing Range.

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Signature: M Ellis

DATE: June 24, 1989

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 10 CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4.7 8.3.1.17-168	This Study represents the attempt to evaluate the subsurface geometry of faults at YM. All related activities involve geophysical techniques; none involve field mapping or verification of existing maps, of the surrounding region, nor laboratory-based techniques (such as reconstruction of structural sections) that may also shed light on the problem.

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COMMENT NO.: 11 CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4.12.2 8.3.1.17-203	This Activity (related to Study 8.3.1.17.4.12) is entitled "Evaluate Tectonic Models". It requires detailed work on regional faults and an evaluation of steady-state vs. non-steady-state displacement rates, critical evaluation of current tectonic models and a reexamination of the appropriate evidence for these models. None of this is planned in this Activity.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.8, 8.3.1.17 pg. 1 of 1	General Statement: This version of the SCP seems admirably thorough, in the sense that it lists a bewildering array of hypotheses and investigations that encompass almost every tectonic event that could concievably affect the integrity of the site in the next 10,000 years. The SCP is not thorough, however, in the sense that this list seems dominantly to consist of unconnected singular events or accidents; what is the probability of "a" volcano or "an" earthquake disrupting the repository? More work should be done on the effects of one event or process on other events or processes, and the relationships between categories of studies. To my mind, this shortcoming is caused by a lack of any systematic a priori statement of the overall goal of tectonic studies at Yucca Mountain. This goal should be to produce an accurate synthesis of the tectonic setting of Yucca Mountain, which would be used to help direct site characterization study <u>as well as</u> function as one end product. The lack of this clearly described overall purpose produces an incomplete and disorganized investigation of diminished scientific validity, and an unfeasible investigation timetable. The following pages will reference specific sections of the SCP that illustrate these comments.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.2 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.17.4. 12.1,2 pg. 1 of 3	These sections pertain to evaluation of tectonic processes and stability at the site, and evaluation of tectonic models, respectively. The evaluation consists of synthesis of studies on the Beatty 1:100,000 quadrangle. These results will be used to prepare reports on potentially harmful tectonic processes in the region, such as volcanism and faulting.

Various tectonic hypothese are presented on page 8.3.1.17-204. This list and the ones in table 8.3.1. 17-7 and 17-8 are not complete. What is presented are kinematic mechanisms, not regional tectonic models. Regional tectonic models require some convincing explanation for the dynamic history and interrelationship of all features of an area, in addition to an abstracted, simplified kinematic mechanism. The procedure for this activity implies that this requirement will be taken into consideration during synthesis of models, but fails to describe exactly how this will be accomplished. For example, an attempt will be made to relate volcanism to either an incipient rift zone or a leaky transform, but a number of key points are left unclear. How do the rift zone or transform explain detachment faults and basin-range normal faults, in addition to volcanism? How are all these influenced by preexisting mechanical heterogeneities, and by progressive deformation? With what tests does the DOE plan to investigate these questions during model "synthesis"?

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.2 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.17.4. 12.1,2 pg. 2 of 3	According to the timetable for this activity that is presented in section 4.12.1, figure 8.3.1.17.14 and table 8.3.1.17-11, data for the activity consists solely of field geologic, gravity, and magnetics studies of the Beatty 1:100,000 scale quadrangle. The timetable also suggests that the activity will be completed in two years. Neither of these statements is satisfactory, and in fact both are contradicted by the rest of section 8.3.1.17.4.

The data listed for the activity are inadequate. For example, chemistry of volcanic rocks, and seismological results must be satisfactorily explained by a tectonic model, in addition to geological and geophysical map relationships. The relationship of the area under study to the surrounding region must also be explained by that model, for it to be complete.

In other words, the proposed plan of activity does not explicitly include all the activities generally necessary to choose a tectonic model for a particular area. Furthermore, it is unclear that this plan of activity accounts for the fact that different tectonic hypotheses may require substantially different data bases for verification. It is unlikely that it will be possible to distinguish between an incipient rift and a leaky transform without making any specialized tests.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.2 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.17.4. 12.1,2 pg. 3 of 3	The proposed timetable is inadequate. A problem such as a regional tectonic synthesis seems very difficult to complete in only two years. The evolution of thinking described on page 8.3.1.17-204 should be an ongoing process of hypothesis statement, testing, modification and retesting, not one cycle of hypothesis statement, testing and verification, which is all that seems practical in two years. In fact, the very plan of conducting this activity <u>during</u> site characterization is unacceptable, since many of the characterization tests require an accurat, a priori understanding of regional tectonics.
	Finally, the list of tectonic models to be tested is not complete in the sense that the terms "wrench fault" and "transform" seem to be used interchangeably. These are not at all the same mechanisms, and the SCP should account for the difference in its plan of activity. In addition, the SCP should explicitly state plans to distinguish wrench fault systems undergoing pure shear or simple shear, as these will produce distinct tectonic effects.

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DATE: June 20, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.3 | CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4. 8,9,10 pg. 1 of 2	These sections deal with evaluation of local and regional stress field, tectonic geomorphology, and geodetic leveling respectively. The intended outcome of these activities seems to be reports on the potential dangers to the site from uplift and subsidence. According to the timetable, the three activities are to be conducted more or less simultaneously with synthesis of regional tectonic models. This is difficult to accept, because accurate performance of these activities depends on an accurate understanding of regional tectonics, if only in the sense of quantitatively knowing which are the most likely tectonic models. For example, activity 8.3.1.17.4.8.4 involves calculation of theoretical stress distributions associated with potential tectonic settings of the site. How can this activity possibly be completed until after activity 4.12 is finished? Activity 4.8.4 would seem to require the final finished product of activity 4.12 as input data, and would in turn serve as a way to calibrate the latter activity. As noted, activities 4.9 and 4.10 are concerned with tectonic geomorphology and geodetic leveling, respectively. These are related topics, but the SCP does not make clear how data from each activity will be used to calibrate the conclusions of the other. The SCP does state that the data will be used to help constrain the tectonic modeling process, but that statement contradicts the description of activity 8.4.12 as previously noted.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.3 | CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4. 8,9,10 pg. 2 of 2	It also does not make clear whether the tectonic modeling process will be used to help plan the conduct of activities 4.8,9, and 10. This suggests that the scientific basis of the planned procedure for these activites is not clearly defined, which raises questions as to the accuracy of the planned investigations.

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.41 | CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.4.4 pg. 2 of 2	this should be corrected, because it implies that the basis of the procedure for performing activity 4.4 is incomplete, and the data base for regional tectonic synthesis is inadequate.

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.5 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
pg. 1 of 1 8.3.1.8.3	This section is concerned with studies to provide information on the effect of tectonic events on saturated and unsaturated zone hydrology. In general, the studies are concerned with the effects of uplift, faulting, or constructional volcanism on flux rates and path lengths. However, another potential effect of tectonism on hydrologic setting might be the climatic effect of large scale volcanism. If a major eruption anywhere in the world introduced a significant amount of ash into the upper atmosphere, would it change world climate enough to affect climate at the site? If so, would it cause more precipitation, and consequently more infiltration and erosion? In general, what are the climatic effects of volcanism, and how do they affect the site?

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1.6 | CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.8, 8.3.1.17 pg. 1 of 1	General Summary: The preceding are examples from the SCP that illustrate my objections. These objections are: a) The common goal of data acquisition activities in these two sections is given as synthesis of tectonic models leading to accurate predictions of tectonic risks to the site and vicinity. However, data acquisition activities are inconsistently described, incomplete, and seem incapable of achieving that goal. The proposed data base seems somewhat overgeneralized and arbitrary, and does not allow for the specific needs of different tectonic hypotheses. b) The SCP states that an "evolution" of thinking will be allowed for in tectonic synthesis. The timetable allows only two years for this evolution, and it is difficult to imagine how it could take place in such a short time. No leeway seems to have been allowed for equipment breakdowns, tests that must be redone or data that must be reacquired, or simple calibration of thinking based on ongoing work. The fact that the final report on tectonic synthesis is due well before some tests are completed implies that the DOE does not plan to allow the synthesis to adapt to the results of those tests.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.3.2.2.1 100-102	The CP thrust in the CP Hills is a west-vergent thrust and correlates with neither the east-vergent thrust ("Belted Range Thrust" (Caskey et al., in preparation)) beneath Rainier Mesa or the Spotted Range thrust east of Mercury. Existing literature demonstrates a poor understanding of the pre-Tertiary structural framework of the NTS and vicinity. Which thrust at Bare Mountain is being called the CP thrust (page 1-102, paragraph 2, line 9)? There are two major thrusts exposed at Bare Mountain, each with an opposite sense of vergence.

REVIEWER: S.J. Caskey

Signature: SJ Caskey

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 2 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.3.2.2.1 105, 115	There are contradictory comments regarding 30 degrees of clockwise rotation about a vertical axis at the southern end of Yucca Mountain. On page 1-105, paragraph 3, lines 7-10, this rotation is attributed to displacemnt along postulated detachment structures. On page 1-115, paragraph 2, lines 4-8, this rotation is attributed to deformation within a right-lateral (shear) couple. It is unclear in the document as to which model is preferred or whether rotation is due to a combination of processes.

REVIEWER: S.J. CASKEY

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3	CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.8 8.3.1.8-4 Table 8.3.1.8-1b	Listed under the column "Characterization parameter" is "Evaluation of structural controls on volcanism." "Key studies or activities supplying data" assigned to this characterization paramenter (i.e. 8.3.1.8.1.1.1 and 8.3.1.8.5.1.3) fail to address the importance of the regional tectonic and structural framework. Important Tertiary detachment surfaces and/or unrecognized Tertiary or pre-Tertiary transform faults and thrusts (both east and west-vergent) may structurally control the location of volcanic centers. Particularly in the case of the primative (?) basaltic volcanics in Crater Flat, there appears to be a deep-seated structural control which is poorly understood or unrecognized at present.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 4 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.8 8-22	(Pertaining to page 8-22, paragraph 3, lines 8-14) Where in this document can you find the values from the analysis of the tectonics program at which the site would fail to meet the system performance objective? Do they exist? This is a serious oversite by the preparers of the SCP document.

REVIEWER: S. J. Caskey

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 5 | CHAPTER NO.: 3

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
3.9.3.3 3-204	Paragraph 1 states "... recharge to the regional carbonate aquifer, which underlies much of the NTS and vicinity..." It is not clear as to which aquifer is being referred. Silurian carbonates at the Tertiary-pre-Tertiary interface have only been penetrated by a single drill hole (i.e. UE25p#1). Subsurface boundary conditions at the Tertiary -pre-Tertiary contact are, therefore, poorly understood at the present. Pre-Middle Miocene low angle normal faults, Mesozoic folds and thrusts (both east and west-vergent), and unrecognized transform faults are likely to exist beneath the southern Nevada volcanic field, thus greatly complicating subsurface boundary conditions.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: Summary CHAPTER NO.: 1,8

SEC. NO., PAGE NO., DRWG. NO.	COMMENT
Chapter 1, especially section pertaining to Quaternary tectonics, and Chapter 8, especially schedule of major events for preclosure and postclosure tectonics.	Most of the discussion on Quaternary faults near Yucca Mountain seems reasonably considering some of the most recent publications were not used in this report. However, the Stateline/Pahrump Valley fault zone has been documented in the literature since Liggett and Childs (1973, Argus Exploration Co.) first discovered it on a remote sensing project. This fault zone may be a major component of the Walker Lane system and must be considered in site characterization. The schedule of major events timetables need a lot of work, both from the standpoint of developing more realistic completion deadlines and from the standpoint of general organization of the table to allow a more thorough evaluation of the schedule. As the schedule stands now, it is difficult if not impossible to follow the flow of events through time due to omission of major input activities for completion of studies and due to omission of deadlines for input activities to large-scale studies.

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Signature: Joanne L. Hoffard DATE: June 23, 1989

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: JLH-1-1 CHAPTER NO.: 8

SEC. NO., PAGE NO., DRWG. NO.	COMMENT
8.3.1.8-131-141, Figure 8.3.1.8-10 and Table 8.3.1.8-9, and 8.3.1.17-207-226, Figure 8.3.1.17-14 and Table 8.3.1.17-11.	This comment is a summary on the timetables developed for major events and planned completion dates for studies in the postclosure and preclosure tectonics programs. In general I find the schedules to be unrealistic in that it seems many of the studies could not possibly be completed in the time frames described here. However, it is very difficult to assess how realistic the time schedules are due to the poor organization of this section. The first and most obvious problem is that many of the time schedules for completion of studies have not taken into account some of the activities which would provide data for completion of the study, in the schedule. One example of this in Table 8.3.1.8-9 on page 8.3.1.8-135, study number 8.3.1.8.2.1. This study is due to be completed (final report to DOE) by 4/94. However, the major event schedule does not mention when data will be brought into this study from strombolian volcanic activity (activity 8.3.1.8.1.2.1),

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COMMENT NO.: JLH-1-2 CHAPTER NO.: 8

SEC. NO., PAGE NO., DRWG. NO.	COMMENT
8.3.1.8-131-141, Figure 8.3.1.8-10 and Table 8.3.1.8-9, and 8.3.1.17-207-226, Figure 8.3.1.17-14 and Table 8.3.1.17-11, (continued).	exploratory trenching in Midway Valley (activity 8.3.1.17.4.2.2), age and recurrence of movement on Quaternary faults (activity 8.3.1.17.4.6.4), etc. (see page 8.3.1.8-65, Figure 8.3.1.8-4, Logic diagram for investigation 8.3.1.8.2, tectonic effects on waste package). This are just three examples of input activities that are not mentioned in the major events schedule for study number 8.3.1.8.2.1. Since there is no schedule for completion of these activities (they are all sub-activities for completion of other studies), it is very difficult to determine if each of these can be completed in a timely manner to allow study 8.3.1.8.2.1 to be completed on time. The flow charts for postclosure and preclosure tectonics major events schedules (Figures 8.3.1.8-10 and Figure 8.3.1.17-14, respectively) do not help with this since the omission of several of the input activities occurs here too.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: JLH-2-1 CHAPTER NO.: 1

SEC. NO., PAGE NO., DRWG. NO.	COMMENT
Page 1-107, Figure 1-33.	There are proposed detachments along the Spring Mountains, and along the Kingston Range which may also be important to Site Characterization.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: JLH-3-1 CHAPTER NO.: 1

SEC. NO., PAGE NO., DRWG. NO.	COMMENT
Page 1-114	This discussion on Quaternary strike-slip faults of the Walker lane consistently omits a major fault zone which runs approximately N-NW along the California-NV border through Pahrump Valley. This system has been called both the Pahrump Fault zone and the State Line fault zone. Stewart (1988), (Ernst, ed., Ruby Volume IV), discusses this fault system and its relation to the Walker Lane.

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TASK 6

STATE OF NEVADA
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QUALITY ASSURANCE PROCEDURE

QAP-3.4
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JANUARY 20, 1989

SUMMARY OF TECHNICAL REVIEW COMMENTS

REVIEWER: James R. Carr

Chapter 2, section 2.3.2, page 2-60:

G Tunnel data should not, at any time, be used in the characterization of Yucca Mountain. Characterization of Yucca Mountain should be site specific.

Chapter 2, section 2.1, page 2-22:

State of the art geostatistical methods, specifically kriging and advanced forms of kriging, must be used to map and characterize the spatial variability in rock mass mechanical properties at Yucca Mountain.

Chapter 8, section 8.3.1.10, page 1:

Population density and distribution should be included in the SCP. Methods should be included to project population growth. Included with population should be lifeline networks, such as roads, gas, telephone, power transmission lines, and so on.

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NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1; pg. 1 of 1 | CHAPTER NO.: 2

SEC. NO PAGE NO. DRWG. NO.	COMMENT
2.3.2 2-60	G-Tunnel data should not, at any time, be used in the characterization of Yucca Mountain. Characterization of Yucca Mountain should be site specific.

REVIEWER: James R. Carr

James R. Carr
Signature

ORGANIZATION:
University of Nevada-Reno

DATE: June 26, 1989

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 2; pg. 1 of 1 | CHAPTER NO.: 2

SEC. NO PAGE NO. DRWG. NO.	COMMENT
2.1 2-22	State of the art geostatistical methods, specifically kriging and advanced forms of kriging, must be used to map and characterize the spatial variability in rock mass mechanical properties at Yucca Mountain.

REVIEWER: James R. Carr

James R. Carr
Signature

ORGANIZATION:
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DATE: June 26, 1989

STATE OF NEVADA
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QUALITY ASSURANCE PROCEDURE

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1; pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.10 page 1.	Population density and distribution should be included in the SCP. Methods should be included to project population growth. Included with population should be lifeline networks, such as roads, gas, telephone, power transmission lines, and so on.

REVIEWER: James R. Carr

James R. Carr

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ORGANIZATION:
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DATE: June 26, 1989

TASK 7

SUMMARY COMMENTS ON THE SITE CHARACTERIZATION PLAN

Robert J. Watters, P.I., Task 7

Many of the issues pertaining to rock characterization, thermal and mechanical characteristics, and the underground design of the repository have been considered in the SCP. However, key points remain either to be addressed or expanded.

1. The seismic stability appraisal of the underground excavations is extremely limited in content. Major concerns which have either not been addressed or are limited are :

a) dynamic displacement along joints or fractures due to seismic loading would appear not to be scheduled in laboratory testing. Very limited empirical information exists on this type of displacement, so testing is required.

b) The frequencies most likely to cause damage to subsurface facilities are significantly higher than the frequencies that cause damage to surface structures. Given this situation, the design basis and corresponding response spectra for the underground openings will be assessed using band widths which do not encompass higher frequencies. These higher frequencies can be developed by near field displacements from nearby fault movement or volcanic activity. If the stability of the openings is assessed using lower frequencies than actually occur, failure of the excavations could develop.

2. The investigation to establish the lithology, geologic structure, and geomechanical properties of the repository horizon rock mass depends totally on a) the locations of the shafts and drifts, and b) the number and location of boreholes.

The position of the shafts is suggestive of "putting the cart in front of the horse" in that the requirements to best investigate the repository block have been usurped by the needs to a) position the shafts where they best serve the operational requirements of the repository b) save time and c) comply with the dictates of 10 CFR 960. In their present positions the central and southern portions of the block will not be investigated. A competent investigation establishes the best positions for the shaft, not the converse.

3. Only 24 cored holes (perhaps less) are planned to be drilled to the repository horizon. These holes will have spacings up to 4200 feet and consequently with such a large distance between holes, many geotechnical features and rock mass characteristics will be lost or overlooked.

4. The vast majority of boreholes are vertical, even though many of the features of interest, fractures etc. which affect hydrogeology and rock mass behavior are vertical. Hence, these features are either overlooked or minimized.

5. More rock testing in terms of numbers of tests and locations are needed to better explain rock mass behavior and the range in in situ stress magnitudes.

6. Few details are discussed about "feature of interest drilling" e.g. faults. Geologic structures within the perimeter boundary may well be crucial to both the short and long term stability of the excavations.

7. An emphasis on geostatistical approaches in analyzing the collected data, supports the overall conclusion that the minimum number of boreholes, drifts, tests, and analyses are to be performed. Geostatistical methods are normally performed when scatter of data exists, and the normal refinement of additional raw data collection, to reduce the scatter and improve the data quality, can not be performed due to time constraints, lack of money or politics.

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan		
COMMENT NO.:	1; 1 of 1	CHAPTER NO. 2

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
2.2.2	Dynamic shear testing of rock joints appears not to be planned for the laboratory testing of discontinuities. As very limited empirical information exists on this type of displacement, dynamic shear testing is required for design purposes.

REVIEWER: Robert J. Watters (Print)	ORGANIZATION: University of Nevada - Reno
R. Watters (Signature)	DATE: June 30, 1989

Form 3.4.1

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	2; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.15.1	Numerical modeling techniques utilizing data from small scale rock tests are to be used in lieu of large numbers of large scale in situ rock tests. Rock tests using small samples will not adequately characterize samples with large lithophysaes. Similarly small scale tests will not significantly consider the effects of anisotrophy within the rock mass.

REVIEWER: Robert J. Watters
Print

[signature]
Signature

ORGANIZATION:
University of Nevada - Reno

DATE: June 30, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	3; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.15.1.5	Effects of shaft sinking on the surrounding rock mass will not be monitored continuously. Monitoring will only be provided for up to 100 feet below breakout rooms. Continuous monitoring of rock behavior should be performed the entire length of the shaft.

REVIEWER: Robert J. Watters
Print

R. J. Watters
Signature

ORGANIZATION:
University of Nevada -Reno

DATE: June 30, 1989

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	4: pg. 1 of 1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
8.3.1.17.4.8	Comparing in situ results for establishing the stress field shows important differences between shallow results (obtained from triaxial strain and hydrofrac measurements) and deeper measurements (focal plane analyses). Additional locations should be planned for hydrofrac and triaxial strain tests to establish the in situ stress picture.	

REVIEWER: Robert J Watters
Print

W J. Watters
Signature

ORGANIZATION:
University of Nevada - Reno

DATE: June 30, 1989

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NEVADA NUCLEAR WASTE PROJECT OFFICE
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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	5; pg. 1 of 1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
8.3.1.4.2.2.3	Vast majority of cored holes are to be vertical. This will yield lithologic spatial information but will do little to establish fracture frequency and orientations as the majority of fractures are vertical to sub-vertical. Angled cored holes should be drilled at each borehole location to provide this information.	

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	6; pg. 1 of 1	CHAPTER NO. 8
SEC. NO. PAGE NO. DRWG. NO.	COMMENT	
8.3.1.4.2.2.4	No mention of fractal assessment is discussed in the mapping of the shafts or drifts. This omission should be corrected to permit comparisons between surface mapping and underground mapping to be possible using fractal techniques.	

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University of Nevada - Reno

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	7; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.2.2.4	No borehole is to be drilled at the shaft locations prior to shaft sinking. Comparison of borehole data to the geologic mapping of the shaft would assist in developing three dimensional geology and show limitations in borehole information.

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	8; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.2.2.4	The shaft locations appear to have been decided on the requirements for an operational facility, not on the best locations to provide geologic and geotechnical input to the design. Position requirements should be based on site characterization needs. Shaft locations should be repositioned to obtain the best information.

REVIEWER: Robert J. Watters
Print

R. J. Watters
Signature

ORGANIZATION:
University of Nevada - Reno

DATE: June 30, 1989

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	9; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.3.1.1	The large grid spacing for exploratory boreholes will produce significant omissions in geologic and geotechnical information which may seriously affect the design.

REVIEWER: Robert J. Watters Print W. J. Watters Signature	ORGANIZATION: University of Nevada - Reno DATE: June 30, 1989

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	10; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.1.1.3	"feature of interest" drilling should be used in the first phase of drilling, not as is suggested that it may be used later for sitting additional holes.

REVIEWER: Robert J. Watters Print	ORGANIZATION: University of Nevada - Reno
W. J. Watters Signature	DATE: June 30, 1989

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NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.:	11; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.4.2.2.2	No discussion of the technique to be applied in the fractal analysis of roughness, interconnect-ivity or aperture is detailed. More than one technique exists.

REVIEWER: Robert J. Watters Print M. Watters Signature	ORGANIZATION: University of Nevada - Reno DATE: June 30, 1989

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan		
COMMENT NO.:	12; pg. 1 of 1	CHAPTER NO. 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.2.5.7	The frequencies most likely to cause damage to subsurface facilities are significantly higher than the frequencies which damage surface facilities. The bandwidths proposed for the seismic stability appraisal of the underground excavations will not be performed using these higher frequencies.

REVIEWER: Robert J. Watters Print R. J. Watters Signature	ORGANIZATION: University of Nevada - Reno DATE: June 30, 1989

Form 3.4.1

TASK 8

TASK 8: SCP REVIEW

I. Sections Covered by this Review:

Chapter 1

1.2 Stratigraphy and Lithology (pre-Cenozoic rocks only)

1.7.2 Hydrocarbon Resources

1.8 Summary (Stratigraphy and Hydrocarbon Resources only)

8.3.1.9.2 Investigation: Studies to provide the information required on present and future value of energy, mineral, land and ground-water resources (Hydrocarbon Resources only)

II. General Comments

The sections reviewed here present a fragmented, compartmentalized, view of the topics, with apparently no understanding of the important inter-relationships between topics. This is a fundamental flaw, which not only fails to acknowlege that (for example) understanding Mesozoic structure is crucial to evaluating hydrocarbon potential, but also demonstrates that those writing the SCP -- and doing the studies -- don't recognize the **necessity** of integrating data from all possible sources. There are no built-in mechanisms to force (or even allow) workers from one field to obtain and use new data being generated by workers in another field.

The sections reviewed here demonstrate little or no understanding of the regional context of the subjects being discussed. This, too, is a fundamental flaw, because without such context it is impossible to predict trends and hence to recognize anomalies. Testing of predictions is the scientific method ... and the only way to test the validity of an interpretation.

III. Important Geological Topics not Addressed by the SCP

Basin analysis, particularly for potential source and reservoir units for liquid hydrocarbons: It is obvious that three-dimensional geometry, burial history, etc. of these units must be known for evaluating hydrocarbon potential.

Mesozoic thrust structure: This is important to evaluating hydrocarbon potential for several reasons. First, thrusting has juxtaposed rocks that may have been widely separated at the time they were deposited. Measurements of stratigraphic thicknesses, organic content of potential source rocks, porosity and permeability of potential reservoir rocks, etc.

must be done separately for each thrust sheet. Likewise, interpretation of depositional environments should be done separately for each thrust sheet. Ideally, the offset on each thrust should also be determined, so thrust sheets can be restored to their original configuration for purposes of stratigraphic and sedimentologic interpretations.

Second, thrusting has juxtaposed thrust sheets with different thermal histories. Data pertaining to thermal history (and hence hydrocarbon maturation) should be compiled separately for each thrust sheet.

Third, thrusting itself dramatically influences the thermal history of the affected rocks. In general, the upper plate undergoes a rapid drop in temperature and pressure during thrust emplacement, while the lower plate experiences an abrupt increase in both temperature and pressure. This is another reason that thermal data should be complied separately for each thrust sheet.

Fourth, thrust-related structures often make good traps for hydrocarbons, e.g. anticlines, up-dip truncations, places where a reservoir rock is emplaced over a source rock, etc. Thrust geometry must therefore be well understood in order to evaluate hydrocarbon potential.

Complete structural and thermal evolution (Mesozoic thrusting, pre-volcanic normal faults, post-volcanic normal faults, etc.): This is vital to predicting the location (or existence) of hydrocarbons, because the geometry of stratigraphic units, presence of fractures, etc. at the time of migration determine how and where hydrocarbons migrate.

IV. Specific Comments on the SCP:

1.2.1 Stratigraphy and lithology of rocks and surficial deposits in the southern Great Basin

1.2.1.1 Pre-Cenozoic Rocks

1.2.1.1.1 Proterozoic and Paleozoic rocks

Reasonable review of the literature; nothing new.

Several minor problems with figures:

(1) Figure 1-12: Devonian and Mississippian units are shown as carbonates, but the Eleana Fm. (Late Devonian and Mississippian) comprises siliciclastics.

(2) Figure 1-13: The Eleana Fm. at the NTS is several hundred meters thicker than indicated here.

(3) Figure 1-16: The Late Devonian and Mississippian rocks at Yucca Mountain are Eleana Fm. -- siliciclastic rocks of the Antler

foreland basin -- not shelf carbonates, as indicated here. The Mississippian carbonate shelf may be represented by the Narrow Canyon (Monte Cristo) limestone east of Mercury, at the southeastern edge of the NTS. (Note that this limestone is in a different thrust sheet than the units at Yucca Mountain, and was deposited much farther from these units than the present separation between them indicates.)

1.2.1.1.2 Mesozoic rocks

One-paragraph summary (very general) of Mz sedimentary rocks in the region, with no mention of a paleogeographic framework which would explain the relationships (e.g. between marine and non-marine rocks). With no regional paleogeographic context, there is no way to predict what types of Mesozoic sedimentary rock might have been deposited at Yucca Mountain, to evaluate the significance of finding certain rock types, etc. This section is not very informative as it stands.

1.2.2 Stratigraphy and lithology of rocks and surficial deposits at Yucca Mountain

1.2.2.1 Pre-Cenozoic Rocks

This section is brief, because of the paucity of data on the pre-Cenozoic deposits under Yucca Mountain. There is one drill hole that has penetrated pre-Tertiary deposits; everything else is interpreted from geophysical data and/or extrapolated from the surrounding area. The single drill hole only penetrates 553 m into the pre-Cenozoic rocks. This is completely inadequate even for determining the structure and stratigraphy in this one place ... and one hole of any depth is inadequate for evaluating the "pre-Cenozoic rocks at Yucca Mountain", as Section 1.2.2.1 purports to do.

There are several problems with this section:

(1) There is no mention of the thrust structure that might repeat the section (below the Silurian section encountered in the drillhole, for example).

(2) There is no mention of why or how the subsurface structure might allow for the presence of the Eleana Fm. below northern, but not southern, Yucca Mountain (as suggested by Bath and Jahren, 1984), while at the same time, the pre-Cenozoic unconformity is much deeper (i.e. 3500 m, as opposed to 1000 m) below northern Yucca Mountain.

(3) Is the inferred metamorphism of the Eleana Fm. the only evidence for the reference to possible granitic intrusive rock at depth under northern Yucca Mountain? If so, this seems pretty speculative.

1.7.2 Hydrocarbon Resources

1.7.2.1 Deposits of coal, tar sands and oil shale

1.7.2.1.1 Coal Resources

The conclusion that coal is not a potential resource in the Yucca Mountain area is a reasonable one.

It is noted that since Tertiary lacustrine deposits with coal seams have the potential of being source rocks for liquid hydrocarbons, such deposits will be assessed for source rock potential as well as for the primary coal resource. It is not clear, however, whether there will be an active attempt to locate and study Tertiary lacustrine deposits.

1.7.2.1.2 Tar Sand Resources

The conclusion that there is no known potential for tar sands in the Yucca Mountain area is reasonable.

The documented oil seeps elsewhere in the state occur at areas of ground water discharge. The lack of reported oil seeps in southern Nevada may be due to a lack of ground water discharge, rather than to a lack of hydrocarbons.

1.7.2.1.3 Oil Shale Resources

The reasoning for concluding that there is no oil shale potential in the Yucca Mountain vicinity is flawed:

(1) One argument for the above conclusion is that no oil shales were encountered in the one (!) drillhole (UE-25p#1) that penetrated the Paleozoic section under Yucca Mountain. This hole penetrated the Silurian section below the Cenozoic volcanics, and only went 553 m into the Silurian before drilling was stopped. There are no known oil shales in the Silurian anywhere in the state, so their absence here is not a useful (or surprising) piece of information.

There is no mention of the possibility of thrust faults under the Silurian section in the drillhole. The Eleana Fm., the most likely source of hydrocarbons in the Paleozoic section (see below), may occur beneath the Silurian carbonates, in the footwall of a thrust fault. Although these would be too deep for surface mining -- and therefore not an oil shale resource -- they should not be overlooked as a potential source rock for liquid hydrocarbons.

(2) Another argument is that none of the stratigraphic units known to be oil shales elsewhere in the state are found in the Yucca Mountain vicinity. There is no mention of lateral and/or facies equivalents of these units.

The Mississippian Eleana Fm. of southern Nye Co. is correlative with the Chainman Shale of east-central Nevada. (While not an oil shale, the Chainman is cited in section 1.7.2.1.3 as an organic-rich shale which is thought to be the source rock for liquid hydrocarbons elsewhere in the state.) Task 8 field work to date has shown that at Bare Mountain, the CP Hills and the Eleana Range, the Eleana Fm. comprises dark shales and argillites which are presumably organic-rich. These are tentatively interpreted to have a depositional environment similar to that of the Chainman Shale in the Diamond Range of east-central Nevada. The Eleana Fm. of the Yucca Mountain vicinity should also be regarded as a potential source rock for liquid hydrocarbons.

1.7.2.2 Known Occurrences of Oil and Gas in Nevada

There is clearly a problem of terminology -- and understanding (!) -- here. The writer thinks that the "Western overthrust belt", or "Cordilleran thrust belt", is different than (specifically, is in a different place than) the "Sevier-Laramide belt". The first two terms are very general, and somewhat out-dated, names for the thrust belt which, in Nevada, Utah and Wyoming, would be more precisely termed the Sevier-Laramide belt.

If this is an indication of the familiarity of the writer with the regional geology and with the literature on the subject, then other conclusions by this writer are of questionable reliability.

1.7.2.2.1 Potential for oil and gas resources in the vicinity of Yucca Mountain

There are numerous problems with this section:

(1) Paragraph 1: The region over which 60 exploratory wells have been drilled is not specified. It is therefore impossible to evaluate whether this is good evidence for a low probability of hydrocarbons or not.

(2) Paragraph 2: There are many other possible reasons for the lack of productive oil fields in southern Nevada, including lack of economic incentive to explore an untested area (due to the relatively recent recognition of the hydrocarbon potential of Antler foreland basin deposits in eastern Nevada coupled with the generally low price of imported oil), and lack of access to much of the southern Antler foreland basin (the preferred exploration target) because it occurs in the NTS and Nellis AFB.

(3) Paragraph 4: The productive Railroad Valley area is surrounded by Tertiary caldera complexes, yet the geothermal gradient has not resulted in over-maturation of Paleozoic hydrocarbons.

Alteration studies on rocks from drillhole USW G-2 indicate temperatures "as high as" 230°. If this is the upper end of a possible range, what is the low end of this range (and why is it not mentioned)? (See also (7) below.) By choosing only the highest possible temperature, the writer makes the worst possible case for hydrocarbon potential.

Note also that the above temperature is from one drillhole, and may not be at all representative of the region. This is particularly problematical for a region such as this, where proximity to a fault with hydrothermal solutions or to a volcanic feeder would give locally anomalously results.

(4) Paragraph 5: The statement that no source rocks are known is both blatantly incorrect and contradicted by other sections of the SCP. Mississippian clastic rocks are shown in the stratigraphic column for the Yucca Mountain region (p. 1-38), and Mississippian clastic rocks are described as source rocks (p. 1-316). Also, the possibility that carbonates might be source rocks is not even considered.

(5) Paragraph 6: Although the general summary of the CAI data is not incorrect, it is not presented in a geologically meaningful context. Hence, some potentially important pieces of information are lost. Once again, the significance of thrusting in the region is not mentioned. In the context of thermal maturity, thrusting is important because different thrust sheets may have different thermal histories. This is true for two reasons: First, the thrust sheets originated in different places, and possibly at different depths, which could mean very different thermal histories prior to thrusting. Second, thermal affects associated with thrust emplacement are the opposite for the footwall and the hanging wall (i.e. increased heat and pressure for the footwall, decreased heat and pressure for the hanging wall). In the case of an area with multiple thrust sheets, like the NTS, the thermal histories can be complex because a given sheet may have been the hanging wall for one thrust fault and the footwall for another. Data relating to thermal maturation, therefore, MUST be considered separately for each thrust sheet. When the existing CAI data are examined in this context, it appears that one thrust sheet in particular may have had a thermal history conducive to oil generation, while other sheets may have been right for gas generation.

(6) Paragraph 7: The quantitative thermal analysis using Lopatin's time-temperature index is meaningless, because the values used for time and temperature are general values for the region. Because of the complex deformation history of the area (see above), the thermal history of each thrust sheet must be considered separately.

The temperature used is a maximum (see (3) above), even for the thrust sheet in which the measurement was made; the results using the minimum possible temperature for this thrust sheet are not presented. (See also (7) below.)

There is no evaluation of the accuracy, or range or accuracy, of the method (i.e. Lopatin's time-temperature index), nor is any other method considered.

(7) Paragraph 8: Hidden in this summary paragraph, the writer drops a bombshell which negates most of the preceding discussion -- "new" information from both conodont alteration and from clay alteration in drillhole UE-25p#1 at Yucca Mountain indicate maximum temperatures af 175°, rather than the 230° mentioned in the paragraph on paleogeothermal history (!). Even assuming the Lopatin's time-temperature index is correct, and that the other temperatures and times used in the calculation are correct, a quantitative thermal analysis using this maximum temperature gives a result at the maximum gas generation phase for the Paleozoic section under Yucca Mountain! The omission of these new data in the preceding discussion (p. 320) is so egregious it gives the appearance of deliberate deception.

(8) There is a final, major, philosophical problem with this whole section: it is all based on literature review and on theoretical calculations, with NO field data to test the conclusions. Although such field studies are apparently planned, some of the most obvious things should have been done, at least in reconnaissance, at the beginning of the study.

Volume V, Part B

8.3.1.9.2 Investigation: Studies to provide the information required on present and future value of energy, mineral, land and groundwater resources

Alternative Conceptual Models

Table 8.3.1.9-3 contains some inaccuracies, and seriously underestimates the potential for oil and gas at Yucca Mountain. The "low" uncertainty rating is also inaccurate -- in part because it only considers the possibility of hydrocarbons in the tuff, which is not the most probable reservoir rock. We suggest the following changes to this table:

Current representation

no changes

Uncertainty and rationale

High -- Although no oil or gas has been reported from drillholes in the tuff, only one drillhole (UE25p#1) has gone through the tuff to the underlying Paleozoic section, and even this one only went 500m in the Paleozoic, never getting out of the Silurian section. Based on the regional geology, it seems highly probable that this Silurian section is in the upper plate of a thrust fault, with other Paleozoic section (including the Eleana Formation, see below) underneath.

Potential source rocks have been identified in the region: Mississippian Eleana Formation crops out to the west of the site at Bare Mountain, and to the east at the CP Hills, Calico Hills, Mine Mountain and Eleana Range. The Eleana is also thought to exist below northern Yucca Mountain, based on geophysical data, and its presence below southern Yucca Mountain cannot be ruled out at this point.

Conodont alteration indices (CAI) from UE25p#1 indicate that the Silurian carbonates are well within the gas generating window (3). CAI from elsewhere in the region (Harris and others, 1980) are in the oil generating window (2) locally; preliminary indications are that these low values are characteristic of a single thrust sheet, and that this sheet may underlie Yucca Mountain.

A thrust fault underlying the Silurian rocks in UE25p#1 could also have created a structural trap which would prevent the migration of liquid hydrocarbons into the overlying section.

Alternative hypotheses

No changes

Performance measure, design or performance parameter

No changes

Needed confidence in parameter or performance measure

No changes

Sensitivity of parameter or performance measure to hypothesis

High -- Regional geology suggests possible resource potential. The thermal history of the rocks within the drift perimeter boundary is poorly understood. The Silurian carbonates immediately underlying the tuffs in UE25p#1 are in the "gas generating window"; the thermal history may be significantly different for different thrust sheets.

Need to reduce uncertainty

High

8.3.1.9.2.1 Study: Natural resource assessment of Yucca Mountain, Nye County, Nevada

Paragraph 5: Because of the fact that liquid hydrocarbons can migrate, a much larger area must be understood in order to evaluate hydrocarbon resources in the 10 km diameter circle.

Paragraph 7: Although this section states that drillholes will be one of the sources of information used to evaluate the potential for hydrocarbon resources, it also states that no drillholes deep enough to intersect Paleozoic rocks are planned. As noted above, the little bit of Paleozoic section drilled in UE25p#1 may be in the upper plate of a thrust fault, and hence may not be representative of the rest of the Paleozoic section under Yucca Mountain.

8.3.1.9.2.1.4 Activity: Assessment of hydrocarbon resources at and near the site

Objectives

2. The assessment of hydrocarbon potential will include "a review and assessment of drillholes emplaced for oil and gas exploration within the geographic area of the site". What drillholes does this refer to? None of the existing USGS/DOE drillholes within the area of the site constitute hydrocarbon exploration holes. Will new holes be drilled? If so, where? How many? On what basis will the site(s) be chosen? How deep will they go?

Parameters

Paragraph 1: Analysis for the presence of organic matter in "certain Paleozoic rocks" is planned. Since the preferred hypothesis (from Table 8.3.1.9-3) is that there are no known source rocks in outcrop or subsurface, what rock will be analyzed? How will the sample locations be chosen? One unit specifically mentioned as an example of rock to be analyzed is the Paleozoic rock from drillhole UE25p#1; as noted many times above, this hole sampled only the Silurian carbonates, and these are not potential source rocks. Also (as noted above), these are from one thrust sheet, and in no way reflect the thermal history of other thrust sheets in the area.

Choice of samples is extremely important; the analyses (organic content, thermal maturation, thermal history) are worthless if not applied to the most appropriate rocks. Location and structural position should be taken into account, including samples from all thrust sheets and from different positions along strike in each thrust sheet. The Mississippian Eleana Fm is the most likely source rock, so it should be sampled wherever it crops out. Who will do the work, and what are their qualifications?

Paragraph 4: The existence of Mesozoic thrust faults and folds in the Yucca Mountain area is well established, completely independent of the reference cited. The oil-bearing potential of these structures is unknown.

Methods and technical procedures:

The methods and procedures are allegedly given in the table....but every section of the table says "to be determined".

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 1; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.1.1 1.2.2.1 1.7.2 p. 37-47 p. 49-54 p.313-323	The sections reviewed here present a fragmented, compartmentalized, view of the topics, with apparently no understanding of the important inter-relationships between topics. This is a fundamental flaw, which not only fails to acknowlege that (for example) understanding Mesozoic structure is crucial to evaluating hydrocarbon potential, but also demonstrates that those writing the SCP -- and doing the studies -- don't recognize the necessity of integrating data from all possible sources. There are no built-in mechanisms to force (or even allow) workers from one field to obtain and use new data being generated by workers in another field.

REVIEWER: Dr. Patricia H. Cashman

Signature: P. H. Cashman

ORGANIZATION:
Center for Neotectonic Studies
University of Nevada - Reno

DATE: June 5, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 2; 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.1.1 1.2.2.1 1.7.2 p. 37-47 p. 49-54 p. 313-323	The sections reviewed here demonstrate little or no understanding of the regional context of the subjects being discussed. This, too, is a fundamental flaw, because without such context it is impossible to predict trends and hence to recognize anomalies. Testing of predictions is the scientific method ... and the only way to test the validity of an interpretation.

REVIEWER: Dr. Patricia H. Cashman

Signature: P.H. Cashman

ORGANIZATION:
Center for Neotectonic Studies
University of Nevada - Reno

DATE: June 5, 1989

State of Nevada
Agency for Nuclear Projects
Nuclear Waste Project Office

QAP - 3.4
Revision 0
January 20, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3; 1 of 2 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2 p. 313-318	**Important geological topics not addressed by the SCP:** Basin analysis, particularly for potential source and reservoir units for liquid hydrocarbons: It is obvious that three-dimensional geometry, burial history, etc. of these units must be known for evaluating hydrocarbon potential. Mesozoic thrust structure: This is important to evaluating hydrocarbon potential for several reasons. First, thrusting has juxtaposed rocks that may have been widely separated at the time they were deposited. Measurements of stratigraphic thicknesses, organic content of potential source rocks, porosity and permeability of potential reservoir rocks, etc. must be done separately for each thrust sheet. Likewise, interpretation of depositional environments should be done separately for each thrust sheet. Ideally, the offset on each thrust should also be determined, so thrust sheets can be restored to their original configuration for purposes of stratigraphic and sedimentologic interpretations. Second, thrusting has juxtaposed thrust sheets with different thermal histories. Data pertaining to thermal history (and hence hydrocarbon maturation) should be compiled separately for each thrust sheet. Third, thrusting itself dramatically influences the thermal history of the affected rocks. In general, the upper plate undergoes a rapid drop in temperature and pressure during thrust emplacement, while the lower plate experiences an abrupt increase in both temperature and pressure. This is another reason that thermal data should be complied separately for each thrust sheet.

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SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2 p. 313-318	Fourth, thrust-related structures often make good traps for hydrocarbons, e.g. anticlines, up-dip truncations, places where a reservoir rock is emplaced over a source rock, etc. Thrust geometry must therefore be well understood in order to evaluate hydrocarbon potential. Complete structural and thermal evolution (Mesozoic thrusting, pre-volcanic normal faults, post-volcanic normal faults, etc.): This is vital to predicting the location (or existence) of hydrocarbons, because the geometry of stratigraphic units, presence of fractures, etc. at the time of migration determine how and where hydrocarbons migrate.

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COMMENT NO.: 4; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.1.1 Fig. 1-12 p. 41	Figure 1-12: Devonian and Mississippian units are shown as carbonates, but the Eleana Fm. (Late Devonian and Mississippian) comprises siliciclastics.

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COMMENT NO.: 5; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.1.1 Fig. 1-13 p. 42	Figure 1-13: The Eleana Fm. at the NTS is several hundred meters thicker than indicated here.

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COMMENT NO.: 6; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.1.1 Fig. 1-16 p. 47	Figure 1-16: The Late Devonian and Mississippian rocks at Yucca Mountain are Eleana Fm. -- siliciclastic rocks of the Antler foreland basin -- not shelf carbonates, as indicated here. The Mississippian carbonate shelf may be represented by the Narrow Canyon (Monte Cristo) limestone east of Mercury, at the southeastern edge of the NTS. (Note that this limestone is in a different thrust sheet than the units at Yucca Mountain, and was deposited much farther from these units than the present separation between them indicates.)

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COMMENT NO.: 7; p. 1 of 1	CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.1.1.2 p. 46	One-paragraph summary (very general) of Mz sedimentary rocks in the region, with no mention of a paleogeographic framework which would explain the relationships (e.g. between marine and non-marine rocks). With no regional paleogeographic context, there is no way to predict what types of Mesozoic sedimentary rock might have been deposited at Yucca Mountain, to evaluate the significance of finding certain rock types, etc. This section is not very informative as it stands.

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COMMENT NO.: 8; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.2.1 p. 54	This section is brief, because of the paucity of data on the pre-Cenozoic deposits under Yucca Mountain. There is one drill hole that has penetrated pre-Teritary deposits; everything else is interpreted from geophysical data and/or extrapolated from the surrounding area. The single drill hole penetrates 553 m into the pre-Cenozoic rocks. This is completely inadequate even for determining the structure and stratigraphy in this one place... and one hole of any depth is inadequate for evaluating the "pre-Cenozoic rocks at Yucca Mountain", as 1.2.2.1 purports to do.

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COMMENT NO.: 9; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.2.1 p. 54	There is no mention of the thrust structure that might repeat the section (below the Silurian section encountered in the drillhole, for example).

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COMMENT NO.: 10; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.2.1 p. 54	There is no mention of why or how the subsurface structure might allow for the presence of the Eleana Fm. below northern, but not southern, Yucca Mountain (as suggested by Bath and Jahren, 1984), while at the same time, the pre-Cenozoic unconformity is much deeper (i.e. 3500 m, as opposed to 1000 m) below northern Yucca Mountain.

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COMMENT NO.: 11; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.2.2.1 p. 54	Is the inferred metamorphism of the Eleana Fm. the only evidence for the reference to possible granitic intrusive rock at depth under northern Yucca Mountain? If so, this seems pretty speculative.

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COMMENT NO.: 12; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.1.1 p. 314	It is noted that since Tertiary lacustrine deposits with coal seams have the potential of being source rocks for liquid hydrocarbons, such deposits will be assessed for source rock potential as well as for the primary coal resource. It is not clear, however, whether there will be an active attempt to locate and study Tertiary lacustrine deposits.

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COMMENT NO.: 13; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.1.2 p. 314 - 315	The documented oil seeps elsewhere in the state occur at areas of ground water discharge. The lack of reported oil seeps in southern Nevada may be due to a lack of ground water discharge, rather than to a lack of hydrocarbons.

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COMMENT NO.: 14; p. 1 of 2 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.1.3	The reasoning for concluding that there is no oil shale potential in the Yucca Mountain vicinity is flawed: (1)
p. 315 - 316	One argument for the above conclusion is that no oil shales were encountered in the one (!) drillhole (UE-25p#1) that penetrated the Paleozoic section under Yucca Mountain. This hole penetrated the Silurian section below the Cenozoic volcanics, and only went 553 m into the Silurian before drilling was stopped. There are no known oil shales in the Silurian anywhere in the state, so their absence here is not a useful (or surprising) piece of information.

There is no mention of the possibility of thrust faults under the Silurian section in the drillhole. The Eleana Fm., the most likely source of hydrocarbons in the Paleozoic section (see below), may occur beneath the Silurian carbonates, in the footwall of a thrust fault. Although these would be too deep for surface mining -- and therefore not an oil shale resource -- they should not be overlooked as a potential source rock for liquid hydrocarbons.

(2) Another argument is that none of the stratigraphic units known to be oil shales elsewhere in the state are found in the Yucca Mountain vicinity. There is no mention of lateral and/or facies equivalents of these units.

The Mississippian Eleana Fm. of southern Nye Co. is correlative with the Chainman Shale of east-central Nevada. (While not an oil shale, the Chainman is cited in section 1.7.2.1.3 as an organic-rich shale which is thought to be the source rock for liquid hydrocarbons elsewhere in the state.) Task 8 field work to date has shown that at Bare Mountain, the CP Hills and the Eleana Range, the Eleana Fm. comprises dark shales and argillites which are presumably organic-rich.

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DRWG. NO. |

These are tentatively interpreted to have a depositional environment similar to that of the Chainman Shale in the Diamond Range of east-central Nevada. The Eleana Fm. of the Yucca Mountain vicinity should also be regarded as a potential source rock for liquid hydrocarbons.

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COMMENT NO.: 15; p. 1 of 1	CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2 p. 316 - 319	There is clearly a problem of terminology -- and understanding (!) -- here. The writer thinks that the "Western overthrust belt", or "Cordilleran thrust belt", is different than (specifically, is in a different place than) the "Sevier-Laramide belt". The first two terms are very general, and somewhat out-dated, names for the thrust belt which, in Nevada, Utah and Wyoming, would be more precisely termed the Sevier-Laramide belt. If this is an indication of the familiarity of the writer with the regional geology and with the literature on the subject, then other conclusions by this writer are of questionable reliability.

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COMMENT NO.: 16; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 319	Paragraph 1: The region over which 60 exploratory wells have been drilled is not specified. It is therefore impossible to evaluate whether this is good evidence for a low probability of hydrocarbons or not.

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COMMENT NO.: 17; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 319	Paragraph 2: There are many other possible reasons for the lack of productive oil fields in southern Nevada, including lack of economic incentive to explore an untested area (due to the relatively recent recognition of the hydrocarbon potential of Antler foreland basin deposits in eastern Nevada coupled with the generally low price of imported oil), and lack of access to much of the southern Antler foreland basin (the preferred exploration target) because it occurs in the NTS and Nellis AFB.

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COMMENT NO.: 18; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 319	Paragraph 4: The productive Railroad Valley area is surrounded by Tertiary caldera complexes, yet the geothermal gradient has not resulted in over-maturation of Paleozoic hydrocarbons.

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COMMENT NO.: 19; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 320	Paragraph 4: Alteration studies on rocks from drillhole USW G-2 indicate temperatures "as high as" 230°. If this is the upper end of a possible range, what is the low end of this range (and why is it not mentioned)? (See also Comment No. 46 below.) By taking the highest possible temperature, the writer makes the worst possible case for hydrocarbon potential.

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COMMENT NO.: 20; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 320	Paragraph 4: The above temperature (see Comment No. 19) is from one drillhole, and may not be at all representative of the region. This is particularly problematical for a region such as this, where proximity to a fault with hydrothermal solutions or to a volcanic feeder would give locally anomalously results.

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COMMENT NO.: 21; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 320	Paragraph 5: The statement that no source rocks are known is both blatantly incorrect and contradicted by other sections of the SCP. Mississippian clastic rocks are shown in the stratigraphic column for the Yucca Mountain region (p. 1-38), and Mississippian clastic rocks are described as source rocks (p. 1-316). Also, the possibility that carbonates might be source rocks is not even considered.

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COMMENT NO.: 22 ; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 320	Paragraph 6: Although the general summary of the CAI data is not incorrect, it is not presented in a geologically meaningful context. Hence, some potentially important pieces of information are lost. Once again, the significance of thrusting in the region is not mentioned. In the context of thermal maturity, thrusting is important because different thrust sheets may have different thermal histories. This is true for two reasons: First, the thrust sheets originated in different places, and possibly at different depths, which could mean very different thermal histories prior to thrusting. Second, thermal affects associated with thrust emplacement are the opposite for the footwall and the hanging wall (i.e. increased heat and pressure for the footwall, decreased heat and pressure for the hanging wall). In the case of an area with multiple thrust sheets, like the NTS, the thermal histories can be complex because a given sheet may have been the hanging wall for one thrust fault and the footwall for another. Data relating to thermal maturation, therefore, MUST be considered separately for each thrust sheet. When the existing CAI data are examined in this context, it appears that one thrust sheet in particular may have had a thermal history conducive to oil generation, while other sheets may have been right for gas generation.

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COMMENT NO.: 23; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 320 - 323	Paragraph 7: The quantitative thermal analysis using Lopatin's time-temperature index is meaningless, because the values used for time and temperature are general values for the region. Because of the complex deformation history of the area (see above), the thermal history of each thrust sheet must be considered separately.

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COMMENT NO.: 24; p. 1 of 1	CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 322	Paragraph 7: The temperature used is a maximum (see Comment No. 19 above), even for the thrust sheet in which the measurement was made; the results using the minimum possible temperature for this thrust sheet are not presented. (See also Comment No. 26 below.)

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COMMENT NO.: 25; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 320 - 323	Paragraph 7: There is no evaluation of the accuracy, or range or accuracy, of the method (i.e. Lopatin's time-temperature index), nor is any other method considered.

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COMMENT NO.: 26; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2.2.1 p. 322	Paragraph 8: Hidden in this summary paragraph, the writer drops a bombshell which negates most of the preceding discussion -- "new" information from both conodont alteration and from clay alteration in drillhole UE-25p#1 at Yucca Mountain indicate maximum temperatures af 175°, rather than the 230° mentioned in the paragraph on paleogeothermal history (!). Even assuming the Lopatin's time-temperature index is correct, and that the other temperatures and times used in the calculation are correct, a quantitative thermal analysis using this maximum temperature gives a result at the maximum gas generation phase for the Paleozoic section under Yucca Mountain! The omission of these new data in the preceding discussion (p. 320, Comment No. 19) is so egregious it gives the appearance of deliberate deception.

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COMMENT NO.: 27; p. 1 of 1 | CHAPTER NO.: 1

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
1.7.2 p. 313 - 323	There is a final, major, philosophical problem with this whole section (i. e. 1.7.2): it is all based on literature review and on theoretical calculations, with NO field data to test the conclusions. Although such field studies are apparently planned, some of the most obvious things should have been done, at least in reconnaissance, at the beginning of the study.

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COMMENT NO.: 28; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2 Table 8.3.1.9.2 p. 25 - 26	Table 8.3.1.9-3 contains some inaccuracies, and seriously underestimates the potential for oil and gas at Yucca Mountain. The "low" uncertainty rating is also inaccurate -- in part because it only considers the possibility of hydrocarbons in the tuff, which is not the most probable reservoir rock. We suggest the following changes to this table: (see Comment No.s 29 - 34)

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COMMENT NO.: 29; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2 p. 25 - 26	Uncertainty and rationale High -- Although no oil or gas has been reported from drillholes in the tuff, only one drillhole (UE25p#1) has gone through the tuff to the underlying Paleozoic section, and even this one only went 500m in the Paleozoic, never getting out of the Silurian section. Based on the regional geology, it seems highly probable that this Silurian section is in the upper plate of a thrust fault, with other Paleozoic section (including the Eleana Formation, see below) underneath.

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COMMENT NO.: 30; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2 p. 25 - 26	Uncertainty and rationale High -- Potential source rocks have been identified in the region: Mississippian Eleana Formation crops out to the west of the site at Bare Mountain, and to the east at the CP Hills, Calico Hills, Mine Mountain and Eleana Range. The Eleana is also thought to exist below northern Yucca Mountain, based on geophysical data, and its presence below southern Yucca Mountain cannot be ruled out at this point.

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COMMENT NO.: 31; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. PAGE NO. DRWG. NO.	COMMENT
8.3.1.9.2 p. 25 - 26	Uncertainty and rationale High -- Conodont alteration indices (CAI) from UE25p#1 indicate that the Silurian carbonates are well within the gas generating window (3). CAI from elsewhere in the region (Harris and others, 1980) are in the oil generating window (2) locally; preliminary indications are that these low values are characteristic of a single thrust sheet, and that this sheet may underlie Yucca Mountain.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 32; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2 p. 25 - 26	Uncertainty and rationale High -- A thrust fault underlying the Silurian rocks in UE25p#1 could also have created a structural trap which would prevent the migration of liquid hydrocarbons into the overlying section.

REVIEWER: Dr. Patricia H. Cashman

Signature: P.H. Cashman

ORGANIZATION:
Center for Neotectonic Studies
University of Nevada - Reno

DATE: June 5, 1989

State of Nevada
Agency for Nuclear Projects
Nuclear Waste Project Office

QAP - 3.4
Revision 0
January 20, 1989

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 33; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2 p. 25 - 26	<u>Sensitivity of parameter or performance measure to hypothesis</u> High -- Regional geology suggests possible resource potential. The thermal history of the rocks within the drift perimeter boundary is poorly understood. The Silurian carbonates immediately underlying the tuffs in UE25p#1 are in the "gas generating window"; the thermal history may be significantly different for different thrust sheets.

REVIEWER: Dr. Patricia H. Cashman

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DATE: June 5, 1989

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SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2	<u>Need to reduce uncertainty</u> – High
p. 25 - 26	

REVIEWER: Dr. Patricia H. Cashman

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COMMENT NO.: 35; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2.1 p. 28	Paragraph 5: Because of the fact that liquid hydrocarbons can migrate, a much larger area must be understood in order to evaluate hydrocarbon resources in the 10 km diameter circle.

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COMMENT NO.: 36; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2.1 p. 29	Paragraph 7: Although this section states that drillholes will be one of the sources of information used to evaluate the potential for hydrocarbon resources, it also states that no drillholes deep enough to intersect Paleozoic rocks are planned. As noted above, the little bit of Paleozoic section drilled in UE25p#1 may be in the upper plate of a thrust fault, and hence may not be representative of the rest of the Paleozoic section under Yucca Mountain.

REVIEWER: Dr. Patricia H. Cashman

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COMMENT NO.: 37; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2.1.4 p. 37	The assessment of hydrocarbon potential will include "a review and assessment of drillholes emplaced for oil and gas exploration within the geographic area of the site". What drillholes does this refer to? None of the existing USGS/DOE drillholes within the area of the site constitute hydrocarbon exploration holes. Will new holes be drilled? If so, where? How many? On what basis will the site(s) be chosen? How deep will they go?

REVIEWER: Dr. Patricia H. Cashman

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DATE: June 5, 1989

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COMMENT NO.: 38; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2.1.4 p. 37	Paragraph 1: Analysis for the presence of organic matter in "certain Paleozoic rocks" is planned. Since the preferred hypothesis (from Table 8.3.1.9-3) is that there are no known source rocks in outcrop or subsurface, what rock will be analyzed? How will the sample locations be chosen? One unit specifically mentioned as an example of rock to be analyzed is the Paleozoic rock from drillhole UE25p#1; as noted many times above, this hole sampled only the Silurian carbonates, and these are not potential source rocks. Also (as noted above), these are from one thrust sheet, and in no way reflect the thermal history of other thrust sheets in the area. Choice of samples is extremely important; the analyses (organic content, thermal maturation, thermal history) are worthless if not applied to the most appropriate rocks. Location and structural position should be taken into account, including samples from all thrust sheets and from different positions along strike in each thrust sheet. The Mississippian Eleana Fm is the most likely source rock, so it should be sampled wherever it crops out. Who will do the work, and what are their qualifications?

REVIEWER: Dr. Patricia H. Cashman

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DATE: June 5, 1989

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COMMENT NO.: 39; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2.1.4 p. 38	Paragraph 4: The existence of Mesozoic thrust faults and folds in the Yucca Mountain area is well established, completely independent of the reference cited. The oil-bearing potential of these structures is unknown.

REVIEWER: Dr. Patricia H. Cashman

Signature: P.H. Cashman

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DATE: June 5, 1989

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 40; p. 1 of 1 | CHAPTER NO.: 8

SEC. NO. / PAGE NO. / DRWG. NO.	COMMENT
8.3.1.9.2.1.4 p. 39	Methods and technical procedures: The methods and procedures are allegedly given in the table....but every section of the table says "to be determined".

REVIEWER: Dr. Patricia H. Cashman

Signature: P.H. Cashman

ORGANIZATION:
Center for Neotectonic Studies
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DATE: June 5, 1989

TASK 9

STATE OF NEVADA
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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan, December, 1988

Comment No.: 1 ; page 1 of 1	CHAPTER NO. all
Sec. No. Page No. Figure No.	**COMMENT**
all	Authors of each section of the SCP should be identified.

Reviewer: John G. Anderson	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557
John G. Anderson Signature	Date: June 14, 1989

STATE OF NEVADA
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Comment No.: 2 ; page 1 of 1	CHAPTER NO. 1
Sec. No. Page No. Figure No.	COMMENT
1.4.1 pg 1-164 Table 1-9 Table 1-10	Completeness of record (p160). Can Rogers prove that the record is complete in Nevada for M=7 events since 1845? That sounds almost incredible to me considering the sparse population. In contrast, Topozada considers it likely that M7 events in California could have been missed even in the 1880's (My recollection is that is his conclusion but I did not check the reference). If the record is complete the implications are remarkable - 1845 to 1931, no events over M 7 in Nevada (86 years) (should we count 1972 Owens Valley?) 1932-1954, 2 events with M>7, 5 with M>6.5. (22 years) This suggests that the seismicity is strongly episodic, and introduces an additional complication into the seismic hazard analysis.

Reviewer: John G. Anderson John G Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 3 ; page 1 of 1	CHAPTER NO. 1
Sec. No. Page No. Figure No.	COMMENT
1.4.1.1.2 pg 1-170	Strike slip mechanisms - is it common for small shock mechanisms to differ from the largest events? I know that some of the largest events in Nevada also have strike slip mechanisms. But also consider that if we were to study the San Andreas stress province from the Coalinga sequence, our conclusions might be wrong.
Reviewer: John G. Anderson John G Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 4 ; page 1 of 1	CHAPTER NO. 1
Sec. No. Page No. Figure No.	**COMMENT**
1.4.1.1.3 pg 1-170 Fig 1-53 Fig 1-57 also 1.4.1.2.1 pg 1-175 also 1.8.1.4.2 pg 1-335	The report claims that Yucca Mountain is in a region of locally very low strain energy release. The claim is not valid. This is a statistical sample over a much smaller area than for greater distances and thus subject to statistical uncertainty. The results are very sensistive to the size of the largest event in the annulus, and a single larger event in the nearest 10 km would completely change the picture. The text leaves the impression that the seismic quiescence within 10 km is significant. This invalid conclusion is repeated in the three sections noted.

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Comment No.: 5 ; page 1 of 1	CHAPTER NO. 1

Sec. No. Page No. Figure No.	COMMENT
1.4.1.5 pg 1-189 to 1-196 Fig 1-67	The risk assessment is presented without discussion of the attenuation model. Without this, the model is useless. The identification of preferred hypotheses cannot be accepted until more regional study has been completed. Is the preferred method to assess seismic hazard the probabilistic method or Appendix A?

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Comment No.: 6 ; page 1 of 1	CHAPTER NO. 1

Sec. No. Page No. Figure No.	COMMENT
1.4.2.3 pg 1-198 to 1-199	Induced seismicity does not include the possibility of seismicity caused by the repository. It should, for it is possible that the repository will induce earthquakes.

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Comment No.: 7 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -1b pg 8.3.1.8-4	Tentative parameter goal implies about one chance in 100 of volcanic eruption that penetrates the repository during the lifetime of the repository.

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Comment No.: 8 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -1b pg 8.3.1.8-5	Goal that <0.1% of repository area is disrupted by a volcanic event with a probability of less than 0.1% in 10,000 years, when combined with the goal of 10^{-6} of a volcanic eruption that penetrates the repository, implies that only one out of 10 volcanic eruptions that penetrate the reposistory will disrupt over 0.1% of the repository area. This implies a great understanding of the mechanism and pathway of volcanic intrusions, and tremendous engineering ingenuity to prepare barricades to volcanic effects. I think that these two goals are mutually inconsistent. I doubt that the necessary understanding can be obtained from field geologic studies. For a volcanic eruption in the basin & range, leading to a small basaltic cone, what is the ratio of volume of intrusive to extrusive volcanics? How thoroughly does the eruption permeate the available subsurface weak zones? Are subsurface weak zones filled first, and only then the eruption becomes extrusive?

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Comment No.: 9 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -2a pg 8.3.1.8-6	Goal that <0.1 probability in 1000 years that > 0.5% of the waste packages will be ruptured by tectonic events. In 10,000 years, this corresponds to a probability of less than .65, ie it is not very restrictive. Thus these probabilities are essentially assuming that more likely than not, tectonic events will disrupt the cannisters.

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Comment No.: 10 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -2b pg 8.3.1.8-7	I think the goal to restrict the probability of faulting disrupting the cannisters is best achieved when the tunneling and cannister holes are being emplaced. So long as the big faults are avoided, it should be easy to re-route some drifts to be sure they don't go down fault zones, and to drill holes for the cannisters that are in intact rock. I don't see how minor faults can be identified during the SCP activities. An SCP activity should be to figure out how to get a reliable geologist in on dynamic revision of drift locations and cannister hole locations so that faults are avoided. Perhaps that is mentioned in a different part of the CDSCP.

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Comment No.: 11 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -2b pg 8.3.1.8-8	These probabilities for ground motion values are so high that it is essentially certain that they will be exceeded during the lifetime of the repository. If ground motion is important, then the levels should be set at smaller probability. If it is not important, the performance parameter should be eliminated.
Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 12 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -2b pg 8.3.1.8-8	Waste emplacement boreholes might also deform due to creep. This would be the same as folding in an undisturbed environment, but in the disturbed waste repository creep can occur independent of folding.

Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 13 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -4a & -4b pg 8.3.1.8-13 & -15	On what basis do they conclude that an igneous intrusive event has to be within 500 meters of the site to affect the water table? Assuming a uniform spatial distribution of volcanic events, and the current estimate of the probability of one within 500 m, the probability of one within 5 km could exceed the parameter goal. Can they show that an igneous intrusive event 5 km away will not affect the water table?
Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 14 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.8 -4b pg 8.3.1.8 -16 & elsewhere	The slip rate of less than 0.01 mm/yr, implying an average slip of 1 m/10,000 yrs, does not assure that the tentative parameter goal will be met. If the slip were accomplished by creep, the performance parameter would be met. But if earthquakes occur less often than 10,000 years, with corresponding slip of greater than 1 m, the probability of the earthquake is about the probability of meeting the parameter goal. The tentative parameter goal might not be achieved.
Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 15 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
pg 8.3.1.8 -27 & -65	What do we know about the spatial extent of aftershocks from a fault? At times, they are spread out some, but how much? This is crucial for the waste package integrity from faulting. If aftershocks from the Windy Wash or Paintbrush Canyon fault might occur on small faults in the repository, it will have an important impact on these estimates.

Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 16 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Activity 8.3.1.8.5.2.3 pg 8.3.1.8 -127ff	What is the effect of ground water on the heat flow? Elsewhere in the SCP it is suggested that downward percolation reduces the heat flow, apparently significantly.

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Comment No.: 17 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Table 8.3.1.17 pg 8.3.1.17 -3 to -25	Confidence in current estimate and needed confidence: These are qualitative, and not subject to rigorous verification. As such, it will be easy to state later that the confidence is higher, and thus to demonstrate that the SCP has accomplished something. I see this column and the next one as political, not scientific.

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Comment No.: 18 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Sec. 8.3.1.17 pg 8.3.1.17 -36ff	The SCP proposes a questionable approach to the determination of seismic ground motions that the repository must resist.
Table 8.3.1.17 -5 & -7 Sec 8.3.1.17.3 pg 8.3.1.17 -28	There are several different approaches to setting the seismic design criteria. I will discuss three in this review. The first approach is a deterministic approach which would require that the pre-closure facilities should withstand "characteristic earthquakes", ie the types of earthquakes that most often occur on the nearest faults to the repository. The repeat time for these earthquakes might be much greater than 10,000 years in many cases. This approach is similar to what is used for nuclear power plants in the United States. This approach is recognized as an "alternative hypothesis" in Table 8.3.1.17-7 (pg. 8.3.1.17-44). The second approach is what I will call the "SCP-deterministic approach". This is sometimes called a deterministic approach in the SCP, but it is different from the deterministic approach described above. This can be seen in the more detailed discussion on page -72, and Table 8.3.1.17-5. Here the proposal is to design to resist earthquakes which results from 10,000 years accumulation of slip on the active faults of the region. Since the repeat time for earthquakes on these faults is expected to be greater than 10,000 years (eg. pg 8.3.1.17-36), the magnitude of the earthquake that would result from 10,000 years accumulation of slip would be somewhat smaller than the characteristic earthquake. The third approach is a probabilistic approach, which would require that the pre-closure facilities withstand the level of ground motion that occurs with probability 10^{-3} from all events (pg 8.3.1.17-14). For Yucca Mountain, a deterministic approach to the seismic hazard estimation is likely to be more "conservative". By a conservative approach, I mean one that requires a greater level of strength in the design to resist earthquake motions. As a comment, it is not unreasonable to demand that the repository be designed to withstand seismic standards set by the deterministic approach, as this approach has been used for other critical facilities (nuclear power plants, dams in California). I am not sure that the authors of the SCP knew what criteria will be used. They seem to be entering the political arena of establishing what the standards are, since they are trying to sell the SCP-deterministic procedure (eg. pg 8.3.1.17-36). I don't accept the argument that the 10,000 year cumulative slip earthquake is better than "conventional methods" because the uncertainty is lower (pg 8.3.1.17-36).

Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Comment No.: 19 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Section 8.3.1.17 page 8.3.1.17 -32 3rd PP	The meaning of "sympathetic faulting" is ambiguous. If they mean faulting on one fault triggered by ground motions from another earthquake, then this might occur for earthquakes greater than 5 km away. In southern California, my recollection (without checking a map) is that there has been such triggered slip at distances of 30 to 50 km. To my knowledge, there is no way to recognize sites of potential triggered slip in advance, no matter how well the fault is characterized. Nobody knows anything about the ground motions that result from triggered slip. The other alternative meaning for "sympathetic faulting" is that a complex of disconnected surface fault traces are formed as a result of a single earthquake. If this is the case, then the size of the earthquake is likely to be larger than what one will estimate from the extent of single fault traces.

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Comment No.: 20 ; page 1 of 1	CHAPTER NO. 8
Sec. No. Page No. Figure No.	COMMENT
Section 8.3.1.17 page 8.3.1.17 -32 to -34	The assumption is that the potential for 7 cm of fault displacement below the ground at the waste handling facilities can be determined from surface exploration. On the contrary, 7 cm of slip can occur in a magnitude 5 earthquake, and most of the time, when a M=5 earthquake is the main shock of a sequence, it is not accompanied by surface rupture. Thus I don't see how the proposed research is able to achieve the goal that has been established.

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Comment No.: 21 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Section 8.3.1.17 page 8.3.1.17 -36 top	I object to characterizing the choice of the "10,000 year cumulative slip earthquake" as merely a more explicit way of defining the maximum earthquake; rather it amounts to a redefinition. See my note for item 28 above.

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Comment No.: 22 ; page 1 of 1	CHAPTER NO. 8

Sec. No. Page No. Figure No.	COMMENT
Investigation 8.3.1.17.3.1.1. page 8.3.1.17 -69	Identify relevant earthquake sources. The premise is that all relevant sources can be identified by geophysical techniques. I doubt that such is the case. It would be better to assess the largest magnitude earthquake that can occur in the region without surface expression, and then to assume that such an earthquake can occur directly beneath the site. This latter approach would be consistent with the NRC approach to siting nuclear power plants in a "tectonic province".

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Sec. No. Page No. Figure No.	COMMENT
Study 8.3.1.17.3.3 page 8.3.1.17 -76	This study does not include any plan to evaluate ground motion from any potential detachment faults.

Reviewer: John G. Anderson

John G. Anderson
Signature

Organization:
Center for Neotectonic Studies
University of Nevada - Reno
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Date: June 14, 1989

STATE OF NEVADA
AGENCY FOR NUCLEAR PROJECTS
NEVADA NUCLEAR WASTE PROJECTS OFFICE

TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan, December, 1988

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Sec. No. Page No. Figure No.	COMMENT
Study 8.3.1.17.3.3. page 8.3.1.17 -76	Ground motion estimation. The approach to ground motion estimation is to use regressions that apply to California unless it can be proven that data from the Basin and Range contradict such regressions in a statistically significant manner. Since there are only very few strong motion data points from the Great Basin, it is very unlikely that such a contradiction will occur. On the other hand, it is well known from study of weak motions that attenuation is less severe in the Great Basin than in California. Thus the proposed procedure has the appearance of being likely to underestimate the ground motion from more distant events. For nearby events, these differences in attenuation are not likely to dominate since geometrical spreading, rather than attenuation is a dominant influence. However, there is no certainty that ground motions from normal faulting earthquakes in the Great Basin are similar to those from faults with much larger slip rates in California. This study does not include any plans to install strong motion instrumentation outside of the Yucca Mountain vicinity. If such an effort were made on a massive scale, there would be a reasonable chance of recording some strong shaking from a major Great Basin earthquake during the duration of the SCP project.

Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

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Sec. No. Page No. Figure No.	COMMENT
Activity 8.3.1.17.3.5.1 page 8.3.1.17 -80	Identify controlling seismic events. The list of parameters leaves off stress drop.

Reviewer: John G. Anderson John G. Anderson Signature	Organization: Center for Neotectonic Studies University of Nevada - Reno Reno, Nevada 89557 Date: June 14, 1989

SUMMARY COMMENTS ON THE SITE CHARACTERIZATION PLAN

Robert J. Watters, P.I., Task 7

Many of the issues pertaining to rock characterization, thermal and mechanical characteristics, and the underground design of the repository have been considered in the SCP. However, key points remain either to be addressed or expanded.

1. The seismic stability appraisal of the underground excavations is extremely limited in content. Major concerns which have either not been addressed or are limited are :

a) dynamic displacement along joints or fractures due to seismic loading would appear not to be scheduled in laboratory testing. Very limited empirical information exists on this type of displacement, so testing is required.

b) The frequencies most likely to cause damage to subsurface facilities are significantly higher than the frequencies that cause damage to surface structures. Given this situation, the design basis and corresponding response spectra for the underground openings will be assessed using band widths which do not encompass higher frequencies. These higher frequencies can be developed by near field displacements from nearby fault movement or volcanic activity. If the stability of the openings is assessed using lower frequencies than actually occur, failure of the excavations could develop.

2. The investigation to establish the lithology, geologic structure, and geomechanical properties of the repository horizon rock mass depends totally on a) the locations of the shafts and drifts, and b) the number and location of boreholes.

The position of the shafts is suggestive of "putting the cart in front of the horse" in that the requirements to best investigate the repository block have been usurped by the needs to a) position the shafts where they best serve the operational requirements of the repository b) save time and c) comply with the dictates of 10 CFR 960. In their present positions the central and southern portions of the block will not be investigated. A competent investigation establishes the best positions for the shaft, not the converse.

3. Only 24 cored holes (perhaps less) are planned to be drilled to the repository horizon. These holes will have spacings up to 4200 feet and consequently with such a large distance between holes, many geotechnical features and rock mass characteristics will be lost or overlooked.

4. The vast majority of boreholes are vertical, even though many of the features of interest, fractures etc. which affect hydrogeology and rock mass behavior are vertical. Hence, these features are either overlooked or minimized.

5. More rock testing in terms of numbers of tests and locations are needed to better explain rock mass behavior and the range in in situ stress magnitudes.

6. Few details are discussed about "feature of interest drilling" e.g. faults. Geologic structures within the perimeter boundary may well be crucial to both the short and long term stability of the excavations.

7. An emphasis on geostatistical approaches in analyzing the collected data, supports the overall conclusion that the minimum number of boreholes, drifts, tests, and analyses are to be performed. Geostatistical methods are normally performed when scatter of data exists, and the normal refinement of additional raw data collection, to reduce the scatter and improve the data quality, can not be performed due to time constraints, lack of money or politics.

STATE OF NEVADA COMMENTS

ON THE

U.S. DEPARTMENT OF ENERGY

SITE CHARACTERIZATION PLAN

YUCCA MOUNTAIN SITE

NEVADA

VOLUME IV

PREPARED BY

NEVADA AGENCY FOR NUCLEAR PROJECTS/
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SEPTEMBER 1989