SUMMARY OF NRC-DOE MEETING ON TECTONICS

August 30-31, 1989
Rockville, Maryland

Agenda: See Attachment 1.

List of Attendees: See Attachment 2.

Summary:

The objectives of the meeting were: (1) for NRC and DOE to discuss NRC's concerns and recommendations regarding DOE's Site Characterization Plan (SCP) in the area of tectonics investigations and to focus on those areas that need to be discussed in follow-up Technical Exchanges on tectonics; and (2) to establish objectives and draft agenda items for the follow-up NRC-DOE Technical Exchanges on tectonics scheduled for the remainder of 1989. The State of Nevada's concerns regarding DOE's SCP in the area of tectonics investigations were also to be presented at this meeting.

After short opening statements by NRC, DOE, and the State of Nevada, NRC presented an introduction and overview of its concerns regarding tectonics (Attachment 3). Then NRC staff members made presentations of NRC concerns in the following areas: Integration of data and models (Attachment 4); Integration of planned testing (Attachment 5); Representativeness of tests and resulting data (Attachment 6); and Investigation of potentially adverse conditions, with specific emphasis on faulting (Attachment 7), ground motion (Attachment 8), and volcanism (Attachment 9). After these presentations NRC made a brief concluding statement about its presentations (Attachment 10). The State of Nevada then presented its SCP concerns regarding tectonics (Attachment 11). During and after each of these presentations there was considerable discussion among the participants concerning the issues raised.

Topics for the Tectonics Technical Exchanges scheduled for September, October, and November were agreed upon at the conclusion of the meeting. The September interaction will involve discussion of the NRC draft Tectonic Models Technical Position, as well as discussion of the relationship of tectonic models to the site characterization program. The October interaction will involve discussion of the range of tectonic models of the Yucca Mountain site that can be supported by the currently existing data base. The November interaction will center around some examples of DOE's planned studies to evaluate the various tectonic models of the Yucca Mountain site.

In closing statements NRC and DOE concluded that the objectives of the meeting had been met. In particular, the meeting discussions were successful in clarifying NRC concerns for DOE, in helping NRC to better understand the logic supporting various portions of DOE's SCP, and in providing a sound basis for the more detailed discussions to take place in the follow-up Technical Exchanges.

In its closing statement, the State of Nevada agreed that the meeting had been useful. The State expressed a continuing concern with what NRC considers to be the priorities in DOE's site characterization program. On a separate point, the State requested that all Technical Exchanges be held in Las Vegas to ensure that the State could be in attendance.

King Stablein 9/15/89

King Stablein, Senior Project Manager
Repository Licensing and Quality Assurance
Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission

Gordon Appel 9/15/89

Gordon Appel, Chief
Licensing Branch
Office of Systems Integration
and Regulations
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy

AGENDA

NRC-DOE MEETING ON TECTONICS

Rockville, Maryland
August 30-31, 1989

OBJECTIVES: The objectives of the meeting are: (1) for NRC and DOE to discuss NRC's concerns and recommendations regarding DOE's Site Characterization Plan (SCP) in the area of tectonics investigations and to focus on those areas that need to be discussed in follow-up Technical Exchanges on tectonics; and (2) to establish objectives and draft agenda items for the follow-up NRC-DOE Technical Exchanges on tectonics scheduled for the remainder of 1989. The State of Nevada will also present its concerns regarding DOE's SCP in the area of tectonics investigations.

N.B. There will be questions and discussion during and after each NRC presentation as well as after the State of Nevada's presentation. The NRC presentations will be brief, and most of the time allotted is for interactive discussion among the attendees.

August 30, 1989

8:30 a.m.	OPENING STATEMENTS	NRC DOE STATE OF NEVADA OTHER AFFECTED PARTIES
8:45 a.m.	INTRODUCTION AND OVERVIEW OF NRC CONCERNS REGARDING TECTONICS	Philip Justus
9:05 a.m.	PRESENTATION AND DISCUSSION OF NRC CONCERNS REGARDING INTEGRATION OF DATA AND MODELS o Shaft Location o Alternative Tectonic Models	Keith McConnell
10:00 a.m.	BREAK	
10:15 a.m.	PRESENTATION AND DISCUSSION OF NRC CONCERNS REGARDING INTEGRATION OF PLANNED TESTING o Drilling Programs o Mapping Programs o Geophysical Surveys o Sequencing of Activities	Charlotte Abrams
11:10 a.m.	PRESENTATION AND DISCUSSION OF NRC CONCERNS REGARDING REPRESENTATIVENESS OF TESTS AND RESULTING DATA o Physical Domain o Potentially Adverse Conditions	Keith McConnell

12:05 p.m.	LUNCH AND CAUCUS	
1:30 p.m.	PRESENTATION AND DISCUSSION OF NRC CONCERNS REGARDING INVESTIGATION OF POTENTIALLY ADVERSE CONDITIONS	
	o Faulting --Imbricate Faults --Fault Characterization --Performance Allocations	Keith McConnell
2:45 p.m.	o Ground Motion --10,000-yr Cumulative Slip Earthquake --Comprehensive Earthquake Data	Abou-Bakr Ibrahim
3:15 p.m.	BREAK	
3:30 p.m.	o Volcanism --Alternative Tectonic Models --Area of Investigation --Volcanic Processes --Performance Goals --Example of Preliminary Evaluation	John Trapp
5:30 p.m.	ADJOURN	

<u>August 31, 1989</u>

8:30 a.m.	PRESENTATION AND DISCUSSION OF STATE OF NEVADA CONCERNS WITH RESPECT TO TECTONICS IN DOE'S SITE CHARACTERIZATION PLAN	Carl Johnson
9:30 a.m.	DISCUSSION OF FOLLOW-UP TECHNICAL EXCHANGES ON TECTONICS	All
10:15 a.m.	BREAK	
10:30 a.m.	DISCUSSION OF FOLLOW-UP TECHNICAL EXCHANGES ON TECTONICS (Continued)	All
11:45 a.m.	CLOSING REMARKS	NRC DOE STATE OF NEVADA OTHER AFFECTED PARTIES
Noon	ADJOURN	

NRC-DOE MEETING ON TECTONICS
AUGUST 30-31, 1989
ATTENDANCE LIST (8/30/89)

Name	Organization	Phone #
King Stablein	NRC	(301)-492-0446
PHILIP S. JUSTUS	NRC HLWM Geol-Geophys	301-492-3460
Keith I. McConnell	"	301-492-0532
Charlotte Abrams	"	(301) 492-0512
Baker Ibrahim	"	(301) 492-0523
CARL JOHNSON	STATE OF NEVADA	(702) 885-3744
Michael P. Miklas, Jr.	CNWRA/SwRI	(512) 522-5250
Sue Gagner	NRC GPA/PA	(301) 492-0240
BOB ADLER	CNWRA	703-979-9129
Jay L. Smith	EEI/UWASTE	(707) 573-8235
Robert L. Johnson	NRC/HLPD	(301) 492-0409
Bruce Crowe	Los Alamos Nat'l Lab	FTS 544-7096
MAL MURPHY	NEVADA	(206) 352-4000
DAVID TILLSON	NEVADA	(801) 363-4093
Susan Bilhorn	NRC/OCM-KR	FTS 492-1850
M. A. GLORA	SAIC	FTS 544-7609
Connie Moeller	DOE/HQ	FTS 896-2837
Mark W. Frei	DOE/HQ	FTS 896-5321
John Bradbury	NRC	FTS-492-0535
Tom Cardone	NRC	(301) 492-0528
HAROLD LEFEVRE	NRC	(301)-492-3464
Claudia Abbate	NRC	(301) 492-0407
KIEN CHANG	NRC	301 492-0525
Mel Silberberg	NRC/RES/WMB	(301) 492-3860
Bob Jackson	Roy F. Weston/DOE-HQ	202-646-6688
David Brooks	NRC/HLWM	(301) 492 3457
STEPHAN BROCOUM	DOE/HQ	202 586-4262
BILL HINZE	ACNW	

Russ McFarland	NWTRB	202/254-4792
W.W. Coons	NWTRB	(202) 254-4792
C.R. Allen	NWTRB - BRWM	(202) 254-4792
Warner North	NWTRB	(202)-254-4792
Jake Philip	NRC	(301) 492 3863
Linda Kovach	NRC/RES/WMB	(301) 492-3869
Michael Voegele	SAIC/YMP	FTS 544-7638
Jean Younker	SAIC/YMP	FTS 544-7650
Scott Dam	WESTON / DOE-HQ	202-646-6660
STEVEN ROSSI	DOE/HQ	202-586-9433
Jerry King	SAIC/YMP	702-794-7648
Jim Hileman	Battelle	(312) 655-8673
Ralph Stein	DOE - HQ	202 586 6046
Ray Wallace	USGS/HQ - DOE/HQ	202-586-1244
Newell J. Trask	USGS - Water Res Div	703-648-5719
Philip Berger	DOE-EH/Energetics	(301) 992-4000
Gene Roseboom	USGS Director's Office	(703) 648-4423
R.B. Raup	USGS - Geol. Div./Denver CO	FTS 776-4272
TERRY GRANT	SAIC/YMP	FTS 544-7647
K. Michael Cline	WESTON/DOE	(202) 646 6654
David F. Fenster	Weston/DOE	(202) 646-6647
Alexander Livnat	Weston/DOE	(202) 646-6662
Gordon Appel	DOE/OCRWM	(202) 586-1462
Maxwell Blanchard	DOE/YMP	702-794-7939
Jeff Kimball	DOE/OCRWM	(202) 586 1063
David Dobson	DOE/YMP	702 794-7940
Dinesh Gupta	NRC	301 492-0547

Bill Melson	Smithsonian	202-357-1947
Chris Newhall	USGS	(703) 648-6709
Mysore Nataraja	NRC	301-492-3459
Chris Henkel	EEI/UWASTE	(202) 778-6693
Stan Echols	DOE	(202) 586 6947
John TRAPP	NRC	301-492-0509

DOE/NRC MEETING ON TECTONICS 8/30–31/89

Introduction and Overview of NRC's Concerns Regarding Tectonics

1. NRC's Tectonics Program
2. Regulatory Requirements - Tectonics
3. SCA Tectonics Concerns

Philip S. Justus
Geology–Geophysics Section
Division of High–Level Waste Management

TECT MTG 08/30/89 AKI 06

Attachment 3

INTRODUCTION AND OVERVIEW

NRC's Tectonics Program

ORGANIZATION

DHLWM
ROBERT E. BROWNING, DIRECTOR
B. JOE YOUNGBLOOD, DEPUTY DIRECTOR

GEOSCIENCES AND SYSTEMS PERFORMANCE BRANCH
RONALD L. BALLARD, CHIEF

GEOLOGY-GEOPHYSICS SECTION

Charlotte Abrams*	Geology	Keith McConnell*	Tectonics
Michael Blackford	Seismology	John Trapp*	Tectonics/
Anthony Cardone	Geology		Performance
Abou-Bakr Ibrahim*	Geophysics		Assessment
Harold Lefevre	Geology	Philip Justus	Section Leader

*Presentors at Tectonics Meeting 8/30/89

Technical Assistance

Center for Nuclear Waste Regulatory Analyses
Lawrence Livermore National Laboratory (expired 2/88)
Weston Geophysical Corp. (expired 3/89)

INTRODUCTION AND OVERVIEW
NRC'S TECTONICS PROGRAM
(Continued)

PRE-LICENSE-APPLICATION PHASE

OBJECTIVE: Identify and Reduce Regulatory and Technical Uncertainties

ACTIVITIES:

1. Develop Assessment Methods, Models and Codes
2. Develop Guidance for DOE on Compliance
3. Review and Implement Rules and Standards
4. Evaluate NWPA Submittals for Technical Adequacy
5. Participate in Inspections and Audits
6. Coordinate Tectonics Research Support
7. Provide Management to Center

COMMUNICATIONS:

1. Proposed Rulemaking
2. Technical Positions
3. Regulatory Guides
4. Review Plans
5. Technical Reports/Letters
6. QA Audit Reports
7. Document and Site Reviews
8. Meeting Transcripts & Summaries

INTRODUCTION AND OVERVIEW

NRC'S TECTONICS PROGRAM
(Continued)

REGULATORY REQUIREMENTS–TECTONICS

DOE IS TO DEMONSTRATE THAT THERE IS REASONABLE ASSURANCE THAT THE PERFORMANCE OBJECTIVES OF 10 CFR PART 60 ARE MET

- Performance Objectives
    - EPA Cumulative Release Standard (60.112)
    - Waste Package Lifetime (60.113)
    - Controlled Releases from EBS (60.113)
    - Groundwater Travel Time (60.113)
- Siting and Design Criteria
    - Favorable and Potentially Adverse Conditions (60.122)
    - Retrievability Option Maintained (60.111)

REGULATORY REQUIREMENTS TECTONICS

Logic for Evaluating Potentially Adverse Condition 60.122(c)(15) "Evidence of Igneous Activity Since Start of the Quaternary Period"

If Quaternary Igneous Activity is Present

TO SHOW

That Quaternary Igneous Activity Does Not Compromise Ability of Repository to Meet Performance Objectives Relating to Waste Isolation

DOE MUST (NRC to Evaluate)

Adequately Investigate Quaternary Igneous Activity. Including Extent to Which Condition May be Present and still be Undetected Taking Into Account Resolution of Investigations

AND

Adequately Evaluate the Effect of Quaternary Igneous Activity Using Analyses and Assumptions Not Likely to Underestimate Its' Effect

AND

Show Quaternary Igneous Activity Does Not Significantly Affect Ability of Repository to Meet Performance Objectives

OR

Show Effect of Quaternary Igneous Activity is Compensated by Favorable Characteristics

OR

Show Quaternary Igneous Activity Can Be Remedied

INTRODUCTION AND OVERVIEW
NRC'S TECTONICS PROGRAM
(Continued)

SCA TECTONICS CONCERNS

- Scope and Level of Detail of SCP Review – Tectonics
  - SCP Review Plan
  - Interdisciplinary Tectonics Review
  - SCA
- Organization and Summary of Tectonics Concerns

  GENERAL
  - Integration of DOE Program Elements
  - Completeness and Adequacy of Characterization

  SPECIFIC
  - Faulting
  - Ground Motion
  - Volcanism

INTRODUCTION AND OVERVIEW

Highlights of SCA Tectonics Statements and Suggestions to DOE

Statements:

1. "The need for improved technical integration of the overall site characterization program is illustrated by . . .tectonic concerns . . .it is unclear how [tectonics segments] are being incorporated into a coordinated and integrated program. For example, . . .geophysical and geological activities intended to gather data required as input to assessments of potentially adverse conditions . . .may not be carried out until well after those assessments have been initiated."

2. " . . . it appears DOE plans to conduct intrusive activities, e.g., drilling and trenching, prior to, or without, conducting nonintrusive geophysical and geological activities that could provide information needed to optimize the locations of proposed drillholes and trenches."

3. " . . . it is not clear that data obtained from holes drilled for one investigation will be utilized as possible input into other investigations or more importantly, that the number of boreholes has been minimized (hence minimizing potential damage to the site) by integrated planning to select borehole locations that could be used to obtain data of diverse investigations."

(R.M. BERNERO TO S. ROUSSO, 7/31/89)

INTRODUCTION AND OVERVIEW

Highlights of SCA Tectonics Statements and Suggestions to DOE

Suggestions:

1. "Provide an early and ongoing evaluation of whether any of the potentially adverse conditions (10 CFR 60.122) significantly effect the ability of the site to meet the 10 CFR Part 60 performance objectives and whether data being gathered are adequate to make this determination."

2. "High priority should be given to conducting those investigations which can lead to a determination of whether the site is subject to an unacceptably high probability of disruption as a result of volcanism, faulting, or seismicity. These investigations need to be conducted as early as possible in site characterization."

3. " . . . a full range of tectonic models reasonably supported by the existing data base should be considered in planning the tectonic investigation . . ."

4. "The full spectrum of site characterization activities should proceed with proper coordination and integration. This recommendation is not intended nor should it be interpreted to mean that there should be a delay in any other surface-based testing or in ESF construction."

(R.M. BERNERO TO S. ROUSSO, 7/31/89)

DOE/NRC MEETING ON TECTONICS 8/30–31/89

Checklist of NRC Handouts

1. Introduction and Overview
2. SCA Concerns – Integration of Data and Models
3. SCA Concerns – Integration of Planned Testing
4. SCA Concerns – Representativeness of Tests and Resulting Data
5. SCA Concerns – Faulting
6. SCA Concerns – Ground Motion
7. SCA Concerns – Volcanism
8. Summary Statements
9. SCA Point Papers on Tectonics with Checklist

DOE/NRC MEETING ON TECTONICS 8/30–31/89

NRC CONCERNS REGARDING INTEGRATION OF DATA AND MODELS

1. SHAFT LOCATION
2. ALTERNATIVE TECTONIC MODELS

Keith I. McConnell
Geology/Geophysics Section
Division of High-Level Waste Management

Attachment 4

INTEGRATION OF DATA AND MODELS

SCA CONCERNS

1. SHAFT LOCATION:
   The process used to integrate all available tectonics data into decisions regarding shaft location appears to have been inadequate (Comment # 127).

2. ALTERNATIVE TECTONIC MODELS:
   Alternative tectonic models do not appear to be fully integrated into the site characterization plan (SCA Comment # 8).

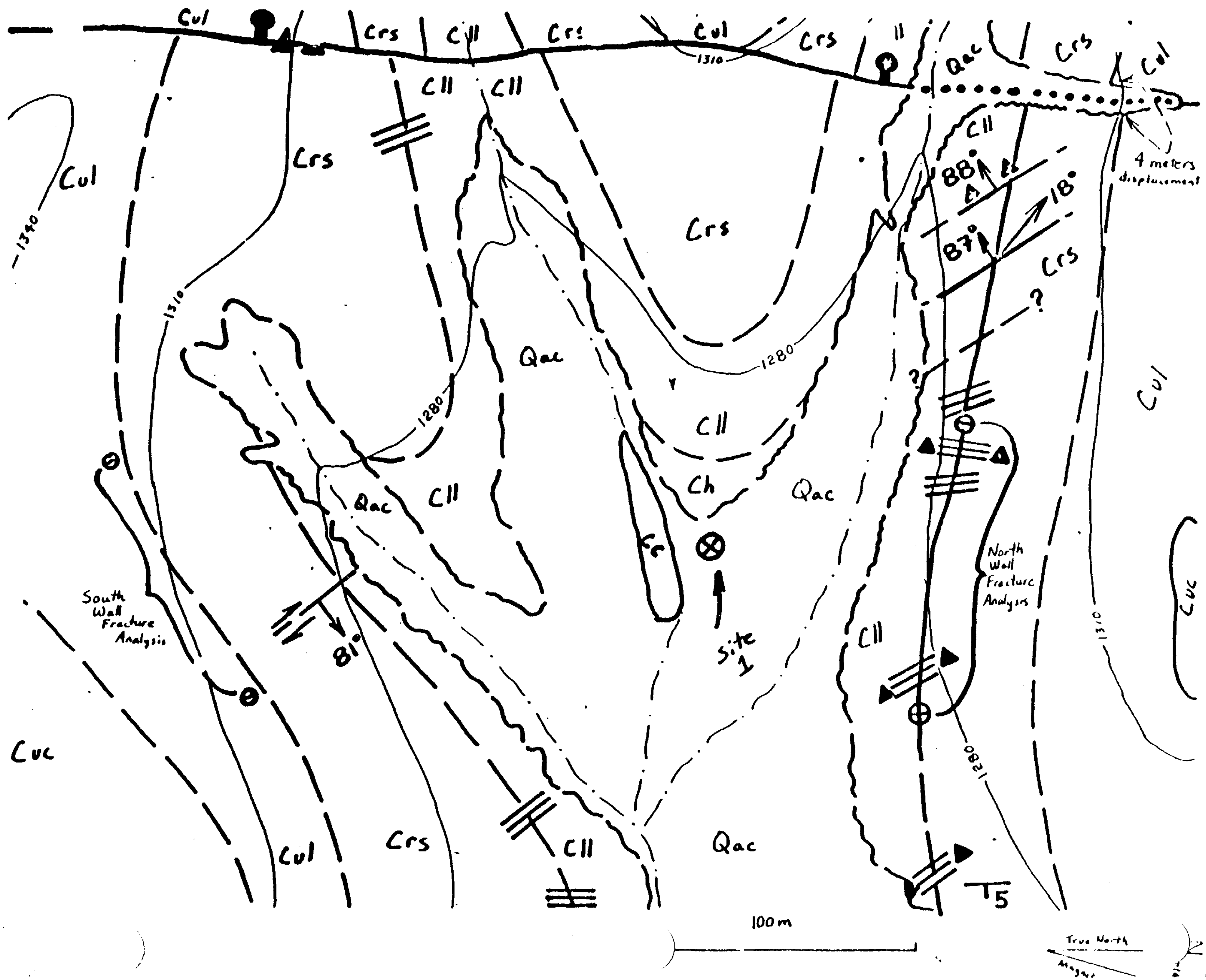
Integration Concern #1: Shaft Location

Key Observations

- Data presented in Smith and Ross (1982) suggest the possible presence of a fault in the vicinity of the ESF.
- DAA did not appear to consider the results of the geophysical testing (i.e., Smith and Ross) near the current location of the exploratory shafts in the assessment of performance.
- The DAA relied on the Bertram (1984) report to conclude that faulting is not a factor in shaft location. The Bertram report, however, did not include the results of activities recommended by the TIG to identify potentially adverse structures.

CHRONOLOGY

- Smith and Ross resistivity work conducted in 1979 (Kimball, 6/27/89).
- March, 1982 working group formed for ES site evaluation.
- June, 1982, working group recommended:
  1) "USGS should prepare detailed surface geologic maps for the nearby vicinity of each of the five candidate exploratory shaft sites.
  2) "USGS should implement a geophysical evaluation ... to determine ... whether subsurface structure exists beneath the washes located on the eastern flank of Yucca Mountain..."
- July, 1982, Dixon to Vieth letter transmitted the results of detailed geologic mapping. Mapping indicates the presence of "Unusually dense clusters of fractures."


Cul
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Qac
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4 meters displacement
88°
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Crs
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1340
Crs
1310
Crs
Qac
1280
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Cul
1280
Cll
Cll
Ch
Qac
Qac
Cll
Qac
Cc
North Wall Fracture Analysis
Cuc
South Wall Fracture Analysis
81°
Site 1
Cll
1310
1280
Cuc
Cul
Crs
Cll
Qac
T5
100m
True North
Magnetic

CHRONOLOGY

- 1984, Bertram report published with recommendations of the Technical Integration Group. One objective for shaft siting was that "known areas of potentially adverse subsurface conditions must be avoided."
- April, 1987, shaft locations changed to present sites.
- December, 1988, Gnirk reported that geophysical tests were performed in borehole G-4 and throughout the Yucca Mountain area.
- February, 1989, the DAA, using Bertram (1984) as a reference, states that "Because Bertram (1984) excluded all areas within 100 feet of faults, all five alternative locations compared by Bertram are in an acceptable zone."

QUESTIONS RAISED

- Considering the new shaft locations, does the detailed mapping presented in the Dixon to Vieth letter cover a sufficient area to fulfill the recommendations of the TIG?
- What geophysical investigations were conducted in the vicinity of the new shaft locations to verify the presence or absence of potentially adverse structures?
- Considering the intensity of fracturing found in the vicinity of the shaft locations and the recommendation of the TIG that the sites be reevaluated if "joint densities are significantly higher at the recommended site," when was this reevaluation done and what were the results?
- Were the objectives of the TIG on shaft location met?
- What are the potential impacts on waste isolation of the possible presence of a major fault connecting the shafts with the waste emplacement areas?

Integration Concern #1: Shaft Location

Recommendations

- Reconsider whether the design process is adequate in light of the apparent failure to consider all relevant information.
- Address apparent conflicts between objectives for shaft siting and the possible presence of a fault in the vicinity of the shafts.
- Re-evaluate the potential impact on waste isolation of the present shaft locations based on an assessment of available data.
- Consider conducting further tests in the vicinity of the proposed shafts.

Integration Concern #2: Alternative Tectonic Models

Key Observations

- Tectonic models do not appear to form a conceptual basis from which to make judgements that will not underestimate the effects of future tectonic events.
- Alternative fault models are not adequately considered.
- The design of EBS does not appear to consider alternative fault models.
- Alternative tectonic models do not appear to have been used as a tool for prioritizing tectonic investigations.

Integration Concern #2: Alternative Tectonic Models

Recommendations

- Integrate alternative tectonic models into preliminary performance allocation and the design of the EBS.

- Use tectonic models to prioritize investigations giving high priority to those assocated with tectonic features, events, or processes that could lead to the determination of whether the site has unacceptable adverse conditions, or to a substantial change in the site characterization program.

DOE/NRC MEETING ON TECTONICS 8/30–31/89

Clarification and Resolution of SCA Concerns
INTEGRATION OF PLANNED TESTING

1. DRILLING PROGRAMS
2. MAPPING PROGRAMS
3. GEOPHYSICAL SURVEYS
4. SEQUENCES OF ACTIVITIES

Charlotte E. Abrams
Geology/Geophysics Section
Division of High-Level Waste Management

Attachment 5

INTEGRATION

SCA CONCERNS

1. Drilling Programs:
   It is unclear as to how data from various holes will be used in support of different studies (SCA Comment 34).

2. Mapping Programs:
   It is unclear as to how various mapping tasks and the resultant information will be integrated (SCA Question 1).

3. Geophysical Surveys:
   The approach used to integrate geophysical activities does not appear to be discussed in the SCP (SCA Comments 32, 52).

4. Sequencing of Activities:
   The sequencing of many geophysical and geological activities related to faulting may lead to collection of data inadequate to support assessments of performance and design bases (SCA Comments 59, 63).

Integration Concern #1: Drilling Programs

Key Observation

It is not clear whether data obtained from holes drilled for one particular investigation or discipline will be utilized as input into other investigations.

Integration Concern #1: Drilling Programs

Recommendations

- Identify, integrate, and evaluate qualified existing data to determine information needs.
- Coordinate the proposed program of exploration with information needs of planned investigations and integrate the planned drilling programs with planned drifting and geophysical programs.
- Supply relevant data from drillholes to all investigations requiring such data.

Integration Concern #2: Mapping Programs

Key Observations

- The SCP provides little information as to how data obtained from one mapping study may provide input or be integrated with another.
- Map scales and areas of study do not appear to be integrated or compatible among various mapping studies.

Integration Concern #2: Mapping Programs

Recommendation

- Consider developing a program to integrate mapping studies to provide integrated products at scales appropriate in detail to fulfill the objectives of the proposed studies.

Integration Concern # 3: Geophysical Surveys

Key Observations

1. Locations and scopes of the geophysical program in the SCP are generally related to specific geologic features or cover areas of limited extent.
2. SCP does not specify a geophysical program to investigate/identify volcanic/igneous features.

Integration Concern #3: Geophysical Surveys

Recommendations

- Integrate and evaluate existing geologic and geophysical data.
- Design and implement a coherent geophysical program to provide sufficient characterization of the site.
- Include and integrate into the geophysical program a subprogram designed specifically for consideration of volcanic/igneous features.

Integration Concern #4: Sequencing of Activities

Key Observation

1. Many activities which will provide input to other scheduled activities will not be completed until after activities to which they will provide input.

Integration Concern #4: Sequencing of Activities

Recommendations

- Consideration should be given to re-examining the sequence of all activities dependent on input from other activities.
- The program for site characterization should integrate pre-existing information and information from ongoing activities prior to implementation.

DOE/NRC MEETING ON TECTONICS 8/30–31/89

NRC CONCERNS REGARDING REPRESENTATIVENESS OF TESTS AND RESULTING DATA

1. PHYSICAL DOMAIN
2. POTENTIALLY ADVERSE CONDITIONS

Keith I. McConnell
Geology/Geophysics Section
Division of High-Level Waste Management

Attachment 6

REPRESENTATIVENESS

SCA CONCERNS

1. Physical Domain:
   The current representation of the physical domain for postclosure tectonics issues appears inadequate (SCA Comment 46). There is no discussion of the relationship between the terms "physical domain" and "geologic setting."

2. Potentially Adverse Conditions:
   The program of drifting in the north, combined with systematic and feature sampling drilling appears unlikely to provide information necessary to adequately investigate potentially adverse conditions (SCA Comments 34, 35).

Representativeness Concern #1: Physical Domain

Key Observations

- There is no clear definition of the term "physical domain" documenting how it relates to "Geologic Setting."
- The physical domain for Postclosure Tectonics given in the SCP is the brittle crust, southern Great Basin. Processes acting in the lower, ductile crust and upper mantle may be the driving forces for events in the upper, brittle crust.
- The Death Valley-Pancake Range volcanic zone (belt) has been projected through the site. Processes that resulted in the formation of the Lunar Crater volcanic field that is outside the southern Great Basin physical domain may be applicable to the site.

Representativeness Concern #1: Physical Domain

Recommendations

- Relate the term "physical domain" to "geologic setting" as defined in 10CFR60.
- Consider extending the area of the geologic setting for postclosure tectonics to include the lower crust and upper mantle as well as areas that could serve as analogs but are outside of the southern Great Basin.

Representativeness Concern #2: Pot. Adverse Cond.

Key Observations

- 60.122 requires that potentially adverse conditions be adequately investigated during site characterization.
- Data collection activities appear to be heavily biased to the northern part of the repository block although other areas may be more geologically complex.
- SCP Section 8.4.2 states that boreholes are unsuited for a statistical evaluation of fault and fracture characteristics.
- Relevant data may be limited due to a lack of drillholes designed to intersect vertical or near vertical discontinuities.
- Barton and Scott (1987) indicated that the detailed character of faults is not predictable from studies of any other part of the repository.

BACKGROUND

- Linehan to Gertz (letter, dated August 28, 1987)
- Stein to Youngblood (letter, received March 11, 1988)
- Youngblood to Stein (letter, dated May, 1988)
- CDSCP Comment 28 (May 11, 1988)

Representativeness Concern #2: Pot. Adverse Cond.

Recommendation

- Demonstrate that the program of drifting and systematic and feature sampling drilling will adequately investigate potentially adverse conditions
- Consider instituting a program of angled drillholes to identify and assist in characterizing vertical or near vertical features.
- Planned drilling programs should be integrated with planned drifting and geophysical programs

DOE/NRC MEETING ON TECTONICS 8/30–31/89

NRC CONCERNS REGARDING INVESTIGATION OF POTENTIALLY ADVERSE CONDITIONS

FAULTING

1. Imbricate Faults
2. Fault Characterization
3. Performance Allocations

Keith I. McConnell
Geology/Geophysics Section
Division of High-Level Waste Management

Attachment 7

FAULTING

SCA CONCERNS

1. Imbricate Faults:
   No studies appear to address the potential impact on performance of a significant number of faults in waste emplacement areas (SCA Comment 36).

2. Fault Characterization:
   Methods for characterizing and assessing the impact of faults do not appear to be sufficient to collect data necessary to adequately investigate preclosure faulting and the potentially adverse condition (SCA Comments 48, 50, 61, 62, 64, 65, 68, 69)

3. Performance Allocation:
   The performance allocation process used in the consideration of faulting does not appear to be adequate (SCA Comments 47, 60, 71)

Faulting Concern #1: Imbricate Faults

Key Observations

- Figures in the SCP (e.g., 8.4.2-4) suggest that the imbricate fault zone on the east extends well into the perimeter drift.
- Section 8.3.1.17.2.1.2 states that the program does not expect to encounter faults in the waste emplacement areas.
- The SCP implies that consideration is being given to emplacing waste in or near recognized fault zones.
- 60.133(h) requires that the engineered barriers be designed to assist the geologic setting in meeting the performance objectives. The presence of significant number of faults in waste emplacement areas suggests that this requirement may not be met.

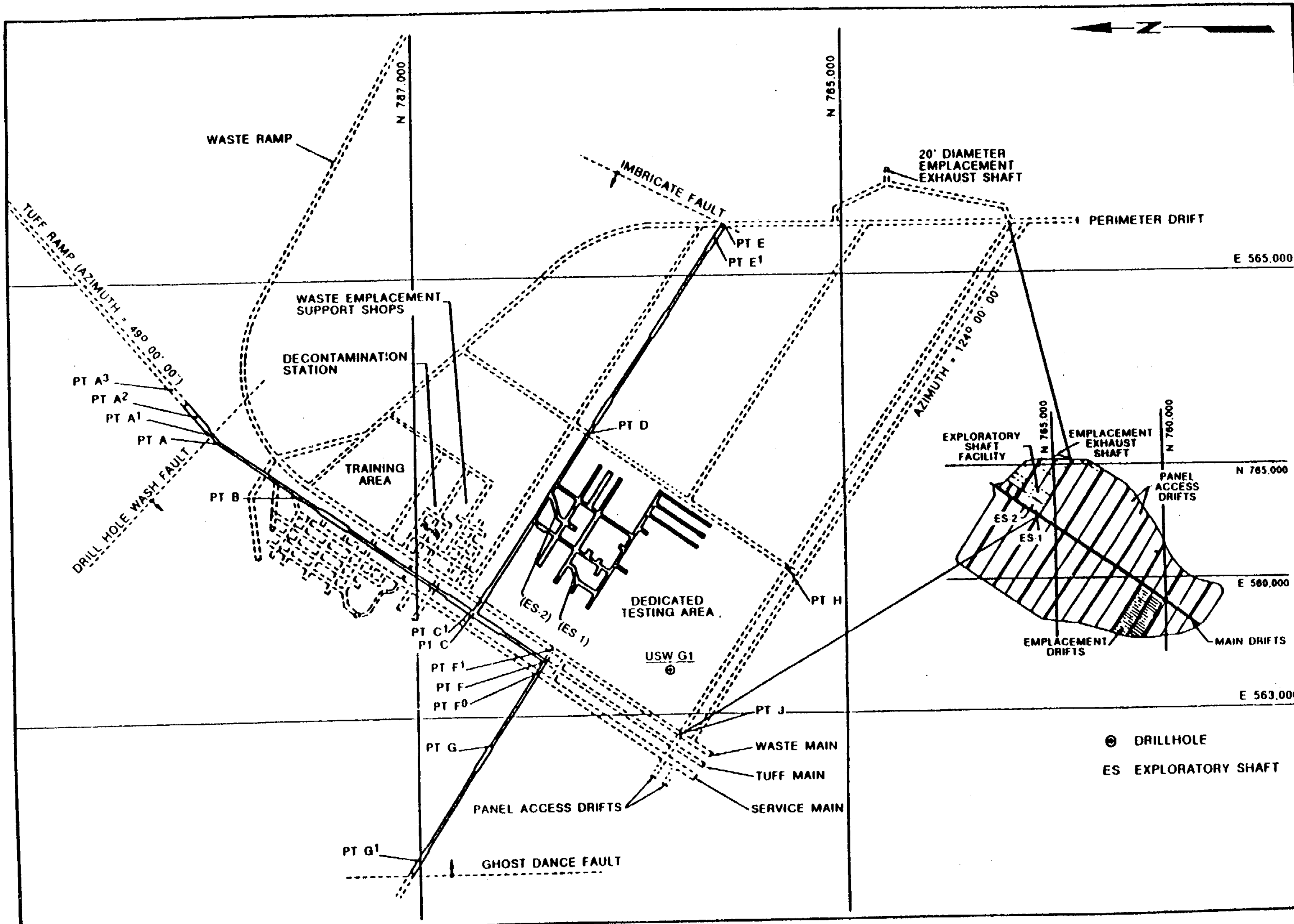


Figure 8.4.2-4. Conceptual repository layout in vicinity of the exploratory shaft facility dedicated test area and exploration drifts.

Faulting Concern #1: Imbricate Faults

Recommendation

- If the imbricate fault zone is present within the perimeter drift, an assessment should be made to demonstrate that the requirements of 60.133(h) will be met.

Faulting Concern #2: Fault Characterization

Key Observations

- The use of fault slip rates to determine the level of hazard posed by faults may result in predictions that are likely to underestimate the effects of faulting on performance (SCA Comment 48).
- Faults appear to be considered as single strands of narrow width (SCA Comment 50).
- The program of investigations for faulting appears to assume that future faulting will follow old fault patterns (SCA Comment 61).
- No information is presented as to how standoff distances from faults will be used in designing the program of investigations and in performing the resultant design and anaylsis (SCA Comment 62).

Faulting Concern #2: Fault Characterization

Key Observations (cont.)

- The characterization parameters for the characterization of faults in the area of the repository block do not appear to fulfill the requirements of Part 60 (SCA Comment 64).
- The use of domains to define areas of "faulting potential" does not appear to be a reasonably conservative approach to assess the potential for fault movement (SCA Comment 65).
- Other aspects of detachment faulting in addition to those described in Section 8.3.1.17.4.5 regarding key questions to be answered on earthquake sources do not appear to be treated as similarly potentially significant (SCA Comment 68).
- The SCP does not appear to integrate and synthesize data from activities related to northwest- trending faults (SCA Comment 69) .

Faulting Concern #2: Fault Characterization

Recommendations

- Consider alternative methods or a combination of methods to assess the hazard to the surface facilities and EBS posed by faulting (SCA Comment 48).
- Characterization of faults should consider alternative models of faulting in which faults are not independent entities (SCA Comment 50).
- Review investigations for FITS to assure that assumptions such as faulting only occurring at the exact locations of past faulting do not bias the program of investigations (SCA Comment 61).
- Demonstrate that the program of investigations for faulting will adequately evaluate all faults that have the potential for movement and assure that the effects of faulting will not compromise the ability of the FITS to meet the performance objectives (SCA Comment 62) .

Faulting Concern #2: Fault Characterization

Recommendations (cont.)

- The site characterization program should assure that any fault that could have a potential impact on isolation will be characterized (SCA Comment 64).
- Consider using domains to only describe areas of similar fault characteristics (SCA Comment 65).
- The significance of detachment faulting as a key element in assessing the potential for faulting at the site needs to be readdressed giving consideration to other key concerns related to detachment faulting (SCA Comment 68) .
- A program of study integrating and synthesizing data on northwest-trending faults should be implemented (SCA Comment 69) .

Faulting Concern # 3: Performance Allocation

Key Observations

- The approach to incorporating postclosure tectonics program data into waste package and EBS performance issues is confusing and may result in an inaccurate assessment of performance (SCA Comment 47).
- The basis and rationale for the design and performance parameters, characterization parameters, and goals proposed for fault displacement have not been justified (SCA Comment 60).
- The tentative goal, design parameter and expected value related to faulting and performance allocation for System Element 1.1.2 are not sufficient to adequately characterize the hazard posed by faulting (SCA Comment 71).

Faulting Concern # 3: Performance Allocation

Recommendations

- Establish a direct path for integration of data collected in the Postclosure Tectonics program into Issues 1.4 and 1.5 (SCA Comment 47).
- Provide justification for design and performance parameters, characterization parameters, and goals for preclosure fault displacement (SCA Comment 60).
- Use alternative fault models as a conceptual basis for assessing the preclosure hazard to the repository (SCA Comment 71).

DOE/NRC MEETING ON TECTONICS 8/30–31/89

Clarification and Resolution of SCA Concerns Investigation of Potentially Adverse Conditions

GROUND MOTION

1. 10,000–Year Cumulative Slip Earthquake
2. Comprehensive Earthquake Data

Abou–Bakr Ibrahim
Geology/Geophysics Section
Division of High–Level Waste Management

Attachment 8

GROUND MOTION

SCA Concerns

1. 10,000-Year Cumulative Slip Earthquake:

The 10,000-year comulative slip earthquake methodology appears to imply an assumed fixed recurrence interval of 10,000 years (SCA Comment 66).

2. Comprehensive Earthquake Data:

The Cut-off of 5.5 Magnitude for Earthquake Data (Activity 8.3.1.17.4.1.2) may not Provide Data Sufficient for Site Characterization (SCA Comment 67).

GROUND MOTION CONCERN #1: 10,000-YEAR CUMULATIVE SLIP EARTHQUAKE

Key Observations

- The 10,000-year recurrence interval selected to characterize the cumulative displacement for the 10,000-year CSE, appears to be the minimum recurrence interval for the region.

- Use of a 10,000-year recurrence interval will result in a minimum cumulative displacement, which results in a minimum magnitude

- The description of the 10,000-year CSE presented in Section 8.3.1.17.1.2 does not appear to clearly address recurrence

GROUND MOTION CONCERN #1: 10,000–YEAR CUMULATIVE SLIP EARTHQUAKE (Continued)

Recommendations

- Give special emphasis to recurrence–rate estimate studies
- Assure that site–characterization activities will permit comparison of the 10,000–year CSE methodology with alternative methodologies

GROUND MOTION CONCERN #2:
COMPREHENSIVE EARTHQUAKE DATA

Key Observations

- Earthquake parameters listed under Activity 8.3.1.7.4.1.1 that are needed for earthquake characterization will only be compiled for the larger ($m \geq 5.5$) earthquakes.

- Based on the 5.5 magnitude cut-off, it is unlikely that enough earthquake parameters will be compiled for Yucca Mountain

GROUND MOTION CONCERN #2: COMPREHENSIVE EARTHQUAKE DATA (Continued)

Recommendations

- Analyze earthquake data that are reasonable and practical without regard to a magnitude distinction

DOE/NRC MEETING ON TECTONICS 8/30–31/89

VOLCANISM

1. Alternative Tectonic Models
2. Area of Investigation
3. Consideration of Volcanic Processes
4. Performance Goals
5. Example: Preliminary Evaluation

John S. Trapp
Geology/Geophysics Section
Division of High-Level Waste Management

Attachment 9

VOLCANISM

SCA CONCERNS

1. Alternative Tectonic Models:

   Alternative tectonic models do not appear to be fully integrated into the SCP (SCA Comment #8).

2. Area of Investigation:

   The current representation of the "physical domain" appears inadequate (SCA Comment #46, Question #12).

3. Consideration of Volcanic Processes:

   Rate calculations appear unconservative, appear, in part, to be unsupported, and are developed independent of the underlying volcano-tectonic processes (SCA Comments 43, 45; Question #13).

4. Performance Goals:

   Meeting the goals set for volcanism studies will not allow the site to meet the EPA standard. (SCA Comment #49)

VOLCANISM CONCERN #1: ALTERNATIVE TECTONIC MODELS

KEY OBSERVATIONS

1. Alternative tectonic models are not fully factored into investigations to address volcanism. Volcanism studies do not appear to be sufficiently integrated with regional fault studies to provide an integrated model (SCA Comment #8).

VOLCANISM CONCERN #1: ALTERNATIVE TECTONIC MODELS

RECOMMENDATIONS

- Integrate alternative tectonic models into preliminary performance allocation and the design of the EBS.

- Use tectonic models to prioritize investigations giving high priority to those associated with tectonic features, events, or processes that could lead to the site being considered unlicensible.

VOLCANISM CONCERN #2: AREA OF INVESTIGATION

KEY OBSERVATIONS

- 10 CFR 60.21 requires that models be supported by an appropriate combination of such methods as field tests, in situ tests, . . ., and natural analog studies (SCA Question #12).

- The 70 km limit on volcanic activities (Section 8.3.1.8.5) appears to exclude the Lunar Crater volcanic field from consideration (SCA Question #12).

- The Death Valley Pancake Range volcanic belt (zone) extends through the site and processes that resulted in the formation of the Lunar Crater Field may be applicable to the site (SCA Comment #46).

VOLCANISM CONCERN #2: TESTING PROGRAM

RECOMMENDATIONS

- The 70 km limit on activities to investigate volcanic processes should be reconsidered.

- Consideration should be given to extending the area of consideration for alternative tectonic models related to volcanism to areas outside the southern Great Basin including the lower crust and upper mantle.

VOLCANISM CONCERN #3: VOLCANIC PROCESSES

KEY OBSERVATIONS

1. Probability calculations do not appear to be conservative in establishing the hazard in that they assume a uniform distribution of volcanism through time and appear to overlook possible structural control, uncertainty in the processes responsible for volcanism, and uncertainty in dating Quaternary volcanic events (SCA Comment #45).

2. Averages of cone counts through time are likely to underestimate the rates of volcanic eruptions over a given period of time (SCA Comment #43).

3. No data appear to be presented in the SCP to adequately support the statement made in Activity 8.3.1.8.5.1.5 that a southwestwardly migration of basaltic activity has occurred (SCA Question #13).

VOLCANISM CONCERN #3: VOLCANIC PROCESSES

RECOMMENDATIONS

- More consideration should be given to characterizing volcanic processes in the geologic setting.

- Goals should be provided that are not likely to underestimate maximum single-event disruptions or average values should be demonstrated to be conservative.

- Assumptions and preferred models of processes should in the geologic setting should be fully supported.

VOLCANISM CONCERN #4: PERFORMANCE GOALS

KEY OBSERVATIONS

1. The annual probability goal of 10E-6 given in the SCP is greater than one chance in 1,000 to 10,000 years that is required by the EPA Standard (SCA Comment #49).

2. A goal for release on the order of one tenth of one percent of repository inventory would result in an EPA ratio of 170 at closure. Even with radioactive decay, the standard would be exceeded (SCA Comment #49).

VOLCANISM CONCERN #4: PERFORMANCE GOALS

RECOMMENDATIONS

- Set goals to assure that the performance objectives can be met.

VOLCANISM EXAMPLE: PRELIMINARY EVALUATION

BASIC QUESTIONS WHEN EVALUATING EXTERNAL OR INTERNAL EVENTS IN ANY LICENSING PROCEDURE

- What can occur?
- Where can it occur?
- How likely is it to occur?
- What are consequences if it does occur?
- How can consequences be prevented or mitigated?

PRIMARY REGULATIONS

40 CFR 191.13 (EPA Standard)

10 CFR 60.112 (Overall System Performance)

10 CFR 60.122 (Siting Criteria)

- 122(A)(2)(I) Adequate Investigations
- 122(A)(2)(II) Analysis Not Likely to Underestimate Effects
- 122(A)(2)(III) No Significant Effect, or Compensated for, or Remedied

The changes do not reflect any departure from the Commission's original philosophy, but they are designed to express its purpose more clearly. Thus, its interest in specifying that the geologic setting shall have exhibited "stability" since the start of the Quarternary Period was to assure only that the processes be such as to enable the recent history to be interpreted and to permit near-term geologic changes to be projected over the relevant time period with relatively high confidence. This concept is best applied by identifying, as potentially adverse conditions, those factors which stand in the way of such interpretation and projection: this is the approach the Commission has chosen to follow.

Federal Register, Vol. 48, No. 120, Pg. 28201, 21 June 1983

MATH BEHIND PROBABILITY CALCULATIONS

cone count = area of site / area of zone X time / time span of cones / number of cones

magma rate = area of site / area of zone X time / critical volume / magma production rate

BASIC QUESTIONS WHEN EVALUATING EXTERNAL OR INTERNAL EVENTS IN ANY LICENSING PROCEDURE

What can occur?

Where can it occur?

How likely is it to occur?

What are consequences if it does occur?

How can consequences be prevented or mitigated?

VIEW OF CRATER FLAT

VIEW OF LATHROP WELLS CONE

BASIC QUESTIONS WHEN EVALUATING EXTERNAL OR INTERNAL EVENTS IN ANY LICENSING PROCEDURE

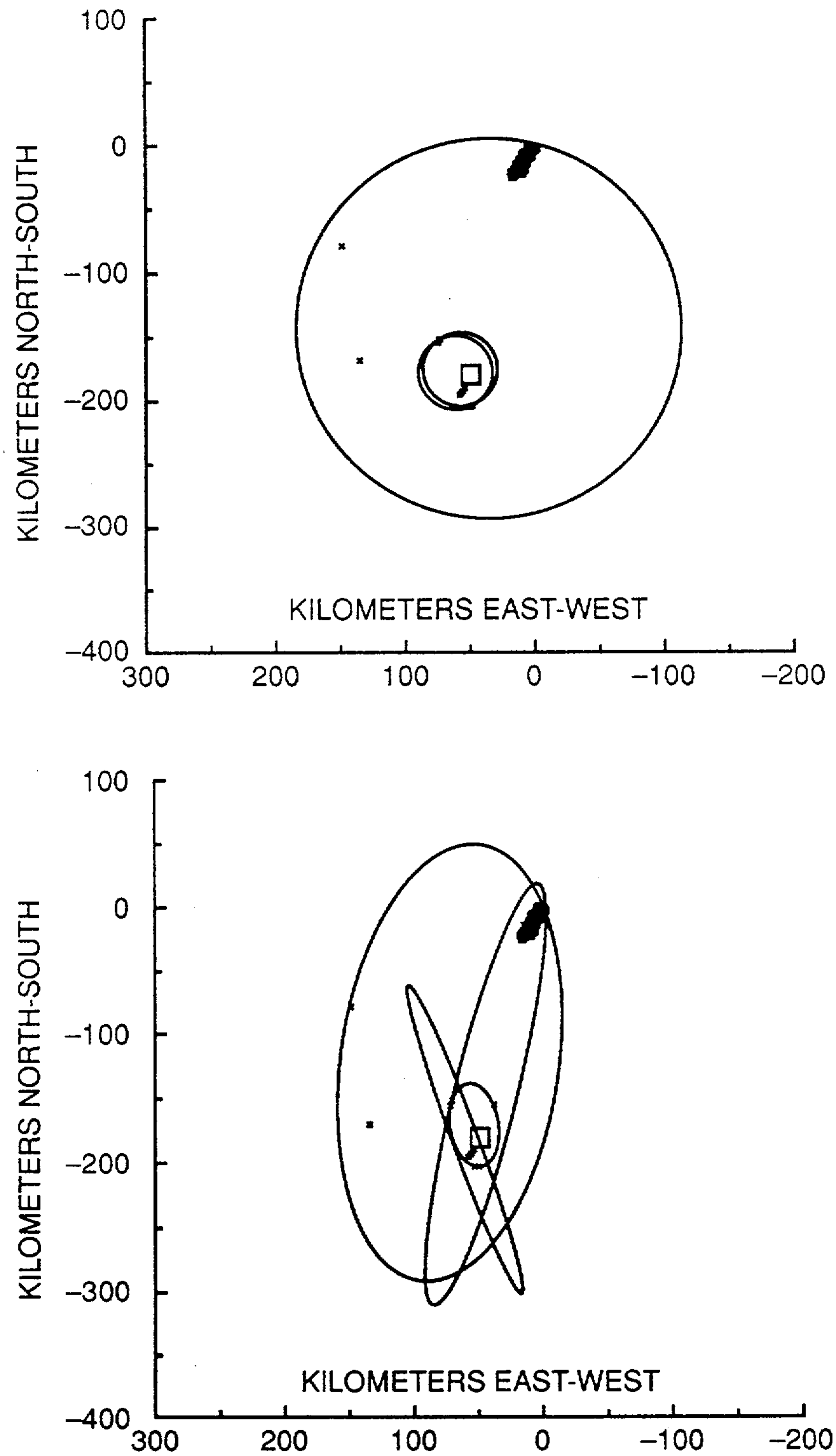
What can occur?

Where can it occur?

How likely is it to occur?

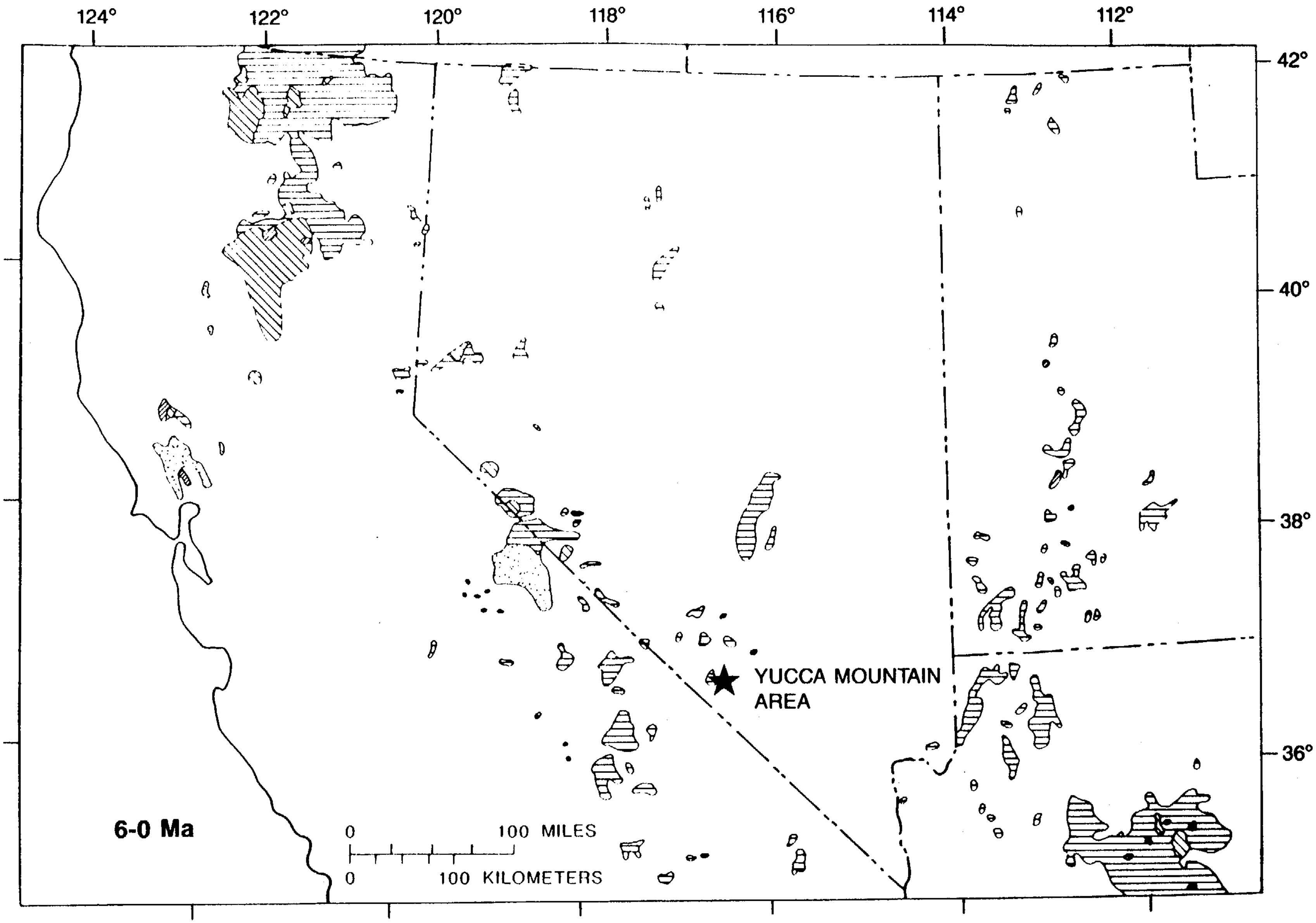
What are consequences if it does occur?

How can consequences be prevented or mitigated?



A: Calculated minimum area circles based on the distribution of Quaternary basalt centers in the southern Great Basin. Cases 1 and 1a are defined by the small circle; cases 2 and 3 are defined by the larger circle. B: Calculated minimum area ellipses based on the distribution of Quaternary basalt centers in the southern Great Basin. Cases 1 and 1a are defined by the two smaller ellipses, case 2 by the intermediate-sized ellipse, case 3 by the large ellipse. The location of volcanic centers is marked by the x's; the repository site by the square.
From CROWE ET AL., 1982

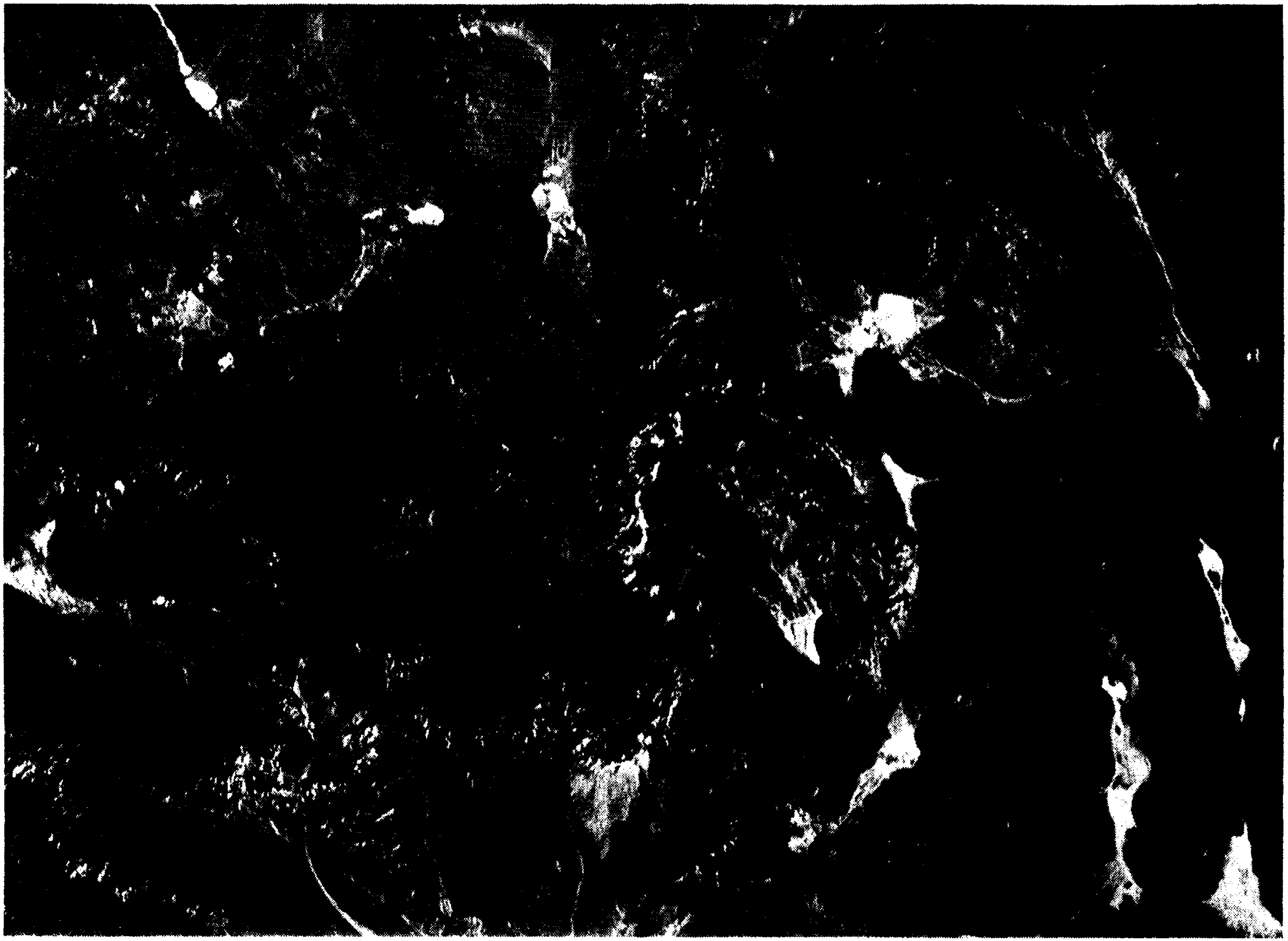
Note: Calculations based on circles and ellipses represented in previous figure assume tectonic model which requires equal probability of eruption at all locations within the chosen border.

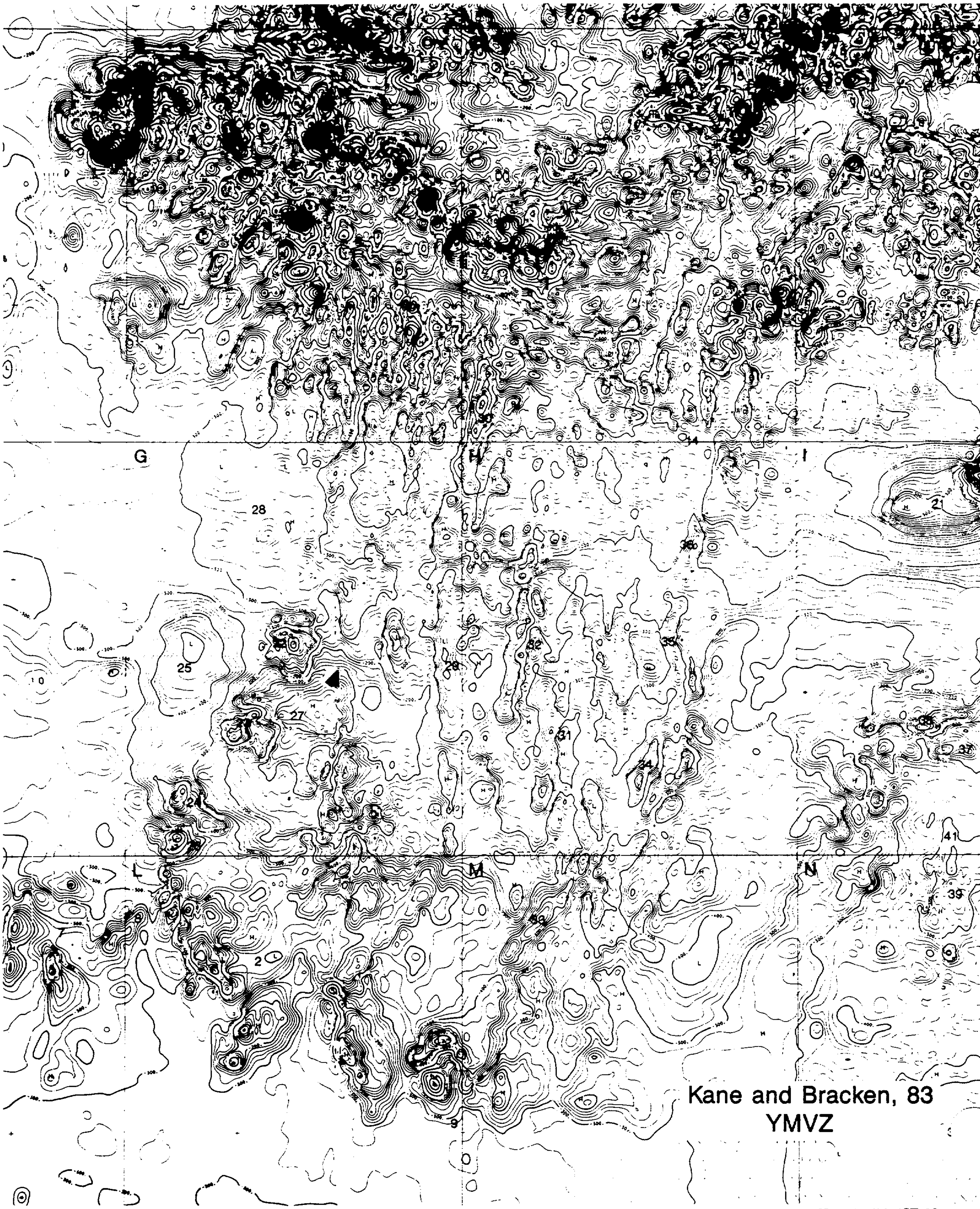


Distribution of the Cenozoic volcanic rocks in the southern Great Basin. Time periods shown are 43-34 Ma (map a), 34-17 Ma (map b), 17-6 Ma (map c), and 6-0 Ma (map d). Ma = million years ago. Modified from Stewart et al. (1977).

From SCP, Chapter 1.

SATELLITE IMAGE OF AREA AROUND YUCCA MOUNTAIN





Kane and Bracken, 83
YMVZ

TECTONIC SETTING OF MAJOR BASALT FIELDS IN THE VOLCANIC BELT OF THE SOUTHCENTRAL GREAT BASIN

Locality	Tectonic Setting
Southern Death Valley	On the Death Valley fault zone, a major NW trending, right-slip fault.
Greenwater-Black Ranges	An area of volcanic activity located within a possible "pull apart" rift basin between the Furnace Creek and Death Valley fault zones.
NTS region (basalts of the silicic cycle)	Within or flanking cauldron complexes, commonly on ring-fracture systems.
NTS Region (rift basalts)	(1) Caldera ring-fracture systems, commonly at their intersection with basin-range faults, (2) basin-range faults, and (3) N-NE trending zones of extension, possibly located between en echelon segments of NW trending strike-slip faults of the Walker Lane structural system. May be analogous to a "leaky transform" setting (see Weaver and Hill, 1979).
Kawich Valley	Basin-Range faults.
Reveille Range	(1) Basin-Range faults and (2) N-NE trending extensional zones between N-NW trending, right-slip faults with a probable older history of left-slip offset (Tybo-Reveille fault system).
Lunar Crater volcanic field	Major N-NE trending rift zone that cuts across a major N-S trending Basin-Range block and older cauldron complexes (20 to 30 Myr). Rift may have followed an older system that localized silicic volcanism (Ekren et al., 1974b). Older basalts were erupted along cauldron ring-fracture zones; younger basalts follow the N-NE trending rift zone.

From Crowe et al., 1983

BASIC QUESTIONS WHEN EVALUATING EXTERNAL OR INTERNAL EVENTS IN ANY LICENSING PROCEDURE

What can occur?

Where can it occur?

How likely is it to occur?

What are consequences if it does occur?

How can consequences be prevented or mitigated?

COMPARISON OF ALTERNATIVE AREAS

Magma production rates

NTS 3 to 8 × 10E-11 KM3/KM2/yr (Crowe, et al., 83)

YMVZ 3 x 10E-10 KM3/KM2/yr

Probability from cone count

DOE 4.7 x 10E-4 to 5.1 x 10E-5 (Crowe, et al., 82)

YMVZ 4.7 x 10E-4

Studies in Western United States

Possible 10 fold increase in activity between 1 – 5 MYBP to 100,000 YBP

Possible increase from 100,000 YBP to present (Smith and Luedke, 1984)

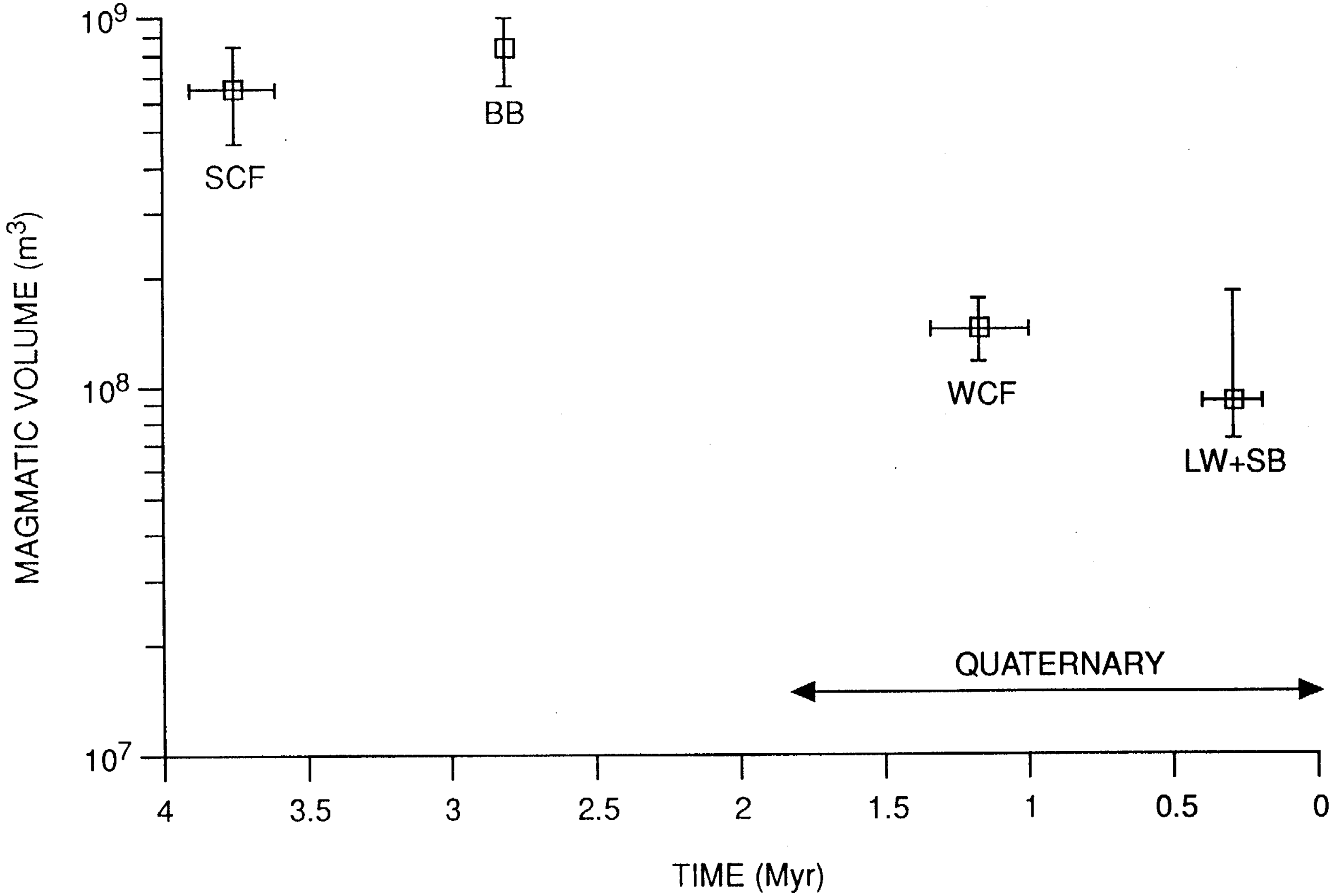
ALTERNATIVE MAGMA RATE CALCULATION

- Crater Flat + Lathrop Wells Equals About 1.9 × 10E+8 Cubic Meters in Last 1.5 m.y. (Crowe, et al., 1982, and Crowe, et al., 1983)

- Rate Equals About 127 Cubic Meters per Year

- Lathrop Wells Equals About 5.7 × 10E + 7 Cubic Meters

- If This Represents Last 100,000 Years Rate Is About 570 Cubic Meters per Year



CROWE, ET AL., 82
CROWE, ET AL., 83

Note: Rate of magma production is assumed to be decreasing based on regression analysis of data represented in previous figure.

TABLE III

Predicted Time of Future Basaltic Activity Based on Annual Rate of Magma Production, Nevada Test Site Region

Rate of Magma Production (m^3 yr^{-1})	Annual rate/area ($km^3/km^2/yr$)	Time of Magma Production[a] (4 m.y.)	Predicted Time of Activity[b] (4 m.y.)	Time of Magma Production[c] (1.8 m.y.)	Predicted Time of Activity (1.8 m.y.)	Time of Magma Production[d] (Smallest Volume)	Predicted Time of Activity (Smallest Volume)
210	8.5×10^{-11}	2.0×10^6	1.7×10^6	5.2×10^5	2.5×10^5	3.6×10^5	9.0×10^4
75.6	3.1×10^{-11}	5.7×10^6	5.4×10^6	1.4×10^6	1.1×10^6	1.0×10^6	7.3×10^5

[a]The time of magma production is the magma volume divided by the rate of magma production. The mean volume of magma cycles during the last 4.0 m.y. (Vm) is 4.3×10^8 m^3. Standard deviation (SD) is 91% of the magma volume.

[b]The predicted time of future volcanic activity (T_p) is T_p = Tm-Tb where Tm is the time of magma production and Tb is the age of the youngest basaltic activity (2.7×10^5 yr).

[c]The mean volume of magma cycles during the last 1.8 m.y. (Vq) is 1.1×10^8 m^3. SD is 40% of the magma volume.

[d]The mean volume of the smallest pulse of basaltic activity erupted during Quaternary time (Vs) is 7.6×10^7 m^3. SD is 60% of the magma volume.

(Table from Crowe, et al., 1982)

Note: Average rate for 4 m.y. is 430 m^3/year and average for 1.8 m.y. is 123 m^3/year. See 10 CFR 60.122(a)(2)(II).

TABLE III

Predicted Time of Future Basaltic Activity Based on Annual Rate of Magma Production, Nevada Test Site Region

Rate of Magma Production (m^3 yr^{-1})	Annual rate/area ($km^3/km^2/yr$)	Time of Magma Production[a] (4 m.y.)	Predicted Time of Activity[b] (4 m.y.)	Time of Magma Production[c] (1.8 m.y.)	Predicted Time of Activity (1.8 m.y.)	Time of Magma Production[d] (Smallest Volume)	Predicted Time of Activity (Smallest Volume)
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[d]The mean volume of the smallest pulse of basaltic activity erupted during Quaternary time (Vs) is 7.6×10^7 m^3. SD is 60% of the magma volume.

(Table from Crowe, et al., 1982)

Note: (1) Predicted time of magma production and activity decreases when comparing 4 m.y. with 1.8 m.y.

TABLE III

Predicted Time of Future Basaltic Activity Based on Annual Rate of Magma Production, Nevada Test Site Region

Rate of Magma Production (m^3 yr^{-1})	Annual rate/area ($km^3/km^2/yr$)	Time of Magma Production[a] (4 m.y.)	Predicted Time of Activity[b] (4 m.y.)	Time of Magma Production[c] (1.8 m.y.)	Predicted Time of Activity (1.8 m.y.)	Time of Magma Production[d] (Smallest Volume)	Predicted Time of Activity (Smallest Volume)
210	8.5×10^{-11}	2.0×10^6	1.7×10^6	5.2×10^5	2.5×10^5	3.6×10^5	9.0×10^4
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[a]The time of magma production is the magma volume divided by the rate of magma production. The mean volume of magma cycles during the last 4.0 m.y. (Vm) is 4.3×10^8 m^3. Standard deviation (SD) is 91% of the magma volume.
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[d]The mean volume of the smallest pulse of basaltic activity erupted during Quaternary time (Vs) is 7.6×10^7 m^3. SD is 60% of the magma volume.

(Table from Crowe, et al., 1982)

Note: (1) Assumes 4 cones in Crater Flat, 1 cone at Lathrop Wells and 2 cones at Sleeping Butte statistically compatable groups. (2) Assumes Lathrop Wells pulse is complete. (3) Assumes Lathrop Wells is not related to Crater Flat pulse.

TABLE III

Predicted Time of Future Basaltic Activity Based on Annual Rate of Magma Production, Nevada Test Site Region

Rate of Magma Production ($m^3\ yr^{-1}$)	Annual rate/area ($km^3/km^2/yr$)	Time of Magma Production[a] (4 m.y.)	Predicted Time of Activity[b] (4 m.y.)	Time of Magma Production[c] (1.8 m.y.)	Predicted Time of Activity (1.8 m.y.)	Time of Magma Production[d] (Smallest Volume)	Predicted Time of Activity (Smallest Volume)
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[a]The time of magma production is the magma volume divided by the rate of magma production. The mean volume of magma cycles during the last 4.0 m.y. (Vm) is $4.3 \times 10^8\ m^3$. Standard deviation (SD) is 91% of the magma volume.
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[c]The mean volume of magma cycles during the last 1.8 m.y. (Vq) is $1.1 \times 10^8\ m^3$. SD is 40% of the magma volume.
[d]The mean volume of the smallest pulse of basaltic activity erupted during Quaternary time (Vs) is $7.6 \times 10^7\ m^3$. SD is 60% of the magma volume.

(Table from Crowe, et al., 1982)

Note: (1) Calculations are for magma pulses, not eruptions or cones. (2) Mean volume of smallest pulse is larger than volume of Lathrop Wells, Little Cone 1, Little Cone 2, Red Cone, Sleeping Butte 1 or Sleeping Butte 2.

PROBABILITY CALCULATIONS USING MAGMA PRODUCTION RATE FOR VOLCANIC DISRUPTION OF A DEEPLY BURIED WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA TEST SITE

λ(a)	1 yr	10 yr	Comments
$\frac{t}{Vm/r_1}$	1.9×10^{-9}	1.9×10^{-4}	A = circle
$\frac{t}{Vm/r_1}$	1.0×10^{9}	1.0×10^{-4}	A = ellipse
$\frac{t}{Vm/r_2}$	6.1×10^{-10}	6.0×10^{5}	A = circle
$\frac{t}{Vm/r_2}$	3.3×10^{-10}*	3.3×10^{5}	A = ellipse
$\frac{t}{Vq/r_1}$	1.3×10^{-8}	1.3×10^{-3}	A = circle
$\frac{t}{Vq/r_1}$	7.2×10^{-9}	7.2×10^{-4}	A = ellipse
$\frac{t}{Vq/r_2}$	2.9×10^{-9}	2.9×10^{-4}	A = circle
$\frac{t}{Vq/r_2}$	1.6×10^{-9}	1.6×10^{-4}	A = ellipse
$\frac{t}{Vs/r_1}$	3.7×10^{-8}**	3.7×10^{-3}	A = circle
$\frac{t}{Vs/r_1}$	2.0×10^{-8}	2.0×10^{-3}	A = ellipse
$\frac{t}{Vs/r_2}$	4.6×10^{-9}	4.6×10^{-4}	A = circle
$\frac{t}{Vs/r_2}$	2.5×10^{-9}	2.5×10^{-4}	A = ellipse

(a)t is time in years, Vm is the mean magma volume for 4 m.y.; Vq is the mean magma volume for Quaternary time; Vs is the mean volume of the smallest pulse of magma during Quaternary time; r_1 is the rate of magma production for 4 m.y.; r_2 is the rate of magma production for Quaternary time.

*Represents the minimum annual probability bound based on rate of magma production.

**Represents worst case annual probability bound based on rate of magma production.

Crowe, et al., 82

Note: Probability calculations presented in previous table are based on an assumed area, an assumed rate of magma production, and an assumed required volume of magma prior to disruption being possible. Probabilities obtained are only as valid as the geologic validity of the assumptions.

COMPARISON OF PROBABILITIES ASSUMING ALTERNATIVE MAGMA PRODUCTION (ERUPTION) RATES AND ALTERNATIVE AREAS

DOE 3.7 × 10E-4 to 3.3 × 10E-8 (Crowe, et al., 82)

YMVZ

Assume magma production rate = 500 m^3/yr

Assume critical volume between 10E+6 to 10E+7 m^3

Time for eruption between 2,000 and 20,000 years

$p = 1/70 \times 5$ to $1/70 \times 1/2 = 7 \times 10E-2$ to $7 \times 10E-3$

The "eruption rate" obtained from these data will differ dramatically depending on the time interval used and the way in which the events are distributed within that interval. Because volcanism is so episodic, both locally and globally, this problem will be encountered in almost every province and on every scale of measure. Unless one can define the temporal pattern of events and can say where we are in a cycle at a given time, the probabilistic calculations have little meaning.

A. R. McBirney, 1989, in Nureg/CR-3964

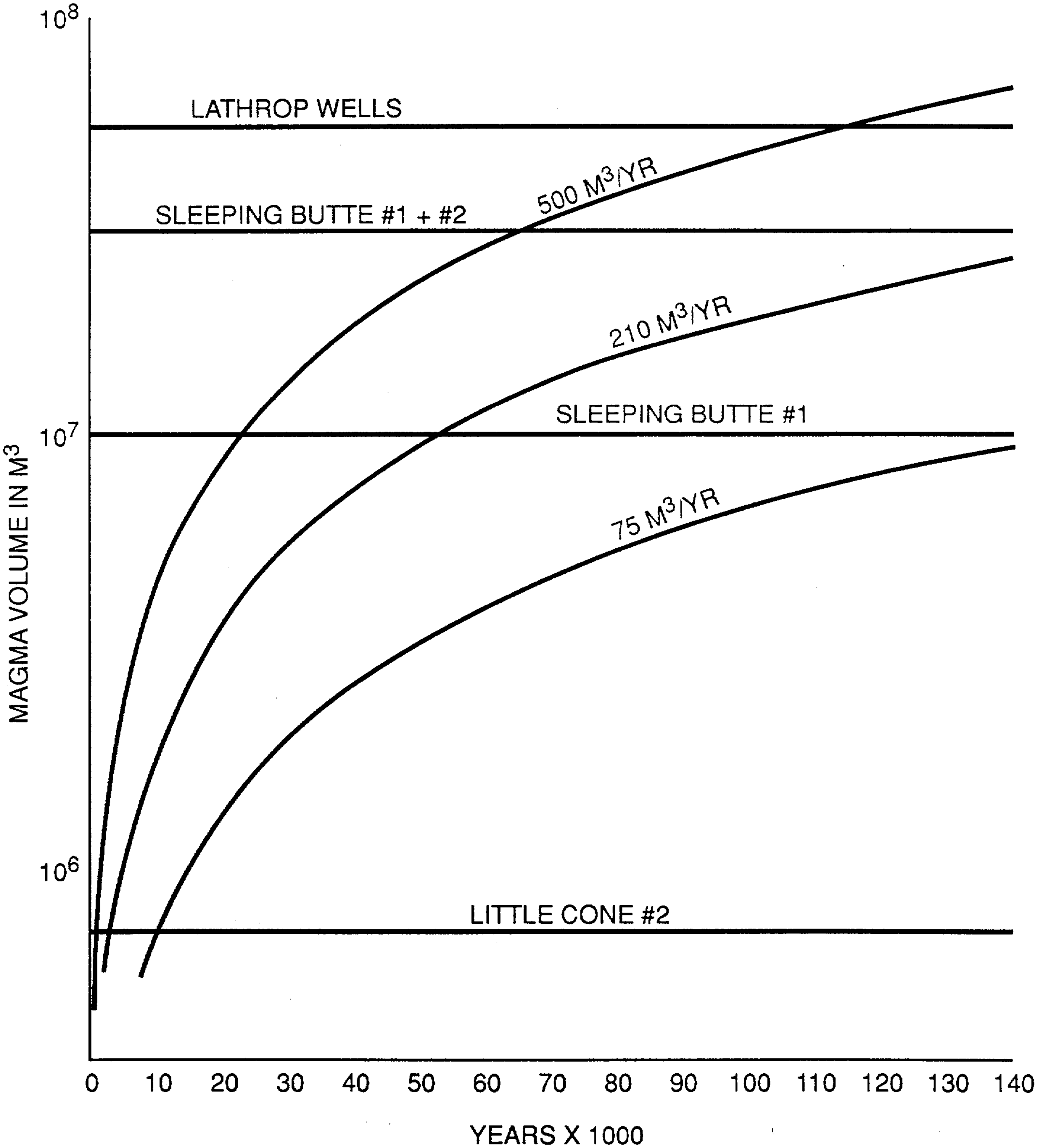
Thus, although present geologic knowledge provides tantalizing hints of the controls of magma production, the knowledge is insufficient to calculate future rates of volcanic activity with a reasonable degree of confidence. This is perhaps most true for regions with low rates of volcanic activity, such as the NTS region.

Crowe, Vaniman, and Carr, 1983, Pg. 37, (LA-9325-MS)

(2) Probability Calculations:

A significant degree of uncertainty is present in the probability calculations as a result of the geologic assumptions required for the rate calculations and their dependence on predictive geology. (Future rates are calculated from past rates of volcanism.) Because of this uncertainty, probability calculations are presented as a range spanning several orders of magnitude, and additional research approaches are used for hazard assessment. Particular attention must be paid to the time sensitivity of the probability method. *Field observations that provide the data base for the probability calculations are limited, and gathered data span a lengthy time period (3.7 × 10^6 yr). Therefore, they are most valid for long-range predictions (10^6 yr) and increasingly less valid for shorter periods of time. In particular, because of the small number of data points used in the probability calculations, the approach may be insensitive to short-term rate changes such as the time period required for waste containment.*

Crowe, Vaniman, and Carr, 1983, Pgs. 41-42, (LA-9325-MS)



10^8
10^7
10^6
MAGMA VOLUME IN M^3
LATHROP WELLS
SLEEPING BUTTE #1 + #2
500 M^3/YR
210 M^3/YR
SLEEPING BUTTE #1
75 M^3/YR
LITTLE CONE #2
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
YEARS X 1000

BASIC QUESTIONS WHEN EVALUATING EXTERNAL OR INTERNAL EVENTS IN ANY LICENSING PROCEDURE

What can occur?

Where can it occur?

How likely is it to occur?

What are consequences if it does occur?

How can consequences be prevented or mitigated?

COMPARISON OF ALTERNATIVE CONSEQUENCES

- From SCP Table 8.3.1.8-1B

  Less than 0.1 Percent of Repository

- Assume Volcanic Plug

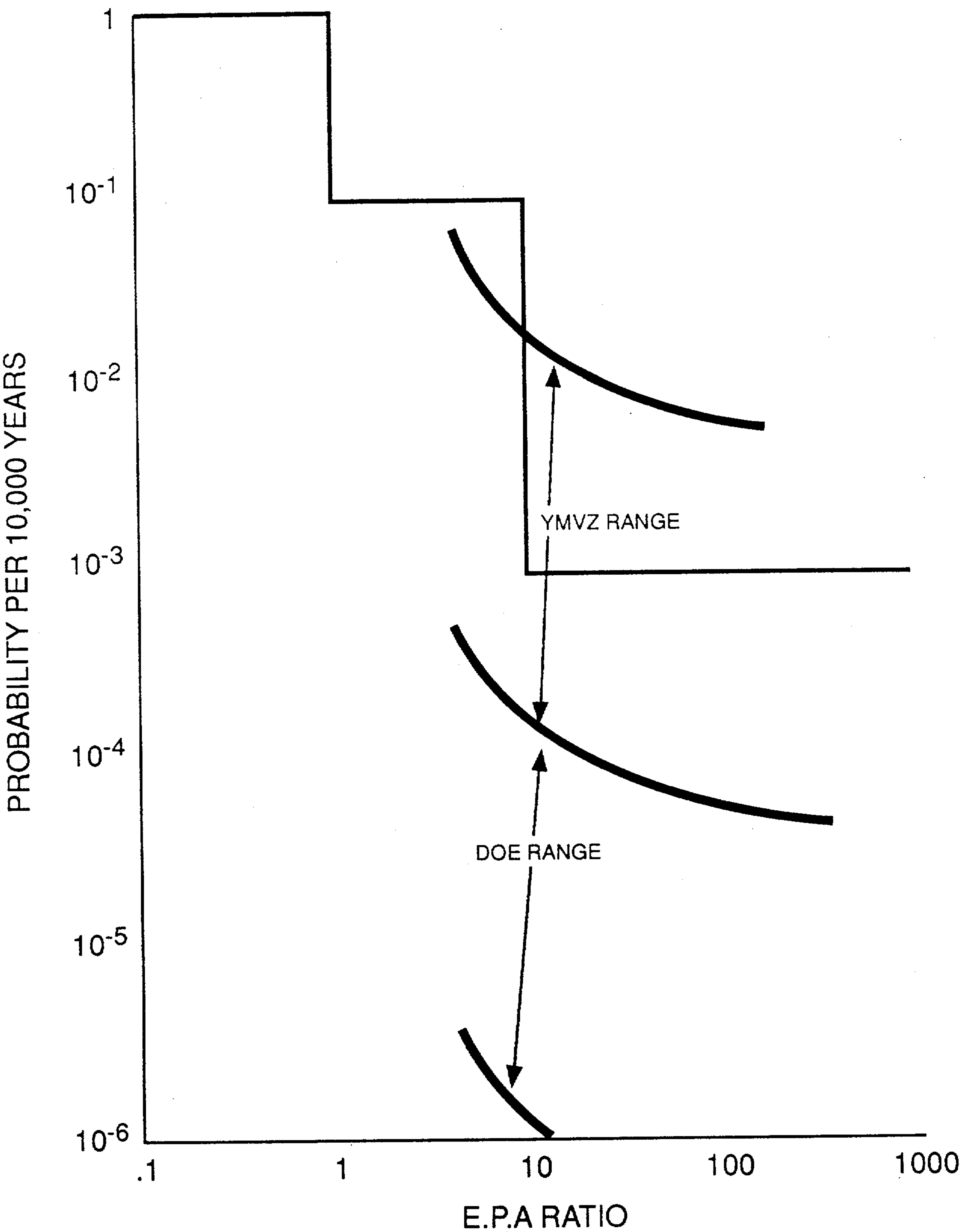
  0.1 to 0.3 Percent of Repository

- Assume Dike Through Respository

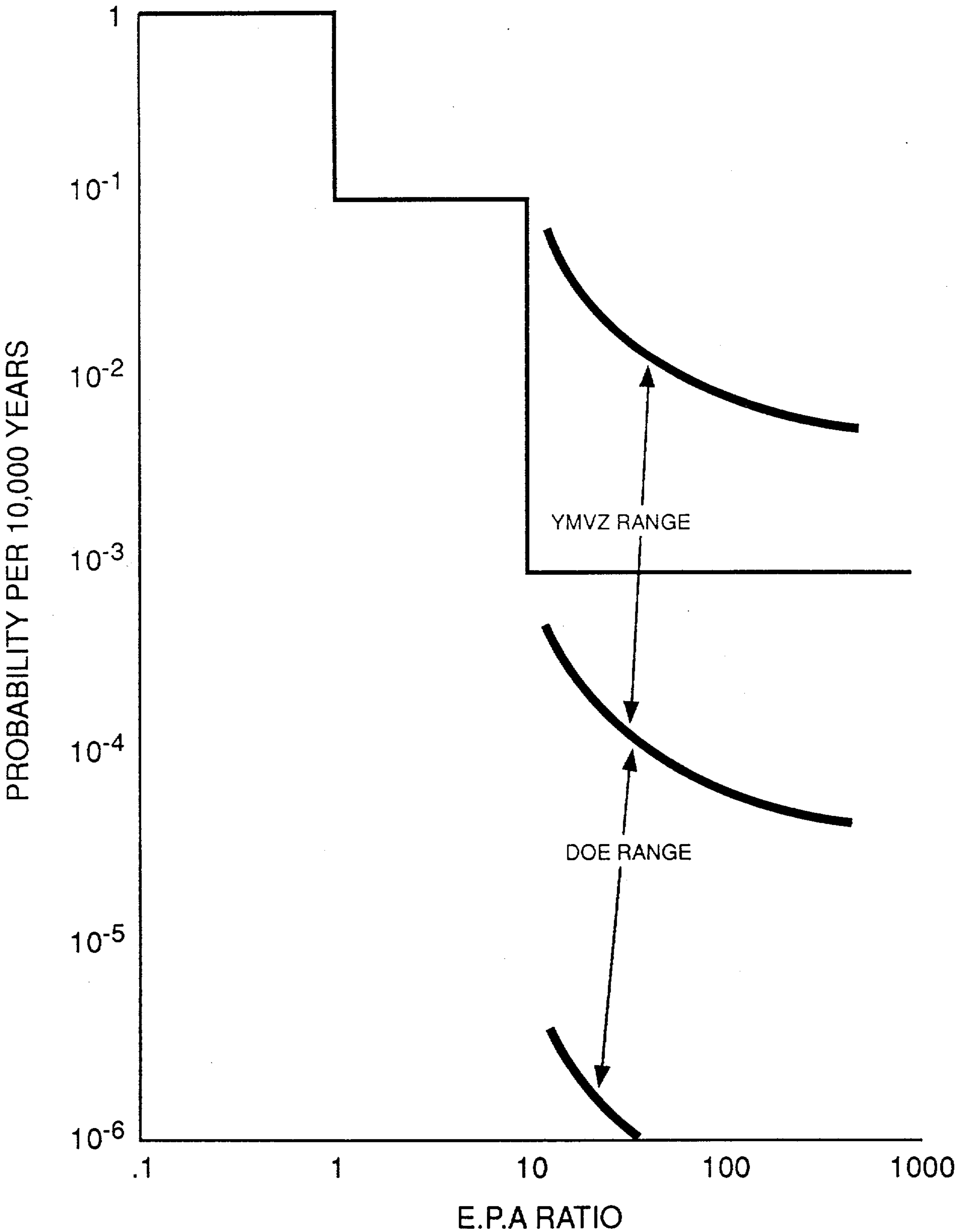
  Less than 0.01 to 0.5 Percent (Link, et al., 1982)

  0.75 Percent from Uniform Spacing

COMPARISON OF VOLCANIC SCENARIOS
.1 PERCENT REPOSITORY DISRUPTED



COMPARISON OF VOLCANIC SCENARIOS
.3 PERCENT REPOSITORY DISRUPTED



MAIN AREAS OF UNCERTAINTY

- Data Base Is Not "Statistically Robust"
- Relationship Between Tectonics and Volcanic Activity

OTHER AREAS OF UNCERTAINTY

- What is effect (both direct and indirect) from eruption near repository?

- How should multiple eruptions be factored into calculations?

- What is expected effect due to hydrovolcanic activity?

BASIC QUESTIONS ABOUT VOLCANISM WHICH MUST BE RESOLVED BY SITE CHARACTERIZATION ACTIVITIES

- What can occur?
  Volcanism
- Where can it occur?
  Can controlling feature(s) be determined?
- How likely is it to occur?
  Magma production (eruption) rate?
  Critical volume?
  Part of cycle?
  Relationship of volcanics to tectonics?
- What are consequences if it does occur?
  Dike vs plug?
  Hydrovolcanics?
  Zone of influence?
  Secondary effects?
- How can consequences be prevented or mitigated?
  ???

CONCLUDING STATEMENTS - TECTONICS

- THE SCA CONCERNS REGARDING TECTONICS PRESENTED TODAY BY NRC STAFF, AS WELL AS SCA CONCERNS IN OTHER AREAS, HAVE LED NRC TO RECOMMEND THAT DOE SET HIGH PRIORITY FOR CONDUCTING INVESTIGATIONS WHICH CAN LEAD TO A DETERMINATION OF WHETHER THE SITE HAS UNACCEPTABLY ADVERSE CONDITIONS.

- THE SCA CONCERNS INDICATE A NEED FOR DOE TO CONDUCT SITE CHARACTERIZATION INVESTIGATIONS TO REDUCE, OR AT LEAST TO BETTER DEFINE THE BOUNDS OF, UNCERTAINTIES.

- THE SCA CONCERNS WITH RESPECT TO VOLCANISM FOCUS ON CONSIDERATION OF ALTERNATIVE INTERPRETATIONS OF DATA PROVIDED BY DOE. THE ALTERNATIVE MODEL PRESENTED BY DR. TRAPP SERVES TO EMPHASIZE THE LARGE UNCERTAINTIES IN THE DATA AND ASSUMPTIONS ABOUT VOLCANISM. ADDITIONAL TECTONIC MODELS CAN BE SUPPORTED BY THE LIMITED DATA BASE PRESENTLY AVAILABLE.

- THE NRC STAFF CONSIDERS THAT IT IS PREMATURE TO MAKE DEFINITIVE JUDGEMENTS ABOUT SITE SUITABILITY GIVEN THE CURRENTLY AVAILABLE INFORMATION.

Attachment 10

STATE OF NEVADA
SITE CHARACTERIZATION PLAN CONCERNS
REGARDING TECTONICS

NEVADA AGENCY FOR NUCLEAR PROJECTS

AUGUST 30 - 31, 1989

Attachment 11

NRC CONCERNS

- INTEGRATION OF DATA AND MODELS
- INTEGRATION OF PLANNED TESTING
- REPRESENTATIVENESS OF TESTS AND RESULTING DATA
- INVESTIGATION OF POTENTIALLY ADVERSE CONDITIONS

ADDITIONAL STATE CONCERNS

SITE CHARACTERIZATION PROGRAM

- Insufficient data set exists upon which an extensive characterization program can be based.

- Insufficient information available within the SCP (or the few Study Plans provided to date) to evaluate the adequacy or probable outcome of the proposed activities.

- SCP approach is too rigid (inflexible) to handle the discovery of fatal flaws.

- SCP approach is unlikely to produce critical data necessary to resolve issues.

TECTONICS PROGRAM

- Tectonic program designed on the basis of discrete initiating events.

- Tectonic program does not consider spatial and/or temporal clustering.

- Need is to first provide an accurate synthesis of the geologic setting of Yucca Mountain. Once the geologic setting has been acceptably defined, it should then be possible to evaluate the appropriateness of the SCP.

- There is no focus on regional or deep structures - only the 2-dimensional surface structures.

TECTONICS PROGRAM (cont'd)

- Preliminary probability risk assessments (and therefore the need for and priority of many activities) are based on unverified assumptions.

- At what point in the SCP process will the values from analysis of the tectonic program be used to test whether the Yucca Mountain site meets system performance requirements?

- Final report on tectonics is scheduled to be available for input into the licensing decision process before many of the tests designed to provide input data are completed.

SCP ISSUE RESOLUTION STRATEGY

Processes

- Issue Identification
- Performance Allocation
- Data Collection and Analysis
- Issue Resolution Documentation

ISSUE RESOLUTION STRATEGY CONCERNS

Alternative Conceptual Models

- Proposed list of Alternative Conceptual Models is incomplete. Conceptual Models represent a laundry list - not a scientific consensus.
- Baseline data inaccurate and/or incompletely compiled.
- Baseline data presented does not support proposed studies.
- Proposed Conceptual Models describe kinematic mechanisms, not tectonic models.
- Conceptual Models do not consider coupled processes.

Performance Allocation

- o Any performance allocation at the present stage is premature.

- o Performance allocation should not be considered except in a conceptual or generic sense until all existing data has been objectively examined.

- o Based on this examination, consensus tectonic models should be developed that encompass the major site disqualifying issues and adverse conditions.

- o Once a set of consensus tectonic models has been established, an appropriate characterization program can be developed.

FORMAL USE OF EXPERT JUDGEMENT

- Expert judgement used as substitute for data collection and qualitative analysis.
- Proposed formal technical decision-making process is not presented in the SCP.
- Program needs to "ask the right question of the right person at the right time."

- <u>Fundamental question</u> is can the Yucca Mountain site ever be adequately characterized to the point where enough data can be obtained to "provide reasonable assurances that the site is suitable" for a high level waste repository?

- Can compliance with the NRC (EPA) regulations be satisfactorily demonstrated for the Yucca Mountain site without destroying the integrity of the site?

HOW CAN WE BE "REASONABLY ASSURED" THAT THE SITE IS SUITABLE?

10 CFR 60 DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

Section 60.122 Siting Criteria

- o Favorable Conditions
- o Potentially Adverse Conditions

10 CFR 960 GUIDELINES FOR RECOMMENDATION OF SITES FOR NUCLEAR WASTE REPOSITORIES

"The technical guidelines provide a set of standards to be used in judging the suitability of a site for repository development and operation. The guidelines specify geotechnical, environmental, and socioeconomic factors for the qualification or disqualification of a potential site for a geologic repository, as well as conditions that would be considered favorable or potentially adverse in site evaluation."

DISQUALIFYING CONDITION

Evaluation of all Potentially Acceptable Sites (960.3-2-2-1)

> "First, in considering sites for nomination, each of the potentially acceptable sites shall be evaluated on the basis of the disqualifying conditions . . .".

- Re-examination of the disqualifying conditions (particularly those conditions related to tectonics) based upon the present content of SCP Chapter 1 could significantly change the conclusions presented in the 1985 Environmental Assessment. State review concludes that all of the major disqualifying conditions directly and indirectly related to tectonic processes and a significant number of adverse conditions are present at the Yucca Mountain site.

Evaluation of all Potentially Acceptable Sites (960.3-2-2-1) (cont'd)

- o Question is the degree to which the presence of known disqualifying and adverse conditions must be demonstrated before a new finding is made and within what timeframe.

  - How many active faults within the proposed repository block are required before the site is disqualified?

  - How close can the occurrence of late Pliestocene/Holocene volcanic activity come to the site before being considered adversely?

DISQUALIFYING CONDITION

Tectonics (960.4-2-7 (d))

"A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur."

- With active faults within the proposed repository block and with active volcanic processes in the near field, now can this condition ever be demonstrated satisfactorily for licensing?

Tectonics (960.4-2-7 (d)) (cont'd)

- o Given that there are major stratigraphic gaps in the Quaternary Record in the southern Great Basin, how will rates of fault movement be determined with reasonable certainty?

- o SCP approach is negative. Program is designed to provide the minimum data that DOE feels may be required to favorably resolve the licensing issues.

  A positive approach would try to find all the fatal flaws in the site at the earliest time (as required by NRC regulations). If no flaws were found, public confidence in the suitability of the Yucca Mountain site would increase substantially.

DISQUALIFYING CONDITION - POSTCLOSURE

Tectonics - Nature and Rates of Fault Movement (960.5-2-11 (d))

"A site shall be disqualified if, based on expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure."

- The presence of active faults transecting and bounding the proposed repository block presents a formidable engineering problem.

Tectonics - Nature and Rates of Fault Movement (960.5-2-11 (d)) (cont'd)

- Without more extensive knowledge than is presently available on the number and 3-dimensional distribution of active faults, the DOE cannot anticipate all of the possible engineering problems that will be encountered let alone establish whether there is "reasonably available technology" to solve these problems.

- Because the physical configuration of each emplacement hole and that the spacing between holes will change unpredictably with time in response to any tectonic perturbations, performance allocation and assessment will need to be treated as a non-linear dynamic problem rather than statically.

DISQUALIFYING CONDITION - POSTCLOSURE

Tectonics - Quaternary Geologic Record (960.4-2-7 (d))

"A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur."

- o SCP Chapter 1 states that there are thirty-two (32) active (Quaternary) faults that transect and immediately surround the Yucca Mountain site.

DISQUALIFYING CONDITION - POSTCLOSURE

Tectonics - Quaternary Geologic Record (960.4-2-7 (d)) (cont'd)

- Demonstrating that the nature of the present active faults transecting and bounding the proposed repository at Yucca mountain do not present an unacceptable condition for waste isolation will be extremely difficult.

- Demonstrating that any future movement on the active faults transecting and bounding the proposed repository at Yucca Mountain will not present an unacceptable condition for waste isolation will be impossible.

o Given the present schedule, it does not seem possible that any of these faults, particularly those transecting the repository, can be described in enough detail to ever reasonably demonstrate that the "nature" of the present fault system is such that the waste can be isolated.

Tectonics - Quaternary Geologic Record (960.4-2-7 (d)) (cont'd)

- The possibility is even less that for the faults transecting and bounding the repository, the "nature" of potential future fault movement can be shown with any reasonable assurance not to contribute to a loss of waste isolation.

- Rates aside, movement on these faults, whatever the source mechanism, has the distinct possibility of causing or continuing a condition where waste isolation will be lost.

DISQUALIFYING CONDITION - POSTCLOSURE

Tectonics - Quaternary Geologic Record (960.4-2-7 (d)) (cont'd)

- Demonstrating that the nature of the present active faults transecting and bounding the proposed repository at Yucca mountain do not present an unacceptable condition for waste isolation will be extremely difficult.

- Demonstrating that any future movement on the active faults transecting and bounding the proposed repository at Yucca Mountain will not present an unacceptable condition for waste isolation will be impossible.

o Given the present schedule, it does not seem possible that any of these faults, particularly those transecting the repository, can be described in enough detail to ever reasonably demonstrate that the "nature" of the present fault system is such that the waste can be isolated.

DISQUALIFYING CONDITION - POSTCLOSURE

Geohydrology - Pre-Waste-Emplacement Ground-Water Travel Time (960.4-2-1 (d))

"A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel."

Geohydrology - Pre-Waste-Emplacement Ground-Water Travel Time (960.4-2-1 (d)) (cont'd)

- Principal Issues Related to Tectonics

  - Ability to demonstrate if and how faults (whether active or inactive and sealed) will change with time in response to active tectonism.

  - Ability to demonstrate if and how the present ground-water table will change in response to active tectonism.

  - Whether active faults that transect or bound the repository block and also connect to the saturated ground-water system must be considered in defining the disturbed zone.

DISQUALIFYING CONDITION - PRECLOSURE

Rock Characteristics - Risk to Health and Safety of Personnel (960.5-2-9 (d))

> "The site shall be disqualified if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to the safety of personnel, taking into account mitigating measures that use reasonably available technology."

- Given that faults are active on Yucca Mountain and that rates of fault movement cannot be predicted with certainty, movement on these faults could present an unacceptable risk to the health and safety of personnel during site characterization, operation, or closure.

SUMMARY

- GIVEN THE PRESENT GEOLOGIC, HYDROLOGIC, AND TECTONIC CONDITIONS, AND FUTURE UNPREDICTABLE PERTURBATIONS TO THOSE CONDITIONS, DISQUALIFYING CONDITIONS CAN NOT BE ADEQUATELY RESOLVED TO MEET REGULATORY REQUIREMENTS OR COMPENSATED FOR WITH ENGINEERING DESIGN.

- REGULATIONS PROVIDE NO MECHANISMS BY WHICH TO DETERMINE SITE SUITABILITY VS. UNSUITABILITY.

- SCP CONTAINS NO MEASURABLE CRITERIA BY WHICH DOE WILL DETERMINE YUCCA MOUNTAIN SUITABILITY OR UNSUITABILITY.

CONCLUSION

DOE'S SITE CHARACTERIZATION PROGRAM IS A STRATEGY TO DEVELOP INFORMATION TO LICENSE, DESIGN, AND OPERATE A REPOSITORY AT YUCCA MOUNTAIN, RATHER THAN TO DETERMINE WHETHER THE NATURAL GEOLOGY AND HYDROLOGY OF THE SITE AND ITS IMMEDIATE ENVIRONS WILL PROVIDE THE NECESSARY WASTE ISOLATION.

RECOMMENDATIONS

- o FUTURE TECTONIC MEETINGS ADDRESS:
  - DEFINITION OF "GEOLOGIC SETTING"
  - EXISTING DATA BASE
- o DOE DEFINE MEASURABLE CRITERIA FOR QUALIFICATION OR DISQUALIFICATION OF YUCCA MOUNTAIN SITE
  - BASED ON 10 CFR 60 AND 10 CFR 960
- o USING THIS CRITERIA, DOE RE-EXAMINE DATA IN SCP CHAPTER 1 FOR QUALIFYING OR DISQUALIFYING CONDITIONS. PREPARE REPORT FOR NRC/STATE REVIEW